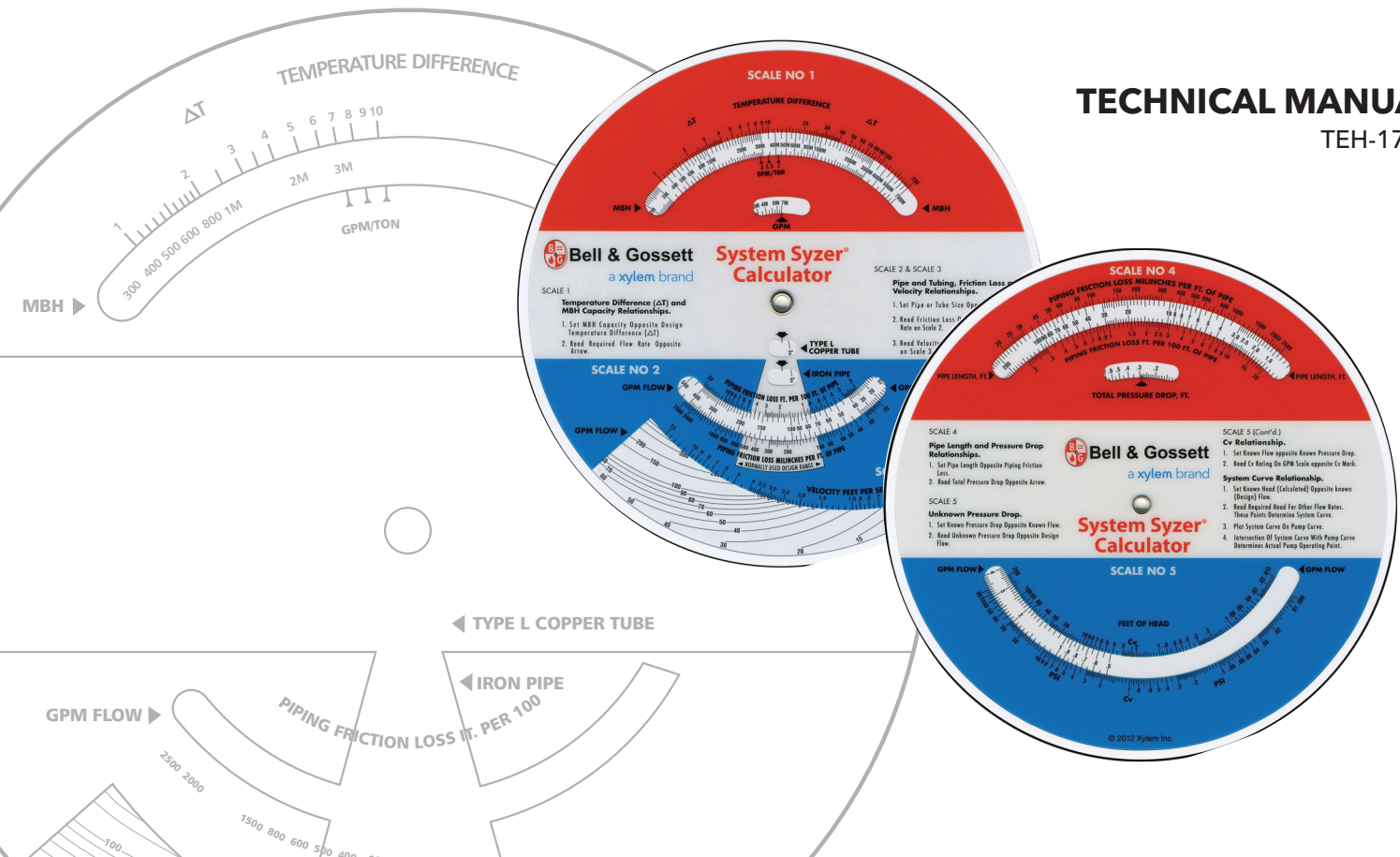




System Syzer® Calculator Instruction Book



Bell & Gossett
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NOTE:

Pump curves and other product data in this bulletin are for illustration only. See Bell & Gossett product literature for more detailed, up to date information. Other training publications as well as the Bell & Gossett design tools described in this booklet including the System Syzer, analog and digital versions, and ESP Plus are all available from your local Bell & Gossett representative. Visit www.bellgossett.com for more information or contact your Bell & Gossett representative.

Introduction

The determination of design data for Hydronic Systems is relatively simple. Often, however, an engineer must consult several different design tables, charts, and formulae to establish GPM flow requirements, pipe size, pipe pressure drops, relative water velocities, pumping heads, system curves, control valve Cv ratings, etc. The B&G System Syzer Calculator consolidates all necessary design information in a simple, easy to use circular slide rule.

The System Syzer Calculator is useful both in final design work and in preliminary system planning. Proposed pump and pipe sizes can be quickly roughed out for estimating purposes.

The System Syzer Calculator has five scales sequenced in the same way in which they would typically be used in designing a Hydronic System. The following states the reference base of the various scales and illustrates their uses with design examples.

Scale #1 - Load / GPM Relationships

Scale #1 is stated in terms of temperature difference, MBH and GPM. These terms are defined as follows:

- A. Temperature difference is the temperature drop (heating) or temperature rise (cooling) taken by the water as it flows through the system.
- B. MBH is a statement of heating or cooling load in Btu per hour where 1 MBH = 1000 Btu per hour; 10 MBH = 10,000 Btu per hour; 1000 MBH = 1,000,000 Btu per hour or 1M as indicated on scale #1.
- C. GPM is the circulation rate in gallons per minute required to convey the design Btu load at design temperature difference.

GPM flow rate, temperature difference and MBH load are related by the following formula:

Heat conveyed in Btu/Hr = Fluid Flow in lbs/hr x temp. diff.
or:

$$\text{Btu/Hr} = \text{GPM} \times \frac{\text{lb.}}{\text{gal.}} \times \text{Sp.Ht.} \times \frac{60 \text{ min.}}{\text{hr.}} \times \Delta T$$

$$\text{GPM} = \frac{\text{Btu/Hr.}}{\text{lb/gal} \times \text{Sp.Ht.} \times 60 \text{ min/hr} \times \Delta T}$$

Scale #1 has been established using a specific heat equal to one and considering water density at 8 1/3 lbs. per gallon (60°F conditions). These values have been employed in hydronic system design since its inception. For 200°F water, the rate of heat conveyance decreases slightly (on the order of 2%) because of reductions in the density and specific heat. This is not normally taken into account, however.

Example #1: Determine required GPM flow rate for a load of 150,000 Btu per hour at a temperature drop of 30°.

Set the 150 MBH capacity in the large window under the 30° design ΔT. Read GPM flow rate in the small window opposite the arrow: 10 GPM.

Example #2: Determine required GPM flow rate for a cooling load of 20 tons at a 10° temperature rise. At 12,000 Btu per ton, a 20 ton load is equivalent to 240,000 Btu per hour or 240 MBH.

Set 240 MBH opposite 10° temperature difference and read 48 GPM on the GPM scale.

Design Temperature Difference: For many years, most hot water systems have been designed for a 20° temperature drop. Basically, this has been done because at a 20° temperature drop, each GPM circulated conveys 10,000 Btu/Hr. This allows simple determination of flow rates by use of the following formula:

$$\text{GPM} = \frac{\text{Btu/Hr.}}{10,000}$$

While the 20° design temperature drop is still valid for the small hydronic system, it is not necessarily best for the larger engineered system. Higher temperature drops permit lower flow rates, smaller pipe and pump sizes and in general return economic benefits.

Scale #1 of the System Syzer Calculator will assist the hydronic designer in establishing minimum flow - maximum temperature difference system design through the various design approaches now available. These include primary-secondary pumping, coil re-circuiting, terminal unit flow evaluation, etc. Because of the simplicity of determining flow rates for various temperature differences, the System Syzer Calculator will aid greatly in the design of higher temperature difference systems.

Example #3: Determine primary to secondary flow rate for a secondary zone using a heat injection pump as illustrated in Figure 1.

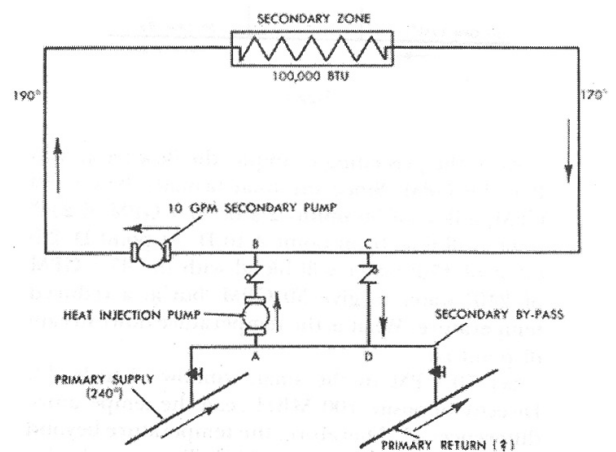


Figure 1

The secondary zone requirements are for 10 GPM of 190° water at a 20° ΔT to provide the zone requirements of 100,000 Btu. 240° water is available at the primary supply main. At design load conditions, the required quantity of 240° water must flow from point A to point B. An equal quantity of 170° water must flow from point C to point D. The temperature difference between point A and point of 70° (240°-170°) and the 100,000 Btu required for the secondary zone determine the flow required from the primary to the secondary.

On scale # 1 of the System Syzer Calculator, set 70° temperature difference opposite 100 MBH. Read the required primary to secondary flow rate: 2.9 GPM. The heat injection pump should be sized to deliver 2.9 GPM against a head determined by circuit A-B-C-D.

Example #4: Determine the temperature drop in the primary main of a one-pipe primary system with a circulation rate of 50 GPM, after supplying a 100,000 Btu secondary zone as illustrated in Figure 2.

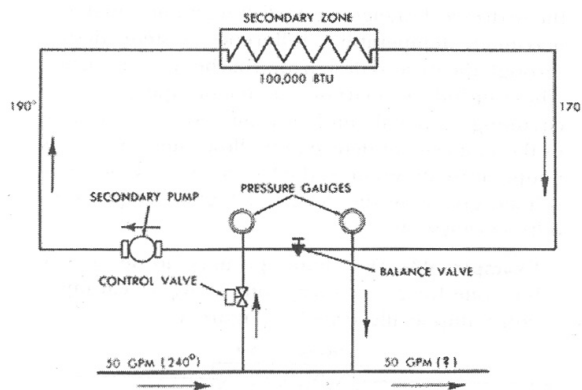


Figure 2

As in the preceding example, the flow from A to B is 2.9 GPM. Since the total primary flow is 50 GPM, a flow of 50 minus 2.9 or 47.1 GPM of 240° water will flow from point A to D. At point D, 2.9 GPM of 170° water will blend with the 47.1 GPM of 240° water to give 50 GPM, but at a reduced temperature. What is the temperature downstream of point D?

Set 50 GPM in the small window of scale #1. Directly opposite 100 MBH read the temperature difference: 4°. Therefore, the temperature beyond point D is 240° minus 4° = 236°. (For control valve selection see Scale #5 – Example 3).

Scale #2 – Flow-Pressure Drop Relationships and Pipe Sizing

Scale #2 relates GPM flow rate to friction loss for both type "L" copper tubing and for schedule 40 steel pipe. Friction loss is stated in terms of milinches per foot and in feet per 100 feet of pipe. Either milinches per foot or feet per 100 feet are valid expressions of pipe friction loss. Defining these terms:

A. Milinch means 1/1000 of an inch or 1/12,000 of a foot of pressure energy head. Milinches per foot have been used for many years as the base for pipe friction loss. Many engineers, however, prefer the use of feet per 100 feet as a measure of friction loss.

B. Feet per 100 feet establishes the rate of pipe friction loss as being foot head of energy loss per 100 feet of pipe.

The pipe friction loss data used as a basis for construction of scale #2 are The Hydraulic Institute Values, The ASHRAE-Giesecke Chart Values and The ASHRAE Unified Pressure Drop Chart data. Both the Hydraulic Institute values and The ASHRAE Unified Pipe Pressure Drop data are based on Moody's pipe pressure drop correlation. Though established by an entirely different experimental approach, the Giesecke Chart values closely approximate Moody's correlation – generally accepted as most valid.

Scale #2 is based on a water temperature of 60° and therefore is actually designed to chilled water usage. When used for hot water design with temperatures in the area of 200° piping pressure drop is over-stated on the order of 10% since pressure drop decreases slightly as water temperature is increased. However, the difference is not of sufficient order to warrant correction.

Friction loss indicated for type "L" copper tubing has been derived from ASHRAE Guide and Data Book information.

The normally used range of pipe friction loss is indicated by a white band on scale #2. Experience indicates that the optimum friction loss range is from 100 to 500 milinches per foot or from approximately 1 foot to 4 feet per 100 feet of piping.

Example #1: Determine pipe size for 70 GPM flow rate. Set the rule so that 70 GPM appears in the "white" or optimum design opening on the rule. It is apparent that either 2 1/2" or 3" pipe can be used. Setting the arrow to 2 1/2" pipe size in the iron pipe window, a pipe friction loss rate of 440 milinches per foot, or 3.7' per 100' are read opposite 70 GPM. A simultaneous reading on scale #3 establishes that at 70 GPM flow rate a water velocity of 4.6' per second will occur.

Setting the rule to 3" pipe illustrates that at 70 GPM flow rate a pipe friction loss rate of 150 milinches per foot or 1.3' per 100' will occur. A simultaneous reading on scale #3 indicates a water velocity of 3.1' per second.

Setting the rule to any pipe size then provides a complete flow-pressure drop-velocity relationship for that particular pipe size.

In the example, either 2 1/2" or 3" piping, could be used for the flow rate of 70 GPM, depending on circuit needs, available pumping head, etc. In many cases, the hydronic system designer may also wish to evaluate water velocity as this affects pipe sizing.

Scale #3 – Water Velocity Considerstions

Scale #3 establishes water velocity in feet per second for any given flow rate through the particular pipe size, or tubing size shown. Water velocity in the hydronic system should be high enough to carry entrained air in the water stream-yet not so high as to cause noise problems.

Water velocity should be above 1 1/2 to 2 feet per second in order to carry entrained air along with the flowing water to the point of air separation (Rolairtrol, IAF, Airtrol Boiler Fitting, etc.) where the air can then be separated from the water and directed to the compression tank.

Piping noise considerations establish the upper velocity limitations. For piping 2" and under a maximum velocity of 4 feet per second is recommended. It will be noted that in the smaller pipe sizes, this velocity limitation permits the use of friction loss rates higher than 500 milinches per foot or 4 feet per hundred foot.

Velocities in excess of 4 feet per second are often used on piping larger than 2 inch. It seems apparent that water velocity noise is caused by entrained system air, sharp pressure drops, turbulence, or a combination of these which in turn cause cavitation and consequent noise in the piping system.

It is generally accepted that if proper air control is provided to eliminate air and turbulence in the system, the maximum flow rate can be established by the piping friction loss rate; at 4 feet per 100 foot or 500 milinches per foot. This permits the use of velocities higher than 4 feet per second in pipe sizes 2" and larger.

Example #1: An express main in an apartment building has a design flow rate of 1600 GPM. Select the proper pipe size.

Setting scale #2 at 8" pipe illustrates that at 1600 GPM, the pipe friction loss is 450 milinches per foot or 3.7 feet per hundred feet. Scale #3 shows that a water velocity in excess of 10 feet per second will result.

Setting the rule at 10" pipe illustrates a pressure drop of 150 milinches per foot or 1.25 feet per 100 foot and a water velocity of 6.5 feet per second.

Because the main must be run adjacent to living quarters, a critical location concerning possible noise generation, the 10" pipe size is selected.

Scale #4 - Circuit Piping Pressure Drop

Scale #4 provides a simple method of determining required pump head from the equivalent circuit piping length and the

resistance per unit length. To use scale #4, it is first necessary to establish the total equivalent length (TEL) of the piping circuit to determine the required pump head. As all fittings have a greater resistance to flow than a straight length of pipe, this must be taken into account. TEL is a summation of the straight lengths of pipe plus the equivalent length of valves fittings, etc.

In preliminary pipe and pump sizing, it is common practice to consider the resistance of fittings in a circuit to be a percentage of the straight length of pipe (usually 50%). In making a more accurate pressure drop calculation, the actual resistance of each fitting should be considered. The table on the back of the System Syzer Calculator envelope indicates the equivalent length of most commonly used fittings.

Example #1: A circuit flowing 200 GPM is sized at 4" providing a friction loss of 275 milinches per foot or 2.3 feet per 100 feet. The circuit has a TEL of 130 feet. What is the total circuit pressure drop?

Set 130 foot pipe length opposite 270 milinches per foot (2.3 feet per 100 feet) and read 3 feet as the total circuit pressure drop.

In some instances, the system designer may wish to make a preliminary pump selection and proportion its available head over the longest circuit in the system to determine the average resistance per foot on which the piping should be sized.

Example #2: A designer has selected a pump with an available head of 50 feet at the design GPM. The longest circuit in the system has a TEL of 1500 feet. At what resistance per foot should the piping be sized?

Set 50 foot head opposite the arrow. At the TEL of 1500 feet, a resistance of 400 milinches per foot or 3.3 feet per 100 feet is indicated.

Scale #5 - Determining Unknown Pressure Drops, System Curves and Control Valve Cv ratings.

Scale #5 is based on the relationship which exists between flow and system resistance wherein the head varies approximately as the square of the flow.

$$\frac{H_1}{H_2} = \left(\frac{W_1}{W_2} \right)^2 \text{ where}$$

W1 = original flow H1 = original head

1% = linum flow H: = final head

Scale #5 can be used in three ways: to determine an unknown pressure drop from a known pressure drop, to establish system curve relationships and to select control valves to their Cv ratings.

To determine unknown pressure drop from a known pressure drop condition, set the known pressure drop opposite tile known flow and read the unknown pressure drop opposite the design flow.

Example #1: From manufacturers data, a chiller has a pressure drop of 12 feet, at a flow of 100 GPM. Determine pressure drop at a design flow of 150 GPM.

Set 100 GPM in the window of scale #5 immediately below 12 feet of head. Read the unknown pressure drop at 150 GPM: 27 feet.

To establish a system curve, set the known (calculated) head opposite the known (design) flow. Read the required head for several other flow rates. These points determine a system curve. Plot the system curve on a pump curve. The intersection of the system curve with the pump curve determines the actual pump operating point (on open systems, adjust the system curve in accordance with the total static head).

Example #2: Through a closed loop piping system, calculations indicate that a 200 GPM flow rate establishes a 30 foot pressure drop. Calculate the resistance at several other flow rates, plot a system curve on the pump curves illustrated below and determine their actual operating points.

Set 200 GPM in the window below 30 foot head. Read the resultant head at 100, 150, 250 and 300 GPM.

GPM	FOOT HEAD
100	7.5
150	17
200	30
250	47
300	68

These points establish the system curve for the particular system. The system curve is illustrated below, plotted on the pump curves.

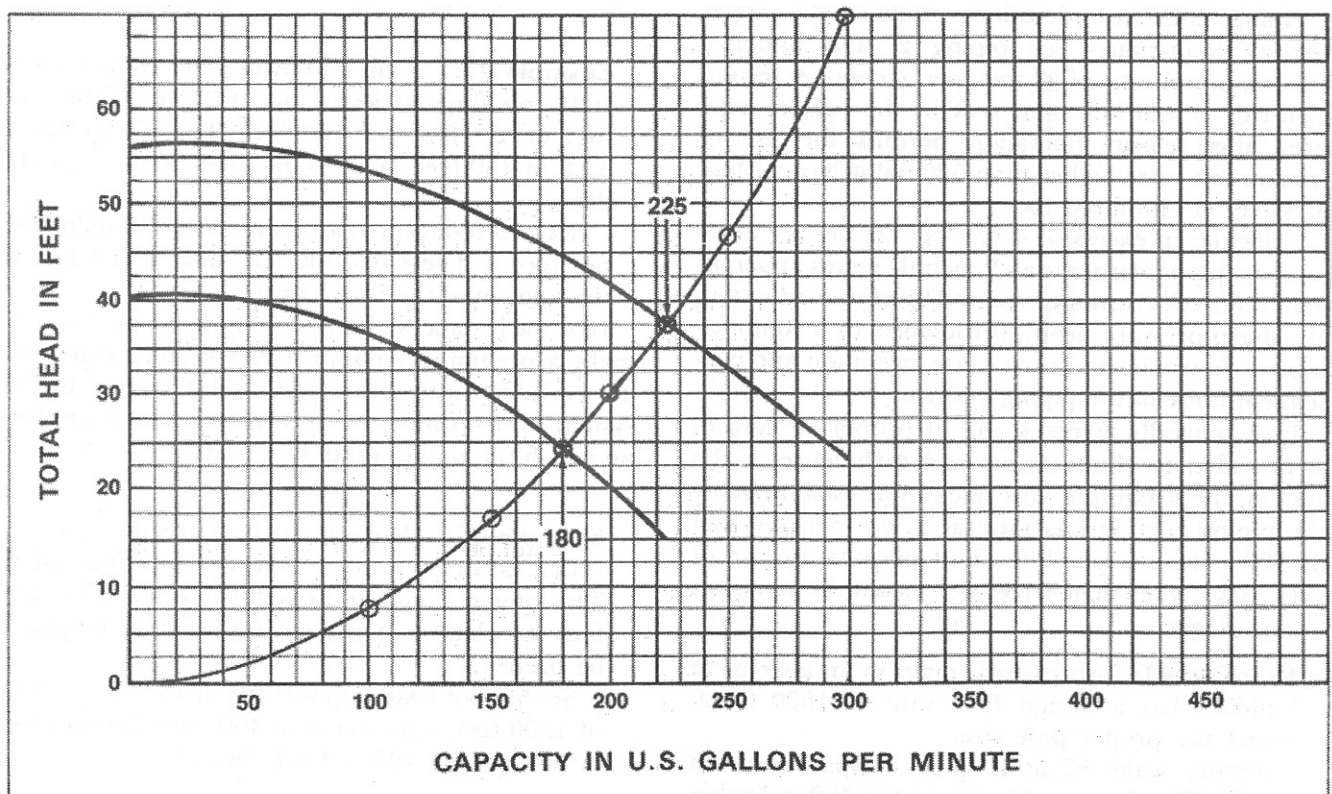


Figure 3

The operation of the pumps on the piping circuit described by the system curve, must be at the intersection of the pump curves with the system curve. This is because of the first law of thermo-dynamics – energy in must equal energy out. Energy put into the water by the pump must exactly match the energy lost by the water as it flows through the piping system. The point of intersection is the only point that can meet this basic engineering law. The specific points of operation for the two pumps illustrated are 180 and 225 GPM. (See Fig. 3).

The application of pumps in parallel always requires a system curve – pump curve analysis. When pumps are placed in parallel (Fig. 4) each pump operates at the same differential head and each supplies 1/2 the total system water flow. A parallel pump curve can be developed by doubling the flows at a constant head for the single pump curve (Fig. 5).

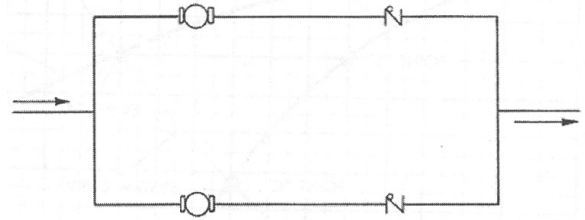


Figure 4 - Parallel Pumps

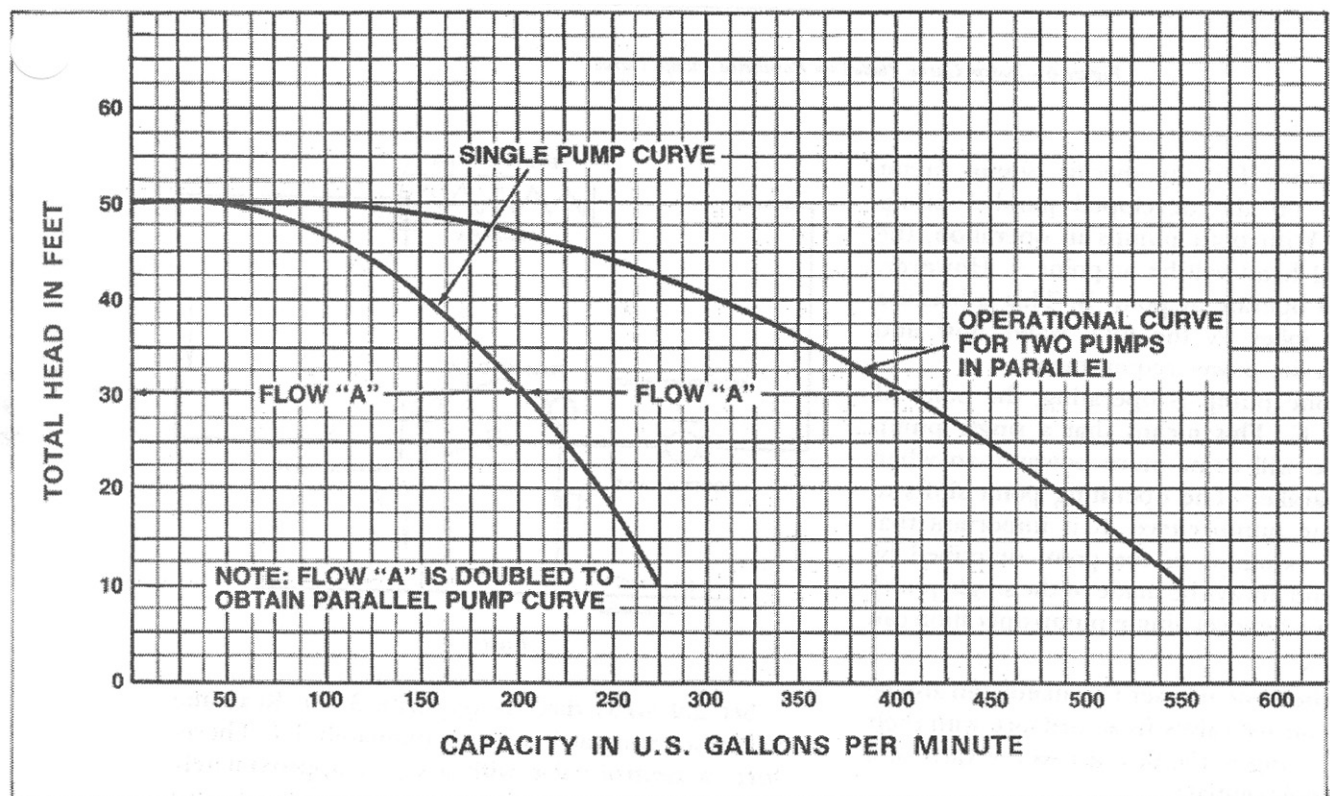


Figure 5 - Parallel Pumps Curve

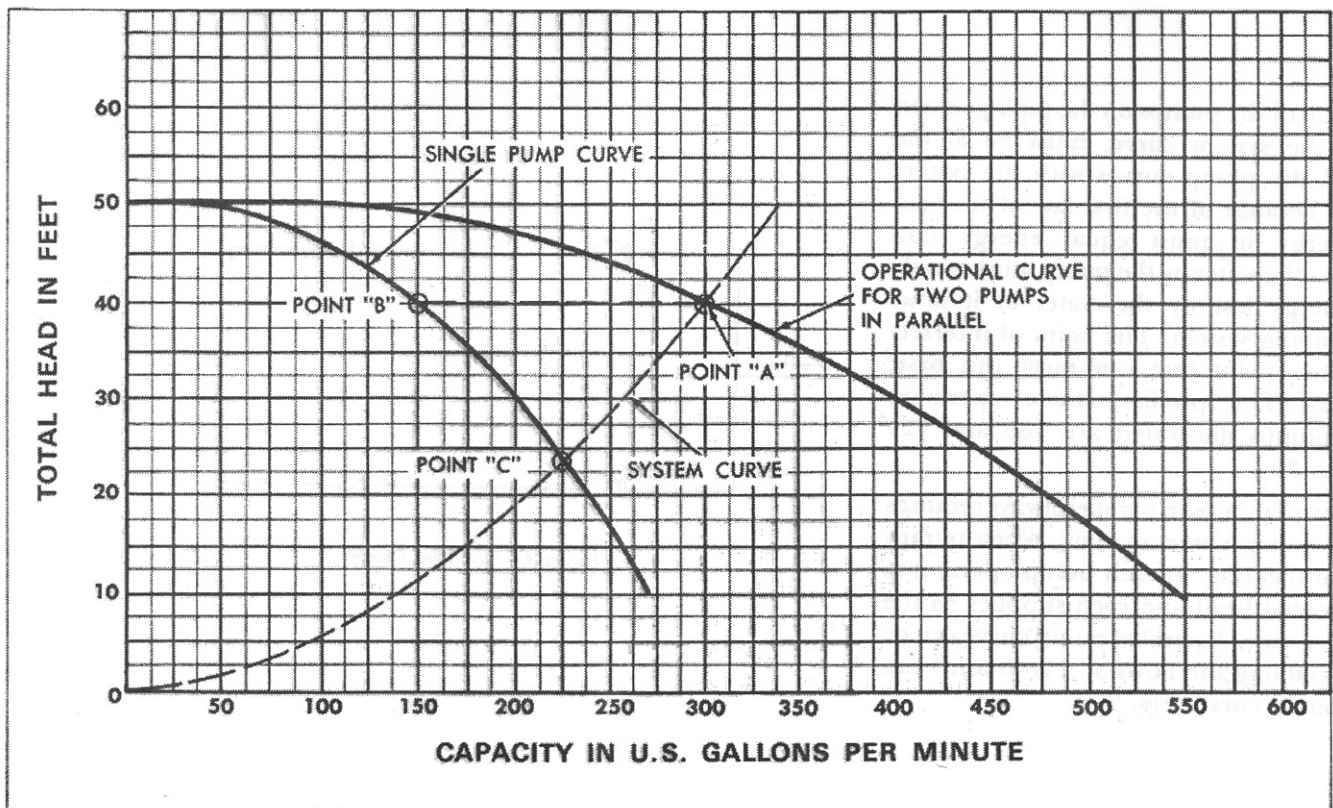


Figure 6 - System Curve Plotted on Parallel Pumps Curve

The systems curve for any specific piping circuit can be plotted on the developed parallel pump curve (Fig. 6). With both the pumps in operation, the system flow and head will be at point A. However, each pump will operate at point B. This is because each pump supplies 1/2 the total water flow and consequently 1/2 the power requirement.

When only one pump is operating, the point of operation is at C. This means that a single pump, operating alone will draw more power than when operating in parallel: The operating point shifts to the right on the pump curve. It is important that each pump be powered to the point described by C. Analysis would always be made of the single pump operating point whenever single pump operation can be expected.

Scale #5 of the System Syzer Calculator can also be used to select control valves in accordance with their Cv rating (Cv rating = the flow across the valve at a 1 psi pressure differential).

Example #3: A control valve for use with a secondary zone as illustrated in Fig. 7 is to be selected for a 3 psi. differential at a 2.9 GPM flow. Determine the control valve's Cv rating.

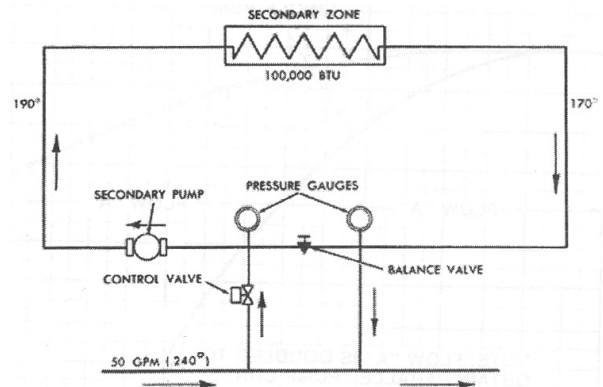


Figure 7

Set 2.9 GPM directly opposite 3 psi. Read the valve Cv rating at 1 psi: approximately .7. Therefore, a control valve with a Cv of approximately 1.7, should be selected, and with the control valve open and the secondary pump on, the pressure drop across the balance valve (See Fig. 7) should be adjusted to 3 psi. This will set the flow into the secondary zone to the design point of 2.9 GPM.

xylem
Let's Solve Water

Xylem Inc.
8200 N. Austin Avenue
Morton Grove, Illinois 60053
Phone: (847) 966-3700
Fax: (847) 965-8379
www.bellgossett.com

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