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EFFECT OF BAFFLES ON INFLOW PATTERNS IN SPHERICAL CONTAINERS DURING WEIGHTLESSNESS

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16. Abstract

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SUMMARY

An experimental investigation of liquid inflow patterns in a spherical container (5-cm radius) during weightlessness was conducted in the Lewis Research Center's 2.2-Second Zero-Gravity Facility. The test liquids used exhibited an essentially zero-degree static contact angle on the surface of the sphere.

The results showed that over the range of Weber numbers examined for unbaffled spheres, complete wetting of the tank walls occurred. Less liquid escaped through the vents as the Weber number was increased. When the vent lines were extended into the sphere through the thin liquid film, no liquid was lost.

Several inlet baffles (solid, screen, and perforated) were examined. The solid baffles included a circular flat plate and a solid hemispherical baffle. The flow patterns for the circular flat plate were more symmetric than those for the solid hemispherical baffle. The screen baffles did not result in uniform wetting of the container walls. It was observed that the coarser mesh screens sprayed the wall more effectively than the smaller sizes. The perforated hemispherical baffle was the most effective baffle tested. The tank walls were wet uniformly and rapidly. Again, when the vents were extended into the sphere, no liquid was lost for any of the containers with baffled inlets.

INTRODUCTION

In previous space missions conducted within the United States Space Program, various liquid propellants were used. In all cases, the filling of the propellant tankage was accomplished in normal gravity. It is believed that in the future, space vehicles will depend on the in-orbit filling or resupply of tankage to complete their mission.

One proposed method of resupplying a cryogenic tank is to initially cool the tank walls with the incoming cryogenic liquid while venting the generated vapor to control tank pressure. Once cooldown is completed, the tank vents will be closed and the tank can be nearly filled without excessive pressure increases due to the condensation of vapor. During inflow to a hot tank, vaporization will occur at the tank walls. The inflow pattern should result in reestablishing only liquid in contact with the container walls since the vapor in direct contact with the walls causes reduced heat transfer. Baffles may be required for directing the incoming flow of cryogenic liquid in order to cool the entire container walls with a minimum of liquid loss through the vents. The proper design of a baffle configuration for the purpose of directing the flow requires a knowledge of the effects of zero gravity and liquid inflow rate on the resulting liquid flow patterns.

This study and a related one (ref. 1) were concerned primarily with isothermal inflow patterns during weightlessness. The study of reference 1 examined an inflow baffle which directed the flow along the walls in the form of a three-dimensional axisymmetric wall jet. It was primarily concerned with the complete circulation which can be expected with a thermal conditioning system (ref. 2); however, it does indicate one type of wall flow pattern which can be obtained during weightlessness. Two other studies (refs. 3 and 4) examined the effect of baffles during weightlessness. Reference 3 was concerned with the isothermal filling of a spherical tank containing an internal surface tension device for positioning the liquid-vapor interface at equilibrium. Reference 4 was concerned with the stable filling of hemispherically ended right circular cylinders containing a variety of inlet baffles.

The purpose of this study was to experimentally examine the effectiveness of a variety of inflow baffle configurations on isothermal liquid flow patterns in a weightless environment. A determination of the success of a particular baffle to cause uniform tank wall wetting during isothermal inflow will make it a candidate for controlling inflow to a hot tank. The baffle location in all cases was directly above the tank inlet. The liquid flow patterns examined in this experimental study were those which resulted in some type of wall jet and yielded a completely wetted container surface. The tank studied was a sphere with an inside radius of 5 centimeters, inlet radius of 0.2 centimeter, and was equipped with two symmetrically located vents. The liquid lost through the vents during inflow was also observed.

SYMBOLS

A_I area of circular inlet, cm^2

Q volumetric flow rate, cm^3/sec

R_I radius of inlet, cm

We Weber number based on inlet radius, $Q^2/\pi^2\beta R_I^3$

β specific surface tension, σ/ρ, cm^3/sec^2

ρ density, g/cm^3

σ surface tension, dynes/cm

APPARATUS AND PROCEDURE

Test Facility

The experimental data for this study were obtained in the Lewis Research Center's 2.2-Second Zero-Gravity Facility. A schematic diagram of this facility is shown in figure 1. The facility consists of a building 6.4 meters square by 30.5 meters tall. Con-

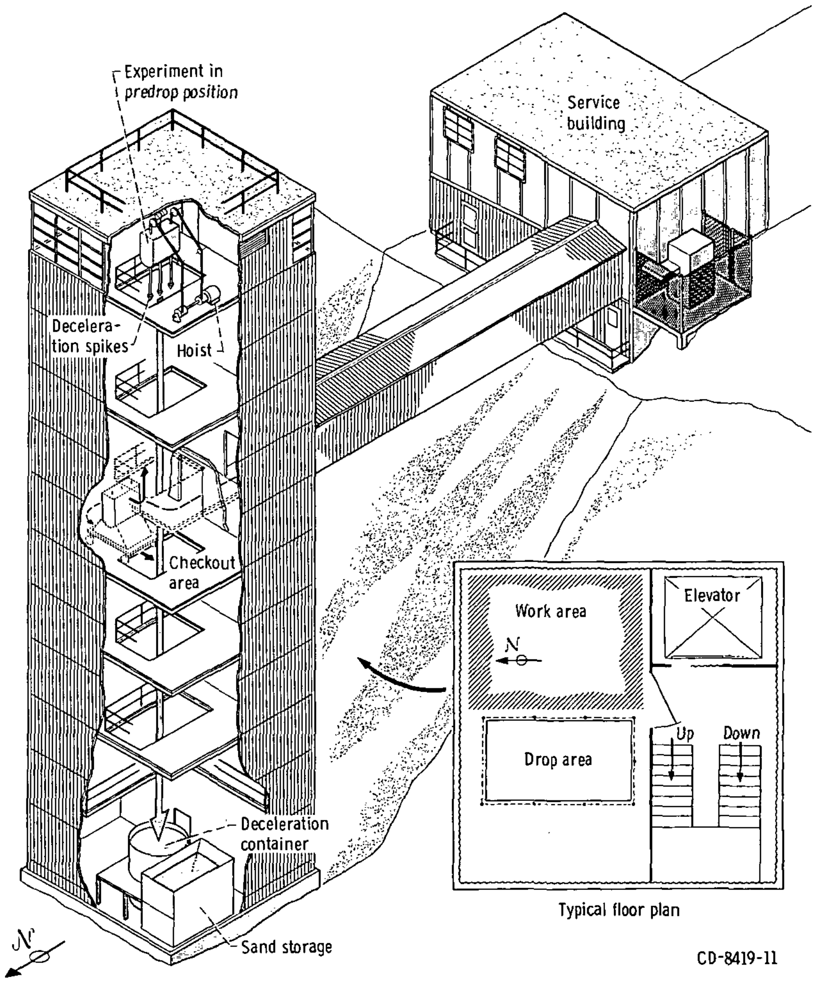


Figure 1. - 2.2-Second Zero-Gravity Facility.

tained within the building is a drop area 27 meters long with a cross section 1.5 by 2.75 meters.

The service building has a shop and service area, a calibration room, and a controlled environment room. Those components of the experiment that required special handling were prepared in the controlled environment room of the facility. This air-conditioned and filtered room contains an ultrasonic cleaning system and the laboratory equipment necessary for handling test liquids.

Mode of operation. - A 2.2-second period of weightlessness is obtained by allowing the experiment package to free fall from the top of the drop area. In order to minimize drag on the experiment package, it is enclosed in a drag shield designed with a high ratio of weight to frontal area and a low drag coefficient. The relative motion of the experiment package with respect to the drag shield during a test is shown in figure 2. Throughout the test, the experiment package, and drag shield fall freely and independently of each other; that is, no guide wires or electrical lines are connected to either. Therefore, the only force acting on the freely falling experiment package is the air drag associated with the relative motion of the package within the enclosure of the drag shield. This air drag results in an equivalent gravitational acceleration acting on the experiment, which is estimated to be below 10^{-5} g's.

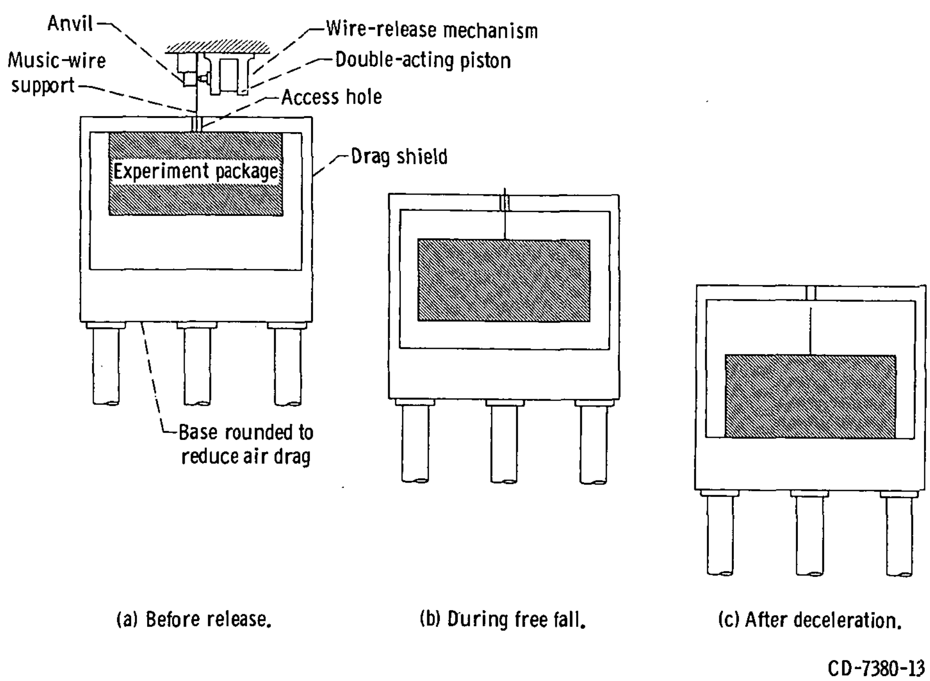


Figure 2. - Position of experiment package and drag shield before, during, and after test drop.

camera, a background lighting scheme, and auxiliary equipment. The auxiliary equipment included batteries, a sequence timer, and a digital clock with divisions of 0.01 second.

Test container. - A spherical tank, 5 centimeters in radius, was fabricated from acrylic plastic and was polished until clear (see fig. 4). The top of the tank was equipped with two symmetrically located circular vents 0.2 centimeter in radius and extending 2 centimeters above the surface of the sphere. The centerlines of the vent holes were

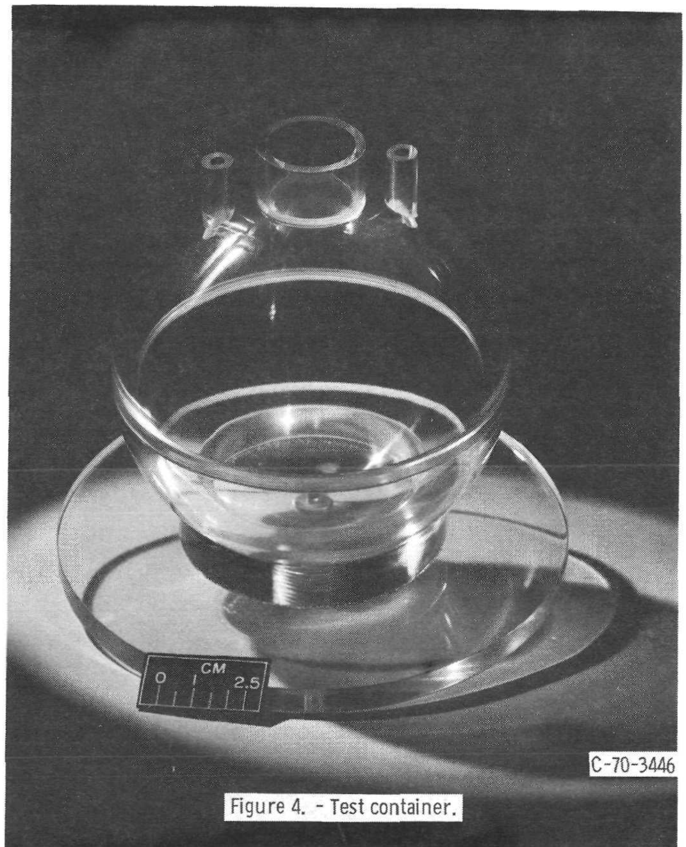


Figure 4. - Test container.

positioned 2.54 centimeters from the tank centerline. The test container was fabricated in two halves and an O-ring seal prevented liquid loss during the inflow process. The inlet to the test container was a circular hole (of radius 0.2 cm for a majority of the tests conducted) located on the tank centerline.

Test liquids. - Three test liquids were employed in the experimental tests: anhydrous ethanol, trichlorotrifluoroethane, and FC-78. These test liquids exhibited an essentially zero-degree static contact angle on the container surface.

Test Procedure

Experiment preparation. - Prior to a test run, the experiment tank was cleaned ultrasonically with a mild detergent. After the tank was rinsed with methanol, it was dried in a warm air dryer.

The required liquid flow rate into the spherical container was calibrated in normal gravity as a function of the accumulator bottle pressure. The pressure drop across all the baffles tested was negligible since the pressure-liquid flow rate curve was not affected by the insertion of baffles into the system.

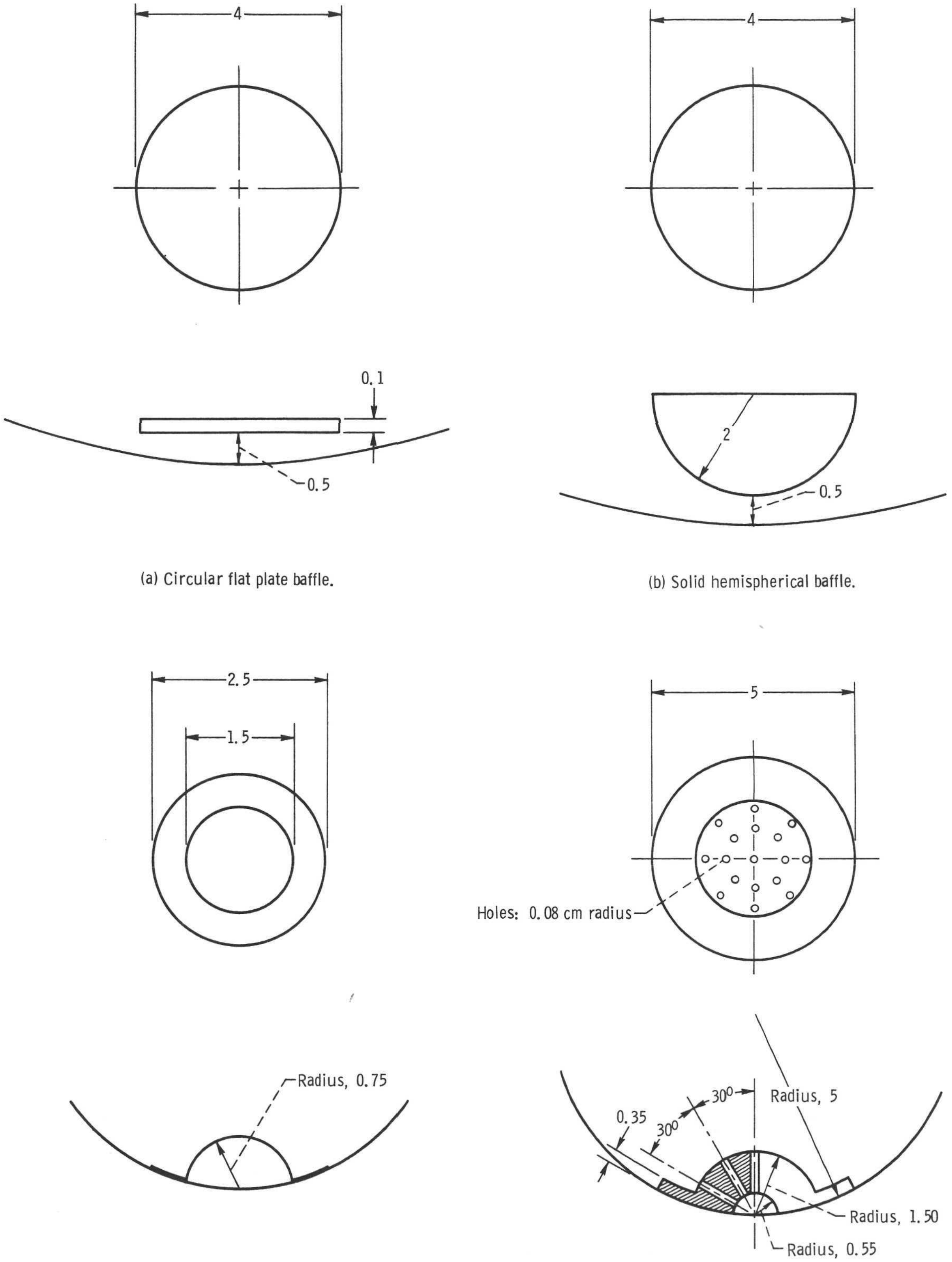
Procedure for test drop. - Two accumulator bottles were located on the test rig and were filled to the predetermined pressure with gaseous nitrogen just prior to the drop. The accumulator bottles were of sufficient volume so that no appreciable decrease in pressure occurred. Electrical timers on the experiment package were set to control the initiation and duration of all functions programmed during the drop. The experiment package was then balanced and positioned within the prebalanced drag shield. The wire support was attached to the experiment package through an access hole in the shield (see fig. 2(a)). Properly sized spike tips were installed on the drag shield. Then the drag shield with the experiment package inside, was hoisted to the predrop position at the top of the facility (fig. 1). The wire support was attached to the release system. The entire assembly was suspended from the wire and connected to an external power source. After final electrical checks were made and the experiment package was switched to internal power, the system was released. After completion of the test, the experiment package and drag shield were returned to the preparation area.

Description of Baffles

A schematic drawing of the baffles employed in the tests, including all pertinent dimensions, is shown in figure 5. The function of the baffles used in the tests was to direct the incoming liquid onto the tank walls in a flow pattern which would completely wet the walls and minimize the loss of liquid through the vents.

Two solid baffles were used. The circular flat plate baffle, made of stainless steel, was 2.0 centimeters in radius, 0.1 centimeter thick, and was located approximately 0.5 centimeter above the tank inlet. It was supported by means of three symmetrically located No. 5 screws. The screws were positioned 1.3 centimeters from the center of the baffle. The solid hemispherical baffle was made of plexiglass and had a radius of 2.0 centimeters. The solid hemispherical baffle was also located approximately 0.5 centimeter above the tank inlet and positioned with the hemispherical section facing the inlet. The solid hemispherical baffle was suspended inside the spherical test container by means of a threaded brass rod 0.32 centimeter in diameter. Both solid baffles were chosen to deflect the incoming liquid onto the lower part of the tank walls.

Three hemispherical screen baffles were also tested; 200×200 mesh, 120×120 mesh, and 80×80 mesh. These bronze screens were shaped into hemispheres with



(c) Hemispherical screen baffle.

(d) Perforated hemispherical baffle.

Figure 5. - Schematic of baffles. (All dimensions in cm unless indicated otherwise.)

radii of 0.75 centimeter and positioned over the inlet. The screens were attached to the test container by means of a rubber-based sealing compound. The intended function of the screens was to directly spray the walls in a uniform pattern.

A perforated hemispherical baffle made from plexiglass was machined into a hemisphere with an outside radius of 1.5 centimeters and an inside radius of 0.55 centimeter. Seventeen holes, 0.08 centimeter radii, were drilled in a symmetric pattern through the top of the baffle. This baffle was attached to the test container by means of four symmetrically located screws. The holes were positioned so that the liquid would directly spray the walls but avoid direct impingement on the vents.

RESULTS AND DISCUSSION

Discussion of Flow Patterns in Spheres

The flow patterns which are of interest are those which uniformly wet the tank walls during inflow with a minimum of liquid loss through the vent lines. A variety of baffles

TABLE I. - SUMMARY OF PARAMETERS

[Tank radius, 5 cm.]

Type of inlet baffle	Liquid	Specific surface tension,[a] β, cm^3/sec^2	Volumetric flow rate, Q, cm^3/sec	Inlet radius, R_I, cm	Weber number, $We = \frac{Q^2}{\pi^2 \beta R_I^3}$
Unbaffled	Anhydrous ethanol	28.3	39	0.20	680
Unbaffled	Trichlorotrifluoroethane	11.8	52		2 900
Unbaffled	FC-78[b]	7.7	84		11 600
Unbaffled; vents extended internally	Anhydrous ethanol	28.3	39		680
Circular flat plate					
Circular flat plate; vents extended internally					
Solid hemisphere					
Hemispherical screen (200 × 200 mesh)					
Hemispherical screen (120 × 120 mesh)					
Hemispherical screen (80 × 80 mesh)					
Perforated hemisphere					
Perforated hemisphere				.50	46
Perforated hemisphere	FC-78[b]	7.7	82	.50	710
Perforated hemisphere; vents extended internally	FC-78[b]	7.7	82	.50	710

[a]At 20° C.

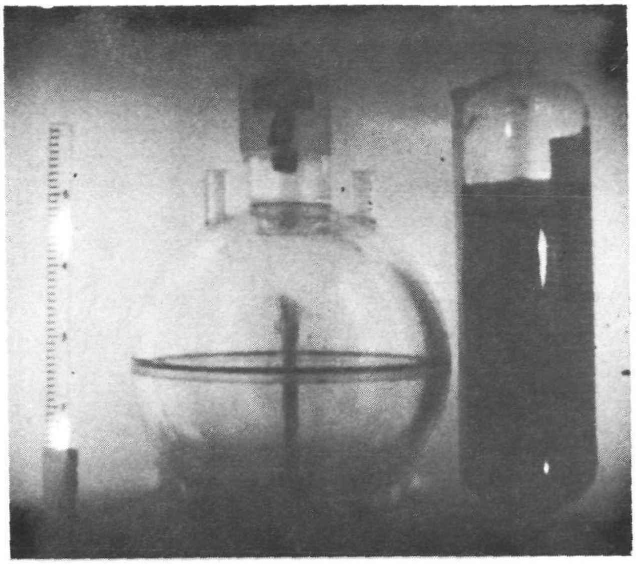
[b]Minnesota Mining and Manufacturing Co. registered trademark for fluorocarbon solvent.

(solid, screen, and perforated hemispherical) was used to achieve this objective. Unbaffled spheres were also examined since this provided a logical starting configuration with which to compare the baffled tests. The flow pattern is caused by liquid entering through the bottom of the initially empty sphere and either impinging upon or flowing along the container walls. The flow pattern in a particular sphere-baffle combination was defined as complete when the entire sphere walls were covered with liquid. An auxiliary test was conducted for each of the tests to determine the time required for a complete flow pattern to occur. Once the time to attain a complete flow pattern was determined, timers onboard the experiment package were set to terminate inflow at the appropriate time. The data points conducted in this experimental program are summarized in table I.

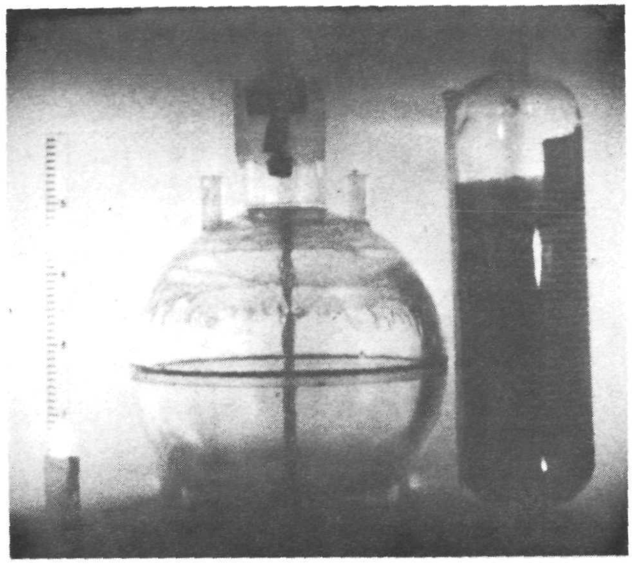
Flow Into Unbaffled Spheres

The development of the flow pattern resulting from liquid flow into an unbaffled spherical container is shown photographically in figure 6. The test Weber number, defined as $We = Q^2/\pi^2 \beta R_I^3$ was 680 for this test, where Q is the volumetric flow rate into the sphere, R_I is the inlet radius, and β is the specific surface tension of the liquid (in this test anhydrous ethanol). In figure 6(a), a columnar jet of liquid is shown entering the container during weightlessness. In figure 6(b), the liquid jet has reached the top of the spherical container and is moving down the walls of the sphere thus coating the container walls with liquid. Liquid at this time is flowing out of the two symmetrically located vents at the top of the spherical container. The liquid continues to flow down the container walls to the tank inlet; at this point, the flow pattern is herein defined as complete. Additional liquid is seen escaping from the vents in figure 6(c), the flow pattern has already been completed. As soon as complete wall wetting occurred, the liquid inflow was stopped; at this point an estimated liquid loss of 1 out of 17 cubic centimeters entering the container was observed.

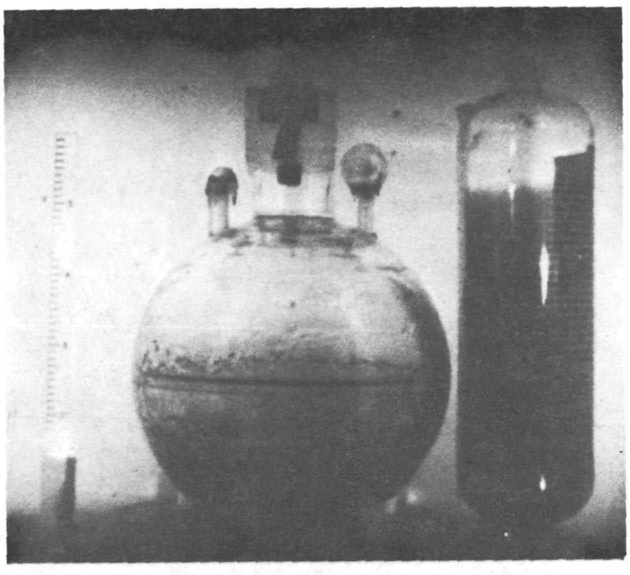
A second test with an unbaffled container was conducted at a system Weber number of 2900. Trichlorotrifluoroethane was employed as the test fluid since its low value of specific surface tension ($\beta = 11.8$) compared to ethanol ($\beta = 28.3$) permitted the use of much lower volumetric flow rates and, therefore, smaller accumulator tank pressures, since the pressure losses due to friction were of the same order for both anhydrous ethanol and trichlorotrifluoroethane. The photographic sequence of events for this test is shown in figure 7. As seen in figures 7(a) and (b) a uniform flow pattern is achieved, very similar to that in figure 6. However, the amount of liquid escaping from the vents is somewhat less than in the test with the Weber number of 680. One interesting feature which occurred during this test is the circulation of the liquid which occurred after the termination of pumping (see fig. 7(c)). The momentum of the liquid causes a columnar geyser to occur which reaches the top of the tank. This geyser is considered to be unde-



(a) Initial jet forming.

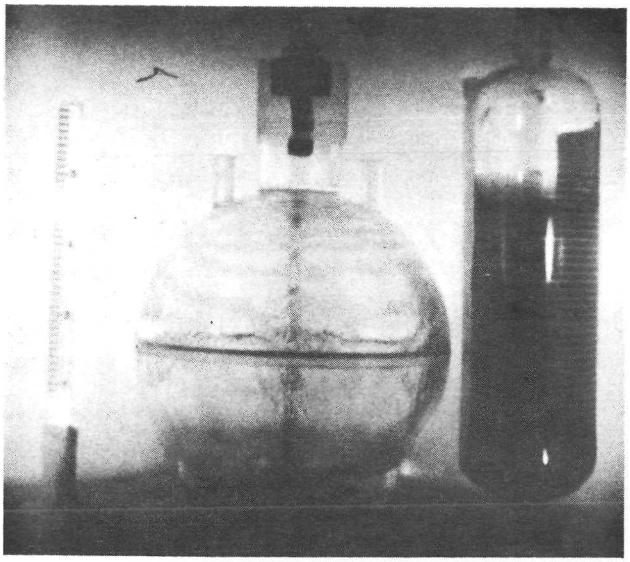


(b) Jet reaches top of tank; flow patterm seen forming with liquid moving down walls oт tank.

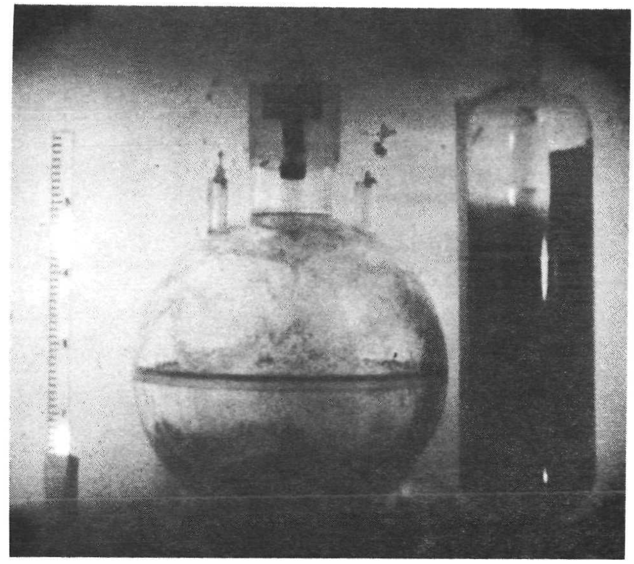


(c) Flow has stopped; liquid escaping through vents.

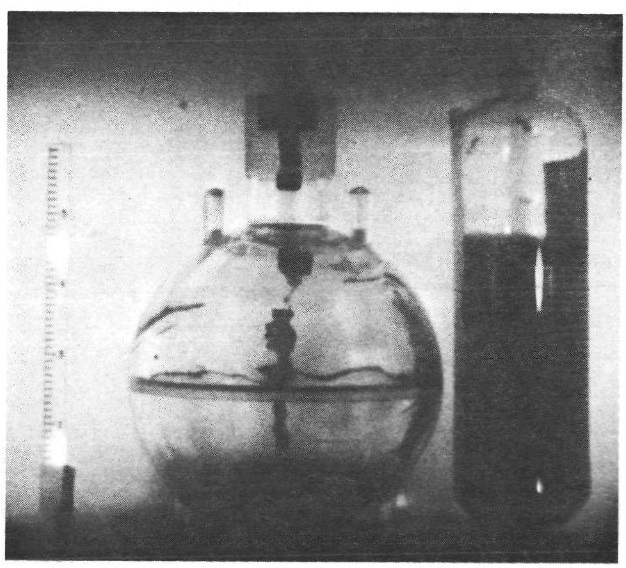
Figure 6. - Flow into unbaffled tank. Weber number We = 680; test liquid, anhydrous ethanol.



(a) Flow pattern forming.



(b) Flow stopped; liquid droplets escaping from vents.



(c) Momentum of liquid, after pumping has stopped forms another geyser which reaches top of tank.

Figure 7. - Flow into unbaffled tank. Weber number We = 2900; test liquid, trichlorotrifluoroethane.

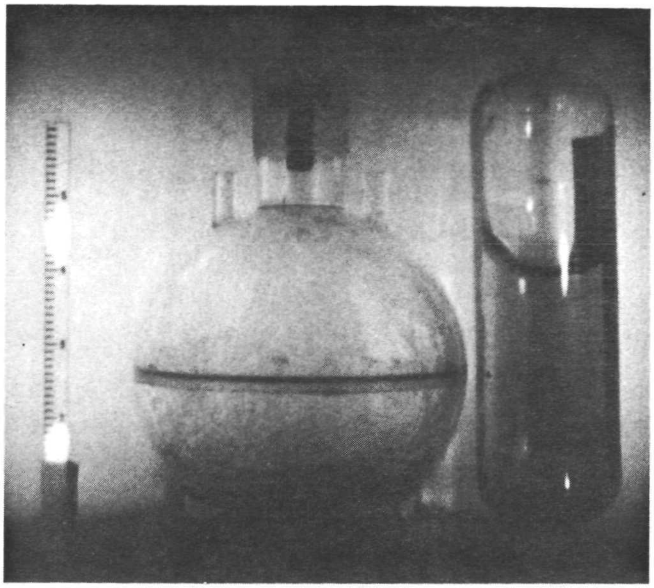


Figure 8. - Flow into unbaffled tank. Weber number We = 11 600; test liquid, FC-78.

sireable due to the possible effect of the impact of the geyser on the tank wall on system control and stability.

A third test with an unbaffled container was conducted at a system Weber number of 11 600 (see fig. 8). FC-78 was used as the test fluid since its low specific surface tension ($\beta = 7.7\ cm^3/sec^2$) permitted the use of smaller volumetric flow rates to achieve the same Weber number since the pressure losses due to friction were of the same order as both anhydrous ethanol and FC-78. In this test a uniform flow pattern was achieved which was very similar to the flow pattern shown in both figures 6 and 7. Also, a columnar geyser is formed at the termination of inflow which is very similar to that observed at a Weber number of 2900 (see fig. 7). This test yielded the smallest amount of liquid lost through the vents for all the unbaffled tests.

The results of these three unbaffled tests lead to the conclusion that less liquid escaped from the two symmetric vents as the system Weber number was increased. Also, for all three tests, a completely wetting flow pattern could be established.

A thin film of liquid covered the entire surface of the spheres in all the unbaffled tests. It appeared that liquid loss could be completely avoided if the cylindrical vents were extended through this liquid film into the sphere. A fourth test was conducted in which thin-walled cylindrical plastic tubing was inserted into the vents such that the tubing extended approximately 1 centimeter into the sphere. In this test the lowest Weber number (We = 680) was run. As seen in figure 9, no liquid is lost through the vents.

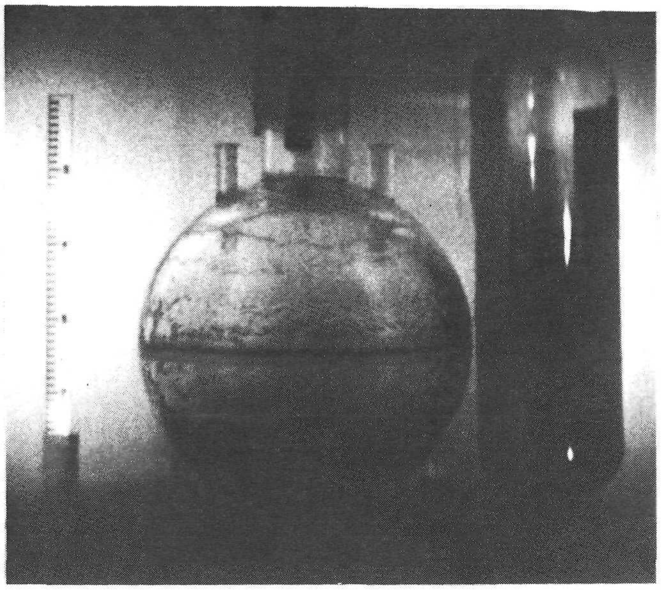
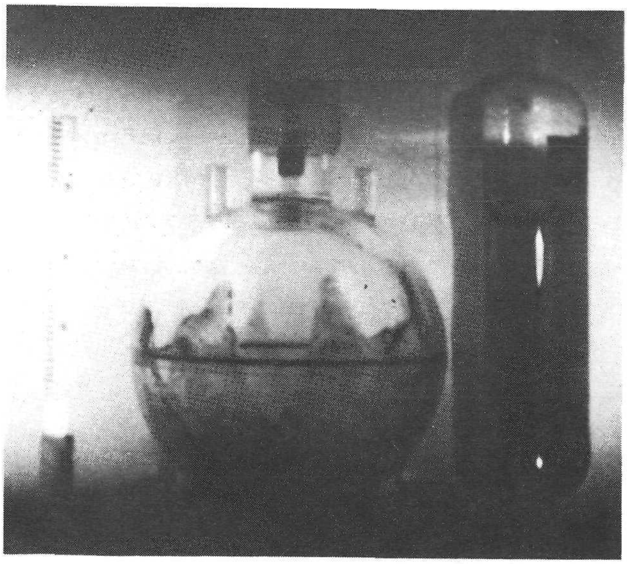
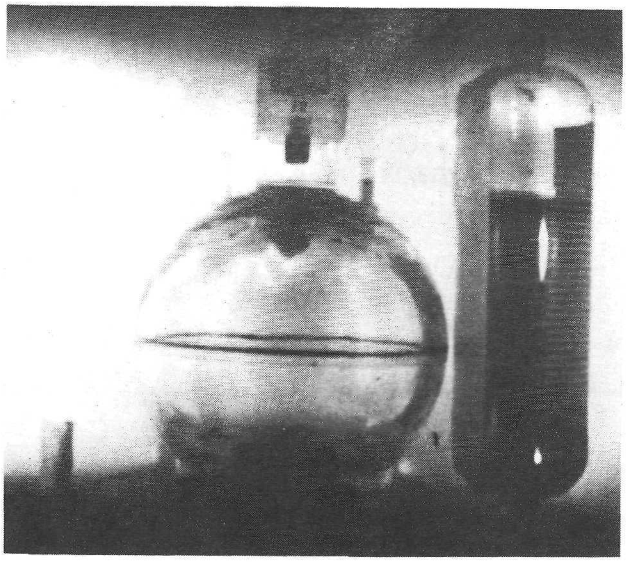


Figure 9. - Flow into unbaffled tank; vents extended internally. Weber number We = 680; test liquid, anhydrous ethanol.



(a) Flow pattern forming; liquid flowing up walls of tank.



(b) Flow stopped; pattern complete.

Figure 10. - Flow into baffled tank; circular flat plate baffle over inlet. Weber number We = 680; test liquid, anhydrous ethanol.

Flow Into Baffled Spheres

Solid baffles. - The flow pattern concerned with the liquid inflow process into a spherical container with a circular flat plate baffle over the inlet is shown in figure 10. The baffle deflects the incoming liquid, causing it to impinge on the tank wall near the bottom of the test container, and then, to flow along the tank wall. The system Weber number for this test is 680, since based on flow patterns in unbaffled spheres, this would be a worst case with respect to liquid loss through the vents. As shown in figure 10(a) the leading edge of the inflowing liquid while appearing symmetric is not very uniform. Very little liquid is lost through the vents in this test, with only one of the vents being half filled after the flow pattern is complete. When the vents are extended into the sphere for the circular flat plate baffle case (see fig. 11), no liquid is lost.

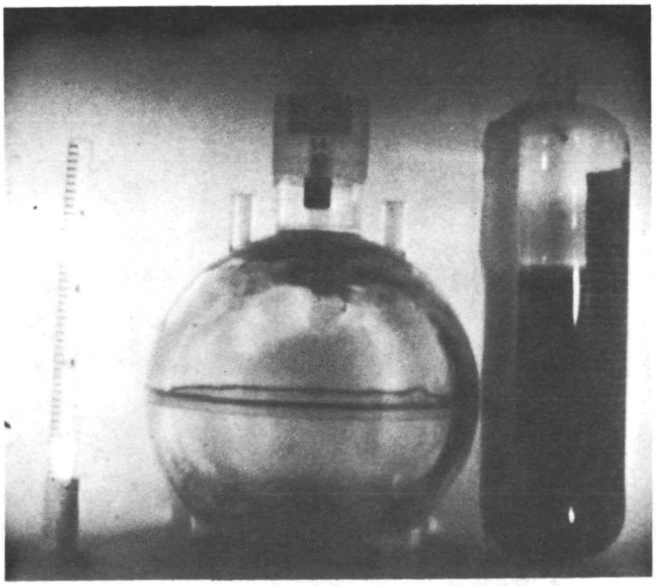
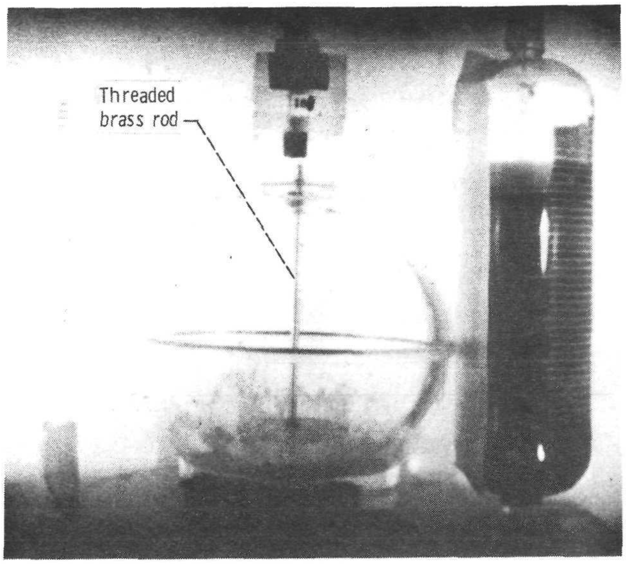


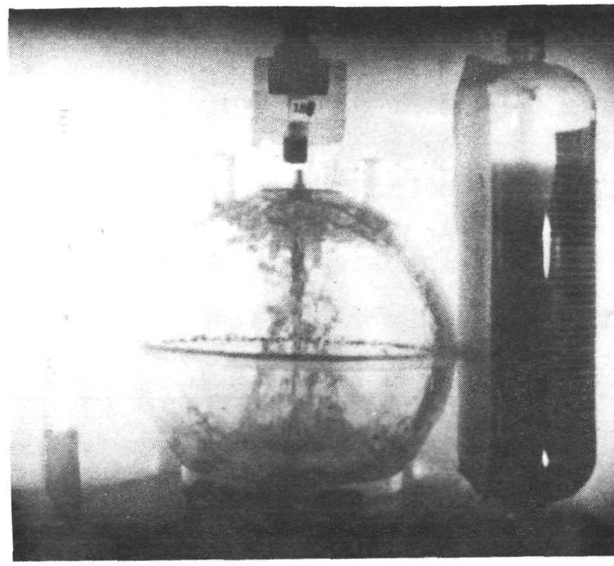
Figure 11. - Flow into baffled tank; circular flat plate baffle over inlet; vents extended internally. Weber number We = 680; test liquid, anhydrous ethanol.

Another solid baffle employed in testing was the solid hemispherical baffle. The system Weber number employed during this test was again 680. In figure 12(a) the flow pattern is shown in its initial phase with liquid being deflected slightly up the side walls but the majority of the liquid moving around the baffle. The liquid does not completely wet the container walls, as shown in figure 12(b), but impinges directly on the opposite end of the tank resulting in considerable liquid loss as shown in figure 12(c).

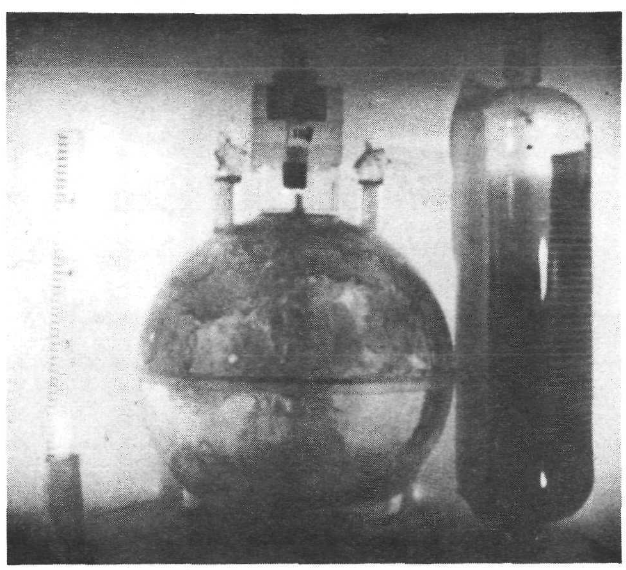
A comparison of the results obtained with the solid baffles was made with those ob-



(a) Flow pattern forming with liquid starting up tank walls.



(b) Liquid reaches top of tank; poor flow pattern; liquid did not completely wet walls.

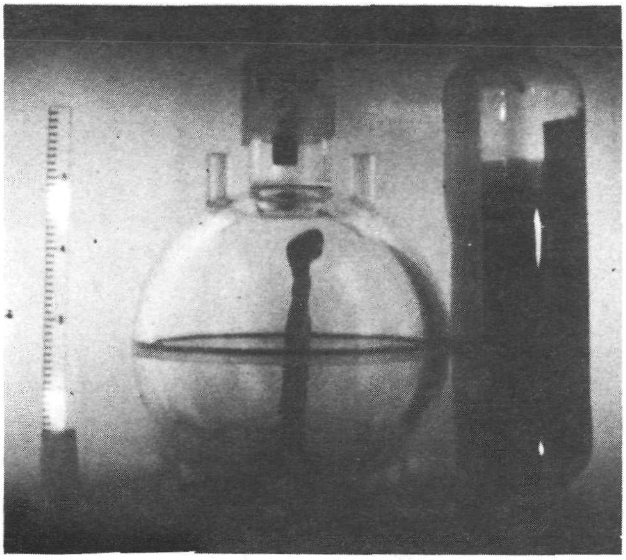


(c) Liquid escaping from both vents.

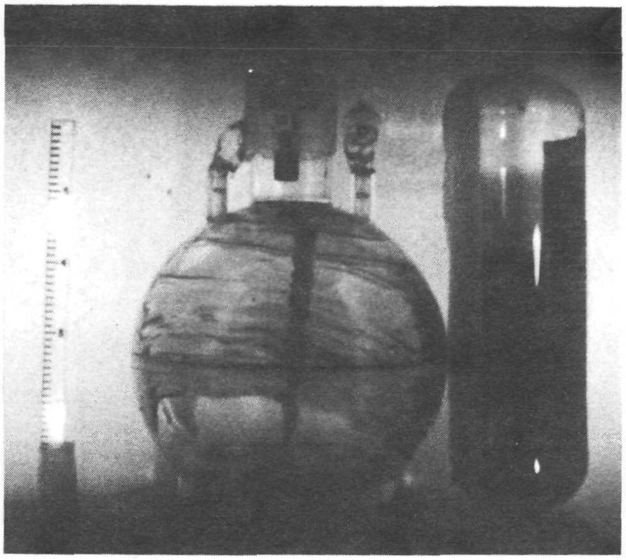
Figure 12. - Flow into baffled tank; solid hemispherical baffle over inlet. Weber number We = 680; test liquid, anhydrous ethanol.

tained in the unbaffled test at the Weber number of 680. The most evenly distributed and symmetric flow pattern was obtained for the unbaffled case, with the circular flat plate baffle being more symmetric than the solid hemispherical baffle. The least liquid loss was obtained with the circular flat plate baffle followed very closely by the unbaffled sphere. The solid hemispherical baffle exhibited the greatest liquid loss.

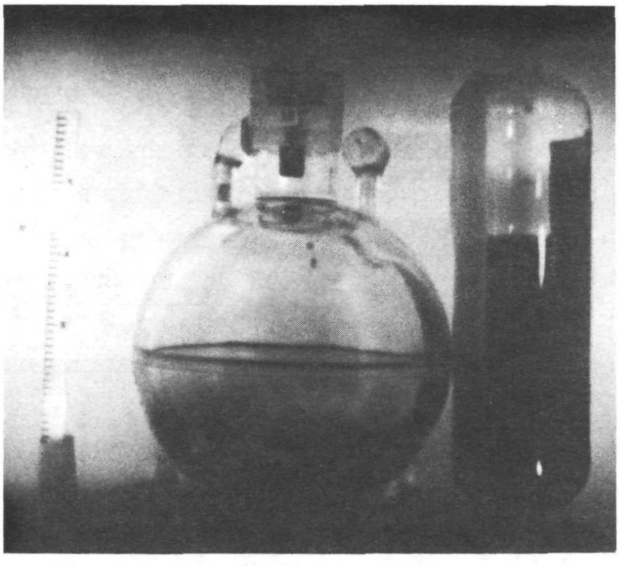
Screen baffles. - An attempt was made to utilize fine woven mesh screens as baffles to spray the container walls uniformly during weightlessness. The screens were formed into hemispherical shapes and attached directly over the inlet line to the spherical container. The resulting flow pattern for a 200 × 200 mesh hemispherical screen during inflow at a Weber number of 680 is presented in figure 13. The screen does not disperse the incoming liquid appreciably at this Weber number and, hence the flow pattern looks very similar to that obtained in the unbaffled tests. Since the object of the screen was to



(a) Initial jet forming.



(b) Flow pattern forming; liquid escaping from both vents.

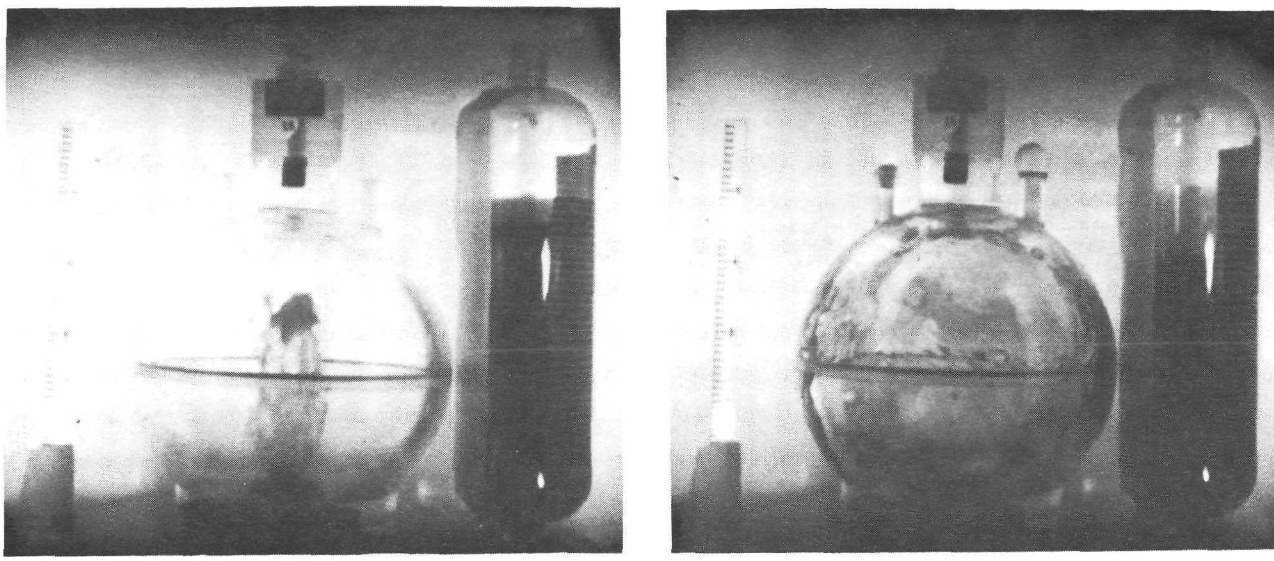


(c) End of flow; liquid escaping from both vents.

Figure 13. - Flow into baffled tank; hemispherical screen (200 x 200 mesh) over inlet. Weber number We = 680; test liquid, anhydrous ethanol.

cause the jet to radially disperse, this baffle was unsuccessful.

A second test with a coarser screen (120 × 120 mesh) was conducted at the same system Weber number (We = 680). The results of this test are shown photographically in figure 14. In figure 14(a) the incoming liquid flow is shown dispersing through the hemispherical screen. Note that there is more dispersion in this test than in the previous test (fig. 13) although the radial pattern is not as symmetric as is desirable. The walls eventually become wet as seen in figure 14(b) but this is the result of the impinged



(a) Initial jet forming.

(b) Pattern complete; liquid escaping through vents.

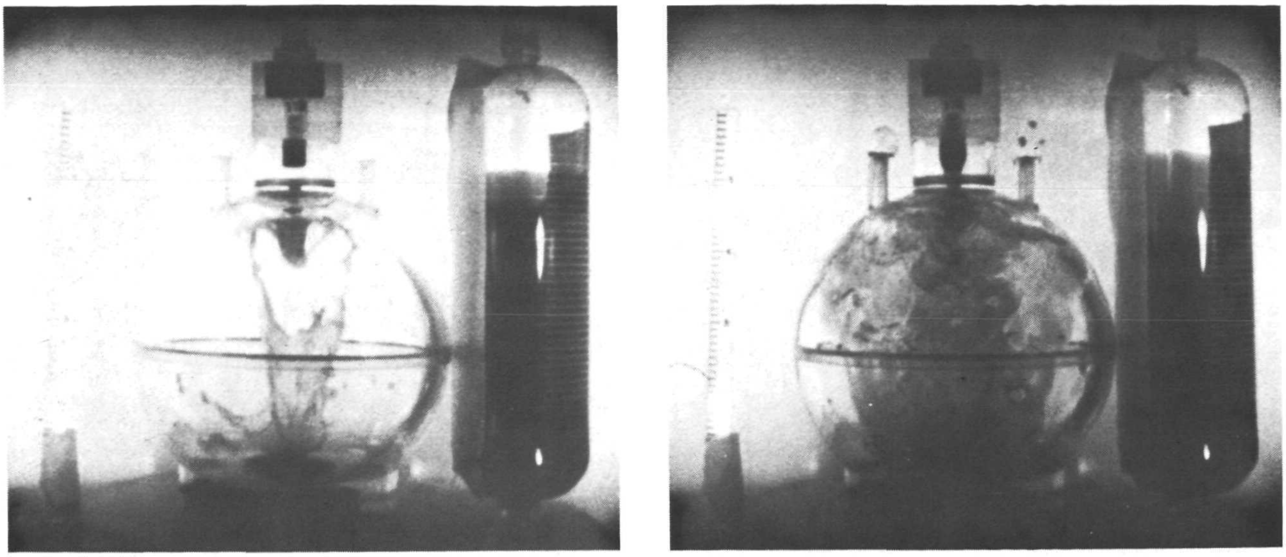
Figure 14. - Flow into baffled tank; hemispherical screen (120 X 120 mesh) over inlet. Weber number We = 680; test liquid, anhydrous ethanol.

liquid on the opposite end of the tank flowing down the walls. Some liquid was lost through the vents during this test due to direct impingement on the vents and from the impinging flow as in the unbaffled case.

The final screen tested was an 80 × 80 mesh and the photographs for this test are shown in figure 15. The flow is more dispersed than both figures 13 and 14, but again the pattern is not uniform. Also, some liquid was lost through the vents.

The screens tested did not meet the objectives of the flow patterns desired due to poor dispersion and uneven wetting characteristics. The only significant conclusion was that the coarser mesh screens dispersed the incoming flow more than the finer meshes.

Perforated hemispherical baffle. - In an effort to radially disperse the incoming flow uniformly and yet not directly impinge on the tank vents a perforated hemispherical baffle was tested. In the initial test with the perforated hemispherical baffle, anhydrous



(a) Initial flow; jet reaches top of tank.

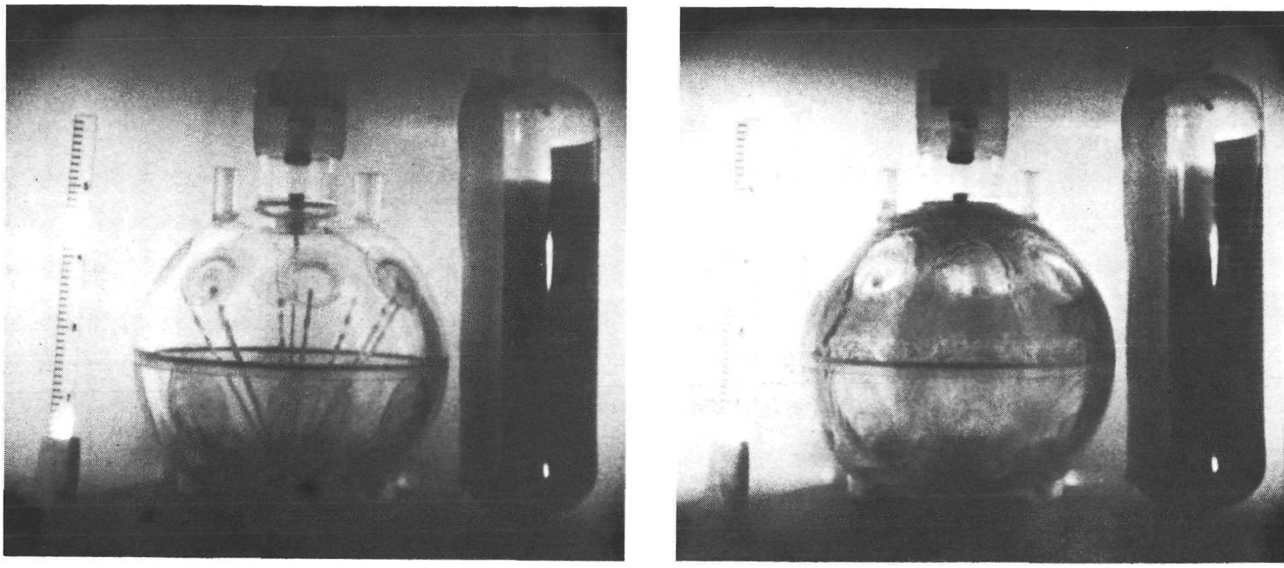
(b) Liquid escaping through vents; pattern not uniform.

Figure 15. - Flow into baffled tank; hemispherical screen (80 x 80 mesh) over inlet. Weber number We = 680; test liquid, anhydrous ethanol.

ethanol was the test liquid and a system Weber number of 680 was run. The inlet to the sphere was 0.20 centimeter and the baffle had an internal radius of 0.55 centimeter. The result of this test was that the flow did not disperse evenly through the outer surface of the perforated hemispherical baffle, but mainly came from the top.

The inlet radius of the sphere was redrilled to a value of 0.50 centimeter. The same test was conducted as in the previous paragraph except the system Weber number was 46 due to the fact that the flow rate and liquid remained identical but the inlet line radius of the sphere was increased. (Recall $We = Q^2/\pi^2 \beta R_I^3$.) The results of this second test are shown photographically in figure 16. The spray pattern forms quite symmetrically as shown in figure 16(a) with no direct impingement of the inflowing liquid on the two vents. The completed liquid flow pattern is shown in figure 16(b), and no liquid was lost through the vents although a small quantity of liquid did enter the vents.

In order to compare the resulting spray pattern for the perforated hemispherical baffle with the others studied, the perforated hemispherical baffle was tested at a Weber number of 710 both with and without the vents extended internally. FC-78 was employed as the test fluid for these two tests. The test for the case where the vents were not extended internally was very similar to the results of figure 16, which was at a low Weber number of 46 with the exception that a slight amount of liquid came out the vents. In the second test the vents were extended internally approximately 1 centimeter with the result that no liquid was lost. The test using this perforated hemispherical baffle caused complete tank wall wetting (much more rapid than for the unbaffled tank) and, thus, would



(a) Initial spray pattern forming.

(b) Complete pattern; no liquid loss.

Figure 16. - Flow into baffled tank; perforated hemispherical baffle over inlet. Weber number We = 46; test liquid, anhydrous ethanol.

result in more uniform cooling. Therefore, the perforated hemispherical baffle was the most effective baffle tested.

CONCLUDING REMARKS

The results of this study showed that, over the range of Weber numbers examined for unbaffled spheres (680 to 11 600), complete wetting of the tank walls occurred. Less liquid escaped from two symmetrically located vents as the Weber number was increased to a maximum of 11 600. When the vent lines were extended into the sphere through the thin liquid film, no liquid was lost.

Several inlet baffles (solid, screen, and perforated) were examined. The solid baffles included a circular flat plate and a solid hemispherical baffle. The flow patterns for the circular flat plate were more symmetric than those for the solid hemispherical baffle. The screen baffles did not result in a uniform wetting of the container walls for square mesh weaves of 200×200, 120×120, and 80×80; it was observed that the larger size open mesh (80×80) sprayed the wells more effectively than did the smaller sizes. The perforated hemispherical baffle was the most effective baffle tested. The tank walls were wet uniformly and rapidly. Again, when the vents were extended into the sphere, no liquid was lost for any of the containers with baffled inlets.

The experimental tests conducted during this program are concerned only with the aspects of isothermal liquid flow patterns in a weightless environment. The complete problem of cooling the hot container walls would necessarily include both heat transfer and thermodynamic considerations. Despite the somewhat simplifying experimental approach, the success of a particular baffle to cause uniform wall wetting during isothermal inflow will make it a serious candidate for controlling inflow to a hot tank.

Lewis Research Center,
National Aeronautics and Space Administration,
Cleveland, Ohio, August 29, 1972,
909-72.

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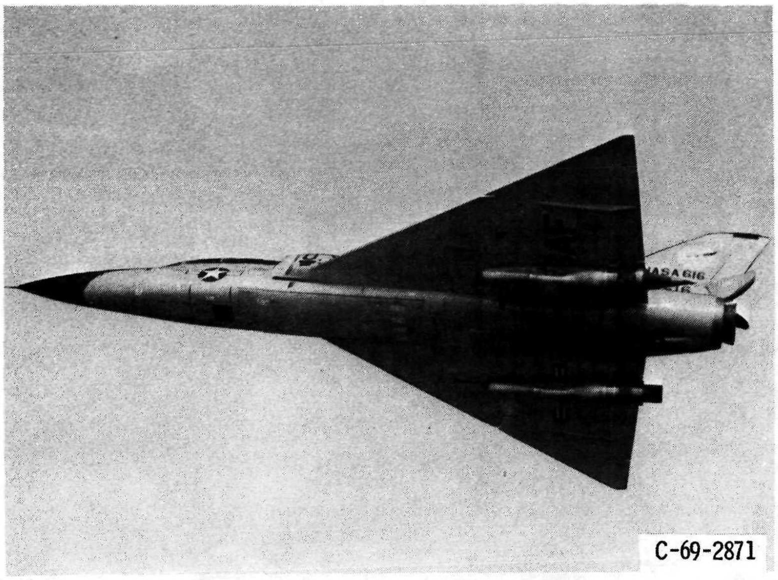

Figure 1. - Modified F-106B aircraft in flight.

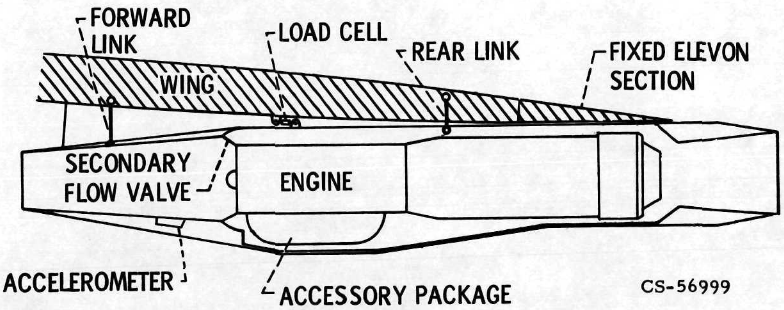

Figure 2. - Nacelle-engine installation.

Release system. - The experiment package, installed within the drag shield, is suspended at the top of the drop area by means of a highly stressed music wire attached to the release system. This release system consists of a double-acting air cylinder with a hard-steel knife edge attached to the piston. Pressurization of the air cylinder drives the knife edge against the wire, which is backed by an anvil. The resulting notch causes the wire to fail, smoothly releasing the experiment. No measurable disturbances are imparted to the package by this release procedure.

Recovery system. - After the experiment package and drag shield have traversed the total length of the drop area, they are recovered by deceleration in a 2.2-meter-deep container filled with sand. The deceleration rate (averaging 15 g's) is controlled by selectively varying the tips of the deceleration spikes mounted on the bottom of the drag shield (fig. 1). At the time of impact of the drag shield in the decelerator container, the experiment package has traversed the vertical distance within the drag shield (compare figs. 2(a) and (c)).

Experiment Package and Test Containers

Experiment package. - The experiment package used to obtain the data for this experimental study is shown in figure 3. It consisted of an aluminum frame in which were mounted the experiment, pressure bottles, a 16-millimeter high-speed motion picture

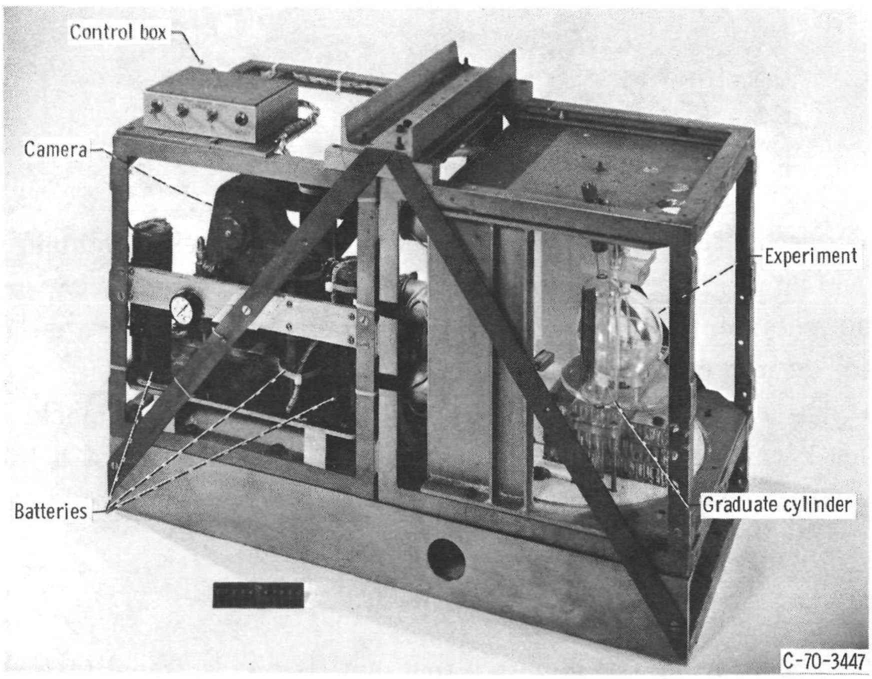

Figure 3. - Experiment package.