ABSTRACT

Title of Document: EVALUATION OF FIRE DYNAMICS SIMULATOR FOR LIQUEFIED NATURAL GAS VAPOR DISPERSION HAZARDS

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The Federal Energy Regulatory Commission (FERC) and Pipeline and Hazardous Material Administration (PHMSA) require vapor dispersion modeling as part of a siting analysis for liquefied natural gas (LNG) facilities. Guidance issued by PHMSA, in consultation with FERC, establishes a protocol for the scientific assessment, verification, and validation of vapor dispersion models. This thesis provides an evaluation of the Fire Dynamic Simulator (FDS), Version 5.5.1, for LNG vapor dispersion hazards. The scientific assessment demonstrates that FDS is capable of modeling LNG vapor dispersion hazards, but raises potential limitations associated with the specification of the source term, initial conditions, and boundary conditions; the verification calls for third party confirmation of modeling results; and the validation recommends a safety factor of up to 2 for modeling LNG vapor concentrations in unobstructed flow fields and a safety factor of up to 3 for modeling LNG vapor concentrations for obstructed flow fields.

EVALUATION OF FIRE DYNAMICS SIMULATOR FOR LIQUEFIED NATURAL GAS VAPOR DISPERSION HAZARDS

By

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Dedication

I would like to dedicate this thesis in the memory of Mr. Richard Goyne. He was supportive and inspirational, and was always a source of encouragement. More importantly, he was a wonderful father, grandfather, great-grandfather, and family member to many. He will truly be missed and always remembered.

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Terminology

ABS	American Bureau of Shipping
BA-H	Berufsakademia - University of Hamburg
BA-TNO	Berfusakademia - Toegepast Natuurwetenschappelijk Onderzoek
BLEVE	Boiling Liquid Expanding Vapor Explosion
CFD	Computational Fluid Dynamics
CFL	Courant Friedrichs Lewy Number
CHRC	Chemical Hazards Research Center
CSF	Concentration Safety Factor
DNS	Direct Numerical Simulation
DOT	Department of Transportation
DSF	Distance Safety Factor
FAC2	Factor of Two
FDS	Fire Dynamic Simulator
FERC	Federal Energy Regulatory Commission
FPC	Federal Power Commission
FPRF	Fire Protection Research Foundation
GASP	Gas Accumulation Over Spreading Pools
HSE	Health and Safety Executive
HSL	Health and Safety Laboratory
LES	Large Eddy Simulation
LFL	Lower Flammability Limit
LNG	Liquefied Natural Gas
MEG	Model Evaluation Group
MG	Geometric Mean Bias
MRB	Mean Relative Bias
MRSE	Mean Relative Square Error
MEP	Model Evaluation Protocol
MER	Model Evaluation Report
NFPA	National Fire Protection Association
NASFM	National Association of State Fire Marshalls
NGL	Natural Gas Liquids
NIST	National Institute of Standards and Technology
QA	Quality Assurance
QC	Quality Control
PHMSA	Pipelines and Hazardous Materials Safety Administration
RANS	Reynolds Averaged Navier-Stokes
RPT	Rapid Phase Transition
SMEDIS	Scientific Model Evaluation of Dense Gas Dispersion Models
SPM	Statistical Performance Measures
UFL	Upper Flammability Limit
USCG	United States Coast Guard
VG	Geometric Variance
VN	Von Neumann Number

Chapter 1: Introduction

The global increase in energy consumption, forecasted demand in developing countries, diminishing supplies in many countries, shale gas discoveries, and global environmental concerns over traditional power generation sources has propelled the expansion of liquefied natural gas (LNG) import and export terminals around the world.

The Federal Energy Regulatory Commission (FERC) is the lead federal agency responsible for the siting of LNG import and export facilities located onshore, or in state waters, and LNG peak-shaving facilities used in interstate commerce [1]-[3]. FERC requires applicants under Title 18 Code of Federal Regulations (CFR) Part 380.12(o)(14) [4] to demonstrate how the proposed LNG facility complies with 49 CFR 193 [5] regulations promulgated by the Pipeline and Hazardous Materials Administration (PHMSA) of the Department of Transportation (DOT), which, in part, adopts portions of the 2001 and 2006 editions of the National Fire Protection Association (NFPA) 59A, *Standard for the Production, Storage, and Handling of Liquefied Natural Gas* [6][7].

The DOT regulations require owners/applicants to model LNG vapor dispersion under 49 CFR 193.2059, and prescribe the use of an integral dispersion model, DEGADIS, a computational fluid dynamics model, FEM3A, or an alternative model subject to the approval of the PHMSA Administrator [5].

Changes in the regulations and the use of different LNG storage tanks have resulted in the realization of limitations using DEGADIS [8] and difficulties using FEM3A. These challenges have led FERC and PHMSA to recognize the need for the use of alternative models. As a result, PHMSA, in consultation with FERC, issued an Advisory Bulletin on how to obtain alternative model approval based on the Model Evaluation Protocol (MEP) described in the Fire Protection Research Foundation reports, *Evaluating Vapor Dispersion Models for Safety Analysis of LNG Facilities* [9], and *Validation Database for Evaluating Vapor Dispersion Models for Safety Analysis of LNG Facilities: Guide to the LNG Model Validation Database* [10].

Similar to other model assessment standards and guidelines [11]-[17], including ASTM E 1355, *Standard Guide for Evaluating the Predictive Capability of Deterministic Fire Models*, to which FDS has styled its Technical Reference Manual [19]-[23], the MEP consists of scientific assessment, model verification, and model validation. The outcomes of the three stages are then compared to qualitative and quantitative assessment criteria and recorded in a Model Evaluation Report (MER) to determine the suitability of the model for LNG vapor dispersion applications.

This thesis evaluates the publically available CFD model, Fire Dynamic Simulator (FDS), Version 5.5.1, developed by the United States Government National Institute of Standards and Technology (NIST) [23] as it relates to LNG vapor dispersion hazards.

Chapter 2: Natural Gas and Liquefied Natural Gas

Natural Gas

Natural gas is a naturally occurring gaseous fuel, often associated with petroleum. Conventional natural gas is often classified as a fossil fuel because it is most abundantly found deep beneath the earth's surface where thousands to millions of years of decomposition of organic material are necessary. However, unconventional natural gas sources are becoming an increasingly important part of the market and may be found at landfills, sewage plants, and other areas of decaying organic matter.

The majority of recoverable natural gas comes from the decomposition of organic material. As organic material decomposes it may deposit into a subsiding basin. Over time, the subsiding basin is in-filled with sediment to form sedimentary layers over the organic matter. Anaerobic ("without air") methanogen microorganisms begin to consume the organic matter and produce methane as a metabolic byproduct in this anoxic ("without oxygen") condition. This type of microbial natural gas is also known as biogenic gas, or biogas, and is the source of marsh gas and other biogenic sources[1].

As the organic material is deposited under additional sediment layers, compression of the organic material can result in lithification of the organic material into black shale and coalbeds. After several million years, the sediment layers reach deeper depths of

[1] Methanogens also produce methane gas in the guts of humans and ruminants.

6,000 to 18,000 feet and heat the organic material to 150°F to 350°F, which results in a slow thermal decomposition of the organic material into crude oil and natural gas [24]. This type of natural gas is known as thermogenic natural gas, and is why natural gas is often associated with petroleum. Deeper depositions will be subjected to higher temperatures and pressures, and will tend to produce more natural gas relative to crude oil.

The crude oil and natural gas will rise to the surface if unabated. When natural gas rises to the Earth's surface it will dissipate into the atmosphere. When crude oil reaches the Earth's surface the lighter hydrocarbon chains preferentially evaporate and leave behind a tar residue composed of only the large complex heavier hydrocarbon chains and asphaltenes. Otherwise, natural gas and crude oil can become trapped or dissolved within its source rock (e.g. shale gas and coalbed gas) or trapped underneath non-porous sedimentary layers to create a gas or oil reservoir, also known as a gas or oil field or well [24].

The amount of natural gas and crude oil produced will depend on the organic material involved. If the original source of the organic material is mostly higher order plants[2], such as trees, shrubs, and grasses, natural gas will be the dominant petroleum product generated with lesser amounts of crude oil, and if the original source of the organic material is mostly plankton, such as algae, copepods, and bacteria, crude oil will be the dominant petroleum product generated with lesser amounts of natural gas. [25]

The actual composition of natural gas will vary from gas field to gas field, but is typically comprised of a mixture of hydrocarbons, constituted primarily of methane, CH_4, with smaller varying amounts of other hydrocarbons, such as ethane, C_2H_6, propane, C_3H_8, butane, C_4H_{10}, and some non-hydrocarbons, such as water, H_2O, nitrogen, N_2, carbon dioxide, CO_2, hydrogen sulfide, H_2S, and mercury, Hg, with trace components of heavier hydrocarbons and various non-hydrocarbons. Crude oil is composed of a much larger number of different hydrocarbons of alkanes, cycloalkanes, aromatic hydrocarbons, asphaltenes, and other more complicated chemicals. The alkanes from pentane, C_5H_{12}, to octane, C_8H_{18}, are refined into gasoline, or petrol; heavier hydrocarbons from nonane, C_9H_{20}, to hexadecane, $C_{16}H_{34}$, are refined into diesel and kerosene (primary component of jet fuels); and even heavier hydrocarbons are responsible for fuel oil, lubricating oil, paraffin wax (C25+), and asphault products (C35+).

The value of natural gas and other petroleum fuels, such as gasoline, is primarily due to the energy chemically stored in the structural arrangement of the atoms and/or molecules. The stored chemical energy may be converted to thermal energy (heat) by locally initiating the oxidation of the fuel via an ignition source (i.e. spark, pilot flame, hot wire, temperature increase, pressure increase, etc). Once a fuel is ignited, it may then self-sustain a chain of rapid exothermic oxidation reactions driven by its own heat release rate. This complex process is better known as combustion. The

[2] Higher order plants are composed mostly of cellulosic carbohydrates (30-50%) and lignin (15-25%) with lesser amounts of protein (3% or less), while plankton are composed mostly of protein (50% or

transferring of chemical energy to thermal energy can then be harnessed to do mechanical work, such as utilizing the expansion of gases—due to the increased temperature—to spin a turbine or generator shaft. The combustible characteristic of fuels is what makes it an important energy source and drives the extraction of natural gas and other fossil fuels from the earth's surface via oil wells, gas wells, or other means. However, the usefulness of natural gas and crude was not always known.

During ancient times, natural gas would rise to the surface and would ignite from natural phenomena, such as lightning, and was a great mystery. One of the most famous instances of these natural gas leaks would be documented in 1000 B.C. when a goat herdsman on Mount Parnassus discovered a fire mysteriously burned atop rock without an apparent source [24]. The Greeks, believing it to be of divine origin, built a temple on the flame, and would eventually become the place where the Oracle of Delphi would preach her prophecies [24]. Similar occurrences of natural gas leaks and fires would become documented in other parts of the World. Five hundred years later, the Chinese would discover the true origins of the fires, and the natural gas was transported via pipelines made of bamboo to areas used to boil sea water to separate the salt from the water to make it drinkable [26].

Presently, there are more than 2,300,000 miles of pipeline that help supply petroleum and natural gas throughout the United States [26], which account for approximately 62 percent of the United States primary energy use [29]. Moreover, approximately 96 percent of the transportation sector, 94 percent of the residential and commercial

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more) and lipids (5-25%). [25]

sector, 81 percent of the industrial sector, and 20 percent of the electric power sector use petroleum and natural gas for energy [29]. In addition, many pharmaceuticals, plastics, resins, and chemicals are derived from petroleum products [28].

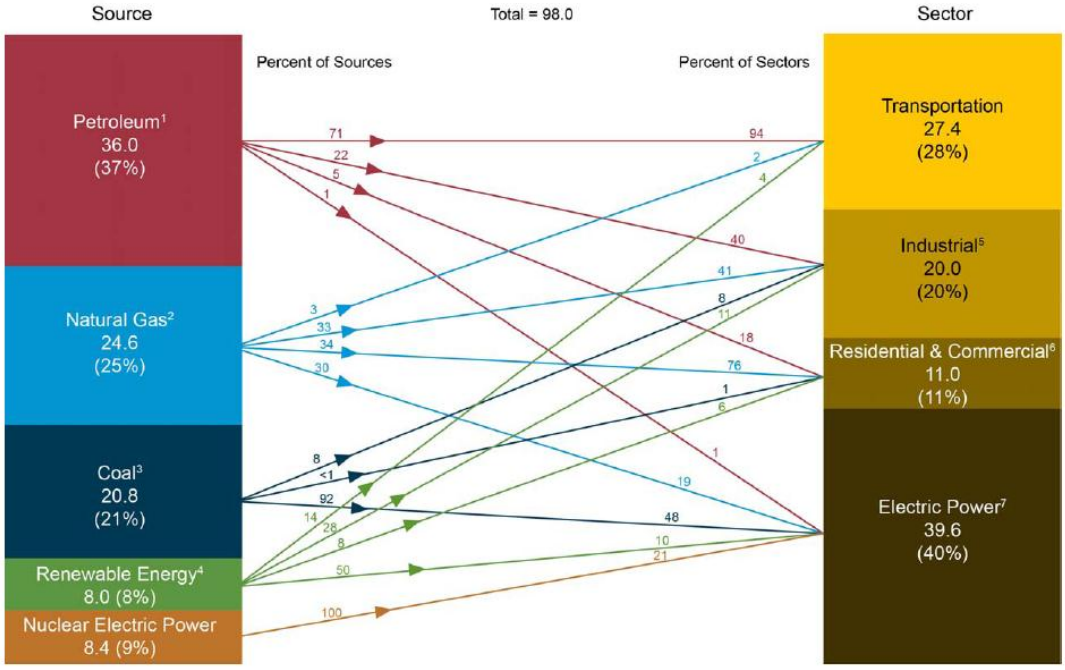

Figure 1 - Primary Energy Consumption by Source and Sector

(Quadrillion BTUs) [29]

Liquefied Natural Gas

Prior to the 1970s, natural gas was often considered a valueless byproduct during petroleum extraction and was commonly flared because it could not be profitably sold. Since then, natural gas prices have exceeded transportation costs and natural gas is commonly transported to local markets using pipelines or is re-injected into geological formations for enhanced oil recovery or for later recovery and transport.

However, in many countries the supply of natural gas and petroleum products is more than the local demand. Moreover, many of the top proven reserves are situated in areas where supplies exceed demand, such as in the Middle East, North Africa, and Russia [30]. At these locations, pipelines may no longer become economically feasible to transport the oil and gas to the larger established demand markets, such as in the European Union, United States, Japan, or developing Asian markets [30]. Therefore, in order to be able to transport the gas economically to these countries, the gas is liquefied to reduce its volume to $1/600^{th}$ the gas volume and transported by ship[3].

However, unlike propane, butane, and some other heavier hydrocarbons, natural gas cannot become a liquid at ambient temperatures through pressurization, and therefore must be cooled to its atmospheric boiling point of approximately -260°F (-162°C) by large refrigerant systems at liquefaction plants. However, before the gas is liquefied, the gas is processed to remove common impurities, such as nitrogen, water, carbon

dioxide, hydrogen sulfide, and mercury, which can freeze out during the liquefaction process and damage or plug downstream equipment, corrode downstream piping and equipment, lower the heating value of the natural gas, and/or pose toxic hazards. Additional processing may occur to strip out more valuable natural gas liquids (NGL), such as propane, ethane, butane, and pentane+, to transport and sell to other markets. Once the processing equipment extracts the impurities and NGLs out of the natural gas, the gas is cooled to become liquefied natural gas (LNG), stored in large well-insulated LNG storage tanks, and then transferred to LNG ships for transport to LNG import terminals around the world.

Typical LNG compositions imported to the United States are 85-90% methane, 5-10% ethane, 1-3% propane, with less than 2-4% coming from other heavier hydrocarbons and non-hydrocarbon constituents. However, shipments have been received with methane concentrations as low as 80%, ethane concentrations as high as 17%, and propane concentrations as high as 4%. The range in composition is due to the extraction of natural gas in various locations of the world. These differences have important impacts on gas interchangeability and the propensity of certain hazards.

The LNG offloaded from the ship is transferred into large well-insulated LNG storage tanks until it is regasified and sent into a natural gas pipeline. The gas is then transported along a vast network of pipelines via compressor stations where it

[3] Compressed natural gas is compressed to typically 2000-3500 psi, reducing its volume to 1/150th - 1/250th

eventually supplies residential, commercial, and industrial demands. Interspersed along the pipeline network, natural gas storage fields and LNG peak-shaving facilities provide economical surge capacity during high periods of demand compared to constructing additional pipelines. The LNG peak-shaving facilities liquefy the natural gas (or receive the LNG via trucks) during low cost off-peak demand periods (typically in summer), store the LNG, and then re-gasify and inject the natural gas back into the pipeline network during higher price peak demand periods (typically in winter).

Presently, there are twelve LNG import facilities, one LNG export facility (in Alaska), and over one-hundred LNG peak-shaving facilities in the United States. In addition, there are another six facilities approved for construction and six proposals pending in the United States. However due to market shifts from shale gas production, many of the import facilities are actually re-exporting the LNG that is imported from other parts of the world – acting as international peak-shavers. In addition, there are two proposals for two of the existing import facilities to install liquefaction equipment to become export facilities with additional facilities expected to follow.

Chapter 3: LNG Hazards

As with all fuels, the combustible characteristic of a fuel that makes it an important energy source is also the source of many of its hazards. An uncontrolled release of LNG can result in harm and damage from the extremely cold temperature of the liquid spill, the dispersion of the vapors, and the ignition of a vapor cloud.

Cryogenic Spill

The first hazard from an uncontrolled LNG release would be from its extremely cold temperatures. A release of LNG could produce both liquid and vapor in the immediate area. Low pressure releases of LNG would primarily result in a stable liquid jet, while high pressure releases of LNG would produce a mechanically fragmented liquid jet and vapor. The inertia of the liquid from pressurized releases would exceed surface tension forces and cause mechanical fragmentation of the liquid into fine aerosol droplets. In addition, pressurized releases allow for the liquid to be superheated above its normal boiling point, which can cause the liquid to flash into a vapor upon its release. The inertia of the expanding vapor from flashing releases may also exceed surface tension forces and cause mechanical fragmentation of the residual liquid into fine aerosol droplets. The aerosol droplets formed from the jetting and flashing would vaporize along their trajectory in the warm surrounding air until they reached the ground and began to form a pool, which is known as rainout. The resultant liquid pool would spread with gravity and quickly cool any materials it contacts. As pressure and temperature increases, finer droplets and higher amounts of flashing will occur, resulting in less liquid rainout.

If LNG contacts water a breakdown from film boiling to nucleate boiling can result in direct contact with the water and much higher heat transfer rates. The higher heat transferred to the cryogenic liquid induces a virtually instantaneous phase change from the liquid state to the vapor state, known as a rapid phase transition (RPT). The rapid expansion from the RPT can cause overpressures. In some test cases, the overpressures generated may be strong enough to cause damage to equipment in the immediate vicinity of the LNG release point. The average overpressures recorded during the Coyote tests have ranged from 0.2 psi to 11 psi.

Human contact with either the cryogenic liquid or cold vapor could cause freeze burns and, depending on the length of exposure, more serious injury, or death. Contact with surrounding equipment could result in extreme thermal stresses, brittleness, loss of tensile strength, or fracture that could lead to structural damage and cascading failures. Cascading failures, also known as domino or knock-on effects, of adjacent equipment and storage vessels could further exacerbate the consequences of the initial hazard.

Vapor Dispersion

Once the cryogenic LNG is released, it will immediately begin to vaporize from the convective heat transfer with the warm surrounding air. Additional vaporization would result from conductive heat transfer with surfaces the liquid contacts.

As the LNG preferentially vaporizes, a cold denser-than-air vapor cloud constituting primarily of methane would begin to form. The cold denser-than-air vapors would travel along the ground with the prevailing wind and condense water vapor in the surrounding air, resulting in a white fog. As the cloud disperses, it will continue to entrain air, condense water vapor, warm, and dilute. As a result, higher concentrations and colder temperatures occur near the vapor sources and lower concentrations and higher temperatures occur near the edge of the vapor cloud. Depending on the ambient conditions, the lower concentrations near the edge of the cloud may no longer be cold enough to condense water vapor in the air, but may still be within the flammable limits. This can result in colorless, odorless, but flammable portions of the vapor cloud extending beyond the visible portion of the cloud. The vapor would continue to disperse and warm as it travels downwind until it either encounters an ignition source or disperses below the lower flammability limit (LFL). The LNG vapors would eventually warm, become buoyant, and rise in the air; however, LNG vapor dispersion experiments and modeling indicate that the LNG vapor cloud would not exhibit positive buoyancy characteristics (i.e. lift off from the ground) before it disperses below its LFL.

The potential harm attributed to the vapor cloud is from the displacement of air and cold temperatures. Inhalation of the vapor can result in oxygen deprivation effects, including asphyxiation and death. In addition, the cold vapors may cause freeze burns.

Vapor Cloud Ignition

If the flammable portion of the vapor cloud encounters an ignition source above its minimum ignition energy the cloud will ignite. The flame generated will propagate through the pre-mixed flammable portions of the cloud, self-driven by heat generated by the flame front. This phenomenon is known as a deflagration.

For a LNG vapor cloud that is unconfined and ignited, the flame front will travel at speeds too slow to produce significant overpressures, and would be categorized as a flash-fire. Although flash-fires do not produce significant overpressures and are relatively short in duration, exposure to a flash-fire could still cause severe burns and death. In addition, combustible materials within the ignited vapor cloud could be subsequently ignited by the heat generated by the flame front.

The flash-fire may propagate back to the spill site if the vapor concentration along this path is sufficiently high to support the combustion process. When this occurs, it would be termed as a flash-back, light-back, or burn-back. Obstructions within a vapor cloud (i.e. congestion) will result in additional turbulence that results in flame wrinkling and higher heat transfer rates and flame speeds. For a LNG vapor cloud that is confined and ignited, the flame front will also travel at a higher rate of speed due to the expansion of the confined hot products of combustion. The expansion of the products of combustion pushes the flame front and causes additional turbulence and flame wrinkling that results in higher heat transfer rates and faster flame propagation. As the flame accelerates to higher rates of speed, the flame front will

begin to produce pressure waves that may cause harmful and damaging overpressures. When damaging overpressures begin to occur, the deflagration is typically classified as an explosion. If the flame front approaches sonic speeds, shock waves will develop and a deflagration to detonation transition may occur. At this point, the flame will be driven by shock compression and attach itself to the shock wave.

In addition to the thermal hazards posed by a low-speed deflagration (i.e. flash-fire), the overpressures generated by a high-speed deflagration (i.e. vapor cloud explosion) can cause serious injury or death. The overpressures may also cause structural damage and cascading failures, which can further exacerbate the initial hazard.

If the flame front reaches vapor concentrations above the upper flammability limit (e.g. near the fuel source), transition from a pre-mixed combustion deflagration to a diffusion combustion fireball may occur. In this case, the flame will attach itself to the outside of the fuel rich vapor, burning around its edges, where the fuel has diffused with the air to form a flammable mixture. As the outside burns, the fireball will rise due to buoyancy and diminish in size due to consumption of fuel.

Similar to flash-fires, fireballs do not produce overpressures and are relatively short in duration, but they can still cause severe burns or death and have the potential to ignite additional materials nearby.

As the fireball dissipates, the diffusion fire may attach itself at the fuel source to form a jet fire or pool fire. The fire will continue to burn until the fuel source is eliminated and the remaining fuel is consumed.

Pool fires and jet fires may also cause severe burns, death, or ignition of additional materials, but will also last much longer in duration compared to deflagrations and fireballs. The longer durations result in longer exposure times to surrounding equipment causing a higher potential of cascading failures of structural steel, equipment, and pressure vessels.

Failures of pressurized vessel could cause fragments of material to fly through the air at high velocities (i.e. projectiles or missiles), resulting in serious injury, death or damage to surrounding structures. In addition, failure of a pressurized vessel where the liquid has been heated significantly above its normal boiling point would cause flashing of the superheated liquid into a vapor upon its release into the lower ambient pressure. This phenomenon is called a boiling-liquid-expanding-vapor-explosion (BLEVE). The energy from the expansion of the liquid to vapor is transformed into mechanical energy in the form of blast waves in addition to the generation of high velocity projectile fragments of the failed vessel. BLEVEs of flammable liquids would also produce a subsequent fireball from the released vapor and additional pool fires or jet fires, resulting in even more cascading failures.

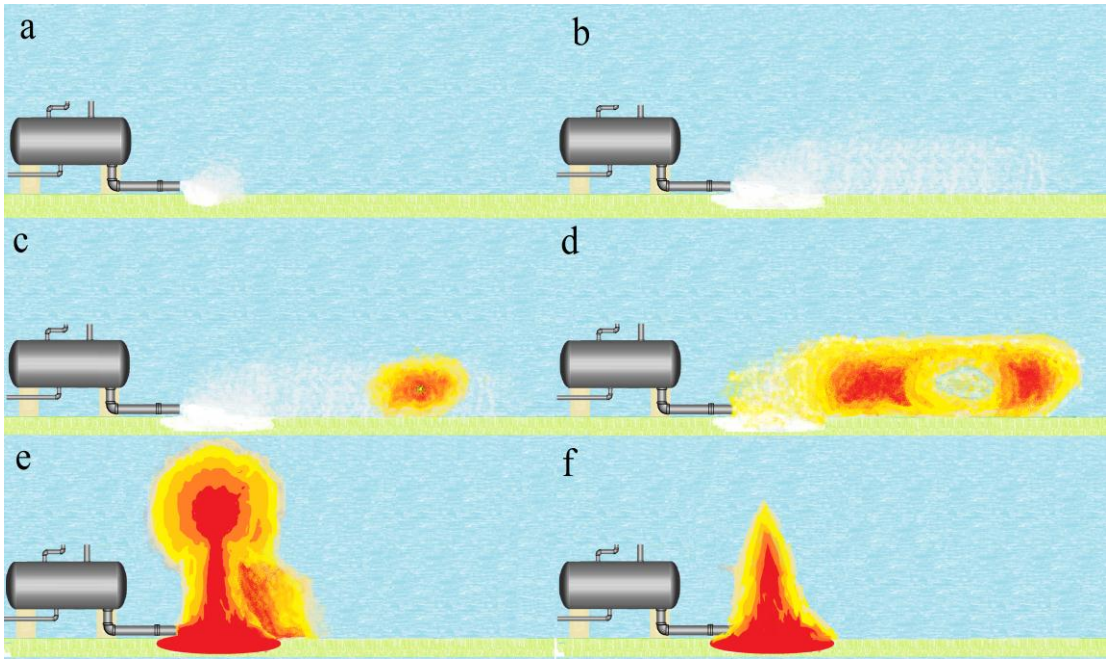

Figure 2 - LNG Hazardous Sequence of Events

a) release, b) dispersion, c) ignition, d) deflagration, e) fireball, f) pool fire

Chapter 4: U.S. Regulatory Requirements

Federal Energy Regulatory Commission

In the mid-1920s and 1930s, low natural gas production costs in the southwest and high natural gas demand nationwide coupled with improved pipeline technology spurred the creation of new interstate gas pipelines [26]. In fact, the total interstate and international transportation of natural gas rose approximately 20 percent in just one year, from 346,816,400,000 cubic feet in 1933 to over 400,000,000,000 cubic feet in 1934 [31]. This rapid increase in unregulated interstate natural gas transportation caused fear of potential monopolies, and led the Federal Trade Commission to investigate the natural gas industry [32], resulting in Congress enacting the Natural Gas Act (NGA) of 1938. The NGA gave the Federal Power Commission, or FPC (now delegated to the Federal Energy Regulatory Commission, or FERC[4]) authority to grant certificates allowing construction and operation of facilities used in interstate and foreign commerce of natural gas transmission and authorizing the provision of services. In 1969, passage of the National Environmental Policy Act (NEPA) provided a national framework for consideration of environmental impacts prior to major federal action. In order to fulfill part of its NEPA obligations, FERC requires LNG facility applicants to file information specified in 18 CFR §380.12. FERC staff uses this information, in part, to review the safety and reliability of LNG applications to determine any public impact.

[4] After the 1973 oil embargo crisis, Congress passed the Department of Energy (DOE) Organization Act of 1977 that created DOE and consolidated energy-related agencies, including the FPC. However,

Department of Transportation

On March 4, 1965, a catastrophic failure of a natural gas pipeline caused an explosion that killed 17 people in Natchitoches, Louisiana [33]. This event along with previous incidents led Congress to pass the Natural Gas Pipeline Safety Act of 1968 [34], which gave the promulgation of safety standards for natural gas facilities to the Department of Transportation (DOT). In 1972, DOT issued its first regulatory requirements for LNG facilities under Title 49 Code of Federal Regulations 192, which wholly adopted the 1972 National Fire Protection Association (NFPA) 59A, *Standard for Production, Storage and Handling of LNG*. In 1980, DOT amended and moved its LNG facility requirements to Title 49 Code of Federal Regulations 193 (49 CFR 193) [5].

Interagency Coordination

In 1985, the FERC and DOT entered a memorandum of understanding (MOU) regarding each agency's jurisdictional responsibilities of LNG facilities. As part of the MOU, FERC is able to impose additional reliability requirements, and, in consultation with DOT, more stringent safety requirements. With the onset of a projected increase in LNG import terminals, the FERC, the DOT, and the USCG entered an Interagency Agreement to ensure that they work in a coordinated matter regarding safety and security of LNG terminals, and established the FERC as the lead

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a need to retain an independent regulatory agency resulted in the delegation of many responsibilities to the FERC.

agency responsible for the preparation of the analysis required under the NEPA. The Energy Policy Act of 2005 and Department of Energy (DOE) Delegation Order No 00-004-00A, effective May 16, 2006, re-affirmed the FERC as having exclusive authority over applications to site, construct, and operate the facilities in an LNG terminal.

As part of the FERC requirements in 18 CFR 380, owners/operators of LNG facilities must demonstrate compliance with 49 CFR 193 and NFPA 59A, which require siting analyses of potential hazards, including the dispersion of flammable LNG vapors. The dispersion of LNG vapors is required to be evaluated using DEGADIS or FEM3A, or an alternative model subject to the requirements in 49 CFR §193.2059 and the approval of the DOT Pipeline and Hazardous Material Safety Administration (PHMSA) Administrator. Limitations of DEGADIS, difficulties using FEM3A, and requirements established by the FERC and PHMSA have led industry to propose the use of alternative models.

In order to evaluate alternative dispersion models for LNG applications, the LNG Technical Committee responsible for NFPA 59A requested the Fire Protection Research Foundation (FPRF) to provide a methodology to approve alternative models. The FPRF, assembled a technical committee, including FERC, PHMSA, USCG, and other stakeholders, and contracted the United Kingdom Health and Safety Laboratory (HSL) of the Health and Safety Executive (HSE) to establish a protocol for evaluating dispersion models to assist in the decision making process for acceptable models for LNG applications. The protocol, entitled the Model

Evaluation Protocol (MEP), is based on earlier work of Hanna [35][36], the Model Evaluation Group (MEG) [37][38], and structured based on a previous protocol developed by HSL during the European Union Scientific Model Evaluation of Dense Gas Dispersion Models (SMEDIS) project [39][40]. The major difference being that the MEP has been specifically tailored for the dispersion of LNG vapors.

Similar to other model assessment standards and guidelines [11]-[17], including ASTM E 1355, *Standard Guide for Evaluating the Predictive Capability of Deterministic Fire Models*, to which FDS has styled its Technical Reference Manual [19]-[23], the MEP consists of a scientific assessment, model verification, and model validation. The outcome of the scientific assessment, model verification, and model validation stages are then compared to qualitative and quantitative assessment criteria and recorded in a Model Evaluation Report (MER) to determine the suitability of the model for LNG vapor dispersion applications.

After the FPRF report was issued, PHMSA commissioned the National Association of State Fire Marshals (NASFM) to independently review the FPRF report [41] NASFM assembled its own panel of technical experts to review the MEP, heard the concerns of FERC and other participants, and raised a number of new concerns in implementing the MEP.

In response to the comments issued on the FPRF report by FERC, other technical committee members, and the independent review by NASFM, PHMSA – in consultation with FERC – issued an Advisory Bulletin on how to obtain approval of

alternative dispersion models used to site LNG facilities. The Advisory Bulletin requires that alternative dispersion models be subjected to the MEP in addition to a number of other provisions.

Chapter 5: Scope

This thesis evaluates the suitability of the Fire Dynamic Simulator (FDS), Version 5.5.1, for LNG vapor dispersion hazards. As required by the MEP and Advisory Bulletin, the evaluation includes three distinct phases – scientific assessment, verification, and validation.

The scientific assessment is used to examine the physics of the model, the mathematical and numerical basis of the model, and the user-oriented aspects of the model. The scientific assessment is then measured against 11 qualitative assessment criteria to determine if the model accounts for the key physical phenomena in LNG vapor dispersion applications that are based on a proper mathematical and numerical basis as well as designed to meet certain user oriented needs.

The model verification is used to confirm that the model accurately and correctly implements the model algorithms. The MEP allows for passive verification of the model, meaning that instead of the evaluator carrying out a specific exercise to verify that the model has been implemented correctly, the verification assessment is based on previous documented efforts demonstrating that the model has been verified adequately and the development has adequate quality assurance and quality control procedures in place. Relying on previous documented efforts does rely on the honesty and integrity of the model developer and/or model verifier, but it is not necessarily less stringent than carrying out the model verification for oneself and does allow for a broader verification in a much shorter amount of time to be examined.

The model validation is used to qualitatively and quantitatively compare the model predictions with experimental datum. The MEP calls for comparisons of model predictions with large-scale field trials and small-scale wind tunnel tests. Using both field trials and wind tunnel tests maximizes the positives of both types of experiments and helps reduce bias errors associated with a particular type of experiment.

Once the model predictions have been compared to the experimental data using statistical performance measures (SPMs) set out in the MEP the outcome is compared against quantitative assessment criteria to determine if the fidelity of the model is adequate.

FDS has undergone similar evaluations as the MEP for its fire model, including ASTM E 1355, *Standard Guide for Evaluating the Predictive Capability of Deterministic Fire Models*. However, the scientific assessment and validation documentation appropriately focuses on fires, and only briefly references dense gas dispersion. This thesis provides an evaluation of the FDS Version 5.5.1 as it relates to LNG vapor dispersion.

Chapter 6: Scientific Assessment

FDS is a publically available Computational Fluid Dynamic Model (CFD) developed by the National Institute of Standards and Technology (NIST) of the United States Government. FDS was developed to model fire-driven fluid flow with an emphasis on smoke and heat transport. FDS is widely used in the fire protection engineering industry for design of smoke handling systems and sprinkler/detector activation studies, as well as residential and industrial fire reconstructions. However, the hydrodynamic model can be used to model other low-speed fluid flow[5], such as vapor dispersion. [23]

A release of LNG will form a denser-than-air vapor cloud that will initially spread by gravity and then travel with the prevailing wind and mix with the surrounding air until the vapor ignites or is diluted below its LFL. The rate at which the vapor cloud dilutes below the flammability limits is dependent on the mixing of the vapor cloud with the surrounding air that is entrained as it is carried with the wind. Higher wind speeds, lower wind stabilities, and higher surface roughness (i.e. rougher ground surface with larger obstructions) will promote turbulent mixing of the vapor cloud with the surrounding air and decrease the duration that a flammable vapor cloud exists and decrease the distance that a flammable vapor cloud travels. It is imperative that a vapor dispersion model accounts for these phenomena based on accepted published science using numerical methods that are based on accepted published good practices.

Correspondingly, the MEP and Advisory Bulletin specifies 11 qualitative assessment criteria used to evaluate the scientific basis of the model:

1. Key details of the model are available for scientific assessment;
2. Model is based on accepted/published science;
3. Model accepts a credible source term;
4. Model accounts for the effects of wind speed;
5. Model accounts for the effects of surface roughness on dispersion;
6. Model accounts for the effects of atmospheric stability on dispersion;
7. Model accounts for passive dispersion;
8. Model accounts for gravity-driven spreading;
9. Model accounts for the effects of buoyancy on dilution;
10. Numerical methods are based on accepted/published good practice; and
11. Model produces output suitable for assessment against MEP statistical performance measures.

FDS satisfies all of the above criteria and is described in more detail below, including the scientific basis of the hydrodynamic model, turbulence model, heat transport model, spatial discretization, numerical methodology, spatial discretization, user input/output, liquid flashing and jetting, liquid pool spreading, wind profile, atmospheric stability, surface roughness, sloped and varying level terrain, and obstructed flow.

[5] Mach numbers less than 0.3

Hydrodynamic Model

FDS numerically solves the partial differential equations for the conservation of mass, momentum, and energy, better known as the Navier Stokes equations, as shown below in tensorial notation [19].

Conservation of mass (continuity equation) in the gas phase,

$$\frac{\partial \rho}{\partial t} + \nabla \cdot \rho \vec{u} - \dot{m}_b''' = 0 \text{ [19]}$$

where ρ is the density of the fluid, $\vec{u}$ is the velocity vector of the fluid, and $\dot{m}_b'''$ is the mass flux of a fluid due to phase change (e.g. evaporating droplets).

Conservation of momentum,

$$\frac{\partial \left(\rho \vec{u}\right)}{\partial t} + \nabla \cdot \rho \vec{u}\vec{u} + \nabla p - \nabla \cdot \tau_{ij} - \rho g_i - \vec{f}_b = 0 \text{ [19]}$$

where p is the pressure, g is the gravity vector, $\vec{f}_b$ is a force vector representing external forces (e.g. drag exerted by liquid droplets), and τ_{ij} is the stress tensor, defined by,

$$\tau_{ij} = \mu\left(2S_{ij} - \frac{2}{3}\delta_{ij}(\nabla\cdot\vec{u})\right);\ \ S_{ij} = \frac{1}{2}\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right);\ \delta_{ij} = \begin{cases} 1 & i = j \\ 0 & i \neq j \end{cases};\ i,j = 1,2,3 \quad [19]$$

where μ is the dynamic viscosity of the fluid.

Transport of Sensible Enthalpy,

$$\frac{\partial(\rho h_s)}{\partial t} + \nabla\cdot\rho h_s\vec{u} + \frac{\partial(p)}{\partial t} - \vec{u}\cdot\nabla p + \nabla\cdot\dot{\vec{q}}'' + \dot{q}_b''' - \varepsilon = 0 \quad [19]$$

where h_s is the sensible enthalpy of the fluid, $\dot{\vec{q}}''$ is the conductive and radiative heat (energy) fluxes, $\dot{q}_b'''$ is the phase change energy (e.g. evaporating droplets)[6], and ε is the dissipation rate, defined by,

$$h_s = \sum Y_\alpha h_{s,\alpha}\ ;\ h_{s,\alpha}(T) = \int_{T_0}^{T} c_{p,\alpha}(T')dT';$$

$$\dot{\vec{q}}'' = -k\nabla T - \sum_\alpha h_{s,\alpha}\rho D_\alpha \nabla Y_\alpha + \dot{\vec{q}}_r'';\ \ \varepsilon \equiv \tau_{ij}\cdot\nabla\vec{u} \quad [19]$$

where T is the temperature of the fluid, c_p is the specific heat of the fluid, and k is the thermal conductivity of the fluid.

Equation of State for a Perfect Gas,

[6] FDS does not account for the condensation of water vapor and subsequent heat gain.

$$p = \frac{\rho RT}{W} \quad [19]$$

The pressure is decomposed into an "averaged" component associated with the "background" pressure (e.g. atmospheric stability, stack effect, sealed enclosures) and a fluctuating component associated with fluid flow, such that,

$$p(x,y,z,t) = \bar{p}(z,t) + \tilde{p}(x,y,z,t) \quad [19]$$

The pressure in the state equation is replaced by this simplified averaged pressure. The temperature may then be solved via the Equation of State (assumes perfect gas) from the density and the calculated "averaged" pressure that is a function of time and height above the ground, such that,

$$\bar{p}(z,t) = \rho \Re T \sum_{\alpha} Y_{\alpha} / W_{\alpha} \quad [19]$$

The solution of the incompressible Navier Stokes equations and pressure assumptions is appropriate to model LNG vapor dispersion applications. The incompressibility and "background" pressure simplification holds true when modeling low speed incompressible fluid flows, such as the case for LNG vapor dispersion, and greatly reduces computational costs associated with otherwise having to temporally resolve the pressure waves that travel at the speed of sound. This assumption would also be

appropriate for turbulent diffusion combustion and low speed deflagrations, however these are out of the scope of the current study.

Turbulence Model

Turbulence is modeled by Large Eddy Simulation (LES) or by Direct Numerical Simulation (DNS). LES directly solves for fluid flow fluctuations for turbulent length scales resolvable by the largest dimension of the specified mesh and utilizes models for fluid flow fluctuations for turbulent length scales smaller than those that are explicitly resolved by the mesh. Alternatively, FDS has an option to directly solve all turbulent length scales using molecular properties by DNS; however DNS is intended for research of laboratory scale because the grid size requirements (typically 1mm grid spacing or less) makes DNS too computationally costly and impractical for industrial scales (typically ~1,000,000 m^3).

Unlike the more commonly used Reynolds Averaged Navier Stokes (RANS) approach that directly solves for the average fluid flow and utilizes models for fluid flow fluctuations for all turbulent length scales, FDS does not "smooth" out turbulent fluctuations that are resolvable by its mesh, allowing for better fidelity of fluid flow behavior from turbulent fluctuations. In theory, this should reduce potential safety factors associated with peak to mean concentrations as a result of turbulent fluctuations. Therefore, LES is more scientifically accurate than other popular CFD turbulence solver approaches, such as RANS, but is more computational expensive.

The LES technique and Smagorinsky sub-grid scale turbulence model would be an appropriate choice to model LNG vapor dispersion.

Lagrangian particles are used to simulate smoke particles, sprinkler discharge, and fuel sprays. Although many facilities use water curtains as a means for vapor dispersion mitigation, and LNG vapor dispersion trials have been conducted with the use of water curtains, this is out of the scope of the current study.

Heat Transport Models

Convective heat transfer between fluid flows (e.g. air and LNG vapor) is modeled via the solution of the basic conservation equations. However, FDS does not account for the heat transfer associated with the condensation of fluids (e.g. LNG vapor temperatures condensing water vapor in air). Neglecting the heat transfer associated with condensation of fluids would result in lesser heat transfer to an LNG vapor cloud and higher concentrations and farther downwind distances. Therefore, the convective heat transfer model would be appropriate for LNG vapor dispersion applications.

Convective heat transfer between the fluid flow and boundaries (e.g. LNG vapor and ground) is obtained from,

$$\dot{q}_c'' = h\left(T_g - T_w\right) \text{ W/m}^2 \text{ [19]}$$

Where $\dot{q}_c^{''}$ is the convective heat transfer rate, T_g is the temperature of the gas, T_w is the temperature of the wall boundary, and h is the convective heat transfer coefficient defined by the maximum of natural and forced convective heat transfer correlations,

$$h = \max\left(1.52\left|T_g - T_w\right|^{1/3}, \frac{k}{L}0.037\,\mathrm{Re}^{4/3}\,\mathrm{Pr}^{1/3}\right)\ \mathrm{W/m^2K}\ [19]$$

This empirical approximation is a weaker point in FDS. However, the convective heat transfer between fluid flows is dominant due to the low velocities experience at the ground, therefore this approximation is not a significant limitation for LNG vapor dispersion applications. In addition, under-prediction of the heat transfer should result in higher concentrations and farther downwind dispersion distances.

Radiative heat transfer is a significant portion of the model, since the main application is for fire events, of which approximately a quarter to a third of the heat release is radiative. The radiative heat transfer is modeled by the radiation transport equation,

$$s \cdot \nabla I_\lambda(x,s) = -[\kappa(x,\lambda) + \sigma_s(x,\lambda)]I_\lambda(x,s) + B(x,\lambda) + \frac{\sigma_s(x,\lambda)}{4\pi}\int_{4\pi}\Phi(s,s')I_\lambda(x,s')ds' \quad [19]$$

To reduce computational costs, the default radiation model in FDS assumes that the radiation is dominated by the non-scattering continuous radiation emission from the soot generated by the fire and therefore assumes the radiation behaves as a grey gas, such that,

$$s \cdot \nabla I(x,s) = \overline{\kappa(x)} \left[\frac{\sigma T(x)^4}{4} - I_\lambda(x,s) \right] \quad [19]$$

Alternatively, a six and nine wide band models assuming the fuel is methane is also available. The mean absorption coefficient is modeled using the RADCAL narrow-band model. The absorption and scattering of liquid droplets are modeled based on Mie theory [19].

The radiative heat transfer models are much more robust than necessary for LNG vapor dispersion and comprises a significant portion of the computational resources. However, FDS has the option of turning off the radiative heat transfer sub-model. Since convective and conductive heat transfer typically dominates the heat transfer in cryogenic vapor dispersion, this is an appropriate approach to use and it would be appropriate to turn off for LNG vapor dispersion applications.

Conduction heat transport is modeled assuming one-dimensional heat conduction into the solid, such that,

$$\rho_s c_s \frac{\partial T_s}{\partial t} = \frac{\partial}{\partial x} \left(k_s \frac{\partial T_s}{\partial x} \right) + \dot{q}'''_{s,c} + \dot{q}'''_{s,r} \quad [19]$$

Solid surfaces are treated as no-slip smooth surfaces and can be specified with thermal boundary conditions. Heat and mass transfer to and from solid surfaces are

modeled with empirical correlations (1D) when using the LES solver, but can be modeled directly when using the DNS solver. The one-dimensional conductive heat transfer model is consistent with other models and would be appropriate to model LNG vapor dispersion.

Spatial Discretization

FDS uses a finite-difference approach on a hexahedral 3D Cartesian grid to discretize the domain (i.e. study area) into control volumes over which it solves the LES equations. FDS is not capable of automatic mesh generation or refinement—grid generation and refinement must be done manually. The structured grid may cause inaccuracies when modeling curved or sloped surfaces. Sloping terrain may be approximated by changing the gravity vector direction. However, approximations of undulating geometries or sloped surfaces relative to the gravity vector will result in a stepped Cartesian mesh. This may introduce artificial obstructions and restrict flow from moving up grade (i.e., stepping blocks flow). Grid refinement will reduce some of these errors. In order to compensate for this artificial manifestation, FDS has a "sawtooth" function that is designed to prevent vorticity from being generated at sharp corners; however it is not recommended for evaluation of boundary layer effects [19]-[23].

In addition, FDS will automatically "snap" vents and obstructions to a grid cell, which can cause unintended consequences if an object does not span an entire grid cell or does not align with the grid, such as gaps in closed surfaces or a reduction or

elimination of a vent (e.g. gaseous source term). For this reason, the user must verify that closed surfaces or corners remain closed within the grid and that openings in walls remain open within the grids. This may be done by visually confirming the objects in the visualization software package supplied with FDS, Smokeview, and adjusting the grid or object to create a solid boundary. Vent dimensions should also be verified to ensure that there is not a significant reduction in the total mass flow rate into the domain. In general, it is recommended that grid sensitivity analyses be conducted for CFD modeling to demonstrate a grid independent result or convergence to a grid independent result.

Numerical method

FDS numerically solves the LES partial differential equations for incompressible flow using the finite difference approach that is second order accurate in space and an explicit predictor-corrector scheme that is second order accurate in time. The convective terms are written as upwind-biased differences in the predictor step and downwind biased differences in the corrector step. A flux transport correction scheme is used at the predictor and corrector steps to manage local overshoots and under-shoots at higher gradients, where values would otherwise exceed physical limits (e.g. mass fraction less than zero). These correction schemes are used in lieu of more accurate higher order solvers to save computational time. However, the accuracy of the numerical solver is expected to be consistent with other CFD numerical solvers and is not expected to be a source of inaccuracy or a limitation of the model for LNG vapor dispersion applications.

Temporal Discretization

FDS time steps are constrained in terms of the Courant Friedrichs Lewy (CFL) number and Von Neumann (VN) number. The CFL number criterion prevents the time step from exceeding the time it takes a fluid particle from crossing more than one grid cell based on convective transport (i.e. fluid flow velocity). The VN number criterion prevents the time step from exceeding the time it takes a fluid particle from crossing more than one grid cell based on diffusive transport. The time step is calculated such that the criterion relating to the CFL and VN numbers are both met. However, for most industrial scale applications, the CFL condition will dominate and therefore the VN condition is only invoked for LES calculations with grid cells smaller than 5mm. For dispersion calculations, a CFL=1 is recommended. If stability problems ensue, the user guide recommends that the CFL numbers be reduced by a factor of 2-4 [23].

User Input/Output

FDS users must specify the following parameters in defining the scenario to be modeled:

- domain (i.e. volumetric region of study);
- initial conditions;
- boundary conditions (e.g. wind profile based on speed, direction, etc.);

- gaseous leak sources (i.e. size/area, location, direction, release rate or velocity as a function of time, temperature, composition);
- optional structures and objects; and
- any optional mitigation (e.g. waterspray, etc).

The FDS User Manual [23] provides guidance on the selection of these parameters in its user manual for several different types of examples. Based on information supplied, FDS provides results according to the 3D, 2D, or scalar data specified to be outputted by the user (e.g. velocity vector field, molar fraction iso-contour surfaces, temperature at a specific location, etc). FDS can model multiple concurrent gaseous leak sources.

Liquid Flashing and Jetting

FDS does not have any sub-models for determining flashing from superheated liquid releases or the mechanical fragmentation of liquid jets into aerosol droplets from high pressure liquid releases. A separate model would need to be used to model these phenomena and input the resultant gaseous source term into FDS.

When a gaseous source term is provided, it is generally recommended that it be aligned to the Cartesian grid and that the grid be refined in the area of the source term. If the grid is not refined and too low of a grid resolution is applied in the jet source cell, the gas concentration may be artificially reduced. It is also recommended

that gaseous source terms do not span across different meshes that are solved on different processors when using multi-processors.

Liquid Pool Spreading

FDS does not have any sub-models for liquid pool spreading that can be used as input. A separate model would need to be used to determine the pool spread and subsequent vaporization. The vaporization rate and pool dimensions (i.e. source term) could then be used as input into FDS.

Wind Profile

FDS is able to simulate steady or unsteady (i.e. transient) wind profiles. The magnitude of the wind velocity and wind direction can be defined by specifying the velocity in the x-, y-, and z- directions along the domain boundaries. Ramp functions can then be used to fluctuate the velocity component in the normal direction. However, the ability to fluctuate the normal velocity only, makes it difficult to reproduce the transient wind field. A more accurate approach would be to create a vent and corresponding ramp function for each time step; however, this is much too tedious for longer duration events, and may exceed computational requirements. Using the ramp function or assuming a steady state or periodic wind speed and direction is often sufficient for hazard analyses, but can pose some limitation in validation against experimental data where varying wind speed and direction cannot be replicated by such simplifications. Assuming a steady wind direction will

generally produce higher downwind concentrations, because there would be less cloud meander and turbulent mixing caused from the change in wind direction. However, this is not always the case as large turbulent eddies, sometimes allow for higher concentrations to be momentarily carried downwind.

Assuming lower wind speeds will generally result in higher downwind concentrations and assuming higher wind speeds will generally result in lower downwind concentrations. FDS should be specified with the lower wind speed that is reflective of the area to produce conservative results. For most applications pertinent to this study, FDS would be used in accordance with 49 CFR Part 193.2059, which specifies the lowest wind speed that occurs 90% of time for the area or 2 m/s. However, the 2 m/s was partially based on the use of an integral model, DEGADIS, that produced the farthest downwind concentrations at 2 m/s; therefore, the user should demonstrate the 2 m/s assumption produces the worst case results for FDS. This is especially important for liquid flows in trenches where the wind speed and direction that produces the farthest downwind distance is much more variable.

Atmospheric Stability

FDS is able to be specified with a linear temperature lapse rate and wind profile exponent to model a range of atmospheric stabilities. However, the wind profile exponent must be determined by the user and inputted into FDS. Lower atmospheric stabilities (i.e. lower wind profile exponents) generally produce lower downwind concentrations and dispersion distances, and higher atmospheric stabilities produce

higher downwind concentrations and dispersion distances. The F stability prescribed in 49 C.F.R. § 193.2059 would generally provide conservative results for LNG releases that disperse over land.

Surface Roughness

FDS does not explicitly use surface roughness as an input, but rather allows the user to specify an atmospheric wind profile with an exponential power that is based on surface roughness and atmospheric stability. Therefore, FDS is limited to the specification of an upwind wind profile that is reflective of a surface roughness at the boundary conditions only. FDS cannot account for terrain with varying surface roughness length. However, assuming an unobstructed flow field with uniform surface roughness is often sufficient to produce conservative results. In addition, FDS can be specified to explicitly model obstructions within the flow field that would be taken into account to determine the surface roughness. Assuming a higher surface roughness will generally result in lower downwind concentrations and assuming a lower surface roughness will generally result in higher downwind concentrations. FDS should be specified with the lowest surface roughness that is reflective of the area to produce conservative results. For most applications pertinent to this study, FDS would be used in accordance with 49 CFR Part 193.2059, which specifies the surface roughness of 0.03 m, so this limitation of the model is not a concern.

Sloped and Varying Level Terrain

As previously discussed, FDS can account for sloped terrain by changing the gravity vector orientation or by using the "sawtooth" function. However, changing the gravity vector would only allow for a constantly sloped terrain, and using the "sawtooth" function is limited to sequential stepping and may also result in inaccuracies near the boundary layer where the highest concentrations of a denser than air vapor cloud typically exist. Generally, assuming a flat surface in lieu of an upward slope would over-predict downwind concentrations, but under-predict cloud widths, and vice-versa for downward slopes. Therefore, FDS should be limited to modeling constant grades and upward slopes, and FDS should not be used for undulating terrain that may result in farther downwind dispersion distances.

Obstructed Flow

FDS models turbulence generated in the flow field and can take into account the change in flow field around obstructions. For most instances, downwind concentrations assuming unobstructed terrain will be over-predictive since less turbulence, and subsequent mixing, would be generated in the flow field and no obstructions would restrict the movement of the dispersing vapor. However, there are instances where downwind concentrations could be under-predictive due to wind channeling effects or a reduction in momentum and subsequent mixing of a gaseous release [42][43]. FDS is able to model these wind channeling effects that may occur between adjacent LNG storage tanks, buildings, or large structures. FDS is also able to model losses of momentum and subsequent entrainment and dilution due to

impingement of a high momentum gaseous jet onto an obstruction. Therefore, for obstructions that can cause wind channeling and obstructions that high momentum jets may impinge upon and reduce the momentum of the jet should be modeled.

Atmospheric turbulent mixing and dilution is solved in FDS by directly solving for fluid flow fluctuations for turbulent length scales resolvable by the specified mesh (i.e. large eddies) and utilizing sub-grid-scale models for fluid flow fluctuations for turbulent length scales smaller than those that are explicitly resolved by the mesh (i.e. small eddies). Since LES directly solves for large eddies, and small eddies are not expected to provide significant concentration fluctuations, a factor of 2 safety margin associated with the turbulence model may not be necessary.

Scientific Assessment Conclusion

FDS includes mathematical models that encompass all 11 qualitative criteria under the MEP and Advisory Bulletin, and therefore has an appropriate scientific basis to describe the physics of the dispersion of LNG vapors when used within the described constraints and limitations. Nonetheless, LNG vapor dispersion modeling in FDS could benefit from the following:

- built-in source term model(s) for superheated and high pressure liquid releases, including associated aerosol formation, rainout, liquid pool spread and vaporization;

- initial condition option for atmospheric wind profiles to reduce computational costs associated with establishing a quasi-steady state wind field prior to initiating a gaseous source into the domain;
- turbulence parameters for "vents" for better approximation of turbulent sources (e.g. wind fields in atmospheric boundary layer);
- ramp functions for each of the x-, y-, and z- components of "vents" for better replication of transient sources (e.g. wind fields in atmospheric boundary layer);
- heat transfer effects from condensation of water vapor in atmosphere; and
- non-Cartesian grid at boundaries and obstructions to reduce errors associated with "stepping" of grid.

Chapter 7: Verification

Similar to many other designed and constructed products, mathematical and computer models should have a quality assurance and quality control (QA/QC) program in place in order to ensure that the design (i.e. theoretical physics/science of the model) is implemented correctly and free of errors (i.e. "bugs") accidentally introduced during the construction (i.e. computer coding) of the design.

Since many computer program codes are proprietary that would not allow for a line-by-line evaluation to assure the model is coded correctly, and such an endeavor would be overly cumbersome, the MEP evaluates the documented QA/QC programs and efforts in place to ensure model has been verified adequately.

Although there are no explicit requirements within the MEP or Advisory Bulletin for verification, the QA/QC programs in place may affect the approval conditions of a particular model, such as third party verification of the model results where QA/QC programs are not present.

NIST has a quality management system that helps assure the models have been translated into the code correctly. NIST follows many of the generally accepted quality assurance publications, certifications, and standards, as well as quality management systems which require a number of software development and maintenance specific items. It is not clear if NIST is ISO 9001 certified or whether their software division adheres to all of the requirements in ISO 90003 or TickIT.

However, quality assurance measures are in place, such as using version control systems when writing source code.

NIST has compiled a FDS Verification Guide [20] that indicates FDS numerical results have been verified for a number of its "sub-models" (e.g. radiation transport solver, one-dimensional heat conduction equation, hydrodynamic solver, etc) against a number of "simple" analytical solutions (e.g. 2D analytical solution to incompressible Navier Stokes, stationary compression waves in 1D and 2D). For more "complex" scenarios where analytical solutions do not exist, NIST has carried out tests to check symmetry and directional similar behavior of numerical schemes. This is done for every version released [20]. Identical simulations are performed to compare results on various software (i.e. Unix, Linux, Windows, Mac OSX) and computer platforms (e.g. IGM, HP, Sun, Apple, Digital Equipment Corporation, Silicon Graphics, Dell, Compaq, etc). Similar tests are also provided for different compilers (e.g. Lahey Fortran, Digital Visual Fortran, Intel Fortran, IBM XL Fortran, etc), and optimizations to discover compiler and optimization errors. NIST's quality assurance program also contains software "issue" tracking logs reported by users of the software, and version control programs, which addresses some of the requirements in ISO 90003 and TickIT. Although it is not clear if NIST is certified to ISO 90001, NIST appears to have an acceptable quality assurance system in place to assure FDS is properly implemented and any bugs are resolved in a timely fashion.

FDS is not proprietary and its executable and source code files are freely available to the public, which makes it possible for users to modify the source code and recompile the executable, making quality control unmanageable from a regulatory standpoint. To address the lack of quality control possible with FDS, it is encouraged that simulations be confirmed by an independent party, agency, or authority having jurisdiction.

Verification Conclusion

NIST has an acceptable quality assurance system in place to assure FDS is properly implemented, but is limited in quality control from a regulatory standpoint by being an open source code. Therefore, FDS results should be confirmed by an independent party or authority having jurisdiction to ensure that the source code has not been modified.

Chapter 8: Validation

In order to assess the validity of a model, the model is compared to experimental data that it is intended to predict. The model validation is used to qualitatively and quantitatively compare the model predictions with experimental datum.

The MEP and Advisory Bulletin includes thirty-three experiments from eight different datasets comprised of field trials and wind tunnel tests. The experiments are categorized into an unobstructed group (Group 1) and an obstructed group (Group 2) and by measurements that are based on short- and long-time averages. Field trials and un-scaled wind tunnel experimental data are co-mingled as part of the Groups, but there is a separate categorization for scaled wind tunnel tests.

Table 1 - MEP Datasets and Tests

Dataset/Series	Tests	Type	Group	Time-Average
Maplin Sands	27, 34, 35	Field	Unobstructed	Long
Burro	3, 7, 8, 9	Field	Unobstructed	Short
Burro	3, 7, 8, 9	Field	Unobstructed	Long
Coyote	3, 5, 6	Field	Unobstructed	Short
Coyote	3, 5, 6	Field	Unobstructed	Long
Falcon	1, 3, 4	Field	Obstructed	Short
Falcon	1, 3, 4	Field	Obstructed	Long
Thorney Island	45, 47	Field	Unobstructed	Long
CHRC	A	Wind tunnel	Unobstructed	Long
CHRC	B, C	Wind tunnel	Obstructed	Long
BA Hamburg	DA0120, DAT223	Wind tunnel	Unobstructed	Long
BA Hamburg	039051, 039072, DA0501, DA0532, 039094, 039097	Wind tunnel	Obstructed	Long
BA Hamburg	DAT647, DAT631, DAT632, DAT637	Wind tunnel	Unobstructed	Long
BA TNO	TUV01, FLS	Wind tunnel	Unobstructed	Long
BA TNO	TUV02	Wind tunnel	Obstructed	Long

FDS is able to simulate dispersion over unobstructed and obstructed flow fields, including sloped terrain. Therefore, the current validation study includes all 33 of the trials:

- LNG Field Trials: Maplin Sands 27, 34, 35; Burro 3, 7, 8, 9; Coyote 3, 5, 6; Falcon 1, 3, 4
- Other Field Trials: Thorney Island 45, 47; and
- Wind Tunnel Experiments: CHRC A, B, C; BA-Hamburg DA0120 (Unobstructed), DAT223 (Unobstructed 2); 039051 (Upwind Fence), 039072 (Upwind Fence 2), DA0501 (Downwind Fence), DA0532 (Downwind Fence 2), 039094/039095 (Circular Fence), 039097 (Circular Fence 2), DAT647 (Slope 1), DAT631 (Slope 2), DAT632 (Slope 3), DAT637 (Slope 4); and BA-TNO TUV01, TUV02, FLS.

The wind tunnel experiments tests were evaluated for scaled scenarios only to better evaluate grid size at the scales of interest.

A description of each experiment, subsequent modeling approach, and a qualitative examination of the model results are described. Statistical performance measures (SPMs) are then provided for a more quantitative examination of the model results.

Maplin Sands Series

The Maplin Sands trials were conducted in 1980 by Shell Research Limited at an experimental establishment of the UK Ministry of Defense located on the coastline of Foulness Island, about 50 miles east of London.

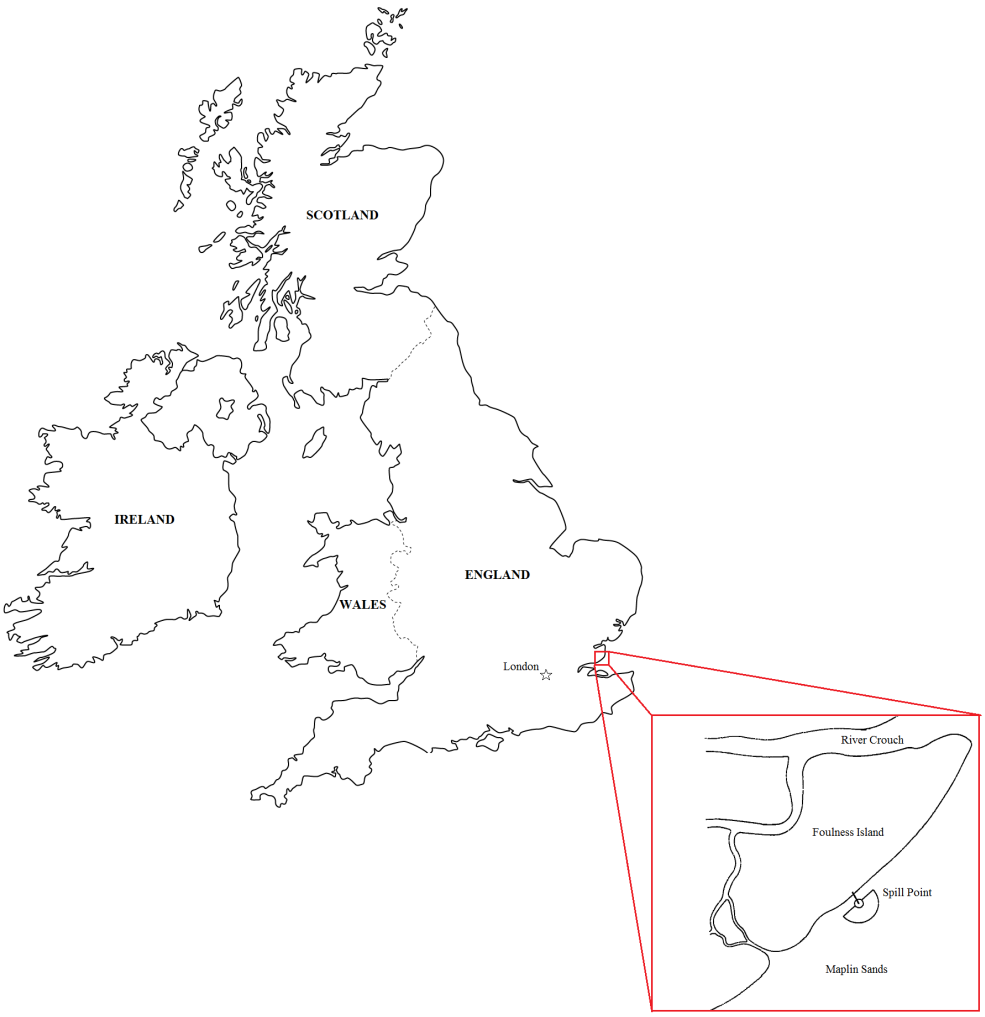


Figure 3 - Maplin Sands Trials Location

The trials consisted of 34 spills of liquefied natural gas and liquefied propane gas released onto water and dispersed over water. Both continuous and instantaneous releases were conducted. However, many of the initial continuous LNG experiments had too little of a volumetric flow rate and quantity to provide useful results. Other trials suffered from wind directions that did not coincide with the sensor arrays or ignited prematurely. Furthermore, instantaneous tests are not relevant for NFPA 59A or 49 CFR 193.2059 applications. Therefore, following the MEP, only Maplin Sands 27, 34, and 35 were selected for evaluation.

Table 2 - Maplin Sands Trials

Trial	Material	Release Rate (m^3/min)	Quantity (m^3)	Notes
27	LNG	2.8-3.2	12.6	Ignited after 183s at 88m, -45°.
34	LNG	3.0	10.2	
35	LNG	3.8-4.7	18.3	

The MEP [10] reports a surface roughness of 0.0003m for Maplin Sands consistent with the Modeler's Data Archive [35]. Ermak et al. [44] reports a surface roughness of 0.000058 m. The Maplin Sands Reports [45]-[48] provides a surface roughness estimate of 0.00002 m based on a 1:20 scale wind tunnel experiment to determine the effect on the surface roughness from the pontoons that were fitted with the sensor arrays. Based on photographic observations and knowledge of the test site, most users could reasonably assume the surface roughness to correspond to open calm water or sea in coastal areas, which typically are reported to have a surface roughness of 0.0001 m for calm open seas and 0.001m for sea in coastal areas. Brutsaert [49]

reports a surface roughness of 0.0001m to 0.0006m for large water surfaces. In accordance with the MEP, a surface roughness of 0.0003m was used to determine the wind profile. In addition, the pontoons were explicitly included in the FDS input files.

The continuous spills were supplied by a 335m long 8-inch diameter cryogenic line with 6-inch diameter vertical discharge pipe that could flow up to $6m^3$/min with an approximate $8m^3$ total capacity of which approximately $6m^3$ capacity between the valve located at the seawall onshore and discharge of the pipe. Offshore winds between 2m/s and 8m/s were necessary to provide safe and desirable experimental data. Unfortunately, these wind conditions most often coincided with low tide, which spurred the construction of a 300m diameter low lying dike to hold the seawater to a minimal depth of 30cm at low tide. No measurements were made of the rate of flow of liquid from the end of the spill pipe, but rather all flow instrumentation was at the landward end of the pipe.

Seventy-one instrument stations with a total of approximately 360 sensors were located on masts atop aluminum pontoons. The instrument stations collected various ambient data in addition to gas concentration and temperature data. A total of approximately two-hundred gas concentration sensors were located on 4m instrument station masts at elevations of approximately 1.0m, 1.5m, and 2.5m above the water surface. The accuracy of the gas sensors are tabulated.

Table 3 - Maplin Sands Trials Gas Sensor Uncertainty

Observed concentration %	90% confidence level
5	-1.9, +1.9
10	-3.4, +3.2
15	-4.8, +4.5
30	-8.7, +9.7

Sixty-six thermocouples were located to collect vapor cloud temperature data. The thermocouples were made of Ni/Cr, Ni/Al with a 0.5mm bead and had a range of -100°C to 500°C.

Wind speed and direction were measured at 10m with cup anemometers, ultrasonic anemometers, and wind vanes. The cup anemometers were accurate within 2% or 0.1m/s and ultrasonic anemometers within 1%. Ambient and seawater temperatures were measured at various elevations by platinum resistance thermometers with a range of 0-50°C and accuracy within 0.3°C. Relative humidity was measured at 10m with a temperature controlled capacitance device, however these devices often failed and data from the Foulness Island Meteorological station located 5km away were relied upon. Insolation was measured with thermopile solarimeters.

The sensors were located concentrically around the spill point at distances of approximately 58m, 90m, 130m, 180m, 250m, 325m, 400m, 525m, and 650m from the center of the spill location.

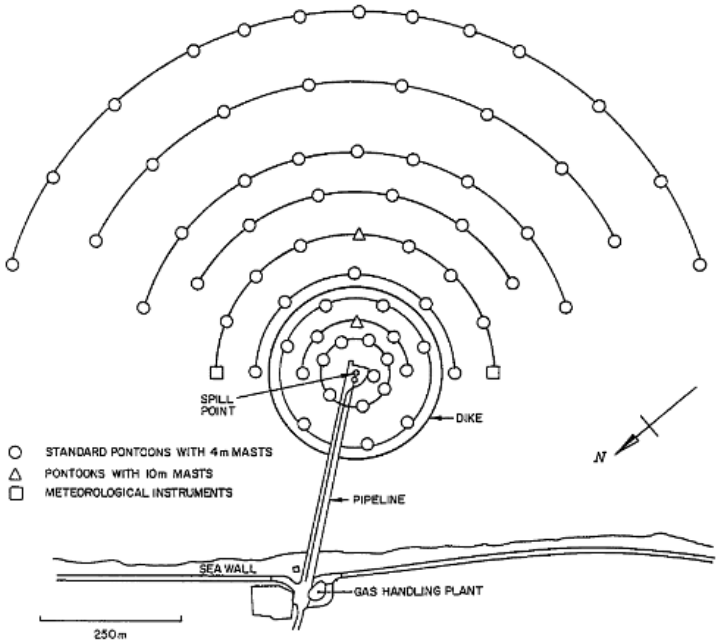


Figure 4 - Maplin Sands Instrumentation Locations

Maplin Sands 27

For Trial 27 the LNG composition taken before discharge was 93.2% methane, 5.4% ethane, 1.1% propane, 0.2% iso-butane, 0.1% n-butane. Prior to the release, the pipe was pre-cooled with liquid nitrogen to reduce vaporization within the discharge pipeline. The discharge lasted for about 4min with about 160seconds of steady state flow at 3.2m^3/min with an initial driving gas pressure of approximately 500kPa and final driving gas pressure of 400kPa. The 6-inch diameter vertical discharge pipe terminated approximately 0.5m above the water surface at low tide. A timeline of the release is tabulated below.

Table 4 - Maplin Sands 27 Spill Sequence

Timeline	Description
Sept 9, 1980 10:37:34 (t=0)	Start of data collection
Sept 9, 1980 10:40:05 (t=151)	Liquid valve at sea wall opened
Sept 9, 1980 10:41:24 (t=230)	Full steady state flow established
Sept 9, 1980 10:44:04 (t=390)	Full steady state flow ends
Sept 9, 1980 10:44:07 (t=393)	Liquid valve at sea wall closed
Sept 9, 1980 10:44:08 (t=394)	Ignition at 88m, -45deg

Using the flow rate and duration, the FERC commissioned, American Bureau of Shipping (ABS/FERC) pool spread model [50][51] was used to determine the source term to be inputted into FDS. The pool spread model is based upon the shallow water equations in Gas Accumulation Over Spreading Pools (GASP) [52] and a mass balance using an empirically derived vaporization rate of 0.167 kg/m^{2}s. Selected ABS/FERC pool spread calculations are included in Appendix A.

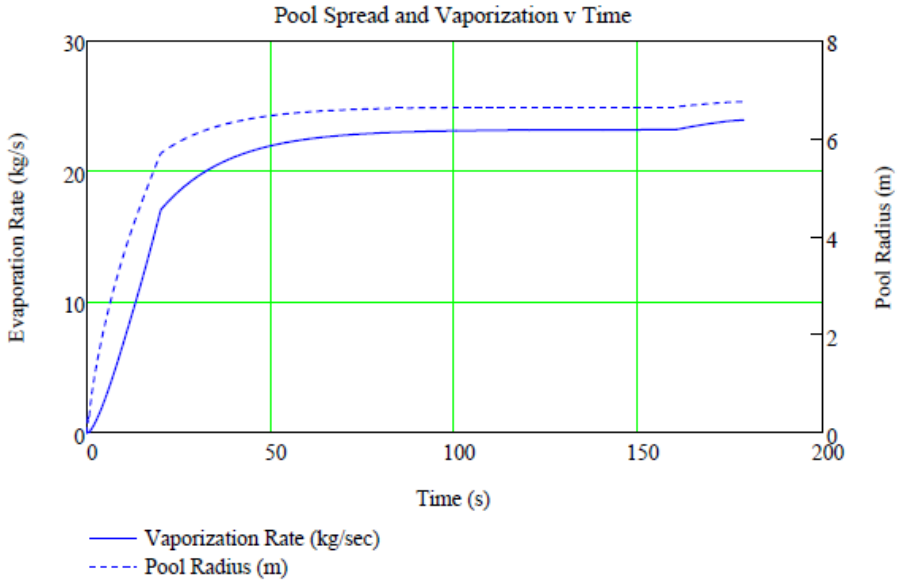


Figure 5 - Maplin Sands 27 ABS/FERC Pool Spread and Vaporization Results

The test was conducted during wind speeds ranging from 3.3 m/s to 9.2 m/s with a domain average of 5.6m/s and standard deviation of 0.7 m/s. The wind direction relative to the array axis ranged from -89.9 degrees to -45.4 degrees with an average of -57 degrees and standard deviation of 5 degrees. Atmospheric stability was category C-D. Ambient temperature had a mean of 288 K with little fluctuation. Relative humidity ranged had a mean of 52% with little fluctuation. Insolation ranged from 301W/m^2 to 566W/m^2 with a mean of 493W/m^2 and standard deviation of 2 W/m^2. The sea temperature was approximately 289 K. The average temperature, average relative humidity, and upwind transient wind field data were used as input into FDS and compared well with the experimental measurements. The FDS simulations were run until a steady or quasi-steady wind profile was established throughout the domain in each test before starting the dispersion. The FDS input files are included in Appendix B. Point-wise data wind sensor data can be found in Appendix C.

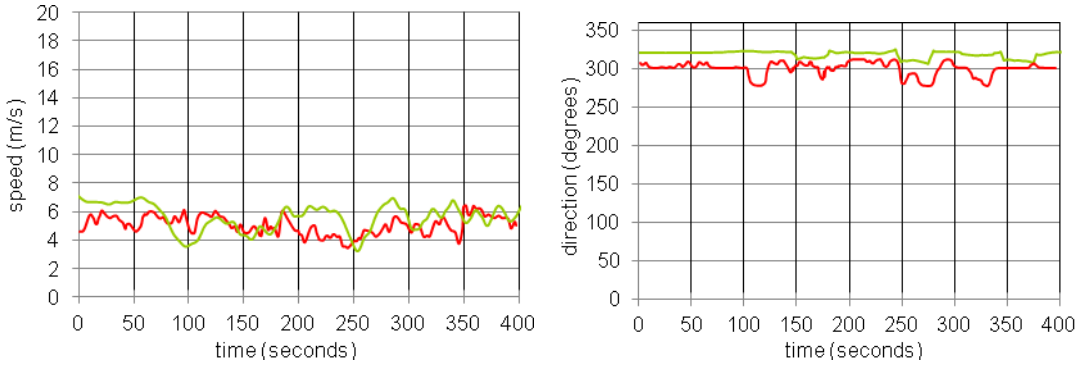


Figure 6 - Maplin Sands 27 Upwind Wind Field Data

(red: experimental data; green: FDS data)

The corresponding vapor concentration of the visible cloud was calculated [53] and compared to the visible cloud contour reported in the data report. FDS generally shows good agreement in the trajectory of the vapor cloud, but shows a narrower and shorter vapor cloud than the experimental data.

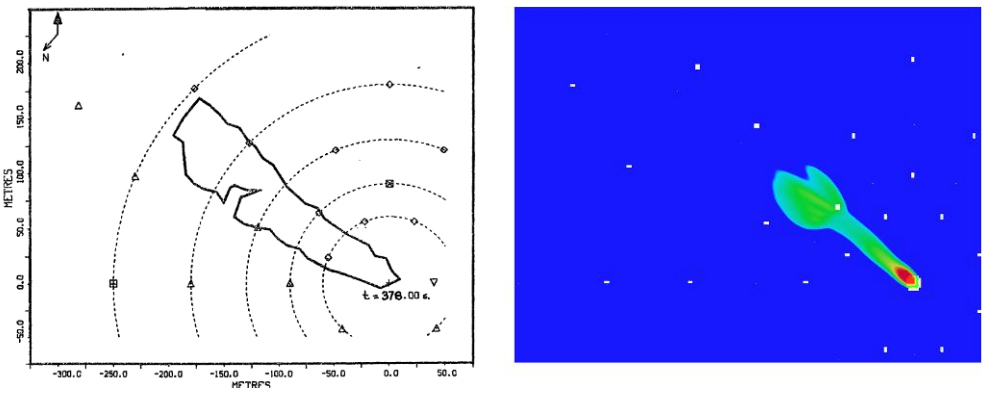


Figure 7 - Maplin Sands 27 Instantaneous Visible Vapor Cloud Contours at Z=2m over 450m (horizontal axis) by 350m (vertical axis) domain at 378 seconds (left: experimental contour; and right: FDS contour)

In addition, FDS included all sensors that were included in the experimental trials. Maximum arc-wise gas concentrations agree very well. Maximum point-wise gas sensor data can be found in Appendix D. Temperature sensor data can be found in Appendix E.

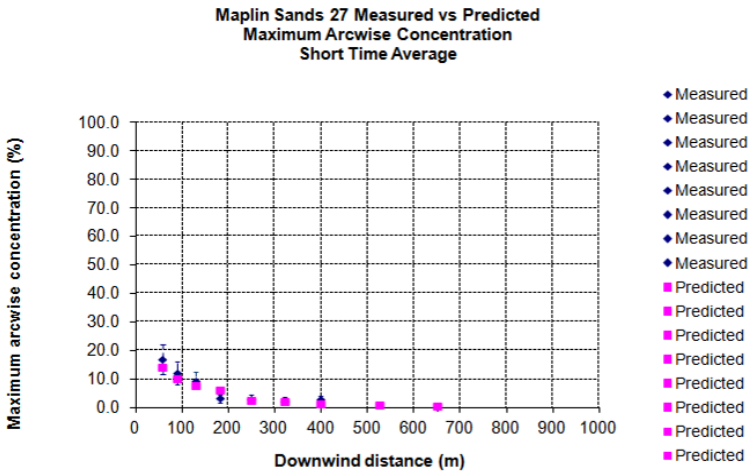


Figure 8 - Maplin Sands 27 Maximum Arcwise Concentrations

Maplin Sands 34

For Trial 34 the LNG composition taken before discharge was 95.9% methane, 2.6% ethane, 0.9% propane, 0.3% isobutene, 0.3%nbutane. Prior to the release, the pipe was pre-cooled with liquid nitrogen to reduce vaporization within the discharge pipeline. The discharge lasted for about 3 minutes and 25 seconds with about 95 seconds of steady state flow at 3.0m^3/min with an initial driving gas pressure of approximately 560kPa and final driving gas pressure of 450kPa. The 6-inch diameter vertical discharge pipe was outfitted with 6-inch diameter flexible hose that terminated approximately 0.7m above the water surface at low tide. A timeline of the release is tabulated below.

Table 5 - Maplin Sands 34 Spill Sequence

Timeline	Description
Sept 17, 1980 10:03:00 (t=0)	Start of data collection
Sept 17, 1980 10:07:54 (t=294)	Liquid valve at sea wall opened, gas flow visible
Sept 17, 1980 10:09:03 (t=363)	First liquid onto sea
Sept 17, 1980 10:09:25 (t=385)	Full steady state pool established
Sept 17, 1980 10:11:00 (t=480)	Full steady state flow ends
Sept 17, 1980 10:11:02 (t=482)	Large increase in gas source.
Sept 17, 1980 10:11:16 (t=496,504)	Liquid valve at sea wall closed

Using the flow rate and duration, the ABS/FERC pool spread model [50][51] was used to determine the source term to be inputted into FDS. The pool spread model is based upon the shallow water equations in GASP [52] and a mass balance using an empirically derived vaporization rate of 0.167 kg/m^{2}s. Selected ABS/FERC pool spread calculations are included in Appendix A.

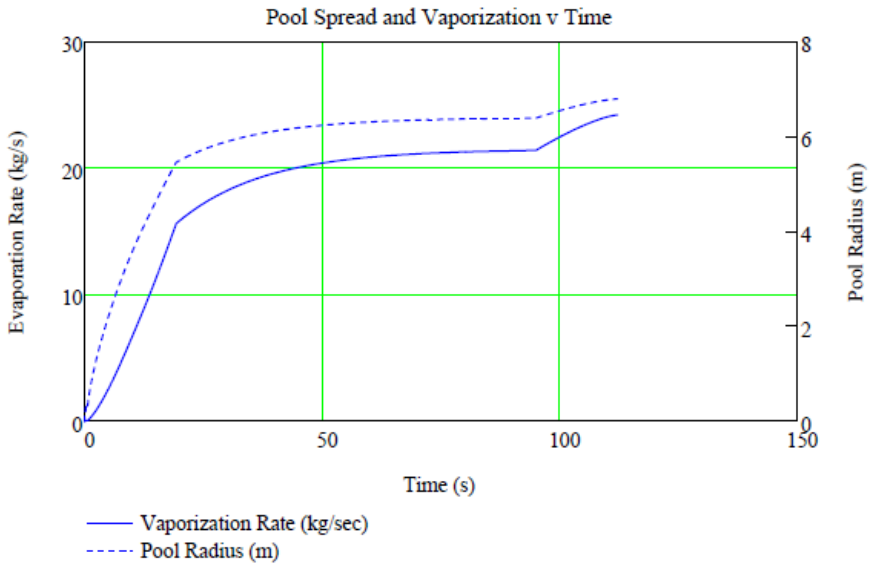


Figure 9 - Maplin Sands 34 ABS/FERC Pool Spread and Vaporization Results

The test was conducted during wind speeds ranging from 6.0 m/s to 9.8 m/s with a domain average of 8.5 m/s and standard deviation of 0.6 m/s. The wind direction relative to the array axis ranged from -57 degrees to -106 degrees with a domain average of -96 degrees and standard deviation of 4 degrees. Atmospheric stability was category D. Ambient temperature had a mean of 288 K with little fluctuation. Relative humidity had a mean of 72% with little fluctuation. Insolation ranged from 427 W/m^2 to 461 W/m^2 with a mean of 449 W/m^2 and standard deviation of 8.5 W/m^2. The sea temperature was approximately 289 K. The average temperature, average relative humidity, and upwind transient wind field data were used as input into FDS and compared well with the experimental measurements. The FDS simulations were run until a steady or quasi-steady wind profile was established throughout the domain in each test before starting the dispersion. The FDS input files are included in Appendix B. Point-wise data wind sensor data can be found in Appendix C.

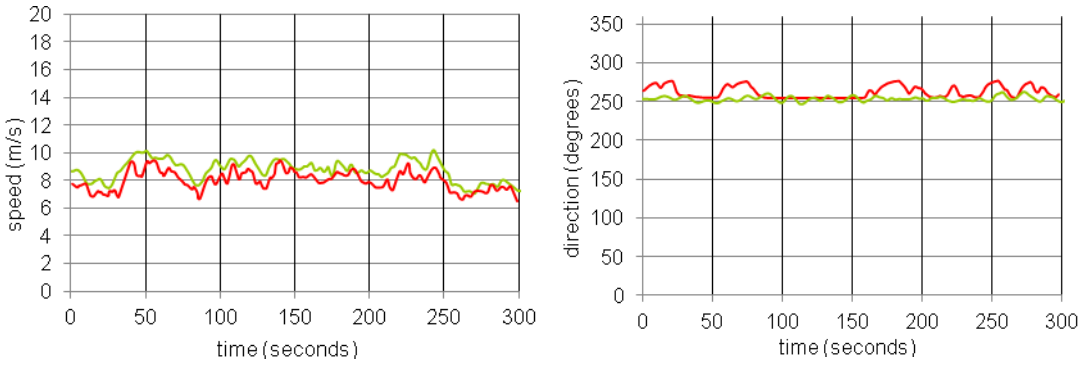


Figure 10 - Maplin Sands 34 Upwind Wind Field Data

(red: experimental data; green: FDS data)

The corresponding vapor concentration of the visible cloud was calculated [53] and compared to the visible cloud contour reported in the data report. FDS generally shows good agreement, but is narrower than the experimental data and does not intersect as many sensors.

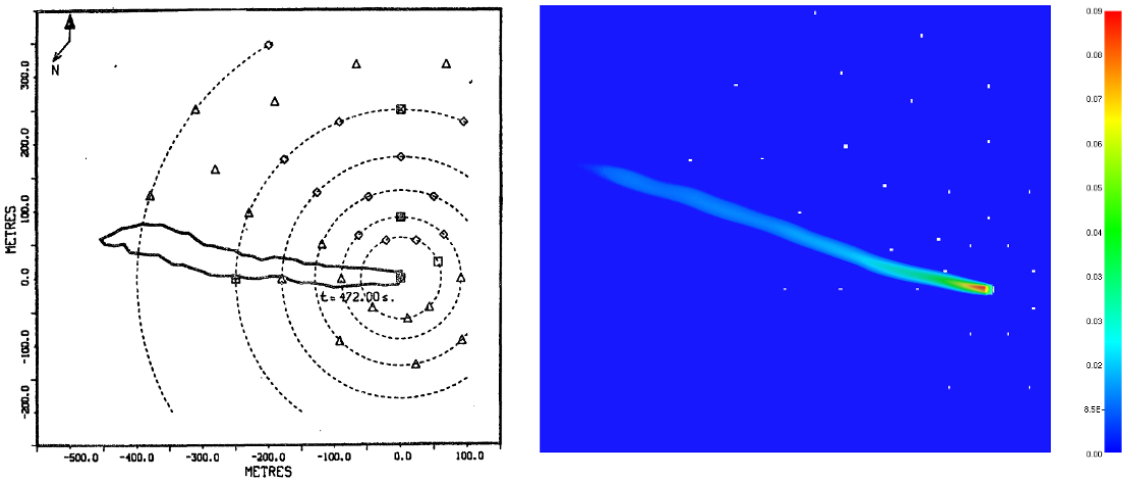


Figure 11 - Maplin Sands 34 Instantaneous Visible Vapor Cloud Contours at Z=2m over 700m (horizontal axis) by 600m (vertical axis) domain at 472 seconds (left: experimental contour; right: FDS contour)

In addition, FDS included all sensors that were included in the experimental trials. Maximum arc-wise gas concentrations does not agree very well, most likely due to the vapor cloud missing the sensor arrays. Maximum point-wise gas sensor data can be found in Appendix D. Temperature sensor data can be found in Appendix E.

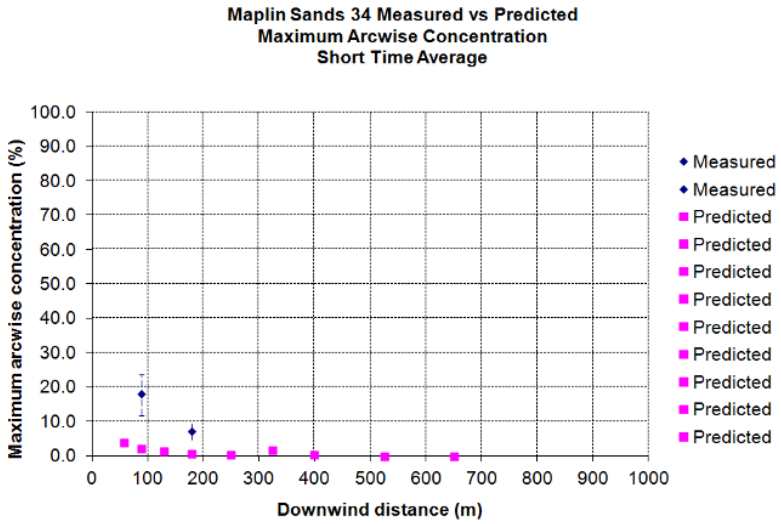


Figure 12 - Maplin Sands 34 Maximum Arcwise Concentrations

Maplin Sands 35

For Trial 35 the LNG composition taken before discharge was 97.8% methane, 1.7% ethane, 0.4% propane, 0.1% isobutene. Prior to the release, the pipe was pre-cooled from Trial 34 to reduce vaporization within the discharge pipeline. The discharge lasted for about 3 minutes and 50 seconds with about 135 seconds of steady state flow at 3.9m^3/min and then an increase to 4.7m^3/min for about 41 seconds with an initial driving gas pressure of approximately 570kPa and final driving gas pressure of 350kPa. The 6-inch diameter vertical discharge pipe was outfitted with 6-inch diameter flexible hose that terminated approximately 0.5m above the water surface at low tide. A timeline of the release is tabulated below.

Table 6 - Maplin Sands 35 Spill Sequence

Timeline	Description
Sept 17, 1980 11:04:45 (t=0)	Start of data collection
Sept 17, 1980 10:07:00 (t=135)	Liquid valve at sea wall opened
Sept 17, 1980 10:08:30 (t=225)	steady state flow established
Sept 17, 1980 10:10:45 (t=360)	steady state flow ends
Sept 17, 1980 10:10:49 (t=365)	Control valve opened further from 50 to 60% to increase flow from 3.9m^3/min to 4.7m^3/min
Sept 17, 1980 10:11:31 (t=406)	Liquid valve at sea wall closed

Using the flow rate and duration, the ABS/FERC pool spread model [50][51] was used to determine the source term to be inputted into FDS. The pool spread model is based upon the shallow water equations in GASP [52] and a mass balance using an empirically derived vaporization rate of 0.167 kg/m^2s. Selected ABS/FERC pool spread calculations are included in Appendix A.

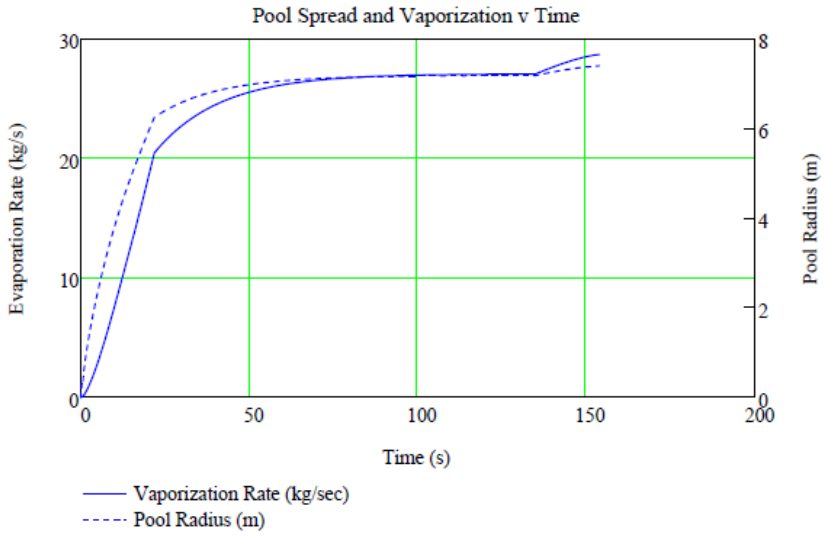


Figure 13 - Maplin Sands 35 ABS/FERC Pool Spread and Vaporization Results

The test was conducted during wind speeds ranging from 6.0 m/s to 14.7 m/s with a domain average of 9.6 m/s and standard deviation of 1.1 m/s. The wind direction relative to the array axis ranged from -59 degrees to -101 degrees with a domain average of -78 degrees and standard deviation of 4 degrees. Atmospheric stability was category D. Ambient temperature ranged had a mean of 289.3 K with little fluctuation. Relative humidity had a mean of 63% with little fluctuation. Insolation ranged from 555 W/m^2 to 564 W/m^2 with a mean of 561 W/m^2 and standard deviation of 6.6 W/m^2. The sea temperature was approximately 289.8 K. The average temperature, average relative humidity, and upwind transient wind field data were used as input into FDS and compared well with the experimental measurements. The FDS simulations were run until a steady or quasi-steady wind profile was established throughout the domain in each test before starting the dispersion. The FDS input files are included in Appendix B. Point-wise data wind sensor data can be found in Appendix C.

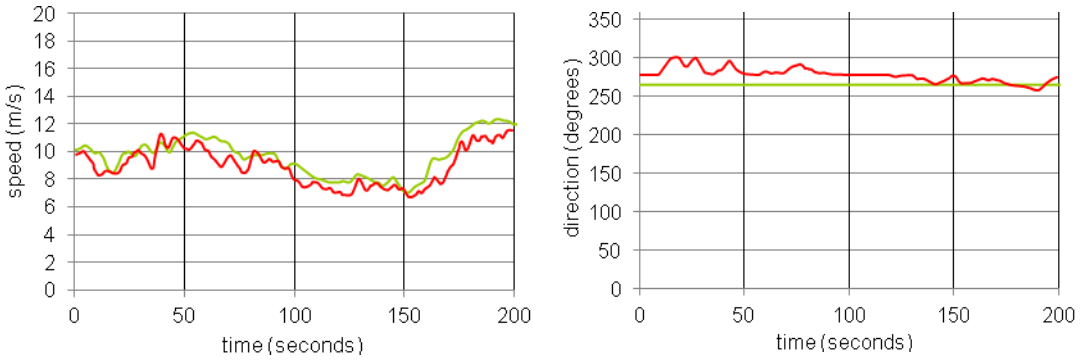


Figure 14 - Maplin Sands 35 Upwind Wind Field Data

(red: experimental data; green: FDS data)

The corresponding vapor concentration of the visible cloud was calculated [53] and compared to the visible cloud contour reported in the data report. FDS is generally under-predictive for the downwind dispersion distance of the visible vapor cloud, and does not match the direction of the visible vapor cloud.

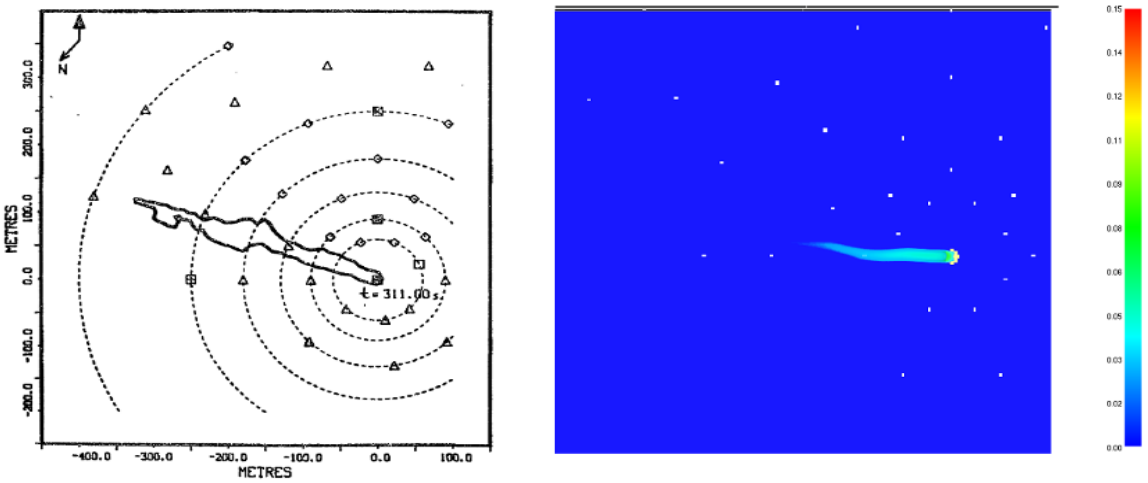


Figure 15 - Maplin Sands 35 Instantaneous Visible Vapor Cloud Contours at Z=2m over 600m (horizontal axis) by 600m (vertical axis) domain at 311 seconds (left: experimental contour; and right: FDS contour)

In addition, FDS included all sensors that were included in the experimental trials. Maximum arc-wise gas concentrations agree fairly well with better agreement in the far field. Maximum point-wise gas sensor data can be found in Appendix D. Temperature sensor data can be found in Appendix E.

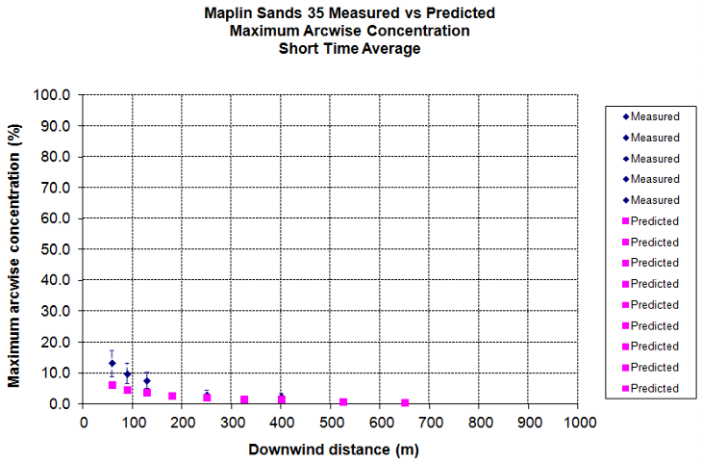


Figure 16 - Maplin Sands 35 Maximum Arcwise Concentrations

Burro Series

The Burro Series trials were conducted in 1980 by Naval Weapons Center and Lawrence Livermore National Laboratory at an experimental establishment of Naval Weapon Center located at China Lake, California, about 150 miles north, northeast of Los Angeles on the western edge of the Mojave Desert.

Figure 17 - Burro Trials Location

The Burro trials were conducted to determine the transport and dispersion of LNG vapor under various atmospheric conditions for continuous releases. Nine tests were carried out. However, the first test released liquid nitrogen onto water to obtain a fog correction algorithm for the infrared gas sensors. Following the MEP, only Burro Series 3, 7, 8, and 9 were selected for evaluation.

Table 7 - Burro Trials

Burro Trial	Material	Release Rate (m^3/min)	Quantity (m^3)	Notes
3	LNG	12.2	34.0	
7	LNG	13.6	39.4	
8	LNG	16.0	28.4	
9	LNG	18.4	24.2	RPTs occurred throughout test

The MEP [10] reports a surface roughness of 0.0002m for Burro and Coyote consistent with the Modeler's Data Archive [35] and Ermak et al. [44]. The Burro Series Report [54]-[57] and Coyote Series Report [57]-[59] provide a value of 0.000205 m. Based on photographic observations of the test site, users could reasonably assume the surface roughness to correspond to a desert or an area with sparse vegetation, which typically have a surface roughness of 0.0005 m for desert and 0.01m for few trees, winter time. Pielke [60] reports a surface roughness of 0.0003m for smooth deserts and 0.01m for the upper range of soils and short grass. Brutsaert [49] reports a surface roughness of 0.04m for grass with some bushes and trees. The terrain was assumed to be flat and free of obstructions with a surface roughness of 0.0002m reported in the MEP was used in FDS to determine the wind profile exponent.

The spills were supplied by a 25cm diameter cryogenic line discharge pipe from an approximate 40m^3 total capacity storage tank. The LNG was released onto water to allow for a near steady state vaporization rate, as the convective motion of the water provided a relatively constant heat transfer rate. The discharge of the pipe is centered 1.5m above a 1m deep water pond. The water pond had an average diameter of 58m

and the water surface was approximately 1.5m below the surrounding grade. The slopes of all the banks except the south bank were reduced to minimize turbulence.

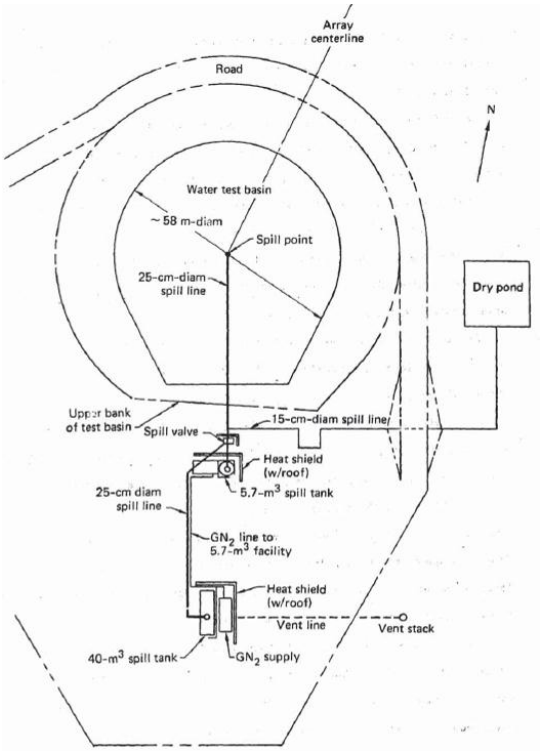


Figure 18 - Burro Trials Spill Setup [54]-[57]

Twenty weather stations and twenty-five instrument stations located on 2m and 10m masts, respectively, collected various ambient data in addition to gas concentration and temperature data.

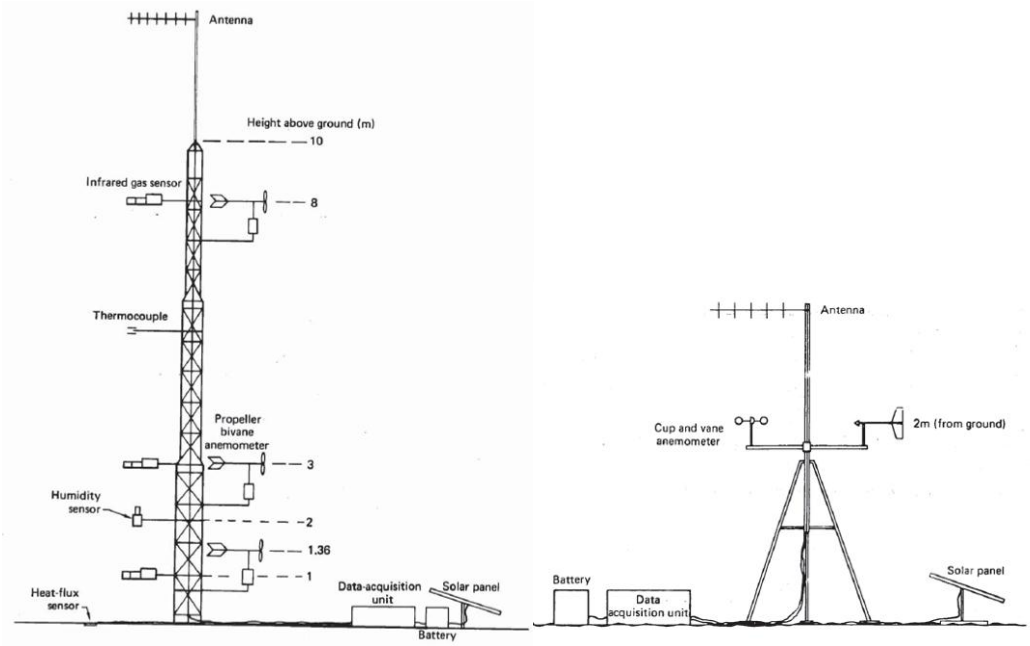


Figure 19 - Burro Trials Instrumentation Arrays [54]-[57]

The weather stations measured wind speed and direction with cup-and-vane anemometers accurate within +/- 1% or 0.07 m/s. The instrument stations were outfitted with standard type K thermocouples made of Cr/Al with a 10mil bead, and various gas concentration sensors at elevations of approximately 1m, 3m, and 8m above grade. The accuracy of the gas sensors are shown below.

Table 8 - Burro Trials Gas Sensor Uncertainty

Sensor	**Uncertainty**
LLNL Infrared Sensor	5.5% of gas sensor reading
MSA Catalytic Sensor	10% of gas sensor reading
IST Solid State Sensor	30% of gas sensor reading (<5% concentrations) 50% of gas sensor reading (>5% concentrations)

The sensors were located in concentric arcs (200° to 250°) around the spill point coincident with the prevailing wind (225°) at distances of approximately 57m, 140m, 400m, and 800m from the center of the spill location.

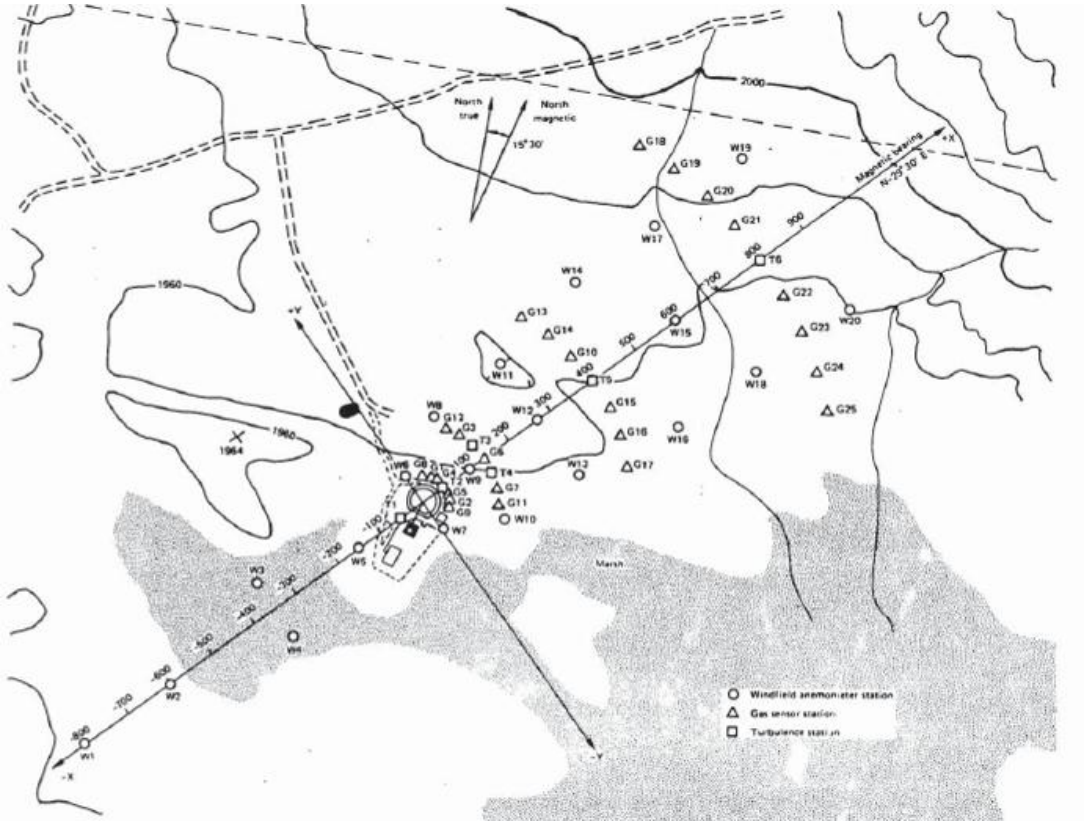


Figure 20 - Burro Trials Instrumentation Locations [54]-[57]

Burro 3

For Trial 3, the LNG composition taken before discharge was 92.5% methane, 6.2% ethane, and 1.3% propane. The discharge lasted for about 2 minutes and 55 seconds with about 2 minutes 47 seconds of steady state flow at 12.2m^3/min. A timeline of the release is tabulated.

Table 9 - Burro 3 Spill Sequence

Timeline	Description
July 2, 1980 15:08:00	Valve begins to open
July 2, 1980 15:08:06 (t=0)	Valve open
July 2, 1980 15:10:47 (t=161)	Valve beings to close
July 2, 1980 15:10:55 (t=169)	Valve closed

Using the flow rate and duration, the ABS/FERC pool spread model [50][51] was used to determine the source term to be inputted into FDS. The pool spread model is based upon the shallow water equations in GASP [52] and a mass balance using an empirically derived vaporization rate of 0.167 kg/m^{2}s. Selected ABS/FERC pool spread calculations are included in Appendix A.

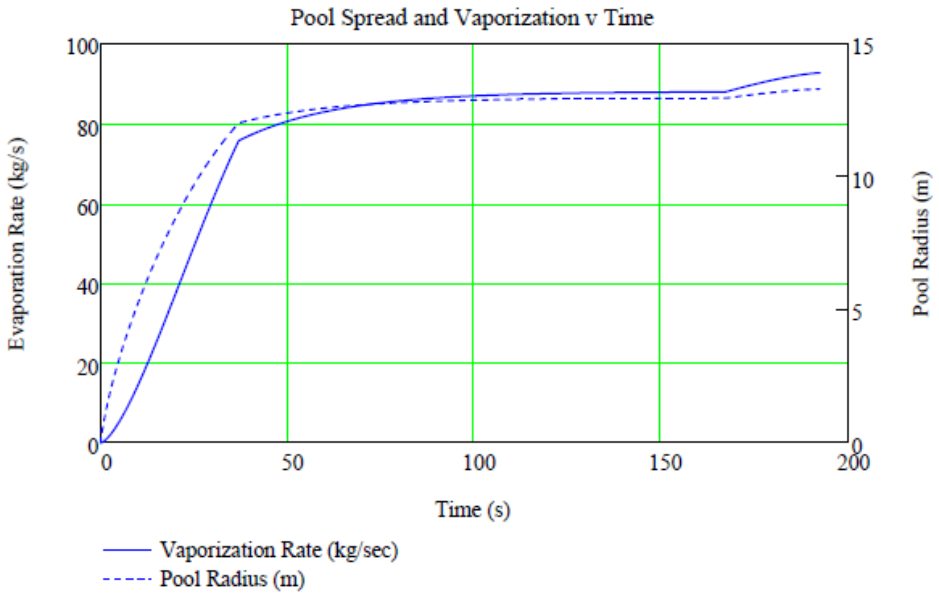


Figure 21 - Burro 3 ABS/FERC Pool Spread and Vaporization Results

The test was conducted during wind speeds ranging from 1.0 m/s to 9.7 m/s with a domain average of 5.4 m/s and standard deviation of 1.2 m/s. The wind direction

relative to the array axis (225 degrees from True North) ranged from -56 degrees to +68 degrees with a domain average of -1 degree and standard deviation of 13 degrees. Atmospheric stability was category B. Ambient temperature had a mean of 307.8 K with very little fluctuation. Relative humidity was approximately 5.2% and insolation was approximately 154 W/m^2. The average temperature, average relative humidity, and upwind transient wind field data were used as input into FDS. The pond temperature was assumed to be equal to the ambient temperature. The FDS simulations were run until a steady or quasi-steady wind profile was established throughout the domain in each test before starting the dispersion. Averaged wind field data compared very well with the experimental measurements. The FDS input files are included in Appendix B. Point-wise data wind sensor data can be found in Appendix C.

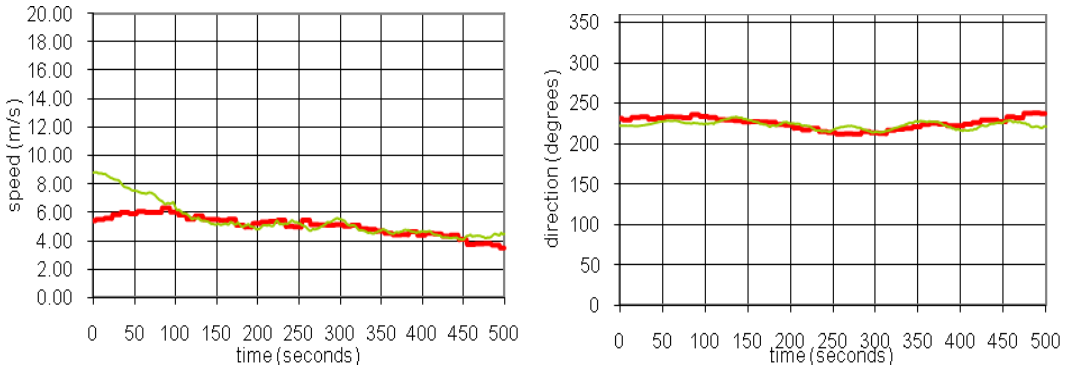


Figure 22 - Burro 3 Average Wind Field Data

(red: experimental data; green: FDS data)

The corresponding FDS vapor concentrations are compared to the cloud contours in the data report. FDS predicts a significantly narrower and longer plume compared to the experimental data.

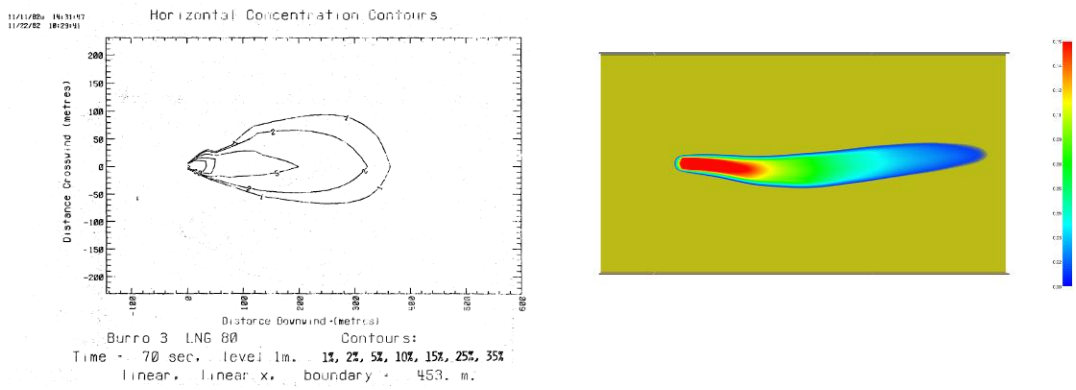


Figure 23 - Burro 3 Instantaneous Vapor Cloud Contours at Z=2m over 750m (horizontal axis) by 450m (vertical axis) domain at 70 seconds (left: experimental contours of 1%, 2%, 5%, 10%, 15% [55] right: FDS contour with scale of 1% blue to 15% red)

In addition, FDS included all sensors that were included in the experimental trials. Maximum arc-wise gas concentrations agree very well for short time averages. FDS maximum arc-wise gas concentrations agree to a lesser extent (over-predictive) with long time averages in the near field, but compare very well in the far field. Maximum point-wise gas sensor data can be found in Appendix D. Temperature sensor data can be found in Appendix E.

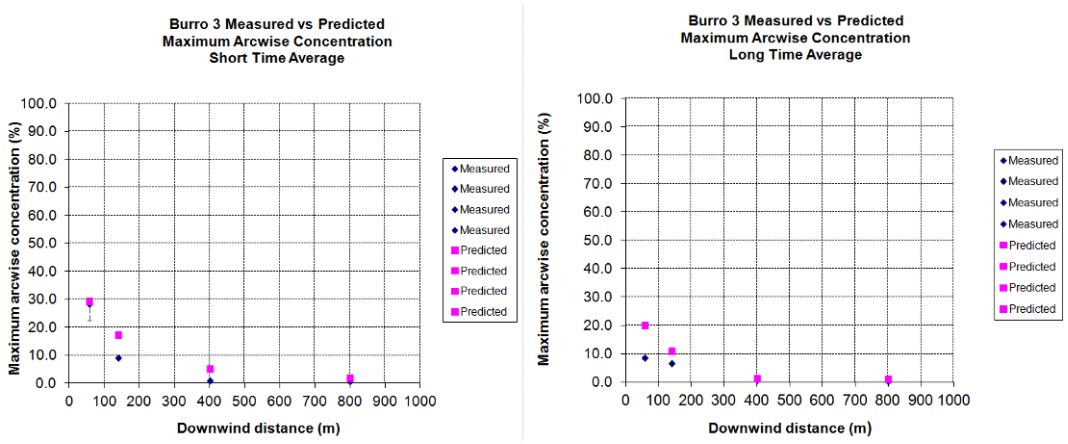


Figure 24 - Burro 3 Maximum Arcwise Concentrations

Burro 7

For Trial 7, the LNG composition taken before discharge was 87.0% methane, 10.4% ethane, and 2.6% propane. The discharge lasted for about 3 minutes and 2 seconds with about 2 minutes 54 seconds of steady state flow at 13.6m^3/min. A timeline of the release is tabulated below.

Table 10 - Burro 7 Spill Sequence

Timeline	Description
August 27, 1980 18:12:15	Valve begins to open
August 27, 1980 18:12:21 (t=0)	Valve open
August 27, 1980 18:15:09 (t=168)	Valve beings to close
August 27, 1980 18:15:17 (t=176)	Valve closed

Using the flow rate and duration, the ABS/FERC pool spread model [50][51] was used to determine the source term to be inputted into FDS. The pool spread model is based upon the shallow water equations in GASP [52] and a mass balance using an empirically derived vaporization rate of 0.167 kg/m^2s. Selected ABS/FERC pool spread calculations are included in Appendix A.

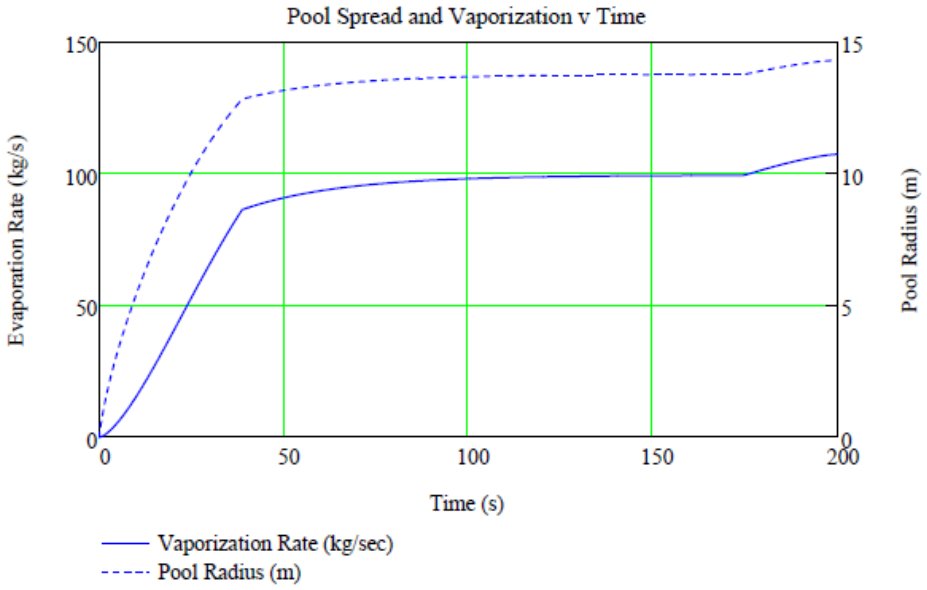


Figure 25 - Burro 7 ABS/FERC Pool Spread and Vaporization Results

The test was conducted during wind speeds ranging from 4.6 m/s to 12.4 m/s with a domain average of 8.4 m/s and standard deviation of 1.2 m/s. The wind direction relative to the array axis (225 degrees from True North) ranged from -36 degrees to -1 degree with a domain average of -16.6 degrees and standard deviation of 5.2 degrees. Atmospheric stability was category D. Ambient temperature had a mean of 307 K with very little fluctuation. Relative humidity ranged from 6.7% to 7.4% and insolation was approximately 41 W/m^2. The average temperature, average relative humidity, and upwind transient wind field data were used as input into FDS and compared well with the experimental measurements. The pond temperature was assumed to be equal to the ambient temperature. The FDS simulations were run until a steady or quasi-steady wind profile was established throughout the domain in each test before starting the dispersion. Averaged wind field data compared well with the

experimental measurements. The FDS input files are included in Appendix B. Point-wise data wind sensor data can be found in Appendix C.

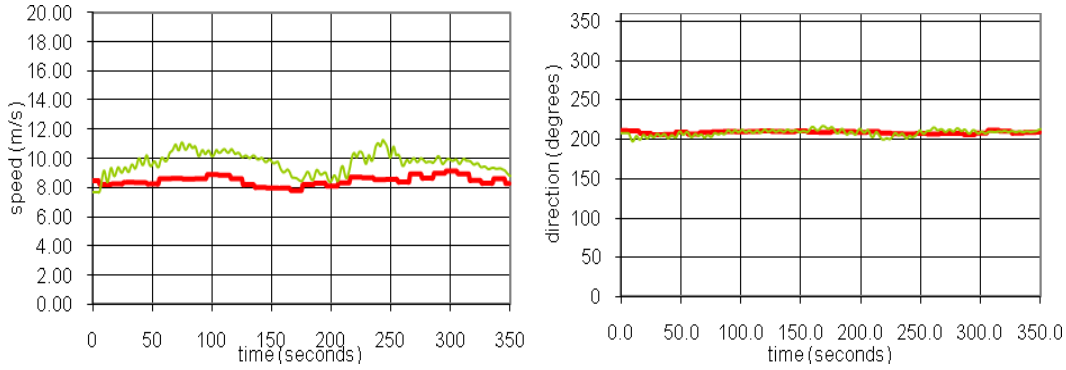


Figure 26 - Burro 7 Average Wind Field Data

(red: experimental data; green: FDS data)

The corresponding FDS vapor concentrations are compared to the cloud contours in the data report. FDS generally shows very good agreement in downward extent, width, and direction of the vapor cloud.

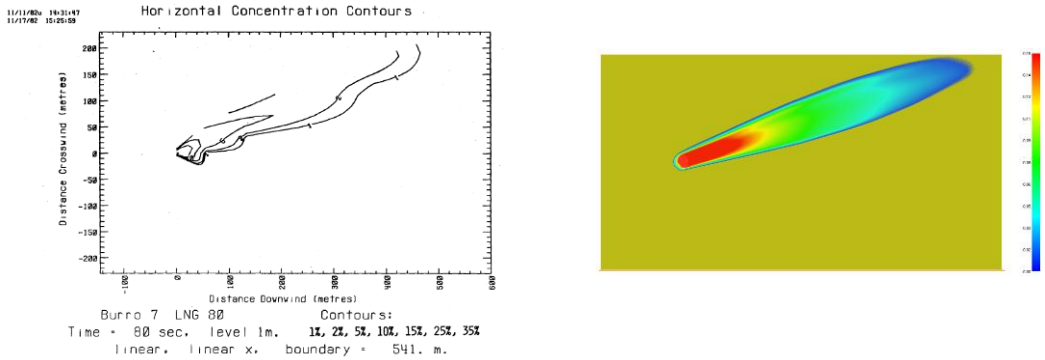


Figure 27 - Burro 7 Instantaneous Vapor Cloud Contours at Z=2m over 750m (horizontal axis) by 450m (vertical axis) domain at 80 seconds (left: experimental contours of 1%, 2%, 5%, 10%, 15% [55] right: FDS contour with scale of 1% blue to 15% red)

In addition, FDS included all sensors that were included in the experimental trials. Maximum arc-wise gas concentrations agree very well for both short and long time averages. Maximum point-wise gas sensor data can be found in Appendix D. Temperature sensor data can be found in Appendix E.

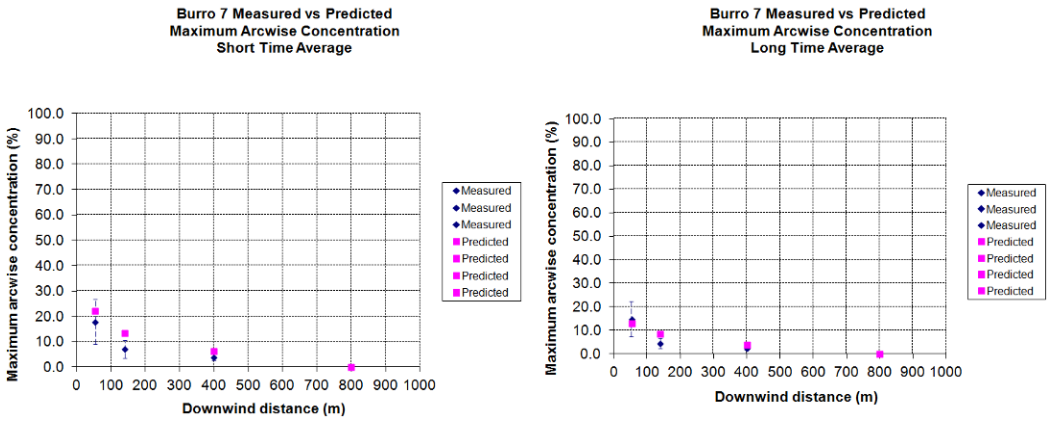


Figure 28 - Burro 7 Maximum Arcwise Concentrations

Burro 8

For Trial 8, the LNG composition taken before discharge was 87.4% methane, 10.3% ethane, and 2.3% propane. The discharge lasted for about 1 minutes and 54 seconds with about 1 minutes 47 seconds of steady state flow at 16.0m^3/min. A timeline of the release is tabulated below.

Table 11 - Burro 8 Spill Sequence

Timeline	Description
September 3, 1980 19:09:16	Valve begins to open
September 3, 1980 19:09:22 (t=0)	Valve open
September 3, 1980 19:11:03 (t=101)	Valve beings to close
September 3, 1980 19:11:10 (t=108)	Valve closed

Using the flow rate and duration, the ABS/FERC pool spread model [50][51] was used to determine the source term to be inputted into FDS. The pool spread model is based upon the shallow water equations in GASP [52] and a mass balance using an empirically derived vaporization rate of 0.167 kg/m^2s. Selected ABS/FERC pool spread calculations are included in Appendix A.

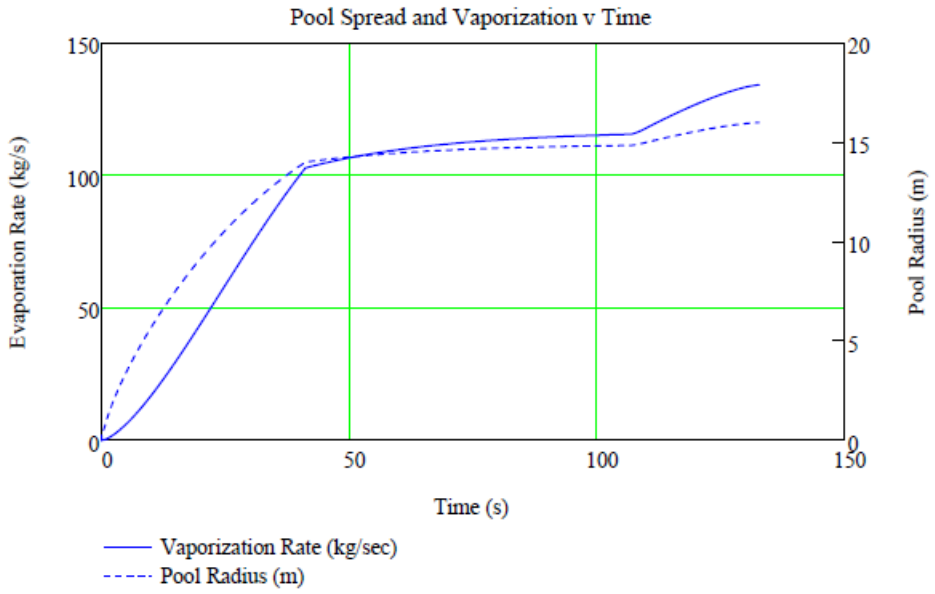


Figure 29 - Burro 8 ABS/FERC Pool Spread and Vaporization Results

The test was conducted during wind speeds ranging from 0.2 m/s to 3.1 m/s with a domain average of 1.8 m/s and standard deviation of 0.3 m/s. The wind direction relative to the array axis ranged from -45 degrees to +45 degrees with a domain average of +9.8 degrees and standard deviation of 5.6 degrees. Atmospheric stability was category E. Ambient temperature had a mean of 306 K with very little fluctuation. Relative humidity ranged from 4.5% to 4.7% and insolation was approximately -2.2 W/m^2. The pond temperature is assumed to be equal to the ambient temperature. The average temperature, average relative humidity, and upwind transient wind field data were used as input into FDS. The FDS simulations were run until a steady or quasi-steady wind profile was established throughout the domain in each test before starting the dispersion. Averaged wind field data compared well with the experimental measurements. The FDS input files are

included in Appendix B. Point-wise data wind sensor data can be found in Appendix C.

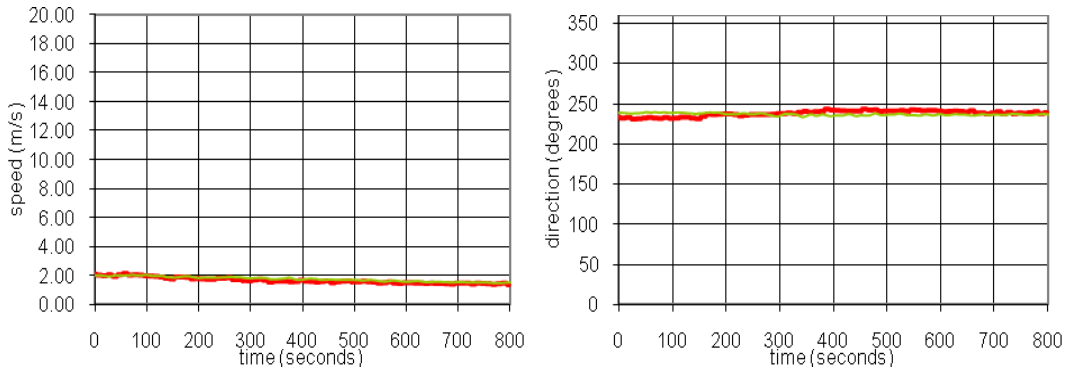


Figure 30 - Burro 8 Average Wind Field Data

(red: experimental data; green: FDS data)

The corresponding FDS vapor concentrations are compared to the cloud contours in the data report. FDS generally shows very good agreement in downward extent, width, and direction of the vapor cloud, but does not indicate any bifurcation of the cloud as experienced in the experimental measurements. The lack of bifurcation may be partly due to the assumption that the terrain was flat and free of obstructions. Buildings and piping were located upstream of the spill pond along its centerline, which is where the bifurcation appears.

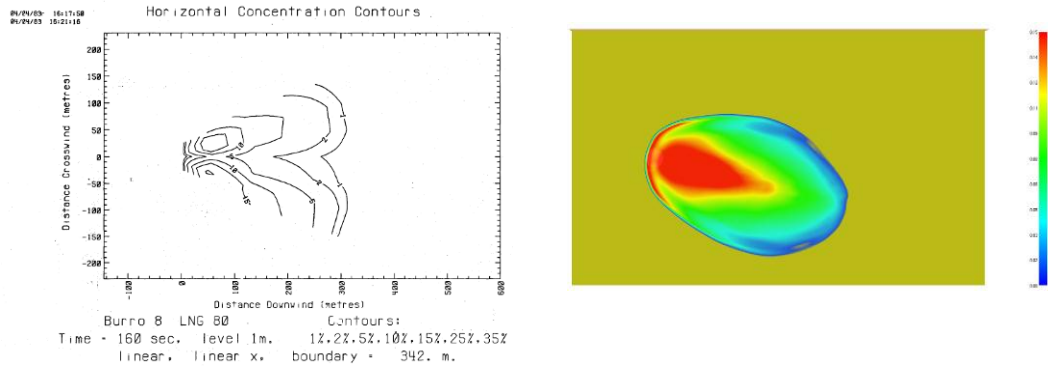


Figure 31 - Burro 8 Instantaneous Vapor Cloud Contours at Z=2m over 750m (horizontal axis) by 450m (vertical axis) domain at 160 seconds (left: experimental contours of 1%, 2%, 5%, 10%, 15% [55] right: FDS contour with scale of 1% blue to 15% red)

In addition, FDS included all sensors that were included in the experimental trials. Maximum arc-wise gas concentrations agree very well for long time averages. FDS maximum arc-wise gas concentrations agree to a lesser extent for short time averages in the near field (under-predictive), but agree very well in the far field. Maximum point-wise gas sensor data can be found in Appendix D. Temperature sensor data can be found in Appendix E.

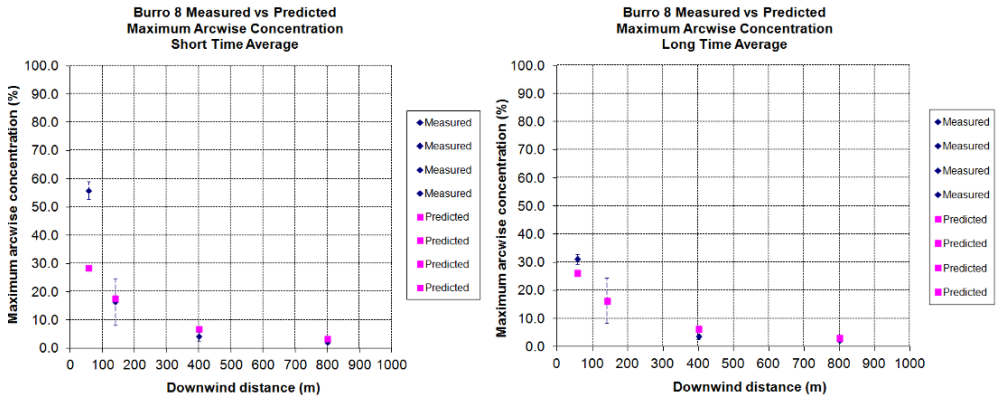


Figure 32 - Burro 8 Maximum Arcwise Concentrations

Burro 9

For Trial 9, the LNG composition taken before discharge was 83.1% methane, 13.9% ethane, and 3.0% propane. The discharge lasted for about 1 minute and 27 seconds with about 1 minutes 19 seconds of steady state flow at 18.4m^3/min. A timeline of the release is tabulated.

Table 12 - Burro 9 Spill Sequence

Timeline	Description
September 17, 1980 18:37:02	Valve begins to open
September 17, 1980 18:37:08 (t=0)	Valve open
September 17, 1980 18:38:21 (t=73)	Valve beings to close
September 17, 1980 18:38:29 (t=81)	Valve closed

Using the flow rate and duration, the ABS/FERC pool spread model was used to determine the source term to be inputted into FDS. The pool spread model is based upon the shallow water equations in GASP and a mass balance using an empirically derived vaporization rate of 0.167 kg/m^2s. The ABS/FERC pool spread calculations are included in Appendix A.

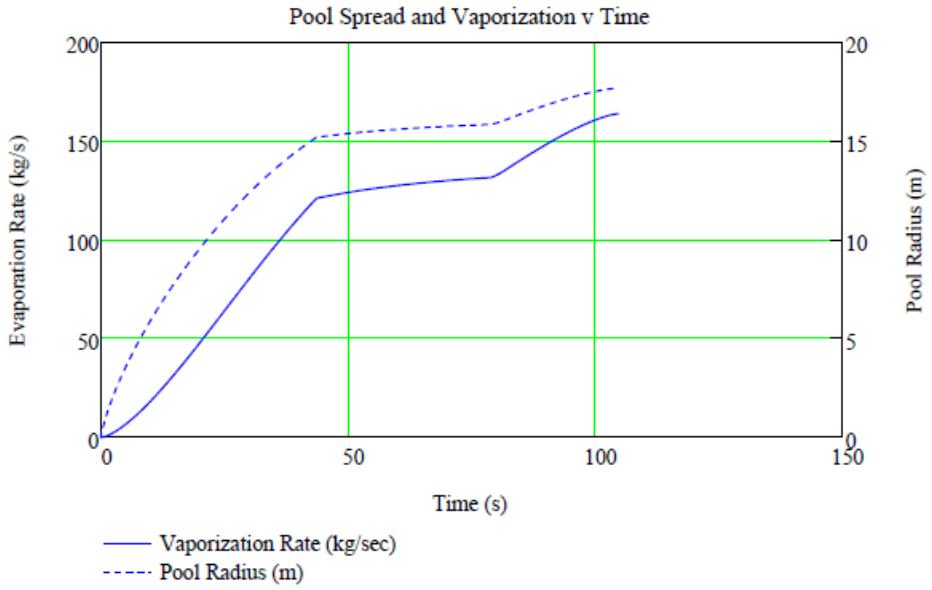


Figure 33 - Burro 9 ABS/FERC Pool Spread and Vaporization Results

The test was conducted during wind speeds ranging from 2.5 m/s to 8.4 m/s with a domain average of 5.7 m/s and standard deviation of 0.7 m/s. The wind direction relative to the array axis (225 degrees from True North) ranged from -11 degrees to +24 degrees with a domain average of +7 degrees and standard deviation of 4.4 degrees. Atmospheric stability was category D. Ambient temperature had a mean of 308.5 K with very little fluctuation. Relative humidity ranged from 11.7% to 14.4% and insolation was approximately 10 W/m^2. The average temperature, average relative humidity, and upwind transient wind field data were used as input into FDS. The pond temperature was assumed to be equal to the ambient temperature. The FDS simulations were run until a steady or quasi-steady wind profile was established throughout the domain in each test before starting the dispersion. Averaged wind field data compared well with the experimental measurements. The FDS input files

are included in Appendix B. Point-wise data wind sensor data can be found in Appendix C.

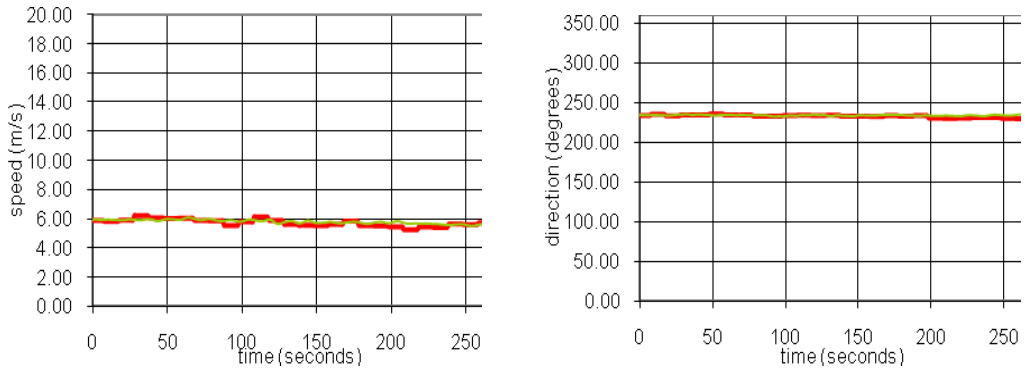


Figure 34 - Burro 9 Average Wind Field Data

(red: experimental data; green: FDS data)

The corresponding FDS vapor concentrations are compared to the cloud contours in the data report. FDS generally shows good agreement in downward extent, width, and direction of the vapor cloud. However, rapid phase transitions were observed throughout the Burro 9 test. This lowered the concentration where the explosions occurred, as illustrated in the measured horizontal concentration contours at 50 seconds and 70 seconds. These RPTS were not attempted to be recreated in the FDS simulation.

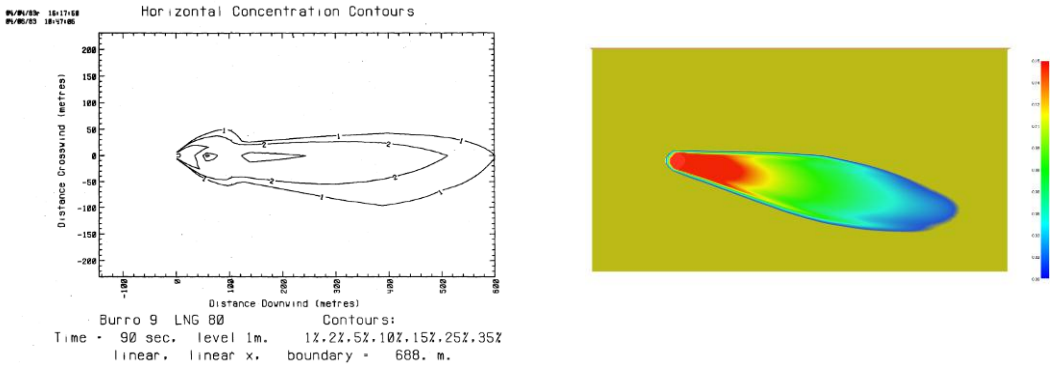


Figure 35 - Burro 9 Instantaneous Vapor Cloud Contours at Z=2m over 750m (horizontal axis) by 450m (vertical axis) domain at 90 seconds (left: experimental contours of 1%, 2%, 5%, 10%, 15% [55] right: FDS contour with scale of 1% blue to 15% red)

In addition, FDS included all sensors that were included in the experimental trials. Maximum arc-wise gas concentrations agree very well for both short and long time averages. Maximum point-wise gas sensor data can be found in Appendix D. Temperature sensor data can be found in Appendix E.

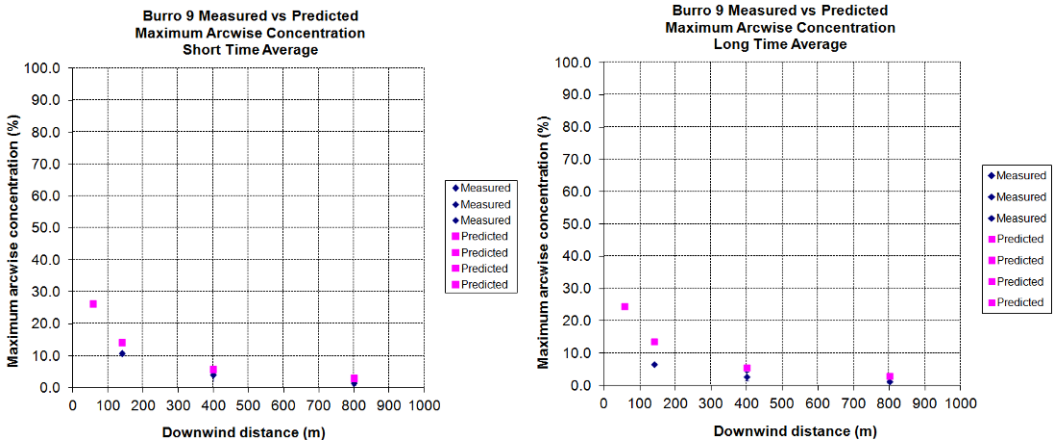


Figure 36 - Burro 9 Maximum Arcwise Concentrations

Coyote Series

The Coyote Series trials were conducted in 1981 by Naval Weapons Center and Lawrence Livermore National Laboratory at the same experimental establishment as the previous Burro trials.

The Coyote trials were conducted to investigate 1) the transport and dispersion of LNG vapor under various atmospheric conditions for continuous releases, 2) the behavior of vapor cloud fires, and 3) the occurrence of RPTs. Ten tests were carried out.

The first vapor fire test (Coyote 2) released a smaller amount of LNG and was ignited to assess the capability and survivability of the instrument array in the presence of a vapor cloud fire. The last vapor fire test (Coyote 7) did not record any gas data. Therefore, following the MEP, only Coyote Tests 3, 5, and 6 were selected for evaluation.

Table 13 - Coyote Trials

Coyote Trial	Material	Release Rate (m^3/min)	Quantity (m^3)	Notes
3	LNG	13.5	14.6	Vapor Fire Test
5	LNG	17.1	28	Vapor Fire Test, large RPT late
6	LNG	16.6	22.8	Vapor Fire Test

Similar to the Burro Tests, the spills were supplied by a 25cm diameter cryogenic line discharge pipe from an approximate $40m^3$ total capacity storage tank. The LNG was released onto water to allow for a near steady state vaporization rate, as the convective motion of the water provided a relatively constant heat transfer rate. The discharge of the pipe is centered on a 1m deep water pond with an average diameter of 58m with water surface 1.5m below the surrounding grade. A splash plate was installed below the spill pipe outlet to limit the penetration of the LNG into the water, and to protect the facility from damage by RPTs. The plate was generally set at shallow depths during the vapor-burn and dispersion tests. The slopes of all the banks except the south bank were reduced to minimize turbulence.

Like the Burro tests, weather stations and instrument stations collected ambient data in addition to gas concentration and temperature data. The same sensors and corresponding uncertainties were used in the Coyote Trials. However, the sensors were relocated to distances of approximately 140m, 200m, 300m, and 400m from the center of the spill location. The relocation of the 57m arc was based on the previous Burro Trial RPTs splashing and damaging the sensors. The relocation of the 800m arc was based on the previous Burro Trial sensors not obtaining much useful data.

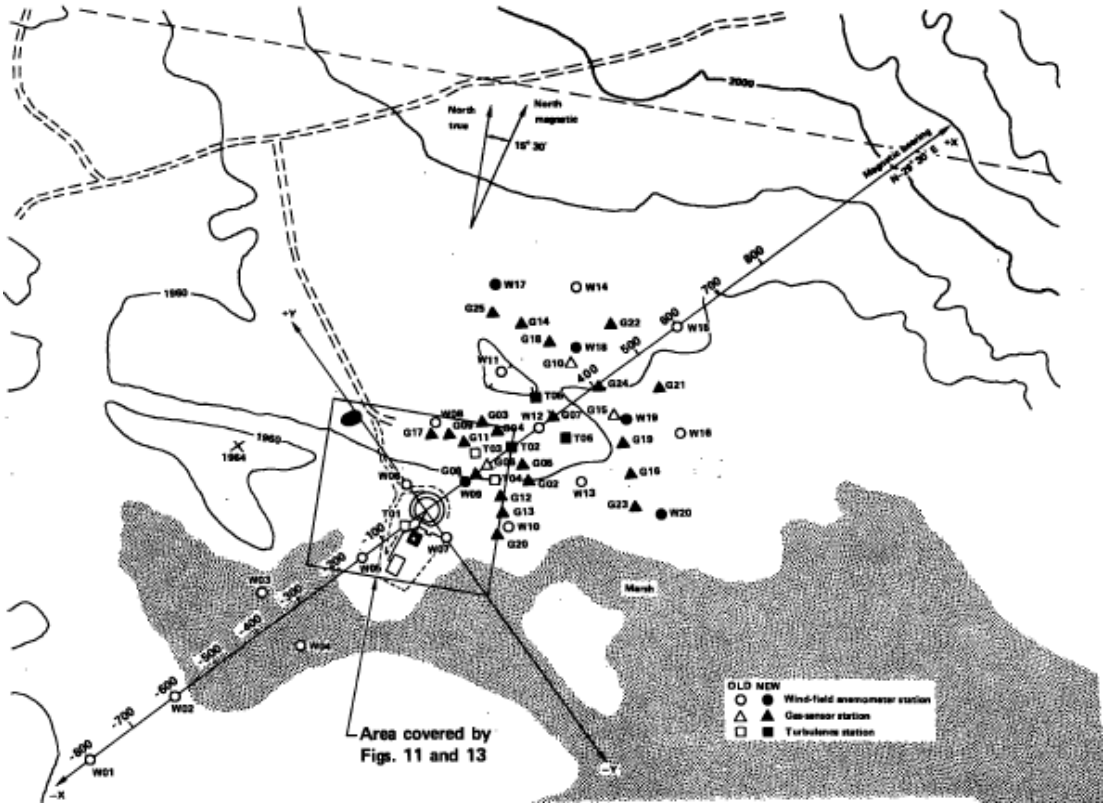


Figure 37 - Coyote Trials Instrumentation [57][59]

Coyote 3

For Trial 3 the LNG composition taken before discharge was 79.4% methane, 16.4% ethane, and 4.2% propane. The discharge lasted for about 1 minute and 6 seconds with about 1 minutes 5 seconds of steady state flow at 13.5m^3/min. A timeline of the release is tabulated below.

Table 14 - Coyote 3 Spill Sequence

Timeline	Description
September 3, 1981 15:38:24	Valve begins to open
September 3, 1981 15:38:26 (t=0)	Valve open
September 3, 1981 15:39:28 (t=62)	Valve beings to close
September 3, 1981 15:39:30 (t=64)	Valve closed

Using the flow rate and duration, the ABS/FERC pool spread model [50][51] was used to determine the source term to be inputted into FDS. The pool spread model is based upon the shallow water equations in GASP [52] and a mass balance using an empirically derived vaporization rate of 0.167 kg/m^{2}s. Selected ABS/FERC pool spread calculations are included in Appendix A.

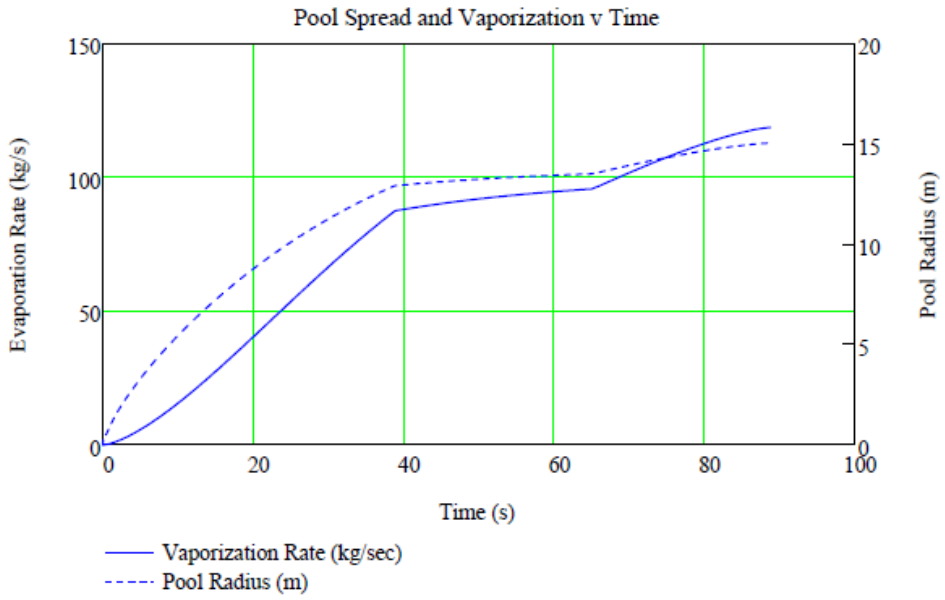


Figure 38 - Coyote 3 ABS/FERC Pool Spread and Vaporization Results

The test was conducted during wind speeds ranging from 2.6 m/s to 9.6 m/s with a domain average of 6.0 m/s and standard deviation of 0.9 m/s. The wind direction relative to the array axis (225 degrees from True North) ranged from -69 degrees to +19 degrees with a domain average of -22 degrees and standard deviation of 11 degrees. Atmospheric stability was category B-C. Ambient temperature had a mean of 311.5 K with very little fluctuation. Relative humidity was approximately 11.3% and insolation was approximately 313 W/m^2. The average temperature, average relative humidity, and upwind transient wind field data were used as input into FDS. The pond temperature was assumed to be equal to the ambient temperature. The FDS simulations were run until a steady or quasi-steady wind profile was established throughout the domain in each test before starting the dispersion. Averaged wind field data compared fairly well with the experimental measurements. The FDS input files are included in Appendix B. Point-wise data wind sensor data can be found in Appendix C.

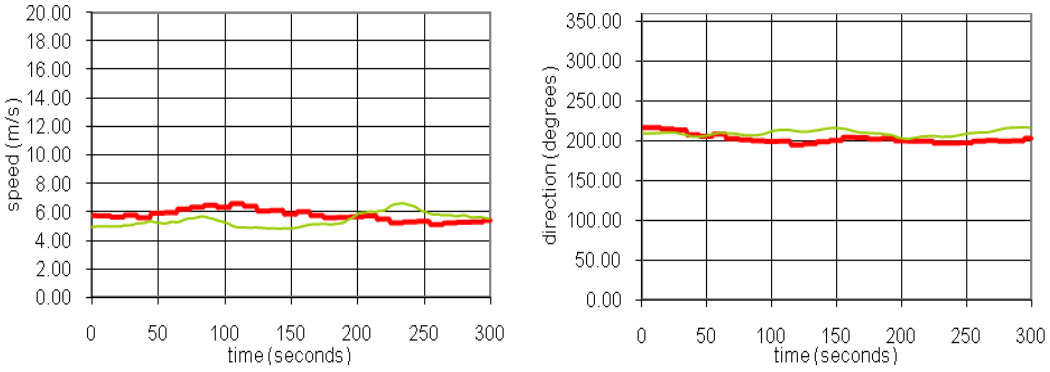


Figure 39 - Coyote 3 Average Wind Field Data

(red: experimental data; green: FDS data)

The corresponding FDS vapor concentrations are compared to the cloud contours in the data report. FDS generally shows good agreement in downward extent, width, and direction of the vapor cloud.

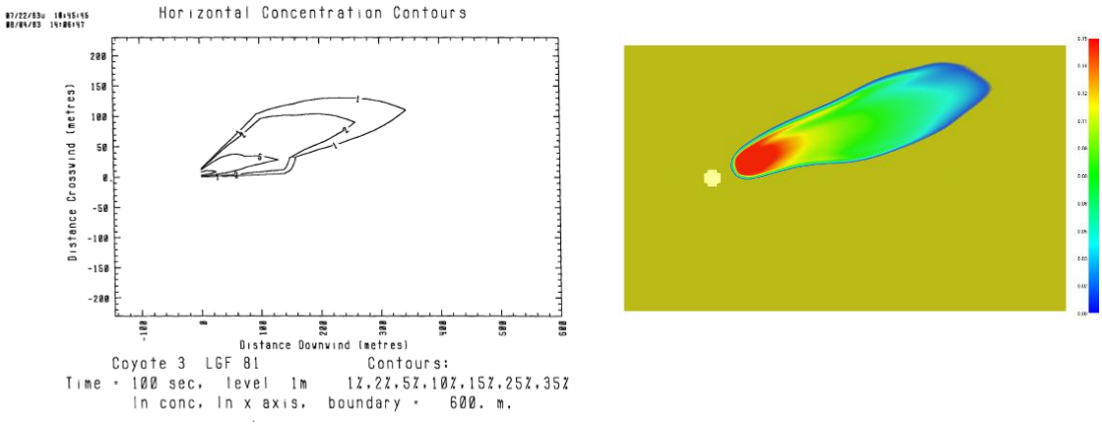


Figure 40 - Coyote 3 Instantaneous Vapor Cloud Contours at Z=2m over 750m (horizontal axis) by 450m (vertical axis) domain at 100 seconds (left: experimental contours of 1%, 2%, 5%, 10%, 15% [59] right: FDS contour with scale of 1% blue to 15% red)

In addition, FDS included all sensors that were included in the experimental trials. FDS maximum arc-wise gas concentrations are over-predictive for both short and long time averages. Maximum point-wise gas sensor data can be found in Appendix D. Temperature sensor data can be found in Appendix E.

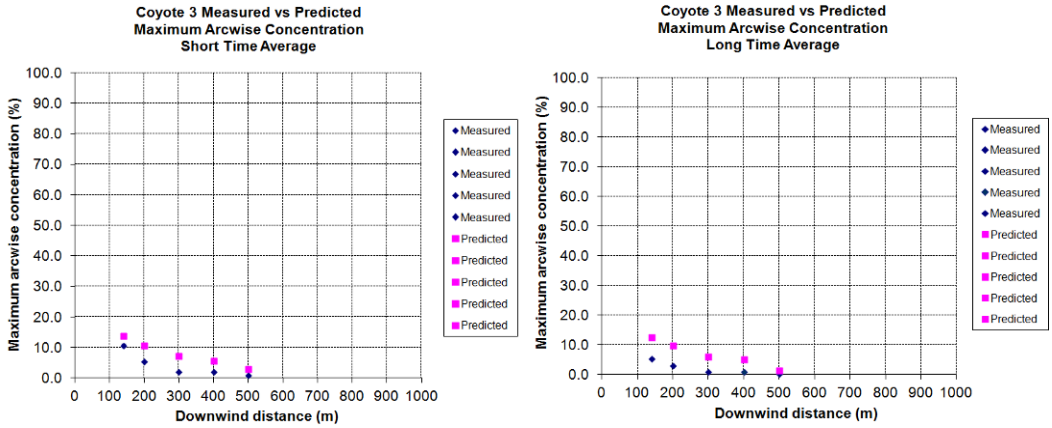


Figure 41 - Coyote 3 Maximum Arcwise Concentrations

Coyote 5

For Trial 5, the LNG composition taken before discharge was 74.9% methane, 20.5% ethane, and 4.6% propane. The discharge lasted for about 1 minute and 51 seconds with about 1 minutes 38 seconds of steady state flow at 17.1m^3/min. A timeline of the release is tabulated below.

Table 15 - Coyote 5 Spill Sequence

Timeline	Description
October 7, 1981 12:08:48	Valve begins to open
October 7, 1981 12:08:50 (t=0)	Valve open
October 7, 1981 12:10:37 (t=107)	Valve beings to close
October 7, 1981 12:10:39 (t=109)	Valve closed

Using the flow rate and duration, the ABS/FERC pool spread model [50][51] was used to determine the source term to be inputted into FDS. The pool spread model is based upon the shallow water equations in GASP [52] and a mass balance using an

empirically derived vaporization rate of 0.167 kg/m^{2}s. Selected ABS/FERC pool spread calculations are included in Appendix A.

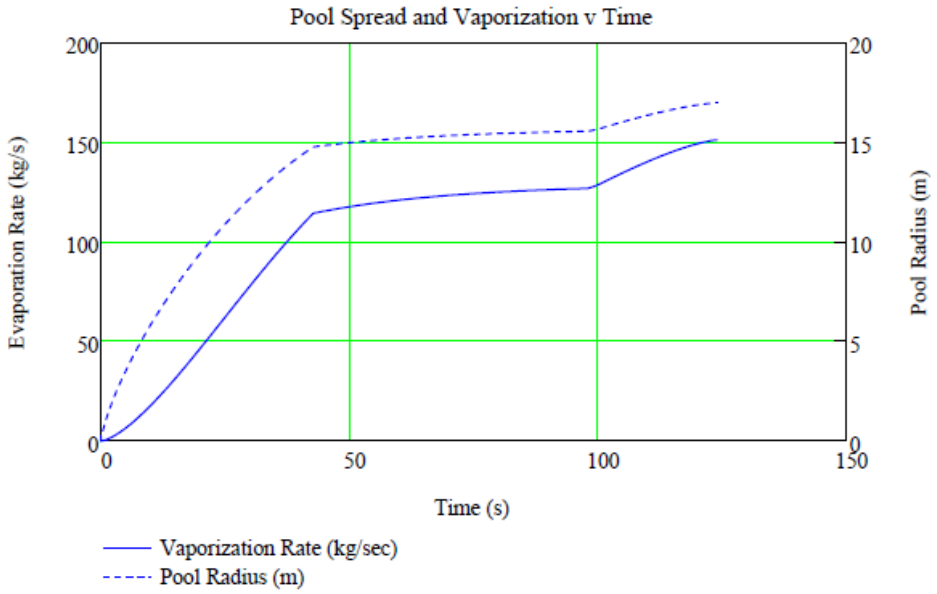


Figure 42 - Coyote 5 ABS/FERC Pool Spread and Vaporization Results

The test was conducted during wind speeds ranging from 4.1 m/s to 14.2 m/s with a domain average of 9.7 m/s and standard deviation of 1.3 m/s. The wind direction relative to the array axis ranged from -30 degrees to +44 degrees with a domain average of +2 degrees and standard deviation of 7 degrees. Atmospheric stability was category C-D. Ambient temperature had a mean of 301.5 K with very little fluctuation. Relative humidity was approximately 22.1% and insolation was approximately 283.5 W/m^2. The average temperature, average relative humidity, and upwind transient wind field data were used as input into FDS. The pond temperature was assumed to be equal to the ambient temperature. The FDS simulations were run until a steady or quasi-steady wind profile was established throughout the domain in

each test before starting the dispersion. Averaged wind field data was under-predictive for wind speeds compared to the experimental measurements, and showed significant more fluctuation in wind direction. The larger wind direction fluctuations are due to the ramp function only acting on the normal velocity. The FDS input files are included in Appendix B. Point-wise data wind sensor data can be found in Appendix C.

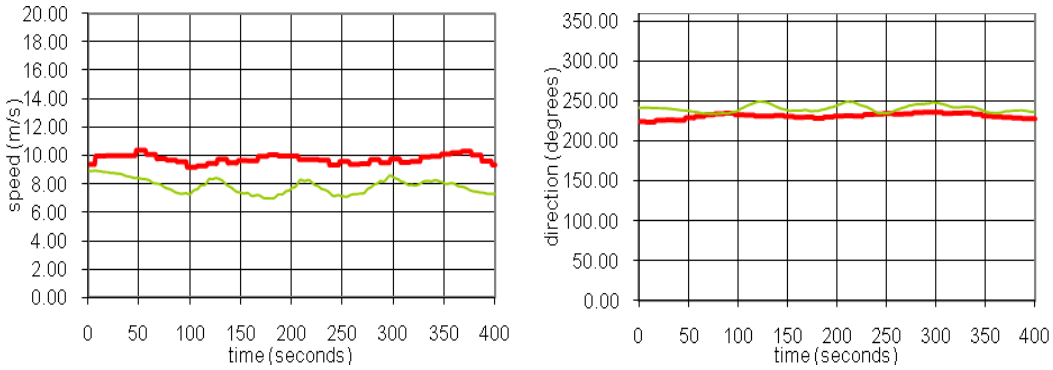


Figure 43 - Coyote 5 Average Wind Field Data

(red: experimental data; green: FDS data)

The corresponding FDS vapor concentrations are compared to the cloud contours in the data report. FDS generally shows good agreement in downward extent, width, and direction of the vapor cloud contours up until 80 seconds after the spill when the experimental measurements indicate a separation of a portion of the vapor cloud and 120 seconds after the spill where the direction of the vapor cloud begins to differentiate between FDS and the experimental results.

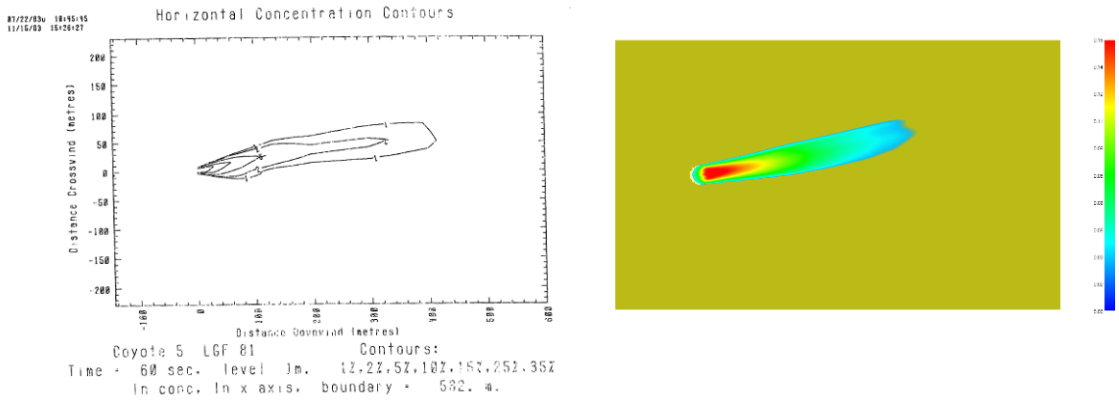


Figure 44 - Coyote 5 Instantaneous Vapor Cloud Contours at Z=2m over 750m (horizontal axis) by 450m (vertical axis) domain at 60 seconds (left: experimental contours of 1%, 2%, 5%, 10%, 15% [59] right: FDS contour with scale of 1% blue to 15% red)

In addition, FDS included all sensors that were included in the experimental trials. FDS maximum arc-wise gas concentrations agree very well for short time averages, and was over predictive for long time averages. Maximum point-wise gas sensor data can be found in Appendix D. Temperature sensor data can be found in Appendix E.

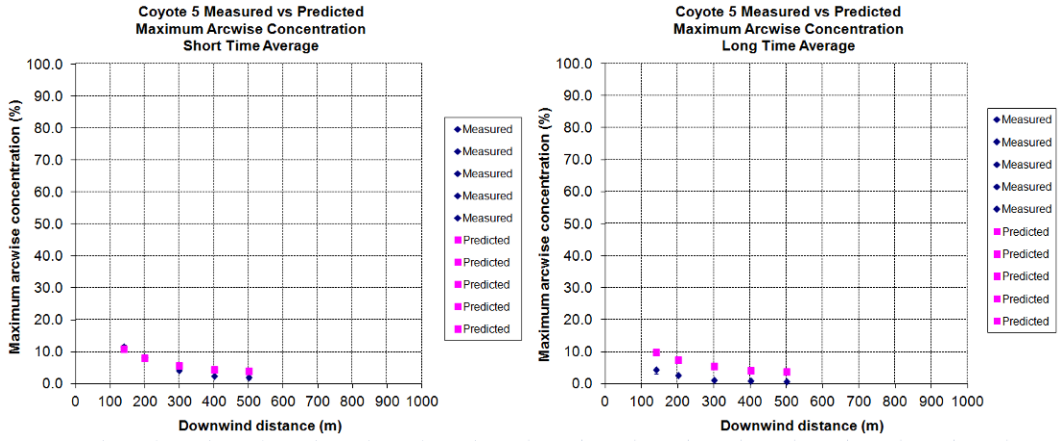


Figure 45 - Coyote 5 Maximum Arcwise Concentrations

Coyote 6

For Trial 6, the LNG composition taken before discharge was 81.8% methane, 14.6% ethane, and 3.6% propane. The discharge lasted for about 1 minute and 19 seconds with about 1 minutes 22 seconds of steady state flow at 16.6m^3/min. A timeline of the release is tabulated below.

Table 16 - Coyote 6 Spill Sequence

Timeline	Description
October 27, 1981 16:43:21	Valve begins to open
October 27, 1981 16:43:23 (t=0)	Valve open
October 27, 1981 16:44:39 (t=73)	Valve beings to close
October 27, 1981 16:44:40 (t=81)	Valve closed

Using the flow rate and duration, the ABS/FERC pool spread model was used to determine the source term to be inputted into FDS. The pool spread model is based upon the shallow water equations in GASP and a mass balance using an empirically derived vaporization rate of 0.167 kg/m^2s. The ABS/FERC pool spread calculations are included in Appendix A.

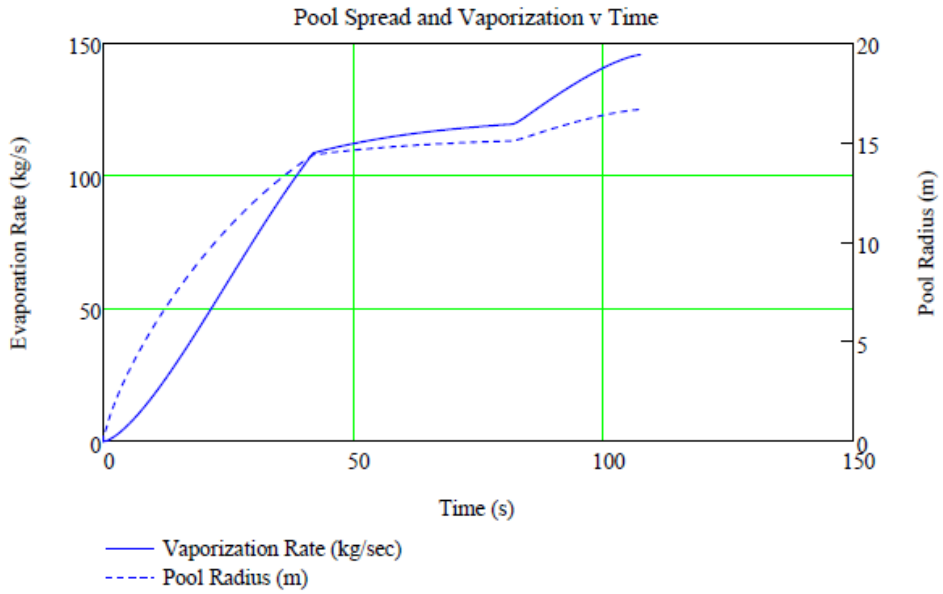


Figure 46 - Coyote 6 ABS/FERC Pool Spread and Vaporization Results

The test was conducted during wind speeds ranging from 2.2 m/s to 11.4 m/s with a domain average of 4.6 m/s and standard deviation of 0.6 m/s. The wind direction relative to the array axis (225 degrees from True North) ranged from -44 degrees to +14 degrees with a domain average of -7 degrees and standard deviation of 5 degrees. Atmospheric stability was category D. Ambient temperature had a mean of 297.3 K with very little fluctuation. Relative humidity was approximately 22.8% and insolation was approximately -9.42 W/m^2. The average temperature, average relative humidity, and upwind transient wind field data were used as input into FDS. The pond temperature was assumed to be equal to the ambient temperature. The FDS simulations were run until a steady or quasi-steady wind profile was established throughout the domain in each test before starting the dispersion. Averaged wind speed compared well with the experimental measurements, but showed significant more fluctuation in wind direction due to the ramp function only acting on the normal

velocity. The FDS input files are included in Appendix B. Point-wise data wind sensor data can be found in Appendix C.

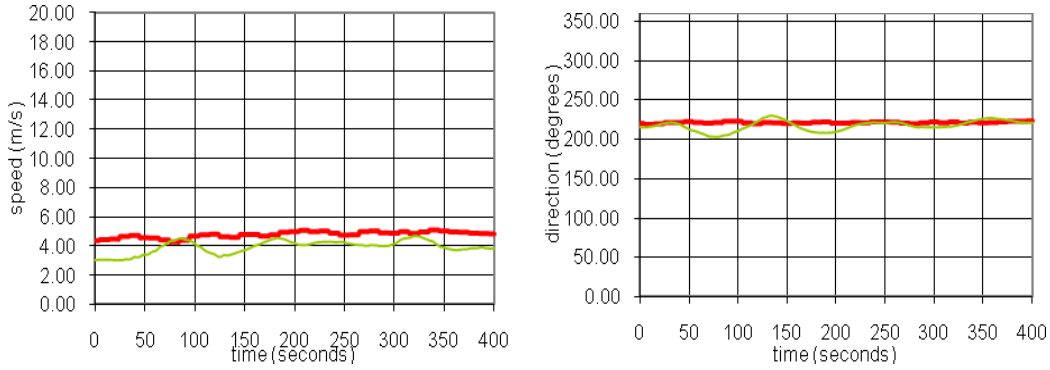


Figure 47 - Coyote 6 Average Wind Field Data

(red: experimental data; green: FDS data)

The corresponding FDS vapor concentrations are compared to the cloud contours in the data report. FDS generally shows very good agreement in general downward extent, width, and direction of the vapor cloud.

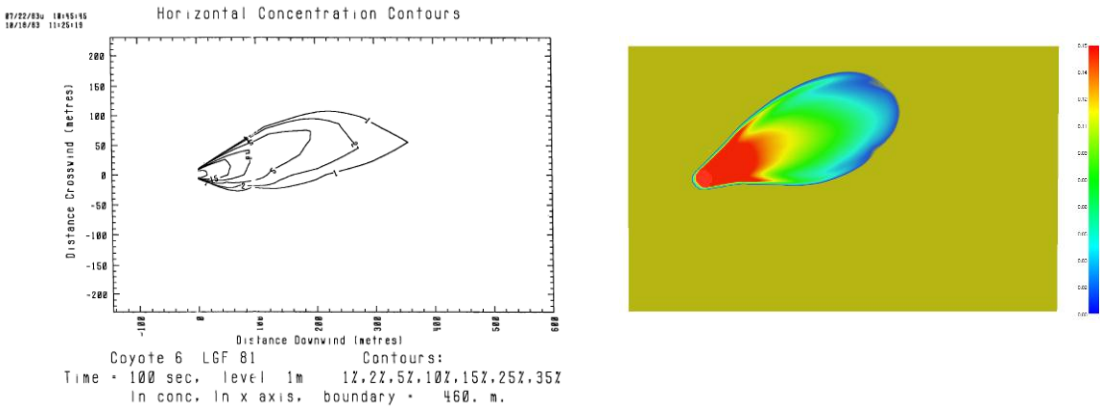


Figure 48 - Coyote 6 Instantaneous Vapor Cloud Contours at Z=2m over 750m (horizontal axis) by 450m (vertical axis) domain at 100 seconds (left: experimental contours of 1%, 2%, 5%, 10%, 15% [59] right: FDS contour with scale of 1% blue to 15% red)

In addition, FDS included all sensors that were included in the experimental trials. FDS maximum arc-wise gas concentrations agree very well for both short and long time averages. Maximum point-wise gas sensor data can be found in Appendix D. Temperature sensor data can be found in Appendix E.

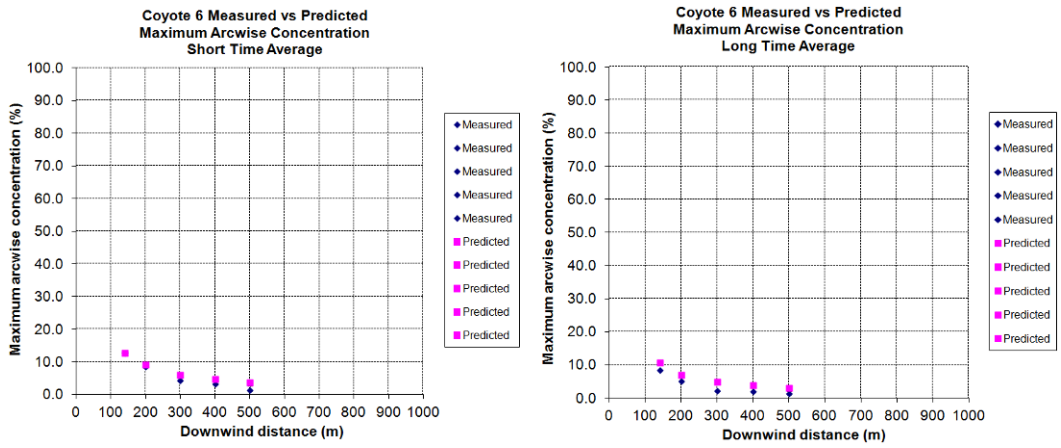


Figure 49 - Coyote 6 Maximum Arcwise Concentrations

Falcon Series

The Falcon Series trials were conducted in 1987 by Lawrence Livermore National Laboratory at an experimental establishment of the Department of Energy Nevada Test Site (now Nevada National Security Site) located at Frenchman Flat, Nevada, about 65 miles northwest of Las Vegas.

Figure 50 - Falcon Trials Location

The Falcon trials were conducted to determine the effectiveness of vapor fences as a mitigation technique for continuous releases of LNG. Five tests were carried out. However, Falcon 2 recorded very low concentrations and Falcon 5 suffered from a number of RPTs and ignited. Therefore, following the MEP, only Falcon Series 1, 3, and 4 were selected for evaluation.

Table 17 - Falcon Trials

Falcon Trial	Material	Release Rate (m^3/min)	Quantity (m^3)	Notes
1	LNG	28.7	66.4	
3	LNG	18.9	50.7	RPTs
4	LNG	8.7	44.9	

The tests released LNG onto water with a circulation system to allow for a near steady state vaporization rate. The vapor dispersed over Frenchman Flats, a dry lakebed spanning 3500m by 5000m with no vegetation and only a 0.3m elevation change from center to edge.

The MEP [10] reports a surface roughness of 0.008m for the Falcon trials. The Falcon Series Reports [61] provide a value of 0.008m. Based on photographic observations [62][63] and knowledge of the test site, users could reasonably assume the surface roughness to correspond to mud flats or a desert, which typically have a surface roughness of 0.00001m for mud flats and 0.0005m for a desert. Pielke [60] reports surface roughness values of 0.00001m for smooth mud flats and 0.0003m for smooth deserts. Brutsaert [49] reports 0.00001m for mud flats. A surface roughness of 0.008m reported in the MEP was used in FDS to determine the wind profile exponent.

The spills were supplied by a 12 inch diameter cryogenic line from two $100m^3$ total capacity storage tanks. The 12 inch diameter line reduced to a 10 inch diameter line before supplying four 6 inch diameter discharge pipes outfitted with an orifice plate (to reduce flashing). Each discharge pipe was approximately 11.6m in length and oriented 90 degrees apart. The lines discharged 0.3m above a 40m by 60m water

pond, 0.76m deep surrounded by a 44m by 88m by 8.7m high fence. A 17.1m wide by 13.3m high fence panel was also located upwind intended to generate turbulence within the fence that would be representative of a storage tank [61]. A schematic of the test site is shown below. The fence, pond, and fence panel were included in FDS assuming the fence had zero thickness.

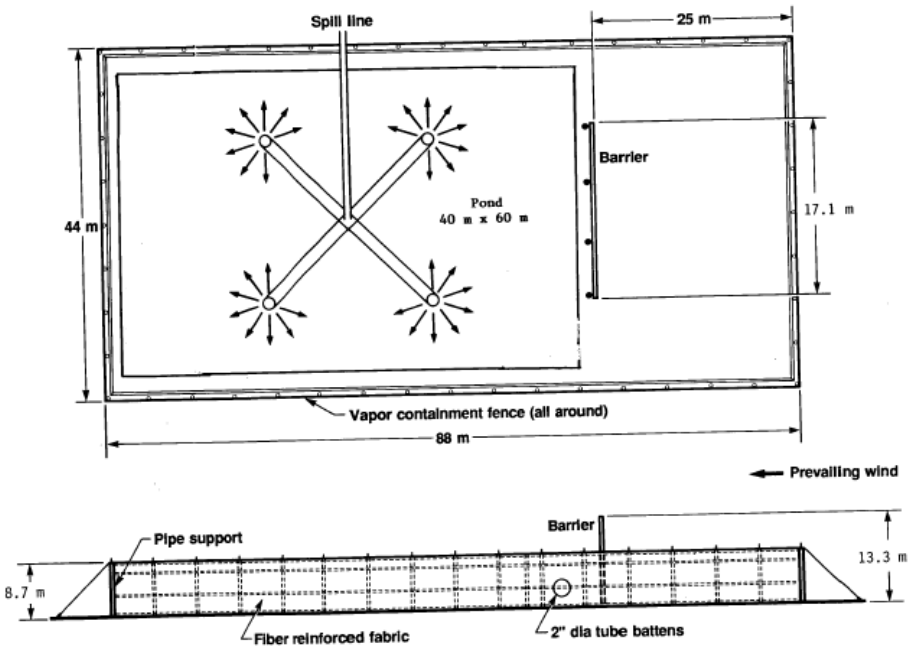


Figure 51 - Falcon Trials Spill Setup [61]

Nineteen weather stations and twenty-one instrument stations collected various ambient data in addition to gas concentration and temperature data. The weather stations measured wind speed and direction with cup-and-vane anemometers accurate within +/- 1% or 0.07m/s and +/-2°. The instrument stations were outfitted with standard type K thermocouples made of Cr/Al with a 20mil bead, and various gas concentration sensors at elevations of approximately 1m, 2m, 4m, 8m, and 16m above

grade and 50m, 150m, and 250m downwind. The accuracy of the gas sensors are shown below.

Table 18 - Falcon Trials Gas Sensor Uncertainty

Sensor	Uncertainty
LLNL Infrared Sensor	10% of gas sensor reading
JPL Infrared Sensor	10% of gas sensor reading with 0.2% minimum
MSA Catalytic Sensor	10% of gas sensor reading

The sensors were located downwind of the spill point in arrays approximately 50m, 150m, and 250m from the downwind edge of the fence, as shown below.

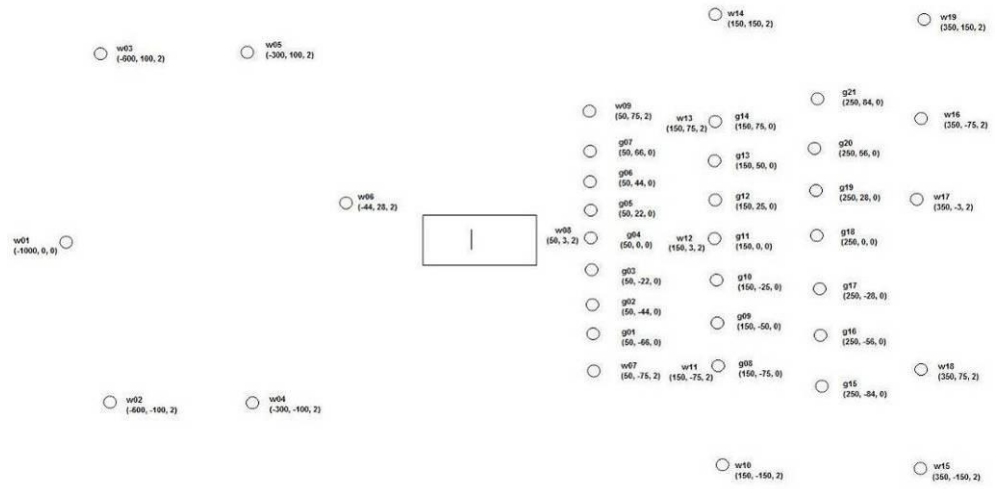


Figure 52 - Falcon Trials Instrumentation

(not to scale)

Falcon 1

For Trial 1, the LNG composition taken before discharge was 94.7% methane, 3.9% heavier hydrocarbons. The discharge lasted for about 2 minute and 19 seconds with about 2 minutes of steady state flow at 28.7m^3/min. A timeline of the release is tabulated below.

Table 19 - Falcon 1 Spill Sequence

Timeline	Description
June 12, 1987 19:47:48	Valve begins to open
June 12, 1987 19:47:56 (t=0)	Valve open
June 12, 1987 19:49:56 (t=120)	Valve beings to close
June 12, 1987 19:50:07 (t=133)	Valve closed

Using the flow rate and duration, the ABS/FERC pool spread model [50][51] was used to determine the source term to be inputted into FDS. The pool spread model is based upon the shallow water equations in GASP [52] and a mass balance using an empirically derived vaporization rate of 0.167 kg/m^{2}s. Selected ABS/FERC pool spread calculations are included in Appendix A.

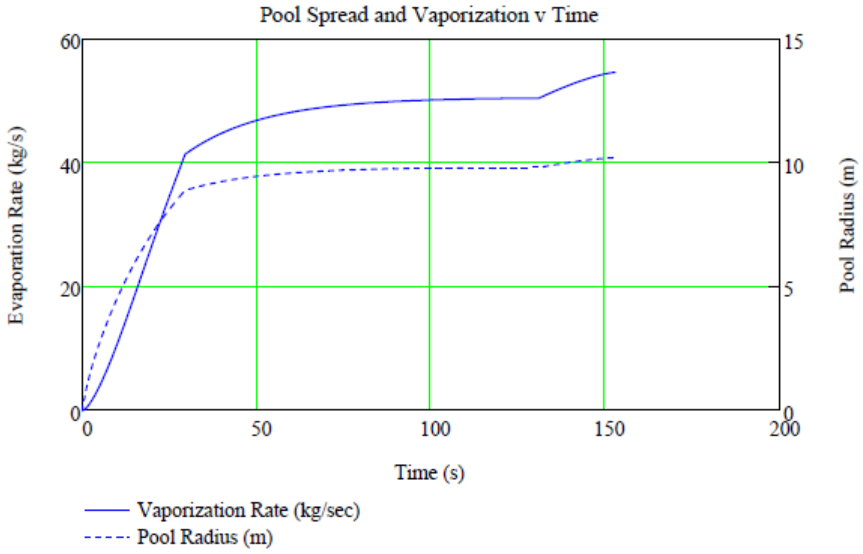


Figure 53 - Falcon 1 ABS/FERC Pool Spread and Vaporization Results

The test was conducted during wind speeds ranging from 0.56 m/s to 4.8 m/s with a domain average of 1.7 m/s and standard deviation of 0.2 m/s. The wind direction relative to the array axis (225 degrees from True North) ranged from -72 degrees to

+83 degrees with a domain average of +9.3 degrees and standard deviation of 5.5 degrees. Atmospheric stability was category G. Ambient temperature had a mean of 305.4 K with very little fluctuation. Relative humidity data was not available and insolation was -3.64 W/m^2. The pond temperature was 301.6 K. The average temperatures, average relative humidity, and upwind transient wind field data were used as input into FDS. The FDS simulations were run until a steady or quasi-steady wind profile was established throughout the domain in each test before starting the dispersion. Averaged wind field data compared well with the experimental measurements. The FDS input files are included in Appendix B. Point-wise data wind sensor data can be found in Appendix C.

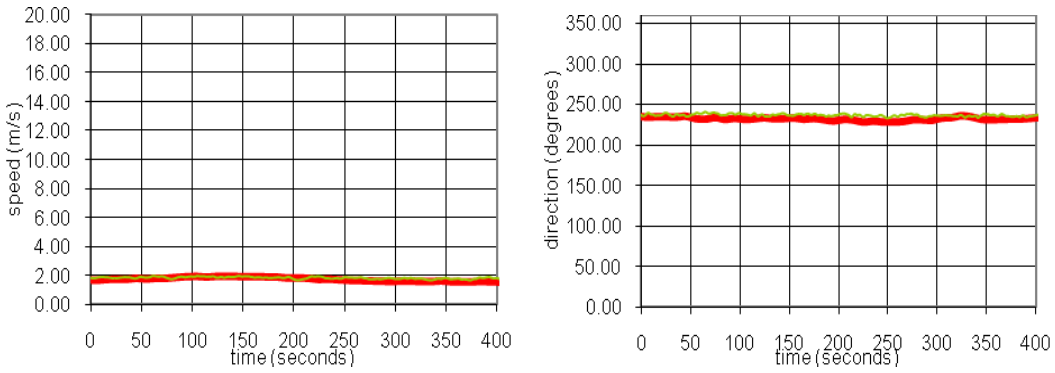


Figure 54 - Falcon 1 Average Wind Field Data

(red: experimental data; green: FDS data)

The Falcon test reports did not include stream-wise contours for comparison. Representative iso-surfaces from FDS show that most of the vapor is contained with the fenced area, which disagrees with photographic evidence of the Falcon series,

which showed that the momentum of the release from the four discharged arms propelled the vapor up and over the fence.

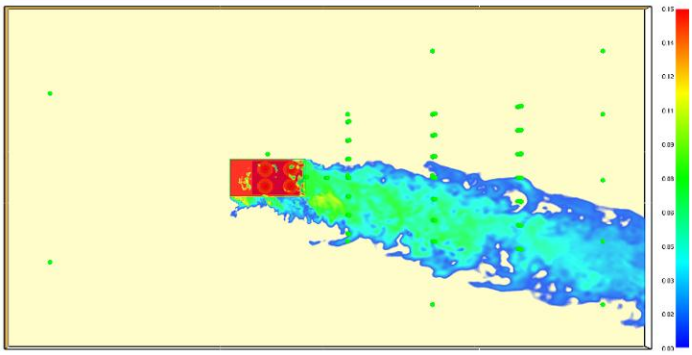


Figure 55 - Falcon 1 Instantaneous Vapor Cloud Contours at Z=2m over 750m (horizontal axis) by 400m (vertical axis) domain at 240 seconds (FDS contour with scale of 1% blue to 15% red)

FDS included all sensors that were included in the experimental trials. FDS maximum arc-wise gas concentrations were under-predictive for both short and long time averages, but showed better agreement in the far field. The under-prediction in the near field may be attributed to the lack of momentum from the release that was evident in photographic documentation of the Falcon series. Maximum point-wise gas sensor data can be found in Appendix D. Temperature sensor data can be found in Appendix E.

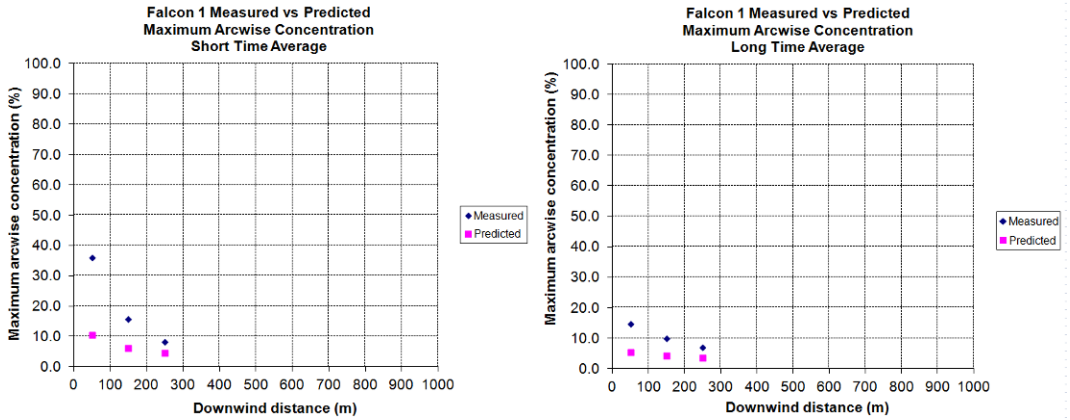


Figure 56 - Falcon 1 Maximum Arcwise Concentrations

Falcon 3

For Trial 3, the LNG composition taken before discharge was 91.0% methane and 8.0% heavier hydrocarbons. The discharge lasted for about 2 minute and 42 seconds with about 2 minutes 23 seconds of steady state flow at 18.9m^3/min. A timeline of the release is tabulated.

Table 20 - Falcon 3 Spill Sequence

Timeline	Description
June 29, 1987 18:51:54	Valve begins to open
June 29, 1987 18:52:02 (t=0)	Valve open
June 29, 1987 18:54:25 (t=143)	Valve beings to close
June 29, 1987 18:54:36 (t=154)	Valve closed

Using the flow rate and duration, the ABS/FERC pool spread model [50][51] was used to determine the source term to be inputted into FDS. The pool spread model is based upon the shallow water equations in GASP [52] and a mass balance using an empirically derived vaporization rate of 0.167 kg/m^2s. Selected ABS/FERC pool spread calculations are included in Appendix A.

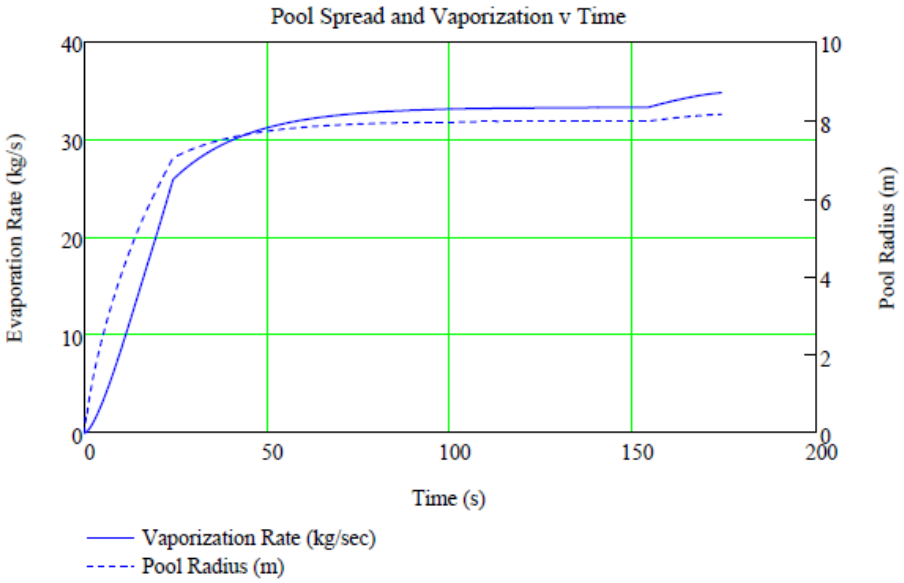


Figure 57 - Falcon 3 ABS/FERC Pool Spread and Vaporization Results

The test was conducted during wind speeds ranging from 0.58 m/s to 7.3 m/s with a domain average of 4.1 m/s and standard deviation of 0.56 m/s. The wind direction relative to the array axis (225 degrees from True North) ranged from -56 degrees to +60 degrees with a domain average of -3 degrees and standard deviation of 8.4 degrees. Atmospheric stability was category D. Ambient temperature had a mean of 308 K with very little fluctuation. Relative humidity was approximately 4% and insolation was approximately 5.46 W/m^2. The average temperature, average relative humidity, and upwind transient wind field data were used as input into FDS. The pond temperature was assumed to be equal to the ambient temperature. The FDS simulations were run until a steady or quasi-steady wind profile was established throughout the domain in each test before starting the dispersion. Averaged wind field data compared well with the experimental measurements. The FDS input files

are included in Appendix B. Point-wise data wind sensor data can be found in Appendix C.

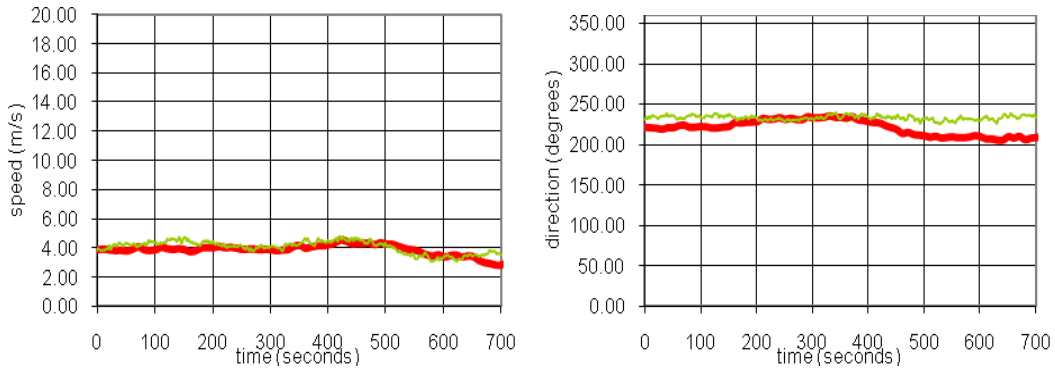


Figure 58 - Falcon 3 Average Wind Field Data

(red: experimental data; green: FDS data)

The Falcon test reports did not include stream-wise contours for comparison. Representative iso-surfaces from FDS show that most of the vapor is contained with the fenced area, which disagrees with photographic evidence of the Falcon series, which showed that the momentum of the release from the four discharged arms propelled the vapor up and over the fence.

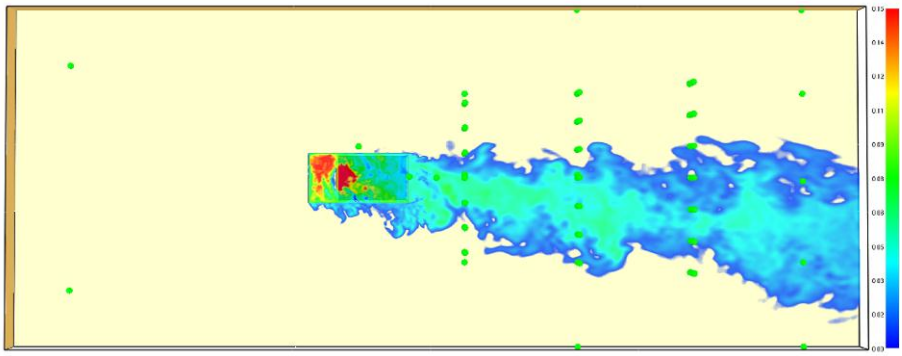


Figure 59 - Falcon 3 Instantaneous Vapor Cloud Contours at Z=2m over 750m (horizontal axis) by 300m (vertical axis) domain at 240 seconds (FDS contour with scale of 1% blue to 15% red)

FDS included all sensors that were included in the experimental trials. FDS maximum arc-wise gas concentrations were under-predictive for both short and long time averages, but showed better agreement in the far field and with longer time averages. The under-prediction in the near field may be attributed to the lack of momentum from the release that was evident in photographic documentation of the Falcon series. Maximum point-wise gas sensor data can be found in Appendix D. Temperature sensor data can be found in Appendix E.

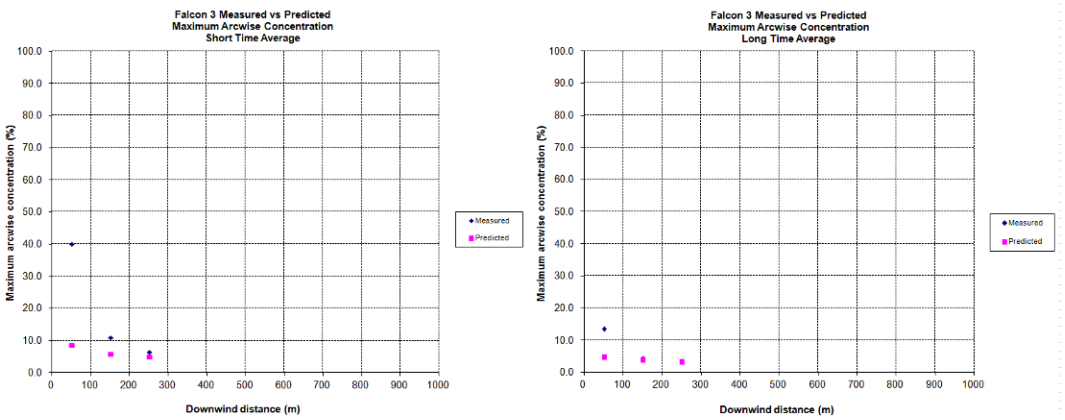


Figure 60 - Falcon 3 Maximum Arcwise Concentrations

Falcon 4

For Trial 4, the LNG composition taken before discharge was 91% methane and 8.0% heavier hydrocarbons. The discharge lasted for about 5 minute and 30 seconds with about 5 minutes 19 seconds of steady state flow at 8.7m^3/min. A timeline of the release is tabulated.

Table 21 - Falcon 4 Spill Sequence

Timeline	Description
August 21, 1987 19:26:56	Valve begins to open
August 21, 1987 19:27:04 (t=0)	Valve open
August 21, 1987 19:31:54 (t=290)	Valve beings to close
August 21, 1987 19:32:05 (t=302)	Valve closed

Using the flow rate and duration, the ABS/FERC pool spread model [50][51] was used to determine the source term to be inputted into FDS. The pool spread model is based upon the shallow water equations in GASP [52] and a mass balance using an empirically derived vaporization rate of 0.167 kg/m^2s. Selected ABS/FERC pool spread calculations are included in Appendix A.

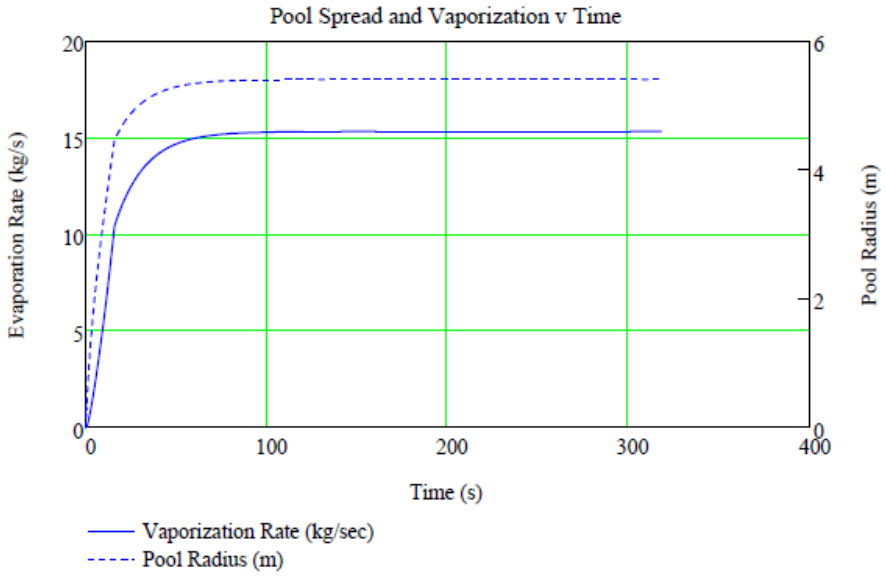


Figure 61 - Falcon 4 ABS/FERC Pool Spread and Vaporization Results

The test was conducted during wind speeds ranging from 0.8 m/s to 8.4 m/s with a domain average of 5.2 m/s and standard deviation of 0.62 m/s. The wind direction relative to the array axis (225 degrees from True North) ranged from -36 degrees to +48 degrees with a domain average of +5.6 degrees and standard deviation of 5.8 degrees. Atmospheric stability was category D-E. Ambient temperature had a mean of 304 K with very little fluctuation. Relative humidity was approximately 12% and insolation was approximately -58.7 W/m^2. The pond temperature was approximately 296 K. The average temperatures, average relative humidity, and upwind transient wind field data were used as input into FDS. The FDS simulations were run until a steady or quasi-steady wind profile was established throughout the domain in each test before starting the dispersion. Averaged wind field data compared

very well with the experimental measurements. The FDS input files are included in Appendix B. Point-wise data wind sensor data can be found in Appendix C.

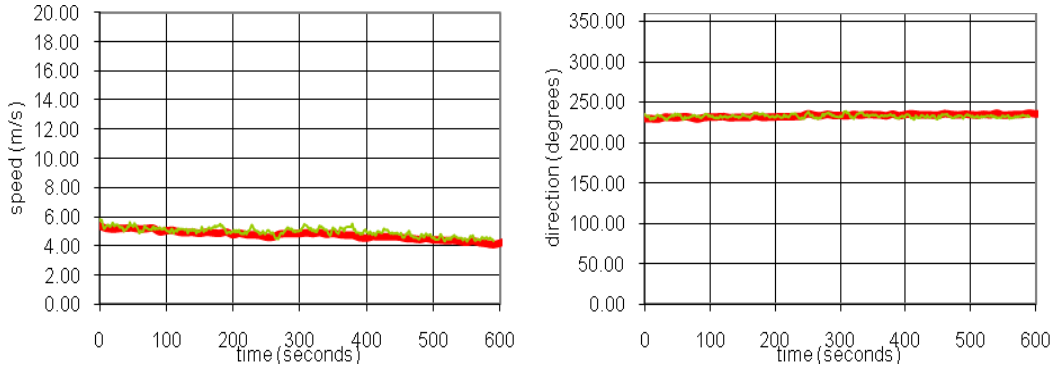


Figure 62 - Falcon 4 Average Wind Field Data

(red: experimental data; green: FDS data)

The Falcon test reports did not include stream-wise contours for comparison. Representative iso-surfaces from FDS show that unlike the other Falcon tests, the fenced area does not fill with vapor.

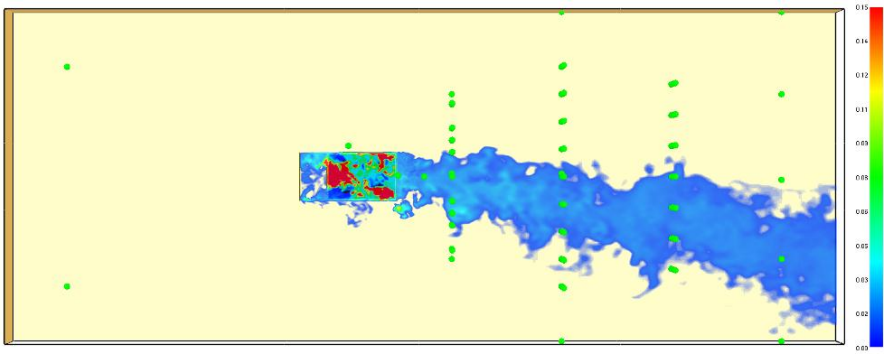


Figure 63 - Falcon 4 Instantaneous Vapor Cloud Contours at Z=2m

over 750m (horizontal axis) by 300m (vertical axis) domain at 240 seconds

(FDS contour with scale of 1% blue to 15% red)

FDS included all sensors that were included in the experimental trials. FDS maximum arc-wise gas concentrations agree very well for both short and long time averages. The better agreement with Falcon 4 may be attributed to the fact that Falcon 4 had the following differences: 1) used a 1.5-inch orifice plate instead of a 4.5-inch orifice plate; 2) had the highest driving pressure and velocity; 2) had the lowest spill rate of all the tests, 3) had the highest wind speed of all the tests, and 4) subsequently had the lowest measured concentrations. The smaller orifice and higher pressures may have broken up the liquid discharge into finer aerosol droplets that may have reduced the momentum. The lower spill rate may have also provided less momentum to carry the vapor over the fence. Finally, the higher wind speed may have become more dominant in preventing less accumulation within the fence in the simulations, which would be captured in both the experimental data and simulation. Maximum point-wise gas sensor data can be found in Appendix D. Temperature sensor data can be found in Appendix E.

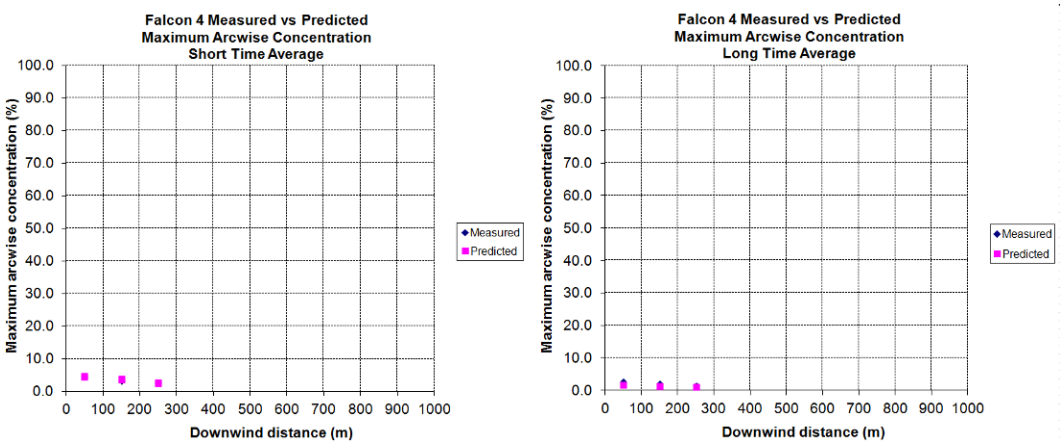


Figure 64 - Falcon 4 Maximum Arcwise Concentrations

Thorney Island Series

The Thorney Island trials were conducted in 1982-1984 by the British Health and Safety Executive at an experimental establishment of the Royal Air Force Station located at Thorney Island Airfield on the south coast of England.

Figure 65 - Thorney Island Trials Location

The Thorney Island trials were conducted to determine the transport and dispersion of heavy gas (mixture of Freon and Nitrogen) under low-wind and stable atmospheric conditions for instantaneous and continuous releases. Three continuous tests were carried out. However, Trial 46 provided only limited data due to wind shifts, and

therefore, following the MEP, only Thorney Islands 45 and 47 were selected for evaluation.

Table 22 - Thorney Island Trials

Thorney Island Trial	Material	Release Rate (kg/s)	Quantity (kg)	Notes
45	Freon/N_2	10.67	4855	
47	Freon/N2	10.22	4752	

The Thorney Island trials were conducted at an abandoned airfield on an island with 3000m of sheltered water downwind and 1000m of runway with a 1 in 100 change in slope and grass periodically cut to 20cm upwind of the prevailing wind direction [64]. The MEP [10] reports a surface roughness of 0.01m for the Thorney Island trials consistent with the Modeler's Data Archive [35]. Ermak et al. [44] reports a surface roughness of 0.005m. Based on photographic observations and knowledge of the test site, users could reasonably assume the surface roughness to users could reasonably assume the surface roughness to correspond to a tarmac or an area with sparse vegetation [64], which typically have a surface roughness of 0.007m for 3cm cut grass, 0.01m for few trees during winter time, and 0.03m for the runway area of airports. Pielke [60] reports a 0.01m surface roughness value for the upper range of soils and short grass and 0.04 m to 0.1m for long grass cut to 25cm to 1m. Brutsaert [49] reports 0.00002m for a smooth tarmac and 0.0045m for grass (airport). The surface roughness value of 0.01m reported in the MEP was used in FDS to determine the wind profile exponent.

The tests released the Freon and nitrogen mixture through an underground 2m diameter circular duct that exited vertically at ground level. A 2m diameter plate situated 0.5m above the release was provided to limit the vertical momentum.

Four weather stations and thirty-eight instrument stations collected various ambient data in addition to gas concentration and temperature data. The weather stations measured wind speed and direction with sonic anemometers. Various gas concentration sensors were located at approximately 40m, 53m, 72m, 90m, 112m, 158m, 212m, 250m, 335m, and 472m downwind.

Thorney Island 45

For Trial 45, the gas composition was 32% Freon (R-12) and 68% nitrogen. The gaseous discharge lasted for about 7 minutes and 35 seconds at 10.67kg/s and exited at grade. The flow rate, duration, and duct dimensions (2m diameter) were used as inputs into FDS for the source term.

The test was conducted during wind speeds with a domain average of 2.3 m/s. The wind direction relative to the array axis had a domain average of -26 degrees. Atmospheric stability was category E-F. Ambient temperature had a mean of 286 K. Relative humidity was reported as 100%. The average wind field data, ambient temperature, and relative humidity were included as inputs into FDS. The FDS simulations were run until a steady or quasi-steady wind profile was established throughout the domain in each test before starting the dispersion.

Thorney Island stream-wise contours were not available for comparison. A representative iso-contour from FDS shows that the vapor cloud has high concentrations underneath the 2m diameter plate used to minimize the vertical momentum of the gas with much lower concentrations surrounding the plate and downwind.

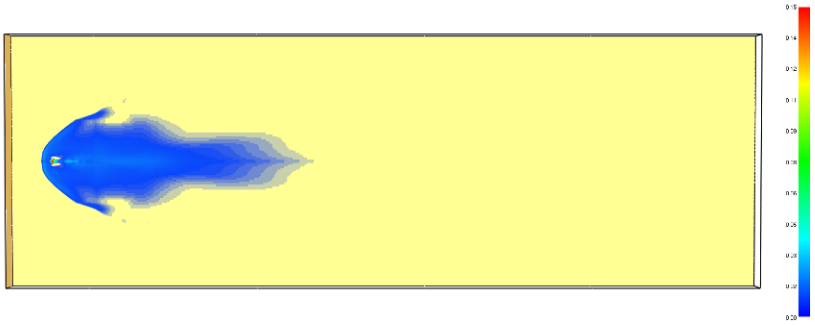


Figure 66 – Thorney Island 45 Instantaneous Vapor Cloud Contours at Z=2m over 900m (horizontal axis) by 300m (vertical axis) domain at 240 seconds (FDS contour scale of 1% blue to 15% red)

FDS included sensors at the downwind locations along the direction of the wind. FDS maximum arc-wise gas concentrations were under-predictive in the near field, but agreed better in the far field.

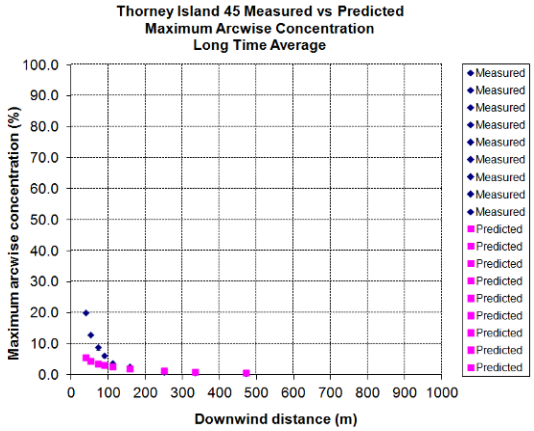


Figure 67 - Thorney Island 45 Maximum Arcwise Concentrations

Thorney Island 47

For Trial 47, the gas composition was 32% Freon (R-12) and 68% nitrogen. The gaseous discharge lasted for about 7 minutes and 45 seconds at 10.22 kg/s and exited at grade. The flow rate, duration, and duct dimensions (2m diameter) were used as inputs into FDS for the source term.

The test was conducted during wind speeds with a domain average of 1.5 m/s at 10m elevation and F stability. The wind direction relative to the array axis had a domain average of -32.5 degrees. Atmospheric stability was category F. Ambient temperature had a mean of 286 K. Relative humidity was reported as 97.4%. The average wind field data, ambient temperature, and relative humidity were included as inputs into FDS. The FDS simulations were run until a steady or quasi-steady wind profile was established throughout the domain in each test before starting the dispersion.

Thorney Island stream-wise contours were not available for comparison. A representative iso-contour from FDS shows similar trends to Thorney Island 45.

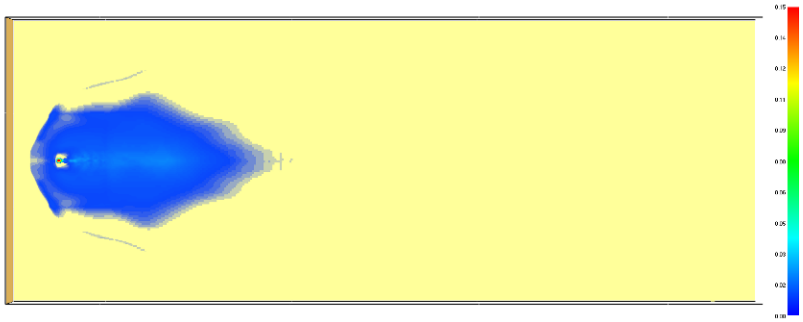


Figure 68 – Thorney Island 45 Instantaneous Vapor Cloud Contours at Z=2m over 860m (horizontal axis) by 300m (vertical axis) domain at 240 seconds (FDS contour scale of 1% blue to 15% red)

FDS included sensors at the downwind locations along the direction of the wind. FDS maximum arc-wise gas concentrations were under-predictive in the near field, but agreed better in the far field.

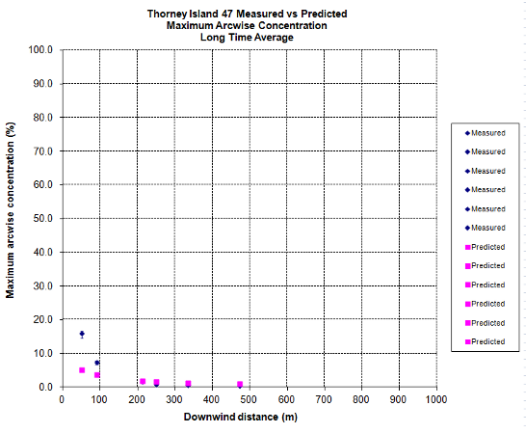


Figure 69 - Thorney Island 47 Maximum Arcwise Concentrations

Chemical Hazards Research Center (CHRC) Trials

The CHRC trials were conducted in 2004-2006 by the Chemical Hazards Research Center at a specially designed wind tunnel at the University of Arkansas. The CHRC trials were conducted to determine the effect of tanks and dikes on the dispersion for steady-state continuous releases representative of LNG releases. Three continuous tests were carried out.

Table 23 - CHRC Trials

CHRC Trial	Material	Release Rate (m^3/min)	Notes
A	CO_2	0.0339	Unobstructed
B	CO_2	0.0339	Tank and Dike
C	CO_2	0.0339	Dike Only

The tests were conducted at a 1:150 scale ultra low speed boundary layer wind tunnel able to simulate the constant stress layer of the atmospheric boundary layer [66]. Airflow of 0.4m/s at 0.067m was established from fans and passed through a circular to rectangular transition and through a honeycomb section with ½ inch cell sizes to four seamless nylon screens. A turbulent boundary layer was established by fourteen Irwin spire shaped turbulence generators measured 0.132m by 0.132m by 0.927m high spaced 0.463m apart and located 0.30m downwind of the nylon screens. Approximately 5.5m downwind of the spires, a 2.1m by 6.1m by 24.4m working region begins. The wind tunnel floor was outfitted with .0381m by .0381m roughness elements staggered 0.305m apart to mimic the turbulence of field scale trials after previous smooth floor tests showed laminarization of the airflow near the floor.

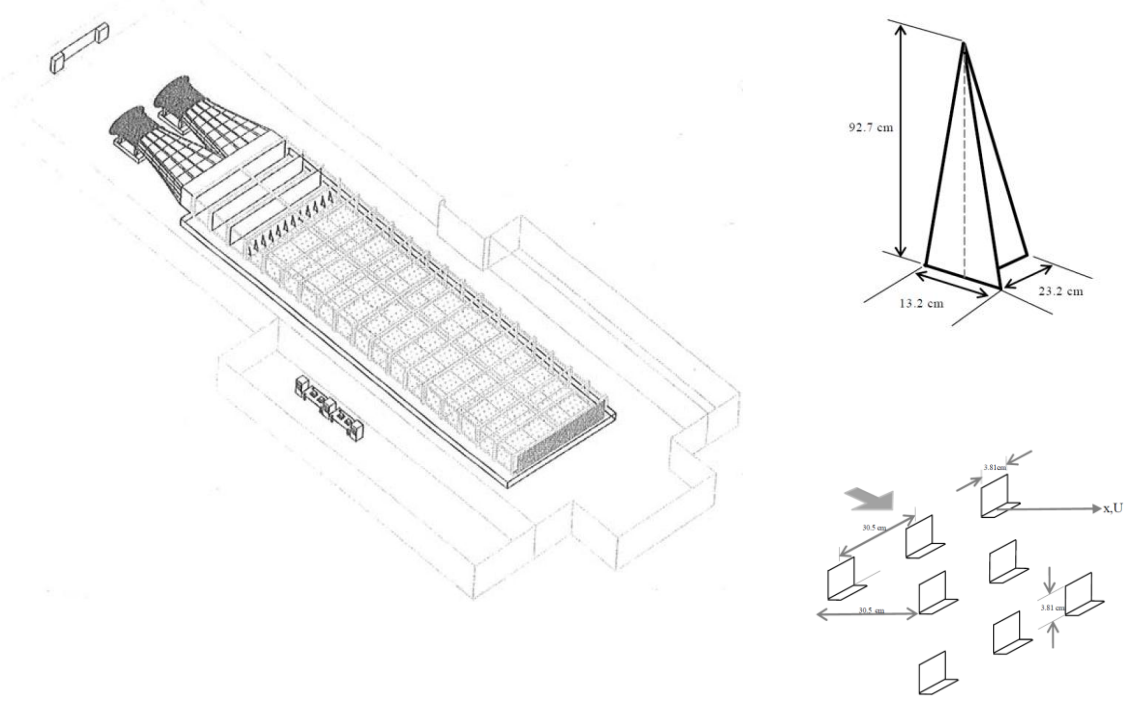


Figure 70 - CHRC Wind Tunnel [66]

Gaseous carbon dioxide (98.5%) with a propane tracer (1.5%) was released at a rate of 0.0339m^3/min for each of the trials through a square shaped 0.3341m^2 screen with a central circular section blanked off (for tank) at the wind tunnel floor. The release lasted for over 120 seconds to ensure a steady state flow was established at 0.0339m^3/min.

The trials were based on a 1:150 length scale model of typical LNG installations with the proposed scaling relationships for length, L, velocity, U, and volumetric flow rates, Q, [10]:

$$L_{wt} = L_f /150$$
$$U_{wt} = \left(U_f /150\right)^{1/2}$$
$$Q_{wt} = \left(Q_f /150\right)^{5/2}$$

The scaled gaseous flow rates of 9341m^3/min and source area of 7517m^2 are the same for all tests and were used as inputs into FDS. The FDS simulations were run until a steady or quasi-steady vapor cloud was established in each test.

The MEP [10] reports a surface roughness of 0.00072m for the CHRC wind tunnel tests and 0.108m for the scaled value. The scaled value of 0.108m reported in the MEP was used in FDS to determine the wind profile exponent.

The scaled airflow is 4.9m/s at an elevation of 10m with D stability. Ambient temperature had a mean of 296 K. Relative humidity was not reported. The scaled airflow velocity and stability, and ambient temperature was the same for all tests and was used to determine the wind profile exponent and ambient conditions inputted into all of the FDS simulations. The airflow was assumed to remain steady in direction and speed, and the relative humidity was assumed to be zero.

The sensors were located downwind of the spill point in arrays approximately 0.55m, 0.88m, 1.75m, 2.36m, and 3.57m from the center of the release at an elevation of 0.067m above the wind tunnel floor. The scaled values of 82.5m, 132m, 262.5m, 354m, 535.5m, respectively, at a scaled elevation of 0.75m were used in FDS.

CHRC A (Unobstructed)

For Trial A, the CO2 release and dispersion was unobstructed and acted as a reference case to evaluate the effectiveness and trends of the tank and dike structure typically found at most LNG facilities.

A representative iso-surface of the quasi-steady state vapor cloud in FDS shows high concentrations near the vapor source and a widening cloud downwind well beyond the sensor arrays.

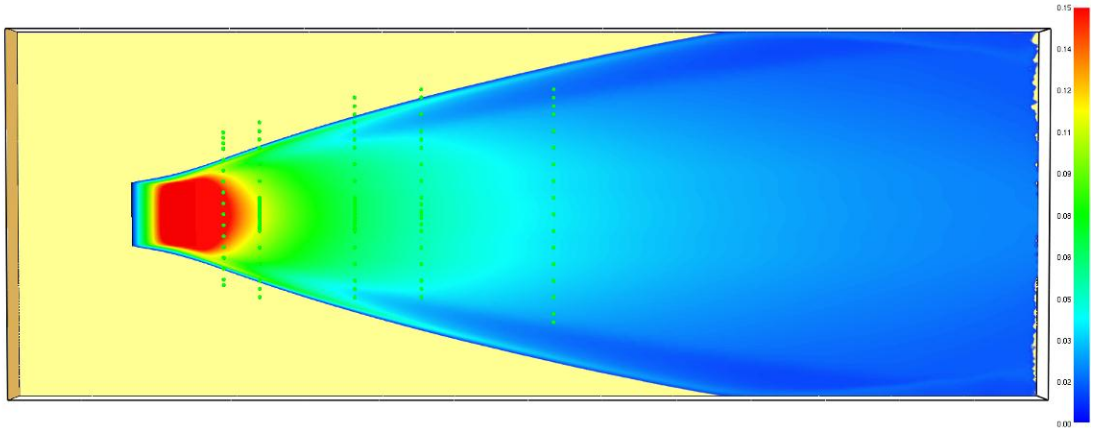


Figure 71 - CHRC A Steady State Vapor Cloud Contours at Z=1m over 1400m (horizontal axis) by 500m (vertical axis) domain (FDS contour with scale of 1% blue to 15% red)

In addition, all sensors in the experimental trials were included in FDS. The maximum arc-wise gas concentrations in FDS agree very well with the experimental data for both short and long time averages. The maximum point-wise gas sensor data also agreed very well, which can be found in Appendix D.

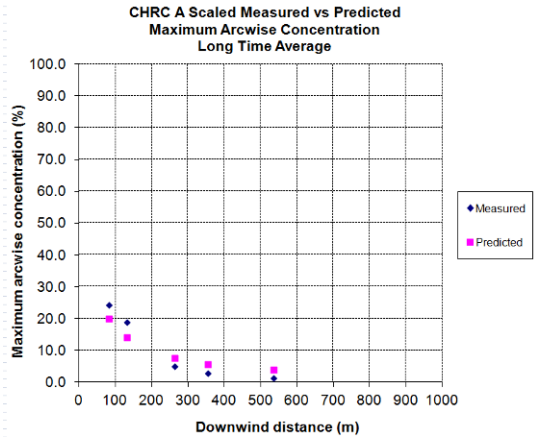


Figure 72 - CHRC A Maximum Arcwise Concentrations

CHRC B (Tank in Dike)

For Trial B, the CO2 was released in the wind tunnel with a tank and dike. The cylindrical tank was 0.31m (23.2m scaled) in diameter with a spherically domed roof for a total height of 0.288m (43.2m scaled). The square shaped dike had an inner dimension of 0.64m (96m scaled) coinciding with the source area and outer dimension of 1.13m (169.5m scaled) with sides sloped up to a 0.025m (3.75m scaled) wide apex 0.037m (5.55m scaled) high.

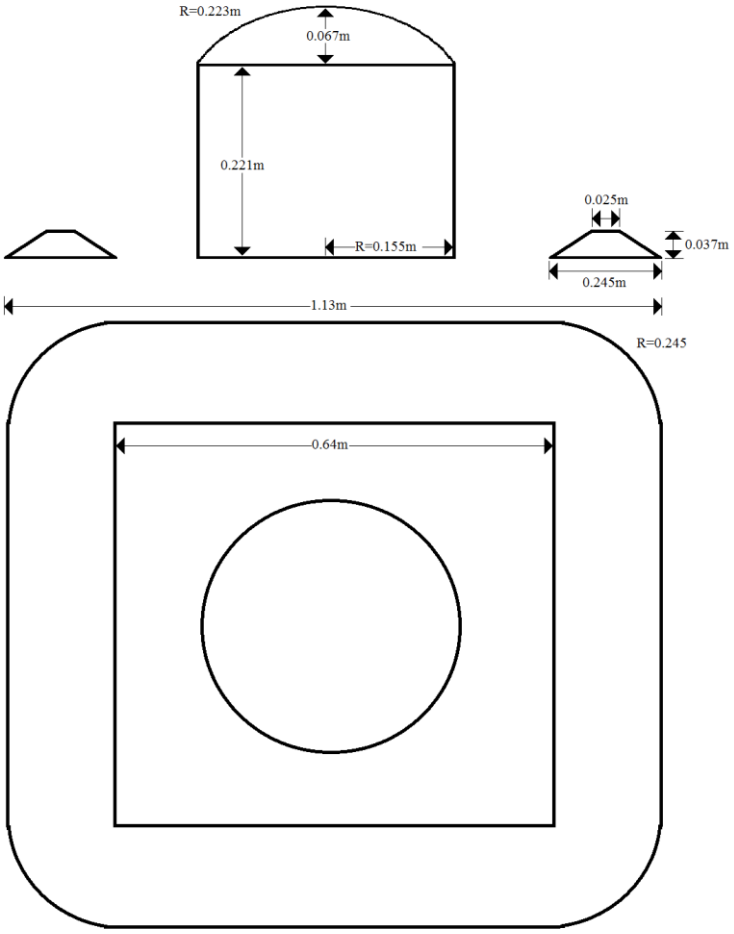


Figure 73 - CHRC Tank and Dike

(not to scale)

A representative iso-surface of the quasi-steady state vapor cloud in FDS shows high concentrations within the dike in the wake of the storage tank and bifurcation of the vapor cloud downwind of the dike as seen in the experiments. Despite the bifurcation, the overall width and downward extent of the vapor cloud concentrations is similar with the unobstructed CHRC A simulation.

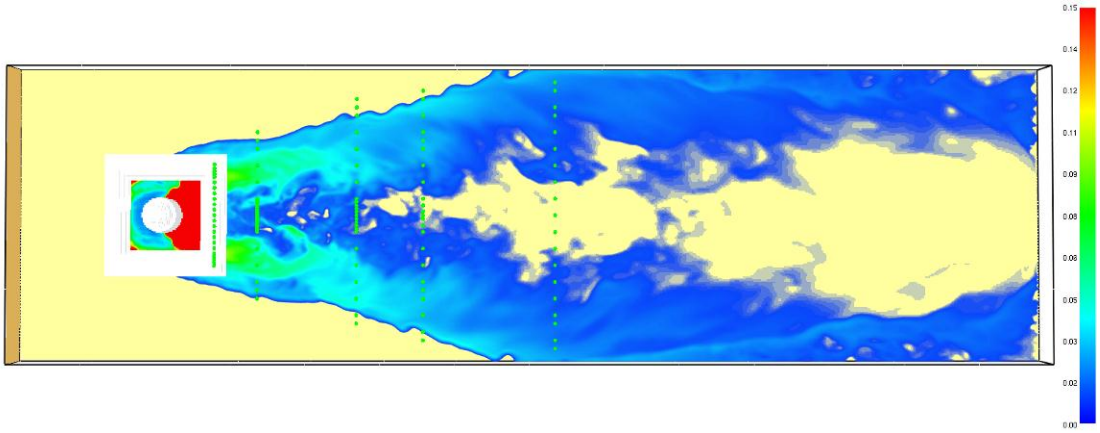


Figure 74 - CHRC B Steady State Vapor Cloud Contours at Z=1m over 1400m (horizontal axis) by 400m (vertical axis) domain (FDS contour with scale of 1% blue to 15% red)

In addition, all sensors in the experimental trials were included in FDS. The maximum arc-wise gas concentrations in FDS agree very well with the experimental data for both short and long time averages. The maximum point-wise gas sensor data also agreed very well, which can be found in Appendix D.

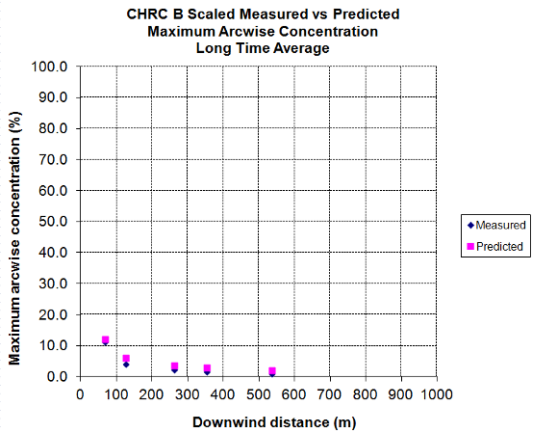


Figure 75 - CHRC B Maximum Arcwise Concentrations

CHRC C (Dike Only)

For Trial C, the CO2 was released in the wind tunnel with the dike only. Dimensions of the dike are the same as that in Trial B.

A representative iso-surface of the quasi-steady state vapor cloud in FDS shows very similar results as the unobstructed CHRC A simulation with high concentrations near the vapor source and a widening cloud downwind well beyond the sensor arrays.

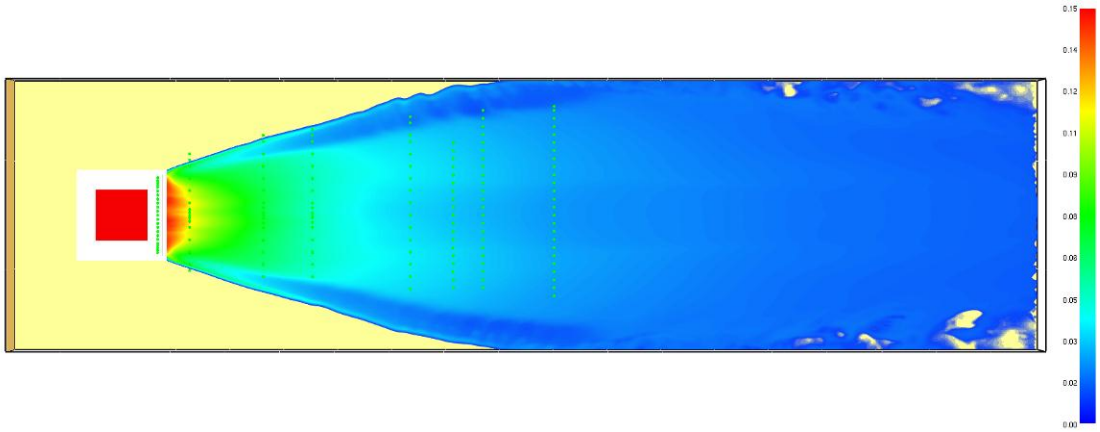


Figure 76 - CHRC C Steady State Vapor Cloud Contours at Z=1m over 1900m (horizontal axis) by 500m (vertical axis) domain (FDS contour with scale of 1% blue to 15% red)

In addition, all sensors in the experimental trials were included in FDS. The maximum arc-wise gas concentrations in FDS agree very well with the experimental data for both short and long time averages. The maximum point-wise gas sensor data also agreed very well, which can be found in Appendix D.

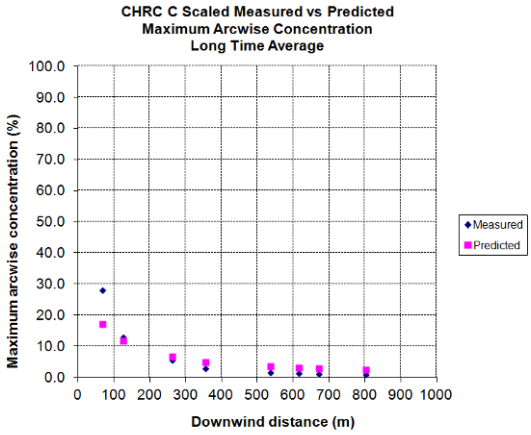


Figure 77 - CHRC C Maximum Arcwise Concentrations

Berufsakademia-Hamburg (BAH) Trials

The Berufsakademia-Hamburg (BAH) trials were conducted in 1994 by the Meteorological Institute at a specially designed wind tunnel at the University of Hamburg in Germany. The BAH trials were conducted to determine the effect of various geometric configurations on the dispersion of instantaneous and continuous releases. Instantaneous releases were carried out ten times each and continuous releases were carried out for sufficient duration to obtain a steady state cloud. In total, one-hundred thirty-three different tests were carried out over a wide range of configurations.

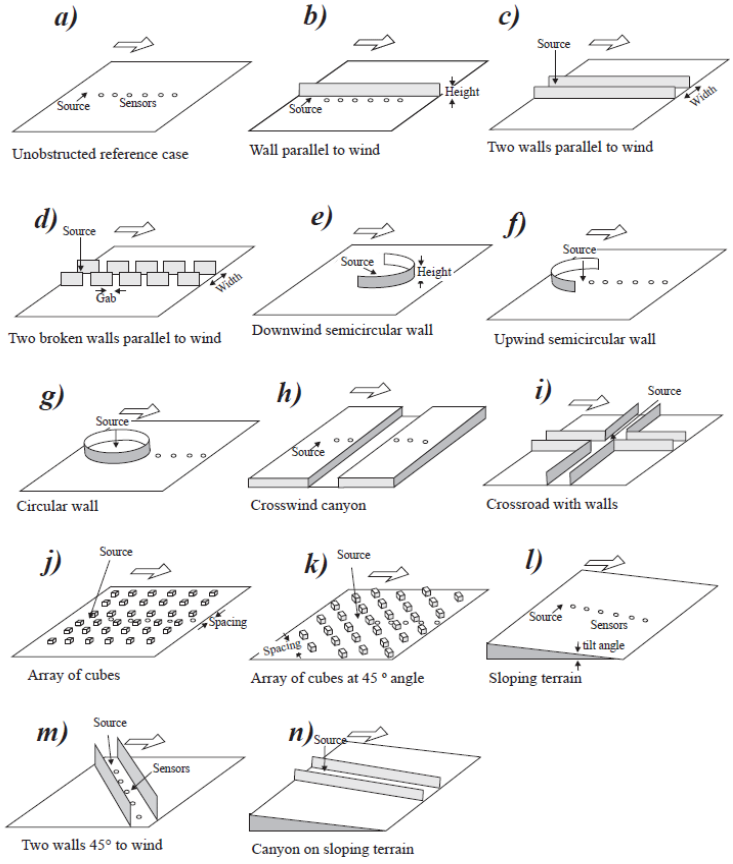


Figure 78 - BA Hamburg Test Configurations [67]

It was impractical to include all tests without an imbalance in field and wind tunnel tests. Therefore, following the MEP, only twelve of the tests were evaluated. The tests selected allow for the evaluation of upwind and downwind fences of varying size and for the evaluation of varying slopes.

Table 24 - BA Hamburg Trials

BAH Trial	Release Rate (kg/s)	Notes
DA0120	0.0001743	Continuous, unobstructed 1 (a)
DAT223	0.0008720	Continuous, unobstructed 2 (a)
039051	0.0008720	Continuous, semi-circular upwind wall 1 (f)
039072	0.0008720	Continuous, semi-circular upwind wall 2 (f)
DA0501	0.0008720	Continuous, semi-circular downwind wall 1 (e)
DA0532	0.0008720	Continuous, semi-circular downwind wall 2 (e)
039094/5	0.0008720	Continuous, circular wall 1 (g)
039097	0.0008720	Continuous, circular wall 2 (g)
DAT647	0.0001743	Continuous, slope 1 (l)
DAT631	0.0002615	Continuous, slope 2 (l)
DAT632	0.0001743	Continuous, slope 3 (l)
DAT637	0.0001743	Continuous, slope 4 (l)

The tests were conducted at 1:164 scale wind tunnel that draws airflow into the wind tunnel by a ventilation system located downstream of the working area. Airflow drawn into the wind tunnel passed through a filter at the intake and at the contraction point. A turbulent boundary layer was established by Counihan spire shaped vortex generators and 0.02m high roughness elements. Downwind of the vortex generators, a 1.5m by 1m by 4m working region begins.

Gaseous sulfur hexafluoride (SF_6) was released through a circular shaped 0.07m diameter inlet flush with the wind tunnel floor.

The trials were based on a 1:164 length scale model with the proposed scaling relationships for length, L, velocity, U, temperature, T, and volumetric flow rates, Q, [10]:

$$L_{wt} = L_f / 164$$
$$U_{wt} = \left(U_f / 164\right)^{1/2}$$
$$T_{wt} = \left(T_f / 164\right)^{1/2}$$
$$Q_{wt} = \left(Q_f / 164\right)^{5/2}$$

The MEP [10] reports a surface roughness of 0.0001m for the BA Hamburg wind tunnel tests corresponding to 0.0164m for the scaled value. The scaled value of 0.0164m reported in the MEP was used in FDS to determine the wind profile exponent.

The gas concentrations were measured using aspirated hot film probes at various downwind locations sampled at the wind tunnel floor.

BA-Hamburg DA0120 (Unobstructed 1)

For Trial DA0120, gaseous SF6 was released at a steady state of 0.0001743kg/s through a 0.07m diameter inlet, corresponding to a scaled value of 60kg/s through a 11.48m diameter source. The scaled values for flow rate and area were used as inputs into FDS.

The airflow was 0.54m/s at 0.00718m with D stability, corresponding to a scaled 6.92m/s at an elevation of 1.177m with D stability. Ambient temperature had a mean of 293 K. Relative humidity was not reported. The scaled airflow velocity and stability, and ambient temperature were used to determine the wind profile exponent and ambient conditions at the upwind boundary condition for the FDS simulation. The airflow was assumed to remain steady in direction and speed and the relative humidity was assumed to be zero. The FDS simulation was run until a steady or quasi-steady vapor cloud was established in each test. FDS input files are provided in Appendix B.

The dense gas release and dispersion was unobstructed and had the same flow rates as the sloped trials. However, DA0120 had a wind speed, while the slope trials did not. Therefore it is difficult to use DA0120 as a reference case for these tests.

Contours for the BA Hamburg trials were not available. A representative iso-surface of the quasi-steady state vapor cloud in FDS shows higher concentrations along the centerline and at the edge of the vapor cloud. The higher concentration at the edge of the vapor cloud was seen for other dispersion trials in lower wind speeds.

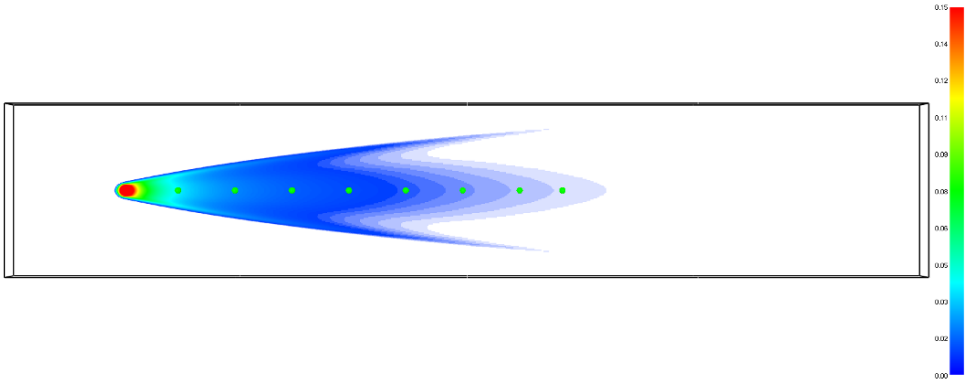


Figure 79 - DA0120 (Unobstructed 1) Steady State Vapor Cloud Contour at Z=0m over 800m (horizontal axis) by 150m (vertical axis) domain (FDS contour with scale of 1% blue to 15% red)

In addition, all sensors in the experimental trials were included in FDS. The maximum arc-wise gas concentrations in FDS were under-predictive for the near field, but showed good agreement in the far field. Point-wise gas sensor data were not available.

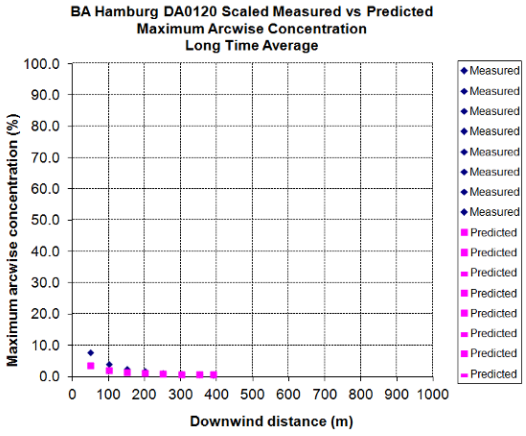


Figure 80 - DA0120 (Unobstructed 1) Maximum Arcwise Concentrations

BA-Hamburg DAT223 (Unobstructed 2)

For Trial DAT223, gaseous SF6 was released at a steady state of 0.000872kg/s through a 0.07m diameter inlet, corresponding to a scaled value of 300kg/s through a 11.48m diameter source. The scaled values for flow rate and area were used as inputs into FDS.

The airflow was 0.74m/s at 0.01367m with D stability, corresponding to a scaled 9.47m/s at an elevation of 2.24m with D stability. Ambient temperature had a mean of 293 K. Relative humidity was not reported. The scaled airflow velocity and stability, and ambient temperature were used to determine the wind profile exponent and ambient conditions at the upwind boundary condition for the FDS simulation. The airflow was assumed to remain steady in direction and speed and the relative humidity was assumed to be zero. The FDS simulation was run until a steady or quasi-steady vapor cloud was established in each test. FDS input files are provided in Appendix B.

The dense gas release and dispersion was unobstructed and acted as a reference case to evaluate the effectiveness and trends of different diameter upwind and downwind fences.

Contours for the BA Hamburg trials were not available. A representative iso-surface of the quasi-steady state vapor cloud in FDS shows higher concentrations along the

centerline. It is unclear if the irregularities at the edge of the cloud are a manifestation of FDS or the higher wind speeds.

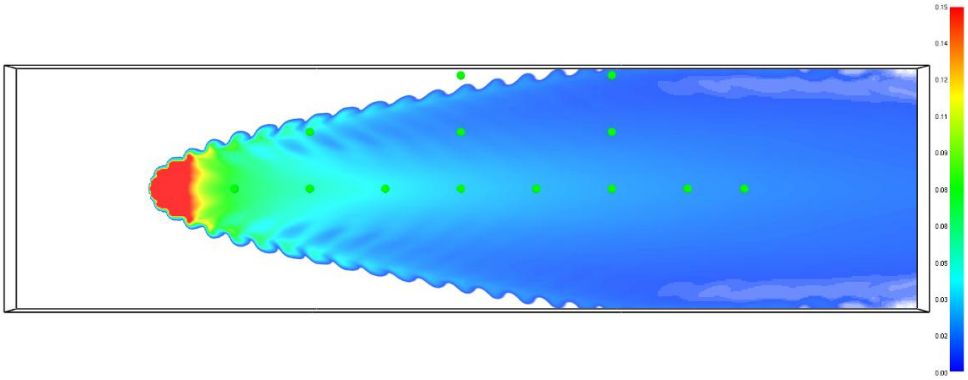


Figure 81 - DAT223 (Unobstructed 2) Steady State Vapor Cloud Contour at Z=0m over 600m (horizontal axis) by 160m (vertical axis) domain (FDS contour with scale of 1% blue to 15% red)

FDS included all sensors that were included in the MEP. FDS maximum arc-wise gas concentrations showed very good agreement with the experimental data. Maximum point-wise gas sensor data can be found in Appendix D.

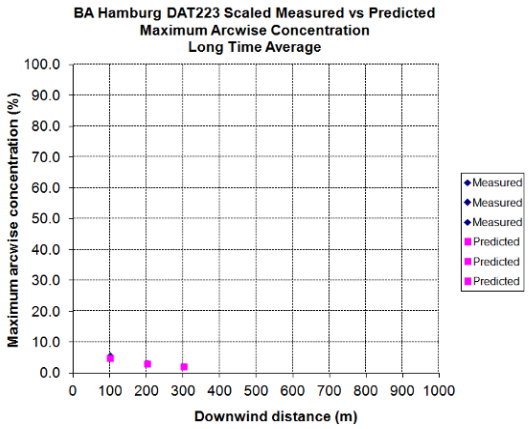


Figure 82 - DAT223 (Unobstructed 2) Maximum Arcwise Concentrations

BA-Hamburg 039051 (Upwind Fence 1)

For Trial 039051, gaseous SF6 was released at a steady state of 0.000872kg/s through a 0.07m diameter inlet, corresponding to a scaled value of 300kg/s through an 11.48m diameter source. The scaled values for flow rate and area were used as inputs into FDS.

The airflow was 0.74m/s at 0.01367m with D stability, corresponding to a scaled 9.47m/s at an elevation of 2.24m with D stability. Ambient temperature had a mean of 293 K. Relative humidity was not reported. The scaled airflow velocity and stability, and ambient temperature were used to determine the wind profile exponent and ambient conditions at the upwind boundary condition for the FDS simulation. The airflow was assumed to remain steady in direction and speed and the relative humidity was assumed to be zero. The FDS simulation was run until a steady or quasi-steady vapor cloud was established in each test. FDS input files are provided in Appendix B.

The dense gas release and dispersion had an upwind semi-circular, 31.16m diameter, 5m high fence (scaled) to evaluate the effectiveness and trends of different diameter upwind fences. The fence was assumed to have near zero thickness and inputted into FDS.

Contours for the BA Hamburg trials were not available. A representative iso-surface of the quasi-steady state vapor cloud in FDS shows high concentrations in the wake of the semi-circular fence and at the edges of the cloud where the vapor cloud bifurcated downwind. The bifurcation of the cloud results in many of the sensors that were arranged along the centerline to be missed by the actual maximum downward extent of the vapor cloud. Compared to DAT223, the downwind concentrations are reduced, most likely due to the increased turbulence promoting dilution of the cloud. In addition, it should be noted that the wake of the upwind vapor fence resulted in the vapor being pulled behind the vapor source.

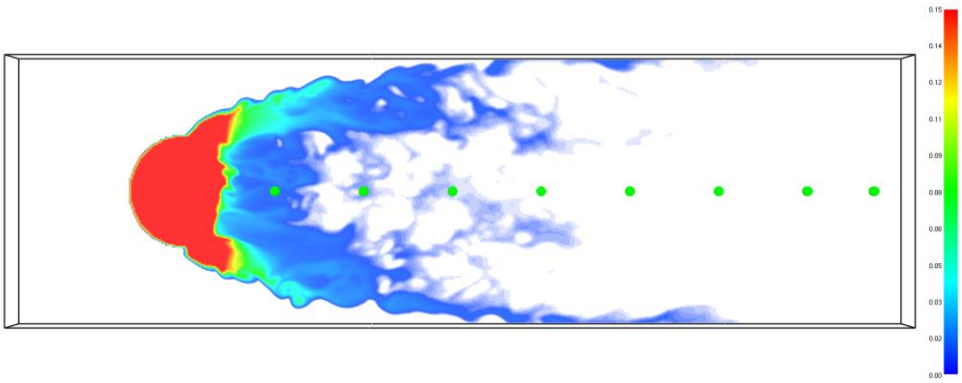


Figure 83 - 039051 (Upwind Fence 1) Quasi-Steady State Vapor Cloud Contour at Z=0m over 500m (horizontal axis) by 150m (vertical axis) domain (FDS contour with scale of 1% blue to 15% red)

FDS included all sensors that were included in the MEP. FDS maximum arc-wise gas concentrations were under-predictive for the near field, but showed better agreement in the far field. The under-prediction may be a result of the bifurcation of the vapor cloud missing the sensor array. In addition, the larger under-prediction in the near field may be partly attributed to the 883 second long averaging time specified in the MEP. Instantaneous maximum arc-wise concentrations were approximately 2.5-2.75 times higher in the near field and 1.75-2 times higher in the far field. However, the under-prediction was by a factor of 4 or more. Maximum point-wise gas sensor data can be found in Appendix D.

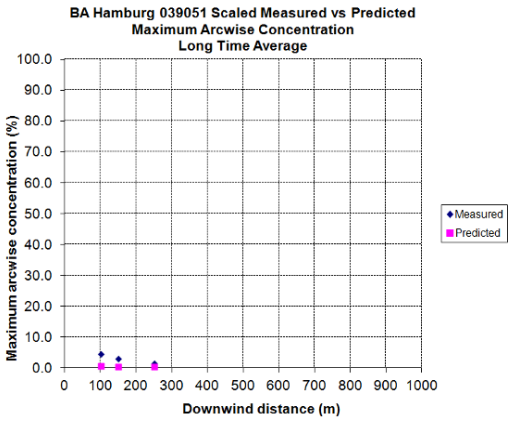


Figure 84 - 039051 (Upwind Fence 1) Maximum Arcwise Concentrations

BA-Hamburg 039072 (Upwind Fence 2)

For Trial 039072, gaseous SF6 was released at a steady state of 0.000872kg/s through a 0.07m diameter inlet, corresponding to a scaled value of 300kg/s through an 11.48m diameter source. The scaled values for flow rate and area were used as inputs into FDS.

The airflow was 0.74m/s at 0.01367m with D stability, corresponding to a scaled 9.47m/s at an elevation of 2.24m with D stability. Ambient temperature had a mean of 293 K. Relative humidity was not reported. The scaled airflow velocity and stability, and ambient temperature were used to determine the wind profile exponent and ambient conditions at the upwind boundary condition for the FDS simulation. The airflow was assumed to remain steady in direction and speed and the relative humidity was assumed to be zero. The FDS simulation was run until a steady or quasi-steady vapor cloud was established in each test. FDS input files are provided in Appendix B.

The dense gas release and dispersion had an upwind semi-circular, 50m diameter, 5m high fence (scaled) to evaluate the effectiveness and trends of different diameter upwind fences. The fence was assumed to have near zero thickness and inputted into FDS.

Contours for the BA Hamburg trials were not available. Similar to the smaller diameter upwind fence, a representative iso-surface of the quasi-steady state vapor cloud in FDS shows high concentrations in the wake of the semi-circular fence. However, unlike the smaller diameter upwind fence, the vapor cloud does not bifurcate downwind. Occasional wisps of vapor can be seen separating from the vapor cloud and traveling downwind, but they are often short lived. Compared to DAT223, the downwind concentrations are reduced, most likely due to the increased turbulence promoting dilution of the cloud. Like 039051, the wake of the upwind

vapor fence resulted in the vapor being pulled behind the vapor source up to the fence.

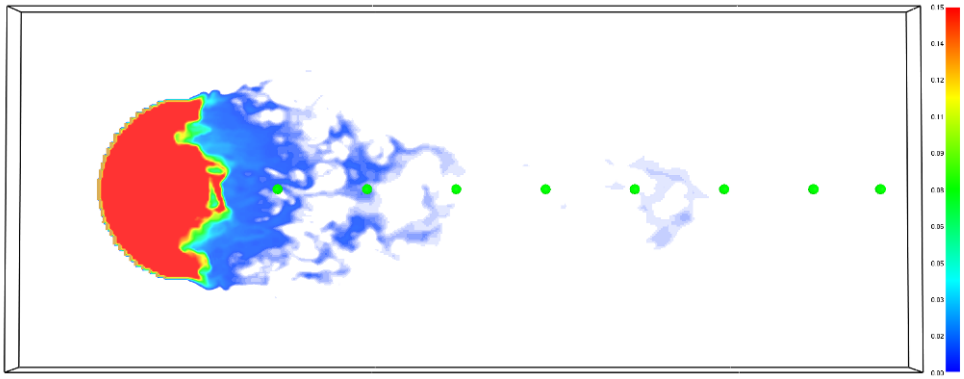


Figure 85 - 039072 (Upwind Fence 2) Quasi-Steady State Vapor Cloud Contour at Z=0m over 500m (horizontal axis) by 200m (vertical axis) domain (FDS contour with scale of 1% blue to 15% red)

FDS included all sensors that were included in the MEP. FDS maximum arc-wise gas concentrations were under-predictive for the near field, but showed better agreement in the far field. The under-prediction in the near field may be partly attributed to the 2880 second long averaging time specified in the MEP. Instantaneous maximum arc-wise concentrations were nearly 5 times higher in the near field and 2 times higher in the far field. Maximum point-wise gas sensor data can be found in Appendix D.

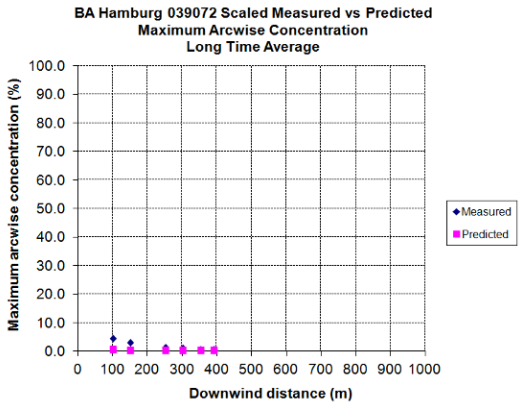


Figure 86 - 039072 (Upwind Fence 2) Maximum Arcwise Concentrations

BA-Hamburg DA0501 (Downwind Fence 1)

For Trial DA0501, gaseous SF6 was released at a steady state of 0.000872kg/s through a 0.07m diameter inlet, corresponding to a scaled value of 300kg/s through an 11.48m diameter source. The scaled values for flow rate and area were used as inputs into FDS.

The airflow was 0.74m/s at 0.01367m with D stability, corresponding to a scaled 9.47m/s at an elevation of 2.24m with D stability. Ambient temperature had a mean of 293 K. Relative humidity was not reported. The scaled airflow velocity and stability, and ambient temperature were used to determine the wind profile exponent and ambient conditions at the upwind boundary condition for the FDS simulation. The airflow was assumed to remain steady in direction and speed and the relative humidity was assumed to be zero. The FDS simulation was run until a steady or quasi-steady vapor cloud was established in each test. FDS input files are provided in Appendix B.

The dense gas release and dispersion had a downwind semi-circular, 50m diameter, 5m high fence (scaled) to evaluate the effectiveness and trends of different diameter downwind fences. The fence was assumed to have near zero thickness and inputted into FDS.

Contours for the BA Hamburg trials were not available. A representative iso-surface of the quasi-steady state vapor cloud in FDS shows high concentrations upwind of the semi-circular fence, and a rapid decrease and highly turbulent concentration profile downwind. Occasional wisps of vapor can be seen separating from the vapor cloud and traveling downwind, but are often short lived. Compared to DAT223, the downwind concentrations are reduced due to the fence obstructing the vapor cloud and also the increased turbulence downwind of the fence promoting dilution of the cloud.

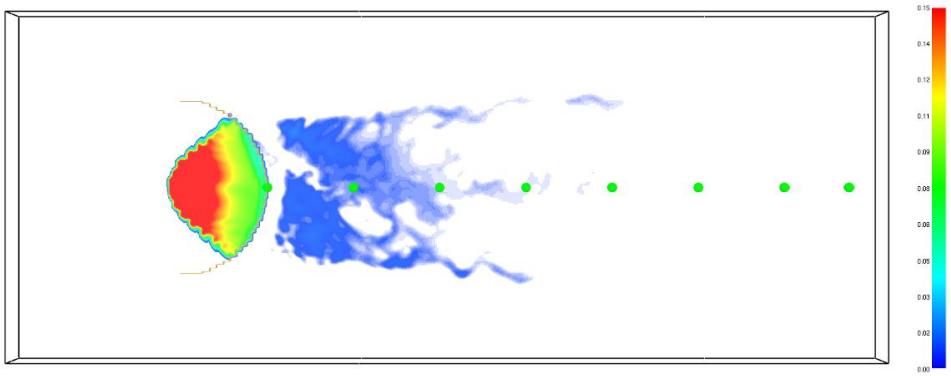


Figure 87 - DA0501 (Downwind Fence 1) Quasi-Steady State Vapor Cloud Contour at Z=0m over 500m (horizontal axis) by 200m (vertical axis) domain (FDS contour with scale of 1% blue to 15% red)

FDS included all sensors that were included in the MEP. FDS maximum arc-wise gas concentrations were vastly under-predictive for the first sensor in the near field, but showed good agreement in the far field. The under-prediction in the near field may be partly attributed to the location of the first sensor at 50.266m, which coincides with the fence at 50m. In addition, the 2048 second long averaging time specified in the MEP may have partly contributed to the lower prediction. Instantaneous maximum arc-wise concentrations were approximately 1.5-2.25 times higher in the near field and 1.3-1.5 times higher in the far field. Maximum point-wise gas sensor data can be found in Appendix D.

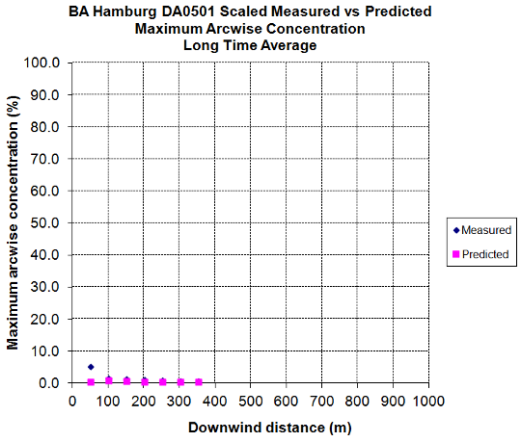


Figure 88 - DA0501 (Downwind Fence 1) Maximum Arcwise Concentrations

BA-Hamburg DA0532 (Downwind Fence 2)

For Trial DA0532, gaseous SF6 was released at a steady state of 0.000872kg/s through a 0.07m diameter inlet, corresponding to a scaled value of 300kg/s through

an 11.48m diameter source. The scaled values for flow rate and area were used as inputs into FDS.

The airflow was 0.74m/s at 0.01367m with D stability, corresponding to a scaled 9.47m/s at an elevation of 2.24m with D stability. Ambient temperature had a mean of 293 K. Relative humidity was not reported. The scaled airflow velocity and stability, and ambient temperature were used to determine the wind profile exponent and ambient conditions at the upwind boundary condition for the FDS simulation. The airflow was assumed to remain steady in direction and speed and the relative humidity was assumed to be zero. The FDS simulation was run until a steady or quasi-steady vapor cloud was established in each test. FDS input files are provided in Appendix B.

The dense gas release and dispersion has a downwind semi-circular, 31.16m diameter, 5m high fence (scaled) to evaluate the effectiveness and trends of different diameter downwind fences. The fence was assumed to have near zero thickness and inputted into FDS.

Contours for the BA Hamburg trials were not available. A representative iso-surface of the quasi-steady state vapor cloud in FDS shows high concentrations upwind of the semi-circular fence, and a rapid decrease and highly turbulent concentration profile downwind. Compared to the unobstructed DAT223, the downwind concentrations are reduced due to the fence obstructing the vapor cloud and also the increased

turbulence downwind of the fence promoting dilution of the cloud. However, the downwind extent of the lowest concentration is not greatly reduced. Compared to the larger diameter downwind fence in DA0501, the downwind concentrations are higher and extend farther.

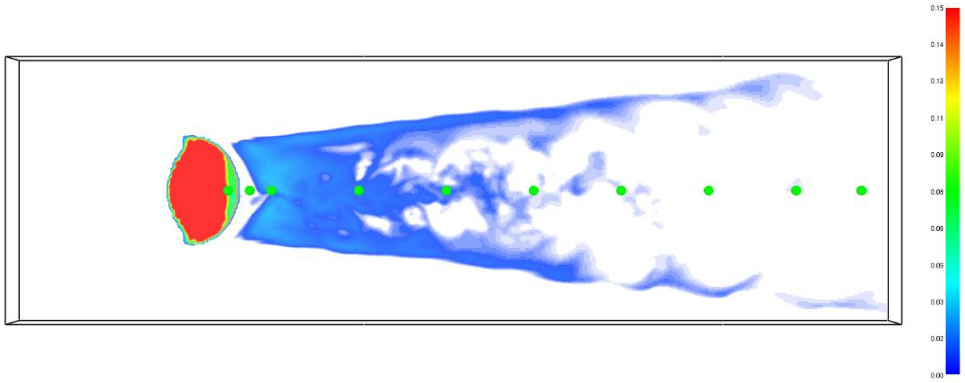


Figure 89 - DA0532 (Downwind Fence 2) Quasi-Steady State Vapor Cloud Contour at Z=0m over 500m (horizontal axis) by 150m (vertical axis) domain (FDS contour with scale of 1% blue to 15% red)

FDS included all sensors that were included in the MEP. FDS maximum arc-wise gas concentrations generally showed good agreement with the experimental data. The gas sensors near the wake of the fence showed similar trends as the experimental data, but were more under-predictive than the other data points. The under-prediction of the gas sensors is likely due to their proximity to the fence. In addition, the 2048 second long averaging time specified in the MEP may have partly contributed to the lower prediction. Instantaneous maximum arc-wise concentrations were approximately 1.3-3.3 times higher at those sensors and approximately 1.5 times

higher at the other sensors. Maximum point-wise gas sensor data can be found in Appendix D.

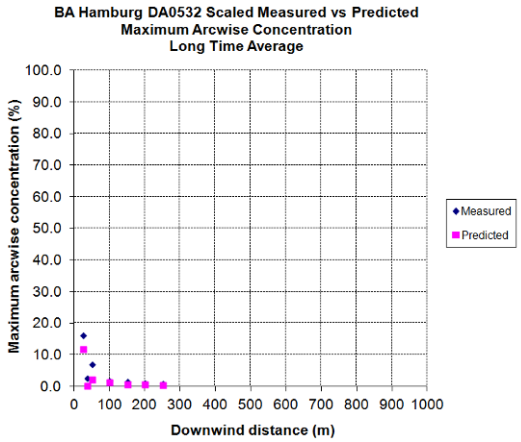


Figure 90 - DA0532 (Downwind Fence 2) Maximum Arcwise Concentrations

BA-Hamburg 039094 (Circular Fence 1)

For Trial 039094, gaseous SF6 was released at a steady state of 0.000872kg/s through a 0.07m diameter inlet, corresponding to a scaled value of 300kg/s through an 11.48m diameter source. The scaled values for flow rate and area were used as inputs into FDS.

The airflow was 0.74m/s at 0.01367m with D stability, corresponding to a scaled 9.47m/s at an elevation of 2.24m with D stability. Ambient temperature had a mean of 293 K. Relative humidity was not reported. The scaled airflow velocity and stability, and ambient temperature were used to determine the wind profile exponent and ambient conditions at the upwind boundary condition for the FDS simulation.

The airflow was assumed to remain steady in direction and speed and the relative humidity was assumed to be zero. The FDS simulation was run until a steady or quasi-steady vapor cloud was established in each test. FDS input files are provided in Appendix B.

The dense gas release and dispersion has a circular, 50m diameter, 5m high fence (scaled) to evaluate the effectiveness and trends of different diameter upwind and downwind fences. The fence was assumed to have near zero thickness and inputted into FDS.

Contours for the BA Hamburg trials were not available. A representative iso-surface of the quasi-steady state vapor cloud in FDS shows high concentrations within the upwind portion of the circular fence, a rapid decrease in the downwind portion of the circular fence, and a highly turbulent concentration profile downwind of the fence. Compared to the unobstructed DAT223, the downwind concentrations are reduced dramatically due to the combination of the upwind portion of the fence increasing turbulence and mixing in its wake, and the downwind portion of the fence obstructing the flow of the vapor cloud and increasing turbulence and mixing in its wake promoting additional dilution of the cloud.

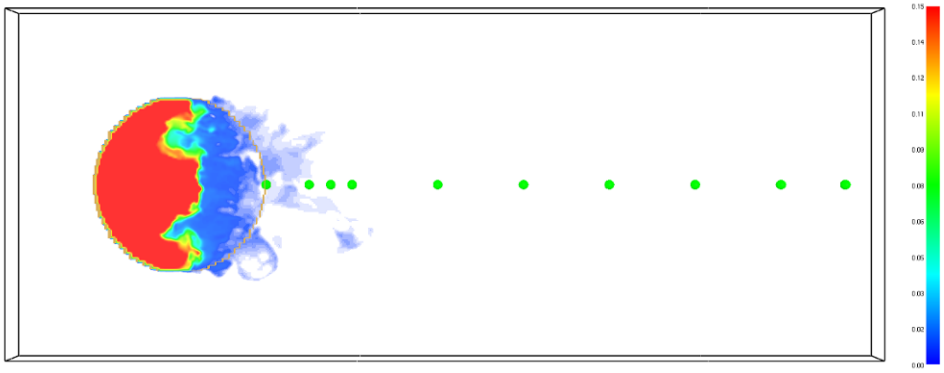


Figure 91 - 039094 (Circular Fence 1) Quasi-Steady State Vapor Cloud Contour at Z=0m over 500m (horizontal axis) by 200m (vertical axis) domain (FDS contour with scale of 1% blue to 15% red)

FDS included all sensors that were included in the MEP. FDS maximum arc-wise gas concentrations were under-predictive compared with experimental data. It is unclear as to the under-prediction as even the 2496 second long averaging time specified in the MEP would not compensate for the under-prediction. Instantaneous maximum arc-wise concentrations were only approximately 1.3-1.5 times higher at in both the near field and far field, while the under prediction was approximately by a factor of 3. Maximum point-wise gas sensor data can be found in Appendix D.

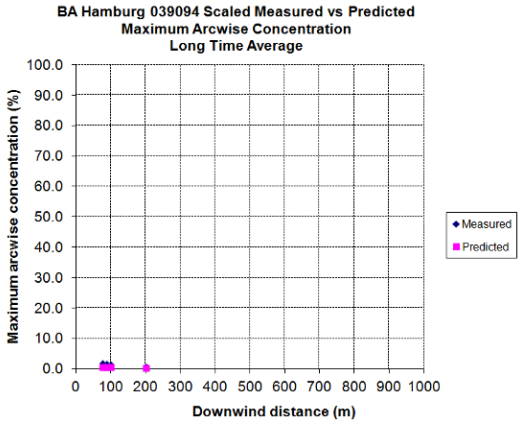


Figure 92 - 039094 (Circular Fence 1) Maximum Arcwise Concentrations

BA-Hamburg 039097 (Circular Fence 2)

For Trial 039097, gaseous SF6 was released at a steady state of 0.000872kg/s through a 0.07m diameter inlet, corresponding to a scaled value of 300kg/s through an 11.48m diameter source. The scaled values for flow rate and area were used as inputs into FDS.

The airflow was 0.74m/s at 0.01367m with D stability, corresponding to a scaled 9.47m/s at an elevation of 2.24m with D stability. Ambient temperature had a mean of 293 K. Relative humidity was not reported. The scaled airflow velocity and stability, and ambient temperature were used to determine the wind profile exponent and ambient conditions at the upwind boundary condition for the FDS simulation. The airflow was assumed to remain steady in direction and speed and the relative humidity was assumed to be zero. The FDS simulation was run until a steady or quasi-steady vapor cloud was established in each test. FDS input files are provided in Appendix B.

The dense gas release and dispersion had a circular, 31.16m diameter, 5m high fence (scaled) to evaluate the effectiveness and trends of different diameter upwind and downwind fences. The fence was assumed to have near zero thickness and inputted into FDS.

Contours for the BA Hamburg trials were not available. A representative iso-surface of the quasi-steady state vapor cloud in FDS shows high concentrations within the entire circular fence, and a greatly reduced and highly turbulent concentration profile downwind of the fence. Compared to the unobstructed DAT223, the downwind concentrations are reduced due to the containment of the vapor within the fence, and increasing turbulence and mixing in the wake of the downwind portion of the fence promoting additional dilution of the cloud. However, the downward extent of the lowest concentration is not greatly reduced. Compared to the larger diameter circular fence 039094, the downwind concentrations are higher and extend farther. This trend is similar for all smaller diameter fences.

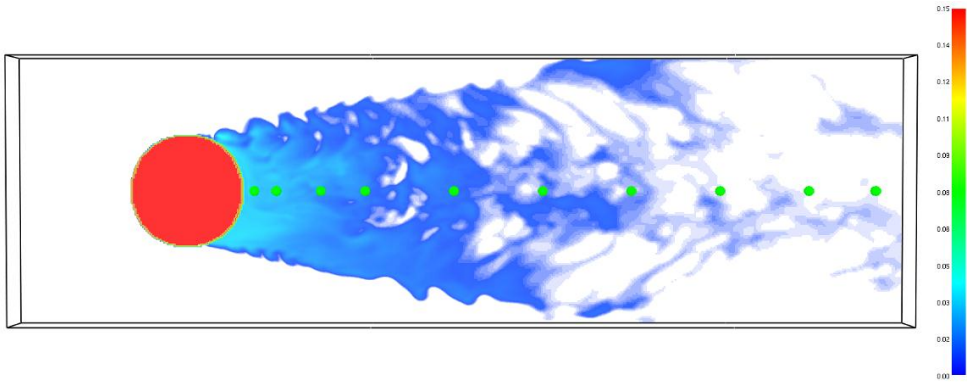


Figure 93 - 039097 (Circular Fence 2) Quasi-Steady State Vapor Cloud Contour at Z=0m over 500m (horizontal axis) by 150m (vertical axis) domain (FDS contour with scale of 1% blue to 15% red)

FDS included all sensors that were included in the MEP. FDS maximum arc-wise gas concentrations showed very good agreement with the experimental data. Instantaneous maximum arc-wise concentrations were approximately 1.35-1.8 times higher at in the near field and far field. Maximum point-wise gas sensor data can be found in Appendix D.

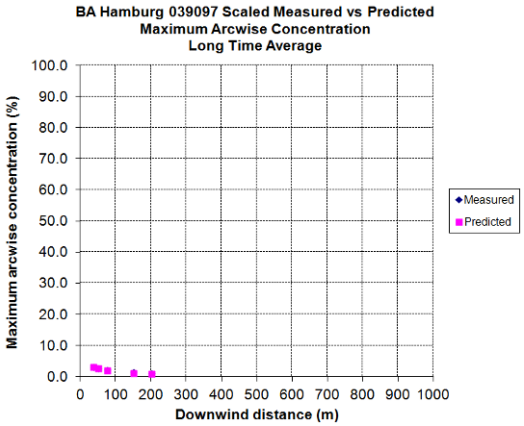


Figure 94 - 039097 (Circular Fence 2) Maximum Arcwise Concentrations

BA-Hamburg DAT647 (Slope 1)

For Trial DAT647, gaseous SF6 was released at a steady state of 0.0001743kg/s through a 0.07m diameter inlet, corresponding to a scaled value of 60kg/s through an 11.48m diameter source. The scaled values for flow rate and area were used as inputs into FDS.

There was no airflow in the sloped trials in order to isolate the effect of the sloped surface. Ambient temperature had a mean of 293 K. Relative humidity was not reported. The ambient temperature was used in the FDS simulation. Relative humidity was assumed to be zero. The FDS simulations were run until a steady or quasi-steady vapor cloud was established in each test. FDS input files are provided in Appendix B.

The dense gas release and dispersion had a mild slope of 4% to evaluate trends of the grade of the slope in relation to the vapor cloud concentrations. The gravity vector was changed in FDS to reflect this grade.

Contours for the BA Hamburg trials were not available. A representative iso-surface of the quasi-steady state vapor cloud in FDS shows high concentrations near the source and along the centerline and lower concentrations downwind and near the edge of the vapor cloud.

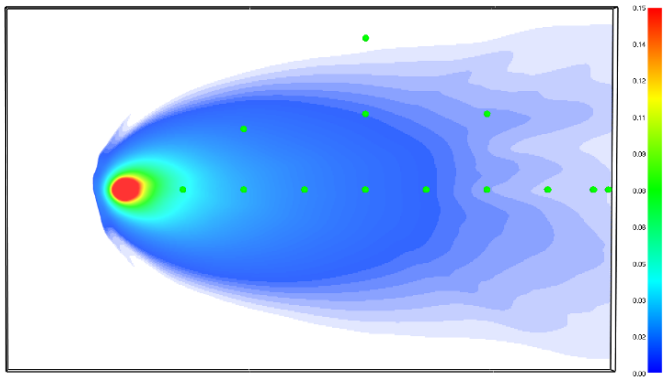


Figure 95 - DAT647 (Slope 1) Steady State Vapor Cloud Contour at Z=2m over 500m (horizontal axis) by 300m (vertical axis) domain (FDS contour with scale of 1% blue to 15% red)

FDS included all sensors that were included in the MEP. FDS maximum arc-wise gas concentrations were under-predictive compared to the experimental data by approximately a factor of 2.5 in both the near field and far field. In addition, unlike previous experiments, instantaneous maximum arc-wise concentrations were less than 1.1 times higher in the near field, but 1.2-1.8 time higher in the far field compared to the 1152 second long time average specified in the MEP. Maximum point-wise gas sensor data can be found in Appendix D.

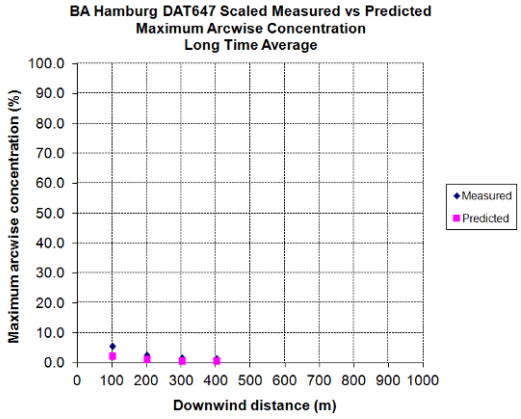


Figure 96 - DAT647 (Slope 1) Maximum Arcwise Concentrations

BA-Hamburg DAT631 (Slope 2)

For Trial DAT631, gaseous SF6 was released at a steady state of 0.0002615kg/s through a 0.07m diameter inlet, corresponding to a scaled value of 90kg/s through an 11.48m diameter source. The scaled values for flow rate and area were used as inputs into FDS.

There was no airflow in the sloped trials in order to isolate the effect of the sloped surface. Ambient temperature had a mean of 293 K. Relative humidity was not reported. The ambient temperature was used in the FDS simulation. Relative humidity was assumed to be zero. The FDS simulations were run until a steady or quasi-steady vapor cloud was established in each test. FDS input files are provided in Appendix B.

The dense gas release and dispersion was identical to DAT632 with the exception of the flow rate to evaluate any trends associated with an increased flow rate on sloped terrains. The gravity vector was changed in FDS to reflect the 8.6% grade.

Contours for the BA Hamburg trials were not available. A representative iso-surface of the quasi-steady state vapor cloud in FDS shows high concentrations near the source and along the centerline and lower concentrations downwind and near the edge of the vapor cloud. Compared to the lesser flow of DAT632, the concentrations are higher, extend farther and wider downwind.

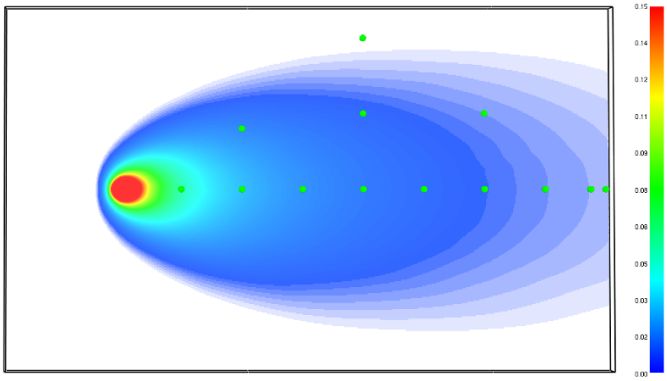


Figure 97 - DAT631 (Slope 2) Steady State Vapor Cloud Contour at Z=0m over 500m (horizontal axis) by 300m (vertical axis) domain (FDS contour with scale of 1% blue to 15% red)

FDS included all sensors that were included in the MEP. FDS maximum arc-wise gas concentrations were under-predictive compared to the experimental data by approximately a factor of 3 in both the near field and far field. In addition, unlike previous experiments, instantaneous maximum arc-wise concentrations were less than

1.15 times higher in the near field, but 1.2-1.65 time higher in the far field compared to the 806 second long time average specified in the MEP. Maximum point-wise gas sensor data can be found in Appendix D.

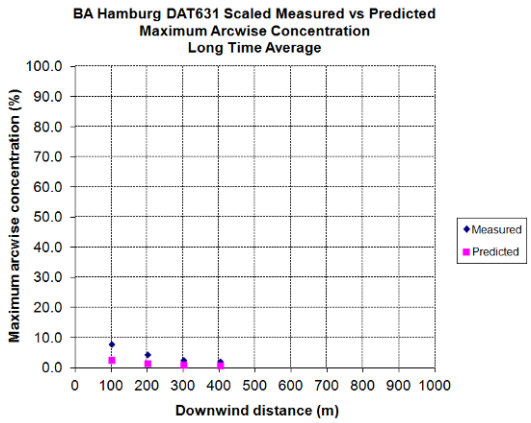


Figure 98 - DAT631 (Slope 2) Maximum Arcwise Concentrations

BA-Hamburg DAT632 (Slope 3)

For Trial DAT632, gaseous SF6 was released at a steady state of 0.0001743kg/s through a 0.07m diameter inlet, corresponding to a scaled value of 60kg/s through an 11.48m diameter source. The scaled values for flow rate and area were used as inputs into FDS.

There was no airflow in the sloped trials in order to isolate the effect of the sloped surface. Ambient temperature had a mean of 293 K. Relative humidity was not reported. The ambient temperature was used in the FDS simulation. Relative humidity was assumed to be zero. The FDS simulations were run until a steady or

quasi-steady vapor cloud was established in each test. FDS input files are provided in Appendix B.

The dense gas release and dispersion had an intermediate slope of 8.6% to evaluate trends of the grade of the slope in relation to the vapor cloud concentrations. The gravity vector was changed in FDS to reflect the 8.6% grade.

Contours for the BA Hamburg trials were not available. A representative iso-surface of the quasi-steady state vapor cloud in FDS shows high concentrations near the source and along the centerline and lower concentrations downwind and near the edge of the vapor cloud. Compared to the less steep DAT647, the concentrations extend only a tiny fraction higher and farther downwind.

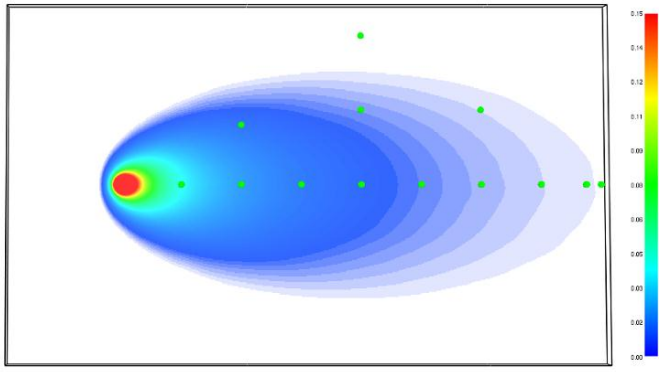


Figure 99 - DAT632 (Slope 3) Steady State Vapor Cloud Contour at Z=0m over 500m (horizontal axis) by 300m (vertical axis) domain (FDS contour with scale of 1% blue to 15% red)

FDS included all sensors that were included in the MEP. FDS maximum arc-wise gas concentrations were under-predictive compared to the experimental data by approximately a factor of 3 in both the near field and far field. Similar to DAT647, peak to mean ratios were higher in the far field than in the near field. Instantaneous maximum arc-wise concentrations were less than 1.15 times higher in the near field, but 1.2-2 times higher in the far field compared to the 742 second long time average specified in the MEP. Maximum point-wise gas sensor data can be found in Appendix D.

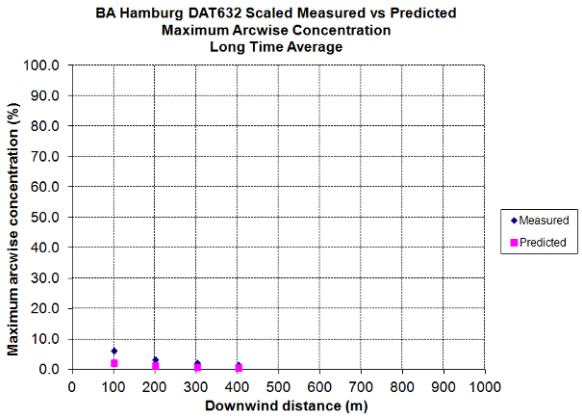


Figure 100 - DAT632 (Slope 3) Maximum Arcwise Concentrations

BA-Hamburg DAT637 (Slope 4)

For Trial DAT637, gaseous SF6 was released at a steady state of 0.0001743kg/s through a 0.07m diameter inlet, corresponding to a scaled value of 60kg/s through an 11.48m diameter source. The scaled values for flow rate and area were used as inputs into FDS.

There was no airflow in the sloped trials in order to isolate the effect of the sloped surface. Ambient temperature had a mean of 293 K. Relative humidity was not reported. The ambient temperature was used in the FDS simulation. Relative humidity was assumed to be zero. The FDS simulations were run until a steady or quasi-steady vapor cloud was established in each test. FDS input files are provided in Appendix B.

The dense gas release and dispersion had the steepest slope of 11.6% to evaluate trends of the grade of the slope in relation to the vapor cloud concentrations. The gravity vector was changed in FDS to reflect the 11.6% grade.

Contours for the BA Hamburg trials were not available. A representative iso-surface of the quasi-steady state vapor cloud in FDS shows high concentrations near the source and along the centerline and lower concentrations downwind and near the edge of the vapor cloud. Compared to the less steep DAT647, the concentrations extend only a tiny fraction higher and farther downwind, and there is negligible difference between the 8.6% grade DAT632.

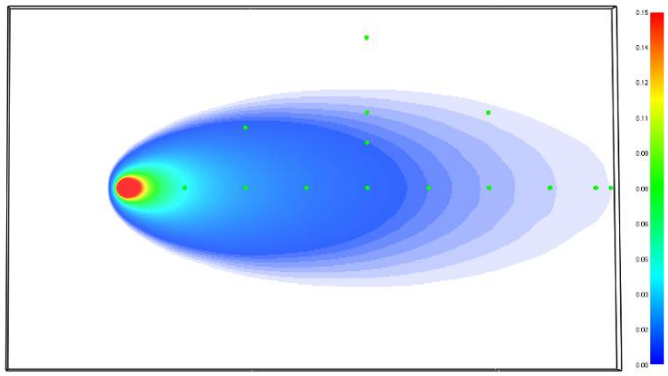


Figure 101 - DAT637 (Slope 4) Steady State Vapor Cloud Contour at Z=0m over 500m (horizontal axis) by 300m (vertical axis) domain (FDS contour with scale of 1% blue to 15% red)

FDS included all sensors that were included in the MEP. FDS maximum arc-wise gas concentrations were under-predictive compared to the experimental data by approximately a factor of 3 in both the near field and far field. Similar to the previous sloped surface, the instantaneous maximum arc-wise concentrations was less in the near field compared to the far field. However, there was also a higher difference in peak to mean ratios, with 1-1.25 times higher concentrations in the near field, and 1.1-2.6 times higher in the far field compared to the 512 second long time average specified in the MEP. Maximum point-wise gas sensor data can be found in Appendix D.

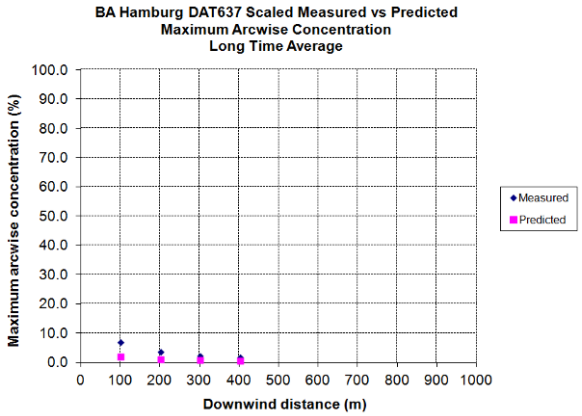


Figure 102 - DAT637 (Slope 4) Maximum Arcwise Concentrations

BA-TNO Trials

The Berufsakademia and Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek[7] (BA-TNO) trials were conducted by the Meteorological Institute at a specially designed wind tunnel at the TNO Pollution Industrial Aerodynamics wind tunnel facility. The BA-TNO trials were conducted to investigate the influence of a linear fence perpendicular to the wind direction.

Table 25 - BA TNO Trials

BA-TNO Trial	Release Rate (kg/s)	Notes
TUV01	0.00025	Unobstructed
TUV02	0.00025	Perpendicular fence
FLS	0.001045	Unobstructed

The BA-TNO tests were conducted at a 1:78 scale wind tunnel that draws airflow into the wind tunnel by a ventilation system located downstream of the working area. Airflow drawn into the wind tunnel passed through a filter at the intake and at the contraction point. A turbulent boundary layer was established by Counihan spire shaped vortex generators. A "smooth carpet" covered the conditioning section and the working region with a corresponding roughness length of 0.00005m [10]. Downwind of the vortex generators, a 6.8m long by 2.65m wide and 1.2m high working region begins.

[7] Netherlands Organization for Applied Scientific Research

Gaseous sulfur hexafluoride (SF_6) was released through a circular shaped 0.107m diameter inlet mesh with 50% porosity at the wind tunnel floor.

The trials were based on a 1:164 length scale model with the proposed scaling relationships for length, L, velocity, U, temperature, T, and volumetric flow rates, Q, [10]:

$$L_{wt} = L_f / 164$$
$$U_{wt} = \left(U_f / 164\right)^{1/2}$$
$$T_{wt} = \left(T_f / 164\right)^{1/2}$$
$$Q_{wt} = \left(Q_f / 164\right)^{5/2}$$

The MEP [10] reports a surface roughness of 0.00005m for the BA Hamburg wind tunnel tests corresponding to 0.0039m for the scaled value. The scaled value of 0.0039m reported in the MEP was used in FDS to determine the wind profile exponent.

The gas concentration was measured using aspirated hot wire probes at various locations downwind sampled at the wind tunnel floor.

BA-TNO TUV01 (Unobstructed)

For Trial TUV01, gaseous SF6 was released at a steady state of 0.00025kg/s through a 0.107m diameter inlet, corresponding to a scaled value of 13.43kg/s through an 8.35m diameter source. The scaled values for flow rate and area were used as inputs into FDS.

The airflow was 0.58m/s at 0.0084m with D stability, corresponding to a scaled 5.12m/s at an elevation of 0.65m with D stability. Ambient temperature had a mean of 293 K. Relative humidity was not reported. The scaled airflow velocity and stability, and ambient temperature were used to determine the wind profile exponent and ambient conditions at the upwind boundary condition for the FDS simulation. The airflow was assumed to remain steady in direction and speed and the relative humidity was assumed to be zero. The FDS simulation was run until a steady or quasi-steady vapor cloud was established in each test. FDS input files are provided in Appendix B.

The dense gas was released and dispersed unobstructed and acted as a reference case for TUV02 to evaluate the effectiveness and trends of a fence.

Contours for the TNO trials were not available. A representative iso-surface of the quasi-steady state vapor cloud in FDS shows a narrow vapor cloud with low concentrations near the source and with even lower concentrations downwind.

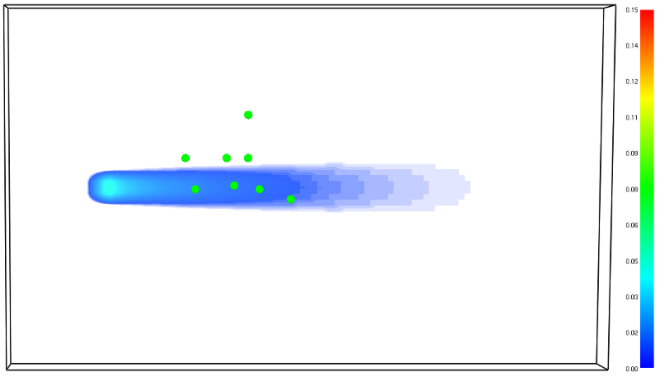


Figure 103 - TUV01 (Unobstructed) Steady State Vapor Cloud Contour at Z=0m over 200m (horizontal axis) by 120m (vertical axis) domain (FDS contour with scale of 1% blue to 15% red)

FDS included all sensors that were included in the MEP. FDS maximum gas concentrations were under-predictive compared to the experimental data by approximately a factor of 2 near the centerline and even more away from the centerline. The instantaneous maximum concentrations were nearly 1-1.35 times higher compared to the 883 second long time average specified in the MEP. Maximum point-wise gas sensor data can be found in Appendix D.

BA-TNO TUV02 (Fence)

For Trial TUV02, gaseous SF6 was released at a steady state of 0.00025kg/s through a 0.107m diameter inlet, corresponding to a scaled value of 13.43kg/s through an 8.35m diameter source. The scaled values for flow rate and area were used as inputs into FDS.

The airflow was 0.58m/s at 0.0084m with D stability, corresponding to a scaled 5.12m/s at an elevation of 0.65m and D stability. Ambient temperature had a mean of 293 K. Relative humidity was not reported. The scaled airflow velocity and stability, and ambient temperature were used to determine the wind profile exponent and ambient conditions at the upwind boundary condition for the FDS simulation. The airflow was assumed to remain steady in direction and speed and the relative humidity was assumed to be zero. The FDS simulation was run until a steady or quasi-steady vapor cloud was established in each test. FDS input files are provided in Appendix B.

The dense gas release and dispersion was identical to TNO TUV01 with the exception of a 2m high fence perpendicular to the flow located 48m downwind to evaluate the effect of the vapor fence on the vapor cloud concentrations. The fence was inputted into FDS.

Contours for the TNO trials were not available. A representative iso-surface of the quasi-steady state vapor cloud in FDS shows a narrow vapor cloud with low

concentrations near the source and with even lower concentrations downwind that becomes obstructed by the downwind fence with only trace concentrations extending downwind.

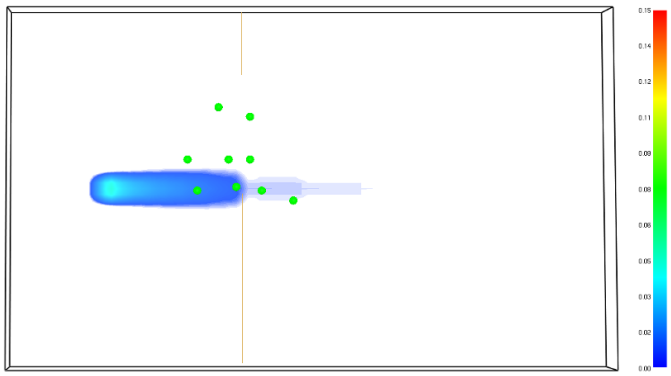


Figure 104 - TUV02 (Linear Fence) Steady State Vapor Cloud Contour at Z=0m over 200m (horizontal axis) by 120m (vertical axis) domain

(FDS contour with scale of 1% blue to 15% red)

FDS included all sensors that were included in the MEP. FDS maximum gas concentrations were under-predictive compared to the experimental data by approximately a factor of 2 near the centerline and even more away from the centerline. The instantaneous maximum concentrations were nearly 1-1.45 times higher near the centerline and up to 4.1 times higher away from the centerline compared to the 883 second long time average specified in the MEP. Maximum point-wise gas sensor data can be found in Appendix D.

BA-TNO FLS (Unobstructed)

For Trial FLS, gaseous SF6 was released at a steady state of 0.001045kg/s through a 0.107m diameter inlet, corresponding to a scaled value of 56.2kg/s through an 8.35m diameter source. The scaled values for flow rate and area were used as inputs into FDS.

The airflow was 0.78m/s at 0.015m with D stability, corresponding to a scaled 6.88m/s at an elevation of 1.17m and D stability. Ambient temperature had a mean of 293 K. Relative humidity was not reported. The scaled airflow velocity and stability, and ambient temperature were used to determine the wind profile exponent and ambient conditions at the upwind boundary condition for the FDS simulation. The airflow was assumed to remain steady in direction and speed and the relative humidity was assumed to be zero. The FDS simulation was run until a steady or quasi-steady vapor cloud was established in each test. FDS input files are provided in Appendix B.

The dense gas was released and dispersed unobstructed and provided a large number of sensors to allow for a more detailed examination of point-wise data.

Contours for the TNO trials were not available. A representative iso-surface of an 883 second average quasi-steady state vapor cloud in FDS shows higher concentrations near the source that quickly fall to concentrations less than 1% before the second row of sensors.

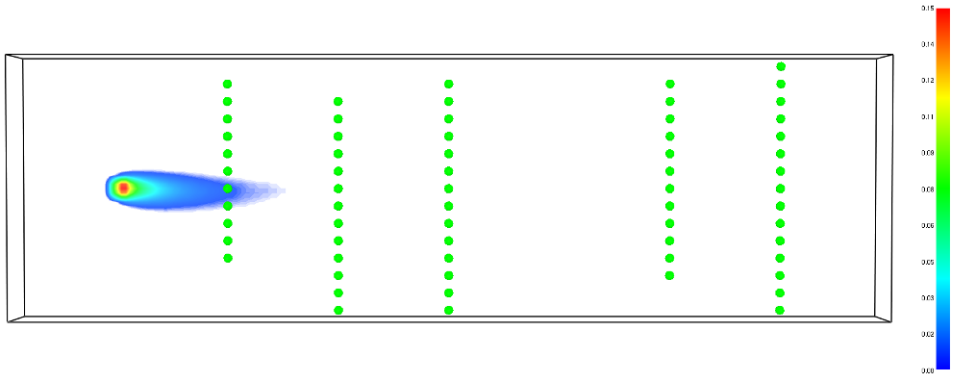


Figure 105 - FLS (Unobstructed) Quasi-Steady State Vapor Cloud Contour at Z=0m over 400m (horizontal axis) by 120m (vertical axis) domain (FDS contour with scale of 1% blue to 15% red)

FDS included all sensors that were included in the MEP. FDS maximum gas concentrations were vastly under-predict the experimental data, but showed better agreement in the far field. The instantaneous maximum concentrations were nearly 1-1.45 times higher near the centerline and up to 4.1 times higher away from the centerline compared to the 883 second long time average specified in the MEP. Maximum point-wise gas sensor data can be found in Appendix D.

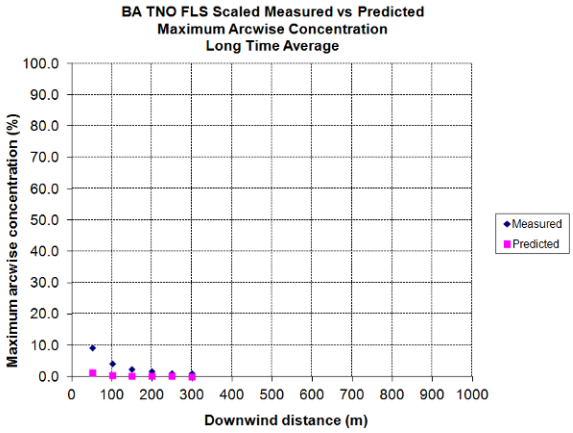


Figure 106 - FLS (Unobstructed) Maximum Arcwise Concentrations

Statistical Performance Measures

The MEP calls for comparisons of model predictions with experimental measurements using statistical performance measures (SPMs) to measure the bias (i.e. under-prediction or over-prediction) and scatter of predictions by a model. The SPMs for the MEP, include the geometric variance (VG), mean relative square error (MRSE), mean relative bias (MRB), geometric mean bias (MG), and factor of 2 fraction (FAC2).

As recommended by FERC to help satisfy concerns raised by NASFM, the PHMSA Advisory Bulletin also requires the determination of four additional SPMs based on a common safety factor calculation – concentration safety factor (CSF), distance safety factor (DSF), and concentration and distance safety factors at the LFL concentration (CSF_LFL and DSF_LFL, respectively).

Table 26 - Statistical Performance Measures

Statistical Performance Measure (SPM)	Calculation	Description
mean relative bias (MRB)	$-0.4 \le \left\langle \frac{C_m - C_p}{\frac{1}{2}(C_m + C_p)} \right\rangle \le 0.4$	A metric used to measure the bias of a model symmetrical about zero with min/max of -2/+2. Small bounds make it less sensitive to large (Cp/Cm>10) differences, but also makes it not a great indicator of large differences. Acceptance bounds based on +/-50% of mean.
geometric mean bias (MG)	$0.67 \le \exp\left\langle \ln\left(\frac{C_m}{C_p}\right) \right\rangle \le 1.5$	A metric used to measure the bias of a model about 1 with min/max of 1/∞. Natural log function makes it less sensitive to large differences, but also makes it not a great indicator of large differences. Acceptance bounds based on +-50% of mean.
mean relative square error (MRSE)	$\left\langle \frac{(C_p - C_m)^2}{\frac{1}{4}(C_p + C_m)^2} \right\rangle \le 2.3$	A metric used to measure the scatter of a model with a min/max of 0/4. Acceptance bounds based on scatter of a factor of 3 from the mean.
geometric variance (VG)	$\exp\left\langle \left[\ln\left(\frac{C_m}{C_p}\right) \right]^2 \right\rangle \le 3.3$	A metric used to measure the scatter of a model with a min/max of 1/∞. Acceptance bounds based on scatter of a factor of 3 from the mean. Sensitive to a single large differences in a dataset.
factor of 2 fraction (FAC2)	$\sum\left(0.5 \le \frac{C_p}{C_m} \le 2.0\right) \ge 0.50$	A metric used to measure the number of predictions within a factor of 2 of the measured value. Acceptance bound based on at least 50% of predictions being within a factor of 2.
safety factor (SF)	$0.5 \le \left\langle \frac{C_p}{C_m} \right\rangle \le 2.0$	A metric used to measure the bias of a model about 1 with a min/max of 0/∞. Acceptance bounds based on predictions being within a factor of 2 of measured values.

FDS predictions of maximum arc-wise gas concentrations, maximum gas concentration arc-wise distances, maximum point-wise gas concentrations, and cloud widths are tabulated by the MEP Groups with the quantitative acceptance criteria of the MEP. Values that exceed MEP quantitative acceptance criteria are highlighted.

Maximum arc-wise concentrations are determined from the maximum measured gas concentration in the experimental data and the maximum predicted gas concentration by FDS using the same sensor placement as the experiment. This comparison is dependent on the sensor placement relative to the vapor cloud, but as long as the vapor cloud intersects sensor arrays in both the experiment and FDS model, there should not be much discrepancy.

Maximum arc-wise distances are determined from the arc-wise distance at which a maximum measured gas concentration was recorded and the distance at which FDS predicts an iso-surface with that maximum measured gas concentration disperses downwind. This comparison is not dependent on the sensor placement relative to the vapor cloud as it relies on iso-surfaces in FDS that are not tied to a sensor location.

Maximum point-wise gas concentrations are determined from the maximum measured gas concentration by a specific sensor in the experimental data and the maximum predicted gas concentration at that same specific sensor location as the experiment. This comparison is the most dependent on the sensor placement relative

to the vapor cloud and is often subject to the most degree of scatter if the experimental data and FDS predictions do not match accurately.

Maximum cloud widths, CW, are determined from the cross-wind point-wise gas concentrations using the equation for the standard deviation of a frequency distribution [10] first proposed by Pasquill,

$$CW^2 = \frac{\sum C \cdot y^2}{\sum C} - \left(\frac{\sum C \cdot y}{\sum C} \right)^2 ,$$

where C is the time-averaged concentration and Y is the cross wind displacement of each sensor. Hanna et al, [35] recommends that at least four sensors on an arc reporting non-zero values, that the maximum concentration is not at either end of the cross-wise sensor locations, and that the lateral concentration distribution must not exhibit bifurcation.

Table 27 - SPM Evaluation Against Quantitative Assessment Critiera: MEP									
Data Set	Quantitative Criteria								
	-0.4<MRB <0.4	**0.67< MG<1.5**	**MRSE<2.3**	**VG<3.3**	**FAC2 >50%**	**0.5<CSF<2**	**0.5< CSF_LFL<2**	**0.5<DSF<2**	**0.5< DSF_LFL<2**
Maximum Arc-wise Gas Concentration									
Unobstructed Field Trials (short time avg.)	-0.17	0.84	0.46	1.81	69%	1.55	1.39	N/A	N/A
Unobstructed Trials (long time avg.)	-0.47	0.58	0.74	2.63	41%	2.29	N/A	N/A	N/A
Obstructed Field Trials (short time avg.)	0.50	1.74	0.49	1.87	67%	0.66	0.87	N/A	N/A
Obstructed Trials (long time avg.)	0.56	1.81	0.41	1.59	67%	0.59	N/A	N/A	N/A
Unobstructed Wind-Tunnel Tests (scaled)	0.71	2.38	0.93	4.59	32%	0.60	N/A	N/A	N/A
Obstructed Wind-Tunnel Tests (scaled)	0.45	1.72	0.72	2.81	49%	0.82	N/A	N/A	N/A
Maximum Gas Concentration Arc-wise Distance									
Unobstructed Field Trials (short time avg.)	-0.15	0.87	0.47	1.79	63%	N/A	N/A	1.46	1.43
Unobstructed Trials (long time avg.)	-0.42	0.63	0.79	2.75	34%	N/A	N/A	2.12	N/A
Obstructed Field Trials (short time avg.)	0.64	3.09	1.34	58.7	33%	N/A	N/A	0.79	0.73
Obstructed Trials (long time avg.)	0.59	1.93	0.65	2.21	44%	N/A	N/A	0.63	N/A
Unobstructed Wind-Tunnel Tests (scaled)	0.65	2.03	0.69	2.31	34%	N/A	N/A	0.60	N/A
Obstructed Wind-Tunnel Tests (scaled)	0.16	1.20	0.44	1.70	62%	N/A	N/A	1.05	N/A

Table 27 (cont'd):- SPM Evaluation Against Quantitative Assessment Critiera: MEP

Data Set	Quantitative Criteria								
	-0.4<MRB <0.4	**0.67< MG<1.5**	**MRSE<2.3**	**VG<3.3**	**FAC2 >50%**	**0.5<CSF<2**	**0.5< CSF_LFL<2**	**0.5<DSF<2**	**0.5< DSF_LFL<2**
Maximum Point-wise Gas Concentration									
Unobstructed Field Trials (Short Time Avg.)	-0.05	31.1	0.93	>1000	54%	1.61	N/A	N/A	N/A
Unobstructed Trials (Long Time Avg.)	-0.15	32.4	1.26	>1000	37%	2.56	N/A	N/A	N/A
Obstructed Field Trials (Short Time Avg.)	0.42	500	1.56	>1000	39%	1.50	N/A	N/A	N/A
Obstructed Trials (Long Time Avg.)	0.62	326	1.83	>1000	33%	1.60	N/A	N/A	N/A
Unobstructed Wind-Tunnel Tests (Scaled)	0.64	268	1.86	>1000	30%	1.26	N/A	N/A	N/A
Obstructed Wind-Tunnel Tests (Scaled)	-0.64	0.53	0.86	17.3	38%	2.95	N/A	N/A	N/A
Cloud Width									
Unobstructed Field Trials (Short Time Avg.)	0.26	1.36	0.23	1.57	92%	N/A	N/A	0.82	N/A
Unobstructed Trials (Long Time Avg.)	0.29	1.45	0.28	2.11	88%	N/A	N/A	0.80	N/A
Obstructed Field Trials (Short Time Avg.)	0.45	1.60	0.26	1.34	78%	N/A	N/A	0.64	N/A
Obstructed Trials (Long Time Avg.)	0.70	2.10	0.54	1.86	44%	N/A	N/A	0.49	N/A
Unobstructed Wind-Tunnel Tests (Scaled)	0.37	1.46	0.25	1.30	73%	N/A	N/A	0.73	N/A
Obstructed Wind-Tunnel Tests (Scaled)	-0.15	0.86	0.03	1.03	100%	N/A	N/A	1.17	N/A

FDS meets all the MEP quantitative acceptance criteria for the following data sets:

- maximum arc-wise gas concentrations for unobstructed cases (Group 1) with short time averages;
- maximum gas concentration arc-wise distances unobstructed cases (Group 1) with short time averages, and obstructed cases (Group 1) of scaled wind tunnel tests; and
- cloud widths for unobstructed cases (Group 1) with short time averages, unobstructed cases (Group 1) with long time averages, unobstructed cases (Group 1) of scaled wind tunnel tests, and obstructed cases (Group 2) of scaled wind tunnel tests.

However, FDS does not meet all the MEP quantitative acceptance criteria for the following datasets:

- maximum arc-wise gas concentrations for unobstructed cases (Group 1) with long time averages, obstructed cases (Group 2) with short time averages, obstructed cases (Group 2) with long time averages, unobstructed cases (Group 1) of scaled wind tunnel tests, and obstructed cases (Group 2) of scaled wind tunnel tests;
- maximum gas concentration arc-wise distances for unobstructed cases (Group 1) with long time averages, obstructed cases (Group 2) with short time averages, obstructed cases (Group 2) with long time averages, and unobstructed cases (Group 1) of scaled wind tunnel tests;

- maximum point-wise concentrations for all cases, which includes cloud widths for all cases, which includes unobstructed cases (Group 1) with short time averages, unobstructed cases (Group 1) with long time averages, obstructed cases (Group 2) with short time averages, obstructed cases (Group 2) with long time averages, unobstructed cases (Group 1) of scaled wind tunnel tests, and obstructed cases (Group 2) of scaled wind tunnel tests; and
- cloud widths for obstructed cases (Group 2) with short time averages, and obstructed cases (Group 2) with long time averages.

FDS is generally over-predictive of maximum arc-wise concentrations for unobstructed short and long time averages, but under-predictive of maximum arc-wise concentrations for obstructed short and long time averages. In addition, FDS is generally under-predictive of maximum arc-wise concentrations for unobstructed and obstructed scaled wind tunnel tests. Nearly half of all FDS maximum arc-wise concentration predictions are within a factor of 2 with the exception of unobstructed scaled wind tunnel tests.

Similar trends exist for FDS predictions of maximum gas concentration arc-wise distances, but with a higher degree of scatter and under-prediction for obstructed cases with short and long time averages and a lower degree of scatter and better agreement for unobstructed and obstructed cases of scaled wind tunnel tests.

FDS exhibits a very high degree of scatter among the results of maximum point-wise concentrations. There is less agreement compared to maximum arc-wise concentrations.

FDS is in good agreement for cloud widths for all cases with the exception of obstructed trials with long time averages. FDS is generally under-predictive of cloud widths for all datasets with the exception of obstructed scaled wind tunnel tests. There is relatively little scatter among the results and a large majority of the FDS cloud width predictions are within a factor of 2.

However, the MEP statistical performance measures and quantitative acceptance criteria are based on an average of all the trials, which can be misleading. Therefore, FERC advised PHMSA that the approval or disapproval of a model should not be contingent based solely on the average of the experiments meeting the MEP quantitative acceptance criteria. Moreover, FERC advised PHMSA to adjust the safety margins of a model based on the careful examination of all the sensor data and trends, in concert with the statistical performance measures and MEP quantitative acceptance criteria. This approach was adopted by PHMSA in the Advisory Bulletin.

These trends provide additional insight into the model performance against various subsets of the data. The FDS predicted maximum arcwise concentrations versus the experimental measured maximum arcwise concentrations are illustrated.

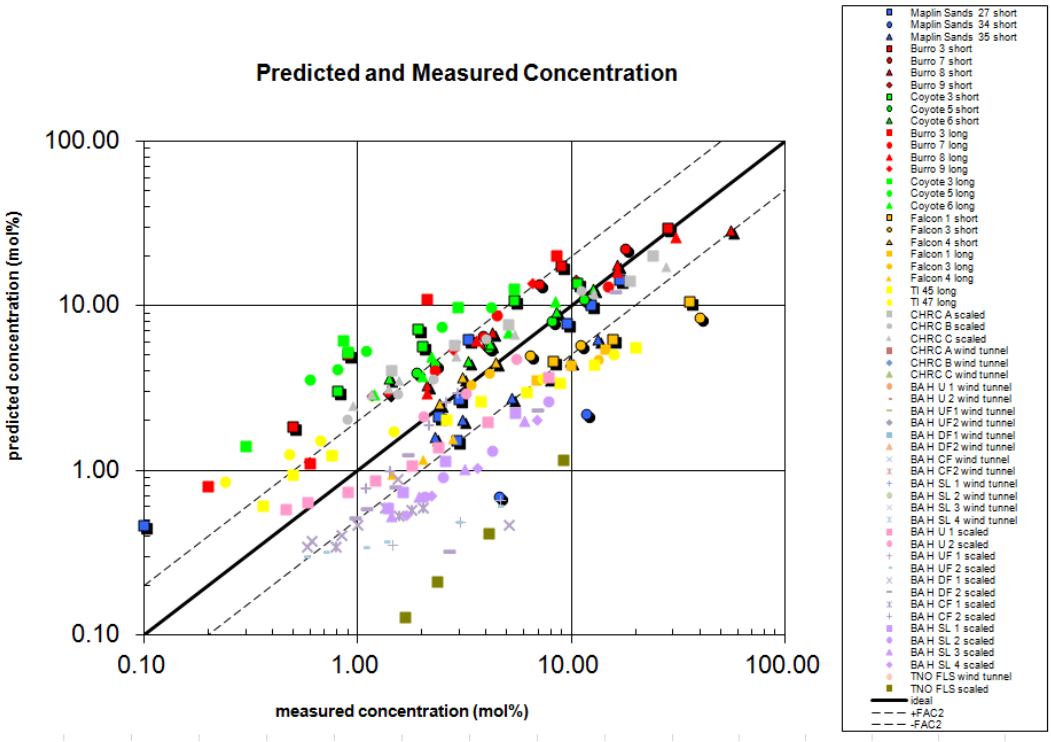


Figure 107 - Predicted Concentration against Measured Concentration

FDS predictions of maximum arc-wise gas concentrations, maximum gas concentration arc-wise distances, maximum point-wise gas concentrations, and cloud widths are tabulated for each test with the quantitative acceptance criteria of the MEP. Values that exceed the MEP quantitative acceptance criteria are highlighted.

Table 28 - SPM Evaluation Against Quantitative Assessment Criteria: Averaged Test Data

Data Set	Quantitative Criteria						
	-0.4<MRB <0.4	**0.67< MG<1.5**	**MRSE<2.3**	**VG<3.3**	**FAC2 >50%**	**0.5<CSF<2**	**0.5< CSF_LFL<2**
Maximum Arc-Wise Gas Concentration							
Maplin Sands 27 (short)	-0.06	0.92	0.32	1.50	88%	1.40	1.35
Maplin Sands 34 (short)	1.43	5.99	2.04	24.9	0%	0.17	0.15
Maplin Sands 35 (short)	0.60	1.86	0.38	1.51	50%	0.54	0.53
Burro 3 (short)	-0.80	0.40	0.91	1.24	50%	3.04	2.51
Burro 3 (long)	-0.98	0.33	1.06	5.49	25%	3.33	N/A
Burro 7 (short)	-0.45	0.63	0.23	1.27	100%	1.60	1.77
Burro 7 (long)	-0.35	0.70	0.24	1.29	100%	1.52	N/A
Burro 8 (short)	-0.08	0.93	0.21	1.25	100%	1.19	1.52
Burro 8 (long)	-0.16	0.85	0.10	1.11	100%	1.22	N/A
Burro 9 (short)	-0.45	0.63	0.24	1.29	67%	1.62	1.41
Burro 9 (long)	-0.72	0.47	0.53	1.79	33%	2.15	N/A
Coyote 3 (short)	-0.83	0.40	0.82	2.15	50%	2.72	2.07
Coyote 3 (long)	-1.22	0.23	1.54	7.34	0%	4.63	N/A
Coyote 5 (short)	-0.31	0.73	0.19	1.13	100%	1.45	1.24
Coyote 5 (long)	-1.17	0.25	1.43	5.78	0%	4.22	N/A
Coyote 6 (short)	-0.32	0.72	0.20	1.06	100%	1.48	1.31
Coyote 6 (long)	-0.54	0.57	0.35	1.32	75%	1.81	N/A
Thorney Island 45 (long)	0.31	1.41	0.51	1.82	56%	0.90	N/A
Thorney Island 47 (long)	-0.20	0.80	0.70	2.32	17%	1.73	N/A
Falcon 1 (short)	0.84	2.49	0.76	2.47	33%	0.41	0.72
Falcon 1 (long)	0.79	2.32	0.64	2.07	33%	0.43	N/A
Falcon 3 (short)	0.73	2.27	0.72	2.63	67%	0.50	0.93
Falcon 3 (long)	0.37	1.49	0.32	1.46	67%	0.74	N/A
Falcon 4 (short)	-0.07	0.93	0.01	1.01	100%	1.07	0.96
Falcon 4 (long)	0.52	1.71	0.28	1.34	100%	0.59	N/A

Table 28 (cont'd) - SPM Evaluation against Quantitative Assessment Criteria: Averaged Test Data							
Data Set	Quantitative Criteria						
	-0.4<MRB <0.4	**0.67< MG<1.5**	**MRSE<2.3**	**VG<3.3**	**FAC2 >50%**	**0.5<CSF<2**	**0.5< CSF_LFL<2**
Maximum Arc-Wise Gas Concentration (cont'd)							
CHRC A (scaled)	-0.31	0.72	0.33	1.45	60%	1.58	N/A
CHRC B (scaled)	-0.46	0.62	0.26	1.33	80%	1.66	N/A
CHRC C (scaled)	-0.42	0.64	0.40	1.56	50%	1.74	N/A
Hamburg DA0120 (scaled)	0.34	1.42	0.23	1.27	75%	0.75	N/A
Hamburg DAT223 (scaled)	0.07	1.07	0.01	1.01	100%	0.93	N/A
Hamburg 039051 (scaled)	1.39	5.69	1.96	21.7	0%	0.18	N/A
Hamburg 039072 (scaled)	1.08	3.58	1.28	6.58	17%	0.31	N/A
Hamburg DA0501 (scaled)	0.79	2.50	0.76	3.41	43%	0.46	N/A
Hamburg DA0532 (scaled)	0.73	2.31	0.70	2.83	71%	0.49	N/A
Hamburg 039094 (scaled)	0.98	2.95	0.98	3.30	0%	0.34	N/A
Hamburg 039097 (scaled)	0.18	1.20	0.06	1.06	100%	0.84	N/A
Hamburg DAT647 (scaled)	0.80	2.32	0.64	2.04	0%	0.43	N/A
Hamburg DAT631 (scaled)	1.00	3.02	1.01	3.40	0%	0.33	N/A
Hamburg DAT632 (scaled)	0.98	2.92	0.96	3.16	0%	0.34	N/A
Hamburg DAT637 (scaled)	1.08	3.34	1.16	4.29	0%	0.30	N/A
TNO FLS (scaled)	1.67	11.5	2.80	400	0%	0.09	N/A

Table 28 (cont'd) - SPM Evaluation against Quantitative Assessment Criteria: Averaged Test Data							
Data Set	Quantitative Criteria						
	-0.4<MRB <0.4	**0.67< MG<1.5**	**MRSE<2.3**	**VG<3.3**	**FAC2 >50%**	**0.5<DSF<2**	**0.5< DSF_LFL<2**
Maximum Gas Concentration Arc-Wise Distance							
Maplin Sands 27 (short)	0.30	1.37	0.29	1.38	88%	0.82	1.51
Maplin Sands 34 (short)	2.00	>1000	4.00	>1000	0%	0.00	0.32
Maplin Sands 35 (short)	0.89	2.85	1.01	4.49	33%	0.42	0.42
Burro 3 (short)	-0.54	0.56	0.42	1.62	50%	1.91	2.19
Burro 3 (long)	-0.84	0.40	0.81	2.75	25%	3.15	N/A
Burro 7 (short)	-0.54	0.57	0.35	1.49	67%	1.83	2.27
Burro 7 (long)	-0.86	0.39	0.78	2.55	33%	2.63	N/A
Burro 8 (short)	-0.13	0.88	0.18	1.20	100%	1.22	1.51
Burro 8 (long)	-0.13	0.87	0.11	1.12	100%	1.17	N/A
Burro 9 (short)	-0.35	0.70	0.17	1.20	100%	1.47	1.45
Burro 9 (long)	-0.69	0.48	0.49	1.71	67%	2.08	N/A
Coyote 3 (short)	-0.87	0.38	0.83	2.78	20%	2.74	2.02
Coyote 3 (long)	-1.06	0.31	1.14	4.24	0%	3.34	N/A
Coyote 5 (short)	-0.54	0.56	0.45	1.69	40%	1.96	1.27
Coyote 5 (long)	-1.24	0.23	1.54	8.52	0%	4.34	N/A
Coyote 6 (short)	-0.33	0.70	0.25	1.34	80%	1.56	1.34
Coyote 6 (long)	-0.68	0.49	0.49	1.72	20%	2.07	N/A
Thorney Island 45 (long)	0.53	1.84	0.74	2.64	44%	0.73	N/A
Thorney Island 47 (long)	0.02	1.07	0.80	2.81	33%	1.39	N/A
Falcon 1 (short)	1.28	7.83	1.98	499	33%	0.26	1.29
Falcon 1 (long)	0.84	2.47	0.73	2.35	33%	0.41	N/A
Falcon 3 (short)	1.20	6.66	1.70	279	0%	0.28	0.33
Falcon 3 (long)	1.09	3.38	1.18	4.43	0%	0.30	N/A
Falcon 4 (short)	-0.55	0.56	0.34	1.46	67%	1.82	0.82
Falcon 4 (long)	-0.15	0.86	0.04	1.04	100%	1.17	N/A

Table 28 (cont'd) - SPM Evaluation against Quantitative Assessment Criteria: Averaged Test Data							
Data Set	Quantitative Criteria						
	-0.4<MRB <0.4	**0.67< MG<1.5**	**MRSE<2.3**	**VG<3.3**	**FAC2 >50%**	**0.5<DSF<2**	**0.5< DSF_LFL<2**
Maximum Gas Concentration Arc-Wise Distance (cont'd)							
CHRC A (scaled)	-0.17	0.84	0.32	1.42	80%	1.39	N/A
CHRC B (scaled)	-0.62	0.52	0.46	1.67	40%	2.00	N/A
CHRC C (scaled)	-0.47	0.61	0.39	1.56	50%	1.80	N/A
Hamburg DA0120 (scaled)	0.35	1.44	0.23	1.29	75%	0.73	N/A
Hamburg DAT223 (scaled)	0.12	1.13	0.04	1.04	100%	0.90	N/A
Hamburg 039051 (scaled)	0.61	1.88	0.37	1.49	100%	0.53	N/A
Hamburg 039072 (scaled)	1.05	3.34	1.18	4.84	0%	0.32	N/A
Hamburg DA0501 (scaled)	0.35	1.44	0.18	1.20	100%	0.72	N/A
Hamburg DA0532 (scaled)	0.10	1.11	0.06	1.07	100%	0.93	N/A
Hamburg 039094 (scaled)	1.00	2.99	1.00	3.34	0%	0.33	N/A
Hamburg 039097 (scaled)	-0.25	0.77	0.09	1.10	100%	1.31	N/A
Hamburg DAT647 (scaled)	0.82	2.39	0.67	2.15	0%	0.42	N/A
Hamburg DAT631 (scaled)	1.03	3.12	1.06	3.67	0%	0.32	N/A
Hamburg DAT632 (scaled)	0.99	2.98	0.99	3.30	0%	0.34	N/A
Hamburg DAT637 (scaled)	1.10	3.44	1.21	4.62	0%	0.29	N/A
TNO FLS (scaled)	1.07	3.34	1.16	4.35	0%	0.30	N/A

Table 28 (cont'd) - SPM Evaluation against Quantitative Assessment Criteria: Averaged Test Data							
Data Set	Quantitative Criteria						
	-0.4<MRB <0.4	**0.67< MG<1.5**	**MRSE<2.3**	**VG<3.3**	**FAC2 >50%**	**0.5<CSF<2**	**0.5< CSF_LFL<2**
Maximum Point-wise Gas Concentration							
Burro 3 (short)	-0.34	0.68	0.48	1.87	64%	1.88	N/A
Burro 3 (long)	-0.02	1.10	0.76	4.50	45%	1.43	N/A
Burro 7 (short)	0.07	3.03	0.66	>1000	80%	1.17	N/A
Burro 7 (long)	0.16	4.83	1.17	>1000	50%	1.33	N/A
Burro 8 (short)	0.08	3.20	0.53	>1000	62%	1.19	N/A
Burro 8 (long)	0.01	3.37	0.50	>1000	57%	1.27	N/A
Burro 9 (short)	0.00	>1000	1.05	>1000	50%	1.40	N/A
Burro 9 (long)	-0.26	>1000	1.43	>1000	20%	2.31	N/A
Coyote 3 (short)	-0.02	26.4	1.50	>1000	33%	1.81	N/A
Coyote 3 (long)	-0.26	25.9	2.10	>1000	0%	3.48	N/A
Coyote 5 (short)	0.46	>1000	2.08	>1000	29%	1.50	N/A
Coyote 5 (long)	0.17	>1000	2.66	>1000	14%	4.18	N/A
Coyote 6 (short)	-0.58	0.52	0.57	2.21	62%	2.38	N/A
Coyote 6 (long)	-0.76	0.39	0.80	4.49	46%	3.95	N/A
Falcon 1 (short)	1.09	>1000	2.62	>1000	3%	1.90	N/A
Falcon 1 (long)	1.06	>1000	2.82	>1000	7%	2.68	N/A
Falcon 3 (short)	0.55	41.1	1.40	>1000	40%	0.94	N/A
Falcon 3 (long)	0.66	85.4	1.88	>1000	31%	1.36	N/A
Falcon 4 (short)	0.07	255	1.26	>1000	53%	1.67	N/A
Falcon 4 (long)	0.30	>1000	1.28	>1000	50%	1.73	N/A

Table 28 (cont'd) - SPM Evaluation against Quantitative Assessment Criteria: Averaged Test Data							
Data Set	Quantitative Criteria						
	-0.4<MRB <0.4	**0.67< MG<1.5**	**MRSE<2.3**	**VG<3.3**	**FAC2 >50%**	**0.5<CSF<2**	**0.5< CSF_LFL<2**
Maximum Point-Wise Gas Concentration (cont'd)							
CHRC A (scaled)	-0.23	4.23	1.12	>1000	43%	2.41	N/A
CHRC B (scaled)	-0.65	0.48	0.63	2.29	49%	2.45	N/A
CHRC C (scaled)	-0.69	>1000	1.03	>1000	29%	3.40	N/A
Hamburg DAT223 (scaled)	0.29	3.75	0.68	>1000	75%	0.96	N/A
Hamburg DAT647 (scaled)	0.49	1.68	0.35	1.48	50%	0.63	N/A
Hamburg DAT631 (scaled)	0.55	1.82	0.62	2.08	50%	0.68	N/A
Hamburg DAT632 (scaled)	0.50	1.72	0.56	1.94	50%	0.71	N/A
Hamburg DAT637 (scaled)	0.65	2.06	0.71	2.38	38%	0.59	N/A
TNO TUV01 (scaled)	1.15	13.7	1.65	>1000	25%	0.31	N/A
TNO TUV02 (scaled)	1.21	45.3	2.06	>1000	22%	0.33	N/A
TNO FLS (scaled)	1.89	>1000	3.58	>1000	0%	0.03	N/A

Table 28 (cont'd) - SPM Evaluation against Quantitative Assessment Criteria: Averaged Test Data							
Data Set	Quantitative Criteria						
	-0.4<MRB <0.4	**0.67< MG<1.5**	**MRSE<2.3**	**VG<3.3**	**FAC2 >50%**	**0.5<DSF<2**	**0.5< DSF_LFL<2**
Maximum Cloud Width							
Burro 3 (short)	0.03	1.03	0.01	1.01	100%	0.98	N/A
Burro 3 (long)	0.17	1.19	0.08	1.08	100%	0.86	N/A
Burro 7 (short)	0.12	1.13	0.02	1.02	100%	0.89	N/A
Burro 7 (long)	0.19	1.22	0.08	1.08	100%	0.84	N/A
Burro 8 (short)	0.18	1.20	0.04	1.05	100%	0.84	N/A
Burro 8 (long)	0.22	1.24	0.05	1.06	100%	0.81	N/A
Burro 9 (short)	0.34	1.41	0.15	1.17	100%	0.72	N/A
Burro 9 (long)	0.28	1.32	0.11	1.12	100%	0.77	N/A
Coyote 3 (short)	0.53	1.72	0.31	1.41	67%	0.59	N/A
Coyote 3 (long)	0.50	1.69	0.30	1.39	67%	0.61	N/A
Coyote 5 (short)	0.97	>1000	1.28	>1000	60%	0.45	N/A
Coyote 5 (long)	0.99	>1000	1.45	>1000	40%	0.48	N/A
Coyote 6 (short)	-0.09	0.91	0.02	1.02	100%	1.10	N/A
Coyote 6 (long)	-0.10	0.91	0.02	1.03	100%	1.11	N/A
Falcon 1 (short)	0.70	2.11	0.54	1.85	33%	0.49	N/A
Falcon 1 (long)	0.87	2.55	0.77	2.50	0%	0.40	N/A
Falcon 3 (short)	0.31	1.37	0.13	1.14	100%	0.74	N/A
Falcon 3 (long)	0.56	1.77	0.32	1.40	100%	0.57	N/A
Falcon 4 (short)	0.34	1.42	0.12	1.13	100%	0.71	N/A
Falcon 4 (long)	0.67	2.05	0.53	1.83	33%	0.51	N/A
CHRC A (un-scaled)	0.02	1.02	0.02	1.02	100%	0.99	N/A
CHRC B (un-scaled)	-0.02	0.98	0.01	1.01	100%	1.02	N/A
CHRC C (un-scaled)	-0.15	0.86	0.03	1.03	100%	1.17	N/A
TNO FLS (scaled)	0.66	1.98	0.43	1.50	50%	0.51	N/A

FDS is generally in good agreement or conservative for maximum arc-wise concentrations for unobstructed field trials with short and long time averages. Only Maplin Sands and Thorney Island 45 were under-predictive, but were still generally within a factor of 2. With the exception of Burro 8, FDS generally over-predicts maximum arc-wise gas concentrations for unobstructed field trials with short time averages by a factor of 2 or less, and over-predicts maximum arc-wise gas concentrations for unobstructed field trials with long time averages by a factor of 2 or more. Therefore, FDS may be considered to be in good agreement or over-predictive for dispersion over land, and under-predictive for dispersion over water.

FDS is generally under-predictive in the near field, but over-predictive in the far field. This appears to possibly be a result of the transient wind fluctuations and higher wind speeds in the near field compared to the far field. FDS does not appear to show a strong bias for trials with low wind speeds (<2 m/s) or high atmospheric stabilities (F stability), which is especially pertinent to the current federal regulations under 49 C.F.R. Part 193. With the exception of Maplin Sands 34, concentration safety factors at the lower flammability limit (CSF_LFL) are within the quantitative acceptance criteria or conservative.

FDS is also generally in good agreement with maximum arc-wise concentrations for unobstructed wind tunnel experiments. Nearly all predictions are within a factor of 2 with the exception of unobstructed sloped trials, which were under-predictive by a factor of 3 in both the near and far field.

FDS is generally under-predictive by approximately a factor of 2 for maximum arc-wise concentrations for Falcon 1 and Falcon 3 obstructed field trials. However, FDS is in good agreement and over-predictive for Falcon 4, which had the best agreement with the wind data. The disagreement could be attributed to the lower concentration measured in Falcon 3, but may also be from the an inaccurate representation of the source term, as significant amounts of flashing and source turbulence were observed in the Falcon trials. The under-prediction may also be partly attributed to the sensor placement within the simulation not coinciding with the maximum concentration.

FDS shows worse agreement with maximum arc-wise concentrations for obstructed scaled wind tunnel experiments with most data being under-predictive by a factor of 2 or more. FDS was under-predictive for downwind and upwind fences, but compared better with fences downwind where there was less bifurcation of the cloud. FDS was over-predictive for circular fences where no bifurcation occurred.

The maximum arc-wise concentrations for field trials over land are most applicable to the scenarios to be considered under the 49 CFR Part 193 regulations. Although FDS generally showed good agreement, there are uncertainties that indicate potential under-prediction. Until these uncertainties are resolved, it is recommended that a safety factor of 2 be used when evaluating predicted maximum arc-wise concentrations from FDS for unobstructed cases, and a factor of 3 be used when evaluating predicted maximum arc-wise concentrations from FDS for obstructed and sloped scenarios.

FDS compares similarly with maximum gas concentration distances, including similar trends as the maximum arc-wise concentrations. Nearly all of the data is within a factor of 2. FDS may become more conservative using distance because large concentration differences may manifest themselves as much smaller differences in distance and because the maximum distance was not based on a particular sensor location and therefore not subject to the same spatial uncertainties as was the maximum arc-wise concentration.

FDS shows a wide degree of scatter for prediction of point-wise gas concentrations for unobstructed and obstructed field trials with short and long time averages, but is generally in good agreement or over-predictive for most point-wise concentrations. FDS predicts more accurately and conservatively for point-wise concentrations that are located at an angle corresponding to the wind direction where the maximum arc-wise concentration often occurred (i.e. along the "centerline"). FDS often predicts near-zero concentrations for point-wise gas concentrations for field trials that are located farther from the "centerline", which heavily contributed to the large statistical performance measures for scatter. FDS shows similar over-predictive trends for scaled wind tunnel tests.

FDS is in good agreement for cloud widths for all datasets, but is generally under-predictive. However, nearly all of the predictions are within a factor of 2. The better agreement with cloud widths compared to point-wise gas concentrations is due to the lesser influence by large concentration differences away from the "centerline".

Although point-wise gas concentrations and cloud widths are not a particular concern with 49 CFR Part 193, they are important for risk analyses and performance based design of gas detector placement in addition to cloud arrival and departure times.

Validation Conclusion

For unobstructed trials, FDS generally over-predicts maximum arc-wise concentrations by a factor of 2 or less. However, there were still unobstructed trials where FDS under-predicts maximum arc-wise concentrations by approximately a factor of 2. Therefore, FDS should be used with a safety factor of 2 (i.e. ½ LFL) for modeling LNG vapor dispersion in unobstructed flow fields. For obstructed and sloped trials, FDS generally under-predicts maximum arc-wise concentrations by a factor of 3 or less. Although there were obstructed trials where FDS under-predicts by more than a factor of 3, these trials were generally wind tunnel tests that included substances with denser vapor clouds than LNG vapor clouds and would have benefited from finer resolution of the grid near the boundary. Therefore, it is recommended that FDS be used with a safety factor of 3 (i.e. ⅓ LFL) for modeling LNG vapor dispersion in sloped terrain or obstructed flow fields.

Uncertainty Analyses

There are a number of sources of uncertainty associated with the modeling of experimental data, including: the source term, time averaging, spatial averaging and grid size, wind field approximation, surface roughness determination, ambient condition representation, and vapor composition.

Source Term

All the LNG field trial releases were conducted over water and the associated source terms will be different than those used on land. For spills over water with significant depth, the heat transfer to the pool is generally considered constant due to convective motion of the water. For spills over land, the heat transfer to the pool is generally considered to be transient due to conductive cooling of the substrate. Pressurized releases may further deviate from the more idealized source term for spills over water. Therefore it is important that any source term model that is used to calculate an exclusion zone for an LNG facility have a suitable basis to comply with the siting requirements in 49 C.F.R. Part 193.

Time Averaging

FDS automatically determines the time step based on the CFL and VN criteria specified, and the value is typically on the order of $1/10^{th}$ of a second or less. Subsequent time-averaging can then be taken from the data output. As with experimental data, longer time averages in FDS predictions will result in lesser

concentrations as peak concentrations are smoothed out over longer time averages. For higher wind speeds and lower atmospheric stability where turbulent fluctuations and cloud meander may have higher amplitudes, there is a greater reduction in gas concentration when averaged. This is demonstrated best in Burro 3 and Coyote 3, where higher atmospheric stabilities showed a greater reduction in concentration between the short and long time averages. FDS tends to compares more conservatively with longer time averages, indicating that the turbulent fluctuations may not be fully captured in FDS. This may be partially attributed to assuming a flat unobstructed terrain and the lack of ability to specify a turbulence profile at the boundary condition. The reduction of turbulence seems to be more prevalent in the far field, where turbulent fluctuations in the wind have been further suppressed in the domain as the wind travels within the domain. Due to the potential reduction in concentrations below the lower flammable limit as time averages increase, short time averages should be used when predicting flammable vapor centerline concentrations.

Grid Size

The grid dependence of CFD codes can often be extrapolated based on the order of the numerical solver and grid refinement studies. In addition, FDS will use the largest grid dimension for filtering, and therefore reducing the grid in one dimension may not be sufficient for demonstrating grid convergence of the numerical solver. A base grid of 2m x 2m x 1m was used in the Maplin Sands, Burro, Coyote, and Thorney Island field trials and CHRC scaled wind tunnel tests; a base grid of 2m x 2m x 0.5m was used for the Falcon field trials; a base grid of 1m x 1m x 0.5m was

used for the BA Hamburg scaled wind tunnel tests; and a base grid of 2m x 2m x 1m was used for the BA TNO wind tunnel tests.

The validation results suggest that the grid sizes may be sufficient for LNG trials and the CHRC scaled wind tunnel tests, but finer grids may be beneficial for scaled wind tunnel tests. This is most likely due to the scaled wind tunnel tests dispersing substances with denser vapor clouds than LNG vapor clouds, and subsequently higher gradients near the boundary layer.

The grid size and subsequent grid independence may be case specific; therefore, it is recommended that a grid sensitivity analysis accompanies LNG vapor dispersion submittals to ensure a grid independent or convergent solution. Demonstration of a grid independent or convergent solution better ensures that potential user-error or differences among the approaches taken by various users/stakeholders are reduced. This is consistent with the FDS User Guide, which recommends grid sensitivity tests, and is consistent with other technical submittals to other entities, such as the ASME Journal of Fluids Engineering [68].

Wind Field

Transient wind speeds and directions were used for the field trials to more closely match the wind speed of the actual tests, as shown in Appendix C. Generally, inclusion of the transient wind speed and direction invokes higher turbulence near the boundary condition and higher concentrations near the source, but lower

concentrations away from the source. However, as the wind moves throughout the domain the transient wind speed and resultant turbulent fluctuations specified at the boundary conditions become suppressed and the wind speed and turbulent fluctuations decrease. The reduction in turbulence may be partially attributed to assuming a flat unobstructed terrain and the lack of ability to specify a turbulence profile at the boundary conditions. The reduction of turbulence seems to be more prevalent in the far field, where turbulent fluctuations in the wind have been further suppressed in the domain as the wind travels within the domain. This appears to partly contribute for more over-predictions in the far field compared to the near field. Therefore, using the average wind speed and direction in FDS may produce over-predictive (i.e. conservative) results in the far field, but under-predictive (non-conservative) results in the near field. The lower flammability limit generally appears in the far field, as is reflected by the general over-predictive values for CSF_LFL.

Surface Roughness and Atmospheric Stability

FDS cannot directly input surface roughness or atmospheric stability, but the user is able to specify the wind profile, which is determined from the surface roughness and atmospheric stability. The wind profile exponent must be determined by a separate mathematical model to determine the appropriate wind profile exponent to input into FDS.

The surface roughness values have the largest uncertainties. The surface roughness values specified in the MEP are generally low and would result in higher

concentrations and longer dispersion distances to the LFL, which may cause the model to appear more conservative than it actually is. Using reasonable, higher surface roughness values from published literature would result in lower concentrations and shorter downwind distances, which in some cases would show better agreements to data that were over-predictive (e.g. Coyote tests). The 0.03m surface roughness prescribed in 49 C.F.R. § 193.2059 would generally provide reasonable, or conservative, results for LNG releases that disperse over land.

Lower atmospheric stabilities would generally produce lower downwind concentrations and dispersion distances, and higher atmospheric stabilities would produce higher downwind concentrations and dispersion distances. The Pasquill Class of F for atmospheric stability prescribed in 49 C.F.R. § 193.2059 would generally provide conservative results for LNG releases that disperse over land. FDS should use a wind profile exponent of 0.386 to model a 2m/s wind speed with F stability and a surface roughness of 0.03m.

Ambient Conditions

Higher ambient temperatures, surface temperatures, and humidity would generally produce lower gas concentrations and downwind dispersion distances, while higher ambient pressures would produce higher concentrations and downwind dispersion distances. However, the time scales associated with dispersion of LNG vapor generated from a 10-minute spill prescribed in 49 C.F.R. § 193.2059 would generally

show little fluctuation in ambient conditions, and therefore may be assumed as constant throughout the vapor cloud dispersion.

Vapor Composition

The composition specified in the MEP reflects the composition of the LNG and does not take into account preferential boiloff. The lower molecular weight of methane should generally result in higher concentrations and longer dispersion distances. The molecular weight of methane is recommended to be used to account for potential preferential boiloff and conservatism.

Chapter 9: Model Suitability and Limitations

FDS does not have a built-in source term to calculate flashing, jetting, rainout, or pool formation and vaporization. Separate source term models must be used to determine the resultant gaseous source term input into FDS. The specification of the source term is a key parameter in determining the gas concentrations and dispersion distances, but is not examined under the MEP or the Advisory Bulletin. However, any source term model that is used to calculate an exclusion zone for an LNG facility must have a suitable basis to comply with the siting requirements in 49 C.F.R. Part 193.

FDS may be used to model the maximum arc-wise concentration for:

- Dispersion from irregular and regular LNG pools with low- or high-aspect ratios, including all impoundments and trenches with appropriate modification of the vaporization rate to account for the Cartesian grid;
- Dispersion from horizontally or vertically oriented releases, including releases from flashing, venting, vent stacks, and pressure relief discharge;
- Dispersion from multiple coincident releases, including multiple release locations;
- Dispersion over sloped terrain; and
- Dispersion over obstructions, including large obstructions that may cause wind-channeling.

FDS should be used with the ambient conditions required under 49 CFR § 193.2059, which should produce conservative results (i.e. higher downwind gas concentrations and dispersion distances).

FDS should be used with a safety factor of 2 (i.e. ½ LFL) when modeling LNG vapor dispersion without obstructions, and a safety factor of 3 (i.e. ⅓ LFL) when modeling LNG vapor dispersion with obstructions or sloped terrain.

FDS results should be verified by an independent party or authority having jurisdiction to ensure that the source code has not been modified

These recommendations are contingent on the parameters, including grid resolution, used in this study. FDS limitations and recommended safety factors may benefit from the following:

- built-in source term model(s) for superheated and high pressure liquid releases, including associated aerosol formation, rainout, liquid pool spread and vaporization;
- initial condition option for atmospheric wind profiles to reduce computational costs associated with establishing a quasi-steady state wind field prior to initiating a gaseous source into the domain;
- turbulence parameters for "vents" for better approximation of turbulent sources (e.g. wind fields in atmospheric boundary layer);

- ramp functions for each of the x-, y-, and z- components of “vents” for better replication of transient sources (e.g. wind fields in atmospheric boundary layer);
- heat transfer effects from condensation of water vapor in atmosphere;
- non-Cartesian grid at boundaries and obstructions to reduce errors associated with “stepping” of grid; and
- finer grid resolutions at the boundary layer to demonstrate grid convergent values.

Appendix A

Selected ABS/FERC Source Term Calculation

LNG Source Term and Dispersion Modeling Input Data

Constants and Conversion Factors

Unit conversions

$kJ \equiv 1000 \cdot joule$ $lbmole \equiv \frac{lb}{kg} 10^3 mole$ $kgmole \equiv 10^3 mole$ $kgmol \equiv 10^3 \cdot mol$

$kW \equiv 1000 \cdot watt$ $gmole \equiv mole$ $gmol \equiv mol$

Universal gas constant

$R_u \equiv 8.314472 \cdot \frac{kJ}{kgmole \cdot K}$ $R_u = 1545 \cdot \frac{ft \cdot lbf}{lbmole \cdot R}$

Material Properties

Ambient pressure

$p_a := 101325 \cdot Pa$ $p_a = 14.7 \cdot psi$

Molecular weight

$M := 16.043 \cdot \frac{kg}{kgmole}$

Normal boiling point

$T_b := 111.66 \cdot K$ $T_b = 200.988 \cdot R$

Vapor density (at T_b, using ideal gas law)

$\rho_v := \frac{p_a}{\frac{R_u}{M} \cdot T_b}$ $\rho_v = 1.751 \cdot \frac{kg}{m^3}$ $\rho_v = 0.109 \cdot \frac{lb}{ft^3}$

Vapor viscosity (at T_b)

$\mu_v := 4.362 \cdot 10^{-6} Pa\,sec$

Kinematic viscosity of vapor (at T_b)

$\nu_v := \frac{\mu_v}{\rho_v}$ $\nu_v = 2.491 \times 10^{-6} \cdot \frac{m^2}{sec}$

Density of Liquid (at T_b)

$\rho_l := 422.5 \cdot \frac{kg}{m^3}$

Liquid viscosity (at T_b)

$\mu_l := 1.168 \cdot 10^{-4} Pa\,sec$

Kinematic viscosity of vapor (at T_b)

$\nu_l := \frac{\mu_l}{\rho_l}$ $\nu_l = 2.764 \times 10^{-7} \cdot \frac{m^2}{sec}$

Heat of vaporization

$h_{fg} := 509331.9 \cdot \frac{joule}{kg}$

Surface Tension (at T_b)

$\sigma := 0.0133 \frac{newton}{m}$

Thermal conductivity of vapor

$\lambda_v := 0.01269 \frac{watt}{m \cdot K}$

Heat capacity of vapor

$C_p := 2075.56 \frac{joule}{kg \cdot K}$

Vapor thermal diffusivity $\alpha_v := \frac{\lambda_v}{\rho_v \cdot C_p}$ $\alpha_v = 3.492 \times 10^{-6} \cdot \frac{m^2}{sec}$

Seawater density $\rho_w := 1025 \cdot \frac{kg}{m^3}$

Water viscosity $\mu_w := 1.021 \cdot 10^{-3} Pa\,sec$

Water kinematic viscosity of vapor $\nu_w := \frac{\mu_w}{\rho_w}$ $\nu_w = 9.961 \times 10^{-7} \cdot \frac{m^2}{sec}$

Release and Deinventory

Function for evaporation rate as a function of time for use in pool spread calculations

$$q_S(t) := \begin{cases} 0 \cdot \frac{kg}{sec} & \text{if } t > 160 sec \\ 23.2 \cdot \frac{kg}{sec} & \text{otherwise} \end{cases}$$

Film Boiling Heat Flux and Evaporation Rate

Heat flux $Q_{film} := 85 \cdot \frac{kW}{m^2}$ $Q_{film} = 26944.9 \cdot \frac{BTU}{hr \cdot ft^2}$

Evaporation mass flux $M_{film} := \frac{Q_{film}}{h_{fg}}$ $M_{film} = 0.167 \cdot \frac{kg}{m^2 \cdot sec}$ $M_{film} = 0.034 \cdot \frac{lb}{ft^2 \cdot sec}$

Mass evaporation rate as a function of pool radius $m_e(r) := \frac{\pi \cdot \left(r^2\right) \cdot Q_{film}}{h_{fg}}$

Spread Equations

Reduced gravitational acceleration (TNO 3.34) $g_r := g \cdot \frac{\rho_w - \rho_l}{\rho_w}$

Minimum frontal depth based on surface tension (TNO 3.48) $h_\sigma := \sqrt{\frac{\sigma}{g \cdot \rho_l}}$ $h_\sigma = 0.18 \cdot cm$

Minimum frontal depth based on viscous effects (TNO 3.11) $h_c(q_S) := \left(\frac{6 \cdot \nu_l \cdot q_S}{\rho_l \cdot \pi \cdot g}\right)^{0.25}$

Choose minimum depth (TNO 3.49) $h_{0max}(q) := \max\left(h_\sigma, h_c(q)\right)$

Pool shape factor

$$sh(u,h,h_{0max}) := \begin{cases} 1 & \text{if } h < 0.01\cdot m \\ \text{otherwise} & \\ \quad Fr \leftarrow 1.078 & \\ \quad N \leftarrow \dfrac{u^2}{2\cdot Fr^2\cdot g_r\cdot h} & \text{if } u > 0 \\ \quad N \leftarrow 0 & \text{otherwise} \\ \quad sh \leftarrow N + \sqrt{N^2 + \left(\dfrac{h_{0max}}{h}\right)^2} & \\ \quad sh & \end{cases}$$

Gravity term coefficient (TNO 3.63)

$$\Phi(sh) := (1 - sh)\cdot(sh \le 2) + \left(\frac{-sh^2}{4}\right)(sh > 2)$$

Vapor film thickness for friction estimation

$$\delta := 6.3\cdot 10^{-5}\cdot m \qquad \delta = 0.063\cdot mm$$

Resistance term (TNO 3.72), modified to estimate friction from shear stress in the vapor film

$$C_F(u,h) := \begin{cases} sign(u)\cdot\dfrac{u\,\mu_v}{\delta\cdot\rho_l\cdot h} & \text{if } h > 0 \\ 0\cdot\dfrac{m}{sec^2} & \text{otherwise} \end{cases}$$

Acceleration of the leading edge of the pool (TNO 3.62)

$$a(\Phi,h,r,C_F) := \frac{4\cdot\Phi\cdot g_r\cdot h}{r} - C_F$$

Acceleration as a function of current speed, radius, height, and mass addition rate

$$acc(u,r,h,q) := \begin{cases} h_{0max} \leftarrow h_{0max}(q) & \\ sh \leftarrow sh(u,h,h_{0max}) & \\ \Phi \leftarrow \Phi(sh) & \\ C_F \leftarrow C_F(u,h) & \\ a(\Phi,h,r,C_F) & \end{cases}$$

Pool Spread and Evaporation Algorithm

Time step

$$dt := .1\cdot sec$$

$$
\begin{aligned}
&\text{pool} := \left|
\begin{array}{l}
t_0 \leftarrow 0 \cdot \text{sec} \\
V_0 \leftarrow 0 \cdot \text{m}^3 \\
r_0 \leftarrow 0 \cdot \text{m} \\
h_0 \leftarrow 0 \cdot \text{m} \\
u_0 \leftarrow 0 \cdot \frac{\text{m}}{\text{sec}} \\
q_0 \leftarrow q_S(0 \cdot \text{sec}) \\
a_0 \leftarrow \text{acc}(u_0, r_0, h_0, q_0) \\
e_0 \leftarrow m_e(r_0) \\
V_{\text{add}_0} \leftarrow \frac{q_0 \cdot dt}{\rho_l} \\
V_{\text{evap}_0} \leftarrow \frac{e_0 \cdot dt}{\rho_l} \\
i \leftarrow 0 \\
\text{while } (i < 1) \vee \left(V_i > 0 \cdot \text{m}^3\right) \\
\quad \left|
\begin{array}{l}
i \leftarrow i + 1 \\
t_i \leftarrow i \cdot dt \\
V_i \leftarrow V_{i-1} + V_{\text{add}_{i-1}} - V_{\text{evap}_{i-1}} \\
V_i \leftarrow 0 \cdot \text{m}^3 \quad \text{if } V_i < 0 \\
r_i \leftarrow r_{i-1} + u_{i-1} \cdot dt \\
r_i \leftarrow \left(V_i\right)^{\frac{1}{3}} \quad \text{if } r_i = 0 \cdot \text{m} \\
h_i \leftarrow \frac{V_i}{\pi \cdot \left(r_i\right)^2} \\
u_i \leftarrow u_{i-1} + a_{i-1} \cdot dt \\
q_i \leftarrow q_S(i \cdot dt) \\
h_{\min} \leftarrow h_{0\max}\left(q_i\right) \\
\text{if } h_i < h_{\min} \qquad \text{if } q_i > 0 \\
\quad \left|
\begin{array}{l}
h_i \leftarrow h_{\min} \\
r \leftarrow \sqrt{\frac{V_i}{}}
\end{array}
\right.
\end{array}
\right.
\end{array}
\right.
\end{aligned}
$$

$$r_i \leftarrow \sqrt{\pi \cdot h_i}$$

$$e_i \leftarrow m_e\left(r_i\right)$$

$$a_i \leftarrow acc\left(u_i, r_i, h_i, q_i\right)$$

$$V_{add_i} \leftarrow \frac{q_i \cdot dt}{\rho_l}$$

$$V_{evap_i} \leftarrow \frac{e_i \cdot dt}{\rho_l}$$

if $\left(V_i + V_{add_i} - V_{evap_i}\right) \le 0 \cdot m^3$ if $q_i > 0 \cdot \frac{kg}{sec}$

$$r_i \leftarrow \sqrt{\frac{q_i \cdot h_{fg}}{\pi \cdot Q_{film}}}$$

$$h_i \leftarrow \frac{V_i}{\pi \cdot \left(r_i\right)^2}$$

$$e_i \leftarrow q_i$$

$$V_{evap_i} \leftarrow V_{add_i}$$

$$M^{\langle 0 \rangle} \leftarrow \frac{t}{sec}$$

$$M^{\langle 1 \rangle} \leftarrow \frac{V}{m^3}$$

$$M^{\langle 2 \rangle} \leftarrow \frac{V_{add}}{m^3}$$

$$M^{\langle 3 \rangle} \leftarrow \frac{V_{evap}}{m^3}$$

$$M^{\langle 4 \rangle} \leftarrow \frac{a}{\frac{m}{s^2}}$$

$$M^{\langle 5 \rangle} \leftarrow \frac{u}{\frac{m}{s}}$$

$$M^{\langle 6 \rangle} \leftarrow \frac{r}{m}$$

$$M^{\langle 7 \rangle} \leftarrow \frac{h}{m}$$

$$M^{\langle 8 \rangle} \leftarrow \frac{q}{kg}$$

$$M^{\langle 9 \rangle} \leftarrow \frac{\frac{kg}{sec}}{\frac{e}{\frac{kg}{sec}}}$$

$$M$$

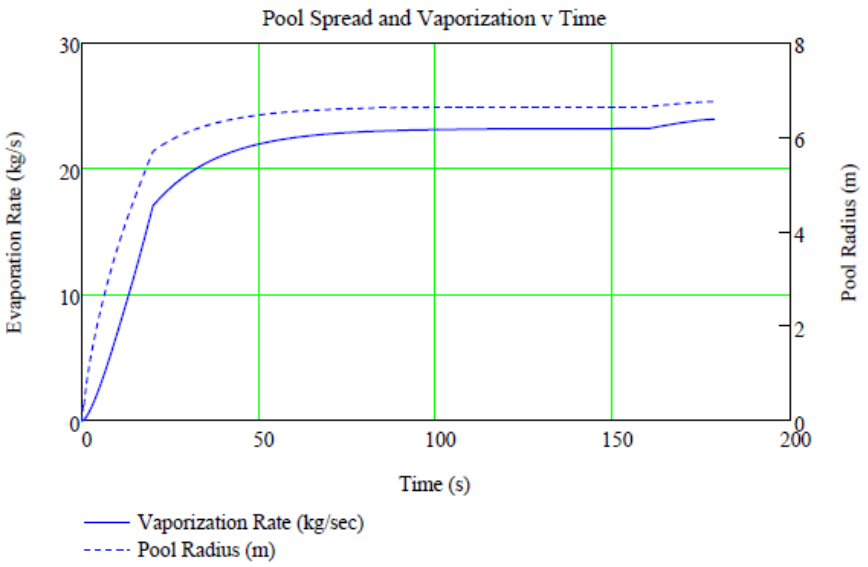
Pool Spread and Evaporation Results

Time for complete evaporation $t_{total} := \max\left(pool^{\langle 0 \rangle}\right) \cdot sec$ $t_{total} = 179 \cdot sec$ $t_{total} = 3 \cdot min$

Maximum pool radius $r_{max} := \max\left(pool^{\langle 6 \rangle}\right) \cdot m$ $r_{max} = 7\,m$ $r_{max} = 22 \cdot ft$

pool =

	t	V	V.add	V.evap	acc	u
	0	1	2	3	4	5
0	0	0	$5.491 \cdot 10^{-3}$	0	0	0
1	0.1	$5.491 \cdot 10^{-3}$	$5.491 \cdot 10^{-3}$	$3.862 \cdot 10^{-6}$	6.376	0
2	0.2	0.011	$5.491 \cdot 10^{-3}$	$3.862 \cdot 10^{-6}$	6.626	0.638
3	0.3	0.016	$5.491 \cdot 10^{-3}$	$7.158 \cdot 10^{-6}$	-16.855	1.3
4	0.4	0.022	$5.491 \cdot 10^{-3}$	$1.701 \cdot 10^{-5}$	2.715	-0.385
5	0.5	0.027	$5.491 \cdot 10^{-3}$	$1.365 \cdot 10^{-5}$	5.004	-0.114
6	0.6	0.033	$5.491 \cdot 10^{-3}$	$1.273 \cdot 10^{-5}$	5.584	0.387
7	0.7	0.038	$5.491 \cdot 10^{-3}$	$1.599 \cdot 10^{-5}$	-2.499	0.945
8	0.8	0.044	$5.491 \cdot 10^{-3}$	$2.551 \cdot 10^{-5}$	-0.254	0.695
9	0.9	0.049	$5.491 \cdot 10^{-3}$	$3.393 \cdot 10^{-5}$	-0.457	0.67
10	1	0.055	$5.491 \cdot 10^{-3}$	$4.318 \cdot 10^{-5}$	-0.351	0.624
11	1.1	0.06	$5.491 \cdot 10^{-3}$	$5.28 \cdot 10^{-5}$	-0.275	0.589
12	1.2	0.066	$5.491 \cdot 10^{-3}$	$6.276 \cdot 10^{-5}$	-0.224	0.561
13	1.3	0.071	$5.491 \cdot 10^{-3}$	$7.306 \cdot 10^{-5}$	-0.187	0.539
14	1.4	0.077	$5.491 \cdot 10^{-3}$	$8.368 \cdot 10^{-5}$	-0.159	0.52
15	1.5	0.082	$5.491 \cdot 10^{-3}$	$9.462 \cdot 10^{-5}$	-0.138	0.504



Transient Source Term

Time step $step := \frac{t_{total}}{38}$ $step = 4.697\ s$ $deg :=$

For each time step, use the evaporation rate and pool radius for the midpoint

for $i \in 0..37$

$t_i \leftarrow i \cdot \frac{step}{sec}$

$t_{mid} \leftarrow t_i + \frac{step}{2 \cdot sec}$

$e_i \leftarrow linterp(pool^{\langle 0 \rangle}, pool^{\langle 9 \rangle}, t_{mid})$

$r_i \leftarrow linterp(pool^{\langle 0 \rangle}, pool^{\langle 6 \rangle}, t_{mid})$

$t_{38} \leftarrow \frac{38 \cdot step}{sec}$

$t_{39} \leftarrow t_{38} + 1$

$M^{\langle 0 \rangle} \leftarrow t$

$M^{\langle 1 \rangle} \leftarrow e$

$M^{\langle 2 \rangle} \leftarrow r$

M

g =

	0	1	2
0	0.00	0.84	1.27
1	4.70	4.29	2.86
2	9.39	8.58	4.04
3	14.09	13.17	5.01
4	18.79	17.40	5.76
5	23.49	18.70	5.97
6	28.18	19.70	6.13
7	32.88	20.48	6.25
8	37.58	21.09	6.34
9	42.28	21.56	6.41
10	46.97	21.92	6.47
11	51.67	22.21	6.51
12	56.37	22.43	6.54
13	61.07	22.60	6.57
14	65.76	22.73	6.59
15	70.46	22.84	6.60
16	75.16	22.92	6.61
17	79.86	22.98	6.62
18	84.55	23.03	6.63
19	89.25	23.07	6.63
20	93.95	23.10	6.64
21	98.64	23.12	6.64
22	103.34	23.14	6.64
23	108.04	23.15	6.65
24	112.74	23.16	6.65
25	117.43	23.17	6.65
26	122.13	23.18	6.65
27	126.83	23.18	6.65
28	131.53	23.19	6.65
29	136.22	23.19	6.65
30	140.92	23.19	6.65
31	145.62	23.19	6.65
32	150.32	23.20	6.65
33	155.01	23.20	6.65
34	159.71	23.31	6.67
35	164.41	23.55	6.70
36	169.11	23.75	6.73
37	173.80	23.90	6.75
38	178.50	0.00	0.00
39	179.50	0.00	0.00

Write data to text file for input

WRITEPRN("deg.txt") := deg

LNG Source Term and Dispersion Modeling Input Data

Constants and Conversion Factors

Unit conversions

$kJ \equiv 1000 \cdot joule$ $\quad lbmole \equiv \frac{lb}{kg} 10^3 mole$ $\quad kgmole \equiv 10^3 mole$ $\quad kgmol \equiv 10^3 \cdot mol$

$kW \equiv 1000 \cdot watt$ $\quad gmole \equiv mole$ $\quad gmol \equiv mol$

Universal gas constant

$R_u \equiv 8.314472 \cdot \frac{kJ}{kgmole \cdot K}$ $\quad R_u = 1545 \cdot \frac{ft \cdot lbf}{lbmole \cdot R}$

Material Properties

Ambient pressure

$p_a := 101325 \cdot Pa$ $\quad p_a = 14.7 \cdot psi$

Molecular weight

$M := 16.043 \cdot \frac{kg}{kgmole}$

Normal boiling point

$T_b := 111.66 \cdot K$ $\quad T_b = 200.988 \cdot R$

Vapor density (at T_b, using ideal gas law)

$\rho_v := \frac{p_a}{\frac{R_u}{M} \cdot T_b}$ $\quad \rho_v = 1.751 \cdot \frac{kg}{m^3}$ $\quad \rho_v = 0.109 \cdot \frac{lb}{ft^3}$

Vapor viscosity (at T_b)

$\mu_v := 4.362 \cdot 10^{-6} Pa\,sec$

Kinematic viscosity of vapor (at T_b)

$\nu_v := \frac{\mu_v}{\rho_v}$ $\quad \nu_v = 2.491 \times 10^{-6} \cdot \frac{m^2}{sec}$

Density of Liquid (at T_b)

$\rho_l := 422.5 \cdot \frac{kg}{m^3}$

Liquid viscosity (at T_b)

$\mu_l := 1.168 \cdot 10^{-4} Pa\,sec$

Kinematic viscosity of vapor (at T_b)

$\nu_l := \frac{\mu_l}{\rho_l}$ $\quad \nu_l = 2.764 \times 10^{-7} \cdot \frac{m^2}{sec}$

Heat of vaporization

$h_{fg} := 509331.9 \cdot \frac{joule}{kg}$

Surface Tension (at T_b)

$\sigma := 0.0133 \frac{newton}{m}$

Thermal conductivity of vapor

$\lambda_v := 0.01269 \frac{watt}{m \cdot K}$

Heat capacity of vapor

$C_p := 2075.56 \frac{joule}{kg \cdot K}$

Vapor thermal diffusivity $\alpha_v := \frac{\lambda_v}{\rho_v \cdot C_p}$ $\alpha_v = 3.492 \times 10^{-6} \cdot \frac{m^2}{sec}$

Seawater density $\rho_w := 1025 \cdot \frac{kg}{m^3}$

Water viscosity $\mu_w := 1.021 \cdot 10^{-3} Pa\,sec$

Water kinematic viscosity of vapor $\nu_w := \frac{\mu_w}{\rho_w}$ $\nu_w = 9.961 \times 10^{-7} \cdot \frac{m^2}{sec}$

Release and Deinventory

$q_{spill} := 116.93 \frac{kg}{sec}$

$t_{spill} := 107 sec$

Function for evaporation rate as a function of time for use in pool spread calculations

$$q_S(t) := \begin{cases} 0 \cdot \frac{kg}{sec} & \text{if } t > t_{spill} \\ q_{spill} & \text{otherwise} \end{cases}$$

$Q := q_{spill} \cdot t_{spill} = 12511.51\,kg$

Film Boiling Heat Flux and Evaporation Rate

Heat flux $Q_{film} := 85 \cdot \frac{kW}{m^2}$ $Q_{film} = 26944.9 \cdot \frac{BTU}{hr \cdot ft^2}$

Evaporation mass flux $M_{film} := \frac{Q_{film}}{h_{fg}}$ $M_{film} = 0.167 \cdot \frac{kg}{m^2 \cdot sec}$ $M_{film} = 0.034 \cdot \frac{lb}{ft^2 \cdot sec}$

Mass evaporation rate as a function of pool radius $m_e(r) := \frac{\pi \cdot (r^2) \cdot Q_{film}}{h_{fg}}$

Spread Equations

Reduced gravitational acceleration (TNO 3.34) $g_r := g \cdot \frac{\rho_w - \rho_l}{\rho_w}$

Minimum frontal depth based on surface tension (TNO 3.48) $h_\sigma := \sqrt{\frac{\sigma}{g \cdot \rho_l}}$ $h_\sigma = 0.18 \cdot cm$

Minimum frontal depth based on viscous effects (TNO 3.11) $h_c(q_S) := \left(\frac{6 \cdot \nu_l \cdot q_S}{\rho_l \cdot \pi \cdot g} \right)^{0.25}$

Choose minimum depth (TNO 3.49)

$$h_{0max}(q) := \max\left(h_\sigma, h_c(q)\right)$$

Pool shape factor

$$sh\left(u, h, h_{0max}\right) := \begin{cases} 1 & \text{if } h < 0.01 \cdot m \\ \text{otherwise} & \\ \quad Fr \leftarrow 1.078 & \\ \quad N \leftarrow \dfrac{u^2}{2 \cdot Fr^2 \cdot g_r \cdot h} & \text{if } u > 0 \\ \quad N \leftarrow 0 & \text{otherwise} \\ \quad sh \leftarrow N + \sqrt{N^2 + \left(\dfrac{h_{0max}}{h}\right)^2} & \\ \quad sh & \end{cases}$$

Gravity term coefficient (TNO 3.63)

$$\Phi(sh) := (1 - sh) \cdot (sh \le 2) + \left(\frac{-sh^2}{4}\right)(sh > 2)$$

Vapor film thickness for friction estimation

$$\delta := 6.3 \cdot 10^{-5} \cdot m \qquad \delta = 0.063 \cdot mm$$

Resistance term (TNO 3.72), modified to estimate friction from shear stress in the vapor film

$$C_F(u, h) := \begin{cases} \text{sign}(u) \cdot \dfrac{u \, \mu_v}{\delta \cdot \rho_l \cdot h} & \text{if } h > 0 \\ 0 \cdot \dfrac{m}{sec^2} & \text{otherwise} \end{cases}$$

Acceleration of the leading edge of the pool (TNO 3.62)

$$a\left(\Phi, h, r, C_F\right) := \frac{4 \cdot \Phi \cdot g_r \cdot h}{r} - C_F$$

Acceleration as a function of current speed, radius, height, and mass addition rate

$$acc(u, r, h, q) := \begin{cases} h_{0max} \leftarrow h_{0max}(q) & \\ sh \leftarrow sh\left(u, h, h_{0max}\right) & \\ \Phi \leftarrow \Phi(sh) & \\ C_F \leftarrow C_F(u, h) & \\ a\left(\Phi, h, r, C_F\right) & \end{cases}$$

Pool Spread and Evaporation Algorithm

Time step

$$dt := .1 \cdot sec$$

pool :=

$t_0 \leftarrow 0 \cdot sec$

$V_0 \leftarrow 0 \cdot m^3$

$r_0 \leftarrow 0 \cdot m$

$h_0 \leftarrow 0 \cdot m$

$u_0 \leftarrow 0 \cdot \frac{m}{sec}$

$q_0 \leftarrow q_S(0 \cdot sec)$

$a_0 \leftarrow acc(u_0, r_0, h_0, q_0)$

$e_0 \leftarrow m_e(r_0)$

$V_{add_0} \leftarrow \frac{q_0 \cdot dt}{\rho_l}$

$V_{evap_0} \leftarrow \frac{e_0 \cdot dt}{\rho_l}$

$i \leftarrow 0$

while $(i < 1) \vee (V_i > 0 \cdot m^3)$

$i \leftarrow i + 1$

$t_i \leftarrow i \cdot dt$

$V_i \leftarrow V_{i-1} + V_{add_{i-1}} - V_{evap_{i-1}}$

$V_i \leftarrow 0 \cdot m^3$ if $V_i < 0$

$r_i \leftarrow r_{i-1} + u_{i-1} \cdot dt$

$r_i \leftarrow (V_i)^{\frac{1}{3}}$ if $r_i = 0 \cdot m$

$h_i \leftarrow \frac{V_i}{\pi \cdot (r_i)^2}$

$u_i \leftarrow u_{i-1} + a_{i-1} \cdot dt$

$q_i \leftarrow q_S(i \cdot dt)$

$h_{min} \leftarrow h_{0max}(q_i)$

if $h_i < h_{min}$ if $q_i > 0$

$h_i \leftarrow h_{min}$

$r \leftarrow \sqrt{\frac{V_i}{}}$

$r_i \leftarrow \sqrt{\pi \cdot h_i}$

$e_i \leftarrow m_e(r_i)$

$a_i \leftarrow acc(u_i, r_i, h_i, q_i)$

$V_{add_i} \leftarrow \frac{q_i \cdot dt}{\rho_l}$

$V_{evap_i} \leftarrow \frac{e_i \cdot dt}{\rho_l}$

if $\left(V_i + V_{add_i} - V_{evap_i}\right) \le 0 \cdot m^3$ if $q_i > 0 \cdot \frac{kg}{sec}$

$r_i \leftarrow \sqrt{\frac{q_i \cdot h_{fg}}{\pi \cdot Q_{film}}}$

$h_i \leftarrow \frac{V_i}{\pi \cdot (r_i)^2}$

$e_i \leftarrow q_i$

$V_{evap_i} \leftarrow V_{add_i}$

$M^{\langle 0 \rangle} \leftarrow \frac{t}{sec}$

$M^{\langle 1 \rangle} \leftarrow \frac{V}{m^3}$

$M^{\langle 2 \rangle} \leftarrow \frac{V_{add}}{m^3}$

$M^{\langle 3 \rangle} \leftarrow \frac{V_{evap}}{m^3}$

$M^{\langle 4 \rangle} \leftarrow \frac{a}{\frac{m}{s^2}}$

$M^{\langle 5 \rangle} \leftarrow \frac{u}{\frac{m}{s}}$

$M^{\langle 6 \rangle} \leftarrow \frac{r}{m}$

$M^{\langle 7 \rangle} \leftarrow \frac{h}{m}$

$M^{\langle 8 \rangle} \leftarrow \frac{q}{kg}$

$$\left| \begin{array}{l} \\ M^{\langle 9 \rangle} \leftarrow \dfrac{\dfrac{kg}{sec}}{\dfrac{e}{\dfrac{kg}{sec}}} \\ \\ M \end{array} \right.$$

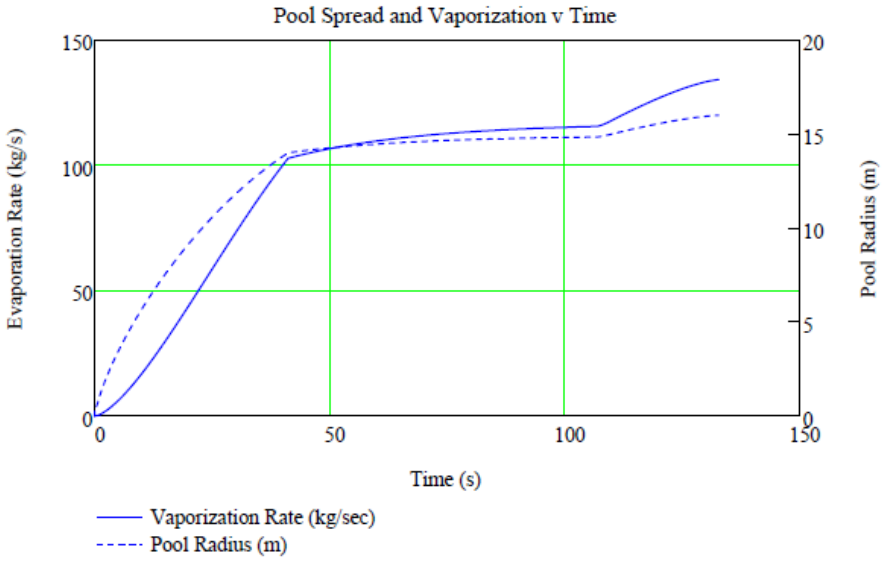
Pool Spread and Evaporation Results

Time for complete evaporation $t_{total} := \max\left(pool^{\langle 0 \rangle}\right) \cdot sec$ $t_{total} = 133 \cdot sec$ $t_{total} = 2.2 \cdot min$

Maximum pool radius $r_{max} := \max\left(pool^{\langle 6 \rangle}\right) \cdot m$ $r_{max} = 16\,m$ $r_{max} = 52 \cdot ft$

pool =

	t	V	V.add	V.evap	acc	u
	0	1	2	3	4	5
0	0	0	0.028	0	0	0
1	0.1	0.028	0.028	$1.135 \cdot 10^{-5}$	6.497	0
2	0.2	0.055	0.028	$1.135 \cdot 10^{-5}$	9.728	0.65
3	0.3	0.083	0.028	$1.676 \cdot 10^{-5}$	-12.403	1.623
4	0.4	0.111	0.028	$3.482 \cdot 10^{-5}$	4.314	0.382
5	0.5	0.138	0.028	$4.002 \cdot 10^{-5}$	1.479	0.814
6	0.6	0.166	0.028	$5.231 \cdot 10^{-5}$	-0.484	0.961
7	0.7	0.194	0.028	$6.895 \cdot 10^{-5}$	-0.452	0.913
8	0.8	0.221	0.028	$8.688 \cdot 10^{-5}$	-0.359	0.868
9	0.9	0.249	0.028	$1.058 \cdot 10^{-4}$	-0.293	0.832
10	1	0.276	0.028	$1.258 \cdot 10^{-4}$	-0.246	0.803
11	1.1	0.304	0.028	$1.466 \cdot 10^{-4}$	-0.211	0.778
12	1.2	0.331	0.028	$1.684 \cdot 10^{-4}$	-0.184	0.757
13	1.3	0.359	0.028	$1.91 \cdot 10^{-4}$	-0.163	0.739
14	1.4	0.386	0.028	$2.144 \cdot 10^{-4}$	-0.146	0.722
15	1.5	0.414	0.028	$2.386 \cdot 10^{-4}$	-0.132	0.708



Transient Source Term

Time step $step := \frac{t_{total}}{38}$ $step = 3.495\ s$

For each time step, use the evaporation rate and pool radius for the midpoint

$deg :=$ for $i \in 0 .. 37$

$t_i \leftarrow i \cdot \frac{step}{sec}$

$t_{mid} \leftarrow t_i + \frac{step}{2 \cdot sec}$

$e_i \leftarrow linterp(pool^{\langle 0 \rangle}, pool^{\langle 9 \rangle}, t_{mid})$

$r_i \leftarrow linterp(pool^{\langle 0 \rangle}, pool^{\langle 6 \rangle}, t_{mid})$

$t_{38} \leftarrow \frac{38 \cdot step}{sec}$

$t_{39} \leftarrow t_{38} + 1$

$M^{\langle 0 \rangle} \leftarrow t$

$M^{\langle 1 \rangle} \leftarrow e$

$M^{\langle 2 \rangle} \leftarrow r$

M

Write data to text file for input

WRITEPRN("MEP6a.txt") := deg

deg =

	0	1	2
0	0.00	1.28	1.56
1	3.49	6.60	3.55
2	6.99	13.88	5.14
3	10.48	22.42	6.54
4	13.98	31.79	7.79
5	17.47	41.70	8.92
6	20.97	51.89	9.95
7	24.46	62.16	10.89
8	27.96	72.31	11.74
9	31.45	82.18	12.52
10	34.95	91.61	13.22
11	38.44	100.48	13.84
12	41.94	104.06	14.09
13	45.43	105.58	14.19
14	48.93	106.91	14.28
15	52.42	108.09	14.36
16	55.92	109.13	14.43
17	59.41	110.05	14.49
18	62.91	110.86	14.54
19	66.40	111.57	14.59
20	69.89	112.20	14.63
21	73.39	112.76	14.67
22	76.88	113.25	14.70
23	80.38	113.68	14.73
24	83.87	114.06	14.75
25	87.37	114.40	14.77
26	90.86	114.70	14.79
27	94.36	114.96	14.81
28	97.85	115.19	14.82
29	101.35	115.40	...

LNG Source Term and Dispersion Modeling Input Data

Constants and Conversion Factors

Unit conversions

$kJ \equiv 1000 \cdot joule$ $\quad lbmole \equiv \frac{lb}{kg} 10^3 mole$ $\quad kgmole \equiv 10^3 mole$ $\quad kgmol \equiv 10^3 \cdot mol$

$kW \equiv 1000 \cdot watt$ $\quad gmole \equiv mole$ $\quad gmol \equiv mol$

Universal gas constant

$R_u \equiv 8.314472 \cdot \frac{kJ}{kgmole \cdot K}$ $\quad R_u = 1545 \cdot \frac{ft \cdot lbf}{lbmole \cdot R}$

Material Properties

Ambient pressure

$p_a := 101325 \cdot Pa$ $\quad p_a = 14.7 \cdot psi$

Molecular weight

$M := 16.043 \cdot \frac{kg}{kgmole}$

Normal boiling point

$T_b := 111.66 \cdot K$ $\quad T_b = 200.988 \cdot R$

Vapor density (at T_b, using ideal gas law)

$\rho_v := \frac{p_a}{\frac{R_u}{M} \cdot T_b}$ $\quad \rho_v = 1.751 \cdot \frac{kg}{m^3}$ $\quad \rho_v = 0.109 \cdot \frac{lb}{ft^3}$

Vapor viscosity (at T_b)

$\mu_v := 4.362 \cdot 10^{-6} Pa\,sec$

Kinematic viscosity of vapor (at T_b)

$\nu_v := \frac{\mu_v}{\rho_v}$ $\quad \nu_v = 2.491 \times 10^{-6} \cdot \frac{m^2}{sec}$

Density of Liquid (at T_b)

$\rho_l := 422.5 \cdot \frac{kg}{m^3}$

Liquid viscosity (at T_b)

$\mu_l := 1.168 \cdot 10^{-4} Pa\,sec$

Kinematic viscosity of vapor (at T_b)

$\nu_l := \frac{\mu_l}{\rho_l}$ $\quad \nu_l = 2.764 \times 10^{-7} \cdot \frac{m^2}{sec}$

Heat of vaporization

$h_{fg} := 509331.9 \cdot \frac{joule}{kg}$

Surface Tension (at T_b)

$\sigma := 0.0133 \frac{newton}{m}$

Thermal conductivity of vapor

$\lambda_v := 0.01269 \frac{watt}{m \cdot K}$

Heat capacity of vapor

$C_p := 2075.56 \frac{joule}{kg \cdot K}$

Vapor thermal diffusivity $\alpha_v := \frac{\lambda_v}{\rho_v \cdot C_p}$ $\alpha_v = 3.492 \times 10^{-6} \cdot \frac{m^2}{sec}$

Seawater density $\rho_w := 1025 \cdot \frac{kg}{m^3}$

Water viscosity $\mu_w := 1.021 \cdot 10^{-3} Pa\,sec$

Water kinematic viscosity of vapor $\nu_w := \frac{\mu_w}{\rho_w}$ $\nu_w = 9.961 \times 10^{-7} \cdot \frac{m^2}{sec}$

Release and Deinventory

$q_{spill} := 123.03 \frac{kg}{sec}$

$t_{spill} := 82 sec$

Function for evaporation rate as a function of time for use in pool spread calculations

$$q_S(t) := \begin{cases} 0 \cdot \frac{kg}{sec} & \text{if } t > t_{spill} \\ q_{spill} & \text{otherwise} \end{cases}$$

$Q := q_{spill} \cdot t_{spill} = 10088.46\,kg$

Film Boiling Heat Flux and Evaporation Rate

Heat flux $Q_{film} := 85 \cdot \frac{kW}{m^2}$ $Q_{film} = 26944.9 \cdot \frac{BTU}{hr \cdot ft^2}$

Evaporation mass flux $M_{film} := \frac{Q_{film}}{h_{fg}}$ $M_{film} = 0.167 \cdot \frac{kg}{m^2 \cdot sec}$ $M_{film} = 0.034 \cdot \frac{lb}{ft^2 \cdot sec}$

Mass evaporation rate as a function of pool radius $m_e(r) := \frac{\pi \cdot (r^2) \cdot Q_{film}}{h_{fg}}$

Spread Equations

Reduced gravitational acceleration (TNO 3.34) $g_r := g \cdot \frac{\rho_w - \rho_l}{\rho_w}$

Minimum frontal depth based on surface tension (TNO 3.48) $h_\sigma := \sqrt{\frac{\sigma}{g \cdot \rho_l}}$ $h_\sigma = 0.18 \cdot cm$

Minimum frontal depth based on viscous effects (TNO 3.11) $h_c(q_S) := \left(\frac{6 \cdot \nu_l \cdot q_S}{\rho_l \cdot \pi \cdot g} \right)^{0.25}$

Choose minimum depth (TNO 3.49)

$$h_{0max}(q) := \max\left(h_\sigma, h_c(q)\right)$$

Pool shape factor

$$sh\left(u, h, h_{0max}\right) := \begin{cases} 1 \text{ if } h < 0.01 \cdot m \\ \text{otherwise} \\ \quad Fr \leftarrow 1.078 \\ \quad N \leftarrow \dfrac{u^2}{2 \cdot Fr^2 \cdot g_r \cdot h} \text{ if } u > 0 \\ \quad N \leftarrow 0 \text{ otherwise} \\ \quad sh \leftarrow N + \sqrt{N^2 + \left(\dfrac{h_{0max}}{h}\right)^2} \\ \quad sh \end{cases}$$

Gravity term coefficient (TNO 3.63)

$$\Phi(sh) := (1 - sh) \cdot (sh \le 2) + \left(\frac{-sh^2}{4}\right)(sh > 2)$$

Vapor film thickness for friction estimation

$$\delta := 6.3 \cdot 10^{-5} \cdot m \qquad \delta = 0.063 \cdot mm$$

Resistance term (TNO 3.72), modified to estimate friction from shear stress in the vapor film

$$C_F(u, h) := \begin{cases} \text{sign}(u) \cdot \dfrac{u \, \mu_v}{\delta \cdot \rho_l \cdot h} \text{ if } h > 0 \\ 0 \cdot \dfrac{m}{sec^2} \text{ otherwise} \end{cases}$$

Acceleration of the leading edge of the pool (TNO 3.62)

$$a\left(\Phi, h, r, C_F\right) := \frac{4 \cdot \Phi \cdot g_r \cdot h}{r} - C_F$$

Acceleration as a function of current speed, radius, height, and mass addition rate

$$acc(u, r, h, q) := \begin{cases} h_{0max} \leftarrow h_{0max}(q) \\ sh \leftarrow sh\left(u, h, h_{0max}\right) \\ \Phi \leftarrow \Phi(sh) \\ C_F \leftarrow C_F(u, h) \\ a\left(\Phi, h, r, C_F\right) \end{cases}$$

Pool Spread and Evaporation Algorithm

Time step

$$dt := .1 \cdot sec$$

$$
\begin{aligned}
&\text{pool} := \\
&\quad t_0 \leftarrow 0 \cdot \text{sec} \\
&\quad V_0 \leftarrow 0 \cdot \text{m}^3 \\
&\quad r_0 \leftarrow 0 \cdot \text{m} \\
&\quad h_0 \leftarrow 0 \cdot \text{m} \\
&\quad u_0 \leftarrow 0 \cdot \frac{\text{m}}{\text{sec}} \\
&\quad q_0 \leftarrow q_S(0 \cdot \text{sec}) \\
&\quad a_0 \leftarrow \text{acc}(u_0, r_0, h_0, q_0) \\
&\quad e_0 \leftarrow m_e(r_0) \\
&\quad V_{\text{add}_0} \leftarrow \frac{q_0 \cdot dt}{\rho_l} \\
&\quad V_{\text{evap}_0} \leftarrow \frac{e_0 \cdot dt}{\rho_l} \\
&\quad i \leftarrow 0 \\
&\quad \text{while } (i < 1) \vee \left(V_i > 0 \cdot \text{m}^3\right) \\
&\qquad i \leftarrow i + 1 \\
&\qquad t_i \leftarrow i \cdot dt \\
&\qquad V_i \leftarrow V_{i-1} + V_{\text{add}_{i-1}} - V_{\text{evap}_{i-1}} \\
&\qquad V_i \leftarrow 0 \cdot \text{m}^3 \quad \text{if } V_i < 0 \\
&\qquad r_i \leftarrow r_{i-1} + u_{i-1} \cdot dt \\
&\qquad r_i \leftarrow \left(V_i\right)^{\frac{1}{3}} \quad \text{if } r_i = 0 \cdot \text{m} \\
&\qquad h_i \leftarrow \frac{V_i}{\pi \cdot \left(r_i\right)^2} \\
&\qquad u_i \leftarrow u_{i-1} + a_{i-1} \cdot dt \\
&\qquad q_i \leftarrow q_S(i \cdot dt) \\
&\qquad h_{\min} \leftarrow h_{0\max}\left(q_i\right) \\
&\qquad \text{if } h_i < h_{\min} \qquad \text{if } q_i > 0 \\
&\qquad\quad h_i \leftarrow h_{\min} \\
&\qquad\quad r \leftarrow \sqrt{\frac{V_i}{}}
\end{aligned}
$$

$$r_i \leftarrow \sqrt{\pi \cdot h_i}$$

$$e_i \leftarrow m_e(r_i)$$

$$a_i \leftarrow acc(u_i, r_i, h_i, q_i)$$

$$V_{add_i} \leftarrow \frac{q_i \cdot dt}{\rho_l}$$

$$V_{evap_i} \leftarrow \frac{e_i \cdot dt}{\rho_l}$$

if $\left(V_i + V_{add_i} - V_{evap_i}\right) \le 0 \cdot m^3$ if $q_i > 0 \cdot \frac{kg}{sec}$

$$r_i \leftarrow \sqrt{\frac{q_i \cdot h_{fg}}{\pi \cdot Q_{film}}}$$

$$h_i \leftarrow \frac{V_i}{\pi \cdot (r_i)^2}$$

$$e_i \leftarrow q_i$$

$$V_{evap_i} \leftarrow V_{add_i}$$

$$M^{\langle 0 \rangle} \leftarrow \frac{t}{sec}$$

$$M^{\langle 1 \rangle} \leftarrow \frac{V}{m^3}$$

$$M^{\langle 2 \rangle} \leftarrow \frac{V_{add}}{m^3}$$

$$M^{\langle 3 \rangle} \leftarrow \frac{V_{evap}}{m^3}$$

$$M^{\langle 4 \rangle} \leftarrow \frac{a}{\frac{m}{s^2}}$$

$$M^{\langle 5 \rangle} \leftarrow \frac{u}{\frac{m}{s}}$$

$$M^{\langle 6 \rangle} \leftarrow \frac{r}{m}$$

$$M^{\langle 7 \rangle} \leftarrow \frac{h}{m}$$

$$M^{\langle 8 \rangle} \leftarrow \frac{q}{kg}$$

$$M^{\langle 9 \rangle} \leftarrow \frac{\frac{kg}{sec}}{\frac{e}{\frac{kg}{sec}}}$$

M

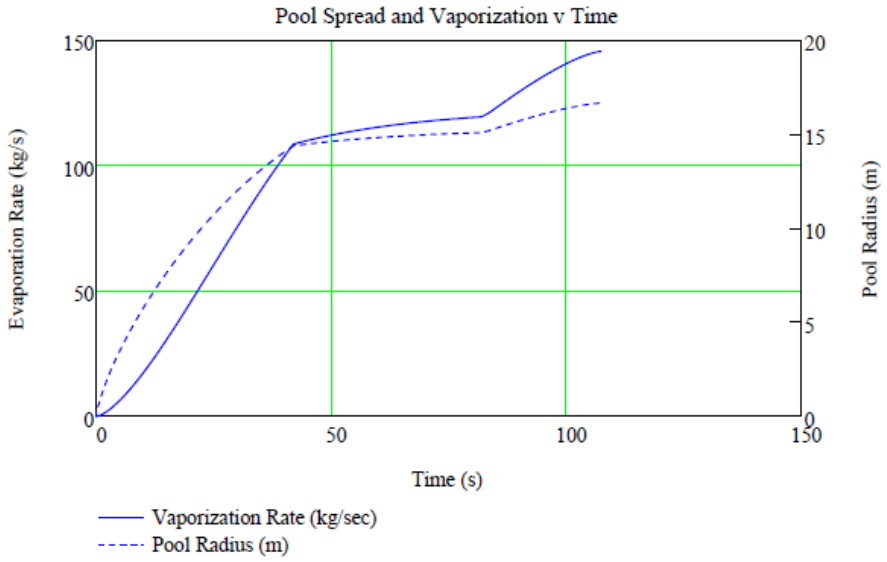
Pool Spread and Evaporation Results

Time for complete evaporation $t_{total} := \max\left(pool^{\langle 0 \rangle}\right) \cdot sec$ $t_{total} = 107 \cdot sec$ $t_{total} = 1.8 \cdot min$

Maximum pool radius $r_{max} := \max\left(pool^{\langle 6 \rangle}\right) \cdot m$ $r_{max} = 17\,m$ $r_{max} = 55 \cdot ft$

pool =

	t	V	V.add	V.evap	acc	u
	0	1	2	3	4	5
0	0	0	0.029	0	0	0
1	0.1	0.029	0.029	$1.175 \cdot 10^{-5}$	6.501	0
2	0.2	0.058	0.029	$1.175 \cdot 10^{-5}$	9.803	0.65
3	0.3	0.087	0.029	$1.723 \cdot 10^{-5}$	-12.187	1.63
4	0.4	0.116	0.029	$3.561 \cdot 10^{-5}$	4.287	0.412
5	0.5	0.146	0.029	$4.129 \cdot 10^{-5}$	1.302	0.84
6	0.6	0.175	0.029	$5.42 \cdot 10^{-5}$	-0.499	0.971
7	0.7	0.204	0.029	$7.129 \cdot 10^{-5}$	-0.448	0.921
8	0.8	0.233	0.029	$8.966 \cdot 10^{-5}$	-0.356	0.876
9	0.9	0.262	0.029	$1.091 \cdot 10^{-4}$	-0.292	0.84
10	1	0.291	0.029	$1.295 \cdot 10^{-4}$	-0.245	0.811
11	1.1	0.32	0.029	$1.509 \cdot 10^{-4}$	-0.211	0.787
12	1.2	0.349	0.029	$1.732 \cdot 10^{-4}$	-0.184	0.766
13	1.3	0.378	0.029	$1.964 \cdot 10^{-4}$	-0.163	0.747
14	1.4	0.407	0.029	$2.204 \cdot 10^{-4}$	-0.147	0.731
15	1.5	0.435	0.029	$2.452 \cdot 10^{-4}$	-0.133	0.716



Transient Source Term

Time step $step := \frac{t_{total}}{38}$ $step = 2.826\ s$

For each time step, use the evaporation rate and pool radius for the midpoint

$deg :=$ for $i \in 0 .. 37$

$t_i \leftarrow i \cdot \frac{step}{sec}$

$t_{mid} \leftarrow t_i + \frac{step}{2 \cdot sec}$

$e_i \leftarrow linterp(pool^{\langle 0 \rangle}, pool^{\langle 9 \rangle}, t_{mid})$

$r_i \leftarrow linterp(pool^{\langle 0 \rangle}, pool^{\langle 6 \rangle}, t_{mid})$

$t_{38} \leftarrow \frac{38 \cdot step}{sec}$

$t_{39} \leftarrow t_{38} + 1$

$M^{\langle 0 \rangle} \leftarrow t$

$M^{\langle 1 \rangle} \leftarrow e$

$M^{\langle 2 \rangle} \leftarrow r$

M

Write data to text file for input

WRITEPRN("MEP10a.txt") := deg

deg =

	0	1	2
0	0.00	0.94	1.34
1	2.83	4.95	3.07
2	5.65	10.48	4.47
3	8.48	17.04	5.70
4	11.31	24.34	6.81
5	14.13	32.18	7.83
6	16.96	40.40	8.78
7	19.78	48.86	9.65
8	22.61	57.44	10.47
9	25.44	66.04	11.22
10	28.26	74.56	11.93
11	31.09	82.91	12.58
12	33.92	91.01	13.18
13	36.74	98.78	13.73
14	39.57	106.15	14.23
15	42.39	109.55	14.45
16	45.22	110.83	14.54
17	48.05	111.99	14.62
18	50.87	113.04	14.68
19	53.70	113.99	14.75
20	56.53	114.85	14.80
21	59.35	115.63	14.85
22	62.18	116.33	14.90
23	65.01	116.97	14.94
24	67.83	117.55	14.97
25	70.66	118.07	15.01
26	73.48	118.54	15.04
27	76.31	118.97	15.06
28	79.14	119.35	15.09
29	81.96	120.93	...

LNG Source Term and Dispersion Modeling Input Data

Constants and Conversion Factors

Unit conversions

$kJ \equiv 1000 \cdot joule$ $\quad lbmole \equiv \frac{lb}{kg} 10^3 mole$ $\quad kgmole \equiv 10^3 mole$ $\quad kgmol \equiv 10^3 \cdot mol$

$kW \equiv 1000 \cdot watt$ $\quad gmole \equiv mole$ $\quad gmol \equiv mol$

Universal gas constant

$R_u \equiv 8.314472 \cdot \frac{kJ}{kgmole \cdot K}$ $\quad R_u = 1545 \cdot \frac{ft \cdot lbf}{lbmole \cdot R}$

Material Properties

Ambient pressure

$p_a := 101325 \cdot Pa$ $\quad p_a = 14.7 \cdot psi$

Molecular weight

$M := 16.043 \cdot \frac{kg}{kgmole}$

Normal boiling point

$T_b := 111.66 \cdot K$ $\quad T_b = 200.988 \cdot R$

Vapor density (at T_b, using ideal gas law)

$\rho_v := \frac{p_a}{\frac{R_u}{M} \cdot T_b}$ $\quad \rho_v = 1.751 \cdot \frac{kg}{m^3}$ $\quad \rho_v = 0.109 \cdot \frac{lb}{ft^3}$

Vapor viscosity (at T_b)

$\mu_v := 4.362 \cdot 10^{-6} Pa\,sec$

Kinematic viscosity of vapor (at T_b)

$\nu_v := \frac{\mu_v}{\rho_v}$ $\quad \nu_v = 2.491 \times 10^{-6} \cdot \frac{m^2}{sec}$

Density of Liquid (at T_b)

$\rho_l := 422.5 \cdot \frac{kg}{m^3}$

Liquid viscosity (at T_b)

$\mu_l := 1.168 \cdot 10^{-4} Pa\,sec$

Kinematic viscosity of vapor (at T_b)

$\nu_l := \frac{\mu_l}{\rho_l}$ $\quad \nu_l = 2.764 \times 10^{-7} \cdot \frac{m^2}{sec}$

Heat of vaporization

$h_{fg} := 509331.9 \cdot \frac{joule}{kg}$

Surface Tension (at T_b)

$\sigma := 0.0133 \frac{newton}{m}$

Thermal conductivity of vapor

$\lambda_v := 0.01269 \frac{watt}{m \cdot K}$

Heat capacity of vapor

$C_p := 2075.56 \frac{joule}{kg \cdot K}$

Vapor thermal diffusivity $\alpha_v := \frac{\lambda_v}{\rho_v \cdot C_p}$ $\alpha_v = 3.492 \times 10^{-6} \cdot \frac{m^2}{sec}$

Seawater density $\rho_w := 1025 \cdot \frac{kg}{m^3}$

Water viscosity $\mu_w := 1.021 \cdot 10^{-3} Pa\,sec$

Water kinematic viscosity of vapor $\nu_w := \frac{\mu_w}{\rho_w}$ $\nu_w = 9.961 \times 10^{-7} \cdot \frac{m^2}{sec}$

Release and Deinventory

$q_{spill} := \frac{202.23}{4} \frac{kg}{sec}$

$t_{spill} := 131 sec$

Function for evaporation rate as a function of time for use in pool spread calculations

$$q_S(t) := \begin{cases} 0 \cdot \frac{kg}{sec} & \text{if } t > t_{spill} \\ q_{spill} & \text{otherwise} \end{cases}$$

$Q := q_{spill} \cdot t_{spill} = 6623.03\,kg$

Film Boiling Heat Flux and Evaporation Rate

Heat flux $Q_{film} := 85 \cdot \frac{kW}{m^2}$ $Q_{film} = 26944.9 \cdot \frac{BTU}{hr \cdot ft^2}$

Evaporation mass flux $M_{film} := \frac{Q_{film}}{h_{fg}}$ $M_{film} = 0.167 \cdot \frac{kg}{m^2 \cdot sec}$ $M_{film} = 0.034 \cdot \frac{lb}{ft^2 \cdot sec}$

Mass evaporation rate as a function of pool radius $m_e(r) := \frac{\pi \cdot (r^2) \cdot Q_{film}}{h_{fg}}$

Spread Equations

Reduced gravitational acceleration (TNO 3.34) $g_r := g \cdot \frac{\rho_w - \rho_l}{\rho_w}$

Minimum frontal depth based on surface tension (TNO 3.48) $h_\sigma := \sqrt{\frac{\sigma}{g \cdot \rho_l}}$ $h_\sigma = 0.18 \cdot cm$

Minimum frontal depth based on viscous effects (TNO 3.11) $h_c(q_S) := \left(\frac{6 \cdot \nu_l \cdot q_S}{\rho_l \cdot \pi \cdot g} \right)^{0.25}$

Choose minimum depth (TNO 3.49)

$$h_{0max}(q) := \max\left(h_\sigma, h_c(q)\right)$$

Pool shape factor

$$sh\left(u, h, h_{0max}\right) := \begin{cases} 1 & \text{if } h < 0.01 \cdot m \\ \text{otherwise} & \\ \quad Fr \leftarrow 1.078 & \\ \quad N \leftarrow \dfrac{u^2}{2 \cdot Fr^2 \cdot g_r \cdot h} & \text{if } u > 0 \\ \quad N \leftarrow 0 & \text{otherwise} \\ \quad sh \leftarrow N + \sqrt{N^2 + \left(\dfrac{h_{0max}}{h}\right)^2} & \\ \quad sh & \end{cases}$$

Gravity term coefficient (TNO 3.63)

$$\Phi(sh) := (1 - sh) \cdot (sh \le 2) + \left(\frac{-sh^2}{4}\right)(sh > 2)$$

Vapor film thickness for friction estimation

$$\delta := 6.3 \cdot 10^{-5} \cdot m \qquad \delta = 0.063 \cdot mm$$

Resistance term (TNO 3.72), modified to estimate friction from shear stress in the vapor film

$$C_F(u, h) := \begin{cases} \text{sign}(u) \cdot \dfrac{u \, \mu_v}{\delta \cdot \rho_l \cdot h} & \text{if } h > 0 \\ 0 \cdot \dfrac{m}{sec^2} & \text{otherwise} \end{cases}$$

Acceleration of the leading edge of the pool (TNO 3.62)

$$a\left(\Phi, h, r, C_F\right) := \frac{4 \cdot \Phi \cdot g_r \cdot h}{r} - C_F$$

Acceleration as a function of current speed, radius, height, and mass addition rate

$$acc(u, r, h, q) := \begin{cases} h_{0max} \leftarrow h_{0max}(q) \\ sh \leftarrow sh\left(u, h, h_{0max}\right) \\ \Phi \leftarrow \Phi(sh) \\ C_F \leftarrow C_F(u, h) \\ a\left(\Phi, h, r, C_F\right) \end{cases}$$

Pool Spread and Evaporation Algorithm

Time step

$$dt := .1 \cdot sec$$

$$
\begin{aligned}
\text{pool} := \;& t_0 \leftarrow 0 \cdot \text{sec} \\
& V_0 \leftarrow 0 \cdot \text{m}^3 \\
& r_0 \leftarrow 0 \cdot \text{m} \\
& h_0 \leftarrow 0 \cdot \text{m} \\
& u_0 \leftarrow 0 \cdot \frac{\text{m}}{\text{sec}} \\
& q_0 \leftarrow q_S(0 \cdot \text{sec}) \\
& a_0 \leftarrow \text{acc}\left(u_0, r_0, h_0, q_0\right) \\
& e_0 \leftarrow m_e\left(r_0\right) \\
& V\text{add}_0 \leftarrow \frac{q_0 \cdot dt}{\rho_l} \\
& V\text{evap}_0 \leftarrow \frac{e_0 \cdot dt}{\rho_l} \\
& i \leftarrow 0 \\
& \text{while } (i < 1) \vee \left(V_i > 0 \cdot \text{m}^3\right) \\
& \quad i \leftarrow i + 1 \\
& \quad t_i \leftarrow i \cdot dt \\
& \quad V_i \leftarrow V_{i-1} + V\text{add}_{i-1} - V\text{evap}_{i-1} \\
& \quad V_i \leftarrow 0 \cdot \text{m}^3 \quad \text{if } V_i < 0 \\
& \quad r_i \leftarrow r_{i-1} + u_{i-1} \cdot dt \\
& \quad r_i \leftarrow \left(V_i\right)^{\frac{1}{3}} \quad \text{if } r_i = 0 \cdot \text{m} \\
& \quad h_i \leftarrow \frac{V_i}{\pi \cdot \left(r_i\right)^2} \\
& \quad u_i \leftarrow u_{i-1} + a_{i-1} \cdot dt \\
& \quad q_i \leftarrow q_S(i \cdot dt) \\
& \quad h_{min} \leftarrow h_{0max}\left(q_i\right) \\
& \quad \text{if } h_i < h_{min} \qquad \text{if } q_i > 0 \\
& \quad\quad h_i \leftarrow h_{min} \\
& \quad\quad r_i \leftarrow \sqrt{\frac{V_i}{}}
\end{aligned}
$$

$r_i \leftarrow \sqrt{\frac{V_i}{\pi \cdot h_i}}$

$e_i \leftarrow m_e(r_i)$

$a_i \leftarrow acc(u_i, r_i, h_i, q_i)$

$V_{add_i} \leftarrow \frac{q_i \cdot dt}{\rho_l}$

$V_{evap_i} \leftarrow \frac{e_i \cdot dt}{\rho_l}$

if $\left(V_i + V_{add_i} - V_{evap_i}\right) \le 0 \cdot m^3$ if $q_i > 0 \cdot \frac{kg}{sec}$

$r_i \leftarrow \sqrt{\frac{q_i \cdot h_{fg}}{\pi \cdot Q_{film}}}$

$h_i \leftarrow \frac{V_i}{\pi \cdot (r_i)^2}$

$e_i \leftarrow q_i$

$V_{evap_i} \leftarrow V_{add_i}$

$M^{\langle 0 \rangle} \leftarrow \frac{t}{sec}$

$M^{\langle 1 \rangle} \leftarrow \frac{V}{m^3}$

$M^{\langle 2 \rangle} \leftarrow \frac{V_{add}}{m^3}$

$M^{\langle 3 \rangle} \leftarrow \frac{V_{evap}}{m^3}$

$M^{\langle 4 \rangle} \leftarrow \frac{a}{\frac{m}{s^2}}$

$M^{\langle 5 \rangle} \leftarrow \frac{u}{\frac{m}{s}}$

$M^{\langle 6 \rangle} \leftarrow \frac{r}{m}$

$M^{\langle 7 \rangle} \leftarrow \frac{h}{m}$

$M^{\langle 8 \rangle} \leftarrow \frac{q}{kg}$

$$M^{\langle 9 \rangle} \leftarrow \frac{\frac{kg}{sec}}{\frac{e}{\frac{kg}{sec}}}$$

$$M$$

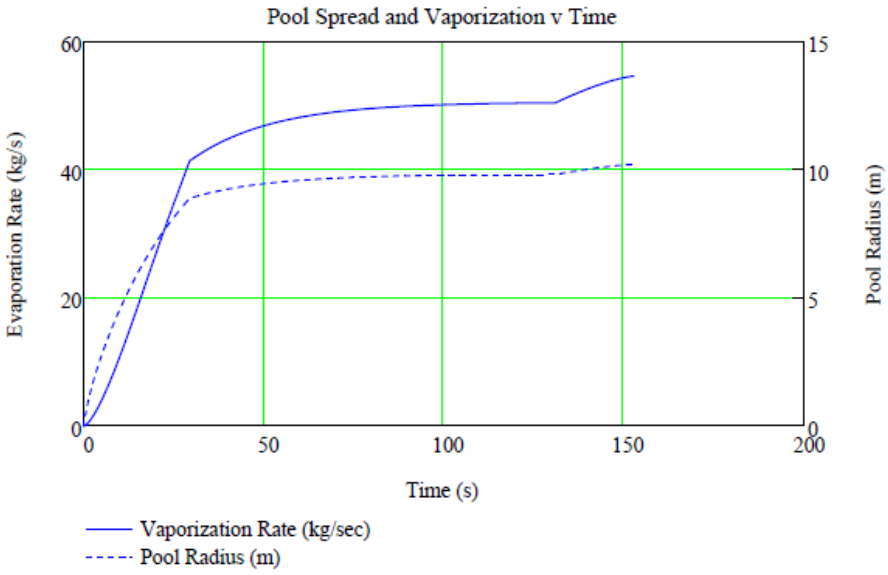
Pool Spread and Evaporation Results

Time for complete evaporation $t_{total} := \max(pool^{\langle 0 \rangle}) \cdot sec$ $t_{total} = 153 \cdot sec$ $t_{total} = 2.5 \cdot min$

Maximum pool radius $r_{max} := \max(pool^{\langle 6 \rangle}) \cdot m$ $r_{max} = 10\,m$ $r_{max} = 33 \cdot ft$

pool =

	t	V	V.add	V.evap	acc	u
	0	1	2	3	4	5
0	0	0	0.012	0	0	0
1	0.1	0.012	0.012	$6.492 \cdot 10^{-6}$	6.436	0
2	0.2	0.024	0.012	$6.492 \cdot 10^{-6}$	8.312	0.644
3	0.3	0.036	0.012	$1.066 \cdot 10^{-5}$	-15.619	1.475
4	0.4	0.048	0.012	$2.409 \cdot 10^{-5}$	3.637	-0.087
5	0.5	0.06	0.012	$2.314 \cdot 10^{-5}$	4.575	0.277
6	0.6	0.072	0.012	$2.62 \cdot 10^{-5}$	1.338	0.734
7	0.7	0.084	0.012	$3.524 \cdot 10^{-5}$	-0.84	0.868
8	0.8	0.096	0.012	$4.766 \cdot 10^{-5}$	-0.499	0.784
9	0.9	0.108	0.012	$6.048 \cdot 10^{-5}$	-0.371	0.734
10	1	0.119	0.012	$7.386 \cdot 10^{-5}$	-0.292	0.697
11	1.1	0.131	0.012	$8.781 \cdot 10^{-5}$	-0.239	0.668
12	1.2	0.143	0.012	$1.023 \cdot 10^{-4}$	-0.201	0.644
13	1.3	0.155	0.012	$1.173 \cdot 10^{-4}$	-0.173	0.624
14	1.4	0.167	0.012	$1.329 \cdot 10^{-4}$	-0.151	0.606
15	1.5	0.179	0.012	$1.489 \cdot 10^{-4}$	-0.134	0.591



Transient Source Term

Time step $step := \frac{t_{total}}{38}$ $step = 4.021\ s$ $deg :=$

For each time step, use the evaporation rate and pool radius for the midpoint

for $i \in 0..37$

$t_i \leftarrow i \cdot \frac{step}{sec}$

$t_{mid} \leftarrow t_i + \frac{step}{2 \cdot sec}$

$e_i \leftarrow linterp(pool^{\langle 0 \rangle}, pool^{\langle 9 \rangle}, t_{mid})$

$r_i \leftarrow linterp(pool^{\langle 0 \rangle}, pool^{\langle 6 \rangle}, t_{mid})$

$t_{38} \leftarrow \frac{38 \cdot step}{sec}$

$t_{39} \leftarrow t_{38} + 1$

$M^{\langle 0 \rangle} \leftarrow t$

$M^{\langle 1 \rangle} \leftarrow e$

$M^{\langle 2 \rangle} \leftarrow r$

M

Write data to text file for input

WRITEPRN("MEP11a.txt") := deg

deg =

	0	1	2
0	0.00	1.01	1.38
1	4.02	5.22	3.16
2	8.04	10.80	4.54
3	12.06	17.07	5.71
4	16.08	23.62	6.71
5	20.11	30.12	7.58
6	24.13	36.33	8.32
7	28.15	41.65	8.91
8	32.17	43.10	9.07
9	36.19	44.31	9.19
10	40.21	45.33	9.30
11	44.23	46.18	9.39
12	48.25	46.89	9.46
13	52.27	47.49	9.52
14	56.29	47.99	9.57
15	60.32	48.41	9.61
16	64.34	48.76	9.64
17	68.36	49.05	9.67
18	72.38	49.30	9.70
19	76.40	49.50	9.72
20	80.42	49.67	9.73
21	84.44	49.82	9.75
22	88.46	49.94	9.76
23	92.48	50.04	9.77
24	96.51	50.12	9.78
25	100.53	50.19	9.78
26	104.55	50.25	9.79
27	108.57	50.30	9.80
28	112.59	50.34	9.80
29	116.61	50.38	...

Appendix B

Selected FDS Input Files

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RADIATION=.FALSE. /

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      THICKNESS         =1 /


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&RAMP ID='WindRamp', T=711, F=0.53/
&RAMP ID='WindRamp', T=715, F=0.47/
&RAMP ID='WindRamp', T=718, F=0.33/
&RAMP ID='WindRamp', T=721, F=0.33/
&RAMP ID='WindRamp', T=724, F=0.29/
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&RAMP ID='WindRamp', T=726, F=0.28/
&RAMP ID='WindRamp', T=727, F=0.21/
&RAMP ID='WindRamp', T=730, F=0.16/
&RAMP ID='WindRamp', T=733, F=0.16/
&RAMP ID='WindRamp', T=737, F=0.45/
&RAMP ID='WindRamp', T=740, F=0.53/
&RAMP ID='WindRamp', T=742, F=0.54/
&RAMP ID='WindRamp', T=746, F=0.54/
&RAMP ID='WindRamp', T=748, F=0.55/
&RAMP ID='WindRamp', T=749, F=0.54/
&RAMP ID='WindRamp', T=750, F=0.53/
&RAMP ID='WindRamp', T=751, F=0.52/
&RAMP ID='WindRamp', T=753, F=0.53/
&RAMP ID='WindRamp', T=756, F=0.53/
&RAMP ID='WindRamp', T=757, F=0.51/
&RAMP ID='WindRamp', T=759, F=0.48/
&RAMP ID='WindRamp', T=761, F=0.47/
&RAMP ID='WindRamp', T=762, F=0.46/
&RAMP ID='WindRamp', T=764, F=0.45/
&RAMP ID='WindRamp', T=772, F=0.44/
&RAMP ID='WindRamp', T=775, F=0.48/
&RAMP ID='WindRamp', T=777, F=0.48/
&RAMP ID='WindRamp', T=779, F=0.43/
&RAMP ID='WindRamp', T=780, F=0.41/
&RAMP ID='WindRamp', T=781, F=0.41/
&RAMP ID='WindRamp', T=782, F=0.44/
&RAMP ID='WindRamp', T=783, F=0.46/
&RAMP ID='WindRamp', T=785, F=0.49/
&RAMP ID='WindRamp', T=786, F=0.50/
&RAMP ID='WindRamp', T=788, F=0.50/
&RAMP ID='WindRamp', T=789, F=0.49/
&RAMP ID='WindRamp', T=791, F=0.48/
&RAMP ID='WindRamp', T=793, F=0.49/
&RAMP ID='WindRamp', T=794, F=0.50/
&RAMP ID='WindRamp', T=798, F=0.50/
&RAMP ID='WindRamp', T=900, F=0.50/

&RAMP ID='TempRamp', T=0.0, F=1.0/
&RAMP ID='TempRamp', T=600, F=1.0/



/OPEN SIDES, TOP
&VENT MB='XMIN', SURF_ID='WIND'  /
&VENT MB='XMAX', SURF_ID='OPEN'  /
&VENT MB='YMIN', SURF_ID='WIND2' /
&VENT MB='YMAX', SURF_ID='OPEN'  /
&VENT MB='ZMAX', SURF_ID='MIRROR'/
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/LNG Vaporization Source
&SURF ID= 'LNG_vapor1', MASS_FLUX(1)= 0.187, RAMP_MF(1)='LNG_ramp1',
TMP_BACK=-161.55, TMP_INNER=-161.55, TMP_FRONT=-161.55,
RAMP_T='temp_ramp'/
&SURF ID= 'LNG_vapor2', MASS_FLUX(1)= 0.187, RAMP_MF(1)='LNG_ramp2',
TMP_BACK=-161.55, TMP_INNER=-161.55, TMP_FRONT=-161.55,
RAMP_T='temp_ramp'/
&SURF ID= 'LNG_vapor3', MASS_FLUX(1)= 0.187, RAMP_MF(1)='LNG_ramp3',
TMP_BACK=-161.55, TMP_INNER=-161.55, TMP_FRONT=-161.55,
RAMP_T='temp_ramp'/
&SURF ID= 'LNG_vapor4', MASS_FLUX(1)= 0.187, RAMP_MF(1)='LNG_ramp4',
TMP_BACK=-161.55, TMP_INNER=-161.55, TMP_FRONT=-161.55,
RAMP_T='temp_ramp'/
&SURF ID= 'LNG_vapor5', MASS_FLUX(1)= 0.187, RAMP_MF(1)='LNG_ramp5',
TMP_BACK=-161.55, TMP_INNER=-161.55, TMP_FRONT=-161.55,
RAMP_T='temp_ramp'/
&SURF ID= 'LNG_vapor6', MASS_FLUX(1)= 0.187, RAMP_MF(1)='LNG_ramp6',
TMP_BACK=-161.55, TMP_INNER=-161.55, TMP_FRONT=-161.55,
RAMP_T='temp_ramp'/
&SURF ID= 'LNG_vapor7', MASS_FLUX(1)= 0.187, RAMP_MF(1)='LNG_ramp7',
TMP_BACK=-161.55, TMP_INNER=-161.55, TMP_FRONT=-161.55,
RAMP_T='temp_ramp'/
&SURF ID= 'LNG_vapor8', MASS_FLUX(1)= 0.187, RAMP_MF(1)='LNG_ramp8',
TMP_BACK=-161.55, TMP_INNER=-161.55, TMP_FRONT=-161.55,
RAMP_T='temp_ramp'/
&SURF ID= 'LNG_vapor9', MASS_FLUX(1)= 0.187, RAMP_MF(1)='LNG_ramp9',
TMP_BACK=-161.55, TMP_INNER=-161.55, TMP_FRONT=-161.55,
RAMP_T='temp_ramp'/
&SURF ID= 'LNG_vapor10', MASS_FLUX(1)= 0.187,
RAMP_MF(1)='LNG_ramp10', TMP_BACK=-161.55, TMP_INNER=-161.55,
TMP_FRONT=-161.55, RAMP_T='temp_ramp'/

/Ramp function to describe temperature of vaporization area
&RAMP ID='temp_ramp', T=0.0, F=0.0/
&RAMP ID='temp_ramp', T=399, F=0.0/
&RAMP ID='temp_ramp', T=400, F=1.0/
&RAMP ID='temp_ramp', T=567, F=1.0/
&RAMP ID='temp_ramp', T=580, F=0.0/
&RAMP ID='temp_ramp', T=900, F=0.0/


/Ramp function to describe mass flux rate (vaporization rate)
&RAMP ID='LNG_ramp1', T=0.0, F=0.0/
&RAMP ID='LNG_ramp1', T=399, F=0.0/
&RAMP ID='LNG_ramp1', T=400, F=1.0/
&RAMP ID='LNG_ramp1', T=404.7, F=1.0/
&RAMP ID='LNG_ramp1', T=573.8, F=1.0/
&RAMP ID='LNG_ramp1', T=574.8, F=0.0/
&RAMP ID='LNG_ramp1', T=900, F=0.0/

&RAMP ID='LNG_ramp2', T=0.0, F=0.0/
&RAMP ID='LNG_ramp2', T=404.7, F=0.0/
&RAMP ID='LNG_ramp2', T=405.7, F=1.0/
&RAMP ID='LNG_ramp2', T=409.4, F=1.0/
&RAMP ID='LNG_ramp2', T=573.8, F=1.0/
&RAMP ID='LNG_ramp2', T=574.8, F=0.0/
&RAMP ID='LNG_ramp2', T=900, F=0.0/
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&RAMP ID='LNG_ramp3', T=0.0, F=0.0/
&RAMP ID='LNG_ramp3', T=409.39, F=0.0/
&RAMP ID='LNG_ramp3', T=410.39, F=1.0/
&RAMP ID='LNG_ramp3', T=414.09, F=1.0/
&RAMP ID='LNG_ramp3', T=573.8, F=1.0/
&RAMP ID='LNG_ramp3', T=574.8, F=0.0/
&RAMP ID='LNG_ramp3', T=900, F=0.0/

&RAMP ID='LNG_ramp4', T=0.0, F=0.0/
&RAMP ID='LNG_ramp4', T=414.09, F=0.0/
&RAMP ID='LNG_ramp4', T=415.09, F=1.0/
&RAMP ID='LNG_ramp4', T=418.79, F=1.0/
&RAMP ID='LNG_ramp4', T=573.8, F=1.0/
&RAMP ID='LNG_ramp4', T=574.8, F=0.0/
&RAMP ID='LNG_ramp4', T=900, F=0.0/

&RAMP ID='LNG_ramp5', T=0.0, F=0.0/
&RAMP ID='LNG_ramp5', T=418.79, F=0.0/
&RAMP ID='LNG_ramp5', T=419.79, F=1.0/
&RAMP ID='LNG_ramp5', T=423.49, F=1.0/
&RAMP ID='LNG_ramp5', T=573.8, F=1.0/
&RAMP ID='LNG_ramp5', T=574.8, F=0.0/
&RAMP ID='LNG_ramp5', T=900, F=0.0/

&RAMP ID='LNG_ramp6', T=0.0, F=0.0/
&RAMP ID='LNG_ramp6', T=423.49, F=0.0/
&RAMP ID='LNG_ramp6', T=424.39, F=1.0/
&RAMP ID='LNG_ramp6', T=428.18, F=1.0/
&RAMP ID='LNG_ramp6', T=573.8, F=1.0/
&RAMP ID='LNG_ramp6', T=574.8, F=0.0/
&RAMP ID='LNG_ramp6', T=900, F=0.0/

&RAMP ID='LNG_ramp7', T=0.0, F=0.0/
&RAMP ID='LNG_ramp7', T=428.18, F=0.0/
&RAMP ID='LNG_ramp7', T=429.18, F=1.0/
&RAMP ID='LNG_ramp7', T=442.28, F=1.0/
&RAMP ID='LNG_ramp7', T=573.8, F=1.0/
&RAMP ID='LNG_ramp7', T=574.8, F=0.0/
&RAMP ID='LNG_ramp7', T=900, F=0.0/

&RAMP ID='LNG_ramp8', T=0.0, F=0.0/
&RAMP ID='LNG_ramp8', T=442.28, F=0.0/
&RAMP ID='LNG_ramp8', T=443.28, F=1.0/
&RAMP ID='LNG_ramp8', T=475.16, F=1.0/
&RAMP ID='LNG_ramp8', T=573.8, F=1.0/
&RAMP ID='LNG_ramp8', T=574.8, F=0.0/
&RAMP ID='LNG_ramp8', T=900, F=0.0/

&RAMP ID='LNG_ramp9', T=0.0, F=0.0/
&RAMP ID='LNG_ramp9', T=475.16, F=0.0/
&RAMP ID='LNG_ramp9', T=476.16, F=1.0/
&RAMP ID='LNG_ramp9', T=555.01, F=1.0/
&RAMP ID='LNG_ramp9', T=573.8, F=1.0/
&RAMP ID='LNG_ramp9', T=574.8, F=0.0/
&RAMP ID='LNG_ramp9', T=900, F=0.0/
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&RAMP ID='LNG_ramp10', T=0.0, F=0.0/
&RAMP ID='LNG_ramp10', T=555.01, F=0.0/
&RAMP ID='LNG_ramp10', T=556.01, F=1.0/
&RAMP ID='LNG_ramp10', T=573.8, F=1.0/
&RAMP ID='LNG_ramp10', T=574.8, F=0.0/
&RAMP ID='LNG_ramp10', T=900, F=0.0/



/LNG VAPORIZATION LOCATION
&VENT XB= -2.02, 2.02, -2.02, 2.02, 0, 0, SURF_ID='LNG_vapor1' /
&VENT XB= -2.48, -2.02, -1.43, 1.43, 0, 0, SURF_ID='LNG_vapor1' /
&VENT XB=  2.02,  2.48,  -1.43,  1.43, 0, 0, SURF_ID='LNG_vapor1' /
&VENT XB= -1.43, 1.43, -2.48, -2.02, 0, 0, SURF_ID='LNG_vapor1' /
&VENT XB= -1.43, 1.43, 2.02, 2.48, 0, 0, SURF_ID='LNG_vapor1' /
&VENT XB= -2.64, -2.48, -1.09, 1.09, 0, 0, SURF_ID='LNG_vapor1' /
&VENT XB=  2.48,  2.64,  -1.09,  1.09, 0, 0, SURF_ID='LNG_vapor1' /
&VENT XB= -1.09, 1.09, -2.64, -2.48, 0, 0, SURF_ID='LNG_vapor1' /
&VENT XB= -1.09, 1.09, 2.48, 2.64, 0, 0, SURF_ID='LNG_vapor1' /
&VENT XB= -2.76, -2.64, -0.74, 0.74, 0, 0, SURF_ID='LNG_vapor1' /
&VENT XB=  2.64,  2.76,  -0.74,  0.74, 0, 0, SURF_ID='LNG_vapor1' /
&VENT XB= -0.74, 0.74, -2.76, -2.64, 0, 0, SURF_ID='LNG_vapor1' /
&VENT XB= -0.74, 0.74, 2.64, 2.76, 0, 0, SURF_ID='LNG_vapor1' /

&VENT XB= -2.86,  2.86, -2.86,   2.86, 0, 0, SURF_ID='LNG_vapor2' /
&VENT XB= -3.50, -2.86, -2.02,   2.02, 0, 0, SURF_ID='LNG_vapor2' /
&VENT XB=  2.86,   3.50, -2.02,   2.02, 0, 0, SURF_ID='LNG_vapor2' /
&VENT XB= -2.02,   2.02, -3.50, -2.86, 0, 0, SURF_ID='LNG_vapor2' /
&VENT XB= -2.02,   2.02,   2.86,  3.50, 0, 0, SURF_ID='LNG_vapor2' /
&VENT XB= -3.73, -3.50, -1.55,   1.55, 0, 0, SURF_ID='LNG_vapor2' /
&VENT XB=  3.50,   3.73, -1.55,   1.55, 0, 0, SURF_ID='LNG_vapor2' /
&VENT XB= -1.55,   1.55, -3.73, -3.50, 0, 0, SURF_ID='LNG_vapor2' /
&VENT XB= -1.55,   1.55,   3.50,  3.73, 0, 0, SURF_ID='LNG_vapor2' /
&VENT XB= -3.90, -3.73, -1.05,   1.05, 0, 0, SURF_ID='LNG_vapor2' /
&VENT XB=  3.73,   3.90, -1.05,   1.05, 0, 0, SURF_ID='LNG_vapor2' /
&VENT XB= -1.05,   1.05, -3.90, -3.73, 0, 0, SURF_ID='LNG_vapor2' /
&VENT XB= -1.05,   1.05,   3.73,  3.90, 0, 0, SURF_ID='LNG_vapor2' /

&VENT XB= -3.54, 3.54, -3.54, 3.54, 0, 0, SURF_ID='LNG_vapor3' /
&VENT XB= -4.34, -3.54, -2.51, 2.51, 0, 0, SURF_ID='LNG_vapor3' /
&VENT XB=  3.54,  4.34,  -2.51, 2.51, 0, 0, SURF_ID='LNG_vapor3' /
&VENT XB= -2.51, 2.51, -4.34, -3.54, 0, 0, SURF_ID='LNG_vapor3' /
&VENT XB= -2.51, 2.51, 3.54,  4.34,  0, 0, SURF_ID='LNG_vapor3' /
&VENT XB= -4.63, -4.34, -1.92, 1.92, 0, 0, SURF_ID='LNG_vapor3' /
&VENT XB=  4.34,  4.63,  -1.92, 1.92, 0, 0, SURF_ID='LNG_vapor3' /
&VENT XB= -1.92, 1.92, -4.63, -4.34, 0, 0, SURF_ID='LNG_vapor3' /
&VENT XB= -1.92, 1.92, 4.34,  4.63,  0, 0, SURF_ID='LNG_vapor3' /
&VENT XB= -4.84, -4.63, -1.30, 1.30, 0, 0, SURF_ID='LNG_vapor3' /
&VENT XB=  4.63,  4.84,  -1.30, 1.30, 0, 0, SURF_ID='LNG_vapor3' /
&VENT XB= -1.30, 1.30, -4.84, -4.63, 0, 0, SURF_ID='LNG_vapor3' /
&VENT XB= -1.30, 1.30, 4.63,  4.84,  0, 0, SURF_ID='LNG_vapor3' /

&VENT XB= -4.07, 4.07, -4.07, 4.07, 0, 0, SURF_ID='LNG_vapor4' /
&VENT XB= -4.99, -4.07, -2.88, 2.88, 0, 0, SURF_ID='LNG_vapor4' /
&VENT XB=  4.07, 4.99, -2.88, 2.88, 0, 0, SURF_ID='LNG_vapor4' /
&VENT XB= -2.88, 2.88, -4.99, -4.07, 0, 0, SURF_ID='LNG_vapor4' /
&VENT XB= -2.88, 2.88, 4.07, 4.99, 0, 0, SURF_ID='LNG_vapor4' /
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&VENT XB= -5.32, -4.99, -2.20, 2.20, 0, 0, SURF_ID='LNG_vapor4' /
&VENT XB=  4.99, 5.32, -2.20, 2.20, 0, 0, SURF_ID='LNG_vapor4' /
&VENT XB= -2.20, 2.20, -5.32, -4.99, 0, 0, SURF_ID='LNG_vapor4' /
&VENT XB= -2.20, 2.20, 4.99, 5.32, 0, 0, SURF_ID='LNG_vapor4' /
&VENT XB= -5.56, -5.32, -1.49, 1.49, 0, 0, SURF_ID='LNG_vapor4' /
&VENT XB=  5.32, 5.56, -1.49, 1.49, 0, 0, SURF_ID='LNG_vapor4' /
&VENT XB= -1.49, 1.49, -5.56, -5.32, 0, 0, SURF_ID='LNG_vapor4' /
&VENT XB= -1.49, 1.49, 5.32, 5.56, 0, 0, SURF_ID='LNG_vapor4' /

&VENT XB= -4.22, 4.22, -4.22, 4.22, 0, 0, SURF_ID='LNG_vapor5' /
&VENT XB= -5.17, -4.22, -2.99, 2.99, 0, 0, SURF_ID='LNG_vapor5' /
&VENT XB=  4.22, 5.17, -2.99, 2.99, 0, 0, SURF_ID='LNG_vapor5' /
&VENT XB= -2.99, 2.99, -5.17, -4.22, 0, 0, SURF_ID='LNG_vapor5' /
&VENT XB= -2.99, 2.99, 4.22, 5.17, 0, 0, SURF_ID='LNG_vapor5' /
&VENT XB= -5.52, -5.17, -2.28, 2.28, 0, 0, SURF_ID='LNG_vapor5' /
&VENT XB=  5.17, 5.52, -2.28, 2.28, 0, 0, SURF_ID='LNG_vapor5' /
&VENT XB= -2.28, 2.28, -5.52, -5.17, 0, 0, SURF_ID='LNG_vapor5' /
&VENT XB= -2.28, 2.28, 5.17, 5.52, 0, 0, SURF_ID='LNG_vapor5' /
&VENT XB= -5.77, -5.52, -1.55, 1.55, 0, 0, SURF_ID='LNG_vapor5' /
&VENT XB=  5.52, 5.77, -1.55, 1.55, 0, 0, SURF_ID='LNG_vapor5' /
&VENT XB= -1.55, 1.55, -5.77, -5.52, 0, 0, SURF_ID='LNG_vapor5' /
&VENT XB= -1.55, 1.55, 5.52, 5.77, 0, 0, SURF_ID='LNG_vapor5' /

&VENT XB= -4.33, 4.33, -4.33, 4.33, 0, 0, SURF_ID='LNG_vapor6' /
&VENT XB= -5.31, -4.33, -3.07, 3.07, 0, 0, SURF_ID='LNG_vapor6' /
&VENT XB=  4.33, 5.31, -3.07, 3.07, 0, 0, SURF_ID='LNG_vapor6' /
&VENT XB= -3.07, 3.07, -5.31, -4.33, 0, 0, SURF_ID='LNG_vapor6' /
&VENT XB= -3.07, 3.07,  4.33, 5.31, 0, 0, SURF_ID='LNG_vapor6' /
&VENT XB= -5.66, -5.31, -2.35, 2.35, 0, 0, SURF_ID='LNG_vapor6' /
&VENT XB=  5.31, 5.66, -2.35, 2.35, 0, 0, SURF_ID='LNG_vapor6' /
&VENT XB= -2.35, 2.35, -5.66, -5.31, 0, 0, SURF_ID='LNG_vapor6' /
&VENT XB= -2.35, 2.35,  5.31, 5.66, 0, 0, SURF_ID='LNG_vapor6' /
&VENT XB= -5.92, -5.66, -1.59, 1.59, 0, 0, SURF_ID='LNG_vapor6' /
&VENT XB=  5.66, 5.92, -1.59, 1.59, 0, 0, SURF_ID='LNG_vapor6' /
&VENT XB= -1.59, 1.59, -5.92, -5.66, 0, 0, SURF_ID='LNG_vapor6' /
&VENT XB= -1.59, 1.59,  5.66, 5.92, 0, 0, SURF_ID='LNG_vapor6' /

&VENT XB= -4.53, 4.53, -4.53, 4.53, 0, 0, SURF_ID='LNG_vapor7' /
&VENT XB= -5.55, -4.53, -3.21, 3.21, 0, 0, SURF_ID='LNG_vapor7' /
&VENT XB=  4.53, 5.55, -3.21, 3.21, 0, 0, SURF_ID='LNG_vapor7' /
&VENT XB= -3.21, 3.21, -5.55, -4.53, 0, 0, SURF_ID='LNG_vapor7' /
&VENT XB= -3.21, 3.21,  4.53, 5.55, 0, 0, SURF_ID='LNG_vapor7' /
&VENT XB= -5.92, -5.55, -2.45, 2.45, 0, 0, SURF_ID='LNG_vapor7' /
&VENT XB=  5.55, 5.92, -2.45, 2.45, 0, 0, SURF_ID='LNG_vapor7' /
&VENT XB= -2.45, 2.45, -5.92, -5.55, 0, 0, SURF_ID='LNG_vapor7' /
&VENT XB= -2.45, 2.45,  5.55, 5.92, 0, 0, SURF_ID='LNG_vapor7' /
&VENT XB= -6.19, -5.92, -1.66, 1.66, 0, 0, SURF_ID='LNG_vapor7' /
&VENT XB=  5.92, 6.19, -1.66, 1.66, 0, 0, SURF_ID='LNG_vapor7' /
&VENT XB= -1.66, 1.66, -6.19, -5.92, 0, 0, SURF_ID='LNG_vapor7' /
&VENT XB= -1.66, 1.66,  5.92, 6.19, 0, 0, SURF_ID='LNG_vapor7' /

&VENT XB= -4.67, 4.67, -4.67, 4.67, 0, 0, SURF_ID='LNG_vapor8' /
&VENT XB= -5.72, -4.67, -3.31, 3.31, 0, 0, SURF_ID='LNG_vapor8' /
&VENT XB=  4.67, 5.72, -3.31, 3.31, 0, 0, SURF_ID='LNG_vapor8' /
&VENT XB= -3.31, 3.31, -5.72, -4.67, 0, 0, SURF_ID='LNG_vapor8' /
&VENT XB= -3.31, 3.31,  4.67, 5.72, 0, 0, SURF_ID='LNG_vapor8' /
&VENT XB= -6.11, -5.72, -2.53, 2.53, 0, 0, SURF_ID='LNG_vapor8' /
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&VENT XB=  5.72, 6.11, -2.53, 2.53, 0, 0, SURF_ID='LNG_vapor8' /
&VENT XB= -2.53, 2.53, -6.11, -5.72, 0, 0, SURF_ID='LNG_vapor8' /
&VENT XB= -2.53, 2.53,  5.72, 6.11, 0, 0, SURF_ID='LNG_vapor8' /
&VENT XB= -6.38, -6.11, -1.71, 1.71, 0, 0, SURF_ID='LNG_vapor8' /
&VENT XB=  6.11, 6.38, -1.71, 1.71, 0, 0, SURF_ID='LNG_vapor8' /
&VENT XB= -1.71, 1.71, -6.38, -6.11, 0, 0, SURF_ID='LNG_vapor8' /
&VENT XB= -1.71, 1.71,  6.11, 6.38, 0, 0, SURF_ID='LNG_vapor8' /

&VENT XB= -4.70, 4.70, -4.70, 4.70, 0, 0, SURF_ID='LNG_vapor9' /
&VENT XB= -5.76, -4.70, -3.33, 3.33, 0, 0, SURF_ID='LNG_vapor9' /
&VENT XB=  4.70, 5.76, -3.33, 3.33, 0, 0, SURF_ID='LNG_vapor9' /
&VENT XB= -3.33, 3.33, -5.76, -4.70, 0, 0, SURF_ID='LNG_vapor9' /
&VENT XB= -3.33, 3.33,  4.70, 5.76, 0, 0, SURF_ID='LNG_vapor9' /
&VENT XB= -6.14, -5.76, -2.54, 2.54, 0, 0, SURF_ID='LNG_vapor9' /
&VENT XB=  5.76, 6.14, -2.54, 2.54, 0, 0, SURF_ID='LNG_vapor9' /
&VENT XB= -2.54, 2.54, -6.14, -5.76, 0, 0, SURF_ID='LNG_vapor9' /
&VENT XB= -2.54, 2.54,  5.76, 6.14, 0, 0, SURF_ID='LNG_vapor9' /
&VENT XB= -6.42, -6.14, -1.72, 1.72, 0, 0, SURF_ID='LNG_vapor9' /
&VENT XB=  6.14, 6.42, -1.72, 1.72, 0, 0, SURF_ID='LNG_vapor9' /
&VENT XB= -1.72, 1.72, -6.42, -6.14, 0, 0, SURF_ID='LNG_vapor9' /
&VENT XB= -1.72, 1.72,  6.14, 6.42, 0, 0, SURF_ID='LNG_vapor9' /

&VENT XB= -4.77, 4.77, -4.77, 4.77, 0, 0, SURF_ID='LNG_vapor10',
COLOR='BLACK' /
&VENT XB= -5.85, -4.77, -3.38, 3.38, 0, 0, SURF_ID='LNG_vapor10',
COLOR='BLACK' /
&VENT XB=  4.77, 5.85, -3.38, 3.38, 0, 0, SURF_ID='LNG_vapor10',
COLOR='BLACK' /
&VENT XB= -3.38, 3.38, -5.85, -4.77, 0, 0, SURF_ID='LNG_vapor10',
COLOR='BLACK' /
&VENT XB= -3.38, 3.38,  4.77, 5.85, 0, 0, SURF_ID='LNG_vapor10',
COLOR='BLACK' /
&VENT XB= -6.24, -5.85, -2.58, 2.58, 0, 0, SURF_ID='LNG_vapor10',
COLOR='BLACK' /
&VENT XB=  5.85, 6.24, -2.58, 2.58, 0, 0, SURF_ID='LNG_vapor10',
COLOR='BLACK' /
&VENT XB= -2.58, 2.58, -6.24, -5.85, 0, 0, SURF_ID='LNG_vapor10',
COLOR='BLACK' /
&VENT XB= -2.58, 2.58,  5.85, 6.24, 0, 0, SURF_ID='LNG_vapor10',
COLOR='BLACK' /
&VENT XB= -6.52, -6.24, -1.75, 1.75, 0, 0, SURF_ID='LNG_vapor10',
COLOR='BLACK' /
&VENT XB=  6.24, 6.52, -1.75, 1.75, 0, 0, SURF_ID='LNG_vapor10',
COLOR='BLACK' /
&VENT XB= -1.75, 1.75, -6.52, -6.24, 0, 0, SURF_ID='LNG_vapor10',
COLOR='BLACK' /
&VENT XB= -1.75, 1.75,  6.24, 6.52, 0, 0, SURF_ID='LNG_vapor10',
COLOR='BLACK' /

/Obstructions
/58m arc
&OBST XB= 51.6, 55.6, 21.2, 23.2, 0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB= 21.2, 23.2, 51.6, 55.6, 0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB= 51.6, 55.6,-23.2,-21.2, 0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/
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&OBST XB= 21.2, 23.2,-55.6,-51.6, 0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB=-55.6,-51.6,-23.2,-21.2, 0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB=-21.2,-23.2,-55.6,-51.6, 0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB=-55.6,-51.6, 21.2, 23.2, 0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/

/90m arc
&OBST XB= 86,   90,   -1,    1,   0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/67
&OBST XB= 60.2, 64.2, 60.2, 64.2, 0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/58
&OBST XB= -1,    1,   86,   90,   0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/38
&OBST XB= 60.2, 64.2,-64.2,-60.2, 0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB= -1,    1,  -83.3,-79.3, 0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/39
/130m arc
&OBST XB=117.2, 121.2,  48.4,  50.4, 0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB= 48.4,  50.4, 117.2, 121.2, 0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB=117.2, 121.2, -50.2, -48.2, 0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB= 50.4,  48.4,-117.2,-121.2, 0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB=-50.4, -48.4,-117.2,-121.2, 0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB=-117.2,-121.2,-50.2, -48.2, 0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB=-117.2,-121.2, 50.2,  48.2, 0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/

//181m arc
&OBST XB= 179, 183,  -1,   1, 0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/54
&OBST XB= 126, 130, 126, 130, 0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/53
&OBST XB=  -1,   1, 179, 183, 0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/31
&OBST XB= 126, 130,-126,-130, 0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/55
&OBST XB=  -1,   1,-179,-183, 0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/32

//248-250m arc
&OBST XB=248,   252,    -1,     1,   0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB=229,   233,    94.7,  96.7, 0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB=174.8, 178.8, 174.8, 178.8, 0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB= 94.7,  96.7, 229,   233,   0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/
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&OBST XB= -1,     1,   248,   252,   0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB=229,   233,   -94.7, -96.7, 0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB=174.8, 178.8,-174.8,-178.8, 0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB= 96.7,  94.7,-229,  -233,   0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB= -1,     1,  -248,  -252,   0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/

//322m arc
&OBST XB= 309, 313, 82.3,   84.3, 0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB= 264, 268, 179,   181,   0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB= 160, 162, 276.9, 280.9, 0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB= 309, 313, -84.3, -81.3, 0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB= 264, 268,-179,  -181,   0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB= 160, 162,-276.9,-280.9, 0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/

//399m arc
&OBST XB= 397,   401,   -1,      1,   0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB= 383,   387,  115.9,  117.9, 0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB= 337,   341,  211,    213,   0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB= 250.1, 252.1,308.1,  312.1, 0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB= 158,   160,  364,    368,   0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB= 383,   387, -115.9, -117.9, 0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB= 337,   341, -211,   -213,   0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB= 250.1, 252.1,-308.1,-312.1, 0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB= 158,   160,  -364,  -368,   0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/

//525m arc
&OBST XB= 515,   519,    90,   92, 0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/04
&OBST XB= 443,   447,   277,  279, 0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/03
&OBST XB= 369,   373,   369,  373, 0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/01
&OBST XB= 515,   519,   -90,  -92, 0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/43
&OBST XB= 443,   447,  -277, -279, 0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/06
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&OBST XB= 369,   373,  -369, -373, 0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/09
&OBST XB= 329.4, 331.3, 406,  410, 0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/



/650m arc
&OBST XB= 648,   652,    -1,     1,   0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB= 638.1, 642.1, 111.9, 113.9, 0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB= 608,   612,   221,   223,   0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB= 543.1, 547.1, 353,   355,   0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB= 457.6, 461.6, 457.6, 461.6, 0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB= 353,   355,   543.1, 547.1, 0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/

&OBST XB= 638.1, 642.1,-111.9,-113.9, 0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB= 608,   612,  -221,  -223,   0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB= 543.1, 547.1,-353,  -355,   0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB= 457.6, 461.6,-457.6,-461.6, 0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB= 353,   355,  -543.1,-547.1, 0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB= 324,   326,  -560.9,-564.9, 0, 0.5, SURF_ID='INERT',
COLOR='WHITE'/

/Isosurfaces
&ISOF QUANTITY='METHANE_VF', VALUE(1)=0.169, VALUE(2)=0.123,
VALUE(3)=0.095, VALUE(4)=0.033, VALUE(5)=0.030, VALUE(6)=0.029,
VALUE(7)=0.024, VALUE(8)=0.001/

/Slice Files
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&SLCF PBY=  0, QUANTITY='RELATIVE HUMIDITY'/

&SLCF PBY=  0, QUANTITY='VELOCITY', VECTOR=.TRUE./
&SLCF PBY=500, QUANTITY='VELOCITY', VECTOR=.TRUE./
&SLCF PBZ=  2, QUANTITY='VELOCITY', VECTOR=.TRUE./

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&SLCF PBX= 89, QUANTITY='METHANE_VF'/
&SLCF PBX=129, QUANTITY='METHANE_VF'/
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&SLCF PBX=322, QUANTITY='METHANE_VF'/
&SLCF PBX=399, QUANTITY='METHANE_VF'/
&SLCF PBX=650, QUANTITY='METHANE_VF'/
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&DEVC ID='722S', XYZ= 249, 0,  3.3, QUANTITY='VELOCITY' /
&DEVC ID='723S', XYZ= 249, 0,  0.9, QUANTITY='VELOCITY' /

&DEVC ID='651S', XYZ= 0, 251, 10.7, QUANTITY='VELOCITY' /
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&DEVC ID='823S', XYZ= 0, 1000, 1.9, QUANTITY='VELOCITY' /

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&DEVC ID='661V', XYZ= 0, 251,  1.0, QUANTITY='V-VELOCITY' /

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/58m arc
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&DEVC ID='58m0b', XYZ= 58, 0,  1.3, QUANTITY='METHANE_VF' /
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&DEVC ID='58m13c', XYZ= 22.2, -53.6,  2.2, QUANTITY='METHANE_VF' /

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&DEVC ID='58m14b', XYZ= 41, -41,  1.3, QUANTITY='METHANE_VF' /
&DEVC ID='58m14c', XYZ= 41, -41,  2.2, QUANTITY='METHANE_VF' /

&DEVC ID='58m15a', XYZ= 53.6, -22.2,  0.9, QUANTITY='METHANE_VF' /
&DEVC ID='58m15b', XYZ= 53.6, -22.2,  1.3, QUANTITY='METHANE_VF' /
&DEVC ID='58m15c', XYZ= 53.6, -22.2,  2.2, QUANTITY='METHANE_VF' /

&DEVC ID='58m16a', XYZ= 58.0, 0.0,  0.9, QUANTITY='METHANE_VF' /
&DEVC ID='58m16b', XYZ= 58.0, 0.0,  1.3, QUANTITY='METHANE_VF' /
&DEVC ID='58m16c', XYZ= 58.0, 0.0,  2.2, QUANTITY='METHANE_VF' /

/88m ar
&DEVC ID='88m1a', XYZ= 88.0, 0.0,  0.9, QUANTITY='METHANE_VF' /
&DEVC ID='88m1b', XYZ= 88.0, 0.0,  1.4, QUANTITY='METHANE_VF' /
&DEVC ID='88m1c', XYZ= 88.0, 0.0,  2.4, QUANTITY='METHANE_VF' /

&DEVC ID='88m2a', XYZ= 81.3, 33.7,  0.9, QUANTITY='METHANE_VF' /
&DEVC ID='88m2b', XYZ= 81.3, 33.7,  1.4, QUANTITY='METHANE_VF' /
&DEVC ID='88m2c', XYZ= 81.3, 33.7,  2.4, QUANTITY='METHANE_VF' /

&DEVC ID='88m3a-582', XYZ= 62.2, 62.2,  0.9, QUANTITY='METHANE_VF' /
&DEVC ID='88m3b-583', XYZ= 62.2, 62.2,  1.4, QUANTITY='METHANE_VF' /
&DEVC ID='88m3c-584', XYZ= 62.2, 62.2,  2.4, QUANTITY='METHANE_VF' /

&DEVC ID='88m CL', XYZ= 56.01, 69.17,  0.9, QUANTITY='METHANE_VF' /
&DEVC ID='88m CL', XYZ= 56.01, 69.17,  1.4, QUANTITY='METHANE_VF' /
&DEVC ID='88m CL', XYZ= 56.01, 69.17,  2.4, QUANTITY='METHANE_VF' /

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&DEVC ID='88m4b', XYZ= 33.7, 81.3,  1.4, QUANTITY='METHANE_VF' /
&DEVC ID='88m4c', XYZ= 33.7, 81.3,  2.4, QUANTITY='METHANE_VF' /

&DEVC ID='88m5a', XYZ= 0.0, 88.0,  0.9, QUANTITY='METHANE_VF' /
&DEVC ID='88m5b', XYZ= 0.0, 88.0,  1.4, QUANTITY='METHANE_VF' /
&DEVC ID='88m5c', XYZ= 0.0, 88.0,  2.4, QUANTITY='METHANE_VF' /

&DEVC ID='88m6a', XYZ= -33.7, 81.3,  0.9, QUANTITY='METHANE_VF' /
&DEVC ID='88m6b', XYZ= -33.7, 81.3,  1.4, QUANTITY='METHANE_VF' /
&DEVC ID='88m6c', XYZ= -33.7, 81.3,  2.4, QUANTITY='METHANE_VF' /
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&DEVC ID='88m7b', XYZ= -62.2, 62.2,  1.4, QUANTITY='METHANE_VF' /
&DEVC ID='88m7c', XYZ= -62.2, 62.2,  2.4, QUANTITY='METHANE_VF' /

&DEVC ID='88m8a', XYZ= -81.3, 33.7,  0.9, QUANTITY='METHANE_VF' /
&DEVC ID='88m8b', XYZ= -81.3, 33.7,  1.4, QUANTITY='METHANE_VF' /
&DEVC ID='88m8c', XYZ= -81.3, 33.7,  2.4, QUANTITY='METHANE_VF' /

&DEVC ID='88m9a', XYZ= -88.0, 0.0,  0.9, QUANTITY='METHANE_VF' /
&DEVC ID='88m9b', XYZ= -88.0, 0.0,  1.4, QUANTITY='METHANE_VF' /
&DEVC ID='88m9c', XYZ= -88.0, 0.0,  2.4, QUANTITY='METHANE_VF' /

&DEVC ID='88m10a', XYZ= -81.3, -33.7,  0.9, QUANTITY='METHANE_VF' /
&DEVC ID='88m10b', XYZ= -81.3, -33.7,  1.4, QUANTITY='METHANE_VF' /
&DEVC ID='88m10c', XYZ= -81.3, -33.7,  2.4, QUANTITY='METHANE_VF' /

&DEVC ID='88m11a', XYZ= -62.2, -62.2,  0.9, QUANTITY='METHANE_VF' /

&DEVC ID='88m11b', XYZ= -62.2, -62.2,  1.4, QUANTITY='METHANE_VF' /
&DEVC ID='88m11c', XYZ= -62.2, 62.2,  2.4, QUANTITY='METHANE_VF' /

&DEVC ID='88m12a', XYZ= -33.7, -81.3,  0.9, QUANTITY='METHANE_VF' /
&DEVC ID='88m12b', XYZ= -33.7, -81.3,  1.4, QUANTITY='METHANE_VF' /
&DEVC ID='88m12c', XYZ= -33.7, -81.3,  2.4, QUANTITY='METHANE_VF' /

&DEVC ID='88m13a', XYZ= 0.0, -88.0,  0.9, QUANTITY='METHANE_VF' /
&DEVC ID='88m13b', XYZ= 0.0, -88.0,  1.4, QUANTITY='METHANE_VF' /
&DEVC ID='88m13c', XYZ= 0.0, -88.0,  2.4, QUANTITY='METHANE_VF' /

&DEVC ID='88m14a', XYZ= 33.7, -81.3,  0.9, QUANTITY='METHANE_VF' /
&DEVC ID='88m14b', XYZ= 33.7, -81.3,  1.4, QUANTITY='METHANE_VF' /
&DEVC ID='88m14c', XYZ= 33.7, -81.3,  2.4, QUANTITY='METHANE_VF' /

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&DEVC ID='88m15b', XYZ= 62.2, -62.2,  1.4, QUANTITY='METHANE_VF' /
&DEVC ID='88m15c', XYZ= 62.2, -62.2,  2.4, QUANTITY='METHANE_VF' /

&DEVC ID='88m16a', XYZ= 81.3, -33.7,  0.9, QUANTITY='METHANE_VF' /
&DEVC ID='88m16b', XYZ= 81.3, -33.7,  1.4, QUANTITY='METHANE_VF' /
&DEVC ID='88m16c', XYZ= 81.3, -33.7,  2.4, QUANTITY='METHANE_VF' /

/128m arc
&DEVC ID='128m1a', XYZ= 129.0, 0.0, 0.9, QUANTITY='METHANE_VF' /
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&DEVC ID='128m1c', XYZ= 129.0, 0.0, 2.4, QUANTITY='METHANE_VF' /
&DEVC ID='128m1d', XYZ= 129.0, 0.0, 2.8, QUANTITY='METHANE_VF' /

&DEVC ID='128m2a', XYZ= 117.8, 50.0, 0.9, QUANTITY='METHANE_VF' /
&DEVC ID='128m2b', XYZ= 117.8, 50.0, 1.8, QUANTITY='METHANE_VF' /
&DEVC ID='128m2c', XYZ= 117.8, 50.0, 2.4, QUANTITY='METHANE_VF' /
&DEVC ID='128m2d', XYZ= 117.8, 50.0, 2.8, QUANTITY='METHANE_VF' /

&DEVC ID='128m3a', XYZ= 91.2, 91.2, 0.9, QUANTITY='METHANE_VF' /
&DEVC ID='128m3b', XYZ= 91.2, 91.2, 1.8, QUANTITY='METHANE_VF' /
&DEVC ID='128m3c', XYZ= 91.2, 91.2, 2.4, QUANTITY='METHANE_VF' /
&DEVC ID='128m3d', XYZ= 91.2, 91.2, 2.8, QUANTITY='METHANE_VF' /
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&DEVC ID='128m CL', XYZ= 81.18, 100.25, 0.9, QUANTITY='METHANE_VF' /
&DEVC ID='128m CL', XYZ= 81.18, 100.25, 1.8, QUANTITY='METHANE_VF' /
&DEVC ID='128m CL', XYZ= 81.18, 100.25, 2.4, QUANTITY='METHANE_VF'
/564
&DEVC ID='128m CL', XYZ= 81.18, 100.25, 2.8, QUANTITY='METHANE_VF' /

&DEVC ID='128m4a', XYZ= 48.3, 119.6, 0.9, QUANTITY='METHANE_VF' /
&DEVC ID='128m4b', XYZ= 48.3, 119.6, 1.8, QUANTITY='METHANE_VF' /
&DEVC ID='128m4c', XYZ= 48.3, 119.6, 2.4, QUANTITY='METHANE_VF' /
&DEVC ID='128m4d', XYZ= 48.3, 119.6, 2.8, QUANTITY='METHANE_VF' /

&DEVC ID='128m5a', XYZ= 0.0, 129.0, 0.9, QUANTITY='METHANE_VF' /
&DEVC ID='128m5b', XYZ= 0.0, 129.0, 1.8, QUANTITY='METHANE_VF' /
&DEVC ID='128m5c', XYZ= 0.0, 129.0, 2.4, QUANTITY='METHANE_VF' /
&DEVC ID='128m5d', XYZ= 0.0, 129.0, 2.8, QUANTITY='METHANE_VF' /

&DEVC ID='128m6a', XYZ= -49.4, 119.2, 0.9, QUANTITY='METHANE_VF' /
&DEVC ID='128m6b', XYZ= -49.4, 119.2, 1.8, QUANTITY='METHANE_VF' /
&DEVC ID='128m6c', XYZ= -49.4, 119.2, 2.4, QUANTITY='METHANE_VF' /
&DEVC ID='128m6d', XYZ= -49.4, 119.2, 2.8, QUANTITY='METHANE_VF' /

&DEVC ID='128m7a', XYZ= -91.2, 91.2, 0.9, QUANTITY='METHANE_VF' /
&DEVC ID='128m7b', XYZ= -91.2, 91.2, 1.8, QUANTITY='METHANE_VF' /
&DEVC ID='128m7c', XYZ= -91.2, 91.2, 2.4, QUANTITY='METHANE_VF' /
&DEVC ID='128m7d', XYZ= -91.2, 91.2, 2.8, QUANTITY='METHANE_VF' /

&DEVC ID='128m8a', XYZ= -119.2, 49.4, 0.9, QUANTITY='METHANE_VF' /
&DEVC ID='128m8b', XYZ= -119.2, 49.4, 1.8, QUANTITY='METHANE_VF' /
&DEVC ID='128m8c', XYZ= -119.2, 49.4, 2.4, QUANTITY='METHANE_VF' /
&DEVC ID='128m8d', XYZ= -119.2, 49.4, 2.8, QUANTITY='METHANE_VF' /

&DEVC ID='128m9a', XYZ= -129.0, 0.0, 0.9, QUANTITY='METHANE_VF' /
&DEVC ID='128m9b', XYZ= -129.0, 0.0, 1.8, QUANTITY='METHANE_VF' /
&DEVC ID='128m9c', XYZ= -129.0, 0.0, 2.4, QUANTITY='METHANE_VF' /
&DEVC ID='128m9d', XYZ= -129.0, 0.0, 2.8, QUANTITY='METHANE_VF' /

&DEVC ID='128m10a', XYZ= -119.2, -49.4, 0.9, QUANTITY='METHANE_VF' /
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&DEVC ID='128m10c', XYZ= -119.2, -49.4, 2.4, QUANTITY='METHANE_VF' /
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&DEVC ID='128m11a', XYZ= -91.2, -91.2, 0.9, QUANTITY='METHANE_VF' /
&DEVC ID='128m11b', XYZ= -91.2, -91.2, 1.8, QUANTITY='METHANE_VF' /
&DEVC ID='128m11c', XYZ= -91.2, -91.2, 2.4, QUANTITY='METHANE_VF' /
&DEVC ID='128m11d', XYZ= -91.2, -91.2, 2.8, QUANTITY='METHANE_VF' /

&DEVC ID='128m12a', XYZ= -49.2, -119.2, 0.9, QUANTITY='METHANE_VF' /
&DEVC ID='128m12b', XYZ= -49.2, -119.2, 1.8, QUANTITY='METHANE_VF' /
&DEVC ID='128m12c', XYZ= -49.2, -119.2, 2.4, QUANTITY='METHANE_VF' /
&DEVC ID='128m12d', XYZ= -49.2, -119.2, 2.8, QUANTITY='METHANE_VF' /

&DEVC ID='128m13a', XYZ= 0.0, -129.0, 0.9, QUANTITY='METHANE_VF' /
&DEVC ID='128m13b', XYZ= 0.0, -129.0, 1.8, QUANTITY='METHANE_VF' /
&DEVC ID='128m13c', XYZ= 0.0, -129.0, 2.4, QUANTITY='METHANE_VF' /
&DEVC ID='128m13d', XYZ= 0.0, -129.0, 2.8, QUANTITY='METHANE_VF' /
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&DEVC ID='128m14a', XYZ= 49.4, -119.2, 0.9, QUANTITY='METHANE_VF' /
&DEVC ID='128m14b', XYZ= 49.4, -119.2, 1.8, QUANTITY='METHANE_VF' /
&DEVC ID='128m14c', XYZ= 49.4, -119.2, 2.4, QUANTITY='METHANE_VF' /
&DEVC ID='128m14d', XYZ= 49.4, -119.2, 2.8, QUANTITY='METHANE_VF' /

&DEVC ID='128m15a', XYZ= 91.2, -91.2, 0.9, QUANTITY='METHANE_VF' /
&DEVC ID='128m15b', XYZ= 91.2, -91.2, 1.8, QUANTITY='METHANE_VF' /
&DEVC ID='128m15c', XYZ= 91.2, -91.2, 2.4, QUANTITY='METHANE_VF' /
&DEVC ID='128m15d', XYZ= 91.2, -91.2, 2.8, QUANTITY='METHANE_VF' /

&DEVC ID='128m16a', XYZ= 119.2, -49.4, 0.9, QUANTITY='METHANE_VF' /
&DEVC ID='128m16b', XYZ= 119.2, -49.4, 1.8, QUANTITY='METHANE_VF' /
&DEVC ID='128m16c', XYZ= 119.2, -49.4, 2.4, QUANTITY='METHANE_VF' /
&DEVC ID='128m16d', XYZ= 119.2, -49.4, 2.8, QUANTITY='METHANE_VF' /


/181m arc
&DEVC ID='188m1a', XYZ= 181, 0.0, 1.4, QUANTITY='METHANE_VF' /

&DEVC ID='188m2a', XYZ= 167.2, 69.3, 1.4, QUANTITY='METHANE_VF' /

&DEVC ID='188m3a', XYZ= 128.0, 128.0, 1.0, QUANTITY='METHANE_VF' /
&DEVC ID='188m3b', XYZ= 128.0, 128.0, 1.4, QUANTITY='METHANE_VF' /
&DEVC ID='188m3c', XYZ= 128.0, 128.0, 1.6, QUANTITY='METHANE_VF' /
&DEVC ID='188m3d', XYZ= 128.0, 128.0, 2.4, QUANTITY='METHANE_VF' /

&DEVC ID='181m CL', XYZ= 113.90, 140.67, 1, QUANTITY='METHANE_VF' /
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/
&DEVC ID='181m CL', XYZ= 113.90, 140.67, 1.6, QUANTITY='METHANE_VF'
/
&DEVC ID='181m CL', XYZ= 113.90, 140.67, 2.4, QUANTITY='METHANE_VF'
/

&DEVC ID='188m4a', XYZ= 69.3, 167.2, 1.4, QUANTITY='METHANE_VF' /
&DEVC ID='188m5a', XYZ= 0.0, 181, 1.4, QUANTITY='METHANE_VF' /
&DEVC ID='188m6a', XYZ= -69.3, 167.2, 1.4, QUANTITY='METHANE_VF' /
&DEVC ID='188m7a', XYZ= -128, 128, 1.4, QUANTITY='METHANE_VF' /
&DEVC ID='188m8a', XYZ= -167.2, 69.3, 1.4, QUANTITY='METHANE_VF' /
&DEVC ID='188m9a', XYZ= -181, 0.0, 1.4, QUANTITY='METHANE_VF' /
&DEVC ID='188m10a', XYZ= -167.2, -69.3, 1.4, QUANTITY='METHANE_VF' /
&DEVC ID='188m11a', XYZ= -128, -128, 1.4, QUANTITY='METHANE_VF' /
&DEVC ID='188m12a', XYZ= -69.3, -167.2, 1.4, QUANTITY='METHANE_VF' /
&DEVC ID='188m13a', XYZ=  0.0, -181, 1.4, QUANTITY='METHANE_VF' /
&DEVC ID='188m14a', XYZ= 69.3, -167.2, 1.4, QUANTITY='METHANE_VF' /
&DEVC ID='188m15a', XYZ= 128, -128, 1.4, QUANTITY='METHANE_VF' /
&DEVC ID='188m16a', XYZ= 167.2, -69.3, 1.4, QUANTITY='METHANE_VF' /


/248-250m arc
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&DEVC ID='250m1b', XYZ= 250.0,  0.0, 1.4, QUANTITY='METHANE_VF' /
&DEVC ID='250m1c', XYZ= 250.0,  0.0, 1.6, QUANTITY='METHANE_VF' /
&DEVC ID='250m1d', XYZ= 250.0,  0.0, 2.4, QUANTITY='METHANE_VF' /

&DEVC ID='250m2a', XYZ= 231.0,  95.7, 1,   QUANTITY='METHANE_VF' /
&DEVC ID='250m2b', XYZ= 231.0,  95.7, 1.4, QUANTITY='METHANE_VF' /
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&DEVC ID='250m2d', XYZ= 231.0,  95.7, 2.4, QUANTITY='METHANE_VF' /

&DEVC ID='250m3a', XYZ= 175.4,  175.4, 1,   QUANTITY='METHANE_VF' /
&DEVC ID='250m3b', XYZ= 175.4,  175.4, 1.4, QUANTITY='METHANE_VF' /
&DEVC ID='250m3c', XYZ= 175.4,  175.4, 1.6, QUANTITY='METHANE_VF' /
&DEVC ID='250m3d', XYZ= 175.4,  175.4, 2.4, QUANTITY='METHANE_VF' /

&DEVC ID='250m CL', XYZ= 156.07,  192.74, 1,   QUANTITY='METHANE_VF'
/492
&DEVC ID='250m CL', XYZ= 156.07,  192.74, 1.4, QUANTITY='METHANE_VF'
/493
&DEVC ID='250m CL', XYZ= 156.07,  192.74, 1.6, QUANTITY='METHANE_VF'
/
&DEVC ID='250m CL', XYZ= 156.07,  192.74, 2.4, QUANTITY='METHANE_VF'
/494

&DEVC ID='250m4a', XYZ= 93.7,  231.8, 1,   QUANTITY='METHANE_VF' /
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&DEVC ID='250m4c', XYZ= 93.7,  231.8, 1.6, QUANTITY='METHANE_VF' /
&DEVC ID='250m4d', XYZ= 93.7,  231.8, 2.4, QUANTITY='METHANE_VF' /

&DEVC ID='250m5a', XYZ= 0.0,  250.0, 1,   QUANTITY='METHANE_VF' /
&DEVC ID='250m5b', XYZ= 0.0,  250.0, 1.4, QUANTITY='METHANE_VF' /
&DEVC ID='250m5c', XYZ= 0.0,  250.0, 1.6, QUANTITY='METHANE_VF' /
&DEVC ID='250m5d', XYZ= 0.0,  250.0, 2.4, QUANTITY='METHANE_VF' /

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&DEVC ID='250m6c', XYZ= -95.7,  231.0, 1.6, QUANTITY='METHANE_VF' /
&DEVC ID='250m6d', XYZ= -95.7,  231.0, 2.4, QUANTITY='METHANE_VF' /

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&DEVC ID='250m7c', XYZ= -176.8,  176.8, 1.6, QUANTITY='METHANE_VF' /
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&DEVC ID='250m8b', XYZ= -231.0,  95.7, 1.4, QUANTITY='METHANE_VF' /
&DEVC ID='250m8c', XYZ= -231.0,  95.7, 1.6, QUANTITY='METHANE_VF' /
&DEVC ID='250m8d', XYZ= -231.0,  95.7, 2.4, QUANTITY='METHANE_VF' /

&DEVC ID='250m9a', XYZ= -250.0,  0.0, 1,   QUANTITY='METHANE_VF' /
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&DEVC ID='250m9c', XYZ= -250.0,  0.0, 1.6, QUANTITY='METHANE_VF' /
&DEVC ID='250m9d', XYZ= -250.0,  0.0, 2.4, QUANTITY='METHANE_VF' /

&DEVC ID='250m10a', XYZ= -231.0,  -95.7, 1,  QUANTITY='METHANE_VF' /
&DEVC ID='250m10b', XYZ= -231.0,  -95.7, 1.4,QUANTITY='METHANE_VF' /
&DEVC ID='250m10c', XYZ= -231.0,  -95.7, 1.6,QUANTITY='METHANE_VF' /
&DEVC ID='250m10d', XYZ= -231.0,  -95.7, 2.4,QUANTITY='METHANE_VF' /

&DEVC ID='250m11a', XYZ= -176.8,  -176.8, 1, QUANTITY='METHANE_VF' /
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&DEVC ID='250m11c', XYZ= -176.8,  -176.8, 1.6,QUANTITY='METHANE_VF'/
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&DEVC ID='250m12b', XYZ= -95.7,  -231.0, 1.4, QUANTITY='METHANE_VF'/
&DEVC ID='250m12c', XYZ= -95.7,  -231.0, 1.6, QUANTITY='METHANE_VF'/
&DEVC ID='250m12d', XYZ= -95.7,  -231.0, 2.4, QUANTITY='METHANE_VF'/

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&DUMP DT_DEVC=1, DT_SLCF=1, DT_ISOF=1, DT_RESTART=4000,
DT_BNDF=4000, DT_PL3D=4000,  DT_HRR=4000, NFRAMES=900/

/Ambient Conditions and Miscellaneous information
&MISC TMPA=32.87, P_INF=94131, LAPSE_RATE=-0.0097, RESTART=.FALSE.,
U0=0, V0=0, W0=0, SURF_DEFAULT='GROUND', RADIATION=.FALSE. /

/SPECIES DEFINITIONS
&SPEC ID= 'METHANE', MASS_FRACTION_0=0.0, MW= 18.12/
&SPEC ID='WATER VAPOR', MASS_FRACTION_0=0.00151/

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&MATL ID                ='SOIL'
      CONDUCTIVITY      =0.69
      SPECIFIC_HEAT     =0.88
      DENSITY           =1200. /

/SURFACE DEFINITIONS
&SURF ID                ='GROUND'
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      COLOR             ='OLIVE'
      BACKING           ='INSULATED'
      THICKNESS         =0.2 /

&SURF ID='WIND', TMP_FRONT=33.1, VEL=-2.11, VEL_T=-0.46, 0.0,
RAMP_V='WindRamp', PROFILE='ATMOSPHERIC', Z0=2., PLE=0.253,
MASS_FRACTION(2)=0.00150 /

&SURF ID='WIND2', TMP_FRONT=33.1, VEL=-0.46, VEL_T=2.11, 0.0,
RAMP_V='WindRamp', PROFILE='ATMOSPHERIC', Z0=2., PLE=0.253,
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TMP_FRONT=-161.55, RAMP_T='temp_ramp'/
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&RAMP ID='temp_ramp', T=829.3, F=1.0/
&RAMP ID='temp_ramp', T=830.3, F=0.0/
&RAMP ID='temp_ramp', T=1500, F=0.0/

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&RAMP ID='LNG_ramp1', T=830.3, F=0.0/
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/LNG VAPORIZATION LOCATION
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104 for B5

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&DEVC ID='C147', XYZ=40, -40.6, 1, QUANTITY='METHANE_VF' /
&DEVC ID='C148', XYZ=49, -28.7, 1, QUANTITY='METHANE_VF' /
&DEVC ID='C149', XYZ=55.6, -14.9, 1, QUANTITY='METHANE_VF' /
&DEVC ID='C150', XYZ=57, 0, 1, QUANTITY='METHANE_VF' /
&DEVC ID='C151', XYZ=55.6, 14.9, 1, QUANTITY='METHANE_VF' /
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&DEVC ID='C152', XYZ=49, 28.7, 1, QUANTITY='METHANE_VF' /
&DEVC ID='C153', XYZ=37, 38, 1, QUANTITY='METHANE_VF' /

&DEVC ID='C154', XYZ=40, -40.6, 3, QUANTITY='METHANE_VF' /
&DEVC ID='C155', XYZ=49, -28.7, 3, QUANTITY='METHANE_VF' /
&DEVC ID='C156', XYZ=55.6, -14.9, 3, QUANTITY='METHANE_VF' /
&DEVC ID='C157', XYZ=57, 0, 3, QUANTITY='METHANE_VF' /
&DEVC ID='C158', XYZ=55.6, 14.9, 3, QUANTITY='METHANE_VF' /
&DEVC ID='C159', XYZ=49, 28.7, 3, QUANTITY='METHANE_VF' /
&DEVC ID='C160', XYZ=37, 38, 3, QUANTITY='METHANE_VF' /

&DEVC ID='C161', XYZ=112, -84, 8, QUANTITY='METHANE_VF' /
&DEVC ID='C162', XYZ=127, -58, 8, QUANTITY='METHANE_VF' /seems to
incorrectly omit negative sign, therefore put in
&DEVC ID='C163', XYZ=137, -30, 8, QUANTITY='METHANE_VF' /
&DEVC ID='C164', XYZ=140, 0, 8, QUANTITY='METHANE_VF' /
&DEVC ID='C165', XYZ=137, 30, 8, QUANTITY='METHANE_VF' /
&DEVC ID='C166', XYZ=127, 58, 8, QUANTITY='METHANE_VF' /
&DEVC ID='C167', XYZ=112, 84, 8, QUANTITY='METHANE_VF' /

&DEVC ID='C168', XYZ=112, -84, 1, QUANTITY='METHANE_VF' /
&DEVC ID='C169', XYZ=127, -58, 1, QUANTITY='METHANE_VF' /seems to
incorrectly omit negative sign, therefore put in
&DEVC ID='C170', XYZ=137, -30, 1, QUANTITY='METHANE_VF' /
&DEVC ID='C171', XYZ=140, 0, 1, QUANTITY='METHANE_VF' /
&DEVC ID='C172', XYZ=137, 30, 1, QUANTITY='METHANE_VF' /
&DEVC ID='C173', XYZ=127, 58, 1, QUANTITY='METHANE_VF' /
&DEVC ID='C174', XYZ=112, 84, 1, QUANTITY='METHANE_VF' /

&DEVC ID='C175', XYZ=112, -84, 3, QUANTITY='METHANE_VF'/
&DEVC ID='C176', XYZ=127, 58, 3, QUANTITY='METHANE_VF' /
&DEVC ID='C177', XYZ=137, -30, 3, QUANTITY='METHANE_VF' /
&DEVC ID='C178', XYZ=140, 0, 3, QUANTITY='METHANE_VF' /
&DEVC ID='C179', XYZ=137, 30, 3, QUANTITY='METHANE_VF' /
&DEVC ID='C180', XYZ=127, 58, 3, QUANTITY='METHANE_VF' /
&DEVC ID='C181', XYZ=112, 84, 3, QUANTITY='METHANE_VF' /

&DEVC ID='C182', XYZ=360, -174, 8, QUANTITY='METHANE_VF'/
&DEVC ID='C184', XYZ=382, -118, 8, QUANTITY='METHANE_VF'/
&DEVC ID='C185', XYZ=395.5, -59.8, 8, QUANTITY='METHANE_VF'/
&DEVC ID='C186', XYZ=400, 0, 8, QUANTITY='METHANE_VF'/
&DEVC ID='C187', XYZ=395.5, 59.8, 8, QUANTITY='METHANE_VF'/
&DEVC ID='C188', XYZ=382, 118, 8, QUANTITY='METHANE_VF'/
&DEVC ID='C189', XYZ=360, 174, 8, QUANTITY='METHANE_VF'/

&DEVC ID='C191', XYZ=360, -174, 1, QUANTITY='METHANE_VF'/
&DEVC ID='C193', XYZ=382, -118, 1, QUANTITY='METHANE_VF'/
&DEVC ID='C194', XYZ=395.5, -59.8, 1, QUANTITY='METHANE_VF'/
&DEVC ID='C195', XYZ=400, 0, 1, QUANTITY='METHANE_VF'/
&DEVC ID='C196', XYZ=395.5, 59.8, 1, QUANTITY='METHANE_VF'/
&DEVC ID='C197', XYZ=382, 118, 1, QUANTITY='METHANE_VF'/
&DEVC ID='C198', XYZ=360, 174, 1, QUANTITY='METHANE_VF'/

&DEVC ID='C200', XYZ=360, -174, 3, QUANTITY='METHANE_VF'/
&DEVC ID='C202', XYZ=382, -118, 3, QUANTITY='METHANE_VF'/
&DEVC ID='C203', XYZ=395.5, -59.8, 3, QUANTITY='METHANE_VF'/
&DEVC ID='C204', XYZ=400, 0, 3, QUANTITY='METHANE_VF' /
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&DEVC ID='C207', XYZ=360, 174, 3, QUANTITY='METHANE_VF'/

&DEVC ID='C211', XYZ=784, -159, 8, QUANTITY='METHANE_VF'/
&DEVC ID='C212', XYZ=796, -79.9, 8, QUANTITY='METHANE_VF'/
&DEVC ID='C213', XYZ=800, 0, 8, QUANTITY='METHANE_VF'/
&DEVC ID='C214', XYZ=796, 79.9, 8, QUANTITY='METHANE_VF'/
&DEVC ID='C215', XYZ=784, 159, 8, QUANTITY='METHANE_VF'/

&DEVC ID='C220', XYZ=784, -159, 1, QUANTITY='METHANE_VF'/
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&DEVC ID='C222', XYZ=800, 0, 1, QUANTITY='METHANE_VF'/
&DEVC ID='C223', XYZ=796, 79.9, 1, QUANTITY='METHANE_VF'/
&DEVC ID='C224', XYZ=784, 159, 1, QUANTITY='METHANE_VF'/

&DEVC ID='C229', XYZ=784, -159, 3, QUANTITY='METHANE_VF'/
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&DEVC ID='C241', XYZ=127, 58, 8, QUANTITY='METHANE_VF' /

&DEVC ID='C242', XYZ=37, 38, 1, QUANTITY='METHANE_VF' /
&DEVC ID='C243', XYZ=37, 38, 3, QUANTITY='METHANE_VF' /
&DEVC ID='C244', XYZ=37, 38, 8, QUANTITY='METHANE_VF' /

&DEVC ID='C245', XYZ=40, -40.6, 1, QUANTITY='METHANE_VF' /
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&DEVC ID='C248', XYZ=395.5, 59.8, 1, QUANTITY='METHANE_VF' /
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&DEVC ID='C250', XYZ=395.5, 59.8, 8, QUANTITY='METHANE_VF' /

&DEVC ID='C251', XYZ=112, -84, 1, QUANTITY='METHANE_VF'/
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&DEVC ID='C253', XYZ=112, -84, 8, QUANTITY='METHANE_VF'/
&DEVC ID='C254', XYZ=112, 84, 1, QUANTITY='METHANE_VF' /
&DEVC ID='C255', XYZ=112, 84, 3, QUANTITY='METHANE_VF' /
&DEVC ID='C256', XYZ=112, 84, 8, QUANTITY='METHANE_VF' /

&DEVC ID='C257', XYZ=360, 174, 1, QUANTITY='METHANE_VF'/
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&DEVC ID='C259', XYZ=360, 174, 8, QUANTITY='METHANE_VF'/

&DEVC ID='C260', XYZ=382, 118, 1, QUANTITY='METHANE_VF'/
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&DEVC ID='C262', XYZ=382, 118, 8, QUANTITY='METHANE_VF'/

&DEVC ID='C263', XYZ=395.5, -59.8, 1, QUANTITY='METHANE_VF'/
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&DEVC ID='C265', XYZ=395.5, -59.8, 8, QUANTITY='METHANE_VF'/
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&DEVC ID='C270', XYZ=360, -174, 3, QUANTITY='METHANE_VF'/
&DEVC ID='C271', XYZ=360, -174, 8, QUANTITY='METHANE_VF'/

&DEVC ID='C272', XYZ=784, 159, 1, QUANTITY='METHANE_VF'/
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&DEVC ID='C275', XYZ=796, 79.9, 1, QUANTITY='METHANE_VF'/
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&DEVC ID='S290', XYZ=-350, 60, 2, QUANTITY='VELOCITY' /
&DEVC ID='S293', XYZ=-350, -60, 2, QUANTITY='VELOCITY' /
&DEVC ID='S296', XYZ=-150, 0, 2, QUANTITY='VELOCITY' /
&DEVC ID='S299', XYZ=0, 60, 2, QUANTITY='VELOCITY' /
&DEVC ID='S302', XYZ=0, -60, 2, QUANTITY='VELOCITY' /
&DEVC ID='S305', XYZ=104, 120, 2, QUANTITY='VELOCITY' /
&DEVC ID='S308', XYZ=104, 0, 2, QUANTITY='VELOCITY' /
&DEVC ID='S311', XYZ=104, -120, 2, QUANTITY='VELOCITY' /
&DEVC ID='S314', XYZ=275, 130, 2, QUANTITY='VELOCITY' /
&DEVC ID='S317', XYZ=275, 0, 2, QUANTITY='VELOCITY' /
&DEVC ID='S320', XYZ=275, -130, 2, QUANTITY='VELOCITY' /
&DEVC ID='S323', XYZ=480, 170, 2, QUANTITY='VELOCITY' /
&DEVC ID='S326', XYZ=600, 0, 2, QUANTITY='VELOCITY' /
&DEVC ID='S329', XYZ=480, -170, 2, QUANTITY='VELOCITY' /
&DEVC ID='S332', XYZ=670, 170, 2, QUANTITY='VELOCITY' /
&DEVC ID='S335', XYZ=670, -170, 2, QUANTITY='VELOCITY' /
&DEVC ID='S338', XYZ=882, 180, 2, QUANTITY='VELOCITY' /
&DEVC ID='S341', XYZ=882, -180, 2, QUANTITY='VELOCITY' /labeled as
same coordinates as S338 in REDIPHEM, believe is mistake so put in
negative.


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&DEVC ID='S287U', XYZ=-600, 0, 2, QUANTITY='U-VELOCITY' /
&DEVC ID='S290U', XYZ=-350, 60, 2, QUANTITY='U-VELOCITY' /
&DEVC ID='S293U', XYZ=-350, -60, 2, QUANTITY='U-VELOCITY' /
&DEVC ID='S296U', XYZ=-150, 0, 2, QUANTITY='U-VELOCITY' /
&DEVC ID='S299U', XYZ=0, 60, 2, QUANTITY='U-VELOCITY' /
&DEVC ID='S302U', XYZ=0, -60, 2, QUANTITY='U-VELOCITY' /
&DEVC ID='S305U', XYZ=104, 120, 2, QUANTITY='U-VELOCITY' /
&DEVC ID='S308U', XYZ=104, 0, 2, QUANTITY='U-VELOCITY' /
&DEVC ID='S311U', XYZ=104, -120, 2, QUANTITY='U-VELOCITY' /
&DEVC ID='S314U', XYZ=275, 130, 2, QUANTITY='U-VELOCITY' /
&DEVC ID='S317U', XYZ=275, 0, 2, QUANTITY='U-VELOCITY' /
&DEVC ID='S320U', XYZ=275, -130, 2, QUANTITY='U-VELOCITY' /
&DEVC ID='S323U', XYZ=480, 170, 2, QUANTITY='U-VELOCITY' /
&DEVC ID='S326U', XYZ=600, 0, 2, QUANTITY='U-VELOCITY' /
&DEVC ID='S329U', XYZ=480, -170, 2, QUANTITY='U-VELOCITY' /
&DEVC ID='S332U', XYZ=670, 170, 2, QUANTITY='U-VELOCITY' /
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&DEVC ID='S338U', XYZ=882, 180, 2, QUANTITY='U-VELOCITY' /
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&DEVC ID='S284V', XYZ=-800, 0, 2, QUANTITY='V-VELOCITY' /
&DEVC ID='S287V', XYZ=-600, 0, 2, QUANTITY='V-VELOCITY' /
&DEVC ID='S290V', XYZ=-350, 60, 2, QUANTITY='V-VELOCITY' /
&DEVC ID='S293V', XYZ=-350, -60, 2, QUANTITY='V-VELOCITY' /
&DEVC ID='S296V', XYZ=-150, 0, 2, QUANTITY='V-VELOCITY' /
&DEVC ID='S299V', XYZ=0, 60, 2, QUANTITY='V-VELOCITY' /
&DEVC ID='S302V', XYZ=0, -60, 2, QUANTITY='V-VELOCITY' /
&DEVC ID='S305V', XYZ=104, 120, 2, QUANTITY='V-VELOCITY' /
&DEVC ID='S308V', XYZ=104, 0, 2, QUANTITY='V-VELOCITY' /
&DEVC ID='S311V', XYZ=104, -120, 2, QUANTITY='V-VELOCITY' /
&DEVC ID='S314V', XYZ=275, 130, 2, QUANTITY='V-VELOCITY' /
&DEVC ID='S317V', XYZ=275, 0, 2, QUANTITY='V-VELOCITY' /
&DEVC ID='S320V', XYZ=275, -130, 2, QUANTITY='V-VELOCITY' /
&DEVC ID='S323V', XYZ=480, 170, 2, QUANTITY='V-VELOCITY' /
&DEVC ID='S326V', XYZ=600, 0, 2, QUANTITY='V-VELOCITY' /
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&DEVC ID='S332V', XYZ=670, 170, 2, QUANTITY='V-VELOCITY' /
&DEVC ID='S335V', XYZ=670, -170, 2, QUANTITY='V-VELOCITY' /
&DEVC ID='S338V', XYZ=882, 180, 2, QUANTITY='V-VELOCITY' /
&DEVC ID='S341V', XYZ=882, -180, 2, QUANTITY='V-VELOCITY' /

&DEVC ID='S284W', XYZ=-800, 0, 2, QUANTITY='W-VELOCITY' /
&DEVC ID='S287W', XYZ=-600, 0, 2, QUANTITY='W-VELOCITY' /
&DEVC ID='S290W', XYZ=-350, 60, 2, QUANTITY='W-VELOCITY' /
&DEVC ID='S293W', XYZ=-350, -60, 2, QUANTITY='W-VELOCITY' /
&DEVC ID='S296W', XYZ=-150, 0, 2, QUANTITY='W-VELOCITY' /
&DEVC ID='S299W', XYZ=0, 60, 2, QUANTITY='W-VELOCITY' /
&DEVC ID='S302W', XYZ=0, -60, 2, QUANTITY='W-VELOCITY' /
&DEVC ID='S305W', XYZ=104, 120, 2, QUANTITY='W-VELOCITY' /
&DEVC ID='S308W', XYZ=104, 0, 2, QUANTITY='W-VELOCITY' /
&DEVC ID='S311W', XYZ=104, -120, 2, QUANTITY='W-VELOCITY' /
&DEVC ID='S314W', XYZ=275, 130, 2, QUANTITY='W-VELOCITY' /
&DEVC ID='S317W', XYZ=275, 0, 2, QUANTITY='W-VELOCITY' /
&DEVC ID='S320W', XYZ=275, -130, 2, QUANTITY='W-VELOCITY' /
&DEVC ID='S323W', XYZ=480, 170, 2, QUANTITY='W-VELOCITY' /
&DEVC ID='S326W', XYZ=600, 0, 2, QUANTITY='W-VELOCITY' /
&DEVC ID='S329W', XYZ=480, -170, 2, QUANTITY='W-VELOCITY' /
&DEVC ID='S332W', XYZ=670, 170, 2, QUANTITY='W-VELOCITY' /
&DEVC ID='S335W', XYZ=670, -170, 2, QUANTITY='W-VELOCITY' /
&DEVC ID='S338W', XYZ=882, 180, 2, QUANTITY='W-VELOCITY' /
&DEVC ID='S341W', XYZ=882, -180, 2, QUANTITY='W-VELOCITY' /

&PROP ID='type-K', QUANTITY='THERMOCOUPLE', BEAD_DIAMETER=0.000254,
BEAD_EMISSIVITY=0.85/10 mil thermocouple according to REDIPHEM,
unknown emissivity

/test to see if there is a difference using thermocouple device.
&DEVC ID='TC1b', XYZ=49, 28.7, 1, PROP_ID='type-K' /
&DEVC ID='TC21b', XYZ=49, 28.7, 1, PROP_ID='type-K' /
&DEVC ID='TC101b', XYZ=49, 28.7, 1, PROP_ID='type-K' /
&DEVC ID='TC113b', XYZ=49, 28.7, 1, PROP_ID='type-K' /
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&HEAD CHID='Coyote6a', TITLE='Coyote 6' /

&MESH ID='mesh1', IJK=200, 300, 10, XB=-950,-550,-300, 300, 0, 10 /
&MESH ID='mesh2', IJK=200, 300, 10, XB=-950,-550,-300, 300, 10, 20 /
&MESH ID='mesh3', IJK=200, 300, 10, XB=-550,-150,-300, 300, 0, 10 /
&MESH ID='mesh4', IJK=200, 300, 10, XB=-550,-150,-300, 300, 10, 20 /
&MESH ID='mesh5', IJK=200, 300, 10, XB=-150, 250,-300, 300, 0, 10 /
&MESH ID='mesh6', IJK=200, 300, 10, XB=-150, 250,-300, 300, 10, 20 /
&MESH ID='mesh7', IJK=200, 300, 10, XB=250, 650,-300, 300, 0, 10 /
&MESH ID='mesh8', IJK=200, 300, 10, XB=250, 650,-300, 300, 10, 20 /
&MESH ID='mesh9', IJK=200, 300, 10, XB=650, 1050,-300, 300, 0, 10 /
&MESH ID='mesh10', IJK=200, 300, 10, XB=650, 1050,-300, 300, 10, 20/
&MESH ID='mesh11', IJK=200, 300, 10, XB=1050, 1450,-300, 300, 0, 10/
&MESH ID='mesh12', IJK=200, 300, 10, XB=1050, 1450,-300, 300, 10,20/


&TIME TWFIN=800.00, DT=0.5, SYNCHRONIZE=.TRUE. /
&DUMP DT_RESTART=399, DT_DEVC=1, DT_SLCF=1, DT_ISOF=1, DT_BNDF=1000,
DT_PL3D=2000, DT_HRR=2000, NFRAMES=800/

/Ambient Conditions and Miscellaneous information
&MISC RESTART=.TRUE., TMPA=24.11, P_INF=93000, LAPSE_RATE=0.00,
U0=0, V0=0, W0=0, HUMIDITY=22.8, SURF_DEFAULT='GROUND',
RADIATION=.FALSE. /

/SPECIES DEFINITIONS
&SPEC ID= 'METHANE', MASS_FRACTION_0=0.0, MW= 20.19/
&SPEC ID='WATER VAPOR', MASS_FRACTION_0=0.00458/

/MATERIAL DEFINITIONS
&MATL ID                ='SOIL'
      CONDUCTIVITY      =0.69
      SPECIFIC_HEAT     =0.88
      DENSITY           =1200. /

/SURFACE DEFINITIONS
&SURF ID                ='GROUND'
      MATL_ID           ='SOIL'
      COLOR             ='OLIVE'
      BACKING           ='INSULATED'
      THICKNESS         =0.2 /


/WEATHER
&SURF ID='WIND', TMP_FRONT=24.11, RAMP_T='TempRamp', VEL=-6.53,
VEL_T=0.85, 0.0, RAMP_V='WindRamp', PROFILE='ATMOSPHERIC', Z0=2.,
PLE=0.142, MASS_FRACTION(2)=0.00458 /

&SURF ID='WIND2', TMP_FRONT=24.11, RAMP_T='TempRamp', VEL=-0.85,
VEL_T=6.53, 0.0, RAMP_V='WindRamp', PROFILE='ATMOSPHERIC', Z0=2.,
PLE=0.142, MASS_FRACTION(2)=0.00458 /

&RAMP ID='TempRamp', T=0.0, F=1.0/
&RAMP ID='TempRamp', T=800, F=1.0/
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&RAMP ID='WindRamp', T=409, F=0.60/
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&RAMP ID='WindRamp', T=589, F=0.79/
&RAMP ID='WindRamp', T=590, F=0.84/
&RAMP ID='WindRamp', T=599, F=0.84/
&RAMP ID='WindRamp', T=600, F=0.87/
&RAMP ID='WindRamp', T=609, F=0.87/
&RAMP ID='WindRamp', T=610, F=0.83/
&RAMP ID='WindRamp', T=619, F=0.83/
&RAMP ID='WindRamp', T=620, F=0.70/
&RAMP ID='WindRamp', T=629, F=0.70/
&RAMP ID='WindRamp', T=630, F=0.75/
&RAMP ID='WindRamp', T=639, F=0.75/
&RAMP ID='WindRamp', T=640, F=0.71/
&RAMP ID='WindRamp', T=649, F=0.71/
&RAMP ID='WindRamp', T=650, F=0.73/
&RAMP ID='WindRamp', T=659, F=0.73/
&RAMP ID='WindRamp', T=660, F=0.87/
&RAMP ID='WindRamp', T=669, F=0.87/
&RAMP ID='WindRamp', T=670, F=0.83/
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&RAMP ID='WindRamp', T=679, F=0.83/
&RAMP ID='WindRamp', T=680, F=0.77/
&RAMP ID='WindRamp', T=689, F=0.77/
&RAMP ID='WindRamp', T=690, F=0.75/
&RAMP ID='WindRamp', T=699, F=0.75/
&RAMP ID='WindRamp', T=700, F=0.68/
&RAMP ID='WindRamp', T=709, F=0.68/
&RAMP ID='WindRamp', T=710, F=0.69/
&RAMP ID='WindRamp', T=719, F=0.69/
&RAMP ID='WindRamp', T=720, F=0.70/
&RAMP ID='WindRamp', T=729, F=0.70/
&RAMP ID='WindRamp', T=730, F=0.72/
&RAMP ID='WindRamp', T=739, F=0.72/
&RAMP ID='WindRamp', T=740, F=0.71/
&RAMP ID='WindRamp', T=749, F=0.71/
&RAMP ID='WindRamp', T=750, F=0.69/
&RAMP ID='WindRamp', T=759, F=0.69/
&RAMP ID='WindRamp', T=760, F=0.72/
&RAMP ID='WindRamp', T=769, F=0.72/
&RAMP ID='WindRamp', T=770, F=0.59/
&RAMP ID='WindRamp', T=779, F=0.59/
&RAMP ID='WindRamp', T=780, F=0.48/
&RAMP ID='WindRamp', T=789, F=0.48/
&RAMP ID='WindRamp', T=790, F=0.59/
&RAMP ID='WindRamp', T=799, F=0.59/
&RAMP ID='WindRamp', T=800, F=0.59/

/OPEN SIDES, TOP
&VENT MB='XMIN', SURF_ID='WIND'   /
&VENT MB='XMAX', SURF_ID='OPEN'   /
&VENT MB='YMIN', SURF_ID='WIND2'  /
&VENT MB='YMAX', SURF_ID='OPEN'   /
&VENT MB='ZMAX', SURF_ID='MIRROR' /

/LNG Vaporization Source
&SURF ID= 'LNG_vapor1', MASS_FLUX(1)= 0.167, RAMP_MF(1)='LNG_ramp1',
TMP_BACK=-161.55, TMP_INNER=-161.55, TMP_FRONT=-161.55,
RAMP_T='temp_ramp'/
&SURF ID= 'LNG_vapor2', MASS_FLUX(1)= 0.167, RAMP_MF(1)='LNG_ramp2',
TMP_BACK=-161.55, TMP_INNER=-161.55, TMP_FRONT=-161.55,
RAMP_T='temp_ramp'/
&SURF ID= 'LNG_vapor3', MASS_FLUX(1)= 0.167, RAMP_MF(1)='LNG_ramp3',
TMP_BACK=-161.55, TMP_INNER=-161.55, TMP_FRONT=-161.55,
RAMP_T='temp_ramp'/
&SURF ID= 'LNG_vapor4', MASS_FLUX(1)= 0.167, RAMP_MF(1)='LNG_ramp4',
TMP_BACK=-161.55, TMP_INNER=-161.55, TMP_FRONT=-161.55,
RAMP_T='temp_ramp'/
&SURF ID= 'LNG_vapor5', MASS_FLUX(1)= 0.167, RAMP_MF(1)='LNG_ramp5',
TMP_BACK=-161.55, TMP_INNER=-161.55, TMP_FRONT=-161.55,
RAMP_T='temp_ramp'/
&SURF ID= 'LNG_vapor6', MASS_FLUX(1)= 0.167, RAMP_MF(1)='LNG_ramp6',
TMP_BACK=-161.55, TMP_INNER=-161.55, TMP_FRONT=-161.55,
RAMP_T='temp_ramp'/
&SURF ID= 'LNG_vapor7', MASS_FLUX(1)= 0.167, RAMP_MF(1)='LNG_ramp7',
TMP_BACK=-161.55, TMP_INNER=-161.55, TMP_FRONT=-161.55,
RAMP_T='temp_ramp'/
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&SURF ID= 'LNG_vapor8', MASS_FLUX(1)= 0.167, RAMP_MF(1)='LNG_ramp8',
TMP_BACK=-161.55, TMP_INNER=-161.55, TMP_FRONT=-161.55,
RAMP_T='temp_ramp'/
&SURF ID= 'LNG_vapor9', MASS_FLUX(1)= 0.167, RAMP_MF(1)='LNG_ramp9',
TMP_BACK=-161.55, TMP_INNER=-161.55, TMP_FRONT=-161.55,
RAMP_T='temp_ramp'/
&SURF ID= 'LNG_vapor10', MASS_FLUX(1)= 0.167,
RAMP_MF(1)='LNG_ramp10', TMP_BACK=-161.55, TMP_INNER=-161.55,
TMP_FRONT=-161.55, RAMP_T='temp_ramp'/
&SURF ID= 'LNG_vapor11', MASS_FLUX(1)= 0.167,
RAMP_MF(1)='LNG_ramp11', TMP_BACK=-161.55, TMP_INNER=-161.55,
TMP_FRONT=-161.55, RAMP_T='temp_ramp'/

/Ramp function to describe temperature of vaporization area
&RAMP ID='temp_ramp', T=0.0, F=0.0/
&RAMP ID='temp_ramp', T=399, F=0.0/
&RAMP ID='temp_ramp', T=400, F=1.0/
&RAMP ID='temp_ramp', T=504.6, F=1.0/
&RAMP ID='temp_ramp', T=505.6, F=0.0/
&RAMP ID='temp_ramp', T=900, F=0.0/

/Ramp function to describe mass flux rate (vaporization rate)
&RAMP ID='LNG_ramp1', T=0.0, F=0.0/
&RAMP ID='LNG_ramp1', T=399, F=0.0/
&RAMP ID='LNG_ramp1', T=400, F=1.0/
&RAMP ID='LNG_ramp1', T=504.6, F=1.0/
&RAMP ID='LNG_ramp1', T=505.6, F=0.0/
&RAMP ID='LNG_ramp1', T=900, F=0.0/

&RAMP ID='LNG_ramp2', T=0.0, F=0.0/
&RAMP ID='LNG_ramp2', T=401.826, F=0.0/
&RAMP ID='LNG_ramp2', T=402.826, F=1.0/
&RAMP ID='LNG_ramp2', T=504.6, F=1.0/
&RAMP ID='LNG_ramp2', T=505.6, F=0.0/
&RAMP ID='LNG_ramp2', T=900, F=0.0/

&RAMP ID='LNG_ramp3', T=0.0, F=0.0/
&RAMP ID='LNG_ramp3', T=404.653, F=0.0/
&RAMP ID='LNG_ramp3', T=405.653, F=1.0/
&RAMP ID='LNG_ramp3', T=504.6, F=1.0/
&RAMP ID='LNG_ramp3', T=505.6, F=0.0/
&RAMP ID='LNG_ramp3', T=900, F=0.0/

&RAMP ID='LNG_ramp4', T=0.0, F=0.0/
&RAMP ID='LNG_ramp4', T=407.479, F=0.0/
&RAMP ID='LNG_ramp4', T=408.479, F=1.0/
&RAMP ID='LNG_ramp4', T=504.6, F=1.0/
&RAMP ID='LNG_ramp4', T=505.6, F=0.0/
&RAMP ID='LNG_ramp4', T=900, F=0.0/

&RAMP ID='LNG_ramp5', T=0.0, F=0.0/
&RAMP ID='LNG_ramp5', T=413.13, F=0.0/
&RAMP ID='LNG_ramp5', T=414.13, F=1.0/
&RAMP ID='LNG_ramp5', T=504.6, F=1.0/
&RAMP ID='LNG_ramp5', T=505.6, F=0.0/
&RAMP ID='LNG_ramp5', T=900, F=0.0/
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&RAMP ID='LNG_ramp6', T=0.0, F=0.0/
&RAMP ID='LNG_ramp6', T=415.96, F=0.0/
&RAMP ID='LNG_ramp6', T=416.96, F=1.0/
&RAMP ID='LNG_ramp6', T=504.6, F=1.0/
&RAMP ID='LNG_ramp6', T=505.6, F=0.0/
&RAMP ID='LNG_ramp6', T=900, F=0.0/

&RAMP ID='LNG_ramp7', T=0.0, F=0.0/
&RAMP ID='LNG_ramp7', T=421.61, F=0.0/
&RAMP ID='LNG_ramp7', T=422.61, F=1.0/
&RAMP ID='LNG_ramp7', T=504.6, F=1.0/
&RAMP ID='LNG_ramp7', T=505.6, F=0.0/
&RAMP ID='LNG_ramp7', T=900, F=0.0/

&RAMP ID='LNG_ramp8', T=0.0, F=0.0/
&RAMP ID='LNG_ramp8', T=424.44, F=0.0/
&RAMP ID='LNG_ramp8', T=425.44, F=1.0/
&RAMP ID='LNG_ramp8', T=504.6, F=1.0/
&RAMP ID='LNG_ramp8', T=505.6, F=0.0/
&RAMP ID='LNG_ramp8', T=900, F=0.0/

&RAMP ID='LNG_ramp9', T=0.0, F=0.0/
&RAMP ID='LNG_ramp9', T=432.92, F=0.0/
&RAMP ID='LNG_ramp9', T=433.92, F=1.0/
&RAMP ID='LNG_ramp9', T=504.6, F=1.0/
&RAMP ID='LNG_ramp9', T=505.6, F=0.0/
&RAMP ID='LNG_ramp9', T=900, F=0.0/

&RAMP ID='LNG_ramp10', T=0.0, F=0.0/
&RAMP ID='LNG_ramp10', T=438.57, F=0.0/
&RAMP ID='LNG_ramp10', T=439.57, F=1.0/
&RAMP ID='LNG_ramp10', T=504.6, F=1.0/
&RAMP ID='LNG_ramp10', T=505.6, F=0.0/
&RAMP ID='LNG_ramp10', T=900, F=0.0/

&RAMP ID='LNG_ramp11', T=0.0, F=0.0/
&RAMP ID='LNG_ramp11', T=492.27, F=0.0/
&RAMP ID='LNG_ramp11', T=493.27, F=1.0/
&RAMP ID='LNG_ramp11', T=504.6, F=1.0/
&RAMP ID='LNG_ramp11', T=505.6, F=0.0/
&RAMP ID='LNG_ramp11', T=900, F=0.0/


/LNG VAPORIZATION LOCATION
&VENT XB= -2.17, 2.17, -2.17, 2.17, 0, 0, SURF_ID='LNG_vapor1' /
&VENT XB= -2.66, 2.66, -1.54, 1.54, 0, 0, SURF_ID='LNG_vapor1' /
&VENT XB= -2.84, 2.84, -1.18, 1.18, 0, 0, SURF_ID='LNG_vapor1' /
&VENT XB= -2.97, 2.97, -0.80, 0.80, 0, 0, SURF_ID='LNG_vapor1' /
&VENT XB= -1.54, 1.54, -2.66, 2.66, 0, 0, SURF_ID='LNG_vapor1' /
&VENT XB= -1.18, 1.18, -2.84, 2.84, 0, 0, SURF_ID='LNG_vapor1' /
&VENT XB= -0.80, 0.80, -2.97, 2.97, 0, 0, SURF_ID='LNG_vapor1' /

&VENT XB= -3.16, 3.16, -3.16, 3.16, 0, 0, SURF_ID='LNG_vapor2' /
&VENT XB= -3.87, 3.87, -2.24, 2.24, 0, 0, SURF_ID='LNG_vapor2' /
&VENT XB= -4.13, 4.13, -1.71, 1.71, 0, 0, SURF_ID='LNG_vapor2' /
&VENT XB= -4.32, 4.32, -1.16, 1.16, 0, 0, SURF_ID='LNG_vapor2' /
&VENT XB= -2.24, 2.24, -3.87, 3.87, 0, 0, SURF_ID='LNG_vapor2' /
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&VENT XB= -1.71, 1.71, -4.13, 4.13, 0, 0, SURF_ID='LNG_vapor2' /
&VENT XB= -1.16, 1.16, -4.32, 4.32, 0, 0, SURF_ID='LNG_vapor2' /

&VENT XB= -4.03, 4.03, -4.03, 4.03, 0, 0, SURF_ID='LNG_vapor3' /
&VENT XB= -4.94, 4.94, -2.85, 2.85, 0, 0, SURF_ID='LNG_vapor3' /
&VENT XB= -5.27, 5.27, -2.18, 2.18, 0, 0, SURF_ID='LNG_vapor3' /
&VENT XB= -5.51, 5.51, -1.48, 1.48, 0, 0, SURF_ID='LNG_vapor3' /
&VENT XB= -2.85, 2.85, -4.94, 4.94, 0, 0, SURF_ID='LNG_vapor3' /
&VENT XB= -2.18, 2.18, -5.27, 5.27, 0, 0, SURF_ID='LNG_vapor3' /
&VENT XB= -1.48, 1.48, -5.51, 5.51, 0, 0, SURF_ID='LNG_vapor3' /

&VENT XB= -5.54, 5.54, -5.54, 5.54, 0, 0, SURF_ID='LNG_vapor4' /
&VENT XB= -6.78, 6.78, -3.92, 3.92, 0, 0, SURF_ID='LNG_vapor4' /
&VENT XB= -7.24, 7.24, -3.00, 3.00, 0, 0, SURF_ID='LNG_vapor4' /
&VENT XB= -7.57, 7.57, -2.03, 2.03, 0, 0, SURF_ID='LNG_vapor4' /
&VENT XB= -3.92, 3.92, -6.78, 6.78, 0, 0, SURF_ID='LNG_vapor4' /
&VENT XB= -3.00, 3.00, -7.24, 7.24, 0, 0, SURF_ID='LNG_vapor4' /
&VENT XB= -2.03, 2.03, -7.57, 7.57, 0, 0, SURF_ID='LNG_vapor4' /

&VENT XB= -6.21, 6.21, -6.21, 6.21, 0, 0, SURF_ID='LNG_vapor5' /
&VENT XB= -7.60, 7.60, -4.39, 4.39, 0, 0, SURF_ID='LNG_vapor5' /
&VENT XB= -8.11, 8.11, -3.36, 3.36, 0, 0, SURF_ID='LNG_vapor5' /
&VENT XB= -8.48, 8.48, -2.27, 2.27, 0, 0, SURF_ID='LNG_vapor5' /
&VENT XB= -4.39, 4.39, -7.60, 7.60, 0, 0, SURF_ID='LNG_vapor5' /
&VENT XB= -3.36, 3.36, -8.11, 8.11, 0, 0, SURF_ID='LNG_vapor5' /
&VENT XB= -2.27, 2.27, -8.48, 8.48, 0, 0, SURF_ID='LNG_vapor5' /

&VENT XB= -7.40, 7.40, -7.40, 7.40, 0, 0, SURF_ID='LNG_vapor6' /
&VENT XB= -9.07, 9.07, -5.24, 5.24, 0, 0, SURF_ID='LNG_vapor6' /
&VENT XB= -9.67, 9.67, -4.01, 4.01, 0, 0, SURF_ID='LNG_vapor6' /
&VENT XB= -10.11, 10.11, -2.71, 2.71, 0, 0, SURF_ID='LNG_vapor6' /
&VENT XB= -5.24, 5.24, -9.07, 9.07, 0, 0, SURF_ID='LNG_vapor6' /
&VENT XB= -4.01, 4.01, -9.67, 9.67, 0, 0, SURF_ID='LNG_vapor6' /
&VENT XB= -2.71, 2.71, -10.11, 10.11, 0, 0, SURF_ID='LNG_vapor6' /

&VENT XB= -7.93, 7.93, -7.93, 7.93, 0, 0, SURF_ID='LNG_vapor7' /
&VENT XB= -9.72, 9.72, -5.61, 5.61, 0, 0, SURF_ID='LNG_vapor7' /
&VENT XB= -10.37, 10.37, -4.29, 4.29, 0, 0, SURF_ID='LNG_vapor7' /
&VENT XB= -10.84, 10.84, -2.90, 2.90, 0, 0, SURF_ID='LNG_vapor7' /
&VENT XB= -5.61, 5.61, -9.72, 9.72, 0, 0, SURF_ID='LNG_vapor7' /
&VENT XB= -4.29, 4.29, -10.37, 10.37, 0, 0, SURF_ID='LNG_vapor7' /
&VENT XB= -2.90, 2.90, -10.84, 10.84, 0, 0, SURF_ID='LNG_vapor7' /

&VENT XB= -9.32, 9.32, -9.32, 9.32, 0, 0, SURF_ID='LNG_vapor8' /
&VENT XB= -11.41, 11.41, -6.59, 6.59, 0, 0, SURF_ID='LNG_vapor8' /
&VENT XB= -12.18, 12.18, -5.04, 5.04, 0, 0, SURF_ID='LNG_vapor8' /
&VENT XB= -12.73, 12.73, -3.41, 3.41, 0, 0, SURF_ID='LNG_vapor8' /
&VENT XB= -6.59, 6.59, -11.41, 11.41, 0, 0, SURF_ID='LNG_vapor8' /
&VENT XB= -5.04, 5.04, -12.18, 12.18, 0, 0, SURF_ID='LNG_vapor8' /
&VENT XB= -3.41, 3.41, -12.73, 12.73, 0, 0, SURF_ID='LNG_vapor8' /

&VENT XB= -10.06, 10.06, -10.06, 10.06, 0, 0, SURF_ID='LNG_vapor9' /
&VENT XB= -12.32, 12.32, -7.12, 7.12, 0, 0, SURF_ID='LNG_vapor9' /
&VENT XB= -13.15, 13.15, -5.45, 5.45, 0, 0, SURF_ID='LNG_vapor9' /
&VENT XB= -13.75, 13.75, -3.68, 3.68, 0, 0, SURF_ID='LNG_vapor9' /
&VENT XB= -7.12, 7.12, -12.32, 12.32, 0, 0, SURF_ID='LNG_vapor9' /
&VENT XB= -5.45, 5.45, -13.15, 13.15, 0, 0, SURF_ID='LNG_vapor9' /
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&VENT XB= -3.68, 3.68, -13.75, 13.75, 0, 0, SURF_ID='LNG_vapor9' /

&VENT XB= -11.36, 11.36, -11.36, 11.36, 0, 0, SURF_ID='LNG_vapor10'
/
&VENT XB= -13.91, 13.91, -8.03, 8.03, 0, 0, SURF_ID='LNG_vapor10' /
&VENT XB= -14.84, 14.84, -6.15, 6.15, 0, 0, SURF_ID='LNG_vapor10' /
&VENT XB= -15.51, 15.51, -4.16, 4.16, 0, 0, SURF_ID='LNG_vapor10' /
&VENT XB= -8.03, 8.03, -13.91, 13.91, 0, 0, SURF_ID='LNG_vapor10' /
&VENT XB= -6.15, 6.15, -14.84, 14.84, 0, 0, SURF_ID='LNG_vapor10' /
&VENT XB= -4.16, 4.16, -15.51, 15.51, 0, 0, SURF_ID='LNG_vapor10' /


&VENT XB= -11.77, 11.77,-11.77,11.77, 0, 0, SURF_ID='LNG_vapor11' /
&VENT XB= -14.41, 14.41, -8.32, 8.32, 0, 0, SURF_ID='LNG_vapor11' /
&VENT XB= -15.37, 15.37, -6.37, 6.37, 0, 0, SURF_ID='LNG_vapor11' /
&VENT XB= -16.07, 16.07, -4.31, 4.31, 0, 0, SURF_ID='LNG_vapor11' /
&VENT XB= -8.32, 8.32, -14.41, 14.41, 0, 0, SURF_ID='LNG_vapor11' /
&VENT XB= -6.37, 6.37, -15.37, 15.37, 0, 0, SURF_ID='LNG_vapor11' /
&VENT XB= -4.31, 4.31, -16.07, 16.07, 0, 0, SURF_ID='LNG_vapor11' /

/Isosurfaces
&ISOF QUANTITY='METHANE_VF', VALUE(1)=0.127, VALUE(2)=0.085,
VALUE(3)=0.042, VALUE(4)=0.033, VALUE(5)=0.014, VALUE(6)=0.0845,
VALUE(7)=0.051, VALUE(8)=0.022, VALUE(9)=0.020, VALUE(10)=0.012/

/Slice Files
&SLCF PBY=0, QUANTITY='TEMPERATURE'  /
&SLCF PBY=0, QUANTITY='RELATIVE HUMIDITY'  /

&SLCF PBY=0, QUANTITY='VELOCITY', VECTOR=.TRUE./
&SLCF PBY=800, QUANTITY='VELOCITY', VECTOR=.TRUE./
&SLCF PBZ=2, QUANTITY='VELOCITY' , VECTOR=.TRUE. /

&SLCF PBX= 53, QUANTITY='METHANE_VF' /
&SLCF PBX=140, QUANTITY='METHANE_VF' /
&SLCF PBX=400, QUANTITY='METHANE_VF' /
&SLCF PBX=800, QUANTITY='METHANE_VF' /
&SLCF PBZ=  0, QUANTITY='METHANE_VF' /
&SLCF PBZ=  1, QUANTITY='METHANE_VF' /
&SLCF PBZ=  2, QUANTITY='METHANE_VF' /

/Instruments

&DEVC ID='TC1', XYZ=-62, 0, 0.50, QUANTITY='TEMPERATURE' /
&DEVC ID='TC2', XYZ=-62, 0, 1, QUANTITY='TEMPERATURE' /
&DEVC ID='TC3', XYZ=-62, 0, 2, QUANTITY='TEMPERATURE' /
&DEVC ID='TC4', XYZ=-62, 0, 4, QUANTITY='TEMPERATURE' /
&DEVC ID='TC5', XYZ=0, -1, -0.20, QUANTITY='TEMPERATURE' /

&DEVC ID='TC7', XYZ=186.5, -72, 1, QUANTITY='TEMPERATURE' /
&DEVC ID='TC8', XYZ=186.5, -72, 3, QUANTITY='TEMPERATURE' /
&DEVC ID='TC9', XYZ=186.5, -72, 5, QUANTITY='TEMPERATURE' /
&DEVC ID='TC10', XYZ=186.5, -72, 8, QUANTITY='TEMPERATURE' /
&DEVC ID='TC11', XYZ=186.5, 72, 1, QUANTITY='TEMPERATURE' /
&DEVC ID='TC12', XYZ=186.5, 72, 3, QUANTITY='TEMPERATURE' /
&DEVC ID='TC13', XYZ=186.5, 72, 5, QUANTITY='TEMPERATURE' /
&DEVC ID='TC14', XYZ=186.5, 72, 8, QUANTITY='TEMPERATURE' /
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&DEVC ID='TC15', XYZ=196.6, 36.9, 1, QUANTITY='TEMPERATURE' /
&DEVC ID='TC16', XYZ=196.6, 36.9, 3, QUANTITY='TEMPERATURE' /
&DEVC ID='TC17', XYZ=196.6, 36.9, 0, QUANTITY='TEMPERATURE' /
&DEVC ID='TC18', XYZ=196.6, 36.9, 8, QUANTITY='TEMPERATURE' /
&DEVC ID='TC19', XYZ=196.6, 36.9, 0.25, QUANTITY='TEMPERATURE' /
&DEVC ID='TC20', XYZ=196.6, 36.9, 0.5, QUANTITY='TEMPERATURE' /

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&DEVC ID='W272', XYZ=600, 0, 2, QUANTITY='W-VELOCITY' /
&DEVC ID='W275', XYZ=480, -170, 2, QUANTITY='W-VELOCITY' /
&DEVC ID='W281', XYZ=410, 85, 2, QUANTITY='W-VELOCITY' /
&DEVC ID='W284', XYZ=410, -85, 2, QUANTITY='W-VELOCITY' /
&DEVC ID='W287', XYZ=355, -275, 2, QUANTITY='W-VELOCITY' /
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&HEAD CHID='Falcon1a2', TITLE='Falcon1 test simulation' /

&MESH IJK=125, 200, 40, XB=-350, -100, -200, 200, 0, 20 /
&MESH IJK=120, 120, 30, XB=-100, 20, -30, 30, 0, 15 /
&MESH IJK=120, 60, 10, XB=-100, 20, -30, 30, 15, 20/
&MESH IJK=120, 170, 40, XB=-100, 20, -200, -30, 0, 20 /
&MESH IJK=120, 170, 40, XB=-100, 20, 30, 200, 0, 20 /
&MESH IJK=90, 200, 40, XB=20, 200, -200, 200, 0, 20 /
&MESH IJK=100, 200, 40, XB=200, 400, -200, 200, 0, 20 /

&TIME TWFIN=1100.00, DT=0.5, SYNCHRONIZE=.TRUE. /
&DUMP DT_RESTART=4000, DT_DEVC=1, DT_SLCF=10, DT_ISOF=1,
DT_BNDF=4000, DT_PL3D=4000, DT_HRR=4000, NFRAMES=550/

/Ambient Conditions and Miscellaneous information
&MISC RESTART=.FALSE., TMPA=32.2, P_INF=89700, LAPSE_RATE=-0.04,
U0=0, V0=0, W0=0, HUMIDITY=0.0, SURF_DEFAULT='GROUND',
RADIATION=.FALSE./

/SPECIES DEFINITIONS
&SPEC ID= 'METHANE', MASS_FRACTION_0=0.0, MW= 16.04/

/MATERIAL DEFINITIONS
&MATL ID                ='SOIL'
      CONDUCTIVITY      =0.69
      SPECIFIC_HEAT     =0.88
      DENSITY           =1200. /

/SURFACE DEFINITIONS
&SURF ID                ='GROUND'
      MATL_ID           ='SOIL'
      COLOR             ='TAN'
      BACKING           ='INSULATED'
      THICKNESS         =1 /

/MATERIAL DEFINITIONS
&MATL ID                ='FENCE_MAT'
      CONDUCTIVITY      =0.05
      SPECIFIC_HEAT     =1.50
      DENSITY           =100. /

/SURFACE DEFINITIONS
&SURF ID                ='FENCE'
      MATL_ID           ='FENCE_MAT'
      COLOR             ='OLIVE'
      BACKING           ='INSULATED'
      THICKNESS         =0.2 /

/MATERIAL DEFINITIONS
&MATL ID                ='WATER'
      CONDUCTIVITY      =0.58
      SPECIFIC_HEAT     =4.18
      DENSITY           =1000. /
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/SURFACE DEFINITIONS
&SURF ID                ='POND'
      MATL_ID           ='WATER'
      COLOR             ='BLUE'
      BACKING           ='INSULATED'
      THICKNESS         =0.5 /

/WEATHER
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VEL_T=-0.44, 0.0, RAMP_V='WindRamp', PROFILE='ATMOSPHERIC', Z0=2.,
PLE=0.120 /

&SURF ID='WIND2', TMP_FRONT=32.2, RAMP_T='TempRamp', VEL=-0.44,
VEL_T=1.91, 0.0, RAMP_V='WindRamp', PROFILE='ATMOSPHERIC', Z0=2.,
PLE=0.120 /

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/OPEN SIDES, TOP
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&VENT MB='XMAX', SURF_ID='OPEN'   /
&VENT MB='YMIN', SURF_ID='OPEN'   /
&VENT MB='YMAX', SURF_ID='WIND2'  /
&VENT MB='ZMAX', SURF_ID='MIRROR' /
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/FENCE
&OBST XB=  -88,  -87.8,  -22,    22, 0, 8.7, SURF_ID='FENCE' /
&OBST XB=  -0.2,     0,  -22,    22, 0, 8.7, SURF_ID='FENCE' /
&OBST XB=  -88,      0,  -22, -21.8, 0, 8.7, SURF_ID='FENCE' /
&OBST XB=  -88,      0, 21.8,    22, 0, 8.7, SURF_ID='FENCE' /

/"BILLBOARD"
&OBST XB= -63, -63.2, -8.55, 8.55, 0, 13.3, SURF_ID='FENCE' /

/POND
&OBST XB= -62, -2, -20, 20, 0, 0.5, SURF_ID='POND' /

/LNG Vaporization Source
&SURF ID= 'LNG_vapor1', MASS_FLUX(1)= 0.187, RAMP_MF(1)='LNG_ramp1',
TMP_BACK=-161.55, TMP_INNER=-161.55, TMP_FRONT=-161.55,
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&SURF ID= 'LNG_vapor2', MASS_FLUX(1)= 0.174, RAMP_MF(1)='LNG_ramp2',
TMP_BACK=-161.55, TMP_INNER=-161.55, TMP_FRONT=-161.55,
RAMP_T='temp_ramp', COLOR='RED'/

&SURF ID= 'LNG_vapor3', MASS_FLUX(1)= 0.175, RAMP_MF(1)='LNG_ramp3',
TMP_BACK=-161.55, TMP_INNER=-161.55, TMP_FRONT=-161.55,
RAMP_T='temp_ramp', COLOR='PURPLE'/

&SURF ID= 'LNG_vapor4', MASS_FLUX(1)= 0.178, RAMP_MF(1)='LNG_ramp4',
TMP_BACK=-161.55, TMP_INNER=-161.55, TMP_FRONT=-161.55,
RAMP_T='temp_ramp', COLOR='GREEN'/

&SURF ID= 'LNG_vapor5',  MASS_FLUX(1)= 0.172,
RAMP_MF(1)='LNG_ramp5', TMP_BACK=-161.55, TMP_INNER=-161.55,
TMP_FRONT=-161.55, RAMP_T='temp_ramp', COLOR='YELLOW'/

&SURF ID= 'LNG_vapor6', MASS_FLUX(1)= 0.182, RAMP_MF(1)='LNG_ramp6',
TMP_BACK=-161.55, TMP_INNER=-161.55, TMP_FRONT=-161.55,
RAMP_T='temp_ramp', COLOR='GRAY'/

&SURF ID= 'LNG_vapor7', MASS_FLUX(1)= 0.172, RAMP_MF(1)='LNG_ramp7',
TMP_BACK=-161.55, TMP_INNER=-161.55, TMP_FRONT=-161.55,
RAMP_T='temp_ramp', COLOR='WHITE'/

&SURF ID= 'LNG_vapor8', MASS_FLUX(1)= 0.176, RAMP_MF(1)='LNG_ramp8',
TMP_BACK=-161.55, TMP_INNER=-161.55, TMP_FRONT=-161.55,
RAMP_T='temp_ramp', COLOR='BROWN'/

&SURF ID= 'LNG_vapor9', MASS_FLUX(1)= 0.176, RAMP_MF(1)='LNG_ramp9',
TMP_BACK=-161.55, TMP_INNER=-161.55, TMP_FRONT=-161.55,
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&RAMP ID='temp_ramp', T=548.8, F=1.0/
&RAMP ID='temp_ramp', T=549.8, F=0.0/
&RAMP ID='temp_ramp', T=700, F=1.0/
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&RAMP ID='LNG_ramp1', T=549.8, F=0.0/
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/LNG VAPORIZATION LOCATIONS
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&VENT XB= -48.5, -45.5, -10.5, -9.5, 0.5, 0.5, SURF_ID='LNG_vapor1'/
&VENT XB= -47.5, -46.5, -11.5, -8.5, 0.5, 0.5, SURF_ID='LNG_vapor1'/

&VENT XB= -49.5, -44.5, -12.0, -8.0, 0.5, 0.5, SURF_ID='LNG_vapor2'/
&VENT XB= -49.0, -45.0, -12.5, -7.5, 0.5, 0.5, SURF_ID='LNG_vapor2'/
&VENT XB= -50.0, -44.0, -11.0, -9.0, 0.5, 0.5, SURF_ID='LNG_vapor2'/
&VENT XB= -48.0, -46.0, -13.0, -7.0, 0.5, 0.5, SURF_ID='LNG_vapor2'/

&VENT XB= -50.5, -43.5, -13.0, -7.0, 0.5, 0.5, SURF_ID='LNG_vapor3'/
&VENT XB= -50.0, -44.0, -13.5, -6.5, 0.5, 0.5, SURF_ID='LNG_vapor3'/
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&VENT XB= -48.5, -45.5, -16.5, -3.5, 0.5, 0.5, SURF_ID='LNG_vapor4'/

&VENT XB= -52.5, -41.5, -15.5, -4.5, 0.5, 0.5, SURF_ID='LNG_vapor5'/
&VENT XB= -53.0, -41.0, -14.5, -5.5, 0.5, 0.5, SURF_ID='LNG_vapor5'/
&VENT XB= -53.5, -40.5, -14.0, -6.0, 0.5, 0.5, SURF_ID='LNG_vapor5'/
&VENT XB= -54.0, -40.0, -13.0, -7.0, 0.5, 0.5, SURF_ID='LNG_vapor5'/
&VENT XB= -54.5, -39.5, -12.0, -8.0, 0.5, 0.5, SURF_ID='LNG_vapor5'/
&VENT XB= -51.5, -42.5, -16.0, -4.0, 0.5, 0.5, SURF_ID='LNG_vapor5'/
&VENT XB= -51.0, -43.0, -16.5, -3.5, 0.5, 0.5, SURF_ID='LNG_vapor5'/
&VENT XB= -50.0, -44.0, -17.0, -3.0, 0.5, 0.5, SURF_ID='LNG_vapor5'/
&VENT XB= -49.0, -45.0, -17.5, -2.5, 0.5, 0.5, SURF_ID='LNG_vapor5'/

&VENT XB= -53.0, -41.0, -16.0, -4.0, 0.5, 0.5, SURF_ID='LNG_vapor6'/
&VENT XB= -53.5, -40.5, -15.0, -5.0, 0.5, 0.5, SURF_ID='LNG_vapor6'/
&VENT XB= -54.0, -40.0, -14.0, -6.0, 0.5, 0.5, SURF_ID='LNG_vapor6'/
&VENT XB= -54.5, -39.5, -13.0, -7.0, 0.5, 0.5, SURF_ID='LNG_vapor6'/
&VENT XB= -55.0, -39.0, -12.0, -8.0, 0.5, 0.5, SURF_ID='LNG_vapor6'/
&VENT XB= -52.5, -41.5, -17.0, -3.0, 0.5, 0.5, SURF_ID='LNG_vapor6'/
&VENT XB= -51.5, -42.5, -18.0, -2.0, 0.5, 0.5, SURF_ID='LNG_vapor6'/
&VENT XB= -50.5, -43.5, -18.5, -1.5, 0.5, 0.5, SURF_ID='LNG_vapor6'/
&VENT XB= -49.5, -44.5, -19.0, -1.0, 0.5, 0.5, SURF_ID='LNG_vapor6'/
```

```
&VENT XB= -53.5, -40.5, -16.5, -3.5, 0.5, 0.5, SURF_ID='LNG_vapor7'/
&VENT XB= -54.0, -40.0, -15.5, -4.5, 0.5, 0.5, SURF_ID='LNG_vapor7'/
&VENT XB= -55.0, -39.0, -14.5, -5.5, 0.5, 0.5, SURF_ID='LNG_vapor7'/
&VENT XB= -55.5, -38.5, -13.5, -6.5, 0.5, 0.5, SURF_ID='LNG_vapor7'/
&VENT XB= -56.0, -38.0, -12.5, -7.5, 0.5, 0.5, SURF_ID='LNG_vapor7'/
&VENT XB= -52.5, -41.5, -17.0, -3.0, 0.5, 0.5, SURF_ID='LNG_vapor7'/
&VENT XB= -51.5, -42.5, -18.0, -2.0, 0.5, 0.5, SURF_ID='LNG_vapor7'/
&VENT XB= -50.5, -43.5, -18.5, -1.5, 0.5, 0.5, SURF_ID='LNG_vapor7'/
&VENT XB= -49.5, -44.5, -19.0, -1.0, 0.5, 0.5, SURF_ID='LNG_vapor7'/

&VENT XB= -54.0, -40.0, -17.0, -3.0, 0.5, 0.5, SURF_ID='LNG_vapor8'/
&VENT XB= -55.0, -39.0, -16.0, -4.0, 0.5, 0.5, SURF_ID='LNG_vapor8'/
&VENT XB= -55.5, -38.5, -15.0, -5.0, 0.5, 0.5, SURF_ID='LNG_vapor8'/
&VENT XB= -56.5, -37.5, -14.0, -6.0, 0.5, 0.5, SURF_ID='LNG_vapor8'/
&VENT XB= -57.0, -37.0, -11.5, -8.5, 0.5, 0.5, SURF_ID='LNG_vapor8'/
&VENT XB= -53.0, -41.0, -18.0, -2.0, 0.5, 0.5, SURF_ID='LNG_vapor8'/
&VENT XB= -52.0, -42.0, -18.5, -1.5, 0.5, 0.5, SURF_ID='LNG_vapor8'/
&VENT XB= -51.0, -43.0, -19.5, -0.5, 0.5, 0.5, SURF_ID='LNG_vapor8'/
&VENT XB= -48.5, -45.5, -20.0,  0.0, 0.5, 0.5, SURF_ID='LNG_vapor8'/

&VENT XB= -54.0, -40.0, -17.0, -3.0, 0.5, 0.5, SURF_ID='LNG_vapor9'/
&VENT XB= -55.0, -39.0, -16.0, -4.0, 0.5, 0.5, SURF_ID='LNG_vapor9'/
&VENT XB= -56.0, -38.0, -15.0, -5.0, 0.5, 0.5, SURF_ID='LNG_vapor9'/
&VENT XB= -56.5, -37.5, -14.0, -6.0, 0.5, 0.5, SURF_ID='LNG_vapor9'/
&VENT XB= -57.0, -37.0, -12.5, -7.5, 0.5, 0.5, SURF_ID='LNG_vapor9'/
&VENT XB= -53.0, -41.0, -18.0, -2.0, 0.5, 0.5, SURF_ID='LNG_vapor9'/
&VENT XB= -52.0, -42.0, -19.0, -1.0, 0.5, 0.5, SURF_ID='LNG_vapor9'/
&VENT XB= -51.0, -43.0, -19.5, -0.5, 0.5, 0.5, SURF_ID='LNG_vapor9'/
&VENT XB= -49.5, -44.5, -20.0,  0.0, 0.5, 0.5, SURF_ID='LNG_vapor9'/

/second pool
&VENT XB= -48.0, -46.0, 11.0, 9.0, 0.5, 0.5, SURF_ID='LNG_vapor1' /
&VENT XB= -48.5, -45.5, 10.5, 9.5, 0.5, 0.5, SURF_ID='LNG_vapor1' /
&VENT XB= -47.5, -46.5, 11.5, 8.5, 0.5, 0.5, SURF_ID='LNG_vapor1' /

&VENT XB= -49.5, -44.5, 12.0, 8.0, 0.5, 0.5, SURF_ID='LNG_vapor2' /
&VENT XB= -49.0, -45.0, 12.5, 7.5, 0.5, 0.5, SURF_ID='LNG_vapor2' /
&VENT XB= -50.0, -44.0, 11.0, 9.0, 0.5, 0.5, SURF_ID='LNG_vapor2' /
&VENT XB= -48.0, -46.0,-13.0, -7.0, 0.5, 0.5, SURF_ID='LNG_vapor2' /

&VENT XB= -50.5, -43.5, 13.0, 7.0, 0.5, 0.5, SURF_ID='LNG_vapor3' /
&VENT XB= -50.0, -44.0, 13.5, 6.5, 0.5, 0.5, SURF_ID='LNG_vapor3' /
&VENT XB= -51.0, -43.0, 12.5, 7.5, 0.5, 0.5, SURF_ID='LNG_vapor3' /
&VENT XB= -49.5, -44.5, 14.0, 6.0, 0.5, 0.5, SURF_ID='LNG_vapor3' /
&VENT XB= -51.5, -42.5, 11.0, 9.0, 0.5, 0.5, SURF_ID='LNG_vapor3' /
&VENT XB= -48.0, -46.0, 14.5, 5.5, 0.5, 0.5, SURF_ID='LNG_vapor3' /

&VENT XB= -51.5, -42.5, 14.5, 5.5, 0.5, 0.5, SURF_ID='LNG_vapor4' /
&VENT XB= -52.5, -41.5, 14.0, 6.0, 0.5, 0.5, SURF_ID='LNG_vapor4' /
&VENT XB= -53.0, -41.0, 13.5, 6.5, 0.5, 0.5, SURF_ID='LNG_vapor4' /
&VENT XB= -53.5, -40.5, 11.5, 8.5, 0.5, 0.5, SURF_ID='LNG_vapor4' /
&VENT XB= -51.0, -43.0, 15.5, 4.5, 0.5, 0.5, SURF_ID='LNG_vapor4' /
&VENT XB= -50.5, -43.5, 16.0, 4.0, 0.5, 0.5, SURF_ID='LNG_vapor4' /
&VENT XB= -48.5, -45.5, 16.5, 3.5, 0.5, 0.5, SURF_ID='LNG_vapor4' /

&VENT XB= -52.5, -41.5, 15.5, 4.5, 0.5, 0.5, SURF_ID='LNG_vapor5' /
&VENT XB= -53.0, -41.0, 14.5, 5.5, 0.5, 0.5, SURF_ID='LNG_vapor5' /
```

```
&VENT XB= -53.5, -40.5, 14.0, 6.0, 0.5, 0.5, SURF_ID='LNG_vapor5' /
&VENT XB= -54.0, -40.0, 13.0, 7.0, 0.5, 0.5, SURF_ID='LNG_vapor5' /
&VENT XB= -54.5, -39.5, 12.0, 8.0, 0.5, 0.5, SURF_ID='LNG_vapor5' /
&VENT XB= -51.5, -42.5, 16.0, 4.0, 0.5, 0.5, SURF_ID='LNG_vapor5' /
&VENT XB= -51.0, -43.0, 16.5, 3.5, 0.5, 0.5, SURF_ID='LNG_vapor5' /
&VENT XB= -50.0, -44.0, 17.0, 3.0, 0.5, 0.5, SURF_ID='LNG_vapor5' /
&VENT XB= -49.0, -45.0, 17.5, 2.5, 0.5, 0.5, SURF_ID='LNG_vapor5' /

&VENT XB= -53.0, -41.0, 16.0, 4.0, 0.5, 0.5, SURF_ID='LNG_vapor6' /
&VENT XB= -53.5, -40.5, 15.0, 5.0, 0.5, 0.5, SURF_ID='LNG_vapor6' /
&VENT XB= -54.0, -40.0, 14.0, 6.0, 0.5, 0.5, SURF_ID='LNG_vapor6' /
&VENT XB= -54.5, -39.5, 13.0, 7.0, 0.5, 0.5, SURF_ID='LNG_vapor6' /
&VENT XB= -55.0, -39.0, 12.0, 8.0, 0.5, 0.5, SURF_ID='LNG_vapor6' /
&VENT XB= -52.5, -41.5, 17.0, 3.0, 0.5, 0.5, SURF_ID='LNG_vapor6' /
&VENT XB= -51.5, -42.5, 18.0, 2.0, 0.5, 0.5, SURF_ID='LNG_vapor6' /
&VENT XB= -50.5, -43.5, 18.5, 1.5, 0.5, 0.5, SURF_ID='LNG_vapor6' /
&VENT XB= -49.5, -44.5, 19.0, 1.0, 0.5, 0.5, SURF_ID='LNG_vapor6' /

&VENT XB= -53.5, -40.5, 16.5, 3.5, 0.5, 0.5, SURF_ID='LNG_vapor7' /
&VENT XB= -54.0, -40.0, 15.5, 4.5, 0.5, 0.5, SURF_ID='LNG_vapor7' /
&VENT XB= -55.0, -39.0, 14.5, 5.5, 0.5, 0.5, SURF_ID='LNG_vapor7' /
&VENT XB= -55.5, -38.5, 13.5, 6.5, 0.5, 0.5, SURF_ID='LNG_vapor7' /
&VENT XB= -56.0, -38.0, 12.5, 7.5, 0.5, 0.5, SURF_ID='LNG_vapor7' /
&VENT XB= -52.5, -41.5, 17.0, 3.0, 0.5, 0.5, SURF_ID='LNG_vapor7' /
&VENT XB= -51.5, -42.5, 18.0, 2.0, 0.5, 0.5, SURF_ID='LNG_vapor7' /
&VENT XB= -50.5, -43.5, 18.5, 1.5, 0.5, 0.5, SURF_ID='LNG_vapor7' /
&VENT XB= -49.5, -44.5, 19.0, 1.0, 0.5, 0.5, SURF_ID='LNG_vapor7' /

&VENT XB= -54.0, -40.0, 17.0, 3.0, 0.5, 0.5, SURF_ID='LNG_vapor8' /
&VENT XB= -55.0, -39.0, 16.0, 4.0, 0.5, 0.5, SURF_ID='LNG_vapor8' /
&VENT XB= -55.5, -38.5, 15.0, 5.0, 0.5, 0.5, SURF_ID='LNG_vapor8' /
&VENT XB= -56.5, -37.5, 14.0, 6.0, 0.5, 0.5, SURF_ID='LNG_vapor8' /
&VENT XB= -57.0, -37.0, 11.5, 8.5, 0.5, 0.5, SURF_ID='LNG_vapor8' /
&VENT XB= -53.0, -41.0, 18.0, 2.0, 0.5, 0.5, SURF_ID='LNG_vapor8' /
&VENT XB= -52.0, -42.0, 18.5, 1.5, 0.5, 0.5, SURF_ID='LNG_vapor8' /
&VENT XB= -51.0, -43.0, 19.5, 0.5, 0.5, 0.5, SURF_ID='LNG_vapor8' /
&VENT XB= -48.5, -45.5, 20.0, 0.0, 0.5, 0.5, SURF_ID='LNG_vapor8' /

&VENT XB= -54.0, -40.0, 17.0, 3.0, 0.5, 0.5, SURF_ID='LNG_vapor9' /
&VENT XB= -55.0, -39.0, 16.0, 4.0, 0.5, 0.5, SURF_ID='LNG_vapor9' /
&VENT XB= -56.0, -38.0, 15.0, 5.0, 0.5, 0.5, SURF_ID='LNG_vapor9' /
&VENT XB= -56.5, -37.5, 14.0, 6.0, 0.5, 0.5, SURF_ID='LNG_vapor9' /
&VENT XB= -57.0, -37.0, 12.5, 7.5, 0.5, 0.5, SURF_ID='LNG_vapor9' /
&VENT XB= -53.0, -41.0, 18.0, 2.0, 0.5, 0.5, SURF_ID='LNG_vapor9' /
&VENT XB= -52.0, -42.0, 19.0, 1.0, 0.5, 0.5, SURF_ID='LNG_vapor9' /
&VENT XB= -51.0, -43.0, 19.5, 0.5, 0.5, 0.5, SURF_ID='LNG_vapor9' /
&VENT XB= -49.5, -44.5, 20.0, 0.0, 0.5, 0.5, SURF_ID='LNG_vapor9' /

/third pool
&VENT XB= -18.0, -16.0, -11.0, -9.0, 0.5, 0.5, SURF_ID='LNG_vapor1'/
&VENT XB= -18.5, -15.5, -10.5, -9.5, 0.5, 0.5, SURF_ID='LNG_vapor1'/
&VENT XB= -17.5, -16.5, -11.5, -8.5, 0.5, 0.5, SURF_ID='LNG_vapor1'/
&VENT XB= -19.5, -14.5, -12.0, -8.0, 0.5, 0.5, SURF_ID='LNG_vapor2'/
&VENT XB= -19.0, -15.0, -12.5, -7.5, 0.5, 0.5, SURF_ID='LNG_vapor2'/
&VENT XB= -20.0, -14.0, -11.0, -9.0, 0.5, 0.5, SURF_ID='LNG_vapor2'/
&VENT XB= -18.0, -16.0, -13.0, -7.0, 0.5, 0.5, SURF_ID='LNG_vapor2'/
```

```
&VENT XB= -20.5, -13.5, -13.0, -7.0, 0.5, 0.5, SURF_ID='LNG_vapor3'/
&VENT XB= -20.0, -14.0, -13.5, -6.5, 0.5, 0.5, SURF_ID='LNG_vapor3'/
&VENT XB= -21.0, -13.0, -12.5, -7.5, 0.5, 0.5, SURF_ID='LNG_vapor3'/
&VENT XB= -19.5, -14.5, -14.0, -6.0, 0.5, 0.5, SURF_ID='LNG_vapor3'/
&VENT XB= -21.5, -12.5, -11.0, -9.0, 0.5, 0.5, SURF_ID='LNG_vapor3'/
&VENT XB= -18.0, -16.0, -14.5, -5.5, 0.5, 0.5, SURF_ID='LNG_vapor3'/

&VENT XB= -21.5, -12.5, -14.5, -5.5, 0.5, 0.5, SURF_ID='LNG_vapor4'/
&VENT XB= -22.5, -11.5, -14.0, -6.0, 0.5, 0.5, SURF_ID='LNG_vapor4'/
&VENT XB= -23.0, -11.0, -13.5, -6.5, 0.5, 0.5, SURF_ID='LNG_vapor4'/
&VENT XB= -23.5, -10.5, -11.5, -8.5, 0.5, 0.5, SURF_ID='LNG_vapor4'/
&VENT XB= -21.0, -13.0, -15.5, -4.5, 0.5, 0.5, SURF_ID='LNG_vapor4'/
&VENT XB= -20.5, -13.5, -16.0, -4.0, 0.5, 0.5, SURF_ID='LNG_vapor4'/
&VENT XB= -18.5, -15.5, -16.5, -3.5, 0.5, 0.5, SURF_ID='LNG_vapor4'/

&VENT XB= -22.5, -11.5, -15.5, -4.5, 0.5, 0.5, SURF_ID='LNG_vapor5'/
&VENT XB= -23.0, -11.0, -14.5, -5.5, 0.5, 0.5, SURF_ID='LNG_vapor5'/
&VENT XB= -23.5, -10.5, -14.0, -6.0, 0.5, 0.5, SURF_ID='LNG_vapor5'/
&VENT XB= -24.0, -10.0, -13.0, -7.0, 0.5, 0.5, SURF_ID='LNG_vapor5'/
&VENT XB= -24.5, -09.5, -12.0, -8.0, 0.5, 0.5, SURF_ID='LNG_vapor5'/
&VENT XB= -21.5, -12.5, -16.0, -4.0, 0.5, 0.5, SURF_ID='LNG_vapor5'/
&VENT XB= -21.0, -13.0, -16.5, -3.5, 0.5, 0.5, SURF_ID='LNG_vapor5'/
&VENT XB= -20.0, -14.0, -17.0, -3.0, 0.5, 0.5, SURF_ID='LNG_vapor5'/
&VENT XB= -19.0, -15.0, -17.5, -2.5, 0.5, 0.5, SURF_ID='LNG_vapor5'/

&VENT XB= -23.0, -11.0, -16.0, -4.0, 0.5, 0.5, SURF_ID='LNG_vapor6'/
&VENT XB= -23.5, -10.5, -15.0, -5.0, 0.5, 0.5, SURF_ID='LNG_vapor6'/
&VENT XB= -24.0, -10.0, -14.0, -6.0, 0.5, 0.5, SURF_ID='LNG_vapor6'/
&VENT XB= -24.5, -09.5, -13.0, -7.0, 0.5, 0.5, SURF_ID='LNG_vapor6'/
&VENT XB= -25.0, -09.0, -12.0, -8.0, 0.5, 0.5, SURF_ID='LNG_vapor6'/
&VENT XB= -22.5, -11.5, -17.0, -3.0, 0.5, 0.5, SURF_ID='LNG_vapor6'/
&VENT XB= -21.5, -12.5, -18.0, -2.0, 0.5, 0.5, SURF_ID='LNG_vapor6'/
&VENT XB= -20.5, -13.5, -18.5, -1.5, 0.5, 0.5, SURF_ID='LNG_vapor6'/
&VENT XB= -19.5, -14.5, -19.0, -1.0, 0.5, 0.5, SURF_ID='LNG_vapor6'/

&VENT XB= -23.5, -10.5, -16.5, -3.5, 0.5, 0.5, SURF_ID='LNG_vapor7'/
&VENT XB= -24.0, -10.0, -15.5, -4.5, 0.5, 0.5, SURF_ID='LNG_vapor7'/
&VENT XB= -25.0, -09.0, -14.5, -5.5, 0.5, 0.5, SURF_ID='LNG_vapor7'/
&VENT XB= -25.5, -08.5, -13.5, -6.5, 0.5, 0.5, SURF_ID='LNG_vapor7'/
&VENT XB= -26.0, -08.0, -12.5, -7.5, 0.5, 0.5, SURF_ID='LNG_vapor7'/
&VENT XB= -22.5, -11.5, -17.0, -3.0, 0.5, 0.5, SURF_ID='LNG_vapor7'/
&VENT XB= -21.5, -12.5, -18.0, -2.0, 0.5, 0.5, SURF_ID='LNG_vapor7'/
&VENT XB= -20.5, -13.5, -18.5, -1.5, 0.5, 0.5, SURF_ID='LNG_vapor7'/
&VENT XB= -19.5, -14.5, -19.0, -1.0, 0.5, 0.5, SURF_ID='LNG_vapor7'/

&VENT XB= -24.0, -10.0, -17.0, -3.0, 0.5, 0.5, SURF_ID='LNG_vapor8'/
&VENT XB= -25.0, -09.0, -16.0, -4.0, 0.5, 0.5, SURF_ID='LNG_vapor8'/
&VENT XB= -25.5, -08.5, -15.0, -5.0, 0.5, 0.5, SURF_ID='LNG_vapor8'/
&VENT XB= -26.5, -07.5, -14.0, -6.0, 0.5, 0.5, SURF_ID='LNG_vapor8'/
&VENT XB= -27.0, -07.0, -11.5, -8.5, 0.5, 0.5, SURF_ID='LNG_vapor8'/
&VENT XB= -23.0, -11.0, -18.0, -2.0, 0.5, 0.5, SURF_ID='LNG_vapor8'/
&VENT XB= -22.0, -12.0, -18.5, -1.5, 0.5, 0.5, SURF_ID='LNG_vapor8'/
&VENT XB= -21.0, -13.0, -19.5, -0.5, 0.5, 0.5, SURF_ID='LNG_vapor8'/
&VENT XB= -18.5, -15.5, -20.0,  0.0, 0.5, 0.5, SURF_ID='LNG_vapor8'/
```

```
&VENT XB= -24.0, -10.0, -17.0, -3.0, 0.5, 0.5, SURF_ID='LNG_vapor9'/
&VENT XB= -25.0, -09.0, -16.0, -4.0, 0.5, 0.5, SURF_ID='LNG_vapor9'/
&VENT XB= -26.0, -08.0, -15.0, -5.0, 0.5, 0.5, SURF_ID='LNG_vapor9'/
&VENT XB= -26.5, -07.5, -14.0, -6.0, 0.5, 0.5, SURF_ID='LNG_vapor9'/
&VENT XB= -27.0, -07.0, -12.5, -7.5, 0.5, 0.5, SURF_ID='LNG_vapor9'/
&VENT XB= -23.0, -11.0, -18.0, -2.0, 0.5, 0.5, SURF_ID='LNG_vapor9'/
&VENT XB= -22.0, -12.0, -19.0, -1.0, 0.5, 0.5, SURF_ID='LNG_vapor9'/
&VENT XB= -21.0, -13.0, -19.5, -0.5, 0.5, 0.5, SURF_ID='LNG_vapor9'/
&VENT XB= -19.5, -14.5, -20.0,  0.0, 0.5, 0.5, SURF_ID='LNG_vapor9'/

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&DEVC ID='C09m', XYZ=150, -50,  5, QUANTITY='METHANE_VF' /
&DEVC ID='C09h', XYZ=150, -50, 11, QUANTITY='METHANE_VF' /
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&DEVC ID='C10h', XYZ=150, -25, 11, QUANTITY='METHANE_VF' /
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&DEVC ID='C11l', XYZ=150,   0,  1, QUANTITY='METHANE_VF' /
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&DEVC ID='C11h', XYZ=150,   0, 11, QUANTITY='METHANE_VF' /
&DEVC ID='C11t', XYZ=150,   0, 17, QUANTITY='METHANE_VF' /

&DEVC ID='C12l', XYZ=150,  25,  1, QUANTITY='METHANE_VF' /
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&DEVC ID='C12h', XYZ=150,  25, 11, QUANTITY='METHANE_VF' /
&DEVC ID='C12t', XYZ=150,  25, 17, QUANTITY='METHANE_VF' /

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&DEVC ID='C13h', XYZ=150,  50, 11, QUANTITY='METHANE_VF' /
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&DEVC ID='C14l', XYZ=150,  75,  1, QUANTITY='METHANE_VF' /
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&DEVC ID='C14h', XYZ=150,  75, 11, QUANTITY='METHANE_VF' /
&DEVC ID='C14t', XYZ=150,  75, 17, QUANTITY='METHANE_VF' /

&DEVC ID='C15l', XYZ=250, -84,  1, QUANTITY='METHANE_VF' /
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&DEVC ID='C15h', XYZ=250, -84, 11, QUANTITY='METHANE_VF' /
&DEVC ID='C15t', XYZ=250, -84, 17, QUANTITY='METHANE_VF' /

&DEVC ID='C16l', XYZ=250, -56,  1, QUANTITY='METHANE_VF' /
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&DEVC ID='C16h', XYZ=250, -56, 11, QUANTITY='METHANE_VF' /
&DEVC ID='C16t', XYZ=250, -56, 17, QUANTITY='METHANE_VF' /

&DEVC ID='C17l', XYZ=250, -28,  1, QUANTITY='METHANE_VF' /
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&DEVC ID='C17h', XYZ=250, -28, 11, QUANTITY='METHANE_VF' /
&DEVC ID='C17t', XYZ=250, -28, 17, QUANTITY='METHANE_VF' /

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&DEVC ID='C18m', XYZ=250,   0,  5, QUANTITY='METHANE_VF' /
&DEVC ID='C18h', XYZ=250,   0, 11, QUANTITY='METHANE_VF' /
&DEVC ID='C18t', XYZ=250,   0, 17, QUANTITY='METHANE_VF' /
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&DEVC ID='C19t', XYZ=250,  28, 17, QUANTITY='METHANE_VF' /

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&DEVC ID='C20h', XYZ=250,  56, 11, QUANTITY='METHANE_VF' /
&DEVC ID='C20t', XYZ=250,  56, 17, QUANTITY='METHANE_VF' /

&DEVC ID='C21l', XYZ=250,  84,  1, QUANTITY='METHANE_VF' /
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&DEVC ID='C21h', XYZ=250,  84, 11, QUANTITY='METHANE_VF' /
&DEVC ID='C21t', XYZ=250,  84, 17, QUANTITY='METHANE_VF' /

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&DEVC ID='S03', XYZ=-600, 100, 2, QUANTITY='VELOCITY' /
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&DEVC ID='S05', XYZ=-300, 100, 2, QUANTITY='VELOCITY' /
&DEVC ID='S06', XYZ=-44, 28, 2, QUANTITY='VELOCITY' /
&DEVC ID='S07', XYZ=50, -75, 2, QUANTITY='VELOCITY' /
&DEVC ID='S08', XYZ=50, 3, 2, QUANTITY='VELOCITY' /
&DEVC ID='S09', XYZ=50, 75, 2, QUANTITY='VELOCITY' /
&DEVC ID='S10', XYZ=150, -150, 2, QUANTITY='VELOCITY' /
&DEVC ID='S11', XYZ=150, -75, 2, QUANTITY='VELOCITY' /
&DEVC ID='S12', XYZ=150, 3, 2, QUANTITY='VELOCITY' /
&DEVC ID='S13', XYZ=150, 75, 2, QUANTITY='VELOCITY' /
&DEVC ID='S14', XYZ=150, 150, 2, QUANTITY='VELOCITY' /
&DEVC ID='S15', XYZ=350, -150, 2, QUANTITY='VELOCITY' /
&DEVC ID='S16', XYZ=350, -75, 2, QUANTITY='VELOCITY' /
&DEVC ID='S17', XYZ=350, -3, 2, QUANTITY='VELOCITY' /
&DEVC ID='S18', XYZ=350, 75, 2, QUANTITY='VELOCITY' /
&DEVC ID='S19', XYZ=350, 150, 2, QUANTITY='VELOCITY' /

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&DEVC ID='U02', XYZ=-600, -100, 2, QUANTITY='U-VELOCITY' /
&DEVC ID='U03', XYZ=-600, 100, 2, QUANTITY='U-VELOCITY' /
&DEVC ID='U04', XYZ=-300, -100, 2, QUANTITY='U-VELOCITY' /
&DEVC ID='U05', XYZ=-300, 100, 2, QUANTITY='U-VELOCITY' /
&DEVC ID='U06', XYZ=-44, 28, 2, QUANTITY='U-VELOCITY' /
&DEVC ID='U07', XYZ=50, -75, 2, QUANTITY='U-VELOCITY' /
&DEVC ID='U08', XYZ=50, 3, 2, QUANTITY='U-VELOCITY' /
&DEVC ID='U09', XYZ=50, 75, 2, QUANTITY='U-VELOCITY' /
&DEVC ID='U10', XYZ=150, -150, 2, QUANTITY='U-VELOCITY' /
&DEVC ID='U11', XYZ=150, -75, 2, QUANTITY='U-VELOCITY' /
&DEVC ID='U12', XYZ=150, 3, 2, QUANTITY='U-VELOCITY' /
&DEVC ID='U13', XYZ=150, 75, 2, QUANTITY='U-VELOCITY' /
&DEVC ID='U14', XYZ=150, 150, 2, QUANTITY='U-VELOCITY' /
&DEVC ID='U15', XYZ=350, -150, 2, QUANTITY='U-VELOCITY' /
&DEVC ID='U16', XYZ=350, -75, 2, QUANTITY='U-VELOCITY' /
&DEVC ID='U17', XYZ=350, -3, 2, QUANTITY='U-VELOCITY' /
&DEVC ID='U18', XYZ=350, 75, 2, QUANTITY='U-VELOCITY' /
&DEVC ID='U19', XYZ=350, 150, 2, QUANTITY='U-VELOCITY' /
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&DEVC ID='V02', XYZ=-600, -100, 2, QUANTITY='V-VELOCITY' /
&DEVC ID='V03', XYZ=-600, 100, 2, QUANTITY='V-VELOCITY' /
&DEVC ID='V04', XYZ=-300, -100, 2, QUANTITY='V-VELOCITY' /
&DEVC ID='V05', XYZ=-300, 100, 2, QUANTITY='V-VELOCITY' /
&DEVC ID='V06', XYZ=-44, 28, 2, QUANTITY='V-VELOCITY' /
&DEVC ID='V07', XYZ=50, -75, 2, QUANTITY='V-VELOCITY' /
&DEVC ID='V08', XYZ=50, 3, 2, QUANTITY='V-VELOCITY' /
&DEVC ID='V09', XYZ=50, 75, 2, QUANTITY='V-VELOCITY' /
&DEVC ID='V10', XYZ=150, -150, 2, QUANTITY='V-VELOCITY' /
&DEVC ID='V11', XYZ=150, -75, 2, QUANTITY='V-VELOCITY' /
&DEVC ID='V12', XYZ=150, 3, 2, QUANTITY='V-VELOCITY' /
&DEVC ID='V13', XYZ=150, 75, 2, QUANTITY='V-VELOCITY' /
&DEVC ID='V14', XYZ=150, 150, 2, QUANTITY='V-VELOCITY' /
&DEVC ID='V15', XYZ=350, -150, 2, QUANTITY='V-VELOCITY' /
&DEVC ID='V16', XYZ=350, -75, 2, QUANTITY='V-VELOCITY' /
&DEVC ID='V17', XYZ=350, -3, 2, QUANTITY='V-VELOCITY' /
&DEVC ID='V18', XYZ=350, 75, 2, QUANTITY='V-VELOCITY' /
&DEVC ID='V19', XYZ=350, 150, 2, QUANTITY='V-VELOCITY' /

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&DEVC ID='W03', XYZ=-600, 100, 2, QUANTITY='W-VELOCITY' /
&DEVC ID='W04', XYZ=-300, -100, 2, QUANTITY='W-VELOCITY' /
&DEVC ID='W05', XYZ=-300, 100, 2, QUANTITY='W-VELOCITY' /
&DEVC ID='W06', XYZ=-44, 28, 2, QUANTITY='W-VELOCITY' /
&DEVC ID='W07', XYZ=50, -75, 2, QUANTITY='W-VELOCITY' /
&DEVC ID='W08', XYZ=50, 3, 2, QUANTITY='W-VELOCITY' /
&DEVC ID='W09', XYZ=50, 75, 2, QUANTITY='W-VELOCITY' /
&DEVC ID='W10', XYZ=150, -150, 2, QUANTITY='W-VELOCITY' /
&DEVC ID='W11', XYZ=150, -75, 2, QUANTITY='W-VELOCITY' /
&DEVC ID='W12', XYZ=150, 3, 2, QUANTITY='W-VELOCITY' /
&DEVC ID='W13', XYZ=150, 75, 2, QUANTITY='W-VELOCITY' /
&DEVC ID='W14', XYZ=150, 150, 2, QUANTITY='W-VELOCITY' /
&DEVC ID='W15', XYZ=350, -150, 2, QUANTITY='W-VELOCITY' /
&DEVC ID='W16', XYZ=350, -75, 2, QUANTITY='W-VELOCITY' /
&DEVC ID='W17', XYZ=350, -3, 2, QUANTITY='W-VELOCITY' /
&DEVC ID='W18', XYZ=350, 75, 2, QUANTITY='W-VELOCITY' /
&DEVC ID='W19', XYZ=350, 150, 2, QUANTITY='W-VELOCITY' /
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&MESH ID='mesh2', IJK=100, 100, 20, XB=-50, 50,-50, 50, 0, 20 /
&MESH ID='mesh3', IJK=100, 50, 20, XB=-50, 50, 50, 150, 0, 20 /
&MESH ID='mesh4', IJK=100, 150, 20, XB=50, 250,-150, 150, 0, 20 /
&MESH ID='mesh5', IJK=100, 150, 20, XB=250, 450,-150, 150, 0, 20 /
&MESH ID='mesh6', IJK=100, 150, 20, XB=450, 650,-150, 150, 0, 20 /
&MESH ID='mesh7', IJK=100, 150, 20, XB=650, 850,-150, 150, 0, 20 /
&MESH ID='mesh8', IJK=100, 150, 20, XB=850, 1050,-150, 150, 0, 20 /
&MESH ID='mesh9', IJK=100, 150, 20, XB=1050, 1250,-150, 150, 0, 20 /
&MESH ID='mesh10', IJK=100, 150, 20, XB=1250, 1450,-150, 150, 0, 20/
&MESH ID='mesh11', IJK=100, 150, 20, XB=1450, 1650,-150, 150, 0, 20/
&MESH ID='mesh12', IJK=100, 150, 20, XB=1650, 1850,-150, 150, 0, 20/
&MESH ID='mesh13', IJK=100, 150, 20, XB=1850, 2050,-150, 150, 0, 20/
&MESH ID='mesh14', IJK=100, 150, 20, XB=2050, 2250,-150, 150, 0, 20/

&TIME TWFIN=1800.00, DT=0.5, SYNCHRONIZE=.TRUE. /
&DUMP DT_DEVC=1, DT_SLCF=1, DT_ISOF=1, DT_BNDF=4000, DT_PL3D=4000,
DT_HRR=4000, NFRAMES=900/

/Ambient Conditions and Miscellanious information
&MISC TMPA=14.3, LAPSE_RATE=-0.0097, U0=0, V0=0, W0=0,
SURF_DEFAULT='INERT', RADIATION=.FALSE./

&SPEC ID='R12', MW=57.8/
&SPEC ID='WATER VAPOR', MASS_FRACTION_0=0.0104/

/WEATHER
&SURF ID='WIND', VEL=-1.5, PROFILE='ATMOSPHERIC', Z0=10., PLE=0.349,
MASS_FRACTION(2)=0.0104 /

/OPEN SIDES, TOP
&VENT MB='XMIN', SURF_ID='WIND'   /
&VENT MB='XMAX' , SURF_ID='OPEN'   /
&VENT MB='YMIN', SURF_ID='MIRROR' /
&VENT MB='YMAX' , SURF_ID='MIRROR' /
&VENT MB='ZMAX' , SURF_ID='MIRROR' /

/Source Term mass flux.
&SURF ID= 'R12_source',  MASS_FLUX(1)=3.40, RAMP_MF(1)='R12_ramp',
TMP_FRONT=14.3, TMP_INNER=14.3, TMP_BACK=14.3, COLOR='BLACK'/

/Ramp function to describe mass flux rate
&RAMP ID='R12_ramp', T=0.0, F=0.0/
&RAMP ID='R12_ramp', T=699, F=0.0/time when wind profile stabilizes
throughout domain
&RAMP ID='R12_ramp', T=700, F=1.0/start of vaporization
&RAMP ID='R12_ramp', T=1165, F=1.0/
&RAMP ID='R12_ramp', T=1166, F=0.0/spill ends after 107seconds
ref:MEP
&RAMP ID='R12_ramp', T=2500, F=0.0/simulation ends

/Source Dimensions
&VENT XB= -1, 1, -1, 1, 0, 0, SURF_ID='R12_source' /
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/plate
&OBST XB= -1, 1, -1, 1, 0.5, 0.5, SURF_ID='R12_source' /

/Isosurfaces
&ISOF QUANTITY='R12_VF', VALUE(1)=0.159, VALUE(2)=0.074,
VALUE(3)=0.015, VALUE(4)=0.007, VALUE(5)=0.005, VALUE(6)=0.002/

/Slice Files
&SLCF PBY=0, QUANTITY='RELATIVE HUMIDITY'  /

&SLCF PBX=0, QUANTITY='VELOCITY', VECTOR=.TRUE. /
&SLCF PBZ= 2, QUANTITY='VELOCITY' , VECTOR=.TRUE. /
&SLCF PBZ=10, QUANTITY='VELOCITY' , VECTOR=.TRUE. /

&SLCF PBX=0.0, QUANTITY='R12_VF'/
&SLCF PBX=50, QUANTITY='R12_VF'/
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&SLCF PBX=212, QUANTITY='R12_VF'/
&SLCF PBX=250, QUANTITY='R12_VF'/
&SLCF PBX=335, QUANTITY='R12_VF'/
&SLCF PBX=472, QUANTITY='R12_VF'/
&SLCF PBY=0.0, QUANTITY='R12_VF' /
&SLCF PBZ=0.0, QUANTITY='R12_VF' /
&SLCF PBZ=0.5, QUANTITY='R12_VF' /
&SLCF PBZ=1.0, QUANTITY='R12_VF' /
&SLCF PBZ=1.5, QUANTITY='R12_VF' /
&SLCF PBZ=2.0, QUANTITY='R12_VF' /

/Instruments
&DEVC ID='C21', XYZ=  50,  0, 0, QUANTITY='R12_VF' /
&DEVC ID='C36', XYZ=  90,  0, 0, QUANTITY='R12_VF' /
&DEVC ID='C48', XYZ= 212, 0, 0, QUANTITY='R12_VF' /
&DEVC ID='C26', XYZ= 250, 0, 0, QUANTITY='R12_VF' /
&DEVC ID='C32', XYZ= 335, 0, 0, QUANTITY='R12_VF' /
&DEVC ID='C19', XYZ= 472, 0, 0, QUANTITY='R12_VF' /
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&MESH IJK=100,  50, 50, XB= -100,  100, -200, -100, 0, 50 / 2
&MESH IJK=100, 100, 50, XB= -100,  100, -100,  100, 0, 50 / 3
&MESH IJK=100,  50, 50, XB= -100,  100,  100,  200, 0, 50 / 4
&MESH IJK= 50, 200, 50, XB=  100,  200, -200,  200, 0, 50 / 5
&MESH IJK= 50, 200, 50, XB=  200,  300, -200,  200, 0, 50 / 6
&MESH IJK= 50, 200, 50, XB=  300,  400, -200,  200, 0, 50 / 7
&MESH IJK= 50, 200, 50, XB=  400,  500, -200,  200, 0, 50 / 8
&MESH IJK= 50, 200, 50, XB=  500,  600, -200,  200, 0, 50 / 9
&MESH IJK= 50, 200, 50, XB=  600,  700, -200,  200, 0, 50 / 10
&MESH IJK= 50, 200, 50, XB=  700,  800, -200,  200, 0, 50 / 11
&MESH IJK= 50, 200, 50, XB=  800,  900, -200,  200, 0, 50 / 12
&MESH IJK= 50, 200, 50, XB=  900, 1000, -200,  200, 0, 50 / 13
&MESH IJK= 50, 200, 50, XB= 1000, 1100, -200,  200, 0, 50 / 14
&MESH IJK= 50, 200, 50, XB= 1100, 1200, -200,  200, 0, 50 / 15

&TIME TWFIN=1500.00, DT=0.5, SYNCHRONIZE=.TRUE. /
&DUMP DT_DEVC=1, DT_SLCF=1, DT_ISOF=1, DT_BNDF=4000, DT_PL3D=4000,
DT_HRR=4000, NFRAMES=750/

/Ambient Conditions and Miscellanious information
&MISC RESTART=.FALSE., TMPA=22.85, P_INF=96600, LAPSE_RATE=0.0, U0=-
4.9, V0=0, W0=0, HUMIDITY=0.0, SURF_DEFAULT='INERT',
RADIATION=.FALSE./

&SPEC ID='CO2', MASS_FRACTION_0=0, MW=44.011/ MW based on MEP

/WEATHER
&SURF ID='WIND', TMP_FRONT=22.85, VEL=-4.9, VEL_T=0.0, 0.0,
PROFILE='ATMOSPHERIC', Z0=10., PLE=0.210  /

/OPEN SIDES, TOP
&VENT MB='XMIN', SURF_ID='WIND'   /
&VENT MB='XMAX' , SURF_ID='OPEN'   /
&VENT MB='YMIN', SURF_ID='MIRROR' /
&VENT MB='YMAX' , SURF_ID='MIRROR' /
&VENT MB='ZMAX' , SURF_ID='MIRROR' /

/Source
&SURF ID='CO2_in', MASS_FLUX(1)= 0.03873, RAMP_MF(1)='CO2_ramp' /

/Ramp function to describe mass flux rate (vaporization rate)
&RAMP ID='CO2_ramp', T=0.0, F=0.0/
&RAMP ID='CO2_ramp', T=99, F=0.0/
&RAMP ID='CO2_ramp', T=100, F=1.0/
&RAMP ID='CO2_ramp', T=1500, F=1.0/

/Source Location
&VENT XB= -47.7, 47.7, -47.7, 47.7, 0, 0, SURF_ID='CO2_in',
COLOR='BLACK' /
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/Dike
&OBST XB=-69.75,-62.7,-69.75, 69.75, 0, 5.55, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB= 62.7, 69.75,-69.75, 69.75, 0, 5.55, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB=-69.75,69.75,-69.75,-62.7,  0, 5.55, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB=-69.75,69.75, 62.7,  69.75, 0, 5.55, SURF_ID='INERT',
COLOR='WHITE'/

&OBST XB=-71.25,-61.2,-71.25, 71.25, 0, 5.05, SURF_ID='INERT',
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&OBST XB= 61.2, 71.25,-71.25, 71.25, 0, 5.05, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB=-71.25,71.25,-71.25,-61.2,  0, 5.05, SURF_ID='INERT',
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&OBST XB=-71.25,71.25, 61.2,  71.25, 0, 5.05, SURF_ID='INERT',
COLOR='WHITE'/

&OBST XB=-72.75,-59.7,-72.75, 72.75, 0, 4.55, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB=59.7, 72.75,-72.75, 72.75, 0, 4.55, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB=-72.75,72.75,-72.75,-59.7,  0, 4.55, SURF_ID='INERT',
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&OBST XB=-72.75,72.75, 59.7, 72.75, 0, 4.55, SURF_ID='INERT',
COLOR='WHITE'/

&OBST XB=-74.25,-58.2,-74.25, 74.25, 0, 4.05, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB=58.2, 74.25,-74.25, 74.25, 0, 4.05, SURF_ID='INERT',
COLOR='WHITE' /
&OBST XB=-74.25,74.25,-74.25,-58.2,  0, 4.05, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB=-74.25,74.25,  58.2, 74.25, 0, 4.05, SURF_ID='INERT',
COLOR='WHITE'/

&OBST XB=-75.75,-56.7,-75.75, 75.75, 0, 3.55, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB=56.7, 75.75,-75.75, 75.75, 0, 3.55, SURF_ID='INERT',
COLOR='WHITE' /
&OBST XB=-75.75,75.75,-75.75,-56.7,  0, 3.55, SURF_ID='INERT',
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&OBST XB=-75.75,75.75, 56.7, 75.75, 0, 3.55, SURF_ID='INERT',
COLOR='WHITE' /

&OBST XB=-77.25,-55.2,-77.25, 77.25, 0, 3.05, SURF_ID='INERT',
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&OBST XB=55.2, 77.25, -77.25, 77.25, 0, 3.05, SURF_ID='INERT',
COLOR='WHITE'/
&OBST XB=-77.25, 77.25,-77.25,-55.2, 0, 3.05, SURF_ID='INERT',
COLOR='WHITE'/
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COLOR='WHITE'/

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&TIME TWFIN=1000.00, DT=0.5, SYNCHRONIZE=.TRUE. /
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DT_HRR=5000, NFRAMES=1000/

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RADIATION=.FALSE./

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PROFILE='ATMOSPHERIC', Z0=1.177, PLE=0.295 /

/OPEN SIDES, TOP
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&VENT MB='YMIN', SURF_ID='MIRROR' /
&VENT MB='YMAX' , SURF_ID='MIRROR' /
&VENT MB='ZMAX' , SURF_ID='MIRROR' /

/SF6 Source
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&RAMP ID='temp_ramp', T=350, F=1.0/simulation ends, assumes areas
remains at LNG temp

/Ramp function to describe mass flux rate (vaporization rate)
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&RAMP ID='SF6_ramp', T=99, F=0.0/
&RAMP ID='SF6_ramp', T=100, F=1.0/
&RAMP ID='SF6_ramp', T=350, F=1.0/

/LNG VAPORIZATION LOCATION
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COLOR='BLACK' /
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/Slice Files
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&SLCF PBX=389.60, QUANTITY='SF6_VF'/
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&SLCF PBZ=2.240, QUANTITY='VELOCITY' , VECTOR=.TRUE. /

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&TIME TWFIN=2596, DT=0.5, SYNCHRONIZE=.TRUE. /
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/Ambient Conditions and Miscellanious information
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/WEATHER
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/OPEN SIDES, TOP
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/FENCE
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&OBST XB=-23.16, -24.16, 20.9, 20.9, 0,  5, SURF_ID='INERT'/42b
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&OBST XB=-22.03, -22.03, 22.0, 23.0, 0,  5, SURF_ID='INERT'/45
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&SLCF PBX=301.61, QUANTITY='SF6_VF'/
&SLCF PBX=351.89, QUANTITY='SF6_VF'/
&SLCF PBX=389.60, QUANTITY='SF6_VF'/
&SLCF PBY=0.0, QUANTITY='SF6_VF' /
&SLCF PBZ=0, QUANTITY='SF6_VF' /

&SLCF PBX=0, QUANTITY='VELOCITY', VECTOR=.TRUE. /
&SLCF PBZ=1.177, QUANTITY='VELOCITY' , VECTOR=.TRUE. /
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&SLCF PBZ=2.240, QUANTITY='VELOCITY' , VECTOR=.TRUE. /

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&DEVC ID='C200', XYZ=100.53, 0, 0, QUANTITY='SF6_VF' /
&DEVC ID='C300', XYZ=150.814, 0, 0, QUANTITY='SF6_VF' /
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&DEVC ID='C500', XYZ=251.34, 0, 0, QUANTITY='SF6_VF' /
&DEVC ID='C600', XYZ=301.61, 0, 0, QUANTITY='SF6_VF' /
&DEVC ID='C700', XYZ=351.89, 0, 0, QUANTITY='SF6_VF' /
&DEVC ID='C800', XYZ=389.60, 0, 0, QUANTITY='SF6_VF' /

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&DEVC ID='C200b', XYZ=100.53, 0, 0.5, QUANTITY='SF6_VF' /
&DEVC ID='C300b', XYZ=150.814, 0, 0.5, QUANTITY='SF6_VF' /
&DEVC ID='C400b', XYZ=201.08, 0, 0.5, QUANTITY='SF6_VF' /
&DEVC ID='C500b', XYZ=251.34, 0, 0.5, QUANTITY='SF6_VF' /
&DEVC ID='C600b', XYZ=301.61, 0, 0.5, QUANTITY='SF6_VF' /
&DEVC ID='C700b', XYZ=351.89, 0, 0.5, QUANTITY='SF6_VF' /
&DEVC ID='C800b', XYZ=389.60, 0, 0.5, QUANTITY='SF6_VF' /

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&DEVC ID='C200c', XYZ=100.53,   0, 1, QUANTITY='SF6_VF' /
&DEVC ID='C300c', XYZ=150.814, 0, 1, QUANTITY='SF6_VF' /
&DEVC ID='C400c', XYZ=201.08,   0, 1, QUANTITY='SF6_VF' /
&DEVC ID='C500c', XYZ=251.34,   0, 1, QUANTITY='SF6_VF' /
&DEVC ID='C600c', XYZ=301.61,   0, 1, QUANTITY='SF6_VF' /
&DEVC ID='C700c', XYZ=351.89,   0, 1, QUANTITY='SF6_VF' /
&DEVC ID='C800c', XYZ=389.60,   0, 1, QUANTITY='SF6_VF' /
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&MESH ID='mesh2', IJK=200, 300, 20, XB= 105, 305, -150, 150, 0, 10/
&MESH ID='mesh3', IJK=100, 300, 20, XB= 305, 405, -150, 150, 0, 10/

&TIME TWFIN=612, DT=0.5 /
&DUMP DT_DEVC=1, DT_SLCF=1, DT_ISOF=1, DT_BNDF=5000, DT_PL3D=5000,
DT_HRR=5000, NFRAMES=1000/

/Ambient Conditions and Miscellanious information
&MISC RESTART=.FALSE., TMPA=19.85, P_INF=101325, LAPSE_RATE=0.0,
U0=0, V0=0, W0=0, HUMIDITY=0.0, SURF_DEFAULT='INERT',
RADIATION=.FALSE, gvec=1.,0.,1., RAMP_GX='x-ramp', RAMP_GZ='z-ramp'
/

&RAMP ID='x-ramp', X=0, F=1.13038 /
&RAMP ID='x-ramp', X=1000, F=1.13038 /

&RAMP ID='z-ramp', X=0, F=-9.744657 /
&RAMP ID='z-ramp', X=1000, F=-9.744657 /

&SPEC ID='SF6', MASS_FRACTION_0=0, MW=146.1/ MW based on MEP

/OPEN SIDES, TOP
&VENT MB='XMIN', SURF_ID='OPEN'   /
&VENT MB='XMAX' , SURF_ID='OPEN'   /
&VENT MB='YMIN', SURF_ID='OPEN' /
&VENT MB='YMAX' , SURF_ID='OPEN' /
&VENT MB='ZMAX' , SURF_ID='OPEN' /

/SF6 Source
&SURF ID='SF6_in', MASS_FLUX(1)= 0.580, RAMP_MF(1)='SF6_ramp' ,
RAMP_T='temp_ramp'/

/Ramp function to describe temperature of vaporization area
&RAMP ID='temp_ramp', T=0.0, F=1.0/
&RAMP ID='temp_ramp', T=350, F=1.0/

/Ramp function to describe mass flux rate (vaporization rate)
&RAMP ID='SF6_ramp', T=0.0, F=0.0/
&RAMP ID='SF6_ramp', T=99, F=0.0/
&RAMP ID='SF6_ramp', T=100, F=1.0/
&RAMP ID='SF6_ramp', T=350, F=1.0/

/LNG VAPORIZATION LOCATION
&VENT XB= -1.00, 1.00, -5.74, 5.74, 0, 0, SURF_ID='SF6_in',
COLOR='BLACK' /
&VENT XB= -4.06, 4.06, -4.06, 4.06, 0, 0, SURF_ID='SF6_in',
COLOR='BLACK' /
&VENT XB= -5.74, 5.74, -1.00, 1.00, 0, 0, SURF_ID='SF6_in',
COLOR='BLACK' /
&VENT XB= -4.97, 4.97, -2.87, 2.87, 0, 0, SURF_ID='SF6_in',
COLOR='BLACK' /
&VENT XB= -2.87, 2.87, -4.97, 4.97, 0, 0, SURF_ID='SF6_in',
COLOR='BLACK' /
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/Isosurfaces
&ISOF QUANTITY='SF6_VF', VALUE(1)=0.069, VALUE(2)=0.036,
VALUE(3)=0.022, VALUE(4)=0.017/

/Slice Files
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&SLCF PBX=100.53, QUANTITY='SF6_VF'/
&SLCF PBX=150.81, QUANTITY='SF6_VF'/
&SLCF PBX=201.08, QUANTITY='SF6_VF'/
&SLCF PBX=251.34, QUANTITY='SF6_VF'/
&SLCF PBX=301.61, QUANTITY='SF6_VF'/
&SLCF PBX=351.89, QUANTITY='SF6_VF'/
&SLCF PBX=389.60, QUANTITY='SF6_VF'/
&SLCF PBY=0.0, QUANTITY='SF6_VF' /
&SLCF PBZ=0.0, QUANTITY='SF6_VF' /
&SLCF PBZ=0.5, QUANTITY='SF6_VF' /
&SLCF PBZ=1.0, QUANTITY='SF6_VF' /

&SLCF PBX=0, QUANTITY='VELOCITY', VECTOR=.TRUE. /
&SLCF PBZ=1.177, QUANTITY='VELOCITY' , VECTOR=.TRUE. /
&SLCF PBZ=2.240, QUANTITY='VELOCITY' , VECTOR=.TRUE. /

/Instruments
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&DEVC ID='C300', XYZ=150.814, 0, 0, QUANTITY='SF6_VF' /
&DEVC ID='C400', XYZ=201.08, 0, 0, QUANTITY='SF6_VF' /
&DEVC ID='C400b', XYZ=201.08, 62.8448, 0, QUANTITY='SF6_VF' /
&DEVC ID='C400c', XYZ=201.08, 125.6732, 0, QUANTITY='SF6_VF' /
&DEVC ID='C400d', XYZ=201.08, 37.7036, 0, QUANTITY='SF6_VF' /
&DEVC ID='C500', XYZ=251.34, 0, 0, QUANTITY='SF6_VF' /
&DEVC ID='C600', XYZ=301.61, 0, 0, QUANTITY='SF6_VF' /
&DEVC ID='C600b', XYZ=301.61, 62.8448, 0, QUANTITY='SF6_VF' /
&DEVC ID='C700', XYZ=351.89, 0, 0, QUANTITY='SF6_VF' /
&DEVC ID='C800', XYZ=389.60, 0, 0, QUANTITY='SF6_VF' /
&DEVC ID='C900', XYZ=402.1608, 0, 0, QUANTITY='SF6_VF' /


&DEVC ID='C100b', XYZ=50.266, 0, 0.5, QUANTITY='SF6_VF' /
&DEVC ID='C200b', XYZ=100.53, 0, 0.5, QUANTITY='SF6_VF' /
&DEVC ID='C300b', XYZ=150.814, 0, 0.5, QUANTITY='SF6_VF' /
&DEVC ID='C400b', XYZ=201.08, 0, 0.5, QUANTITY='SF6_VF' /
&DEVC ID='C500b', XYZ=251.34, 0, 0.5, QUANTITY='SF6_VF' /
&DEVC ID='C600b', XYZ=301.61, 0, 0.5, QUANTITY='SF6_VF' /
&DEVC ID='C700b', XYZ=351.89, 0, 0.5, QUANTITY='SF6_VF' /
&DEVC ID='C800b', XYZ=389.60, 0, 0.5, QUANTITY='SF6_VF' /

&DEVC ID='C100c', XYZ=50.266,   0, 1, QUANTITY='SF6_VF' /
&DEVC ID='C200c', XYZ=100.53,   0, 1, QUANTITY='SF6_VF' /
&DEVC ID='C300c', XYZ=150.814, 0, 1, QUANTITY='SF6_VF' /
&DEVC ID='C400c', XYZ=201.08,   0, 1, QUANTITY='SF6_VF' /
&DEVC ID='C500c', XYZ=251.34,   0, 1, QUANTITY='SF6_VF' /
&DEVC ID='C600c', XYZ=301.61,   0, 1, QUANTITY='SF6_VF' /
&DEVC ID='C700c', XYZ=351.89,   0, 1, QUANTITY='SF6_VF' /
&DEVC ID='C800c', XYZ=389.60,   0, 1, QUANTITY='SF6_VF' /
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&MESH IJK=100, 60, 10, XB=-30, 170, -60, 60, 0, 10 /

&TIME TWFIN=1000.00, DT=0.5, SYNCHRONIZE=.TRUE. /
&DUMP DT_DEVC=1, DT_SLCF=1, DT_ISOF=1, DT_BNDF=4000, DT_PL3D=4000,
DT_HRR=4000, NFRAMES=500/

/Ambient Conditions and Miscellaneous information
&MISC TMPA=19.85, LAPSE_RATE=-0.0097, U0=0, V0=0, W0=0, HUMIDITY=0,
SURF_DEFAULT='INERT', RADIATION=.FALSE./

&SPEC ID='SF6', MASS_FRACTION_0=0, MW=146.1/

/WEATHER
&SURF ID='WIND', VEL=-5.12, VEL_T=0.0, 0.0, PROFILE='ATMOSPHERIC',
Z0=0.65, PLE=0.242 /

/OPEN SIDES, TOP
&VENT MB='XMIN', SURF_ID='WIND'   /
&VENT MB='XMAX' , SURF_ID='OPEN'   /
&VENT MB='YMIN', SURF_ID='MIRROR' /
&VENT MB='YMAX' , SURF_ID='MIRROR' /
&VENT MB='ZMAX' , SURF_ID='MIRROR' /

/Source
&SURF ID='SF6_in', MASS_FLUX(1)=0.245, RAMP_MF(1)='SF6_ramp' ,
RAMP_T='temp_ramp', COLOR='BLACK'/

/Ramp function to describe temperature of vaporization area
&RAMP ID='temp_ramp', T=0.0, F=1.0/
&RAMP ID='temp_ramp', T=150, F=1.0/

/Ramp function to describe mass flux rate (vaporization rate)
&RAMP ID='SF6_ramp', T=0.0, F=1.0/
&RAMP ID='SF6_ramp', T=150, F=1.0/

/Source Location
&VENT XB= -4, 4, -4, 4, 0, 0, SURF_ID='SF6_in', COLOR='BLACK' /

/fence
&OBST XB= 48, 48, -60, 60, 0, 2/

&ISOF QUANTITY='SF6_VF', VALUE(1)=0.016, VALUE(2)=0.044,
VALUE(3)=0.008, VALUE(4)=0.040, VALUE(5)=0.006, VALUE(6)=0.020,
VALUE(7)=0.013, VALUE(8)=0.014, VALUE(9)=0.025/

/Slice Files
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&SLCF PBY=  0,       QUANTITY='VELOCITY', VECTOR=.TRUE./
&SLCF PBY= 50,       QUANTITY='VELOCITY', VECTOR=.TRUE./
&SLCF PBZ=  0.65,    QUANTITY='VELOCITY', VECTOR=.TRUE./
&SLCF PBZ=  5,       QUANTITY='VELOCITY', VECTOR=.TRUE./
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&SLCF PBX=  50.778,  QUANTITY='SF6_VF' /
&SLCF PBX=  29.64,   QUANTITY='SF6_VF' /
&SLCF PBX=  65.286,  QUANTITY='SF6_VF' /
&SLCF PBX=  43.524,  QUANTITY='SF6_VF' /
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&SLCF PBX=  54.678,  QUANTITY='SF6_VF' /
&SLCF PBX=  46.098,  QUANTITY='SF6_VF' /
&SLCF PBZ=    0,     QUANTITY='SF6_VF' /
&SLCF PBZ=    0.5,   QUANTITY='SF6_VF' /
&SLCF PBZ=    1.0,   QUANTITY='SF6_VF' /
&SLCF PBZ=    1.5,   QUANTITY='SF6_VF' /
&SLCF PBZ=    2.0,   QUANTITY='SF6_VF' /

/Instruments
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&DEVC ID='C02', XYZ=50.778,   9.906,  0, QUANTITY='SF6_VF' /
&DEVC ID='C03', XYZ=40.17,   27.69,   0, QUANTITY='SF6_VF' /
&DEVC ID='C04', XYZ=29.64,    9.906,  0, QUANTITY='SF6_VF' /
&DEVC ID='C05', XYZ=65.286,  -3.978,  0, QUANTITY='SF6_VF' /
&DEVC ID='C06', XYZ=43.524,   9.906,  0, QUANTITY='SF6_VF' /
&DEVC ID='C07', XYZ=50.778,  24.414,  0, QUANTITY='SF6_VF' /
&DEVC ID='C08', XYZ=54.678,  -0.624,  0, QUANTITY='SF6_VF' /
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&TIME TWFIN=1500.00, DT=0.5, SYNCHRONIZE=.TRUE. /
&DUMP DT_DEVC=1, DT_SLCF=1, DT_ISOF=1, DT_BNDF=4000, DT_PL3D=4000,
DT_HRR=4000, NFRAMES=750/

/Ambient Conditions and Miscellanious information
&MISC TMPA=19.85, LAPSE_RATE=-0.0097, U0=0, V0=0, W0=0, HUMIDITY=0,
SURF_DEFAULT='INERT', RADIATION=.FALSE./

&SPEC ID='SF6', MASS_FRACTION_0=0, MW=146.1/

/WEATHER
&SURF ID='WIND', VEL=-6.88, PROFILE='ATMOSPHERIC', Z0=1.17,
PLE=0.218 /

/OPEN SIDES, TOP
&VENT MB='XMIN', SURF_ID='MIRROR'   /
&VENT MB='XMAX', SURF_ID='OPEN'   /
&VENT MB='YMIN', SURF_ID='WIND' /
&VENT MB='YMAX', SURF_ID='MIRROR' /
&VENT MB='ZMAX', SURF_ID='MIRROR' /

/Source
&SURF ID='SF6_in', MASS_FLUX(1)=1.0263, RAMP_MF(1)='SF6_ramp' ,
RAMP_T='temp_ramp'/

/Ramp function to describe temperature of vaporization area
&RAMP ID='temp_ramp', T=    0, F=0.0/
&RAMP ID='temp_ramp', T=   99, F=1.0/
&RAMP ID='temp_ramp', T=  100, F=1.0/
&RAMP ID='temp_ramp', T= 1500, F=1.0/

/Ramp function to describe mass flux rate (vaporization rate)
&RAMP ID='SF6_ramp', T=    0, F=0.0/
&RAMP ID='SF6_ramp', T=   99, F=0.0/
&RAMP ID='SF6_ramp', T=  100, F=1.0/
&RAMP ID='SF6_ramp', T= 1500, F=1.0/

/Source Location
&VENT XB= -4, 4, -4, 4, 0, 0, SURF_ID='SF6_in', COLOR='BLACK' /

/Isosurfaces
&ISOF QUANTITY='SF6_VF', VALUE(1)=0.092, VALUE(2)=0.041,
VALUE(3)=0.024, VALUE(4)=0.017, VALUE(5)=0.010/

/Slice Files
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&SLCF PBY=   0,    QUANTITY='VELOCITY', VECTOR=.TRUE./
&SLCF PBY= 200,    QUANTITY='VELOCITY', VECTOR=.TRUE./
&SLCF PBZ=   1.17, QUANTITY='VELOCITY', VECTOR=.TRUE./
&SLCF PBZ=  10,    QUANTITY='VELOCITY', VECTOR=.TRUE./
&SLCF PBX=  49.92, QUANTITY='SF6_VF' /
&SLCF PBX=  99.84, QUANTITY='SF6_VF' /
&SLCF PBX=149.76, QUANTITY='SF6_VF' /
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&SLCF PBX=249.6,  QUANTITY='SF6_VF' /
&SLCF PBX=299.52, QUANTITY='SF6_VF' /
&SLCF PBZ=  0.0,  QUANTITY='SF6_VF' /
&SLCF PBZ=  0.5,  QUANTITY='SF6_VF' /
&SLCF PBZ=  1.0,  QUANTITY='SF6_VF' /
&SLCF PBZ=  1.5,  QUANTITY='SF6_VF' /
&SLCF PBZ=  2.0,  QUANTITY='SF6_VF' /


/Instruments
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&DEVC ID='C02', XYZ=49.92, 23.4, 0.078, QUANTITY='SF6_VF' /
&DEVC ID='C03', XYZ=49.92, 15.6, 0.078, QUANTITY='SF6_VF' /
&DEVC ID='C04', XYZ=49.92, 7.8, 0.078, QUANTITY='SF6_VF' /
&DEVC ID='C05', XYZ=49.92, 0, 0.078, QUANTITY='SF6_VF' /
&DEVC ID='C06', XYZ=49.92, -7.8, 0.078, QUANTITY='SF6_VF' /
&DEVC ID='C07', XYZ=49.92, -15.6, 0.078, QUANTITY='SF6_VF' /
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&DEVC ID='C09', XYZ=49.92,  -31.2, 0.078, QUANTITY='SF6_VF' /
&DEVC ID='C10', XYZ=49.92, -39, 0.078, QUANTITY='SF6_VF' /
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&DEVC ID='C41', XYZ=199.76, 31.2, 0.078, QUANTITY='SF6_VF' /
&DEVC ID='C42', XYZ=199.76, 23.4, 0.078, QUANTITY='SF6_VF' /
&DEVC ID='C43', XYZ=199.76, 15.6, 0.078, QUANTITY='SF6_VF' /
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&DEVC ID='C46', XYZ=199.76, -7.8, 0.078, QUANTITY='SF6_VF' /
&DEVC ID='C47', XYZ=199.76, -15.6, 0.078, QUANTITY='SF6_VF' /
&DEVC ID='C48', XYZ=199.76, -23.4, 0.078, QUANTITY='SF6_VF' /
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&DEVC ID='C50', XYZ=199.76, -39, 0.078, QUANTITY='SF6_VF' /
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&DEVC ID='C53', XYZ=249.6, 39, 0.078, QUANTITY='SF6_VF' /
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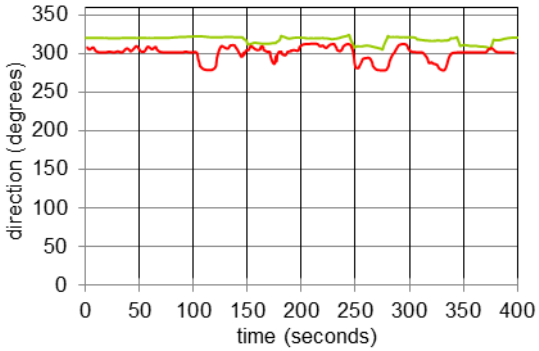
Appendix C

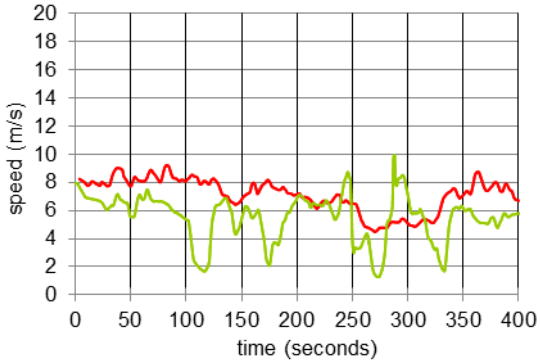
Point-Wise Wind Speeds

(red lines: experimental data; green lines: FDS data)

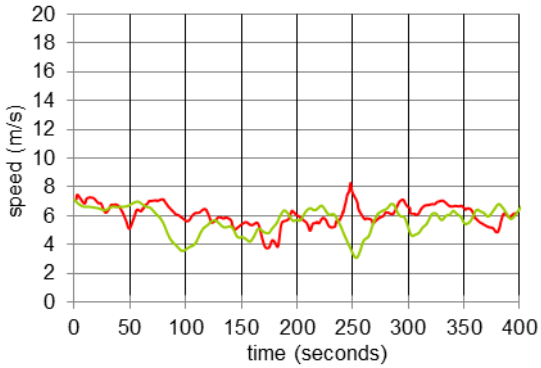
Maplin Sands 27



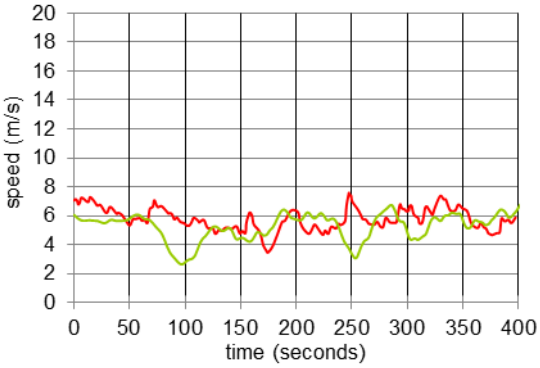
Wind Direction at r=249m, r=90°, z=10.3m



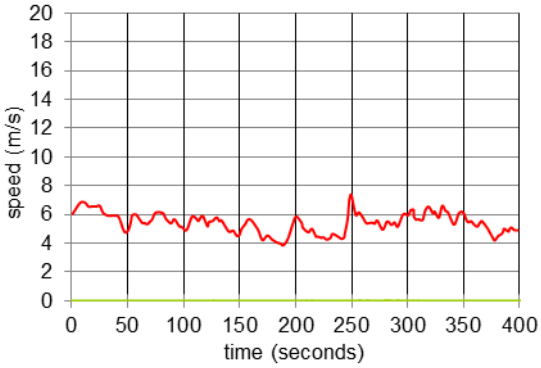
Wind Direction at r=246m, r=270°, z=10.1m



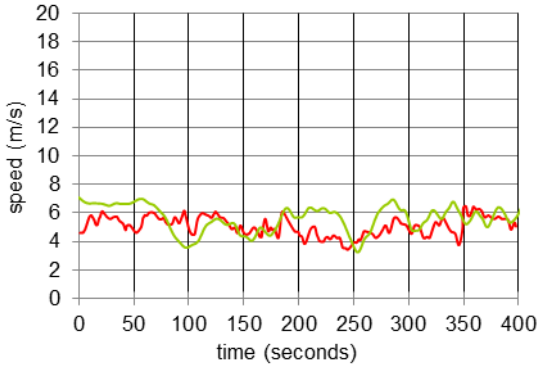
Wind Direction at r=249m, r=90°, z=10.4m



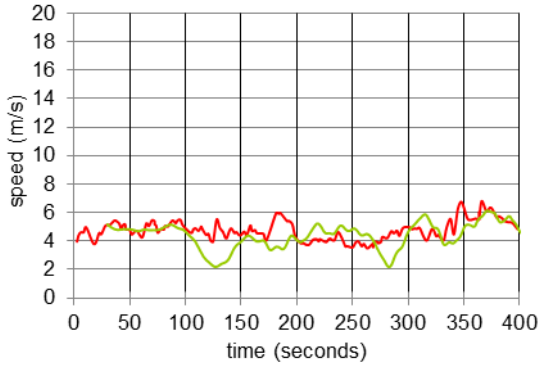
Wind Direction at r=249m, r=90°, z=3.3m



Wind Direction at r=249m, r=90°, z=0.9m

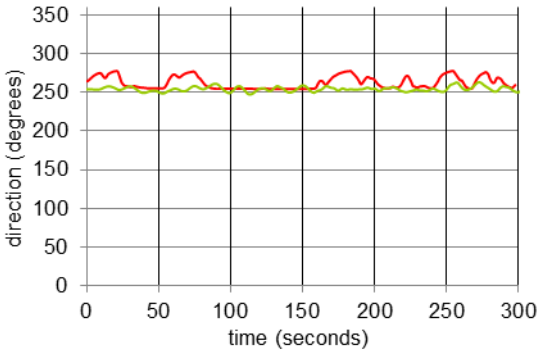


Wind Direction at r=251m, r=0°, z=1.0m

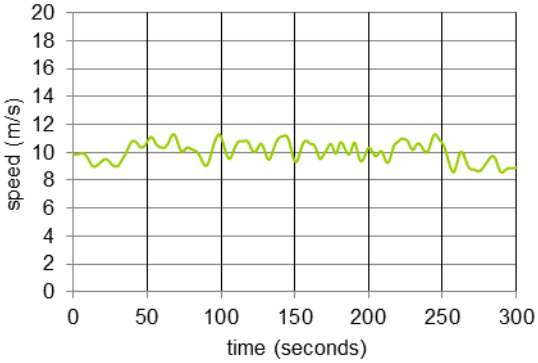


Wind Direction at r=251m, r=0°, z=1.0m

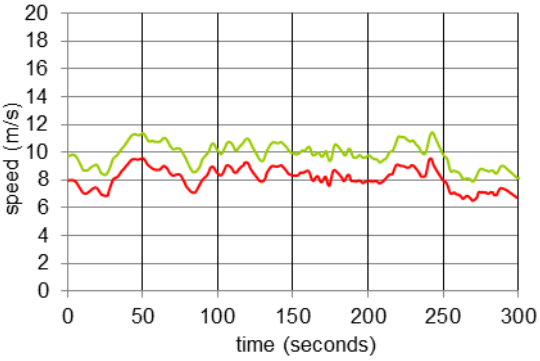
Maplin Sands 34



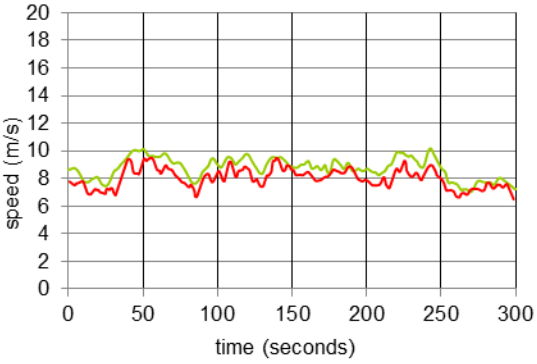
Wind Direction at r=249m, r=90°, z=10.3m



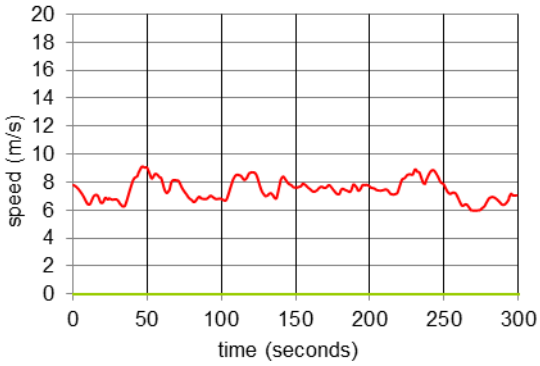
Wind Direction at r=246m, r=270°, z=10.1m



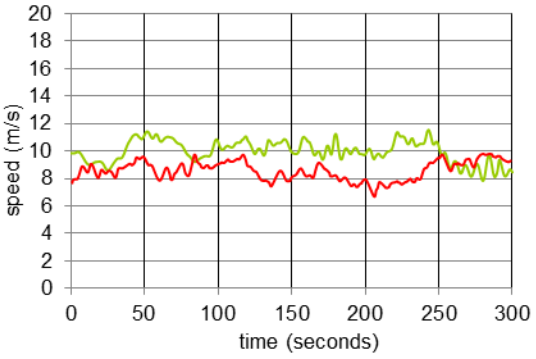
Wind Direction at r=249m, r=90°, z=10.4m



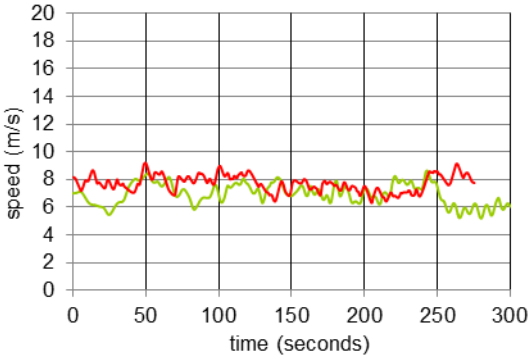
Wind Direction at r=249m, r=90°, z=3.3m



Wind Direction at r=249m, r=90°, z=0.9m

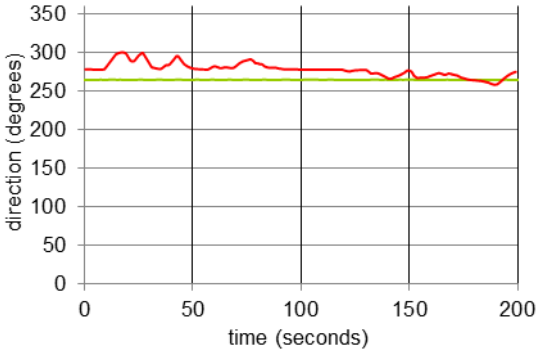


Wind Direction at r=251m, r=0°, z=1.0m

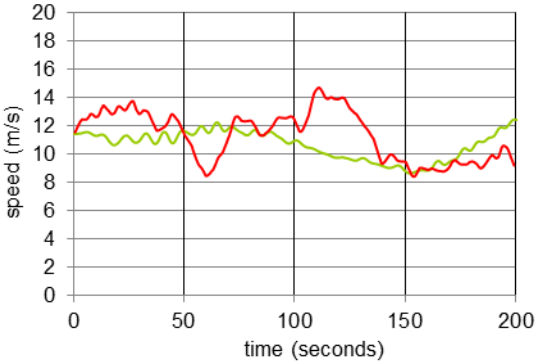


Wind Direction at r=251m, r=0°, z=1.0m

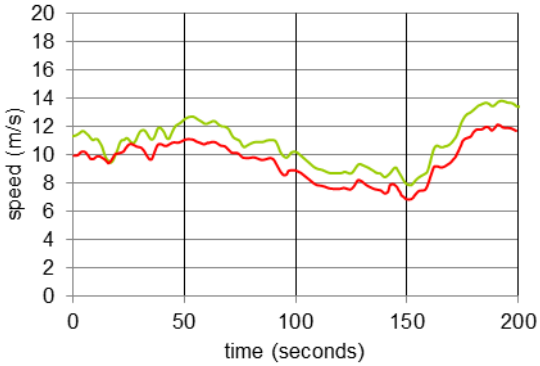
Maplin Sands 35



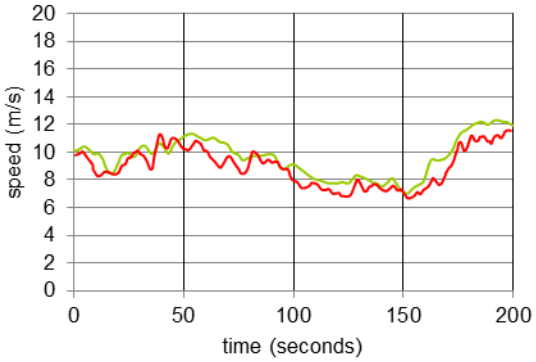
Wind Direction at r=249m, r=90°, z=10.3m



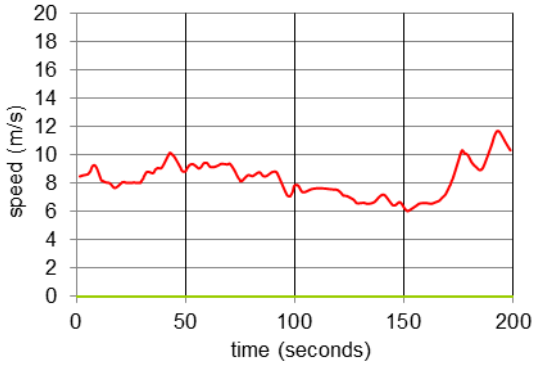
Wind Direction at r=246m, r=270°, z=10.1m



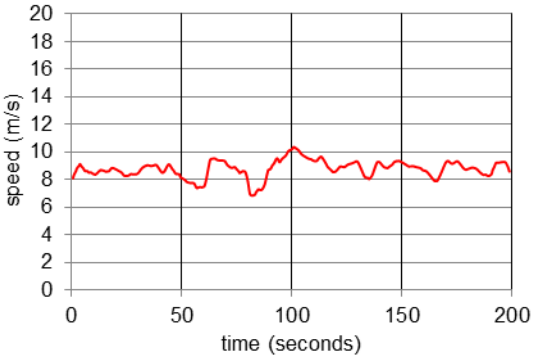
Wind Direction at r=249m, r=90°, z=10.4m



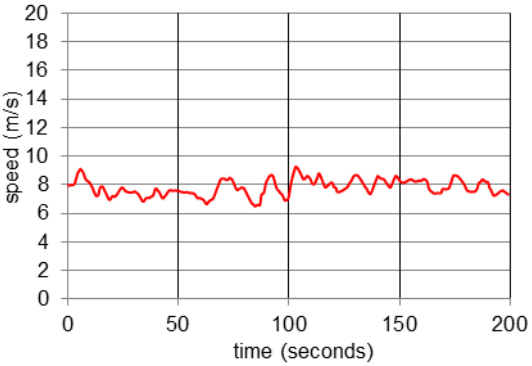
Wind Direction at r=249m, r=90°, z=3.3m



Wind Direction at r=249m, r=90°, z=0.9m

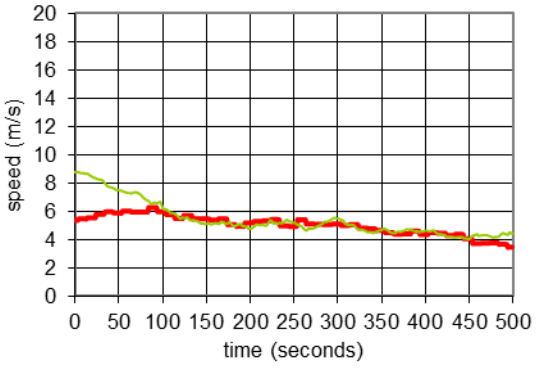


Wind Direction at r=251m, r=0°, z=1.0m

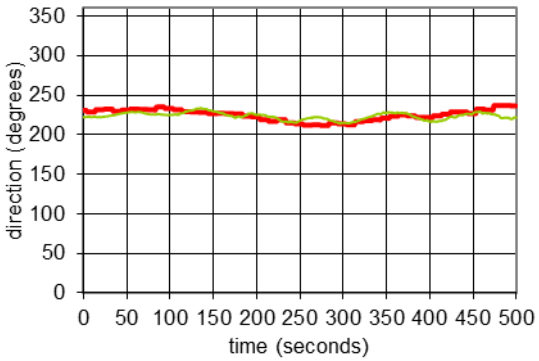


Wind Direction at r=251m, r=0°, z=1.0m

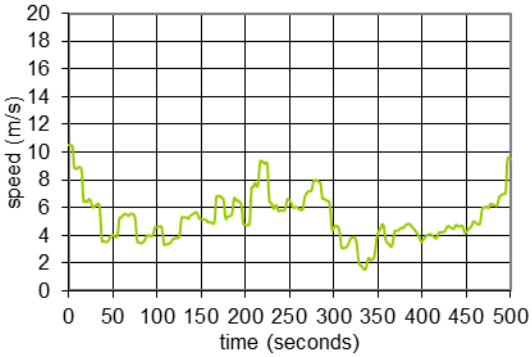
Burro 3



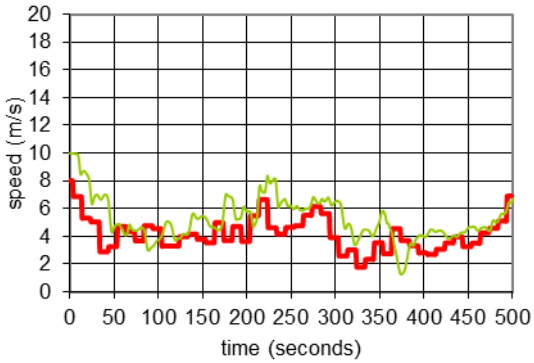
Average Wind Speed



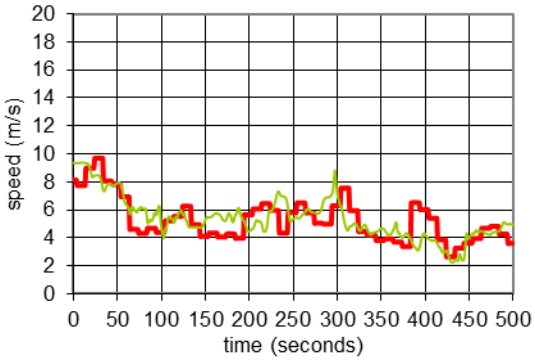
Averaged Wind Direction



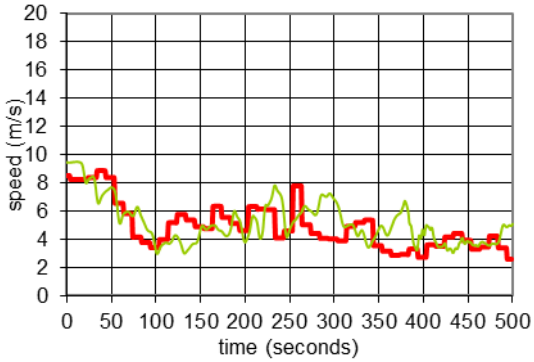
Wind Speed at x=-800m, y=0m, z=2m



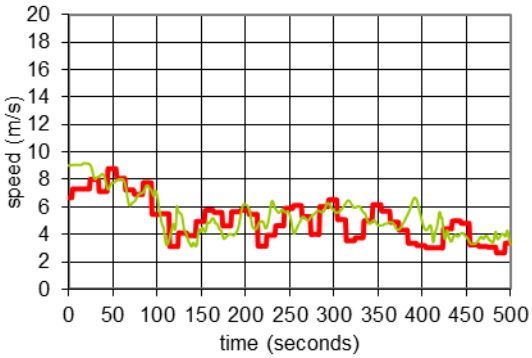
Wind Speed at x=-600m, y=0m, z=2m



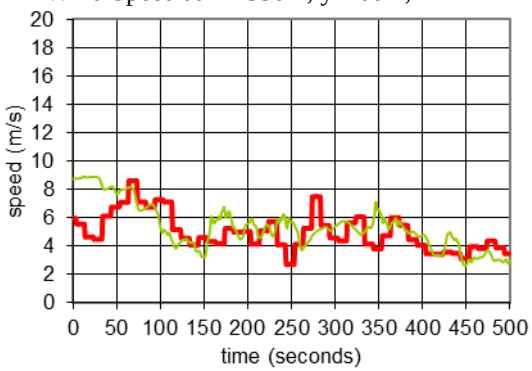
Wind Speed at x=-350m, y=60m, z=2m



Wind Speed at x=-350m, y=-60m, z=2m

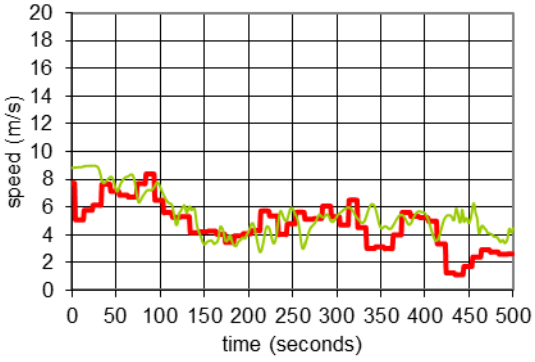


Wind Speed at x=-150m, y=0m, z=2m

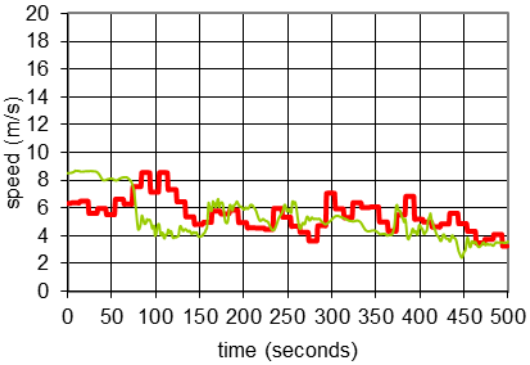


Wind Speed at x=0m, y=60m, z=2m

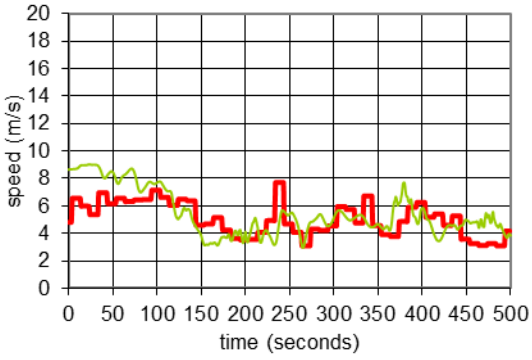
Burro 3 (continued)



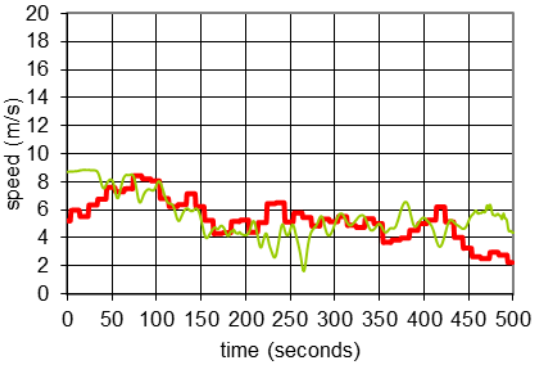
Wind Speed at x=0m, y=-60m, z=2m



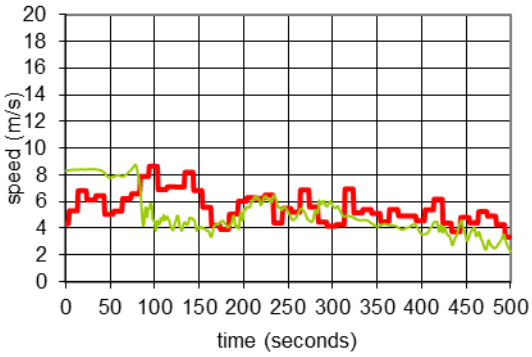
Wind Speed at x=104m, y=120m, z=2m



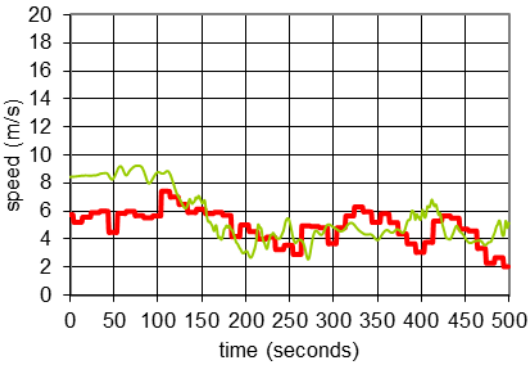
Wind Speed at x=104m, y=0m, z=2m



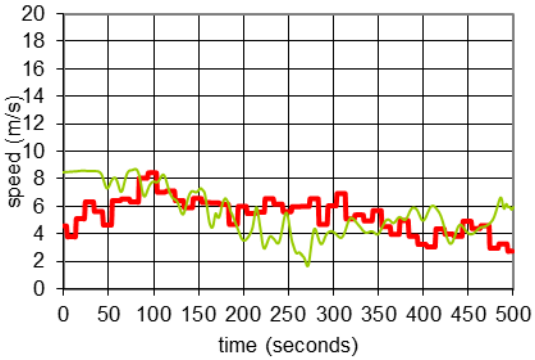
Wind Speed at x=104m, y=-120m, z=2m



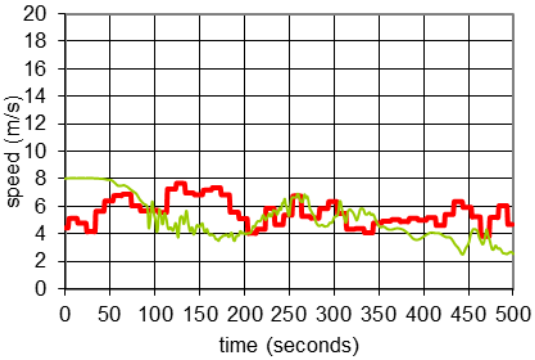
Wind Speed at x=275m, y=130m, z=2m



Wind Speed at x=275m, y=0m, z=2m

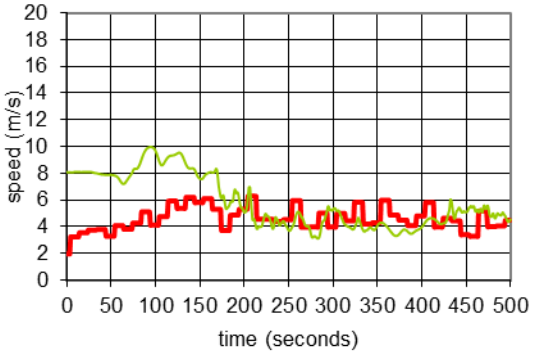


Wind Speed at x=275m, y=-130m, z=2m

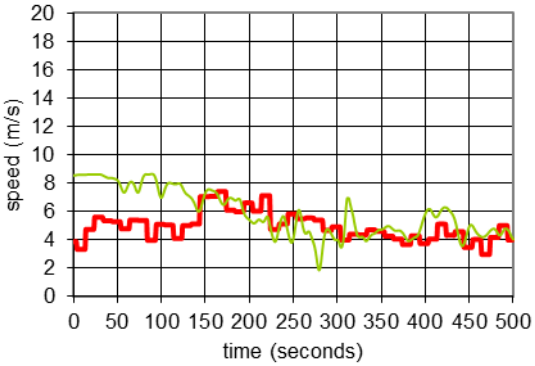


Wind Speed at x=480m, y=170m, z=2m

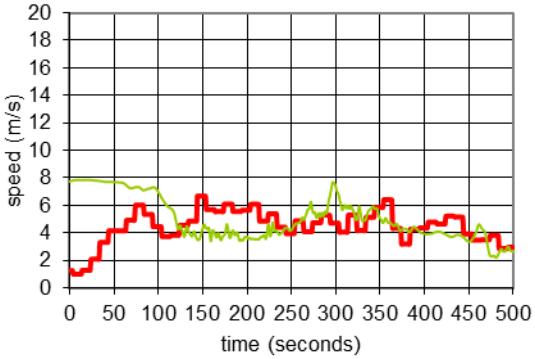
Burro 3 (continued)



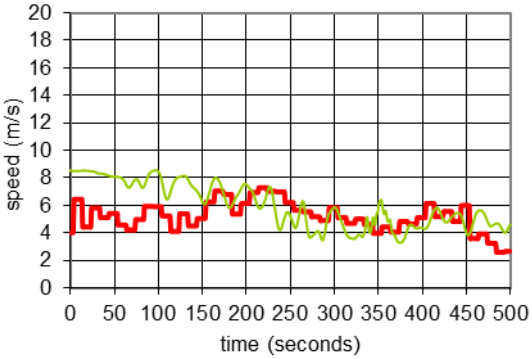
Wind Speed at x=600m, y=0m, z=2m



Wind Speed at x=480, y=-170m, z=2m

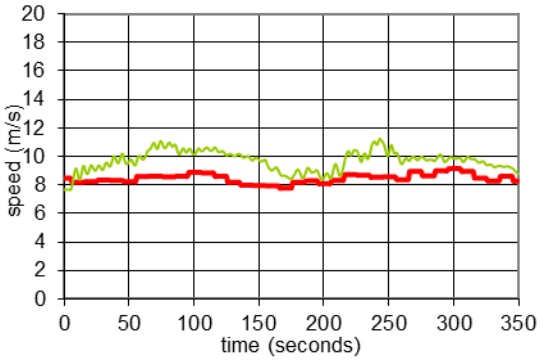


Wind Speed at x=670m, y=170m, z=2m

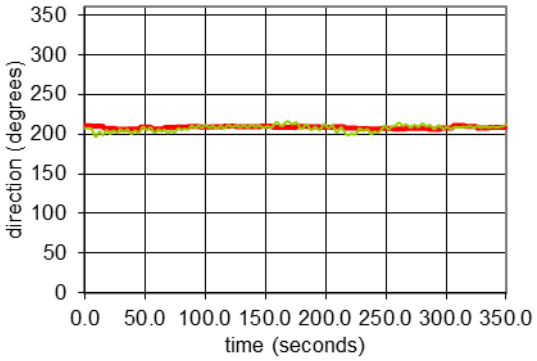


Wind Speed at x=670m, y=170m, z=2m

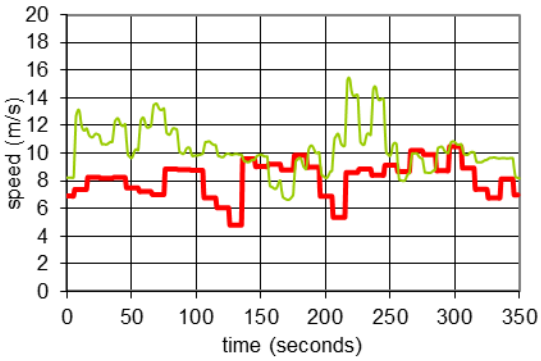
Burro 7



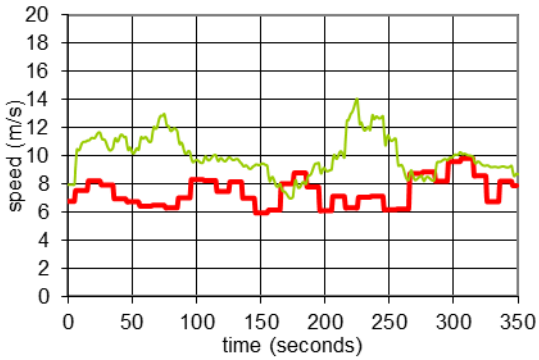
Average Wind Speed



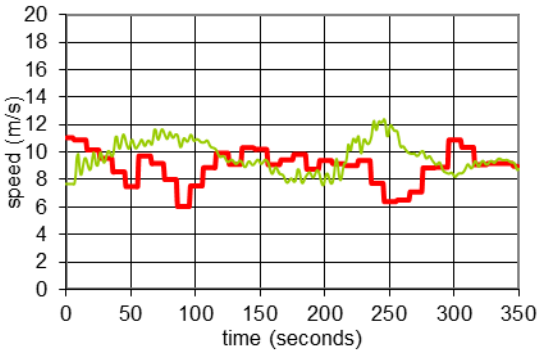
Averaged Wind Direction



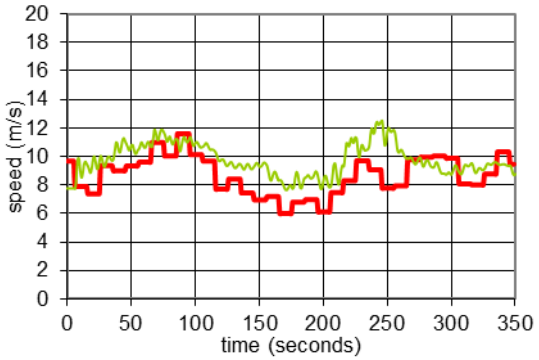
Wind Speed at x=-800m, y=0m, z=2m



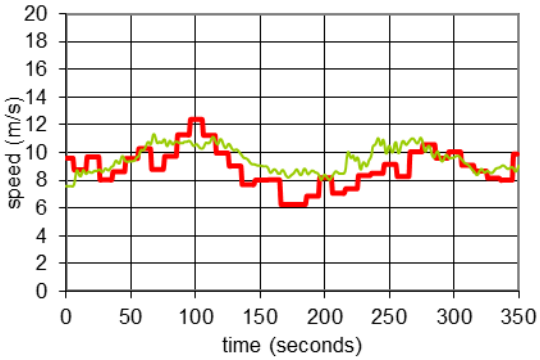
Wind Speed at x=-600m, y=0m, z=2m



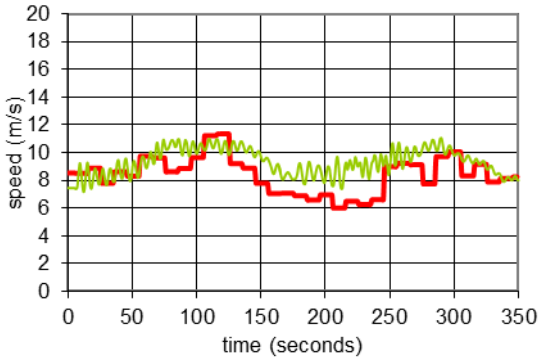
Wind Speed at x=-350m, y=60m, z=2m



Wind Speed at x=-350m, y=-60m, z=2m

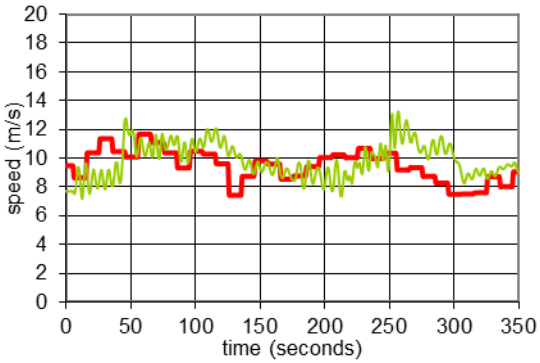


Wind Speed at x=-150m, y=0m, z=2m

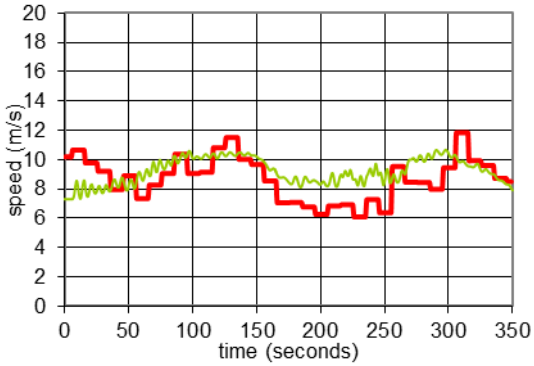


Wind Speed at x=0m, y=60m, z=2m

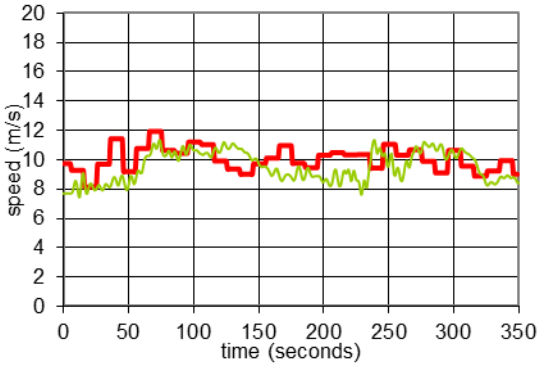
Burro 7 (continued)



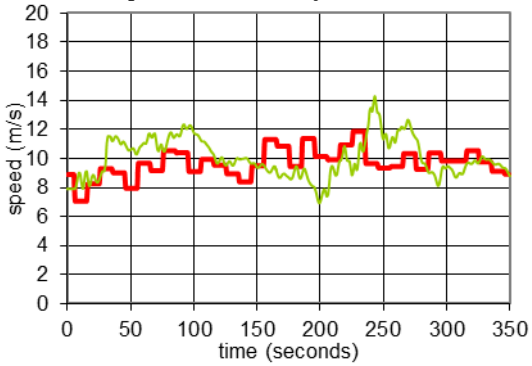
Wind Speed at x=0m, y=-60m, z=2m



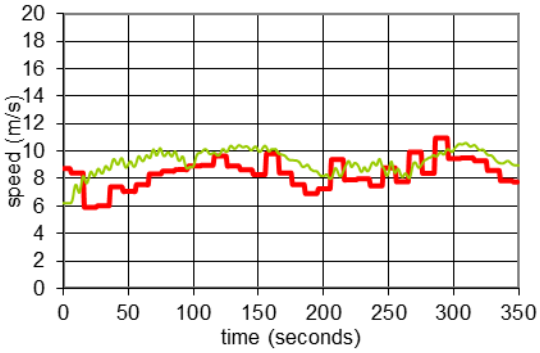
Wind Speed at x=104m, y=120m, z=2m



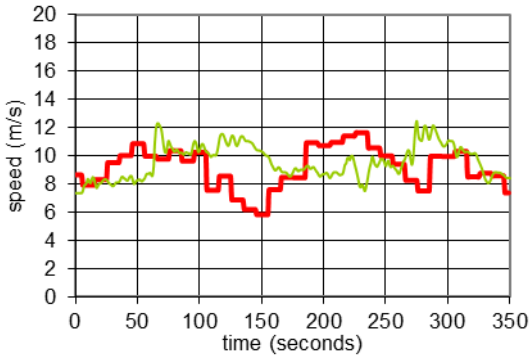
Wind Speed at x=104m, y=0m, z=2m



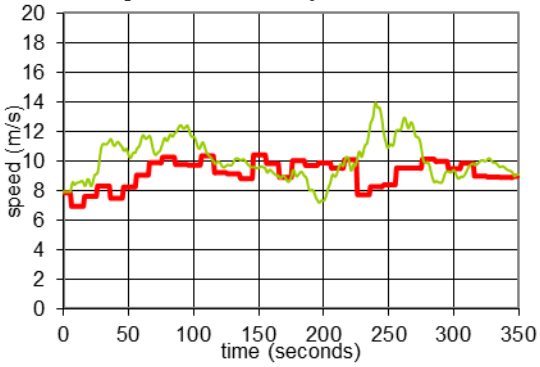
Wind Speed at x=104m, y=-120m, z=2m



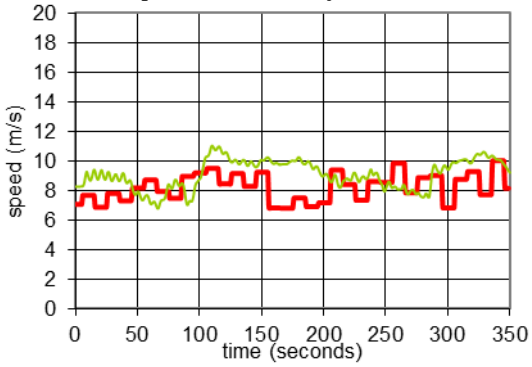
Wind Speed at x=275m, y=130m, z=2m



Wind Speed at x=275m, y=0m, z=2m

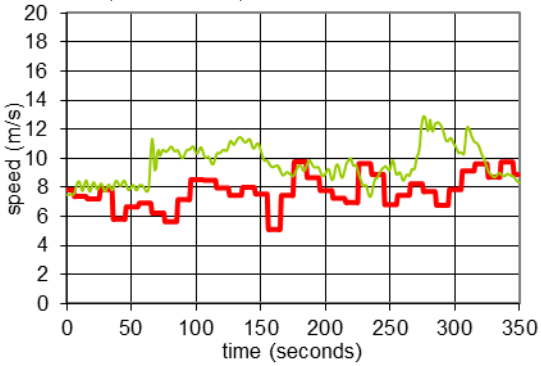


Wind Speed at x=275m, y=-130m, z=2m

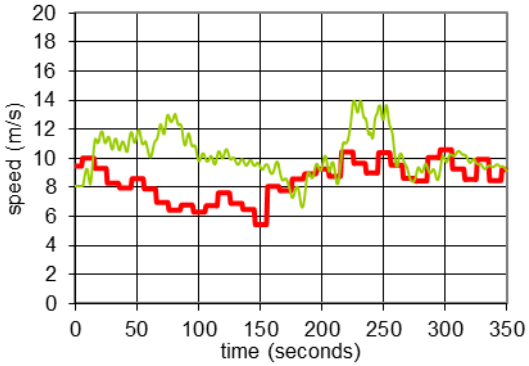


Wind Speed at x=480m, y=170m, z=2m

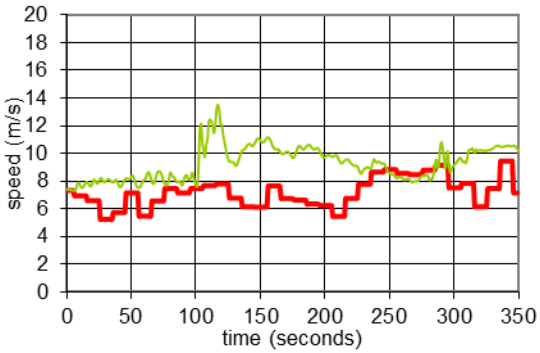
Burro 7 (continued)



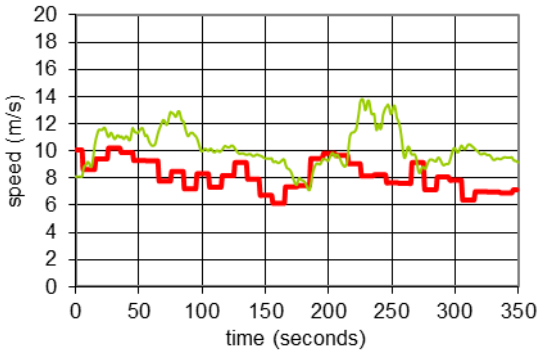
Wind Speed at x=600m, y=0m, z=2m



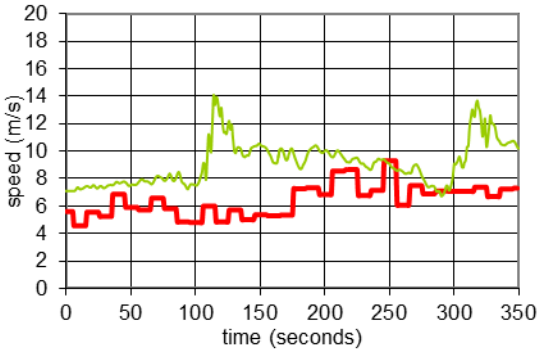
Wind Speed at x=480, y=-170, z=2m



Wind Speed at x=670m, y=170m, z=2m

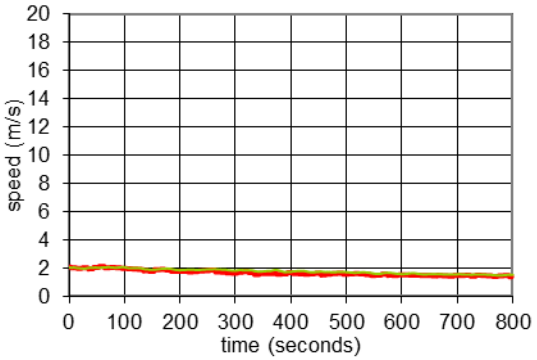


Wind Speed at x=670m, y=-170m, z=2m

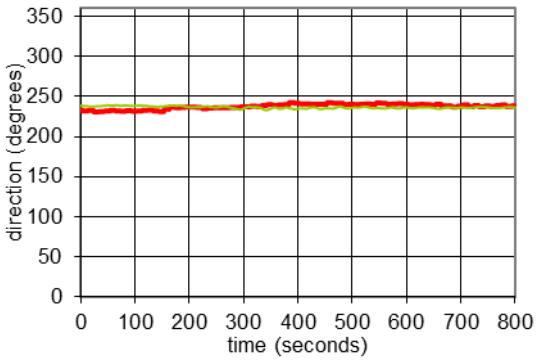


Wind Speed at x=882m, y=180m, z=2m

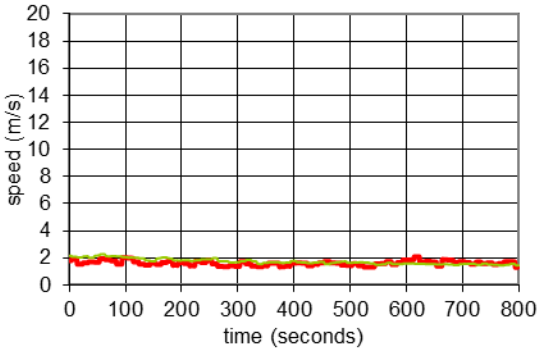
Burro 8



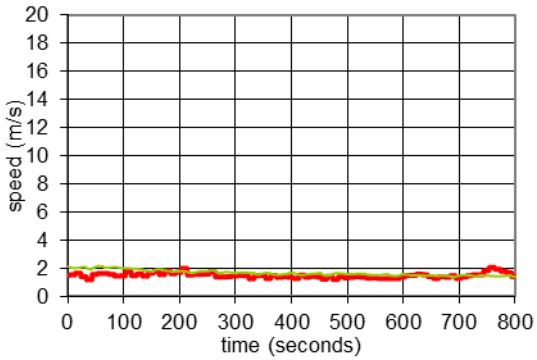
Average Wind Speed



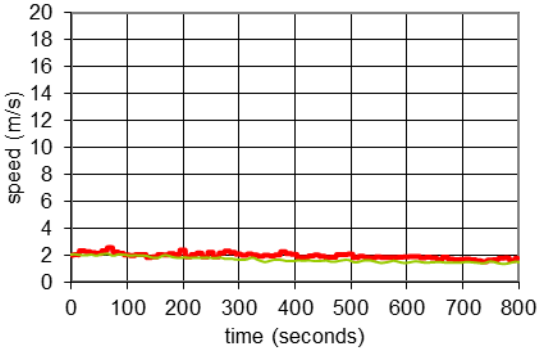
Averaged Wind Direction



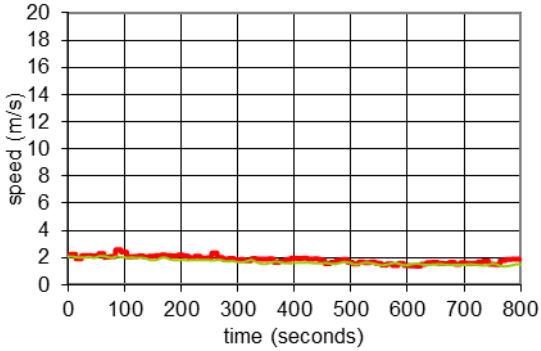
Wind Speed at x=-800m, y=0m, z=2m



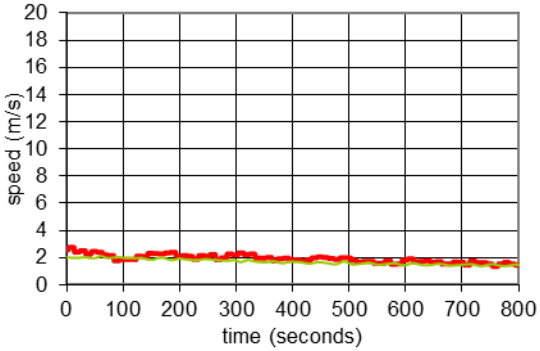
Wind Speed at x=-600m, y=0m, z=2m



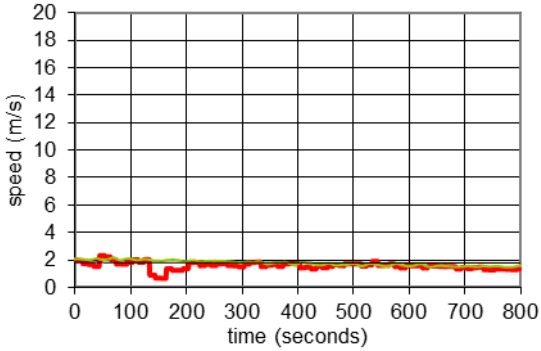
Wind Speed at x=-350m, y=60m, z=2m



Wind Speed at x=-350m, y=-60m, z=2m

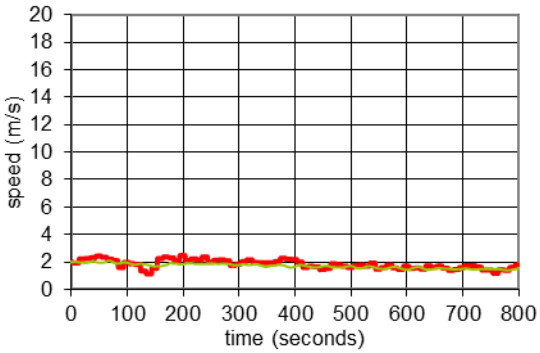


Wind Speed at x=-150m, y=0m, z=2m

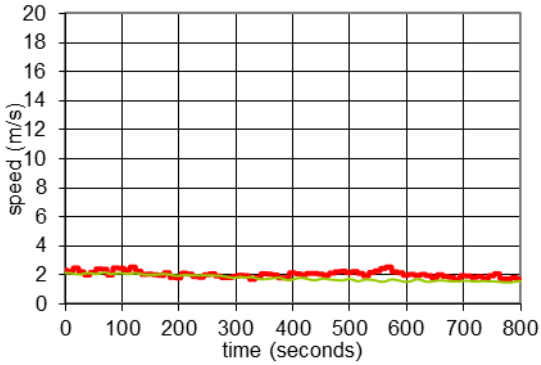


Wind Speed at x=0m, y=60m, z=2m

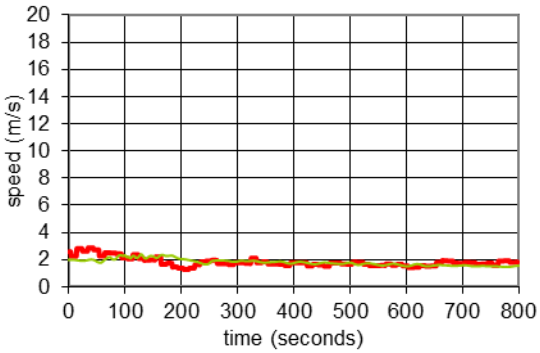
Burro 8 (continued)



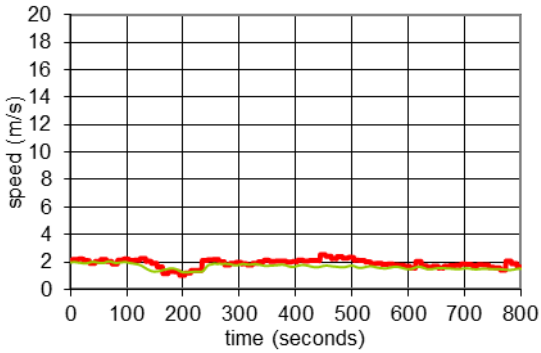
Wind Speed at x=0m, y=-60m, z=2m



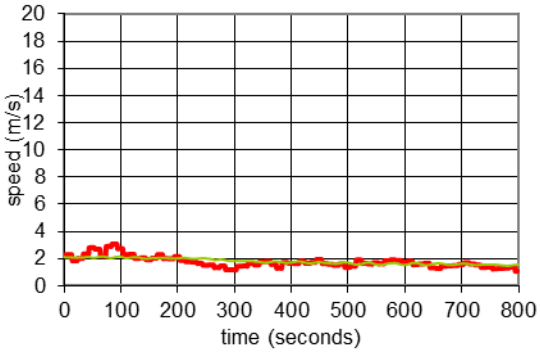
Wind Speed at x=104m, y=120m, z=2m



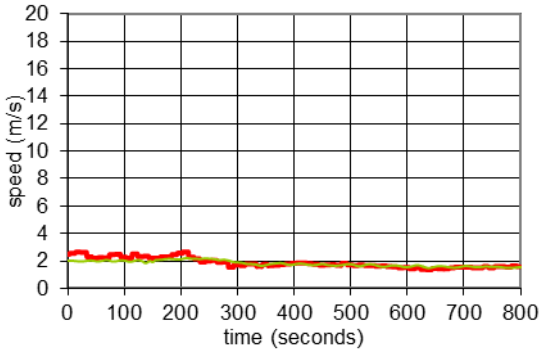
Wind Speed at x=104m, y=0m, z=2m



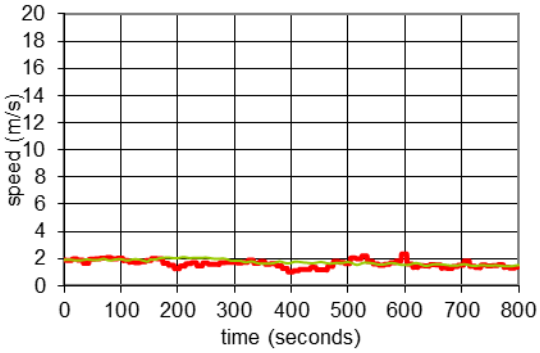
Wind Speed at x=104m, y=-120m, z=2m



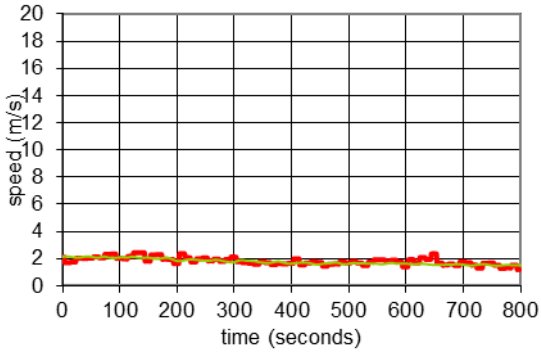
Wind Speed at x=275m, y=130m, z=2m



Wind Speed at x=275m, y=0m, z=2m

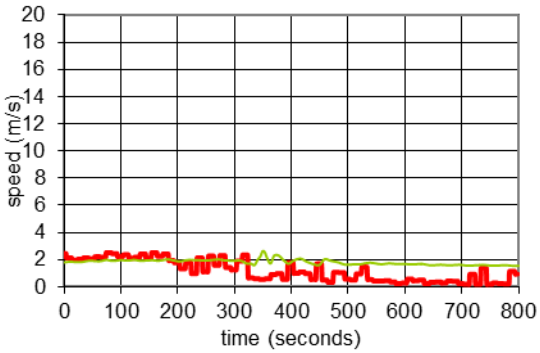


Wind Speed at x=275m, y=-130m, z=2m

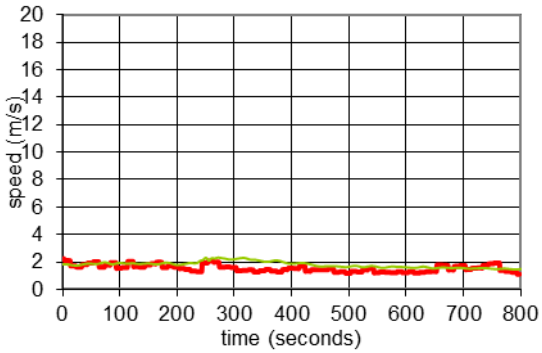


Wind Speed at x=480m, y=170, z=2m

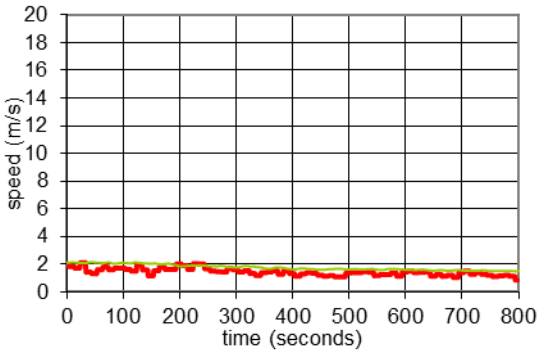
Burro 8 (continued)



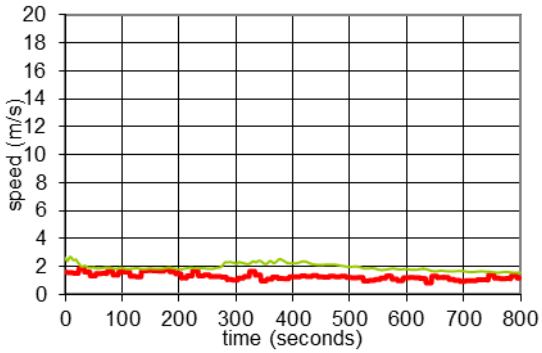
Wind Speed at x=600m, y=0m, z=2m



Wind Speed at x=480m, y=-170m, x=2m

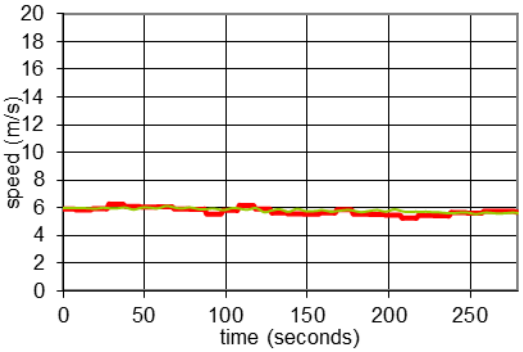


Wind Speed at x=670m, y=170m, z=2m

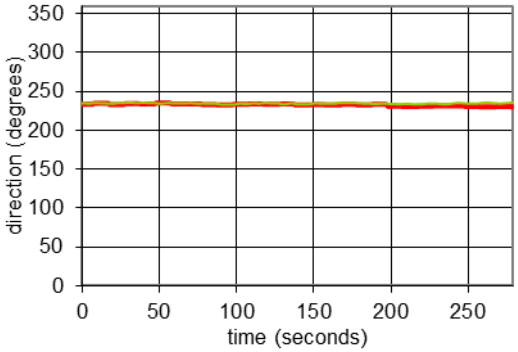


Wind Speed at x=670m, y=-170m, z=2m

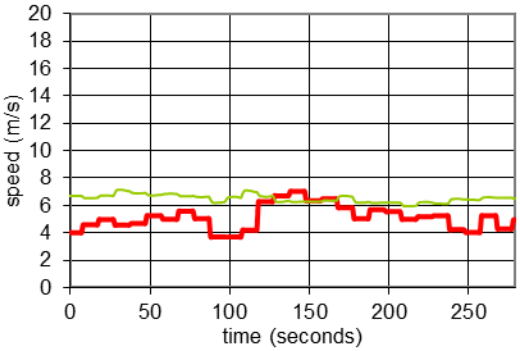
Burro 9



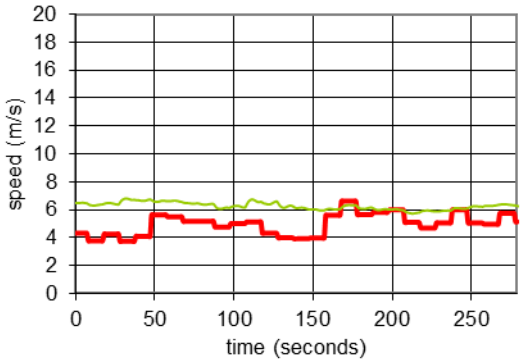
Average Wind Speed



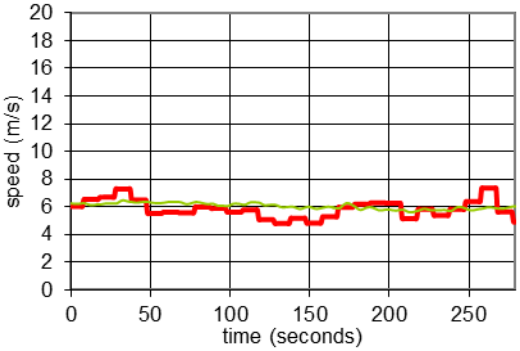
Average Wind Direction



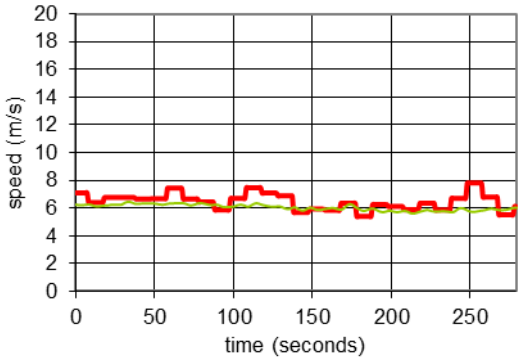
Wind Speed at x=-800m, y=0m, z=2m



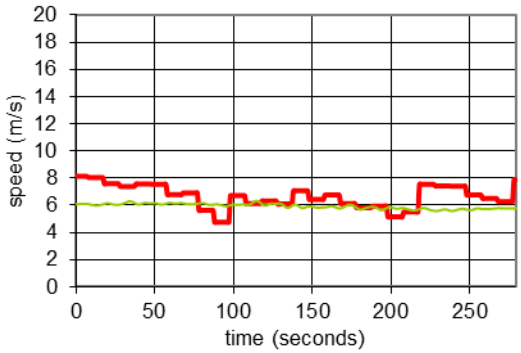
Wind Speed at x=-600m, y=0m, z=2m



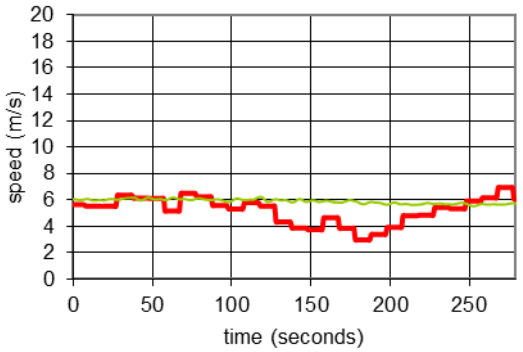
Wind Speed at x=-350m, y=60m, z=2m



Wind Speed at x=-350m, y=-60m, z=2m

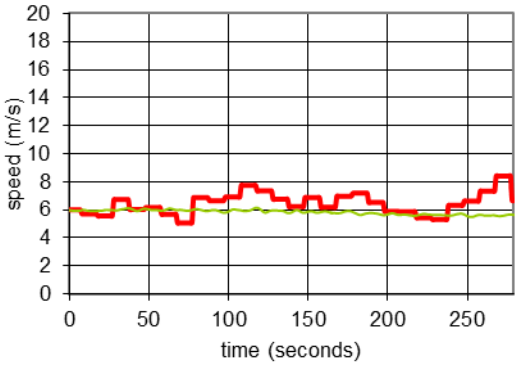


Wind Speed at x=-150m, y=0m, z=2m

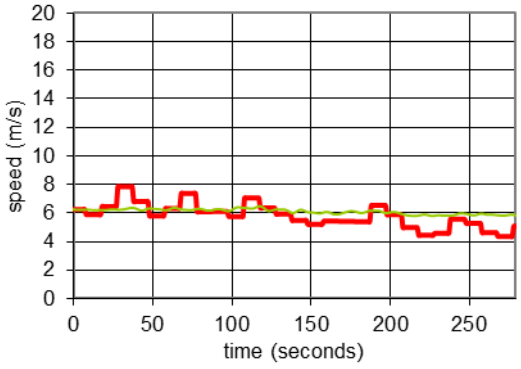


Wind Speed at x=0m, y=60m, z=2m

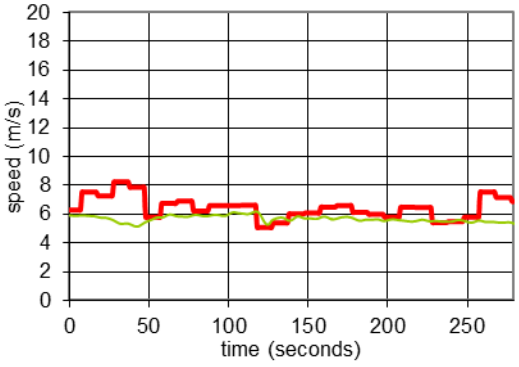
Burro 9 (continued)



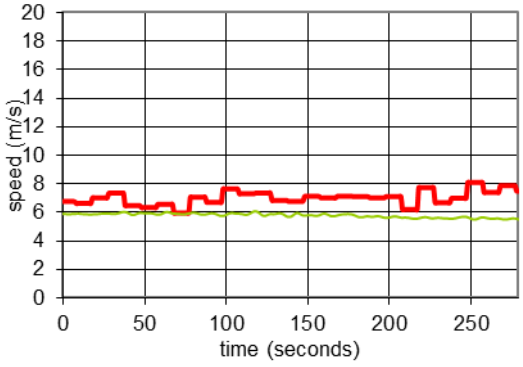
Wind Speed at x=0m, y=-60m, z=2m



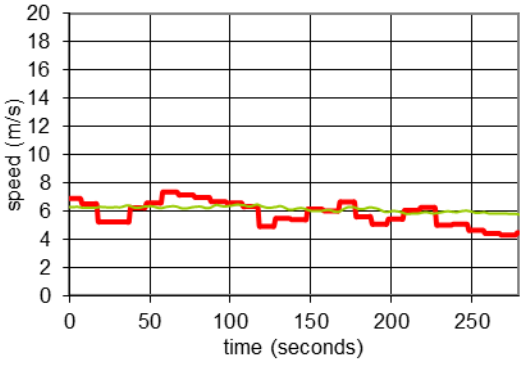
Wind Speed at x=104m, y=120m, z=2m



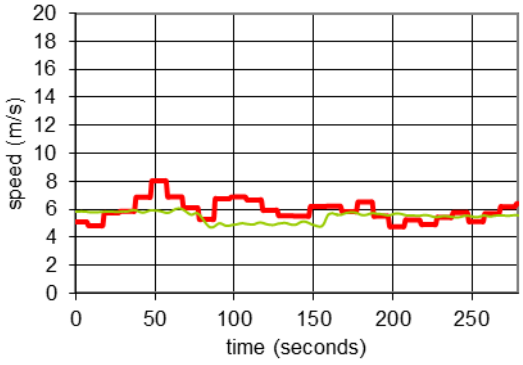
Wind Speed at x=104m, y=0m, z=2m



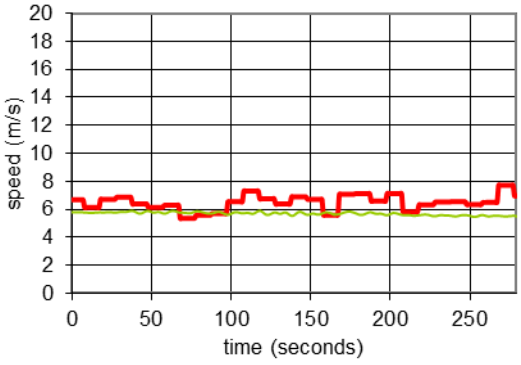
Wind Speed at x=104m, y=-120m, z=2m



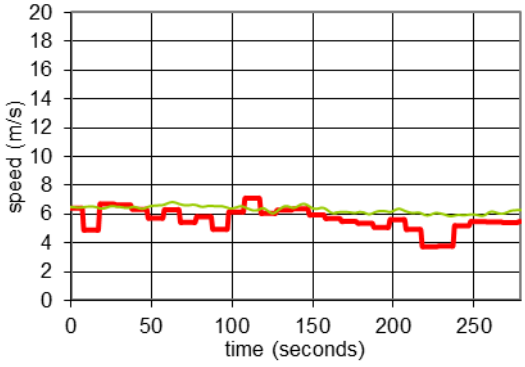
Wind Speed at x=275m, y=130m, z=2m



Wind Speed at x=275m, y=0m, z=2m

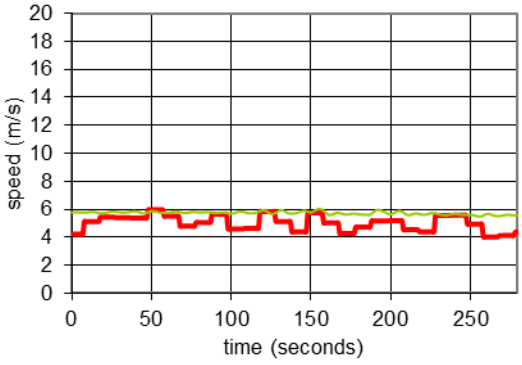


Wind Speed at x=275m, y=-130m, z=2m

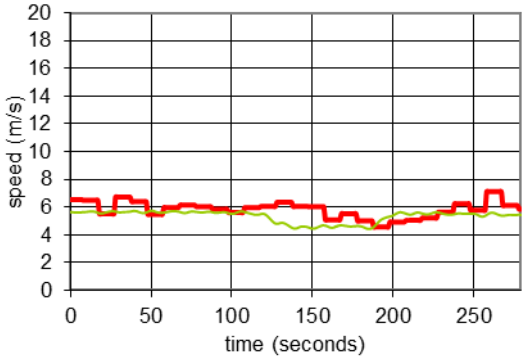


Wind Speed at x=480m, y=170m, z=2m

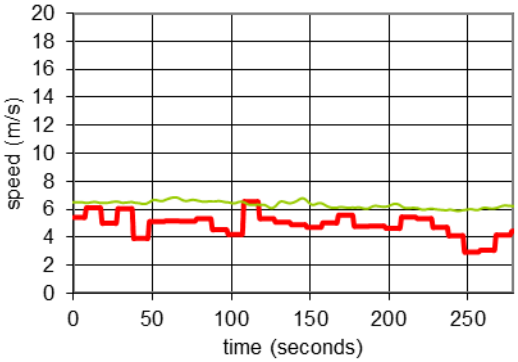
Burro 9 (continued)



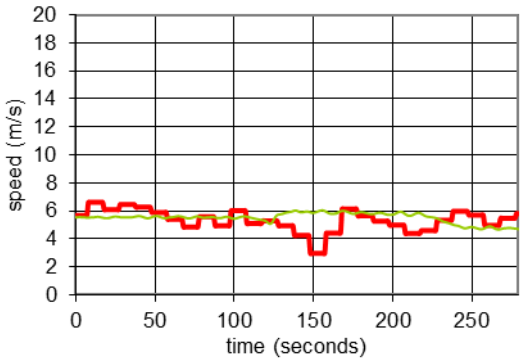
Wind Speed at x=600m, y=0m, z=2m



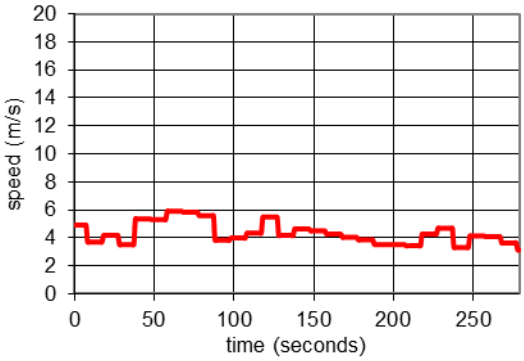
Wind Speed at x=480m, y=-170m, z=2m



Wind Speed at x=670m, y=170m, z=2m

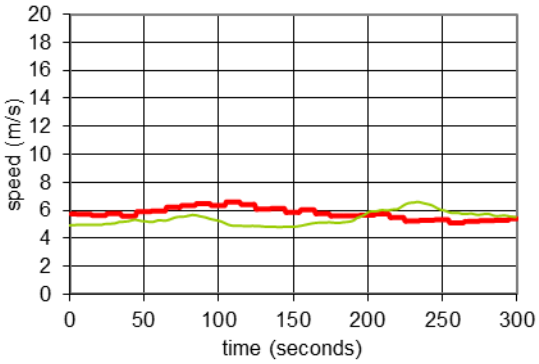


Wind Speed at x=670m, y=-170m, z=2m

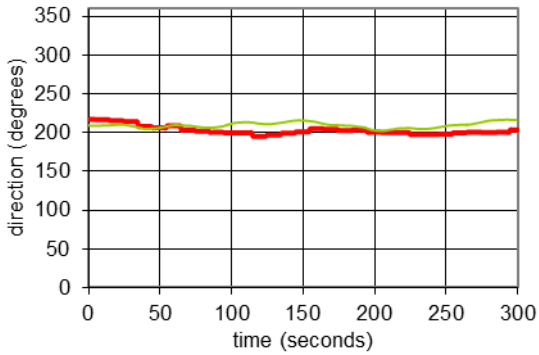


Wind Speed at x=882m, y=180m, z=2m

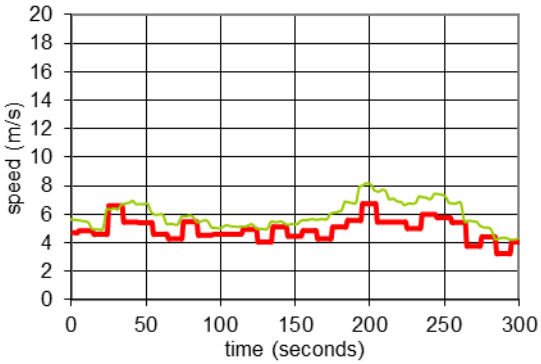
Coyote 3



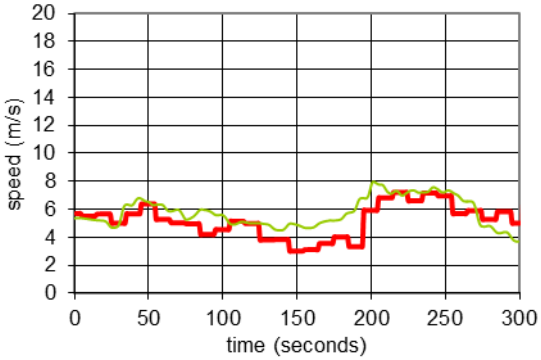
Average Wind Speed



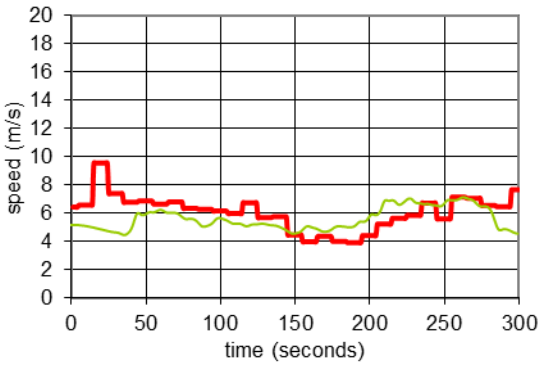
Average Wind Direction



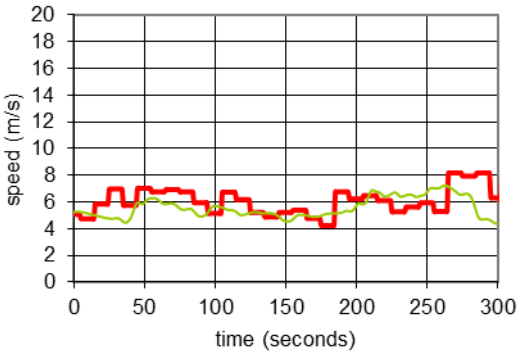
Wind Speed at x=-800m, y=0m, z=2m



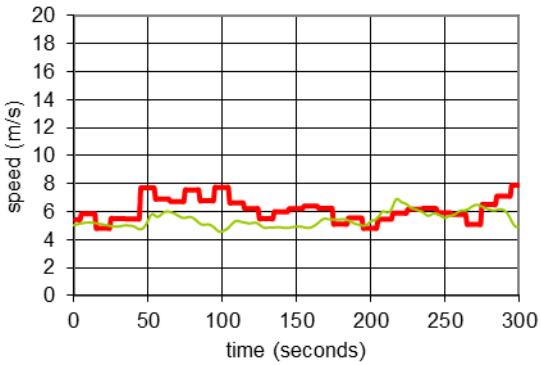
Wind Speed at x=-600m, y=0m, z=2m



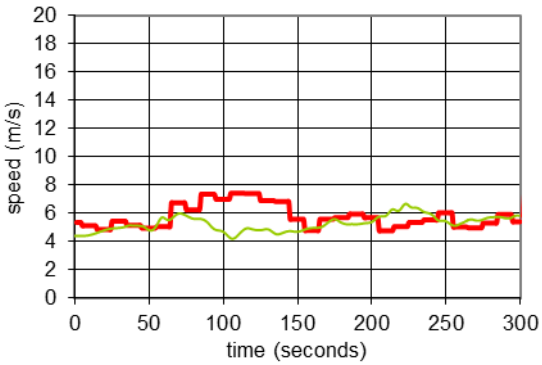
Wind Speed at x=-350m, y=60m, z=2m



Wind Speed at x=-350m, y=-60m, z=2m

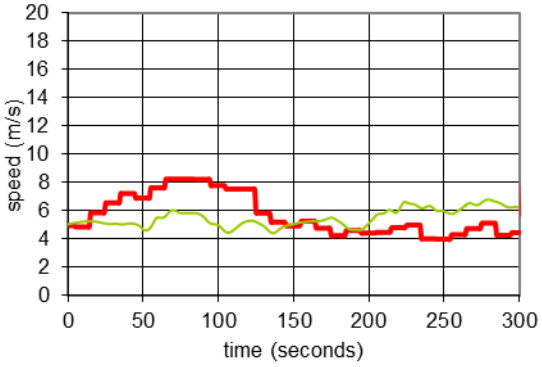


Wind Speed at x=-150m, y=0m, z=2m

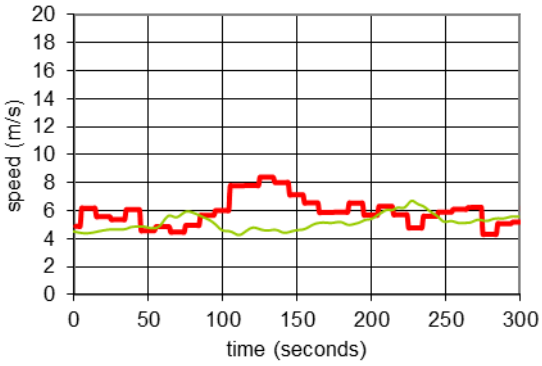


Wind Speed at x=0m, y=60m, z=2m

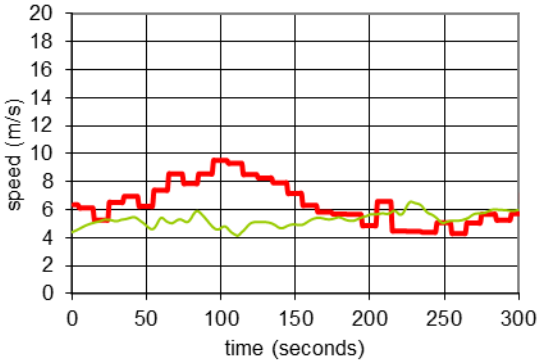
Coyote 3 (continued)



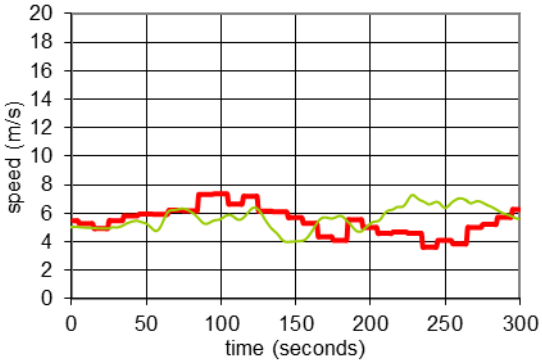
Wind Speed at x=0m, y=-60m, z=2m



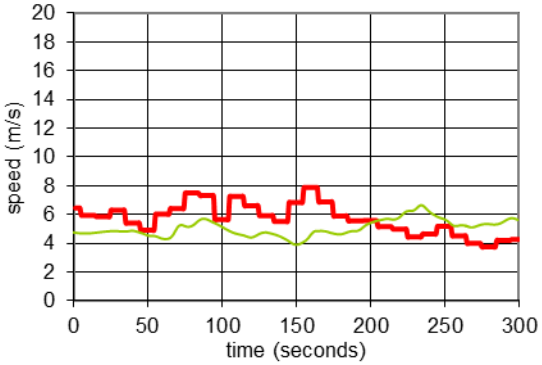
Wind Speed at x=104m, y=120m, z=2m



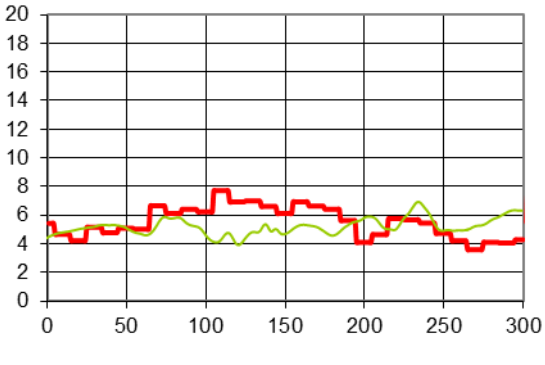
Wind Speed at x=90m, y=0m, z=2m



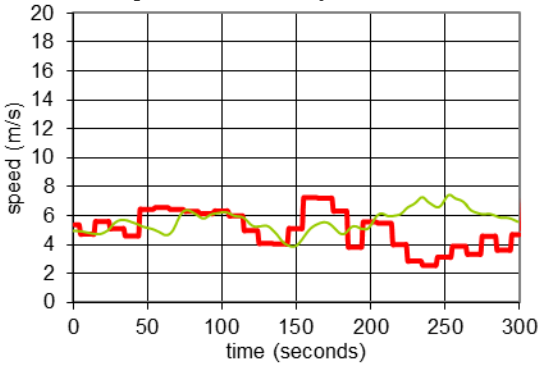
Wind Speed at x=104m, y=-120m, z=2m



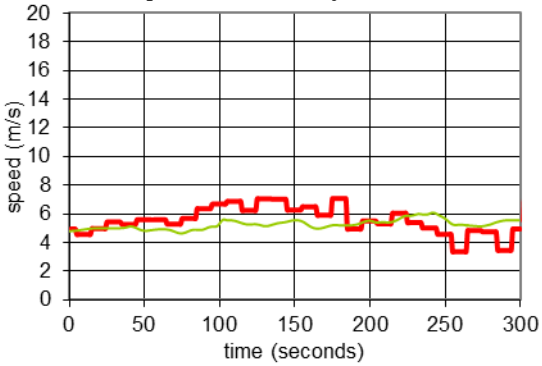
Wind Speed at x=275m, y=130m, z=2m



Wind Speed at x=275m, y=0m, z=2m

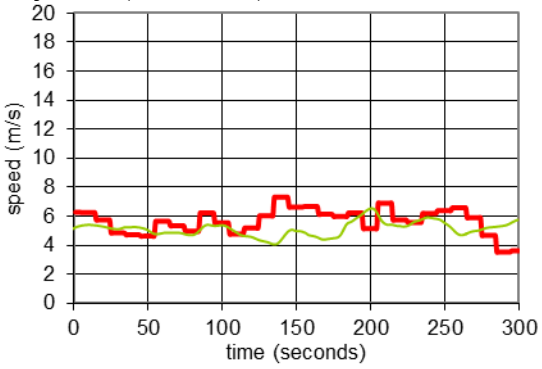


Wind Speed at x=275m, y=-130m, z=2m

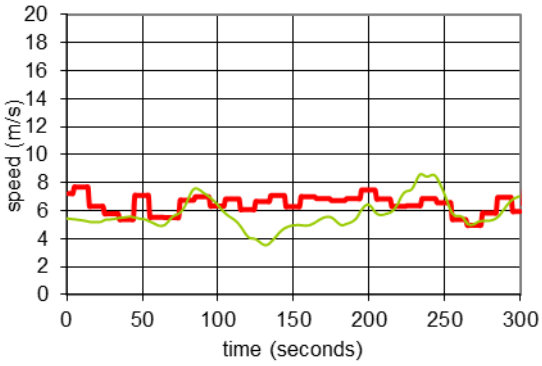


Wind Speed at x=480m, y=170m, z=2m

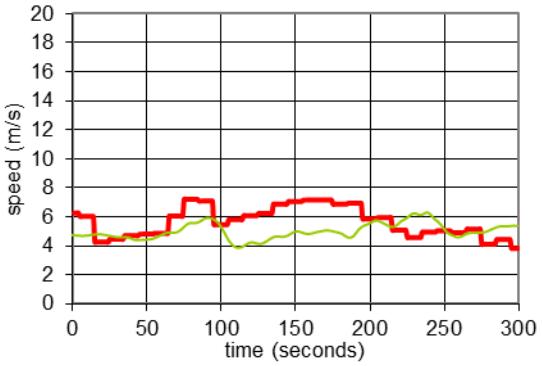
Coyote 3 (continued)



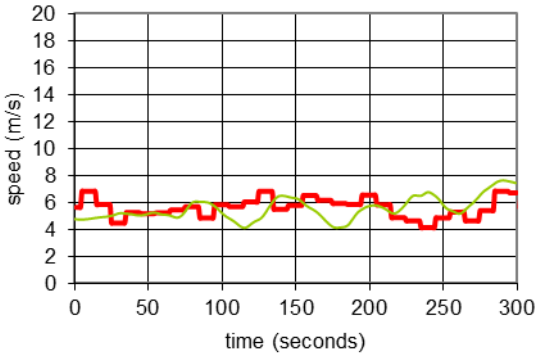
Wind Speed at x=600m, y=0m, z=2m



Wind Speed at x=480m, y=-170m, z=2m

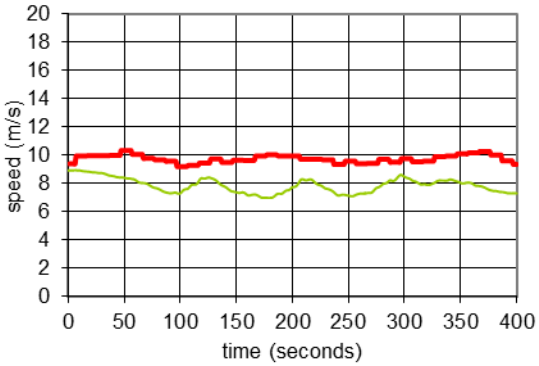


Wind Speed at x=355m, y=275m, z=2m

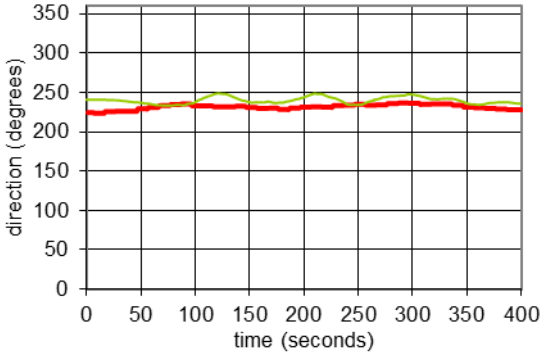


Wind Speed at x=410m, y=85m, z=2m

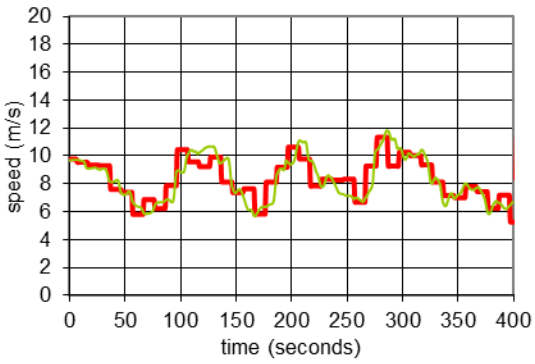
Coyote 5



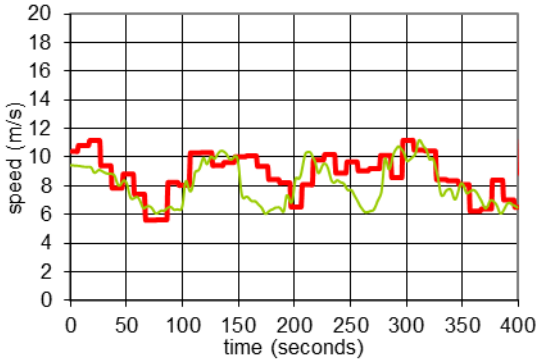
Average Wind Speed



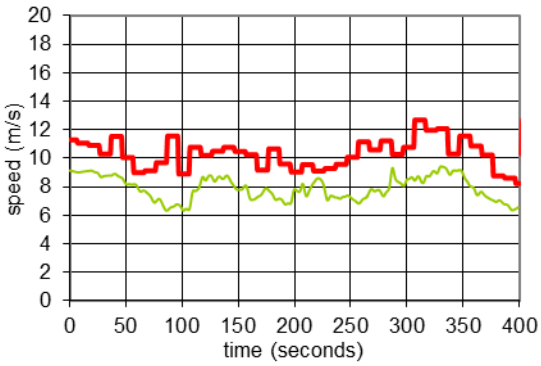
Average Wind Direction



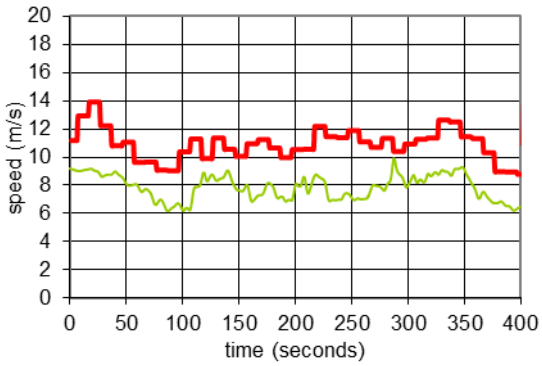
Wind Speed at x=-800m, y=0m, z=2m



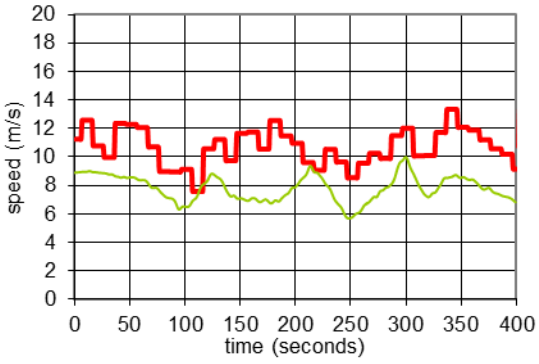
Wind Speed at x=-600m, y=0m, z=2m



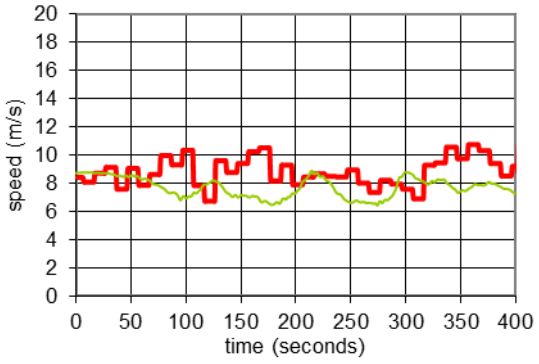
Wind Speed at x=-350m, y=60m, z=2m



Wind Speed at x=-350m, y=-60m, z=2m

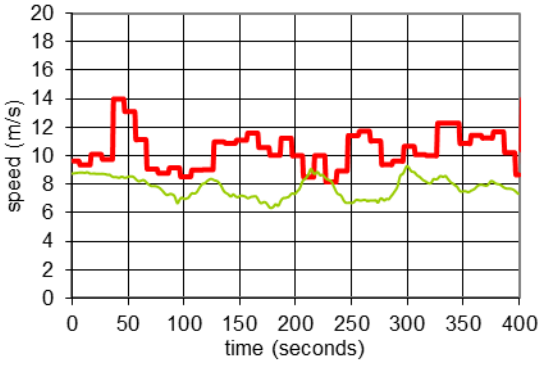


Wind Speed at x=-150m, y=0m, z=2m

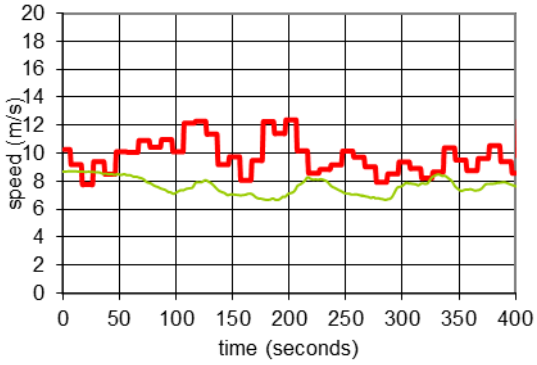


Wind Speed at x=0m, y=60m, z=2m

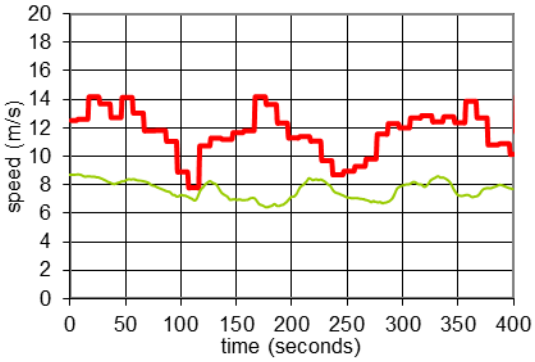
Coyote 5 (continued)



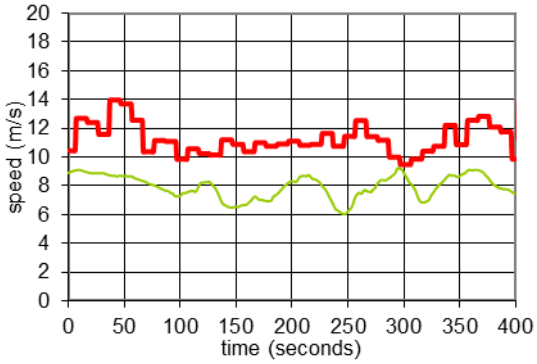
Wind Speed at x=0m, y=-60m, z=2m



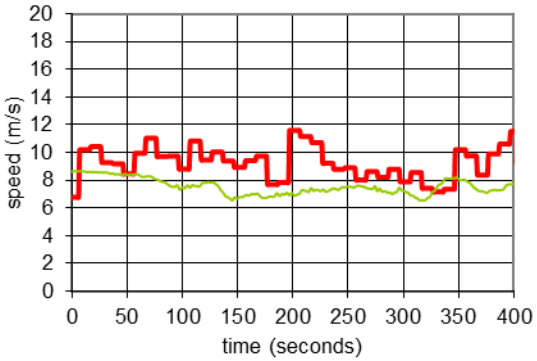
Wind Speed at x=104m, y=120m, z=2m



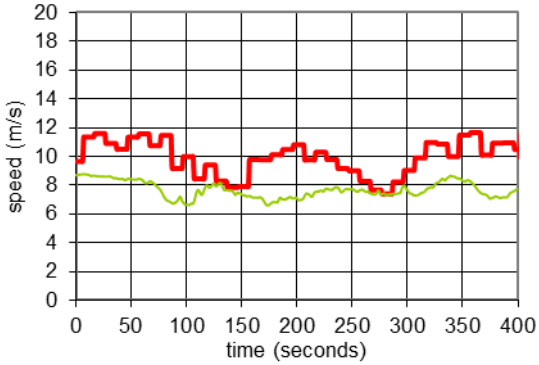
Wind Speed at x=90m, y=0m, z=2m



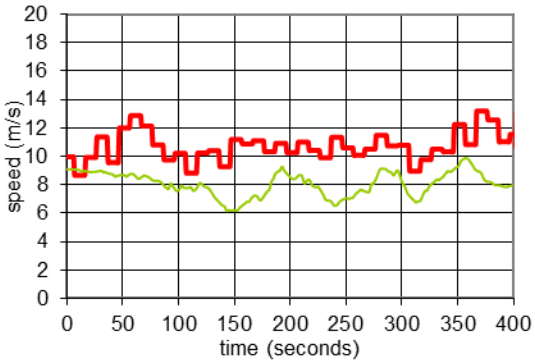
Wind Speed at x=104m, y=-120m, z=2m



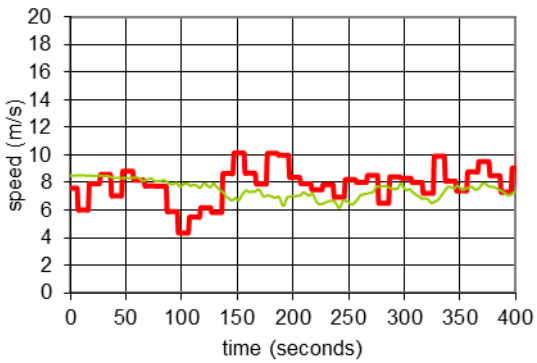
Wind Speed at x=275m, y=130m, z=2m



Wind Speed at x=275m, y=0m, z=2m

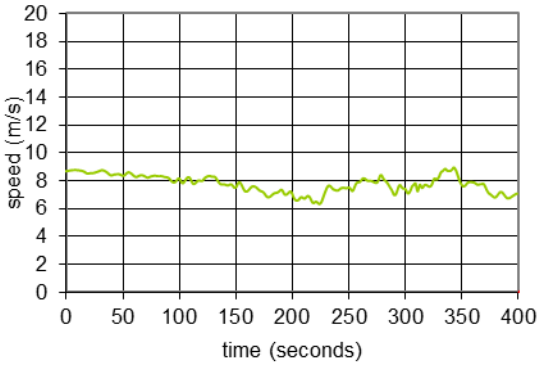


Wind Speed at x=275m, y=-130m, z=2m

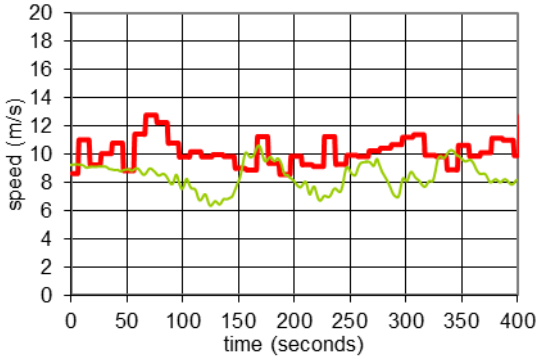


Wind Speed at x=480m, y=170m, z=2m

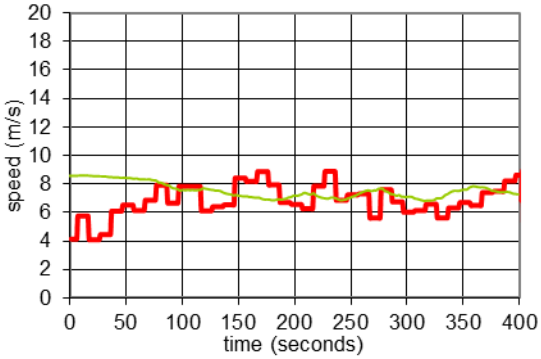
Coyote 5 (continued)



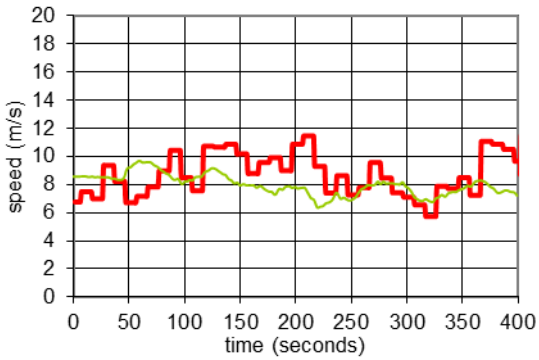
Wind Speed at x=600m, y=0m, z=2m



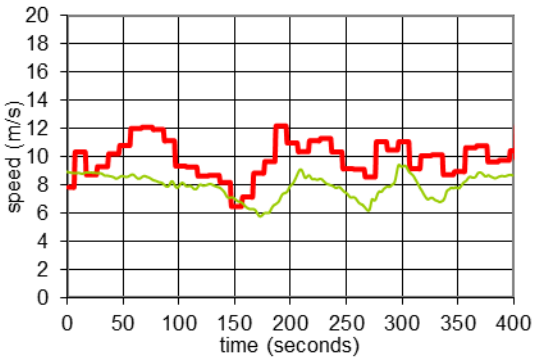
Wind Speed at x=480m, y=-170m, z=2m



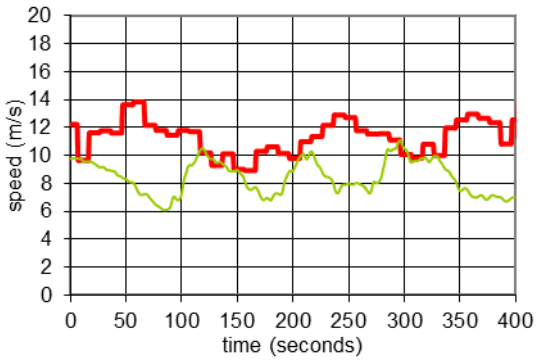
Wind Speed at x=355m, y=275m, z=2m



Wind Speed at x=410m, y=85m, z=2m

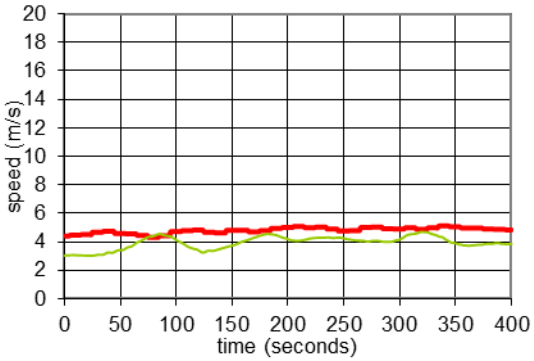


Wind Speed at x=410m, y=-85m, z=2m

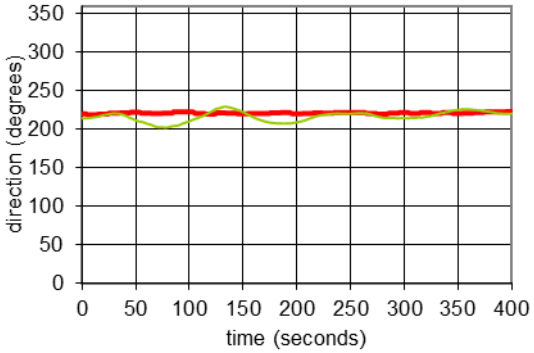


Wind Speed at x=355m, y=-275m, z=2m

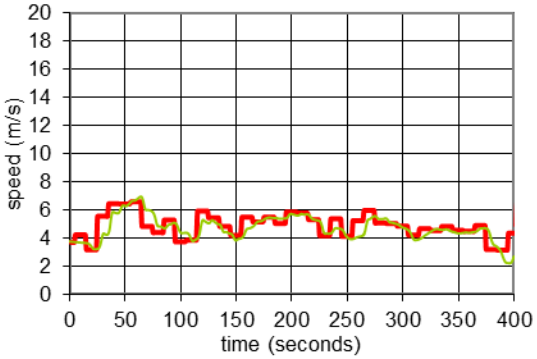
Coyote 6



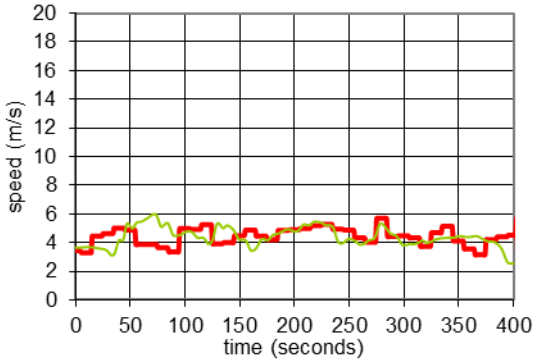
Average Wind Speed



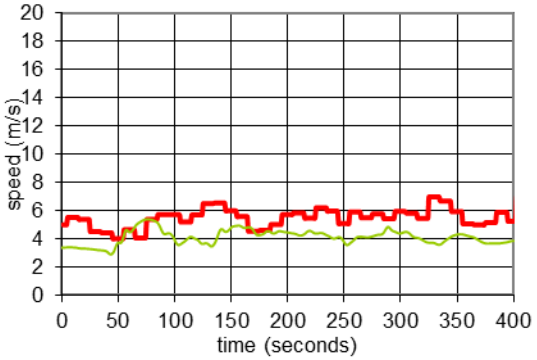
Average Wind Direction



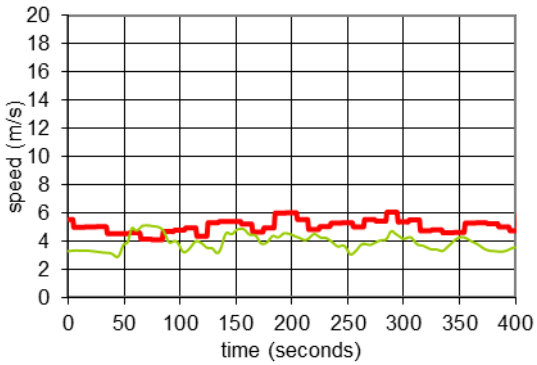
Wind Speed at x=-800m, y=0m, z=2m



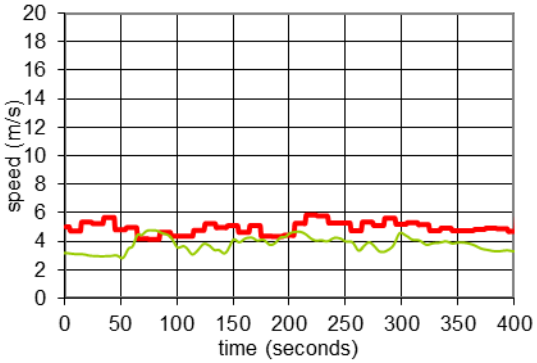
Wind Speed at x=-600m, y=0m, z=2m



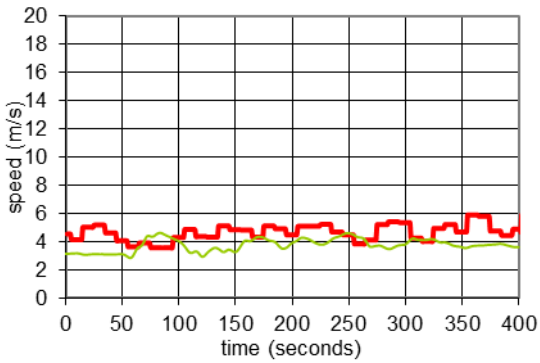
Wind Speed at x=-350m, y=60m, z=2m



Wind Speed at x=-350m, y=-60m, z=2m

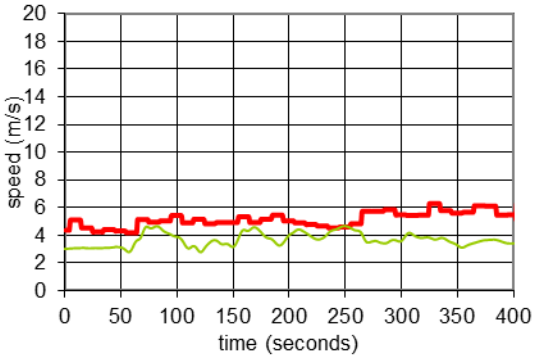


Wind Speed at x=-150m, y=0m, z=2m

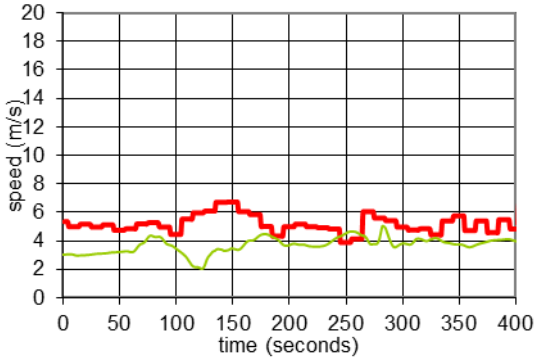


Wind Speed at x=0m, y=60m, z=2m

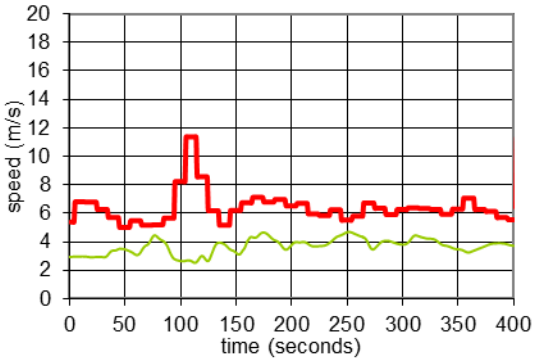
Coyote 6 (continued)



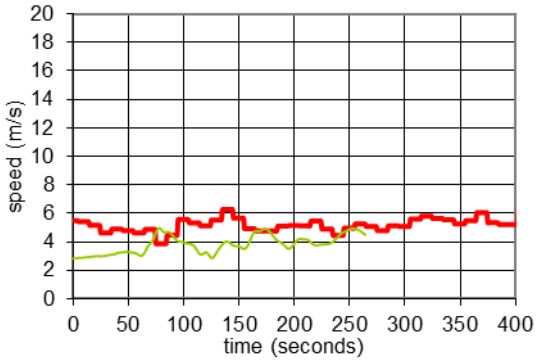
Wind Speed at x=0m, y=-60m, z=2m



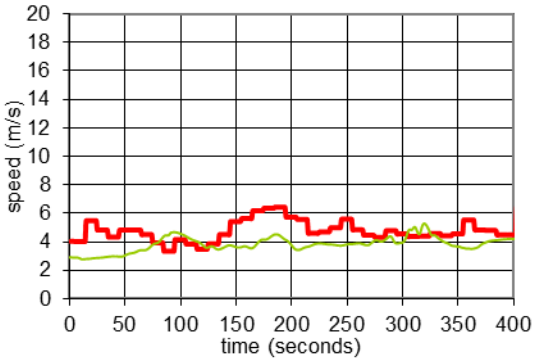
Wind speed at x=104m, y=120m, z=2m



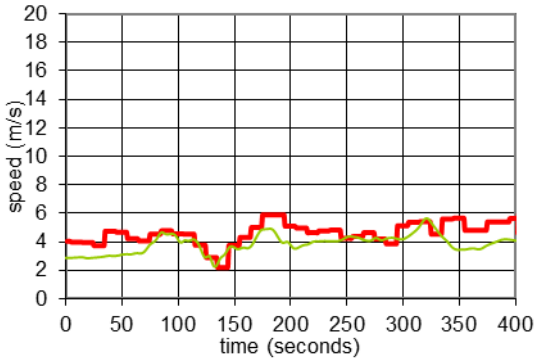
Wind Speed at x=90m, y=0m, z=2m



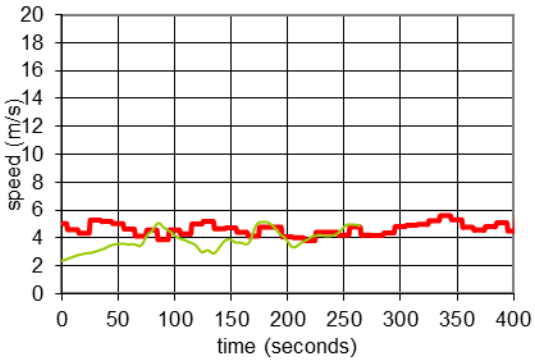
Wind Speed at x=104m, y=-120m, z=2m



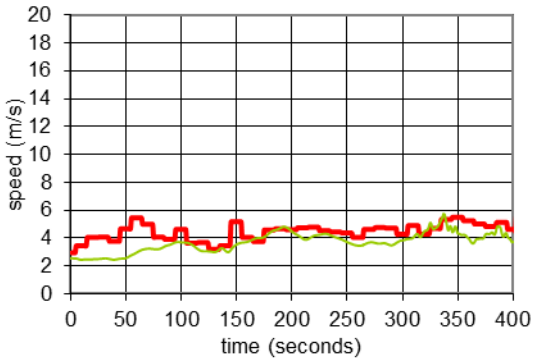
Wind Speed at x=275m, y=130m, z=2m



Wind Speed at x=275m, y=0m, z=2m

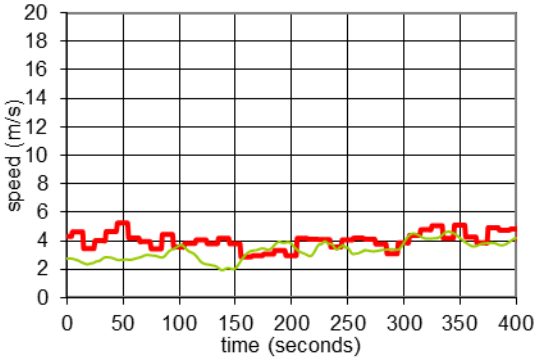


Wind Speed at x=275m, y=-130m, z=2m

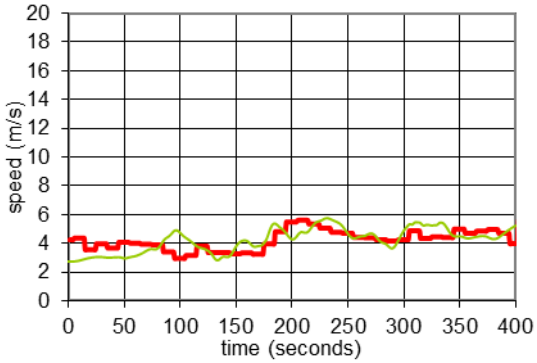


Wind Speed at x=480m, y=170m, z=2m

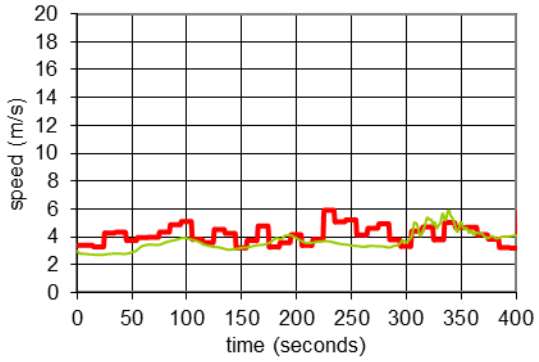
Coyote 6 (continued)



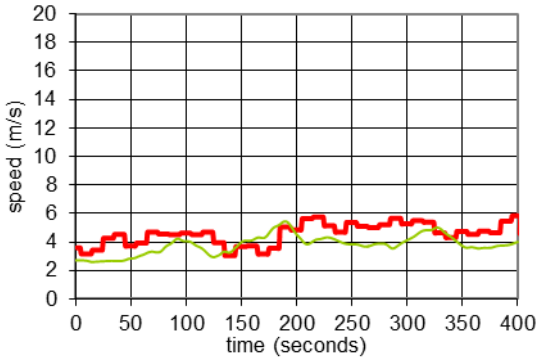
Wind Speed at x=600m, y=0m, z=2m



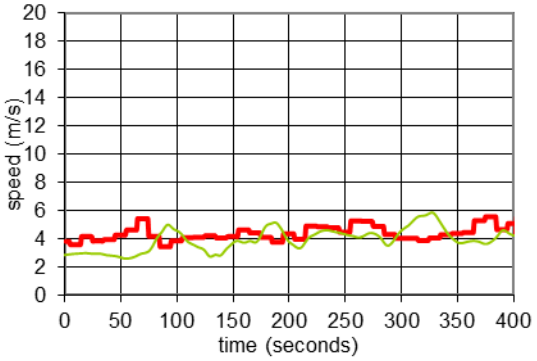
Wind Speed at x=480, y=-170m, z=2m



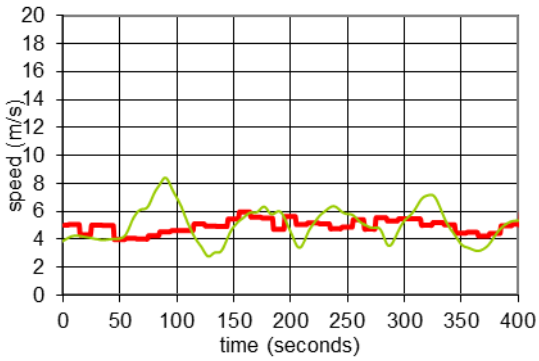
Wind Speed at x=355m, y=275m, z=2m



Wind Speed at x=410m, y=85m, z=2m

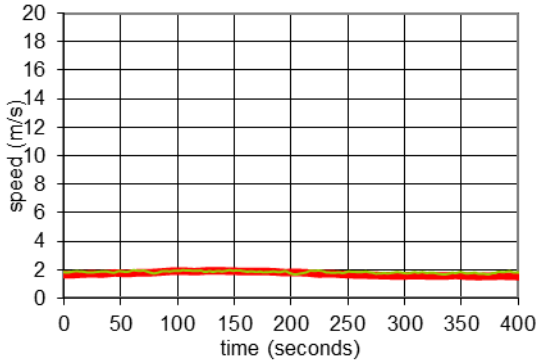


Wind Speed at x=480m, y=-85m, z=2m

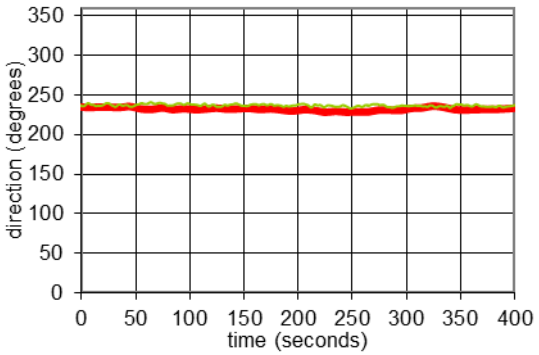


Wind Speed at x=355m, y=-275m, z=2m

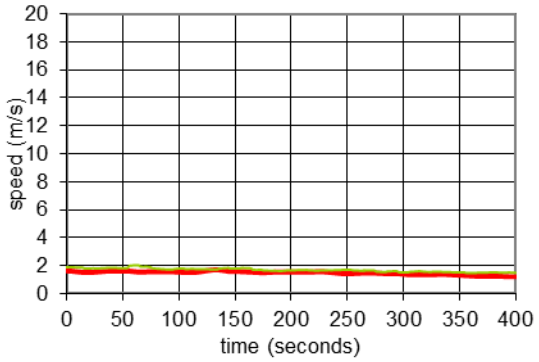
Falcon 1



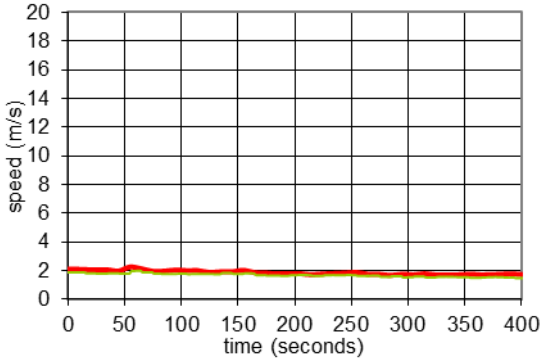
Average Wind Speed



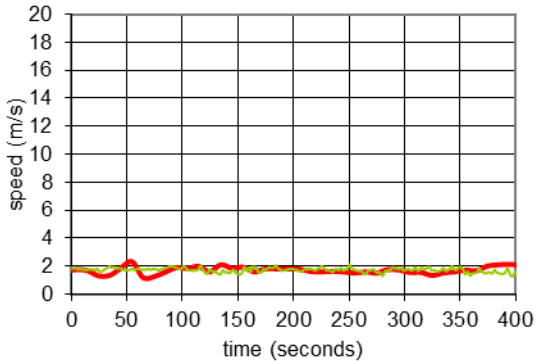
Average Wind Direction



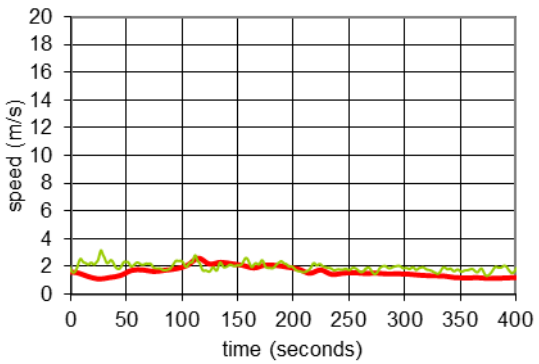
Wind Speed at x=-300m, y=-100m, z=2m



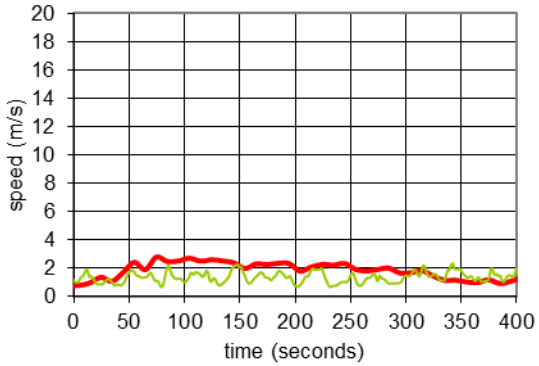
Wind Speed at x=-300m, y=100m, z=2m



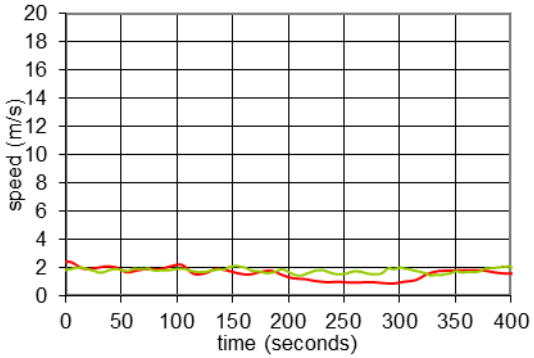
Wind Speed at x=-44m, y=28m, z=2m



Wind Speed at x=50m, y=-75m, z=2m

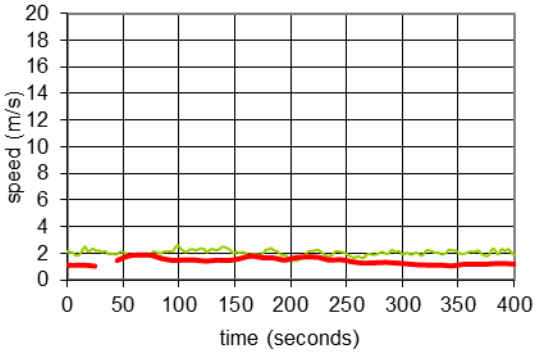


Wind Speed at x=50m, y=3, z=2m

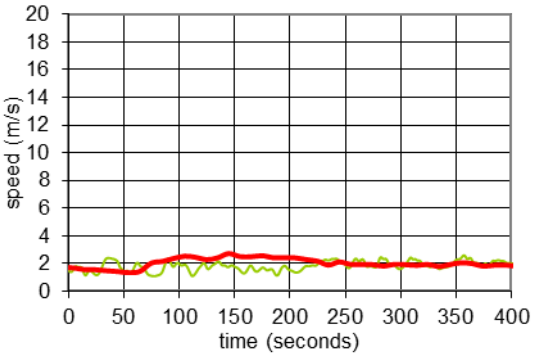


Wind Speed at x=50m, y=75m, z=2m

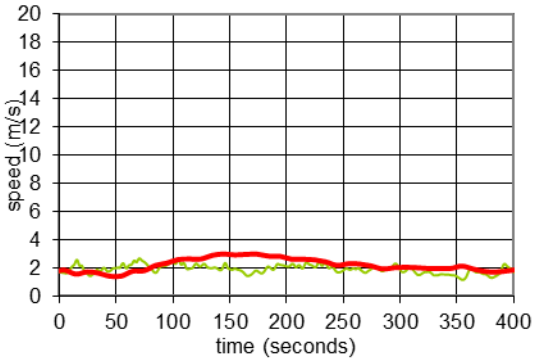
Falcon 1 (continued)



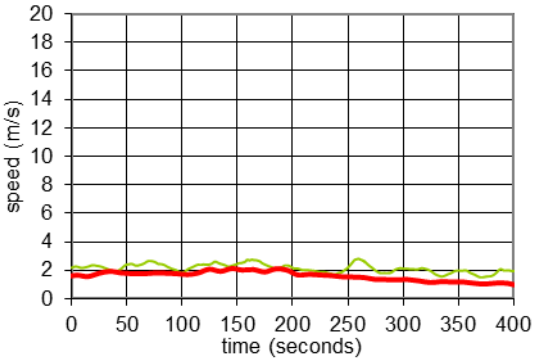
Wind Speed at x=150m, y=-150m, z=2m



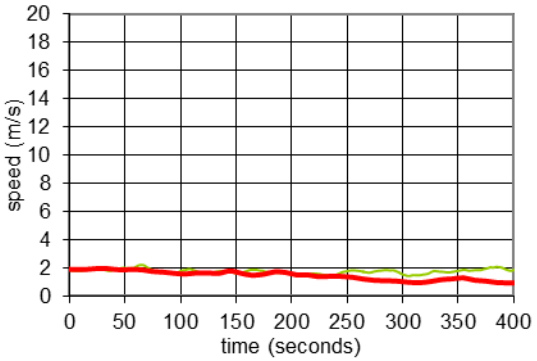
Wind Speed at x=150m, y=-75m, z=2m



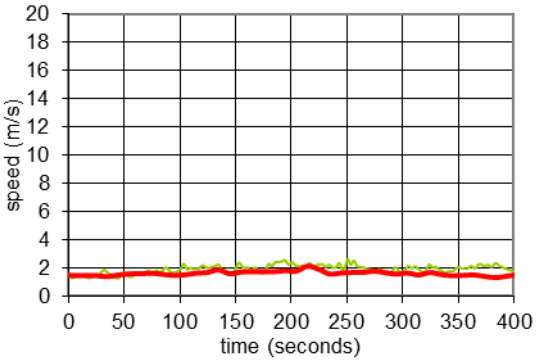
Wind Speed at x=150m, y=3m, z=2m



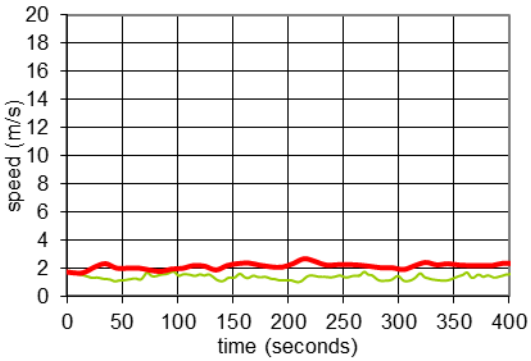
Wind Speed at x=150m, y=75m, z=2m



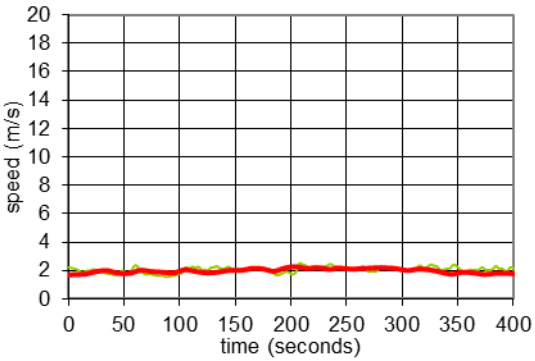
Wind Speed at x=150m, y=150m, z=2m



Wind Speed at x=350m, y=-150m, z=2m

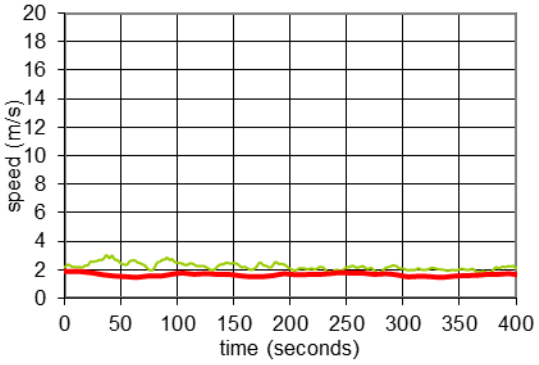


Wind Speed at x=350m, y=-75m, z=2m

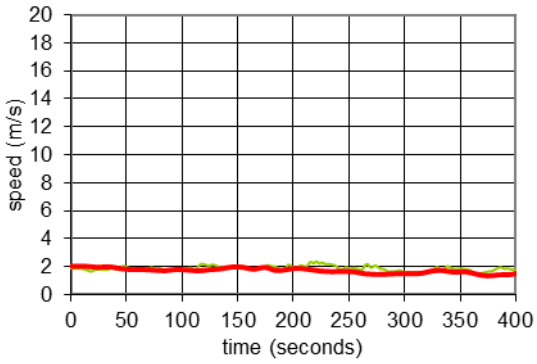


Wind Speed at x=350m, y=-3m, z=2m

Falcon 1 (continued)

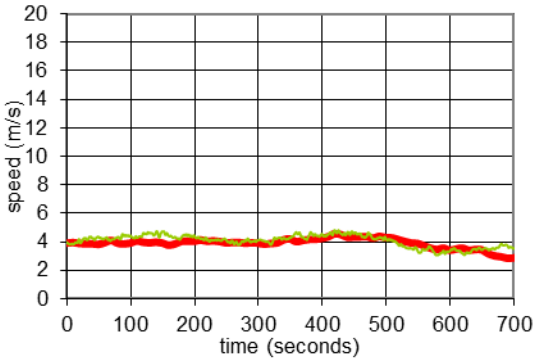


Wind Speed at x=350m, y=75m, z=2m

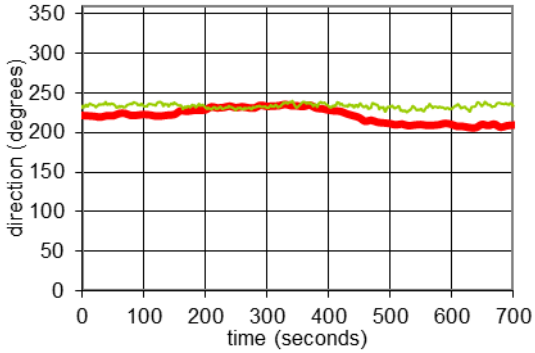


Wind Speed at x=350m, y=150m, z=2m

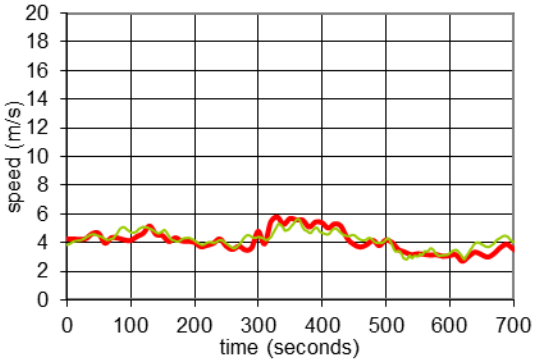
Falcon 3



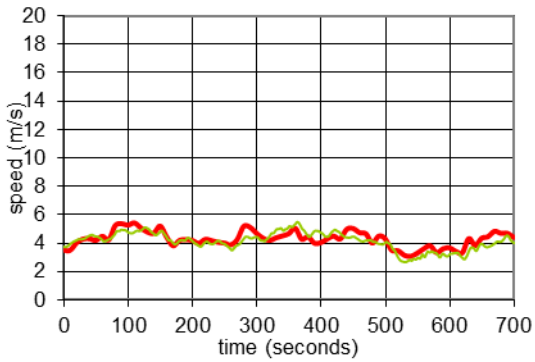
Average Wind Speed



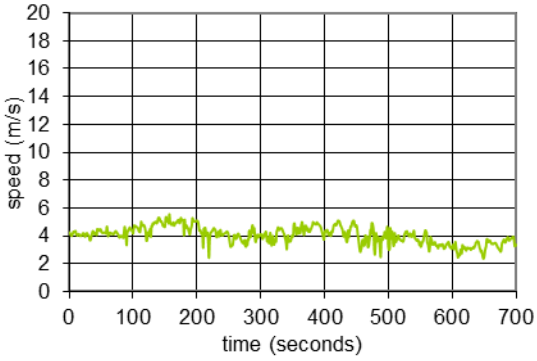
Average Wind Direction



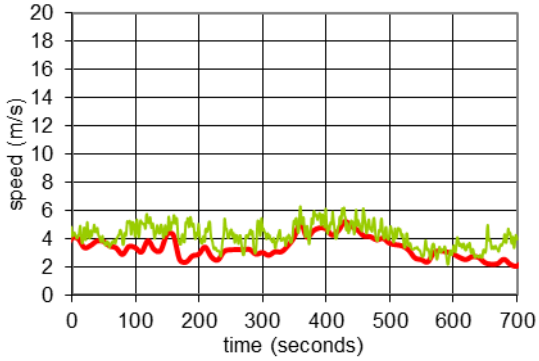
Wind Speed at x=-300m, y=-100m, z=2m



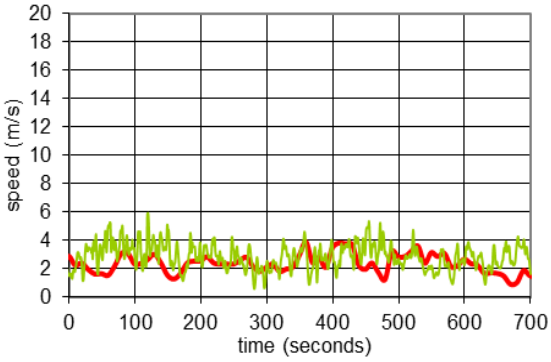
Wind Speed at x=-300m, y=100m, z=2m



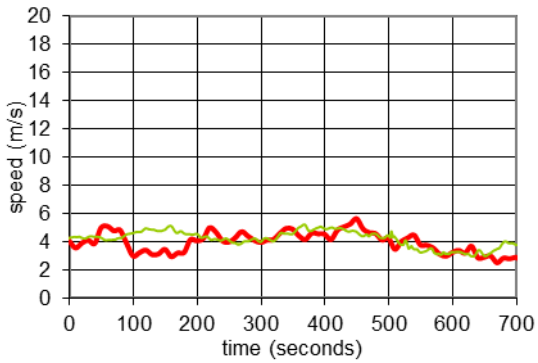
Wind Speed at x=-44m, y=28m, z=2m



Wind Speed at x=50m, y=-75m, z=2m

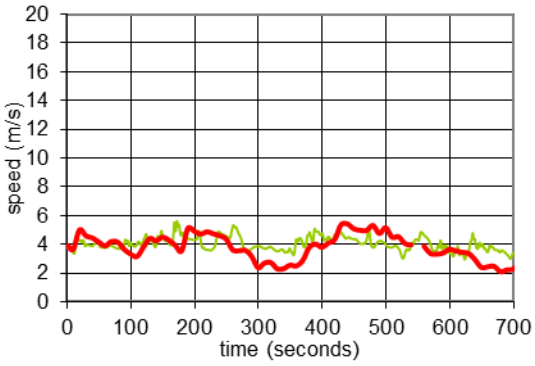


Wind Speed at x=50m, y=3m, z=2m

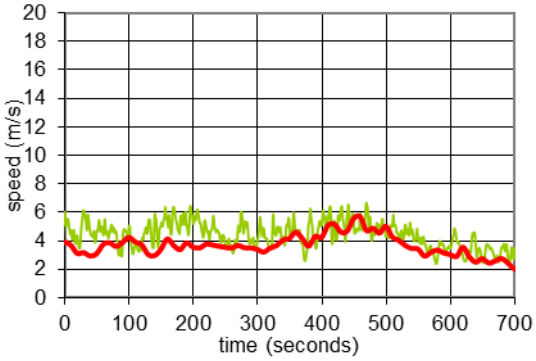


Wind Speed at x=50m, y=75m, z=2m

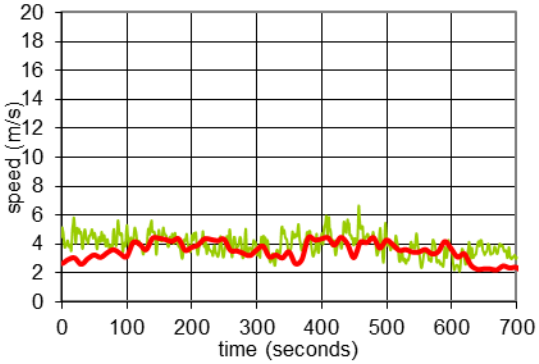
Falcon 3 (continued)



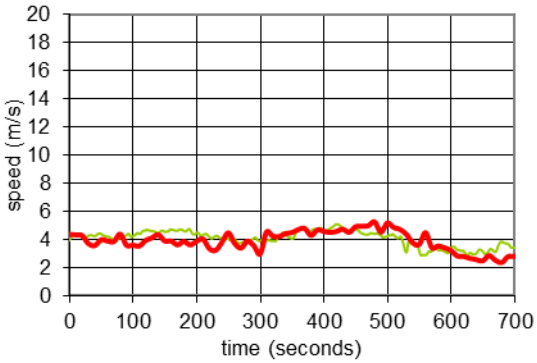
Wind Speed at x=150m, y=-150m, z=2m



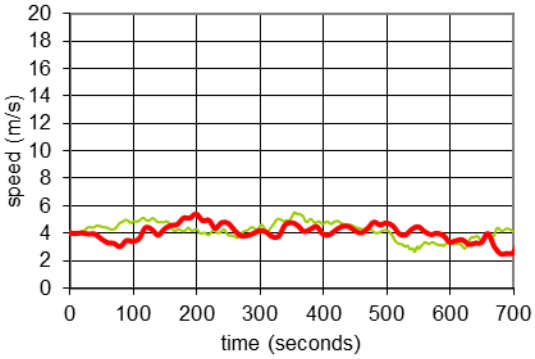
Wind Speed at x=150, y=-75m, z=2m



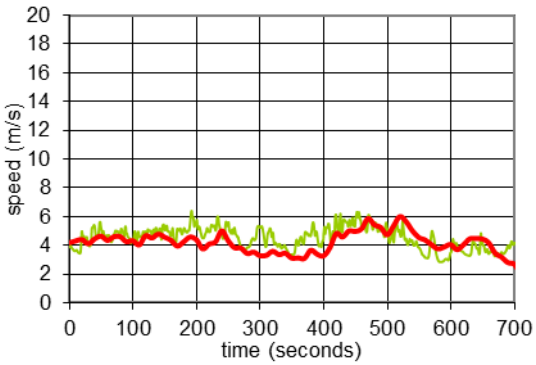
Wind Speed at x=150m, y=3m, z=2m



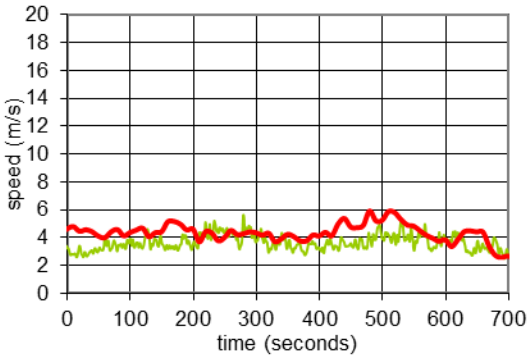
Wind Speed at x=150m, y=75m, z=2m



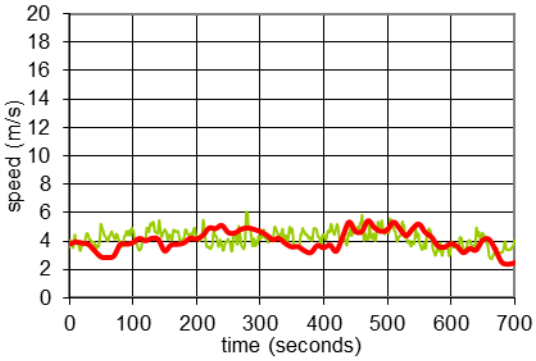
Wind Speed at x=150m, y=150m, z=2m



Wind Speed at x=350m, y=-150m, z=2m

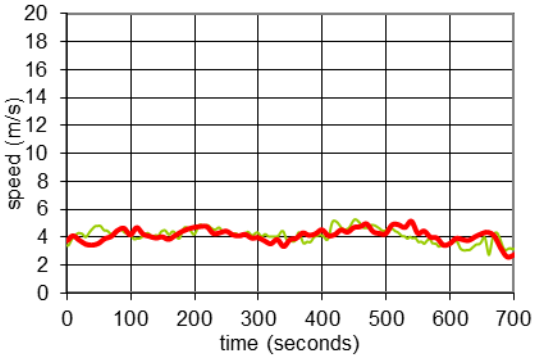


Wind Speed at x=350m, y=-75m, z=2m

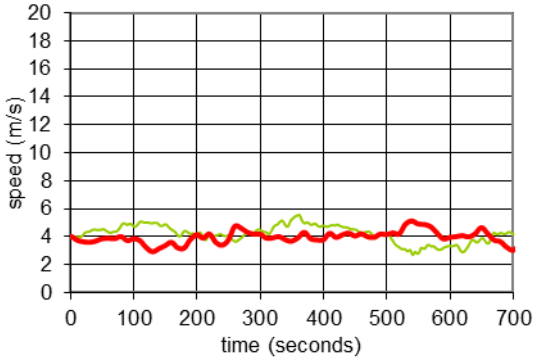


Wind Speed at x=350m, y=-3m, z=2m

Falcon 3 (continued)

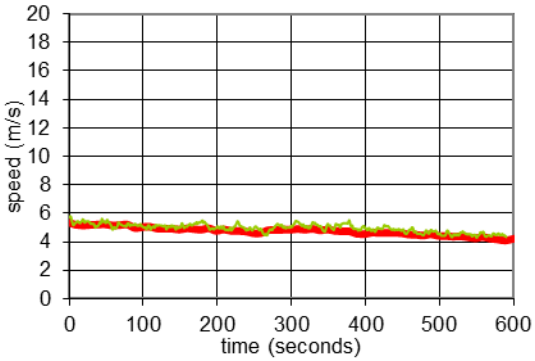


Wind Speed at x=350m, y=75m, z=2m

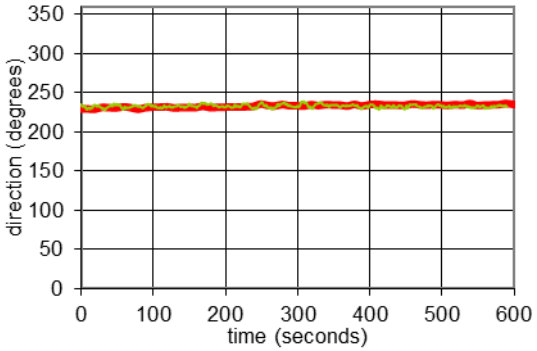


Wind Speed at x=350m, y=150m, z=2m

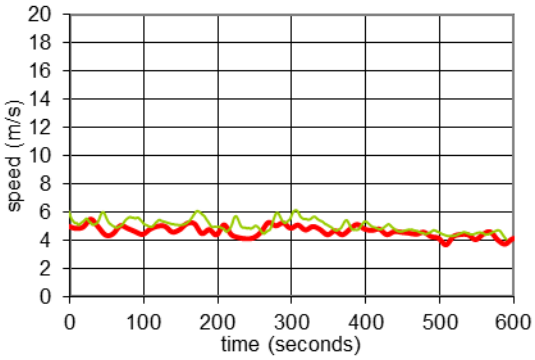
Falcon 4



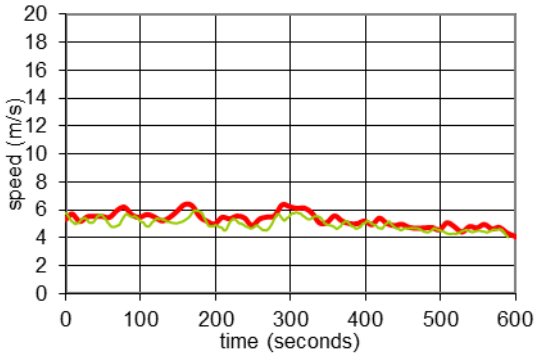
Average Wind Speed



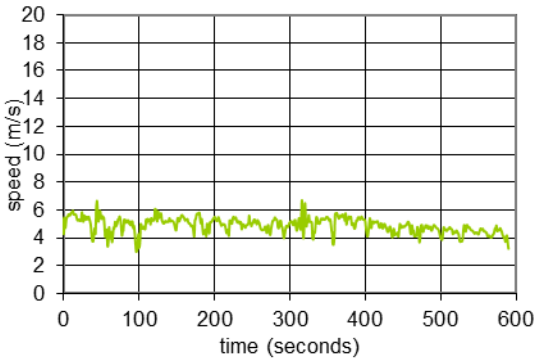
Average Wind Direction



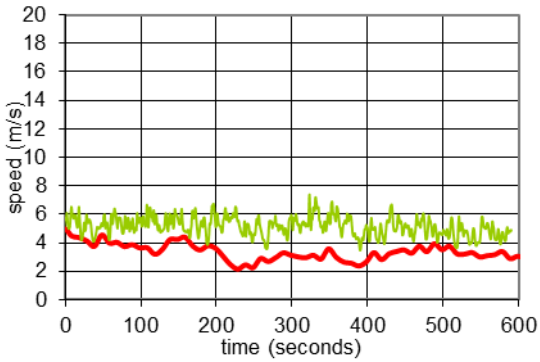
Wind Speed at x=-300m, y=-100m, z=2m



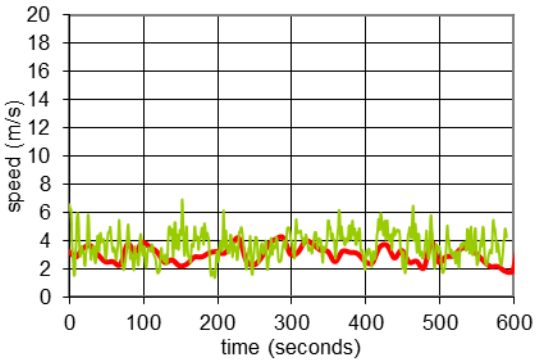
Wind Speed at x=-300m, y=100m, z=2m



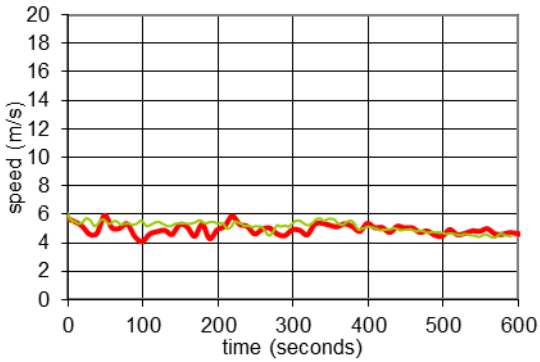
Wind Speed at x=-44m, y=28m, z=2m



Wind Speed at x=50m, y=-75m, z=2m

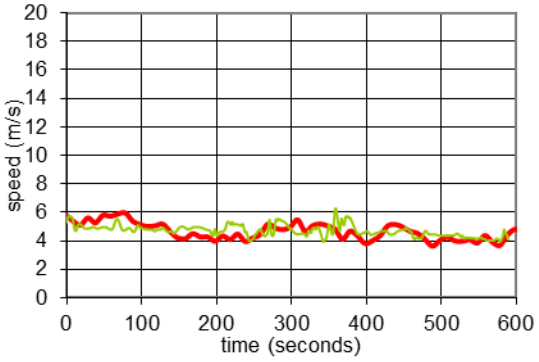


Wind Speed at x=50m, y=3m, z=2m

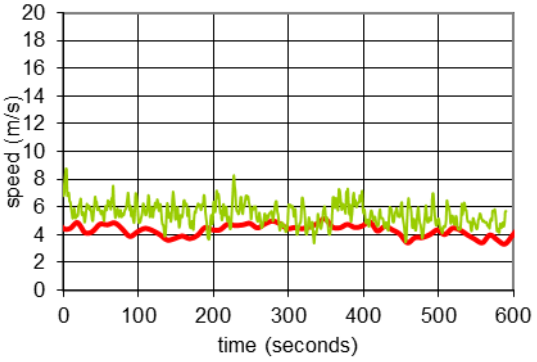


Wind Speed at x=50m, y=75m, z=2m

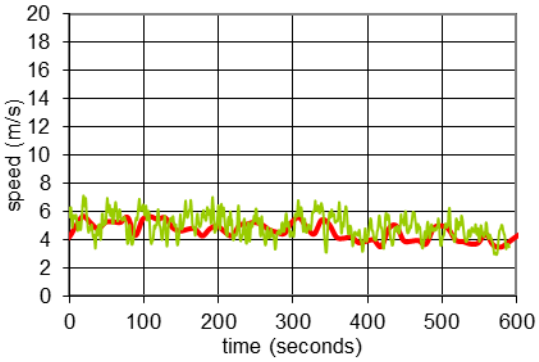
Falcon 4 (continued)



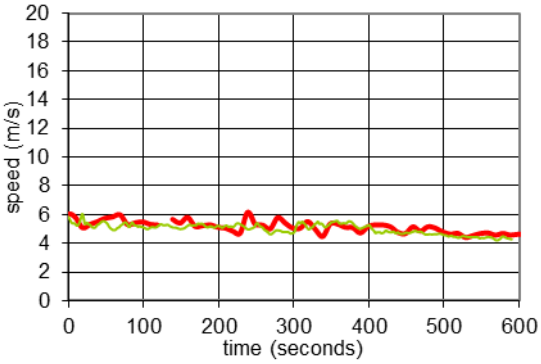
Wind Speed at x=150m, y=-150m, z=2m



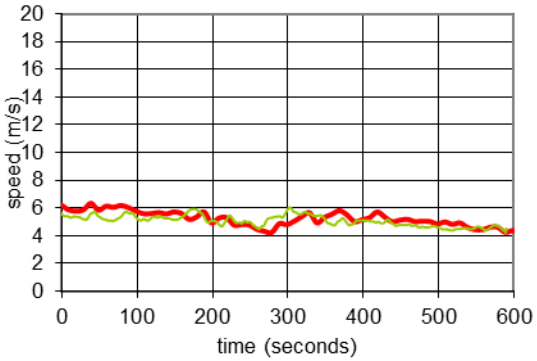
Wind Speed at x=150, y=-75m, z=2m



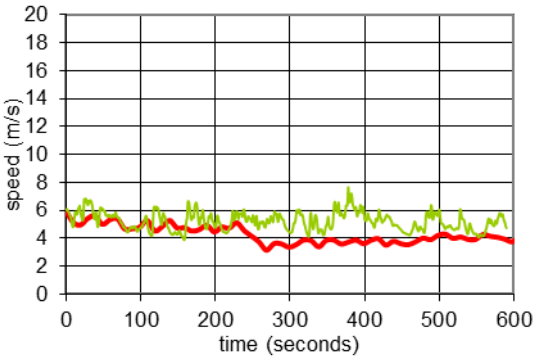
Wind Speed at x=150m, y=3m, z=2m



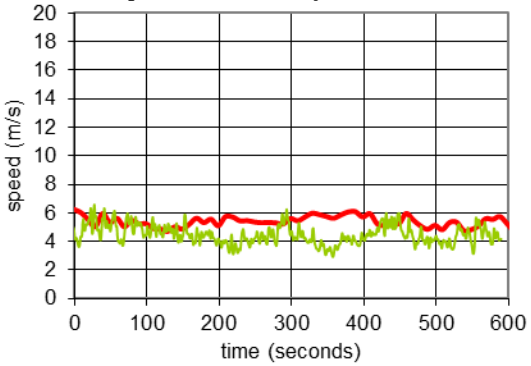
Wind Speed at x=150m, y=75m, z=2m



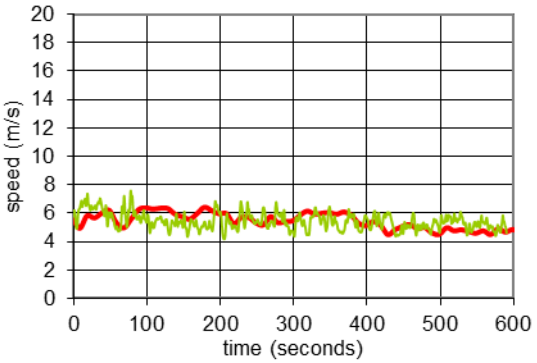
Wind Speed at x=150m, y=150m, z=2m



Wind Speed at x=350mm, y=-150m, z=2m

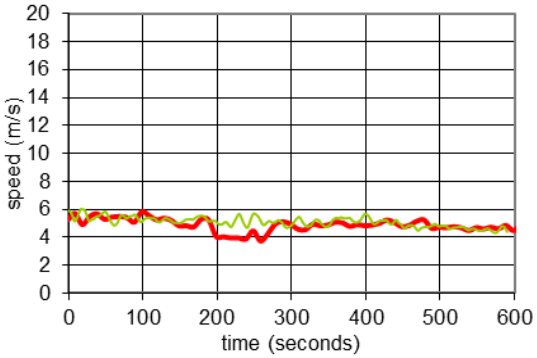


Wind Speed at x=350m, y=-75m, z=2m

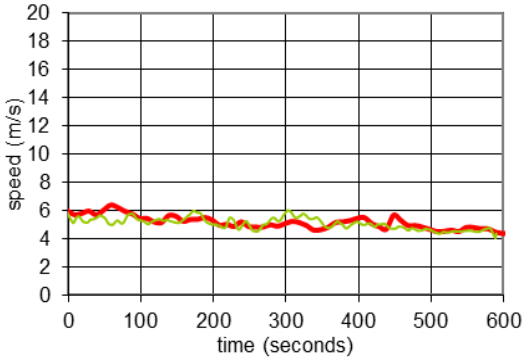


Wind Speed at x=350m, y=-3m, z=2m

Falcon 4 (continued)



Wind Speed at x=350m, y=75m, z=2m



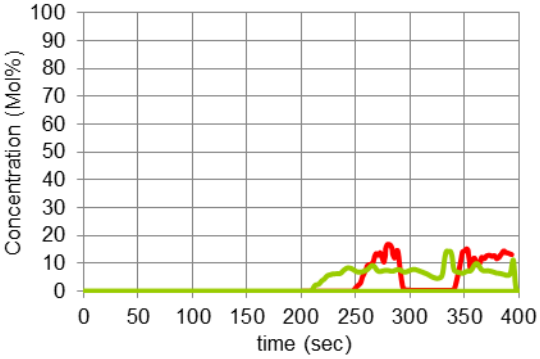
Wind Speed at x=350m, y=75m, z=2m

Appendix D

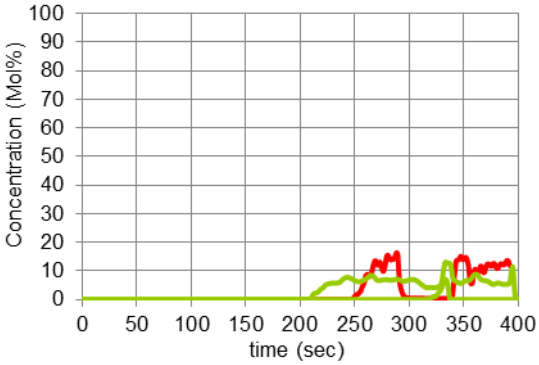
Point-Wise Gas Concentrations

(red lines: experimental data; green lines: FDS data)

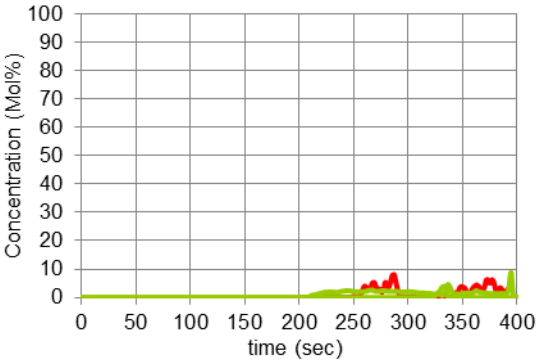
Maplin Sands 27



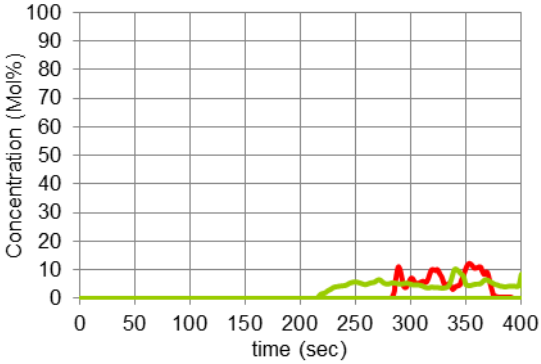
Gas Concentration at x=22m, y=54m, z=0.9m



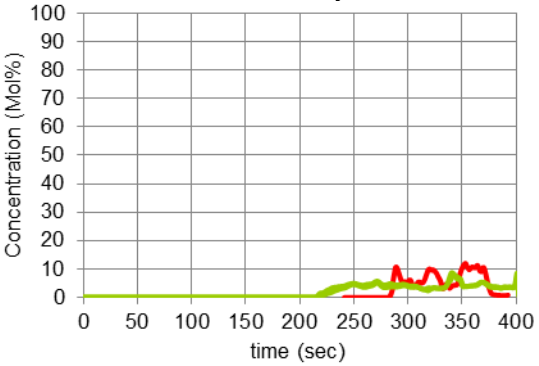
Gas Concentration at x=22m, y=54m, z=1.3m



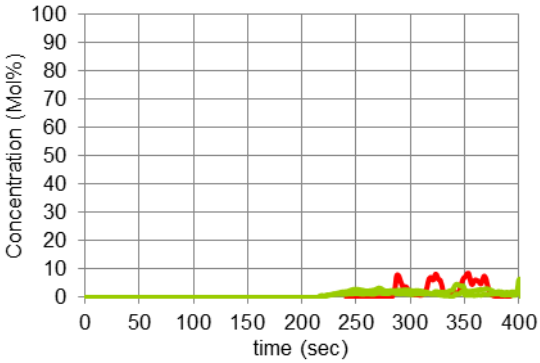
Gas Concentration at x=22m, y=54m, z=2.2m



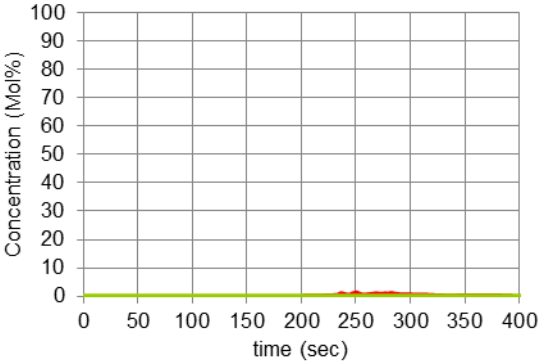
Gas Concentration at x=62m, y=62m, z=0.9m



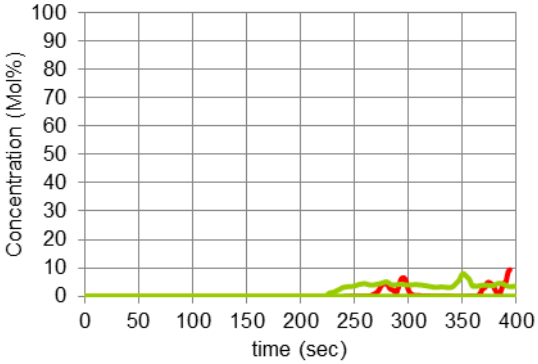
Gas Concentration at x=62m, y=62m, z=1.4m



Gas Concentration at x=62m, y=62m, z=2.4m

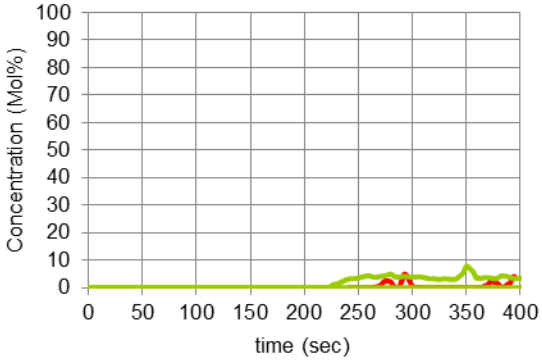


Gas Concentration at x=118m, y=50m, z=2.4m

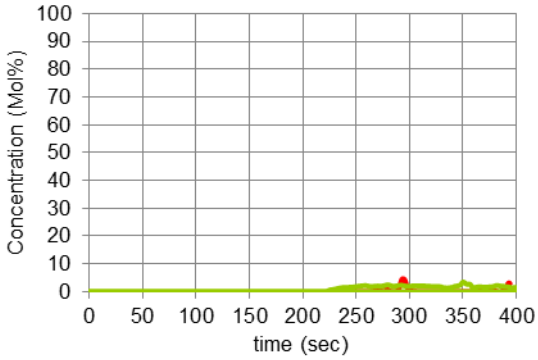


Gas Concentration at x=48m, y=120m, z=0.9m

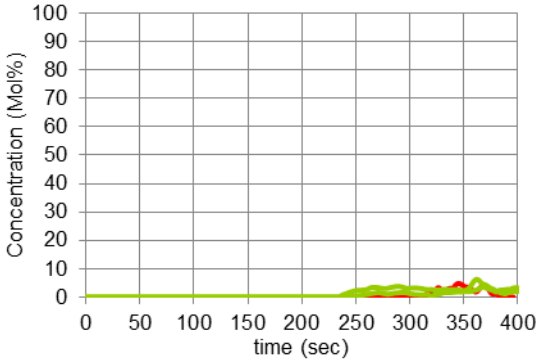
Maplin Sands 27 (continued)



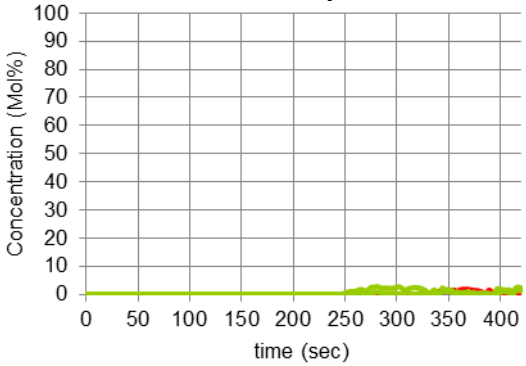
Gas Concentration at x=48m, y=120m, z=1.8m



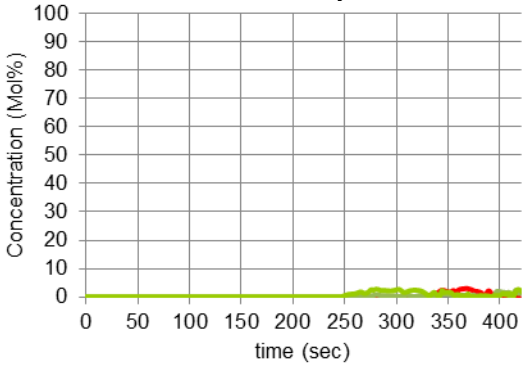
Gas Concentration at x=48m, y=120m, z=2.8m



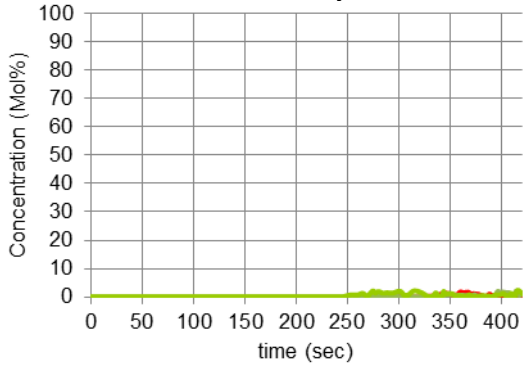
Gas Concentration at x=128m, y=128m, z=1.4m



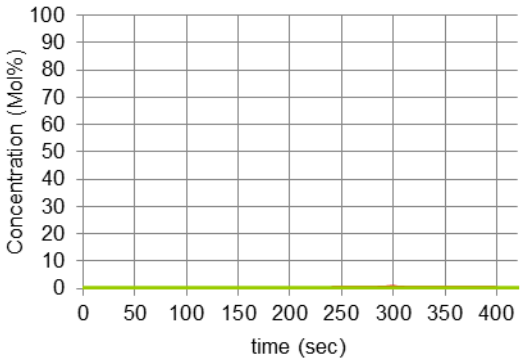
Gas Concentration at x=175m, y=175m, z=1.0m



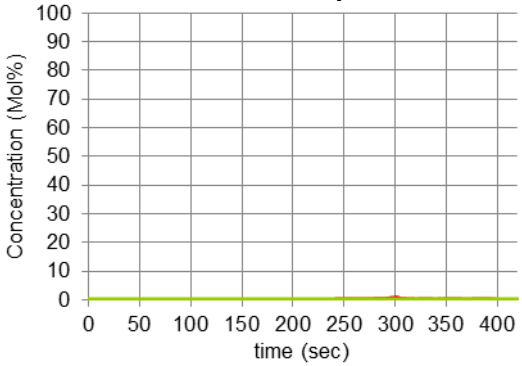
Gas Concentration at x=175m, y=175m, z=1.4m



Gas Concentration at x=175m, y=175m, z=2.4m

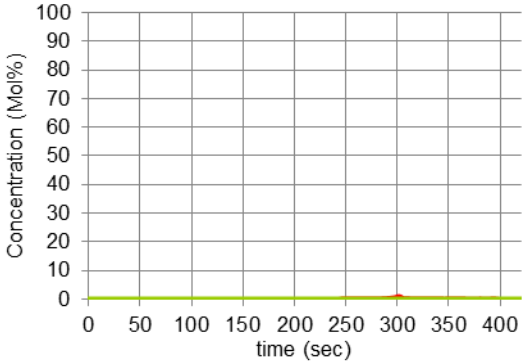


Gas Concentration at x=94m, y=232m, z=1.0m

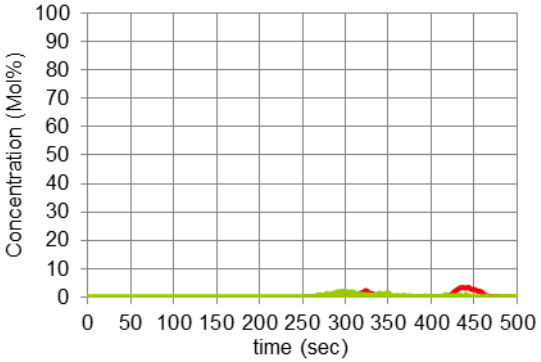


Gas Concentration at x=94m, y=232m, z=1.6m

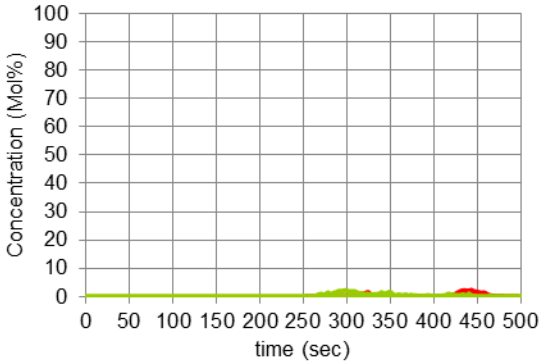
Maplin Sands 27 (continued)



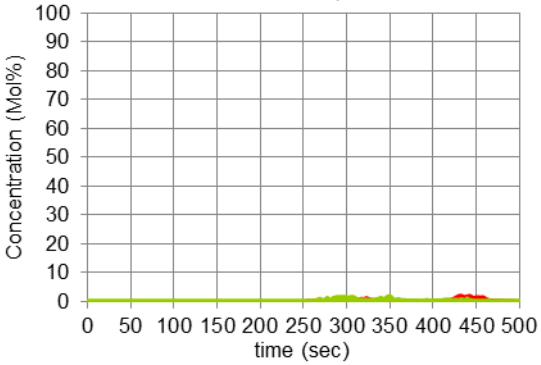
Gas Concentration at x=94m, y=232m, z=2.4m



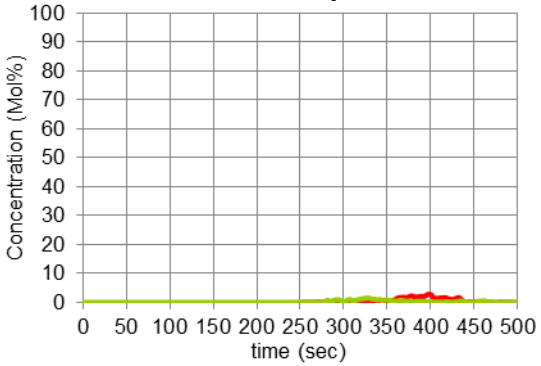
Gas Concentration at x=161m, y=279m, z=1.0m



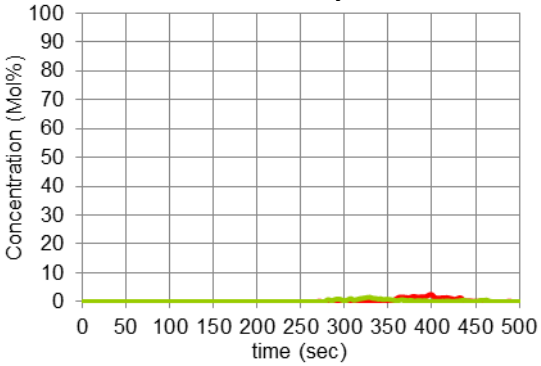
Gas Concentration at x=161m, y=279m, z=1.4m



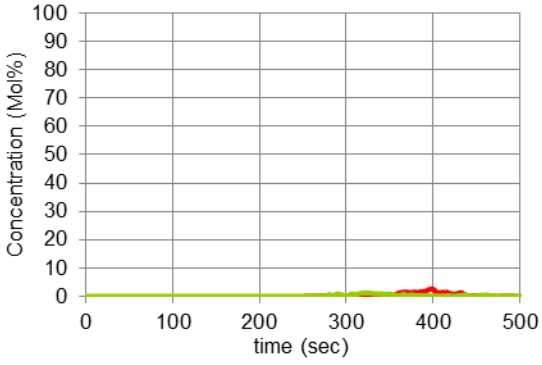
Gas Concentration at x=161m, y=279m, z=2.4m



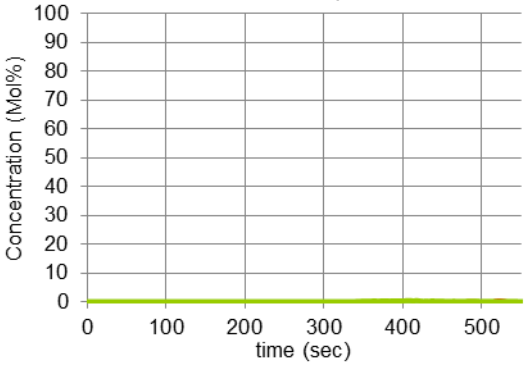
Gas Concentration at x=251m, y=310m, z=1.0m



Gas Concentration at x=251m, y=310m, z=1.5m

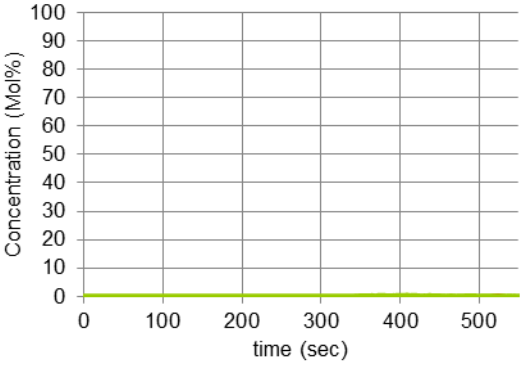


Gas Concentration at x=251m, y=310m, z=2.5m

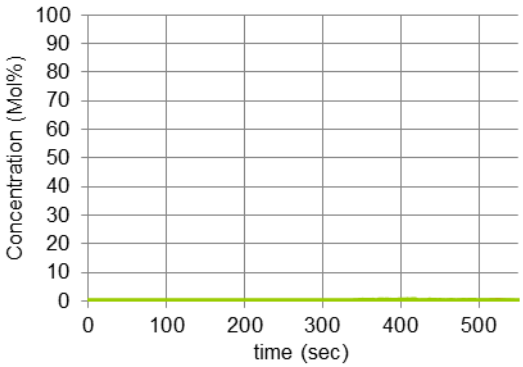


Gas Concentration at x=354m, y=545m, z=1.0m

Maplin Sands 27 (continued)

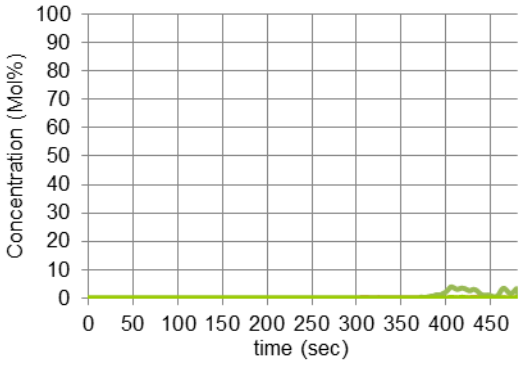


Gas Concentration at x=354m, y=545m, z=1.4m

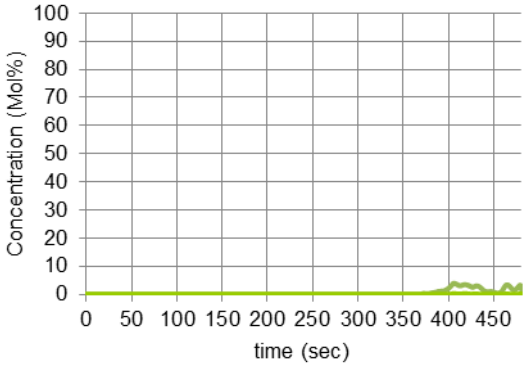


Gas Concentration at x=354m, y=545m, z=2.4m

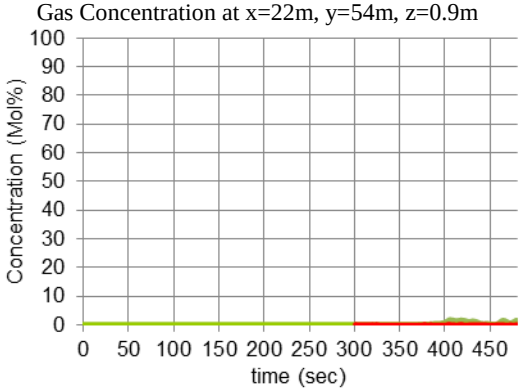
Maplin Sands 34



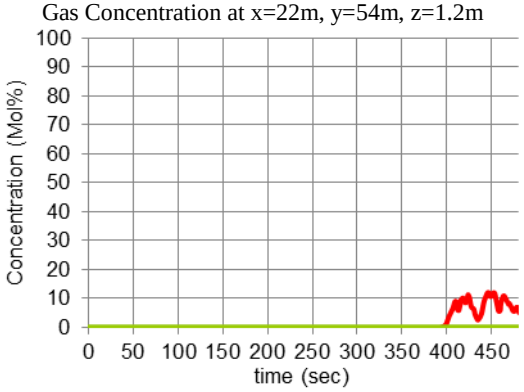
Gas Concentration at x=22m, y=54m, z=0.9m



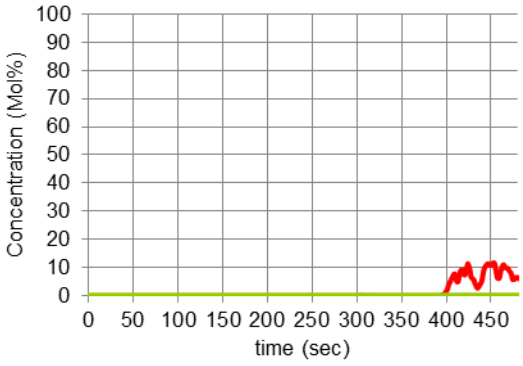
Gas Concentration at x=22m, y=54m, z=1.2m



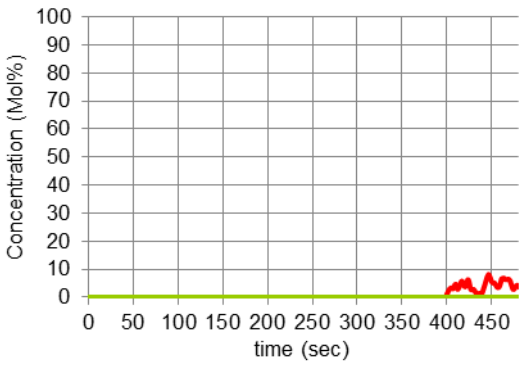
Gas Concentration at x=22m, y=54m, z=2.2m



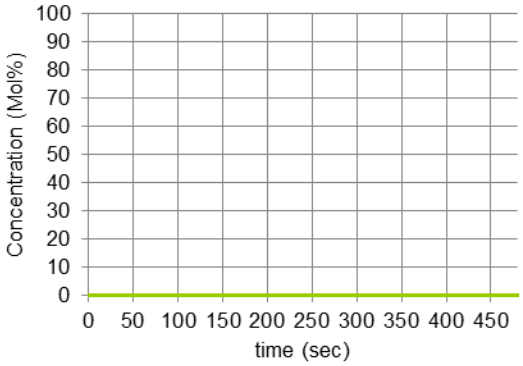
Gas Concentration at x=0m, y=89m, z=0.9m



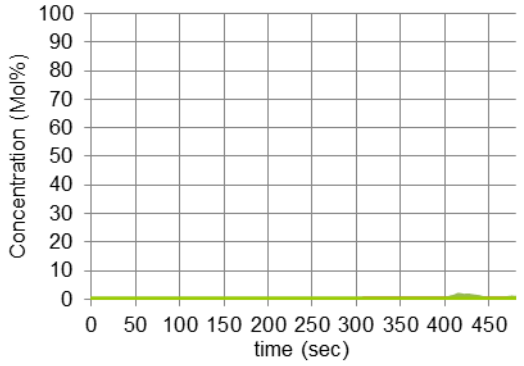
Gas Concentration at x=0m, y=89m, z=1.3m



Gas Concentration at x=0m, y=89m, z=2.3m

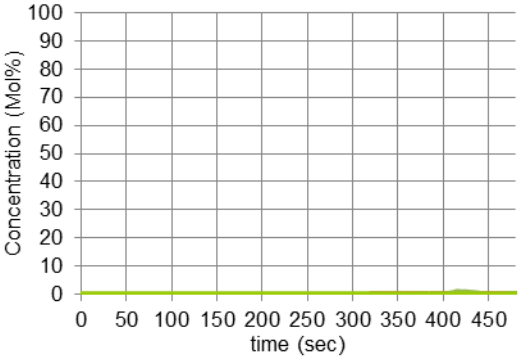


Gas Concentration at x=48m, y=120m, z=0.9m

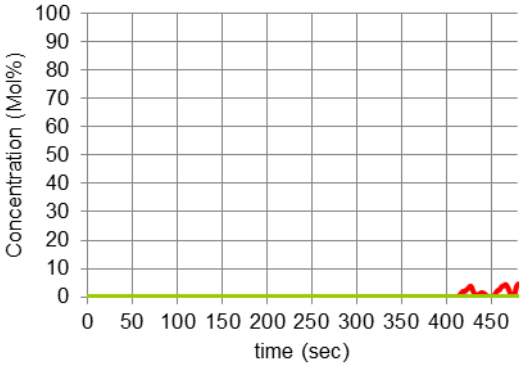


Gas Concentration at x=48m, y=120m, z=1.8m

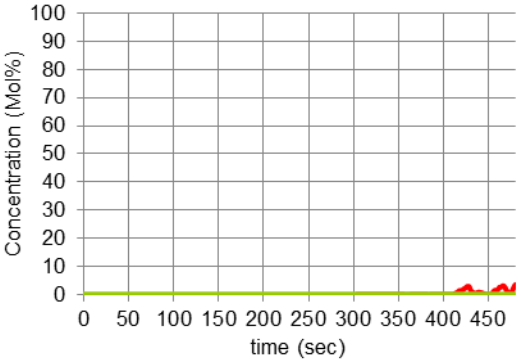
Maplin Sands 34 (continued)



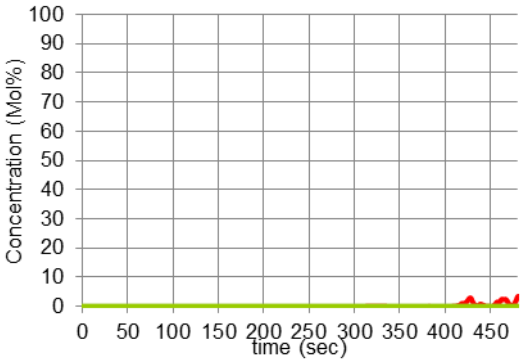
Gas Concentration at x=48m, y=120m, z=2.8m



Gas Concentration at x=0m, y=180m, z=1.0m

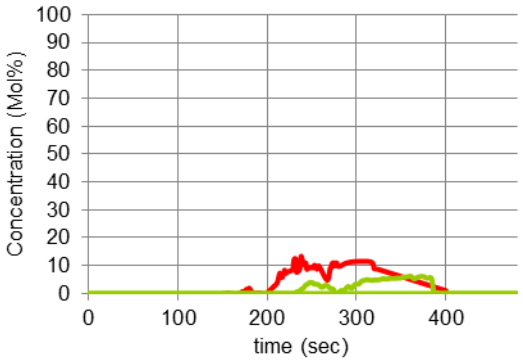


Gas Concentration at x=0m, y=180m, z=1.5m

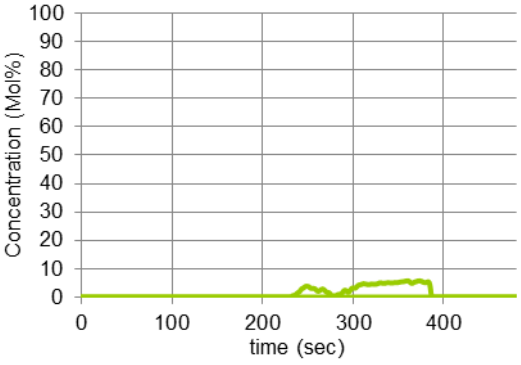


Gas Concentration at x=0m, y=180m, z=2.4m

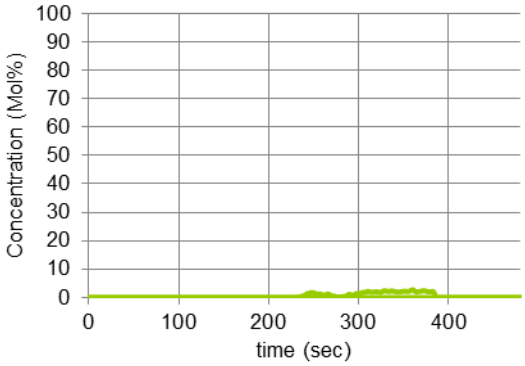
Maplin Sands 35



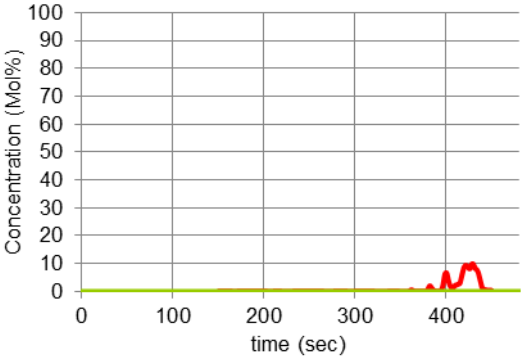
Gas Concentration at x=22m, y=54m, z=0.9m



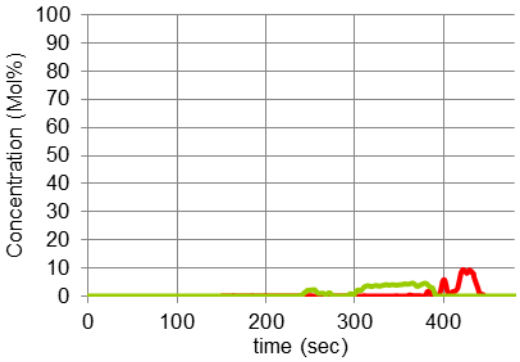
Gas Concentration at x=22m, y=54m, z=1.3m



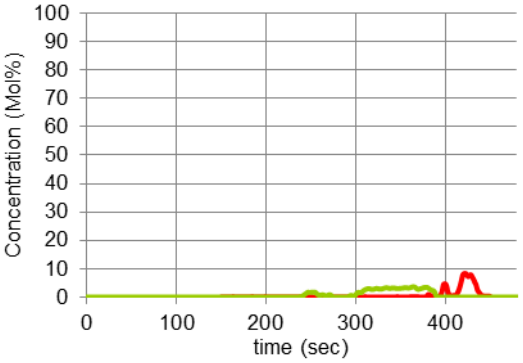
Gas Concentration at x=22m, y=54m, z=2.2m



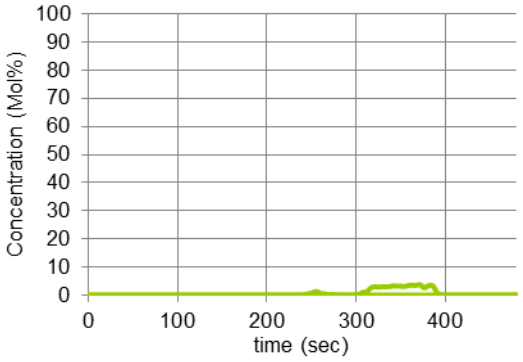
Gas Concentration at x=0m, y=89m, z=0.9m



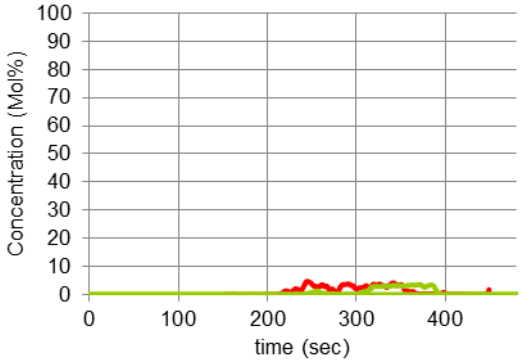
Gas Concentration at x=0m, y=89m, z=1.3m



Gas Concentration at x=0m, y=89m, z=2.3m

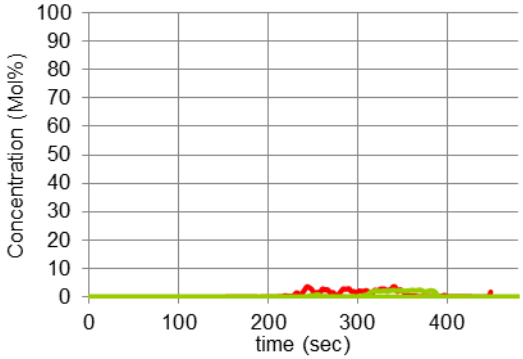


Gas Concentration at x=48m, y=120m, z=0.9m

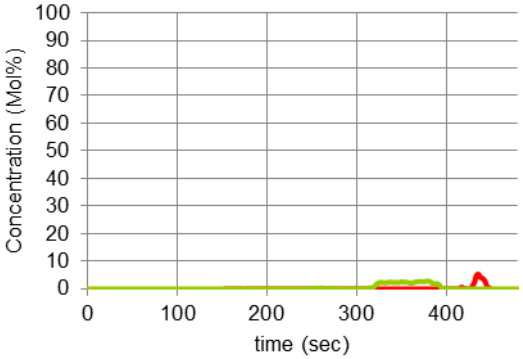


Gas Concentration at x=48m, y=120m, z=1.8m

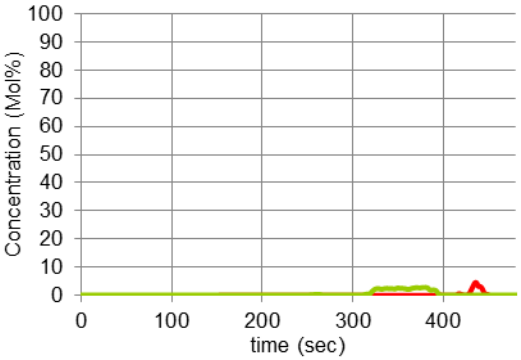
Maplin Sands 35 (continued)



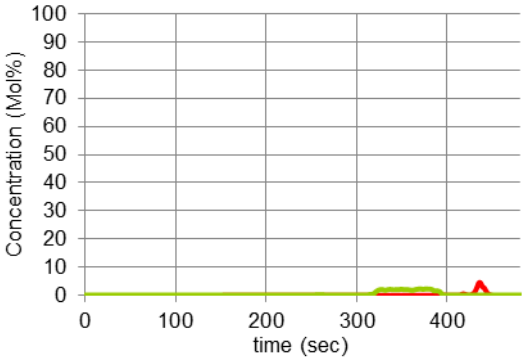
Gas Concentration at x=48m, y=120m, z=2.8m



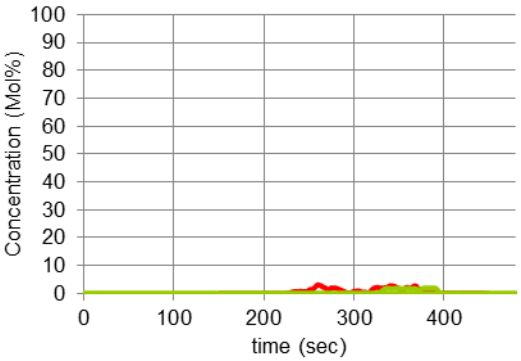
Gas Concentration at x=0m, y=180m, z=1.0m



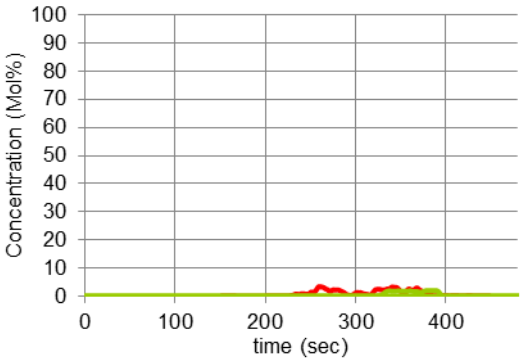
FiGas Concentration at x=0m, y=180m, z=1.5m



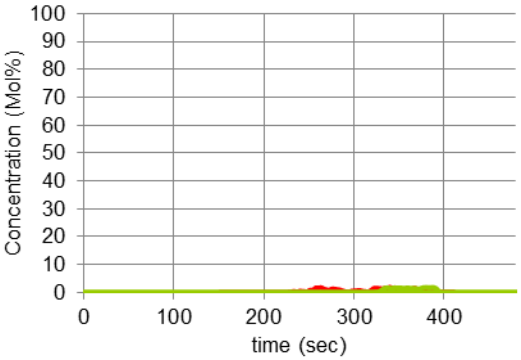
Gas Concentration at x=0m, y=180m, z=2.4m



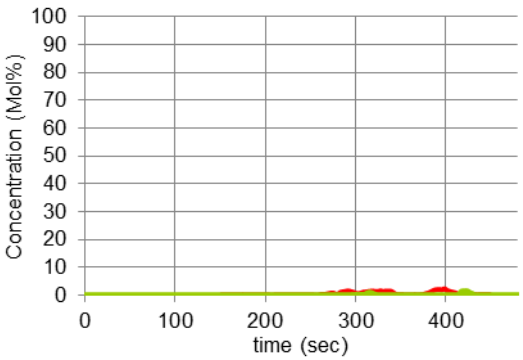
Gas Concentration at x=94m, y=232m, z=1.0m



Gas Concentration at x=94m, y=232m, z=1.6m

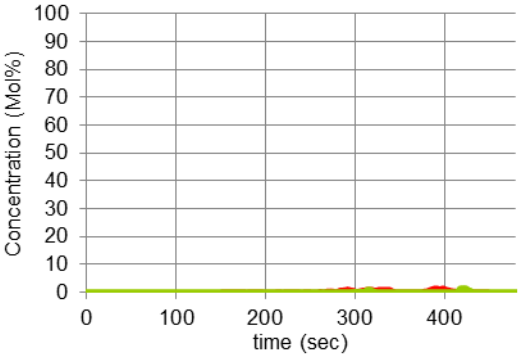


Gas Concentration at x=94m, y=232m, z=2.4m

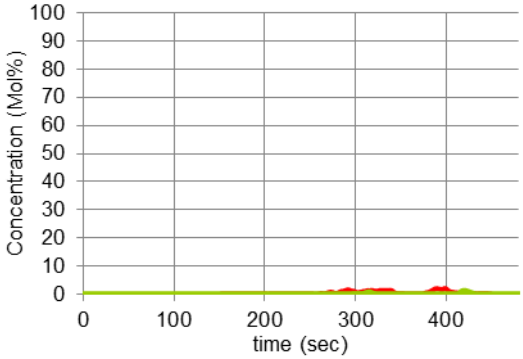


Gas Concentration at x=124m, y=380m, z=1.0m

Maplin Sands 35 (continued)

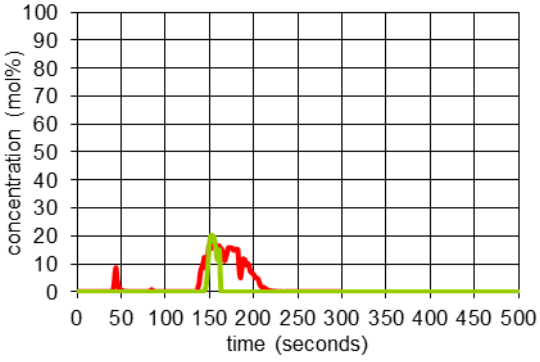


Gas Concentration at x=124m, y=380m, z=1.9m

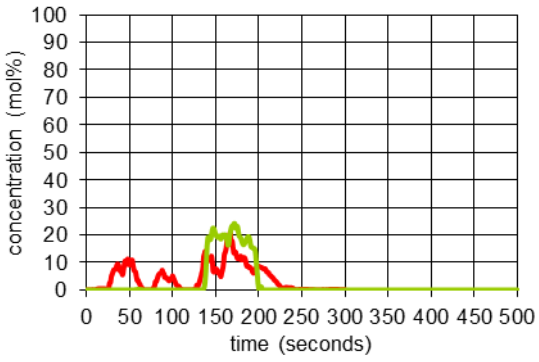


Gas Concentration at x=124m, y=380m, z=2.4m

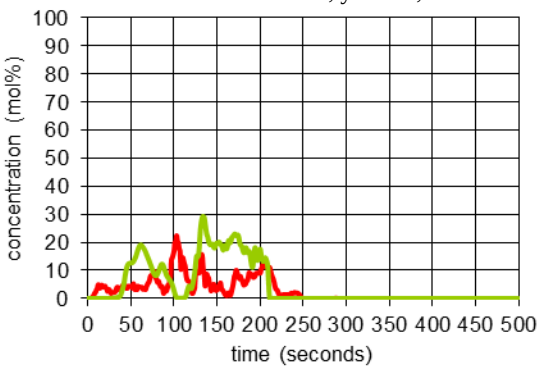
Burro 3



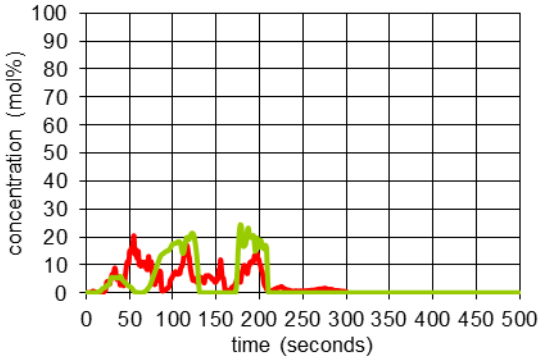
Gas Concentration bat x=40m, y=-41m, z=1m



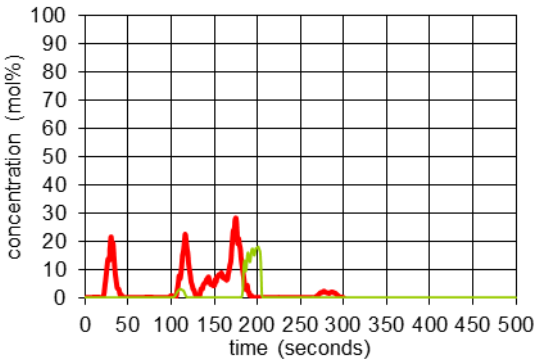
Gas Concentration at x=49m, y=-29m, z=1m



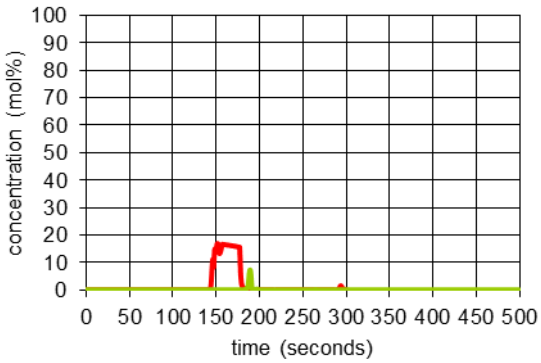
Gas Concentration at x=56m, y=-15m, z=1m



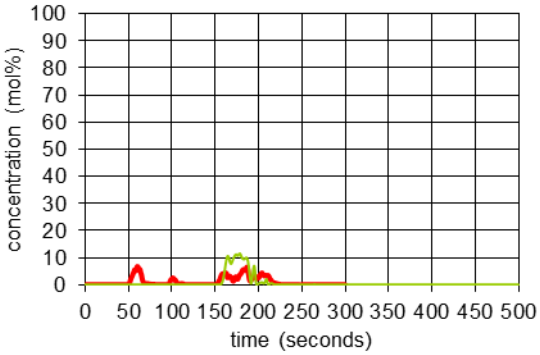
Gas Concentration at x=56m, y=15m, z=1m



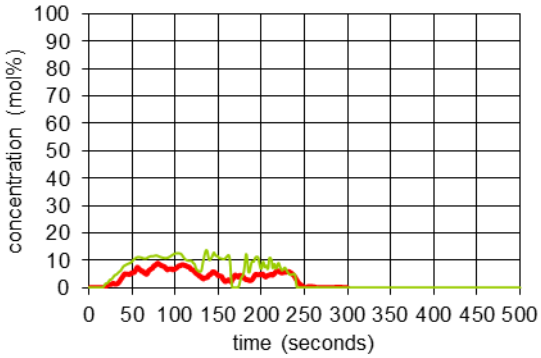
Gas Concentration at x=49m, y=29m, z=1m



Gas Concentration at x=37m, y=38m, z=1m

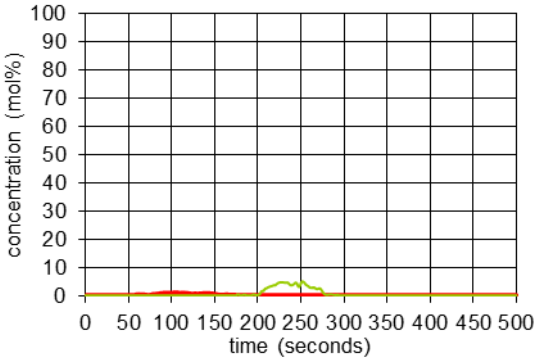


Gas Concentration at x=127m, y=58m, z=1m

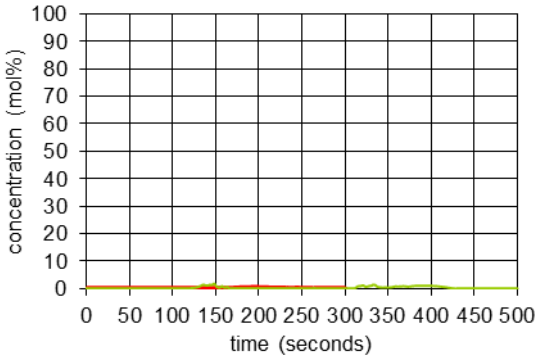


Gas Concentration at x=140m, y=0m, z=1m

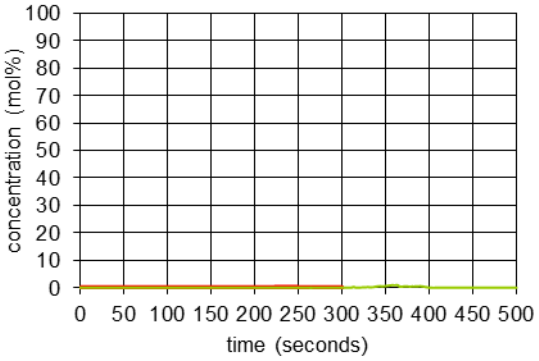
Burro 3 (continued)



Gas Concentration at x=396m, y=-60m, z=1m

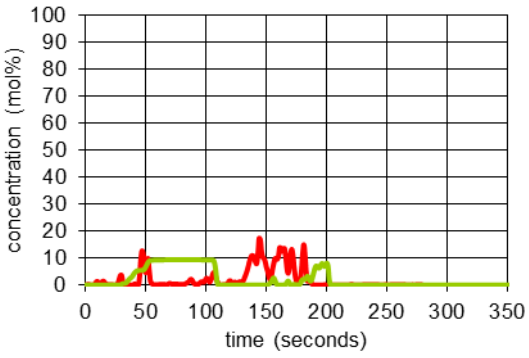


Gas Concentration at x=796m, y=80m, z=1m

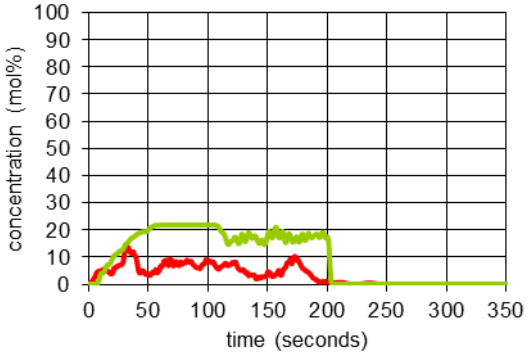


Gas Concentration at x=784m, y=159m, z=1m

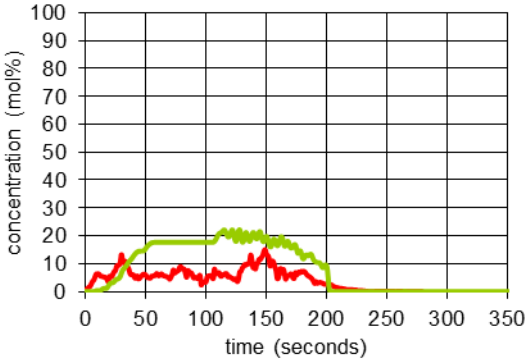
Burro 7



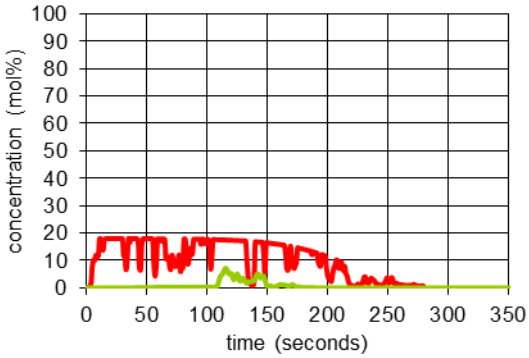
Gas Concentration at x=57m, y=0m, z=1m



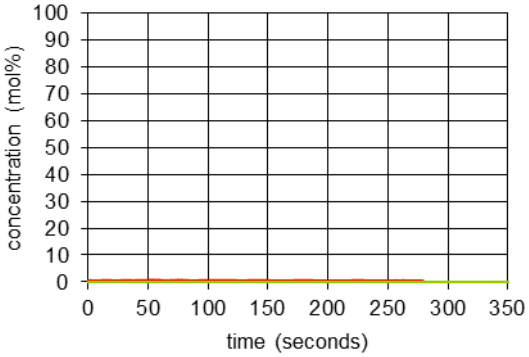
Gas Concentration at x=56m, y=15m, z=1m



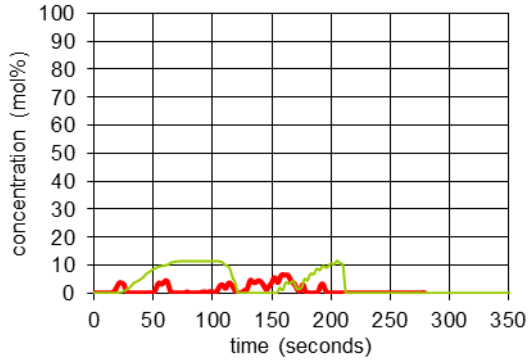
Gas Concentration at x=49m, y=29m, z=1m



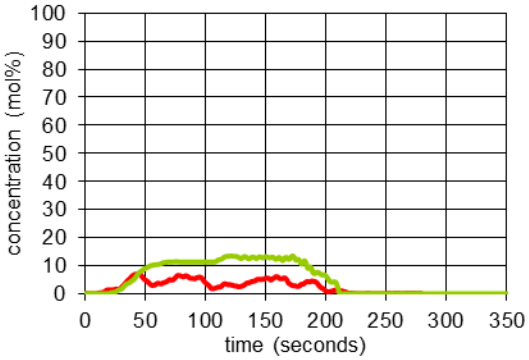
Gas Concentration at x=37m, y=38m, z=1m



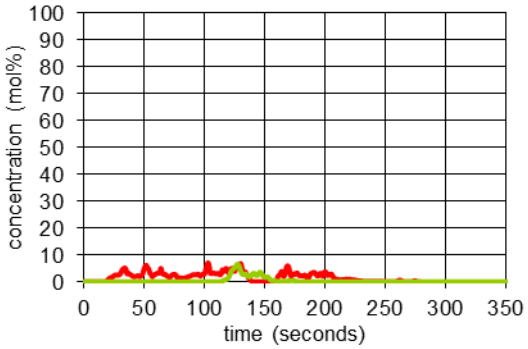
Gas Concentration at x=140m, y=0m, z=1m



Gas Concentration at x=137m, y=30m, z=1m

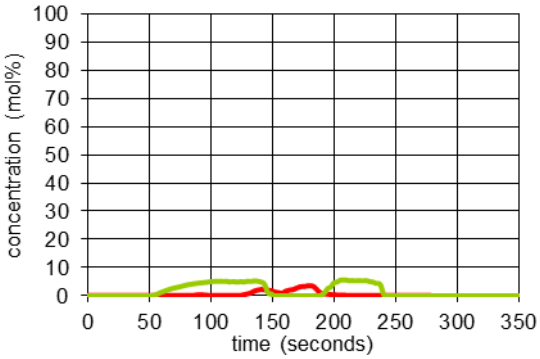


Gas Concentration at x=127m, y=58m, z=1m

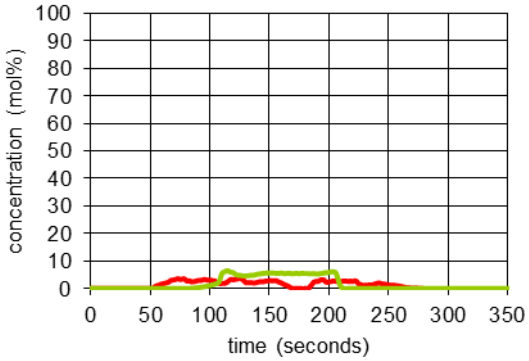


Gas Concentration at x=112m, y=84m, z=1m

Burro 7 (continued)

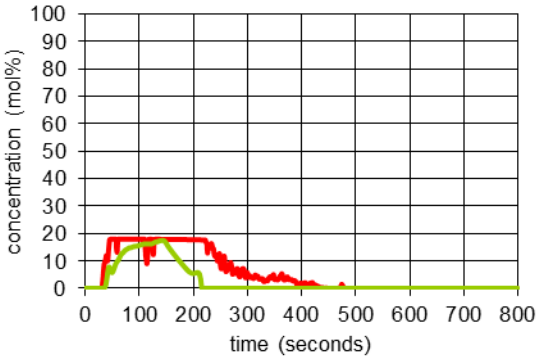


Gas Concentration at x=382m, y=118m, z=1m

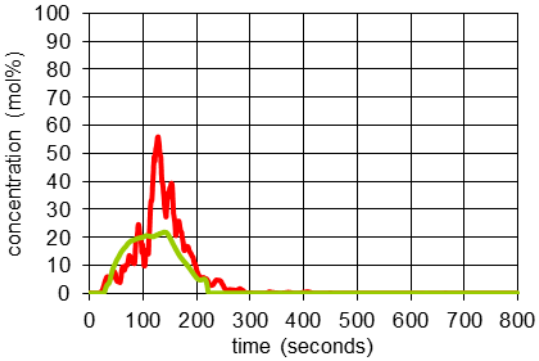


Gas Concentration at x=360m, y=174m, z=1m

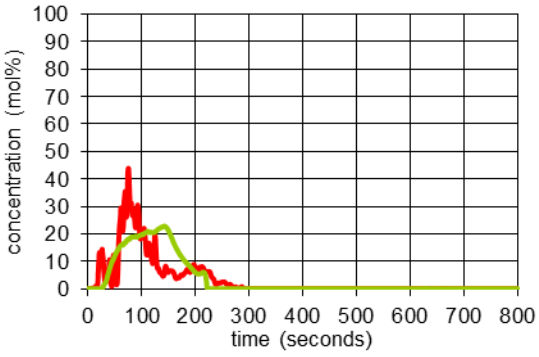
Burro 8



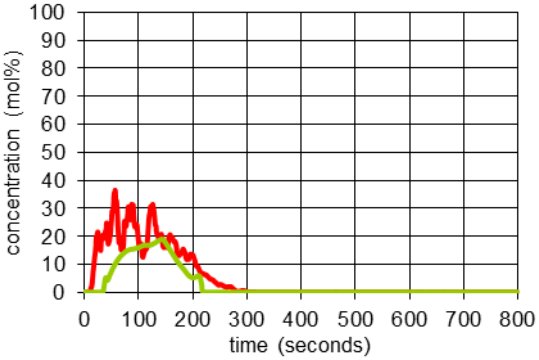
Gas Concentration at x=40m, y=-41m, z=1m



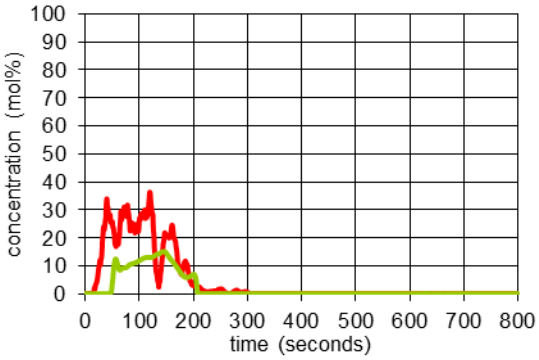
Gas Concentration at x=49m, y=-29m, z=1m



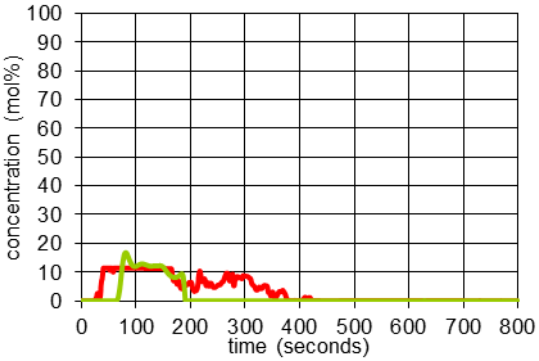
Gas Concentration at x=57m, y=0m, z=1m



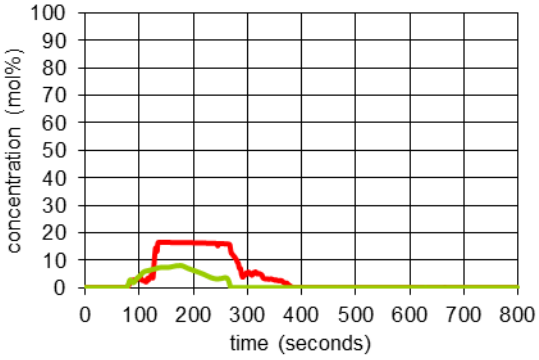
Gas Concentration at x=56m, y=15m, z=1m



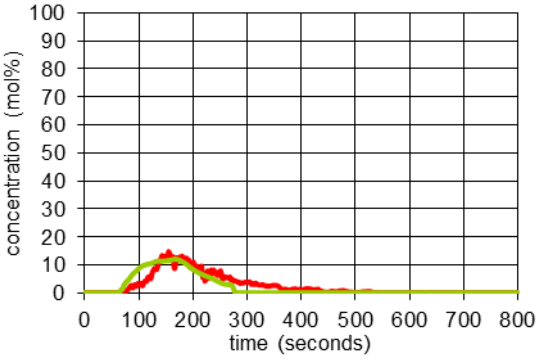
Gas Concentration at x=49m, y=29m, z=1m



Gas Concentration at x=37m, y=38m, z=1m

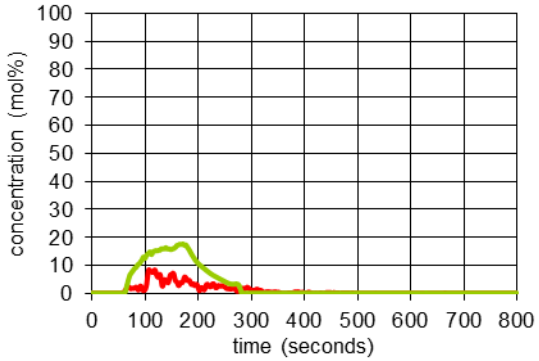


Gas Concentration at x=112m, y=-84m, z=1m

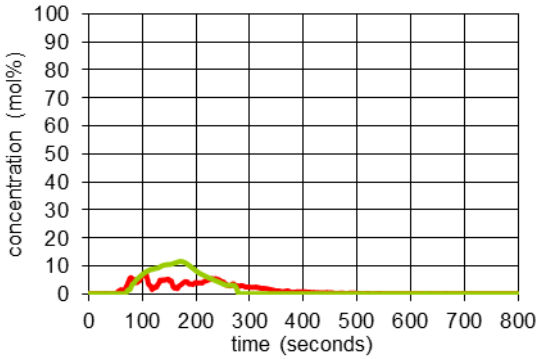


Gas Concentration at x=127m, y=-58m, z=1m

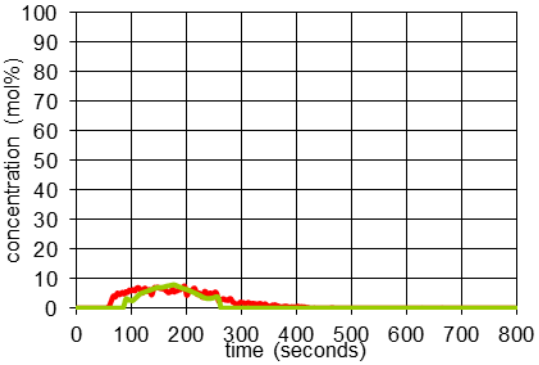
Burro 8 (continued)



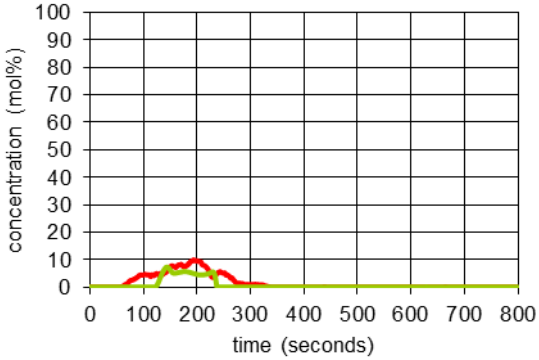
Gas Concentration at x=137m, y=-30m, z=1m



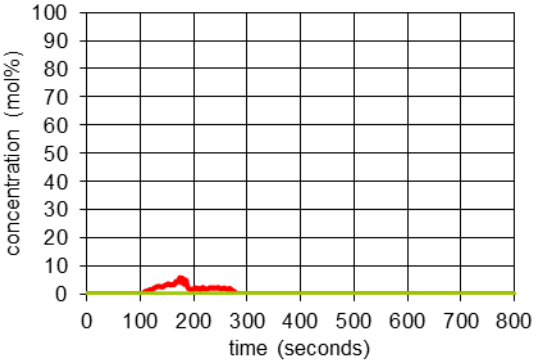
Gas Concentration at x=140m, y=0m, z=1m



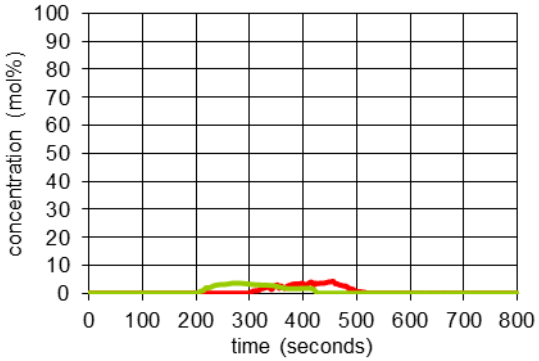
Gas Concentration at x=137m, y=30m, z=1m



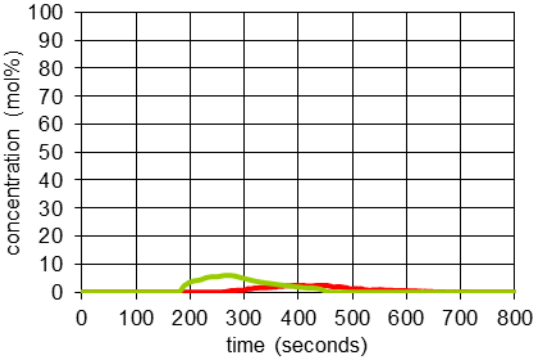
Gas Concentration at x=127m, y=58m, z=1m



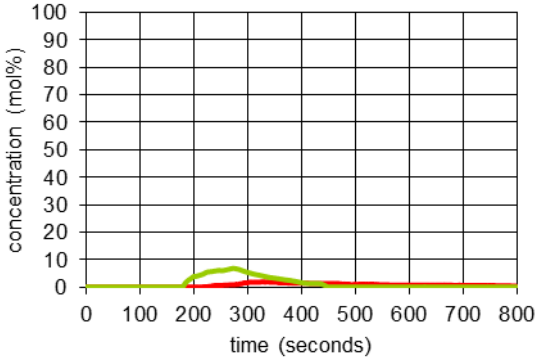
Gas Concentration at x=112m, y=84m, z=1m



Gas Concentration at x=360m, y=-174m, z=1m

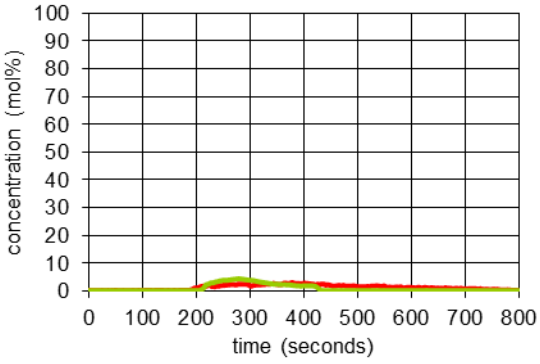


Gas Concentration at x=382m, y=-118m, z=1m

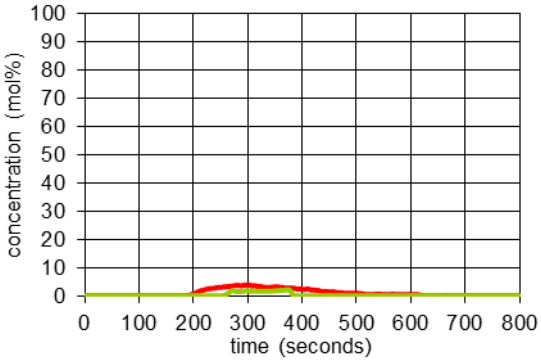


Gas Concentration at x=396m, y=-60m, z=1m

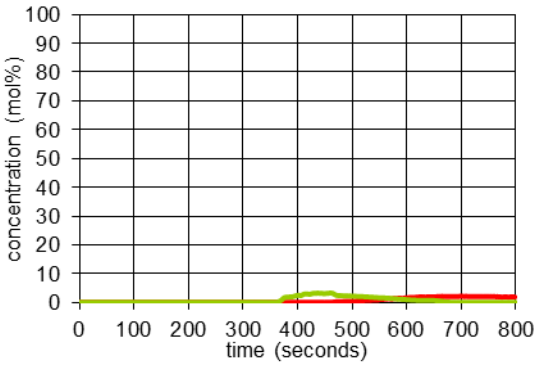
Burro 8 (continued)



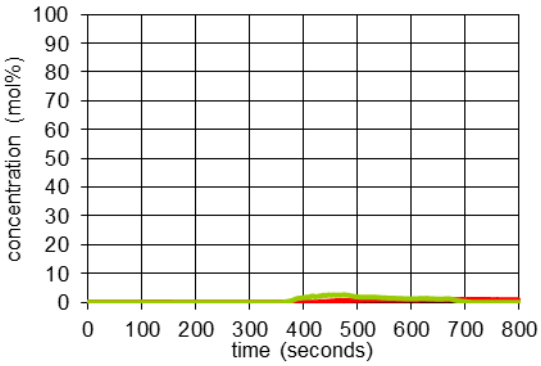
Gas Concentration at x=400m, y=0m, z=1m



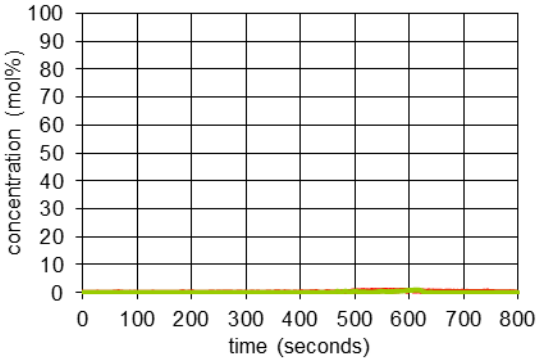
Gas Concentration at x=396m, y=60m, z=1m



Gas Concentration at x=784m, y=-159m, z=1m

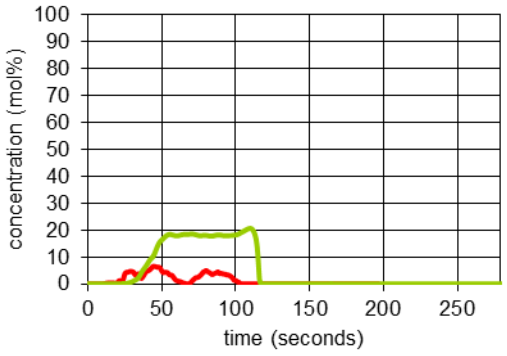


Gas Concentration at x=796m, y=-80m, z=1m

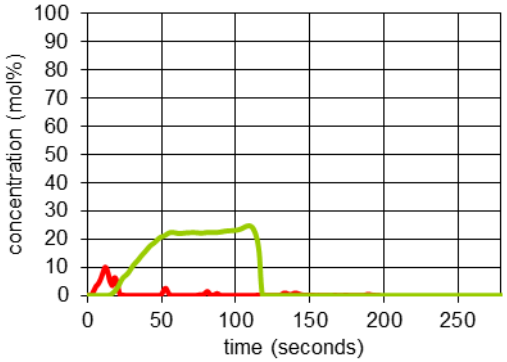


Gas Concentration at x=800m, y=0m, z=1m

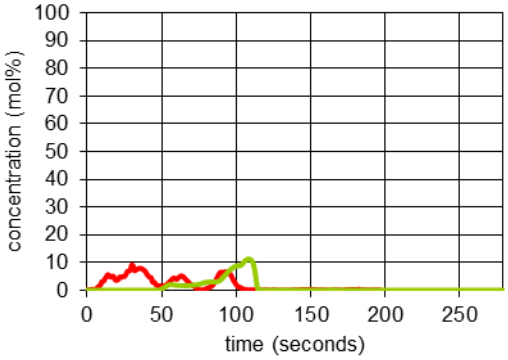
Burro 9



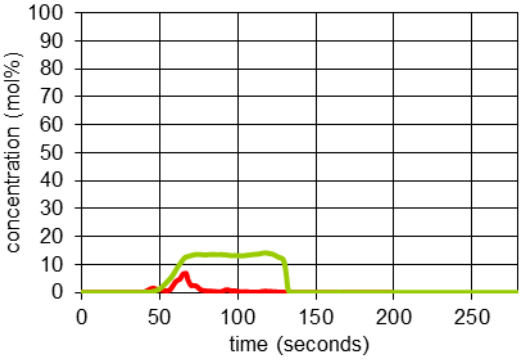
Gas Concentration at x=49m, y=29m, z=1m



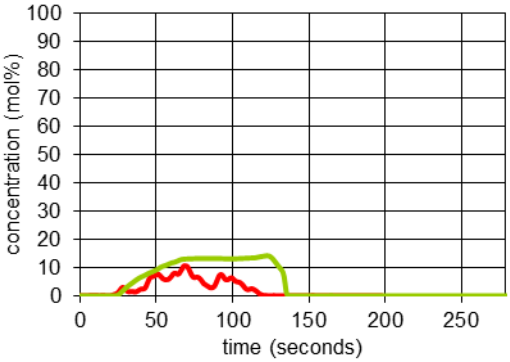
Gas Concentration at x=57m, y=0m, z=1m



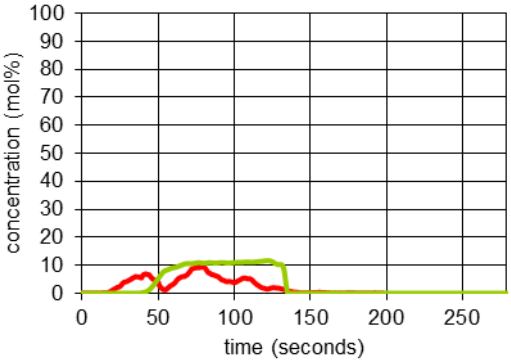
Gas Concentration at x=56m, y=15m, z=1m



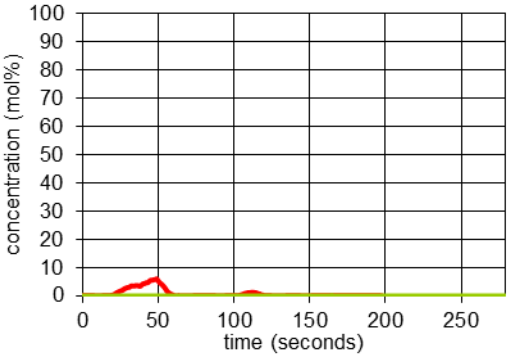
Gas Concentration at x=127m, y=-58m, z=1m



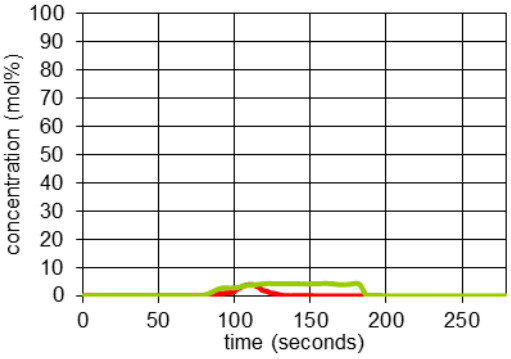
Gas Concentration at x=137m, y=-30m, z=1m



Gas Concentration at x=140m, y=0m, z=1m

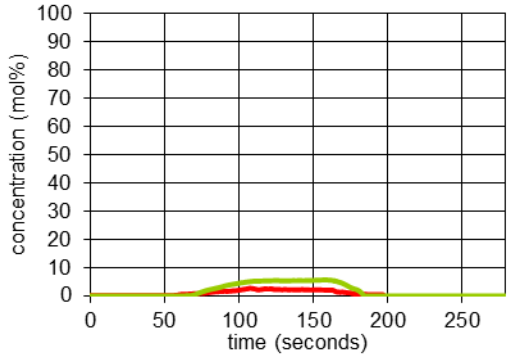


Gas Concentration at x=127m, y=58m, z=1m

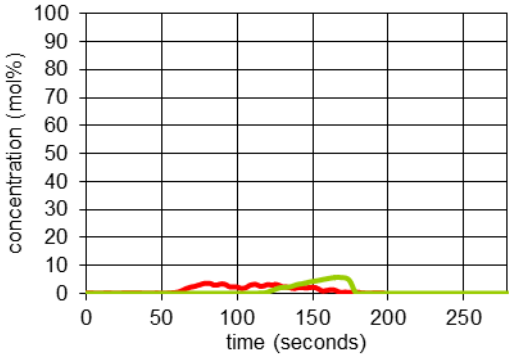


Gas Concentration at x=382m, y=-118m, z=1m

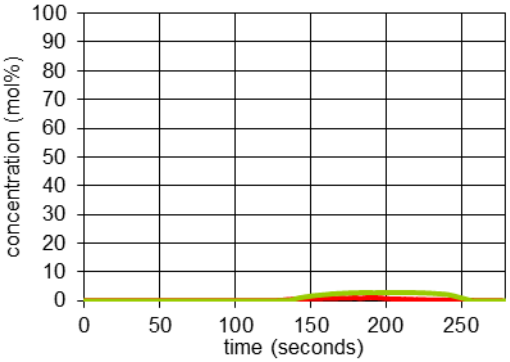
Burro 9 (continued)



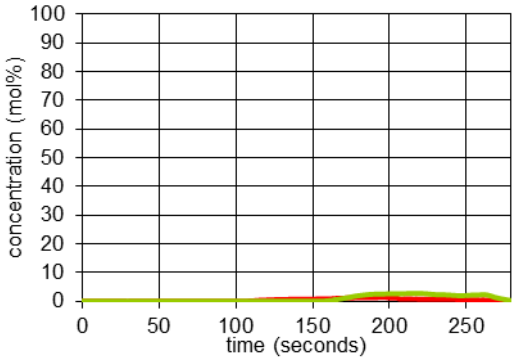
Gas Concentration at x=396m, y=-60m, z=1m



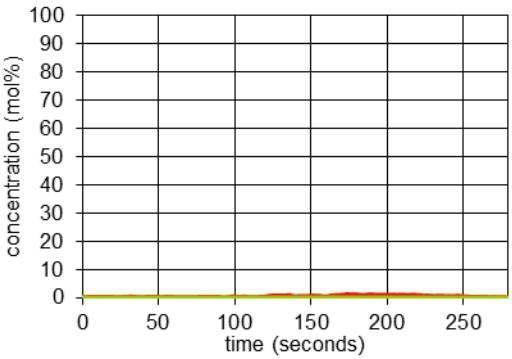
Gas Concentration at x=400m, y=0m, z=1m



Gas Concentration at x=784m, y=-159m, z=1m

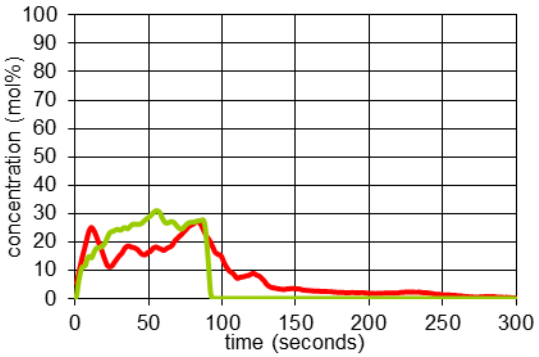


Gas Concentration at x=796m, y=-80m, z=1m

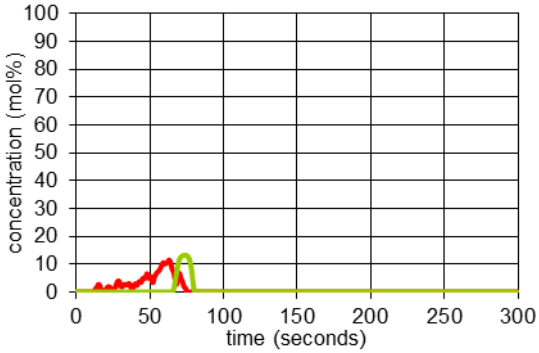


Gas Concentration at x=800m, y=0m, z=1m

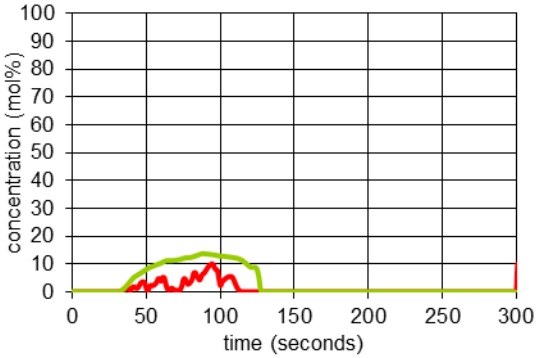
Coyote 3



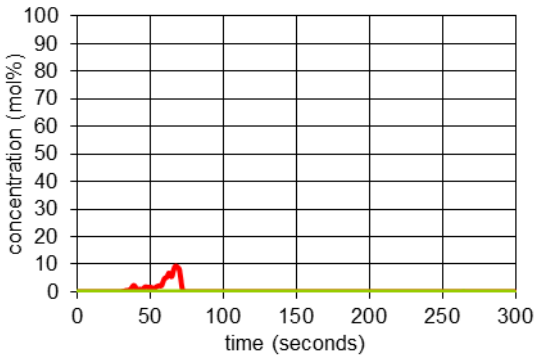
Gas Concentration at x=5.4m, y=0m, z=1m



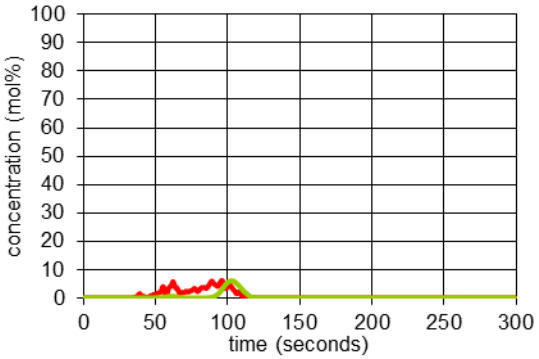
Gas Concentration at x=110m, y=0m, z=1m



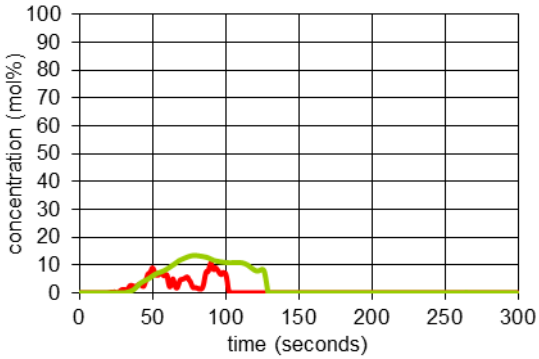
Gas Concentration at x=127m, y=58m, z=1m



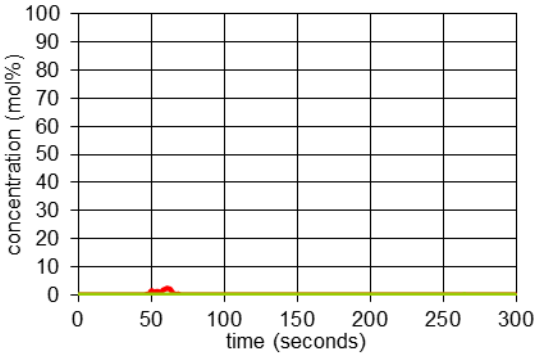
Gas Concentration at x=140m, y=0m, z=1m



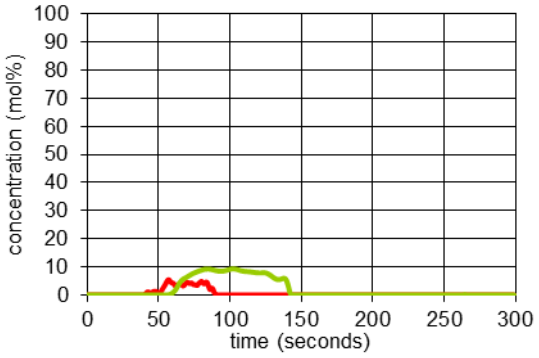
Gas Concentration at x=112m, y=84m, z=1m



Gas Concentration at x=137m, y=30m, z=1m

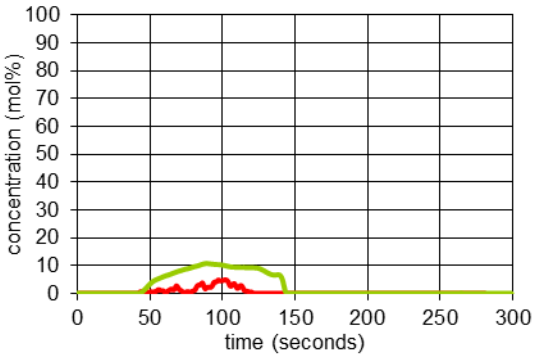


Gas Concentration at x=200m, y=0m, z=1m

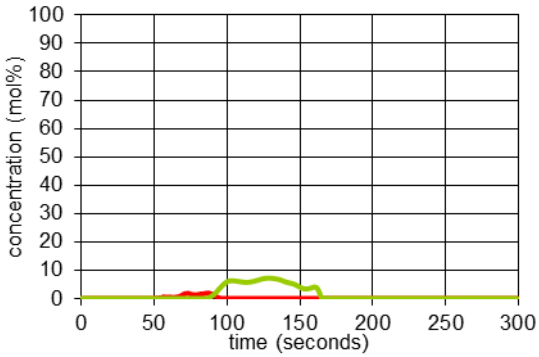


Gas Concentration at x=197m, y=37m, z=1m

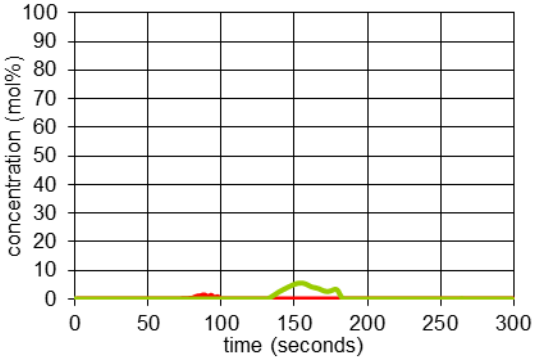
Coyote 3 (continued)



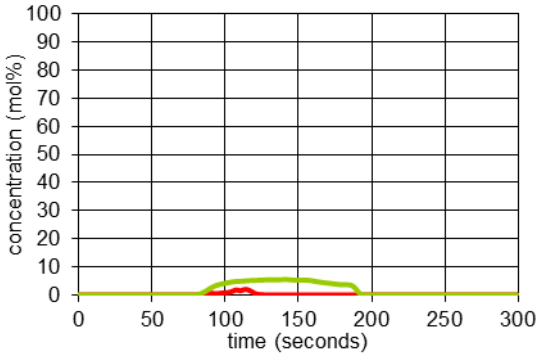
Gas Concentration at x=187m, y=72m, z=1m



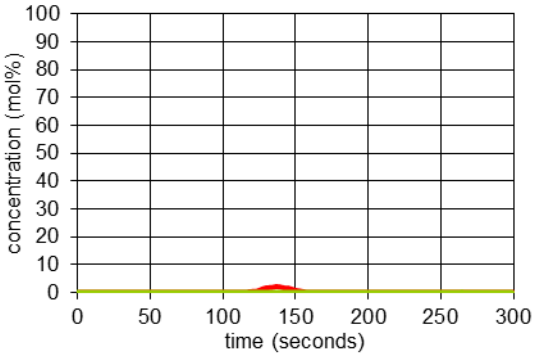
Gas Concentration at x=296m, y=48m, z=1m



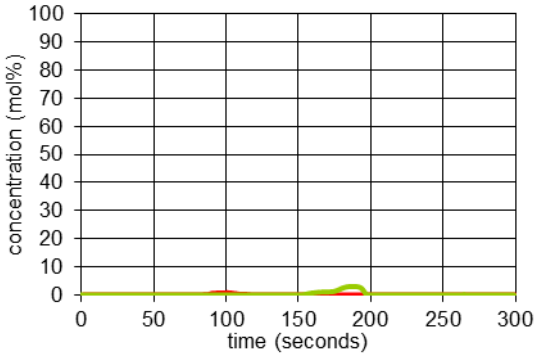
Gas Concentration at x=396m, y=60m, z=1m



Gas Concentration at x=382m, y=118m, z=1m

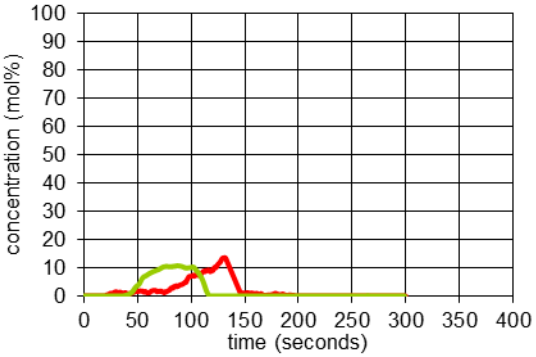


Gas Concentration at x=330m, y=226m, z=1m

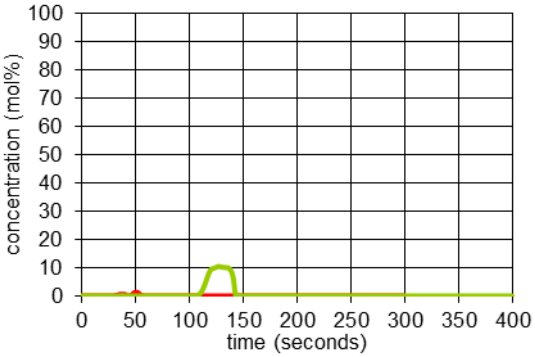


Gas Concentration at x=495m, y=71m, z=1m

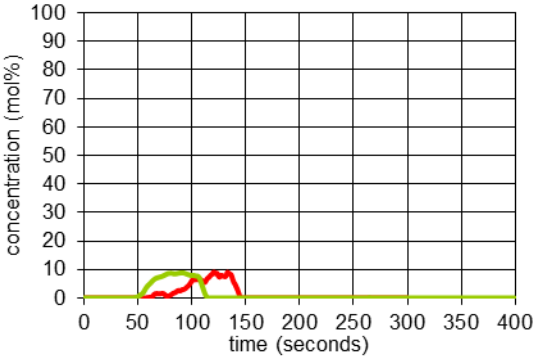
Coyote 5



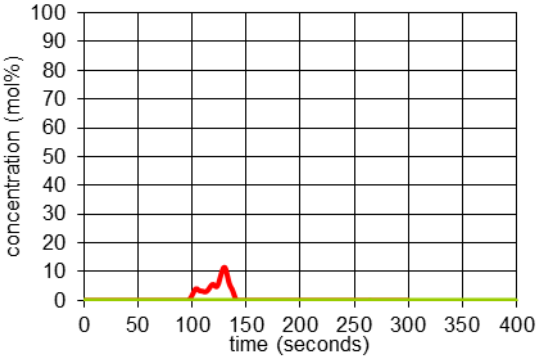
Gas Concentration at x=110m, y=0m, z=1m



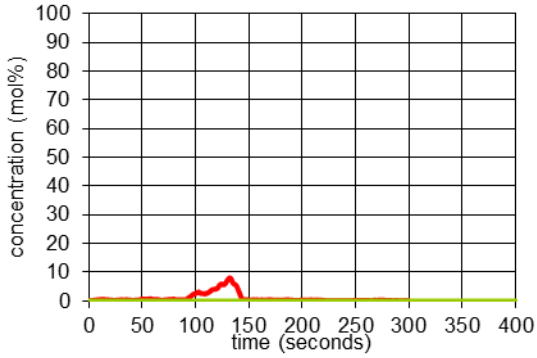
Gas Concentration at x=127m, y=58m, z=1m



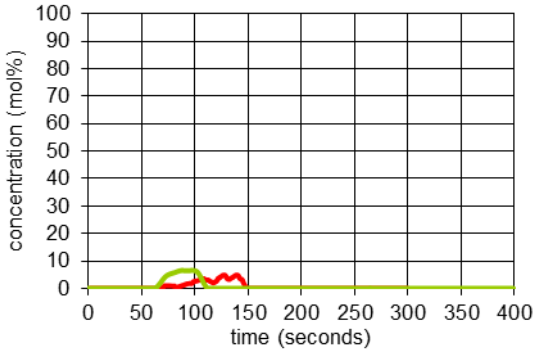
Gas Concentration at x=140m, y=0m, z=1m



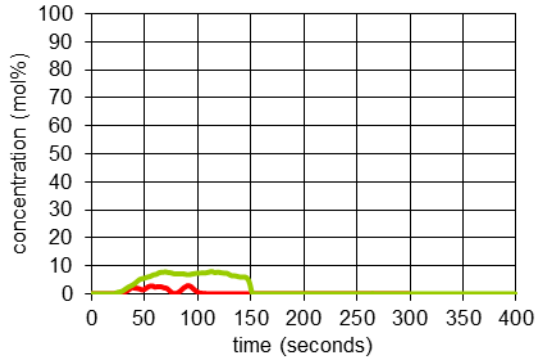
Gas Concentration at x=137m, y=-30m, z=1m



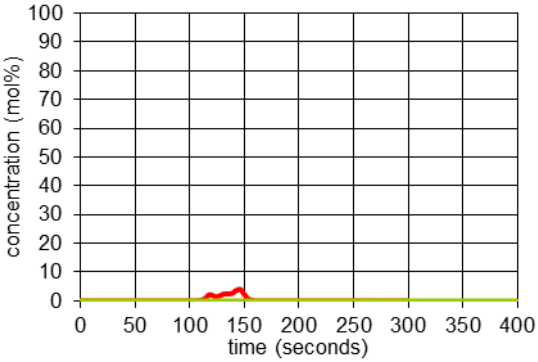
Gas Concentration at x=197m, y=-37m, z=1m



Gas Concentration at x=200m, y=0m, z=1m

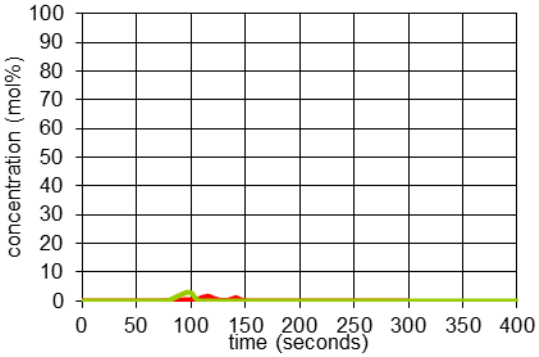


Gas Concentration at x=197m, y=37m, z=1m

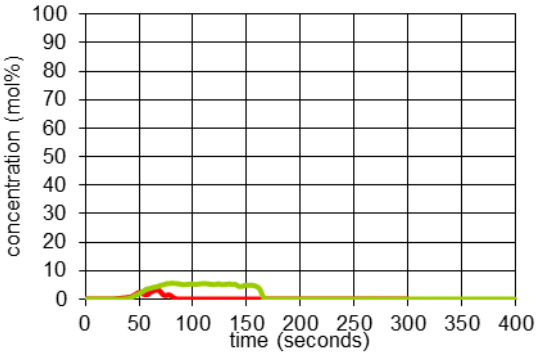


Gas Concentration at x=296m, y=-48m, z=1m

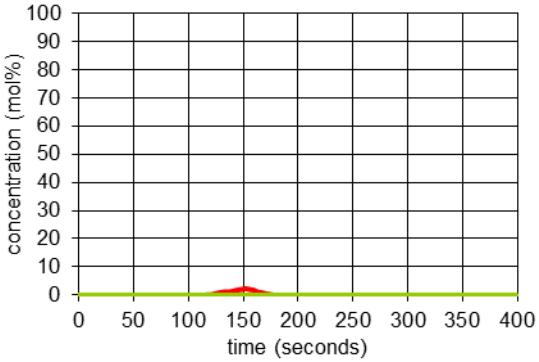
Coyote 5 (continued)



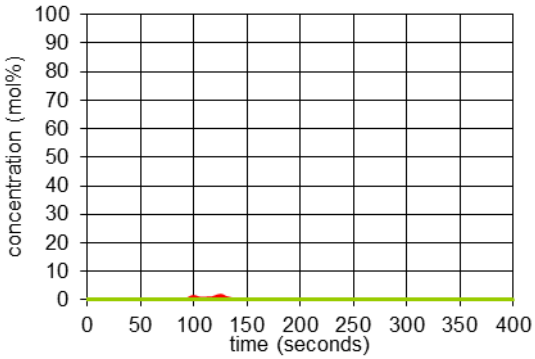
Gas Concentration at x=300m, y=0m, z=1m



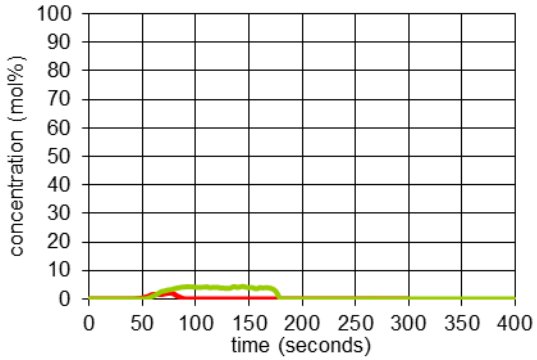
Gas Concentration at x=296m, y=48m, z=1m



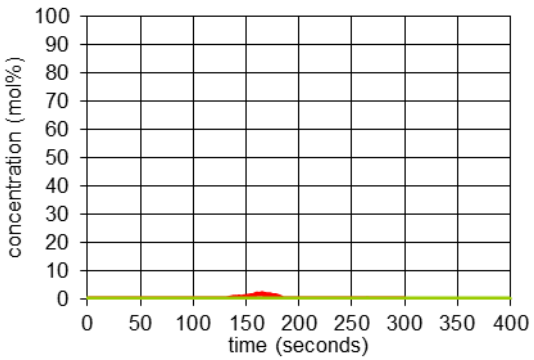
Gas Concentration at x=396m, y=-60m, z=1m



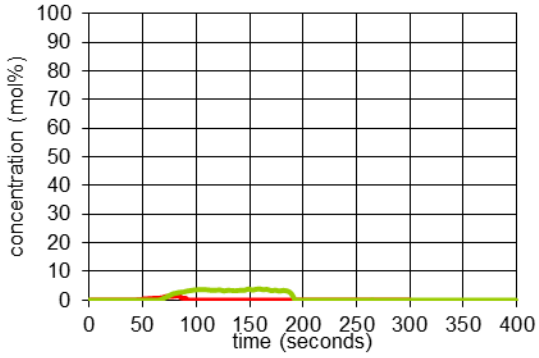
Gas Concentration at x=400m, y=0m, z=1m



Gas Concentration at x=396m, y=60m, z=1m

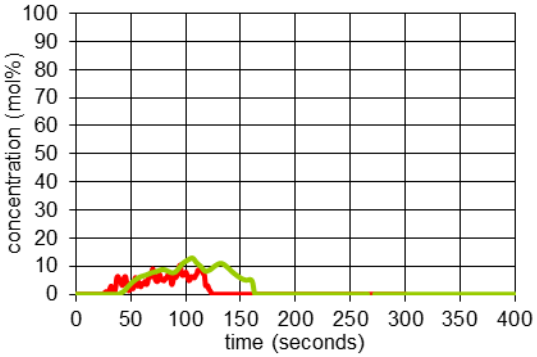


Gas Concentration at x=495m, y=-71m, z=1m

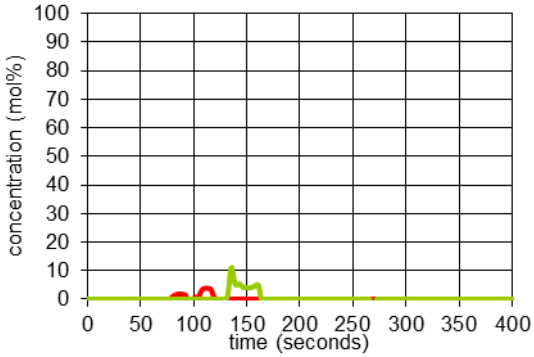


Gas Concentration at x=495m, y=71m, z=1m

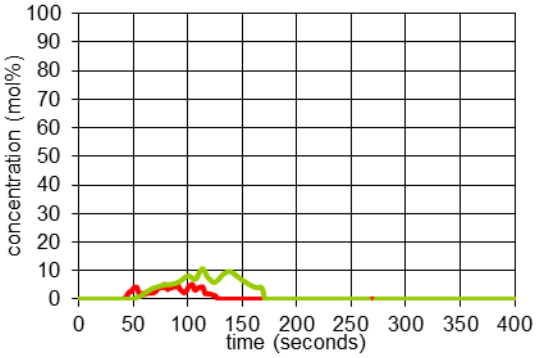
Coyote 6



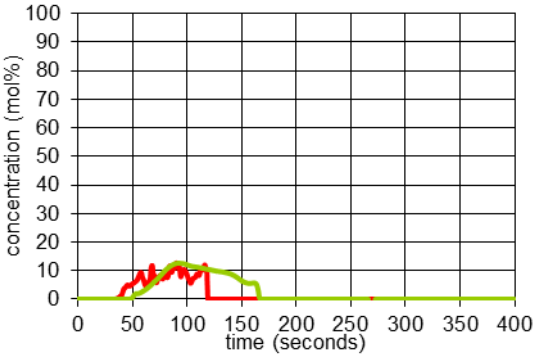
Gas Concentration at x=110m, y=0m, z=1m



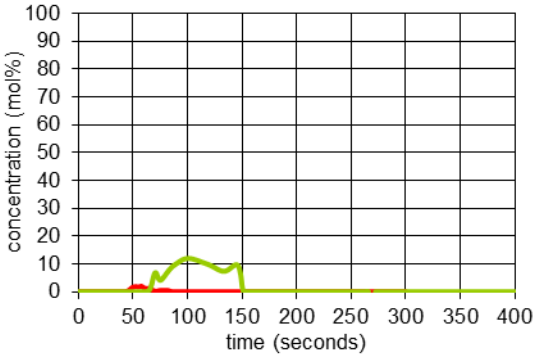
Gas Concentration at x=137m, y=-30m, z=1m



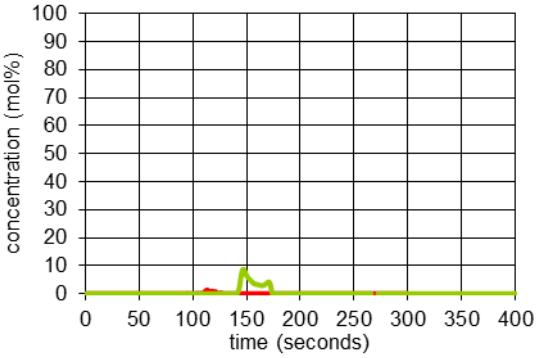
Gas Concentration at x=140m, y=0m, z=1m



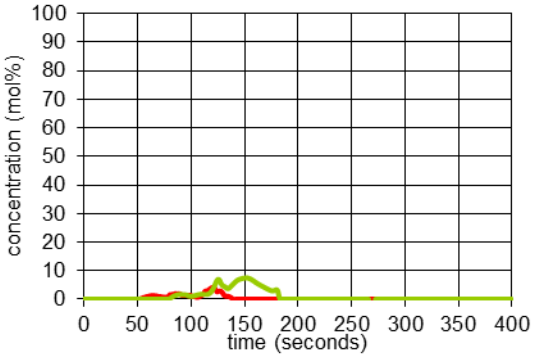
Gas Concentration at x=127m, y=58m, z=1m



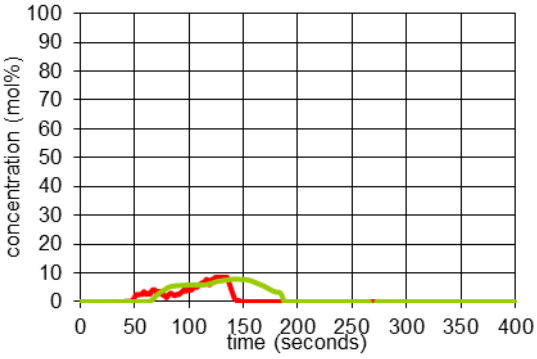
Gas Concentration at x=112m, y=84m, z=1m



Gas Concentration at x=197m, y=-37m, z=1m

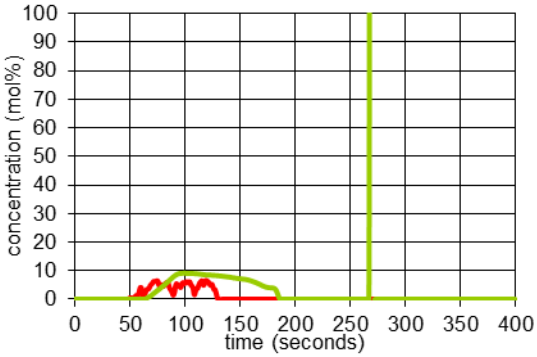


Gas Concentration at x=200m, y=0m, z=1m

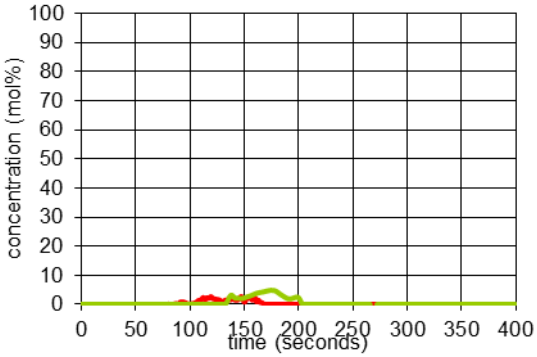


Gas Concentration at x=197m, y=37m, z=1m

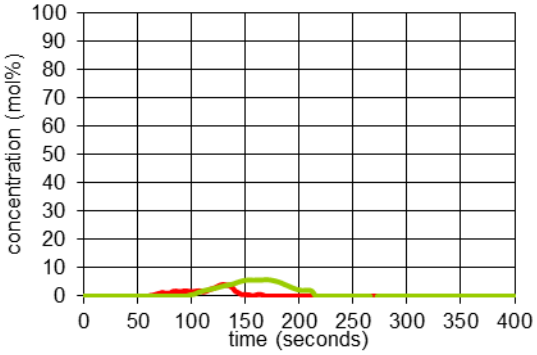
Coyote 6 (continued)



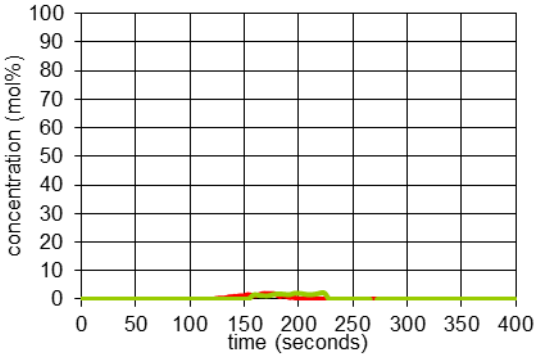
Gas Concentration at x=187m, y=72m, z=1m



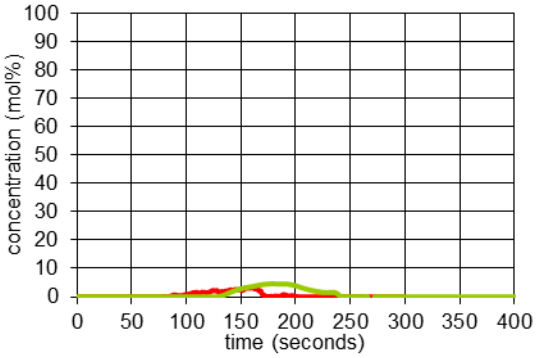
Gas Concentration at x=300m, y=0m, z=1m



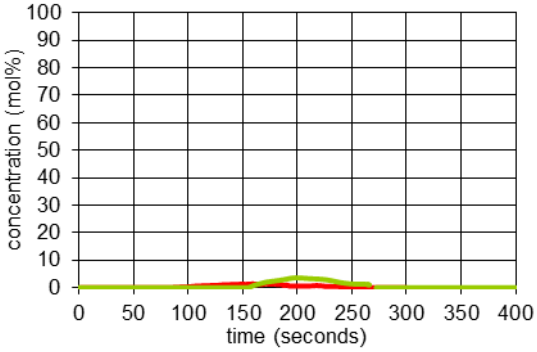
Gas Concentration at x=296m, y=48m, z=1m



Gas Concentration at x=400m, y=0m, z=1m

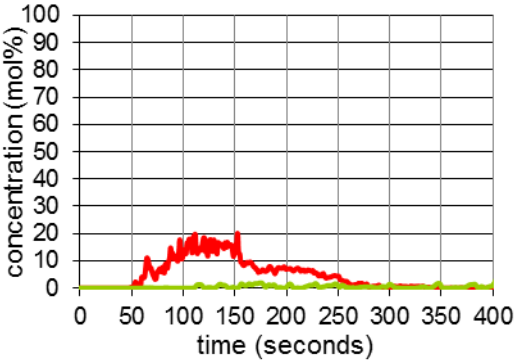


Gas Concentration at x=396m, y=60m, z=1m

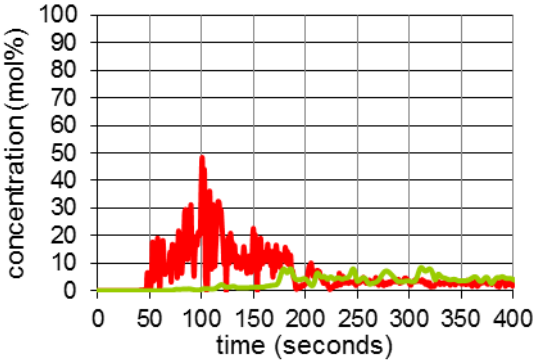


Gas Concentration at x=495m, y=71m, z=1m

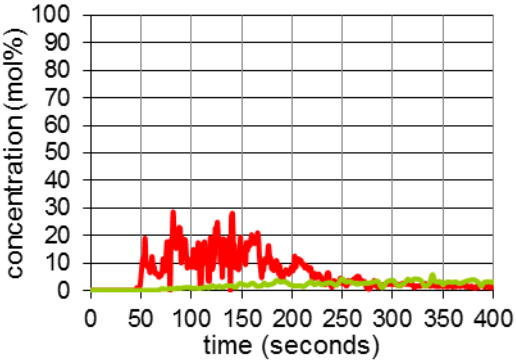
Falcon 1



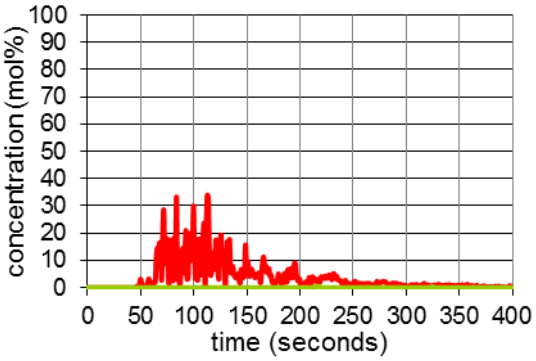
Gas Concentration at x=50m, y=-66m, z=1m



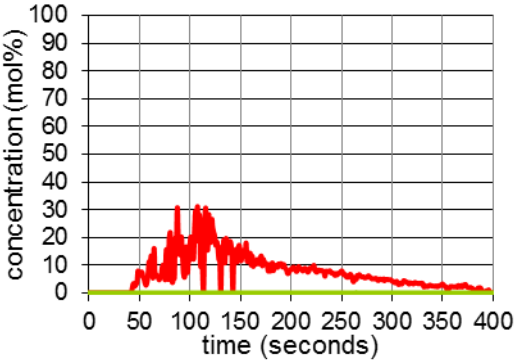
Gas Concentration at x=50m, y=-22m, z=1m



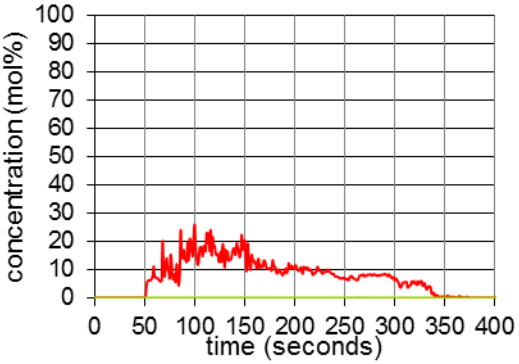
Gas Concentration at x=50m, y=0m, z=1m



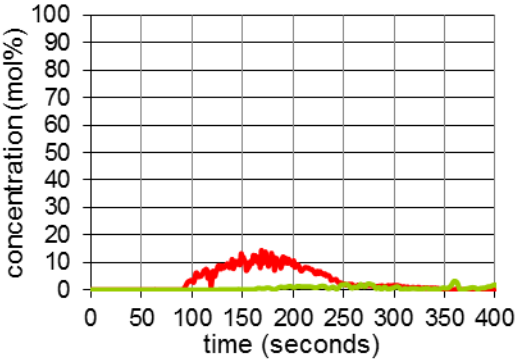
Gas Concentration at x=50m, y=22m, z=1m



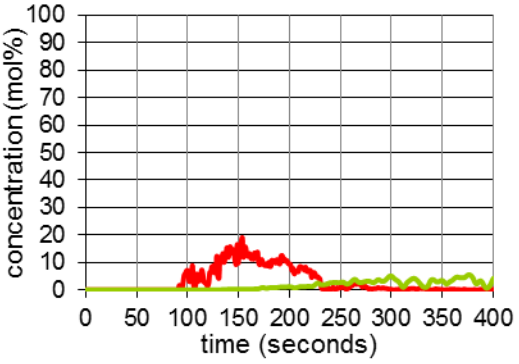
Gas Concentration at x=50m, y=44m, z=1m



Gas Concentration at x=50m, y=66m, z=1m

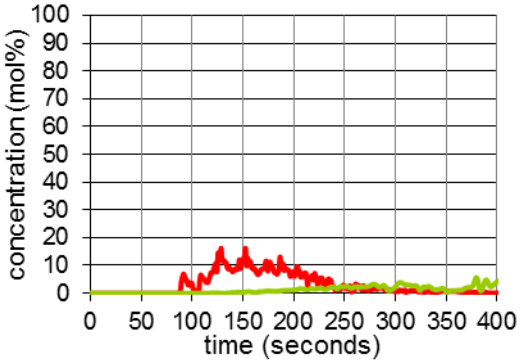


Gas Concentration at x=150m, y=-75m, z=1m

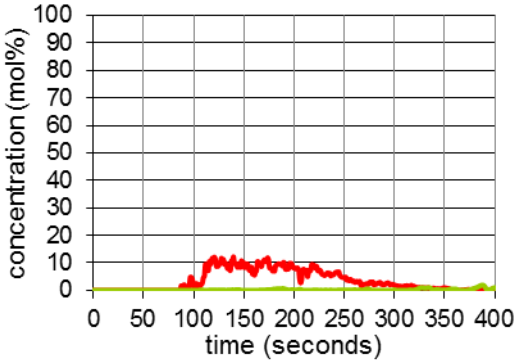


Gas Concentration at x=150m, y=-50m, z=1m

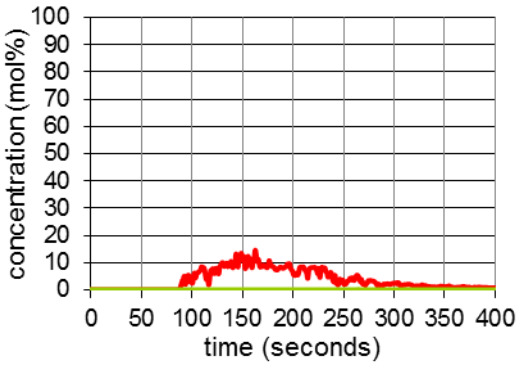
Falcon 1 (continued)



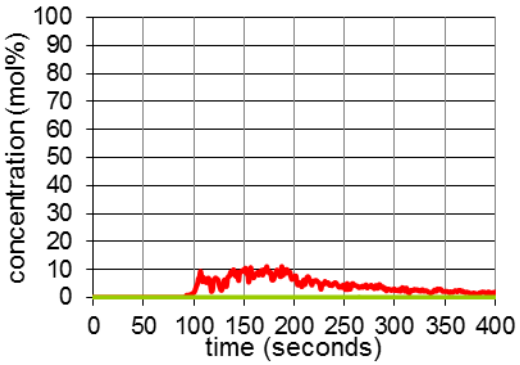
Gas Concentration at x=150m, y=-25m, z=1m



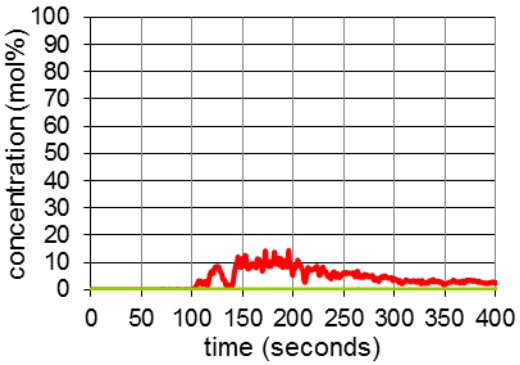
Gas Concentration at x=150m, y=0m, z=1m



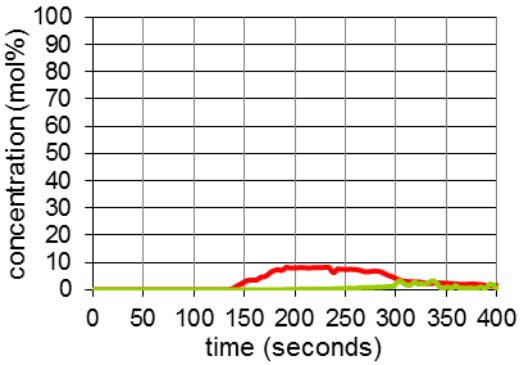
Gas Concentration at x=150m, y=25m, z=1m



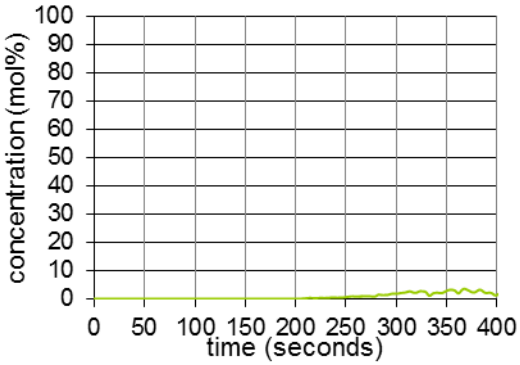
Gas Concentration at x=150m, y=50m, z=1m



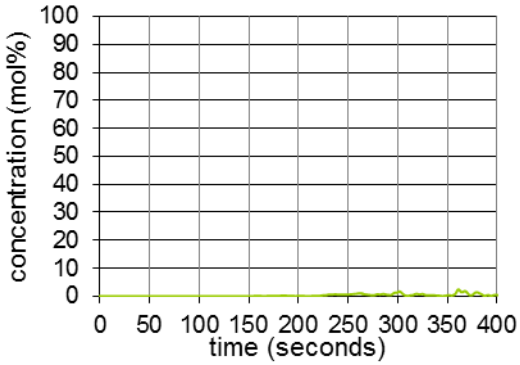
Gas Concentration at x=150m, y=75m, z=1m



Gas Concentration at x=250m, y=-84m, z=1m

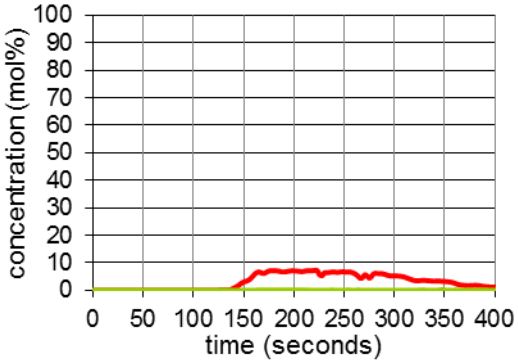


Gas Concentration at x=250m, y=-56m, z=1m

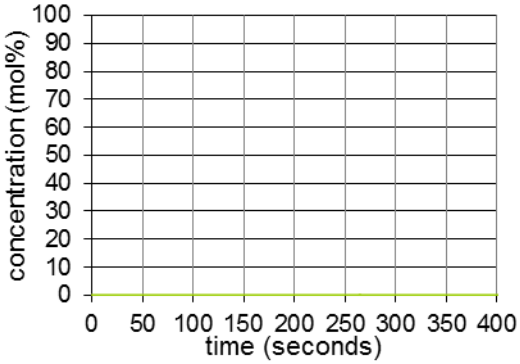


Gas Concentration at x=250m, y=-28m, z=1m

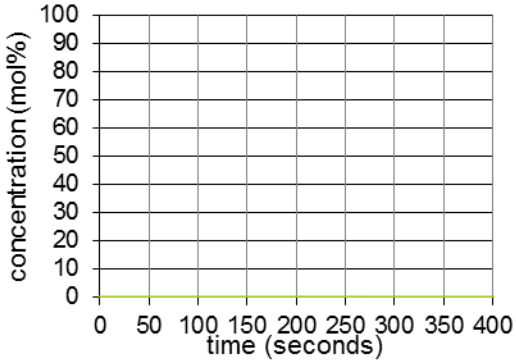
Falcon 1 (continued)



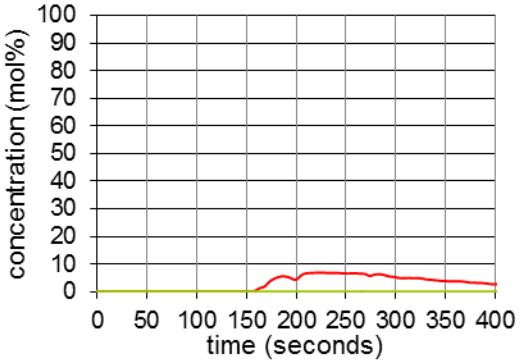
Gas Concentration at x=250m, y=0m, z=1m



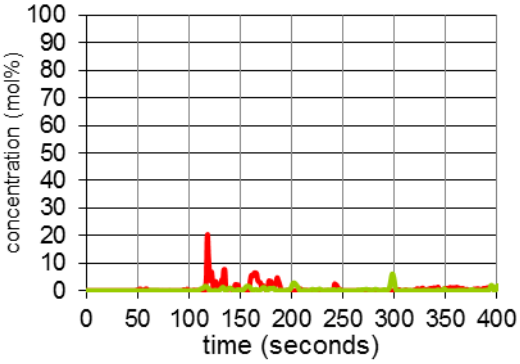
Gas Concentration at x=250m, y=28m, z=1m



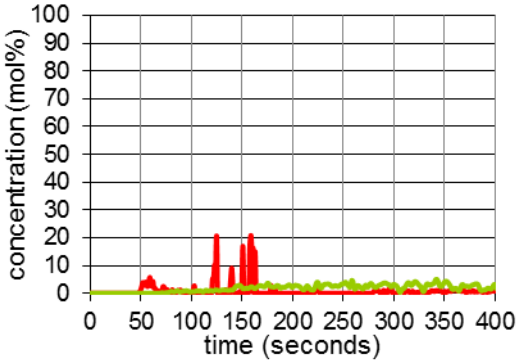
Gas Concentration at x=250m, y=56m, z=1m



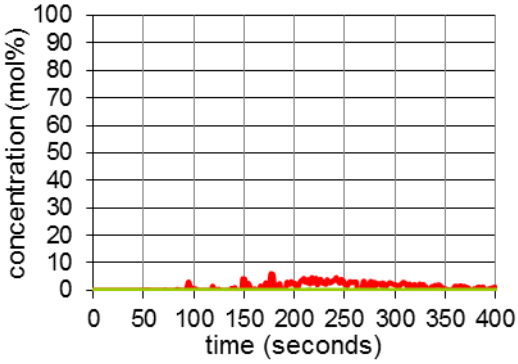
Gas Concentration at x=250m, y=84m, z=1m



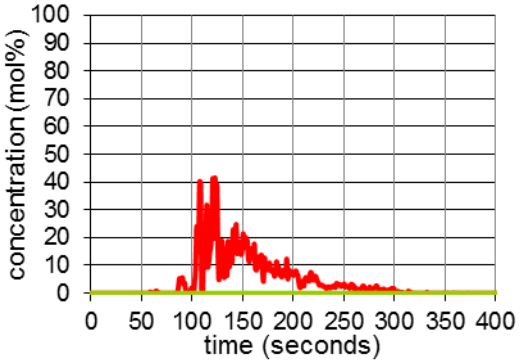
Gas Concentration at x=50m, y=-66m, z=5m



Gas Concentration at x=50m, y=0m, z=5m

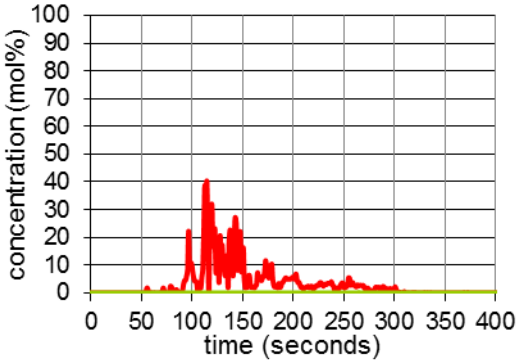


Gas Concentration at x=50m, y=22m, z=5m

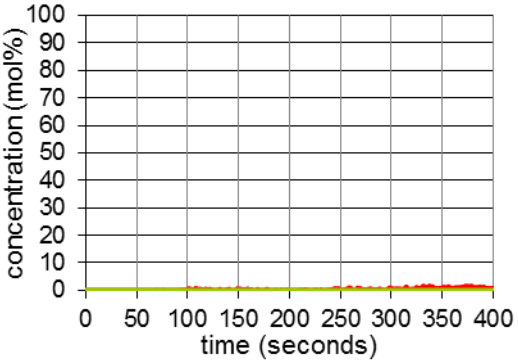


Gas Concentration at x=50m, y=44m, z=5m

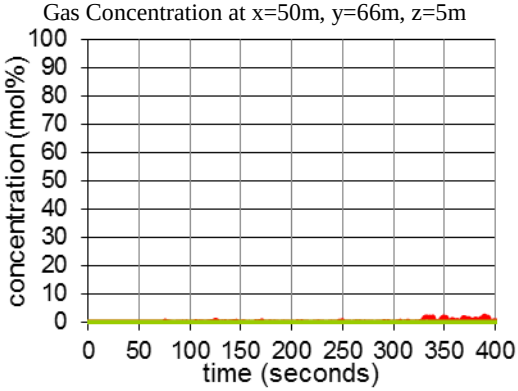
Falcon 1 (continued)



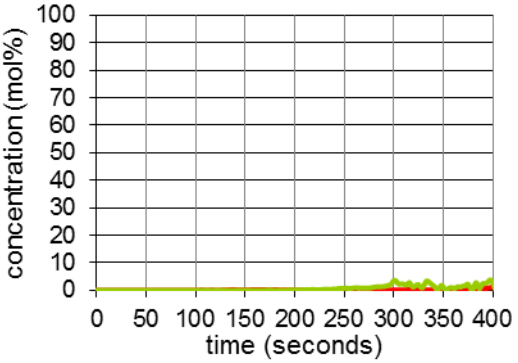
Gas Concentration at x=50m, y=66m, z=5m



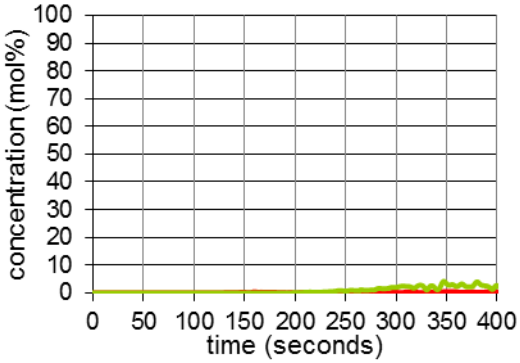
Gas Concentration at x=150m, y=50m, z=5m



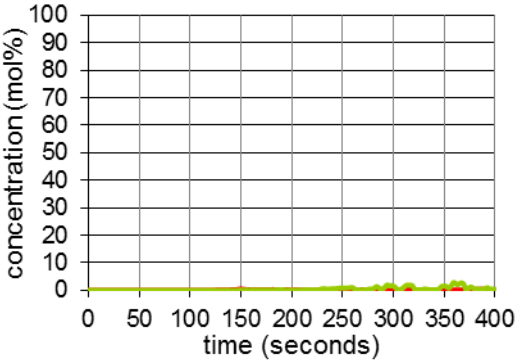
Gas Concentration at x=150m, y=75m, z=5m



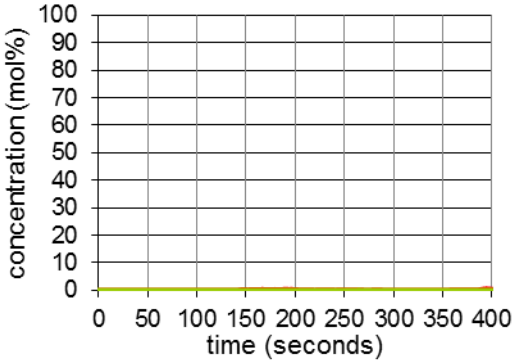
Gas Concentration at x=250m, y=-84m, z=5m



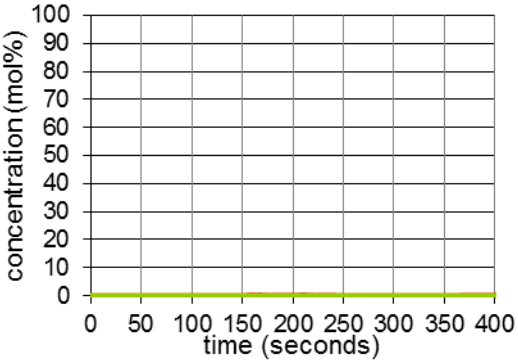
Gas Concentration at x=250m, y=-56m, z=5m



Gas Concentration at x=250m, y=-28m, z=5m

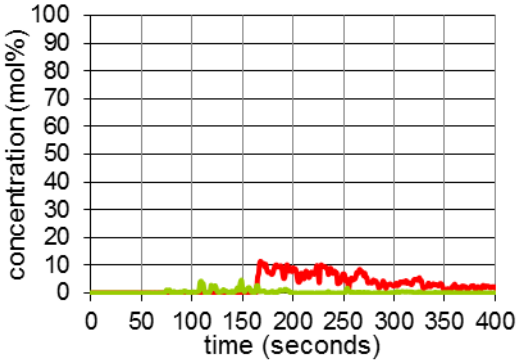


Gas Concentration at x=250m, y=56m, z=5m

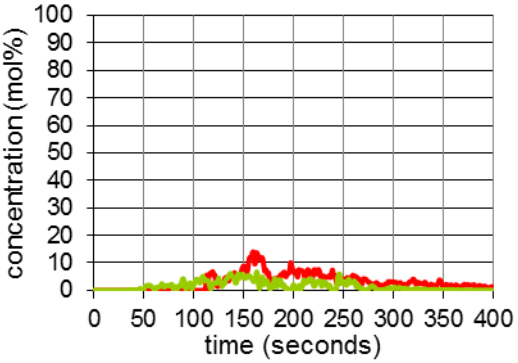


Gas Concentration at x=250m, y=84m, z=5m

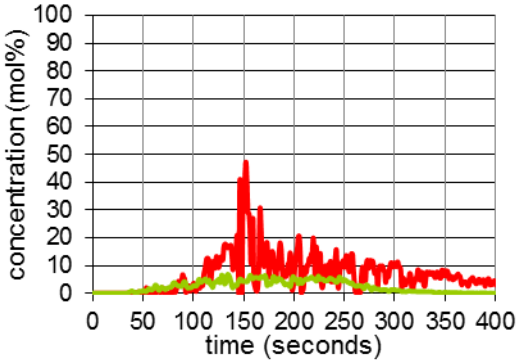
Falcon 3



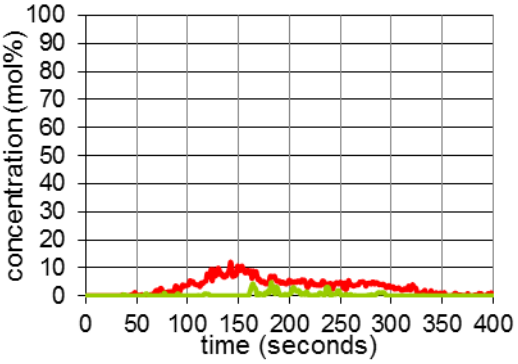
Gas Concentration at x=50m, y=-66m, z=1m



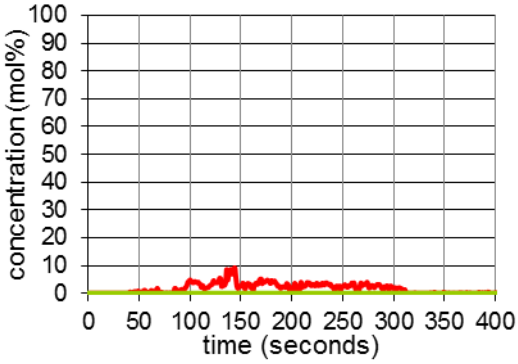
Gas Concentration at x=50m, y=-44m, z=1m



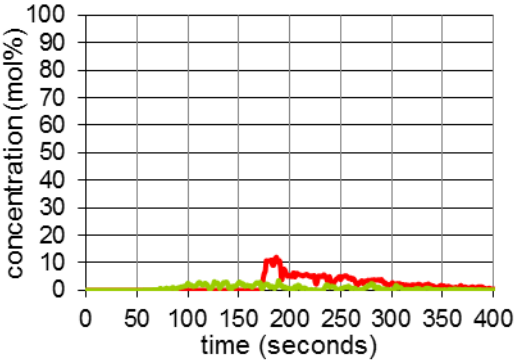
Gas Concentration at x=50m, y=-22m, z=1m



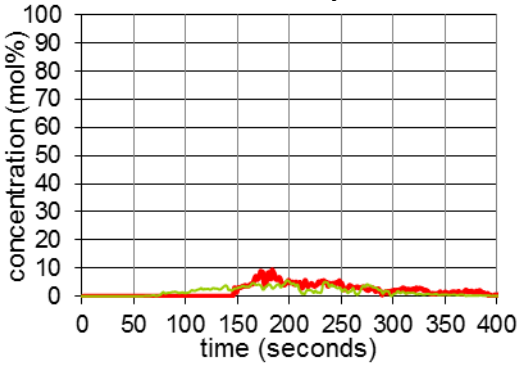
Gas Concentration at x=50m, y=22m, z=1m



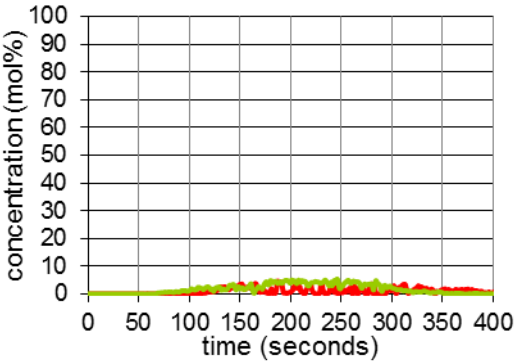
Gas Concentration at x=50m, y=44m, z=1m



Gas Concentration at x=150m, y=-75m, z=1m

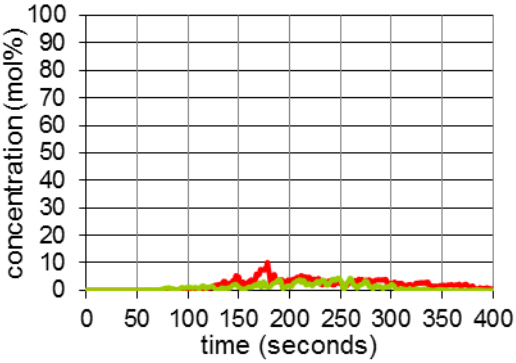


Gas Concentration at x=150m, y=-50m, z=1m

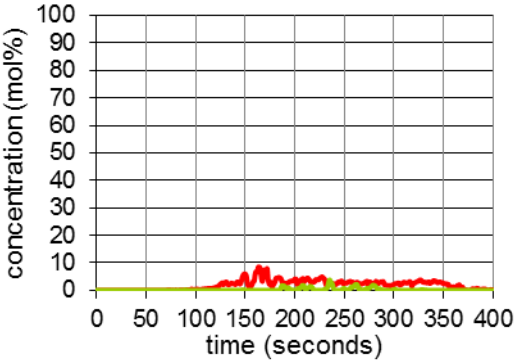


Gas Concentration at x=150m, y=-25m, z=1m

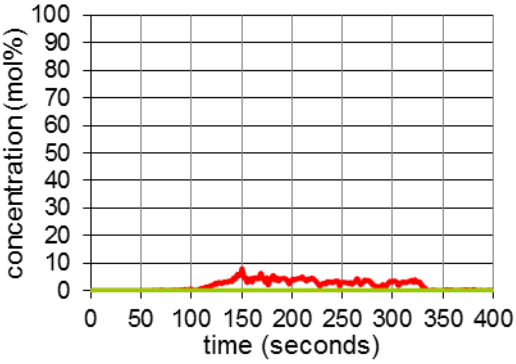
Falcon 3 (continued)



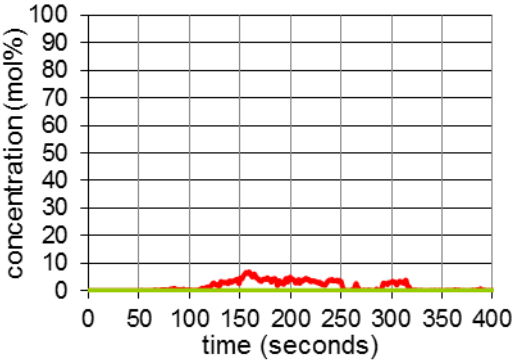
Gas Concentration at x=150m, y=0m, z=1m



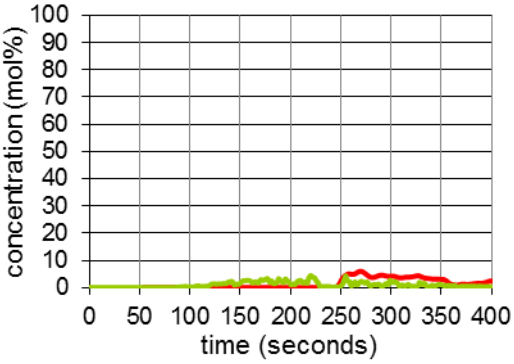
Gas Concentration at x=150m, y=25m, z=1m



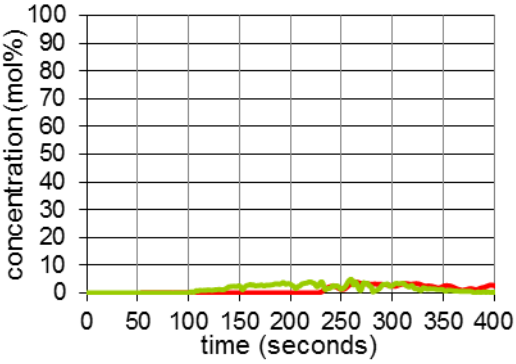
Gas Concentration at x=150m, y=50m, z=1m



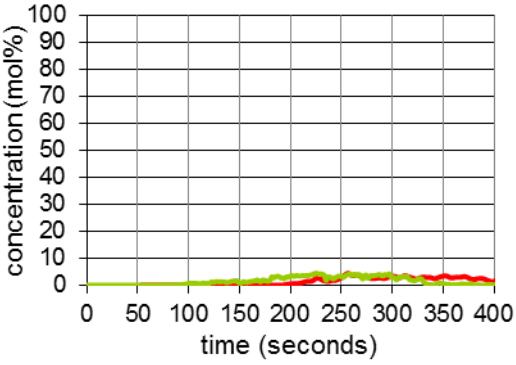
Gas Concentration at x=150m, y=75m, z=1m



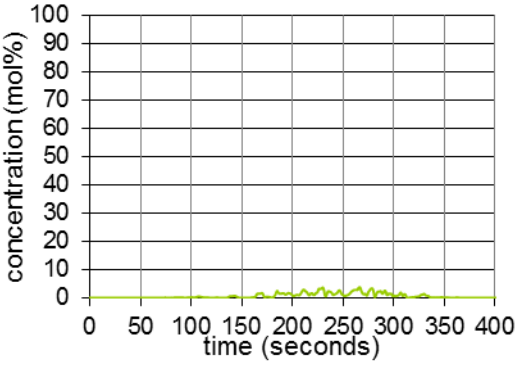
Gas Concentration at x=250m, y=-84m, z=1m



Gas Concentration at x=250m, y=-56m, z=1m

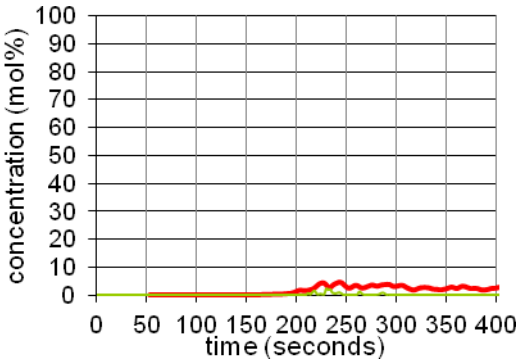


Gas Concentration at x=250m, y=-28m, z=1m

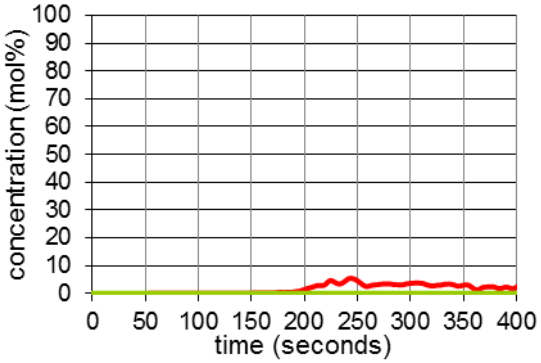


Gas Concentration at x=250m, y=0m, z=1m

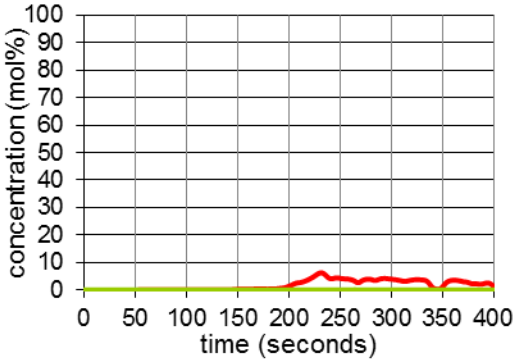
Falcon 3 (continued)



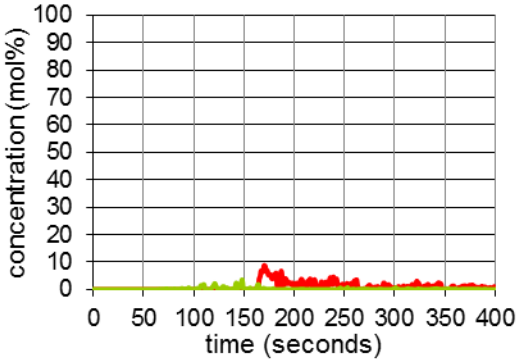
Gas Concentration at x=250m, y=28m, z=1m



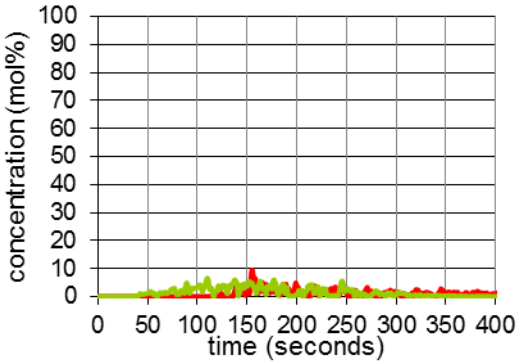
Gas Concentration at x=250m, y=56m, z=1m



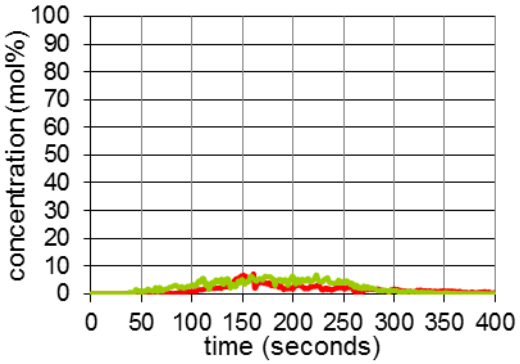
Gas Concentration at x=250m, y=84m, z=1m



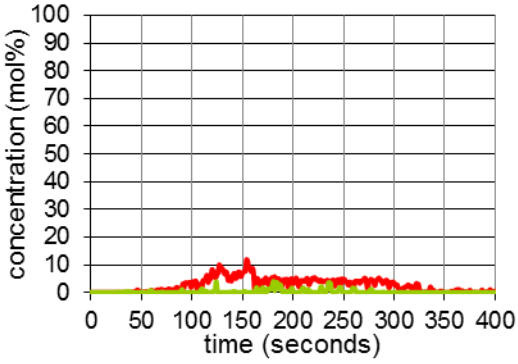
Gas Concentration at x=50m, y=-66m, z=5m



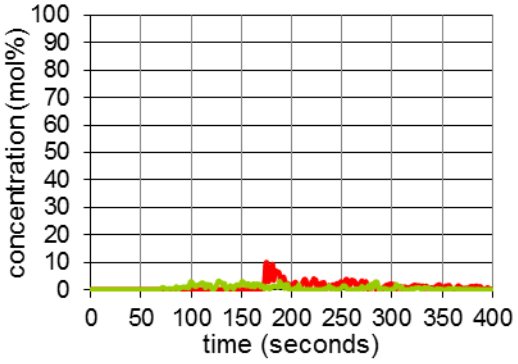
Gas Concentration at x=50m, y=-44m, z=5m



Gas Concentration at x=50m, y=-22m, z=5m

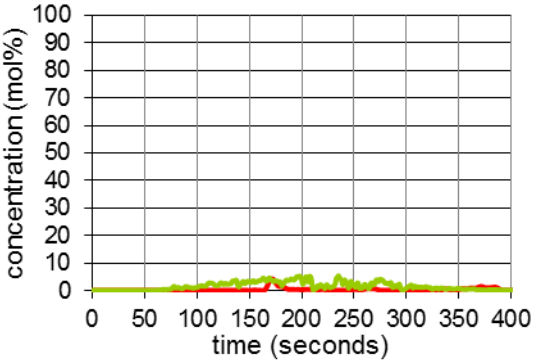


Gas Concentration at x=50m, y=22m, z=5m

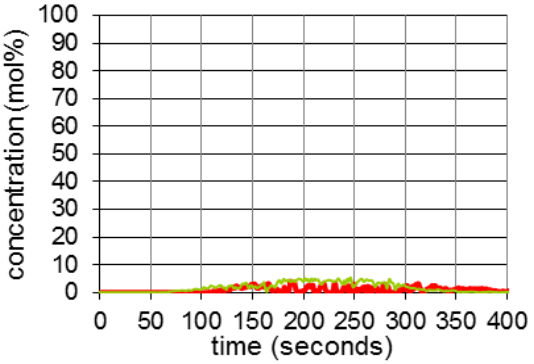


Gas Concentration at x=150m, y=-75m, z=5m

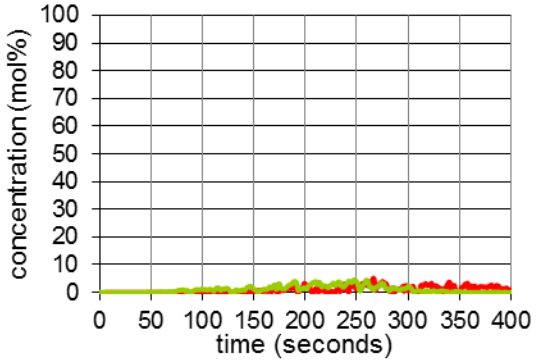
Falcon 3 (continued)



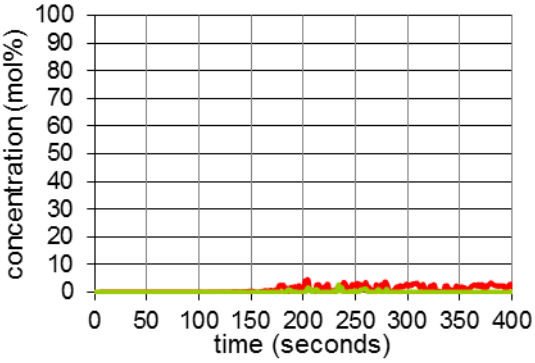
Gas Concentration at x=150m, y=-50m, z=5m



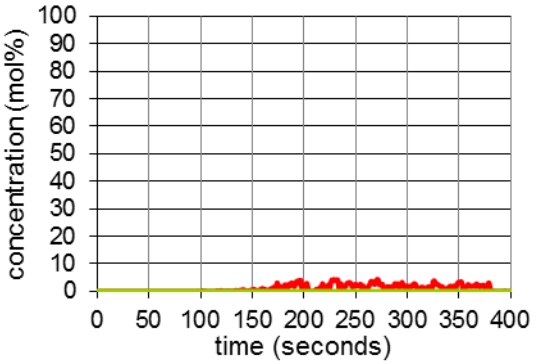
Gas Concentration at x=150m, y=-25m, z=5m



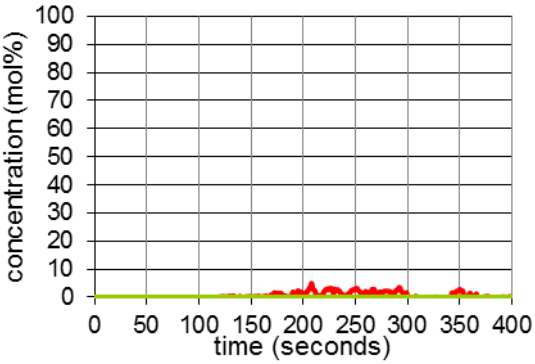
Gas Concentration at x=150m, y=0m, z=5m



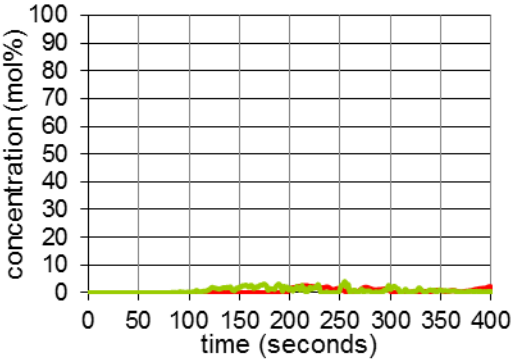
Gas Concentration at x=150m, y=25m, z=5m



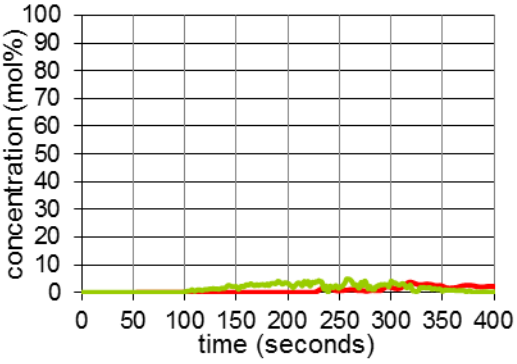
Gas Concentration at x=150m, y=50m, z=5m



Gas Concentration at x=150m, y=75m, z=5m

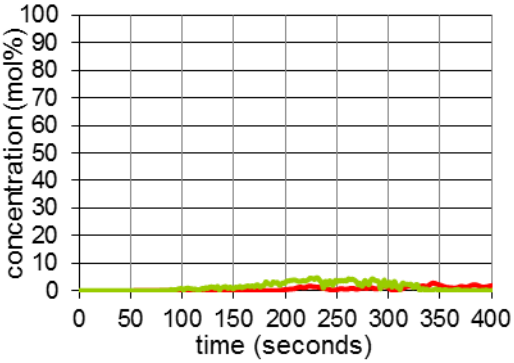


Gas Concentration at x=250m, y=-84m, z=5m

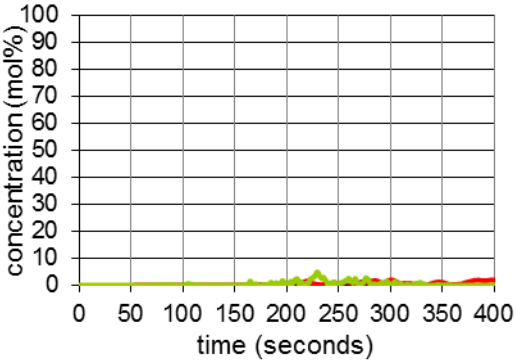


Gas Concentration at x=250m, y=-56m, z=5m

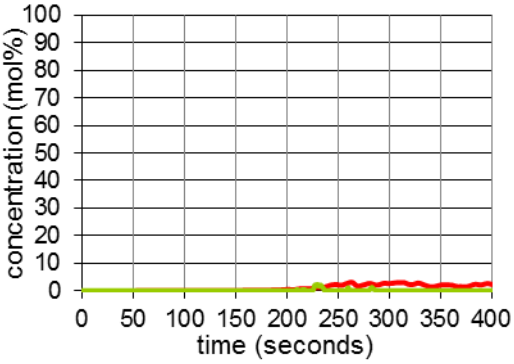
Falcon 3 (continued)



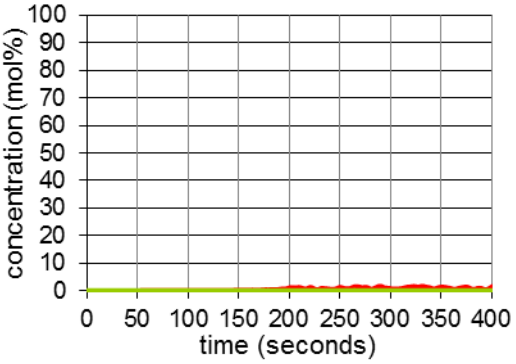
Gas Concentration at x=250m, y=-28m, z=5m



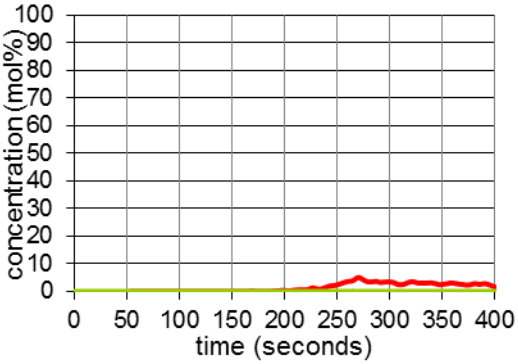
Gas Concentration at x=250m, y=0m, z=5m



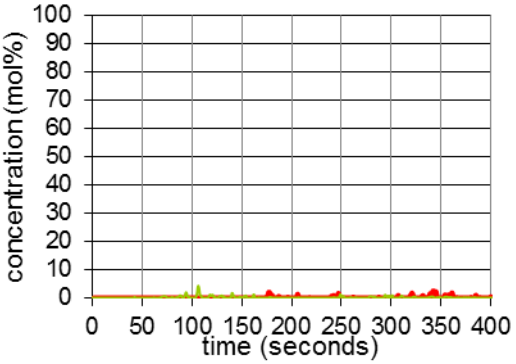
Gas Concentration at x=250m, y=28m, z=5m



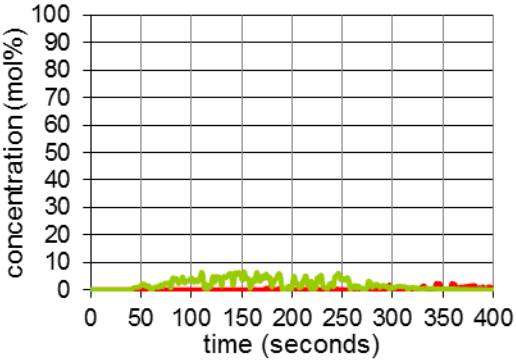
Gas Concentration at x=250m, y=56m, z=5m



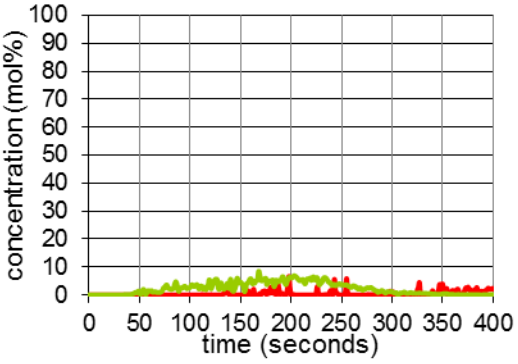
Gas Concentration at x=250m, y=84m, z=5m



Gas Concentration at x=50m, y=-66m, z=11m

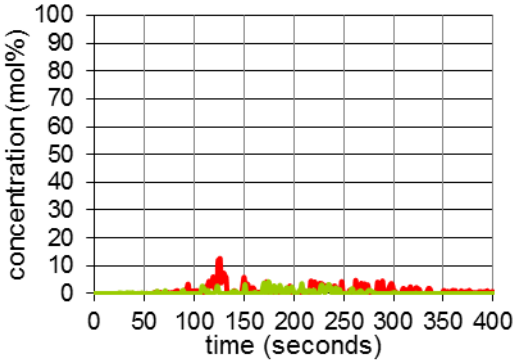


Gas Concentration at x=50m, y=-44m, z=11m

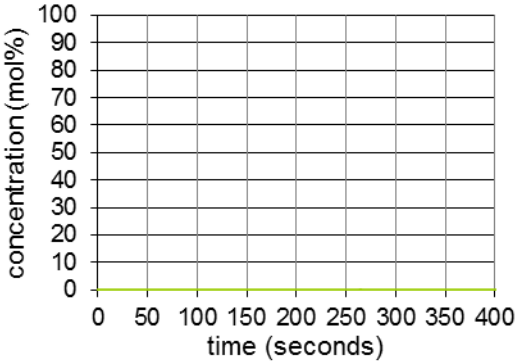


Gas Concentration at x=50m, y=-22m, z=11m

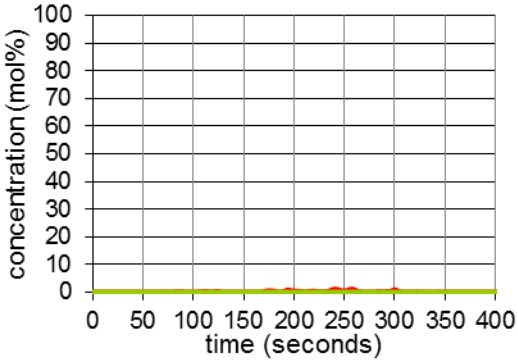
Falcon 3 (continued)



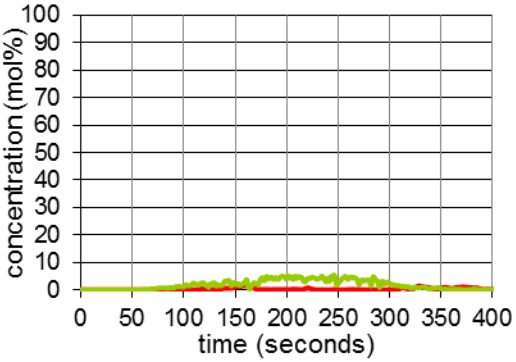
Gas Concentration at x=50m, y=22m, z=11m



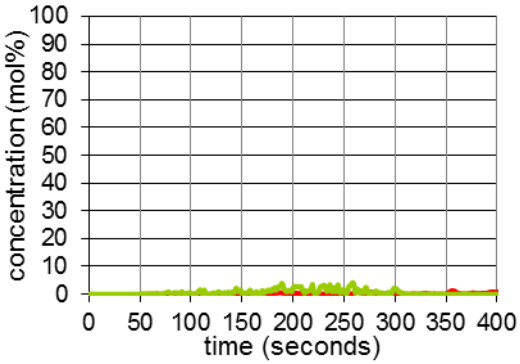
Gas Concentration at x=50m, y=44m, z=11m



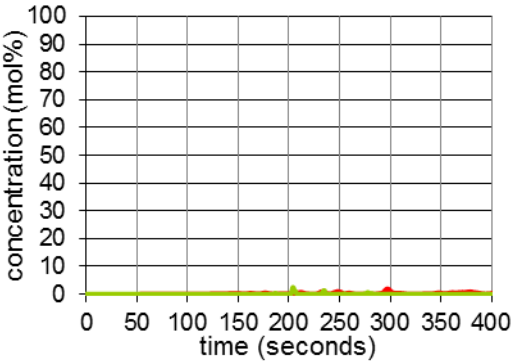
Gas Concentration at x=150m, y=50m, z=11m



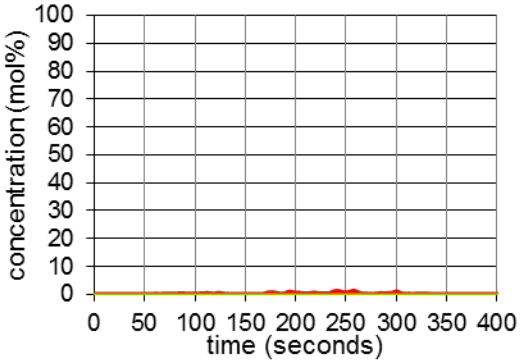
Gas Concentration at x=150m, y=-25m, z=11m



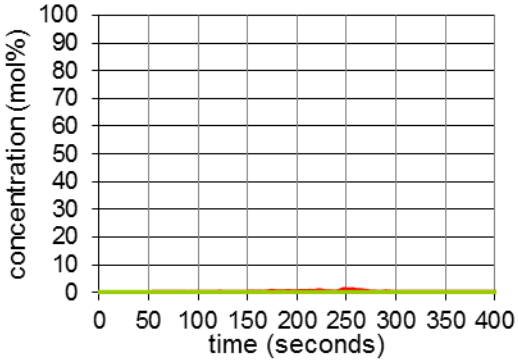
Gas Concentration at x=150m, y=0m, z=11m



Gas Concentration at x=150m, y=25m, z=11m

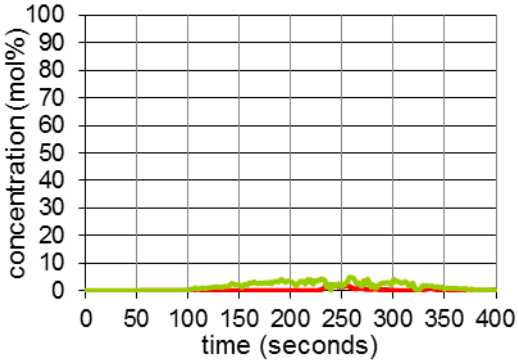


Gas Concentration at x=150m, y=50m, z=11m

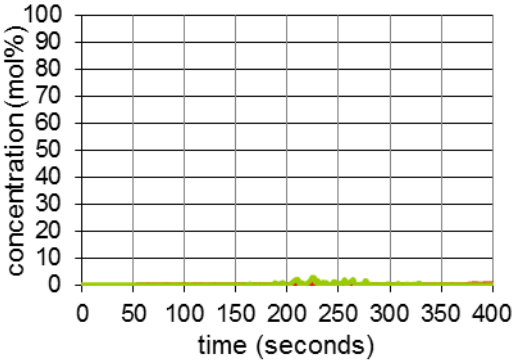


Gas Concentration at x=150m, y=75m, z=11m

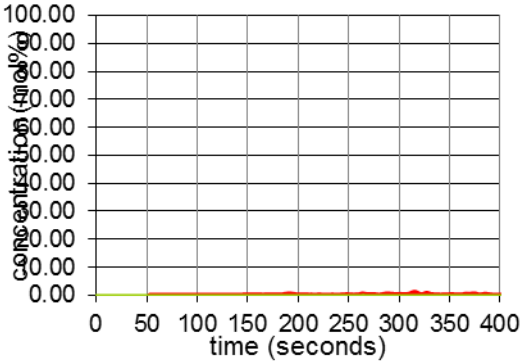
Falcon 3 (continued)



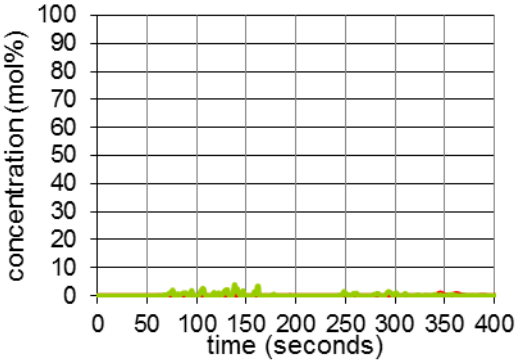
Gas Concentration at x=250m, y=-56m, z=11m



Gas Concentration at x=250m, y=0m, z=11m

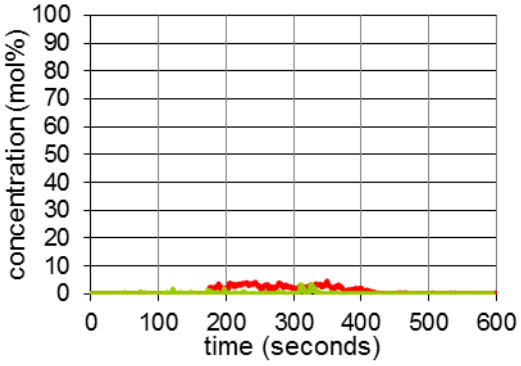


Gas Concentration at x=250m, y=56m, z=11m

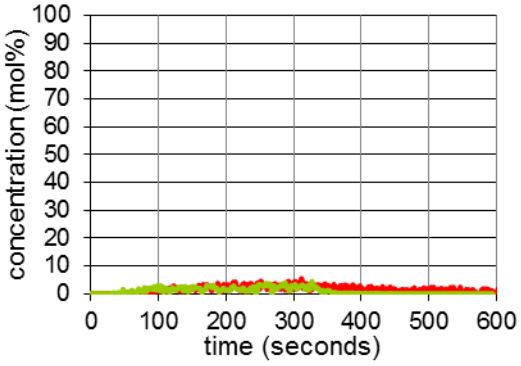


Gas Concentration at x=50m, y=-66m, z=17m

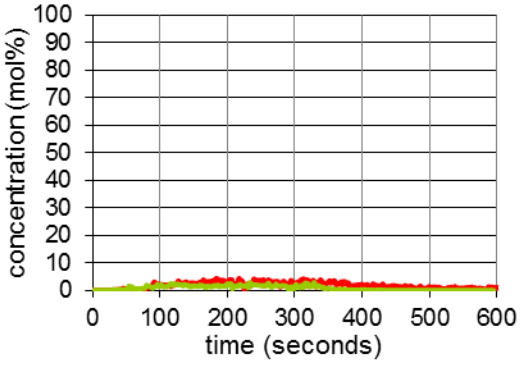
Falcon 4



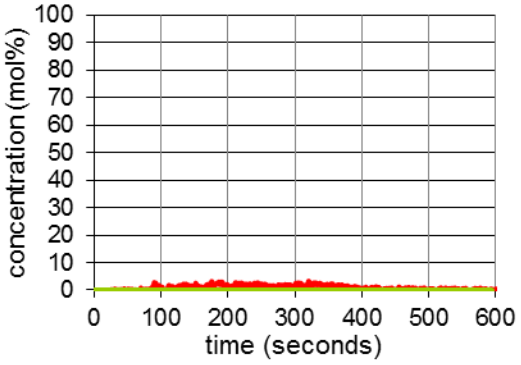
Gas Concentration at x=50m, y=-66m, z=1m



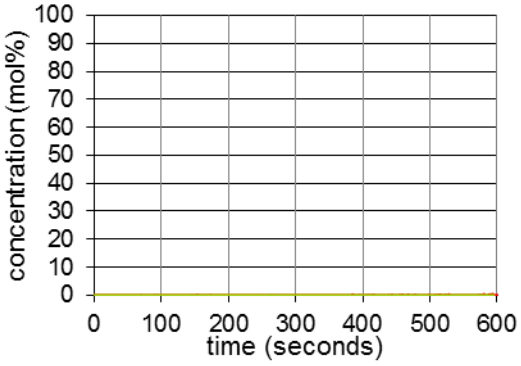
Gas Concentration at x=50m, y=-33m, z=1m



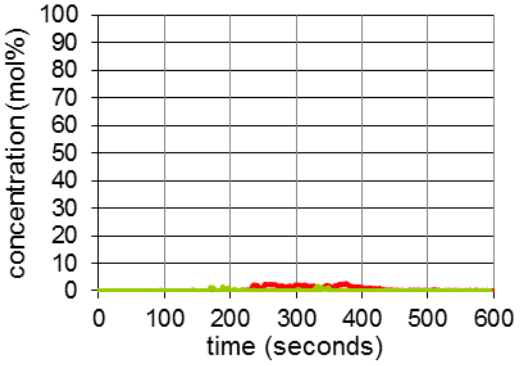
Gas Concentration at x=50m, y=0m, z=1m



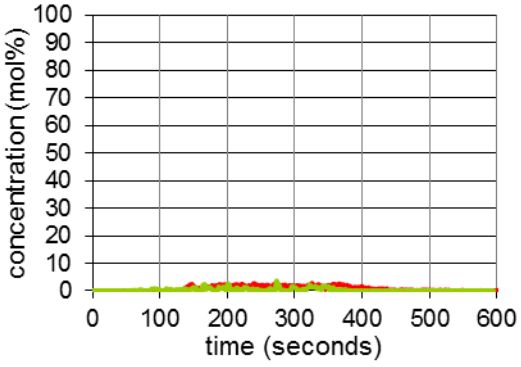
Gas Concentration at x=50m, y=33m, z=1m



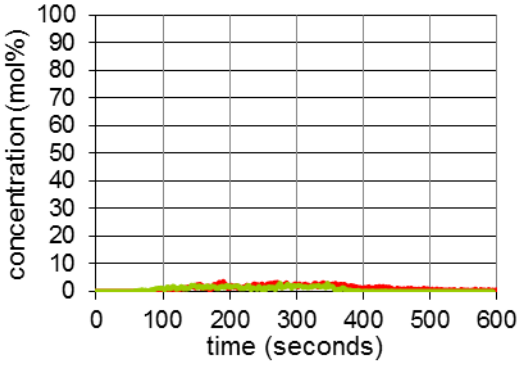
Gas Concentration at x=50m, y=66m, z=1m



Gas Concentration at x=150m, y=-100m, z=1m

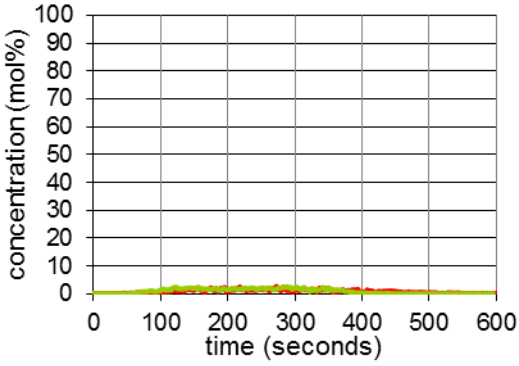


Gas Concentration at x=150m, y=-75m, z=1m

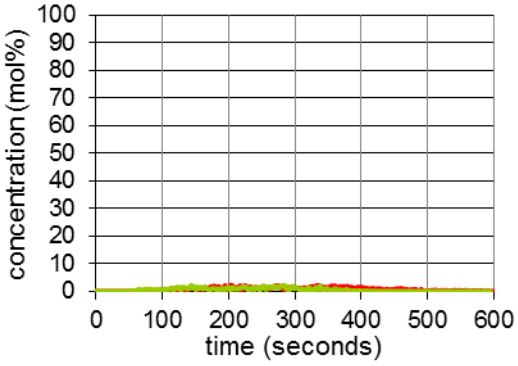


Gas Concentration at x=150m, y=-50m, z=1m

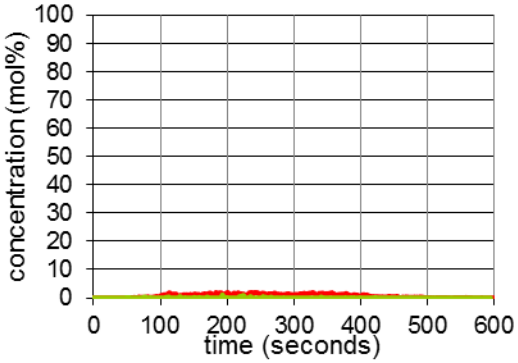
Falcon 4 (continued)



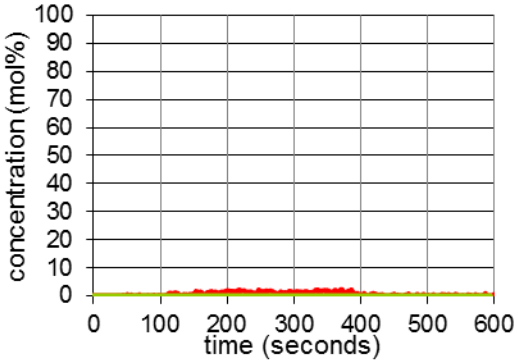
Gas Concentration at x=150m, y=-25m, z=1m



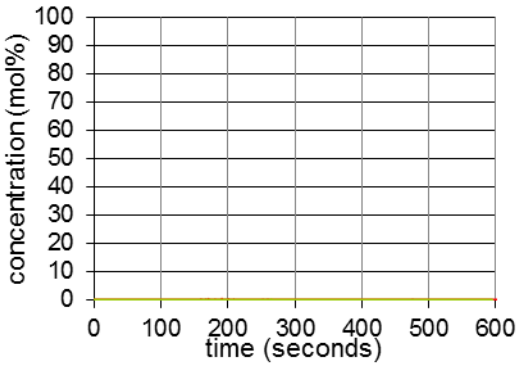
Gas Concentration at x=150m, y=0m, z=1m



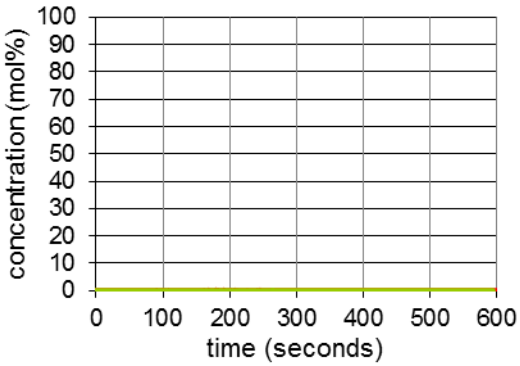
Gas Concentration at x=150m, y=25m, z=1m



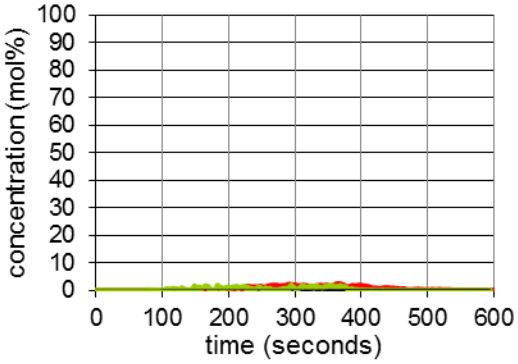
Gas Concentration at x=150m, y=50m, z=1m



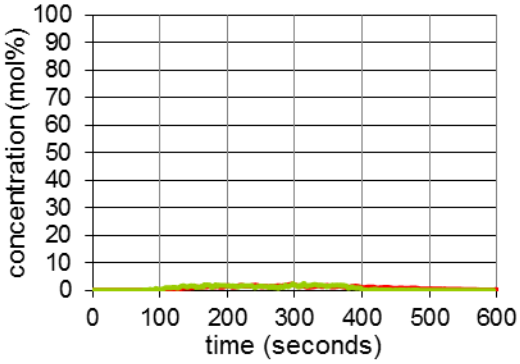
Gas Concentration at x=150m, y=75m, z=1m



Gas Concentration at x=150m, y=100m, z=1m

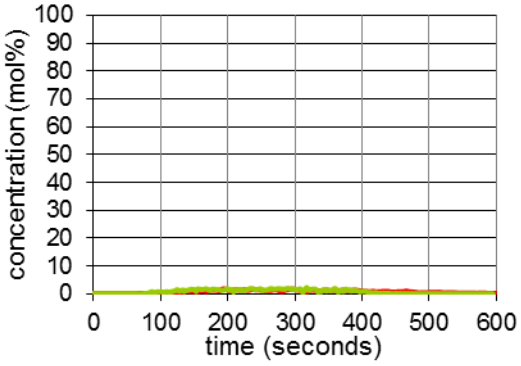


Gas Concentration at x=250m, y=-84m, z=1m

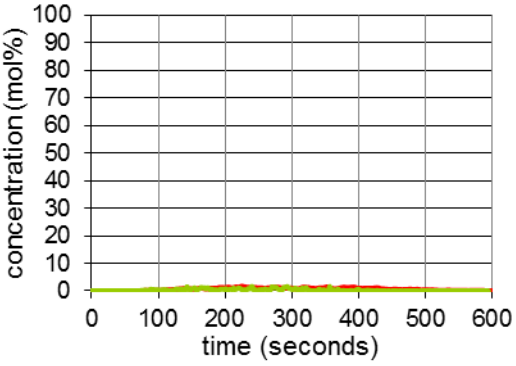


Gas Concentration at x=250m, y=-56m, z=1m

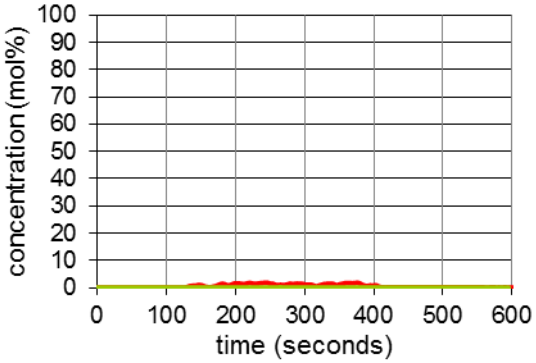
Falcon 4 (continued)



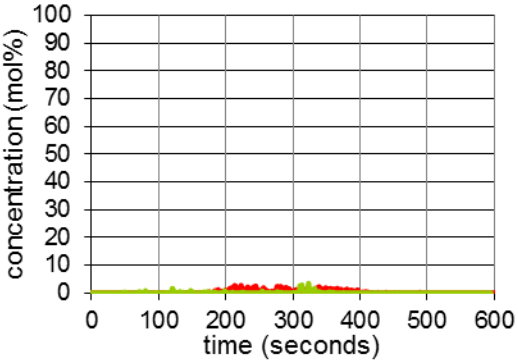
Gas Concentration at x=250m, y=-28m, z=1m



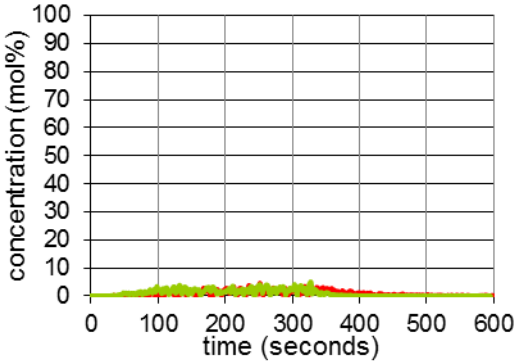
Gas Concentration at x=250m, y=0m, z=1m



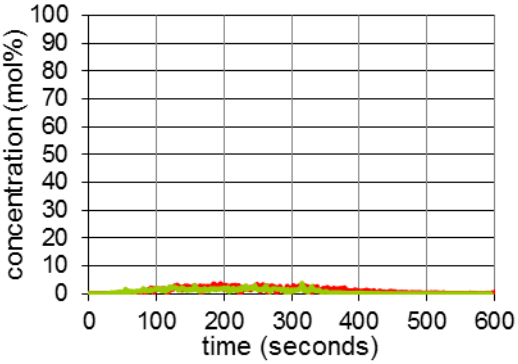
Gas Concentration at x=250m, y=56m, z=1m



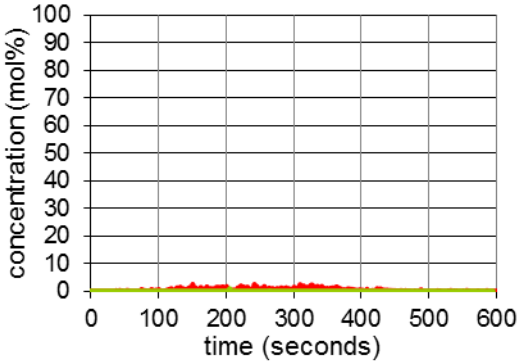
Gas Concentration at x=50m, y=-66m, z=5m



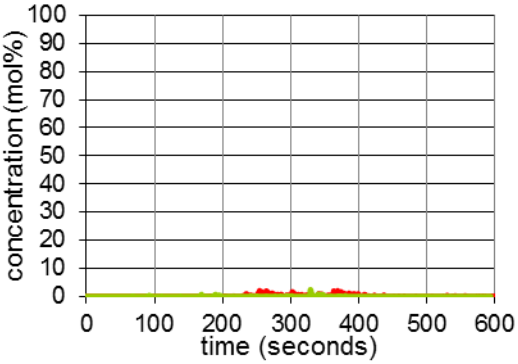
Gas Concentration at x=50m, y=-33m, z=5m



Gas Concentration at x=50m, y=0m, z=5m

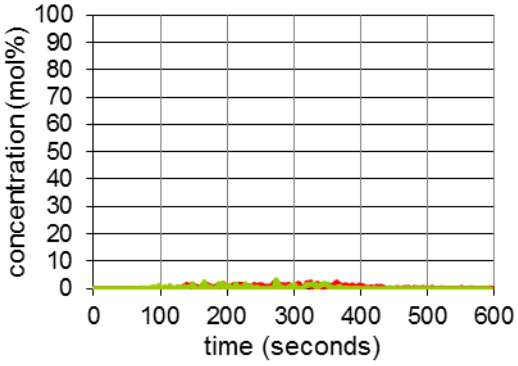


Gas Concentration at x=50m, y=33m, z=5m

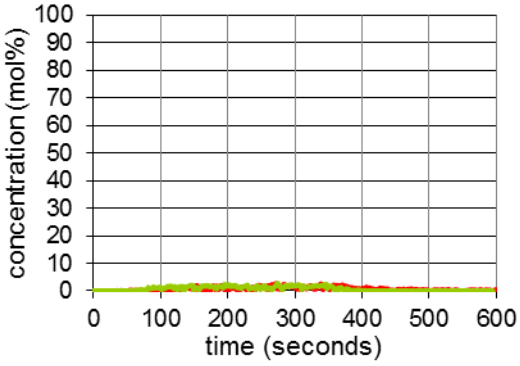


Gas Concentration at x=150m, y=-100m, z=5m

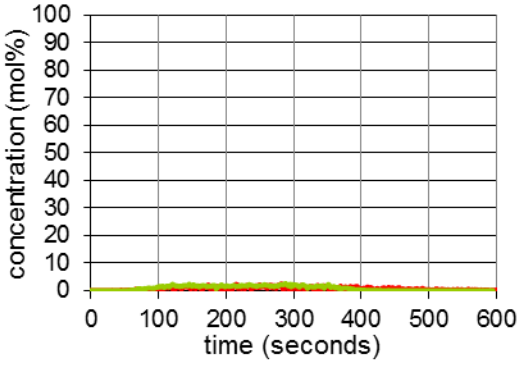
Falcon 4 (continued)



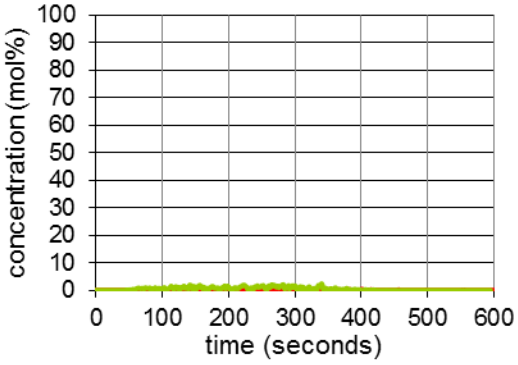
Gas Concentration at x=150m, y=-75m, z=5m



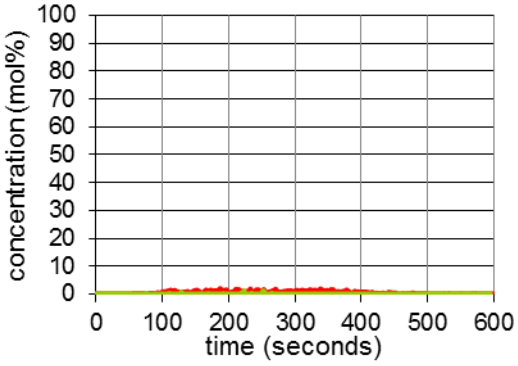
Gas Concentration at x=150m, y=-50m, z=5m



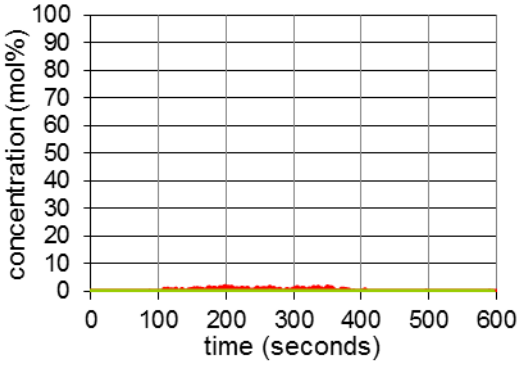
Gas Concentration at x=150m, y=-25m, z=5m



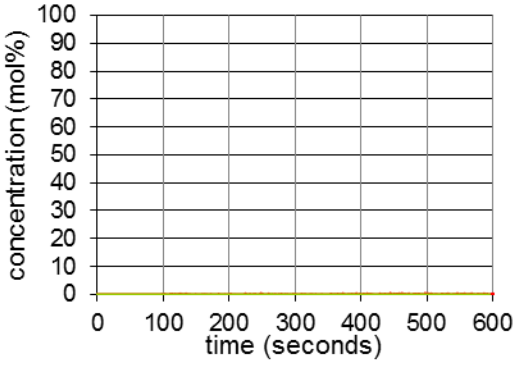
Gas Concentration at x=150m, y=0m, z=5m



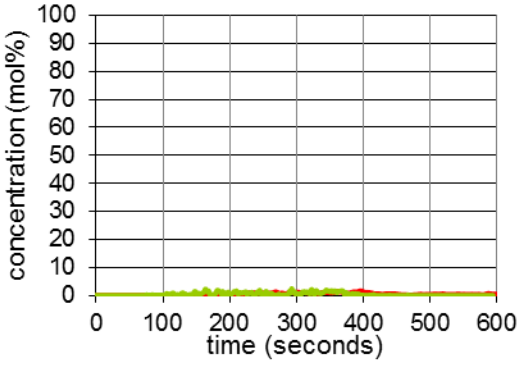
Gas Concentration at x=150m, y=25m, z=5m



Gas Concentration at x=150m, y=50m, z=5m

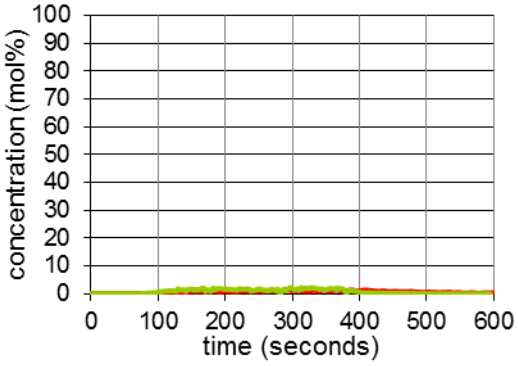


Gas Concentration at x=150m, y=100m, z=5m

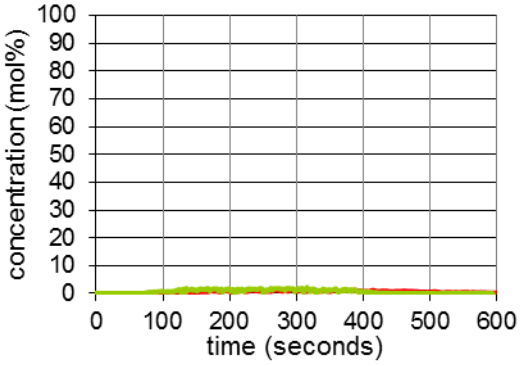


Gas Concentration at x=250m, y=-84m, z=5m

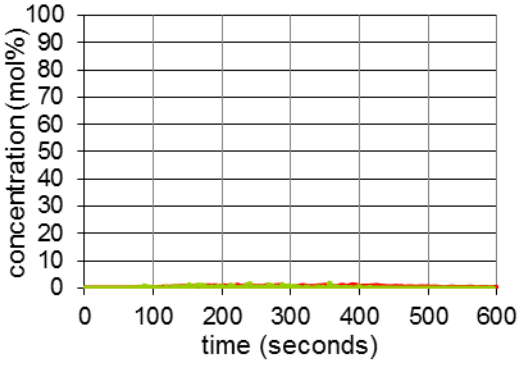
Falcon 4 (continued)



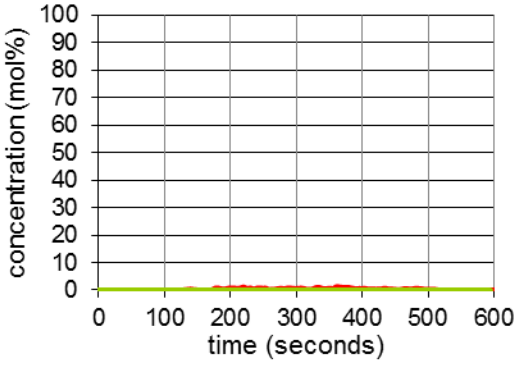
Gas Concentration at x=250m, y=-56m, z=5m



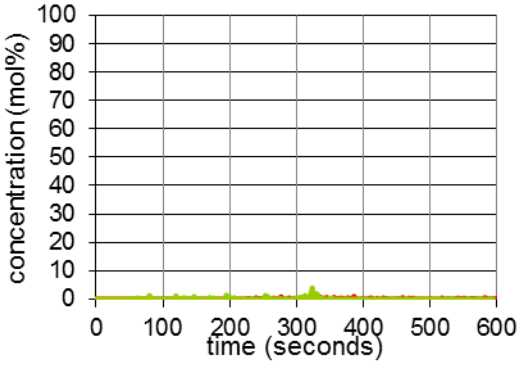
Gas Concentration at x=250m, y=-28m, z=5m



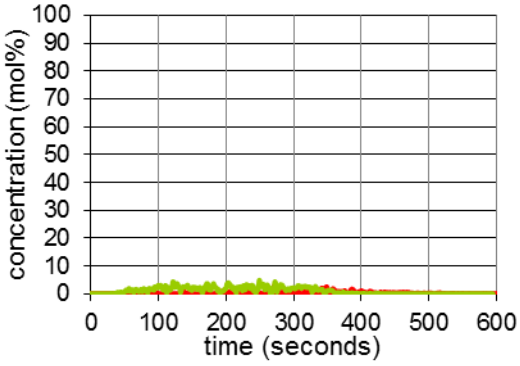
Gas Concentration at x=250m, y=0m, z=5m



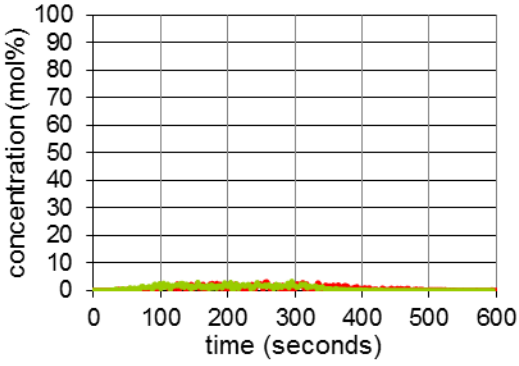
Gas Concentration at x=250m, y=56m, z=5m



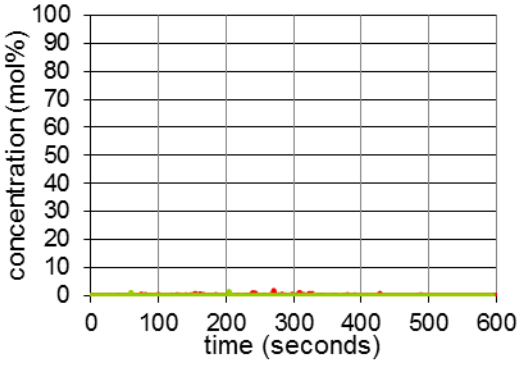
Gas Concentration at x=50m, y=-66m, z=11m



Gas Concentration at x=50m, y=-33m, z=11m

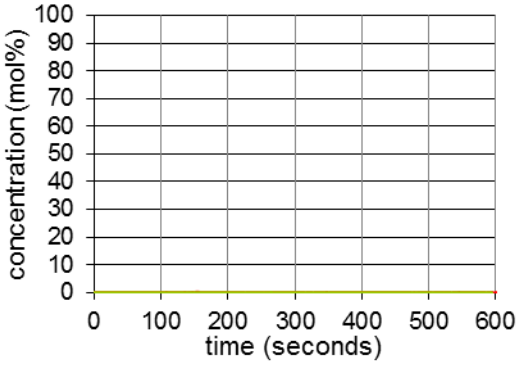


Gas Concentration at x=50m, y=0m, z=11m

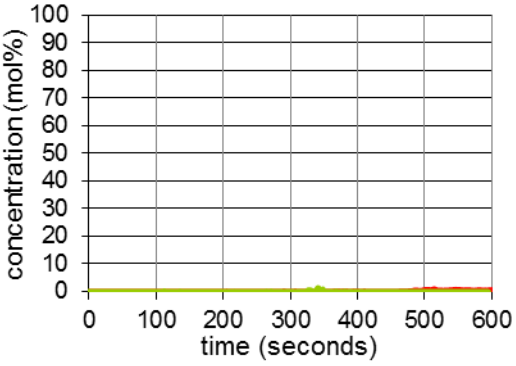


Gas Concentration at x=50m, y=33m, z=11m

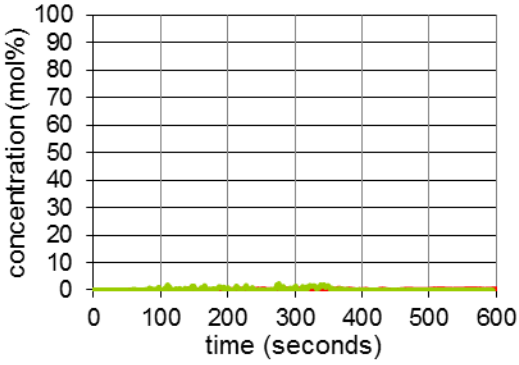
Falcon 4 (continued)



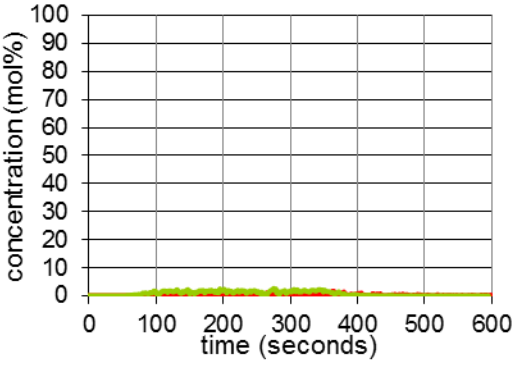
Gas Concentration at x=50m, y=66m, z=11m



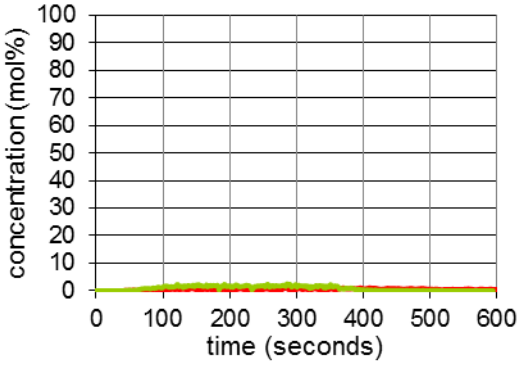
Gas Concentration at x=150m, y=-100m, z=11m



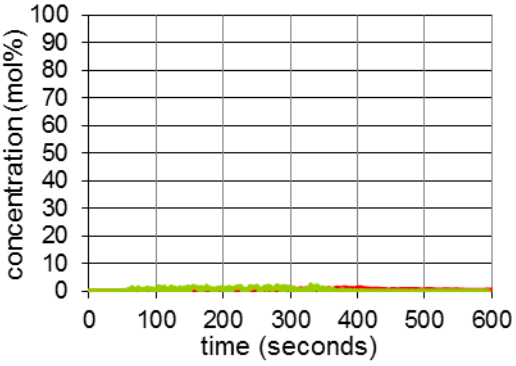
Gas Concentration at x=150m, y=-75m, z=11m



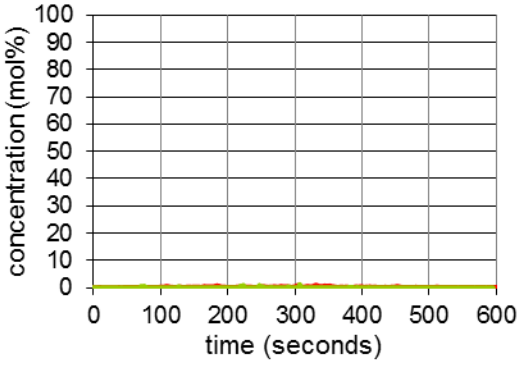
Gas Concentration at x=150m, y=-50m, z=11m



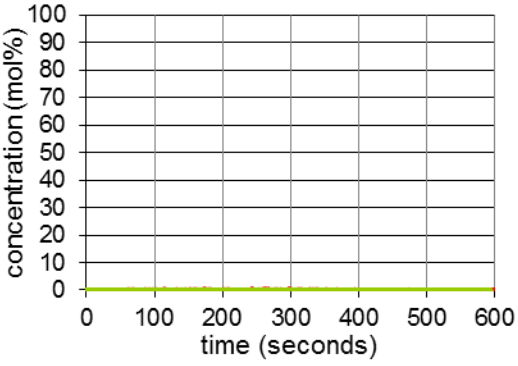
Gas Concentration at x=150m, y=-25m, z=11m



Gas Concentration at x=150m, y=0m, z=11m

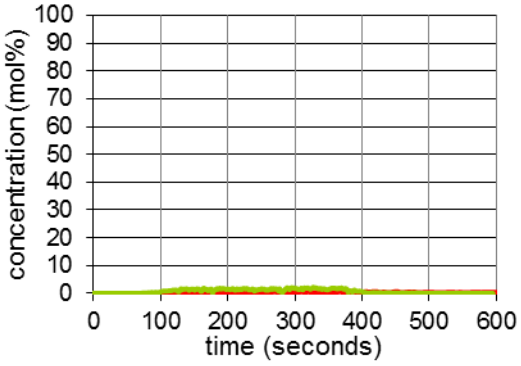


Gas Concentration at x=150m, y=25m, z=11m

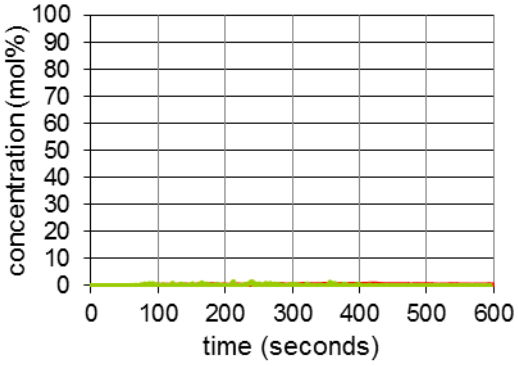


Gas Concentration at x=150m, y=50m, z=11m

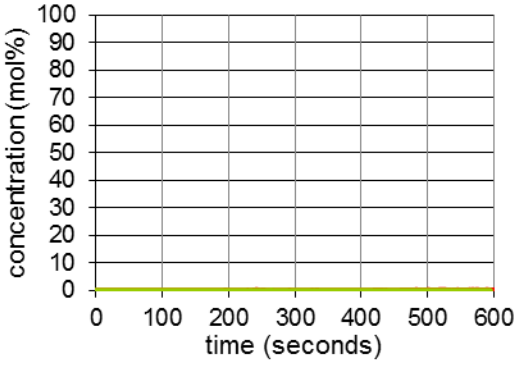
Falcon 4 (continued)



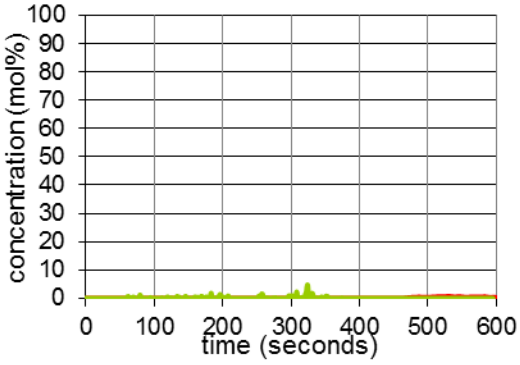
Gas Concentration at x=250m, y=-56m, z=11m



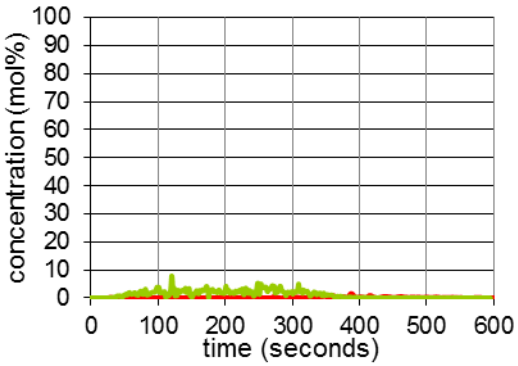
Gas Concentration at x=250m, y=0m, z=11m



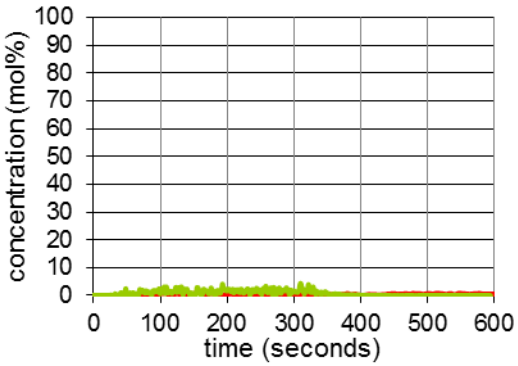
Gas Concentration at x=250m, y=56m, z=11m



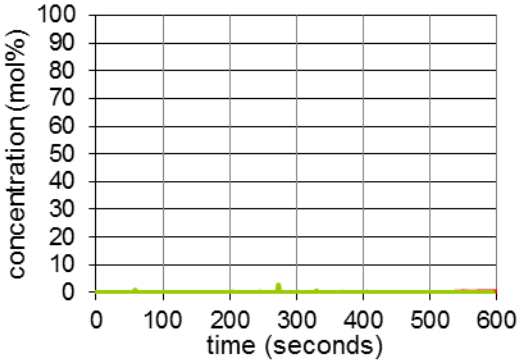
Gas Concentration at x=50m, y=-66m, z=17m



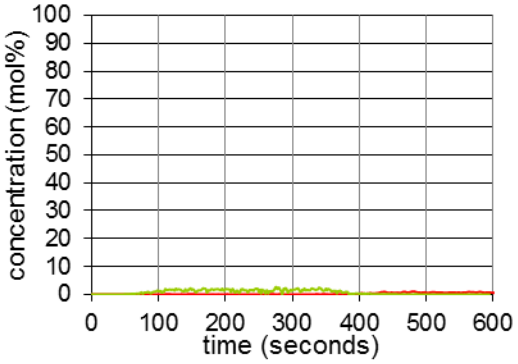
Gas Concentration at x=50m, y=-33m, z=17m



Gas Concentration at x=50m, y=0m, z=17m

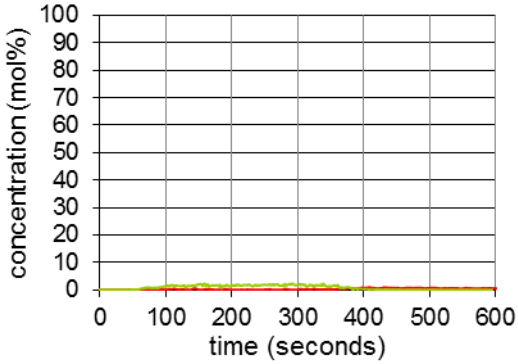


Gas Concentration at x=50m, y=33m, z=17m

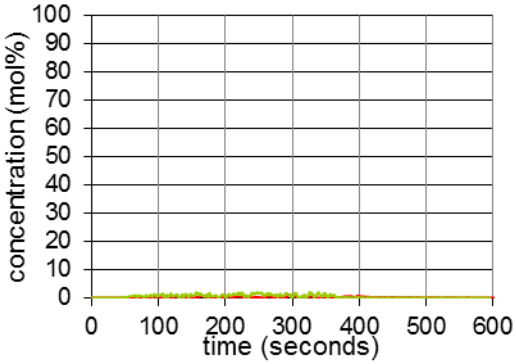


Gas Concentration at x=150m, y=-50m, z=17m

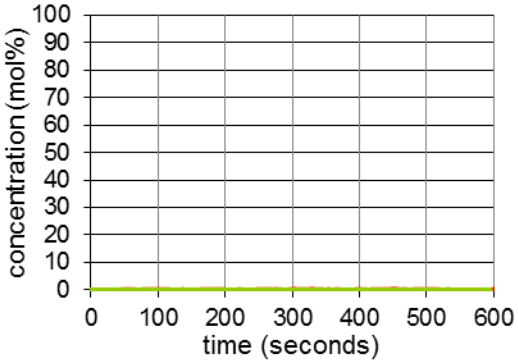
Falcon 4 (continued)



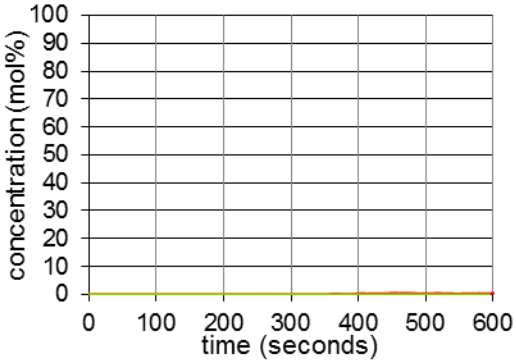
Gas Concentration at x=150m, y=-25m, z=17m



Gas Concentration at x=150m, y=0m, z=17m

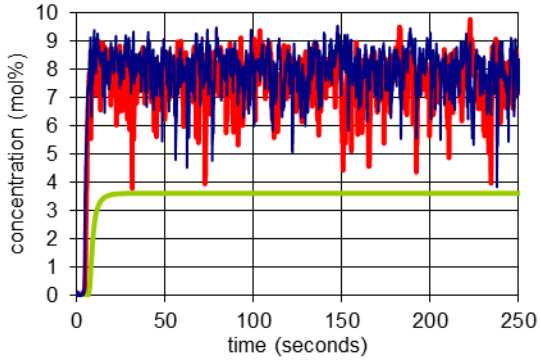


Gas Concentration at x=150m, y=25m, z=17m

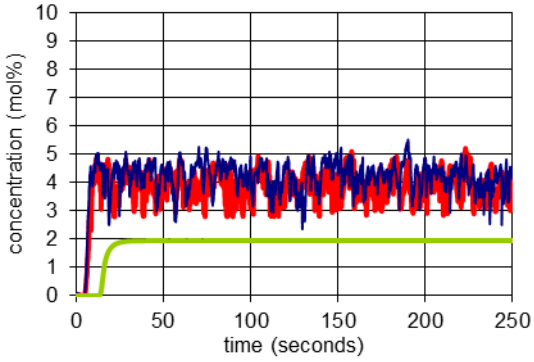


Gas Concentration at x=150m, y=50m, z=17m

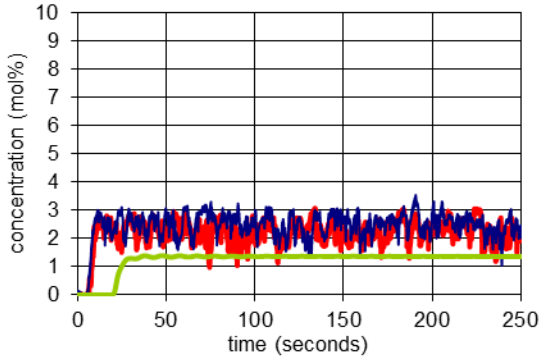
BAH DA0120 (Unobstructed 1)



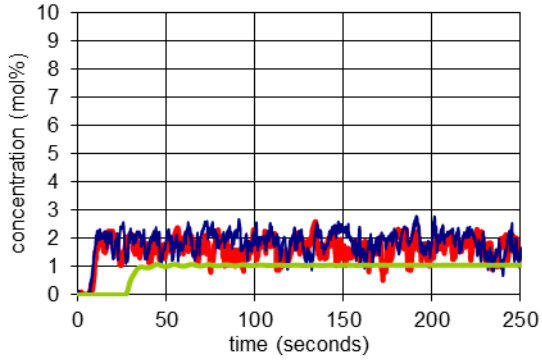
Gas Concentration at x=50m, y=0m, z=0m



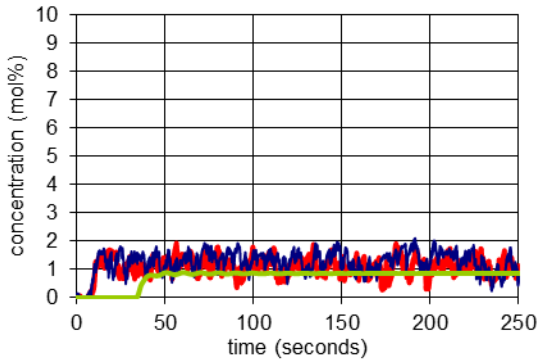
Gas Concentration at x=101m, y=0m, z=0m



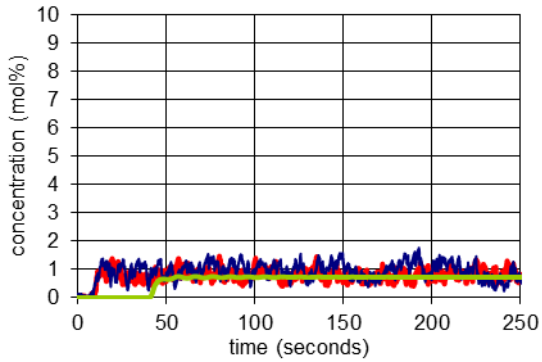
Gas Concentration at x=151m, y=0m, z=0m



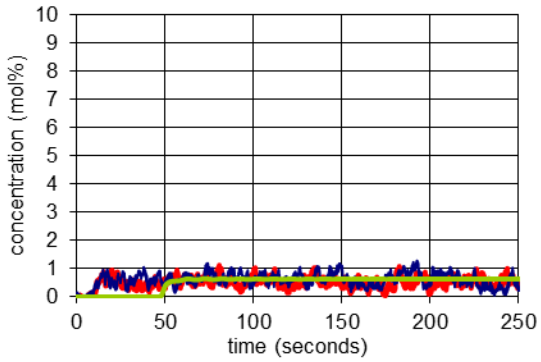
Gas Concentration at x=201m, y=0m, z=0m



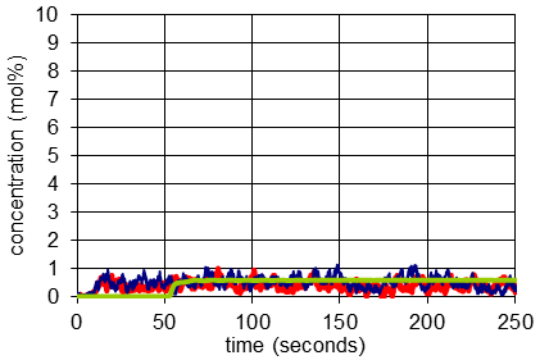
Gas Concentration at x=251m, y=0m, z=0m



Gas Concentration at x=302m, y=0m, z=0m

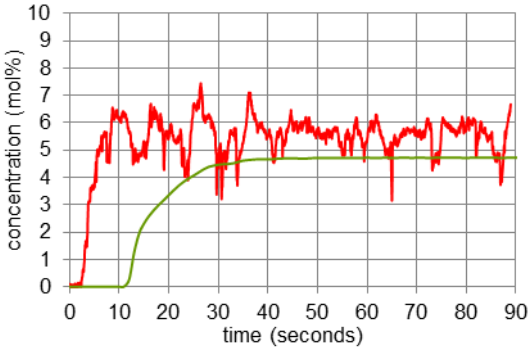


Gas Concentration at x=352m, y=0m, z=0m

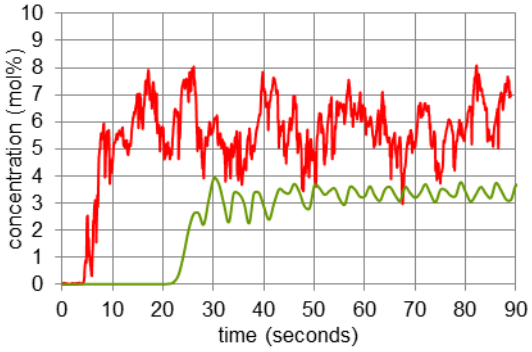


Gas Concentration at x=390m, y=0m, z=0m

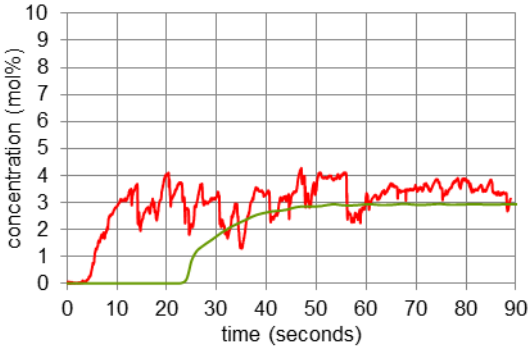
BAH DAT223 (Unobstructed 2)



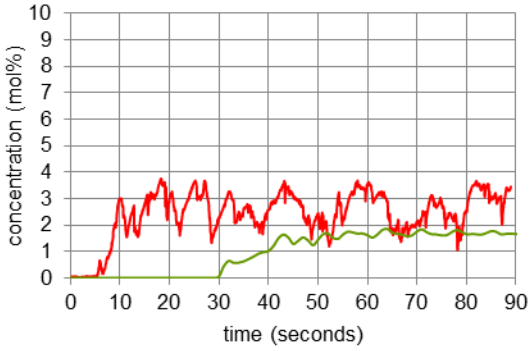
Gas Concentration at x=101m, y=0m, z=0m



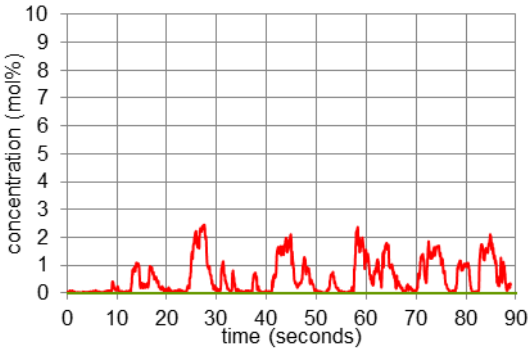
Gas Concentration at x=101m, y=38m, z=0m



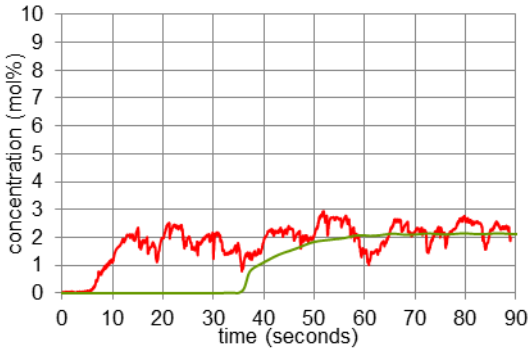
Gas Concentration at x=201m, y=0m, z=0m



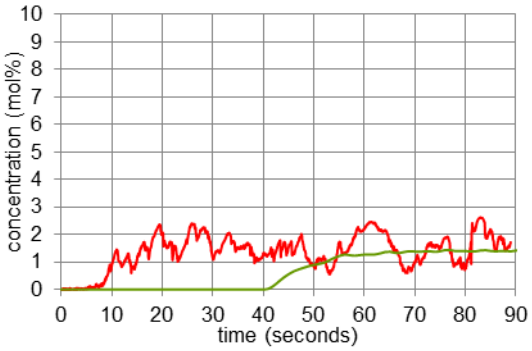
Gas Concentration at x=201m, y=38m, z=0m



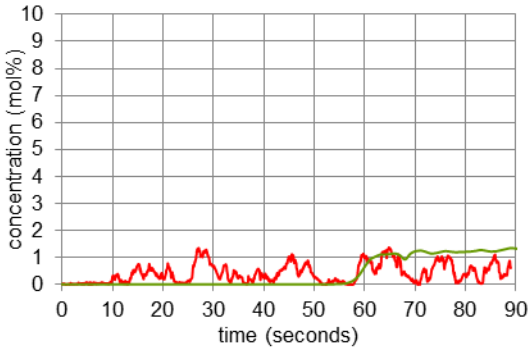
Gas Concentration at x=201m, y=75m, z=0m



Gas Concentration at x=301m, y=0m, z=0m

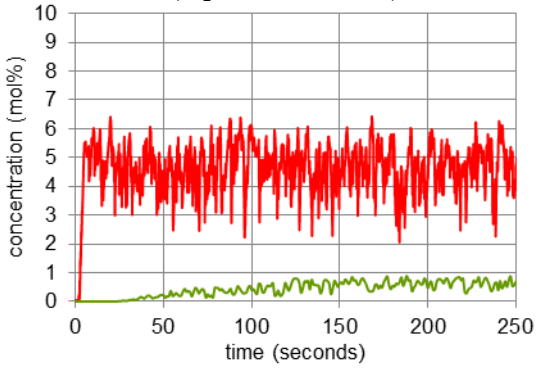


Gas Concentration at x=301m, y=38m, z=0m

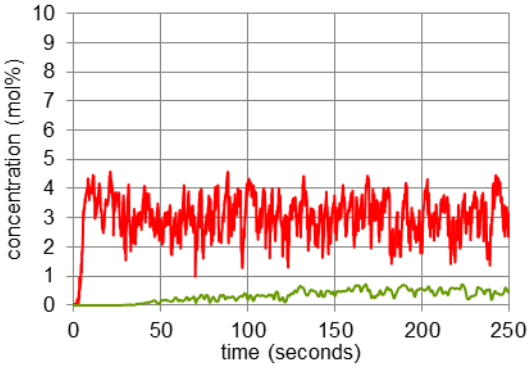


Gas Concentration at x=301m, y=75m, z=0m

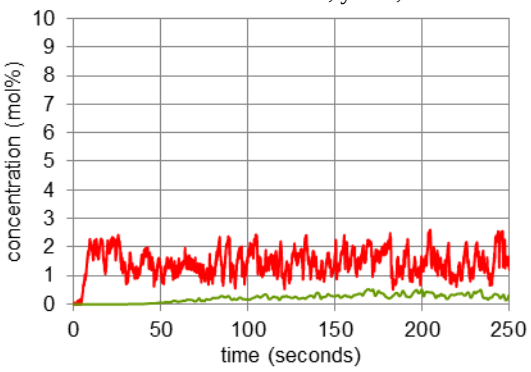
BAH 039051 (Upwind Fence 1)



Gas Concentration at x=101m, y=0m, z=0m

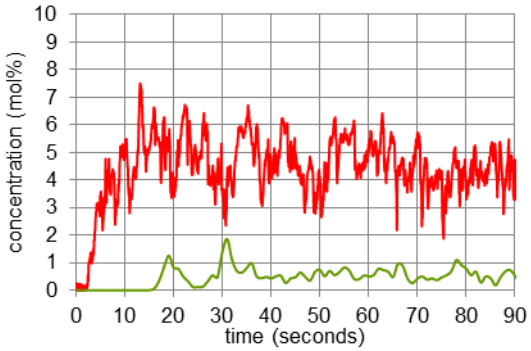


Gas Concentration at x=151m, y=0m, z=0m

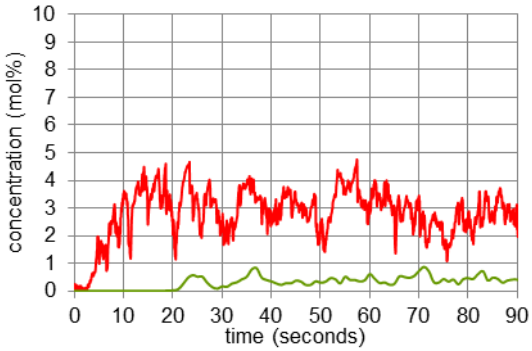


Gas Concentration at x=251m, y=0m, z=0m

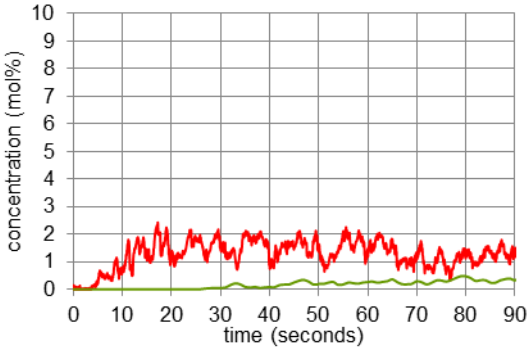
BAH 039072 (Upwind Fence 2)



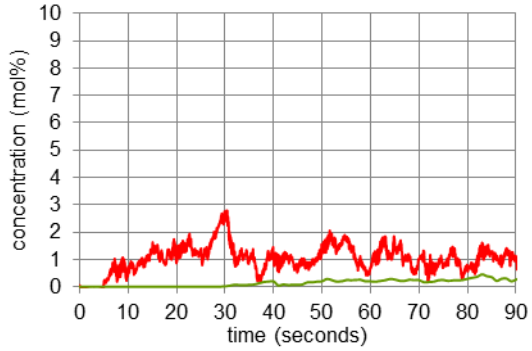
Gas Concentration at x=101m, y=0m, z=0m



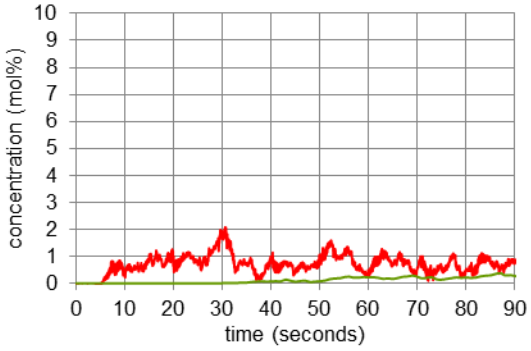
Gas Concentration at x=101m, y=38m, z=0m



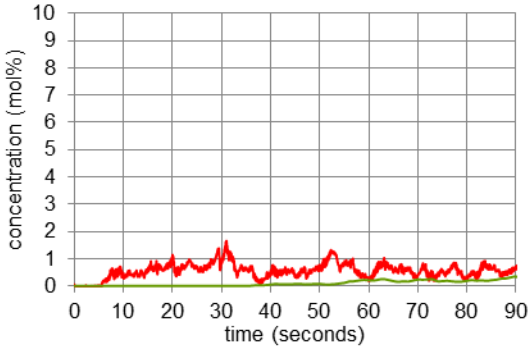
Gas Concentration at x=201m, y=0m, z=0m



Gas Concentration at x=201m, y=38m, z=0m

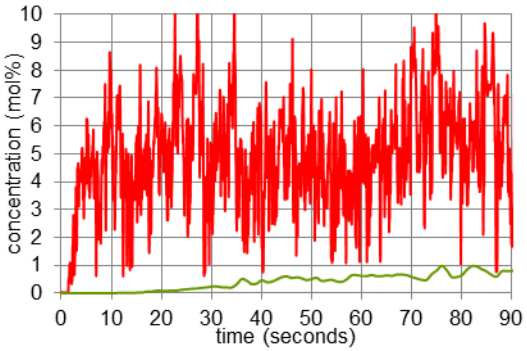


Gas Concentration at x=201m, y=75m, z=0m

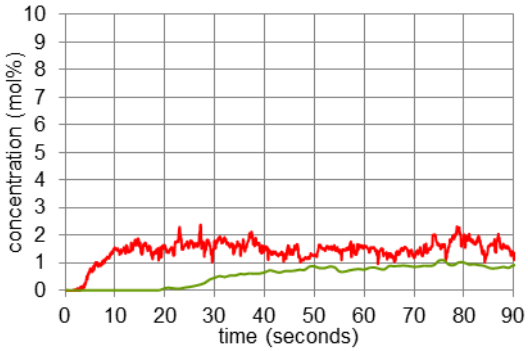


Gas Concentration at x=301m, y=0m, z=0m

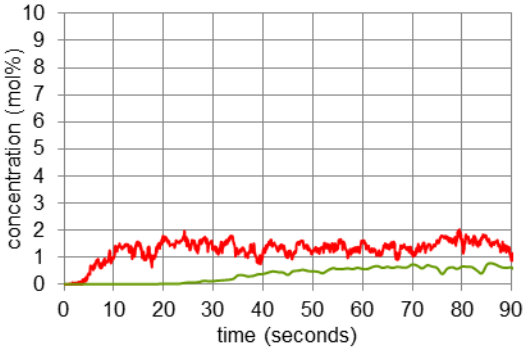
BAH DA0501 (Downwind Fence 1)



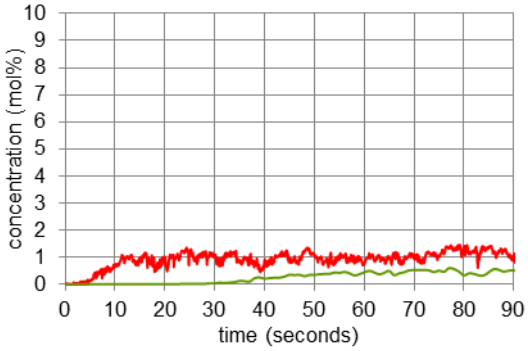
Gas Concentration at x=50m, y=0m, z=0m



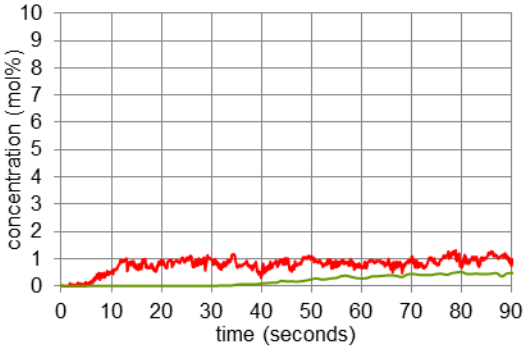
Gas Concentration at x=101m, y=0m, z=0m



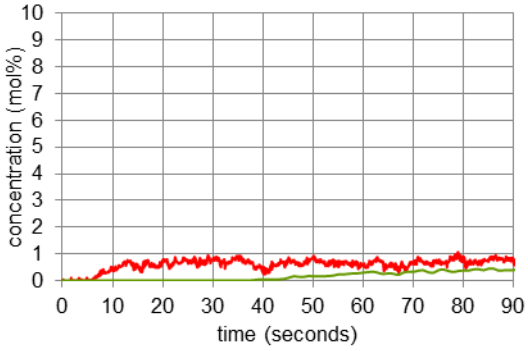
Gas Concentration at x=151m, y=0m, z=0m



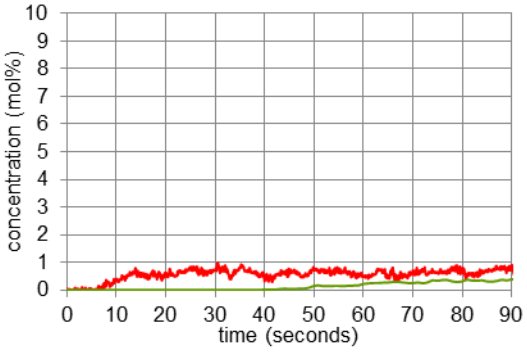
Gas Concentration at x=201m, y=0m, z=0m



Gas Concentration at x=251m, y=0m, z=0m

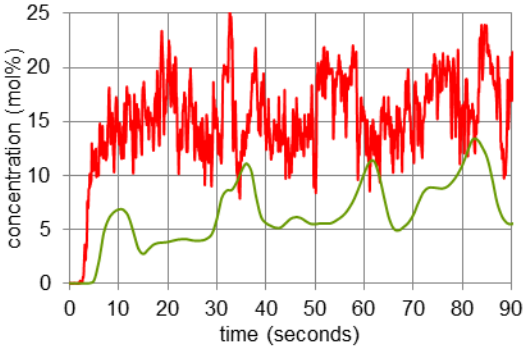


Gas Concentration at x=302m, y=0m, z=0m

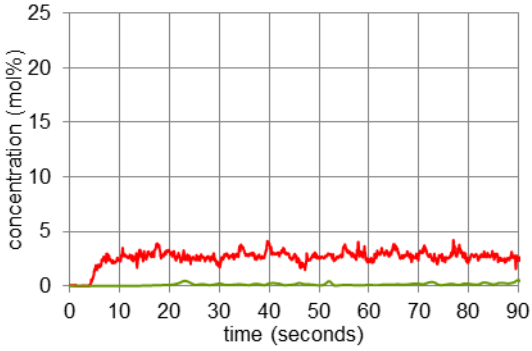


Gas Concentration at x=352m, y=0m, z=0m

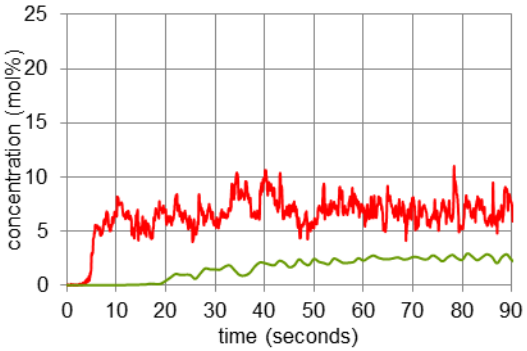
BAH DA0532 (Downwind Fence 2)



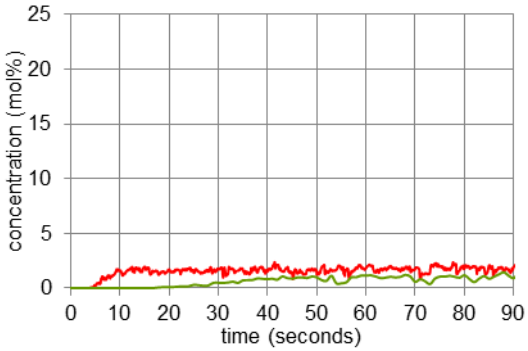
Gas Concentration at x=25m, y=0m, z=0m



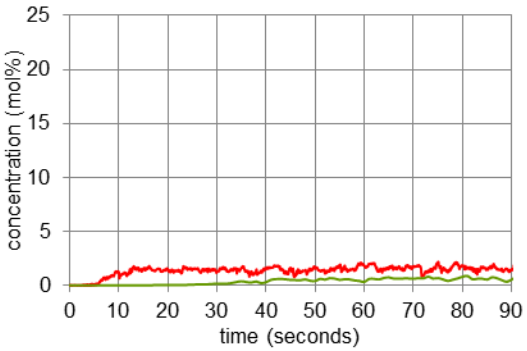
Gas Concentration at x=38m, y=0m, z=0m



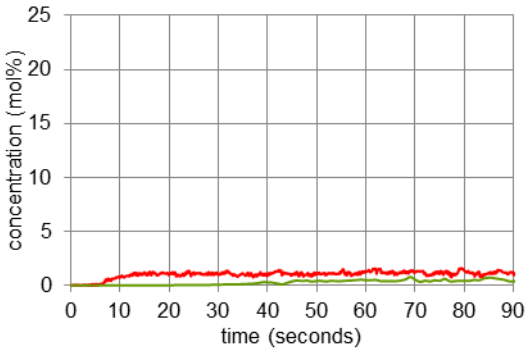
Gas Concentration at x=50m, y=0m, z=0m



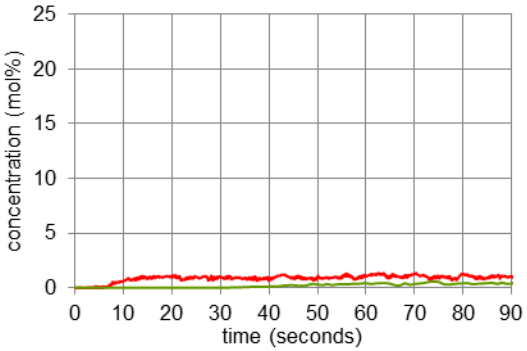
Gas Concentration at x=101m, y=0m, z=0m



Gas Concentration at x=151m, y=0m, z=0m

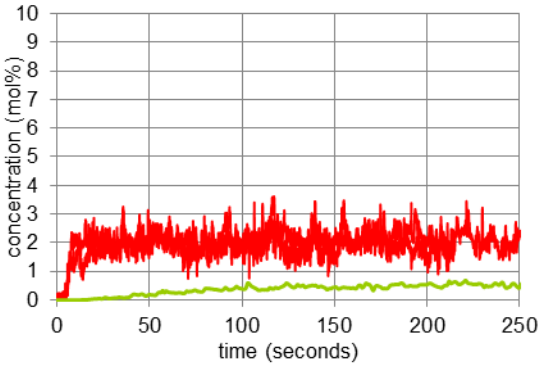


Gas Concentration at x=201m, y=0m, z=0m

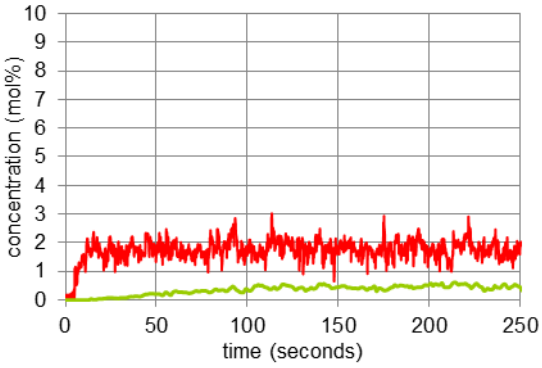


Gas Concentration at x=251m, y=0m, z=0m

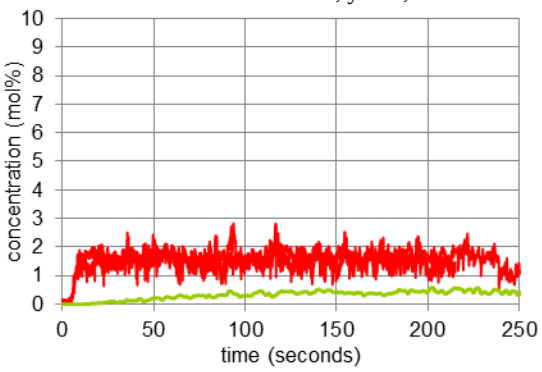
BAH 039094/039095 (Circular Fence 1)



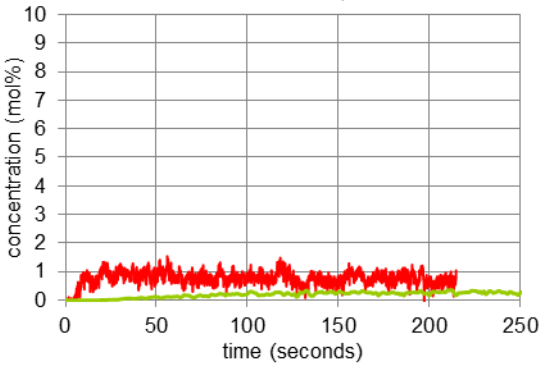
Gas Concentration at x=75m, y=0m, z=0m



Gas Concentration at x=88m, y=0m, z=0m

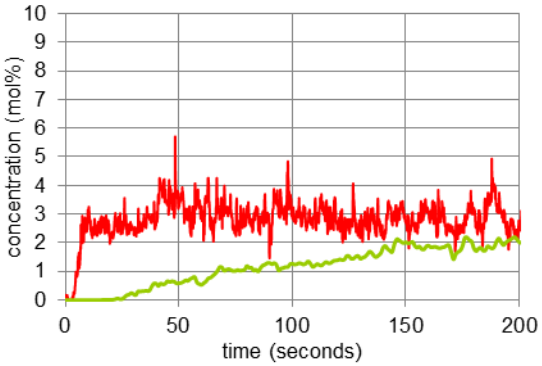


Gas Concentration at x=101m, y=0m, z=0m

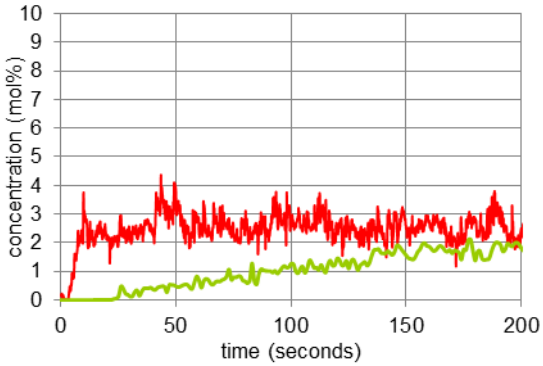


Gas Concentration at x=201m, y=0m, z=0m

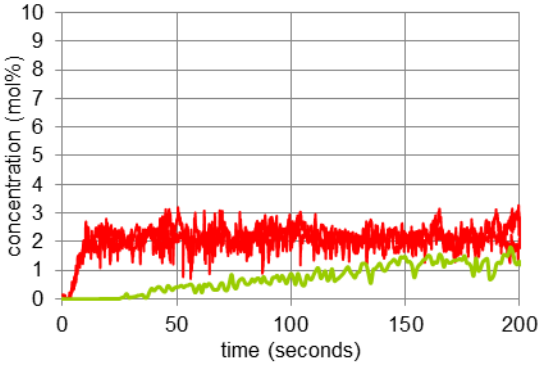
BAH 039097 (Circular Fence 2)



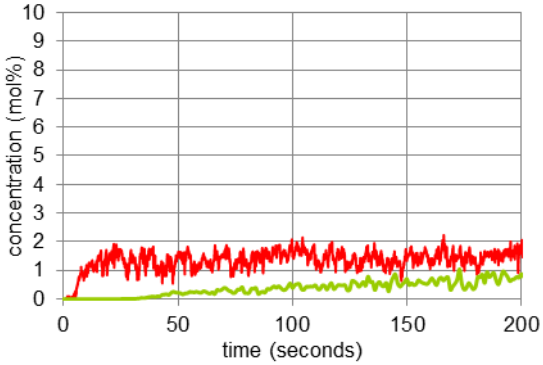
Gas Concentration at x=38m, y=0m, z=0m



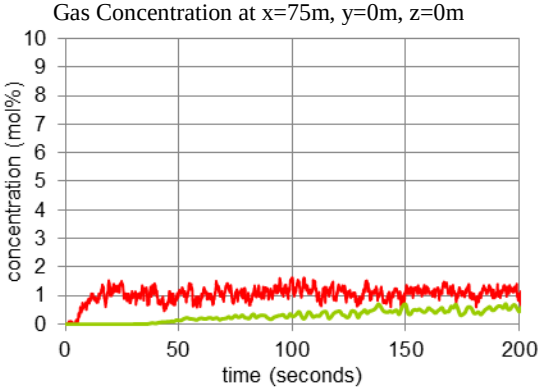
Gas Concentration at x=50m, y=0m, z=0m



Gas Concentration at x=75m, y=0m, z=0m

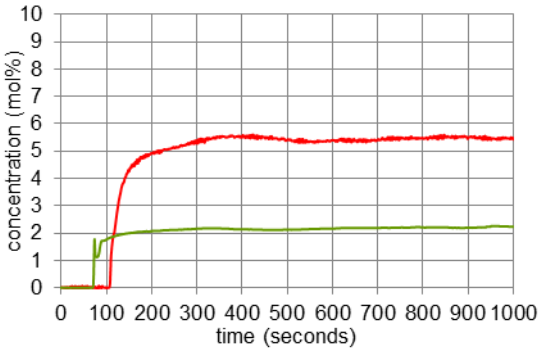


Gas Concentration at x=151m, y=0m, z=0m

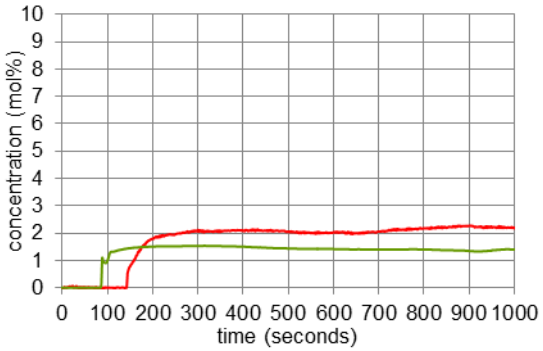


Gas Concentration at x=201m, y=0m, z=0m

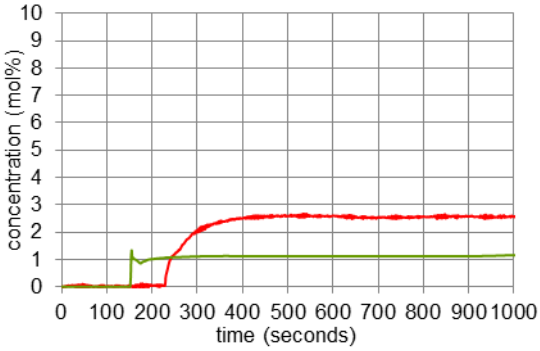
BAH DAT647 (Slope 1)



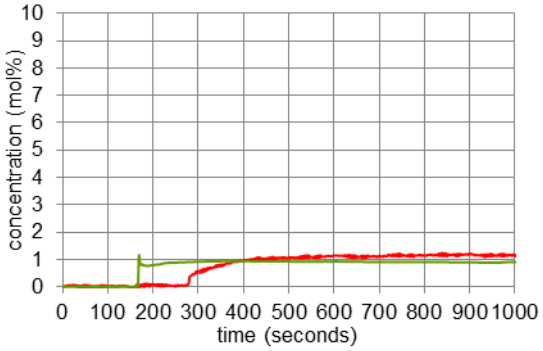
Gas Concentration at x=100m, y=0m, z=0m



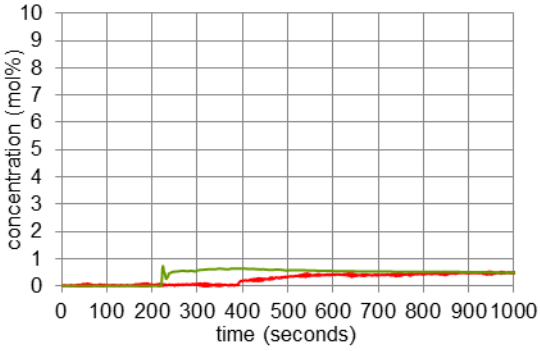
Gas Concentration at x=100m, y=50m, z=0m



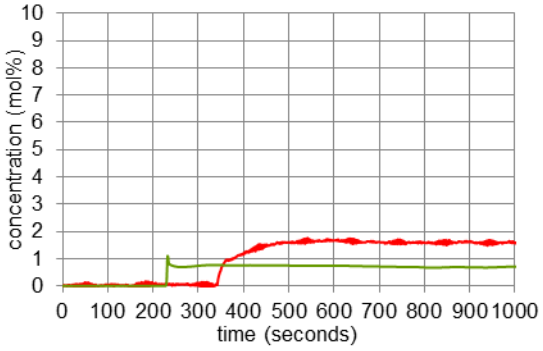
Gas Concentration at x=201m, y=0m, z=0m



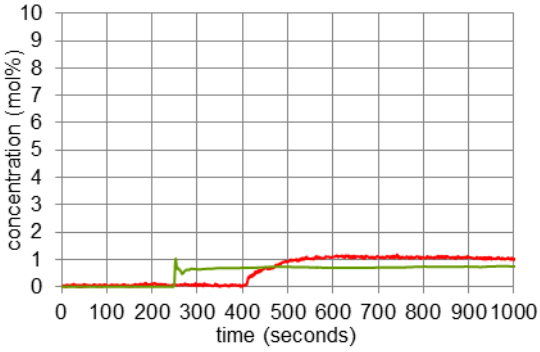
Gas Concentration at x=201m, y=63m, z=0m



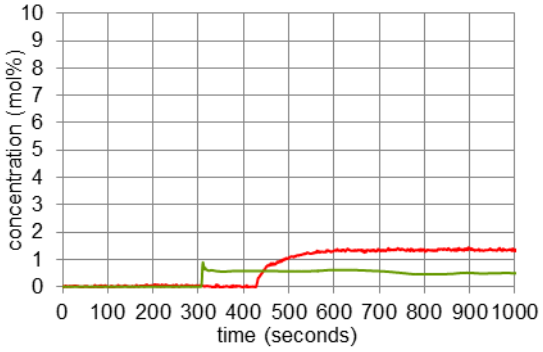
Gas Concentration at x=201m, y=126m, z=0m



Gas Concentration at x=302m, y=0m, z=0m

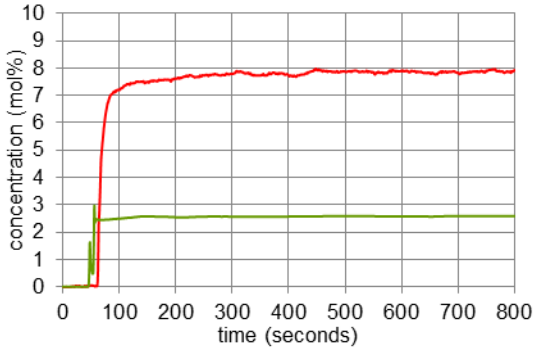


Gas Concentration at x=302m, y=63m, z=0m

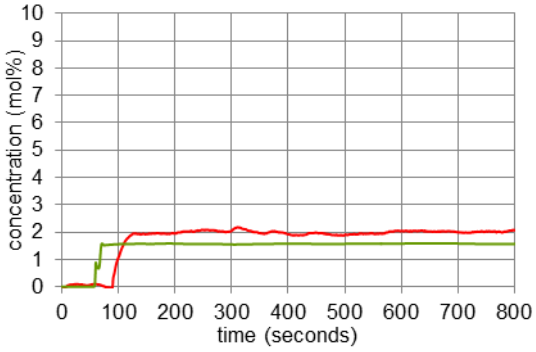


Gas Concentration at x=402m, y=0m, z=0m

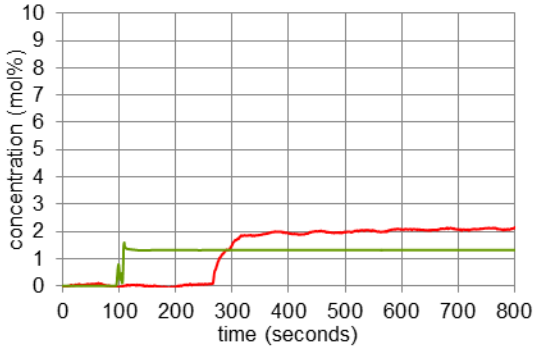
BAH DAT631 (Slope 2)



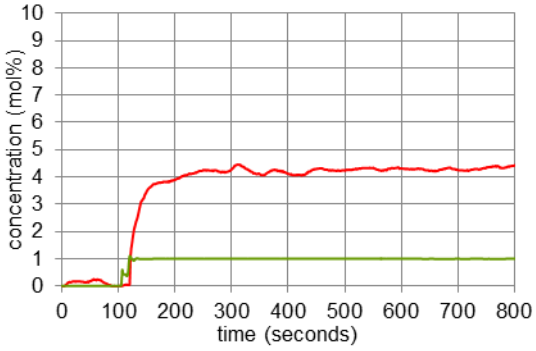
Gas Concentration at x=100m, y=0m, z=0m



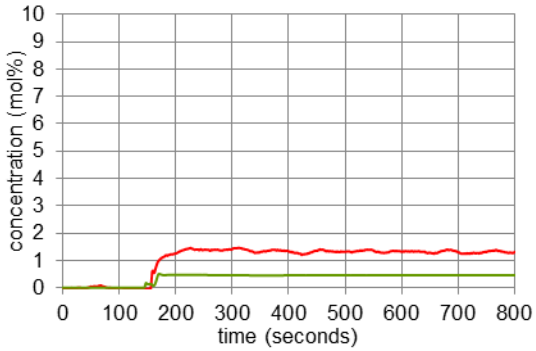
Gas Concentration at x=100m, y=50m, z=0m



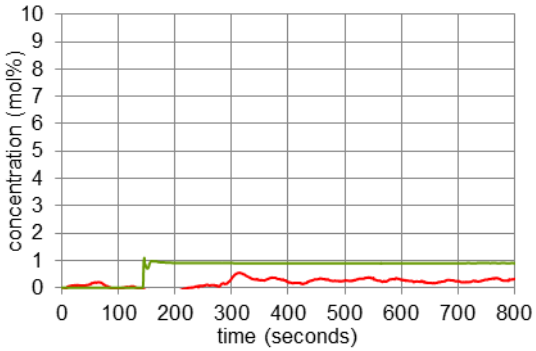
Gas Concentration at x=201m, y=0m, z=0m



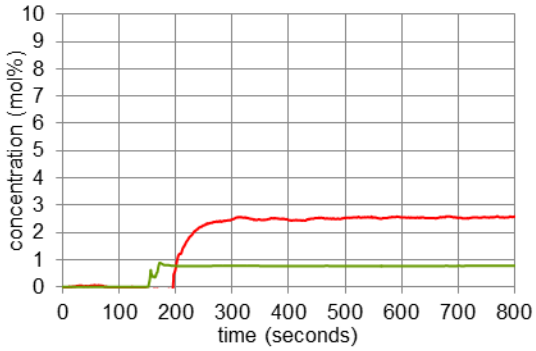
Gas Concentration at x=201m, y=63m, z=0m



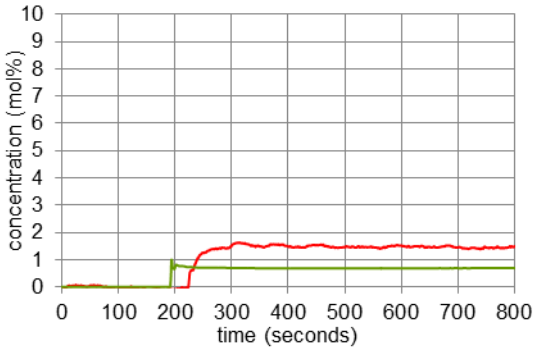
Gas Concentration at x=201m, y=126m, z=0m



Gas Concentration at x=302m, y=0m, z=0m

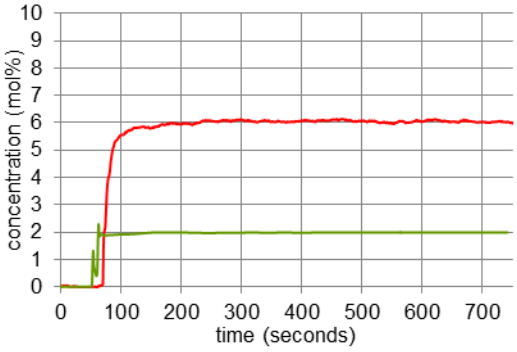


Gas Concentration at x=302m, y=63m, z=0m

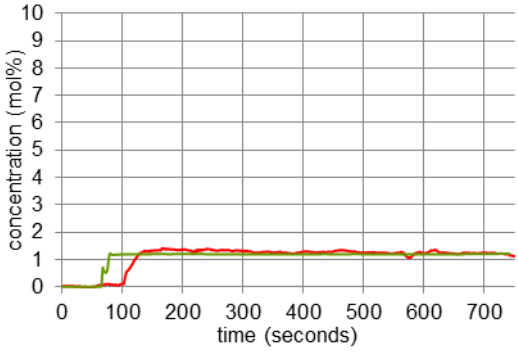


Gas Concentration at x=402m, y=0m, z=0m

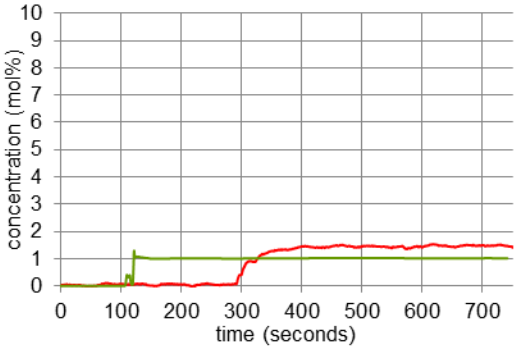
BAH DAT632 (Slope 3)



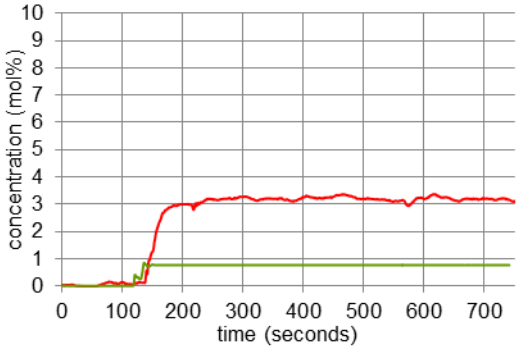
Gas Concentration at x=100m, y=0m, z=0m



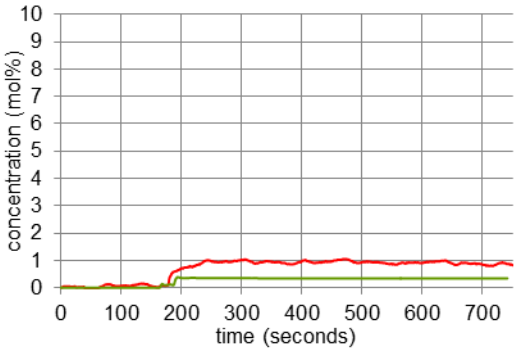
Gas Concentration at x=100m, y=50m, z=0m



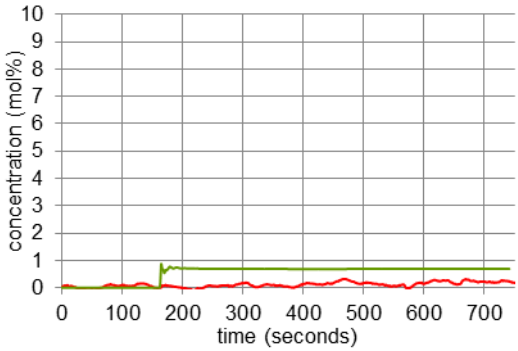
Gas Concentration at x=201m, y=0m, z=0m



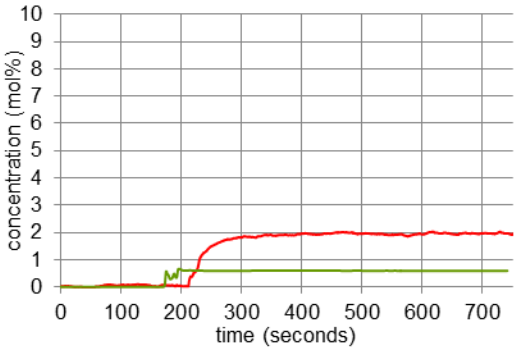
Gas Concentration at x=201m, y=63m, z=0m



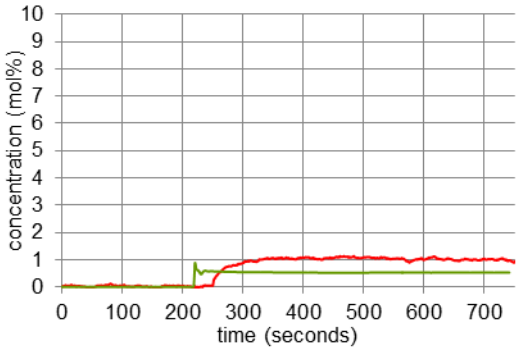
Gas Concentration at x=201m, y=126m, z=0m



Gas Concentration at x=302m, y=0m, z=0m

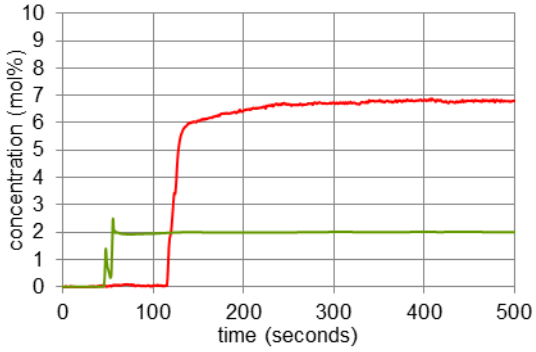


Gas Concentration at x=302m, y=63m, z=0m

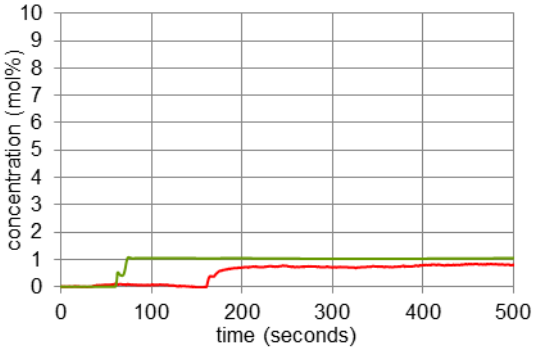


Gas Concentration at x=402m, y=0m, z=0m

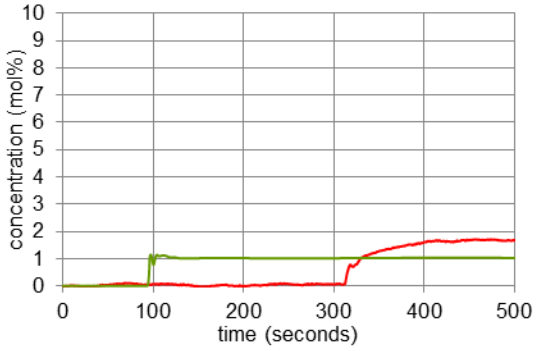
BAH DAT637 (Slope 4)



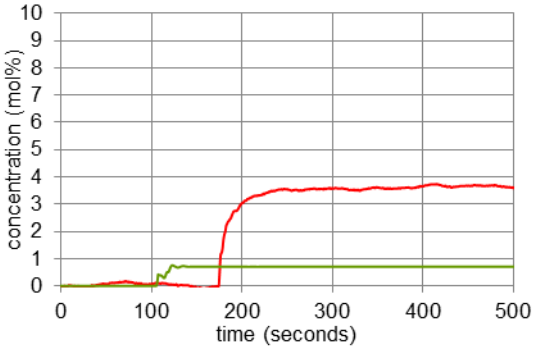
Gas Concentration at x=100m, y=0m, z=0m



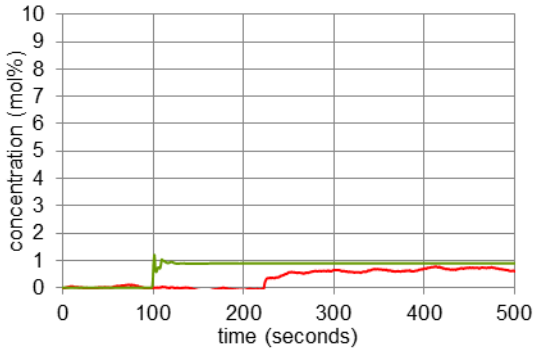
Gas Concentration at x=100m, y=50m, z=0m



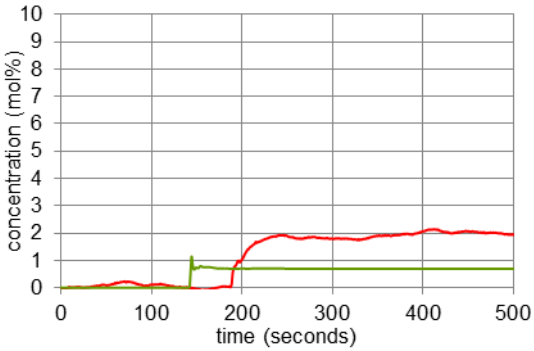
Gas Concentration at x=201m, y=0m, z=0m



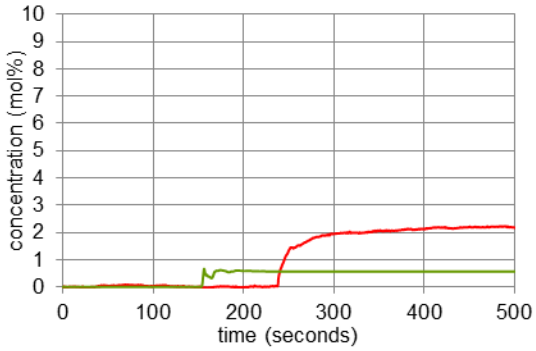
Gas Concentration at x=201m, y=63m, z=0m



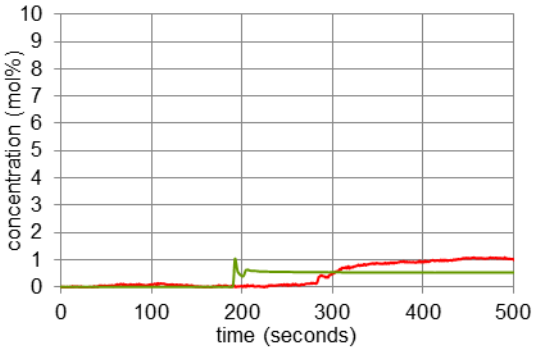
Gas Concentration at x=201m, y=126m, z=0m



Gas Concentration at x=302m, y=0m, z=0m

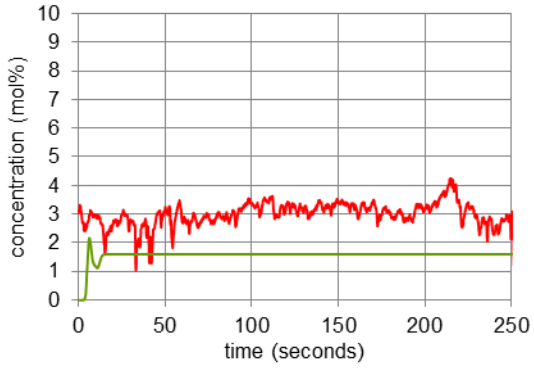


Gas Concentration at x=302m, y=63m, z=0m

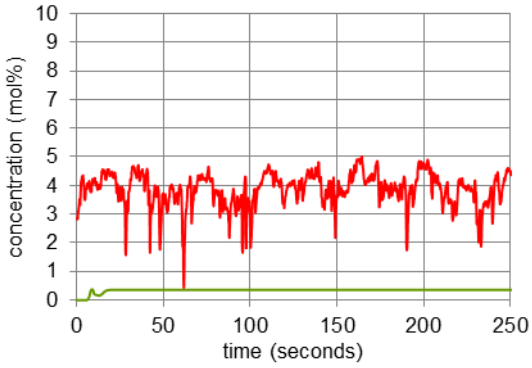


Gas Concentration at x=402m, y=0m, z=0m

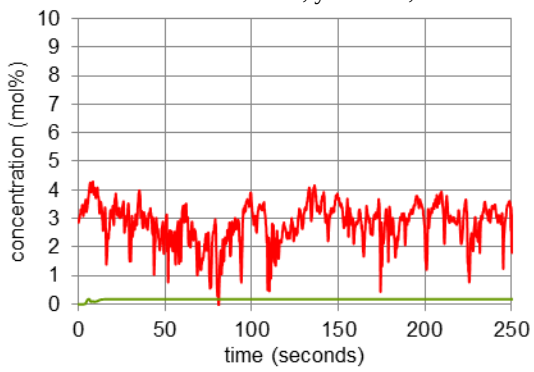
TNO TUV01 (Unobstructed)



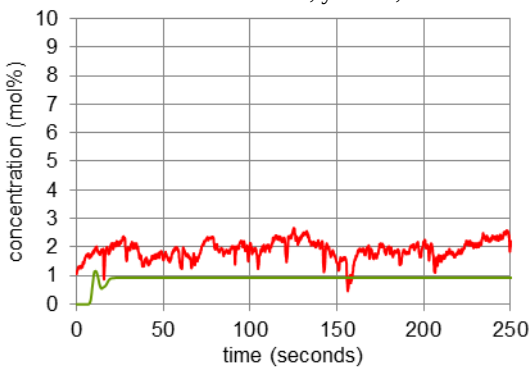
Gas Concentration at x=33m, y=-0.62m, z=0m



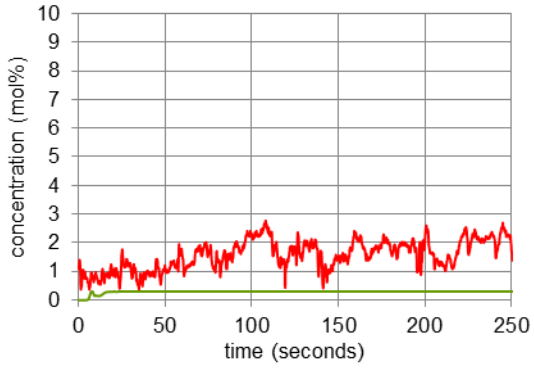
Gas Concentration at x=51m, y=9.9m, z=0m



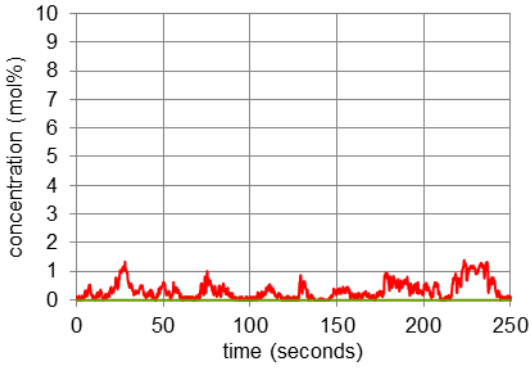
Gas Concentration at x=30m, y=9.9m, z=0m



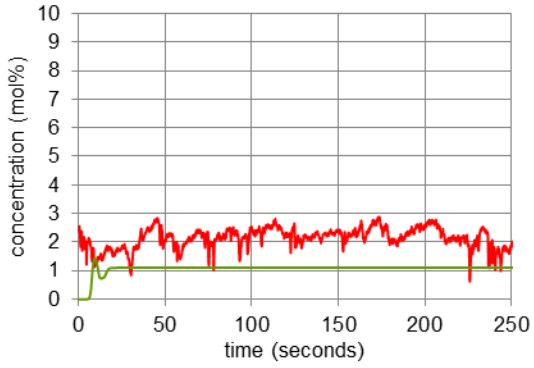
Gas Concentration at x=65m, y=-4.0m, z=0m



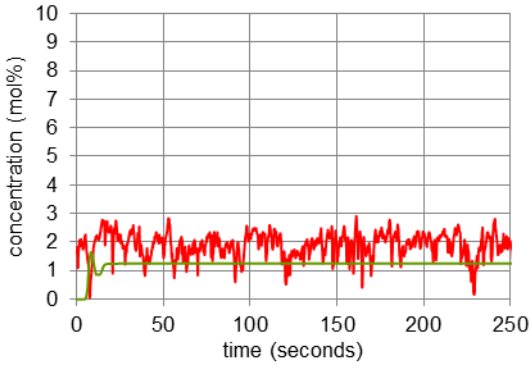
Gas Concentration at x=44m, y=9.9m, z=0m



Gas Concentration at x=51m, y=24m, z=0m

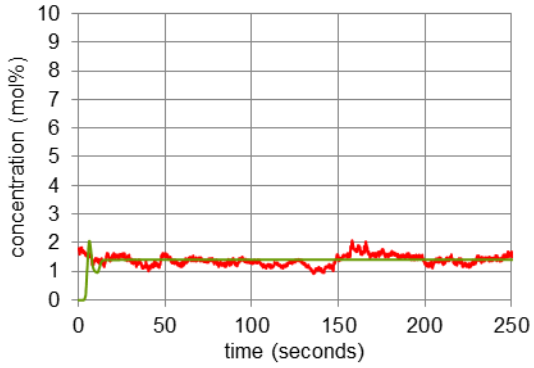


Gas Concentration at x=55m, y=-0.62m, z=0m

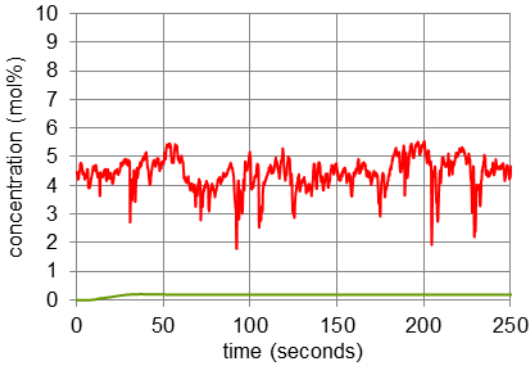


Gas Concentration at x=46m, y=0.62m, z=0m

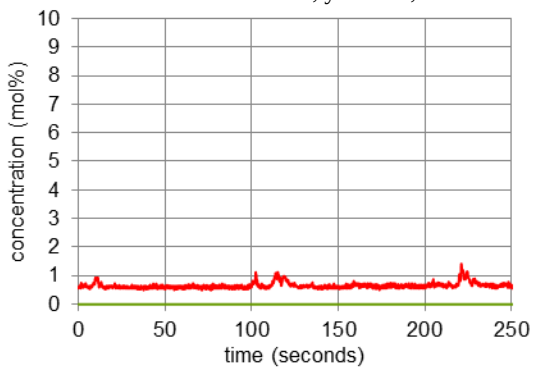
TNO TUV02 (Fence)



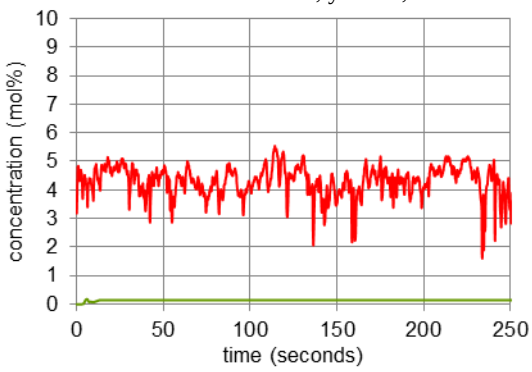
Gas Concentration at x=33m, y=0.62m, z=0m



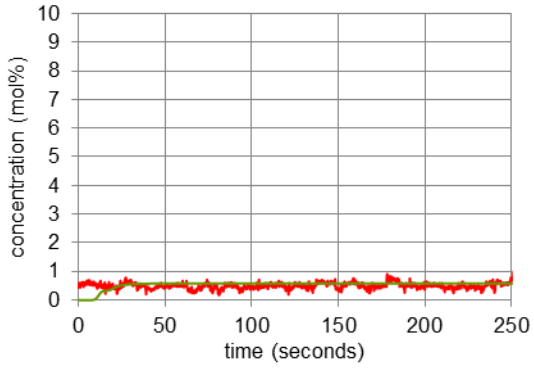
Gas Concentration at x=51m, y=9.9m, z=0m



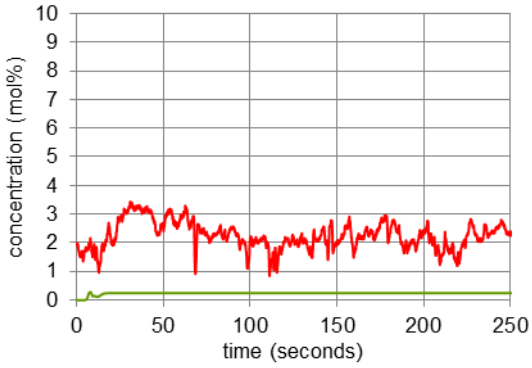
Gas Concentration at x=40m, y=28m, z=0m



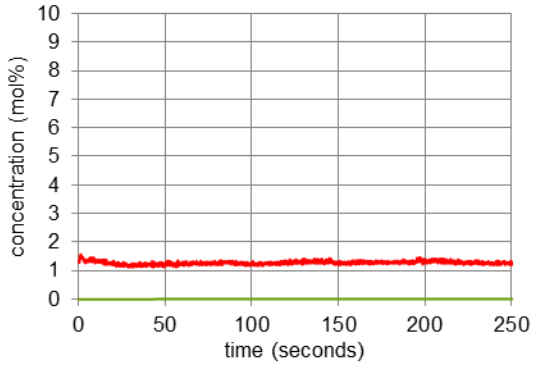
Gas Concentration at x=30m, y=9.9m, z=0m



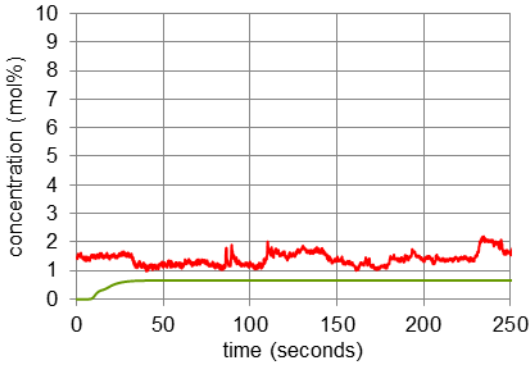
Gas Concentration at x=65m, y=-4.0m, z=0m



Gas Concentration at x=44m, y=9.9m, z=0m

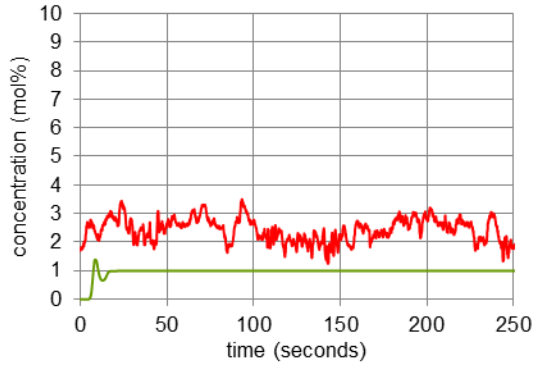


Gas Concentration at x=51m, y=24m, z=0m



Gas Concentration at x=55m, y=-0.62m, z=0m

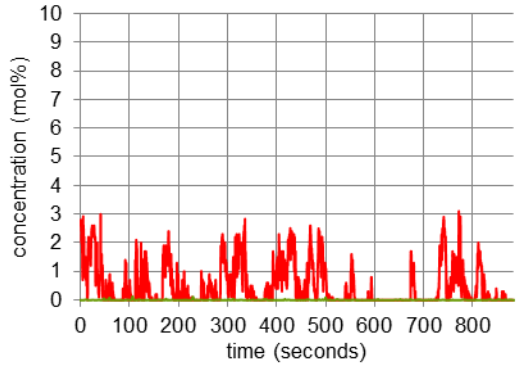
TNO TUV02 (Fence) (Continued)



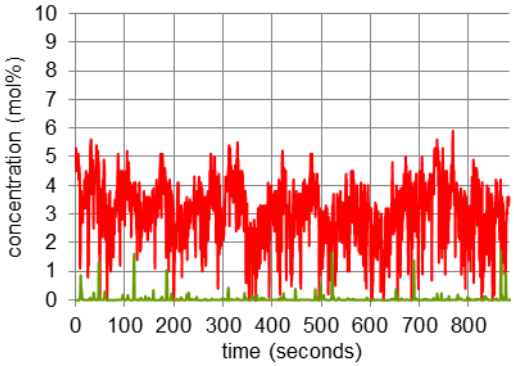
Gas

Concentration at x=46m, y=0.62m, z=0m

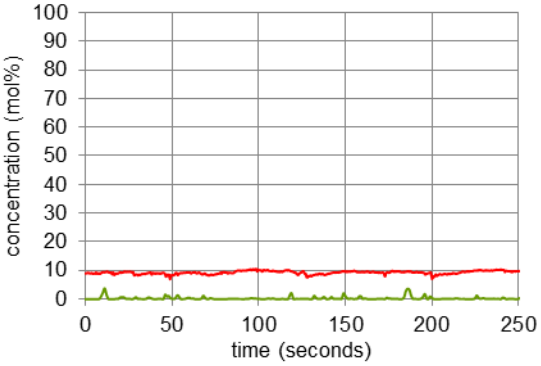
TNO FLS



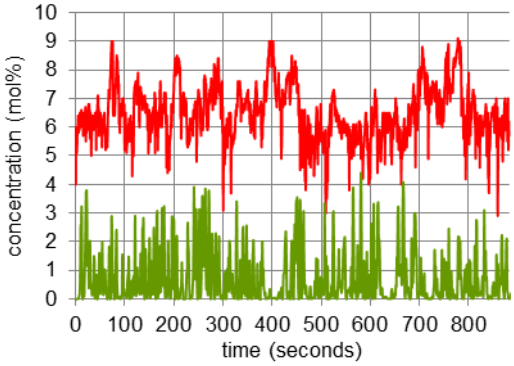
Gas Concentration at x=50m, y=31m, z=0.078m



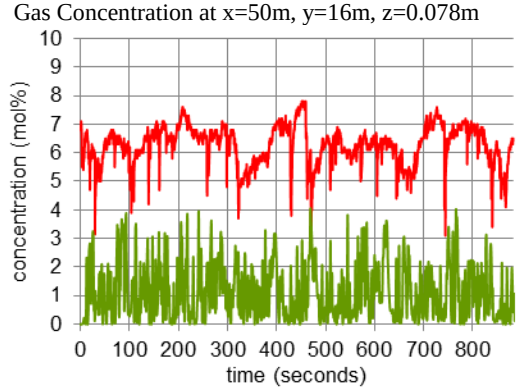
Gas Concentration at x=50m, y=23m, z=0.078m



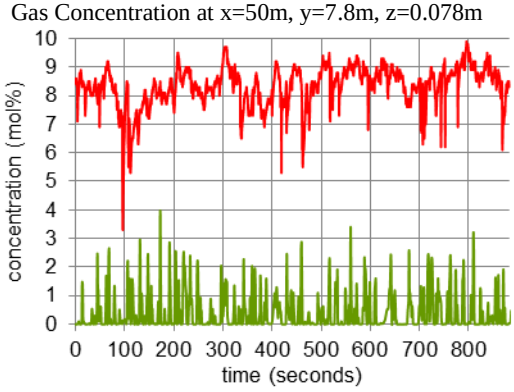
Gas Concentration at x=50m, y=16m, z=0.078m



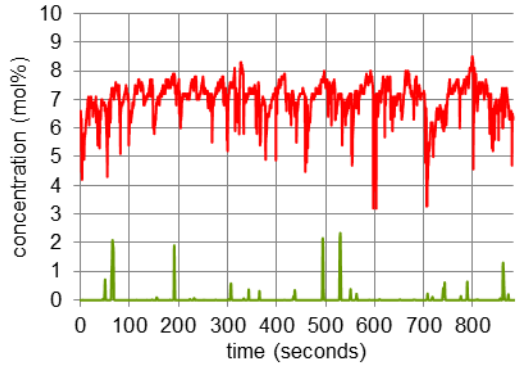
Gas Concentration at x=50m, y=7.8m, z=0.078m



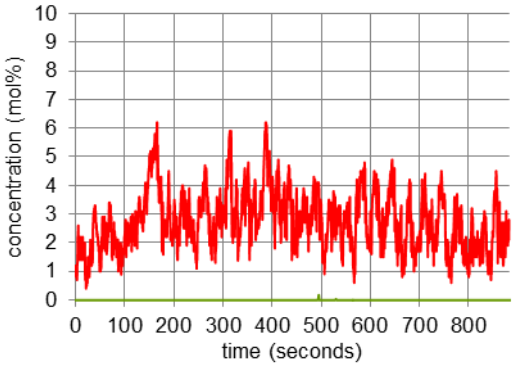
Gas Concentration at x=50m, y=0m, z=0.078m



Gas Concentration at x=50m, y=-7.8m, z=0.078m

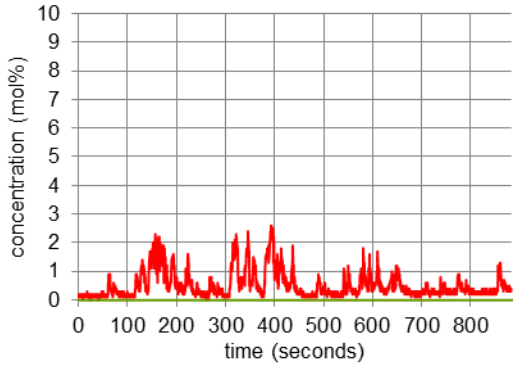


Gas Concentration at x=50m, y=-16m, z=0.078m

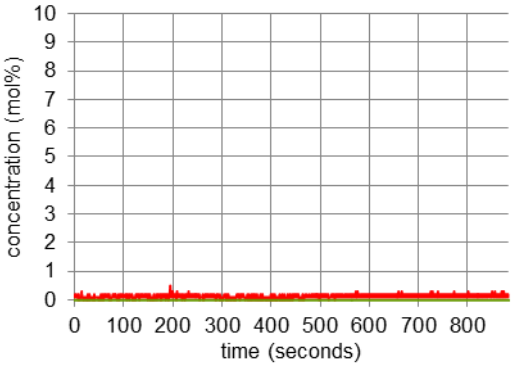


Gas Concentration at x=50m, y=-23m, z=0.078m

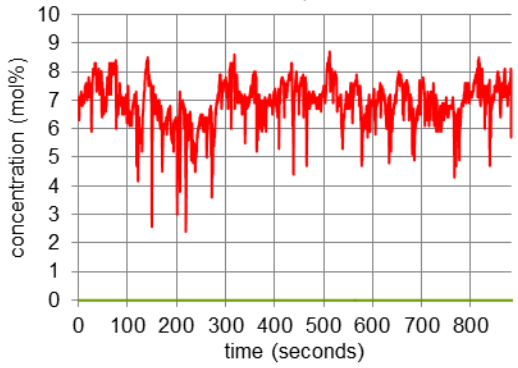
TNO FLS (continued)



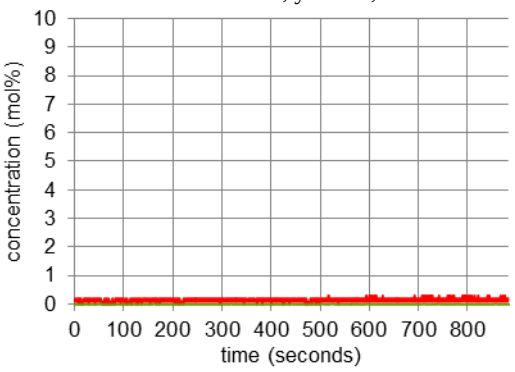
Gas Concentration at x=50m, y=-31m, z=0.078m



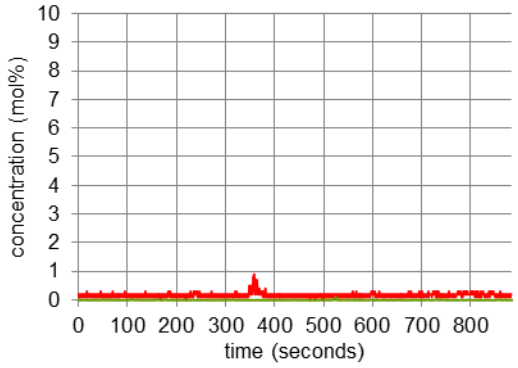
Gas Concentration at x=50m, y=-39m, z=0.078m



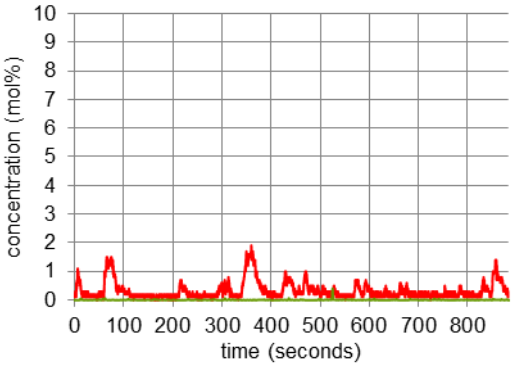
Gas Concentration at x=50m, y=-47m, z=0.078m



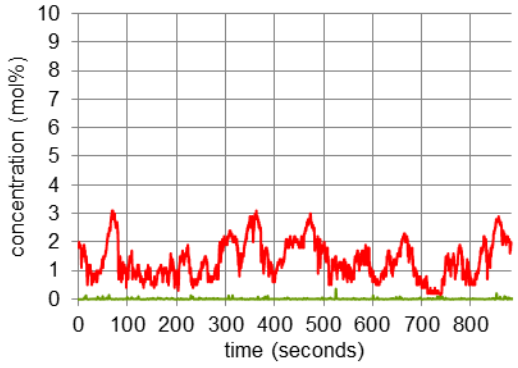
Gas Concentration at x=100m, y=55m, z=0.078m



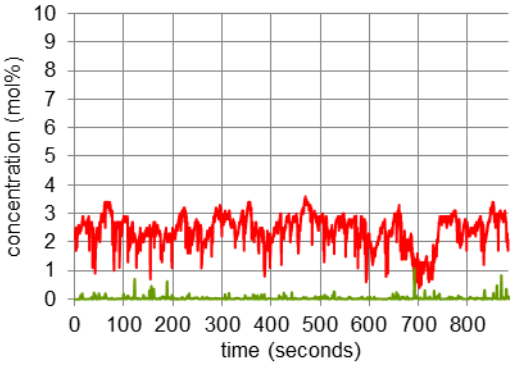
Gas Concentration at x=100m, y=47m, z=0.078m



Gas Concentration at x=100m, y=39m, z=0.078m

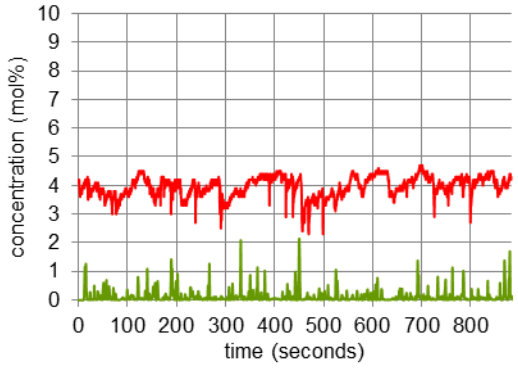


Gas Concentration at x=100m, y=31m, z=0.078m

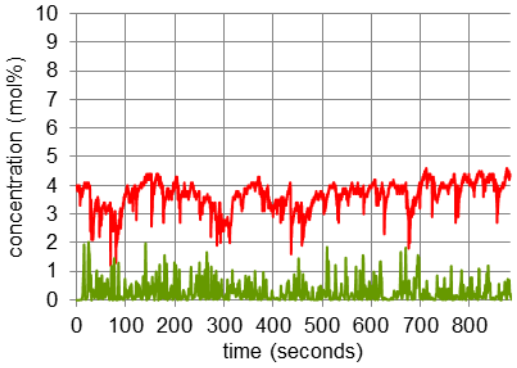


Gas Concentration at x=100m, y=23m, z=0.078m

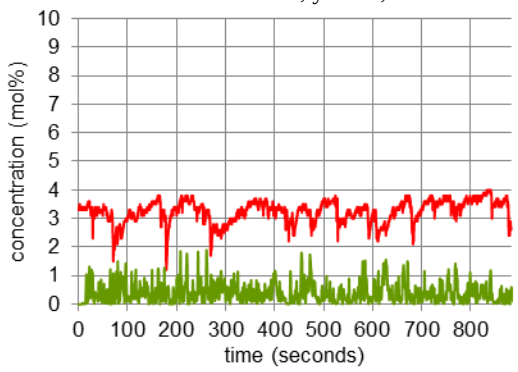
TNO FLS (continued)



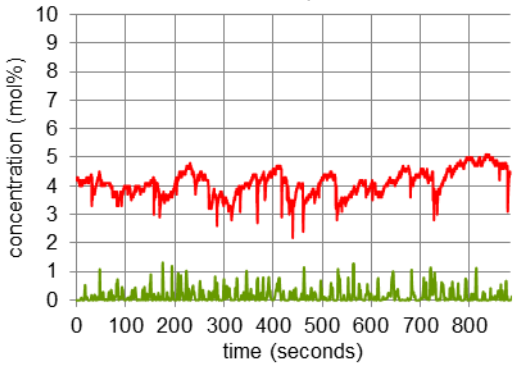
Gas Concentration at x=100m, y=16m, z=0.078m



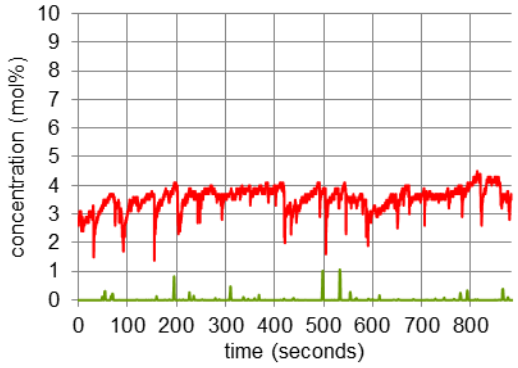
Gas Concentration at x=100m, y=7.8m, z=0.078m



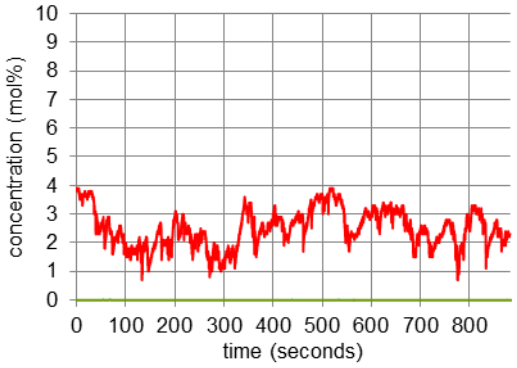
Gas Concentration at x=100m, y=0m, z=0.078m



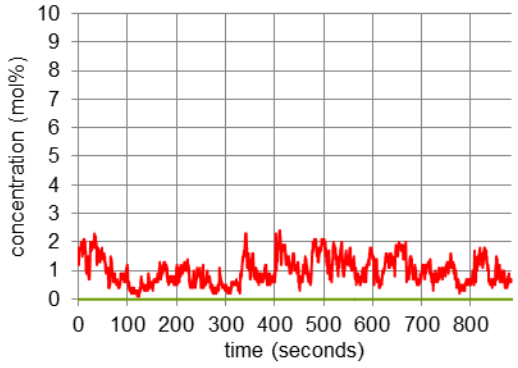
Gas Concentration at x=100m, y=-7.8m, z=0.078m



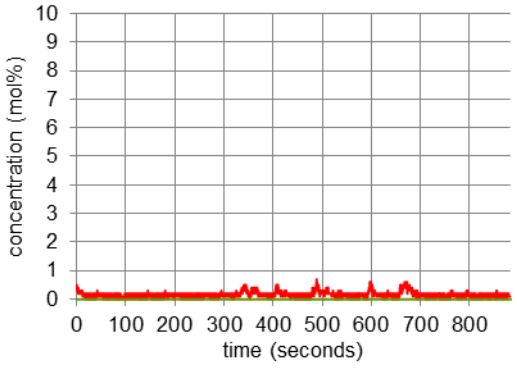
Gas Concentration at x=100m, y=-16m, z=0.078m



Gas Concentration at x=100m, y=-23m, z=0.078m

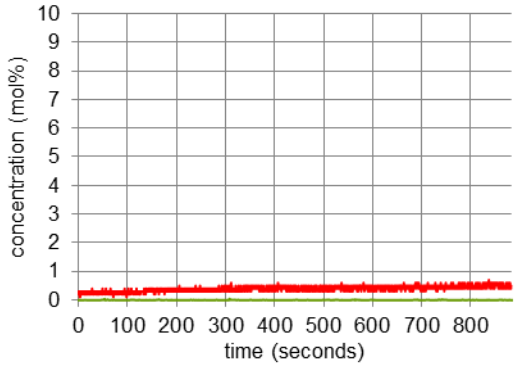


Gas Concentration at x=100m, y=-31m, z=0.078m

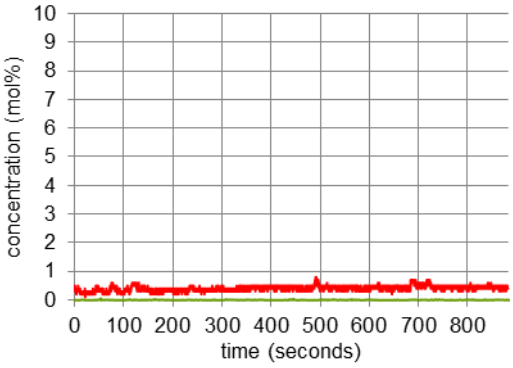


Gas Concentration at x=100m, y=-39m, z=0.078m

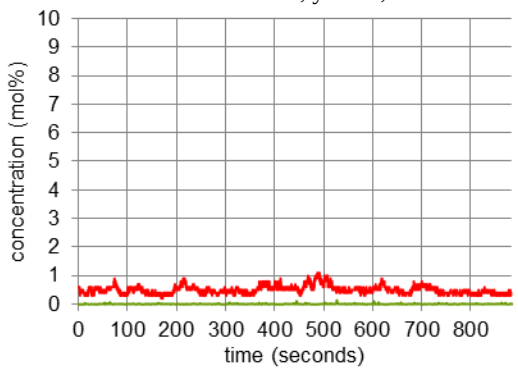
TNO FLS (continued)



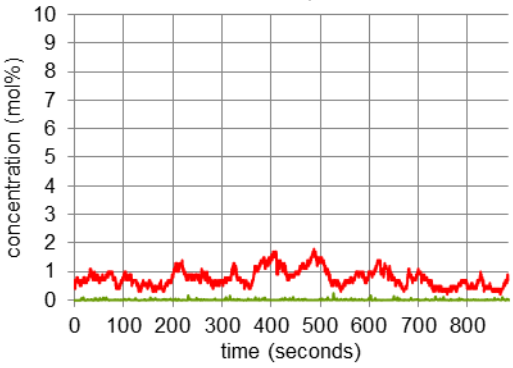
Gas Concentration at x=150m, y=55m, z=0.078m



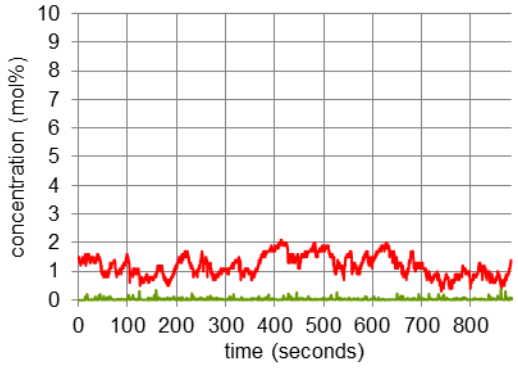
Gas Concentration at x=150m, y=47m, z=0.078m



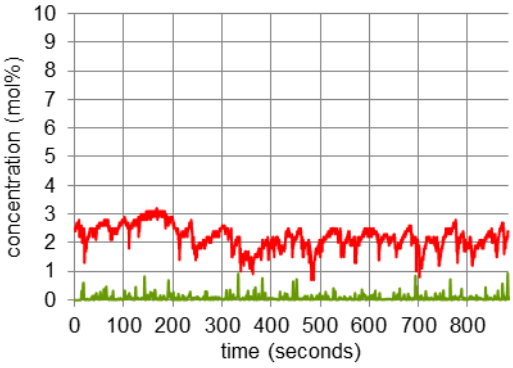
Gas Concentration at x=150m, y=39m, z=0.078m



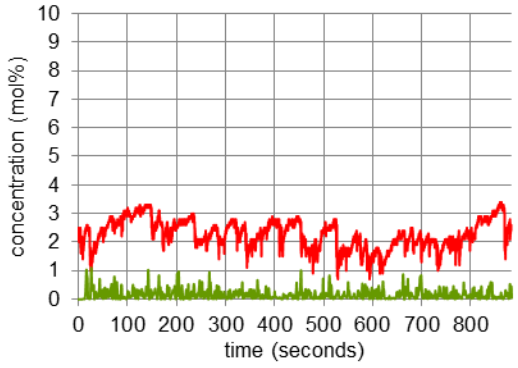
Gas Concentration at x=150m, y=31m, z=0.078m



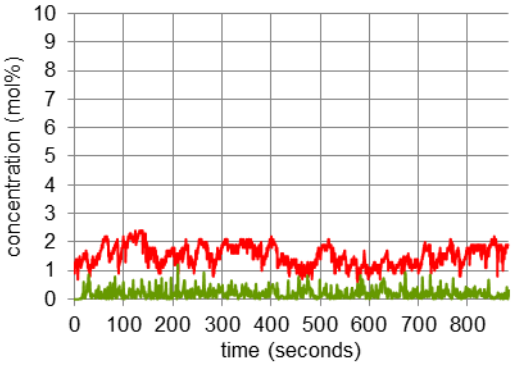
Gas Concentration at x=150m, y=23m, z=0.078m



Gas Concentration at x=150m, y=16m, z=0.078m

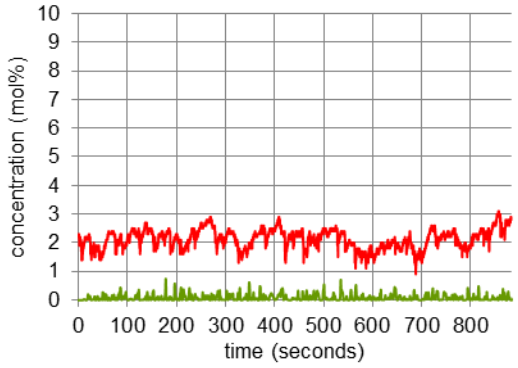


Gas Concentration at x=150m, y=7.8m, z=0.078m

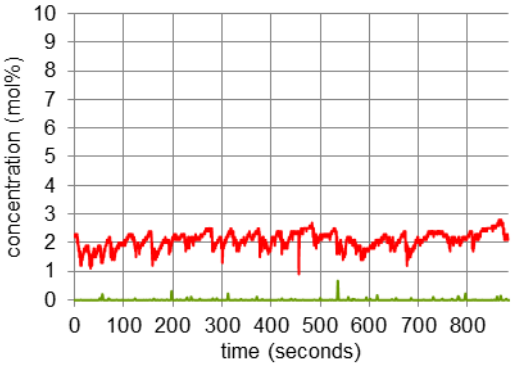


Gas Concentration at x=150m, y=0m, z=0.078m

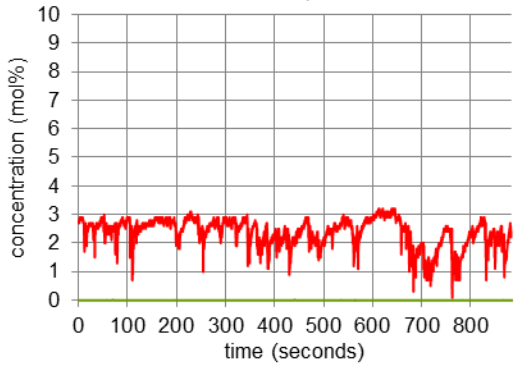
TNO FLS (continued)



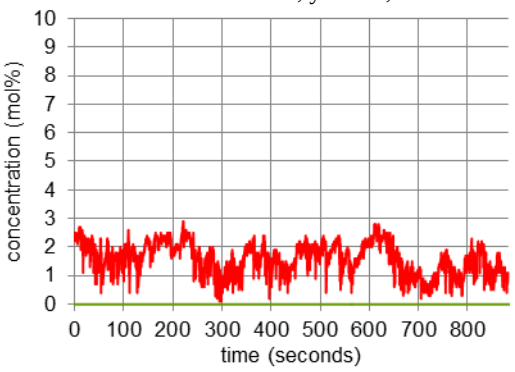
Gas Concentration at x=150m, y=-7.8m, z=0.078m



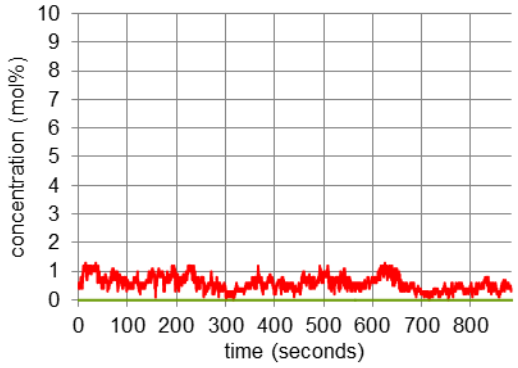
Gas Concentration at x=150m, y=-16m, z=0.078m



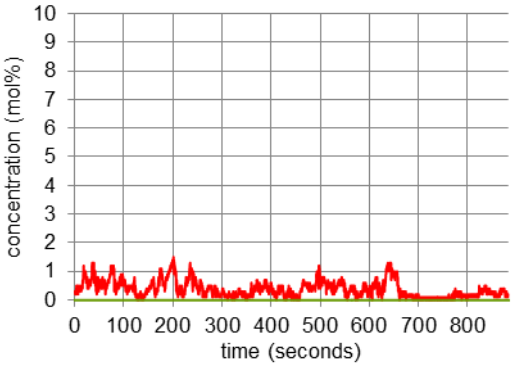
Gas Concentration at x=150m, y=-23m, z=0.078m



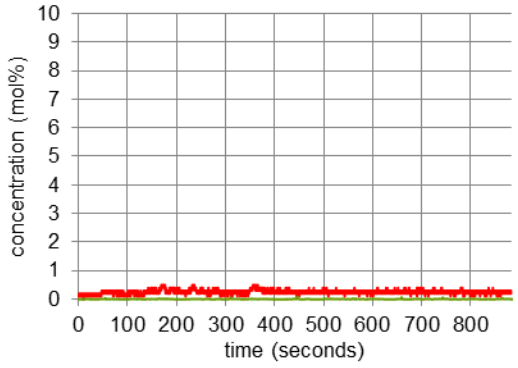
Gas Concentration at x=150m, y=-31m, z=0.078m



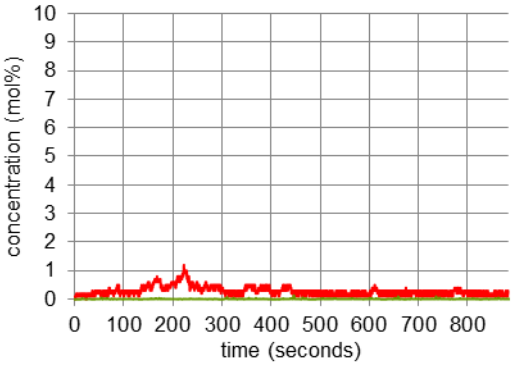
Gas Concentration at x=150m, y=-39m, z=0.078m



Gas Concentration at x=150m, y=-47m, z=0.078m

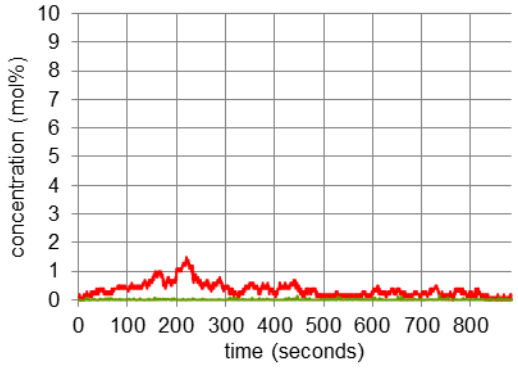


Gas Concentration at x=200m, y=47m, z=0.078m

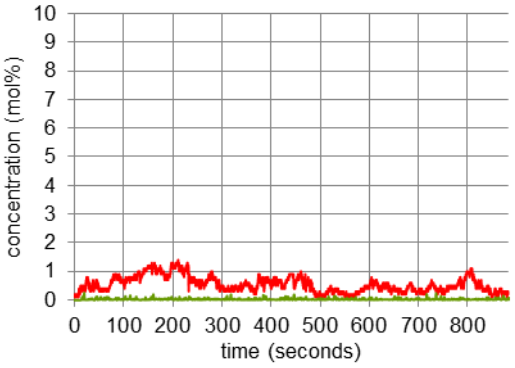


Gas Concentration at x=200m, y=39m, z=0.078m

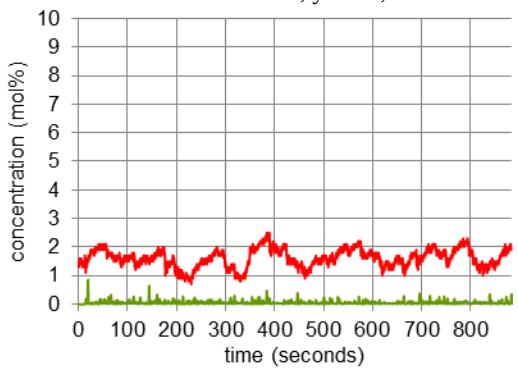
TNO FLS (continued)



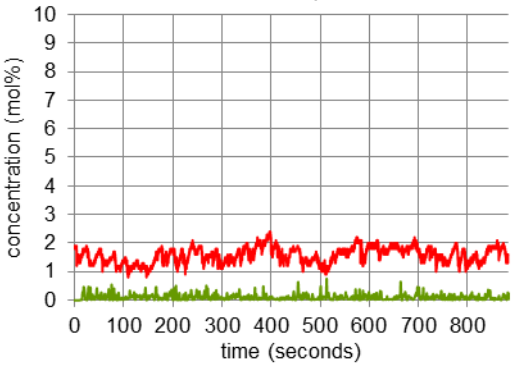
Gas Concentration at x=200m, y=31m, z=0.078m



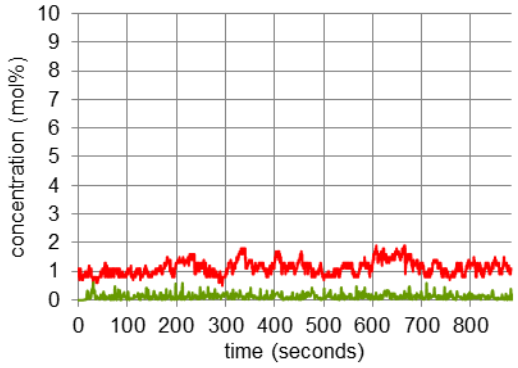
Gas Concentration at x=200m, y=23m, z=0.078m



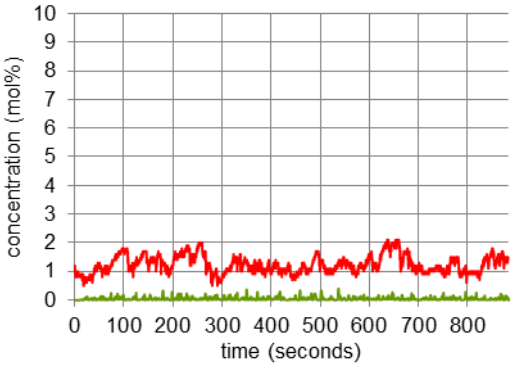
Gas Concentration at x=200m, y=16m, z=0.078m



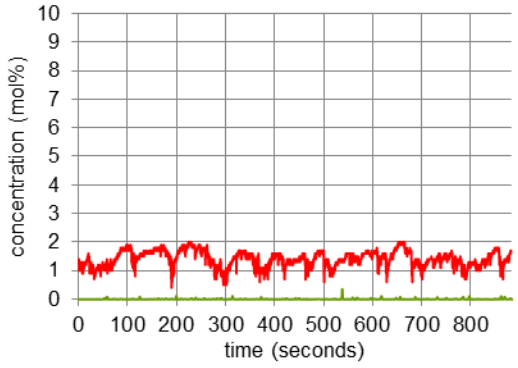
Gas Concentration at x=200m, y=7.8m, z=0.078m



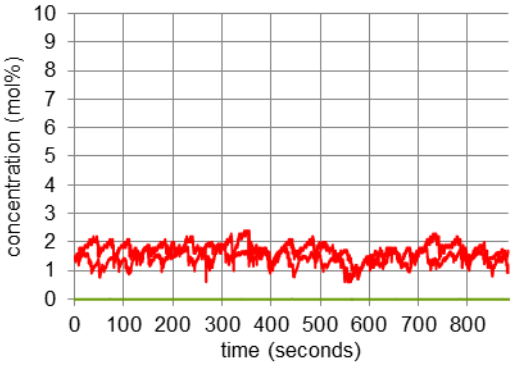
Gas Concentration at x=200m, y=0m, z=0.078m



Gas Concentration at x=200m, y=-7.8m, z=0.078m

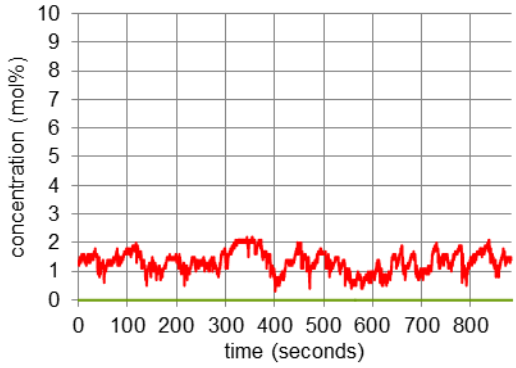


Gas Concentration at x=200m, y=-16m, z=0.078m

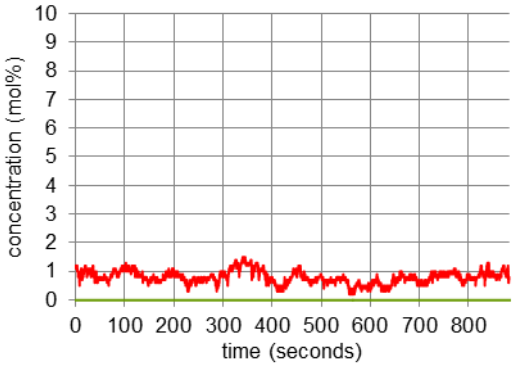


Gas Concentration at x=200m, y=-23m, z=0.078m

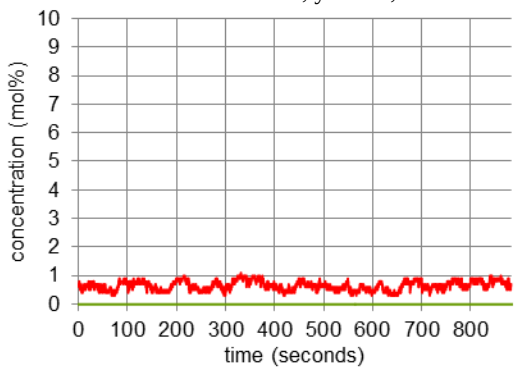
TNO FLS (continued)



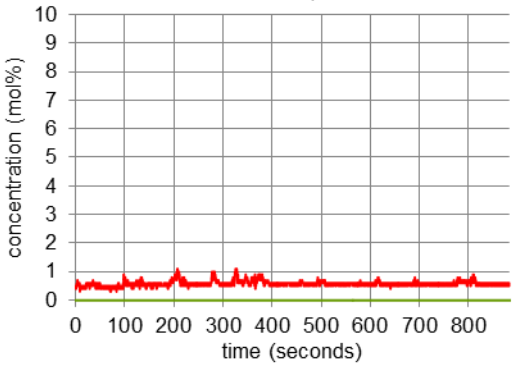
Gas Concentration at x=200m, y=-31m, z=0.078m



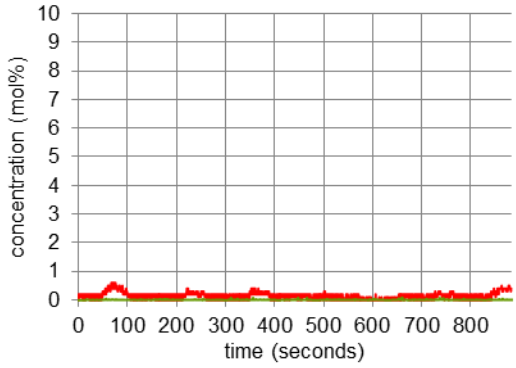
Gas Concentration at x=200m, y=-39m, z=0.078m



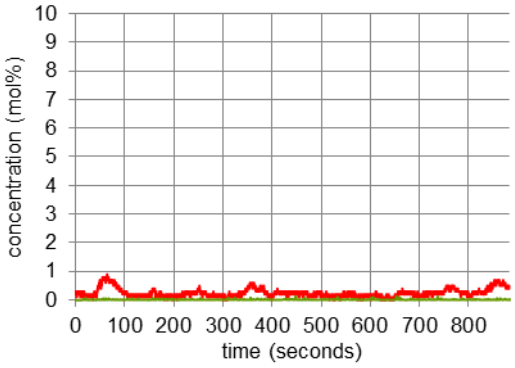
Gas Concentration at x=200m, y=-47m, z=0.078m



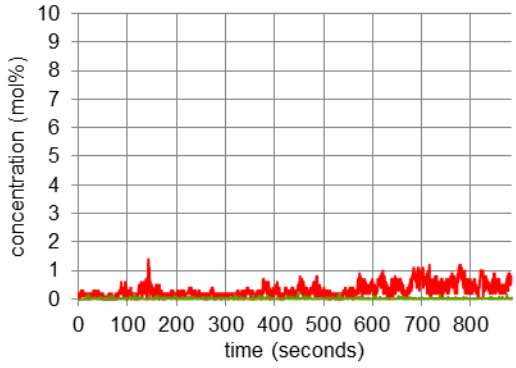
Gas Concentration at x=200m, y=-55m, z=0.078m



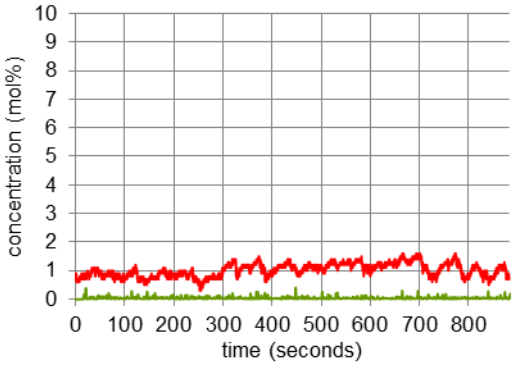
Gas Concentration at x=250m, y=39m, z=0.078m



Gas Concentration at x=250m, y=31m, z=0.078m

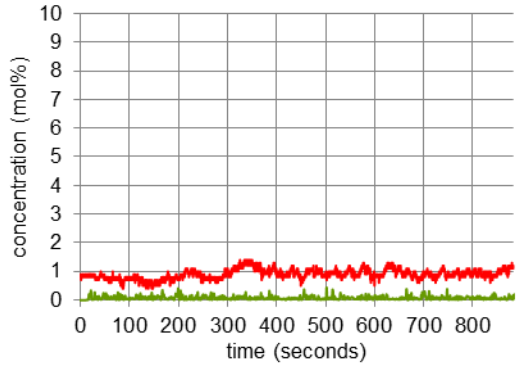


Gas Concentration at x=250m, y=23m, z=0.078m

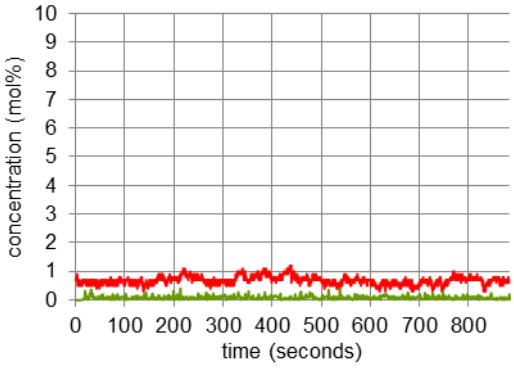


Gas Concentration at x=250m, y=16m, z=0.078m

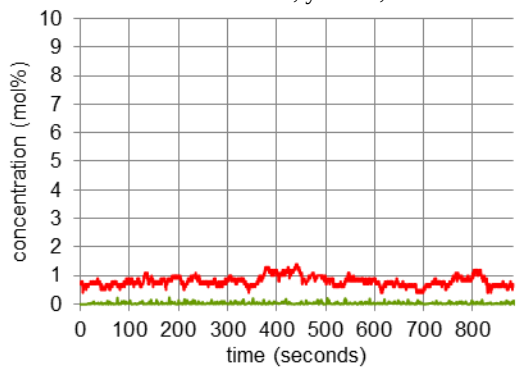
TNO FLS (continued)



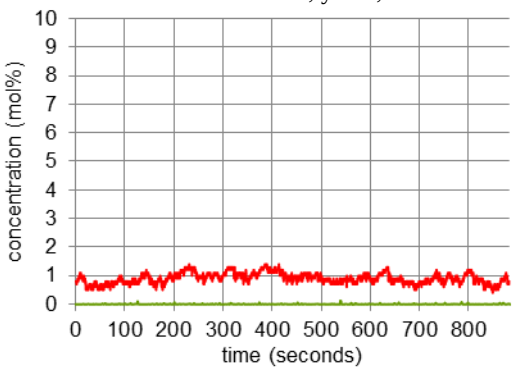
Gas Concentration at x=250m, y=7.8m, z=0.078m



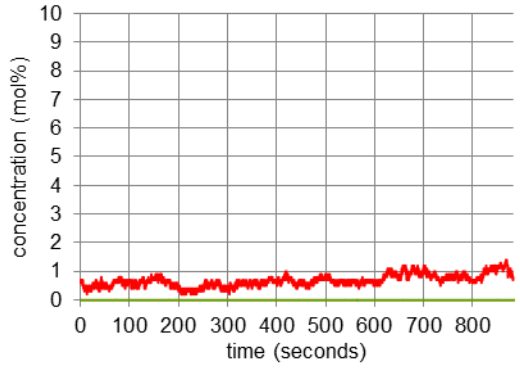
Gas Concentration at x=250m, y=0m, z=0.078m



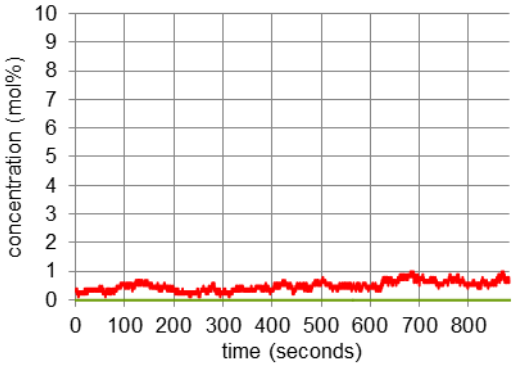
Gas Concentration at x=250m, y=-7.8m, z=0.078m



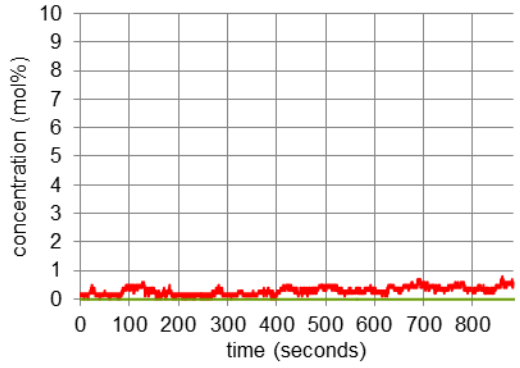
Gas Concentration at x=250m, y=-16m, z=0.078m



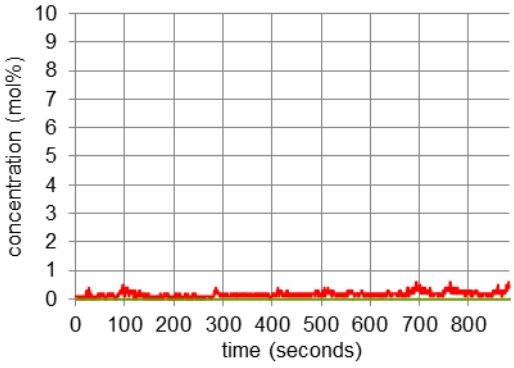
Gas Concentration at x=250m, y=-23m, z=0.078m



Gas Concentration at x=250m, y=-31m, z=0.078m

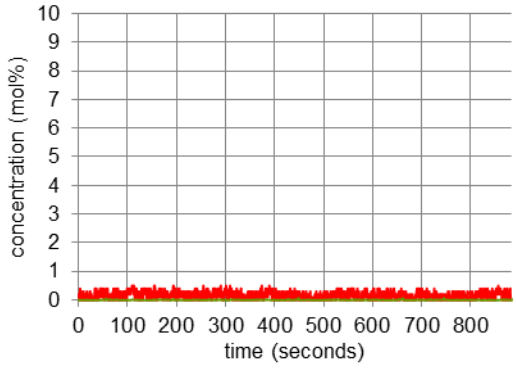


Gas Concentration at x=250m, y=-39m, z=0.078m

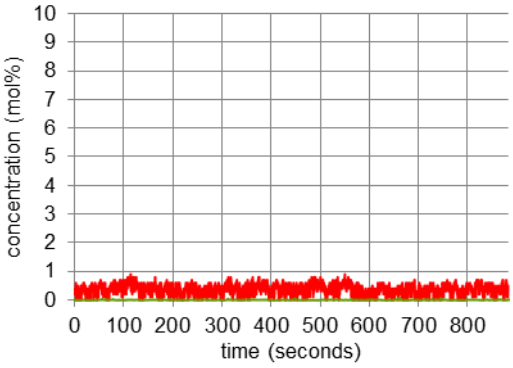


Gas Concentration at x=250m, y=-47m, z=0.078m

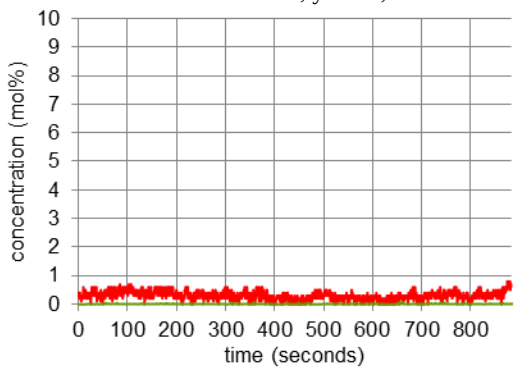
TNO FLS (continued)



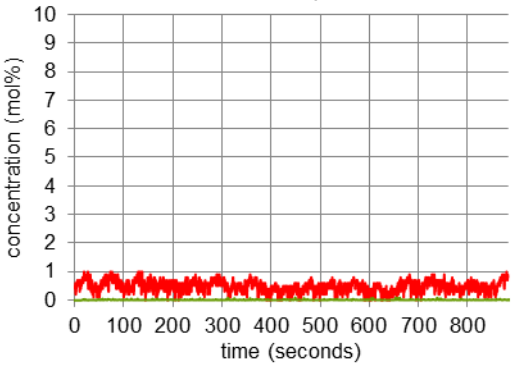
Gas Concentration at x=300m, y=55m, z=0.078m



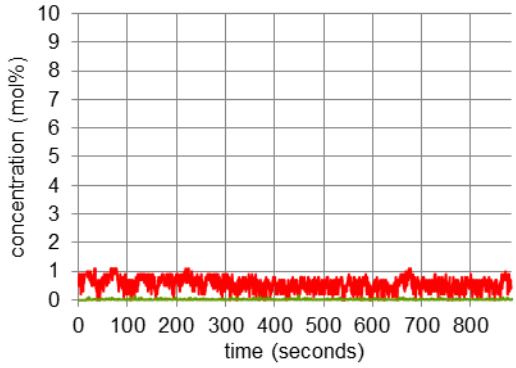
Gas Concentration at x=300m, y=47m, z=0.078m



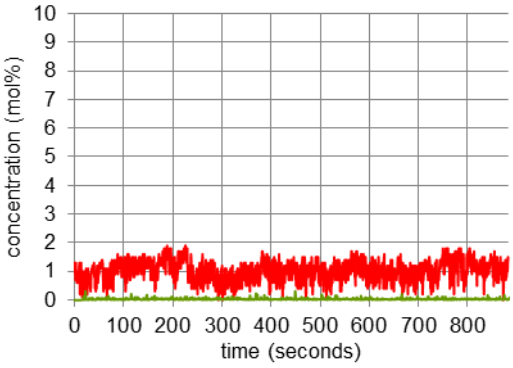
Gas Concentration at x=300m, y=39m, z=0.078m



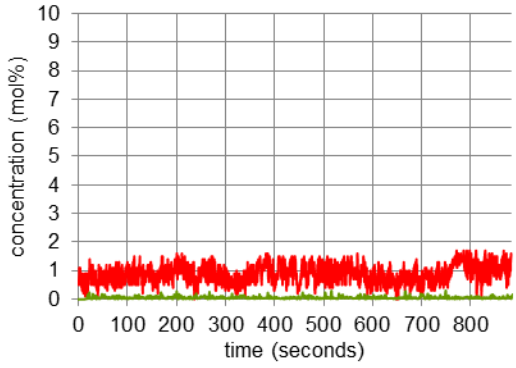
Gas Concentration at x=300m, y=31m, z=0.078m



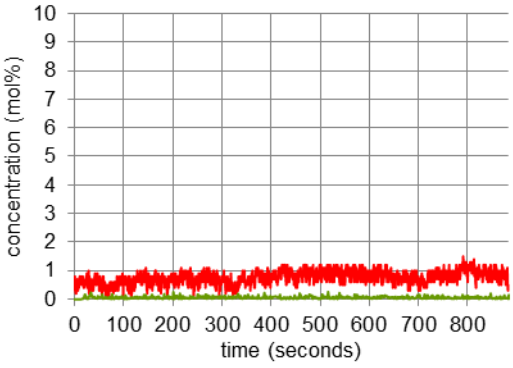
Gas Concentration at x=300m, y=23m, z=0.078m



Gas Concentration at x=300m, y=16m, z=0.078m

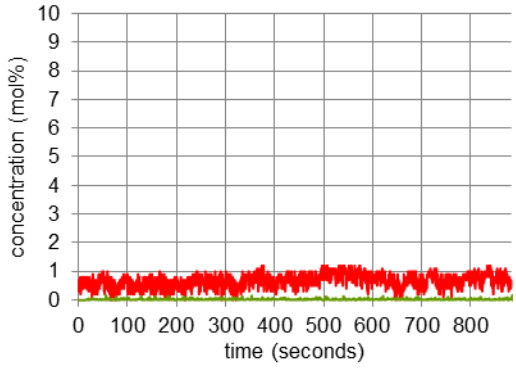


Gas Concentration at x=300m, y=7.8m, z=0.078m

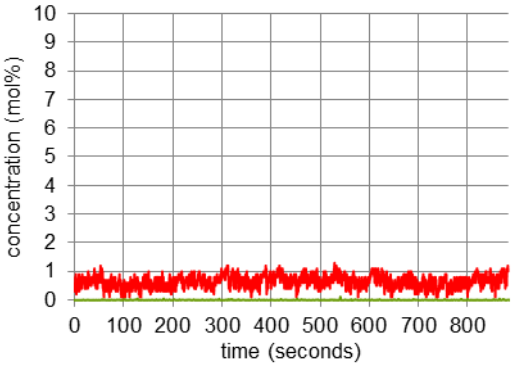


Gas Concentration at x=300m, y=0m, z=0.078m

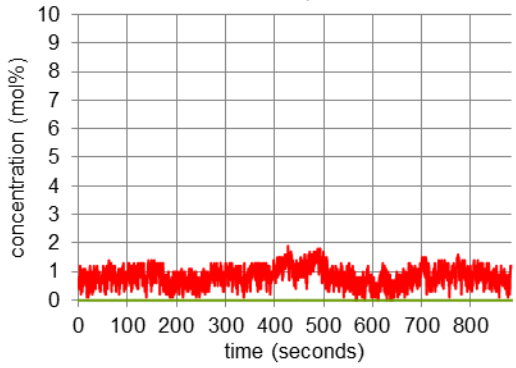
TNO FLS (continued)



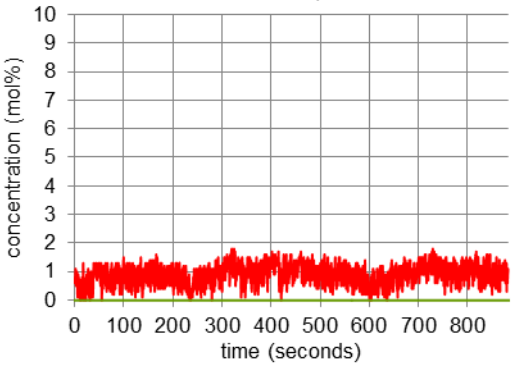
Gas Concentration at x=300m, y=-7.8m, z=0.078m



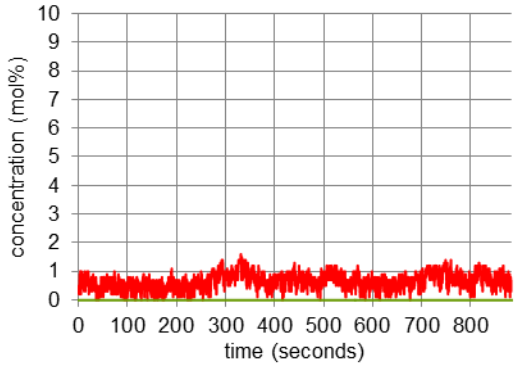
Gas Concentration at x=300m, y=-16m, z=0.078m



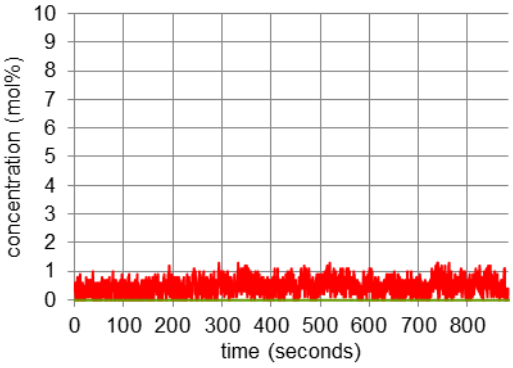
Gas Concentration at x=300m, y=-23m, z=0.078m



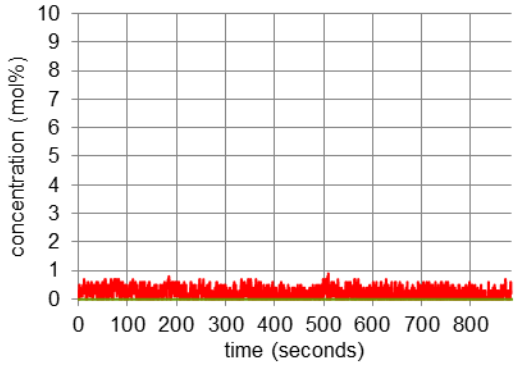
Gas Concentration at x=300m, y=-31m, z=0.078m



Gas Concentration at x=300m, y=-39m, z=0.078m



Gas Concentration at x=300m, y=-47m, z=0.078m



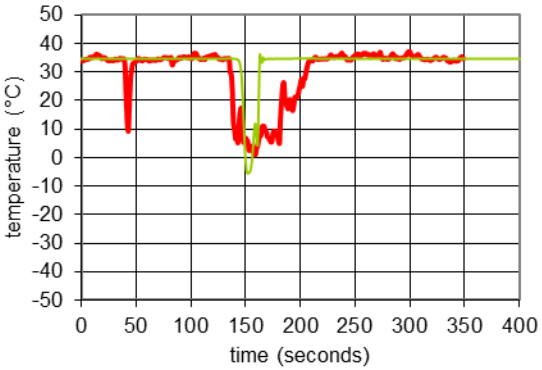
Gas Concentration at x=300m, y=-55m, z=0.078m

Appendix E

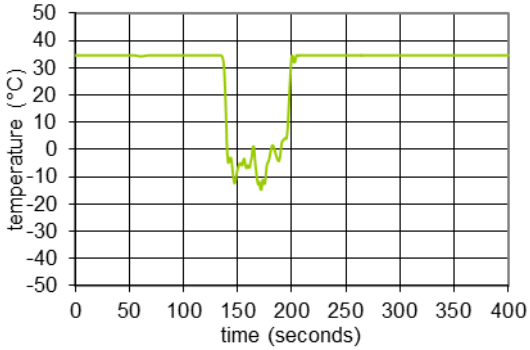
Point-Wise Temperatures

(red lines: experimental data; green lines: FDS data)

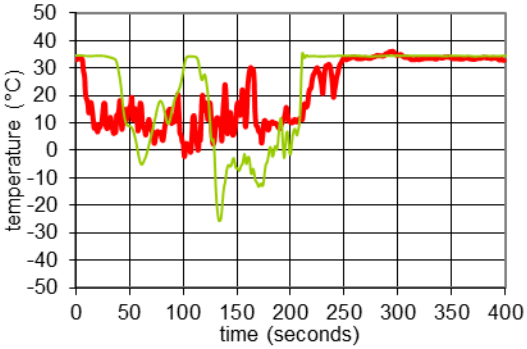
Burro 3



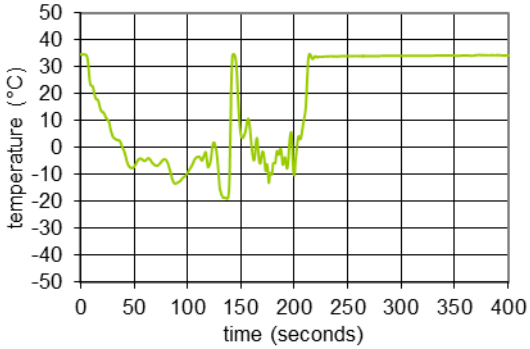
Temperature at x=40m, y=-41m, z=1m



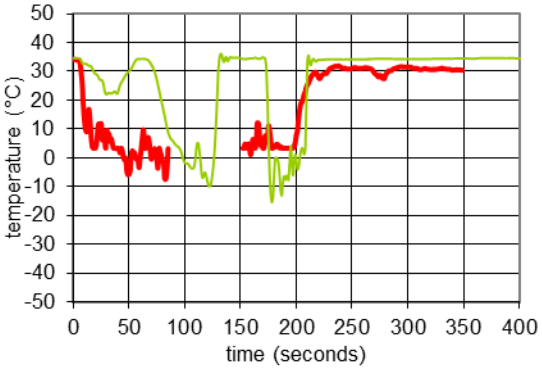
Temperature at x=49m, y=-29m, z=1m



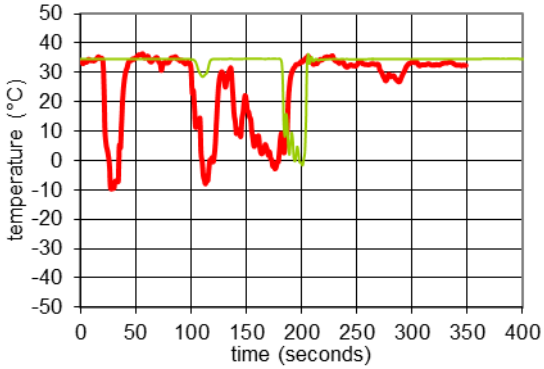
Temperature at x=56m, y=-15m, z=1m



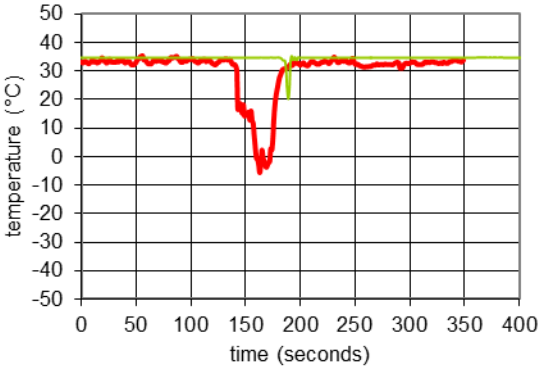
Temperature at x=57m, y=0m, z=1m



Temperature at x=56m, y=15m, z=1m

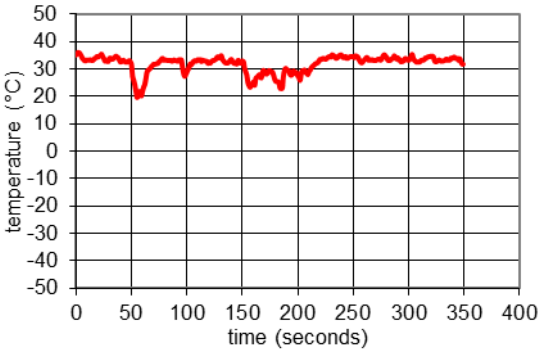


Temperature at x=49m, y=29m, z=1m

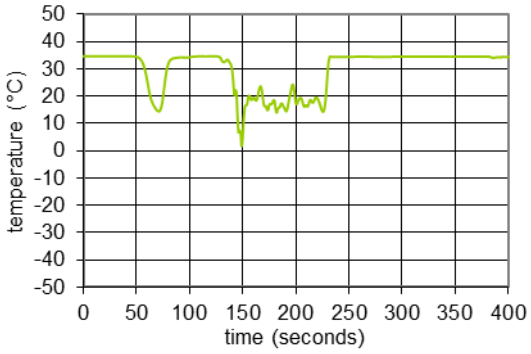


Temperature at x=37m, y=38m, z=1m

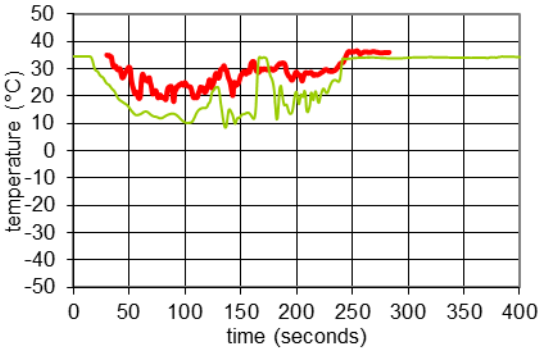
Burro 3 (continued)



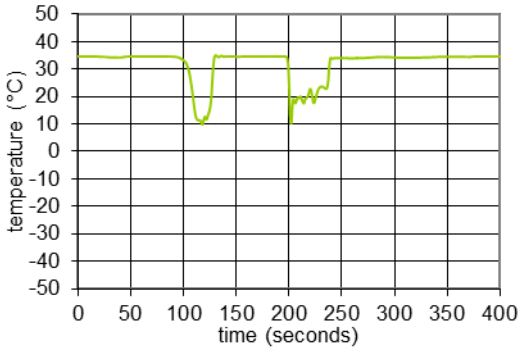
Temperature at x=127m, y=-58m, z=1m



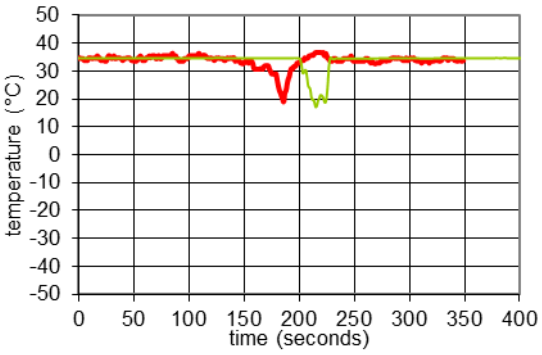
Temperature at x=137m, y=-30m, z=1m



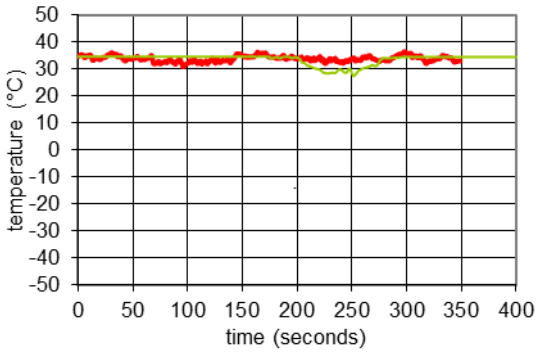
Temperature at x=140m, y=0m, z=1m



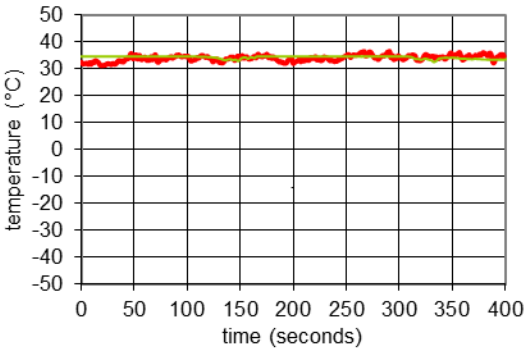
Temperature at x=137m, y=30m, z=1m



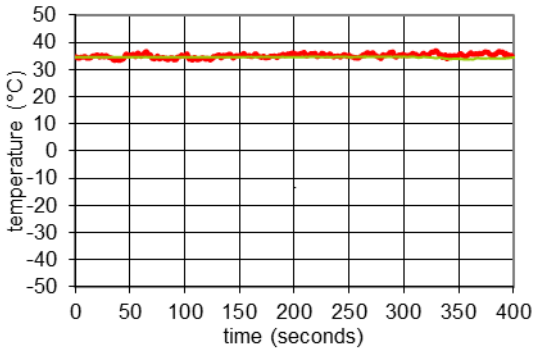
Temperature at x=127m, y=-58m, z=1m



Temperature at x=396m, y=-60m, z=1m

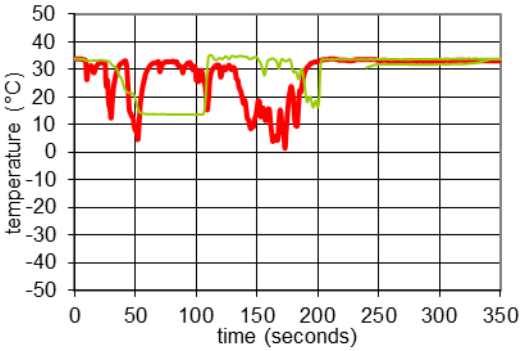


Temperature at x=796m, y=80m, z=1m

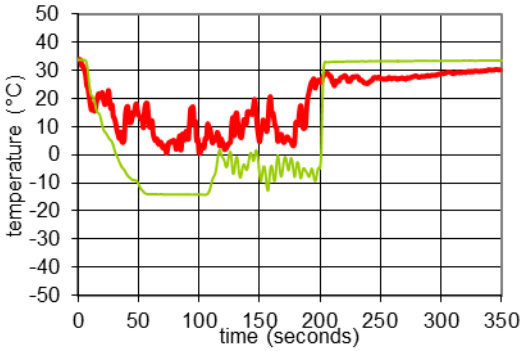


Temperature at x=784m, y=159m, z=1m

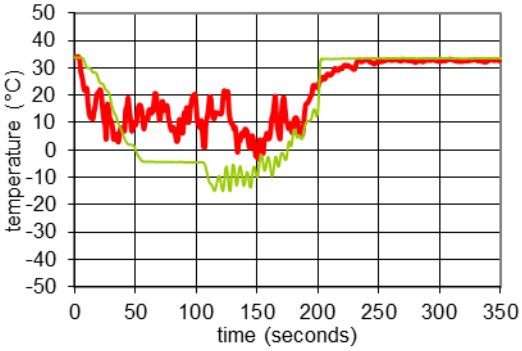
Burro 7



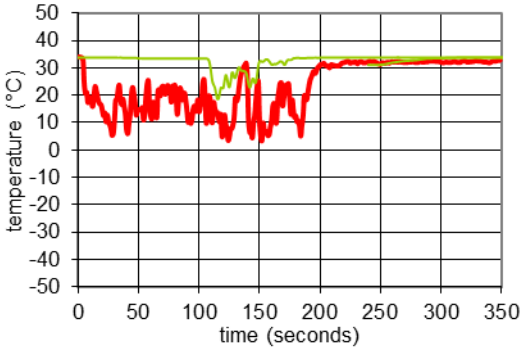
Temperature at x=57m, y=0m, z=1m



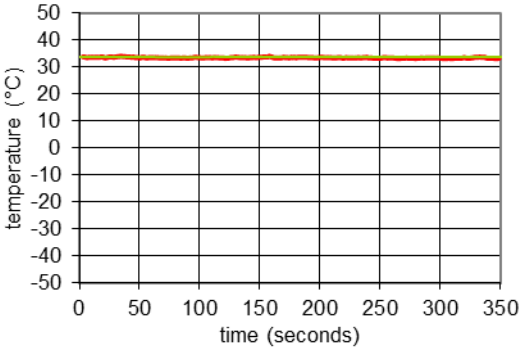
Temperature at x=56m, y=15m, z=1m



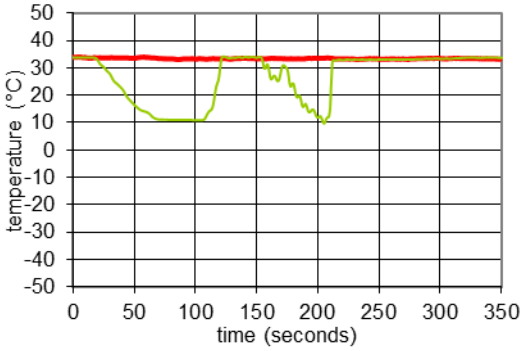
Temperature at x=49m, y=29m, z=1m



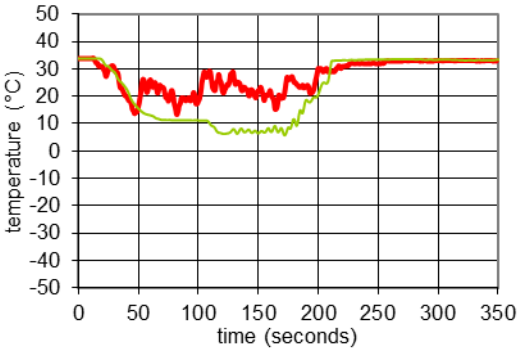
Temperature at x=37m, y=38m, z=1m



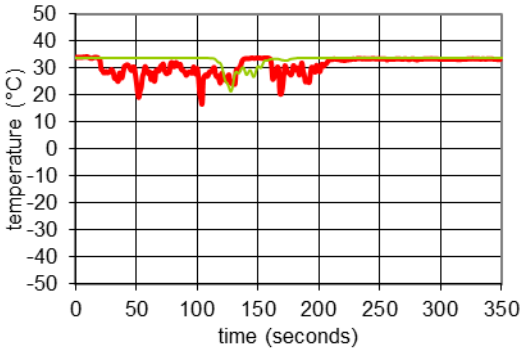
Temperature at x=140m, y=0m, z=1m



Temperature at x=137m, y=30m, z=1m

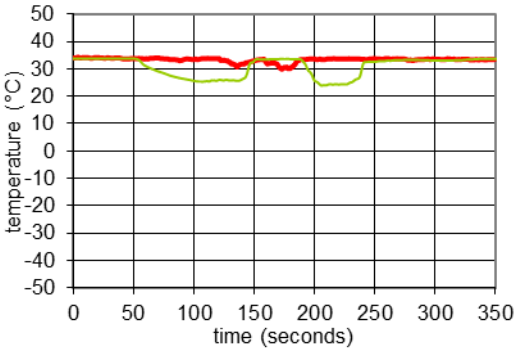


Temperature at x=127m, y=58m, z=1m

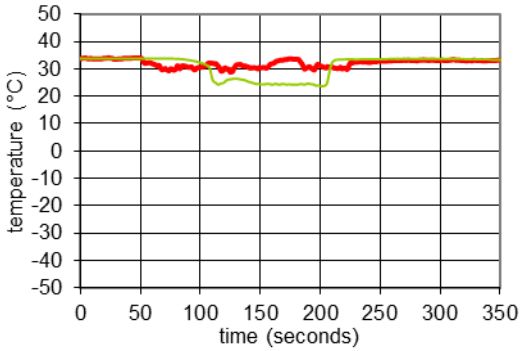


Temperature at x=112m, y=84m, z=1m

Burro 7 (continued)

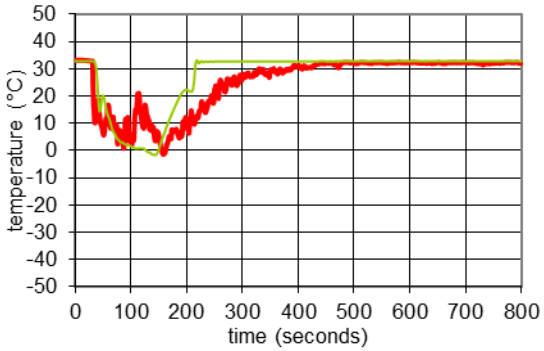


Temperature at x=382m, y=118m, z=1m

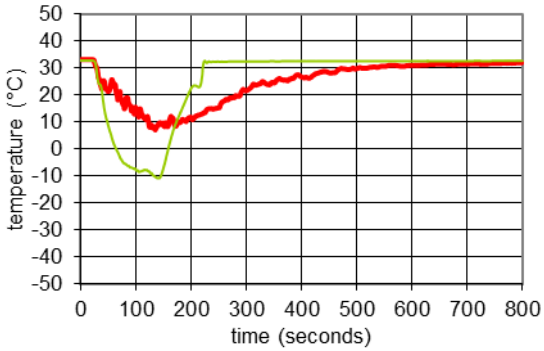


Temperature at x=360m, y=174m, z=1m

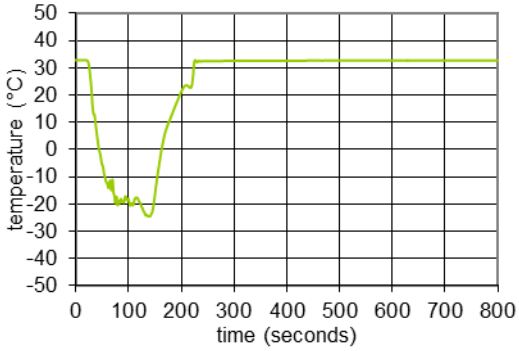
Burro 8



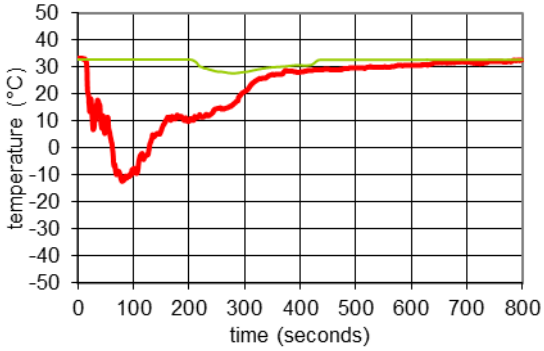
Temperature at x=40m, y=-41m, z=1m



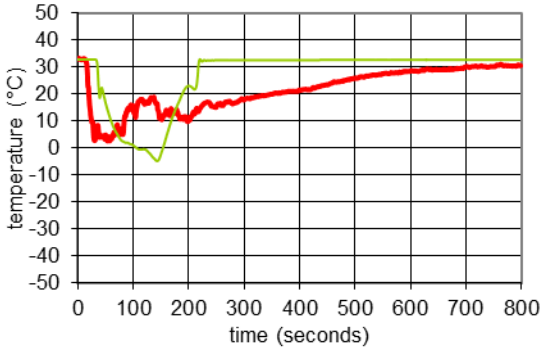
Temperature at x=49m, y=-29m, z=1m



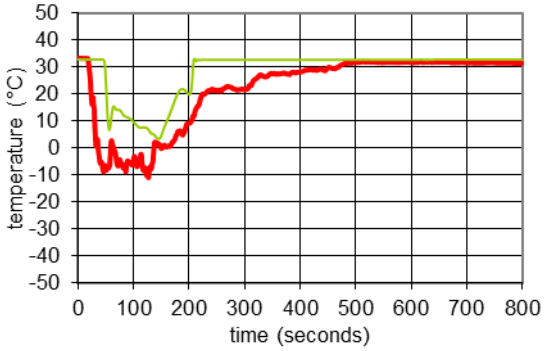
Temperature at x=56m, y=-15m, z=1m



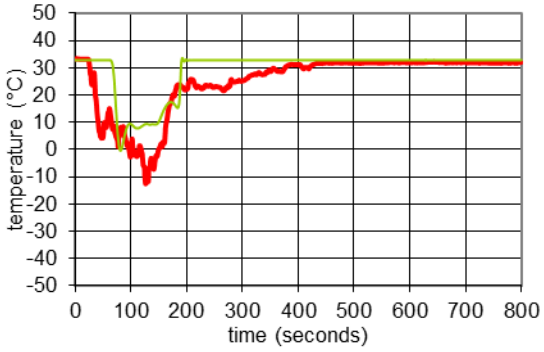
Temperature at x=57m, y=0m, z=1m



Temperature at x=56m, y=15m, z=1m

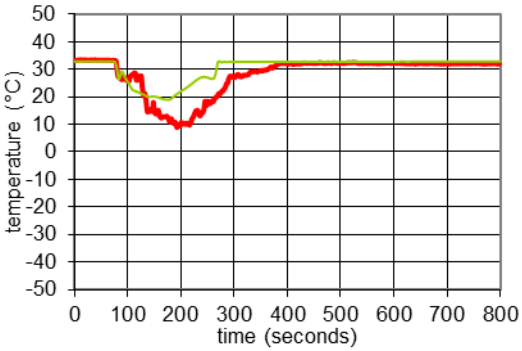


Temperature at x=49m, y=29m, z=1m

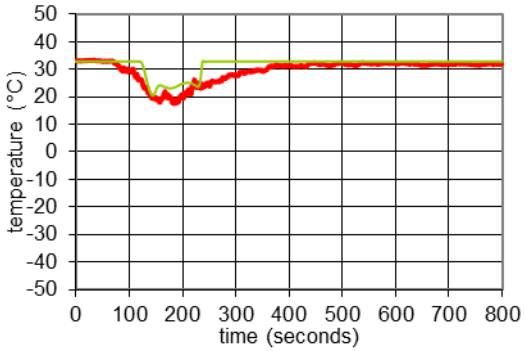


Temperature at x=37m, y=38m, z=1m

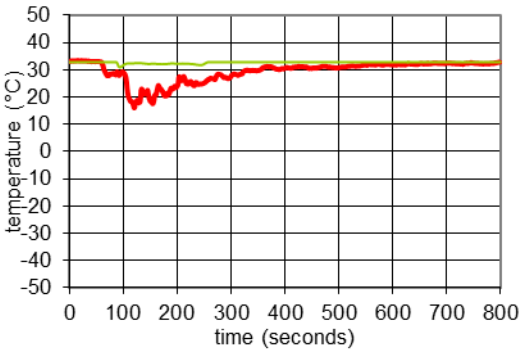
Burro 8 (continued)



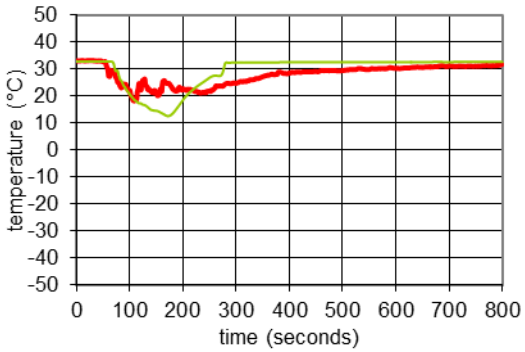
Temperature at x=112m, y=-84m, z=1m



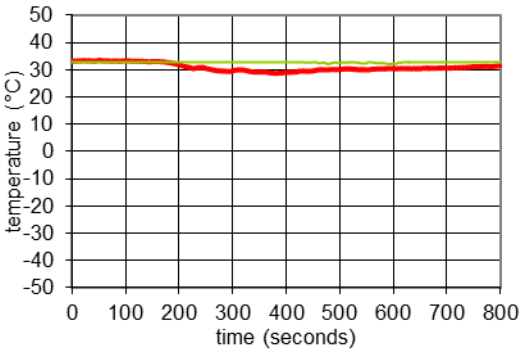
Temperature at x=127m, y=-58m, z=1m



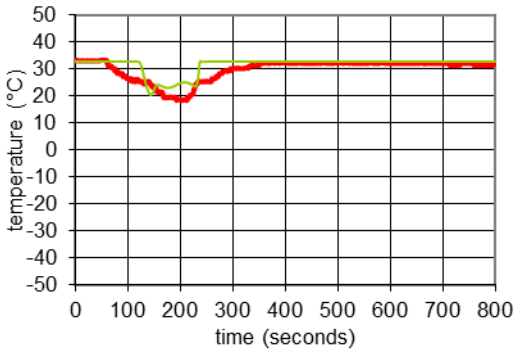
Temperature at x=137m, y=-30m, z=1m



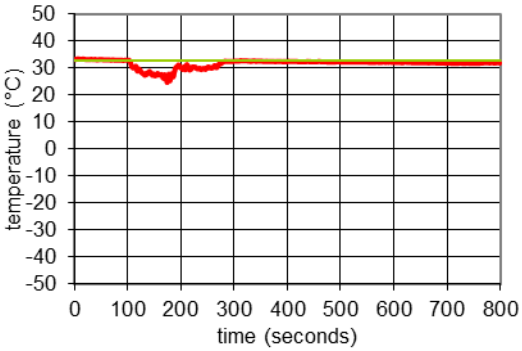
Temperature at x=140m, y=0m, z=1m



Temperature at x=137m, y=-30m, z=1m

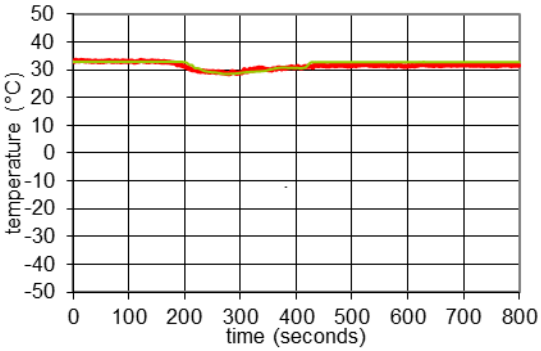


Temperature at x=127m, y=58m, z=1m

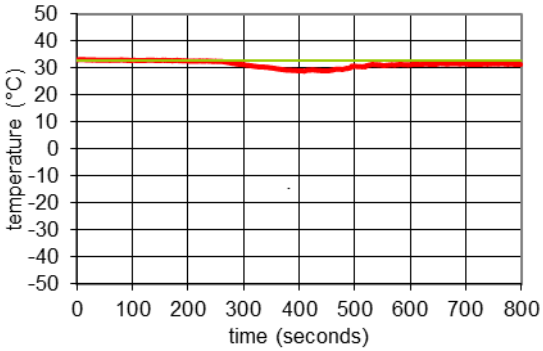


Temperature at x=112m, y=84m, z=1m

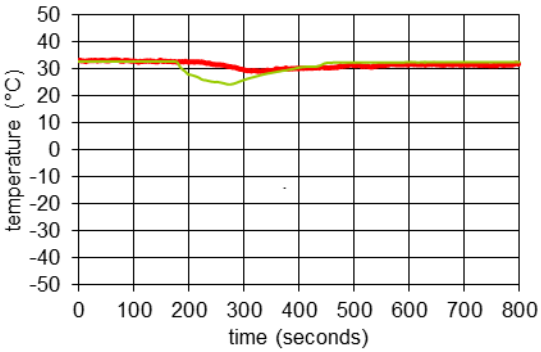
Burro 8 (continued)



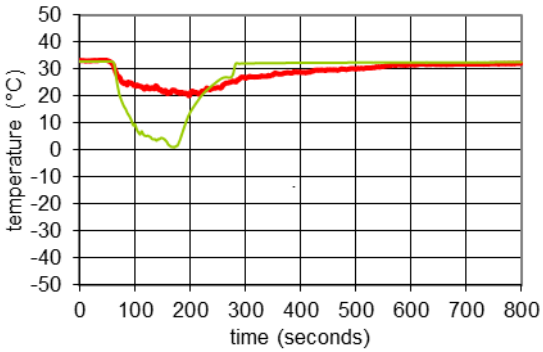
Temperature at x=360m, y=-174m, z=1m



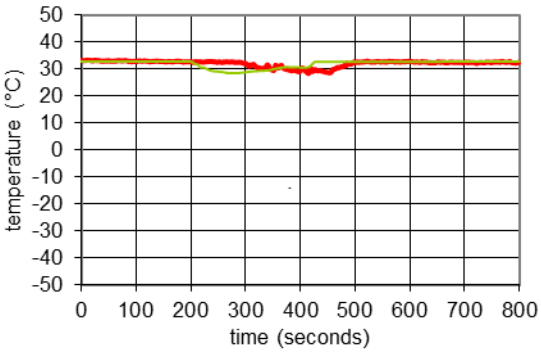
Temperature at x=382m, y=-118m, z=1m



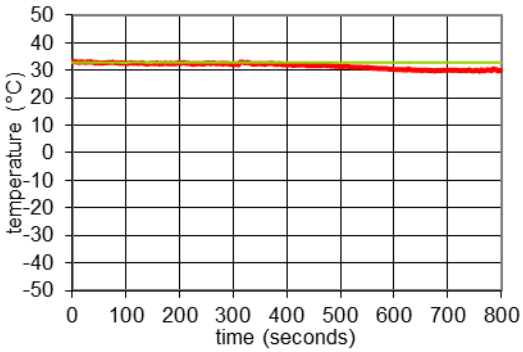
Temperature at x=396m, y=-60m, z=1m



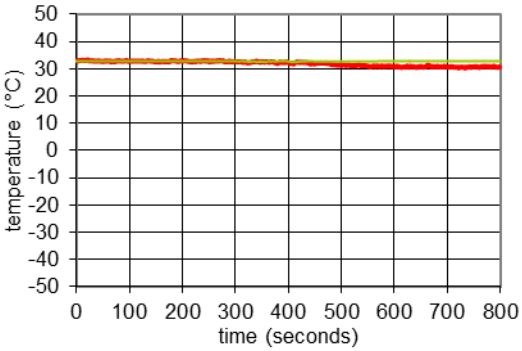
Temperature at x=400m, y=0m, z=1m



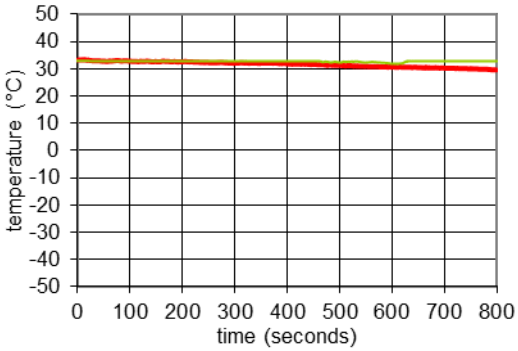
Temperature at x=396m, y=60m, z=1m



Temperature at x=784m, y=-159m, z=1m

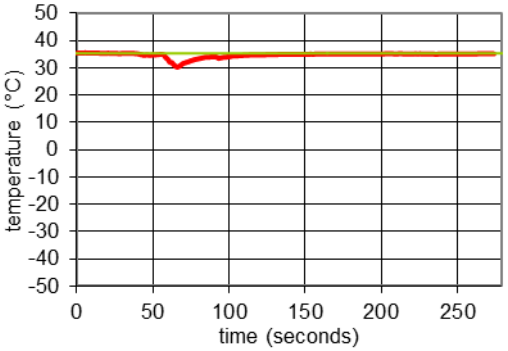


Temperature at x=796m, y=-80m, z=1m

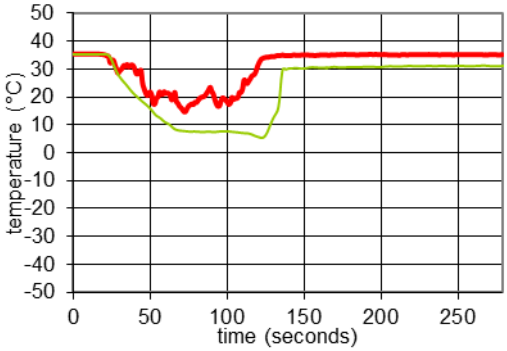


Temperature at x=800m, y=0m, z=1m

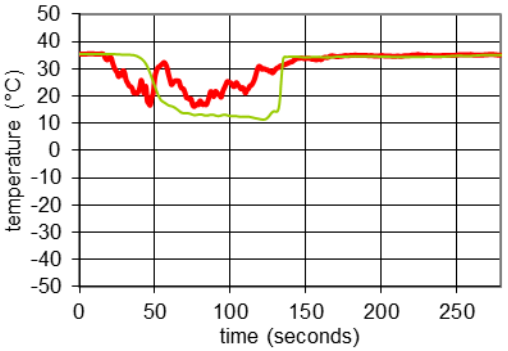
Burro 9



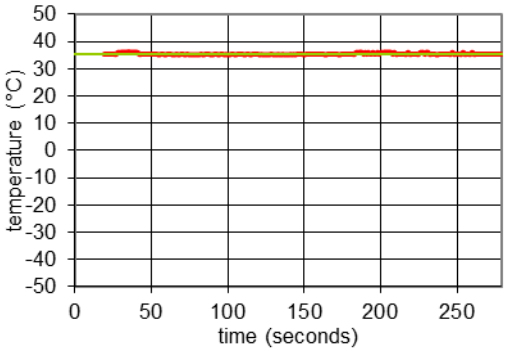
Temperature at x=127m, y=-58m, z=1m



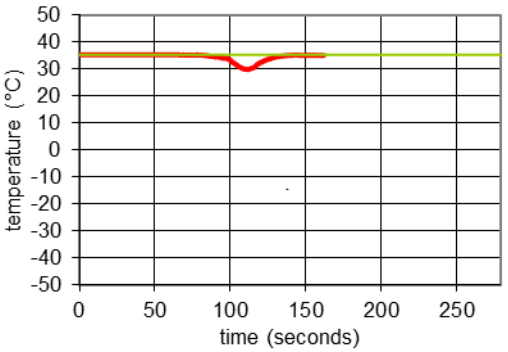
Temperature at x=137m, y=-30m, z=1m



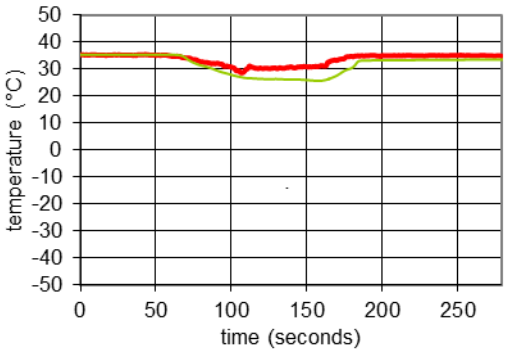
Temperature at x=140m, y=0m, z=1m



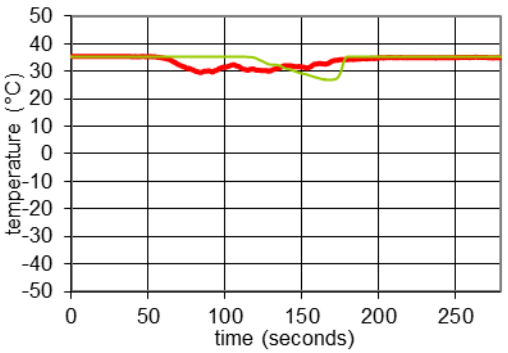
Temperature at x=127m, y=58m, z=1m



Temperature at x=382m, y=-118m, z=1m

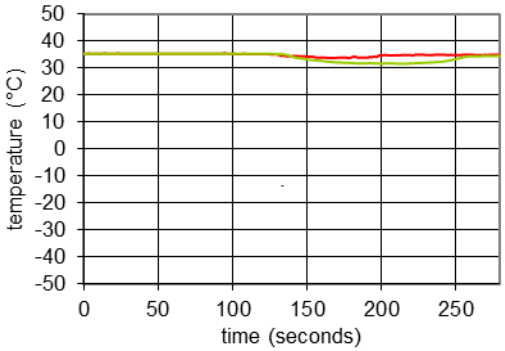


Temperature at x=396m, y=-60m, z=1m

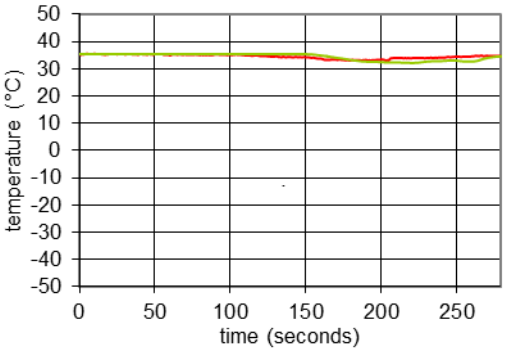


Temperature at x=400m, y=0m, z=1m

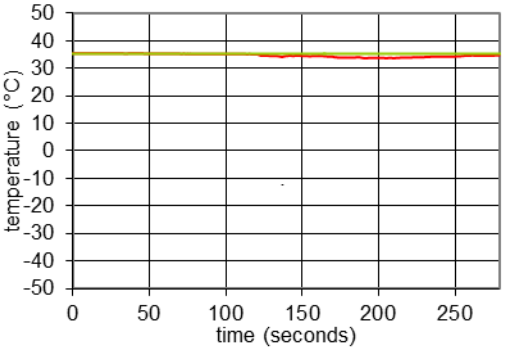
Burro 9 (continued)



Temperature at x=784m, y=-159m, z=1m

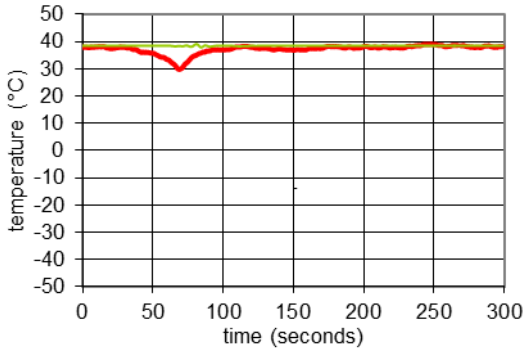


Temperature at x=796m, y=-80m, z=1m

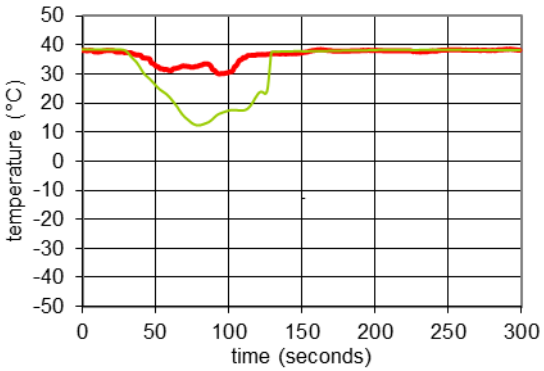


Temperature at x=800m, y=0m, z=1m

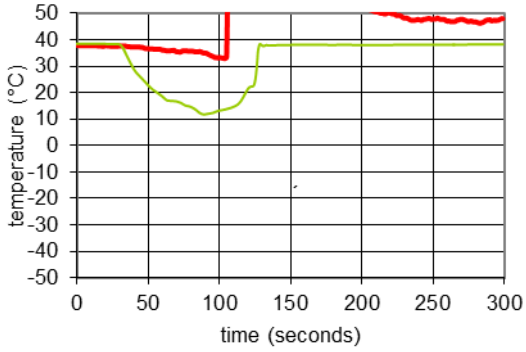
Coyote 3



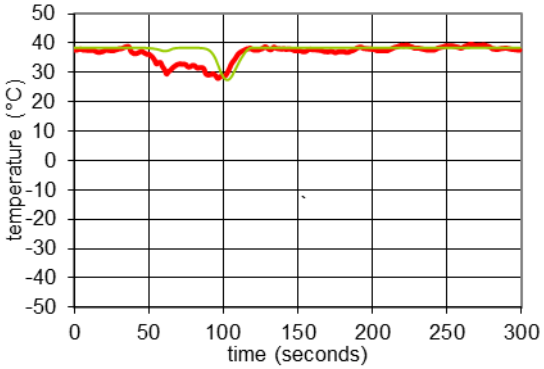
Temperature at x=140m, y=0m, z=1m



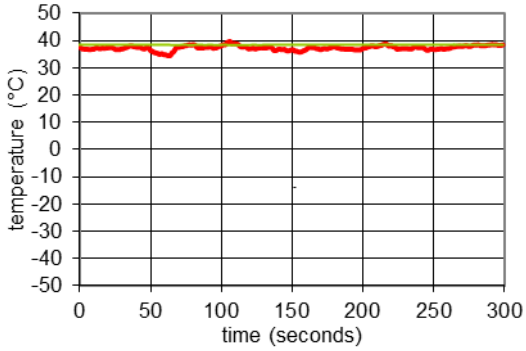
Temperature at x=137m, y=30m, z=1m



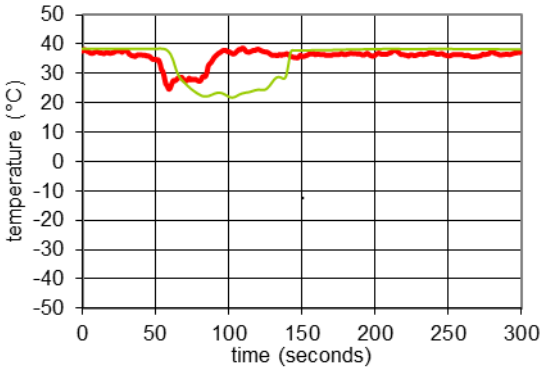
Temperature at x=127m, y=58m, z=1m



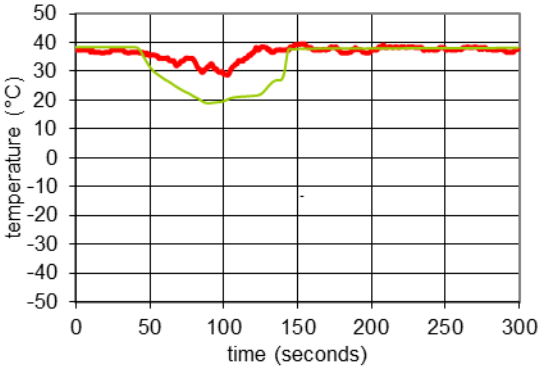
Temperature at x=112m, y=84m, z=1m



Temperature at x=200m, y=0m, z=1m

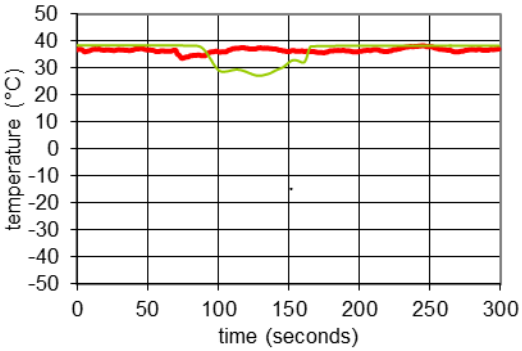


Temperature at x=197m, y=37m, z=1m

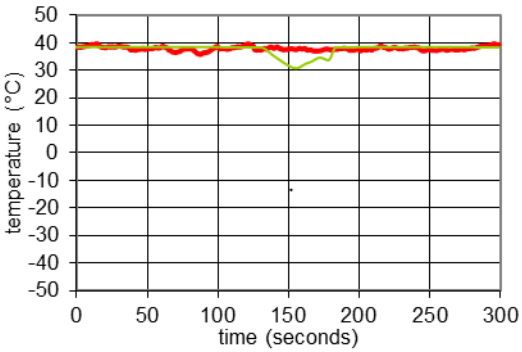


Temperature at x=187m, y=72m, z=1m

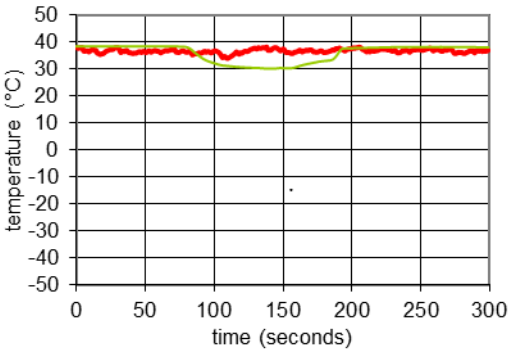
Coyote 3 (continued)



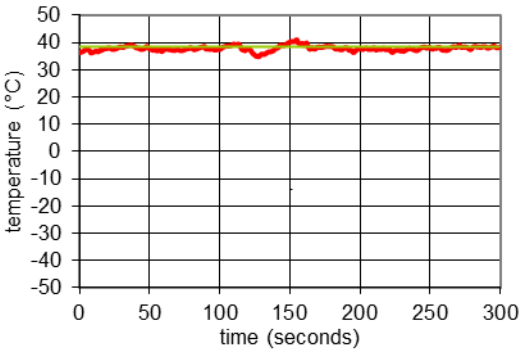
Temperature at x=296m, y=48m, z=1m



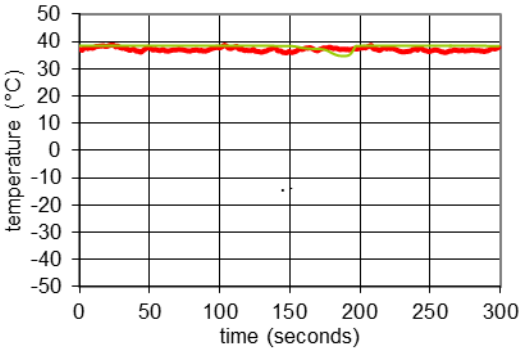
Temperature at x=396m, y=60m, z=1m



Temperature at x=382m, y=118m, z=1m

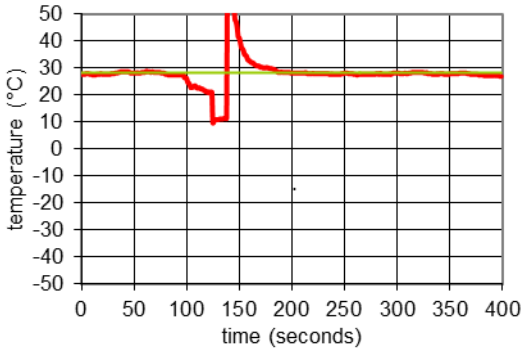


Temperature at x=330m, y=226m, z=1m

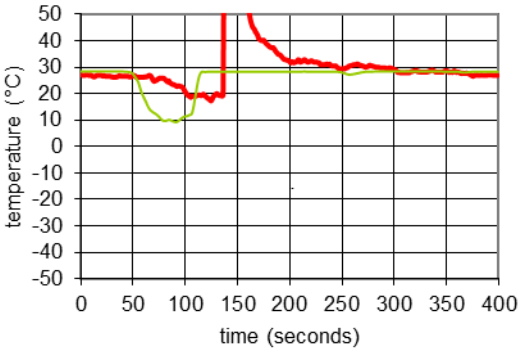


Temperature at x=495m, y=71m, z=1m

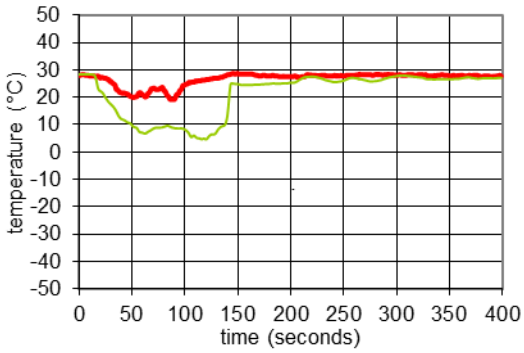
Coyote 5



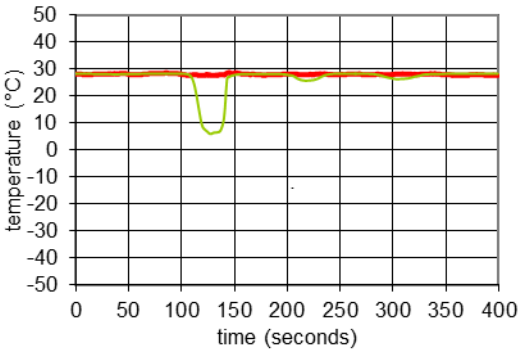
Temperature at x=137m, y=-30m, z=1m



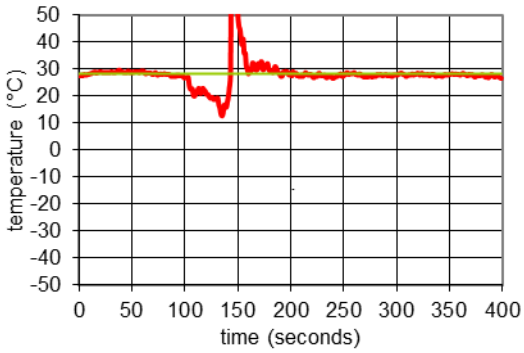
Temperature at x=140m, y=0m, z=1m



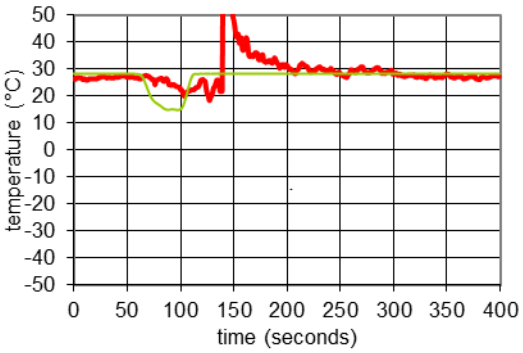
Temperature at x=137m, y=30m, z=1m



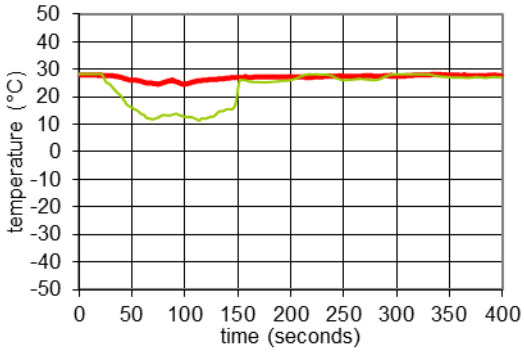
Temperature at x=127m, y=58m, z=1m



Temperature at x=197m, y=-37m, z=1m

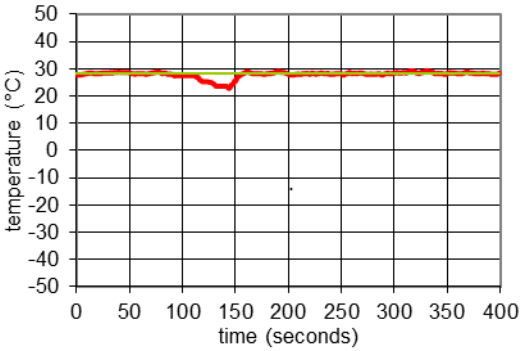


Temperature at x=200m, y=0m, z=1m

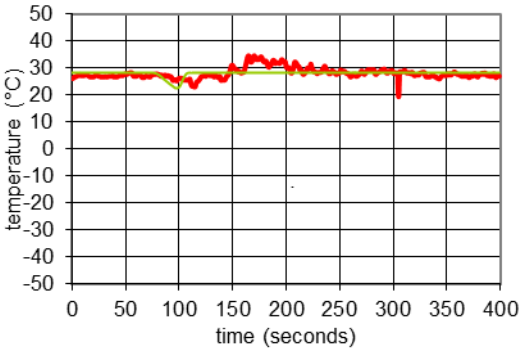


Temperature at x=197m, y=37m, z=1m

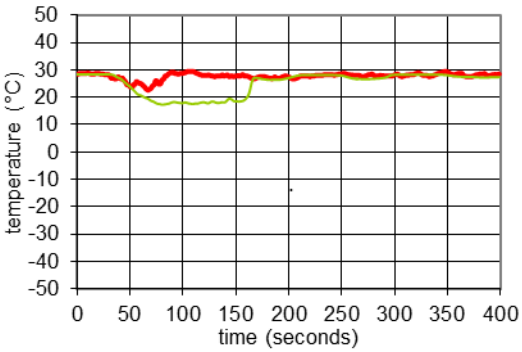
Coyote 5 (continued)



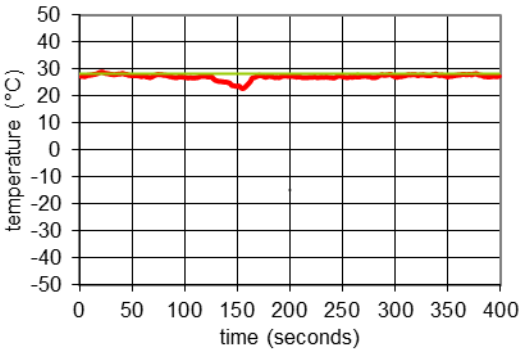
Temperature at x=296m, y=-48m, z=1m



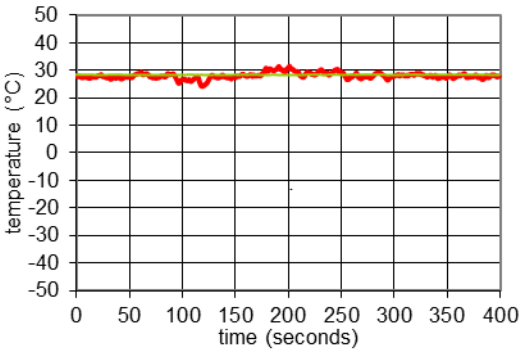
Temperature at x=300m, y=0m, z=1m



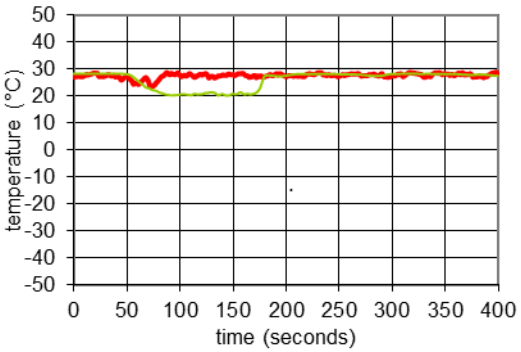
Temperature at x=296m, y=48m, z=1m



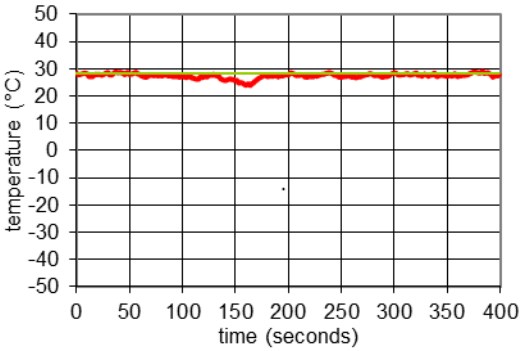
Temperature at x=396m, y=-60m, z=1m



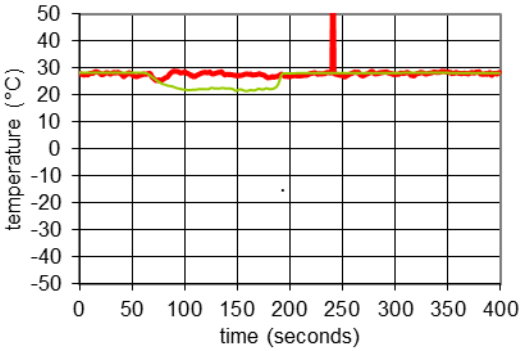
Temperature at x=400m, y=0m, z=1m



Temperature at x=396m, y=60m, z=1m

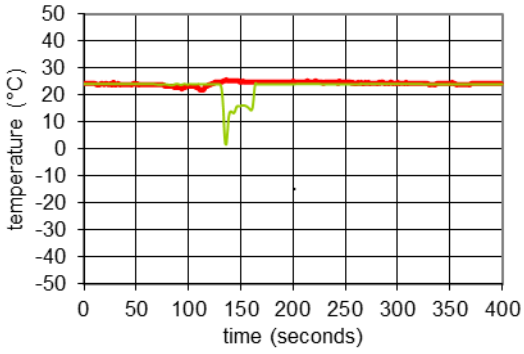


Temperature at x=495m, y=-71m, z=1m

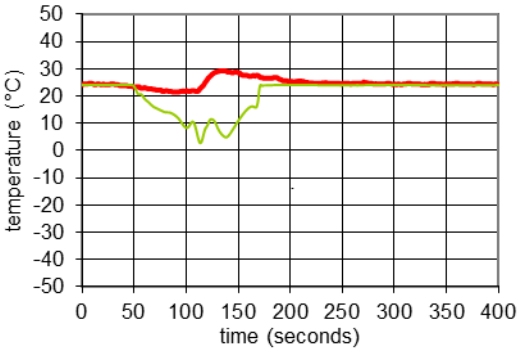


Temperature at x=495m, y=71m, z=1m

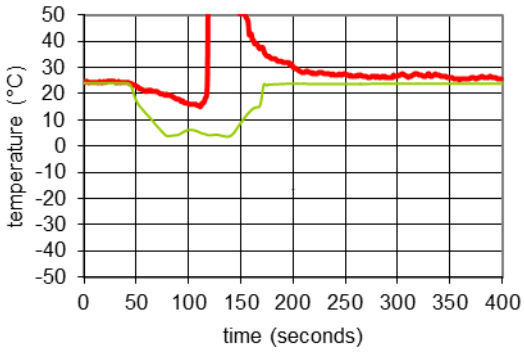
Coyote 6



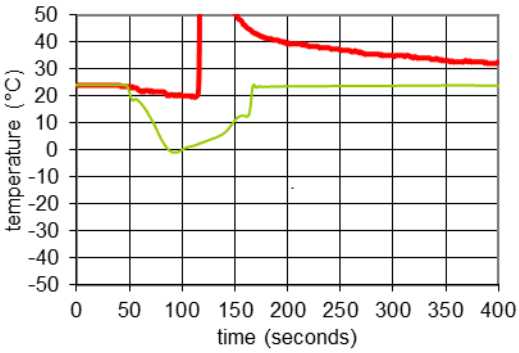
Temperature at x=137m, y=-30m, z=1m



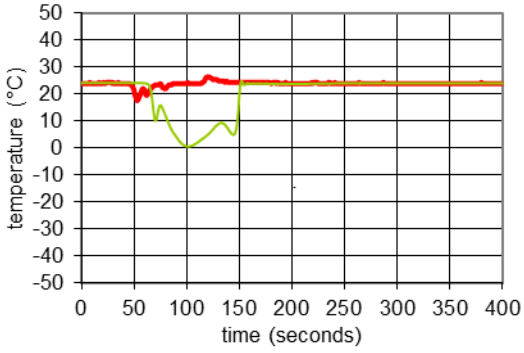
Temperature at x=140m, y=0m, z=1m



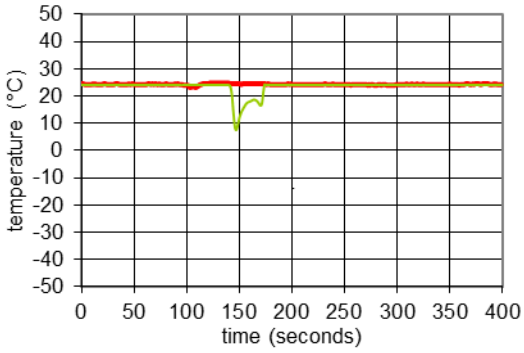
Temperature at x=137m, y=30m, z=1m



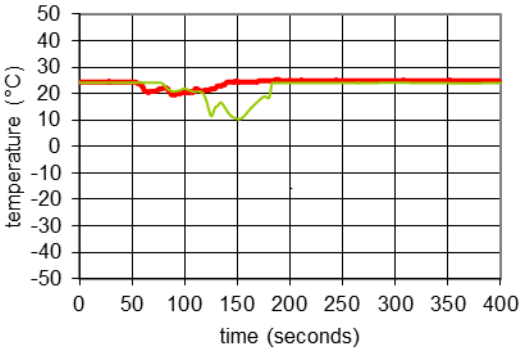
Temperature at x=127m, y=58m, z=1m



Temperature at x=112m, y=84m, z=1m

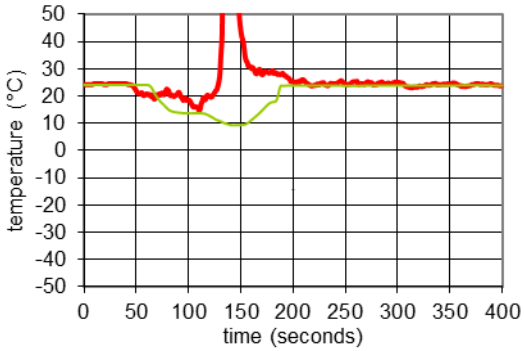


Temperature at x=197m, y=-37m, z=1m

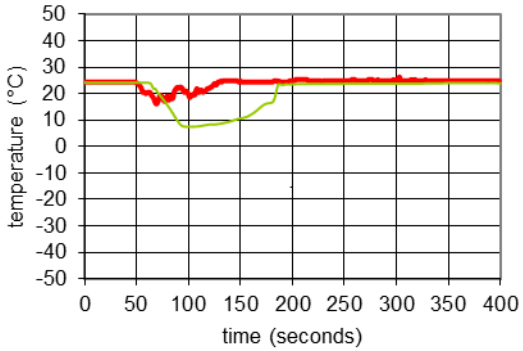


Temperature at x=200m, y=0m, z=1m

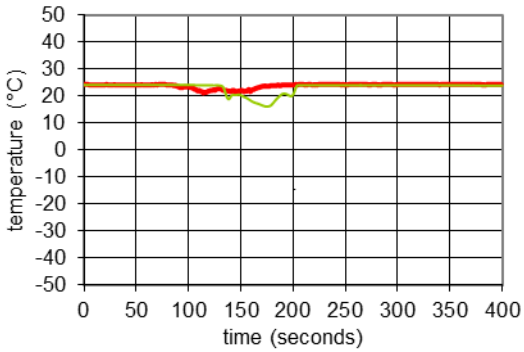
Coyote 6 (continued)



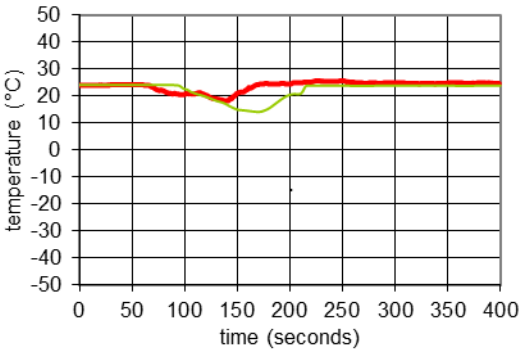
Temperature at x=197m, y=37m, z=1m



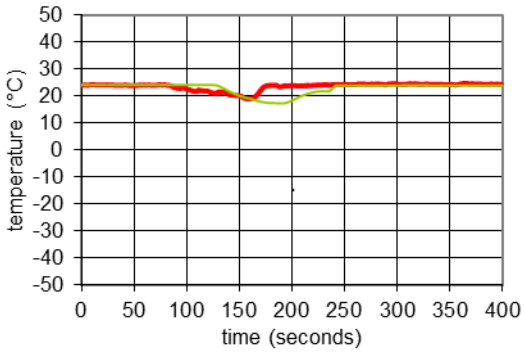
Temperature at x=187m, y=72m, z=1m



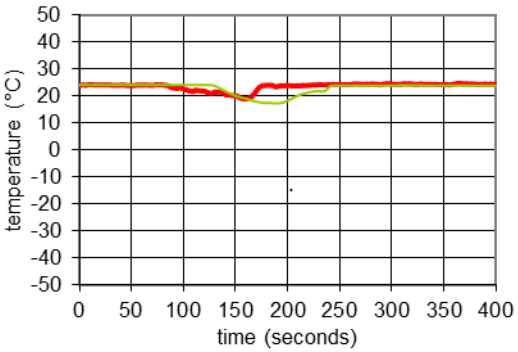
Temperature at x=300m, y=0m, z=1m



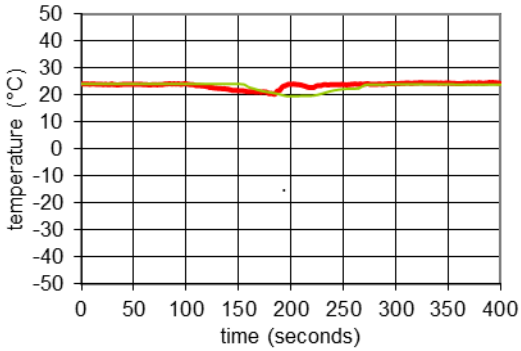
Temperature at x=296m, y=48m, z=1m



Temperature at x=400m, y=0m, z=1m

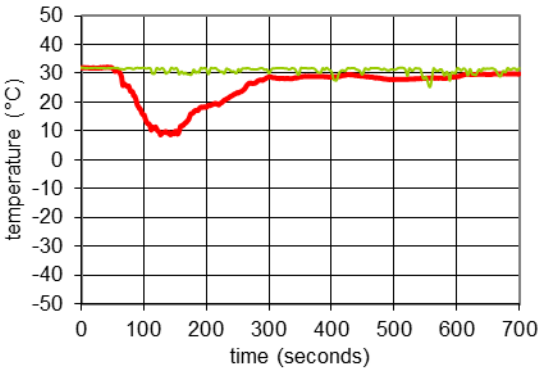


Temperature at x=396m, y=60m, z=1m

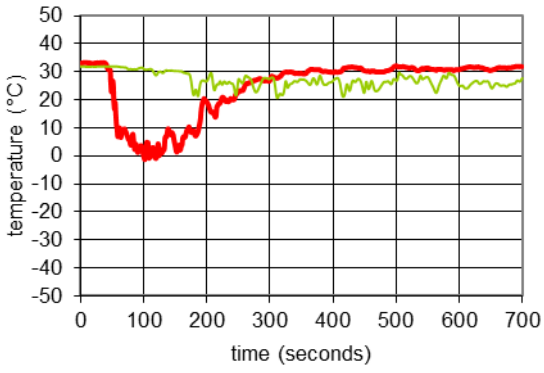


Temperature at x=495m, y=71m, z=1m

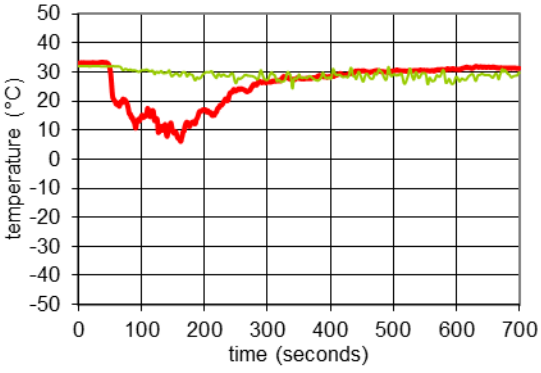
Falcon 1



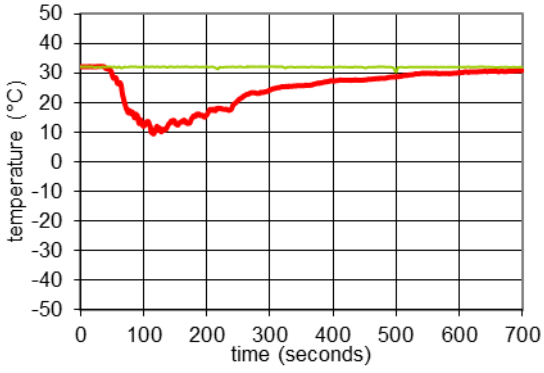
Temperature at x=50m, y=-66m, z=1m



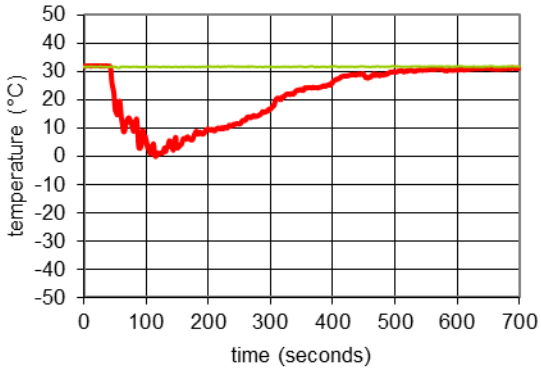
Temperature at x=50m, y=-22m, z=1m



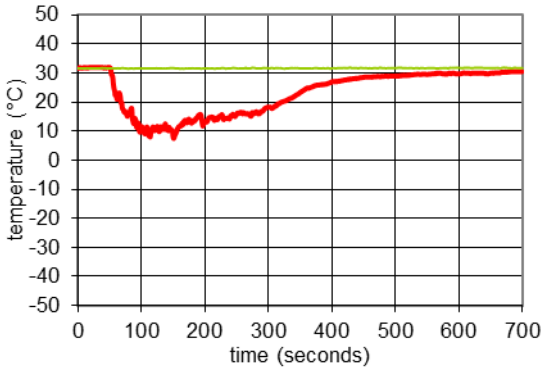
Temperature at x=50m, y=0m, z=1m



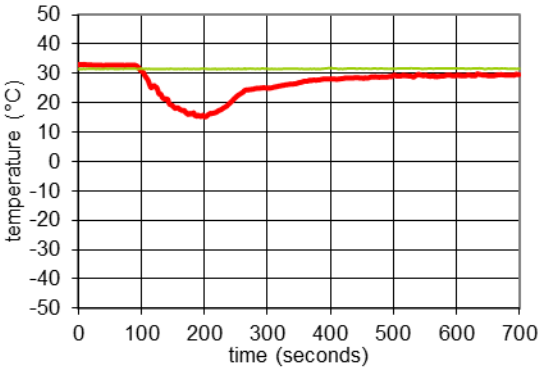
Temperature at x=50m, y=22m, z=1m



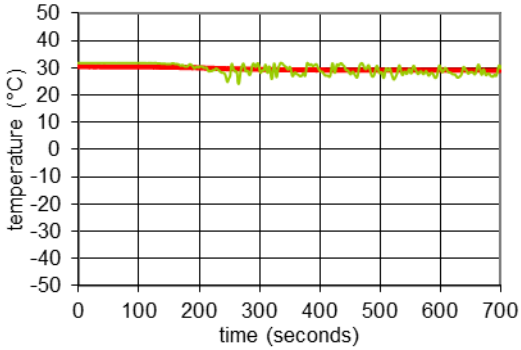
Temperature at x=50m, y=44m, z=1m



Temperature at x=50m, y=66m, z=1m

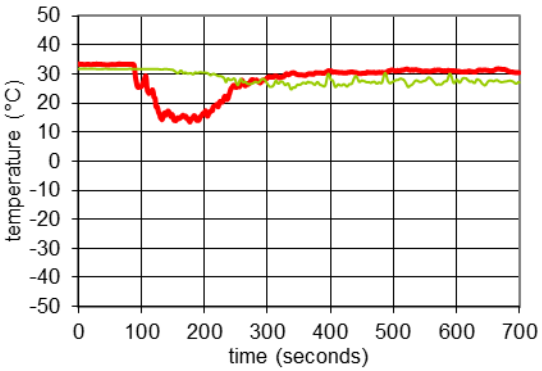


Temperature at x=150m, y=-75m, z=1m

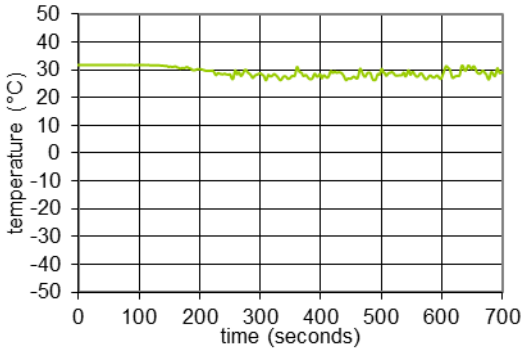


Temperature at x=150m, y=-50m, z=1m

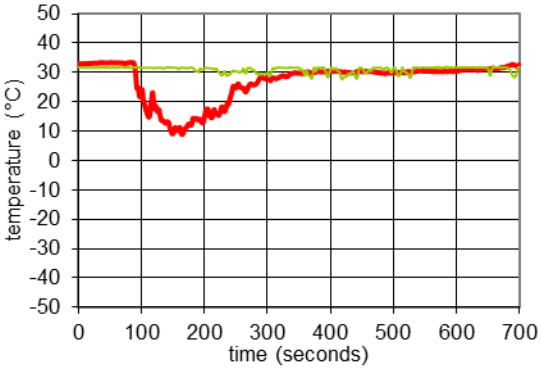
Falcon 1 (continued)



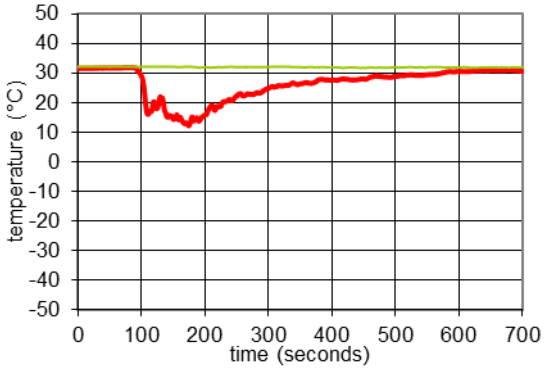
Temperature at x=150m, y=-25m, z=1m



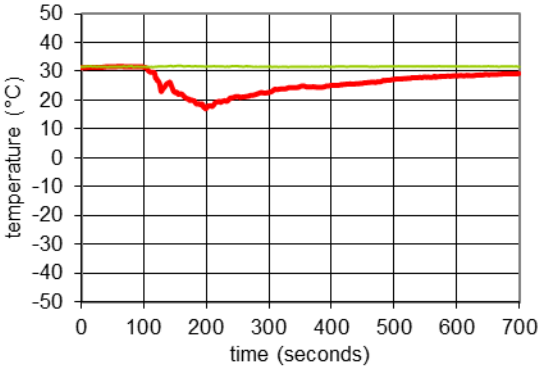
Temperature at x=150m, y=0m, z=1m



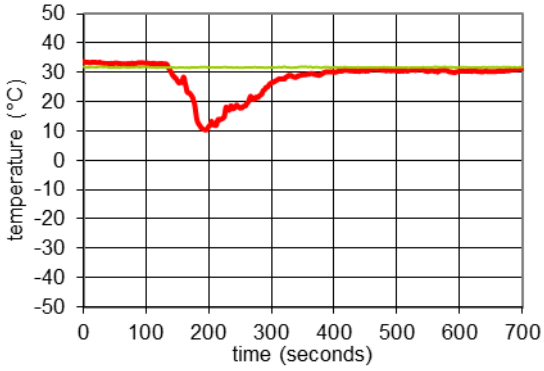
Temperature at x=150m, y=25m, z=1m



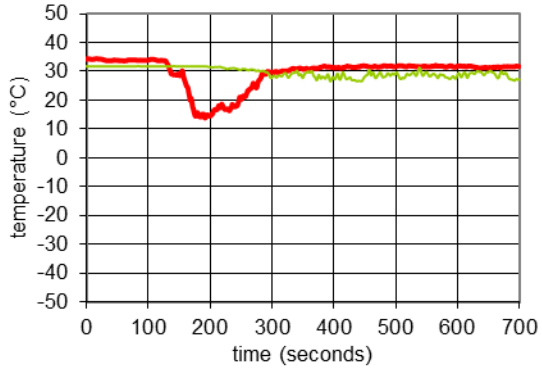
Temperature at x=150m, y=50m, z=1m



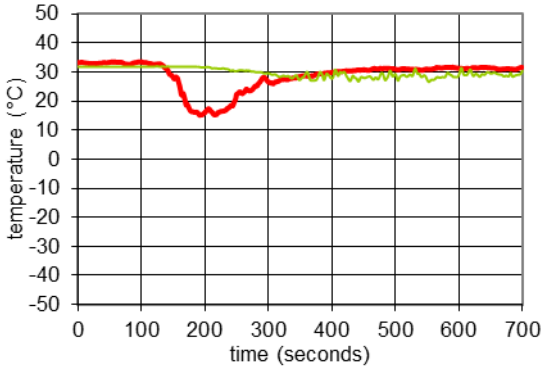
Temperature at x=150m, y=75m, z=1m



Temperature at x=250m, y=-84m, z=1m

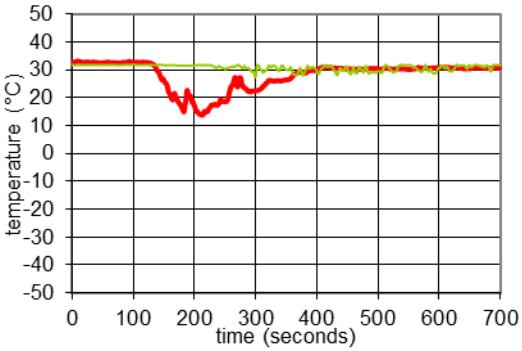


Temperature at x=250m, y=-56m, z=1m

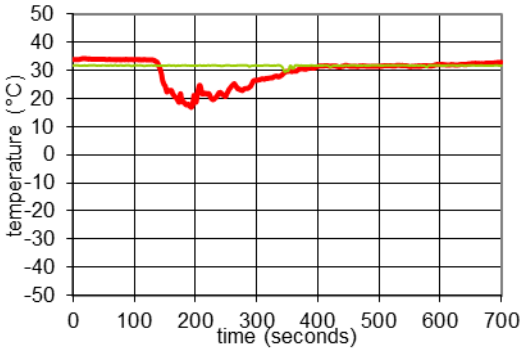


Temperature at x=250m, y=-28m, z=1m

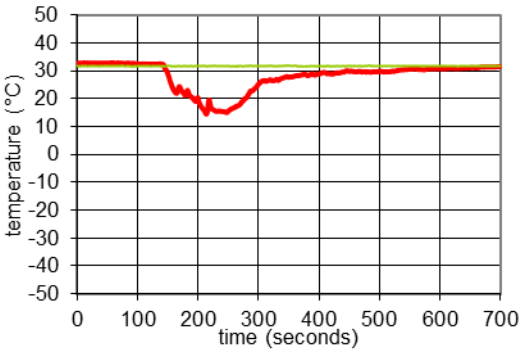
Falcon 1 (continued)



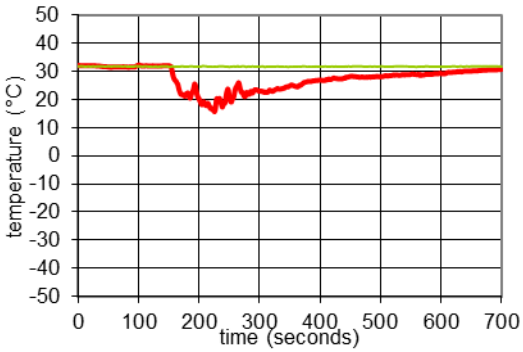
Temperature at x=250m, y=0m, z=1m



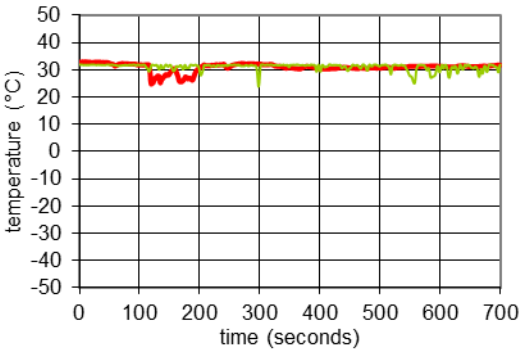
Temperature at x=250m, y=28m, z=1m



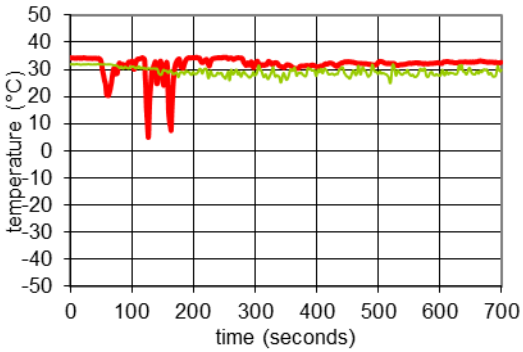
Temperature at x=250m, y=56m, z=1m



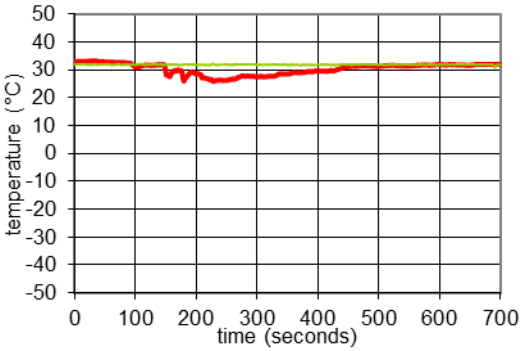
Temperature at x=250m, y=84m, z=1m



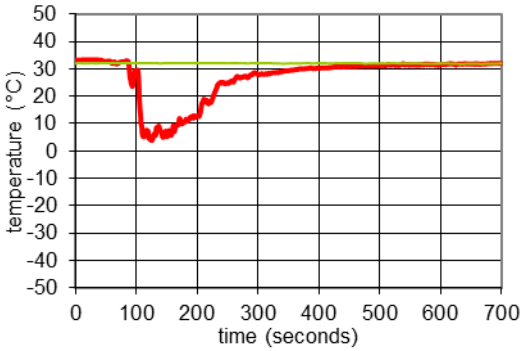
Temperature at x=50m, y=-66m, z=5m



Temperature at x=50m, y=0m, z=5m

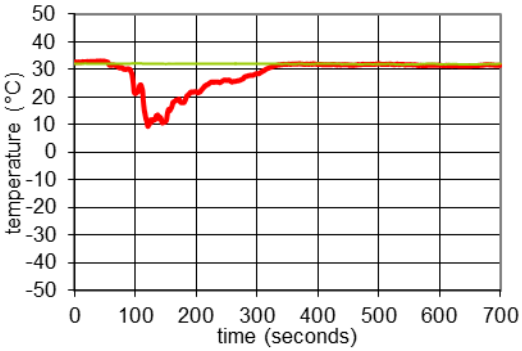


Temperature at x=50m, y=22m, z=5m

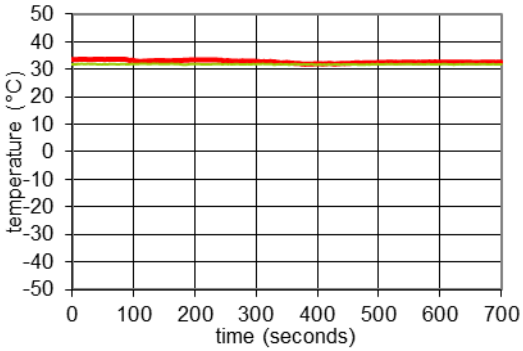


Temperature at x=50m, y=44m, z=5m

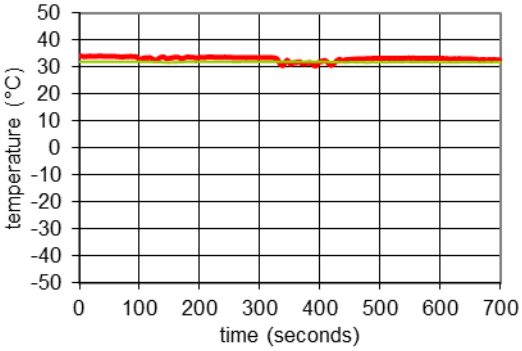
Falcon 1 (continued)



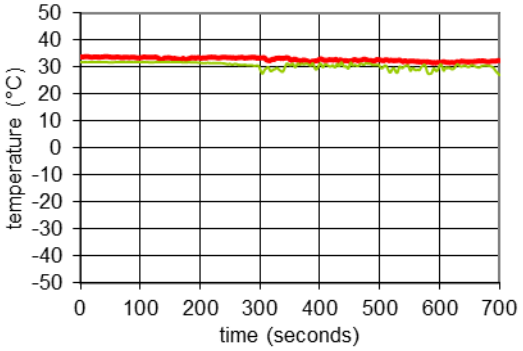
Temperature at x=50m, y=66m, z=5m



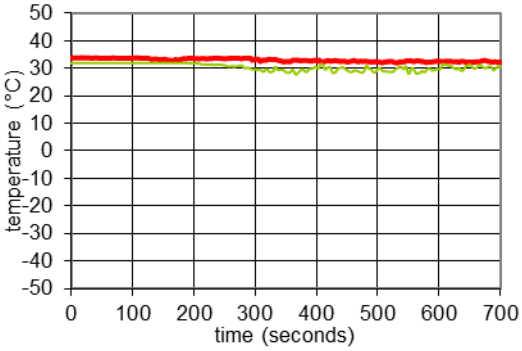
Temperature at x=150m, y=50m, z=5m



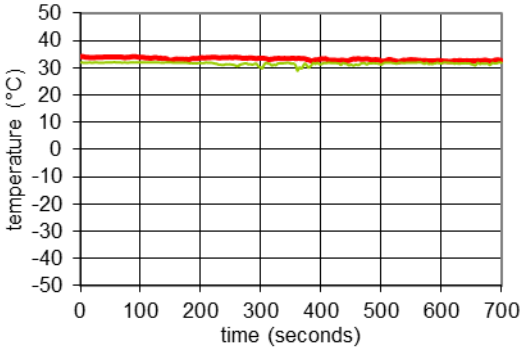
Temperature at x=150m, y=75m, z=5m



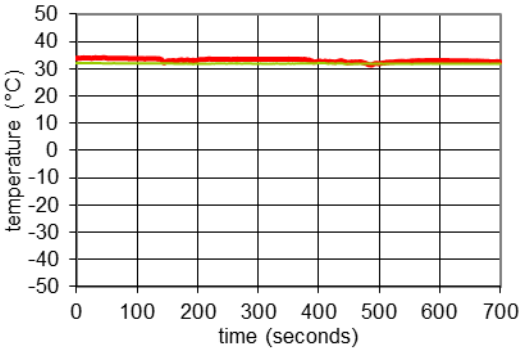
Temperature at x=250m, y=-84m, z=5m



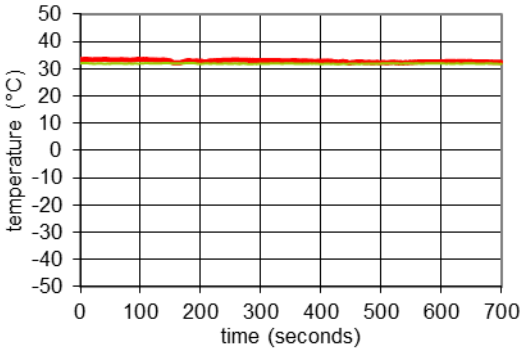
Temperature at x=250m, y=-56m, z=5m



Temperature at x=250m, y=-28m, z=5m

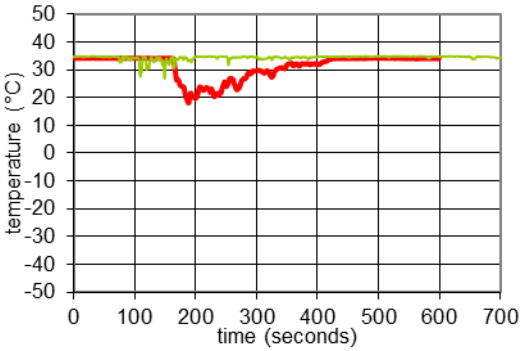


Temperature at x=250m, y=56m, z=5m

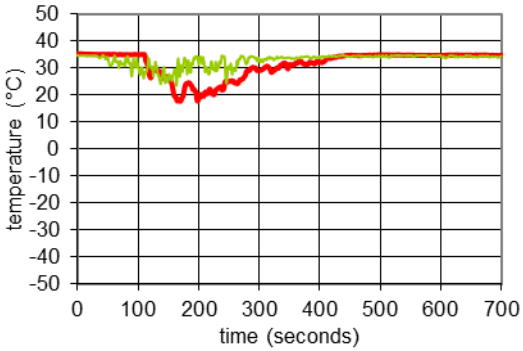


Temperature at x=250m, y=84m, z=5m

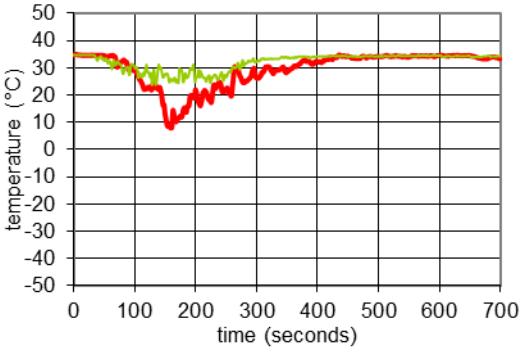
Falcon 3



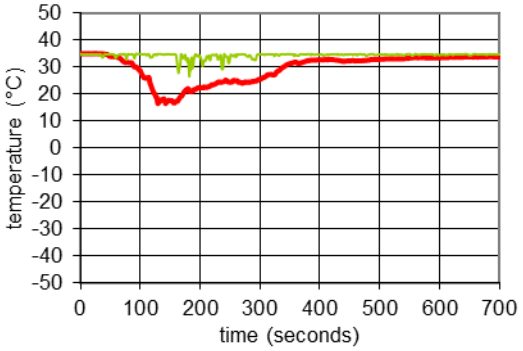
Temperature at x=50m, y=-66m, z=1m



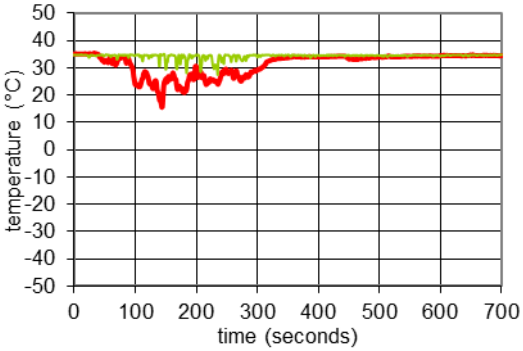
Temperature at x=50m, y=-44m, z=1m



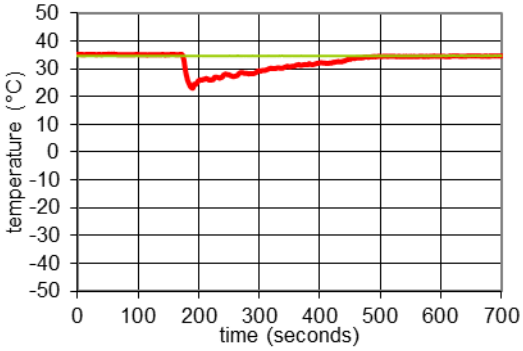
Temperature at x=50m, y=-22m, z=1m



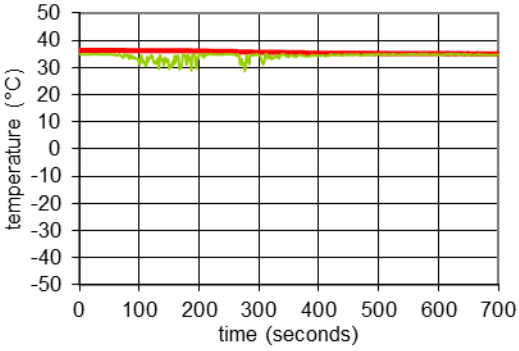
Temperature at x=50m, y=22m, z=1m



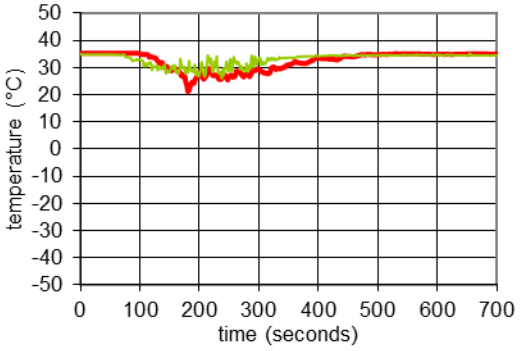
Temperature at x=50m, y=44m, z=1m



Temperature at x=150m, y=-75m, z=1m

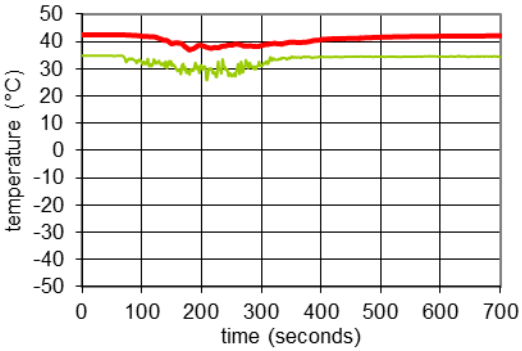


Temperature at x=150m, y=-50m, z=1m

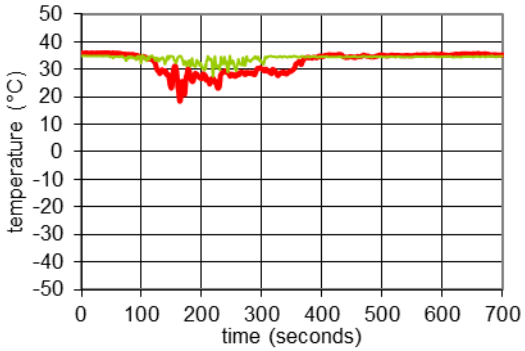


Temperature at x=150m, y=-25m, z=1m

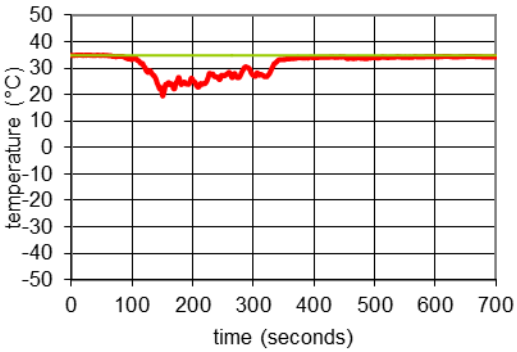
Falcon 3 (continued)



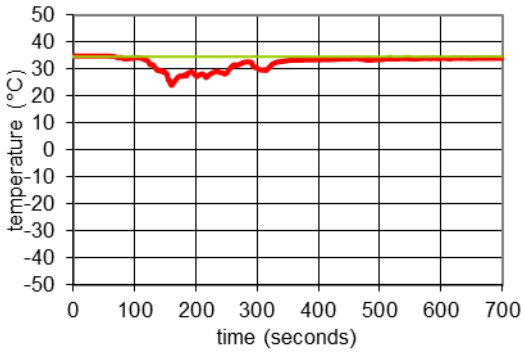
Temperature at x=150m, y=0m, z=1m



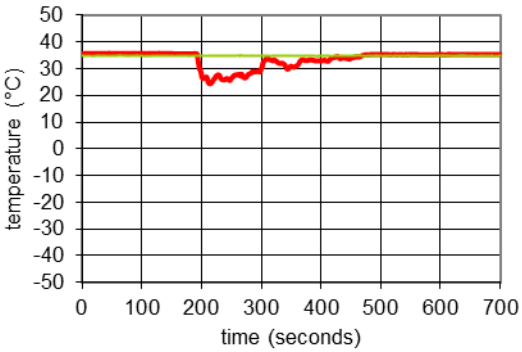
Temperature at x=150m, y=25m, z=1m



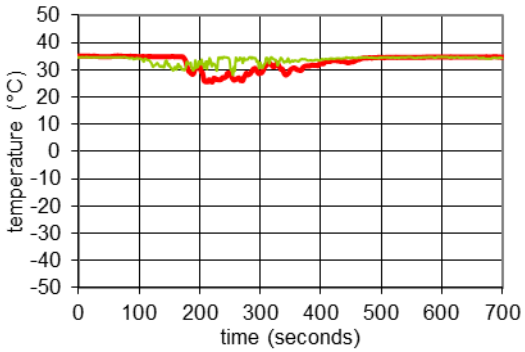
Temperature at x=150m, y=50m, z=1m



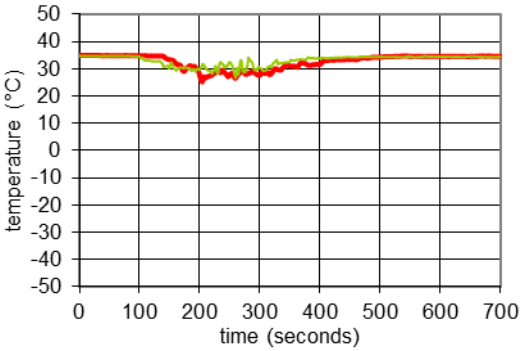
Temperature at x=150m, y=75m, z=1m



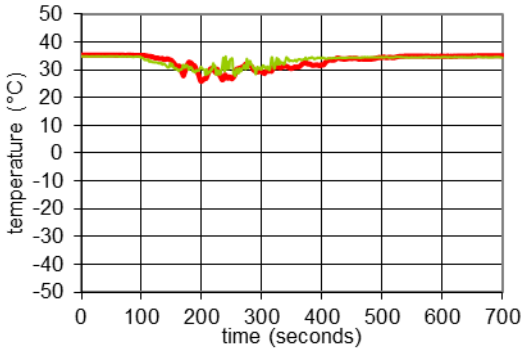
Temperature at x=250m, y=-84m, z=1m



Temperature at x=250m, y=-56m, z=1m

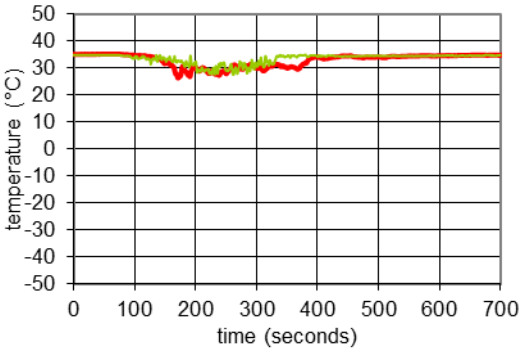


Temperature at x=250m, y=-28m, z=1m

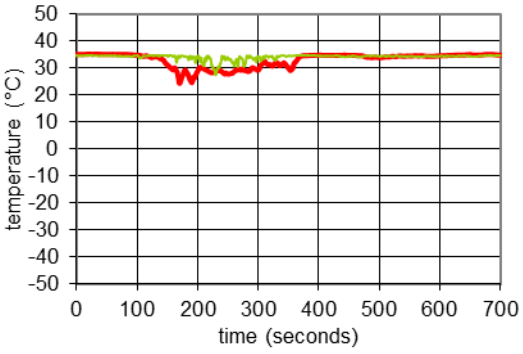


Temperature at x=250m, y=0m, z=1m

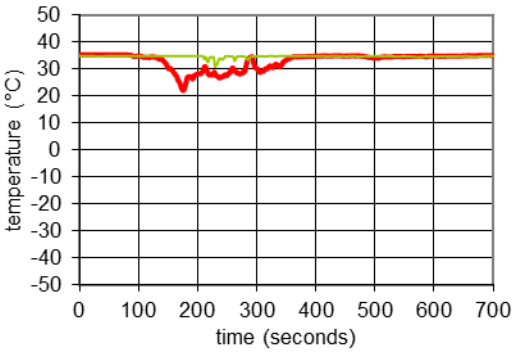
Falcon 3 (continued)



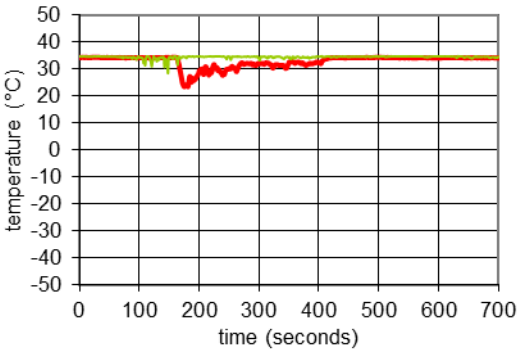
Temperature at x=250m, y=28m, z=1m



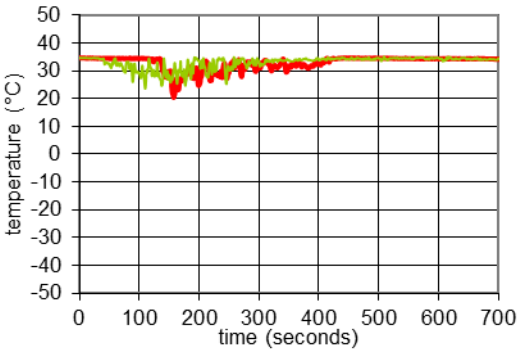
Temperature at x=250m, y=56m, z=1m



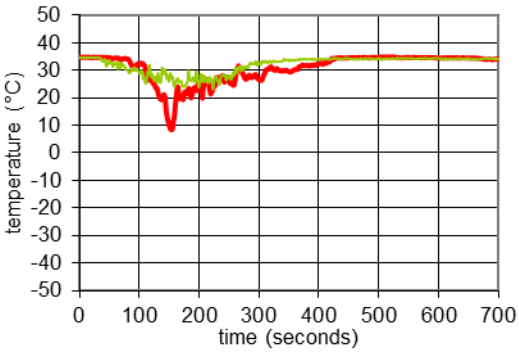
Temperature at x=250m, y=84m, z=1m



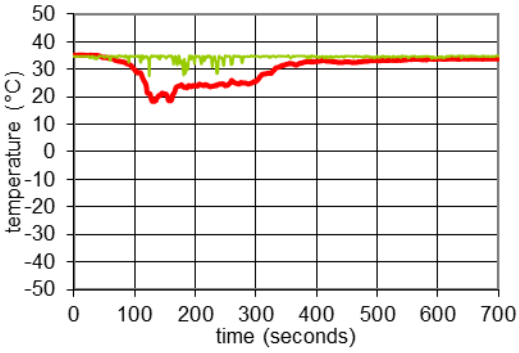
Temperature at x=50m, y=-66m, z=5m



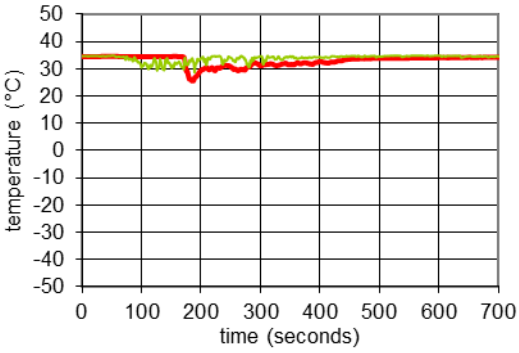
Temperature at x=50m, y=-44m, z=5m



Temperature at x=50m, y=-22m, z=5m

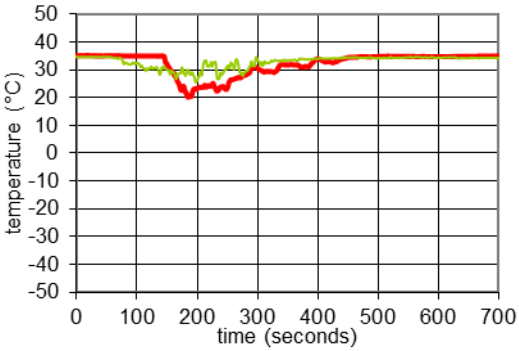


Temperature at x=50m, y=22m, z=5m

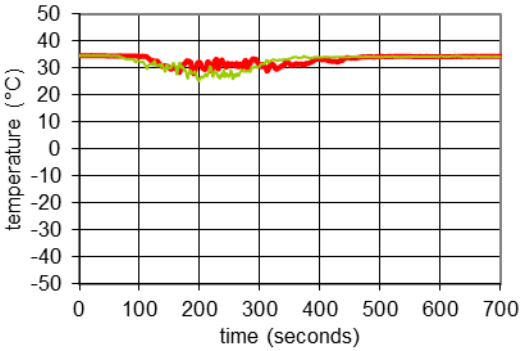


Temperature at x=150m, y=-75m, z=5m

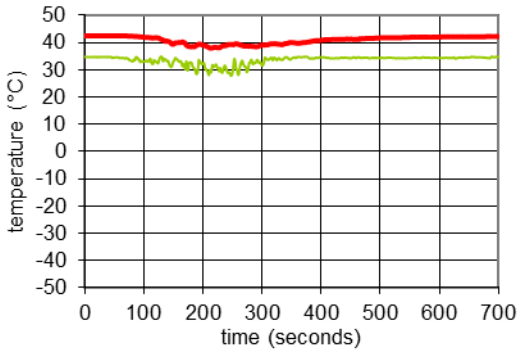
Falcon 3 (continued)



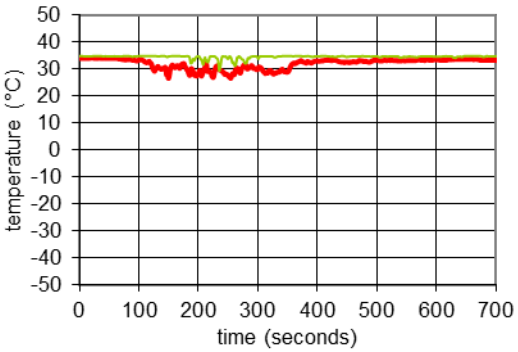
Temperature at x=150m, y=-50m, z=5m



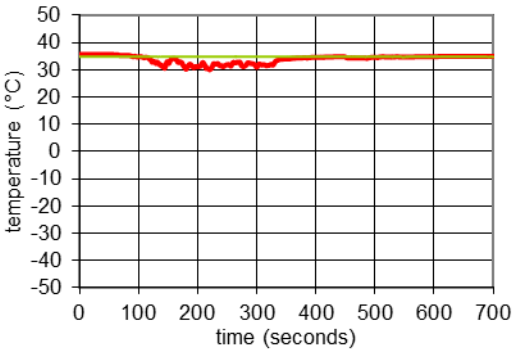
Temperature at x=150m, y=-25m, z=5m



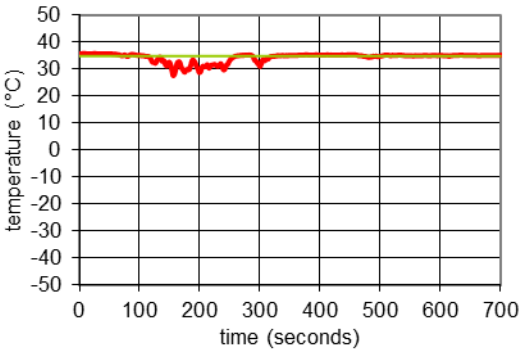
Temperature at x=150m, y=0m, z=5m



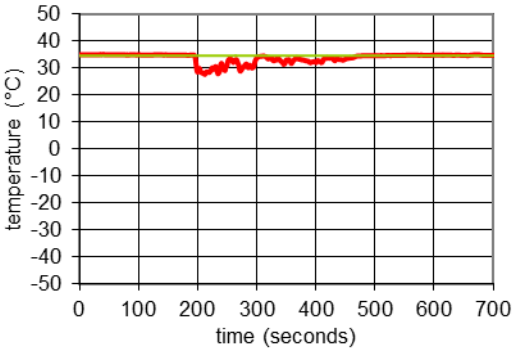
Temperature at x=150m, y=25m, z=5m



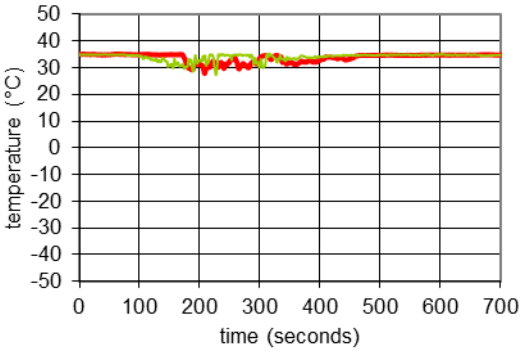
Temperature at x=150m, y=50m, z=5m



Temperature at x=150m, y=75m, z=5m

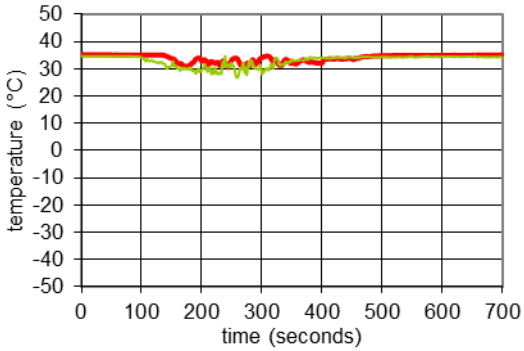


Temperature at x=250m, y=-84m, z=5m

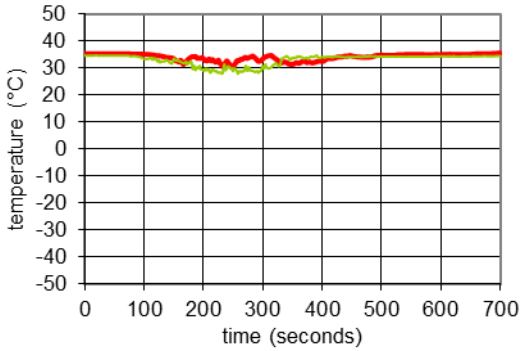


Temperature at x=250m, y=-56m, z=5m

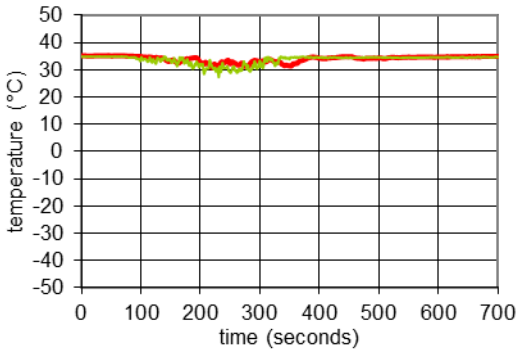
Falcon 3 (continued)



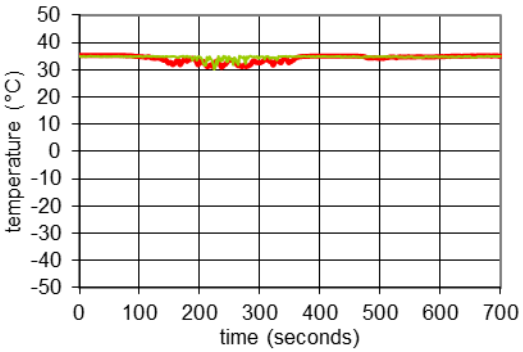
Temperature at x=250m, y=-28m, z=5m



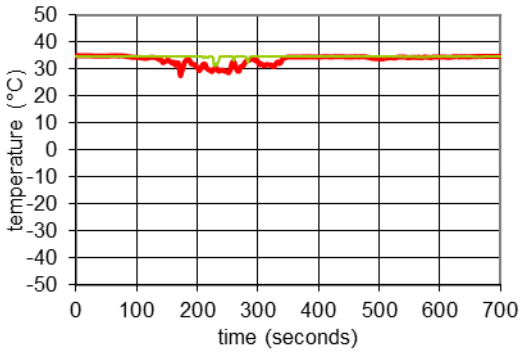
Temperature at x=250m, y=0m, z=5m



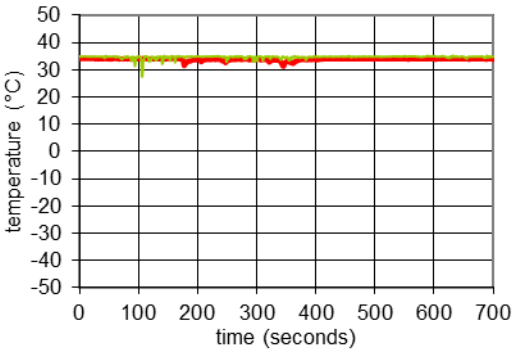
Temperature at x=250m, y=28m, z=5m



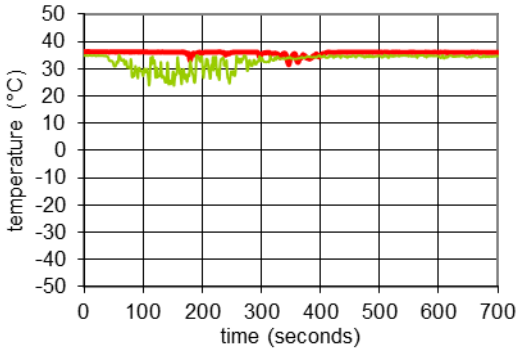
Temperature at x=250m, y=56m, z=5m



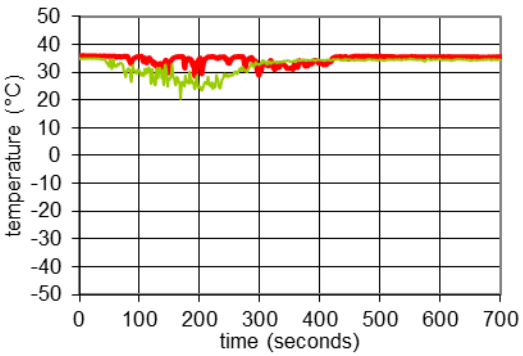
Temperature at x=250m, y=84m, z=5m



Temperature at x=50m, y=-66m, z=11m

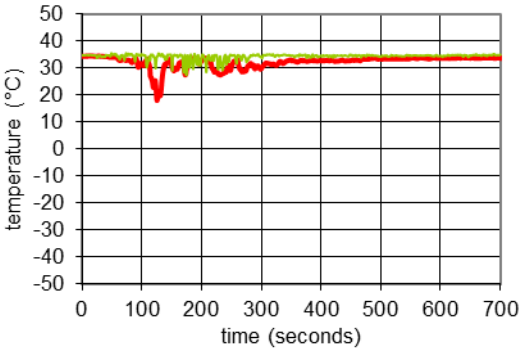


Temperature at x=50m, y=-44m, z=11m

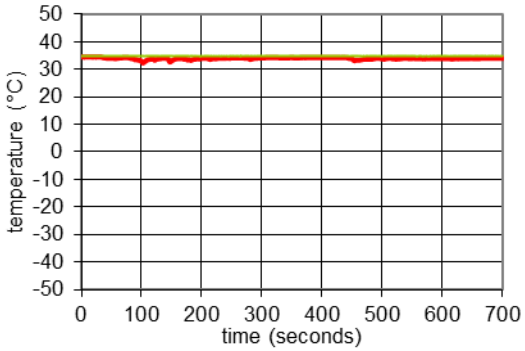


Temperature at x=50m, y=-22m, z=11m

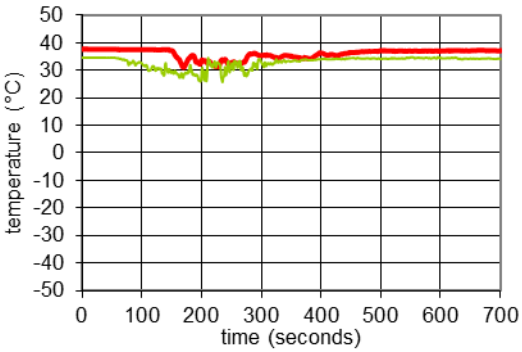
Falcon 3 (continued)



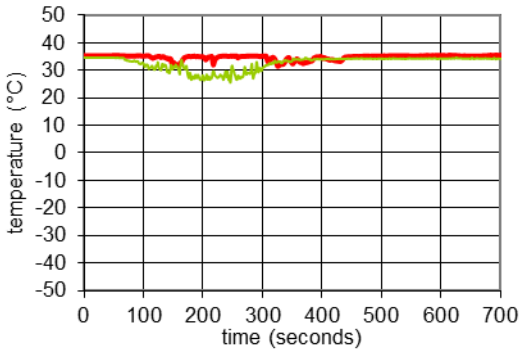
Temperature at x=50m, y=22m, z=11m



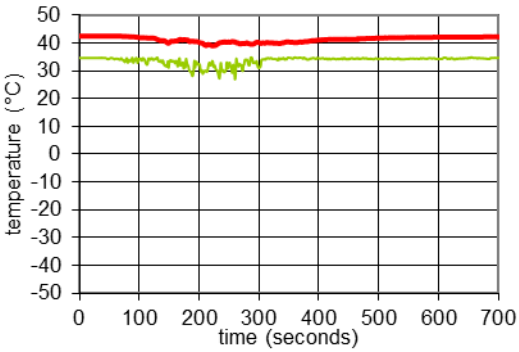
Temperature at x=50m, y=44m, z=11m



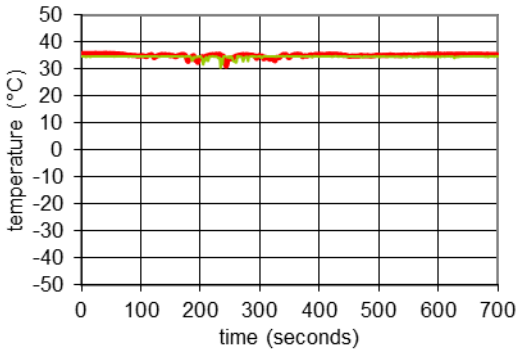
Temperature at x=150m, y=-50m, z=11m



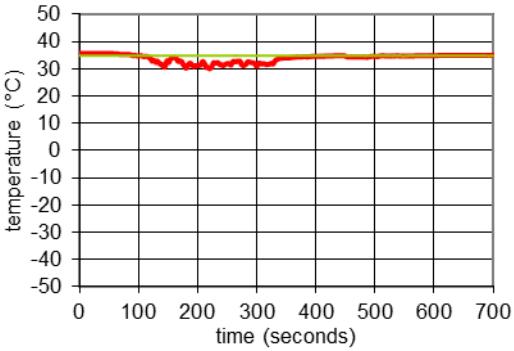
Temperature at x=150m, y=-25m, z=11m



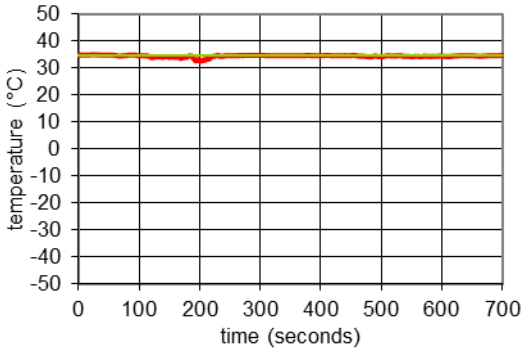
Temperature at x=150m, y=0m, z=11m



Temperature at x=150m, y=25m, z=11m

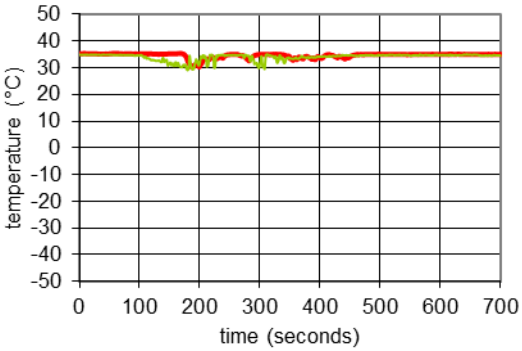


Temperature at x=150m, y=50m, z=11m

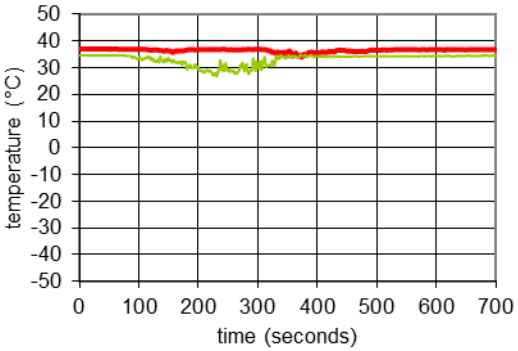


Temperature at x=150m, y=75m, z=11m

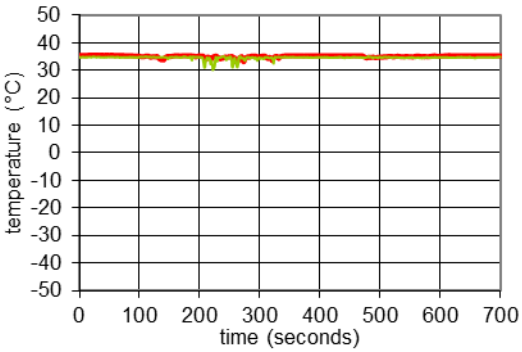
Falcon 3 (continued)



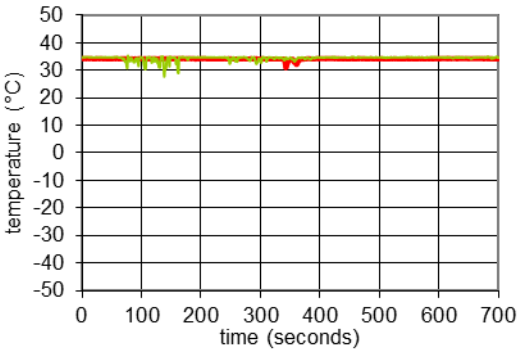
Temperature at x=250m, y=-56m, z=11m



Temperature at x=250m, y=0m, z=11m

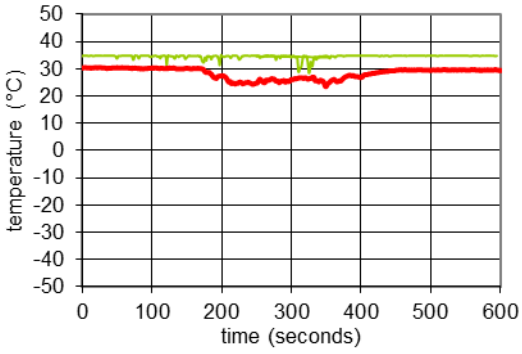


Temperature at x=250m, y=56m, z=11m

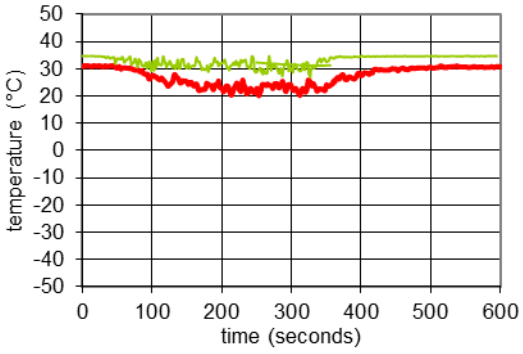


Temperature at x=50m, y=66m, z=17m

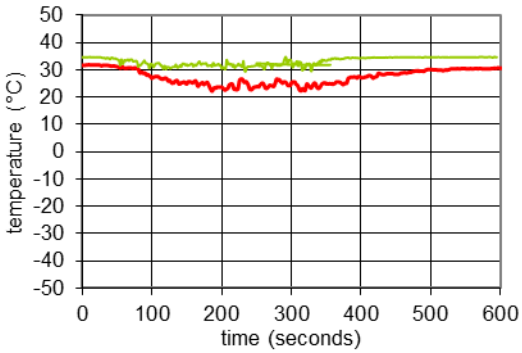
Falcon 4



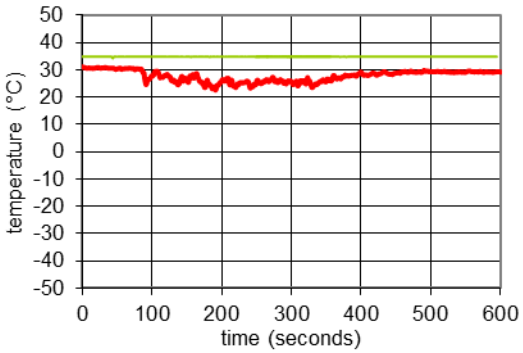
Temperature at x=50m, y=-66m, z=1m



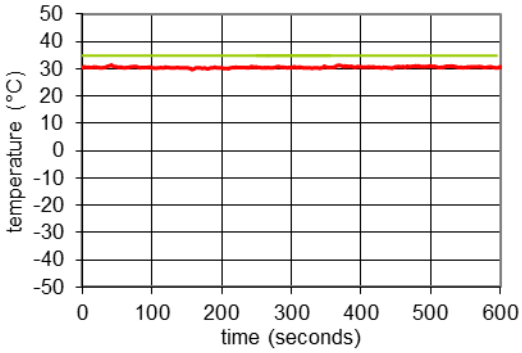
Temperature at x=50m, y=-33m, z=1m



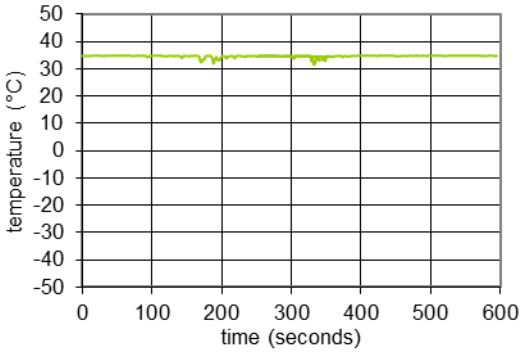
Temperature at x=50m, y=0m, z=1m



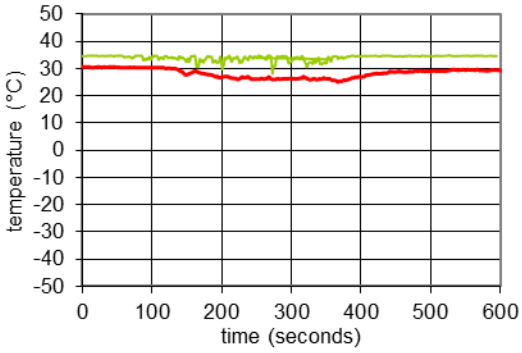
Temperature at x=50m, y=33m, z=1m



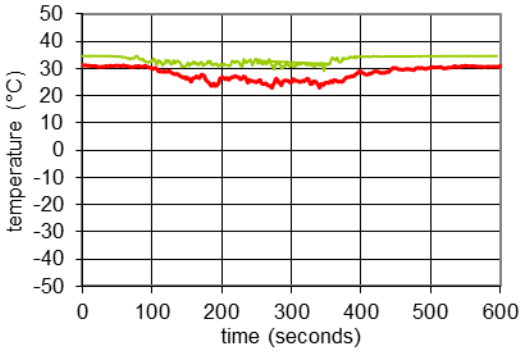
Temperature at x=50m, y=66m, z=1m



Temperature at x=150m, y=-100m, z=1m

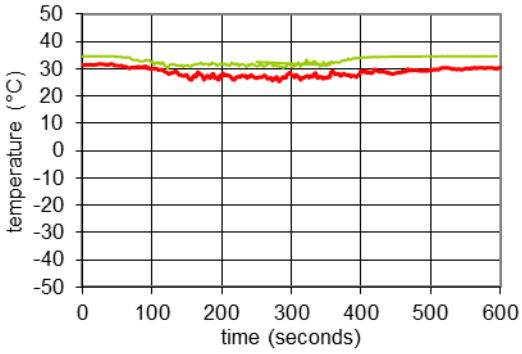


Temperature at x=150m, y=-75m, z=1m

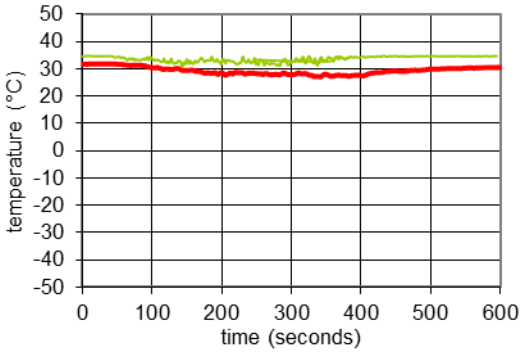


Temperature at x=150m, y=-50m, z=1m

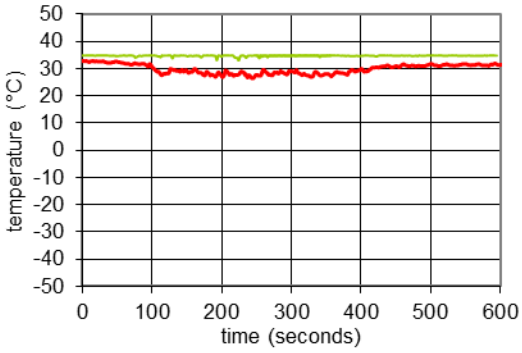
Falcon 4 (continued)



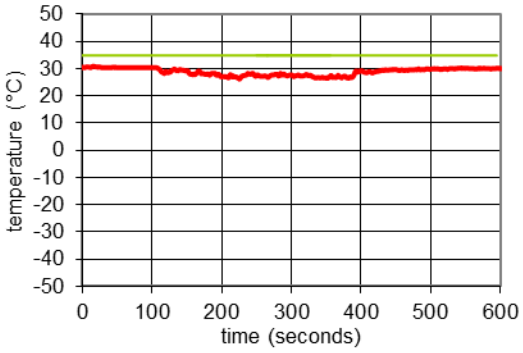
Temperature at x=150m, y=-25m, z=1m



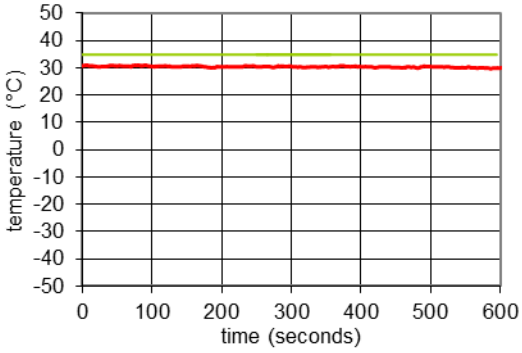
Temperature at x=150m, y=0m, z=1m



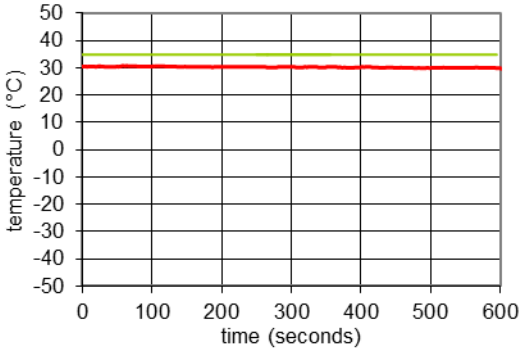
Temperature at x=150m, y=25m, z=1m



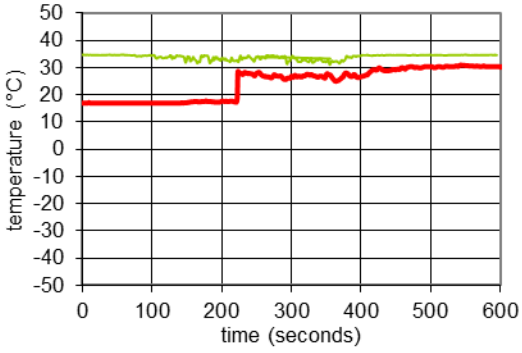
Temperature at x=150m, y=50m, z=1m



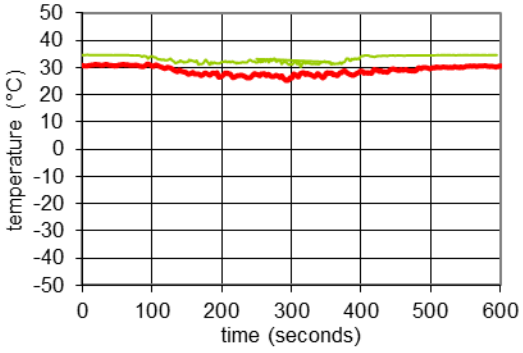
Temperature at x=150m, y=75m, z=1m



Temperature at x=150m, y=100m, z=1m

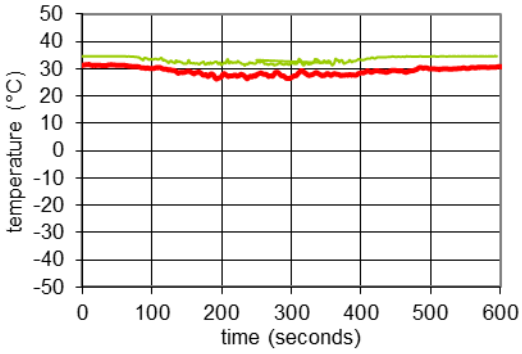


Temperature at x=250m, y=-84m, z=1m

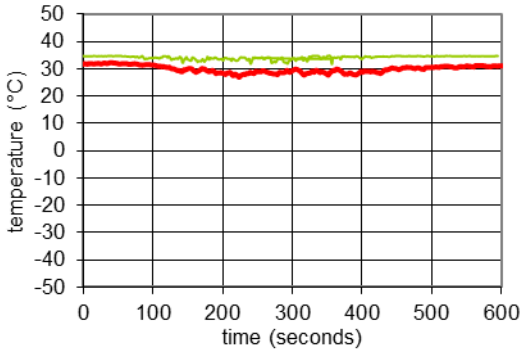


Temperature at x=250m, y=-56m, z=1m

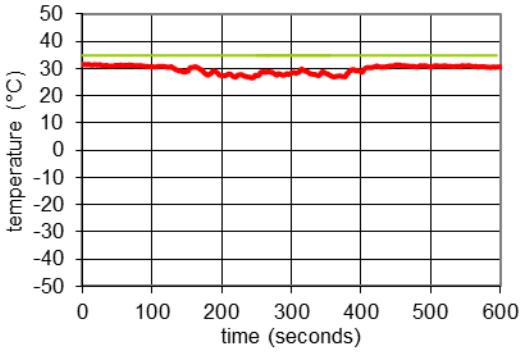
Falcon 4 (continued)



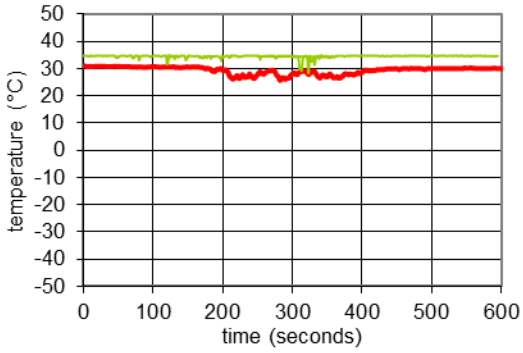
Temperature at x=250m, y=-28m, z=1m



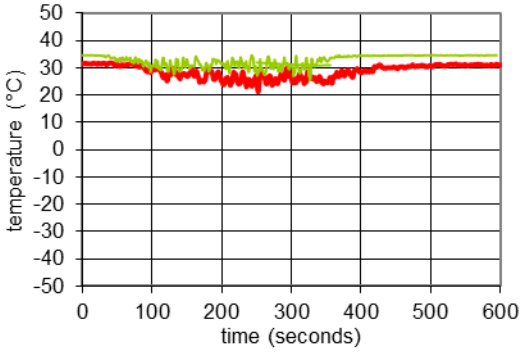
Temperature at x=250m, y=0m, z=1m



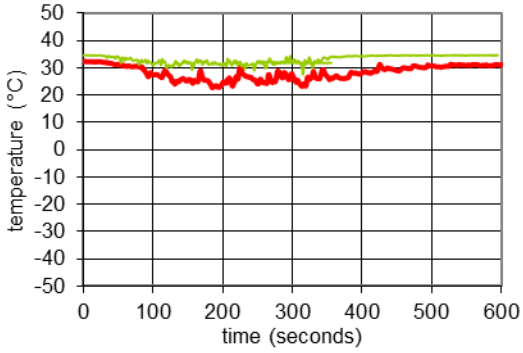
Temperature at x=250m, y=56m, z=1m



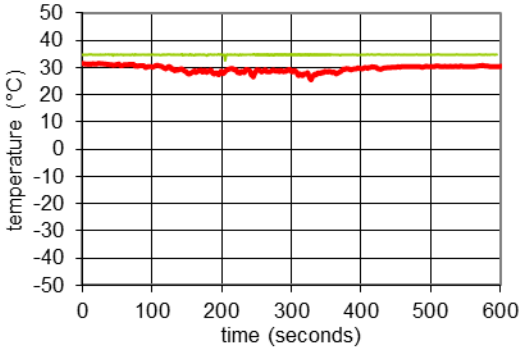
Temperature at x=50m, y=-66m, z=5m



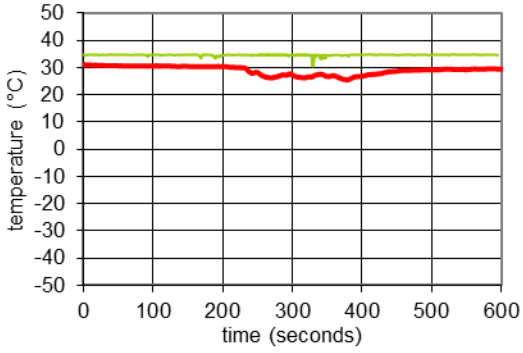
Temperature at x=50m, y=-33m, z=5m



Temperature at x=50m, y=0m, z=5m

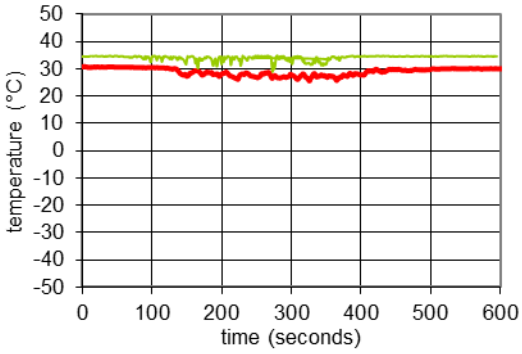


Temperature at x=50m, y=33m, z=5m

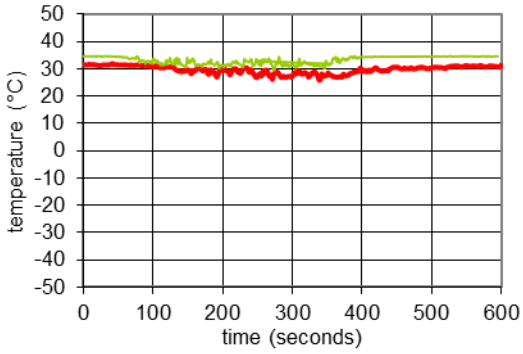


Temperature at x=150m, y=-100m, z=5m

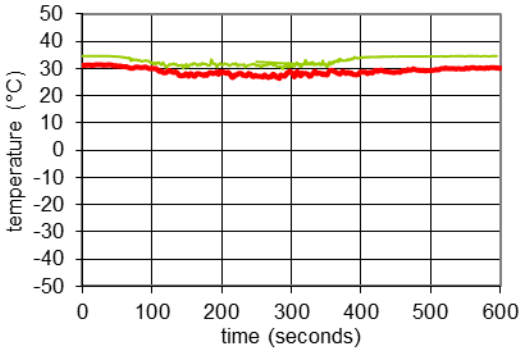
Falcon 4 (continued)



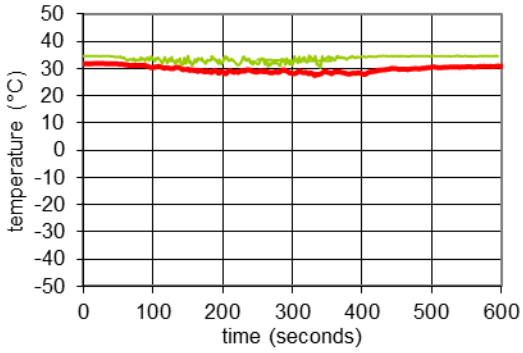
Temperature at x=150m, y=-75m, z=5m



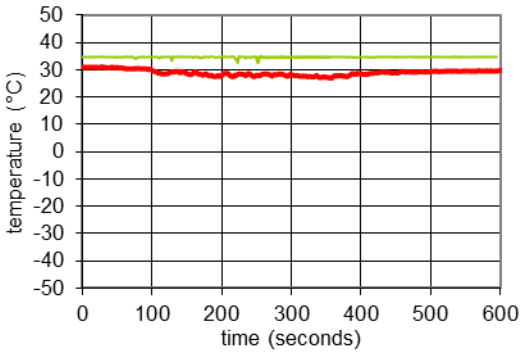
Temperature at x=150m, y=-50m, z=5m



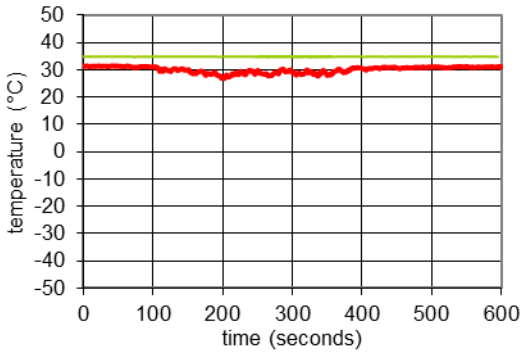
Temperature at x=150m, y=-25m, z=5m



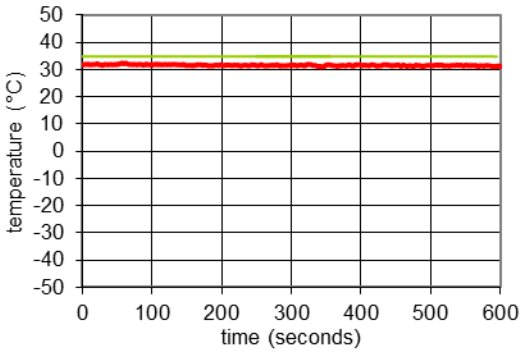
Temperature at x=150m, y=0m, z=5m



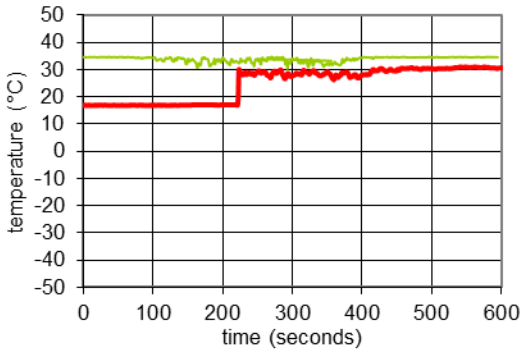
Temperature at x=150m, y=25m, z=5m



Temperature at x=150m, y=50m, z=5m

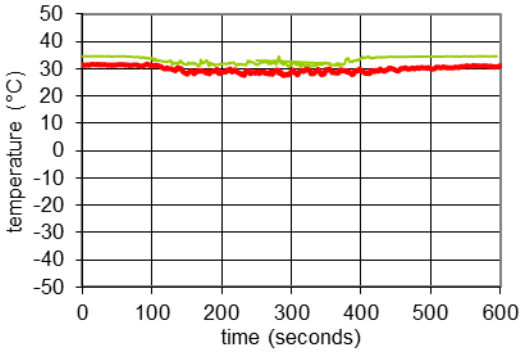


Temperature at x=150m, y=100m, z=5m

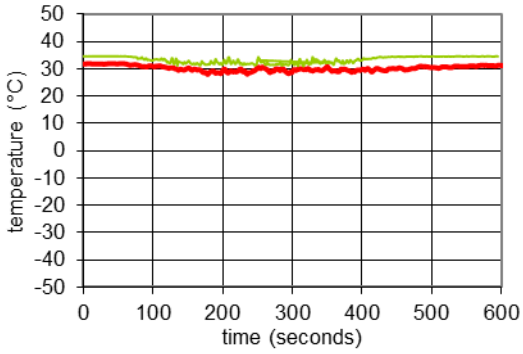


Temperature at x=250m, y=-84m, z=5m

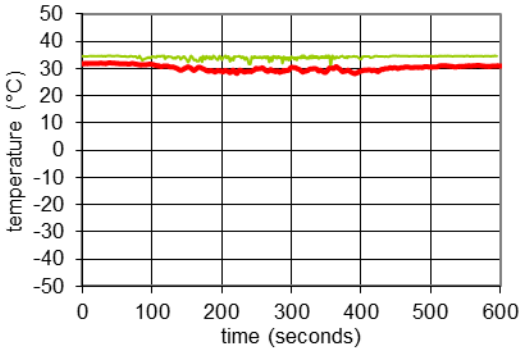
Falcon 4 (continued)



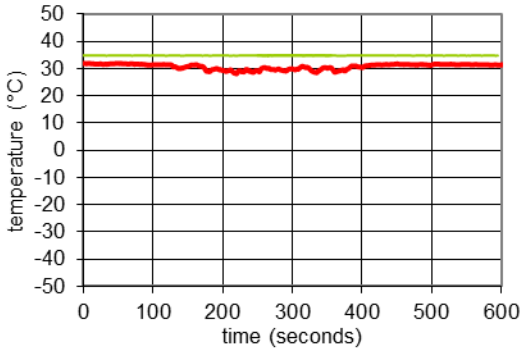
Temperature at x=250m, y=-56m, z=5m



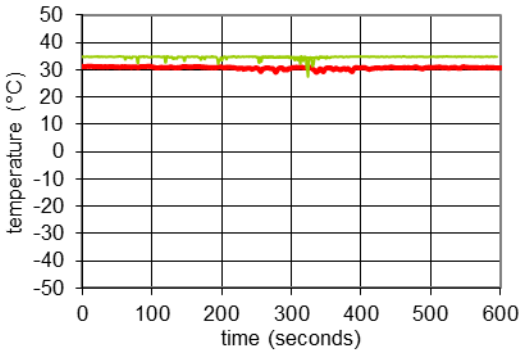
Temperature at x=250m, y=-28m, z=5m



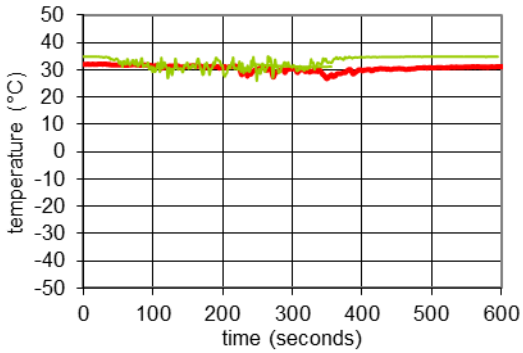
Temperature at x=250m, y=0m, z=5m



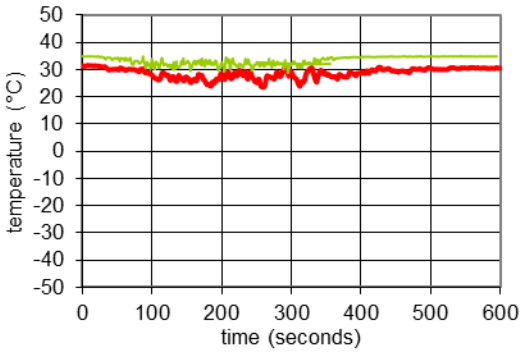
Temperature at x=250m, y=56m, z=5m



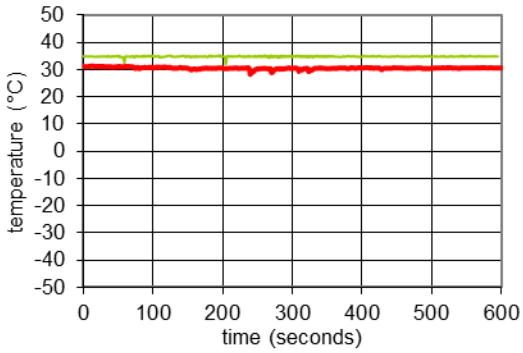
Temperature at x=50m, y=-66m, z=11m



Temperature at x=50m, y=-33m, z=11m

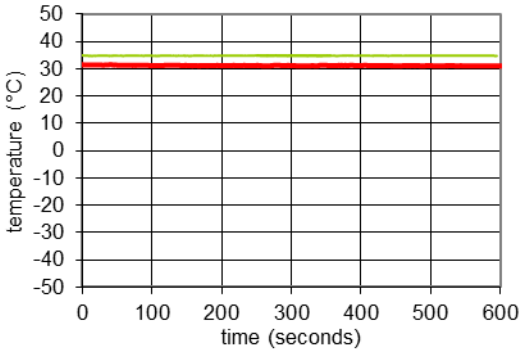


Temperature at x=50m, y=0m, z=11m

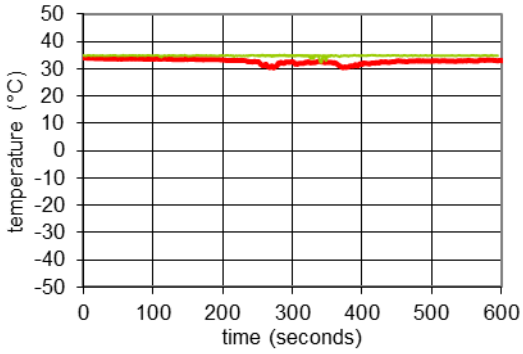


Temperature at x=50m, y=33m, z=11m

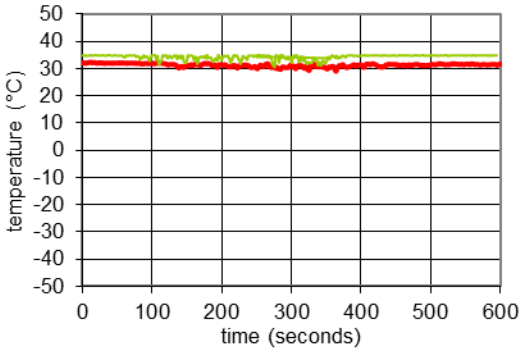
Falcon 4 (continued)



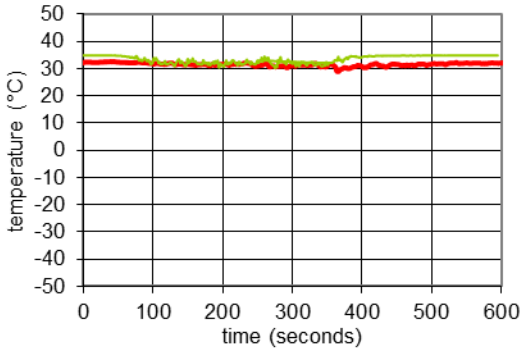
Temperature at x=50m, y=66m, z=11m



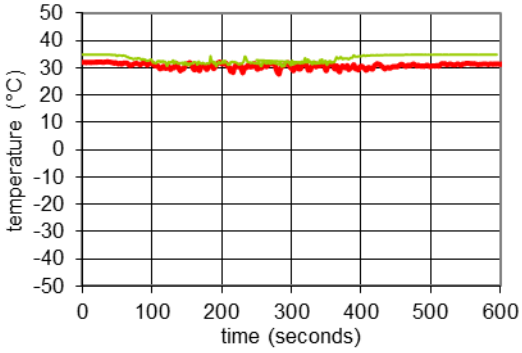
Temperature at x=150m, y=-100m, z=11m



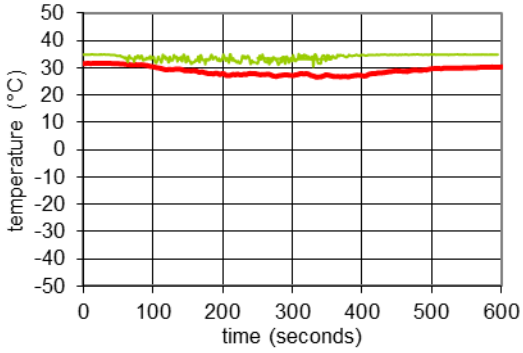
Temperature at x=150m, y=-75m, z=11m



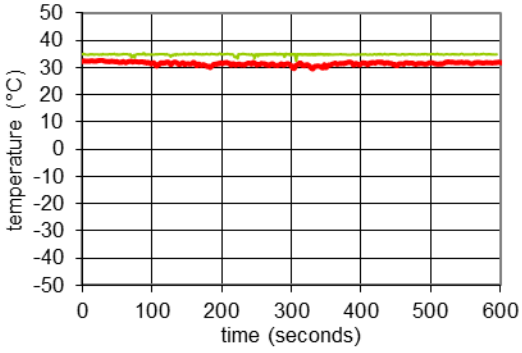
Temperature at x=150m, y=-50m, z=11m



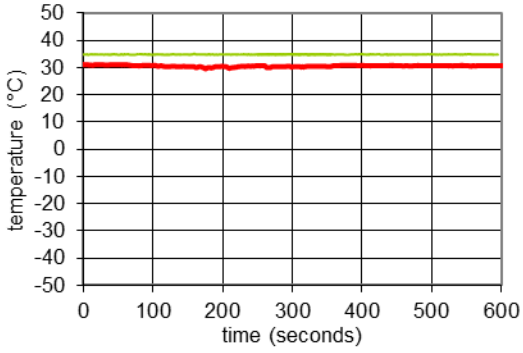
Temperature at x=150m, y=-25m, z=11m



Temperature at x=150m, y=0m, z=11m

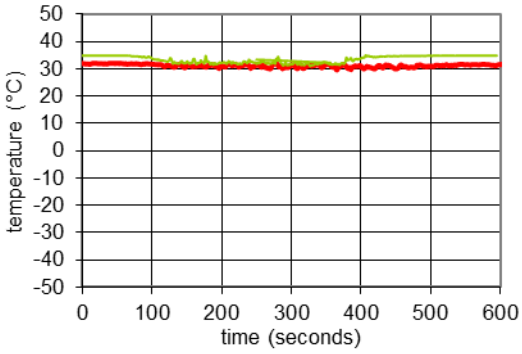


Temperature at x=150m, y=25m, z=11m

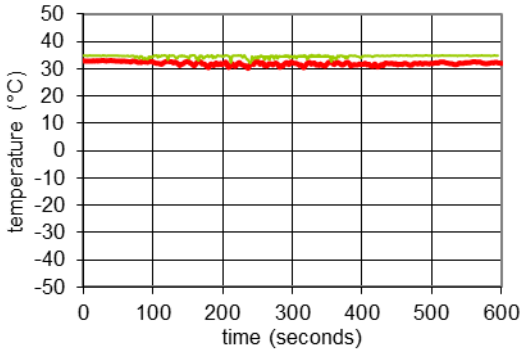


Temperature at x=150m, y=50m, z=11m

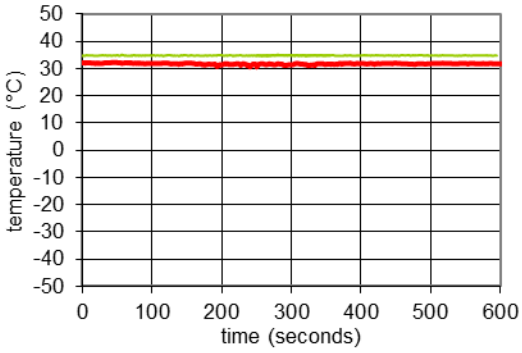
Falcon 4 (continued)



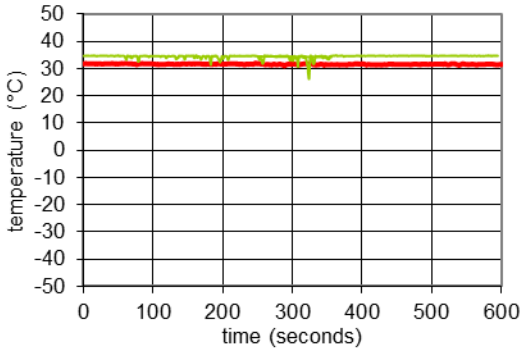
Temperature at x=250m, y=-56m, z=11m



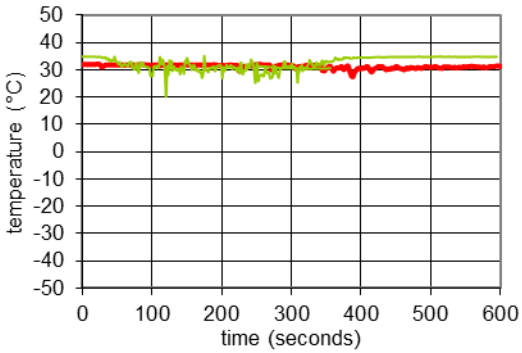
Temperature at x=250m, y=0m, z=11m



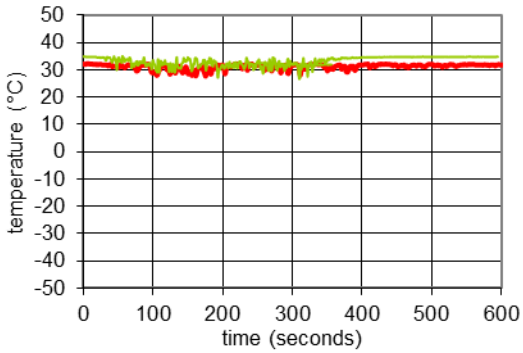
Temperature at x=250m, y=56m, z=11m



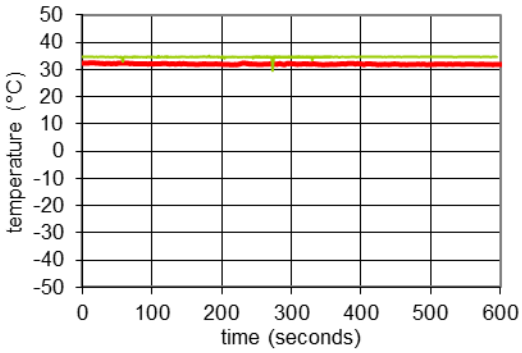
Temperature at x=50m, y=-66m, z=17m



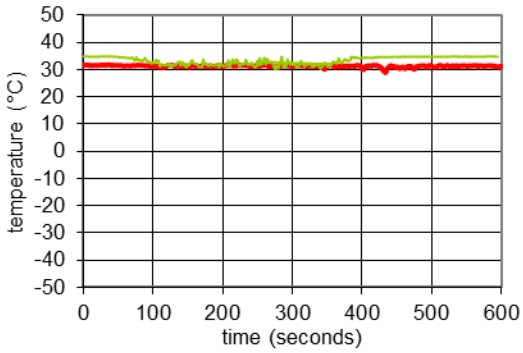
Temperature at x=50m, y=-33m, z=17m



Temperature at x=50m, y=0m, z=17m

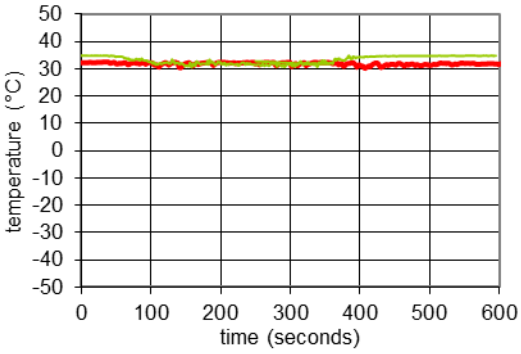


Temperature at x=50m, y=33m, z=17m

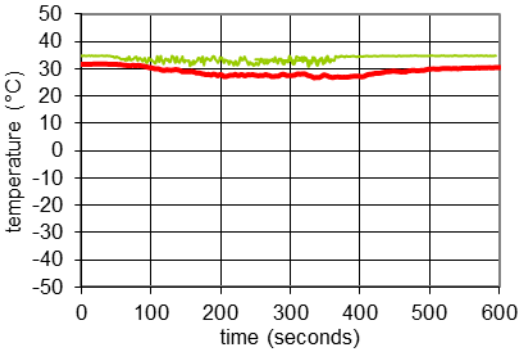


Temperature at x=150m, y=-50m, z=17m

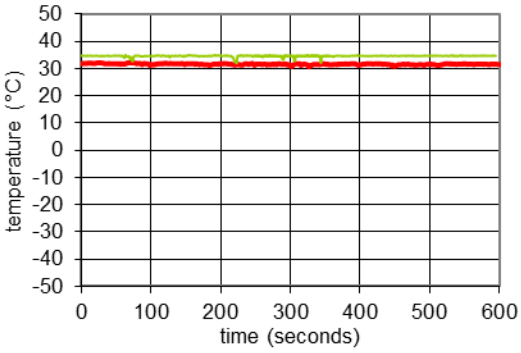
Falcon 4 (continued)



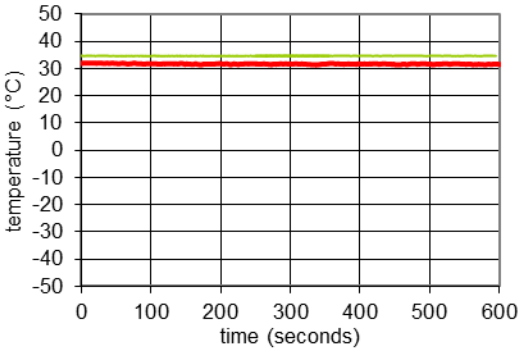
Temperature at x=150m, y=-25m, z=17m



Temperature at x=150m, y=0m, z=17m



Temperature at x=150m, y=25m, z=17m



Temperature at x=150m, y=50m, z=17m

Bibliography

[1] *Federal Power Act of 1935*, 16 United States Code Chapter 12, Federal Regulation and Development of Power, 1935.

[2] *Natural Gas Act of 1938*, 15 United States Code Chapter 717, 1938.

[3] *Energy Policy Act of 2005*, 42 United States Code Title III Oil and Gas, Subtitle B Natural Gas, Section 311, 2005.

[4] Conservation of Power and Water Resources, *Environmental Reports for Natural Gas Applications*, Title 18 Code of Federal Regulations Part 380.12, 2011.

[5] Transportation, *Liquefied Natural Gas Facilities: Federal Safety Standards*, Title 49 Code of Federal Regulations, Part 193, 2011.

[6] NFPA 59A, *Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)*, 2001 Edition.

[7] NFPA 59A: *Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)*, 2006 Edition.

[8] Federal Energy Regulatory Commission, *Evaluation of DEGADIS 2.1 Using Advisory Bulletin ADB-10-07*, 2011. http://www.ferc.gov/industries/gas/indus-act/lng/safety/degadis-report.pdf, http://www.ferc.gov/industries/gas/indus-act/lng/safety/degadis-database.xls

[9] Ivings, M.J., Jagger, S.F., Lea, C.J., Webber, D.M., *Evaluating Vapor Dispersion Models for Safety Analysis of LNG Facilities*, Fire Protection Research Foundation, Quincy, Massachusetts, 2007. http://www.nfpa.org/assets/files/pdf/research/LNGVaporDispersionModel.pdf

[10] Coldrick, S., Lea, C.J., Ivings, M.J., *Validation Database for Evaluating Vapor Dispersion Models for Safety Analysis of LNG Facilities*, Version 11.0, The Fire Protection Research Foundation, Quincy, Massachusetts, 2010. http://www.nfpa.org/assets/files/pdf/research/lng_database_guide.pdf

[11] ASTM E 1355, *Standard Guide for Evaluating the Predictive Capability of Deterministic Fire Models*, ASTM International, West Conshohocken, PA, 2011.

[12] ASTM E 1472, *Standard Guide for Documenting Computer Software for Fire Models*, ASTM International, West Conshohocken, PA, 2011.

[13] ASTM E 1591, *Standard Guide for Obtaining Data for Deterministic Fire Models*, ASTM International, West Conshohocken, PA, 2011.

[14] ASTM E 1895, *Standard Guide for Determining Uses and Limitations of Deterministic Fire Models*, ASTM International, West Conshohocken, PA, 2011.

[15] *SFPE Engineering Guide to Substantiating a Fire Model for a Given Application*, Society of Fire Protection Engineers, Bethesda, MD, 2011.

[16] AIAA, *Guide for the Verification and Validation of Computation Fluid Dynamics Simulations*, AIAA G-077-1998, 1998.

[17] ERCOFTAC. *The ERCOFTAC Best Practice Guidelines for Industrial Computation Fluid Dynamics*, Version 1.0, ERCOFTAC Special Interest Group on Quality and Trust in Industrial CFD, 2000.

[18] NPARC Alliance, *CFD Verification and Validation Web Site*, NASA Glenn Research Center and Arnold Engineering Development Center, USA, 2004. http://www.grc.nasa.gov/www/wind/valid/homepage.html

[19] McGrattan K., Hostikka, S., Floyd, J., Baum, H., Rehm, R., Mell, W., McDermott, R., *Fire Dynamics Simulator (Version 5) Technical Reference Guide, Volume 1: Mathematical Model*, NIST Special Publication 1018-5, 2009.
http://fds-smv.googlecode.com/svn/trunk/FDS/trunk/Manuals/All_PDF_Files/FDS_Technical_Reference_Guide.pdf

[20] McDermott, R., McGrattan K., Hostikka, S., Floyd, J., *Fire Dynamics Simulator (Version 5) Technical Reference Guide, Volume 2: Verification*, NIST Special Publication 1018-5, 2009.
http://fds-smv.googlecode.com/svn/trunk/FDS/trunk/Manuals/All_PDF_Files/FDS_Verification_Guide.pdf

[21] McGrattan K., Hostikka, S., Floyd, J., McDermott, R., Prasad, K., *Fire Dynamics Simulator (Version 5) Technical Reference Guide, Volume 3: Validation*, NIST Special Publication 1018-5, 2009.
http://fds-smv.googlecode.com/svn/trunk/FDS/trunk/Manuals/All_PDF_Files/FDS_Validation_Guide.pdf

[22] McGrattan, K., Fire Dynamics Simulation (Version 5), *Technical Reference Guide, Volume 4: Software Configuration Management Plan*, NIST Speical Publication 1018-5, 2010.
http://fds-smv.googlecode.com/svn/trunk/FDS/trunk/Manuals/All_PDF_Files/FDS_Configuration_Management_Plan.pdf

[23] McGrattan K., Klein, B., Hostikka, S., Floyd, J., *Fire Dynamics Simulator (Version 5) User's Guide*, NIST Special Publication 1019-5, 2008.
http://fds-smv.googlecode.com/svn/trunk/FDS/trunk/Manuals/All_PDF_Files/FDS_User_Guide.pdf

[24] Speight, J.G., *Synthetic Fuels Handbook: Properties, Process, and Performance*, McGraw-Hill, 2008.

[25] Tissot, B.P., Welte, D.H., *Petroleum Formation and Occurrence: A New Approach to Oil and Gas Exploration*, 2nd Edition, New York: Springer-Verlag, 1984.

[26] United States Congress, Senate Committee Report 110-418 of 110th Congress, *Transportation, Housing and Urban Development, and Related Agencies Appropriates Bill*, Pipeline Safety, 2009.

[27] Cleveland, C.J., *Concise Encyclopedia of the History of Energy*, Academic Press, 2009.

[28] Pipelines and Informed Planning Alliance, *Partnering to Further Enhance Pipeline Safety in Communities Through Risk-Informed Land Use Planning*, Final Report of Recommended Practices, 2010. http://primis.phmsa.dot.gov/comm/publications/PIPA/PIPA-Report-Final-20101117.pdf

[29] United States Energy Information Administration, *Annual Energy Review*, 2010. http://www.eia.gov/aer/

[30] Central Intelligence Agency, *The World Factbook*, Washington, DC, 2011. https://www.cia.gov/library/publications/the-world-factbook/

[31] United States Congress, *Hearing of Sub-Committee of the Committee on Interstate and Foreign Commerce*, House of Representatives, H.R. 5736, 1936.

[32] Federal Trade Commission, *Annual Report of the Federal Trade Commission for the Fiscal Year Ended June 30, 1936*, United States Government Printing Office, 1936.

[33] Federal Power Commission, Bureau of National Gas, *Report on Investigation of Tennessee Gas Transmission Company Pipeline Failure Near Natchitoches, Louisiana, March 4, 1965*, Docket CP65-267, 1965.

[34] Natural Gas Pipeline Safety Act of 1968, 49 Unite States Code Chapter 601, Transportation, Subtitle VIII Pipelines, Chapter 601 Safety, 1968.

[35] Hanna, S.R., Strimaitis, D.G., and Chang, J.C., *Hazard Response Modeling Uncertainty (a Quantitative Method), Volume II: Evaluation of Commonly-Used Hazardous Gas Dispersion Models*, Air Force Engineering & Services Center, Environics Division, AD-A270-095, ESL-TR-91-28, 1993.

[36] Hanna, S.R., Change, J.J, and Strimaitas, D.G., *Hazardous Gas Model Evaluation with Field Observations*, Atmospheric Environment, Vol. 27 A, No 15, pp 2265-2285, 1993.

[37] Model Evaluation Group, *Model Evaluation Protocol*, European Communities Directorate, General XII Science Research and Development, 1994.

[38] Model Evaluation Group, *Guidelines for Model Developers*, European Communities Directorate, General XII Science Research and Development, 1994.

[39] Daish, N.C., Britter, R.E., Linden, P.F., Jagger, S.F., Carissimo, B., *SMEDIS: Scientific Model Evaluation of Dense Gas Dispersion Models*, International Journal of Environment and Pollution, Vol 14, Nos. 1-6, 2000.

[40] Carissimo, B., Jagger, S.F., Daish, N.C., Halford, A., Selmer-Olsen, S., Riikonen, K., Perroux, J.M., Wurtz, J., *The SMEDIS Database and Validation Exercise*, In. J. Environment and Pollution, Vol. 16, Nos. 1-6, 2001.

[41] NASFM, *Review of the LNG Vapor Dispersion Model Evaluation Protocol*, National Association of State Fire Marshals, 2009.

[42] Melton, T.A., Cornwell, J.B., *LNG Trench Dispersion Modeling Using Computational Fluid Dynamics*, 12th Annual Symposium, Mary Kay O'Connor Process Safety Center, 2009.

[43] Gavelli, F., Davis, S.G., Hansen, O.H., *User Beware: When Simple Consequence Models Can Give the Wrong Answers*, Proceedings of AIChE Spring Meeting, 7th Global Congress on Process Safety, Chicago, IL, March 16, 2011.

[44] Ermak, D.L, Chapman, R., Goldwire, H.C., Gouveia, F.J., Rodean, H.C., *Heavy Gas Dispersion Test Summary Report*, Lawrence Livermore National Laboratory, 1989.

[45] Puttock, J.S., Blackmore, D.R., Colenbrander, G.W., Davies, P.T., Evans, A., Homer, J.B., Redfearn, J.J., Vant Sant, W.C., Wilson, R.P., *Spill Tests of LNG and Refrigerated Liquid Propane on the Sea, Maplin Sands, 1980: Experimental Details of the Dispersion Tests*. Shell Research Limited, TNER.84.046, 1984.

[46] Colenbrander, G.W., Evans, A., Puttock, J.S., *Spill Tests of LNG and Refrigerated Liquid Propane on the Sea, Maplin Sands, 1980: Dispersion Data Digest: Trial 27*, Shell Research Limited, TNER.84.028, 1984.

[47] Colenbrander, G.W., Evans, A., Puttock, J.S., *Spill Tests of LNG and Refrigerated Liquid Propane on the Sea, Maplin Sands, 1980: Dispersion Data Digest: Trial 34*. Shell Research Limited, TNER.84.030, 1984.

[48] Colenbrander, G.W., Evans, A., Puttock, J.S., *Spill Tests of LNG and Refrigerated Liquid Propane on the Sea, Maplin Sands, 1980: Dispersion Data Digest: Trial 35*, Shell Research Limited, TNER.84.031, 1984.

[49] Brutsaert, W., *Evaporation into the Atmosphere: Theory, History, and Applications*, Kluwer Academic Publishers, Netherlands, 1982.

[50] Federal Energy Regulatory Commission, *Consequence Assessment Methods for Incidents Involving Releases from Liquefied Natural Gas Carriers*, Docket No. AD04-6-000, 2004. http://www.ferc.gov/industries/gas/indus-act/lng/safety/cons-model.pdf

[51] Federal Energy Regulatory Commission, *Staff's Responses to Comments on the Consequence Assessment Methods for Incidents Involving Releases from Liquefied Natural Gas Carriers*, Docket No. AD04-6-000, 2004. http://www.ferc.gov/industries/gas/indus-act/lng/safety/cons-model-comments.pdf

[52] Webber, D.M., *A Model for Pool Spreading and Vaporization and its Implementation in the Computer Code GASP*, Safety & Reliability Directorate, UK Atomic Energy Authority, Report SRD/HSE/R507, 1990.

[53] Phani K. Raj, *Where in a LNG vapor cloud is the flammable concentration relative to the visible cloud boundary?*, NFPA Journal, May/June 2006.

[54] Koopman, R.P, Cederwall, R.T., Ermak, D.L., Goldwire, H.C., McClure, J.W., McRae, T.G., Morgan, D.L., Rodean, H.C., Shinn, J.H., *Description and Analysis of Burro Series 40-m3 LNG Spill Experiments*, Lawrence Livermore National Laboratory, UCRL-53186, 1981.

[55] Koopman, R.P, Baker, J., Cederwall, R.T., Goldwire, H.C., Hogan, W.J., Kamppinen, L.M., Kiefer, R.D., McClure, J.W., McRae, T.G., Morgan, D.L., Morris, L.K., Spann, M.W., Lind, C.D., *Burro Series Data Report LLNL/NWC 1980 LNG Spill Tests*, Lawrence Livermore National Laboratory, UCID-19075, Volume 1, 1982.
https://e-reports-ext.llnl.gov/pdf/194414.pdf

[56] Koopman, R.P, Baker, J., Cederwall, R.T., Goldwire, H.C., Hogan, W.J., Kamppinen, L.M., Kiefer, R.D., McClure, J.W., McRae, T.G., Morgan, D.L., Morris, L.K., Spann, M.W., Lind, C.D., *Burro Series Data Report LLNL/NWC 1980 LNG Spill Tests, The Appendices*, Lawrence Livermore National Laboratory, UCID-19075, Volume 2, 1982
https://e-reports-ext.llnl.gov/pdf/194606.pdf

[57] Koopman, R.P, Cederwall, R.T., Ermak, D.L., Goldwire, H.C., Hogan, W.J., McClure, J.W., McRae, T.G., Morgan, D.L., Rodean, H.C., Shinn, J.H., *Analysis of Burro Series 40-m3 LNG Spill Experiments*. Journal of Hazardous Materials, Vol 6, 1982.

[58] Goldwire, H.C., Rodean, H.C., Cederwall, R.T., Kansa, E.J., Koopman, R.P., McClure, J.W., McRae, T.G., Morris, L.K., Kamppinen, L., Kiefer, R.D., Urtiew, P.A., Lind, C.D., *Coyote Series Data Report LLNL/NWC 1981 LNG Spill Tests, Dispersion, Vapor Burn, and Rapid Phase Transition*, Lawrence Livermore National Laboratory, UCID-19953, Volume 1, 1983.
https://e-reports-ext.llnl.gov/pdf/195030.pdf

[59] Goldwire, H.C., Rodean, H.C., Cederwall, R.T., Kansa, E.J., Koopman, R.P., McClure, J.W., McRae, T.G., Morris, L.K., Kamppinen, L., Kiefer, R.D., Urtiew, P.A., Lind, C.D., *Coyote Series Data Report LLNL/NWC 1981 LNG Spill Tests, Dispersion, Vapor Burn, and Rapid Phase Transition*, Lawrence Livermore National Laboratory, UCID-19953, Volume 2, 1983.
https://e-reports-ext.llnl.gov/pdf/195363.pdf

[60] Pielke, R.A., *Mesoscale Meteorological Modeling*, 2nd Edition, Academic Press, New York, 2002

[61] Brown, T.C., Cederwall, R.T., Chan, S.T., Ermak, D.L., Koopman, R.P., Lamson, K.C., McClure, J.W., Morris, L.K., *Falcon Series Data Report LLNL, 1987 LNG Vapor Barrier Verification Field Trials*, Lawrence

Livermore National Laboratory, UCRL-DR-104316, 1990.
http://www.osti.gov/bridge/servlets/purl/6633087-9HP88a/

[62] Gavelli, F., Bullister, E., Kytomaa, H., *Application of CFD (Fluent) to LNG Spills into Geometrically Complex Environments*, Journal of Hazardous Materials, Vol. 159, 2008.

[63] Gavelli, F., Chernovsky, M.K., Bullister, E., Kytomaa, H.K., *Quantification of Source-Level Turbulence During LNG Spills Onto a Water Pond*, Journal of Loss Prevention in the Process Industries, Vol. 22, 2009.

[64] Johnson, D.R., *Thorney Island: Its Geography and Meteorology, Heavy Gas Dispersion Trials at Thorney Island*, Proceedings of a Symposium held at University of Sheffield, Great Britain, April 3-5, 1984.

[65] Leck, M.J., Lowe, D.J., *Development and Performance of the Gas Sensor System, Heavy Gas Dispersion Trials at Thorney Island*, Proceedings of a Symposium held at University of Sheffield, Great Britain, April 3-5, 1984.

[66] Havens, J., Spicer, T., *Vapor Dispersion and Thermal Hazard Modeling*, Final Topical Report, Gas Technology Institute, 2006.

[67] Nielson, M., Ott, S., *A Collection of Data from Dense Gas Experiments*, Riso-R-845 (EN), Riso National Laboratory, Denmark, 1995.

[68] Roache, P.J., K. Ghia, and F. White, *Editorial Policy Statement on the Control of Numerical Accuracy*, ASME Journal of Fluids Engineering, Vol. 108, 1986.