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HEAT EXCHANGER INSTALLATION AND OPERATING MANUAL

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1. INTRODUCTION

Scope of Material

This document provides guidance to the installation and operation of VPE manufactured Micro Channel Heat Exchangers (HEAT EXCHANGERs) in a Hydrogen pre-cooling service.

The following supporting documents are also provided reference and use.

- HEAT EXCHANGER Technical data sheet
- HEAT EXCHANGER Manufacturing drawing
- Name plate Drawing
- Weld map drawing
- Bill of Material Drawing
- Weight data sheet

2. DESCRIPTION OF EQUIPMENT

HEAT EXCHANGERs are plate type Heat Exchangers constructed by diffusion bonding stacked shims with fluid flow channel. Channel sizes are sizes are sized to meet mechanical design conditions and thermal-hydraulic performance requirements.

Diffusion bonding is a solid state metal joining process by promoting grain growth at between plate surfaces. It provides parent material strength without the use of a filler or braze metal.

HEAT EXCHANGERs are high integrity exchangers that are typically used for high pressure and/or high temperature applications due to their mechanical integrity.

VPE's Microchannel Heat Exchangers meet ASME Section VIII, DIV 1 requirements are constructed as per mandatory Appendix 42. VPE holds an ASME ' U' stamp certification.

The exchanger core is manufactured from stainless steel of dual certified grade 316/316L.

The function of this exchanger is to cool a hydrogen gas by using a low temperature heat transfer fluid (R744 Refrigerant)

3. DEFINITIONS

Definitions of main components in HEAT EXCHANGER construction are briefly listed here.

3.1 Shims

Flat sheet plates on to which, fluid flow small channels are formed using chemical etching or other methods.

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3.2 Integral Headers

Fluid distributing internal port that are formed by aligned aperture cut through plates in the bonded block.

Integral headers are mostly used for high pressure streams due to their mechanical capability as a result of diffusion bond strength and removal of external weld.

3.3 Welded External Headers

Rolled plate formed to semi-circle headers that are externally welded on the inlet and outlet section of the diffusion bonded block. Depending on the thermal duty, in some cases multiple blocks are required to meet the thermal duty, which are welded together and use a common header.

3.4 Nozzles

These are short pipe sections that connect the exchanger to the rest of process piping using standard flanges, tube fittings (Swagelok, Maximator, Parker connections) or other compact flanges. The high pressure hydrogen stream is using high cone and thread connections rated for high pressure.

3.5 Mounting Brackets

Depending on the size of the exchanger, various methods of supporting the exchanger can be used such as end mounted supports, saddle supports and simple mounting brackets. The Hydrogen pre-cooler offered here uses simple mounting brackets shown in the manufacturing drawing.

4. INSTALLATION

Safety Note
Always ensure use of appropriate personnel protection in accordance with national and local site regulations. Fit the exchanger with guards, insulation or warning signs as it carries fluids with operating temperatures exceeding 60°C and therefore touching the surface of the unit during operation could cause injury.

Prior to installing the exchanger or connecting to the rest of process pipe work carry out inspection of the delivered exchanger.

Make sure that the unit is free from shipping damage.

Use the lifting lugs provided to lift the exchanger.

Flanges and Swagelok fittings are delivered with blind flanges using temporary rubber gaskets and plug installed on fittings respectively.

Upon removing the temporary flange blind, if any corrosion products are found, a pickling and passivation of the exchanger can be carried out. Flush and drain to remove any corrosion particles.

Flush and draining should needs to be done to remove any corrosion particles.

There are no special instruments required to install VPE's HEAT EXCHANGER

Identify correctly the high pressure stream connectors and low pressure cooling system connectors. The exchanger is designed to their individual design conditions, which are shown in the name plate and arrangement drawing. Any fluid stream switch between the high pressure and low pressure can cause mechanical failure to the low pressure channels and internal ports.

After filling the units and bleeding any trapped air, replace the temporary gasket with appropriate gasket that is rated for the design pressure. Ensure flange bolting is correctly tightened prior to testing.

Before connecting the nozzles to the process piping make sure that nozzle loads resulting from the external system do not exceed the allowable values given in the manufacturing drawing.

The Heat Exchangers are largely self venting and draining through the process nozzles. Consequently provision for venting and draining should be made in the adjacent pipework.

4.1 Installing Maximator Fittings

MAXIMATOR high pressure tubing are made of high-quality coldworked stainless steels and are drawn without joints. They are used in all high pressure equipment, partially for extremely high pressures and for fluids and gases. Some aspects need to be taken into account when handling high pressure tubing: As the high pressure tubing are made of a cold-worked stainless steel they need to be protected against being heated to over 800°F (427°C) (see also Pressure vs. Temperature Chart for cold worked 316 SS on page 2 of this chapter). Heating above and beyond would weaken the material. For this reason, the high pressure tubing must not be welded or soldered.
The reason why these so-called high pressure screw connections are used for rated pressure levels of up to 10,500 bar is connected to the type of seal and the force required. High pressure screw connections primarily comprise three components:

- **Specially processed tubing end**

A cone with an inclination of 58° and a left-handed thread (usually UNF) is cut onto the end of the tube.

- **Collar**

The collar is screwed onto the left-handed thread and serves force transmission.

- **Gland**

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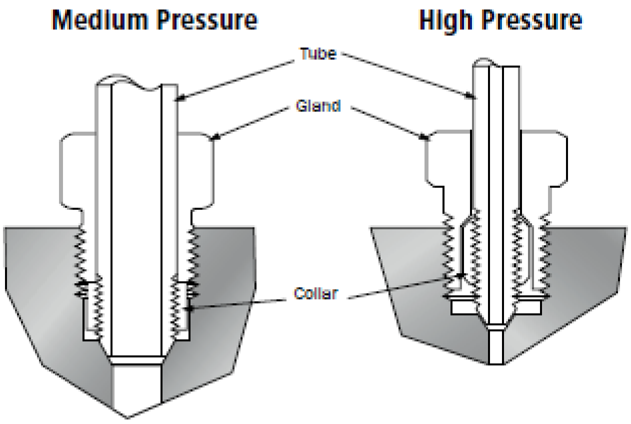
The gland serves to connect with the counter-piece into which a cone with an angle of 60° is cut. By screwing the pressure screw into the connection borehole with a defined torque, the tube/collar connection is pressed into the cone and mutually seal.



Structure of a high-pressure screw connection Structure of an anti-vibration screw connection

Assembly Instructions:

1. Insert the gland onto the tubing. Thread the left-handed collar onto the tube until at least one or two threads are exposed from the tapered coned end.
2. Apply a compatible lubricant to the gland threads and the back side of the collar where it comes in contact with the gland. Also lubricate the tapered cone portion of the tube. This will help protect the sealing surfaces from galling during the assembly process.
3. Insert the tubing into the connection and tighten the assembly hand tight. Then use a torque wrench to tighten the connection to the appropriate value in the table of attachment 13.1. It is good practice to use an additional wrench to prevent the opposite connection from turning. This type of connection ensures that the sealing surface between the tube and the counterpiece is as small as possible (In this way, the sealing force is kept as low as possible). To ensure that the connection does not tear in the event of a leak, there is a relief borehole in the counterpiece to which the tube is connected.

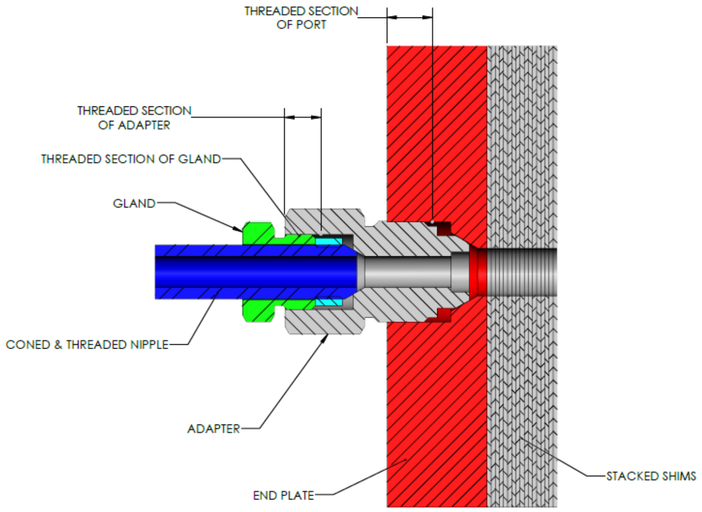
13.1 Torque Values

Tubing Size O.D. x I.D. in. (mm)	Tubing Pressure psi (bar) @ R.T.	Connection Type	Tube Gland Hex Size in. (mm)	Required Torque ft-lbs. (Nm)
1/4 x .109 **(6.35 x 2.77)**	22,500 **(1,550)**	4M	1/2 **(12.7)**	20 **(28)**
3/8 x .203 **(9.53 x 5.17)**	22,500 **(1,550)**	6M	5/8 **(15.9)**	30 **(41)**
9/16 x .312 **(14.29 x 7.93)**	22,500 **(1,550)**	9M	15/16 **(23.8)**	55 **(75)**
9/16 x .359 **(14.29 x 9.13)**	15,200 **(1,050)**	9M	15/16 **(23.8)**	55 **(75)**
3/4 x .438 **(19.05 x 11.12)**	22,500 **(1,550)**	12M	1-3/16 **(30.2)**	90 **(122)**
3/4 x .516 **(19.05 x 13.1)**	15,200 **(1,050)**	12M	1-3/16 **(30.2)**	90 **(122)**
1 x .562 **(25.4 x 14.27)**	22,500 **(1,550)**	16M	1-3/8 **(34.9)**	150 **(204)**
1 x .688 **(25.4 x 17.47)**	15,200 **(1,050)**	16M	1-3/8 **(34.9)**	150 **(204)**
1/4 x .083 **(6.35 x 2.11)**	65,000 **(4,500)**	4H	5/8 **(15.9)**	25 **(34)**
3/8 x .125 **(9.53 x 3.17)**	65,000 **(4,500)**	6H	13/16 **(20.6)**	50 **(68)**
9/16 x .188 **(14.29 x 4.77)**	65,000 **(4,500)**	9H	1-3/16 **(30.2)**	110 **(150)**
1 x .438 **(25.4 x 11.13)**	43,000 **(2,965)**	16M	1-3/8 **(34.9)**	150 **(204)**
1/4 x .063 **(6.35 x 1.59)**	101,000 **(7,000)**	4U	5/8 **(15.9)**	25 **(34)**
3/8 x .125 **(9.53 x 3.17)**	101,000 **(7,000)**	6U	13/16 **(20.6)**	50 **(68)**
9/16 x .188 **(14.29 x 4.77)**	101,000 **(7,000)**	9U	1-3/16 **(30.2)**	110 **(150)**
5/16 x .062 **(7.94 x 1.58)**	152,000 **(10,500)**	5U	3/4 **(19.05)**	70 **(95)**

All dimensions are for references only and are subject to change.

In this particular heat exchanger we have used adapters between the block and the cone and thread nipple.

We have already tightened the adapter to the correct torque. We suggest that the adapter should be left fixed to the block so that the block internal cone surface do not wear out from a repeated dis-assembly.



The cone and thread are also assembled to the right torque level, but this can be disassembled and assembled back as needed by following the above instruction and torque levels. Please hold the adapter in-fixed position as you disassemble the cone and thread nipple.

If the unit is installed horizontally, there may be trapped coolant in the exchanger and self draining cannot be ensured for the utility stream. However, separate drain and vent nozzles can be provided or alternatively vacuum pumps can be used. These are relatively small exchangers that the unit can also be removed from the frame mounting on one side for tilting and draining the trapped liquid.

Pressure relief equipment is not supplied with the Heat Exchanger.

The user is responsible for installing suitable pressure relief valves and other equipment in the adjoining pipework to ensure temperatures and pressures are kept within the design limitations.

5. STRAINERS

In general, compact Heat Exchangers require strainer protection to protect HEAT EXCHANGER passages from blocking by oversize particulates.

Excessive build-up of particulates in strainers can lead to rupture of the strainer element, with the particulate load making its way downstream to the exchanger inlet.

In case of using refrigerants, additional consideration should be given to system cleanness before charging the refrigerant. Compressor or other rotating equipments may have seal degradation, which can result as particulate leading to the exchanger. Avoid also seal lubricant oil contamination that may result in poor performance as a result of oil film forming on heat transfer surface.

As a minimum, it is strongly recommended that the operator use an in-line strainer during commissioning.

6. CONTROL

Control equipment is not provided with the HEAT EXCHANGER.

In order to avoid inducing thermal fatigue in the unit, the control system must not introduce substantial instabilities to the operation of the exchanger. Initial controller settings should be considered carefully, with particular attention to the low thermal mass, and hence fast response, of HEAT EXCHANGERs. The initial settings should be reviewed early during commissioning, in the light of experience, to confirm they are suitable.
VPE's hydrogen precoolers are tested for pressure cyclic and proven to be safe as high as 360000 cyces.

7. INSTRUMENTATION

In order to assess the performance of the exchanger and for troubleshooting of control problems, the following can be monitored and preferably recorded:

- Stream inlet and outlet temperatures

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- Stream pressure drops - across exchanger and across strainers
- Stream flow rates
- Control valve positions
- Utility stream operating pressures

8. COMMISSIONING AND OPERATION

Safety Note
The exchanger has been designed for use with the fluids specified on the HEAT EXCHANGER Technical Data Sheet. The decomposition of unstable fluids has not been specified as a design issue, and has therefore not been considered.

The design temperatures and pressures are shown on the Manufacturing Drawing and Nameplate Detail. **Do not operate outside these limitations**.

During start up, establish coolant flow prior to working fluid flow to make sure desired exit conditions will be met.

When shutting down, discontinue the working fluid to be cooled first, while maintaining a coolant flow.

During Emergency conditions, HEAT EXCHANGERS can be shut down rapidly by isolation valves. However make sure that the low pressure circuit chamber does not see a higher pressure than the allowable limit shown in the name plate.

For long term shutdown, ensure that the contents cannot cause corrosion to the HEAT EXCHANGER. Complete purging of the process fluids and filling with an inert gas is recommended.

The hot and cold streams should be allowed to naturally reach their specified outlet temperatures.

Control of the H2 exit temperature is achieved by adjustment of the utility stream. However coolant control valves should have a physical minimum stop to avoid poorly set controller.

Note that compact Heat Exchangers have a very small thermal mass so that the internal metal temperature responds very rapidly to changes in process conditions, particularly flows. In general, monitoring of coolant circuit control should be done in such a way that rapidly responding coolant control valve setting is avoided.

Ensure all connections are checked for correct sealing and bolt torque before operations.

Make note of the maximum design conditions and hydrostatic test pressures provided on the name plate and manufacturing drawing. Do not exceed these conditions under any circumstance including during system pressure testing of the associated pipe work.

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When performing any integrity testing such as hydrostatic test, use low chloride water with chloride level less than 10 ppm. After testing, it is recommended that the unit with associated pipe work is thoroughly drained and dried.

In case of ambient conditions below freezing point of the fluid, measures should be taken to inhibit freezing of the fluid inside the exchanger channels.

9. MAINTENANCE

It is recommended that the exchangers be given external and internal visual inspections periodically. Internal inspections checks are carried out for signs of debris or fouling. These are recommended to be incorporated into the routine maintenance schedules.

Items associated with the exchangers, which may require inspection and intermittent replacement are the strainers and gaskets between the exchangers and mating process piping.

There is no specific schedule of maintenance activities required for satisfactory performance of the HEAT EXCHANGER.

Performance parameters noted should be monitored and will give early warning of potential problems.

Instability of flow rates or control valve positions indicate that damaging thermal cycling may be occurring.

A marked increase in pressure drop or reduction in performance indicate that cleaning may be necessary or hydrates may have formed.

Exchangers which are known to be subject to fouling or scaling should be cleaned periodically as a sludge or scale coating on passage walls reduces efficiency.

The process nozzle can be used to access the Heat Exchanger core for cleaning using Ultar High Pressure (UHP) water, which is an effective cleaning method for HEAT EXCHANGERS.

Alternatively, other cleaning methods such as back puffing, back flushing, chemical cleaning and steam cleaning can be employed if found appropriate.