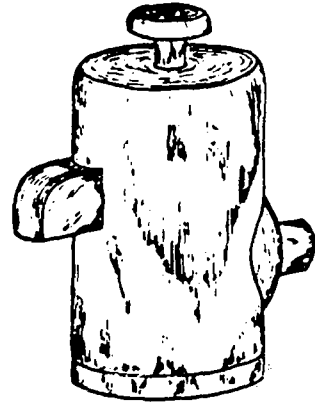
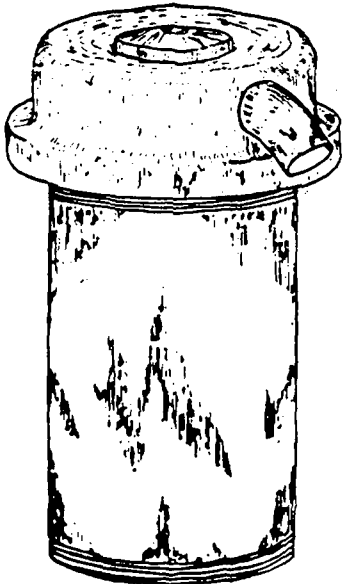


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# FINAL REPORT ON THE DEVELOPMENT AND TESTING OF THE ROBOVALVE

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FINAL REPORT  
on the  
DEVELOPMENT AND TESTING OF THE ROBOVALVE

Prepared for  
The U.S. Agency for International Development

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## TABLE OF CONTENTS

SUMMARY . . . . .	iii
INTRODUCTION . . . . .	1
DESCRIPTION OF THE ROBOVALVE . . . . .	6
EXPERIMENTAL WORK . . . . .	10
Sealing and Wear Characteristics . . . . .	10
Valve and Seat Assembly Housing-Casing Design . . . . .	18
Robovalve - Public Hydrant on Stand Pipe. . . . .	19
Robovalve - House or Yard Connection . . . . .	20
Additional Experimental Work . . . . .	20
ROBOVALVE MANUFACTURING . . . . .	22
Public Hydrant or Stand Pipe Robovalve . . . . .	22
Yard or Household Robovalve . . . . .	24
Water Container Robovalve . . . . .	25
CONCLUSIONS AND RECOMMENDATIONS . . . . .	29

### TABLES

I. Wear Characteristics of Valve and Seat Assemblies (Sharp-Edged Valve Seat) . . . . .	13
II. Leakage of Valve and Seat Assemblies (Sharp-Edged Valve Seat) . . . . .	15
III. Wear Characteristics of Valve and Seat Assemblies (Bevelled Valve Seat). . . . .	17
IV. Leakage of Valve and Seat Assemblies (Bevelled Valve Seat). . . . .	17

## TABLE OF CONTENTS

### FIGURES

1. Public Hydrant Robovalve . . . . .	4
2. Private Household or Yard Connection Robovalve . . . . .	5
3. Cross Section of Public Hydrant Robovalve . . . . .	8
4. Cross Section of Private Household Robovalves . . . . .	9
5. Robovalve Testing Apparatus . . . . .	11
6. Robovalves Undergoing Testing . . . . .	11
7. Plastic Water Container Robovalve . . . . .	26
8. Cross Section of Water Container Robovalve . . . . .	27

### APPENDICES

A. Review of Plastic and Elastomer Materials . . . . .	31
B. Public Hydrant Robovalve - Working Drawings . . . . .	42
C. Household or Yard Robovalve - Working Drawings . . . . .	52
D. Plastic Water Container Robovalve - Working Drawings . . . . .	58
E. Photographic Presentation of Robovalves . . . . .	65

## SUMMARY

A new valve, Robo valve, made almost entirely of P.V.C. has been developed and tested in the laboratory for wear and leakage. Valves that have been operated approximately 350,000 cycles show almost no wear and good sealing characteristics resulting in essentially zero volume leakage.

Three Robo valve project designs are proposed for:

- (1) a public hydrant or stand pipe,
- (2) a household or yard tap, and
- (3) a tap for plastic water containers.

The valves can be manufactured from standard P.V.C. stock or by injection molding. The cost of material and labor for machine shop production of the above valves rule out this production method for large numbers of valves. It is estimated that the cost per valve using injection molding process will be approximately \$1.00 to \$1.25 for the public hydrant valve, \$0.75 to \$1.00 for the household valve, and \$0.65 to \$0.75 for the water container valve. The cost, however, of die development and production which may be substantial is not reflected in the above estimated costs and will probably be borne by interested government units or entrepreneurs interested in local manufacture and sale possibilities.

## INTRODUCTION

In many urban and rural areas of the world, water is supplied by means of distribution pipes and a public hydrant or private house connection hydrant. With anticipated increase in water resources development in rural areas of LDC's, the demand for faucets/valves for dispensing water will significantly increase. Various types of faucets/valves for dispensing water from public or private hydrants are presently in use. Generally, these valves represent a cross section of the equipment used in developing countries. Because a public hydrant may be the only source of water for thousands of people, the valves in such hydrants are subjected to extremely intensive use.

The bulk of the present faucets/valves are made of brass, bronze, or other metals. Typically, such valves include rubber or neoprene washers, springs and other components which tend to wear out quickly under intensive use. Even if replacement parts are available and someone is in charge of repairing the water dispensing devices, such devices are generally not suitable for use in LDC's. Most faucets/valves require the user to turn a handle in order to stop the flow of water. In most areas where water from a public stand pipe is obtained free of charge, the users lack the incentive to turn off the faucet. In addition, water dispensing devices made of brass or containing brass components have a certain monetary value because the brass can be melted and fashioned into jewelry, ornaments, etc. Replacement parts

generally are not available in rural areas, and in many cases the knowledge or the personnel to repair the valve is not readily available. Thus, many valves fail after a short period of operation, leading to waste of precious water, as well as an unhealthy environment in the vicinity of the hydrant due to continuous flow of water on the ground, where, typically, no adequate drainage system is usually provided. Puddles of stagnant water near a public hydrant are breeding grounds for various diseases, such as malaria, etc. Moreover, such an environment appeals to small children and domestic animals, thus increasing the health hazards.

The Fordilla valve was specifically developed for use in LDC's. It was, however, intended for use by a family or a small group of users, e.g., private house connection, and not as a valve for a public hydrant. The Fordilla valve which has had limited success in some countries in Latin America, is rugged and dependable, but is mechanically complicated, expensive (\$18.00-\$22.00), and spare parts are not readily available. To operate the Fordilla valve, the user depresses a spring loaded shaft which opens the valve and allows water to flow. The valve shuts off automatically after a certain volume (1-2 liters) has been dispensed. To obtain more water, the user must again depress the valve. For users who come to a public hydrant to fill containers of a volume from 2-5 gallons, the water drawing process can be frustrating. Thus, it is not uncommon for users under such circumstances to remove or break the valve so that they can get a continuous flow of water.

Review of the water dispensing mechanisms in LDC's suggests that there is an urgent need for a low cost, locally manufacturable, essentially leak-proof heavy duty faucet/valve for both public and private hydrants. Such valves should be self-closing, should not have any significant parts which wear out under intensive use, and should have components which have low monetary value and would not be subjected to pilferage.

The objectives of this research and development project were to develop and test a faucet/valve which answers to the above requirements and can be used in public stand pipes, as well as in private yard or home connections. The valve should be simple to operate, rugged, reliable with an absolute minimum of moving parts, essentially leak-proof, and capable of local manufacture in the LDC's. The valve developed, Robovalve, appears to answer most or all of the above demands. Typical Robovalves for public hydrants and private taps are shown in Figures 1 and 2, respectively.



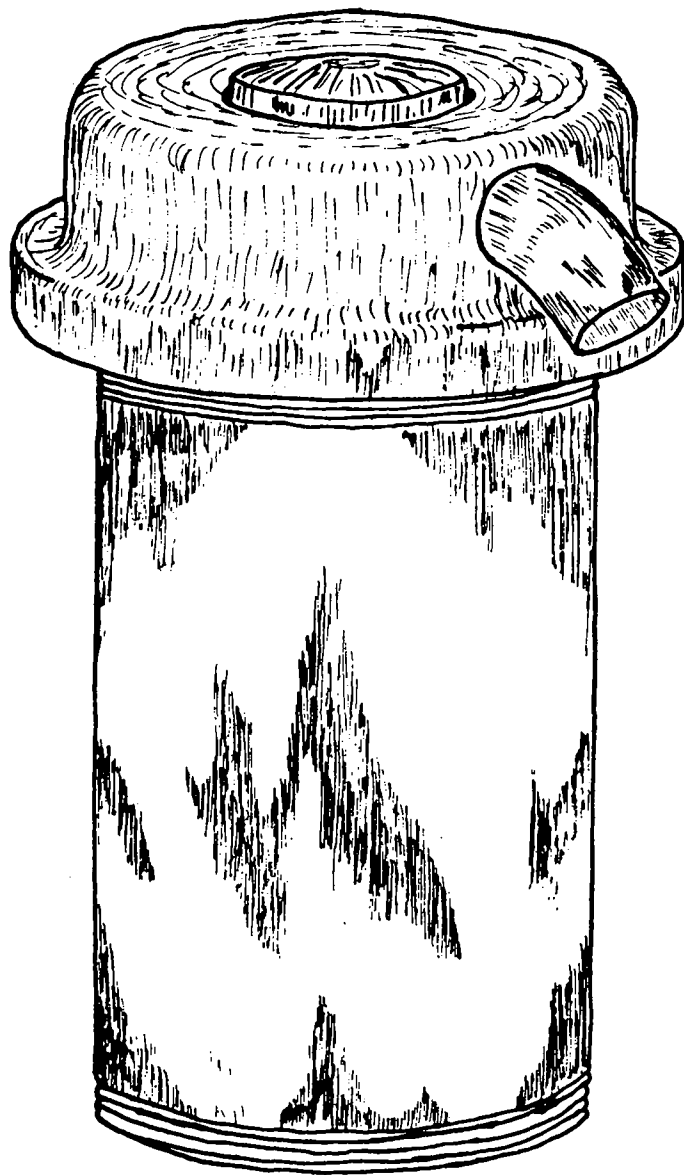


FIGURE 1. PUBLIC HYDRANT ROBOVALVE

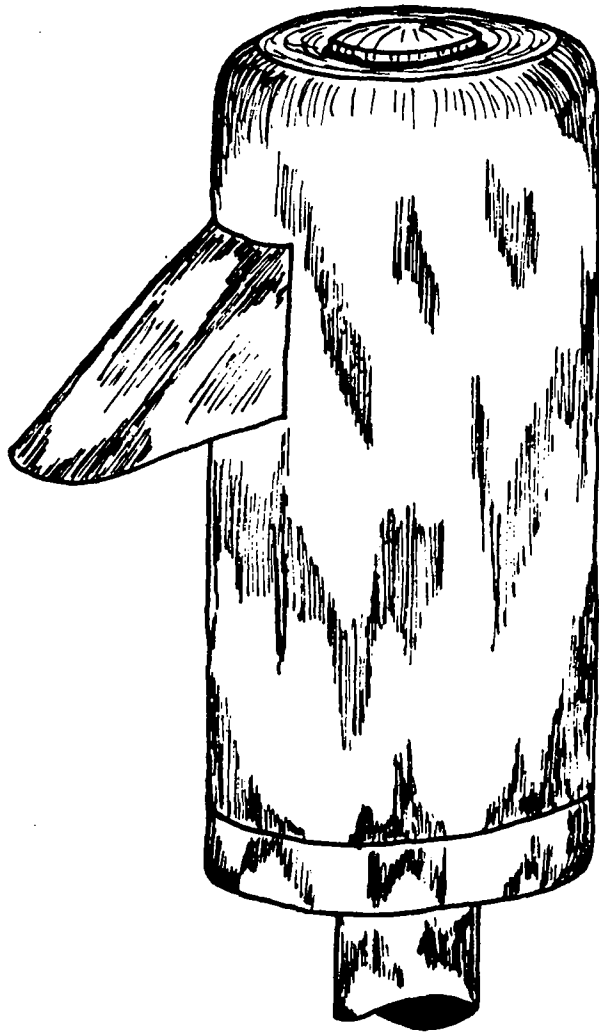


FIGURE 2. PRIVATE HOUSEHOLD OR YARD  
CONNECTION ROBOVALVE

## DESCRIPTION OF THE ROBOVALVE

Robovalve is constructed entirely of P.V.C. The valves can be machined out of P.V.C. stock, or produced by injection molding. Most LDC's have the capabilities of extruding or injection-molding P.V.C.

The initial research work was directed toward the development of one valve for both public hydrant and private connection. Subsequent development work resulted in two distinct versions of the Robovalve, satisfying the different users' requirements relating to public and private connections. The principle of operation, described below, is the same for both types of Robovalves.

Robovalve, as shown in Figures 3 and 4, has two major components: the float valve, and the casing which houses the valve seat. The Robovalve assembly, which is similar for both public hydrant and private taps, is a P.V.C. housing with a water chamber and a valve seat. The float valve is a hollow P.V.C. cone mounted on a length of P.V.C. rod which travels in the guide, provided in the casing.

The concept of the Robovalve is simple; use is made of two basic principles - buoyancy and pressure differential. Under no-water-in-the-pipe condition, the valve cone rests at the base of the valve assembly. As water enters through the inlet pipe, the float valve (which is buoyant) rises into position on the valve seat. The water pressure acts on the flat bottom surface of the valve forcing it against the seating surface. The float valve experiences a pressure differential above and below the seat; atmospheric pressure above

the valve seat, and line pressure below.

To activate or open the valve, the user simply depresses the button/float valve. As soon as the applied force on the button exceeds the force on the bottom of the float valve, the valve moves vertically downward and water flows around the float valve, through the outflow port and out the exit nozzle to the consumer's container. As long as the consumer maintains a light pressure on the button, the valve will remain open. When the consumer removes his hand, the button is released and the line pressure firmly raises the float valve once again against its seat. The absence of springs, levers, or any other wearing parts, makes this valve a very attractive one. It should be noted that as the float valve or the seat assembly wears, its sealing characteristics improve because the valve is wedged further into the valve seat.

The description of the casings for both public hydrants and private connection are given in the following section.

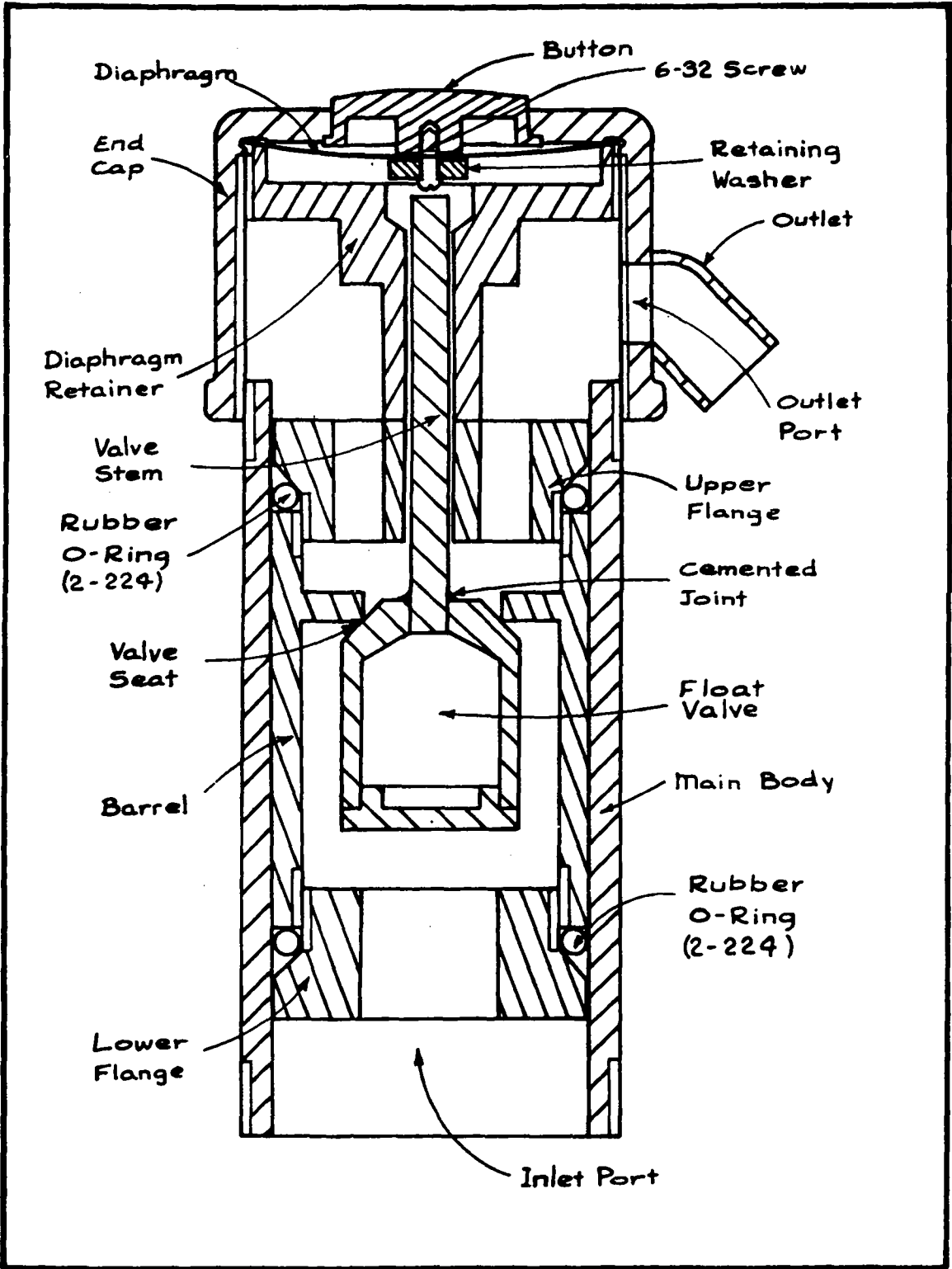


FIGURE 3. CROSS SECTION OF PUBLIC HYDRANT ROBOVALVE

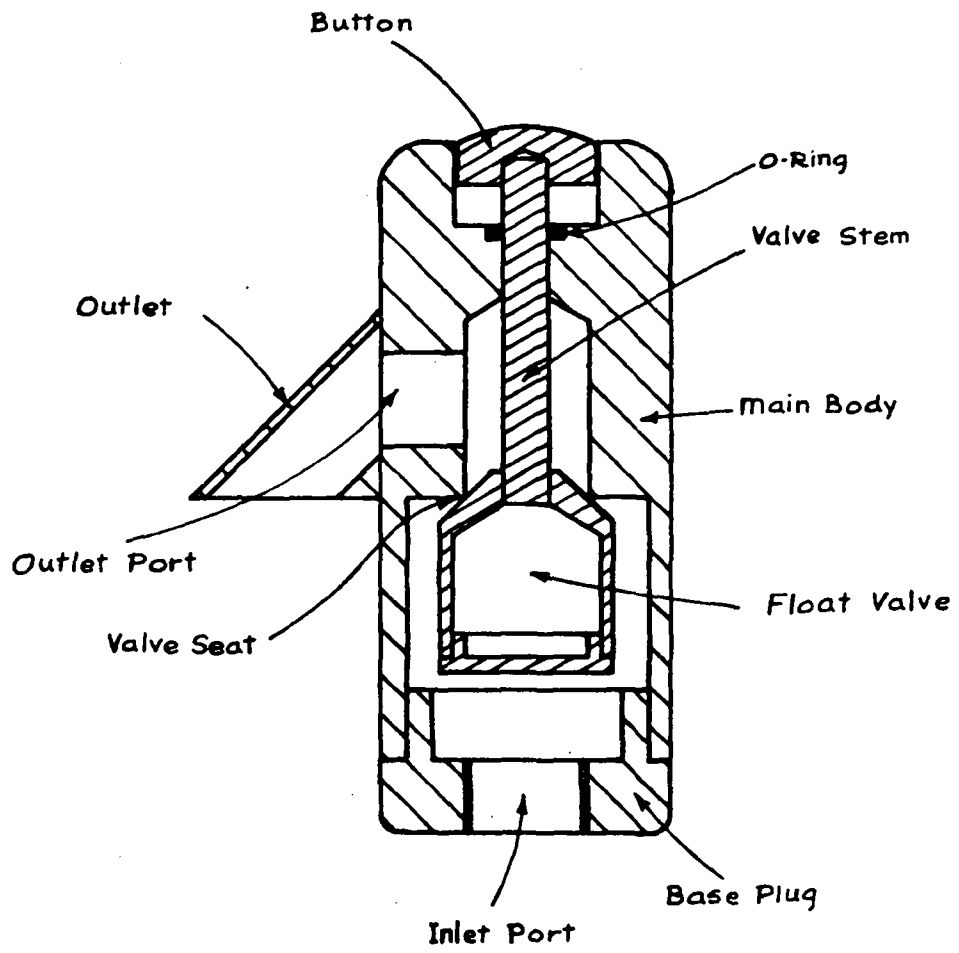


FIGURE 4. CROSS SECTION OF PRIVATE HOUSEHOLD ROBOVALVE

## EXPERIMENTAL WORK

Review of the pertinent literature on elastomers (see Appendix A) revealed that there are a number of materials which because of their physical and wear characteristics make them an ideal choice for the valve and seat assembly. These elastomers, often referred to as "exotic materials" are expensive, however, and not readily available in most LDC's. The almost universal LDC availability of P.V.C., coupled with its good wear characteristics, low cost, and ease in manufacturing, i.e., with extrusion or injection molding, suggested that P.V.C. should be tried as the basic material for the valve and seat assembly. It was tried and found to work very satisfactorily.

### Sealing and Wear Characteristics

The first phase of the experimental work was directed toward evaluating the sealing and wear characteristics of various valve and seat assemblies at pressures of 3 psi to 25 psi. Some preliminary tests suggested that cone valves with narrow angles seat better than those with wider angles. Eight valves were constructed with cone angles of  $20^{\circ}$  to  $90^{\circ}$  in increments of  $10^{\circ}$ , using P.V.C. round stock. Production machines such as a lathe, milling machine, drill press, etc., were employed in the manufacture of the component parts. The eight valves were placed in a testing machine shown in Figures 5 and 6. The speed of the cam was approximately 6 rpm provided by an electric

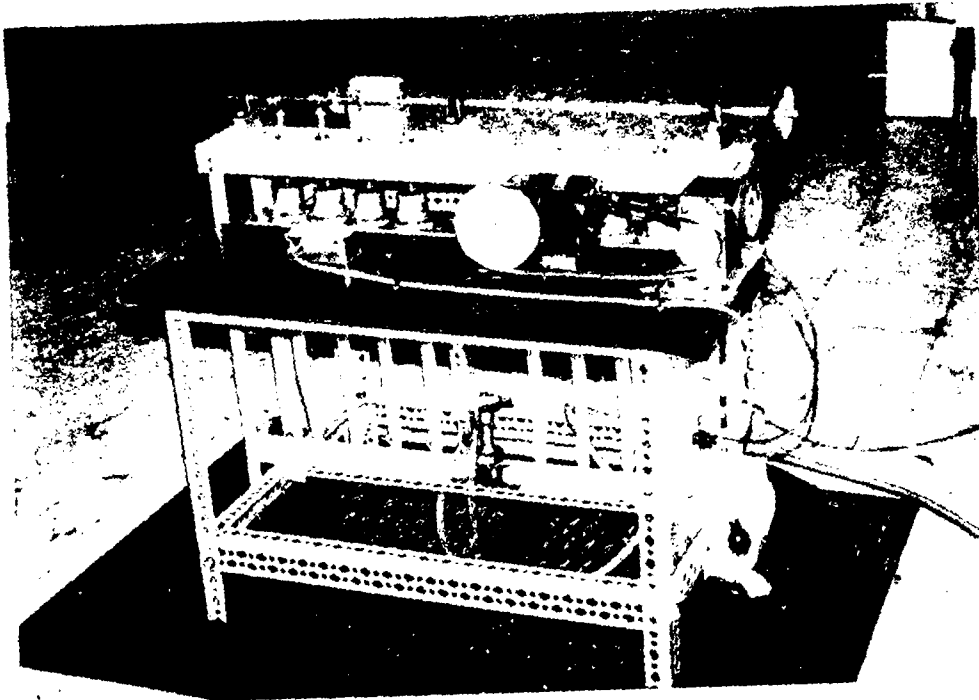


FIGURE 5. ROBOVALVE TESTING APPARATUS

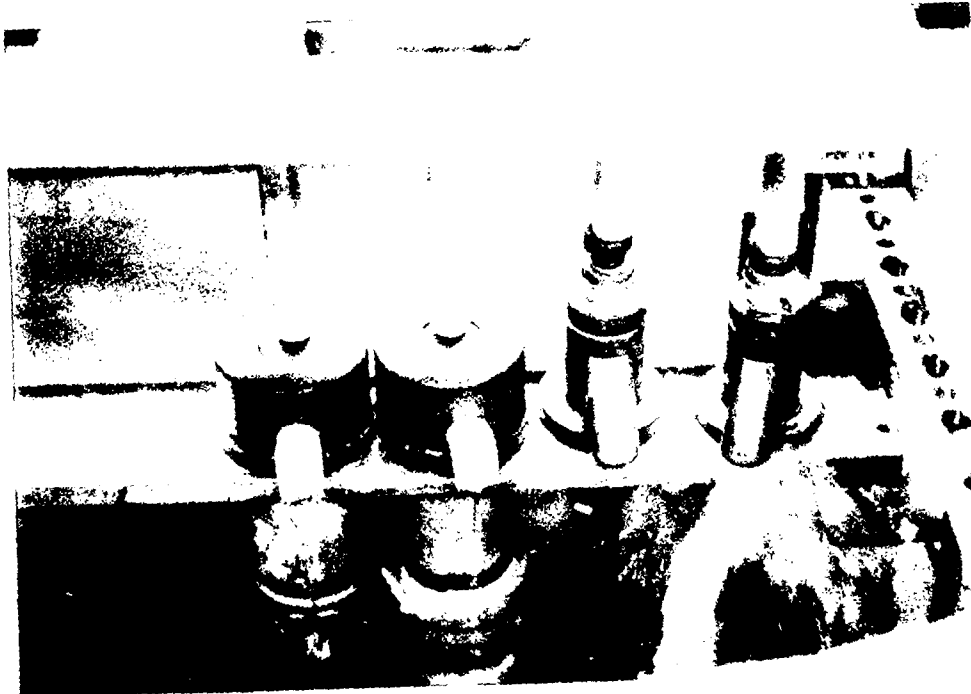


FIGURE 6. ROBOVALVES UNDERGOING TESTING



motor and a reduction gear box. The eight lobes on the cam were positioned in such a way that at any one time only two valves were open and six closed. Each valve dispensed approximately 0.25 liter in the open mode upon each opening. Testing was conducted in the following manner:

The valves were installed in the testing machine and the operating pressure adjusted to the desired pressure.

Each test lasted for approximately 50,000 cycles during a period of approximately one week.

At the end of the test, the sealing of each valve was determined by collecting and measuring any leakage during a period of 30 minutes.

Later, the valves were disassembled and the wear of the valve and the seat was measured and recorded.

The valves were then reassembled, installed in the machine, a new line pressure selected, and the test repeated for another 50,000 cycles

The wear characteristics of the eight valves tested are summarized in Table 1. After approximately 200,000 cycles with line pressure of 3 psi to 25 psi, the maximum wear was 0.003 inches. No discernable wear pattern can be observed. While the maximum wear of the valve and the valve seat was 0.003 inches (valve with 60° cone), some of the valves and valve seats data suggest expansion rather than wear. The slight expansion may be due to variations in temperature or minute swelling of the P.V.C. due to absorption of water. In any case, the wear of the valve and seat assembly for all angles tested was essentially zero after 200,000 cycles; this corresponds to almost three years of operation, assuming the valve is operated 200 times a day. Thus,

TABLE I

Wear Characteristics of Valve and Seat Assemblies  
(Sharp-edged Valve Seat)

Cone Angle	50,000 cycles @ 3 psi		103,000 cycles @ 10 psi		151,700 cycles @ 15 psi		201,400 cycles @ 25 psi		250,000 cycles @ 15 psi		300,000 cycles @ 15 psi		350,000 cycles @ 15 psi	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B
20°	.000	.001	.000	.001	.003	.001	.002	.001	.002	.001	.003	.003	.003	.003
30°	-.001	-.001	-.001	.000	.000	.000	.000	.001						
40°	-.001	-.001	.002	-.002	.001	-.002	.001	-.002	.001	-.001	.001	-.001	.001	-.001
50°	-.002	-.000	-.002	-.001	-.002	.001	-.001	.000						
60°	-.001	.002	.003	.001	.003	.001	.003	.001	.002	.002	.002	.002	.002	.002
70°	.002	.002	.000	.001	-.003	.001	-.003	.001						
80°	-.002	.000	-.002	.001	-.002	-.001	-.001	-.001	-.001	-.001	-.001	-.001	-.001	-.001
90°	-.002	.001	-.001	.001	-.001	.000	-.001	-.001						

Note: Positive wear or expansion [-] is given in inches

A - Wear of cone valve

B - Wear of valve seat

it was concluded that there is no apparent optimum angle for maximum sealing and minimum wear. Subsequent valves were manufactured with a cone angle of  $45^{\circ}$  because such an angle can be easily machined.

Leakage tests conducted at the end of each 50,000 cycle test are summarized in Table II. Only the  $60^{\circ}$  valve did not seal properly. Generally, all the valves tend to seal and seat better at higher operating pressures, but even in low pressures the valves sealed very satisfactorily. Moreover, even the slight wear noted in Table I improved the sealing characteristics of some of the valves as the valve is bedded further into the valve seat.

The first phase of the experimental work was terminated after the wear and leakage tests proved the validity of the basic concept of the Robovalve. Discussions with sanitary engineers with experience in LDC's pointed out that the quality of the water in distribution lines in LDC's may be different from the tap water used in the first phase. The above wear and leakage tests (200,000 cycles) were conducted with tap water. It was suspected that turbid water containing soil particles and small pieces of organic material, such as leaves, twigs, etc. may accelerate the wear of the valve and seat assembly. For the second phase of the experiment, therefore, it was decided to test the valves with turbid water containing 1,200 ppm of clay and fine sand, and small pieces of leaves, twigs, etc. Although the sealing characteristics of the original eight valve and seat assemblies were good, it was suggested that the sealing characteristics of bevelled valve seats be investigated. The valve and bevelled valve seat is similar to the intake or exhaust valve and valve seat in

TABLE II

## LEAKAGE OF VALVE AND SEAT ASSEMBLIES (SHARP-EDGED VALVE SEAT)

Angle	50,000 Cycles @ 3 psi	103,000 Cycles @ 10 psi	151,700 Cycles @ 15 psi	201,440 Cycles @ 25 psi	250,000 Cycles @ 15 psi	300,000 Cycles @ 15 psi	350,000 Cycles @ 15 psi
20°	tr	dry	dry	dry	dry	dry	dry
30°	tr	1.5 ml	tr	dry			
40°	tr	tr	dry	dry	dry	dry	dry
50°	tr	tr	dry	dry			
60°	7 ml	1.5 ml	1.5 ml	1.0 ml	tr	tr	tr
70°	tr	tr	tr	dry			
80°	tr	tr	tr	dry	tr	dry	dry
90°	tr	1.0 ml	tr	dry			

NOTE: Leakage was measured when the valve was closed at the designated line pressure for a period of 30 minutes

tr-trace, designates a volume less than 3 drops  
ml-mililiter

internal combustion engines. Four valves with cone angles of  $20^{\circ}$ ,  $40^{\circ}$ ,  $60^{\circ}$ , and  $80^{\circ}$ , and the corresponding bevelled (same angle) valve seats were tested along with four of the original valves and (sharp-edged) seat assemblies with identical cone angles. It should be noted that the four original valves were already subjected to approximately 200,000 cycles, and the second phase for these valves was simply a continuation of wear and sealing testing using turbid water. The reason for testing four valves with bevelled valve seats was to compare the performance of such valves with the original ones. After approximately 150,000 cycles at an operating pressure of 15 psi, the sealing and wear characteristics of the bevelled and sharp-edged valve and seat assemblies were evaluated.

Wear data for the four valves with bevelled valve seats is given in Table III. Comparison of the wear of these valves with the sharp-edged ones (Table I - after 150,000 cycles) suggests that the wear for bevelled valve seat assemblies (Table III) is slightly less than the sharp-edged assemblies. This comparison is not for identical operating conditions (the sharp-edged seat and valve assemblies were operated under pressures of 3 psi to 15 psi for the first 150,000 cycles). Maximum wear for the sharp-edged seat and valve assembly was .003" (after 350,000 cycles). The wear of both groups of valves is so slight that it was concluded that future valve seats will be sharp-edged since it is easier to manufacture.

TABLE III

Wear Characteristics of Valve and Seat Assemblies  
(Bevelled Valve Seat)

Angle	50,000 Cycles @ 15 psi	100,000 Cycles @ 15 psi	150,000 Cycles @ 15 psi
20°	.000	.001	.001
40°	.000	.000	.000
60°	.000	.000	.000
80°	.000	.001	.001

Note: Data are for the combined wear of valve and valve seat.

TABLE IV

Leakage of Valve and Seat Assemblies  
(Bevelled Valve Seat)

Angle	50,000 Cycles @ 15 psi	100,000 Cycles @ 15 psi	150,000 Cycles @ 15 psi
20°	tr	tr	dry
40°	tr	tr	dry
60°	tr	tr	dry
80°	tr	dry	dry

Note: Leakage was measured when the valve was closed at the designated line pressure for a period of 30 minutes.

tr-trace designates a volume less than 3 drops

Leakage for both sharp-edged and bevelled edge seat and valve assemblies are given in Tables II and IV. The sealing of both sets of valves was good with no appreciable difference between them. Based on the above tests it was concluded that a P.V.C. float valve and seat assembly (sharp-edged) functioned very satisfactorily and essentially did not leak. The Thrust of the research effort was now directed toward construction of a complete valve and the development of working drawings for local manufacture.

#### Valve and Seat Assembly Housing-Casing Design

The first two phases of this investigation showed that a P.V.C. conical float valve and a valve seat, i.e., the heart of the faucet/valve works well. The next step in the development was the design and construction of the valve housing or casing. Two typical water outlets in LDC's are the public hydrant or stand pipe, and the house or yard connection. The requirements for valves for each of the above connections differ. The identified requirements for the public hydrant valve include dispensing 20 gal/min at 20 psi, heavy duty casing to prevent vandalism, and the ruggedness to conform to the intended heavy use. The house or yard connection should dispense 1 gal/min at 2 psi, and be moderately rugged. To prevent possible contamination of the individual's or the community water supply, valves must be water tight around the valve stem to prevent water from striking the consumer's hand and being diverted into

his container or back into the supply line. Leaky faucets also waste water and create ponding in the vicinity of the hydrant. Drainage is seldom provided and the ensuing stagnant water contributes to an unhealthy environment. Because the requirements for public and yard valves differ, two discrete Robovalves were designed, constructed, and tested. A description of each of these valves is given below.

#### Robovalve - Public Hydrant or Stand Pipe

The stand pipe model will be supplied in a locally manufactured kit form. With the use of a few simple tools, the kit can convert any piece of standard 2" water pipe into a useful, efficient faucet. Figure 3 shows the detail of a Robovalve for public stand pipe. The kit consists of a barrel (part of which is the valve seat), a valve and stem, and an end cap assembly. The barrel has two tapered and threaded flanges. As the flanges are tightened into the barrel, "O" rings are compressed against the wall of the pipe. This located the barrel positively in the pipe and forms a seal ensuring that water can only pass through the faucet via the valve and seat. The upper flange also provides a guide for the valve stem.

The principle of operation of the valve has been previously described. The end cap provides the water outlet and also houses a diaphragm assembly and push button. The diaphragm prevents leakage around the activating button.



As can be seen in Figure 3, the valve stem and push button are not connected, but are separated by the diaphragm.

### Robovalve - House or Yard Connection

The household Robovalve is a self-contained unit made entirely of P.V.C.. It can be readily adapted to any existing pipe line. A pipe reducer may be required in the case where the domestic pipe diameter differs from that of the Robovalve.

Physically, the Robovalve is 1 1/2" in diameter and 3 3/4" in height. The valve casing can be machined or molded in one piece. A proposed design is presented in Figure 4. The base of the valve is drilled and threaded to accept a 3/8" or 1/2" pipe, which will be threaded or cemented into the casing after the valve and stem is in place. The button is the activating mechanism of the valve and is depressed by pressure exerted by fingers or the palm of the user's hand. It is easy to activate, even if the line pressure is 40 psi. To eliminate water leaking up past the valve stem, an "O" ring will be fitted to the upper casing. When the button is depressed it will sit on this "O" ring and form a seal.

### Additional Experimental Work

Several designs have been proposed to eliminate the leakage through the stem. A number of different valve configurations have been constructed and

tested prior to selecting the recommended design given in Appendices B-D. Two public hydrant Robovalves and two house connection Robovalves were tested for leakage through the valve stem. After more than 75,000 cycles no leakage was detected in either Robovalve. Neither the diaphragm membrane, similar to the one used in fuel pumps of internal combustion engines nor the "O" ring showed any signs of wear. It was concluded that the diaphragm (public Robovalve) and the "O" ring (house connection) function well in preventing water from leaking around the button.

## ROBOVALVE MANUFACTURING

All of the Robovalves developed in this project were machined from P.V.C. stock. Robovalves, however, can be produced by injection molding. An analysis of the labor and material required for manufacture of the Robovalve using machine shop methods and injection molding for (1) public hydrant, (2) house or yard, and (3) water container Robovalves is given below. To provide instruction on simple machine shop methods is not the purpose of this report. It will be assumed, therefore, that the individual(s) involved in the fabrication of Robovalves will be familiar with accepted machine shop practices, and will have no problems producing good reliable valves from the working drawings if provided with some technical assistance. There are, however, certain subtle points to which attention should be drawn, particularly with the public stand pipe model. This will allow the manufacturer to by-pass some of the difficulties encountered during the development stages.

### Public Hydrant or Stand Pipe Robovalve

#### A. Machine Shop Manufacture:

The manufacture of parts for the Robovalve from P.V.C. stock are basically straightforward lathe operations. The material required is as follows:

3" dia. x 2"	1 pc.
2" dia. x 2 3/4"	1 pc.
2" dia. x 1"	2 pcs.
2 1/2" dia. x 2"	1 pc.

1" dia. x 1 1/2"	1 pc.
1 1/4" dia. x 1/2"	1 pc.
1/4" dia. x 3"	1 pc.
45° pipe bend	1 pc.
P.V.C. cement	
Diaphragm material 2 3/8" dia. x $\frac{1}{32}$ " thick	

Total weight of P.V.C. required is approximately 2.4 lbs. The weight of the completed valve is 0.85 lb.. Thus, about 1.5 lbs. of P.V.C. per valve are wasted. Working or shop drawings for the valve are given in Appendix B.

Attention in machining should be given to the following points:

#### End Cap.

The end cap requires one operation which is somewhat different from normal. In order to allow the female thread to accommodate both the insert which secures the diaphragm and the tapered thread of a standard 2" pipe, the cap was bored out to 2.230" diameter. It was then threaded 11 1/2 T.P.I. (parallel). Next, a tap was used to bring the thread at the mouth of the end cap to a 2" Standard Pipe Thread (tapered). Care should also be taken to recess the thread to house a diaphragm of 2 3/8" diameter.

#### Valve.

(1) There is nothing complicated about making the valve. Concentricity between the stem and cone is essential for good sealing characteristics. To ensure that this condition prevails after cementing, the cemented assembly (stem, cone, and base) should again be set up in the lathe, locating by the stem, and lightly remachine the 45° contact surface. This additional operation will guarantee the required concentricity.

(2) The other precaution is to ensure that the valve stem length is such that when the valve is tightly seated there will be a clearance of 1/32" between the top of the valve stem and the diaphragm.

Estimated labor time for machining component parts is four hours.

## B. Injection Molding Production

The valve can be produced by injection molding its various parts, i.e., end cap, valve and stem, seat and main body, flanges, button and diaphragm retainer. It is possible to produce the above components using three dies. The weight of P.V.C. required is about 0.85 lb. per valve. Optimization of the valve configuration may result in less material (P.V.C.) requirements. The cost of the diaphragm, attaching screw, and P.V.C. cement is estimated at \$0.15. Time required for assembly of the Robovalve is about 5 minutes. It is estimated that the cost per valve is approximately \$1.00 to \$1.25.

### Yard or Household Robovalve

#### A. Machine Shop Manufacture

The manufacture of the household Robovalve from P.V.C. stock is a straightforward lathe operation. The P.V.C. material required is given below:

1 1/2" dia. x 3.5"	1 pc.
1 1/2" dia. x 1.5"	1 pc.
1" dia. x 1 1/2"	1 pc.
3/4" dia. x 1/2"	1 pc.
1/4" dia. x 1 1/2"	1 pc.
1 1/4" x 1 1/4" x 3/4"	1 pc.
"0" ring, 1/4" I.D. 3/8" O.D.	1 pc.
P.V.C. cement	

Total weight of P.V.C. stock required is approximately 7.70lb. The weight of the completed valve is 0.25lb. Thus, 0.45 lb. of P.V.C. per valve is wasted. Working or shop drawings for the valve are given in Appendix C.

The only points to note with this model concern the valve and stem. As previously described the valve should be again remachined lightly after cementing to ensure concentricity. The length of the stem is not critical. Estimated labor time for machining component parts is two hours.

#### B. Injection Molding Production

The yard or household valve can be produced by injection molding its various parts, i.e., main body, valve and stem assembly, etc.. The weight of P.V.C. required is 0.25 lb. per valve. Optimization of the valve may result in less material (P.V.C.) requirements. The cost of the "O" ring and P.V.C. cement is estimated at \$0.20. Time required for assembly of the Robovalve is about 5 minutes. It is estimated that the cost per valve is approximately \$0.75 to \$1.00.

#### Water Container Robovalve

During the course of developing the Robovalves for public hydrant and house connection a third valve shown in Figures 7 and 8 was developed for use with plastic water containers. The valve is a scaled down version of the household Robovalve and is not equipped with an "O" ring. The valve can be attached to the side of the container using plastic cement. Working drawings for this valve are given in Appendix D.

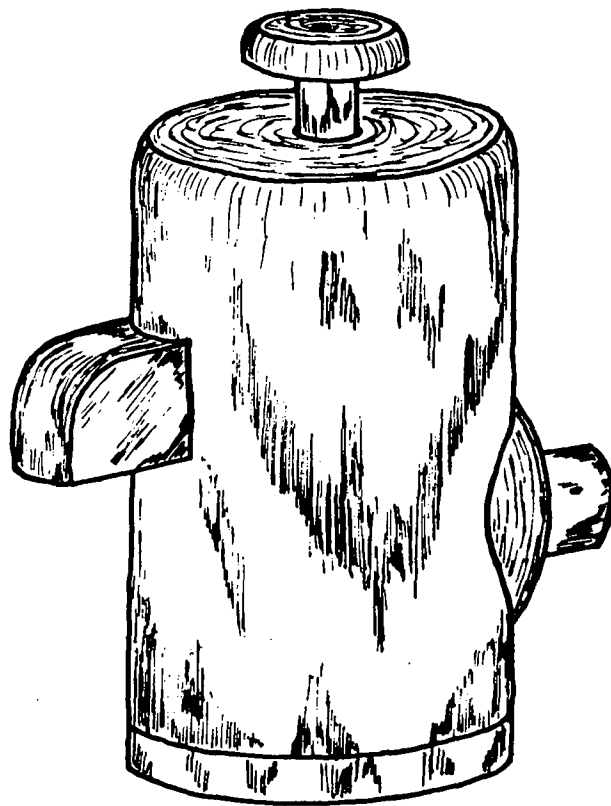


FIGURE 7. PLASTIC WATER CONTAINER ROBOVALVE

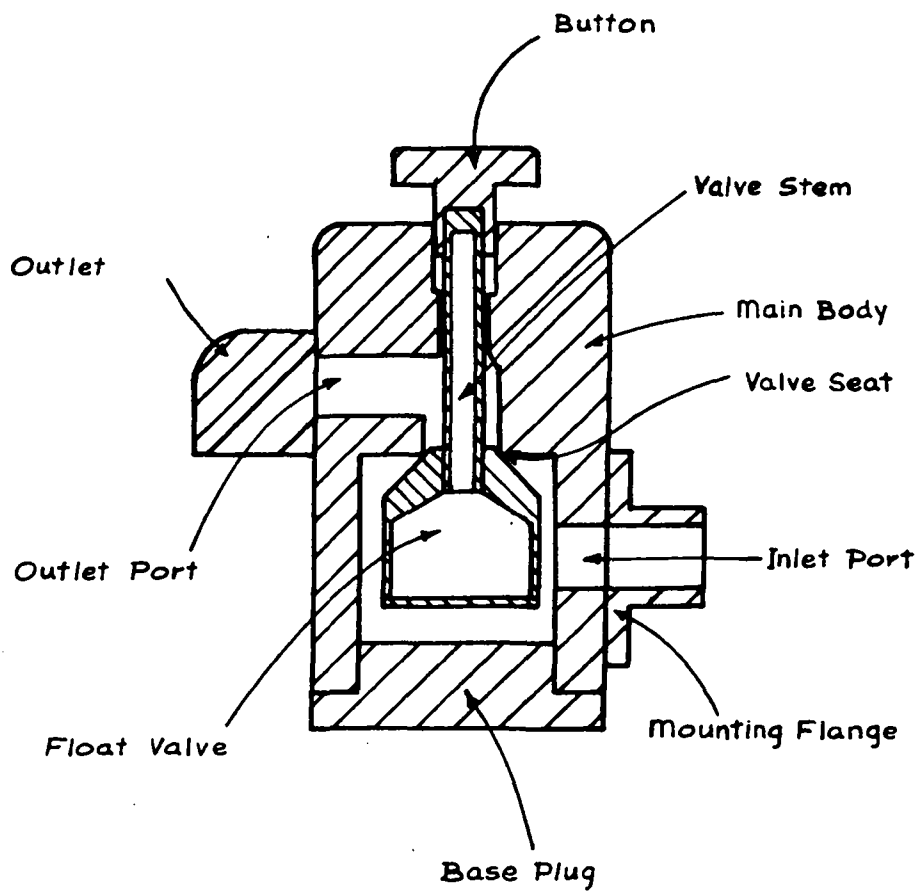


FIGURE 8. CROSS SECTION OF WATER CONTAINER ROBOVALVE



#### A. Machine Shop Manufacture

The materials required in the construction of this valve are:

1 1/2" dia. x 3"	1 pc.
3/4" dia. x 1"	1 pc.
1/4" dia. x 1 1/2"	1 pc.
3/4" dia. x 5/8"	1 pc.
1 1/8" dia. x 3/4"	1 pc.
3/4" x 3/4" x 5/8" thick	1 pc.
P.V.C. cement	

There are no particular precautions to take with this model. It was considered wise, however, in view of the small volume of the float valve, to drill out the stem in order to aid the bouyancy of the assembly. Total weight of material required is approximately 0.52 lb. The weight of the completed valve is 0.21 lb. Thus, 0.31 lb. of P.V.C. per valve is wasted. Estimated labor time for machining component parts is two and one-half hours.

#### B. Injection Molding Production

The water container valve can be produced by injection molding its various parts. The weight of P.V.C. required is about 0.21 lb. Optimization of the valve may result in less material (P.V.C.) requirements. It is estimated the the cost per valve is approximately \$0.65 to \$0.75.

## CONCLUSIONS AND RECOMMENDATIONS

Robovalves have not been subjected to any field testing and no amount of laboratory testing can replace actual field consumer use trials. A comprehensive field testing program should be undertaken in order to:

- (a) Determine the wear and sealing characteristics of Robovalves under intensive LDC consumer use.
- (b) Evaluate the acceptability of the valve by LDC consumers of different cultures.
- (c) Work with interested national government and local plastic manufacturers to stimulate LDC production of valves.
- (d) Modify and adapt, if necessary, the proposed present design based on information obtained from (a), (b), and (c) above.

In order to obtain maximum information from the proposed field testing, the following program is suggested:

- (a) Select a total of five LDC sites for valve testing; preferably the countries selected should have consumers of diverse social and cultural backgrounds. Each of the five sites will be suitable for installation of Robovalves of the public, yard, and container types. Locally, each selected LDC should manufacture 200 Robovalves of each type.
- (b) The team which developed the Robovalve will visit each site and will extend technical assistance to interested national governments and plastic manufacturers on injection molding and/or machine shop production of Robovalves. The valves will be produced in LDC's with guidance from the team
- (c) The team will instruct the LDC implementing organizations on the installation, and monitoring of valves. The type of data required, collection frequency, data forms, etc., will be worked out with the implementing organization. Data

will be forwarded to the implementing organization in the LDC on a regular basis. Review and analysis of the data will be partly done by the implementing organization, and partly by the team. Periodic technical assistance visits by the team to the various sites are recommended as appropriate.

- (d) Modification and adaptation, if necessary, will be proposed by the team in cooperation with the LDC implementing organization. At the end of the field testing program, some of the valves will be removed, checked and reinstalled. Final design version of Robovalves will be distributed to interested manufacturers and national governments. Field testing will occur over a five-year user cycle.

**APPENDIX A**

**REVIEW OF PLASTIC AND ELASTOMER  
MATERIALS**

## PLASTIC AND ELASTOMER MATERIALS

### List of Materials to be Considered For Robovalve

1. ABS (Acrylonitrile Butadiene Styrene)
2. PVC (Polyvinyl Chloride)
3. Acrylic Plastics (Plexiglas)
4. Acetal Resins (Celcon)
5. Styrene (Polystrene)
6. Polybutylene (Thermo Plastic)
7. Elastomer (Styrene - butadiene rubber) "SBR"
8. Polyurethane ("Elastoplastic")

### Outline of Plastic or Elastomer Selection

- I. Plastics and Elastomers
  - A. General Definition & Application
  - B. Material Characteristics (Engineering Properties)
    1. Tensile strength
    2. Flexural Modulus
    3. % Elongation
    4. Specific Gravity
    5. Hardness (Rockwell)
    6. Impact strength
    7. Compressive strength
    8. Weatherability
  - C. Property Charts
    1. Compatibility Chart Among Materials
  - D. Cost of Materials

## A. General Definitions & Application

### 1. ABS (Acrylonitrile butadiene styrene)

ABS plastics are thermoplastics of the styrene family. They are comprised of monomers of styrene plastic and acrylonitrile and butadiene rubbers. Because styrene is a non-crystalline or glassy material by itself, it lacks the toughness and impact strength required for many applications.\* ABS in all versions possesses greater impact strength and ductility than does polystyrene. It is used for luggage, safety helmets, sports car underbodies, tool handles and many household appliances. It is anticipated that the market of ABS which will show the greatest growth are DWV (drain-waste-vent) pipe.

#### List of Important Properties

1. High degree of hardness (variable)
2. Great flexibility & toughness
3. Easy to obtain (universal use)
4. Fairly cheap
5. Used for pipe fittings in some S. American countries

### 2. PVC (Polyvinyl Chloride)

Rigid PVC is a vinyl polymer that is self-extinguishing and resists creep within a specific temperature range, thus making it suited for chemical and domestic piping. Flexible PVC has replaced rubber and other materials in areas like gasketing, automobile wire connectors and vacuum tubing, packaging, toys, floor mats, garden hose, and many more.

#### Important Properties

1. Chemical & abrasion resistance
2. Good weatherability (resists)
3. Will not burn
4. No fungus growth possible

### 3. Acrylic Plastics (Plexiglas)

Crystal clear transparency and resistance to deterioration in all types of outdoor environments are characteristics of acrylics. The acrylics also offer exceptional stiffness and intermediate toughness. Acrylics are based on methyl methacrylate and are used primarily in the aircraft, appliance, automotive, building and sign industries. Acrylic rods are also used for light piping.

#### Important Properties

1. Somewhat brittle
2. High resistance to weather
3. Hard to work with (manufacturing)

### 4. Acetal Resins (Celcon)

The acetal resins are a highly crystalline, stable form of polymerized formaldehyde, and were originally designed to overcome the shortcomings of other thermoplastics, for the replacement of die castings and metal components. The special properties achieved are rigidity, resilience, toughness, high strength and resistance to common solvents.

#### Important properties

1. High rigidity (not wanted)
2. High resilience
3. High toughness
4. High strength
5. Resistance to solvents
6. Low density - lightweight
7. "Probability" high cost (new material) i.e., celcon

### 5. Styrene (Polystyrene)

Polystyrene is a rigid, hard thermoplastic whose chief attribute seems to be its ability to be blended with other materials to arrive at a myriad of properties within the polystyrene family. General-purpose polystyrene is among the lowest

cost materials. Although polystyrenes exhibits about double the stiffness of polyethylenes, they are "quite brittle."

#### Important properties

1. \*Brittle, hard
2. \*Low impact resistance
3. \*Rapidly degraded by sunlight

#### 6. Polybutylene (Thermoplastic)

Polybutylene resins were introduced to the market in 10 standard grades during 1973. These thermoplastic resins exhibit unusual flexibility, toughness and abrasion resistance and are finding a variety of uses in pipe, film and molding applications.

#### Important Properties

1. Flexibility
2. Toughness
3. Abrasion resistance
4. Resistance to environmental stress cracking
5. High molecular weight (strength cast conger with aging -  
See Page 92 "Patton")
- \*6. Pressure piping for cold water and irrigation uses

#### 7. Elastomers (Styrene-butadiene rubber) "SBR"

This is the general-purpose rubber, used in tires, belts, hose, rubber floor tile and rubber cements. It is a copolymer of 25 percent styrene, 75 percent butadiene. In abrasion resistance and skid resistance it is superior to natural rubber, with better resistance to solvents and weathering.

#### Important Properties

1. Abrasion resistance
2. Weather resistance
3. High flexibility



## 8. Polyurethane (Elastomer)

The polyurethane rubbers are available in a range of Durometer hardness, generally from 65 to 100 (Rockwell). A typical polyurethane rubber has a tensile strength of 5000 psi, with high elongation, great tear strength, and outstanding abrasion resistance.

### Important Properties

1. flexibility
2. High shear strength
3. Abrasion resistance

<u>Plastic Engineering Properties</u> Chart	<u>ABS (Acrylonitrile-butadiene-styrene)</u> (Medium Impact)	<u>PVC (Polyvinyl Chloride)</u> Rigid	<u>Acrylic Plastics</u> (Multipolymer)	<u>Acetal Resins</u> (Celcon) Copolymer	<u>Polystyrene</u> (Medium Impact)
*1. Specific Gravity (density)	1.03-1.06	1.28-1.40	1.09-1.14	1.41*	1.04-1.10
*2. Specific Volume (cu. in/lb)	28.0-27.0	21.4-18.05	25.6-23.3	19.7	28.1-25.2
*3. Tensile Strength (psi)	6500-7500	5000-8000	6000-8000	8800*	1500-7000
*4. % Elongation	5-25.0	100.0-140.0	3.0-40.0	40-75	2.0-90.0
*5. Tensile Elastic Modulus (10 <sup>5</sup> x psi)	3.0-4.5	3.5-4.5*	3.1-4.3	4.1	1.4-5.0
*6. Compressive strength (psi)	1800-12500	7750-11700	8000-11500	16000	4000-9000
*7. Flexural Yield Strength (psi)	11000-13000	10000-15400*	9500-13000	13000	3000-12000
*8. Impact Strength (ft. lb/in)	2.0-6.0 @ 73°F	0.36-32.00*	1.0-3.0 @ 73°F	1.0-1.5 @ 73°F	0.4-2.5 @ 23°C
*9. Hardness (Rockwell Test)	R107-115	R107-119	R-108-119*	M78-M80	R30-100
*10. Flexural Modulus (10 <sup>5</sup> x psi)	3.0-4.6	3.52-5.04*	3.0-4.0	3.75	1.5-4.6*
*11. Effect of Sunlight	None to Yellows Slightly & Some Embrittlement	Slight to Poor (Depends on Grade)	Slight Color Change, Slight Embrittlement	Chalks Slightly	Some Strength Loss; Yellows Slightly
*12. Effect of Weak Acids	None	None	None	Resists Some	None
*13. Effect of Strong Acids	Attacked by Concentrated Oxidizing Acids	None to Slight	Attacked by High Concentration of O <sub>2</sub> Agents	*Attacked	Attacked by Oxidizing Agents

\*See 1974-1975 Modern Plastics Encyclopedia, pg. 543.

Plastic Engineering Properties Chart	Polybutylene	Elastomer (Styrene-butadiene)		Polyurethane "Elastoplastic"
		Rubber	SBR	
*1. Specific Gravity (density)	0.912	0.93-1.10		1.05-1.25
*2. Specific Volume (cu. in/lb)	30.4-30.2	37.4-27.5*		26.5-22.0
*3. Tensile Strength (psi)	3800-4400	600-3000		4500-8400
*4. % Elongation	300.0-380.0	300.0-100.0*		100-650
*5. Tensile Elastic Modulus (10 <sup>5</sup> x psi)	0.26-0.50	0.008-0.500		0.1-3.5
*6. Compressive strength (psi)	-	5000 (No Break)		20000*
*7. Flexural Yield Strength (psi)	-	60-900 (No Break)		700-9000
*8. Impact Strength (ft. lb/in)	No Break	No Break		Does Not Break
*9. Hardness (Rockwell Test)	55-65 (Shore D)	40-95 (Shore A)		65A-80D (Shore R60)
*10. Flexural Modulus (10 <sup>5</sup> x psi)	0.49	0.04-1.50		0.1-1.3
*11. Effect of Sunlight	Crazes rapidly* Cracks with UV	Slight color change		None to Slight Yellow
*12. Effect of Weak Acids	Resistant	None		Slight to dissolves
*13. Effect of Strong Acids	Attacked by Oxidizing	Attacked by Oxidizing		Moderate to dissolves

\*See 1974-1975 Modern Plastics Encyclopedia, pg. 543.

\*COST DATA

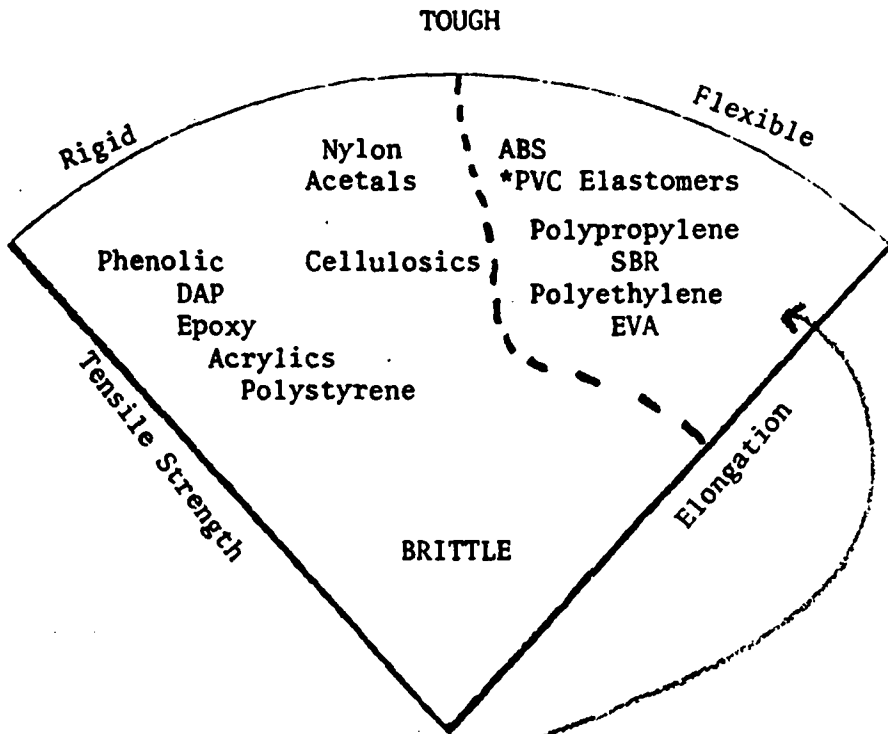
<u>Material</u>	<u>Cost per lb.</u>	<u>Form of Material</u>
ABS	\$36.00(1)	SLAB
Polyethylene	\$10.00	Pellets
Polystyrene	\$ 6.00	FLAKES
PVC	\$ 8.00	SLAB
Acetal Resins	\$11.00	SLAB
Polybutylene	\$18.00	SLAB
Styrene-butadiene-Rubber	\$36.00(2)	SLAB
Styrene	\$ 2.00 (?)	SLAB

\*See ALDRICH CATALOG HANDBOOK OF ORGANIC AND BIOCHEMICALS (1976-1977)

(1) Check cost data by Manufacturing Co.

(2) IBIC

\* SCHEMATIC OF ENGINEERING PROPERTIES  
FOR VARIOUS PLASTICS



Region of Design Materials  
Wear = function (toughness, flexibility)

\*Ronald Beck, Plastic Product Design, 1970, p. 421

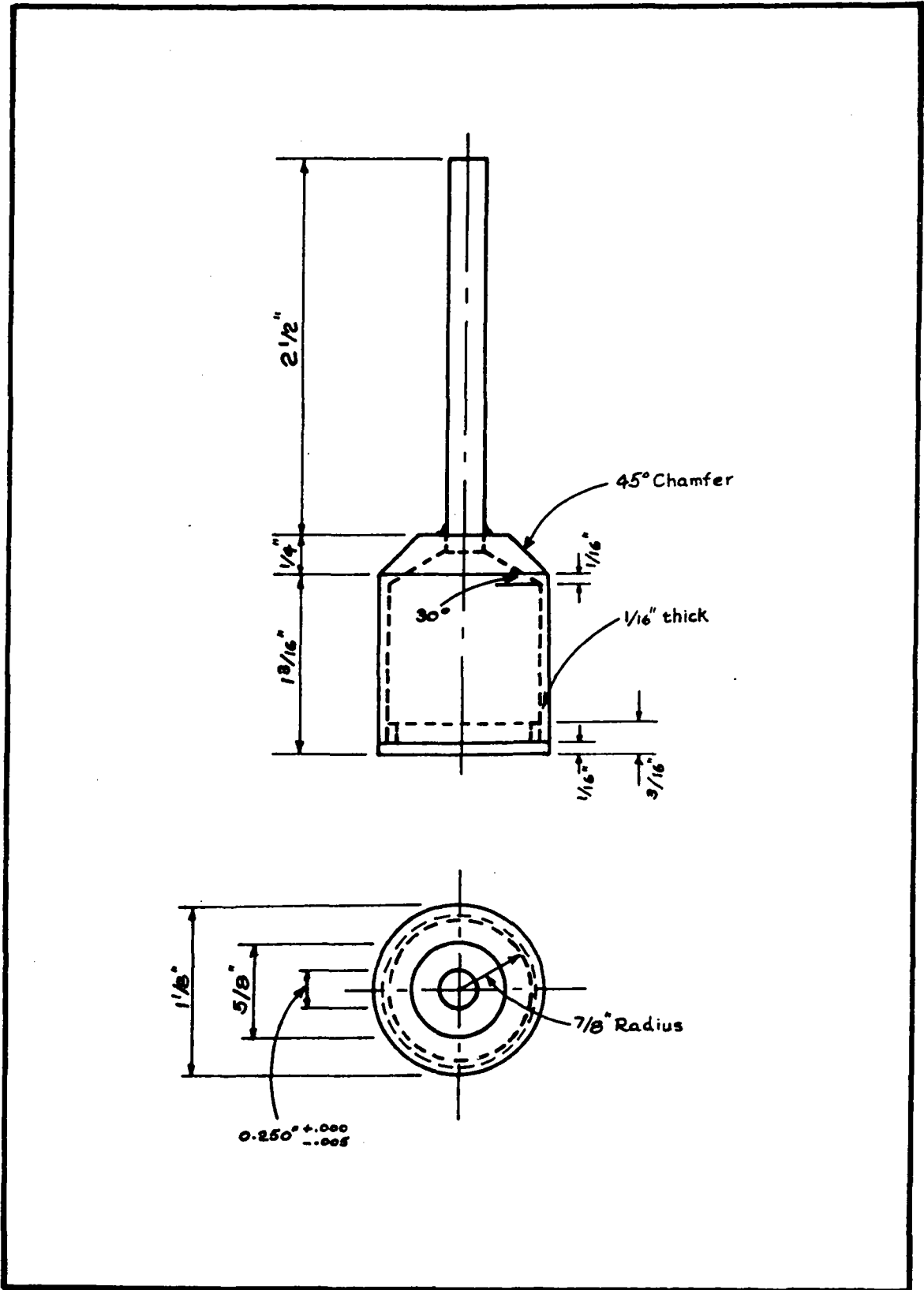
## Plastic Material Selection

Based on availability, cost, and suitable physical and chemical characteristics only two materials, ABS and P.V.C. can be considered as suitable for manufacturing of Robovalves. Because P.V.C. is available in most LDC's and the technology for injection molding of this material is available in most developing countries, P.V.C. was chosen as the material for Robovalves.

**APPENDIX B**

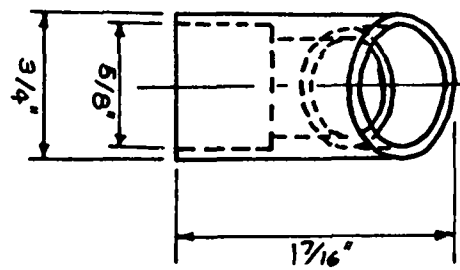
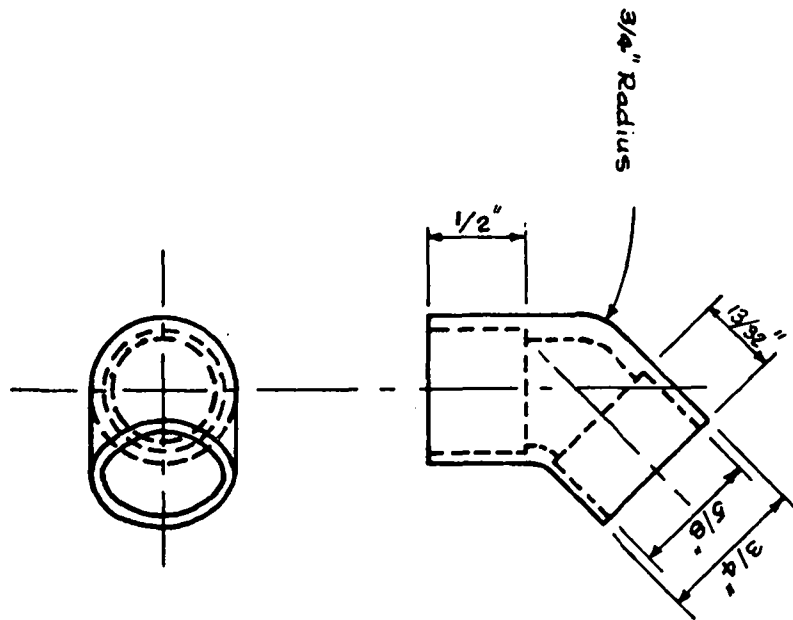
**PUBLIC HYDRANT ROBOVALVE  
WORKING DRAWINGS**

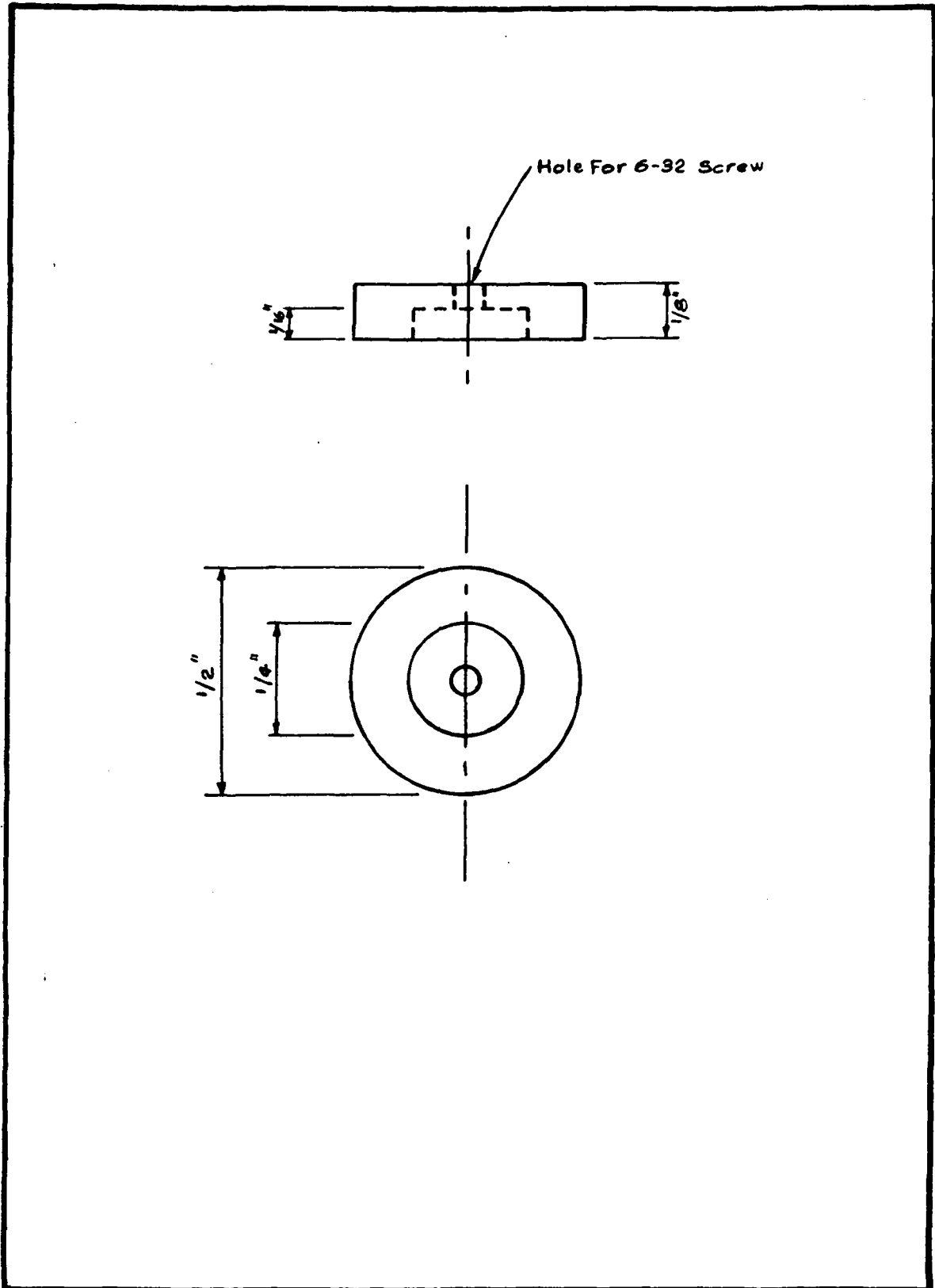
**Note: All drawing dimensions are as shown.**



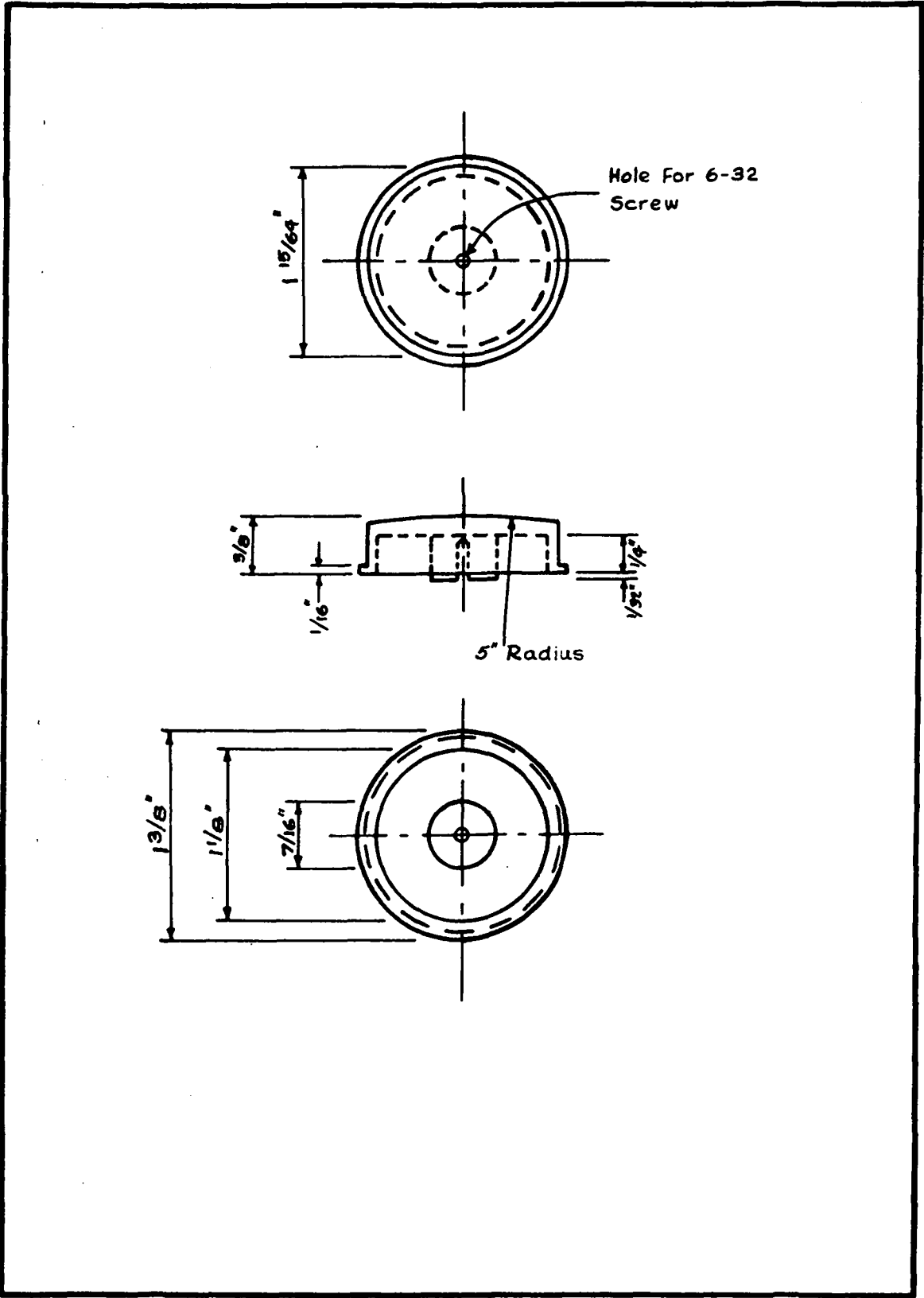
Float Valve Assembly



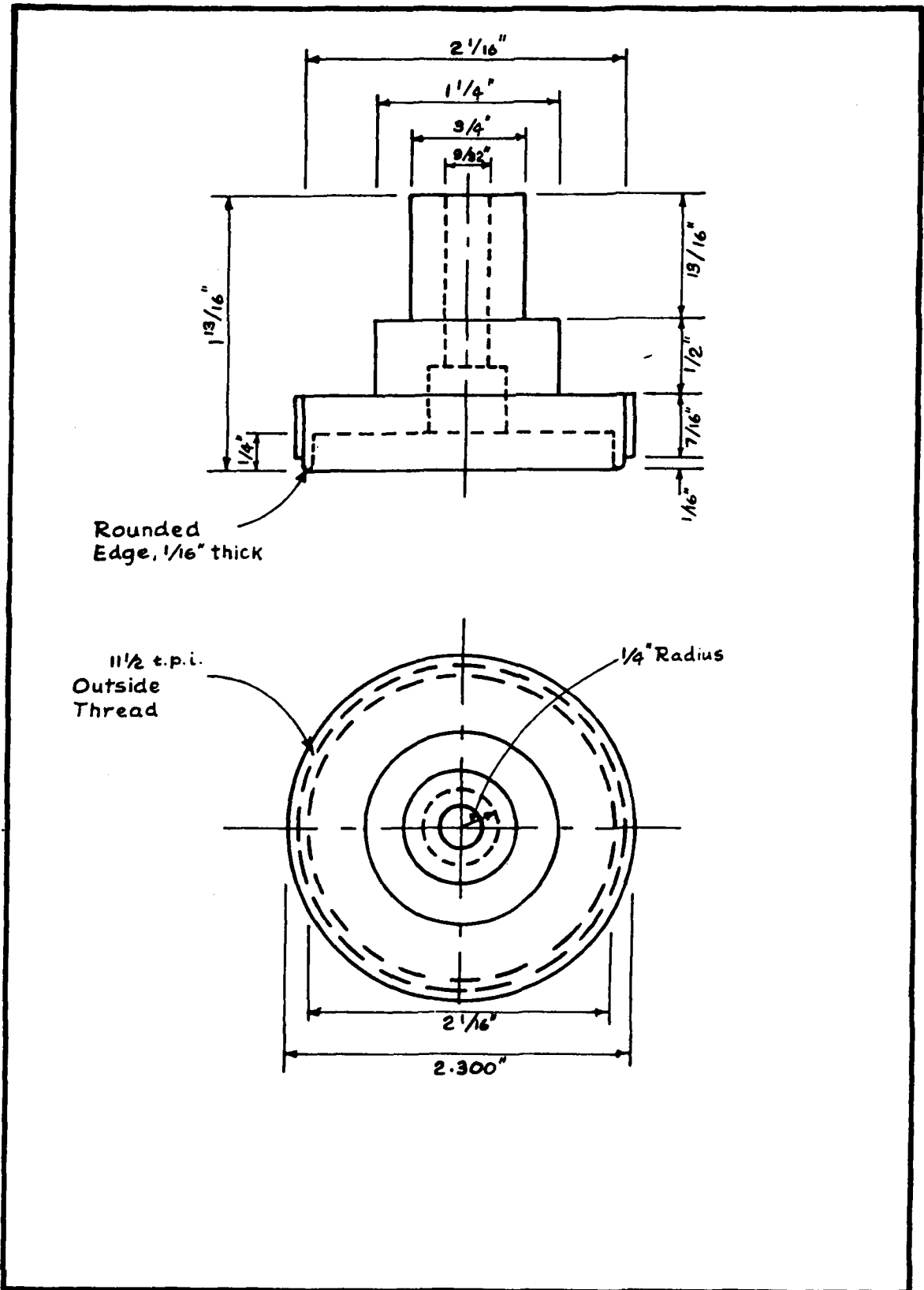




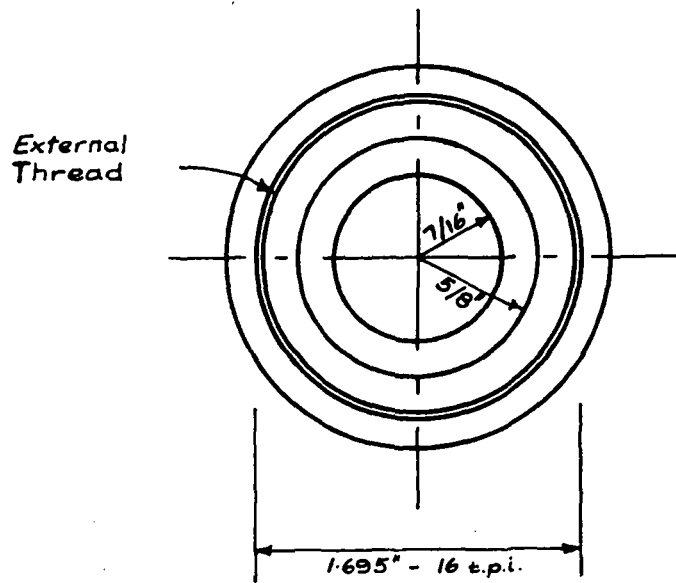
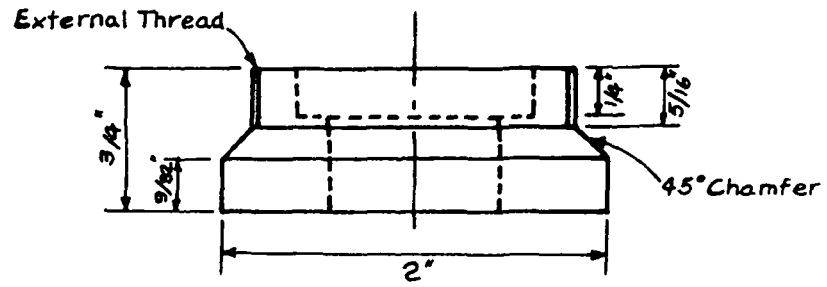
Retaining Washer



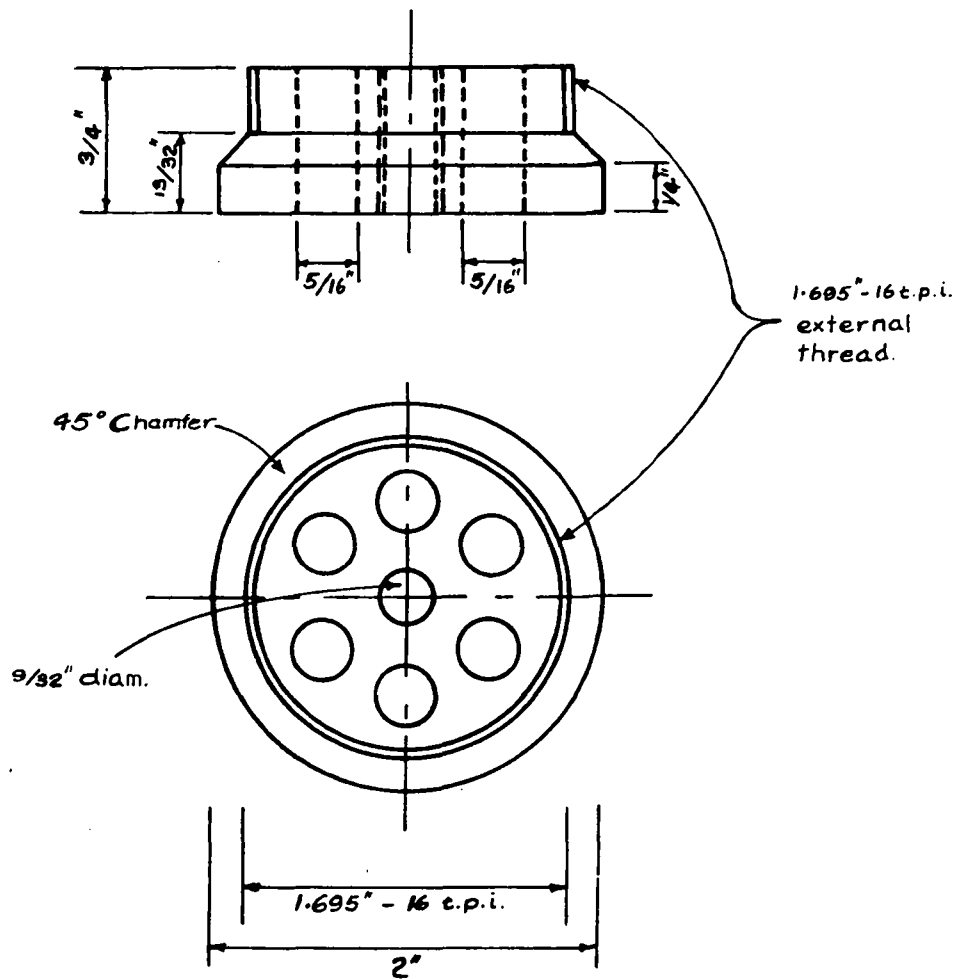
Button



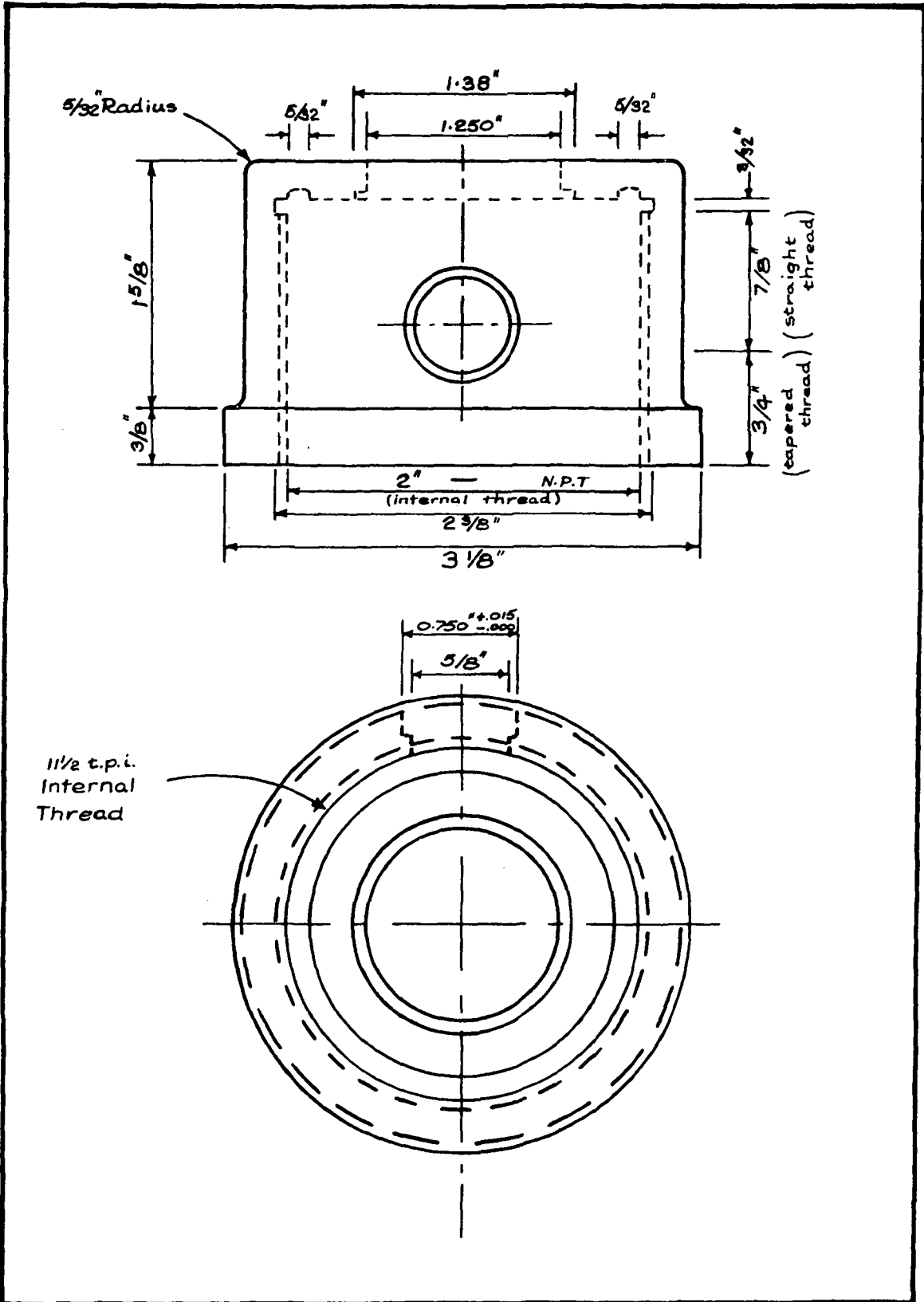
Diaphragm Retainer



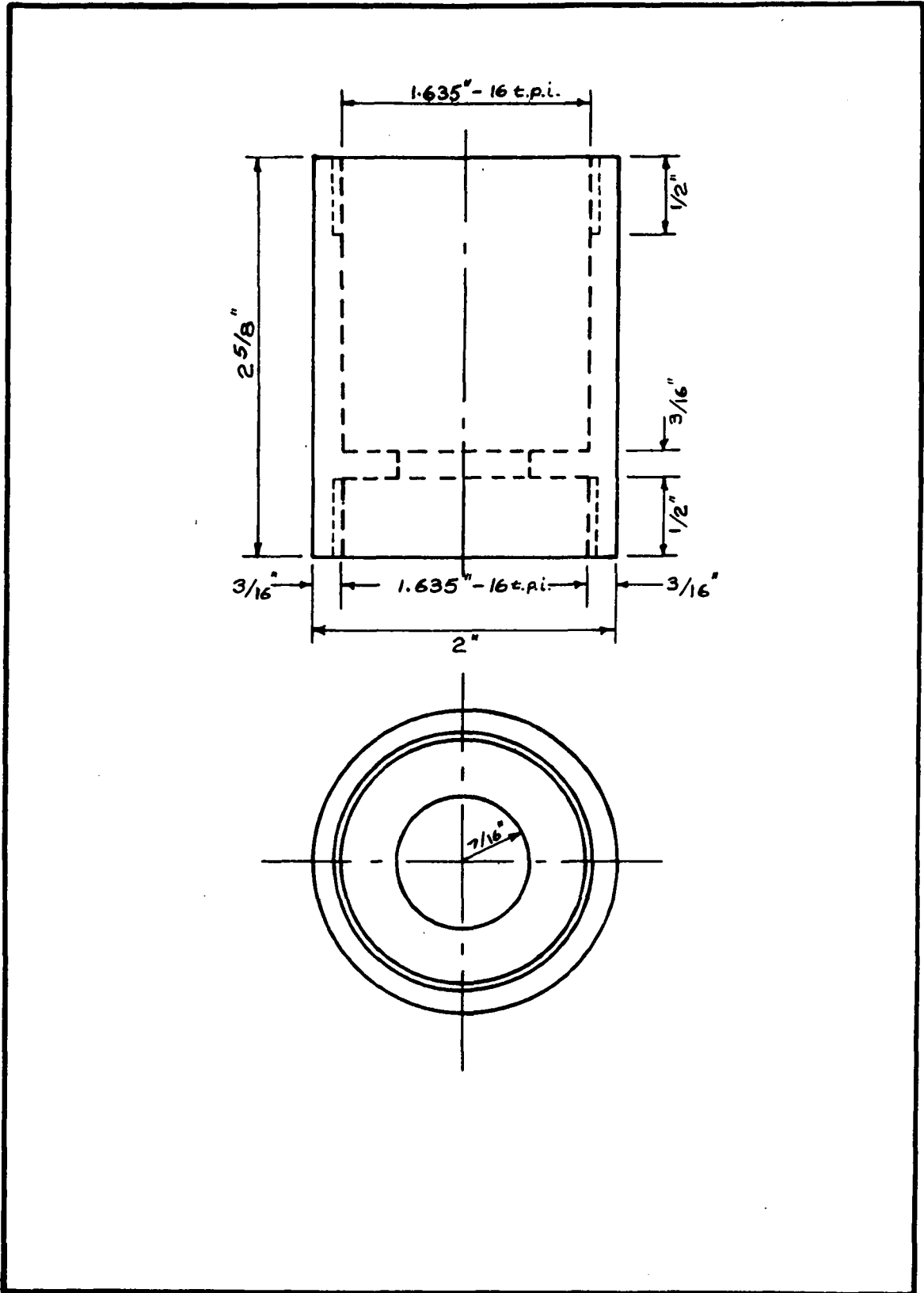
Lower Flange



Upper Flange



End Cap

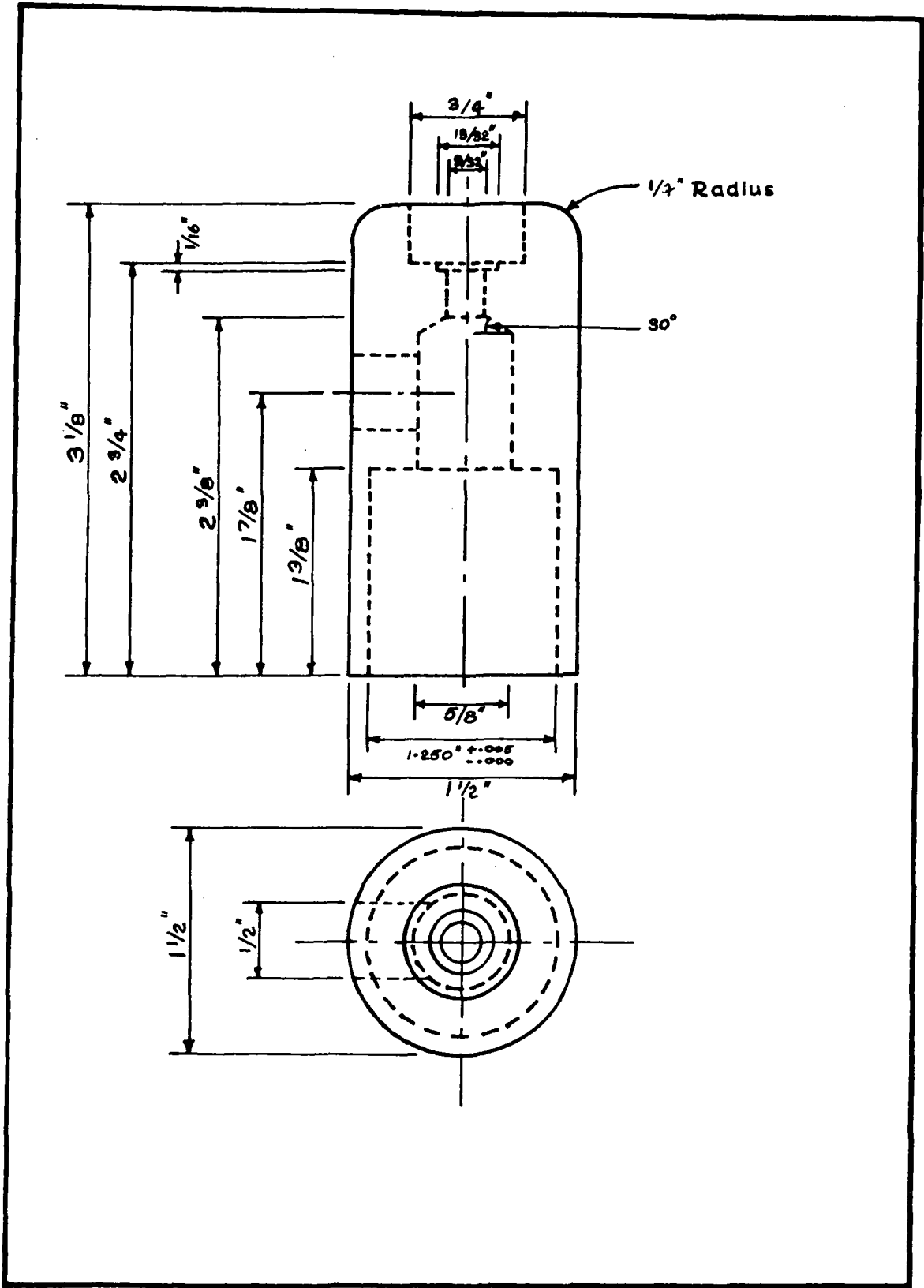


Barrel

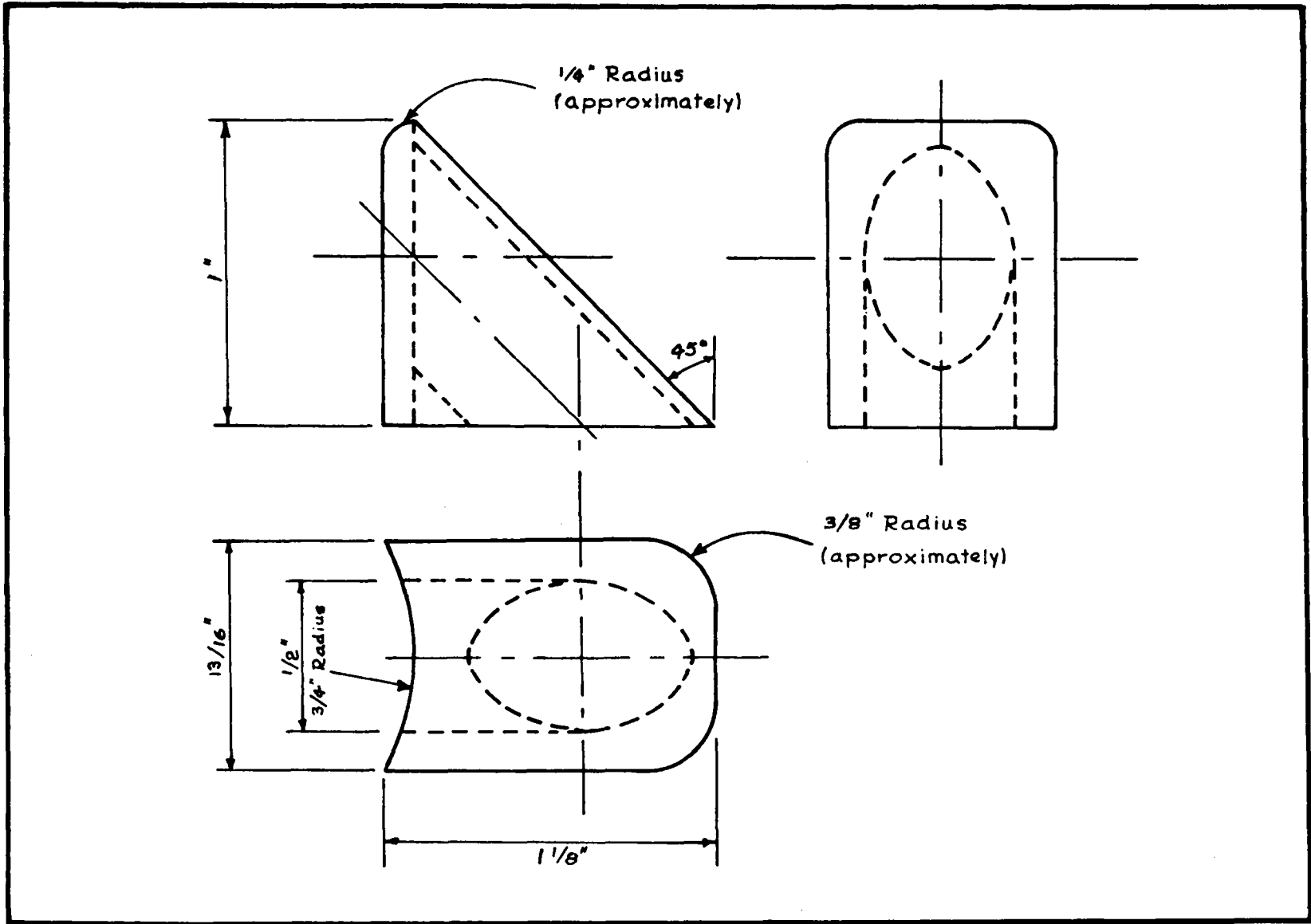


APPENDIX C  
HOUSEHOLD OR YARD ROBOVALVE  
WORKING DRAWINGS

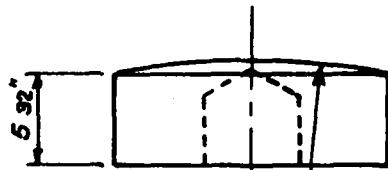
Note: All drawing dimensions are as shown



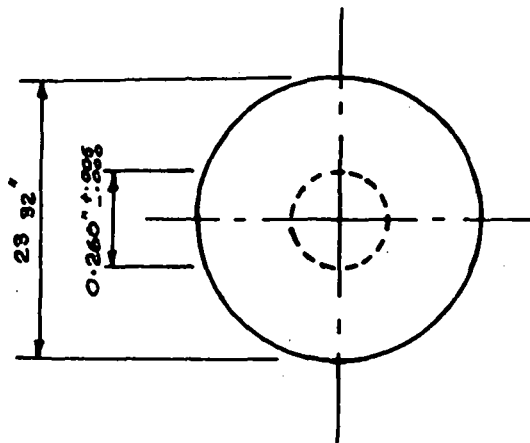
Main Body



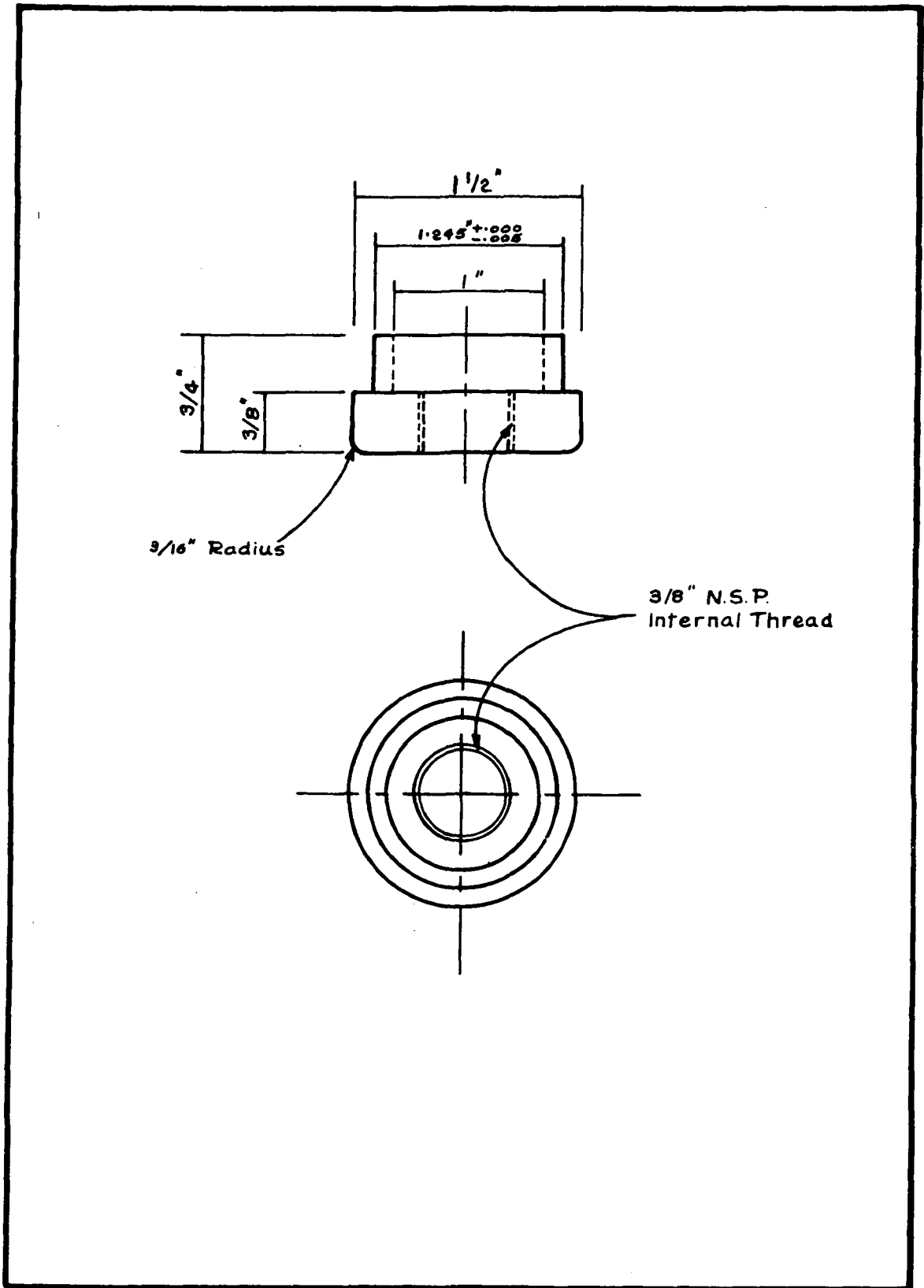
Outlet



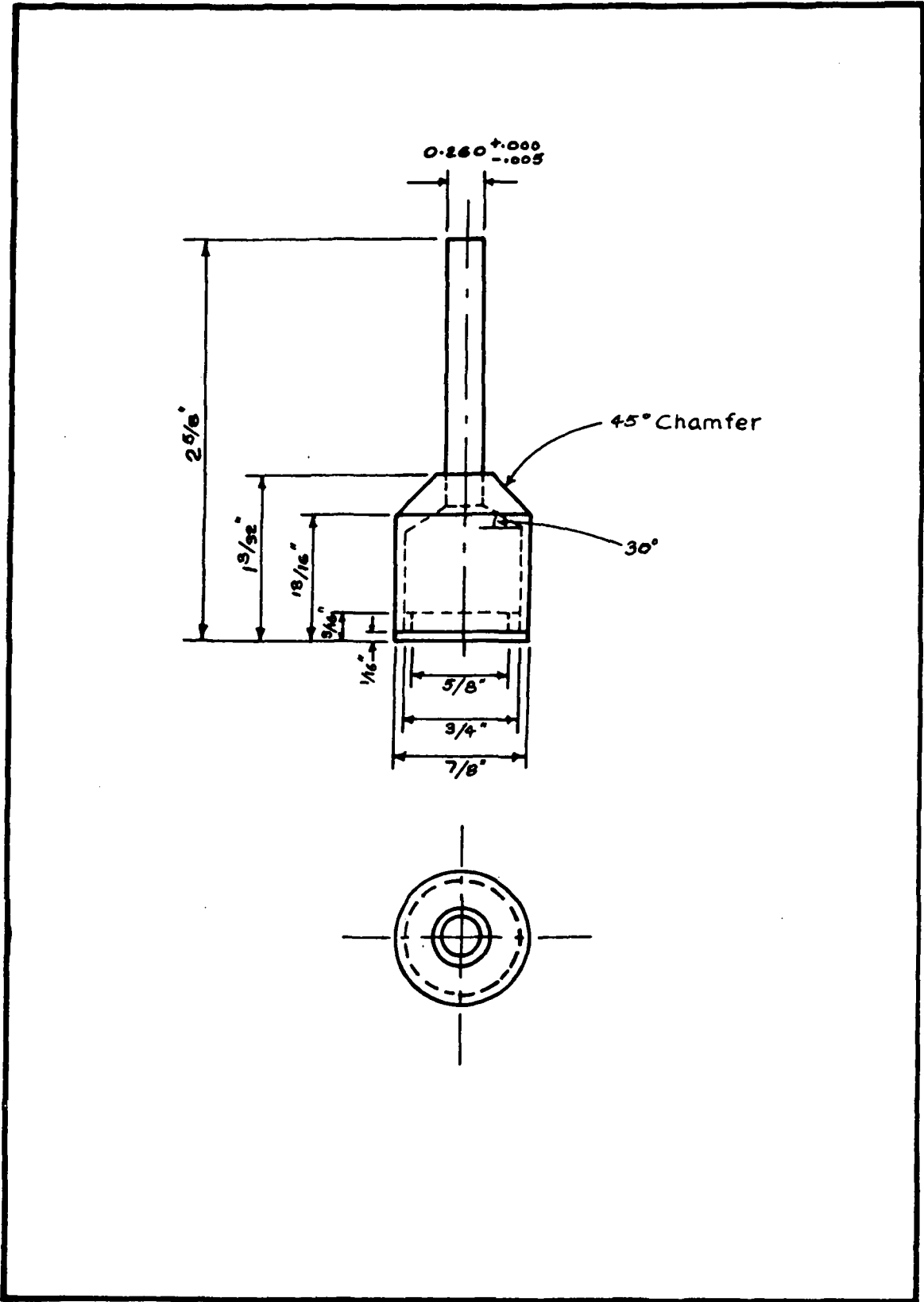
4" Radius



Button



Base Plug

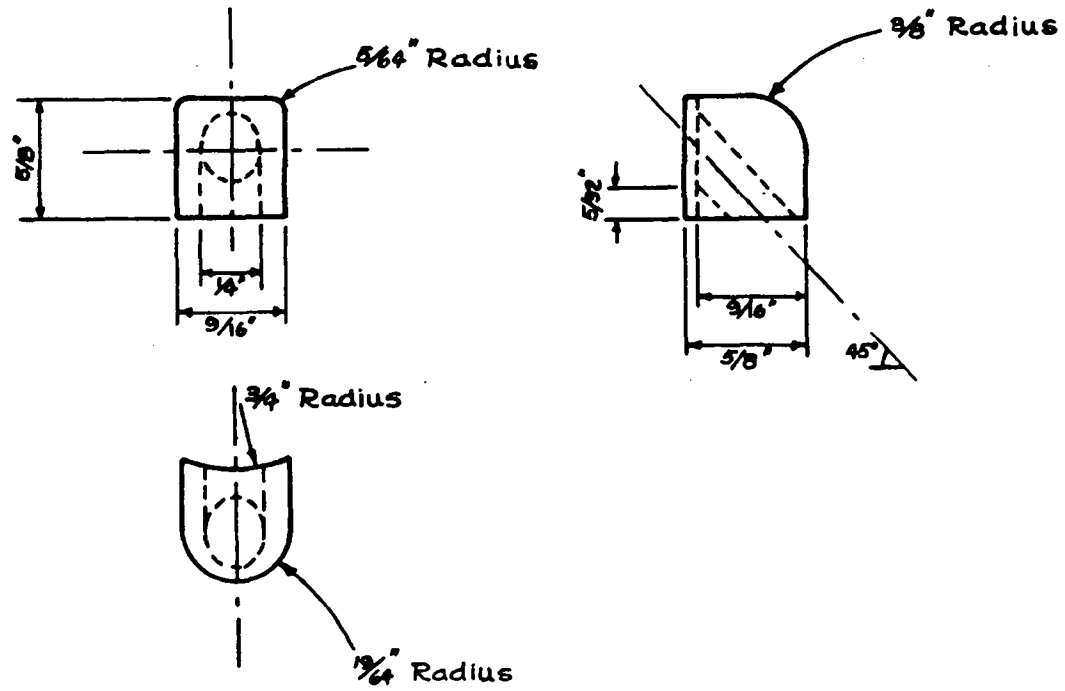


Float Valve Assembly

APPENDIX D

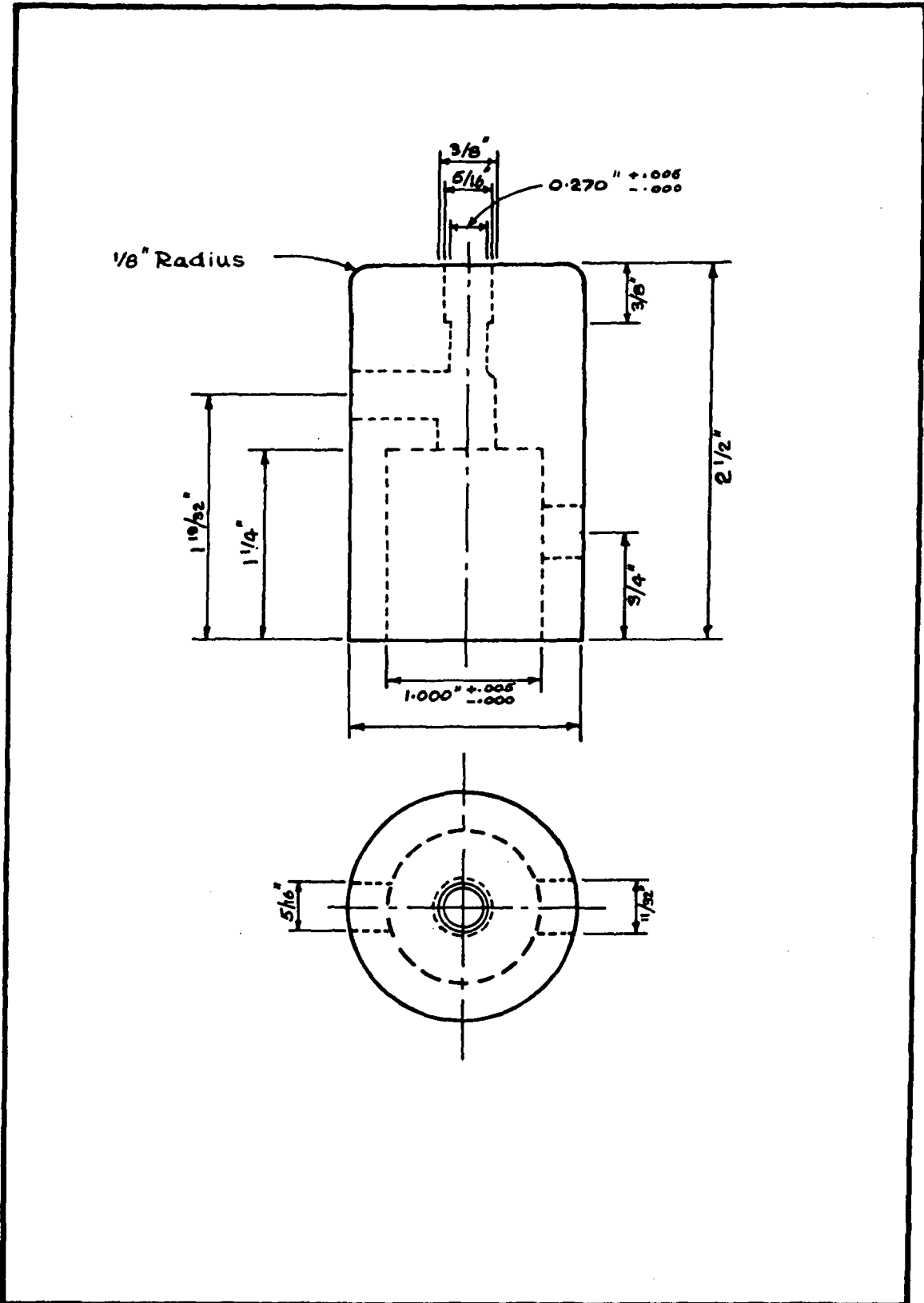
PLASTIC WATER CONTAINER  
WORKING DRAWINGS

Note: All drawing dimensions are as shown.

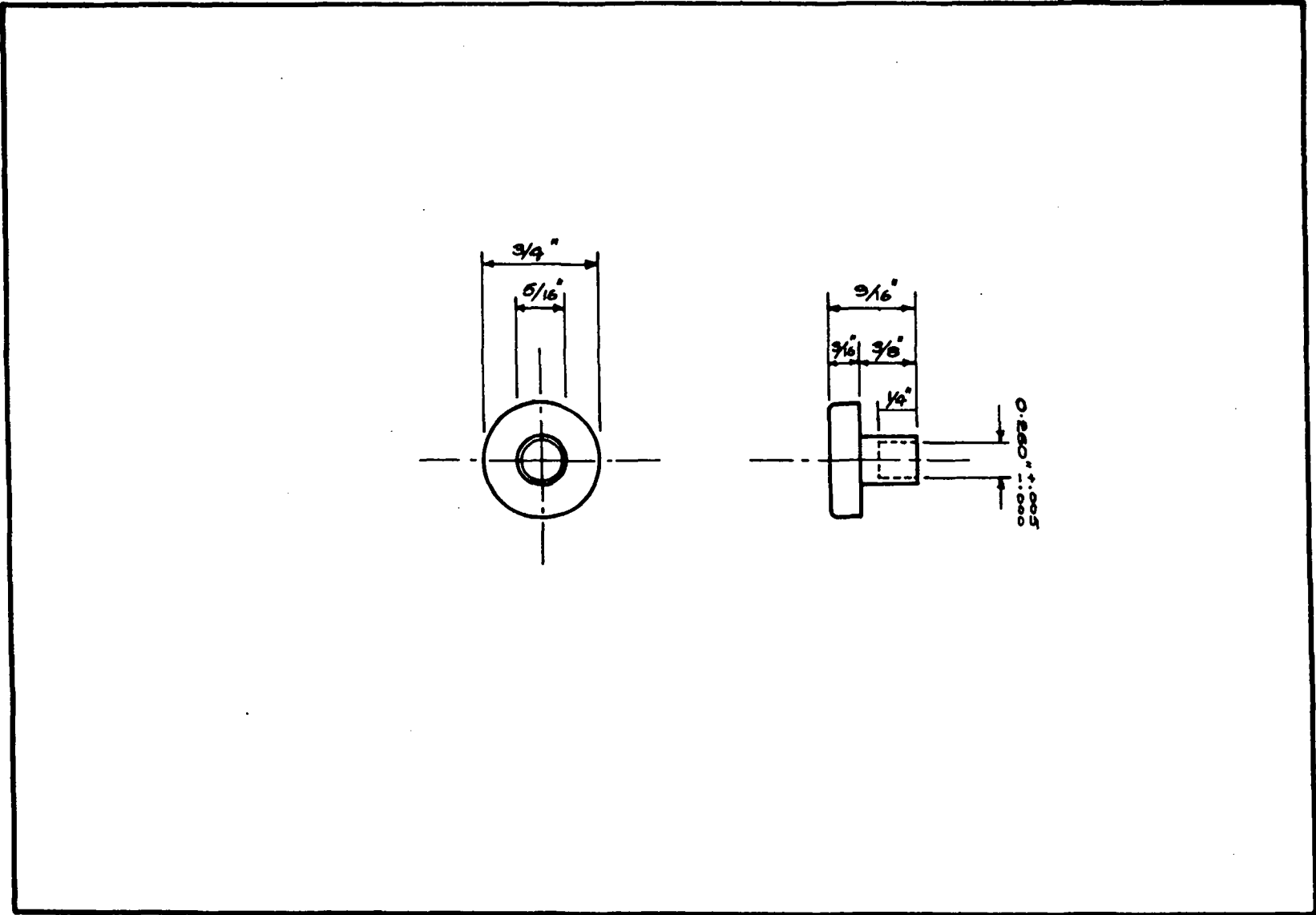


Outlet

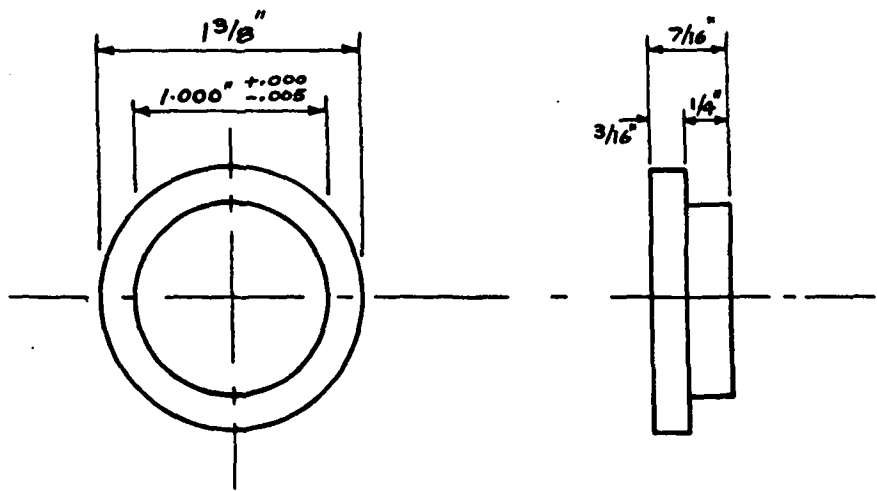




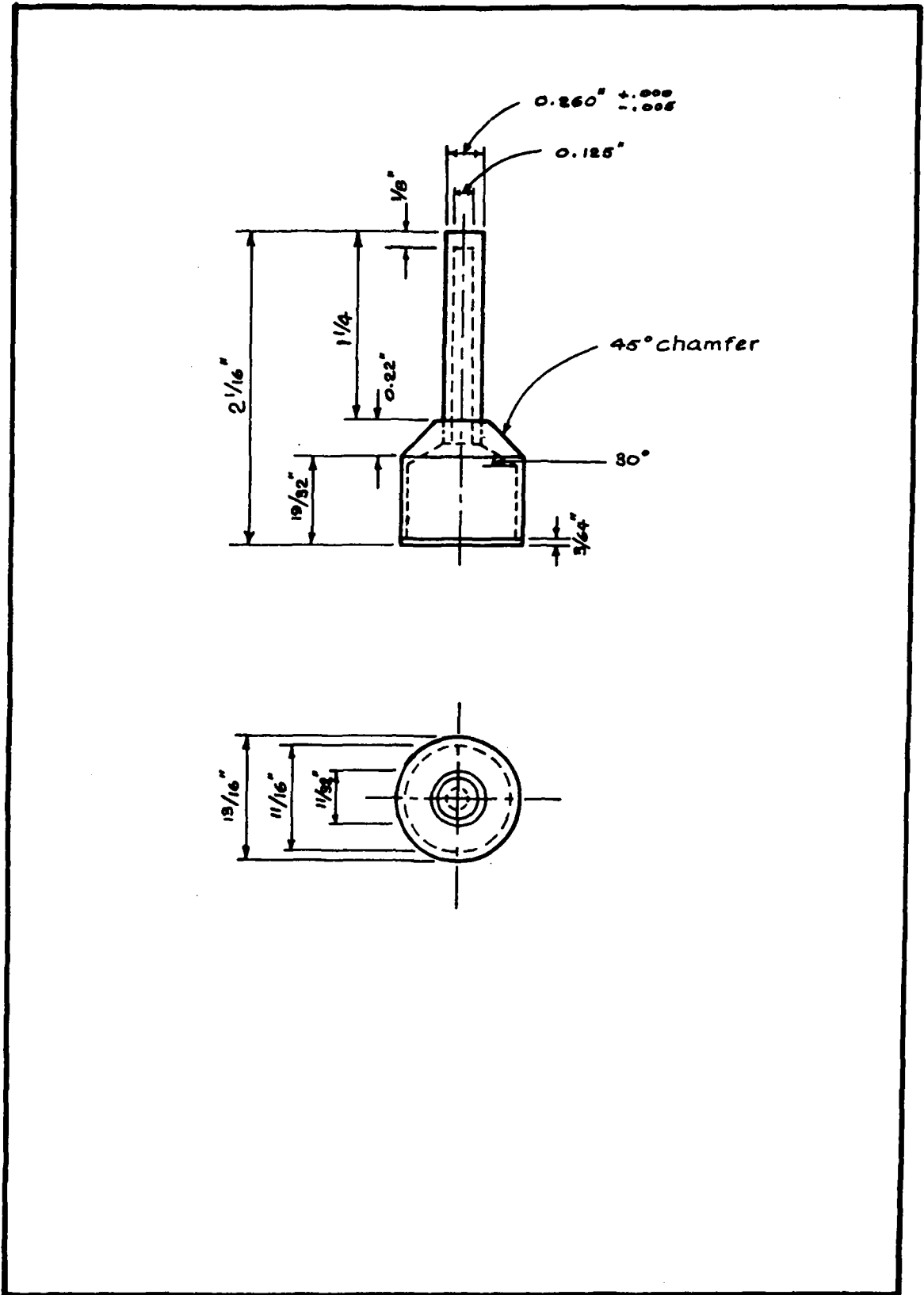
Main Body



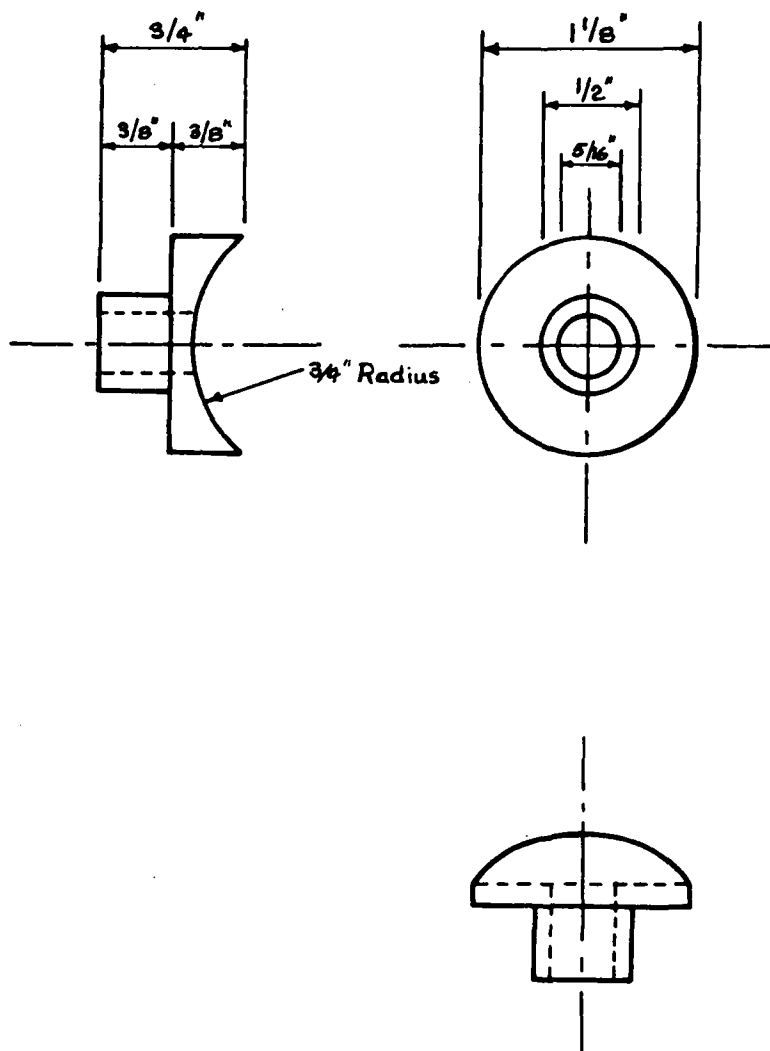
Button



Base Plug



Float Valve Assembly



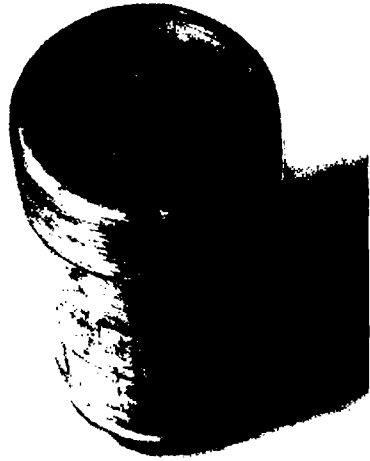
Mounting Flange

**APPENDIX E**

**PHOTOGRAPHIC PRESENTATION OF  
ROBOVALVES**



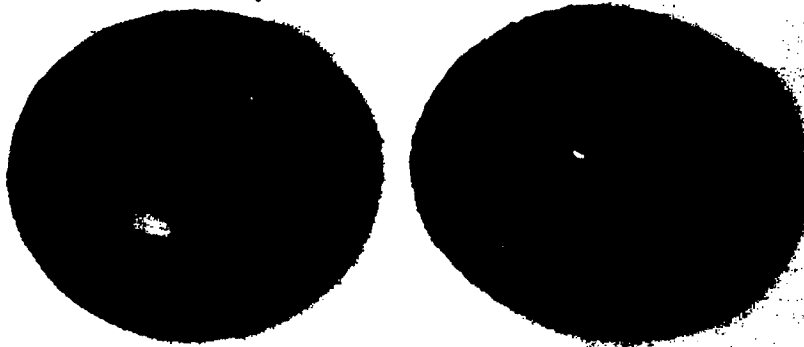
Public Hydrant Robovalve



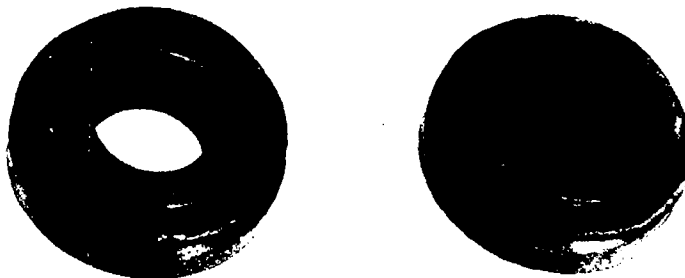
Inside View of Valve



Hydrant Valve Barrel



Diaphragm and Button

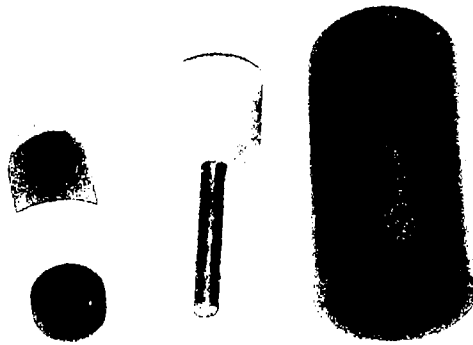


Interior Components

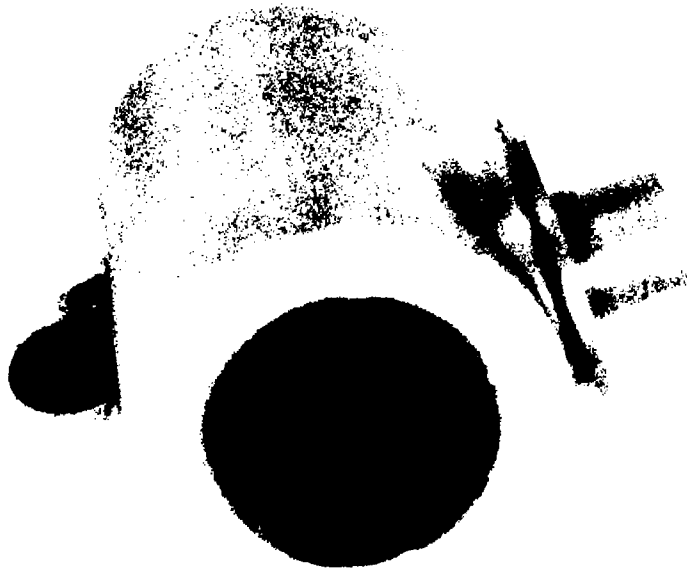




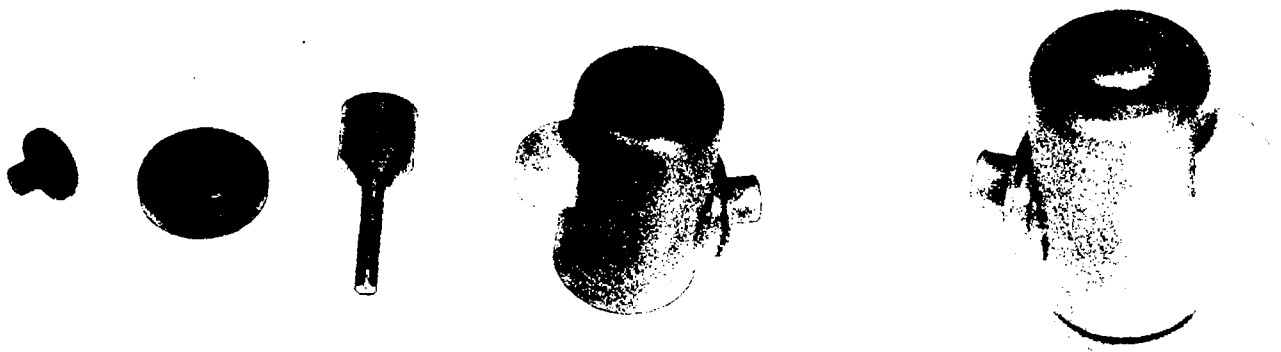
Household Robovalve



Component Parts

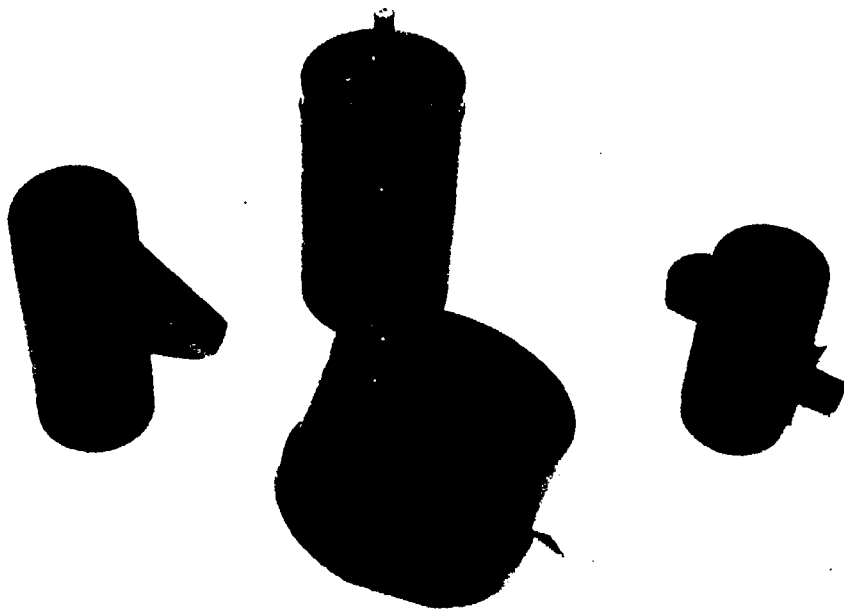


Inside View of Valve



Component Parts

Water Container Robovalve



The Robovalve Family



The Robovalve Inventors