Determining Surge Potential in Water and Sewage Forcemains and Preventing or Minimizing the Consequences Using Automatic Control Valves

by

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DETERMINING SURGE POTENTIAL IN WATER AND SEWAGE FORCEMAINS AND PREVENTING OR MINIMIZING THE CONSEQUENCES USING AUTOMATIC CONTROL VALVES

By: J. E. Lescovich

A paper written by this author and presented at the Southwest Section of the AWWA in Austin, Texas in 1966 entitled "The Control of Water Hammer By Automatic Valves" has been given to interested people for over thirty years. Now over thirty years later this writer has decided to re-write the article to include some more useful information and incorporate some practical information gained after more than forty-five years of minimizing pressure surge problems by the use of automatic control valves.

Prevention of pressure transients (surges) should be one of the first considerations in an Engineer's mind when designing a pumping system or flow control facility. This article will emphasize some of the factors to be evaluated when designing a pumping system. While conceding that the analysis of pressure transients in a pumping system can be a very complex subject, and knowing there are many fine technical publications and computer software programs available, this writing will provide a shortened version for estimating the surge potential in a pumping system. Emphasizing again, this paper should not replace a comprehensive surge analysis where one is required. The article will suggest valves than can be employed to prevent the surge problems or by the use of overpressure relief valves, minimize the consequences.

REVIEW OF SURGE THEORY

Before attempting to deal with pressure surges, it would be appropriate to review some basic principles regarding the cause, magnitude and prevention of surge pressures. Pressure Transients or Surge, sometimes called waterhammer when a noise is associated with it, results when any attempt is made to alter the velocity of a column of water. It matters not if the column of water is at rest and is being put into motion, or if the water is in motion and is being brought to a stop or slowed down. The magnitude of the resulting pressure surge is directly proportional to the rate of change of velocity produced on the water column. It is not the total velocity change produced over a period of time which is the prime concern, but the rate of change. This factor will be elaborated on later in this writing. By applying Joukowsky's equation for determining the pressure rise in a pipe,

$$hmax = a\ dV / g$$

In English units, "hmax" equals the headrise in feet of water, "dV" being the change in the water velocity in feet per second, and "g" being gravity or 32.14. The "a" denoting the velocity at which the surge wave travels once created. The surge wave travels at the speed of sound in that particular pipe. The velocity "a" is not the same for every pipe. For example, in a typical small diameter Ductile Iron pipe "a" is nearly four times the speed of sound in air, or approximately 4000 fps. The surge wave velocity is a function of the pipe diameter, the pipe wall thickness, and the modulus of the pipe material. The other factor affecting the velocity of the surge wave is the water bulk modulus, which itself is affected by the water temperature and its pressure. Changing water pressure and temperature, however, have little effect on the surge wave velocity. Dissolved air however, can have a significant effect on the wave speed. It has been written that 1 part of air in 10000 parts of water by volume at standard conditions can reduce the wave speed by about 50 percent. The equation for determining the surge wave velocity is expressed by various equations. One such equation is shown here. (A pipe restraint factor sometimes mentioned being omitted.)

$$a = 4720 / sq..rt. (1 + k\ d / E\ t)$$

K represents water bulk modulus which is nearly 300,000 psi. (NOTE: the modulus for steel is nearly 30,000,000 psi which means that water is 100 times more compressible than steel. All liquids have their own bulk modulus, 230,000 PSI for crude oil, 130,000 psi for gasoline, etc. Illustrating that liquids are very elastic substances.) "d" being the pipe diameter in inches. "t" is the pipe wall thickness in inches. "E" is the pipe material modulus. A few examples are given. (All values are in psi.)

Steel	30,000,000
Ductile Iron	24,000,000
Cast Iron	15,000,000
Asbestos Cement	3,400,000
PVC	400,000
HDPE	110,000

A graphical chart is included which can solve for surge wave velocities for any liquid or pipe material up to 96 inch dia. (See Figure 1)

For example, a 48 inch Ductile Iron pipe with a 0.51 inch wall thickness would have a surge wave velocity of 3228 fps. The equation given earlier for hmax is derived from Newton's force and impulse equations, or rate of change of momentum. This should not be confused with Newton's F=MA expression which applies to solid or rigid bodies. Water is elastic, and there is no physical process known where a force can be applied to all particles of an elastic substance simultaneously. The equation assumes the velocity change was produced instantly.

It is commonly known that nothing can be done instantly, however, it is not commonly understood that a flow need not be stopped instantly to obtain the same result as an instantaneous flow stoppage. It so happens in hydraulics, that any flow stoppage occurring within one surge period is equivalent to an instantaneous flow stoppage.

A surge period must now be defined. To simplify this concept, visualize a long straight pipeline, for example, a 48 inch D.I. pipeline from a reservoir with a valve at its discharge end. Assume also that water is discharging from the pipe and valve at say ten fps neglecting line friction. The potential surge or headrise would be hmax = 3228 x 10 / 32.2 = 1002 feet. You may have noticed the headrise in feet is 100 times the flowing velocity in fps. This will be true for this pipe at any flowing velocity because a constant can be made for 3228 / 32.2 which is nearly 100. At 5 fps, the resulting potential headrise would be 500 feet. For each pipe diameter, wall thickness, and pipe material, a similar constant can be determined.

When the discharge valve flowing at 10 fps is closed suddenly, the flow at the valve inlet is suddenly stopped with a pressure wave created of 1000 feet which begins its travel up the pipe at the speed of sound or 3228 fps. The water at the valve's inlet is of course stopped, but water at the reservoir end continues to enter the pipe because water there feels no effect of the discharge valve being closed, and it will not feel any effect until the surge wave arrives at the reservoir. The time required for the surge wave to arrive at the reservoir depends on the pipeline length. If we assume, for simplicity, the pipe is 32280 feet long, then the surge wave will require 32280 / 3228 or 10 seconds to reach the reservoir.

At this time it should be remembered that the surge resulting from closing the discharge valve is only the increase in pipeline pressure not the total pressure. The static pipeline head must be added to the surge pressure to obtain the total pressure. To re-emphasize, surge is independent of the existing pressure. An upsurge is the increase in pressure, not the total pressure. Assuming the reservoir static head is 100 feet then, the total head in the pipe would be (Capital H) Hmax or 1000 plus 100 equaling 1100 feet. At time equals 10 seconds after valve closure, the surge wave arrives at the reservoir, the pipeline is now pressurized to 1100 feet of head. With a reservoir head of only 100 feet, the pipeline water in a compressed state (which is what pressure is), immediately begins to relieve its excess pressure back into the reservoir creating a reversing pressure wave traveling at back towards the closed valve at the same speed of sound. This returning surge wave will require 10 seconds to reach the closed valve. At that time the head in the pipe for an instant is equal to the static head, or 100 feet. The required time for the round trip of the initial upsurge is therefore, 20 seconds.

A second surge wave is immediately created which is a downsurge and a mirror image of the upsurge but of the opposite intensity. This downsurge wave likewise travels to the reservoir and returns as a downsurge. Upon reaching the closed valve, the downsurge again becomes an upsurge and this cycle keeps repeating resembling a square sine wave until pipe friction reduces the pressure in ever diminishing intensities to static conditions. Should a downsurge intensity exceed the available head, water column separations may occur, but such events are too involved to discuss in this writing.

A very important point to remember from the above description is the time required for the surge wave to make one round trip of the pipeline. That time is known as the "Surge period" (T=2L/a) sometimes referred to as a "Critical period." The reason this time period is so important is that any flow stoppage made within one surge period duration or less results in a surge equivalent to an instantaneous flow stoppage. In the previous example, the potential surge was 1000 feet plus the static head for the instantaneous stopping of a flowing velocity of 10 fps. From the above statement, any total flow stoppage in one surge period (20 seconds) or less will result in an equivalent surge of 1000 feet. For a partial valve closure, the initial surge will be calculated using the amount of velocity destroyed within one surge period.

When closing a valve slowly and uniformly, the same procedure is followed, except for the second increment of valve closure the initial upsurge is subtracted from second time period upsurge because, the first period upsurge has traversed the system and is now beginning its second round trip as a downsurge while upsurges are still being generated. And so on, and so on, to where the results would appear as an arithmetic integration tabulation. Computer programs perform these steps routinely.

Pipelines frequently have branches which can complicate the analysis. A surge wave reaching a pipe junction or lateral, causes the pressure wave to travel both branches. Should one branch be shorter than the other, the upsurge wave reflecting from the end of its branch, will begin a return to its point of origin. During its travels the upsurge may encounter downsurges or perhaps upsurges traveling in the opposite direction. Pressure waves traveling in opposite direction will pass through each other without interfering with each other. The pressure intensity at the point of interception is the algebraic sum of each pressure intensity.

VALVE CHARACTERISTICS

In the above example, an unspecified valve at the pipe's end was closed suddenly. It was shown that closing that valve instantly or in any time up to 20 seconds would produce the same results. We will now review the effects of various real valve types should they have been employed.

Every valve type during its opening and closing stroke will effect flow differentially, which is called the valve's characteristic. For example, assume the valve at the end of the pipe is a common gate valve, and assume this valve was closed uniformly in say 60 seconds. Also assume the valve's flow and stroke were recorded during its closure. It would be found that the gate valve could be closed about 50 percent with little noticeable change in the flow. Closing the gate valve another 10 percent may reduce the flow only about 4 percent. Notice, at 60 percent closed, this gate valve has 96 percent of the flow still passing through it. It is during the final 20 percent of the valve stroke where about 75 percent of the flow is cut-off. The cut-off characteristic resembles parabolic curve from which it can be concluded that an effective closing time of a gate valve is roughly about 30 to 35 percent of its total time. (See Figure 2)

COMPARISON OF VALVE EFFECTIVE CLOSING TIMES

An interesting observation can be made, that closing this gate valve in 60 seconds stopped the flow in an equivalent time of about 20 seconds. Remembering that one surge period is 20 seconds, the resulting upsurge would still be 1000 feet, the same as for an instantaneous flow stoppage, even though the valve was closed in one minute. It should now be apparent that the valve closing time does not equal flow stoppage time. For the gate valve it was the final 30 percent of the valve stroke which produced a very high rate of change in the water column velocity. The effective closing time for a Butterfly valve may be assumed as about 20 percent of its total time. A Rotary Ball valve or Cone valve will have an effective closing time of about 50 percent of its total time.

The Vee-Ported Differential Piston valve as manufactured by GA Industries, is comprised of a piston which moves up and down within a Vee-ported cage. As the piston rises six or eight small triangles initiate flow. As the valve opens further, the triangles become larger increasing the flow in a programmed manner. When the valve is fully open, the total areas of the Vee-Ports equals the full area of the nominal pipe diameter. During its closing stroke, the Vee-Ports become increasingly smaller similar to a vee notch weir pinching off the flow in an ideal manner. This provides the Vee-Ported valve with an extended effected closing time of over 60 percent, meaning the Vee-Ported valve can be closed more quickly than the above valves with less resulting pressure rise. (For comparison of valves 50% open - See Figure 3)

To be most effective, the Vee-Ports should be downstream of valve's seating surface. Throttling is then done by the Vee-Ports and not by the valve seat where maintenance would be a problem. It is possible to close valves that have unsatisfactory closing characteristics in two stages. The initial closing stroke made at one speed and the final closing at a slower speed. This requires some additional control piping.

SURGE PREVENTION

From the preceding discussion, the reader should have become aware that long pipelines equals long surge periods, and slower the valve's closing times are required to minimize surges. An example of estimating a required valve closing time may be seen in the following example.

Using our previous example of a pipeline 32280 feet long, flowing at 10 fps, select a gate valve closing time which will limit the surge to 100 feet, and also select a closing time for a GA Vee-Ported valve. (For headrise versus valve closure -See Figure 4)

The potential surge established previously was 1000 feet for a total flow stoppage in 20 seconds or less. Lets assume the allowable surge is 100 feet or 10 percent of the potential surge. Referring to the graph fig. 4 which shows headrise versus valve closure time. The vertical scale represents percent of surge for an instantaneous flow stoppage, and the horizontal scale showing valve closure time in units of Surge Periods (2L/a). In our example, each unit on the "Perfect" valve scale represents 20 seconds. Calculate the "K" or pipeline constant. The equation is given where K = a v / (2 g H). "a" = the surge wave velocity in fps as given previously. "v" = the pipeline water velocity in fps. "g" = 32.14. "H" = the normal system head, in this case reservoir head. For our example, K = 3228 x 10 / (64.34 x 100) = 5 On fig. 4 graph, read horizontally to the "5" curve, then down to the result of about 7.5 on the "Perfect" scale. This scale represents a perfect valve with a perfectly linear closing characteristic. Such a valve would need to be closed uniformly in 7.5 surge periods or 7.5 times 20 seconds or 150 seconds. The valve being a gate valve, requires reading down to the gate valve scale, to 19 surge periods which is 19 times 20 or 380 seconds (6.33 minutes) of valve closure time. A GA Vee-Ported valve would need to be closed in 14.5 surge periods, or 14.5 times 20 equals 290 seconds (4.8 minutes). These results are fairly good approximations, but to be more sure using the actual valves installed characteristic curve with any of the Transient analysis computer programs will provide more comprehensive results. Pipeline constants are typically about 1.0. When pipeline constant K's become larger this implies a larger momentum exists for the water column. Water column separation potential should then be investigated.

VALVE CHARACTERISTICS

The fact that all valves do not perform equally was mentioned before. Every valve type can be represented by its Inherent Characteristic curve. Such a curve plots the valve stroke versus its Cv. The Cv as you may know is a flow capacity coefficient, and for water is found by dividing the GPM flow through the valve by the square root of the differential pressure across the valve in psi. Plotting a curve of Cv versus stroke for a valve for each increment of its stroke produces the Inherent Characteristic curve that can be used to compare valves on an equal basis. In simplified terms, the curve shows how many gallons per minute of flow is required to produce a one psi pressure drop at that particular stroke position. (In European units the Cv becomes "K" with flow is in M3/hr, and pressure in Bars.)

There is another valve characteristic curve called the Installed characteristic curve which depicts the flow through a particular valve in an actual installation. Curves are drawn by stroking the valve fully and plotting stroke versus actual flow. The valve's differential pressure is automatically accounted for. This curve will change for the same valve in every installation.

SURGE PREVENTION (CHECK VALVE SELECTION)

The previous discussions described how surges are created. The obvious conclusion to minimizing surges, is to produce gradual changes in the fluid velocity. The importance of valve closing time is not specifically in seconds, but in units of surge periods. A pipeline that is only 400 feet long, for example, with a surge wave velocity of say 4000 fps, will have a surge period of only 2 x 400 / 4000 = 0.2 seconds. Each second of valve closure time or each second of pump coastdown time represents 5 surge periods. Pumps often coast for several seconds on a power failure, except for very high head installations. There are pumps that coast for long periods producing in effect a gradual flow stoppage. (See Figure 5, 6, 7, & 8)

Any simple mechanical check valve, such as a swing check, tilting disc, wafer check, etc. are at the mercy of the flow. Such valves can only respond to the flow, and therefore cannot affect a gradual rate of change in the fluid velocity. Every pump shutdown with simple check valves is therefore equivalent to a pump power failure. The resulting surge can be determined as described earlier. Shutting down a pump employing a simple mechanical check valve may result in a check valve bang. Do not equate the noise with a surge. The check valve slam is a mechanical problem - there may actually be little surge. Also, do not assume that a quietly closing check valve means no surge occurred. Surge is an hydraulic phenomenon. Pump control check valves such as power operated Cone valves, Rotary Ball valves, GA Electric Check valves and the like, change the flow gradually on startup or shutdown of the pump. Surges therefore can be limited to any desired intensity. (See Figure 9 & 10)

A pump with a GA Electric Check valve installed would function as follows. When the pump is first started the pump check valve is closed. As the pump pressure exceeds the system static head, the Electric Valve is energized to open at a controlled rate producing a gradual acceleration of the water column. The surge can be held to any desired minimum. When a pump shutdown command is given, the pump continues to run while the check valve begins a controlled closing sequence resulting in a gradual deceleration of the water column. Just prior to the check valve seating, the check valve actuates a limit switch to shut down the pump. Valve operating times can be adjusted for several minutes if line lengths require it. Should a power failure occur, an emergency solenoid which is a standard feature, permits the check valve to close at a much faster but adjustable rate to minimize pump reversal.

The pump Control Check valve can be provided with additional controls to perform secondary functions. This could be a back pressure sustaining or discharge pressure control. There are many options that the valve manufacturer can inform you about. An article entitled "Check Valves With Brains" by this author offers a description of several of these features.

SURGE DISSIPATION

The Electric Check valve just described is a valve which prevents surges normally associated with the starting and stopping of pumps. However, surges cannot always be prevented such as those resulting from a pump power failure. For such occasions, devices are employed to minimize the consequences. There are Surge Tanks, Surge Chambers, Surge Relief Valves, Surge Anticipators, and Accumulators to mention a few. Tanks and chambers are large unsightly expensive and require frequent inspections. This article will elaborate mainly on the Surge Relief valve and Surge Anticipators to minimize surge intensities.

SURGE RELIEF VALVE

A Surge Relief valve is normally installed on a tee directly downstream of the pump check valve. Surges are always greatest at their point of creation, so it is logical that the over pressure control be located near there. Surge Relief valves are usually arranged to discharge to atmosphere, sometimes to a wet well or clear well. Surge valves can sometimes be arranged to discharge back to the Pump suction if conditions there are considered. The Surge valve opening setpoint is typically a pressure about 10% to 15% above the pump maximum discharge pressure, and when responding to overpressure, the valve opens only as much as required to prevent further pressure rise. (See Figure 11 thru 16)

There are Engineers that view the Surge Relief valve as a safety device and therefore prefer to have two valves (sometimes more) in parallel. In such instances, each valve has a slightly higher set point. The valves then open in sequence, but only as much as necessary. The Relief valve is a pilot operated valve that does not have the accumulation problem inherent in a direct spring loaded valve. (See Figure 17)

A question often asked about Relief valves, is the valve's ability to respond to surges traveling at the speed of a bullet. The answer is that surge waves do travel at great speeds, but the rise in pressure is at the same rate the surge was created. A pump coastdown of just a few seconds, produces a surge wave with a front resembling an inclined plane traveling very fast. The horizontal movement is rapid, but the vertical pressure rise is gradual compared to surge valve response time.

SURGE ANTICIPATOR VALVE

In pumping installations where the surge pressure rise is very abrupt, or in installations where three way surge protection is desired, a Surge Anticipator valve can be employed. The Surge Anticipator valve is programmed to respond to the cause of a surge prior to the arrival of the surge itself. (See Figure 18)

A power failure will result in a surge, so will a pump failure which is not a power failure. The Surge Anticipator, referred to as the Surge Sentinel, opens immediately upon pump power failure by way of a solenoid pilot valve, or a pump failure such a broken pump shaft, motor winding failure, etc., by way of a pressure switch. The Surge Anticipator will remain fully open for an exact number of seconds, awaiting the completion of the downsurge cycle and creation of the upsurge, then begin a controlled closing sequence limiting the upsurge to an acceptable pressure. Any subsequent over pressures that occur above a preset pilot setpoint will cause the valve to reopen as much as necessary as an over pressure relief valve.

SURGE VALVE SIZING

Sizing an overpressure relief for water service either raw water or filtered water, equation labeled "Relief Valve Sizing" may be used. Relief valves such as the fig. no. 6600-D (Angle pattern), or the fig. no. 6700-D (Globe pattern) cannot be oversized. If any back pressure exists, or any extraordinary relief valve discharge piping exists, then the valve size may need to be increased.

RELIEF VALVE SIZING EQUATION

A common equation for sizing pilot operated relief valves for water is, Relief Valve Size for water = C times Sqrt (gpm / sqRt (PSI)). C = 0.284 for Angle Valves, or "C" = 0.326 for Globe Valves.

The sewage surge valve size may be determined by referring to chart fig. 24 with similar comments as above. The valve fig. no. would be 625-D for an LR Elbow pattern valve in sizes to 8 inch. Valve sizes 10 inch to 12 inch in the LR Elbow pattern valves have a fig. no. of 624-D. The fig. 626-D being a Wye pattern valve may be specified when an inline flange valve is preferred.

SIZING THE SURGE ANTICIPATOR VALVE

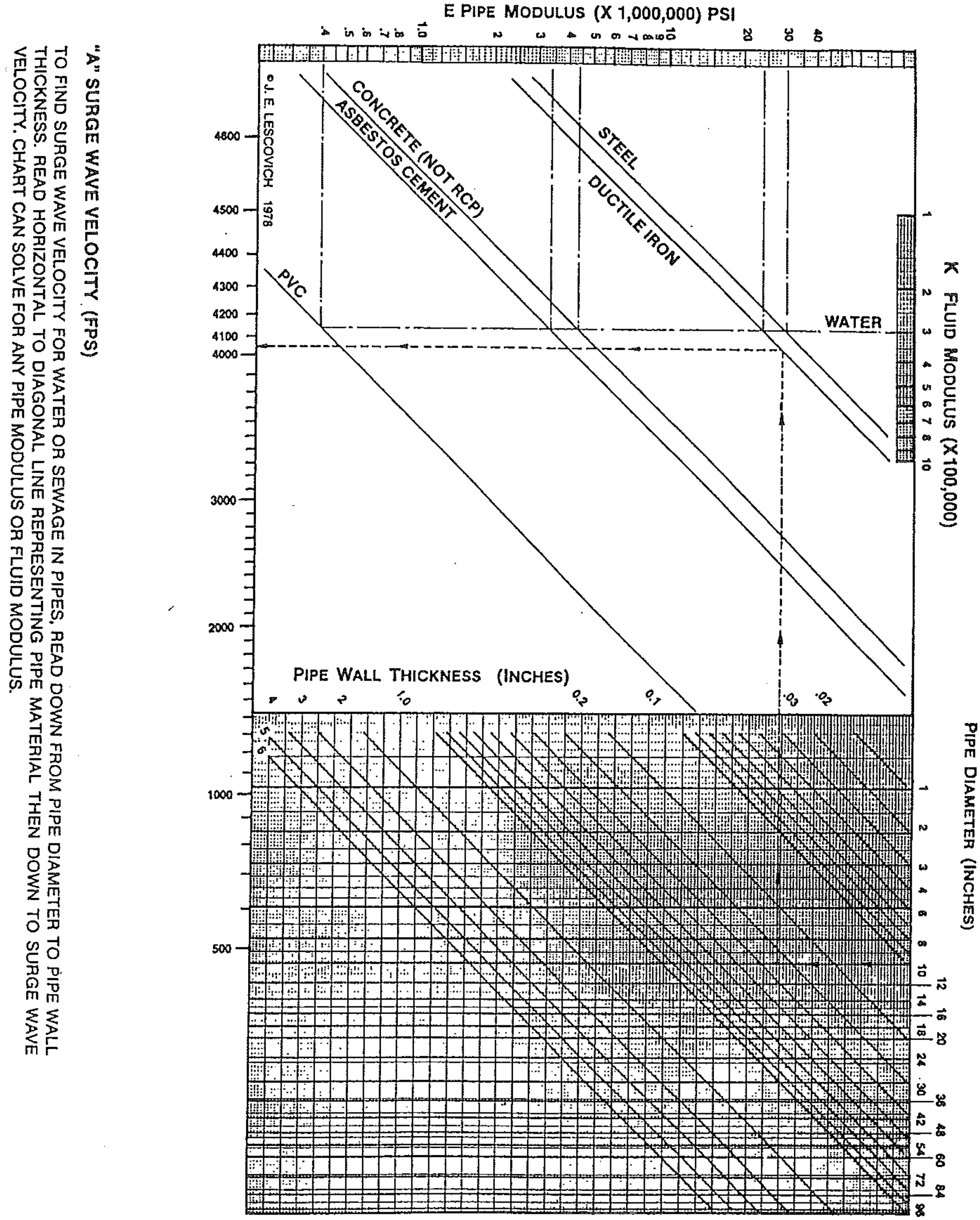
We stated earlier that over pressure relief valves cannot be oversized. However, the Anticipator valve should not be oversized. The Anticipator valve opening on power failure or pump failure will open fully. The valve could then establish an undesirable and unnecessary excess reverse flow.

It is difficult to present in this writing a sizing method which is correct for every case, or knowing if the reader will apply the input data correctly.

A sizing procedure will be presented here mainly to be used as a guide. Refer to fig. 19 chart. Read across the bottom scale to the pipeline velocity. Next, read up to the diagonal line representing the head in feet, and then left to the vertical scale. Read the required anticipator valve discharge capacity as a percent of the line flow. To determine the proper angle body valve or globe body valve refer to charts fig. 20-23. On the USGPM scale locate the required discharge rate obtained above and read vertically to the horizontal line representing the valve relief setpoint in feet. Chances are you will arrive at a point between two valves sizes. The conservative decision is to select the larger of the two sizes. If more than one relief valve is preferred, then divide the flow by the number of valves, and refer to the charts again. The discharge charts apply to the valves alone, if a long or complex relief valve discharge piping exists that could affect the discharge capacity of the relief valve, then the relief valve size may need to be increased.

When applying a surge anticipator to a pumping system with a widely varying flow rate, it is suggested that there be two valves selected. One valve being a surge anticipator valve and the other being a standard over pressure relief valve. Being both the same size, their parts are interchangeable. If desired, the relief valve can be converted to an anticipator. This will prevent oversizing the anticipator at lower flow rates.

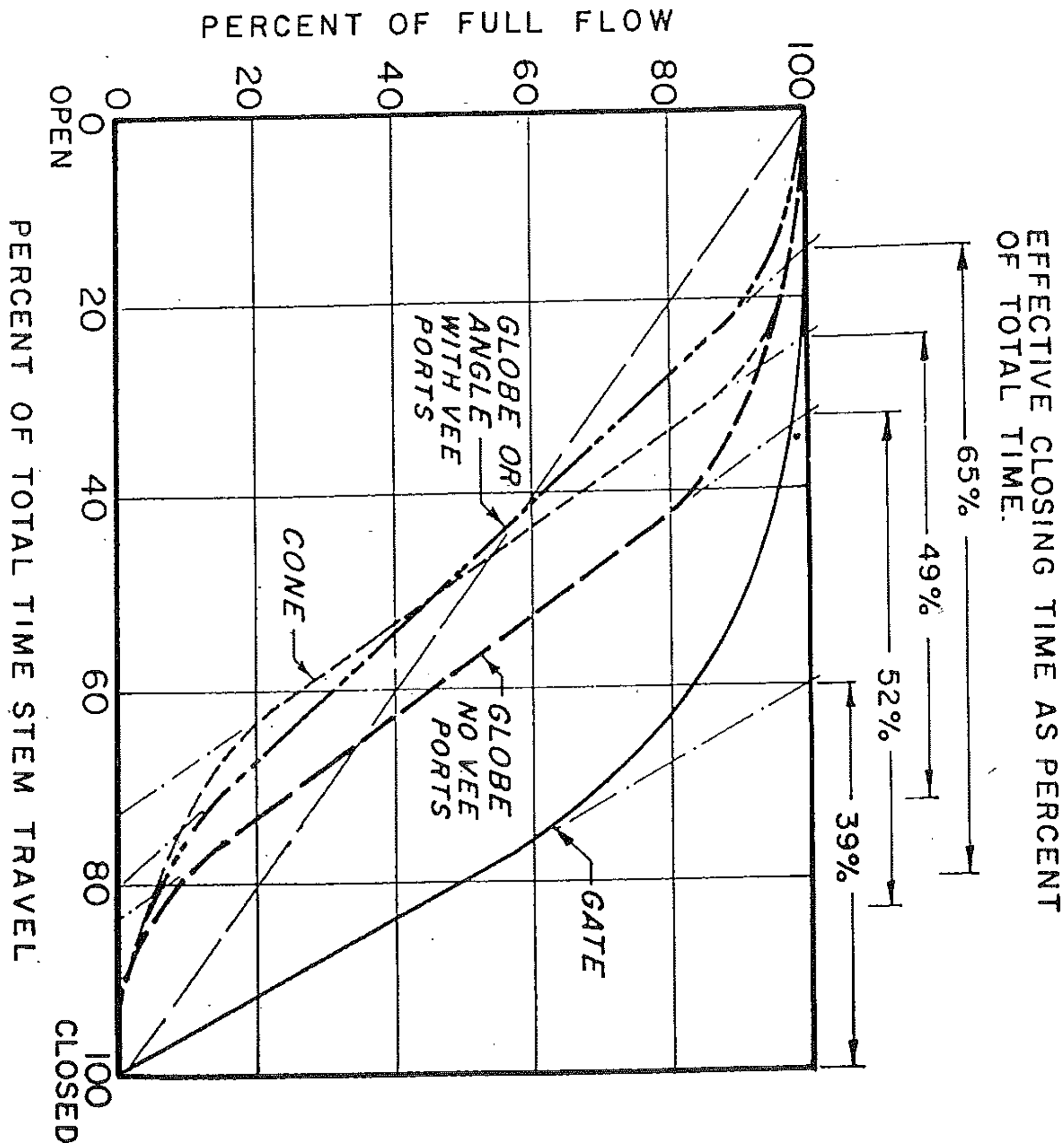
Should a valve application problem arise, contacting a valve manufacturer experienced in this field will afford you a satisfactory solution.



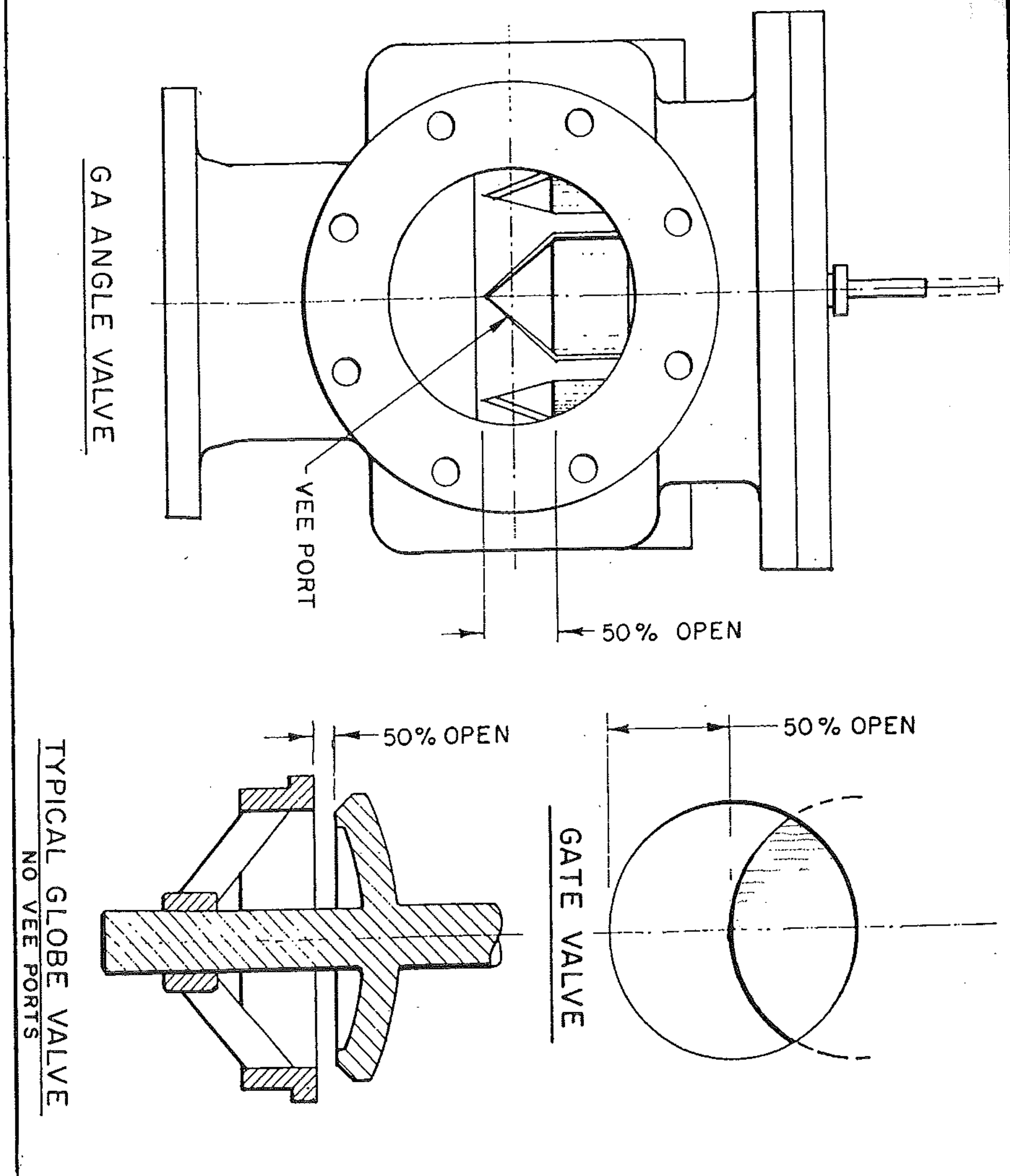
EXAMPLE:

10 INCH DUCTILE IRON PIPE WALL THICKNESS .35 INCHES WAVE VELOCITY 4050.

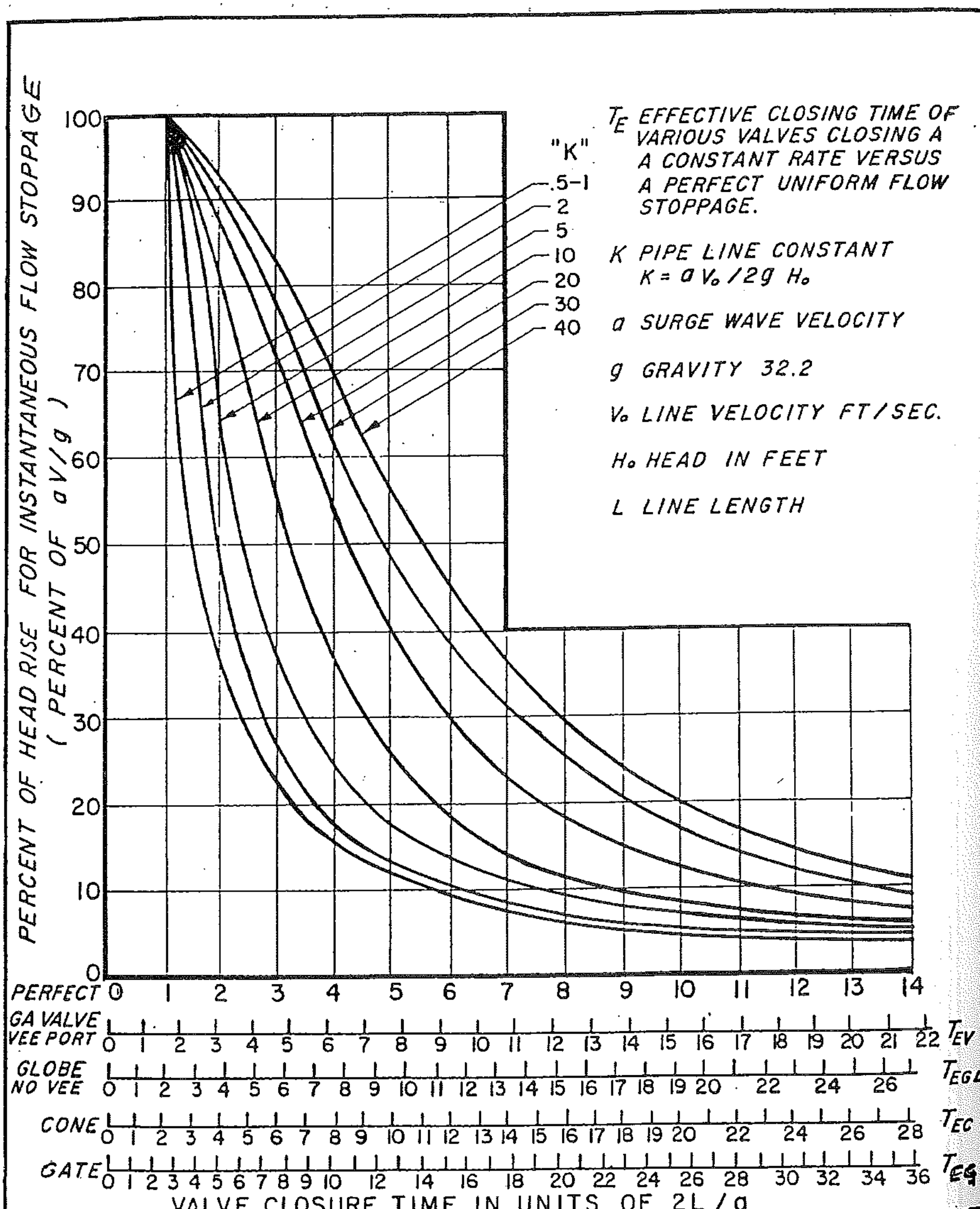
FIGURE 1



GA INDUSTRIES INC.	REFERENCES	SCALE NO	DRAWN BY JEL
COMPARISON OF VALVE EFFECTIVE CLOSING TIMES		FIG. NO.	DATE 8 18 66
		FILE:	DWG NO: Fig. 2

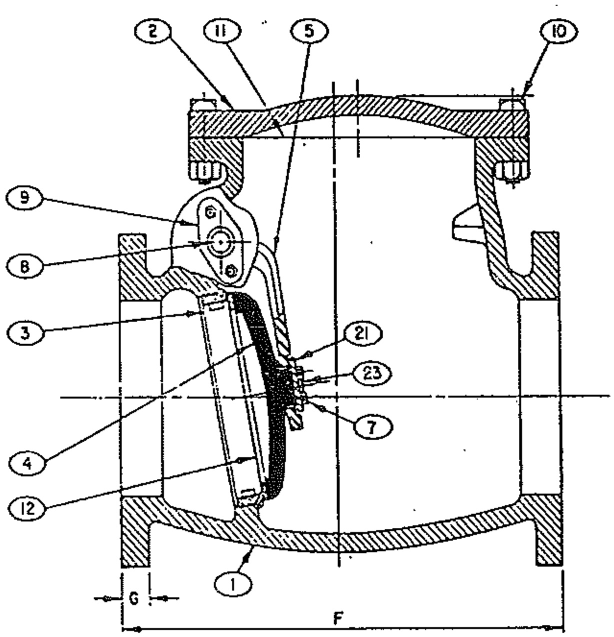


GA INDUSTRIES INC.	REFERENCES	SCALE NO	DRAWN BY JEL
COMPARISON OF VALVES 50% OPEN		FIG NO	DATE 8 18 66
		FILE	DWG NO Fig. 3



GA INDUSTRIES INC.	REFERENCES	SCALE NO	DRAWN BY JEL
HEAD RISE VERSUS VALVE CLOSURE TIME FOR PERFECT VALVE, GA VALVE, STD GLOBE, CONE, AND GATE VALVE.		FIG. NO.	DATE 818
		FILE	DWG. NO. Fig. 4

FIG. 5 PLAIN CHECK VALVE



1	1	BODY	CAST IRON
2	1	COVER	CAST IRON
3	1	BODY RING	BRONZE
4	1	CLAPPER	CAST IRON
5	1	CLAPPER ARM	BRONZE
7	VARIES	CAPSCREW	BRONZE
8	1	HINGE PIN	STN STL
9	2	GLAND (BRONZE BUSHED)	CAST IRON
10	VARIES	COVER BOLTS AND NUTS	STEEL
11	1	COVER GASKET	ASBESTOS
12	1	CLAPPER RING	BRONZE
15	1	WEIGHT LEVER ARM	CAST STL
16	1	WEIGHT	CAST IRON
17	1	SPRING LEVER ARM	BRONZE
18	1	SPRING	STEEL
19	1	SPRING BRACKET	STEEL
20	1	SPRING EYEBOLT	STEEL
21	1	CAP PLATE	CAST IRON
22	VARIES	SPRING BRACKET CAPSCREW	STEEL
23	1	LOCK WIRE	COPPER

FIG. 6 BALL CHECK VALVE

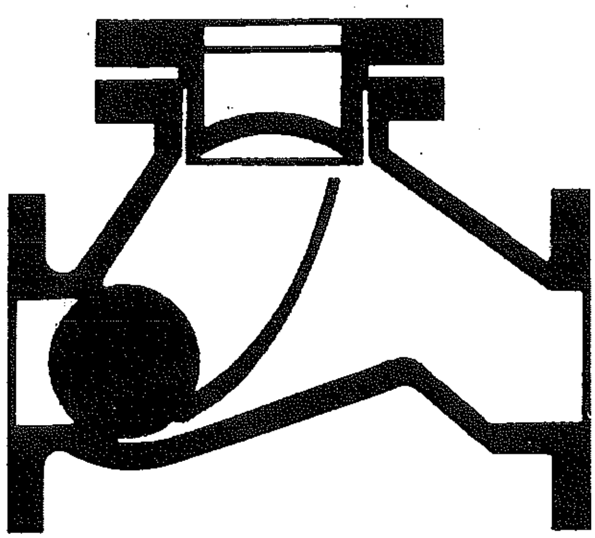


FIG. 7 CLOSING ASSISTED CHECK VALVE

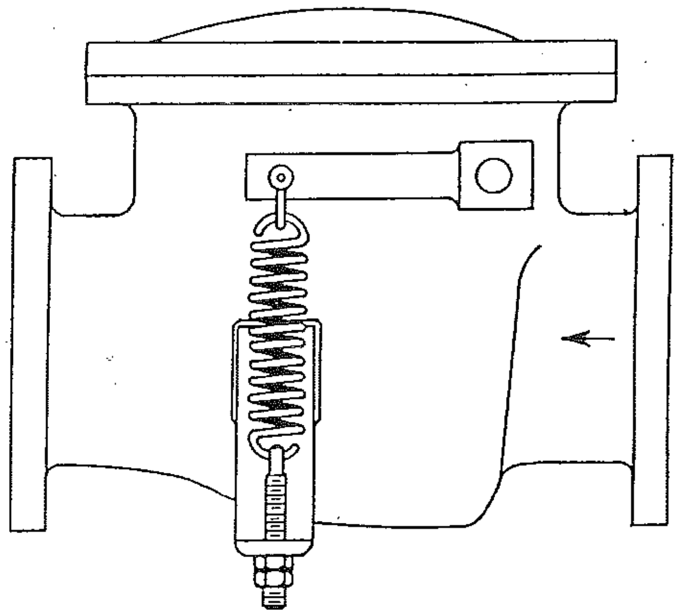
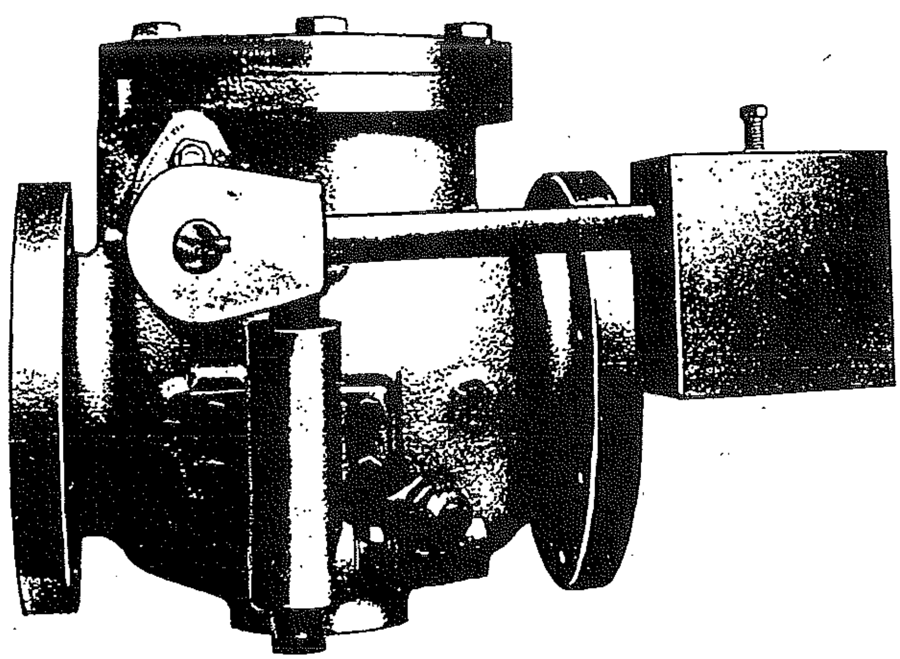
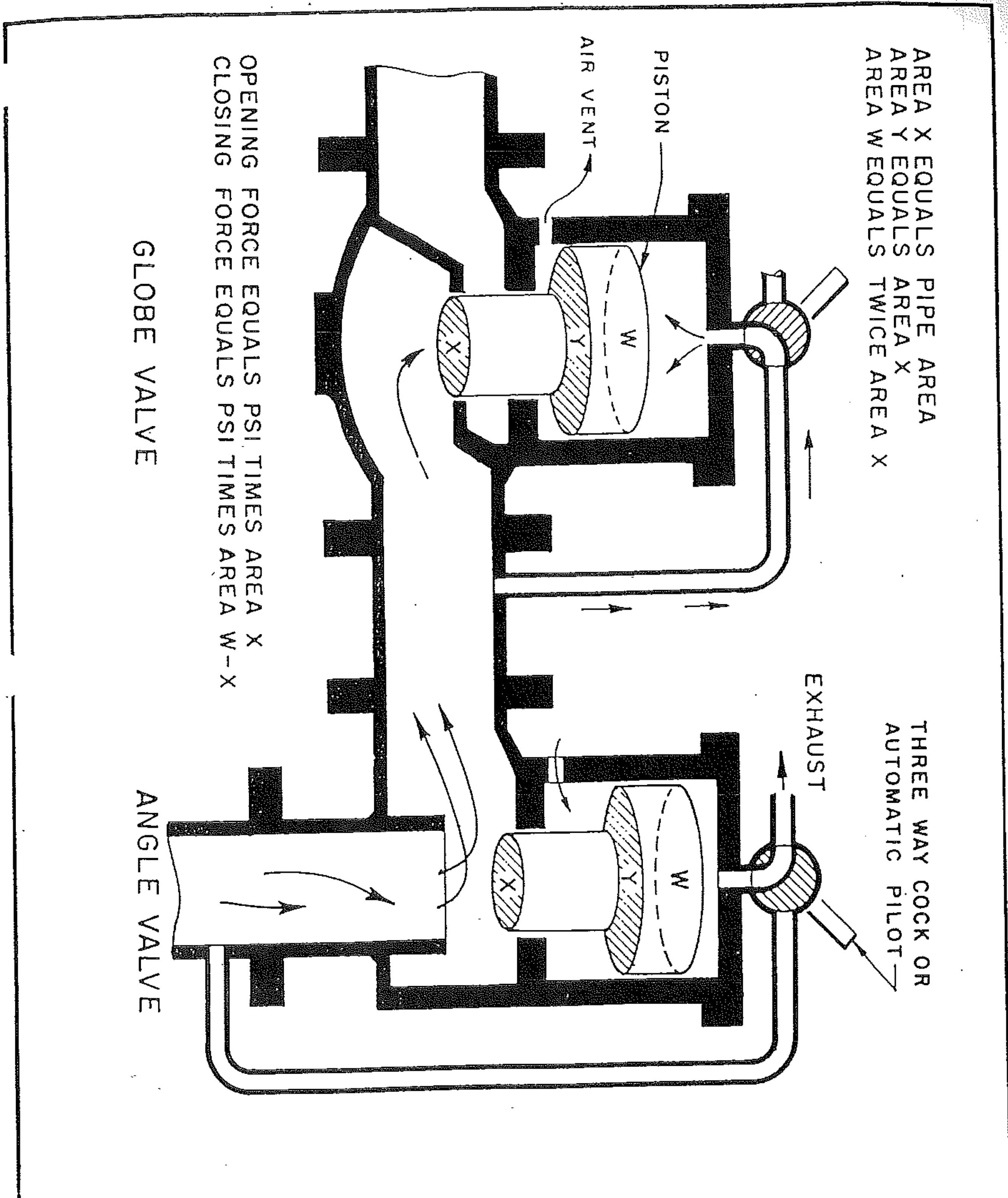


FIG. 8 AIR CUSHIONED LEVER AND WEIGHT SWING CHECK VALVE





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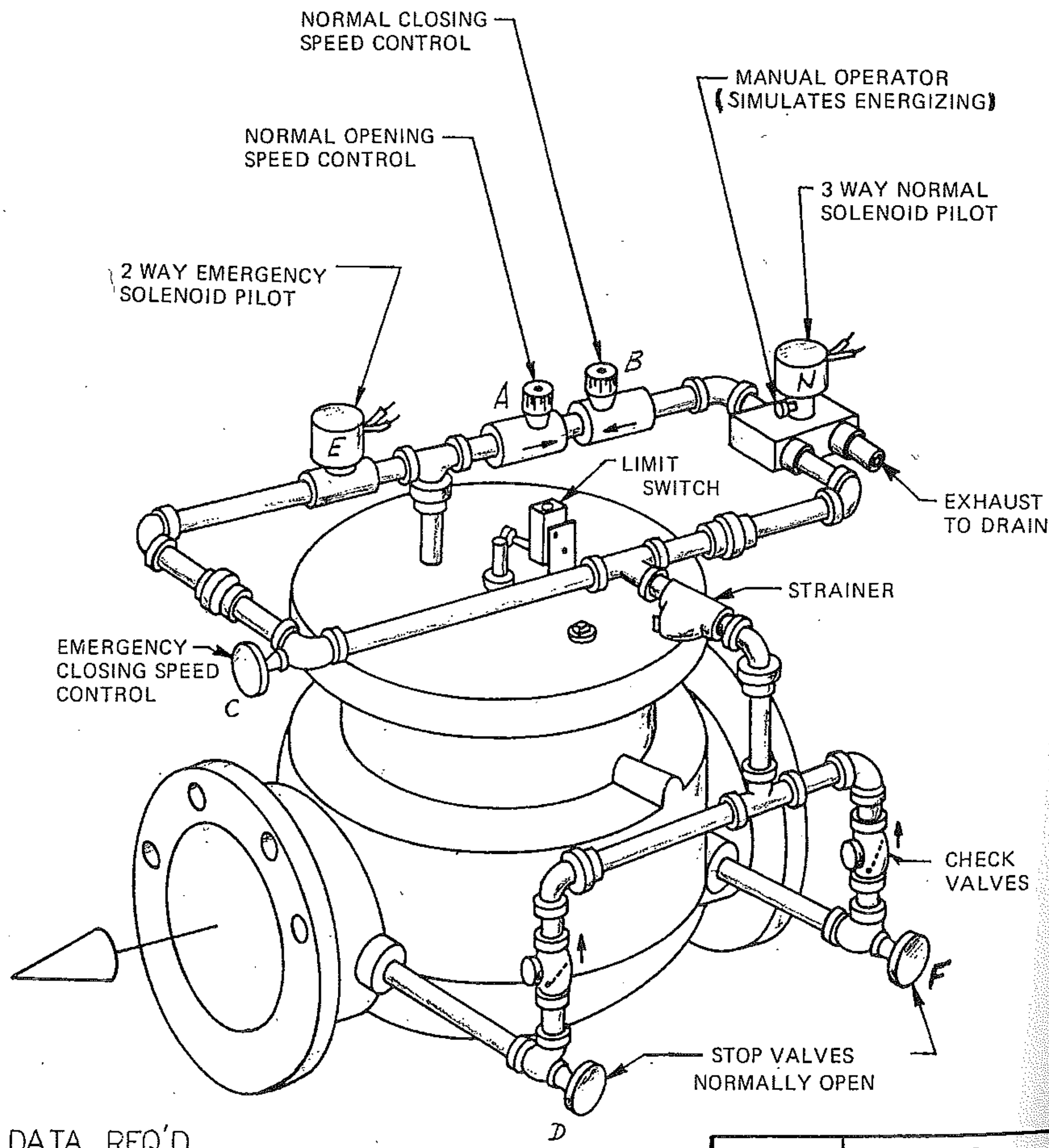
OPERATING PRINCIPLE OF THE DIFFERENTIAL AREA VALVE

REFERENCES

SCALE NO | DRAWN BY JEL | FIG NO. | DATE 8 18 66 | FILE | DWG NO Fig. 9



DATA REQ'D

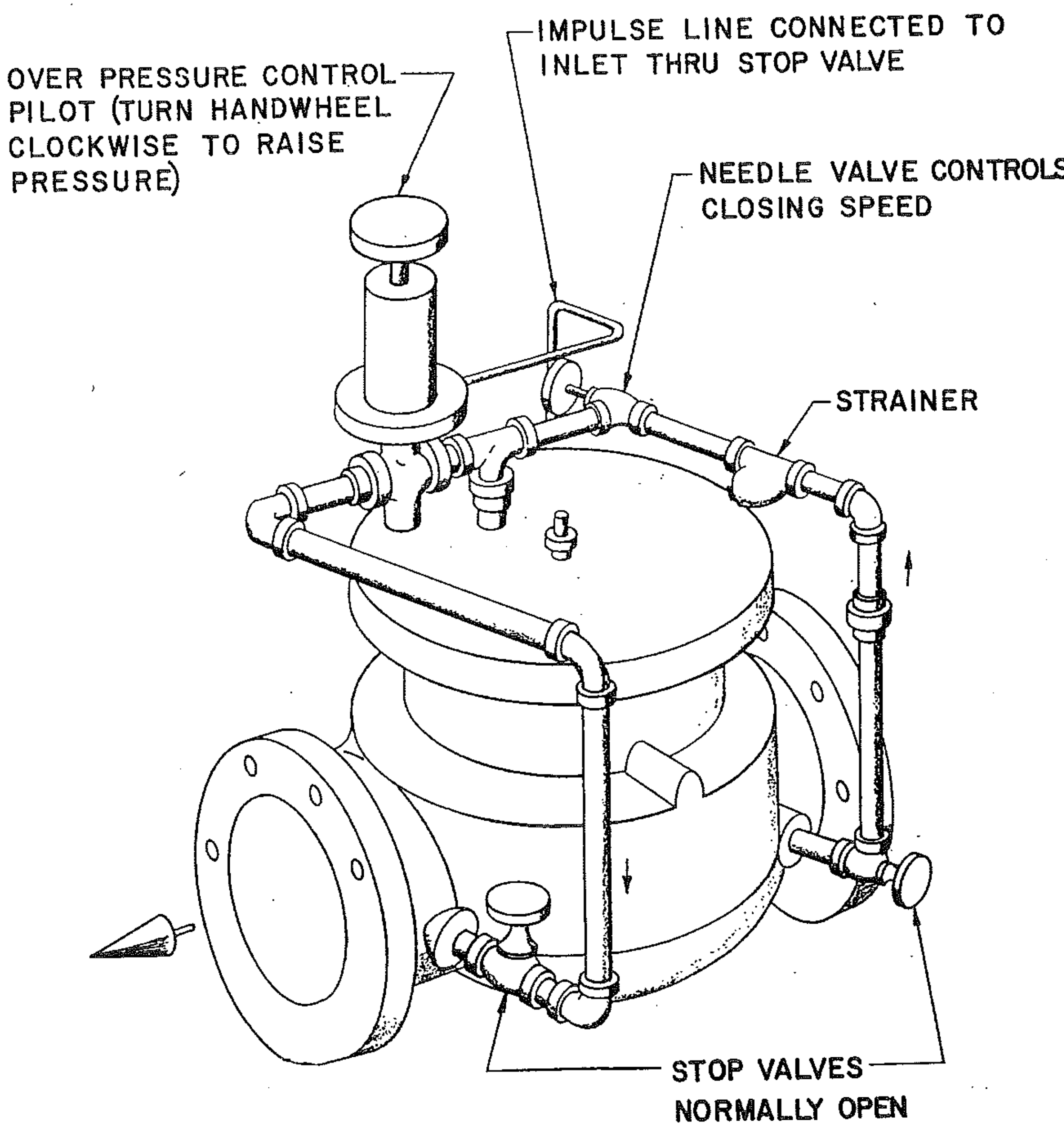
MIN ____ MAX ____ INLET PRESS

VOLTAGE ____ CYCLES ________

FIG NO	FLANGES
1730 D	FF D 125 ANSI
1730 U	FF D 250 ANSI

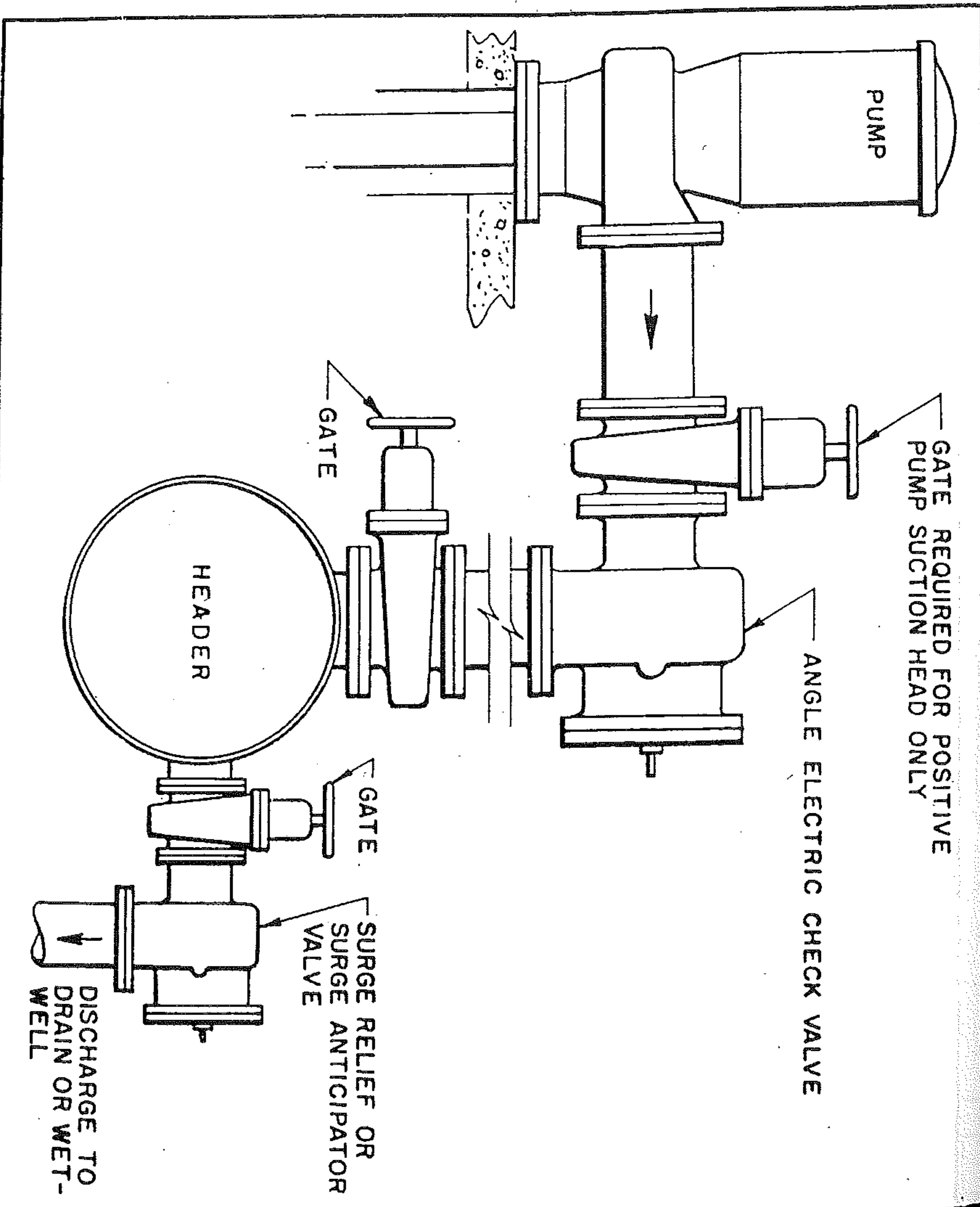
GA INDUSTRIES INC. PITTSBURGH, PA.	REFERENCES:	SCALE: ∞	DRAWN BY: RD
GLOBE DOUBLE CUSHIONED ELECTRIC CHECK VALVE W/NORMAL, MANUAL & EMERGENCY CONTROLS		FIG. NO. 1730	DATE 1-24-77
		FILE 34 E-1	DWG NO. E-1029

FIGURE 10

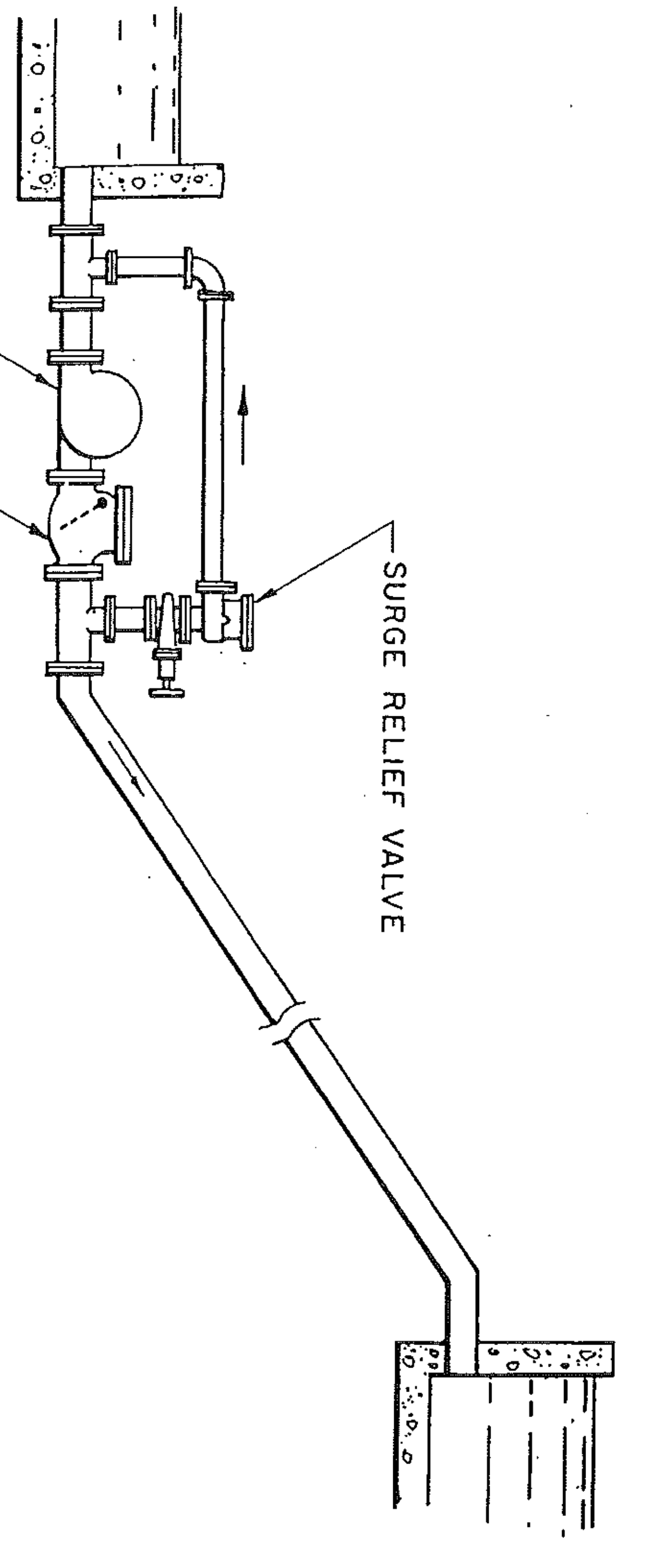


GA INDUSTRIES INC. PITTSBURGH, PA.	REFERENCES:	SCALE:	DRAWN BY:
$2\frac{1}{2}$"-16" GLOBE SURGE RELIEF VALVE		FIG. NO: 6700	DATE: 3-3-77
		FILE: 34 B-1	DWG. NO: B-1045

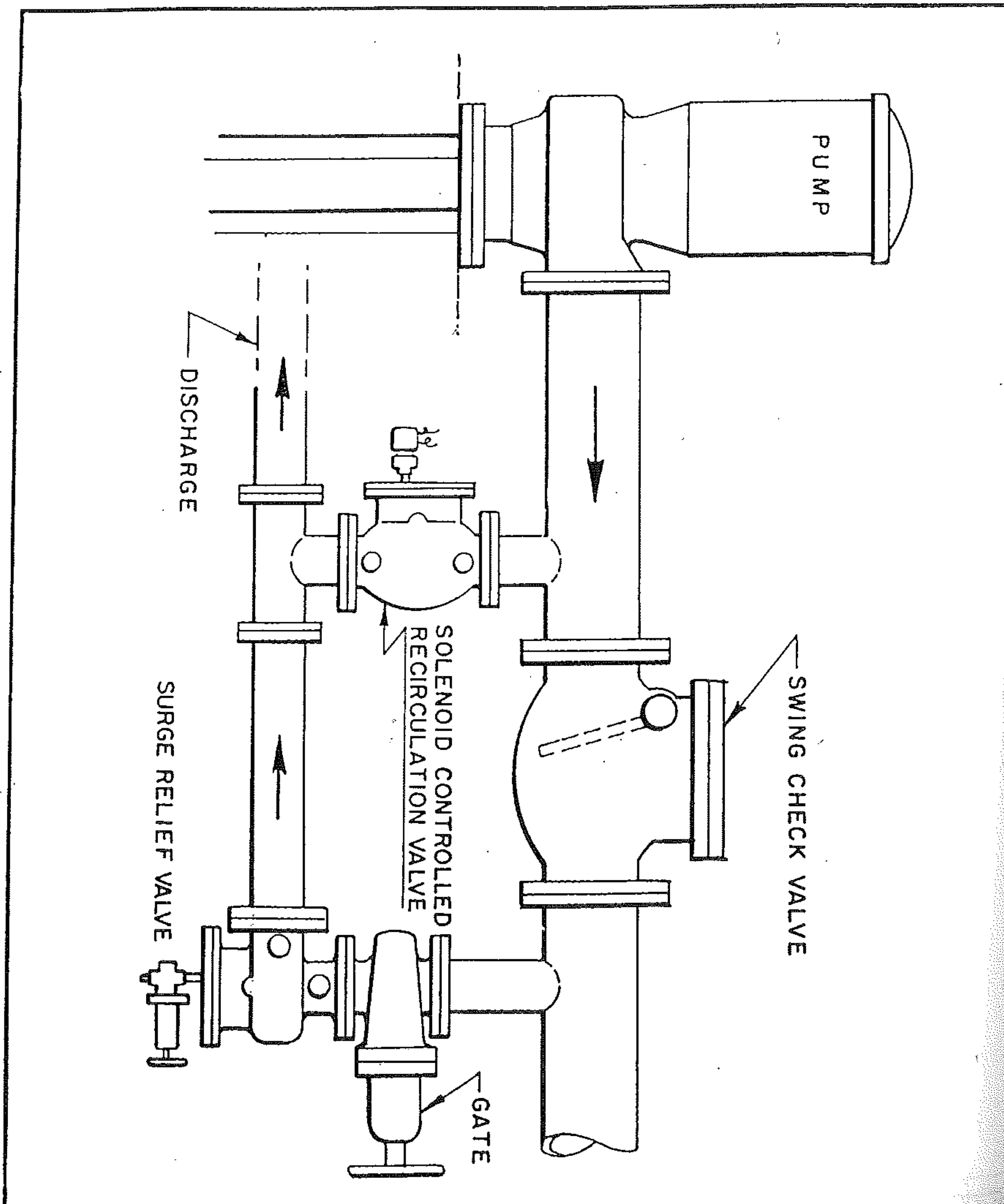
FIGURE 11



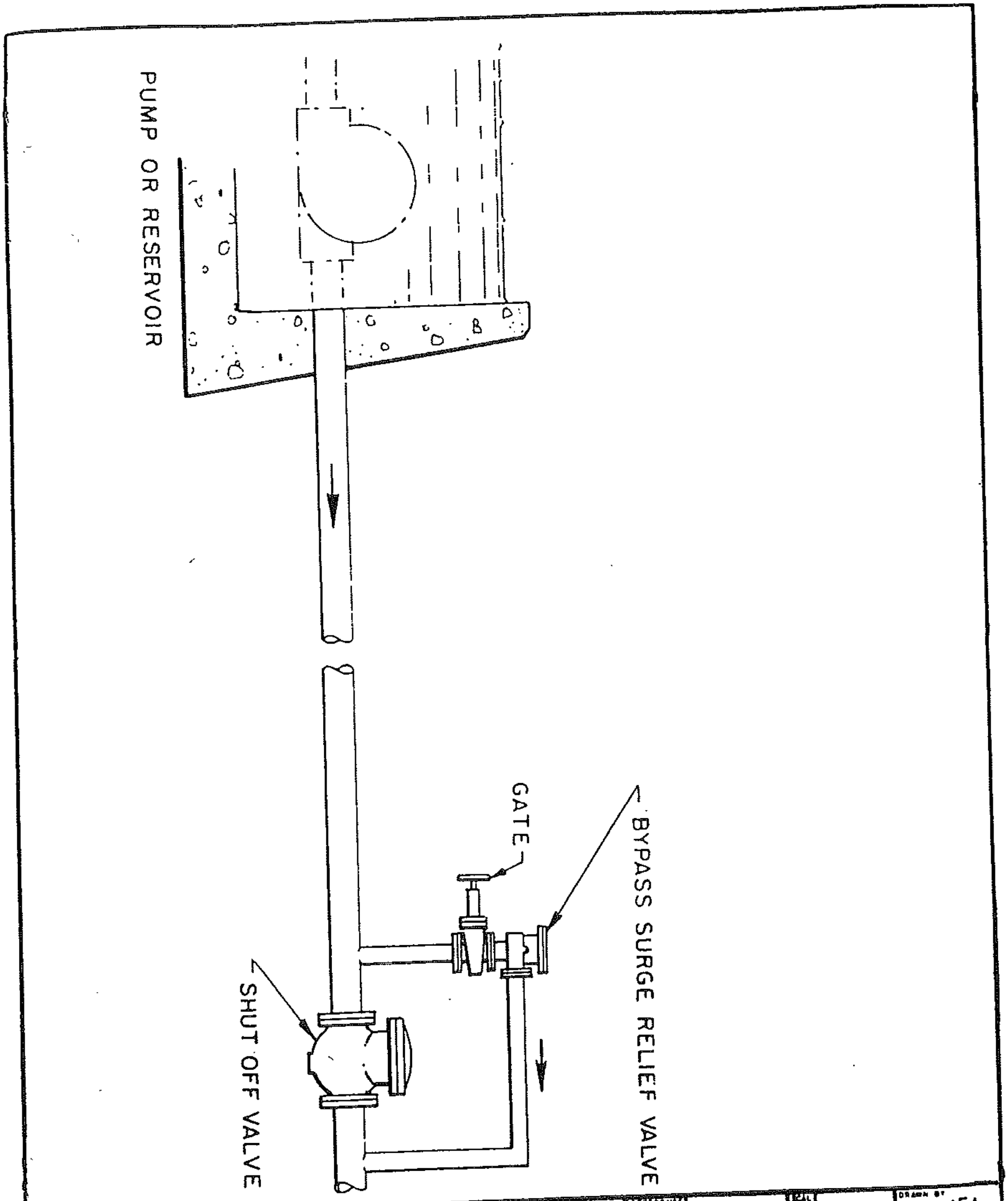
GA INDUSTRIES INC.	REFERENCES:	SCALE: NO	DRAWN BY: JEL
TYPICAL INSTALLATION ELECTRIC CHECK AND SURGE RELIEF VALVE			DATE: 8 18 66
			Fig. 12



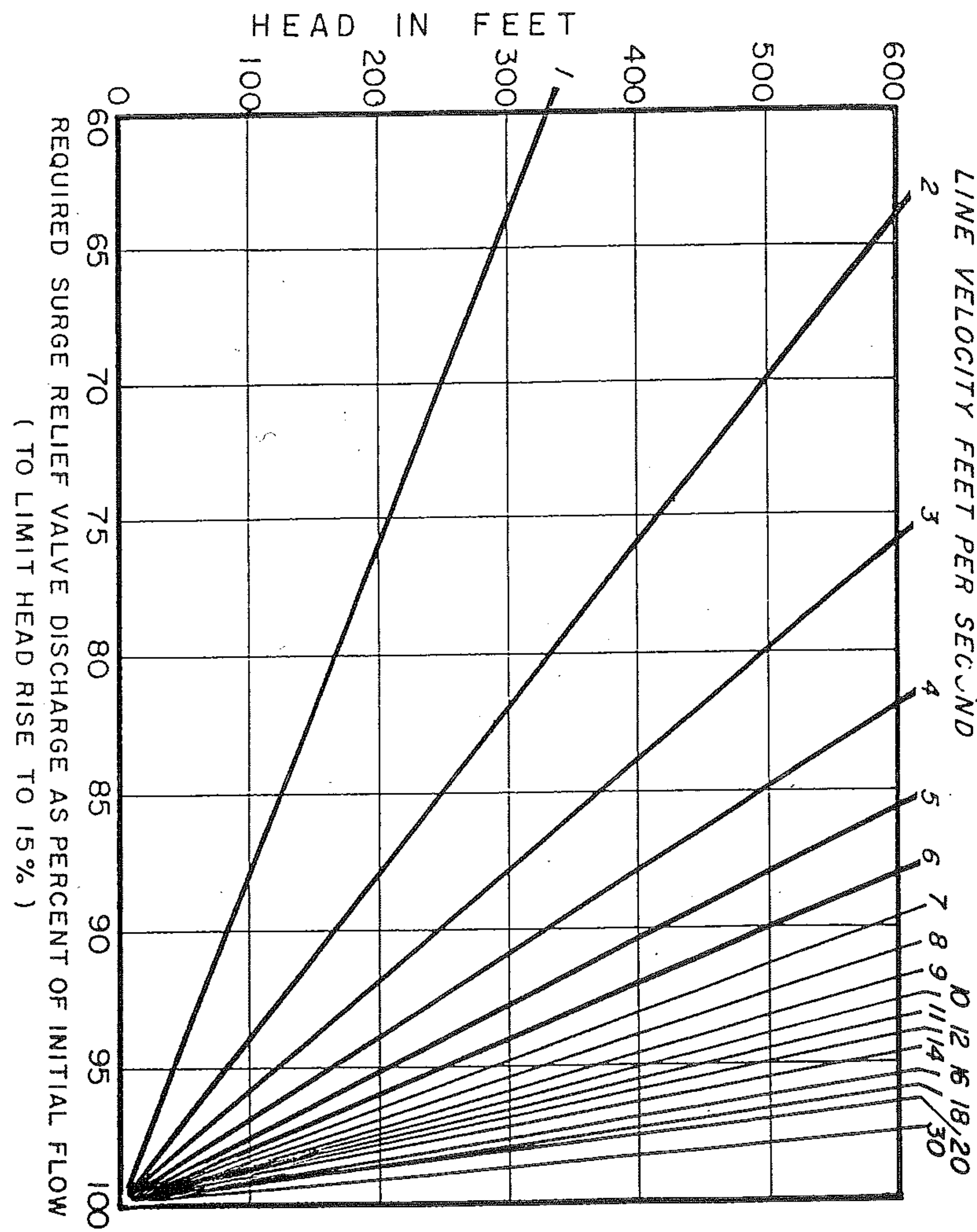
GA INDUSTRIES INC.	REFERENCES:	SCALE NO	DRAWN BY: JEL
SIMPLE UP-HILL PUMPING SYSTEM WITH SURGE RELIEF VALVE		FIG. NO. 66	DATE 8 19 66
		FILE:	DWG NO. Fig. 13



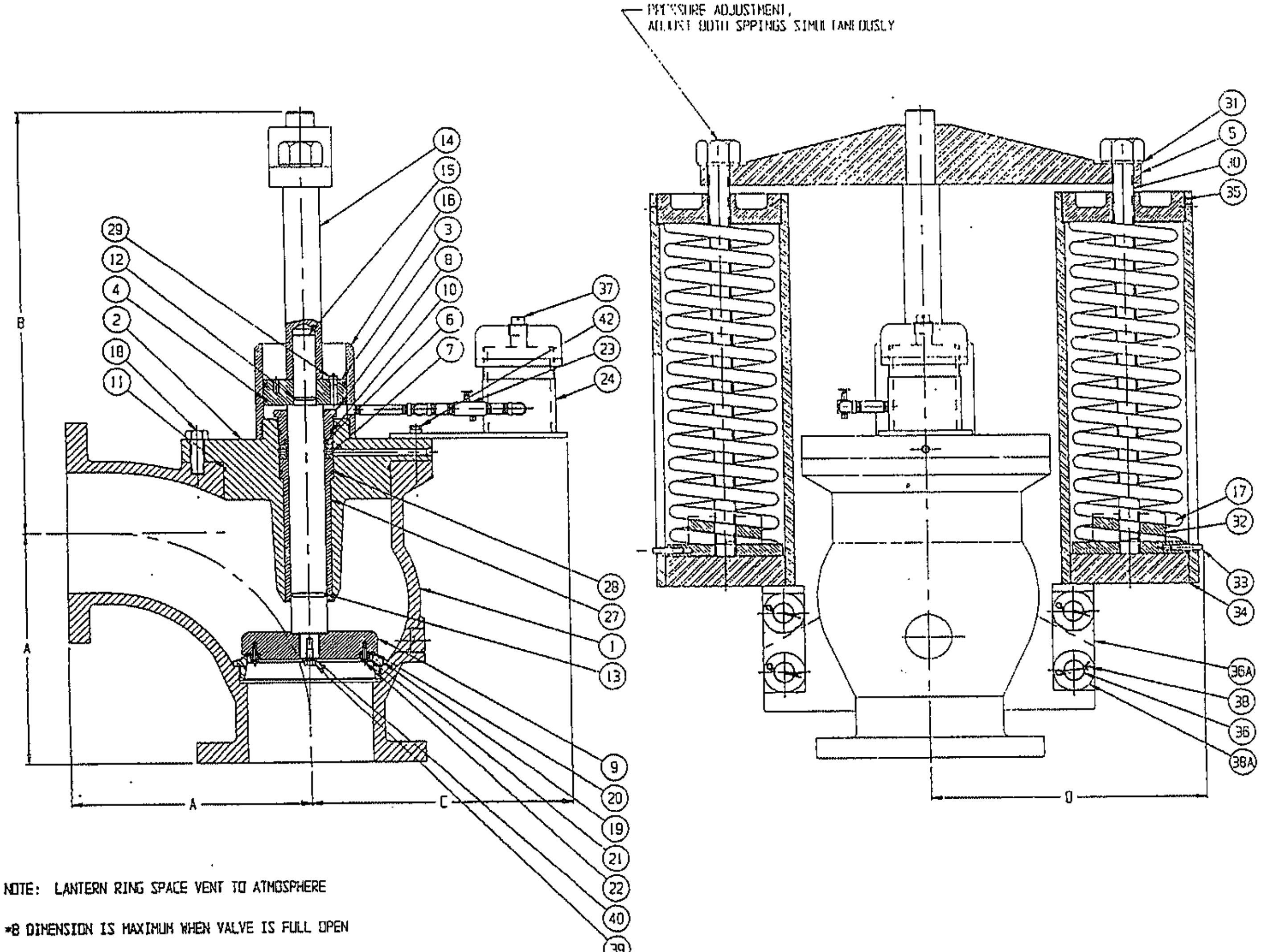
GA INDUSTRIES INC.	REFERENCES	SCALE NO	DRAWN BY JEL
RECIRCULATION VALVE ARRANGEMENT WITH SURGE RELIEF VALVE PROTECTION		FIG. NO.	DATE 8 18 66
		FILE	DWG NO Fig. 14



GA INDUSTRIES INC.	REFERENCES	SCALE	DRAWN BY JEL
TYPICAL ARRANGEMENT GRAVITY FLOW LINE. SURGE RELIEF VALVE BY-PASSING DISCHARGE FLOW CONTROL VALVE.		FIG NO / FILE	DATE 8 18 66 / DWG NO Fig. 15



GA INDUSTRIES INC.	REFERENCES:	SCALE:	DRAWN BY JEL
REQUIRED SURGE DISCHARGE FOR GRAVITY OR SIMPLE PUMPING SYSTEMS WITH CONTROL VALVE AT DISCHARGE END.		FIG. NO.:	DATE 8 18 66
		FILE:	DWG. NO.: Fig. 16



NO.	PART NAMES
1	BODY
2	COVER
3	PISTON
4	PISTON SEAL
5	SPRING YOKE
6	GLAND PACKING
7	LANTERN RING
8	GLAND
9	DISC
10	GLAND SEAL
11	COVER SEAL
12	PISTON ROD SEAL
13	DISC SEAL
14	PISTON ROD
15	DISC STEM
16	CYLINDER
17	SPRING
18	COVER BOLTS
19	SEAT
20	SEAT RING
21	SEAT RING FOLLOWER
22	SEAT RING FOLLOWER SCREWS
23	FLOW CONTROL VALVE
24	OIL RESERVOIR
27	BUSHING
28	BUSHING SEAL
29	PISTON VENT PLUG
30	SPRING ADJUSTING SCREW ASSEMBLY
31	ADJUSTING SCREW WASHER
32	SPRING ADJUSTING WASHER
33	SPRING ADJUSTING WASHER PIN
34	SPRING CHAMBERS
35	SPRING RETAINER CAPS
36	CLEVIS PINS
36A	CLEVIS LINKS
37	AIR VENT PLUG
38	CLEVIS PIN COTTER PINS
38A	CLEVIS PIN WASHERS
39	DISC STEM LOCKING SCREW
40	DISC STEM LOCKING WASHER
42	OIL RESERVOIR MOUNTING BOLTS

NOTE: LANTERN RING SPACE VENT TO ATMOSPHERE

*B DIMENSION IS MAXIMUM WHEN VALVE IS FULL OPEN

NOTE: "A" DIMENSION ON VALVES WITH RAISED FACE FLANGES DOES NOT INCLUDE THE RAISED FACE HEIGHT.

FLANGES PER ANSI

	DIMENSIONS					
	4"		6"		8"	
NO.	IN.	MM	IN.	MM	IN.	MM
A	9	229	11 1/2	292	14	356
B	23	584	24 1/2	622	26	660
C	10	254	9	229	10	254
D	10	254	13	330	14	356

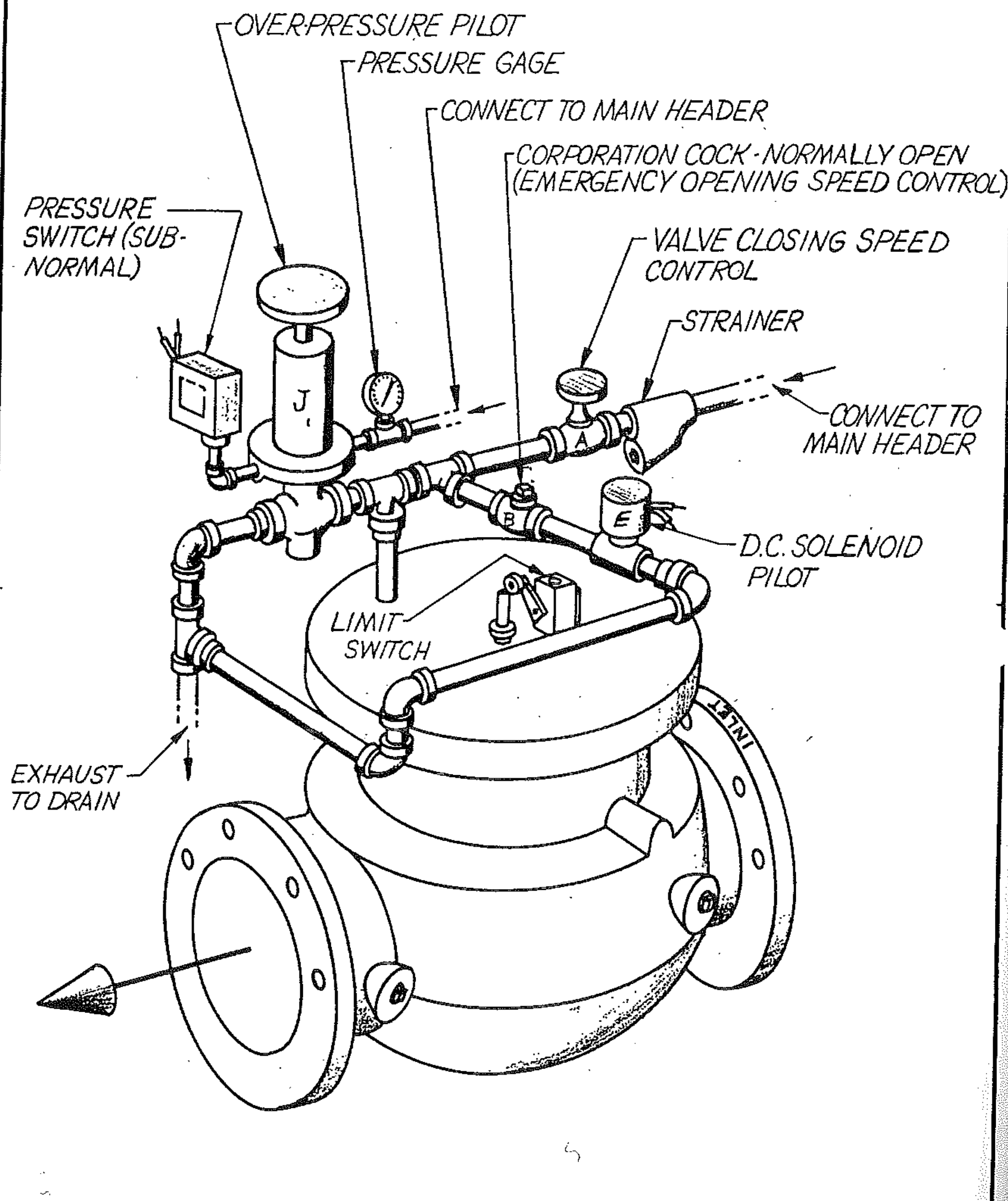
DATA REQUIRED
A. VALVE OPEN WHEN INLET PRESSURE EXCEEDS ______ PSI
B. INLET FLOW DIRECTION ______
C. OUTLET FLOW DIRECTION ______
D. SERIAL NUMBER ______

GA INDUSTRIES, INC.

4"-8" ELBOW SEWAGE RELIEF VALVE

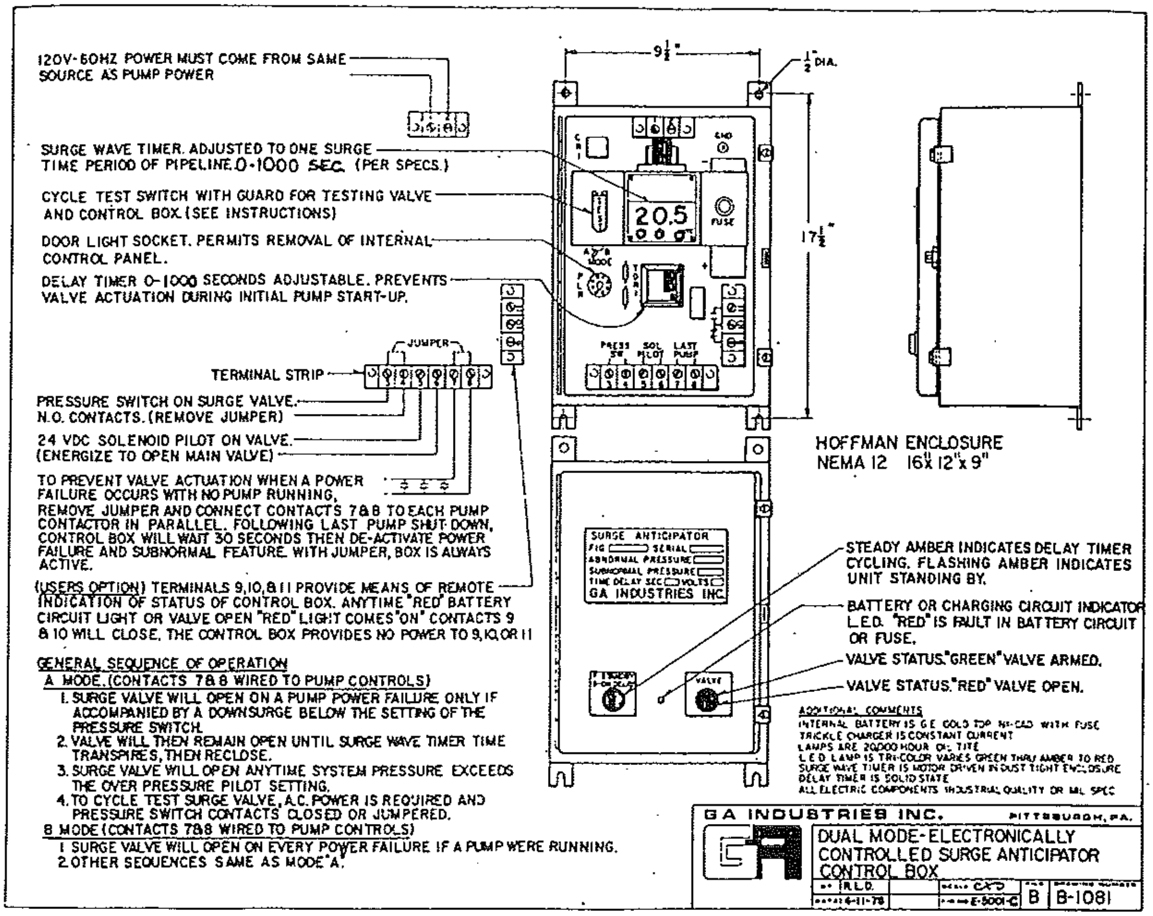
SERIAL NO.	SCALE: NONE	DRAWN BY: HGH
		APPR. BY
REFERENCES: K-1011-2	EFFECTIVE DATE: 9-29-95	TO
	FIG. NUMBER: 625-D	FILE: K	DRAWING NO.: Y-1011	REV.: A

FIGURE 17



GA INDUSTRIES INC. PITTSBURGH, PA.	REFERENCES:	SCALE:	DRAWN BY:
ELECTRONICALLY CONTROLLED SURGE ANTICIPATOR VALVE - GLOBE PATTERN		FIG. NO. EG-5000-B	DATE 2-1-7
		FILE 34 B-1	DWG. NO.: B-1036

FIGURE 18


120V-60HZ POWER MUST COME FROM SAME SOURCE AS PUMP POWER
SURGE WAVE TIMER. ADJUSTED TO ONE SURGE TIME PERIOD OF PIPELINE 0-1000 SEC. (PER SPECS.)
CYCLE TEST SWITCH WITH GUARD FOR TESTING VALVE AND CONTROL BOX. (SEE INSTRUCTIONS)
DOOR LIGHT SOCKET. PERMITS REMOVAL OF INTERNAL CONTROL PANEL.
DELAY TIMER 0-1000 SECONDS ADJUSTABLE. PREVENTS VALVE ACTUATION DURING INITIAL PUMP START-UP.
JUMPER
TERMINAL STRIP
PRESSURE SWITCH ON SURGE VALVE. N.O. CONTACTS. (REMOVE JUMPER)
24 VDC SOLENOID PILOT ON VALVE. (ENERGIZE TO OPEN MAIN VALVE)
TO PREVENT VALVE ACTUATION WHEN A POWER FAILURE OCCURS WITH NO PUMP RUNNING, REMOVE JUMPER AND CONNECT CONTACTS 7&8 TO EACH PUMP CONTACTOR IN PARALLEL. FOLLOWING LAST PUMP SHUT-DOWN, CONTROL BOX WILL WAIT 30 SECONDS THEN DE-ACTIVATE POWER FAILURE AND SUBNORMAL FEATURE. WITH JUMPER, BOX IS ALWAYS ACTIVE.
(USERS OPTION) TERMINALS 9,10,&11 PROVIDE MEANS OF REMOTE INDICATION OF STATUS OF CONTROL BOX. ANYTIME "RED" BATTERY CIRCUIT LIGHT OR VALVE OPEN "RED" LIGHT COMES "ON" CONTACTS 9 & 10 WILL CLOSE. THE CONTROL BOX PROVIDES NO POWER TO 9,10,OR 11
GENERAL SEQUENCE OF OPERATION
A MODE. (CONTACTS 7&8 WIRED TO PUMP CONTROLS)
1. SURGE VALVE WILL OPEN ON A PUMP POWER FAILURE ONLY IF ACCOMPANIED BY A DOWNSURGE BELOW THE SETTING OF THE PRESSURE SWITCH.
2. VALVE WILL THEN REMAIN OPEN UNTIL SURGE WAVE TIMER TIME TRANSPIRES, THEN RECLOSE.
3. SURGE VALVE WILL OPEN ANYTIME SYSTEM PRESSURE EXCEEDS THE OVER PRESSURE PILOT SETTING.
4. TO CYCLE TEST SURGE VALVE, A.C. POWER IS REQUIRED AND PRESSURE SWITCH CONTACTS CLOSED OR JUMPERED.
B MODE (CONTACTS 7&8 WIRED TO PUMP CONTROLS)
1 SURGE VALVE WILL OPEN ON EVERY POWER FAILURE IF A PUMP WERE RUNNING.
2 OTHER SEQUENCES SAME AS MODE "A".
9½"
½" DIA.
17½"
20.5
FUSE
PRESS SW
SOL PILOT
LAST PUMP
HOFFMAN ENCLOSURE
NEMA 12 16" x 12" x 9"
SURGE ANTICIPATOR
FIG
SERIAL
ABNORMAL PRESSURE
SUBNORMAL PRESSURE
TIME DELAY SEC
VOLTS
GA INDUSTRIES INC
VALVE
STEADY AMBER INDICATES DELAY TIMER CYCLING. FLASHING AMBER INDICATES UNIT STANDING BY.
BATTERY OR CHARGING CIRCUIT INDICATOR L.E.D. "RED" IS FAULT IN BATTERY CIRCUIT OR FUSE.
VALVE STATUS "GREEN" VALVE ARMED.
VALVE STATUS "RED" VALVE OPEN.
ADDITIONAL COMMENTS
INTERNAL BATTERY IS G.E. GOLD TOP NI-CAD WITH FUSE
TRICKLE CHARGER IS CONSTANT CURRENT
LAMPS ARE 20,000 HOUR OIL TITE
L.E.D. LAMP IS TRI-COLOR VARIES GREEN THRU AMBER TO RED
SURGE WAVE TIMER IS MOTOR DRIVEN IN DUST TIGHT ENCLOSURE
DELAY TIMER IS SOLID STATE
ALL ELECTRIC COMPONENTS INDUSTRIAL QUALITY OR MIL SPEC
GA INDUSTRIES INC. PITTSBURGH, PA.
DUAL MODE-ELECTRONICALLY CONTROLLED SURGE ANTICIPATOR CONTROL BOX
R.L.D.
4-11-78
CXD
E-5001-C
B
B-1081

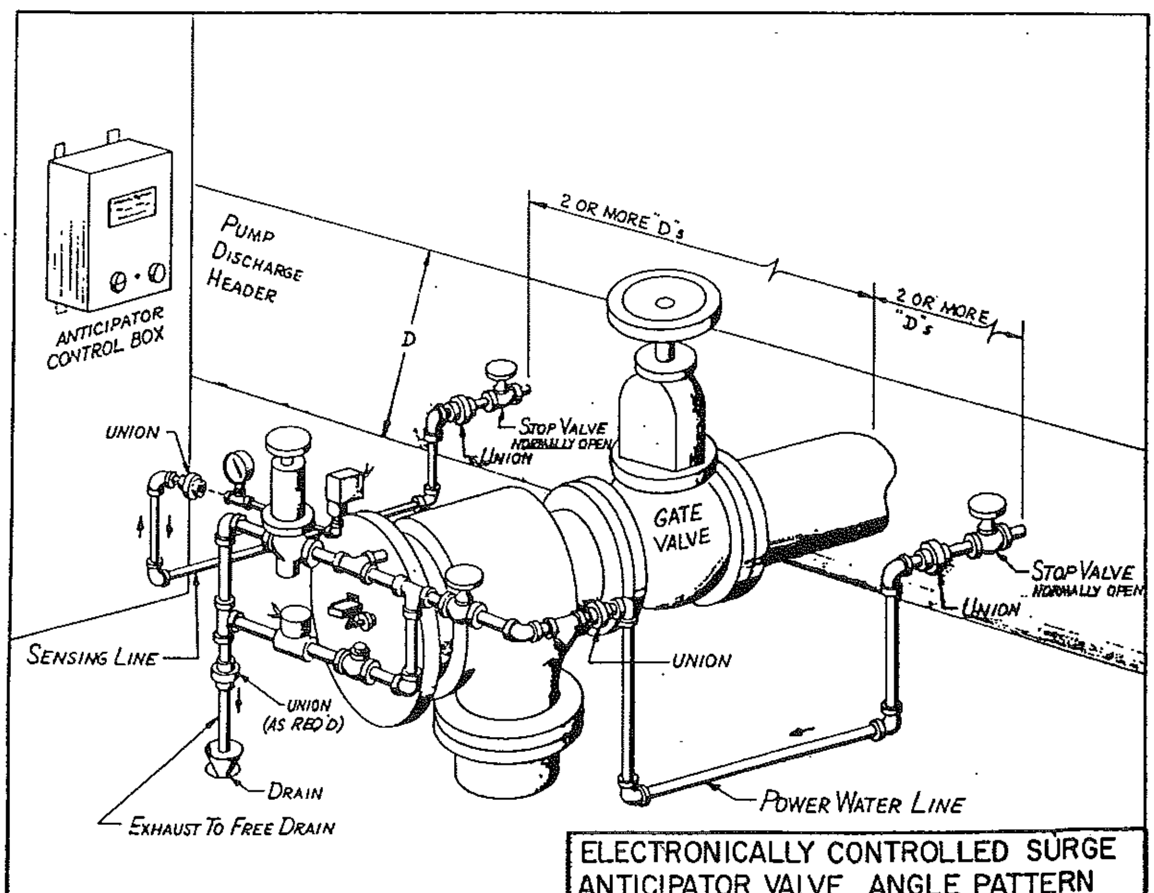
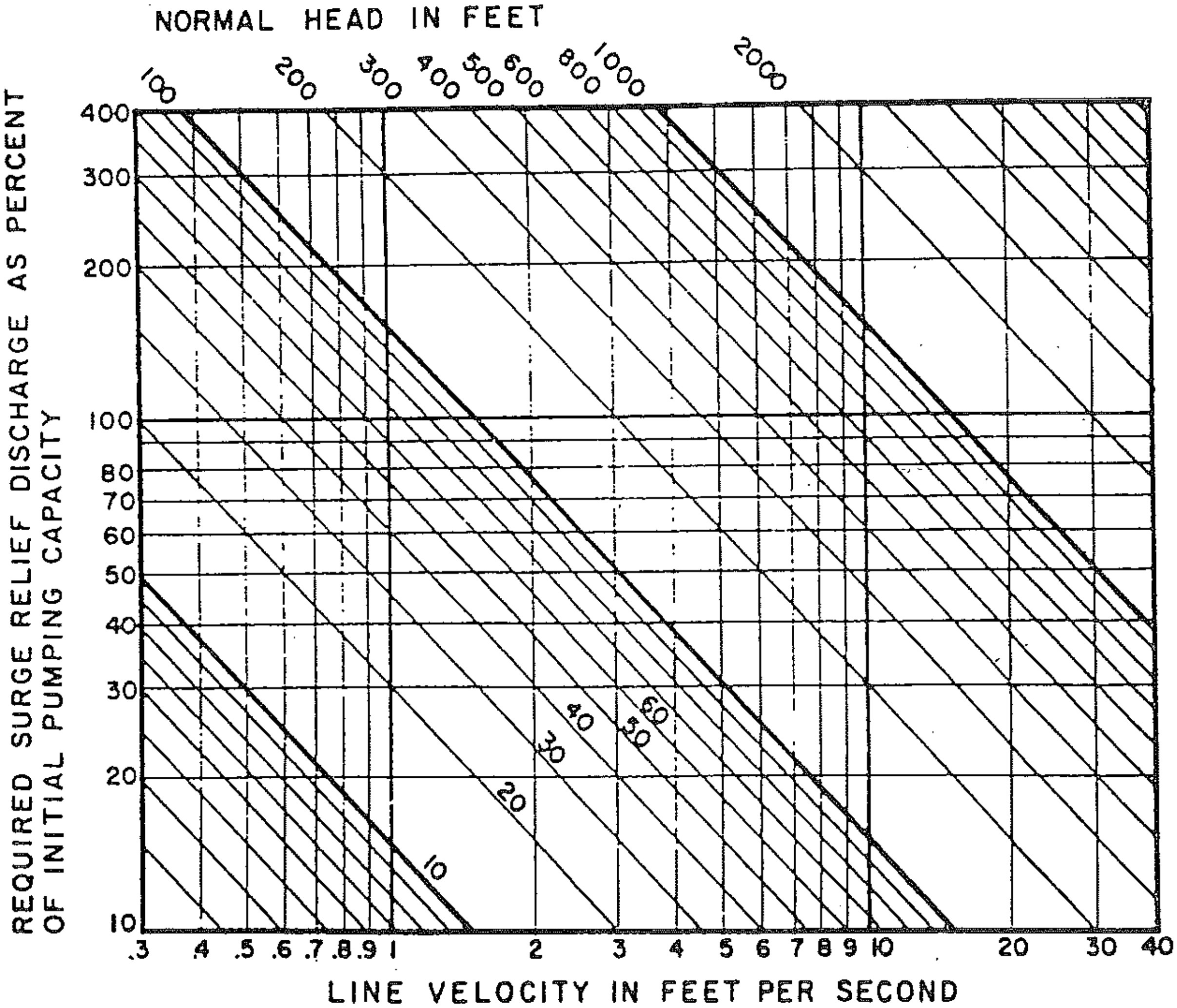

PUMP DISCHARGE HEADER
ANTICIPATOR CONTROL BOX
2 OR MORE "D"s
2 OR MORE "D"s
D
STOP VALVE NORMALLY OPEN
UNION
UNION
GATE VALVE
STOP VALVE NORMALLY OPEN
UNION
SENSING LINE
UNION
UNION (AS REQ'D)
DRAIN
EXHAUST TO FREE DRAIN
POWER WATER LINE
ELECTRONICALLY CONTROLLED SURGE ANTICIPATOR VALVE ANGLE PATTERN

Fig. 18–A



(NOTE: CHART ASSUMES NO WATER COLUMN SEPARATION OCCURS)
(CHART ALSO ASSUMES NO LINE FRICTION)

GA INDUSTRIES INC.			
REQUIRED SURGE ANTICIPATOR DISCHARGE FOR PUMPING SYSTEMS			JEL
			8 18 66
			Fig. 19

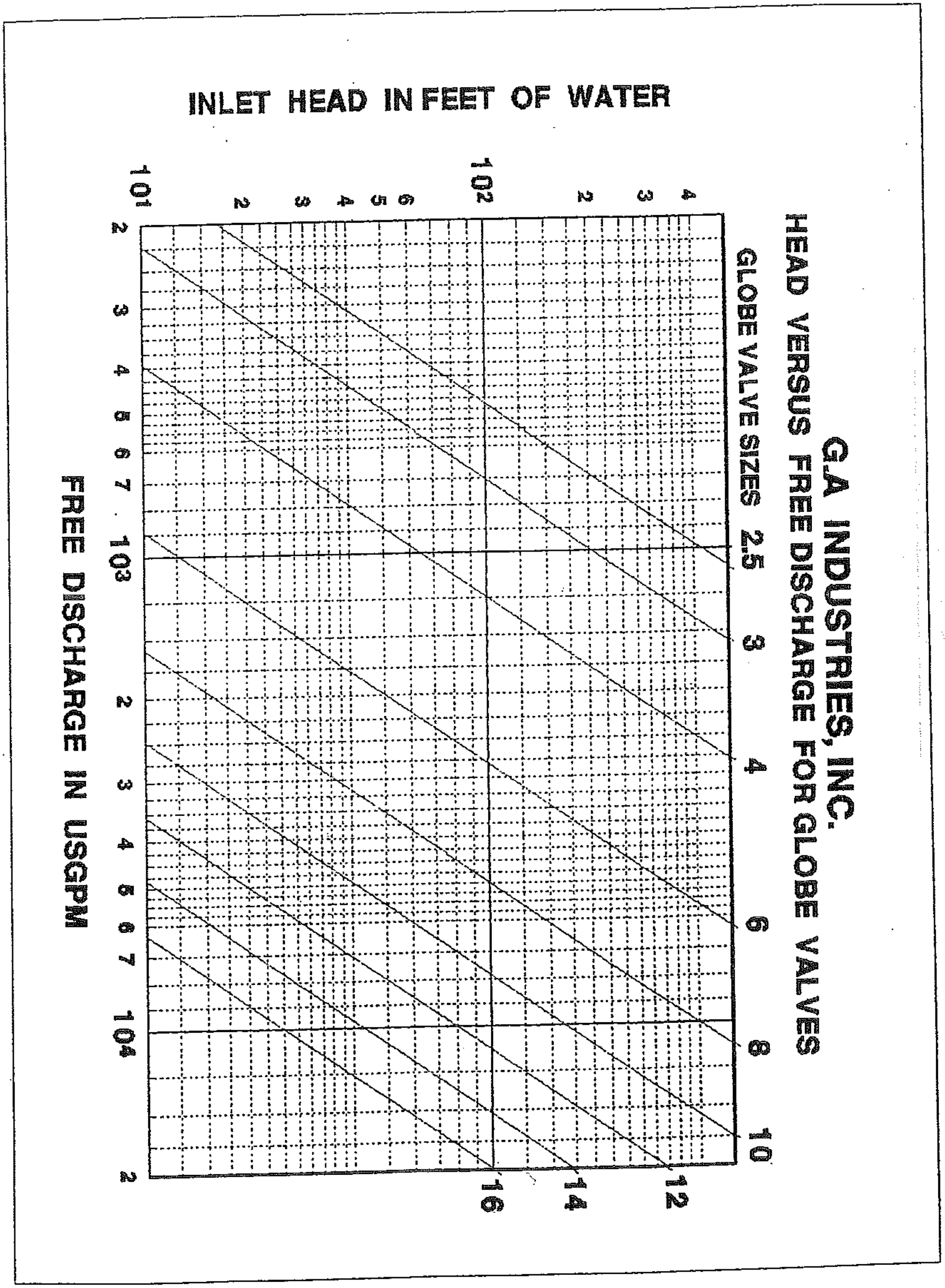

G.A INDUSTRIES, INC.
HEAD VERSUS FREE DISCHARGE FOR GLOBE VALVES
GLOBE VALVE SIZES
2.5
3
4
6
8
10
12
14
16
INLET HEAD IN FEET OF WATER
10^1
2
3
4
5
6
10^2
2
3
4
FREE DISCHARGE IN USGPM
2
3
4
5
6
7
10^3
2
3
4
5
6
7
10^4
2

FIGURE 20

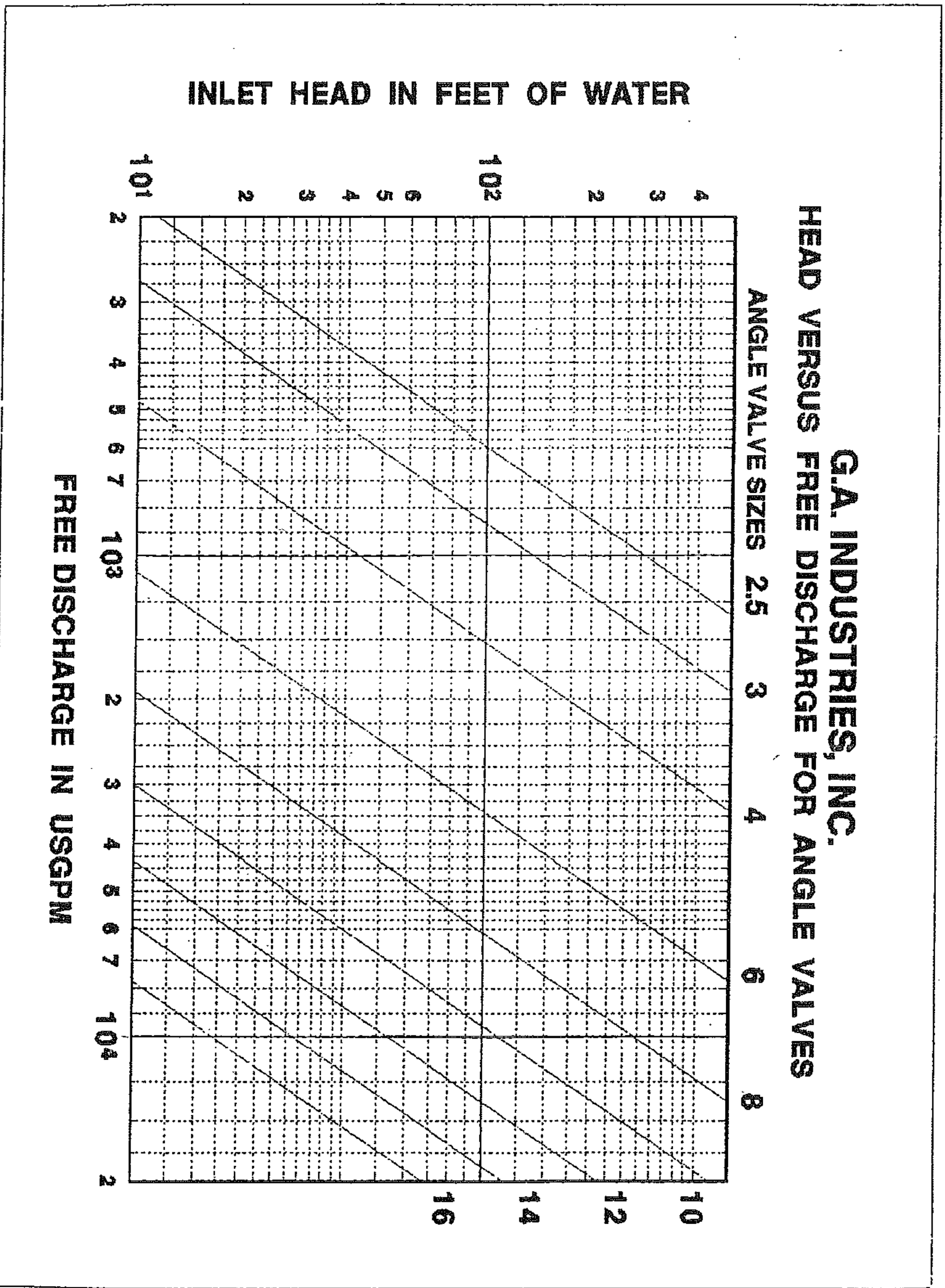

G.A. INDUSTRIES, INC.
HEAD VERSUS FREE DISCHARGE FOR ANGLE VALVES
ANGLE VALVE SIZES 2.5 3 4 6 8 10 12 14 16
INLET HEAD IN FEET OF WATER
FREE DISCHARGE IN USGPM

FIGURE 21

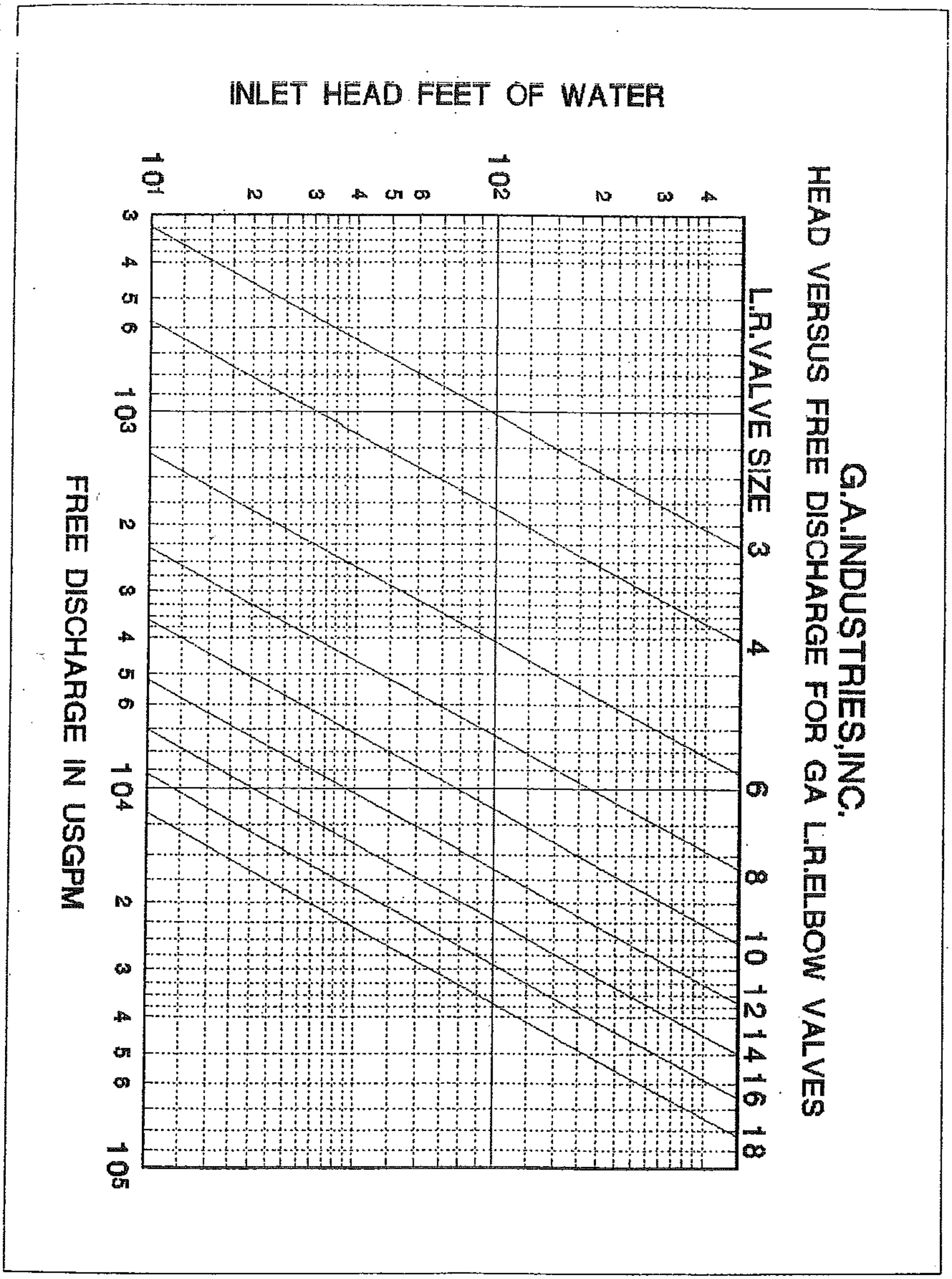
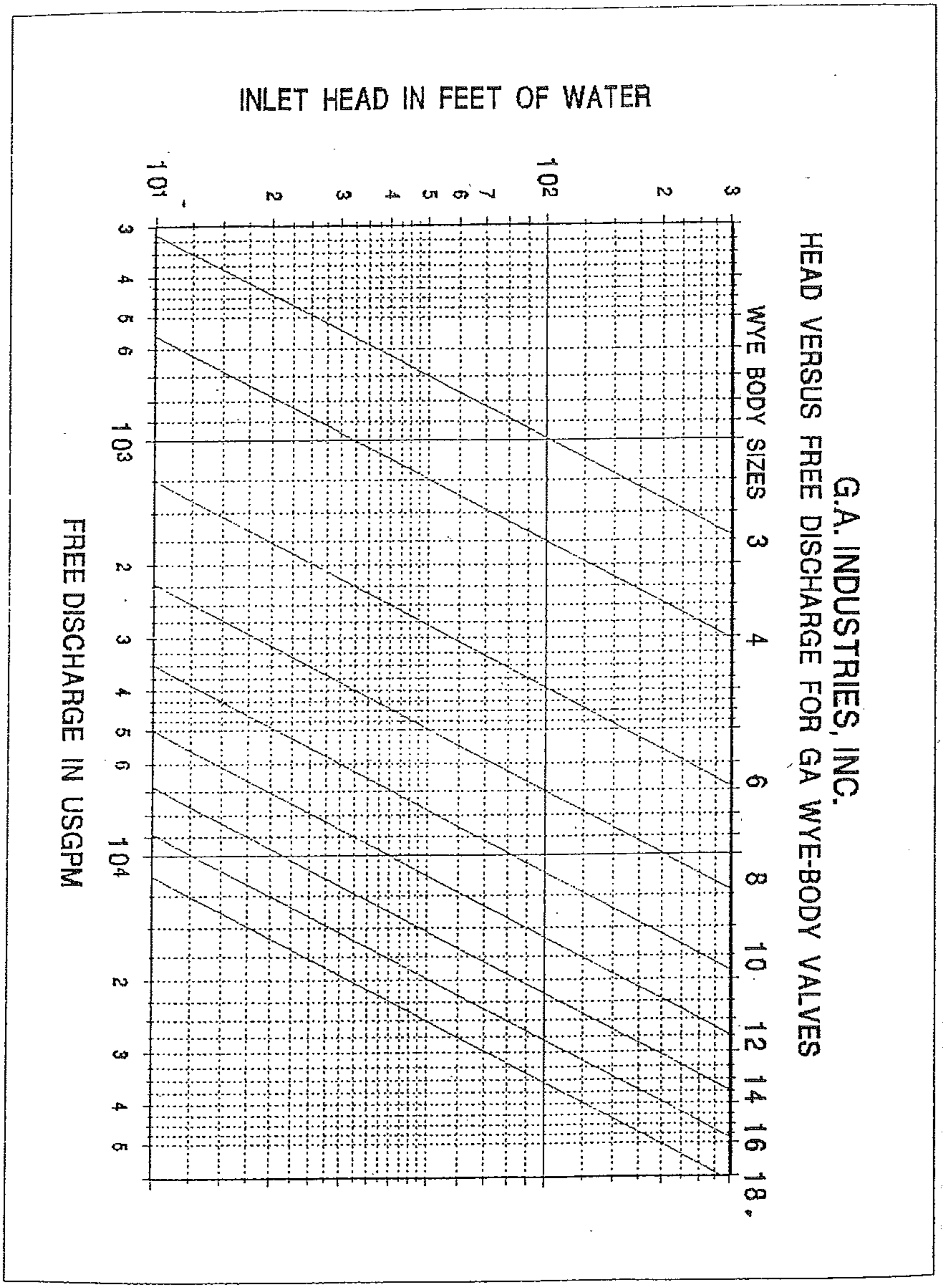

G.A.INDUSTRIES,INC.
HEAD VERSUS FREE DISCHARGE FOR GA L.R.ELBOW VALVES
INLET HEAD FEET OF WATER
FREE DISCHARGE IN USGPM
L.R.VALVE SIZE 3 4 6 8 10 12 14 16 18

FIGURE 22



G.A. INDUSTRIES, INC.
HEAD VERSUS FREE DISCHARGE FOR GA WYE-BODY VALVES
WYE BODY SIZES
3 4 6 8 10 12 14 16 18
INLET HEAD IN FEET OF WATER
FREE DISCHARGE IN USGPM

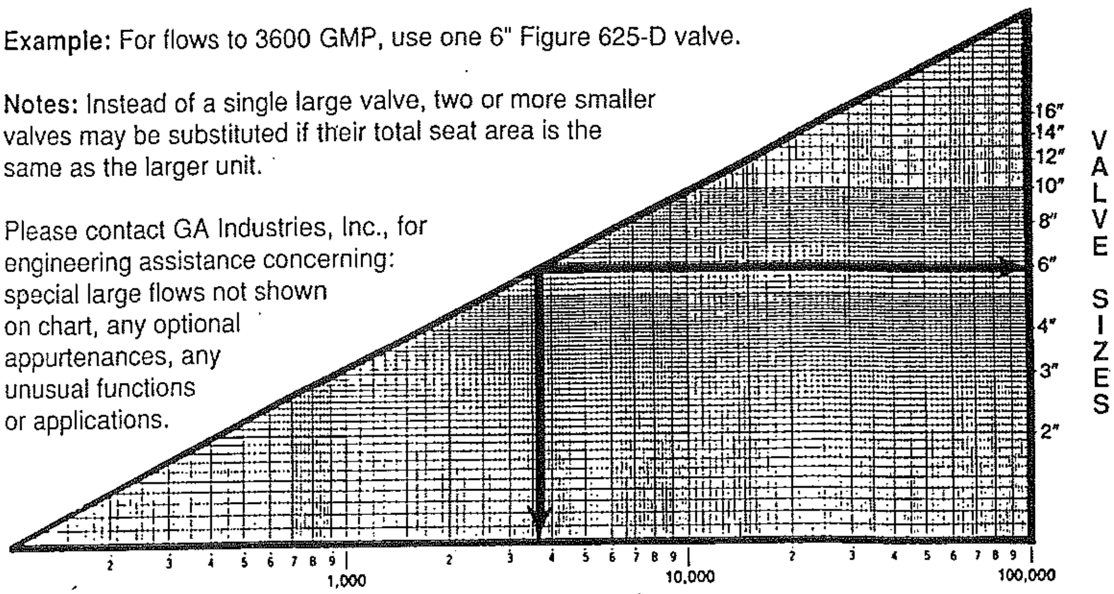
FIGURE 23

SIZING

Example: For flows to 3600 GMP, use one 6" Figure 625-D valve.

Notes: Instead of a single large valve, two or more smaller valves may be substituted if their total seat area is the same as the larger unit.

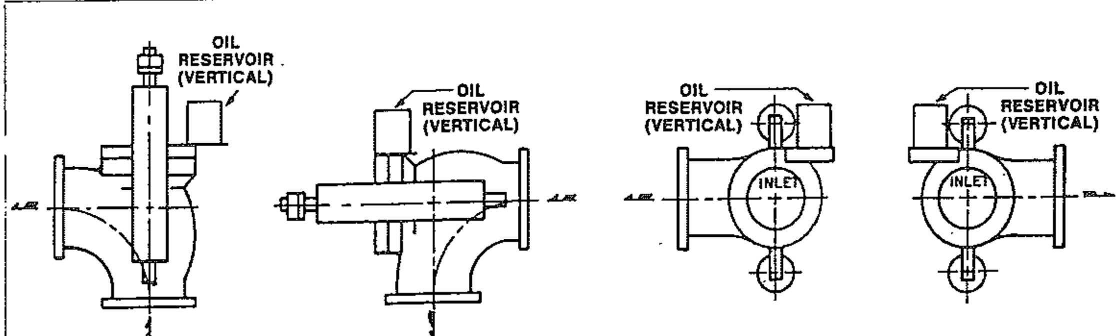
Please contact GA Industries, Inc., for engineering assistance concerning: special large flows not shown on chart, any optional appurtenances, any unusual functions or applications.



SYSTEM FLOW IN GMP

SUGGESTED VALVE SIZE SELECTION CHART

INSTALLATION



VH	HV	HHL	HHR
Vertical Inlet Horizontal Outlet	Horizontal Inlet Vertical Outlet	Horizontal Inlet Horizontal Left Outlet	Horizontal Inlet Horizontal Right Outlet

Depending on the pipe-pump arrangement, GA Sewage Surge Relief Valves may be installed in any of the four positions shown. However, it will be noted that in all cases the **oil reservoir must be in a vertical position.**

INSTALLATION ARRANGEMENTS

FIGURE 24