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FLOW INITIATION STUDY FOR PROPOSED TUBE WIND TUNNEL PHASE I PRELIMINARY EVALUATION OF CANDIDATE SYSTEMS

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SUMMARY

FluiDyne Engineering Corporation has conducted a study of quick-opening valves and/or diaphragms for flow initiation in the National Aeronautics and Space Administration proposed High Reynolds Number Facility tube tunnel. This work was carried out under Phase I of Contract NAS8-20214. During this study, the relative merits and disadvantages of several valve types were analyzed on the basis of a literature survey, hydraulic analogy tests and calculations. As a result of the analysis, two valve subtypes (a 20 sq. ft. gate valve and a 94 sq. ft. multiple butterfly valve) were selected as being most promising and worthy of closer study in Phase II of the contract.

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1.0 INTRODUCTION

The first paragraph of the contract scope of work subsection states:

"The purpose of this study is to determine the optimum quick opening valve and/or diaphragm configuration for use in the MSFC High Reynolds Number Facility, to experimentally investigate all areas which may be required to completely demonstrate the ultimate feasibility of the proposed quick opening valve and/or diaphragm, and to design the proposed valve and/or diaphragm complete with all necessary support equipment."

This report covers only Phase 1 of the contract which was "...a general study of all quick opening valve and diaphragm techniques considered to show promise to define the relative advantages, limitations, and the probability for successful design of each."

The MSFC High Reynolds Number Facility is to be what is known as a tube-tunnel which was first described by Ludwieg in References 1 and 2. In this type of facility, the source of flow is a long, tube-like storage tank. Flow is initiated by quickly opening up the downstream end of the tank, giving a period of constant Reynolds number run at a stagnation pressure equal to the initial storage tank pressure which lasts until the initial expansion wave comes back to the downstream end of the storage tank. In the facility under consideration, a 300 foot long, 11 foot diameter storage tube is proposed to give a 0.6 sec. run time at stagnation pressure from 500 psi on down over the range of Mach numbers 0.3-0.8, 1.5-4.0 in a nominally 20 sq. ft. test section. To provide the subsonic Mach number range some form of choking device will have to be located downstream of the test section. It is envisioned that this device will be so designed as to serve as an efficient supersonic diffuser to permit low stagnatior pressure running. The basic tunnel arrangement is shown in Figure 1. According to the Statement of Work, if an upstream quick-opening valve location is proposed, a downstream blow-away diaphragm must be considered so that the test section can be pumped down prior to a run to reduce starting loads. During tube repump the downstream end of the tank must be shut off tightly. The tight shutoff function could possibly be provided by the quick opening device, but it may be necessary to provide a tight shutoff valve in addition to the quick acting one.

In the task of selecting suitable valves there are a number of considerations and requirements that determine which of the many possible valve concepts best fills the needs of the proposed facility. The following list of requirements and desirables for the quick opening valve itself was used in this job as the basis for selecting the best valve concepts.

1. In order to make possible the attainment of the entire Mach number range proposed, the residual blockage of any valve located in the 20 sq. ft. section must not exceed 4%.
2. Total pressure losses due to valve residual blockage must not exceed 1% of the tunnel total pressure.
3. It is desirable that the test section Mach number variation lie within ± 1% although ± 2% is acceptable.
4. It is desirable that the quick-opening valve be able to open within 0.05 sec., and an opening time of less than 0.20 sec. is an arbitrary absolute requirement.
5. The valve position should be chosen so as not to reduce the effective run time by its effect on

flow development time.

6. The valve should be positioned so as to minimize starting and stopping loads on the test article.
7. The valve should be positioned so as to minimize test hardware and instrumentation problems (prerun pressure extremes and lag problems).
8. The valve should be designed or positioned so as to minimize the possibility of either valve material hitting the test article or flying parts of the test article damaging the valve.
10. The valve position should be chosen with due regard for space and the location of model support, diffuser, nozzle, etc.
11. It is desirable that the valve be quickly reclosable at the end of the initial test period.
12. The valve shall be capable of sealing the tunnel adequately enough to keep leakage within the capacity of the compressors at full stagnation pressure.
13. Valve actuation must be positive.
14. The valve motion must be capable of being stopped at the end of the valve travel without damage to the valve and tunnel structure.

In addition to the foregoing list, cost must be considered, and operator and equipment safety must not be overlooked. The study program described below was used to evaluate each of a number of valve concepts on the basis of the foregoing considerations.

2.0 STUDY PROGRAM

The study program consisted of three major parts as follows:

a. categorization of valve types
b. analysis of all valves types to see how well they met the requirements
c. a selection of promising examples of each major valve type and a cost estimate on these examples.

In any study program there are limits to how exhaustive an analysis one can make. Certainly, the analysis must fall short of the expenditure required to provide 100% surety that a particular valve type or types would be satisfactory. The analysis, therefore, observed reasonable limits. Where answers could be obtained by just thinking about the problem or by simple calculations, nothing further was done. Hydraulic analogy tests were conducted to answer some questions about the flow process which would have otherwise required extensive calculations. Some questions were attacked with more elaborate calculations while in other cases, the required calculations or preliminary tests would have been so extensive that our conclusions had to be based on experienced opinion.

2.1 CATEGORIZATION OF VALVE TYPES

One of the first things that was done during the study program consisted of an attempt to list all major valve types and promising subtypes. This was done to minimize the possibility of overlooking a really good candidate in the haste to get on with the business of selecting a valve. The resulting list of major types is presented here with a definitive statement for each type.

a.	Gate:	The blockage elements move normal to the passage centerline in opening.
b.	Plug:	The blockage elements move parallel to the passage centerline in opening.
c.	Normal Rotary:	The valve is opened by rotating the blockage elements about an axis normal to the passage centerline.
d.	Axial Rotary:	One of two matched blockage elements is rotated about the passage centerline.
e.	Frangible:	This type of valve is opened by destroying the principal blockage element.

Under the gate valve category, three subtypes appeared to be worth considering, namely: the common gate valve with one or more elements which are pulled completely out of the stream (Figure 2); a variation of the former in which only a relatively thin plate blockage element is removed from the stream leaving residual blockage in the form of support structure; and a variation which involves using the throat of the wind tunnel nozzle as a gate (this could be a fixed block nozzle or an Orlin type nozzle as shown in Figure 3; however, for this study, only the Orlin nozzle concept is analyzed). Only one plug valve concept was considered to have any potential, and that leaves considerable residual blockage when open (Figure 4). Two types of normal rotary valves were considered: the multiple butterfly (Figure 5) and a collapsible valve, the two-door version of which is shown in Figure 6. The axial rotary concept is shown in Figure 7. Like the plug valve, it leaves considerable residual blockage in the passage when open. The frangible valve, which is not illustrated, consists of a thin diaphragm supported by a grid-like structure. Breaking of the diaphragm is accomplished by puncturing it or weakening it with heat, etc. Some of the subtypes listed above are self-actuating while others need a considerable force to open them within the desired time.

During the study it was kept in mind that not only valve type is important but also valve location in the tunnel. Four possible locations were considered during the study program: upstream of the nozzle in the 11 ft. storage tube, upstream of the nozzle throat in the 20 sq. ft. area, downstream of the nozzle and model support structure in the 20 sq. ft. area, and downstream of the diffuser at some area greater than the nozzle area (11 ft. diameter location for analysis purposes). Some of the valve types will work in all four locations while others can only be used in one or two of the four possible locations. The Orlin nozzle subtype could only serve if located upstream of the test region but downstream of the 11 ft. section. Other valves will be shown to have too much residual blockage to put in the 20 sq. ft. area.

2.2 STUDY PROGRAM METHODS AND RESULTS

2.2.1 Literature Survey

A brief review of the literature was made in the following categories: 1) tube wind tunnel, 2) Orlin nozzle, 3) hydraulic analogy, and a variety of other subjects pertinent to the current study.

The tube tunnel concept was first presented by H. Ludwieg who recognized and defined the advantages of this type of tunnel (References 1 and 2). The tube tunnel, shown in Figure 1, features a closed system to provide constant stagnation conditions for short test durations and is less costly than a conventional blowdown tunnel of similar flow capability. Performance of the tube tunnel has been further defined in more recent studies (Reference 3). All experimental studies thus far have been made using small scale tunnels which featured frangible diaphragms downstream of the test section. Since the current study is concerned primarily with the development of a valve concept for a large scale, high pressure ($P_{o_{max}}$ = 500 psia) tube tunnel, the literature was searched for information pertaining to valve design and location. One of the considerations is the possible effect of valve location on starting loads and starting time.

The starting process and the starting time in particular is of special interest when considering a short duration run time facility such as the tube wind tunnel. Efforts have been made (Reference 4) to experimentally verify theoretical solutions of the starting process. Tests were made using a supersonic facility and the valve (diaphragm) located either downstream of the test section (similar to the tube tunnel arrangement) or upstream of the nozzle. Test results indicated no significant difference in starting time due to valve location. Other attempts have been made to theoretically predict the effects of valve location and initial pressure ratio on starting time, but the effect of valve location alone was not clearly established; thus, the need for further study was indicated.

Hydraulic analogy was considered as a means of observing the effects of valve location on the tube tunnel starting process. The analogy between free surface water flow and two-dimensional compressible gas flow has been theoretically established (References 5 and 6) and experimentally verified (Reference 7). Advantages of using hydraulic analogy in the current study include:

1. Excellent simulation of the tube tunnel flow can be obtained.
2. Starting process occurs slow enough in water to be observed visually, thus eliminating the requirement for sophisticated instrumentation.
3. Test apparatus is inexpensive to construct and operate.

The quantities of interest to be considered in applying hydraulic analogy to the tube tunnel starting process are tabulated below.

	Two-Dimensional Compressible Gas Flow $\gamma = 2$		Analogous Valves in Liquid Flow
Density Ratio	ρ/ρ_o		d/d_o
Pressure Ratio	p/p_o		$(d/d_o)^2$
Velocity of Sound	$a = \sqrt{\frac{\gamma p}{\rho}}$	Wave Velocity	$\sqrt{gd}$
Mach Number	v/a	Mach Number	$\left[\frac{2(d_o - d_\ell)}{d_\ell}\right]^{1/2}$
Shock Wave			Hydraulic Jump

where ρ, density
p, pressure
d, liquid depth
g, gravitational constant

v, flow velocity

γ, ratio of specific heat

subscripts - o refers to stagnation conditions

ℓ refers to local conditions

The Orlin nozzle was reviewed for possible application as a contained valve - nozzle for the tube tunnel. This nozzle consists of a movable non-flexible section which includes the subsonic contraction, the throat and a small portion of the supersonic expansion contour. Attached to this upstream section is a flexible plate which provides the remainder of the supersonic expansion contour. Experimental studies of this variable Mach number nozzle configuration (References 8, 9, 10, and 11) have shown it will provide Mach numbers from 1.5 to 3.5 with test section Mach number variations as low as one percent. It is possible that the Mach number range could be extended with a small sacrifice in test section flow uniformity. The data available is all from small scale configuration tests (maximum test section size of 6 x 6 inches). Larger scale nozzles have been constructed (Reference 12) for use in conventional blowdown tunnels. As yet, however, no apparent attempt has been made to utilize the Orlin nozzle as a quick opening valve and its application has been limited to facilities with a maximum design stagnation pressure p_o = 100 psia as compared to the $p_{o_{max}}$ = 500 psia requirement for the currently considered tube tunnel.

The possibility of using a multi-nozzle (Reference 13) both to establish the required flow and to serve as a supporting gridwork for a thin gate valve or frangible diaphragm was considered. The multi-nozzle concept would result in large flow non-uniformities (3 to 4 percent variation in test section Mach number typically, maybe $\pm$ 2% at best).

2.2.2 Estimation of Valve Residual Blockages, Total Pressure Losses Due to Blockage, and the Wake of Valve Parts

2.2.2.1 Estimation of Valve Residual Blockages

Each of the valves considered in this analysis (see 2.1) has a peculiar geometry which dictates the fraction of residual blockage existing when the valve is open. The amount of blockage is important for two reasons. First of all the blockage results in total pressure losses which must be kept within certain limits. Secondly, the valve parts produce wakes which can influence the test section flow quality. From the preliminary structural analyses, values of valve residual blockage have been estimated and tabulated in Table 1. The values listed are admittedly preliminary and in some cases would vary with the number of elements but the effect of these variations on total pressure losses, etc., is small as will be shown below.

2.2.2.2 Calculation of Total Pressure Losses Due to Valve Residual Blockage

For calculating total pressure losses due to valve residual blockage, it was assumed that the valve residual blockage was equivalent to a screen with the same blockage. Curves presented in NACA Wartime Report L-23 (Reference 14) were used as the basis for the calculation. The calculations were made for the 11 ft. upstream location only because at the other locations the losses are either so sensitive to even the smallest blockage (5 ft.

upstream) or don't influence the test section flow conditions at all (downstream locations).

Since the losses depend upon the approach Mach number to the valve as well as the valve blockage, they vary with the nozzle throat area and throat Mach number. Consequently, they can be plotted as a function of test Mach number with valve residual blockage as a parameter as in Figure 8. From this plot it appears that a valve effective residual blockage of almost 50% can be tolerated without exceeding 1% total pressure loss. Therefore, none of the valve designs listed in Table 1 have too much residual blockage for the 11 ft. section.

2.2.2.3 Estimation of Test Section Flow Distortion Caused by the Wake of Valve Ports

The phenomena of wakes and velocity disturbances was analyzed for the 11' upstream valve concepts which leave some residual blockage in the tunnel when fully open. The decay of velocity disturbances was investigated as a function of the distance downstream of the blockage and the effects of a contraction on the velocity disturbances were also checked.

For the purpose of the preliminary investigation, the blockage was assumed to consist of a row of cylindrical bars. Then, using the equation given for subsonic velocity disturbance downstream of cylindrical bars in Reference 15, disturbances were calculated as a function of the distance downstream of the bars. Various combinations of bar diameters and center to center spacings were analyzed. It was found that for small bar diameters (6" and smaller) the velocity disturbances were inversely proportional to the distance downstream of the bars and the values of the disturbances were quite small (10% maximum for all cases). It was also found that for constant bar diameters, the disturbances decayed faster as the bar spacing was decreased. Disturbances were more critical for the larger bars considered which would approximate the disturbances expected with the axial rotary and plug type valves.

The effect of a contraction on the wake velocity decrement was then analyzed for two of the worst cases of test section Mach number = .30 and 1.0. Assuming isentropic flow with no viscous mixing between the wake and free stream, it was found that the velocity disturbance would be reduced by a factor of 30 for the M = .30 case and by a factor of 50 for the M = 1.0 case. Therefore, it was concluded that the lateral variation in test section Mach number will be less than .5% for bars smaller than about one foot diameter.

2.2.3 Estimate of Valve Weight and Determination of Actuation Requirements

All of the important valve types and subtypes listed in Section 2.1 were analyzed structurally to withstand a 500 psi pressure differential. The structural analyses were made for the purpose of estimating weight, for the case of the valve types with translational motion, and mass moment of inertia for the case of the valve types with rotational motion. These designs were not final type designs, but were strictly estimates as to the structural requirements. Estimates were also made on the weight of the actuating mechanisms for the non-self actuating concepts. The opening times were found for the self actuating valve types and the actuator requirements were found that would produce the desired opening time for the non-self actuating valve types.

In all cases it was assumed that the valves would operate through an applied program of constant acceleration, through half the stroke, and constant deceleration, through the last half of stroke, to zero velocity at the end of the stroke.

Various valve subtypes were analyzed under each major valve category. The following is a description of each of the subtypes that were investigated, the main assumptions made for the purpose of calculation, and some of the more important results.

2.2.3.1 Gate Valve

Four distinct subtypes were considered: an 11-foot gate, an 11-foot gate with supporting gridwork, a 5-foot gate and an Orlin type nozzle. In the first three subtypes listed, variations were considered which utilized multiple elements or segments which would be withdrawn, in an attempt to reduce the moving mass and the total travel. For example, one, two, and four element valves were investigated for the three cases.

Figure 9 shows the force required to actuate each element for the 11-foot gate without blockage, 11-foot gate with blockage, and the 5-foot gate without blockage. These curves do not include the weight of the actuating mechanisms in the estimate of the moving weight. The force required assumed being applied over one-half the stroke of the valve and a negative force of the same magnitude being applied through the last one-half stroke to achieve the constant acceleration, constant deceleration program.

Figures 10 and 11 show the opening time as a function of actuator piston area. The weight of the actuator was included in the total moving weight of the valve and was estimated by the following formula:

$$\text{Weight}_{\substack{\text{actuating}\\ \text{mechanism}}} = \text{Weight}_{\substack{\text{valve}\\ \text{element}}} \left(\frac{\text{area piston}}{\substack{\text{area valve}\\ \text{element}}} \right)^{1.5}$$

The frictional force is also included in the total force required by the actuator and the coefficient of friction was estimated to be .10 in all cases. It was assumed that 500 psi would act on the actuator piston through one-half the stroke and the snubber would provide a negative force through the last one-half stroke of a magnitude such that the sum of forces would be a negative force equal to the positive force on the piston. In all cases shown, it was assumed the gate segments would be accelerated, decelerated and stopped at the tunnel wall.

In the case of the Orlin nozzle, several variations besides the standard Orlin nozzle were analyzed in an attempt to reduce the mass and the severe stresses in the flexible plate. For example, one method considered was to provide stationary and adjustable intermediate supports that the flexible plate would rest against in the open position. Another method was considered in which the flexible plate would be pressure vented on the underside to reduce air loads.

Figure 12 shows the opening time for the Orlin nozzle. As stated above, several variations of the Orlin nozzle were analyzed in hopes of finding a workable concept. The opening time shown corresponds to a variation of the Orlin nozzle utilizing several stationary and adjustable supports beneath the flexible plate to reduce the air load stresses and deflections. The following is a list of some conclusions that have arisen from the investigations of the various methods considered.

1. The flexible plate thickness determined from the maximum allowable bending stress in the closed position was 3 inches ($\sigma_{allowable}$ = 120,000 psi for high strength stainless steel). Pressure loads are considerably higher than those currently imposed on the Orlin nozzle. For example, the atmospheric pressure in the chamber beneath the flexible plate, at M = 1.5 the pressure load would be approximately 1,000,000 lbs. which would result in a bending stress of 200,000 psi. If the tolerable level of the sum of the contour bending-stress plus those due to pressure loads is 100,000, then the Orlin nozzle is not suitable for operation between M = 1.5 and 2.5.

2. The possibility of reducing pressure loads by controlling the chamber pressure under the flexible plate was considered. To be consistent with nozzle opening and starting times, the pressure must be introduced as the nozzle is opening. One method of achieving this was the use of fast acting valves which would operate after nozzle opening is initiated. However, since the bleed valve would have to operate more quickly than the nozzle, the valve size and piping requirements become intolerable. Another method considered was the possibility of a gap between the flexible plate and sidewalls which would allow air to bleed underneath the flexible plate

once the nozzle has been opened. From scaling up the tolerable gaps of previous Orlin nozzles, (Reference 8), the maximum gap would allow a bleed rate approximately two orders of magnitude less than what is required.

3. Reduction of stress due to air loads in the full open position can be accomplished with intermediate supports under the flexible plate. Since the nozzle will not operate fast enough to make it appear particularly attractive, a detailed stress analysis was made only for the end conditions (closed and open positions). It seems quite possible that the transient loads (for example, the instant before the flex-plate is supported) and the dynamic loads due to opening and snubbing forces might be significant and intolerable.

2.2.3.2 Plug Valve

Only one type of plug valve was analyzed and that consisted of a 45° cone shaped plug with eight radial ports. For the purposes of the initial estimates, it was assumed that the total weight of the movable plug was relatively independent of the number of radial ports. As can be seen in Figure 4, the plug was considered to have a total travel of six feet and the stationary radial members were to be three feet in length so that the plug would have a distance of three feet in which to accelerate before actually opening.

Figure 12 shows the opening time for the plug valve as a function of the number of radial ports. Since it was assumed that the weight was independent of the number of ports, the opening time was not a function of the number of ports. Since it was also assumed that the plug had a total travel of six feet and would accelerate to three feet before actually opening, the time shown for opening is the time to travel from X = 3 to X = 6 feet assuming constant deceleration.

2.2.3.3 Normal Rotary Valve

In this category, both self actuating and non-self actuating concepts were considered. For the self actuating concepts, the rotary element or elements were assumed to be either square or rectangular shaped segments and the opening time was checked for various positions of the axis of rotation. By varying the axis from the center to the edge of the segment, it was determined what axis position produced the minimum opening time. Also, various numbers of segments were tried to discover how this affected the opening time.

The results of opening time as a function of the number of segments is shown in Figure 12. It was also found that the minimum opening time could be produced with the axis of rotation one-half the distance from the center to the edge of the segment. The curves shown assume this axis position.

The non-self actuating normal rotary valves were analyzed assuming a large number of full length segments with the axis of rotation at the center of the segment and with intermediate bearing supports to minimize deflections. Various width to unsupported length ratios were considered from the standpoint of actuator and snubber requirements, bearing loads, total bearing friction, deflections, fabrication complexity, residual blockage, sealing problems, etc.

The table on the following page summarizes some of the more important vane sizes that were considered. The 9" x 9" size vanes appeared to merit further study because their actuator, sealing, bearing loads, etc. seem to represent average values for all the sizes considered.

2.2.3.4 Axial Rotary Valve

In this category, structural analyses were made for various numbers of radial ports and the actuator requirements were found for each case.

Figure 9 shows the actuator requirements for the axial rotary valve as a function of the number of radial ports. Structural analyses were made for the four and six port models and it was found that the mass moment of inertia was relatively independent of the number of radial ports. Therefore, the actuator requirements vary approximately as the angle of rotation necessary to fully open the valve.

2.2.3.5 Frangible Valve

In this category, the diaphragm was assumed to be supported by a stationary gridwork which had square openings. Using the equations of stress and deflection for a square shaped membrane, the minimum thickness membrane was calculated assuming various membrane materials and various size square openings.

Figure 13 shows the required thicknesses of several different materials which could be used as diaphragms. The thicknesses were calculated from the equations for square membranes given in Reference 16. Using the maximum tensile stress values for the various materials, the thicknesses were calculated and then the deflections were found. For all the materials shown, deflections were between 4% and 12% of the edge length of the square.

Unsupported Length	Width	Max. Thickness at Center of Vane	Required Torque*	Loads per Bearing	Maximum Deflection Between Bearings	Total No. Bearings Required	Blockage**	Total Sealing Length Required
12 in.	6 in.	2.60 in.	3920 ft-lb	42,000 lb	.012 in.	200	43.3%	230 ft.
9 in.	9 in.	2.32 in.	7030 ft-lb	49,500 lb	.009 in.	156	25.8%	160 ft.
6 in.	12 in.	1.84 in.	9190 ft-lb	48,000 lb	.006 in.	160	15.3%	130 ft.
12 in.	12 in.	3.10 in.	18810 ft-lb	84,000 lb	.012 in.	100	25.8%	130 ft.
6 in.	9 in.	1.71 in.	9470 ft-lb	34,000 lb	.006 in.	208	19.0%	160 ft.

* .05 second opening; constant acceleration and deceleration; no friction; total number of vanes.

**not considering stiffeners

NON-SELF ACTUATING NORMAL ROTARY VALVES

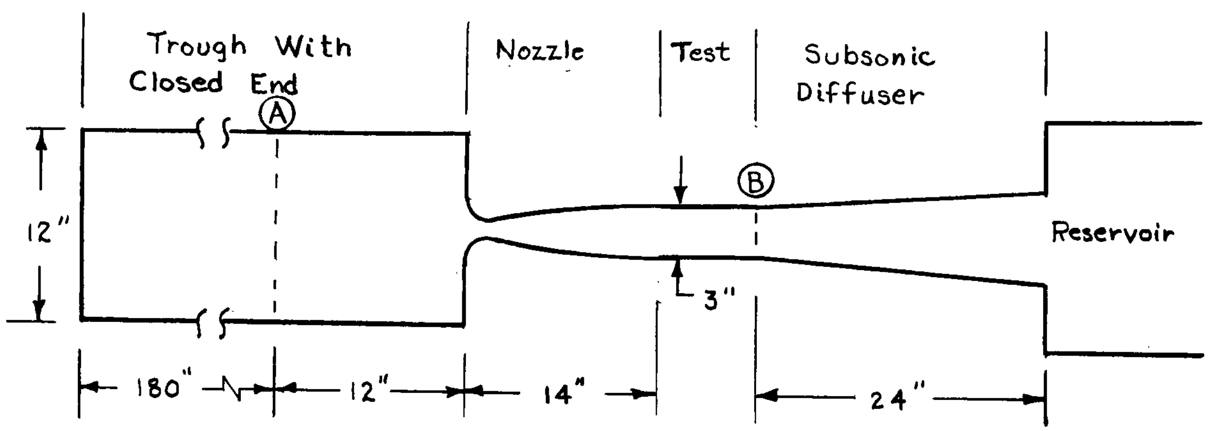
2.2.4 Calculation of Permissible Valve Leakage and Leakage Potential

To get an idea of what fabrication tolerances would be acceptable and the amount of sealing that would be required, the maximum permissible valve leakage was calculated. This was done by finding the mass flow output of the compressor, assuming an eighty minute re-pump time. Then, by assuming a discharge coefficient of 1.0, the maximum tolerable cross-sectional area opening was determined that would have a mass flow rate equal to the compressor output. The maximum opening was found to have an area of 1.35 in^2.

The linear leakage path was also determined for the various concepts and is plotted in Figure 14 as a function of the number of segments or radial ports for each concept. It was intended that the length of seal required would give an indication of the difficulties that would be encountered in achieving a tight shut-off. However, sealing problems are a function of more than the required seal length. They are also a function of the specific type of seal, for example, whether or not the air pressure on the valve tends to compress the seal, whether or not the valve must be loaded externally to achieve a tight seal (as in the case of the seal between the segments of a two segment gate valve), whether or not the valve must slide over the seal during opening and closing as opposed to the valve simply butting against the seal in the closed position.

2.2.5 Hydraulic Analogy Tests

Hydraulic analogy tests were made to determine the effect of valve location on starting time. The water tunnel used for testing is shown sketched in plan view below. The critical dimensions, the ratio of trough to nozzle and test section lengths were scaled down from the proposed tube tunnel. Three nozzles were designed in accordance with the principles of hydraulic analogy to provide equivalent Mach numbers, M_{eq}, of 1.0, 2.0, and 4.0. No attempt was made to hold the nozzle contours to close tolerance, so actual M_{eq} = 1.1, 2.0 and 3.8 were obtained.



Quick opening valves were simulated using manually operated sluice gates at the indicated upstream and downstream valve locations, A and B respectively. Accurate measurement of valve opening time was not considered necessary since the gate could be opened in a small fraction (approximately 1/10) of the measured starting time.

The test procedure was as follows:

1. With a pressure head (4 to 6 inches of water) upstream of the sluice gate, the gate was opened and the expansion wave in the trough was observed. Run time,

the time required for the expansion wave to travel to the closed end of the trough and return to the nozzle, was eight seconds.

2. For each of the three nozzles continuous water flow was obtained by pumping water from the reservoir into the trough. The equivalent Mach number for a nozzle was obtained from both water depth measurements and measurements of the shock wave angle from a thin plate inserted in the test section flow.

3. Using the same procedure as described in (1) above, the starting time was determined as the time required for the normal shock (as indicated by a hydraulic jump) to move downstream through the nozzle expansion and test section. This was done using the valves at either location A or B and with various initial pressure ratios (water levels) across the valves.

4. Special set-ups included: (1) introduction of a 50% blockage segment at location A and (2) locating the valve at the exit of the subsonic diffuser.

5. Trough geometry was varied by installing a linear taper in the trough sidewall simulating a conical tube with zero area at the closed end.

The results of the hydraulic analogy tests are graphically presented in Figure 15. The plot contains the ratio of starting to available running time plotted versus the ratio of valve back pressure to the value of back pressure that resulted in a no-start condition. With the valve located upstream of the nozzle (position A), the time required to establish steady flow at a

$d_{O_{2 initial}} = 0$ condition (zero backpressure) was approximately 1/8 of the available run time for all the Mach numbers. Increasing the initial valve back pressure resulted in increasing the starting time. Locating the valve downstream of the test section (position B) resulted in doubling the Mach 1 starting time up to a back pressure ratio of 0.7. For the $M_{eq} = 2$ and 4 nozzles, the starting times are equal (within the limit of accuracy of measurement) for valve positions A and B. The Mach 4 configuration was also tested with the valve located at the downstream end of the subsonic diffuser. Starting times increased as indicated by the broken curve on the $M = 4$ plot.

The $M = 2$ configuration was tested with a 50% blockage segment at location A and no effect on starting time due to blockage was noted. This configuration was also tested with the valve at location A plus a blow-off valve located midway axially in the subsonic diffuser. Simulation in this case was that of a tunnel with an upstream valve, an evacuated test section, and a downstream blow-off valve. Starting times were unaffected by the pressure level downstream of the blow-off valve over the range tested and equaled 1/8 of the available run time.

Using the upstream valve (location A) the pressure level in the trough remained constant during the first eight second run cycle. During succeeding cycles, the pressure level dropped as expected, but considerable unsteadiness was observed in the pressure head suggesting that a valve location well upstream of the nozzle contraction might cause reflected disturbances in the storage tube. A valve was then located immediately upstream of the nozzle contraction and the unsteadiness described above was eliminated.

Tapering the water trough linearly from zero inches width at the upstream end to the full 12-inch width at the nozzle resulted in a decay of pressure head occurring in approximately four seconds or 1/2 the available run time for the untapered version.

In reference to starting time versus valve location, the results of the hydraulic analogy tests generally agree with those of Reference 4 for supersonic flow. In the transonic range, however, definite influence of valve location on starting time was noted.

2.2.6 Simple Rationalization and Application of Experienced Opinion

Several of the questions related to valve selection were answered without recourse to calculations of any kind. Among these was the question of how valve location influences starting and unstarting transient loads. At Mach numbers of unity and below the starting loads and running loads are equal. Above Mach 1.0, transient loads are often estimated by assuming that normal shock pressure rise acts across the test article reference area. During the transient periods the normal shock pressure rise is proportional to the existing diffuser back pressure. Ordinarily this would be essentially atmospheric pressure. It is possible to reduce the starting loads in some cases by installing a blowaway diaphragm downstream of the test section and pumping down the test section to a low initial pressure. This technique will not influence starting time or loads if the tunnel back pressure is already lower than the running free stream static pressure in the test section. Pre-run pumpdown is not possible with a downstream valve location and of course unstarting will occur at atmospheric back pressure even with the pre-run test section pumpdown. If a recloseable valve is used in a location downstream of the test section, closing this valve while the storage tube pressure is still high will result in extremely high unstarting transient loads.

In considering how much damage might be done to a test article during the transient loading period, it is necessary to consider the length of time that the loading exists as well as its magnitude. If the unstart occurs with atmospheric back pressure, the length of time the unstart occurs will depend on how rapidly the upstream stagnation pressure is being lowered. If the upstream flow is shut off rapidly with a valve, the transient loading period will be much shorter than it will be if the storage tube is allowed to bleed down in pressure after a run.

A second question for which answers were simply rationalized involved the influence of valve location on hazards to the test article or valve as well as the influence of location on instrumentation problems. With a frangible valve only, placing the valve upstream of the test section would subject the model to the hazard of flying pieces of valve diaphragm. Valves located downstream, on the other hand, are in danger of being hit by pieces of the test article. Also having the valve downstream subjects the test article and instrumentation to full stagnation pressure prior to each run regardless of the test Mach number. While this usually can be made tolerable by using special instrumentation techniques, etc., it complicates the instrumentation problem and might limit the maximum stagnation pressure which could be run in some situations.

The frangible valve has a problem with respect to initiation of opening which could not easily be analyzed mathematically. Calculations of minimum diaphragm thickness made for a reasonable support grid spacing showed that most candidate materials resulted in extremely thick diaphragms. Even brass required almost 1/8 inch thickness. This poses a considerable problem as to how the diaphragm is going to be ruptured since it is necessary that all grids rupture simultaneously. The thickness of diaphragm precludes the use of any simple electrical system and simultaneous initiation using a mechanical system doesn't seem possible either. Of course the frangible valve must be replaced between runs also, and the design and accurate costing of any mechanical system for replacement was considered to be beyond the scope of this program.

The certainty that the various valves could be actuated repeatedly without damage was a subjective evaluation based upon some knowledge of the state of the art of such things as seals, snubbers, pneumatic actuators, etc. Generally, it was felt that simple compression type seals stood a good chance of success while sliding seals, large snubbers, and large actuators had significant development problems which needed attention before these elements could be applied with confidence.

2.3 CONCLUSIONS

As a result of the study program, a multitude of conclusions can be drawn about how well the various combinations of valve design and location meet the requirements and desirables. The following list of conclusions was used directly to form part of the basis for numerically rating the valves.

a. One Orlin nozzle could conceivably provide satisfactory flow quality over the Mach number range.

b. Valves having some residual blockage could be used in the 5' location upstream of the nozzle throat if the valve blockage formed a multi-nozzle; however, the test section Mach number variation would be no better than ± 2%.

c. Only the gate and wall-hinged collapsible type valves will permit the full range of Mach numbers while located at the test section area since all others have more than 4% residual blockage.

d. The blockage of all valves considered can be made small enough to permit their installation in the 11' section without causing undue total pressure losses.

e. The sliding plug and axial rotary valves would have to be built with a large number of ports (12 to 18) to avoid creating significant wake disturbances in the test section.

f. In every valve category, one or more structurally sound designs can be found which will open in 0.05 seconds.

g. The Orlin nozzle subtype will require about 0.08 seconds to open with a storage tube pressure of 500 psi (it will take longer to open at lower pressures).

h. Except at Mach numbers within the transonic regime, the flow development time is the same if the valve is immediately downstream of the test section, just upstream of the nozzle throat, or in the 11' tube.

i. The flow development time and starting transient loads can be made small regardless of tunnel backpressure if a blowaway diaphragm or door is placed in the subsonic diffuser and the test section pressure is pumped down prior to a run.

j. For most runs at Mach numbers below 2.0, the test section static pressure will be greater than atmospheric pressure, so pumping down the test section will have no appreciable effect on starting time or loads.

k. Pre-run test section pumpdown is only possible with the quick opening device located upstream of the test section.

l. Extremely high unstarting transient loads will occur if a downstream located valve is shut while the storage tube pressure is still high.

m. With the quick opening valve positioned downstream of the test section, the instrumentation and model hardware will be subjected to full stagnation pressure prior to each run. In some cases, this might limit the maximum stagnation pressure which could be run.

n. Downstream valves having residual blockage are subject to possible impingement by test article parts.

o. With an upstream located frangible valve, the model would be in danger of being hit by pieces of the diaphragm.

p. Having the quick opening device located well upstream of the nozzle contraction will result in reflected disturbances within the storage tube which adversely influence the steadiness of flow after the initial expansion period.

q. No mechanical or space limitations will absolutely prevent placing the quick opening device either in the 11' tube, upstream or downstream of the test section at the 20 square foot area, or downstream in the subsonic diffuser; however, placing it in the 20 square foot (5') section does result in some possible interference with the nozzle, model support, or diffuser.

r. Positive actuation of the frangible valve will be practically impossible considering the diaphragm thickness requirements and the number of panels which must be opened simultaneously.

2.4 VALVE GROUP SELECTION AND COST ANALYSIS

The analysis of the various aspects of valve performance actually considered an infinite number of variations. For purposes of cost analysis and final rating, it was necessary to reduce the number of valve subtypes being analyzed. This appeared to be practical because in most cases it was clear that the most economical valve of a particular subtype would be the one with a small number of valve elements which would still permit opening within 0.05 seconds. In some case a single choice was not obviously suitable, so two extreme alternates were chosen for costing.

Before making the cost analysis on these valves, the rating system described in Section 3.0 was applied without the cost included. This gave a good indication of which valves were the most promising. Consequently, the cost analysis on the most promising valves was carried out with more accuracy than on those that would be less likely to rate high for other reasons. The most promising valves turned out to be the 11' multidoor normal rotary and the 5' 2-door gate.

In addition to costing the valve itself, it was necessary to estimate costs on the wind tunnel nozzle since some of these valve types would eliminate the nozzle and also to cost a tight shutoff valve, since some of the quick acting valves cannot be sealed tightly. In estimating the cost of the frangible valve, an automatic diaphragm replacing system had to be included and provision for a supply of diaphragm material had to be made. A test section box was needed, too. Some of the other valves could be built with a quick closing feature to conserve air. Since this would result in a model load hazard with the valve in downstream location, these valves were priced both with and without the ability to close quickly against pressure.

The cost breakdown which follows gives an approximate "range" of costs likely for valves considered in this study. A "range" of costs is necessary because many of the designs did not warrant detailed preliminary design, and costs also vary depending on the sophistication of a given design. The cost for the adjustable nozzle is based on scaling costs of existing flexible-plate nozzles.

APPROXIMATE COST ANALYSIS

Nozzles, Test Section, and Support Hardware

Item	Cost ($1000)
Adjustable Nozzle and Test Section	750 - 1100
5-foot Tight Shutoff Valve	110 - 130

Valve costs for the two-door 5-foot gate valve and the 11-foot multidoor valve in the following table are based on preliminary drawings 0478-901 and 0478-902. Costs on larger valves of similar types are scaled up from smaller valves. Costs include development (Phase II), Final Design (Phase III), and fabrication.

Approximate Cost Analysis for Valves

Valve Type	Valve Subtype	Cost Range $1000 Recloseable	Cost Range $1000 Not Recloseable
Gate	Orlin Nozzle	1500 - 2000	
	2-Door (5 ft)	350 - 400	300 - 350
	2-Door (11 ft)	1200 - 1800	1000 - 1600
	2-Door with residual blockage (5 ft)	350 - 400 (add 200 for test section box if used as multinozzle)	300 - 350
	2-Door with residual blockage (11 ft)	800 - 1200	650 - 1050
Plug	(11 ft)		1200 - 1800
Normal Rotary	2-Door (11 ft)	500 - 800	450 - 750
	Multi-Door (11 ft)	230 - 280	230 - 280
	Collapsible (5 ft)		350 - 400
	Collapsible (11 ft)		1200 - 1800
Axial Rotary	(11 ft)	1200 - 1800	1100 - 1700
Frangible	(5 ft)		250 - 350 (add 200 for test section box if used as multinozzle)
	(11 ft)		1000 - 1500

The cost used in the rating described in Section 3.0 is the sum of the costs of the valve, nozzle and support hardware as required.

3.0 VALVE RATING

With the many considerations entering into valve selection, it was necessary to devise a rating system and apply this to each of several valve types which had been analyzed and costed. The rating system provided a numerical score from which the two or three most promising valves could be selected for closer review in the Phase 11 program.

3.1 DESCRIPTION OF THE RATING SYSTEM

In the list of requirements and desirables (Section 1.0) the requirements form a standard that the valve must meet if it is going to be considered useful at all. Although the laying down of the requirements is a somewhat arbitrary job, they are based upon an understanding of what is acceptable which has either been developed over a considerable period of practical wind tunnel test experience or which is dictated by the performance requirements of the proposed facility. On the other hand, the importance of certain requirements and the desirables is a rather subjective matter, and it can only be stated that the rating system was intended to be fair. In addition, there are bound to be certain doubts about the valves' performances as obtained from admittedly preliminary calculations, and it is not possible always to appreciate the degree of certainty available.

The valve rating score N was set up to be the product of a group of multipliers, M_1 , M_2 , etc.

$$N = M_1 \times M_2 \times M_3 \times M_4$$

where:

M_1 measures basic feasibility, etc.

$$M_1 = m_1 \times m_2 \times m_3 \times m_4$$

(m_n = 1.0 except as noted below)

a. If valve limits Mach no. or total pressure range slightly $m_1 = 0.5$; limits it significantly or is completely unsuitable $m_1 = 0$.

b. m_2 measures severity of reflected disturbances in storage tube (depends on location of valve with respect to nozzle contraction). If valve is in contraction, $m_2 = 1.00$. If valve is located between contraction entrance and a point two feet upstream of entrance, $m_2 = 0.90$. For valve location greater than two feet upstream of entrance, $m_2 = 0.75$.

c. m_3 measures whether or not the valve can meet the opening time requirements or whether valve position results in loss of run time.

$t_{open\ or\ lost}$	m_3	$t_{open\ or\ lost}$	m_3
0-0.05	1.0	0.10-0.12	0.4
0.05-0.06	0.9	0.12-0.14	0.3
0.06-0.07	0.8	0.14-0.16	0.2
0.07-0.08	0.7	0.16-0.18	0.1
0.08-0.09	0.6	0.18-0.20	0
0.09-0.10	0.5		

d. If valve results in a test section Mach number variation of over $\pm$ 2%, $m_4 = 0.75$; if variation is greater than $\pm$ 3%, $m_4 = 0.5$, greater than $\pm$ 4%, $m_4 = 0$.

M_2 measures the influence of valve location on starting transient loads. If valve location permits prerun test chamber pumpdown to reduce loads $M_2 = 1.0$; if not,

$M_2 = 0.75$.

M_3 measures the existence of any hazard either to the valve or test article. With no appreciable hazard, $M_3 = 1.0$. If the valve poses a hazard to the test article or flying test article parts form a hazard to the valve, $M_3 = 0.75$.

M_4 measures the cost of the valve and the certainty that the estimated cost will not be exceeded as well as the ease with which the particular valve design under consideration can be reclosed.

$$M_4 = A_1 + A_2 + A_3 + A_4$$

where:

A_1 measures the cost

$$A_{1_{ref}} = 10 \frac{C_{max} - C_{ref}}{C_{max} - C_{min}}$$

A_2 measures the subjective certainty that the valve can be actuated positively and stopped without damage.

$$A_{2_{max}} = 5$$

A_3 measures the certainty that the valve can be made adequately leak tight

$$A_3 = a_1 + a_2$$

$$a_1 = \frac{60}{\text{length to be sealed}} \qquad (a_{1_{max}} = 3)$$

$$a_2 = \begin{array}{l} 2 \text{ for compression type seal} \\ 0 \text{ for sliding seal} \end{array}$$

A_4 is determined by whether or not the costed valve can be closed mechanically at pressure or must be closed after tank blowdown. If it can be closed at pressure, $A_4 = 5$; if not, $A_4 = 0$.

3.2 RATING PROCEDURE

Appendix A contains rating sheets for each valve type and location as well as valuation and rating summary sheets. Overall rating and ranking summaries which show the relative potential of each type appear as Tables 2 and 3. By studying these sheets and tables, one can understand the procedure used in applying the rating system to arrive at a selection of promising valve types. In the rating sheets for each individual valve, the reasons behind each valuation are given. This means that one can appreciate the effect of different requirements when rating valves for a difference situation. A discussion of the results of the rating appears in the following section.

4.0 DISCUSSION OF RESULTS

4.1 GENERAL RESULTS OF RATING

Two results can be summarized from Tables 2 and 3, namely:

a. Downstream valve locations show less promise than upstream valve locations in all cases.

b. Lightweight valves having zero residual blockage (especially the 2-door gate valve) show considerable promise since they can be placed at or near the 20 sq. ft. area just upstream of the nozzle throat.

c. The multiple butterfly (multi-door normal rotary) also shows considerable promise because the cost of the actuating system is small and the certainty of success is high.

The downstream valve locations are less desirable for several reasons: it is not possible to pump the test chamber down prior to a run to reduce starting loads, the valve is in danger of being hit by flying test hardware, any attempt to close the valve with tunnel flow could result in severe unstarting loads, and placing the valve well downstream of the test section can reduce the effective run time by prolonging the flow development process.

The upstream multi-door normal rotary valve (multiple butterfly) rates second while the upstream five foot gate rates highest. Both of these valves satisfy most of the requirements and desirables listed in Section 1.0. Details of their relative advantages and disadvantages appear below in separate discussions covering these two valves.

4.2 VALVE SELECTION AND DESCRIPTION

Although the five foot upstream gate rated highest, it appears wise to carry both this and the multiple butterfly into Phase II. The gate valve has more development problems and there is a good deal of uncertainty about whether or not it can be made to operate consistently and safely.

4.2.1 The Multiple Butterfly Valve (Multi-Door Normal Rotary)

4.2.1.1 General (Refer to Drawing 0478-901)

The multiple butterfly valve actuates with a 90° rotation of a series of vanes to go from closed to open position. Because of the residual blockage when the valve is open, it must be located in the larger section upstream of the nozzle contraction. The valve is built in a rectangular shape to achieve sealing at the ends of the vanes.

The main advantage of this valve over other types (from a mechanical design standpoint) is its low actuation inertia. This results in much smaller actuation and snubbing hardware to accomplish the 0.05 second opening time. This also permits easy closing at the end of the run.

The main disadvantage of the multi-vane valve is the difficulty in obtaining a tight seal. The total length of the sealing surfaces is quite large (160 lineal feet) and the types of seals are not the most desirable for tight shut off at 500 psi. At this time, it is anticipated that the leakage can be kept below the total compressor capacity; however a 100% tight shut off valve will be required between this valve and the test section.

4.2.1.2 Vanes

Thirteen rotating vanes comprise the opening and closing elements. Each of these is a continuous diamond shaped machined piece extending horizontally the full width of the valve. The vanes are supported at 11 inch intervals by bearing brackets attached to a stiffener gridwork located just downstream of the vanes. The 11 inch spacing is dictated by vane deflection, and by bearing capacities needed to support the 500 psi load.

4.2.1.3 Seals

Each of the 11 center vanes has a compression seal along one edge and a machined sealing surface along the opposite edge. The actuation is such that adjacent vanes are rotated in opposite directions in order to seat and unseat the seals by means of a rolling action, as opposed to a sliding action which would result from rotating all vanes in the same direction. The two edge vanes (top and bottom) seal with a stationary edge strip by means of a leaf type seal. Because an odd number of vanes is used, each of these edge seals approaches the edge strip seat from the high pressure side.

The ends of the vanes are sealed with the walls of the valve by compression tupe seals embedded in the vanes. These contact with ring type seals to prevent leakage around the shafts extending through the walls.

4.2.1.4 Actuating Mechanism

The vanes are rotated by the rack and gear arrangement located outside the housing. One end of the rack forms the piston rod of the pneumatic cylinder actuator which furnishes the driving power. The other end of the rack drives against a snubber which decelerates or cushions the rack to a stop. The rack meshes with the alternate or driving gears (wide faced), which in turn mesh with the adjacent or driven gears (narrow faced). Thus each vane rotates oppostie to the vane on either side of it. The 90° rotation of the gears is equivalent to approximately 7 inches of rack and piston travel.

The actuator consists of a 12" diameter 7" stroke pneumatic cylinder. The opening cycle is accomplished by first pressurizing the piston with 500 psi storage air pressure. A squib mechanism is fired releasing the piston which drives the rack and gears thus rotating the vanes open. As the piston passes the mid-point of travel, (approximately 3 1/2" of rod travel or 22 1/2° vane rotation) the ports in the walls of the cylinder are exposed which vent the driving pressure to the opposite side of the piston. At this point the opposite end of the rack contacts a hydraulic piston type snubber which decelerates the motion through the last 3 1/2 inches of travel. The closing cycle is similar to the opening cycle, except that a longer closing time can be used. Therefore lower driving pressures are used, and motion can be initiated by venting pressure from the front side of the piston.

4.2.1.5 Body Structure

The valve body structure is a weldment approximately 11 1/2 ft. sq. by 2 1/2 ft. long with 2 inch wide internal stiffeners running both vertically and horizontally. These stiffeners form a gridwork which serves both as a tension tie restraining the 500 psi internal pressure (thus eliminating an external stiffening structure) and as a mounting surface for the bearing support blocks supporting the vanes. This structure is sandwiched between the transition on the downstream end of the 11 ft. diameter storage vessel and the nozzle contraction.

4.2.2 Two-Door Gate Valve

4.2.2.1 General

The two-door gate valve (Dwg. 0478-902) is located in a 5-foot square section just upstream of the nozzle throat. It consists of two gates each 2'-6" wide which meet at the tunnel centerline. The valve functions both as a quick opening valve and as a shut-off valve at the end of the run.

Potential advantages of the two-door gate valve are:

(1) The valve can be located in the 5-ft. sq. section immediately upstream of the nozzle throat.

(2) The vale can act as a shut-off valve in addition to a quick opening valve.

(3) The valve does not introduce any blockage into the tunnel.

Disadvantages of the two-door gate valve are:

(1) The valve requires accelerating a relatively large mass (i.e., about 1800 lbs.) very quickly and decelerating the same mass in equal or less time. Deceleration requires development of rather large snubbers which must act almost instantaneously.

(2) All seals will be on sliding surfaces. This increases chances of seal tear out or destuction during actuation, even if the seals are of the inflatable variety.

(3) The valve occupies a great amount of floor space.

(4) Because of fast opening times and the large masses involved, the valve is not safe and reliable as is the multi-vane valve.

4.2.2.2 Detailed Description

The two-door gate valve (Dwg. 0478-902) is located in a 5-ft. sq. section just upstream of the nozzle throat. It consists of two gates each 2'-6" wide which meet at the tunnel centerline. Splitting the gate in half reduces the mass of the gate and cuts the opening time in half.

A piston actuated by 500 psi air opens the gate in 0.05 sec. Immediately after the gate passes the full open position, snubbers start decelerating the gate. After approximately 0.6 sec. the pressure difference across the piston is reversed, and the valve closes. Small snubbers stop the gate assembly at the end of the closing cycle.

4.2.2.2.1 Gate Assembly

The gate assembly consists of the gate, piston rod, and piston. The gate is a welded alloy steel structure. The piston rod is an aluminum alloy tube which threads into the cylindrical tube of the gate structure. The opposite end threads into and extends through the piston and out through the end of the pressure container. The firing squibs act in tension at the end of the piston rod. The piston is fabricated of aluminum alloy while the entire gate assembly is fabricated of high strength or light weight materials to reduce mass. The gate is of sufficient depth to minimize deflections due to pressure loads.

4.2.2.2.2 Pressure Box

The pressure box encloses the section of the tunnel where the gate valve is located, and also encloses the opening slots for the gate. The tunnel portion is enclosed by tunnel box sections and the top and bottom frames (See Dwg. 0478-902). The opening slots for the gate are enclosed by the top and bottom frames and sidewalls. The end flanges of the pressure box also act as anchors for the opening snubbers.

4.2.2.2.3 Seals

All seals for the gates are of the inflatable type. The seals between the gate and the tunnel section are located in the tunnel section. One length of seal (between the two gates) must be located in one of the moving gates. The seals must be deflated during both the opening and closing cycle.

4.2.2.2.4 Snubbers

Four snubbers in line stop the gate in the opening cycle. The snubbing action occurs over a distance of at least one foot. In the closing cycle, two snubbers of smaller size engage the piston to stop the gate assembly in the fully closed position. A development program is necessary to properly size the snubbers and determine forces associated with the snubbing action.

4.2.2.2.5 Firing Squibs

Explosive tensile bolts connected to the end of the piston rod restrain the gate assembly until firing. When the squibs explode the pressure behind the piston drives the gate assembly to the open position.

4.2.2.2.6 Control Systems

Dwg. 0478-902 shows two alternate control systems conceived for the two-door gate valve. Control system No. 1 is the simplest and most promising of the two. Control system No. 1 depends on trapped air in the far end storage system for actuating the closing cycle. Control system No. 2 requires actuation of a valve to fill the far end storage system and initiate the closing cycle.

4.2.2.3 Operation

The time history of the gate valve for a typical tunnel run is as follows:

Time (sec.)	Action
-1.0	Depressurize seals
0.00	Fire squibs
+0.05	Gate valve fully open
+0.65	Gate valve starts closing
+1.20	Gate valve fully closed
+2.2	Pressurize seals

The sequence of operation for each of the two control systems appears on Dwg. 0478-902. Either system would be fully automatic under normal operation, with an option of manual operation when desired. Safety interlocks prevent operation of the valve unless all necessary conditions are met. Indicator lights will monitor the necessary conditions for opening or closing.

4.3 COST ANALYSIS OF MULTIPLE BUTTERFLY VALVE AND TWO-DOOR GATE VALVE

The following cost estimates are based on preliminary design drawings 0478-901 and 0478-902. These costs are in addition to Phase II costs described in section 5.

4.3.1 Multiple Butterfly Valve

(Requires slow-acting tight shut-off valve for workable system)

Item	Cost ($1000)
Butterfly Valve	
Final Design	24.7
Fabrication	168.9
Assemble, Install, & Checkout	32.5
Other	6.5
Total Final Design and Fabrication	232.6
Tight Shut off Valve	
Final Design	13.0
Fabrication	104.0
Install & Checkout	13.0
	130.0

4.3.2 Two-Door Gate Valve

Item	Cost ($1000)
Final Design	23.0
Fabrication	255.0
Install & Checkout	38.9
Other	8.0
	329.9

5.0 PHASE II TASKS

5.1 GENERAL

Phase II work will consist of developing and verifying valve design concepts to a degree which will permit final valve selection and detail design. A detailed outline of the Phase II work on the two candidate valves is given in the following sections. The sequence of this design and testing will be to perform the work on the multiple butterfly valve first, especially with relation to sealing. If the work showsup serious deficiencies in this concept, the Phase II program will shift emphasis to development of the two-door gate valve. If the multiple butterfly concept proves satisfactory, this valve design will be carried through to completion, and no development work will be done on the gate valve.

5.2 MULTIPLE BUTTERFLY

The preliminary design and testing of the multiple butterfly concept will be focused on the following problems:

a. Seals
b. Actuator and Control System
c. Snubbers.

The first step will be to make a literature and catalog search to determine what hardware has been designed and built which applies to these problem areas.

The second step will be to design, build, and test a small section of the valve. Three vanes will be built: each full size in cross-section and of a length to span three stiffener spacings. These will be assembled in a rectangular pressure housing approximately 30 in. x 33 in. which will contain the stiffener gridwork as anticipated in the full scale valve. The seals, bearings, shafts, rack, and gears will all be full scale. The actuator and snubbers will be scaled down to match the inertia and friction forces of the model. The model valve will be tested at full design conditions for the following objectives:

a. Seals: Determine the optimum seal configuration with respect to leakage, required actuator driving force, and seal life for the four types of seals required (edge compression seal, edge lip seal, shaft seal, and end compression seal). The maximum tolerable leakage will be related to compressor pump up capacity.

b. Actuator and Control System: Determine time history of the inertia and friction forces encountered at the design valve opening and closing conditions. Also check out the feasibility of the proposed control system to accomplish the opening and closing requirements.

c. Snubbers: Determine the time history of the snubber decelerating forces. Also investigate recovery time, overtravel, and other problems relating to snubbing.

It is anticipated that from these tests, sufficient information will be gathered to permit a final design which reflects a high degree of confidence in the performance of the full scale hardware.

In addition to the development work on the mechanical aspects of the valve problem, it is anticipated that aerodynamic testing will be undertaken to verify that the test section flow quality is not influenced by the valve blockage. Scaled down tests of the tube tunnel concept with an operational mechanical valve may also be included.

5.3 TWO-DOOR GATE VALVE

If preliminary design and testing of the multiple butterfly valve reveals serious deficiencies in this concept, the Phase II program will shift emphasis to development of the two-door gate valve. Several problems associated with the two-door gate valve will require extensive testing and development:

a. Large (Opening) Snubbers
b. Small (Closing) Snubbers
c. Explosive Squibs
d. Seals.

Literature and catalog searches for solutions to some of these problems will have been previously made in preliminary design of the multiple butterfly valve. Thus, the first step in development of the two-door gate valve will be preliminary design to determine approximate sizes of components and forces associated with the operation of the valve.

The second step will be to design and fabricate a pneumatic acceleration tube to test the large snubber. The tube will accelerate a projectile of one-fourth the mass of the gate assembly to the maximum velocity expected of the assembly in operation. The projectile will impact on the snubber. A time history of the projectile-snubber movement and accelerating forces will be recorded.

Testing of the small snubber will require only a small additional cost. The basic test hardware for the large snubber can be utilized for these tests.

It is anticipated that several design variations for explosive squibs will be studied. Factors which will enter into the evaluation will be (1) reliability of firing, (2) possible damage to hardware resulting from explosion, (3) ease of recharge, and (4) cost of recharge. Some testing of the squibs appears necessary particularly to evaluate (2) above.

Seals for the two-door gate valve present serious problems. The seals must be inflated for sealing but must be deflated for opening and closing. Seal tests are required to determine (1) adequacy of design to achieve 100% seal, (2) pressure required to achieve a good seal, and (3) the maximum gap which the system can effectively seal.

After completing the above tests, changes resulting from the development program will be incorporated into the preliminary design.

If mechanical development tests are carried out on the gate valve, aerodynamic tests should also be carried out to show how a gap in the wall at the valve location influences test section flow quality. Here, too, it may be worthwhile to check the tube tunnel flow process with a scaled down mechanical valve.

5.4 DEVELOPMENT COSTS

The estimated costs of preliminary design and developmental testing for the two valves are given below:

Multiple Butterfly	Cost
Engineering	$10,000
Model Valve Hardware and Testing	$14,000
Aerodynamic Tests	$20,000
	$44,000
Two-Door Gate	
Preliminary Design	$5,500
Hardware and Testing	
Large Snubber	$26,000
Small Snubber	$3,700
Squibs	$3,900
Seal Tests	$6,500
Aerodynamic Tests	$15,000
	$60,600

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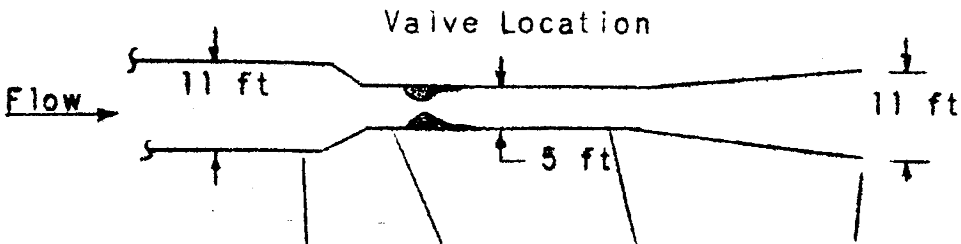
TABLE 1 SUMMARY OF VALVE RESIDUAL BLOCKAGES

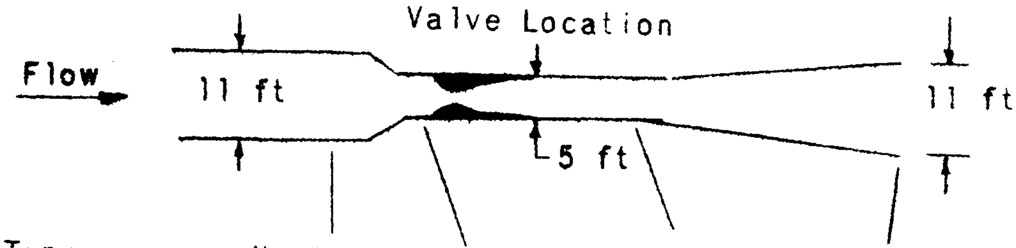
Valve Type	Subtype	% Blockage
Gate	Orlin Nozzle	0
	Plain Gate	0
	Gate with Residual Blockage	20
Plug	Tapered	40
Normal Rotary	Butterfly	40
	2-Door Collapsible	0
Axial Rotary	Tapered	40
Frangible		20

TABLE 2 VALVE RATING SUMMARY



	Valve Type	Upstream 11 ft.	Upstream 5 ft.	Downstream 5 ft.	Downstream 11 ft.
GATE	Orlin Nozzle	0	2.9	0	0
GATE	2 Door	7.9	16.4	4.7	1.5
GATE	2 Door With Resid. Blockage	11.1	7.3	3.5	1.8
	PLUG - 12 Port	3.2	0	0	.95
NORMAL ROTARY	2 Door	11.3	0	0	2.3
NORMAL ROTARY	Multi - Door	15.6	0	0	2.8
NORMAL ROTARY	2 Door Collapsible	2.9	10.4	4.2	1.1
	AXIAL ROTARY 18 Port	5.4	0	0	0.6
	FRANGIBLE	4.3	4.5	3.8	1.4

TABLE 3 VALVE RANK SUMMARY



	Valve Type	Upstream 11 ft.	Upstream 5 ft.	Downstream 5 ft.	Downstream 11 ft.
GATE	Orlin Nozzle	-	16	-	-
GATE	2 Door	6	1	8	20
GATE	2 Door With Resid. Blockage	4	7	13	19
	PLUG - 12 Port	14	-	-	23
NORMAL ROTARY	2 Door	3	-	-	18
NORMAL ROTARY	Multi - Door	2	-	-	17
NORMAL ROTARY	2 Door Collapsible	15	5	11	22
	AXIAL ROTARY 18 Port	7	-	-	24
	FRANGIBLE	10	9	12	21

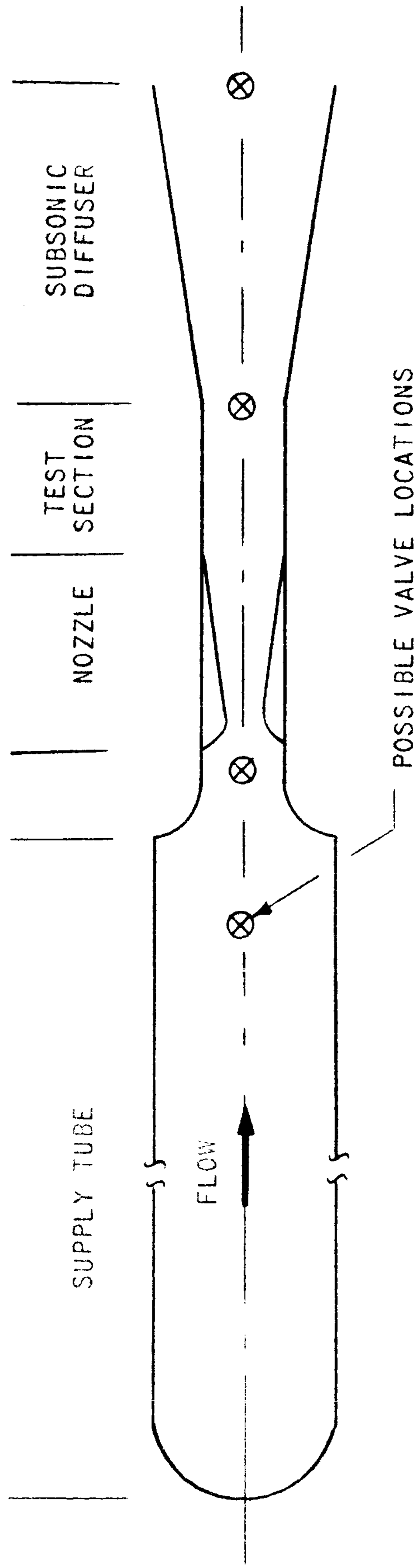


FIGURE 1 SKETCH OF TUBE TUNNEL ARRANGEMENT

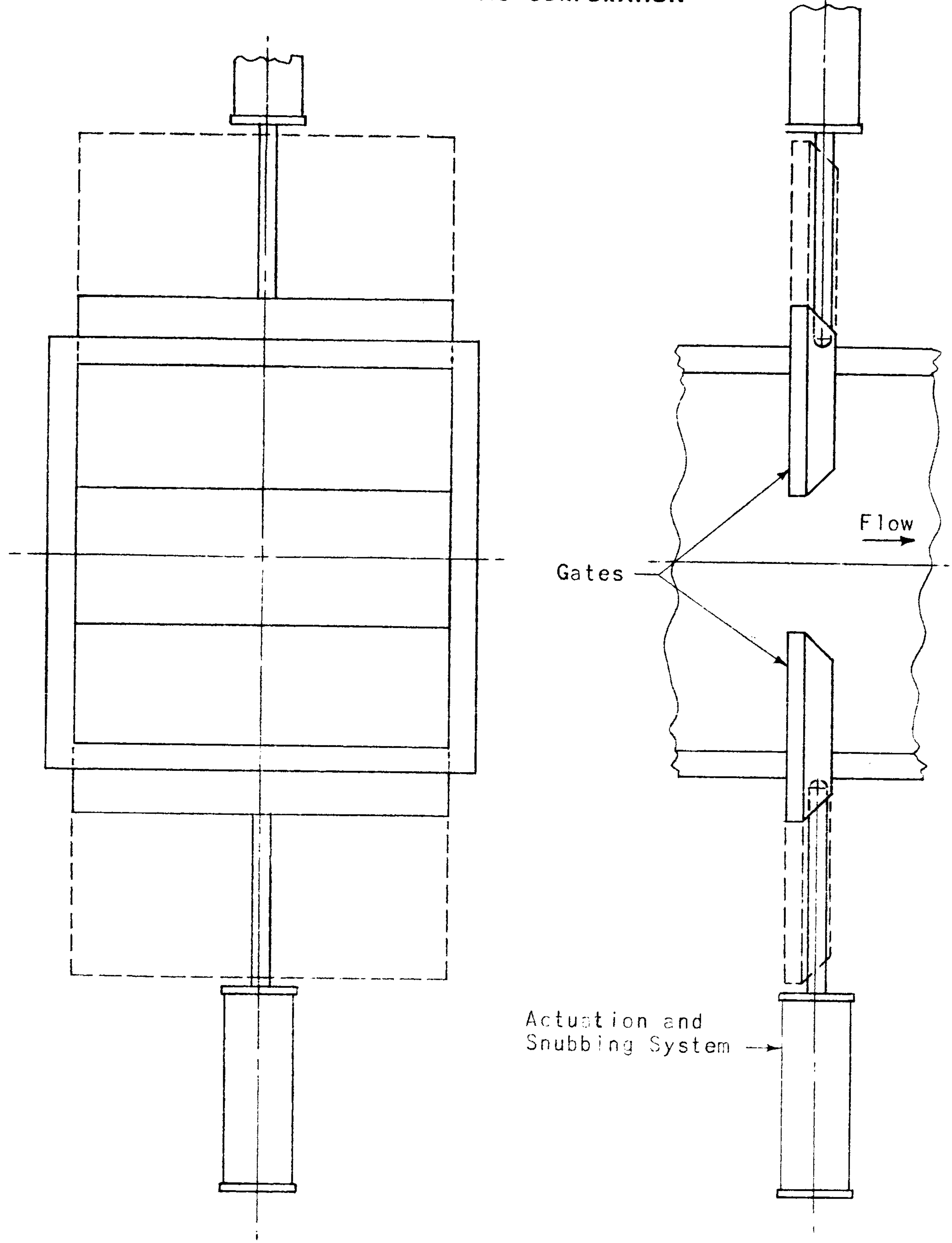


FIGURE 2. SKETCH OF GATE VALVE CONCEPT

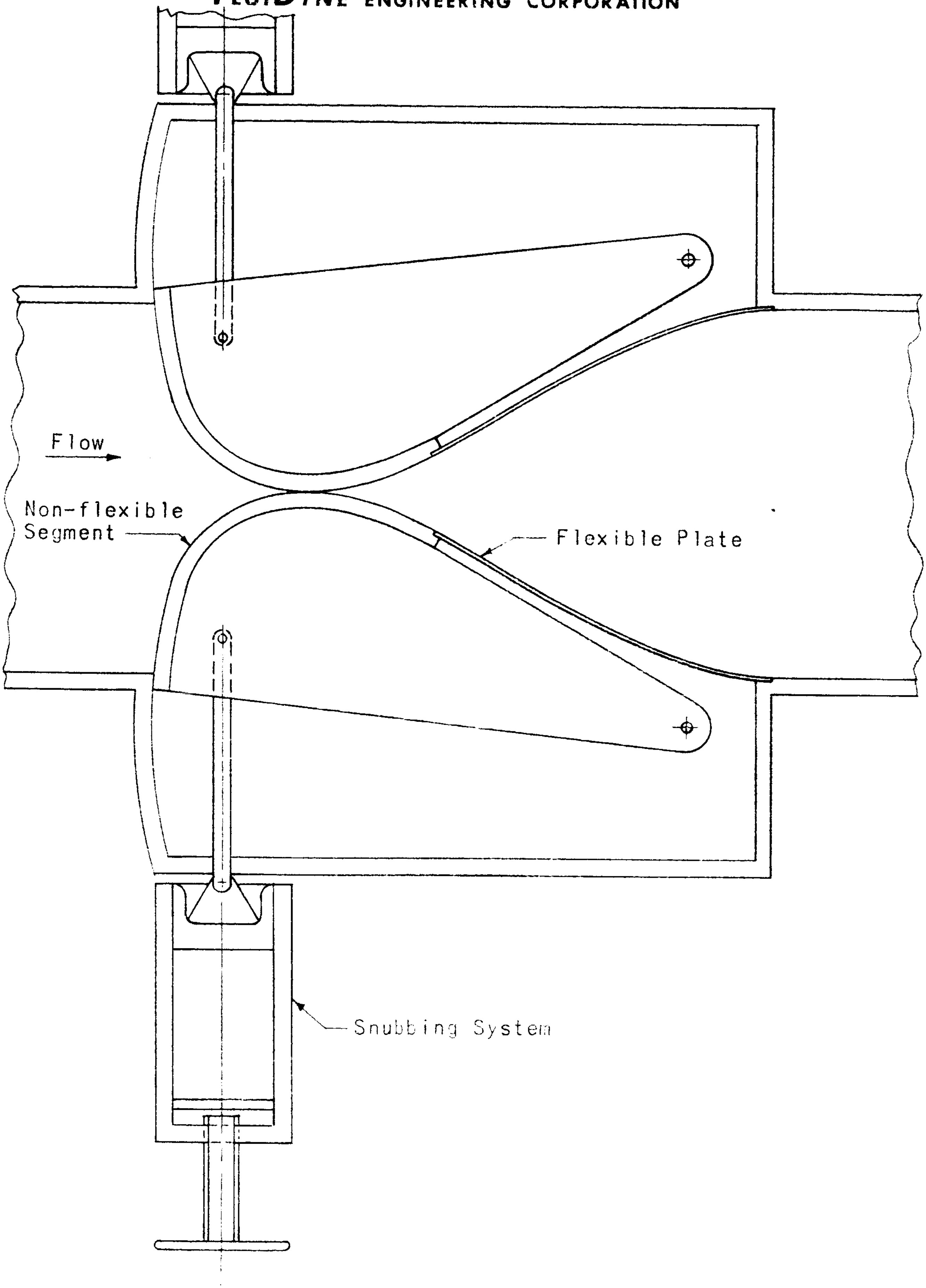


FIGURE 3. SKETCH OF ORLIN NOZZLE-VALVE CONCEPT

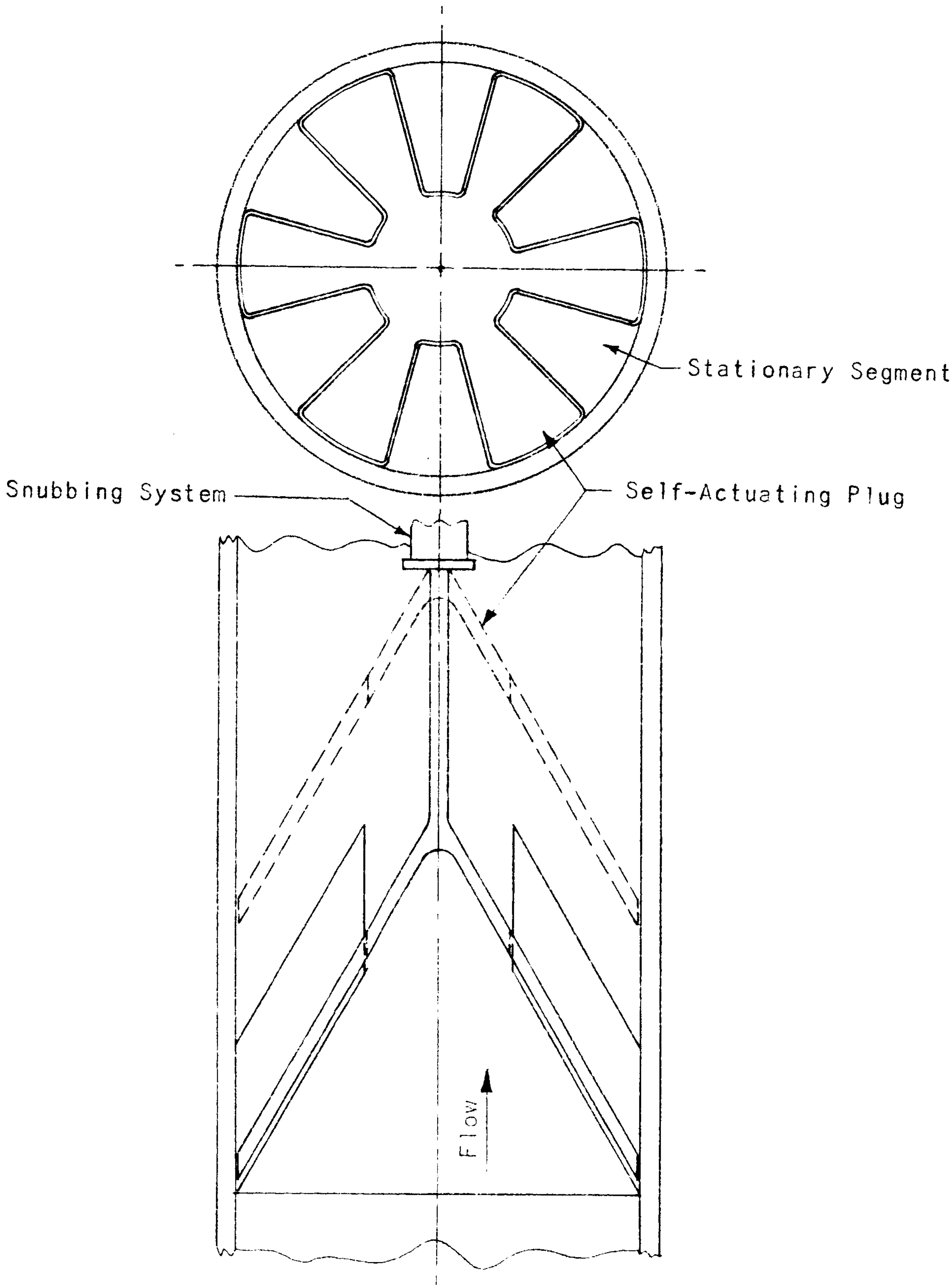


FIGURE 4. SKETCH OF PLUG VALVE CONCEPT

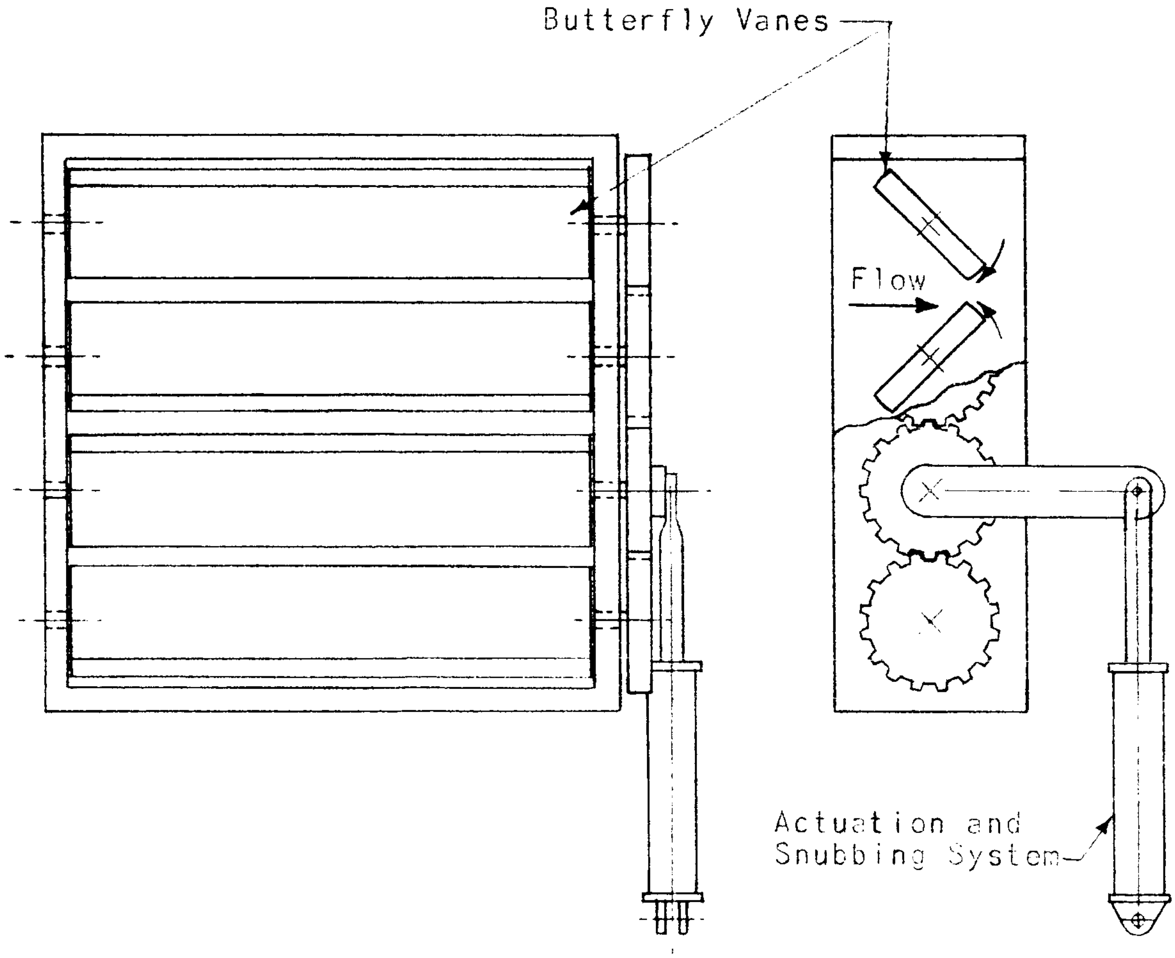


FIGURE 5. SKETCH OF MULTIPLE BUTTERFLY VALVE CONCEPT

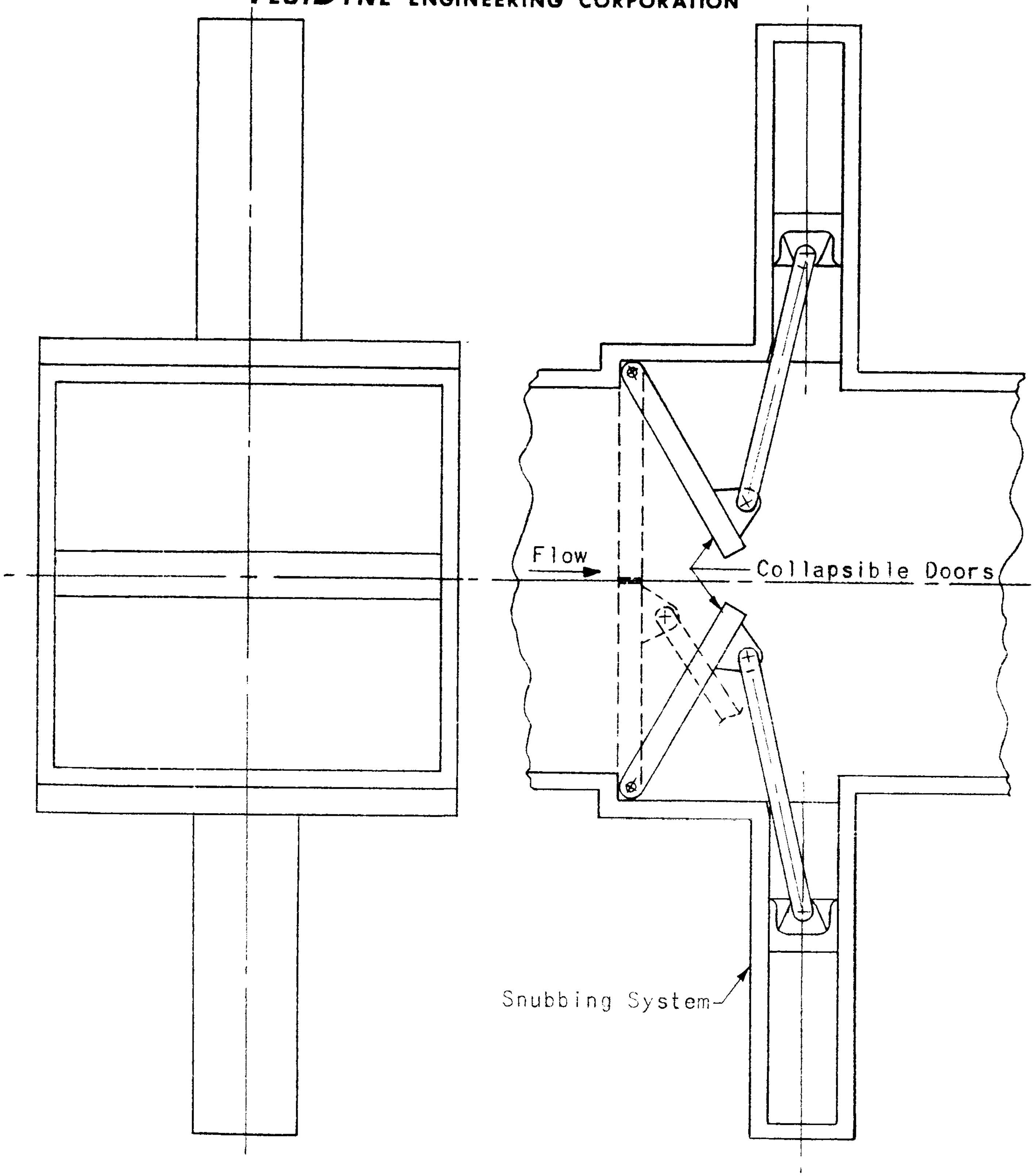


FIGURE [illegible]. SKETCH OF COLLAPSIBLE VALVE CONCEPT

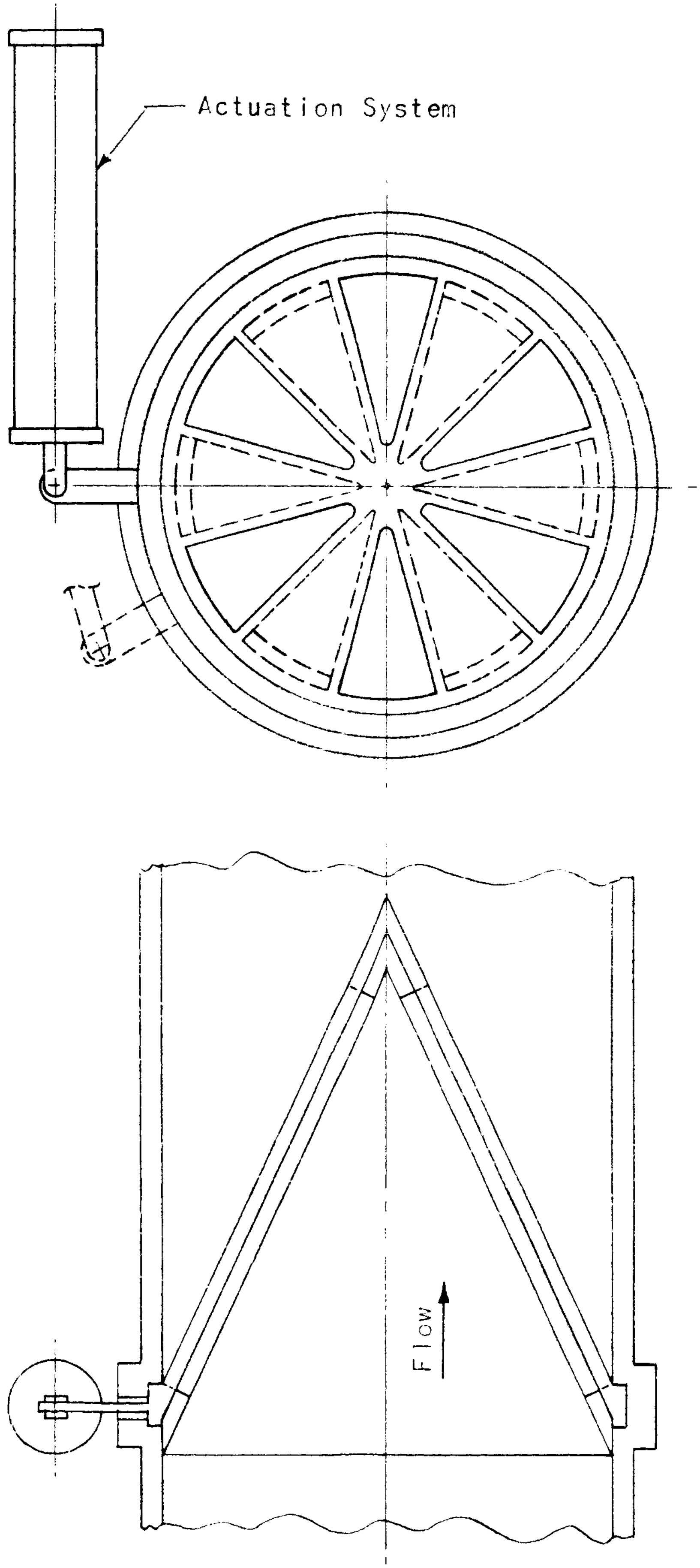


FIGURE 7. SKETCH OF AXIAL ROTARY VALVE CONCEPT

FIGURE 8 TOTAL PRESSURE LOSSES DUE TO VALVE RESIDUAL BLOCKAGE

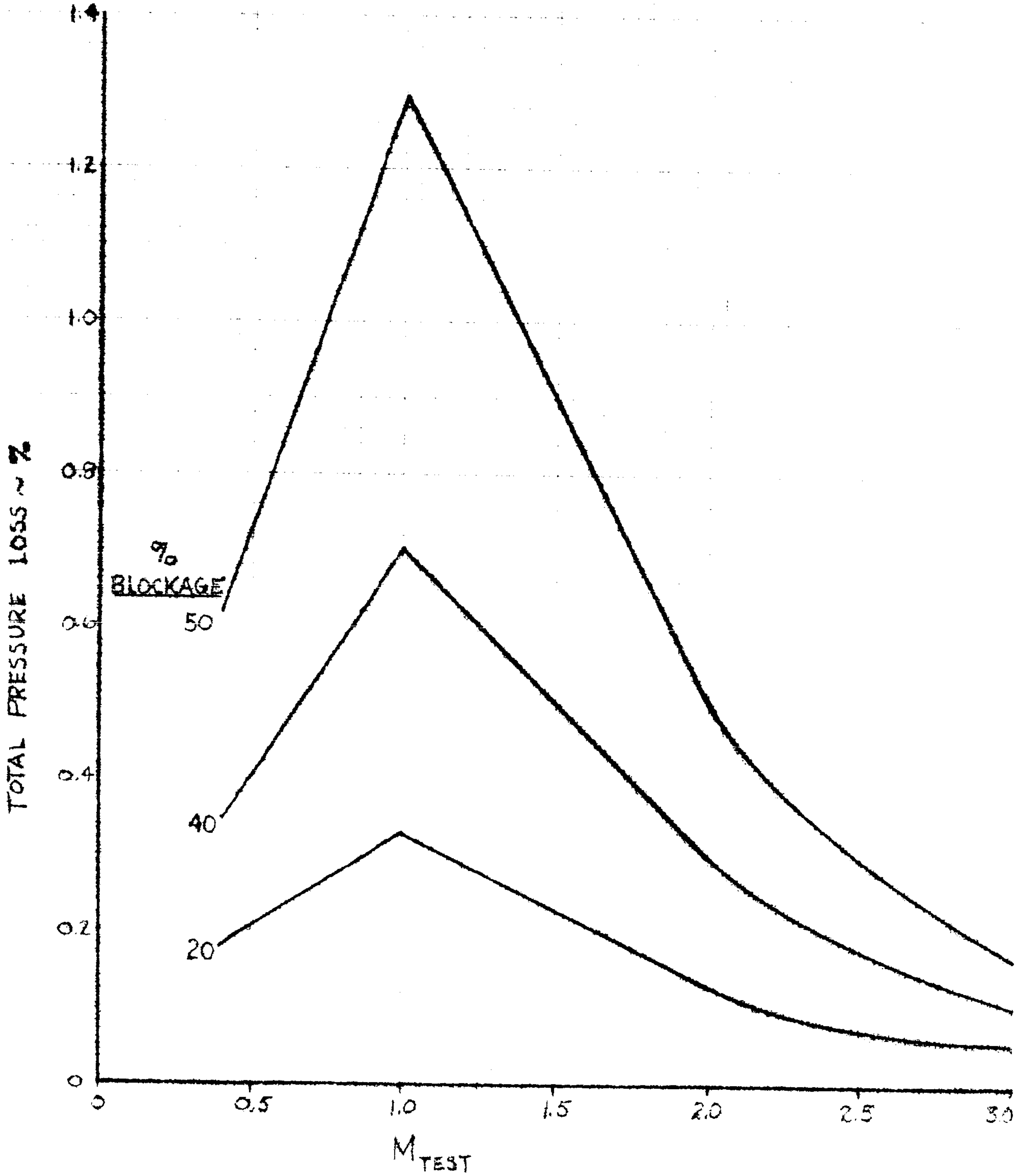


FIGURE 9 ACTUATING FORCE FOR NON-SELF-ACTUATING VALVES

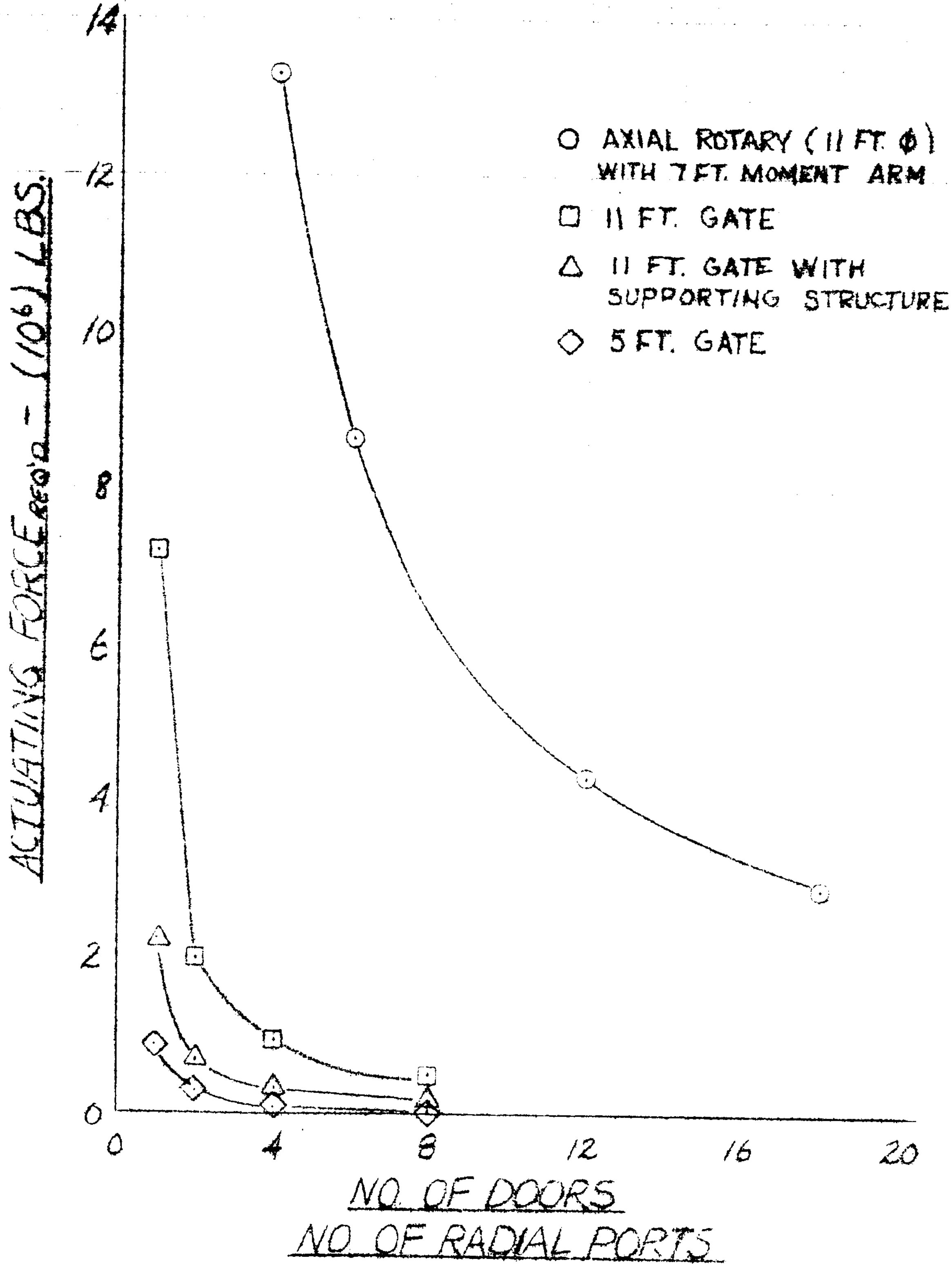
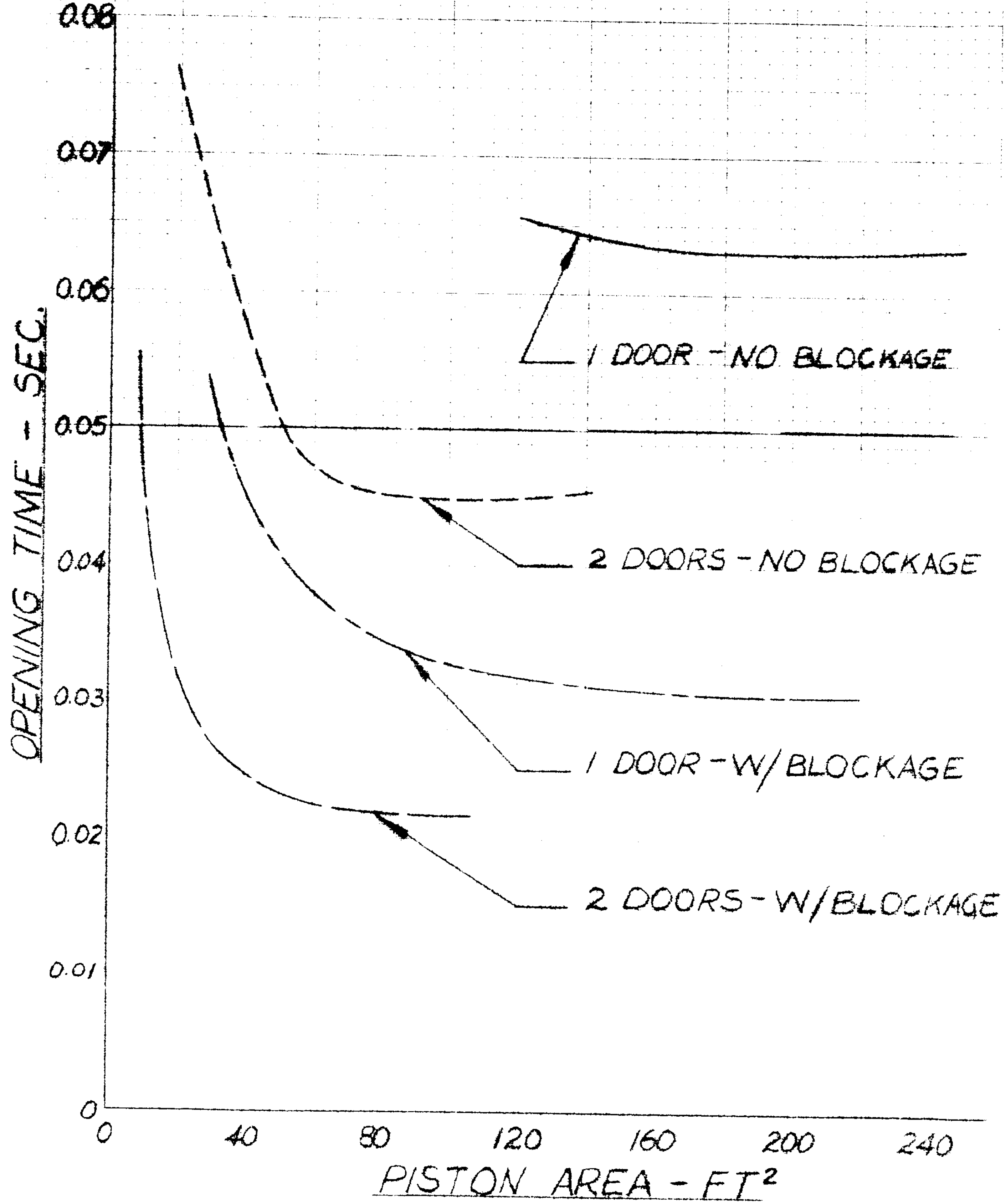


FIGURE 10 OPENING TIME VS. PISTON AREA FOR ELEVEN FOOT GATE VALVES



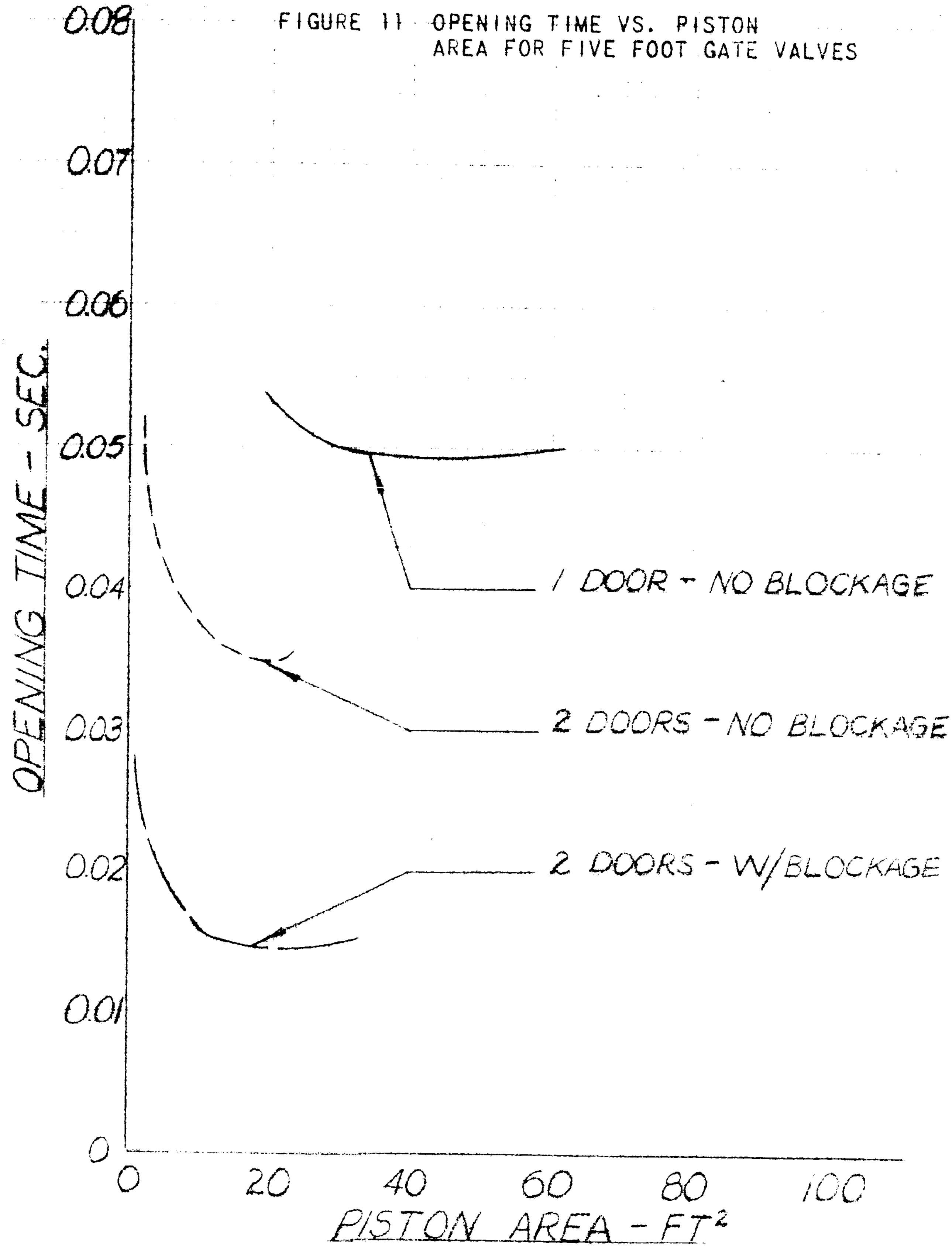
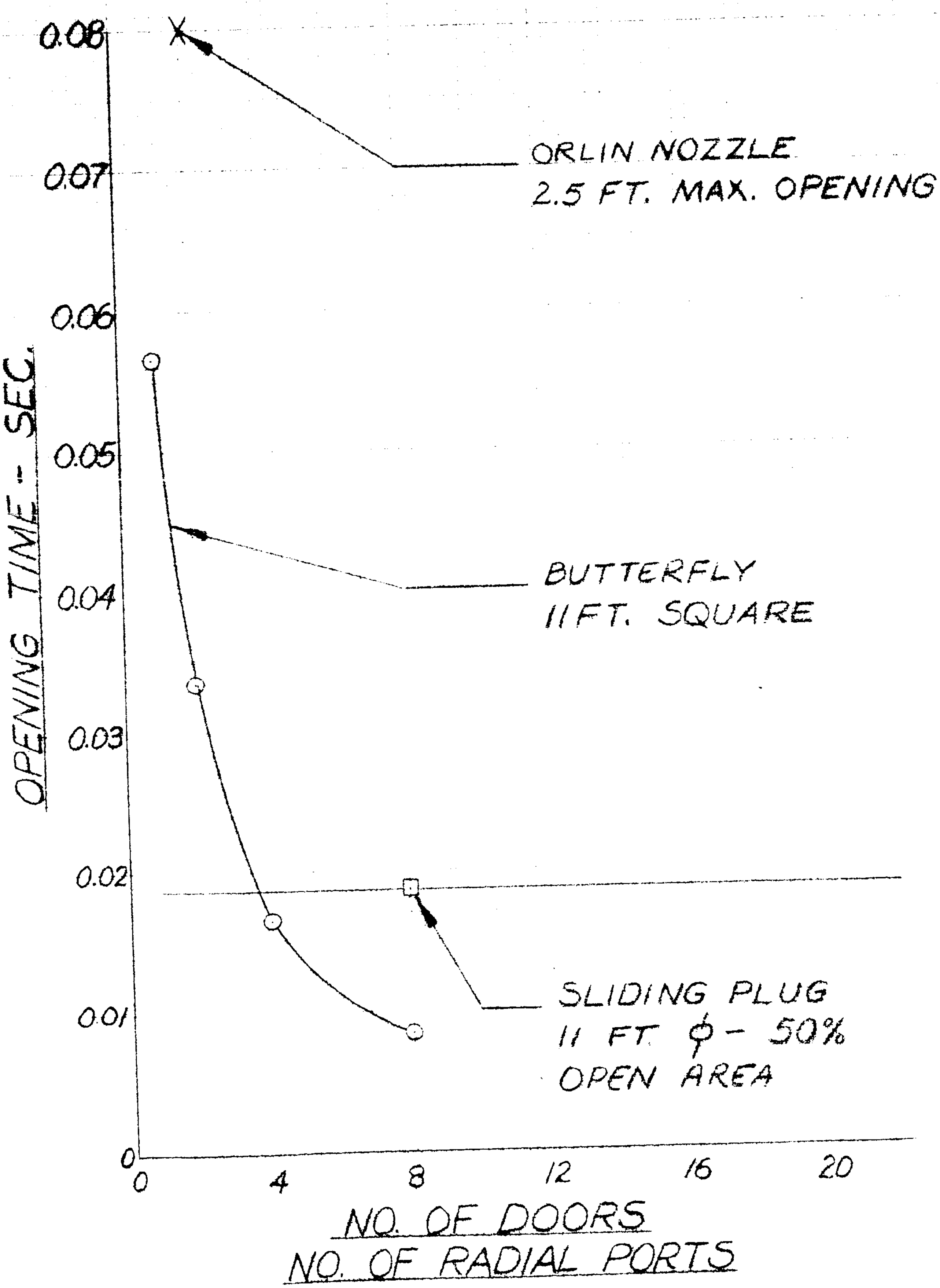


FIGURE 11 OPENING TIME VS. PISTON AREA FOR FIVE FOOT GATE VALVES

FIGURE 12 OPENING TIME FOR SELF ACTUATING VALVES



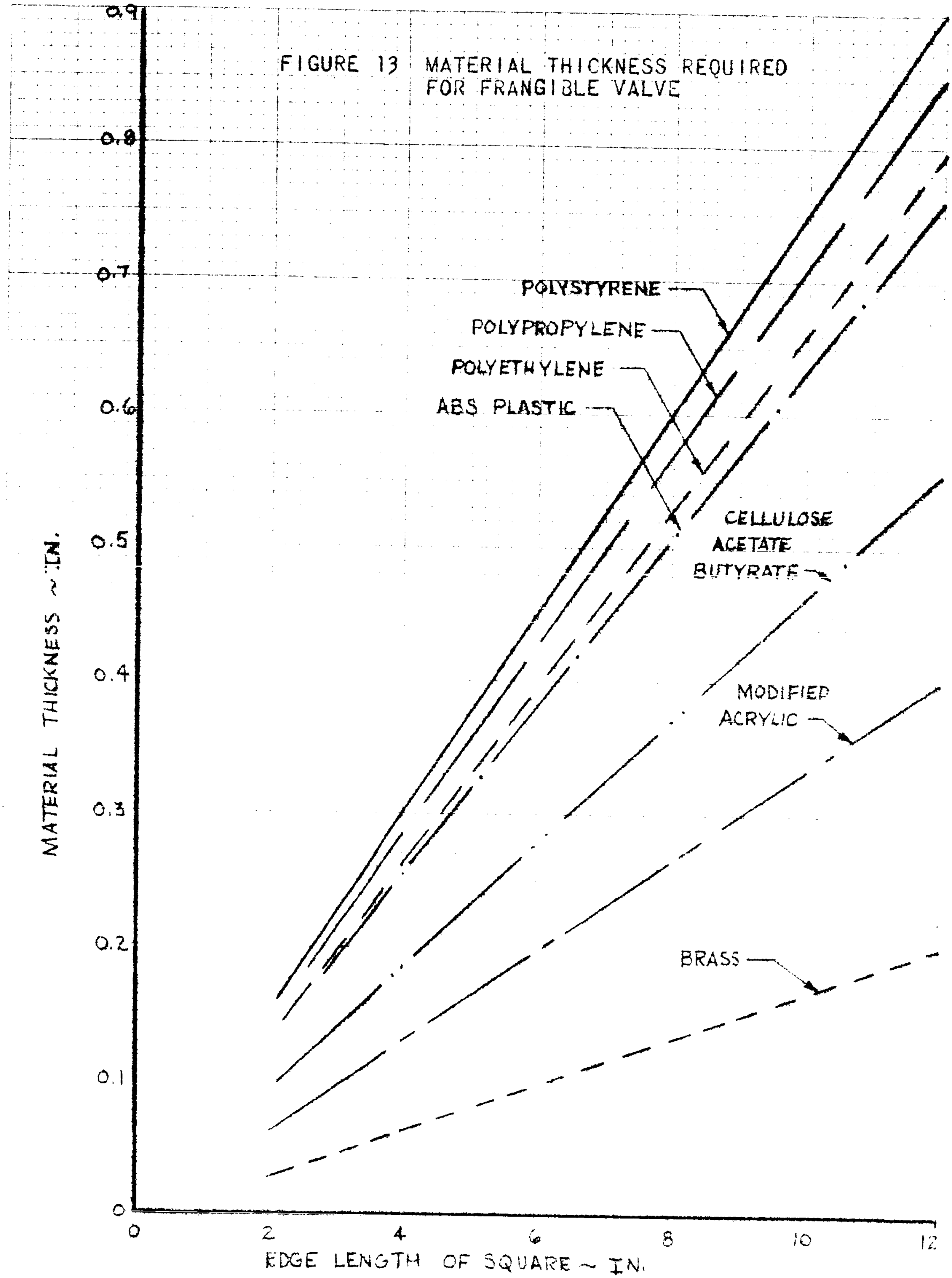


FIGURE 13 MATERIAL THICKNESS REQUIRED FOR FRANGIBLE VALVE
POLYSTYRENE
POLYPROPYLENE
POLYETHYLENE
ABS PLASTIC
CELLULOSE ACETATE BUTYRATE
MODIFIED ACRYLIC
BRASS
MATERIAL THICKNESS ~ IN.
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
EDGE LENGTH OF SQUARE ~ IN.
2
4
6
8
10
12

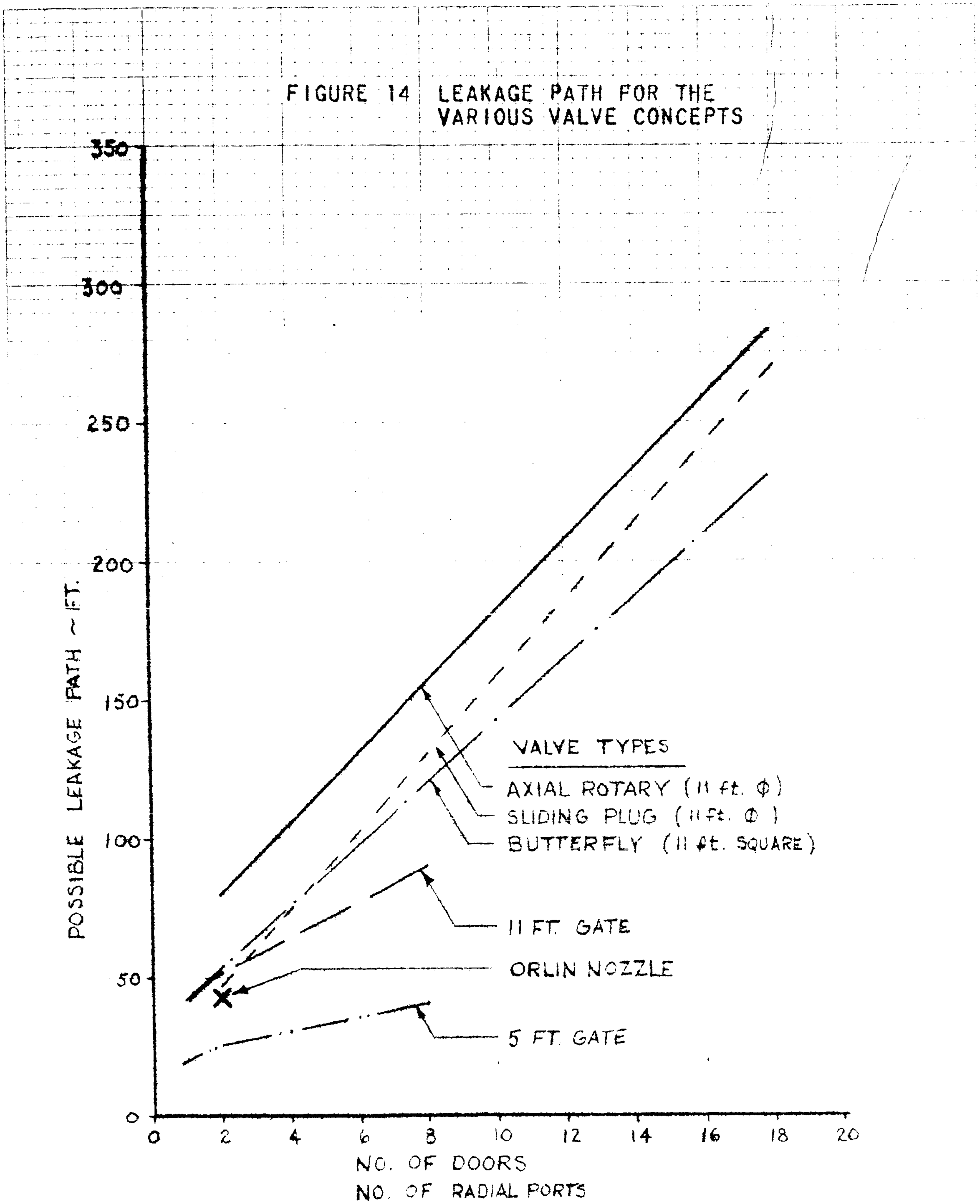
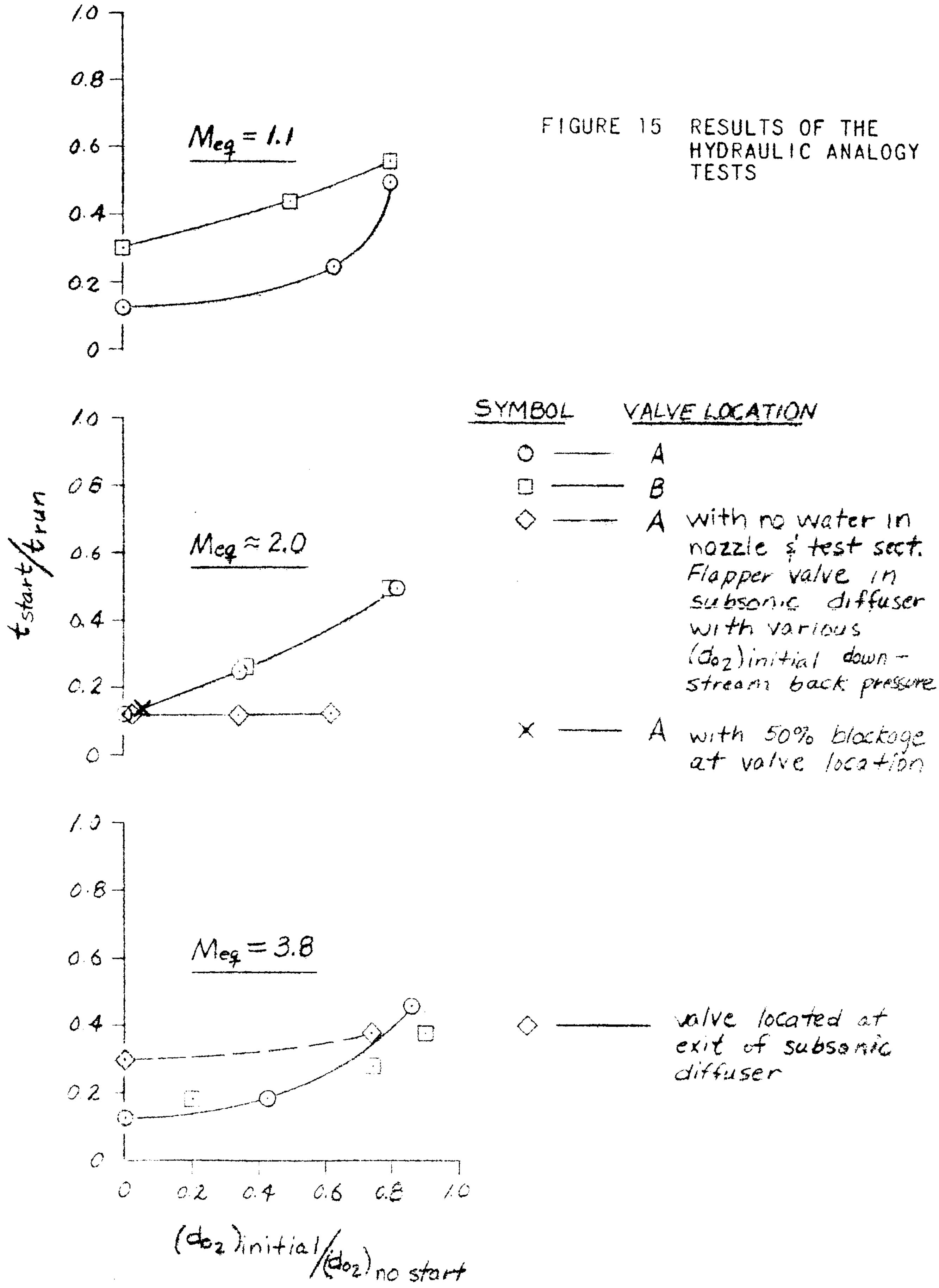


FIGURE 14 LEAKAGE PATH FOR THE VARIOUS VALVE CONCEPTS
350
300
250
200
150
100
50
0
POSSIBLE LEAKAGE PATH ~ FT.
0
2
4
6
8
10
12
14
16
18
20
NO. OF DOORS
NO. OF RADIAL PORTS
VALVE TYPES
AXIAL ROTARY (11 ft. Φ)
SLIDING PLUG (11 ft. Φ)
BUTTERFLY (11 ft. SQUARE)
11 FT. GATE
ORLIN NOZZLE
5 FT. GATE

FIGURE 15 RESULTS OF THE HYDRAULIC ANALOGY TESTS



APPENDIX A

Valve Rating Sheets and Valuation Summary Sheets

FluiDyne Engineering Corporation

NASA QUICK OPENING VALVE · SHEET NO 1 OF
[illegible] VALVE RATING · DATE · BY

[illegible]	GATE
[illegible]	2 DOOR
[illegible]	UPSTREAM
[illegible]	11′

	[illegible] VARIATION	[illegible]
[illegible]	1.0	VALVE IN NO WAY LIMITS OPERATION
[illegible]	.9	MINOR REFLECTED DISTURBANCES IN TUBE
[illegible]	1.0	VALVE MEETS OPENING TIME REQ'M'NT
[illegible]	1.0	VALVE DOES NOT INFLUENCE FLOW QUALITY
[illegible]	.9	
[illegible]	1.0	VALVE PERMITS [illegible] IN TEST SECT PUMP DN
[illegible]	1.0	NO APPRECIABLE HAZARD TO VALVE OR TEST ARTICLE
[illegible]	.7	# [illegible] VALVE PLUS NOZZLE
	2.0	CERTAINTY OF ACTUATION AND [illegible]
	[illegible]	[illegible]
	0	[illegible]
	[illegible]	
	[illegible]	VALVE [illegible] AGAINST [illegible]
	[illegible]	
	7.9	

FLUIDYNE ENGINEERING CORPORATION

FOR NASA QUICK OPENING VALVE CODE —

SHEET NO. 2 OF

DATE

BY

INDIVIDUAL VALVE RATING

)

VALVE TYPE GATE

VALVE SUBTYPE 2-DOOR WITH RESIDUAL BLOCKAGE

VALVE LOCATION UPSTREAM

VALVE SIZE 11'

QUANTITY	VALUATION	REASON FOR VALUATION
m_1	1.0	VALVE IN NO WAY LIMITS OPERATION
m_2	.9	MINOR EXPECTED DISTURBANCES IN TUBE
m_3	1.0	VALVE MEETS OPENING TIME REQ'MNT
m_4	1.0	VALVE DOES NOT INFLUENCE FLOW QUALITY
M_1	.9	
M_2	1.0	VALVE PERMITS FREE ON TEST SECT PUMPDN
M_3	1.0	NO APPRECIABLE HAZARD TO VALVE OR TEST ARTICLE
A_1	3.2	# 1,550,000 VALVE PLUS NOZZLE
A_2	3.0	CERTAINTY OF ACTUATION AND DAMAGE FREE STOPPING SOMEWT QUEST.
[illegible]	1.1	54 FT OF STL
[illegible]	0	SLIDING SEALS PREDOMINATE
[illegible]	1.1	
m_4	5.0	VALVE CAN BE CLOSED AGAINST PRESS
M_4	12.3	
[illegible]	11.1	

FLUIDYNE ENGINEERING CORPORATION

NASA QUICK OPENING VALVE CODE SHEET NO. 3 OF ____

DATE ____

VALVE RATING BY ____

VALVE TYPE PLUG

VALVE SUBTYPE 12-PORT

VALVE LOCATION UPSTREAM

VALVE SIZE 11'

QUANTITY	VALUATION	REASON FOR VALUATION
m_1	1.0	VALVE IN NO WAY LIMITS OPERATION
m_2	.75	SIGNIFICANT REFLECTIONS IN TUBE
m_3	1.0	VALVE MEETS OPENING TIME REQ'M'NT
m_4	1.0	VALVE DOES NOT INFLUENCE FLOW QUALITY
M_1	.75	
M_2	1.0	VALVE PERMITS PRERUN TEST SECT PUMPD'N
M_3	1.0	NO APPRECIABLE HAZARD TO VALVE OR TEST ARTICLE
A_1	0	\$2,060,000 VALVE PLUS NOZZLE & TIGHT SHUT OFF VALVE
A_2	4.0	GOOD POSSIBILITY OF POSITIVE ACTUATION AND STOPPING
a_1	.3	200 FT OF SEAL
a_2	0	SLIDING SEALS PREDOMINATE
A_3	.3	
A_4	0	VALVE CAN NOT BE CLOSED AGAINST PRESSURE
M_4	4.3	
N	3.2	

FLUIDYNE ENGINEERING CORPORATION

FOR NASA QUICK OPENING VALVE CODE ___ SHEET NO. 4 OF ___

DATE ___

INDIVIDUAL VALVE RATING BY ___

VALVE TYPE NORMAL ROTARY

VALVE SUBTYPE 2-DOOR

VALVE LOCATION UPSTREAM

VALVE SIZE 11'

QUANTITY	VALUATION	REASON FOR VALUATION
m_1	1.0	VALVE IN NO WAY LIMITS OPERATION
m_2	.75	SIGNIFICANT REFLECTIONS IN TUBE
m_3	1.0	VALVE MEETS OPENING TIME REQ'M'NT
m_4	1.0	VALVE DOES NOT INFLUENCE FLOW QUALITY
M_1	.75	
M_2	1.0	VALVE PERMITS PRERUN TEST SECT PUMPD'N
M_3	1.0	NO APPRECIABLE HAZARD TO VALVE OR TEST ARTICLE
A_1	5.0	\$ 1,250,000 VALVE PLUS NOZZLE
A_2	3.0	CERTAINTY OF ACTUATION AND DAMAGE FREE OPERATION SOMEW'T QUEST.
a_1	1.1	54 FT OF SEAL
a_2	1.0	SLIDING AND SIMPLE COMPRESSION SEALS EVENLY DIVIDED
A_3	2.1	
A_4	5.0	VALVE CAN BE CLOSED AGAINST PRESS.
M_4	15.1	
N	11.3	

FLUIDYNE ENGINEERING CORPORATION

JOB NASA QUICK OPENING VALVE CODE

SHEET NO 5 OF

DATE

INDIVIDUAL VALVE RATING

BY

VALVE TYPE NORMAL ROTARY

VALVE SUBTYPE MULTI-DOOR

VALVE LOCATION UPSTREAM

VALVE SIZE 11'

QUANTITY	VALUATION	REASON FOR VALUATION
m_1	1.0	VALVE IN NO WAY LIMITS OPERATION
m_2	.9	MINOR REFLECTED DISTURBANCES IN TUBE
m_3	1.0	VALVE MEETS OPENING TIME REQ'MNT
m_4	1.0	VALVE DOES NOT INFLUENCE FLOW QUALITY
M_1	.9	
M_2	1.0	VALVE PERMITS PRERUN TEST SECT PUMPD'N
M_3	1.0	NO APPRECIABLE HAZARD TO VALVE OR TEST ARTICLE
A_1	6.0	$ 1,090,000 VALVE PLUS NOZZLE AND TIGHT SHUTOFF VALVE
A_2	4.0	GOOD POSSIBILITY OF POSITIVE ACTUATION AND STOPPING
a_1	.3	180 FT OF SEAL
a_2	2.0	SIMPLE COMPRESSION SEALS PREDOM.
A_3	2.3	
A_4	5.0	VALVE CAN BE [illegible] AGAINST [illegible]
M_4	17.3	
N	15.6	

FLUIDYNE ENGINEERING CORPORATION

JOB NASA QUICK OPENING VALVE CODE ____ SHEET NO. 6 OF ____

DATE ____

INDIVIDUAL VALVE RATING BY ____

VALVE TYPE NORMAL ROTARY

VALVE SUBTYPE 2-DOOR COLLAPSIBLE

VALVE LOCATION UPSTREAM

VALVE SIZE 11'

QUANTITY	VALUATION	REASON FOR VALUATION
m_1	1.0	VALVE IN NO WAY LIMITS OPERATION
m_2	.75	[illegible]ICANT REFLECTIONS IN [illegible]
[illegible]	[illegible]	[illegible] MEETS OPENING TIME REQ'MNT
m_4	1.0	VALVE DOES NOT INFLUENCE FLOW QUALITY
M_1	.75	
M_2	1.0	VALVE PERMITS PRERUN TEST SECT. PUMPDN
M_3	1.0	NO APPRECIABLE HAZARD TO VALVE OR TEST ARTICLE
A_1	.7	$1,950,000 VALVE PLUS NOZZLE
A_2	1.0	LITTLE CERTAINTY OF DAMAGE FREE STOPPING
a_1	1.1	54 FT OF SEAL
a_2	1.0	SLIDING SEALS AND SIMPLE COMPRESSION SEALS EVENLY DISTR.
A_3	2.1	
A_4	0	VALVE CAN NOT BE CLOSED AGAINST PRESSURE
M	3.8	
N	2.9	

FLUIDYNE ENGINEERING CORPORATION

JOB NASA QUICK OPENING VALVE CODE

SHEET NO. 7 OF

DATE

INDIVIDUAL VALVE RATING

VALVE TYPE AXIAL ROTARY

VALVE SUBTYPE 18 - PORT

VALVE LOCATION UPSTREAM

VALVE SIZE 11'

QUANTITY	VALUATION	REASON FOR VALUATION
m_1	1.0	VALVE IN NO WAY LIMITS OPERATION
m_2	.75	SIGNIFICANT REFLECTIONS IN TUBE
m_3	1.0	VALVE MEETS OPENING TIME REQ'M'NT
m_4	1.0	VALVE DOES NOT INFLUENCE FLOW QUALITY
M_1	.75	
M_2	1.0	VALVE PERMITS PRERUN TEST SECT PUMPDN
M_3	1.0	NO APPRECIABLE HAZARD TO VALVE OR TEST ARTICLE
A_1	0	# 2,860,000 VALVE PLUS NOZZLE AND TIGHT SHUT OFF VALVE
A_2	2.0	CERTAINTY OF ACTUATION AND DAMAGE FREE STOPPING QUESTIONABLE
a_1	.2	280 FT OF SEAL
a_2	0	SLIDING SEALS PREDOMINATE
A_3	.2	
A_4	5.0	VALVE CAN BE CLOSED AGAINST PRESS
M_4	7.2	
N	5.4	

FLUIDYNE ENGINEERING CORPORATION

JOB NASA QUICK OPENING VALVE CODE ____ SHEET NO. 8 OF ____

DATE ____

INDIVIDUAL VALVE RATING BY ____

VALVE TYPE FRANGIBLE

VALVE SUBTYPE ____

VALVE LOCATION UPSTREAM

VALVE SIZE 11'

QUANTITY	VALUATION	REASON FOR VALUATION
m_1	1.0	VALVE IN NO WAY LIMITS OPERATION
m_2	.9	~~MINOR~~ REFLECTED DISTURBANCES
m_3	1.0	VALVE MEETS OPENING TIME REQM'NT
m_4	1.0	VALVE DOES NOT INFLUENCE FLOW QUALITY
M_1	.9	
M_2	1.0	VALVE PERMITS PRERUN TEST SECT PUMPDN
M_3	.75	VALVE PRESENTS HAZARD TO TEST ART.
A_1	1.9	$ 1,750,000 VALVE PLUS NOZZLE
A_2	1.0	LITTLE CERTAINTY OF POSITIVE ACTUATION
a_1	1.5	40 FT OF SEAL (EST)
a_2	2.0	SIMPLE COMPRESSION SEALS PREDOM.
A_3	3.5	
A_4	0	VALVE CAN NOT BE CLOSED AGAINST PRESS.
M_4	6.4	
N	4.3	

FLUIDYNE ENGINEERING CORPORATION

JOB NASA QUICK OPENING VALVE

SHEET NO 9 OF

DATE

BY

INDIVIDUAL VALVE RATING

VALVE TYPE: GATE

VALVE SUBTYPE: ORLIN NOZZLE

VALVE LOCATION: UPSTREAM

VALVE SIZE: 5'

QUANTITY	VALUATION	REASON FOR VALUATION
m_1	1.0	VALVE IN NO WAY LIMITS OPERATION
m_2	1.0	NO REFLECTED DISTURBANCES IN TUBE
[illegible]	[illegible]	[illegible]ING TIME ABOUT 0.1 SEC AVG
m_4	1.0	VALVE DOES NOT INFLUENCE FLOW QUALITY
M_1	0.5	
M_2	1.0	VALVE PERMITS PRE RUN TEST SECT PUMPDOWN
M_3	1.0	NO APPRECIABLE HAZARD TO VALVE OR TEST ARTICLE
A_1	3.5	# 1,500,000 "VALVE" ONLY
A_2	1.0	LITTLE CERTAINTY OF POSITIVE ACTUATION OR DAMAGE FREE STOPPING
a_1	1.4	42 FT OF SEAL
a_2	0	SLIDING SEALS PREDOMINATE
A_3	1.4	
A_4	0	VALVE CAN NOT BE CLOSED AGAINST PRESS
[illegible]	[illegible]	
N	2.9	

FLUIDYNE ENGINEERING CORPORATION

JOB NASA QUICK OPENING VALVE CODE ____ SHEET NO 10 OF ____

DATE ____

INDIVIDUAL [illegible]

VALVE TYPE GATE

VALVE SUBTYPE 2-DOOR

VALVE LOCATION UPSTREAM

VALVE SIZE 5'

QUANTITY	VALUATION	REASON FOR VALUATION
m_1	1.0	VALVE IN NO WAY LIMITS OPERATION
m_2	1.0	NO REFLECTED DISTURBANCES IN TUBE
m_3	1.0	VALVE MEETS OPENING TIME REQM'N'T
m_4	1.0	VALVE DOES NOT INFLUENCE FLOW QUALITY
M_1	1.0	
M_2	1.0	VALVE PERMITS PRERUN TEST SECT PUMPD'N
M_3	1.0	NO APPRECIABLE HAZARD TO VALVE OR TEST ARTICLE
A_1	6.0	$ 1,100,000 VALVE PLUS NOZZLE
A_2	3.0	CERTAINTY OF ACTUATION AND DAMAGE FREE STOPPING SOMEWT QUEST
a_1	2.4	25 FT OF SEAL
a_2	0	SLIDING SEALS PREDOMINATE
A_3	2.4	
A_4	5.0	VALVE CAN BE CLOSED AGAINST PRESS.
M_4	16.4	
N	16.4	

FLUIDYNE ENGINEERING CORPORATION

JOB NASA QUICK OPENING VALVE — SHEET NO 11 OF ____

DATE ____

INDIVIDUAL VALVE RATING

VALVE TYPE: GATE

VALVE SUBTYPE: 2-DOOR WITH RESIDUAL BLOCKAGE

VALVE LOCATION: UPSTREAM

VALVE SIZE: 5'

QUANTITY	VALUATION	REASON FOR VALUATION
m_1	.5	VALVE RESIDUAL BLOCKAGE LIMITS TRANSONIC OPERATION
m_2	1.0	NO REFLECTED DISTURBANCES IN TUBE
m_3	1.0	VALVE DOES NOT INFLUENCE FLOW QUALITY
m_4	.75	REQUIRES APPLICATION OF MULTI-NOZZLE WITH ±2% M VARIATION
M_1	.375	
M_2	1.0	VALVE PERMITS PRERUN TEST SECT PUMPDN
M_3	1.0	NO APPRECIABLE HAZARD TO VALVE OR TEST ARTICLE
A_1	9.4	$ 550,000 "VALVE" PLUS TEST SECT BOX
A_2	3.0	CERTAINTY OF ACTUATION AND DAMAGE FREE STOPPING SOMEWT QUEST
a_1	3.4	25 FT OF SEAL
a_2	0	SLIDING SEALS PREDOMINATE
A_3	3.4	
A_4	5.0	VALVE CAN BE CLOSED AGAINST PRESS
M_4		
N		

FLUIDYNE ENGINEERING CORPORATION

FOR NASA QUICK OPENING VALVE CODE

SHEET NO 12 OF ____

DATE ____

BY ____

INDIVIDUAL VALVE RATING

VALVE TYPE PLUG

VALVE SUBTYPE 12-PORT

VALVE LOCATION UPSTREAM

VALVE SIZE 5'

QUANTITY	VALUATION	REASON FOR VALUATION
m_1	0	VALVE RESIDUAL BLOCKAGE SEVERELY LIMITS MACH NO RANGE
m_2		
[illegible]		
m_4		
M_1	0	
M_2		
M_3		
A_1		
A_2		
a_1		
a_2		
A_3		
A_4		
M_4		
N	0	

FLUIDYNE ENGINEERING CORPORATION

JOB NASA QUICK OPENING VALVE CODE SHEET NO 13 OF

DATE

INDIVIDUAL VALVE RATING

VALVE TYPE NORMAL ROTARY

VALVE SUBTYPE 2-DOOR

VALVE LOCATION UPSTREAM

VALVE SIZE 5'

QUANTITY	VALUATION	REASON FOR VALUATION
$\dot{m}_1$	0	VALVE RESIDUAL BLOCKAGE SEVERELY LIMITS MACH NO RANGE
$\dot{m}_2$		
$\dot{m}_3$		
m_4		
M_1	0	
M_2		
M_3		
A_1		
A_2		
a_1		
a_2		
A_3		
A_4		
M_4		
N	0	

FLUIDYNE ENGINEERING CORPORATION

JOB NASA QUICK OPENING VALVE CODE SHEET NO 14 OF

DATE

INDIVIDUAL VALVE RATING

VALVE TYPE NORMAL ROTARY

VALVE SUBTYPE MULTI-DOOR

VALVE LOCATION UPSTREAM

VALVE SIZE 5'

QUANTITY	VALUATION	REASON FOR VALUATION
m_1	0	VALVE RESIDUAL BLOCKAGE SEVERELY LIMITS MACH NUMBER RANGE
m_2		
m_3		
m_4		
M_1	0	
M_2		
M_3		
A_1		
A_2		
a_1		
a_2		
A_3		
A_4		
[illegible]		
N	0	

FLUIDYNE ENGINEERING CORPORATION

JOB NASA QUICK OPENING VALVE

SHEET NO 15 OF ____

DATE ____

INDIVIDUAL VALVE RATING

BY ____

VALVE TYPE NORMAL ROTARY

VALVE SUBTYPE 2-DOOR COLLAPSIBLE

VALVE LOCATION UPSTREAM

VALVE SIZE 5'

QUANTITY	VALUATION	REASON FOR VALUATION
m_1	1.0	VALVE IN NO WAY LIMITS OPERATION
m_2	1.0	NO REFLECTED DISTURBANCES IN TUBE
m_3	1.0	VALVE MEETS OPENING TIME REQMNT
m_4	1.0	VALVE DOES NOT INFLUENCE FLOW QUALITY
M_1	1.0	
M_2	1.0	VALVE PERMITS PRERUN TEST SECT PUMPD'N
M_3	1.0	NO APPRECIABLE HAZARD TO VALVE OR TEST ARTICLE
A_1	6.0	# 1,100,000 VALVE PLUS NOZZLE
A_2	1.0	LITTLE CERTAINTY OF DAMAGE FREE STOPPING
a_1	2.4	25 FT OF SEAL
a_2	1.0	SLIDING SEALS AND SIMPLE COMPRESSION SEALS EVENLY DISTR.
A_3	3.4	
A_4	0	VALVE CAN NOT BE CLOSED AGAINST PRESS
M_4	10.4	
N	10.4	

FluiDyne Engineering Corporation

JOB NASA QUICK OPENING VALVE CODE SHEET NO 16 OF

DATE

INDIVIDUAL VALVE RATING BY

VALVE TYPE AXIAL ROTARY

VALVE SUBTYPE 18 - PORT

VALVE LOCATION UPSTREAM

VALVE SIZE 5'

QUANTITY	VALUATION	REASON FOR VALUATION
m_1	0	VALVE RESIDUAL BLOCKAGE SEVERELY LIMITS MACH NUMBER RANGE
m_2		
m_3		
m_4		
M_1	0	
M_2		
M_3		
A_1		
A_2		
a_1		
a_2		
A_3		
A_4		
M_4		
N	0	

FLUIDYNE ENGINEERING CORPORATION

JOB NASA QUICK OPENING VALVE CODE

SHEET NO 17 OF

DATE

INDIVIDUAL VALVE RATING

BY

)

VALVE TYPE FRANGIBLE

VALVE SUBTYPE •

VALVE LOCATION UPSTREAM

VALVE SIZE 5'

QUANTITY	VALUATION	REASON FOR VALUATION
m_1	.5	VALVE RESIDUAL BLOCKAGE LIMITS TRANSONIC OPERATION
m_2	1.0	NO REFLECTED DISTURBANCES IN TUBE
m_3	1.0	VALVE MEETS OPENING TIME REQ'M'NT
m_4	.75	REQUIRES APPLICATION OF MULTI-NOZZLE WITH ±2% M VARIATION
M_1	.375	
M_2	1.0	VALVE PERMITS PRERUN TEST SECT PUMPD'N
M_3	.75	VALVE PRESENTS HAZARD TO TEST ART.
A_1	10.0	$ 450,000 "VALVE" PLUS TEST SECT BOX
A_2	1.0	LITTLE CERTAINTY OF POSITIVE ACTUATION
a_1	3.0	20 FT OF SEAL (EST)
a_2	2.0	SIMPLE COMPRESSION SEALS PREDOM
A_3	5.0	
A_4	0	VALVE CAN NOT BE CLOSED AGAINST PRESS.
M_4	[illegible]	
N	4.5	

FLUIDYNE ENGINEERING CORPORATION

JOB NASA QUICK OPENING VALVE CODE ____ SHEET NO 18 OF ____

DATE ____

INDIVIDUAL VALVE RATING

VALVE TYPE GATE

VALVE SUBTYPE 2-DOOR

VALVE LOCATION DOWNSTREAM

VALVE SIZE 5'

QUANTITY	VALUATION	REASON FOR VALUATION
m_1	.5	TEST SECTION MUST BE AT FULL STAGN. PRESS PRIOR TO RUN (POSSIBLY LIMITS P_0)
m_2	1.0	NO REFLECTED DISTURBANCES IN TUBE
[illegible]	[illegible]	VALVE MEETS OPENING TIME REQ'M'NT
m_4	1.0	VALVE DOES NOT INFLUENCE FLOW QUALITY
M_1	.5	
M_2	.8	VALVE DOES NOT PERMIT PRERUN TEST SECTION PUMPDOWN
M_3	1.0	NO APPRECIABLE HAZARD TO VALVE OR TEST ARTICLE
A_1	6.3	$ 1,050,000 VALVE PLUS NOZZLE
A_2	3.0	CERTAINTY OF ACTUATION AND DAMAGE FREE STOPPING SOMEW'T QUEST
a_1	2.4	25 FT OF SEAL
a_2	.0	SLIDING SEALS PREDOMINATE
A_3	2.4	
A_4	0	VALVE CAN NOT BE CLOSED AGAINST PRESS
M	11.7	
N	4.7	

FLUIDYNE ENGINEERING CORPORATION

FOR NASA QUICK OPENING VALVE CODE

SHEET NO. 19 OF ___

DATE ___

INDIVIDUAL VALVE RATING

VALVE TYPE: GATE

VALVE SUBTYPE: 2-DOOR WITH RESIDUAL BLOCKAGE

VALVE LOCATION: DOWNSTREAM

VALVE SIZE: 5'

QUANTITY	VALUATION	REASON FOR VALUATION
m_1	.5	VALVE RESIDUAL BLOCKAGE LIMITS MACH NUMBER RANGE, ETC
m_2	1.0	NO REFLECTED DISTURBANCES IN TUBE
m_3	1.0	VALVE MEETS OPENING TIME REQ'M'NT
m_4	1.0	VALVE DOES NOT INFLUENCE FLOW QUALITY
M_1	.5	
M_2	.8	VALVE DOES NOT PERMIT PRERUN TEST SECTION PUMPDOWN
M_3	.75	TEST ARTICLE PRESENTS HAZARD TO VALVE
A_1	6.3	$1,050,000 VALVE PLUS NOZZLE
A_2	3.0	CERTAINTY OF ACTUATION AND DAMAGE FREE STOPPING SOMEWHAT QUESTIONABLE
a_1	2.4	35 FT OF SEAL
a_2	0	SLIDING SEALS PREDOMINATE
A_3	2.4	
A_4	0	VALVE CAN NOT BE CLOSED AGAINST PRESS
M_4	11.7	
N	3.5	

INDIVIDUAL VALVE RATING

VALVE TYPE PLUG

VALVE SUBTYPE 12-PORT

VALVE LOCATION DOWNSTREAM

VALVE SIZE 5'

QUANTITY	VALUATION	REASON FOR VALUATION
m_1	0	VALVE RESIDUAL BLOCKAGE SEVERELY LIMITS MACH NO RANGE
m_2		
m_3		
m_4		
M_1	0	
M_2		
M_3		
A_1		
A_2		
a_1		
a_2		
A_3		
A_4		
M_4		
N	0	

FLUIDYNE ENGINEERING CORPORATION

JOB NASA QUICK OPENING VALVE FILE SHEET NO 21 OF ____

DATE ____

INDIVIDUAL VALVE RATING BY ____

VALVE TYPE NORMAL ROTARY

VALVE SUBTYPE 2 - DOOR

VALVE LOCATION DOWNSTREAM

VALVE SIZE 5'

QUANTITY	VALUATION	REASON FOR VALUATION
m_1	0	VALVE RESIDUAL BLOCKAGE SEVERELY LIMITS MACH NO RANGE
m_2		
m_3		
m_4		
M_1	0	
M_2		
M_3		
A_1		
A_2		
α_1		
α_2		
A_3		
A_4		
M_4		
N	0.	

FLUIDYNE ENGINEERING CORPORATION

JOB NASA QUICK OPENING VALVE CODE SHEET NO 22 OF

DATE

INDIVIDUAL VALVE RATING

VALVE TYPE NORMAL ROTARY

VALVE SUBTYPE MULTI-DOOR

VALVE LOCATION DOWNSTREAM

VALVE SIZE 5'

QUANTITY	VALUATION	REASON FOR VALUATION
m_1	0	VALVE RESIDUAL BLOCKAGE SEVERELY LIMITS MACH NO RANGE
m_2		
m_3		
m_4		
M_1	0	
M_2		
M_3		
A_1		
A_2		
a_1		
a_2		
A_3		
A_4		
M_4		
N	0	

FLUIDYNE ENGINEERING CORPORATION

FOR NASA QUICK OPENING VALVE

INDIVIDUAL VALVE RATING

VALVE TYPE — NORMAL ROTARY

VALVE SUBTYPE — 2-DOOR COLLAPSIBLE

VALVE LOCATION — DOWNSTREAM

VALVE SIZE — 5'

QUANTITY	VALUATION	REASON FOR VALUATION
m_1	.5	TEST SECTION MUST BE AT FULL STAGN PRESS PRIOR TO RUN (POSSIBLY LIMITS P_0)
m_2	1.0	NO REFLECTED DISTURBANCES IN TUBE
[illegible]	1.0	VALVE MEETS OPENING TIME REQ'M'NT
m_4	1.0	VALVE DOES NOT INFLUENCE FLOW QUALITY
M_1	.5	
M_2	.8	VALVE DOES NOT PERMIT PRERUN TEST SECTION PUMPDN
M_3	1.0	NO APPRECIABLE HAZARD TO VALVE OR TEST ARTICLE
A_1	6.0	$ 1,100,000 VALVE PLUS NOZZLE
A_2	1.0	LITTLE CERTAINTY OF DAMAGE FREE STOPPING
a_1	3.4	25 FT OF SEAL
a_2	1.0	SLIDING SEALS AND SIMPLE COMPRESSION SEALS EVENLY DISTRIBUTED
A_3	3.4	
A_4	0	VALVE CAN NOT BE CLOSED AGAINST PRESS
M_4	10.[illegible]	
N	4.2	

SHEET 1

FLUIDYNE ENGINEERING CORPORATION

JOB NASA QUICK OPENING VALVE

INDIVIDUAL VALVE RATING

SHEET NO 24 OF

DATE

BY

VALVE TYPE AXIAL ROTARY

VALVE SUBTYPE 18-PORT

VALVE LOCATION DOWNSTREAM

VALVE SIZE 5'

QUANTITY	VALUATION	REASON FOR VALUATION
m_1	0	VALVE RESIDUAL BLOCKAGE SEVERELY LIMITS MACH NO RANGE
m_2		
m_3		
m_4		
[illegible]	0	
M_2		
M_3		
A_1		
A_2		
[illegible]		
[illegible]		
A_3		
A_4		
[illegible]		
N	0	

FLUIDYNE ENGINEERING CORPORATION

JOB NASA QUICK OPENING VALVE CODE

SHEET NO 25 OF

DATE

BY

INDIVIDUAL VALVE RATING

VALVE TYPE FRANGIBLE

VALVE SUBTYPE

VALVE LOCATION DOWNSTREAM

VALVE SIZE 5'

QUANTITY	VALUATION	REASON FOR VALUATION
m_1	.5	VALVE RESIDUAL BLOCKAGE LIMITS TRANSONIC OPERATION, ETC
m_2	1.0	NO REFLECTED DISTURBANCES IN TUBE
m_3	1.0	VALVE MEETS OPENING TIME REQ'M'NT
m_4	1.0	VALVE DOES INFLUENCE FLOW QUALITY
M_1	.5	
M_2	.8	VALVE DOES NOT PERMIT PRE-RUN TEST SECTION PUMPDOWN
M_3	.75	TEST ARTICLE PRESENTS HAZARD TO VALVE
A_1	66	$1,000,000 VALVE PLUS NOZZLE
A_2	1.0	LITTLE CERTAINTY OF POSITIVE ACTUATION
L_1	3.0	20 FT OF SEAL (EST)
L_2	2.0	SIMPLE COMPRESSION SEAL PROBLEM
A_3	5.0	
A_4	0	VALVE CAN NOT BE CLOSED AGAINST PR
M_4	12.6	
N	3.8	

FluiDyne Engineering Corporation

JOB NASA QUICK OPENING VALVE CODE ____ SHEET NO. 26 OF ____

INDIVIDUAL VALVE RATING DATE ____

BY ____

VALVE TYPE GATE

VALVE SUBTYPE 2-DOOR

VALVE LOCATION DOWNSTREAM

VALVE SIZE 11'

QUANTITY	VALUATION	REASON FOR VALUATION
m_1	.5	TEST SECTION MUST BE AT FULL STAGN PRESS PRIOR TO RUN, ETC
m_2	1.0	NO REFLECTED DISTURBANCES IN TUBE
m_3	.75	VALVE POSITION MAY LENGTHEN FLOW DEVELOPMENT TIME
m_4	1.0	VALVE DOES NOT INFLUENCE FLOW QUALITY
M_1	.375	
M_2	.8	VALVE DOES NOT PERMIT PRERUN TEST SECTION PUMPDOWN
M_3	1.0	NO APPRECIABLE HAZARD TO VALVE OR TEST ARTICLE
A_1	1.9	$ 1,750,000 VALVE PLUS NOZZLE
A_2	2.0	CERTAINTY OF ACTUATION AND DAMAGE FREE STOPPING QUESTIONABLE
a_1	1.1	54' OF SEAL
a_2	0	SLIDING [illegible] PREDOMINATE
A_3	-1.1	
A_4	0	VALVE CAN NOT BE CLOSED AGAINST PRESS.
M_4	5.0	
N	1.5	

FLUIDYNE ENGINEERING CORPORATION

JOB NASA QUICK OPENING VALVE CODE ____ SHEET NO. 87 OF ____

INDIVIDUAL VALVE RATING DATE ____

BY ____

VALVE TYPE: GATE

VALVE SUBTYPE: 2-DOOR WITH RESIDUAL BLOCKAGE

VALVE LOCATION: DOWNSTREAM

VALVE SIZE: 11'

QUANTITY	VALUATION	REASON FOR VALUATION
m_1	.5	TEST SECTION MUST BE AT FULL STAGN PRESS PRIOR TO RUN (MAY LIMIT P_0).
m_2	1.0	NO REFLECTED DISTURBANCES IN TUBE
m_3	.75	VALVE POSITION MAY LENGTHEN FLOW DEVELOPMENT TIME
m_4	1.0	VALVE DOES NOT INFLUENCE FLOW QUALITY
M_1	.375	
M_2	.8	VALVE DOES NOT PERMIT PRERUN TEST SECTION PUMPDOWN
M_3	.75	TEST ARTICLE PRESENTS HAZARD TO VALVE
A_1	4.1	$1,400,000 VALVE PLUS NOZZLE
A_2	3.0	CERTAINTY OF ACTUATION AND DAMAGE FREE [illegible] SOMEWHAT QUESTIONABLE
[illegible]	1.1	54' OF SEAL
[illegible]	0	SLIDING SEALS PREDOMINATE
[illegible]	1.1	
A_4	0	[illegible] CAN NOT BE CLOSED AGAINST PRESS.
M_4	8.2	
N	1.8	

FLUIDYNE ENGINEERING CORPORATION

JOB NASA QUICK OPENING VALVE CODE

SHEET NO. 28 OF

DATE

BY

INDIVIDUAL VALVE RATING

VALVE TYPE PLUG

VALVE SUBTYPE 12 - PORT

VALVE LOCATION DOWNSTREAM

VALVE SIZE 11'

QUANTITY	VALUATION	REASON FOR VALUATION
m_1	.50	TEST SECTION MUST BE AT FULL STAGN PRESS PRIOR TO RUN (MAY LIMIT P_0)
m_2	1.0	NO REFLECTED DISTURBANCES IN TUBE
m_3	.75	VALVE POSITION MAY LENGTHEN FLOW DEVELOPMENT TIME
m_4	1.0	VALVE DOES NOT INFLUENCE FLOW QUALITY
M_1	.375	
M_2	.8	VALVE DOES NOT PERMIT PRERUN TEST SECTION PUMPDOWN
M_3	.75	TEST ARTICLE PRESENTS HAZARD TO VALVE
A_1	0	# 2,960,000 VALVE PLUS NOZZLE & AND TIGHT SHUTOFF VALVE
A_2	4.0	GOOD POSSIBILITY OF POSITIVE ACTUATION AND STOPPING
μ_1	.3	200 FT OF SEAL
μ_2	0	SLIDING SEALS ARE [illegible]
A_3	.3	
A_4	0	VALVE CAN NOT BE CLOSED AGAINST PRESS.
M_4	4.3	
N	.95	

FLUIDYNE ENGINEERING CORPORATION

JOB NASA QUICK OPENING VALVE CODE ______ SHEET NO 29 OF ____

DATE ________

INDIVIDUAL VALVE RATING BY ________

VALVE TYPE NORMAL ROTARY

VALVE SUBTYPE 2-DOOR

VALVE LOCATION DOWNSTREAM

VALVE SIZE 11'

QUANTITY	VALUATION	REASON FOR VALUATION
m_1	.5	TEST SECTION MUST BE AT FULL STAGN PRESS. PRIOR TO RUN (MAY LIMIT P_0)
m_2	1.0	NO REFLECTED DISTURBANCES IN TUBE
m_3	.75	VALVE POSITION MAY LENGTHEN FLOW DEVELOPMENT TIME
m_4	1.0	VALVE DOES NOT INFLUENCE FLOW QUALITY
M_1	.375	
M_2	.8	VALVE DOES NOT PERMIT PRERUN TEST SECTION PUMPDOWN
M_3	.75	TEST ARTICLE PRESENTS HAZARD TO VALVE
A_1	5.3	$1,200,000 VALVE PLUS NOZZLE
A_2	3.0	CERTAINTY OF ACTUATION AND DAMAGE FREE OPERATION SOMEW'T QUESTIONABLE
α_1	1.1	54 FT OF SEAL
α_2	1.0	SLIDING AND SIMPLE COMPRESSION SEALS EVENLY DISTRIBUTED
A_3	2.1	
A_4	0	VALVE CAN NOT BE CLOSED AGAINST PRESS.
M_4	10.4	
N	2.3	

FLUIDYNE ENGINEERING CORPORATION

JOB NASA QUICK OPENING VALVE CODE

SHEET NO. 30 OF

DATE

BY

INDIVIDUAL VALVE RATING

VALVE TYPE NORMAL ROTARY

VALVE SUBTYPE MULTI-DOOR

VALVE LOCATION DOWNSTREAM

VALVE SIZE 11'

QUANTITY	VALUATION	REASON FOR VALUATION
m_1	.5	TEST SECTION MUST BE AT FULL STAGN PRESS. PRIOR TO RUN (MAY LIMIT P_0)
m_2	1.0	NO REFLECTED DISTURBANCES IN TUBE
m_3	.75	VALVE POSITION MAY LENGTHEN FLOW DEVELOPMENT TIME
m_4	1.0	VALVE DOES NOT INFLUENCE FLOW QUALITY
M_1	.375	
M_2	.8	VALVE DOES NOT PERMIT PRERUN TEST SECTION PUMPDOWN
M_3	.75	TEST ARTICLE PRESENTS HAZARD TO VALVE
A_1	6.0	$ 1,090,000 VALVE PLUS NOZZLE + TIGHT SHUTOFF VALVE
A_2	4.0	GOOD POSSIBILITY OF POSITIVE ACTUATION AND DAMAGE FREE STOPPING
a_1	.3	180 FT OF SEAL
a_2	2.0	SIMPLE COMPRESSION SEALS PREDOMINATE
A_3	2.3	
A_4	0	VALVE CAN NOT BE CLOSED AGAINST PRESS
M_4	12.3	
N	2.8	

FLUIDYNE ENGINEERING CORPORATION

JOB NASA QUICK OPENING VALVE CODE

SHEET NO. 31 OF

DATE

BY

INDIVIDUAL VALVE RATING

)

VALVE TYPE NORMAL ROTARY

VALVE SUBTYPE 2-DOOR COLLAPSIBLE

VALVE LOCATION DOWNSTREAM

VALVE SIZE 11'

QUANTITY	VALUATION	REASON FOR VALUATION
m_1	.5	TEST SECTION MUST BE AT FULL STAGN PRESS PRIOR TO RUN (MAY LIMIT P_0)
m_2	1.0	NO REFLECTED DISTURBANCES IN TUBE
m_3	.75	VALVE POSITION MAY LENGTHEN FLOW DEVELOPMENT TIME
m_4	1.0	VALVE DOES NOT INFLUENCE FLOW QUALITY
M_1	.375	
M_2	.8	VALVE DOES NOT PERMIT PRERUN TEST SECTION PUMPDOWN
M_3	1.0	NO APPRECIABLE HAZARD TO VALVE OR TEST ARTICLE
A_1	.7	$1,950,000 VALVE PLUS NOZZLE
A_2	1.0	LITTLE POSSIBILITY OF DAMAGE FROM STOPPING
a_1	1.1	54 FT OF SEAL
a_2	1.0	SLIDING AND SIMPLE COMPRESSION OR STATIC SEALS EVENLY DISTRIBUTED
A_3	2.1	
A_4	0	VALVE CAN NOT BE CLOSED AGAINST RR.
M_4	3.8	
N	1.1	

FLUIDYNE ENGINEERING CORPORATION

JOB NASA QUICK OPENING VALVE CODE

SHEET NO. 32 OF

DATE

BY

INDIVIDUAL VALVE RATING

VALVE TYPE AXIAL ROTARY

VALVE SUBTYPE 18 - PORT

VALVE LOCATION DOWNSTREAM

VALVE SIZE 11'

QUANTITY	VALUATION	REASON FOR VALUATION
m_1	.5	TEST SECTION MUST BE AT FULL STAGN PRESS PRIOR TO RUN (MAY LIMIT P_0)
m_2	1.0	NO REFLECTED DISTURBANCES IN TUBE
m_3	.75	VALVE POSITION MAY LENGTHEN FLOW DEVELOPMENT TIME
m_4	1.0	VALVE DOES NOT INFLUENCE FLOW QUALITY
M_1	.375	
M_2	.8	VALVE DOES NOT PERMIT PRERUN TEST SECTION PUMPDOWN
M_3	.75	TEST ARTICLE PRESENTS HAZARD TO VALVE
A_1	.6	$ 1,960,000 VALVE PLUS NOZZLE AND TIGHT SHUTOFF VALVE
A_2	2.0	CERTAINTY OF ACTUATION AND DAMAGE FREE STOPPING QUESTIONABLE
α_1	.2	280 FT OF SEAL
α_2	0	SLIDING SEALS ARE DOMINANT
A_3	.2	
A_4	0	VALVE CAN NOT BE RESTORED AGAINST PR.
M_4	2.8	
N	6	

FluiDyne Engineering Corporation

NASA QUICK OPENING VALVE CODE SHEET NO 33 OF

INDIVIDUAL VALVE RATING DATE

BY

VALVE TYPE FRANGIBLE

VALVE SUBTYPE ______

VALVE LOCATION DOWNSTREAM

VALVE SIZE 11'

QUANTITY	VALUATION	REASON FOR VALUATION
m_1	.5	TEST SECTION MUST BE AT FULL STAGN PRESS PRIOR TO RUN (MAY LIMIT P_0)
m_2	1.0	NO REFLECTED DISTURBANCES IN TUBE
m_3	.75	VALVE POSITION MAY LENGTHEN FLOW DEVELOPMENT TIME
m_4	1.0	VALVE DOES NOT INFLUENCE FLOW QUALITY
M_1	.375	
M_2	.8	VALVE DOES NOT PERMIT PRERUN TEST SECTION PUMPDOWN
M_3	.75	TEST ARTICLE PRESENTS HAZARD TO VALVE
[illegible]	1.9	$1,750,000 VALVE PLUS NOZZLE
A_2	1.0	LITTLE CERTAINTY OF POSITIVE ACTUATION
[illegible]	1.5	40 FT OF SEAL (EST)
[illegible]	2.0	SIMPLE COMPRESSION SEALS PREDOMINATE
[illegible]	3.5	
A_4	0	VALVE CANNOT BE CLOSED AGAINST PRESS
M_4		
[illegible]		

FluiDyne Engineering Corporation

JOB NASA QUICK OPENING VALVE CODE

SHEET NO. 1 OF ____

DATE ____

BY ____

VALUATION AND RATING SUMMARY

VALVE LOCATION UPSTREAM VALVE SIZE 11'

VALVE TYPE	SUB TYPE	m_1	m_2	m_3	m_4	M_1	M_2	M_3	A_1	A_2	A_3	A_4	M_4	N	RANK
GATE	OPEN NOZZLE	0				0								0	
	[illegible]	1.0	.9	1.0	1.0	.9	1.0	1.0	.7	2.0	1.1	5.0	8.8	7.9	6
	[illegible]	1.0	.9	1.0	1.0	.9	1.0	1.0	3.2	3.0	1.1	5.0	12.3	11.1	4
[illegible]	[illegible]	1.0	.75	1.0	1.0	.75	1.0	1.0	0	4.0	.3	0	4.3	3.2	14
[illegible]	[illegible]	1.0	.75	1.0	1.0	.75	1.0	1.0	5.0	3.0	2.1	5.0	15.1	11.3	3
[illegible]	[illegible]	1.0	.9	1.0	1.0	.9	1.0	1.0	6.0	4.0	2.3	5.0	17.3	15.6	2
[illegible]	[illegible]	1.0	.75	1.0	1.0	.75	1.0	1.0	.7	1.0	2.1	0	3.3	2.9	15
[illegible]	[illegible]	1.0	.75	1.0	1.0	.75	1.0	1.0	0	2.0	.2	5.0	7.2	5.4	7
[illegible]		1.0	.9	1.0	1.0	.9	1.0	.75	1.9	1.0	3.5	0	6.4	4.3	10

FLUIDYNE ENGINEERING CORPORATION

SHEET 2

JOB NASA QUICK OPENING VALVE CODE

SHEET NO. 2 OF

DATE

VALUATION AND RATING SUMMARY

BY

VALVE LOCATION UPSTREAM VALVE SIZE 5'

VALVE TYPE	[illegible] TYPE	m	n	[illegible]	n_4	M_1	M_2	M_3	A_1	A_2	A_3	A_4	M_4	N	RANK
GATE	OPEN NOZZLE	1.0	1.0	0.5	1.0	0.5	1.0	1.0	3.5	1.0	1.4	0	5.9	2.9	16
"	[illegible]	1.5	1.0	1.0	1.0	1.0	1.0	1.0	6.0	3.0	2.4	5.0	16.4	16.4	1
"	SLOPED WITH [illegible]	.5	1.0	1.0	.75	.375	1.0	1.0	9.4	3.0	2.4	5.0	19.4	7.3	7
[illegible]	[illegible]	0				0								0	
[illegible]	[illegible]	0				0								0	
"	[illegible]	0				0								0	
"	[illegible]	1.0	1.0	1.0	1.0	1.0	1.0	1.0	6.0	1.0	3.4	0	10.4	10.4	5
AXIAL [illegible]	[illegible]	0				0								0	
[illegible]		.5	1.0	1.0	.75	.375	1.0	.75	10.0	1.0	5.0	0	16.0	4.5	9

FLUIDYNE ENGINEERING CORPORATION

JOB NASA QUICK OPENING VALVE CODE

SHEET NO 3 OF

DATE

BY

[illegible] VALUATION AND RATING SUMMARY

VALVE LOCATION DOWNSTREAM VALVE SIZE 5'

VALVE TYPE	[illegible] TYPE	m_1	m_2	m_3	m_4	M	M_2	M_3	A_1	A_2	A_3	A_4	M_4	N	RANK
GATE	OPEN NOZZLE	0				0								0	
[illegible]	[illegible]	.5	1.0	1.0	1.0	.5	.8	1.0	6.3	3.0	2.4	0	11.7	4.7	8
[illegible]	[illegible]	.5	1.0	1.0	1.0	.5	.8	.75	6.3	3.0	2.4	0	11.7	3.5	13
[illegible]	[illegible]	0				0								0	
[illegible]	[illegible]	0				0								0	
	[illegible]	0				0								0	
	[illegible]	.5	1.0	1.0	1.0	.5	.8	1.0	6.0	1.0	3.4	0	10.4	4.2	11
[illegible]	[illegible]	0				0								0	
[illegible]		.5	1.0	1.0	1.0	.5	.8	.75	6.6	1.0	5.0	0	12.6	3.8	12

FLUIDYNE ENGINEERING CORPORATION

JOB NASA QUICK OPENING VALVE CODE

SHEET NO 4 OF

VALUATION AND RATING SUMMARY

DATE

BY

VALVE LOCATION DOWNSTREAM VALVE SIZE 11'

VALVE TYPE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	M_1	M_2	M_3	A_1	A_2	A_3	A_4	M_4	N	RANK
[illegible]	[illegible]	0				0								0	—
	[illegible]	.5	1.0	.75	1.0	.375	.8	1.0	1.9	2.0	1.1	0	5.0	1.5	20
	[illegible]	.5	1.0	.75	1.0	.375	.8	.75	4.1	3.0	1.1	0	8.2	1.8	19
[illegible]	[illegible]	.5	1.0	.75	1.0	.375	.8	.75	0	4.0	.3	0	4.3	.95	23
[illegible]	[illegible]	.5	1.0	.75	1.0	.375	.8	.75	5.3	3.0	2.1	0	10.4	2.3	18
	[illegible]	.5	1.0	.75	1.0	.375	.8	.75	6.0	4.0	2.3	0	12.3	2.8	17
	[illegible]	.5	1.0	.75	1.0	.375	.8	1.0	.7	1.0	2.1	0	3.8	1.1	22
[illegible]	[illegible]	.5	1.0	.75	1.0	.375	.8	.75	.6	2.0	.2	0	2.8	.6	24
[illegible]		.5	1.0	.75	1.0	.375	.8	.75	1.9	1.0	3.5	0	6.4	1.4	21

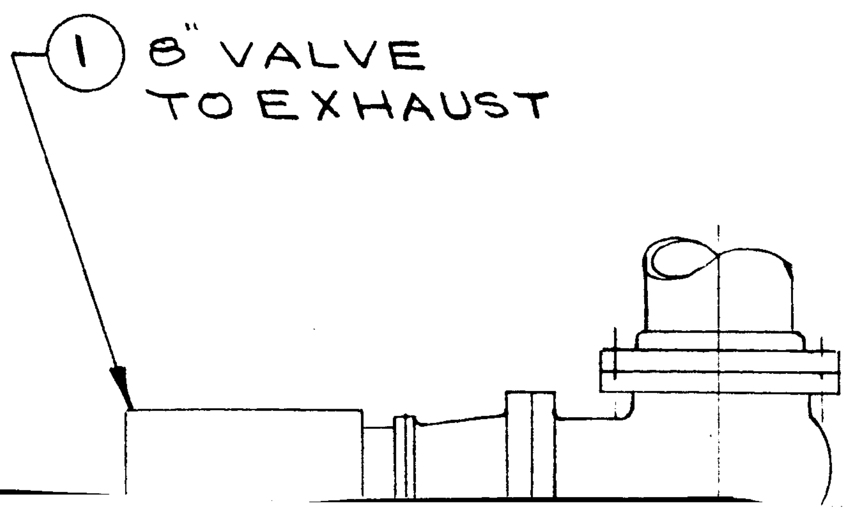
TOP1

STRIP1

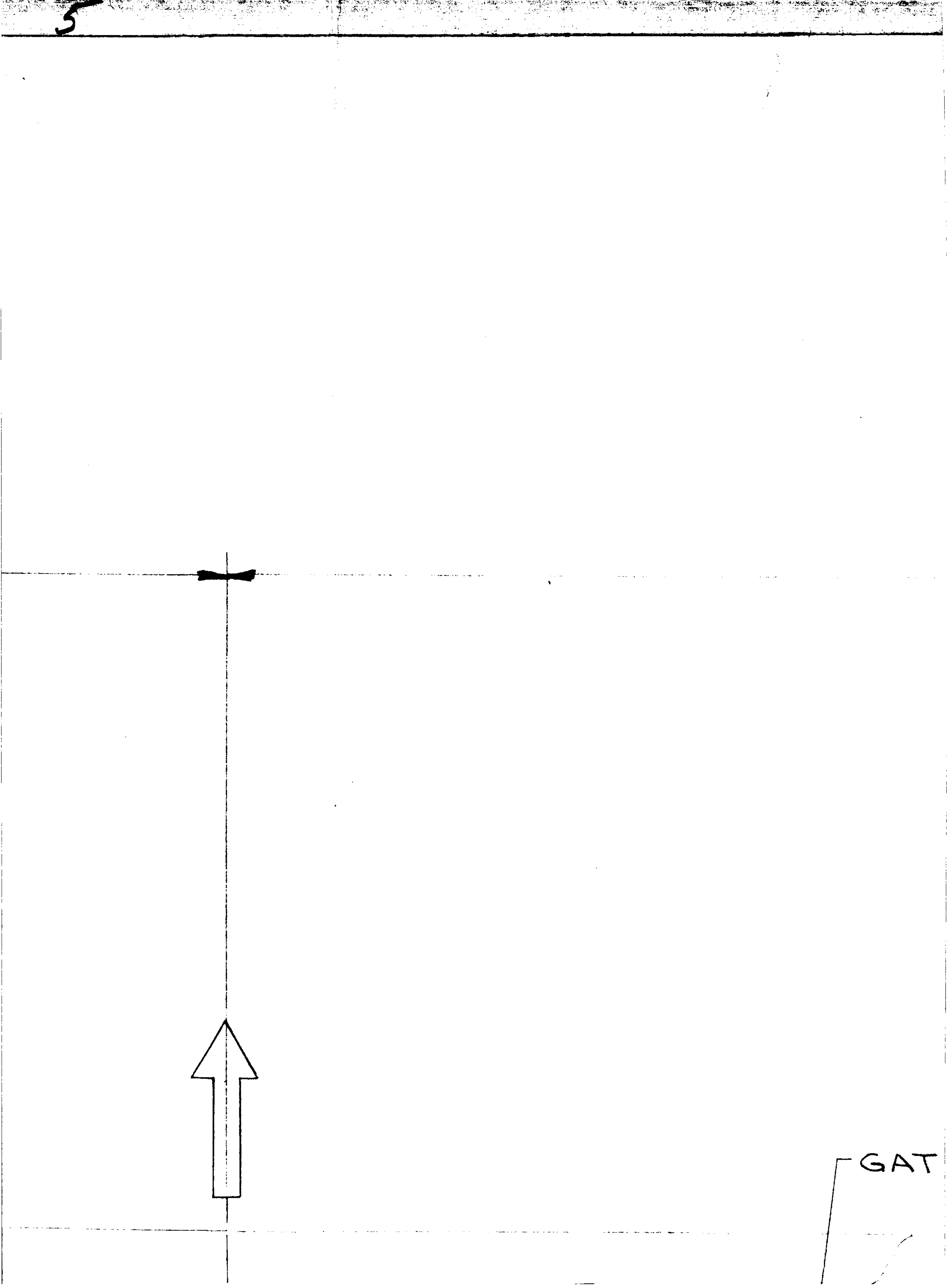
3 500 P.S.I. AIR-TANK A
2" VALVE

3

27'-8"

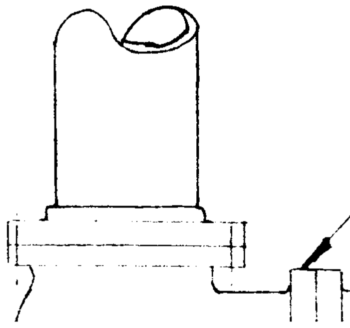


4

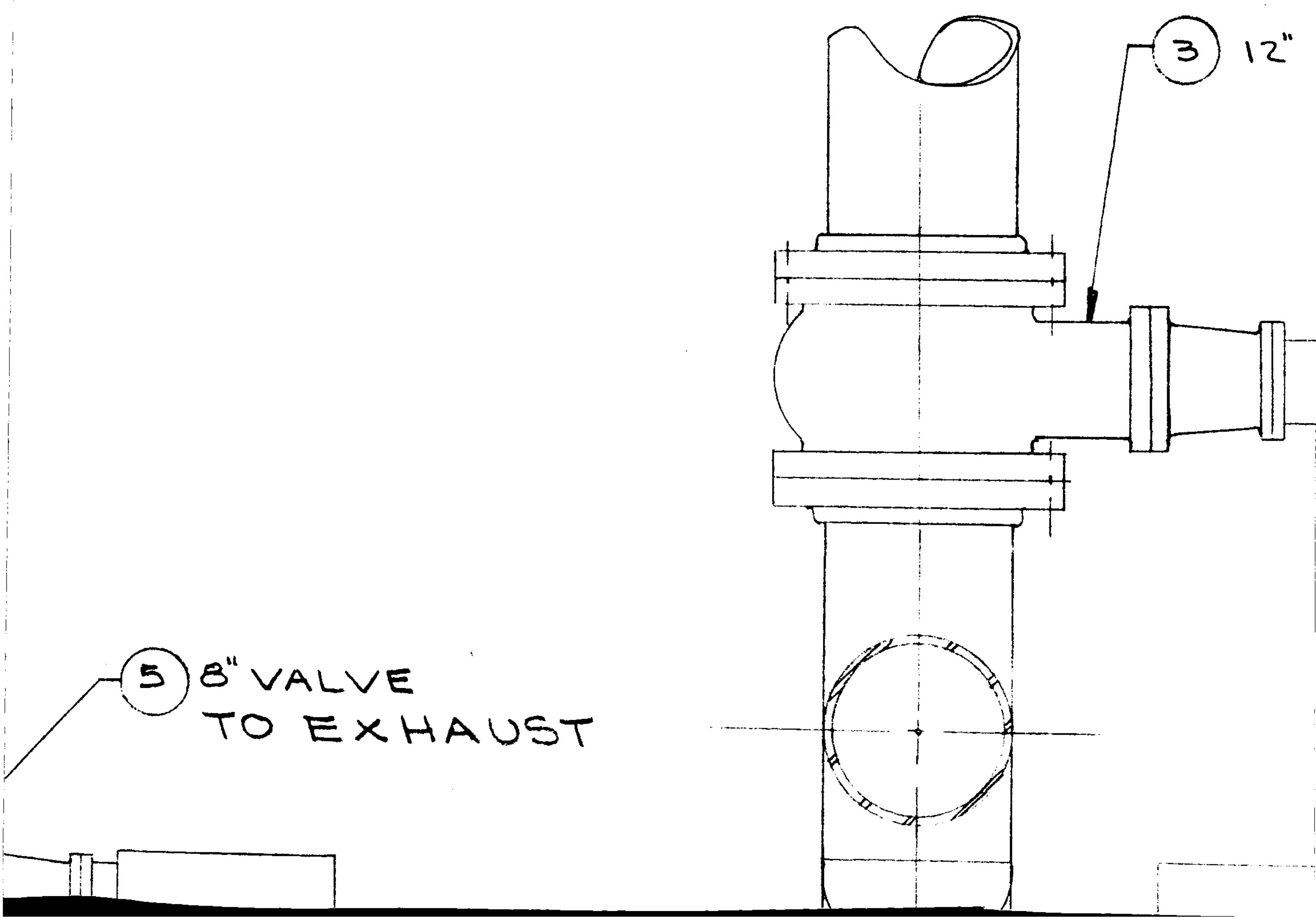

5
GAT

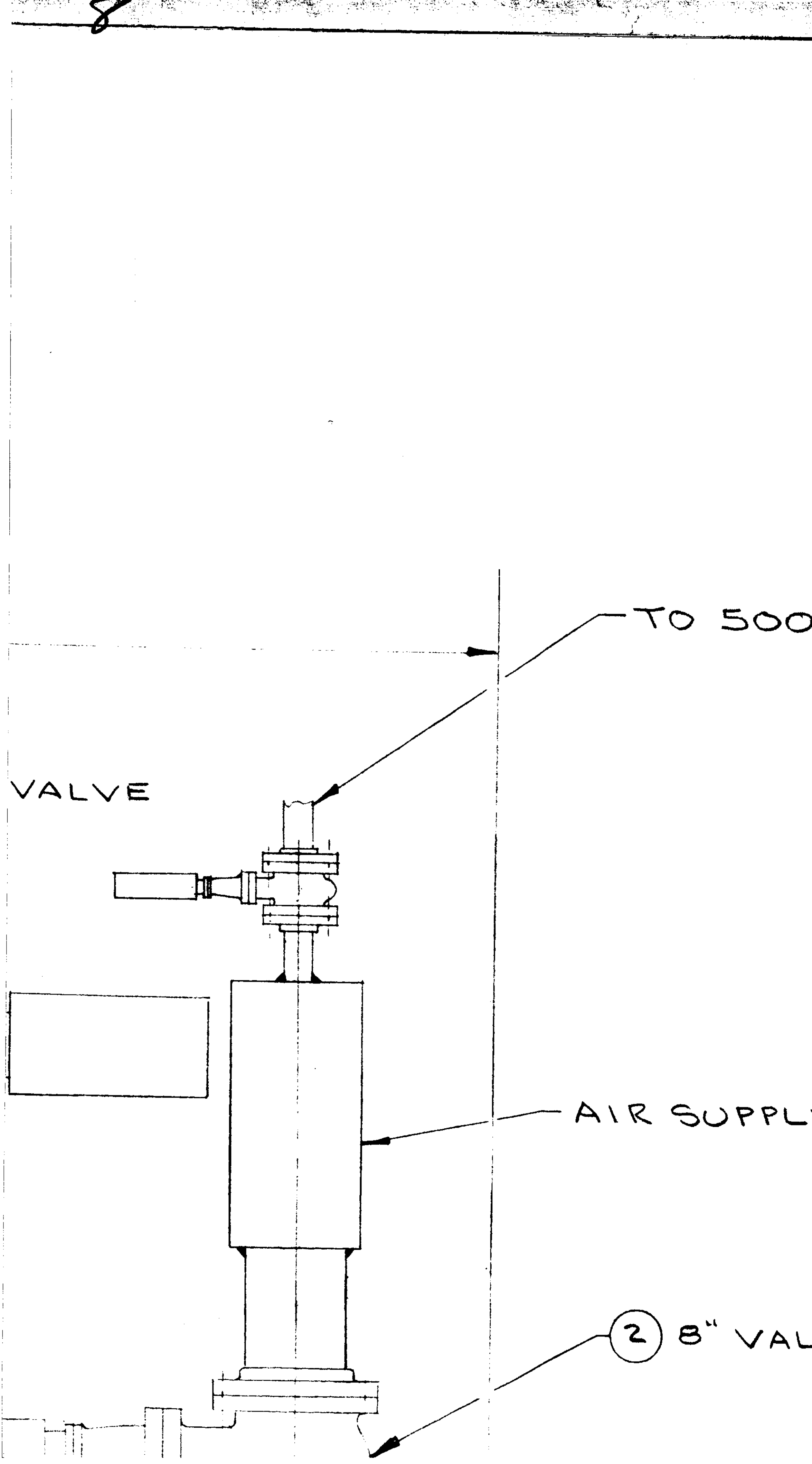
6

25' - 6"



PISTON ROD


3
12"
5
8" VALVE
TO EXHAUST



TO 500
VALVE
AIR SUPPL
2 8" VAL

9

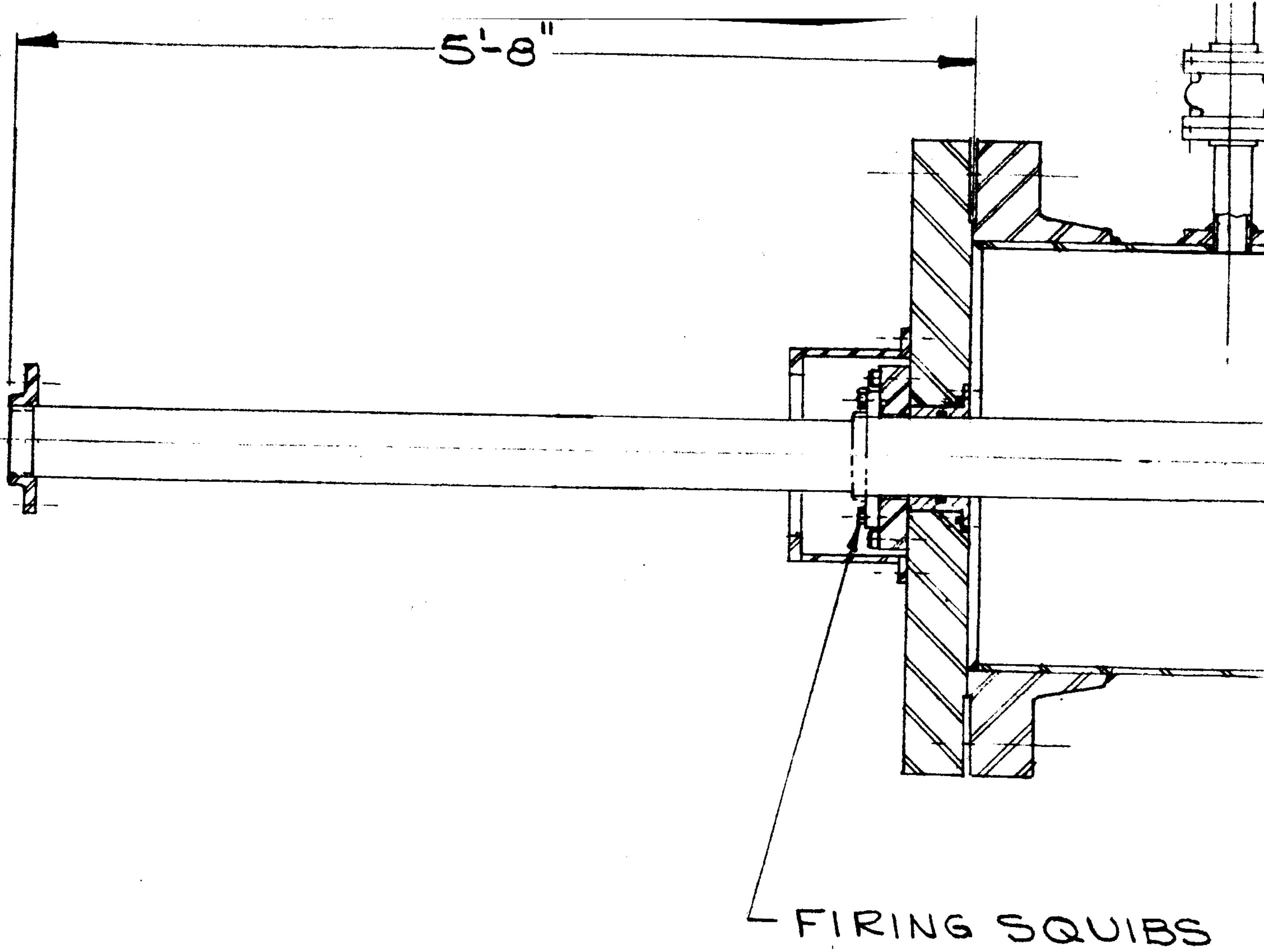
P.S.I. AIR - TANK A

Y TANK

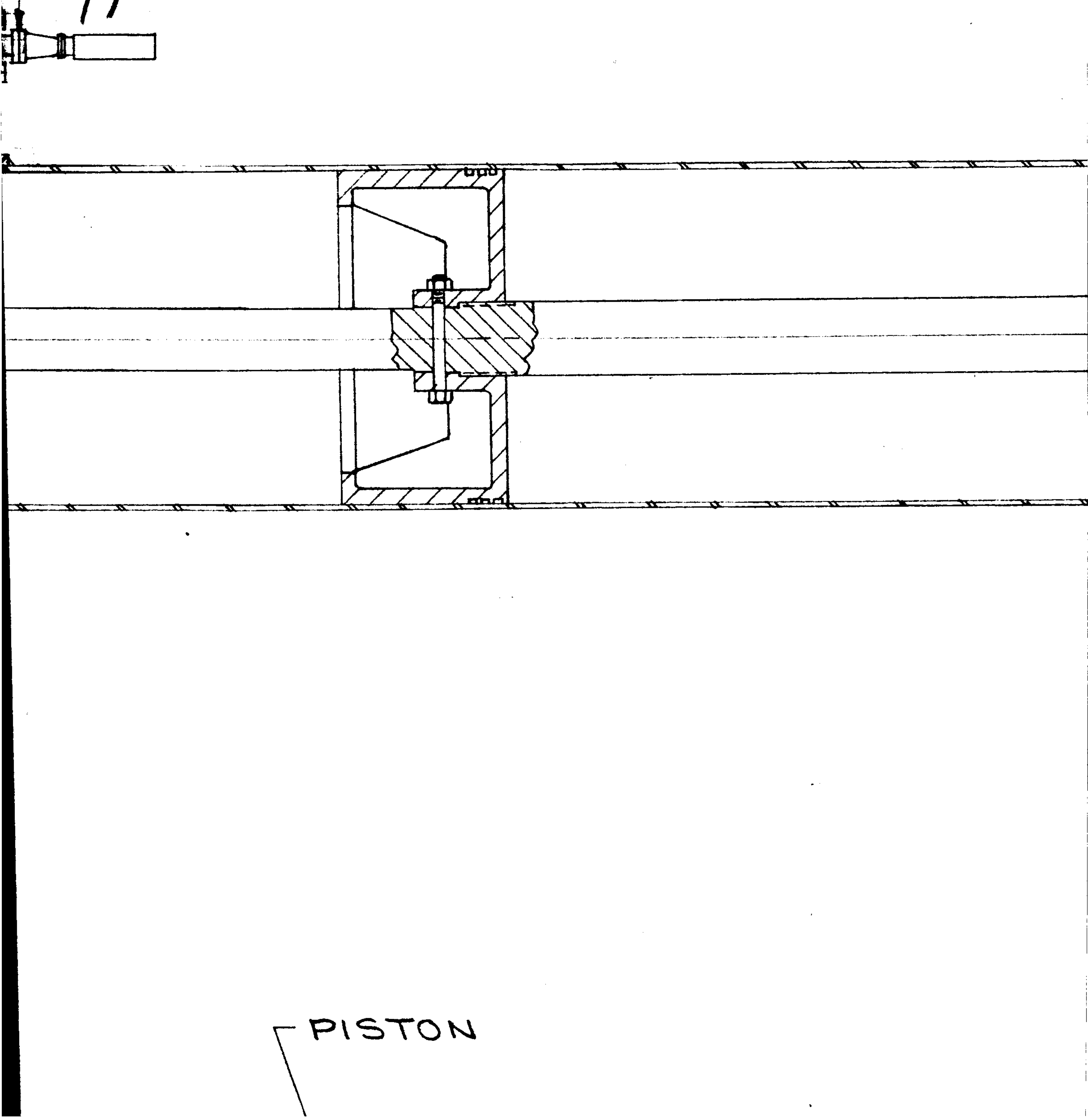
VE

10

STRIP 3

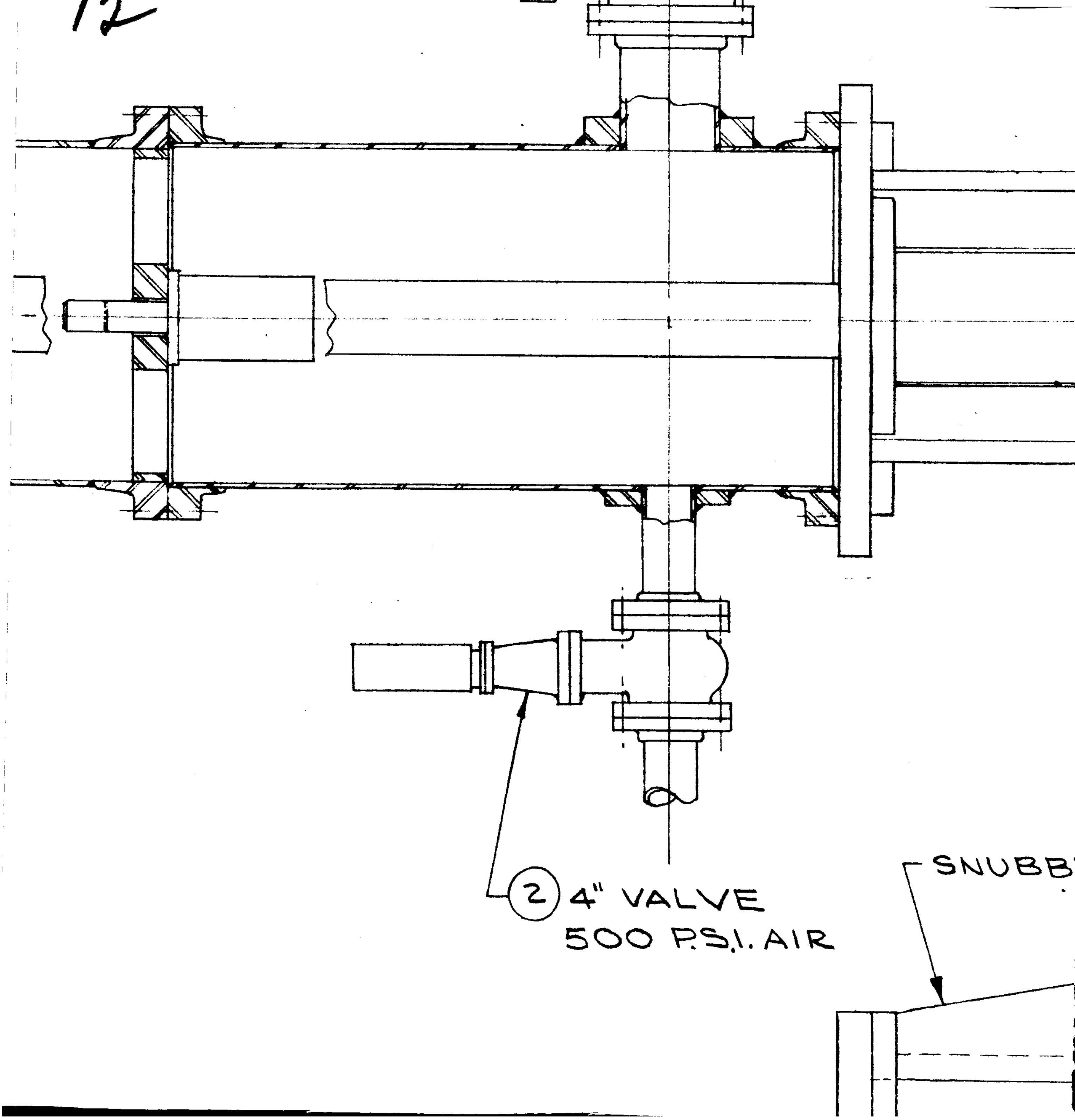


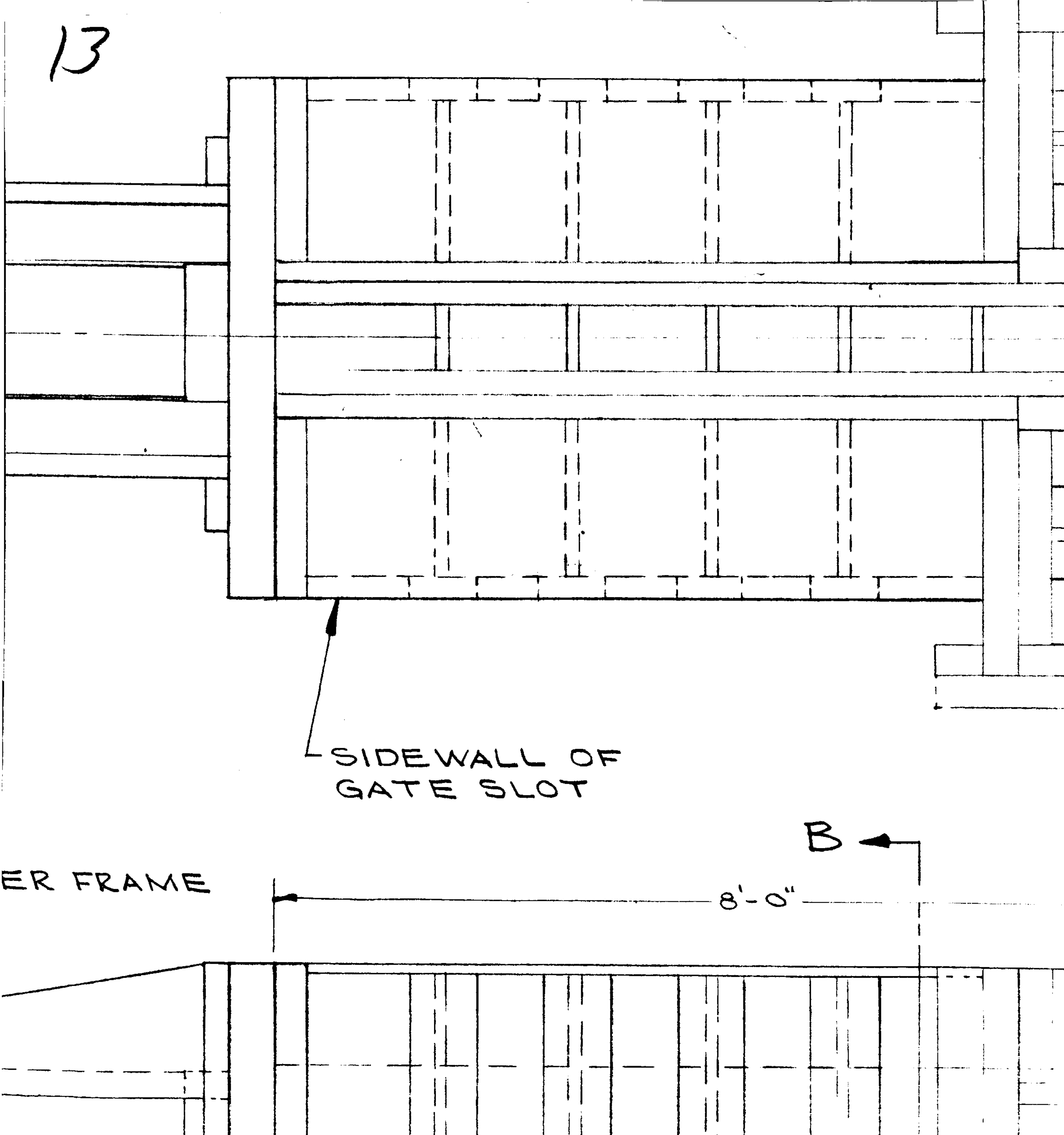
TOP CENTER

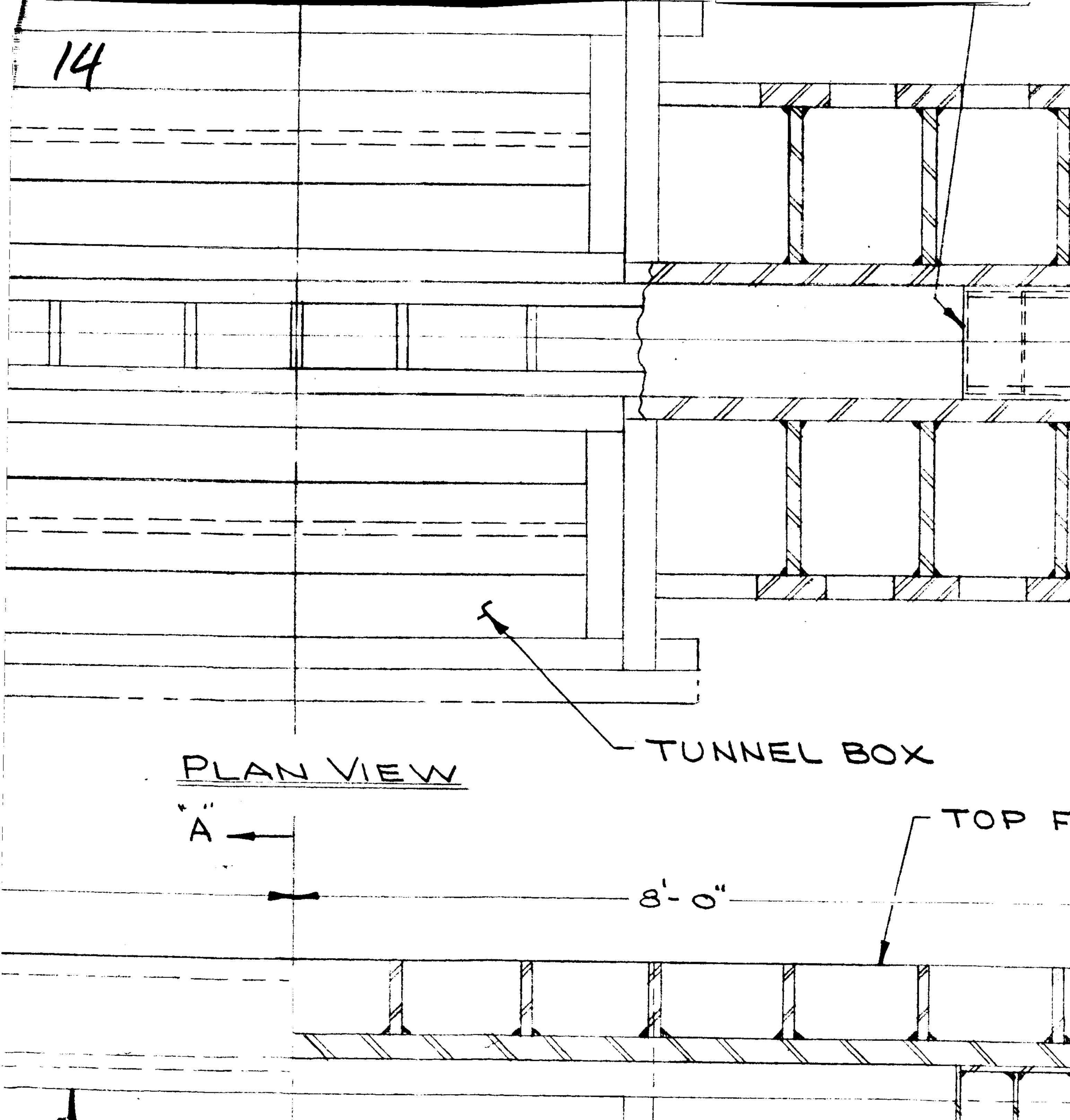


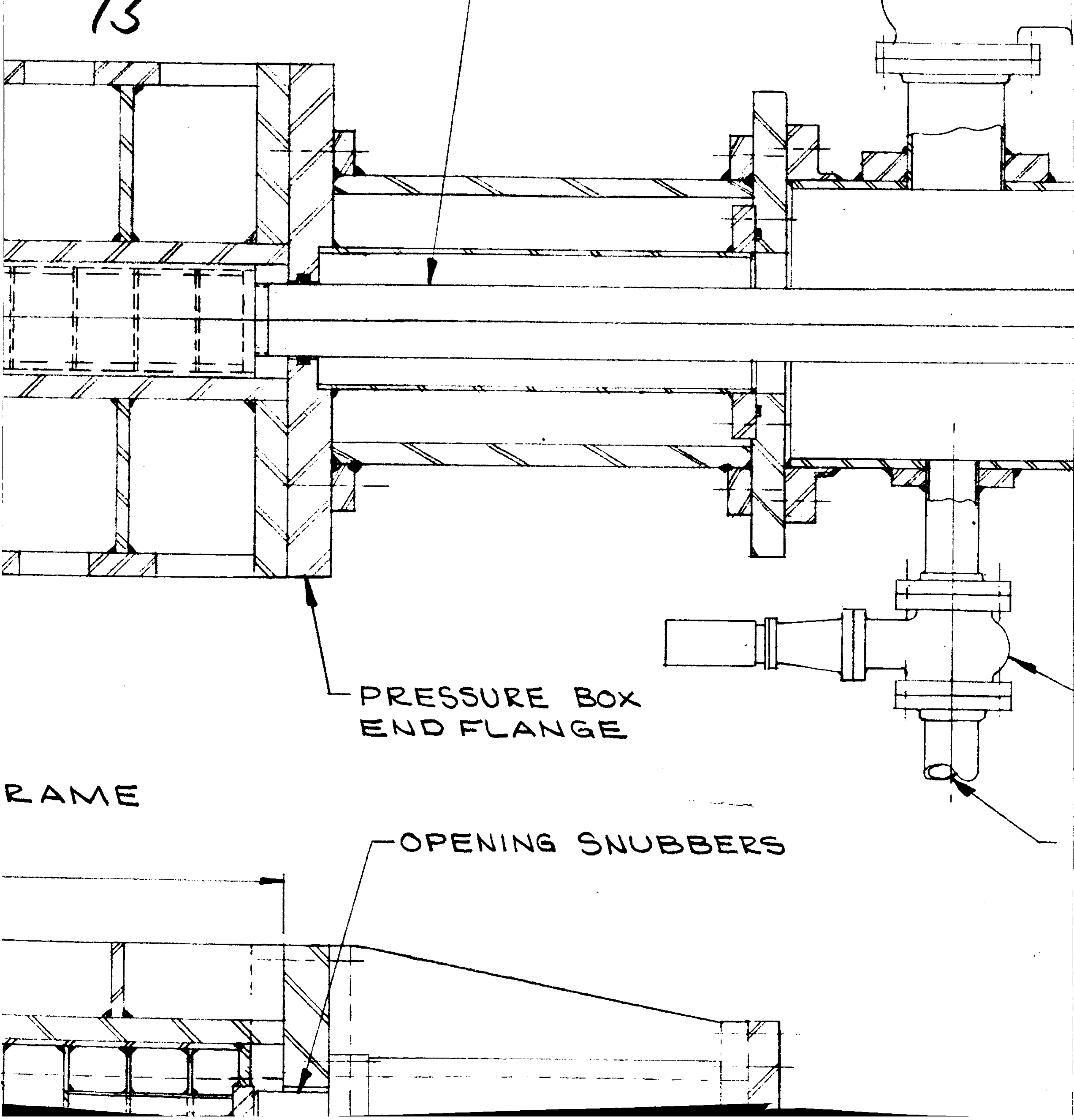
PISTON

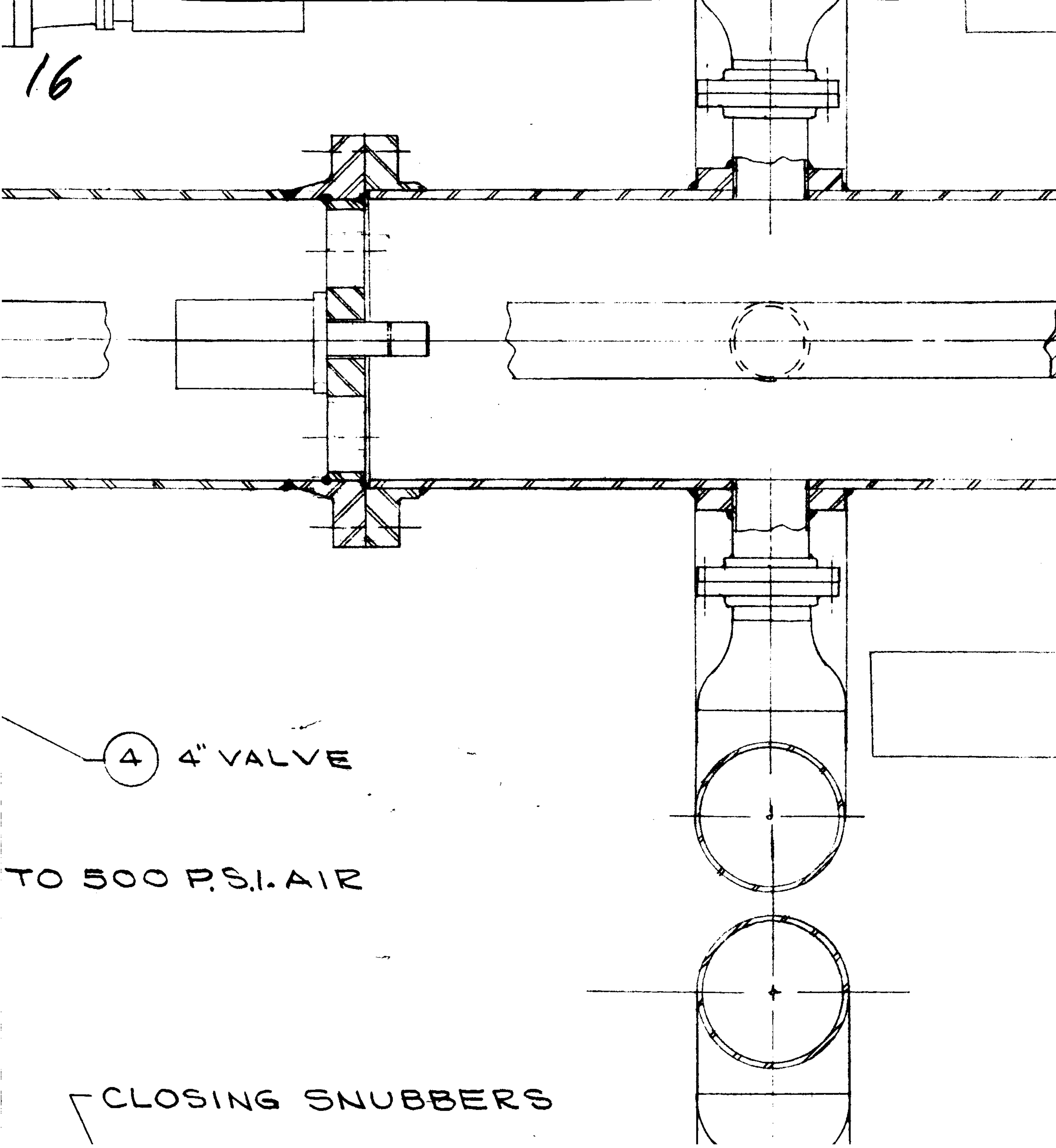
12

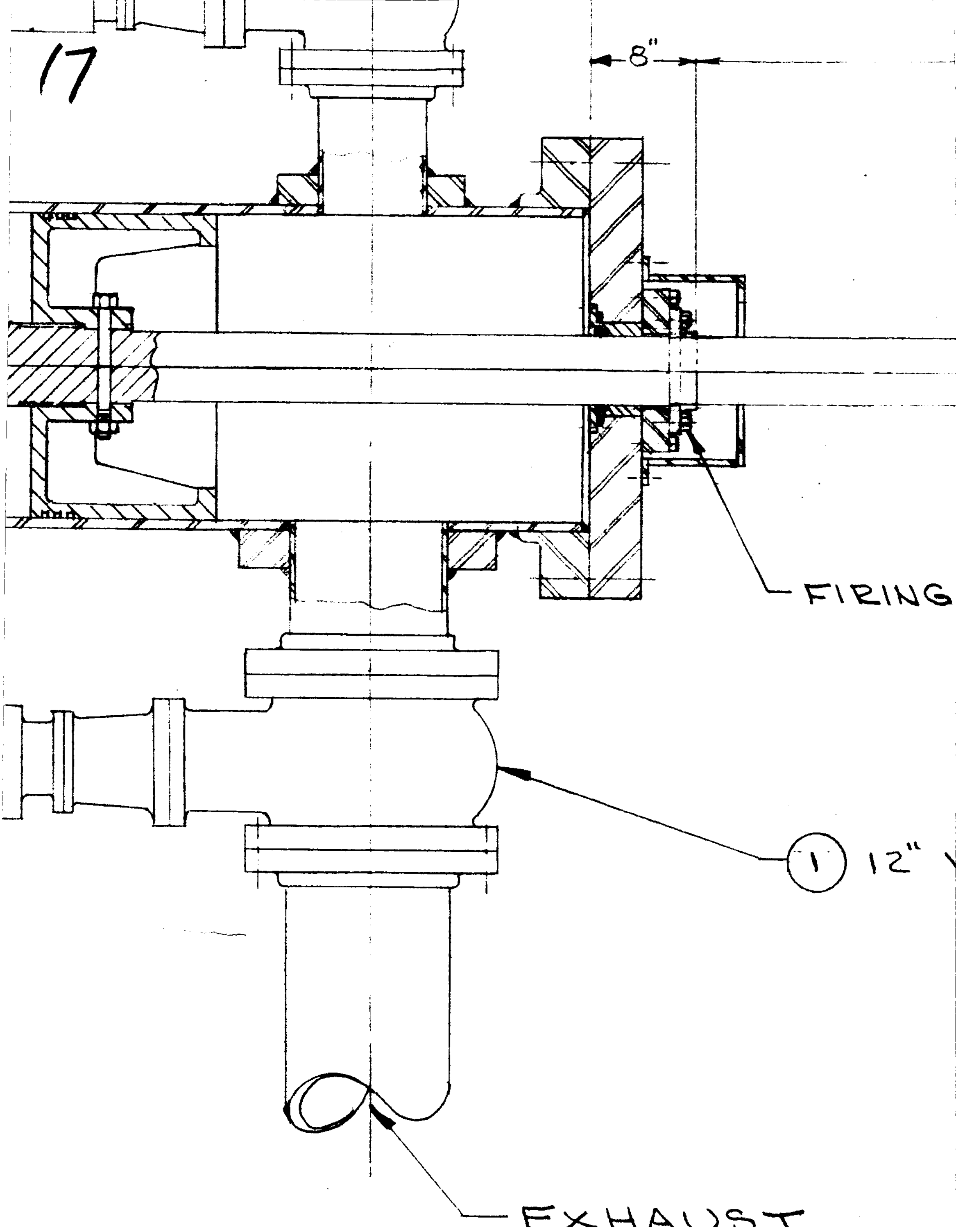


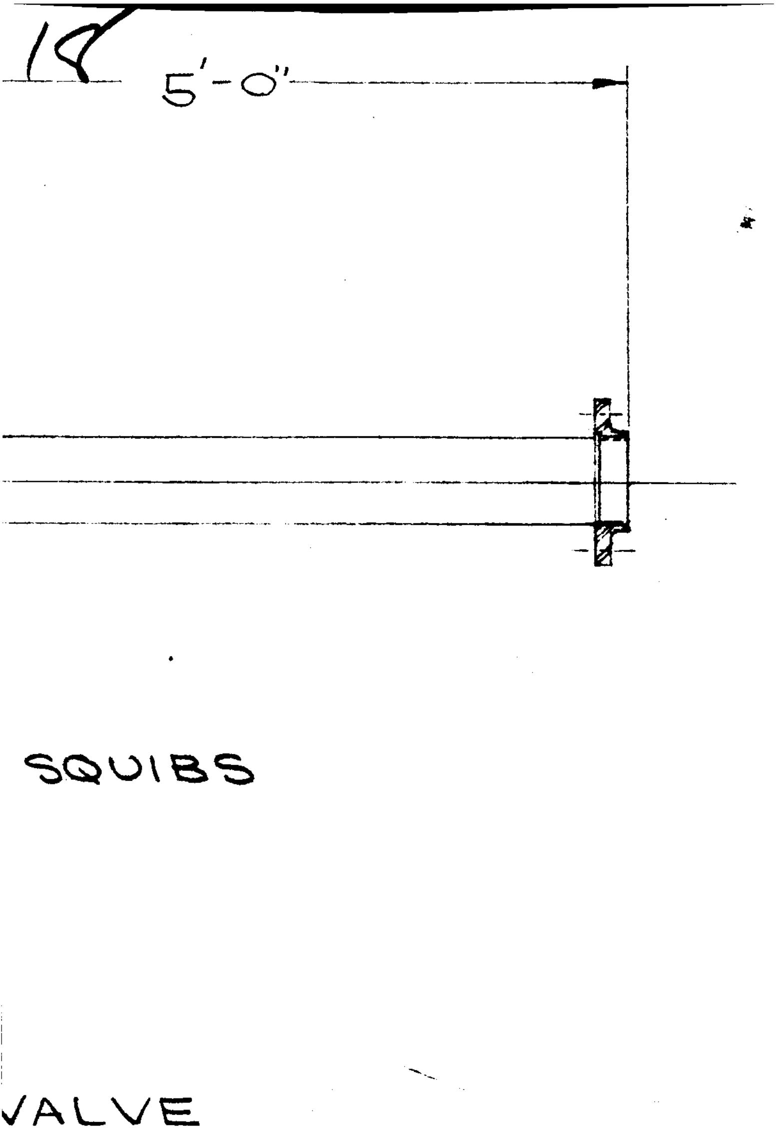

13
SIDEWALL OF
GATE SLOT
B
ER FRAME
8'-0"


14
TUNNEL BOX
PLAN VIEW
"A"
8'-0"
TOP F


PRESSURE BOX
END FLANGE
RAME
OPENING SNUBBERS

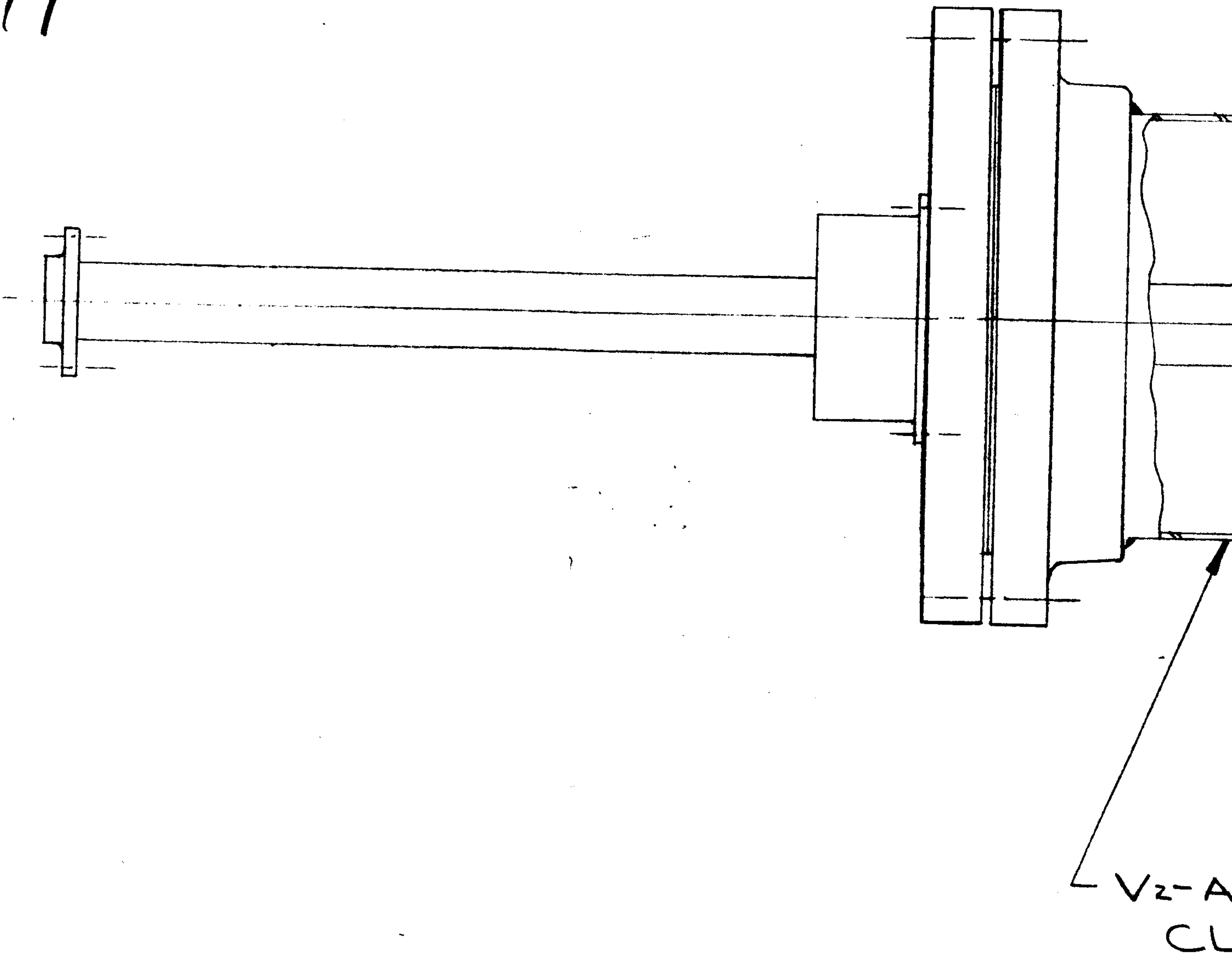

16
4
4" VALVE
TO 500 P.S.I. AIR
CLOSING SNUBBERS


17
8"
FIRING
1
12"
EXHAUST


18
5'-0"
SQUIBS
VALVE

19

STRIP 3



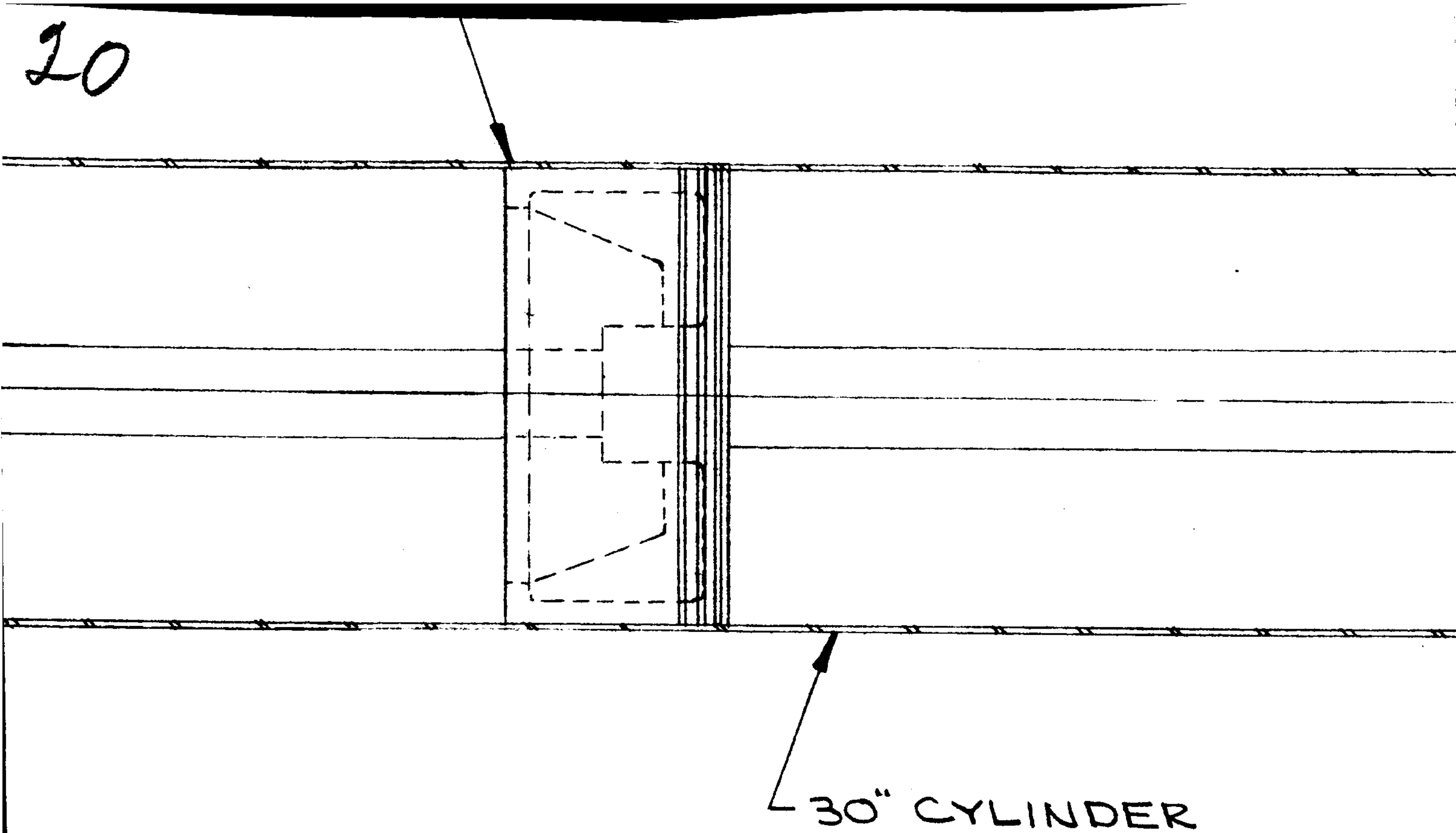
CONTROL SYSTEM #1

OPERATIONAL SEQUENC

I NECESSARY CONDITIONS BEFORE GATE CAN

A. GATE SEAL DEFLATED.
B. PRESSURE IN V_1 = 500 P.S.I.
C. PRESSURE IN V_2 = 40 P.S.I.
D. GATE IS CLOSED.

BOTTOM CENTER



IR STORAGE FOR
OSING VALVE

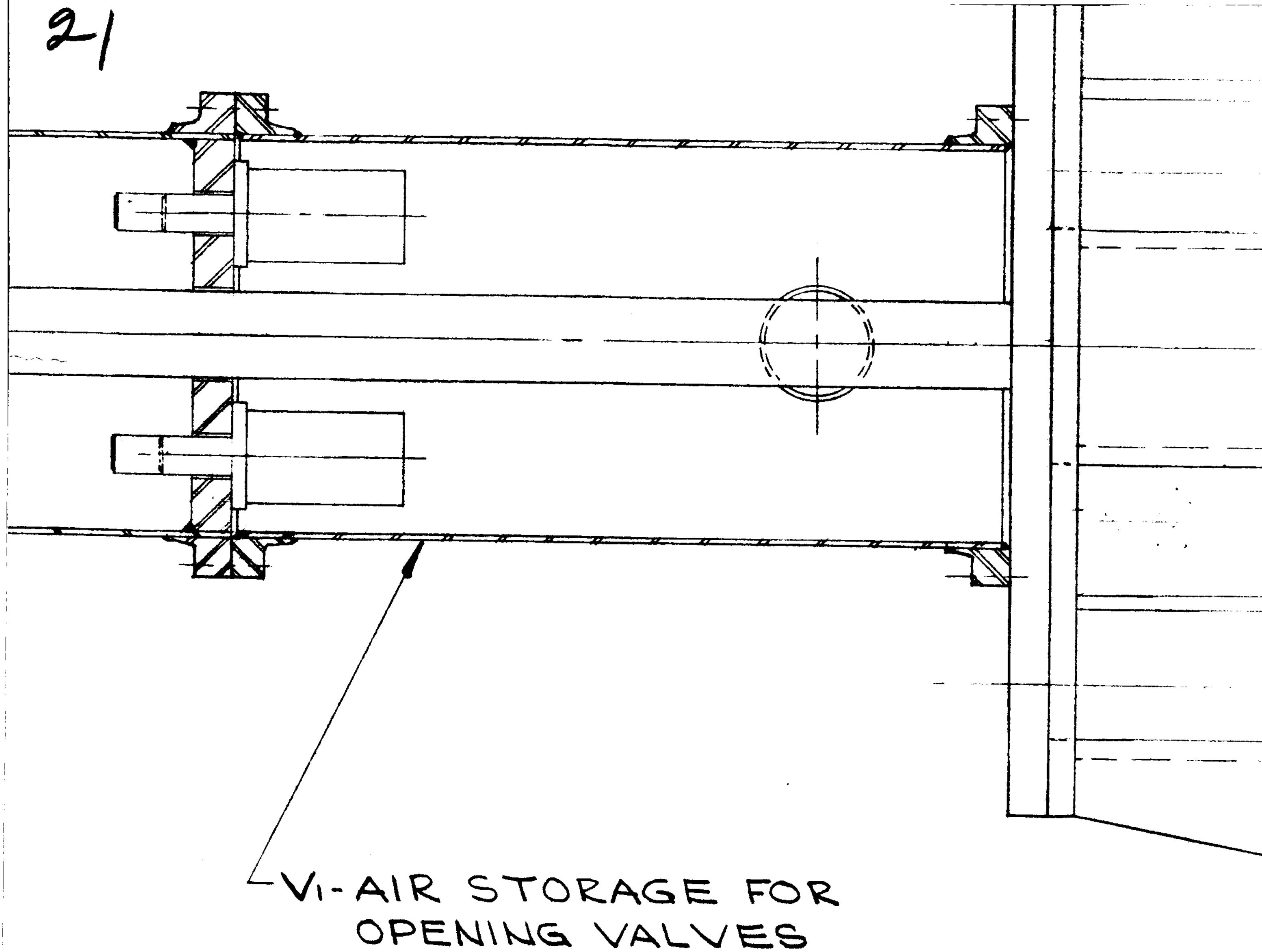
LE

BE OPENED.

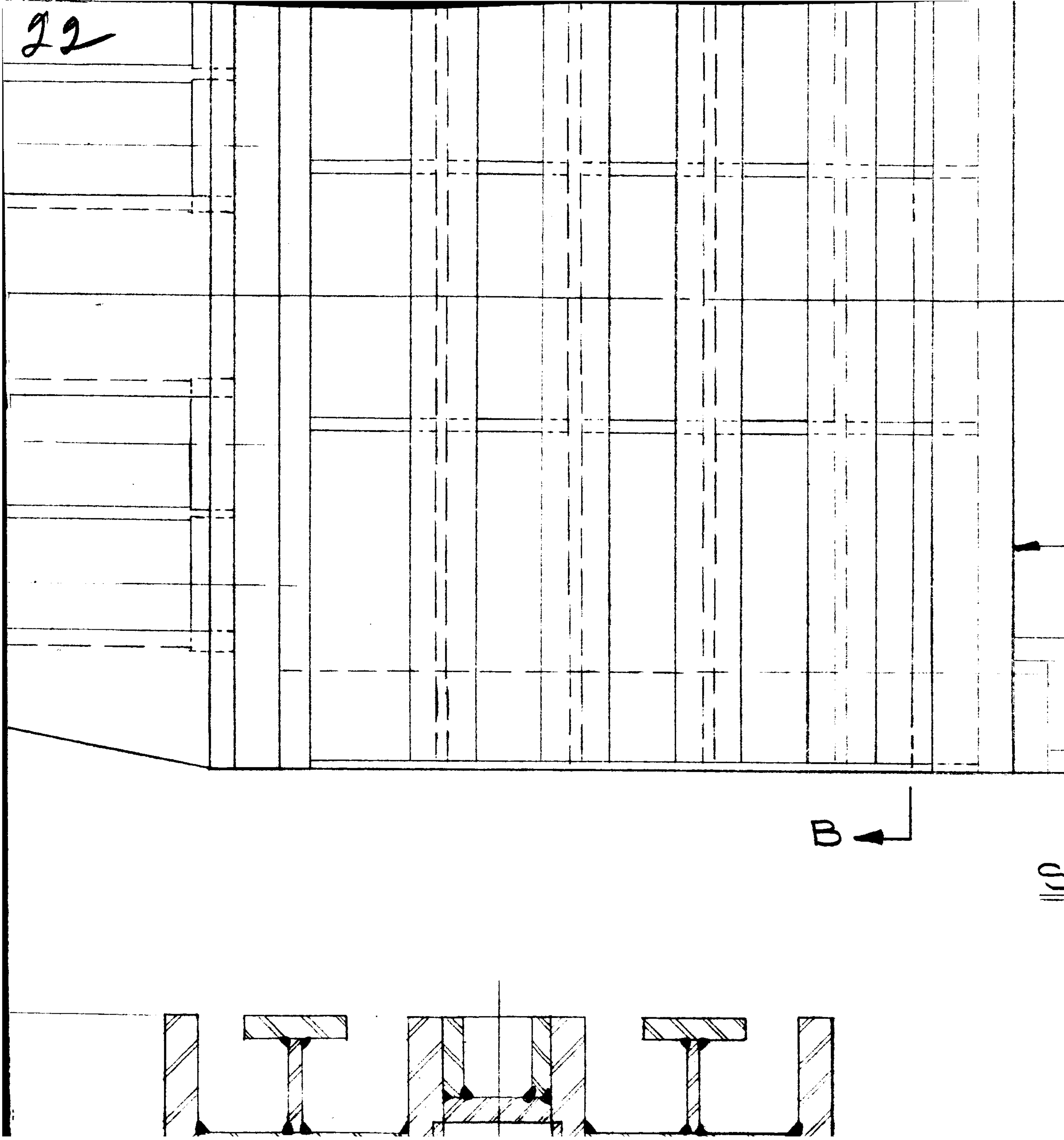
IV MANUAL OPERATION.

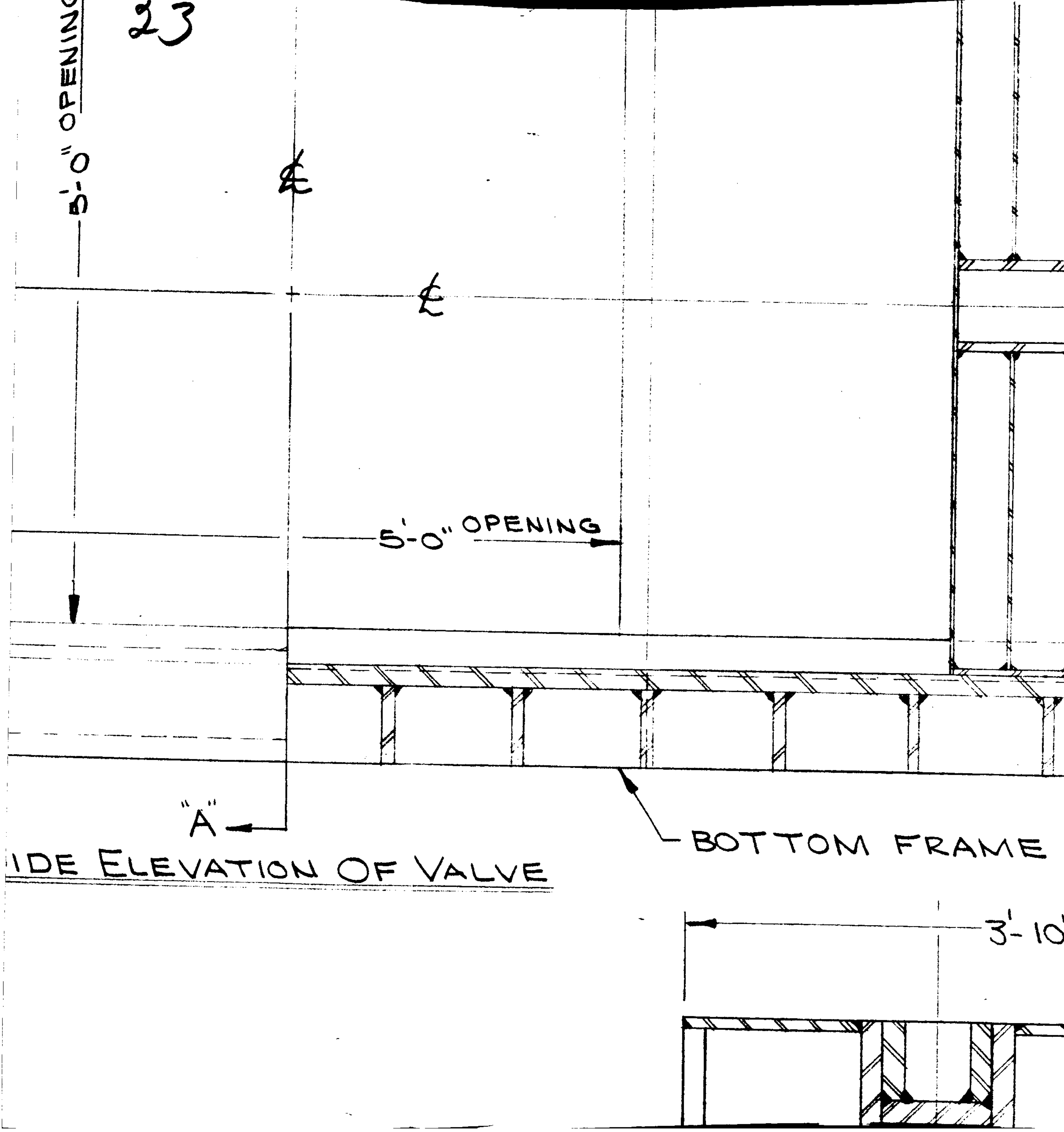
CONDITIONS & SEQUENCE
EACH STEP IS MANUALL

V. CONSOLE

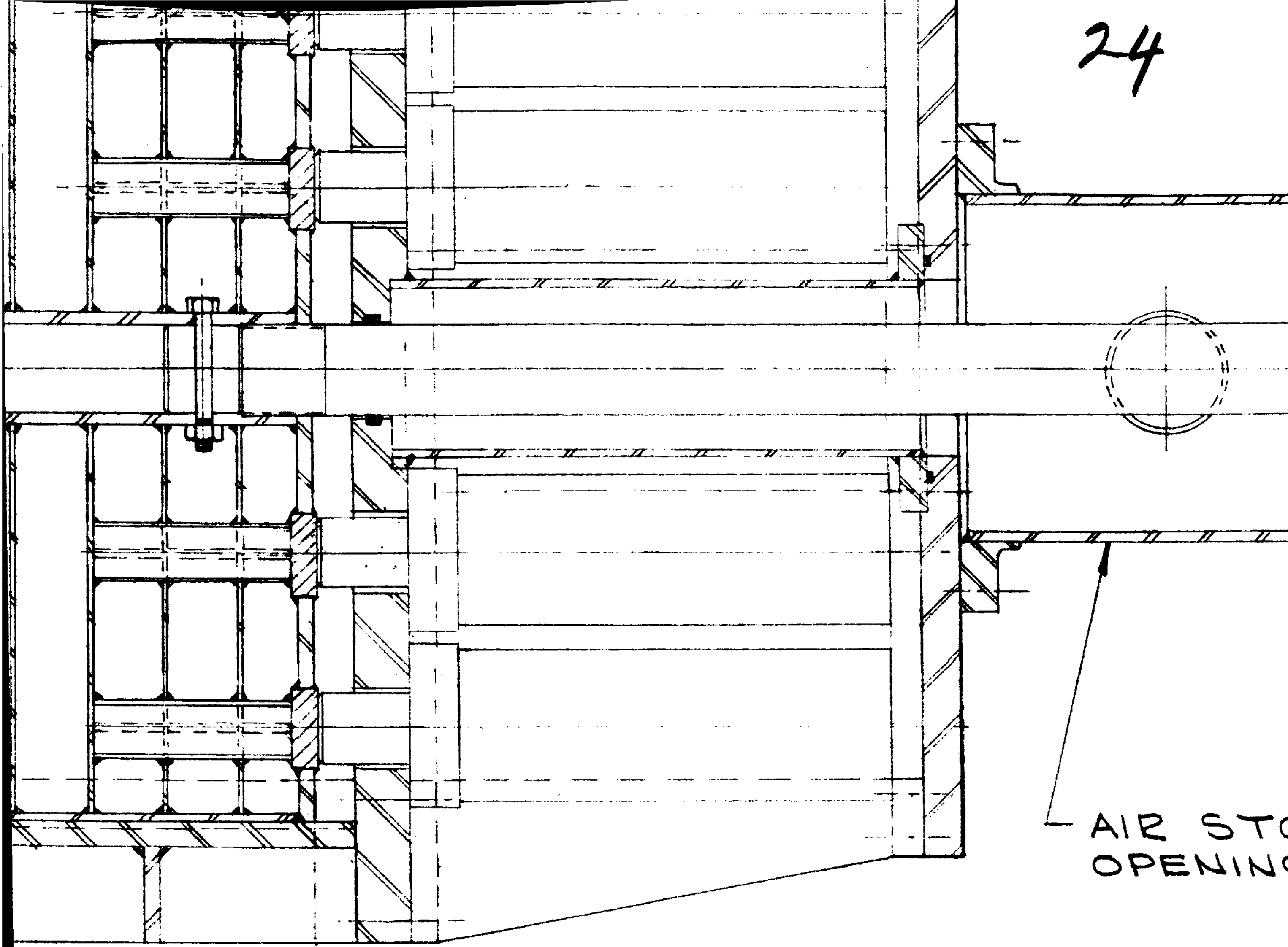


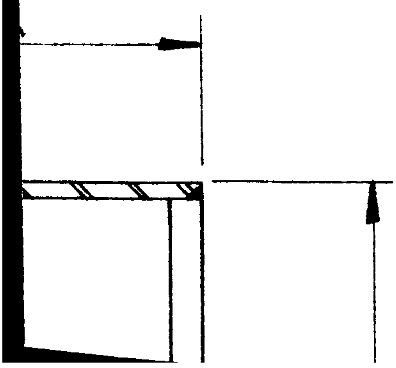
SAME AS FOR III, BUT
INITIATED.


B



IDE ELEVATION OF VALVE



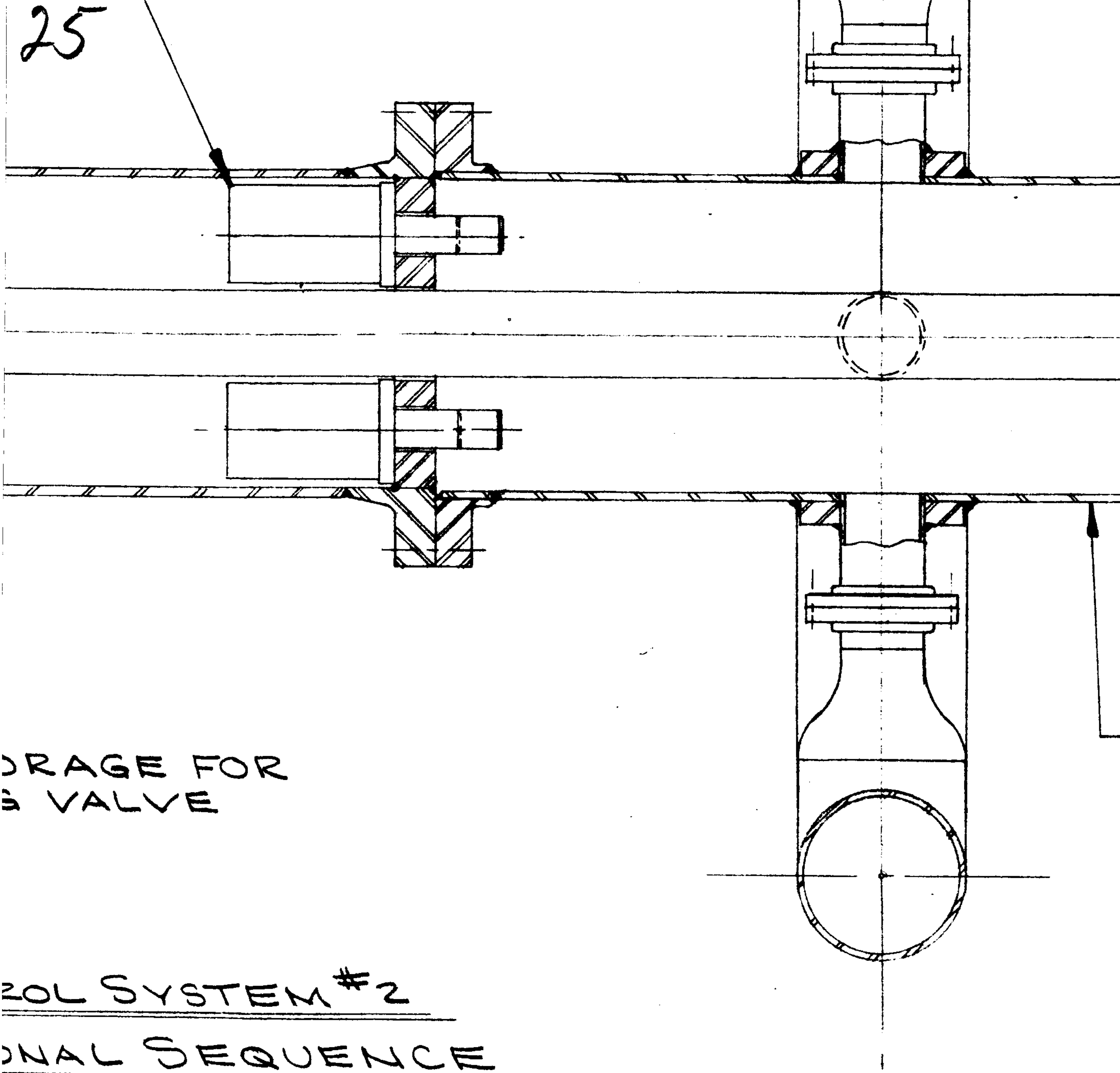


CONT

OPERATIO

ASSUME GATE
NOT PRESSU

GATE SEAL LO
IN CYLINDER
ROD IS SEAL



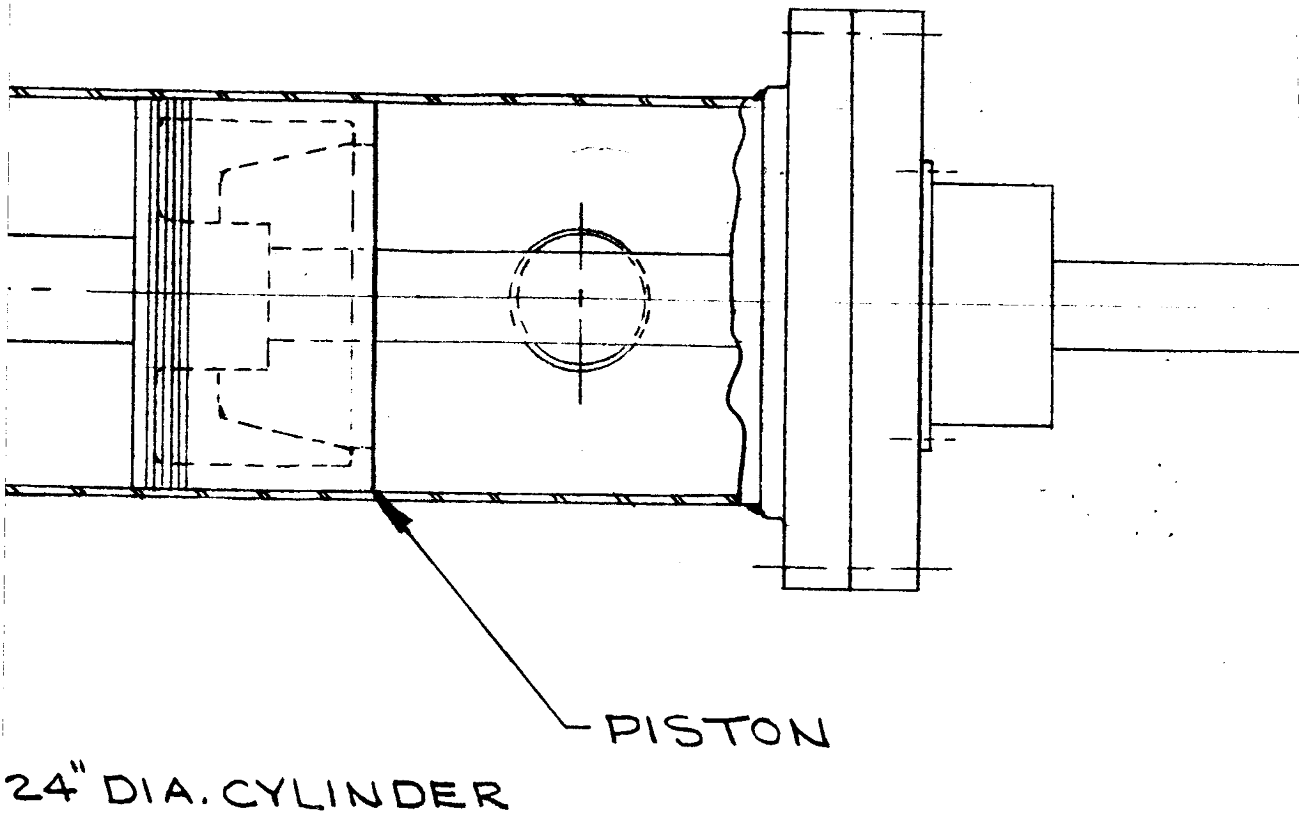
ROL SYSTEM #2

ONAL SEQUENCE

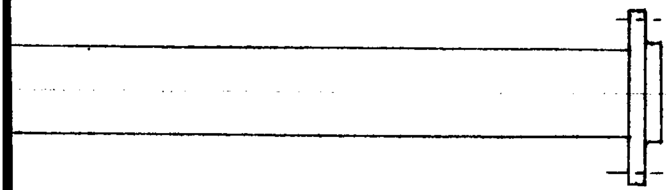
. IS OPEN, TUNNEL & TANK "A"
RIZED.

OCATED DOWNSTREAM & OPENING
& BOX STRUCTURE FOR PISTON
LED.

26



21



18

STRIP 4

C. SQUIB CIRCUIT IS COMPLETE.

II NECESSARY CONDITIONS BEFORE GATE CA

A. GATE SEAL DEFLATED.

B. PRESSURE IN V_1 =

C. PRESSURE IN V_2 =

D. GATE IS OPEN.

III AUTOMATIC OPERATION.

A. INITATE CYCLE BY PRESSURIZING TUN
FOLLOWING SEQUENCE OF EVENTS TA
IF GATE IS CLOSED, SEAL IS PRESSURI
CIRCUIT IS COMPLETE, V_2 = 40 P.S.I.

1. V_1 IS CHARGED TO 500 P.S.I. THRU PCV
2. VALVE #2 CLOSES.
3. SEAL DEFLATES.
4. SQUIB FIRED.
5. GATE-OPEN SIGNAL RECEIVED.
6. INTERVAL TIMER STARTS.
7. IF CONDITIONS IN II ARE MET, VALVE #1 O
8. GATE CLOSES & LOCKS.
9. VALVE #1 CLOSES.
10. SEALS INFLATE.
11. 40 P.S.I. MAINTAINED IN V_2.

B. SQUIBS ARE REPLACED.

BOTTOM

29

BE CLOSED.

A. INDICATORS.

1. PRESSURE DIALS.

a. COMPRESSOR PI-3

b. V_2 PI-2

c. V_1 PI-1

d. SEAL PI-4

2. LIGHTS.

A. RED & GREEN FOR EAC
FOR BOTH OPENING & C
ALL GREEN LIGHTS SHO
READY TO GO.

B. INTERVAL TIMER SE

C. MODE SELECTOR S

D. AUTO. BUTTON

E. MANUAL BUTTON S

F. PRESSURE INDICATI

G. SQUIB CIRCUIT CON

NEL AND
KES PLACE,
ZED, EQUIPMENT

2 & VALVE #2.

ENS.

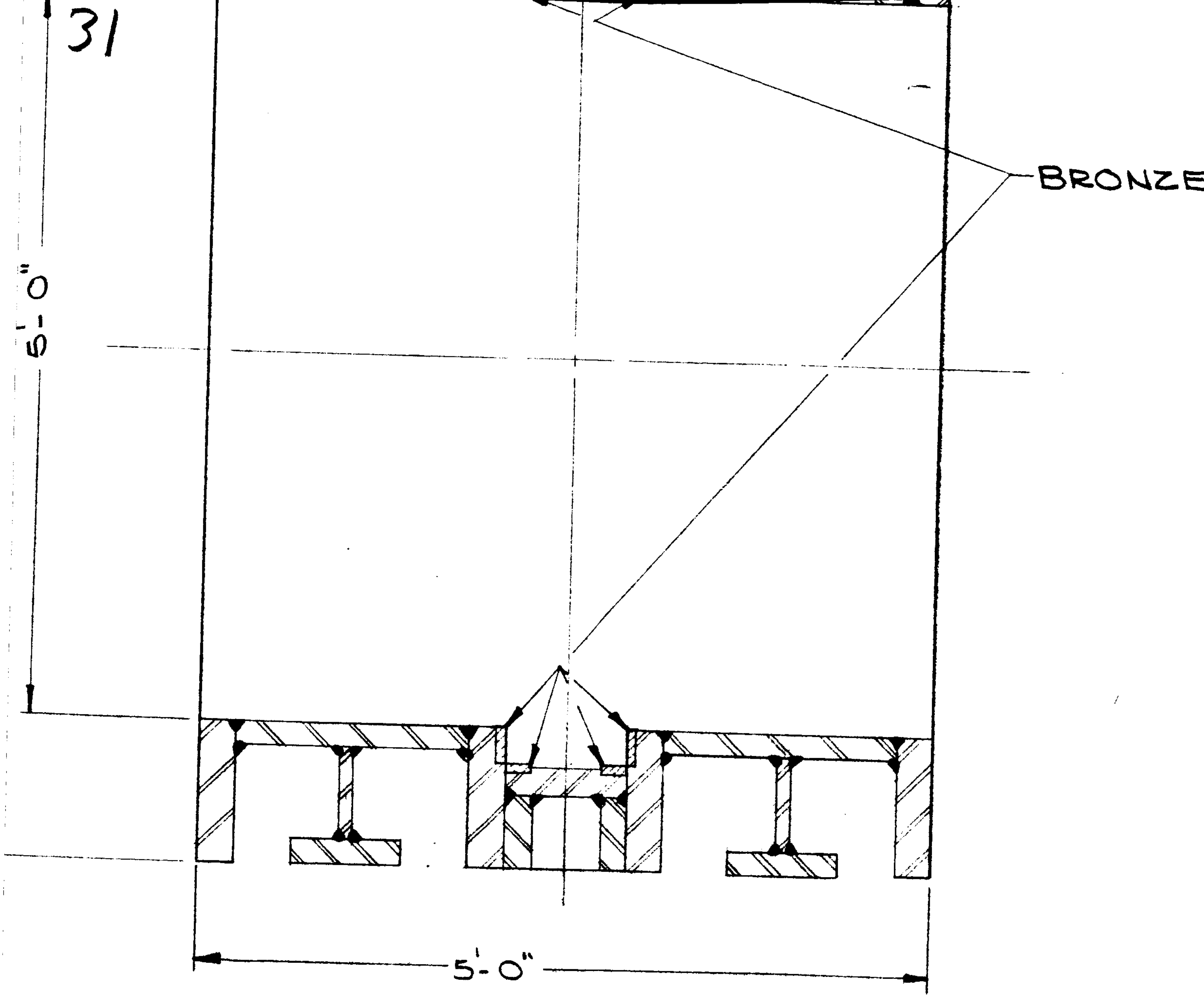
H NECESSARY CONDITION
LOSING POSITION OF CYCLE,
W BEFORE ½ CYCLE IS

POINT.
VITCH.

VITCH.
NG ALARMS PIA-1,2,3.
TINUITY INDICATOR.

0
1

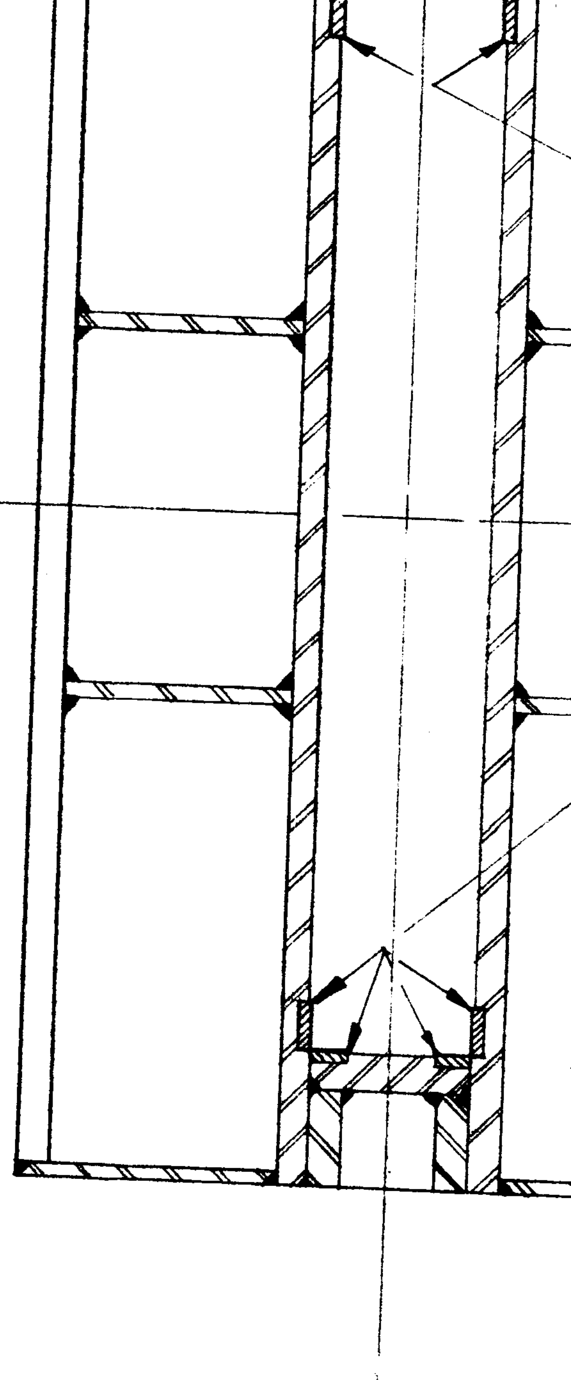
31



SECTION A-A

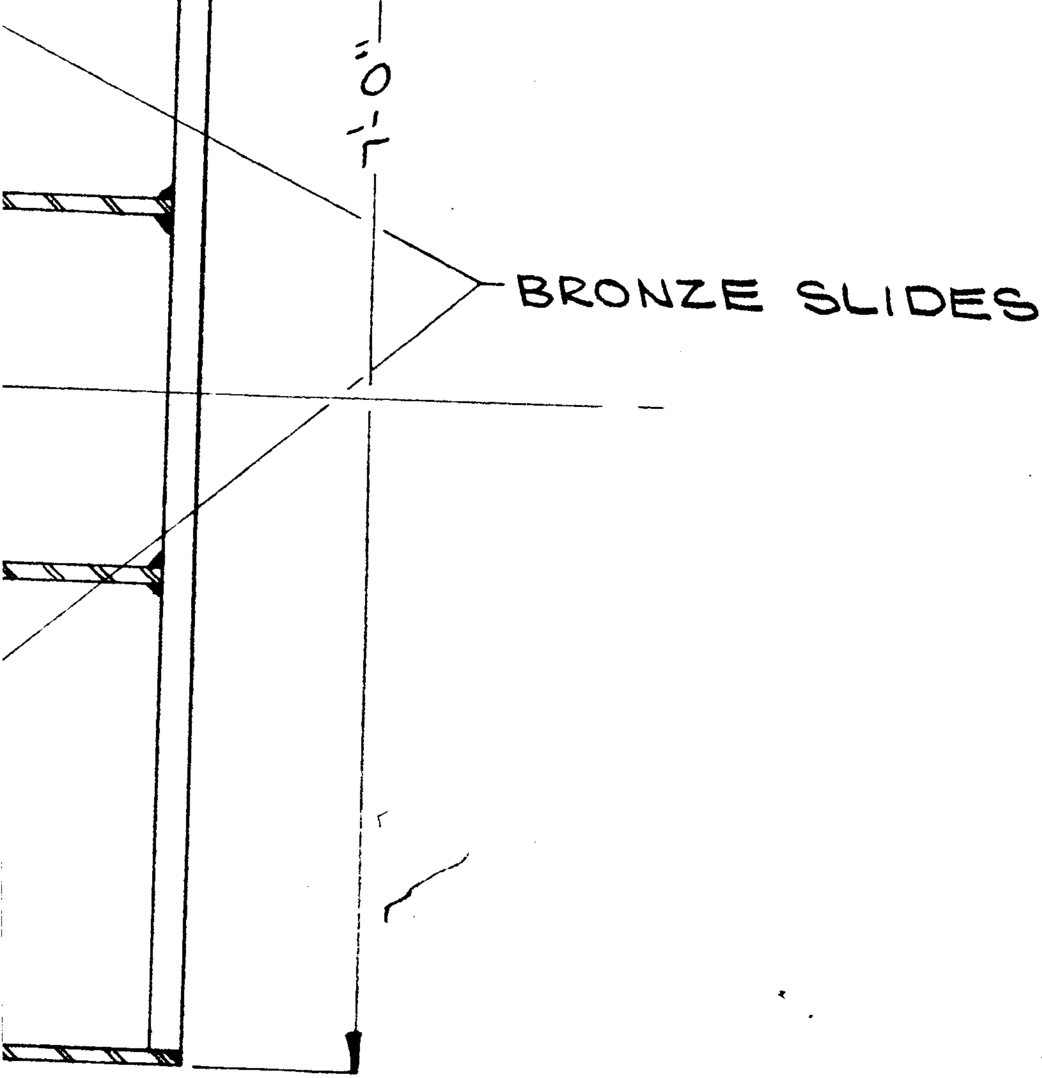
32

SLIDES



SECTION

33



3-B

1. CLOSE VAL
2. OPEN VAL
3. PRESSURIZE
4. OPEN VALVE
5. GATE CLOSE
6. INFLATE SEA
7. SET FIRING S
8. BEGIN TO PRE
9. WHEN TUNNE
10. RE-PRESSURI
11. OPEN VALVES
12. CLOSE VAL
13. RELEASE INF
14. FIRE SQUIBS
15. GATE ACCEL
16. GATE DECEL
17. AFTER RUN IS
18. OPEN VALVE
19. GATE CLOSE
20. INFLATE SEAL
21. RE-SET FIRIN
22. RE-PRESSURI
23. WHEN TUNNE
   CLOSE VAL
24. RE-PRESSURI
25. OPEN VALVE
26. CLOSE VAL

ES 1, 2, 3 & 4. 27
E 5. 2
E TANK "A". 2
. 2.
ES.
LS AROUND GATE FROM TANK "A". 30
SQUIBS. 3
ESSURIZE TUNNEL. 3
L PRESSURE = 500 P.S.I., CLOSE VALVES 2 & 5. 3
ZE TANK "A". 3
1, 3 & 4. 3
VE 4.
LATABLE SEALS.
.
ERATES 2.5 FT.- ACTUATOR PRESSURE EXH
-ERATES & STOPS AT 5 FT.
COMPLETED, CLOSE VALVES 1 & 3.
S 2 & 5.
S.
LS.
G SQUIBS.
ZE TUNNEL.
L PRESSURE = 500 P.S.I.,
VES 2 & 5.
ZE TANK "A".
S 1, 3 & 4.
VE 4.

7. RELEASE INFLATABLE SEALS. 35

8. FIRE SQUIBS.

9. GATE ACCELERATES 2.5 FT. - ACTUAT
PRESSURE EXHAUSTS THROUGH VALV

0. GATE DECELERATES & STOPS AT 5 FT.

1. AFTER RUN IS COMPLETED, CLOSE VA

2. OPEN VALVES 2 & 5.

3. GATE CLOSES.

4. INFLATE SEALS.

5. RE-SET FIRING SQUIBS.

AUSTS THROUGH VALVE 3.

REQ.	ITEM	PART NO.	DESCRIPTION	DIA. | THICK | WIDTH NOMINAL STO
LIST OF MATE				

PROG. APPD.			FLU
ENG. APPD.			5
PROJ. ENGR.	JLG		TITLE TWO D
STRESS			
CHECKED	PK		NAS
DRAWN	SA	10-6-65	V
	BY	DATE	SCALE

NEXT ASSY

THIS DRAWING AN

36

TOR
E.

LVES 1 & 3.

LGTH / CK	MATERIAL	MATL. SPEC.	HEAT TREAT	FINISH	UNIT WT.

RIAL

DYNE ENGINEERING CORP.
900 OLSON MEMORIAL HIGHWAY
MINNEAPOLIS, MINNESOTA

OOR GATE VALVE

A QUICK ACTING
ALVE STUDY

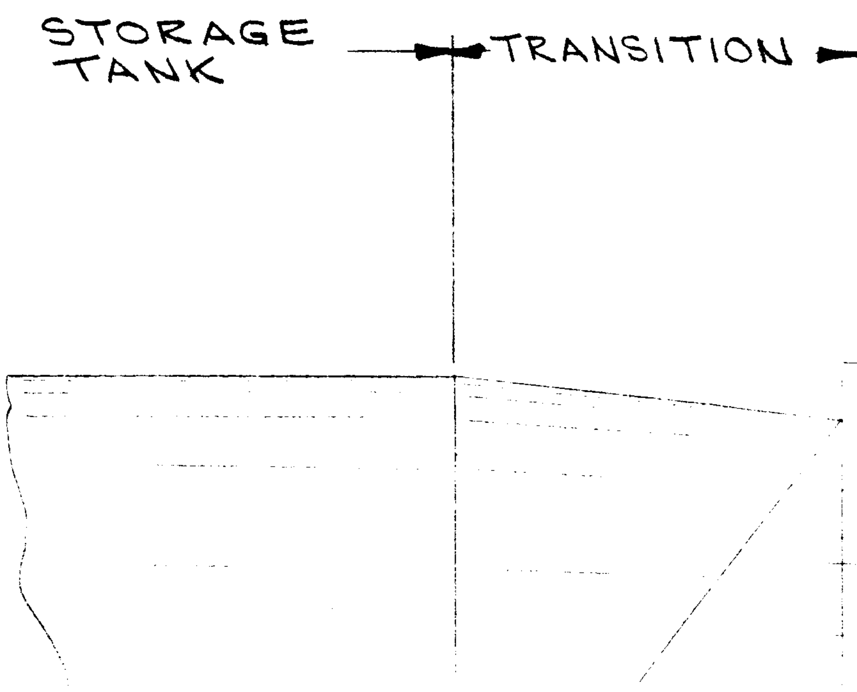
-0" | JOB. NO. 0478

UNLESS OTHERWISE SPECIFIED
TOLERANCES ON
2 PLACE DECIMAL ±
3 PLACE DECIMAL ±
FRACTIONS ±
MACH. ANGLES ±
OTHER ANGLES ±

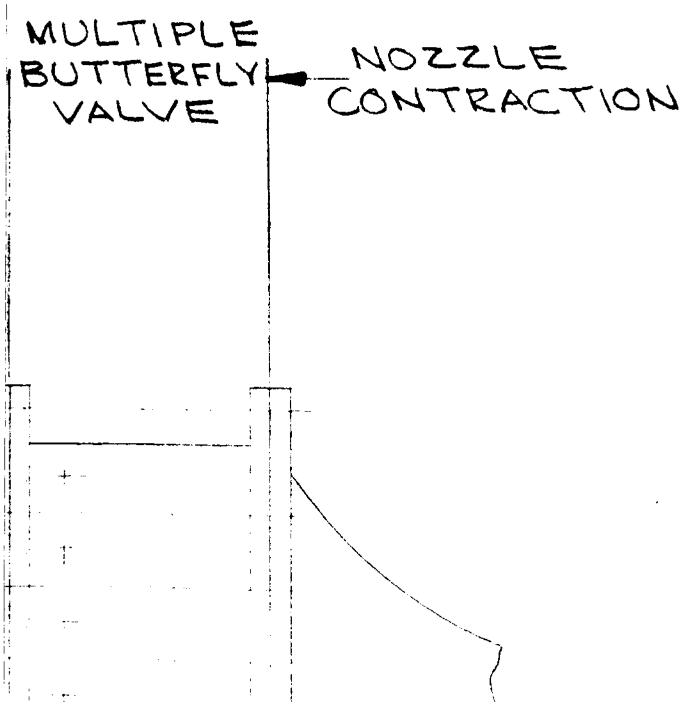
DRAWING NO. 0478-902

REV.

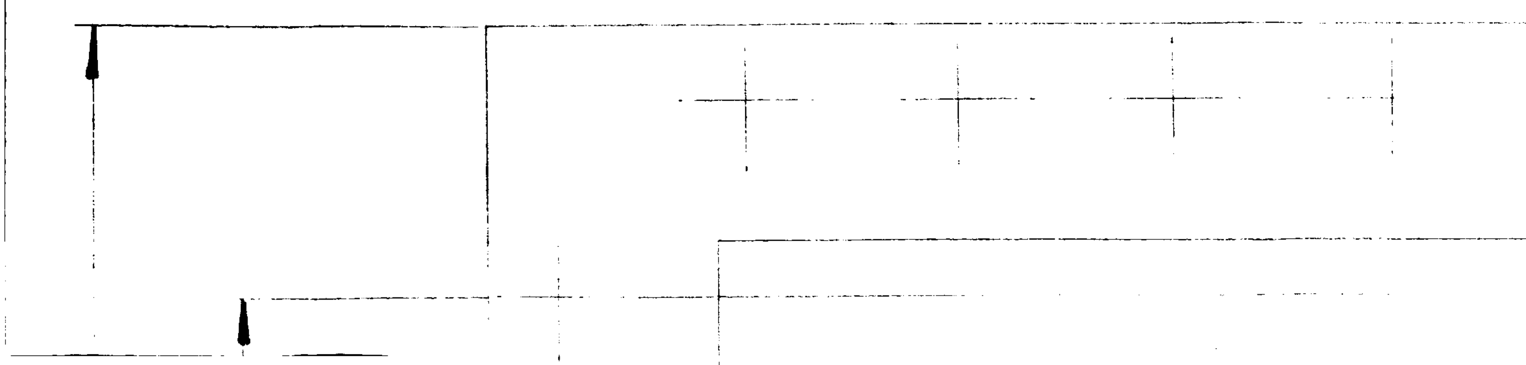
TOP STRIP 1

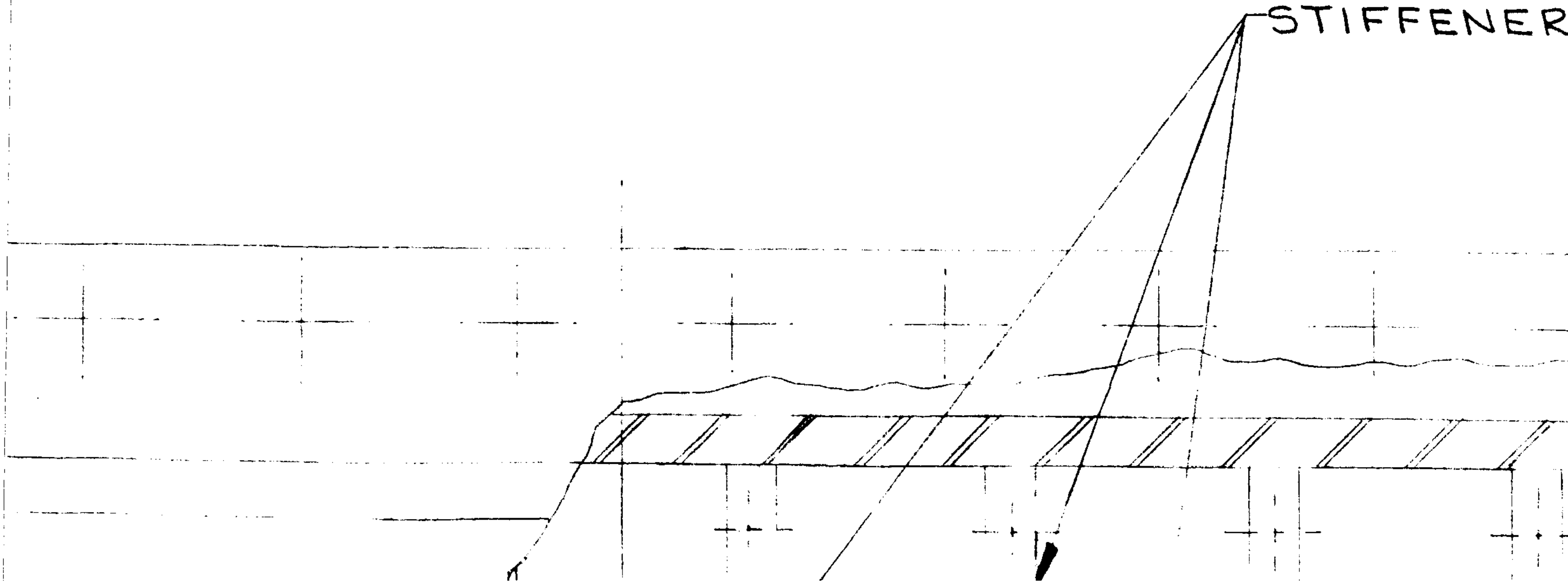


2

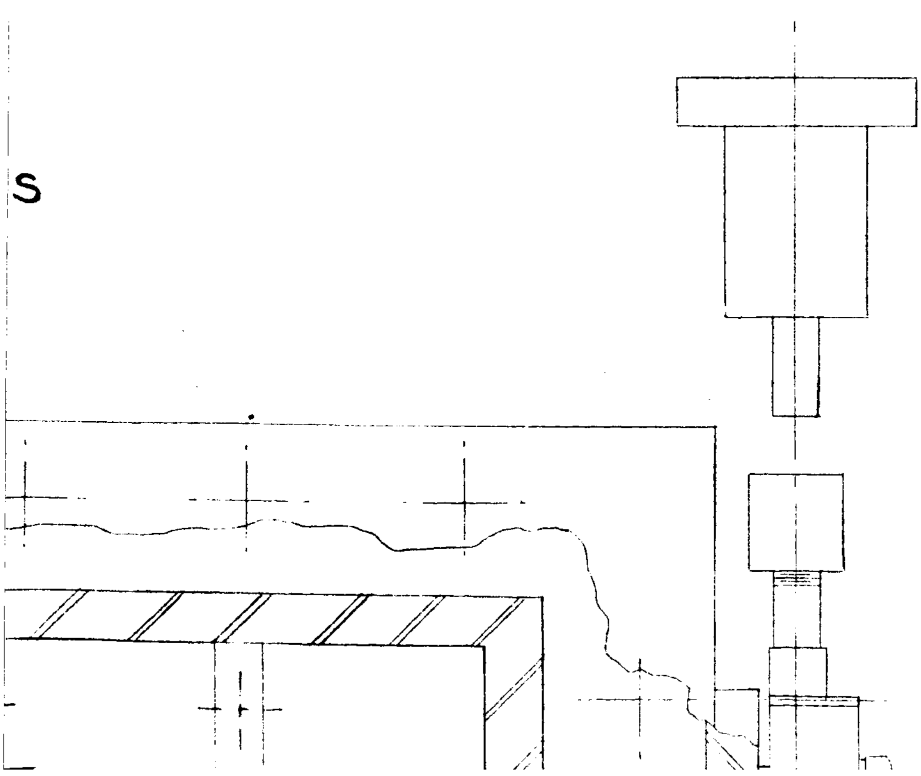


3



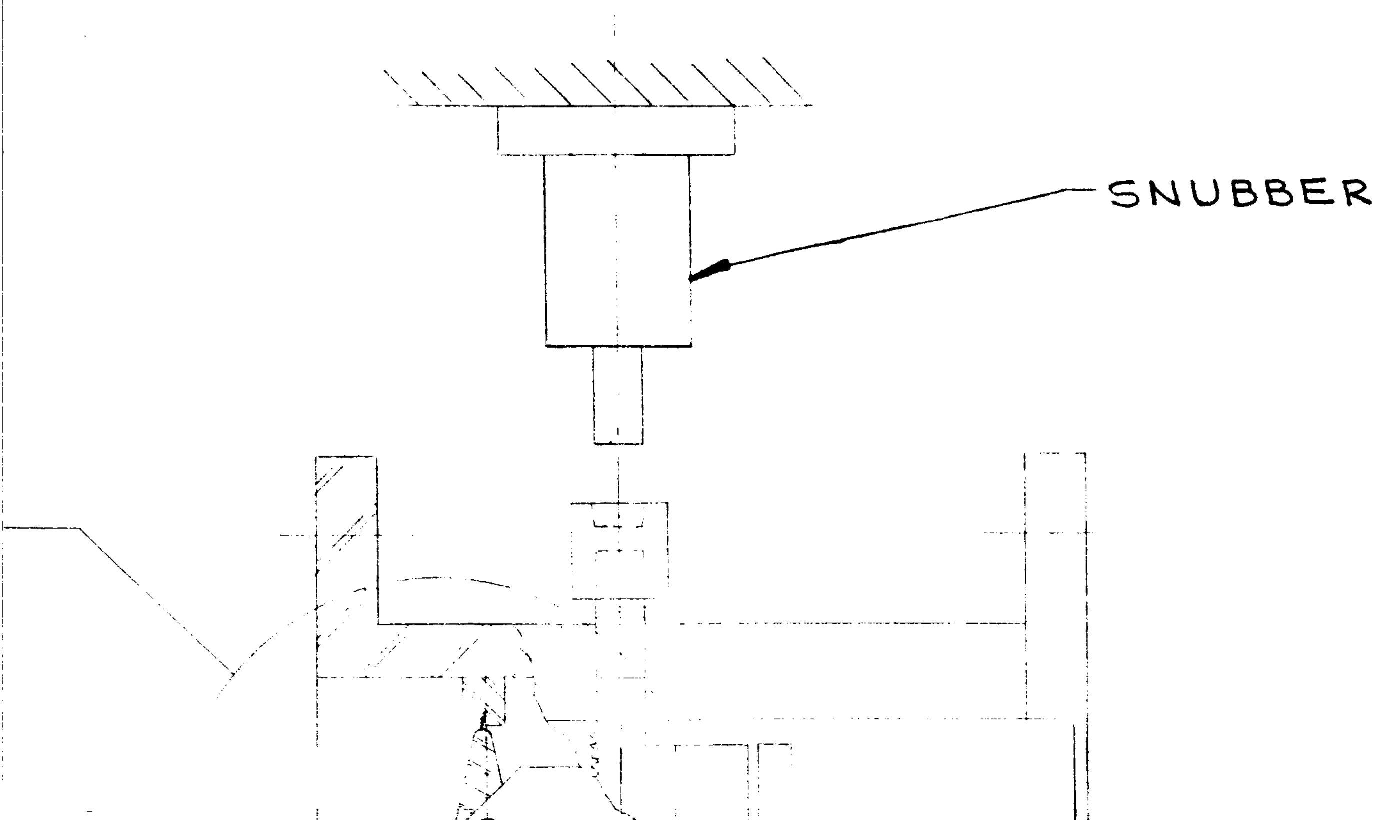

STIFFENER

S

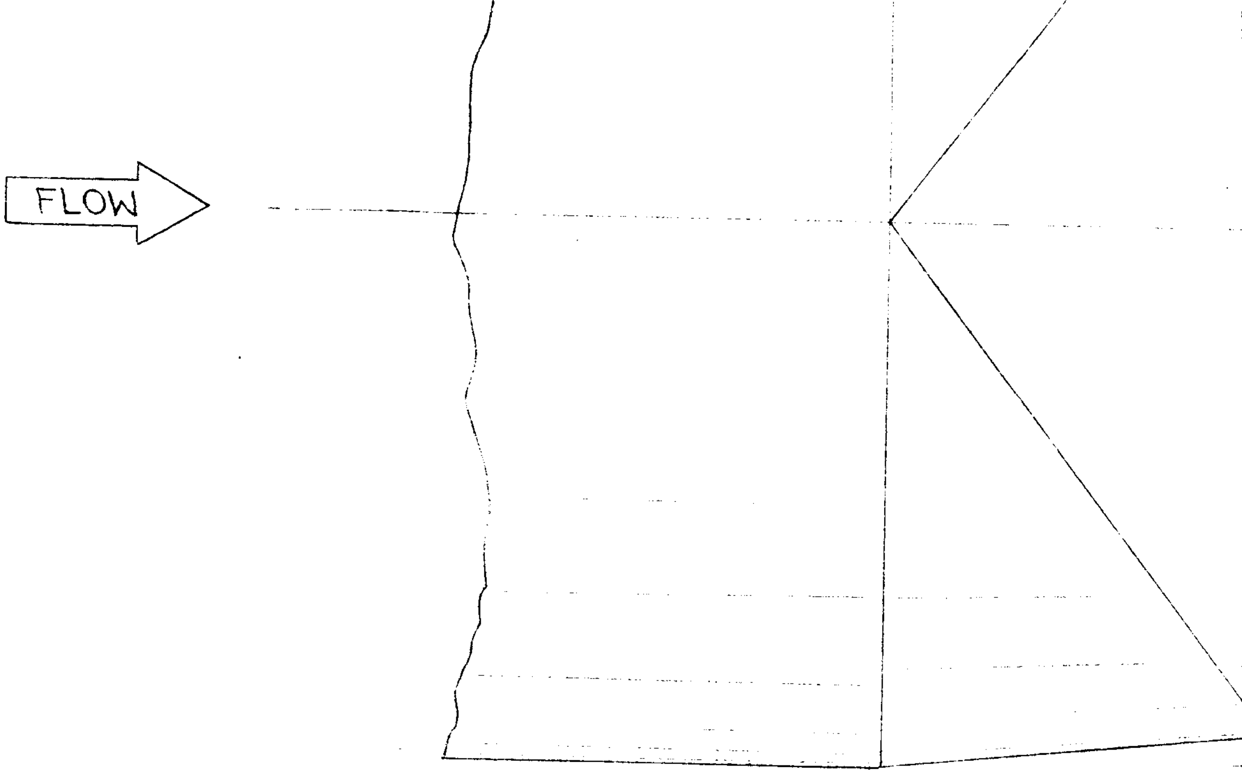


SEE DETAIL B

6

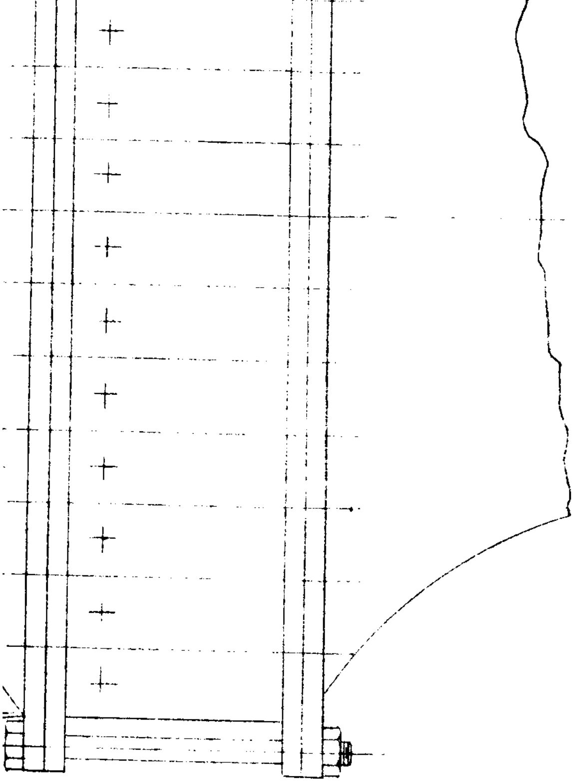


TOP CENTER STRIP



VALVE IN

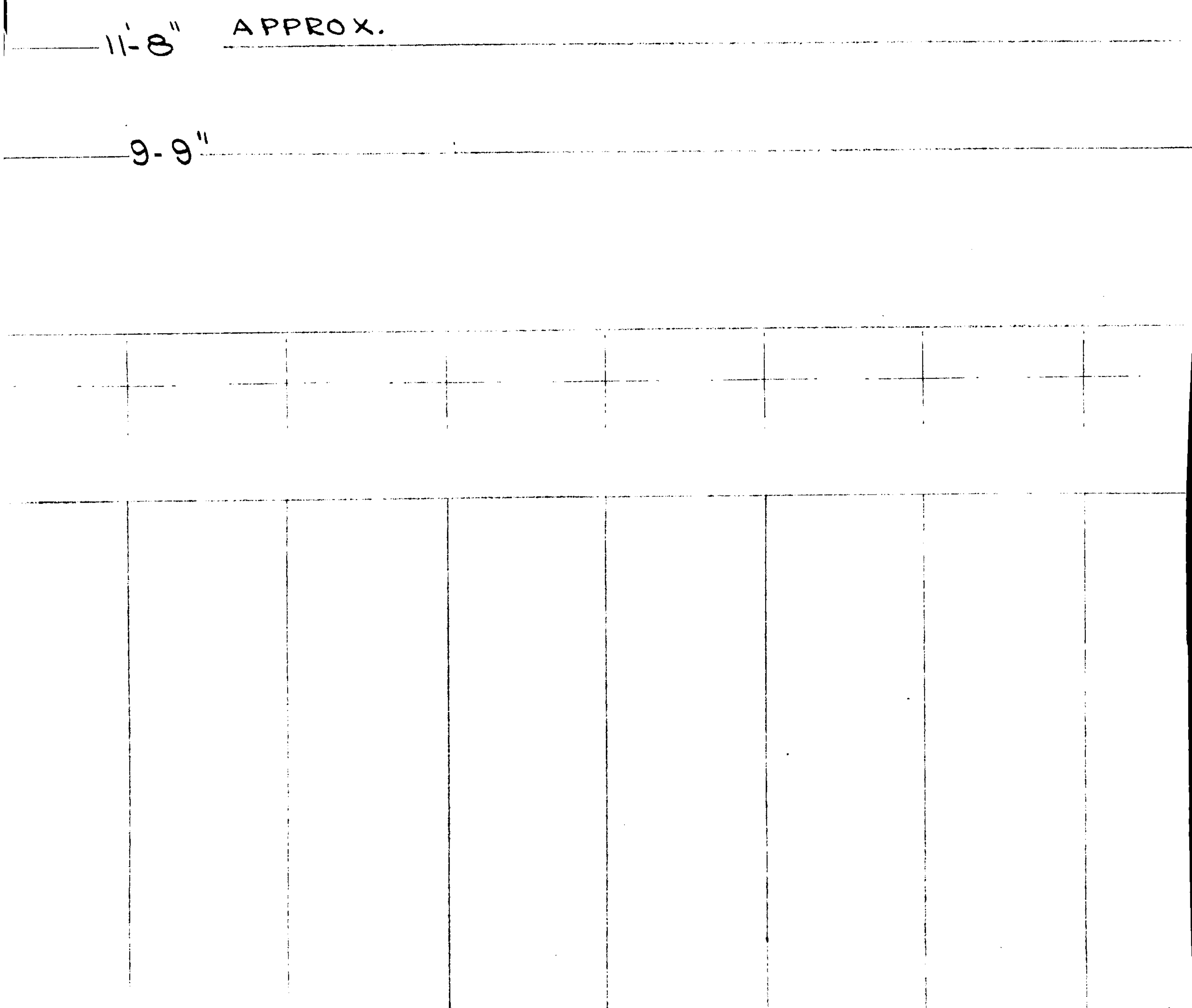
SCALE –



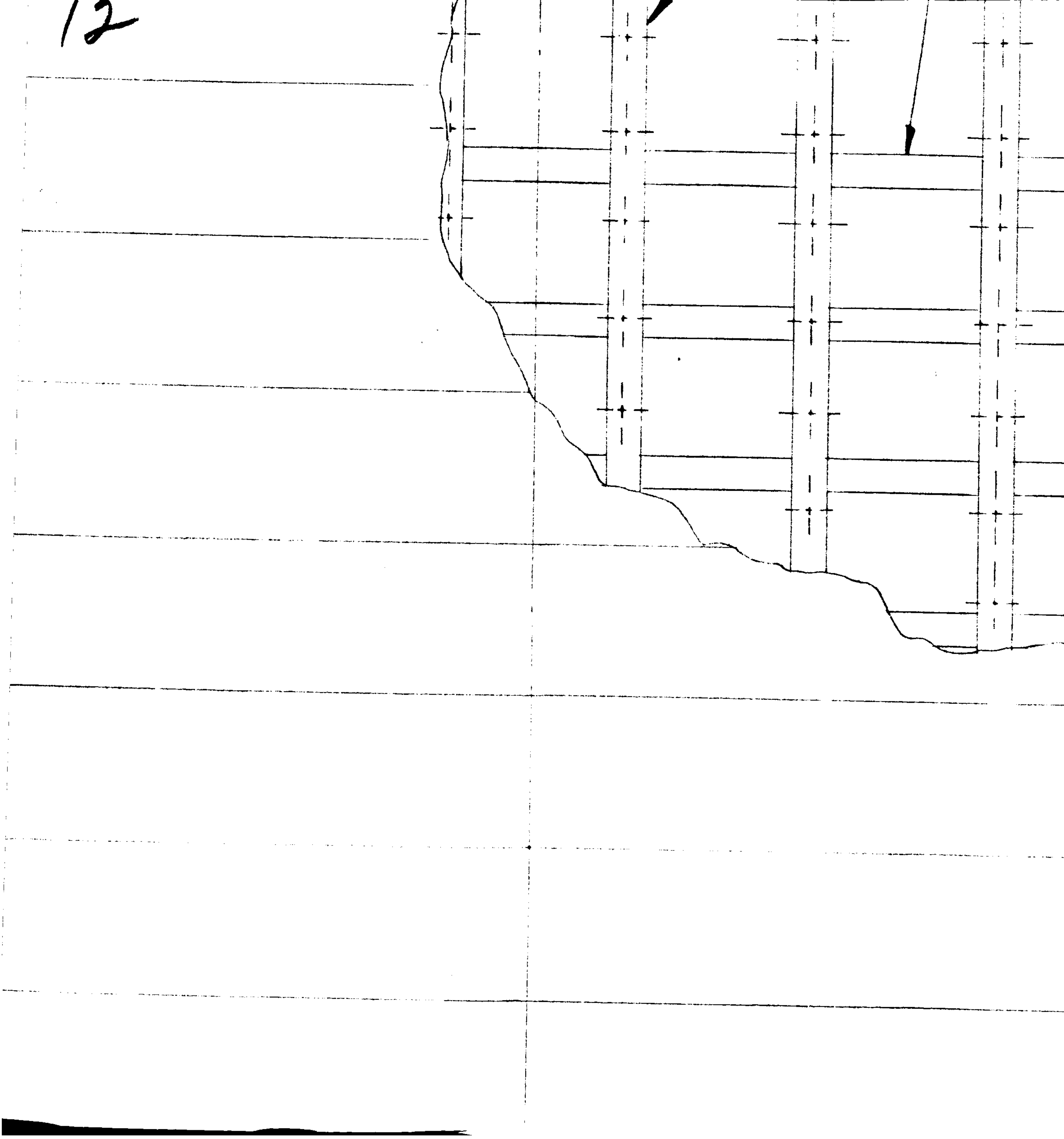
STALLATION

1/2 INCH = 1 FT.

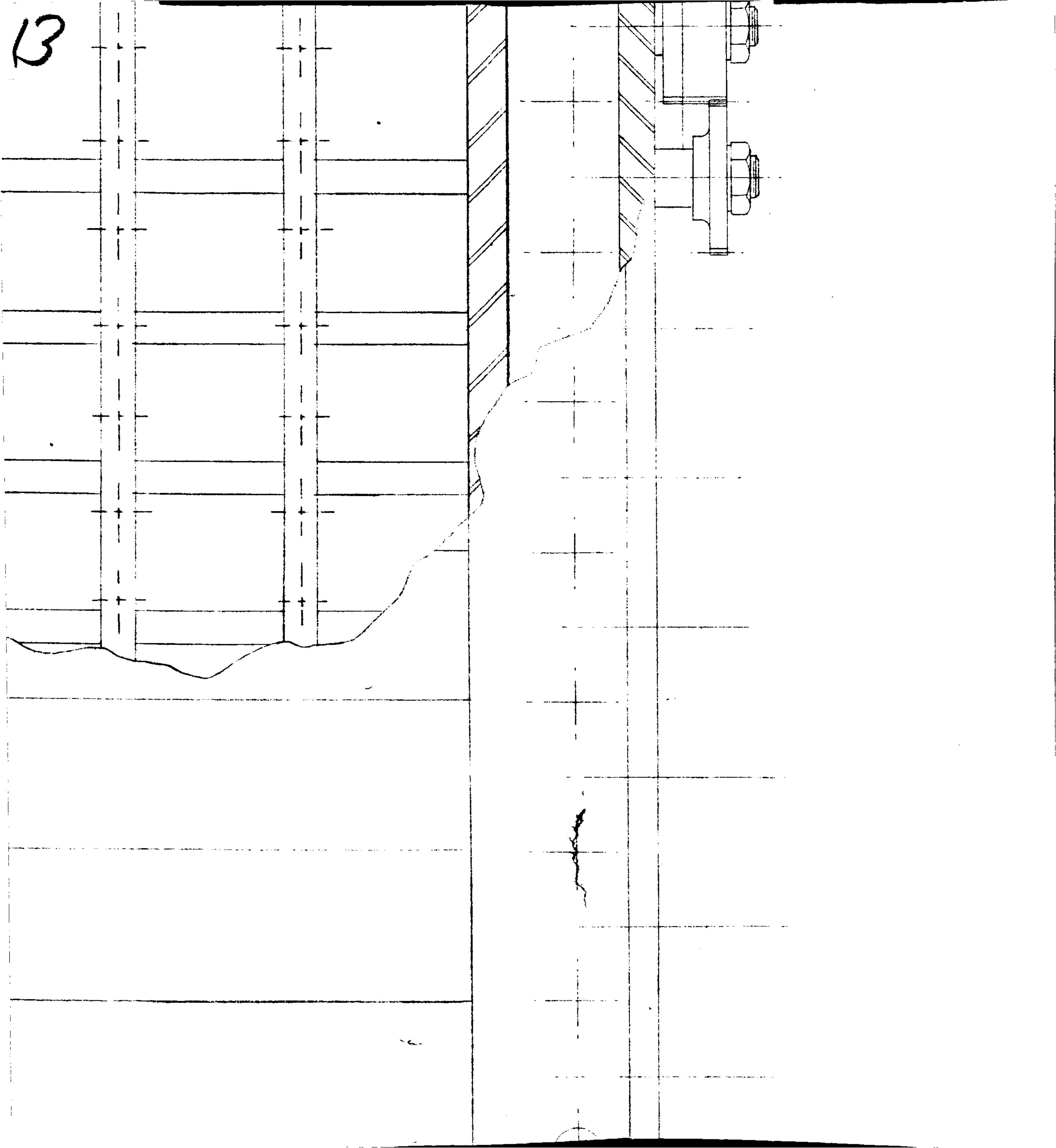
11



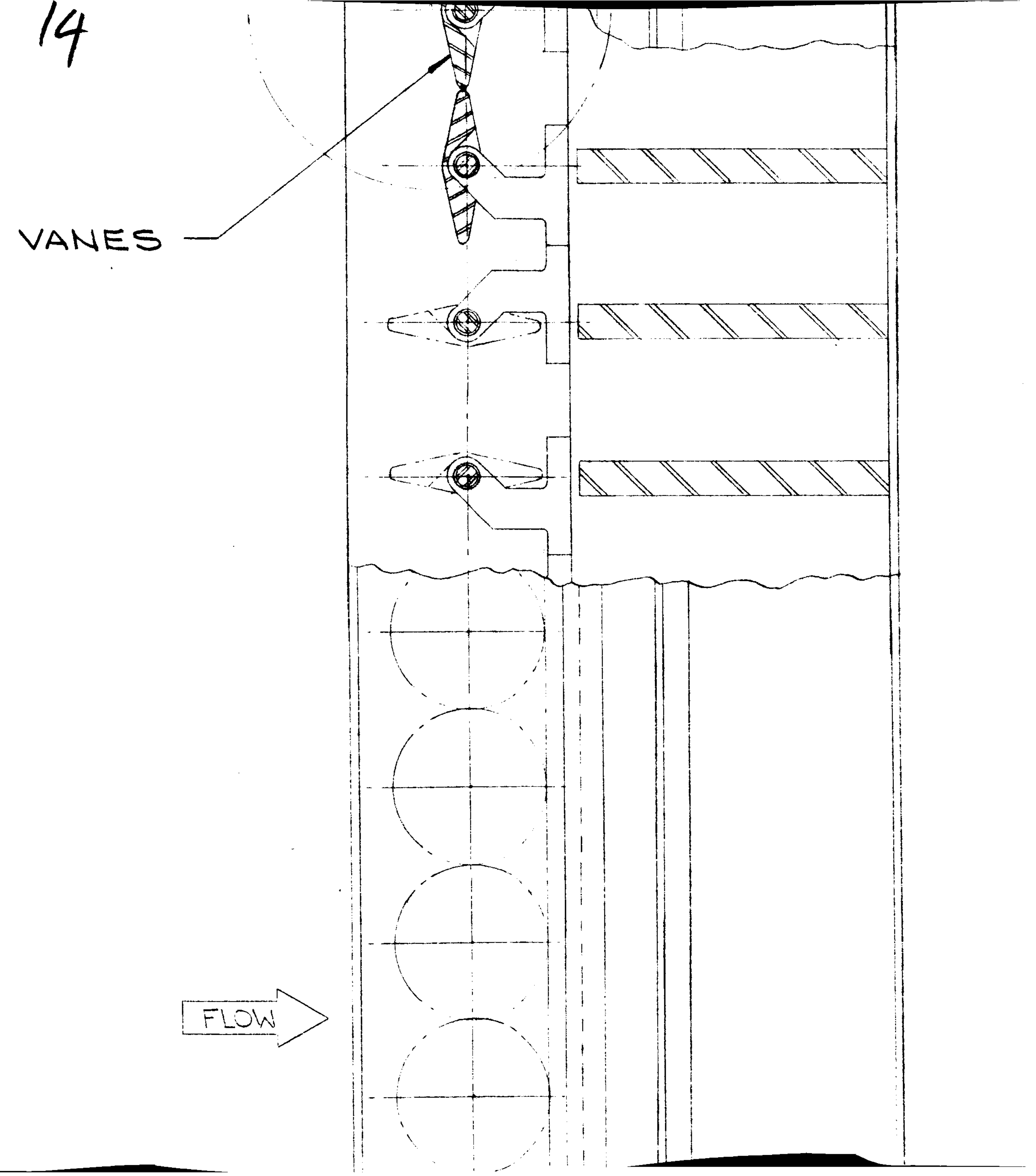
12



13



14

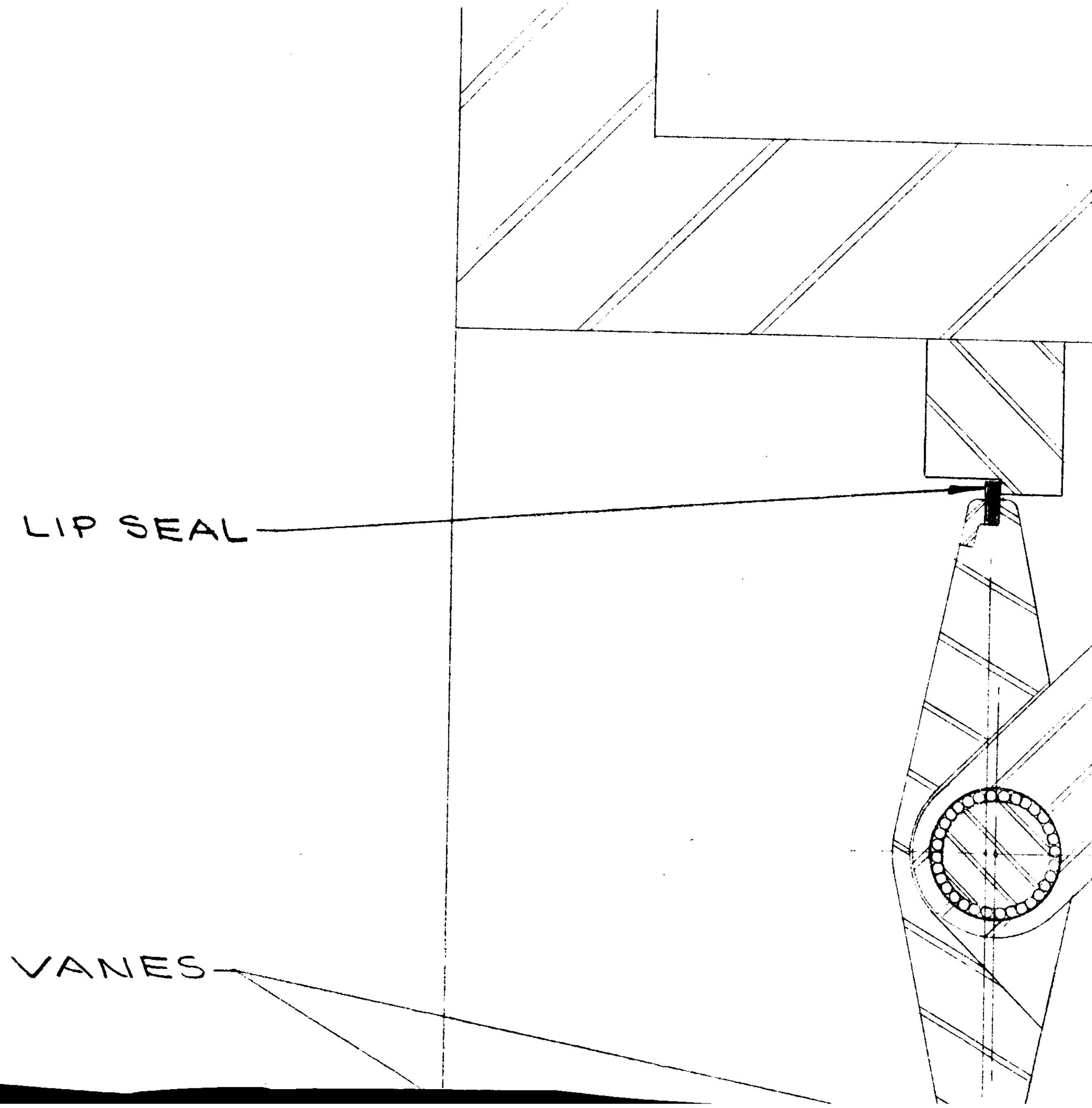


15

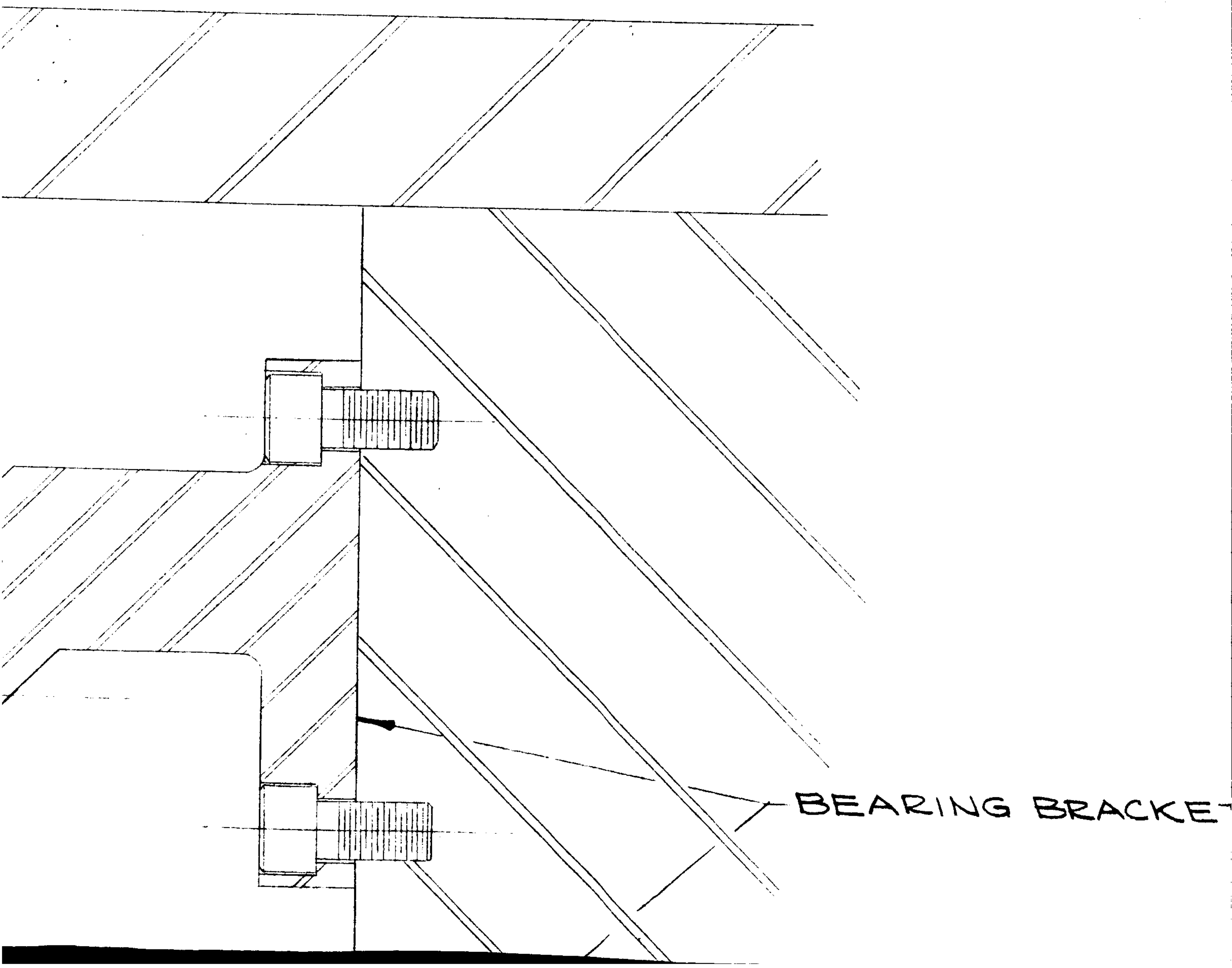
16

17

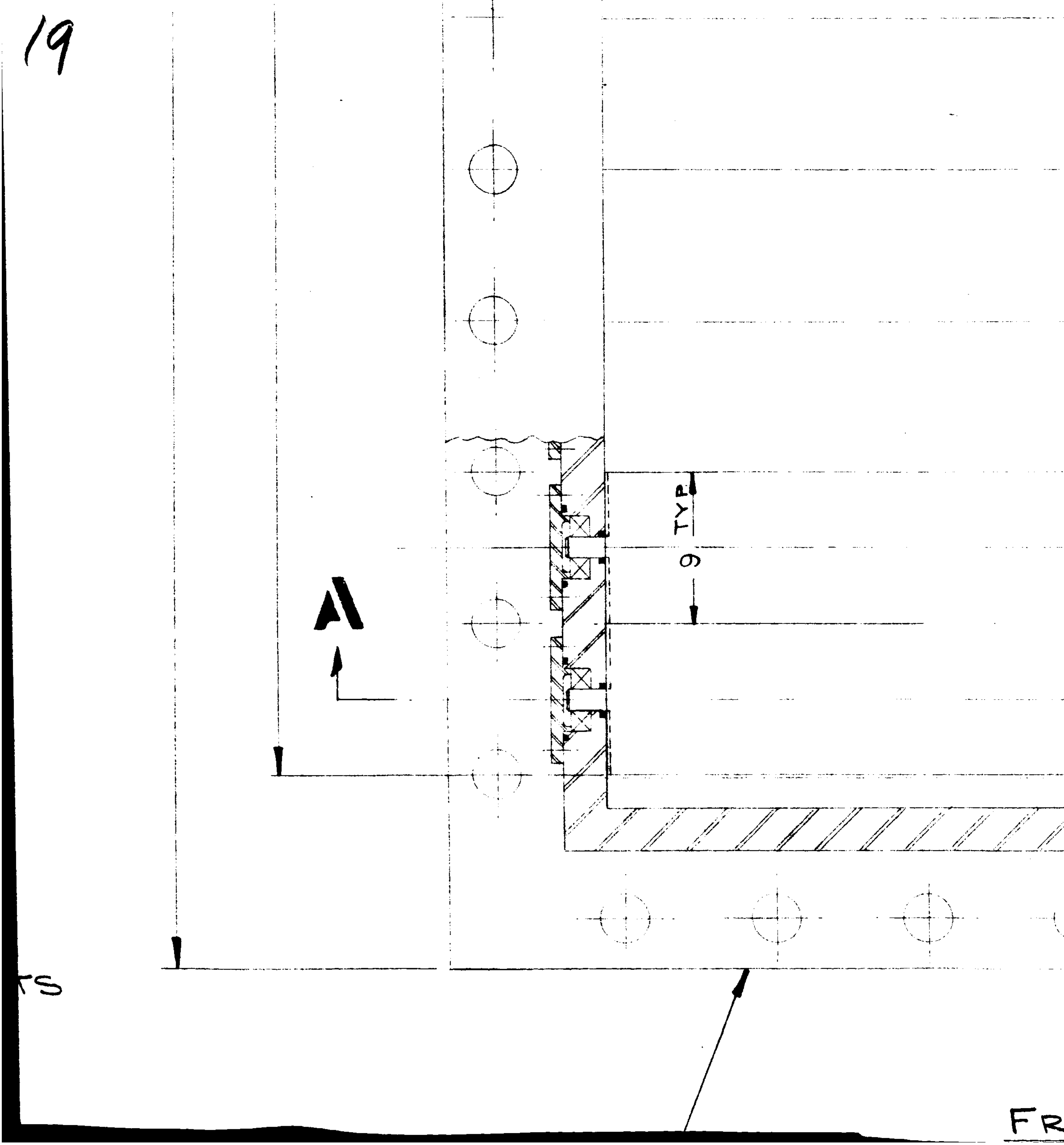
BOTTOM CENTER STRIP



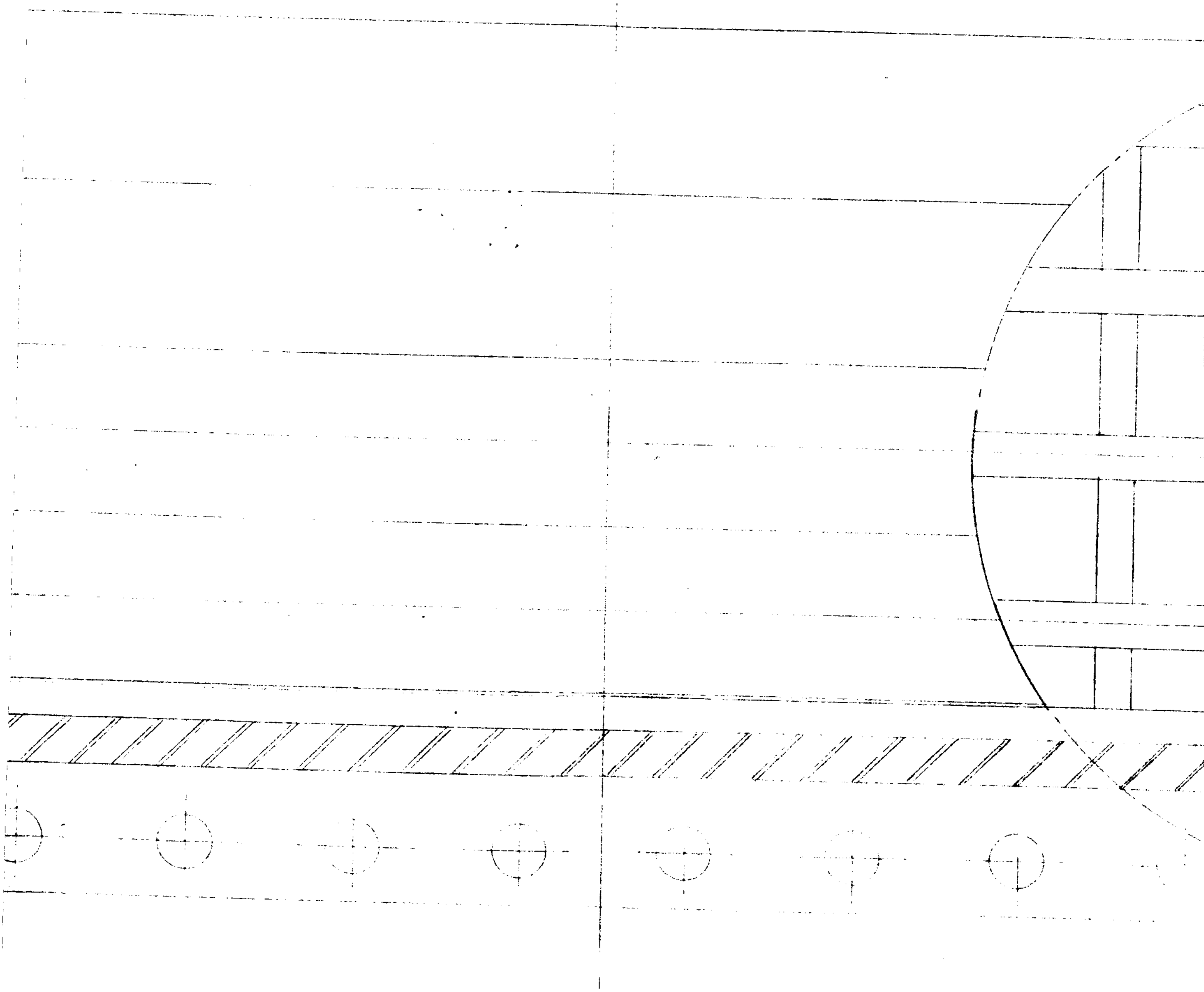
18



19

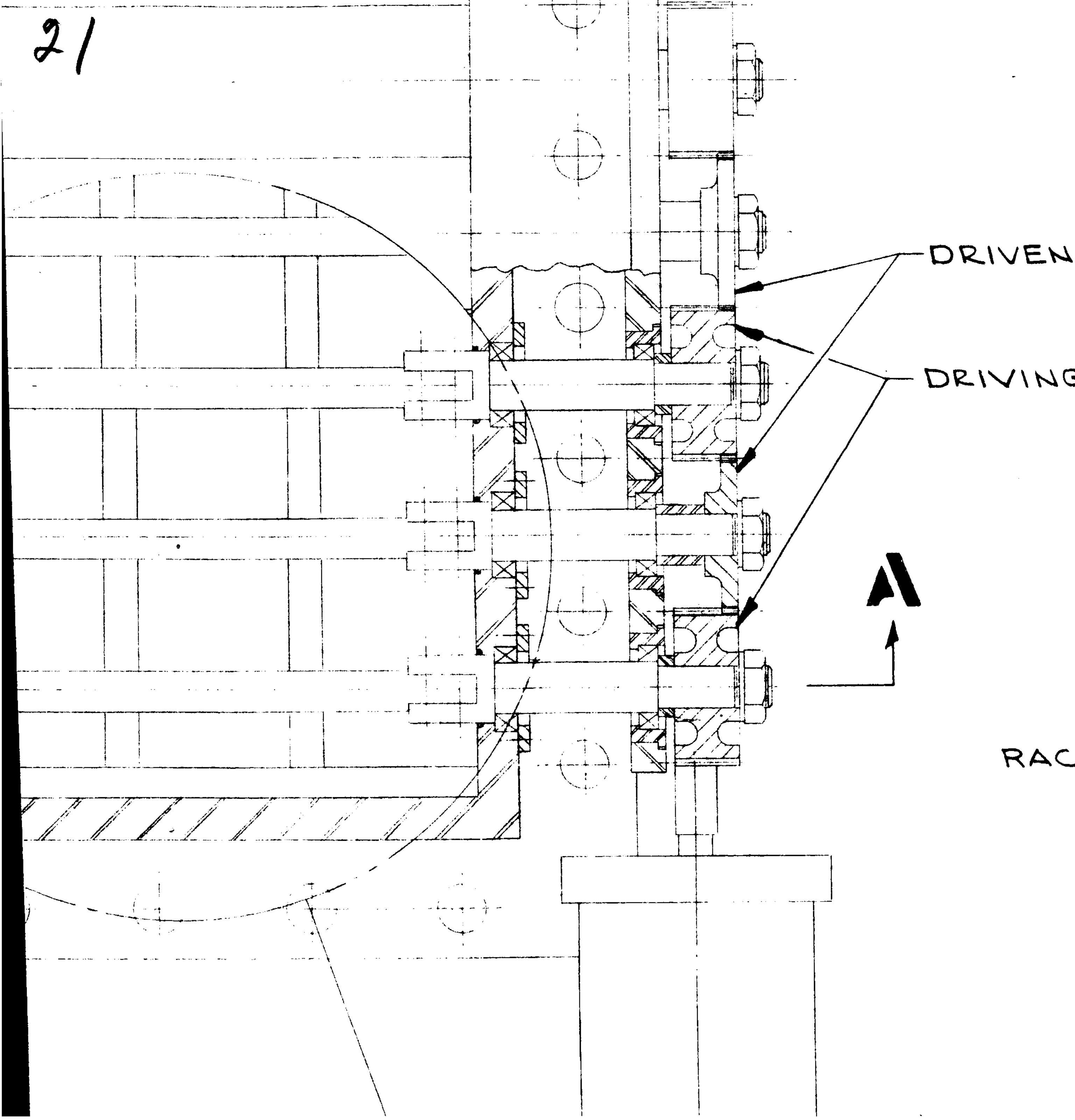


20

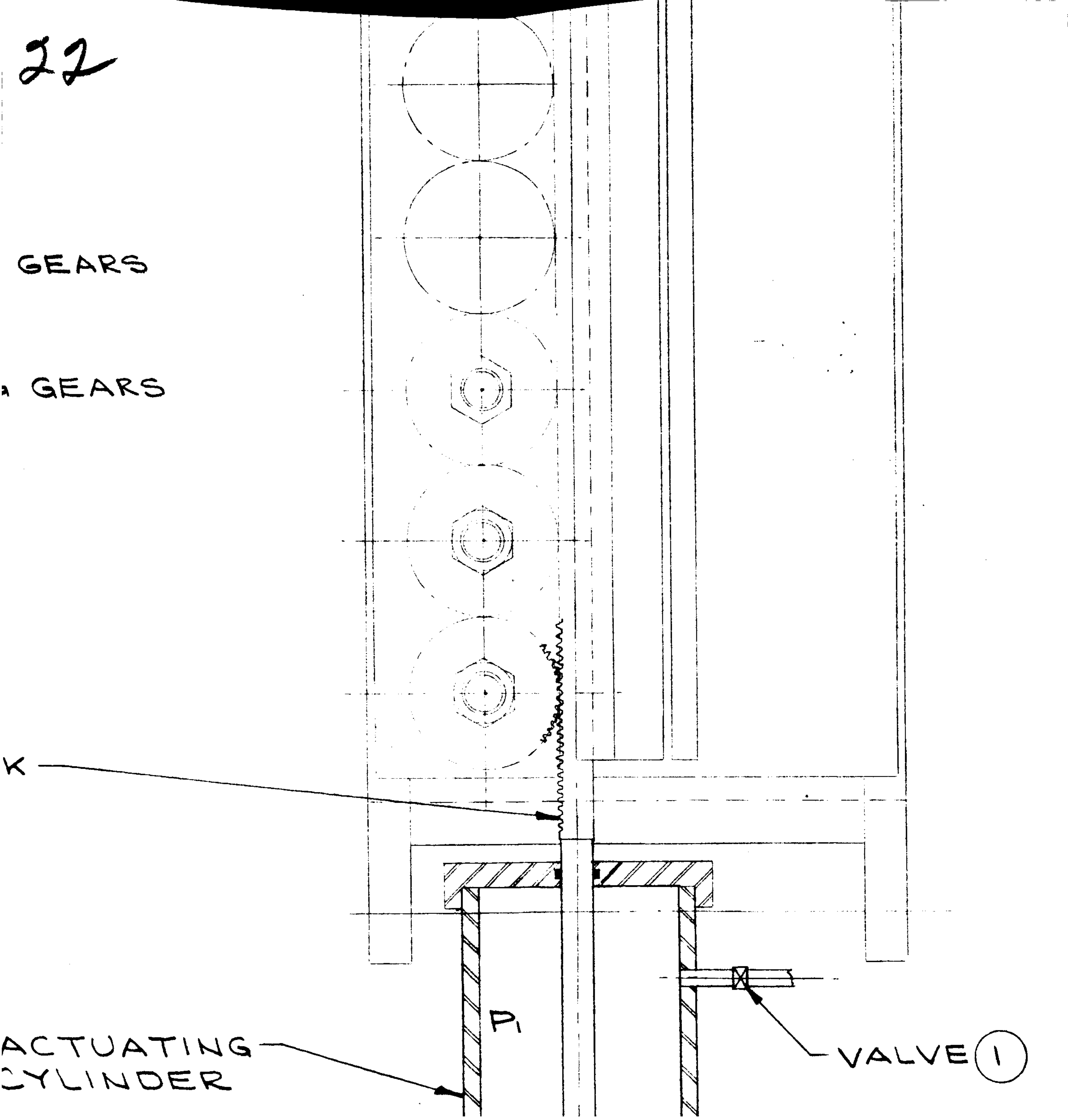


ONTAL VIEW OF VALVE

VANES IN


DRIVEN
DRIVING
A
RAC

22



23

OPERATIONA

STARTING COND

1. MULTIPLE B
2. EXPLOSION
3. VALVE 1 O
4. VALVE 2 C
5. VALVE 3 O

OPENING SEQ

1. PRESSURIZ
2. CLOSE VAL
3. FIRE EXP. BOLTS
MULTIPLE
4. CLOSE VALV

CLOSING SEQUE

1. OPEN VALV
MULTIPLE B

24

L SEQUENCE

ITIONS:

BUTTERFLY CLOSED

BOLTS IN PLACE

PEN

LOSED

PEN

UENCE:

E P_1 TO OPERATING PRESSURE

VE 1

S; PISTON TRAVELS 7" TO OPEN

BUTTERFLY (0.05 SEC.)

E 3 AFTER FULL TRAVEL OF PISTON

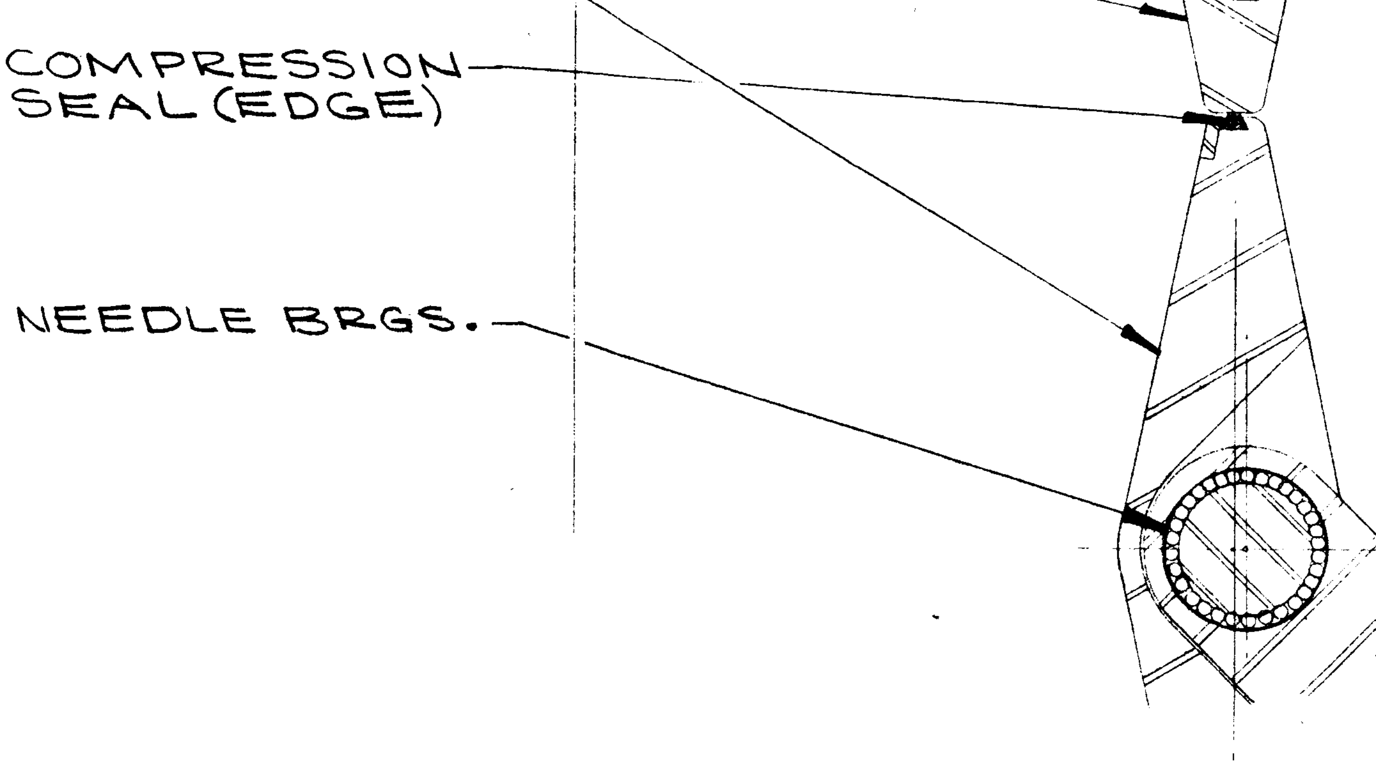
ENCE:

E 2, PISTON TRAVELS 7" TO CLOSE

BUTTERFLY (0.5 TO 1.0 SEC.)

25

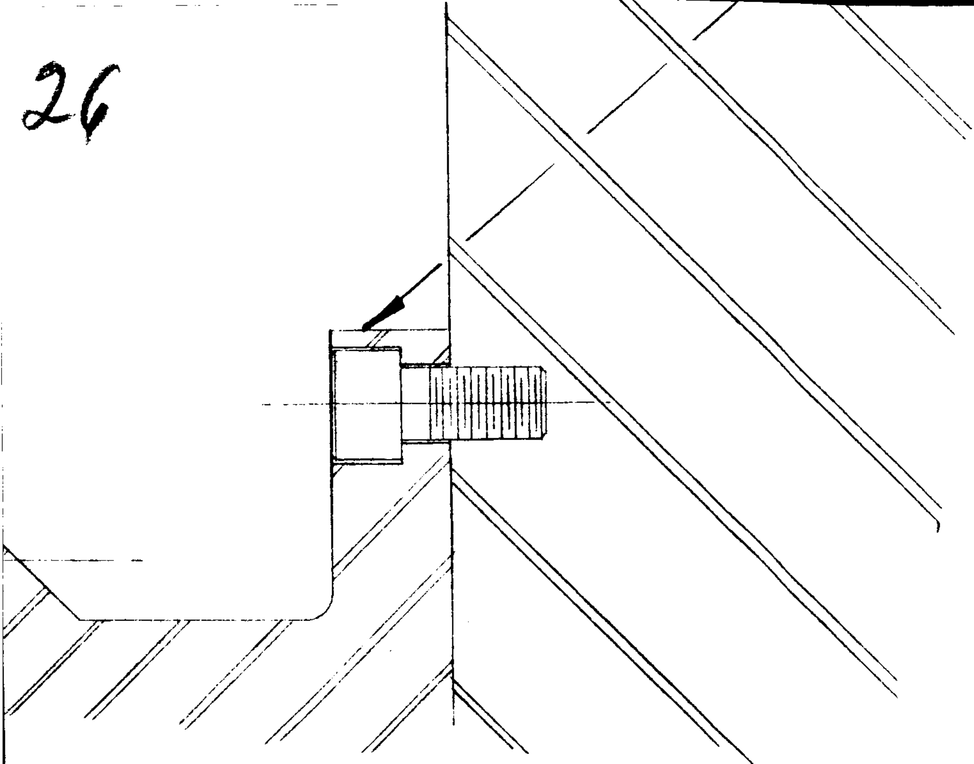
BOTTOM STRIP



D

SC

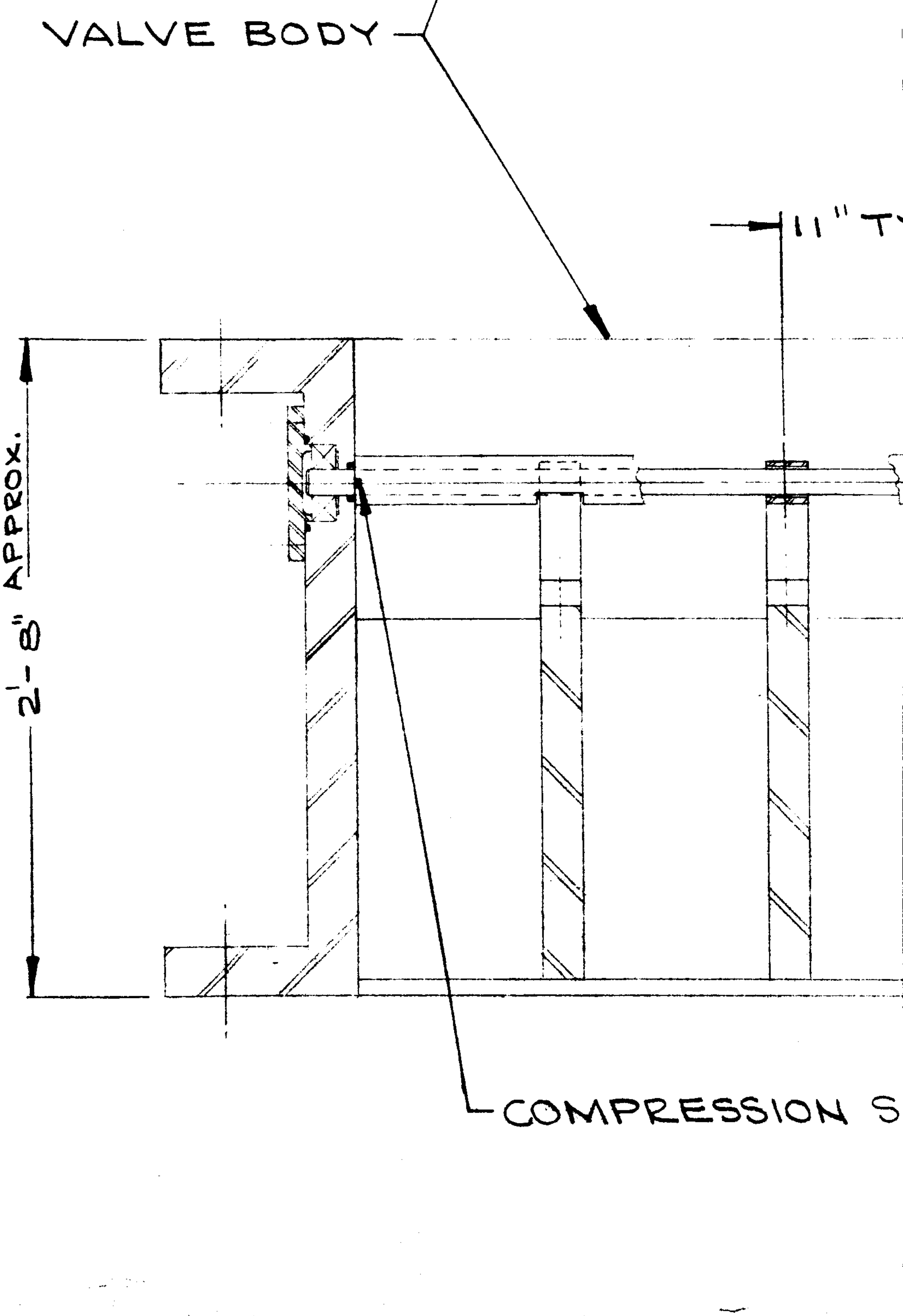
26



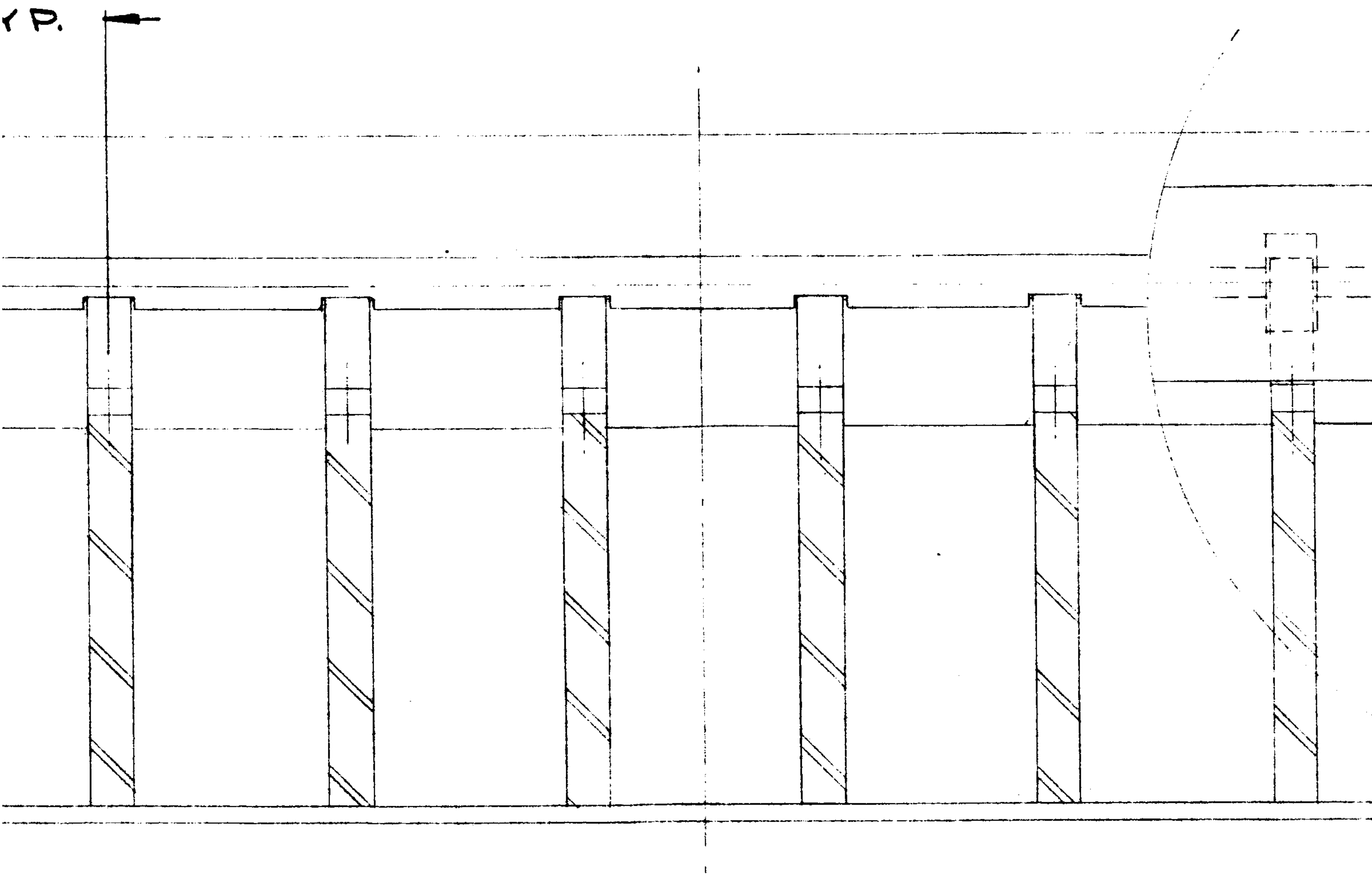
ETAIL B

CALE - HALF

27



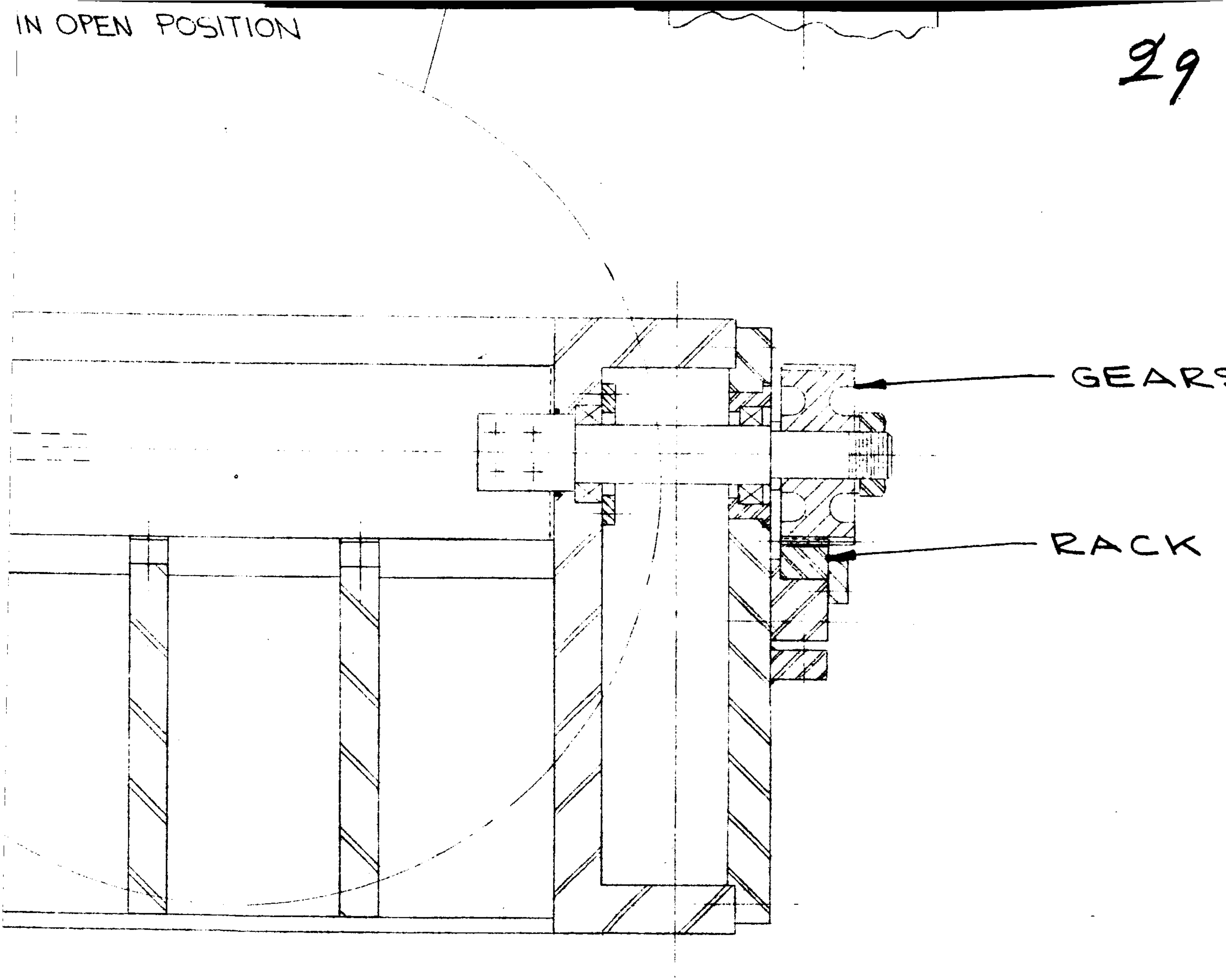
SHOWN



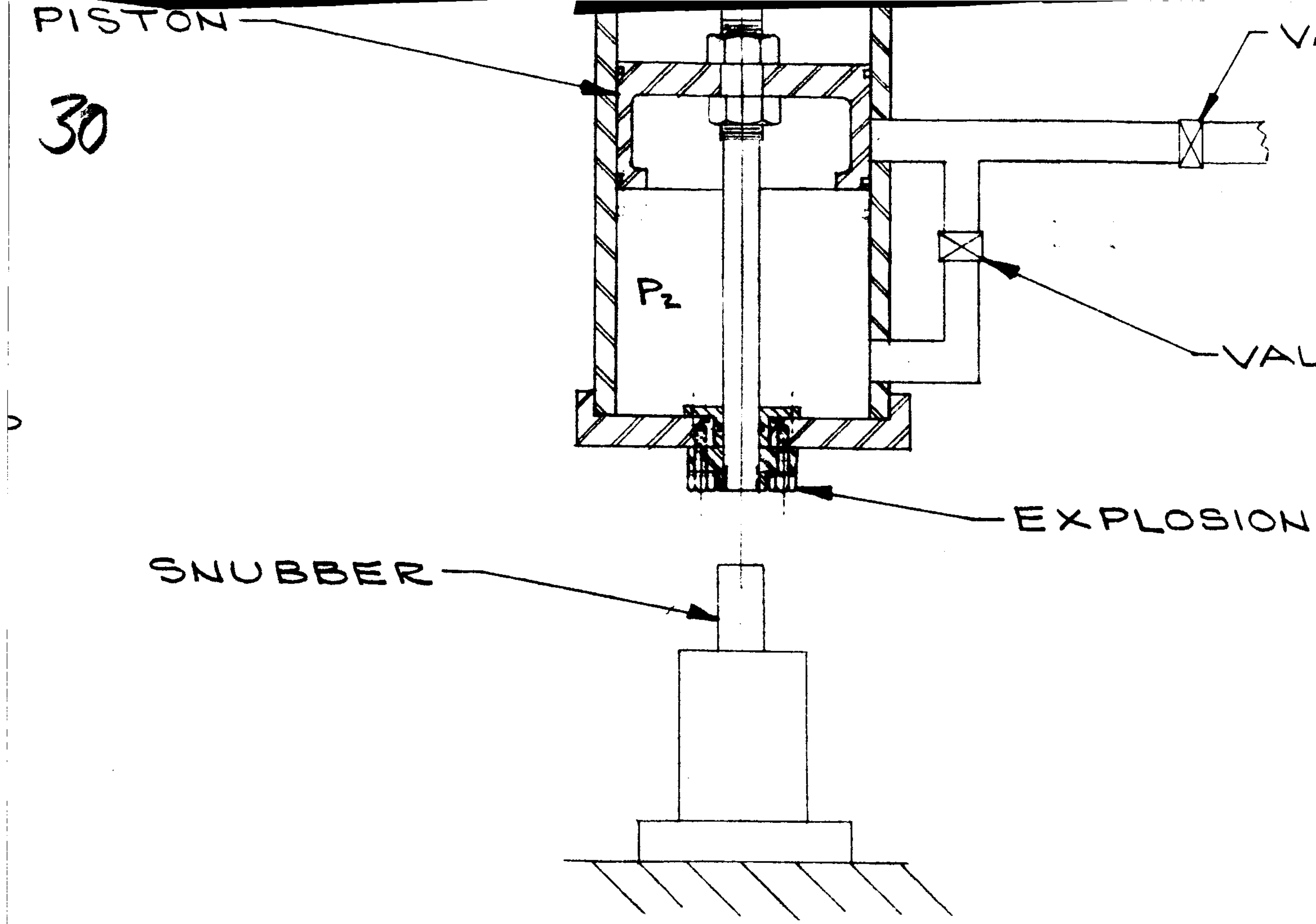
EAL(END)

SECTION A-A

IN OPEN POSITION



30



31

VE(3)

BOLTS

REQ.	ITEM	PART NO.	DESCRIPTION

LI

NEXT ASSY			
	PROG. APPD.		
	ENG. APPD.		
	PROJ. ENGR.	JLG	
	STRESS		
	CHECKED	WBH	
	DRAWN	M.S.S.	
		BY	DA

32

DIA.	THICK	WIDTH	LGTH	MATERIAL	MATL. SPEC.	HEAT TREAT	FINISH	UNIT WT.
NOMINAL STOCK								

ST OF MATERIAL

FLUIDYNE ENGINEERING CORP.
5900 OLSON MEMORIAL HIGHWAY
MINNEAPOLIS, MINNESOTA

TITLE
MULTIPLE BUTTERFLY VALVE

NASA QUICK ACTING
VALVE STUDY

SCALE 1/8" = 1" NOTED JOB. NO 0478.21

UNLESS OTHERWISE SPECIFIED
TOLERANCES ON
2 PLACE DECIMAL ±
3 PLACE DECIMAL ±
FRACTIONS ±
MACH. ANGLES ±
OTHER ANGLES ±

DRAWING NO. 0478-901
REV.

CUT HERE GUARANTEED 12-64