TECHNICAL MANUAL
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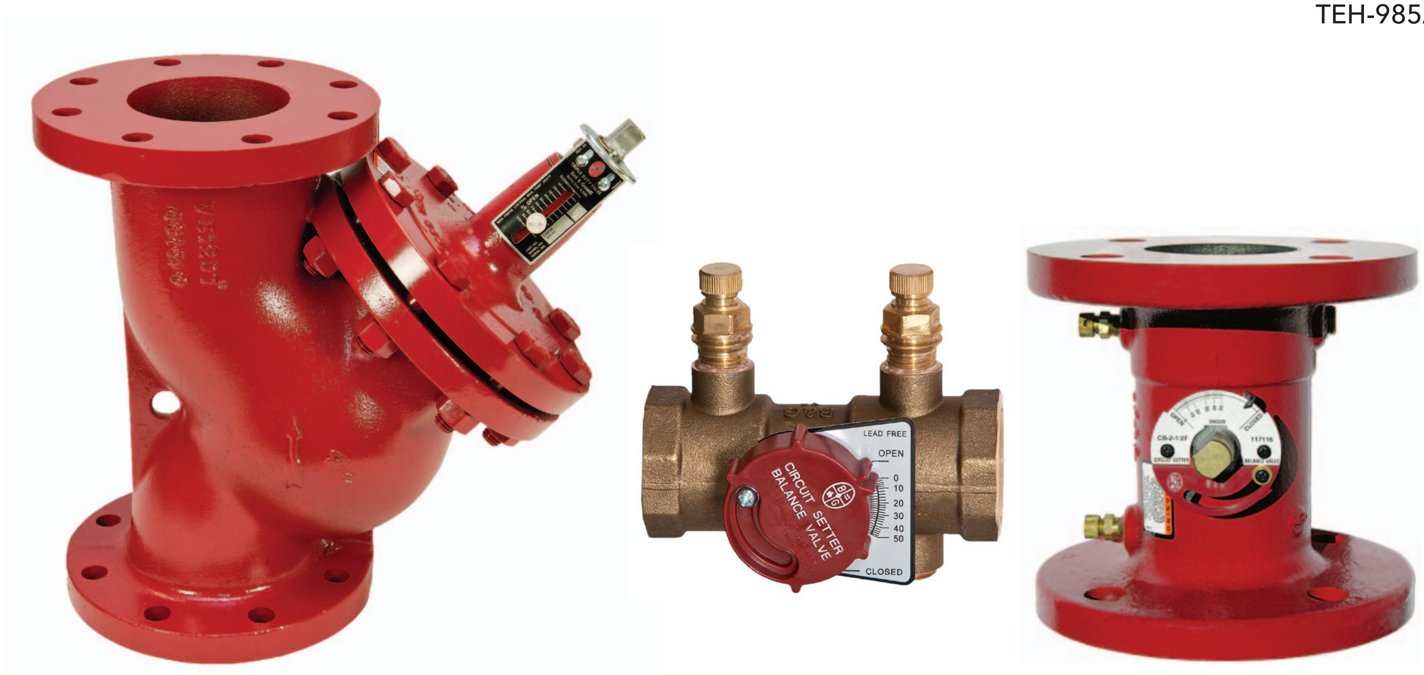

Circuit Setter® Valve Balance Procedure

Bell & Gossett
a xylem brand

This Manual is divided into four sections.

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BALANCE PROCEDURE EVALUATION

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CIRCUIT SETTER VALVE BALANCE PROCEDURES

HISTORICAL BACKGROUND

Hydronic system water side specifications have always stated: "the system shall be balanced". Until recently, however, there was no real attempt to enforce this specification. There was no truly applicable procedural balance outline - and a final balance "report" was not called for. Thus, for many years, Hydronic systems have been simply started without any real attempt at water side balance and they have either initially worked or they have not.

Strong inherent safety factors* most often established an operable system that initially worked in spite of many obstacles including minimal or no actual mechanical balance work.

The lack of a balance report specification and the usual repetitive satisfactory hot water "balance" experience combined with competitive bidding practice forced most Mechanical Contractors to eliminate funding for water side balance as a part of their bid.

The problem was and is, however, that balance and other problems can appear. Some systems did not work and Mechanical Contractors were occasionally driven to the brink of bankruptcy because of:

1. A lack of balance- bid funds.
2. No procedural direction in terms of defining and solving the real problem - whether balance or one that only <u>appeared</u> to be a balance problem.
3. A lack of informational balance tools.

B&G's efforts to help under these circumstances over a period of many years has helped develop background for the procedures later provided in this discussion.

**See article reprints - <u>HYDRONIC SYSTEMS: Analysis and Evaluation</u> - ASHRAE Journal, October, November, December, 1968 and January, February, March, 1969.*

RECENT BACKGROUND

During recent years Consultant designed Hydronic Systems have changed from almost all hot water to dual temperature or combination hot and chilled or to chilled only. A large measure of inherent safety factor was lost by this change - increasing balance problem intensity.

Water side balance problems have also been increased by a simple system size increase; the number of circuits per system have increased thus increasing short circuit possibilities.

In sum and substance, water side balance trouble potential increased while protective balance procedures and report requirements remained virtually non-existent. The problem area was recognized by AABC** who have provided balance procedures and report requirements intended for total system balance; the air side and its necessary complement, the water side.

AABC balance procedures are presently stated to water temperature difference measurement as the basis for water side balance.

WATER SIDE BALANCE BY TEMPERATURE DIFFERENCE

Most balance procedure methods developed to date have been based on water temperature difference measurement. This is because of its seemingly logical relationship to terminal unit selection methods.

TO ILLUSTRATE:
The consultant selects cooling terminal equipment for a calculated sensible and latent design load. When air handling coils are selected, the air side load is carried by design load CFM based on design entering and leaving air DB and WB conditions. The coil size selected will be based on air side requirements projected against a specified inlet water temperature and a proposed water temperature rise. The water temperature rise is translated to GPM for the applied load. Coil pressure drop can now be determined based on the proposed design GPM.

***Associated Air Balance Council*

CIRCUIT SETTER VALVE BALANCE PROCEDURES

Since the coil selection is based on a design water temperature difference, a conceptually simple (but often false) balance premise seems evident:

"Design GPM will be provided when design water temperature rise is set".

This usual premise for water side temperature difference balance is generally invalid because it overlooks a most basic engineering relationship; load balance input must equal output.

The measured water side temperature rise across any specific coil must be a function of water flow rate and the applied air side load at the time of measurement. Water side load will and must equal air side load. The load balance relationship states that:

1. Setting of design water temperature rise will only provide design GPM when air side loading exactly matches design; a very improbable circumstance.
2. Setting of design water temperature rise cannot establish design GPM when air side loading differs from design; the usual circumstance.
3. Water side balance by temperature difference measurement can only be established by:
   a) Measurement of the true applied load at the time of balance and determination of the ratio between applied and design load.
   b) Water temperature difference setting to a ratio adjusted difference; if applied load is 50% design, a design 10° ΔT would be "balance set" to 5° water temperature difference for the design GPM balance point.

WATER SIDE TEMPERATURE DIFFERENCE BALANCE ACCURACY

While structured from a theoretically sound base, the load correlated temperature difference balance method (3) has significant practical limitations. Meaningful results will only be established by absolutely precise differential measurements. Since the working differentials are of minor order, seemingly inconsequential instrumentation or read-out error may invalidate results because of compounding error introduction.

TO ILLUSTRATE:

If the actual accuracy of thermometer read-out is $\pm$ 1/2°, the actual temperature rise could be either 4° or 6°– even though a 5° rise is observed and recorded. Actual flow rate could then vary somewhere between 83 to 125% of design even though the applied load is precisely determined.

It is difficult, however, to estimate the actual applied instantaneous air side load with precision. Actual air side flow rates may only have an accuracy order of $\pm$ 10% while the necessary WB measurements can be affected by stratification and by instrumentation and read-out error.

Temperature difference balance procedures could provide actual flow rates varying from 60% to 175%* of design under circumstances of actual 50% load operation when the air flow is estimated at $\pm$10% accuracy with $\pm$1/2° read-out accuracy applied to both the WB and water side thermometers.

The order of flow balance accuracy finally attained will be greatly affected by the compound errors introduced and as affected by precision read-out capability and care.

Flow balance accuracy will also be affected by the inter-dependence of balance points; each time any balance valve is adjusted all other previously balanced coils will be affected. This means that several round trips will have to be provided to obtain a maximized accuracy (each balance point adjusted several times). Even so, the order of accuracy will and must be sharply limited because of compounded error introduction.

**The order of accuracy indicated is not intended to represent actual temperature difference procedure accuracy range. The actual accuracy range cannot really be defined since this is a function of both controllable and uncontrollable circumstance; instrument calibration, read-out care, stratification, water side thermal bulb resistance, system load stability, etc. Actual accuracy may be a great deal less than illustrated and, at times, greater.*

The inherent problem proposed by temperature difference water side balance procedures is that minimal results are obtained at maximum cost. Results are minimal in terms of definable accuracy, while costs are high due to the necessity for several visits to each coil and the labor time consumed for WB and water temperature read-outs at each working visit.

WATER AND AIR SIDE BALANCE CORRELATION; B&G VIEW POINT

There is only one reason for the cost and effort required for a final water side balance report; the owner, consultant and contractor want sure knowledge that each terminal heat transfer unit is provided with a flow rate equal to or greater than design requirements. The system should not be expected to work "in spite of" flow rates that may be considerably less than design – even though reported at full design. This condition may well occur with any temperature difference water side balance procedure because of inherent accuracy limitations and would be most especially true for temperature difference balance carried out without an accurate air side load reference.

Separate balancing of the air and water sides of the system will increase the accuracy of the final balance report and reduce system balance costs.

CIRCUIT SETTER VALVE BALANCE PROCEDURES

The air and water side balance functions can be separated because a properly- sized coil must have design load capability when:

1. **Design CFM** is provided at design entry DB and WB conditions.
2. **Design GPM** is provided at design entry temperature.

**Many systems operate "in spite of" low flow rates relative to design. This is because of inherent safety factor. See Article reprints.*

The need for great accuracy can be questioned, except when the function of the final balance report is defined. The final balance report should be an analysis tool used to determine the final adequacy of water side operation. Unless accurate, it is useless.

The water side balance procedure should be aimed at direct GPM determination. This balance approach can have high accuracy because of elimination of the compounding errors introduced by temperature difference procedures. Direct GPM balance procedure accuracy will only be effected by accuracy of the water side balance instrumentation.

The separated water side balance procedure must reduce balance costs because:

1. It provides a reliable pre-set balance procedure ... thus reducing field balance labor costs (see page 8).
2. It eliminates the costly aggravation caused by the "temperature difference" balance requirement that air side balance be provided before water side balance can take place.
3. It eliminates need for many of the thermometers and wells now employed for temperature balance. These thermometers and wells can establish a high summation cost and seem, in actual practice, relatively useless ornaments when a real trouble problem appears.
4. Finally to be considered are the relative degrees of complexity and reliability involved in the two methods; temperature difference vs. GPM water side balance.

Temperature difference balance requires extraordinary capability (air to water side integration). Even so, results may have limited meaning because of the improbability of being able to determine exact system load conditions at the time of system balance. Thus, data obtained may be so unreliable as to cause rather than prevent trouble.

Water side GPM balance procedures will be more accurate, by comparison. They require only that field personnel have instrument read-out and reporting capability. This is true because their work will be basically supervised by report analysis aimed at trouble interception.

WATER SIDE BALANCE PROCEDURES AND COST

Workable Hydronic System water side balance can be achieved by any of several different procedural methods. There is a great difference, however, between a "workable" balance procedure as compared with an engineered procedure. The difference is basically stated by satisfactory results and cost; the comparative cost of achieving balance as well as final comparative year-to-year system operating cost. The engineered balance procedure will establish maximum performance at minimum cost in both instances.

A WORKABLE BALANCE PROCEDURE; FLOW METER AND BALANCE VALVE

Flow balance can be achieved in the water system by use of a flow meter and separate balance valve in each flow circuit. The approach is simple and direct; the circuit balance valve is adjusted until design flow rate is read on the circuit flow meter.

It is well known, however, that each time any one circuit balance valve is adjusted, flow rate through all other circuits will be changed ... including those circuits which had been previously adjusted. By the time the last circuit has been adjusted to design flow, the first circuit must be re-adjusted. A large multiple circuited system usually requires a minimum of three (3) "round-trips"; with each flow measurement point needing several separate work periods for meter read-out and valve adjustment. This means that direct field labor cost must be of very high order and will be virtually impossible to accurately estimate.

The initial high cost of separate flow meters and balance valves will be reduced by the combination flow meter and balance valve function of the B&G Circuit Setter Valve. The disadvantage of a high and difficult to estimate direct labor cost will remain, however, as with any read and set flow meter procedure. Pumps are often specified for more than actual required head. There are several reasons for this:

1. The design engineer does not have sure knowledge as to the specific chiller, terminals, etc., that will finally be used; his head selection must be based on highest pressure drop possibilities even though lower pressure drop units may be actually installed.
2. Safety Factor; the engineer may want to provide excess head to insure more than adequate terminal flow rate capability.*
3. The pump head estimation may be excessive because of use of improper piping pressure drop data.*

System operating cost must and will be increased by "read and set" procedure since excess head will be absorbed by the balance valves.

**Safety factor head should not be applied to Hydronic Systems and the systems should be designed to "clean" pipe pressure drop data; Hydraulic Institute or B&G System Syzer. Reasons are established in a B&G article reprint "How to Save Pumping Power" HPAC, Jan.. 1968.*

CIRCUIT SETTER VALVE BALANCE PROCEDURES

Use of the "read and set" procedure establishes that excess head will be absorbed by the balance valve; terminal flow rate will not be "safety factor" increased. If a 100 ft. head pump were used for an actual 50 ft. head need, the "read and set" procedure must establish that 50 ft. excess head will be absorbed by the system balance valves. System pump operating cost, in this case, would be to the order of twice than actually needed while trouble potential due to noise and excess head would be increased.

The "read and set" balance procedure thus has the following inherent disadvantages:

1. Accurate field labor cost estimations are virtually impossible.
2. A high field labor cost is insured.
3. A high year-to-year operating cost can result because of excess pump head.
4. A high potential for noise and control problems is established by excess pump head.

THE ENGINEERED BALANCE PROCEDURE; PRE-SET BALANCE

The pre-set balance procedure reduces balance cost because of a major reduction in field labor cost. A simple office supervised analysis defines the degree of unbalance existing in each circuit. Calibrated balance valves can then be "pre- set" to balance requirements, even before the system is filled with water. Given a nominally accurate analysis and open non-plugged piping, the system will be in proportional balance when the pump is started. Flow meter readings can then be taken at selected points for several reasons:

1. To verify flow rate and system balance.
2. To locate possible pipe blockage.
3. To assess the degree of over-pumping and to establish parameters for possible reduction of pump head with a resultant decrease in noise and control trouble potential. This will also establish lowest system pump operating costs.

It will be noted that a major difference between the "read-out and set" and the "pre-set" procedure is a transfer of cost from a lengthy indeterminate field time requirement to a much shorter time need in the more easily supervised office.

THE CIRCUIT SETTER VALVE
A TOOL FOR ENGINEERED PRE-SET BALANCE

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THE CIRCUIT SETTER VALVE
A TOOL FOR ENGINEERED PRE-SET BALANCE

NEW CIRCUIT SETTER PLUS

The new CIRCUIT SETTER PLUS calibrated balance valve is designed to pre-set proportional system balance. This system balance method, developed by B&G, assures optimum system flow balance at minimum pump operating horsepower. Terminal unit balance valves can be simply pre-set using B&G Circuit Setter Calculator and the system piping plan. With this procedure, system balance and start-up time is reduced dramatically. Pump impeller trim after system balance will reduce system horsepower and operating costs to minimum levels.

CIRCUIT SETTER PLUS OFFERS SIGNIFICANT BENEFITS (Calibrated Balance Valves)

1. Proportional Balance Capability
Knowing terminal unit pressure drops and using only the piping plan and B&G Calculators, the required setting of each Circuit Setter Plus calibrated balance valve can be easily determined.

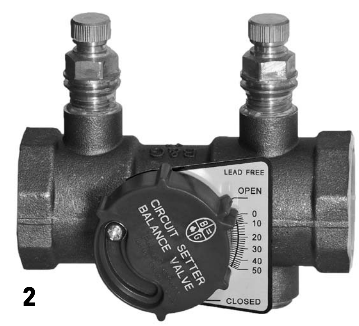
2. Pre-Set Balance
Each valve can be pre-set to the required degree opening for proper balance prior to system startup.

3. Memory Stop
Valve setting can be locked in place. Valve can be closed for service and returned to set position without readjustment.

4. Drain/Purge Port
Valves are provided with a tapped and plugged drain connection. Optional drain valves are available as illustrated.

5. Valved Readout Ports
Built-in check valves facilitate taking gauge readings. Each Circuit Setter Plus calibrated balance valve is a precision flow meter as well as balance device.

1



2

THE CIRCUIT SETTER VALVE
A TOOL FOR ENGINEERED PRE-SET BALANCE

CIRCUIT SETTER VALVE CHARACTERISTICS

The B&G Circuit Setter Plus calibrated balance valve has been designed, manufactured and tested to provide the cost saving advantages of pre-set proportional balance. Such precision is built into the B&G Circuit Setter Valve which is a combination:

1.Precisely calibrated pre-settable balance valve.

2. Precisely calibrated variable orifice flow meter.

3. Drip-tight service valve.

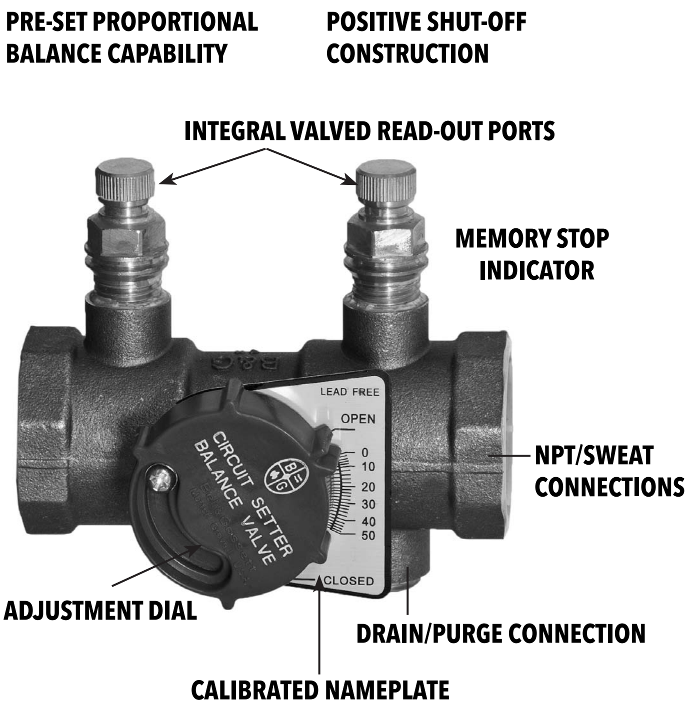


Figure 1
Circuit Setter Valve Characteristics

Circuit Setter precision is established by its method of construction. The valve will maintain settings and has a two-stage pressure reduction which allows greater pressure drops without noise. The Circuit Setter Balance Valve is a precision manufactured, dual purpose balancing instrument, calibrated for use as a pre-settable balance valve and as an adjustable flow meter (Figure 1). Circuit Setter Balance Valves are equipped with integral upstream and downstream pressure taps which are fitted with readout valves. These contain an integral check valve designed to protect the user from being wetted when setting up to use the Circuit Setter Balance Valve as a flow meter.

Valves are furnished with a calibrated nameplate and memory stop indicator which permits the valve to be pre-set to a fixed open position and then closed for service without disturbing the valve setting.

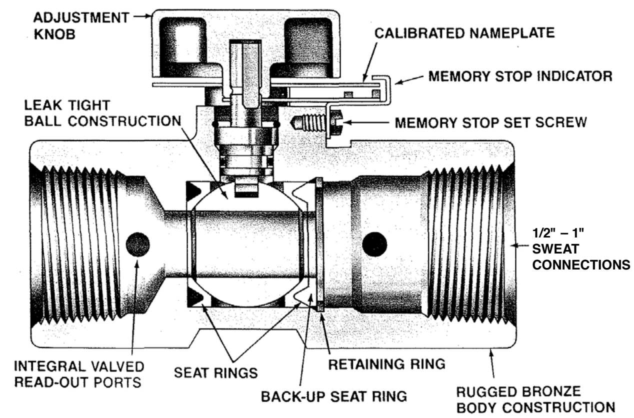


Figure 2
Valve Internal Construction

CIRCUIT SETTER VALVE MANUFACTURING PROCEDURE

The pre-set system balance will not be possible unless each valve of a particular line size has a predictable and reproducible defined calibrated characteristic. The precise orifice setting assures that all valves of a specific size will have similar pressure drop characteristics.

THE CIRCUIT SETTER VALVE
A TOOL FOR ENGINEERED PRE-SET BALANCE

Quality manufacturing and materials provide leak-tight construction and reproducible performance in every valve. The precision machined brass ball is backed up with 20% glass and carbon filled (TFE) seat rings. Valve seats do not distort with extended use. Permanent valve accuracy is assured.

CIRCUIT SETTER TEST & CALIBRATION

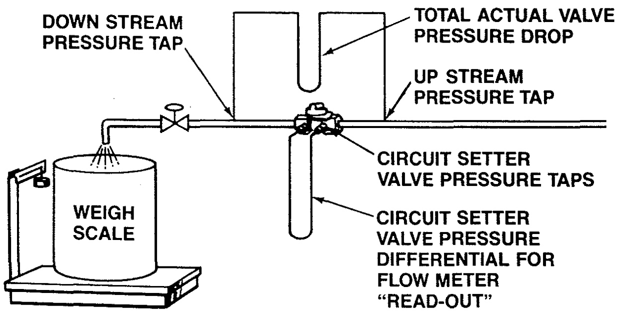


Figure 3
Circuit Setter Test & Calibration

All Circuit Setter Plus Balance Valves are tested and calibrated by means of a weigh scale test procedure. Flow rates and differential pressure readings are taken for all nameplate settings for all valve sizes. Two separate pressure drop readings are taken for each incremental setting. The pressure drop reading across the integral readout valve differs from the pressure drop readings up and downstream because of velocity head recovery. This difference is of sufficient order to require two separate Circuit Setter calibration scales.

BALANCE INSTRUMENTS

1. Readout Kits
Differential pressure meters feature full over-range protection, have readout probes, filters, covering case and Circuit Setter Calculator. They may also be used to check differential pressure across other system components including B&G pumps, suction diffusers, strainers, coils, etc.

Figure 4
Readout Kits

MODEL NO.	SCALE		ACCURACY** ±%
	RANGE*	INCREMENTS	
	FEET OF WATER		
RO-2	0-100	0.5	.5
RO-3	0-16	1.0	1.0
RO-4	0-35		
RO-5*	0-25	0-5 FT @ 1 .25 FT 5-25 FT @ 1.0 FT	3.0
	0-0.7 kg/cm	0.05 kg/cm	

Table 1

Table 1 shows the accuracy of the various RO Meters.

2. Circuit Setter Balance Valve Calculator
The Circuit Setter Calculator is the result of rigorous laboratory tests.

SIDE 1 Plots actual system imposed head loss versus flow for various valve settings. This scale is used for pre-set balance determinations

SIDE 2 Is used when taking gauge readings across the Circuit Setter Balance Valve using the valve as a flow meter.

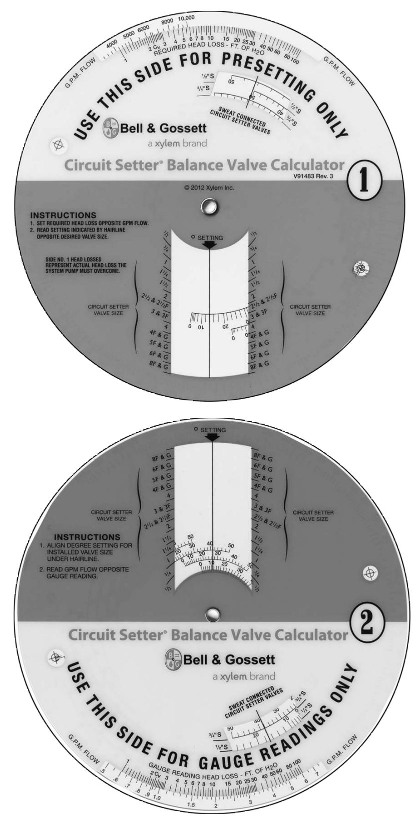


Figure 5
Circuit Setter Balance Valve Calculator

THE CIRCUIT SETTER VALVE
A TOOL FOR ENGINEERED PRE-SET BALANCE

THE FLOW METER CIRCUIT SETTER CALCULATOR APPLICATION

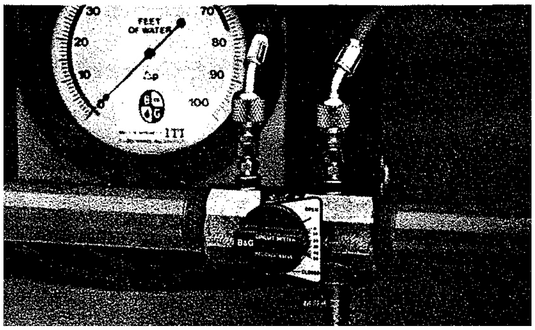
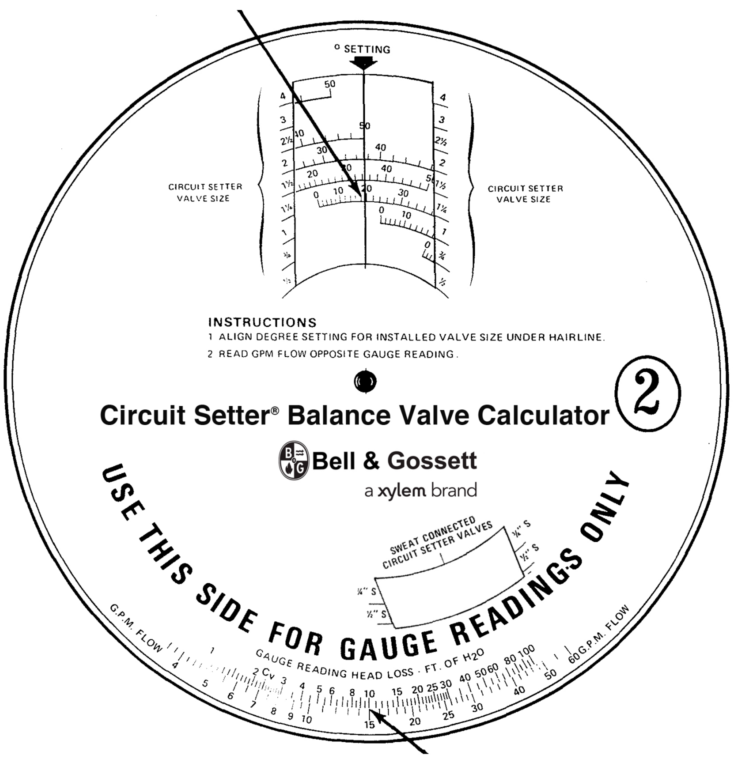


Figure 6
Variable Orifice Flow Meter

The Circuit Setter Valve can be used as an accurate variable orifice flow meter. When so used, a pressure differential meter is applied directly across the built-in Circuit Setter Valve pressure tap ports - the same pressure tap ports used in the laboratory calibration tests.

1 1/4" VALVE @ 19°



10' HD. = 15 GPM

Figure 7
Circuit Setter "Flow Meter" Calibration With Calculator

Given an installed valve size, actual flow rate can be determined by noting the valve setting and the"readout" differential head loss across the valve pressure tap ports.

AS AN EXAMPLE:
A 1-1/4" valve is set at 19°, differential gauge pressure is at 10'. What is the flow rate?

The "Flow Meter" side (Side 2) of the Calculator is used (Figure 8.). The Calculator is adjusted to align 19° at 1-1/4" valve size. The actual flow rate of 15 GPM is read opposite 10' gauge reading pressure differential.

Flow Meter accuracy of the Circuit Setter Valve is high. This has been proven in the laboratory weigh scale flow tests in the following manner:

Valve flow rate is predicted by valve setting and differential head as applied to the Circuit Setter Calculator. The predicted flow rate is then compared to an actual flow rate as proven by the weigh scale flow test.

Because of the precision manufacturing and testing techniques, deviation from predicted flow rate is established basically by human error in reading differential head and degree setting.

It will be noted that the Circuit Setter Valve can be used as an adjustable combination flow meter and balance valve to achieve any required design flow rate.

More usually, however, the flow meter characteristics of the Circuit Setter Valve will be used for checking actual system flow rates after proportional system flow balance has been established by Circuit Setter Valve pre-setting.

THE CIRCUIT SETTER "PRE-SET" CALCULATOR

Side two (2) of the Circuit Setter Calculator should not be used for pre-setting of Circuit Setter Valves. This is because the readout "Flow Meter" pressure differential is greater than the actual total valve pressure drop since velocity head recovery is not accounted for.

Actual total pressure drop will be to the order of .7 to .9 of the valve mounted gauge-read pressure drop; the degree of variation being basically a function of valve orifice area to pipe size area ratios as determined by valve setting.

THE CIRCUIT SETTER VALVE
A TOOL FOR ENGINEERED PRE-SET BALANCE

VELOCITY HEAD RECOVERY AND CIRCUIT SETTER VALVE

Static pressure as read by a gauge is influenced by water velocity. Static pressure is reduced as water velocity increases. The converse is also true. The velocity - head inter-relationship is defined by the term:

$$\text{Velocity Head} = \frac{V^2}{2g}$$

V – Velocity Ft. /Sec.
g – Gravitational Constant, 32.2 Ft./Sec.^{2}

These differences are significant enough to require two different sets of pressure drop data to be shown on the Circuit Setter Balance Valve Calculator.

Changes in velocity through the Circuit Setter Valve can be pictured as in Figure 9.

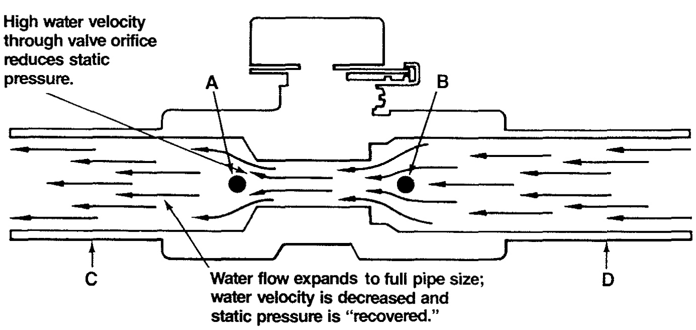


Figure 8
Velocity Head Recovery And Circuit Setter Valve

Circuit Setter pre-set calibration data must be based on actual total pressure drop and is significantly different from the Flow Meter calibration data.

As an example, concerning the use of pre-set calibration data, a system balance calculation has defined that a particular circuit requires an additional 8' or 8 ft. pressure drop to set it in balance with the overall piping system. The circuit flow rate requirement is 4 GPM. Select a Circuit Setter Valve for 8' or 8 ft. at 4 GPM and determine its pre-set setting.

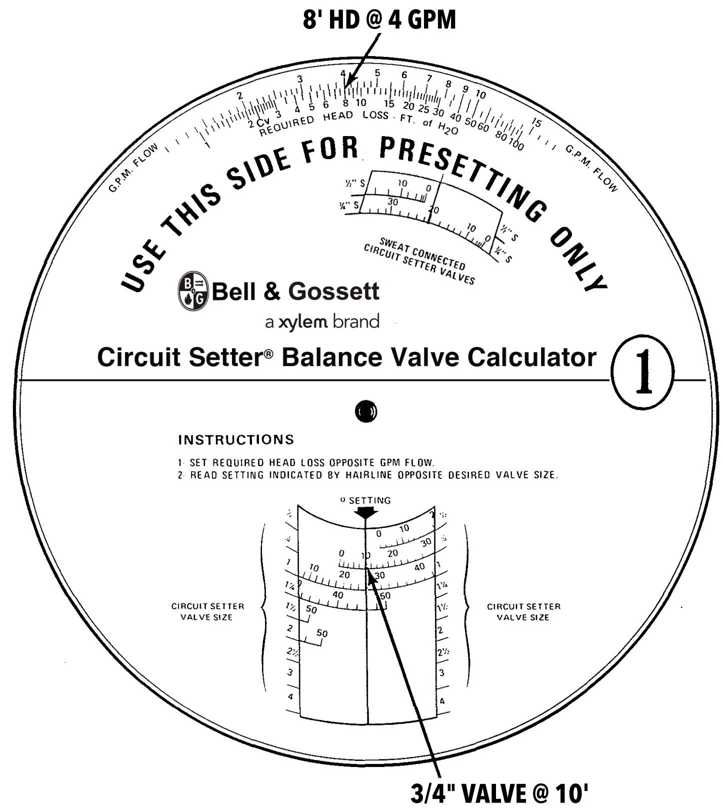


Figure 9
Circuit Setter"Pre-Set" Calibration With Calculator: Do Not Use For "Flow Meter" Readout

Adjust Side 1 ("Pre-Set" side) of the Circuit Setter Calculator, setting 8' or 8 ft. head loss opposite 4 GPM. Read settings for various valve sizes in lower window. The valve setting index shows that requirements will be met by:

1. CB 3/4" Valve 10°
2. CB 3/4" S Valve 20°
3. CB 1" Valve 26°

The Circuit Setter Valve would generally be selected as line size. Assuming that circuit pipe size is 3/4", the CB 3/4" Valve set at 10° would be used.

THE CIRCUIT SETTER VALVE
A TOOL FOR ENGINEERED PRE-SET BALANCE

FOR HYDRONIC APPLICATIONS

When terminal equipment and control valves are piped as illustrated (Figures 1 and 2), the combined use of a service valve and the Circuit Setter Plus calibrated balance valve permits complete isolation of the terminal unit and control valve. Drain connection on Circuit Setter balance valve should be toward terminal unit.

Two alternative examples of vertically fed reverse return circuits are shown in Figures 3 and 4. When terminal units have unequal pressure drops, balance valves should be installed as in Figure 3. When upper floor terminal unit has higher pressure drop than lower floor terminals, a single balance valve can be installed (Figure 4) .

Other alternative balance methods can be designed to fit specific piping and terminal unit pressure drop conditions. Individual terminal units should be piped as detailed in Figures 1 and 2.

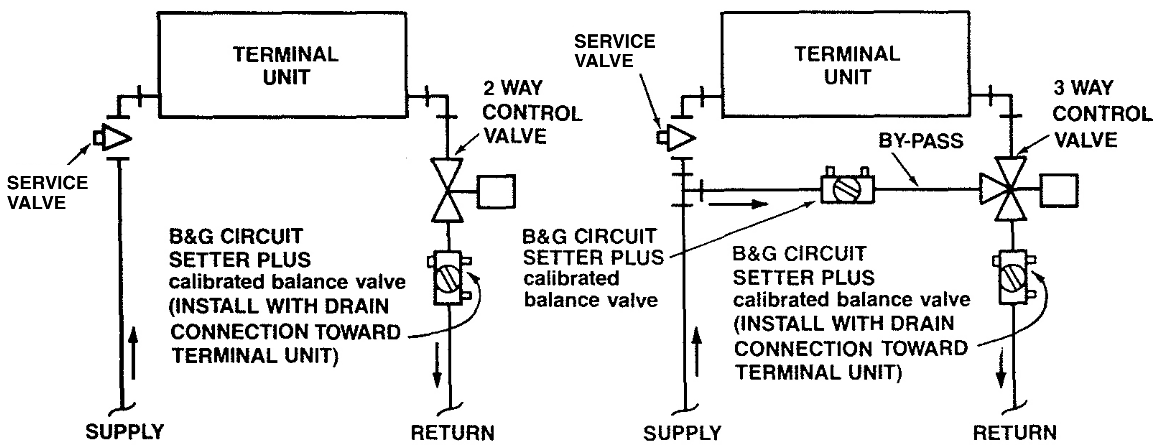


FIG. 1

PIPING ARRANGEMENT WITH 2 WAY CONTROL VALVE

FIG. 2

PIPING ARRANGEMENT* WITH 3 WAY CONTROL VALVE

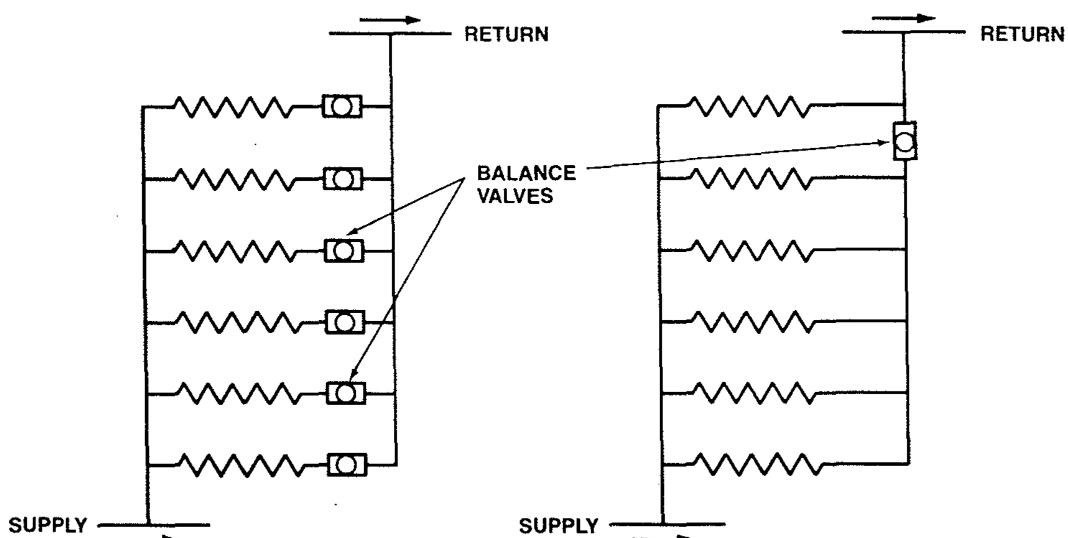


FIG. 3

FIG. 4

RISER BALANCE ALTERNATIVES

*** Piping arrangements with 3-Way control valves shown within this technical manual are provided by Bell & Gossett as reference information of existing systems only. As an active participating member of ASHRAE, it is Bell & Gossett's recommendation that engineers and system designers consult with the most current ASHRAE Standards for design guidance on Variable Flow Systems or Constant Flow Systems as indicated in ASHRAE Standard 90.1 Section 6.5.4.**

THE CIRCUIT SETTER VALVE
A TOOL FOR ENGINEERED PRE-SET BALANCE

TYPICAL SPECIFICATION

Furnish and install as shown on plans and with manufacturers recommendations Model CB calibrated balance valves.

Pre-Set Balance Feature: Valves to be designed to allow installing contractor to pre-set balance points for proportional system balance prior to system start-up in accordance with pre-set balance schedule.

Valve Design and Construction: All valves 1/2" to 3" pipe size to be of bronze body /brass ball construction with glass and carbon filled TFE seat rings. Valves to have differential pressure readout ports across valve seat area. Readout ports to be fitted with internal EPT inserts and check valves. Valve bodies to have 1/4" NPT tapped drain /purge port. Valves to have memory stop feature to allow valve to be closed for service and then re-opened to set point without disturbing balance position. All valves to have calibrated nameplates to assure specific valve settings. Valves to be leak-tight at full rated working pressure.

Valves 4" pipe size to be of cast iron body / brass vane construction with differential pressure readout ports and valves as above.

Design Pressure /Temperature:

A. 1/2" – 3" NPT connections 300 psig at 250°F
B. 1/2" – 1" Sweat connections 200 psig at 250°F
C. 4" flanged connections 125 psig at 250°F

NOTE: 4" flanged Circuit Setter not designed for drip-tight shut-off.

CIRCUIT SETTER PRE-SET BALANCE PROCEDURE

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CIRCUIT SETTER PRE-SET BALANCE PROCEDURE

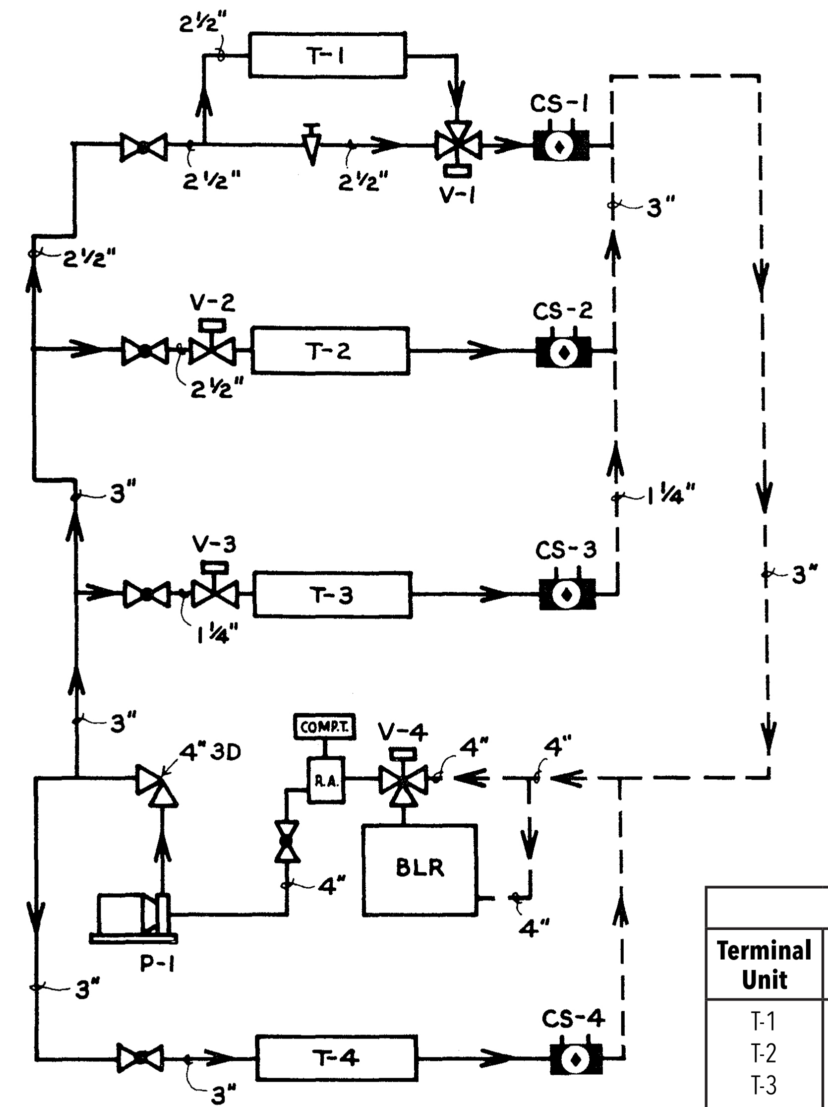

Figure 1 is representative of a "to scale" piping layout and equipment schedule as provided by a consultant's office. Figure 1 will be used as an example to illustrate pre-set balance procedure.

Figure 1*
Example Balance Problem

TERMINAL UNIT SCHEDULE					
Terminal Unit	**Mfg. & No.**	**MBH Capacity**	**GPM Flow**	**Ft. Hd.**	**Control**
T-1	-	-	50	6'	3-Way
T-2	-	-	70	12'	2-Way
T-3	-	-	10	3'	2-Way
T-4	-	-	80	4'	F&B

PUMP SCHEDULE				
Pump No.	**Mfg. No.**	**GPM**	**Ft. Hd.**	**HP**
P-1	B&G	210	80	

NOTES:

Indicates Gate Valve

Indicates Non-Calibrated Clock

CS Indicates Line Sized Circuit Setter

CONTROL VALVE SCHEDULE				
Valve No.	**Mfg.**	**Size**	**Type**	**Cv***
V-1	-	2-1/2"	3-Way	24
V-2	-	2-1/2"	2-Way	24
V-3	-	1-1/4"	2-Way	6.7
V-4	-	4"	3-Way	185

*Cv often not shown, but generalized head loss limitation is stated in specification

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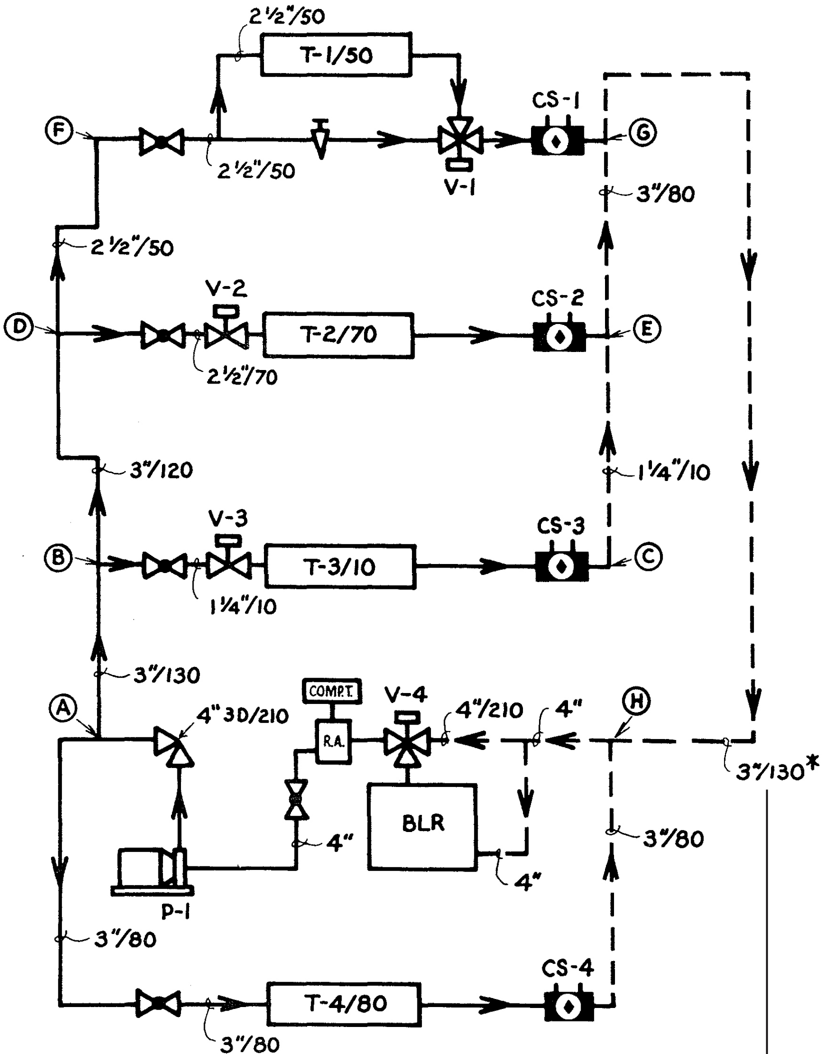
CIRCUIT SETTER PRE-SET BALANCE PROCEDURE



*** 3" /130 Means:**
3" Piple @ 130 GPM for Pipe Section G-H

Figure 2*
Pipe Sizing Identification/Flow Rate

Bid Section

TERMINAL UNIT SCHEDULE				
Terminal Unit	**Mfg. & No.**	**MBH Capacity**	**GPM Flow**	**Ft. Hd.**
T-1	-	-	50	-
T-2	-	-	70	-
T-3	-	-	10	-
T-4	-	-	80	-

PIPE SECTION FLOW DETERMINATION

Terminals T-1 (50 GPM) and T-2 (70 GPM) draw their required flow from the tee located at "D". Since (50 + 70) or 120 GPM leaves "D", 120 GPM must enter through pipe section B- D.

The tee located at "B" must provide 120 GPM to B-D plus 10 GPM to T-2; section A-B must then flow 130 GPM to "B". etc.

STEP 1

IDENTIFY PIPE SECTIONS AND PIPE SECTION FLOW RATES

Pipe sections are letter identified from "tee to tee " as shown on Figure 2.

Pipe section flow rates are derived from terminal unit flow rate needs and on the simple premise that water flow into a tee equals water flow away from the tee. The procedure is shown on Figure 2.

The method* used for determining terminal unit flow rate need should be established by the consulting firm; either in the specifications or by confirmation letter to those concerned with balance. In this case, a "bid accepted" terminal unit schedule will be used.

It will be noted that the schedule shown on the plan illustrates the terminals used as a basis for design; pipe sizing, etc .... while the specification may state alternative units which are "bid acceptable".

Should another manufacturer's terminal units be accepted, the terminal unit schedule shown on the plans should be disregarded and replaced by a schedule illustrating the terminals that will actually be used.

For this example, the terminal units schedule on the plans are also "bid accepted" and form the basis for the pipe section flow rates shown on Figure 2.

*Other methods; GPM by temperature difference and GPM by unit size are shown in Examples 2 & 3.

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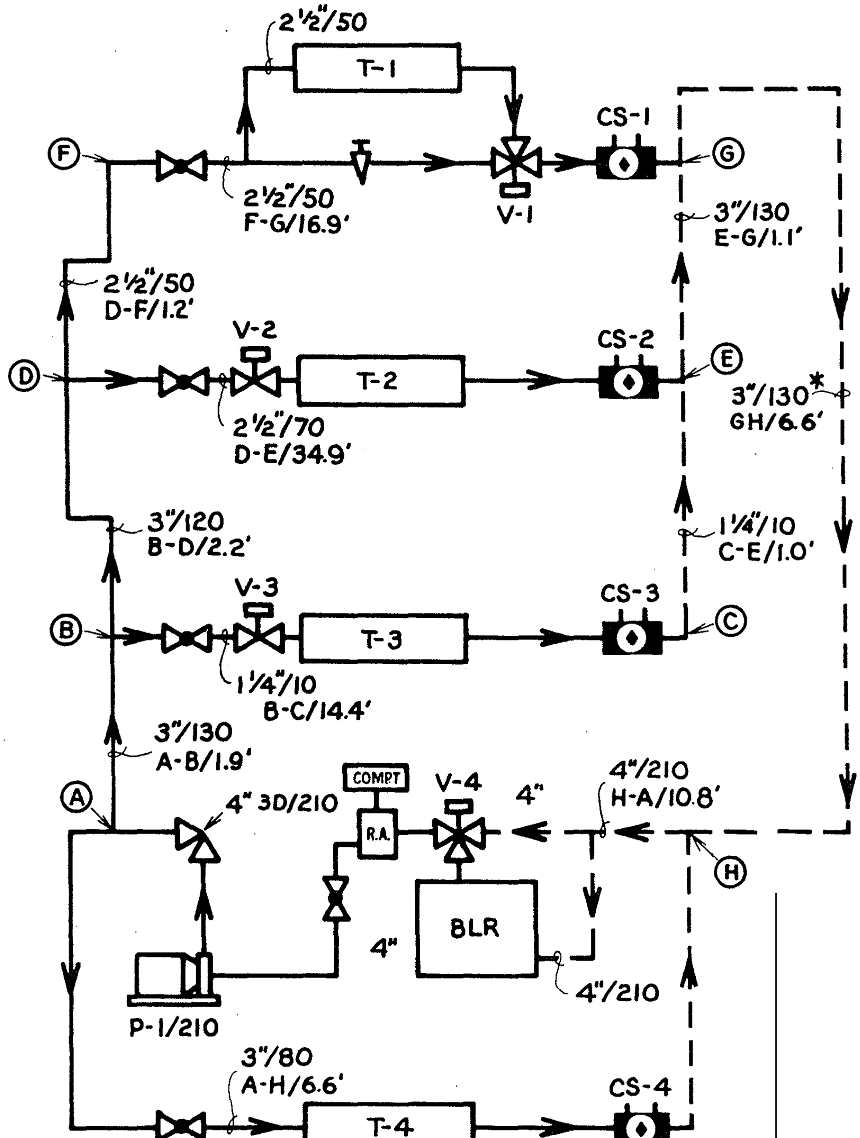
CIRCUIT SETTER PRE-SET BALANCE PROCEDURE



*** 3" /130**
G-H /6.6' Means:
3" Pile @ 130 GPM with 6.6' Hd.
Loss for Pipe Section G-H

Figure 3*
Pipe Section Head Loss Shown On Plan

STEP 2

DETERMINE ESTIMATE PIPE SECTION HEAD LOSS BY TABULATED PROCEDURE AND SHOW ON PLAN

The procedure used for determining pipe section loss (ft. Hd.) has been simplified by Bell & Gossett through use of Tables and Charts. (See Section 2; Head Loss Estimation).

In order to establish basic pre-set balance procedure most quickly, it will be assumed that pipe section head loss have been estimated* by simple procedures later shown and that these sectional head losses appear as below:

PIPE SECTION	FLOW RATE	ESTIMATED HEAD LOSS*
A B	130	1. 9'
B D	l20	2.2'
D F	50	1.2'
C E	10	1.0'
E G	80	1.1'
G H	130	6.6'
F G (T_1)	50	16.9'
D E (T_2)	70	34.9'
B C (T_3)	10	14.4'
A H (T_4)	80	6.6'
H A (Equip. Room)	210	10.8'

These estimated head losses are shown on the piping plan.

*Pipe section head loss estimation for this particular example is shown in **Section 2; Head Loss Estimation; Example 1.**

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CIRCUIT SETTER PRE-SET BALANCE PROCEDURE

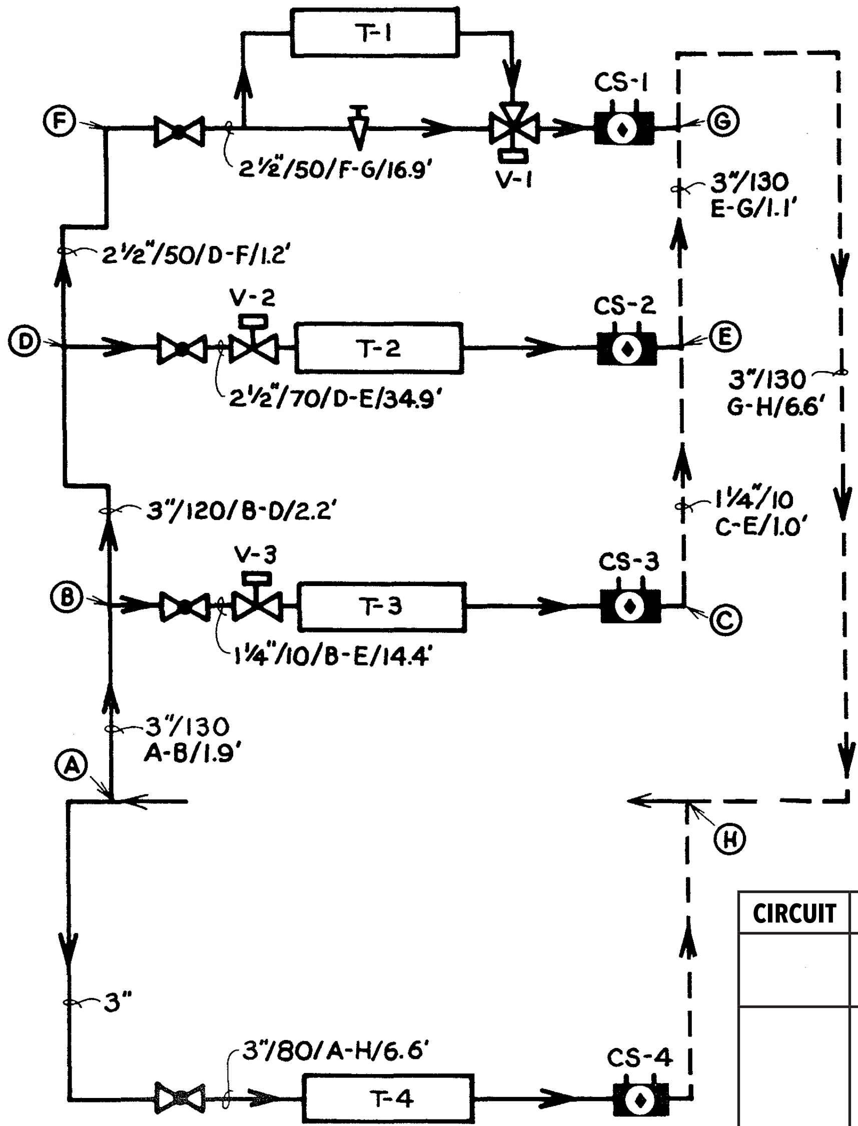

Figure 4*
Highest Head Loss Circuit, A-H Through T-2 @ 45. 7'

STEP 3

USING PIPING PLAN AS "ROAD MAP", FIND HIGHEST HEAD LOSS CIRCUIT

Since the equipment room piping (H-A) flows all the water delivered to the terminal circuits, it is not part of the proportional balance problem. The considerations pertaining to proportional balance start at the first junction take-off from the supply main (in Figure 4 at A) and end at the last circuit return to the return main (in Figure 4 at H).

The pipe plan is now used as a road map and all possible flow paths from A to H through the various terminal units are determined. Pipe section head loss for each possible circuit flow path are added.

The circuit flow path that has the highest head loss is found by comparison. For this example, the circuit flow path from A--H through terminal T-2 has the highest head loss as shown in the comparison below:

CIRCUIT	A H Thru T-1		A H Thru T-2		A H Thru T-4		
	Pipe Section	Head Loss	Pipe Section	Head Loss	Head Loss	Pipe Section	Head Loss
	A-B	1. 9'	A-B	1. 9'	A-B	A-H (T4)	6. 6'
	B-D	2. 2'	B-D	2,2'	B-C (T3)		
	D-F	1.2'	D-E (T2)	34.9'	C-E		
	F-G	16.9'	E-G	1.1'	E-G		
	G-H	6.6'	G-H	6.6'	G-H		
Total Required Circuit Hd. Loss		28.8'		45.7'	25.0		6. 6'
Highest Hd. Loss	———	——→		45.7'			

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CIRCUIT SETTER PRE-SET BALANCE PROCEDURE

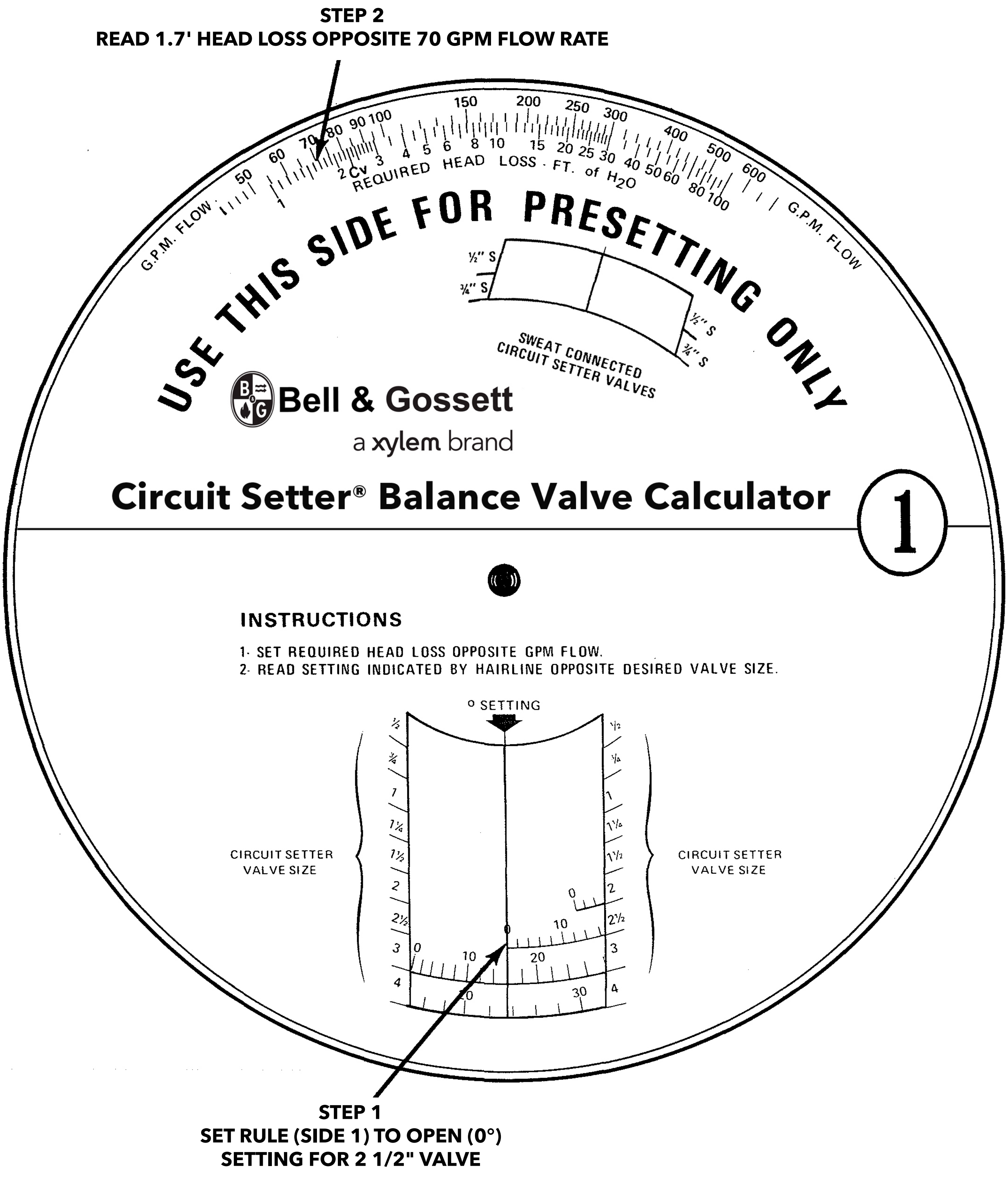


Figure 5
Find Open Circuit Setter Valve Head Loss

CIRCUIT SETTER PRE-SET BALANCE PROCEDURE

STEP 3a
FIND BALANCE GOVERNING HEAD LOSS; ADD OPEN CIRCUIT SETTER HEAD LOSS TO HIGH HEAD LOSS CIRCUIT

The highest head loss circuit (A-H thru T_2) includes an open circuit setter valve (CS-2) in pipe section D-E. The head loss of this valve must be added to its circuit head loss to establish the balance governing head loss.

The open circuit setter valve is contained in pipe section D-E; which is abstracted from Figure 4 as below:

The open circuit setter valve is line-sized at 2-1/2" and flows 70 GPM. Figure 5 shows that for this condition, the circuit setter valve will cause 1. 7' head loss.

Balance governing head loss now becomes:

HIGHEST CIRCUIT HEAD LOSS (A-H thru T_1)	= 45.7'
OPEN 2-1/2" CIRCUIT SETTER @ 70 GPM	= 1. 7'
TOTAL BALANCE GOVERNING HEAD LOSS	= 47.4'

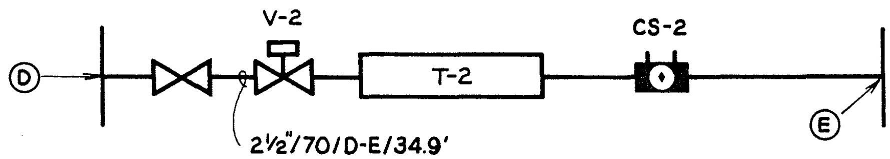
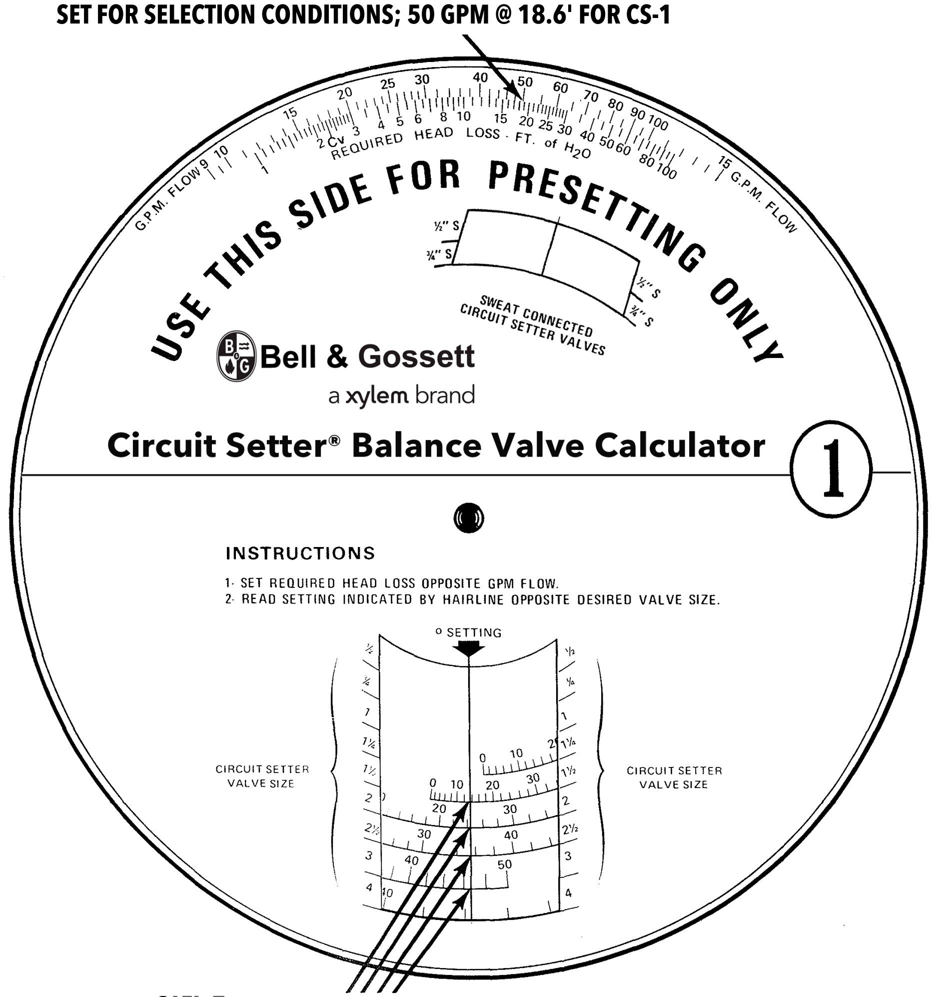


Figure 5a
Section D-E Abstracted From Figure 4.

STEP 1
SET FOR SELECTION CONDITIONS; 50 GPM @ 18.6' FOR CS-1



READ POSSIBLE SELECTIONS FOR CONDITIONS 50 GPM 18.6'
1 1/2" @ 14°
2" @ 24°
21/2" @ 36°
3" @ 47°

Figure 6
Selection For CS-1; 2-1/2" Line-Sized Circuit Setter @ 36 Used

CIRCUIT SETTER PRE-SET BALANCE PROCEDURE

STEP 4
DETERMINE "PRE-SET" CIRCUIT HEAD LOSS REQUIREMENT AND CIRCUIT SETTER SETTING EQUIVALENT

The piping layout shown in Figure 4 will be set in proportional flow balance when each separate flow-circuit path has equal head loss at its design flow rate.

In order to achieve this objective, circuit setter valves will be "pre-set" for the head loss difference between that needed for the "balance governing" circuit and the "total required") head loss for all other circuits. This can be tabulated as below:

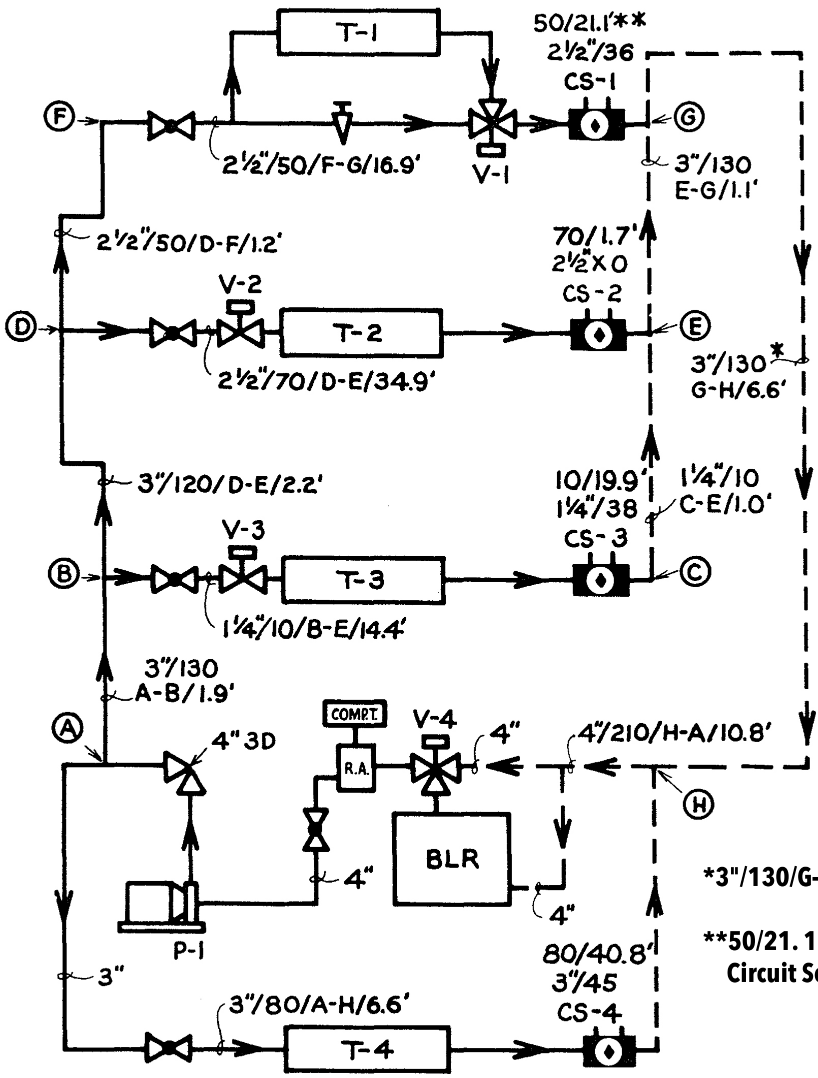
CIRCUIT	A-H thru T_1	A-H thru T_2	A-H thru T_3	A-H thru T_4
"Balance Governing" Head Loss	47.4'	47.4'	47.4'	47.4'
Total Required Head Loss / Circuit	-28.8'	- 45. 7'	-25.0	- 6. 6'
Circuit Head Loss Difference	18.6'	1.7'	22.4'	40.8'
Circuit Setter Flow	50 GPM	70 GPM	10 GPM	80 GPM
Circuit Setter No.	CS-1	CS-2	CS-3	CS-4
Circuit Setter Pre-set	18.6' @ 50 GPM	1. 7' @ 70 GPM	22.4' @ 10 GPM	40.8' @ 80 GPM

The circuit setter valves are selected for the conditions shown in the last tabulated line. The procedure for selection is shown in Figure 6 for CS-1.

While circuit setter valves will often be selected smaller than line-size, for this example a line-size selection is made as follows:

CIRCUIT SETTER NO.	CS-1	CS-3	CS-3	CS-4
VALVE SIZE	2-1/2"	2-1/2"	1-1/4"	3"
SETTING	36°	Open (O)	39°	45°

CIRCUIT SETTER PRE-SET BALANCE PROCEDURE



*3"/130/G-H/6. 6' Means: 3" Pipe, 130 GPM, G-H Head Loss = 6. 6'

**50/21. 1'/2-1/2"/36°CS-1. .. Means: 50 GPM @ 21. 1 Ft. Hd., 2-1/2" Circuit Setter @ 36° for CS-1

Figure 7*
Final Pipe Layout Plan Showing Circuit Setter Settings For Proportional Flow Balance

Actual Terminal Flow

System Flow Condition	Actual Pump Flow	% Flow Design	T-1	T-2	T-3	T-4
DESIGN	210	100	50	70	10	80
Over Design	231	110	55	77	11	88
Over Design	252	120	60	84	12	96
Under Design	199	95	47.5	66.5	9.5	75.5

The usual system pump application results in over-design system flow rate and therefore, is more than required terminal unit flow rate. This circumstance will be true so long as usual conditions apply; specified pump head greater than required pump head.

STEP 4a
SHOW CIRCUIT SETTER VALVE SETTINGS ON PLAN

The circuit setter valve settings derived from Step 4 are shown on the plan as illustrated in Figure 7.

When the circuit setter valves have been "set" as per plan and the system started, each terminal unit will receive its proportionate share of the flow rate provided by the pump to the system.

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CIRCUIT SETTER PRE-SET BALANCE PROCEDURE

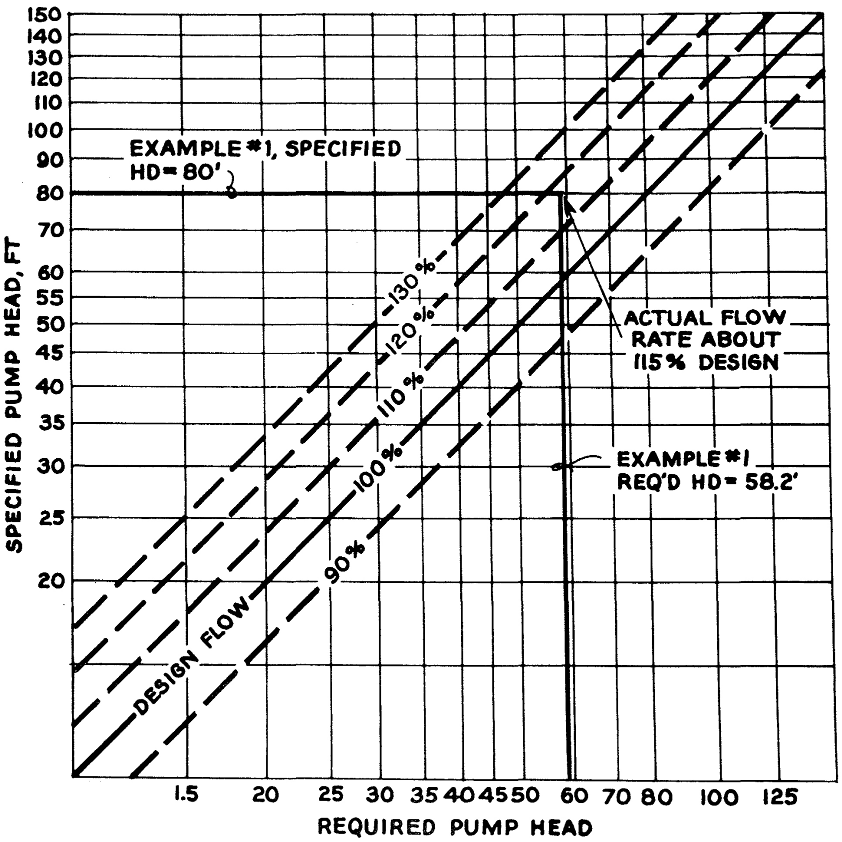

Chart 1

The anticipated actual flow rates for example #1 can be illustrated as below:

		Design Flow	Antlcipated Approximate Flow (115% Design)
Pump (P-1)		210	242
Terminal Circuits	T-1	50	57.5
	T-2	70	80.5
	T-3	10	11.5
	T-4	80	92

STEP 5

CHECK REQUIRED PUMP HEAD AND COMPARE WITH SPECIFIED

The required system head loss for this example will be composed of two parts:

1. Head loss caused by design flow rate from "A" through the balanced terminal circuits to "H". This head loss is the balance governing circuit head loss of 47.4'. (See Step 3a).
2. Head loss caused by design flow from "H" through the equipment room to "A". This head loss is shown in Step 2 as pipe section (H-A) head loss of 10.8'.

The required pump head will then be 47.4' **plus** 10.8' = 58.2'.

Since the specified pump head (80') is greater than required head (58. 2') terminal flow rates can be expected to be greater than required.

Had the specified pump head been less than required, terminal unit flow rates would be less than required. This circumstance should be brought to the Consultant's attention.

STEP 5a

CHECK ANTICIPATED TERMINAL FLOW RATE AFTER PUMP START

While not absolutely necessary, it will be useful to estimate the effect of a difference between specified and required pump heads on total system and terminal unit flow rates. Chart #1 can be used for this purpose and illustrates that if the specified head of 80 ft. is applied to the example system (required head = 58.2'), the system flow rate will be to the order of 115% **of design**.

This means that each terminal will receive about 115% of its design flow. Terminal T-1 has a design requirement of 50 GPM; it will actually receive the order of 50 x 1.15 or 57.5 GPM as shown in the table under Chart #1.

HEAD LOSS ESTIMATION PROCEDURES

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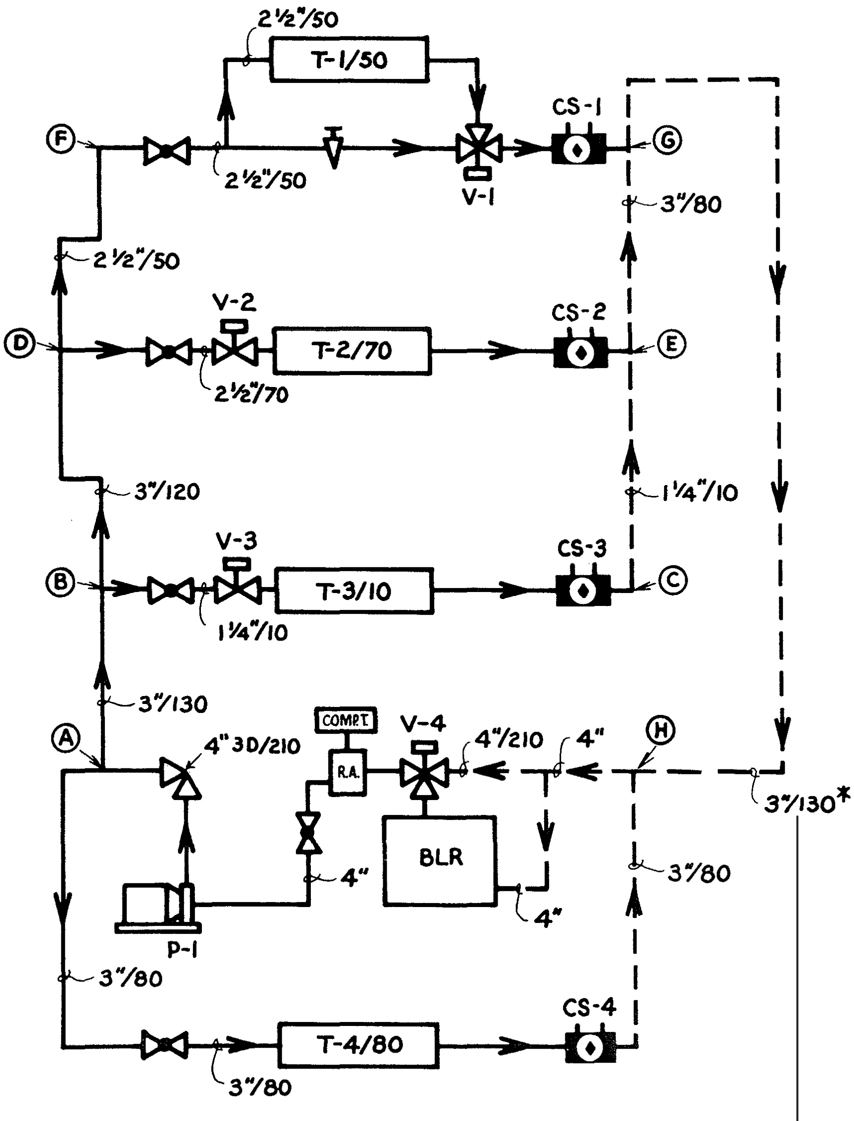
HEAD LOSS ESTIMATION PROCEDURES



*** 3" /130 Means:**
3" Piple @ 130 GPM for Pipe Section G-H

Figure 1*
Example Balance Problem

HEAD LOSS ESTIMATION PROCEDURES

Pre-set balance procedures require that each pipe section be evaluated in terms of its head loss. For purposes of evaluation, system piping sections can be broken into three types:

1. Distribution Pipe Sections
The distribution pipe sections are the supply and return pipe sections between the equipment room and the terminal unit pipe circuits. Distribution pipe sections are exemplified in Figure 1, by pipe sections A-B, B-D, D-F, C-E, E-G and G-H. Distribution pipe sections usually contain only pipe length, elbows and tees.

2. Terminal Sub-Circuit Pipe Section
The "sub-circuit" contains the terminal unit and its control valve (if used) together with shut-off valves, etc. and is exemplified in Figure 1 by pipe sections B-C (thru T_3), D-E (Thru T_2), F-G (thru T_1 and A-H (thru T_4).

3. Equipment Room Pipe Section
The equipment room pipe section flows total system flow rate and is exemplified in Figure Figure 1 by section H-A (thru boiler, etc.). Equipment room pipe section head loss is not necessary for proportional pre-set balance, but is useful for final flow estimation.

Bid Section

TERMINAL UNIT SCHEDULE				
Terminal Unit	**Mfg. & No.**	**MBH Capacity**	**GPM Flow**	**Ft. Hd.**
T-1	-	-	50	-
T-2	-	-	70	-
T-3	-	-	10	-
T-4	-	-	80	-

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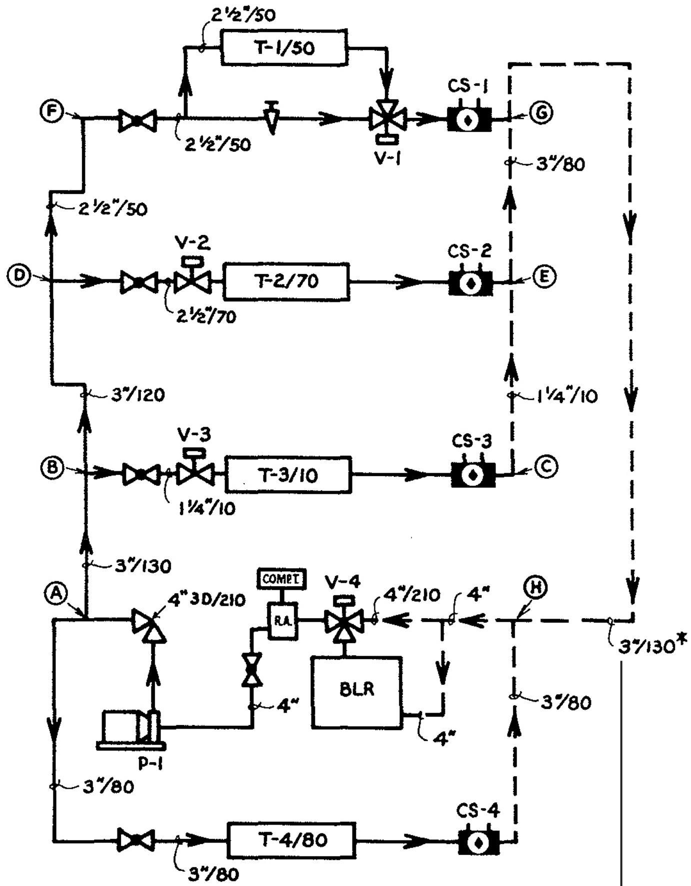
HEAD LOSS ESTIMATION PROCEDURES



*** 3" /130 Means:**
3" Piple @ 130 GPM for Pipe Section G-H

Figure 2*
Distribution Pipe Sections Represented by Sections A-B, B-D, D-F, C-E, E-G and G-H

ESTIMATING DISTRIBUTION PIPE SECTION HEAD LOSS

Actual estimation of pipe section head loss is best explained by reference to the examples stated for use with the head loss estimation table (Table 1 - page 28). The examples used are for pipe sections A-B and -D in Figure 2.

Table 1 states the relationships between pipe size, pipe flow and piping head loss as affected by total equivalent pipe length (TEL). Since pipe size and flow rate is known, the balance contractor need only establish TEL to determine pipe section head loss.

TEL will be the sum of measured (scaled) pipe length plus the equivalent fitting length as shown on Table 2, page 29.

Reference to the examples stated for the head estimation tables illustrates such procedural simplicity that tabulation forms (though shown in worksheet 1 are not needed. Head loss results can be directly entered on the plans since only a simple addition (measured plus fitting equivalent length) permits entry into Table 1.

NOTES CONCERNING DISTRIBUTION PIPE SECTION HEAD LOSS

Distribution piping will commonly occur as between two tees; see section B-D (Figure 2). When estimating distribution piping fitting equivalent length, however, only one tee is used for estimation (as at "B" in pipe section B-D). This is because the tee at "D" will be included in the evaluation for pipe section D-F.

Distribution Pipe Section	Measured Length
A-B	30'
B-D	40'
D-F	42'
C-E	50'
E-G	60'
G-H	132'

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Distribution Pipe Section Head Loss Tabulation Form							
Pipe Section		**A-B**	**B-D**	**D-F**	**C-E**	**E-G**	**G-H**
Flow Rate		130	120	50	10	80	130
Pipe Size		3"	3"	2 1/2"	1 1/4"	3"	3"
Measured Length		30'	40'	42'	50'	60'	132'
Equivalent Length (Table 2)	**E1 or Thru Tee**		3/24'	3/18'	1/3/'2'	1/8'	4/32'
	Side Tee	1/16'					
	Valve						
	Other						
	Other						
Total Equivalent Length		46'	64'	60'	53'/2'	68'	164'
Pipe & Fitting Head Loss (Table 1)		19'	22'	12'	1.0'	1.1'	6.6'

WORKSHEET 1

HEAD LOSS ESTIMATION PROCEDURES

Table 1

TABLE 1 FT. HEAD LOSS ESTIMATION TABLE

PIPE LENGTH, FT.

Total Friction Loss (Ft.) \ Friction Loss Rate; Ft. /100'	.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8
.1	12.5	10	8.3	7.1	6.25	5.5	5	4.5	4.2	3.8	3.6
.2	25	20	16.6	14.3	12.5	11.1	10	8.1	8.3	7.7	7.2
.3	37.5	30	25	21.4	18.7	16.6	15	13.6	12.5	11.6	10.7
.4	50	40	33.3	28.6	25	22.2	20	18.2	16.6	15.3	14.3
.5	62.5	50	41.6	35.7	31.2	27.7	25	22.7	20.8	19.2	17.9
.6	75	60	50	42.8	37.4	33.2	30	27.2	25	23.2	21.4
.7	87.5	70	58.3	50	43.7	38.8	35	31.8	29.1	26.9	25
.8	100	80	66.6	57.2	50	44.4	40	36.4	33.2	30.6	28.6
.9	112.5	90	75	64.3	56.2	50	45	40.9	37.4	34.5	32.1
1.0	125	100	83.3	71.4	62.4	55.5	50	45.4	41.6	38.4	36.7
1.1	137.5	110	91.3	78.5	68.6	60.9	55	49.9	45.8	42.4	39.2
1.2	150	120	100	85.6	74.8	66.4	60	54.4	50	46.4	47.8
1.3	162.5	130	108.3	92.8	81.1	72	65	59	54.1	50	46.4
1.4	175	140	116.6	100	87.4	77.6	70	63.6	58.2	53.8	50
1.5	187.5	150	125	107.2	93.7	83.2	75	68.2	62.3	57.5	53.6
1.6	200	160	133.3	114.4	100	88.8	80	72.8	66.4	61.2	57.2
1.7	212.5	170	141.6	121.5	106.2	94.4	85	77.3	70.6	65.1	60.7
1.8	225	180	150	128.6	112.4	100	90	81.8	75	69	64.3
1.9	237.5	190	158.3	135.7	118.6	105.5	95	86.3	79	72.9	67.9
2.0	250	200	166.6	142.8	124.8	111	100	90.8	83.2	76.8	71.4
2.1	262.5	210	175	150	131	116.4	105	95.3	87.4	80.8	75
2.2	275	220	183.3	157.1	137.2	121.8	110	100	91.6	84.8	78.6
2.3	287.5	230	191.3	164.1	143.4	127.3	115	104.3	95.8	88.8	82
2.4	300	240	200	171.2	149.6	132.8	120	108.3	100	92.8	85.6
2.5	312.5	250	208.3	178.4	155.9	138.4	125	113.4	104.1	96.4	89.2
2.6	325	260	216.6	185.6	162.2	144	130	118	108.2	100	92.8
2.7	337.5	270	225	192.8	168.5	149.6	135	122.6	112.3	103.8	96.4
2.8	350	280	233.3	200	174.8	155.2	140	127.2	116.4	107.6	100
2.9	362.5	290	241.6	207.2	181.1	160.8	145	131.8	120.5	111.3	103.6
3.0	375	300	250	214.4	187.4	166.4	150	136.4	124.6	115	107.2
3.2	400	320	258.3	228.8	200	177.6	160	145.6	132.8	122.4	114.4
3.4	425	340	283.2	250	212.4	188.8	170	154.6	141.2	130.4	125
3.6	450	360	300	257.2	224.8	200	180	163.6	150	138	128.6
3.8	475	380	316	271.4	237.2	211	190	172.6	158	145.8	135.7
4.0	500	400	333	285.6	249.6	222	200	181.6	166.4	153.6	142.8
4.2	525	420	350	300	262	232.4	210	190.6	174.8	161.6	150
4.4	550	440	366	314.2	274.4	243.6	220	200	183.2	169.6	157.1
4.6	575	460	379	328.2	286.8	254.6	230	208.6	191.6	177.6	164.1
4.8	600	480	400	342.4	289.2	265.6	240	217.6	200	185.6	171.2
5.0	625	500	416	357	312	278	250	226.8	208.2	192.8	178.5

GPM

Nominal Pipe Size	.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8
3/8	--	.46	.51	.55	.6	.63	.67	.7	.74	.76	.8
1/2	.76	.86	.95	1.07	1.12	1.2	1.27	1.33	1.4	1.46	1.52
3/4	1.62	1.85	2	2.2	2.4	2.55	2.7	2.85	2.95	3.1	3.22
1	3.1	3.5	3.9	4.3	4.55	4.8	5.2	5.4	5.7	5.9	6.2
1-1/4	6.6	7.2	8.2	8.8	9.6	10.5	10.75	11.2	11.8	12.5	13
1-1/2	9.8	11.1	12.2	13.3	14.2	15.1	16	17	17.8	18.5	19.2
2	19.2	21.5	24	26	28	29.8	31.5	33	34.5	36	37.5
2-1/2	30.5	35	38	42	44	47	50	53	56	58	60
3	55	63	69	75	80	85	90	95	100	105	110
4	115	128	142	153	165	175	188	198	208	215	224
5	208	232	258	280	300	320	340	360	378	390	408
6	335	380	420	450	490	520	550	580	610	640	670
8	700	780	820	940	1000	1090	1130	1200	1280	1310	1370
10	1260	1410	1580	1700	1810	1950	2060	2160	2290	2390	2500
12	2000	2250	2500	2700	2900	3100	3300	3400	3600	3700	3900

Copper Tube Nominal (I.D. Size) "Type L"	.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8
3/8	--	--	--	--	.4	.43	.45	.48	.5	.52	.55
1/2	--	--	.64	.7	.75	.8	.85	.9	.95	1.0	1.05
5/8	.9	1.0	1.15	1.25	1.34	1.42	1.5	1.6	1.68	1.75	1.82
3/4	1.4	1.6	1.75	1.9	2.05	2.2	2.3	2.45	2.55	2.65	2.8
1	3.0	3.4	3.7	4.1	4.4	4.7	5.0	5.2	5.5	5.7	6.0
1-1/4	5.2	5.9	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5
1-1/2	8.5	9.5	10.0	10.5	11.2	13.0	13.8	14.5	15.0	15.8	16.5
2	18.0	20.0	22.0	24.0	26.0	28.0	30.0	31.0	33.0	34.0	35.5
2-1/2	32.0	36.5	40.0	44.0	47.0	50.0	52.5	55.5	58.0	62.0	64.0
3	51.0	57.0	63.0	70.0	74.0	79.0	83.0	88.0	93.0	97.0	100

TABLE 1 FT. HEAD LOSS ESTIMATION TABLE

PIPE LENGTH, FT.

Friction Loss Rate; ft. /100'	3.0	3.2	3.4	3.6	3.8	4.0	4.2	4.4	4.6	4.8	5.0	Total Friction Loss (Ft.)
	3.3	3.1	2.9	2.7	2.6	2.5	2.4	2.3	2.2	2.1	2	.1
	6.6	6.2	5.9	5.5	5.2	5	4.7	4.5	4.3	4.1	4	.2
	10	9.3	8.8	8.3	7.9	7.5	7.1	6.8	6.5	6.2	6	.3
	13.3	12.5	11.7	11.1	10.5	10	9.5	9.0	8.7	8.3	8	.4
	16.6	15.6	14.7	13.8	13.1	12.5	11.9	11.3	10.8	10.4	10	.5
	20	18.7	17.6	16.6	15.7	15	14.3	13.6	13	12.5	12	.6
	23.3	21.8	20.5	19.4	18.4	17.5	16.7	15.9	15.2	14.6	14	.7
	26.6	25	23.4	22.2	21	20	19	18.2	17.4	16.6	16	.8
	30	28.1	26.4	25	23.6	22.5	21.4	20.7	19.5	18.7	18	.9
	33.3	31.2	29.4	27.7	26.2	25	23.8	22.3	21.6	20.8	20	1.0
	36.6	34.3	32.3	30.4	28.9	27.5	26.2	24.9	23.8	22.9	22	1.1
	40	37.8	35.2	33.2	31.4	30	28.6	27.2	26	25	24	1.2
	43.3	40.6	38.1	36	34.1	32.5	31	29.5	28.2	27	26	1.3
	46.6	43.7	41	38.8	36.8	35	33.4	31.8	30.4	29.1	28	1.4
	50	46.9	43.9	41.6	39.4	37.5	35.7	34.1	32.6	31.1	30	1.5
	53.3	50	46.8	44.4	42	40	38	36.4	34.8	33.2	32	1.6
	56.6	53.1	50	47.2	44.6	42.5	40.4	38.7	36.9	35.3	34	1.7
	60	56.2	52.8	50	47.2	45	42.4	40.9	39	37.5	36	1.8
	63.3	59.3	55.8	52.7	50	47.5	45.2	43.1	41.1	39.5	38	1.9
	66.6	62.4	58.8	55.5	52.4	50	47.6	45.4	43.2	41.6	40	2.0
	70	65.5	61.7	58.7	55.1	52.5	50	47.7	45.4	43.7	42	2.1
	73.3	68.6	64.6	60.9	57.8	55	52.4	50	47.6	45.8	44	2.2
	76.6	71.7	67.5	63.6	60.3	57.5	54.8	52.1	50	47.9	46	2.3
	80	74.8	70.4	66.4	62.8	60	57.2	54.4	52	50	48	2.4
	83.3	77.9	73.3	69.2	65.5	62.5	59.6	56.7	54.2	52	50	2.5
	86.6	81.1	76.2	72	68.2	65	62	59	56.4	54.1	52	2.6
	90	84.3	79.1	74.8	70.9	67.5	64.4	61.3	58.6	56.1	54	2.7
	93.3	87.4	82	77.6	73.6	70	66.8	63.6	60.4	58.2	56	2.8
	96.6	90.5	84.9	80.4	76.2	72.5	69.1	65.9	63	60.2	58	2.9
	100	93.7	87.8	83.2	78.8	75	71.4	68.2	65.2	62.3	60	3.0
	106.6	100	93.6	88.8	84	80	73.7	72.8	67.4	66.4	64	3.2
	113.2	106.2	100	94.4	89.2	85	80.8	77.3	73.8	70.6	68	3.4
	120	112.4	105.6	100	94.4	90	84.8	81.6	78	75	72	3.6
	126.6	118.6	111.6	105.5	100	95	90.4	86.3	82.2	79	76	3.8
	133.2	124.8	117.6	111	104.8	100	95.2	90.8	86.4	83.2	80	4.0
	140	131	123.4	116.2	110.2	105	100	95.3	90.8	87.4	84	4.2
	146.6	137.2	129.2	121.8	115.6	110	104.8	100	95.2	91.6	88	4.4
	153.2	143.4	135	127.3	120.6	115	109.6	104.3	100	95.8	92	4.6
	160	150	140.8	132.8	125.6	120	114.4	108.8	104	100	96	4.8
	166.6	156	146.6	139	131	125	119.2	113.4	108.4	104.1	100	5.0

GPM

	3.0	3.2	3.4	3.6	3.8	4.0	4.2	4.4	4.6	4.8	5.0	Nominal Pipe Size
	.84	.86	.89	.92	.95	.97	1	1.02	1.05	1.07	1.1	3/8
	1.59	1.62	1.68	1.75	1.8	1.85	1.9	1.95	2	2.04	2.08	1/2
	3.35	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	3/4
	6.4	6.6	6.9	7.1	7.3	7.5	7.7	7.9	8.1	8.3	8.4	1
	13.4	13.8	14.2	14.8	15	15.5	16	16.4	16.8	17.2	17.5	1-1/4
	20	20.8	21.4	22	22.8	23.6	24.2	24.8	25.4	26	26.5	1-1/2
	39	40.5	42	43	44	45	46	47	48	50	51	2
	62.5	65	67	69	71	73	75	77	78	80	82	2-1/2
	114	118	122	126	128	132	136	139	142	146	150	3
	233	242	250	257	265	270	278	286	296	302	306	4
	425	440	455	468	481	495	505	520	535	550	560	5
	700	720	750	770	800	820	840	860	880	900	920	6
	1420	1490	1530	1580	1630	1680	1730	1760	1800	1850	1900	8
	2600	2700	2750	2850	2930	3000	3100	3200	3250	3300	3400	10
	4100	4200	4350	4500	4650	4800	4950	5100	5250	5400	5500	12

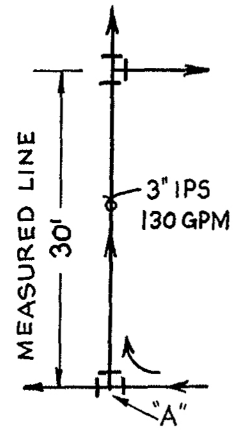
	3.0	3.2	3.4	3.6	3.8	4.0	4.2	4.4	4.6	4.8	5.0	Copper Tube Nominal (I.D. Sizes) "Type L"
	.57	.59	.61	.63	.65	.67	.68	.7	.72	.74	.75	3/8
	1.06	1.1	1.13	1.17	1.2	1.2	1.25	1.3	1.35	1.38	1.4	1/2
	1.9	1.95	2.0	2.07	2.15	2.2	2.25	2.3	2.35	2.4	2.45	5/8
	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	3/4
	6.2	6.5	6.8	7.0	7.2	7.5	7.7	8.0	8.2	8.3	8.5	1
	11.0	11.5	11.2	11.8	12.1	12.5	12.9	13.3	13.6	13.8	14.0	1-1/4
	17.2	18.0	18.4	19.0	19.5	20.0	20.5	21.0	21.5	22.0	22.5	1-1/2
	37.0	38.0	39.0	41.0	42.0	43.0	44.0	45.0	46.0	47.0	48.0	2
	66.0	68.0	68.0	70.0	72.0	74.0	76.0	78.0	80.0	82.0	84.0	2-1/2
	106.0	110.0	116.0	120.0	124.0	128.0	130	132.0	135.0	139.0	142	3

HEAD LOSS ESTIMATION PROCEDURES

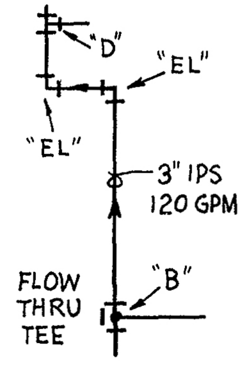
Nominal Pipe Size	90° El Or Tee; Flow Thru		Tee; Side Branch Flow In Or Out *		90° Miter	45° Miter	VALVES		
							GATE	GLOBE	PLUG
	Screw	Cu Or Weld	Screw	Cu Or Weld	Weld	Weld	All	All	All
1/2"	1	1/2	2	1	2-1/2	1/2	1/2	15	1
3/4"	2	1	4	2	4	3/4	1/2	20	1-1/2
1"	3	1-1/2	6	3	5	1	3/4	25	2
1-1/4"	3-1/2	1-3/4	7	3-1/2	6	1-1/4	1	30	2-1/2
1-1/2"	4	2	8	4	7-1/2	1-1/2	1-1/4	40	3
2"	5	2-1/2	10	5	10	2	1-1/2	50	4
2-1/2"	6	3	12	6	12-1/2	2-1/2	2	80	5
3"	8	4	16	9	15	3	2-1/2	90	6
4"		5-1/2		12	20	4	3	110	8
5"		8		15	25	5	3-1/2	140	10
6"		9		18	30	6	4	170	12
8"		11		24	40	8	5	240	16
10"		15		30	50	10	7	290	20
12"		18		36	60	12	8	320	24

*Applies to Side Branch Flow

Table 2
Fitting Equivalent Length Table



Example 1 Diagram



Example 2 Diagram

EXAMPLE 1:
Estimate friction loss from A to B given the following:
(1) Pipe Size is 3".
(2) Flow is 130 GPM.
(3) Measured length (plan) = 30'
(4) Tee @ "A" is screwed and 3" side branch size; flow is side branch.

SOLUTION:
(1) Determine Fitting Equivalent Length
From Table 2 , 3" screwed tee, side branch flow equivalent length = 16'. **Do not include equivalent length for fitting @ "B".**
(2) Determine Total Equivalent Length (TEL)
TEL = Measured Length + Fitting E. L. 30' + 60'=46' TEL
(3) Determine Friction Loss By Use of Table 1
Enter Table 1 @ 3" I. P. S. Proceed to 130 GPM or next greater (132). Proceed upward to TEL equal to or greater than 46' (47.5'). Read 1.9' fricton loss (See Table 1).

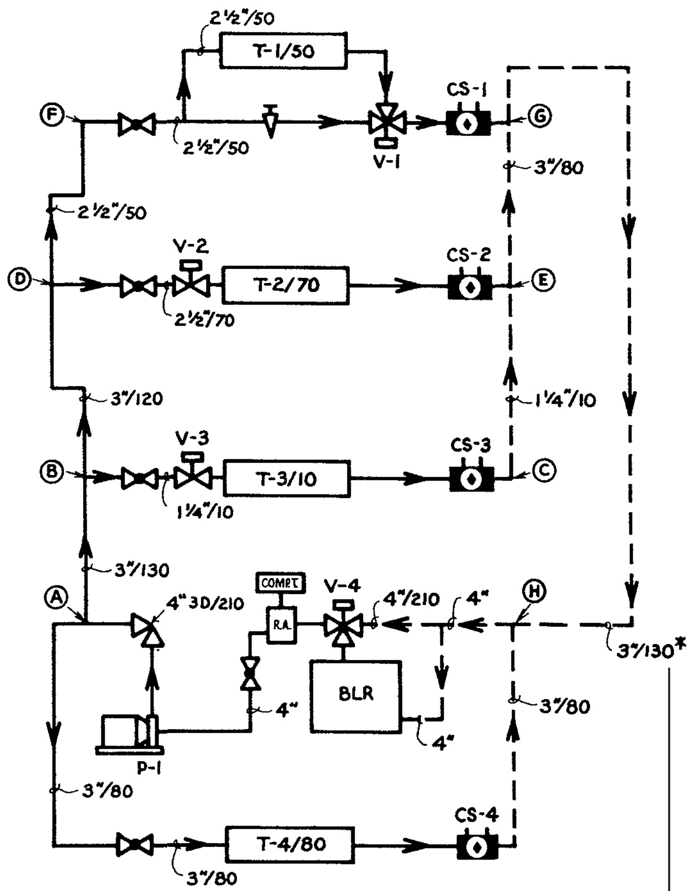
EXAMPLE 2:
Estimate friction loss from B to D given:
(1) Pipe Size is 3"
(2) Flow is 120 GPM
(3) Measured Length = 40'
(4) Pipe Section Includes Screwed Fittings as:
2 Els + 1 Flow Thru Tee

SOLUTION:
(1) Determine Fitting Equivalent Length from Table 2, each fitting = 8' E. L.; Fitting E. L. 3 x 8 = 24'
(2) Determine B-D Total Equivalent Length:
TEL = 40' + 24' = 64'
(3) Determine Friction Loss by use of Table 1.
Enter @ 3" to 120 GPM (122) upward, to 64' TEL (64.6); Read 2. 2' Friction Loss

EXAMPLE 3:
Determine head loss for 3" pipe, 130 GPM when TEL =164' (Section G-H, Example Problem).

SOLUTION:
Enter Table 1 @ 3" pipe, proceed to 130 GPM (132), proceeding upward it is found that 164' is not shown on Table.
164' = 100' + 64' SO:
Head Loss @ 100' = 4. 0'
Head Loss @ 64' (65) =2. 6'
TOTAL HEAD LOSS = 6.6'

HEAD LOSS ESTIMATION PROCEDURES



*** 3" /130 Means:**
3" Piple @ 130 GPM for Pipe Section G-H

Figure 3*
Terminal Or Sub-Circuit Pipe Sections Represented By Pipe Sections F-G (Thru T_1) D-E (Thru T_2), B-C (Thru T_3) And A-H (Thru T_4)

Bid Section

TERMINAL UNIT SCHEDULE				
Terminal Unit	**Mfg. & No.**	**MBH Capacity**	**GPM Flow**	**Ft. Hd.**
T-1	-	-	50	5'
T-2	-	-	70	12'
T-3	-	-	10	3'
T-4	-	-	80	4'

VALVE C_V SCHEDULE

Valve No.	C_V	GPM
V_1	24	50
V_2	24	70
V_3	4.8	10
V_4	185	210

* Piping arrangements with 3-Way control valves shown within this technical manual are provided by Bell & Gossett as reference information of existing systems only. As an active participating member of ASHRAE, it is Bell & Gossett's recommendation that engineers and system designers consult with the most current ASHRAE Standards for design guidance on Variable Flow Systems or Constant Flow Systems as indicated in ASHRAE Standard 90.1 Section 6.5.4.

HEAD LOSS ESTIMATION PROCEDURES

Distribution Pipe Section Head Loss Tabulation Form												
Pipe Section		**A-B**	**B-D**	**D-F**	**C-E**	**E-G**	**G-H**		**F-G**	**D-E**	**B-C**	**A-H**
Flow Rate		130	120	50	10	80	130		50	70	10	80
Pipe Size		3"	3"	2 1/2"	1 1/4"	3"	3"		2 1/2"	2 1/2"	1 1/4"	3"
Measured Length		30'	40'	42'	50'	60'	132'		50'	50'	64'	110'
Equivalent Length (Table 2)	**E1 or Thru Tee**		3/24'	3/18'	1/3/'2'	1/8'	4/32'		1/18'		1/3'/2'	4/32'
	Side Tee	1/16'							2/24'	2/24'	1/7'	1/6'
	Valve								1/2'	1/2'	1/1'	1/2-1/2'
	Other											
Total Equivalent Length		46'	64'	60'	53'/2'	68'	164'		94'	76'	75 1/2'	160 1/2'
Pipe & Fitting Head Loss (Table 1)		1.9'	2.2'	1.2'	1.0'	1.1'	6.6'		1.9'	2.9'	1.4'	2.6'
Terminal	**Unit No.**								T-1	T-2	T-3	T-4
	Head Loss								5'	12'	3'	4'
Control Valve	**C_V**								24/	24/	48/	—
	Head Loss								10'	20'	10'	—
Total Head Loss with Control Valve									16.9'	34.9'	14.4'	6.6'

Worksheet 2

TERMINAL SUB-CIRCUIT HEAD LOSS ESTIMATION

The terminal sub-circuits (Figure 3, page 30) differ from the distribution piping circuits in that they contain terminal units and fittings. Head loss estilnation is therefore broken into three parts:

1. Pipe and Fitting Head Loss
2. Control Valve Head Loss
3. Terminal Unit Head Loss

The total terminal or sub-circuit head loss is the summation of the head losses described as illustrated in the calculation sheet under Worksheet 2.

Pipe and fitting head loss procedures for the terminal circuit are exactly the same as already described for the distribution pipe sections (see page 24).

Control valve head loss determination procedures are based on "C_V "description of valve capacity. While the procedure is simple, it does require separate discussion. C_V head loss procedures are described on the next pages (pages 32-33).

Terminal unit head losses are usually based on "Bid Selected" terminal unit manufacturer's data. Notes concerning terminal unit head loss determinates are described on the following pages.

HEAD LOSS ESTIMATION PROCEDURES

CONTROL VALVE HEAD LOSS; C_V PROCEDURE

The temperature control contractor will provide valve C_V descriptions to the balance contractor for each control valve in the piping system.

The terminal C_V describes the valve flow-head loss relationship and means the valve flow rate that is required to cause 1 PSI or 2. 3 ft. head loss across the valve. Since head loss varies as the square of the flow change, the C_V valve can be used as the base for estimating head loss for other flow rates.

Scale 5 on the B&G System Syzer has been particularly arranged for C_V head loss evaluation. To illustrate its use, the example problem will be used. The problem states that the control valves used for T_1 and T_2 have a $C_V = 24$. Flow rates are 50 GPM through T_1 and 70 GPM through T_2.

For this circumstance, the C_V mark on Scale 5 is set opposite 2 4 GPM. Valve head loss is read opposite the specified flow rate as below in Figure 4.

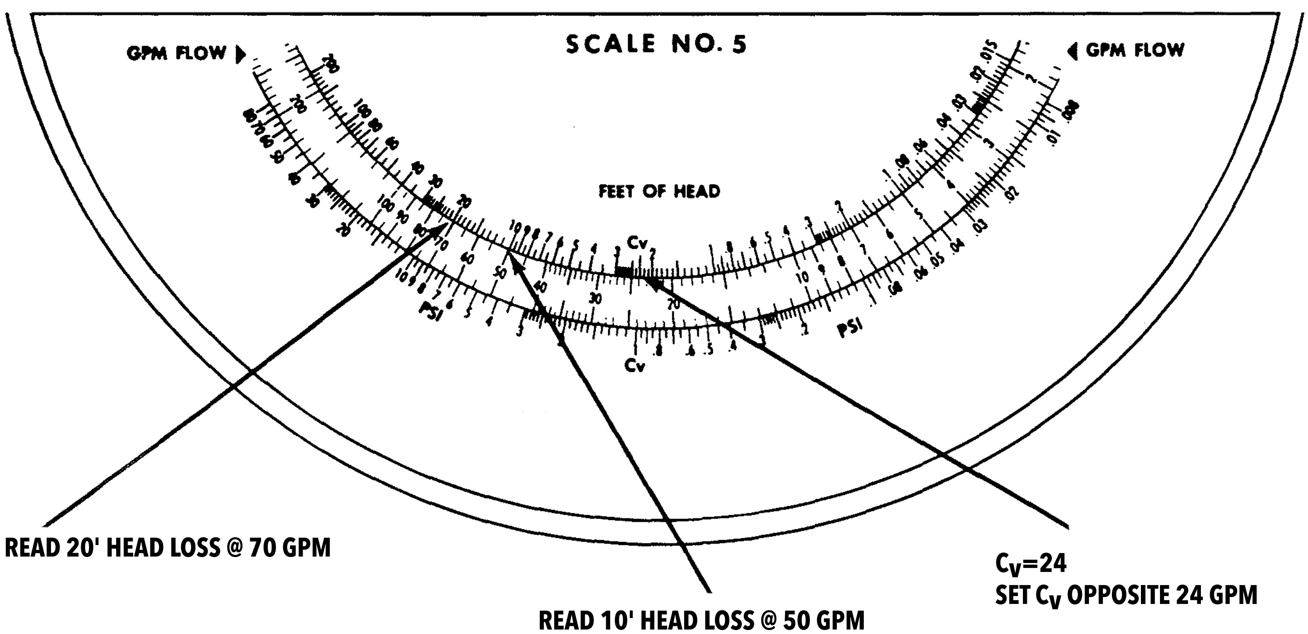


Figure 4

HEAD LOSS ESTIMATION PROCEDURES

TERMINAL UNIT HEAD LOSS NOTES

The plans will generally contain "scheduled" terminal equipment capacity, flow rate and head loss. The scheduled equipment may or may not be used, however, dependent on final bid selection. The terminal equipment schedule finally used must be based on the equipment actually "Bid Selected". The "Bid Selected" terminal equipment manufacturer should supply "certified" flow rate and head loss information for use by the balance contractor.

The terminal manufacturer may only be able to provide a single certified point for some terminal units; head loss for a single flow rate point. Given that required flow rate is different from that provided how can the new head loss be determined for the required flow?

Scale 5 of the B&G System Syzer can be used again. To illustrate, the terminal manufacturer states that a particular unit has 6' head loss at 4 GPM. Required flow rate is only 3 GPM. The procedure for establishing the head loss at 3 GPM is shown below as in Figure 5.

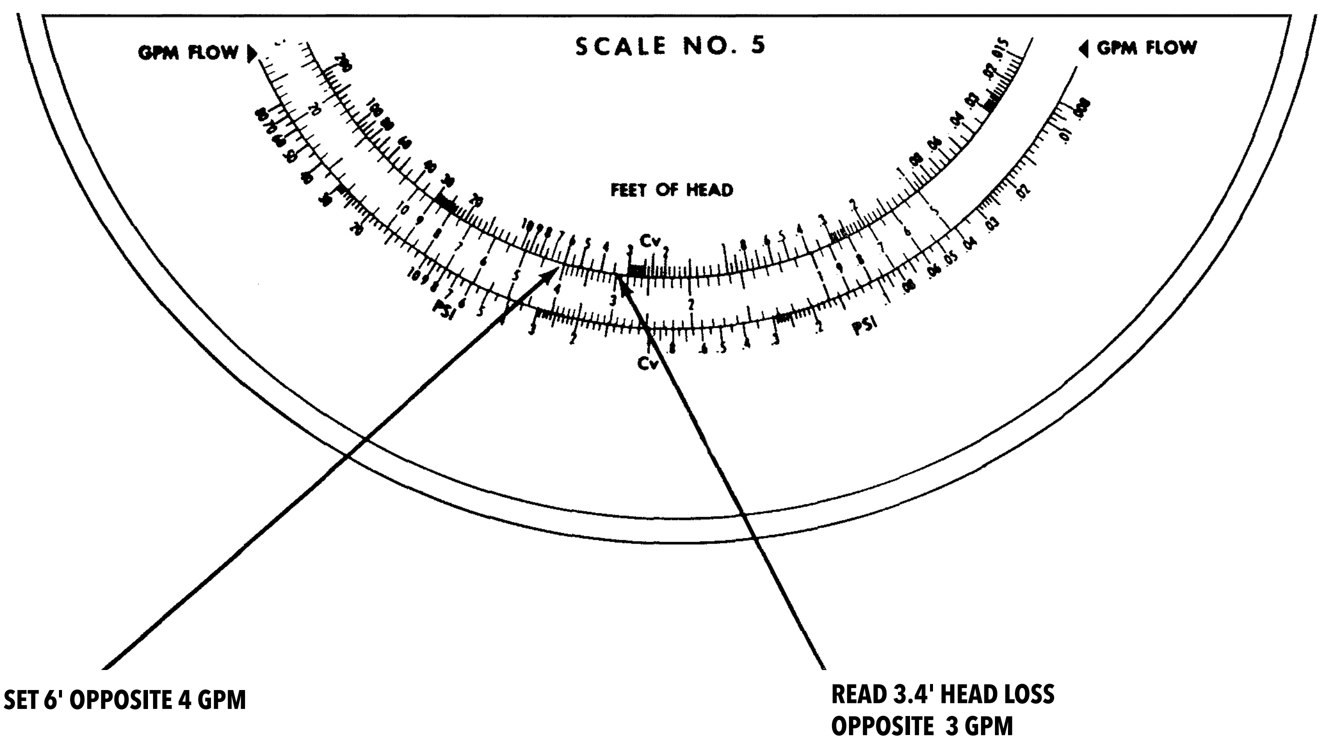


Figure 5

HEAD LOSS ESTIMATION PROCEDURES

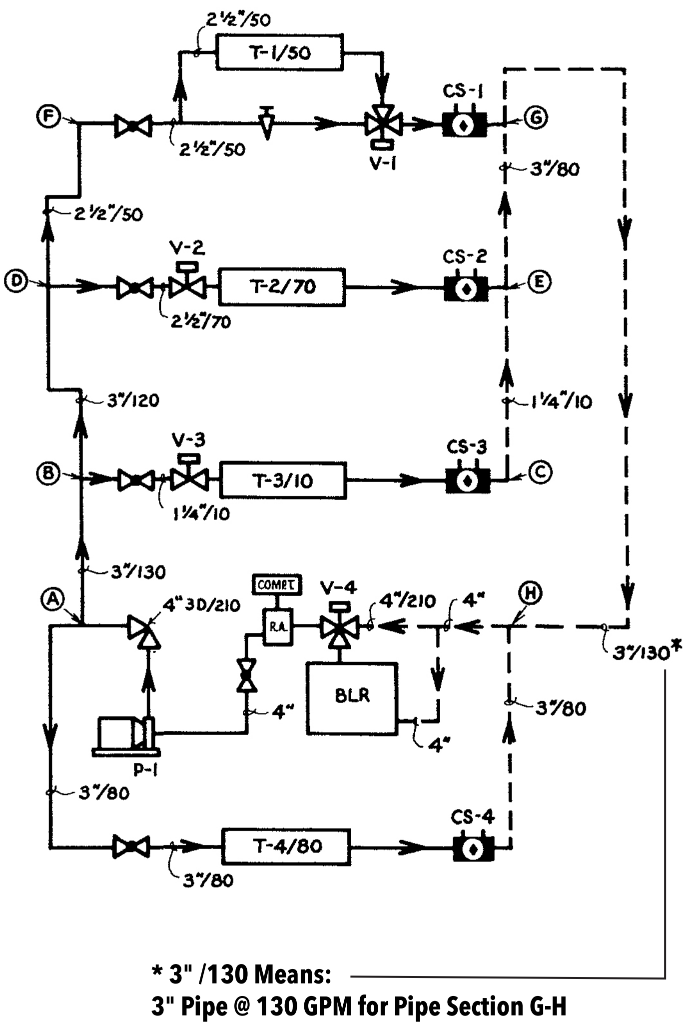


Figure 6*
Equipment Room Pipe Section
Represented By H-A (Thru Boiler)

Bid Section

TERMINAL UNIT SCHEDULE				
Terminal Unit	**Mfg. & No.**	**MBH Capacity**	**GPM Flow**	**Ft. Hd.**
T-1	-	-	50	5'
T-2	-	-	70	12'
T-3	-	-	10	3'
T-4	-	-	80	4'

VALVE C_V SCHEDULE

Valve No.	C_V	GPM
V_1	24	50
V_2	24	70
V_3	4.8	10
V_4	185	210

*** Piping arrangements with 3-Way control valves shown within this technical manual are provided by Bell & Gossett as reference information of existing systems only. As an active participating member of ASHRAE, it is Bell & Gossett's recommendation that engineers and system designers consult with the most current ASHRAE Standards for design guidance on Variable Flow Systems or Constant Flow Systems as indicated in ASHRAE Standard 90.1 Section 6.5.4.**

HEAD LOSS ESTIMATION PROCEDURES

Distribution Pipe Section Head Loss Tabulation Form														
Pipe Section		**A-B**	**B-D**	**D-F**	**C-E**	**E-G**	**G-H**		**F-G**	**D-E**	**B-C**	**A-H**		**H-A**
Flow Rate		130	120	50	10	80	130		50	70	10	80		210
Pipe Size		3"	3"	2 1/2"	1 1/4"	3"	3"		2 1/2"	2 1/2"	1 1/4"	3"		4"
Measured Length		30'	40'	42'	50'	60'	132'		50'	50'	64'	110'		62'
Equivalent Length (Table 2)	**E1 or Thru Tee**		3/24'	3/18'	1/3/'2'	1/8'	4/32'		1/18'		1/3'/2'	4/32'		5/275'
	Side Tee	1/16'							2/24'	2/24'	1/7'	1/6'		1/12'
	Valve								1/2'	1/2'	1/1'	1/2-1/2'		1/3'
	Other													
Total Equivalent Length		46'	64'	60'	53'/2'	68'	164'		94'	76'	75 1/2'	160 1/2'		104.5'
Pipe & Fitting Head Loss (Table 1)		19'	22'	12'	1.0'	1.1'	6.6'		1.9'	2.9'	1.4'	2.6'		2.8'
Terminal	**Unit No.**								T-1	T-2	T-3	T-4		—
	Head Loss								5'	12'	3'	4'		—
Control Valve	**C_V**								24/	24/	48/	—		185/
	Head Loss								10'	20'	10'	—		3'
Total Head Loss with Control Valve									16.9'	34.9'	14.4'	6.6'		—
												3-D		1.5'
												Rolairtrol		1.5'
												Boiler		2'
												Total		10.8'

Worksheet 3

EQUIPMENT ROOM HEAD LOSS

While equipment room head loss evaluation is not necessary for the proportional "pre-set" balance procedure, it is useful for evaluation of final pump head requirement and for prediction of estimated flow rates through each terminal (see page 23).

Equipment room head loss determination is essentially the same as for the terminal sub-circuit in that it is composed of several parts:

1. Pipe and Fitting Head Los s
2. Control Valve Head Loss
3. Prime Equipment Head Loss (Boilers, Chillers, etc.)
4. Specialty Equipment Head Loss (Strainers, Air Separators, 3-D, Checks, etc.)

Pipe and fitting head loss procedures are the same as described for distribution piping head losses. Equivalent length for equipment room strainers, checks, etc. shown on the calculation chart.

Control valve head losses are the same as described on page 32.

Head loss for boilers and chillers is available from the manufacturer.

Head loss for Bell & Gossett specialty equipment (Rolairtrol, 3-D and Suction Strainer refer to B&G Product Catalog).

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