BUSINESS CONFIDENTIAL RNW File **PROJECT REPORT**

SUSPENSION VINYL RESINS:

BENCH-SCALE

IN-BIN BLENDING STUDIES

RECEIVED
NOV 8 1968
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DATE: October 31, 1968

PROJECT NO.: 347B10

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FILE NO.: 10446

SUMMARY The Suspension Polyvinyl Chloride (PVC) Operations Team requested the development of a blender to be installed within existing storage bins. This request is a result of recurring customer complaints on non-uniformity of PVC resin particles within blends.

Studies were made of different blending procedures by the use of bench-scale equipment. As a result, a unique blending method was developed. This method utilizes the blending action of air bubbles dispersed throughout the bin of resin, maintaining a semi-fluidized bed. Full-scale blenders using the air bubble blending method are envisioned in the aluminum production bins at Building 178 if scale-up tests in Bin 610 are successful. A price comparison of proposed blenders is given below:

Texas City Bubble Blender*	$3,300/bin
Texas City Lanier Blender**	5,000/bin
Fuller Company "Airmerge" Blender**	5,000/bin
P-SG Silo Blender***	260,000/9 bins

* Blender to be installed in existing bins, costs include piping.
** Blender to be installed in existing bins, costs exclude piping.
*** Blender to be installed outside of existing bins, costs include transfer lines to 9 bins.

INTRODUCTION Suspension PVC is produced by a batch process. Consecutive batches usually vary somewhat in resin properties. The major varying properties of interest are particle size, moisture and amounts of fisheyes contained. Due to these inconsistent properties, customer complaints and shipment rejections have occurred. For this reason, a method to uniformly blend PVC particles within the storage bins is needed. The storage bins for which the blender is initially needed are the high altitude aluminum bins at Building 178 in Texas City. These bins consist of a ten-foot diameter cylinder 20-feet high, mounted on a 45° bottom cone (see Figure 1).

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The basic requirements for the desired PVC In-Bin Blender are economical installation, ease of operation, and functionality. The Texas City Lanier blender, fluidized bed blender, P-SG silo blender, and the Fuller Company "airmerge" blender may be adequate for blending PVC. However, due to the high capital requirements of these blenders, a more economical blender was sought. This new blender should be preferably free of moving parts which might contaminate the resin because of frictional burning of the resin.

The purpose of this report is to present the information gained by in-bin blending studies carried out in bench-scale bins. The blending action achieved in these studies was obtained by using compressed air only.

DISCUSSION Bench-scale storage bins, described below, were used to visually study the blending action of air streams flowing upward through PVC resin beds. From these studies the following mechanism was defined: When a bed of resin is fluidized, the resin particles take on fluid-like flow properties. As air flow within the resin becomes greater than the minimum fluidization velocity, bubbles of air are formed. Resin particles flow around the upper portion of the bubbles and into the bubbles' lower cavities, forcing the bubble upward. Some particles of resin lying directly above the bubbles are forced upward as others are pushed aside. Each rising bubble follows a path which yields the least flow resistance, giving each bubble a different zigzag flow path. Resin particles from different depths of the bin are scattered over surface of the resin bed as rising bubbles exit the bed. The size of the bubbles is largely a function of air velocity, being inversely proportioned. However, large and small bubbles both give the same type of blending action.

To uniformly blend PVC resin by this bubble type blending, it is necessary to have an even dispersion of air throughout the bin. The following air dispersion tests were made in bench-scale bins.

1/40 Scale Bin

The initial tests were made in a vertical glass tube 30-inches long and 3-inches I.D. plugged at the bottom with a No. 13 rubber stopper (see Figure 2). For each test, the tube was proportionately filled from 80 to 100% loading capacity with PVC. Air was charged through the center of the rubber stopper into the resin at a rate which gave the best observed mixing action (25 SCFH) for 2 hours. Blending occurred only in the top 4-inches of resin. Air was next injected at the edge of the stopper, running air bubbles up one side of the glass tube. This time, blending occurred on the airstream side only. After injecting 3 more evenly-spaced airstreams up the cylinder wall, blending occurred uniformly throughout the tube.

1/12 Scale Bin

Next, a more exactly-scaled storage bin was constructed. This bench-scale bin was made of a 4-foot long 10-inch O.D. Plexiglas cylinder mounted on a stainless steel 45° cone. The bin was an exact 1/12-scale of the aluminum storage bins. Four 1/2 in. x 2 in. nipples were evenly spaced around the upper edge of the cone, with a 1 in. x 3/4 in. nipple in the bottom of the cone (See Figure 3). To represent full loading capacity, the bin was filled with 20 in. of normal, white QYTQ-7 with 2 in. of colored QYTQ-7 on top. A total air flow-rate of 2-3 SCFM was set so as to give adequate bubbling action. After blending for 10 minutes, all resin which was at least 2 in. above the cone was uniformly blended. However, portions of the cone were untouched by the rising bubbles. In an effort to better blend the cone region, 4 more 1/2 in. x 2 in. nipples were installed (staggered below the original 4, half-way up the cone). All 9 air inlets were still directed vertically into the resin. This arrangement of air inlets improved blending within the cone, but still left unblended areas. Total blending was found to occur when the air supply to each of the 9 air inlets was pulsed at the same frequency. Each pulse lasted just long enough for bubbles to travel to the top of the bed of resin. Recognizing that air pulsating equipment would be rather expensive, a cheaper method was still sought.

For the next test, a perforated plate was placed between the top of the cone, and the base of the Plexiglas cylinder. This plate contained 1/8 in. holes spaced 1/2 in. apart. For a trial blend, air was charged in through all the existing inlets. As before, all resin 2 in. above the top of the cone was uniformly blended, whereas resin in the cone was not. Nozzles were then connected perpendicular to the cone walls, in an effort to blend resin within the cone. This trial also failed. Air dispersion pads were placed around the cone section, giving moderate blending within the cone. To use air dispersion pads, it would be necessary to cover the entire cone wall with dispersion pads so this idea was also abandoned.

A double-cone nozzle was then constructed for the bottom of the cone. This nozzle was made of a 45° brass funnel having a 1 in. long wall, with a 45° cone sitting inside of it. Air was fed into the bottom of the funnel and forced between the two cones. Thus, a steady stream of air was sent up the cone walls. This system gave complete blending action. However, to extend the air stream up to the vertical bin walls, an enormous volume of air was required. An air flow rate of over 10 SCFM was required for the 1/12 scale bin to produce adequate blending.

Another central dispersion type nozzle was made up for the bottom of the 1/12 scaled bin cone. This nozzle had 6 outlets made of 1/8 in. stainless steel tubing 1/2 in. long, evenly spaced around a 1/2 in. pipe cap. The nozzle outlets were directed parallel to the cone wall of the bin. By forcing small individual air streams from this nozzle along the cone wall to the vertical wall of the bin, blending action occurred throughout the bin.

The central dispersion nozzle described above was selected as the best blending mechanism, and subjected to further tests. The following tests were set up in the 1/12 scale bin. To represent a proportionate 80% load capacity, 15 in. of normal, white QYTQ-7 was added to the bin with 2 in. of colored QYTQ-7 on top. The colored resin was added to aid visual observation of the blending process. (Coloration of the resin particles was accomplished with oil red dye dissolved in isopropanol). An air pressure of 15 PSIG and a flow of 2-3 SCFM were used to obtain the best blending action. After 10 minutes of blending, samples were taken from various regions of the test bin and analyzed for uniformit, in colored particles. All samples contained essentially the same proportions of colored particles to white particles. A check was made to see if fines (resin particles much smaller than the average) would become segregated during blending. This test was set up the same as the previous one, only instead of using QYTQ-7 resin (having an average particle size of 140 microns) for the colored particles, VYHH (having an average particle size of 50 microns) was used. The resin was blended for 10 minutes and samples taken. The fine colored particles had blended uniformly with the larger white particles. To further test for fines segregation, the air stream was left on for 16 hours. At the end of this blending period, no fines segregation had occurred. The same test was run again. This time large resin particles were used instead of fines. A 2 in. layer of colored, large-particle QXAL-12 was placed on top of the 15 in. of white QYTQ-7 resin. After blending for a minimum period of one minute, samples were taken, revealing a uniform blend. Other tests were made by placing the colored resin in different positions in the bed of white resin, with the same end result of a uniform blend. Duplicate runs of the previously-mentioned tests were made on VMCH, QYSA, QXAL-12, QYTQ-7, VYNS, VYHH, and VYAR resins. All resins blended uniformly. The smaller particle resins required greater air flow and longer blending periods to reach uniformity. This difference is apparently due to the greater surface attraction exerted between the smaller particles.

Cross-sectional Bin

To observe more closely the blending action taking place in the center of the bin, a cross-sectional bin was constructed of Plexiglas. This test bin was made of 1/4 in. Plexiglas, 20 in. wide, 1-1/2 in. deep and 50 in. high, with 45° walls for the cone section (see Figure 4). A nozzle was placed at the bottom, having a 1/8 in. stainless steel tube 1/2 in. long for air outlet directed parallel to each of the two 45° walls. The bin was filled with 40 in. of mixed white and colored resin. While blending, the resin particles were scattered radially by each rising bubble. As the air streams swept up from the nozzle along the cone wall, small eddy currents of air separated and diffused upward into the bed of resin, fluidizing it. Air bubbles were not formed until the air stream changed velocity by hitting the vertical wall. Some bubbles bounced back into the bed of resin while others followed the bin walls upward. Thus, the entire column of resin above the cone was set in bubbling motion. Resin particles within the cone slowly work down into the air streams and are blown up to the top edge of the cone into the bubbling region.

1/6 Scale Bin

While observing the blending action in the cross-sectional bin, a pocket of motionless resin was noticed in the center of the cone. Samples taken from the 1/12 scale bin did not indicate this unblended area. It was believed that the unblended pocket was caused by the increased wall area of the thin bin restricting resin motion. A larger test bin was constructed to test this theory. The large bin was constructed of 1/4 in. Plexiglas, having rectangular column dimensions of 20 in. x 20 in. x 50 in. (see Figure 5). Tests were run in this bin using colored resin as before. After blending 10 minutes, samples were taken from various regions of the bin including the central portion of the cone. All samples contained the same uniform distribution of colored particles. A small amount of QXAL-12 resin was later added to the bin to simulate fisheyes. Respro samples were taken from different sections of the bin before and after blending. Repeated tests of the respro counts indicated the existence of a uniform blend.

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The minimum total air flowrate to produce suitable blending within the larger test bin was 6-7 SCFM. At this air flowrate, it became necessary to filter resin particles out of air exiting from the bin. A single layer of filter cloth one-foot square was sufficient for this separation.

Proposed Scale-up Plans

Reliable correlations for scale-up factors were not obtainable from the bench-scale studies, so scaleup tests are to be run on an actual storage bin. From these tests, the necessary air flow rate, nozzle size, and nozzle positions for complete blending will be determined. Bin No. 610 at Building 178 has been set aside for these scaleup studies.

One adjustable nozzle will be installed along the bottom of the cone on Bin No. 610. Directly above this nozzle, one-foot above the upper edge of the cone, a Plexiglas window will be installed. This window is located at the critical blending spot.

The bin will then be filled with resin to approximately 80% maximum volume. Different nozzle sizes and air flow rates will be tried until satisfactory blending action is observed at the Plexiglas window. The correct spacing of nozzles may be determined by observing the width of the section of resin being blended by one nozzle. Knowing the air flow rate, nozzle, size and positioning needed for adequate blending, the remaining fixed nozzles will be installed. The nozzles will be placed as low in the cone as possible. Blending tests will be made by adding extra fisheyes to the bin of resin, and taking resin samples from different positions in the bin before and after blending. Respro fisheye ratings of the samples should indicate the efficiency of the blender.

PATENTABLE FEATURES There are several blenders on the market which use compressed air to create their blending action. However, these blenders use air stream turbulence and baffled flow patterns rather than air bubbling action. The use of air bubbles for blending small particles seems to be a unique method used only by the blender described within this report.

CONCLUSION

1. In-bin blending of PVC by the air bubble type method was successful in bench-scale bins.

2. The only installations needed for production-scale bubble blending are suitable nozzles at the bottom of the bin, and a filter sock at the top of the bin.

3. This type of blender would be much more economical for PVC than either the Texas City blender, Fluid-Bed blender or the Pichney-St. Gobain silo blender which were previously under consideration.

4. Complete scaleup tests using this blender should be completed as soon as possible.

5. This air bubble type blender is adequate for resins having particle sizes ranging from 30 to 600 microns in diameter.

6. The loading capacity of bins used for blending should be about 80%. This allows for bed expansion and disengaging space.

ACKNOWLEDGEMENTS Respro fisheye tests and analytical work were performed by J. L. Hockersmith's Texas City Quality Control Group. Order-of-magnitude price estimates were submitted by J. E. Llana of the Texas City Engineering Group.

ATTACHMENT: 5 Figures

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FIGURES

BENCH-SCALE EQUIPMENT

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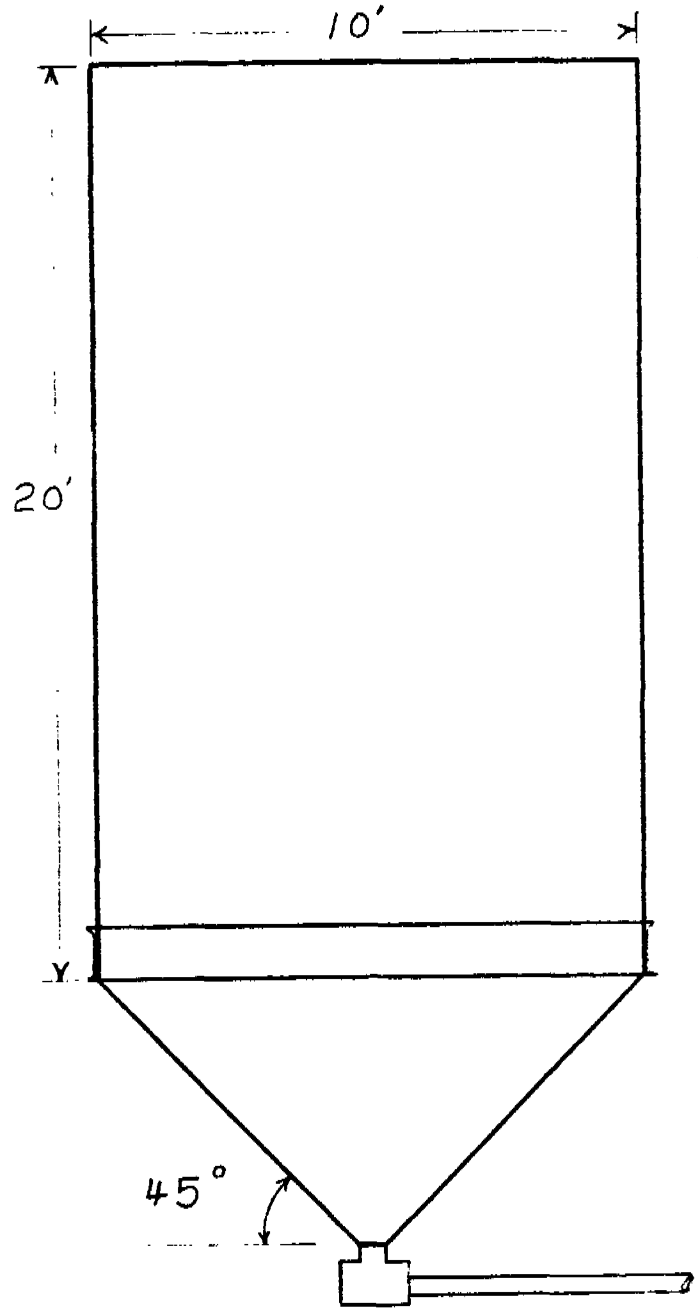

Circ for Walls of
1/4" Aluminum

PVC Sorage Bin

figure # 1

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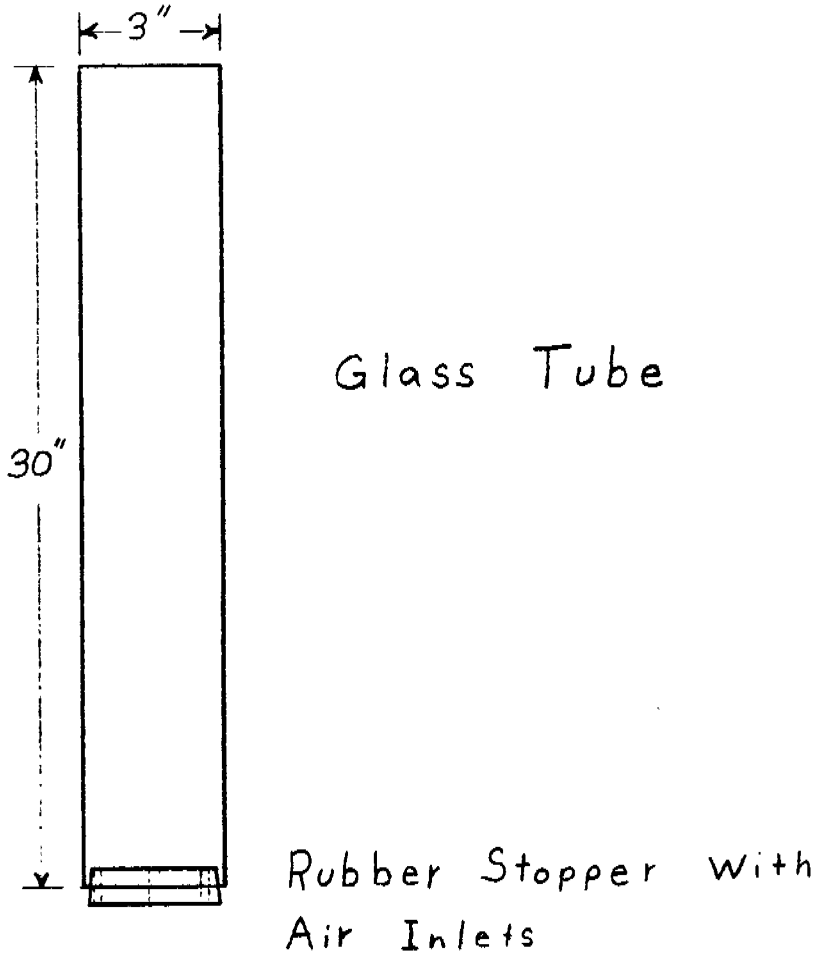

$\frac{1}{40}$ Scale Bin

figure # 2

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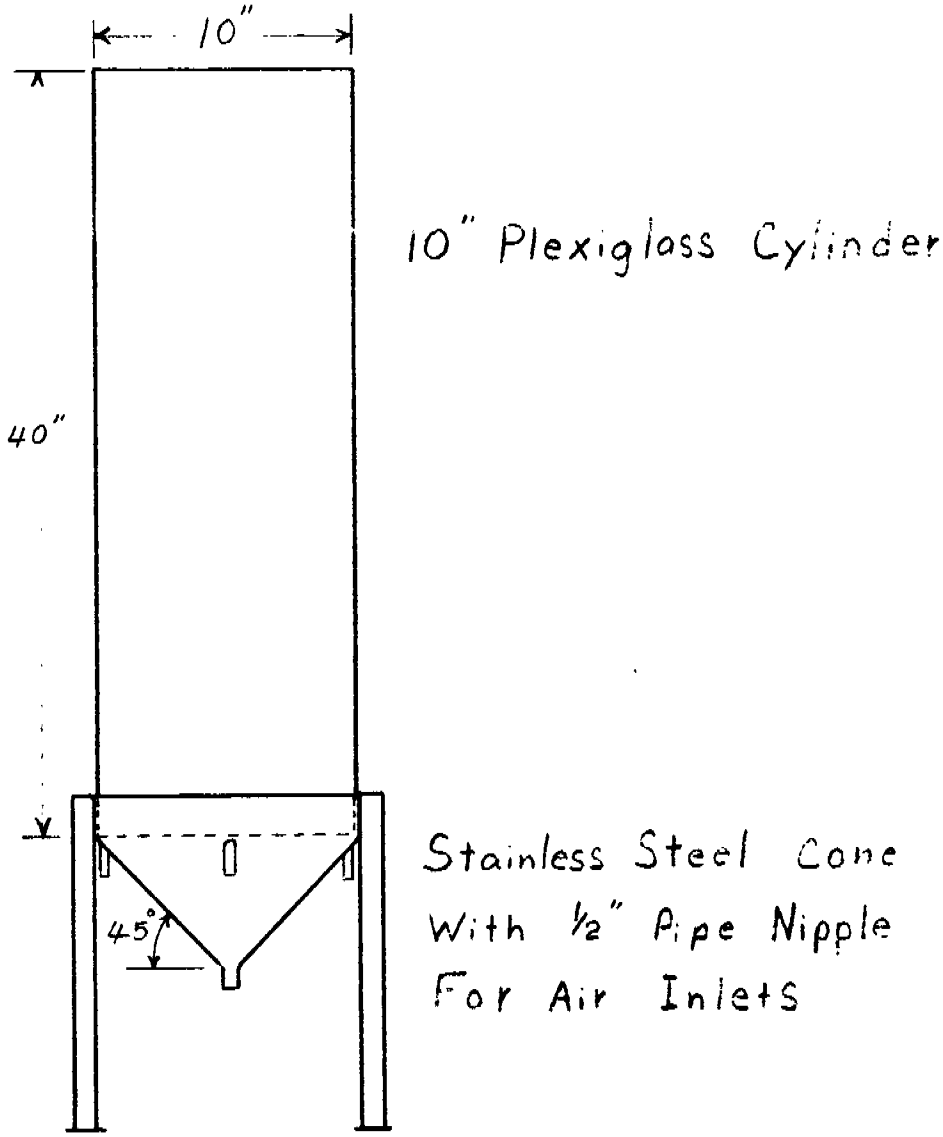

$\frac{1}{12}$ Scale Bin   figure # 3

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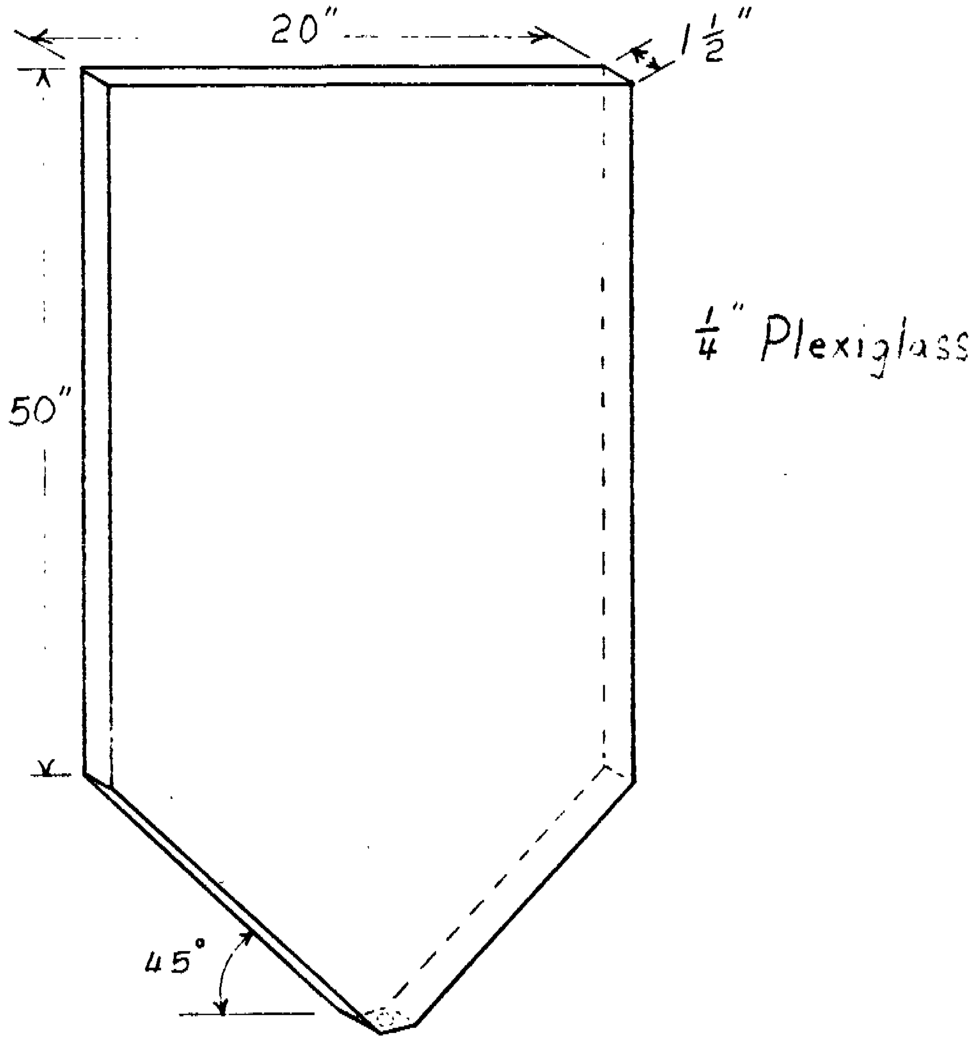
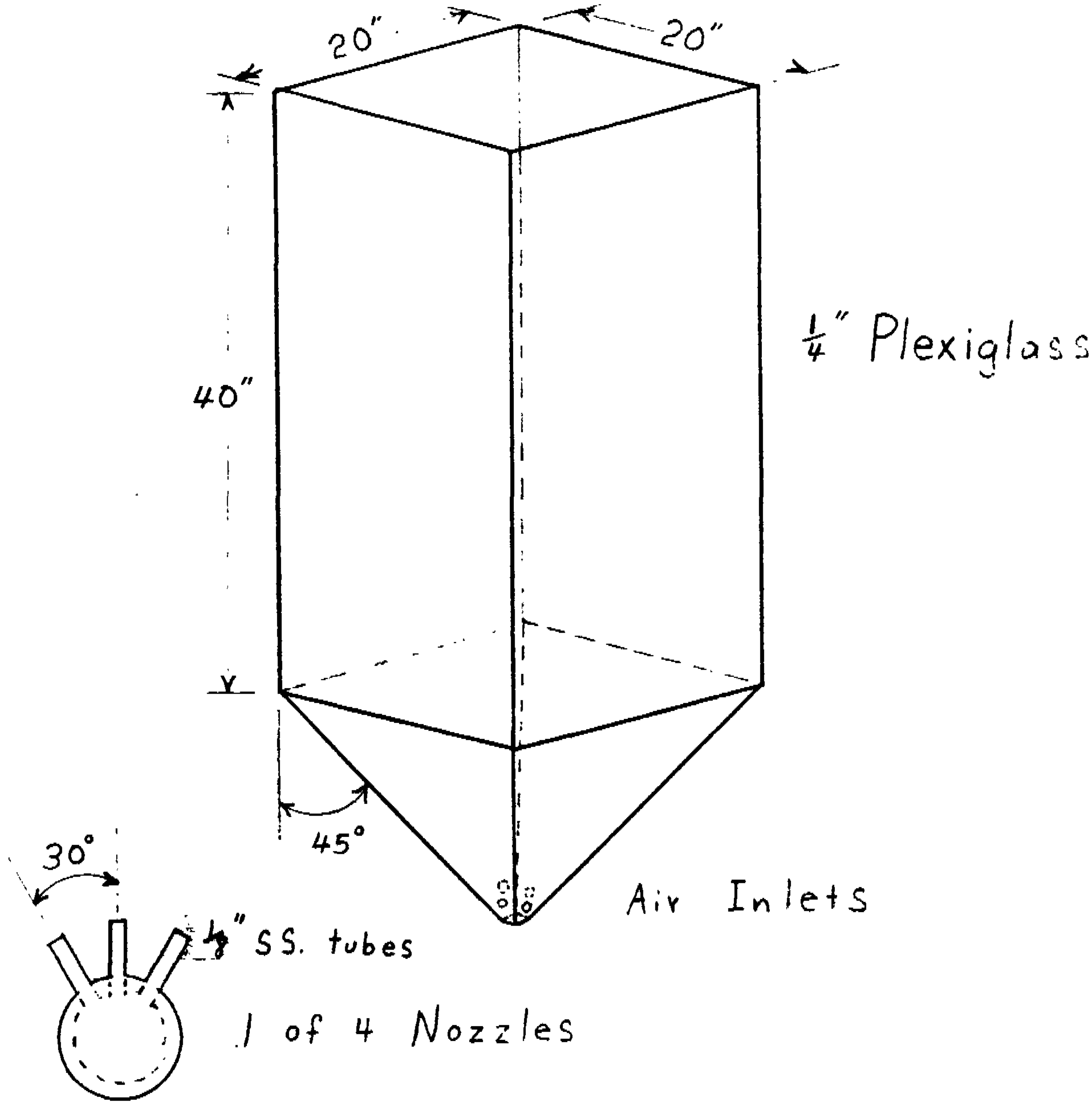


Crossectional Bin figure # 4



1/6 Scale Bin figure # 5

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