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Department for Business, Energy & Industrial Strategy

NZIP Industrial Fuel Switching
Zero Emission Industrial Steam

Start Date: 28/03/2022
Finish Date: 30/09/2022

Final Report

Executive Summary

The Net Zero Innovation Portfolio: Industrial Fuel Switching Competition Phase1 allowed Steamology to develop its industrial fuel switching technology for industrial sector steam and medium grade heat users currently reliant on oil and gas fired boilers.

The IFS Phase 1 Project developed and proved the feasibility of Steamology's Steam Generator technology to generate industrial steam using Zero Emission Hydrogen and Oxygen Steam Generator technology. The project had four main work packages. The first developed the Steam Generator hardware to run at industrial steam conditions. The second identified the steps required for certification. The third an fourth work package used a case study to assess the feasibility of the Steam Generator technology on a real world site to provide a representative duty cycle.

Contents

Project Aims

- Demonstrate the potential for reducing industrial greenhouse gas emissions through fuel switching to hydrogen-based technology.
- Demonstrate commercial viability of zero emission steam and heat solution.
- Inform future industrial decarbonisation policy by engaging with industrial steam and heat users including, distilleries, food and beverage, chemical manufacturing and assessing industrial hydrogen and electricity use.
- Increase awareness of novel zero emission steam and heat technology with range of steam quality, quantity, rapid response, point of use solutions engaging and disseminating with industry and investors
- Engage with supply chain of hydrogen supply, fuel compression and storage, steam certification, installation, service, maintenance business users and financiers.

Project Objectives

WP1: Steam Generator Tech Feasibility and Performance

- Steam Generator Detailed Design
- Steam Generator Test Data
- Steam Generator Costing Report
- Test Cell Fuel and Steam Exhaust
- Control Hardware

WP2: Steam Regulatory Feasibility

- Outline System Boundary Scheme
- Certification Report
- Risk Register

WP3: Demonstration Site Engineering Design

- Demonstration site concept report

WP4: Phase2 Planning

- Phase2 outline plan report.

Work Package 1

WP1: Saturated steam generation design and test data to demonstrate industrial quality and quantity steam in the test cell equipped with data and video capture. Steam generator hardware and control system will be modified from power turbine applications to deliver industrial steam duty service loads for potentially open and closed loop steam systems.

Deliverable	Milestone	Title	Description	Format
1.1	1	Steam Generator Detailed Design	Steam generator CAD detail design package	CAD Drawings
1.2	2	Steam Generator Test Data	Steam generator test data from test cell	Report showing data from test cell recording steam generator tests
1.3	2	Steam Generator Costing Report	Review of steam generator BOM with cost report	Report describing cost breakdown of the Bill of Materials of Steam Generator
1.4	1	Test Cell Fuel and Steam Exhaust	Test cell water, gas and steam exhaust systems prepared for testing	Picture report of test cell water, gas fuel and exhaust system
1.5	2	Control Hardware	Electronic controller PCB assemblies	Pictures of PCB electronic controller hardware

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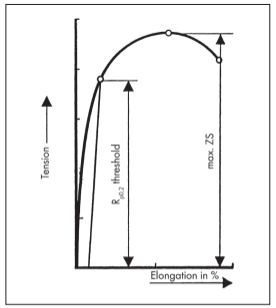
Deliverable 1.1 – Steam Generator Detailed Design

Deliverable 1.1 – Steam Generator Detailed Design

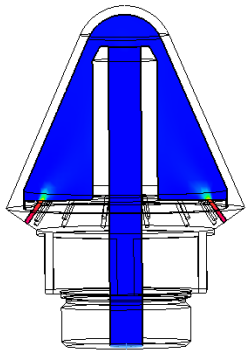
Steam Generator Detailed Design - Overview

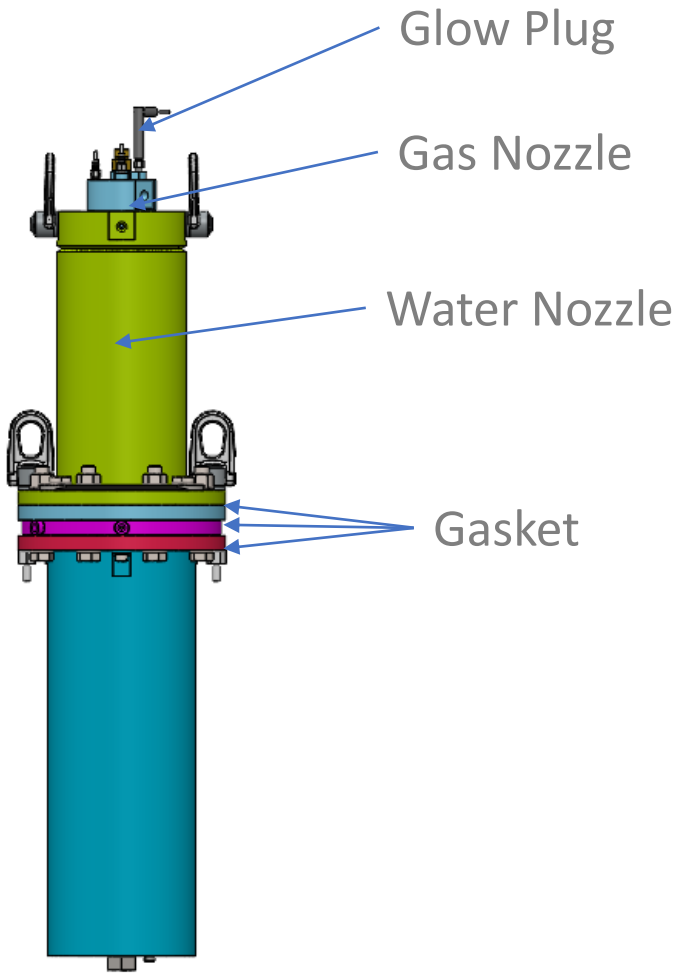
- Industrial Steam is generally used at 10 Bar, 185°C.
- Focus has been on moving running pressure down from 40 Bar, 400°C to 10 Bar, 185°C.
- Design has been informed by first round of certification considerations.
- Activities included:
  - Tightening Torque Analysis.
  - Water Nozzle Sizing.
  - Gasket Compression Analysis.
  - Gas Nozzle Sizing.



Stress-strain diagram of a screw with strength class 10.9 (qualitative)
Fig. D

Minimum Preload on Bolt For Gasket		
Req. Pressure	4500	PSI
Gasket area	13723.4	mm2
ø Nominal	16	mm
Friction Coefficient	0.2	%
M16 10.9 Yield at 20°C	900	N/mm2
M16 Pitch ø	14.7	mm
M16 Root ø	13.546	mm
Req. Pressure	**31.0**	**N/mm2**
Force on gasket	**425.8**	**kN**
Force per bolt	**53.2**	**kN**
Load at Yield	**141.0**	**kN**
% of Yield	**0.378**	**%**
Torque	**170.3**	**Nm**



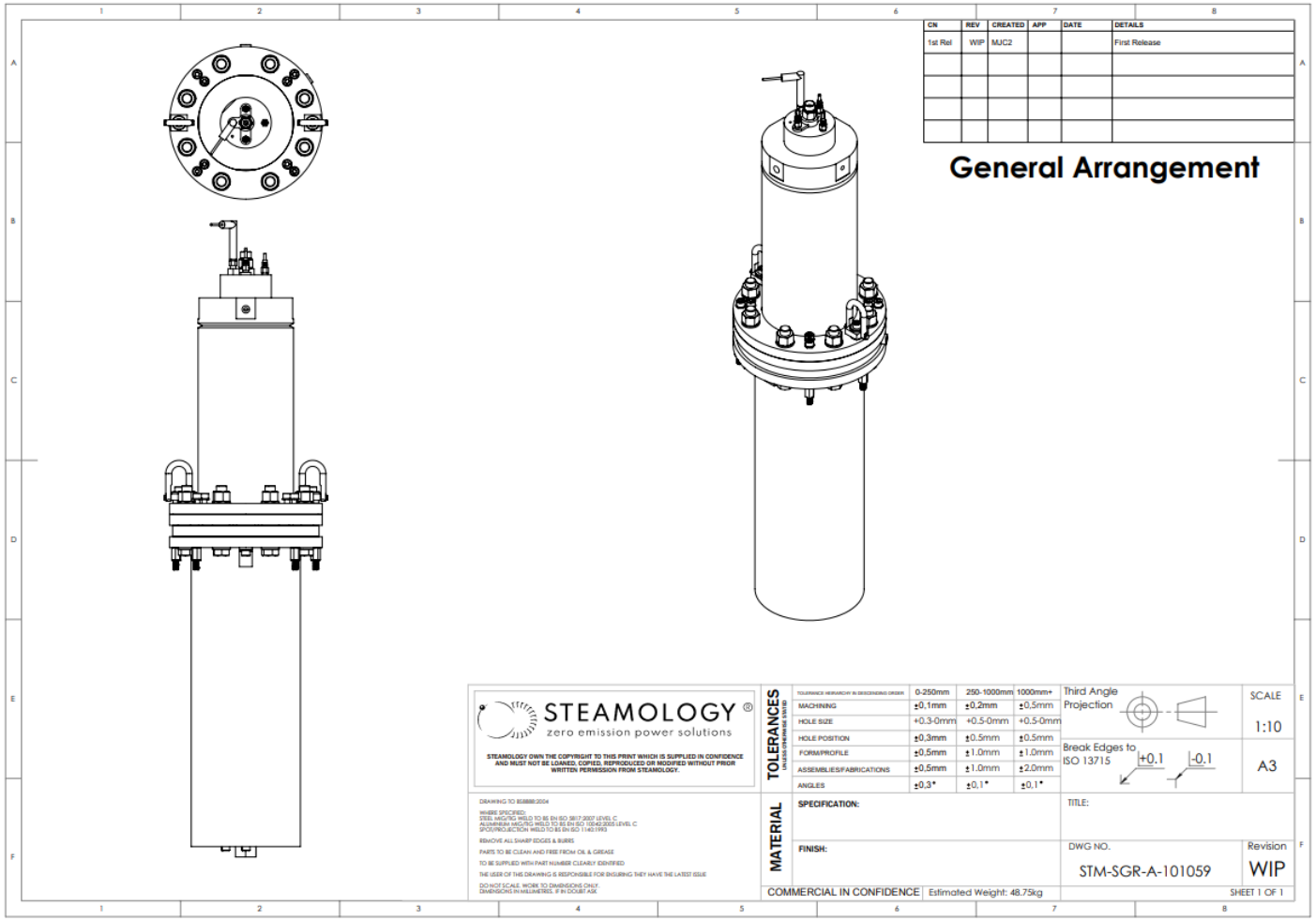


Deliverable 1.1 – Steam Generator Detailed Design

Steam Generator Detailed Design

- Complete drawing pack produced.
- Initial tests of the Mk. 3 Steam Generator have been highly positive.

- This deliverable provides the foundation of the Steam Generator design for Industrial Steam applications.



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Deliverable 1.2 – Steam Generator Test Data

Deliverable 1.2 – Steam Generator Test Data

Steam Generator Test Data

Objectives of steam testing throughout the project:

1. Achieve stable steady state running at 10 Bar in Mk. 2 Steam Generator.

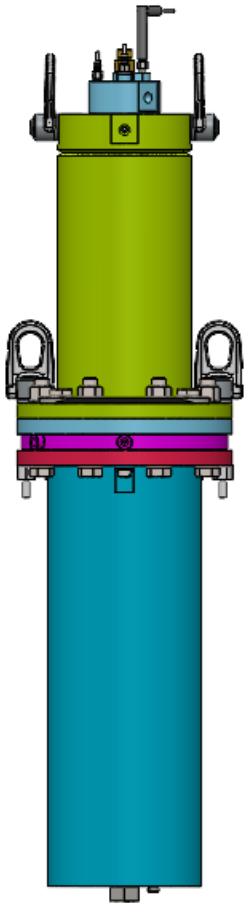
2. Measure Hydrogen and Oxygen mass flow rates required to maintain 10 Bar running.

3. Design, install and commission exhaust testing loop.

4. Achieve stable steady state 10 Bar running with the test loop installed.

Mk. 2

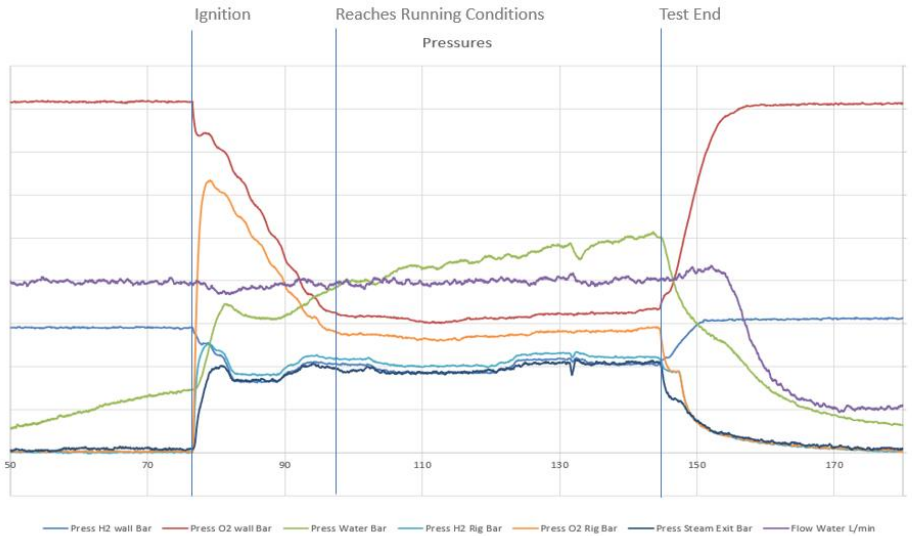
Mk. 3

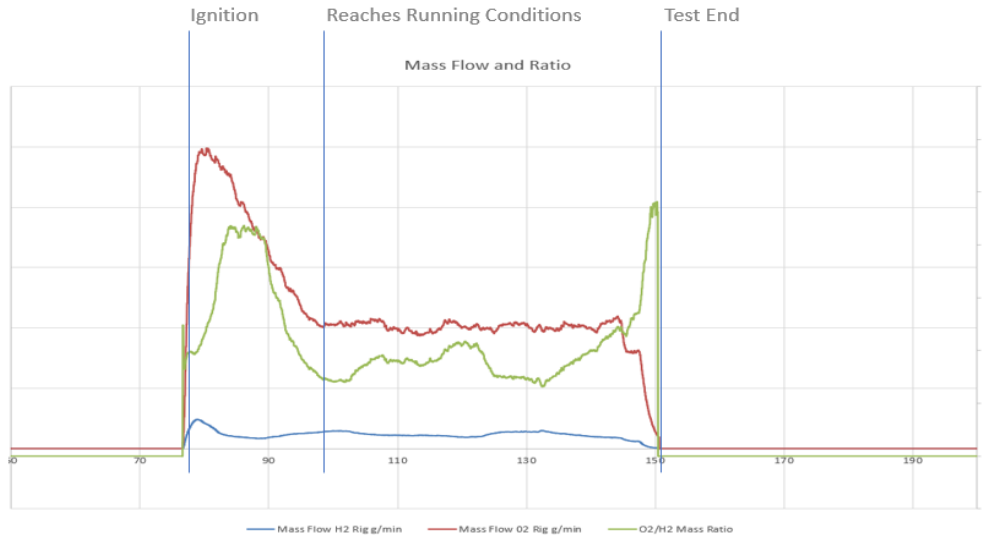


Deliverable 1.2 – Steam Generator Test Data

<u>Objective 1 and 2:</u>
Achieve stable steady state running at 10 Bar.

- Multiple tests to calibrate the outlet valve to reach the correct running pressure.
- Achieved 10 bar steady state running.
- Measured mass flow rates of Hydrogen and Oxygen during this stable run.





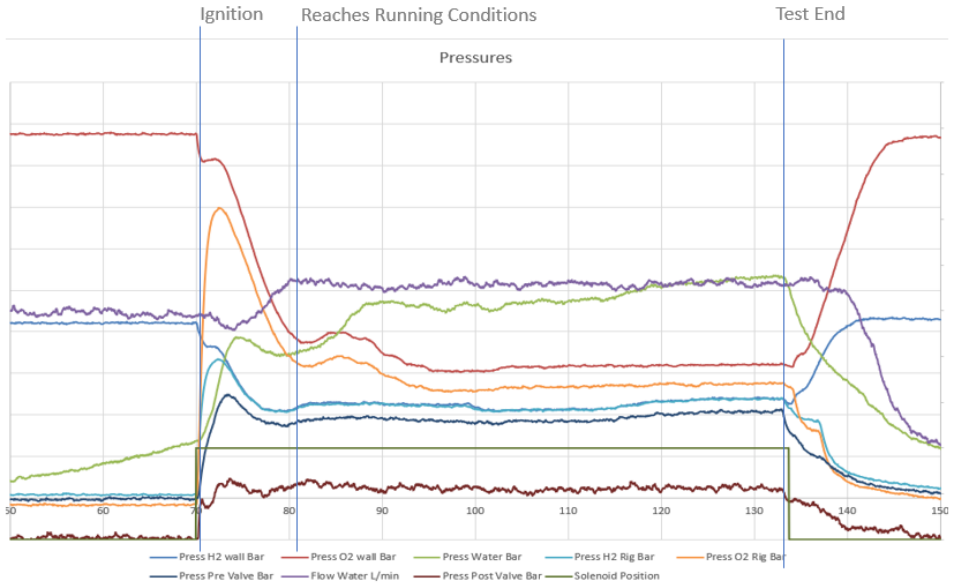
Deliverable 1.2 – Steam Generator Test Data

<u>Steam Testing Objective 3 and 4:</u>
Achieve stable steady state 10 Bar running with the test loop installed.

- Multiple tests and minor modifications to the test loop were conducted before it ran successfully.

- Test at 10 bar steady state running with the test loop installed has now been completed.

- The success of these tests demonstrates the Steam Generator can provide industrial standard steam.



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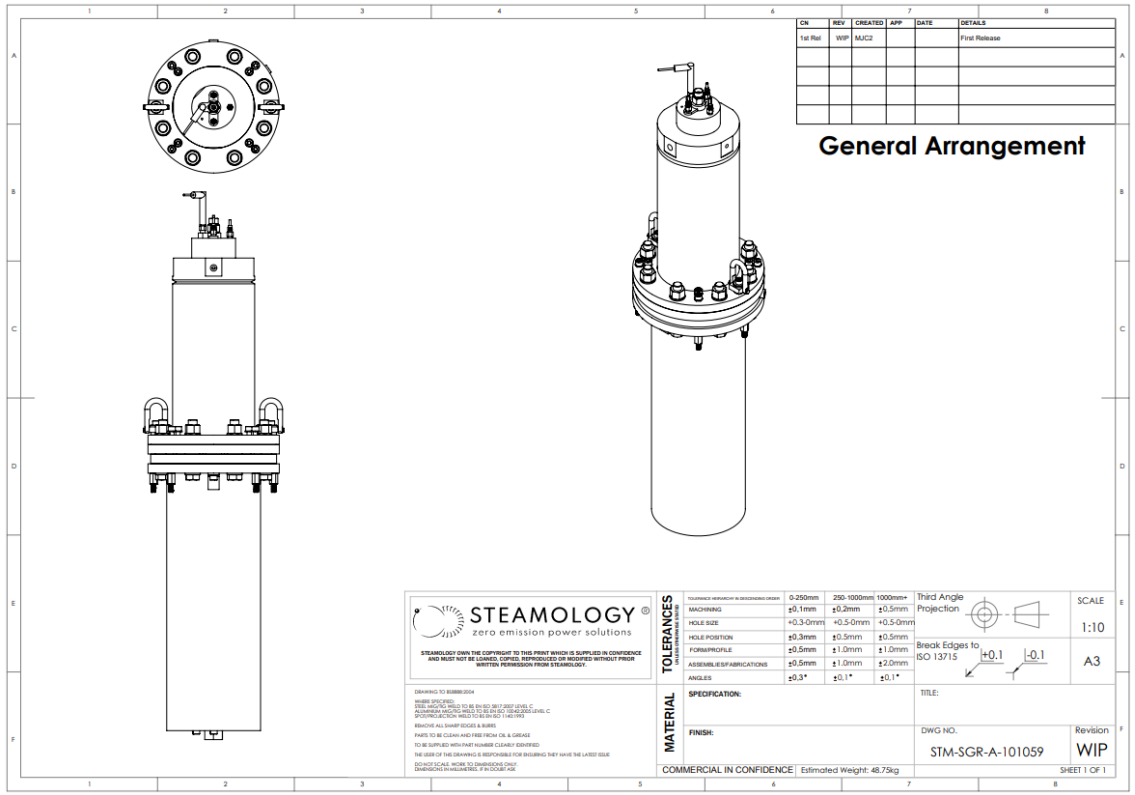
Deliverable 1.3 – Steam Generator Costing Report

Deliverable 1.3 – Steam Generator Costing Report

Steam Generator Costing Report

- The costing report of a Mk. 3 Steam Generator has been created.
- This is inclusive of the material costs, manufacturing costs and purchase costs associated with assembling a Mk. 3 Steam Generator.
- This costing report provides the foundation for the business case for the Steam Generator to provide industrial steam.



Deliverable 1.3 – Steam Generator Costing Report

PART NUMBER	DESCRIPTION	REV	QTY Per S	Column1	QTY Or	Total £	Supplier
51277180	Glow Plug Cable	WIP	1	13.2	4	52.8	Bestpart Store.co.uk
HTBHN-M8-20-A4	M8 X 20mm Hexagonal Connector Nut	WIP	5		20	0	Accu
HTB-M8-45-A4	M8 X 45mm Threaded Bars - ACCU	WIP	5		20	0	Accu
1050515-12-12	3/4 " BSPP Male (60 coned) to 3/4 " BSPP Fixed Female Adaptor		1		4	0	
438-44-0077	Bosch - 0 250 202 022-EAF955		4	11.54	10	115.4	Euro-Car Parts
4-4F3MK4S	1/4" BSP Male - 1/4" BSPT Male		1		2	0	
695-201	Swivel Lifting Rings - Double Swivel - Male	WIP	1	61.32	1	61.32	
724-8903	Insulation			51.5	1	51.5	RS Components
BSP Self Centered Dowty Se	1//8" Self Centered Dowty Seal	0	2		8	0	
Copper Washer	copper washer 22x16x1.4	-	1		4	0	
copper washer 22x16x1.4	copper washer 22x16x1.4	1	1		4	0	
ISO - 4034 - M16 - N	Hexagon nut ISO 4034 - M16		10		40	0	TR Fasteners
ISO 4014 - M16 x 100 x 38-N	Hexagon head bolt ISO 4014 - M16 x 100		10		40	0	Westfield
~~ISO 4762 M6 x 12 - 12N~~	~~Hexagon socket head cap screw ISO 4762 - M6 x 12~~		~~0.25~~		~~1~~	~~0~~	
ISO 4762 M8 x 12 - 12N	Hexagon socket head cap screw ISO 4762 - M8 x 12		5		20	0	Westfield
ISO 4762 M8 x 16 - 16N	Hexagon socket head cap screw ISO 4762 - M8 x 16		5		20	0	Westfield
O'Ring ISO 3601	12 ID x1.5 Section	0	1	2	10	20	Simply Bearings
O'Ring ISO 3601	13 ID x1.5 Section	0	1	2	10	20	Simply Bearings
O'Ring ISO 3601	72 ID x3 Section	0	1	2.88	10	28.8	Simply Bearings
STM-SGR-A-101048	Water Jacket Post Weld Machining	4	1		4	0	Microtec
STM-SGR-A-101048	Water Jacket Weldment	4	1	186	4	744	Dave Massey
STM-SGR-A-101049	Upper Chamber Post Weld Machining	3	1		4	0	Microtec
STM-SGR-A-101049	Upper Chamber Weldment	3	1	186	4	744	Dave Massey
STM-SGR-A-101057	Lower Chamber Post Weld Machining	3	1		4	0	Microtec
STM-SGR-A-101057	Lower Chamber Weldment	3	1	186	4	744	Dave Massey
STM-SGR-A-101058	Merc Badge Assy - Welded	1	1	35	4	140	Dave Massey
STM-SGR-A-101115	Merc Badge Lite	2			2	0	Dave Massey
STM-SGR-P-101013	Lower Flange	4	1	211.5	4	846	Microtec
STM-SGR-P-101014	Middle Flange	4	1	251.5	4	1006	Microtec
~~STM-SGR-P-101015~~	~~Upper Flange~~	~~6~~	~~1~~	~~191.5~~	~~4~~	~~766~~	~~Microtec~~
STM-SGR-P-101016	Lower Tube	3	1	80	4	320	Microtec
STM-SGR-P-101017	Outer Tube	2	1	80	4	320	Microtec
STM-SGR-P-101018	Inner Tube	3	1	80	4	320	Microtec
STM-SGR-P-101019	Lower Gasket	2	1	7.8	4	31.2	Dobson
STM-SGR-P-101020	Middle Gasket	3	1	8.6	4	34.4	Dobson
STM-SGR-P-101021	Upper Gasket	4	1	5.1	4	20.4	Dobson
STM-SGR-P-101022	Outer Cap	3	1	188.2	4	752.8	Microtec
STM-SGR-P-101023	Inner Cap	2	1	370	4	1480	Microtec
STM-SGR-P-101024	Surface Mix Nozzle	3	1	75	4	300	Microtec

Deliverable 1.3 – Steam Generator Costing Report

STM-SGR-P-101025	Glow Plug Sealing Washer	WIP			2	0	
STM-SGR-P-101026	Insulation Cover	2	1	108.12	4	432.48	RNC
STM-SGR-P-101029	Insulation End Plate	2	1	11.21	4	44.84	RNC
STM-SGR-P-101030	Superheater Duct, Inner Chamber	4	1	2570.05	1	2570.05	Xometry
STM-SGR-P-101031	Superheater Casing, Inner Chamber	2	1	102.8	4	411.2	Microtec
~~STM-SGR-P-101032~~	~~Bullet Insert~~	~~2~~	~~1~~	~~233.5~~	~~4~~	~~934~~	~~Microtec~~
STM-SGR-P-101034	Handle	2	1			0	
STM-SGR-P-101061	Outlet Cap Concentric	3	1	250	4	1000	Microtec
STM-SGR-P-101086	Bullet Gasket	1	1		10	0	
STM-SGR-P-10113	Merc Hub				2	0	
STM-SGR-P-10113	Merc Hub - Test Piece from bham print				1	0	Microtec
STM-SGR-P-10114	Merc Lite - Flange				2	0	Microtec
Washer ISO 7089 - 8	Washer ISO 7089 - 8		10		40	0	Westfield
Washer ISO 7092 - 16	Washer ISO 7092 - 16		20		80	0	Westfield
Washer ISO 7092 - 8	Washer ISO 7092 - 8		10		40	0	Westfield
	1/4" BSPP Female - 6mm Tube fitting				4	0	Swaglok
	1/4" BSPT Male - 6mm Tube fitting				4	0	Swaglok
	FITTINGS FOR DYNO CELL - AUDIT CELL AND PRODUCE BOM					0	
	FITTINGS FOR TEST CELL - AUDIT CELL AND PRODUCE BOM - New Hoses					0	
	Long Thermo couple ?				5	0	
	Parallel Pin (Dowel Pin) 6 x 18mm in A1 Stainless Steel		10		40	0	Westfield
	Pressure Transducer				10	0	
	Pressure Transducer Pig Tail				4	0	Steamology
	Shorter Thermo couple ?				5	0	
	Thermocouple glands 1/8"				12	0	
			0			0	
						0	

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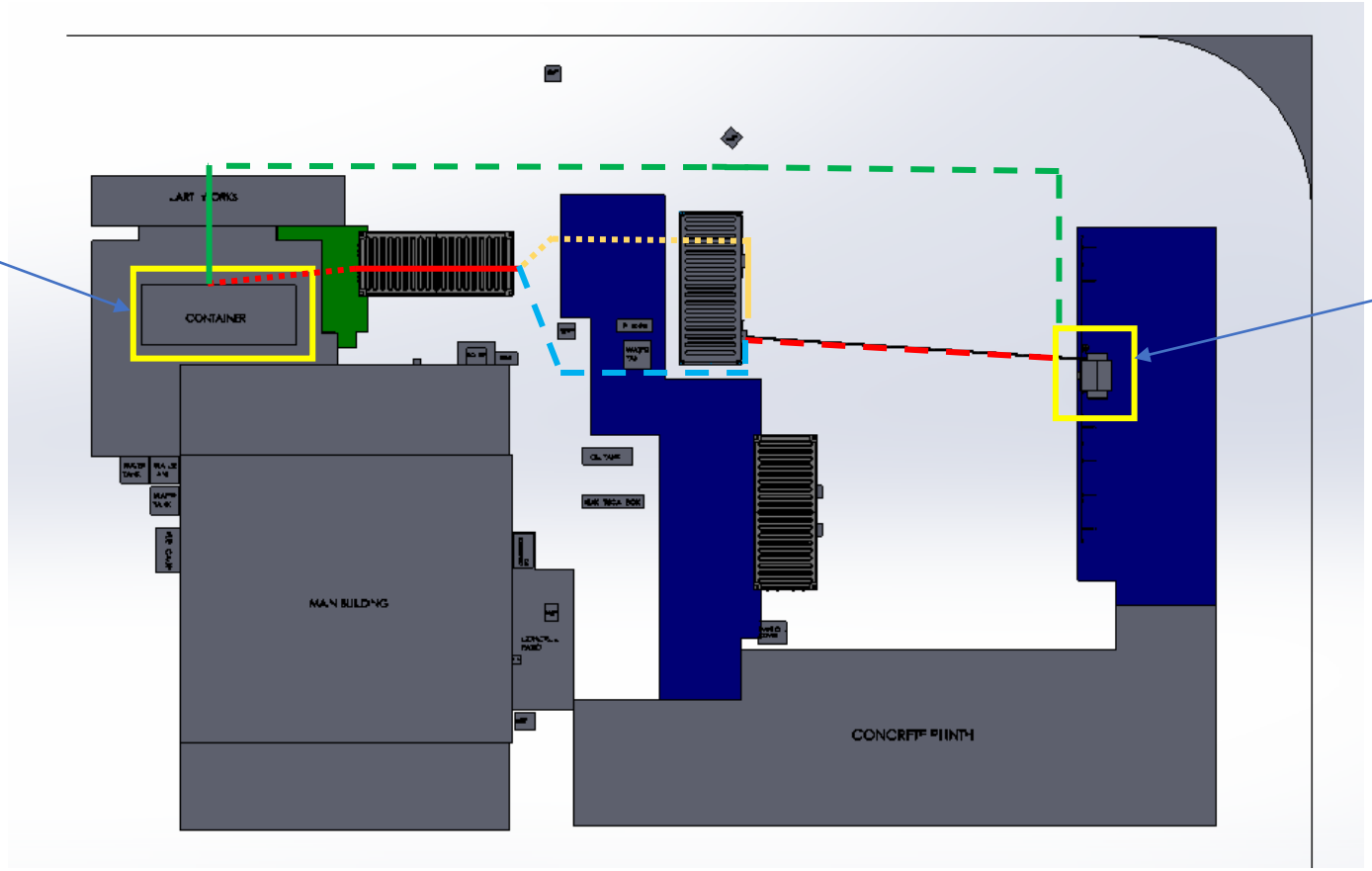
Deliverable 1.4 – Test Cell Fuel and Steam Exhaust

Initial Deliverable 1.02 – Gas and Water System Design Review

Initial Gas farm and gas fuel supply review and upgrade planning

Container Requiring Connection



Hydrogen and Oxygen Supply

- Common to all Routes
- Route 1
- Route 2
- Route 3

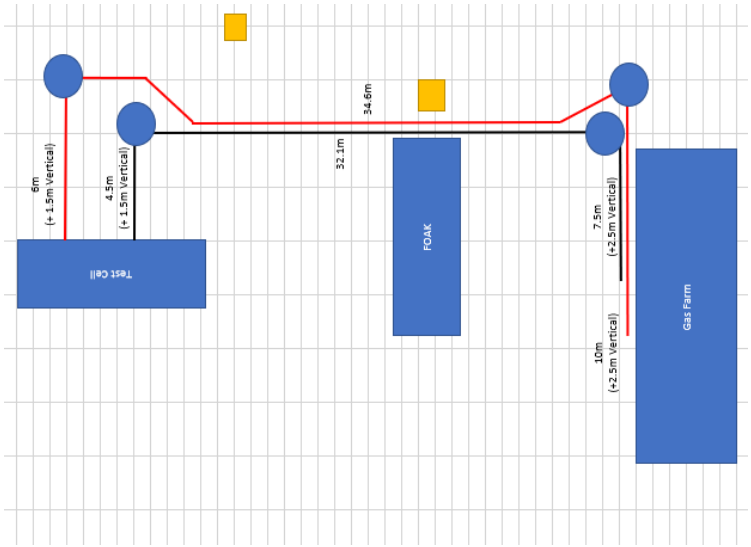
- Underground
- Ground Level
- Elevated

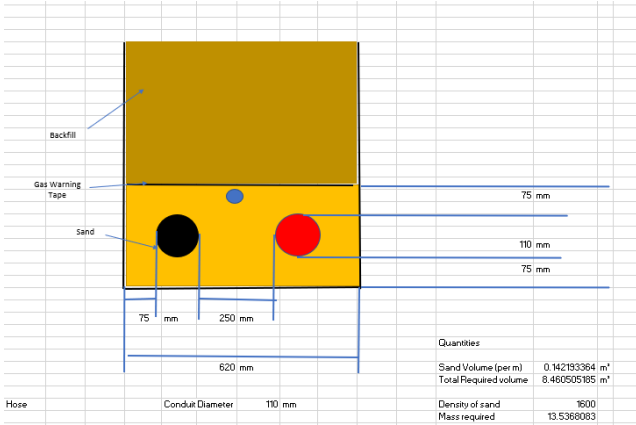
Deliverable 1.4 – Test Cell Fuel and Steam Exhaust

Test Cell Fuel

- Test Cell currently runs from its own supply of Oxygen and Hydrogen bottles.
- Have since installed a gas farm.
- Connection installed to the gas farm.

- Opportunity to learn about the best process to install connections on industrial sites.

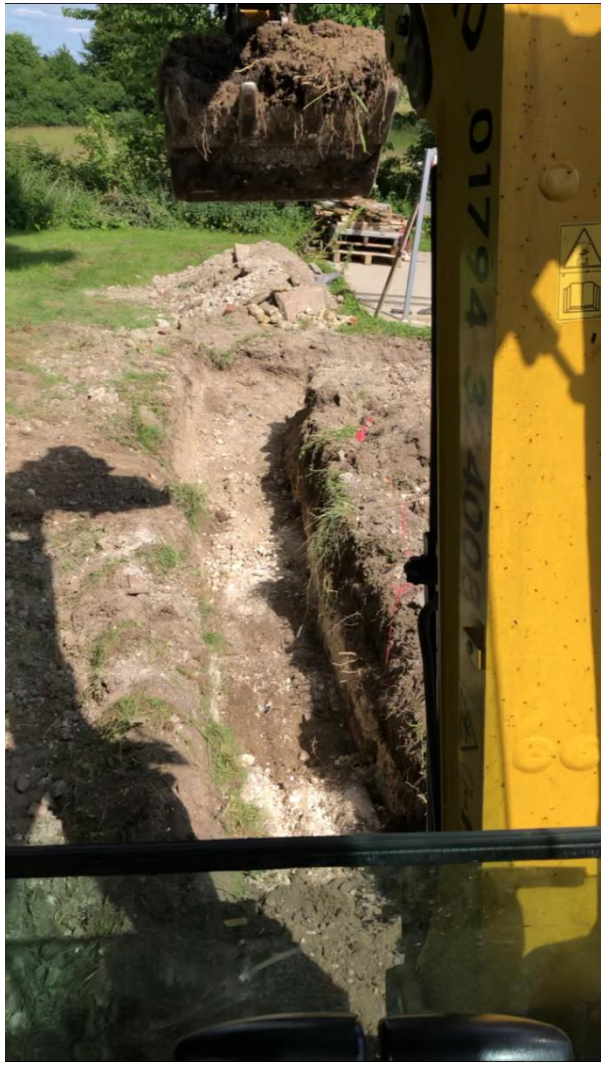




Deliverable 1.4 – Test Cell Fuel and Steam Exhaust

Test Cell Fuel

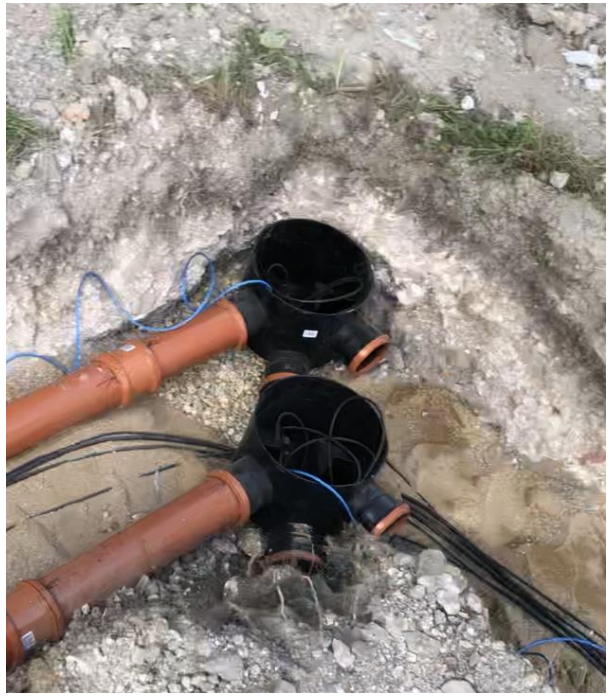
- Hired Digger and Dumper.
- Flattened the yard prior to the trench excavation.
- Trenches excavated using the Digger and hand tools.



Deliverable 1.4 – Test Cell Fuel and Steam Exhaust

Test Cell Fuel

- Trench backfilled with layer of sand.
- Container pipe then laid and buried in sand.
- Backfilled on top of sand and ground flatted out.

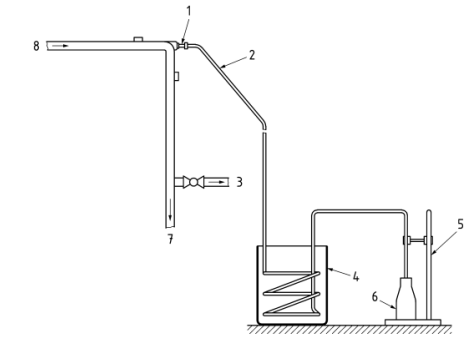


Deliverable 1.4 – Test Cell Fuel and Steam Exhaust

Steam Exhaust

- Industrial standards for steam applications.
- EN285 is the standard for Industrial Sterile Steam.
- EN285 contains 3 tests for:
  - Non-Condensable Gases.
  - Steam Quality.
  - Superheat.
  - Steam Condensate Contaminants.

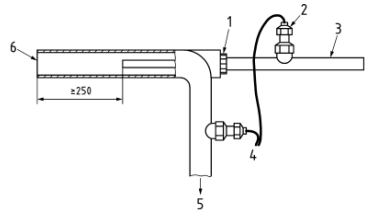
- These tests demonstrate the Steam produced is suitable for industrial steam applications.



Key

1	pitot tube	5	burette stand
2	polypropylene tube, coiled as shown	6	250 ml polypropylene bottle
3	to sterilizer	7	to trap set
4	8 000 ml container	8	from steam service

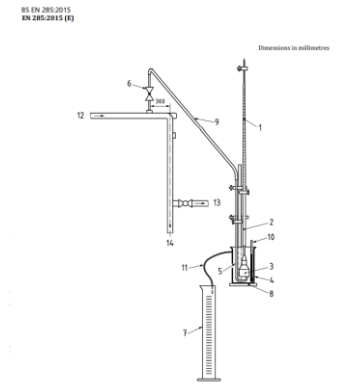
Figure 12 — Apparatus for sampling steam condensate



Key

1	pitot tube	4	to temperature measuring instrument
2	temperature probes fitting	5	to sterilizer
3	expansion tube	6	from steam service

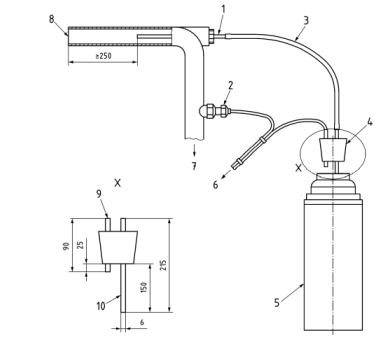
Figure 11 — Diagrammatic representation of the apparatus for the measurement of superheat



Key

1	50 ml burette	6	needle valve	12	from steam service
2,9	rubber tubing	7	250 ml measuring cylinder	13	to sterilizer
3	funnel with parallel sides	8	burette stand	14	to trap set
4	2 000 ml container	10	temperature measurement system		
5	steam sampling pipe	11	overflow pipe		

Figure 7 — Diagrammatic representation of the apparatus for the measurement of non-condensable gases



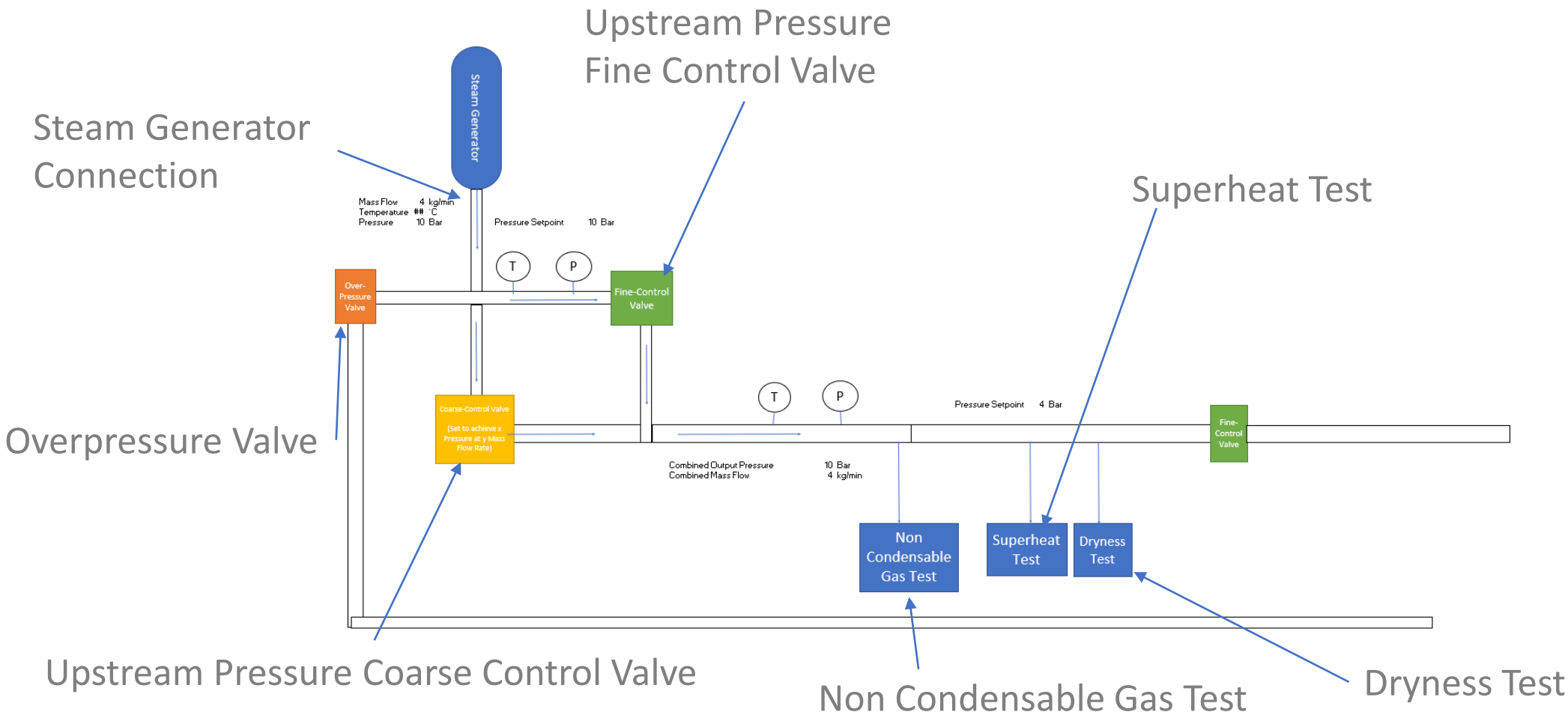
Key

1	pitot tube	6	to temperature measuring instrument
2	temperature probes entry gland	7	to sterilizer
3	rubber tube	8	from steam service
4	rubber stopper assembly	9	pipe for temperature probes and vent
5	one-litre Dewar flask	10	sample pipe

Figure 9 — Diagrammatic representation of the apparatus for the measurement of steam dryness value

Deliverable 1.4 – Test Cell Fuel and Steam Exhaust

Steam Exhaust - Schematic



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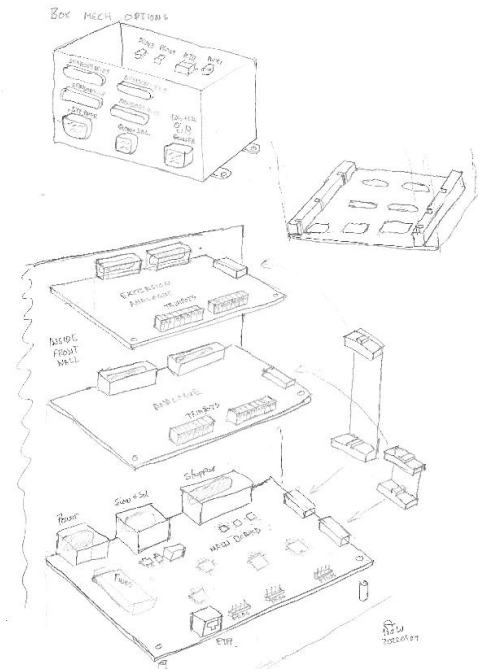
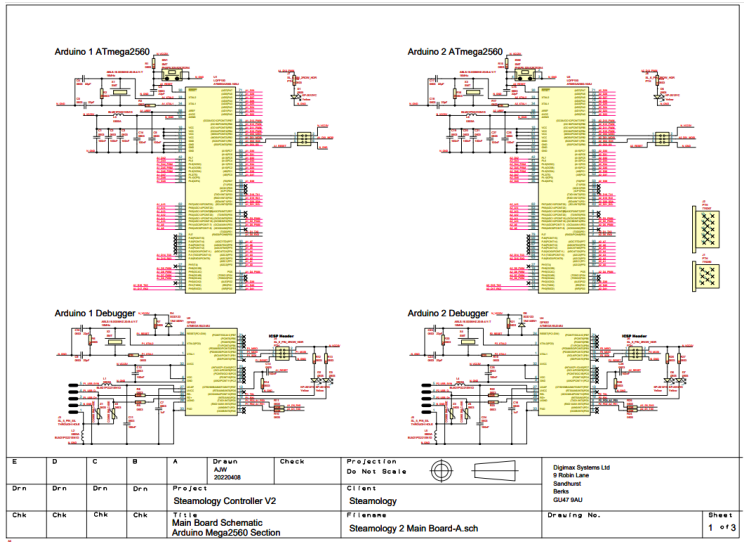
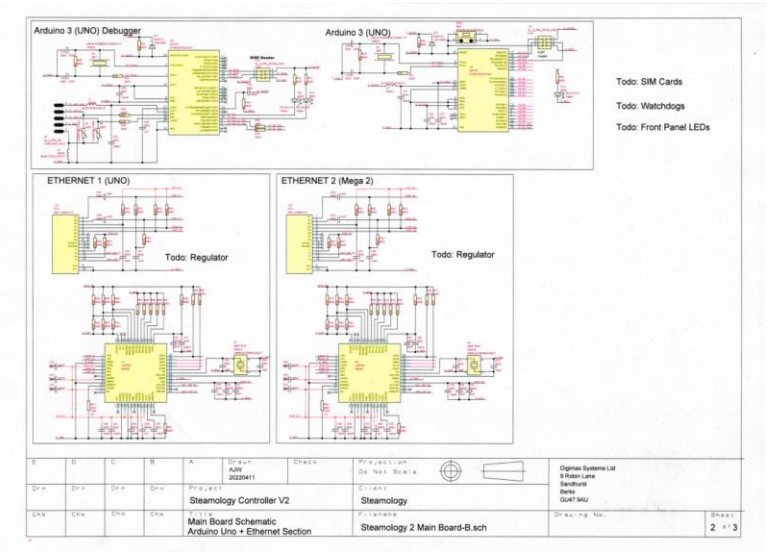
Deliverable 1.5 – Controller Hardware

Deliverable 1.5 – Control Hardware

- The board layouts for the Arduino control elements are based on the open source layouts available from Arduino.cc.
- In order to obtain the most compact layout it was decided with Revision 3a to separate the controller function between multiply boards housed in the same enclosure.
- The micro controllers and comms would be on one board and the inputs on a second board.



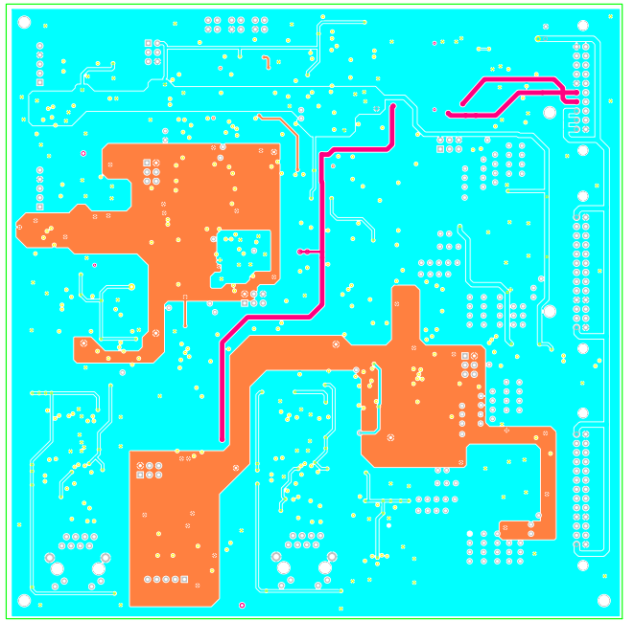


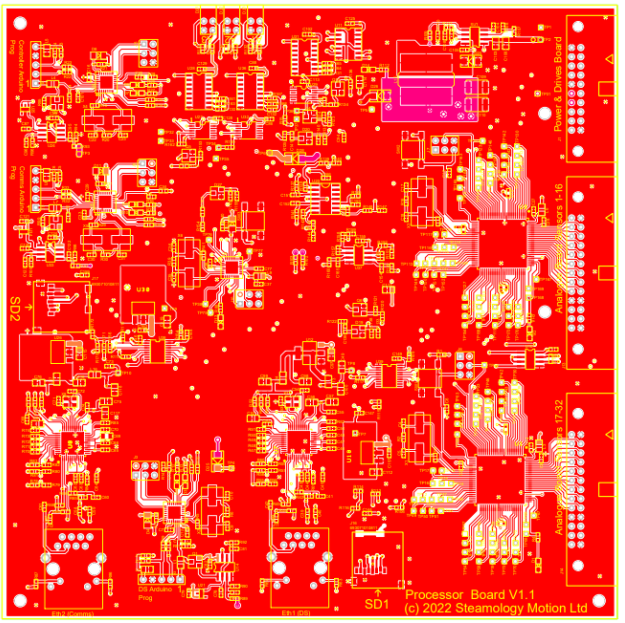


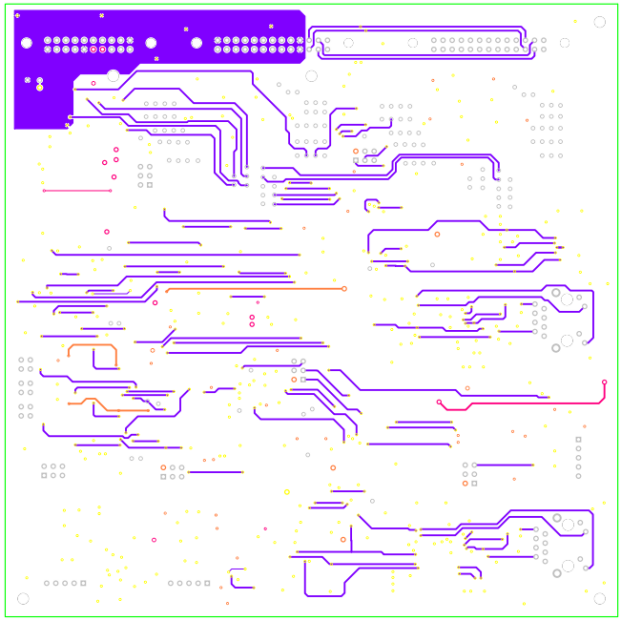
Deliverable 1.5 – Control Hardware

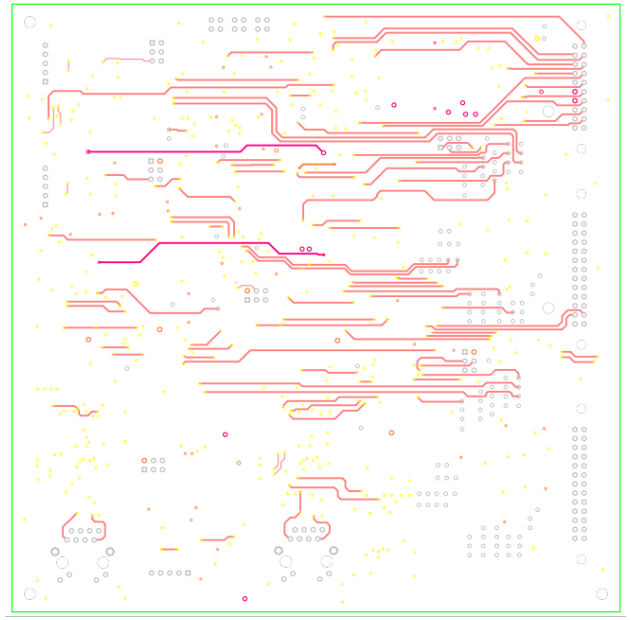
- PCB architecture designed before being sent out for print.

- Includes all elements of the boards:
  - Surface mounted components.
  - Power inputs and delivery.
  - Data storage components.
  - Communications.



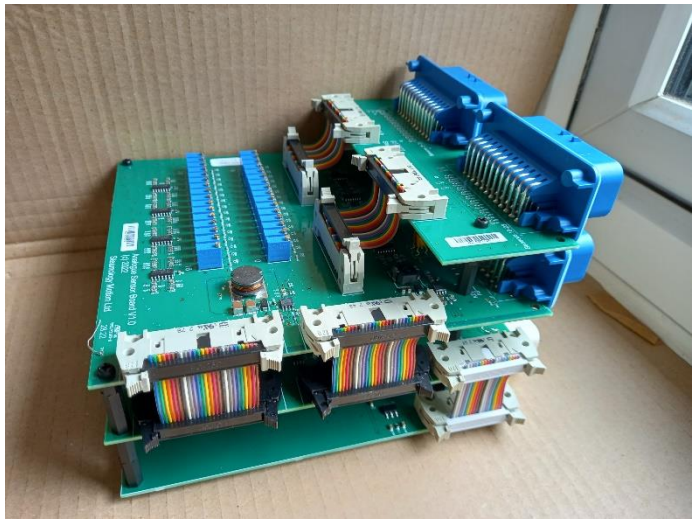


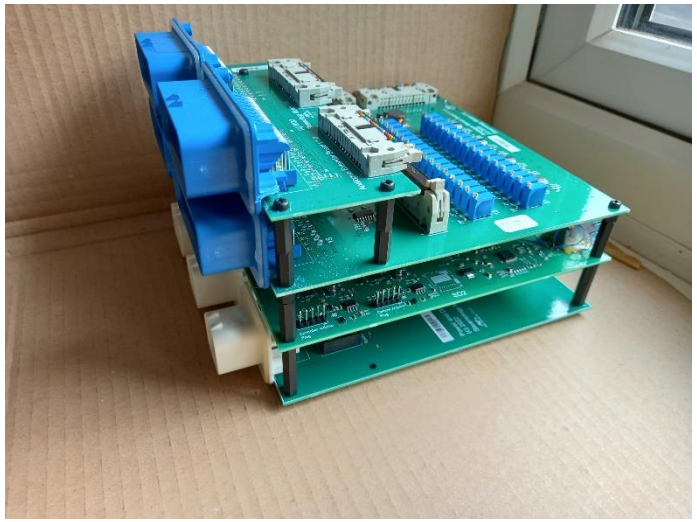


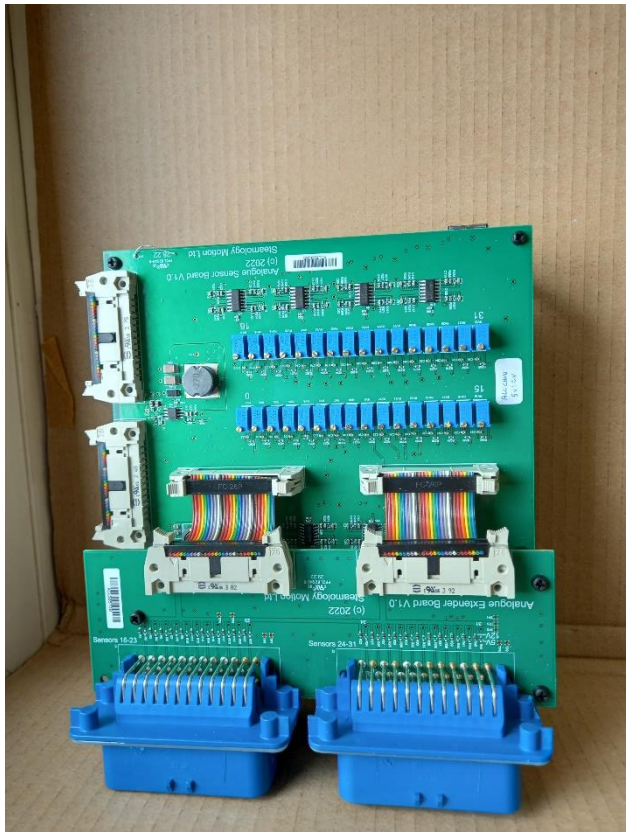


Deliverable 1.5 – Control Hardware

- Control Hardware has been assembled by manufacturer.
- Testing is sufficiently advanced to allow the manufacture of initial batch of boards.
- Testing with Steam Generator hardware has been conducted.
- These controllers improve the suitability and reliability of the Steam Generator system for use in an industrial application.







Work Package 2

WP2: Compliance roadmap defining the certification requirements, HAZID, risk assessments for zero emission steam generators within industrial steam site deployment in Phase2.

Deliverable	Milestone	Title	Description	Format
2.1	1	Outline System Boundary Scheme	Steam system scheme defining system boundaries for compliance roadmap	Report of schematic layout defining steam system boundaries informed by compliance roadmap
2.2	2	Certification Report	Report capturing compliance roadmap and certification plan for steam system	Report capturing compliance roadmap and certification plan for steam system
2.3	1	Risk Register	Risk register review and update	Updated risk register spreadsheet
2.4	2	Risk Register	Risk register review and update	Updated risk register spreadsheet

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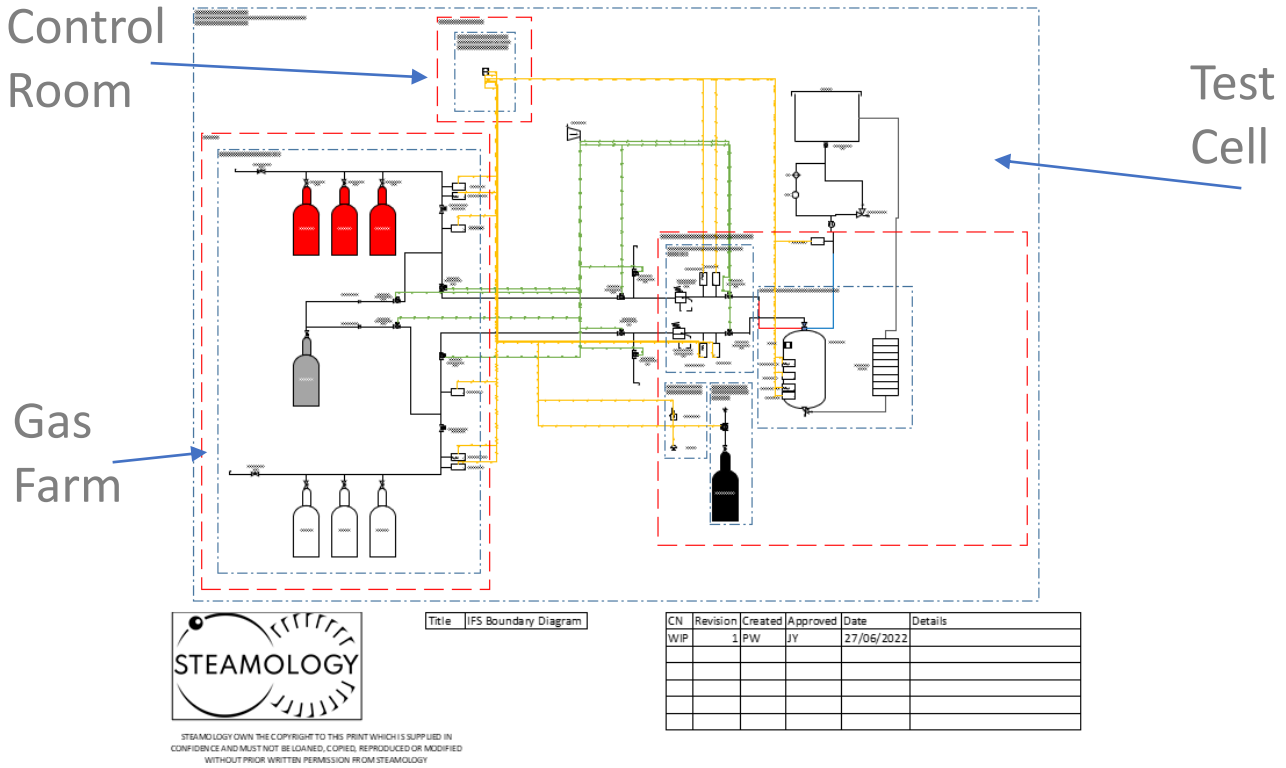
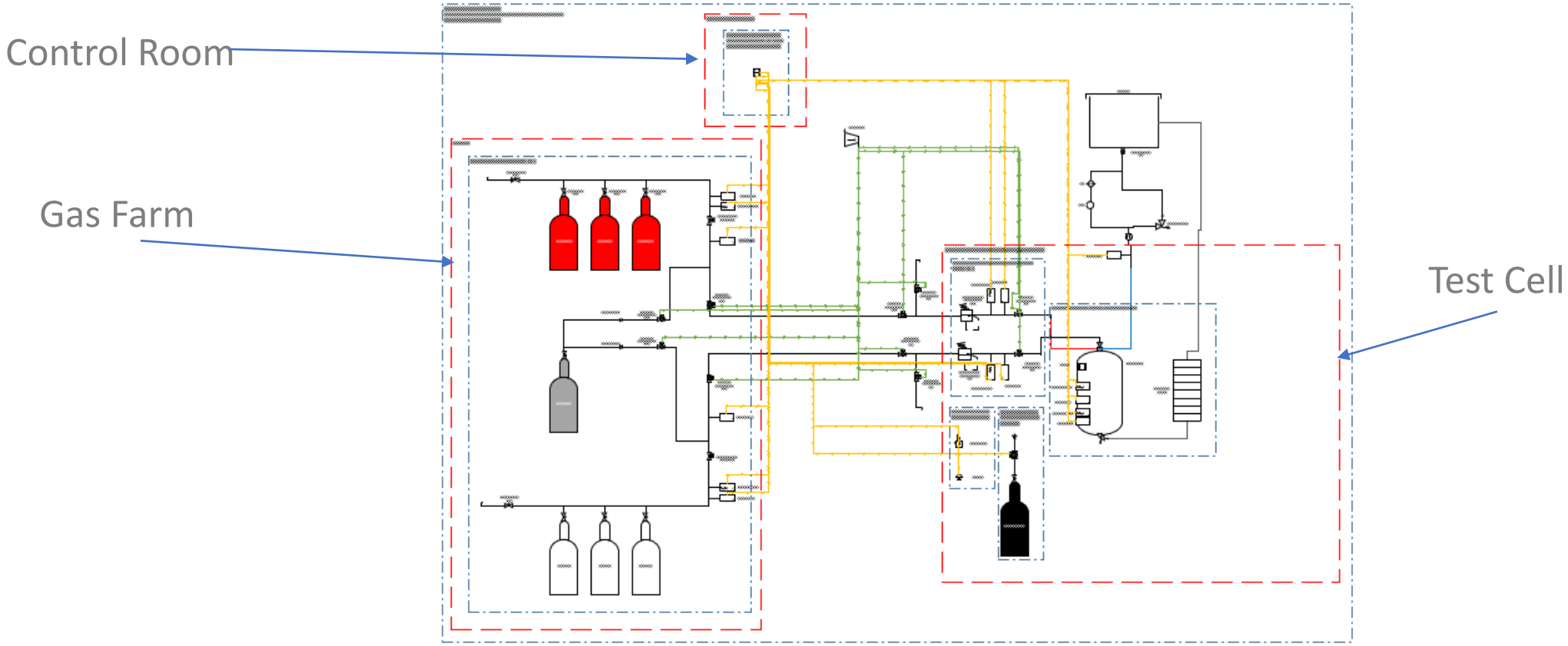
Deliverable 2.1 – Outline System Boundary Scheme

Deliverable 2.1 – Outline System Boundary Scheme

- System has many different elements, each of which must adhere to different certification requirements.
- System boundary scheme shows the breakdown of the system and where different certifications and regulations apply.
- Provides a scheme which we can continue to populate with certification information as more information is gained.



Deliverable 2.1 – Outline System Boundary Scheme



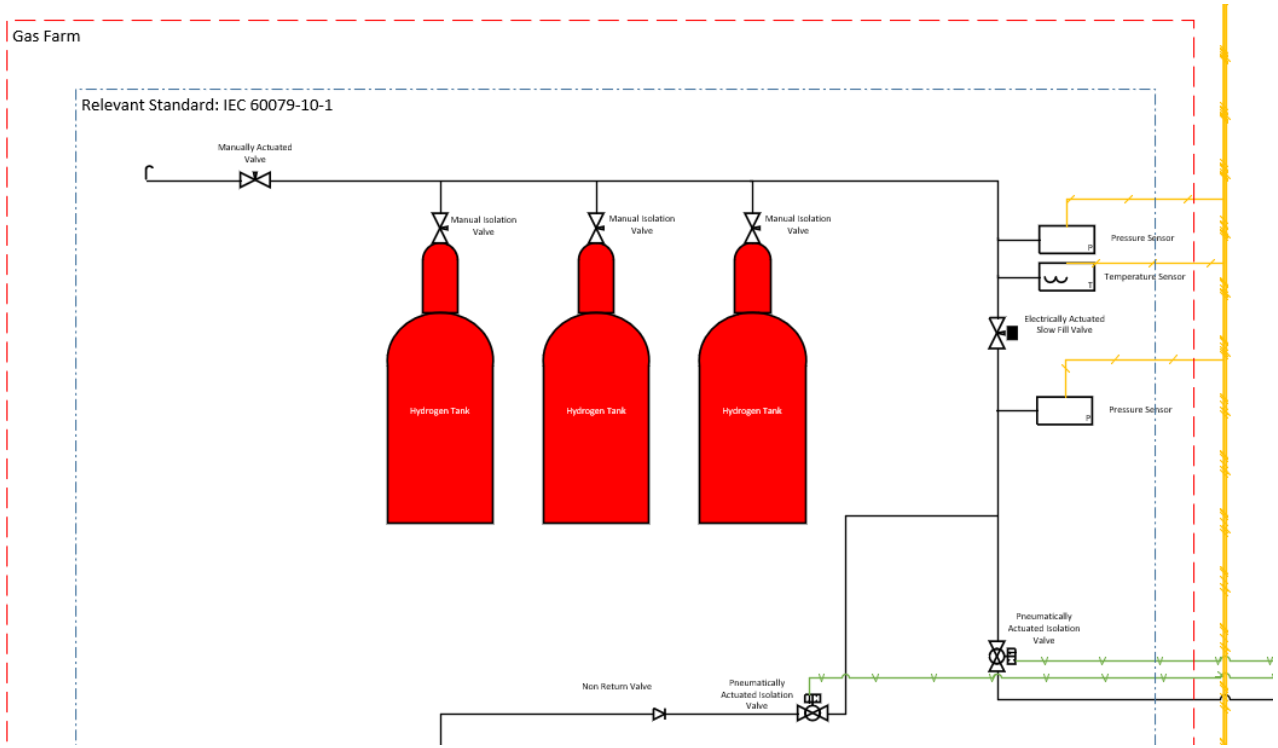
Title	IFS Boundary Diagram

CN	Revision	Created	Approved	Date	Details
WIP	1	PW	JY	27/06/2022	

Deliverable 2.1 – Outline System Boundary Scheme

Gas Farm:

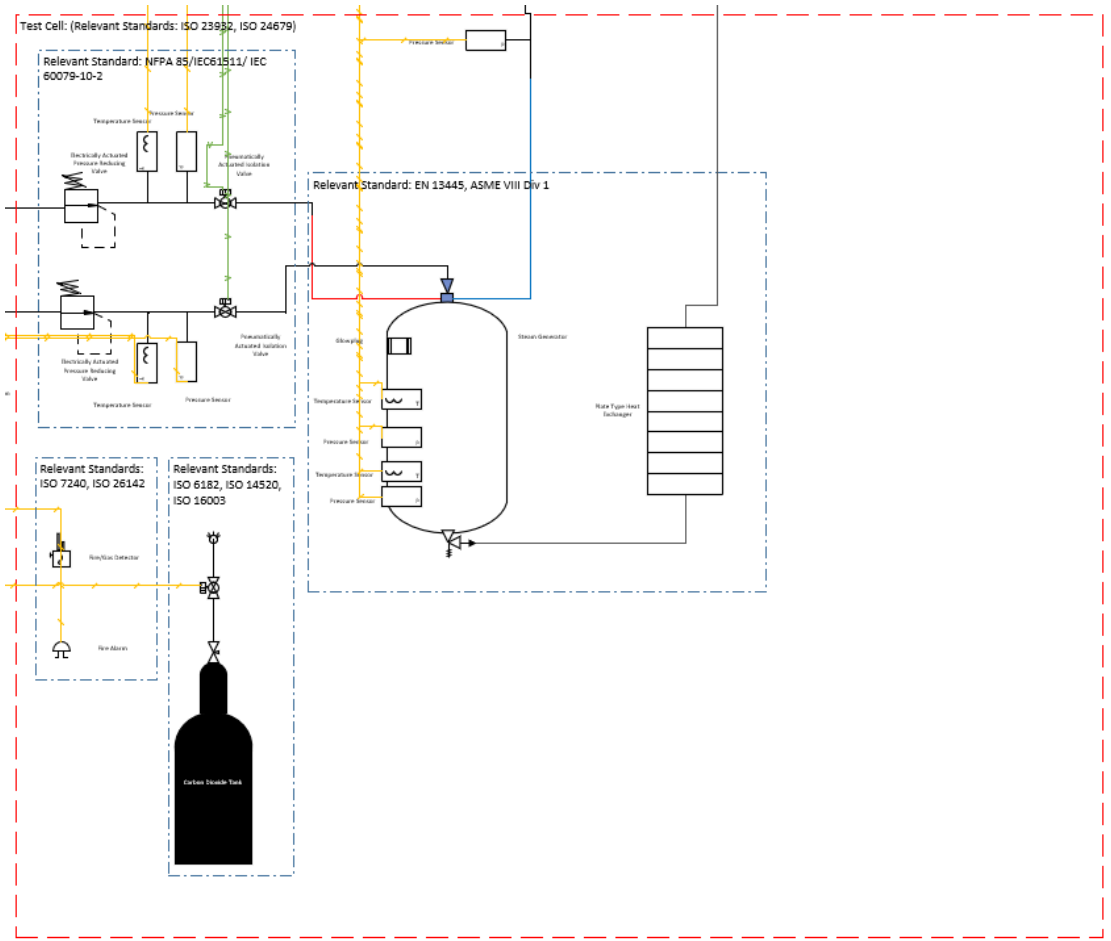
- IEC 60079 - Explosive Atmospheres
- IEC/ISO 80079 – Non electrical equipment for explosive atmospheres
- IEC 60364 – Low Voltage Electrical Installations
- ISO 26142 – Hydrogen Detection Apparatus
- EN 50104 – Electrical Equipment for the detection of Oxygen



Deliverable 2.1 – Outline System Boundary Scheme

Test Cell:

- IEC 60079 - Explosive Atmospheres
- IEC/ISO 80079 – Non electrical equipment for explosive atmospheres
- IEC 60364 – Low Voltage Electrical Installations
- ISO 26142 – Hydrogen Detection Apparatus
- EN 50104 – Electrical Equipment for the detection of Oxygen



Steam Generator:

- EN 13445 – Unfired Pressure Vessels
- ASME VIII Div 1. – Boiler and Pressure Vessel Code

Fire System:

- ISO 6182 – Fire Protection – Automatic Sprinkler Systems
- ISO 16003 – Components for fire extinguishing systems using gas

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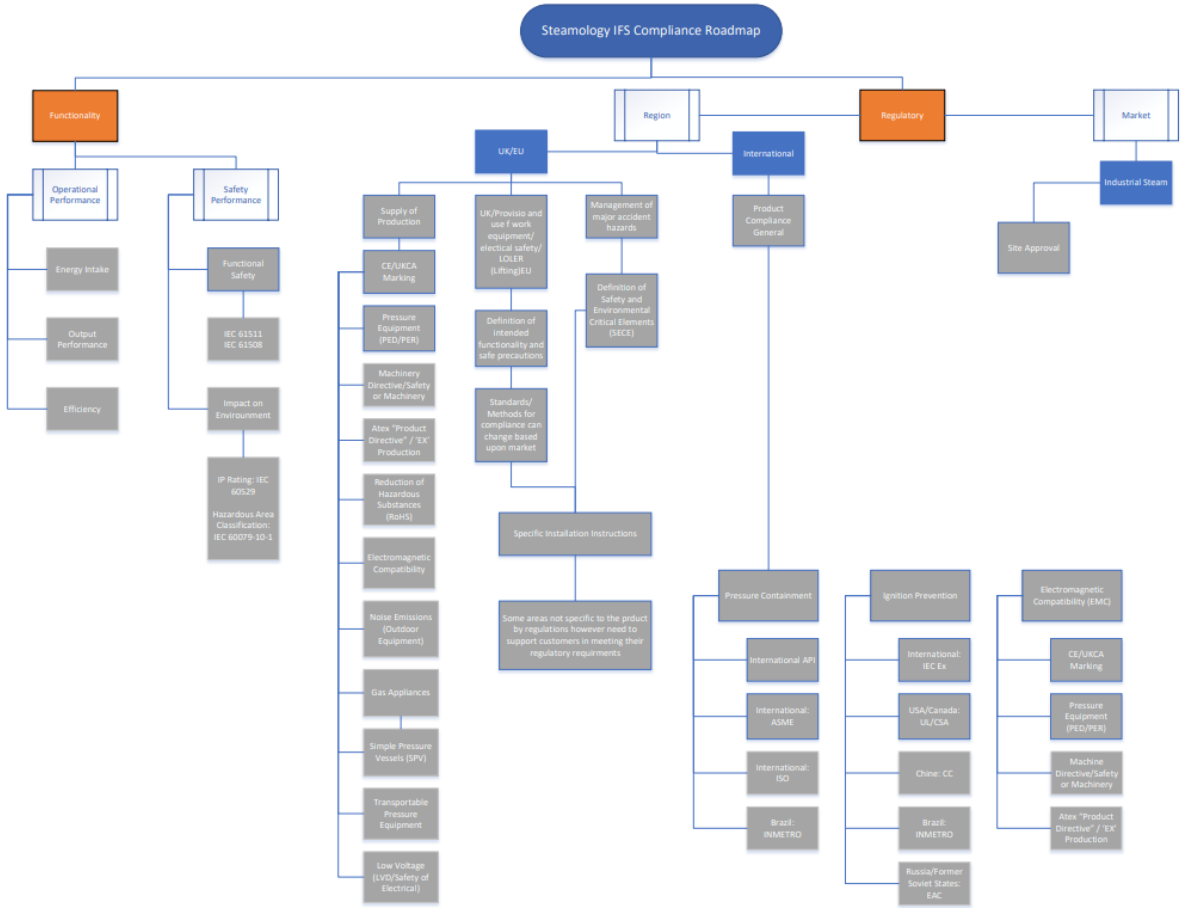
Deliverable 2.2 – Certification Report

Deliverable 2.2 – Certification Report

Certification for the steam system is composed of a few different elements:

1. Steam Generator specific certification.
2. Steam Generator certification within the context of an industrial steam application.
3. Supporting hardware certification within the context of an industrial steam application.
4. Whole system certification.



Deliverable 2.2 – Certification Report

1 and 2:

1. Steam Generator specific certification.

2. Steam Generator certification within the context of an industrial steam application.

Have engaged with the DNV and have received final report towards Mk. 3 Steam Generator Certification roadmap, both generic and within the context of an industrial steam application.

DNV

1 PURPOSE

The purpose of this report if to provide guidance to the customer on what potential routes to compliance are available and what steps to undertake when managing hazards from pressure containment and ignition.

This report sets out the steps for allowing the customer to determine what method of demonstration they wish to follow and what expected information should be provided when applying for certification, should that option be selected by the customer.

2 PESSURE EQUIPMENT (SAFETY) REGULATIONS ASSESSMENT STEPS

Steamology may complete below simplified cookbook steps to demonstrate that the manufacturer obligations, which are stated in part 2 of the Pressure Equipment (Safety) Regulations 2016, are satisfied.

2.1 Step 1

The manufacturer shall assess if the PER 2016 regulation applies to the pressure equipment intended to be manufacturer by them and be placed in the UK market. The exclusion to the regulations are stated in schedule 1 of PER 2016. DNV understands that the regulations applies to Steamology pressure equipment.

2.2 Step 2

Assess the pressure equipment category as per schedule 1B of PER 2016. The basis for categorizations are:

- The pressure equipment maximum allowable pressure PS; It is assumed to be 50[barg]
- The pressure equipment volume V or nominal size DN; Based on Steamology drawing STM-SGR-A-101048 Rev 04, it is assumed to be ~4.73[L]
- Fluids group. It is assumed the pressure equipment is heated or fired pressure equipment with risk of overheating intended for steam generation or superheated water at temperatures higher than 110[°C].

Based on above, Table 5 of schedule 1B of PER applies for categorization. This table is shown Figure 2-1. Therefore, the category for the pressure equipment *is IV*.

DNV

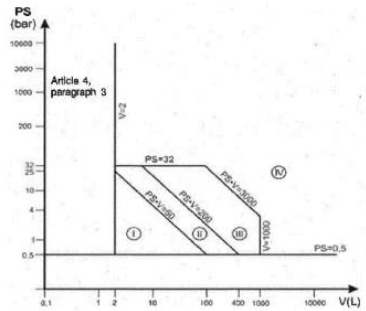


Figure 2-1: Table 5 for categorization of fired or heated pressure vessel

2.3 Step 3

At the choice of manufacturer one of the following modules shall be selected for conformity assessment of category IV pressure equipment:

- Module B (production type) + Module D
- Module B (production type) + Module F
- Module G
- Module H1

Modules B(production type)+D or H1 options are suitable for series production while Modules G or B(production type)+F options are suitable for unit production. Conformity assessment procedures for each module are as per schedule 1A of PER 2016. Simplified description of above modules are provided below to guide Steamology for selection the suitable module.

Module B(production type): is type approval design examination by the Approved Body. In addition to assessment of relevant design document, the manufacturer shall manufacture a prototype for type examination testing.

Module D: is based on quality assurance in production(manufacturing) process. The manufacturer's production process is subjected to audit by an Approved Body.

Module F: is based on conformity to type based on pressure equipment verification. An Approved Body chosen by the manufacturer will carry out the appropriate examinations and tests in order to check the conformity of the pressure equipment, or assembly, with the approved type described in the type examination certificate (Module B) and with the appropriate requirements of these Regulations.

Module G: is conformity based on unit verification. An Approved Body chosen by the manufacturer will carry out a design examination and complete the appropriate examinations and tests in order to check the conformity of the pressure equipment, or assembly, with the verified design and with the appropriate requirements of these Regulations.

Deliverable 2.2 – Certification Report

2, 3 and 4:

2. Steam Generator certification within the context of an industrial steam application.

3. Supporting hardware certification within the context of an industrial steam application.

4. Whole system certification.

Have engaged with the DNV who have conducted a compliance support technical requirements analysis. This lists all relevant standards the steam system needs to comply with, inclusive of an industrial steam application.

DNV

3 IGNTION PREVENTION

3.1 Hazard Extent

A study to define the hazardous environment in which the steam generator will eb located needs to be conducted to support the adequate selection of equipment to be utilised. Being able to define the extend of the hazard during normal operation and credible failure scenarios is an expectation under DSEAR (Dangerous Substances and Explosive atmosphere Regulations)

3.1.1 Area Classification

Area classification looks to define the extends of the hazard during normal operational conditions. This considers the types of material, pressures, volumes, ignition energy, ignition temperatures and release points/types to define the extents of the hazardous zones. These are typically grouped based around:

Continuous release: Flammable atmosphere is likely to occur frequently or for long periods. Examples of these would be open surfaces on tanks or vapours within enclosed pipework or vessels

Primary release: Flammable atmosphere is likely to occur periodically or occasionally: Examples would be vent points or pressure relief valves

Secondary release: Flammable atmosphere is not normally expected to occur and will only occur for short periods, infrequently. Examples of these would be leakage from connection points.

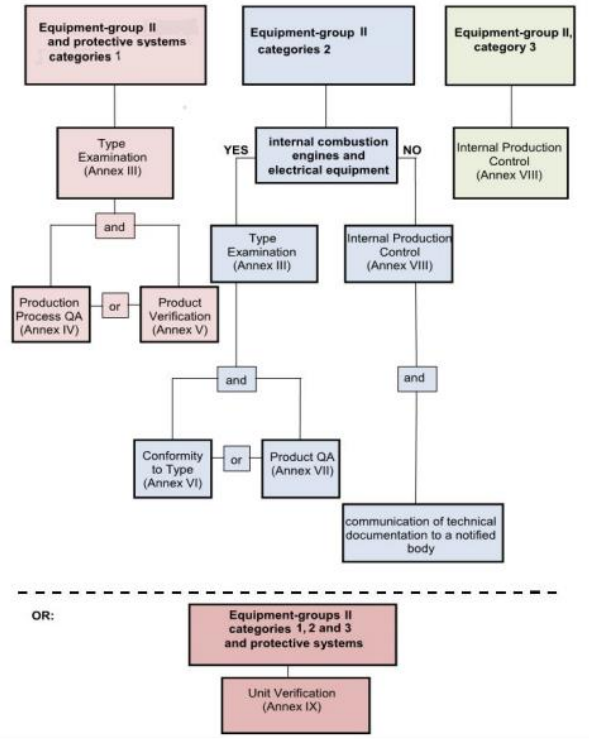
The most commonly used stanrd for evaluation of the extent of hazardous zones from flammable gasses is IEC 60079-10-1. Other methods such as EI IP 15 are used in the UK however the IEC standard is globally recognised. Alternative methods utilising CSA/NEMA standard for are classification for North America also exist. These utilise a Class/Division method rather than zones to define the hazard within the area. There is however a direct correlation between zones from the IEC standards and the North America requirements and demonstration using the IEC method will typically be acceptable. Within Annex K of IEC 60079-10-1 there are details which show the correlation of national requirement.

Annex F of IEC 60079-10-1 provided flow charts for determining the type of hazardous zone that will occur. These relate to the assessment of release source detailed above. It is suggested that starting by reviewing the layout of equipment ot identify the release grades points and grades would be the logical starting point.

Once the release points are known then an analysis, as detailed in the IEC 60079-10-1standrd, can be documented to determine the extent of the hazardous zones around each release point. It is important to take into account the impacts from ventilation either where forced air ventilation is provided or where there is limited ventilation as these factors can increase or decrease the zone.

When utilising a product which will contain flammable material it is important to consider the release sources may be caused by the product itself and not just the external environment the item is placed into. Although for the steam generator itself, the majority of hazards will come from external sources, as a device with flammable gas inside and with external connections, the hazard generated by the generator along will need to be considered as well as the hazard from any surrounding equipment.

The internals of the steam generator would eb considered in the same way as a combustion chamber. These are not typically considered to be hazardous providing it can be confirmed/demonstrate that there are no gasses in the chamber which are unburnt. Start up and shutdown conditions need to reflect this confirmation otherwise it would require the internals of the generator to be considered hazardous. Although the chamber would be considered for handling the explosion during normal combustion, it should be proven that if unburnt gasses can occur hat these are either limited to within the acceptable/demonstratable containment if ignited or that the maximum achievable gas concentration would not lead to a failure and subsequent explosion of the combustion chamber.



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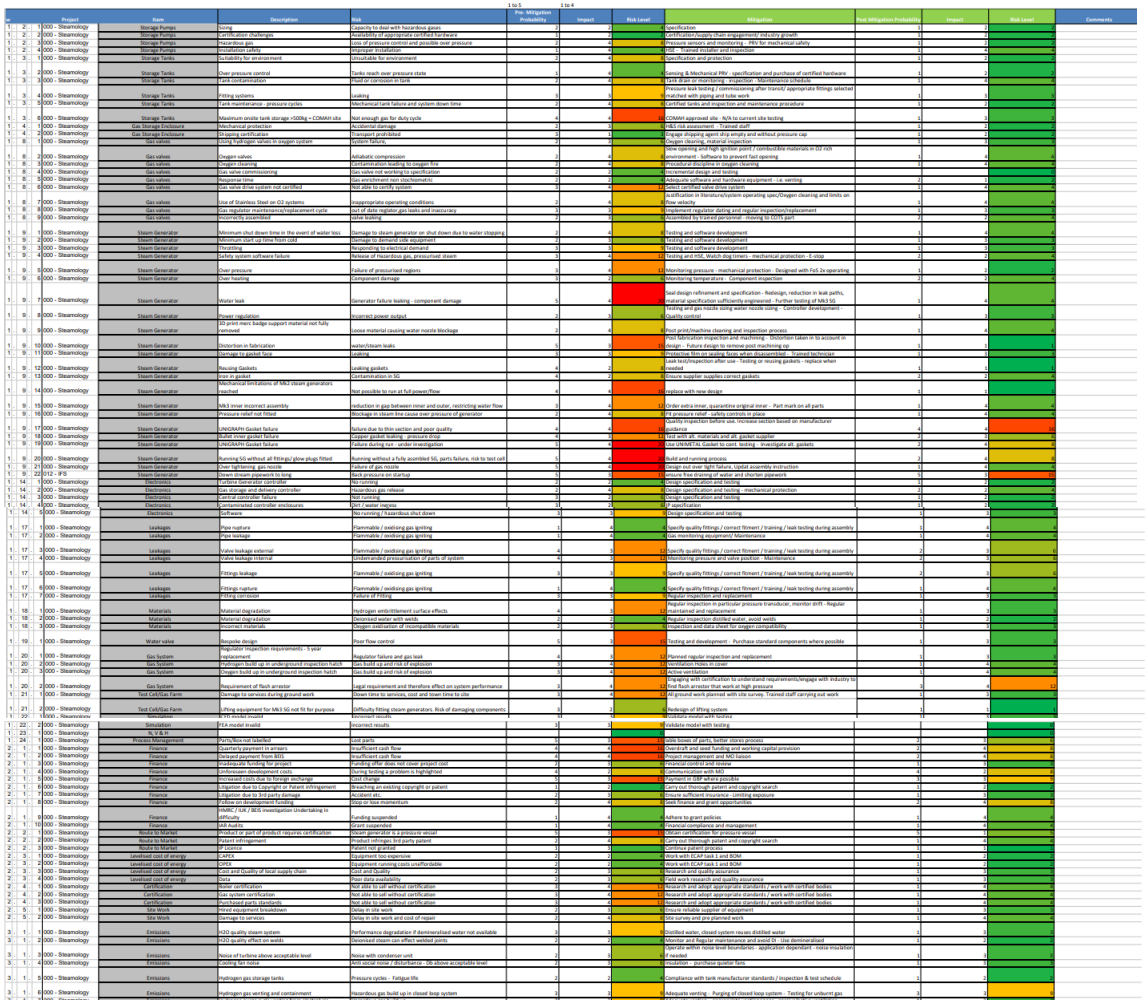
Deliverable 2.4 – Risk Register Update

Deliverable 2.4 – Risk Register Update

- The risk register was updated regularly throughout the project.
- Individuals from all departments and diverse backgrounds were included to ensure a wide scope and variety of risks were covered.
- New risks were identified and added whilst existing risks were mitigated as much as was reasonably possible.

- The regular updating of the risk register meant that all technical and project risks were captured, recorded and mitigated where possible.
- The project suffered no major issues and achieved all deliverables on time.



#	Project	Item	Description	Risk	Pre- Mitigation Probability (1 to 5)	Impact (1 to 4)	Risk Level	Mitigation	Post Mitigation Probability	Impact	Risk Level	Comments
1 2 1	1000 - Steamology	Storage Pumps	Sizing	Capacity to deal with hazardous gases	2	3	6	Specification	1	2	2	
1 2 2	2000 - Steamology	Storage Pumps	Certification challenges	Availability of appropriate certified hardware	3	2	6	Certification/supply chain engagement/ industry growth	1	2	2	
1 2 3	3000 - Steamology	Storage Pumps	Hazardous gas	Loss of pressure control and possible over pressure	2	4	8	Pressure sensors and monitoring – PRV for mechanical safety	1	2	2	
1 2 4	4000 - Steamology	Storage Pumps	Installation safety	Improper installation	2	3	6	PSSR – Trained installer and inspection	1	1	1	
1 3 1	1000 - Steamology	Storage Tanks	Suitability for environment	Unsuitable for environment	2	4	8	Specification and protection	1	2	2	
1 3 2	2000 - Steamology	Storage Tanks	Over pressure control	Tanks reach over pressure state	1	4	4	Sensing & Mechanical PRV - specification and purchase of certified hardware	1	2	2	
1 3 3	3000 - Steamology	Storage Tanks	Tank contamination	Fluid or corrosion in tank	3	4	12	Tank type or maintaining - inspection - Mechanical checks	1	4	4	
1 3 4	4000 - Steamology	Storage Tanks	Fitting systems	Leaking	3	3	9	Pressure leak testing / commissioning after transit/ appropriate fittings selected matched with piping and tube work	1	3	3	
1 3 5	5000 - Steamology	Storage Tanks	Tank maintenance - pressure cycles	Mechanical tank failure and system down time	2	4	8	MOC - Certified tanks and inspection and maintenance procedure	1	4	4	
1 3 6	6000 - Steamology	Storage Tanks	Maximum onsite tank storage >500kg = COMAH site	Not enough gas for duty cycle	4	4	16	COMAH approved site - N/A to current site testing	1	1	1	
1 4 1	1000 - Steamology	Gas Storage Enclosure	Mechanical protection	Accidental damage	2	3	6	H&S risk assessment - Trained staff	1	2	2	
1 4 2	2000 - Steamology	Gas Storage Enclosure	Dropping certificate	Transport prohibited	1	3	3	Engage shipping agent ship empty and without pressure cap	1	1	1	
1 5 1	1000 - Steamology	Gas valves	Using Hydrogen valves in oxygen system	System failure,	3	3	9	Oxygen cleaning, material inspection	1	3	3	
1 6 2	2000 - Steamology	Gas valves	Oxygen valves	Adiabatic compression	2	4	8	Slow opening and high ignition point / combustible materials in O2 rich environment - Software to prevent fast opening	1	4	4	
1 6 3	3000 - Steamology	Gas valves	Oxygen cleaning	Contamination leading to oxygen fire	2	4	8	Procedural discipline in oxygen cleaning	1	4	4	
1 6 4	4000 - Steamology	Gas valves	Gas valve commissioning	Gas valve not working to specification	3	2	6	Incremental design and testing	1	2	2	
1 6 5	5000 - Steamology	Gas valves	Response time	Gas enrichment non stoichiometric	2	3	6	Adequate software and hardware equipment - i.e. venting	2	3	6	
1 6 6	6000 - Steamology	Gas valves	Gas valve drive system not certified	Not able to certify system	3	4	12	Select certified valve drive system	1	4	4	
1 8 7	7000 - Steamology	Gas valves	Use of Stainless Steel on O2 systems	Inappropriate operating conditions	2	4	8	Justification in literature/system operating spec/Oxygen cleaning and limits on flow velocity	1	4	4	
1 8 8	8000 - Steamology	Gas valves	Gas regulator maintenance/replacement cycle	Out of date regulator gas leaks and inaccuracy	3	3	9	Implement regulator dating and regular inspection/replacement	1	3	3	
1 8 9	9000 - Steamology	Gas valves	Incorrectly assembled	Valve leaking	3	3	9	Assembled by trained personnel - moving to 100% part	2	3	6	
1 9 1	1000 - Steamology	Steam Generator	Minimum shut down time in the event of water loss	Damage to steam generator on shut down due to water stopping	2	4	8	Testing and software development	1	4	4	
1 9 2	2000 - Steamology	Steam Generator	Minimum start up time from cold	Damage to demand side equipment	2	3	6	Testing and software development	1	3	3	
1 9 3	3000 - Steamology	Steam Generator	Throttling	Responding to electrical demand	3	3	9	Testing and software development	1	3	3	
1 9 4	4000 - Steamology	Steam Generator	Safety system software failure	Release of Hazardous gas, pressurised steam	3	4	12	Testing and HSE, Watch dog timers - mechanical protection - E-stop	2	2	4	
1 9 5	5000 - Steamology	Steam Generator	Over pressure	Failure of pressurised regions	3	4	12	Monitoring pressure - mechanical protection - Designed with FoS 2x operating	1	2	2	
1 9 6	6000 - Steamology	Steam Generator	Over heating	Component damage	3	2	6	Monitoring temperature - Component inspection	2	2	4	
1 9 7	7000 - Steamology	Steam Generator	Water leak	Generator failure leaking - component damage	5	4	20	Seal design refinement and specification - Reboiogn, reduction in leak paths, material specification sufficiently engineered - Further testing of MK3 SG	1	4	4	
1 9 8	8000 - Steamology	Steam Generator	Power regulation	Incorrect power output	2	3	6	Testing and gas nozzle sizing water nozzle sizing - Controller development - Quality control	1	3	3	
1 9 9	9000 - Steamology	Steam Generator	3D print merc badge support material not fully removed	Loose material causing water nozzle blockage	2	4	8	Post print/machine cleaning and inspection process	1	4	4	
1 9 10	10000 - Steamology	Steam Generator	Distortion in fabrication	Water/steam leaks	5	3	15	Post fabrication inspection and machining - Distortion taken in to account in design - Failure design to remove post machining op	1	3	3	
1 9 11	11000 - Steamology	Steam Generator	Damage to gasket face	Leaking	3	3	9	Protective film on sealing faces when disassembled - Trained technician	1	3	3	
1 9 12	12000 - Steamology	Steam Generator	Reusing Gaskets	Leaking gaskets	4	2	8	Leak test/inspection after use - Testing or reusing gaskets - replace when needed	1	2	2	
1 9 13	13000 - Steamology	Steam Generator	Iron in gasket	Contamination in SG	4	2	8	Ensure supplier supplies correct gaskets	2	2	4	
1 9 14	14000 - Steamology	Steam Generator	Mechanical limitations of MK3 steam generators reached	Not possible to run at full power/flow	4	4	16	Replace with new design	1	1	1	
1 9 15	15000 - Steamology	Steam Generator	MK3 inner incorrect assembly	Reduction in gap between inner and outer, restricting water flow	3	4	12	Order extra inner, quarantine original inner - Part mark on all parts	1	4	4	
1 9 16	16000 - Steamology	Steam Generator	Pressure relief not fitted	Blockage in steam line cause over pressure of generator	3	4	12	PPE pressure relief, safety controls in place	1	4	4	
1 9 17	17000 - Steamology	Steam Generator	UNIGRAPH Gasket failure	Failure due to thin section and poor quality	4	4	16	Quality inspection before use. Increase section based on manufacturer guidance	4	4	16	
1 9 18	18000 - Steamology	Steam Generator	Bullet inner gasket failure	Copper gasket leaking - pressure drop	4	3	12	Test with alt. materials and alt. gasket supplier	2	3	6	
1 9 19	19000 - Steamology	Steam Generator	UNIGRAPH Gasket failure	Failure during run - under investigation	3	4	12	Use UNIMETAL Gasket to cont. testing - investigate alt. gaskets	2	3	6	
1 9 20	20000 - Steamology	Steam Generator	Running SG without all fittings/ glow plugs fitted	Running without a fully assmbled SG, parts failure, risk to test cell	3	4	12	Build and running process	2	4	8	
1 9 21	21000 - Steamology	Steam Generator	Over tightening gas nozzle	Failure of gas nozzle	3	4	12	Design out over tight failure, Updat assembly instruction	1	4	4	
1 9 22	012 - IFS	Steam Generator	Steam stream pipework to long	Back pressure on startup	5	3	15	Ensure free draining of water and shorten pipework	5	3	15	
1 14 1	1000 - Steamology	Electronics	Turbine Generator controller	Not running	3	2	6	Design specification and testing	1	2	2	
1 14 2	2000 - Steamology	Electronics	Gas storage and delivery controller	Hazardous gas release	2	4	8	Design specification and testing - mechanical protection	2	2	4	
1 14 3	3000 - Steamology	Electronics	Central controller failure	Not running	3	2	6	Design specification and testing	1	2	2	
1 14 4	4000 - Steamology	Electronics	Contaminated controller enclosures	Ctrl c/water ingress	5	3	15	IP specification	1	3	3	
1 14 5	5000 - Steamology	Electronics	Software	Not running / hazardous shut down	3	3	9	Design specification and testing	1	3	3	
1 17 1	1000 - Steamology	Leakages	Pipe rupture	Flammable / oxidising gas igniting	3	4	12	Specify quality fittings / correct fitment / training / leak testing during assembly	1	4	4	
1 17 2	2000 - Steamology	Leakages	Pipe leakage	Flammable / oxidising gas igniting	3	4	12	Gas monitoring equipment/ Maintenance	1	4	4	
1 17 3	3000 - Steamology	Leakages	Valve leakage external	Flammable / oxidising gas igniting	4	3	12	Specify quality fittings / correct fitment / training / leak testing during assembly	2	3	6	
1 17 4	4000 - Steamology	Leakages	Valve leakage internal	Undemanded pressurisation of parts of system	4	3	12	Monitoring pressure and valve position - Maintenance	2	3	6	
1 17 5	5000 - Steamology	Leakages	Fittings leakage	Flammable / oxidising gas igniting	3	3	9	Specify quality fittings / correct fitment / training / leak testing during assembly	2	3	6	
1 17 6	6000 - Steamology	Leakages	Fittings rupture	Flammable / oxidising gas igniting	1	4	4	Specify quality fittings / correct fitment / training / leak testing during assembly	1	4	4	
1 17 7	7000 - Steamology	Leakages	Fitting corrosion	Failure of fitting	3	3	9	Regular inspection and replacement	1	3	3	
1 18 1	1000 - Steamology	Materials	Material degradation	Hydrogen embrittlement surface effects	4	3	12	Regular inspection in particular pressure transducer, monitor drift - Regular maintained and replacement	1	3	3	
1 18 2	2000 - Steamology	Materials	Material degradation	Deionised water with welds	2	2	4	Regular inspection distilled water, avoid welds	1	2	2	
1 18 3	3000 - Steamology	Materials	Incorrect materials	Oxygen inetruction of incompatible materials	3	3	9	Inspection and data sheet for oxygen compatibility	1	3	3	
1 19 1	1000 - Steamology	Water valve	Bespoke design	Poor flow control	3	3	9	Testing and development - Purchase standard components where possible	1	3	3	
1 20 1	1000 - Steamology	Gas System	Regulator inspection requirements - 5 year replacement	Regulator failure and gas leak	4	3	12	Planned regular inspection and replacement	1	3	3	
1 20 2	2000 - Steamology	Gas System	Hydrogen build up in underground inspection hatch	Will build up and risk of explosion	3	4	12	Ventilation holes in cover	1	4	4	
1 20 3	3000 - Steamology	Gas System	Oxygen build up in undergrou nd inspection hatch	Gas build up and risk of explosion	3	4	12	Active ventilation	1	4	4	
1 21 2	2000 - Steamology	Gas System	Requirement of flash arrestor	Legal requirement and therefore effect on system performance	3	4	12	Engaging with certification to understand requirements/engage with industry to find flash arrestor that work at high pressure	3	4	12	
1 21 3	3000 - Steamology	Test Cell/Gas Farm	Damage to services during ground work	Down time to services, cost and down time to site	3	4	12	All ground work planned with site survey. Trained staff carrying out work	1	4	4	
1 21 4	4000 - Steamology	Test Cell/Gas Farm	Lifting equipment for MK3 SG not fit for purpose	Difficulty fitting steam generators, Risk of damaging components	3	2	6	Redesign of lifting system	1	1	1	
1 22 1	1000 - Steamology	Simulation	FEA model invalid	Incorrect results	3	3	9	Validate model with testing	1	1	1	
1 23 1	1000 - Steamology	H, V & H			3	3	9		1	1	1	
1 24 1	1000 - Steamology	Process Management	Parts/Box not labelled	Lost parts	3	3	9	Label boxes of parts, better stores process	2	3	6	
2 1 1	1000 - Steamology	Finance	Quarterly payment in arrears	Insufficient cash flow	4	4	16	Overdraft and seed funding and working capital provision	2	4	8	
2 1 2	2000 - Steamology	Finance	Delayed payment from BEIS	Insufficient cash flow	4	4	16	Project management and MO liaison	2	4	8	
2 1 3	3000 - Steamology	Finance	Inadequate funding for project	Funding offer does not cover project cost	2	3	6	Financial control and review	1	3	3	
2 1 4	4000 - Steamology	Finance	Unforeseen development costs	During testing a problem is highlighted	4	3	12	Communication with MO	4	3	12	
2 1 5	5000 - Steamology	Finance	Increased costs due to foreign exchange	Cost change	3	4	12	Payment in GBP where possible	3	4	12	
2 1 6	6000 - Steamology	Finance	Litigation due to Copyright or Patent infringement	Breaching an existing copyright or patent	1	2	2	Carry out thorough patent and copyright search	1	2	2	
2 1 7	7000 - Steamology	Finance	Litigation due to 3rd party damage	Accident occ	2	3	6	Ensure sufficient insurance - Limiting exposure	2	3	6	
2 1 8	8000 - Steamology	Finance	Follow on development funding	Stop or loss momentum	2	3	6	Seek finance and grant opportunities	2	3	6	
2 1 9	9000 - Steamology	Finance	HMRC / IUK / BEIS Investigation Undertaking in difficulty	Funding suspended	3	4	12	Adhere to grant policies	1	4	4	
2 1 10	10000 - Steamology	Finance	IAR Audits	Grant suspended	1	4	4	Financial compliance and management	1	4	4	
2 2 1	1000 - Steamology	Route to Market	Product or part of product requires certification	Steam generator is a pressure vessel	4	4	16	Obtain certification for pressure vessel	1	4	4	
2 2 2	2000 - Steamology	Route to Market	Patent infringement	Product infringes 3rd party patent	2	4	8	Carry out thorough patent and copyright search	1	4	4	
2 2 3	3000 - Steamology	Route to Market	IP control	Patent not granted	2	4	8	Continue patent process	1	4	4	
2 3 1	1000 - Steamology	Levelised cost of energy	CaPEX	Equipment too expensive	2	2	4	Work with ECAP task 1 and BOM	1	2	2	
2 3 2	2000 - Steamology	Levelised cost of energy	OPEX	Equipment running costs unaffordable	2	2	4	Work with ECAP task 1 and BOM	1	2	2	
2 3 3	3000 - Steamology	Levelised cost of energy	Cost and Quality of local supply chain	Cost and Quality	2	3	6	Research and quality assurance	1	3	3	
2 3 4	4000 - Steamology	Levelised cost of energy	Data	Poor data availability	2	3	6	Field work research and quality assurance	1	3	3	
2 4 1	1000 - Steamology	Certification	Boiler certification	Not able to self without certification	3	4	12	Research and adopt appropriate standards / work with certified bodies	1	4	4	
2 4 2	2000 - Steamology	Certification	Gas system certification	Not able to self without certification	3	4	12	Research and adopt appropriate standards / work with certified bodies	1	4	4	
2 4 3	3000 - Steamology	Certification	Purchased parts standards	Not able to self without certification	2	4	8	Research and adopt appropriate standards / work with certified bodies	1	4	4	
2 5 1	1000 - Steamology	Site Work	Hired equipment breakdown	Delay in site work	2	3	6	Ensure reliable supplier of equipment	1	3	3	
2 5 2	2000 - Steamology	Site Work	Damage to property	Delay in site work and cost of repair	2	4	8	Site survey and pre planned work	1	4	4	
3 1 1	1000 - Steamology	Emissions	H2O quality steam system	Performance degradation if demineralised water not available	3	1	3	Distilled water, closed system reuses distilled water	1	1	1	
3 1 2	2000 - Steamology	Emissions	H2O quality effect on welds	Deionised steam can effect welded joints	2	2	4	Monitor and Regular maintenance and avoid DI - Use demineralised	1	2	2	
3 1 3	3000 - Steamology	Emissions	Noise of turbine above acceptable level	Noise with condenser unit	2	3	6	Operate within noise level boundaries - application dependant - noise insulation if needed	1	3	3	
3 1 4	4000 - Steamology	Emissions	Cooling fan noise	Anti social noise / disturbance - Db above acceptable level	2	3	6	Insulation - purchase quieter fans	1	3	3	
3 1 5	5000 - Steamology	Emissions	Hydrogen gas storage tanks	Pressure cycles - Fatigue life	2	2	4	Compliance with tank manufacturer standards / inspection & test schedule	1	2	2	
3 1 6	6000 - Steamology	Emissions	Hydrogen gas venting and containment	Hazardous gas build up in closed loop system	3	3	9	Adequate venting - Purging of closed loop system - Testing for unburnt gas	3	3	9	

Deliverable 2.4 – Risk Register Update

Key Risks

- 2.1.6: Litigation due to copyright or patent infringement.
  - Pre-mitigation scores: Probability = 4, Impact = 4.
  - Mitigation: Carry out Patent research.
  - Post-mitigation scores: Probability = 1, Impact = 4.

- 3.2.8: Global events impacting Tariff, Inflation and Delivery Times.
  - Pre-mitigations scores: Probability = 4, Impact = 3.
  - Mitigation: Manage and communicate with suppliers, widen supplier base. Order parts as early as possible.
  - Post-mitigation scores: Probability = 3, Impact = 3.

Deliverable 2.4 – Risk Register Update

Key Risks

- 1.3.4: Risk of the fitting system leaking.
  - Pre-mitigation scores: Probability = 3, Impact = 3.
  - Mitigation: Pressure leak testing/ commissioning after transit / appropriate fittings selected and matched with piping and tube work.
  - Post-mitigation scores: Probability = 1, Impact = 3.

- 3.2.22: Controller delay due to supply chain issues
  - Pre-mitigations scores: Probability = 5, Impact = 3.
  - Mitigation: Ordering parts early - Design for availability.
  - Post-mitigation scores: Probability = 3, Impact = 3.

Deliverable 2.4 – Risk Register Update

Key Risks

- 1.21.1: Risk of damaging services during ground work.
  - Pre-mitigation scores: Probability = 3, Impact = 4.
  - Mitigation: All ground work planned with site survey. Trained staff carrying out work
  - Post-mitigation scores: Probability = 2, Impact = 4.

- 3.1.10: Hazardous gas buildup during water purge.
  - Pre-mitigations scores: Probability = 5, Impact = 3.
  - Mitigation: Adequate venting - appropriate venting zones - passive/active ventilation
  - Post-mitigation scores: Probability = 3, Impact = 3.

Work Package 3

WP3: Engineering design layout and specification for full demonstration installation of industrial steam system including fuel, water, steam systems.

Deliverable	Milestone	Title	Description	Format
3.1	2	Demonstration site concept report	Layout report of industrial pilot site for steam system	Layout report of industrial pilot site for steam system ppt report

STEAMOLOGY®
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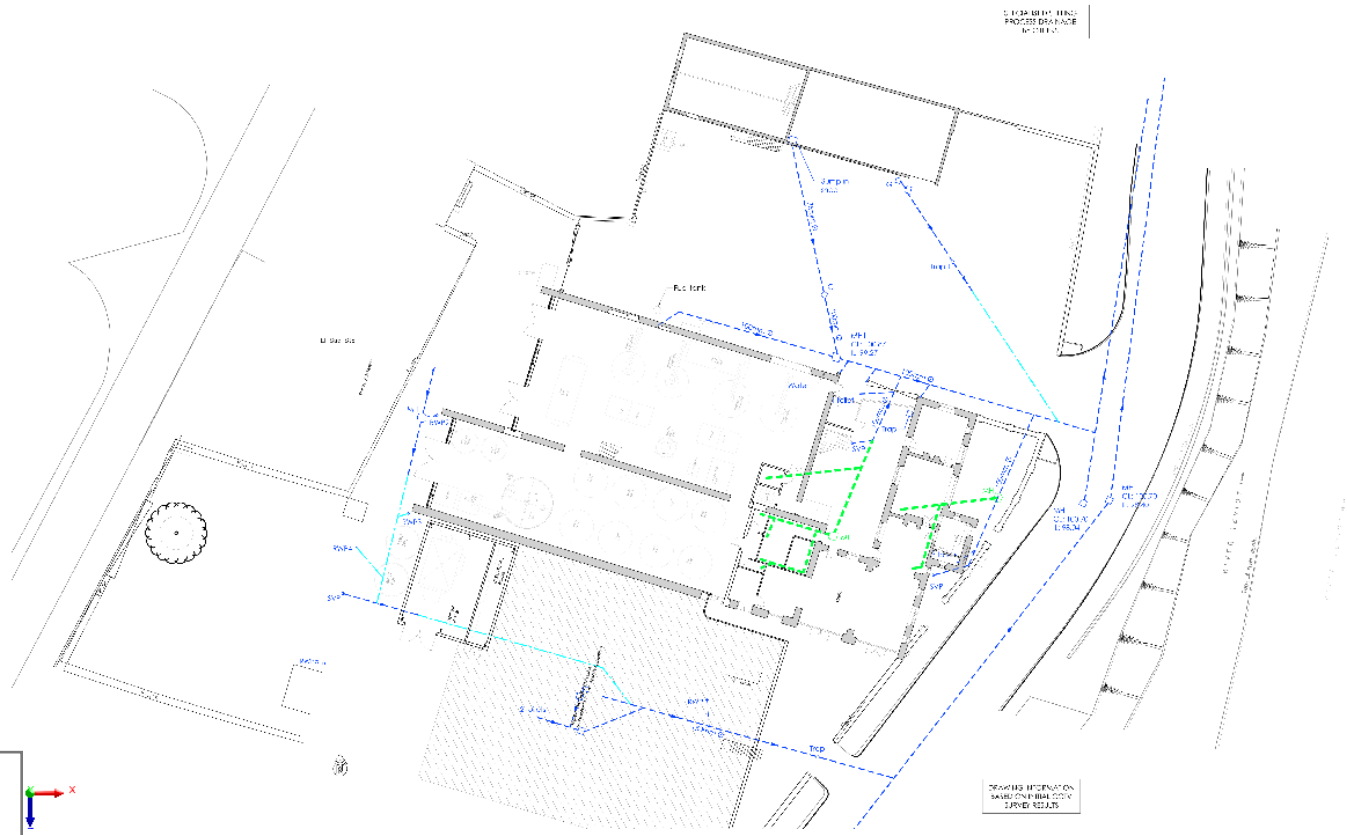
NZIP Industrial Fuel Switching

Deliverable 3.1 – Demonstration Site Concept Report

Deliverable 3.1 – Demonstration Site Concept Report

- Basing site concept on The Borders Distillery.
- Provided with a site layout plan.

- Three different concepts proposed based on different fuel storage options.
  - Tube trailer Hydrogen and Liquid Oxygen.
  - Gaseous Hydrogen and Liquid Oxygen.
  - Gaseous Hydrogen and Gaseous Oxygen, with Electrolyser.

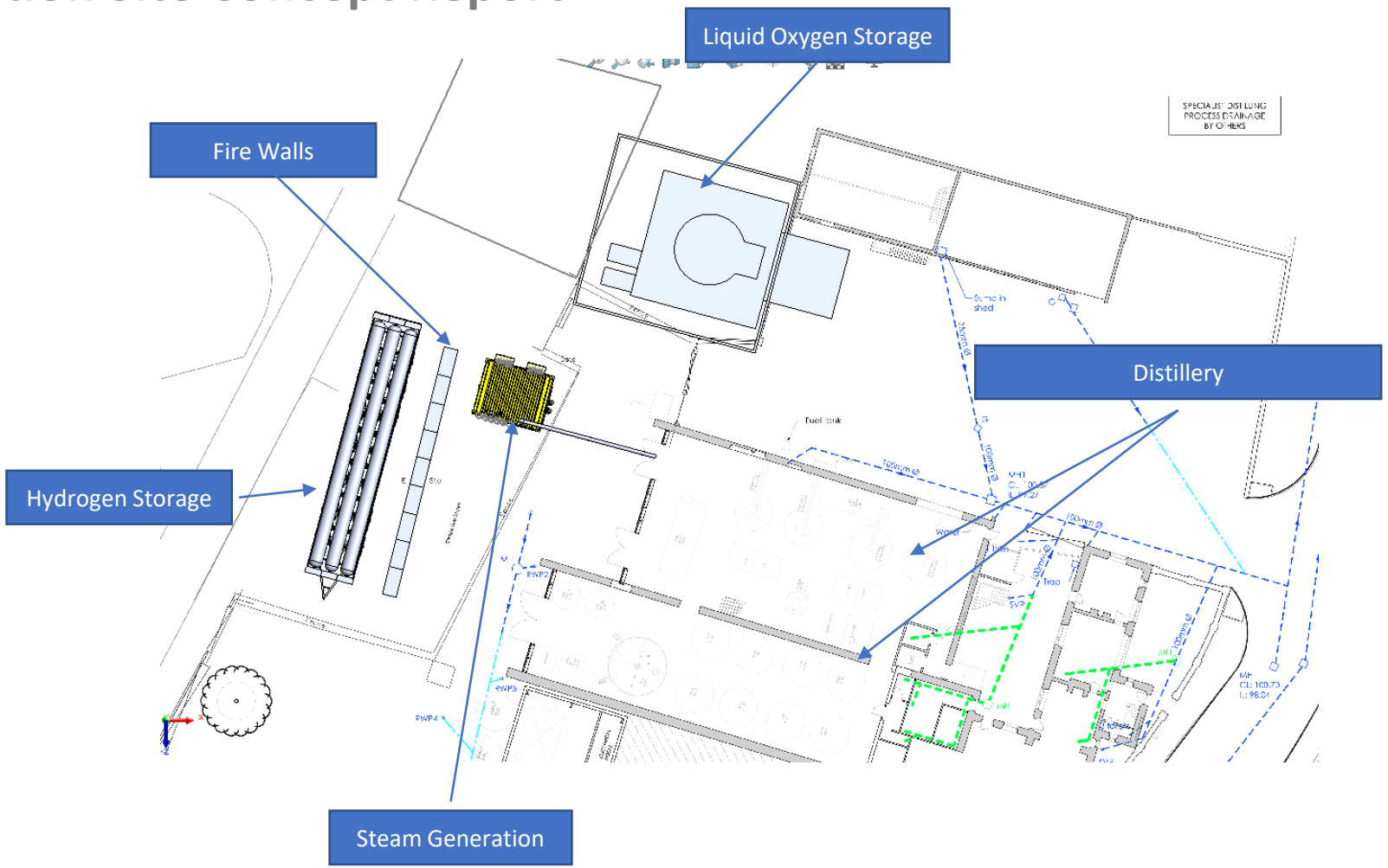


- Detailed Concept and BOM produced for Phase 2 infrastructure.
- Forms the basis for the Phase 2 proposal.

Deliverable 3.1 – Demonstration Site Concept Report

Tube trailer Hydrogen and Liquid Oxygen.

- Gaseous Hydrogen will be delivered via Tube Trailer, where the Tube Trailer will be left on site.
- Liquid Oxygen will be delivered at night from a BOC Liquid Oxygen delivery.



Deliverable 3.1 – Demonstration Site Concept Report

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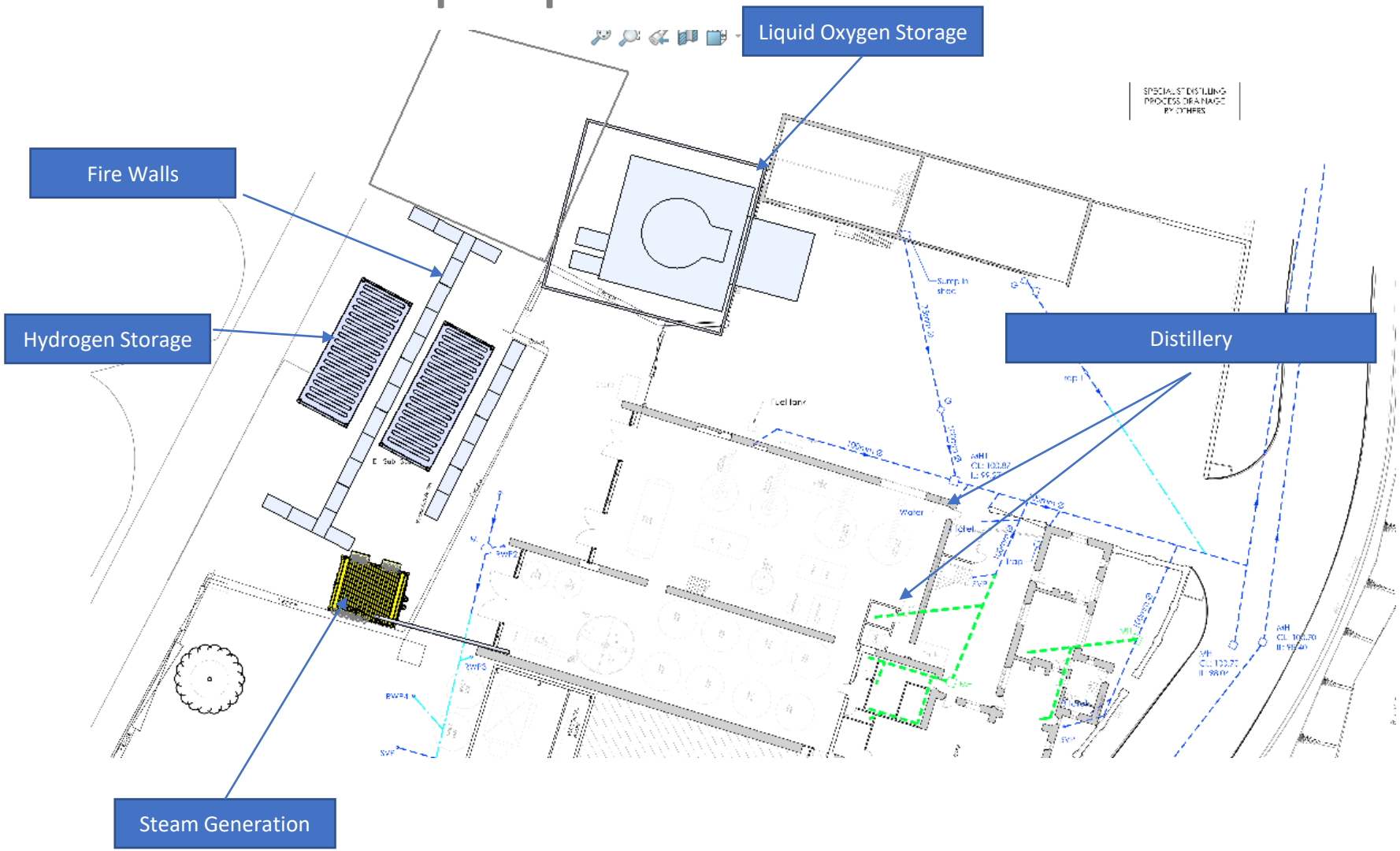
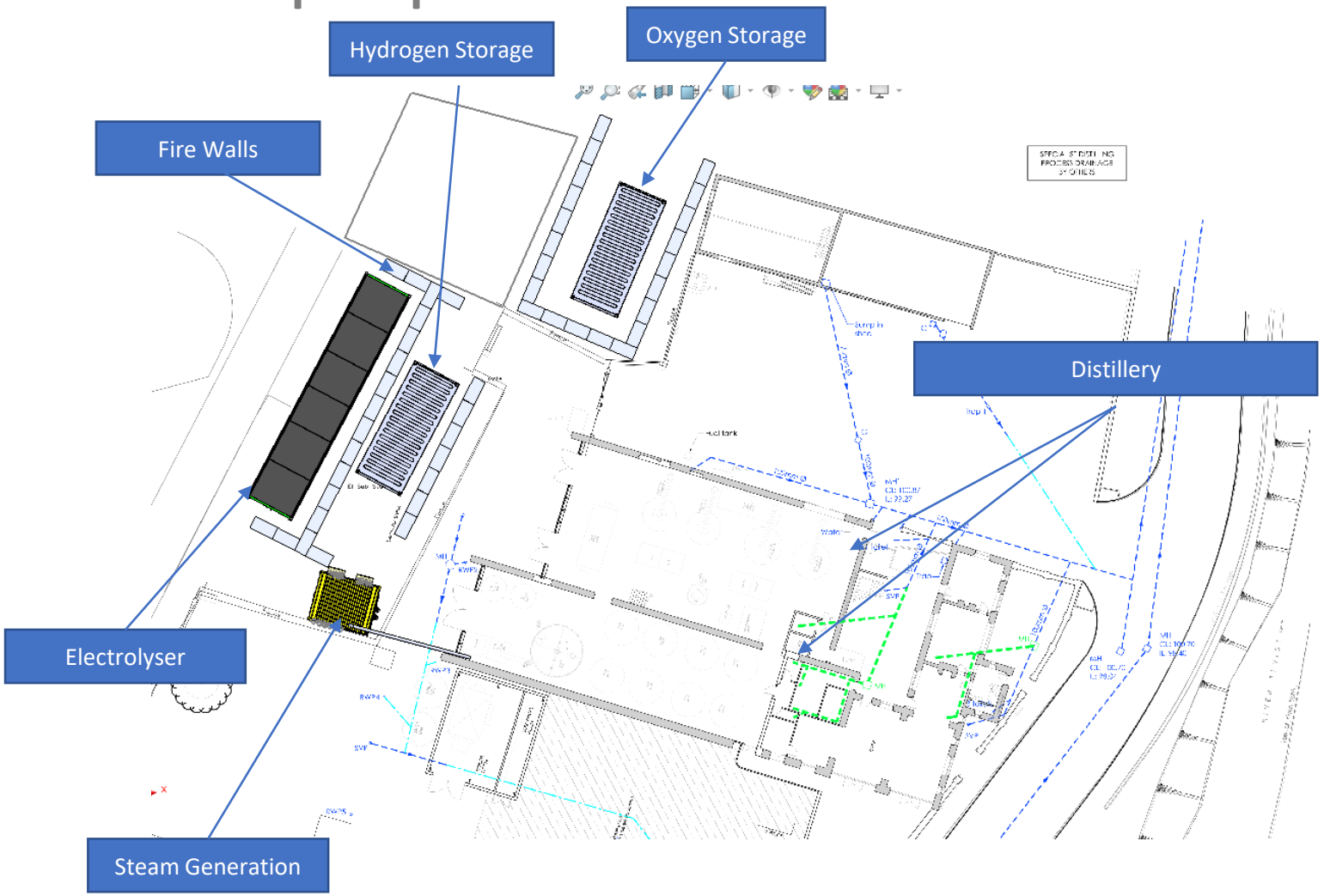


Deliverable 3.1 – Demonstration Site Concept Report

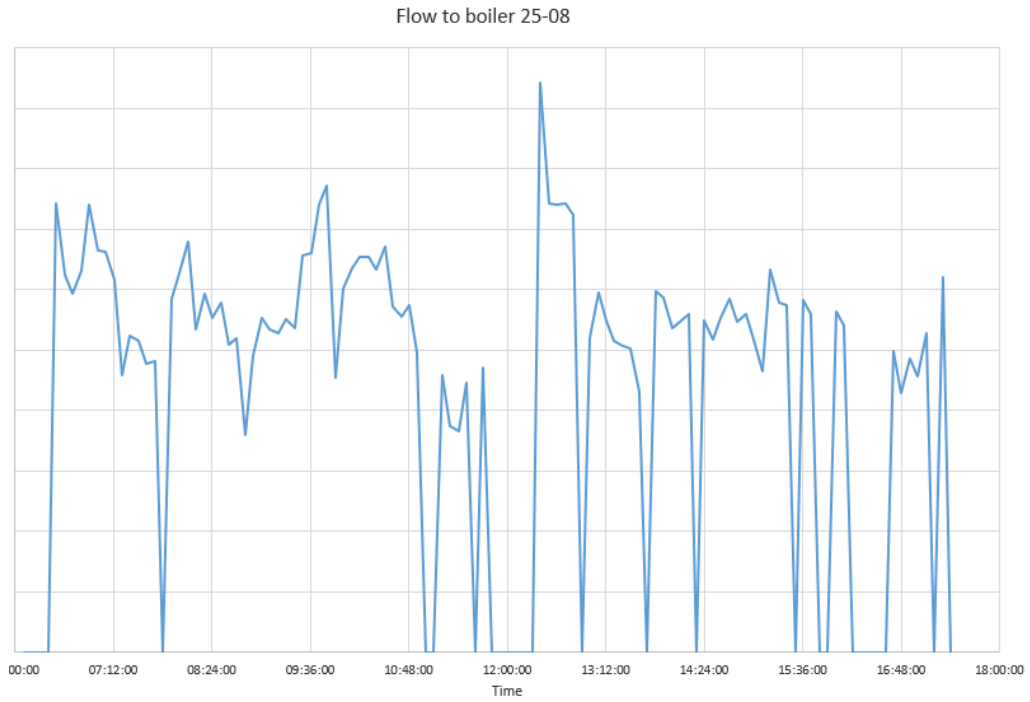
Gaseous Hydrogen and Gaseous Oxygen, with Electrolyser.

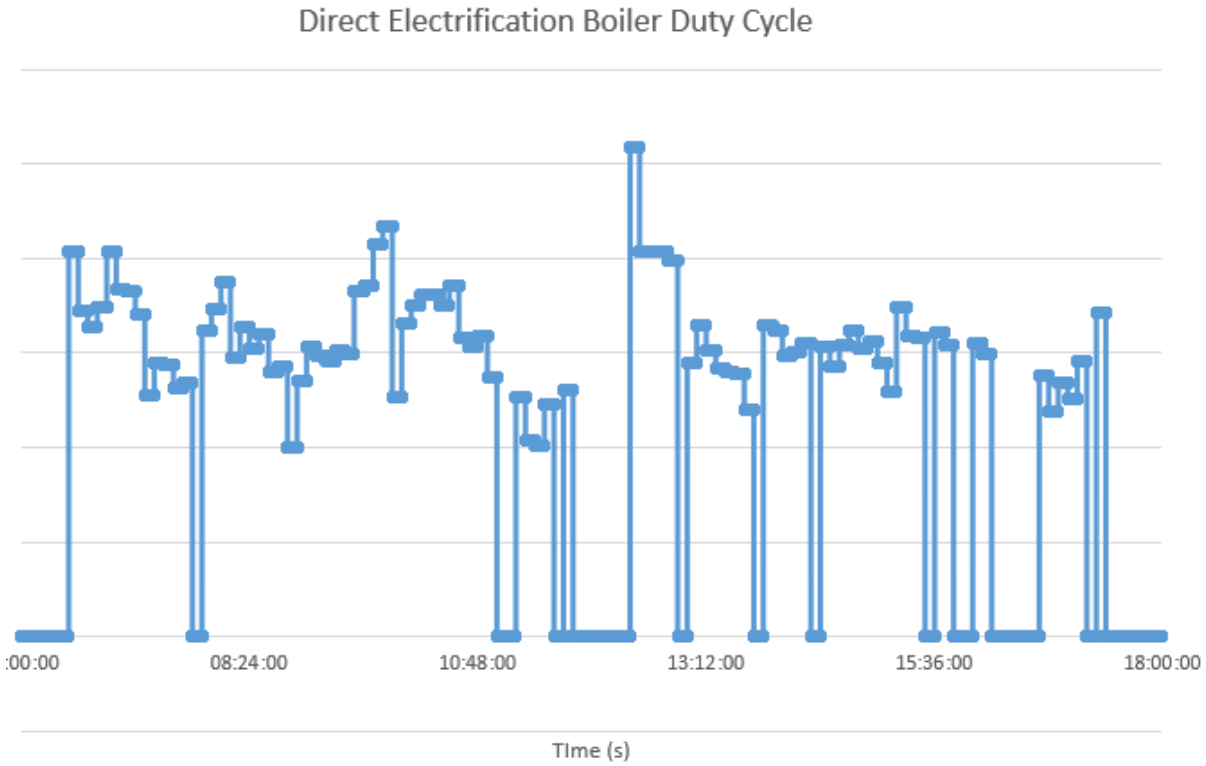
- Gaseous Hydrogen and Gaseous Oxygen storage will be installed on site.
- An on site electrolyser will continuously provide Hydrogen and Oxygen refill.



Deliverable 3.1 – Demonstration Site Concept Report

Duty cycle modelling based on real distillery data.





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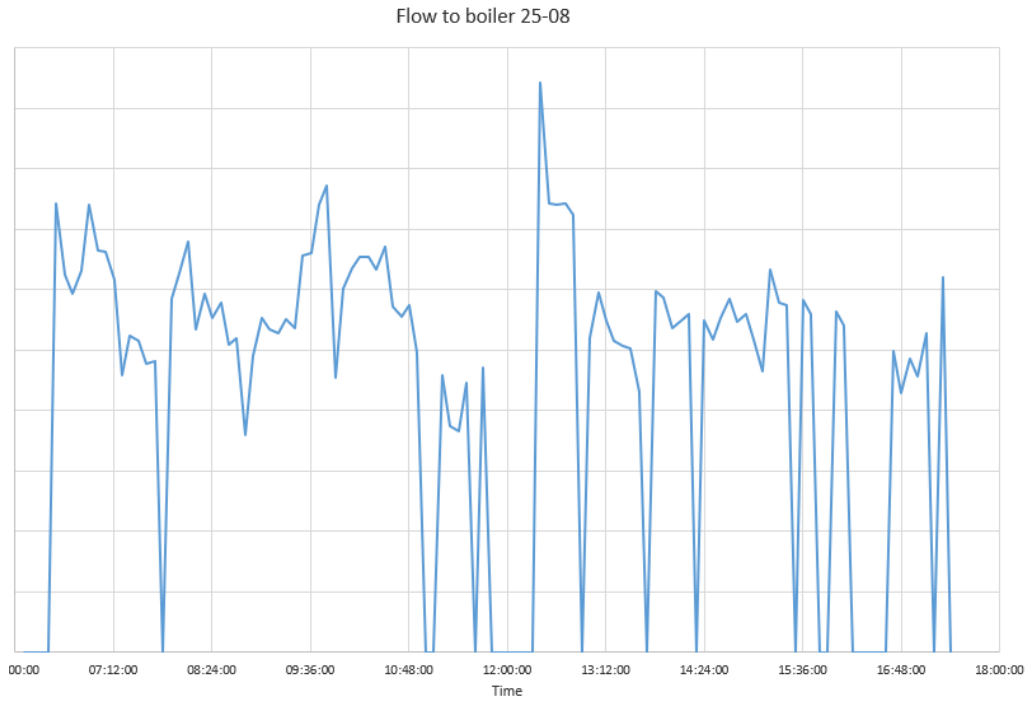
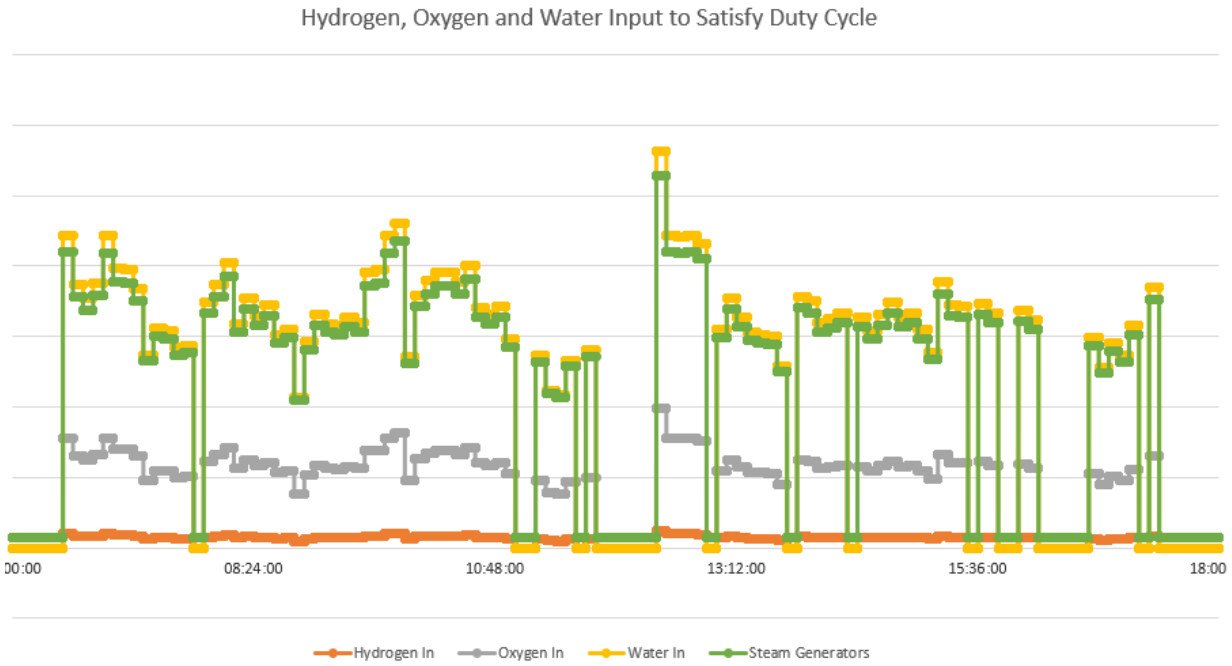
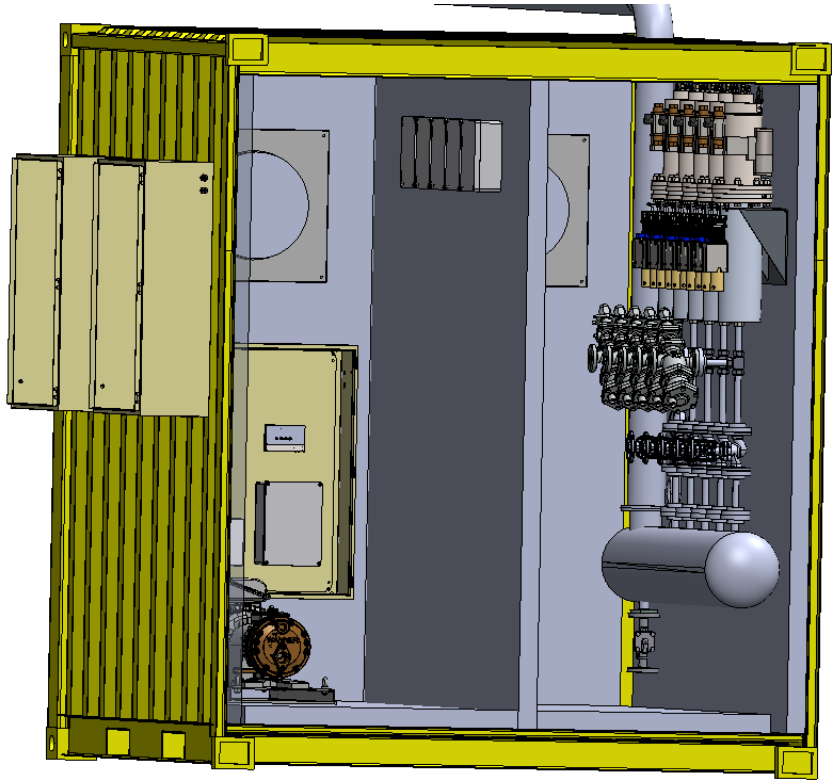
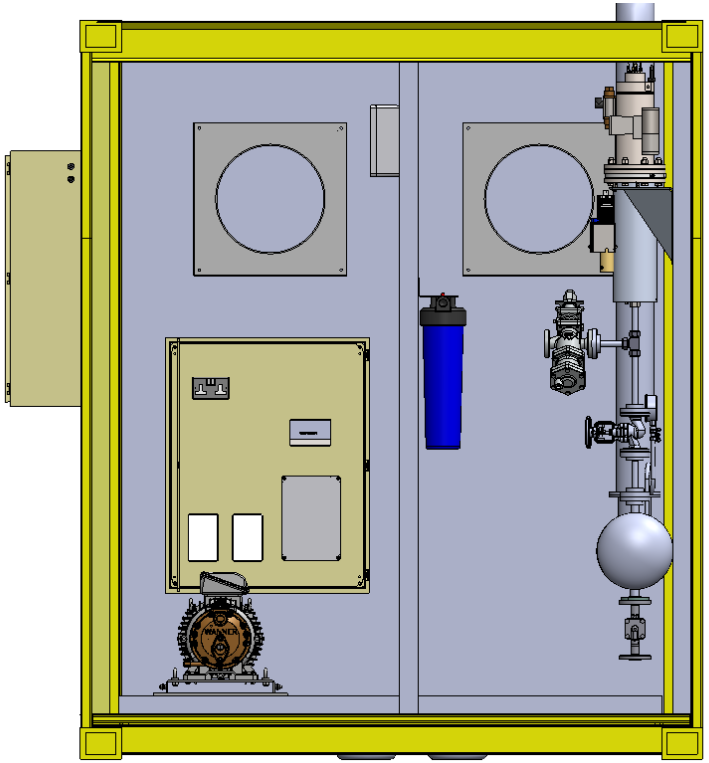




Deliverable 3.1 – Demonstration Site Concept Report

- Basing Site Concept on The Borders Distillery.
- Includes all kit necessary to supply Steam to the distillery.





Deliverable 3.1 – Demonstration Site Concept Report

Generating a complete BOM for the Distillery Steam Concept. Inclusive of:

- Gas Storage
- Gas Connection
- Water Connection
- Steam Generator Hardware
- Steam Generator Ancillaries
- Steam Header and Connection to the Distillery

Category	Part	Part Number (if available)	Description	Quantity	Material Cost	Manufacturing Cost	Purchase Cost	Total Cost	Cost Estimate or Exact
Steam Exhaust	Steam Pipe 1		1" Stainless Steel Steam Pipe	5	50	0	0	250	Estimate
Steam Exhaust	Steam Pipe 2		1" Stainless Steel Steam Pipe	5	50	0	0	250	Estimate
Steam Exhaust	Steam Pipe 3		1" Stainless Steel Steam Pipe	5	50	0	0	250	Estimate
Steam Exhaust	Steam Pipe 4		1" Stainless Steel Steam Pipe	5	50	0	0	250	Estimate
Steam Exhaust	Steam Pipe 5		1" Stainless Steel Steam Pipe	5	50	0	0	250	Estimate
Steam Exhaust	1" Tee Connectors	SS-1610-3	Swagelok Tube 1" Equal Tee	5	0	0	137.7	688.5	Exact
Steam Exhaust	Steam Feed Pipe to Distillery	N/A	6" Stainless Steel Steam Pipe with Insulation	1				0	
Steam Exhaust	Steam Pressure Relief Valve	cos3x-025-a0150-00	Flanged Steam Pressure Relief Valve	5				0	
Steam Exhaust	Analogue Pressure Sensor	PGP Assembly	Analogue Pressure Sensor with Pig Tail	2	0	0	50	100	Estimate
Steam Exhaust	Steam Trap	jj3sx0-025-a0300-00	TLV Steam Trap	1	0	0		0	Exact
Steam Exhaust	Thermocouple		Thermocouple for Steam Exhaust	10	0	0	50	500	Estimate
Steam Exhaust	Pressure Sensor		Pressure Sensor for Steam Exhaust	10	0	0	140	1400	Estimate
Steam Exhaust	Isolation Valve	DN25 BE8H PN25	Flanged Steam Isolation Valve	5	0	0		0	
Steam Exhaust	DIN Flanges		Flanges for Steam Exhaust Connections	30	0	0	100	3000	Estimate
Steam Exhaust	Gaskets		Gaskets for Flanged Connections	60	0	0	20	1200	Estimate
Steam Exhaust	Electrical Loom		Electrical Loom for Steam Exhaust Hardware	1	0	500	0	500	Estimate
Cell Gas Supply	Gas Enclosure Box	701 8455	1000mm x 800mm x 300mm Schneider Electrica Box	2	0	0	350	700	Estimate
Cell Gas Supply	Tube Fittings		Tube Fittings associated with the Hydrogen and Oxygen Gas Supply Connections	2	0	800	0	1600	Estimate
Cell Gas Supply	Welded Tube and Fittings		Welded Fittings associated with the Hydrogen and Oxygen Gas Supply Connections	2	0	2500	0	5000	Estimate
Cell Gas Supply	Flexible Hoses and Fittings		Flexible Hoses and fittings for the Hydrogen and Oxygen Supply	2	0	500	0	1000	Estimate
Cell Gas Supply	Thermocouple		Thermocouple for Cell Gas Supply	4	0	0	50	200	Estimate
Cell Gas Supply	Pressure Sensor		Pressure Sensor for Cell Gas Supply	6	0	0	140	840	Estimate
Cell Gas Supply	Valving, PRV and Regulators		Pneumatic/Electrical Control Valves, PRV's and Non Return Valves for Cell Gas Supply	2	0	0	1000	2000	Estimate
Cell Gas Supply	Fasteners and Fixings		Fasteners and Fixings for Cell Gas Boxes	2	0	0	100	200	Estimate
Cell Gas Supply	Gas Supply Loom		Loom for Cell Gas Supply Hardware	2	0	50	0	100	Estimate
Cell Gas Supply	ATEX Equipment		Equipment to get Cell Gas Supply ATEX approved	2	0	1000	0	2000	Estimate
Steam Generator	Steam Generator		Complete Mk 3. Steam Generator	5	0	£ 8,133.80	0	40669	Exact
Steam Generator	Oxygen Flowmeter		Oxygen Bronkhorst Flow Meter and Associated Hardware	5	0	0	4000	20000	Estimate
Steam Generator	Hydrogen Flowmeter		Hydrogen Bronkhorst Flow Meter and Associated Hardware	5	0	0	4000	20000	Estimate
Steam Generator	Water Flowmeter		Water Flow Meter and Associated Hardware	5	0	0	2000	10000	Estimate
Steam Generator	Mounting Hardware		Fittings and Misc	5	0	0	100	500	Estimate
Steam Generator	Fittings and Misc			5	0	0	100	500	Estimate
Cell Water Supply	Water Pipework		Pipework associated with Water Supply	1	0	0	500	500	Estimate
Cell Water Supply	Water Flexible Hoses		Flexible Hoses associated with Water Supply	1	0	0	500	500	Estimate
Cell Water Supply	Water Fittings		Fittings associated with Water Supply	1	0	0	500	500	Estimate
Cell Water Supply	Water Filters	SM-WS-B001	Big Blue Water Filter	3	0	0	80	240	Exact
Cell Water Supply	Water Filter Bracket	SM-WS-P001	3mm Stainless Steel Water Filter Bracket	3	0	50	0	150	Estimate
Cell Infrastructure	Lights								

Work Package 4

WP4: Phase2 planning report reviewing resourcing, regulatory, commercial requirements for Phase2 project and commercial roll out of technology in pilot and production adoption of zero emission steam and heat technology with industrial partners championing Scope1 emission reduction and elimination to comply with net zero targets.

Deliverable	Milestone	Title	Description	Format
4.1	2	Phase2 outline plan report	Commercial and business plan for Phase 2 development	Report describing the business and commercial exploitation planning for Phase2 and future commercial roll out

Deliverable 4.1 – Phase 2 Outline Report

STEAMOLOGY
zero emission power solutions

Industrial Fuel Switching Phase1
Zero Emission Industrial Steam

Phase 2 Outline Report

- Summarises the learnings from the Phase 1 project in an industrial context.
- Outlines the Phase 2 plan for Steam Generation in the distillery which was the focus of the Demonstration Site Concept Report.

Contents

Deliverable 4.1 – Phase 2 Outline Report

Phase 2 Outline Report

Executive Summary

Steamology, founded to commercially exploit the technology legacy of a successful landspeed world record attempt, to explore the potential of clean green renewable hydrogen steam.

Steamology deliver scalable and modular solutions for industrial steam heat and power, embracing the hydrogen economy, eliminating emissions, replacing fossil fuels and fossil fuel engines.
Steamology zero emission energy solutions address three markets using a common core technology:

- Zero emission process steam for industrial applications including the food, beverage and pharmaceutical sectors
- Drop-in zero emission diesel engine replacement unit with power ratings from 250 kW to Megawatt scale output through mechanical, electrical or hybrid drivetrains for powering trains, trucks, ships transport or static applications
- Renewable Energy (RE) storage and power generation

Deliverable 4.1 – Phase 2 Outline Report

Phase 2 Outline Report

Executive Summary (Continued)

Steamology has spent many years developing innovative hydrogen-based zero-emission steam systems for steam, heat and power turbines. The company's technical team have been working together for over ten years on superheated steam engineering. We have prioritised developing clean, energy-dense hydrogen and oxygen fuelled steam for industrial steam, heat and power commercial applications. The closed loop or open loop steam system is emission free, combustion of hydrogen and oxygen in our steam generators creates high energy steam and produces zero carbon, NOx, Sulphur or particulate emissions in a repeatable cycle.

Steam can be supplied at standard 10 bar ~185°C for industry. Culinary steam can be supplied for the Distillery, Food and beverage industry. Pure steam can be supplied for pharmaceutical applications.

Steam can be generated at high pressure 46bar in saturated steam condition ideal for replacing oil and gas fired thermal oil heating circuits up to 250°C.

Thank you

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