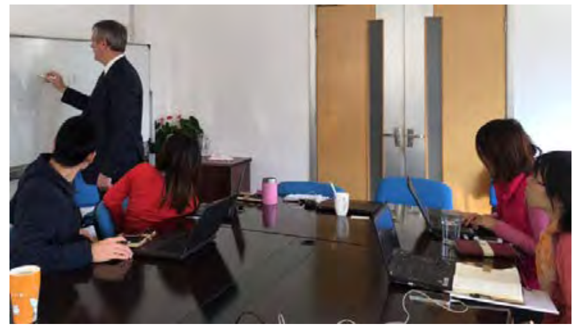
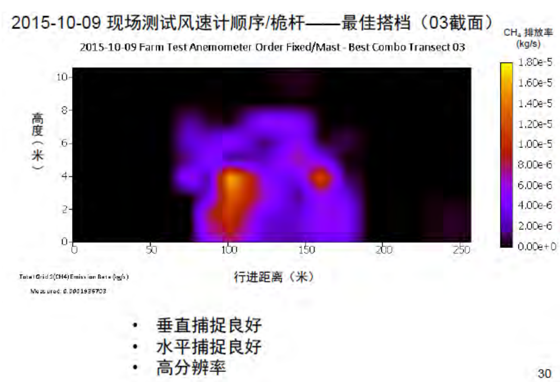
REPORT





Nov 30, 2015

A Report on the China Workshop (Nov 2015)

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ACKNOWLEDGEMENTS

The development of this report has been sponsored by the Climate and Clean Air Coalition (CCAC). The productive engagement of all the workshop participants and the hosting of the workshop by China Academy of Environmental Planning and Shanghai Academy of Environmental Science are gratefully acknowledged.

1 INTRODUCTION

This document presents a report on the technical workshop conducted in China (i.e., the final workshop). The purpose of the workshop was to demonstrate a measurement technology, the *plume transect system*, for remotely quantifying atmospheric emissions of methane (CH_4), carbon dioxide (CO_2), volatile organic compounds (VOC), hydrogen sulphide (H_2S), and ammonia (NH_3) from fugitive sources (e.g., building vents, equipment leaks, storage tanks, waste water treatment ponds, contaminated soils, etc.). Additionally, presentations were made on the inline tracer gas technique used to measure flaring rates at oil and natural gas facilities.

The workshop was split into two sessions: one conducted in Beijing on 20 November 2015 at the offices of China Academy of Environmental Planning (http://www.caep.org.cn/toptypeEN.asp?typeid=43), and the other conducted in Shanghai on 27 November 2015 at the offices of Shanghai Academy of Environmental Sciences (http://www.saes.sh.cn/en/aboutsaes.asp). The attendee list and presentations made at each workshop are presented in "APPENDIX – CAEP Workshop (20 Nov 2015)" and "APPENDIX – SAES Workshop (27 Nov 2015)", respectively.

Initially planning was that each workshop would comprise both a classroom session and a field demonstration of the *Plume Transect* measurement technology. Unfortunately, .unfavorable weather conditions in Beijing precluded the field demonstration component for CAEP. However, both source screening and emission measurement demonstrations of the technology were successfully conducted in Shanghai for the SAES.

1.1 CLASSROOM COMPONENT

The classroom component of each workshop was a half-day event. The key participants included senior management and researchers of the relevant departments of CAEP and SAES. In addition, representatives of a Chinese consulting firm and the local government participated in the CAEP workshop.

The participants at both workshops showed keen interest in the *Plume Transect* remote emissions measurement technology and expressed a desire for continued cooperation on opportunities to demonstration and apply of the *Plume Transect* system and other VOC/GHG emissions measurement technologies in China. Their interest is driven largely by two key factors:

- Effective 1 October 2015 – the Chinese government has begun applying a charge to industrial and commercial emitters of VOC emissions. A copy of the relevant assessment guidelines are presented in “APPENDIX – China’s VOC Guideline”. The particular regulatory interest in VOC emissions is because they are limiting precursor to the significant urban haze issue being experienced many major Chinese cities including Beijing and Shanghai. The VOC calculation method presented in the Chinese Guidelines has been adapted by China from *Emissions Estimation Protocol for Petroleum Refineries* published by the US Environmental Protection Agency (EPA).

- Effective 2017, the China will be implementing a country-wide GHG emissions trading program. Preliminary trading initiatives have been piloted over the last 6 years in 7 different jurisdictions in China. In 2015, China’s National Democratic Reform Commission (NDRC) released a set of GHG quantification guidelines. A copy of these is provided in “APPENDIX – China’s GHG Guideline”.

1.2 FIELD DEMONSTRATION COMPONENT

The *Plume Transect* system was validated and used to measure emissions from both coal mining and oil & gas facilities in Canada in advance of being taken to China. These results were shared with the workshop participants during the classroom portion of the workshops.

The plans developed with SAES for the field demonstration of the Plume Transect system in Shanghai are provided in “APPENDIX – Field Demonstration Plans For SAES”.

1.3 NEXT STEPS

Both CAEP and SAES expressed an interest in continued collaborative efforts to demonstrate and apply GHG/VOC emissions measurement technologies in China. Additionally, a 2016 workshop on the subject matter was proposed.

As part of the 2015 CCAC sponsored work in China, a Green Completions flowback skid design was prepared based on current best practices in North America for managing emissions from flowback events associated with multi-stage hydraulic fracturing of tight oil and gas wells. A copy of the design is presented in “APPENDIX – Green Completions Flowback Skid Design”. The design was shared with both China National Petroleum Corporation (CNPC) and Sinopec Limited. Both companies expressed an interest in having a follow-up 2016 workshop on the matter as well as participating in a study tour to Canada or the United States to discuss the technology with leading service providers before proceeding to purchase their own units.

Ideally, both initiatives would be combined into a single workshop for both government and industry stakeholders on VOC/GHG emissions measurement and control technologies.

2 APPENDIX – CAEP WORKSHOP (20 NOV 2015)

Two presentations were made by Clearstone during the workshop:

- Technology Demonstration (Current Results & Accomplishments)
- The Economic Case for Emissions Reduction.

A copy of each of these presentations follows.

Event: Presentation to Chinese Academy of Environmental Planning

Date: Nov. 20, 2015 **Location:** Beijing, China

Presented by: Jan Gorski

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1	Rui Ma	CAEP	13681595358	marui@caep.org.cn	[signature]
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Nov. 20, 2015
Beijing, P.R. China

Mobile Plume Transect System for Remote Monitoring of Emissions

Prepared by: Jan Gorski and Dan Field
Clearstone Engineering Ltd.

Plume Transect Emissions Quantification Strategy

Screening

- Screen for reference compounds and pollutants of interest to locate emission plumes and possible sources of interference
- Reference compounds: CH_4, CO_2
- Pollutants of interest: VOCs, H_2S, NH_3

Transect

- Quantify emissions of reference pollutants (CH_4 and CO_2)
- Spotter needed to look for overheard obstructions such as power lines due to height of mast

Stationary Measurement

- Monitor the ratio of pollutants of interest to the reference compounds
- Determine the best reference pollutant for correlation with pollutants of interest
- Calculate the pollutant emissions

Grab Sample

- Lab analysis for more accurate and detailed speciation of VOC emissions and possible quantification of other pollutants
- Upwind and downwind grab samples required

VOC Quantification Strategy

- Quantify reference pollutant emission rate (CH_4 or CO_2)
- Determine ratio of reference pollutant to VOCs based on mass spectrometer data OR grab sample analysis
- Determine VOC emission rate:

$$\dot{m}_{VOC} = \dot{m}_{ref} \frac{C_{VOC} - C_{VOC,\, background}}{C_{ref} - C_{ref,\, background}}$$

Where,

$\dot{m}_{VOC}$	=	VOC emission rate
$\dot{m}_{ref}$	=	reference pollutant emission rate
C_{VOC}	=	VOC concentration in plume
$C_{VOC,\, background}$	=	background VOC concentration
C_{ref}	=	reference pollutant concentration in plume
$C_{ref,\, background}$	=	background reference pollutant concentration

System Capabilities and Limitations

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Capabilities

- Real time measurement, mobile deployment, off-site access
- High Sensitivity (able to measure 0.00017 kg/s CH_4 100 m from source)
- Accuracy and Precision ≤ 25%
- Grid resolution
  Horizontal: ≤ 10 m
  Vertical: 1 m

Limitations

- Moderate, steady wind required
- 10 m height limit (mitigate by measuring closer to the source)
- Resolution dependent on driving speed

Gas Analyzer Specifications

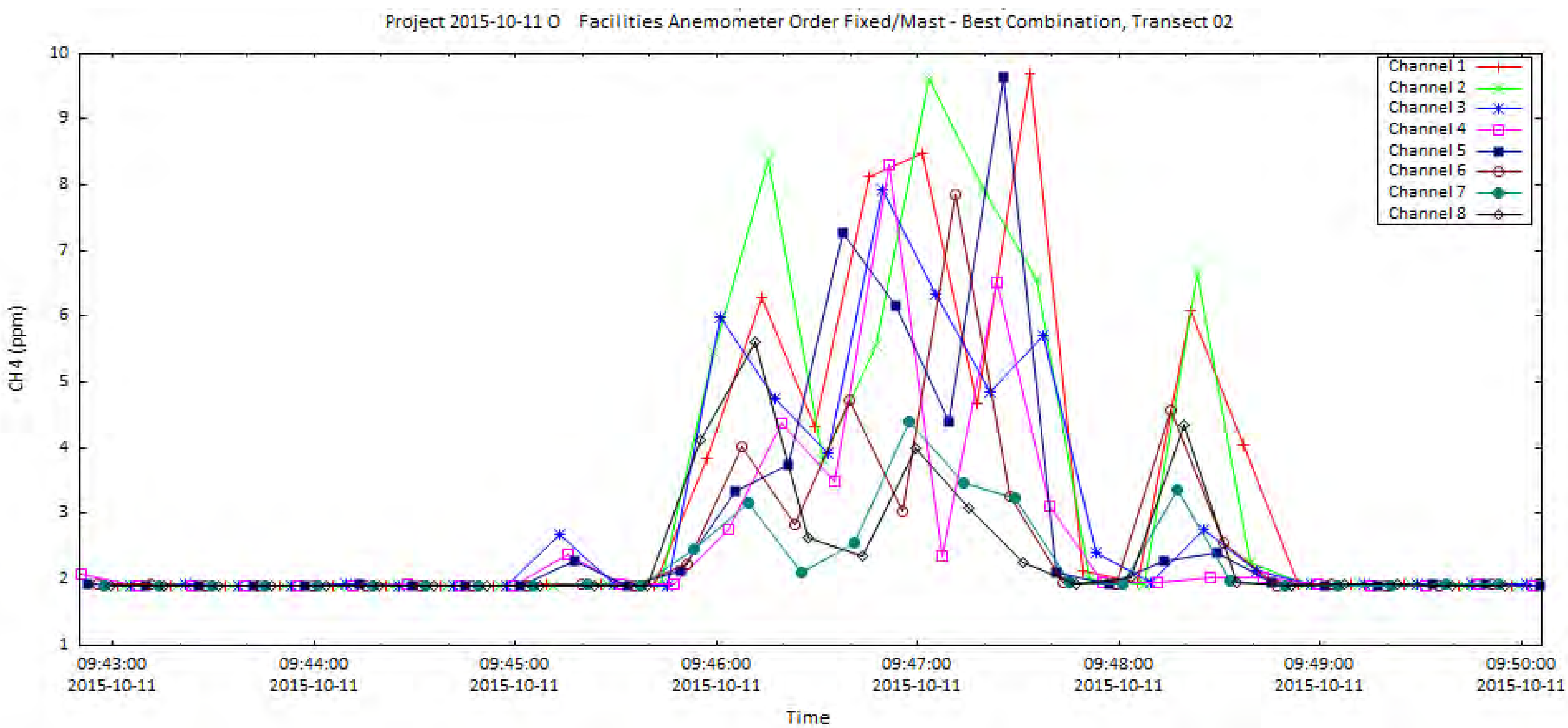
- $CH_4/CO_2/H_2O$ – Off-axis cavity output spectrometer
- VOCs – Portable mass spectrometer
- H_2S/NH_3 – Off-axis cavity output spectrometer

Analyzer	Substance	Measurement Range (ppm)	Precision, 1-σ (ppm)	Response Time (s)
1	Methane (CH_4)	0.1 to 1000	0.007 (10 Hz)	1.5
	Carbon Dioxide (CO_2)	200 to 4,000	1 (10 Hz)	1.5
	Water (H_2O)	100 to 70,000	100 (10 Hz)	1.5
2	Volatile Organic Compounds (VOCs, semi-quantitative)	MDL: 0.001 to 0.05	<0.001 (1 Hz)	60 to 180
3	Ammonia (NH_3)	0.001 to 10	0.0006 (0.1 Hz)	5
	Hydrogen Sulphide (H_2S)	0.05 to 50	0.005 (0.1 Hz)	5

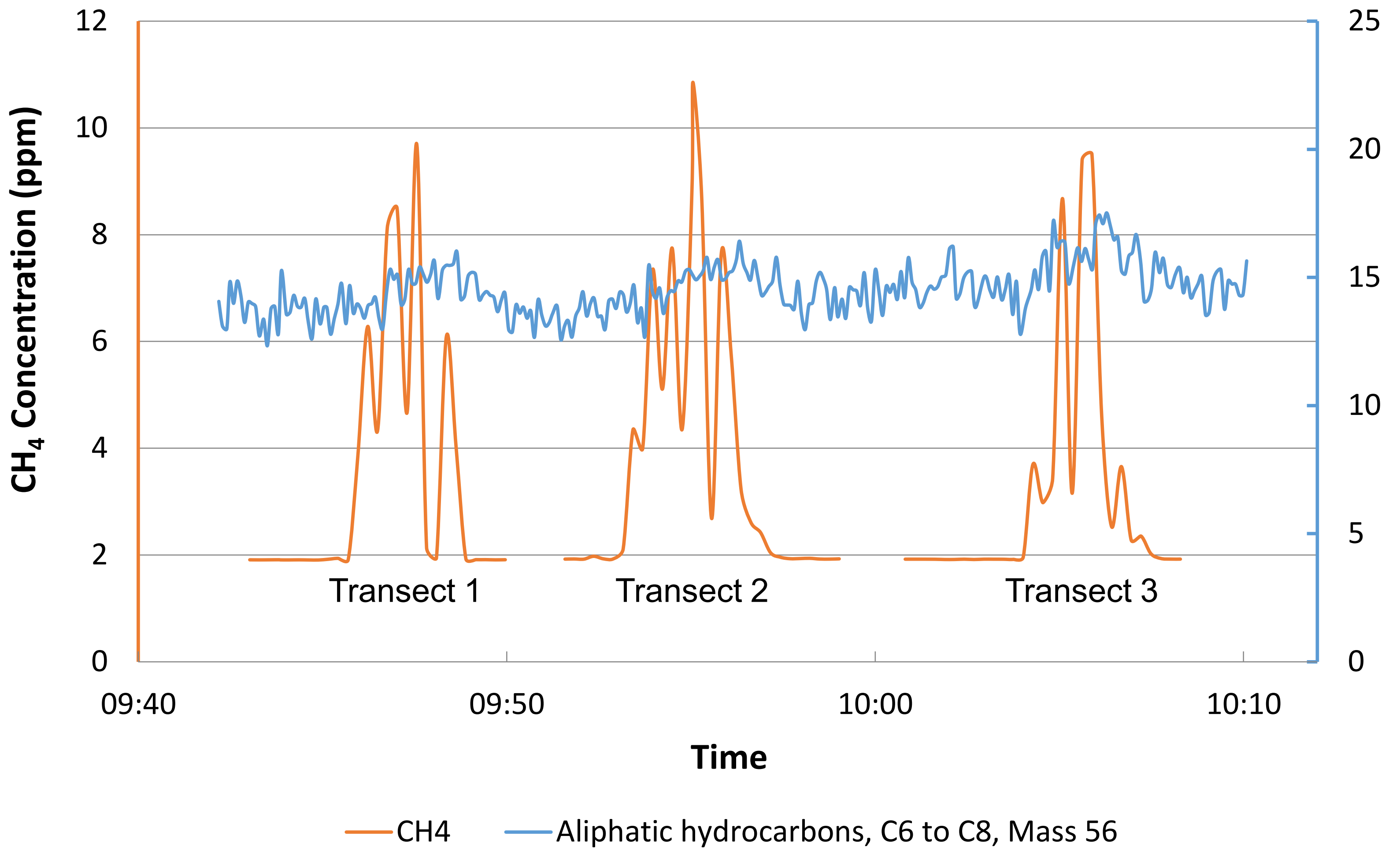
Oil Battery Measurements

Oil Battery – Transect Path

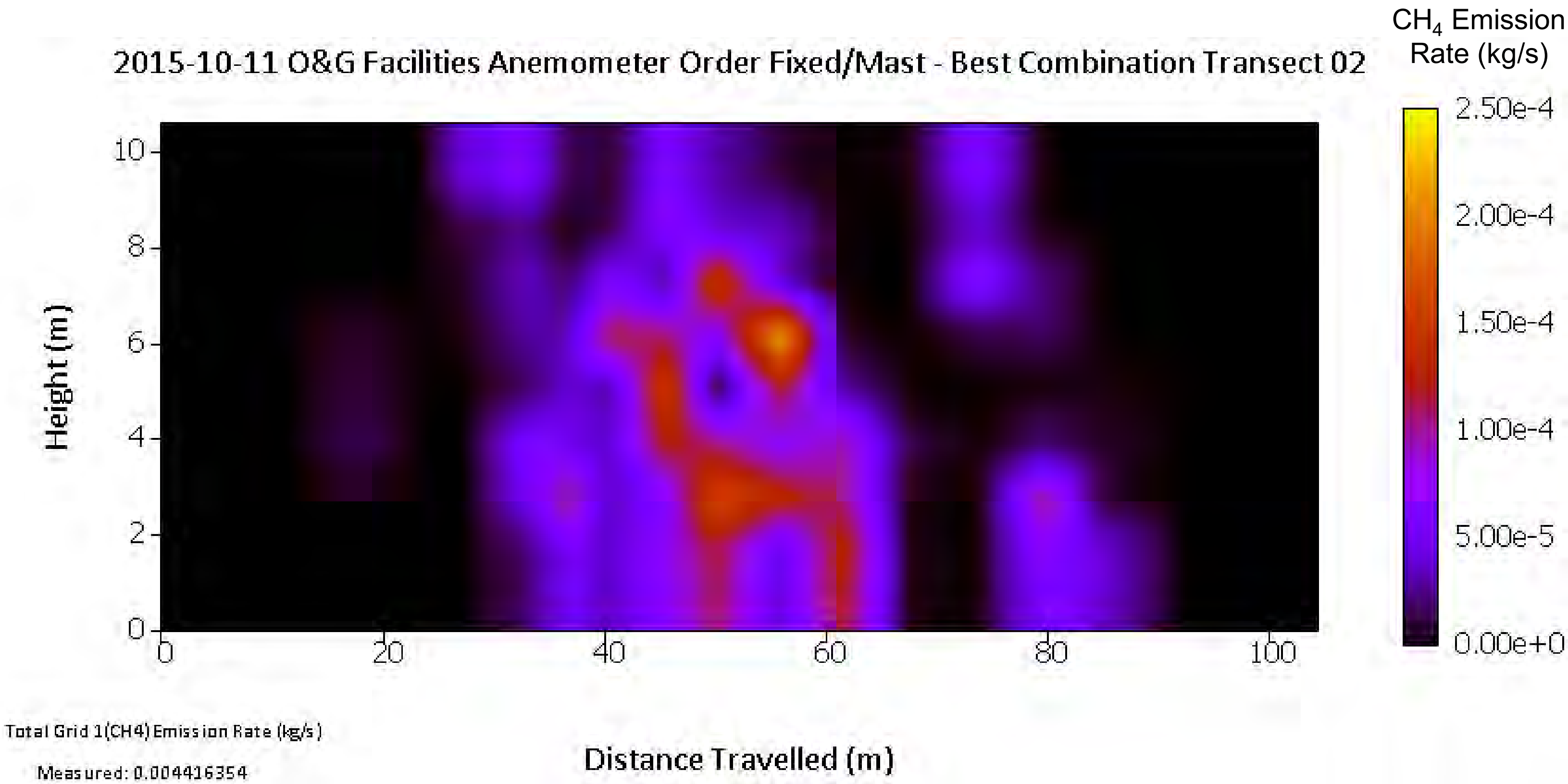
Oil Battery – Downwind Concentrations



Oil Battery – VOC results

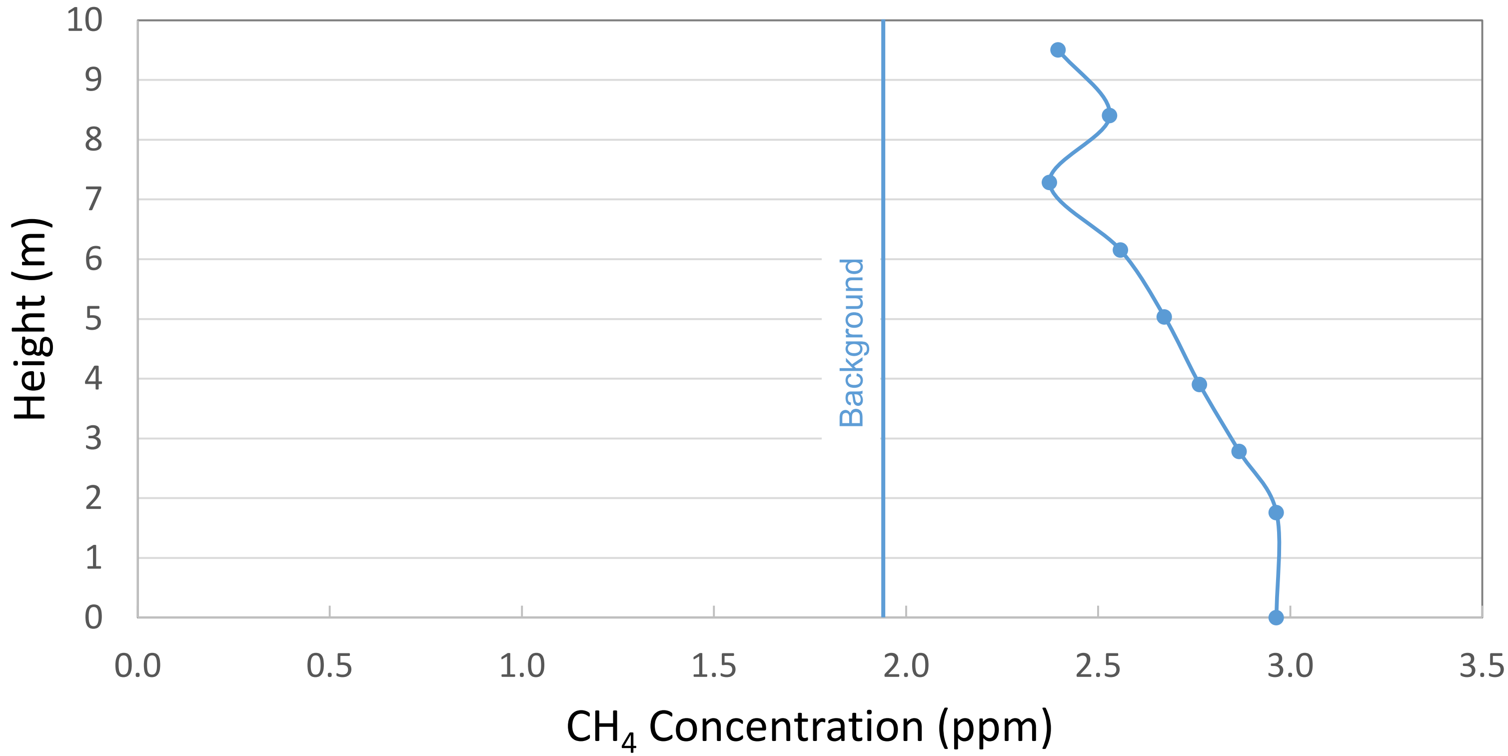


Oil Battery – Emission Rate Contour Plot



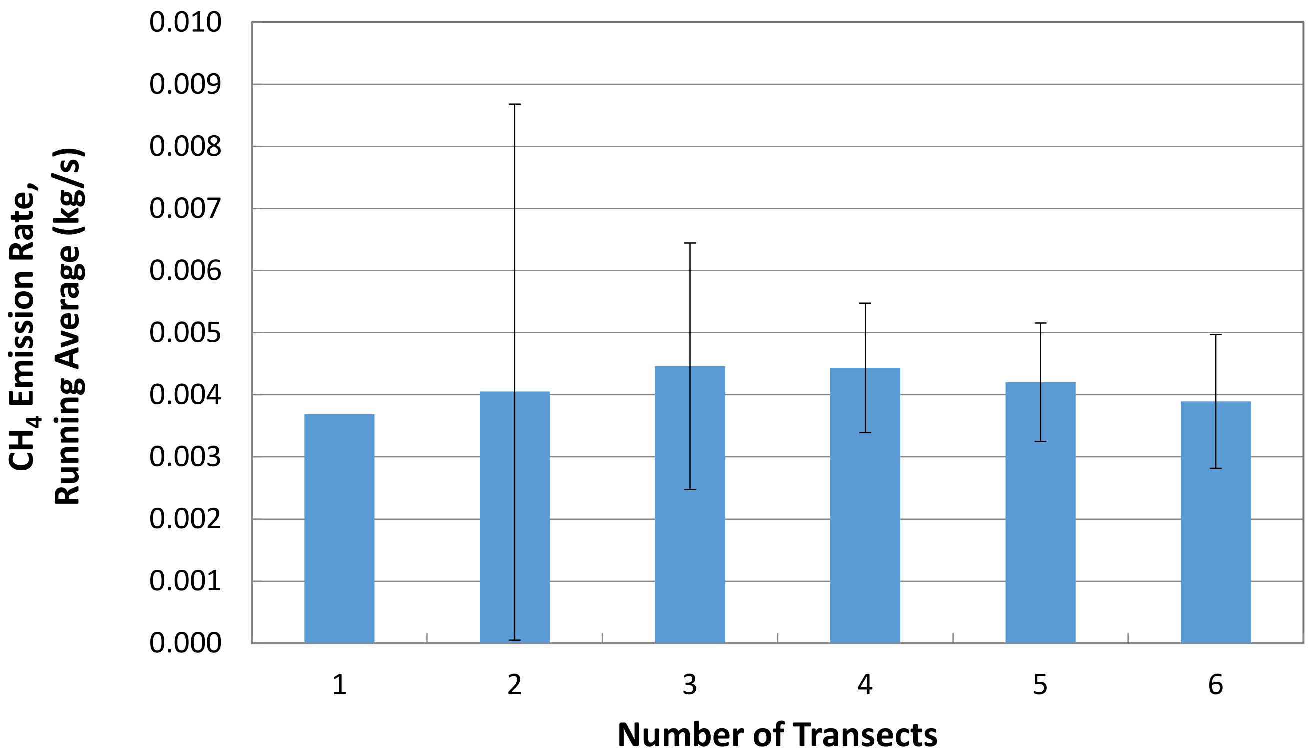
- Good vertical capture
- Good horizontal capture
- Good resolution

Oil Battery – Averaged Vertical Concentration Profile



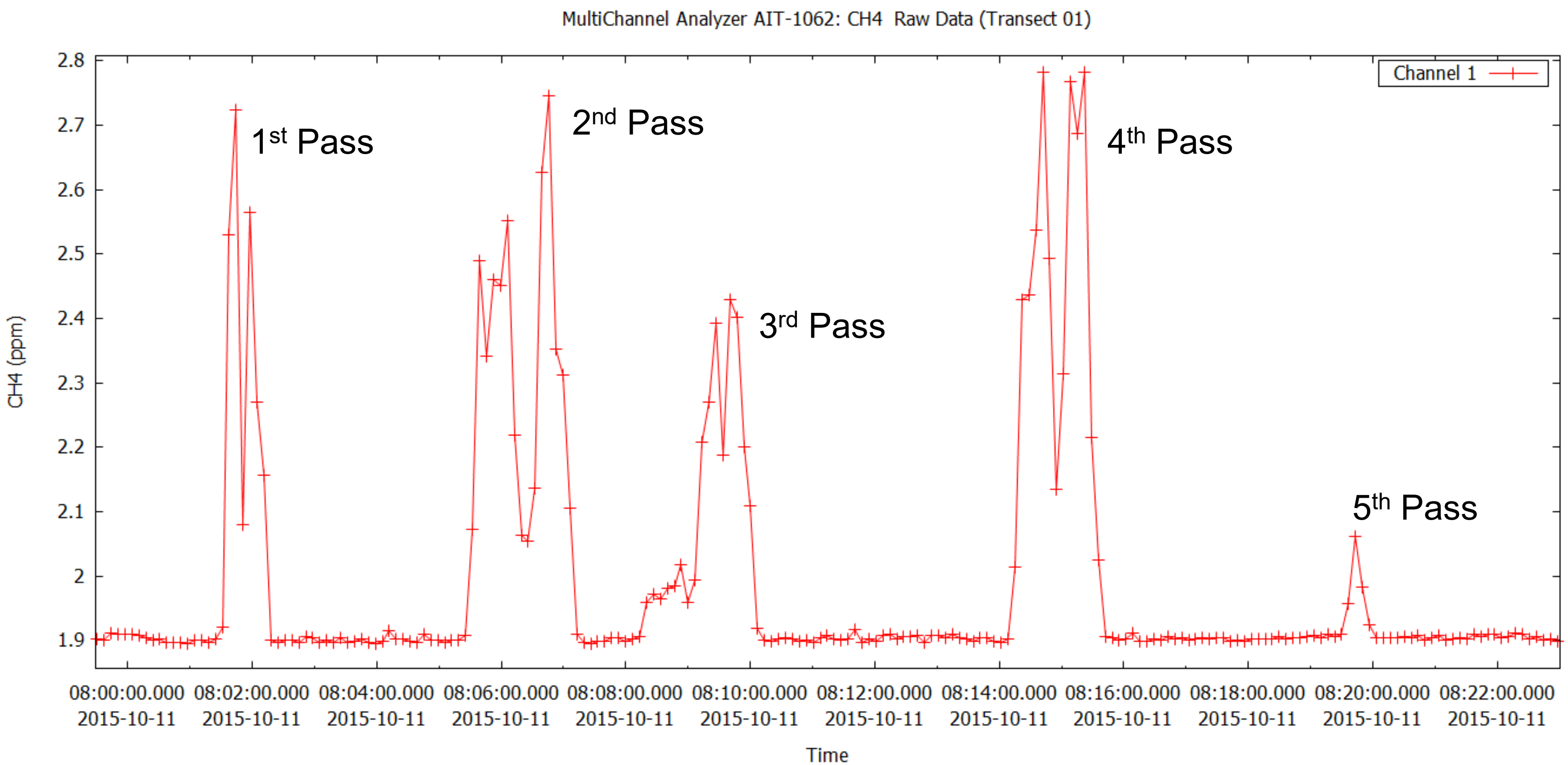
Based on 4 minute stationary measurement in plume, 200 m from source.

Oil Battery – Convergence



95% confidence interval is below
25% of mean after 4 transects

Gas Plant Screening



Passes 1 to 4: 400 m downwind of source
Pass 5: 2 km downwind of source

Coal Mine Tests – Site 4

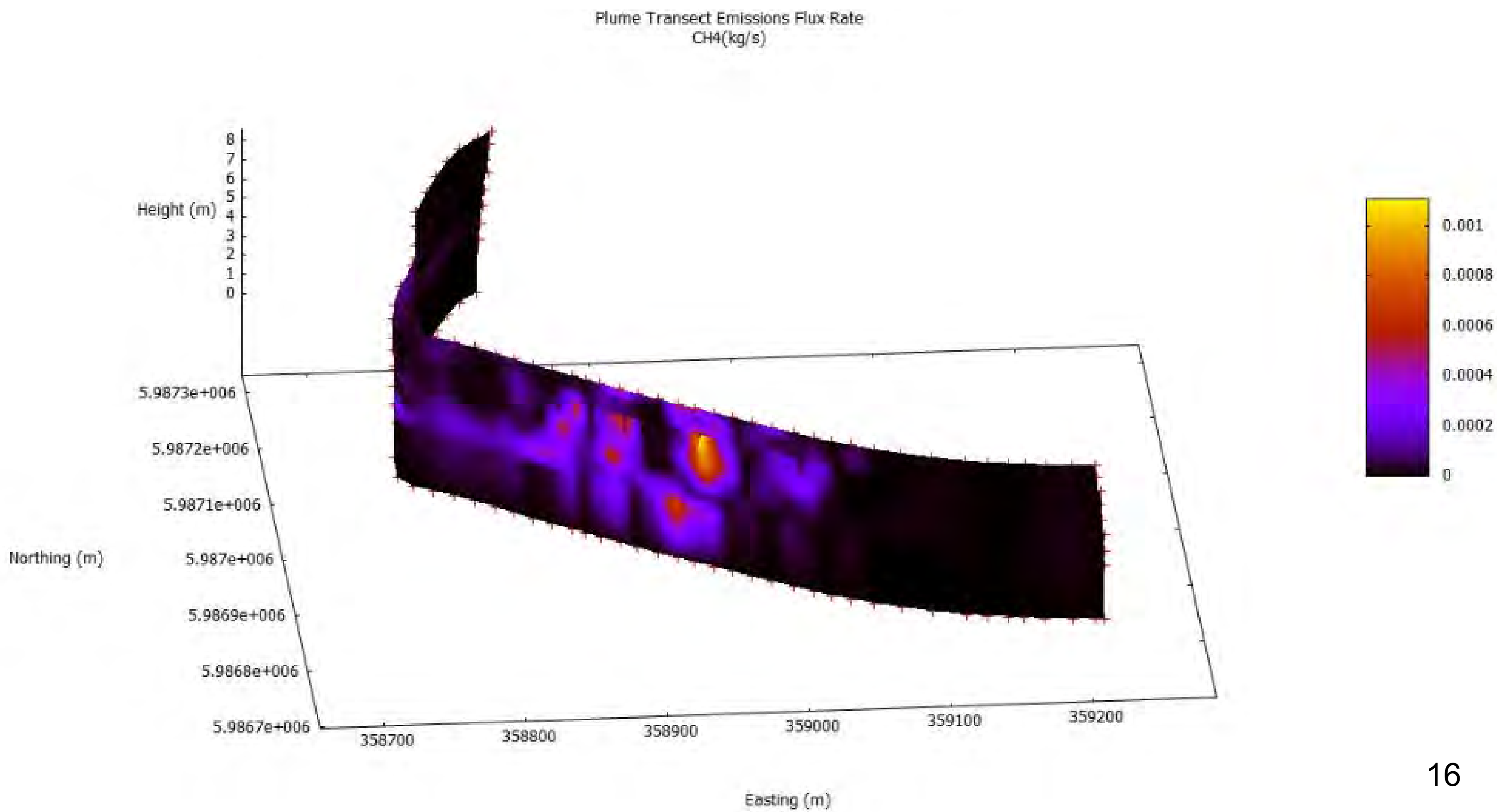
NE Corner of Pit (Mostly Inactive)

SW Corner of Pit (Active)

Immediately Downwind of Active Mine Pit – Site 4

Immediately Downwind of Active Mine Pit – Site 4

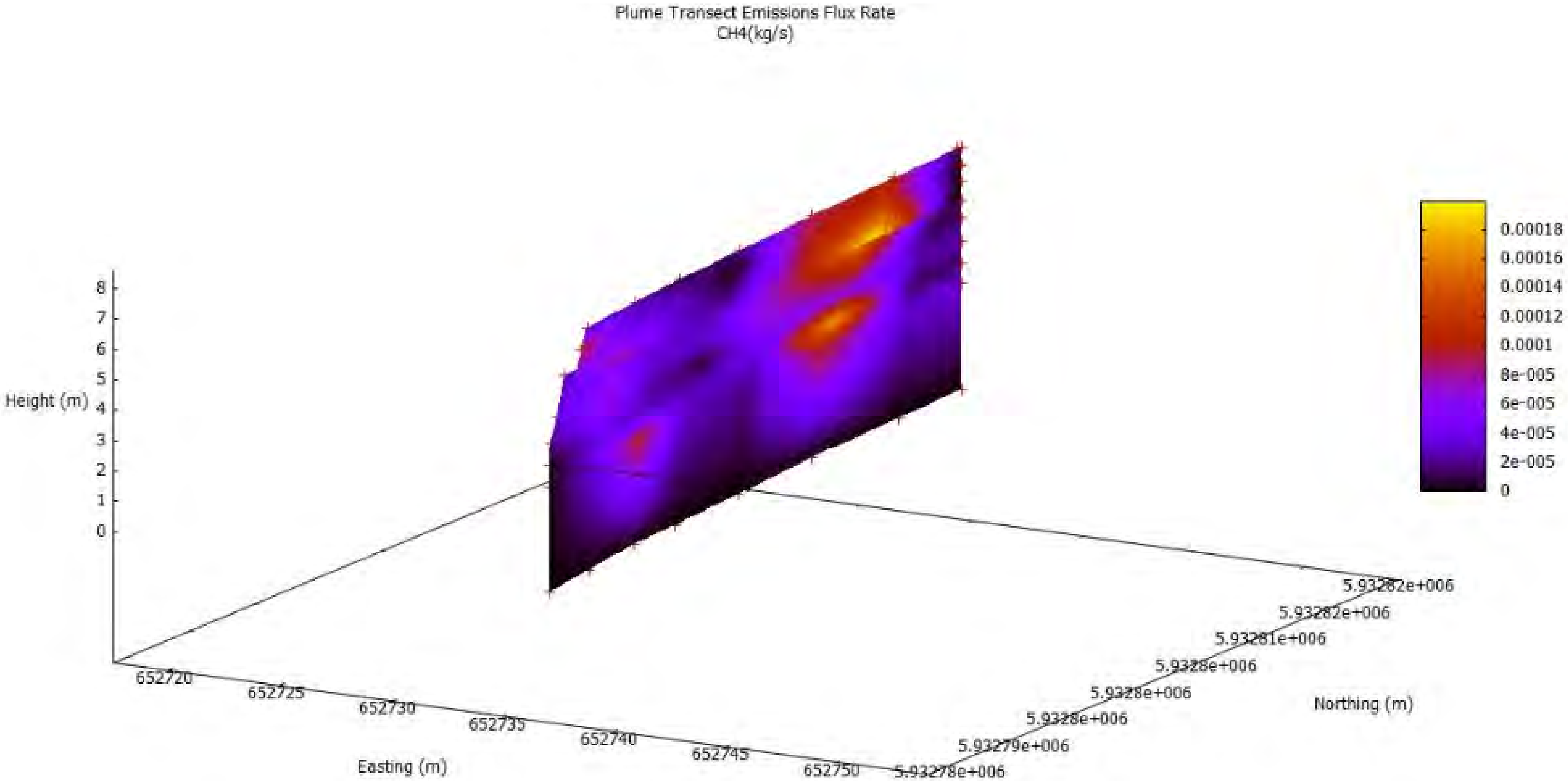
Methane Emissions (kg/s)



Downwind of Truck & Shovel Operation – Site 2

Downwind of Truck & Shovel Operation – Site 2

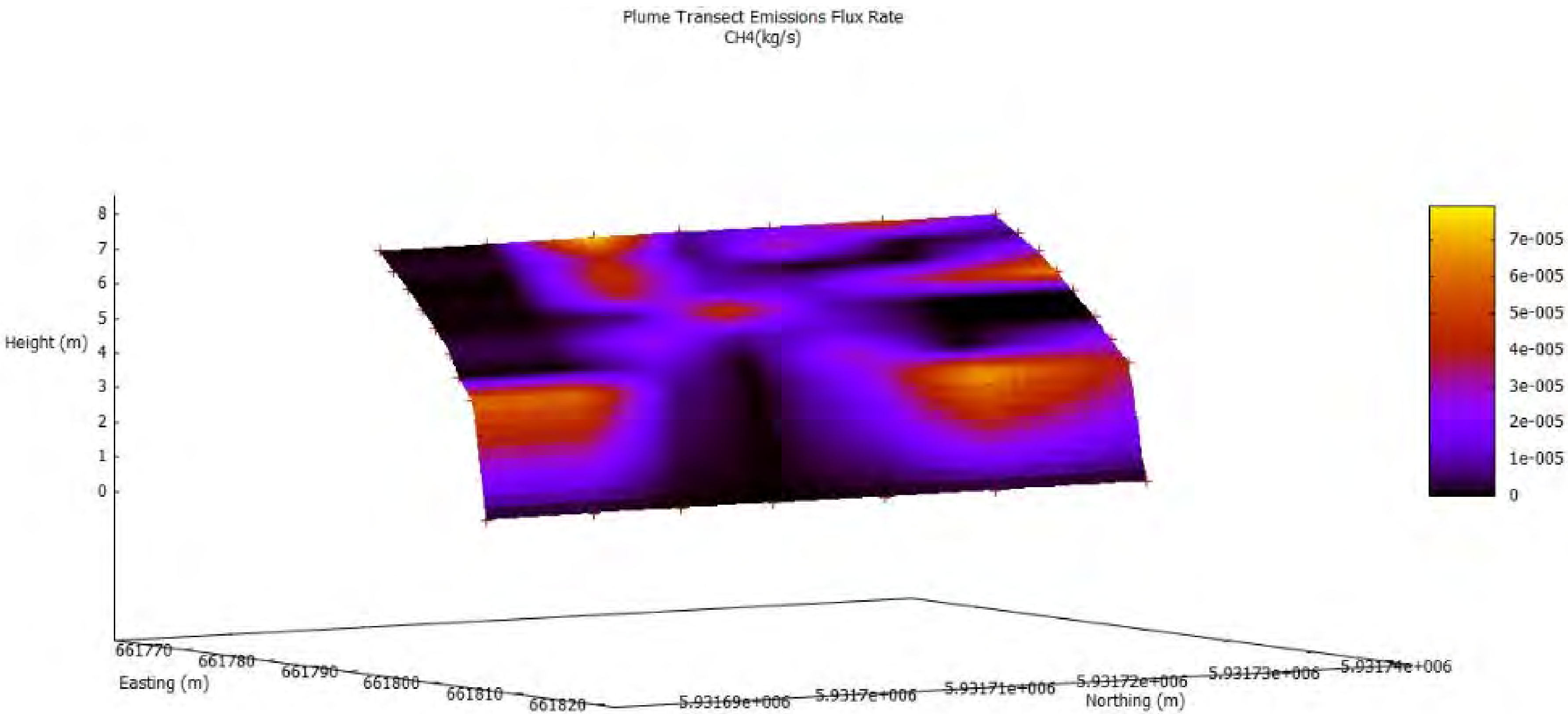
Methane Emissions (kg/s)



Coal Stacking Operation – Site 2

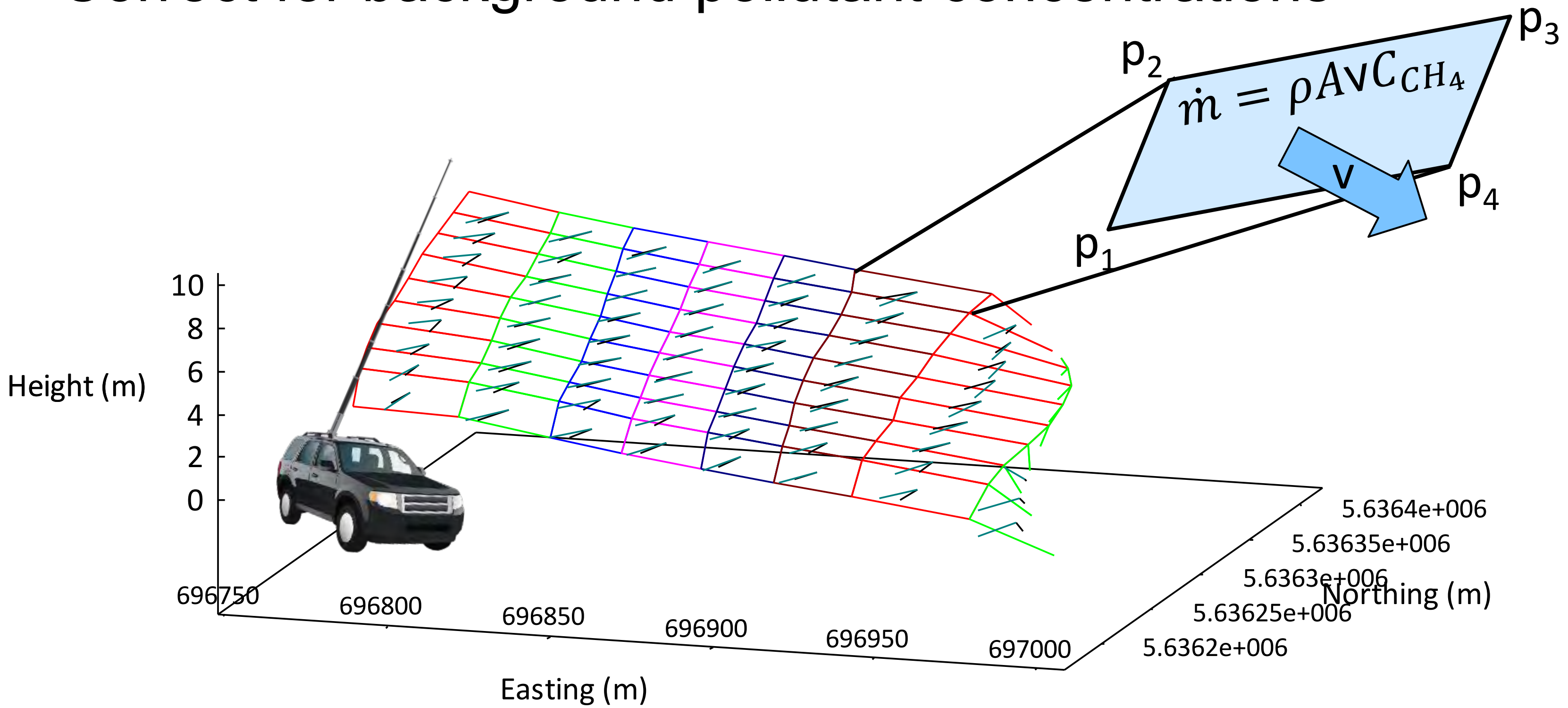
Downwind of Coal Stacking Operation – Site 2

Methane Emissions (kg/s)



Mobile Plume Transect Method

- Vehicle mounted monitoring system
- Traverse emission plume downwind of source
- Measure 2D wind and concentration profiles
- Correct for background pollutant concentrations



Key System Components

Gas Analysis

- $CH_4/CO_2/H_2O$ (fast-response, high-accuracy and high-precision)
- Portable mass spectrometer (real time VOC measurement)
- H_2S/NH_3

Sampling

- Telescoping carbon fiber mast (developed in-house)
- Multi-channel sampling system (developed in-house)

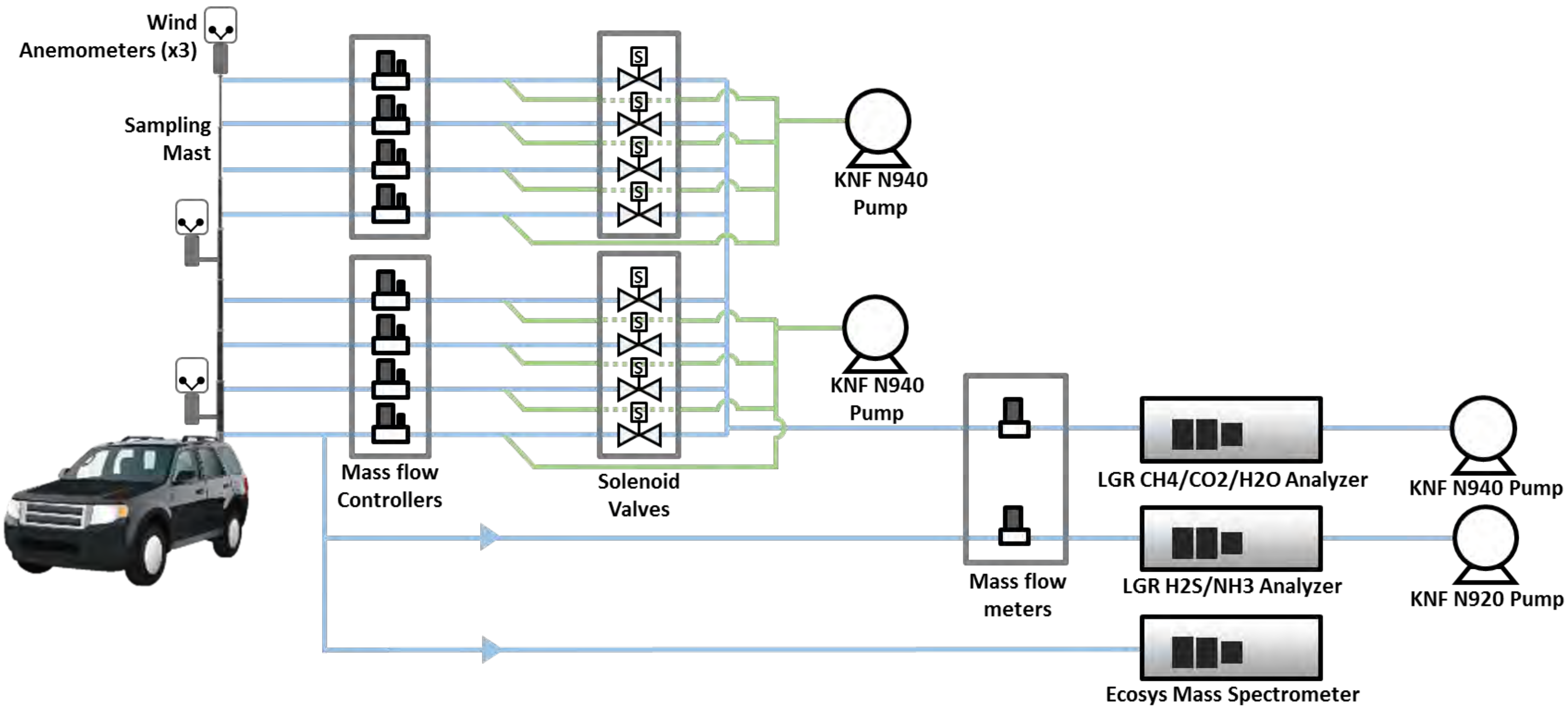
GPS and Wind

- High accuracy global positioning system (GPS) and inertial measurement unit (IMU)
- 3x 3D ultrasonic wind anemometers

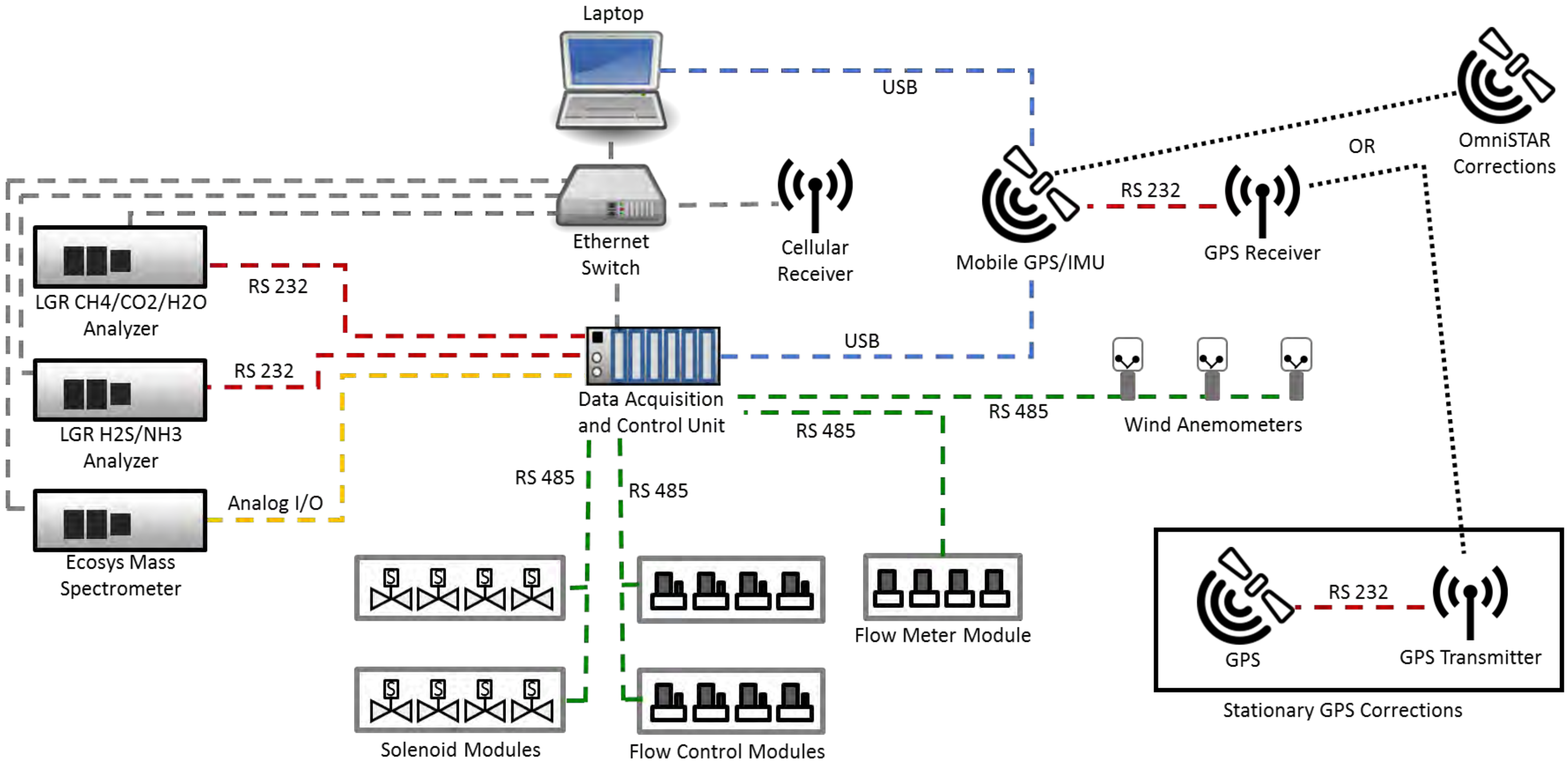
Software

- Real time data acquisition and control
- Near real-time data processing and emissions quantification (developed in-house)

System Setup – Flow Diagram



System Setup – Data Schematic



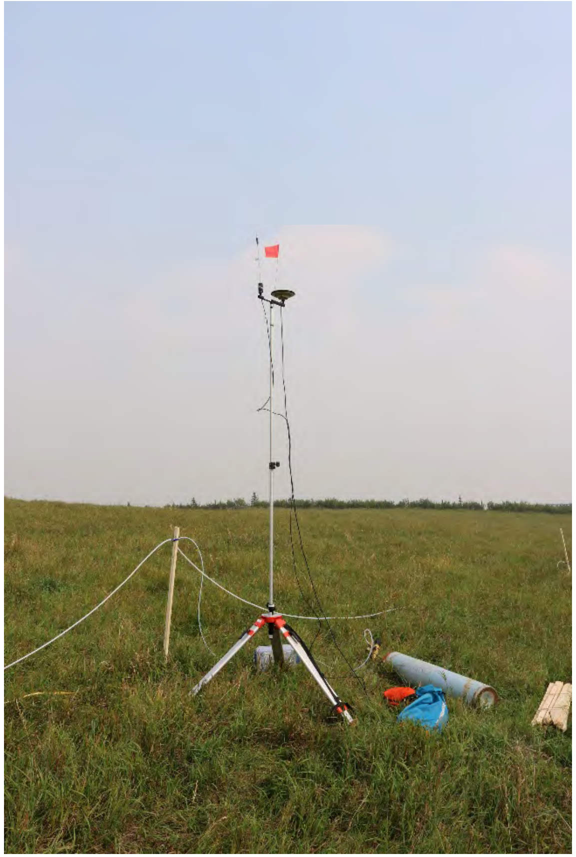
System Setup – Hitch Mounted Mast

Hitch mounted mast for easy setup and take-down

System Setup – Extended Mast

9 m tall mast with
8 sampling channels

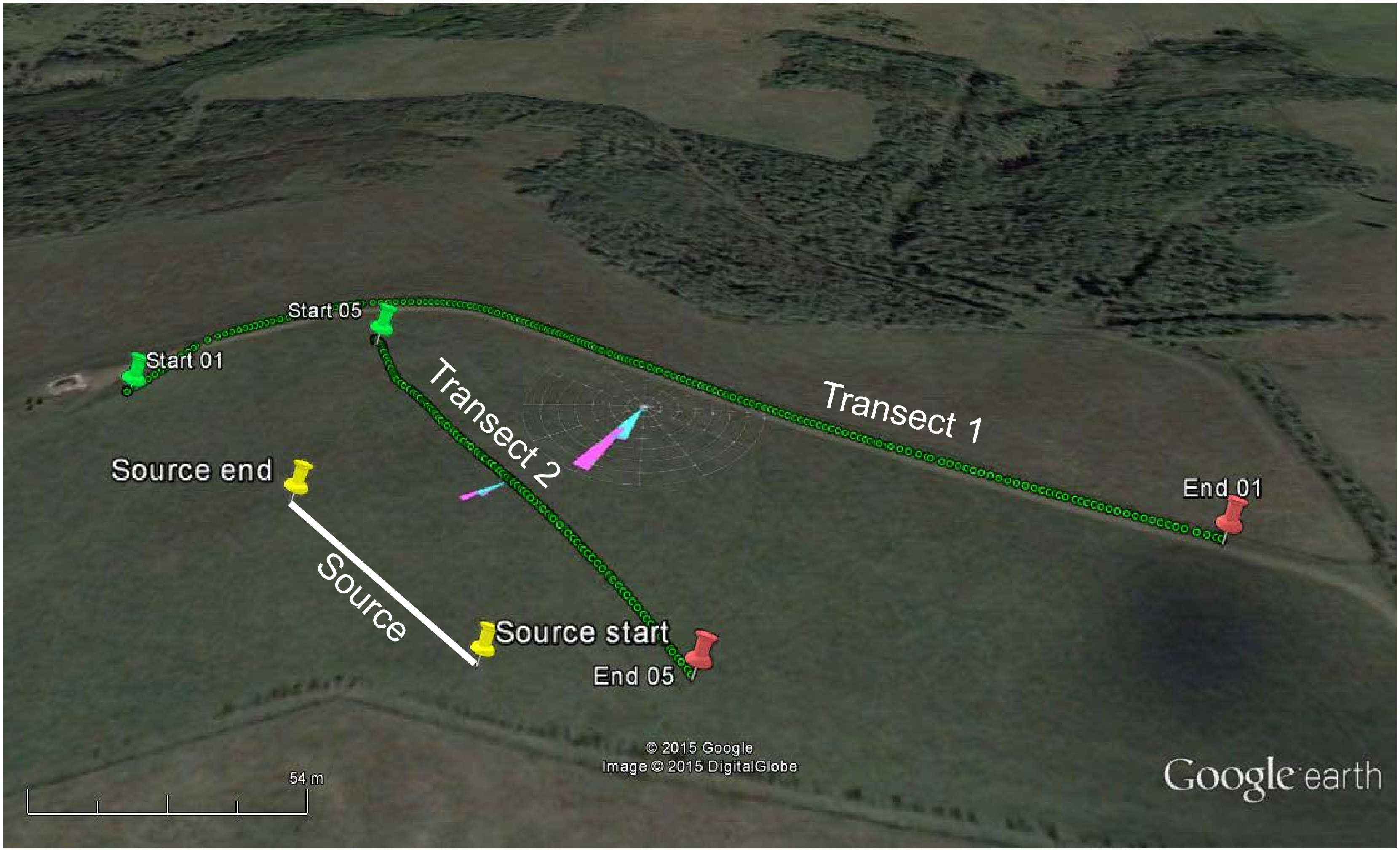
Validation Testing



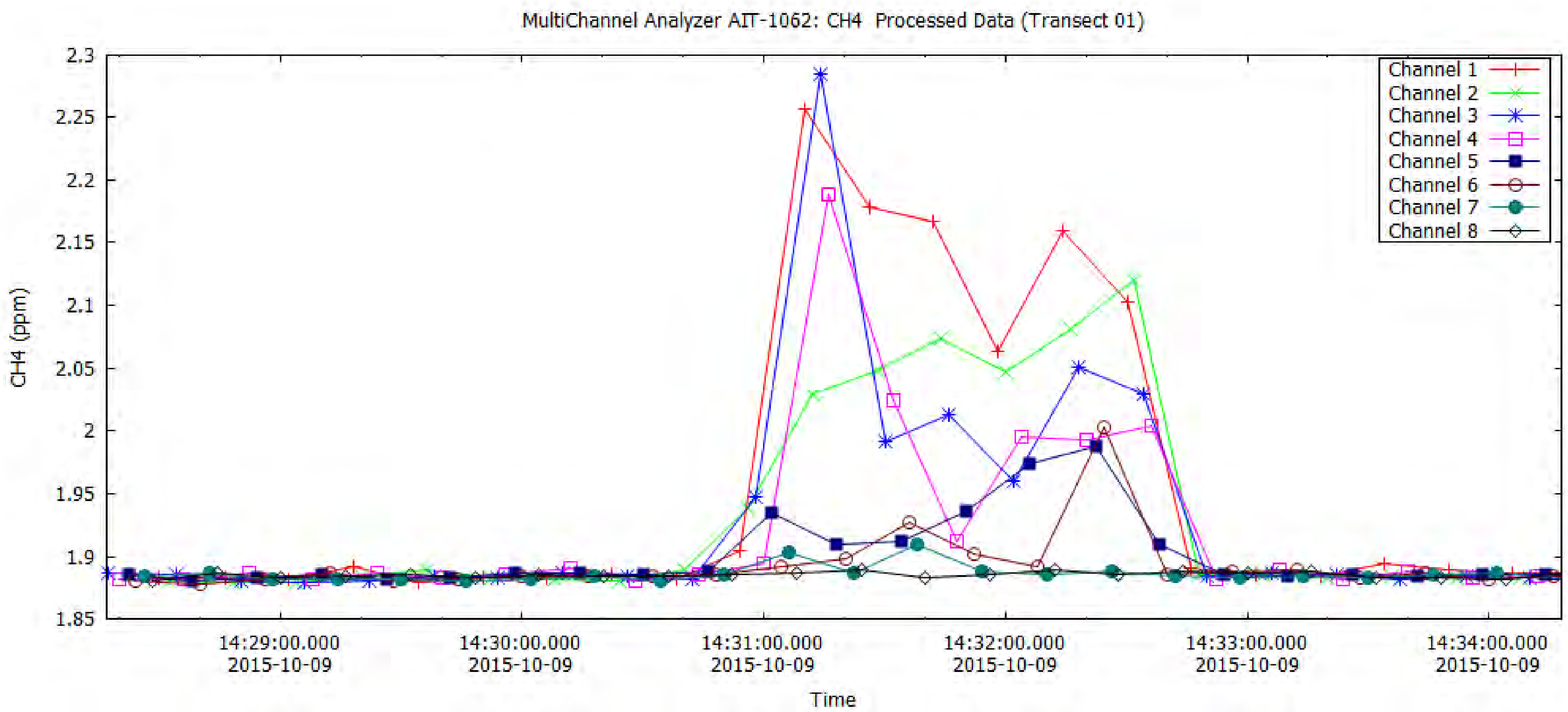
Base station GPS and transmitter (provides correction data)

73 m long line source,
CH_4 release at 0.00017 to 0.00057 kg/s

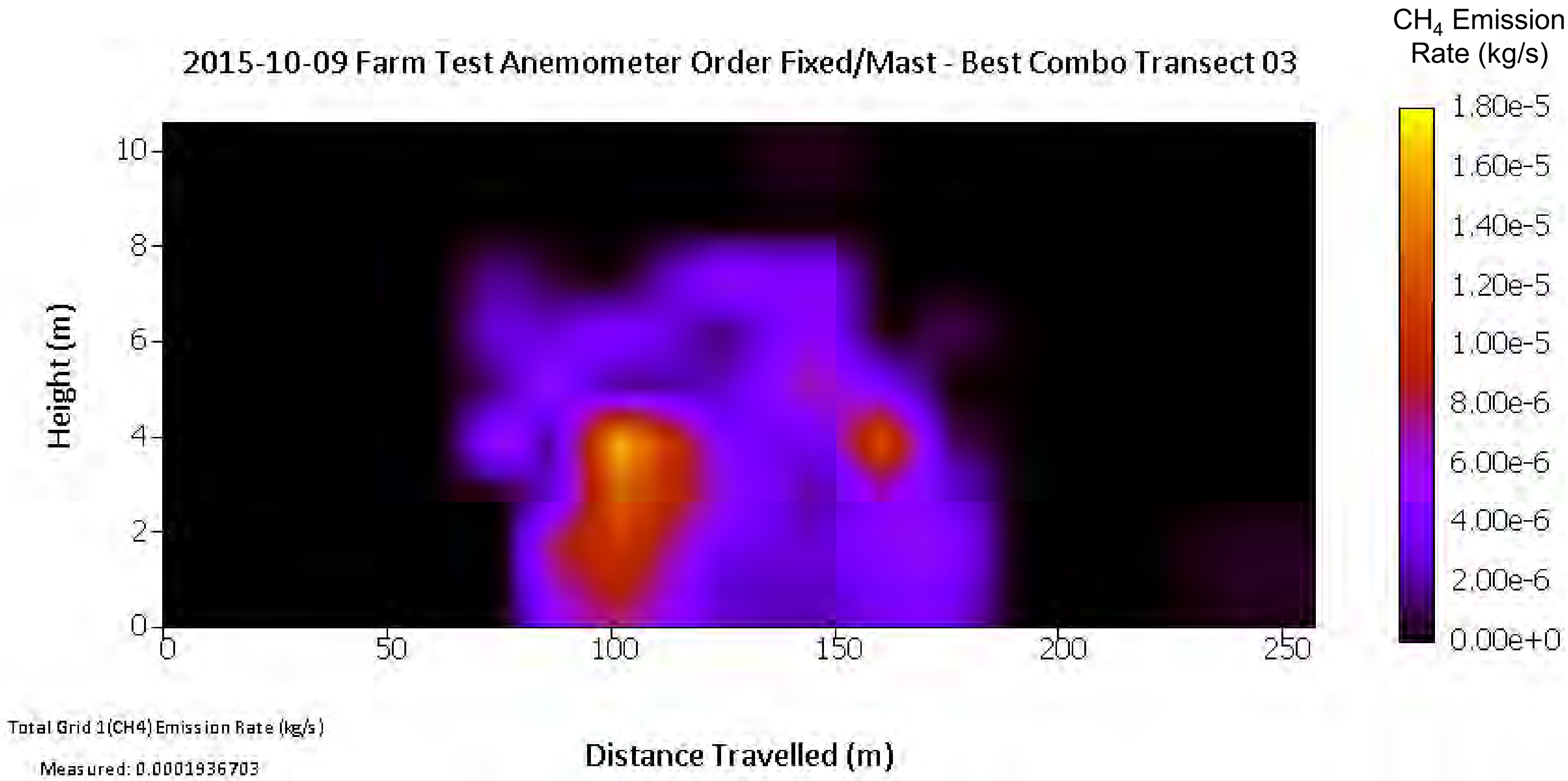
Validation Testing – Transect Path



Validation Testing – Downwind Concentrations

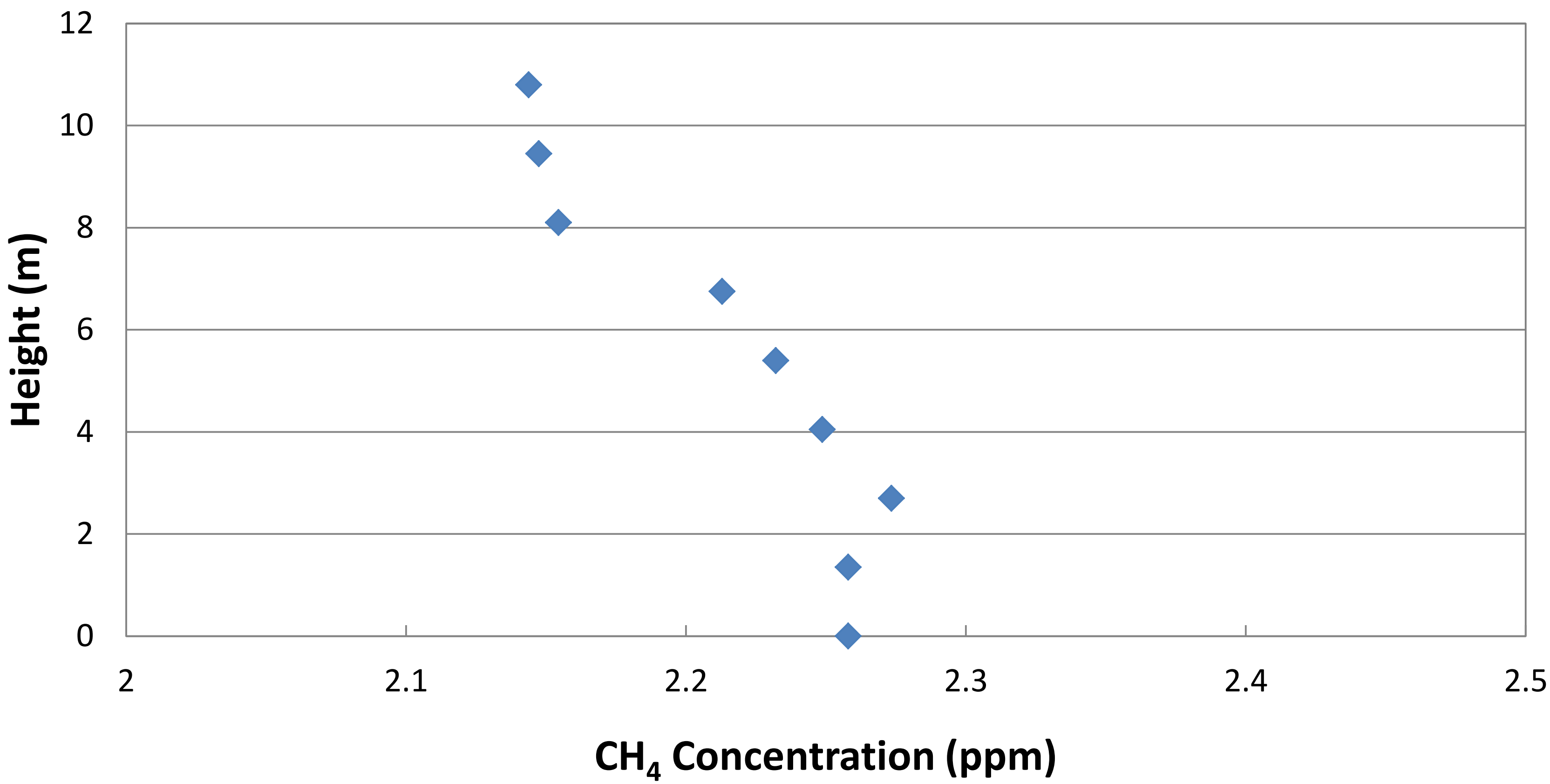


Validation Testing – Emission Rate Contour Plot



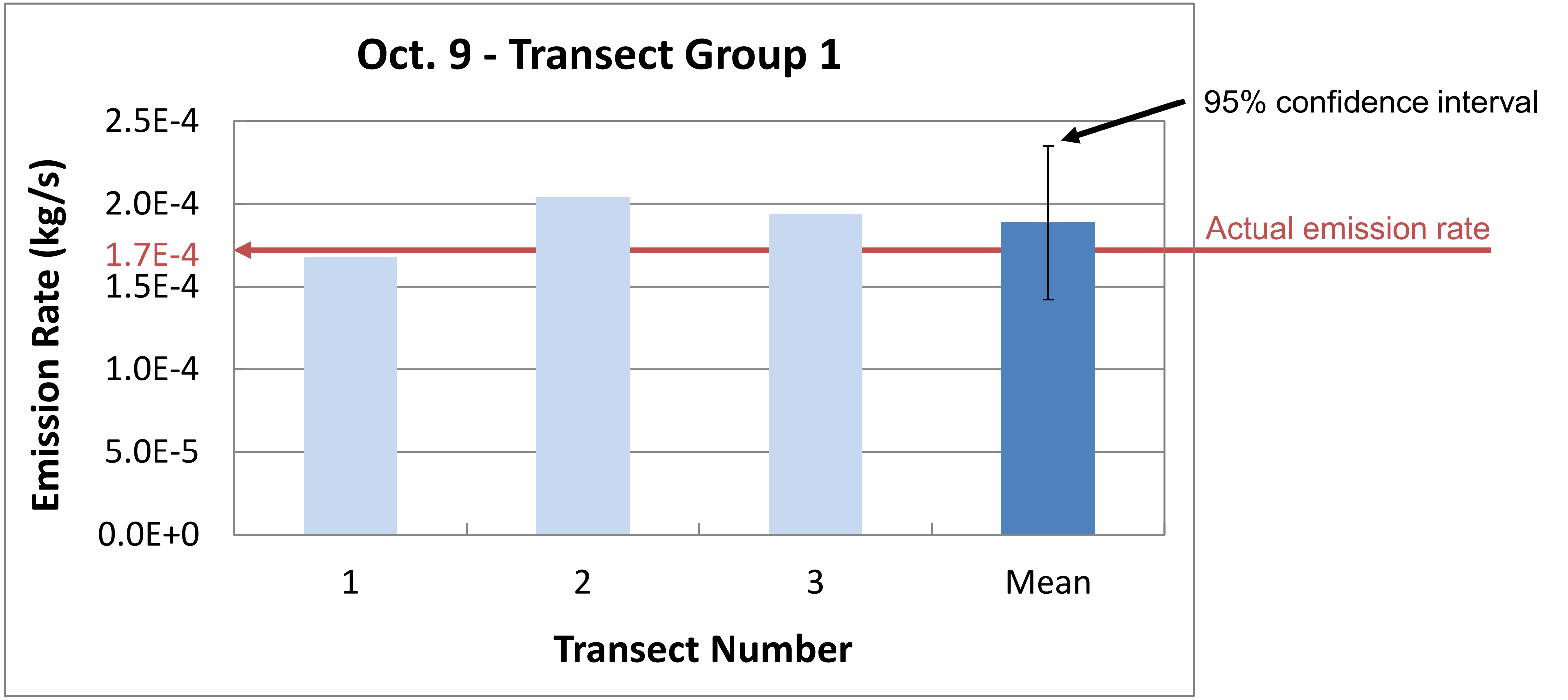
- Good vertical capture
- Good horizontal capture
- Good resolution

Validation Testing – Averaged Vertical Concentration Profile



Based on 4 minute stationary measurement in the plume, 90 m away from the source

Validation Testing – Accuracy



Emission source: methane (CH_4)

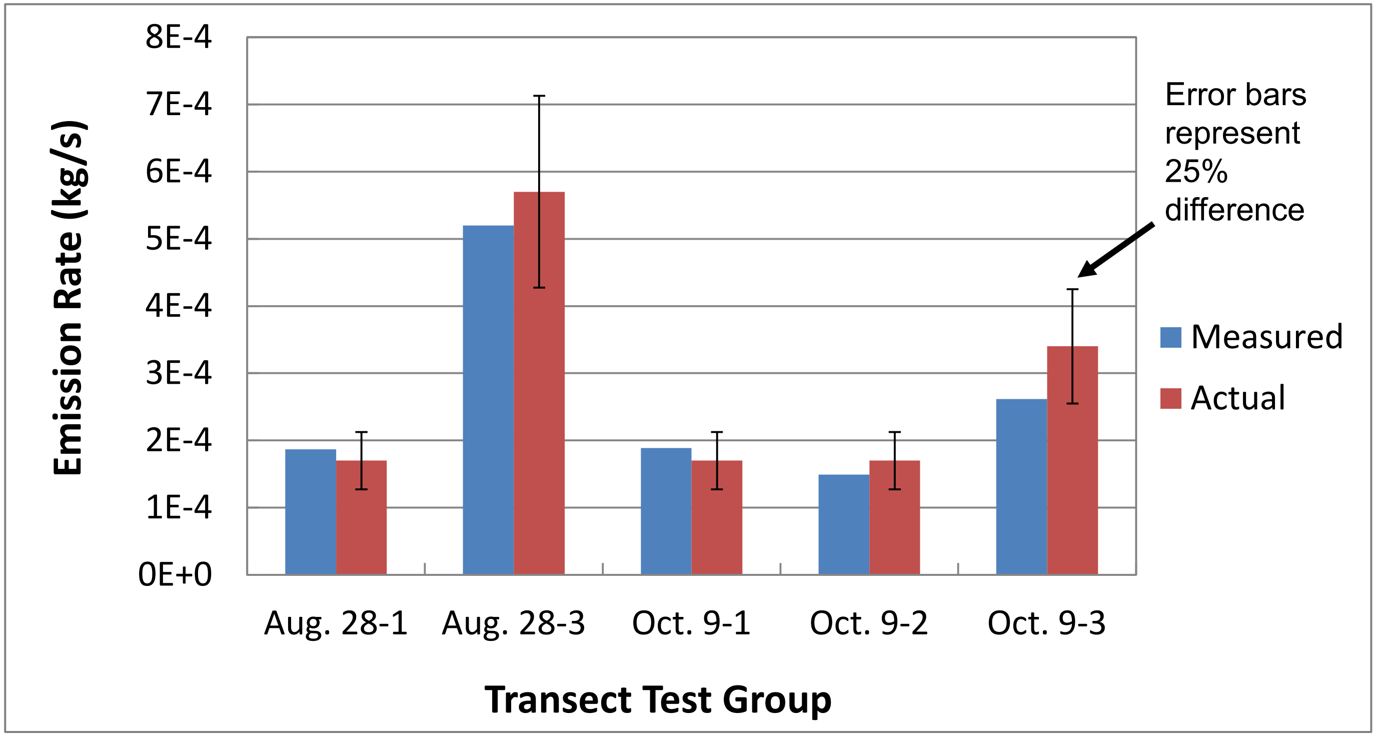
Source type: line source, 73 m long, at a height of 1 m

Emission rate: 0.00017 kg/s

Distance from source: 100 m

Grid resolution (width of cell): 13 m

Validation Testing – Accuracy



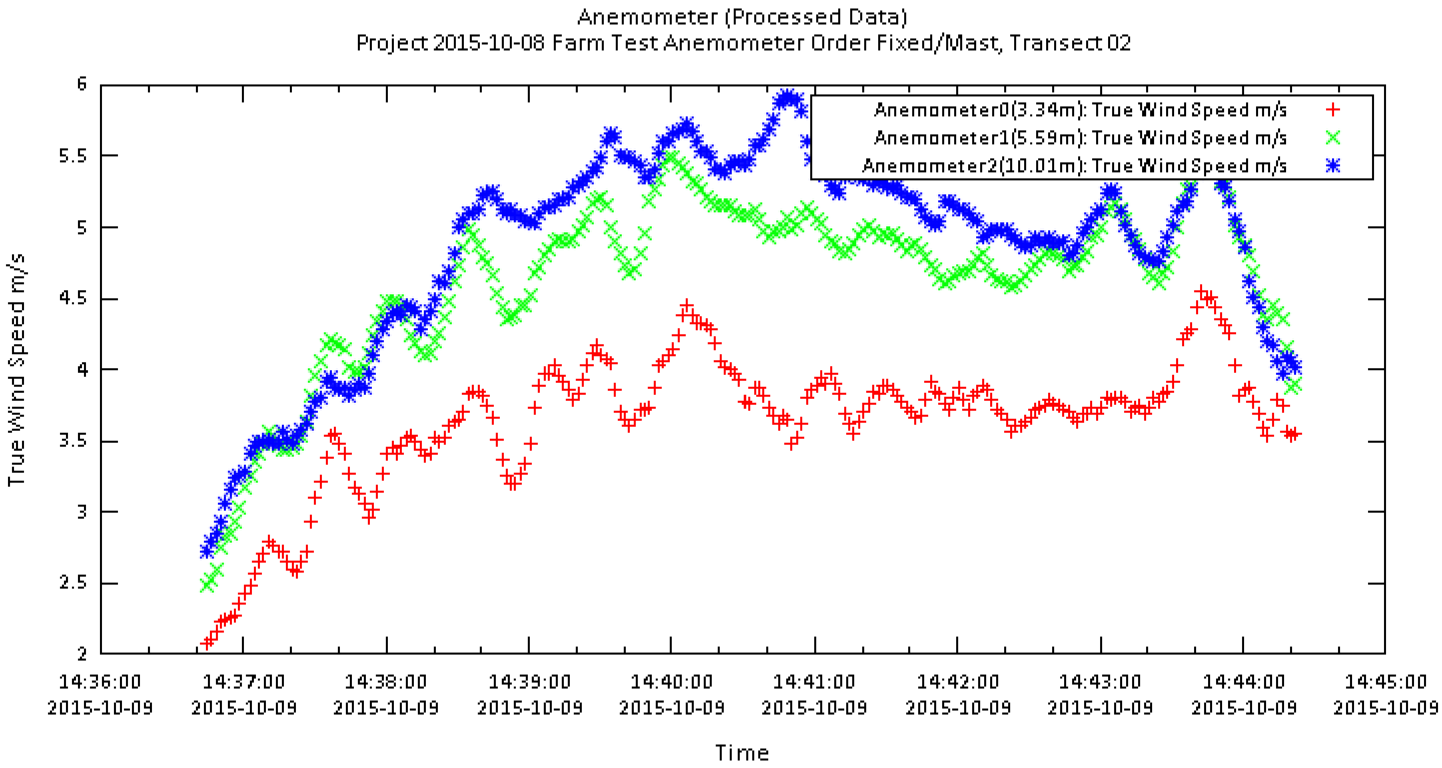
Emission source: methane (CH_4)
Source type: line, 73 m long, @ height of 1 m
Testing conducted on Aug. 28 and Oct. 9, 2015
Average of 3 transects (except Aug. 28-3, which has 2)

Summary

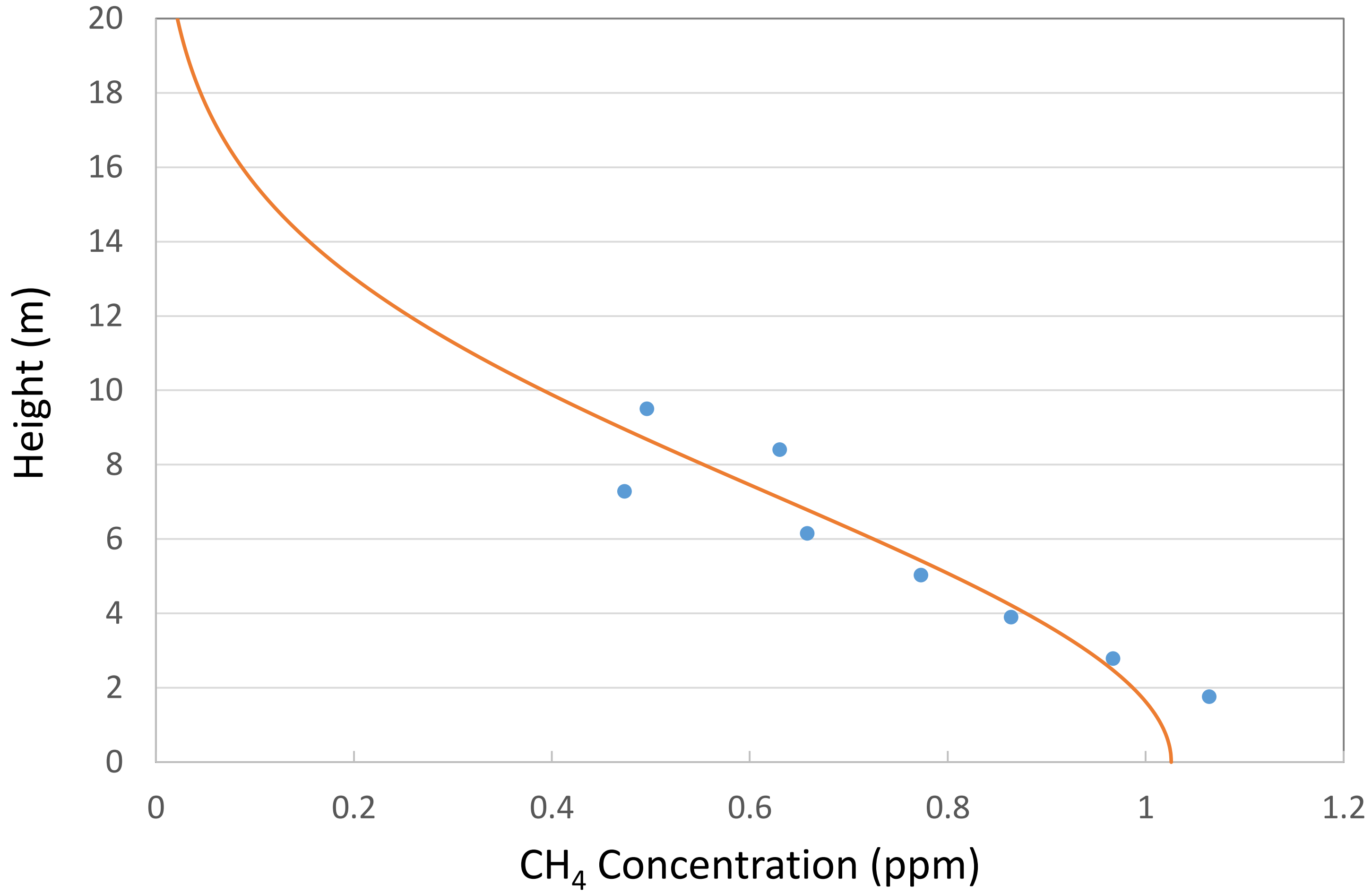
- Mobile system for remote monitoring of emissions
- Tested applications: gas plants, oil batteries, coal mines
- Steps: screening → transect → stationary measurement
- Advantages:
  - Real time measurement of VOCs
  - Methane emission rate, sensitivity ≤ 5E-5 kg/s, accuracy ≤ 25%
  - Resolution ≤ 10 m (horizontal), 1 m (vertical)
- Limitations:
  - 10 m height limit
  - Steady wind required
  - Downwind access required

Questions?

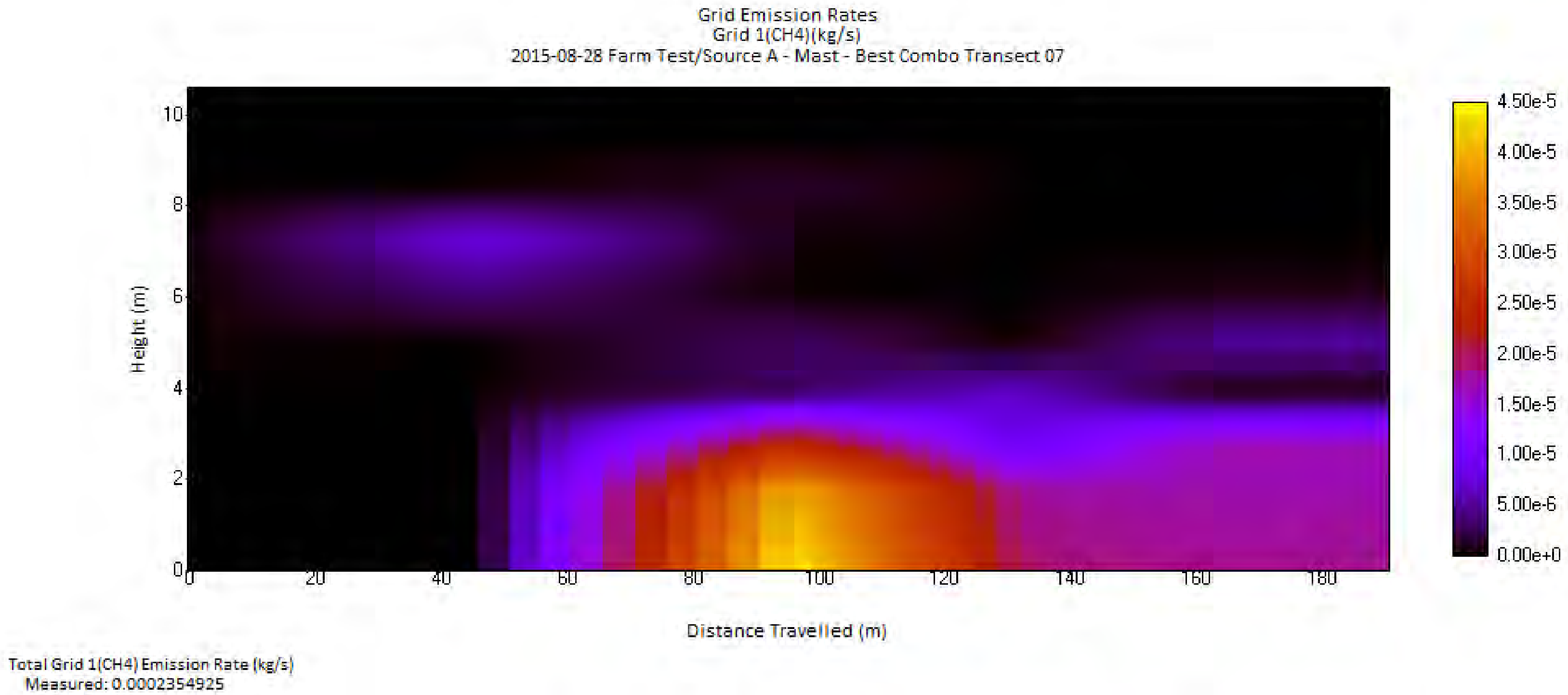
Wind Anemometer Data



Oil Battery – Vertical Plume Capture Correction

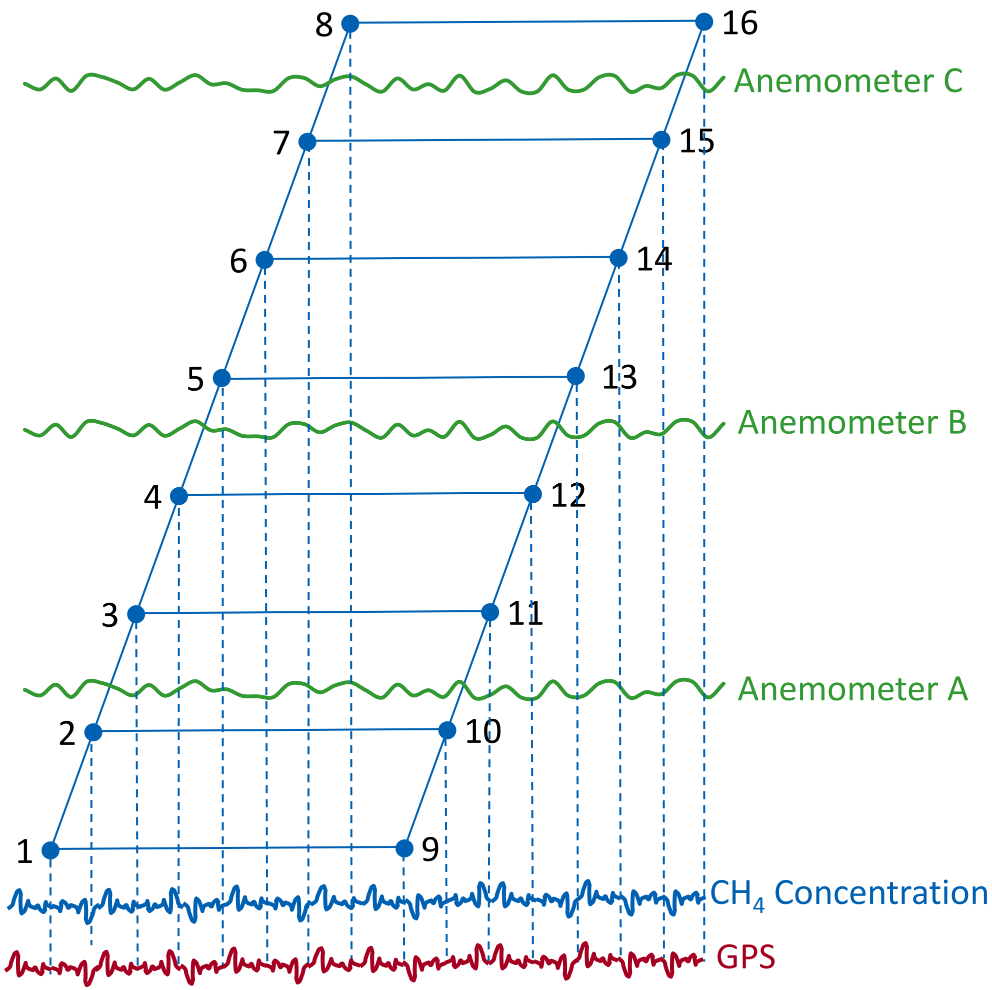


Validation Testing – Emission Rate Contour Plot 2



- Ground level plume (mitigate with ground level profiling)
- Good horizontal capture
- Poor resolution

Plume Transect Method



2015年11月20日
中国，北京

远程监测排放量的移动烟缕截面系统

由Jan Gorski和Dan Field制作
Clearstone Engineering Ltd.

烟缕截面排放量化策略

筛选 → **截面** → **固定测量** → **随机取样**

筛选

- 筛选参照化合物和关注污染物定位排放烟缕和可能的干扰来源
- 参照化合物：CH_4，CO_2
- 关注污染物：VOCs，H_2S，NH_3

截面

- 量化参照污染物排放量（CH_4和CO_2）
- 测位仪需寻找监听障碍，如天线杆较高的输电线

固定测量

- 监控关注污染物与参照化合物的比率
- 确定关注污染物相关最佳参照污染物
- 计算污染物排放量

随机取样

- 通过实验室分析获取更准确详细的VOC排放量形成及其他可能污染物量化
- 上风向和下风向随机取样

VOC（挥发性有机化合物） 量化策略

- 量化参照污染物排放率（CH_4或CO_2）
- 根据质谱仪数据或随机取样分析确定参照污染物与VOCs的比率
- 确定VOC排放率：

$$\dot{m}_{VOC} = \dot{m}_{ref} \frac{C_{VOC} - C_{VOC,\,background}}{C_{ref} - C_{ref,\,background}}$$

$\dot{m}_{VOC}$	=	VOC排放率
$\dot{m}_{ref}$	=	参照污染物排放率
C_{VOC}	=	烟缕中的VOC浓度
$C_{VOC,\,background}$	=	VOC背景浓度
C_{ref}	=	烟缕中的参照污染物浓度
$C_{ref,\,background}$	=	参照污染物背景浓度

系统功能和局限

功能

- 实时测量，移动部署，离线访问
- 高灵敏度，可在一百米外测量0.00017kg/s CH_4
- 准确率和精确度≤25%
- 网格分辨率≤10m

局限

- 需适宜且稳定的风
- 高度限制为10m（靠近测量）
- 分辨率依赖于行驶速度

气体分析仪说明

- $CH_4/CO_2/H_2O$ – 离轴积分腔输出光谱仪
- VOCs – 便携式质谱仪
- H_2S/NH_3 – 离轴积分腔输出光谱仪

分析器	物质	测量范围 (百万分率)	精确度, 1-σ (百万分率)	响应时间 (秒)
1	甲烷 (CH_4)	0.1 - 1000	0.007 (10 Hz)	1.5
	二氧化碳 (CO_2)	200 - 4,000	1 (10 Hz)	1.5
	水 (H_2O)	100 - 70,000	100 (10 Hz)	1.5
2	挥发性有机化合物 (VOCs, 半定量)	MDL: 0.001 - 0.05	<0.001 (1 Hz)	60 - 180
3	氨 (NH_3)	0.001 - 10	0.0006 (0.1 Hz)	5
	硫化氢 (H_2S)	0.05 - 50	0.005 (0.1 Hz)	5

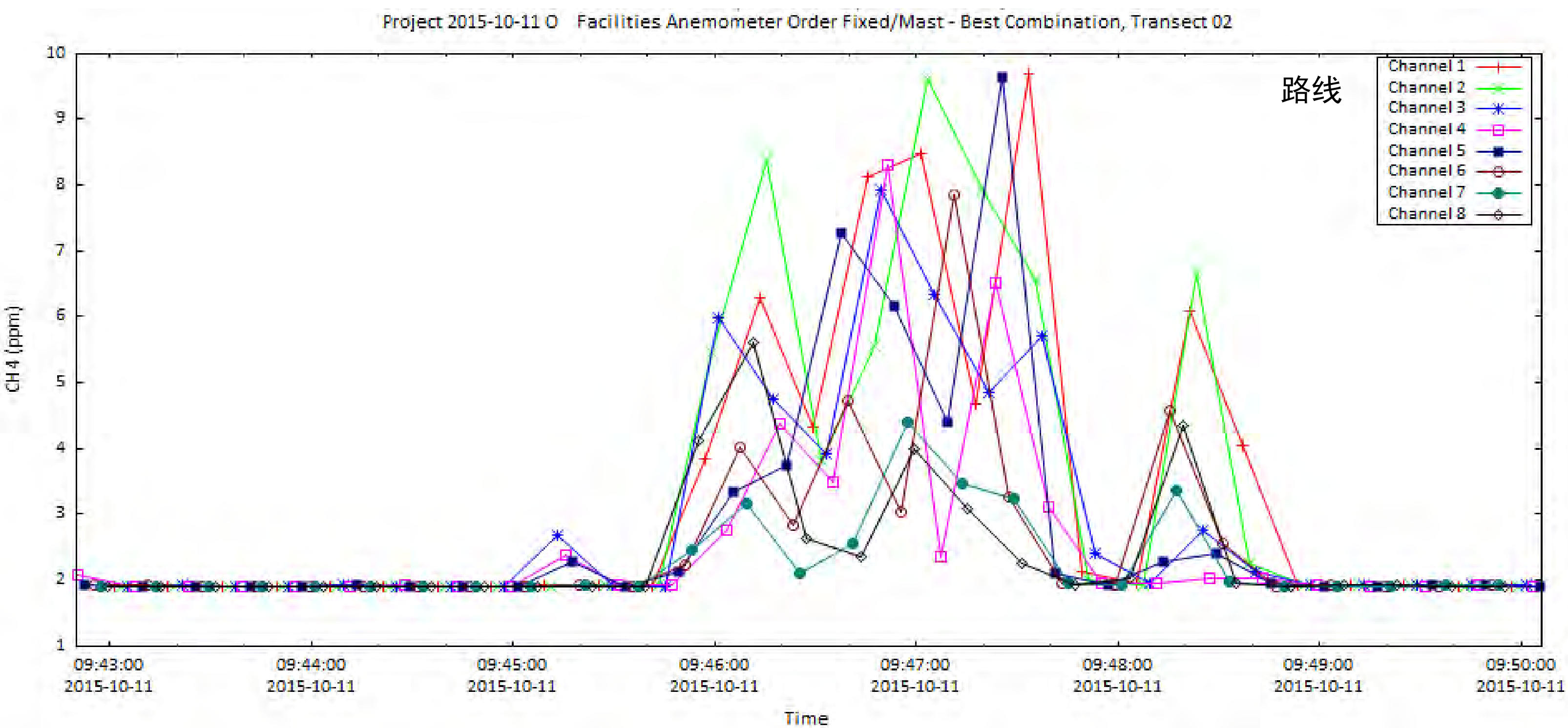
油罐区测量

油罐区 – 截面路线


终点
End 01
油罐区
Start 01
起点
Image © 2015 DigitalGlobe
© 2015 Google
66 m
Google earth

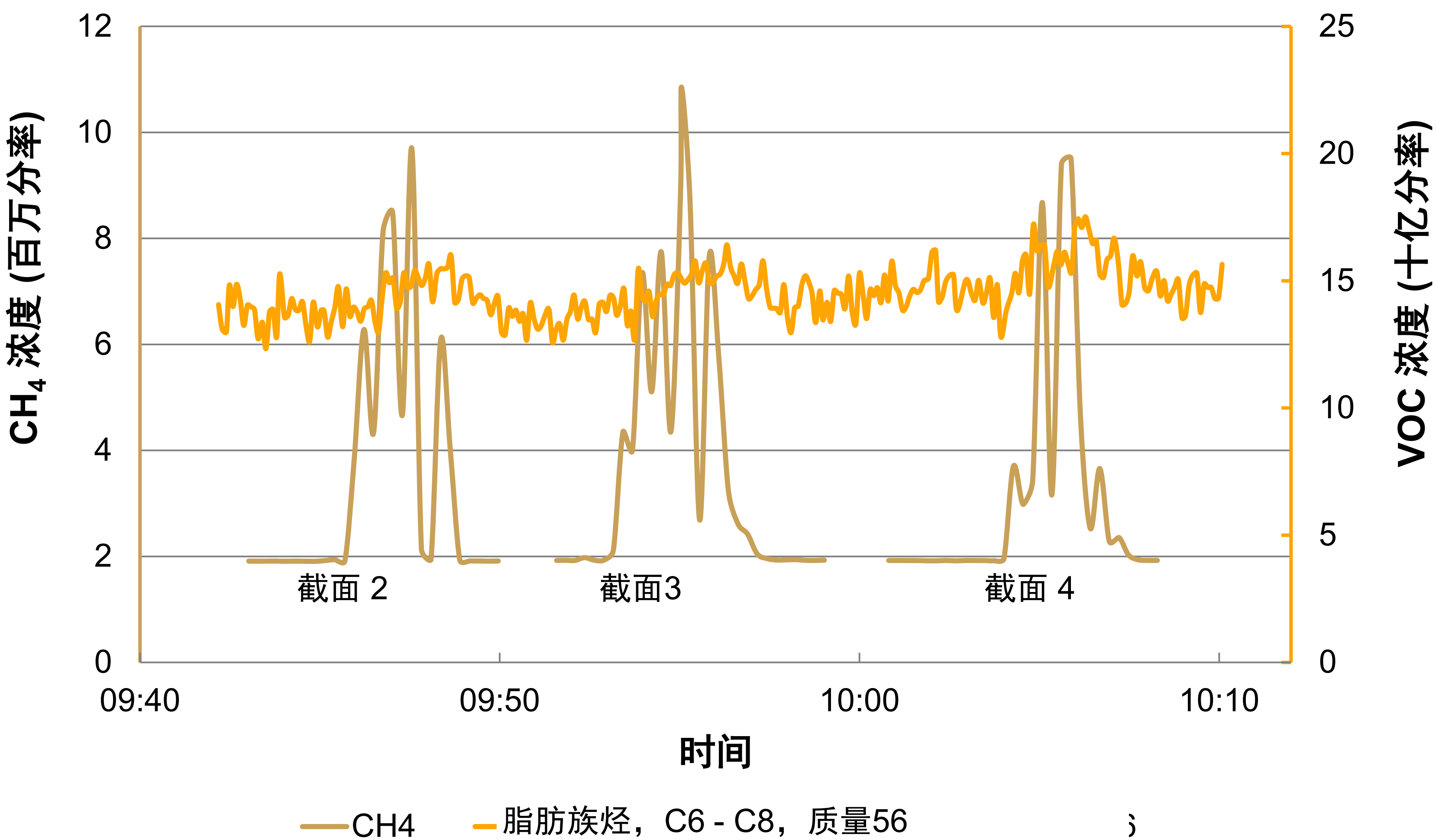
油罐区 – 下风向浓度

2015-10-11项目 设备风速计固定顺序/桅杆——最佳搭档　02截面



时间

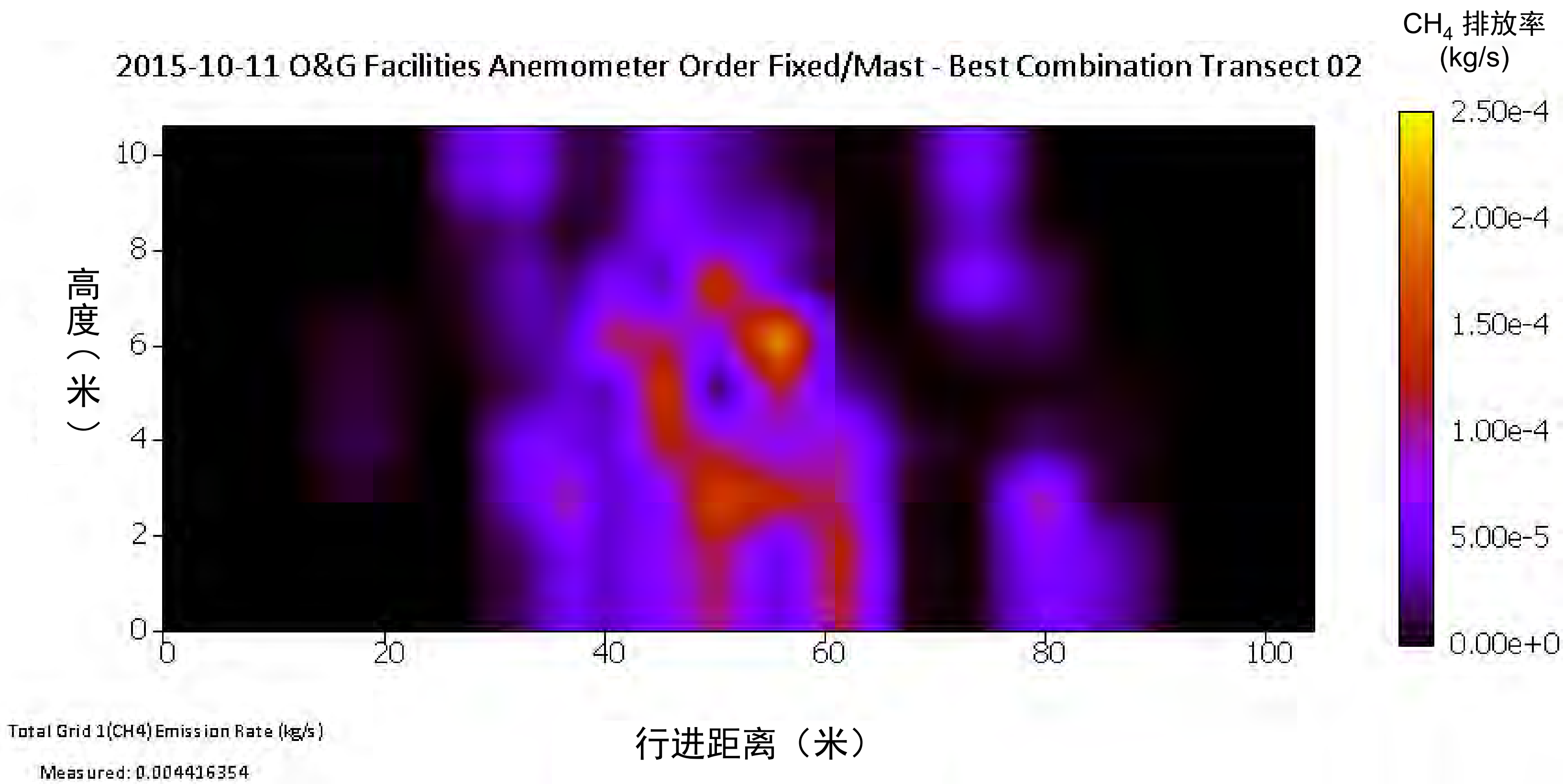
油罐区 – VOC 结果



12
10
8
6
4
2
0
25
20
15
10
5
0
CH_4 浓度 (百万分率)
VOC 浓度 (十亿分率)
截面 2
截面3
截面 4
09:40
09:50
10:00
10:10
时间
CH4
脂肪族烃，C6 - C8，质量56

油罐区 – 排放率等高线图

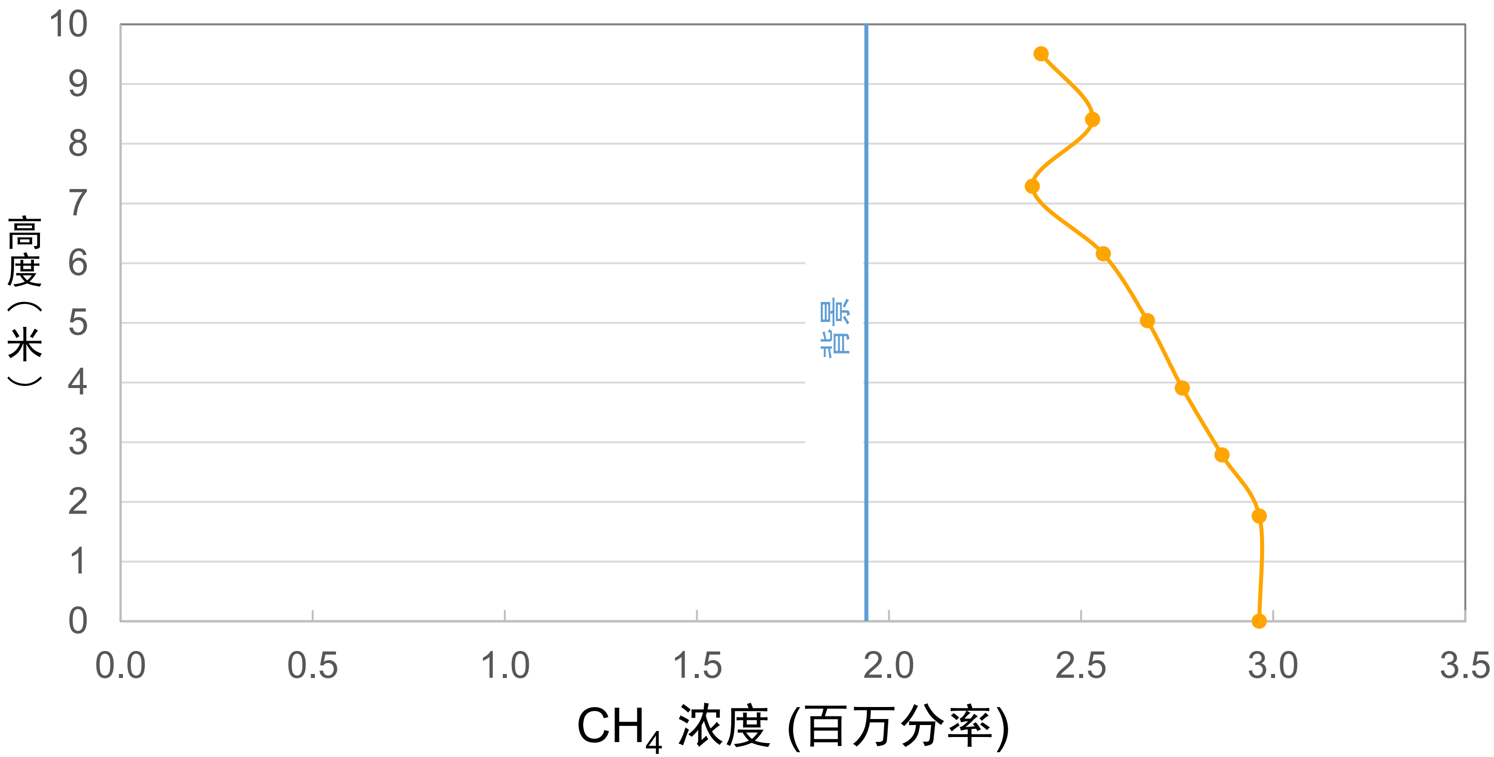
2015-10-11项目 油气设备风速计固定顺序/桅杆——最佳搭档 02截面



总释放速率

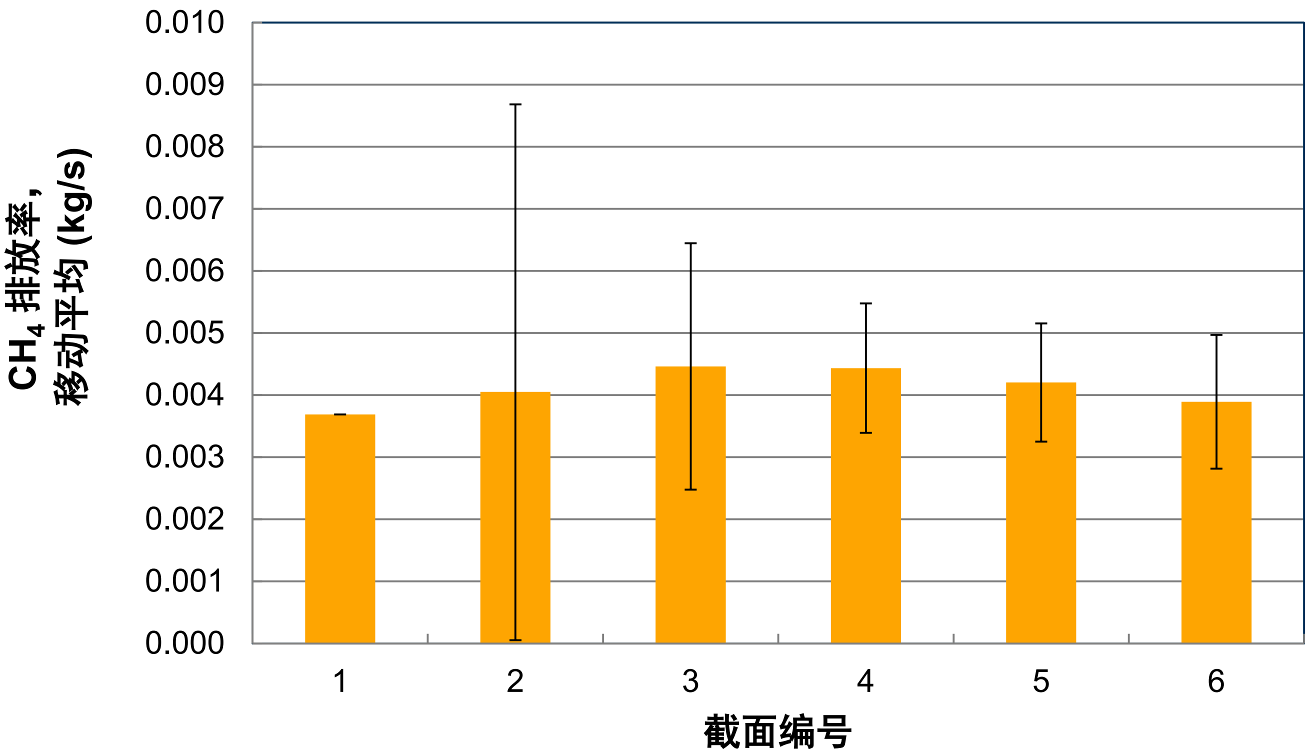
- 垂直捕捉良好
- 水平捕捉良好
- 高分辨率

油罐区 – 平均垂直浓度图



根据间隔4分钟的烟缕固定测量，距离来源200米

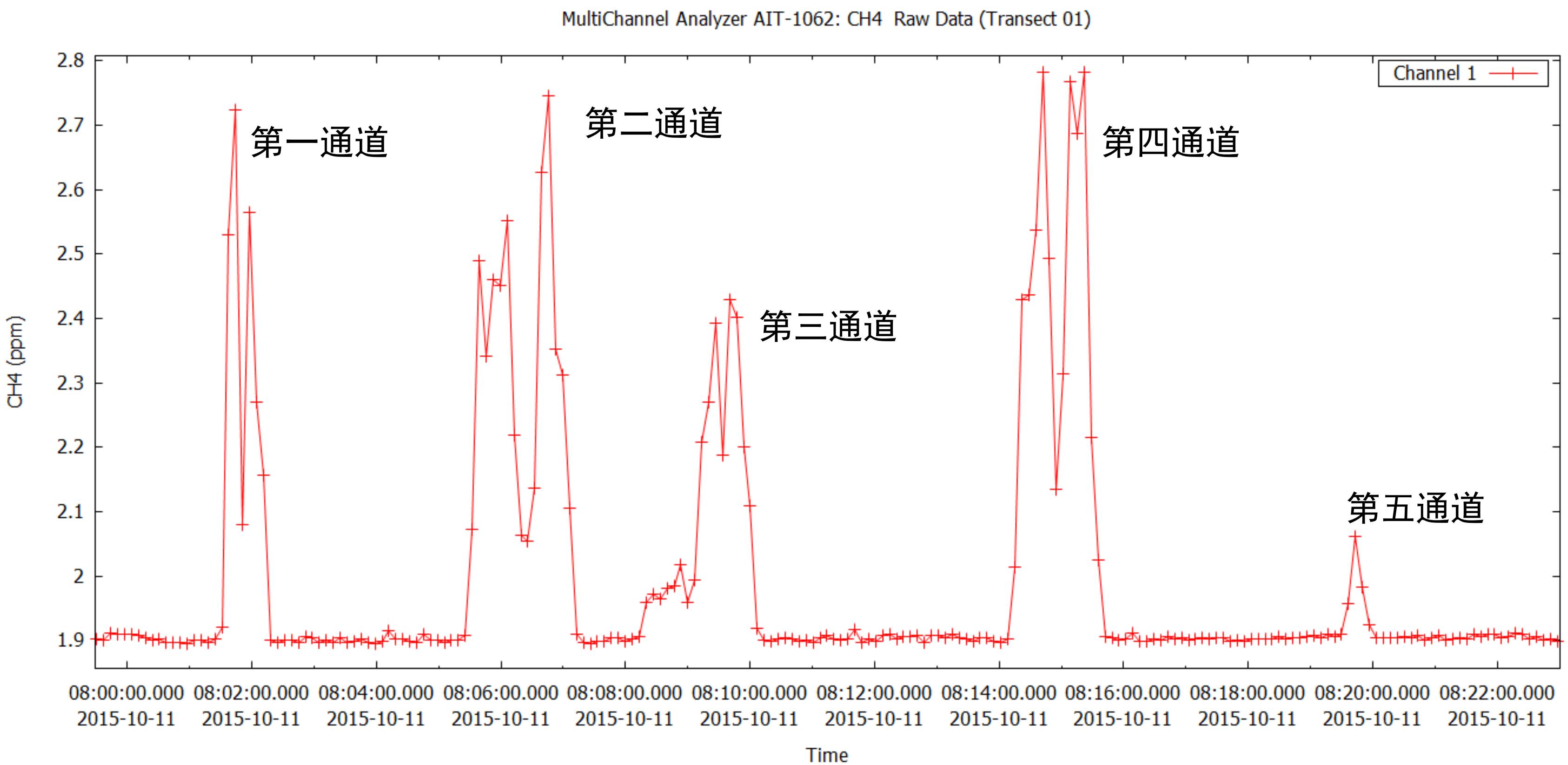
油罐区 – 收敛



4个截面后的95%置信区间低于中数的25%

燃气站筛选

多通道分析器 甲烷原始数据（01截面）



通道 1 - 4: 来源400米处下风向
通道 5: 来源2000米处下风向

煤矿测试 – 工地 4

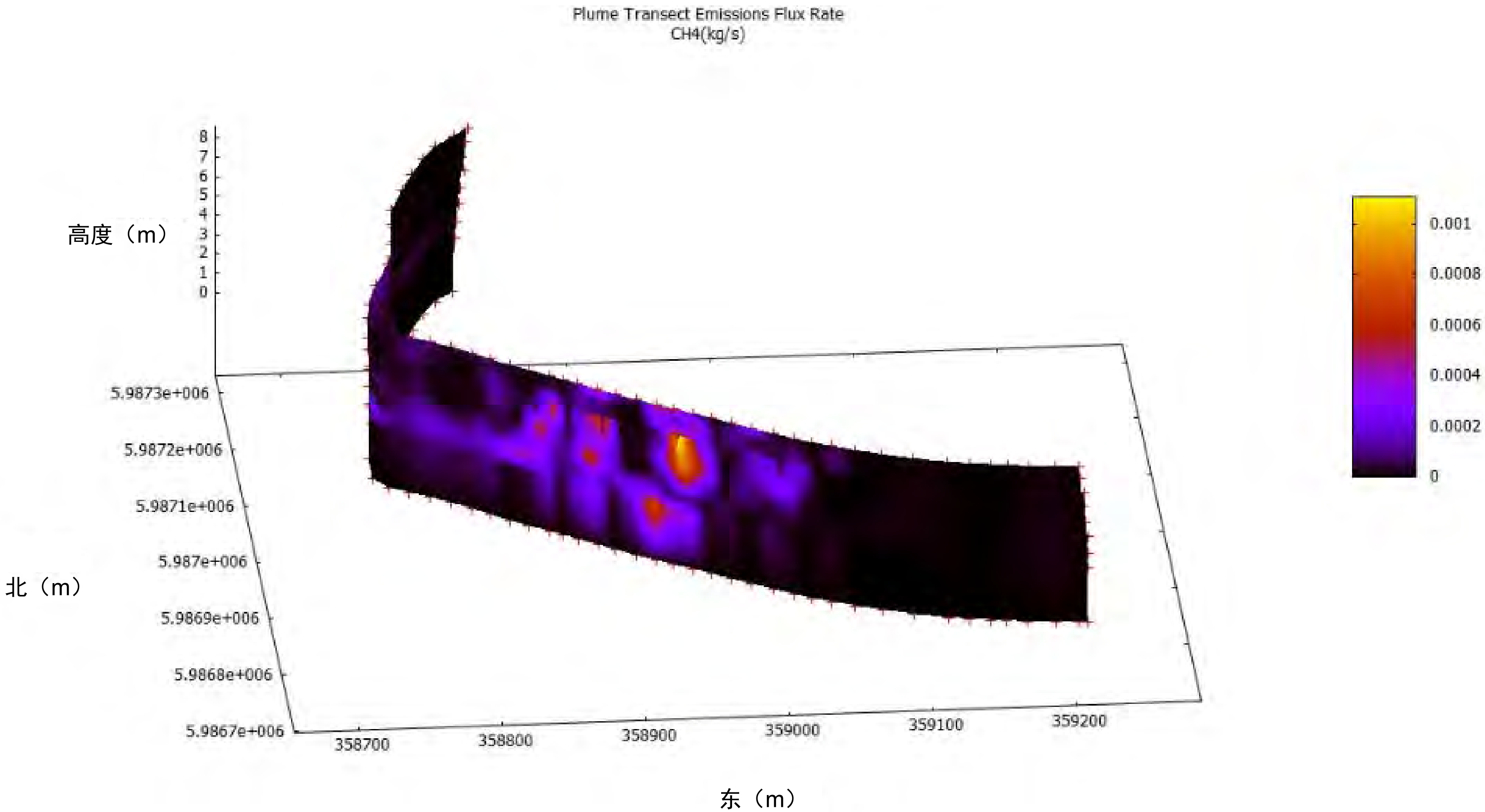
矿井东北角 （几乎不开采）

矿井西南角（积极开采）

积极开采矿井的即时下风向 – 工地 4

积极开采矿井的即时下风向 – 工地 4

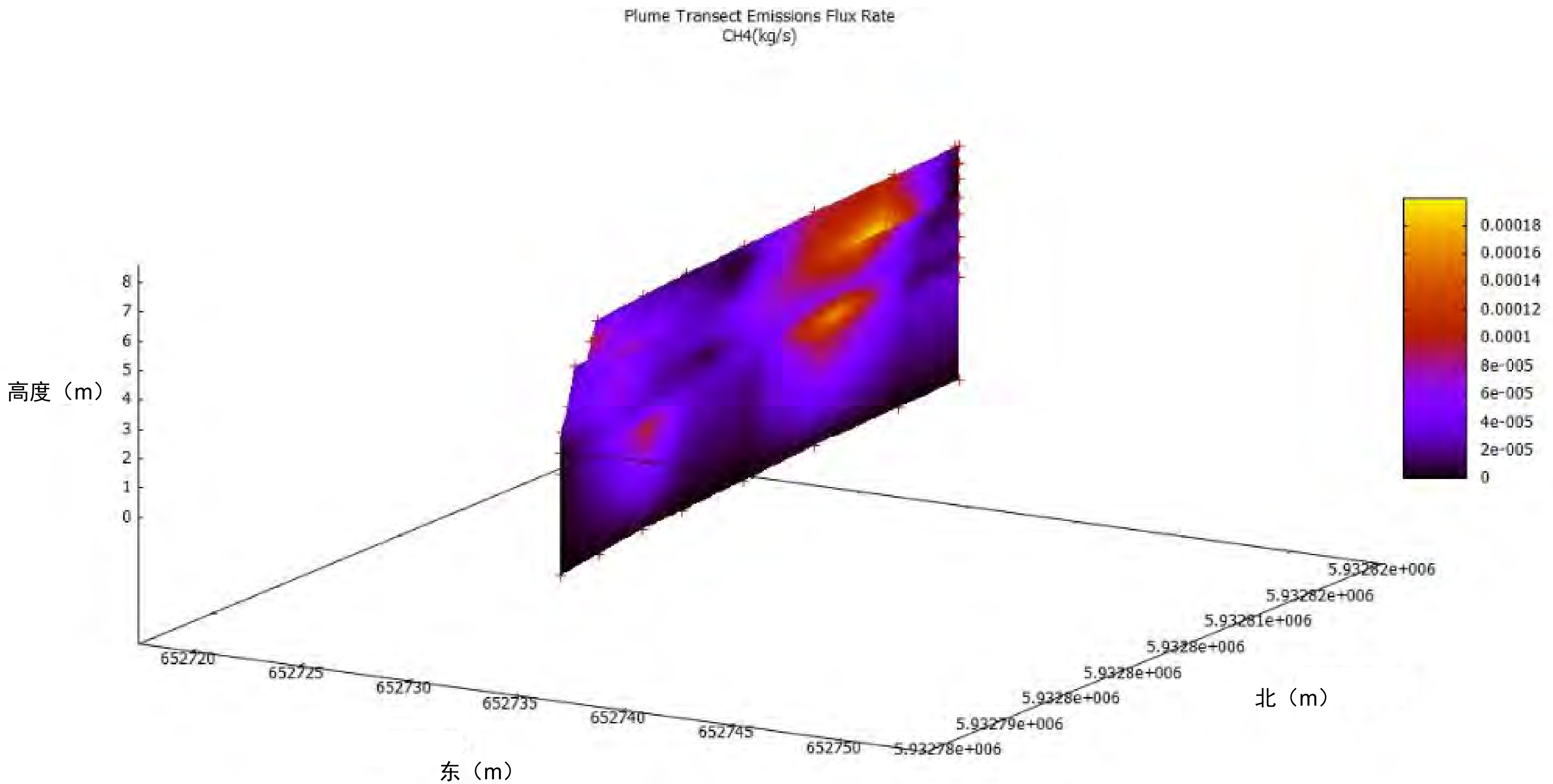
甲烷排放量 (kg/s)



卡车&挖掘机操作的下风向 – 工地 2

卡车&挖掘机操作的下风向 – 工地 2

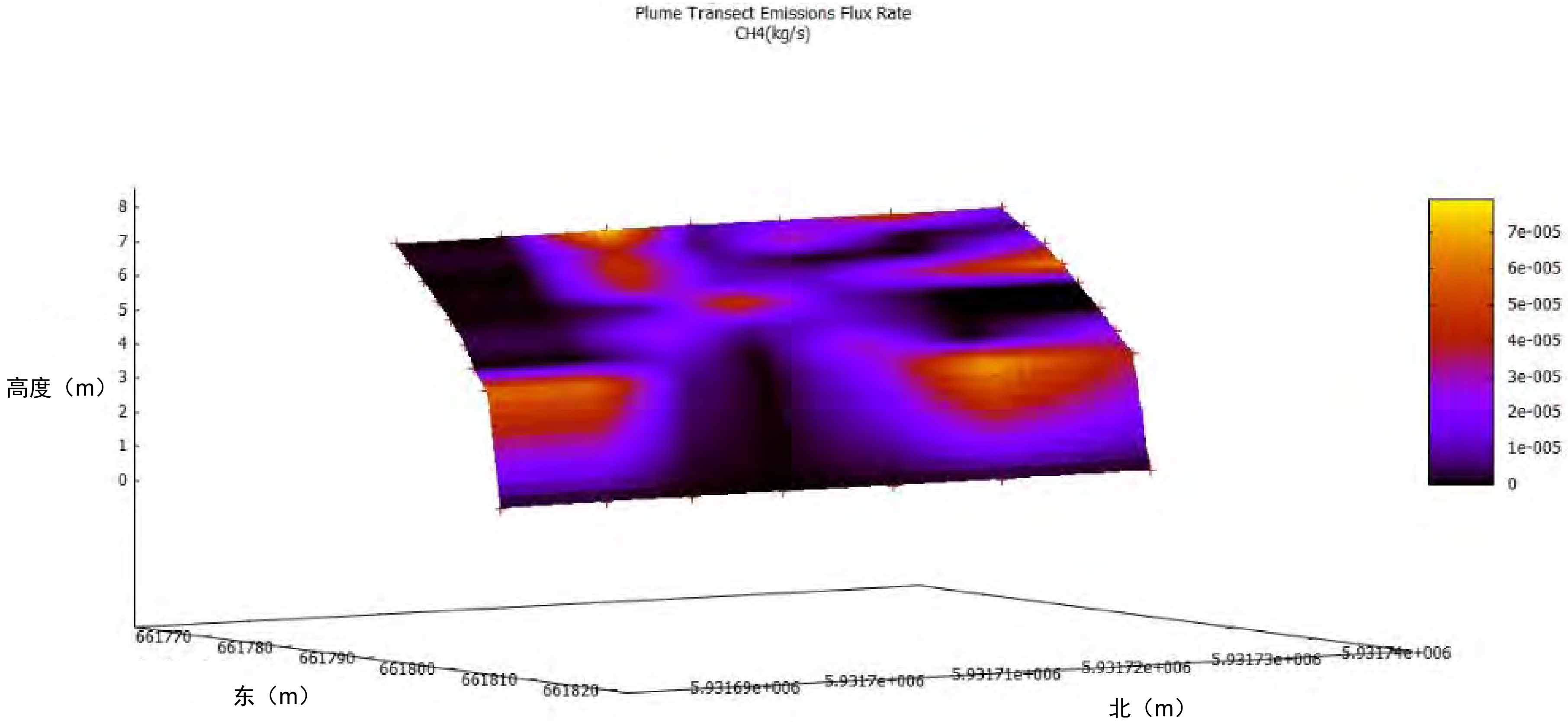
甲烷排放量 (kg/s)



煤炭堆积操作 – 工地 2

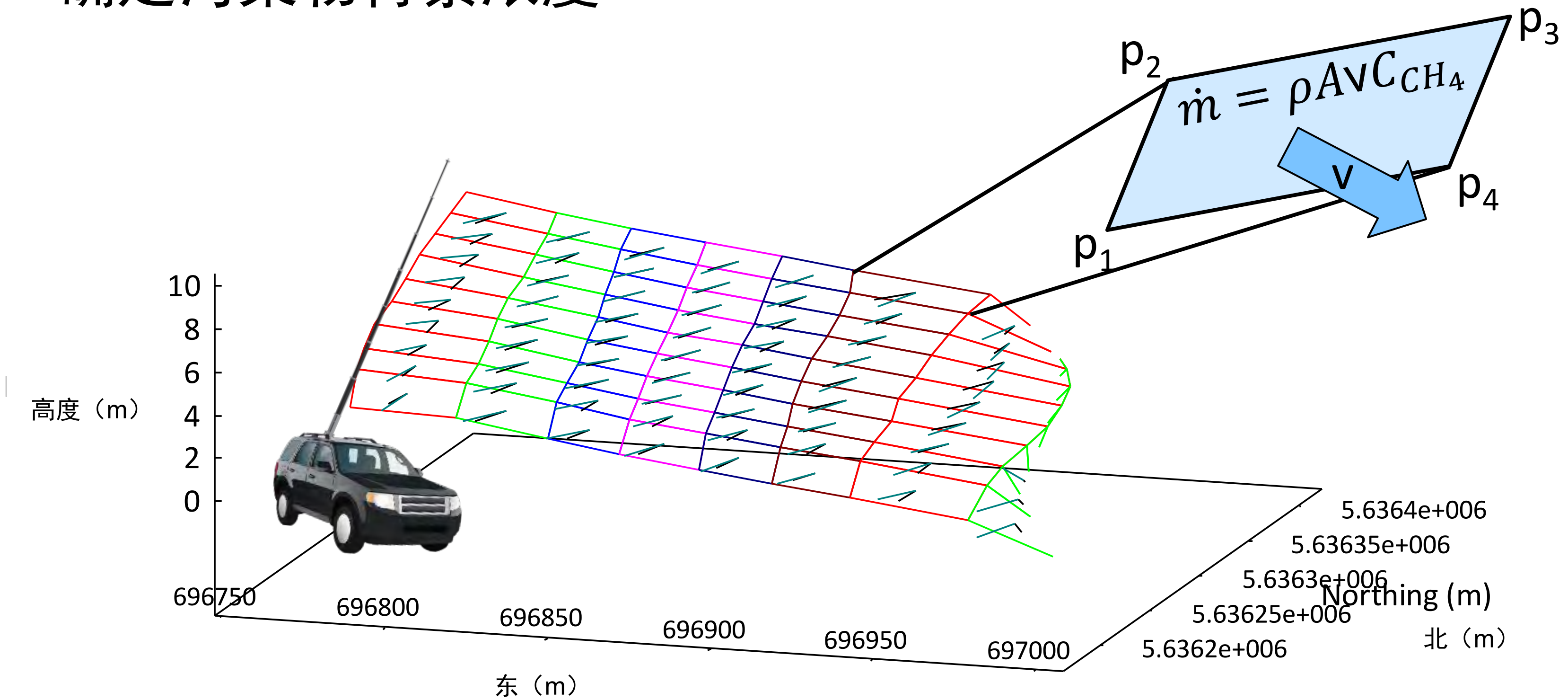
煤炭堆积操作的下风向 – 工地 2

甲烷排放量 (kg/s)



移动烟缕截面方法

- 安装监控系统的车辆
- 穿过排放烟缕来源下风向
- 测量2D风和浓度图
- 确定污染物背景浓度



系统关键组成部分

气体分析

$CH_4/CO_2/H_2O$（快速反应，高准确率、高精确度

便携质谱仪（实时VOC测量）

H_2S/NH_3

取样

可伸缩碳纤维天线杆（内部开发）

多通道采样系统（内部开发）

GPS和风

高精确度的全球定位系统（GPS）

3x 3D 超声波风速计

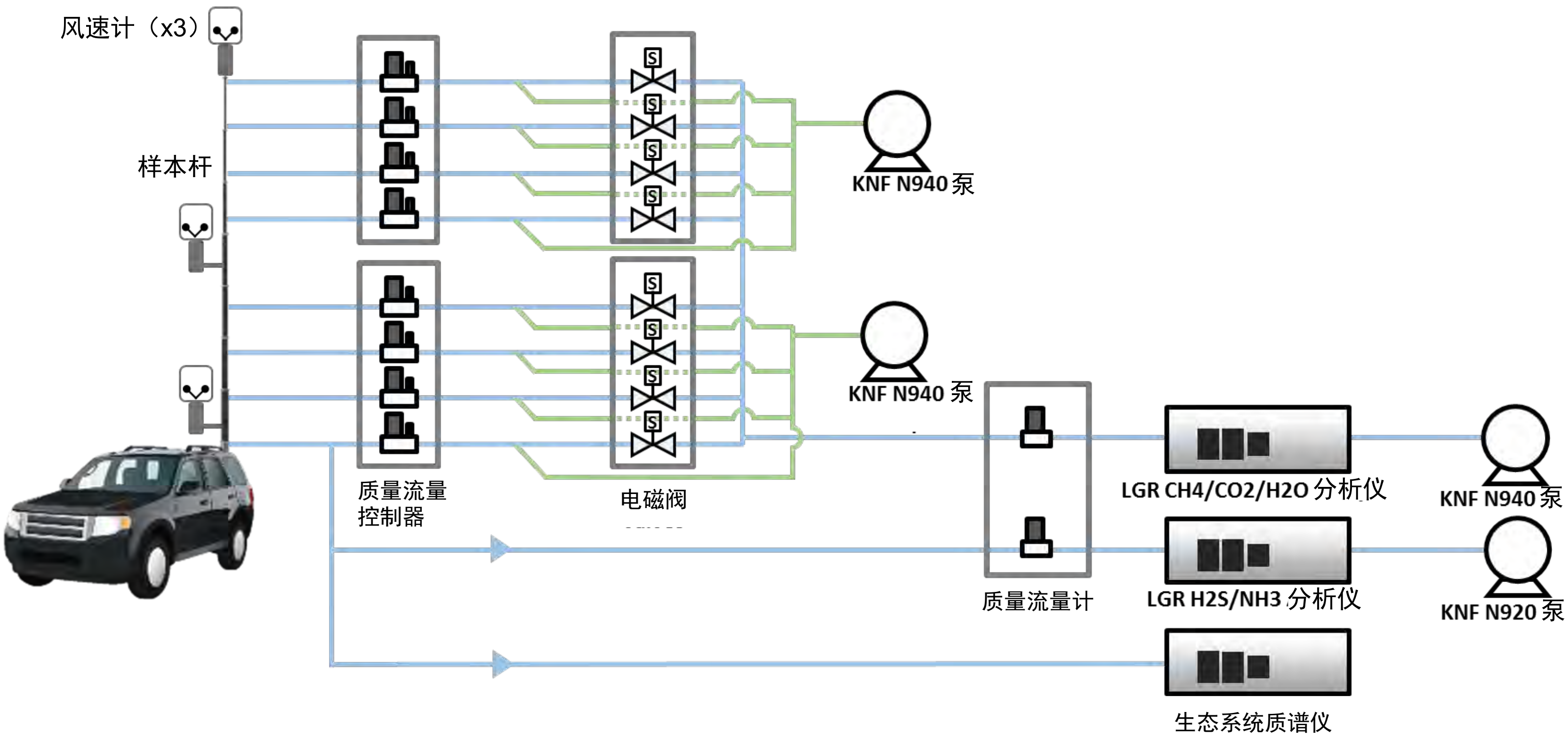
软件

实时数据获取和控制

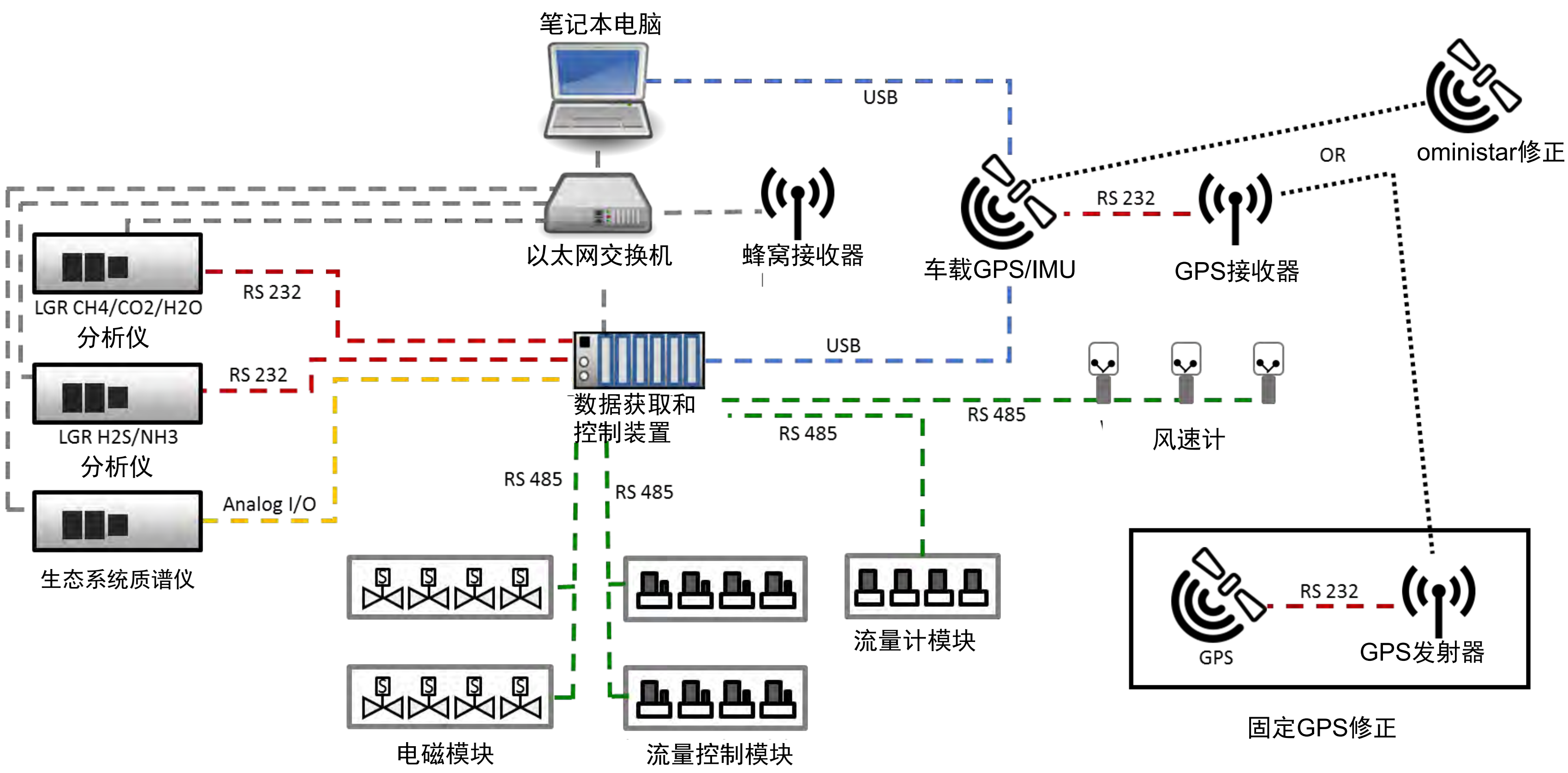
近实时数据进程和排放量量化（内部开发）

CLEARSTONE ENGINEERING

系统设定 – 流程图



系统设定 – 数据原理图



笔记本电脑
USB
oministar修正
OR
RS 232
以太网交换机
蜂窝接收器
车载GPS/IMU
GPS接收器
LGR CH4/CO2/H2O
分析仪
RS 232
RS 232
USB
LGR H2S/NH3
分析仪
数据获取和
控制装置
RS 485
RS 485
风速计
Analog I/O
RS 485
RS 485
生态系统质谱仪
RS 232
GPS
GPS发射器
流量计模块
电磁模块
流量控制模块
固定GPS修正

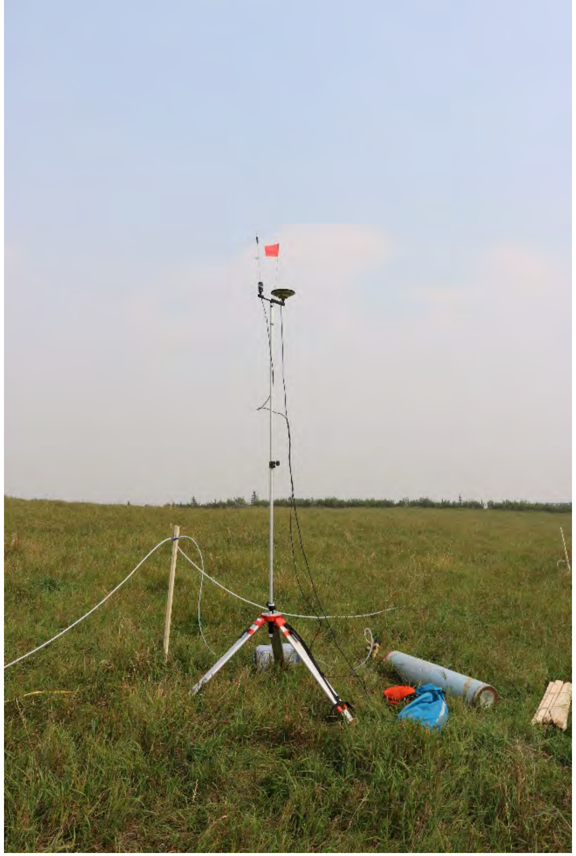
系统设定 – 装杆车

易于安装及拆卸的装杆车

系统设定 – 伸长杆

9米杆位于8个取样通道

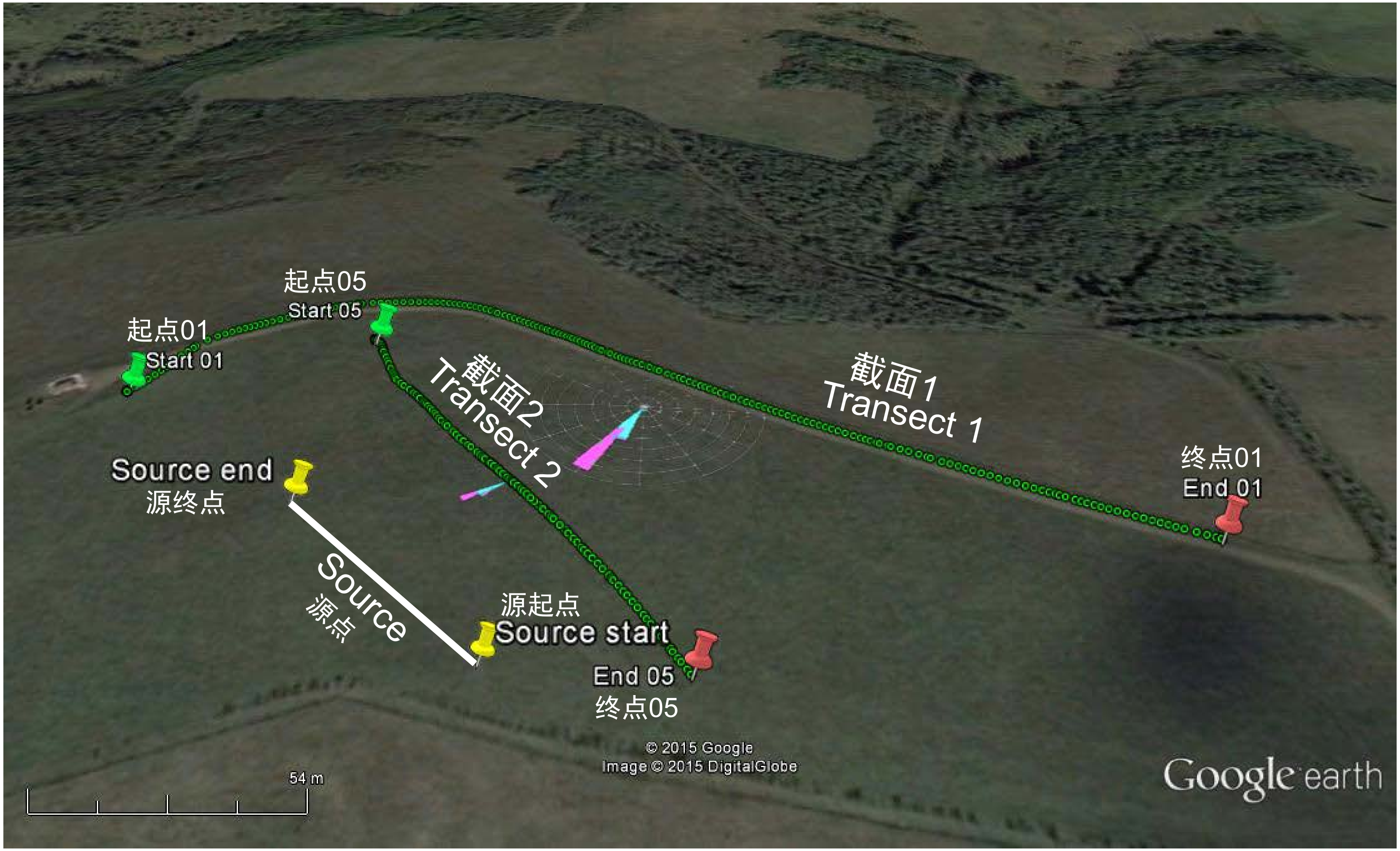
验证测试



基站GPS和发射器（
提供修正数据)

73米长线源，
CH_4 释放速率0.00017 - 0.00057 kg/s

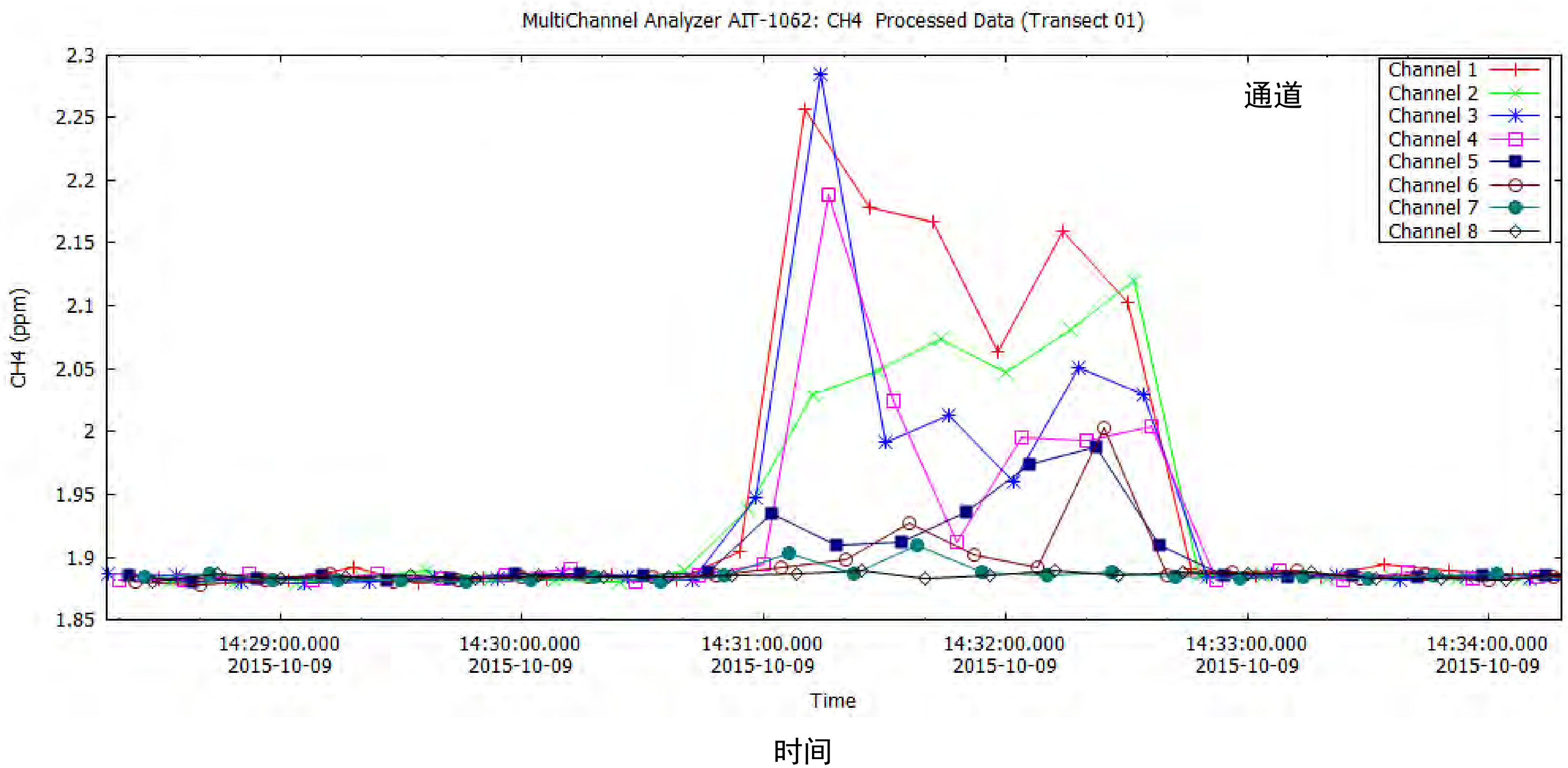
验证测试 – 截面路线



起点05
Start 05
起点01
Start 01
截面2
Transect 2
截面1
Transect 1
终点01
End 01
Source end
源终点
Source
源点
源起点
Source start
End 05
终点05
© 2015 Google
Image © 2015 DigitalGlobe
54 m
Google earth

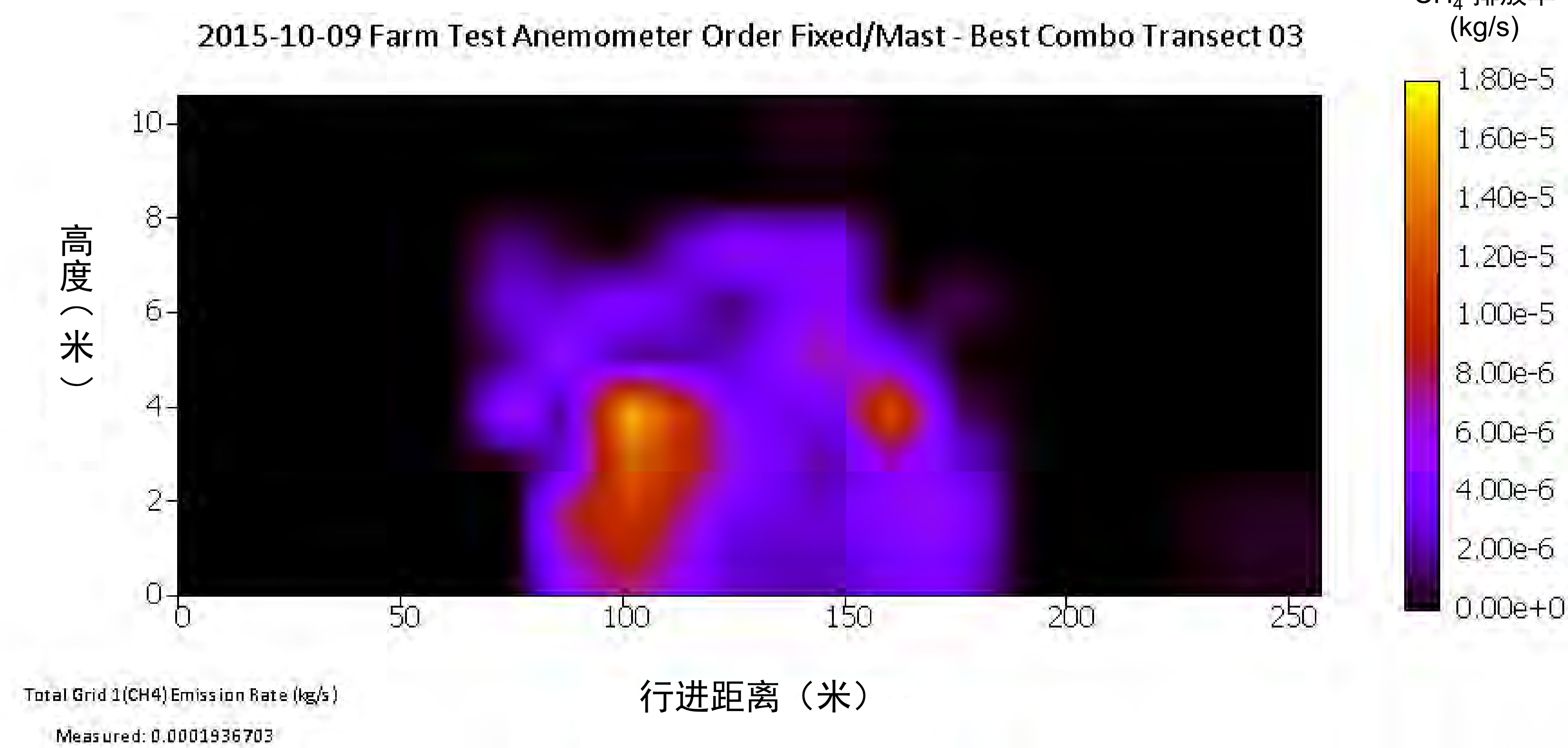
验证测试 – 下风向浓度

多通道分析仪 甲烷加工数据（01截面）



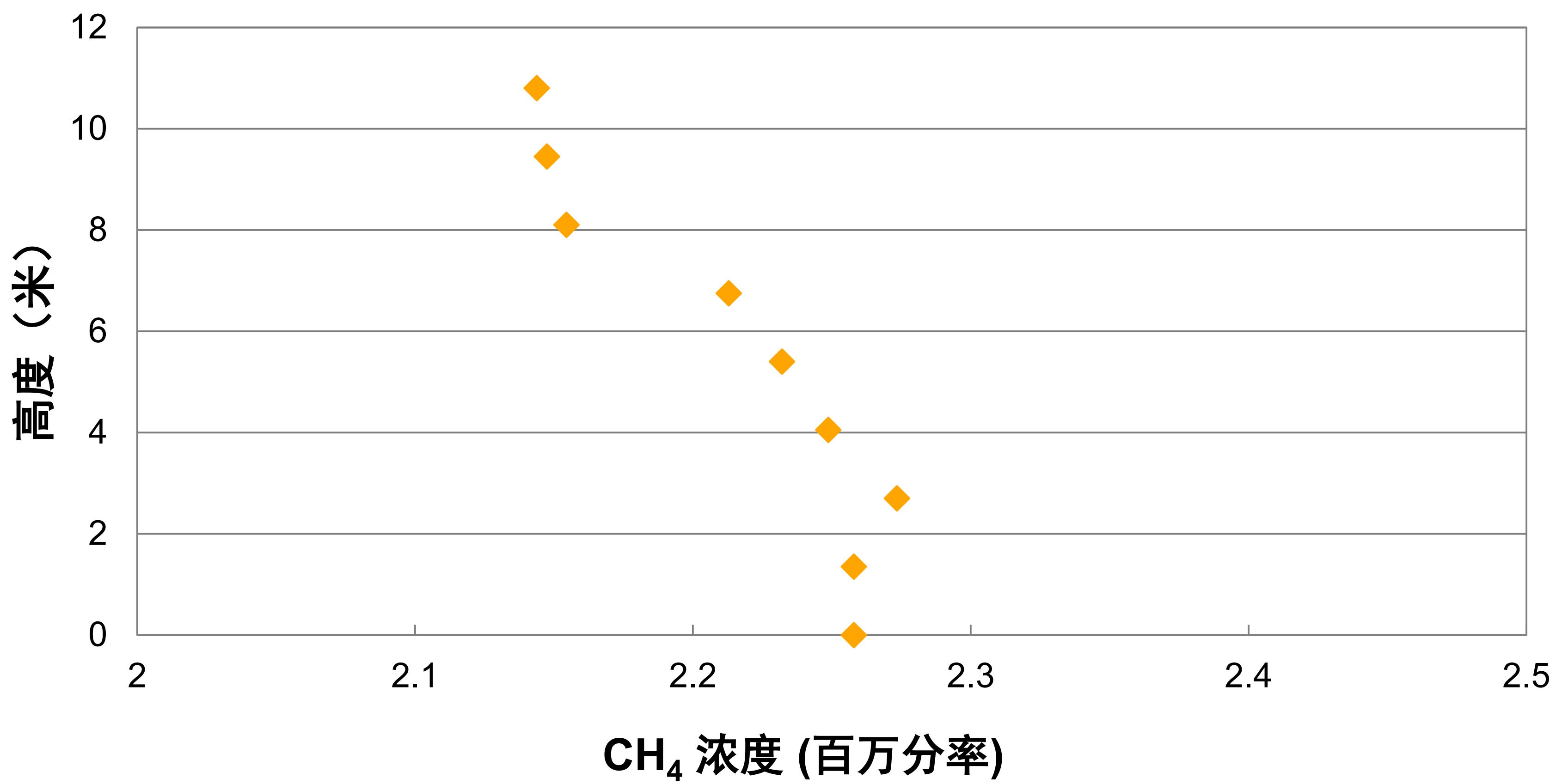
验证测试 – 排放率等高线图

2015-10-09 现场测试风速计顺序/桅杆——最佳搭档（03截面）



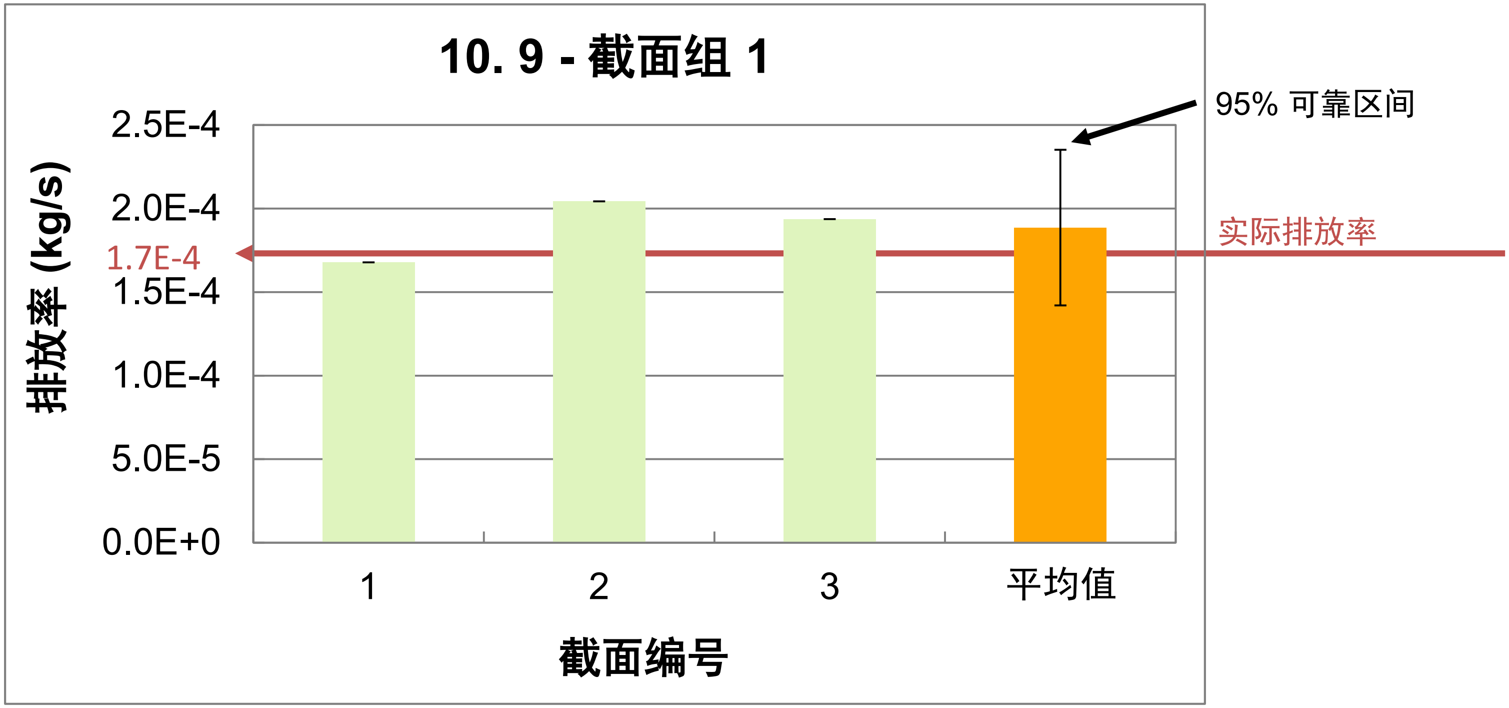
- 垂直捕捉良好
- 水平捕捉良好
- 高分辨率

验证测试 – 平均垂直浓度图



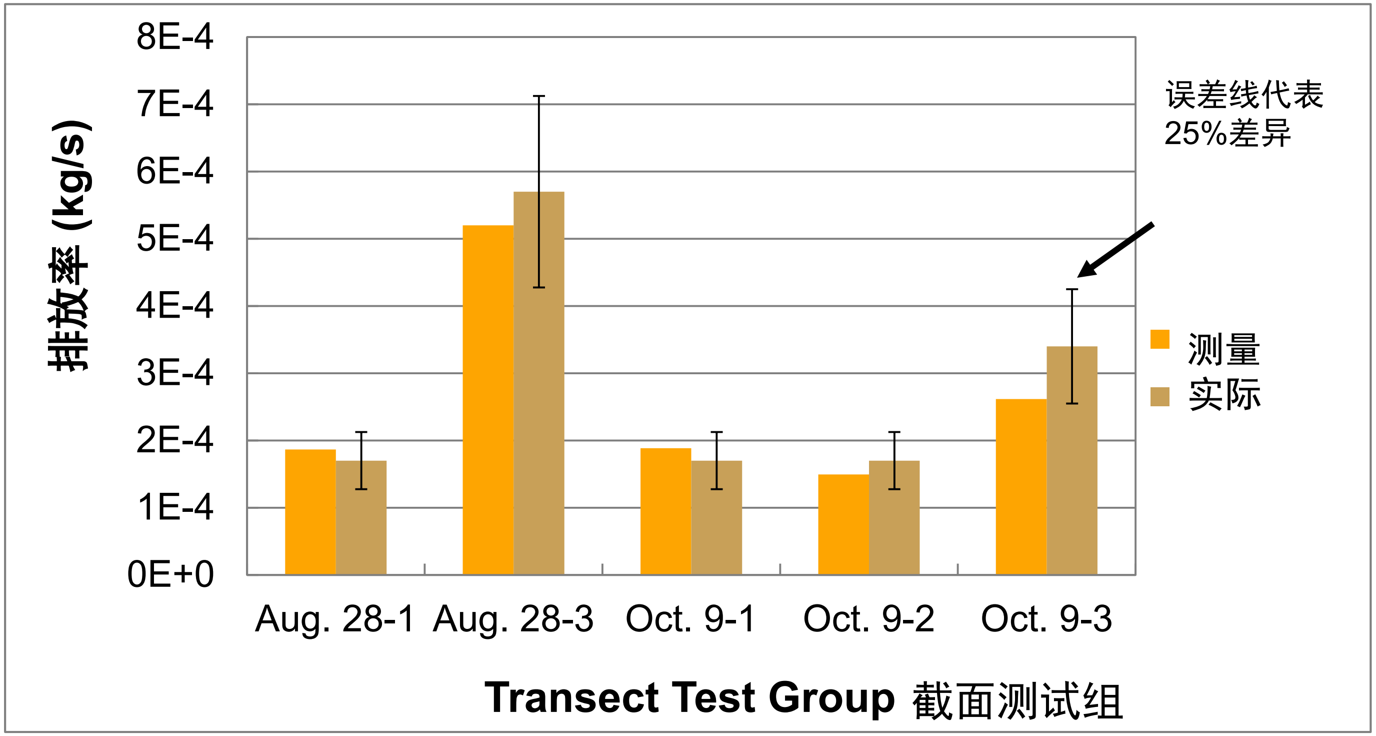
烟缕固定测量（间隔4分钟），距来源90米

验证测试 – 准确率



排放源: 甲烷 (CH_4)
来源类型: 线源长 73米, 高1米
排放率: 0.00017 kg/s
距离来源: 100m
网格分辨率 (单元格宽度): 13 m

验证测试 – 准确率



排放源: 甲烷 (CH_4)

来源类型：线型, 长73米, 高1米

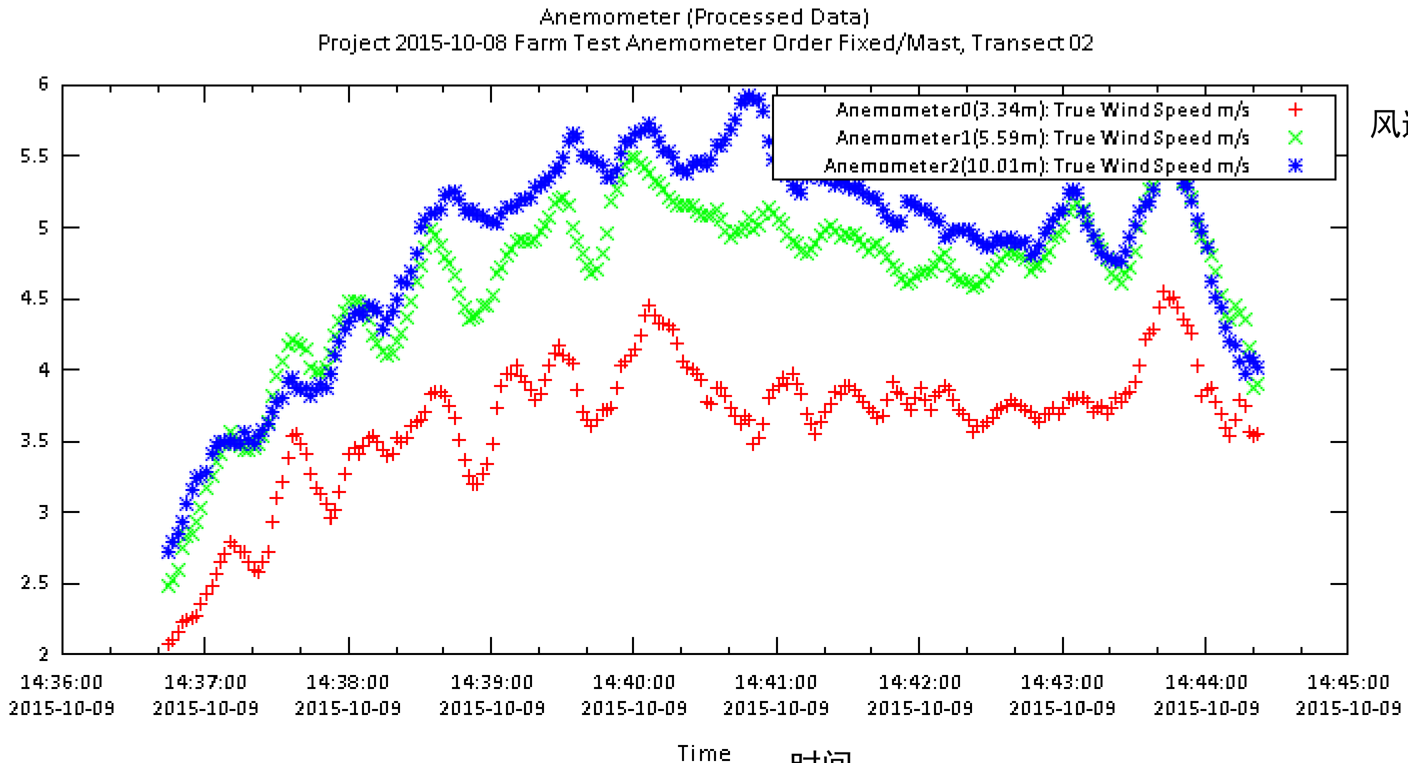
测试日期：2015年8月28日及10月9日

3个截面的平均值 (除2个8月28日-3)

问题？

风速计数据

风速计：（加工数据)

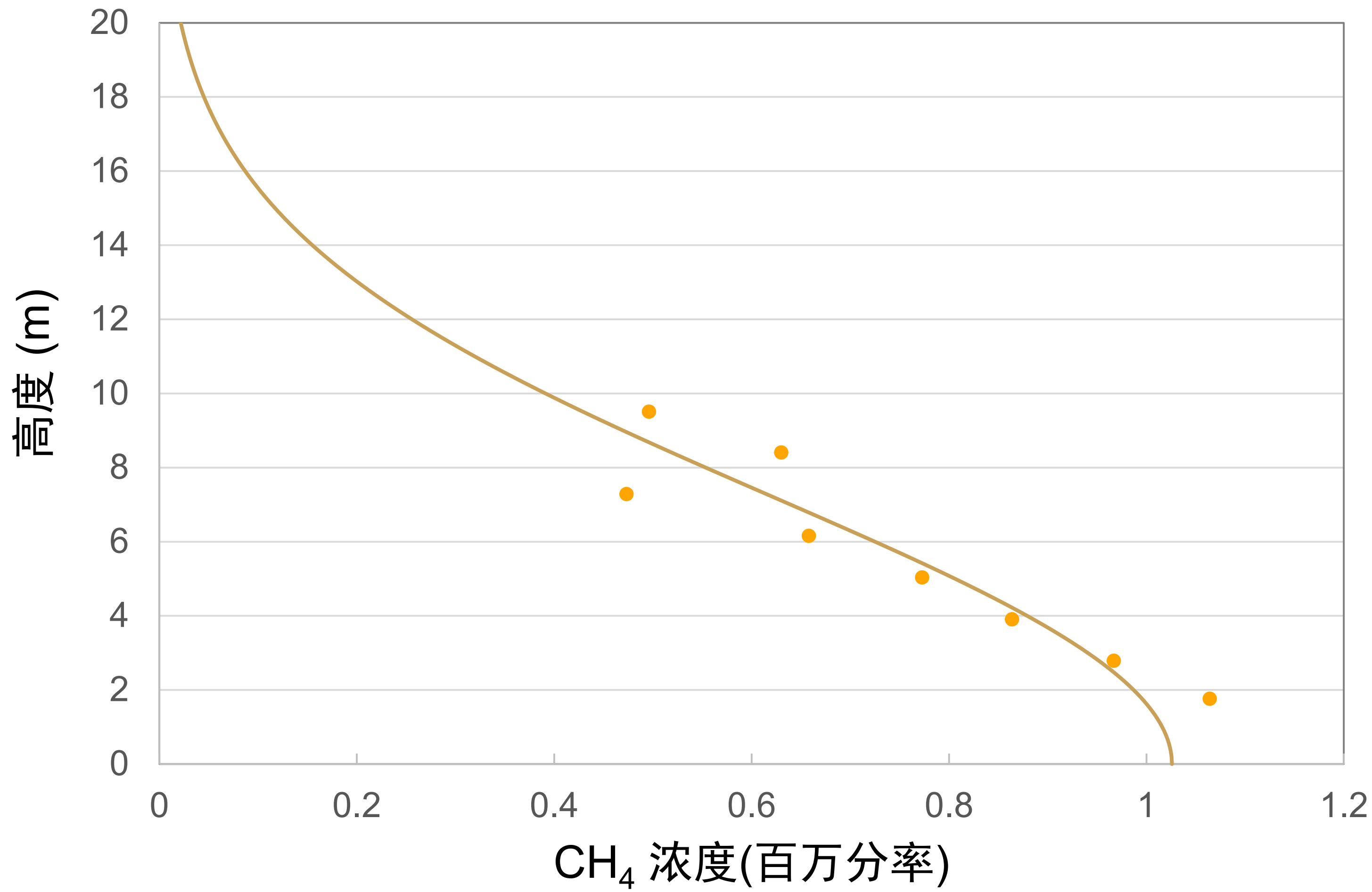


实际风速m/s

风速计：实际风速

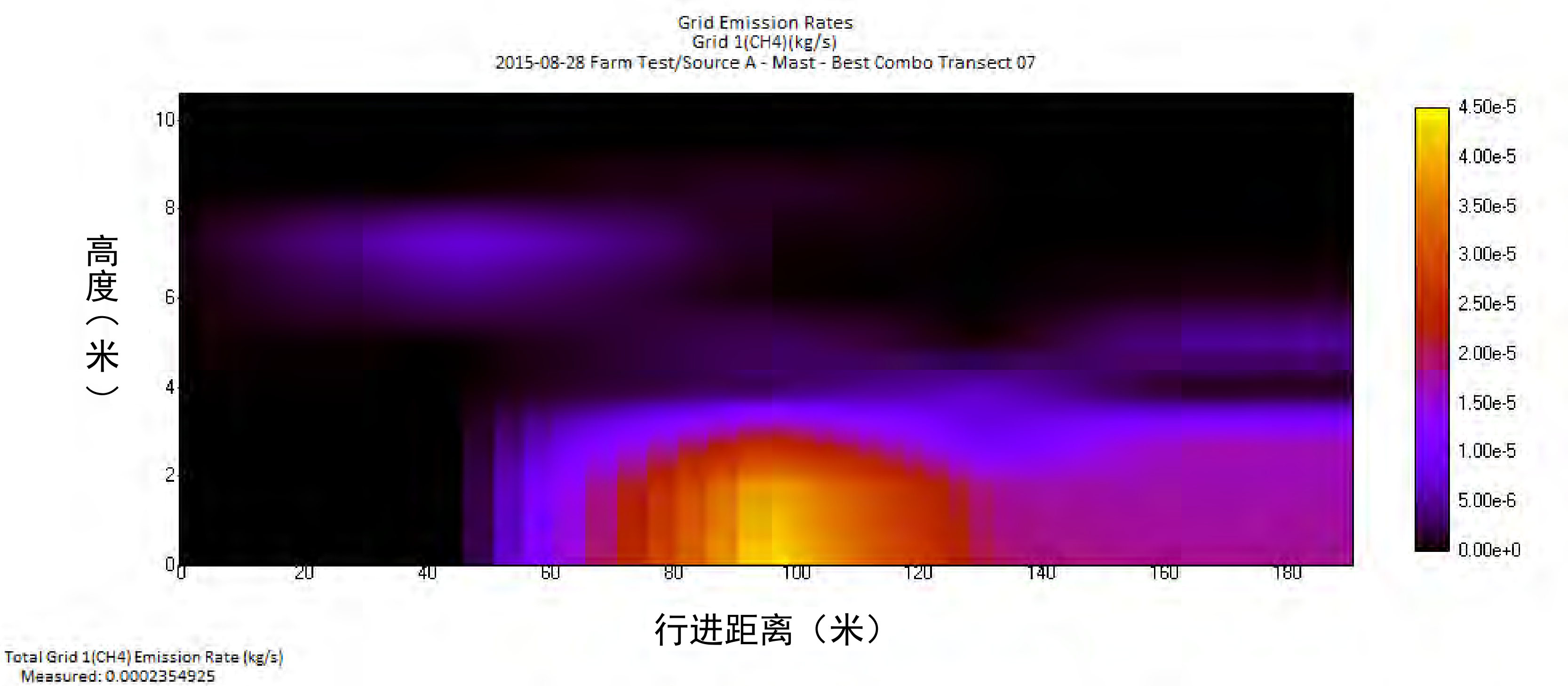
时间

油罐区 – 垂直烟缕捕捉校正



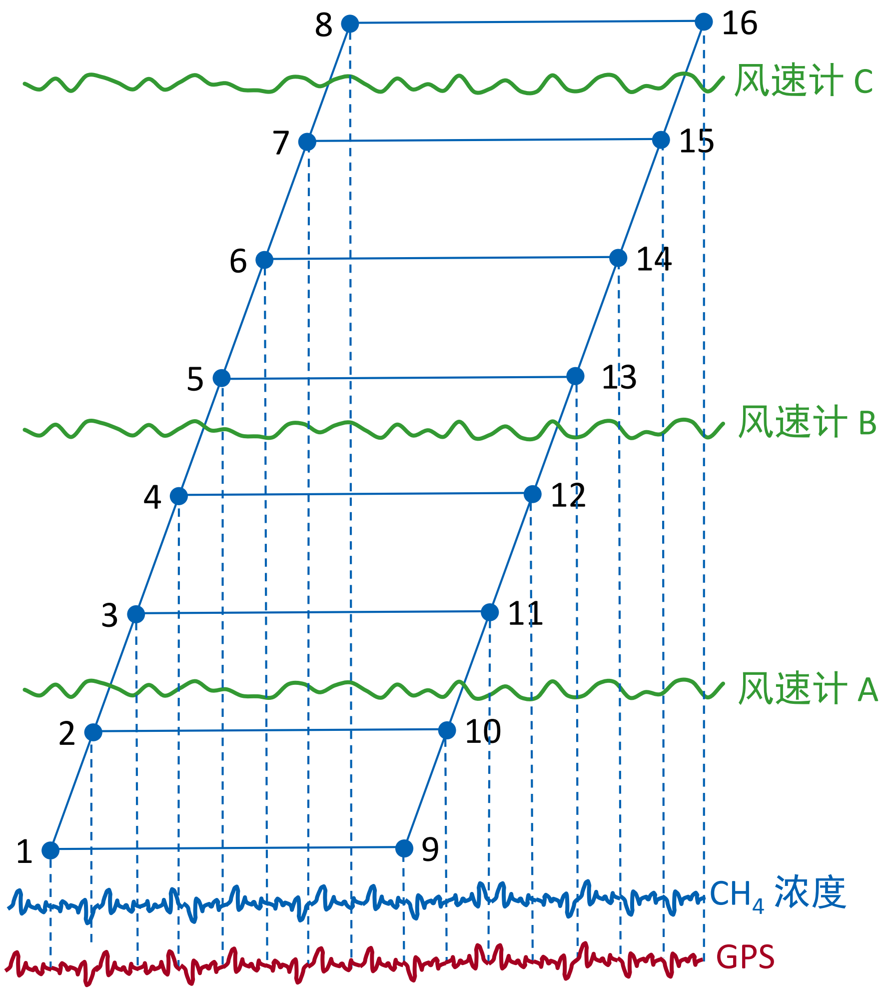
验证测试 – 排放率等高线图2

网格1 甲烷释放速率
2015-8-28 现场测试 来源A-桅杆 07截面



- 地平面烟缕 (缓和地平面剖面图)
- 水平捕捉良好
- 低分辨率

烟缕截面方法



总结

- 远程监控排放量的移动系统
- 经测试的应用设施: 燃气站, 油罐区, 煤矿
- 步骤: 筛选 → 截面 → 固定测量
- 优点:
  - VOCs实时测量
  - 甲烷排放率，灵敏度 ≤ 5E-5 kg/s，准确率 ≤ 25%
  - 分辨率 ≤ 10 m (水平), 1 m (垂直)
- 局限:
  - 10 m 高度限制
  - 稳定的风
  - 下风向通道

IN-LINE TRACER TESTS

A preferred option for temporary monitoring & validation of existing meters. May also be considered for permanent flare monitoring.

PORTABLE FLARE MONITORING SYSTEM

Reliable Flare Monitoring Program for Nigeria

Key Features

- Real-time or near real-time data access via the internet.
- Reporting of critical parameters:
  - Volumetric flare rate (in-line tracer test).
  - Volumetric oil production rate (clamp-on ultrasonic transducers).
  - Separator temperature and pressure.
  - Flare gas composition (on-line process analyzers).
  - Atmospheric emissions from the flaring activity (GHGs, NO_x, SO2, CO, PM).
  - Economic value of the flared gas.
- Rotate the monitoring system monthly between sites to minimize costs.

Key Features

- Use of cellular and, if unavailable, satellite networks.
- Onboard data logging to avoid loss of data.
- Use of non-intrusive flare and oil measurement flow techniques.
- Use of online process analyzer.

SCADA SYSTEM DESIGN

A portable stand-alone system.

Topic: SCADA System Design

- Main Challenges for SCADA System Deployment:
  - Must be non-intrusive to existing DCS/SCADA systems at sites where being deployed.
  - Requires options for power autonomy or supplied power (24VDC, Solar or 120VAC).
  - Must be able to communicate/interface with a wide variety of instruments. Both wireless and wired. HART, Modbus, etc.
  - Requires on-board calculation capabilities, and both continuous or event driven, non-volatile data logging capability.
  - Flexible back-haul communications options (IP or Serial) with industry standard SCADA protocols.
  - Easy system deployment and re-deployment (portable), with minimal “SCADA” expertise by installers and plant personnel.
  - Withstand harsh environmental conditions

Topic: SCADA System Design

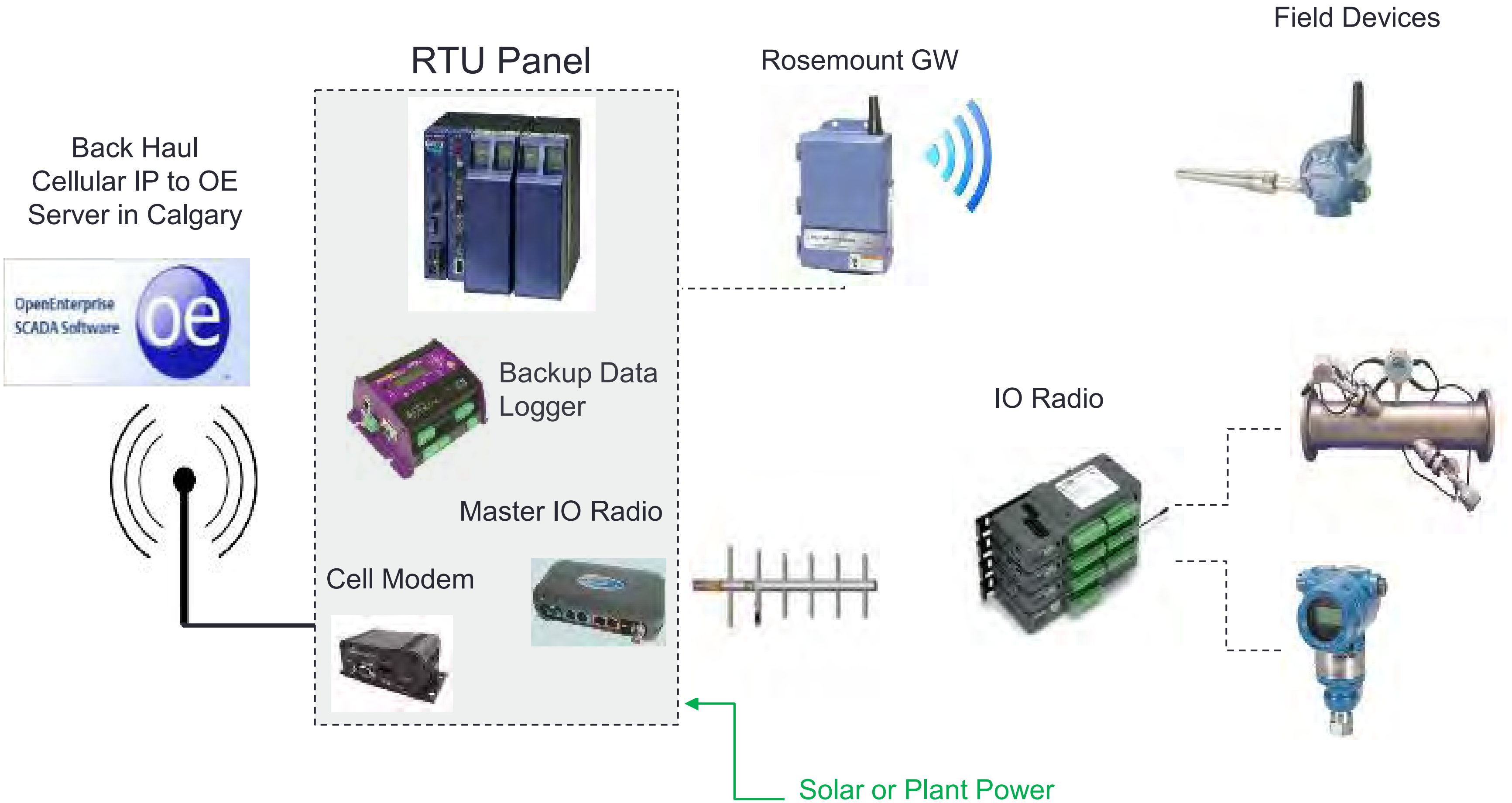
- **Key Considerations for Graphical User Interface Development**:
  - Web based interface to be globally accessible with specific customer portals via public internet
  - Live real-time data displays.
  - Available diagnostics and instrument health monitoring.
  - Flexible and dynamically configurable displays of historical data.
  - Secure and reliable.
  - Cater to all types of users; operations, accounting, plant supervisors, environmental agencies etc.

Topic: SCADA System Design

- **Other Key Considerations for Overall System Design**:
  - Secure and reliable internet connectivity via public IP networks
  - Intelligent sensor selection (both mechanical installation and electrical interface) to preclude process disruptions during implementation.
  - Programmable real-time monitoring and calculation on measured parameters (e.g., T, P, Q, I, etc.).
  - Real time and historical trend analysis of calculated parameters:
    - Gas composition: based on measured molecular weight.
    - Losses or Avoidable Energy Consumption: CH_4, LPG, NGL, H_2 and $$$.
    - Emissions: GHGs, CACs (CO, VOCs, SO_2, NO_x, PM).
    - Emission Reductions: GHGs and CACs

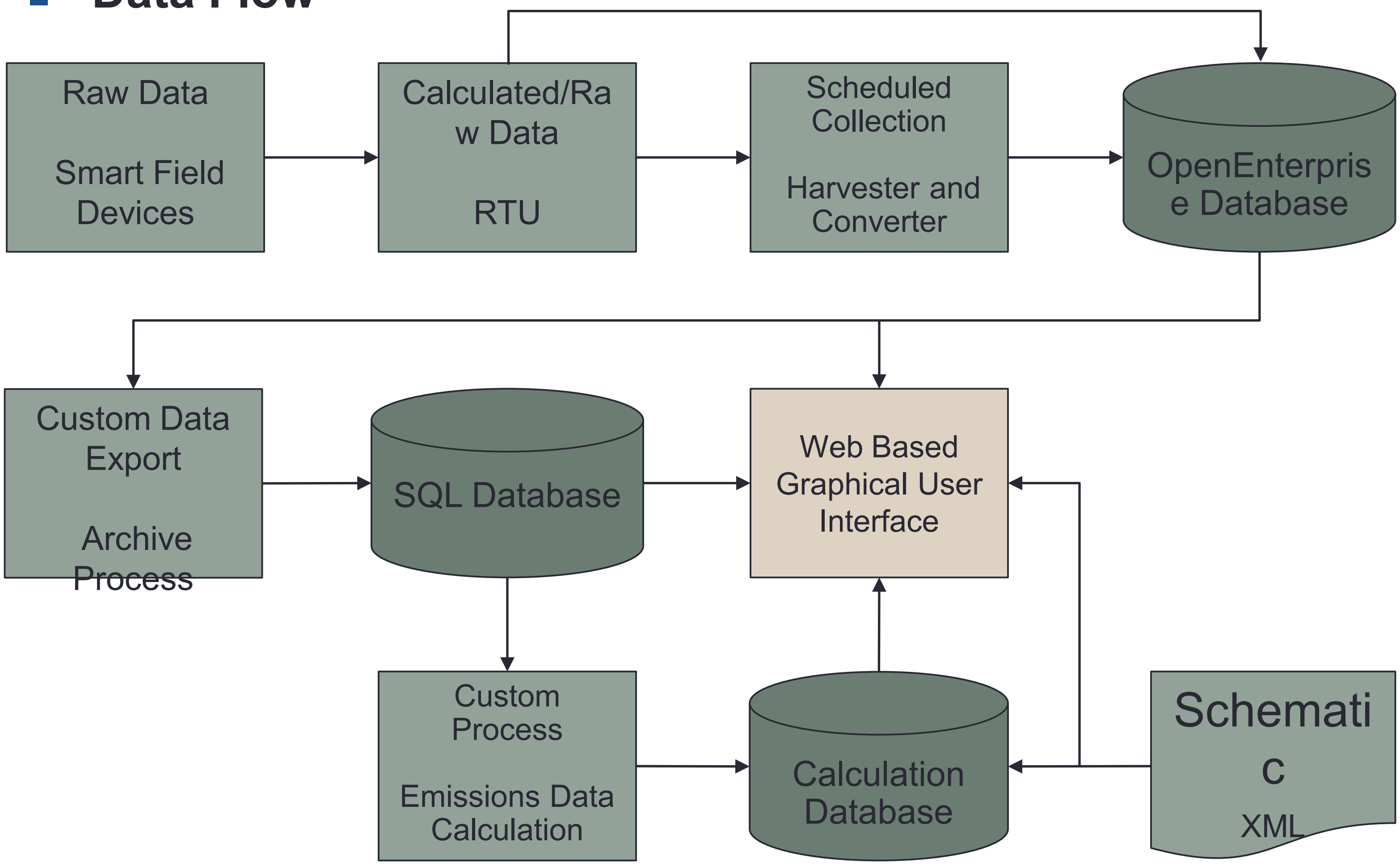
Topic 2 – SCADA System Design

- **Flexible Field Data Capture**



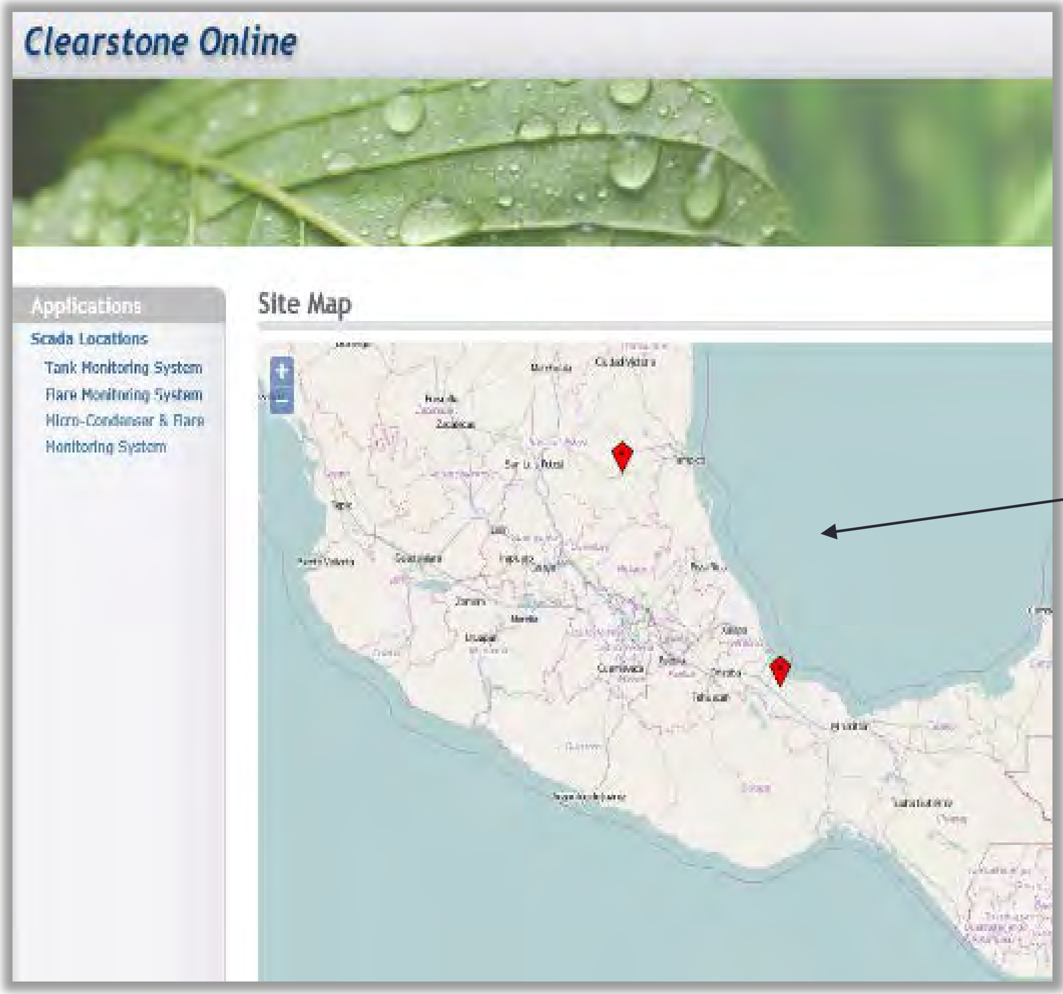
Topic: SCADA System Design

- **Data Flow**



Topic: SCADA System Design

- **Global System Access Through Web Portal**

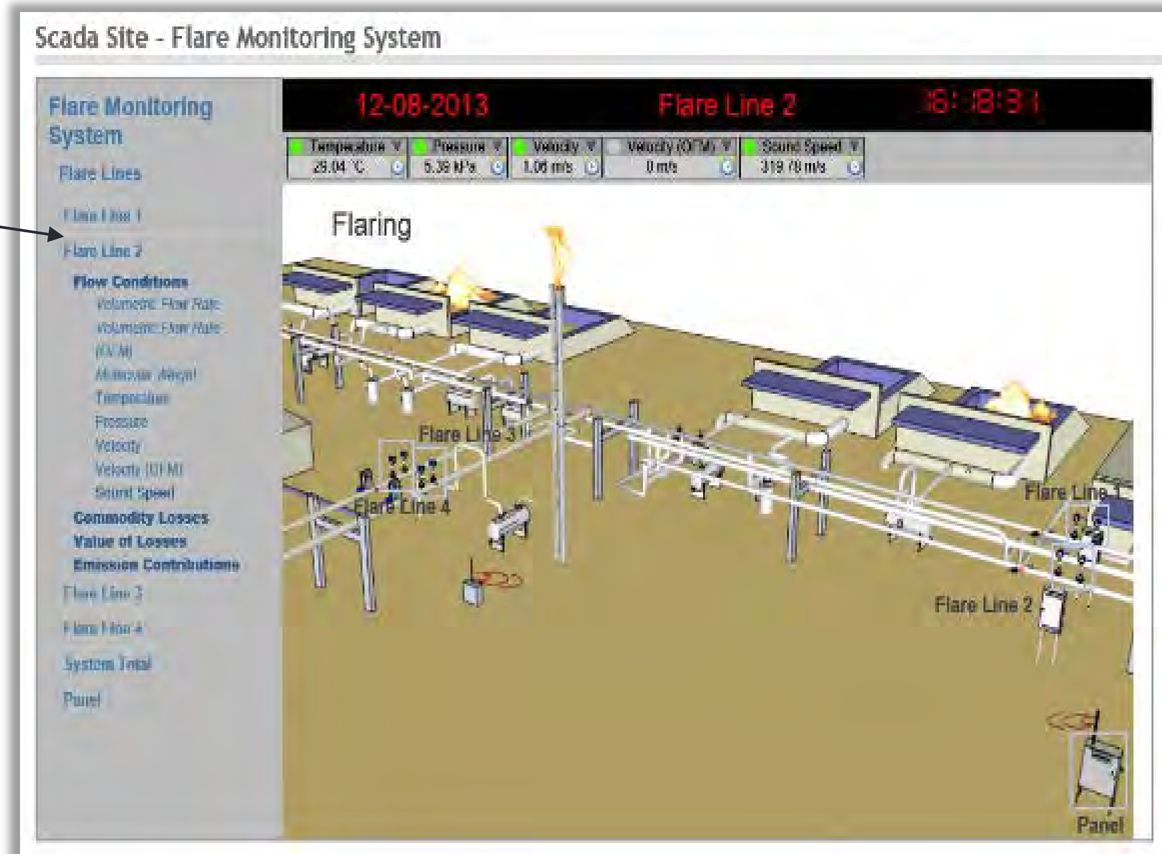


Users can access individual sites through their secure Web Portal.

Topic: SCADA System Design

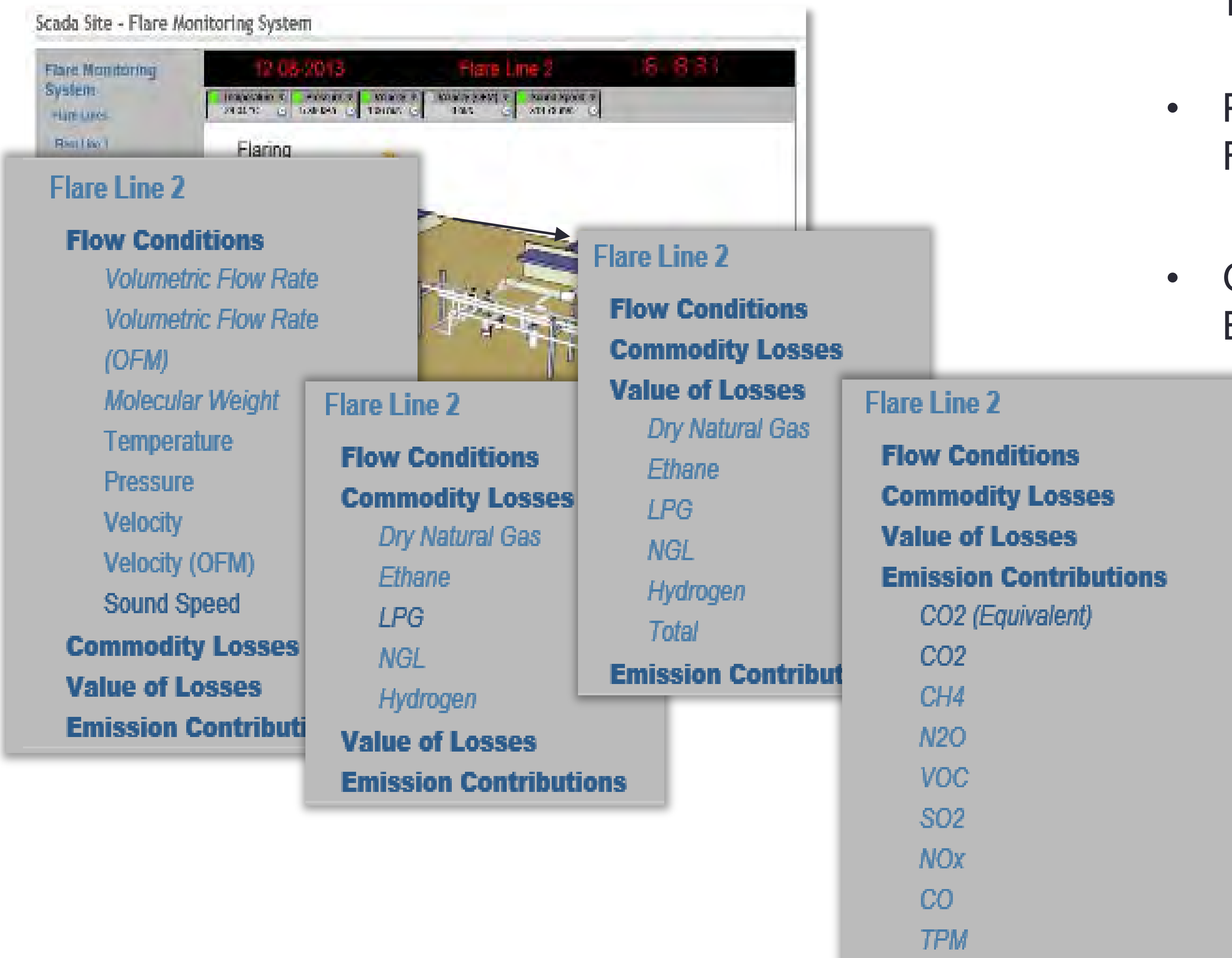
- **Site Overviews and Categorized Data Access**

Each site and individual systems within have categorized data access via intelligent menus.



Topic: SCADA System Design

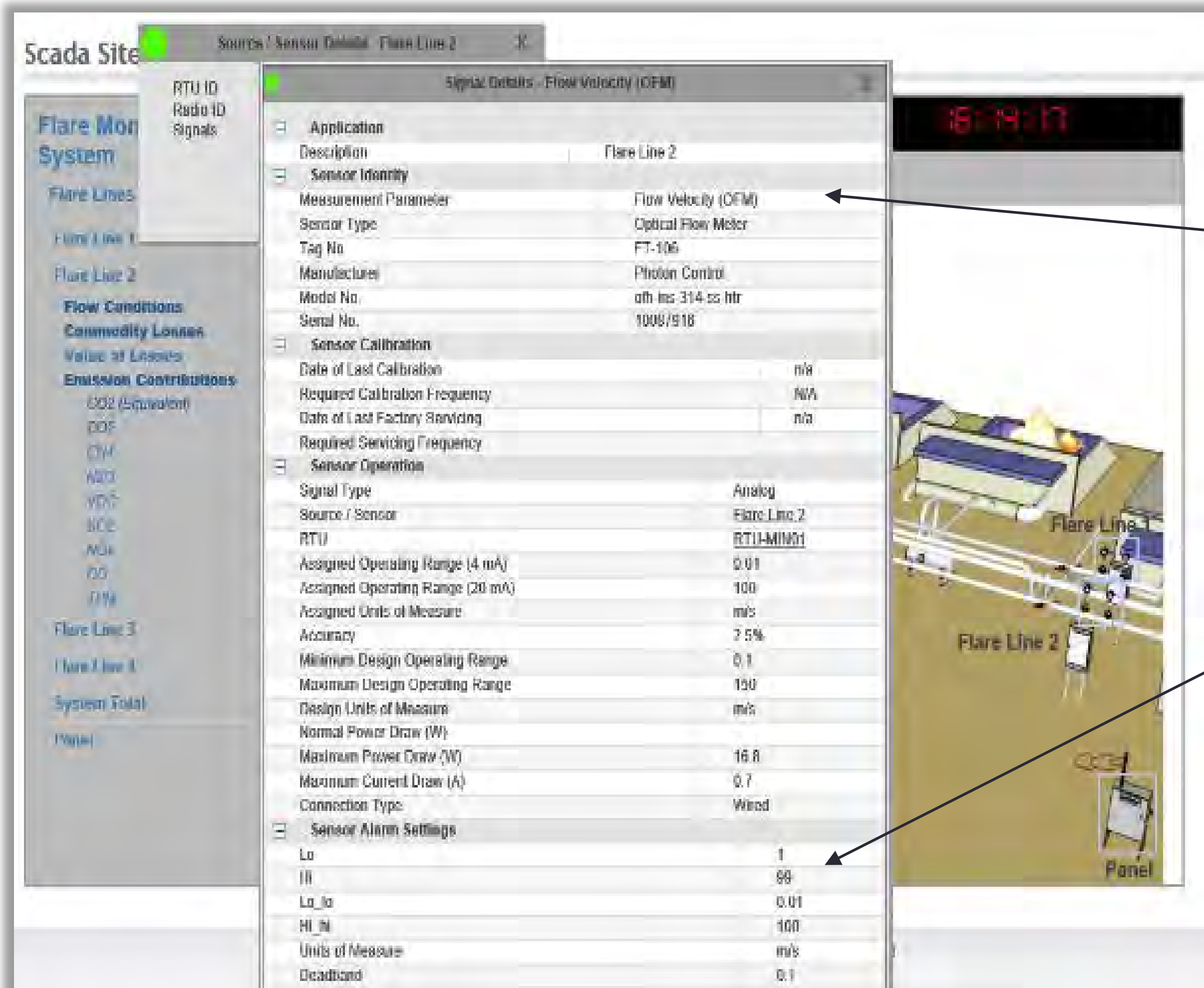
- **Data Access for all stakeholders**



- Operations and Plant Engineers
- Production and Finance
- Government and Environmental Agencies

Topic: SCADA System Design

- **Instrument Data and Diagnostics**

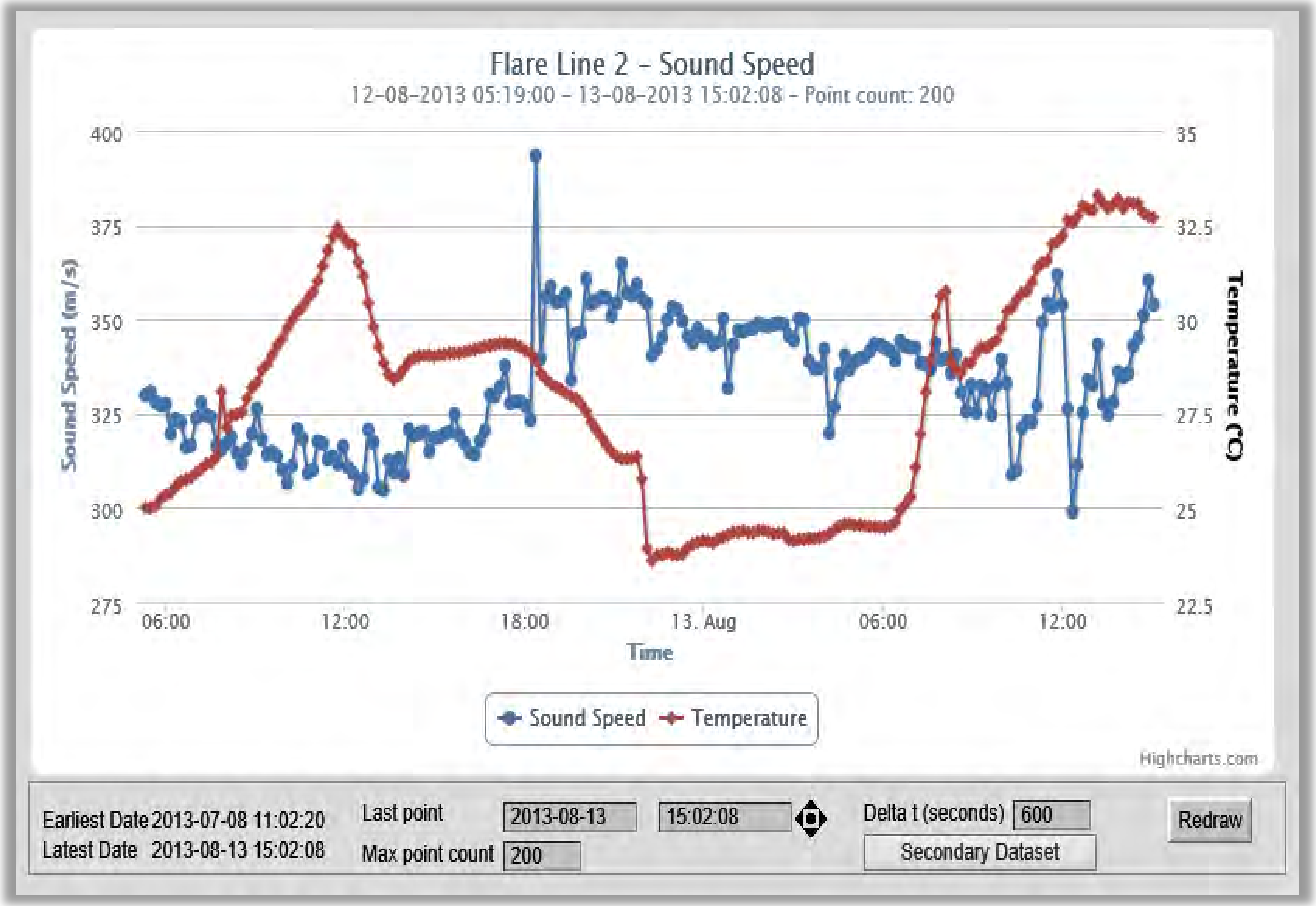


All relevant data for instruments and SCADA components are available for asset tracking.

Configuration and alarming parameters available.

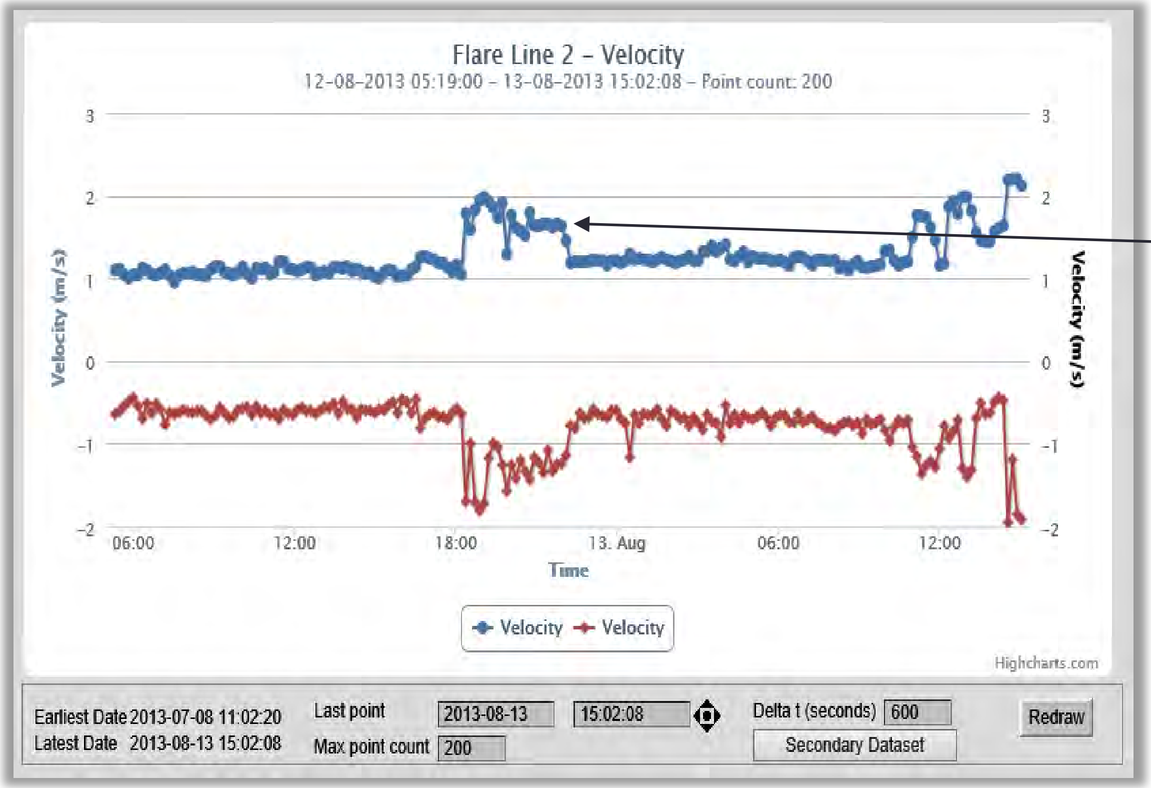
Topic: Business Results Achieved

- Data for Operations; understanding flare process characteristics, speed of sound, temperature etc...



Topic: Business Results Achieved

- **Data for the Plant Engineer; visualizing the cause and effects of upstream or downstream processes in their flaring system.**



Here they discovered that when the velocity on the 42" line (blue) increased it caused a proportional reverse flow on the larger 48" adjacent flare line.

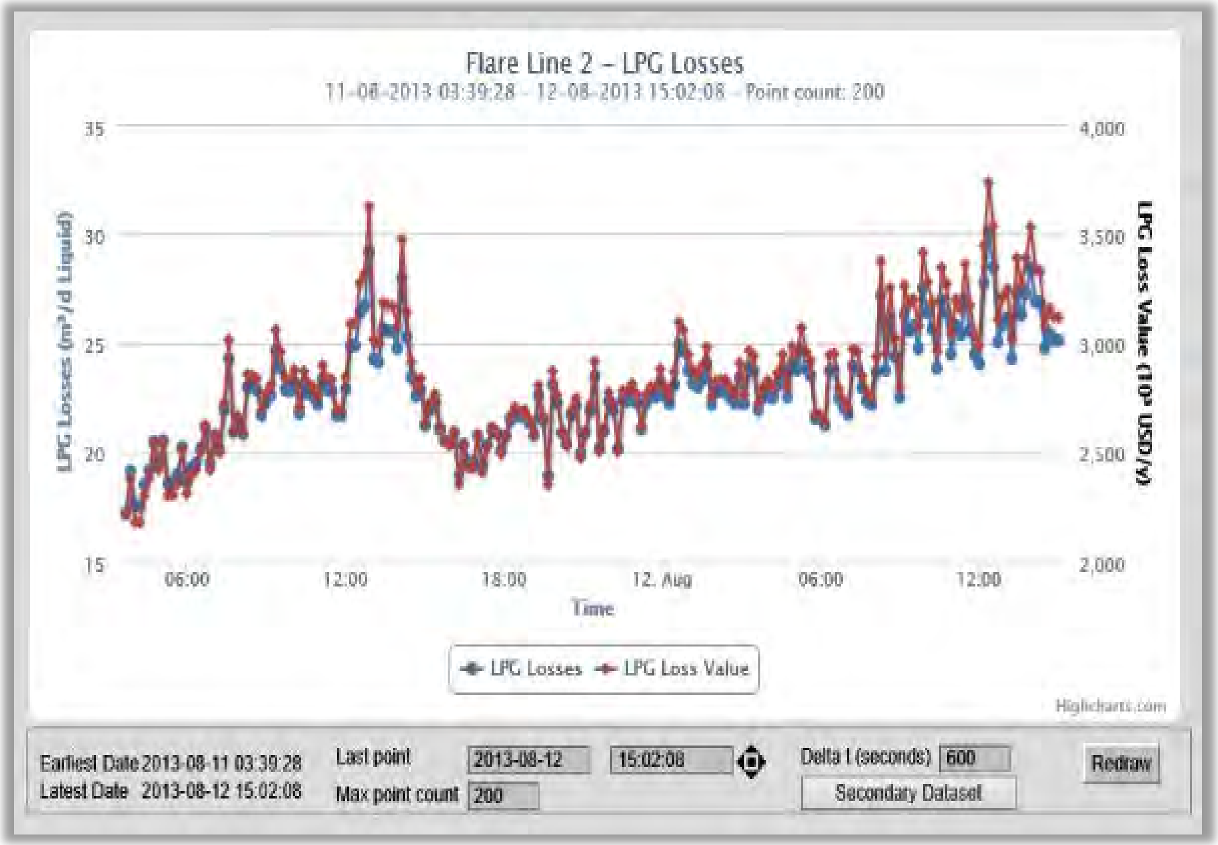
This could raise operational concerns not previously noted.

Topic: Business Results Achieved

- Data for the production managers and accountants; losses in commodities and dollars side by side.

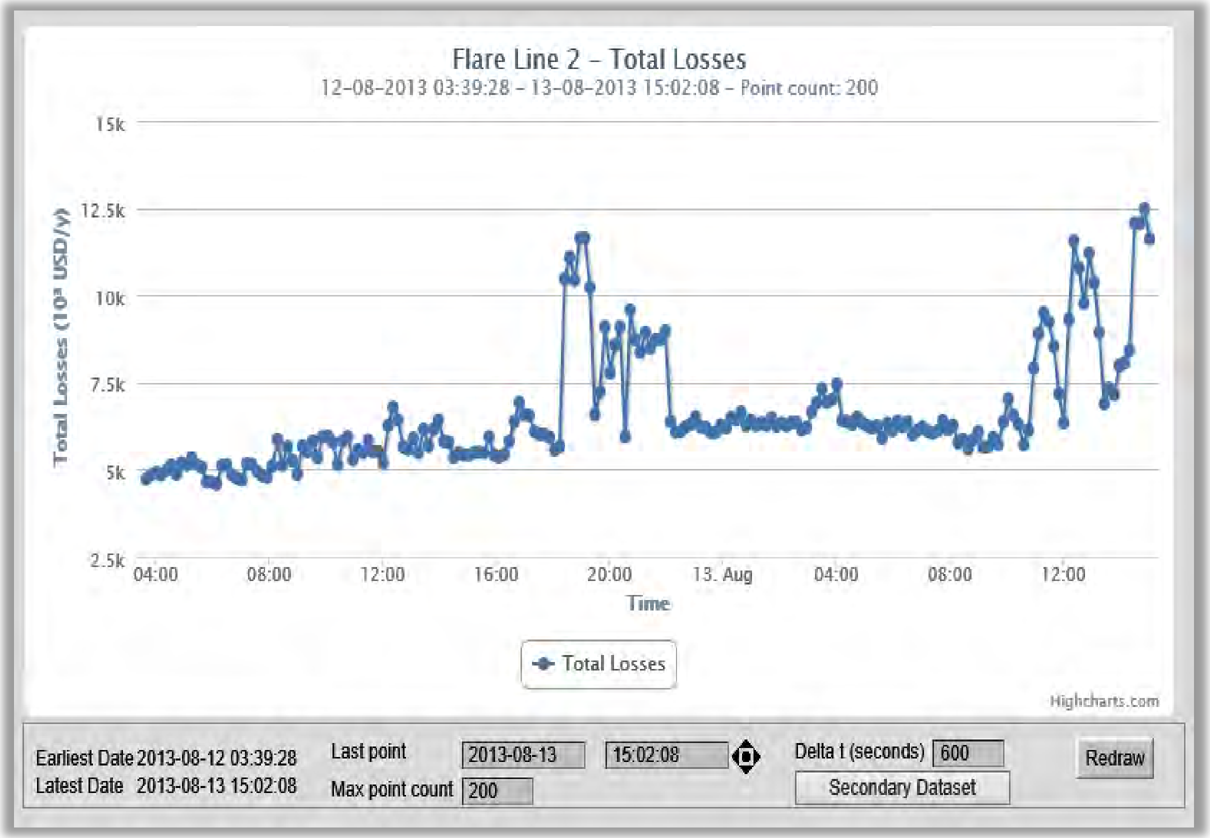
In this period of 36 hours you can see that they flared LPG at an average rate of ~$2.5M USD per year.

Or ~$10,000 in 36 hours of normal operations.



Topic: Business Results Achieved

- Data showing total value of losses; impacts to the bottom line, here peaking at times in the 10's of Millions.

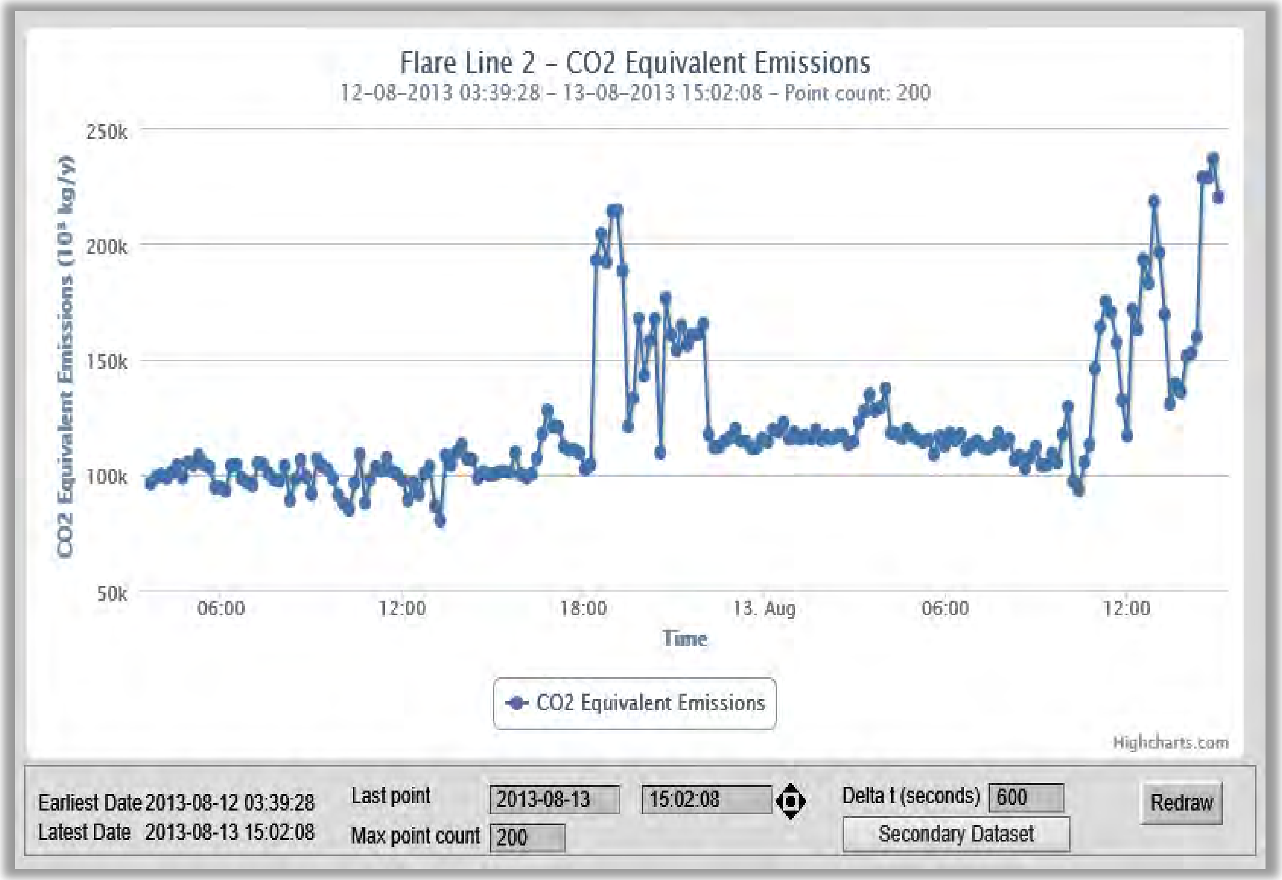


If you look at the value of all commodity losses to Flare Line 2 alone, this amounts to an avoidable financial loss in excess of \$7.5M USD per year.

Topic: Business Results Achieved

- Data for Government and Environmental Agencies; CO_2 and other GHG emissions.

With the global focus on climate change the GHG emissions data is a large driver for this type of application.



Topic: Business Results Achieved

- Key Findings on first Flare System Deployment in Mexico:
  - Extreme swings in Flare Gas Composition, dependent on upstream processes. Points to possible process improvements.
  - Large losses of valuable product and revenues through flaring of commodities. Early data indicates losses per year averaging >$7.5M on 1st of numerous flare mains to be monitored at the facility.
  - Quantified and Verifiable GHG emissions for proper reporting to agencies.
  - Provides “True” GHG reporting based on actual carbon intensities and flows, rather than estimates.

FLARE RATE MEASUREMENT TECHNIQUE

Continuous In-line Tracer Test

Inline Tracer Technique

- Inject tracer gas at a known rate.
- Measure amount of dilution by flare gas 20 pipe diameters downstream.
- Calculate flare rate based on a mass balance.
  - $Q_{Flare} = Q_{Tracer} \cdot \left(\frac{1-y_{Tracer}}{y_{Tracer}}\right)$
- $Q_{Flare} = Flare\ gas\ flow\ rate\ (m^3/h)$
- $Q_{Tracer} = Tracer\ gas\ injection\ rate\ (m^3/h)$
- $y_{Tracer} = Tracer\ gas\ mole\ fraction\ in\ flare\ gas.$
- Suitable injection ports and sampling ports generally much easier to find than suitable ports for insertion flow measurements.

Key Advantages

- Easy to install while the flare is in operation:
  - Often able to be install by utilizing existing access ports and fittings on the associated flare line, purge gas system, knock-out drum or inlet separator.
  - Otherwise, hot taps may be required.
- Competitive capital cost.
- Excellent rangeability: 1:10,000
- Utilization of readily available and low-cost tracer gas: acetylene.
- Low operating cost: only uses a few mL/min to L/min of tracer gas.
- No corrections required for temperature, pressure, or flare gas composition.

Power Requirements

- Mass flow controller for the tracer gas injection system is powered using a small ultra-portable battery pack.
- Site power or power generated by an automobile's electrical system are used for the analyzer and a field laptop.

Acetylene Injection System

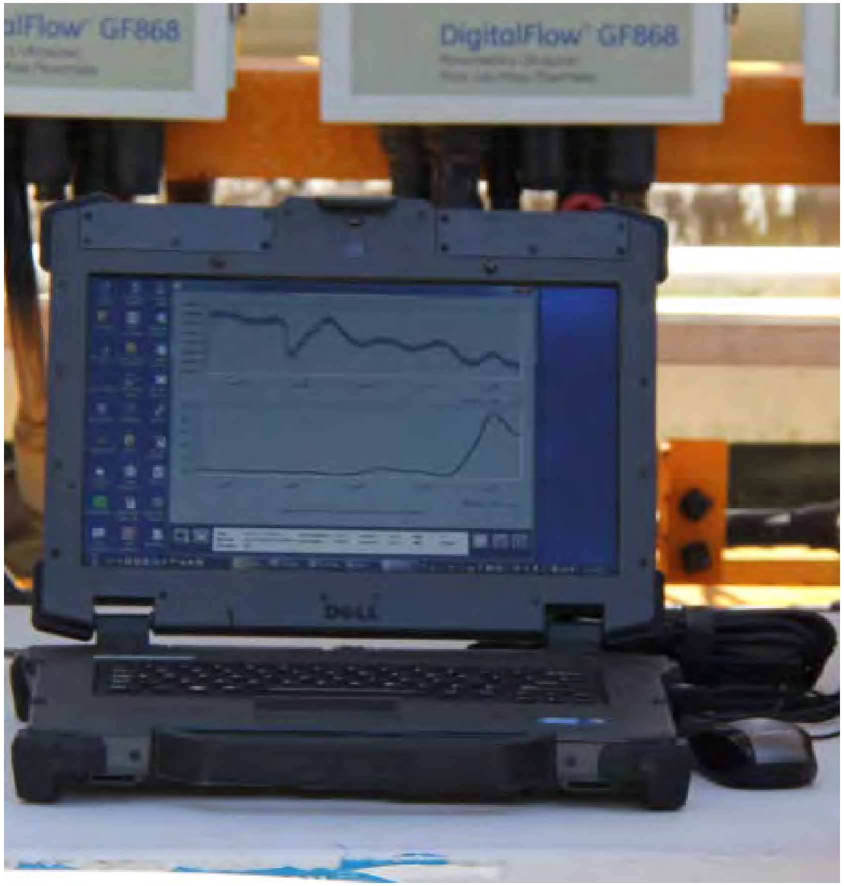
Example Injection & Sampling Points






Analyzer and Real-time Graphical Display

Real-time Graphing of Results





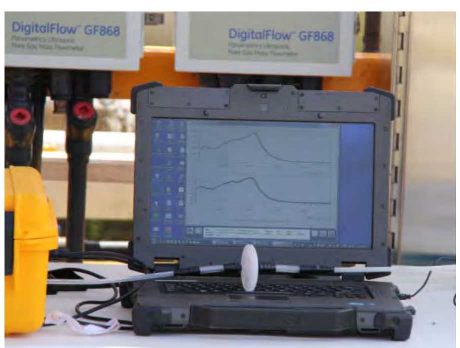
CLEARSTONE ENGINEERING

EMISSIONS DATA

Prepared by: D.Picard
Clearstone Engineering Ltd

CAEP - November 23, 2015
Beijing, China





Active Jurisdictions

Country	Years	Fugitive Equipment Leaks	Process Vents	Flares	Engines	Heaters	Storage Tanks
Azerbaijan	2008-2009		X				
Canada	1989-2015	X	X	X	X	X	X
China	1992, 2007-2015	X	X	X	X	X	X
Colombia	2013-2015	X	X		X	X	X
Mexico	2007-2015	X	X	X	X	X	X
Nigeria	2016			X			X
Romania	2008	X					
Russia	2013	X					
Uzbekistan	2008-2009			X			

Model 600 Analog Ex
Stop Polling
Controls
Registers
Stop Logger
Flare (Caruto
Methane 31.06
Ethane 16.03
Prqpane 10.95
i Butane 12.57
n Butane 23.13
Pentane 0.06
Co2 7.53
H2S 0.21
Cell Press 1.00
Cell Temp. (° 59.95
Src. Intense 55.48
Baseline 0.00
CV 81.58
WI 69.93
Op Status 0
Watchdog 852
Zero Beam 20
Purge Ave 30
Fault De-Energized
Cell Lo Temp. Energized
Cell Hi Temp. Energized
Purging Energized
Re-Zeroing De-Energized
Exec.Re-Zero De-Energized

Baseline Conditions

Table 1: Baseline commodity losses associated with flaring at the surveyed facilities.

Facility	Source[3]	Tag No.	Service/Activity	Value of Gas Losses (USD/y)		Total Gas Loss (m^3/h)	Residue Gas (10^3 m^3/d)	Ethane (m^3/d liq)	LPG (m^3/d liq)	NGL (m^3/d)	Hydrogen (m^3/d)
				Energy Basis	Commodity Basis						
Oil Battery 1	Flare Stack (Unassisted)	CB-Alamo	Associated Gas Disposal	1,951,420	4,836,457	1,299.89	15.40	14.71	15.91	1.04	0.00
Compressor Station 1	Flare Stack (Unassisted)	CB-102B	Blowcase Waste Gas Disposal'	805,698	1,558,869	536.89	8.42	5.04	3.84	0.66	0.00
	Flare Stack (Unassisted)	CB-103B	Emergency or Intermittent Waste Gas Disposal	0	0	0.00	0.00	0.00	0.00	0.00	0.00
	Flare Pit	CB-104A	Pilot Gas	203,353	303,195	135.40	2.48	1.44	0.49	0.10	0.00
			Purge Gas & Leakage Into Flare Header	843,052	1,256,971	561.34	10.29	5.95	2.05	0.40	0.00
Oil Terminal & Gas Processing Facility 1	Flare Stack (Unassisted)	CB-700	Continuous Waste Gas Disposal	23,297,496	53,082,206	12,707.37	187.57	185.37	134.78	42.14	0.00
	Flare Stack (Air Assist)	CB-800	Stabilizer Overheads Disposal	1,622,139	6,917,047	443.79	1.28	6.42	16.04	15.18	0.00
	Flare Stack (Unassisted)	CB-900	Continuous Waste Gas Disposal	4,491,142	11,408,518	2,269.82	27.24	43.00	31.27	9.79	0.00
Oil Battery 2	Flare Stack (Unassisted)	CB-Horcon	Associated Gas Disposal	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Oil Battery 3	Flare Stack (Unassisted)	CB-Hidalgo	Associated Gas Disposal	1,570,636	2,530,507	1,080.90	21.44	4.85	5.28	0.41	0.00

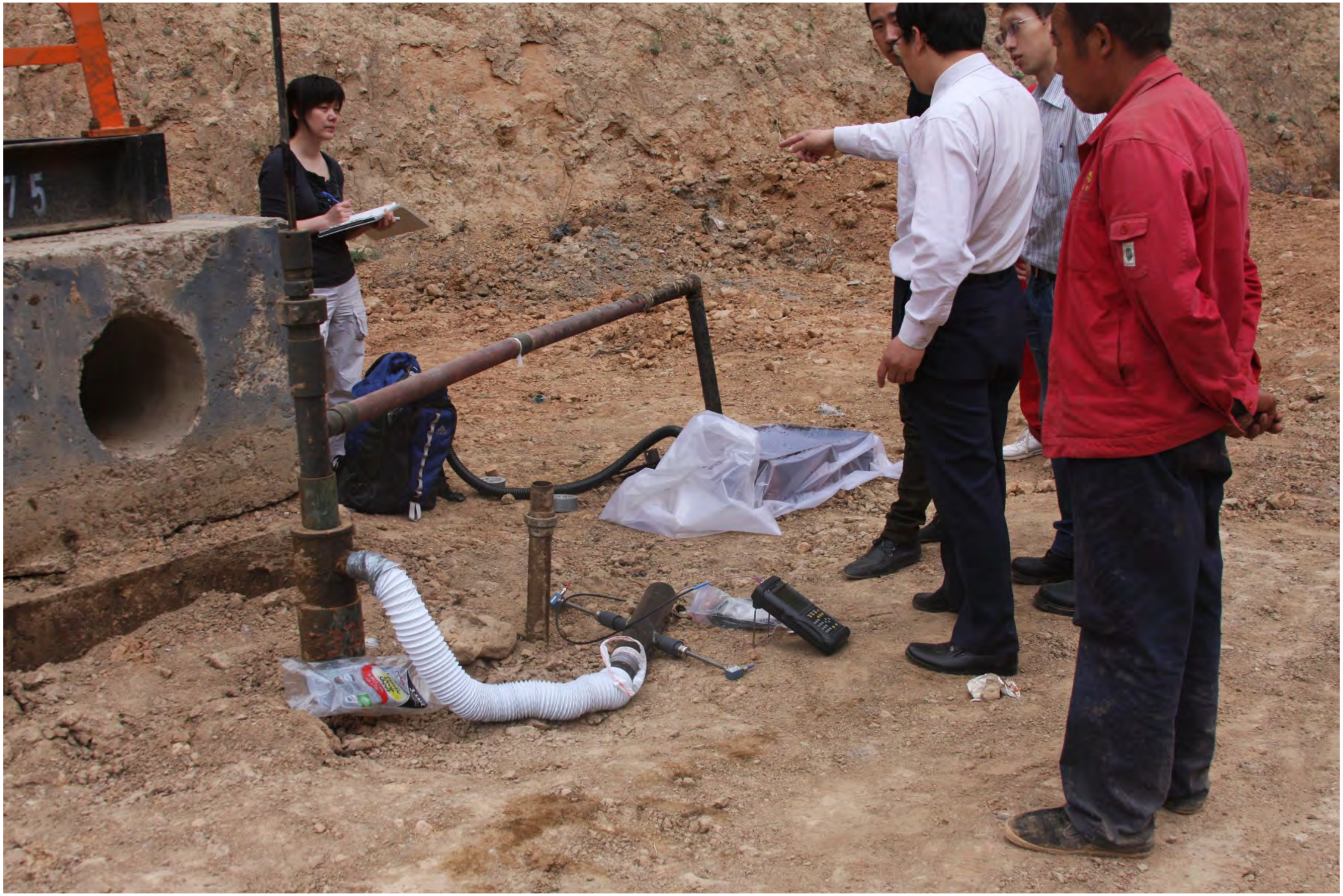
Refinery #2 Results

Table 1: Commodity losses associated with current reported flaring at Refinery #2.							
Source	Value of Avoidable Fuel/Product Losses ($/y)	Total Avoidable Fuel or Product Loss (m^3/h)	Residue Gas (10^3 m^3/d)	Ethane (m^3/d liq)	LPG (m^3/d liq)	NGL (m^3/d)	Hydrogen (m^3/d)
Ground Flare Q-8	162,651,735	33,377.17	122.40	225.15	666.10	268.33	297,439.93
Ground Flare Q-11	7,110,973	1,380.77	6.19	12.36	28.91	11.71	9,736.55
Ground Flare Q-12	54,681	11.00	0.03	0.07	0.38	0.02	77.88
Stack (Assisted) QE-2	44,252,069	37,989.89	127.65	110.63	109.30	24.11	501,466.55
Stack (Assisted) QE-3	8,833,258	10,286.75	17.78	1.23	2.88	2.41	224,662.62
Stack (Assisted) QE-3 (AG)	136,211	1,230.00	0.03	0.38	1.04	0.00	0.00
Stack (Assisted) QE-4	13,643,701	11,712.96	39.36	34.11	33.70	7.43	154,611.07
Stack (Assisted) A1-31001	308,210	2,783.17	0.07	0.86	2.35	0.00	0.00
Total	236,990,838	98,772	314	385	845	314	1,187,995

SCADA Monitoring System At a Refinery

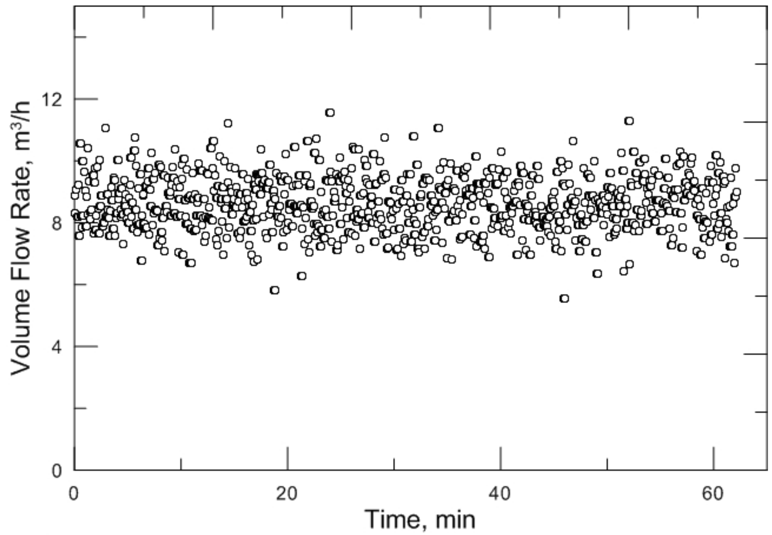
Casing Gas Vent Flow Measurement

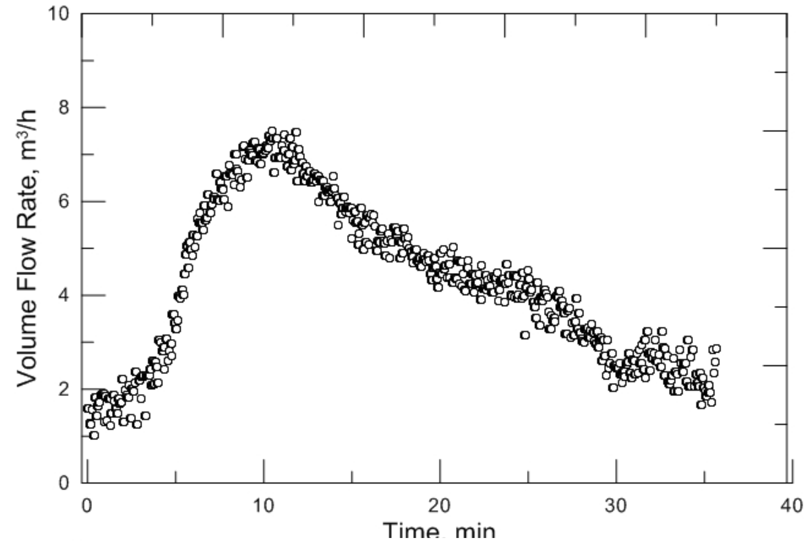
Casing-Gas Flow Measurement

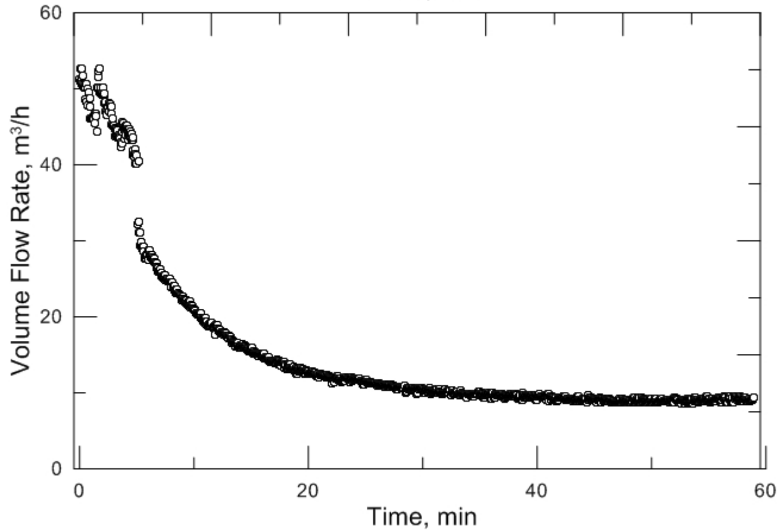


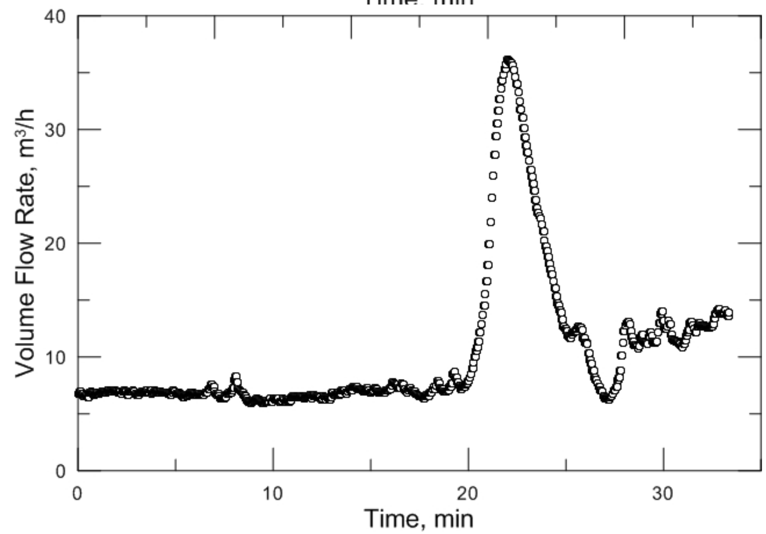
Hi-Flow Sampler Measurement of Emissions from a Sump

Variations in Casing Gas Flows



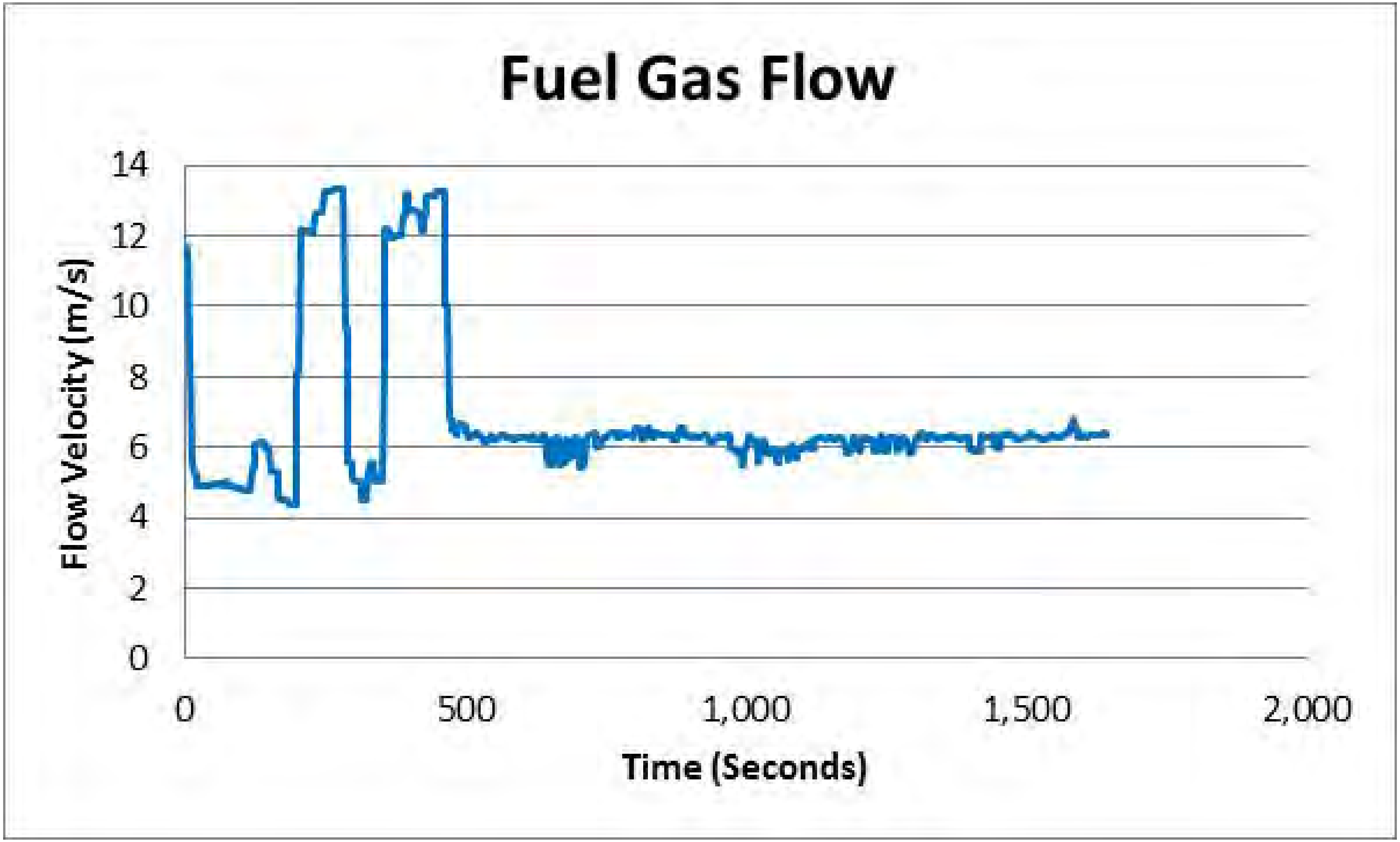






Engines – Starter Vent Measurements

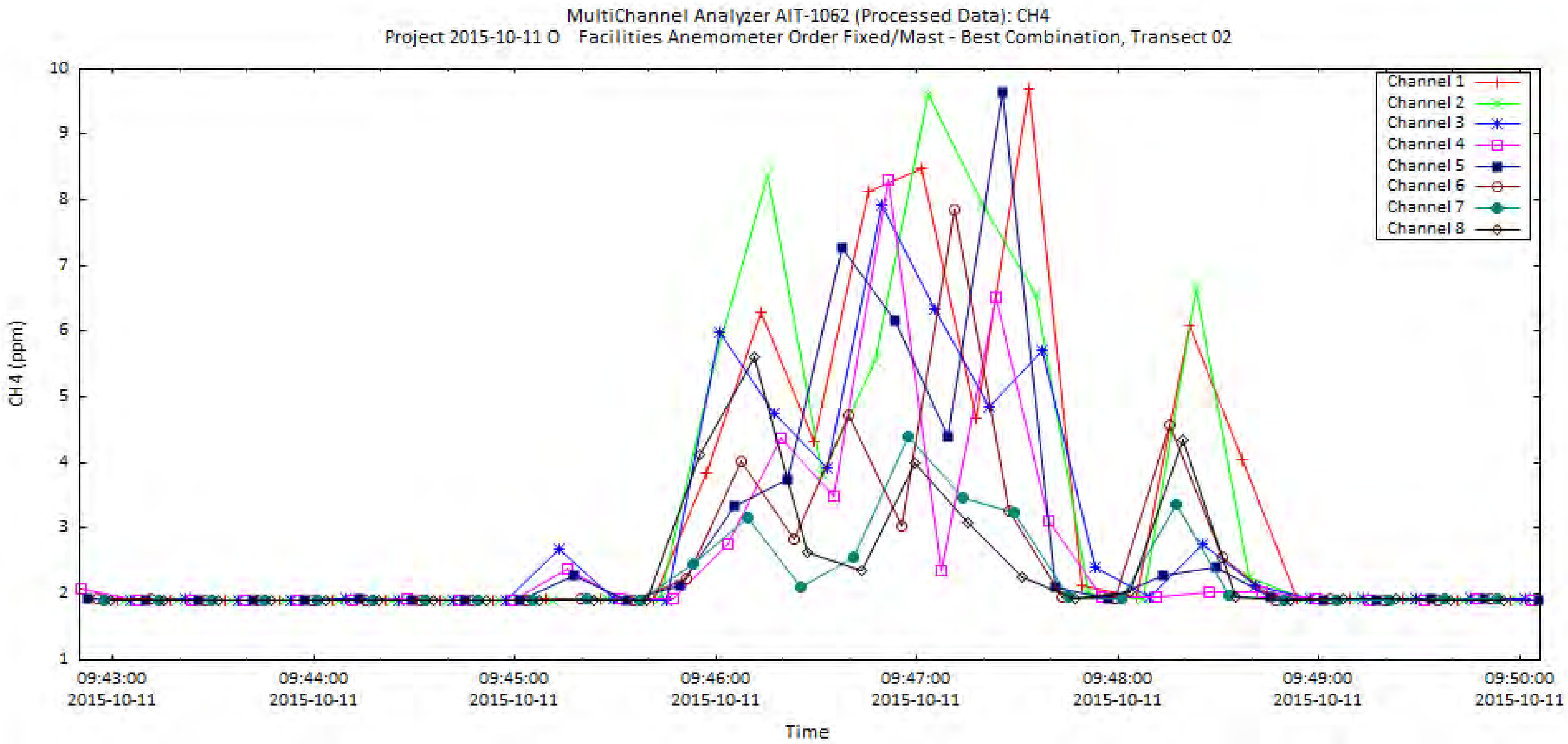
Engines – Starter Flow Vent Measurements



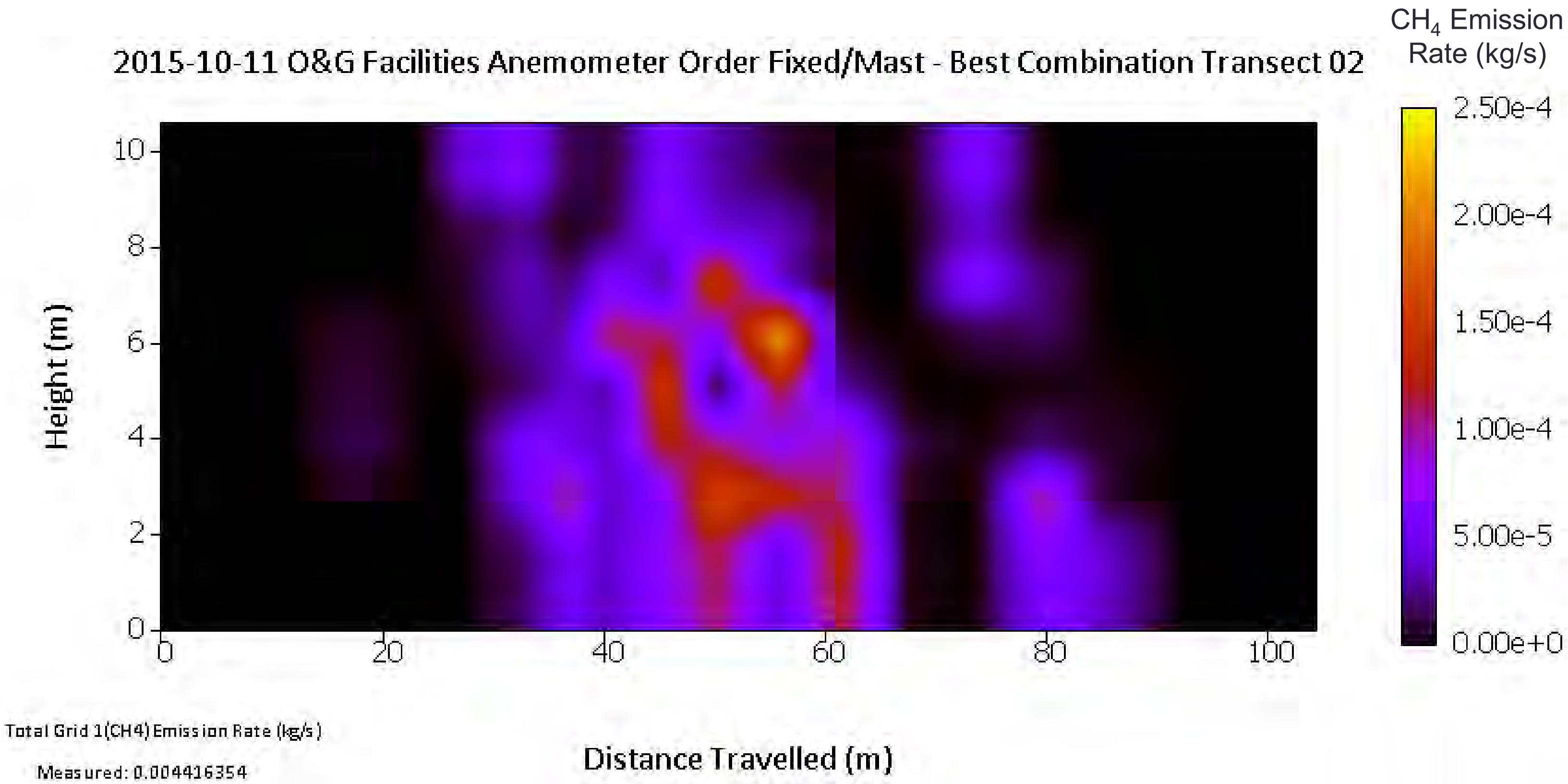
Hydraulic Fracturing Flow-Back Event in China

Oil Battery – Transect Path

Oil Battery – Downwind Concentrations



Oil Battery – Emission Rate Contour Plot



- Good vertical capture
- Good horizontal capture
- Good resolution

N_2O Study

- Rationale:
  - Limited data on N_2O EFs for natural gas fueled equipment used in the UOG.
  - Data collected in 1990’s (grab sample techniques).
  - Sampling bias where N_2O is generated in the sampling container in the presence of NO_x, SO_2 and moisture (Ryan and Karns, 1993; Hayhurst and Lawrence, 1992).
- Objective:
  - Develop updated factors for:
    - Process heaters (10).
    - Reciprocating engines (8).
    - Turbine engines (3).

Continuous Measurement Equipment

- Three cavity ringdown spectrometers:
  - N_2O: 0 to 4 ppm [0 to 10 ppm] (0.3 ppb precision) (high CO upgrade)
  - CO: 5 ppm to 10% (3 ppm precision)
    5 to 4000 ppb (0.15 ppb precision)
  - CO_2: 1000 ppm to 100 percent (20 ppm precision)
  - CH_4: 10 ppb to 100% (2 ppb precision)
  - O_2: 300 ppm to 100 percent (300 ppm precision)
  - H_2O: 100 to 70,000 ppm (0.4% precision)
- Chemiluminescence $NO/NO_2/NO_x$ analyzer: 0 to 3,000 ppm (10 ppb resolution).
- Optical NG Analyzer (CO_2, C_1, C_2,C_3,i-C_4, n-C_4,C_5) 0-100% C_1, 0-25% C_2 & C_3, 0-10% C_4, 0-3% C_5 (0.02% precision)

Observed N_2O Concentrations

- N_2O concentrations in flue gas <1 ppm for all sources but one 4-stroke lean-burn reciprocating engine <4 ppm.

- Hayhurst and Lawrence (1992) report values of <5 ppm for all combustion sources except fluidized beds.
  - Fast destruction reactions of N_2O during high temperatures.

Summary Results & Confidence Limits

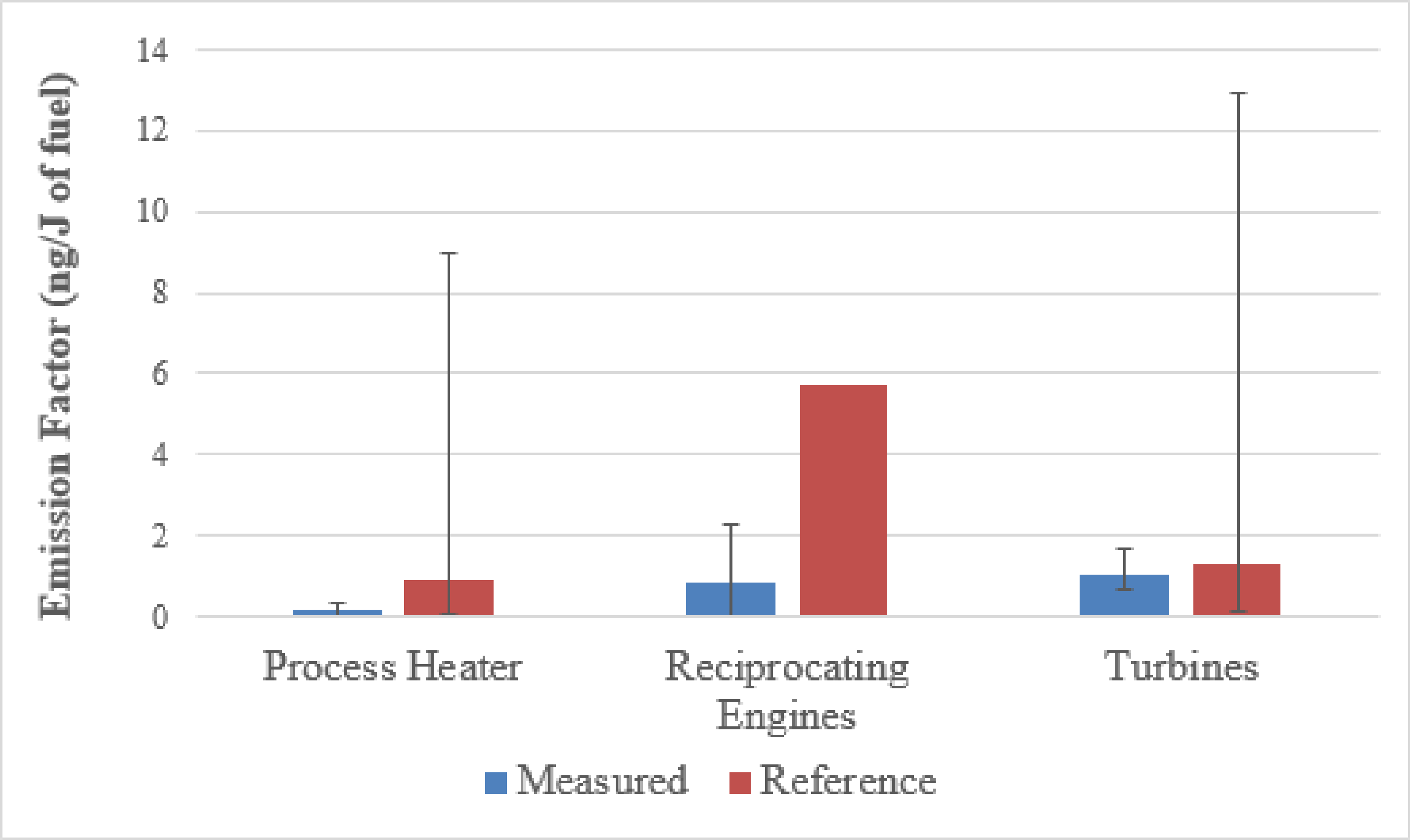


Figure 2: Comparison of emission factors determined from measurements with reference emission factors.

Comparison of Heater EFs to EPA Values

Table 2: Actual and reference GHG and CAC emission factors for process heaters on an energy input basis.

Equipment Category	Unit ID	Emission Factors (ng/J of Fuel[1])											
		N_2O[2]		CH_4		CO_2		CO		NO_x		NO	NO_2
		Actual	EPA	Actual	EPA	Actual	EPA	Actual	EPA	Actual	EPA	Actual	Actual
> 29 MW	PTAC.1.19[2]	NA	0.9	2301.3	1	49697	50579	1203.2	35	9.8	118	9.7	0.1
≤ 29 MW, Low NOx Burner	PTAC.1.4	0.07	0.26	6.8	1	49697	50579	0.0	35	14.6	21	13.9	0.7
≤ 29 MW	PTAC.1.1	0.04	0.9	0.4	1	49697	50579	0.1	35	25.2	42	23.3	1.9
	PTAC.1.3	0.05	0.9	0.1	1	49697	50579	0.1	35	25.4	42	24.9	0.5
	PTAC.1.5	0.03	0.9	0.3	1	49697	50579	0.6	35	34.4	42	31.6	2.8
	PTAC.1.6	0.03	0.9	7.5	1	49697	50579	0.1	35	43.6	42	40.8	2.8
	PTAC.1.18[2]	NA	0.9	22.2	1	49697	50579	90.1	35	10.9	42	5.6	5.3
	PTAC.2.9	0.70	0.9	2.8	1	50741	50579	12.9	35	30.5	42	28.1	2.4
	PTAC.2.10	0.15	0.9	0.5	1	50741	50579	3.8	35	13.5	42	10.0	3.5
	PTAC.3.11	0.29	0.9	2.1	1	50870	50579	19.8	35	24.0	42	16.9	7.1
	Average	**0.19**	**0.9**	**4.5**	**1**	**50105**	**50579**	**15.9**	**35**	**25.4**	**42**	**22.7**	**2.7**

NA Not available

1. Referenced based on the gross (or higher) heating value of the fuel.
2. N_2O was not successfully measured from two heaters due to analyzer performance limitations.

Comparison of Recip EFs to EPA Values

Table 3: Actual and reference GHG and CAC emission factors for reciprocating engines on an energy input basis.

Equipment Category	Unit ID	Emission Factors (ng/J of Fuel[1])											
		N_2O		CH_4		CO_2		CO		NO_x		NO	NO_2
		Actual	EC[2]	Actual	EPA	Actual	EPA	Actual	EPA	Actual	EPA	Actual	Actual
2-Stroke Lean Burn	PTAC.2.12	0.24	5.72	5,236.3	624	50741	47291	53.2	152	18.5	834	3.1	15.4
4-Stroke Lean Burn	PTAC.4.16	0.26	5.72	187.5	537	50871	47291	196.7	239	371.8	364	289.9	81.9
	PTAC.4.18	0.54	5.72	229.1	537	50871	47291	253.8	239	552.3	364	461.7	90.6
	PTAC.3.13	0.27	5.72	518.8	537	50870	47291	141.7	239	94.8	364	81.2	13.6
	PTAC.3.15	0.23	5.72	193.6	537	50870	47291	200.9	239	190.0	364	127.2	62.9
	PTAC.5.20	3.62	5.72	241.1	537	49628	47291	1.3	239	274.7	364	269.7	4.9
	Average	**0.99**	**5.72**	**274.0**	**537**	**50622**	**47291**	**158.9**	**239**	**296.7**	**364**	**245.9**	**50.8**
4-Stroke Rich Burn	PTAC.3.14[3]	NA	5.72	208.9	99	50870	47291	15613.5	1509	45.7	976	45.5	0.2
	PTAC.4.17[3]	NA	5.72	388.6	99	50871	47291	16498.1	1509	36.3	976	32.9	3.4
	Average	**NA**	**5.72**	**298.7**	**99**	**50870**	**47291**	**16055.8**	**1509**	**41.0**	**976**	**39.2**	**1.8**

1. Referenced based on the gross (or higher) heating value of the fuel.
2. There are no EPA AP-42 N_2O emission factors for reciprocating engines. The N_2O emission factor for reciprocating engines is from an Environment Canada repot (EC 2014)
3. N_2O was not successfully measured from the four stroke rich burn engines due to analyzer performance limitations.

Comparison of Turbine EFs to EPA Values

Table 4: Actual and reference GHG and CAC emission factors for stationary gas turbine engines on an energy input basis.

Equipment Category	Unit ID	Emission Factors (ng/J of Fuel[1])												
		N_2O		CH_4		CO_2		CO		NO_x		NO	NO_2
		Actual	EPA	Actual	EPA	Actual	EPA	Actual	EPA	Actual	EPA	Actual	Actual
All	PTAC.1.7	1.09	1.29	14.8	3.7	50036	47291	63.5	35	64.6	138	39.1	25.6
	PTAC.1.8	0.75	1.29	2.7	3.7	50119	47291	5.2	35	71.4	138	60.9	10.5
	PTAC.1.2	1.28	1.29	0.2	3.7	50119	47291	35.5	35	237.0	138	196.4	40.6
	Average	**1.04**	**1.29**	**5.9**	**3.7**	**50091**	**47291**	**34.7**	**35**	**124.3**	**138**	**98.8**	**25.6**

1. Referenced based on the gross (or higher) heating value of the fuel.

N_2O & O_2 Flue Gas Concentrations During On/Off Cycling of a Heater

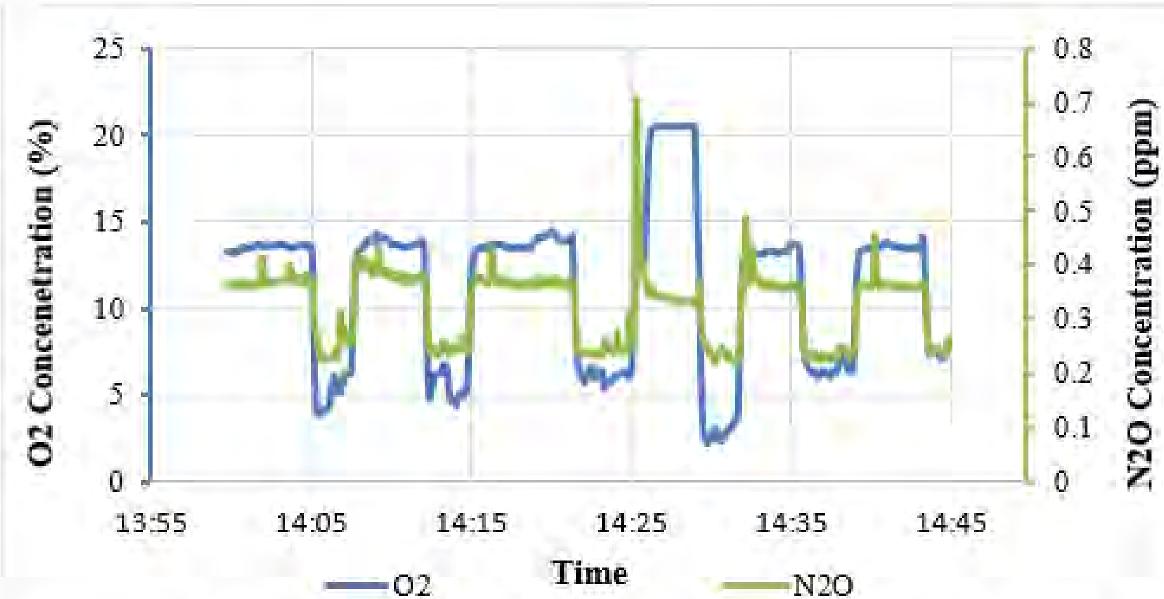


Figure 3: **Measured concentrations of O_2 and N_2O in the exhaust gas of utility heater PTAC.3.11.**

Thank you!

3 APPENDIX – SAES WORKSHOP (27 NOV 2015)

SAES

Shanghai Academy of Environmental Sciences

(Conference Attendance Book) 2015.11.27. No.300# Room

No.	Name	Institution/Organization	Title	Phone
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3	Shuhui Zhu	SAES		13671939634
4	Yingge Ma.	SAES. AEI		13482286879
5	Li Li	SAES		13636655726
6	Hongli Wang	SAES		13564397932
7	Dai Haixia	SAES		13818002686
8	D. Picard	CBL		14036076528
9				
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19				

2015年11月27日
中国，北京

远程监测排放量的移动烟缕截面系统

David Picard
Clearstone Engineering Ltd.

烟缕截面排放量化策略

筛选	截面	固定测量	随机取样
• 筛选参照化合物和关注污染物定位排放烟缕和可能的干扰来源 • 参照化合物：CH_4，CO_2 • 关注污染物：VOCs，H_2S，NH_3	• 量化参照污染物排放量（CH_4和CO_2） • 测位仪需寻找监听障碍，如天线杆较高的输电线	• 监控关注污染物与参照化合物的比率 • 确定关注污染物相关最佳参照污染物 • 计算污染物排放量	• 通过实验室分析获取更准确详细的VOC排放量形成及其他可能污染物量化 • 上风向和下风向随机取样

VOC（挥发性有机化合物） 量化策略

- 量化参照污染物排放率（CH_4或CO_2）
- 根据质谱仪数据或随机取样分析确定参照污染物与VOCs的比率
- 确定VOC排放率：

$$\dot{m}_{VOC} = \dot{m}_{ref} \frac{C_{VOC} - C_{VOC,\, background}}{C_{ref} - C_{ref,\, background}}$$

$\dot{m}_{VOC}$	=	VOC排放率
$\dot{m}_{ref}$	=	参照污染物排放率
C_{VOC}	=	烟缕中的VOC浓度
$C_{VOC,\, background}$	=	VOC背景浓度
C_{ref}	=	烟缕中的参照污染物浓度
$C_{ref,\, background}$	=	参照污染物背景浓度

系统功能和局限

功能

- 实时测量，移动部署，离线访问
- 高灵敏度，可在一百米外测量0.00017kg/s CH_4
- 准确率和精确度≤25%
- 网格分辨率≤10m

局限

- 需适宜且稳定的风
- 高度限制为10m（靠近测量）
- 分辨率依赖于行驶速度

气体分析仪说明

- $CH_4/CO_2/H_2O$ – 离轴积分腔输出光谱仪
- VOCs – 便携式质谱仪
- H_2S/NH_3 – 离轴积分腔输出光谱仪

分析器	物质	测量范围 (百万分率)	精确度, 1-σ (百万分率)	响应时间 (秒)
1	甲烷 (CH_4)	0.1 - 1000	0.007 (10 Hz)	1.5
	二氧化碳 (CO_2)	200 - 4,000	1 (10 Hz)	1.5
	水 (H_2O)	100 - 70,000	100 (10 Hz)	1.5
2	挥发性有机化合物 (VOCs, 半定量)	MDL: 0.001 - 0.05	<0.001 (1 Hz)	60 - 180
3	氨 (NH_3)	0.001 - 10	0.0006 (0.1 Hz)	5
	硫化氢 (H_2S)	0.05 - 50	0.005 (0.1 Hz)	5

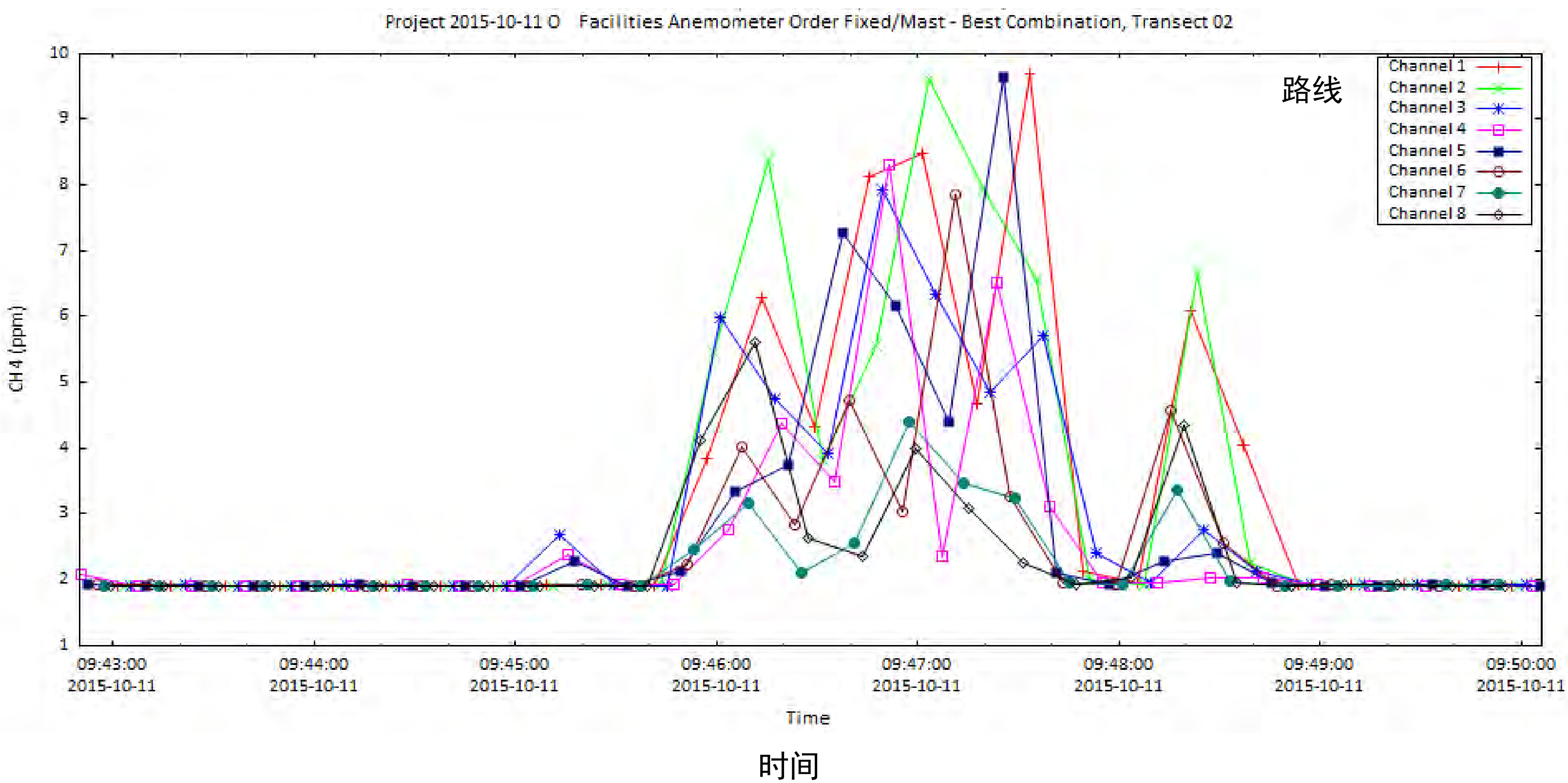
油罐区测量

油罐区 – 截面路线

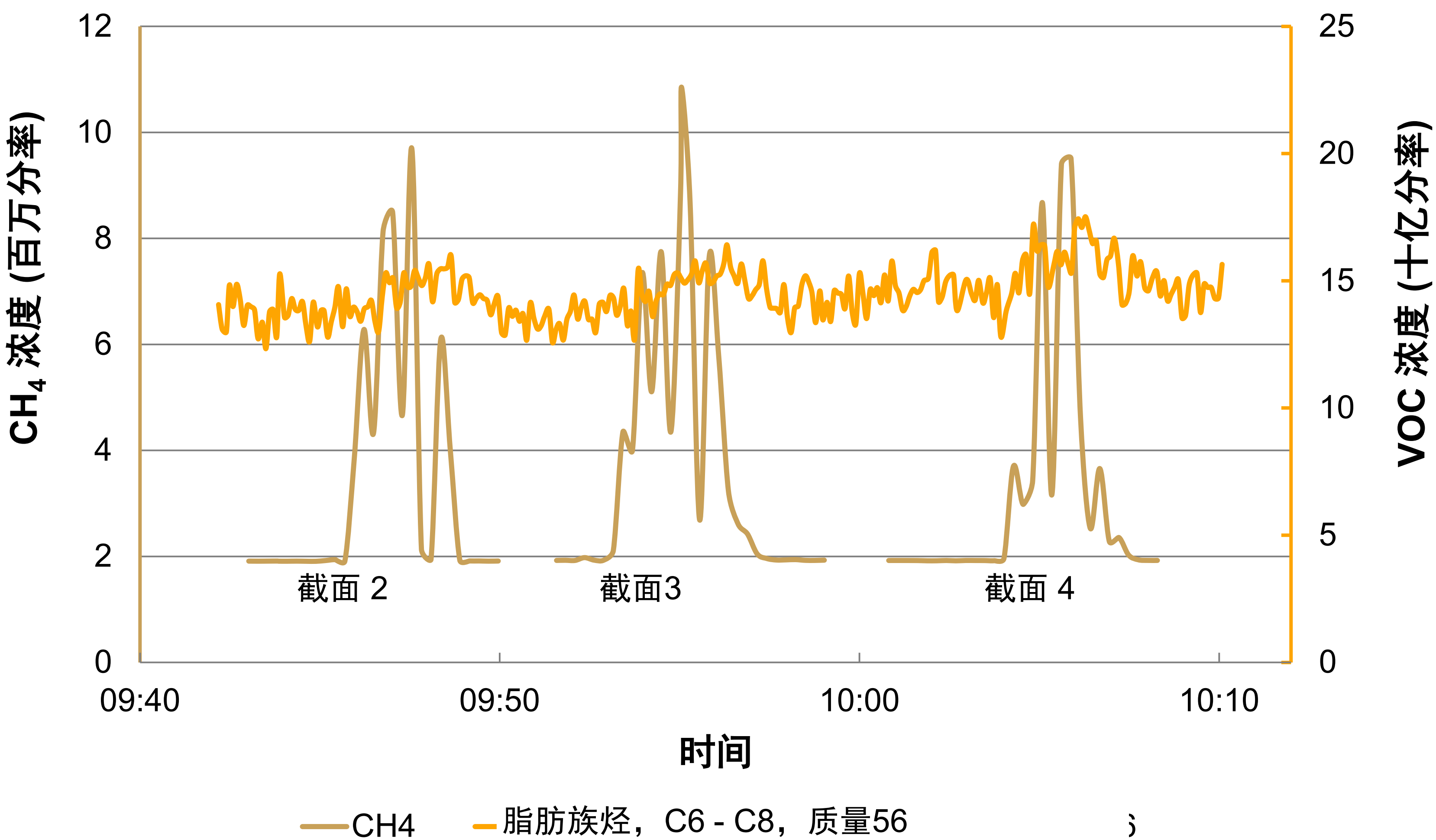

终点
End 01
油罐区
Start 01
起点
Image © 2015 DigitalGlobe
© 2015 Google
66 m
Google earth

油罐区 – 下风向浓度

2015-10-11项目 设备风速计固定顺序/桅杆——最佳搭档　02截面



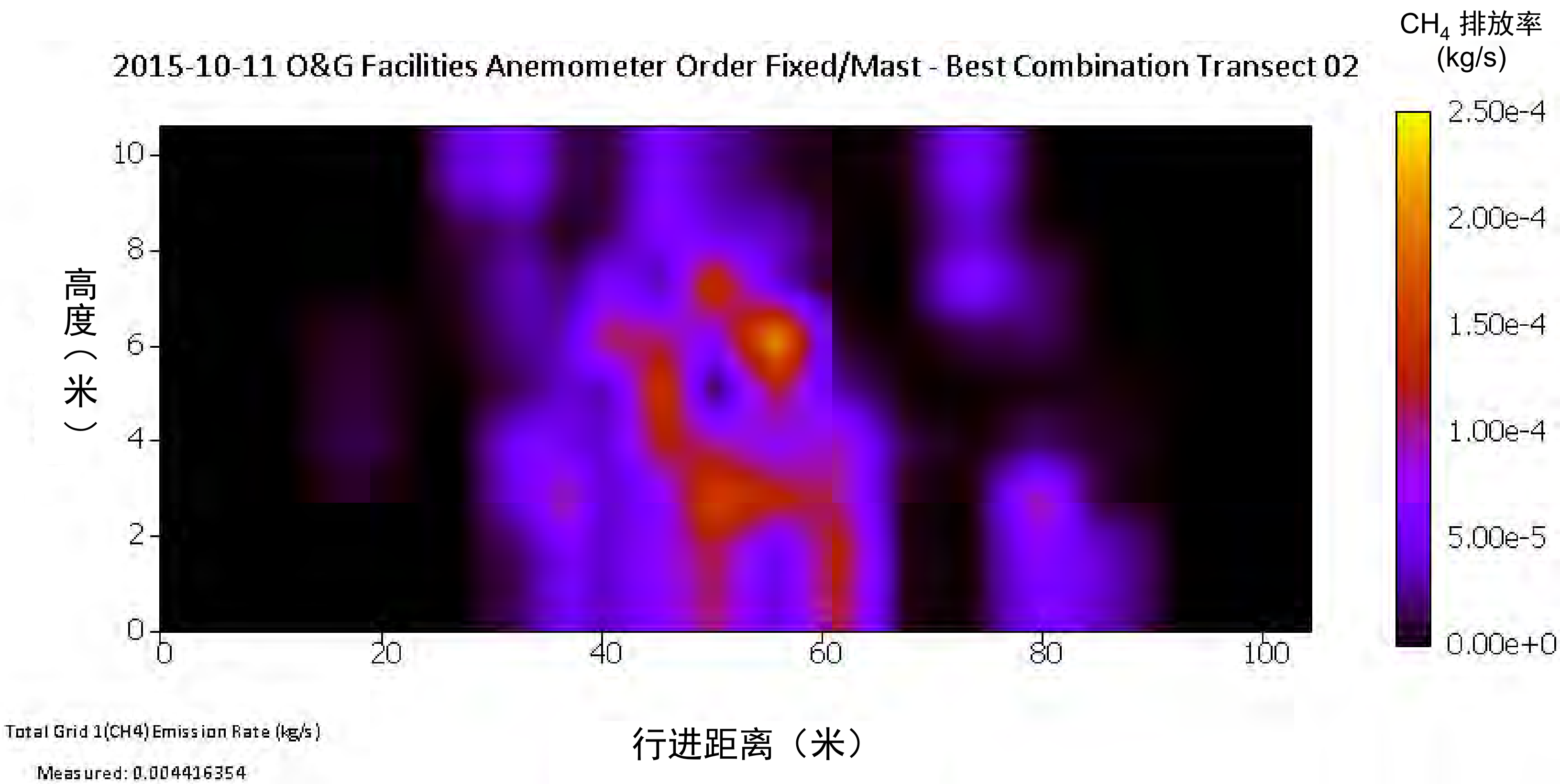
油罐区 – VOC 结果



12
10
8
6
4
2
0
25
20
15
10
5
0
CH4 浓度 (百万分率)
VOC 浓度 (十亿分率)
截面 2
截面3
截面 4
09:40
09:50
10:00
10:10
时间
CH4
脂肪族烃，C6 - C8，质量56

油罐区 – 排放率等高线图

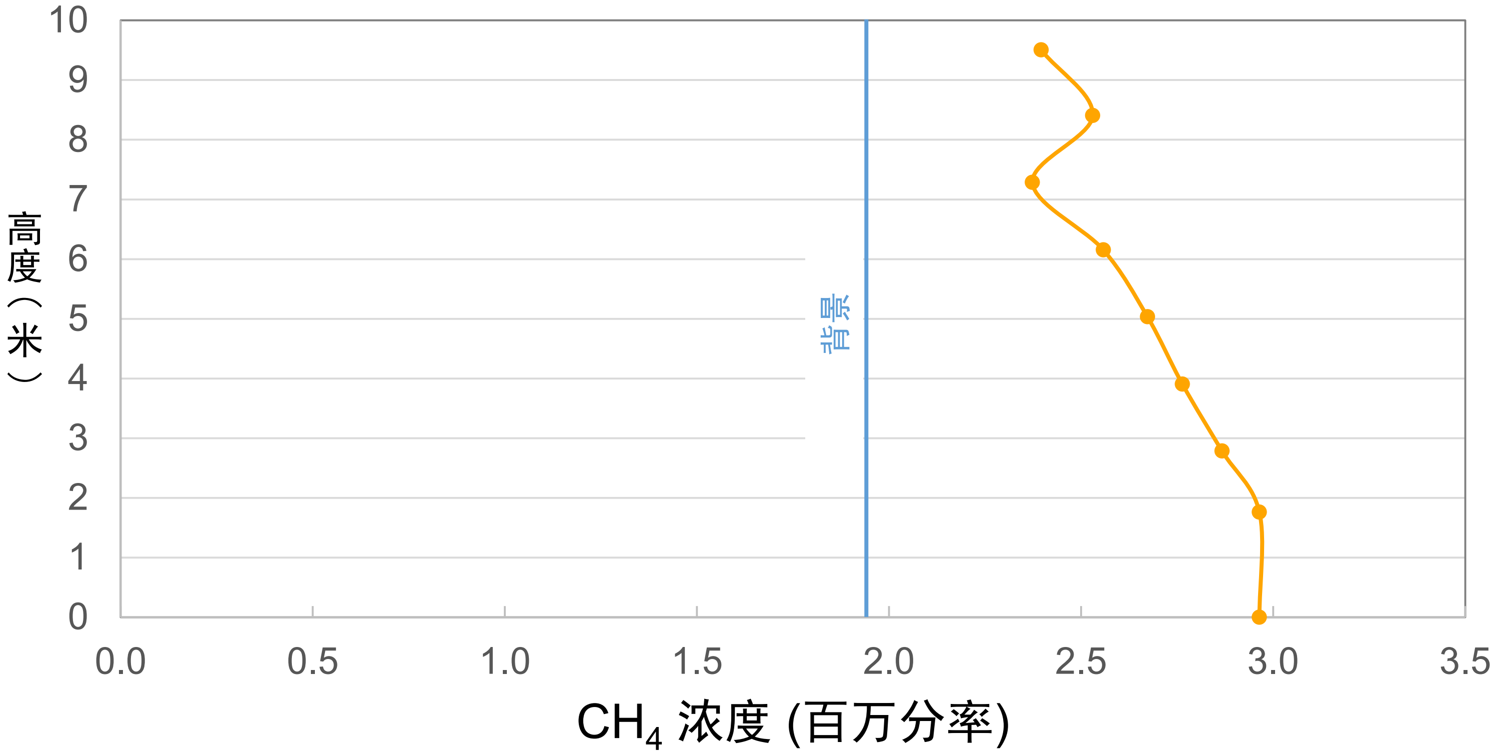
2015-10-11项目 油气设备风速计固定顺序/桅杆——最佳搭档 02截面



总释放速率

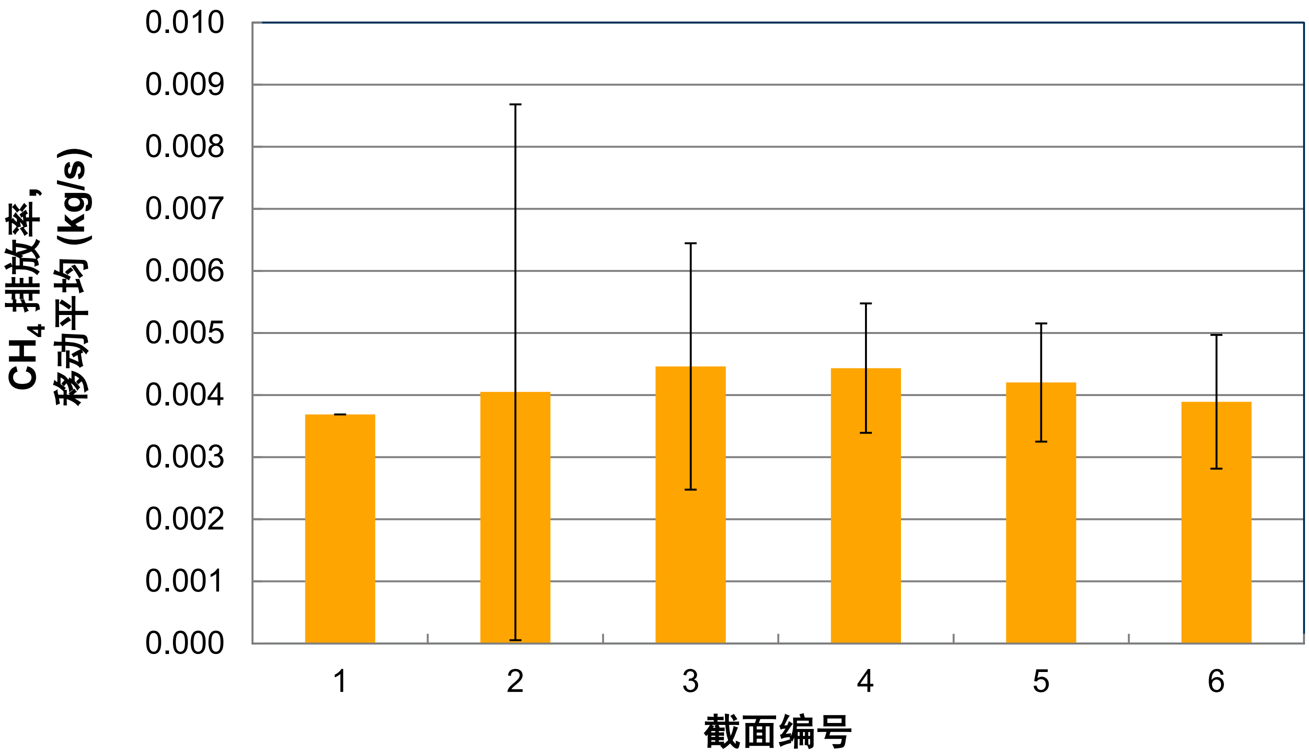
- 垂直捕捉良好
- 水平捕捉良好
- 高分辨率

油罐区 – 平均垂直浓度图



根据间隔4分钟的烟缕固定测量，距离来源200米

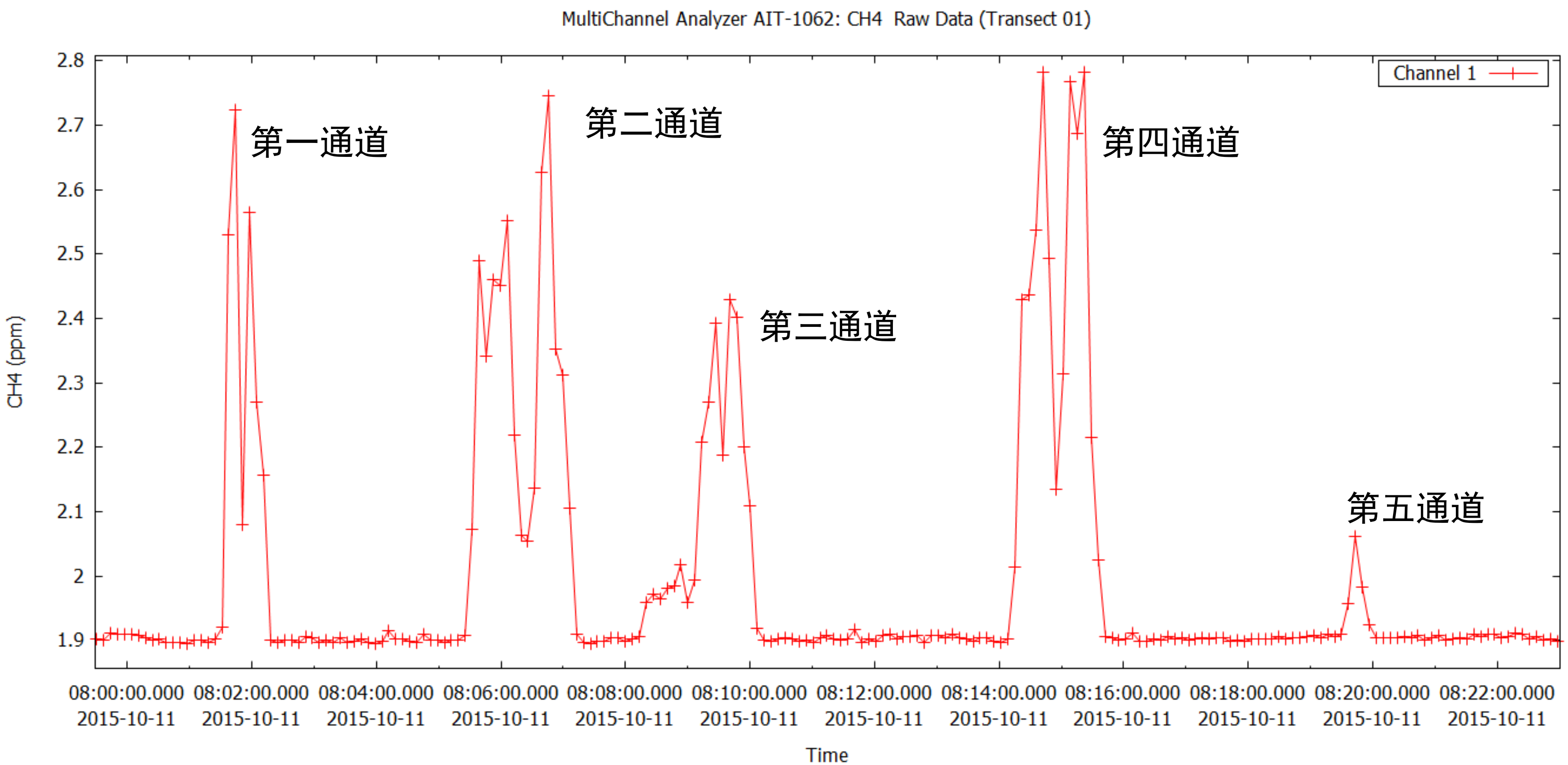
油罐区 – 收敛



4个截面后的95%置信区间低于中数的25%

燃气站筛选

多通道分析器 甲烷原始数据（01截面）



通道 1 - 4：来源400米处下风向

通道 5：来源2000米处下风向

煤矿测试 – 工地 4

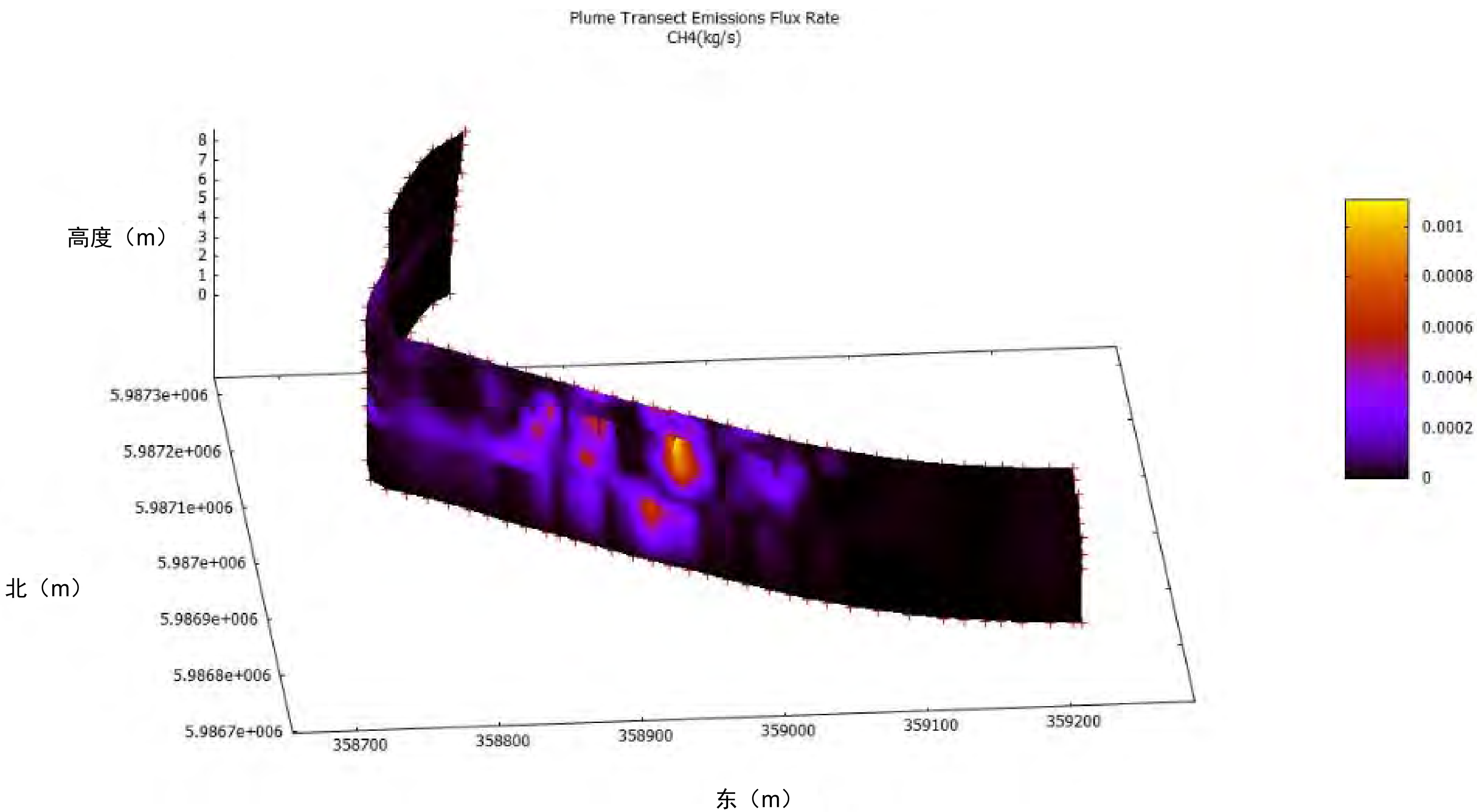
矿井东北角 （几乎不开采）

矿井西南角（积极开采）

积极开采矿井的即时下风向 – 工地 4

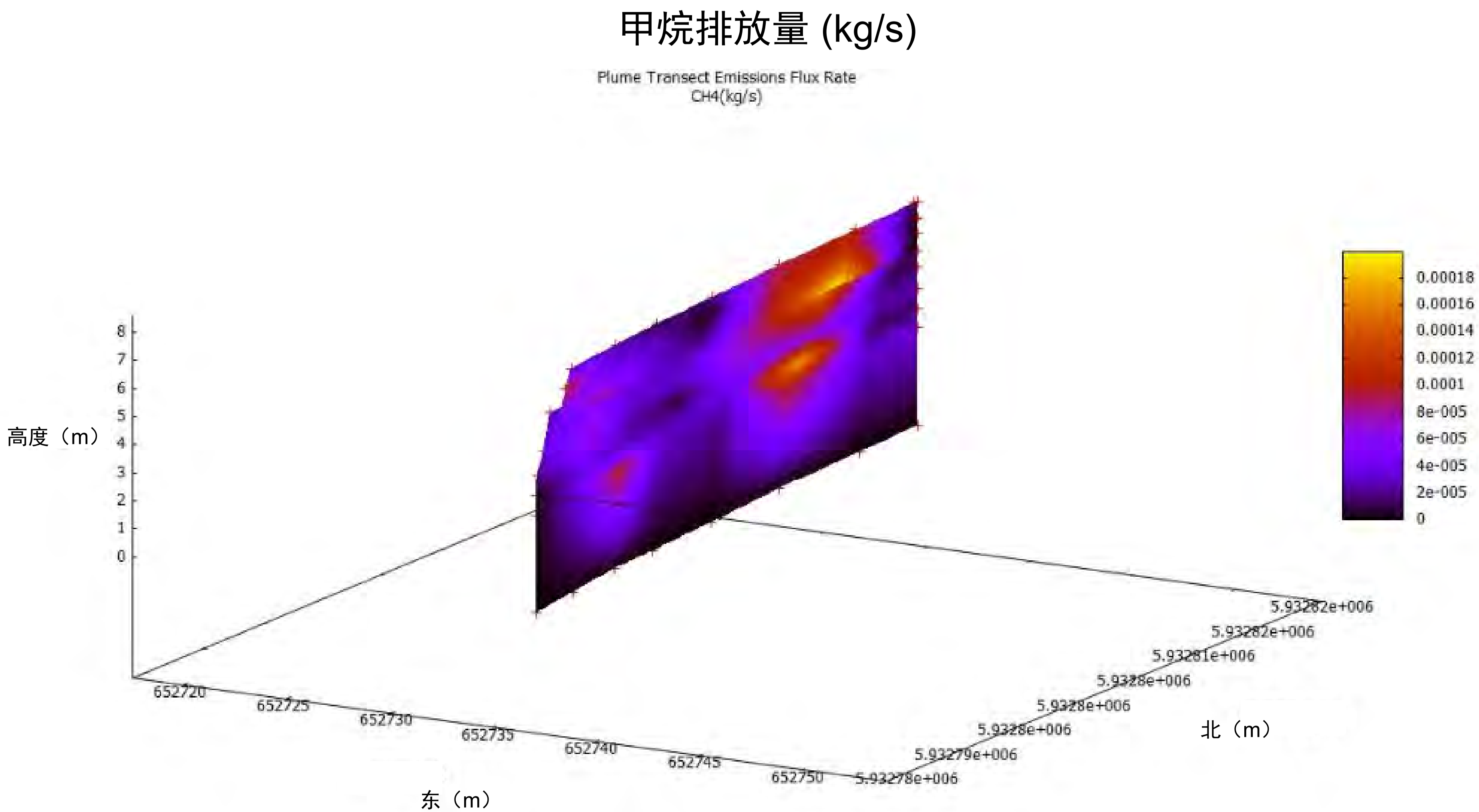
积极开采矿井的即时下风向 – 工地 4

甲烷排放量 (kg/s)



卡车&挖掘机操作的下风向 – 工地 2

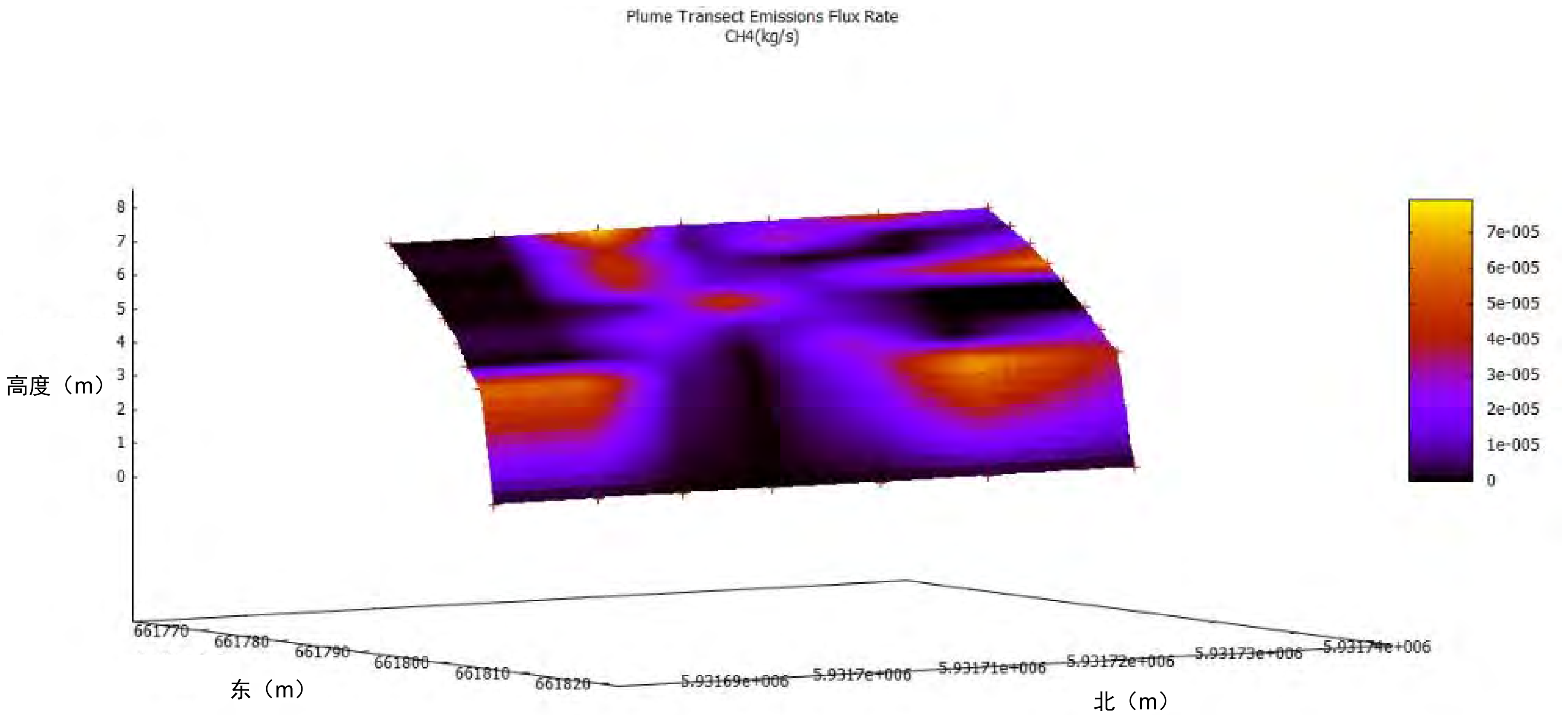
卡车&挖掘机操作的下风向 – 工地 2



煤炭堆积操作 – 工地 2

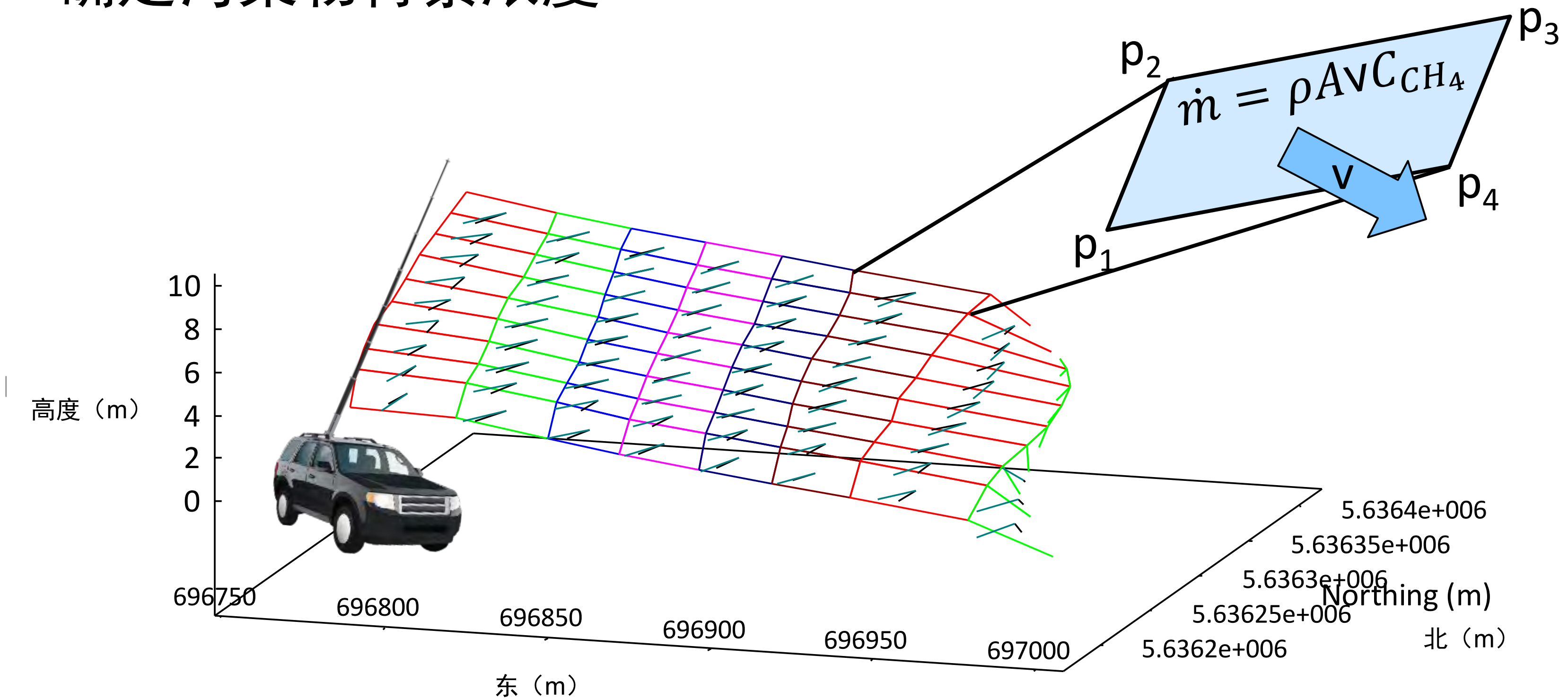
煤炭堆积操作的下风向 – 工地 2

甲烷排放量 (kg/s)



移动烟缕截面方法

- 安装监控系统的车辆
- 穿过排放烟缕来源下风向
- 测量2D风和浓度图
- 确定污染物背景浓度



系统关键组成部分

气体分析

- $CH_4/CO_2/H_2O$（快速反应，高准确率、高精确度
- 便携质谱仪（实时VOC测量）
- H_2S/NH_3

取样

- 可伸缩碳纤维天线杆（内部开发）
- 多通道采样系统（内部开发）

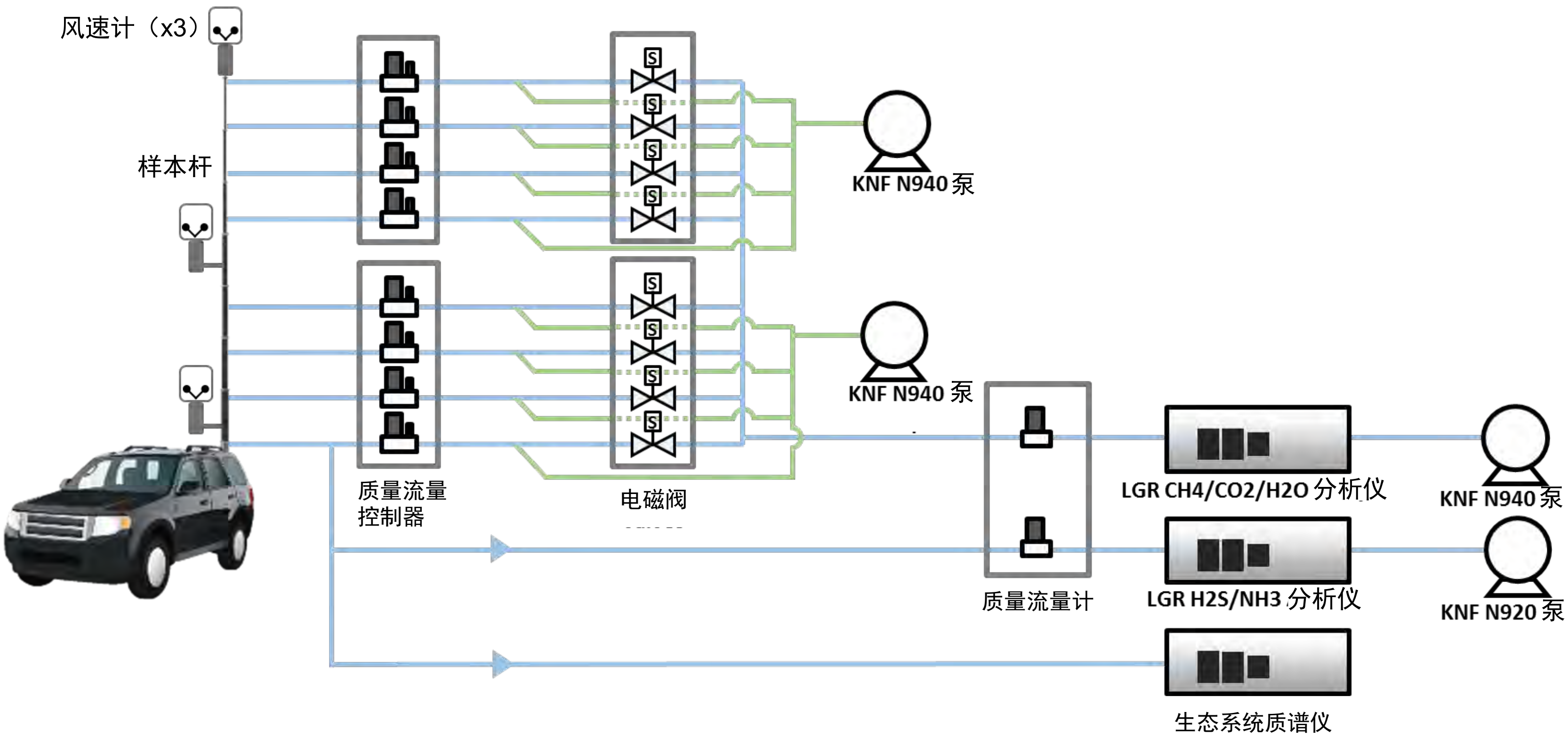
GPS和风

- 高精确度的全球定位系统（GPS）
- 3x 3D 超声波风速计

软件

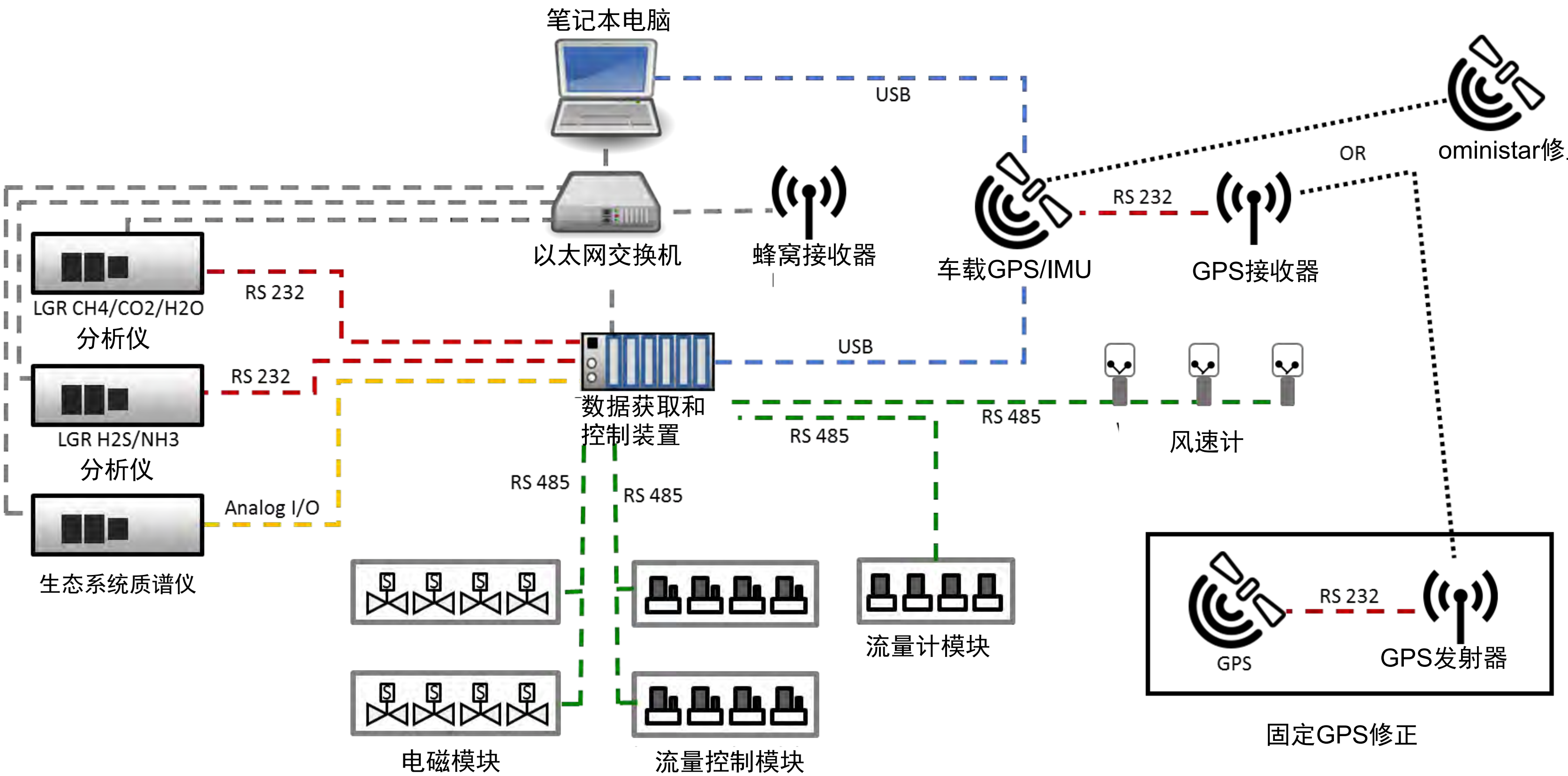
- 实时数据获取和控制
- 近实时数据进程和排放量量化（内部开发）

系统设定 – 流程图



风速计（x3）
样本杆
质量流量
控制器
电磁阀
KNF N940 泵
KNF N940 泵
质量流量计
LGR CH4/CO2/H2O 分析仪
LGR H2S/NH3 分析仪
生态系统质谱仪
KNF N940 泵
KNF N920 泵

系统设定 – 数据原理图


笔记本电脑
USB
以太网交换机
蜂窝接收器
车载GPS/IMU
RS 232
GPS接收器
OR
oministar修正
LGR CH4/CO2/H2O
分析仪
RS 232
LGR H2S/NH3
分析仪
RS 232
Analog I/O
生态系统质谱仪
USB
数据获取和
控制装置
RS 485
RS 485
RS 485
RS 485
风速计
电磁模块
流量控制模块
流量计模块
GPS
RS 232
GPS发射器
固定GPS修正

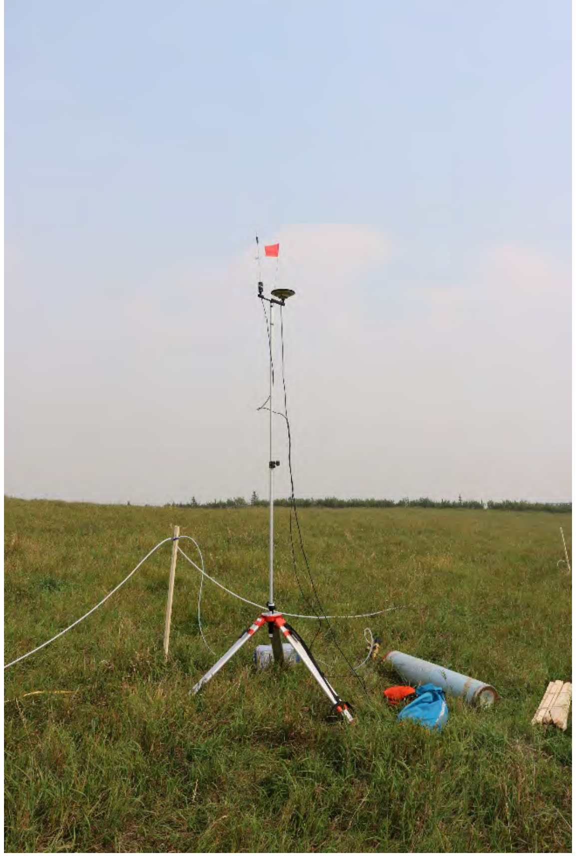
系统设定 – 装杆车

易于安装及拆卸的装杆车

系统设定 – 伸长杆

9米杆位于8个取样通道

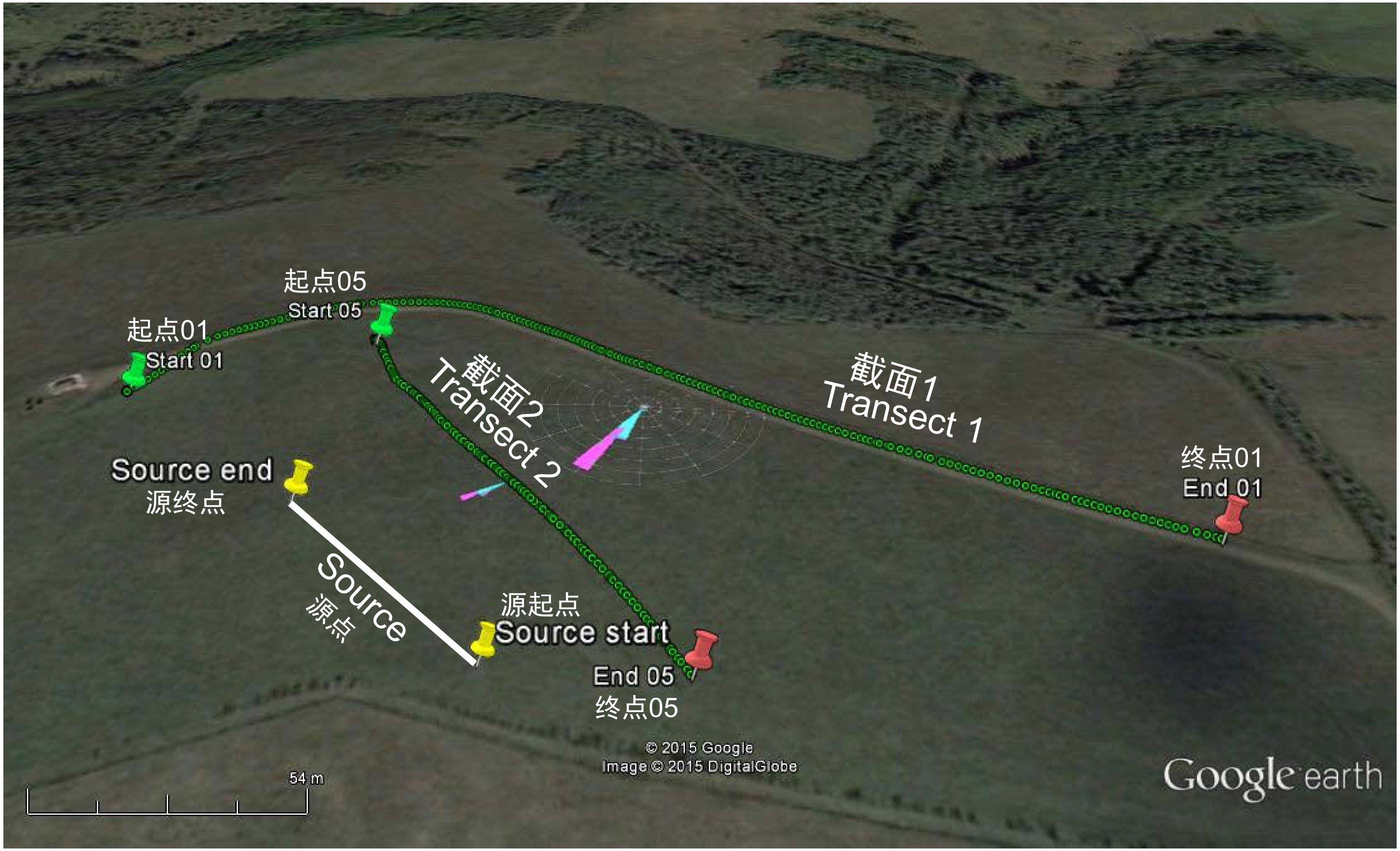
验证测试



基站GPS和发射器（
提供修正数据)

73米长线源，
CH_4 释放速率0.00017 - 0.00057 kg/s

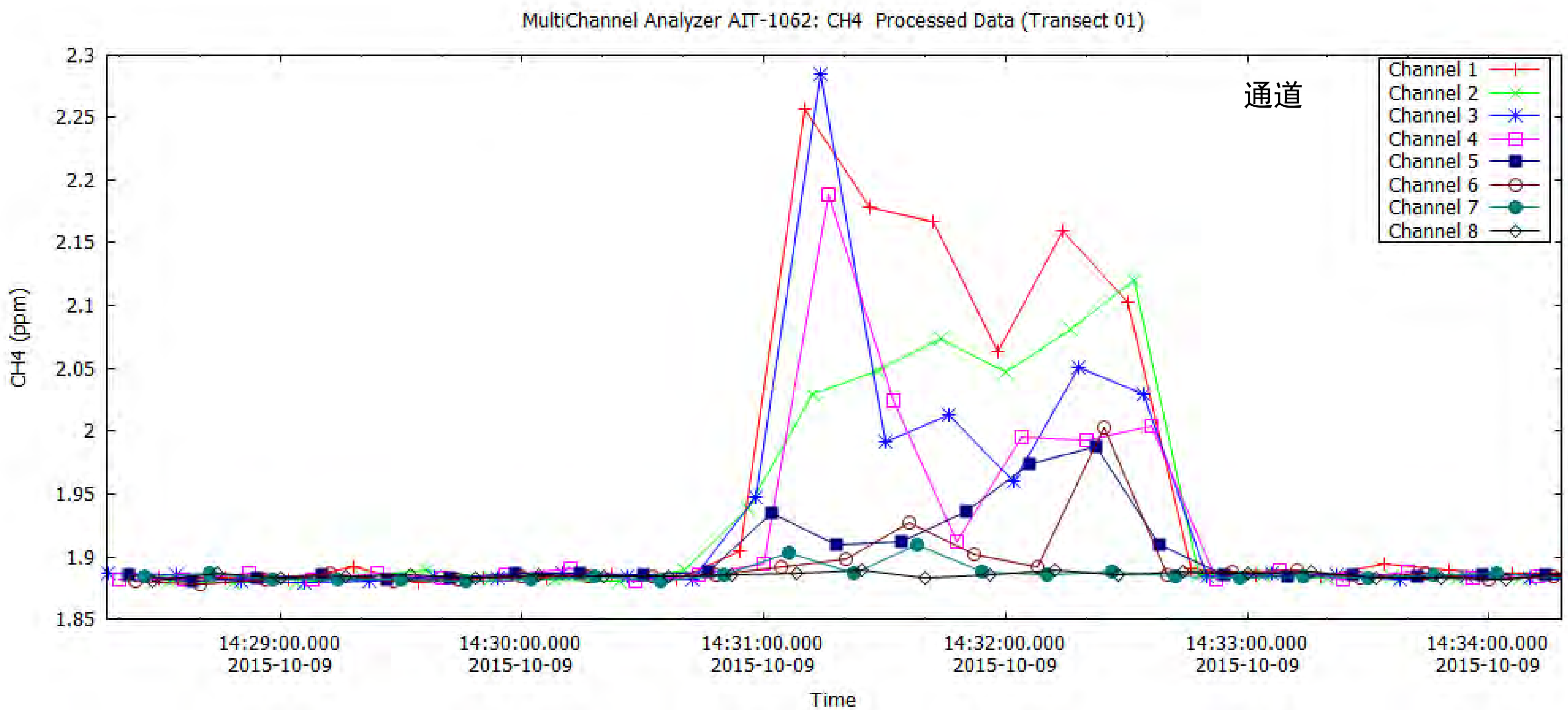
验证测试 – 截面路线



起点05
Start 05
起点01
Start 01
截面2
Transect 2
截面1
Transect 1
终点01
End 01
Source end
源终点
Source
源点
源起点
Source start
End 05
终点05
© 2015 Google
Image © 2015 DigitalGlobe
54 m
Google earth

验证测试 – 下风向浓度

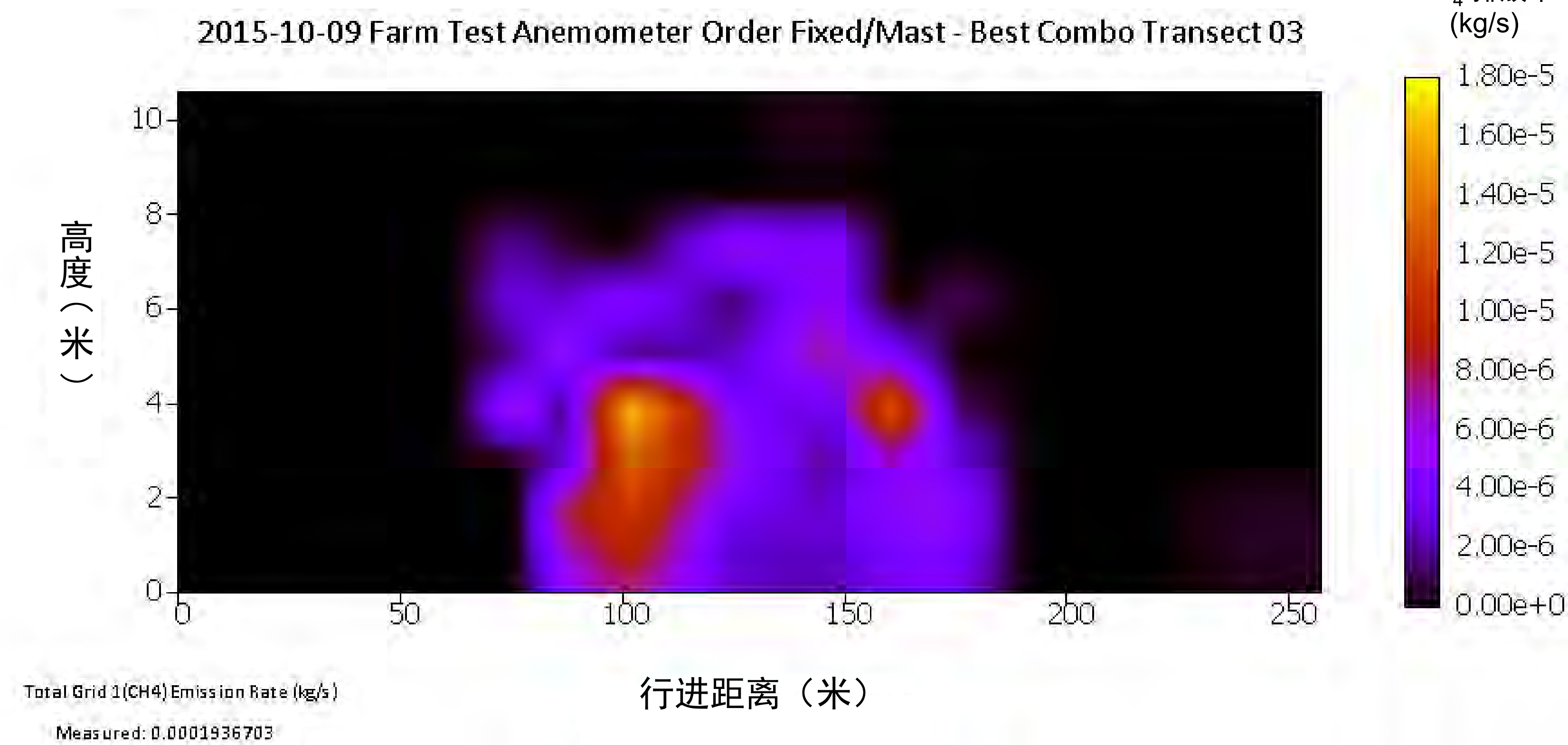
多通道分析仪 甲烷加工数据（01截面）



时间

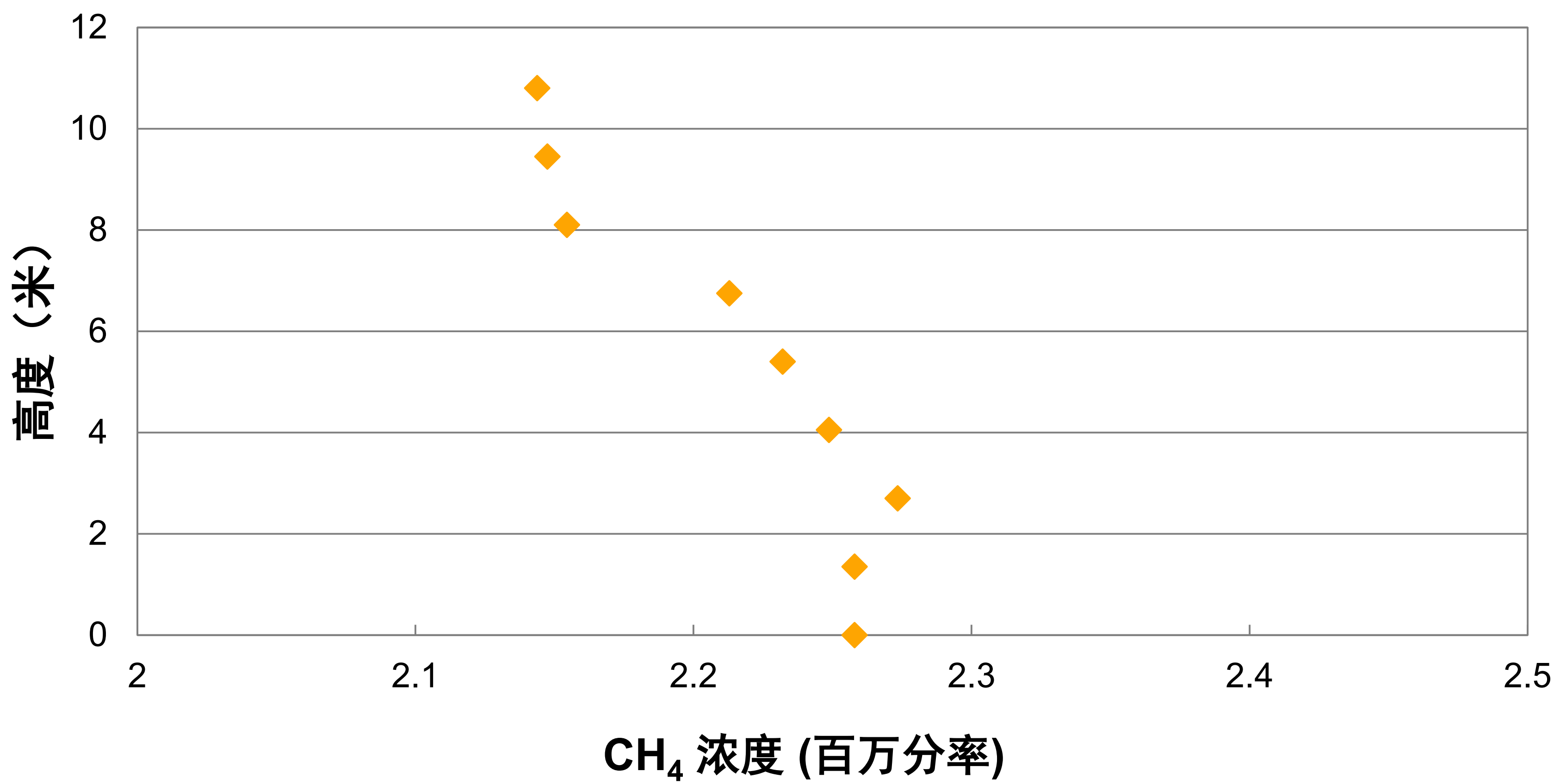
验证测试 – 排放率等高线图

2015-10-09 现场测试风速计顺序/桅杆——最佳搭档（03截面）



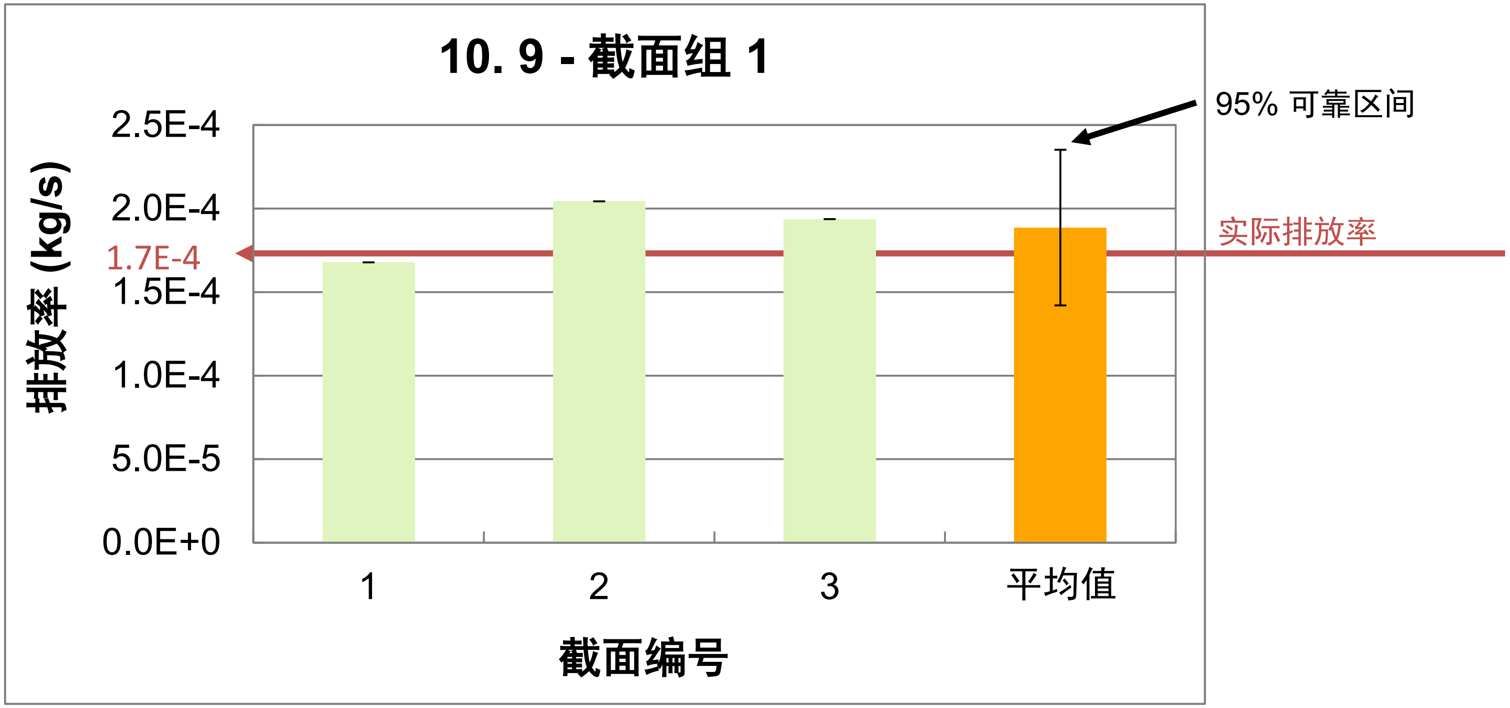
- 垂直捕捉良好
- 水平捕捉良好
- 高分辨率

验证测试 – 平均垂直浓度图



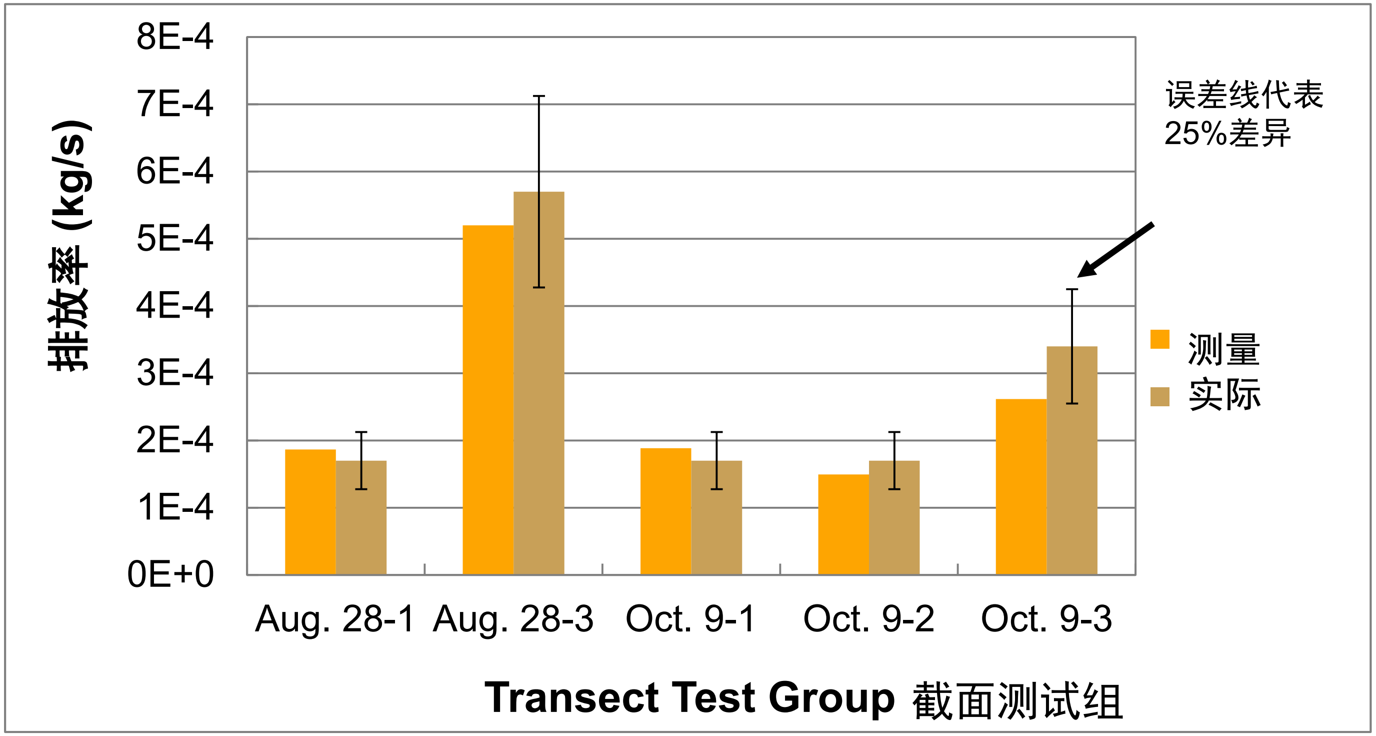
烟缕固定测量（间隔4分钟），距来源90米

验证测试 – 准确率



排放源: 甲烷 (CH_4)
来源类型: 线源长 73米, 高1米
排放率: 0.00017 kg/s
距离来源: 100m
网格分辨率 (单元格宽度): 13 m

验证测试 – 准确率

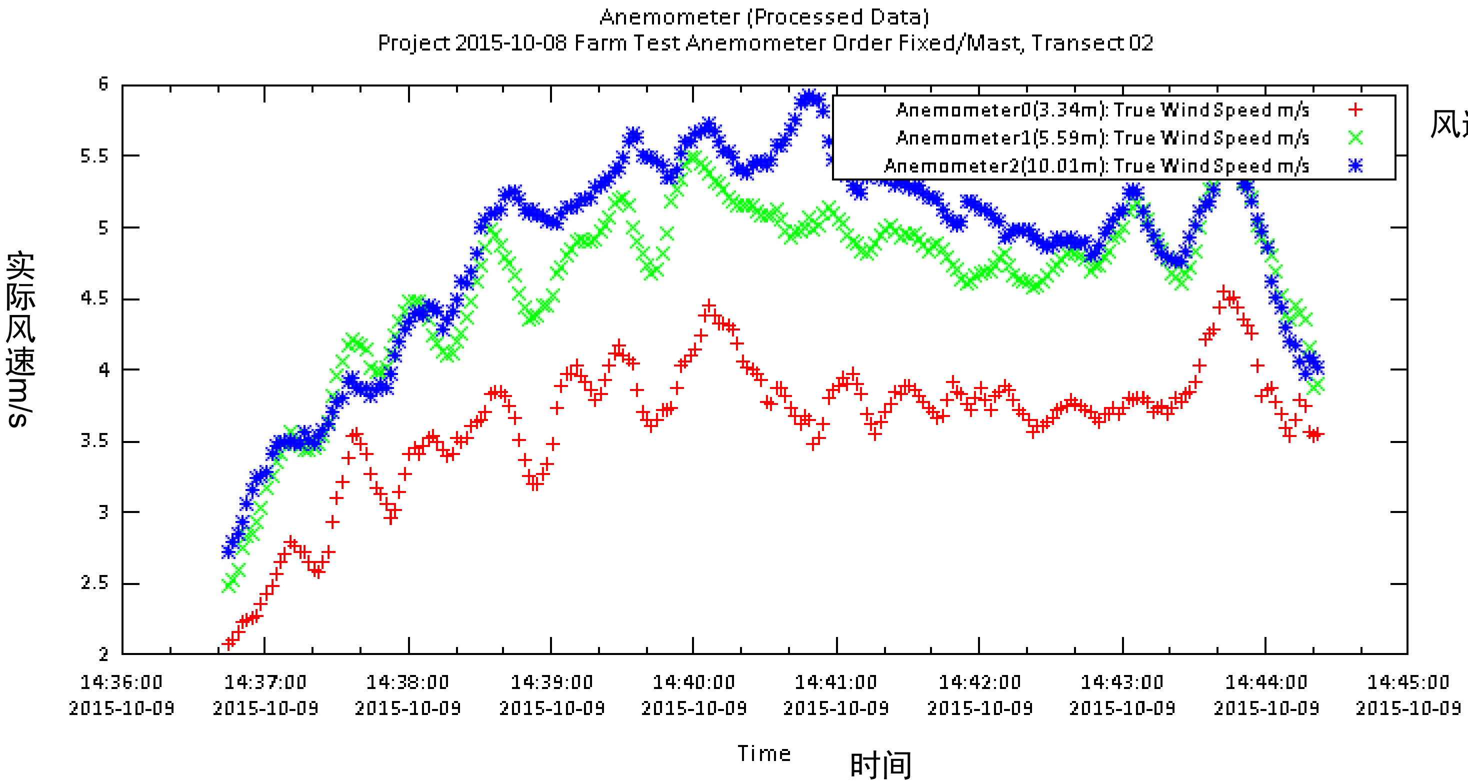


排放源: 甲烷 (CH_4)
来源类型：线型, 长73米, 高1米
测试日期：2015年8月28日及10月9日
3个截面的平均值 (除2个8月28日-3)

问题?

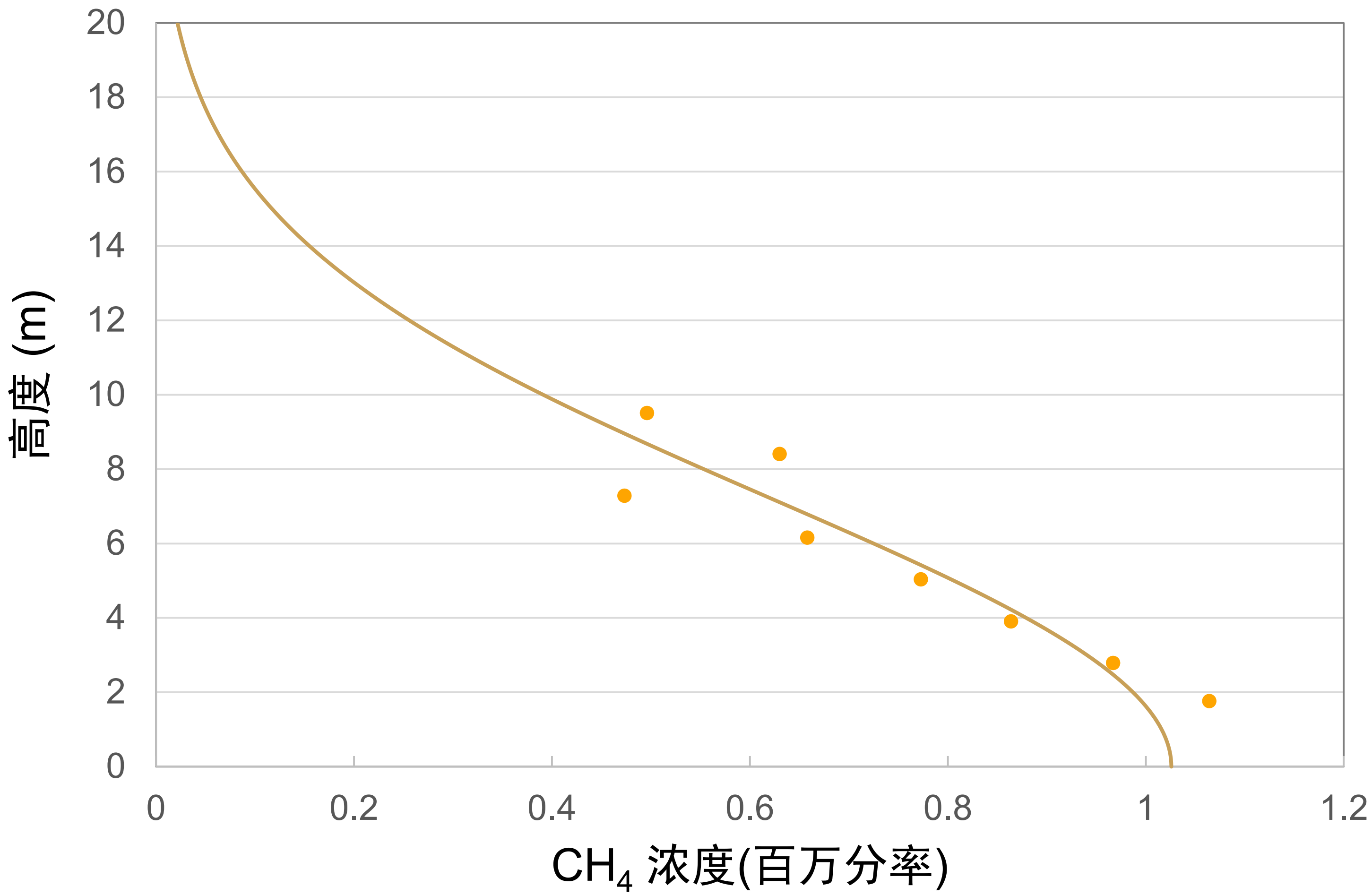
风速计数据

风速计：（加工数据)



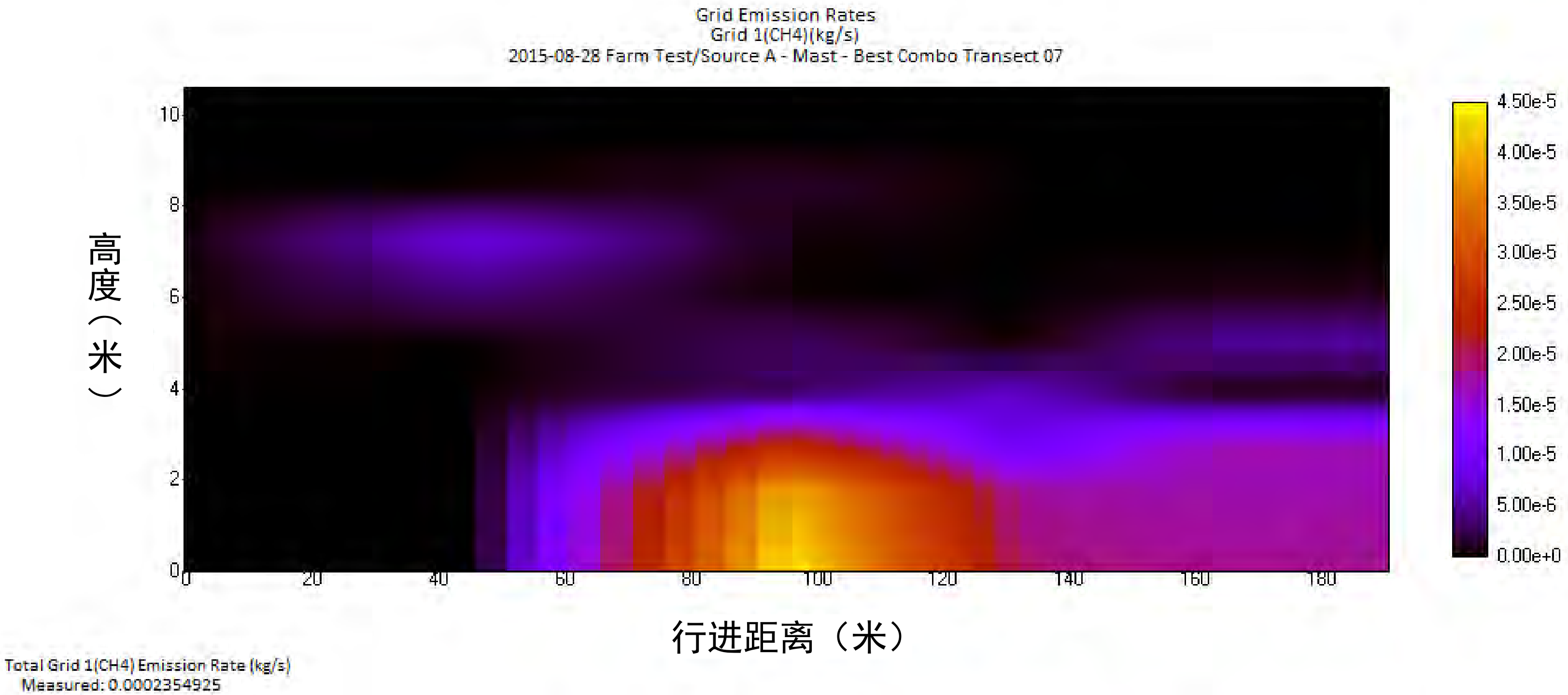
风速计：实际风速

油罐区 – 垂直烟缕捕捉校正



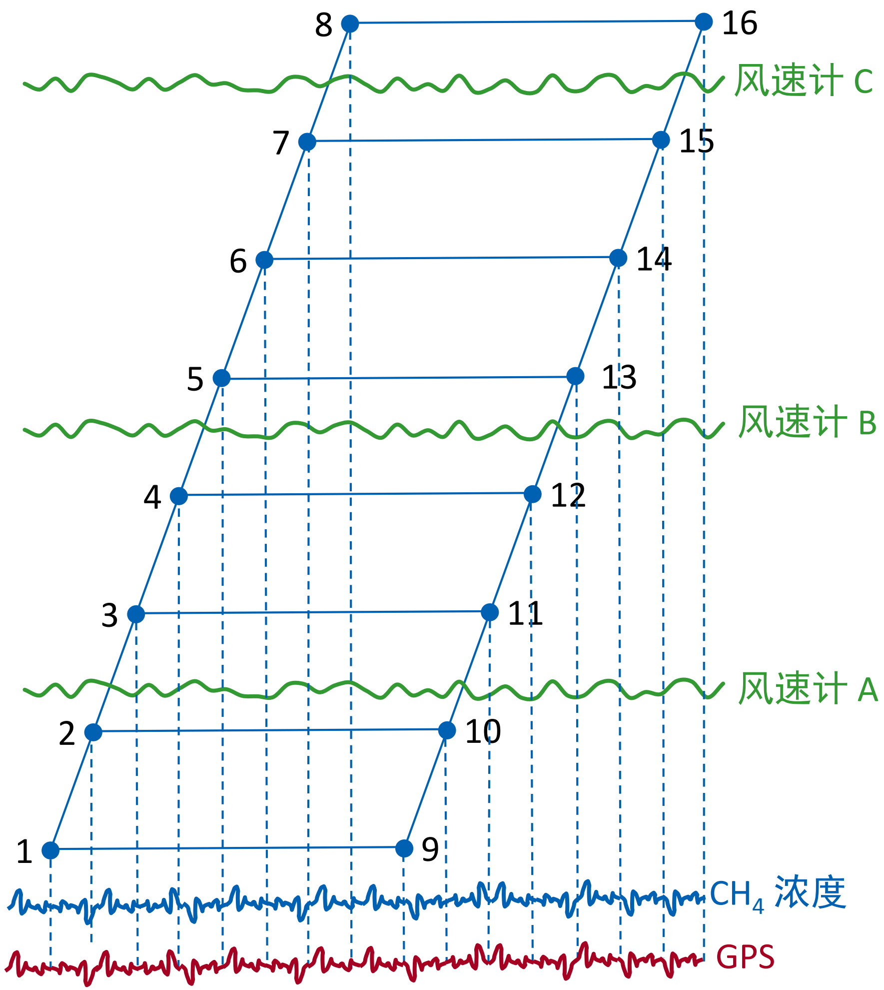
验证测试 – 排放率等高线图2

网格1 甲烷释放速率
2015-8-28 现场测试 来源A-桅杆 07截面



- 地平面烟缕 (缓和地平面剖面图)
- 水平捕捉良好
- 低分辨率

烟缕截面方法



总结

- 远程监控排放量的移动系统
- 经测试的应用设施: 燃气站, 油罐区, 煤矿
- 步骤: 筛选 → 截面 → 固定测量
- 优点:
  - VOCs实时测量
  - 甲烷排放率，灵敏度 ≤ 5E-5 kg/s，准确率 ≤ 25%
  - 分辨率 ≤ 10 m (水平), 1 m (垂直)
- 局限:
  - 10 m 高度限制
  - 稳定的风
  - 下风向通道

4 APPENDIX – CHINA'S VOC GUIDELINES

关于印发《挥发性有机物排污收费试点办法》的通知

财税 [2015]71号

各省、自治区、直辖市、计划单列市财政厅（局）、发展改革委、物价局、环境保护厅（局）：

为了规范挥发性有机物排污收费管理，改善环境质量，根据《中华人民共和国大气污染防治法》、《排污费征收使用管理条例》、《国务院关于印发大气污染防治行动计划的通知》（国发〔 2013〕37号）等规定，性有机物排污收费试点办法》，现印发给你们，请遵照执行。

附件：挥发性有机物排污收费试点办法

财政部 国家发展改革委 环境保护部

2015 年

附件:

挥发性有机物排污收费试点办法

第一条

为了促使企业减少挥发性有机物（以下简称 VOCs）排放，提高VOCs污染控制技术，改善生活和生态环境据《中华人民共和国大气污染防治法》、《排污费征收使用管理条例》、《国务院关于印发大气污染防治行动计划的通知》（国发〔 2013〕37号）等规定，制定本办法。

第二条

石油化工行业和包装印刷行业（以下简称试点行业） VOCs排污费征收、使用和管理适用本办法。试点行业范围见附 1。

各省、自治区、直辖市可以根据本地区实际情况增加 VOCs排污收费试点行业，并制定增加试点行业VO办法。

第三条

本办法所称 VOCs，是指特定条件下具有挥发性的有机化合物的统称。具有挥发性的有机化合物主要包括非甲烷总烃（烷烃、烯烃、炔烃、芳香烃）、含氧有机化合物（醛、酮、醇、醚等）、卤代烃、含氮化合物、含硫化合物等。

第四条 直接向大气排放VOCs的试点行业企业（以下简称排污者）应当缴纳VOCs排污费。

第五条 每一排放口排放的VOCs均征收VOCs排污费，不受目前3项污染物征收排污费限制。

第六条 VOCs排污费按VOCs排放量折合的污染当量数计征。计算公式如下:

VOCs 污染当量数 =VOCs排放量（千克）/V

石油化工行业排污者的 VOCs排放量，应区分生产过程的VOCs污染源项，分别采取实测、物料衡算和模型等方行计算，具体计算办法见附 2。包装印刷行业排污者的VOCs排放量，应根据生产工艺过程中投用原辅料及回收溶剂量，按物料衡算法进行计算，具体计算办法见附 3。

对VOCs中的苯、甲苯、二甲苯等污染物已征收排污费的，应当将其排放量从 VOCs排放量中扣除。

VOCs 污染当量值暂定为 0.95千克。

第七条 有关VOCs排污费征收标准的规定，由国家发展改革委、财政部、环境保护部确定。

第八条 VOCs排污费由地方环境保护主管部门按照污染源管理权限负责征收。

第九条

排污者应在规定期限内向地方环境保护主管部门报送《试点行业 VOCs排放申报登记表》（见附4），放量。

石油化工行业排污者在报送《试点行业 VOCs排放申报登记表》时，应一并填报各污染源项情况表，详细列源项生产装置、工作流程、处理设施等信息。

包装印刷行业排污者在报送《试点行业 VOCs排放申报登记表》时，应一并提供购买、使用原辅料和有机溶剂、结算或领料凭证；原料供货商提供的 VOCs含量说明；危险废物处理发票等材料。

第十条 排污者应当保证其报送材料的真实性、有效性和完整性。

第十一条

地方环境保护主管部门应当对排污者报送的申报材料进行审核。发现申报材料不完整的，应当要求排污者限期补报。

地方环境保护主管部门认为有必要的，可以委托有能力的第三方机构对排污者报送的申报材料进行审核。

第十二条

地方环境保护主管部门根据石油化工行业排污者各污染源项　　　　　　　　ＶＯＣs排放情况，以及包装印刷行业排污者 VOCs　　含

准，确定排污者应缴纳的排污费数额，并予以公告。

第十三条

地方环境保护主管部门应当定期对排污者进行专项稽查。发现排污者申报不实、少缴纳排污费的，应当追缴排污费并按《中华人民共和国大气污染防治法》的有关规定予以处罚。

第十四条

地方环境保护主管部门应当定期向社会公布本地区排污者应缴纳　ＶＯＣs排污费数额、实际缴纳ＶＯＣs排污费数额和缴ＶＯＣ排污费数额。

第十五条　地方□境保□主管部□征收的ＶOCs排□□，□全□上□国□，□入一般公共□算管理。

第十六条　ＶOCs排□□的具体征收□□、使用管理、□□□理等按□行排□□有关□定□行。

第十七条　各省、自治区、直□市根据本□法制定具体□施□法，并□□政部、国家□展改革委、□境保□部□案。

第十八条　本□法由□政部会同国家□展改革委、□境保□部□□解□。

第十九条　本□法自2015年10月1日起施行。

附件下载：

附1 ＶOCs排□□□点行□情况表.docx

附2 石化行□ＶOCs排放量□算□法.doc

附3 包装印刷行□ＶOCs排放量□算□法.docx

附4 □点行□ＶOCs排放申□登□表.docx

附 2

石油化工行业VOCs排放量计算办法

本办法所涉及监测和检测方法应符合相关标准规范要求。

石化行业的VOCs排放源分为：设备动静密封点泄漏；有机液体储存与调和挥发损失；有机液体装卸挥发损失；废水集输、储存、处理处置过程逸散；燃烧烟气排放；工艺有组织排放；工艺无组织排放；采样过程排放；火炬排放；非正常工况（含开停工及维修）排放；冷却塔、循环水冷却系统释放；事故排放等12类源项。

企业某个核算周期（以年计）VOCs排放量为：

$$E_{石化}=\sum_{m=1}^{11}E_m \qquad （公式1）$$

式中：

E_m　　石化行业各源项污染源VOCs排放量，千克/年。

各源项污染源的VOCs排放量应为该源项每一种污染物排放量的加和，见公式 2：

$$E_m=\sum_{i=1}^{n}E_i \qquad （公式 2）$$

式中：

E_i　　某源项污染源排放的污染物 i 的排放量，千克/年

$$E_i = \sum_{n=1}^{N}\left(E_{排放源n,\,i} \times \frac{WF_i}{WF_{VOCs}}\right) \qquad （公式3）$$

式中:

E_i　　污染物 i 的排放量，千克/年；

$E_{排放源\,n,i}$ 含污染物 i 的第 n 个排放源的 VOCs 排放量，千克/年；

N　　含污染物 i 的排放源总数；

WF_i　　流经或储存于排放源的物料中污染物 i 的平均质量分数；

WF_{VOCs} 流经或储存于排放源的物料中 VOCs 的平均质量分数。

有机液体储存与调和、装卸过程中涉及附表 1 中单一物质的,应按本办法进行单一污染物排放量核算,并可在 VOCs 总量中予以扣除。鼓励有条件的企业进行全过程单一污染物排放量核算。

进入气相的 VOCs，可按以下方法进行核算：VOCs 排放量=废气处理设施未投用的排放量+废气处理设施投用但未收集的排放量+废气处理设施投用收集后未去除的排放量=VOCs 产生量总量-废气处理设施投用收集且去除的量。

一、设备动静密封点泄漏

排放量核算结果的准确度从高到低排序为：实测法、相关方程法、筛选范围法、平均排放系数法。前三种方法是基于检测的核算方法，需获得检测仪器对物料的（合成）响应因子，见附录一。企业可根据自身 LDAR 开展情况，选择核算方法。

$$E_{设备}=\sum_{i=1}^{n}\left(e_{TOC,i}\times\frac{WF_{VOCs,i}}{WF_{TOC,i}}\times t_i\right) \qquad （公式 4）$$

式中：

$E_{设备}$　密封点的 VOCs 年排放量，千克/年；

t_i　密封点 i 的运行时间段，小时/年；

$e_{TOCs,i}$　密封点 i 的 TOCs 排放速率，千克/小时；

$WF_{VOCs,i}$　运行时间段内流经密封点 i 的物料中 VOCs 的平均质量分数；

$WF_{TOC,i}$　运行时间段内流经密封点 i 的物料中 TOC 的平均质量分数

如未提供物料中 VOCs 的平均质量分数，则 $\frac{WF_{VOCs}}{WF_{TOC}}$ 按 1 计。

（一）排放速率。

1.实测法。

采用包袋法和大体积采样法对密封点进行实测，所得排

放速率最接近真实排放情况，企业可选用该方法对密封点排放速率进行检测。

2.相关方程法。

$$e_{TOC}=\sum_{i=1}^{n}\begin{cases}e_{0,i} & (0\le SV<1)\\ e_{p,i} & (SV\ge 50000)\\ e_{f,i} & (1\le SV<50000)\end{cases}$$ （公式 5）

式中：

e_{TOC}　　密封点的 TOC 排放速率，千克/小时；

SV　　修正后的净检测值，μmol/mol；

$e_{0,i}$　　密封点 i 的默认零值排放速率，千克/小时；

$e_{p,i}$　　密封点 i 的限定排放速率，千克/小时；

$e_{f,i}$　　密封点 i 的相关方程核算排放速率，千克/小时

。

各类型密封点的排放速率按表 1 计算。

表 1 石油炼制和石油化工设备组件的设备排放速率[a]

密封点类型	**默认零值排放速率（千克/小时/排放源）**	**限定排放速率（千克/小时/排放源）>50000 μmol/mol**	**相关方程[b]（千克/小时/排放源）**
石油炼制的排放速率（炼油、营销终端和油气生产）			
阀门	7.8E-06	0.14	$2.29E-06\times SV^{0.746}$
泵	2.4E-05	0.16	$5.03E-05\times SV^{0.610}$
其它	4.0E-06	0.11	$1.36E-05\times SV^{0.589}$
连接件	7.5E-06	0.030	$1.53E-06\times SV^{0.735}$
法兰	3.1E-07	0.084	$4.61E-06\times SV^{0.703}$
开口阀或开口管线	2.0E-06	0.079	$2.20E-06\times SV^{0.704}$
石油化工的排放速率			
气体阀门	6.6E-07	0.11	$1.87E-06\times SV^{0.873}$
液体阀门	4.9E-07	0.15	$6.41E-06\times SV^{0.797}$
轻液体泵[c]	7.5E-06	0.62	$1.90E-05\times SV^{0.824}$
连接件	6.1E-07	0.22	$3.05E-06\times SV^{0.885}$

注：表中涉及的千克/小时/排放源＝每个排放源每小时的 TOC 排放量（千克）。

a：美国环保署，1995b 报告的数据。对于密闭式的采样点，如果采样瓶连在采样口，则使用“连接件”的排放系数；如采样瓶未与采样口连接，则使用“开口管线”的排放系数。

b：SV 是检测设备测得的净检测值（SV，μmol/mol）；

c：轻液体泵系数也可用于压缩机、泄压设备和重液体泵。

3.筛选范围法。

石油炼制工业排放速率计算公式：

$$e_{TOC} = \sum_{i=1}^{n}\left(F_{A,i} \times \frac{WF_{TOC,i}}{WF_{TOC,i} - WF_{甲烷,i}} \times WF_{TOC,i} \times N_i\right) \quad （公式 6）$$

石油化学工业排放速率计算公式：

$$e_{TOC} = \sum_{i=1}^{n}\left(F_{A,i} \times WF_{TOC,i} \times N_i\right) \quad （公式 7）$$

式中：

e_{TOC}　　密封点的 TOC 排放速率，千克/小时；

$F_{A,i}$　　密封点 i 排放系数；

WF_{TOC}　　流经密封点 i 的物料中 TOC 的平均质量分数；

$WF_{甲烷}$　　流经密封点 i 的物料中甲烷的平均质量分数，最大取 10%；

N_i　　密封点的个数。

表 2 筛选范围排放系数 [a]

设备类型	介质	石油炼制系数 [b]		石油化工系数 [c]	
		≥10000μmol/mol 排放系数（千克/小时/排放源）	<10000μmol/mol 排放系数（千克/小时/排放源）	≥10000μmol/mol 排放系数（千克/小时/排放源）	<10000μmol/mol 排放系数（千克/小时/排放源）
法兰、连接件	所有	0.0375	0.00006	0.113	0.000081

注：a：EPA，1995b 报告的数据。

b：这些系数是针对非甲烷有机化合物排放。

c：这些系数是针对总有机化合物排放。

筛选范围法用于核算某套装置不可达法兰或连接件的 VOCs 排放速率，需至少检测 50%该装置的可达法兰或连接

件，并且至少包含 1 个净检测值大于等于 10000μmol/mol 的点，以 10000μmol/mol 为界，分析已检测法兰或连接件净检测值可能≥10000μmol/mol 的数量比例，将该比例应用到同一装置的不可达法兰或连接件，且按比例计算的大于等于 10000μmol/mol 的不可达点个数向上取整，采用表 2 系数并按公式 6 和公式 7 计算排放速率。

4.平均排放系数法。

未开展 LDAR 工作的企业，或不可达点（除符合筛选范围法适用范围的法兰和连接件外），应采用表 3 系数并按公式 6 和公式 7 计算排放速率。

表 3 石油炼制和石油化工组件平均排放系数 [a]

设备类型	介质	石油炼制排放系数（千克/小时/排放源）[b]	石油化工排放系数（千克/小时/排放源）[c]
阀	气体	0.0268	0.00597
	轻液体	0.0109	0.00403
	重液体	0.00023	0.00023
泵 [d]	轻液体	0.114	0.0199
	重液体	0.021	0.00862
压缩机	气体	0.636	0.228
泄压设备	气体	0.16	0.104
法兰、连接件	所有	0.00025	0.00183
开口阀或开口管线	所有	0.0023	0.0017
采样连接系统	所有	0.0150	0.0150

注：对于表中涉及的千克/小时/排放源＝每个排放源每小时的 TOC 排放量（千克）。对于开放式的采样点，采用平均排放系数法计算排放量。如果采样过程中排出的置换残液或气未经处理直接排入环境，按照“取样连接系统”和“开口管线”排放系数分别计算并加和；如果企业有收集处理设施收集管线冲洗的残液或气体，并且运行效果良好，可按“开口阀或开口管线”排放系数进行计算。

a：摘自 EPA，1995b；

b：石油炼制排放系数用于非甲烷有机化合物排放速率；

c：石油化工排放系数用于 TOC（包括甲烷）排放速率；

d：轻液体泵密封的系数可以用于估算搅拌器密封的排放速率。

（二）排放时间。

采用中点法确定该密封点的排放时间，即第 n 次检测值代表时间段的起始点为第 n-1 次至第 n 次检测时间段的中点，终止点为第 n 次至第 n+1 次检测时间段的中点。发生泄漏修复的情况下，修复复测的时间点为泄漏时间段的终止点。

二、有机液体储存与调和挥发损失

（一）实测法。

设有 VOCs 有机气体控制设施的储罐或罐区，其排放量应采用实测法核算，监测频次不少于 1 次/月。

$$E_{储罐}=\sum_{i=1}^{n}\left[E_{计算量,i}-10^{-6}\times(C_{入口,i}-C_{出口,i})\times Q_i\times t_i\right]$$

（公式 8）

式中：

$E_{储罐}$ 含有机气体控制设施的储罐 VOCs 年排放量千克/年；

$E_{计算量,i}$ 连接在有机气体控制设施 i 上的储罐的排放量，由公式法计算，千克/年；

$C_{入口,i}$ 有机气体控制设施 i 的入口 VOCs 浓度年平均值，毫克/标立方米；

$C_{出口,i}$ 有机气体控制设施 i 的出口 VOCs 浓度年平均值，毫克/标立方米；

Q_i　　有机气体控制设施 i 的出口流量，标立方米/小时；

t_i　　有机气体控制设施 i 的运行时间，小时/年。

（二）公式法。

该核算方法可应用于固定顶罐和浮顶罐。不适用于以下情况：所储物料组分不稳定或真实蒸汽压高于大气压、蒸气压未知或无法测量的；储罐浮盘设施失效的；其他不符合相关环保要求的。

公式法核算过程采用美制单位。完成核算后，可将排放量的美制单位（磅）转为国际单位制（千克）。

$$E_{储罐}=\sum_{i=1}^{n}\left(E_{固,i}+E_{浮,i}\right)$$ （公式 9）

式中：

$E_{储罐}$　　储罐的 VOCs 年排放量，千克/年；

$E_{固}$　　固定顶罐 i 的 VOCs 年排放量，千克/年；

$E_{浮}$　　浮顶罐 i 的 VOCs 年排放量，千克/年。

1.固定顶罐总损失。

$$E_{固}=E_S+E_W$$ （公式 10）

式中：

$E_{固}$　　固定顶罐总损失，磅/年；

E_S　　静置损失，磅/年，见公式 11；

E_W　　工作损失，磅/年，见公式 28。

（1）静置损失，E_S。

$$E_S = 365 V_V W_V K_E K_S \qquad \text{（公式 11）}$$

式中：

E_S　静置损失（地下卧式罐的 E_S 取 0），磅/年；

V_V　气相空间容积，立方英尺，见公式 12；

W_V　储藏气相密度，磅/立方英尺；

K_E　气相空间膨胀因子，无量纲量；

K_S　排放蒸气饱和因子，无量纲量。

立式罐气相空间容积 V_V，通过公式 12 计算：

$$V_V = \left(\frac{\pi}{4} D^2\right) H_{VO} \qquad \text{（公式 12）}$$

式中：

V_V　气相空间容积，立方英尺；

D　罐径，英尺；

H_{VO}　气相空间高度，英尺。

卧式罐气相空间容积 V_V，通过公式 13 核算：

$$V_V = \frac{\pi}{4} D_E^2 H_{VO} \qquad \text{（公式 13）}$$

式中：

V_V　固定顶罐蒸气空间体积，立方英尺；

H_{VO}　蒸气实际空间高度（H_{VO}=D），英尺；

D_E　卧式罐有效直径，英尺；

$$D_E = \sqrt{\frac{LD}{0.785}} \qquad \text{（公式 14）}$$

A.气相空间膨胀因子 K_E

$$K_E = 0.0018\Delta T_V = 0.0018\left[0.72\left(T_{AX} - T_{AN}\right) + 0.028\alpha I\right]$$

（公式 15）

式中：

K_E　　气相空间膨胀因子，无量纲量；

ΔT_V　　日蒸气温度范围，兰氏度；

T_{AX}　　日最高环境温度，兰氏度；

T_{AN}　　日最低环境温度，兰氏度；

α　　罐漆太阳能吸收率，无量纲量，见表 4;

I　　太阳辐射强度，英热/（平方英尺·天）；

0.0018　　常数，（兰氏度）$^{-1}$；

0.72　　常数，无量纲量；

0.028　　常数，兰氏度·平方英尺·天 / 英热。

表 4 罐漆太阳能吸收率（α）

序号	罐漆颜色	太阳能吸收因子	序号	罐漆颜色	太阳能吸收因子
1	白色	0.34	4	浅灰色	0.63
2	铝色	0.68	5	中灰色	0.74
3	黑色	0.97	6	绿色	0.91

B.气相空间高度，H_{VO}

$$H_{VO} = H_S - H_L + H_{RO}$$

（公式 16）

式中：

H_{VO}　　气相空间高度，英尺；

H_S　　罐体高度，英尺；

H_L　　液体高度，英尺；

H_{RO}　　罐顶计量高度，英尺，锥顶罐见注释 a，拱顶罐见注释 b。

公式 16 注释：

a.对于锥顶罐，顶高度 H_{RO} 核算方法如下：

$$H_{RO} = 1/3H_R \qquad \text{（公式 17）}$$

式中：

H_{RO}　　罐顶计量高度，英尺；

H_R　　罐顶高度，英尺；

$$H_R = S_R R_S \qquad \text{（公式 18）}$$

式中：

S_R　　罐锥顶斜率，英尺/英尺；如未知，则取 0.0625；

R_S　　罐壳半径，英尺。

b.对于拱顶罐，罐顶计量高度 H_{RO} 核算方法如下：

$$H_{RO} = H_R\left[\frac{1}{2} + \frac{1}{6}\left[\frac{H_R}{R_S}\right]^2\right] \qquad \text{（公式 19）}$$

式中：

H_{RO}　　罐顶计量高度，英尺；

R_S　　罐壳半径，英尺；

H_R　　罐顶高度，英尺；

$$H_R = R_R - \left(R_R^2 - R_S^2\right)^{0.5} \qquad \text{（公式 20）}$$

R_R　　罐拱顶半径，英尺；

R_S　　罐壳半径，英尺；

R_R 的值一般介于 0.8D-1.2D 之间，其中 $D=2R_S$。如果 R_R 未知，则用罐体直径代替。

C.气相空间饱和因子，K_S

$$K_s = \frac{1}{1 + 0.053 P_{VA} H_{VO}} \qquad \text{（公式 21）}$$

式中：

K_S 气相空间饱和因子，无量纲量；

P_{VA} 日平均液面温度下的饱和蒸气压，磅/平方英寸（绝压），或参照公式 26 计算；

H_{VO} 气相空间高度，英尺，见公式 16；

0.053 常数，（磅/平方英寸（绝压）·英尺）$^{-1}$。

D.气相密度，W_V

$$W_V = \frac{M_V P_{VA}}{R T_{LA}} \qquad \text{（公式 22）}$$

式中：

W_V 气相密度，磅/立方英尺；

M_V 气相分子质量，磅/磅-摩尔；

R 理想气体状态常数，10.741 磅/（磅-摩尔·英尺·兰氏度）；

P_{VA} 日平均液面温度下的饱和蒸气压，磅/平方英寸（绝压），见公式 26；

T_{LA} 日平均液体表面温度，兰氏度，取年平均实际储存温度，如无该数据，用公式 23 计算。

公式 22 注释：

a.日平均液体表面温度，T_{LA}

$$T_{LA}=0.44T_{AA}+0.56T_B+0.0079\alpha I \quad （公式 23）$$

$$T_{AA}=\left(\frac{T_{AX}+T_{AN}}{2}\right) \quad （公式 24）$$

$$T_B=T_{AA}+6\alpha-1 \quad （公式 25）$$

式中：

T_{LA}　　日平均液体表面温度，兰氏度；

T_{AA}　　日平均环境温度，兰氏度；

T_{AX}　　计算月的日最高环境温度，兰氏度；

T_{AN}　　计算月的日最低环境温度，兰氏度。

T_B　　储液主体温度，兰氏度；

α　　罐漆太阳能吸收率，无量纲量，见表 4；

I　　太阳辐射强度，英热/（平方英尺·天）。

当 T_{LA} 值无法取得时，可用表 5 计算。

表 5 年平均储藏温度计算表

罐体颜色	**年平均储藏温度，T_S（华氏度）**
白	T_{AA}+0
铝	T_{AA}+2.5
灰	T_{AA}+3.5
黑	T_{AA}+5.0

注：此表格中 T_{AA} 为年平均环境温度（华氏度）。

E.真实蒸气压，P_{VA}

对于石油液体储料的日平均液体表面蒸气压，可通过公式 26 计算：

$$P_{VA}=\exp\left[A-\left(\frac{B}{T_{LA}}\right)\right] \quad （公式 26）$$

式中：

A　　　　蒸气压公式中的常数，无量纲量；

B　　　　蒸气压公式中的常数，兰氏度；

T_{LA}　　　　日平均液体表面温度，兰氏度；

P_{VA}　　　　日平均液体表面蒸气压，磅/平方英寸（绝压）

。

对于油品：

$$A=15.64-1.854S^{0.5}-\left(0.8742-0.3280\,S^{0.5}\right)\ln\left(RVP\right)$$

$$B=8742-1042S^{0.5}-\left(1049-179.4\,S^{0.5}\right)\ln\left(RVP\right)$$

对于原油：

$$A=12.82-0.9672\ln\left(RVP\right)$$

$$B=7261-1216\ln\left(RVP\right)$$

式中：

RVP　　　　雷德蒸气压，磅/平方英寸；

S　　　　10%蒸发量下 ASTM 蒸馏曲线斜率，°F /vol%

。

$$S=\frac{15\%\text{馏出温度}-5\%\text{馏出温度}}{15-5}$$

单一物质（如苯、对二甲苯）的日平均液体表面蒸气压，采用安托因方程计算。

$$\lg P_{VA} = A - \left(\frac{B}{T_{LA} + C} \right)$$ （公式 27）

式中：

A、B、C 为安托因常数；

T_{LA} 日平均液体表面温度，摄氏度；

P_{VA} 日平均液面温度下的饱和蒸气压，毫米汞柱。

（2）工作损失，E_W。

$$E_W = \frac{5.614}{RT_{LA}} M_V P_{VA} Q K_N K_P K_B$$ （公式 28）

式中：

E_W 工作损失，磅/年；

M_V 气相分子量，磅/磅-摩尔；

T_{LA} 日平均液体表面温度，兰氏度；

P_{VA} 真实蒸气压，磅/平方英寸（绝压），见公式26；

Q 年周转量，桶/年；

K_P 工作损失产品因子，无量纲量；

对于原油 K_P=0.75；

对于其它有机液体 K_P=1；

K_N 工作排放周转（饱和）因子，无量纲量；

当周转数＞36，K_N=（180+N）/6N；

当周转数≤36，K_N=1；

K_B 呼吸阀工作校正因子。

呼吸阀工作时的校正因子，K_B 可用公式 29 和公式 30 计算：

当

$$K_N\left[\frac{P_{BP}+P_A}{P_I+P_A}\right]>1.0 \qquad \text{（公式 29）}$$

时

$$K_B=\left[\frac{\dfrac{P_I+P_A}{K_N}-P_{VA}}{P_{BP}+P_A-P_{VA}}\right] \qquad \text{（公式 30）}$$

式中：

K_B 呼吸阀校正因子，无量纲量；

P_I 正常工况条件下气相空间压力，磅/平方英寸（表压）；

P_I 是一个实际压力（表压），如果处在大气压下（不是真空或处在稳定压力下），P_I 为 0；

P_A 大气压，磅/平方英寸（绝压）；

K_N 工作排放周转（饱和）因子，无量纲量，见公式 28；

P_{VA} 日平均液面温度下的蒸气压，磅/平方英寸（绝压），见公式 26；

P_{BP} 呼吸阀压力设定，磅/平方英寸（表压）。

2.浮顶罐总损失。

$$E_{浮}=E_R+E_{WD}+E_F+E_D \qquad \text{（公式 31）}$$

式中：

$E_{浮}$　浮顶罐总损失，磅/年；

E_R　边缘密封损失，磅/年，见公式 32；

E_{WD}　挂壁损失，磅/年，见公式 34；

E_F　浮盘附件损失，磅/年，见公式 35；

E_D　浮盘缝隙损失（只限螺栓连接式的浮盘或浮顶），磅/年，见公式 38。

（1）边缘密封损失，E_R。

$$E_R=\left(K_{Ra}+K_{Rb}v^n\right)DP^*M_VK_C \quad （公式 32）$$

式中：

E_R　边缘密封损失，磅/年；

K_{Ra}　零风速边缘密封损失因子，磅-摩尔/英尺・年，见表 6；

K_R　有风时边缘密封损失因子，磅-摩尔/（迈^n・英尺・年），见表 6；

v　罐点平均环境风速，迈；

n　密封相关风速指数，无量纲量，见表 6；

P^*　蒸气压函数，无量纲量；

$$P^*=\frac{\frac{P_{VA}}{P_A}}{\left[1+\left(1-\frac{P_{VA}}{P_A}\right)^{0.5}\right]^2} \quad （公式 33）$$

式中：

P_{VA}　　日平均液体表面蒸气压，磅/平方英寸（绝压），见公式 26；

P_A　　大气压，磅/平方英寸（绝压）；

D　　罐体直径，英尺；

M_V　　气相分子质量，磅/磅-摩尔；

K_C　　产品因子，原油 0.4，其它挥发性有机液体 1。

表 6 浮顶罐边缘密封损失系数

罐体类型	密封	K_{Ra}（磅-摩尔/英尺·年）	K_{Rb} 磅-摩尔/（迈^n·英尺·年）	n
焊接	机械式鞋形密封			
	只有一级	5.8	0.3	2.1
	边缘靴板	1.6	0.3	1.6
	边缘刮板	0.6	0.4	1.0
	液体镶嵌式（接触液面）			
	只有一级	1.6	0.3	1.5
	挡雨板	0.7	0.3	1.2
	边缘刮板	0.3	0.6	0.3
	气体镶嵌式（不接触液面）			
	只有一级	6.7	0.2	3.0
	挡雨板	3.3	0.1	3.0
	边缘刮板	2.2	0.003	4.3
铆接	机械式鞋形密封			
	只有一级	10.8	0.4	2.0
	边缘靴板	9.2	0.2	1.9
	边缘刮板	1.1	0.3	1.5

注：**表中**边缘密封损失因子 k_{ra}，k_{rb}， n 只适用于风速 6.8 米/秒以下

（2）挂壁损失，E_{WD}。

$$E_{WD}=\frac{(0.943)QC_SW_L}{D}\left[1+\frac{N_CF_C}{D}\right] \qquad \text{（公式 34）}$$

式中：

E_{WD}　　挂壁损失，磅/年；

Q　　　年周转量，桶/年；

C_S　　　罐体油垢因子，见表 7；

W_L　　　有机液体密度，磅/加仑，部分物料参数见附表 2；

D　　　罐体直径，英尺；

0.943　　常数，1000 立方英尺·加仑/桶^2；

N_C　　　固定顶支撑柱数量（对于自支撑固定浮顶或外浮顶罐：N_C=0。），无量纲量；

F_C　　　有效柱直径，取值 1。

表 7 储罐罐壁油垢因子

介质	罐壁状况（桶/1000 平方英尺）		
	轻锈	中锈	重锈
汽油	0.0015	0.0075	0.15
原油	0.006	0.03	0.6
其它油品	0.0015	0.0075	0.15

备注：

储罐内壁平均 3 年以上（包括 3 年）除锈一次，为重锈；平均两年除锈一次，为中锈；平均每年除锈一次，为轻锈。

（3）浮盘附件损失，E_F。

$$E_F = F_F P^* M_V K_C \qquad （公式 35）$$

式中：

E_F　　　浮盘附件损失，磅/年；

F_F　　　总浮盘附件损失因子，磅-摩尔/年；

$$F_F = \left[\left(N_{F1} K_{F1} \right) + \left(N_{F2} K_{F2} \right) + \ldots + \left(N_{Fn} K_{Fn} \right) \right] \qquad （公式 36）$$

式中：

N_{Fi}　　　某类浮盘附件数，无量纲量；

K_{Fi}　　　某类附件损失因子，磅-摩尔/年，见公式 37；

n_f　　某类的附件总数，无量纲量；

P^*，M_V，K_C的定义见公式 26。

F_F的值可由罐体实际参数中附件种类数（N_F）乘以每一种附件的损失因子（K_F）计算。

对于浮盘附件，K_{Fi}可由公式 37 计算：

$$K_{Fi} = K_{Fa_i} + K_{Fb_i}(K_v v)^{m_i} \quad \text{（公式 37）}$$

式中：

K_{Fi}　　浮盘附件损失因子，磅-摩尔/年；

K_{Fai}　　无风情况下浮盘附件损失因子，磅-摩尔/年，见表 8；

K_{Fbi}　　有风情况下浮盘附件损失因子，磅-摩尔/（迈^m•年），见表 8；

m_i　　某类浮盘损失因子，无量纲量，见表 8；

K_v　　附件风速修正因子，无量纲量（外浮顶罐，K_v=0.7；内浮顶罐和穹顶外浮顶罐，K_v=0）；

v　　平均气压平均风速，迈。

表 8 浮顶罐浮盘附件损失系数表

附件	状态	k_{fa}（磅-摩尔/年）	k_{fb}（磅-摩尔/（迈^n•年））	m
人孔	螺栓固定盖子，有密封件	1.6	0	0
	无螺栓固定盖子，无密封件	36	5.9	1.2
	无螺栓固定盖子，有密封件	31	5.2	1.3
计量井	螺栓固定盖子，有密封件	2.8	0	0
	无螺栓固定盖子，无密封件	14	5.4	1.1
	无螺栓固定盖子，有密封件	4.3	17	0.38
支柱井	内嵌式柱形滑盖，有密封件	33	/	/
	内嵌式柱形滑盖，无密封件	51	/	/

附件	状态	k_{fa}（磅-摩尔/年）	k_{fb}（磅-摩尔/（迈 ^{n} • 年））	m
	管柱式滑盖，有密封件	25	/	/
	管柱式挠性纤维衬套密封	10	/	/
取样管/井	有槽管式滑盖/重加权，有密封件	0.47	0.02	0.97
	有槽管式滑盖/重加权，无密封件	2.3	0	0
	切膜纤维密封（开度 10%）	12		
有槽导杆和取样井	无密封件滑盖（不带浮球）	43	270	1.4
	有密封件滑盖（不带浮球）			
	无密封件滑盖（带浮球）	31	36	2.0
	有密封件滑盖（带浮球）			
	有密封件滑盖（带导杆凸轮）	41	48	1.4
	有密封件滑盖（带导杆衬套）	11	46	1.4
	有密封件滑盖（带导杆衬套及凸轮）	8.3	4.4	1.6
	有密封件滑盖（带浮球和导杆凸轮）	21	7.9	1.8
	有密封件滑盖（带浮球、衬套和凸轮）	11	9.9	0.89
无槽导杆和取样井	无衬垫滑盖	31	150	1.4
	无衬垫滑盖带导杆	25	2.2	2.1
	衬套衬垫带滑盖	25	13	2.2
	有衬垫滑盖带凸轮	14	3.7	0.78
	有衬垫滑盖带衬套	8.6	12	0.81
呼吸阀	附重加权，未加密封件	7.8	0.01	4.0
	附重加权，加密封件	6.2	1.2	0.94
浮盘支柱	可调式（浮筒区域）有密封件	1.3	0.08	0.65
	可调式（浮筒区域）无密封件	2.0	0.37	0.91
	可调式（中心区域）有密封件	0.53	0.11	0.13
	可调式（中心区域）无密封件	0.82	0.53	0.14
	可调式，双层浮顶	0.82	0.53	0.14
	可调式（浮筒区域），衬垫	1.2	0.14	0.65
	可调式（中心区域），衬垫	0.49	0.16	0.14
	固定式	0	0	0
边缘通气阀	配重机械驱动机构，有密封件	0.71	0.1	1.0
	配重机械驱动机构，无密封件	0.68	1.8	1.0
楼梯井	滑盖，有密封件	98		
	滑盖，无密封件	56		
浮盘排水	/	1.2		

注：表中浮盘附件密封损失因子 k_{ra}，k_{rb}， n 只适用于风速 6.8 米/秒以下

（4）浮盘缝隙损失，E_D。

螺栓固定的浮盘存在盘缝损失，由公式38计算：

$$E_D = K_D S_D D^2 P^* M_V K_C \qquad \text{（公式38）}$$

式中：

K_D　　盘缝损耗单位缝长因子，0.14 磅-摩尔/（英尺·年）；

S_D　　盘缝长度因子，英尺/平方英尺，为浮盘缝隙长度与浮盘面积的比值，见表9；

D，P^*，M_V 和 K_C 的定义见公式32。

表9　盘缝长度因子

序号	浮盘构造	盘缝长度因子
1	浮筒式浮盘	4.8
2	双层板式浮盘	0.8

三、有机液体装卸挥发损失

（一）实测法。

$$E_{装卸} = E_0 - E_1 + E_2 \qquad \text{（公式39）}$$

$$E_0 = Q \times C_0 \qquad \text{（公式40）}$$

$$E_1 = 10^{-6} \times Q_1 \times C_1 \times t_{投用} \qquad \text{（公式41）}$$

$$E_2 = 10^{-6} \times Q_2 \times C_2 \times t_{投用} \qquad \text{（公式42）}$$

$$C_0 = \frac{P_T M}{RT} \qquad \text{（公式43）}$$

式中：

$E_{装卸}$　　装载过程VOCs年排放量，千克/年；

E_0　　装载物料的VOCs理论挥发量，千克/年；

E_1　　进入有机气体控制设施的 VOCs 量，千克/年
；

E_2　　从有机气体控制设施出口排入大气的 VOCs 量
，千克/年；

Q　　物料年周转量，立方米/年；

Q_1　　有机气体控制设施入口气体流量，标立方米/小时；如未检测，可等同于出口流量；

Q_2　　有机气体控制设施出口气体流量，标立方米/小时；

C_0　　装载罐车气、液相处于平衡状态，将挥发物料看做理想气体下的物料密度，千克/立方米；

C_1　　有机气体控制设施入口 VOCs 浓度，毫克/标立方米；

C_2　　有机气体控制设施出口 VOCs 浓度，毫克/标立方米；

$t_{投用}$　　有机气体控制设施实际年投用时间，小时；

T　　实际装载温度，开氏度；

P_T　　温度 T 时装载物料的真实蒸气压，千帕；

M　　油气的分子量，克/摩尔；

R　　理想气体常数，8.314 焦耳/（摩尔·开氏度）
。

若无法监测有机气体控制设施进、出口浓度时，对于

挥发油气进行回收再利用的回收设施，可采用收集的物料量表示经油气处理系统处理掉的物料量（即：Q_1- Q_2）。

（二）公式法。

$$E_{装卸}=\frac{L_L\times Q}{1000}\times\left(1-\eta_{总}\right) \qquad （公式 44）$$

$$\eta_{总}=\eta_{收集}\times\eta_{处理}\times\eta_{投用} \qquad （公式 45）$$

$$\eta_{收集}=E_1\div E_0 \qquad （公式 46）$$

$$\eta_{处理}=\left(E_1-E_2\right)\div E_1 \qquad （公式 47）$$

$$\eta_{投用}=t_{投用}\div t_{理论} \qquad （公式 48）$$

式中：

L_L　　装载损失排放因子，千克/立方米；

$\eta_{总}$　　总控制效率，%，见表 10；

$\eta_{收集}$　　收集效率，%；

$\eta_{处理}$　　处理效率，%；

$\eta_{投用}$　　投用效率，%；

$t_{投用}$　　有机气体控制设施实际年投用时间，小时；

$t_{理论}$　　伴随油气装载过程理论运行时间，小时。

表 10 装载总控制效率取值表

取值条件	效率
装载系统未设蒸气平衡/处理系统	0（总控制效率）
真空装载且保持真空度小于-0.37 千帕	100%（收集效率）
罐车与油气收集系统法兰、硬管螺栓连接	100%（收集效率）
其他情况	按公式 45 计算

1.公路、铁路装载损失排放因子。

$$L_L=C_0\times S \qquad （公式 49）$$

式中：

S　　饱和因子，代表排出的挥发性有机物接近饱

和的程度，见表 11；

C_0　　装载罐车气、液相处于平衡状态，将挥发性物料视为理想气体下的密度，千克/立方米；见公式 43。

表 11 公路、铁路装载损失计算中饱和因子

操作方式		饱和因子 s
底部/液下装载	新罐车或清洗后的罐车	0.5
	正常工况（普通）的罐车	1.0
喷溅式装载	新罐车或清洗后的罐车	1.45
	正常工况（普通）的罐车	1.0

2.船舶装载损失排放因子。

（1）船舶装载原油时：

$$L_L = L_A + L_G \qquad \text{（公式 50）}$$

式中：

L_A　　已有排放因子，千克/立方米，见表 12；

L_G　　生成排放因子，千克/立方米，见公式 51。

表 12 装载原油时的已有排放因子 L_A

船舱情况	上次装载	已有排放因子 L_A（千克/立方米）
未清洗	挥发性物质[a]	0.103
装有压舱物	挥发性物质	0.055
清洗后/无油品蒸气	挥发性物质	0.040
任何状态	不挥发物质	0.040

注：a：指真实蒸气压大于 10 千帕的物质。

生成排放因子 L_G：

$$L_G = (0.064P_T - 0.42)\frac{MG}{RT} \qquad \text{（公式 51）}$$

式中：

L_G　　生成排放因子，千克/立方米；

P_T　　温度 T 时装载原油的饱和蒸气压，千帕；

M　　蒸气的分子量， 克/摩尔；

G　　　蒸气增长因子 1.02，无量纲量；

T　　　装载时蒸气温度，开氏度；

R　　　理想气体常数，8.314 焦耳/（摩尔·开氏度）

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（2）船舶装载汽油时：

船舶装载汽油的损失排放因子 L_L 见表 13。

表 13 船舶装载汽油时损失排放因子 L_L

舱体情况	上次装载物	油轮/远洋驳船 [a]（千克/立方米）	驳船 [b]（千克/立方米）
未清洗	挥发性物质	0.315	0.465
装有压舱物	挥发性物质	0.205	驳船不压舱
清洗后	挥发性物质	0.180	无数据
无油品蒸气 [c]	挥发性物质	0.085	无数据
任何状态	不挥发物质	0.085	无数据
无油品蒸气	任何货物	无数据	0.245
典型总体状况 [d]	任何货物	0.215	0.410

注：a：远洋驳船（船舱深度 12.2 米）表现出排放水平与油轮相似。

b：驳船（船舱深度 3.0-3.7 米）则表现出更高的排放水平。

c：指从未装载挥发性液体，舱体内部没有 VOCs 蒸气。

d：基于测试船只中 41%的船舱未清洁、11%船舱进行了压舱、24%的船舱进行了清洁、24%为无蒸气。驳船中 76%为未清洁。

（3）船舶装载汽油和原油以外的产品时：

装载损失排放因子 L_L 可利用公式 49 计算，饱和因子 s 取值见表 14。

表 14 船舶装载汽油和原油以外油品时的饱和因子 s

交通工具	操作方式	饱和因子 s
水运	轮船液下装载（国际）	0.2
	驳船液下装载（国内）	0.5

（三）排放系数法。

按公式 44 核算排放量，典型的公路及铁路装载特定情况下装载损耗排放因子 L_L 的取值见表 15 和表 16。

1.公路及铁路装载。

表 15 铁路和公路装载损失排放因子（千克/立方米）

装载物料	底部/液下装载		喷溅装载	
	新罐车或清洗后的罐车	正常工况（普通）的罐车	新罐车或清洗后的罐车	正常工况（普通）的罐车
汽油	0.812	1.624	2.355	1.624
煤油	0.518	1.036	1.503	1.036
柴油	0.076	0.152	0.220	0.152
轻石脑油	1.137	2.275	3.298	2.275
重石脑油	0.426	0.851	1.234	0.851
原油	0.276	0.552	0.800	0.552
轻污油	0.559	1.118	1.621	1.118
重污油	0.362	0.724	1.049	0.724

注：基于设计或标准中雷德蒸气压最大值计算，装载温度取 25 摄氏度。

2.船舶装载。

表 16 船舶装载损失排放因子[a]（千克/立方米）

排放源	汽油[b]	原油	航空油（JP4）	航空煤油（普通）	燃料油（柴油）	渣油
远洋驳船	表 13	0.073	0.060	0.00063	0.00055	0.000004
驳船	表 13	0.12	0.15	0.0016	0.0014	0.000011

注：a：排放因子基于 16 摄氏度油品获取，表中汽油的雷德蒸气压为 69 千帕。原油的雷德蒸气压为 34 千帕。

b：汽油损失排放因子从表 13 中选取。

四、废水集输、储存、处理处置过程逸散

废水集输、储存、处理处置过程 VOCs 排放量核算方法主要包括实测法、物料衡算法和排放系数法，见表 17。核算过程需各种方法配合使用。

表 17 废水收集和处理设施 VOCs 排放量核算方法

核算方法	适用范围
实测法	加盖并设废气处理设施的废水收集和处理设施（不包括生化处理装置）
物料衡算法	未加盖或加盖但废气未收集处理、加盖处理但排气口未监测的废水收集和处理设施（不包括生化处理装置）

排放系数法	未加盖或加盖并设废气处理设施的废水收集和处理设施

（一）实测法。

适用于加盖并设废气处理设施的废水收集和处理系统，通过测定废气处理设施出口废气流量、VOCs 浓度、废气回收处理装置的收集效率、去除效率、设施投用率等计算 VOCs 排放量。

$$E_{废水}=\left[\sum_{j=1}^{n}Q_{w,j}\times\left(VOCs_{j,进水}-VOCs_{j,出水}\right)\times t_{j,总}-\sum_{j=1}^{m}Q_{w,j}\times\left(VOCs_{j,进水}-VOCs_{j,出水}\right)\times\eta_{收集效率}\times\eta_{去除效率}\times t_{j,投用}\right]\times10^{-3} \quad （公式 52）$$

$$\eta_{收集效率}=\frac{Q_{g}\times VOCs_{进气}\times10^{-3}}{\sum_{j=1}^{m}Q_{w,j}\times\left(VOCs_{j,进水}-VOCs_{j,出水}\right)}\times100\% \quad （公式 53）$$

$$\eta_{去除效率}=\frac{Q_{g}\times\left(VOCs_{进气}-VOCs_{出气}\right)}{Q_{g}\times VOCs_{进气}}\times100\% \quad （公式 54）$$

式中：

$E_{废水}$ 挥发性有机物逸散量，千克/年；

$Q_{w,j}$ 废水收集、处理系统 j 工段的废水流量，立方米/小时；

$VOCs_{j,进水}$ 废水收集、处理系统 j 工段进水中的挥发性有机物浓度，毫克/升；

$VOCs_{j,出水}$ 废水收集、处理系统 j 工段出水中的挥发性有机物浓度，毫克/升；

$t_{未投用}$ j 工段未被废气处理设施收集处理的小时数，小时；

$t_{投用}$　j 工段被废气处理设施收集处理的小时数，小时；

n　废水收集、处理系统工段个数；

m　加盖并设废气处理设施的收集和处理系统工段个数；

Q_g　废气处理设施进口废气处理流量，立方米/小时；

$VOCs_{进气}$　废气处理设施进口挥发性有机物浓度，毫克/立方米；

$VOCs_{出气}$　废气处理设施出口挥发性有机物浓度，毫克/立方米；

$\eta_{收集效率}$　加盖收集进入废气处理设施挥发性有机物的收集效率，%；

$\eta_{去除效率}$　废气处理设施挥发性有机物的去除效率，%。

（二）物料衡算法。

$$E_{废水} = E_{油相} + E_{水相} \quad \text{（公式 55）}$$

式中：

$E_{油相}$　收集系统集水井、处理系统浮选池和隔油池中油层的 VOCs 排放量，千克/年，见公式 10，无浮油真实蒸气压的，按 85 千帕计算；

$E_{水相}$　　废水收集支线和废水处理厂水相中 VOCs 排放量，千克/年，见公式 56。

$$E_{水相}=\sum_{i=1}^{n}\left[10^{-3}\times Q_i\times\left(EVOCs_{进水,i}-EVOCs_{出水,i}\right)\times t_i\right]$$

（公式 56）

式中：

$E_{水相}$　　废水收集或处理设施的挥发性有机物年排放量，千克/年；

Q_i　　废水收集或处理设施 i 的废水流量，立方米/小时；

$EVOCs_{进水,i}$　　废水收集或处理设施 i 进水中的逸散性挥发性有机物浓度，毫克/升；参照《水质 总有机碳的测定 燃烧氧化-非分散红外吸收法》HJ 501－2009 中可吹脱有机碳（POC）的测试和计算方法，其中 POC 为总有机碳（TOC）与不可吹脱有机碳（NPOC）的差值；

$EVOCs_{出水,i}$　　废水收集或处理设施 i 出水中的逸散性挥发性有机物浓度，毫克/升；

t_i 废气处理设施 i 的年运行时间，小时/年。

（三）排放系数法。

$$E_{废水}=\sum_{i=1}^{n}\left(S\times Q_i\times t_i\right)\qquad（公式 57）$$

式中：

S 排放系数，千克/立方米，见表 18；

Q_i 废水处理设施 i 的处理量，立方米/小时；

t_i 废水处理设施 i 的年运行时间，小时/年。

表 18 石化废水处理设施 VOCs 排放量排放系数法

适用范围	单位排放强度（千克/立方米）	备注
废水收集系统及油水分离	0.6	排放量（千克）=排放系数×废水处理量（**立方米**）
废水处理厂-废水处理设施[a]	0.005	排放量（千克）=排放系数×废水处理量（**立方米**）

注：a：废水处理设施指除收集系统及油水分离外的其他处理设施。

五、燃烧烟气排放

（一）实测法。

$$E_{燃烧} = \sum_{n=1}^{N}\left(10^{-6} \times C_n \times Q_n \times t\right) \qquad （公式 58）$$

式中：

$E_{燃烧}$ 燃烧烟气 VOCs 的排放速率，千克/年；

N 每年测量次数，次/年，（如自动检测仪每 1 小时记录 1 次测量值，则 N=8760）；

n 测量次数，第 n 次测量；

Q_n 第 n 次测量时的烟气流量（干基），标立方米/小时；

C_n 第 n 次测量时排放口的 VOCs 浓度，毫克/标立方米；

t 两次测量之间间隔的时长，小时。

（二）排放系数法。

$$E_{燃烧} = \sum_{i=1}^{n} \left(10^{-3} \times Q_{fuel,i} \times EF_i \times t\right) \quad （公式 59）$$

式中：

$Q_{fuel,i}$　燃料 i 的消耗量，煤（吨/小时）、天然气（立方米/小时）、液化石油气（立方米/小时，液态）；

EF_i　燃料 i 的排放系数，千克/单位燃料消耗，见表 19；

t　装置的年运行时间，小时/年。

表 19 燃料 VOCs 排放系数

燃料类型	锅炉形式	排放系数（千克/吨-煤）
烟煤和亚烟煤 [a]	煤粉炉，固态排渣	0.030
	煤粉炉，液态排渣	0.020
	旋风炉	0.055
	抛煤机链条炉排炉	0.025
	上方给料炉排炉	0.025
	下方给料炉排炉	0.650
	手烧炉	5.000
	流化床锅炉	0.025
褐煤 [a]	煤粉炉，固态排渣，切圆燃烧	0.020
	旋风炉	0.035
	抛煤机链条炉排炉	0.015
	上部给料链条炉排炉	0.015
	常压流化床锅炉	0.015
无烟煤 [b]	炉排炉	0.150
燃油 [a]	电站锅炉	0.038（千克/吨-油）
	工业燃油锅炉	0.140（千克/吨-油）
	工业燃馏分油锅炉	0.100（千克/吨-油）
天然气 [b]	-	1.762E-04 (千克/立方米天然气)
丁烷 [b]	-	0.132（千克/立方米液化石油气，液态）
丙烷 [b]	-	0.120（千克/立方米液化石油气，液态）

注：a：此处排放系数以总非甲烷有机物（TNMOC）代替 VOCs；
b：此处排放系数以总有机化合物（TOC）代替 VOCs。

六、工艺有组织排放

（一）实测法。

$$E_{有组织}=\sum_{n=1}^{N}\left(10^{-6}\times Q_n\times C_n\times t\right)$$ （公式 60）

式中：

$E_{有组织}$ 有组织排放工艺废气的 VOCs 年排放量，千克/年；

N 每年测量次数，次/年，（如自动检测仪每 1 小时记录 1 次测量值，则 N=8760）；

n 测量次数，第 n 次测量；

Q_n 第 n 次测量时排放口的废气流量（干基），标立方米/小时；

C_n 第 n 次测量时排放口的 VOCs 浓度（干基），毫克/标立方米；

t 两次测量之间间隔的时长，小时。

（二）物料衡算法。

没有化学反应的操作单元或过程的 VOCs 排放量可用核算：

$$\Sigma G_{排放i}=\Sigma G_{进料i}-\Sigma G_{产(副)品i}-\Sigma G_{废物i}-\Sigma G_{回收i}$$ （公式 61）

式中：

$\Sigma G_{排放}$ 单元或过程 VOCs 年排放量，千克/年；

$\sum G_{进料}$　单元或过程进料量，千克/年；

$\sum G_{产（副）品}$单元或过程产品和副产品量，千克/年；

$\sum G_{废物}$　单元或过程排放液体及固体废物量，千克/年

；

$\sum G_{回收}$　单元或过程回收的物料量，千克/年。

采用物料平衡法核算 VOCs 排放量时，需分析生产工艺过程、物料组成、产品（副产品）转化率、污染物控制指标基本运行参数。

（三）排放系数法。

用于延迟焦化装置开焦炭塔之前的 VOCs 排放量核算。

$$E_{焦炭塔} = \sum_{i=1}^{n} \left(\frac{t_i}{r_i} \times EF \times N_i \right) \qquad （公式 62）$$

式中：

$E_{有组织}$　延迟焦化装置焦炭塔 VOCs 年排放量，千克/年；

t_i　延迟焦化装置 i 的年运行时间，小时/年；

r_i　延迟焦化装置 i 的生焦周期，次/小时；

EF　排放系数，千克/（单塔·单次循环），取 25.9

；

N_i　延迟焦化装置 i 的单次循环焦炭塔个数。

七、工艺无组织排放

排放系数法适用于延迟焦化装置切焦过程的 VOCs 排放量核算。

$$E_{无组织}=\sum_{i=1}^{n}\left(EF\times Flow_{进料i}\times t_i\right) \qquad （公式 63）$$

式中：

$E_{无组织}$ 延迟焦化装置切焦过程 VOCs 年排放量，千克/年；

$Flow_{进料,i}$ 延迟焦化装置 i 的进料量，吨/小时；

EF VOCs 排放系数，吨/吨-装置进料，取 1.63E-04；

t_i 延迟焦化装置 i 的年运行时间，小时/年。

八、采样过程排放

采样过程的排放量核算依据设备动静密封点的核算方法。

密闭式采样或等效设施的排放速率可采用相关方程法，见公式 5 和表 1。采样瓶与采样口连接的，采用“连接件”系数核算排放量；采样瓶不与采样口连接的，采用“开口管线”系数核算排放量。

开口式采样的排放速率应采用平均排放系数法，见表 3 和公式 6。采样过程中排出的置换残液或气未经处理直接

排入环境的，采用“采样连接系统”和“开口管线”系数分别核算排放量；置换残液或气排入收集处理设施的，采用“开口管线”系数核算排放量。

九、火炬排放

（一）基于火炬的物料衡算法。

$$E_{\text{火炬},\ i}=\sum_{n=1}^{N}\left[Q_n\times t_n\times C_n\times\frac{M_n}{22.4}\times\left(1-F_{eff}\right)\right]\quad\text{（公式 64）}$$

式中：

$E_{\text{火炬},\ i}$ 火炬 i 的 VOCs 排放量，千克/年；

n　测量序数，第 n 次测量；

N　年测量次数或火炬每次工作时的测量次数；

Q_n　第 n 次测量时火炬气的流量，立方米/小时；

t_n　第 n 次测量时火炬的工作时间，小时；

C_n　第 n 次测量时 VOCs 的体积分数；

M_n　第 n 次测量时 VOCs 的分子量，千克/千摩尔；

22.4 摩尔体积转换系数，立方米/千摩尔；

F_{eff}　火炬的燃烧效率，%。

本方法需对进入火炬气体的成分和流量进行连续测量。当火炬非连续工作时，在火炬工作状态下应至少每 3 小时取样分析一次。本方法假定火炬正常操作过程中 Feff＞98%。部分条件下需修正火炬排放效率，见表 20。

表 20 火炬的燃烧效率取值

<table>
<tr><th>火炬工况</th><th>助燃气体类型</th><th>火炬操作条件</th><th>火炬燃烧效率</th></tr>
<tr><td rowspan="3">正常</td><td>无助燃</td><td>A. 火炬气体的净热值≥7.45MJ/m³；
B. 当直径≥DN80 mm、氢含量≥8%（体积百分数）时，出口流速＜37.2 m/s 且＜V_{max}；
C. 出口流速＜18.3 m/s，但当燃烧气体的净热值＞37.3 MJ/m³ 时，允许排放流速≥18.3 m/s，但应＜V_{max} 且＜122 m/s</td><td>98%</td></tr>
<tr><td>蒸汽助燃</td><td>A. 火炬气体的净热值≥11.2MJ/m³
B. 出口流速＜18.3 m/s，但当燃烧气体的净热值＞37.3 MJ/m³ 时，允许排放流速≥18.3 m/s，但应＜V_{max} 且＜122 m/s；
C. 蒸汽/气体≤4</td><td>98%</td></tr>
<tr><td>空气助燃</td><td>A. 火炬气体的净热值≥11.2MJ/m³；
B. 出口流速＜V_{max}</td><td>98%</td></tr>
<tr><td rowspan="4">非正常</td><td>无助燃</td><td>不满足火炬气净热值、出口流速的条件</td><td>93%</td></tr>
<tr><td rowspan="2">蒸汽助燃</td><td>不满足火炬气净热值、出口流速的条件</td><td>93%</td></tr>
<tr><td>不满足蒸汽与气体比值的条件</td><td>80%</td></tr>
<tr><td>空气助燃</td><td>不满足火炬气净热值、出口流速的条件</td><td>93%</td></tr>
<tr><td>故障</td><td></td><td>火炬气流量超过设计值、火炬故障停用或未投用</td><td>0%</td></tr>
</table>

（二）基于装置的物料衡算法。

$$E_{火炬}=\sum_{n=1}^{N}\left[Q_n\times\left(1-Feff\right)\right] \qquad （公式\ 65）$$

式中：

$E_{火炬}$　火炬系统的 VOCs 年排放量，千克/年；

N　每年排放次数，次/年；

n　排放次数，第 n 次排放；

Q_n　第 n 次排放时的排入火炬的总废气量（干基），千克；

Feff　火炬燃烧效率。

本方法适用于未对火炬进行实际测量的情况，假定火炬

燃烧效率为 80%。

（三）基于热值的排放系数法。

$$E_{火炬，i}=\sum_{n=1}^{N}\left(Q_n\times t_n\times LHV_n\times EF\right) \qquad （公式66）$$

式中：

$E_{火炬，i}$ 火炬 i 的 VOCs 排放量，千克/年；

n 测量序数，第 n 次测量；

N 年测量次数或火炬每次工作时的测量次数；

Q_n 第 n 次测量时火炬气的体积流量，立方米/小时；

t_n 第 n 次测量时火炬的工作时间，小时；

LHV_n 第 n 次测量时火炬气的低热值，兆焦耳/立方米；

EF VOCs 的排放系数，千克/兆焦，成分是总烃（以甲烷计）的情况下，系数取 6.02 E-05。

测量气体体积应和测定气体热值的标准条件相同。火炬停用或故障时，公式 66 应乘以 1/（1-*Feff*），其中 *Feff* 默认值取 98%。

十、非正常工况（含开停工及维修）排放

除火炬系统按公式 64 和公式 66 核算 VOCs 排放量时，开停工过程的 VOCs 排放量可不重复核算外，均应单独核算。

（一）公式法（气体加工容器）。

$$E_{开停工}=\sum_{i=1}^{n}\left[10^{-6}\times\frac{P_V+101.325}{101.325}\times\frac{273.15}{T}\times\left(V_V\times f_{空置}\right)\times C\right]_i$$

（公式 67）

$E_{开停工}$　开停工过程的 VOCs 排放量，千克/年；

P_V　泄压气体排入大气时容器的表压，千帕

T　泄压气体排入大气时容器的温度，开氏度；

V_v　容器的体积，立方米；

$f_{空置}$　容器的体积空置分数，除去填料、催化剂或塔盘等所占体积后剩余体积的百分数，在容器中不存在内构件时，取 1；

C　泄压气体中 VOCs 的浓度，毫克/标立方米；

i　每年的开停工次数。

（二）公式法（液体加工容器）。

$$E_{开停工}=\sum_{i=1}^{n}\left[V_v\times\left(1-V'\right)\times f_1\times d\times WF\times\left[f_2\times\left(1-F_{eff}\right)+\left(1-f_2\right)\right]\right]_i$$（公式 68）

式中：

$E_{开停工}$ 开停工过程的 VOCs 排放量，千克/年；

V_v　容器的体积，立方米；

V'　容器内填料、催化剂或塔盘等所占体积分数，在容器中不存在内构件时，取 0；

f_1　容器吹扫前液体薄层或残留液体的体积分数

，取值在 0.1%至 1%之间；

d　液体的密度，千克/立方米；

WF　容器内 VOCs 的质量分数；

f_2　液体薄层或残留液体被吹扫至火炬或其它处理设施的质量分数；

E_{eff}　火炬或处理设施的效率%，其中火炬效率可在九火炬排放中查找，处理设施的效率采用实测值。

十一、冷却塔、循环水冷却系统释放

（一）物料衡算法。

$$E_{冷却塔}=\sum_{i=1}^{n}\left[10^{-3}\times Q_i\times\left(EVOCs_{入口i}-EVOCs_{出口i}\right)\times t_i\right]$$

（公式 69）

式中：

$E_{冷却塔}$　冷却塔 VOCs 排放量，千克/年；

Q_i　冷却塔 i 的循环水流量，立方米/小时；

$EVOCs_{入口}$　冷却水暴露空气前 EVOCs 的浓度，毫克/升；

$EVOCs_{出口}$　冷却水暴露空气后 EVOCs 的浓度，毫克/升；

t_i　冷却塔 i 的年运行时间，小时/年；

$EVOCs_{入口}$和 $EVOCs_{出口}$有多组检测数据的，取平均值。公式 69 假定冷却水补水与蒸发损失、风吹损失相等且冷却

塔进出流速不变。

（二）排放系数法。

无循环水检测数据时，可采用排放系数法进行核算：

$$E_{冷却塔} = \sum_{i=1}^{n}\left(Flow_{冷却水i} \times EF \times t_i\right) \qquad （公式 70）$$

式中：

$E_{冷却塔}$ 冷却塔 VOCs 年排放量，千克/年；

$Flow_{冷却水,i}$ 冷却塔 i 的循环水量，立方米/小时；

EF VOCs 排放系数，千克/立方米-循环水，取 7.19E-04；

t_i 冷却塔 i 的年运行时间，小时/年。

十二、事故排放

（一）工艺装置事故。

在工艺装置处于正常运行状态下使用特定排放系数或本书提供的其他方法进行排放量计算时，均应考虑工艺装置的去除效率。表 21 提供了催化裂化装置和焦化装置默认去除效率和事故状态下的修正系数。如果控制状态的排放量数据已知，则事故状态或停机状态下的非控制排放量可使用公式 71 进行计算。

$$E_{事故,i} = e_{事故,i} \times EM_i \times t \qquad （公式 71）$$

式中：

$E_{事故,i}$ 事故状态或停机状态下污染物 i 的排放量，千克/事件；

$e_{事故,i}$ 根据测量数据或现场的排放测试数据得出的控制状态下的污染物 i 的排放速率，千克/小时；

EM_i 基于21 工艺装置中污染物 i 的受控排放乘数；

t 事故持续时间，小时/事件。

表 21　工艺装置的效率及工艺装置事故乘数

污染源/工艺装置描述	污染物种类[a]	工艺装置效率[b]/%	受控排放的乘数[c]
催化裂化或焦化/静电除尘	PM、金属 HAP	92	12.5
	VOCs、有机 HAP	0	1
催化裂化或焦化/锅炉	VOCs、多数有机 HAP	98%	50
	PAH、甲醛	～100%	0.5

注：a 污染物种类。仅列出受工艺装置影响的污染物。对其他污染物，假定工艺装置的去除效率为 0%且排放倍数为 1。

b 工艺装置效率。负值表示工艺装置会造成某种污染物的增加。

c 受控排放的乘数。提高控制状态排放系数使之能反应事故状态的排放，该乘数=1/（1−工艺装置效率）。

（二）容器超压排放。

如容器超压排放气体送入火炬，并且对进入火炬气体进行监测，并选择合适的方法进行排放量估算，则可不单独计算容器超压，否则需单独计算容器超压排放的 VOCs。

（三）喷溅。

喷溅出的液体蒸发分为闪蒸蒸发、热量蒸发和质量蒸发三种，其蒸发总量为这三种蒸发之和，可用以下公式进行排

放量计算。

（1）闪蒸量的估算。

过热液体闪蒸量可按下式估算：

$$Q_1 = \frac{F \times W_T}{t_1} \qquad \text{（公式 72）}$$

式中：

Q_1　闪蒸量，千克/秒；

W_T　液体泄漏总量，千克；

t_1　闪蒸蒸发时间，秒；

F　蒸发的液体占液体总量的比例；按下式计算：

$$F = C_P \frac{T_L - T_b}{H} \qquad \text{（公式 73）}$$

式中：

C_P　液体的定压比热，焦耳/（千克·开氏度）；

T_L　泄漏前液体的温度，开氏度；

T_b　液体在常压下的沸点，开氏度；

H　液体的气化热，焦耳/千克。

（2）热量蒸发估算。

热量蒸发的蒸发速度 Q_2 按下式计算：

$$Q_2 = \frac{\lambda S \times (T_0 - T_b)}{H\sqrt{\pi \alpha t}} \qquad \text{（公式 74）}$$

式中：

Q_2　热量蒸发速度，千克/秒；

λ　　表面热导系数，瓦/（ 米·开氏度）；

T_0　　环境温度，开氏度；

T_b　　沸点温度，开氏度；

S　　液池面积，平方米；

H　　液体气化热，焦耳/千克；

α　　表面热扩散系数（见表22），平方米/秒；

t　　蒸发时间，秒。

（3）质量蒸发估算。

质量蒸发速度 Q_3：

$$Q_3 = \alpha \times P \times M / \left(R \times T_0\right) \times u^{(2-n)\times(2+n)} \times r^{(4+n)/(2+n)} \quad \text{（公式 75）}$$

式中：

Q_3　　质量蒸发速度，千克/秒；

α，n 大气稳定度系数，见表23；

P　　液体表面蒸汽压，帕；

R　　气体常数，焦耳/摩尔·开氏度；

M　　分子量，克/摩尔；

T_0　　环境温度，开氏度；

u　　风速，米/秒；

r　　液池半径，米。

有围堰时，以围堰最大等效半径为液池半径；无围堰时，设定液体瞬间扩散到最小厚度时，推算液池等效半径。

（4）液体蒸发总量的计算。

$$W_P = Q_1 t_1 + Q_2 t_2 + Q_3 t_3$$ （公式 76）

式中：

W_P 液体蒸发总量，千克；

Q_1 闪蒸蒸发液体量，千克；

Q_2 热量蒸发速率，千克/秒；

t_1 闪蒸蒸发时间，秒；

t_2 热量蒸发时间，秒；

Q_3 质量蒸发速率，千克/秒；

t_3 从液体泄漏到液体全部处理完毕的时间，秒。

表 22 某些地面的热传递性质

地面情况	λ/[瓦/（ 米·开氏度）]	α/（平方米/秒）
水泥	1.1	1.29×10^{-7}
土地（含水 8%）	0.9	4.3×10^{-7}
干阔土地	0.3	2.3×10^{-7}
湿地	0.6	3.3×10^{-7}
砂砾地	2.5	11.0×10^{-7}

表 23 液池蒸发模式参数

稳定度条件	n	α
不稳定（A，B）	0.2	3.846×10^{-3}
中性（D）	0.25	4.685×10^{-3}
稳定（E，F）	0.3	5.285×10^{-3}

附录

附录一 响应因子确定

根据物料的组分及浓度，查阅仪器制造商提供的数据或按照 HJ 733 中 3.2.1 规定的方法通过实验确定仪器对各组分的响应因子。如果各组分的响应因子在泄漏定义浓度到仪器最大测量值范围内均小于 3，则不需要修正检测值；如果有一种或多种组分的响应系数大于等于 3，则需要按照公式 77 计算检测仪器对物料的合成响应因子。RF_m＜3，不需要修正检测值；3≤RF_m＜10，需要修正检测值；如果 RF_m≥10，则需要更换仪器或选择其它校准气体校准仪器，并测定新响应因子，直到物料响应因子 RF_m＜10 为止。

$$RF_m = \frac{1}{\sum_{i=1}^{n} \frac{X_i}{RF_i}} \quad \text{（公式 77）}$$

式中：

RF_m　　物料合成响应因子；

RF_i　　组分 i 的响应因子；

X_i　　组分 i 占物料中 TOC 的摩尔百分数。

$$SV = SV_0 \times RF_m \quad \text{（公式 78）}$$

式中：

SV　　修正后的净检测值，μmol/mol；

SV_0　　净检测值，μmol/mol；

附录二　废气流量干基、标准状态转化

$$Q_n = Q_{act} \times \left[1-\left(f_{H_2O}\right)_n\right] \times \left(\frac{T_0}{T_n}\right) \times \left(\frac{P_n}{P_0}\right)$$

Q_n　　第 n 次测量时的气体流量（干基），

标立方米/小时；

Q_{act}　　第 n 次测量时的气体流量，立方米；

f_{H2O}　　$\left(f_{H_2O}\right)_n$ 第 n 次测量时烟气的含水量，体积分数（% V）；

T_0　　标准状态下温度，273.15K；

T_n　　第 n 次测量时的温度，开氏度；

P_n　　第 n 次测量时的平均压力， 千帕；

P_0　　标准状态下压力，101.325 千帕；

附表

附表 1 需单独核算的污染物

序号	污染物	污染当量值（千克）
1	苯	0.05
2	甲苯	0.18
3	二甲苯	0.27
4	丙烯醛	0.06
5	甲醇	0.67
6	酚类	0.35
7	苯胺类	0.21
8	氯苯类	0.72
9	硝基苯	0.17
10	丙烯氢	0.22
11	二甲二硫	0.28
12	苯乙烯	25
13	二硫化碳	20
14	苯并[a]芘	0.000002

附表 2 存储物料理化参数（部分）

油品名称	液体密度（吨/立方米）	温度（℃）	真实蒸气压（千帕）	15.6°C 时油气分子量（克/摩尔）
轻质原油	0.86	37.8	65	50
重质原油	0.86	37.8	45	50
汽油	0.77	37.8	85	68
轻石脑油	0.72	37.8	100	80
重石脑油	0.72	37.8	40	80
航煤	0.78	37.8	30	140
柴油	0.84	37.8	7	140
烷基化油	0.7	37.8	80	68
抽余油	0.67	37.8	80	80
污油	0.77	37.8	85	68
热蜡油	0.88	100	0.67	190
热渣油	0.92	100	0.39	190

注：表中的真实蒸气压取值为理论计算的最大值

附表 3 单位换算表

类别	单位换算
长度	1 米=4.2808 英尺
体积	1 立方米=264.2 加仑
	1 立方米=6.28 桶

类别	单位换算
	1 立方米=45.41 立方英尺
质量	1 千克=2.20 磅
密度	1 克/立方米=8.44 磅/加仑
	1 克/立方米=0.00006 磅/立方英尺
压力	1 千帕=7.5 毫米汞柱
	1 千帕=0.145 磅/平方英寸（绝压）
风速	1 米/秒=2.24 迈
边缘密封损失系数	1 摩尔/（米・年）=0.67 磅-摩尔/（英尺・年）
油垢因子	1 立方米/1000 平方米=0.58 桶/1000 平方英尺
太阳辐射因子	1 瓦/平方米= 4.711 英热/（平方英尺・天）

附 4

表 1 石油化工行业 VOCs 排放申报登记表

企业名称					
机构代码					
企业地址					
所属行业类型					
所属省市					
核算起始日期	年　月　日		核算截止日期	年　月　日	
企业法人代表（签字或盖章）			单位盖章		
填报日期		填报人		联系方式	
VOCs 排放总污染当量：（各核算环节总排放量/0.95）					

装置数量		企业建立时间	年　月
原料		原料加工能力（万吨/年）	
含 VOCs 原辅材料	原辅材料消耗量（万吨/年）	主要产品	主要产品生产能力（万吨/年）
（1）	（1）	（1）	（1）
（2）	（2）	（2）	（2）
（3）	（3）	（3）	（3）
…			

污染源项	总排放量（千克/年）	核算期当量数	核算方法	减排措施
设备动静密封点泄漏			□实测法□相关方程法 □筛选范围法 □平均排放系数法	□泄漏维修
有机液体储存与调和挥发损失			□实测法□公式法	□增加末端治理设施（冷凝、吸附吸收、催化燃烧）
有机液体装卸挥发损失			□实测法□公式法 □排放系数法	□优化装卸方式 □增加末端治理设施（冷凝、吸附吸收、催化燃烧）
废水集输、储存、处理处置过程逸散			□实测法□物料衡算法 □排放系数法	□加盖密闭 □增加末端治理设施（冷凝、吸附吸收、催化燃烧）
燃烧烟气排放			□实测法□排放系数法	□提高燃烧效率
工艺有组织排放			□实测法□物料衡算法 □排放系数法	□增设末端治理设施（冷凝、吸附吸收、催化燃烧）
工艺无组织排放			□排放系数法	□增设末端治理设施（冷凝、吸附吸收、催化燃烧）
采样过程排放			□实测法□相关方程法 □平均排放系数法	□物料回收 □密闭式采样

火炬排放			□物料衡算法□基于热值的排放系数法	□提高燃烧效率 □增设气柜 □加强火炬来气检测
非正常工况（含开停工及维修）			□公式法	□提升装置平稳运行率
冷却塔、循环水冷却系统释放			□物料衡算法 □排放系数法	□检测与维修
事故排放				□提升装置平稳运行率 □加强员工日常培训
总计				
备注				

注：企业应一并提交表中数据核算过程及核算依据。

表 1-1 企业设备动静密封点泄漏 VOCs 污染源情况表

污染源项	企业设备动静密封点泄漏 VOCs 污染源
LDAR 基本情况	本企业_______年加工量（产量）_______ 104t，共有_______套生产装置，其中涉 VOCs 装置_______套，开展 LDAR 工作_______套生产装置，尚未开展的装置有_______套，豁免装置_______套。 _______企业受控密封点共计_______个，不可达点_______个，_______套生产装置已完成______轮 LDAR 工作。
LDAR 技术规范相符性承诺	是否按照《石化企业泄漏检测与修复技术规范》等国家标准开展相关工作 是☐否☐
设备泄漏 VOCs 排放估算结果	_______年度 第 1 轮检测密封点_______个，泄漏密封点_______个，修复_______个； … 采用____________估算方法，本企业_______年度设备泄漏 VOCs 排放量为______t。
设备泄漏 VOCs 损耗量削减潜力分析	达标性分析：达标☐不达标☐，削减潜力：_______ t/a 国内平均水平：已满足☐未满足☐，削减潜力：_______ t/a 国内先进水平：已满足☐未满足☐，削减潜力：_______ t/a
备注	其他需要说明的排查结果

表 1-2 挥发性有机液体储存与调和 VOCs 污染源情况表

污染源项	企业有机液体储存调和 VOCs 污染源
监测实施单位 a	_______公司
监测时间 a	_______年_______月_______日
储罐设施基本情况	本企业_______年加工量（产量）_______ 104t，总罐容_______ 104m3，年周转量_______ 104t/a。全厂低压和常压储罐共有_______座，其中低压储罐_______座，常压固定顶罐_______座，常压内浮顶罐_______座，常压外浮顶罐_______座。 各罐区现有 VOCs 末端控制设施_______套，主要用于_______罐区，处理

	工艺各为_______，装置规模各为_______ m3/h。
有机液体储存与调和 VOCs 排放估算结果	采用_______方法核算企业_______年度有机液体储存与调和过程 VOCs 排放量为_______ t。
有机液体储存与调和 VOCs 损耗量削减潜力分析	达标性分析：达标☐不达标☐，削减潜力：_______ t/a 国内平均水平：已满足☐未满足☐，削减潜力：_______ t/a 国内先进水平：已满足☐未满足☐，削减潜力：_______ t/a
备注	其他需要说明的排查结果

a 采用实测法时须填写

表 1-3 有机液体装卸 VOCs 污染源情况表

污染源项	企业有机液体装卸 VOCs 污染源
监测实施单位 a	_______公司
监测时间 a	_______年_______月_______日
装车设施基本情况	本企业_______年加工量（产量）_______ 104t，原辅材料及产品装在形式为_______，装载方式为_______，共有_______个装卸站台，_______个装载鹤管，装载物料_______，年装载量分别为_______； 企业设末端治理设施_______套数，主要用于_______站台, 处理工艺各为_______，装置规模各为_______ m3/h。
装载过程 VOCs 排放估算结果	采用_______方法核算企业_______年度挥发性有机液体装卸过程 VOCs 排放量为_______ t；设置末端治理设施时，末端治理设施效率为_______ %（收集效率、处理效率、投用效率、总效率）。
装载过程 VOCs 损耗量削减潜力分析	达标性分析：达标☐不达标☐，削减潜力：_______ t/a 国内平均水平：已满足☐未满足☐，削减潜力：_______ t/a 国内先进水平：已满足☐未满足☐，削减潜力：_______ t/a
备注	其他需要说明的排查结果。

a 采用实测法时须填写

表 1-4 废水收集及处理系统污染源情况表

污染源项	企业废水集输、储存、处理处置过程 VOCs 污染源
监测实施单位 a	_______公司
监测时间 a	_______ 年_______ 月_______日

废水收集和处理系统基本情况	本企业有_______套废水处理系统，_______套循环水系统；废水收集系统检查井数量和受控数量分别为_______个、_______个，集水井数量和受控数量分别为_______个、_______个，各股来水的名称和流量分别为_______，_______ m3/h；废水处理系统处理工艺流程为_______，处理量为_______ m3/h。 废水处理系统现有 VOCs 末端处理设施_______套，主要收集______构筑物，处理工艺为_______，装置规模各为_______ m3/h。
废水收集和处理系统 VOCs 排放估算结果	采用_______方法核算企业_______年度废水收集处理系统 VOCs 排放量为_______ t。
废水收集处理系统 VOCs 逸散量削减潜力分析	达标性分析：达标□不达标□，削减潜力：_______ t/a 国内平均水平：已满足□未满足□，削减潜力：_______ t/a 国内先进水平：已满足□未满足□，削减潜力：_______ t/a
备注	其他需要说明的排查结果

a 采用实测法时须填写

表 1-5 燃烧烟气污染源情况表

污染源项	燃烧烟气 VOCs 污染源
监测实施单位	_______公司
监测时间	_______年_______月_______日
燃烧设备基本情况	企业有工艺装置_______ 套，加热炉_______个，使用燃料的种类； 动力站________个，锅炉_______台，使用燃料的种类；自备电站_______个，内燃机及燃汽轮机_______台，使用燃料的种类。 设置废气处理设施数量，规模，采用的工艺技术，处理效率。
燃烧烟气 VOCs 排放估算结果	采用________方法核算企业_______年度燃烧烟气 VOCs 排放量为_______ t。
燃烧烟气 VOCs 排放削减潜力分析	达标性分析：达标□不达标□，削减潜力：_______ t/a 国内平均水平：已满足□未满足□，削减潜力：_______ t/a 国内先进水平：已满足□未满足□，削减潜力：_______ t/a
备注	其他需要说明的排查结果

a 采用实测法时须填写

表 1-6 工艺有组织废气污染源情况表

污染源项	工艺有组织废气 VOCs 污染源
监测实施单位 a	_______公司
监测时间 a	_______年_______月_______日

工艺装置基本情况	本企业_______年加工量（产量）_______ 104t，在役工艺装置数量，装置规模，采用的工艺技术；废气处理设施数量，规模，采用的工艺技术，处理效率。
工艺装置 VOCs 排放估算结果	采用_______方法核算企业_______年度工艺有组织 VOCs 排放量为_______ t。
其他源项 VOCs 排放削减潜力分析	达标性分析：达标□不达标□，削减潜力：_______ t/a 国内平均水平：已满足□未满足□，削减潜力：_______ t/a 国内先进水平：已满足□未满足□，削减潜力：_______ t/a
备注	其他需要说明的排查结果

a 采用实测法时须填写

表 1-7 工艺无组织废气污染源情况表

污染源项	工艺无组织废气 VOCs 污染源
监测实施单位 a	_______公司
监测时间 a	_______年_______月_______日
工艺装置基本情况	本企业_______年加工量（产量）_______ 104t，在役工艺装置数量，装置规模，采用的工艺技术；工艺无组织污染源排放位置，采取的措施。
工艺装置 VOCs 排放估算结果	采用_______方法核算企业_______年度工艺无组织 VOCs 排放量为_______ t。
其他源项 VOCs 排放削减潜力分析	达标性分析：达标□不达标□，削减潜力：_______ t/a 国内平均水平：已满足□未满足□，削减潜力：_______ t/a 国内先进水平：已满足□未满足□，削减潜力：_______ t/a
备注	其他需要说明的排查结果

a 采用实测法时须填写

表 1-8 采样过程污染源情况表

污染源项	采样过程 VOCs 污染源
监测实施单位 a	_______公司
监测时间 a	_______年_______月_______日
采样过程污染源基本情况	企业采样数量、类型。
采样过程 VOCs 排放估算结果	采用_______方法核算企业_______年度火炬废气 VOCs 排放量为_______ t。

采取过程 VOCs 排放削减潜力分析	达标性分析：达标☐不达标☐，削减潜力：_______ t/a 国内平均水平：已满足☐未满足☐，削减潜力：_______ t/a 国内先进水平：已满足☐未满足☐，削减潜力：_______ t/a
备注	其他需要说明的排查结果

a 采用实测法时须填写

表 1-9 火炬燃烧废气污染源情况表

污染源项	火炬燃烧废气 VOCs 污染源
监测实施单位 a	_______公司
监测时间 a	_______年_______月_______日
火炬系统污染源基本情况	企业火炬设置数量、类型、规模、服务范围、油气回收设施设置、监测设施设置、达标排放情况。
火炬废气 VOCs 排放估算结果	采用_______方法核算企业_______年度火炬废气 VOCs 排放量为_______ t。
火炬废气 VOCs 排放削减潜力分析	达标性分析：达标☐不达标☐，削减潜力：_______ t/a 国内平均水平：已满足☐未满足☐，削减潜力：_______ t/a 国内先进水平：已满足☐未满足☐，削减潜力：_______ t/a
备注	其他需要说明的排查结果

a 采用实测法时须填写

表 1-10 非正常工况 VOCs 污染源情况表

污染源项	非正常工况（含开停车及维修）VOCs 污染源
企业非正常工况基本情况	企业装置的开停车、检维修信息，包括开停车、检维修频次、规模、方式等；开停车、检维修装置的物料信息、装置容器形式，开停车、检维修装置的状态信息：装置温度、压力等。同时，收集企业火炬的服务范围等。
非正常工况 VOCs 排放估算结果	采用_______方法核算企业_______年度非正常工况 VOCs 排放量为____ t。
非正常工况 VOCs 排放削减潜力分析	达标性分析：达标☐不达标☐，削减潜力：_______ t/a 国内平均水平：已满足☐未满足☐，削减潜力：_______ t/a 国内先进水平：已满足☐未满足☐，削减潜力：_______ t/a
备注	其他需要说明的排查结果

表 1-11 冷却塔、循环水系统污染源情况表

污染源项	企业冷却塔、循环水冷却系统 VOCs 污染源
监测实施单位 a	_______公司
监测时间 a	_______年_______月_______日
循环水系统基本情况	企业循环水场_______个，各自规模及服务范围。
循环水系统 VOCs 排放估算结果	采用_______方法核算企业_______年度循环水系统 VOCs 排放量为_______ t。
循环水系统 VOCs 逸散量削减潜力分析	达标性分析：达标☐不达标☐，削减潜力：_______ t/a 国内平均水平：已满足☐未满足☐，削减潜力：_______ t/a 国内先进水平：已满足☐未满足☐，削减潜力：_______ t/a
备注	其他需要说明的排查结果

a 采用实测法时须填写

表 1-12 事故排放污染源情况表

污染源项	企业事故 VOCs 污染源
事故基本情况	企业发生事故的设施及事故类型，事故基本情况及事故处理情况。
事故 VOCs 排放估算结果	企业_______年事故状态下 VOCs 排放量为_______ t。
事故 VOCs 削减潜力分析	达标性分析：达标☐不达标☐，削减潜力：_______ t/a 国内平均水平：已满足☐未满足☐，削减潜力：_______ t/a 国内先进水平：已满足☐未满足☐，削减潜力：_______ t/a
备注	其他需要说明的排查结果

表 2 包装印刷行业 VOCs 排放申报登记表

企业名称					
企业地址					
机构代码					
所属行业					
是否重点源	国控 □ 省控 □ 非重点源 □				
填报日期		填报人		联系方式	

VOCs 排放总污染当量： =(A+B-C-D)/0.95

应缴 VOCs 排污费（元）：

一、有机类原料投用情况（包括油墨、胶黏剂、涂布液、润版液、洗车水）

核算期投用的有机类原料 VOCs 排放量共计（千克，A）：

名称	型号	生产厂家及联系方式	使用工段	核算期购买量	VOCs 含量	VOCs 量
1、						
2、						
……						

上述申报需包含所有有机类原料

二、稀释剂使用情况

核算期稀释剂购买量合计（千克,B）：

名称	型号	生产厂家及联系方式	使用工段	核算期购买量
1、				
2、				
……				

上述申报需包含所有使用的稀释剂

三、VOCs 去除情况

核算期 VOCs 去除量合计（千克，C）：

工段	投用有机类原料中 VOCs 的量(a)	其他有机溶剂使用量(b)	去除率 (ER)	核算期去除量 (a+b) ×ER
1、				
2、				
……				

上述申报需包含所有工段

如采用监测法计算 VOCs 去除量，则申报下列内容

工段	设计单位	处理工艺	通过环保验收时间	年运行时间，天	日运行时间，h	处理装置排风量，m^3/h	处理装置进口平均浓度，mg/m^3	处理装置出口平均浓度，mg/m^3	VOCs 去除量
1、									
2、									
……									

<table>
<tr><td colspan="6">上述申报需包含所有工段</td></tr>
<tr><td colspan="6" align="center">四、VOCs 回收情况</td></tr>
<tr><td colspan="6">核算期回收的各种废有机溶剂合计（千克，D）：</td></tr>
<tr><td>名称</td><td>型号</td><td colspan="2">回收单位或回收再利用项目名称</td><td colspan="2">回收量</td></tr>
<tr><td>1、</td><td></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td>2、</td><td></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td>……</td><td></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td colspan="6">上述申报需包含所有废有机溶剂</td></tr>
<tr><td colspan="6" align="center">五、其他信息</td></tr>
<tr><td rowspan="3">核算期 VOCs 处理装置运行情况</td><td>处理装置综合去除率（%）</td><td></td><td>活性炭更换周期</td><td colspan="2"></td></tr>
<tr><td>催化剂更换周期</td><td></td><td>处理装置不正常运行次数（次）</td><td colspan="2"></td></tr>
<tr><td>核算期上年同期排污申报登记表申报的去除率</td><td colspan="4"></td></tr>
</table>

5 APPENDIX – CHINA'S GHG GUIDELINES

Guidelines for Accounting and Reporting

Greenhouse Gas Emissions

China Petroleum and Natural Gas Producing Enterprises

(Trial)

Instructions

I. Purpose and Significance of the Guidelines

In order to carry out the task of "establishing and perfecting greenhouse gas accounting system and gradually setting up a carbon emission trading market" as proposed in the *Outline of the 12th Five-Year Plan* and to implement the requirements of "building greenhouse gas emission accounting system at the national, local and enterprise levels and carrying out the system of direct energy and greenhouse gas emission data reporting by key enterprises" as proposed in the *Work Plan for Greenhouse Gas Emission Control during the 12th Five-Year Plan* (GF[2011] No. 41), the National Development and Reform Commission (NDRC) issued the *Notice on Organizing and Implementing Greenhouse Gas Emission Reporting by Key Enterprises (Institutes)* (FGQH [2014] No. 63) and organized research on and preparation of the guidelines on greenhouse gas emission accounting and reporting of enterprises in key industries. The *Guidelines for Accounting and Reporting Greenhouse Gas Emissions from China Petroleum and Natural Gas Producing Enterprises (Trial)*(the Guidelines) are prepared to help petroleum and natural gas producing enterprises with (i) accurate accounting and standard reporting of greenhouse gas emissions; (ii) scientific formulation of the action plan; and (iii) preparation of countermeasures for greenhouse gas emissions control. The Guidelines also lay a foundation for the authority to establish and implement greenhouse gas emission reporting system for key enterprises.

II. Preparation Process

The Guidelines are prepared by the National Centre for Climate Change Strategy and International Cooperation (NCSC) under the authorization of the NDRC. Using the findings of research in China and abroad on greenhouse gas emission accounting and reporting from enterprises and relevant practical experiences and the *Guideline for Preparation of Provincial Greenhouse Gas List (Trial)* issued by the NDRC Office as the reference, the preparation team completed the *Guidelines for Accounting and Reporting Greenhouse Gas Emissions from China Petroleum and Natural Gas Producing Enterprises (Trial)* through field survey and in depth research. Efforts have been made to ensure that the Guidelines are science-based, comprehensive, standardized and practical. During the preparation of the Guidelines, strong support has been received from China Petroleum and Chemical Industry Federation, China National Petroleum Corporation, China Petrochemical Corporation, China National Offshore Oil Corporation, and Petro China Pipeline R&D Center.

III. Main Contents

The *Guidelines for Accounting and Reporting Greenhouse Gas Emissions from China Petroleum and Natural Gas Producing Enterprises (Trial)* consist of the main text and two appendices. The text is comprised of seven sections, namely, scope of application, references, terms and definitions, accounting boundary, accounting methods, quality assurance and documentation, and contents of the report. The Guidelines apply to independent legal enterprises and independent accounting entities considered legal persons that are engaged in petroleum and natural gas production in China. Categories of emission sources and types of gases subject to accounting and reporting mainly include carbon dioxide (CO_2) emissions from fuel combustion, $CO_2$and CH_4emissions from flare burning, $CO_2$and CH_4 emissions from process ventilation, CH_4 fugitive emissions from equipment leakage, recycled and utilized CH_4, recycled and utilized CO_2, and CO_2 emissions embodied in net purchased electric power and heating power.

IV. Issues that Need Clarification

Petroleum and natural gas producing enterprises using the Guidelines shall deem independent corporate enterprises or independent accounting entities considered as legal persons at the lowest level as the boundary to account and report emissions of greenhouse gasses from all production facilities whose operation is under their control. Where the reporting entity is engaged in other product production activities with greenhouse gas emissions apart from production of petroleum and natural gas, references shall be made to the guidelines on greenhouse gas emission accounting and reporting of enterprises in the relevant industries for accounting and reporting the greenhouse gas emissions of these production activities.

Enterprises shall provide corresponding activity level and emission factor data used for calculation of the discharge amount, which shall be used as the basis for checking and verification. Enterprises shall measure their activity level and emission factor data as far as possible. For the sake of users, the Guidelines refer to many literatures including *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories,* and *Guidelines for Preparation of Provincial Greenhouse Gas Inventories (Trial)*. The Guidelines also sort out the parameters related with the types of some common fossil fuels and the emission factors of different facilities of the petroleum and natural gas system for the reference of enterprises in need of measurement conditions.

Considering the fact that enterprise-based GHG emissions accounting and reporting are a completely new endeavor, some inadequacies may be found in practical application of the Guidelines, and it is hoped that those application units may provide their individual feedback in a timely manner, all aimed at making further revision and improvement in the future.

The Guidelines are published by the National Development and Reform Commission, which is responsible for their interpretation and revision when appropriate.

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1. Application Scope

The Guidelines are applicable to the accounting and reporting of greenhouse gas emissions of Chinese petroleum and natural gas producing enterprises. Enterprises engaged in the production of petroleum and natural gas within the Chinese territory may refer to the Guidelines to account and report their greenhouse gas emissions. Where enterprises are engaged in other product production activities with greenhouse gas emissions apart from production of petroleum and natural gas, references shall be made to the guidelines of greenhouse gas emission accounting and reporting for enterprises in the relevant industries for accounting and reporting the greenhouse gas emissions of these production activities.

2. References

The following documents are referred to in the Guidelines:

General Guideline of Greenhouse Gas Emission Accounting and Reporting for Industrial Enterprises;

ISO 14064-1 Greenhouse Gases Part 1: Specification with Guidance at the Organization Level for Quantification and Reporting of Greenhouse Gas Emissions and Removals;

Guideline for Preparation of Provincial Greenhouse Gas Inventories (Trial);

The People's Republic of China National Greenhouse Gas Inventory 2005;

2006 IPCC Guidelines for China National Greenhouse Gas Inventory;

GB 17167General Principle for Equipping and Managing of the Measuring Instrument of Energy in Energy Using Organization;

GB/T 213Determination of Calorific Value of Coal;

GB/T 384Determination of Calorific Value of Petroleum Products;

GB/T 22723Energy Determination for Natural Gas;

GB/T 476Determination of Carbon and Hydrogen in Coal;

SH/T 0656Standard Test Methods for Instrumental Determination of Carbon, Hydrogen and Nitrogen in Petroleum Products and Lubricants (Element Analyzer Method);

*GB/T 13610Analysis of Natural Gas (by Gas Chromatography Method);*and

GB/T 8984Determination of Carbon Monoxide, Carbon Dioxide and Hydrocarbon in Gases – Gas

Chromatographic Method.

3. Terminology and Definitions

For the purpose of the Guidelines, the following terminology and definitions apply.

3.1 Petroleum and natural gas production

Petroleum and natural gas production refer to the exploitation process of natural crude oil and liquefied or gaseous natural gas on land or at sea, including activities such as exploration, drilling, gathering and transfer, separate treatment, storage and transportation.

3.2 Oil and gas exploration

Oil and gas exploration refers to activities conducted to identify exploration areas and prove oil and gas reserves, such as geological survey, geophysical exploration and drilling.

3.3 Oil and gas exploitation

Oil and gas exploitation refers to the whole process of bringing crude oil and natural gas from reserves to the surface through the oil or gas well, including underground work, gathering and transportation at mines, offshore platforms and onshore transfer, loading and unloading, and storage.

3.4 Oil and gas treatment

Oil and gas treatment refers to the purification process of oil-gas separation, stabilizing treatment of crude oil, and removal of impurities, water and acid gas from oil or natural gas.

3.5 Oil and gas storage and transportation

Oil and gas storage and transportation refer to the long-distance pipeline transfer and storage of petroleum and natural gas, including the process of receiving liquefied natural gas through submarine pipelines, underground gas storage reservoir, and the entry/exit stations of liquefied natural gas, storing liquefied natural gas, gasifying liquefied natural gas and transporting it to the transfer or delivery facilities of natural gas.

3.6 Greenhouse gases (GHGs)

A greenhouse gas is natural or man-made atmospheric component in gaseous state that absorbs and emits radiation within the thermal infrared range. The GHGs addressed in the Guidelines refer to the six types of GHGs which are listed in Annex A of the Kyoto Protocol: carbon dioxide(CO_2), methane(CH_4), nitrous oxide(N_2O), hydrofluorocarbons(HFCs), perfluoro-carbon (PFCs) and sulfur hexafluoride (SF_6). The Guidelines require that petroleum and natural gas producing enterprises shall account CO_2 and CH_4.

3.7 Reporting entity

Reporting entity refers to independent corporate enterprises or independent accounting entities considered as legal persons with greenhouse gas emissions.

3.8 Emissions from fuel combustion

Emissions from fuel combustion refer to emissions of greenhouse gases produced from intentional oxidation of fossil fuels for the purpose of energy utilization[1].

3.9 Emissions from flare combustion

Emissions from flare combustion refer to the emissions of CO_2 and CH_4 produced from the combustion of combustible waste gases, for the sake of safety, before their discharge that are from all links of the production of petroleum and natural gas.

3.10 Emissions from process ventilation

Emissions from process ventilation refer to the emissions of greenhouses gases carried by waste gas flow that are discharged into the atmosphere as needed by the process in the production and petroleum and natural gas, apart from fuel combustion and flare emissions.

3.11 Fugitive emissions

Fugitive emissions refer to unorganized emissions caused by the leakage of equipment, rather than for purposeful reasons.

3.12 CH_4 recovery and utilization

CH_4 recovery and utilization refer to recovery and utilization of CH_4 carried by the waste gas flow of process ventilation by the reporting entity as so as to prevent it from being discharged into the atmosphere.

3.13 CO_2 recovery and utilization

CO_2 recovery and utilization refer to recovery of CO_2 produced by the reporting entity, used as the raw material of production, supplied to other units as products so as to prevent it from being discharged into the atmosphere.

3.14 CO_2 emissions embodied in net purchased electric power and heating power

CO_2 emissions embodied in net purchased electric power and heating power refer to emissions of

[1] The purpose of fuel combustion is to provide heat or mechanical power for certain process.

CO_2 of net electric power or heating power (steam, hot water) purchased by an enterprise that is equivalent to fuel combustion in the production process.

3.15 Activity level

Activity level refers to the quantification of those activities of the reporting entity during the reporting period, which result in emissions or removal or certain greenhouse gases, such as the combustion of each fossil fuel, usage of fossil fuel as the raw material, purchased or sold electricity quantity, purchased or sold heat quantity, etc.

3.16 Emission factors

Emission factor refers to the quantified rate of GHG emissions per unit of activity. Emission factors are generally acquired on the basis of sample measurement or statistical analysis. They indicate the representative emission rates or removal rates at certain activity level under given operational conditions.

3.17 Coal oxidation rate

Coal oxidation rate refers to the rate of carbon oxidized in the process of coal combustion. It represents the combustion efficiency of coal.

4. Accounting Boundary

4.1 Enterprise boundary

The reporting entity shall deem independent corporate enterprise or the independent accounting entity considered as the legal person as the enterprise boundary for accounting and reporting of greenhouse gas emissions from all production facilities whose operation is under its control. The scope of the facilities includes the basic production system that is directly related with the exploration, exploitation, treatment, storage and transportation of petroleum and natural gas, auxiliary production system and the affiliated production system that directly serves production. Among them, the auxiliary production system includes dynamics, power supply, water supply, heating, refrigeration, machine maintenance, assay, instrumentation, warehouse (raw material stock yard) and transportation in the plant area. The affiliated production system includes the production control and management system (headquarter) and the departments and units (such as the staff cafeteria and workshop bathrooms) serving production in the plant area.

4.2 Emission sources and types of gases

The reporting entity shall account the following categories of emission sources and types of gases:

4.2.1 CO_2emissions from fuel combustion

CO_2 emissions from fuel combustion refer to emissions of CO_2 produced in the combustion of fossil fuels to supply power and heat in various links of the production chain of petroleum and natural gas.

4.2.2 Emissions from flare combustion

For the sake of safety, petroleum and natural gas producing enterprises usually concentrate combustible waste gas produced in all production activities to one or several flare systems for combustion before discharge. Besides CO_2, flare combustion may also produce a small amount of CH_4 and the flare system of petroleum and natural gas production needs to account the emissions of both CO_2 and CH_4.

4.2.3 Process ventilation

Process ventilation mainly refers to the purposeful emissions of CH_4 or CO_2 through the release outlets or safety valves of process devices in various links of petroleum and natural gas production, such as natural gas emissions from pneumatic devices, pressure release emissions, emissions from equipment purge, exhaust emissions in the process, emissions of dissolved gases from storage tanks. The businesses and links of petroleum and natural gas producing enterprises are many and unique, and thus the process ventilation of various businesses and links shall be accounted separately.

4.2.4 CH_4 fugitive emissions

CH_4 fugitive emissions mainly refer to unorganized emissions of CH_4 produced by equipment leakage in various businesses and links of petroleum and natural gas production, such as the leakage of valves, flanges, pump encapsulation, compressor seal, pressure reducing valves, sampling connection, process drain, opening pipelines, casing pipes, storage tanks, and the leakage of other pressure equipment that are not defined as process ventilation. The businesses and links of petroleum and natural gas producing enterprises are many and unique, and thus the fugitive emissions of various businesses and links shall be accounted separately.

4.2.5 CH_4 recovery and utilization

CH_4 recovery and utilization refer to recovery of CH_4 carried in the waste gas flow of process ventilation by enterprises through energy-saving and emissions reduction technologies, so as to prevent it from being discharged into the atmosphere. Recovered and utilized CH_4 can be deducted from the total emissions amount of the enterprise.

4.2.6 CO_2 recovery and utilization

CO_2 recovery and utilization include the recovery of CO_2 produced from fuel combustion or industrial production process, recovered by the enterprise and used as raw production material and that is supplied to other entities as product. Recovered and utilized CO_2 can be deducted from the total emissions amount of the enterprise. Due to lack of appropriate accounting methods, the geological storage of CO_2 and the emissions reduction issue in the displacement of reservoir oil are not considered here.

4.2.7 CO_2 emissions embodied in net purchased electric power and heating power

Such emissions are actually from enterprises producing electric power and heating power, but caused by the consumption of the reporting entity, and in line with the agreement, are calculated in the name of the reporting entity.

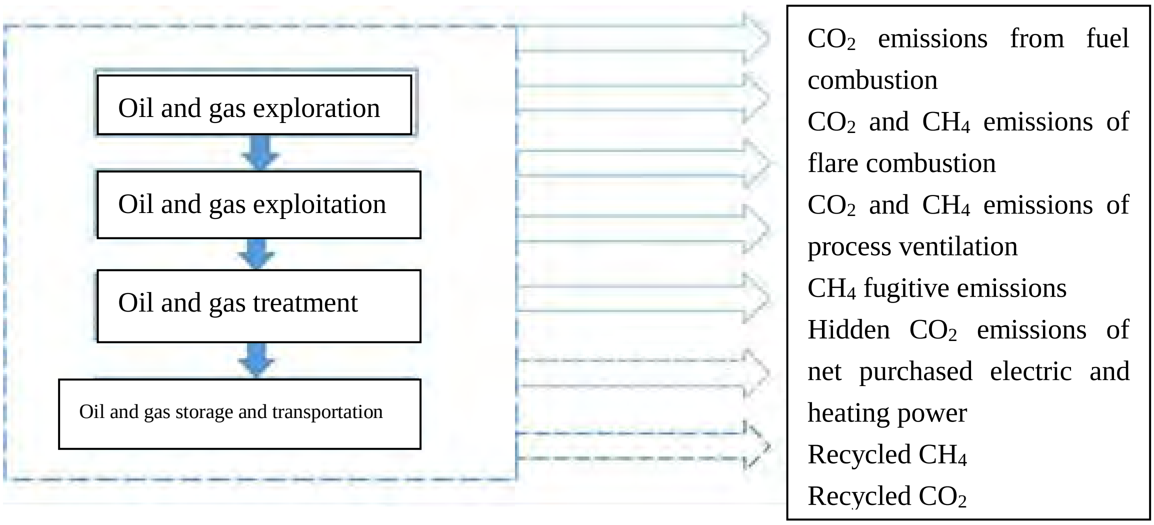

Fig. 1 Emission sources and types of greenhouse gas emissions in the production of petroleum and natural gas

5. Accounting Methodology

After the accounting boundary being identified, greenhouse gas emissions can be accounted through the following steps:

(1) Identify the greenhouse gas emission businesses and links owned by enterprises and determine the emission sources and types of gases;
(2) Select corresponding calculation equations for the emissions of greenhouse gases;
(3) Acquire activity level and emission factor data;
(4) Account the emissions of greenhouse gases according to corresponding equation based on acquired data;
(5) In line with stipulated form, describe and summarize the calculation process and results of greenhouse gas emissions.

Total greenhouse gas emissions of the reporting entity shall be equal to CO_2 emissions from fuel combustion plus emissions from flare combustion, process ventilation and fugitive emissions of various businesses and links (non-CO_2gases shall be converted to CO_2in line with the global warming potential, i.e. GWP) minus CO_2 recovery and utilization of the enterprise, plus CO_2 emissions embodied in net electric power and heating power purchased by the enterprise.

$$E_{GHG}=E_{CO2\_combustion}+E_{GHG\_flare}+\sum_{s}(E_{GHG\_process}+E_{GHG\_fugitive})-R_{CH4\_recovery}\times GWP_{CH4}-R_{CO2\_recovery}+E_{CO2\_net\ power}+E_{CO2\_net\ heat} \quad ......(1)$$

Where,

E_{GHG} refers to the total greenhouse gas emissions of the reporting entity. It is expressed in unit ton CO_2;

E_{CO_2}-combustion refers emissions of CO_2 produced from combustion of fossil fuel in various types of combustion equipment in the accounting boundary. It is expressed in unit ton CO_2;

E_{GHG_flare} refers to emissions of greenhouse gases caused by flare combustion. It is expressed in unit ton CO_2;

$E_{GHG-process}$ refers to process ventilation of various businesses by enterprises. It is expressed in unit ton CO_2;

$E_{GHG-fugitive}$ refers to equipment fugitive emissions of various businesses by enterprises. It is expressed in unit ton CO_2;

s refers to types of businesses involved by enterprises, including exploration, exploitation, treatment, storage and transportation of petroleum and natural gas;

$R_{CH4-recovery}$ refers to the amount of CH_4 recovered and utilized by enterprises. It is expressed in unit ton CH_4;

GWP_{CH4} refers to the GWP value of CH_4 compared with CO_2. In line with the second evaluation of IPCC, 1ton of CH_4 is equivalent to the warming capacity of 21 tons of CO_2 in 100 years, and thus GWP_{CH4} is equal to 21;

$R_{CO2\ -recovery}$ refers to the recovered CO_2 of enterprises and is expressed in unit ton CO_2;

E_{CO_2}-net power refers to the CO_2 emissions embodied in net electric power purchased by the reporting entity. It is expressed in unit ton CO_2; and

E_{CO_2}-net heat refers to the CO_2 emissions embodied in net heating power purchased by the reporting entity. It is expressed in unit ton CO_2.

5.1 CO_2 emissions from fuel combustion

5.1.1 Calculation equation

CO_2 emissions from fossil fuel combustion of the reporting entity is equal to the sum of fossil fuel combustion of various combustion facilities multiplied by corresponding carbon level and carbon oxidation rate, as shown by the following equation:

$$ECO2\_combustion = \sum_j \sum_i (ADi, jXCCi, jXOFi, jX \frac{44}{12}) \text{ ...... (2)}$$

E_{CO_2}-combustion refers to CO_2emissions produced from the combustion of fossil fuel of enterprises. It is expressed in unit tonCO_2;

i stands for the category of the fossil fuel;

j stands for the code of the combustion facility type;

$AD_{i,j}$ refers to the consumption capacity of the i^{th} fossil fuel combusted in the combustion facility of *j*, and for solid or liquefied fuels, is expressed in unit t; and other gaseous fuels, in unit 10,000 Nm^3 of the standard condition of gaseous fuels; and the volume of non-standard condition shall be converted to that of standard condition;

$CC_{i,j}$ refers to carbon content in fuel gas *i*in facility *j*, and is expressed in unit ton carbon/10,000 Nm^3, for solid and liquefied fuels; in unit ton carbon/10,000 Nm^3, for gaseous fuels; and

$OF_{i,j}$ refers to the coal oxidation rate of fuel gas *i*, and ranges from 0 to 1.

5.1.2 Data monitoring and acquisition

The burning capacity of various fossil fuels for combustion equipment shall be determined based on the original record or statistical ledger of enterprise energy consumption, and refers to the fossil fuel to be fed into the combustion equipment and burned as fuel, including types of energy produced and recovered by enterprises.

5.1.2.1 Carbon content of fossil fuel

Wherever practical, the enterprise may determine for itself or entrust a competent professional certification body to determine the carbon content of the fuel on a regular basis. The determination of the carbon content in the raw material (fuel) shall be conducted in accordance with *GB/T 476Determination of Carbon and Hydrogen in Coal*, *SH/T 0656 Standard Test Methods for Instrumental Determination of Carbon , Hydrogen , and Nitrogen in Petroleum Products and Lubricants(element analyzer method)*, *GB/T 13610 Analysis of Natural Gas Composition—Gas Chromatography*, or *GB/T 8984 Determination of Carbon Monoxide, Carbon Dioxide and Hydrocarbon in Gases—Gas Chromatographic Method*. (i) For coal, the determination of carbon content shall be conducted when every batch of coal is transported into the plant or at least on a monthly basis, and the carbon content in such type of coal shall be determined based on the quantity of incoming coal or monthly coal consumption weighted average. (ii) For oil, the determination of carbon content shall be conducted when every batch of oil is transported into the plant or at least on a quarterly basis, and the arithmetic mean value shall be obtained and deemed to be the carbon content in such type of oil. (iii) For fuel gas such as natural gas, the determination of gas components shall be conducted when every batch of gas is transported into the plant or at least on a half year basis, and the carbon content in the gas shall be calculated based on the volume concentration of every type of component and the number of carbon atoms in the chemical equation of such component.

$$CC_g = \sum_n \left(\frac{12 \times CN_n \times V_n}{22.4} \times 10 \right)$$

………(3)

Where:

n: component of gas to be determined;

CC_g: carbon content of gas (g) to be determined, ton carbon/10,000 Nm^3;

V_n: volume concentration of every type of component (n) of gas to be determined, with the value range of 0~1, e.g. 0.95 for volume concentration 95%;

CN_n: number of carbon atoms in chemical formula of gas component (n);

12: molar mass of carbon, kg/kmol; and

22.4: ideal molar volume of gas in standard conditions, Nm^3/kmol.

For common commercial fuels, the low heating value of the fuel may be determined regularly for estimation of the carbon content in such fuel by Equation (4).

$$CC_i = NCV_i \times EF_i$$

......(4)

Where:

CC_i: carbon content in the fossil fuel (i), with ton carbon/ton fuel as the unit for solid and liquid fuel while ton carbon/10,000 Nm^3 for gas fuel;

NCV_i: low heating value of the fossil fuel (i), MkJ (GJ)/Ton for solid and liquid fuel while GJ /10,000 Nm^3 for gas fuel; and

EF_i: carbon content of unit heat value in fossil fuel (i), ton carbon/GJ. For carbon content of unit heat value in common commercial energies, see Table 2.1 of Appendix II.

The determination of low heating value of fuels shall be conducted in accordance with *GB/T 213 Determination of Calorific Value of Coal*, *GB/T 384 Determination of Calorific Value of Petroleum Products*, and *GB/T 22723 Energy Determination for Natural Gas*. (i) For coal, the determination of low heating value shall be conducted when every batch of coal is transported into the plant or at least on a monthly basis, and the low heating value of such type of coal shall be determined based on the quantity of incoming coal or monthly coal consumption weighted average. (ii) For oil, the determination of low heating value shall be conducted when every batch of oil is transported into the plant or at least on a quarterly basis, and the arithmetic mean value shall be obtained and deemed to be the low heating value of such type of oil. (iii) For fuel gas, the determination of low heating value shall be conducted when every batch of gas is transported into the plant or at least on a half year basis, and the arithmetic mean value shall be obtained and deemed to be the low heating value of such gas.

In case the determination is impractical, the enterprise may take directly the default values as the low heating value of some common fossil fuels from Table 2.1 of Appendix II.

5.1.2.2 Oxidation rate of fuel carbon

The default value 0.98 may be taken as the oxidation rate of liquid fuel. The default value 0.99 may be taken as the oxidation rate of gas fuel. For solid fuel, the default value may be taken from Table 2.1 in Appendix II as per the type of solid fuels.

5.2 Emissions from flare combustion

Flare combustion of petroleum and natural gas producing enterprises can be divided into flare gas combustion under normal process conditions and that caused by accidents, which, in light of their difference data monitoring basis, are suggested to be accounted separately. In addition, in light of the fact that the relatively high content of CH_4 and insufficient combustion of flare gas of petroleum and natural gas producing enterprises, flare combustion of petroleum and natural gas producing enterprises shall consider the emissions of both CO_2 and CH_4.

$$E_{GHG\_flare}=E_{CO2\_normal\ flare} + E_{CO2\_accident\ flare} + (E_{CH4\_normal\ flare} + E_{CH4\_accident\ flare}) \times (GWP_{CH4}) \qquad ......(5)$$

Where,

$E_{CO2\text{-}flare}$ refers to the emissions of CO_2 produced in flare combustion. It is expressed in unit ton CO_2;

$E_{CO2\text{-}normal\ flare}$ refers to the emissions of CO_2produced by the flare system under normal process conditions. It is expressed in unit ton CO_2;

$E_{CO2\text{-}accident\ flare}$ refers to the emissions of CO_2produced by accident flare. It is expressed in unit ton CO_2;

$E_{CH4\text{-}normal\ flare}$ refers to the emissions of CH_4 produced by the flare system under normal process conditions. It is expressed in unit ton CH_4; and

$E_{CH4\text{-}accident\ flare}$ refers to the emissions of CH_4produced by accident flare. It is expressed in unit ton CH_4.

5.2.1 Greenhouse gas emissions under the normal operation condition

5.2.1.1 Calculation equation

$$E_{CO2\_normal\ flare} = \sum_{i} [Q_{normal\ flare} \times (CC_{non\ CO2} \times OF \times \frac{44}{12} + VCO2 \times 19.7)]_i \qquad ......(6)$$

$$E_{CH4\_normal\ flare} = \sum_{i} [Q_{normal\ flare} \times V_{CH4} \times OF \times (1—OF) \times 7.17]_i \qquad ......(7)$$

Where,

f refers to the number of the flare system;

$Q_{normal\ flare}$ refers to the flare gas flow of No.*i*flare system under normal production conditions. It is expressed in unit 10,000 Nm^3;

$CC_{non\text{-}CO2}$ refers to the total carbon amount of other carbon containing compounds except for

CO_2 in flare gas. It is expressed in unit 10,000 Nm^3. See Equation (8) for its calculation method;

OF refers to the carbon oxidation rate of No. *i*flare system. If there is no measured value, the default value 0.98 may be used;

V_{CO2} refers to the volume concentration of CO_2 in flare gas and ranges between 0 and 1. For example, the volume concentration of CO_2in flare gas is 2%, and V_{CO2} is 0.02;

V_{CH4} refers to the volume concentration of CH_4 in flare gas; $\frac{44}{12}$ is the conversion coefficient of carbon and CO_2;

19.7 refers to the concentration of CO_2 under the standard condition and is expressed in unit ton/10,000 Nm^3; and

7.17 refers to the concentration of CH_4 under the standard condition and is expressed in unit ton/10,000 Nm^3.

5.2.1.2 Data monitoring and acquisition

For the flare system under normal process conditions, the flare gas amount $Q_{\text{normal flare}}$ in the reporting period can be calculated based on the flow monitoring system, engineering calculation or similar estimation methods.

The CO_2 and CH_4 concentration in Equation (6) and Equation (7) shall be acquired based on gas content analyzer or flare gas, and the $CC_{non\text{-}CO2}$ of other carbon containing compounds except for CO_2 in the flare gas shall be calculated based on the volume concentration of each gas content and the number of carbon atoms in the chemical formula of this content as the following equation:

$$CC_{non\text{-}CO2}=\sum_{n}\left(\frac{12 \times Vn \times CNn \times 10}{22.4}\right) \quad \text{...... (8)}$$

Where,

n refers to the gas components in flare gas, except for CO_2;

$CC_{non\text{-}CO2}$ refers to the carbon content of other carbon-containing compounds in flare gas, except for CO_2, and it is expressed in unit ton carbon/10,000Nm3;

V_n refers to the volume concentration of the n^{th} carbon-containing compound (including carbon monoxide) in flare gas, except for CO2, and ranges from 0 to 1. For example, if the volume concentration of a certain carbon-containing compound is 90%, then V_n is 0.9; and

CN_n refers to the number of carbon atoms in the chemical formula of the n^{th}carbon-containing compound in flare gas.

5.2.2 Greenhouse gas emission of accidental flare

5.2.2.1 Calculation equation

Currently, flare gas combustion caused by accidents in petroleum and natural gas producing enterprises is not monitored, so direct access to flare gas data is very difficult. It is suggested that the flare gas combustion amount shall be estimated based on the average gas flow into the flare of accident facilities and the persisting time of accidents, and the emissions of CO_2 and CH_4 shall be estimated based on the combustion of accident flare:

$$E_{CO2-accident\ flare} = \sum_j GF_{accident,j} \times T_{accident,j} \times (CC(non-CO2) \times OF \times \frac{44}{12} + V(CO2)j \times 19.7 \qquad \ldots\ldots (9)$$

$$E_{CH4-accident\ flare} = \sum_j [GF_{accident,j} T_{accident,j} \times VCH4 \times (1 - OF) \times 7.17]j \qquad \ldots\ldots (10)$$

where,

j refers to the number of accidents;

$GF_{accident\ j}$ refers to the flare gas flow velocity of the j^{th} accident in the reporting period, it is expressed in unit 10,000 Nm^3/hour;

$T_{accident\ j}$ refers to the duration of the j^{th} accident in the reporting period, it is expressed in unit hour;

$CC_{(non-CO2)j}$ refers to the total carbon amount of other carbon-containing compounds in flare gas, except for CO_2, in the j^{th} accident and is expressed in unit ton carbon/10,000 Nm^3. Its calculation method is shown by Equation (8);

OF refers to the carbon oxidation rate of flare combustion, and if there is no measured value, default value 0.98 may be used;

$V_{(CO2)j}$ refers to the volume concentration of CO_2 in flare gas in the j^{th} accident; and

V_{CH4} refers to the volume concentration of CO_2 in flare gas in accidents.

5.2.2.2 Data supervision and acquisition

The duration time of accident flare $T_{accident,j}$ and the average gas flow $GF_{accident,j}$ shall be based on the accident survey report. The CO_2 and CH_4 concentration in accident flare shall be acquired based on the gas component analyzer or the source of flare gas accidents. The $CC_{non\text{-}CO2}$ of other carbon-containing compounds in flare gas, except for CO_2, shall be calculated based on the volume concentration of each gas component and the number of carbon atoms of the chemical formula of corresponding component, in line with Equation (8).

5.3 Greenhouse gas emissions of petroleum and natural gas exploration

The CO_2 emissions from fossil fuel combustion in petroleum and natural gas exploration are accounted and reported in the "CO_2 emissions of fuel combustion"; the emissions of flare combustion in petroleum and natural gas exploration are accounted and reported in the "emissions of flare combustion"; CH_4 emissions of process ventilation in petroleum and natural gas exploration are calculated as follows.

5.3.1 Calculation equation

In accordance with the current domestic petroleum and gas exploration process, combustible gases such as CH_4 are seldom ventilated in the petroleum and gas exploration process. Unimpeded ventilation through test wells of natural gas is possible, and usually recovered or processed through flare combustion. If ventilated directly, CH_4 emissions shall be calculated based on Equation (11):

$$E_{CH4\text{-test well}} = \sum_{k=1}^{N} (Q_k \times Hk \times VCH4,k \times 7.17 \times 10^{-4}) \quad \text{...... (11)}$$

where,

$E_{CH\text{-test well}}$ refers to the CH_4amount directly emitted through the test wells of natural gas and is expressed in unit ton CH_4;

k refers to the serial number of natural gas well through which gases are emitted directly in well testing operation;

Q_k refers to the unimpeded flow of natural gas well of the k^{th} well testing that conducts unimpeded ventilation; the unimpeded flow shall be converted into the volume of gas under the standard condition and expressed in unit Nm^3/hour;

H_k refers to the hours of well testing operation of the k^{th} natural gas well, and is expressed in unit hour;

$V_{CH4,k}$ refers to the volume concentration of CH_4 of the ventilated gas of the k^{th} natural gas well, and ranges from 0 to 1; and

7.17 refers to the concentration of CH_4 under the standard condition and is expressed in unit ton/10,000 Nm^3.

5.3.2 Data monitoring and acquisition

The unimpeded flow Q_k of the natural gas well and the volume concentration, $V_{CH4,k}$**,** of CH_4 in the discharge shall use their arithmetic average values based on the detected data of enterprises; the work hour, H_k, shall be acquired from the operation record of enterprises.

5.4 Greenhouse gas emissions of petroleum and gas exploitation

The CO_2 emissions of fossil fuel combustion in petroleum and gas exploration are accounted and reported in the "CO_2emissions of fuel combustion"; the emissions of flare combustion in petroleum and gas exploration are accounted and reported in the "emissions of flare combustion".

The CH_4 emissions and CH_4 fugitive emissions in process ventilation of petroleum and gas exploitation are mainly from the wellhead, single-well storage device, block station, and united station of crude oil exploitation, and the wellhead, gas-gathering station, measurement/distribution station and storage station of natural gas exploitation. Their calculation methods are as follows:

5.4.1 Process ventilation of petroleum and gas exploitation

5.4.1.1 Calculation equation

CH_4 emissions in process ventilation of petroleum and gas exploitation can be calculated based on the number of facilities in various exploitation links and the emission factor of process ventilation of different facilities:

$$E_{CH4\_exploitation\ ventilation} = \sum_{j} (Num_j \times EF_j) \qquad \text{...... (12)}$$

where,

$E_{CH4\_exploitation\ ventilation}$ refers to the CH_4 emissions of process ventilation in petroleum and gas exploitation, and is expressed in unit ton CH_4;

j refers to the device type of the petroleum and gas exploitation system, including the wellhead, single-well storage device, block station, and united station of crude oil exploitation, and the wellhead, gas-gathering station, measurement/distribution station and storage station of natural gas exploitation;

Num_j refers to the number of the j^{th} device, and is expressed in unit piece; and

EF_j refers to the CH_4 emission factor of process ventilation of the j^{th} device, and is expressed in unit ton CH_4/year/piece.

5.4.1.2 Data monitoring and acquisition

The number of various devices, Num_j, in Equation (12) applies the practical production and operation data of enterprises, the CH_4 emission factor of process ventilation of various devices, EF_j, shall apply the measured value of enterprises on a priority basis; enterprises having no measurement capability may use the default values based on corresponding device type, as stipulated in Table 2.2 in Appendix II.

5.4.2 CH_4 fugitive emissions of petroleum and gas exploitation

5.4.2.1 Calculation equation

CH_4 fugitive emissions of petroleum and gas exploitation may be calculated based on the number of various facilities in the exploitation link and the fugitive emission factor of various facilities.

$$E_{CH4\_exploitation\ fugitive} = \sum_{j} (Num_{oil,j} \times EF_{oil,j}) + \sum_{j} (Num_{gas,j} \times EF_{gas,j}) \quad ...... (13)$$

where,

$E_{CH4\_exploitation\ fugitive}$ refers to the CH_4 fugitive emissions produced by various facilities in the exploitation of petroleum and natural gas (including the wellhead, single-well storage device, block station, and united station of crude oil exploitation, and the wellhead, gas-gathering station, measurement/distribution station and storage stations of natural gas exploitation), and is expressed in unit ton CH_4;

J refers to the type of various facilities;

$Num_{oil,j}$ refers to the number of leaking facilities involved in the exploitation of petroleum and natural gas, and is expressed in unit piece;

$EF_{oil,j}$ refers to the CH_4 fugitive emission factor of various types of facilities involved in the exploitation of petroleum and natural gas, and is expressed in unit ton CH_4/year/piece;

$Num_{gas,j}$ refers to the number of leaking facilities involved in the exploitation of petroleum and natural gas, and is expressed in unit piece; and

$EF_{gas,j}$ refers to the CH_4 fugitive emission factor of various types of facilities, *j* involved in the exploitation of natural gas, and is expressed in unit ton CH_4/year/piece.

5.4.2.2 Data monitoring and acquisition

$Num_{oil,j}$ and $Num_{gas,j}$ of various types of facilities in Equation (13) apply the realistic operation data of enterprises; the CH_4 fugitive emission factor of various facilities, $EF_{oil,j}$ and $EF_{gas,j}$ shall prefer the measured values of enterprises; enterprises having no measurement capability may use the default value based on corresponding device type, as stipulated in Table 2.2 in Appendix II.

5.5 Greenhouse gas emissions in petroleum and gas treatment

The CO_2 emissions of fossil fuel combustion in petroleum and gas treatment are accounted and reported in "CO_2 emissionsof fuel combustion"; the emissions of flare combustion in petroleum and gas treatment are accounted and reported in the "emissions of flare combustion"; the process ventilation and fugitive emissions of petroleum and gas treatment are accounted as follows.

5.5.1 Process ventilation of petroleum and natural gas treatment

The process ventilation of petroleum and natural gas treatment is mainly in the treatment of natural gas and produced greenhouse gases include CH_4 and CO_2. The accounting methods of the two greenhouse gases are as follows:

5.5.1.1 The CH_4 emissions of process ventilation in natural gas treatment

5.5.1.1.1 Calculation equation

The CH_4 emissions of process ventilation in natural gas treatment are mainly in the reproduction of ethanediol in the dehydration device. The amount of CH_4emissions can apply the following equation:

$$E_{CH4\_gas\ process\ ventilation}=Q_{gas} \times EF_{CH4\_gas\ process\ ventilation} \quad ......\ (14)$$

where,

$E_{CH4\_gas\ process\ ventilation}$ refers to the CH_4emissions of process ventilation in natural gas treatment, and is expressed in unit ton CH_4;

Q_{gas} refers to the amount of treated natural gas and is expressed in 100 million Nm^3; and

$EF_{CH4\_gas\ process\ ventilation}$ refers to the CH_4 emission factor of process ventilation in natural gas treatment and is expressed in unit ton CH_4 /100 million Nm^3.

5.5.1.1.2 Data monitoring and acquisition

The amount of treated natural gas in Equation (14) applies the data of corporate accounts; the CH_4emission factor in natural gas treatment prefers the measured values of enterprises; enterprises having no measurement capability may use the default value based on corresponding device type, as stipulated by Table 2.2 in Appendix II.

5.5.1.2 The CO_2 emissions of process ventilation in natural gas treatment

5.5.1.2.1 Calculation equation

The acid gas removal (amine, membrane, molecular sieve, etc.), CO_2 removal and other processes in natural gas treatment may emit CO_2, whose amount can be accounted based on the entrance and exit gas amount of the acid gas removal equipment and the volume concentration of CO_2, in line with Equation (15).

$$E_{CO2\_acid\ gas\ removal} = \sum_{k=1}^{N} (Q_{in,k} \times V_{CO2,in,k} - Q_{out,k} \times V_{CO2,out,k}) \times \frac{44}{22.4} \times 10 \quad ......(15)$$

where,

$E_{CO2\_acid\ gas\ removal}$ refers to the annual CO_2 emissions produced in the acid removal process and is expressed in unit ton CO_2;

k refers to the serial number of acid removal equipment;

$Q_{in,k}$ refers to the volume of gases treated by the k^{th} acid gas removal equipment and is expressed in unit 10,000 Nm^3;

$V_{CO2,in,k}$ refers to the volume concentration of CO_2 in (untreated) gases through the entrance of the k^{th} acid gas removal equipment, and ranges from 0 to 1;

$Q_{out,k}$ refers to the volume of gases treated by the k^{th} acid gas removal equipment and is expressed in unit 10,000 Nm^3;

$V_{CO2,out,k}$ refers to the volume concentration of CO_2 in gases through the treatment of the k^{th} acid gas equipment, and ranges from 0 to 1; and

44 refers to the molecular weight of CO_2, and is expressed in unit kg/kmol.

5.5.1.2.1 Data monitoring and acquisition

The amount of natural gas that flows into and out of the acid gas removal equipment shall be monitored by the flowmeter in a continuous manner; if the flowmeter is not available, other methods can also be used to identify the amount of gas flow.

The volume concentration of CO_2 before and after acid gas removal may be measured by the continuous gas analyzer. If the continuous gas analyzer is not available, it can be measured by calculating the average concentration value of CO_2samples on a monthly basis.

5.5.2 CH_4 fugitive emissions of petroleum and natural gas treatment

5.5.2.1 Calculation equation

CH_4 fugitive emissions in petroleum and natural gas treatment are mainly in the link of natural gas treatment; CH_4fugitive emissions in natural gas emission can be measured based on the treated amount of natural gas, in line with the following equation:

$$E_{CH4\_fugitive\ gas\ in\ treatment}=Q_{gas} \times EF_{CH4\_fugitive\ gas\ in\ treatment}$$

…… (16)

where,

$E_{CH4\_fugitive\ gas\ in\ treatment}$ refers to theCH_4 fugitive emissions in natural gas treatment, and is expressed in unit ton CH_4;

Q_{gas} refers to the treated amount of natural gas, and is expressed in unit 100 million Nm^3; and

$EF_{CH4\_fugitive\ gas\ in\ treatment}$ refers to the CH_4fugitive emission factor in treated per unit of treated natural gas, and is expressed in unit tonCH_4/100 million Nm^3 natural gas.

5.5.2.1 Data monitoring and acquisition

The treated amount of natural gas in Equation (16) applies the data of corporate accounts; the CH_4 fugitive emission factor prefers the measured values of enterprise; enterprises having no measurement capability may use the default value based on corresponding device type, as stipulated by Table 2.2 in Appendix II.

5.6 Greenhouse gas emissions of petroleum and natural gas storage and transportation

The CO_2 emissions of fossil fuel combustion in petroleum and gas storage and transportation are accounted and reported in the "CO_2emissions of fuel combustion"; emissions of flare combustion in petroleum and natural gas storage and transportation are accounted and reported in the "emissions of flare combustion"; the process ventilation and fugitive emissions in petroleum and natural gas storage and transportation are accounted and reported as follows.

5.6.1 Emissions of process ventilation of petroleum and natural gas storage and transportation

5.6.1.1 Calculation equation

Emissions of process ventilation in petroleum and natural gas storage and transportation are mainly from ventilation activities of compressor/booster stations, pipelines (check valves), measurement/distribution stations and pigging stations. The emissions of process ventilation of these facilities are calculated based on the number of facilities and the emission factor of process ventilation of various facilities:

$$E_{CH4\_ventilation\ in\ gas\ transportation} = \sum_{j} (Num_j \times EF_j)$$

…… (17)

where,

$E_{CH4\_ventilation\ in\ gas\ transportation}$ refers to the emissions of process ventilation produced in the transportation of natural gas, and is expressed in unit ton CH_4;

j refers to various types of facilities in the transportation of natural gas, including compressor/booster stations, measurement/distribution stations, pipelines (check valves), and pigging stations;

Num_j refers to the number of the j^{th} petroleum and natural gas transportation facility, and is expressed in piece

EF_j refers to the emission factor of the process ventilation of the j^{th} petroleum and natural gas transportation facility, and is expressed in unit ton CH_4/year/piece;

5.6.1.2 Data monitoring and acquisition

The number of various types of facilities, Num_i, in Equation(17) applies the data in the actual operation of enterprises. The emission factor of the process ventilation of various types of facilities, EFi, shall first use the measured values of enterprises; enterprises having no measurement capability may refer to the default value based on corresponding device type, as stipulated in Table 2.2 in Appendix II.

5.6.2 CH_4 fugitive emissions of petroleum and natural gas storage and transportation

CH_4fugitive emissions of petroleum and natural gas storage and transportation are mainly from the leakage in the transportation of crude oil and natural gas. The leakage in the transportation of petroleum products is low and thus, CH_4fugitive emissions in this process are not calculated.

5.6.2.1 Calculation equation

CH_4fugitive emissions produced in the transportation of crude oil are mainly from the leakage of crude oil transportation pipelines and may be estimated based on the transported amount of crude oil in line with the following equation:

$$E_{CH4\_leakage\ in\ oil\ transportation}=Q_{oil}\times EF_{CH4\_leakage\ in\ oil\ transportation}$$

...... (18)

where,

$E_{CH4\_ leakage\ in\ oil\ transportation}$ refers to the CH_4 fugitive emissions in the transportation of crude oil and is expressed in unit ton CH_4;

Q_{oil} refers to the transported amount of crude oil and is expressed in unit 100 million ton; and

$EF_{CH4\_ leakage\ in\ oil\ transportation}$ refers to the CH_4 fugitive emission factor of crude oil transportation, and is expressed in unit ton CH_4/100 million ton crude oil.

The fugitive emissions in natural gas transportation are mainly from leakage in valves, compressor/booster stations, measurement/distribution stations, pipelines (check valves), and other facilities and may be calculated based on the number of various facilities and the CH_4 fugitive emission factor of various types of facilities:

$$E_{CH4\_fugitive\ emission\ in\ gas\ transportation}=\sum_{j}(Num_j\times EF_j)$$

...... (19)

where,

$E_{CH4\_fugitive\ emission\ in\ gas\ transportation}$ refers to the CH_4 fugitive emissions in the transportation of natural gas and is expressed in unit ton CH_4;

Num_j refers to the number of facilities*j* (including compressor/booster stations, measurement/distribution stations, pipelines, check valves) that have leakage in the transportation of natural gas and is expressed in unit piece; and

EF_j refers to the CH_4fugitive emission factor of every facility *j*, and is expressed in unit ton CH_4/year/piece.

5.6.2.2 Data monitoring and acquisition

The amount of various types of facilities in natural gas transportation applies the actual production and operation data of enterprises; the CH_4fugitive emission factor of various types of facilities shall prefer the measured values of enterprises; enterprises having no measurement capability may refer to the default value based on corresponding device type, as stipulated in Table 2.2 of Appendix II.

5.7 Recovered and utilized CH_4

5.7.1 Calculation formula

If the reporting entity has recovered CH_4 and the CH_4emission factor in the process ventilation mentioned above has failed to reflect the effect of CH_4 recovery technology, then the recovered and utilized amount of CH_4 shall be calculated in line with the following equation and deducted from the total CH_4emissions mount of enterprises:

$$R_{CH4\_recovery} = Q_{re} \times PUR_{CH4} \times 7.17 \qquad \text{...... (20)}$$

where

$R_{CH4\_recovery}$ refers to the recovered and utilized amount of CH_4 of the reporting entity, and is expressed in unit ton CH_4;

Q_{re} refers to the recovered volume of $CH_4$of the reporting entity, and is expressed in 10,000 Nm3;

PUR_{CH4} refers to the purity of CH_4(the volume concentration of CH_4) and ranges from 0 to 1; and

7.17 refers to the concentration of CH_4under standard conditions, and is expressed in unit ton/10,000 Nm3.

5.7.2 Data monitoring and acquisition

The recovered volume of $CH_4$of the reporting entity shall be determined based on corporate accounts or statistical statements. The purity of CH_4shall be determined based on corporate accounts.

5.8Recycled CO_2

5.8.1Calculation equation

The CO_2 recycled amount of the report entity shall be calculated as per the following equation:

$$R_{CO2\_recycle}=Q_{re} \times PUR_{CO2} \times 19.7$$

...... (21)

where:

$R_{CO2\_recycle}$: CO_2recycled amount of the report entity, ton CO_2;

Q_{re}: volume of CO_2recycled by the report entity, 10,000 Nm^3; and

PUR_{CO2}: degree of purity (volume concentration) of CO_2, with the value range of 0~1.

5.8.2 Data monitoring and acquisition

The amount of CO_2recovered of the reporting entity shall be determined in accordance with the ledger or statistical statements of the enterprise. The purity of CO_2 shall be determined by the leger of the enterprise.

5.9 Indirect CO_2emissions from net purchase of power and heat

5.9.1 Calculation equation

The indirectCO_2emissions from net purchase of power and heat by the report entity shall be calculated as per Equations (22) and (23) respectively.

$$E_{CO2\_net\ power}=AD_{electric\ power}\times EF_{electric\ power} \quad \text{...... (22)}$$

$$E_{CO2\_net\ heat}=AD_{heat}\times EF_{heat} \quad \text{...... (23)}$$

where:

$E_{CO2\_net\ power}$: hidden CO_2emissions from net purchase of power by the report entity, ton CO_2;

$E_{CO2\_net\ heat}$: hidden CO_2emissions from net purchase of heat by the report entity, ton CO_2;

$AD_{electric\ power}$: consumption of net electric power purchased by the enterprise, MWh;

AD_{heat}: consumption of net heat purchased by the enterprise, GJ;

$EF_{electric\ power}$: CO_2emission factor of electric power supply, ton CO2/MWh; and

EF_{heat}: CO_2emission factor of heat supply, ton CO_2/GJ.

5.9.2 Data monitoring and acquisition

The consumption of net electric power purchased by the enterprise shall be calculated based on the electric instrument reading for settlement between the enterprise and the power grid company or the ledger or statistical statements for energy consumption of the enterprise, and shall be equivalent to the net difference between the power purchased and the power for external supply.

The consumption of net heat purchased by the enterprise shall be calculated based on the settlement document for purchase of heat or the ledger or statistical statements for energy consumption of the enterprise, and shall be equivalent to the difference between the total heat of purchased steam and hot water and the total heat of the steam and hot water for external supply.

The hot water measured in mass unit may be converted to that in heat unit as per Equation (24):

$AD_{hot\ water}=Ma_w\times(Tw-20)\times4.1868\times10-3$ …… (24)

where:

$AD_{hot\ water}$: heat of hot water, GJ;

Ma_w: mass of hot water, ton hot water;

Tw: hot water temperature, °C; and

4.1868: specific heat of water at normal temperature and pressure, kJ/(kg•°C).

The steam measured in mass unit may be converted to that in heat unit as per Equation (25):

$AD_{steam}= Ma_{st}\times(En_{st}-83.74)\times10-3$ …… (25)

where:

AD_{steam}: heat of steam, GJ;

Ma_{st}: mass of steam, ton steam; and

En_{st}: corresponding temperature of steam, enthalpy per kg of steam under pressure, kJ/kg. For the enthalpy of saturated steam and superheated steam, see Table 2 and Table 2.4 of Appendix II respectively.

The CO_2emission factor of electric power supply shall be the CO_2 emission factor of average power supplied by power grid in the area where the production site of the enterprise is located, and shall be valued in accordance with the latest data issued by the competent department.

The CO_2emission factor of heat supply shall prioritize the CO_2emission factor provided by the heat supply entity; if this value is unavailable, 0.11 ton CO_2/GJ may be employed as the CO_2emission factor.

6. Quality Assurance and Documentation

The report entity shall establish the quality assurance and document archiving system for the greenhouse gases emissions report of the enterprise, including:

6.1 Establish the rules and regulations for quantification and reporting of greenhouse gases of the enterprise, including the organization mode, responsible organ, workflows, etc.

6.2 Develop the list of main greenhouse gases emission sources of the enterprise, determine, document, and archive the appropriate quantification method of greenhouse gases.

6.3 Make feasible monitoring plan for parameters involved in the calculation process. The monitoring plan shall include: Parameters to be measured, specific location of sampling point or measuring equipment, sampling method and procedure, monitoring method and procedure, monitoring frequency or time point, data collection or delivery process, responsible department, quality assurance and quality control (QA/QC) procedure, etc. The enterprise shall appoint relevant department and special personnel for sampling, monitoring, analysis, recording, collection, and archiving of data. If default values are taken as parameters for calculation of some emission factors, the data source of the default values shall be provided and the updated plan shall be checked on a regular basis.

6.4 Make the periodic calibration schedule of the measuring equipment and verify and calibrate all the measuring equipment in accordance with relevant specifications on a regular basis. In case it is found that any equipment performance fails to meet relevant requirements, the enterprise shall take necessary correction and rectification measures promptly.

6.5 Develop the countermeasures for missing data, change of production activities or reporting methods. In case the activity level or emission factor of specific emissions is missed through calculation, the enterprise shall employ appropriate calculation methods to determine the corresponding period and the conservative surrogate data for the missed data.

6.6 Stipulate the specifications for document management, store and maintain the documents and data records of annual report for greenhouse gases, and ensure that relevant documents can be available wherever requested by the third party for checking and reported to the competent department.

6.7 Establish the internal audit and verification procedure for data, summarize the data fluctuation status during the calculation period by means of cross validation of different data sources, compare with historic operation data in past years to determine the main logic audit relationship, and ensure the completeness and accuracy of the activity level data.

7. Contents of Report

The reporting entity shall report the following contents as per the format shown in Appendix I.

7.1 Basic information of the reporting entity

The basic information of the reporting entity shall include the name of the reporting entity, the reporting year, nature of the unit, the industry involved, the organization or branch, the geographical position (including the registered address and the production place), the time of establishment, the development history, the legal representative, the preparer of the report and its contact information.

7.2 Emissions of greenhouse gas

The information about greenhouse gas emissions to be reported shall include the total emissions of greenhouse gases during the reporting period of the enterprise, and shall report, in mass units, the CO_2emissions from combustion of fossil fuels, $CO_2$and CH_4 emissions of flare combustion, CO_2 and CH_4emissions of process ventilation, CH_4fugitive emissions, recycled $CH_4$and CO_2, hiddenCO_2emissions implied in net amounts of electric power and heating power purchased, and the emission sources and amounts of relevant greenhouse gases that are not included in the Guidelines but shall be accounted and reported in line with other guidelines released by the authorities.

7.3 Explanation of activity level and data sources

The reporting entity shall report the data of activity level of each emission source calculated respectively while taking into consideration of the accounting boundaries and classification of the emission sources. In addition, the reporting entity shall state the monitoring plans and implementation of these plans in detail, including data sources or monitoring positions, monitoring methods, and recording frequency.

7.4 Explanation of emission factor and data sources

The reporting entity shall report the carbon contents that correspond to each activity level or other emission factor calculating parameters respectively. If the data is actually measured, then the monitoring plan and its implementation shall be introduced, or the data sources, the references, related consumption and the reasons shall be provided.

7.5 Other explanations

If the reporting entity wishes to provide other explanations, the reporting entity can state issues one by one or provide suggestions on how to amend the Guidelines.

Appendix I: Report Format Template

Greenhouse Gas Emissions Report

China Petroleum and Natural Gas Producing Enterprises

Reporting entity (seal):

Reporting year:

Date of preparation:

According to the *Guidelines for Accounting and Reporting Greenhouse Gas Emissions for China Petroleum and Natural Gas Producing Enterprises (Trial)*, the enterprise calculated its greenhouse gas emissions of the year _______and filled out the related data sheets. The entity herewith reports the relevant information as follows:

I Basic information of the reporting entity

II Emission conditions of greenhouse gas

III Description of data of activity level and the data sources

IV Description of data of emission factor and the data sources

V Description of other conditions

This report is true and reliable. If the information provided in this report fails to reflect the reality, this enterprise will bear the corresponding legal responsibility.

Legal person (Signature):

Date

Attachments:

Table 1-1: Summary Sheet of Greenhouse Gas Emissions of the Reporting Entity in

Table 1-2: Data Sheet of Activity Level and Emission Factor for Major Combustion Facilities

Table 1-3: Data Sheet of Activity Level and Emission Factor for Other Combustion Facilities

Table 1-4: Data Sheet of Activity Level and Emission Factor of Flare Combustion Emissions

Table 1-5: Data Sheet of Activity Level and Emission Factor of the Process Ventilation of Petroleum and Natural Gas Exploration

Table 1-6: Data Sheet of Activity Level and Emission Factor of the Process Ventilation of Petroleum and Natural Gas Exploitation

Table 1-7: Data Sheet of Activity Level and Emission Factor of CH_4Fugitive Emissions of Petroleum and Natural Gas Exploitation

Table 1-8: Data Sheet of Activity Level and Emission Factor of the Process Ventilation of Petroleum and Natural Gas Treatment

Table 1-9: Data Sheet of Activity Level and Emission Factor of CH_4 Fugitive Emissions of Petroleum and Natural Gas Treatment

Table 1-10: Data Sheet of the Activity Levels and Emission Factors of the Process Ventilation of Petroleum and Natural Gas Storage and Transportation

Table 1-11: Data Sheet of the Activity Levels and Emission Factors of CH_4 Fugitive Emissions of Petroleum and Natural Gas Storage and Transportation

Table 112: Data Sheet of CH_4 Recycled Amounts

Table 1-13: Data Sheet of CO_2 Recycled Amounts

Table 1-14: Data Sheet of Activity Level and Emission Factor of Net Purchased Electric Power and Heating Power

Table 1-1: Summary Sheet of Greenhouse Gas Emissions of the Reporting Entity in __

Type of source	Petroleum and natural gas exploration[1] (unit:ton)	Petroleum and natural gas exploitation[1] (unit: ton)	Petroleum and natural gas treatment[1] (unit: ton)	Petroleum and natural gas storage and transportation[1] (unit: ton)	Subtotal of emissions amount (unit: ton)	Emissions of greenhouse gases[2] (unit: CO_2 equivalent)
CO_2 emissions from combustion of fossil fuels						
CO_2 emissions from flare combustion						
CH_4 Emissions from flare combustion						
CH_4 emissions from process ventilation						
CO_2 emissions from process ventilation						
CH_4 fugitive emissions						
Recycled amount of CH_4						
Recycled amount of CO_2						
CO_2 emissions implied in net amount of						
CO_2 emissions implied in net amount of						
Total emissions of greenhouse gas of the enterprise	Excluding CO_2 emissions implied in net amounts of electric power and heating power					
	Including CO_2 emissions implied in net amounts of electric power and heating power purchased					

Note:[1]If some emission sources are not accounted based on businesses and links or cannot be splited into businesses or links, then “IE” shall be writen in according columns, which means that calculated elsewhere; and the emissions amount shall be writen in the column of emissions amount；

[2]The formula of conversing CH_4 emissions amount into the equivalent amount of CO_2: The equivalent amount of CO_2= CH_4 emission amount X 21

Table 1-2: Data Sheet of Activity Level and Emission Factor for Major Combustion Facilities[1]

Type of fuel	Combusted amount(10,000 Nm^3)	Carbon content(ton carbon/10,000 Nm^3)	Data source	Lower heating value[2](GJ/10,000 Nm^3)	Data source	Carbon content in unit heat value[2](ton carbon/GJ)	Carbon oxidation rate(%)	Data source
Coke oven gas			☐Measured value ☐Calculated value		☐Measured value☐Default value			☐Measured value☐Default value
Blast furnace gas			☐Measured value ☐Calculated value		☐Measured value☐Default value			☐Measured value☐Default value
Converter gas			☐Measured value ☐Calculated value		☐Measured value☐Default value			☐Measured value☐Default value
Other fuel gases[3]			☐Measured value ☐Calculated value		☐Measured value☐Default value			☐Measured value☐Default value

Notes:

1 Combustion facilities with the annual emissions amount above 10,000 ton CO_2 are major combustion facilities. The reporting entity shall copy and fill out this table separately for each major combustion facility.

2 To estimate the carbon content of fuels through the lower heating value of the fuel and carbon content of per unit of heat, please fill out this column.

3 If the type of energy combusted is not listed in the table, the reporting entity is required to add it on its own.

Table 1-3: Data Sheet of Activity Level and Emission Factor for Other Combustion Facilities[1]

Type of fuel	Combusted amount [1] (unit: ton or 10,000 Nm^3)	Carbon content (unit: ton carbon/ton or ton carbon/10,000 Nm^3)	Data source	Lower heating value[2] (unit: GJ/ton or GJ/ 10,000 Nm^3)	Data source	Carbon content in unit heat value [2] (unit: ton carbon/GJ)	Carbon oxidation rate (%)	Data source
Anthracite			☐Measured value ☐Calculated value		☐Measured value ☐Default value			☐Measured value ☐Default value
Bitumite			☐Measured value ☐Calculated value		☐Measured value ☐Default value			☐Measured value ☐Default value
Lignite			☐Measured value ☐Calculated value		☐Measured value ☐Default value			☐Measured value ☐Default value
Cleaned coal			☐Measured value ☐Calculated value		☐Measured value ☐Default value			☐Measured value ☐Default value
Other washed coal			☐Measured value ☐Calculated value		☐Measured value ☐Default value			☐Measured value ☐Default value
Briquette coal			☐Measured value ☐Calculated value		☐Measured value ☐Default value			☐Measured value ☐Default value
Coke			☐Measured value		☐Measured value			☐Measured

			☐Calculated value		☐Default value			value ☐Default value
Crude oil			☐Measured value ☐Calculated value		☐Measured value ☐Default value			☐Measured value ☐Default value
Fuel oil			☐Measured value ☐Calculated value		☐Measured value ☐Default value			☐Measured value ☐Default value
Gasoline			☐Measured value ☐Calculated value		☐Measured value ☐Default value			☐Measured value ☐Default value
Diesel			☐Measured value ☐Calculated value		☐Measured value ☐Default value			☐Measured value ☐Default value
Aviation kerosene			☐Measured value ☐Calculated value		☐Measured value ☐Default value			☐Measured value ☐Default value
Common kerosene			☐Measured value ☐Calculated value		☐Measured value ☐Default value			☐Measured value ☐Default value
Naphtha			☐Measured value ☐Calculated value		☐Measured value ☐Default value			☐Measured value ☐Default value
Petroleum coke			☐Measured value ☐Calculated value		☐Measured value ☐Default value			☐Measured value ☐Default value
Liquefied natural gas			☐Measured value ☐Calculated value		☐Measured value ☐Default value			☐Measured value ☐Default value
Liquefied			☐Measured value		☐Measured value			☐Measured

petroleum gas			☐Calculated value		☐Default value			value ☐Default value
Other petroleum products			☐Measured value ☐Calculated value		☐Measured value ☐Default value			☐Measured value ☐Default value
Coke oven gas			☐Measured value ☐Calculated value		☐Measured value ☐Default value			☐Measured value ☐Default value
Blast furnace gas			☐Measured value ☐Calculated value		☐Measured value ☐Default value			☐Measured value ☐Default value
Converter gas			☐Measured value ☐Calculated value		☐Measured value ☐Default value			☐Measured value ☐Default value
Other gases			☐Measured value ☐Calculated value		☐Measured value ☐Default value			☐Measured value ☐Default value
Natural gas			☐Measured value ☐Calculated value		☐Measured value ☐Default value			☐Measured value ☐Default value
Refinery dry gas			☐Measured value ☐Calculated value		☐Measured value ☐Default value			☐Measured value ☐Default value
Other fuels[3]			☐Measured value ☐Calculated value		☐Measured value ☐Default value			☐Measured value ☐Default value

Notes: 1 The sum of the combusted amount of every type of fuel in all combustion plants other than key combustion plants.

2 To estimate carbon content of fuel with lower heating value of the fuel and carbon content in unit heat value, please fill out this column.

3 If the fuel burnt by the reporting entity is not listed in the table, the reporting entity is required to add the fuel on its own.

Table 1-4: Data Sheet of Activity Level and Emission Factor of Flare Combustion Emission

Type of fuel	Flare gas amount [1] (10,000 Nm^3)	Data source	Total carbon amount of other carbon-containing compounds except for CO2 (GJ/10,000 Nm^3)	Data source	The volume concentration of CO2 in flare gas I (%)	The volume concentration of CH4 in flare gas I (%)	Coal oxidation of flare combustion
Flare system 1		☐Measured value ☐Calculated value		☐Measured value☐Default value			☐Measured value☐Default value
Flare system 2		☐Measured value ☐Calculated value		☐Measured value☐Default value			☐Measured value☐Default value
Flare system…[1]		☐Measured value ☐Calculated value		☐Measured value☐Default value			☐Measured value☐Default value
The 1st accident flare		☐Measured value ☐Calculated value		☐Measured value☐Default value			☐Measured value☐Default value
The 2nd accident flare		☐Measured value ☐Calculated value		☐Measured value☐Default value			☐Measured value☐Default value
The …th accident flare		☐Measured value ☐Calculated value		☐Measured value☐Default			☐Measured value☐Default

				value			value

Notes:

1 Reduced based on the actual number of flare systems within the boundary of the enterprise

2 Reduced based on the actual number of accidents of the reporting entity

Table 1-5: Data Sheet of Activity Level and Emission Factor of the Process Ventilation of Petroleum and Natural Gas Exploration

The number of natural gas well that conducts unimpeded ventilation	The unimpeded amount of natural gas wells (Nm3/hour)	The work hours of ventilation of exploration wells (hour)
1		
2		
……		
n		

Table 1-6: Data Sheet of Activity Level and Emission Factor of the Process Ventilation of Petroleum and Natural Gas Exploitation

Petroleum exploitation	**Type of equipment**	**Number of equipment**	**The CH4 emission factor of process ventilation (ton/year/one)**	**Data source of the emission factor**
	Wellhead equipment			☐Measured value☐Chemical calculation ☐Default value
	Single well storage equipment			☐Measured value☐Chemical calculation ☐Default value
	Transfer station			
	Combination station			
Natural gas exploitation	**Type of equipment**	**Number of equipment**	**The CH_4 emission factor of process ventilation (ton/year/one)**	**Data source of the emission factor**
	Wellhead equipment			☐Measured value☐Chemical calculation ☐Default value
	Gas gathering station			☐Measured value☐Chemical calculation ☐Default value
	Measurement/distribution station			☐Measured value☐Chemical calculation ☐Default value
	Storage station			☐Measured value☐Chemical calculation ☐Default value

Table 1-7: Data Sheet of Activity Level and Emission Factor of CH_4 Fugitive Emissions of Petroleum and Natural Gas Exploitation

Petroleum exploitation	**Type of equipment**	**Number of equipment**	**The CH_4 emission factor of process ventilation (ton/year/one)**	**Data source of the emission factor**
	Wellhead equipment			☐Measured value☐Chemical calculation ☐Default value
	Single well storage equipment			☐Measured value☐Chemical calculation ☐Default value
	Transfer station			
	Combination station			
Natural gas exploitation	**Type of equipment**	**Number of equipment**	**The CH4 emission factor of process ventilation (ton/year/one)**	**Data source of the emission factor**
	Wellhead equipment			☐Measured value☐Chemical calculation ☐Default value
	Gas gathering station			☐Measured value☐Chemical calculation ☐Default value
	Measurement/distribution station			☐Measured value☐Chemical calculation ☐Default value
	Storage station			☐Measured value☐Chemical calculation ☐Default value

Table 1-8: Data Sheet of Activity Level and Emission Factor of Process Ventilation of Petroleum and Natural Gas Treatment

<table>
<tr><th colspan="2" rowspan="2">CH_4ventilation</th><th>Annual treated amount of natural gas (100 million Nm^3)</th><th>CH_4 emission factor of natural gas treatment (ton CH_4/100 million Nm^3)</th><th colspan="2">Data source of the emission factor</th></tr>
<tr><td></td><td></td><td colspan="2">☐Measured value☐Default calculation ☐Others</td></tr>
<tr><td rowspan="6">CO_2 ventilation</td><td rowspan="2">Number of de-acidification equipment</td><td>Amount of entered gas (10,000 Nm3)</td><td>Volume concentration of exited CO_2(%)</td><td>Amount of entered gas (10,000Nm_3)</td><td>The volume concentration of existed CO_2(%)</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>1</td><td></td><td></td><td></td><td></td></tr>
<tr><td>2</td><td></td><td></td><td></td><td></td></tr>
<tr><td>……</td><td></td><td></td><td></td><td></td></tr>
<tr><td>n</td><td></td><td></td><td></td><td></td></tr>
</table>

Table 1-9: Data Sheet of Activity Level and Emission Factor of CH_4 Fugitive Emissions of Petroleum and Natural Gas Treatment

Annual treated amount of natural gas (100 million Nm^3)	The CH4 emission factor of natural gas treatment (ton CH4/100 million Nm^3)	Data source of the emission factor
		☐Measured value☐Default calculation ☐Others

Table 1-10: Data Sheet of the Activity Levels and Emission Factors of the Process Ventilation of Petroleum and Natural Gas Storage and Transportation

Type of equipment	Number of equipment	The emission factor of process ventilation	Data source of emission factor	Emissions amount of CH_4 (ton)[1]
Compressor/booster stations in natural gas transportation			☐Measured value☐ Default calculation ☐ Others	
Measurement/distribution stations in natural gas transportation			☐Measured value☐ Default calculation ☐ Others	
Natural gas pipelines (check valves)			☐Measured value☐ Default calculation ☐ Others	
Pigging stations in natural gas transportation			☐Measured value☐ Default calculation ☐ Others	
Subtotal of CH_4 emissions amount				

Notes: [1]If the enterprise has the measured value or engineering calculated value of ventilation, it can fill out the table with this value and specify the process of measurement or engineering measurement in the report. Enterprises are encouraged to conduct measurement studies on compressors, pipeline check valves, filters and other ventilation sources.

Table 1-11: Data Sheet of the Activity Levels and Emission Factors of CH_4 Fugitive Emissions of Petroleum and Natural Gas Storage and Transportation

Tranportation of crude oil	Type of equipment	Transported amount (100 million ton	Emission factor(ton/100million ton)	**Data source of emission factor**	Emissions amount of
	Transportation pipelines of crude oil			☐Measured value☐Default value☐Others	
Transportation of natral gas	Type of equipment	**Number of equipment**	Emission factor (ton/year/one)	Emission factor data sources	
	Compressor/booster stations in natural gas transportation			☐Measured value☐Measured value☐Others	
	Measurement/distribution stations in natural gas transportation			☐Measured value☐Default value ☐Others	
	Natural gas pipelines (check valves)			☐Measured value☐Default value ☐Others	
	Pigging stations in natural gas transportation			☐Measured value☐Default value ☐Others	
Subtotal of CH_4 emissions amount					

Notes: 1 Enterprises are encouraged to conduct detection studies CH_4 fugitive emissions. If the enterprise has the measured value, it may specify the detection methods, tools and process in the report.

Table 1-12: Data Sheet of CH_4Recycled Amounts

Recycled CH_4 amount (10,000 Nm3)	Volume concentration of CO_2 (％)	Concentration of CO_2(ton/10,000Nm3)

Table 1-13: Data Sheet of CO_2 Recycled Amounts

Recycled CO_2 amount (10,000 Nm^3)	Volume concentration of CH_4 (％)	Concentration of CH_4 (ton/10,000Nm^3)

Table 1-14: Data Sheet of Activity Level and Emission Factor of Net Purchased Electric Power and Heating Power

Type	Net purchased amount (MWh or GJ)			The emission factor of CO_2 (ton CO_2/MWh or ton CO_2/GJ)
		Purchased amount (MWh or GJ)	Amount of external supply (MWh or GJ)	
Power (Grid 1)				
Power (Grid 2)				
Power (Grid …)				
Steam				
Hot water				

Appendix II: Relevant Default Values

Table 2-1: Default Values of Parameters of Common Properties of Fossil Fuels

Type of fuel		Lower heating value	Unit of heat value	Carbon content in unit heat value(Unit ton carbon/GJ)	Carbon oxidation rate of the fuel
Solid fuels	Anthracite*	20.304	GJ/Ton	27.49×10^{-3}	94%
	Bitumite *	19.570	GJ/Ton	26.18×10^{-3}	93%
	Lignite*	14.080	GJ/Ton	28.00×10^{-3}	96%
	Dry-cleaned coal(ash content 10%)	29.727	GJ/Ton	25.40×10^{-3}	93%
	Other washed coal *	8.363	GJ/Ton	25.40×10^{-3}	90%
	Briquette coal	17.460	GJ/Ton	33.60×10^{-3}	90%
	Coke (dry total coke, ash content 13.5%)	28.469	GJ/Ton	29.40×10^{-3}	93%
Liquefied fuels	Crude oil	42.620	GJ/Ton	20.10×10^{-3}	98%
	Fuel oil	40.190	GJ/Ton	21.10×10^{-3}	98%
	Gasoline	44.800	GJ/Ton	18.90×10^{-3}	98%
	Diesel	43.330	GJ/Ton	20.20×10^{-3}	98%
	Common kerosene	44.750	GJ/Ton	19.60×10^{-3}	98%
	Petroleum coke	31.998	GJ/Ton	27.50×10^{-3}	98%
	Other petroleum products	41.031	GJ/Ton	20.00×10^{-3}	98%
	Coal tar	33.496	GJ/Ton	22.00×10^{-3}	98%
	Crude (light) benzene	41.869	GJ/Ton	22.70×10^{-3}	98%
Gaseous fuels	Refinery dry gas	46.050	GJ/Ton	18.20×10^{-3}	99%
	Liquefied petroleum gas	47.310	GJ/Ton	17.20×10^{-3}	99%
	Liquefied natural gas	41.868	GJ/Ton	17.20×10^{-3}	99%

	Natural gas	389.31	GJ/10,000 **Nm^3**	15.30×10^{-3}	99%
	Coke oven gas	167.460	GJ/10,000 **Nm^3**	13.60×10^{-3}	99%
	Blast furnace gas	31.390	GJ/10,000 **Nm^3**	70.80×10^{-3}	99%
	Converter gas	73.270	GJ/10,000 **Nm^3**	49.60×10^{-3}	99%
	Gas of full-enclosed calcium carbide furnace	111.190	GJ/10,000 **Nm^3**	39.51×10^{-3}	99%
	Other coal gases	52.270	GJ/10,000 **Nm^3**	12.20×10^{-3}	99%

*Based on air dried basis

Data sources:

1) As for lower heating value, please refer to *China Energy Statistical Yearbook (2012)*, *The Norm of Energy Consumption per Unit Product of Coke,* and *The People's Republic of China National Greenhouse Gas Inventory*.

2) As for carbon content in unit heat value, please refer to *IPCC Guidelines for National Greenhouse Gas Inventories (2006)* and the *Guidelines for Provincial Greenhouse Gas Inventories(Trial)*;

3) As for carbon oxidation rate, please refer to the *Guidelines for Provincial Greenhouse Gas Inventories(Trial)*.

Table 2-2: Default Value of CH_4 Emission Factor of Various Facilities of the Petroleum and Natural Gas System

Petroleum and gas system	CH_4 emission factor of facilities/equipment	
	Fugitive emissions of facilities	Process ventilation
Natural gas system		
a).Natural gas exploitation		
-Wellhead equipment	2.50(ton/year/piece)	(ton/year/ piece)
Gas gathering station	27.9(ton/year/ piece)	23.6(ton/year/ piece)
-Measurement/distribution station	8.47(ton/year/ piece)	-
-Gas storage station	58.37(ton/year/ piece)	10.0(ton/year/ piece)
b).Natural gas treatment	40.34(ton/100 million Nm3)	13.83(吨/亿 Nm3)
c).Natural gas storage and transportation		
-Compressor/booster station	85.05(ton/year/ piece)	10.05(ton/year/ piece)
-Measurement/distribution	31.50(ton/year/piece)	13.52(ton/year/ piece)
-Pipelines (check valves)	0.85(ton/year/ piece)	5.49(ton/year/ piece)
-Pigging station	0	0.001(ton/year/ piece)
Petroleum system		
a).Regular crude oil exploitation		
-Wellhead equipment	0.23(ton/year/ piece)	-(ton/year/ piece)
-Single well storage equipment	0.38(ton/year/ piece)	0.22(ton/year/ piece)
- Transfer station	0.18(ton/year/ piece)	0.11(ton/year/ piece)
-Combination station	1.40(ton/year/ piece)	0.45(ton/year/ piece)
b).Crude oil storage and transportation		
-Crude oil transportation pipelines	753.29(ton/100 million ton)	-

*Source: the *Research on the List of Greenhouse Gases in China 2005*

Table 2-3: Thermal Enthalpy of Saturated Steam

Pressure (MPa)	Temperature (℃)	Enthalpy (kJ / kg)	Pressure (MPa)	Temperature (℃)	Enthalpy (kJ / kg)
0.001	6.98	2513.8	1.00	179.88	2777.0
0.002	17.51	2533.2	1.10	184.06	2780.4
0.003	24.10	2545.2	1.20	187.96	2783.4
0.004	28.98	2554.1	1.30	191.6	2786.0
0.005	32.90	2561.2	1.40	195.04	2788.4
0.006	36.18	2567.1	1.50	198.28	2790.4
0.007	39.02	2572.2	1.60	201.37	2792.2
0.008	41.53	2576.7	1.40	204.3	2793.8
0.009	43.79	2580.8	1.50	207.1	2795.1
0.010	45.83	2584.4	1.90	209.79	2796.4
0.015	54.00	2598.9	2.00	212.37	2797.4
0.020	60.09	2609.6	2.20	217.24	2799.1
0.025	64.99	2618.1	2.40	221.78	2800.4
0.030	69.12	2625.3	2.60	226.03	2801.2
0.040	75.89	2636.8	2.80	230.04	2801.7
0.050	81.35	2645.0	3.00	233.84	2801.9
0.060	85.95	2653.6	3.50	242.54	2801.3
0.070	89.96	2660.2	4.00	250.33	2799.4
0.080	93.51	2666.0	5.00	263.92	2792.8
0.090	96.71	2671.1	6.00	275.56	2783.3
0.10	99.63	2675.7	7.00	285.8	2771.4
0.12	104.81	2683.8	8.00	294.98	2757.5
0.14	109.32	2690.8	9.00	303.31	2741.8
0.16	113.32	2696.8	10.0	310.96	2724.4
0.18	116.93	2702.1	11.0	318.04	2705.4
0.20	120.23	2706.9	12.0	324.64	2684.8
0.25	127.43	2717.2	13.0	330.81	2662.4
0.30	133.54	2725.5	14.0	336.63	2638.3
0.35	138.88	2732.5	15.0	342.12	2611.6
0.40	143.62	2738.5	16.0	347.32	2582.7
0.45	147.92	2743.8	17.0	352.26	2550.8
0.50	151.85	2748.5	18.0	356.96	2514.4
0.60	158.84	2756.4	19.0	361.44	2470.1
0.70	164.96	2762.9	20.0	365.71	2413.9
0.80	170.42	2768.4	21.0	369.79	2340.2
0.90	175.36	2773.0	22.0	373.68	2192.5

Table 2-4: Thermal Enthalpy of Superheated Steam

(Unit: kJ/kg)

Temperature	Pressure											
	0.01 MPa	0.1 MPa	0.5 MPa	1 MPa	3 MPa	5 MPa	7 MPa	10 MPa	14 MPa	20 MPa	25 MPa	30 MPa
0℃	0	0.1	0.5	1	3	5	7.1	10.1	14.1	20.1	25.1	30
10℃	42	42.1	42.5	43	44.9	46.9	48.8	51.7	55.6	61.3	66.1	70.8
20℃	83.9	84	84.3	84.8	86.7	88.6	90.4	93.2	97	102.5	107.1	111.7
40℃	167.4	167.5	167.9	168.3	170.1	171.9	173.6	176.3	179.8	185.1	189.4	193.8
60℃	2611.3	251.2	251.2	251.9	253.6	255.3	256.9	259.4	262.8	267.8	272	276.1
80℃	2649.3	335	335.3	335.7	337.3	338.8	340.4	342.8	346	350.8	354.8	358.7
100℃	2687.3	2676.5	419.4	419.7	421.2	422.7	424.2	426.5	429.5	434	437.8	441.6
120℃	2725.4	2716.8	503.9	504.3	505.7	507.1	508.5	510.6	513.5	517.7	521.3	524.9
140℃	2763.6	2756.6	589.2	589.5	590.8	592.1	593.4	595.4	598	602	605.4	603.1
160℃	2802	2796.2	2767.3	675.7	676.9	678	679.2	681	683.4	687.1	690.2	693.3
180℃	2840.6	2835.7	2812.1	2777.3	764.1	765.2	766.2	767.8	769.9	773.1	775.9	778.7
200℃	2879.3	2875.2	2855.5	2827.5	853	853.8	854.6	855.9	857.7	860.4	862.8	856.2
220℃	2918.3	2914.7	2898	2874.9	943.9	944.4	945.0	946	947.2	949.3	951.2	953.1
240℃	2957.4	2954.3	2939.9	2920.5	2823	1037.8	1038.0	1038.4	1039.1	1040.3	1041.5	1024.8
260℃	2996.8	2994.1	2981.5	2964.8	2885.5	1135	1134.7	1134.3	1134.1	1134	1134.3	1134.8
280℃	3036.5	3034	3022.9	3008.3	2941.8	2857	1236.7	1235.2	1233.5	1231.6	1230.5	1229.9
300℃	3076.3	3074.1	3064.2	3051.3	2994.2	2925.4	2839.2	1343.7	1339.5	1334.6	1331.5	1329
350℃	3177	3175.3	3167.6	3157.7	3115.7	3069.2	3017.0	2924.2	2753.5	1648.4	1626.4	1611.3
400℃	3279.4	3278	3217.8	3264	3231.6	3196.9	3159.7	3098.5	3004	2820.1	2583.2	2159.1

420℃	3320.96	3319.68	3313.8	3306.6	3276.9	3245.4	3211.0	3155.98	3072.72	2917.02	2730.76	2424.7
440℃	3362.52	3361.36	3355.9	3349.3	3321.9	3293.2	3262.3	3213.46	3141.44	3013.94	2878.32	2690.3
450℃	3383.3	3382.2	3377.1	3370.7	3344.4	3316.8	3288.0	3242.2	3175.8	3062.4	2952.1	2823.1
460℃	3404.42	3403.34	3398.3	3392.1	3366.8	3340.4	3312.4	3268.58	3205.24	3097.96	2994.68	2875.26
480℃	3446.66	3445.62	3440.9	3435.1	3411.6	3387.2	3361.3	3321.34	3264.12	3169.08	3079.84	2979.58
500℃	3488.9	3487.9	3483.7	3478.3	3456.4	3433.8	3410.2	3374.1	3323	3240.2	3165	3083.9
520℃	3531.82	3530.9	3526.9	3521.86	3501.28	3480.12	3458.6	3425.1	3378.4	3303.7	3237	3166.1
540℃	3574.74	3573.9	3570.1	3565.42	3546.16	3526.44	3506.4	3475.4	3432.5	3364.6	3304.7	3241.7
550℃	3593.2	3595.4	3591.7	3587.2	3568.6	3549.6	3530.2	3500.4	3459.2	3394.3	3337.3	3277.7
560℃	3618	3617.22	3613.64	3609.24	3591.18	3572.76	3554.1	3525.4	3485.8	3423.6	3369.2	3312.6
580℃	3661.6	3660.86	3657.52	3653.32	3636.34	3619.08	3601.6	3574.9	3538.2	3480.9	3431.2	3379.8
600℃	3705.2	3704.5	3701.4	3697.4	3681.5	3665.4	3649.0	3624	3589.8	3536.9	3491.2	3444.2
440℃	3362.52	3361.36	3355.9	3349.3	3321.9	3293.2	3262.3	3213.46	3141.44	3013.94	2878.32	2690.3
450℃	3383.3	3382.2	3377.1	3370.7	3344.4	3316.8	3288.0	3242.2	3175.8	3062.4	2952.1	2823.1
460℃	3404.42	3403.34	3398.3	3392.1	3366.8	3340.4	3312.4	3268.58	3205.24	3097.96	2994.68	2875.26
480℃	3446.66	3445.62	3440.9	3435.1	3411.6	3387.2	3361.3	3321.34	3264.12	3169.08	3079.84	2979.58
500℃	3488.9	3487.9	3483.7	3478.3	3456.4	3433.8	3410.2	3374.1	3323	3240.2	3165	3083.9
520℃	3531.82	3530.9	3526.9	3521.86	3501.28	3480.12	3458.6	3425.1	3378.4	3303.7	3237	3166.1
540℃	3574.74	3573.9	3570.1	3565.42	3546.16	3526.44	3506.4	3475.4	3432.5	3364.6	3304.7	3241.7
550℃	3593.2	3595.4	3591.7	3587.2	3568.6	3549.6	3530.2	3500.4	3459.2	3394.3	3337.3	3277.7
560℃	3618	3617.22	3613.64	3609.24	3591.18	3572.76	3554.1	3525.4	3485.8	3423.6	3369.2	3312.6
580℃	3661.6	3660.86	3657.52	3653.32	3636.34	3619.08	3601.6	3574.9	3538.2	3480.9	3431.2	3379.8
600℃	3705.2	3704.5	3701.4	3697.4	3681.5	3665.4	3649.0	3624	3589.8	3536.9	3491.2	3444.2

6 APPENDIX – FIELD DEMONSTRATION PLANS FOR SAES

上海市典型液散码头区域挥发性有机物（VOCs）排放通量测试方案

一、测试目的

利用烟羽通量监测车，开展上海市典型储罐区域的 VOCs 排放通量测试，初步分析储罐区域 VOCs 排放特征，为排放清单和液散码头 VOCs 污染治理提供基础数据。

二、测试对象

（1）中国石油化工股份有限公司上海高桥分公司：年原油周转量约 227 万吨、年成品油周转量约 272 万吨；——The traffic near this area is relatively heavy.

（2）上海高华实业有限公司&中化中石化上海东方石化储运有限公司：合计年原油周转量约 244 万吨、年成品油周转量约 297 万吨；——This source are significant and the roads nearby are relatively free. We suggest this source should be prioritized to be measured.

（3）上海浦航石油有限公司：年成品油周转量约 243 万吨。

三、测试设备

（1）通量监测车：由外方专家提供；

（2）在线总烃测试仪：由上海环科院提供。

四、测试日期

Day1: System arriving and measurement arrangement at SAES;

Day2: Conduct a test around Site (2);

Day3:Finish the measurements of the other two sites.

五、测试流程

1、总路线

按如下顺序依次对 3 家存储企业周边区域进行连续测试：

中国石油化工股份有限公司上海高桥分公司→上海高华实业有限公司→上海浦航石油有限公司

具体位置如下：

图 1　总体测试路线

2、各点位具体路线

（1）中国石油化工股份有限公司上海高桥分公司

拟测试路线如图 2 所示。路线全长约 5.3km，按以下路线往返测试 4 次。

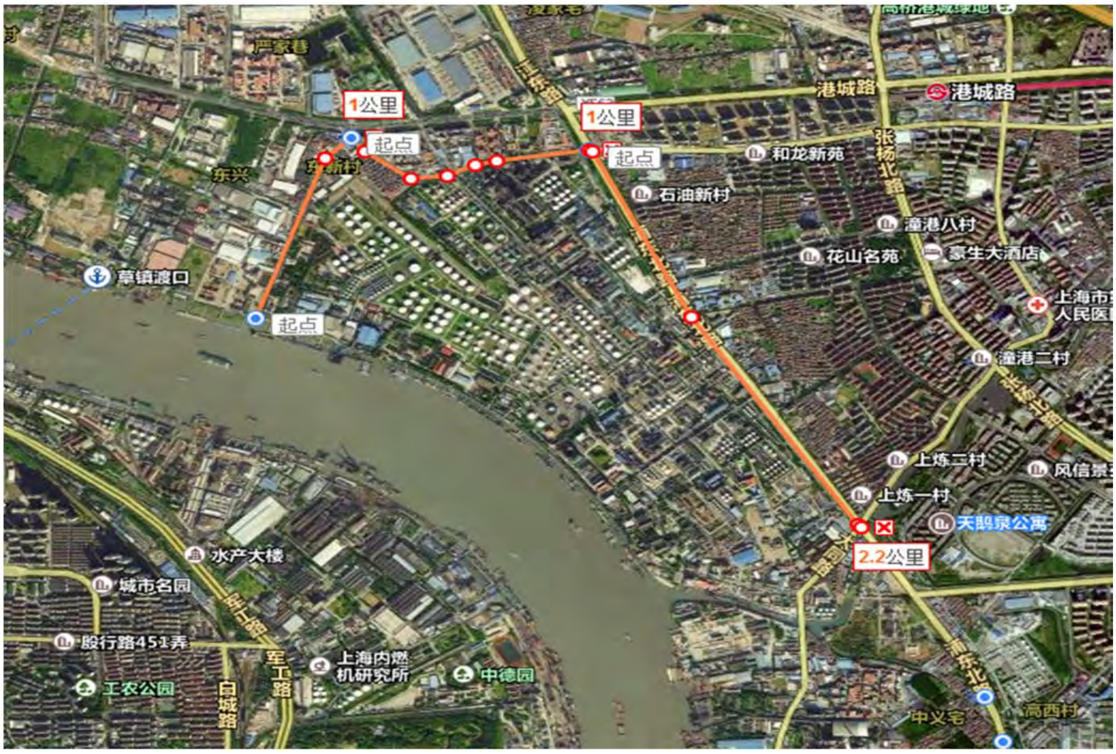

图 2　点位 1 测试路线

①起点位置：中高公路—江心沙路（如图 3 所示）

图 3　点位 1 起点位置

②沿着中高公路向北行驶 1km（如图 4 所示）

图 4

③在此右拐（遇 T 字路口）

图 5

④右拐后沿中高公路行驶 1km 至浦东北路

图 6

⑤十字路口右拐沿浦东北路行驶

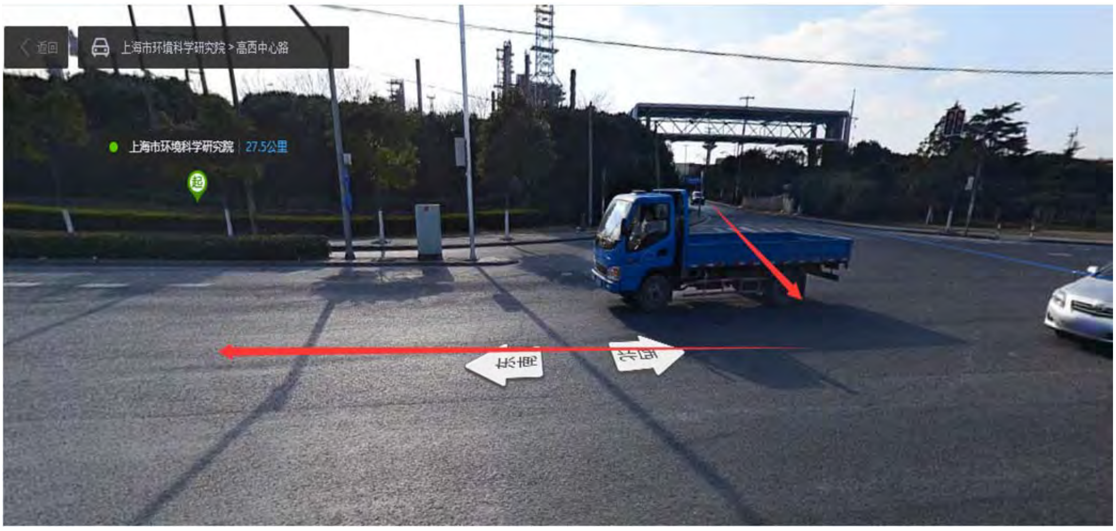

图 7

⑥沿浦东北路行驶约 2.2 公里至大同路

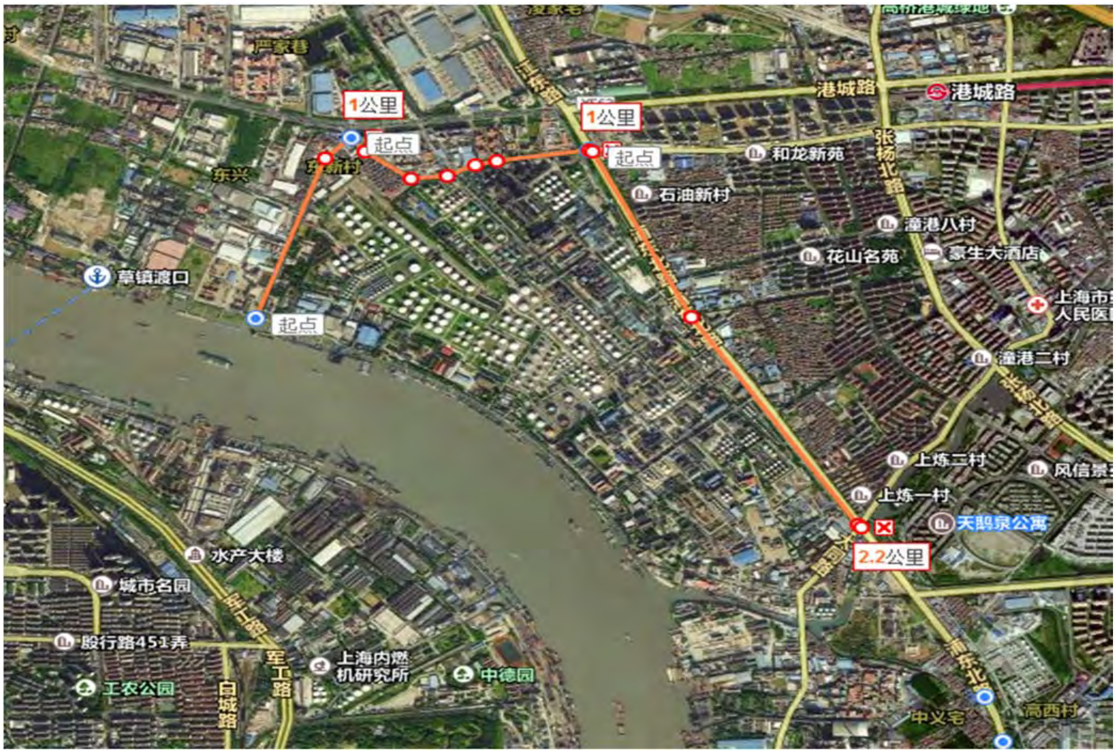

图 8

⑦遇十字路口右拐沿大同路行驶约 1.1km 到达终点

图 9

⑧终点

图 10

（2）上海高华实业有限公司&中化中石化上海东方石化储运有限公司

拟测试路线如图 11 所示。路线全长约 1.6 km，按以下路线往返测试 4 次。

图 11　点位 2 测试路线

①起点位置：　凌海路右拐处小道（如图 12、13 所示）

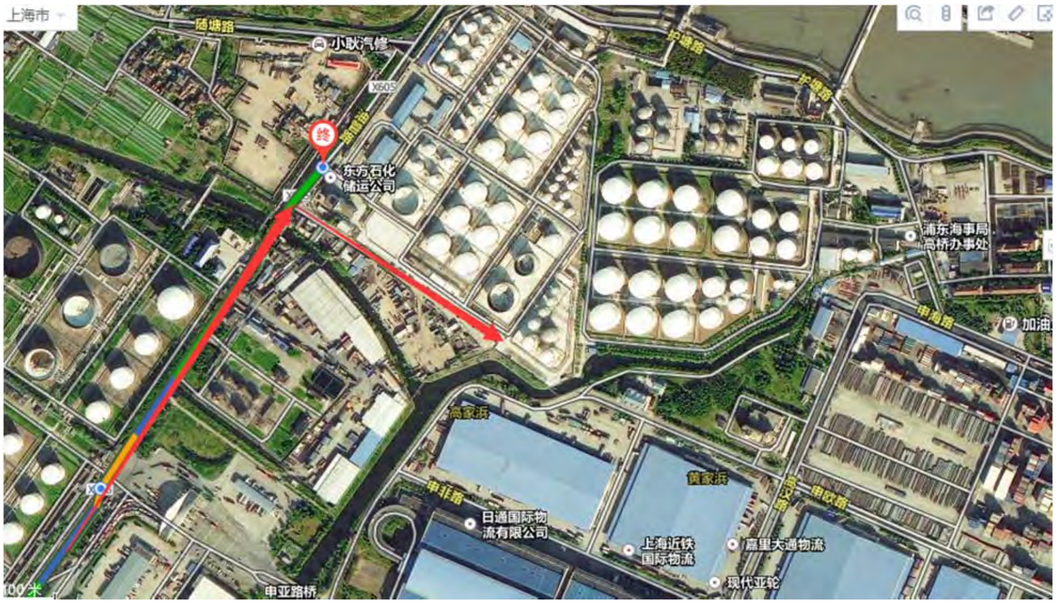

图 12

图 13 起点位置

②由起点直走至油管路—右拐沿油管路至护塘路

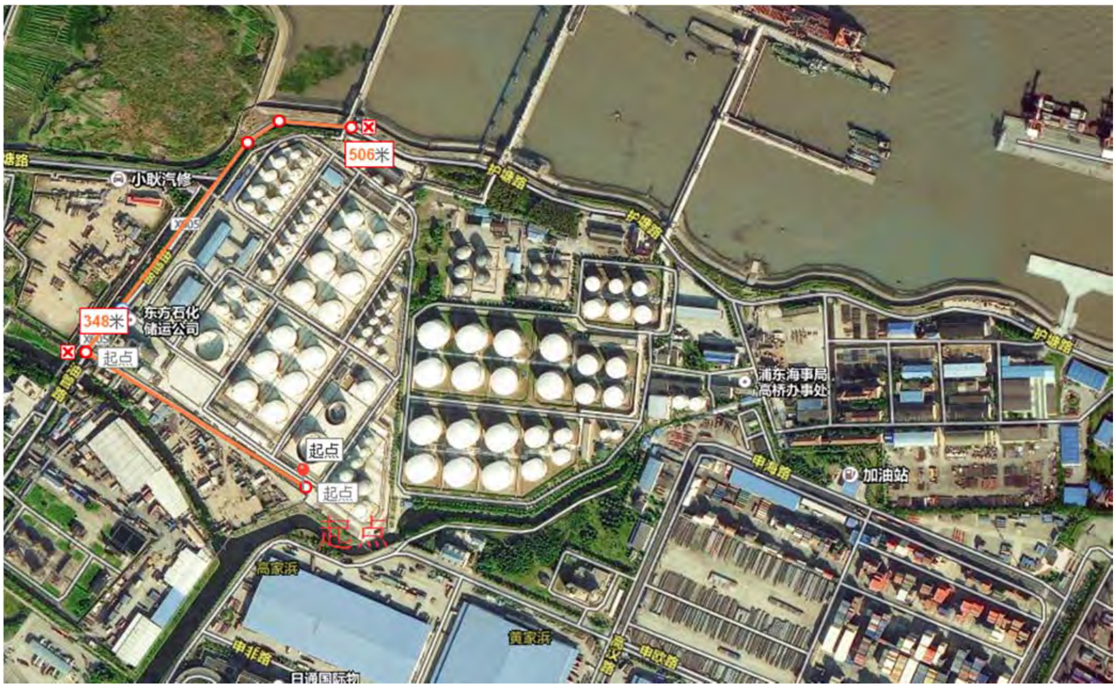

图 14

③沿护塘路至欧高公路—沿欧高公路行驶 183 米（尽头）到达终点

图 15

（3）上海浦航石油有限公司

拟测试路线如图 16 所示。路线全长约 1.3km，按以下路线往返测试 4 次。

① 起点位置：　小华江路

图 16　点位 3 测试路线

7 APPENDIX – GREEN COMPLETIONS FLOWBACK SKID DESIGN

Design Basis Memorandum

Reduced Emissions Completion Package

Rev.	Date	Description	Originator	Checked	Approval
E	June 16/15	Re-issued for Approval	T Mercier	G Deuchar	D Picard

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1 List of Acronyms

- API – American Petroleum Institute
- ASME – American Society of Mechanical Engineers
- DACC - Drilling and Completions Committee of PSAC
- DBM – design basis memorandum
- EPA – United States Environmental Protection Agency
- ESDV – emergency shut down valve
- FEED – front end engineering and design, also referred to as preliminary engineering
- IRP – Industry Recommended Practice
- NSPS – New Source Performance Standards
- OD – outside diameter
- PLC – programmable logic controller
- PSAC - Petroleum Services Association of Canada
- REC – reduced emissions completion, also referred to as green completion

2 Introduction

2.1 Objective

The purpose of this effort is to prepare FEED-level documents and drawings for a complete REC package that fully complies with the requirements, guidelines and emissions reduction intent of EPA Regulations which became effective in the United States on January 1, 2015. Western Canadian petroleum industry experts will be retained to assist with and guide the preliminary design process to ensure best practices are incorporated while maintaining practicality and operability. This document defines the basis for all FEED activities and deliverables such that upon completion the Client and ultimate Owner have sufficiently detailed information to demonstrate that the design meets project objectives and upon which economics and capital deployment decisions can be based.

2.2 Project Description

REC packages were developed several years ago for use in North America and on January 1, 2015 RECs became mandatory for gas wells stimulated by hydraulic fracturing within established fields in the United States.

The project will be implemented in stages commencing with FEED to prepare a design basis memorandum, specifications and data sheets for major equipment items and sufficient scope delineation and definition to estimate cost and schedule for implementing the remaining project stages. Following FEED the Client, Clearstone Engineering Ltd., and ultimate Owner of the Project must decide if the required capital investment is justified and prudent. Should the Project be sanctioned detailed engineering will proceed to produce the necessary specifications, drawings and scope/work package descriptions for tendering, evaluating and awarding procurement and fabrication to suppliers and fabricators in China.

Key project activities and milestones are as follows.

- FEED Q2 2015
- Client and Owner reviews and sanction Q3 2015
- Detailed design, procurement and fabrication Q4 2015 and Q1 2016
- REC package assembly and operator training Q2 2016

3 Hydraulic Fracture Stimulation

Equipment, configuration and procedures for flow back following successful completion of a multistage hydraulic fracturing program are highly dependant on the well bore configuration and fracture stimulation system.

3.1 General

For horizontal wells two fracture stimulation categories exist:

- Open-hole normally with an un-cemented liner but usually including some sort of annular isolation; and
- Cased hole with a cemented liner.

While open-hole completions without a liner are employed, a liner of some sort is normally installed to provide a mechanically stable horizontal wellbore. Liner is inserted into a wellbore with or without positive annular isolation. The former is achieved with packers or a cemented liner. The latter means the annulus (i.e. space between the liner and the wellbore) is open allowing formation fluids to move freely inside and outside of the liner.

Once decisions are made on the liner and positive annular isolation, several different fracture stimulation systems are available. Most of these involve the use of coiled tubing. Advantages of coiled tubing include a working string that can be run into and out of the well quickly and a dead string which enables accurate monitoring of bottom hole pressure (observed surface pressure less calculated hydrostatic head). Coiled tubing also enables rapid adjustment of the downhole slurry mixture by changing injection from the working to the dead string and can be used to flush proppant from the wellbore following screen-out.

The principal disadvantage of coiled tubing is injection rate limitation due to small diameter.

3.2 Frac Systems

a. Ball Drop
This system involves ball-actuated sliding sleeves/frac ports that are covered by the sleeve and closed at the start of operations. The wellbore is divided into multiple segments, using open-hole packers to provide effective annular isolation, and run in with a liner.

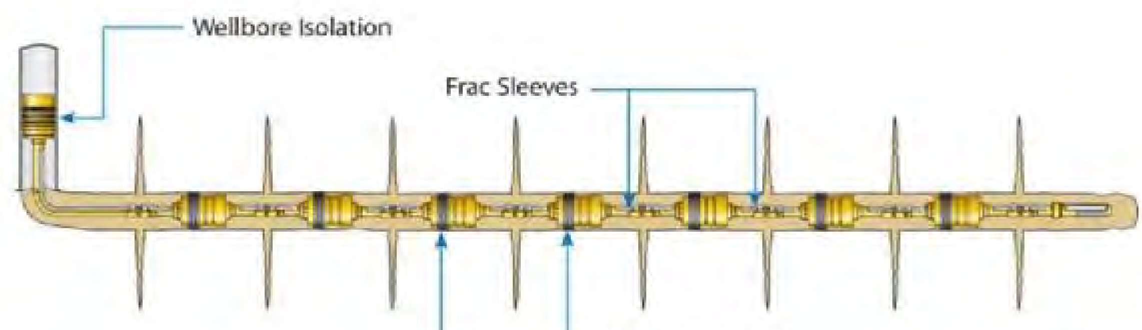
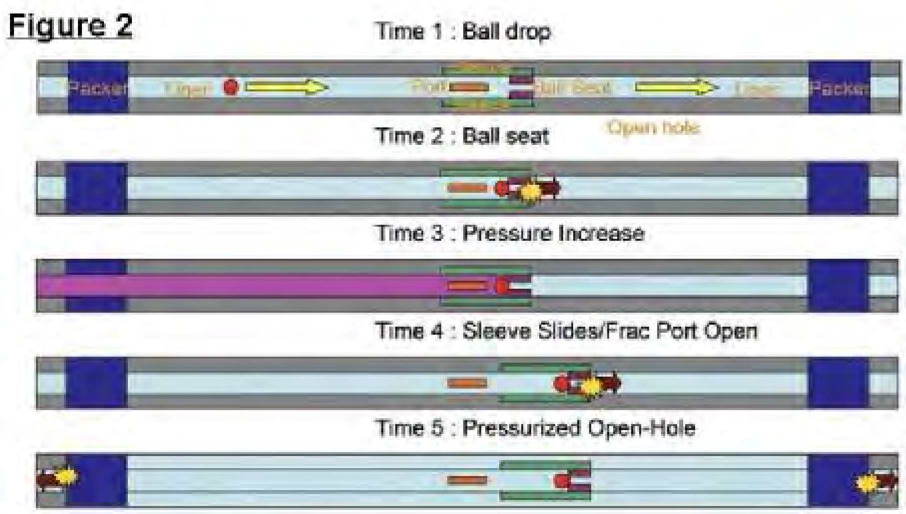
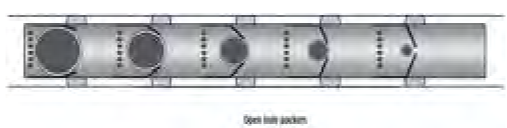


Figure 1

A ball dropped into the fluid and pumped down the string will seat in the mechanical sleeve. This action will open the sleeve exposing the ports and diverting the fluid to the formation, which creates a hydraulic fracture within the isolated zone. The sliding sleeves are opened sequentially for fracturing, starting from the toe of the horizontal well and moving toward the heel by dropping balls. In this system, the seating of the ball at the end of each sleeve creates a differential pressure, which then slides the sleeve and exposes the frac ports. Each separate ball is pumped with the fracturing fluid, and at an appropriate time. Once a set of ports is opened by the sliding sleeve, the injected fluid moves into the annulus between the liner and open hole, and creates the hydraulic fracture(s).

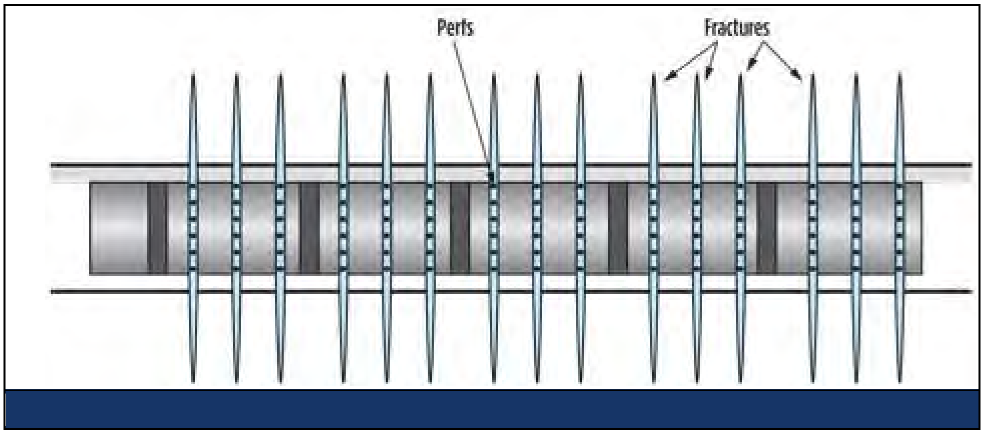


This system is operated by pumping progressively larger-sized balls and operating sleeves from the toe of the well to the heel. Shortly after the planned volume of fluid and proppant is pumped into each stage, the next-largest size of ball is dropped. The seating of this ball isolates the previous zone, opens the next ports and allows fracturing of the next zone.



The well is cleaned out by flow back to the surface, which returns fluid and solid particles. The balls and ball seats can be drilled out with coiled tubing and or in some cases are soluble in downhole formations or are floated back to surface once the fracture treatment is flowed back. The technology allows for a quick and efficient fracture stimulation operation by minimizing fluid use, limiting trips downhole, and streamlining the pumping operation. Challenges include the potential for limited insertion of the tool string and failure of balls and seats in the opening of the sliding sleeves. In most ball drop systems, the internal ball seats are milled after fracturing operations, to allow full-bore access for clean-out and production.

b. Plug and Perforate
This system is exclusively used with a cemented liner. Like other techniques, fracturing is done in multiple stages, with bridge plugs providing isolation between stages. At the start of each fracturing stage, an assembly consisting of a plug and perforation guns is placed (usually pumped) downhole with a wireline at the desired location. The plug is set, and perforation guns are fired at the planned sequence.



The perforations are bunched together in clusters. The distance between these clusters can be selected, based on operator preference, but it is usually in the range of 15 to 60 m apart. The treatment design is based on a limited entry technique, where the number of perforations is determined, based on the planned injection rate, such that, on average, each perforation gets .25 to .5 m3/min of injection. After the perforation guns have been fired, the perforating wireline is pulled out, and the plug is isolated from the previous interval (usually by dropping and pumping a ball that seats in an opening in the middle of the plug). This interval is then fractured, as planned. The sequence of setting a plug, perforating, sealing the plug, and fracturing, is repeated multiple times until the entire horizontal well is fractured.

One noteworthy feature of this completion system is a large number of fractures. For example, if one fractures the well in 20 stages, with each stage having four clusters/fractures, the total number of fractures can be as large as 80. Another feature is resilience. The presence of multiple fractures means that if the proppant obstructs the path of flow in one fracture, the increased wellbore fluid pressure will distribute the fluid to other perforations/fractures. In actual operations, it is not uncommon to have only a portion of total perforations taking fluid. Sometimes, an entire cluster may not be fractured at all. Increasing wellbore pressure can cause breakdown of other perforations or clusters, thus causing a more uniform fluid and proppant distribution. Looking at this from a different perspective, screen-out in one entire segment means an inability to inject into all of its fractures. As long as any of these fractures is capable of extending, one will be able to continue fluid injection, albeit at a lower rate.

c. Mongoose
A system available through NCS Mulitstage, for inside a liner (normally cemented), this downhole system is deployed, using coiled tubing. Isolation between fractures uses a resettable packer. Perforations are cut when sand-laden fluid is pumped down the coiled tubing and through the perforating sub nozzles. The high-velocity slurry cuts through the casing and cement. Fracturing slurry is pumped through the smaller annulus between the coiled tubing and the liner. Bottom hole pressure changes can be monitored through the coiled tubing and as a result, the fracture treatment can be optimized on the fly. Benefits and limitations are very similar to other completions using coiled tubing.

d. Sliding Sleeves

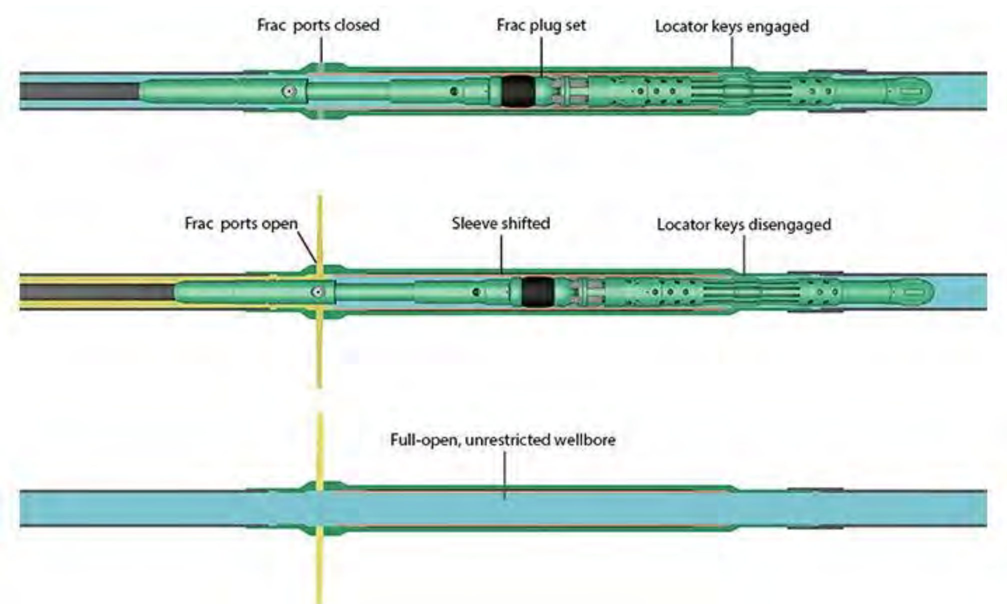
Deployed with cemented liners only, sliding sleeves are run in with the liner at the end of drilling, and are inserted into the liner at various planned fracture stimulation points, and cemented in place with the liner. During fracture treatment, a resettable bridge plug is run on coiled tubing and set and unset with a simple up/down coiled tubing motion. This same tool is also used to shift the sliding sleeves. This system is commercially available through NCS Mulitstage. The following diagrams have been taken from the NCS site, to illustrate the operation of the multistage frac system.

The above Frac-Isolation assembly, has the ability to create new perforations if necessary, in a similar fashion to the Mongossse system described above. It can also isolate and frac through the existing sliding sleeves. To create new perforations through the "Sand-jet perforating sub", sand-laden fluid is pumped down the coiled tubing and through the perforating sub nozzles. The high-velocity slurry cuts through the casing and cement.

During normal fracture operation through the pre-placed sliding sleeves, completions begin at the toe of the well, with the frac-isolation assembly positioned below the first casing sleeve. As the isolation assembly is pulled upward, the first sleeve is located, the resettable bridge plug is then set, followed by an increase in wellbore pressure from above which forces the assembly and the inner barrel down, opening the sleeve's frac ports to the formation. Sleeve shifting is clearly indicated at the surface by weight and pressure changes. The frac is then pumped down the coiled tubing/casing annulus.

During the frac, the coiled tubing serves as a deadleg, transmitting bottom-hole treating pressure to the surface to assist in optimizing the fracture treatment. After the frac is away, a pull on the coiled tubing opens the integral equalizing valve and unsets the frac plug. The isolation assembly is moved up to the next sliding sleeve, and the sequence is repeated.

The NCS site has a short video of the operation, at http://ncsmultistage.com/content/multistage-sleeves-annularfrac_player.html.



3.3 Hydraulic Fracturing Risks

Synchronous operation of numerous pieces of machinery and favourable chemical/mechanical interaction within the frac fluid and between the fluid and the formation are required for a successful fracturing operation. Extensive maintenance and QA/QC programs are required to minimize the risk of frac failure. Reservoir behaviour, occasionally permeability and/or inherent geo-mechanical stresses are the most difficult variables to predict and manage.

A common problem is referred to as a screen out which is when proppant forms a bridge in the fracture at the formation face (i.e. entrance of the fracture immediately beyond the well bore) which causes the frac fluid pumps to spike to maximum pressure and shut down the operation. If sufficient energy exists in the near well bore formation the well will be flowed back to the well testing equipment and containment bins/vessels on surface to clean out the wellbore and resume the hydraulic fracturing program. Otherwise, the well must be circulated (e.g. pump down the tubing and flow back up the annulus) to clean out the screen out. Where hydraulic fracturing is being conducted through production casing only coiled tubing must be run into the well to circulate proppant back to surface.

Screen outs occur more frequently when a viscous frac fluid is used versus a slick frac as proppant concentration is significantly higher in the former. Loss of frac fluid and proppant into more permeable portions of the formation is more common and difficult to control on slick fracs.

3.4 Tight Shale Gas Well Frac Program

Typical fracture stimulation of tight shale gas reservoirs involves 10 to 15 stages with each stage requiring up to 2000 m3 of water-based transfer media (i.e. frac fluid) and 50 to 70 T of proppant (i.e. frac sand).

Following fracture stimulation wells are flowed back at 10-25 m3/hr. The fraction of sand in the flow back stream is significantly reduced if each stage is over flushed with water once all frac sand is forced into the formation. With over flushing sand fraction initially should be less than

5% and within 2 to 4 hours it should be less than 1%. Total sand returns should not exceed 0.5% of total proppant used for the frac.

Once approximately 5% of the frac fluid is recovered hydrocarbon should exist in the flow back stream and combustible quantity will be discharged from the separator. When the well is sufficiently cleaned gas flow rate could be up to 560 E3m3/d (20 mmscf/d).

4 General Data

4.1 Climate and Meteorology

Assumed conditions are similar to those of central Alberta which are summarized as follows.

- 850 m above mean sea level
- Normal atmospheric pressure 90 kPa
- Maximum wind gust velocity 160 km/hr (100 mph)
- Daily average summer temperature 16 ^{o}C
- Daily average winter temperature -10 ^{o}C
- Extreme maximum temperature 40 ^{o}C
- Extreme minimum temperature -40 ^{o}C
- Annual precipitation as rain 400 mm
- Total annual precipitation 500 mm
- Extreme daily rainfall 100 mm
- Extreme daily snowfall 300 mm
- Extreme total snow depth 750 mm

4.2 Seismic

Equipment, components and piping will be designed for set up and operation in areas where common causes for seismic activity (e.g. active fault lines and/or subduction zones) do not exist and where calculated probabilistic ground motion rate is minimal. Being modularized and portable equipment packages are inherently robust and resistant to deformation from handling and movement.

5 Regulations, Standards and Codes

5.1 Environmental Protection Agency

The EPA issued NSPS in April 2012 to reduce air emissions by the oil and natural gas industry, including for the first time regulations for hydraulically fractured natural gas wells. Subsequently the EPA received petitions for reconsideration of the newly-issued regulations from several oil and gas industry and environmental organizations. Submissions and hearings were conducted over the next two (2) years in response to the requests of these organizations and culminated in late 2014 with the EPA's final ruling which contained clarifications and updates to the 2012 NSPS.

Implementation and performance criteria for RECs in the United States are prescribed in the following regulations.

- EPA 40 Code of Federal Regulation ("CFR") Part 60, "Oil and Natural Gas Sector: Reconsideration of Additional Provisions for New Sour Performance Standards ("NSPS"); Final Rule," Dec. 31, 2014 http://www.gpo.gov/fdsys/pkg/FR-2014-12-31/pdf/2014-30630.pdf

- EPA 40 CFR Part 63, "Oil and Natural Gas Sector: NSPS and National Emission Standards for Hazardous Air Pollutants Reviews," April 17, 2012 http://www.epa.gov/airquality/oilandgas/pdfs/20120417finalrule.pdf

Key elements of the new regulations include:

- Two (2) distinct flow back stages exist; initial and separation flow back
- During "initial flow back" the high volume of water containing sand, fracturing fluid and formation debris with little gas and usually in multiphase slugs is routed to a well completion vessel (e.g. frac tank, lined pit or any other vessel)
- There is no requirement for controlling emissions during initial flow back and any gas may be vented however the Operator must route initial flow back to a separator unless it is technically infeasible for a separator to function
- Operators have the responsibility to route initial flow back to a separator as soon as conditions allow a separator to operate which marks the end of the initial flow back stage
- During "separation flow back" no gas may be vented and gas may be directed to flare only if it is unfeasible to route saleable gas from the separator to a gathering system or pipeline, another well for reinjection or on-site equipment as fuel or use the gas for another useful purpose that a purchased fuel or raw material would serve
- Separation flow back ends when: (a) the well is shut in and the flow back equipment is permanently disconnected from the well; or production from the well commences
- Wells subject to the new regulations must use REC commencing January 1, 2015
- Wildcat, delineation and low pressure gas wells are not subject to the new regulations but gas emissions during the separation stage of flow back and testing must be ignited and combusted with a flare stack

5.2 Other Regulations

Other regulations that will be referred to and followed include:

- Alberta Pressure Equipment Safety Regulation
- Alberta Oil and Gas Conservation Regulations
- Alberta Energy Regulator Directive 40, Pressure and Deliverability Testing Oil and Gas Wells http://www.aer.ca/rules-and-regulations/directives/directive-040

5.3 Design Standards and Codes

Key design standards and codes for piping and equipment for RECs are as follows. Unless stated otherwise the most recent edition available publicly is assumed.

- AISC Steel Construction Manual
- International Building Code

- API Recommended Practice 12R1, Production Service Tanks Inspection and Maintenance
- API Recommended Practice 54, Drilling and Servicing Operations Occupational Safety
- API Recommended Practice 521, Guide for Pressure Relief and Depressurizing Systems
- API Specification 6A, Wellhead and Christmas Tree Equipment
- API Specification 12J, Oil and Gas Separators
- API Specification 16C, Choke and Kill Systems

- ASME B31.3, Pressure Piping

- ASME B16.5, Steel Pipe Flanges and Flanged Fittings
- ASME B16.9, Steel Butt Welding Fittings
- ASME B16.10, Steel Valves
- ASME Boiler and Pressure Vessel Code, Section VIII, Division 1

5.4 Industry Recommended Practices

The following publicly available PSAC IRPs (http://www.psac.ca/leadership/health-safety/industry-recommended-practices-irps/) pertaining to well drilling, completing and testing will be referred to and, where applicable, followed.

- DACC Volume # 4 – Well Testing and Fluid Handling
- DACC Volume # 5 – Minimum Wellhead Requirements
- DACC Volume # 20 – Well Site Design Spacing Recommendations

6 Environmental Protection

6.1 Air Quality

Emission requirements contained in the foregoing EPA regulations will be the basis for design and operation of the REC package. Additional air emissions criteria includes:

- Any gas emitted from the sand containment bin/vessel during well bore clean up following a frac screen out will be vented unless deemed unsafe to do so
- Direct venting during the initial flow back stage will be minimized and eliminated wherever possible by continuous use of the separator during all stages of flow back and testing
- Flaring will be limited to emergency situations and combustion of non-saleable low pressure gas and hydrocarbon vapours recovered upon commencement of flow back
- Pumps and process control devices on-board equipment packages will be electrically powered
- Primary vessel and equipment heating to prevent freezing will be steam
- Secondary vessel and equipment heating to prevent freezing will be an on-board glycol heating medium system with a dual fuel (i.e. propane and natural gas) direct-fired heater
- Oil/condensate/frac fluid storage tanks will normally vent directly to atmosphere but a suitable tank connection, thief hatch and low pressure flare will be provided to enable capturing and burning tank gases and vapours

6.2 Soil and Water

Equipment and piping will be continuously attended and monitored by Operations personnel while being set up, operated and dismantled for transportation. Critical parts of equipment packages will be equipped with drip containment lips, approximately 25 mm high, to facilitate cleanup in the event of a spill. Tanks will be single walled and will not be within secondary containment systems.

Piping interconnecting the well, equipment packages, flare and tanks will be placed directly on the ground or on wooden sleepers placed directly on the ground.

6.3 Noise

Noise emission limits for occupational safety in the North American well drilling and servicing industry will be followed.

7 Design Parameters, Criteria and Data

7.1 Process

a. Assumptions and Design Basis
Current North American well completion, stimulation, flow back and testing practices and procedures were assumed. All well stimulation was assumed to be by non-energized hydraulic fracturing. Based on Chinese reservoir and testing/production data a tight shale producing predominantly sweet natural gas was also assumed.

Contingency flow back equipment (open top bin or large, low pressure sand containment vessel) and piping are normally in place to contain the large volume of sand from a screen out. Flow by-passes the debris catcher and choke manifold as returns from a screen out are at essentially atmospheric pressure at surface.

The primary means of preventing hydrates will be methanol injection at the well head (i.e. upstream from the ESDV). Methanol injection equipment and capability will also exist immediately upstream from the separator to prevent ice buildup on instruments and site glasses.

Rates and physical data used for modelling and sizing equipment and piping are contained in Table 7.1a below. The process flow diagram is contained in Appendix B. Mass and energy balance and compositional analysis for the separator inlet and three (3) outlet streams at approximately design conditions are contained in Appendix C.

Table 7.1a: Flow Back ("FB") Process Design Data

Physical Data or Rate	Units	Design	Min.	Max.
Produced gas rate	E^3m^3/d (mmscf/d)	280 (10)	85 (3)	560 (20)
Hydrogen sulphide fraction[1]	%	0	0	0
Liquid hydrocarbon rate	m^3/E^3m^3 (bbl/mmscf)	0.3 (50)	0	0.6 (100)
Frac fluid rate	m^3/hr (bbl/hr)	15 (100)	10 (70)	50 (300)
Initial frac sand rate	% of FB volume	5	0	10
Total frac sand returns[2]	m^3	7.5	0	10
Produced gas specific gravity		0.62	0.58	0.66
Liquid hydrocarbon water cut	%	10	0	15
Liquid hydrocarbon density	kg/m^3	780	720	860
Frac fluid density	kg/m^3	1030	1000	1050
Frac sand recovery	% of total proppant	0.5	0.25	1.0
Frac sand density	kg/m^3	2650	2650	2720
Frac sand particle size	mesh	20/40	20/40	20/40
FB stream initial pressure	MPag (psig)	25 (3600)	20.7 (3000)	69 (10000)
FB stream temperature	^oC (^oF)	20 (68)	5 (41)	50 (122)
Tie-in point pressure	MPag (psig)	5.1 (740)	0.7 (100)	6.9 (1000)

Notes:

1) While separator vessel material is suitable for low concentration of H_2S, fabrication and quality assurance procedures must be enhanced if concentration results in partial pressure of H_2S exceeding 0.3 kPa.

Table 7.1a: Flow Back ("FB") Process Design Data

Physical Data or Rate	Units	Design	Min.	Max.
2) Based on 20 stage frac, 20T proppant per stage and 5% proppant in initial flow back stream.				

b. Pressure Management

Where well surface pressure drops over the course of the separation flow back stage a compressor may be required to complete/continue the well test. Compression is required to reduce back pressure on the well such that flow velocity up the well bore is adequate to lift any remaining frac fluid. If well flowing pressure drops significantly compression may also be required to deliver gas to the gathering system, injection well or other gas conservation scheme.

Minimum pressure and associated gas flow rates at which the separator (4 and 5 feet OD options are currently being considered) can effectively separate water from gas are listed in the following table.

Table 7.1b: Minimum Separator Discharge Pressure

Separator OD by S/S length (mm[feet])	Gas Flow Rate ($E^3 m^3$/d [mmscf/d])	Minimum Pressure (kPag [psig])
1219 by 5486 [4 by 18]	85 [3]	380 [55]
	280 [10]	2240 [325]
	350 [12.5]	3170 [460]
1524 by 5486 [5 by 18]	85 [3]	310 [45]
	280 [10]	1860 [270]
	350 [12.5]	2620 [380]

7.2 Civil-Structural

Equipment and directly associated piping will be mounted on oilfield structural steel skids which will be lifted and moved with cranes (i.e. four (4) lifting points per skid) or by winching over a live roll on a flatbed trailer. Structural steel skids shall meet minimum strength and maximum deflection requirements contained in the AISC Steel Construction Manual. Equipment will be designed to be placed upon and operated from wooden sleeper foundations.

All equipment skids shall fit inside a 45 feet long "high-cube" sea container. Accordingly maximum outside dimensions and weight of the skid and all on-board equipment, piping, instrumentation and controls and accessories are as follows.

- Length 13.5 m (44.3 feet)
- Width 2.3 m (7.7 feet)
- Height 2.6 m (8.5 feet)
- Maximum empty/dry skid weight 30,400 kg (66,139 lbs)

One end of the separator will be within a heated enclosure. The lower portion of the separator vessel will be skirted.

Arrangement of REC equipment on a well site is illustrated in the typical site plan in Appendix D.

7.3 Mechanical

Three (3) piping and equipment pressure classes will exist.

- API 10,000 psig rated working pressure from the wellhead tie-in to and including the ESDV
- ASME Class 600 separator, gas discharge and liquid/slurry discharge piping to skid edge and including dump valves and sacrificial plug valves used for dump rate control of sand laden fluid
- ASME Class 150 relief and flare piping and runs to open pits and sand bins and load fluid and condensate/oil tanks

Minimum and maximum design metal temperature for each pressure class are defined in Table 7.3.

Table 7.3: Design Metal Temperatures ºC (F)

Pressure Class	Min.	Max.
API 10,0000	-60 (-75)	82 (180)
ASME Class 600	-45 (-50)	93 (200)
ASME Class 150	-45 (-50)	93 (200)

Piping will principally be connected with hammer unions which will be different for each of the 3 types of piping so mixing of pressure classes is not possible. Pipe joints, fittings, hammer unions valves, chokes and spare parts will be stored and transported on a separate skid equipped with racks and bins.

Vessels will be equipped with sand jetting nozzles and rings and top-mounted rotating nozzles to enable sand clean out without removing manways. Water for flushing will be supplied and pumped into the vessel by truck.

7.4 Electrical

Electricity, 220 V, 50 Hz will be supplied from existing lease infrastructure or will be generated on site. The generator driver will be dual fuel (i.e. diesel or natural gas) so that scrubbed process gas can be used for fuel once sufficient quantity exists in the flow back stream.

All equipment packages will be equipped with intrinsically safe lights, pumps and devices. On-board electrical equipment will be wired directly to a bank of dedicated intrinsically safe receptacles at skid edge (i.e. panels and junction boxes are not required).

The enclosed end of the separator vessel will be equipped with an electric heater for Operations personnel comfort and to prevent devices from malfunctioning due to low ambient temperature.

7.5 Instrumentation and Controls

Automated instruments and control devices will be actuated and positioned with instrument air and/or electricity. Principal instruments include:

- API ESDV and actuator
- API chokes
- Two (2) chamber orifice meter run on separator gas outlet
- Back pressure control valve on separator gas outlet
- Hydrocarbon liquid level control valve
- Water level control valve
- Turbine hydrocarbon liquid meter
- Turbine water meter

- Site glasses for sand, water and hydrocarbon liquid
- Instrument air package onboard the separator skid

By-passes will exist around the turbine meters and dump valves to enable manual control of water/liquid hydrocarbon level using sacrificial downstream plug valves. Manual control would be necessary where fluid contains too much sand and erosion of instruments is a concern.

Turbine meters are preferred for liquid streams as they are relatively inexpensive and easily replaced and calibrated (i.e. versus mass or ultrasonic meters).

The REC package is designed for principally manual operation and data collection and will not be equipped with a PLC. An automation option enabling data collection and flow totalizing and transmission using a PLC with a communication link (e.g. cellular network or radio) will be evaluated during FEED.

8 Infrastructure and Utilities

The following are considered to be multi-use facilities provided by the Facility Operator rather than the REC Contractor and are not included in the project scope.

- Office trailer(s)
- Lunch trailer
- Portable toilets
- Camp accommodation and kitchen

9 Operations and Maintenance

Alberta regulations, standards, guidelines and recommended practices will be followed for equipment set up, operation, dismantling, transportation and storage. Pressure equipment and piping inspection, maintenance and repair will follow the Alberta Pressure Equipment Safety Regulation.

Operations and Maintenance Manuals will be developed during detailed engineering.

10 Appendices

A. Glossary
B. Process Flow Diagram
C. Mass and Energy Balance and Stream Composition Tables
D. Typical Site Plan Illustrating Frac and REC Equipment Arrangement

Appendix A – Glossary

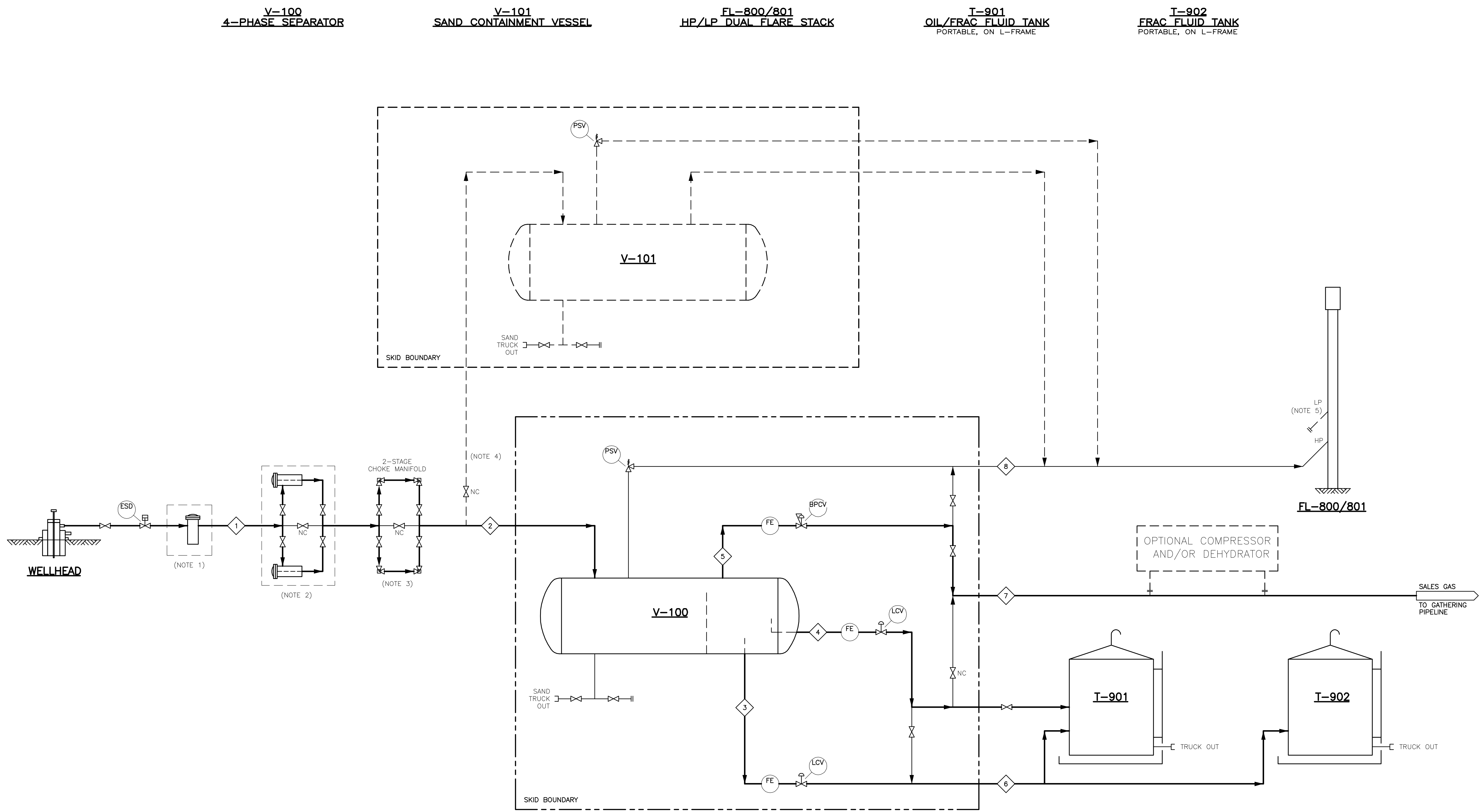
breaker	an additive to frac fluid that after a certain amount of time or pressure reduction allows viscosity to return to that of the fluid prior to addition of gel or cross linker which enables frac fluid to flow back without carrying proppant deposited in the fracture
bridge plug	retrievable or drillable plug set in the cased/lined well bore
cross link	add boron, zirconium, titanium or iron in small quantities to frac fluid to join polymers contained in gelling agents in three dimensional shapes to increase viscosity
dead string or leg	coiled tubing string filled with frac fluid without proppant and used to monitor bottom hole pressure, adjust proppant concentration in fluid at the fracture face in the well bore and flush proppant from the well bore following screen out
design basis memorandum	document containing data, parameter and standards to be used during preliminary engineering, also referred to as FEED to ensure project goals and requirements are addressed. The DBM does not supplant the detailed technical documents including specifications, drawings, shut down key, data sheets, purchase orders, contracts, change orders and procedures that are developed, prepared and/or adopted as subsequent project stages progress (e.g. detailed engineering, procurement, fabrication, installation, commissioning and start-up).
delineation well	well drilled to determine the boundary of a field or producing reservoir
down hole	drilling industry jargon meaning farther from the ground surface in a well or in the case of the horizontal portion, closer to the toe
E^3	10 raised to the power of 3 = 1,000
flow back	stages following hydraulic fracturing to remove frac fluid, proppant and plug and formation debris from the well bore and test and measure hydrocarbon flow rate and pressure to verify well's ability to sustain commercial production
frac	hydraulic fracturing of hydrocarbon bearing formations with reduced or impaired permeability using high pressure fluid to "crack" formation rock and transport proppant into the fissure network to permanently "prop" fractures open and provide a porous path to enable hydrocarbons to flow into the wellbore; general procedure requires pumping fluid at high pressure and rate (e.g. 1.0- 15.0 m3/min) to initiate the fracture or fissure, width of which is controlled by fluid rate and viscosity, and immediately following fracture initiation introducing proppant into the fluid at low concentrations and gradually ramping up to the targeted final concentration
frac fluid	either water or oil-based and may be modified with small amounts of additives to reduce friction coefficient, increase viscosity, alter pH,

Appendix A – Glossary

	inhibit corrosion, scaling and sulphate reducing bacteria, reduce reaction with reservoir rock and/or “break” cross linking and gelling agents to allow viscosity to drop upon completion of the frac
frac (slick water)	technique employing low viscosity fluid (e.g. 2 to 10 cP); typically comprised principally of fresh water with addition of a small quantity of polyacrylamide to increase lubricity; pumped at high velocity to keep proppant in suspension; significantly lower proppant concentration (e.g. 50-400 kg/m3) than techniques employing viscous frac fluid
frac (viscous fluid)	technique employing addition of gelling and/or cross-linking agents to increase viscosity to 500-900 cP; enables suspension of higher concentration of proppant (e.g. 400-1,400 kg/m3); also reduces fluid loss to parts of the formation with higher permeability
full drift	no reduction in the internal diameter along the entire length of a string of drill pipe, tubing or casing/liner
gelling agent	guar gum or polyacrylamide added to frac fluid in small quantities to increase viscosity and lubricity
heel	point on the horizontal portion of a well that is closest to the vertical portion of the well
high pressure flare	design pressure greater than 6.9 kPag (1 psig)
liner	production casing in the horizontal portion of a well and normally cemented in place and either perforated mechanically (e.g. explosive charges or milling/drilling) or equipped with sliding sleeves and ports which can be actuated with pressure of force to open the wellbore to the formation
low pressure gas well	defined in the 2012 NSPS as a gas well where combined effects of reservoir pressure and depth render conservation of gas discharged from the separator during separation flow back unfeasible
low pressure flare	design pressure not exceeding 6.9 kPag (1 psig)
over flushing	once targeted final concentration of proppant is delivered to the formation frac fluid without proppant is pumped down well bore to drive any proppant remaining in or near the well bore into the formation which reduces sand volume during flow back
packer (hydraulic)	device installed on the outside of the liner at desired intervals which seal against the open hole and restrict the movement of fluids in the annulus; typically have elastomer element(s) that are inflated after the liner is in place with internal fluid pressure and expand to seal against the wellbore; typically remains in the well, however systems exist to deflate the packers if an attempt to remove the liner is considered
packer (swell)	device installed on the outside of the liner at desired intervals which swells when exposed to the well bore downhole environment to seal the annulus; oil-based and water-based swell packers are available and matched with other downhole conditions such as temperature;

Appendix A – Glossary

	time is required to allow the packers to swell, usually a matter of a few days; typically remains in the well, however systems exist to deflate the packers if an attempt to remove the liner is considered
proppant	uniformly sized natural or manufactured sand pumped with frac fluid to hold open a fracture following release of hydraulic pressure and to provide a porous flow path for hydrocarbons; most common natural proppant is sand that is sorted by size to ensure uniformity; manufactured proppant consists of resin coated sand, ceramic or bauxite which are also sorted by size; proppant selection depends on economics and reservoir properties, flow capability and depth
screen out	upset condition during hydraulic fracturing where sand bridges across the fracture preventing flow and causing frac pumping pressure to spike and shutdown equipment
slick water frac	
S/S	length between circumferential welds (2) to join vessel shell to each head
toe	farthest point on the horizontal portion of a well from the vertical portion of the well
up hole	drilling industry jargon meaning closer to the ground surface in a well or in the case of the horizontal portion, closer to the heel
wildcat well	well drilled outside known fields or the first well drilled in an oil and gas field where no other oil and gas production exists



NOTES:

1) BALL CATCHER MAY BE REQUIRED FOR FRACS USING SYNTHETIC BALLS TO ISOLATE STAGES.
2) DEBRIS CATCHER MAY BE REQUIRED FOR FRACS USING NON-DISSOLVEABLE PLUGS THAT MUST BE DRILLED OUT PRIOR TO FLOW BACK.
3) MULTIPLE CHOKE MANIFOLDS IN SERIES IF REQUIRED TO MANAGE WELLHEAD PRESSURE.
4) SCREEN OUT FLOW BACK WILL BE THROUGH "GUT" LINE (I.E. BY-PASS CATCHER & CHOKE MANIFOLD) AND DIRECTLY TO SAND CONTAINMENT VESSEL.
5) LOW PRESSURE ("LP") FLARE STACK IS AVAILABLE WHERE RECOVERY OF GAS/VAPOURS FROM TANK VENTS IS MANDATORY AND/OR PREFERRED.

REFERENCE DRAWING TITLE/No.
–

REV	DATE	REVISION DESCRIPTION	BY
C	JUN 16/15	ISSUED FOR APPROVAL	DM
B	MAY 21/15	RE-ISSUED FOR REVIEW	DM
A	APR 13/15	ISSUED FOR REVIEW	SH

ENGINEER'S STAMP

BY	SH	APR 13/15
CHECK	TM	APR 13/15
PROCESS	–	–
MECH	GD	APR 13/15
ELEC, I&C	–	–
CIV/STRUC	–	–
CLIENT	–	–

DRAWING ORIGIN

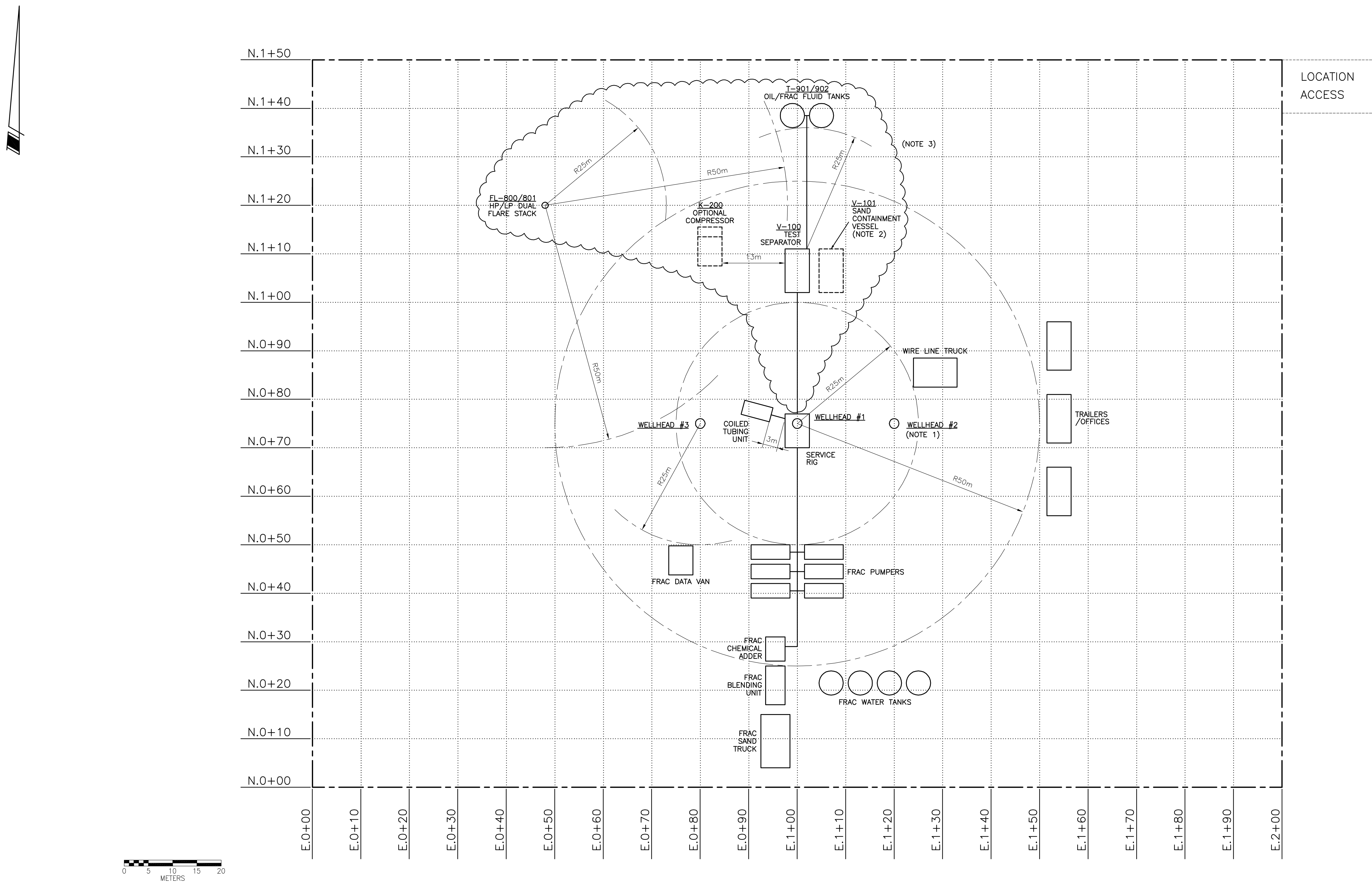
CLIENT: CLEARSTONE ENGINEERING

DRAWING TITLE: TYPICAL REDUCED EMISSIONS WELL COMPLETION PACKAGE PROCESS FLOW DIAGRAM

VANGUARD ENGINEERING INC

PERMIT/CERTIFICATE No.	–
PROJECT No.	CEL-15001
SCALE	NTS
DRAWING No.	10160-0200
REV	C

Name	1		2		3		5		6	
Description					Water Outlet		Oil Outlet		Gas Outlet	
Upstream Op	M1.Out		PCV1.Out		V-100.Liq1		V-100.Liq0		V-100.Vap	
Downstream Op	PCV1.In		V-100.In		PCV4.In		PCV3.In		PCV2.In	
VapFrac	0.24485		0.24988		0.00		0.00		1.00	
T [F]	252.8		248.0		248.0		248.0		248.0	
P [psia]	5000.00		1440.00		1440.00		1440.00		1440.00	
MoleFlow/Composition	Fraction	lbmol/h	Fraction	lbmol/h	Fraction	lbmol/h	Fraction	lbmol/h	Fraction	lbmol/h
METHANE	0.21991	591.59	0.21991	591.59	0.00118	2.39	0.87654	0.00	0.87654	589.21
ETHANE	0.01004	27.01	0.01004	27.01	0.00004	0.08	0.04006	0.00	0.04006	26.93
PROPANE	0.00318	8.56	0.00318	8.56	0.00001	0.02	0.01271	0.00	0.01271	8.55
ISOBUTANE	0.00049	1.32	0.00049	1.32	0.00	0.00	0.00196	0.00	0.00196	1.32
n-BUTANE	0.00061	1.65	0.00061	1.65	0.00	0.00	0.00245	0.00	0.00245	1.64
ISOPENTANE	0.00017	0.46	0.00017	0.46	0.00	0.00	0.00069	0.00	0.00069	0.46
n-PENTANE	0.0002	0.53	0.0002	0.53	0.00	0.00	0.00078	0.00	0.00078	0.53
n-HEXANE	0.00012	0.33	0.00012	0.33	0.00	0.00	0.00049	0.00	0.00049	0.33
n-HEPTANE	0.00012	0.33	0.00012	0.33	0.00	0.00	0.00049	0.00	0.00049	0.33
NITROGEN	0.0082	22.07	0.0082	22.07	0.00003	0.06	0.03275	0.00	0.03275	22.01
CARBON DIOXIDE	0.00184	4.94	0.00184	4.94	0.00008	0.17	0.0071	0.00	0.0071	4.77
WATER	0.75511	2031.33	0.75511	2031.33	0.99865	2015.20	0.02399	0.00	0.02399	16.12
Total	1.00	2690.11	1.00	2690.11	1.00	2017.92	1.00	0.00	1.00	672.20
Mass Flow [lb/h]	48416.00		48416.00		36355.20		0.00		12060.80	
Volume Flow [ft3/s]	0.459		1.097		0.171		0.000		0.926	
Std Liq Volume Flow [ft3/s]	0.329		0.329		0.162		0.000		0.167	
Std Gas Volume Flow [MMSCFD]	2.4501E+1		2.4501E+1		1.8378E+1		2.0079E-42		6.1221E+0	
Energy [Btu/h]	-1.969E+7		-1.969E+7		-2.340E+7		1.216E-36		3.709E+6	
H [Btu/lbmol]	-7319.6		-7319.6		-11595.8		5517.5		5517.5	
S [Btu/lbmol-F]	25.466		26.302		21.964		39.324		39.324	
MW	18.00		18.00		18.02		17.94		17.94	
Mass Density [lb/ft3]	29.3085		12.2591		59.0118		3.6182		3.6182	
Cp [Btu/lbmol-F]	17.071		16.856		18.635		11.516		11.516	
Thermal Conductivity [Btu/h-ft-F]	0.3122		0.3049		0.3949		0.0335		0.0335	
Viscosity [cP]	1.5015E-1		1.3826E-1		2.3577E-1		1.5942E-2		1.4753E-2	
Molar Volume [ft3/lbmol]	0.614		1.468		0.305		4.959		4.959	
Z Factor	0.4280		0.2867		0.0697		0.9383		0.9383	



–
REFERENCE DRAWING TITLE/No.

NOTES

1) IN CASE OF MULTIPLE ACTIVE WELLS ON SITE, EQUIPMENT SPACING MUST BE MET FOR EACH WELL. IF UNABLE TO MEET REQUIRED SPACING, WELL MUST BE MADE INACTIVE FOR DURATION OF WORK (EG: WELLHEAD #3 OK, WELLHEAD #2 SHUT-IN).
2) REQUIRED ONLY FOR "SCREEN OUT".
3) REDUCED EMISSIONS COMPLETION EQUIPMENT IS WITHIN CLOUD.

REV	DATE	REVISION DESCRIPTION	BY
B	JUN 16/15	RE-ISSUED FOR REVIEW	DM
A	MAY 21/15	ISSUED FOR REVIEW	DM

ENGINEER'S STAMP

BY	DM	MAY 07/15
CHECK	–	–
PROCESS	–	–
MECH	GD	MAY 07/15
ELEC, I&C	–	–
CIV/STRUC	–	–
CLIENT	–	–
DRAWING ORIGIN		

CLIENT

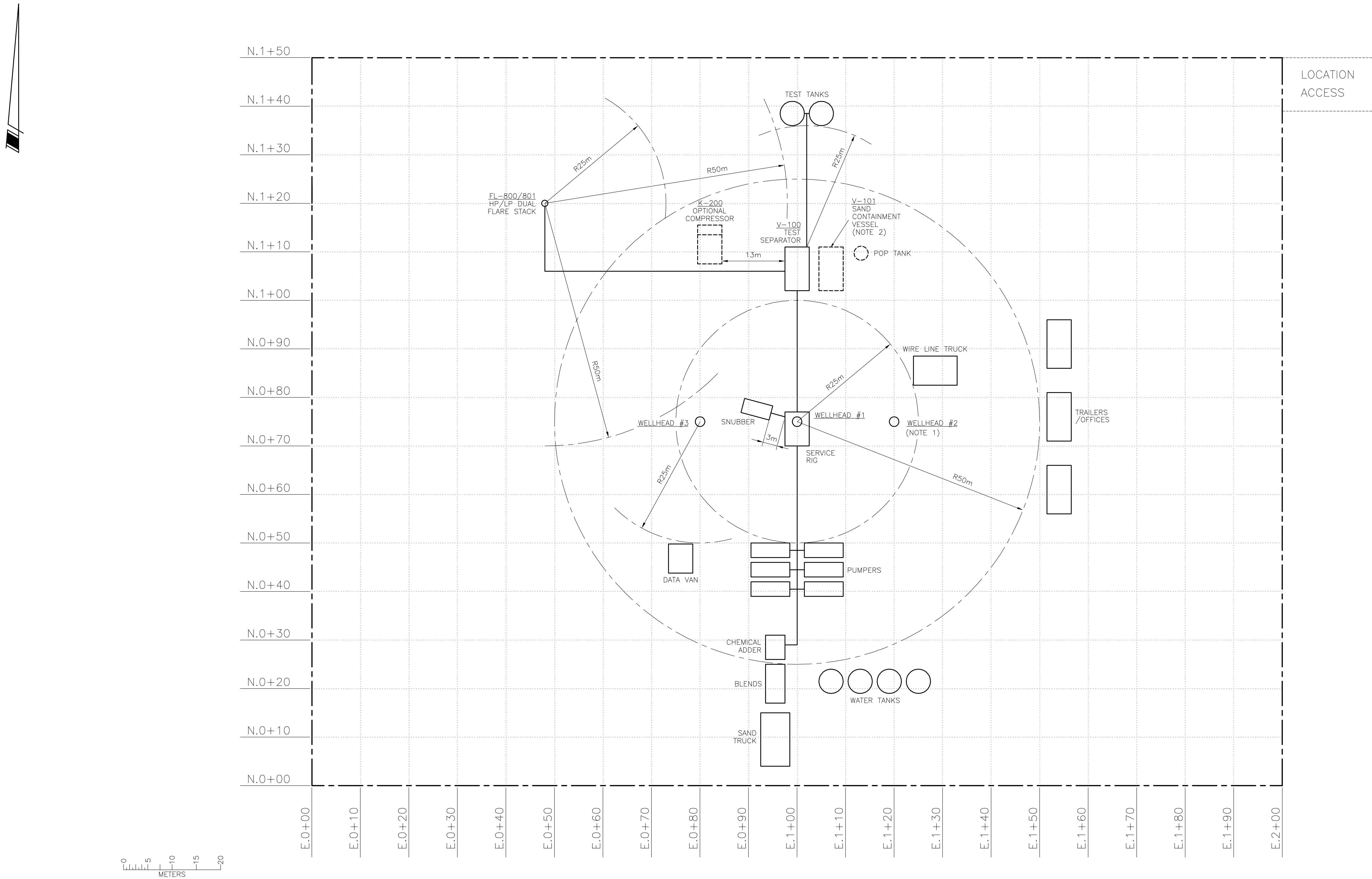
CLEARSTONE ENGINEERING

DRAWING TITLE

TYPICAL REDUCED EMISSIONS WELL COMPLETION PACKAGE SITE PLAN

VANGUARD ENGINEERING INC

PERMIT/CERTIFICATE No.	–
PROJECT No.	CEL-15001
SCALE	1:400
DRAWING No.	10160-0100
REV	B



–	
REFERENCE DRAWING TITLE/No.	

NOTES

1) IN CASE OF MULTIPLE ACTIVE WELLS ON SITE, EQUIPMENT SPACING MUST BE MET FOR EACH WELL. IF UNABLE TO MEET REQUIRED SPACING, WELL MUST BE MADE INACTIVE FOR DURATION OF WORK (EG: WELLHEAD #3 OK, WELLHEAD #2 SHUT-IN).
2) REQUIRED ONLY FOR "SCREEN OUT".

REV	DATE	REVISION DESCRIPTION	BY
A	MAY 21/15	ISSUED FOR REVIEW	DM

ENGINEER'S STAMP

BY	DM	MAY 07/15
CHECK	–	–
PROCESS	–	–
MECH	GD	MAY 07/15
ELEC, I&C	–	–
CIV/STRUC	–	–
CLIENT	–	–

DRAWING ORIGIN

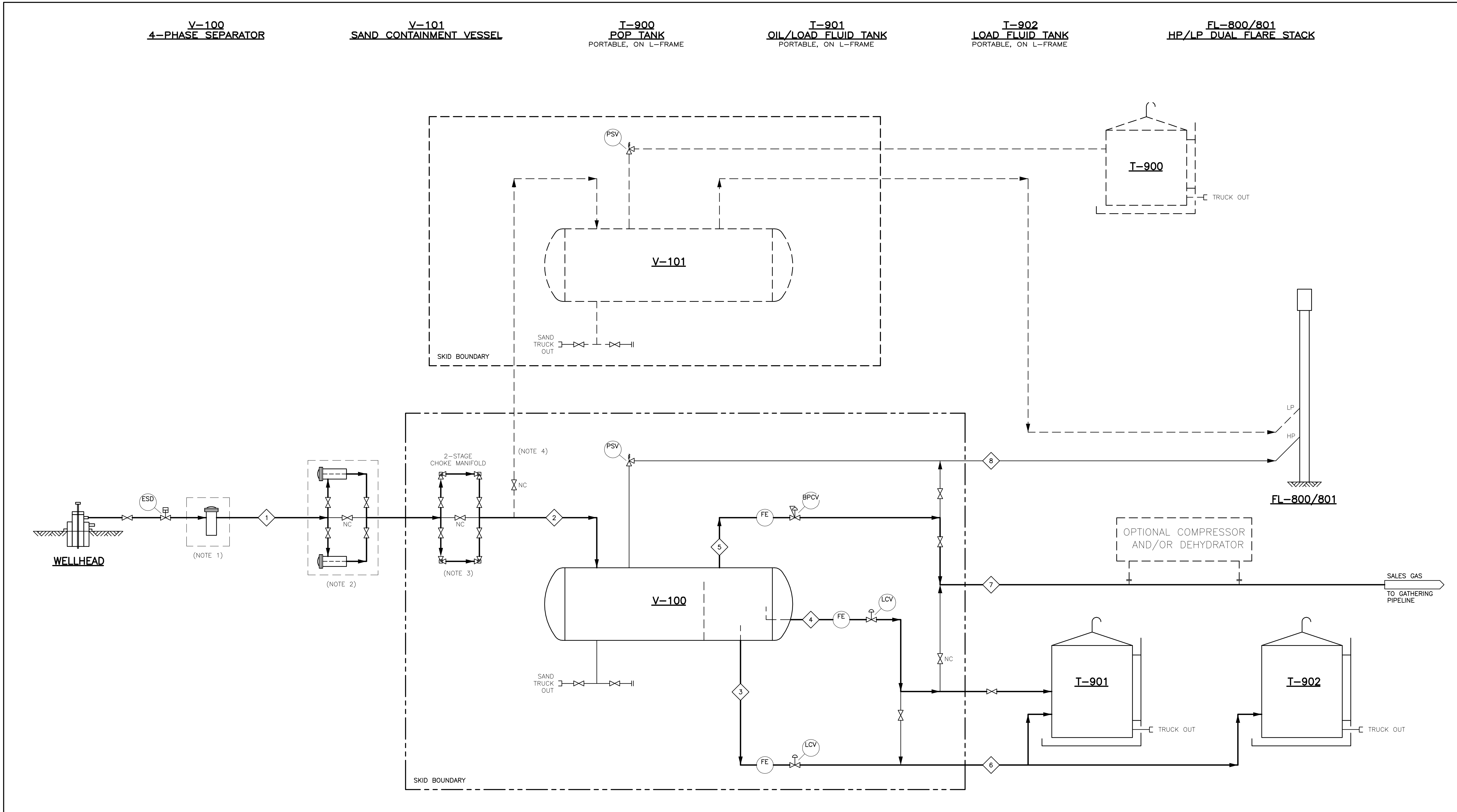
CLIENT
CLEARSTONE ENGINEERING

DRAWING TITLE

TYPICAL REDUCED EMISSIONS WELL COMPLETION PACKAGE SITE PLAN

VANGUARD ENGINEERING INC

PERMIT/CERTIFICATE No.	–
PROJECT No.	CEL-15001
SCALE	1:400
DRAWING No.	10160-0100
REV	A



NOTES:

1) BALL CATCHER IS REQUIRED ONLY FOR FRACS USING PROGRESSIVELY SMALLER SYNTHETIC BALLS TO ISOLATE STAGES.
2) DEBRIS CATCHER IS REQUIRED ONLY FOR FRACS USING NON-DISSOLVEABLE PLUGS THAT MUST BE DRILLED OUT PRIOR TO FLOW BACK.
3) MULTIPLE CHOKE MANIFOLDS IN SERIES IF REQUIRED TO MANAGE WELLHEAD PRESSURE.
4) SCREEN OUT FLOW BACK WILL BE THROUGH "GUT" LINE (I.E. BY-PASS CATCHER & CHOKE MANIFOLD) AND DIRECTLY TO SAND CONTAINMENT VESSEL.

REFERENCE DRAWING TITLE/No.
-

REV	DATE	REVISION DESCRIPTION	BY
B	MAY 21/15	RE-ISSUED FOR REVIEW	DM
A	APR 13/15	ISSUED FOR REVIEW	SH

ENGINEER'S STAMP

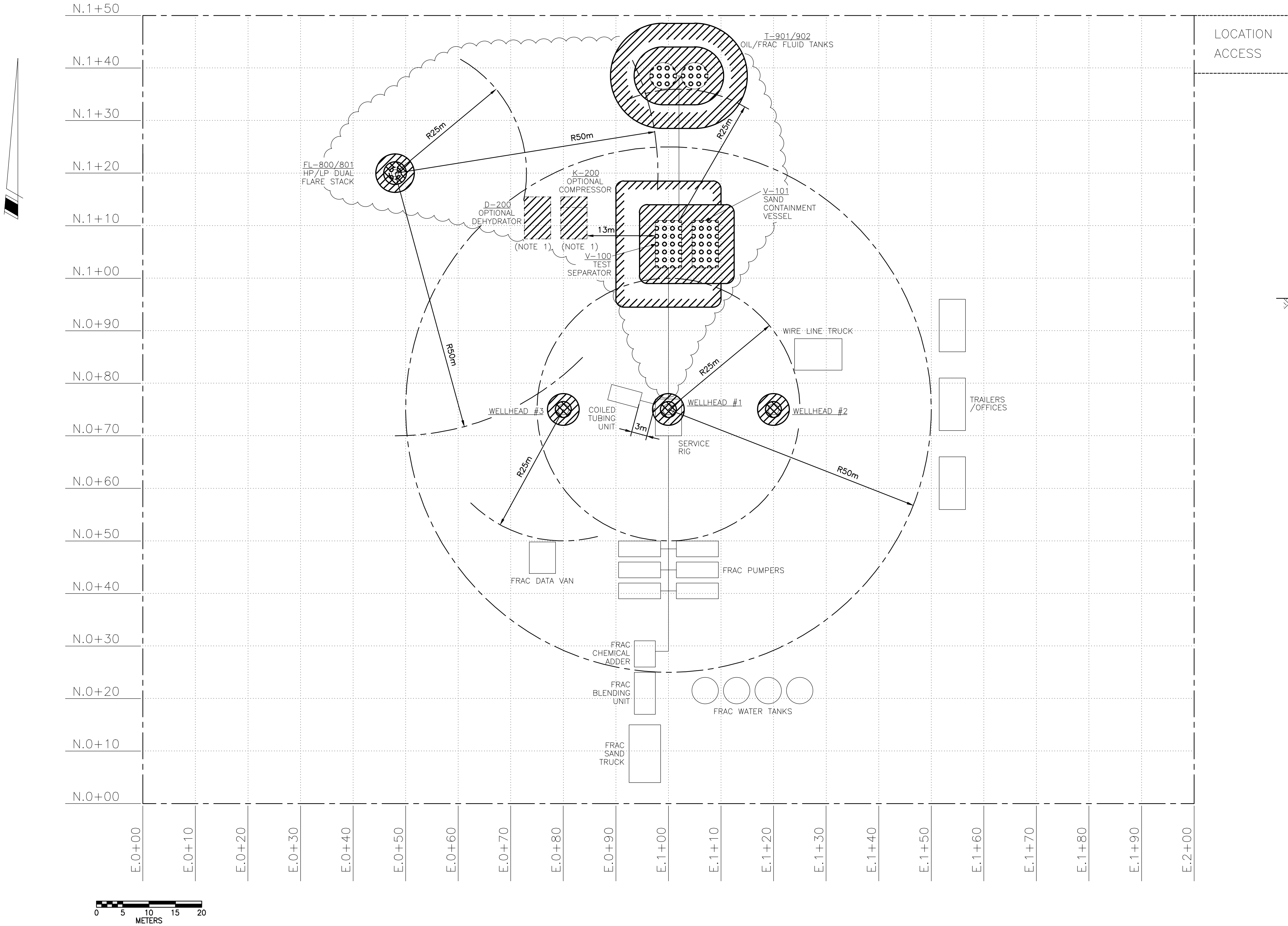
DRAWING ORIGIN		
BY	SH	APR 13/15
CHECK	TM	APR 13/15
PROCESS	–	–
MECH	GD	APR 13/15
ELEC, I&C	–	–
CIV/STRUC	–	–
CLIENT	–	–

CLIENT: CLEARSTONE ENGINEERING

DRAWING TITLE: TYPICAL REDUCED EMISSIONS WELL COMPLETION PACKAGE PROCESS FLOW DIAGRAM

VANGUARD ENGINEERING INC

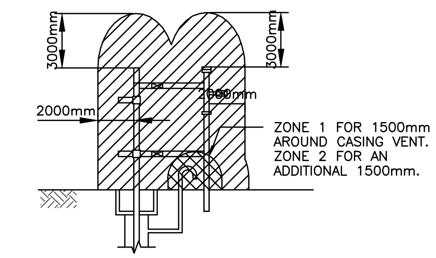
PERMIT/CERTIFICATE No.	–
PROJECT No.	CEL-15001
SCALE	NTS
DRAWING No.	10160-0200
REV	B



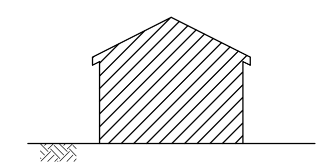
LEGEND:

- CLASS I ZONE 0
- CLASS I ZONE 1
- CLASS I ZONE 2
- CLASS I ZONE 2 600mm ABOVE GRADE (UNLESS OTHERWISE NOTED)
- NONCLASSIFIED

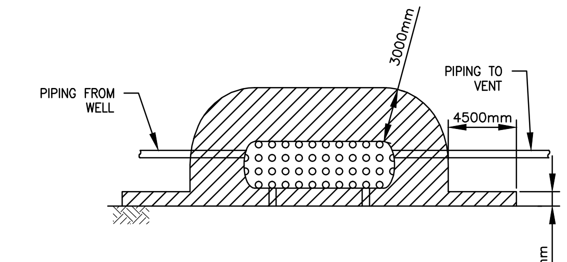
GAS GROUP: IIA, IIB, IIC
TEMP CODE: T2C



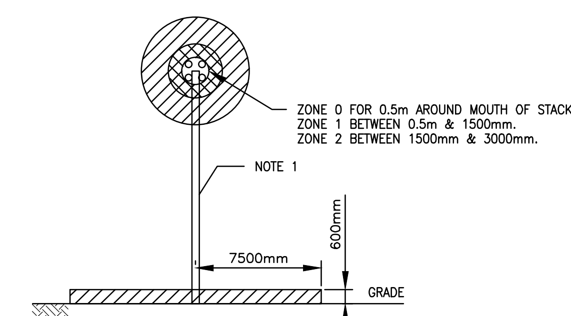
WELLHEAD



CLASS I ZONE 2 BUILDING



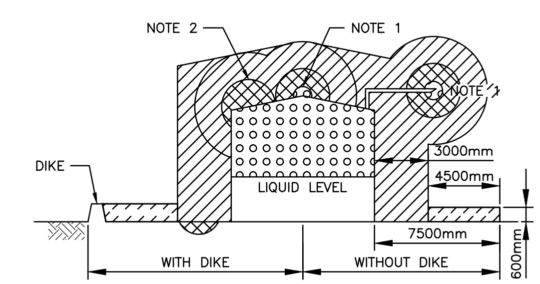
TEST SEPERATOR & SAND CONTAINMENT VESSEL



NOTES:

1. THE INTERIOR OF THE VENT PIPING BELOW RELIEF VALVE IS ZONE 0: CROSS-HATCHING HAS BEEN OMITTED FOR DRAWING CLARITY.

FLARE STACK



NOTES:

1. ZONE 0 FOR 500mm AROUND VENT. ZONE 1 BETWEEN 500mm AND 1500mm. ZONE 2 FOR AN ADDITIONAL 1500mm.
2. ZONE 1 FOR 1500mm AROUND THIEF HATCH. ZONE 2 FOR AN ADDITIONAL 1500mm.

STORAGE TANK FOR FLAMMABLE LIQUID

NOTES

1. THE COMPRESSOR BUILDING SHALL BE DESIGNED TO MEET A CLASS 1 ZONE 2 CLASSIFICATION. AN EMISSION STUDY AND ALL REQUIRED MODIFICATIONS TO THE BUILDING SHALL BE COMPLETED IN ORDER TO ACHIEVE THE CLASSIFICATION. THIS WILL BE IN ACCORDANCE WITH CSA 22.1-12 CANADIAN ELECTRICAL CODE AND API 505.

REFERENCE DRAWING TITLE/No.: –

REV	DATE	REVISION DESCRIPTION	BY
A	JULY 29/15	ISSUED FOR APPROVAL	SS

ENGINEER'S STAMP

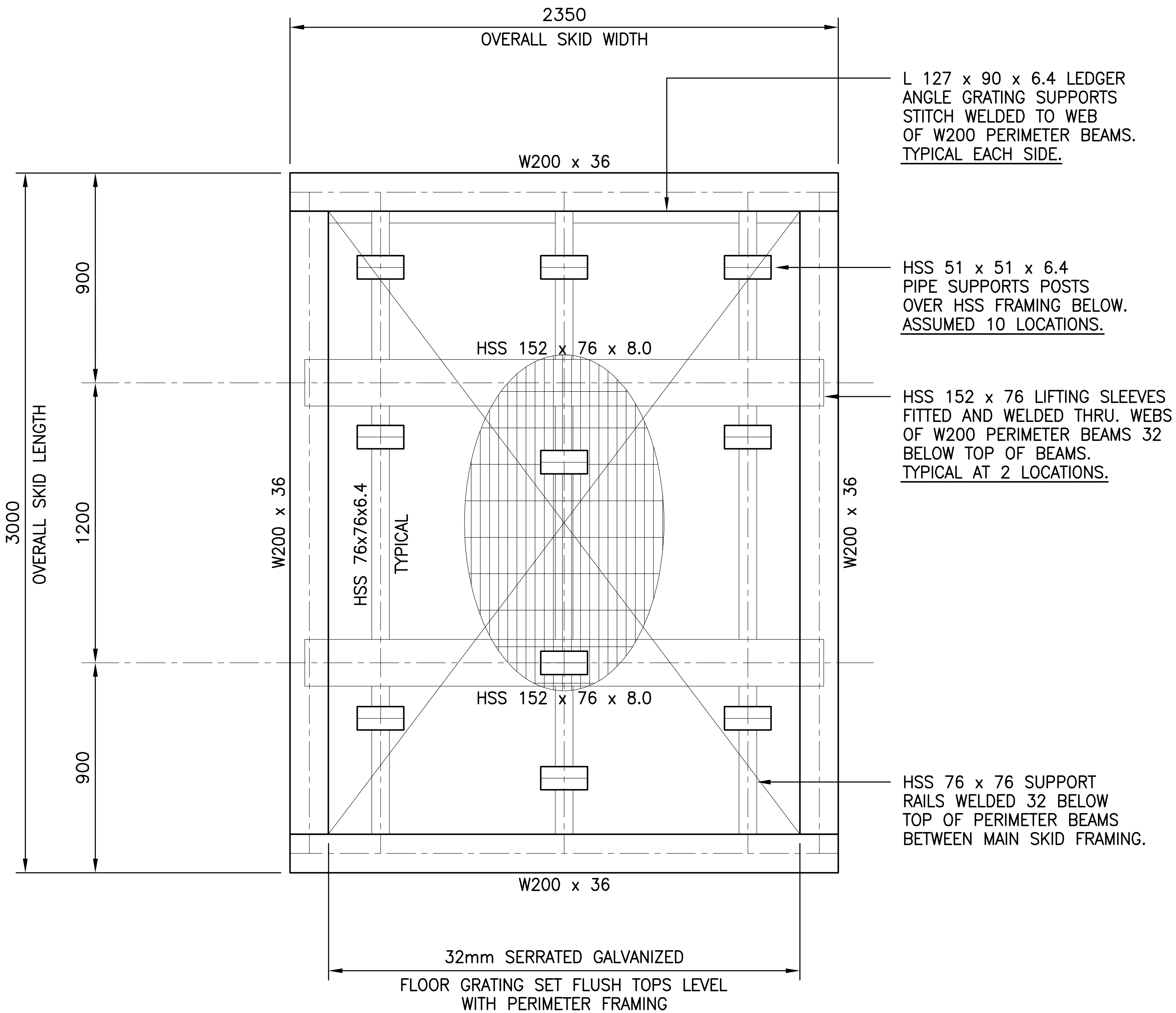
DRAWING ORIGIN		
BY	SS	JULY 02/15
CHECK	–	–
PROCESS	–	–
MECH		
ELEC, I&C	WB	JULY 02/15
CIV/STRUC	–	–
CLIENT	–	–

CLIENT: CLEARSTONE ENGINEERING

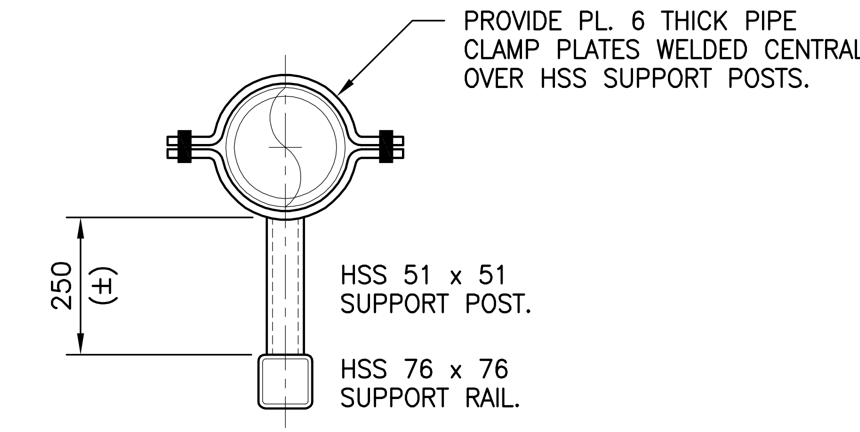
DRAWING TITLE: TYPICAL REDUCED EMISSIONS WELL COMPLETION PACKAGE AREA CLASSIFICATION

VANGUARD ENGINEERING INC

PERMIT/CERTIFICATE No.	–
PROJECT No.	CEL-15001
SCALE	1:400
DRAWING No.	KC15523-ELE-9020
REV	A



FRAMING PLAN



TYPICAL PIPE SUPPORT DETAIL

SCALE: NTS

NOTE :
SKID TO BE INSTALLED ON TIMBER SLEEPERS ON GRADE.

REFERENCE DRAWING TITLE/No.	NOTES	REV	DATE	REVISION DESCRIPTION	BY	ENGINEER'S STAMP
–		A	JUN 16/15	ISSUED FOR REVIEW	DM	

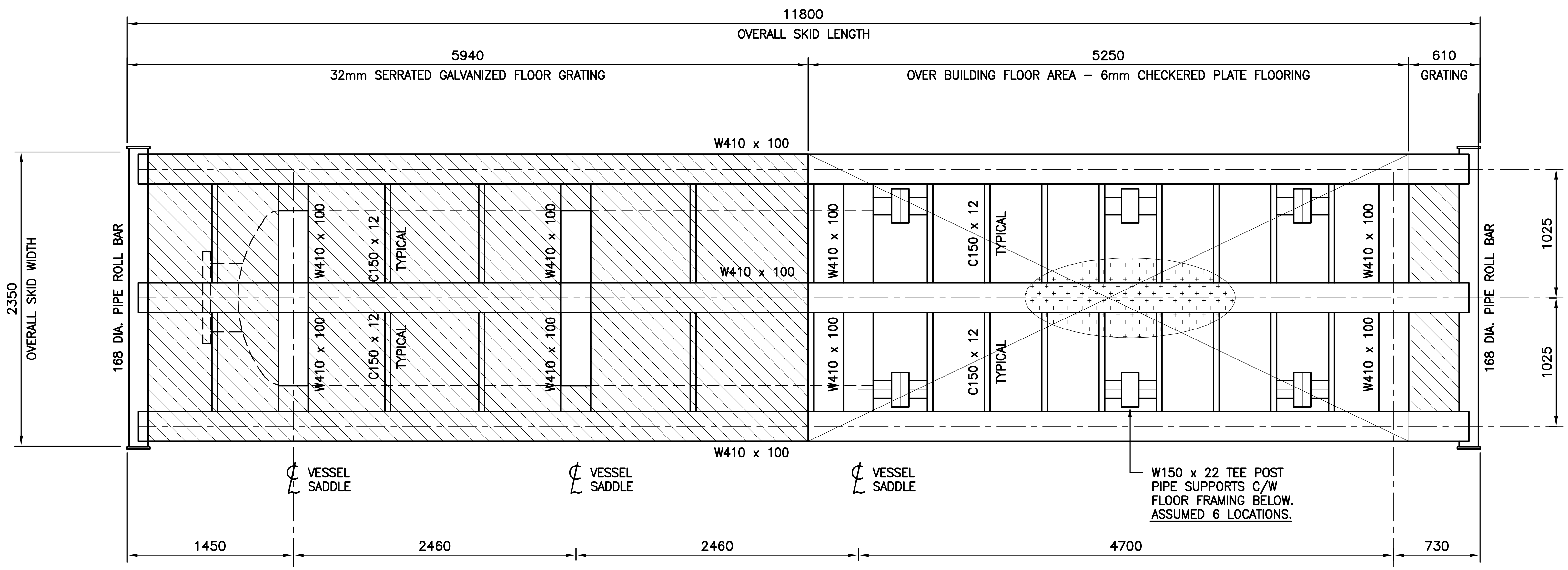
DRAWING ORIGIN		
BY	DM	JUN 16/15
CHECK	–	–
PROCESS	–	–
MECH	TM	JUN 16/15
ELEC, I&C	–	–
CIV/STRUC	–	–
CLIENT	–	–

CLIENT: CLEARSTONE ENGINEERING

DRAWING TITLE: TYPICAL REDUCED EMISSIONS WELL COMPLETION PACKAGE CHOKE MANIFOLD SKID FRAMING CONCEPT

VANGUARD ENGINEERING INC

PERMIT/CERTIFICATE No.	–
PROJECT No.	CEL–15001
SCALE	1:10
DRAWING No.	10160–5000
REV	A



FRAMING PLAN

NOTE :
SKID TO BE INSTALLED ON TIMBER SLEEPERS ON GRADE.

REFERENCE DRAWING TITLE/No.	NOTES	REV	DATE	REVISION DESCRIPTION	BY	ENGINEER'S STAMP
–		A	JUN 16/15	ISSUED FOR REVIEW	DM	

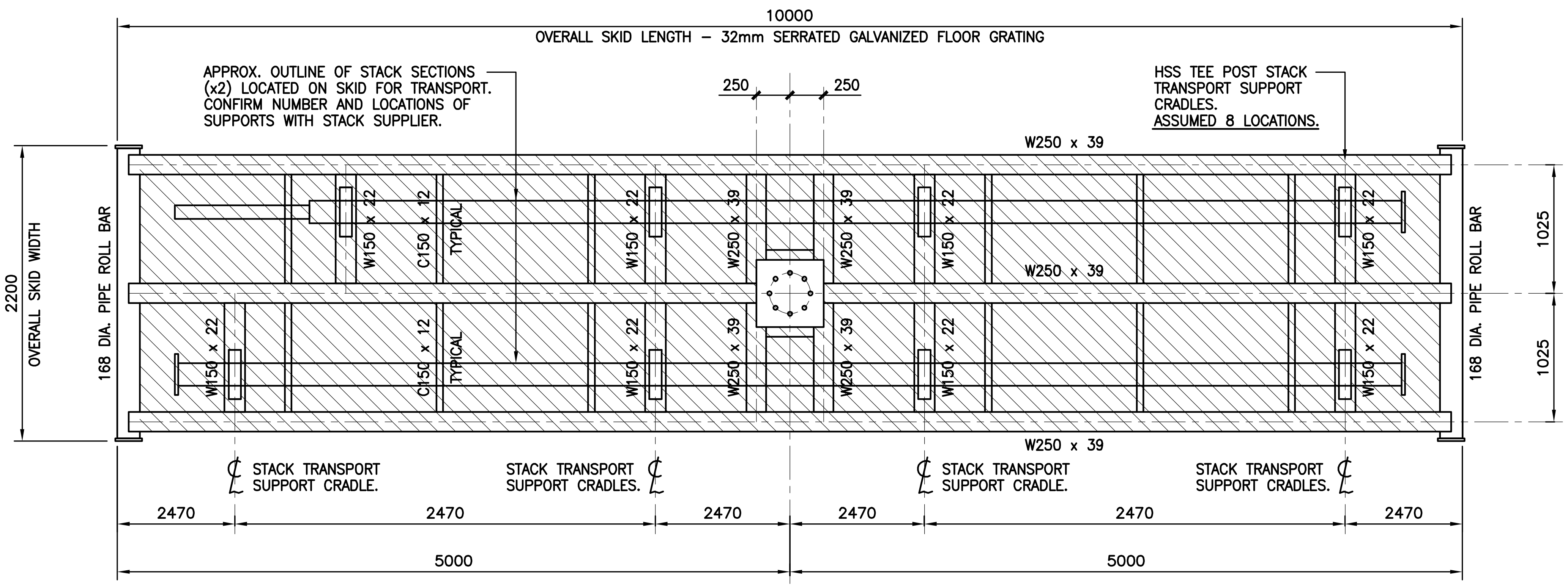
DRAWING ORIGIN		
BY	DM	JUN 16/15
CHECK	–	–
PROCESS	–	–
MECH	TM	JUN 16/15
ELEC. I&C	–	–
CIV/STRUC	–	–
CLIENT	–	–

CLIENT: CLEARSTONE ENGINEERING

DRAWING TITLE: TYPICAL REDUCED EMISSIONS WELL COMPLETION PACKAGE SEPARATOR SKID FRAMING CONCEPT

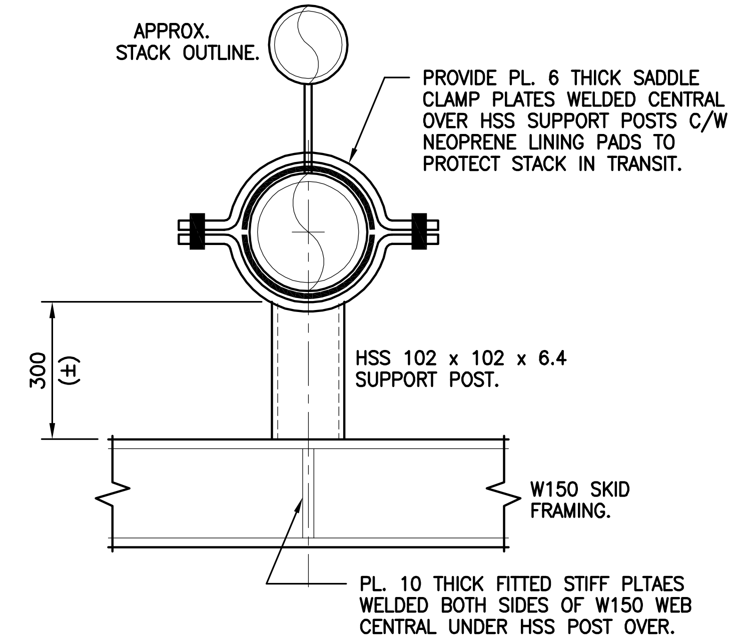
VANGUARD ENGINEERING INC

PERMIT/CERTIFICATE No.	–
PROJECT No.	CEL–15001
SCALE	1:20
DRAWING No.	10160–5001
REV	A



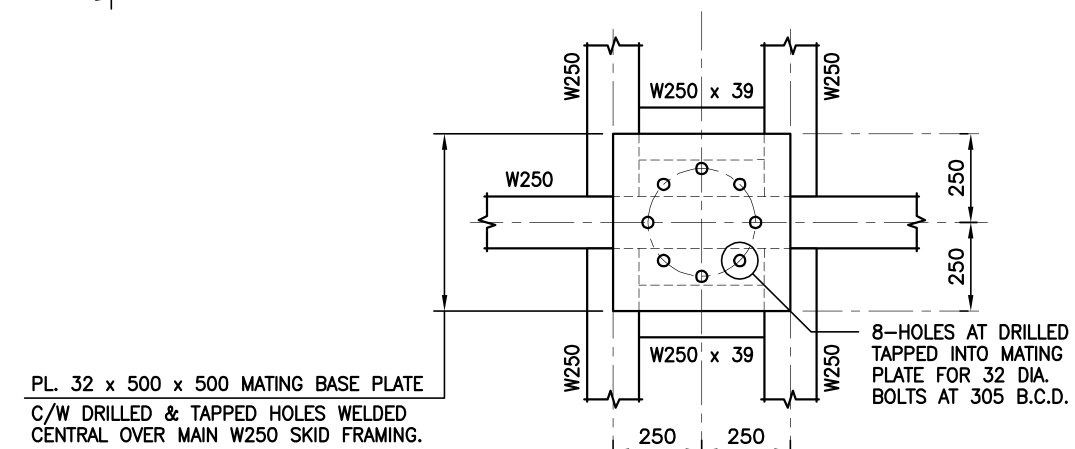
FRAMING PLAN

NOTE :
SKID TO BE INSTALLED ON TIMBER SLEEPERS ON GRADE C/W CONCRETE ANCHOR BLOCKS LOCATED AND INSTALLED AS PER MANUFACTURER'S RECOMMENDATIONS.



TYPICAL SUPPORT CRADLE DETAIL

SCALE: NTS



ENLARGED CENTRAL FRAMING DETAILS

SCALE: 1:10

REFERENCE DRAWING TITLE/No.	NOTES
–	

REV	DATE	REVISION DESCRIPTION	BY
A	JUN 16/15	ISSUED FOR REVIEW	DM

ENGINEER'S STAMP

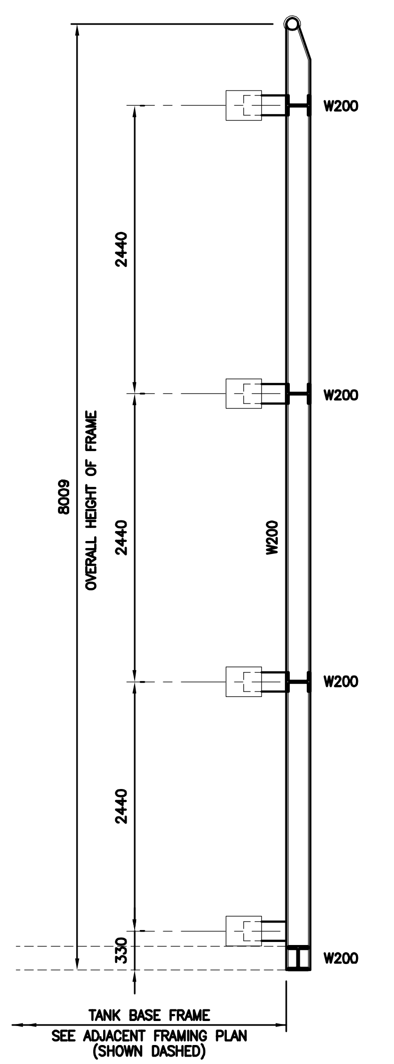
DRAWING ORIGIN		
BY	DM	JUN 16/15
CHECK	–	–
PROCESS	–	–
MECH	TM	JUN 16/15
ELEC. I&C	–	–
CIV/STRUC	–	–
CLIENT	–	–

CLIENT: CLEARSTONE ENGINEERING

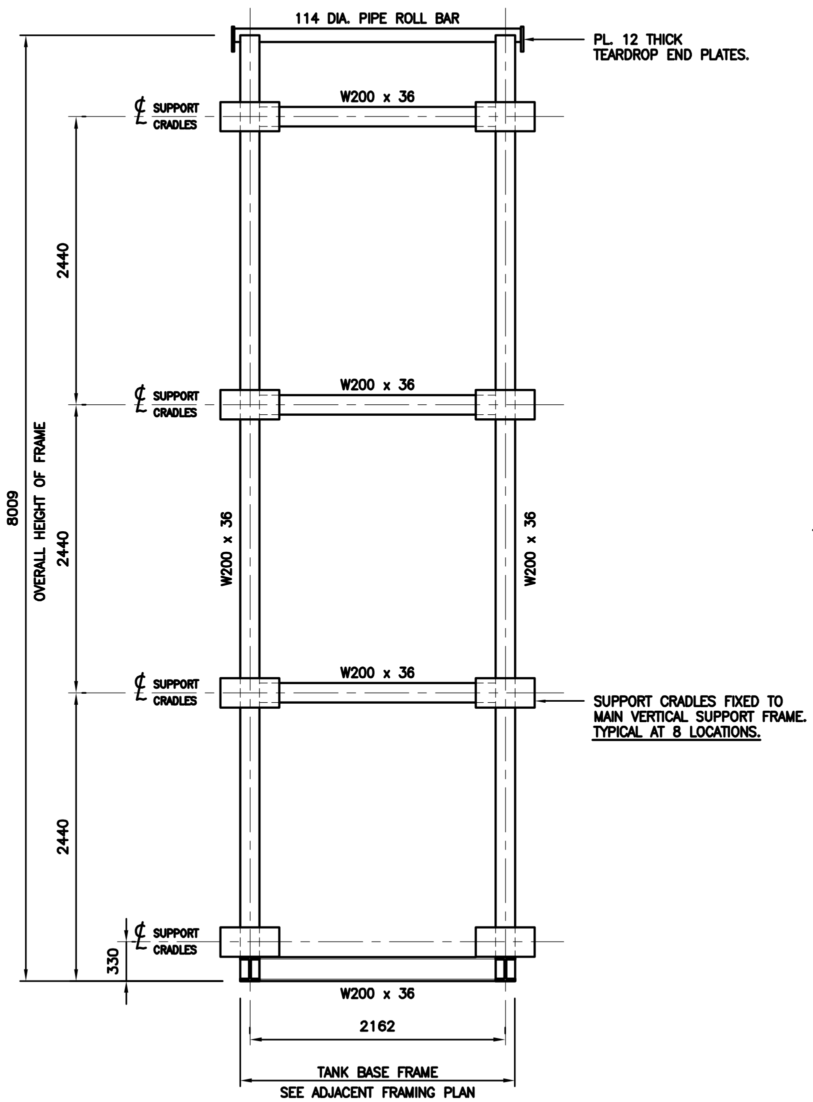
DRAWING TITLE: TYPICAL REDUCED EMISSIONS WELL COMPLETION PACKAGE FLARE STACK SKID FRAMING CONCEPT

VANGUARD ENGINEERING INC

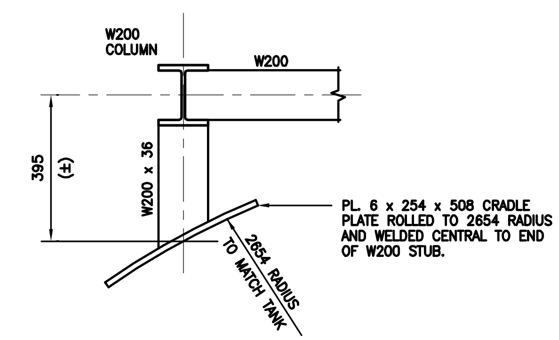
PERMIT/CERTIFICATE No.	–
PROJECT No.	CEL–15001
SCALE	1:20
DRAWING No.	10160–5002
REV	A



SIDE VIEW TO VERTICAL SUPPORT FRAME

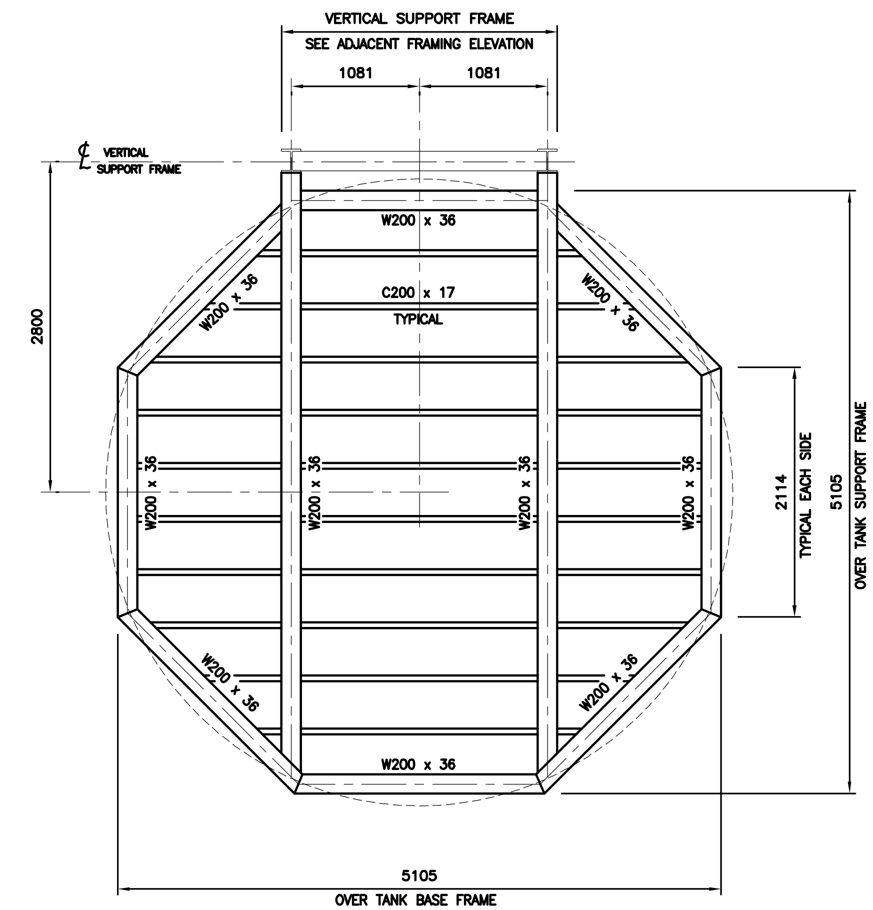


ELEVATION ON VERTICAL SUPPORT FRAME



ENLARGED SUPPORT CRADLE DETAIL

SCALE: NTS



BASE FRAME FRAMING PLAN

NOTE :
SKID TO BE INSTALLED ON TIMBER SLEEPERS ON GRADE.

REFERENCE DRAWING TITLE/No.	NOTES
–	

REV	DATE	REVISION DESCRIPTION	BY
A	JUN 16/15	ISSUED FOR REVIEW	DM

ENGINEER'S STAMP

BY	DM	JUN 16/15
CHECK	–	–
PROCESS	–	–
MECH	TM	JUN 16/15
ELEC, I&C	–	–
CIV/STRUC	–	–
CLIENT	–	–

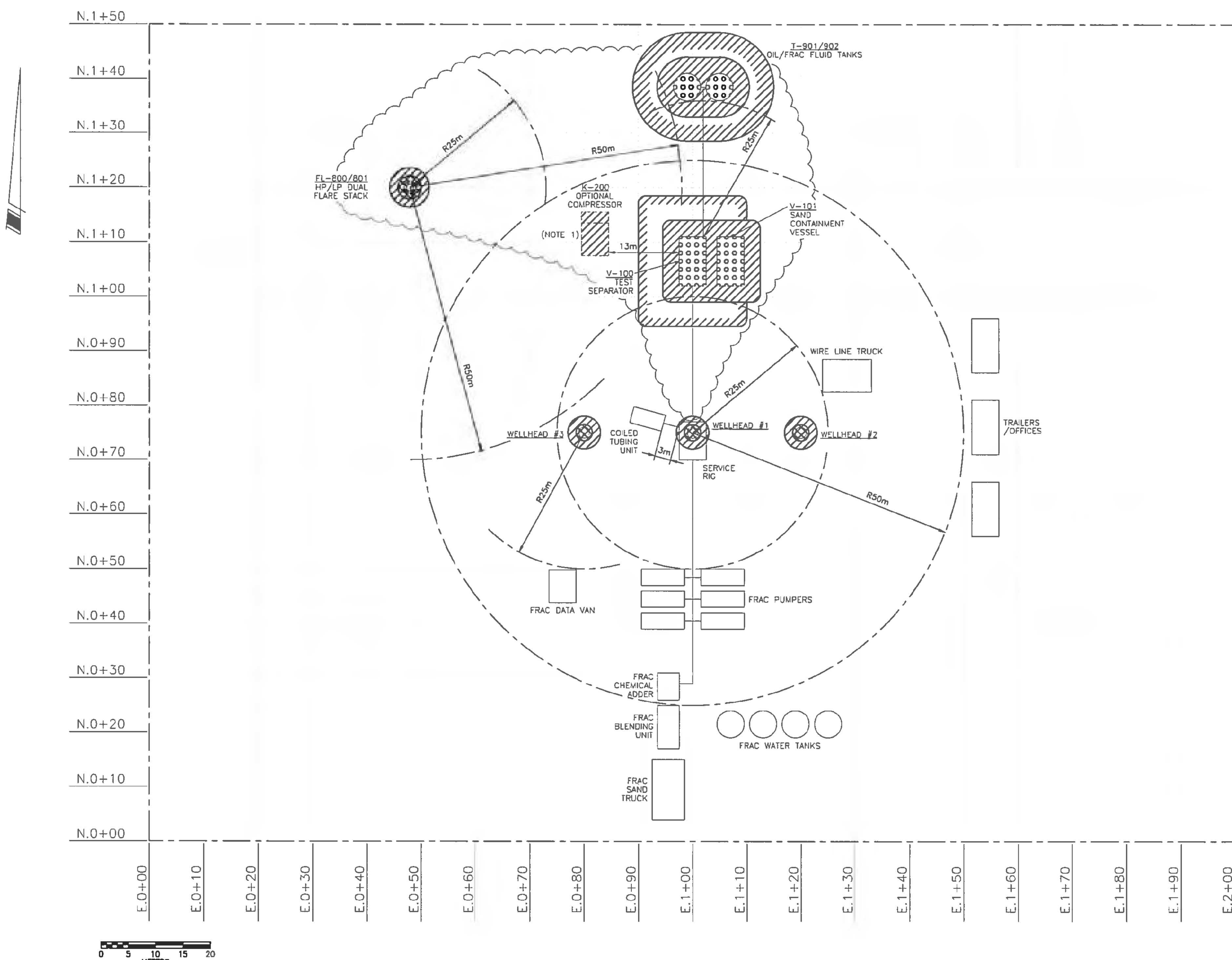
DRAWING ORIGIN

CLIENT: CLEARSTONE ENGINEERING

DRAWING TITLE: TYPICAL REDUCED EMISSIONS WELL COMPLETION PACKAGE 1000 BBL TANK SKID FRAMING CONCEPT

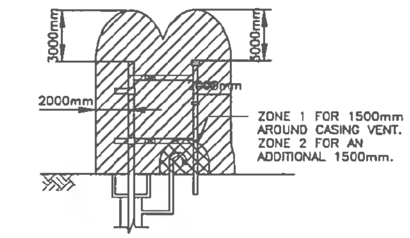
VANGUARD ENGINEERING INC

PERMIT/CERTIFICATE No.	–
PROJECT No.	CEL–15001
SCALE	1:30
DRAWING No.	10160–5003
REV	A

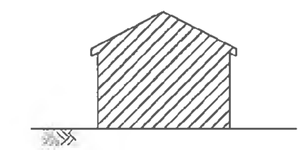


LEGEND:

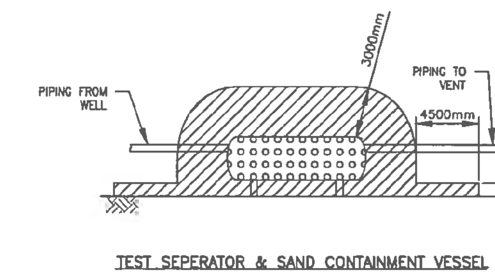
- CLASS I ZONE 0
- CLASS I ZONE 1
- CLASS I ZONE 2
- CLASS I ZONE 2 600mm ABOVE GRADE (UNLESS OTHERWISE NOTED)
- NONCLASSIFIED



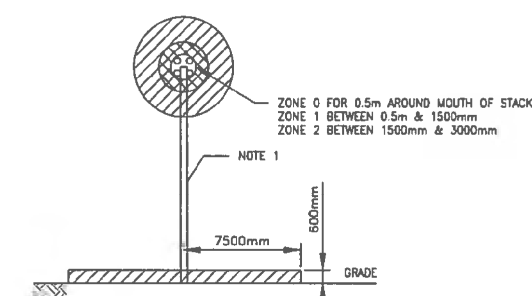
WELLHEAD



CLASS I ZONE 2 BUILDING



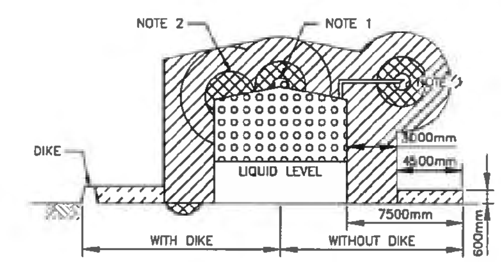
TEST SEPERATOR & SAND CONTAINMENT VESSEL



NOTES:

1. THE INTERIOR OF THE VENT PIPING BELOW RELIEF VALVE IS ZONE 0: CROSS-HATCHING HAS BEEN OMITTED FOR DRAWING CLARITY.

FLARE STACK



NOTES:

1. ZONE 0 FOR 500mm AROUND VENT.
   ZONE 1 BETWEEN 500mm AND 1500mm
   ZONE 2 FOR AN ADDITIONAL 1500mm.
2. ZONE 1 FOR 1500mm AROUND THIEF HATCH.
   ZONE 2 FOR AN ADDITIONAL 1500mm.

STORAGE TANK FOR FLAMMABLE LIQUID

NOTES

1. THE COMPRESSOR BUILDING SHALL BE DESIGNED TO MEET A CLASS I ZONE 2 CLASSIFICATION. AN EMISSION STUDY SHALL BE COMPLETED AND ALL REQUIRED MODIFICATIONS TO THE BUILDING IN ORDER TO ACHIEVE THE CLASSIFICATION.

REV	DATE	REVISION DESCRIPTION	BY
A	JULY 02/15	ISSUED FOR REVIEW	SS

REFERENCE DRAWING TITLE/No.: –

ENGINEER'S STAMP

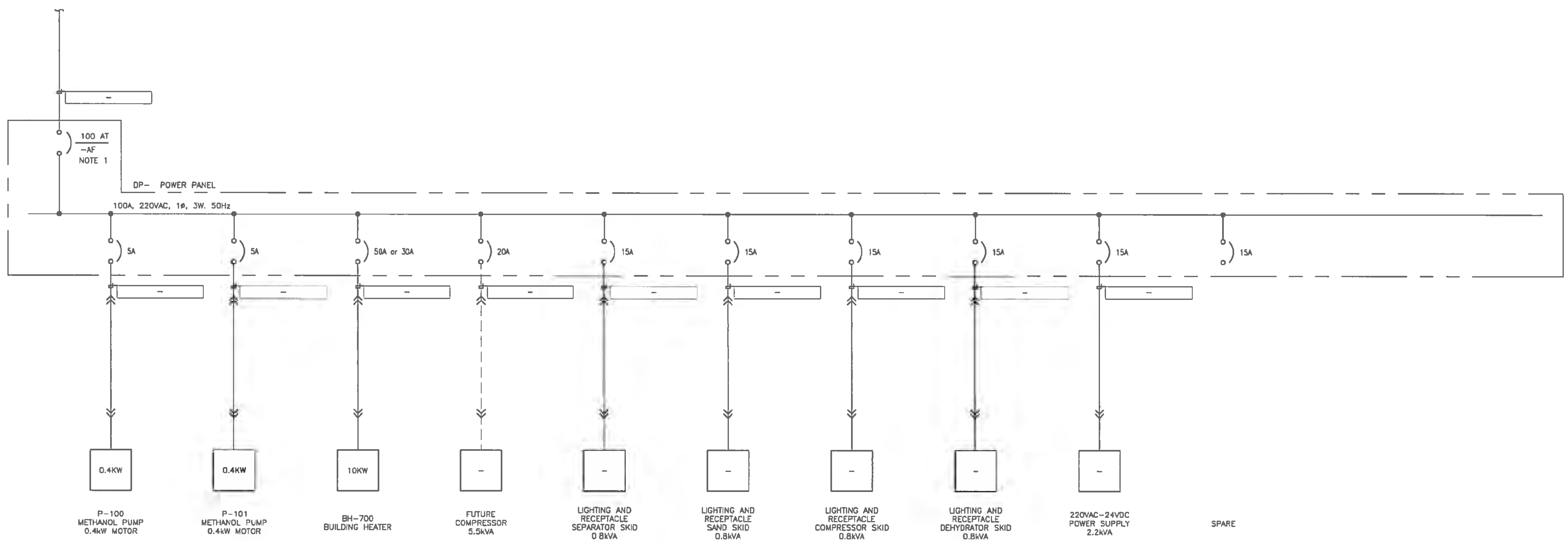
DRAWING ORIGIN		
BY	SS	JULY 02/15
CHECK	–	–
PROCESS	–	–
MECH		
ELEC, I&C	WB	JULY 02/15
CIV/STRUC	–	–
CLIENT	–	–

CLIENT: CLEARSTONE ENGINEERING

DRAWING TITLE: TYPICAL REDUCED EMISSIONS WELL COMPLETION PACKAGE AREA CLASSIFICATION

VANGUARD ENGINEERING INC

PERMIT/CERTIFICATE No	–
PROJECT No	CEL-15001
SCALE	1 400
DRAWING No.	KC15523-ELE-9020
REV	A



NOTES:

1. DEPENDING ON FEEDER THIS BREAKER MAY NOT BE NECESSARY.

-	
REFERENCE DRAWING TITLE/No.	

REV	DATE	REVISION DESCRIPTION	BY
A	JULY 02/15	ISSUED FOR REVIEW	SS

ENGINEER'S STAMP

BY	SS	JULY 02/15
CHECK	-	-
PROCESS	-	-
MECH		
ELEC. I&C	WB	JULY 02/15
CIV/STRUC	-	-
CLIENT	-	-
DRAWING ORIGIN		

CLIENT: CLEARSTONE ENGINEERING

DRAWING TITLE: TYPICAL REDUCED EMISSIONS WELL COMPLETION PACKAGE AREA CLASSIFICATION

VANGUARD ENGINEERING INC

PERMIT/CERTIFICATE No	-
PROJECT No	CE -15001
SCALE	NTS
DRAWING No.	KC15523-ELE-9050
REV	A

	Equipment Number	Equipment Description	Emergency Load (Yes or No)	Rated kVA / kW / HP	Calculation Method (kVA/kW/HP)	Eff	PF	Electrical Load kW	kVA	kVAR	Remarks
								220 Volts, 1Ph			
1	P-100	Methanol Pump Motor	Y	0.4	kW	0.89	0.8	0.4	0.5	0.3	ESTIMATED LOAD
2	P-101	Methanol Pump Motor	Y	0.4	kW	0.89	0.8	0.4	0.5	0.3	ESTIMATED LOAD
3	BH-700	Building Electric Heater	Y	10	kW	1	1	10.0	10.0	0.0	ESTIMATED LOAD
4		DC Power Supply	Y	2.2	kVA	0.89	0.8	1.8	2.2	1.3	ESTIMATED LOAD
5		Future Compressor	Y	4.4	kW	0.89	0.8	4.4	5.5	3.3	ESTIMATED LOAD
6		Seperator Skid Lighting and Receptacle	Y	0.8	kVA	0.89	0.8	0.6	0.8	0.5	ESTIMATED LOAD
7		Sand Skid Lighting Receptacle	Y	0.8	kVA	0.89	0.8	0.6	0.8	0.5	ESTIMATED LOAD
8		Dehydrator Lighting and Receptacle	Y	0.8	kVA	0.89	0.8	0.6	0.8	0.5	ESTIMATED LOAD
9		Compressor Lighting and Receptacle	Y	0.8	kVA	0.89	0.8	0.6	0.8	0.5	ESTIMATED LOAD

Summations	Electrical Load kW	kVA	kVAR
	20	22	7

KLEINFELDER
Bright People. Right Solutions.

HOOD

Project Number	
Project Name	REC SKIDS
Client	VANGUARD

ELECTRICAL LOAD LIST

Checked By	Approved By	Date
		07/15/15

REV	A
SHEET	1
Document Number	

VALVES

- THREADED VALVE
- SOCKET WELD VALVE
- THREADED x SOCKET WELD VALVE
- BUTT WELD VALVE
- FLANGED VALVE
- GATE VALVE
- BALL VALVE
- PLUG VALVE
- GLOBE VALVE
- CHECK VALVE
- PISTON CHECK VALVE
- BUTTERFLY VALVE
- NEEDLE VALVE
- BALL PIG VALVE
- DOUBLE BLOCK & BLEED VALVE
- ANGLE VALVE
- THREE WAY VALVE
- FOUR WAY VALVE

CONTROL VALVES

- DIAPHRAGM OPERATOR FO = FAIL OPEN FC = FAIL CLOSE (FO)
- MOTOR OPERATOR E = ELECTRIC H = HYDRAULIC A = AIR (E)
- ELECTROHYDRAULIC OPERATOR
- CYLINDER PISTON OPERATOR
- DIGITAL OPERATOR
- HAND OPERATOR
- BACK PRESSURE REGULATOR WITH EXTERNAL TAP
- PRESSURE REDUCING REGULATOR WITH EXTERNAL TAP
- BACK PRESSURE REGULATOR SELF-CONTAINED
- PRESSURE REDUCING REGULATOR SELF-CONTAINED
- BACK PRESSURE REGULATOR SELF-CONTAINED, WITH HANDWHEEL ADJUSTABLE SET POINT
- PRESSURE REDUCING REGULATOR SELF-CONTAINED, WITH HANDWHEEL ADJUSTABLE SET POINT
- DIAPHRAGM, PRESSURE BALANCED
- SOLENOID VALVE (ARROW SHOWS FAIL POSITION) (S)
- RESTRICTION ORIFICE DRILLED IN VALVE
- PRESSURE SAFETY VALVE
- PRESSURE AND VACUUM RELIEF VALVE, SPRING OR WEIGHT-LOADED, OR WITH INTEGRAL PILOT (V, P)
- RUPTURE DISC
- IN-LINE CHOKE VALVE
- ANGLE CHOKE VALVE
- DIAPHRAGM VALVE

MISCELLANEOUS SYMBOLS

- HOSE CONNECTION
- BLIND FLANGE
- REDUCING HUB FLANGE
- WELD CAP
- THREADED OR SOCKET WELD CAP
- EXPANSION JOINT
- FLEXIBLE HOSE
- FLAME ARRESTOR
- "Y" STRAINER
- CHANGE IN PIPE SIZE (X"xY")
- SLIP/BLIND
- SPACER
- SPECTABLE BLIND (OPEN)
- SPECTABLE BLIND (CLOSED)
- UNION
- CONICAL SCREEN
- STRAIGHTENING VANES
- STEAM TRAP (T)
- OPEN DRAIN
- TIE-IN SYMBOL (T / XX)
- SPECIALTY ITEM (SP)
- BARRED TEE
- INSULATION KIT
- INSTRUMENT AIR/GAS SUPPLY
- PIPING SPECIFICATION BREAK (SPEC 1 | SPEC 2)
- INSULATED LINE (25H)
- INSULATED LINE C/W TRACING (25H, ET)
- ATMOSPHERIC VENT
- SLOPED LINE (SLOPE)
- BLEED RING (NC)
- HAMMER UNION

FLOW INSTRUMENT SYMBOLS

- ORIFICE PLATE C/W ORIFICE FLANGES
- ORIFICE PLATE IN QUICK CHANGE FITTINGS
- ORIFICE PLATE IN SENIOR METER RUN
- VENTURI TUBE
- AVERAGING PITOT TUBE
- TURBINE METER
- POSITIVE DISPLACEMENT METER
- CORIOLIS METER
- SINGLE PORT PITOT TUBE
- TARGET TYPE SENSOR
- WEIR
- FLUME
- FLOW NOZZLE
- VORTEX SENSOR
- V-CONE METER
- SONIC FLOW METER
- MAGNETIC FLOW METER (M)
- ROTAMETER
- RESTRICTION ORIFICE

ABBREVIATIONS

AC	AIR TO CLOSE
AO	AIR OPEN
AS	AIR TO SUPPLY
BW	BUTT WELD
BLDG	BUILDING
CAP	CAPACITY
C/W	COMPLETE WITH
CSC	CAR SEAL CLOSE
CSO	CAR SEAL OPEN
CHO	CHAIN OPERATED
DC	DRAIN CONNECTION
DB&B	DOUBLE BLOCK & BLEED
DIB	DOUBLE ISOLATION & BLEED
ES	ELECTRICAL SUPPLY
ESD	EMERGENCY SHUTDOWN
ESDV	EMERGENCY SHUTDOWN VALVE
F	FEMALE
FC	FAIL CLOSE
FF	FLAT FACE
FKOD	FLARE KNOCK-OUT DRUM
FO	FAIL OPEN
FOB	FLAT ON BOTTOM
FOT	FLAT ON TOP
FP	FULL PORT
FV	FULL VACUUM
HH	HANDHOLE
HOA	HAND/OFF/AUTO MOTOR CONTROL WITH HOA SWITCH LOCATED AT MOTOR
HPV	HIGH POINT VENT
HS	HYDRAULIC SUPPLY
HT	HEAT TRACING
INSUL	INSULATION
I/S	INSIDE
LOR	LOCATE/OFF/REMOTE MOTOR CONTROL WITH LOR SWITCH LOCATED AT MOTOR
LP	LOCAL PANEL
LPD	LOW POINT DRAIN
MAG	MAGNETIC LEVEL
M	MALE
MA	MANUAL/AUTOMATIC
MCC	MOTOR CONTROL CENTER
NC	NORMALLY CLOSED
NC	NORMALLY OPEN
NNF	NORMALLY NO FLOW
N/I	NO INSULATION
O/S	OUTSIDE
PC	PURGE CONNECTION
PLC	PROGRAMMABLE LOGIC CONTROL
P/L	PIPELINE
RO	RESTRICTION ORIFICE
RP	REDUCED PORT
RF	RAISED FACE
RSV	REMOTE SWITCHING VALVE
RTJ	RING TYPE JOINT
RTU	REMOTE TRANSMISSION UNIT
SC	SAMPLE CONNECTION
SD	SHUTDOWN (INDIVIDUAL EQUIPMENT)
SG	SIGHT GLASS
SO	STEAM OUT CONNECTION
SW	SOCKET WELD
TB	TURBINE
TBC	TO BE CONFIRMED
TE	TURBO EXPANDER
THRD	THREADED
TSS	TEMPORARY SUCTION STRAINER
UA	UNIT ALARM
USD	UNIT SHUTDOWN
U/S	UNDERSIDE
VB	VACUUM BREAKER
VC	VENT CONNECTION
VFD	VARIABLE FREQUENCY DRIVE

INSTRUMENT IDENTIFICATION LETTERS

		A	AH	AHH	AHL	AL	ALL	C	CV	DR	E	FIC	G	I	IC	IS	IT	K	L	Q	R	RC	RR	S	SD	SDH	SDL	SE	SH	SL	SM	SV	T	V	W	Y	SC	SO	DV
		ALARM	ALARM HIGH	ALARM HIGH HIGH	ALARM HIGH/LOW	ALARM LOW	ALARM LOW LOW	CONTROLLER	CONTROL VALVE	DIFFERENTIAL RECORDER	PRIMARY ELEMENT	RATION CONTROLLER	GAUGE GLASS	INDICATOR	INDICATOR CONTROLLER	INDICATOR SWITCH	INDICATOR TRANSMITTER	MANUAL/AUTOMATIC (STATION)	STATUS LIGHT (NOT ALARM)	INTERGRATOR (TOTALIZER)	RECORDER	RECORDER (CONTROLLER)	RATIO RECORDER	SWITCH	SHUTDOWN	SHUTDOWN HIGH	SHUTDOWN LOW	SAFETY ELEMENT (RUPTURE DISC)	SWITCH HIGH	SWITCH LOW	SWITCH MIDDLE	SAFETY VALVE	TRANSMITTER	VALVE	THERMOWELL	RELAY COMPUTING SOLENOID VALVE	SWITCH CLOSED	SWITCH OPEN	DEPRESSURIZING VALVE
A	ANALYSIS		AAH	AAHH	AAHL	AAL	AALL	AC	ACV	ADR	AE			AI	AIC		AIT				AR	ARC	ARR	AS		ASDH	ASDL		ASH	ASL	ASM		AT			AY			
BJ	BURNER FAILURE	BJA																						BJS	BJSD														
E	EMERGENCY																								ESD									ESDV		EY			
F	FLOW		FAH	FAHH	FAHL	FAL	FALL	FC	FCV	FDR	FE	FFIC	FG	FI	FIC	FIS	FIT	FK	FL	FQ	FR	FRC	FRR	FS		FSDH	FSDL		FSH	FSL	FSM	FSV	FT			FY			
H	HAND (MANUAL)							HC	HCV															HS										HV					
J	POWER														JIC																		JT			JY			
K	TIME	KA						KC		KDR									KL	KQ																			
L	LEVEL		LAH	LAHH	LAHL	LAL	LALL	LC	LCV	LDR	LE		LG	LI	LIC	LIS	LIT		LL		LR	LRC	LRR	LS	LSD				LSH	LSL	LSM		LT			LY			
M	MOISTURE		MAH	MAHH	MAHL	MAL	MALL	MC	MCV	MDR	ME			MI	MIC	MIS	MIT		ML		MR	MRC	MRR	MS		MSDH	MSDL		MSH	MSL	MSM		MT			MY			
P	PRESSURE		PAH	PAHH	PAHL	PAL	PALL	PC	PCV	PDR	PE			PI	PIC	PIS	PIT	PK	PL		PR	PRC	PRR	PS		PSDH	PSDL	PSE	PSH	PSL	PSM	PSV	PT			PY			
S	SPEED		SAH	SAHH	SAHL	SAL	SALL	SC	SCV	SDR	SE			SI	SIC	SIS	SIT	SK	SL		SR	SRC	SRR	SS		SSDH	SSDL		SSH	SSL	SSM		ST			SY			
T	TEMPERATURE		TAH	TAHH	TAHL	TAL	TALL	TC	TCV	TDR	TE			TI	TIC	TIS	TIT	TK	TL		TR	TRC	TRR	TS	USD	TSDH	TSDL	TSE	TSH	TSL	TSM		TT		TW	TY			
U	UNIT/MULTI-VARIABLE										FE																						UT						UDV
V	VIBRATION		VAH	VAHH				VC			VE			VI							VR			VS		VSDH			VSH				VT						
W	WEIGHT		WAH	WAHH	WAHL	WAL	WALL	WC	WCV	WDR	WE			WI	WIC	WIS	WIT		WL	WQ	WR	WRC	WRR			WSDH	WSDL		WSH	WSL	WSM		WT			WY			
X	USER DEFINED																																	XV					
Z	LIMIT OR POSITION		ZAH	ZAHH	ZAHL	ZAL	ZALL				ZE			ZI		ZIS	ZIT		ZL							ZSDH	ZSDL		ZSH	ZSL	ZSM		ZT			ZY	ZSC	ZSO	

LINE NUMBER DESIGNATION

eg. PG-6"-CS-1001-38H-ET

- COMMODITY CODE (SEE TABLE)
- PIPE SIZE (NPS)
- SERVICE CLASS (1-4 LETTERS)
- LINE NUMBER (1001 - 9999)
- INSULATION TYPE & THICKNESS (SEE TABLE)
- TRACER TYPE (SEE TABLE)

COMMODITY CODES

ABBREVIATION	DESCRIPTION
AM	AMINE
BD	BLOWDOWN
BFW	BOILER FEED WATER
C	CONDENSATE
CH	CHEMICAL
CM	COOLING MEDIUM
D	DRAIN
FG	FUEL GAS, START GAS
G	GLYCOL
H	HYDRAULIC FLUID
HCL	HYDROCARBON LIQUIDS
HM	HEAT MEDIUM
HPF	HIGH PRESSURE FLARE (>1 psig)
IA	INSTRUMENT AIR
IG	INSTRUMENT GAS
JW	ENGINE JACKET WATER
LO	LUBE OIL, WASTE OIL
LPF	LOW PRESSURE FLARE (<1 psig)
M	METHANOL
MS	MISCELLANEOUS
N	NITROGEN
OD	OPEN DRAIN
P	MISCELLANEOUS OTHER PROCESS
PE	EMULSION
PG	GAS
PO	OIL
PW	PRODUCED WATER
S	STEAM
SAS	SANITARY SEWER
SC	SOUR CONDENSATE
SG	SOUR GAS
WS	POTABLE WATER

INSULATION TYPE

25	INSULATION THICKNESS (mm)
H	HEAT CONSERVATION/FREEZE PROTECTION
C	LOW TEMPERATURE SERVICE
PP	PERSONNEL PROTECTION

TRACER TYPE

GT	GLYCOL TRACE
ET	ELECTRIC TRACE
OT	HOT OIL TRACE
ST	STEAM TRACE

LINE CODE

- PRIMARY PROCESS PIPING
- UTILITY/SECONDARY PROCESS PIPING
- NON-SIGNAL / NON-INSTRUMENT TUBING
- EXISTING PIPING AND EQUIPMENT
- FUTURE PIPING AND EQUIPMENT
- PACKAGE BOUNDARY LIMITS

INSTRUMENT LINE CODE

- ELECTRIC SIGNAL
- PNEUMATIC SIGNAL
- CAPILLARY TUBING
- HYDRAULIC SIGNAL
- SYSTEM LINK
- MECHANICAL LINK
- ELECTROMAGNETIC OR SONIC SIGNAL *

* ELECTROMAGNETIC PHENOMENA INCLUDES: HEAT, RADIO WAVES, NUCLEAR RADIATION AND LIGHT

OPTIONAL BINARY (ON-OFF) SYMBOLS

- PNEUMATIC BINARY SIGNAL
- ELECTRIC BINARY SIGNAL

EQUIPMENT NUMBER DESIGNATION

eg. K-200

- EQUIPMENT DESIGNATION (SEE TABLE)
- SEQUENTIAL NUMBER (IN INCREMENTS OF 1)
- SERIES DESIGNATION (SEE TABLE)

EQUIPMENT DESIGNATION

B	AIR BLOWER OR FAN	I	INCINERATOR
BF	BUILDING EXHAUST FAN	K	COMPRESSOR
BH	BUILDING HEATER	DR	DRIVER
C	COOLERS (AIR EXCHANGERS)	P	PUMP
Q	BUILDING	R	REACTOR OR CONVERTOR
E	EXCHANGER	S	TOWER
F	FILTER	T	STORAGE TANK
FL	FLARE STACK	X	PIG LAUNCHER OR RECEIVER
G	GENERATOR (ELECTRIC)	V	VESSEL
H	FIRED HEATER OR BOILER	D	PACKAGE UNIT
M	MISCELLANEOUS	SP	SPECIALTY
*	– INCLUDES VENDOR EQUIPMENT		

SERIES DESIGNATION

100	INLET AREA (eg. INLET SEP.)
200	COMPRESSION / TREATING
300	DEHYDRATION UNITS
400	PROCESSING UNITS (eg. REFRIG)
500	PROCESSING UNITS (eg. SWEETENING)
600	PROCESSING UNITS
700	UTILITY (eg. Inst.Air, Fuel Gas, GLYCOL H.M., BLDG. HEATERS, DRAINS)
800	VENT / FLARE SYSTEMS
900	TANKS / STORAGE / VAPOUR TIGHT STORAGE TANKS
1000	PIG LAUNCHERS
1100	PIG RECEIVERS

VALVE IDENTIFICATION

eg. 6"GA601S

- VALVE SIZE (NPS")
- VALVE TYPE (SEE VALVE MODIFIER)
- ANSI CLASS & SPECIALS

MATERIALS OPTIONS
- S – SOUR, STD TEMPERATURE (–29°C MIN)
- L – LOW TEMPERATURE (–45°C MIN)
- SL – SOUR, LOW TEMPERATURE (–45°C MIN)
- H – HIGH TEMPERATURE (<344°C)
- SS – SOUR, STAINLESS STEEL
- X – SPECIAL REQUIREMENTS
- M – UNIQUE METALLURGY

END CONNECTIONS
- 1 – RAISED FACE FLANGES
- 2 – THREADED, FEMALE-FEMALE
- 3 – SOCKET WELD ENDS
- 4 – SOCKET WELD x THREADED
- 5 – RING TYPE JOINT FLANGES
- 6 – FLUSH FACED FLANGES
- 7 – BUTT WELD ENDS
- 8 – CLAMP CONNECTOR ENDS (i.e. GRAYLOC)
- 9 – THREADED, MALE-FEMALE

VALVE CODE	ANSI CLASS	THREADED/SOCKET WELD VALVE MINIMUM RATING: BALL (CLASS)	CHECK (CLASS)	GLOBE GATE (API CLASS)	NEEDLE (CLASS)
1	150	3000	3000	800	3000
3	300	3000	3000	800	3000
6	600	3000	3000	800	3000
9	900	6000	6000	1500	6000
15	1500	6000	6000	1500	6000
25	2500	10000	10000	ANSI 2500	10000
30	3000 PSI MAX CWP OR WOG				
60	6000 PSI MAX CWP OR WOG				

VALVE MODIFIER

GATE (GA)
- 0 – STANDARD
- 1 – FULL PORT
- 2 – SLAB
- 3 – BELLOWS SEAL

GLOBE (GL)
- 0 – STANDARD
- 1 – FULL PORT
- 2 – STEAM
- 3 – BELLOWS SEAL

CHECK (CH)
- 0 – SWING OR LIFT
- 1 – SWING FULL PORT
- 2 – PISTON
- 3 – WAFER
- 4 – NON-SLAM

PLUG (PL)
- 0 – REGULAR
- 1 – SHORT
- 2 – JACKET
- 3 – DOUBLE BLOCK & BLEED

BALL (BA)
- 0 – REGULAR
- 1 – FULL PORT

BUTTERFLY (BU)
- 0 – RUBBER LINED
- 1 – TFE SEAT
- 2 – METAL SEAT

NEEDLE (NE)
- 0 – REGULAR
- 1 – LAG EXT.

INSTRUMENT OR FUNCTION SYMBOLS

	FIELD MOUNTED	PRIMARY LOCATION NORMALLY ACCESSIBLE TO OPERATOR	PRIMARY LOCATION NORMALLY INACCESSIBLE TO OPERATOR OR BEHIND PANEL	AUXILIARY LOCATION NORMALLY ACCESSIBLE TO OPERATOR	AUXILIARY LOCATION NORMALLY INACCESSIBLE TO OPERATOR OR BEHIND PANEL
DISCRETE INSTRUMENTS					
SHARED DISPLAY, SHARED CONTROL					
COMPUTER FUNCTION					
PROGRAMMABLE LOGIC CONTROL (PLC)					

- SHARED COMMON HOUSING
- PILOT LIGHT (SHOW COLOR INSIDE SYMBOL)
- PANEL MOUNTED PATCHBOARD POINT 12 (C, 12)
- HEAT TRACED AND INSULATED INSTRUMENTS
- PURGE OR FLUSHING DEVICE (P)
- RESET FOR LATCH-TYPE ACTUATOR (R)
- DIAPHRAGM SEAL
- UNDEFINED INTERLOCK LOGIC
- EMERGENCY SHUTDOWN
- LOGIC INTERFACE

–	A	JUN 19/15	ISSUED FOR INFORMATION	GK	
REFERENCE DRAWING TITLE/No.	REV	DATE	REVISION DESCRIPTION	BY	ENGINEER'S STAMP

NOTES:

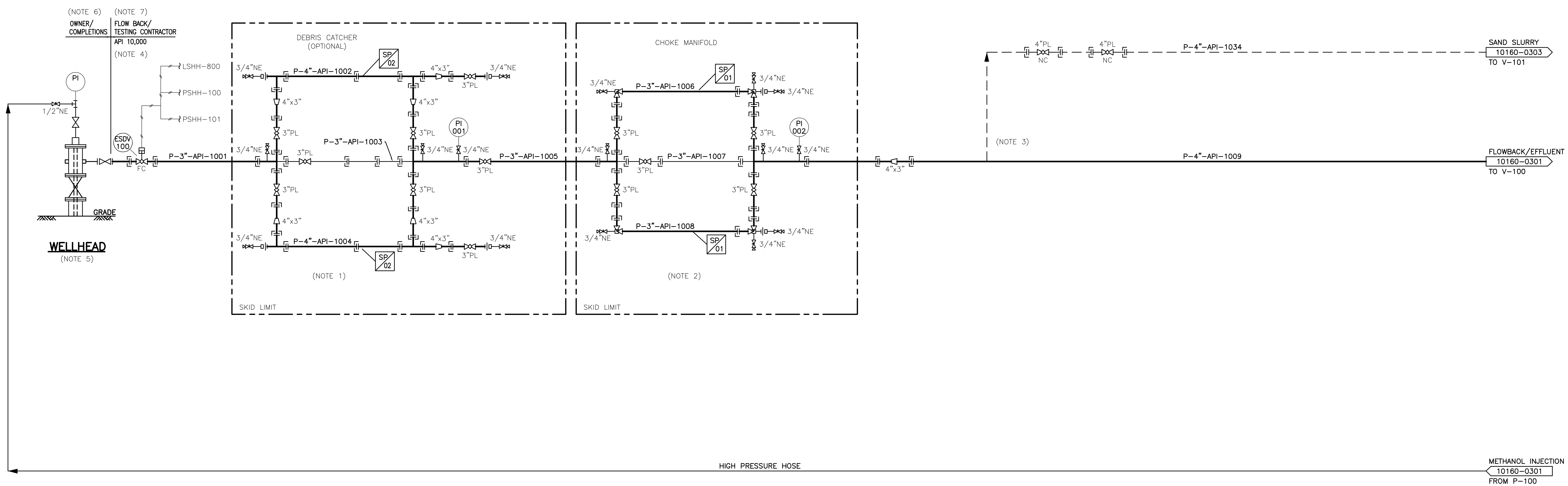
BY	– –
CHECK	– –
PROCESS	– –
MECH	– –
ELEC. I&C	– –
CIV/STRUC	– –
CLIENT	– –
DRAWING ORIGIN	

CLIENT: CLEARSTONE ENGINEERING

DRAWING TITLE: TYPICAL REDUCED EMISSIONS WELL COMPLETION PACKAGE P&ID SYMBOLS

VANGUARD ENGINEERING INC

PERMIT/CERTIFICATE No.	–
PROJECT No.	CEL-15001
SCALE	NTS
DRAWING No.	10160-0001
REV	A



NOTES:

1) DEBRIS CATCHER IS REQUIRED ONLY FOR FRACS USING NON-DISSOLVEABLE PLUGS THAT MUST BE DRILLED OUT PRIOR TO FLOW BACK.
2) MULTIPLE CHOKE MANIFOLDS IN SERIES IF REQUIRED TO MANAGE WELLHEAD PRESSURE.
3) SCREEN OUT FLOW BACK WILL BE THROUGH "GUT" LINE (I.E. BY-PASS CATCHER & CHOKE MANIFOLD) AND DIRECTLY TO SAND CONTAINMENT VESSEL.
4) ALL MATERIAL SHALL BE PER API 6A, PSL-1, PR-1, TEMPERATURE CLASS L, MATERIAL CLASS AA.
5) BALL PLUG CATCHER, IF REQUIRED, AND METHANOL INJECTION POINT(S) ARE ON WELLHEAD.
6) SHUT-IN PRESSURE AT SURFACE SHALL NOT EXCEED 69 MPa(10,000 Psig).
7) WHILE IN OPERATION PERSONNEL CONTINUOUSLY MONITOR AND ATTEND TO FLOW BACK PIPING AND EQUIPMENT.

REFERENCE DRAWING TITLE/No.
–

REV	DATE	REVISION DESCRIPTION	BY
A	JUN 30/15	ISSUED FOR REVIEW	DM

ENGINEER'S STAMP

BY	SH	JUN 05/15
CHECK	–	–
PROCESS	–	–
MECH	VB	JUN 05/15
ELEC. I&C	–	–
CIV/STRUC	–	–
CLIENT	–	–

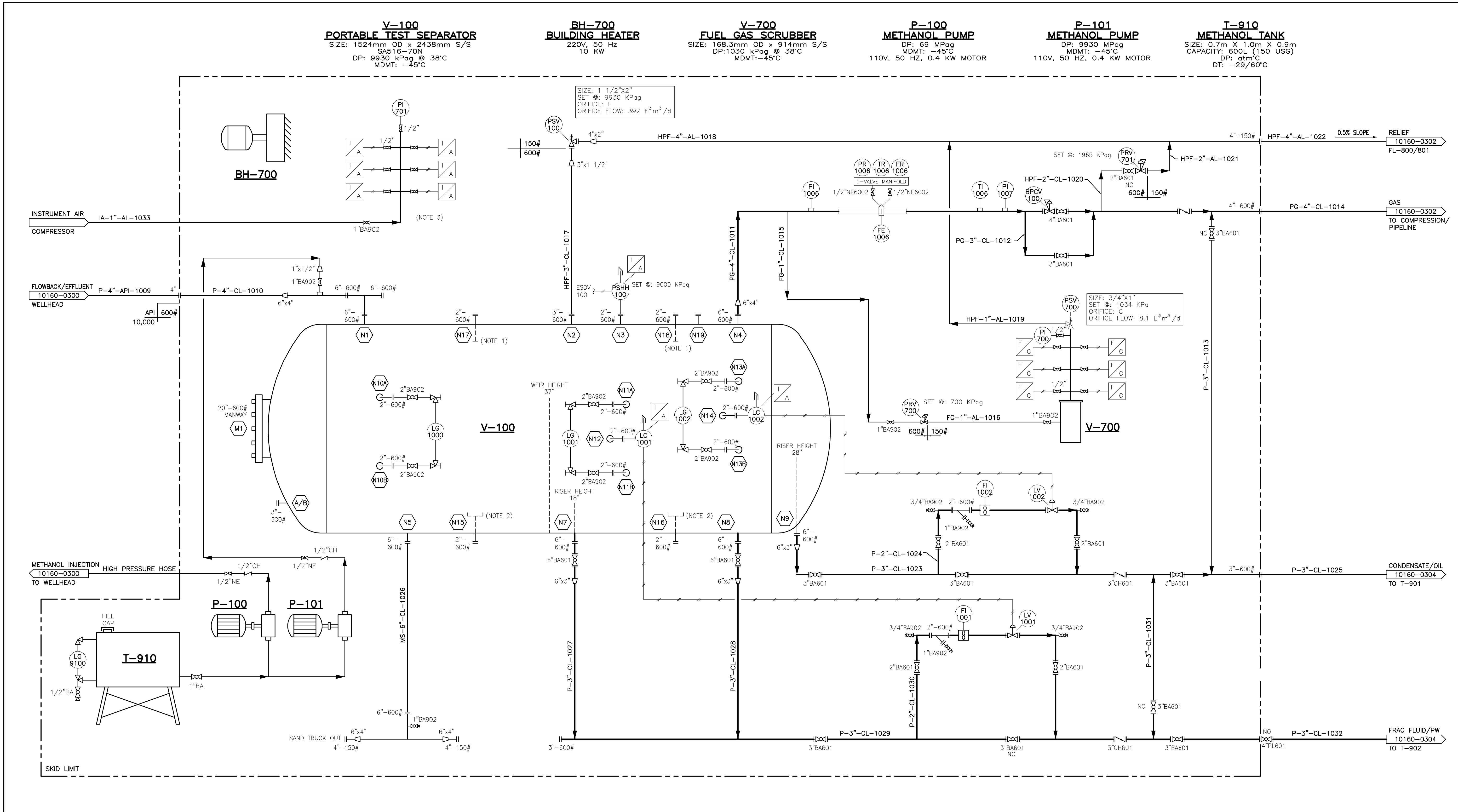
DRAWING ORIGIN

CLIENT: CLEARSTONE ENGINEERING

DRAWING TITLE: TYPICAL REDUCED EMISSIONS WELL COMPLETION PACKAGE CHOKES AND INLET P&ID

VANGUARD ENGINEERING INC

PERMIT/CERTIFICATE No.	–
PROJECT No.	CEL-15001
SCALE	NTS
DRAWING No.	10160-0300
REV	A



NOTES:

1) ROTATING NOZZLE FOR SAND JETTING.
2) SAND JETTING RING.
3) NITROGEN BOTTLE(S) FOR BACK-UP SUPPLY.

BY	SH	JUN 05/15
CHECK	–	–
PROCESS	–	–
MECH	VB	JUN 05/15
ELEC. I&C	–	–
CIV/STRUC	–	–
CLIENT	–	–

REV	DATE	REVISION DESCRIPTION	BY
A	JUN 30/15	ISSUED FOR REVIEW	DM

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REFERENCE DRAWING TITLE/No.

ENGINEER'S STAMP

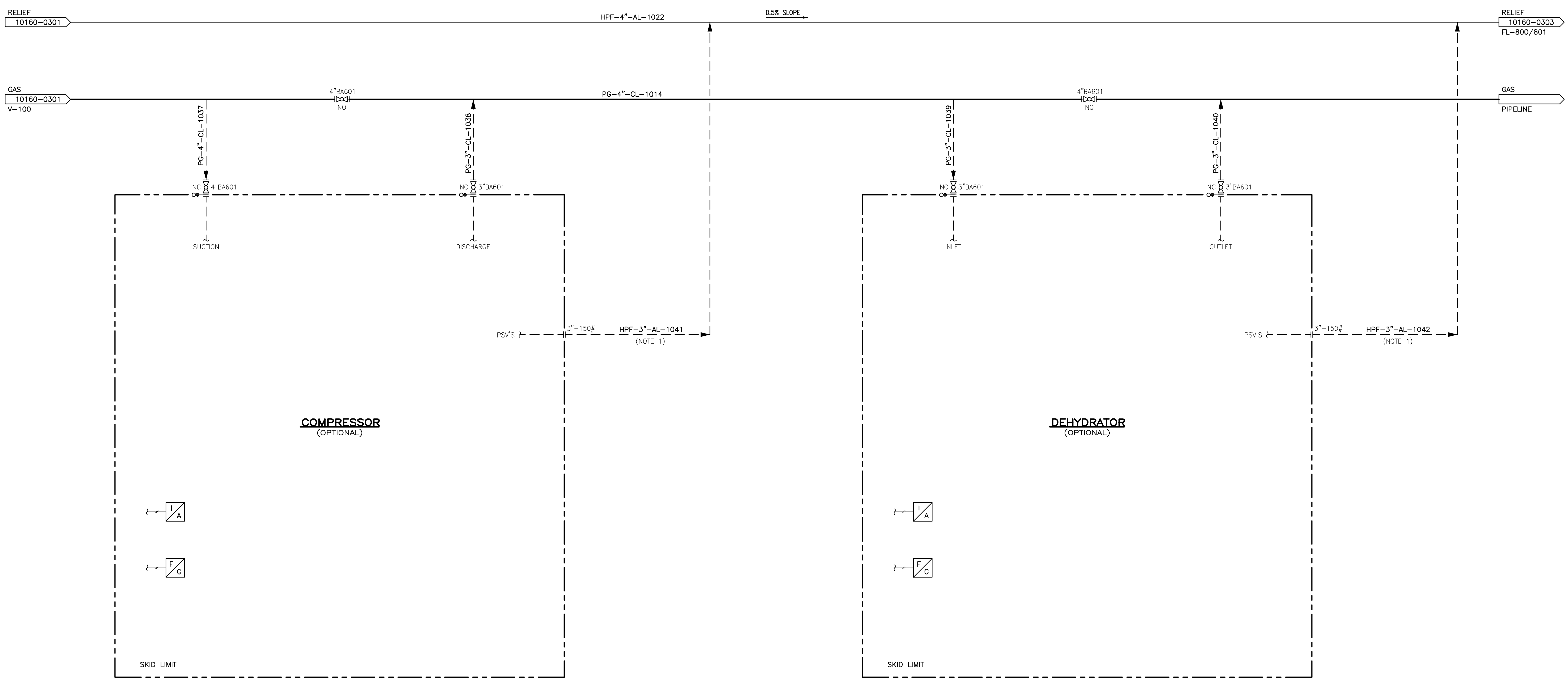
DRAWING ORIGIN

CLIENT: CLEARSTONE ENGINEERING

DRAWING TITLE: TYPICAL REDUCED EMISSIONS WELL COMPLETION PACKAGE TEST SEPARATOR P&ID

VANGUARD ENGINEERING INC

PERMIT/CERTIFICATE No.	–
PROJECT No.	CEL-15001
SCALE	NTS
DRAWING No.	10160-0301
REV	A



NOTES:
1) DO NOT POCKET AND SLOPE TOWARD RELIEF HEADER.

REFERENCE DRAWING TITLE/No.
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A	JUN 30/15	ISSUED FOR REVIEW	DM

ENGINEER'S STAMP

BY	SH	JUN 05/15
CHECK	–	–
PROCESS	–	–
MECH	VB	JUN 05/15
ELEC, I&C	–	–
CIV/STRUC	–	–
CLIENT	–	–

DRAWING ORIGIN

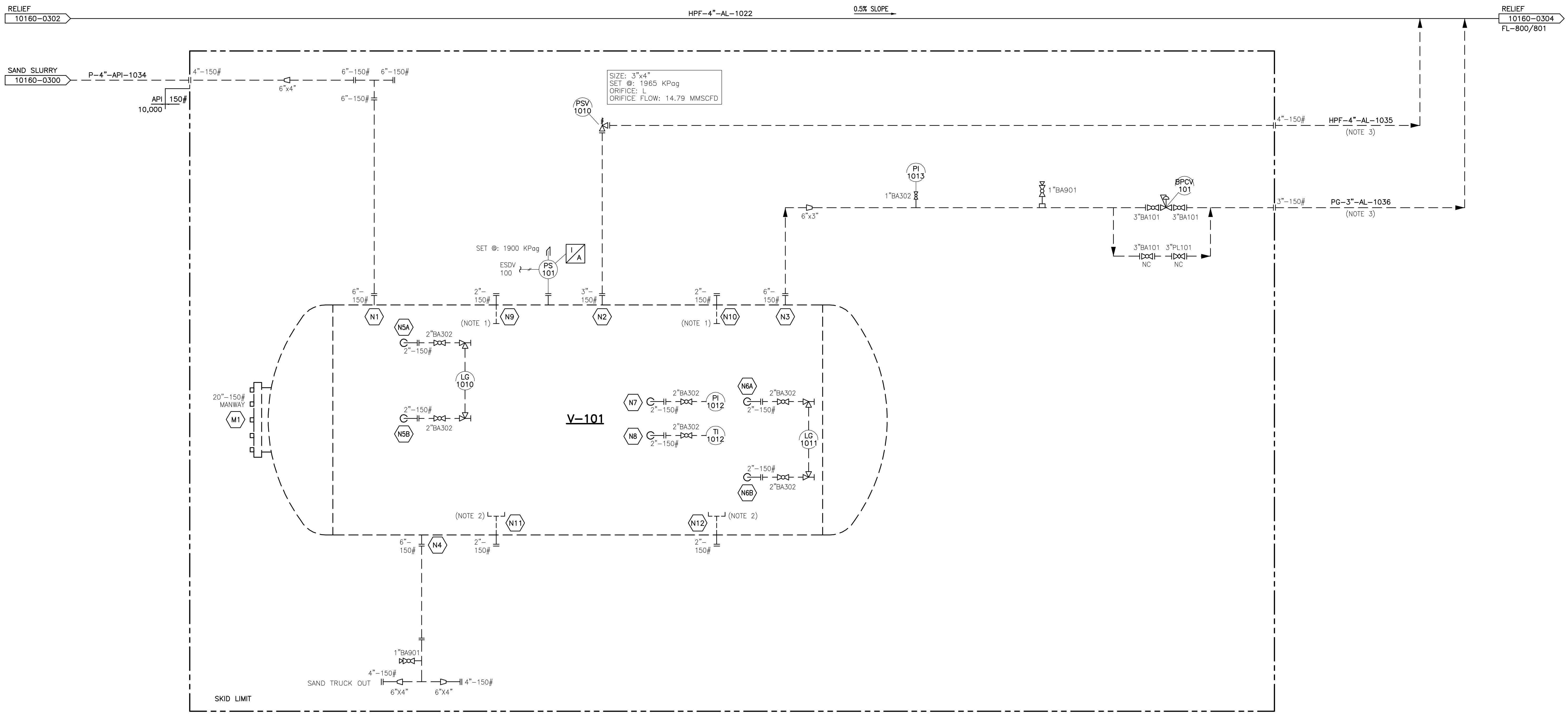
CLIENT: CLEARSTONE ENGINEERING

DRAWING TITLE: TYPICAL REDUCED EMISSIONS WELL COMPLETION PACKAGE COMPRESSOR & DEHYDRATOR (OPTIONAL) P&ID

VANGUARD ENGINEERING INC

PERMIT/CERTIFICATE No.	–
PROJECT No.	CEL-15001
SCALE	NTS
DRAWING No.	10160-0302
REV	A

V–101
SAND CONTAINMENT VESSEL
SIZE: 2438mm OD x 7315mm S/S
DP: 1030 kPag @ 38°C
MDMT: –45°C



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REFERENCE DRAWING TITLE/No.

NOTES:
1) ROTATING NOZZLE FOR SAND JETTING.
2) SAND JETTING RING.
3) DO NOT POCKET AND SLOPE TOWARD RELIEF HEADER.

REV	DATE	REVISION DESCRIPTION	BY
A	JUN 30/15	ISSUED FOR REVIEW	DM

ENGINEER'S STAMP

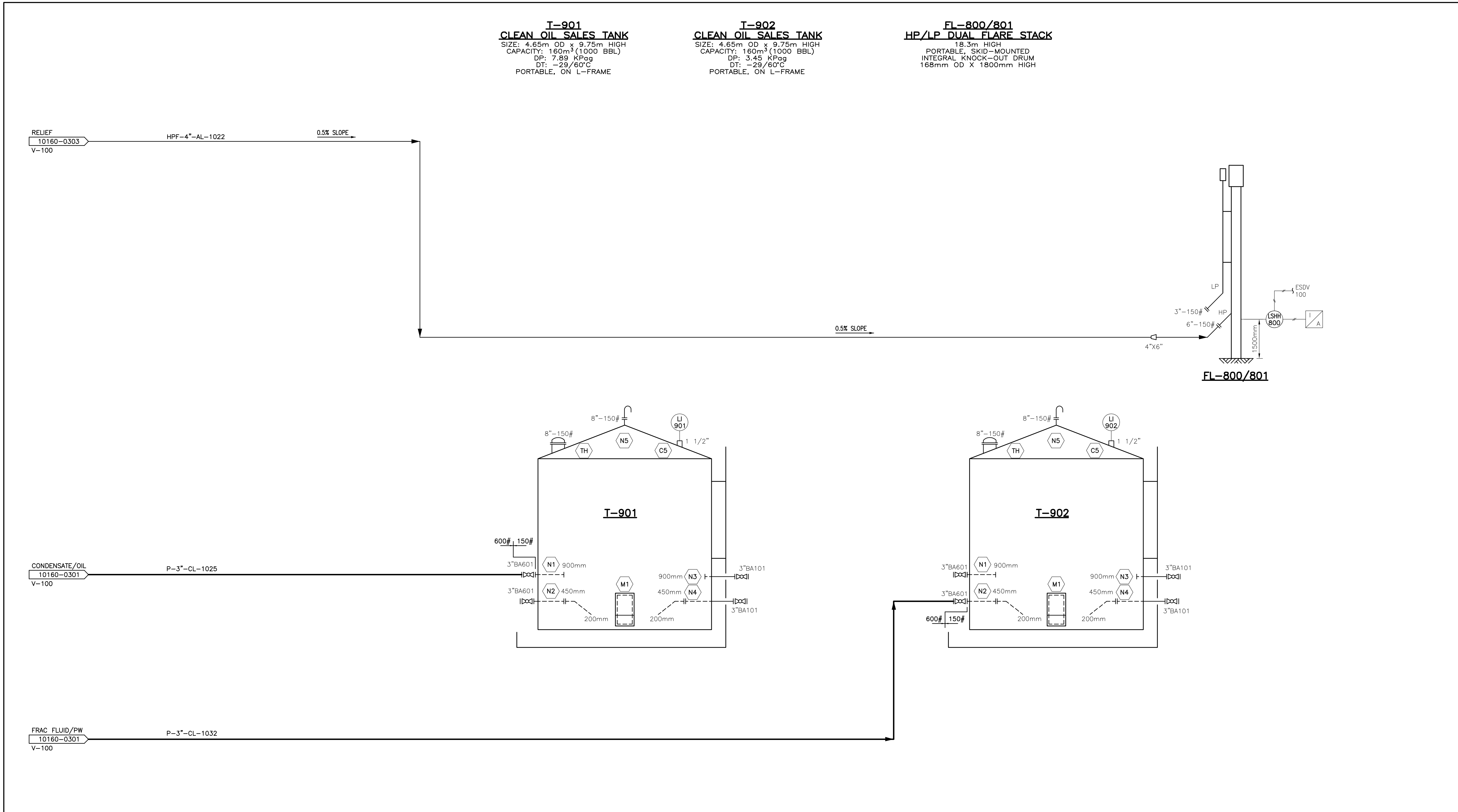
BY	SH	JUN 05/15
CHECK	–	–
PROCESS	–	–
MECH	VB	JUN 05/15
ELEC. I&C	–	–
CIV/STRUC	–	–
CLIENT	–	–
DRAWING ORIGIN		

CLIENT: CLEARSTONE ENGINEERING

DRAWING TITLE
TYPICAL REDUCED EMISSIONS WELL COMPLETION PACKAGE SAND CONTAINMENT VESSEL (OPTIONAL) P&ID

VANGUARD ENGINEERING INC

PERMIT/CERTIFICATE No.	–
PROJECT No.	CEL–15001
SCALE	NTS
DRAWING No.	10160–0303
REV	A



	NOTES:			
-		A	JUN 30/15	ISSUED FOR REVIEW	DM
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ENGINEER'S STAMP

BY	SH	JUN 05/15
CHECK	–	–
PROCESS	–	–
MECH	VB	JUN 05/15
ELEC. I&C	–	–
CIV/STRUC	–	–
CLIENT	–	–

DRAWING ORIGIN

CLIENT

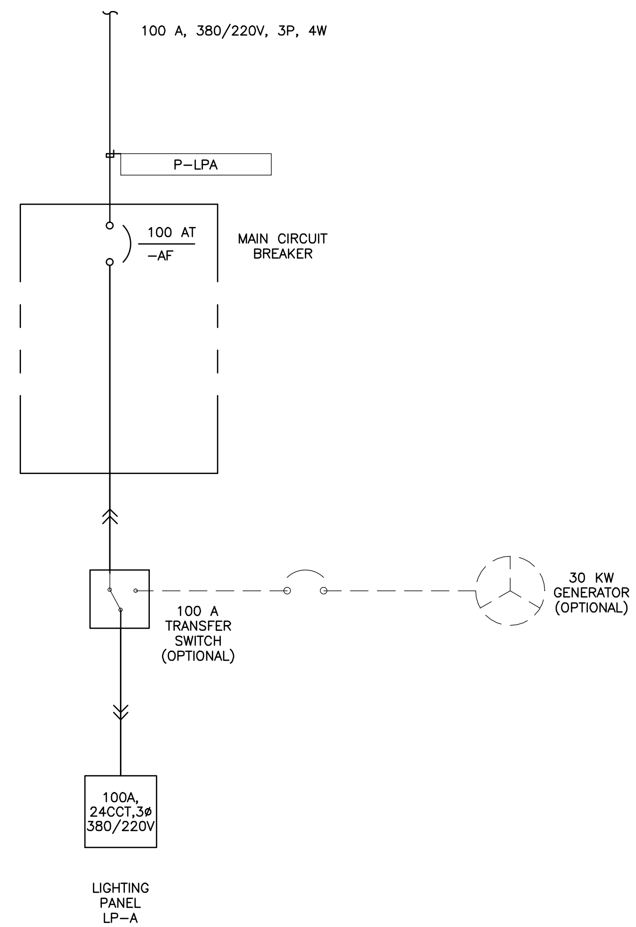
CLEARSTONE ENGINEERING

DRAWING TITLE

TYPICAL REDUCED EMISSIONS WELL COMPLETION PACKAGE TANKS AND FLARE P&ID

VANGUARD ENGINEERING INC

PERMIT/CERTIFICATE No.	–
PROJECT No.	CEL-15001
SCALE	NTS
DRAWING No.	10160-0304
REV	A



SINGLE LINE DIAGRAM

LOCATION – GENERATOR SKID

LIGHTING PANEL 'LP-A'

100A, 380/220V, 3-PHASE, 4-W, 50Hz, MAIN LUG ONLY

	WATTS øA	WATTS øB	WATTS øC	BKR. SIZE (AMPS)	CIRCUIT No.	CIRCUIT No.	BKR. SIZE (AMPS)	WATTS øA	WATTS øB	WATTS øC	
P-100 METHANOL PUMP MOTOR	400			15	1	2	15	800			SEPARATOR SKID LIGHTING & RECEPT
P-101 METHANOL PUMP MOTOR	400			15	3	4	15		800		SAND SKID LIGHTING & RECEPT
UPS 240VAC SUPPLY (FUTURE)			1100	20	5	6	15			800	COMPRESSOR LIGHTING & RECEPT (FUTURE)
	1100			2P	7	8	15	800			DEHYDRATOR LIGHTING & RECEPT (FUTURE)
BH-700 BUILDING HEATER		5000		30	9	10	15		–		SPARE
			5000	2P	11	12	15			–	SPARE
INSTRUMENT AIR COMPRESSOR	2200			20	13	14	15	–			SPARE
		2200		2P	15	16	15		–		SPARE
SPACE					17	18					SPACE
SPACE					19	20					SPACE
SPACE					21	22					SPACE
SPACE					23	24					SPACE
CONNECTED LOAD	4100	7200	6100		NOTE 1 (TYP)			1600	800	800	CONNECTED LOAD
TOTAL CONNECTED LOAD = 20600W								* HEAT TRACE CIRCUITS REQUIRE GFI BREAKERS.			

NOTES:

1. LOAD VALUES FOR LIGHTING & RECEPTACLES ARE ESTIMATED.
2. DESIGN BASED ON CEC 2012.

–	A	JULY 29/15	ISSUED FOR APPROVAL	SS	
REFERENCE DRAWING TITLE/No.	REV	DATE	REVISION DESCRIPTION	BY	ENGINEER'S STAMP

BY	SS	JULY 02/15
CHECK	–	–
PROCESS	–	–
MECH		
ELEC, I&C	WB	JULY 02/15
CIV/STRUC	–	–
CLIENT	–	–
DRAWING ORIGIN		

CLIENT: CLEARSTONE ENGINEERING

DRAWING TITLE: TYPICAL REDUCED EMISSIONS WELL COMPLETION PACKAGE SINGLE LINE AND PANEL SCHEDULE

VANGUARD ENGINEERING INC

PERMIT/CERTIFICATE No. –

PROJECT No. CEL-15001

SCALE NTS

DRAWING No. KC15523-ELE-9050 REV A

VANGUARD ENGINEERING INC

Separator Data Sheet

Document #	**DS01**	Tag #	**V-100**
Owner	**Clearstone Engineering Ltd.**	Model #	
Project	**REC 4-Phase Separator Package FEED**	Serial #	
Manufacturer		CRN	N/A

Properties & Conditions

	Normal Operation	Design
PROCESS FLUID	shale gas and light oil emulsion	shale gas and light oil emulsion
INLET PROPERTIES:		
- Volume Fraction Water	0.9	0.45
- Inlet Temperature (°C) / (°F)	15 / 60	15 / 60
- Specific Gravity of Oil	0.78	0.86
- Specific Gravity of Water	1.03	1.00
- H2S concentration (%)	0.0	0.0
SEPARATING CONDITIONS:		
- Minimum Oil Retention Time (min)	2	1
- Minimum Water Retention Time (min)	2	1
- Minimum Ambient Temperature (°C) / (°F)	-15 / -26	-45 / -50
SEPARATOR PROPERTIES		
- Oil Volume Flow Rate (m3/d) / (bpd)	5.5 / 35	200 / 1258
- Water Volume flow rate (m3/d) / (bpd)	375 / 2359	415 / 2610
- Sand Volume in Settling Zone (m3) / (bbl)	2.0 / 12.5	3.0 / 19.0
- Gas Capacity (E3 m3/d) / (MMSCFD)	280 / 10	540 / 19
- Insulated (Y/N)	N	N
- Ultimate Oil/Water Separation Capacity (m3/d) / (bpd)	380 / 2390	615 / 3868

Vessel Specifications

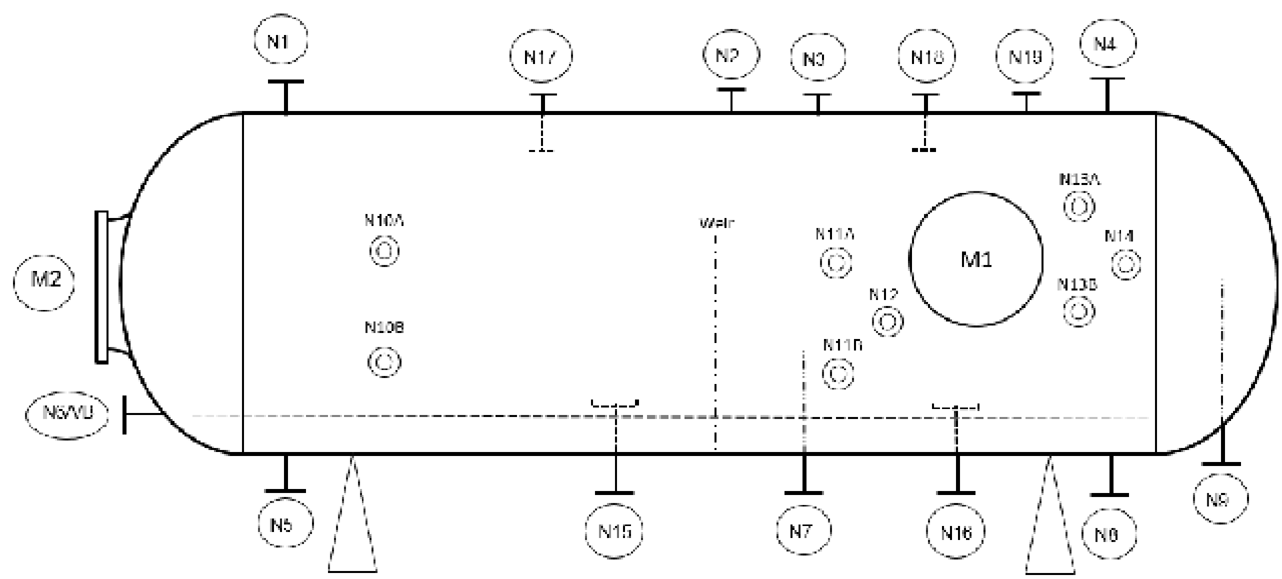
SIZE:	
- Seam to seam Length (mm) / (feet)	5486 / 18
- Outside Diameter (mm) / (feet)	1219 / 4
FLOW ORIENTATION	Horizontal
DESIGN PRESSURE (kPa) / (PSI)	9930 / 1440
MINIMUM DESIGN PRESSURE (kPaa) / (psia)	0 / 0
DESIGN TEMPERATURE (°C) / (°F)	54 / 130
MDMT (°C) / (°F)	-45 / -50
MATERIAL	SA516 - 70
EXTERNAL SURFACE PREPARATION	SSPC SP6 Commercial Blast
EXTERNAL SURFACE COATING	Epoxy Primer - Bar Rust 231 or Intergard 345 (4 - 5 mils)
INTERNAL SURFACE PREPARATION	SSPC SP5 Blast
INTERNAL PRIMER COATING	Devchem 253 (5 - 6 mils)
INTERNAL FINISH COATING	Devchem 253 (5 - 6 mils)
INSULATION	None
RADIOGRAPHY	R100
PWHT	per Design Code
STRESS RELIEF	per Design Code
ESTIMATED WEIGHT (kg) / (lb)	15105 / 33230

REV	Date	Originator	Checked	Approved	Description
B	June 11, 2015	VB	TM		Re-issued for Review

VANGUARD
ENGINEERING INC

Separator Data Sheet

Document #	**DS01**	Tag #	**V-100**
Owner	**Clearstone Engineering Ltd.**	Model #	
Project	**REC 4-Phase Separator Package FEED**	Serial #	
Manufacturer		CRN	N/A



Nozzles & Connections

Description (#)	Size (NPS)	Rating (ASME Class)	Material	Projection (mm)	Internal Coating
inlet (N1)	6	600	SA-333 Gr 6	60	Devchem 253
PSV (N2)	3	600	SA-333 Gr 6	60	Devchem 253
pressure switch (N3)	2	600	SA-333 Gr 6	60	Devchem 253
gas outlet (N4)	6	600	SA-333 Gr 6	60	Devchem 253
sand clean out (N5)	6	600	SA-333 Gr 6	60	Devchem 253
heating coil/tube (N6A/B)	3	600	SA-333 Gr 6	60	Devchem 253
sand slurry outlets (N7 and N8)	6	600	SA-333 Gr 6	60	Devchem 253
oil outlet (N9)	6	600	SA-333 Gr 6	60	Devchem 253
sand site glass (N10A/B)	2	600	SA-333 Gr 6	60	Devchem 253
water site glass (N11A/B)	2	600	SA-333 Gr 6	60	Devchem 253
water level control (N12)	2	600	SA-333 Gr 6	60	Devchem 253
oil site glass (N13A/B)	2	600	SA-333 Gr 6	60	Devchem 253
oil level control (N14)	2	600	SA-333 Gr 6	60	Devchem 253
front sand jetting ring (N15)	2	600	SA-333 Gr 6	60	Devchem 253
rear sand jetting ring (N16)	2	600	SA-333 Gr 6	60	Devchem 253
front spray (N17)	2	600	SA-333 Gr 6	60	Devchem 253
rear spray (N18)	2	600	SA-333 Gr 6	60	Devchem 253
spare (N19)	2	600	SA-333 Gr 6	60	Devchem 253
manway along horizontal (M1)	20	600	SA-333 Gr 6	60	Devchem 253
manway on vessel head (M2)	20	600	SA-333 Gr 6	60	Devchem 253

Notes

1) Sand weir at 3658 mm (12') from inlet; height 762 mm (30")

2) Hydrocarbon riser height: 508 mm (20"); Water riser height: 305 mm (15")

3) Nozzle neck thickness for inlet, sand, gas, water and oil outlets and sand clean out shall be 28.6 mm (1.125").

VANGUARD ENGINEERING INC

Separator Data Sheet

Document #	**DS02**	Tag #	**V-100**
Owner	**Clearstone Engineering Ltd.**	Model #	
Project	**REC 4-Phase Separator Package FEED**	Serial #	
Manufacturer		CRN	N/A

Properties & Conditions

	Normal Operation	Design
PROCESS FLUID	shale gas and light oil emulsion	shale gas and light oil emulsion
INLET PROPERTIES:		
- Volume Fraction Water	0.9	0.45
- Inlet Temperature (°C) / (°F)	15 / 60	15 / 60
- Specific Gravity of Oil	0.78	0.86
- Specific Gravity of Water	1.03	1.00
- H2S concentration (%)	0.0	0.0
SEPARATING CONDITIONS:		
- Minimum Oil Retention Time (min)	2	1
- Minimum Water Retention Time (min)	2	1
- Minimum Ambient Temperature (°C) / (°F)	-15 / -26	-45 / -50
SEPARATOR PROPERTIES		
- Oil Volume Flow Rate (m3/d) / (bpd)	5.5 / 35	500 / 3145
- Water Volume flow rate (m3/d) / (bpd)	375 / 2359	615 / 3868
- Sand Volume in Settling Zone (m3) / (bbl)	3.0 / 20	4.7 / 29.7
- Gas Capacity (E3 m3/d) / (MMSCFD)	280 / 10	630 / 22
- Insulated (Y/N)	N	N
- Ultimate Oil/Water Separation Capacity (m3/d) / (bpd)	380 / 2390	1115 / 7013

Vessel Specifications

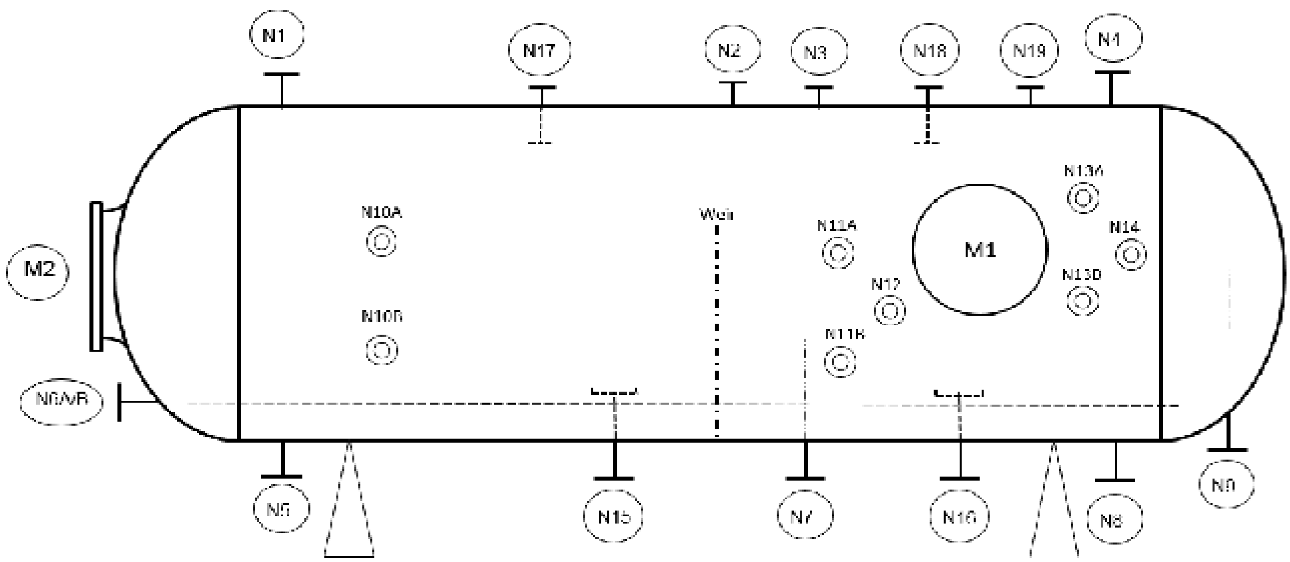
SIZE:	
- Seam to seam Length (mm) / (feet)	5486 / 18
- Outside Diameter (mm) / (feet)	1524 / 5'
FLOW ORIENTATION	Horizontal
DESIGN PRESSURE (kPa) / (PSI)	9930 / 1440
MINIMUM DESIGN PRESSURE (kPaa) / (psia)	0 / 0
DESIGN TEMPERATURE (°C) / (°F)	54 / 130
MDMT (°C) / (°F)	-45 / -50
MATERIAL	SA516 - 70
EXTERNAL SURFACE PREPARATION	SSPC SP6 Commercial Blast
EXTERNAL SURFACE COATING	Epoxy Primer - Bar Rust 231 or Intergard 345 (4 - 5 mils)
INTERNAL SURFACE PREPARATION	SSPC SP5 Blast
INTERNAL PRIMER COATING	Devchem 253 (5 - 6 mils)
INTERNAL FINISH COATING	Devchem 253 (5 - 6 mils)
INSULATION	None
RADIOGRAPHY	R100
PWHT	per Design Code
STRESS RELIEF	per Design Code
ESTIMATED WEIGHT (kg) / (lb)	23041 / 50691

REV	Date	Originator	Checked	Approved	Description
C	June 9, 2015	VB	TM		Re-issued for Review

VANGUARD ENGINEERING INC

Separator Data Sheet

Document #	**DS02**	Tag #	**V-100**
Owner	**Clearstone Engineering Ltd.**	Model #	
Project	**REC 4-Phase Separator Package FEED**	Serial #	
Manufacturer		CRN	N/A



Nozzles & Connections

Description (#)	Size (NPS)	Rating (ASME Class)	Material	Projection (mm)	Internal Coating
inlet (N1)	6	600	SA-333 Gr 6	60	Devchem 253
PSV (N2)	3	600	SA-333 Gr 6	60	Devchem 253
pressure switch (N3)	2	600	SA-333 Gr 6	60	Devchem 253
gas outlet (N4)	6	600	SA-333 Gr 6	60	Devchem 253
sand clean out (N5)	6	600	SA-333 Gr 6	60	Devchem 253
heating coil/tube (N6A/B)	3	600	SA-333 Gr 6	60	Devchem 253
sand slurry outlets (N7 and N8)	6	600	SA-333 Gr 6	60	Devchem 253
oil outlet (N9)	6	600	SA-333 Gr 6	60	Devchem 253
sand site glass (N10A/B)	2	600	SA-333 Gr 6	60	Devchem 253
water site glass (N11A/B)	2	600	SA-333 Gr 6	60	Devchem 253
water level control (N12)	2	600	SA-333 Gr 6	60	Devchem 253
oil site glass (N13A/B)	2	600	SA-333 Gr 6	60	Devchem 253
oil level control (N14)	2	600	SA-333 Gr 6	60	Devchem 253
front sand jetting ring (N15)	2	600	SA-333 Gr 6	60	Devchem 253
rear sand jetting ring (N16)	2	600	SA-333 Gr 6	60	Devchem 253
front spray (N17)	2	600	SA-333 Gr 6	60	Devchem 253
rear spray (N18)	2	600	SA-333 Gr 6	60	Devchem 253
spare (N19)	2	600	SA-333 Gr 6	60	Devchem 253
manway along horizontal (M1)	20	600	SA-333 Gr 6	60	Devchem 253
manway on vessel head (M2)	20	600	SA-333 Gr 6	60	Devchem 253

Notes

1) Sand weir at 3658 mm (12') from inlet; height 940 mm (37")

2) Hydrocarbon riser height: 711 mm (28"); Water riser height: 457 mm (18")

3) Nozzle neck thickness for inlet, sand, gas, water and oil outlets and sand clean out shall be 28.6 mm (1.125").

VANGUARD ENGINEERING INC

DOCUMENT No.	DS-03	TAG No. **G-700**	PAGE **1** OF **1**
CLIENT	**Clearstone Engineering Inc.**	JOB No.	**CEL-15001**

Equipment	Portable Generator		
PROJECT	**REC Separator Package**	SERVICE	**Power Generation**
MANUFACTURER		MODEL No.	QUANTITY **1**

Generator		Engine	
POWER RATING	Prime	MANUFACTURER	By Vendor
kW / kVA	30 / 30	MODEL	By Vendor
VOLTAGE (V)	220	TYPE	naturally aspirated
PHASE	1	CYCLES	4
FREQUENCY (Hz)	50 Hz	CYLINDERS	4
POWER FACTOR	1.0	SPEED (rpm)	By Vendor
OVERLOAD CAPABILITY (%)	10	RATING (hp)	By Vendor
		GOVERNER TYPE	By Vendor
PRIME MOVER	Engine		
FUEL	Dual Fuel: Diesel & Natural Gas		

Additional Systems

COOLING SYSTEM		FUEL SYSTEM	
TYPE	Air Cooled	RECOMMENDED FUEL	By Vendor
MOUNT	Engine Mounted	MAX. FUEL FLOW (Lph) / (gph)	By Vendor
RATING	By Vendor	FUEL PRIME PUMP	By Vendor
		FUEL TANK CAPACITY (L) / (gal.)	By Vendor
LUBRICATING SYSTEM		**ALTERNATOR**	
TYPE	By Vendor	MANUFACTURER	By Vendor
OIL PAN CAPACITY	By Vendor	TYPE	By Vendor
OIL PAN CAPACITY W/ FILTER	By Vendor	LEADS: QUANTITY/TYPE	By Vendor
		INSULATION TYPE/CLASS	By Vendor
		RATING	By Vendor
		VOLTAGE REGULATIONS	By Vendor

PACKAGE DESIGN

PACKAGE DIMENSIONS (L X W X H) (mm) / (in.)	By Vendor
PACKAGE WEIGHT (kg) / (lb)	By Vendor

DESIGN STANDARDS

NEMA	Required
ANSI	Required
IEEE	Required
CSA	Required
OTHER	

REMARKS **VENDOR TO COMPLETE DATA SHEET**

REV	DATE	BY	CK'D	APP.	DESCRIPTION	REV	DATE	BY	CK'D	APP.	DESCRIPTION
0	June 23/15	VB			Issued for review						

VANGUARD ENGINEERING INC	DOCUMENT No.	DS-03	TAG No. **K-700**	PAGE	**1**	OF **1**
	CLIENT	**Clearstone Engineering Inc.**		JOB No.	**CEL-15001**	

EQUIPMENT	**Instrument Air Compressor**				
PROJECT	**REC 4-Phase Separator Package**	SERVICE			
MANUFACTURER		MODEL No.		QUANTITY	**1**

COMPRESSOR	
TYPE	By Vendor
MIN RATED POWER (kW) / (HP)	3.7 / 5
NO. OF STAGES	By Vendor
GEAR RATIO	By Vendor
DRIVER	Electric Driver
INPUT SPEED (rpm)	By Vendor
VOLTAGE / FREQUENCY	220V / 50 Hz
MIN DISCHARGE PRESSURE (kPag) / (psig)	689 / 100
MAX DISCHARGE PRESSURE (kPag) / (psig)	1034 / 150
RATED FLOW (m3/min) / (scfm)	0.5 / 18
MIN DISCHARGE TEMPERATURE (℃) / (℉)	-20C / -4F
MAX DISCHARGE TEMPERATURE (℃) / (℉)	54C / 130F (Note 1)
OIL FLOODED	By Vendor
OIL FLOW FOR COMPRESSION (L/min) / (Gpm)	By Vendor
OIL INJECTION TEMPERATURE (°C) / (°F)	By Vendor
MIN OIL FILL BEFORE STARTUP (L) / (Gal.)	By Vendor
SUGGESTED OIL TYPE&GRADE	By Vendor

ADDITIONAL EQUIPMENT

DRYER		RECEIVER	
REQUIRED	Yes	REQUIRED	Yes
TYPE	Dessicant	ORIENTATION	By Vendor
RATED FLOW (m3/min) / (scfm)	0.5 / 18	SIZE (L) / (Gal.)	300 / 80
DEW POINT (°C) / (°F)	-40C / -40F	DRAIN TYPE	Manual
VOLTAGE / FREQUENCY	220V / 50 Hz		

PACKAGE DESIGN	
PIPING MATERIAL	A106 - B smls
FITTINGS	A105
TUBING MATERIAL	A269 - 316 SS
HI/LO PRESSURE SWITCHES	Required
HIGH TEMPERATURE SHUTDOWN	Required
PACKAGE DIMENSIONS (L X W X H) (mm) / (in.)	By Vendor
PACKAGE WEIGHT (kg) / (lb)	By Vendor

CONNECTIONS

	MK	QTY	SIZE	RATING	TYPE	REMARKS
OUTLET		**1**		**150#**	**NPT**	**By Vendor**
DRAIN		**1**		**150#**	**NPT**	**By Vendor (Note 2)**
INSPECTION PORT		**1**		**150#**	**NPT**	**By Vendor**
PSV		**1**				**By Vendor**

REMARKS **VENDOR TO COMPLETE DATA SHEET**

1. Maximum temperature is based on the design temperature of the REC 4-phase Separator vessel
2. Outlet will feed Instrument Air header and divide into eight (8), 1/2" - 150# NPT connections

REV	DATE	BY	CK'D	APP.	DESCRIPTION	REV	DATE	BY	CK'D	APP.	DESCRIPTION
0	June 23/15	VB			Issued for review						

PRESSURE RELIEF VALVES

CLIENT: Clearstone Engineering Ltd.	REVISIONS				SHT# PSV-01
	NO	BY	DATE	DESCRIPTION	Doc# VEI-DS-011
	A	VB	July 22/2015		CP#
					Req#
PROJECT: REC 4-Phase Separator					PO#
					App'd by:
					Chk'd by: TM

GENERAL	1	Tag Number	PSV-100		PSV-700		PSV-1010			
	2	Service	Gas		Gas		Gas			
	3	Line No./Vessel	V-100		V-700		V-101			
	4	Full Nozzle / Semi Nozzle								
	5	Safety or Relief	Safety		Safety		Safety			
	6	Conv., Bellows, Pilot Op								
	7	Bonnet Type								
CONN.	8	Size: Inlet | Outlet	1 1/2"	2"	1"	1"	2"	3"		
	9	Flange Rating or Screwed	600#	150#	150#	150#	150#	150#		
	10	Type of Facing	RF		npt		RF			
MATERIALS	11	Body and Bonnet	Carbon Steel		Carbon Steel		Carbon Steel			
	12	Seat and Disc	316 SS		316 SS		316 SS			
	13	Resilient Seat Seal								
	14	Guide and Rings	std		std		std			
	15	Spring								
	16	Bellows								
	17									
OPTIONS	18	Cap: Screwed or Bolted								
	19	Lever: Plain or Packed								
	20	Test Gag								
	21									
	22									
	23									
BASIS	24	Code								
	25	Sizing Case								
	26									
FLUID DATA	27									
	28	Fluid and State	Gas		Gas		Gas			
	29	Required Capacity	11,800		250		11,800			
	30	Mol. Wt. | S.G. @ Oper.P/T		0.65		0.65		0.65		
	31	Oper. Press. | Set Press.	6900	9930	690	1034	690	1965		
	32	Oper. Temp. | Rel. Temp.	15	32	15	32	15	32		
(Engineer'g Units)	33	Back Pressure - Constant								
Press. = kPag	34	Back Pressure - Variable								
Temp. = C	35	Back Pressure - Total								
Liq. Flow = Am3/h	36	% Allowable Overpressure								
Gas Flow = Sm3/h	37	Overpressure Factor								
Stm. Flow = kg/h	38	Compressibility Factor	0.9383				0.9383			
	39	Latent Heat of Vaporization								
	40	Ratio of Specific Heats								
	41	Operating Viscosity cP								
	42	Barometric Pressure								
	43	P&ID No.	10160-0301		10160-0301		10160-0303			
	44	Notes								
ORIFICE	45	Calculated Area (sq. in.)	0.2436				1.2277			
	46	Selected Area (sq. in.)	0.337				1.43			
	47	Orifice Designation	F		Carbon Steel		J			
	48	Manufacturer								
	49	Model Number								

NOTES:

** Vendor to provide this information with quotation.

Client:	Vanguard	**Vanguard**	**Document Rev:**	A
Description:	REC skids	**Instrument List**		IFR
Project Name:	REC skids	**REC Skids**		
Job Number:				

ITEM	P&ID	TAG	DESCRIPTION	LINE	SUPPLIED BY	MANUFACTURER	MODEL	SUPPLIER	DATA SHEET	COMMENTS	UNITS	LRL	URL	Calibrated Range	Output	SET POINT	I/O Drawing
1	300	PI-001	1/2" npt bottom mount, liquid filled gauge, 4" face, dual scale		Vanguard	Wika	233.3	Wika		recommend flanged hi pressure diaphragm seal L990 12 or similar	Mpa/Psi	0	69 Mpa/10000 Psi				
2	300	PI-002	1/2" npt bottom mount, liquid filled gauge, 4" face, dual scale		Vanguard	Wika	233.3	Wika		recommend fla ed hi ressure dia hra m seal L990 12 or similar	Mpa/Psi	0	69 Mpa/10000 Psi				
3	300	ESDV-100	Streamflow SSV valve with Hydraulic ESDV actuation system, c/wpneumatic switching valve for esd system.		Vanguard	Streamflow	SSVxxxx	Streamflow		API 10000	Kpa/Psi					0 to 689 Kpa	
4	301	FI-1002	1.5x2" wafer, cdm4 cu rotor with tungsten carbide sleeve bearing, 1 C size lithium battery with 24 vdc option.		Vanguard	Sponsler	turbine WM0200X2 Display IT400-DC-TRL-X	Carbon Controls		1.5x2" wafer, cdm4 cu rotor with tungsten carbide sleeve bearing, 1 C size lithium battery with 24 vdc option.	m3/day	80	1000	80 to 1000	4-20mA option		
5	301	FI-1001	2x2" wafer, cdm4 cu rotor with tungsten carbide sleeve bearing, 1 C size lithium battery with 24 vdc option.		Vanguard	Sponsler	turbine WM0150X2 Display IT400-DC-TRL-X	Carbon Controls		2x2" wafer, cdm4 cu rotor with tungsten carbide sleeve bearing, 1 C size lithium battery with 24 vdc option.	m3/day	218	2180	218 to 2180	4 - 20 mA option		
6	301	LC-1001	Pneumatic controller, 6to 30psi bellows, right hand mount, 2"600# flanged		Vanguard	Norriseal	1001A	CVS		16" displacer, grey spring, enviro-pilot					6 to 30 psi		
7	301	LC-1002	Pneumatic controller, 6to 30psi bellows, right hand mount, 2"600# flanged		Vanguard	Norriseal	1001A	CVS		12" dis lacer, llow s ri , enviro- ilot					6 to 30 psi		
8	301	LG-1000	Penberthy RM flat glass gage		Vanguard	Penberthy	RM	Midfield									
9	301	LG-1001	Penberthy RM flat glass gage		Vanguard	Penberthy	RM	Midfield									
10	301	LG-1002	Penberthy RM flat glass gage		Vanguard	Penberthy	RM	Midfield									
11	301	LG-9100	rate gauge		Vanguard	Kenco	5700	Zimco									
12	301	LV-1001	CVS D body, 667-40 actuator, 3/4" tungsten carbide trim, 2"600#		Vanguard	CVS		CVS			Psi	6	30	14 to 30	air to open	direct acting	
13	301	LV-1002	CVS D body, 667-40 actuator, 1/2" 316 SST/Alloy 6 trim, 2"600#		Vanguard	CVS		CVS			Psi	6	30	14 to 30	air to open		
14	301	BPCV-100	SurFlo bladder valve, 4" 600#.		Vanguard	SurFlo	SF10V-C-75H-S83-X-4.6	SurFlo		Bolt u kit art #SF10V-6 6CK	Psi	300	1440				
15	301	PI-700	1/4" npt bottom mount, liquid filled gauge, 2.5" face, dual scale		Vanguard		233.3	Wika		1/4" npt bottom mount, liquid filled gauge, 2.5" face, dual scale	Kpa/Psi	0	1100 K a/160 Psi				
16	301	PI-701	1/4" npt bottom mount, liquid filled gauge, 2.5" face, dual scale		Vanguard		233 3	Wika		1/4" npt bottom mount, liquid filled gauge, 2 5" face, dual scale	K a/Psi	0	1100 K a/160 Psi				
17	301	PI-1006	1/2" npt bottom mount, liquid filled gauge, 4" face, dual scale		Vanguard		233.3	Wika		1/2" npt bottom mount, liquid filled gauge, 4" face, dual scale	Kpa/Psi	0	13789 Kpa/2000 Psi				
18	301	PI-1007	1/2" npt bottom mount, liquid filled gauge, 4" face, dual scale		Vanguard		233.3	Wika		1/2" npt bottom mount, liquid filled gauge, 4" face, dual scale	Kpa/Psi	0	13789 K a/2000 Psi				
19	301	PRV-700	Fisher 630H, 1" NPT, 275 to 500 psi spring		Vanguard	Fisher	630H	Spartan			Kpa/Ps	1896 K a/275 Psi	3447 K a/500 Psi			3447 K a/500 Psi	
20	301	PRV-700A	Fisher 627, 1" NPT, 15 to 40 psi spring		Vanguard	Fisher	627	Spartan			K a/Ps	103 K a/15 Psi	275 K a/40 Psi			137 K a/20 Psi	
21	301	PRV-701	Fisher 630H, 2" NPT, 150 to 200 psi spring		Vanguard	Fisher	630H	Spartan			Kpa/Ps	1034 Kpa/150 Psi	1378 K a/200 Psi			1378 K a/200 Psi	
22	301	PRV-1001	Fisher 67CFR, 0-35psi spring		Vanguard	Fisher	67CFR	Spartan			Kpa/Ps	0	241 K a/35 Psi			241 K a/35 Psi	
23	301	PRV-1002	Fisher 67CFR, 0-35psi spring		Vanguard	Fisher	67CFR	Spartan			Kpa/Ps	0	241 K a/35 Psi			241 Kpa/35 Psi	
24	301	PSV-100															
25	301	PSV-700															
26	301	PSHH-100	2' npt (other options available), 379 to 12617 psi range		Vanguard	CVS	CVS Series 2000 ressure ilot	CVS			K a	5067 risin	12617 risi		close and vent on trip	set @ 9928 Kpag rising	
27	301	TI-1006	2.5" U insertion, 1/2"npt process connection, 3" face,dual scale		Vanguard	Wika	TI.33	Wika		m ht consider a thermowell	F C	-100 F -70 C	150 F/ 70 C				
28	301	FE-1006	Orifice Jr changer		Vanguard												
29	301	PR-1006	Floboss 103 w/ dongle		Vanguard	Emerson	Floboss 103	Spartan			K a	0	25000				
30	301	TR-1006	Floboss 103 w/ dongle		Vanguard	Emerson	Floboss 103	Spartan			C	-40	150				
31	301	FR-1006	Floboss 103 w/ dongle		Vanguard	Emerson	Floboss 103	Spartan			"H2O	0	1000				
32	303	BPCV-101								Future							
33	303	LG-1010								Future							
34	303	LG-1011								Future							
35	303	PI-1012								Future							
36	303	PI-1013								Future							
37	303	PS-101								Future							
38	303	PSV-1010								Future							
39	303	TI-1012								Future							
40	304	LI-901						Tank gauging systems									
41	304	LI-902						Tank gauging systems									
42	304	LSHH-800	2" npt, with float for lighter density, pneumatic switching, with vent required.		Vanguard	Linc	L282-11-32	Zimco		Ensure low density fluid float specified.							
43																	
44																	
45																	
46																	
47																	
48																	
49																	
50																	

CLIENT/PROJECT NUMBER	DATA SHEET NUMBER	REV NO.
Vanguard		A

KLEINFELDER Bright People. Right Solutions. | HOOD

REV.	DATE	DESCRIPTION	BY
A	July 13 2015	Issue for Review	DO

SPECIFICATION / DATA SHEET FOR:

PRESSURE GAUGES

TYPE: [x] DIRECT READING [ ] 20-100 kPa RECEIVER

[x] WEATHER PROOF IP 66 / NEMA 4X

DIAL SIZE: [ ] 4.5" [ ] 6" [ ] OTHER 4"

MANUFACTURER & MODEL NUMBER:

Wika 233.3

ACCURACY: ± % Span 1 OF FULL SCALE

ELEMENT: [x] BOURDON [ ] BELLOWS [ ] DIAPHRAGM

MATERIALS:

- ELEMENT 316L
- WETTED PARTS 316L
- CASE 316L
- LENS Polycarbonate
- MOVEMENT 316L

LIQUID FILLED: [x] YES [ ] NO

LIQUID (1) Glycerine 99.7 %

LIQUID (2) ______ %

GAUGE COMPLIANT WITH NACE MR0175:

[ ] YES [x] NO

RING TYPE: [x] SCREWED [ ] HINGED [ ] SLIP

[ ] OTHER ______

MOUNTING: [x] PROCESS [ ] SURFACE [ ] FLUSH

[ ] OTHER ______

CONNECTION NPT: [ ] 1/4" [x] 1/2" [ ] M [ ] F

[x] BOTTOM [ ] BACK

[ ] OTHER ______

BLOW-OUT PROTECTION: [ ] VENT [x] BACK [ ] DISC

[ ] SOLID FRONT DISC

[ ] OTHER ______

RUPTURE PRESSURE: ______ Psig

MAX. TEMP.: PROCESS 212 F
AMBIENT 140 F

OPTIONS:

[X] ZERO ADJUSTMENT

[X] WHITE DIAL WITH BLACK PRINTINGS

[ ] VALVE MANIFOLD TYPE ______

[X] OTHER Hi pressure diaphragm L990.12

TAG	PI - SCALE RANGE	OPERATING PRESSURE	DESIGN PRESSURE	DESIGN TEMP	GAS SERVICE
PI-001	0 to 10000 Psig	3600 Psig	13000 Psig	212	
PI-002	0 to 10000 Psig	3600 Psig	13000 Psig	212	
PI-1006	0 to 2000 Psig	1440 Psig	2600 Psig	212	
PI-1007	0 to 2000 Psig	1440 Psig	2600 Psig	212	

UNITS	
PRESSURE	Psig
TEMPERATURE	Deg. F

NOTES:

PI-001 and PI-002 to be ordered with hi pressure diaphragm. This will keep sand out of the device and extend the life of the instrument.

METER DATA SHEET

KLEINFELDER — Bright People. Right Solutions. | HOOD

CLIENT: Vanguard
PROJECT REC skids
FABR. SPEC:
SERIAL No.:

BY: DO
DATE: July 13/2015
APPROVED:
DATE:

GENERAL

P & ID NUMBER: 10160-0301
TAG NUMBER: FI-1001
SERVICE DESCRIPTION: Frac fluid level control (Lower)
LINE: SIZE: 2" 600# SCHEDULE:

OPERATING CONDITIONS

PROCESS: FLUID FracFluid PHASE liquid/solid
ENG. UNITS: FLOW m3/day PRESSURE 1438 Psia

	MIN	NORM	MAX
FLOW:	218		2180
INLET PRESSURE:	330 psig		1424 Psig
OUTLET PRESSURE:	0	3 psig	10 psig
TEMPERATURE °C:	80	80	80

SG (LIQUID) OR MOL WT (GAS): 0.290 ft3/lbmol
VISCOSITY: .86048 cP COMPRESSIBILITY:
PRESSURE: VAPOUR CRITICAL
SPECIFIC: HEAT RATIO VOLUME
PRESSURE DROP: ALLOWABLE

COMMENTS

Body pressure rating: 3700 Psi

METER

METER TYPE

ORIFICE (JR)	☐	PD	☐	MASS	☐
ORIFICE (SR)	☐	TURBINE	x☐	MAGMETER	☐
VORTEX	☐	VENTURI	☐	ROTAMETER	☐
PITOT	☐	ULTRASONIC	☐	OTHER	

CUSTODY TRANSFER
PRESSURE/TEMPERATURE COMPENSATION
REQUIRED ACCURACY
MANUFACTURER: Turbines Inc MODEL NUMBER: WM0200X2
SIZE: 2x2"
END CONNECTIONS: Wafer ANSI RATING:
BODY MATERIAL: 316L SS
INTERNALS: cdm4 cu rotor
BEARINGS: Tunsten Carbide

MISCELLANEOUS

Requires Sponsler M/N# IT400-DC-TRL-X multi-Function flow Indicator. Battery powered with 4-48 Vdc and 4-20 mA output option.

INSTALLATION

PIPE ID/OD
BETA RATIO
ATTITUDE
INDOOR/OUTDOOR
POWER
CSA CLASSIFICATION

SPECIAL CONSIDERATIONS

HIGH/LOW VISCOSITY dP
VARIABLE COMPOSITION
OTHER

OPTIONS & ACCESSORIES

STRAIGHTENING VANES
DUAL PICKUP
BIDIRECTIONAL
MECHANICAL PRINTER
UPSTREAM STRAINER
NACE COMPLIANCE

Job No. REC Skids

Data Sheet No. FI-1001

Rev	Date	Initials
A	7/13/15	DO

METER DATA SHEET

KLEINFELDER — Bright People. Right Solutions. | HOOD

CLIENT: Vanguard — BY: DO
PROJECT: REC skids — DATE: July 13/2015
FABR. SPEC: — APPROVED:
SERIAL No.: — DATE:

GENERAL

P & ID NUMBER: 10160-0301
TAG NUMBER: FI-1002
SERVICE DESCRIPTION: Light hydrocarbon level control (upper)
LINE: — SIZE: 2" 600# — SCHEDULE:

OPERATING CONDITIONS

PROCESS: FLUID oil/cond — PHASE liquid
ENG. UNITS: FLOW m3/day — PRESSURE 1438 Psia

	MIN	NORM	MAX
FLOW:	84		336
INLET PRESSURE:	330 psig		1424 Psig
OUTLET PRESSURE:	0	3 psig	10 psig
TEMPERATURE °C:	80	80	80

SG (LIQUID) OR MOL WT (GAS): 3.255 ft3/lbmol
VISCOSITY: .012905 cP — COMPRESSIBILITY:
PRESSURE: VAPOUR — CRITICAL:
SPECIFIC: HEAT RATIO — VOLUME:
PRESSURE DROP: ALLOWABLE

METER

METER TYPE

ORIFICE (JR)	☐	PD	☐	MASS	☐
ORIFICE (SR)	☐	TURBINE	x ☐	MAGMETER	☐
VORTEX	☐	VENTURI	☐	ROTAMETER	☐
PITOT	☐	ULTRASONIC	☐	OTHER	

CUSTODY TRANSFER
PRESSURE/TEMPERATURE COMPENSATION
REQUIRED ACCURACY
MANUFACTURER: Turbines Inc — MODEL NUMBER: WM0150X2
SIZE: 1.5x2"
END CONNECTIONS: Wafer — ANSI RATING:
BODY MATERIAL: 316L SS
INTERNALS: cdm4 cu rotor
BEARINGS: Tunsten Carbide

SPECIAL CONSIDERATIONS

HIGH/LOW VISCOSITY — dP
VARIABLE COMPOSITION
OTHER

COMMENTS

Body pressure rating: 3700 Psi

MISCELLANEOUS

Requires Sponsler M/N# IT400-DC-TRL-X multi-Function flow Indicator. Battery powered with 4-48 Vdc and 4-20 mA output option.

INSTALLATION

PIPE ID/OD
BETA RATIO
ATTITUDE
INDOOR/OUTDOOR
POWER
CSA CLASSIFICATION

OPTIONS & ACCESSORIES

STRAIGHTENING VANES
DUAL PICKUP
BIDIRECTIONAL
MECHANICAL PRINTER
UPSTREAM STRAINER
NACE COMPLIANCE

Job No. REC Skids

Data Sheet No. FI-1002

Rev	Date	Initials
A	7/13/15	DO

KLEINFELDER — Bright People. Right Solutions. | HOOD

LEVEL INSTRUMENTS (DISPLACER OR FLOAT)

CLIENT: VANGUARD	REVISIONS				SHT #
	No	BY	DATE	DESCRIPTION	Doc # 47-DS-063
	A	DO	7/14/2015	IFR	CP #
					Req #
PROJECT: REC Skids					PO #
					App'd by:
					Chk'd by:

Section	No.	Item		LC-1001		LC-1002	
	1	Tag Number		LC-1001		LC-1002	
	2	Service		V-100 Water		V-100 Oil	
	3	Line No./Vessel		V-100		V-100	
	4	Body or Cage Material					
		Rating		6000 psig		6000 psig	
	5	Conn. Size & Location Upper				2" 600#	
		Type				flanged	
	6	Conn. Size & Location Lower		2" 600#			
		Type		flanged			
BODY/CAGE	7	Case Mounting		RH Mount		RH Mount	
		Type					
	8	Rotable Head		yes		yes	
	9						
	10	Orientation (displacer)		vertical		horizontal	
	11	Cooling Extension		no		no	
	12	Vessel Nozzle Projection					
	13	Dimensions					
	14	Insertion Depth		tbd		tbd	
DISPLACER/	15	Displacer Extension		16" displacer		12" displacer	
FLOAT	16	Displacer or Float Material		tbd		tbd	
	17	Displacer Spring/Tube Mat'l		Grey spring		Yellow Spring	
	18	Sour Specification					
	19						
	20	Function		direct acting		direct acting	
	21	Output		6 to 30 psig		6 to 30 psig	
	22	Control Modes		throttling		throttling	
	23	Differential					
XMTR/CONT.	24	Output Action Level Rise		increases		increases	
	25	Mounting					
	26	Enclosure Class		general		general	
	27	Electric Power or Air Supply		air		air	
	28	Trip Point		field set		field set	
	29	Upper Liquid				oil	
SERVICE	30	Lower Liquid		water			
	31	sp. gr. : Upper	Lower				
(Eng. Units)	32	Pressure: Max.	Normal	9930		9930	
Press. = kPag	33	Temp. : Max.	Normal	27		27	
Temp. = C	34						
	35						
	36	Air Set	Supply Gage				
	37	Gage Glass Connections					
	38	Gage Glass Model No.					
	39	Contacts: No.	Form				
	40	Contact Rating					
OPTIONS	41	Action of Contacts					
	42	Switch Type		Enviro-pilot		Enviro-pilot	
	43						
	44	P&ID No.		10160-0301		10160-0301	
	45	Notes					
	46	Manufacturer / Vendor		Norriseal / CVS		Norriseal / CVS	
	47	Model Number		series 1001A		series 1001A	

NOTES:

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GAGE GLASSES and COCKS

CLIENT: **Vanguard**

PROJECT: **REC**

REVISIONS				SHT#
NO	BY	DATE	DESCRIPTION	Doc#
A	DO	7/14/2015	IFR	CP#
				Req#
				PO#
				App'd by: PTC
				Chk'd by: LJL

1. Gage Column: **Yes** Cocks: **Yes**
   Assembled with Nipples: Unassembled with Nipples: **Yes**

GAGE GLASSES

2. Type: Reflex: **Yes** Transparent:
   Tubular: L'ge Chamb'r
   Weld Pad:
3. Conn: Size and Type: - **1/2" fnpt**
   Top & Bottom: **Yes** Side: Back:
   Vent: Drain:
4. Material: **Carbon Steel**
5. Min. Rating: **9930 kPag** at **38 Deg C**
6. Options Illuminator Mica shield:
   External Tube: Ext. Jacket:
   Non - Frost: Ext. Length:
   Calb. Scale: Other:
7. Manuf & Mod No: **Penberthy Model RM**

GAGE COCKS

8. Type - Offset: **Yes** Straight:
9. Conn - Vessel: **3/4" npt** Gage: **1/2" npt**
   Vent/drain: **1/2" npt**
10. Material - Body: **Carbon Steel** Trim: **316 ss**
11. Min. Rating: **9930 kPag** at **38 °C**
12. Construction:
13. Type of Connection - Vessel: **3/4" npt**
    Body: **1/2" npt**
14. Bonnet:
15. Options - Ball Checks: Renewable Seats: **Yes**
    Other:
16. Manuf. & Model No: **Penberthy Model TBD**

Instrument Tag No.	Visible Glass (mm)	Center - Line Conn. (mm)	P&ID No.	Temp. Norm C	Temp. Max. C	Press. Norm. (kPag)	Press. Max. (kPag)	Service	Notes
LG-1000	tbd	tbd	0301			9818	9930	V-100 level	
LG-1001	tbd	tbd	0301			9818	9930	V-100 water level	
LG-1002	tbd	tbd	0301			9818	9930	V-100 Oil level	

NOTES:

KLEINFELDER Bright People. Right Solutions. | HOOD

GAGE GLASSES and COCKS

CLIENT: **Vanguard**

PROJECT: **REC**

REVISIONS				SHT#
NO	BY	DATE	DESCRIPTION	Doc#
A	DO	7/14/2015	IFR	CP#
				Req#
				PO#
				App'd by: PTC
				Chk'd by: LJL

1. Gage Column: Cocks:
   Assembled with Nipples: Unassembled with Nipples: **Yes**

GAGE GLASSES

2. Type: Reflex: Transparent:
Rate Gauge L'ge Chamb'r **5/8" O.D.**
   Weld Pad:
3. Conn: Size and Type: - **1/2" mnpt**
   Top & Bottom: **Yes** Side: Back:
   Vent: Drain:
4. Material: **5/8" O.D. glass**
5. Min. Rating: at **38 Deg C**
6. Options Illuminator Mica shield: **Polycarbonate**
   External Tube: Ext. Jacket: **ZincPlated CS**
   Non - Frost: Ext. Length:
   Calb. Scale: **tbd** Other: **Fluorocarbon seals**
7. Manuf & Mod No: **Kenco 5700**

GAGE COCKS

8. Type - Offset: Straight:
9. Conn - Vessel: Gage:
   Vent/drain:
10. Material - Body: Trim:
11. Min. Rating: at
12. Construction:
13. Type of Connection - Vessel:
    Body:
14. Bonnet:
15. Options - Ball Checks: Renewable Seats:
    Other:
16. Manuf. & Model No:

Instrument Tag No.	Visible Glass (mm)	Center - Line Conn. (mm)	P&ID No.	Temp. Norm C	Temp. Max. C	Press. Norm. (kPag)	Press. Max. (kPag)	Service	Notes
LG-9100	**tbd**		**0301**	**15**	**36**	**3**	**5**	**methanol tank level**	**1, 2**

NOTES:
1. tank height is 0.9 m.
2. Vendor is Zimco gauge and valve

KLEINFELDER Bright People. Right Solutions. | HOOD

CONTROL VALVE DATA SHEET

CLIENT:	Vanguard	BY:	Dallas Obrigewitch
PROJECT	REC skids	DATE:	July 14/2015
FABR. SPEC:		APPROVED:	
SERIAL No.:		DATE:	

GENERAL

P & ID NUMBER	10160-0301		
TAG NUMBER	LV-1001		
SERVICE DESCRIPTION	V-100 lower water		
LINE:	SIZE 2"	SCHEDULE	600 ANSI

OPERATING CONDITIONS

PROCESS:	FLUID	Frac	PHASE	Liquid		
ENG. UNITS:	FLOW	m3/hr	PRESSURE	kpag		
FLOW:	MIN	15	NORM		MAX	50
INLET PRESSURE:	MIN	2275	NORM		MAX	9831
OUTLET PRESSURE:	MIN	atm	NORM		MAX	68
TEMPERATURE °C:	MIN	20	NORM	26	MAX	50
SG (LIQUID) OR MOL WT (GAS)		995 kg/m3				
VISCOSITY		.86048 cP			COMPRESSIBILITY	
PRESSURE:	VAPOUR				CRITICAL	
SPECIFIC:	HEAT RATIO				VOLUME	
PRESSURE DROP:	SIZING				SHUTOFF	
ALLOWABLE (dB)			CALCULATED (dB)			
VALVE C_v			CALCULATED		ACTUAL	

VALVE

BODY

MANUFACTURER	CVS	MODEL NUMBER	Series D
SIZE	2"	TYPE	D body
END CONNECTIONS	2"	ANSI RATING	600# RF
MATERIAL	LCC Steel body	PACKING	teflon
BONNET TYPE	std		

TRIM

PLUG	M-form	TYPE	
CHARACTERISTIC	equal %		
NUMBER OF PORTS	1	PORT SIZE	3/4"
GUIDING TYPE	Sliding stem		
MATERIAL	Tungsten Carbide		
SEAT	Tungsten Carbide		
PLUG	Tungsten Carbide		
SHAFT			
ANSI LEAKAGE CLASSIFICATION	Class IV		

COMMENTS

Bench set 14 to 30 psi

ACTUATOR

MANUFACTURER	CVS		
MODEL NUMBER	667-40		
TYPE	667	SIZE	40
SIGNAL RANGE	6 to 30 psi		
AIR SUPPLY	35 psi		
FAILURE POSITION	closed		

POSITIONER

MANUFACTURER	n/a		
MODEL NUMBER			
INPUT SIGNAL			
OUTPUT SIGNAL			
GAUGES		BYPASS	

OPTIONS & ACCESSORIES

AIR SET	
HANDWHEEL	
LUBRICATOR	
MOUNTING LOCATION	
ISOLATION VALVE	
SOLENOID VALVE	
VALVE POSITION LIMIT SWITCH	

Job No. ____________________

Data Sheet No. ____________________

Rev	Date	Initials
A	7/14/2015	DO

KLEINFELDER Bright People. Right Solutions. | HOOD

CONTROL VALVE DATA SHEET

CLIENT: Vanguard	BY: Dallas Obrigewitch
PROJECT REC skids	DATE: July 14/2015
FABR. SPEC:	APPROVED:
SERIAL No.:	DATE:

GENERAL

P & ID NUMBER	10160-0301
TAG NUMBER	LV-1002
SERVICE DESCRIPTION	V-100 upper oil
LINE:	SIZE 2" / SCHEDULE 600 ANSI

OPERATING CONDITIONS

PROCESS:	FLUID	Oil	PHASE	Liquid		
ENG. UNITS:	FLOW	m3/day	PRESSURE	kpag		
FLOW:	MIN	84	NORM		MAX	336
INLET PRESSURE:	MIN	2275	NORM		MAX	9831
OUTLET PRESSURE:	MIN	atm	NORM		MAX	68
TEMPERATURE °C:	MIN	20	NORM	26	MAX	50
SG (LIQUID) OR MOL WT (GAS)		88 kg/m3				
VISCOSITY		.012905 cP			COMPRESSIBILITY	
PRESSURE:	VAPOUR				CRITICAL	
SPECIFIC:	HEAT RATIO				VOLUME	
PRESSURE DROP:	SIZING				SHUTOFF	
ALLOWABLE (dB)			CALCULATED (dB)			
VALVE C_v		CALCULATED			ACTUAL	

VALVE

BODY

MANUFACTURER	CVS	MODEL NUMBER	Series D
SIZE	2"	TYPE	D body
END CONNECTIONS	2"	ANSI RATING	600# RF
MATERIAL	LCC Steel body	PACKING	teflon
BONNET TYPE	std		

TRIM

PLUG	M-form	TYPE	
CHARACTERISTIC	equal %		
NUMBER OF PORTS	1	PORT SIZE	1/2"
GUIDING TYPE	Sliding stem		
MATERIAL	316 SST/Alloy 6		
SEAT	316 SST/Alloy 6		
PLUG	316 SST/Alloy 6		
SHAFT			
ANSI LEAKAGE CLASSIFICATION	Class IV		

COMMENTS

Bench set 14 to 30 psi

ACTUATOR

MANUFACTURER	CVS		
MODEL NUMBER	667-40		
TYPE	667	SIZE	40
SIGNAL RANGE	6 to 30 psi		
AIR SUPPLY	35 psi		
FAILURE POSITION	closed		

POSITIONER

MANUFACTURER	n/a		
MODEL NUMBER			
INPUT SIGNAL			
OUTPUT SIGNAL			
GAUGES		BYPASS	

OPTIONS & ACCESSORIES

AIR SET	
HANDWHEEL	
LUBRICATOR	
MOUNTING LOCATION	
ISOLATION VALVE	
SOLENOID VALVE	
VALVE POSITION LIMIT SWITCH	

Job No.

Data Sheet No.

Rev	Date	Initials
A	7/14/2015	DO

KLEINFELDER Bright People. Right Solutions. | HOOD

CONTROL VALVE DATA SHEET

CLIENT: Vanguard — BY: Dallas Obrigewitch
PROJECT: REC skids — DATE: July 14 2015
FABR. SPEC: — APPROVED:
SERIAL No.: — DATE:

GENERAL

P & ID NUMBER: 10160-0301
TAG NUMBER: BPCV-100
SERVICE DESCRIPTION: V-100 Sales back pressure
LINE: SIZE 4" SCHEDULE 600 ANSI

OPERATING CONDITIONS

PROCESS:	FLUID	Gas	PHASE	Gas		
ENG. UNITS:	FLOW	mmscf/d	PRESSURE	PSIG		
FLOW:	MIN	3	NORM		MAX	20
INLET PRESSURE:	MIN	300	NORM		MAX	1440
OUTLET PRESSURE:	MIN		NORM	600	MAX	
TEMPERATURE °C:	MIN	20	NORM	26	MAX	50

SG (LIQUID) OR MOL WT (GAS):
VISCOSITY: .012805 cP — COMPRESSIBILITY:
PRESSURE: VAPOUR — CRITICAL:
SPECIFIC: HEAT RATIO — VOLUME:
PRESSURE DROP: SIZING — SHUTOFF:
ALLOWABLE (dB): — CALCULATED (dB):
VALVE C_v: — CALCULATED: — ACTUAL:

VALVE

BODY

MANUFACTURER: SurFlo — MODEL NUMBER: note 1
SIZE: 4" — TYPE: SF10V
END CONNECTIONS: 4" — ANSI RATING: 600# RF
MATERIAL: — PACKING:
BONNET TYPE:

TRIM

PLUG: Cage and Bladder — TYPE:
CHARACTERISTIC: equal %
NUMBER OF PORTS: 1 — PORT SIZE:
GUIDING TYPE:
MATERIAL:
SEAT:
PLUG:
SHAFT:
ANSI LEAKAGE CLASSIFICATION:

COMMENTS

Note 1: Valve Model number: SF10V-C-75H-S83-X-4.6
Comes with 24" expansion bottle

ACTUATOR

MANUFACTURER: n/a
MODEL NUMBER:
TYPE: — SIZE:
SIGNAL RANGE:
AIR SUPPLY:
FAILURE POSITION:

POSITIONER

MANUFACTURER: n/a
MODEL NUMBER:
INPUT SIGNAL:
OUTPUT SIGNAL:
GAUGES: — BYPASS:

OPTIONS & ACCESSORIES

AIR SET:
HANDWHEEL:
LUBRICATOR:
MOUNTING LOCATION: mounting kit part# SF10V-6.6CK
ISOLATION VALVE:
SOLENOID VALVE:
VALVE POSITION LIMIT SWITCH:

Job No.:

Data Sheet No.:

Rev	Date	Initials
A	7/14/2015	DO

KLEINFELDER Bright People. Right Solutions. | HOOD

CLIENT/PROJECT NUMBER	DATA SHEET NUMBER	REV NO.
Vanguard		A

REV.	DATE	DESCRIPTION	BY
A	July 13/2015	Issue for Review	DO

SPECIFICATION / DATA SHEET FOR:

PRESSURE GAUGES

TYPE: [x] DIRECT READING [ ] 20-100 kPa RECEIVER
[x] WEATHER PROOF IP 66 / NEMA 4X

DIAL SIZE: [ ] 4.5" [ ] 6" [ ] OTHER 2.5"

MANUFACTURER & MODEL NUMBER:
Wika 233.3

ACCURACY: ± % Span 2.5 OF FULL SCALE

ELEMENT: [x] BOURDON [ ] BELLOWS [ ] DIAPHRAGM

MATERIALS:
- ELEMENT 316L
- WETTED PARTS 316L
- CASE 316L
- LENS Polycarbonate
- MOVEMENT 316L

LIQUID FILLED: [x] YES [ ] NO
- LIQUID (1) Glycerine 99.7 %
- LIQUID (2) ______ %

GAUGE COMPLIANT WITH NACE MR0175:
[ ] YES [x] NO

RING TYPE: [x] SCREWED [ ] HINGED [ ] SLIP
[ ] OTHER ______

MOUNTING: [x] PROCESS [ ] SURFACE [ ] FLUSH
[ ] OTHER ______

CONNECTION NPT: [x] 1/4" [ ] 1/2" [ ] M [ ] F
[x] BOTTOM [ ] BACK
[ ] OTHER ______

BLOW-OUT PROTECTION: [X] VENT [ ] BACK [ ] DISC
[ ] SOLID FRONT DISC
[ ] OTHER ______

RUPTURE PRESSURE: ______ Psig

MAX. TEMP.: PROCESS 212 F
AMBIENT 140 F

OPTIONS:
[X] ZERO ADJUSTMENT
[X] WHITE DIAL WITH BLACK PRINTINGS
[ ] VALVE MANIFOLD TYPE ______
[ ] OTHER ______

TAG	PI - SCALE RANGE	OPERATING PRESSURE	DESIGN PRESSURE	DESIGN TEMP	GAS SERVICE
PI-700	0 to 160 Psig	100 Psig	160 Psig	212	
PI-701	0 to 160 Psig	100 Psig	160 Psig	212	

UNITS	
PRESSURE	Psig
TEMPERATURE	Deg. F

NOTES:

	CLIENT/PROJECT/PROJECT NO.	DATA SHEET NO.	REV.
KLEINFELDER *Bright People. Right Solutions.* / HOOD	Vanguard		A

REV	DATE	DESCRIPTION	BY
A	7/14/2015	IFR	DO

SPECIFICATION / DATA SHEET FOR:

PRESSURE REGULATORS

GENERAL	TAG NUMBER		PRV-700	
	FUNCTION		Fuel gas 1st cut	
	SERVICE MEDIA		Natural gas	
	MANUFACTURER/MODEL		Fisher 630H	
	INLET/OUTLET CONNECTIONS		1" NPT	
BODY	Cv			
	VALVE STEM		Brass	
	STEM GUIDE		Zinc plated steel	
	BODY MATERIAL		Cast Iron	
	SPRING CASE MATERIAL		Cast Iron	
	DIAPHRAGM		Neoprene	
	SEAT MATERIALS: orifice/ valve disk		Brass / PTFE	
ACTUATOR/ PILOT	TYPE		Integral	
	REGULATOR SPRING MATERIAL		Plated steel	
	SPRING RANGE	SET POINT	275 to 500 psig	500 psig
ACCESS	FILTER REGULATOR	SUPPLY GAUGE		
	HOUSING VENT	INTERNAL RELIEF	1/4" NPT	
MAXIMUM RATINGS	INLET PRESSURE	OUTLET PRESSURE	1500 psig	500 psig
	TEMPERATURE RANGE		-18 to 149°C	
SERVICE	FLUID		Natural Gas	
	OPER. FLOW RATE	MAX FLOW RATE	tbd	tbd
	OPER. INLET PRESS.	MAX INLET PRESS.	1424 psig	1440 psig
	OPER. TEMPERATURE	MAX TEMPERATURE	20 °C	50 °C
	OPERATING DIFFERENTIAL PRESSURE		924 psig	
	AMBIENT TEMPERATURE (DESIGN)		20 °C	
	MINIMUM Cv	MAXIMUM Cv	tbd	tbd

UNITS	
PRESSURE	Psig
TEMPERATURE	Deg. C
FLOW	Sm3/hr

NOTES:

KLEINFELDER / HOOD	CLIENT/PROJECT/PROJECT NO.	DATA SHEET NO.	REV.
	Vanguard		A

SPECIFICATION / DATA SHEET FOR:	REV	DATE	DESCRIPTION	BY
PRESSURE REGULATORS	A	7/14/2015	IFR	DO

GENERAL	TAG NUMBER		PRV-700A	
	FUNCTION		Fuel gas final cut	
	SERVICE MEDIA		Natural gas	
	MANUFACTURER/MODEL		Fisher 627	
	INLET/OUTLET CONNECTIONS		1" NPT	
BODY	Orifice		1/8"	
	Cv		tbd	
	VALVE STEM		Aluminum	
	STEM GUIDE		Aluminum	
	BODY MATERIAL		WCC Steel	
	SPRING CASE MATERIAL		WCC Steel	
	DIAPHRAGM		Nitrile	
	SEAT MATERIALS: orifice/ valve disk		Aluminum / Nylon (PA)	
ACTUATOR/ PILOT	TYPE		Integral	
	REGULATOR SPRING MATERIAL		Plated steel	
	SPRING RANGE	SET POINT	15 to 40 psig	20 psig
ACCESS	FILTER REGULATOR	SUPPLY GAUGE		
	HOUSING VENT	INTERNAL RELIEF	3/4" NPT	
MAXIMUM RATINGS	INLET PRESSURE	OUTLET PRESSURE	1800 psig	125 psig
	TEMPERATURE RANGE		-40 to 82°C	
SERVICE	FLUID		Natural Gas	
	OPER. FLOW RATE	MAX FLOW RATE	tbd	tbd
	OPER. INLET PRESS.	MAX INLET PRESS.	500 psig	1440 psig
	OPER. TEMPERATURE	MAX TEMPERATURE	20 °C	50 °C
	OPERATING DIFFERENTIAL PRESSURE		480 psig	
	AMBIENT TEMPERATURE (DESIGN)		20 °C	
	MINIMUM Cv	MAXIMUM Cv	tbd	tbd

UNITS	
PRESSURE	Psig
TEMPERATURE	Deg. C
FLOW	Sm3/hr

NOTES:

	CLIENT/PROJECT/PROJECT NO.	DATA SHEET NO.	REV.
KLEINFELDER Bright People Right Solutions / HOOD	Vanguard		A

REV	DATE	DESCRIPTION	BY
A	7/14/2015	IFR	DO

SPECIFICATION / DATA SHEET FOR:

PRESSURE REGULATORS

GENERAL	TAG NUMBER		PRV-701	
	FUNCTION		Flare gas 1st cut	
	SERVICE MEDIA		Natural gas	
	MANUFACTURER/MODEL		Fisher 630H	
	INLET/OUTLET CONNECTIONS		2" NPT	
BODY	Cv			
	VALVE STEM		Brass	
	STEM GUIDE		Zinc plated steel	
	BODY MATERIAL		Cast Iron	
	SPRING CASE MATERIAL		Cast Iron	
	DIAPHRAGM		Neoprene	
	SEAT MATERIALS: orifice/ valve disk		Brass / PTFE	
ACTUATOR/ PILOT	TYPE		Integral	
	REGULATOR SPRING MATERIAL		Plated steel	
	SPRING RANGE	SET POINT	150 to 200 psig	200 psig
ACCESS	FILTER REGULATOR	SUPPLY GAUGE		
	HOUSING VENT	INTERNAL RELIEF	1/4" NPT	
MAXIMUM RATINGS	INLET PRESSURE	OUTLET PRESSURE	1500 psig	500 psig
	TEMPERATURE RANGE		-18 to 149°C	
SERVICE	FLUID		Natural Gas	
	OPER. FLOW RATE	MAX FLOW RATE	tbd	tbd
	OPER. INLET PRESS.	MAX INLET PRESS.	1424 psig	1440 psig
	OPER. TEMPERATURE	MAX TEMPERATURE	20 °C	50 °C
	OPERATING DIFFERENTIAL PRESSURE		924 psig	
	AMBIENT TEMPERATURE (DESIGN)		20 °C	
	MINIMUM Cv	MAXIMUM Cv	tbd	tbd

UNITS	
PRESSURE	Psig
TEMPERATURE	Deg. C
FLOW	Sm3/hr

NOTES:

KLEINFELDER Bright People. Right Solutions. | HOOD

CLIENT/PROJECT/PROJECT NO.	DATA SHEET NO.	REV.
Vanguard		A

SPECIFICATION / DATA SHEET FOR:

PRESSURE REGULATORS

REV	DATE	DESCRIPTION	BY
A	7/14/2015	IFR	DO

GENERAL	TAG NUMBER		PRV-1001	
	FUNCTION		LC-1001 supply	
	SERVICE MEDIA		Instrument Air	
	MANUFACTURER/MODEL		Fisher 67 cfr	
	INLET/OUTLET CONNECTIONS		1/4" NPT	
BODY	Cv			
	VALVE STEM		Brass Stem	
	STEM GUIDE		Polyester resin	
	BODY MATERIAL		Aluminum	
	SPRING CASE MATERIAL		Aluminum	
	DIAPHRAGM		Nitrile	
	SEAT MATERIALS: orifice/ valve disk		Polyester resin / nitrile	
ACTUATOR/ PILOT	TYPE		Integral	
	REGULATOR SPRING MATERIAL		Plated steel	
	SPRING RANGE	SET POINT	0 to 35 psig	35 psig
ACCESS	FILTER REGULATOR	SUPPLY GAUGE	yes	required
	HOUSING VENT	INTERNAL RELIEF	weephole	yes
MAXIMUM RATINGS	INLET PRESSURE	OUTLET PRESSURE	250 psig	50 psig
	TEMPERATURE RANGE		-°C	
SERVICE	FLUID		Natural Gas	
	OPER. FLOW RATE	MAX FLOW RATE	tbd	tbd
	OPER. INLET PRESS.	MAX INLET PRESS.	100 psig	140 psig
	OPER. TEMPERATURE	MAX TEMPERATURE	20 °C	30 °C
	OPERATING DIFFERENTIAL PRESSURE		65 psig	
	AMBIENT TEMPERATURE (DESIGN)		20 °C	
	MINIMUM Cv	MAXIMUM Cv	tbd	tbd

UNITS	
PRESSURE	Psig
TEMPERATURE	Deg. C
FLOW	Sm3/hr

NOTES:

	CLIENT/PROJECT/PROJECT NO.	DATA SHEET NO.	REV.
KLEINFELDER Bright People. Right Solutions / HOOD	Vanguard		A

SPECIFICATION / DATA SHEET FOR:	REV	DATE	DESCRIPTION	BY
PRESSURE REGULATORS	A	7/14/2015	IFR	DO

GENERAL	TAG NUMBER		PRV-1002	
	FUNCTION		LC-1002 supply	
	SERVICE MEDIA		Instrument Air	
	MANUFACTURER/MODEL		Fisher 67 cfr	
	INLET/OUTLET CONNECTIONS		1/4" NPT	
BODY	Cv			
	VALVE STEM		Brass Stem	
	STEM GUIDE		Polyester resin	
	BODY MATERIAL		Aluminum	
	SPRING CASE MATERIAL		Aluminum	
	DIAPHRAGM		Nitrile	
	SEAT MATERIALS: orifice/ valve disk		Polyester resin / nitrile	
ACTUATOR/ PILOT	TYPE		Integral	
	REGULATOR SPRING MATERIAL		Plated steel	
	SPRING RANGE	SET POINT	0 to 35 psig	35 psig
ACCESS	FILTER REGULATOR	SUPPLY GAUGE	yes	required
	HOUSING VENT	INTERNAL RELIEF	weephole	yes
MAXIMUM RATINGS	INLET PRESSURE	OUTLET PRESSURE	250 psig	50 psig
	TEMPERATURE RANGE		-°C	
SERVICE	FLUID		Natural Gas	
	OPER. FLOW RATE	MAX FLOW RATE	tbd	tbd
	OPER. INLET PRESS.	MAX INLET PRESS.	100 psig	140 psig
	OPER. TEMPERATURE	MAX TEMPERATURE	20 °C	30 °C
	OPERATING DIFFERENTIAL PRESSURE		65 psig	
	AMBIENT TEMPERATURE (DESIGN)		20 °C	
	MINIMUM Cv	MAXIMUM Cv	tbd	tbd

UNITS	
PRESSURE	Psig
TEMPERATURE	Deg. C
FLOW	Sm3/hr

NOTES:

KLEINFELDER Bright People. Right Solutions | HOOD

PRESSURE SWITCHES

CLIENT:
Vanguard

PROJECT:
REC Skids

REVISIONS				SHT# 1
NO	BY	DATE	DESCRIPTION	Doc# 47-DS-101
A	DO	7/13/15	IFR	CP#
				Req#
				PO#
				App'd by:
				Chk'd by:

GENERAL

1. Type Press: **Static**
2. Vendor/ Manufacturer: **CVS/CVS**
3. Model Number: **CVS series 2000 pressure pilot**

ELEMENT

4. Type-Diaphragm/bourdon/bellows: **Diaphragm / red spring**
5. Material: **C1018**
6. Connection size: **2" npt**
7. Orientation: **Vertical**
8. Pressure rating: **3500 psig MAWP**
9. Pressure range: **55 to1830 psig**
10. Deadband: **75 to 185 psig**
11. Calibration adjustment: **735 to 1830 psig**

SWITCH

12. Type: **Pnuematic**
13. Quantity: **1**
14: Port size: **1/4" npt**
15. Setpoint: **1440 psig rising**
16. Calibration range:
17. Rating: Amps Volts Hz
    Other: **60 to 150 psig**
18. Load - Inductive: Non-Inductive:
19. Enclosure - General Purpose:
    Weather proof: None:
    Explosion Proof: Class:
20. Conduit Conn-Mfr. Std: Other:
21. Temperature Limits: **Process: -46 to 200 deg C**
    Ambient: -46 to 100 deg C

Instrument Tag No.	Proof Press. (kPag)	Instrument Adj. Range (kPag)	Inst. Set Point (kPag)	P&ID No.	Temperature Norm. C	Temperature Max. C	Pressure Norm. (kPag)	Pressure Max. (kPag)	Service	Notes
PSHH-100	**24131**	**12617**	**9928**	**0301**	**80**		**9652**		**V-100 hihi pressure**	

NOTES:

KLEINFELDER | HOOD

TEMPERATURE GUAGE DATA SHEET
(Bi-metal and glass thermometer)

CLIENT:	Vanguard	BY:	DO
PROJECT:	REC skids	DATE:	07/13/2015
FABR. SPEC:		APPROVED:	
SERIAL No.:		DATE:	

THERMOMETER	THERMOWELL
1. STEM — THREADED [X] PLAIN [ ] UNION [ ]; MATERIAL 304 SS	10. THERMOWELL: NONE [x] INCLUDED [ ] BY OTHERS [ ]
2. STEM OR UNION THREAD: 1/2 IN. [X] 3/4 IN. [ ]	11. MATERIAL 304 SS [ ] 316 SS [ ]
3. STEM DIAMETER: STD [ ] .250 IN. [X] .375 IN. [ ]	12. CONSTRUCTION TAPERED [ ] STRAIGHT [ ] STEPPED [ ]
4. CASE MATERIAL STD [X] OTHER	13. DIMENSIONS: ROOT O.D.
5. DIAL SIZE 3" COLOR White	Note: Thermowell will be client option and vendor specified — BORE SIZE
6. SCALE LENGTH -100 to 150 F COLOR Black	TIP THICKNESS
7. FORM: Fig. 1 ADJUSTABLE [ ]	TIP O.D.
8. EXTERNAL CALIBRATOR [ ] HERM. SEALED CASE [X]	14. PROCESS CONNECTION:
9. MFR. & MODEL No. WIKA /Trend Instruments Model TI.33	15. INTERNAL THREAD:

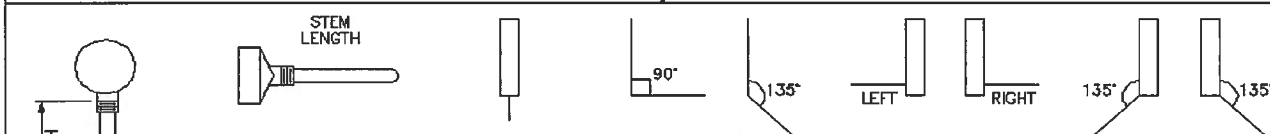

FIG. 1 BOTTOM FORM (STRAIGHT) — FIG. 2 BACK FORM (ANGLE) — FIG. 3 STRAIGHT — FIG. 4–5 BACK — FIG. 6–7 — FIG. 8–9 135° RIGHT–LEFT

Rev	TAG No.	Temperature Range	Operating Temperature	Bi-metal Stem Length	Thermowell Overall Length	Thermowell Insertion Length	Service	P&ID
A	TI-1006	-100 to 150F/C	80 F	2.5"	optional	optional	Gas to pipeline	10160-0301

Job No.

Data Sheet No. TI-1006

Rev	Date	Initials
IFR-A	07/13/15	DO

KLEINFELDER Bright People. Right Solutions. | HOOD

METER DATA SHEET

CLIENT: Vanguard
PROJECT REC skids
FABR. SPEC:
SERIAL No.:

BY: Dallas Obrigewitch
DATE: July 14/2015
APPROVED:
DATE:

GENERAL

P & ID NUMBER 10160-0301
TAG NUMBER FE-1006
SERVICE DESCRIPTION Sales Gas
LINE Sales SIZE 4" SCHEDULE 600# ansi

OPERATING CONDITIONS

PROCESS:	FLUID	Nat gas	PHASE	Gas		
ENG. UNITS:	FLOW	mmscf/d	PRESSURE	PSIG		
FLOW:	MIN	3	NORM		MAX	20
INLET PRESSURE:	MIN	300	NORM		MAX	1440
OUTLET PRESSURE:	MIN		NORM	600	MAX	
TEMPERATURE °C:	MIN	20	NORM	26	MAX	50

SG (LIQUID) OR MOL WT (GAS)
VISCOSITY 0.012805 COMPRESSIBILITY
PRESSURE: VAPOUR CRITICAL
SPECIFIC: HEAT RATIO VOLUME
PRESSURE DROP: ALLOWABLE

METER

METER TYPE

ORIFICE (JR)	☐ x	PD	☐	MASS	☐
ORIFICE (SR)	☐	TURBINE	☐	MAGMETER	☐
VORTEX	☐	VENTURI	☐	ROTAMETER	☐
PITOT	☐	ULTRASONIC	☐	OTHER	

CUSTODY TRANSFER no
PRESSURE/TEMPERATURE COMPENSATION yes
REQUIRED ACCURACY
MANUFACTURER MODEL NUMBER
SIZE TBD
END CONNECTIONS 4" ANSI RATING 600#
BODY MATERIAL
INTERNALS
BEARINGS

SPECIAL CONSIDERATIONS

HIGH/LOW VISCOSITY dP
VARIABLE COMPOSITION
OTHER

COMMENTS

MISCELLANEOUS

INSTALLATION

PIPE ID/OD
BETA RATIO
ATTITUDE
INDOOR/OUTDOOR
POWER
CSA CLASSIFICATION

OPTIONS & ACCESSORIES

STRAIGHTENING VANES required
DUAL PICKUP
BIDIRECTIONAL
MECHANICAL PRINTER
UPSTREAM STRAINER
NACE COMPLIANCE No

Job No.

Data Sheet No.

Rev	Date	Initials
A	7/14/2015	DO

KLEINFELDER — Bright People. Right Solutions. | HOOD

MVT DATA SHEET

CLIENT:	Vanguard	BY:	Dallas Obrigewitch
PROJECT	REC skids	DATE:	July 14/2015
FABR. SPEC:		APPROVED:	
SERIAL No.:		DATE:	

GENERAL

P & ID NUMBER	10160-0301
TAG NUMBER	FR-1006/TR-1006/PR-1006
SERVICE DESCRIPTION	Sales gas meter
LINE	Sales — SIZE 4" — SCHEDULE 600# Ansi

OPERATING CONDITIONS

PROCESS:	FLUID	Gas	PHASE	Gas		
ENG. UNITS:	FLOW	mmscf/d	PRESSURE	PSIG		
FLOW:	MIN	3	NORM		MAX	20
INLET PRESSURE:	MIN	300	NORM		MAX	1440
OUTLET PRESSURE:	MIN		NORM	600	MAX	
TEMPERATURE °C:	MIN	20	NORM	26	MAX	50
SG (LIQUID) OR MOL WT (GAS)						
VISCOSITY		0.012805		COMPRESSIBILITY		
PRESSURE:	VAPOUR			CRITICAL		
SPECIFIC:	HEAT RATIO			VOLUME		
PRESSURE DROP:	ALLOWABLE					

METER

TRANSMITTER TYPE **Mulit-variable Flow tranmsitter (EFM)**

CAPACITANCE	yes	STRAIN GAUGE		DIAPHRAGM	
Temperature element integral:		No	Type:		
Required: Yes	Type:	Platinum 100 RTD			
Body Material:	SST	Element Material:	316L SST	Fill Fluid:	DC200
Body Rating:		Overrange:			
Instrument Conn:	1/4" npt	Process Connections:	1/4"npt	Other:	
	Differential	Static	Temperature		
Units:	"H2O	Kpag	°C		
Range:	0/1000	0/25000	-40 to 150		
Calibrated Range:					
Ambient temp range:	-40 to 75°C	Process temp range:	-40 to 100°C		
Accuracy:	± 0.10% of span				
Vendor:	Spartan	Manufacturer:	Emerson		
Model No:	FB103				

SPECIAL CONSIDERATIONS

Custody Transfer	No	MARP	No
Accuracy Required:	± 0.25% of span		
Communcations (HART):			

COMMENTS

Will require Floboss 103 with dongle, PDA and applicable software. (walk up system)

Dongle, pda and software allow for easy entry of orifice plate size, gas composition, starting and stopping of flow runs, and extraction of flow run data (date stamped for reporting), and location.

This will be a multi-variable transmitter measuring DP, static Press, and temperature.
(FR-1006/PR-1006/TR-1006)

Vendor may specify FB107 better suited for application

MISCELLANEOUS

Require Platinum 100 RTD for temperature element
Battery powered unit with solar panel.

INSTALLATION

Enclosure rating	Class 1 Div 2
Conduit connection	1/2" npt
Display	Required
Power Supply	12 Vdc battery and solar required
Indoor/Outdoor	Outdoor
Mounting:	Pipe bracket required
Area Classification:	Class 1 Div 2

OPTIONS & ACCESSORIES

Platuinum 100 RTd.
PDA and software
Soalr panel
5 valve manifold.

Job No.

Data Sheet No.

Rev	Date	Initials
A	7/14/2015	DO

KLEINFELDER — Bright People. Right Solutions. | HOOD

LEVEL INSTRUMENT

CLIENT: Vanguard

PROJECT: REC skids

REVISIONS				
NO	BY	DATE	DESCRIPTION	SHT # 1
A	DO	7/13/15	IFR	Doc#
				Contract#
				Req #
				PO #
				App'd by:
				Chk'd by:

GENERAL	1	Tag Number (s)	LSHH-800	
	2	Service	Flare stack Hi level	
	3	Line No./Vessel	FL-800/801	
	4	Application	Liquid level	
	5	Function	Hi shutdown	
	6	Fail Safe	vent	
PROBE	7	Probe Tag No.		
	8	Type	float	
	9	Orientation	horizontal	
	#	Material	316 SST	
	#	Sheath		
	12	Process Conn. Size and Rating	2" npt	
	13	Length - Overall	std	
		- Inactive Upper Section		
		- Active Lower Section		
	14	Probe Diameter	std	
	15	Conduit Connection	n/a	
	16	Enclosure Class		
TRANSMITTER / SWITCH	17	Type	Pneumatic	
	18	Rating: MAWP	10342 Kpa	
	19	Temperature	-40 degF to 450 deg F	
	20	Specific Gravity	0.5 minimum	
	21	Materials	316 SST	
	22	Flow rate	40 SCFH @ 30 psi	
	23	Time Delay Set @		
	24	Output	non-bleed, snap acting	
	25	Transmitter Range or Switch Trip Point		
	26	Power supply		
	27	Conduit Connection		
	28	Signal Output Barrier		
	29	Enclosure Class		
OPTIONS	30			
	31	Local Indicator		
	32	Transmitter Mounting Bracket		
	33	Cable (Probe to Transmitter)		
SERVICE Engineering Units Press. = kPag Temp. = C	34	Seal Housing Process Conn.	2" npt	
	35	Seal Housing Assy Material		
	36	Seal Housing Bleed Valve		
	37	Process Isolation Valve		
	38	Notes		
	39	Upper Fluid	oil	
	40	Lower Fluid	water	
	41	Upper Fluid Dielectric Constant		
	42	Lower Fluid Dielectric Constant		
	43	Fluid Viscosity (cp)		
	44	Material Buildup	no	
	45	Press. Max. Norm. (Kpag)	1378 Kpa/ 10 Kpa	
	46	Temp. Max. Norm. (^{0}C)	27 / 27	
	47	Manufacturer / Vendor	LINC / Zimco	
	48	Probe Model No.		
	49	Switch Model No	L282-11-32	

Notes:

KLEINFELDER Bright People. Right Solutions. | HOOD

CONTROL VALVE DATA SHEET

CLIENT: Vanguard
BY: Dallas Obrigewitch
PROJECT REC skids
DATE: July 14 2015
FABR. SPEC:
APPROVED:
SERIAL No.:
DATE:

GENERAL

P & ID NUMBER: 10160-0300
TAG NUMBER: ESDV-100
SERVICE DESCRIPTION: Inlet ESD valve

LINE: SIZE 3" SCHEDULE API 10000

OPERATING CONDITIONS

PROCESS:	FLUID	Frac	PHASE	Liquid		
ENG. UNITS:	FLOW	m3/hr	PRESSURE	kpag		
FLOW:	MIN	15	NORM		MAX	50
INLET PRESSURE:	MIN	20684	NORM	24821	MAX	68947
OUTLET PRESSURE:	MIN	20684	NORM	24821	MAX	68947
TEMPERATURE °C:	MIN	5	NORM	20	MAX	50

SG (LIQUID) OR MOL WT (GAS)
VISCOSITY — COMPRESSIBILITY
PRESSURE: VAPOUR — CRITICAL
SPECIFIC: HEAT RATIO — VOLUME
PRESSURE DROP: SIZING — SHUTOFF
ALLOWABLE (dB) — CALCULATED (dB)
VALVE C_v — CALCULATED — ACTUAL

VALVE

BODY

MANUFACTURER: Streamflow — MODEL NUMBER: SSV
SIZE — TYPE
END CONNECTIONS: 3" NPT — ANSI RATING
MATERIAL — PACKING
BONNET TYPE

TRIM

PLUG — TYPE
CHARACTERISTIC
NUMBER OF PORTS — PORT SIZE
GUIDING TYPE
MATERIAL
SEAT
PLUG
SHAFT
ANSI LEAKAGE CLASSIFICATION

COMMENTS

note: Initial downstream pressure will be 0 psig, creating large differential potential.
Pneumatic switching valve required.

ACTUATOR

MANUFACTURER
MODEL NUMBER: ESDV actuation system
TYPE — SIZE
SIGNAL RANGE
AIR SUPPLY
FAILURE POSITION

POSITIONER

MANUFACTURER
MODEL NUMBER
INPUT SIGNAL
OUTPUT SIGNAL
GAUGES — BYPASS

OPTIONS & ACCESSORIES

AIR SET
HANDWHEEL
LUBRICATOR
MOUNTING LOCATION
ISOLATION VALVE
SOLENOID VALVE: Pneumatic switching valve
VALVE POSITION LIMIT SWITCH

Job No.

Data Sheet No.

Rev	Date	Initials
A	7/14/15	DO

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