

 EXXON ENGINEERING	FIRE HEATERS FIRE HEATER MANIFOLDS		DESIGN PRACTICES	
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Revision Memo

12/99	The highlights of these revisions are:
Page 2	Updated Reference List, added Crude Corrosivity Guide
Page 2	General update to Vaporizing and Single Phase Services
Page 3	Corrected dynamic pressure equation
Page 4	Added Fuels Manifolds section
Pages 4-5	General update Transfer Lines section
Page 5	Corrected sonic velocity equation and added metric version

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SCOPE

This section contains information for the design of manifolds and transfer lines for fired heaters.

REFERENCES

DESIGN PRACTICES

Other Sections of Section VIII

[Section XIV](#) Fluid Flow

[Section XV](#) Safety in Plant Design

OTHER LITERATURE

▶ Crude Corrosivity Guide, TMEE019

Mezey, A., *Header and Manifold Design, Part 1*, Single Phase Systems, HTFS, February 8, 1974.

MANIFOLDS

GENERAL

Manifolds are used for the distribution and collection of process fluids to and from multi-pass fired heaters. The principal use of such manifolds in Exxon refineries is in POWERFORMING fired heaters. Another typical application is in steam superheaters. Manifolds should be designed to achieve uniform flow distribution to all the parallel passes of a fired heater. Significantly uneven flow can lead to tube overheating and in some services can result in coking, excessive tube wear, and other operational problems. Most processes can tolerate some flow maldistribution. A typical tolerance in control applications is 10% of the mean. This will allow applications that are based on balancing coil outlet temperatures at each pass to be implemented. The objective of truly uniform distribution in manifold design has to be tempered by practical and cost considerations.

VAPORIZING SERVICES

Experience has shown that even properly designed manifolds by themselves are not sufficient to ensure proper flow distribution in vaporizing services. Typical vaporizing services are atmospheric and vacuum pipestills and reboilers. Since flow distribution can never be uniform, the pass with the lowest flow could still receive the same amount of heat, or possibly more, than the other passes, and lead to increased vaporization. Higher vaporization would back out more flow and aggravate the maldistribution. Reduced flow, low-pressure drop conditions (during startup) can quickly lead to coked-up passes. Even at normal operating conditions, the hotter pass will coke up faster and become run length limiting.

▶ New multi-pass heaters in coking service should have automatic flow control instrumentation. As a rule, multi-pass flow control is integrated into the computer control of the plant when provided. For multi-pass process heaters in non-coking service control house flow indication and a local manual flow control valve is provided for each pass. In services with a narrow boiling range, these manual valves may be required to be partially closed to increase pressure drop in the pass in order to achieve stable flow. Where flow control valves are provided no special manifold is usually required; a basically symmetrical piping distribution would suffice.

Process streams with significant vaporization at the heater inlet present a special situation. Control valves cannot properly regulate two-phase flow, and therefore significant vaporization upstream of the control valves must be avoided as much as possible. Experience has shown that many heaters operate satisfactorily with up to about 1 wt% vapor before the control valves, and that is the recommended limit for pipestill and similar heaters. If greater vaporization is unavoidable, special measures beyond the scope of this discussion may be required. This could include the use of static mixers or restriction orifices. The inlet piping layout should provide the best possible natural split of flows. This calls for a high degree of symmetry, with flow splits accomplished by Y's or tees in horizontal runs of piping. As a rule, the advice of a fluid flow specialist should be sought for special cases.

SINGLE PHASE SERVICES

Liquid – Fired heaters with all liquid flow throughout are usually treated the same as those in vaporizing service. That is, for non-coking services manual control valves and control house flow indication on each pass are provided. For coking services, automatic flow controllers are provided for each pass. In some cases, individual control valves and flow indicators may be deemed unnecessary or impractical and a manifold would be relied upon to provide the required degree of flow distribution. If manifolds are used in all liquid flow, the sizing criteria is essentially the same as that for all vapor manifolds discussed below.

MANIFOLDS (Cont)

Vapor – Fired heaters used to heat all-vapor streams usually require a large number of parallel flow passes. This is often dictated by pressure drop and other process considerations. To achieve satisfactorily uniform flow distribution for such all-vapor streams does not require individual pass flow control valves. Indeed, such valves would become impractical, not to mention the additional cost, as the number of passes reaches 10 or more. While there is no hard and fast rule, up to 8 parallel passes lend themselves readily to symmetrical branch piping. For 10 and more passes such branching becomes cumbersome and a properly designed manifold is usually the preferred alternative.

POWERFORMING heaters provide the most common application in Exxon of manifolds for the distribution and collection of all-vapor flows. The recommended design criteria for such manifolds is that the dynamic pressure (velocity head) in the manifold at the point of maximum velocity should not exceed 10% of the subsequent pressure drop of the individual tube pass. The following equations are used to determine the manifold inside diameter:

The dynamic pressure is defined as:

$$P_{dyn}^m = \frac{\rho V^2}{2g_c} \quad \text{Eq. (1)}$$

		Customary	Metric
where:	P_{dyn}^m = Dynamic pressure (velocity head)	lb/ft ²	kPa
	V = Linear velocity of fluid	ft/sec	m/sec
	ρ = Fluid density	lb _m /ft ³	kg/m ³
	g_c = Gravitational constant	32.17 ft lb _m /lb _f sec ²	1 kg m/N sec ²

Expressed in units of psi (kPa), and as a function of commonly used flow variables:

$$P'_{dyn} = 3.625 \frac{W^2}{\rho D_i^4} \quad (\text{Customary}) = 0.81 \times 10^9 \frac{W^2}{\rho D_i^4} \quad (\text{Metric}) \quad \text{Eq. (2)}$$

		Customary	Metric
where:	P'_{dyn} = Dynamic pressure (velocity head)	psi	kPa
	W = Total flow rate	lb _m /sec	kg/sec
	ρ = Fluid density	lb _m /ft ³	kg/m ³
	D_i = Inside diameter of manifold	in.	mm

If Δp is the total pressure drop through the coil, in psi (kPa), then the dynamic pressure can be set equal to a fraction of the coil Δp .

$$P'_{dyn} = f \Delta p \quad \text{Eq. (3)}$$

Substituting in **Eq. (2)** and solving for D_i yields:

$$D_i = 1.38 \sqrt[4]{\frac{W^2}{\rho f \Delta p}} \quad (\text{Customary}) = 168.7 \sqrt[4]{\frac{W^2}{\rho f \Delta p}} \quad (\text{Metric}) \quad \text{Eq. (4)}$$

For the commonly used 10% criteria, $f = 0.1$ and **Eq. (4)** becomes:

$$D_i = 2.45 \sqrt[4]{\frac{W^2}{\rho \Delta p}} \quad (\text{Customary}) = 300 \sqrt[4]{\frac{W^2}{\rho \Delta p}} \quad (\text{Metric}) \quad \text{Eq. (5)}$$