THYSON TECHNOLOGY

nZERO

Customer Name: DLC
Project Name: Hydrogen Blending Infrastucture Conceptual Design Pack

Date: 27/03/2023

Revision:	**B2**
Date:	**27/03/23**

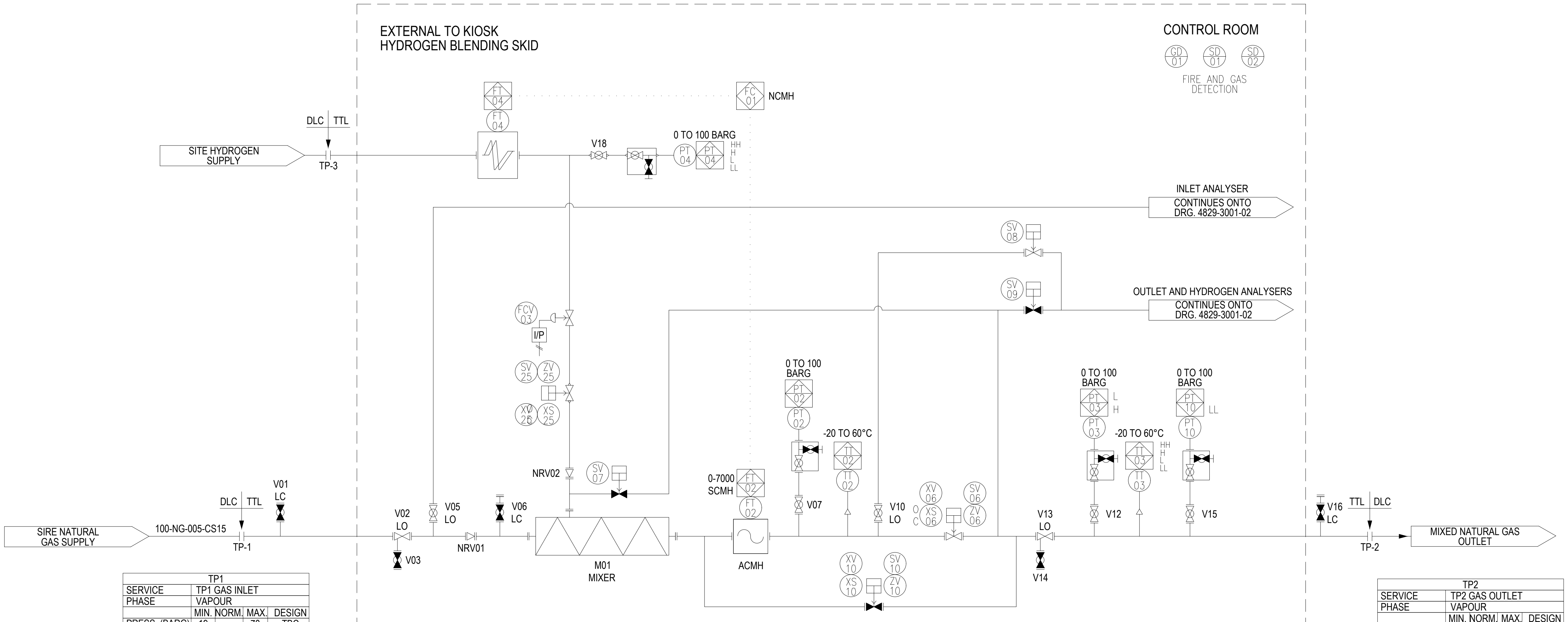
Author: Nayeem Quraishi	(Position) Process Engineer
Signature: Nayeem.	Date: 27/03/23

Approved By: Jordan Davies	(Position) Mechanical/Process Design Lead
Signature:	Date: 27/03/23

Index

Section A Drawings

A.1 Piping Schematic Diagrams



TP1				
SERVICE	TP1 GAS INLET			
PHASE	VAPOUR			
	MIN.	NORM.	MAX.	DESIGN
PRESS. (BARG)	19	-	70	TBC
TEMP. (°C)	TBC	TBC	TBC	TBC
FLOW. (Sm^3/Hr)	TBC	TBC	TBC	511000

TP2				
SERVICE	TP2 GAS OUTLET			
PHASE	VAPOUR			
	MIN.	NORM.	MAX.	DESIGN
PRESS. (BARG)	TBC	TBC	TBC	TBC
TEMP. (°C)	TBC	TBC	TBC	TBC
FLOW. (Sm^3/Hr)	TBC	TBC	TBC	TBC

NOTES

1. 24" PIPE WILL BE USED ON THE BLENDING SKID.
2. ZONE 2 HAZARDOUS AREA WILL BE PRESENT AROUND THE SKID.

THYSON TECHNOLOGY

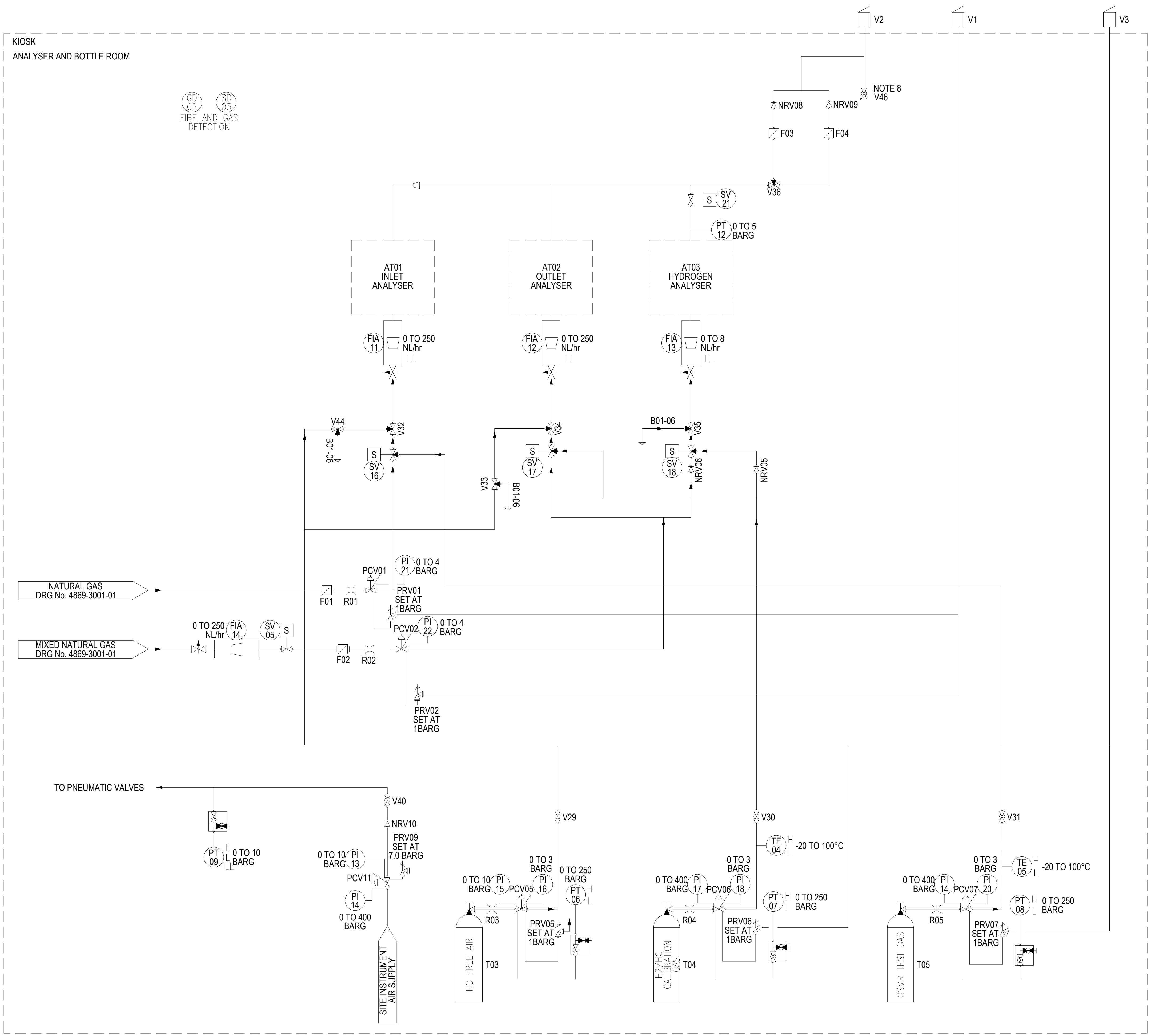
DRAWING NO. 5062-3001-01 | ISSUE B1

DATE	DRAWN	CHKD	APPD	REV	DESCRIPTION
13/01/23	KK	NQ	JD	B1	CENCEPTUAL DESIGN

DLC
HYDROGEN INJECTION SKID
WARBURTON
PIPE SKID
PROCESS SCHEMATIC DIAGRAM

SCALE N.T.S. | MASTER SIZE A3

CLIENT DRAWING NO. | ISSUE



NOTES

1. 6mm OD TUBE TO BE USED FOR ANALYSER TUBING.
2. 12mm OD TUBE TO BE USED FOR PROCESS AND ANALYSER VENTS.
3. INTERNAL OF ANALYSER KIOSK WILL BE CLASSIFIED AS ZONE 1.
4. ZONE 2 HAZARDOUS AREA CLOUD WILL BE PRESENT AROUND THE KIOSK (ON THE OUTSIDE).

THYSON TECHNOLOGY

DRAWING NO. 5062-3001-02 ISSUE B1

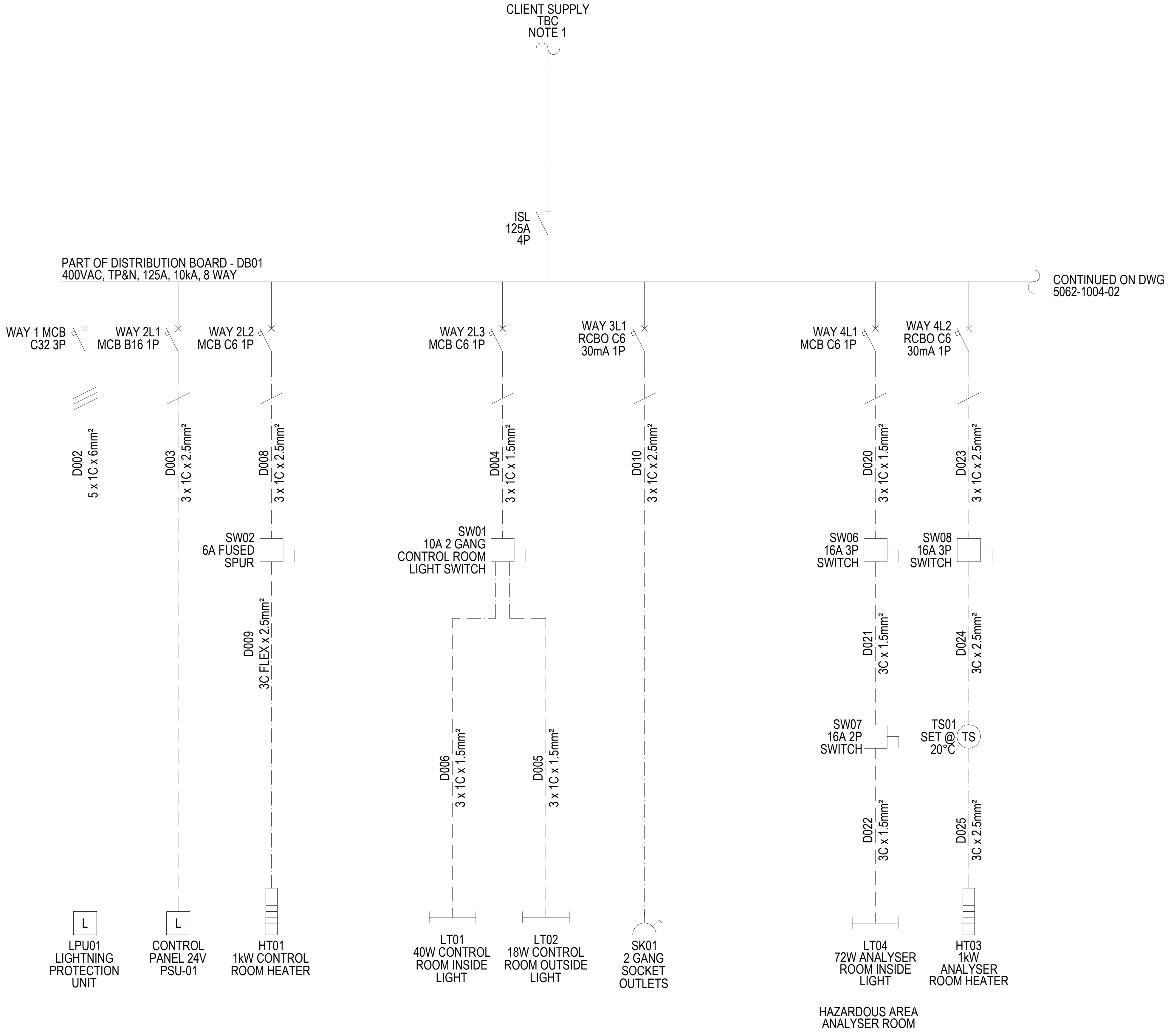
DATE	DRAWN	CHKD	APPD	REV	DESCRIPTION
13/01/23	KK	NQ	JD	B1	CENCEPTUAL DESIGN

DLC
HYDROGEN INJECTION SKID
WARBURTON
PIPE SKID
PROCESS SCHEMATIC DIAGRAM

SCALE N.T.S. MASTER SIZE A3

CLIENT DRAWING NO. ISSUE

A.2 Single Line Diagrams



NOTES

1.

THYSON
TECHNOLOGY

DRAWING NO. 5062-1004-01 | ISSUE B1

DATE	DRAWN	CHKD	APPD	REV	DESCRIPTION
13/01/23	KK	NQ	JD	B1	CENCEPTUAL DESIGN

DLC

HYDROGEN INJECTION SKID

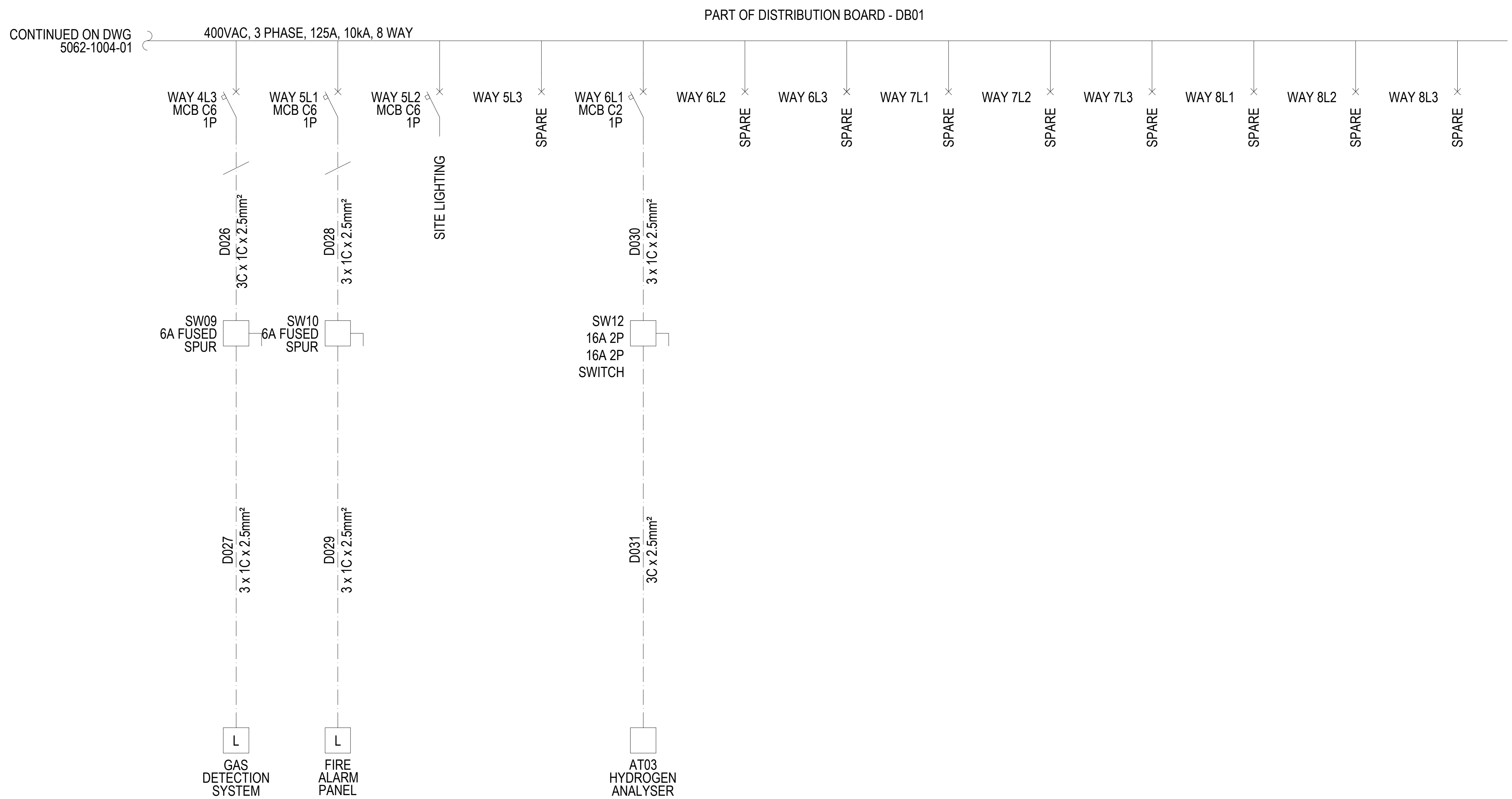
WARBURTON

PIPE SKID

SINGLE LINE DIAGRAM

SCALE N.T.S. | MASTER SIZE A3

CLIENT DRAWING NO. | ISSUE



NOTES

1.

THYSON TECHNOLOGY

DRAWING NO. 5062-1004-02 | ISSUE B1

DATE	DRAWN	CHKD	APPD	REV	DESCRIPTION
13/01/23	KK	NQ	JD	B1	CENCEPTUAL DESIGN

DLC
HYDROGEN INJECTION SKID
WARBURTON
PIPE SKID
SINGLE LINE DIAGRAM

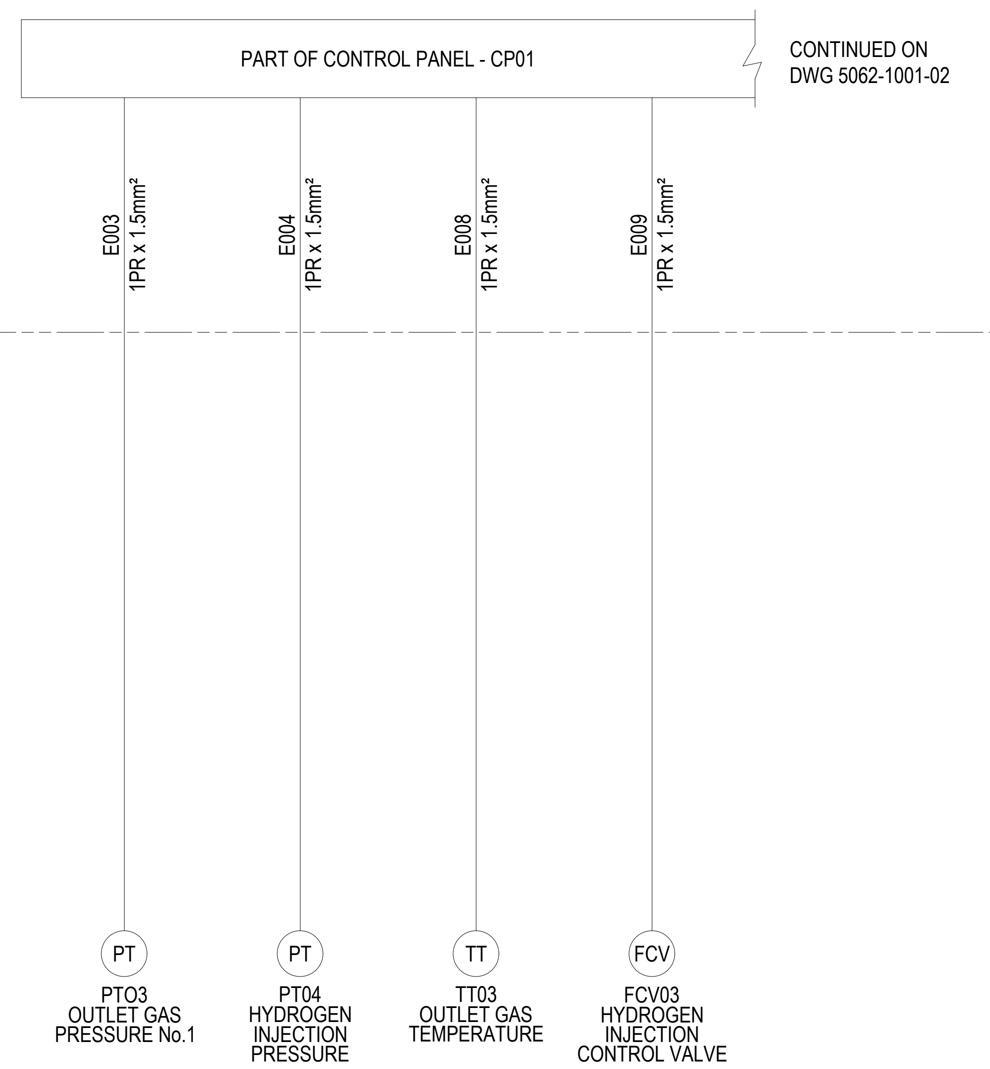
SCALE N.T.S. | MASTER SIZE A3

CLIENT DRAWING NO. | ISSUE

A.3 Instrument Block Diagrams

SAFE AREA

HAZARDOUS AREA



NOTES

1.

THYSON TECHNOLOGY

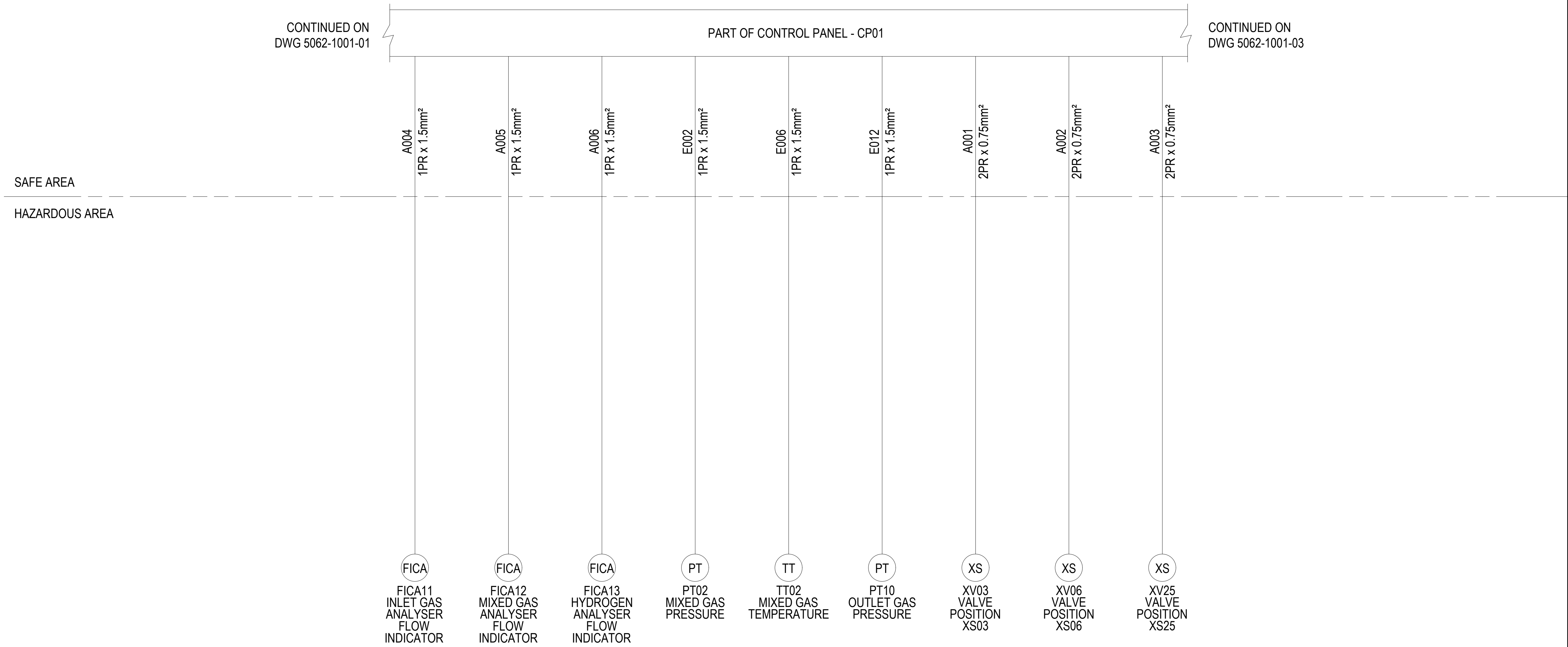
DRAWING NO. 5062-1001-01 ISSUE B1

DATE	DRAWN	CHKD	APPD	REV	DESCRIPTION
13/01/23	KK	NQ	JD	B1	CENCEPTUAL DESIGN

DLC
HYDROGEN INJECTION SKID
WARBURTON
PIPE SKID
ELECTRICAL BLOCK DIAGRAM

SCALE N.T.S. MASTER SIZE A3

CLIENT DRAWING NO. ISSUE



NOTES

1.

THYSON TECHNOLOGY

DRAWING NO. 5062-1001-02 | ISSUE B1

DATE	DRAWN	CHKD	APPD	REV	DESCRIPTION
13/01/23	KK	NQ	JD	B1	CENCEPTUAL DESIGN

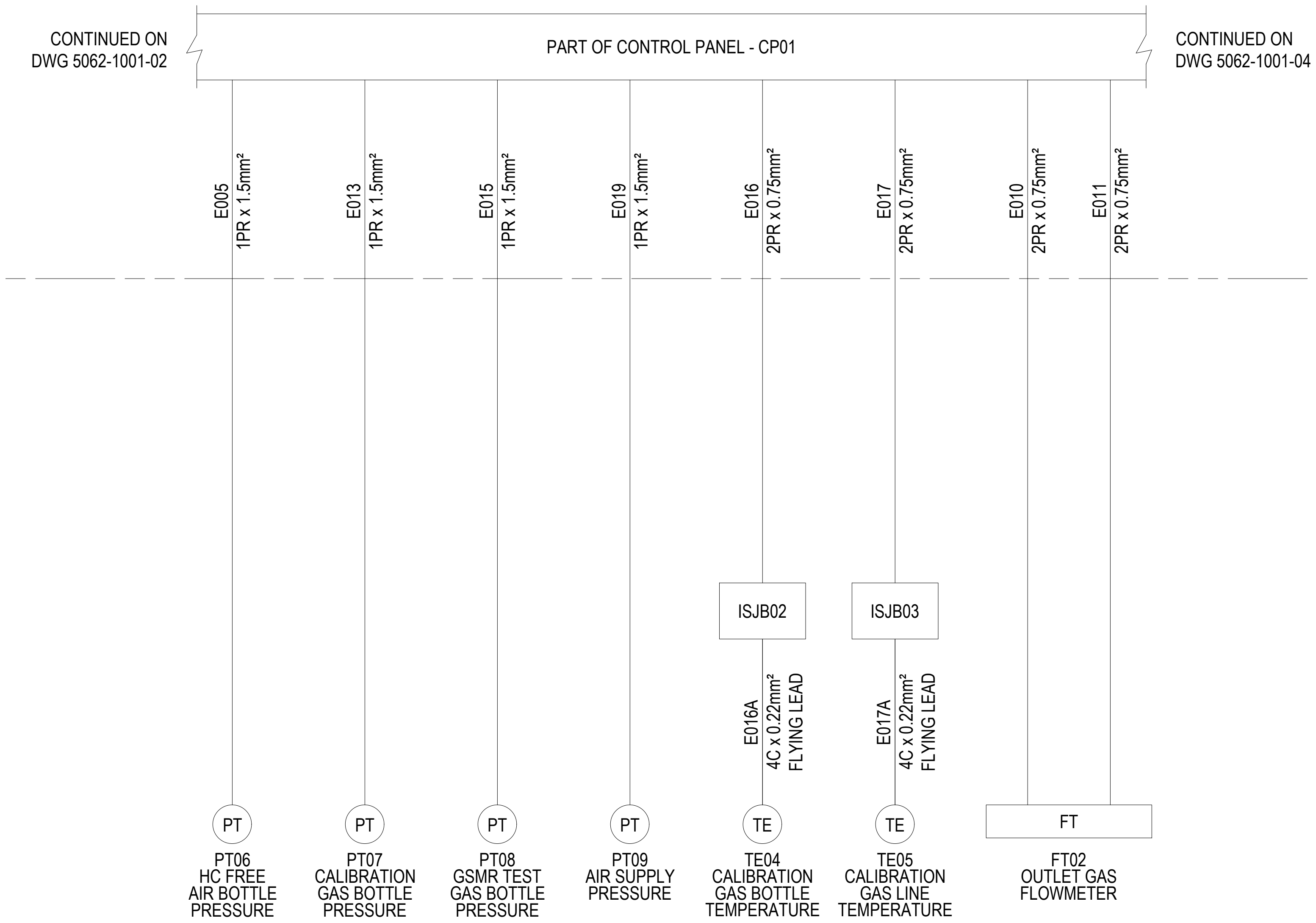
DLC
HYDROGEN INJECTION SKID
WARBURTON
PIPE SKID
ELECTRICAL BLOCK DIAGRAM

SCALE N.T.S. | MASTER SIZE A3

CLIENT DRAWING NO. | ISSUE

A B C D E F G H I J K L

1 2 3 4 5 6 7 8 9 10



NOTES

1.

THYSON TECHNOLOGY

DRAWING NO. 5062-1001-03

ISSUE B1

DATE	DRAWN	CHKD	APPD	REV	DESCRIPTION
13/01/23	KK	NQ	JD	B1	CENCEPTUAL DESIGN

DLC
HYDROGEN INJECTION SKID
WARBURTON
PIPE SKID
ELECTRICAL BLOCK DIAGRAM

THIS DRAWING IS ISSUED BY THYSON TECHNOLOGY PROJECT MANAGEMENT ON BEHALF OF THE ABOVE CLIENT SUBJECT TO THE CONDITIONS THAT IT IS NOT COPIED EITHER IN WHOLE OR IN PART, OR DISCLOSED TO THIRD PARTIES UNLESS PRIOR WRITTEN AUTHORISATION IS GIVEN BY THYSON TECHNOLOGY LIMITED.

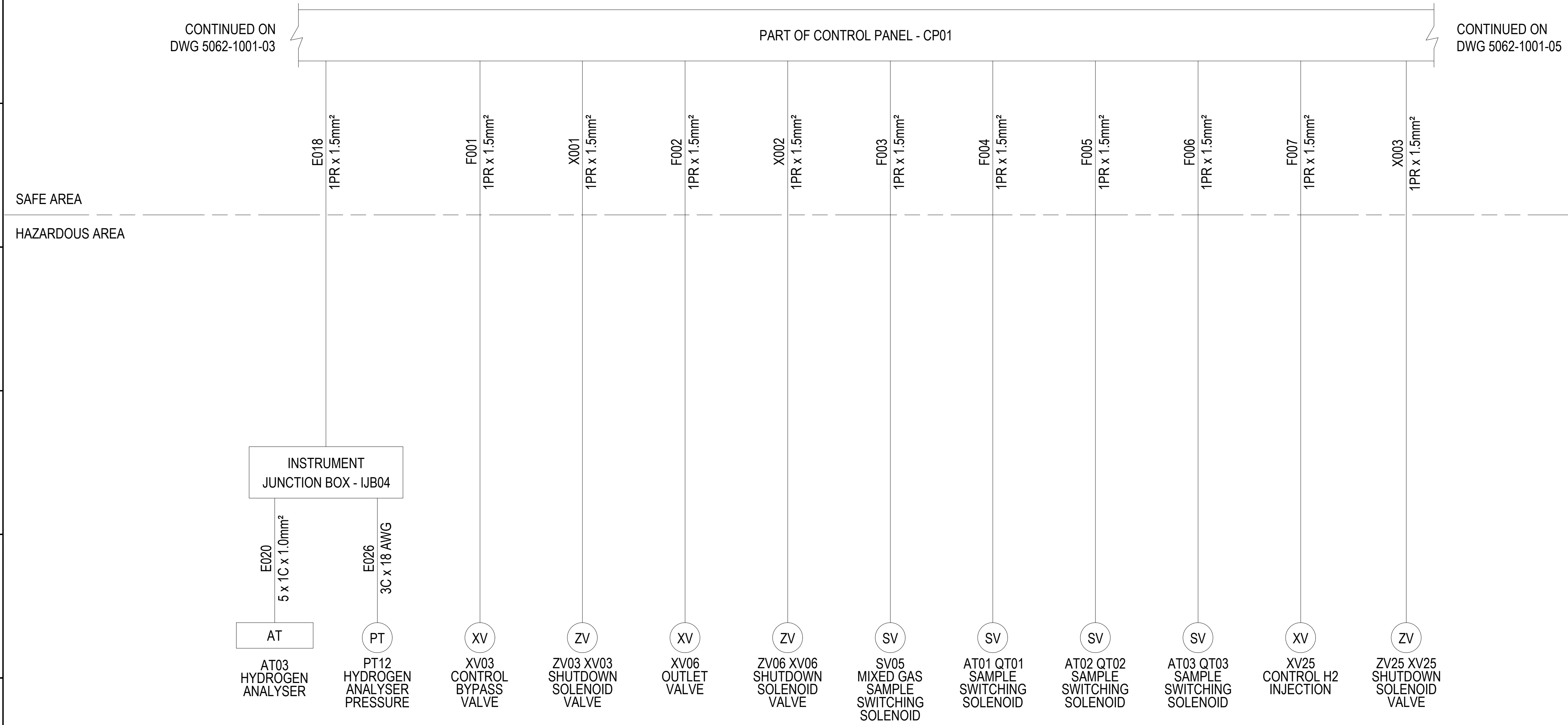
PREVIOUS VERSIONS OF THIS DRAWING SHOULD BE STAMPED SUPERSEDED OR DESTROYED.

SCALE N.T.S.

MASTER SIZE A3

CLIENT DRAWING NO.

ISSUE



NOTES

1.

THYSON TECHNOLOGY

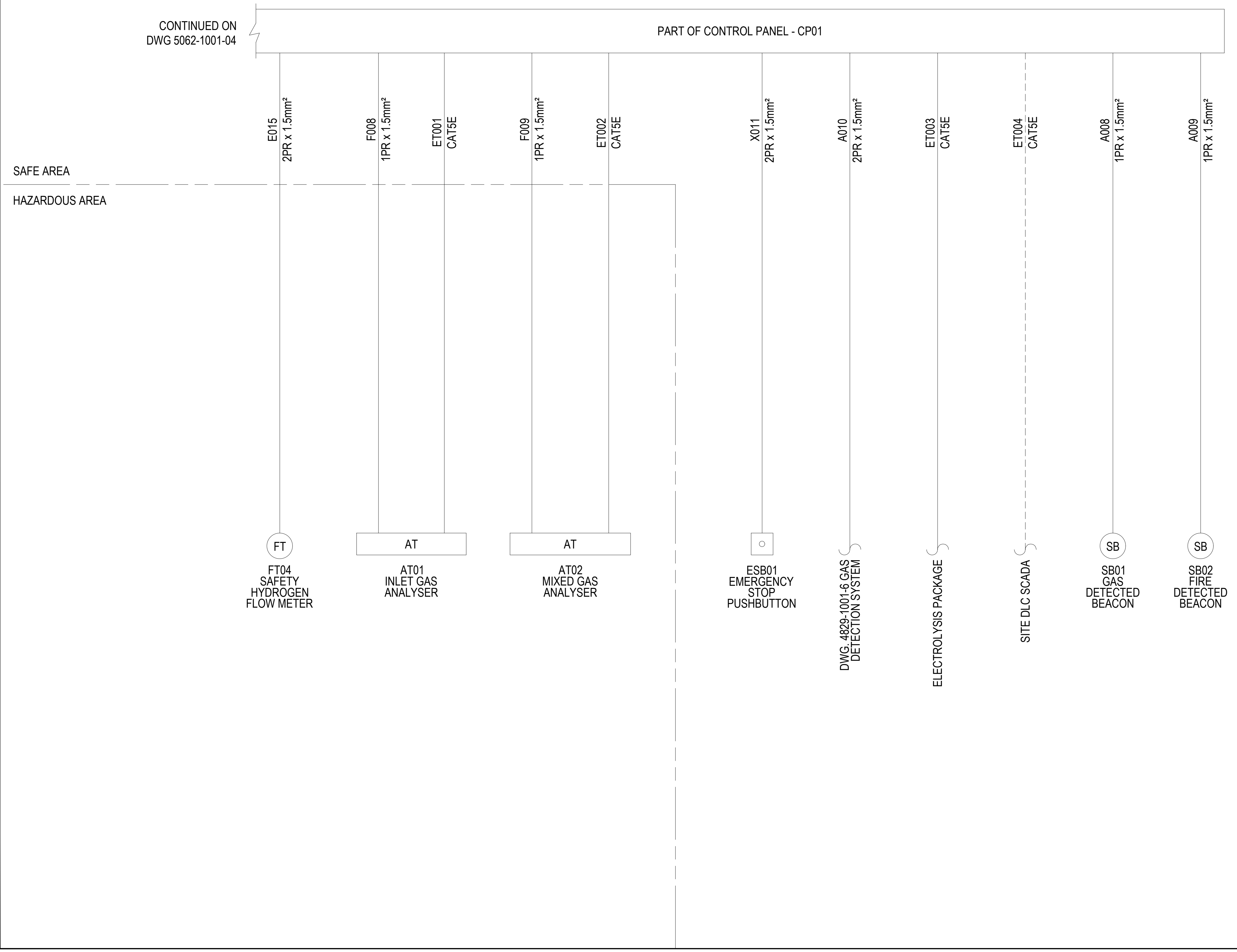
DRAWING NO.	5062-1001-04	ISSUE	B1

DATE	DRAWN	CHKD	APPD	REV	DESCRIPTION
13/01/23	KK	NQ	JD	B1	CENCEPTUAL DESIGN

DLC
HYDROGEN INJECTION SKID
WARBURTON
PIPE SKID
ELECTRICAL BLOCK DIAGRAM

SCALE N.T.S. | MASTER SIZE A3

CLIENT DRAWING NO. | ISSUE



NOTES

1.

THYSON TECHNOLOGY

DRAWING NO. 5062-1001-05 ISSUE B1

DATE	DRAWN	CHKD	APPD	REV	DESCRIPTION
13/01/23	KK	NQ	JD	B1	CENCEPTUAL DESIGN

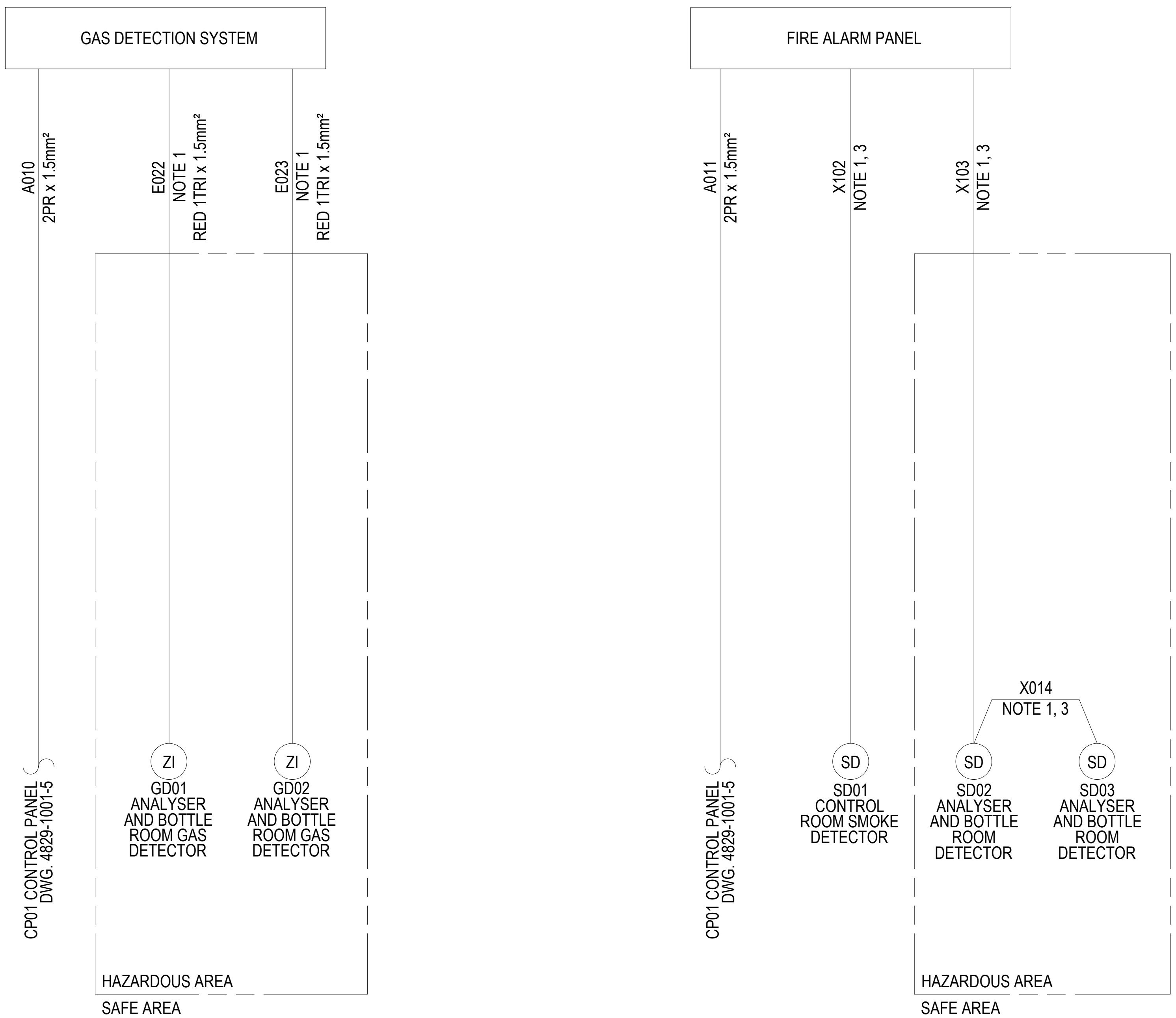
DLC
HYDROGEN INJECTION SKID
WARBURTON
PIPE SKID
ELECTRICAL BLOCK DIAGRAM

SCALE N.T.S. MASTER SIZE A3

CLIENT DRAWING NO. ISSUE

NOTES

1.



THYSON TECHNOLOGY

DRAWING NO.	ISSUE
5062-1001-06	B1

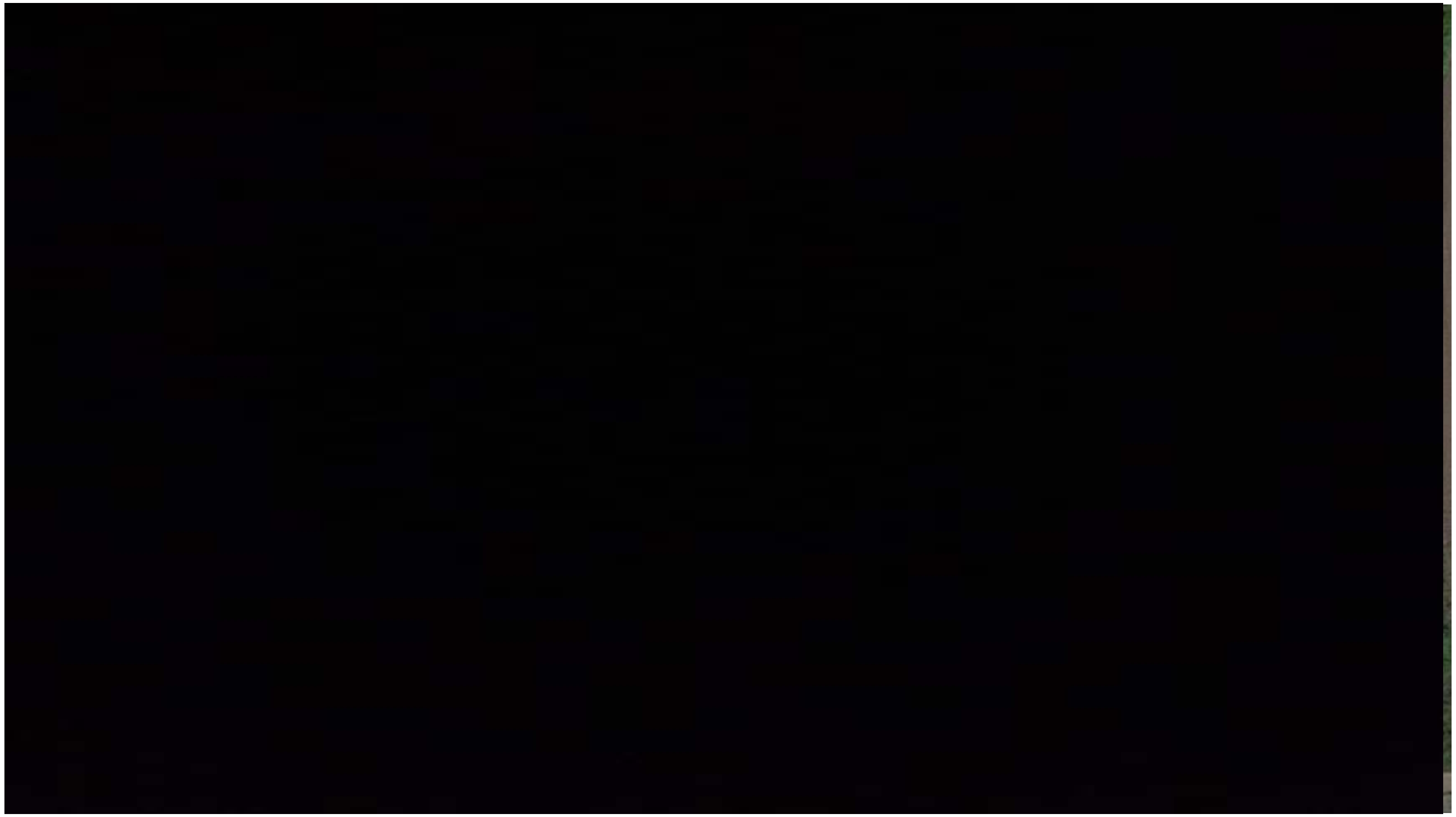
DATE	DRAWN	CHKD	APPD	REV	DESCRIPTION
13/01/23	KK	NQ	JD	B1	CENCEPTUAL DESIGN

DLC
HYDROGEN INJECTION SKID
WARBURTON
PIPE SKID
ELECTRICAL BLOCK DIAGRAM

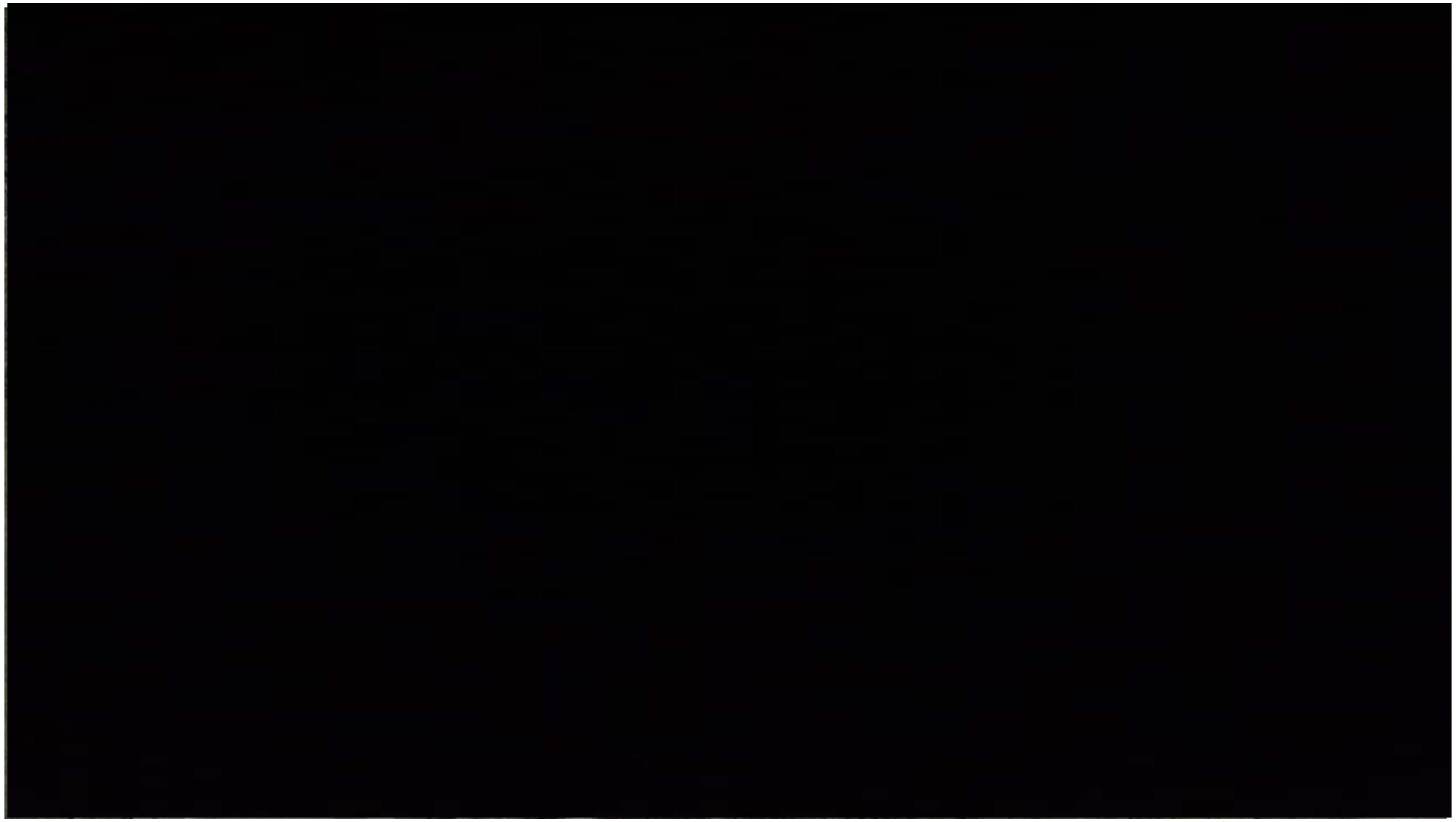
SCALE	MASTER SIZE
N.T.S.	A3
CLIENT DRAWING NO.	ISSUE

A.4 General Arrangement Drawings

A snapshot of Warburton site

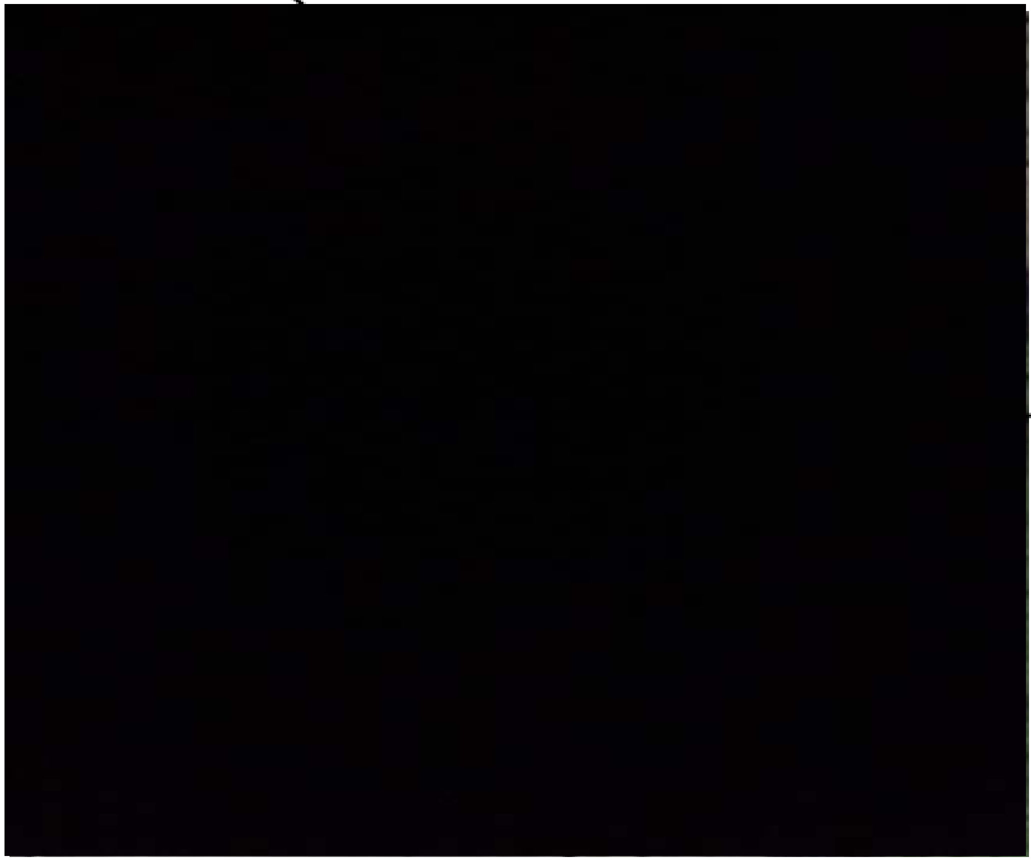


Area where the blending skid and analyser kiosk will be installed



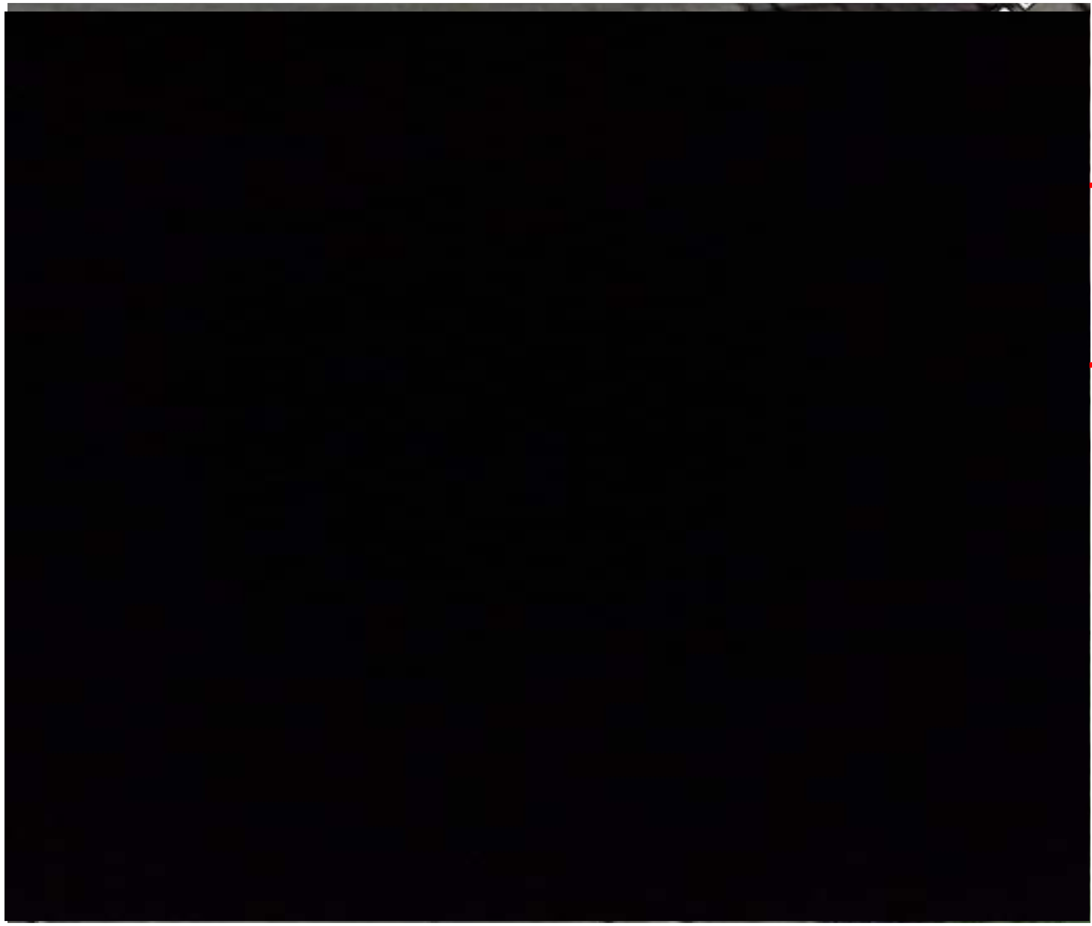
BG 30 Pipe to Winwick

Warburton site layout, potential location for blending skid and analyser room, near the 30 Pipe to Winwick



Existing Valve GF74

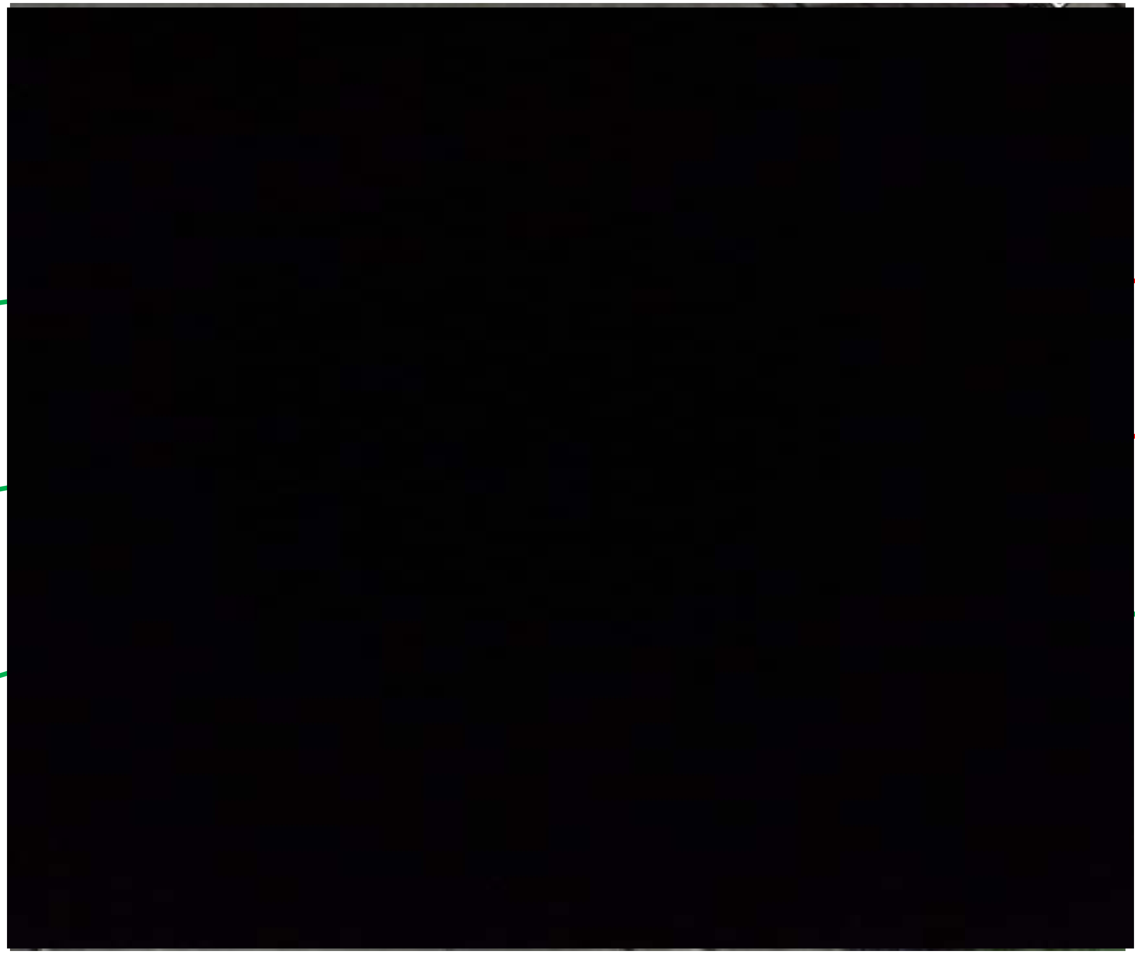
Direction of the travel for the gas pipeline

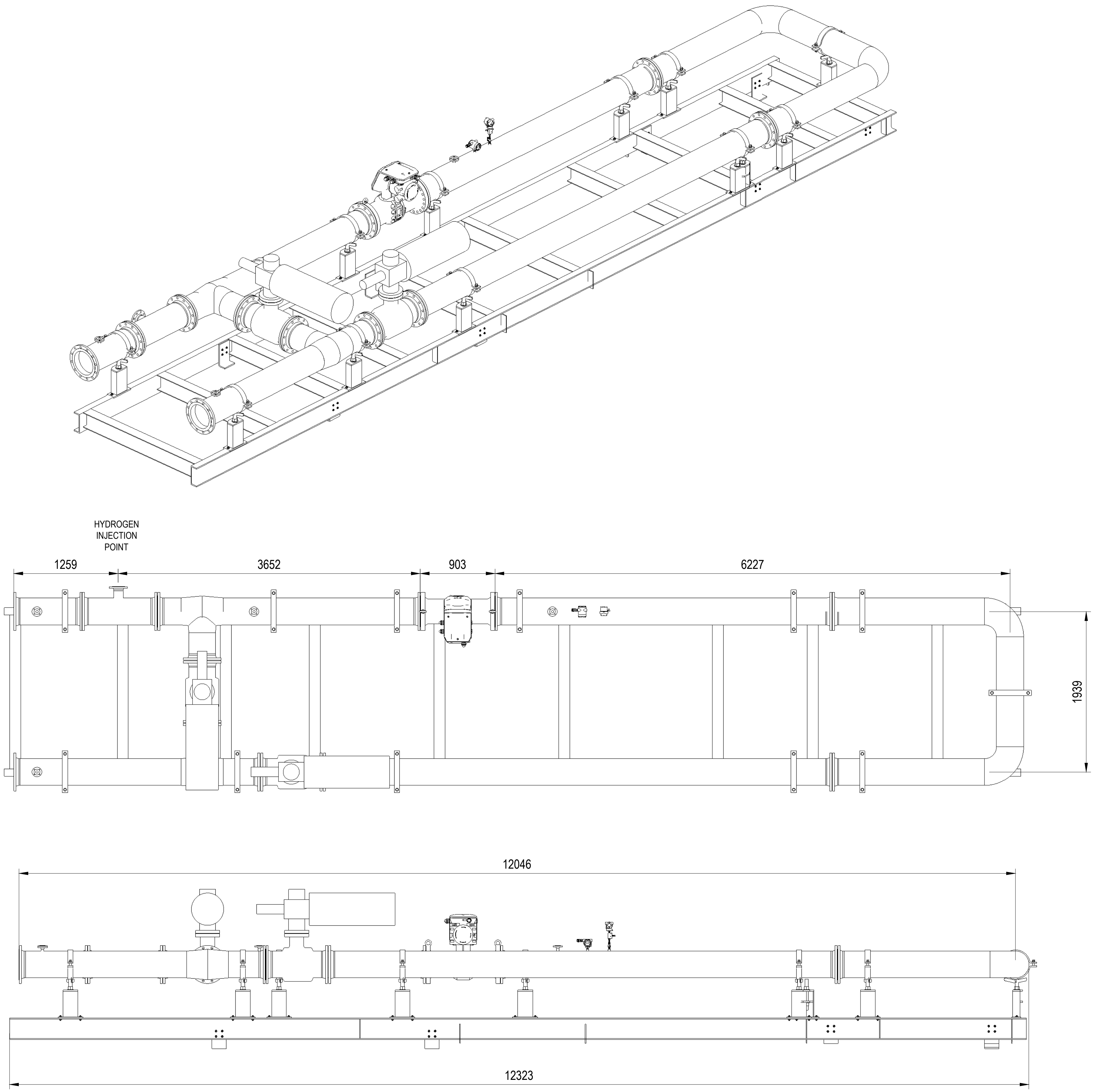


BG 30" Pipe to Winwick

Existing Valve GF74

Potential location for the hydrogen blending skid near pipework


BG Hot Tap and Valve
Blending Skid
AG Hot Tap and Valve
BG 30” Pipe to Winwick
Existing Valve GF74
Analyser Kiosk



NOTES

1. PIPE TO BE DN600 / 24"
2. VOLUME LOOP / TANK TBC
3. SKID LENGTHENED TO ACCOMMODATE 10 x DN300 UPSTREAM OF THE FLOW METERS. POSSIBILITY FOR IT TO BE REDUCED
4. HYDROGEN FEED SUPPLIED BY OTHERS

THYSON TECHNOLOGY

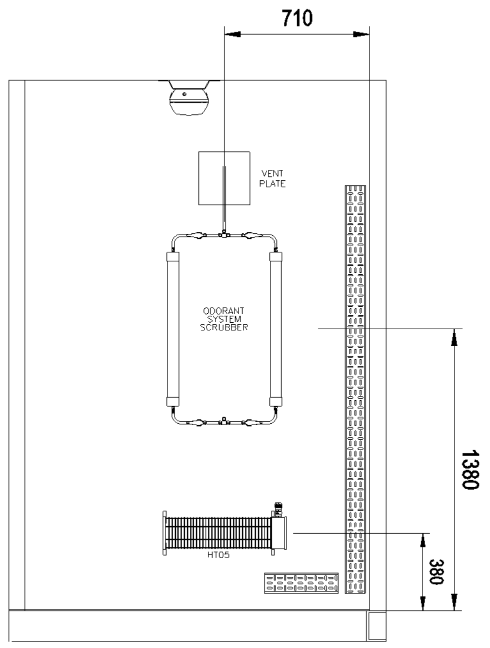
DRAWING NO. 5062-5001-01 ISSUE A1

DATE	DRAWN	CHKD	APPD	REV	DESCRIPTION
11/01/23	JD			A1	CONCEPT

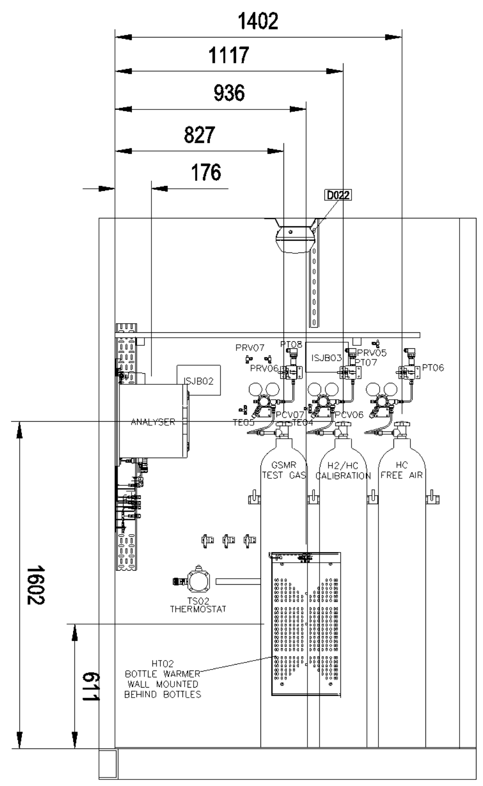
DLC
HYDROGEN INJECTION SKID
WARBURTON
WARBURTON PIPESKID
GENERAL ARRANGEMENT

SCALE N.T.S. MASTER SIZE A3

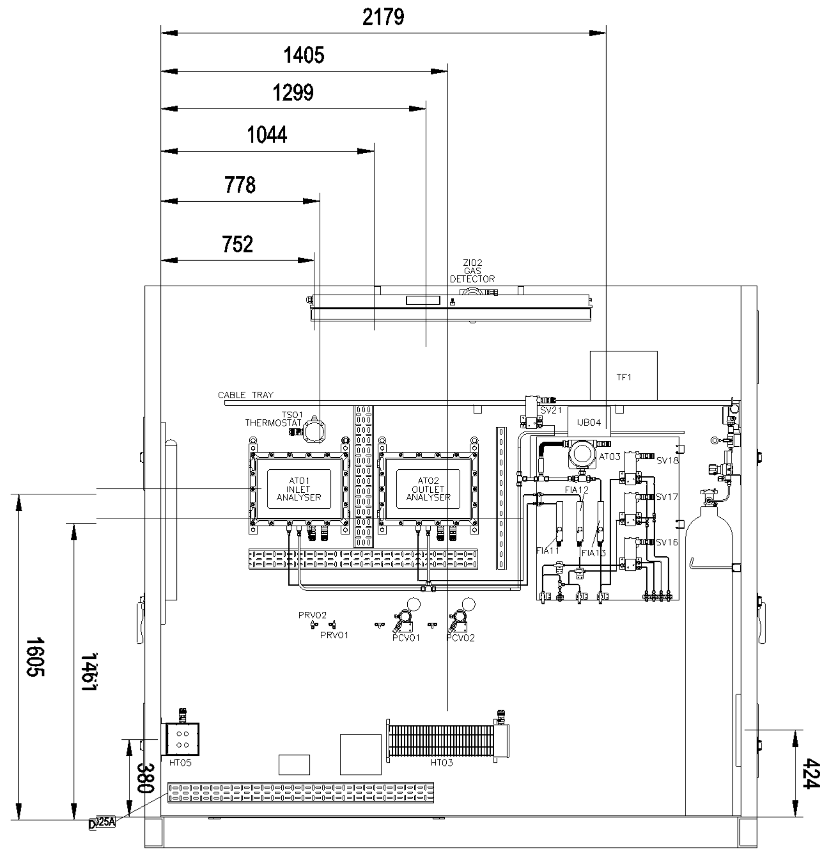
CLIENT DRAWING NO. ISSUE



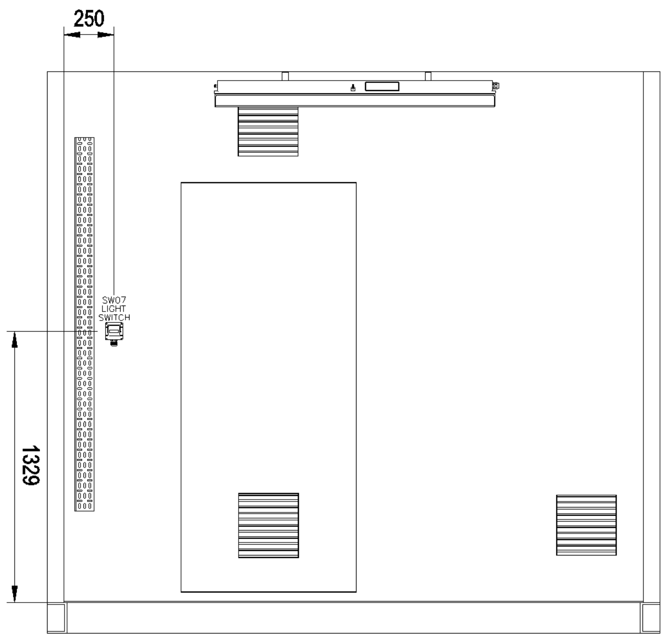
INTERNAL VIEW
LEFT WALL



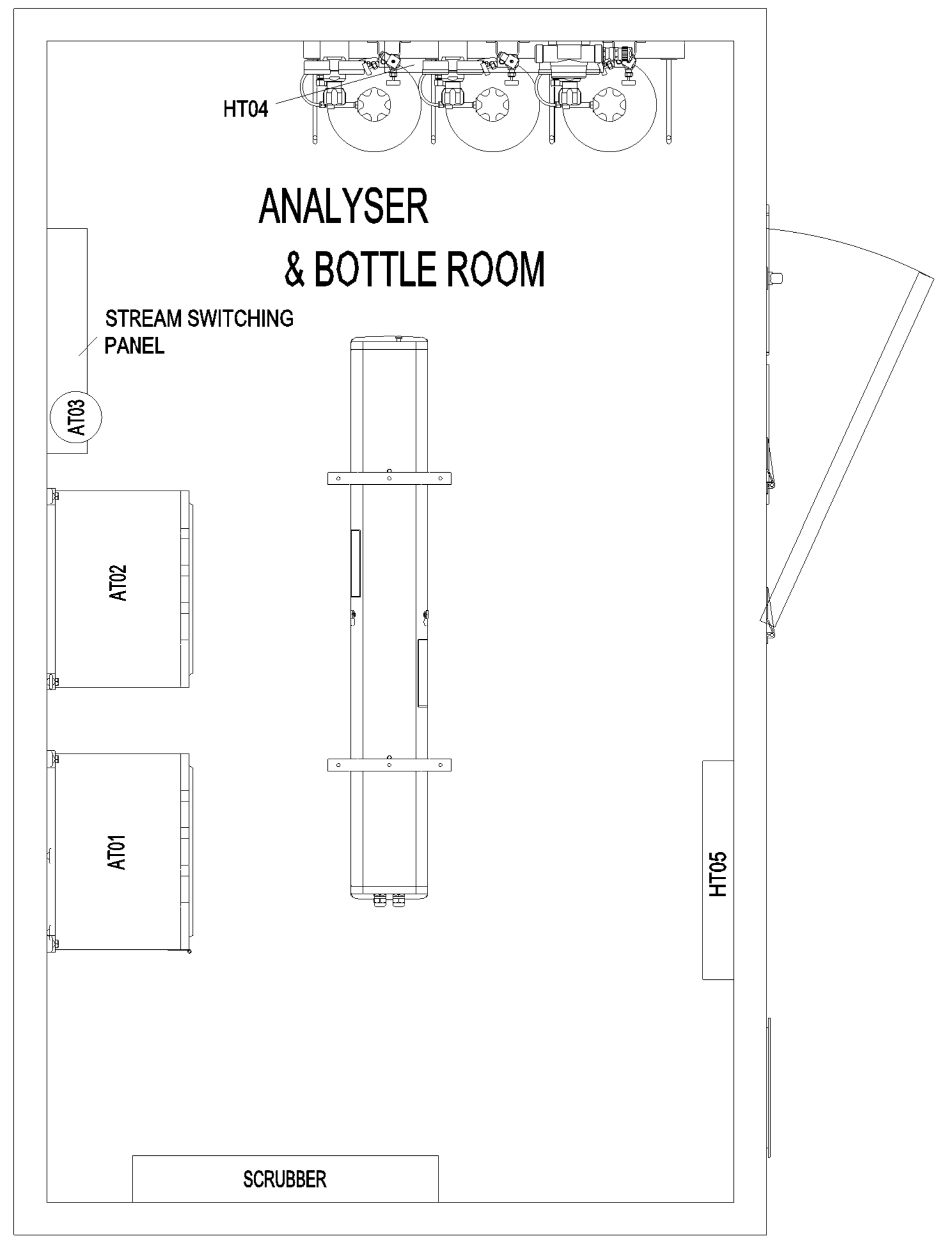
INTERNAL VIEW
RIGHT WALL



INTERNAL VIEW
FRONT WALL



INTERNAL VIEW
BACK WALL



NOTES

THYSON TECHNOLOGY

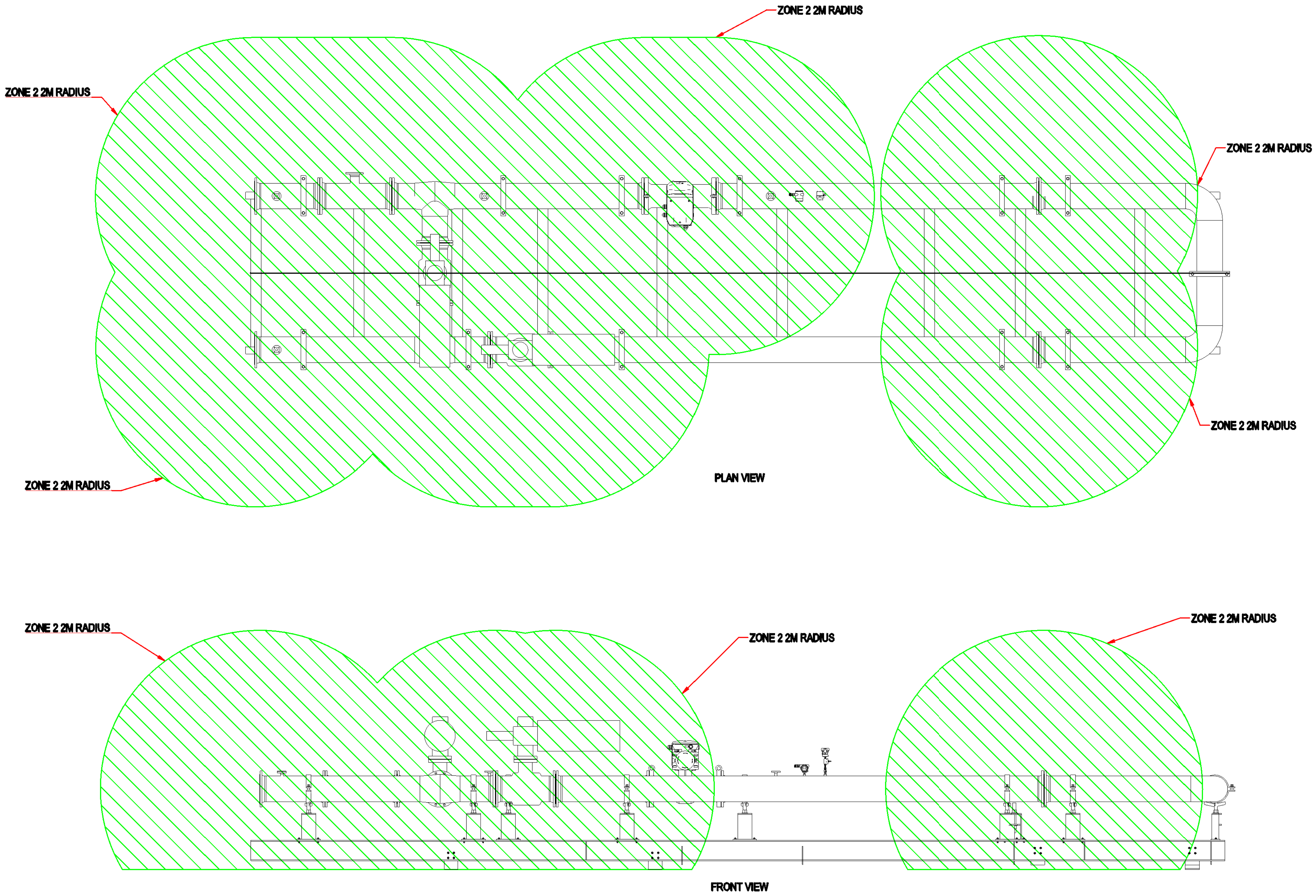
DRAWING NO. 5062-5001-02
ISSUE A1

DATE	DRAWN	CHKD	APPD	REV	DESCRIPTION
11/01/23	JD			A1	CONCEPT

DLC
HYDROGEN INJECTION SKID
WARBURTON
ANALYSER & BOTTLE ROOM
GENERAL ARRANGEMENT

SCALE N.T.S.
MASTER SIZE A3
CLIENT DRAWING NO.
ISSUE

A.5 Hazardous Area Drawings



NOTES

1. PIPE TO BE DN600 / 24"
2. VOLUME LOOP / TANK TBC
3. SKID LENGTHENED TO ACCOMMODATE 10 x DN300 UPSTREAM OF THE FLOW METERS. POSSIBILITY FOR IT TO BE REDUCED
4. HYDROGEN FEED SUPPLIED BY OTHERS

IGEM/SR/25 KEY:

ZONE 0 ZONE 1 ZONE 2

THYSON TECHNOLOGY

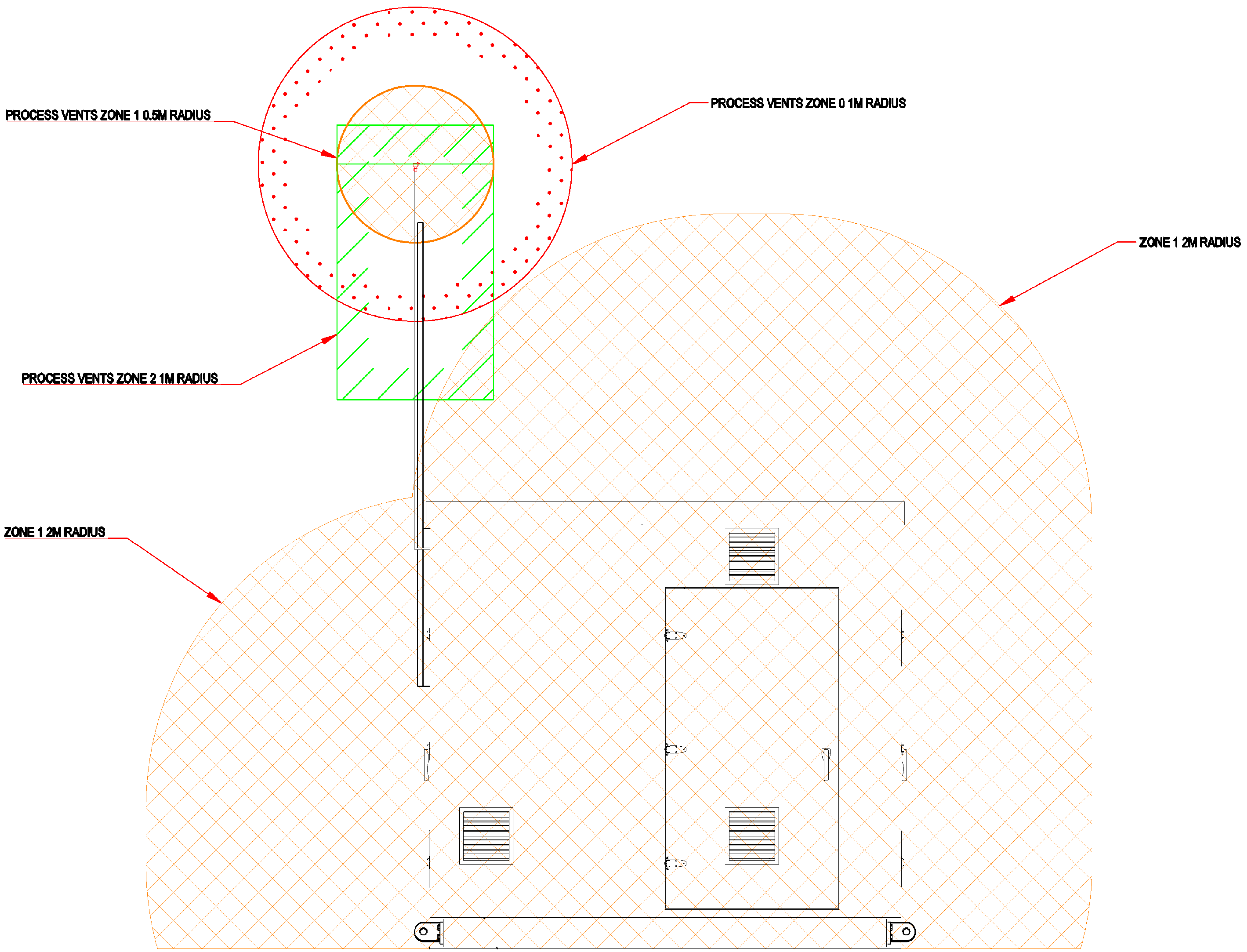
DRAWING NO. 5062-5001-01 ISSUE B1

DATE	DRAWN	CHKD	APPD	REV	DESCRIPTION
16/01/23	KK	NQ	JD	A1	CONECPTUAL DESIGN

DLC
HYDROGEN INJECTION SKID
WARBURTON
WARBURTON PIPESKID
HAZARDOUS AREA

SCALE N.T.S. MASTER SIZE A3

CLIENT DRAWING NO. ISSUE



FRONT ELEVATION
ANALYSER & BOTTLE ROOM

NOTES

1. PIPE TO BE DN600 / 24"
2. VOLUME LOOP / TANK TBC
3. SKID LENGTHENED TO ACCOMMODATE 10 x DN300 UPSTREAM OF THE FLOW METERS. POSSIBILITY FOR IT TO BE REDUCED
4. HYDROGEN FEED SUPPLIED BY OTHERS

IGEM/SR/25 KEY:
ZONE 0 ZONE 1 ZONE 2

THYSON TECHNOLOGY

DRAWING NO. 5062-5001-02 ISSUE B1

DATE	DRAWN	CHKD	APPD	REV	DESCRIPTION
16/01/23	KK	NQ	JD	A1	CONECPTUAL DESIGN

DLC
HYDROGEN INJECTION SKID
WARBURTON
WARBURTON PIPESKID
HAZARDOUS AREA

SCALE N.T.S. MASTER SIZE A3

CLIENT DRAWING NO. ISSUE

Section B Functional Design Specification

Client	Dave Lander Consulting Ltd
Project	Hydrogen Blending Infrastructure
Client Reference	N/A
Site Name	Warburton
Document Title	Functional Design Specification
TTL Doc. Number	5062-9036
TTL Doc. Revision	B1

CHANGES THIS REVISION	
Revision	**Description**
B2	Conceptual Design

TTL DOCUMENT REVISION HISTORY					
Revision	**Description**	**Prepared**	**Checked**	**Approved**	**Date**
B1	Conceptual Design	NQ	JD	NS	16/01/23
B2	Conceptual Design	NQ	JD	NS	27/03/23

TABLE OF CONTENTS

1 GLOSSARY

CDM	– Construction (Design and Management) Regulations
CE	– Conformité Européenne
CV	– Calorific Value
EU	– European Union
FAT	– Factory Acceptance Test
FDS	– Functional Design Specification
GDN	– Gas Distribution Network
GIS	– Gas Industry Specification
GRP	– Glass Reinforced Polyester
GS(M)R	– Gas Safety (Management) Regulations
H_2GEU	– Hydrogen Grid Entry Unit
HMI	– Human Machine Interface
HSE	– Health and Safety Executive
ICF	– Incomplete Composition Factor
IGEM	– Institute of Gas Engineers and Managers
IO	– Input / Output
NDT	– Non-Destructive Testing
OFGEM	– Office of Gas and Electricity Markets
P&ID	– Piping and Instrument Diagram
PID	– Proportional, Integral and Derivative
PLC	– Programmable Logic Controller
PSU	– Power Supply Unit
RTU	– Remote Telemetry Unit
SAT	– Site Acceptance Test
SCADA	– Supervisory Control and Data Acquisition
SI	– Sooting Index
UPS	– Uninterruptable Power Supply

2 REFERENCE DOCUMENTS

The following drawings / documents should be read in conjunction with this FDS:

- 5062-3001 Piping & Instrumentation Diagram
- 5062-1001 Electrical Block Diagram
- 5062-5001 General Arrangement Drawings
- 5062-5002 Hazardous Area Drawings
- 5062-8003 Cable Schedule
- 5062-9175 Hydrogen Blending Report

2.1 Design Standards & Compliance

All equipment shall be Conformité Européene (CE) marked in accordance with relevant European Union (EU) directives.

2.1.1 British / International Codes & Standards

- BS 7671 (Latest edition) – Requirement for Electrical Installations
- BS EN 60079 – Explosive Atmospheres
- BS EN 61439-1 – Low Voltage Switchgear and Controlgear Assemblies
- BS EN 12186 – Gas Infrastructure – Gas Pressure Regulating Stations for Transmission and Distribution
- BS EN ISO 6976 – Natural Gas – Calculation of CV, Density, RD and Wobbe Index from Composition
- BS EN ISO 10715 – Natural Gas – Sampling Guidelines
- BS EN ISO 10723 – Natural Gas – Performance Evaluation for On-line Analytical Systems
- BS EN ISO 14111 – Natural Gas – Guidelines to Traceability in Analysis
- BS EN ISO 12213-2 – Natural Gas – Calculation of Compression Factors
- BS4800 – Schedule of Paint Colours for Building Purposes
- BS EN 61508 – Functional Safety of Electrical/Programmable Electronic Safety Related Systems
- BS EN 61511 – Functional Safety- Safety Instrumented Systems for the Process Industry Sector

2.1.2 EU Directives and UK HSE Regulations

- 2006/42/EC – Machinery Directive
- 2014/30/EU – Electromagnetic Compatibility Directive
- 2014/35/EU – Low Voltage Directive
- 2014/68/EU – Pressure Equipment Directive
- Energy Institute 15 – Area Classification Code for Installations Handling Flammable Fluids
- Electricity at Work Regulations 1989
- Controls of Substance Hazardous to Healthy (COSHH) Regulation 2002
- Dangerous Substances and Explosive Atmospheres Regulation (DSEAR) 2002

2.1.3 IGEM Standards

- IGEM/GM/8 – Non-domestic Meters installations
- IGEM/TD/13 Edition 2 – Pressure Regulating Installations for Transmission and Distribution Systems
- IGEM/SR/25 Edition 2 – Hazardous Areas Classification of Natural Gas Installation

2.1.4 Cadent Gas Specifications

- T/SP/PRS/35 – GRP Housings for Gas Meter Installations and Regulator Installations
- GIS/F7 – Steel Welding Pipe Fittings, Nominal Size 15 mm to 450 mm Inclusive, for OP < 7 Bar
- GIS/V7-1 – Metal-bodied Line Valves for Use at Pressures up to 16 Bar
- GDN/PM/SCO/1 – Management Procedure for Safe Control of Operations
- GDN/PM/SCO/2 – Issue of Permits to Work and Forms of Authority on the Network
- GDN/PM/SCO/4 – The Control of Non-routine Gas Supply Operations
- T/SP/CD/01 – Electrical, Electronics and Telecommunications Symbology
- T/SP/E/55 – Specification for Bolting, Jointing, Threading and Fasteners
- T/SP/EL/1 – Selection and Installation of Luminaires and Lamps
- T/PM/EL/4 – Commissioning of Fixed Electrical Equipment and Systems
- T/PM/EL/5 – Installation of Cables
- T/PM/EL/6 – Working on or Near Electrical Systems and Equipment at Gas Operational Sites

- T/PM/EL/7 – Compliance with the Electricity at Work Regulations 1989
- T/SP/EL/10 – Electrical Surface Heating Systems (Supplementary to BS 6351 & BS EN 62086)
- T/SP/EL13 – Specification for Earthing
- T/SP/EL/17 – Batteries, UPS and Charging Systems
- T/SP/EL/23 – LV and HV Switchgear and Control Gear
- T/SP/EL/24 – Low Voltage Electrical Panels (Supplementary to BS EN 60947)
- T/PM/G/17 – Managing New Works, Modifications and Repairs
- T/SP/HAZ/8 – Hazard Identification Studies (HAZID1 and HAZID2)
- T/PM/HAZ/9 – The Application of Formal Process Safety Assessments During Design & Project Delivery
- T/PM/HAZ/11 – The Application of Construction Hazard Studies During Engineering Design
- T/PM/HAZ/14 – Gas Distribution Formal Process Safety Assessment Studies
- T/PM/PT/1 – Pressure Testing Pipework, Pipelines, Small Bore Pipework
- T/SP/INE/3 – Selection of Telemetered Signals to Operation the National Grid Gas Supply System
- T/PM/INS/9 – Functional Safety in Safety Related Systems
- T/SP/ME/1 – Requirements for Gas Volume and Energy Measurement Systems
- T/PL/ME/12 – Gas Quality, Calorific Values, Volume and Energy Measurement Systems
- T/PM/MSL/1 – Main Laying and Service Laying
- T/PR/NDT/1 – Carrying out Non-destructive Testing of Plant and Equipment
- T/SP/NDT/2 – Non-destructive Testing of Welded Joints in Steel Pipelines and Pipework
- T/SP/P/1 – Welding of Steel Pipe Designed to Operate at Pressures < 7 Bar
- T/SP/PIP/2 – Stainless Steel Tubing and Compression Fittings
- T/SP/PA/10 – New and Maintenance Painting at Works and Site for Above Ground Pipeline and Plant
- T/PM/RE/3 – Engineering Drawing Records
- T/SP/S/21 – General Instrumentation
- T/SP/VA/1 – Fluid Powered Actuators for Two Position Quarter Turn Valves
- T/SP/V/6 – Steel Valves for Use with Natural Gas at Normal Operating Pressures above 7 bar
- T/SP/V/8 – Valves for Instrumentation and Control Purposes

2.1.5 Gas Industry Standard

- GIS/PRS/35:2011 – GRP Housing for Gas Regulator Installations and Associated Operation Equipment
- GIS/F7 – Steel Welding Pipe Fittings, Nominal Size 15 mm to 450 mm Inclusive for Operating Pressures Not Greater than 7 Bar
- GIS/VA1 – Fluid Powered Actuators for Two Position Quarter Turn Valves
- GIS/V6 Part 1 (2019) – Steel Valves for Use with Natural Gas at Normal Operating Pressure Above 7 Bar
- GIS/V8 – Valves (25 mm Nominal Size and Below) for Instrumentation and Control Purposes
- GIS/V7 Part 1 – Metal Bodies Line Valves for use at Pressure up to 16 Bar and Construction Valves for use at Pressures up to 7 bar

2.1.6 – Functional Safety

The latest hydrogen blending system designed and installed at Winlaton (NGN network) was subject to a full risk assessment. For the purposes of this conceptual functional design specification, it has been assumed for this new, high pressure, high flow design, the outcome of a risk assessment would be the same.

During the detailed design stage, a complete Hazard and Operability (HAZOP) study will be carried out on the system. The outcome of this study will determine if there is a requirement for any risk reduction techniques that are over and above good engineering practice and compliance to the standards and specifications detailed in this document and the control of the system by the Basic Plant Control System (BPCS).

3 INTRODUCTION

3.1 PURPOSE

The purpose of this project is to decide where best to install a H_2 blending skid and analyser kiosk should the HSE allow up to 20 vol% to be blended into the gas network. The purpose of this FDS is to prove the proposed solution would technically work on paper.

This document shall detail the design requirements and the operating philosophy of the H_2 blending skid and analyser kiosk and ensure compliance with associated regulations and standards as applicable to this project.

3.2 PROJECT SUMMARY

DLC (Dave Lander Consulting) hydrogen blending is a collaborative project to reduce the carbon footprint of the UK's gas network through hydrogen blending with natural gas. This is partly funded under the Office of Gas and Electricity Markets (OFGEM) Networks Innovation Programme.

The Health & Safety Executive (HSE) currently only permits 0.1% hydrogen in the network, despite formerly distributing town gas with 40 to 60% hydrogen. However, there has been an exemption approved for the use of up to 20% Hydrogen within specified networks such as the Keele University G3 network and NGN Low Thornley.

The hydrogen blending skid and analyser kiosk will safely control and monitor the blending of hydrogen into the gas distribution network at Warburton, which will establish and demonstrate the level of blending which can be safely transported through the local distribution system for use in domestic and commercial appliances.

The control system continuously monitors the inlet and outlet gas flowrate, temperature, pressure, and composition. Hydrogen blending will be done to meet calorific value targets.

3.3 PROJECT SUCCESS FACTORS

This conceptual FDS has four critical factors which have been considered, these are:

1. The plant must guarantee continuity of gas supply to customers regardless of the state of operation.
2. The overall final design must be acceptable to the HSE and suitable for safe UK operation.
3. The H_2 blending skid and analyser kiosk must meet the GDN/NTS performance requirements.
4. Up to 20 vol% blending of hydrogen into a flowing natural gas stream can be safely achieved.

3.4 SCOPE OF WORKS

The Thyson Technology scope of works is to ensure that the conceptual design and manufacture is practically feasible, considering;

- Design and manufacture of hydrogen blending skid and analyser kiosk at Thyson Technology.
- Factory Acceptance Testing (FAT) of H_2 blending skid and analyser kiosk.
- Delivery and installation of H_2 blending skid and analyser kiosk.
- Site Acceptance Testing (SAT) of H_2 blending skid and analyser kiosk.
- On site commissioning of H_2 blending skid and analyser kiosk.

3.5 T/PM/G/17 Scope

The T/PM/G/17 scope is limited to mechanical, process engineering, electrical, instrumentation and safety engineering. Civil / structural, software and cathodic Protection are excluded from the T/PM/G/17 process.

3.6 CDM

Principal Designer and Principal Contractor for the Warburton project in accordance with the Construction (Design & Management) (CDM) Regulations 2015 is to be confirmed.

3.7 Kiosk Construction

The analyser kiosk will be constructed in line with GIS/SP/PRS/35. from Glass Reinforced Plastic (GRP) / 18mm plywood / 35mm foam / GRP. The kiosk external walls will be finished with a Satin Gelcoat. with a common steel base frame with certified lifting eyes with internal durbar floor and doors fitted with stays, handles and locks.

If required, the kiosk will be sub-divided into separate rooms so that hazardous area zoning does not encroach into non-hazardous area rooms. All ventilation is on the external walls of the kiosk with no ventilation between rooms. The roof shall be of fixed construction.

All hazardous areas zones have been classified as per the (IGEM)/SR/25 and Energy Institute EI15 as applicable. All hazardous areas within the kiosk have been designated Zone 1. A Zone 1 hazardous area cloud will extend from the external grills of the kiosk. Process and relief valve vents will be installed 5 m above the kiosk with pipe supports. A 2 m Zone 2 hazardous area will extend from all the flange connections on the blending skid.

3.7.1 Materials of Construction

The process pipe work utilised in the H_2 blending skid has been sized based on the velocity and pressure drop calculations. All pipework will be painted canary yellow and manufactured in accordance with the latest relevant standards (except where stated otherwise). Where applicable all pipework and components have been manufactured from the following materials:

- Flanges: Raised Face GIS/F7
- Forged Bends / Tees / Reducers: GIS/F7
- Threadolets: GIS/F7
- Pipe: GIS/L2
- Gate Valves: GIS/V7-1
- Ball Valves: T/SP/V/6 and T/SP/V/8
- Screwed Fittings: Steel ASTM A105; BS3799 > 7 Bar
- Compression Fittings: GIS/F9
- Instrument Pipe: SS 316 / 316L to BS EN 10216-5
- Gaskets: BS 3381 to T/SP/E/55
- Stud Bolts: GIS:F7 Supplement (Gr. 4.6 bolts)
- Nuts: GIS:F7 Supplement (Gr. 4 nuts)
- Washers: GIS:F7 Supplement

3.7.2 Line Schedule

A full list of all lines excluding weldolets will be detailed in the line schedule (Document 5062-9180)

3.7.3 Valve Schedule

A full list of all valves will be detailed in the valve schedule (Document 5062-9044)

3.7.4 Instrument Schedule

A full list of all instruments will be detailed in the instrument schedule (Document 5062-9040)

3.7.5 Equipment Schedule

A full list of all process equipment will be detailed in the equipment schedule (Document 5062-9031)

3.7.6 Pressure Testing

The pipework spools in the system shall be subjected to a hydrostatic pressure test with clean water for 30 minutes. All pipework shall be dried and cleaned following testing to ensure that no contamination is introduced into the system. An overall tightness test with instrument air will be performed for 30 minutes following assembly. Pressure testing shall be carried out in accordance with T/PM/PT/1.

3.7.7 Design Life

The design life of the H_2 blending skid and analyser kiosk is 15 years subject to routine maintenance and servicing.

3.7.8 Pressure Drop

Pressure drop through the H_2 blending skid and analyser kiosk has been kept to a minimum by the selection and use of suitable equipment.

3.7.9 Noise

The H_2 blending skid and analyser kiosk design aim is to not exceed 80 dB(A) at one metre external to the kiosk. It is understood that an overall noise survey of the compound will be conducted by the main contractor prior and during commissioning.

3.8 Electrical Supply

The incoming supply to the analyser kiosk shall be TN-S TP&N 400VAC, 63A, 50Hz which shall terminate into distribution board within the kiosk and distribute power throughout the kiosk and skid.

The electrical design, system control and earthing throughout the system shall be in accordance with suitable standards and customer specifications as applicable.

The control panel shall be supplied via 24VDC Power Supply Unit (PSU) complete with battery back-up for a minimum of 2 hours which shall be monitored and alarmed as necessary. Should the batteries discharge to their minimum voltage then upon reestablishment of power the PLC shall preform a controlled restart before allowing blending to recommence.

3.9 Labels

3.9.1 External/Internal Labels

All panels and equipment will be fitted with an identification label to detail the name / function of the control panel.

Labels may be stainless steel stamped, white Traffolyte with black lettering, or blue with white lettering as applicable.

3.10 Communication Links

3.10.1 Lightning Protection

Lightning protection units shall be fitted on all communication links entering the analyser kiosk with the clean terminal facing inwards for protection of sensitive equipment within the control panel.

3.10.2 Modbus TCP

Modbus TCP communication links shall support the default port 502 and keep alive messages. Modbus TCP communication links shall be limited to a maximum of 90 metres. If connections are required exceeding 90 metres than fibre optic convertors or Ethernet extenders shall be utilised.

3.10.3 Modbus RS485

Modbus RS485 communication links shall support the communication settings of 9600, 8, N, 1 for baud rate, bits, parity and stop bits.

3.11 External Communications

3.11.1 Telemetry Panel (RTU)

Communication with client will be via a Brightwell RTU panel.

A Modbus RS485 communication link will be provided to the RTU DB1 unit for monitoring of gas quality data and other analytical data. A dedicated Modbus RS485 communication module installed in the analyser kiosk PLC and shall provide the communications interface between the kiosk and the RTU. The kiosk PLC shall be configured as a slave device to the RTU DB1.

3.11.2 Hydrogen Supply Package

The analyser kiosk will be fitted with a hardwired emergency stop signal to shut down the hydrogen supply. A hardwired alarm is provided to site hydrogen supply from the gas detection system, fire alarm system and safety system.

In addition to the above a Profinet communication link will be provided to the site hydrogen supply PLC for data exchange of the key information. Interface is via an interface gateway or direct connection (as required).

3.11.3 Engineering Support

An option has been provided to include remote engineering support to the analyser kiosk utilising an Ewon 4G router connected to the internet to allow dial into the control system remotely to allow monitoring and control of the blending skid and analyser kiosk by Thyson Technology. Thyson Technology is able to modify the main PLC code remotely. UltraVNC server and anti-virus software will be installed on the SCADA PC as part of the engineering support package.

3.12 Process Stop

A Process stop circuit is installed within the analyser kiosk incorporating several inputs. Upon activation of one of these devices the hydrogen injection system will shut down immediately and an alarm will be raised.

4 SCADA System

4.1 Overview

Installed within the control panel will be a Siemens IPC227E Nanobox; hereinafter referred to as the 'SCADA PC'. The SCADA PC shall run a Windows 7 embedded operating system and will be connected to an industrial touch screen monitor; hereinafter referred to as the 'SCADA HMI'.

The SCADA PC will carry out the data collection from the blending skid and analyser kiosk and include Simatic WinCC Advanced software running in the foreground to present a schematic of the system to the on-site operative or remote connection user. The live values of the analysed components, flows, pressures and temperatures will be displayed on the SCADA HMI. Trending and logging of critical data will be provided on the SCADA PC.

The SCADA HMI will be a touch screen colour display to allow the operator to initiate and monitor the plant. In addition, the SCADA HMI notifies the operator of alarms, faults, statuses and other useful information. The operator will set the blend percentage on the HMI, this will be password protected at an administrator level to prevent inadvertent changes; all changes will be logged to a CSV file with time and date stamp.

4.2 HMI Security

There are three levels of security; which are detailed below; that are set up to prevent any unauthorised personnel from modifying the set points or starting / stopping the blending skid and analyser kiosk without permission. For security reasons certain screens will require the engineer or administrator password before access is granted. After a period of 30 minutes inactivity the logged in account will be logged out and the HMI will return to the overview screen.

User:

- Enables read only access of the HMI screens and trends.

Engineer:

- Enables access to all HMI screens and trends.
- Use of the alarm reset and acknowledge button.

Administrator:

- Enables access of all HMI screens and trends.
- Use of the alarm reset and acknowledge button.
- Mask individual alarms on the alarm masking screen.
- Modification of all set points and Proportional, Integral and Derivative (PID) values.
- Control and initiation of items in manual mode.

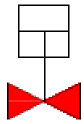
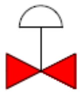
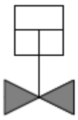
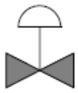
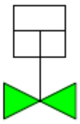
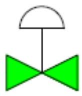
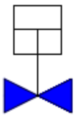
4.3 Data Logging

The SCADA system shall create a historical log of all trended items that shall be kept for a period of 12 months.

4.4 COLOURS KEY

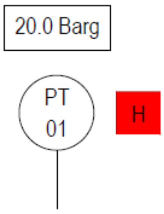
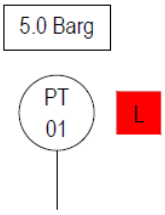
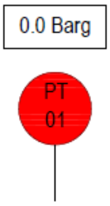
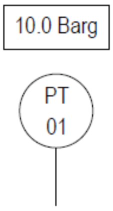
4.4.1 Valves

Actuated and control valves with generic tag and fail position examples shown below:

Actuated Valve Example		Control Valve Example	
Fault – Failed to Close / Fail to Open	 XV01 (FC)	Position beyond process limits if defined	80 %  FCV01
Fully Closed	 XV01 (FC)	Fully Closed	000 %  FCV01
Fully Opened	 XV01 (FC)	Open	50 %  FCV01
In Transit	 XV01 (FC)		

4.4.2 Instrumentation

Instrument with generic tag and typical alarm state examples shown below:

High Alarm (Acknowledged) Alarm/Fault status shall flash until acknowledged	
Low Alarm (Acknowledged) Alarm/Fault status shall flash until acknowledged	
Instrument Range Fault (Acknowledged) Alarm/Fault status shall flash until acknowledged	
Healthy	

4.5 HMI Alarms Screen

A summary of the current alarms will be displayed on the HMI's alarm screen; this screen will incorporate the facility to reset latched alarms and acknowledge any alarms that have been raised. The operator will be required to acknowledge all alarms however only latched alarms will prevent the system from injecting hydrogen.

Access to the historical alarms list will be from this screen.

All alarms will be time and date stamped with a description provided on the HMI's alarm screen.

4.6 Set Points Screen

The set points screen shall display all the set points that can be set for the blending skid and analyser kiosk. Where the operator can adjust set points, the entered set points are validated to ensure that they are within the expected range, invalid entries are rejected, and the PLC continues to utilise the previous valid set point. The set points screen shall only be accessible by the administrator; set point modification is only possible for set points within the main PLC.

4.7 Communication Screen

The communication screen shall display all the data exchanged between the blending skid and analyser kiosk and external plant including live values of all exchanged points; this screen will provide the facility to override the value to allow communication testing.

4.8 TRENDS SCREEN

The trends screen shall display trends for the following analogue values;

Flow Rate Trend
- Inlet gas flow rate
- Outlet gas flow rate
- Hydrogen flow rate
- Flow control valve set point

Gas Pressure Trend
- Inlet gas pressure
- Outlet gas pressure
- Hydrogen header pressure
- Hydrogen injection pressure
- Instrument air header pressure

Gas Temperature Trend
- Inlet gas temperature
- Outlet gas temperature
- Calibration gas line temperature
- GS(M)R check gas line temperature

Bottle Pressure Trend
- HC free air bottle pressure
- Calibration gas bottle pressure
- GS(M)R check gas bottle pressure

Inlet Gas Composition Trend
- Inlet gas CO_2
- Inlet gas methane
- Inlet gas ethane
- Inlet gas propane
- Inlet gas butane
- Inlet gas pentane
- Inlet gas nitrogen

Outlet Gas Composition Trend
- Mixed gas CO_2
- Mixed gas methane
- Mixed gas ethane
- Mixed gas propane
- Mixed gas butane
- Mixed gas pentane
- Mixed gas nitrogen
- Mixed gas hydrogen

Hydrogen Trend
- Hydrogen moisture (signal from site hydrogen supply)

5 Analysis of Functional Specification For Hydrogen Blending Infrastructure

The Functional Specification For Hydrogen Blending Infrastructure submitted by Dave Lander Consulting has been analysed.

As per Sections 5.4 and 5.5, hydrogen injection rate will be controlled by Thyson to achieve a gross calorific value which meets the specification of the gas transmission network. Odorant injection is currently not part of the system being currently proposed by Thyson, however, it can be included into the design to inject odorant at the rate agreed with the gas transporter. If the blended gas does meet the calorific value requirements, **XV06** will close and blended gas supply to the network will be switched off. This has also been described in Section 6.3 of this report. At certain intervals when the gas transporter provides a target calorific value to Thyson, the hydrogen blending system has got the capability to meet it.

Thyson have got experience of designing hydrogen blending skids and grid entry units for biomethane and will be happy to sign a contractual framework with the gas transporter.

In terms of the models proposed in section 6.3, Thyson are happy to work with all three models.

Thyson will comply with IGEM/TD/13 requirements for hydrogen pressure regulation, as per the requirement in Section 7. Thyson can confirm that the proposed system will provide daily hydrogen volume and daily energy flowrate readings required for Flow Weighed Average Calorific Value (FWACV) calculation. Accuracy requirements listed in Table 2 of the document will be met. Other functional requirements listed in Section 7 can also be met.

A remote telemetry unit (RTU) has been included in the proposed design, please refer to section 3.11.1 of this report. All pressure containing components and systems shall be pressure tested and declared safe to commission by Thyson. Testing of electrical and instrument systems and equipment shall be carried out in accordance with BS 7671 and BS EN 60079-14.

General requirements listed in Section 11 will be met. All personnel carrying out the commissioning and validation will be competent and fully trained. A site acceptance test procedure and commissioning procedure will be submitted during the project. During the factory acceptance testing stage, internal validation will be carried out to ensure that the requirements of Table 2 are met. Safety and compliance of the blending skid will be demonstrated during the factory acceptance testing stage. An operations manual will be submitted with the system, comments from the gas transporter will be incorporated into this document.

Odorisation will be controlled and monitored in accordance with IGEM/SR/16, as the project matures it will be decided if this is in the scope of the gas transporter or Thyson. Thyson will ensure that the hydrogen injection flowrate is controlled to ensure that calorific value targets are met.

Electrical and instrumentation equipment installed in hazardous areas shall be maintained to meet the requirements of BS EN 60079-17. Frequency of periodic inspections should not exceed three years, with typical detailed and close inspections carried out annually. Electrical equipment must be maintained to meet the requirements of BS 7671.

Facility will be provided to carry out the validation and calibration of the analyser as per the site standards, gas transporter standards and industry guidance. A separate room for the remote operated valve is not part of the proposed design, however, it can be included.

6 Process Overview

Functional specification of Hydrogen Blending infrastructure has been analysed.

As per section 5.4 of Functional Specification of Hydrogen Blending infrastructure, hydrogen injection rate will by controlled by Thyson to achieve a gross calorific value which meets the specification of the gas transmission network.

The process can be divided into several sub sections as described below:

6.1 Inlet Natural Gas

Natural gas is fed into the H_2 blending skid from the network supply at a flowrate determined by the network. The process conditions entering to the GEU are monitored. The flowrate, pressure, temperature and composition are recorded and trended within the PLC.

The inlet, flowrate, pressure, and temperature will be measured by upstream flowmeter, pressure and temperature transmitters on site. This data will be sent to the PLC inside the analyser kiosk where the flowrate will be corrected to standard metres cubed per hour (SCMH), calculated to compensate for pressure and temperature.

The Thyson P1Z1 hydrocarbon analyser ***AT01*** on the inlet to the mixer, monitors the incoming gas composition to calculate Calorific Value, Wobbe Index and Specific Gravity. Optionally this could be provided by existing Flow Weighted Average Calorific Value (FWACV) GC, although cycle time and GQ variation would need to be considered.

6.2 Hydrogen System

Hydrogen will be supplied by site to the hydrogen blending skid, storage and pressure regulation of hydrogen will be in DLC scope.

6.2.1 H_2 Flow Control

Downstream of the site pressure regulators the flow of hydrogen is modulated by flow control valve **FCV03**. The flow is modulated based on the inlet flowrate of natural gas (provided by site) to the appropriate ratio of hydrogen; the hydrogen flowrate is monitored by flowmeter **FT04**. The percentage hydrogen injection limit being the lower of, the operator requested value, or, as limited by the inlet gas quality (See 6.1). The percentage of hydrogen injection ramps by a whole percentage of the total flow; decreases are initiated instantaneously.

When not in use the hydrogen system is isolated by the hydrogen injection inlet valve **XV25**; this valve is also closed in the event of loss of instrumentation or a fault with the hydrogen system. **XV25** is fitted with two solenoids in series, one for normal operation, and the other as an override on detection of high hydrogen by a hardwired circuit.

Further protection against backflow is included in the form of **NRV02** to prevent backflow into the system.

6.3 Outlet Mixed Natural Gas

The Natural gas from the inlet (See 6.1) is mixed with hydrogen from the hydrogen system (See 6.2); the gas then passes through a flowmeter before a sample offtake allows the resultant mixed gas to be analysed. Whilst the mixed gas is being analysed the gases do not pass through a volume loop, however, this system utilises a re-blend line.

A second sample offtake is situated post **XV05** for use in Bypass mode (See 6.3.1). If an alarm on calorific value is raised by the analysers, the hydrogen supply to the mixer will be shut off via **XV25**, mixed gas supply to the network will be switched off via **XV06** process bypass valve **XV10** will open. Sample offtake will switch to post **XV06.** Sample offtake valve **SV08** will close, sample offtake valve **SV09** and re-blend valve **SV07** will open. Pressure drop across the mixer will be used to mix incoming natural gas with the gas already in the system, affecting its calorific value.

6.3.1 Mixer

The mixer M01 is a proprietary modified "T" piece consisting of engineered mixing nozzles to ensure a sufficient blend is established. A blending report will be submitted along with this document to demonstrate using Computational Fluid Dynamics (CFD) speed of blending, Coefficient of Variation (CoV) across the process characteristics of Warburton.

6.3.2 Sample offtakes and Re-Blend Line

Downstream of the mixer are two sample offtakes, one before **XV06** and one after **XV06**. The sample offtake switches to post **XV06** in bypass mode activating the re-blend line, and pre **XV06** whilst operating normally via solenoid **SV05**.

Bypass mode is activated to prevent mixed natural gas enriched with hydrogen beyond acceptable limits entering the network by re-blending it and (See 7.3.1); To ensure sample offtake is in use, **FIA14** gives a flow indication of the sample offtake. If the flow indicator does measure flow an alarm will be raised.

6.3.3 Mixed Gas Metering

The flow of mixed natural gas is metered by FT02. The mixed natural gas / hydrogen flowrate is compared to the 100% hydrogen injection flowrate FT04; should the instantaneous ratio of the mixed natural gas / hydrogen to the 100% hydrogen exceed a set ratio then it is inferred the hydrogen injection has breached the defined injection limits and re-blend mode is initiated.

6.3.4 Mixed Gas Temperature

The mixed gas outlet temperature is monitored via **TT03** to ensure that the gas is within the required limits for discharging to the gas network; should the temperature move outside of the defined limits, re-blend mode is initiated.

6.4 Process and Network Bypasses

Under normal operation the Process Bypass Valve **XV10** will remain shut. Specific faults will result in the Process Bypass Valve **XV10** opening; the blending skid moves into bypass mode (See 7.3.1) closing the Hydrogen Inlet Valve **XV25** and Mixed Gas Outlet Valve **XV06**. Full list of specific faults will be provided during detailed design and will also be listed on the Cause and Effect document.

The Process Bypass Valve **XV10,** Hydrogen Inlet Valve **XV25** and Mixed Gas Outlet Valve **XV06** all operate with two solenoids; One solenoid for normal operation and a hardwired second solenoid to actuate on the detection of high hydrogen on the Hydrogen Analyser **AT03**.

All three valves are fitted with switch packs to provide position feedback. Failed to open and close alarms are generated by the Main PLC.

6.5 Analyser System

The Inlet Analyser **AT01** samples from the gas entering the H_2 blending skid (prior to mixing), post blending both analyser **AT02** (Hydrocarbons) and Analyser **AT03** (Hydrogen) sample from the same sample point to provide fast gas analysis.

6.5.1 Inlet Gas Analyser

During normal operation the Solenoid **SV16** is open to the inlet offtake to allow sampling to occur; during calibration it redirects to flow from the GSMR Test Gas Bottle. Prior to calibration the analyser is flushed with the calibration gas for a set period before a number of periodic samples are taken; the mean value of the samples is compared against the stated values of the calibration gas within a defined tolerance.

The Inlet Analyser **AT01** monitors the incoming gas composition to calculate Calorific Value, Wobbe Index and Specific Gravity; The Sooting Index and Incomplete combustion factor are then calculated.

The inlet gas composition along with the requested hydrogen percentage are used to predict the properties of the outlet gas. The molar mass, standard compressibility factor, relative density and calorific value by volume are calculated in accordance with ISO 6976 within the main PLC.

The calorific value of component j (CVj) shall be taken from ISO 6976 Table 5 at 15°C and 101.325 kPa.

The predicted qualities of the outlet gas are used to limit the injection of hydrogen such that the limits on Wobbe Index, Sooting Index and ICF are not exceeded. The percentage hydrogen injected is then reduced to the appropriate limit. The reduction of the percentage hydrogen injected is logged and raised on the HMI for operator information and transmitted to DLC via their associated communication link.

The analyser is also monitored for flat line detection to ensure that analyser failures are detected and alarmed.

A flow indicator with a low flow alarm, ***FIA11*** on the sample line to the inlet gas analyser ***AT01*** monitors the sample flow to ensure flow is always present through the analyser. If no flow is detected the hydrogen injection is stopped.

Flow to the analyser is continuously monitored to ensure no interruption to flow via **FIA11**; If no flow is detected the hydrogen injection is stopped.

6.5.2 Mixed Gas Analyser

During normal operation the Solenoid **SV05** is open to the offtake to allow sampling to occur (See 6.3.2). During normal operation the Solenoid **SV17** is open to the inlet offtake to allow sampling to occur; During calibration **SV17** redirects to flow from the H2/HC Calibration Gas Bottle. Prior to calibration the analyser is flushed with the calibration gas for a set period before a number of periodic samples are taken; the mean value of the samples is compared against the stated values of the calibration gas within a defined tolerance.

The Mixed Gas Analyser **AT02** works the same as the inlet Analyser **AT01**, monitoring he gas quality and calculating the Calorific Value, Wobbe Index and Specific Gravity (See above).

Flow to the analyser is continuously monitored to ensure no interruption to flow via **FIA12**, which is fitted with proximity switch to alarm in the event of no flow.

6.5.3 Hydrogen Analyser

As per the Mixed Gas Analyser **AT02** (See above), the Hydrogen Analyser **AT03** samples from either the offtake via **SV05**. During normal operation the Solenoid **SV18** is open to the inlet offtake to allow sampling to occur; During calibration **SV18** redirects to flow from the H2/HC Calibration Gas Bottle. Prior to calibration the analyser is flushed with the calibration gas for a set period before a number of periodic samples are taken; the mean value of the samples is compared against the stated values of the calibration gas within a defined tolerance.

The output from **AT02** is additionally used to force the analyser kiosk into re-blend mode in the event of high hydrogen. To enact this each of the three valves required has a second solenoid hardwired to the output from the analyser (See 7.3.1).

6.5.4 Calibration Checks

Analysers are tested weekly against a calibrated gas. The cycle time for the analyser check is 600 seconds, during which the gas quality data is sent to the site SCADA. The times and durations are hardcoded into the main PLC and are not adjustable by operators.

If checks of analysers AT01, AT02 or AT03 fail then hydrogen injection stops and the Hydrogen Injection Inlet Valve **XV25** closes.

6.5.5 Gas Bottles

There are three bottles stored within the Analyser and Gas Bottle Room, the GSMR Test Gas Bottle, the H2/HC Calibration Gas Bottle and the HC Free Air Bottle.

The GSMR Test Gas Bottle, and the H2/HC Calibration Gas Bottle temperature and pressures are monitored via **PT08** and **TE05**, and **PT07** and **TE04**, respectively. Only the pressure **PT06** of the HC Free Air Bottle is monitored.

6.6 INSTRUMENT AIR

Instrument air will be supplied by a compressor on site. The instrument air is used solely for valve actuation. The pressure of the instrument air supply header is monitored via **PT09**. If low pressure is detected, then an alarm will be activated. In case of an alarm, re-blend line will be activated, opening the Process Bypass valve **XV10**, and closing Hydrogen Inlet Valve **XV25** and Mixed Gas Outlet Valve **XV06**.

7 Control

7.1 Analogue Channel Alarms

The main PLC rack generates analogue channel fault alarms for each analogue input outside of the 4-20mA range as per NAMUR NE43.

7.2 Valve Stroking

As **XV10** could potentially stay shut for long periods it should be stroked periodically to ensure operation on demand. Stroking is initiated by the operator using a hardwired button on the control panel, the result is shown on the HMI screen and an alarm is raised on failure (this will be the process bypass line valve)

7.3 Modes of Operation

7.3.1 Bypass Mode

Bypass Mode runs when Normal Mode is not available, it is also run when too much hydrogen is injected, shutting off the hydrogen supply into the mixer and using the pressure drop across the mixer to lower the calorific value of the gas. In Bypass mode the Process Bypass valve **XV10** is open, the Hydrogen Inlet valve **XV25** and the Mixed Gas Outlet Valve **XV06** are closed. Natural gas enters the blending skid bypassing the hydrogen injection system, mixes with the gas already in the pipes due to the pressure drop across the mixer and flows to the outlet of the blending skid. Gas analysis continues in this mode (See 6.5). The system can be only moved from Bypass mode to Idle mode, and only once the gas is within specification.

7.3.2 Normal Mode

Within Idle mode the natural gas is flowing through the injection system, but no hydrogen is injected. In Idle mode the Process Bypass valve **XV10** and the Hydrogen Inlet valve **XV25** are Closed, and the Mixed Gas Outlet Valve **XV06** is open. If the criteria for injecting hydrogen is met and there is an operator set level of hydrogen injection, the blending skid moves into Injection Mode.

7.3.1 Injection Mode

The operator selects the hydrogen injection setpoint on the HMI, however this can be overridden by the control system should the predicted output gas be out of specification; The hydrogen injection rate is therefore limited by the predicted outlet Wobbe Index (WI), Sooting Index (SI) and Incomplete Combustion Factor (ICF) Indices, hereon called the hydrogen injection limit (See 6.5). Injection Mode runs until either the incoming gas quality is too poor to inject, there is a loss of instrumentation, or out of specification gas is detected.

If the hydrogen set point is de-rated (due to incoming gas quality) an alarm is raised, and the details are logged on the HMI.

If a gas quality excursion is recorded, the bypass mode is initiated closing the Hydrogen Inlet valve **XV25**, opening Process Bypass valve **XV10**, then closing the Mixed Gas Outlet Valve **XV06**. The sample offtake is moved from pre **XV06** to post **XV06**.

8 Safety Engineering / Process Safety

8.1 Fire detection System

There are three fire detection sensors; two ATEX rated in the analyser and gas bottle room, and one non-ATEX rated in the control room. All three connect into the fire detection system in the control room alarming via comms and a beacon located outside the kiosk.

8.2 Gas Detection

There are three gas detection sensors; two ATEX rated in the gas room and the analyser room, and one non-ATEX rated in the control room. All three connect into the gas detection system in the control room alarming via comms and a beacon located outside the kiosk.

9 Commissioning, Handover & Decommissioning

9.1 Commissioning

Commissioning procedures for the hydrogen blending skid and analyser kiosk will be developed in advance of any commissioning activities.

9.1 Handover Documentation

An operation and maintenance manual and a data book will be provided upon completion of the commissioning.

9.2 Decommissioning

The extent of decommissioning required is yet to be finalised as it will be dependent on the conditions attached to the planning permission and site requirements at the time. Until the scope is agreed, no decisions have been taken with regards to the responsibility for the works. At this stage, Thyson do not have any decommissioning activities assigned.

10 Basis Of Design

This document will be submitted before the detailed design stage, 5062-9000.

11 Units

11.1 Engineering Units

The following engineering units shall be utilised within the H_2 blending skid and analyser kiosk control system;

Description	Units
Pressure	Barg or Bara
Temperature	°C
Power	W
Electricity Usage	kWh
Frequency	Hz
Flow	SCMH
Density	kg/m³
Time	Decimal Hours
Velocity	m/s
Composition	Mol %
Weight / Mass	kg
Odorant	mg/m³
Wobbe Index	MJ/m³
Calorific Value	MJ/m³

Standard conditions are defined as 15 ºC and 1.01325 Bara.

11.2 Environmental Conditions

The following environmental conditions shall be utilised in the design of the H_2 blending skid and analyser kiosk.

Condition	Working Range
Ambient Temperature	-15 to 35 °C
Relative Humidity	20 to 70 %

11.3 Project Defined Limits

The following project defined gas quality limits shall be utilised within the H_2 blending skid and analyser kiosk.

Component	Measuring Range	Measurement Type	H_2 GEU Shutdown Limit
Outlet Pressure	0 to 4 Barg	4-20mA Transmitter	< 0.5 & > 1.2 Barg
Outlet Temperature	-20 to 60°C	4-20mA Transmitter	< 1 & > 20 °C
Carbon Dioxide	0 to 100 Mol %	QT02 – Infrared	> 2.5 Mol %
Wobbe Index	40 to 60 MJ/m³	QT02 – Infrared	< 47.2 & > 51.41 MJ/m³
Hydrogen	0.5 to 100 Mol %	QT03 – Thin Film	20% *(Note 1)*
Hydrogen Sulphide	*(Note 2)*	*(Note 2)*	-
Hydrogen Moisture Level	*(Note 3)*	*(Note 3)*	> 10 ppm
Oxygen	*(Note 4)*	*(Note 4)*	-
Sooting Index	-	-	> 0.6
Incomplete Combustion Factor	-	-	> 0.48

Note 1: HSE granted exemption from Gas Safety (Management) Regulations (GS(M)R) for the Hydrogen injection projects
Note 2: Hydrogen Sulphide is not measured as gas is within GS(M)R specification prior to the H_2 blending skid.
Note 3: Hydrogen moisture level is derived from site hydrogen supply from communication link.
Note 4: Oxygen levels within the hydrogen will be below the 0.2 Mol % required for GS(M)R.

Section C Mixing Report

4 Helix Business Park
New Bridge Road
Ellesmere Port
Cheshire
CH65 4LR

TEL. 0151 355 5594
FAX. 0151 355 7961

WWW.THYSON.COM

INTERNAL DOC CONTROL

Document Ref:	N/A
Issue:	N/A
Issue Date:	N/A
Aut/Apvl:	N/A
TTL Review by:	N/A

Client	Dave Lender Consulting Ltd
Project	Hydrogen Blending Infrastructure
Client Reference	N/A
Site Name	Warburton
Document Title	Mixing Report
TTL Doc. Number	5062-9175
TTL Doc. Revision	B2

CHANGES THIS REVISION

Revision	Description
B2	Conceptual Design

TTL DOCUMENT REVISION HISTORY

Revision	Description	Prepared	Checked	Approved	Date
B1	Conceptual Design	NQ	JD	NS	16/01/23
B2	Conceptual Design	NQ	JD	NS	23/03/23

1 Contents

Blending Hydrogen into Natural Gas Distribution Networks

Gas to Gas Static Mixers

Report on the requirement for and product options available

2 1.0 Introduction

The UK Gas Networks are exploring the possibility of injecting a percentage of hydrogen gas into their network to mix with the Natural Gas. Their existing Warburton AGI, located in Greater Manchester, has been selected for a viability report.

Static mixers are a necessary part of hydrogen to grid connections. This report compares three potential static mixers for this purpose.

All of the products considered have the following attributes:

- Materials exposed to 100% hydrogen can be supplied in 316 stainless steel
- No moving parts
- Available in forms for inclusion in UK gas network pressure systems

3 2.0 Summary of Data

Only Greener Blue have supplied 'diameters to homogenous blend figure', other manufacturers can supply this value on receipt of order. For the minimum length of mixing pipe 10D is a commonly used distance for gas-to-gas mixers for homogenous blending, 10D is well within the requirements of available space on a typical UK AGI. For the coefficient of blending please refer to the CFD report.

Greener Blue are the recommended mixer.

Product	Number of pipe diameters to homogenous blend gas sample point	Number of parallel products required	Claimed gas blend at sample point	Natural Gas pressure drop across mixer at maximum flow	Hydrogen pressure drop across mixer at maximum flow	Mixing solution total price (+/- 15%) +VAT	Quoted delivery time	Packing & Carriage (£)
Euromixer Primix	TBC	1	>96% Homogeneity TBC	0.1 bar	TBA	£48,000	27 working weeks	TBA
Greener Blue Teeblender H2 (Recommended)	<10 D	1	>97% Homogeneity	Typically, 1.5 bar	Typically, 1.0 bar	£38,000	12 weeks	TBA
Transvac Ejector	TBA	TBA	TBA	TBA	TBA	TBA	TBA	TBA

Table 1 Hydrogen Mixing Comparison

4 WHY IS A STATIC MIXER NECESSARY?

Where Hydrogen is injected into a natural gas pipeline, it may be necessary to control the % of hydrogen being blended for technical or regulatory reasons.

In order to, control this % blend, a downstream sample of the blended gasses can be taken and analysed to establish the % mix. A feedback signal from this analysis can then be used to control the hydrogen injection rate to provide the required natural gas/hydrogen mix.

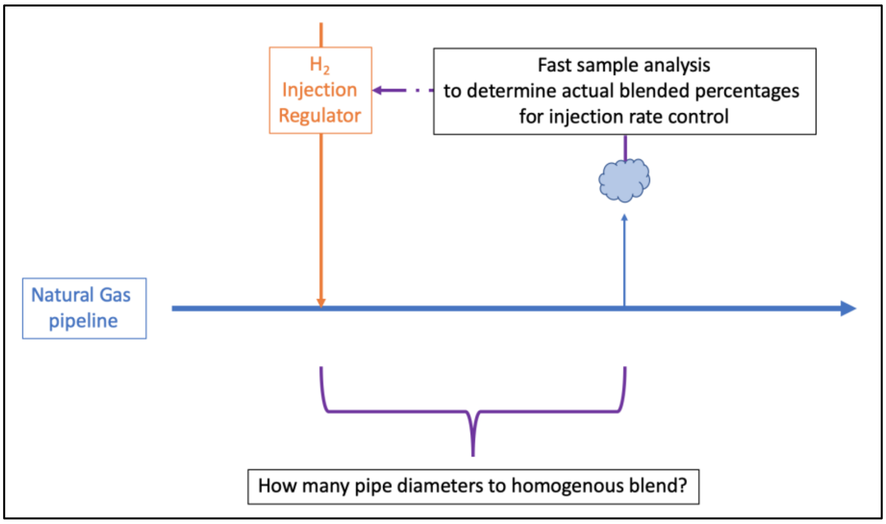


Figure 1 Hydrogen Injection

For this blended gas sample to be fully representative of all of the gas flowing in the downstream pipework, the natural gas and hydrogen need to be homogenously mixed. This homogenous mixing also needs to occur within a short distance of the hydrogen injection point to provide a timely feedback signal to the hydrogen injection controller.

(Due to the disparate densities of the Natural Gas and Hydrogen, larger diameter applications (~>NB 300) will also be subject to greater Hydrogen buoyancy issues, where the Hydrogen will tend to collect at the top of the pipework downstream of the injection point).

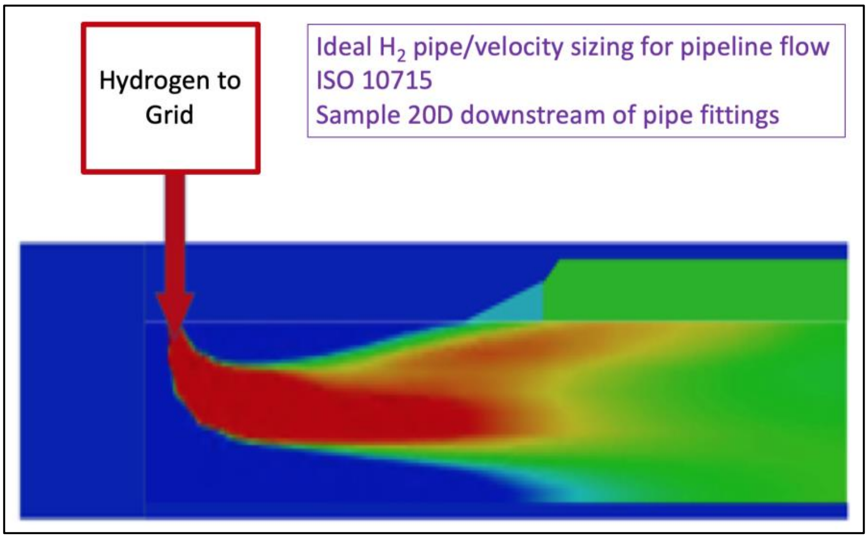


Figure 2 Hydrogen Injection into Pipeline

ISO 10715 provides guidance for gas sample system designers and infers that an homogenous blend can be achieved at a 20 pipe diameter distance downstream of the hydrogen injection point tee fitting.

This is true for specific hydrogen and natural gas velocity combinations that provide pluming of the hydrogen into the fast flowing centre third of the pipeline.

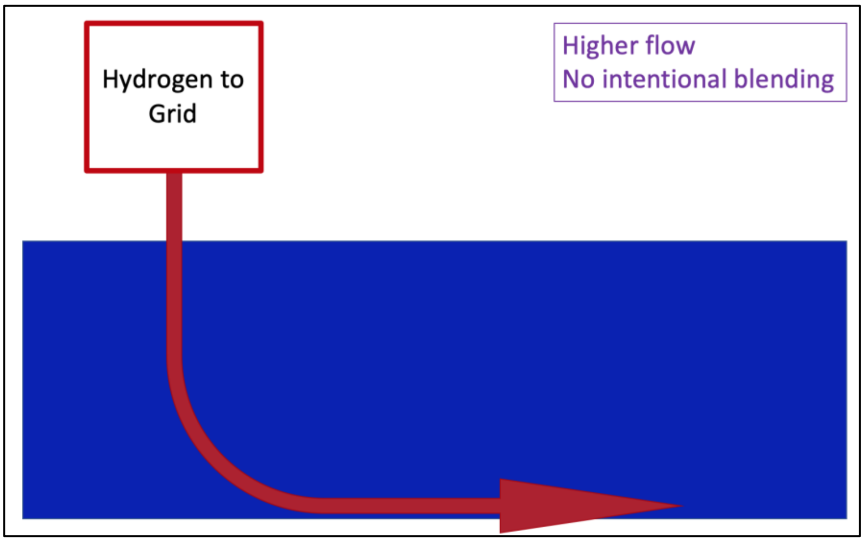


Figure 3 Hydrogen Injection High Velocity

When the velocity of the injected hydrogen exceeds this ideal ratio, the injected gas can linger in the lower velocity pipeline gas on the opposite wall.

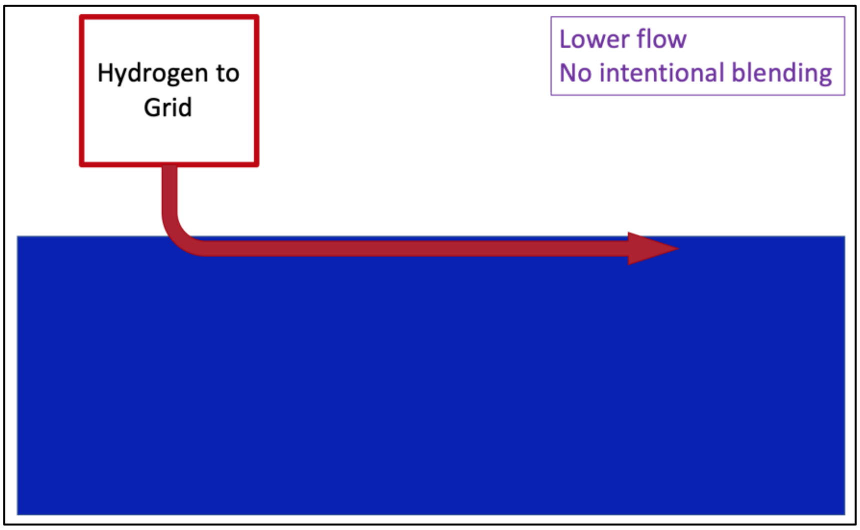


Figure 4 Hydrogen Injection Low Velocity

Similarly, with a lower injection velocity, hydrogen can linger in the nearside lower pipeline velocity gas.

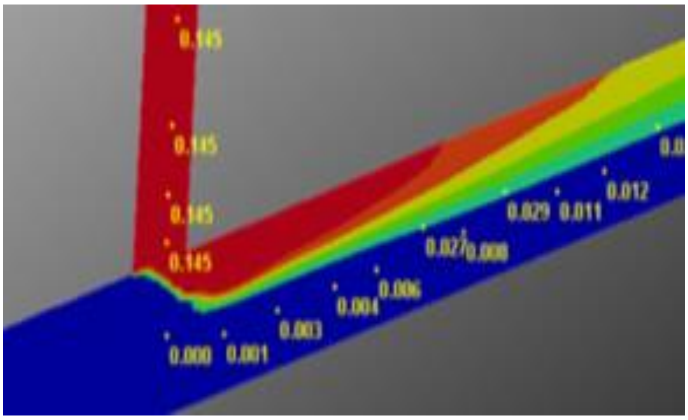


Figure 5 Hydrogen Injection Low Velocity

Digital modelling of low flow velocity injected gas lingering on the wall of the pipeline

A suitably designed static mixer can provide confidence that across all expected flow and pressure scenarios, a representative blend sample can be achieved within a short distance of the hydrogen injection point.

Three approaches to homogenous, short distance blending have been selected for comparison in this report. All of the approaches should be technically acceptable to the UK gas networks. A comparison of performance and cost have been provided. The relatively large parameters of this specific enquiry may require the final proposed solution to vary slightly from the providers given solution.

5 Products considered:

5.1 Euromixers Primix

Figure 6 Euromixer Installation Example

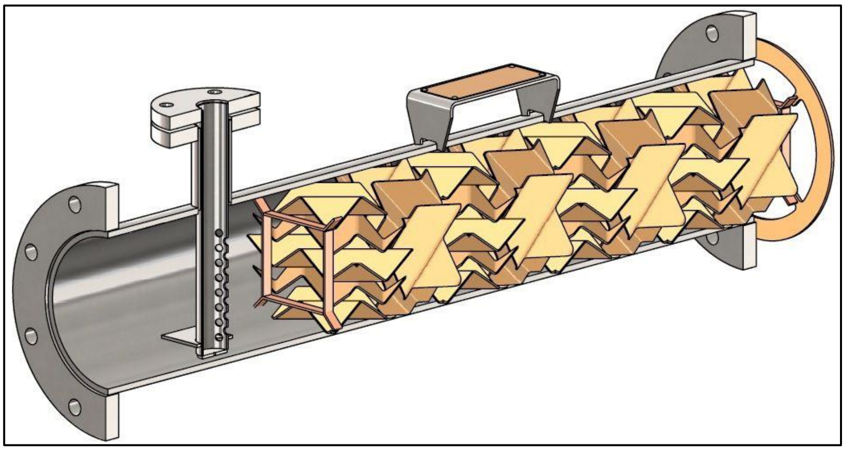


Figure 7 Euromixer Cutout View

5.1.1 Contact:

euromixers.co.uk

sales@euromixers.co.uk

+44(0)161 486 5099

5.1.2 Principle of operation

Flow through the static mixer element is diverted into two separate streams. Optimisation of the profile induces equal radial and axial flow. The helix pitch creates a rotation of the fluid, by which the fluid flows from the outside to the inside and reverse. The difference in velocity that occurs creates a shearing of the fluids.

After one rotation through the static mixer element a second diversion takes place and simultaneously a reverse of the succeeding rotation in the next mixing element occurs. As the number of streams or layers increases, the layer thickness decreases. After 20 rotations in a 50mm diameter static mixer, mixing at molecular level is achieved. 20 diversions of the fluid creates 220 separate layers, each 0.05 micron thick.

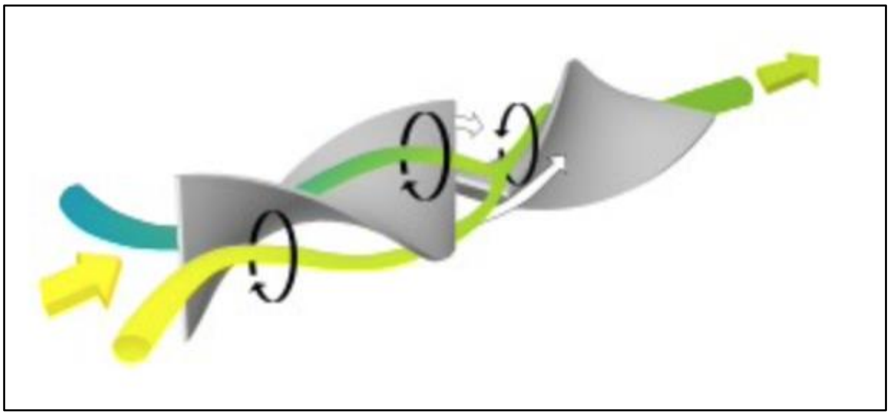


Figure 8 Euromixer Operation

5.2 GREENER BLUE TEEBLENDER H2

Figure 9 Teeblender Example

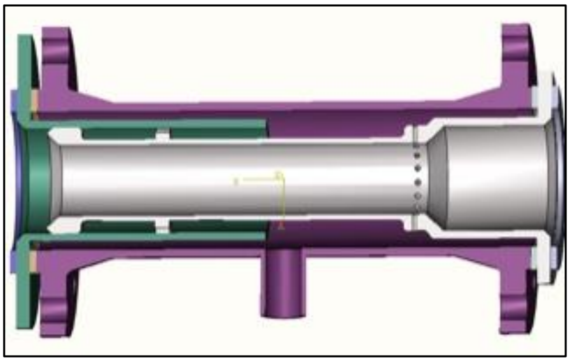


Figure 10 Teeblender Cutout

5.2.1 Contact:

www.greenerblue.co.uk

enquiries@greenerblue.co.uk

+44(0)7527 404856

5.2.2 Principle of operation

The product consists of two intersecting cones, inlet (green in the above diagram) and outlet (silver). The element shown purple is the pressure containment element which is the customers own pipework and not part of the supply. This provides the customer with the flexibility to position and size the gas to grid injection connection (side branch) which can be an equal or reducing forged Tee or proprietary welded connector to a short length of pipe between welded flanges.

The cones are inserted and overlap inside the customers pipework. Each cone is held in a gas tight sandwich between the pipework bolted 'raised face' flanges and conventional gaskets.

The overlapping of the two cones provides a telescopic assembly that self positions to accommodate any fabrication tolerances of the customers pipework and gasket thickness variations.

The inlet and outlet cone mounting flanges have a machined profile that centrally locates the flange relative to the flange bolts. Raised face flange fittings are required on the mating pipework. Other flange types can be accommodated on request.

Figure 11 Teeblender Installation

Each cone has an identifying tag plate

The assembled blender creates a void on the outside of the cones for the hydrogen gas from where it feeds through multiple injection jets against the flow of the Grid Gas. Sizing and directing these equally spaced gas jets induces a vortex swirl as the combined gasses approach an orifice throat.

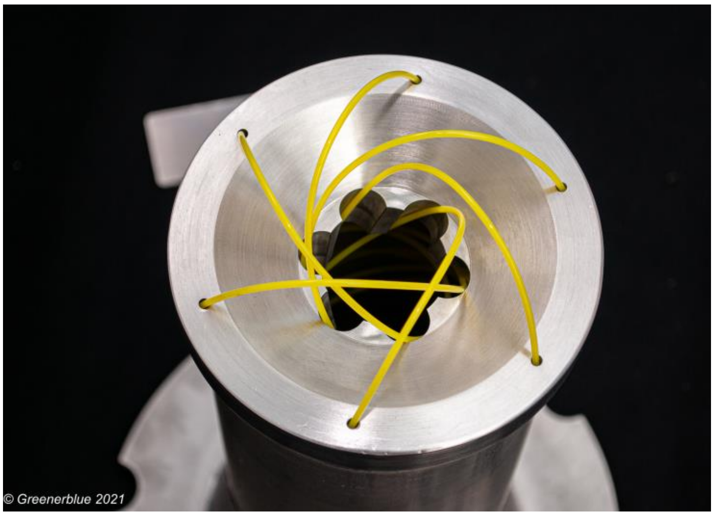


Figure 12 Teeblender Hydrogen Injection

The throat of this orifice is shaped to maximise the combined gas velocity, minimise the pipeline pressure drop and induce secondary vortex swirling.

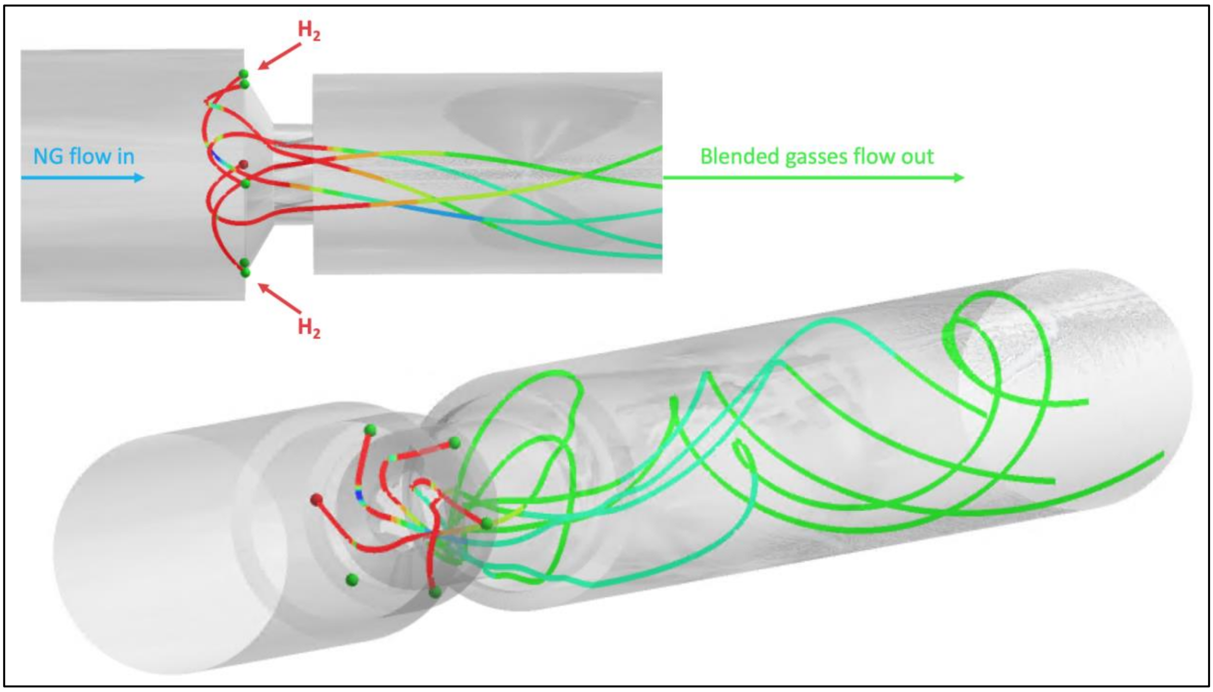


Figure 13 Hydrogne Mixing with Natural Gas

Digitally modelled flow pattern

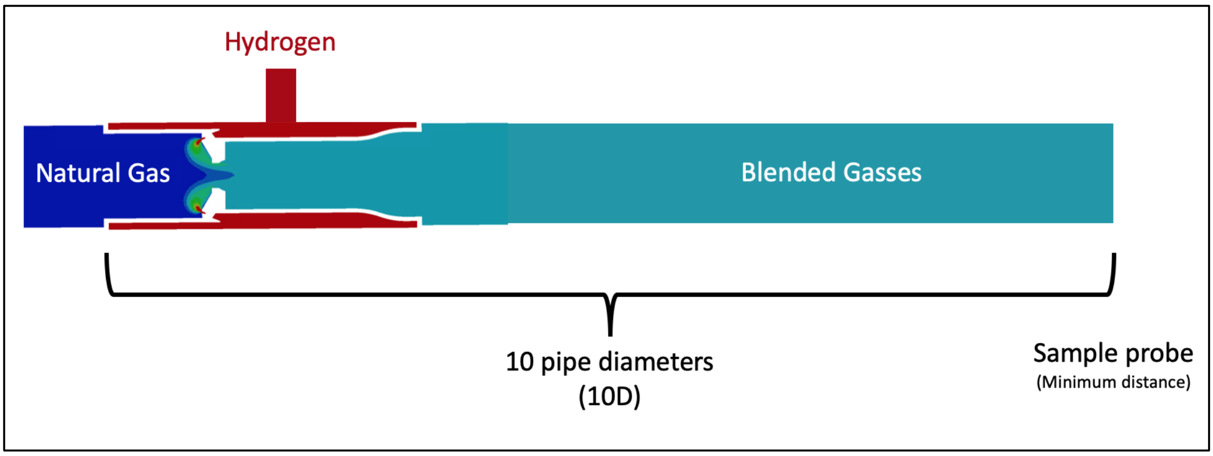


Figure 14 Hydrogen Mixing

Larger diameter applications may have primary and secondary helical swirling orifices and the hydrogen may be injected at the tips of the helical swirling vanes.

5.3 Transvac Ejector

Figure 15 Transvac Hydrogen Eductor

5.3.1 Contact:

www.transvac.co.uk

sales@transvac.co.uk

+44(0)1773 831100

5.3.2 Principle of operation

This type of device can be referred to as an Ejector, Eductor, Surface Jet Pump, Venturi or Velocity Spool. The operating principle is common to all. In addition to their 'jet pump' function, they are also efficient gas mixing devices.

Based upon Bernoulli's Principle, as the velocity of a fluid increases, its pressure decreases, and vice versa.

An ejector works by accelerating a high pressure stream (the 'motive') through a nozzle, converting the pressure energy into velocity. Around the nozzle tip, where velocity is highest, a low pressure region is created. This is often called the suction chamber of the ejector. Where the pressure in this region is lower than the pressure of the suction fluid connected to the ejector side-inlet or 'suction branch', it will be entrained/sucked into the body of the Ejector. The two fluid streams then travel through the diffuser section of the ejector, where velocity is decreased as a result of the diverging geometry and pressure is regained.

Importantly, the low pressure suction stream experiences a pressure increase/compression, whilst the motive stream sees a decrease in pressure, as some of its energy has been used to 'do work' on the suction stream. The resultant discharge pressure is therefore somewhere between the motive and suction pressures.

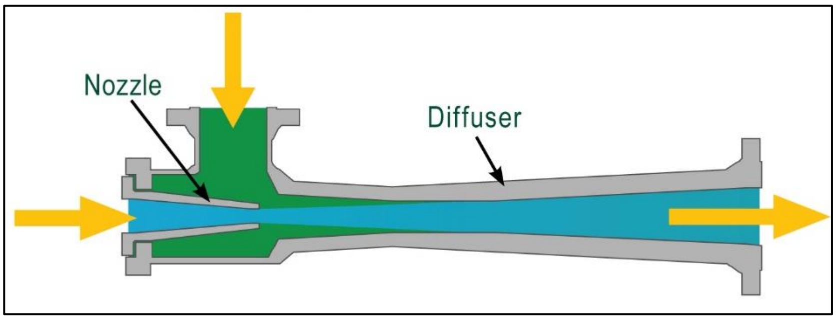


Figure 16 Hydrogen Eductor Cutout

Ejectors are pipeline mounted devices.

They have 3 connections;

1. Motive
2. Suction
3. Discharge

Motive and Discharge will be the natural gas pipeline input and output respectively. Suction will be the hydrogen injection connection.

Some savings associated with raising the pressure of the hydrogen to a level above that of the natural gas pipeline to achieve hydrogen flow, may be present at higher pipeline flows where a 'suction' may be provided by the ejector.

Lower pipeline flows are less likely to have this additional benefit.

Mixing of the two gasses should be a function of operation at all the required pressure/flow scenarios.

6 WARBURTON AGI SPECIFIC DESIGN PARAMETERS

Natural Gas	Minimum	Maximum
Pressure (Barg)	19	38
Flow (m3/hr)	14,115	510,819
Nominal pipe diameter	600mm	

Hydrogen	Minimum	Maximum
% mix by volume	0%	20%
Pipe nominal diameter	TBA	TBA

Pressure system
Class 300

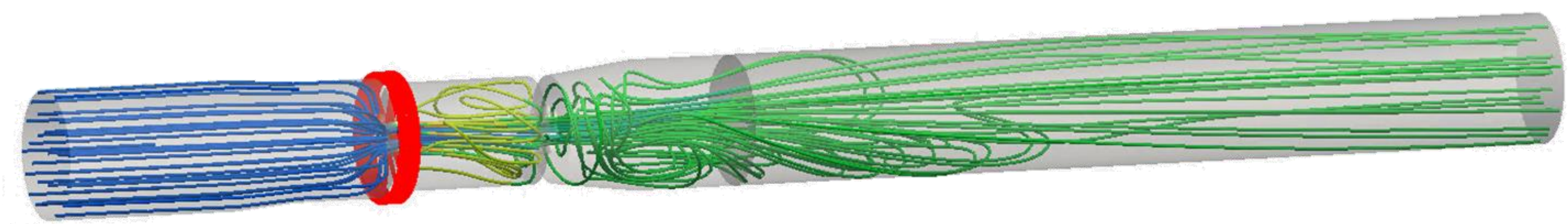
Section.D Warburton proposed CFD modeling report

INTERNAL DOC CONTROL	
Document Ref:	QEMSEN027
Issue:	5
Issue Date:	25/02/22
Aut/Chk/Apvl:	AY/JS/KD
TTL Review by:	25/02/25

THYSON TECHNOLOGY
TEL. 0151 355 5594
FAX. 0151 355 7961
WWW.THYSON.COM

Warburton proposed 24” Hydrogen Blender CFD Modelling Report

Predictions of Performance



Customer: TTL
Author: Greener Blue Ltd
Date: 26 Nov 2022
Project ID: TTL 05062

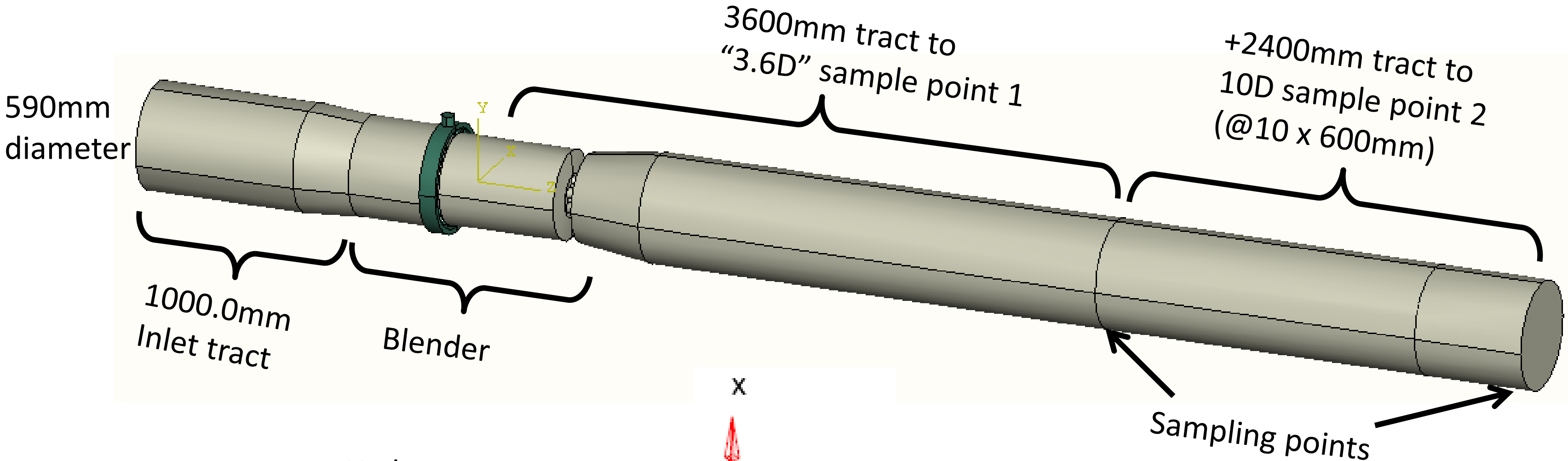
Summary

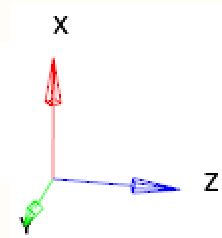
- The UK Gas Networks are exploring what is technically required to mix, inject and transport Hydrogen with Natural Gas.
- Part of this requirement is a static mixer to homogenously blend the two gasses together.
- The blender is to operate over a wide range of input gas pressures and flows.
- This report summarises work done to:
  - Generate suitable 3D model(s) of the static mixer
  - Predict mixer performance over a range of operating conditions
- The overall conclusion from work performed is that the 24” TeeBlender will achieve good mixing within a downstream distance of 10x the inlet pipe diameter from the blender input flange

Modelled Design

The product design was modelled, including up and downstream associated pipework.

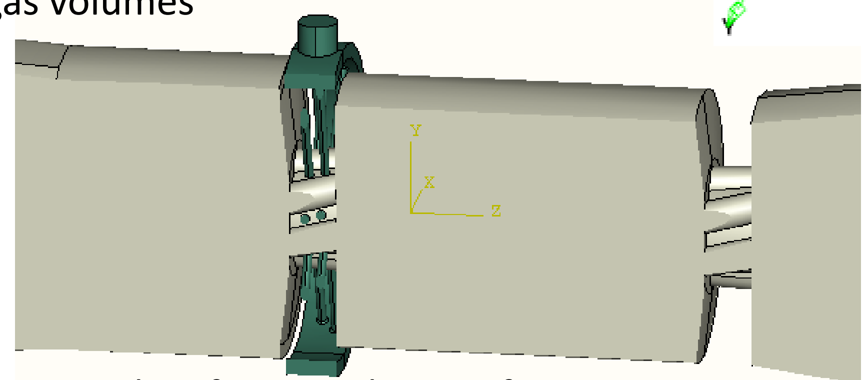
The performance of the blender was tested at 3.6D and 10D intervals downstream of inlet.





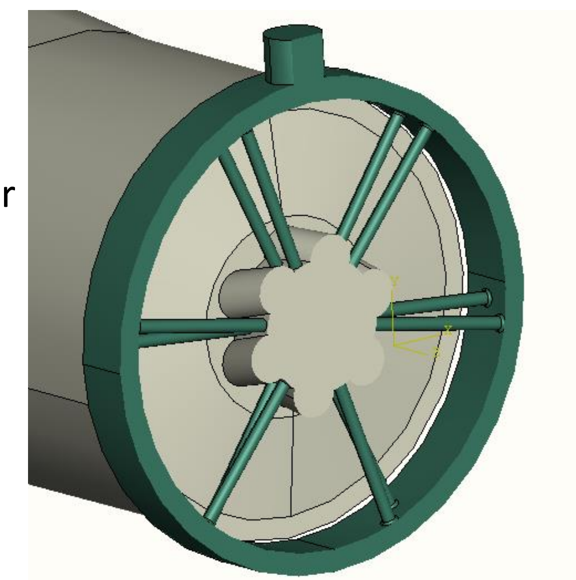
Cross-Section of gas volumes

Hydrogen Inlet tract



A nominal surface roughness of 0.1 mm was assumed for the blender; 0.05mm was assumed for the 12x 16mm diameter hydrogen jet holes, and 0.5mm for the main inlet and outlet pipes.

View on blender internal walls, showing the 12 hydrogen jets, each 16.0mm diameter



Analysis Methodology / Boundary Conditions: Overview

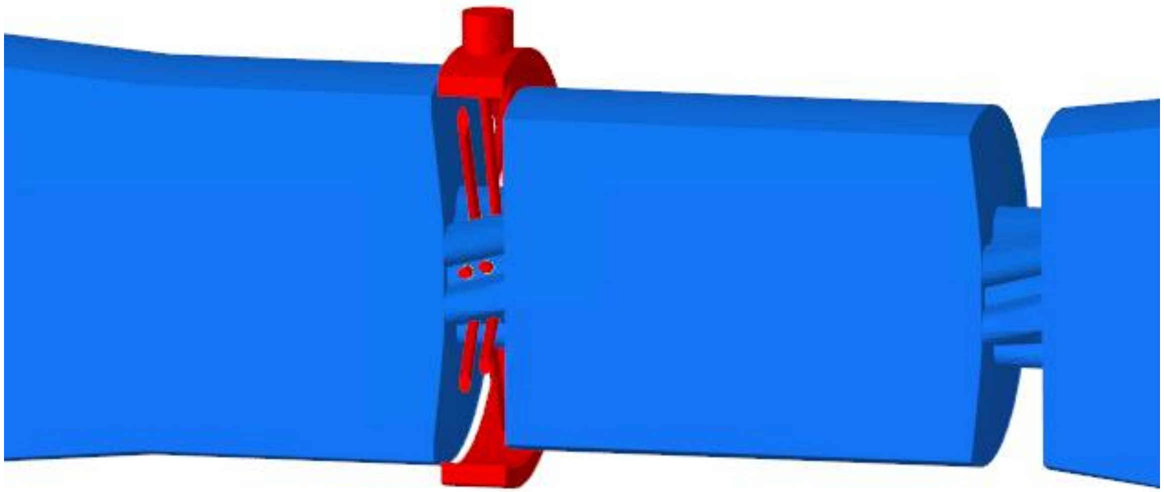
Specified boundary conditions are tabulated later in this report. The analyses were performed by first specifying a set of initial conditions from which the analysis would start. These comprised specification that the main through volume was full of pure natural gas and the external volume of the blender plus the jets were filled with pure hydrogen. A simplified calculation was performed to gain an estimate of the mean gas flow velocity, and this was specified along with initial gas temperatures and an estimate of mean system pressures.

The specified boundary conditions comprised inlet mass flow rates, temperatures, and outlet pressure.

Cross-section of central region initial condition:

Key:

- Hydrogen-filled volume
- (Initially) Natural Gas filled volume



Boundary Conditions

Boundary conditions of input gas flow rates, temperatures and operating pressures were specified in terms of Nm^3/hr, i.e. standardised volumes at reference pressure and temperature. These were converted into mass flow rates, as this avoids the complication of varied volumes with local pressure and temperature changes. Density of the specified mixture of natural gas was calculated according to its composition (assumed 90.67% methane, 4.53% Ethane, plus others).

The determination of boundary conditions also determined the target mixture ratios, and nominal gas flow velocities, which were used to estimate the pressure distribution for initial conditions.

Summarised input and initial conditions as used after analysis iterations appear:

Specified Data						Derived Data				
CFD	NG inlet pressure Barg	Total flow Sm3/hr	Blend - mass base %	H2 inlet Temperature degC	NG inlet temp degC	NG flow Sm3/s	H2 flow Sm3/s	Target Mass ratio -	H2 flow kg/s	NG flow kg/s
Run 1	19	510819	5	15	15	134.79946	7.09470833	0.006262	0.605	95.977
Run 2	19	510819	20	15	15	113.51533	28.3788333	0.029060	2.419	80.823
Run 3	38	14115	5	15	15	3.7247917	0.19604167	0.006262	0.017	2.652
Run 4	38	14115	20	15	15	3.1366667	0.78416667	0.029060	0.067	2.233
Run 5	28.5	262467	5	15	15	69.262125	3.645375	0.006262	0.311	49.315
Run 6	28.5	262467	20	15	15	58.326	14.5815	0.029060	1.243	41.528

Run 1, lo pressure, hi flow, 5% H2

Run 2, lo pressure, hi flow, 20% H2

Run 3, hi pressure, lo flow, 5% H2

Run 4, hi pressure, lo flow, 20% H2

Run 5, mid pressure, mid flow, 5% H2

Run 6, mid, pressure, mid flow, 20% H2

Results Interpretation: CoV Definition

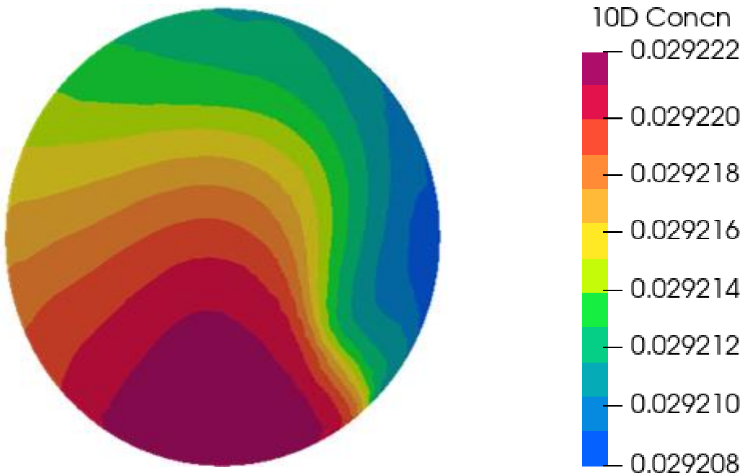
Minimum and maximum values of species are taken over the section, and expressed as variation from the mass-averaged value for the section. Thus:

CoV = (max value – min value) / mean value.

(Where the mean value is extracted directly from the output surface CFD data)

For this example (corresponding to Case 2 at 10D position), this yields:

(0.029222 – 0.029208)/0.029216 = **0.000479**



Target Volume Ratio 20%

Equates to:

Target Mass Ratio **0.029060**

(100% H2 being 0.1)

(0% H2 being 0.0)

Summarised Results

Pressure Data

Analysis Case	Outlet Pressure	NG Inlet Pressure	H2 Inlet Pressure	NG Pressure Drop	H2 Pressure Drop
	BarG	BarG	BarG	Bar	Bar
1	19	27.560	20.040	8.560	1.040
2	19	27.322	27.230	8.322	8.230
3	38	38.003	38.000	0.0034	0.0004
4	38	38.003	38.003	0.003	0.003
5	28.5	30.028	28.670	1.53	0.17
6	28.5	29.750	29.670	1.25	1.17

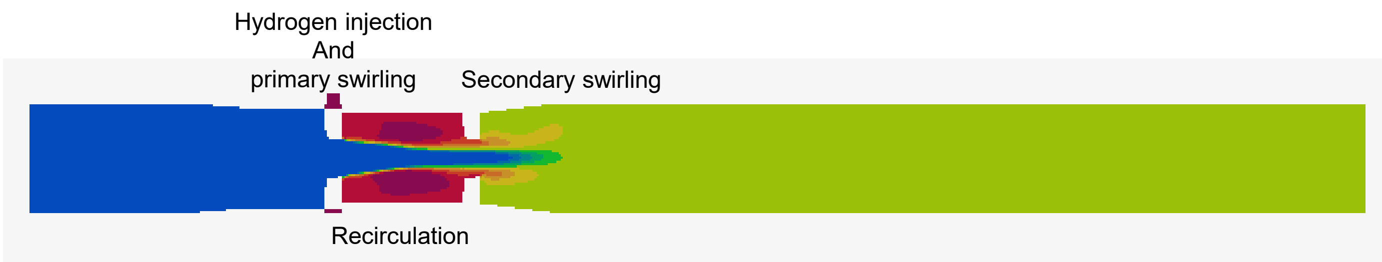
Note: All pressures expressed as Gauge values

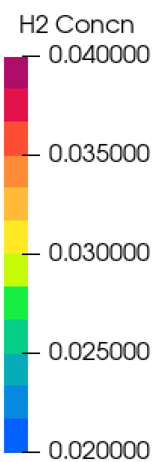
CoV Data

Analysis Case	Av Mass propn @ 3.6D	Max Mass propn @ 3.6D	Min Mass propn @ 3.6D	CoV @ 3.6D	Av Mass propn @ 10D	Max Mass propn @ 10D	Min Mass propn @ 10D	CoV @ 10D
	-	-	-	-	-	-	-	-
1	0.00624	0.00625	0.00623	0.00400	0.00627	0.00628	0.00627	0.00198
2	0.02907	0.02917	0.02893	0.00822	0.02914	0.02919	0.02910	0.00299
3	0.00601	0.00602	0.00600	0.00359	0.00598	0.00599	0.00598	0.00202
4	0.02957	0.02966	0.02949	0.00578	0.02945	0.02950	0.02941	0.00312
5	0.006251	0.006251	0.00625	0.000288	0.00625	0.00625	0.00625	0.000288
6	0.02886	0.02907	0.02868	0.0135	0.0289	0.02916	0.0287	0.0158

Visualisation of Results

Natural gas/Hydrogen blending through 24” **Tee**blender





Represents 40% to 100% hydrogen by mass

Target: 0.02906 by mass (which equates to 0.020 by volume, 20%)

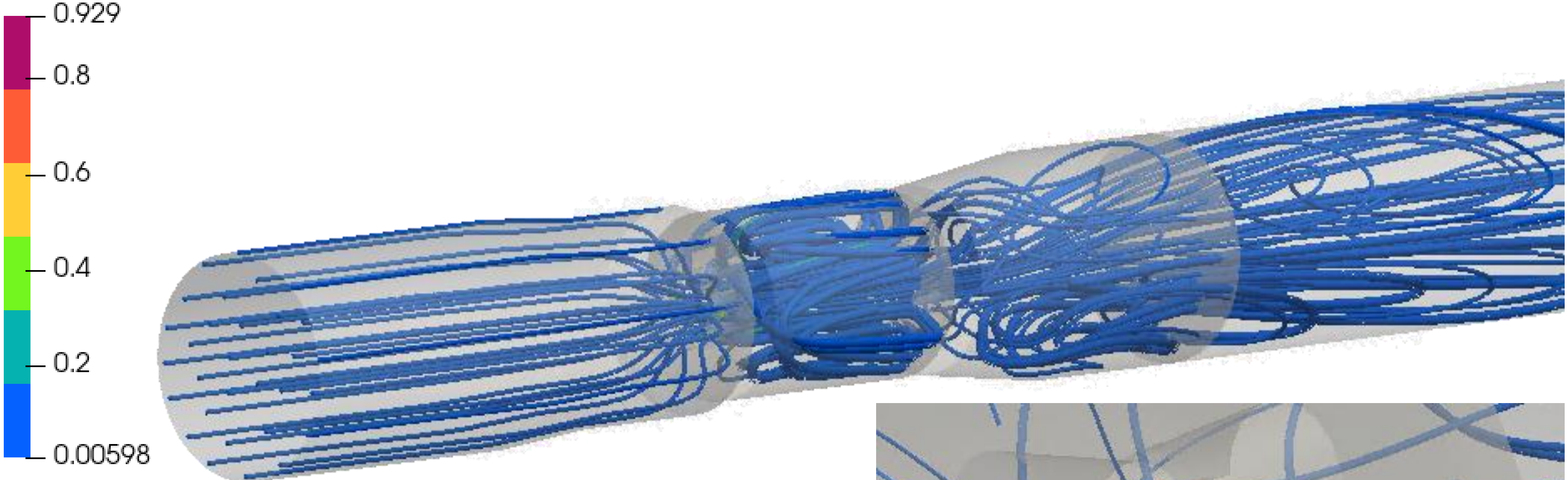
Represents 0% to 20% hydrogen by mass

Appendix: Supplementary Views

This section contains additional views to aid understanding of flow regimes and results obtained

All work was performed using Altair AcuSolve, version 2021.2.

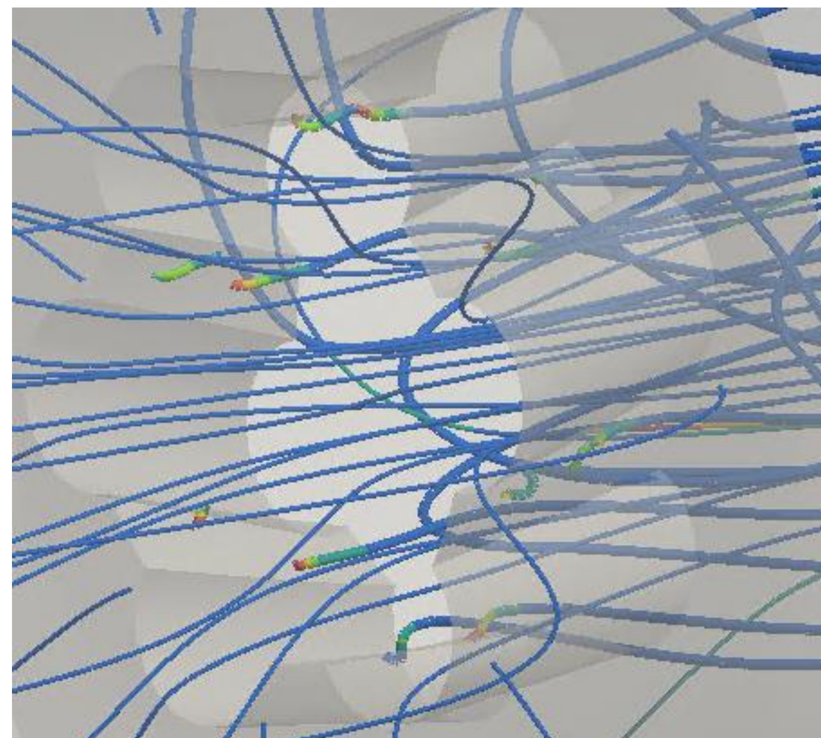
Example Flow Visualisation: Case 1



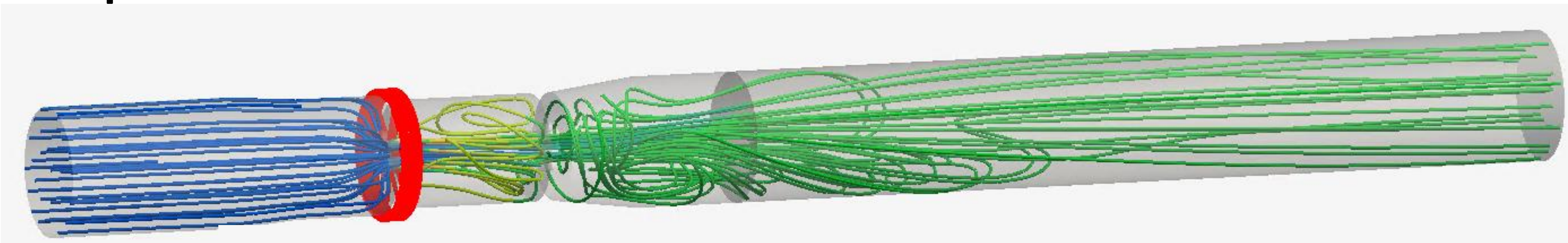
The above view shows typical flow paths for operating Case 1 (High flow, 5% blend). Thick streamlines originate from the hydrogen jets. The streamline contours indicate the proportion of hydrogen as the scale upper left.

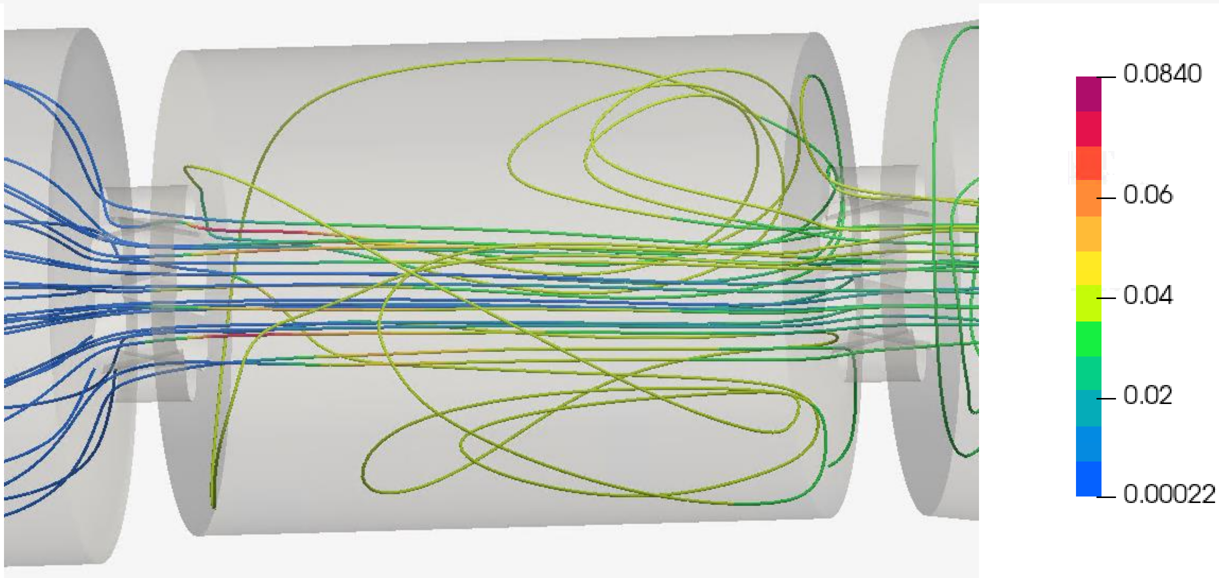
It may be seen that the hydrogen blends at the primary swirling orifice, is recirculated in the central blender chamber, followed by a secondary helical swirling orifice.

The view right is a close-up of the jet entries to the main stream. The hydrogen concentration rapidly falls to below 0.3.



Example Flow Visualisation: Case 2



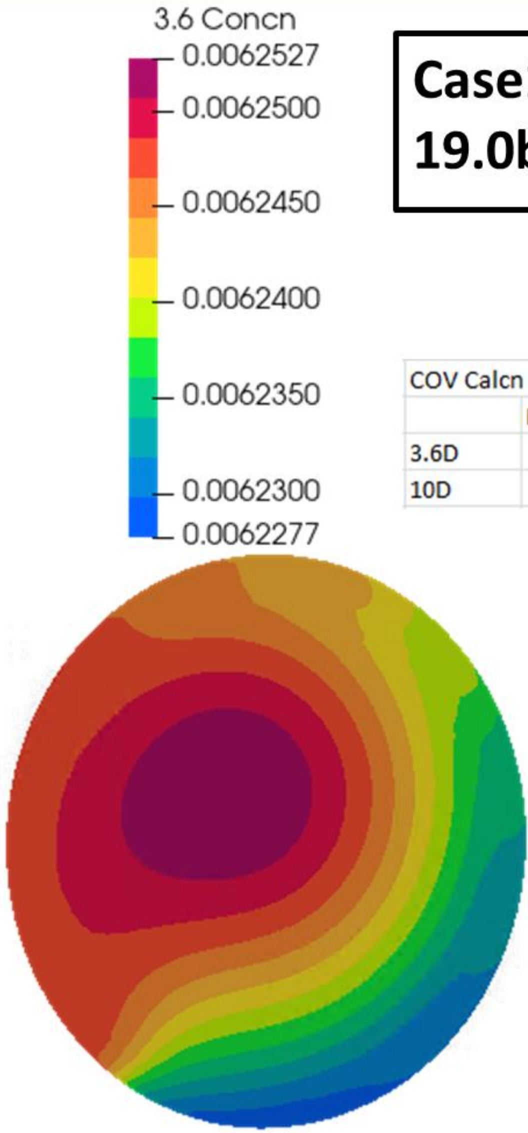


Note: finer scale than previous slide

The top view shows typical flow paths for operating Case 2 (high flow, 20% blend). The streamline contour colours indicate the hydrogen concentration. Note that the gases are almost totally mixed by the time they pass through the second venturi, shown by the green colour (concentration ~0.029).

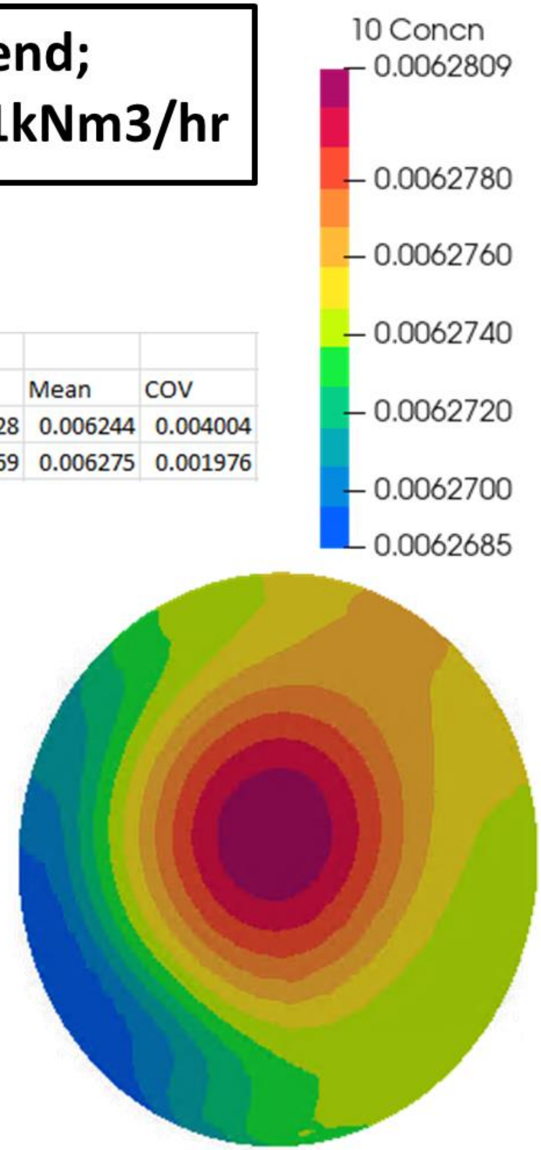
The lower view shows more detail in the main mixing region, i.e. from one venturi to the next. It may be seen that some of the (randomly positioned) stream lines are of almost pure hydrogen (red / violet) on exit from the 1st venturi, as they are close to hydrogen injection points. Also that the central flow gradually changes from mainly natural gas (blue) to mixed as it travels to and then through the 2nd venturi.

Concentration Distributions: Case 1



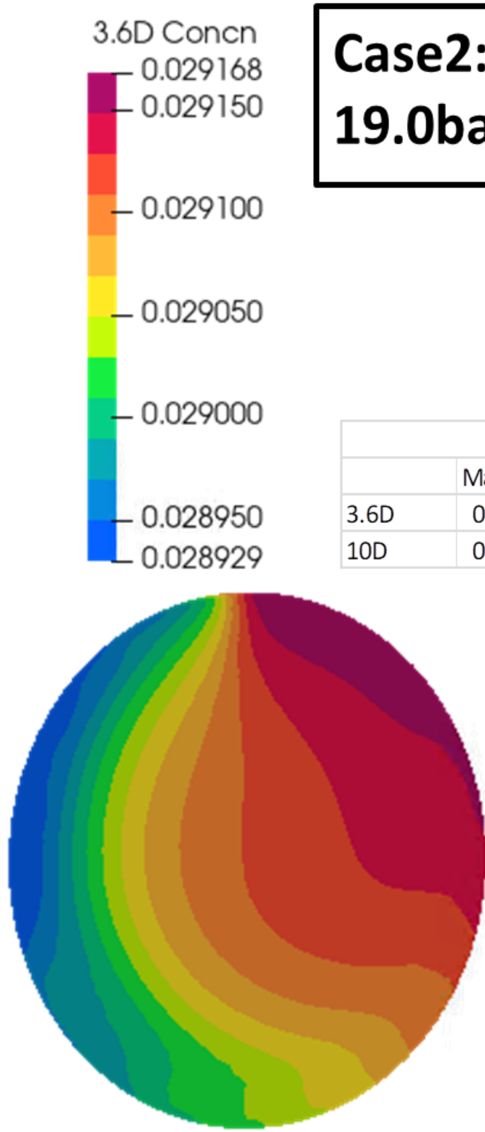
Case1: 5% blend;
19.0barg; 511kNm3/hr

COV Calcn				
	Max	Min	Mean	COV
3.6D	0.006253	0.006228	0.006244	0.004004
10D	0.006281	0.006269	0.006275	0.001976

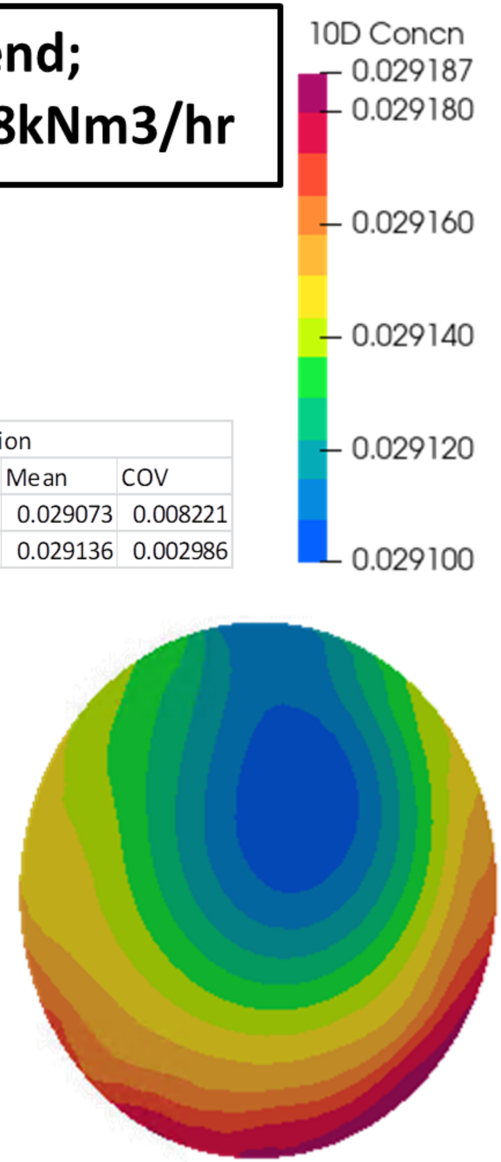


Concentration Distributions: Case 2

Case2: 20% blend; 19.0barg; 510.8kNm3/hr

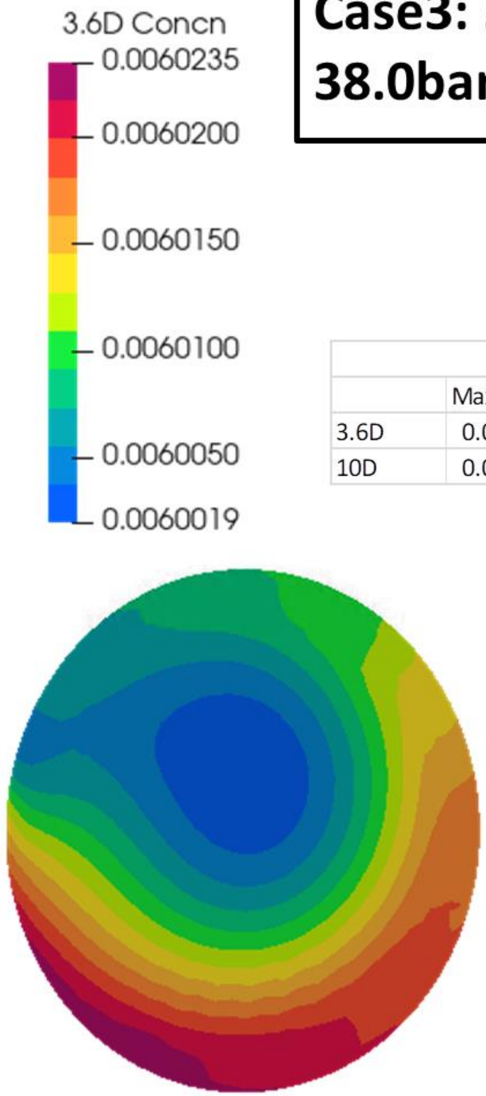


COV Calculation				
	Max	Min	Mean	COV
3.6D	0.029168	0.028929	0.029073	0.008221
10D	0.029187	0.029100	0.029136	0.002986

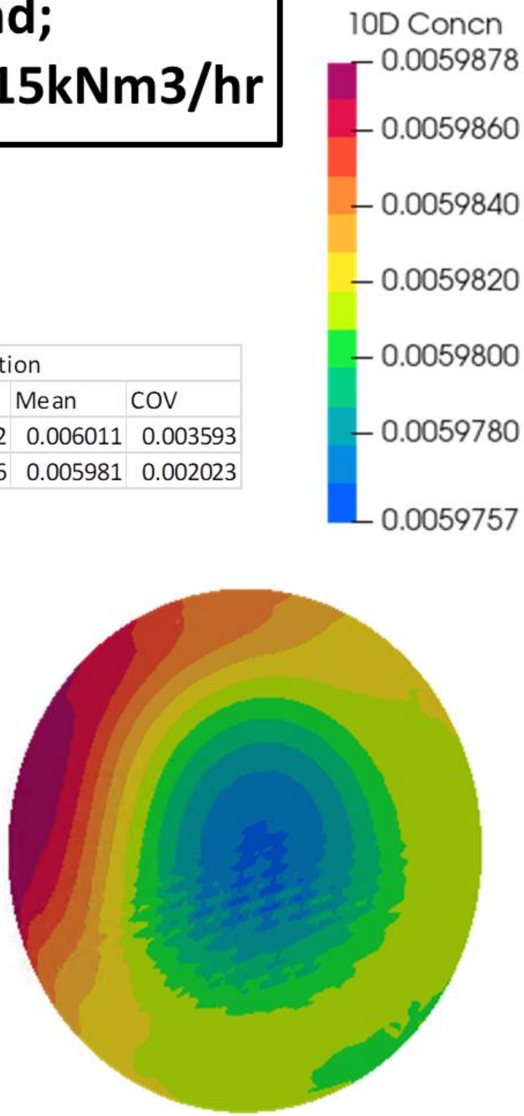


Concentration Distributions: Case 3

Case3: 5% blend;
38.0barg; 14.115kNm3/hr



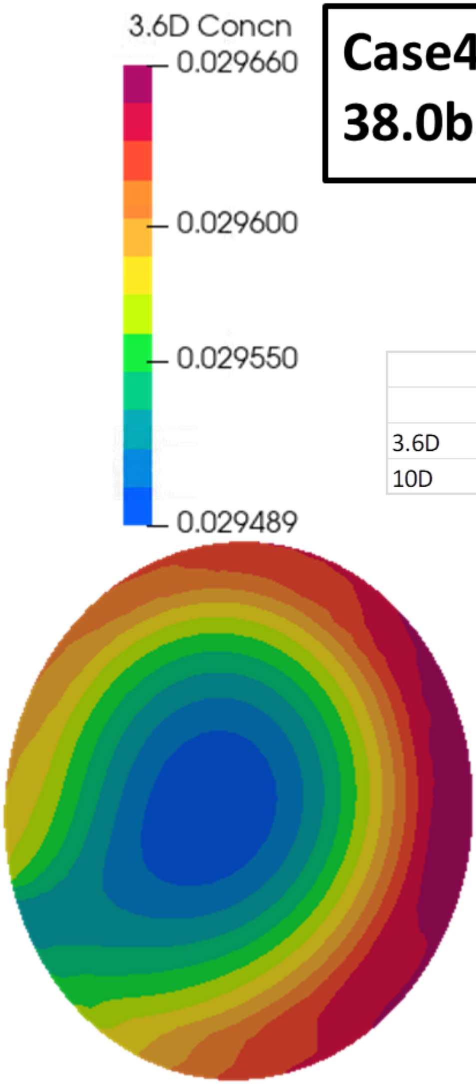
COV Calculation				
	Max	Min	Mean	COV
3.6D	0.006024	0.006002	0.006011	0.003593
10D	0.005988	0.005976	0.005981	0.002023

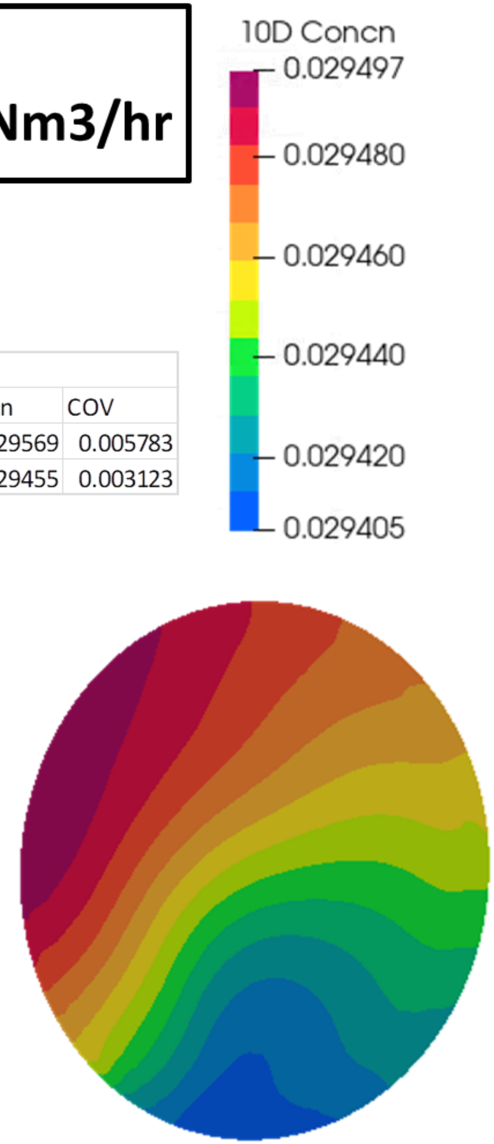


Concentration Distributions: Case 4

Case4: 20% blend; 38.0barg; 14.115kNm3/hr

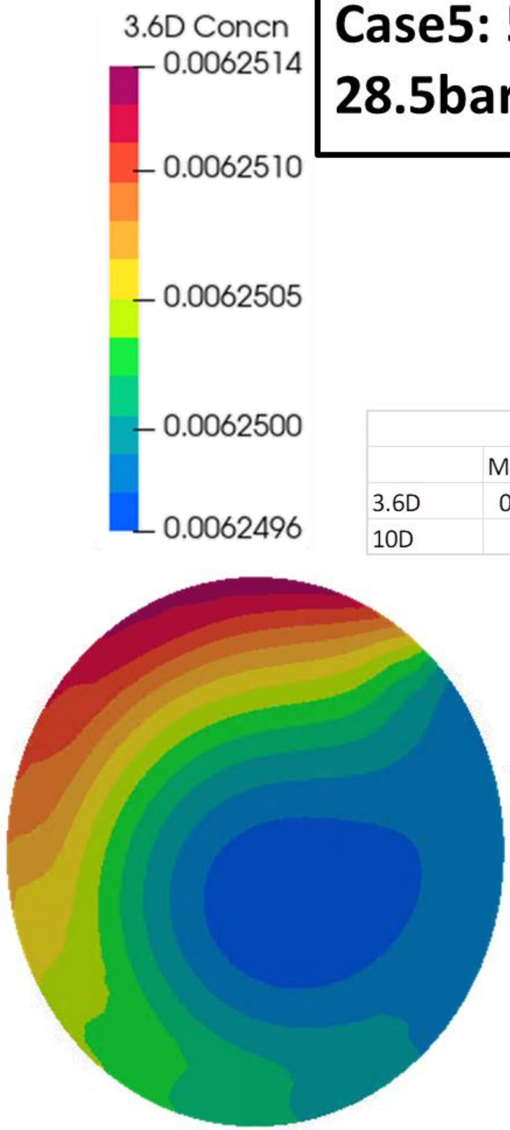
COV Calculation				
	Max	Min	Mean	COV
3.6D	0.02966	0.029489	0.029569	0.005783
10D	0.029497	0.029405	0.029455	0.003123



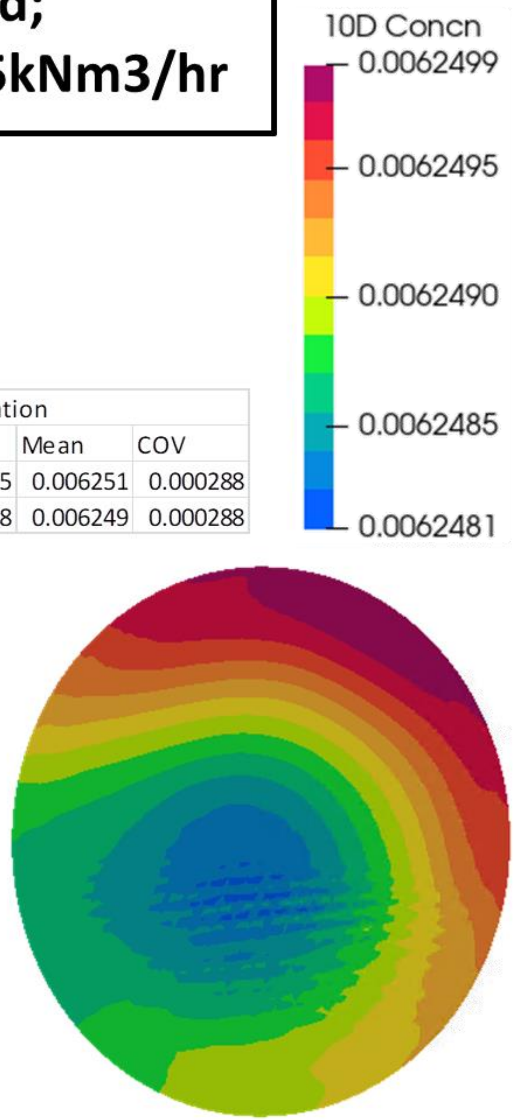


Concentration Distributions: Case 5

Case5: 5% blend; 28.5barg; 262.5kNm3/hr

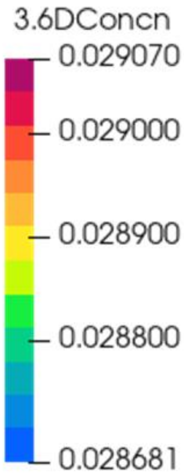


COV Calculation				
	Max	Min	Mean	COV
3.6D	0.006251	0.00625	0.006251	0.000288
10D	0.00625	0.006248	0.006249	0.000288

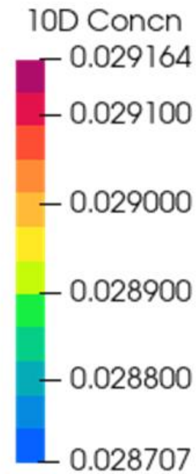


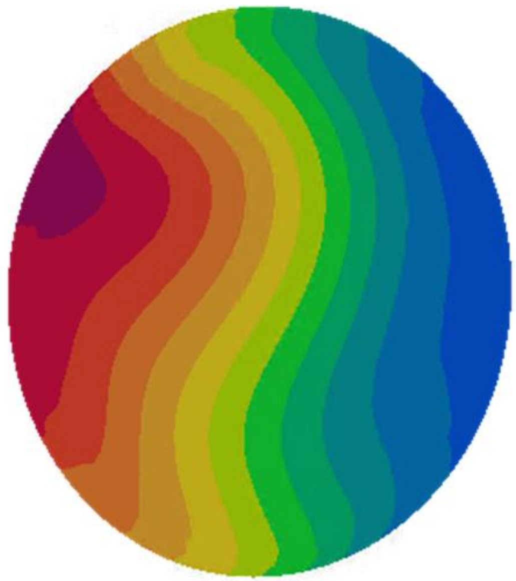
Concentration Distributions: Case 6

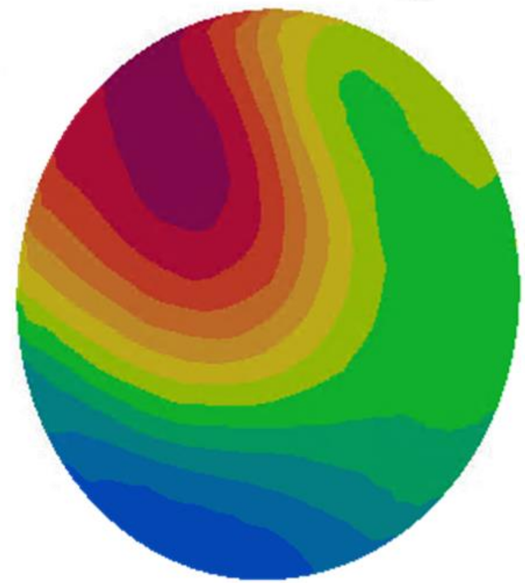
Case6: 20% blend; 28.5barg; 262kNm3/hr



COV Calcn				
	Max	Min	Mean	COV
3.6D	0.02907	0.028681	0.028865	0.013477
10D	0.029164	0.028707	0.028933	0.015795







Section.E Analyser Review

Analyser Technology Comparison

Sensor			Cost	Technology	Accepted Composition			Parameters / Operational Ranges											Error			Mechanical		Electrical		Certification		Operating Conditions				Notes
No.	OEM	Model	Per unit		NG	H2	Both	C1-C5	C6+	CO	CO2	O2	H2O (g)	N2	H2	H2S	CV	Wobbe Index	Repeatability	Accuracy	T90	Gases	Pipes	Power	Output	Haz. Area	Environment	Env. Temp	Op. Temp	Op. Pressure	Flowrate	
1	Martin Loughborough	Fuel cell						To be completed by Martin (Loughborough)																								
2	Martin Loughborough	MEMS						To be completed by Martin (Loughborough)																								
3	Martin Loughborough	Columb Counter						To be completed by Martin (Loughborough)																								
4	Bright Sensors	BlueEye Ex-d: Renewable Ultragreen Hydrogen		TCD IR	X	X	X	CH4 - 70-100 mol% C2H6 - 0-20 mol% C3H8 - 0-5 mol% C4H10 - 0-3 mol%	Higher alkanes 0-1 mol%	-	0-3 mol% 20 mol% 100 mol%	≤ 3 mol%	≤ 0.1 mol%	0-15 mol%	≤ 0.5 mol% 30 mol% 27.52-50.40 MJ/m3 at 15 °C	≤ 0.01 mol%	HHV LHV	Average range: 30-60 MJ/m3 Depends on ref. conditions	≤ 0.2% of reading for unfiltered 1 s cycle measurement	≤ 1% of reading	T90 < 60 s One measurement per second	None stated	-	24 VDC < 2 W	Modus RTU (RS485) Analog (4-20 mA)	CE IECEx ATEX	IP66	0-50 °C	-2 to 52 °C **Inlet:** ± 2 °C of T(env)	**Inlet:** 960-1100 mbara **Burst:** < 250 mbarg	50 mL/min (-±10%)	Flow rate able to be customised Renewable, Ultragreen, Hydrogen are models/versions
5	GasPT	MU (main unit) AU (ancillary unit) MI (safety interface) AI (safety interface)		Acoustic resonator TCD	X	-	-	CH4 - 50-100% C2H6 - 0-15% C3H8 - 0-7% C4H10 - 0-1% C5H12 - 0-0.5%	C6+ total - 0-0.5%	-	CO2 sensor in MU CO2 - 0-5% 0-25% available	Trace	Non-condensing	N2 - 0-10% Extended range available	Trace	< 5 ppm	Error: ± 0.5%	Error: ± 0.5%	± 0.04 MJ/m3 for CV and WI at T(amb)		T90 > 10 s Updates every 2 s	No carrier or calibration gas	-	**MU/AU:** 6.8 VDC, 250 mA, 1.7 W **MI/AI:** 23.5 VDC	RS485 Serial Modbus ASCII or RTU	ATEX IECEx CSA	-	-	**MU/AU:** -20 to 50 °C **MI/AI:** 0 - 50 °C	Max. op P: 0.3 barg	-	CO2 - 0-25% available at no extra cost Safety interfaces = MI and AI
6	Sick	FLOWSIC600		Ultrasonic transit time	X	X	X	**Measured values** Volumetric flow a. c., volume a. c., gas velocity, sound velocity, optional volume correction via integrated, electronic volume corrector (EVC)											± 0.05% of measured value	Dry calibrated: ≤ ± 0.5%	-	None stated	3 to 56" DN80 to DN1400	**Electrically isolated** 12-24 VDC **Intrinsically safe** 6-16 VDC 0.45-2.45 W	1x **analog** : 4-20 mA ≤ 250 Ω 4x **digital**: 2x status & pulse ≤ 30 V, 50 mA Modbus TCP, ASCII or RTU	IECEx ATEX NEC	IP66 IP67	**Ambient:** -40 to 70 °C	-40 to 180 °C	0 to 160 barg	**Q(min):** 5 to 750 m3/hr **Q(max):** 1,000 to 120,000 m3/hr	**Accuracy:** ≤ 0.2% after flow calibration with constant correction adjustment ≤ 0.1% after flow calibration with polynomial correction adjustment **Operating temperature:** -194 to 280 °C available on request **Operating pressure:** 0 to 450 barg available on request
7	H2Scan	HY-OPTIMA 1740	£21,500	Thin-film solid state sensor	-	X	X	-	-	Limit ≤ 20%	-	-	-	-	0.5-100% H2 must be present	Limit ≤ 3%	-	-	0.5-10% H2 - 0.2% 10-100% H2 - 0.4%	0.5-10% H2 - 0.3% 10-100% H2 - 1%	T90 < 90 s	N2	-	**Barrier:** 24 VDC, 10 W **Analyser:** 10 VDC, 6 W	**Analog:** 4-20 mA **Digital:** serial, RS422	ATEX CE	IP64	-20 to 40 °C	-20 to 60 °C	0 to 2 atma 1 atma recommended	0 to 10 slpm	
8	SRA	PGC 490 Micro GC		µTCD	X	X	X	C1 to C10 Quantities not stated	X	-	X	X	-	X	X	X	-	-	<0.5 % RSD for propane at 1 mol %	-	-	Helium, argon, nitrogen, hydrogen 10 mL/min/module 99.9995% purity 5.5 bar	-	220 to 240 VAC 50 to 60 Hz 10 A max	Relay outputs 4-20 mA			0 to 50 °C	15 to 180 °C	**Max.**: 14.5 psi (1 bar)		
9	TTL	P1Z1+																														
10	Emerson	770XA C6+ range C7+ range C9+ range		GC TCD FID µFPD	X	-	-	CH4 - 65-100 mol% C2H6 - 0-20 mol% C3H8 - 0-10 mol% C4H10 - 0-5 mol% C5-H12 - mol%	**C7+ and C9+ only:** C6H14 - 0-1 mol% C7H16 - 0-1 mol% C8H18 - 0-0.5 mol% C9H20 - 0-0.5 mol%	-	CO2 - 0-20 mol%	-	-	N2 - 0-20 mol%	-	-	C6+ C9+	-	C6+ CV ±0.01% C9+ CV 0.0125%	None stated	None stated	Application dependent Zero-grade helium, nitrogen, or hydrogen	-	120/240 VAC 24 VDC 125 to 250 W	Modbus TCP Modbus Serial (RS232, RS422, RS485) Analog 4-20 mA	CE IECEx ATEX CSA	IP66	-18 to 54 °C	TCD - 0 to 54 °C FID - 4 to 54 °C µFPD - 0 to 50 °C	Input: 0-2 barg, (rcmd 1barg) Input, max.: Sample - 6 barg Carrier - 6 barg Actuator - 8 barg		
11	ABB	PGC1000 BBC		GC	X	X	X	CH4 - 0.05-100% MDL 0.01% C2H6 - 0.1-100% MDL 0.02% C3H8 - 0.05-2% MDL 0.01%	-	-	CO2- 0.1-100% MDL 0.02%	-	-	N2 - 0.05-100% MDL 0.01%	H2 - 0.1-10% MDL 0.05%	< 0.05%	When used with BBF, Btu repeatability ±12.5	-	None stated	None stated	Cycle time: 300 s	Helium 1 large bottle should last 9-12 months	-	10.5 to 16 VDC 21 to 28 VDC	Serial x2 Modbus TCP, ASCII or RTU	NEC CE ATEX EMC IECEx INMETRO		-30 to 60 °C	-18 to 55 °C	Carrier: 11 psig (±15%)	6.6 mL/min (±15%)	Different trains can be used for different
12	ABB	PGC1000 BCP		GC	X	X	X	CH4 - 10-100 mol% Min. detectable limit: 1 mol%					< 0.01 mol%		H2 - 0.1-100 mol% Min. detectable limit: 0.01 mol%				None stated for BCP/BCJ	None stated for BCP/BCJ	Cycle time: 30 s	Nitrogen carrier	-						Oven temp.: 60 °C	Carrier: 5 psig (±15%)	Typical: 8.6 mL/min (±15%)	
13	Thermo Scientific	MAX-IR FTIR Gas Analyser with DTGS detector		FTIR StarBoost Tech.	NG not mentioned	X	-	Total - 0.2 ppm CH4 - 0.01 ppm C2H6 - 0.02 ppm C3H8 - 0.04 ppm C4H10 - 0.08 ppm C5H12 - 0.05 ppm	-	0.02 ppm	0.01 ppm	-	0.1 ppm	-	Bulk	-	-	-	Not stated	CO2 - 1.25% CO - 2.91% CH4 - 2.15%	1 s to 1 min response	N2 purge gas optional	-	120/240 VAC 50/60 Hz	Modbus TCP/IP	Not certified	Not stated	20 to 30 °C	5 to 191 °C	**Gas cell:** 1 or 5 atm	Not stated 0.5 L standard volume	DTGS - deuterated triglycine sulfate **Optional Accessories** TOM - thermal oxidiser module FIM - factory interface module
14	Riken Keiki	OHC-800		Opt-sonic through RI and speed of sound	X	-	-	-	-	-	-	-	-	-	-	-	25.00 to 50.00 MJ/m3	25.00 to 50.00 MJ/m3	CV: 0.02 MJ/m3	-	T90 ≤ 5 s Data updated every 0.25 s	Air/N2	-	100-240VAC ±10% 50/60Hz, OR 24VDC ±10% 5 W	0-22 mA Modbus RS485	IECEx ATEX Japan EX CE	IP66 IP67	-20 to 60 °C	-20 to 60 °C No sudden changes	80 to 110 kPa	**Q(min)** Sample: 0.3 L/min Reference: 0.01 L/min **Q(max)** Sample: 1 L/min Reference: 0.5 L/min	**Density** measured as well: 0.5 to 1.5 (SG conversion)

Section.F Appendix/Additional Documents

Warburton Budget Cost

- Project Delivery, CDM & Design £ 482,000
- Supply, Manufacture, Testing £1,282,000
- Civil & Mechanical Site Readiness £ 561,000
- Delivery, Installation and Commissioning £ 178,000

TOTAL BUDGET COST £ 2,504,000

Delivery: 44 to 52 Weeks

Y WAEN PRI

Principal Contractor, CDM 2015

Detailed Design, A&A (Mech, E, C&I, Software), TD/12 Stress Analysis

Supply, Manufacture & Factory Testing

- 12" Blending Skid c/w On skid Analyser Solution
- Supervisory Control Installed in LER & Electrical Distribution from Existing LER

Civil & Mechanical Site Works Readiness

- Plinths, Ducting, Pipe Supports, Relocation of Path
- x2 12" Tee c/w 12" MOV Isolation
- 12" ROV between Tee

Delivery, Installation and Commissioning

- Offloading and Positioning of Blending Skid & Supervisory Control Kiosk
- Mech, E,C&I Interconnections
- Testing

Documentation

Costing for Y WAEN PRI

- Project Delivery, CDM & Design £ 125,000
- Supply, Manufacture, Testing £ 450,000
- Civil & Mechanical Site Readiness £ 375,000
- Delivery, Installation and Commissioning £ 75,000

TOTAL BUDGET COST £ 1,025,000

GREENFIELD LTS

Footprint & Interface similar to Y WAEN PRI

Principal Contractor, CDM 2015

Detailed Design, A&A (Mech, E, C&I, Software), TD/12 Stress Analysis

Site Footprint similar to Y Waen PRI, 12" LTS

Construction

- Hot taps and main line isolation valve, IJ's
- Road Access, Palisade Security Fence, Access Gates, Site Lighting Etc
- Plinth and Ducting

Equipment

- HBCS
- LER including Telemetry and Power Distribution
- Incoming Electrical Meter Kiosk

Delivery, Installation and Commissioning

- Offloading and Positioning of Blending Skid & Supervisory Control Kiosk, EMK
- Mech, E,C&I Interconnections
- Testing

Documentation

Costing for Y Greenfield LTS

- Project Delivery, CDM & Design £ 550,000
- Supply, Manufacture, Testing £ 690,000
- Groundwork, Civil & Mechanical Site Readiness £ 1,950,000
- Delivery, Installation and Commissioning £ 150,000

TOTAL BUDGET COST £ 3,340,000

OPTIONAL COSTS

FWACV System £ 150,000

Odourant Injection skid £ 150,000 --£ 250,000
- H2 7.3 mg/m3

Telemetry £ 50,000

CVDD Analyser £ 25,000
- Target CV

Flow Control £ 50,000 to 300,000
- Mitigate rapid downstream flow changes

Not Included

- Hydrogen supply
- Supply to blending skid
- Any associated works

Planning Application

Land

Local Road Access to Site

ONE OFF COSTS

FWACV Software Update (DANINT) £ 50,000

Hydrogen / Impurity Analyser Evaluation £ 30,000

CVDD (inc H2) Ofgem Approval £ 60,000 --£80,000

TOTAL BUDGET COST £ 310,000