OPERATION OF STATIC MIXER® UNITS

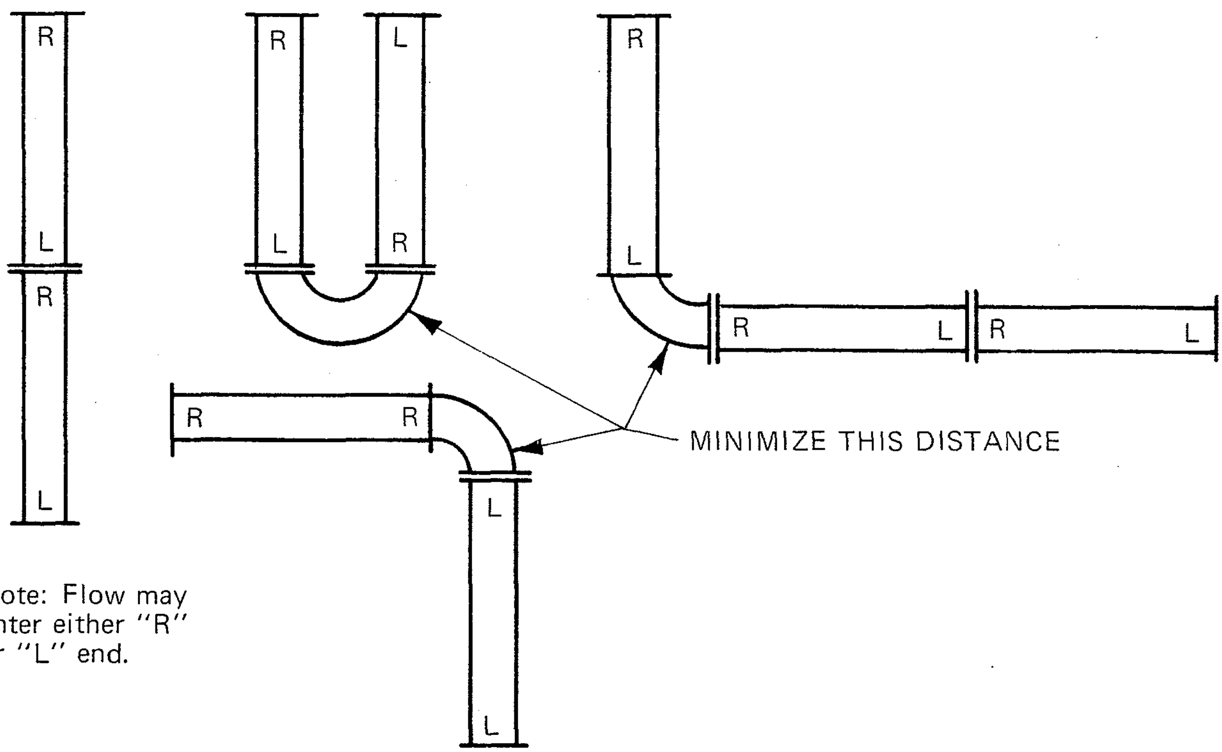
1. **GENERAL** – The proper number of STATIC MIXER modules will intimately mix the fluids, gases, solids or any combination thereof which are passed through it. Due to the unique helical elements, the mixing is a combination of flow division and radial mixing which are independent of variations in system throughput.

   Contact Kenics Technical Services Department to determine the proper size and number of modules required for your mixing process.

2. **ORIENTATION OF MODULES** – When more than one module is required, the STATIC MIXER modules may be bolted together in series or may be separated by an elbow or U as required by system space limitations. The modules can be vertical or horizontal or both. Regardless of module orientation, the following must be done:

   2.1 MATCH-MARK ALIGNMENT – Every STATIC MIXER module is match-marked "R" or "L" at each end corresponding to the right-hand or left-hand rotation of the element at that end.

   The modules used in series must be aligned such that the R of one module is aligned with the L of the adjacent modules. This will insure proper orientation and rotation of elements.



Note: Flow may enter either "R" or "L" end.

   2.2. DISTANCE BETWEEN MODULES – The distance between modules should not exceed 2 – 3 pipe diameters.

   Minimizing this distance is particularly important when dispersing a gas in a liquid or when mixing components whose chemical reactions are extremely dependent on time and/or concentration.

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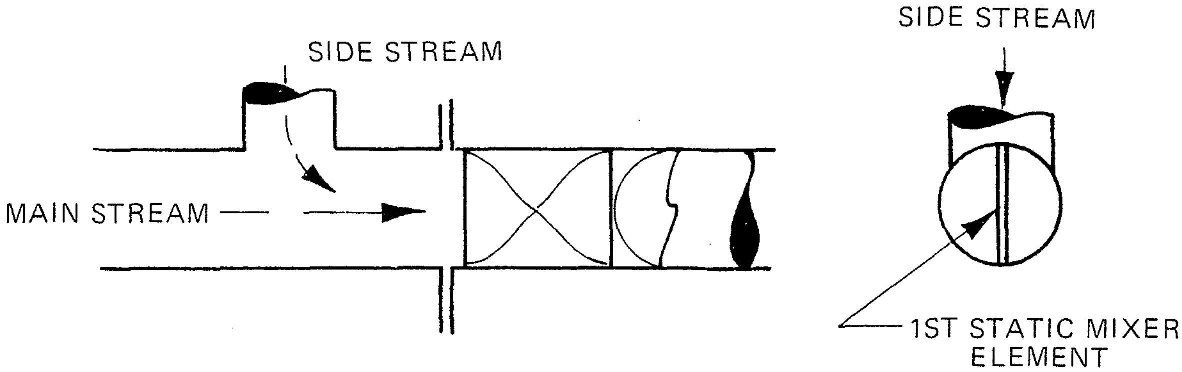
3. TYPE OF INJECTION – The type of injection depends on the components being mixed.

3.1. LIQUID-LIQUID:

3.1.1 FLOW RATES RATIO WITHIN 10:1 RATIO

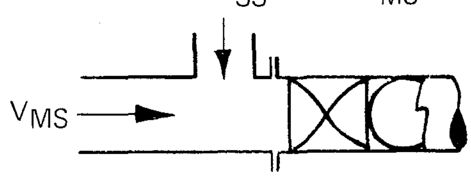


Components may be added by any T– or Y–type connections. The component injection point should be as close as possible to the first element, usually no more than 1 or 2 pipe diameters upstream. The orientation of the T or Y should provide flow division at the first element.

Injection Velocity depends on the ratio of flow rates and the relative viscosities:

A. VISCOSITIES SAME ORDER OF MAGNITUDE – The sidestream should be added through a T connection at a velocity equal to twice the mainstream velocity.

$V_{SS} = 2 \times V_{MS}$



EXAMPLE: Mix 500 GPM of H_2O with 100 GPM of 25% Sulfuric Acid.

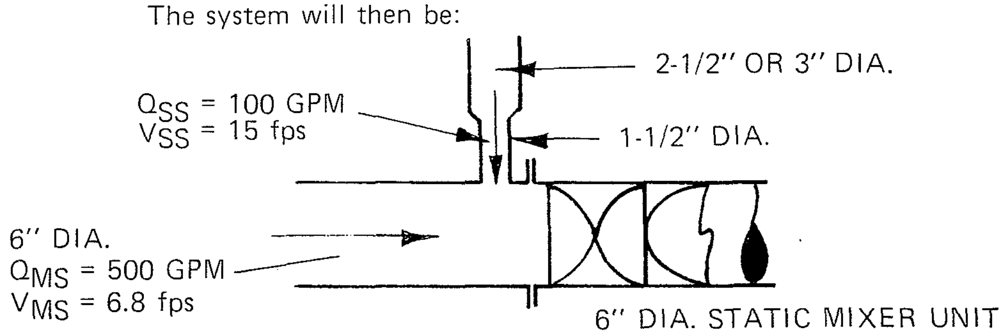
The correct STATIC MIXER unit diameter is 6″.

Entering any set of tables of flow through pipes, for Q_{MS} = 500 GPM, will give V_{MS} = 6.8 feet per second in a 6″ diameter line.

Then $V_{SS} = 2\ V_{MS} = 2 \times 6.8$

Entering the tables with Q_{SS} = 100 GPM, a 1-1/2″ diameter line will give a velocity of 15 fps which approximates the required V_{SS} = 13.6.

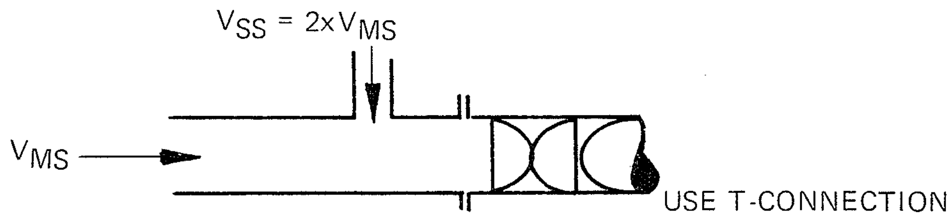
The system will then be:



NOTE: To reduce head loss in the sidestream line, the pipe diameter can be reduced to 1-1/2" just prior to the injection point as shown.

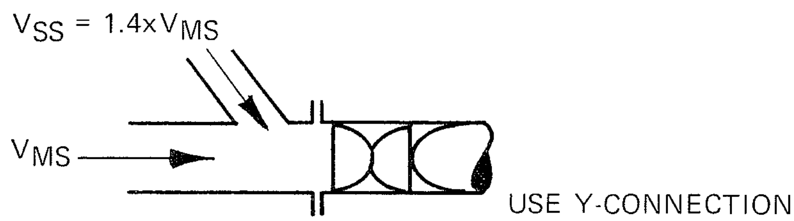
B. VISCOSITY OF MAINSTREAM MUCH GREATER THAN VISCOSITY OF SIDE STREAM – The injection can be divided into 3 cases:

CASE B1. Flow Ratio between 10:1 and 5:1



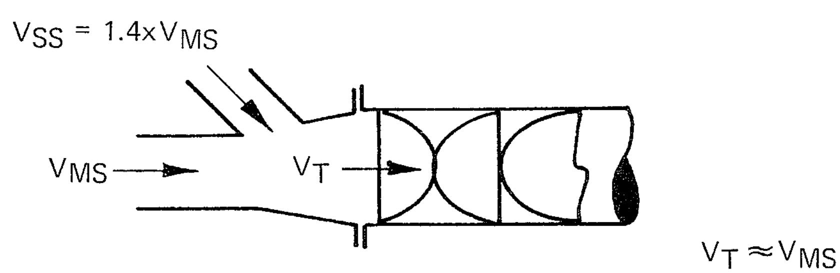
The sidestream velocity should be two times the mainstream velocity.

CASE B2. Flow Ratio between 5:1 and 2:1



The sidestream velocity should be equal to 1.4 times the mainstream velocity.

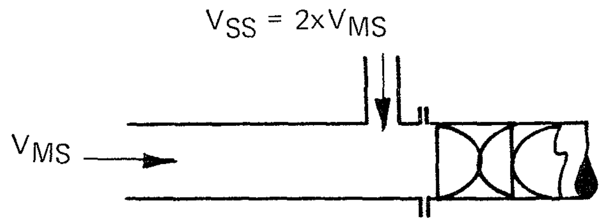
CASE B3. Flow Ratio less than 2:1



The sidestream velocity should be 1.4 times the mainstream velocity. The injection should occur at an expansion such that the velocity of the total mixture, V_T, in the expanded pipeline is approximately equal to the initial mainstream velocity, V_{MS}, in the initial pipeline.

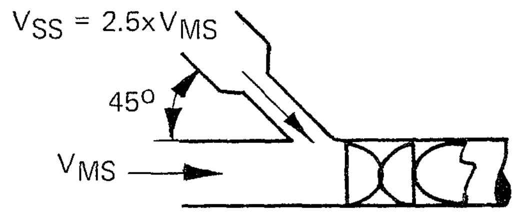
C. VISCOSITY OF THE SIDESTREAM MUCH GREATER THAN VISCOSITY OF MAINSTREAM – The injection can be divided into 3 cases:

CASE C1. Flow Ratio between 10:1 and 5:1



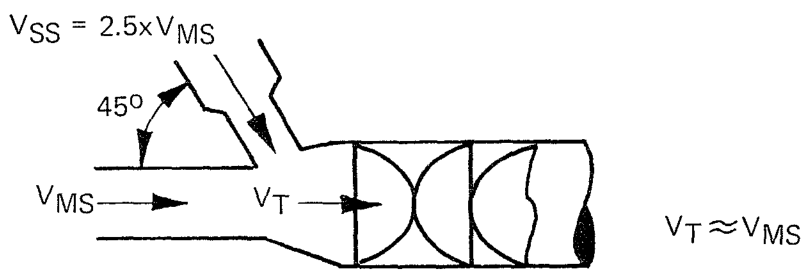
The sidestream velocity should be two times the mainstream velocity.

CASE C2. Flow Ratio between 5:1 and 2:1



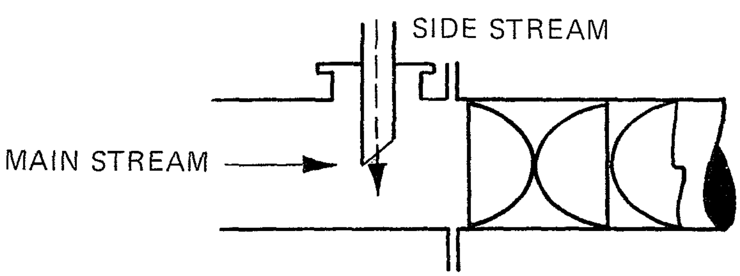
The sidestream velocity should be 2½ times the mainstream velocity.

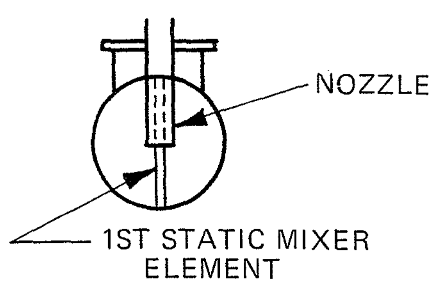
CASE C3. Flow Ratio less than 2:1



The sidestream velocity should be 2½ times the mainstream velocity. The injection should occur at an expansion such that the velocity of the total mixture, V_T, in the expanded pipeline is approximately equal to the initial mainstream velocity, V_{MS}, in the initial pipeline.

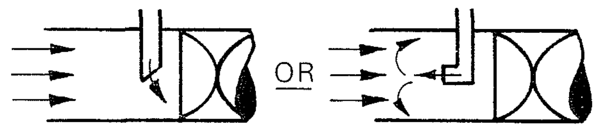
3.1.2. FLOW RATES RATIO IN EXCESS OF 10:1



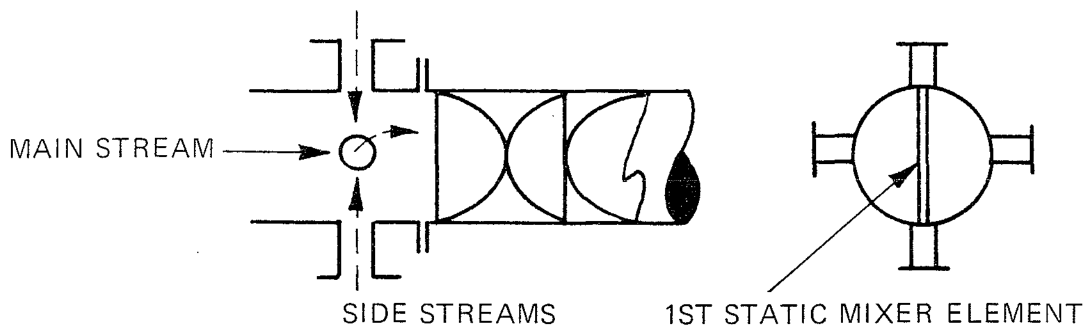


The smaller stream should be injected into the main flow. The injection nozzle of the minor component should be in the center of the pipe and as close to the leading edge of the first element as possible, **less than one pipe diameter**. The smaller stream should have flow division at the first element.

The sidestream velocity should be two times the mainstream velocity, regardless of component viscosities. The injection should be perpendicular to the mainstream or, if conditions permit, opposite the mainstream flow,

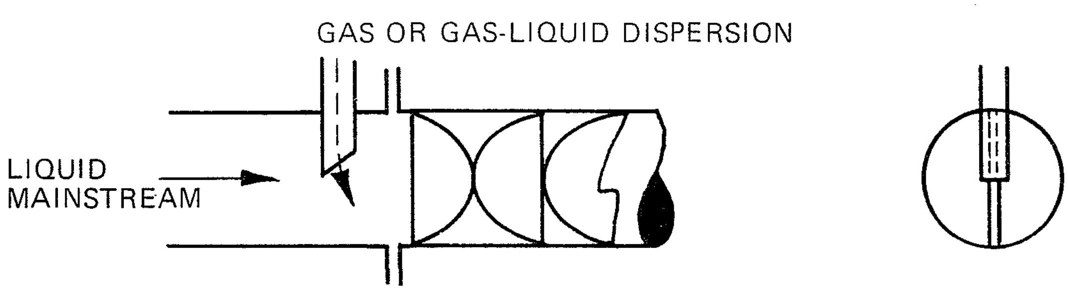


ALTERNATE:



In cases where centerline injection of the minor stream is not feasible, two— or four—point injection of the minor stream is recommended. Flow division of two streams should occur at the first element. Injection velocity should be 2—3 times mainstream velocity, regardless of component viscosities. See Section 4 for recommendations of injection header design.

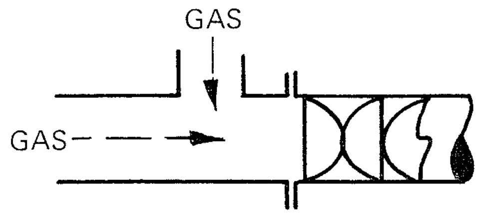
3.2. LIQUID-GAS

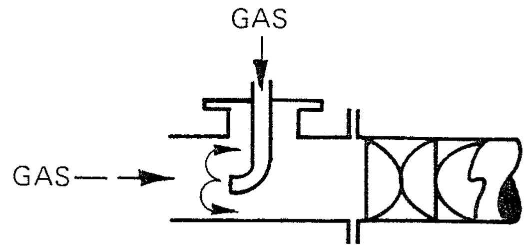


The injection nozzle of the gas should be in the center of the pipe and as close to the first STATIC MIXER element as possible, **less than one pipe diameter**.

The injection velocity should be 2 times the mainstream velocity.

3.3 GAS–GAS





SMALL MINOR COMPONENT
RATIO 15:1

For comparable flow rates, any T-type connection can be used. If the minor component is small, use a nozzle. It is sometimes advantageous to reverse the direction of the minor component to the main flow (As shown in above figure).

The mass velocity of the injected stream should be 2-3 times the mass velocity of the mainstream.

4. **CONTROL OF METERING** – The STATIC MIXER unit is a plug flow processing device, i.e. equal residence time of particles with almost no axial dispersion (back mixing). Therefore, the metering (injection) of components is of paramount importance since plug flow will allow mixing of only those components which are metered into the STATIC MIXER unit at any given time. Excessive surging or pulsating of feed components can cause non-uniformity of the final product. Control can be manual or automatic.

4.1. MANUAL CONTROL – Manual control of metering is sufficient for:

a. Processes in which variations in the feed streams are small.

b. Processes in which some variation of the final product can be tolerated.

c. Processes in which an excess of one component can be economically added to cover the complete range of variation of the other stream.

d. Processes in which variation in the final product of the mixing can be compensated at a later stage in the overall system.

4.2. AUTOMATIC CONTROL – Automatic control of metering is recommended for processes in which variation in one feed stream must be compensated by a corresponding change in the other feed stream(s).

Processes requiring automatic control include:

a. Processes involving a feed stream with potential variations in more than one property, e.g. flow rate and density. The flow rate can be manually controlled by a valve or orifice, and variations in density can be sensed and compensated by feed-forward control of the other feed stream.

b. Processes involving chemical reactions which must be maintained at a specific equilibrium point.

c. Processes whose final product must be uniform even though feed properties are variable.

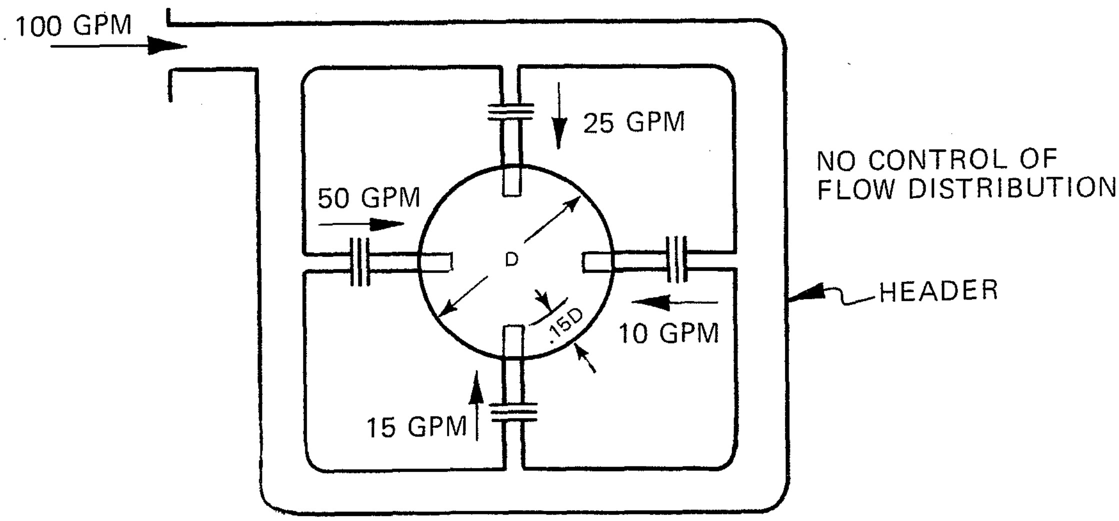
d. Processes whose economics will not permit excess addition of an expensive component.

APPENDIX

TWO– OR FOUR–POINT INJECTION HEADER DESIGN

A. GENERAL – The purpose of the multi-point injection is to insure that the minor component is evenly distributed into the major stream in those cases where single point centerline injection is not practical.

B. FLOW DISTRIBUTION – When a common header is employed to feed the ports, an uneven distribution of flow may occur such that one port may be carrying a majority of flow, with a corresponding decrease in the other ports.



This will occur in headers where the resistance to flow (frictional pressure drop) is so low that there is virtually no change in ΔP thru the ports as the flow changes from 50 to 10 GPM.

Since such a system is in virtual equilibrium regardless of flow distribution, no change will occur to evenly distribute the flow.

C. CONTROLLED FLOW DISTRIBUTION – An even flow distribution can be accomplished by designing the injection system to be in a non-equilibrium condition whenever the flow distribution is not even. In such a system, the flow will automatically adjust to maintain the equilibrium condition of equal flow to each port.

This can most easily be accomplished by inclusion of an orifice plate between the header flange and the port flange as shown:

$P_H + \Delta Po > P_{MS}$

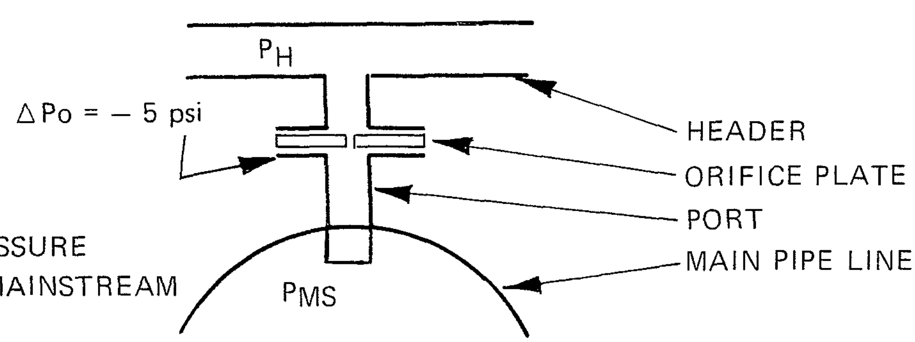
$P_H - 5 > P_{MS}$

$P_H > P_{MS} + 5$ psi

WHERE:

P_H = HEADER PRESSURE

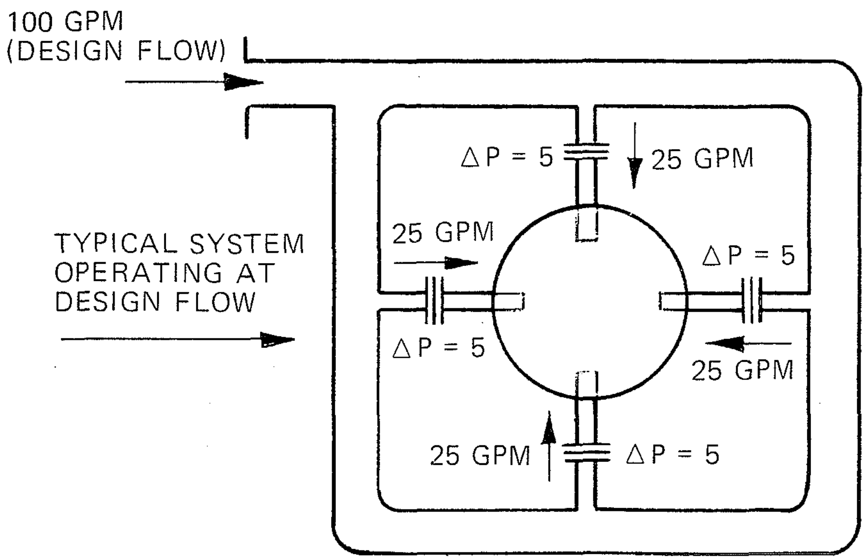
P_{MS} = MAXIMUM MAINSTREAM PRESSURE

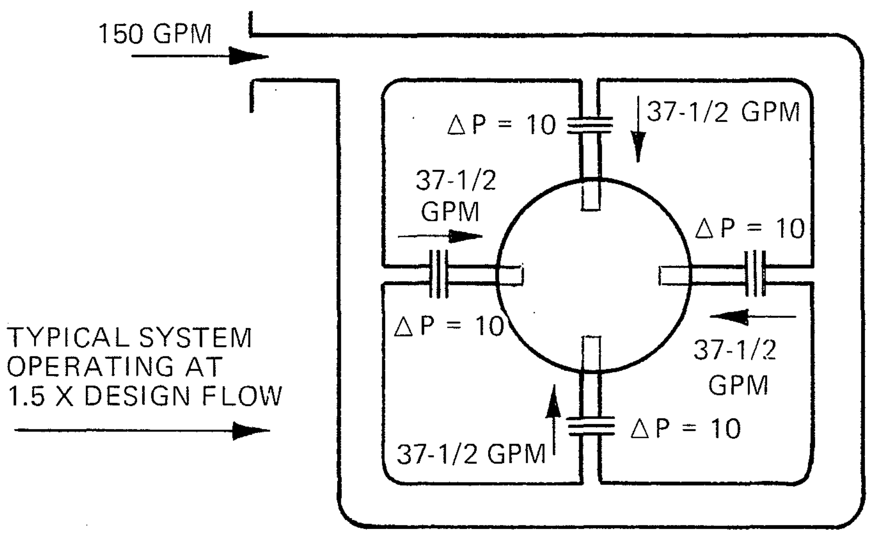


The diameter of the orifice should be sized to provide a pressure drop across the orifice plate, ΔPo, of 5 psi at the design flow rate thru each port. If an unequal flow distribution occurs, the port with the greater flow will have a $\Delta Po >$ 5 psi and the port with the lesser flow will have a $\Delta Po <$ 5 psi corresponding to the differential flow. The flow will automatically redistribute until Δ Po = 5 psi for each port.

Note: Δ Po = 5 psi will effectively insure an even flow distribution for changes in process throughput of $\pm$ 50%.

For systems whose throughput variations are greater than $\pm$ 50%, Δ Po < 5 psi at design flow will provide acceptable automatic control of distribution without causing excessive Δ P at design flow + 50%.





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