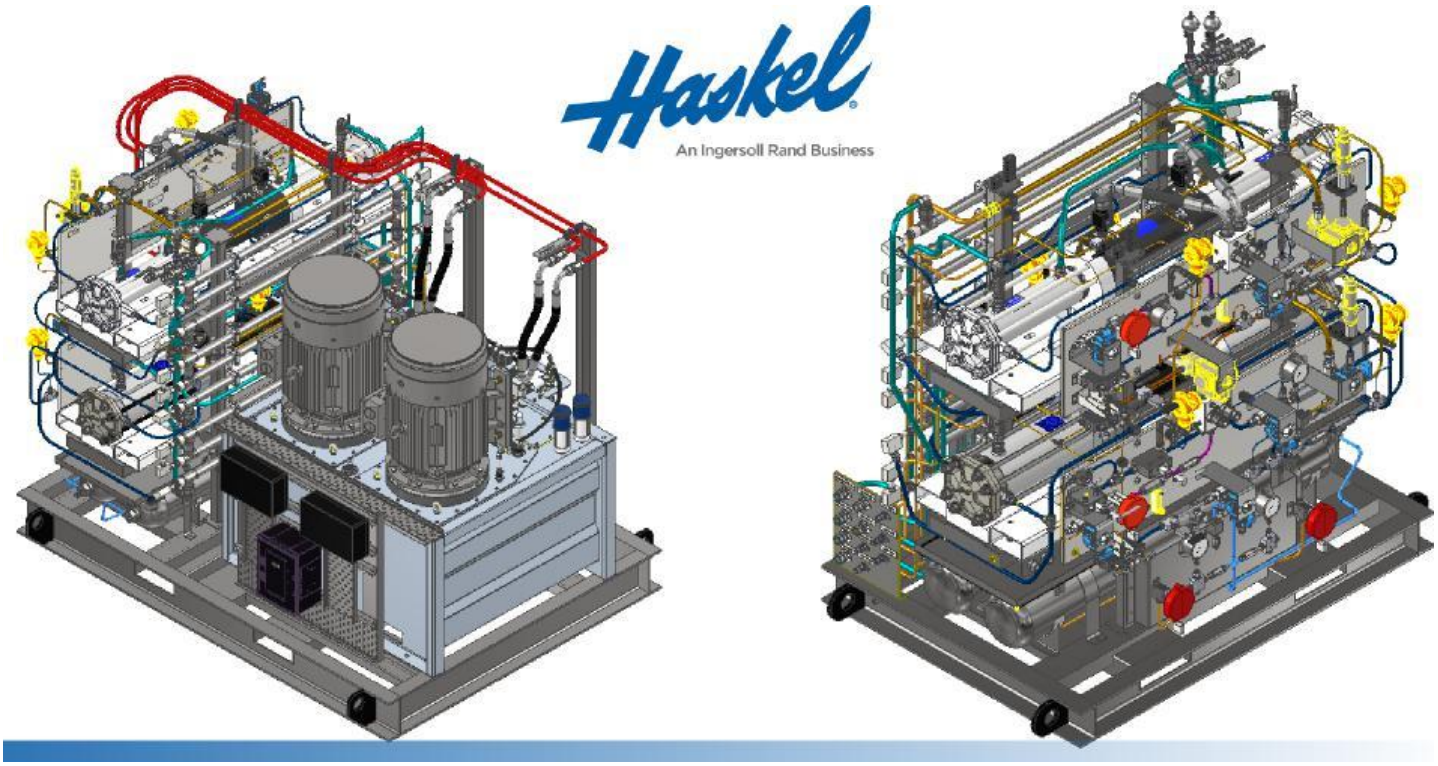
H-DRIVE SM



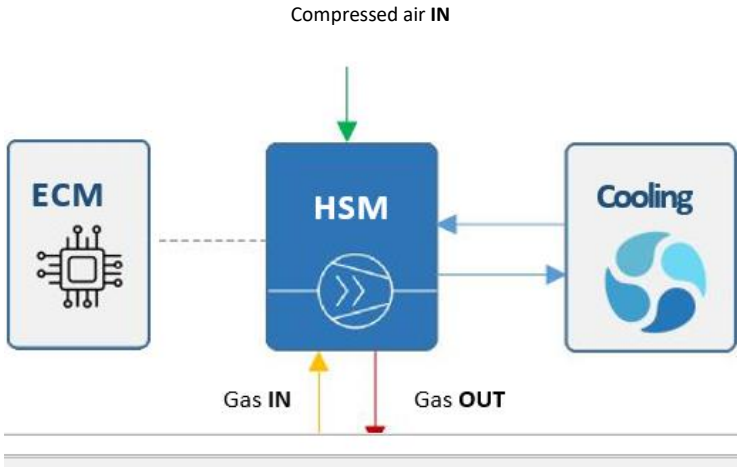
Product Overview:
The H-Drive system module (HSM), is the compression element of a full compression system. It consists of x2 H-Drive compressors installed within a stainless steel frame with an assortment of instruments, controls and piping.

When supplied alone, it cannot operate and requires further system models to create a fully working system. The diagram below illustrates the different inputs and processes required to operate the HSM.

Once connected to the additional system modules and an operational system is established, the HSM can provide pressures of up to 950bar (depending on compressor configuration) and provide flowrates of up to 63kg/hr H2 (depending on compressor configuration and at higher inlet pressures of ~100bar). The additional modules required include:

- **Electrical Control Module (ECM)**
  The ECM is required to provide power to the system and PLC control that automates the operation of the compression system, controlling the start, stop and running conditions.
- **Cooling module – Process Chiller**
  The process chiller provides a supply of coolant to the heat exchangers installed within the HSM and the cooling jackets of the H-Drives to facilitate the cooling process.
- **Supply of compressed air – Air compressor**
  A supply of compressed air is required to actuate the flow control valves within the HSM.

[Rendered Group Shot]

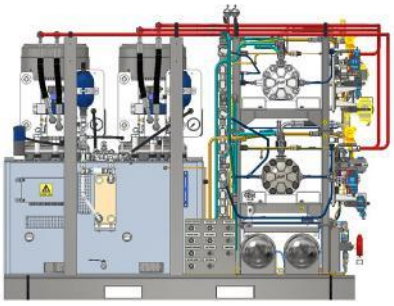


HPU Integration:

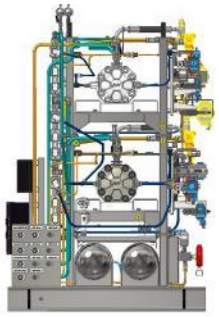
The product provides the option to integrate the hydraulic power unit (HPU) within the compression module or to provide the product without the HPU fully integrated. If the customer does not want the HPU directly coupled to the HSM, it is strongly advised that they buy the HPU separately to install within a non-hazardous/ATEX environment.

Option 1 – This provides the HSM with the HPU fully integrated with a complete hydraulic circuit. This is suitable for system builders that want a product with the least amount of integration.

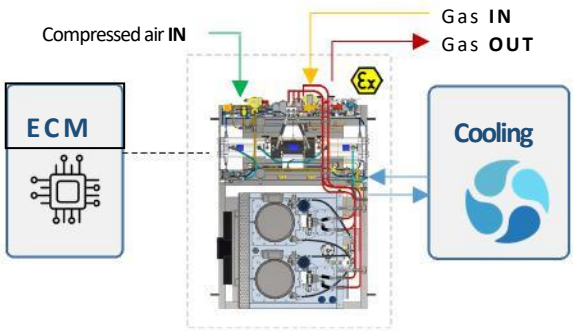
Option 2 – This option provides the HSM without the HPU integrated with the compressor. This allows for more flexibility regarding the positioning and installation of the HPU within the overall system.

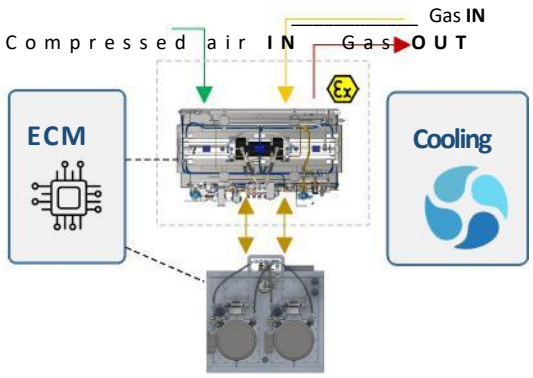


Option 1 – Integrated HPU suitable for Zone 2 Hydrogen environments



Option 2 – Without an integrated HPU. HPU to be supplied separately and installed outside of ATEX zone





Process Description:

H2 compression:

The target output pressure needs to set by the operator via the HMI within the electrical control module (ECM). The software is operating in the background to find the most suitable and efficient way to reach the pressure. If the pressure is reached, the program will stop the process and will start again only if the pressure drops below the target value.

Hydraulic:

An open loop hydraulic system provides a flow of oil to one side of the H-Drive hydraulic cylinder at a time. The oil flowrate dictates the speed that the H-Drive operates which is directly proportionate to the flowrate of gas compressed. Where HSM's are provided with a separate HPU, the hydraulic circuit must be connected with suitably sized hoses

Cooling:
The H-Drive system module provides a connection point for a coolant supply and a connection for the coolant to return to the chiller. These connections facilitate the integration of the external process chiller to provide a suitable flowrate of coolant to the cooling circuit within the HSM. Coolant is supplied to the heat exchangers and cooling jackets to facilitate the transfer of heat from the hot and cold fluids (hot gas & cold coolant).

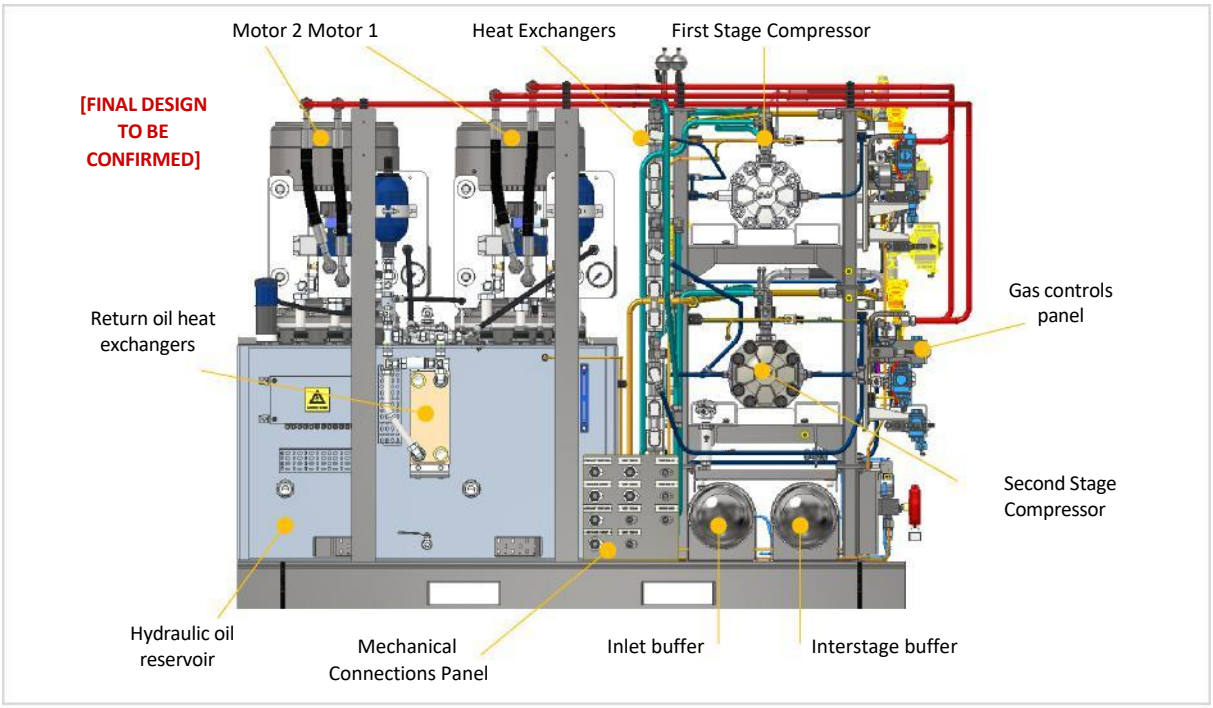
The process gas will significantly increase in temperature through being compressed and therefore this process is crucial to maintain the seal life of the H-Drive and support operational uptimes.

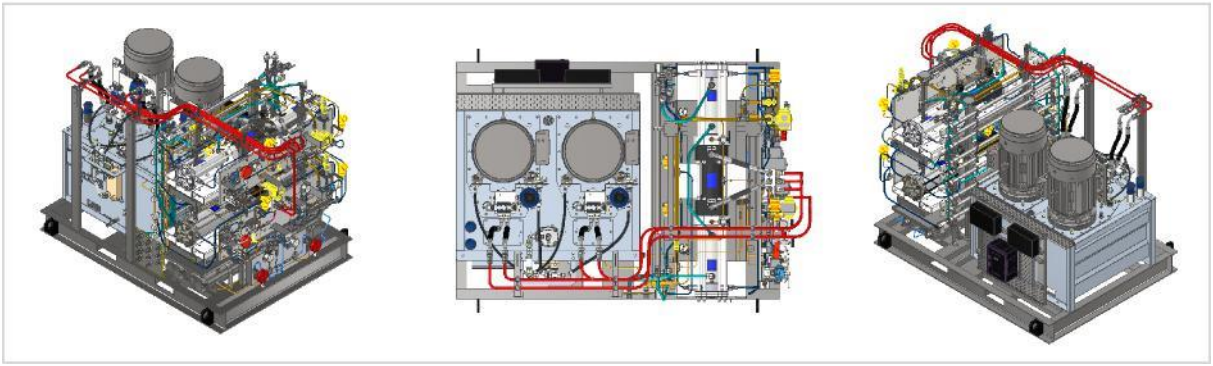
Pneumatic Circuit:
The H-Drive system module provides a connection point for a supply of compressed air which is required to operate the actuators connected to the isolation valves. Standard air compressor solutions can be supplied through our partners within Ingersoll Rand.

Bypass circuit:

The vent port of the H-Drive is connected to a flow meter. Over time, the seals within the H-Drive will degrade and the sealing efficiency of the compressor will deteriorate. The flow meter is used to measure the flowrate of gas bypassing the H-Drive seal in a test condition to indicate the seal condition. Once a certain flowrate of gas is observed, the end user must replace the H-Drive piston seals.

System Overview (with integrated HPU):





Standard Models:

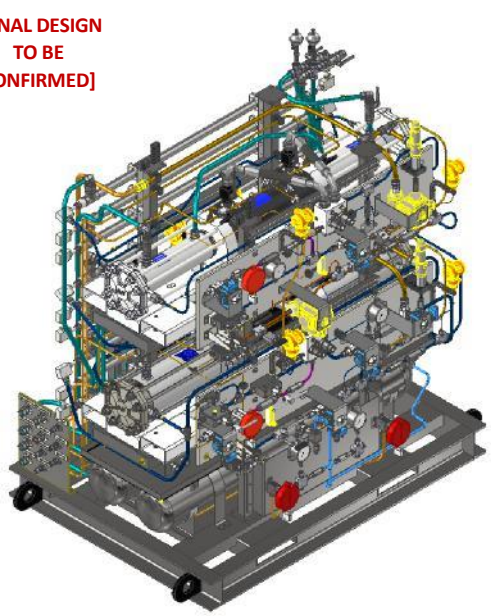
Model:	Application	GA Drawing:	P&ID:	Maintenance Schedule:
HSM-1-2-HAA-AD	Suitable for H2 applications for pressures up to 550 bar	HSM-1-2-HAA-AD-20	HSM-1-2-HAA-AD-10	[TBC]
HSM-1-3-HAA-AD	Suitable for H2 applications for pressures up to 950 bar	HSM-1-3-HAA-AD-20	HSM-1-3-HAA-AD-10	[TBC]

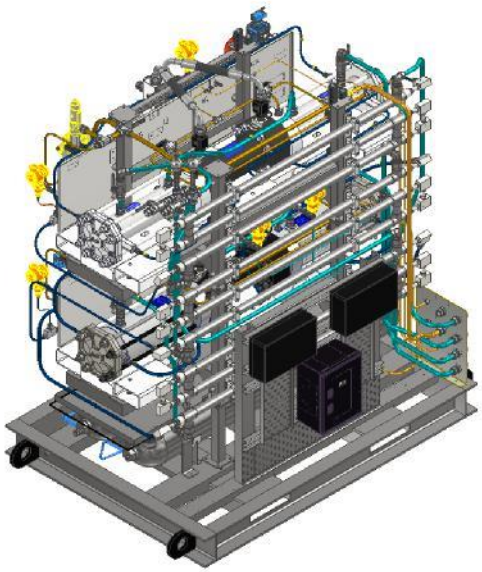
Standardisation:

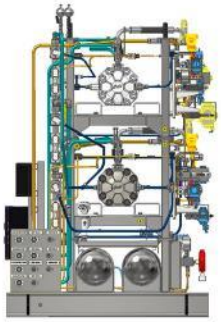
The ‘HAA’ portion of the product model indicates Hydrogen service (H) and standard circuit design (AA) (refer to the part number system). This is the minimum scope of supply required for a hydrogen service system and is our standard offering.

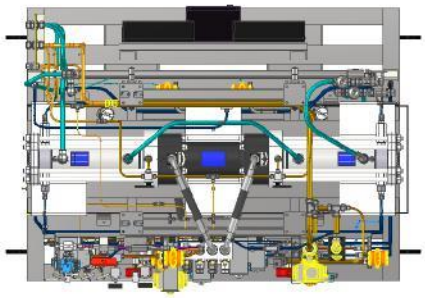
System Overview (without the HPU):

[FINAL DESIGN TO BE CONFIRMED]







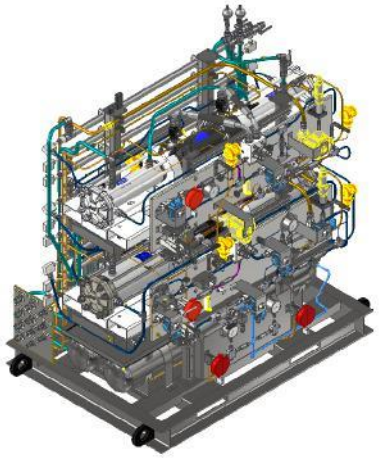


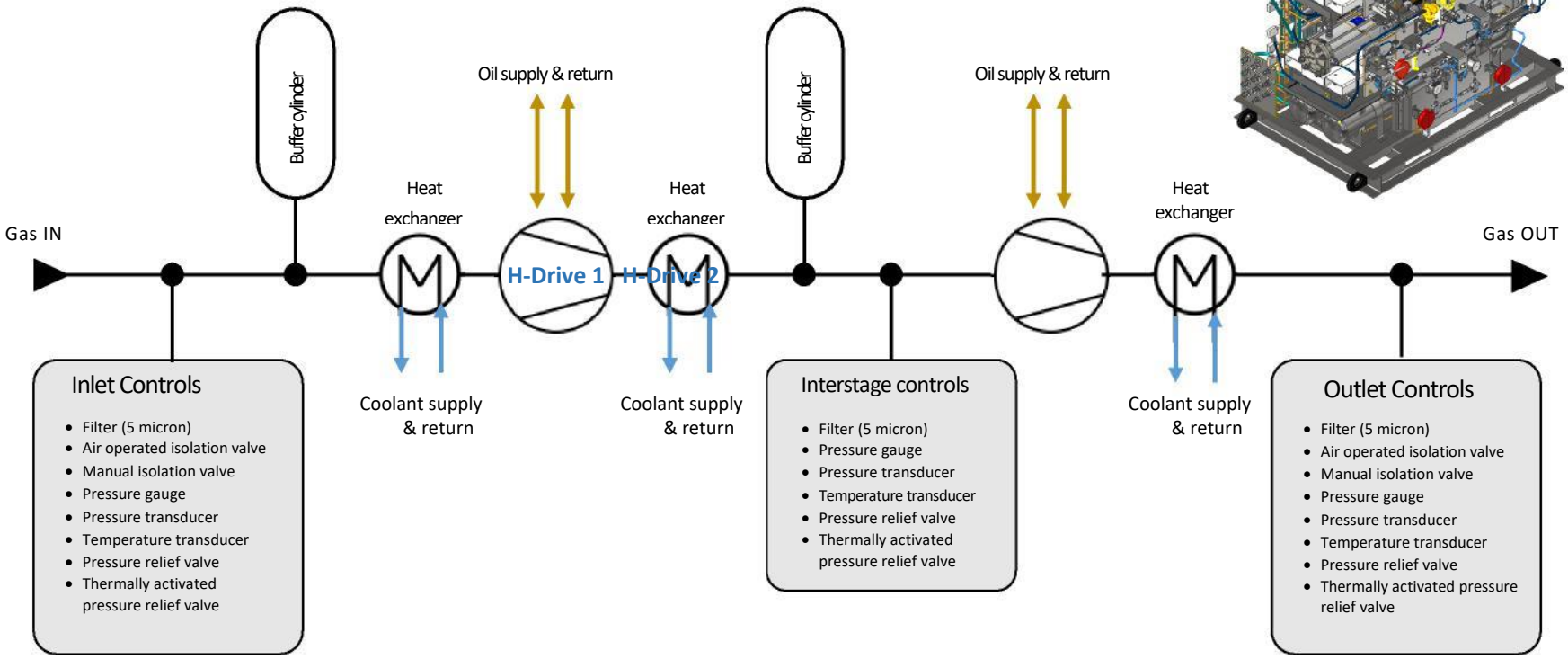
Standard Models:

Model:	Application	GA Drawing:	P&ID:	Maintenance Schedule:
HSM-1-2-HAA-XX	Suitable for H2 applications for pressures up to 550 bar	HSM-1-2-HAA-XX-20	HSM-1-2-HAA-XX-10	[TBC]
HSM-1-3-HAA-XX	Suitable for H2 applications for pressures up to 950 bar	HSM-1-3-HAA-XX-20	HSM-1-3-HAA-XX-10	[TBC]

Standardisation:

The ‘HAA’ portion of the product model indicates Hydrogen service (H) and standard circuit design (AA) (refer to the part number system). This is the minimum scope of supply required for a hydrogen service system and is our standard offering.




Buffer cylinder
Oil supply & return
Heat exchanger
Heat exchanger
Buffer cylinder
Oil supply & return
Heat exchanger
Gas IN
Gas OUT
H-Drive 1
H-Drive 2
Coolant supply & return
Coolant supply & return
Coolant supply & return
Inlet Controls
Filter (5 micron)
Air operated isolation valve
Manual isolation valve
Pressure gauge
Pressure transducer
Temperature transducer
Pressure relief valve
Thermally activated pressure relief valve
Interstage controls
Filter (5 micron)
Pressure gauge
Pressure transducer
Temperature transducer
Pressure relief valve
Thermally activated pressure relief valve
Outlet Controls
Filter (5 micron)
Air operated isolation valve
Manual isolation valve
Pressure gauge
Pressure transducer
Temperature transducer
Pressure relief valve
Thermally activated pressure relief valve

What's included - HSM Features:

Buffer Cylinder:
The system includes a hydrogen buffer cylinder installed within the hydrogen process line and positioned on the inlet of the system and between the compressors. The cylinder provides volume within the pipework of the circuit that mitigates pressure & flow fluctuations. If there is a sudden drop in flow from the gas source, the system can compensate with gas stored within the vessels.

Heat exchangers:
The temperature of a gas naturally increases through the process of compression. During operation, the outlet of an H-Drive compressor can observe gas temperatures of up to 160°C and therefore cooling of the gas is required before it reaches downstream equipment.

Cooling is provided within the system with the provision of 'tube in tube' heat exchangers. A coolant fluid is supplied to the heat exchangers to facilitate the transfer of heat from the hot and cold fluids (hot gas & cold coolant).

Isolation valves:
Valves are provided throughout the system to control the flow of gas and isolate that flow when necessary. The valves are operated either by hand where automation is not required (typically service activities) or by an actuator installed to the stem of the valve which is operated by compressed air.

Manually operated isolation valves = Butech
Air actuated isolation valves = Habonim

Pressure relief device:
To protect the system from potentially generating gas pressures above the working limits of the equipment, pressure relief devices are installed at several points within the system circuit.

Pressure monitoring instruments:
Pressure sensors are installed at various points within the system. They provide real-time data to the ECM on the levels of pressure within the system ensuring that they remain within the operational limits. Once the pre-determined pressure limits are observed, the ECM will stop operation of the system.

Temperature monitoring instruments:
Temperature sensors are installed at various points within the system. They provide real-time data to the ECM on the temperature of the gas within the system ensuring that they remain within the operational limits. Once the pre-determined temperature limits are observed, the ECM will stop operation of the system.

Filtration:
To protect the compressors from particulate potentially provided by the source gas, 5µm filters are provided within the system. The filters also capture any particulate observed from piston deterioration to maintain fuel cell grade hydrogen for hydrogen service applications.

Documentation:

- Instruction and Operating Manual (IOM)
- FAT testing and testing report
- Manufacturing Records Book (MRB)
- EN 10204 3.1 material certification

What's excluded? Outside of Haskel scope of supply:

- All interconnections between system modules are the full responsibility of the integrator unless the customer has commissioned Haskel to install the equipment.
- The system integrator is fully responsible for the overall system design outside of the HSM.
- DSEAR assessment and hazardous zoning compliance is the full responsibility of the system integrator.
- [TBC]

Technical Data:

	Parameter:	
	Weight with integrated HPU:	Refer to model general arrangement drawing
	Weight without integrated HPU:	Refer to model general arrangement drawing
	Dimensions:	Refer to model general arrangement drawing
	Inlet Pressure Range (HSM-1-2...):	15-300 bar*
	Inlet Pressure Range (HSM-1-3...):	25-300 bar*
	Outlet Pressure Range (HSM-1-2...):	550 bar
	Outlet Pressure Range (HSM-1-3...):	950 bar
	Maximum inlet gas temperature =	40°C
	Minimum gas inlet temperature =	-20°C
	Maximum outlet temperature =	Amb + 5°C
	Ambient operating temperature range =	-20°C to +40°C
	Coolant flowrate =	90 LPM / H-Drive
	Coolant temperature =	5°C – 10 °C

*The system can accept lower inlet pressures but would fail to achieve the maximum outlet pressure

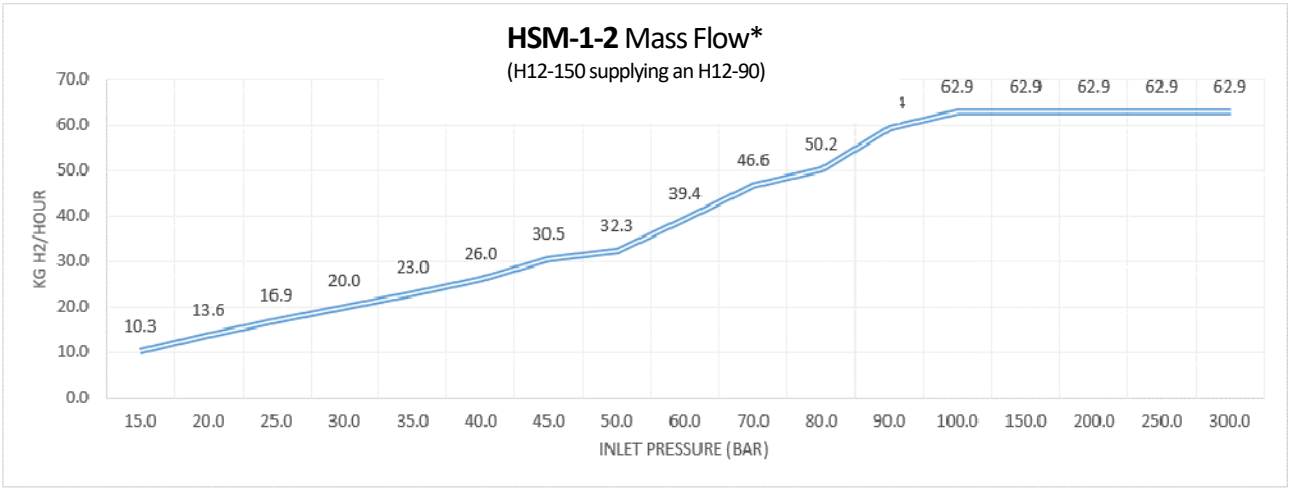
Connections:

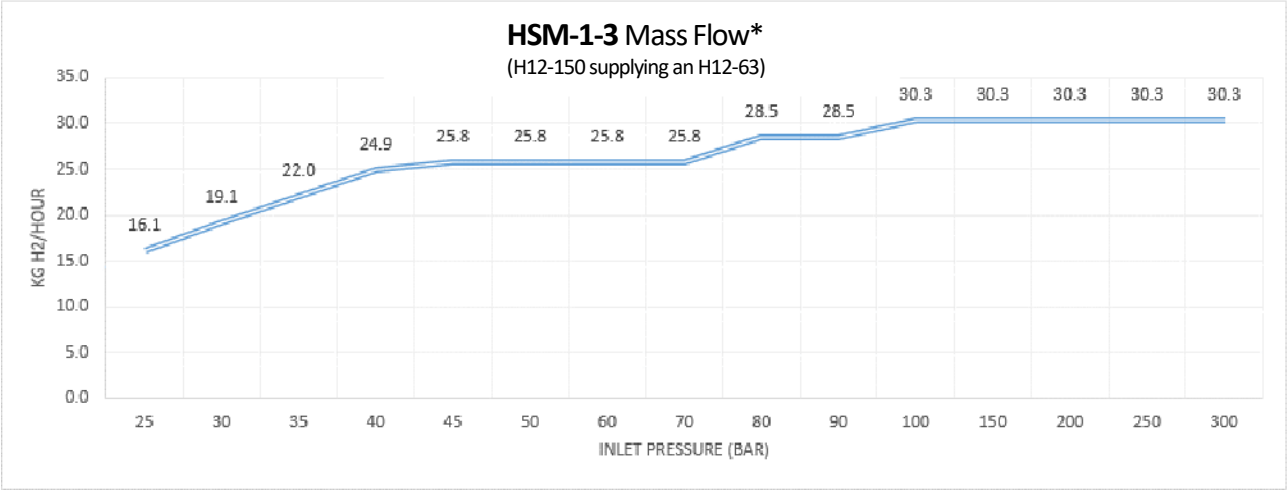
Gas Supply	3/4” O/D
Gas outlet	9/16” MP
Nitrogen (Purge) supply	9/16” MP
Cooling water Supply	1” O/D
Cooling water Return	1” O/D
Compressed air supply:	1/2” O/D
Electrical connection:	[TBC]
Earthing	Labelled stud connection

Compliance:

		HSM	HPU	ECM	Chiller
The ATEX Directive 2014/34/EU	EX II 3G IIC	☒	Optional	☐	☐
The Pressure Equipment Directive (PED) 2014/68/EU		☒	☒	☐	☐
The Machinery Directive 2006/42/EC		Declaration of Inc.	☒	☐	☒
Low Voltage Directive (LVD) 2006/95/EC	[TBC]	☐	☐	☐	☐
The EMC Directive 2014/30/EU	[TBC]	☐	☐	☐	☐

Flow Rates:





*Flowrates based on Haskel's 75kW motor and standard operational sequences at 100% load

How to choose a compression module:

Note: Part numbers must be requested from Product Management

Product Prefix	First stage / comrpessor 1	Second Stage / Compressor 2	Gas Service	System Design	Integrated HPU Module	=	Part Number:
HSM	1	3	H	AA	XX		HSM-1-3-HAA-XX

H-Drive System Module

If a system integrator is looking for a more complete solution with the smallest amount of integration, they may want an HPU integrated and coupled to the compressor.

Integrated HPU	
AA	Single 75kW
AB	Dual 75kW unit
AC	Single 75kW - EX II 3G IIC
AD	Dual 75kW - EX II 3G IIC
XX	None

This controls what circuit design is offered. The products will be released with a standard design. If a customer is looking to operate two compressors simultaneously instead of in parallel, that would require a new circuit design. If a customer is happy to provide more of the circuit design themselves and requires a simplified design, this would also require a new circuit design.

System Design		
AA	Standard	Standard two stage design
A8	Standard	x2 double acting design
AC	(Vacant]	(Vacant]
AD	(Vacant]	(Vacant]

Gaseous medium & application

Gas Service		
H	Hydrogen	
O	Oxygen	Unavailable
E	Helium	Unavailable
N	Nitrogen	Unavailable

This identifies what H-Drive model is being used as the second stage compressor. Typically, this is an H12-90 for applications lookingfor pressures up to 550 bar and H12-63 for applications lookingfor pressures up to 950 bar.

System Design		
1	H12-150-2-2	
2	H12-90-2-2	
3	H12-63-2-2	
4	H12-150/63-2-2	Unavalable
5	H12-150/90-2-3	Unavalable
6	H12-90/63-2-2	Unavalable

This identifies what H-Drive model is being used as the first stage compressor. Typically, this is an H12-150 to push the maximum amount of flow to the second stage compressor.

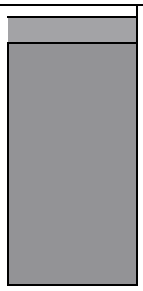
First Stage Compressor		
1	H12-150-2-2	
2	H12-90-2-2	
3	H12-63-2-2	
4	H12-150/63-2-2	Unavalable
5	H12-150/90-2-3	Unavalable
6	H12-90/63-2-2	Unavalable

Example H-Drive Compressor Configurations and Applications:

Compressor 1 / First Stage	Compressor 2 / Second Stage	Gas Service	Applications
H12-150	H12-63	H2	Utilised as a first and second stage compression solution for refuelling applications up to 950 bar
H12-150	H12-90	H2	Utilised as a first and second stage compression solution for refuelling applications up to 550 bar. Also utilised for filling hydrogen storage sources up to 550 bar.
H12-63	H12-63	H2	Utilised as a second stage compressor after a reciprocating or diaphragm compressor in refuelling applications. Receiving inlet pressures between 300 & 500 bar and compressing up to pressures of 950bar.
H12-150/63	H12-150/63	H2	Utilised as a first and second stage compression solution for refuelling applications up to 950 bar. This H-Drive configuration offers 2x 50% redundancy.
H12-150/90	H12-150/90	H2	Utilised as a first and second stage compression solution for refuelling applications up to 550 bar. Also utilised for filling hydrogen storage sources up to 550 bar. This H-Drive configuration offers 2 x 50% redundancy

Additional System Modules:

	**Electrical Control Module (ECM)**
	Intended Use:
	Part Number: [TBC]
	Technical Datasheet: [TBC]

	**Cooling Module - Process Chiller**
	Intended Use:
	Part Number: PC-A001-Q001
	Supplier Information: Parker Hyperchill ICE 116
	Technical Data: See supplier datasheet Cooling capacity = 115.5kW Flow rate = 333LPM (nominal) / 450LPM (max)

	**Hydraulic Control Module - Hydraulic Power Unit**
	Intended Use:
	Part Number: [TBC]
	Technical Datasheet: [TBC]

	**Compressed Air Module**
	Intended Use:
	Part Number: [TBC]
	Technical Data Sheet: [TBC]