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CARBIDE AND CARBON CHEMICALS COMPANY

TEXAS CITY PLANT

AUGUST 8, 1956

To: Mr. Robert Dillon
TEXAS CITY PLANT

SUBJECT: Agitation Studies, Project 817-145

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Attached is your copy of "Agitation Studies" by E. K. Adrian and E. D. McCrory, done under the supervision of J. C. Wright. This work covers various factors involved in the design of tower type polymerization reaction vessels and makes a valuable contribution to the knowledge required to build successfully operating reactors of this type.

Two primary factors were studied. These were: (1) Depth of impellers below surface to prevent vapor entrainment into the liquid phase and (2) Methods of preventing recirculation of particles at the bottom of the reactor. We believe that the findings contained in this report can be extrapolated to the 5-foot diameter continuous polymerizer to permit more continuous operation.

Mr. Adrian and Mr. McCrory are two of our summer hires and we believe their work will benefit them as well as the company. Mr. Adrian is a junior student at Rice Institute majoring in Physics and Mr. McCrory is a senior student at Notre Dame majoring in Chemical Engineering.

W. W. McLean
W. W. McLean

WWM/jn

AGITATION STUDIES

CONDUCTED AND REPORTED

BY

ERLE K. ADRIAN

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PROJECT NUMBER 817-145

PROCESS DEVELOPMENT DEPARTMENT

CARBIDE AND CARBON CHEMICALS COMPANY

A DIVISION OF

UNION CARBIDE AND CARBON CORPORATION

TEXAS CITY, TEXAS

AUGUST 13, 1956

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SUMMARY

Agitation studies were made in the 24-inch and 6-inch diameter glass columns in order to determine the effect on agitator influence (AI) of the following:

(1) Impeller depth below liquid surface
(2) Impeller diameter
(3) Number of blades per impeller
(4) Concentration of agitated material

Mixing properties, such as the point at which entrainment of the vapor phase first appears were noted in each case. It was found that the AI is affected but little by impeller depth except when the impeller is shallow enough to cause entrainment. An optimum impeller diameter to column diameter ratio is found near the value 0.5 for maximum AI. Increasing the concentration of solids lowers the AI to a minimum point beyound which there is no further change upon additional loading.

Studies were made on baffle design in order to limit recirculation caused by a bottom impeller. Slanted baffle sections placed immediately above the impeller were found quite satisfactory, and their relative ease of installation in plant scale equipment far outweighs the slight advantage gained by placing a disk on the agitator shaft above the impeller.

Using the slanted baffles, studies in'column heat distribution were made in order to see if brine coils placed at the bottom of the column would cool the whole column under agitation. The baffles caused a definite hot-cold interface to be set up with a large temperature drop over a slight interval. Therefore, with these baffles it would be possible to place cooling coils in the bottom of an autoclave and kill the reaction in this region without endangering the reaction going on above.

INTRODUCTION:

In order to supplement studies already made on agitation in a tower type vessel (1) and to do special work on the problem of recirculation of particles in a liquid-solid system, investigations were made using glass columns filled with water or water-acetone solutions and polyethylene pellets. The mixing properties of various impellers and baffle systems were observed and described, using as a standard measurement, agitator influence (AI), the distance from the center of the impeller to the nominal boundary of the agitated material. Results were compiled and are presented in this report in graphical form.

PROCEDURE:

A. Twenty-Four Inch Column. All experiments carried out in the 24-inch column were done using polyethylene pellets (Sp.gr, .913) in water. AI was measured from the center of the impeller downward to the lowest point of good pellet movement. Impeller speeds were recorded in revolutions per minute and converted to feet per minute.

B. Bottom Agitation Studies. For bottom agitation studies the 6-inch diameter glass column was used. A conical section was put on the bottom. The tests were carried out using polyethylene pellets (Sp.gr, .943) in an acetone-water solution (Sp.gr, .9). AI in this case was defined as the distance from the lower impeller upward to the highest point of pellet agitation.

C. Heat Transfer Studies. The conical bottom was replaced by a flat bottom and heat transfer studies were made. Brine coils were placed in the bottom two inches of the 6-inch column. Hot water (60 degrees, C.) was allowed to flow into the top of the column, and the flow rate out the bottom was adjusted to keep the water level constant. Thermometers were placed at various intervals in the column in order to record the temperature drop down the column. An impeller was placed 3-inches off the bottom of the column to provide agitation. The equipment used for these tests is illustrated in Figures 7-A, 7-B, and 8.

DISCUSSION:

A. STUDIES OF SURFACE EFFECTS AND MIXING CHARACTERISTICS OF VARIOUS IMPELLERS (24-inch diameter column)

1. The effect on AI of impeller depth below the liquid surface at various peripheral speeds for the 10-inch Mixco impellers containing eight, six, and four blades is shown in Figures 1-A, 1-B, and 1-C. These graphs show that at depths greater than two inches and above peripheral speed 125 feet per minute the difference in AI achieved by changing impeller depth at constant speed is within the range of experimental error. Entrainment of the vapor phase is responsible for the odd curve produced at the two-inch depth. To avoid vapor entrainment the top impeller should be located at least four inches below the liquid level.

(1) Brittain, B. F., Agitation Studies in a Tower Type Vessel, Carbide and Carbon Chemicals Company, Texas City, Texas, 1955.

2. The effect of impeller diameter is shown in Figure 2. Mixco impeller blades (2-1/2" x 2") were mounted on disks, forming impellers ranging from six and one-half inches to fourteen and one-half inches in diameter. The results show that there is an optimum value for maximum AI of the ratio, impeller diameter to column diameter. The high efficiency of the eleven and one-half inch diameter impeller indicates that the ratio lies in the neighborhood of 0.5.

3. Increasing the number of blades on the 10-inch Mixco impeller resulted in increasing the AI proportionally. Figure 3 shows an average of the values from graphs 1-A, 1-B, and 1-C with the exception of the data taken at the two-inch depth. At the 2-inch depth the surface is less turbulent with a greater number of blades; thus vapor entrainment is diminished as the blade number is increased.

B. STUDY OF BOTTOM AGITATION AND RECIRCULATION CONTROL (6-inch column)

1. Agitation in a conical bottom section was accomplished by placing small impellers within a conical glass section fastened to the bottom of the 6-inch column. A series of small disks was horizontally mounted on the rotating shaft within the conical section. This arrangement, however, was unsatisfactory due to poor mixing upon heavy loading.

Observations were then made using a three-bladed, four-inch diameter turbine impeller in the conical section. With the conical section fully baffled, dead spots occurred upon loading. With no baffles there was a swirling effect which kept all particles moving but tended to keep individual particles in the same horizontal plane.

A single disk of slightly less diameter than that of the column was horizontally mounted on the rotating shaft from four to six inches above the impeller in the hope of limiting recirculation. Particles settled past the disk with little trouble, and recirculation was greatly reduced. The effects of the baffles were the same as above.

2. Agitation in a flat bottom vessel was on the whole more successful and practical than that in the cone. The effect of a single rotating disk horizontally mounted four to six inches above the bottom impeller was much the same as in the cone. When vertical baffles were placed above the rotating disk, swirling was eliminated above the disk, but pellets were driven up into the column. The impeller in the bottom of the column gave good agitation, however, even when loaded with pellets.

3. Besides the standard vertical baffles we studied other baffle designs which greatly reduced recirculation. A short vertical baffle section reduced the channeling effect caused by the long vertical baffles. Placing of a disk of slightly less diameter than that of the column below the baffle section and immediately above the impeller reduced recirculation. It was found, however, that the extra recirculation prevention given by the disk was outweighed by the mechanical difficulties involved in installing it in plant scale equipment. Best results were obtained from a slanted baffle section placed just above the impeller. Figure 4 shows the comparison between the slanted and vertical baffles. The slanted baffles provided a

definite limit on the AI and much more efficiently controlled the upward motion of the particles. In a reaction vessel having a limited settling area, a slanted baffle section would decrease chances of recirculation of solid particles.

4. Studies of heat transfer in the 6-inch column showed that with adequate baffling, cooling coils in the bottom of the column would not cool the entire column even with violent bottom agitation. Figures 5-A, 5-B, 5-C, 5-D, 5-E show that for slanted baffles a temperature drop of from 25 to 30 degrees occurred over a range of only two inches. This temperature drop indicated that a definite hot-cold interface is set up very similar to that observed as agitator influence. A change in flow rate through the column did not affect the position of the hot-cold interface but only changed the outlet temperature depending on the amount of contact the water had with the cooling coils.

The setting up of this interface shows that it is possible to have a quench zone to kill the reaction in the bottom of a reactor and yet not affect the reaction occurring in the rest of the column. The slanted baffles determine the limits of this cold zone and also prevent the recirculation of reactants.

C. EFFECT OF VARYING PELLET CONCENTRATION (6-inch column)

Polyethylene pellets were continually added to a column agitated by one 3-bladed, 4-inch diameter turbine impeller. The speed and total volume were kept constant. It was found that the AI dropped off as the column was loaded. This happened probably because of frictional losses of kinetic energy which occurred at higher concentrations. Figure 6 shows the magnitude of these results.

A P P E N D I X

EFFECT OF IMPELLER DEPTH ON AGITATOR INFLUENCE

10 - INCH MIXCO IMPELLER

8 BLADES

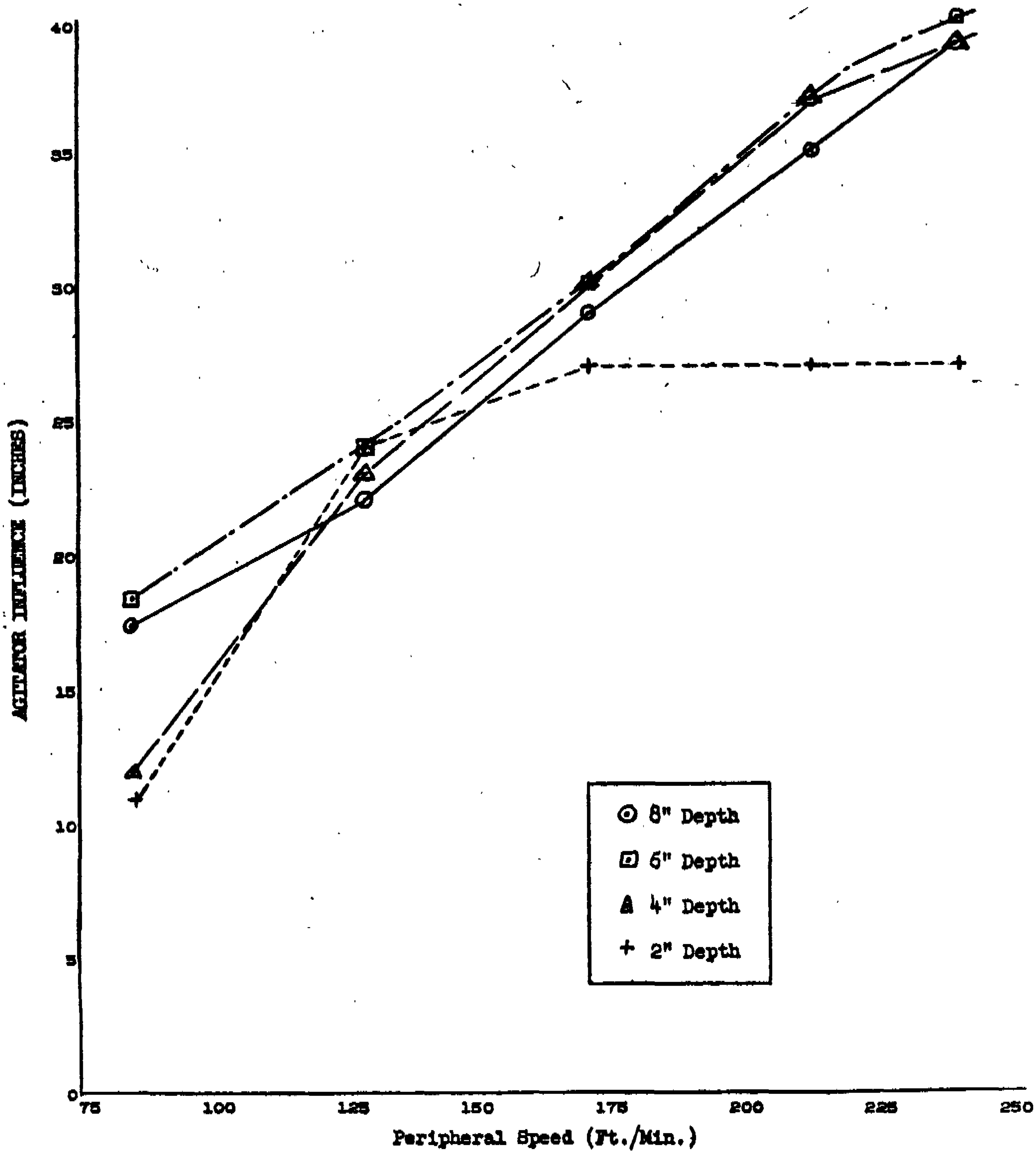

FIGURE 1 - A

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EFFECT OF IMPELLER DEPTH ON AGITATOR INFLUENCE

10 INCH MIXCO IMPELLER

6 BLADES

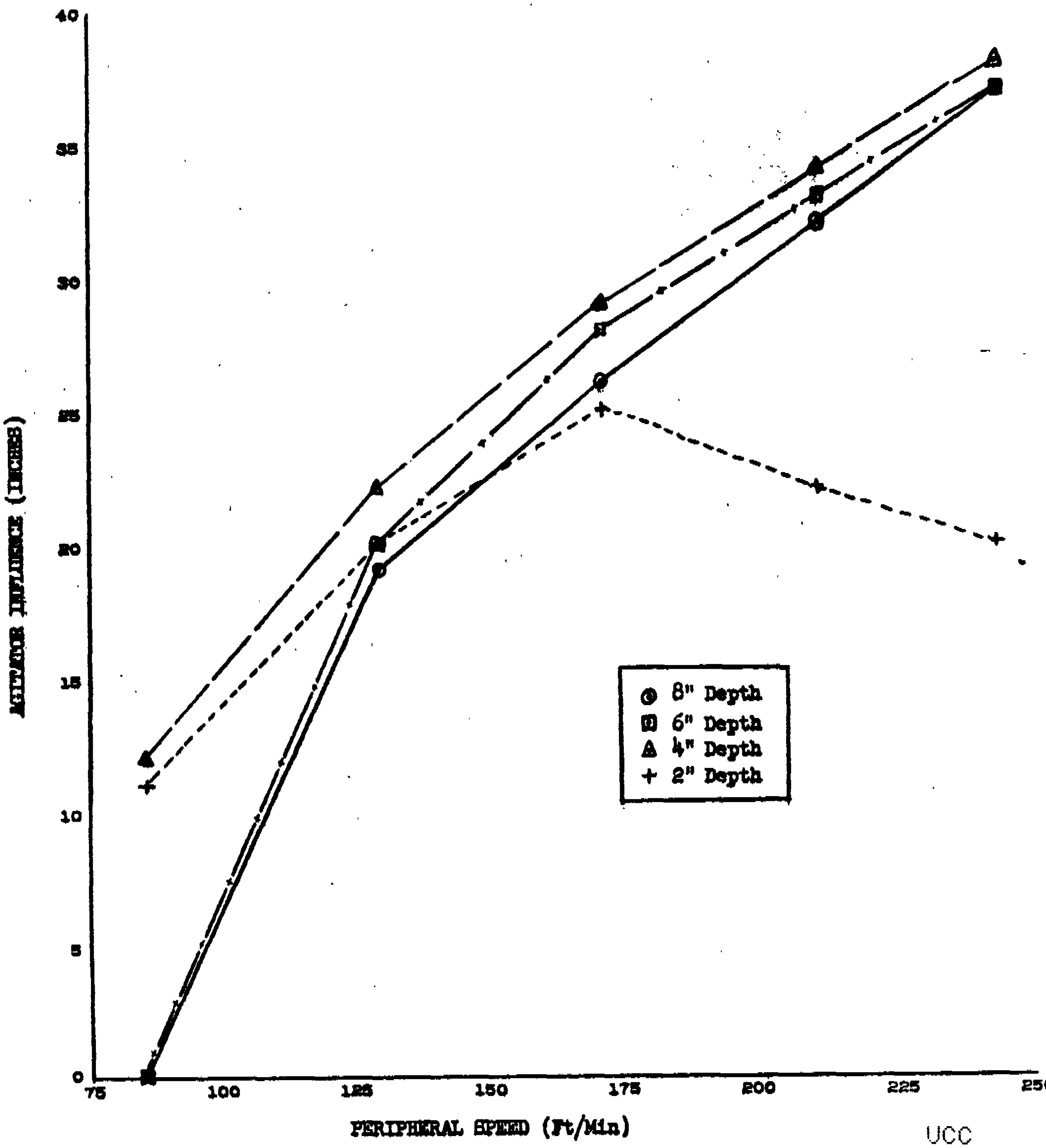

FIGURE 1-B

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EFFECT OF IMPELLER DEPTH ON AGITATOR INFLUENCE

10 INCH MIXCO IMPELLER

4 BLADES

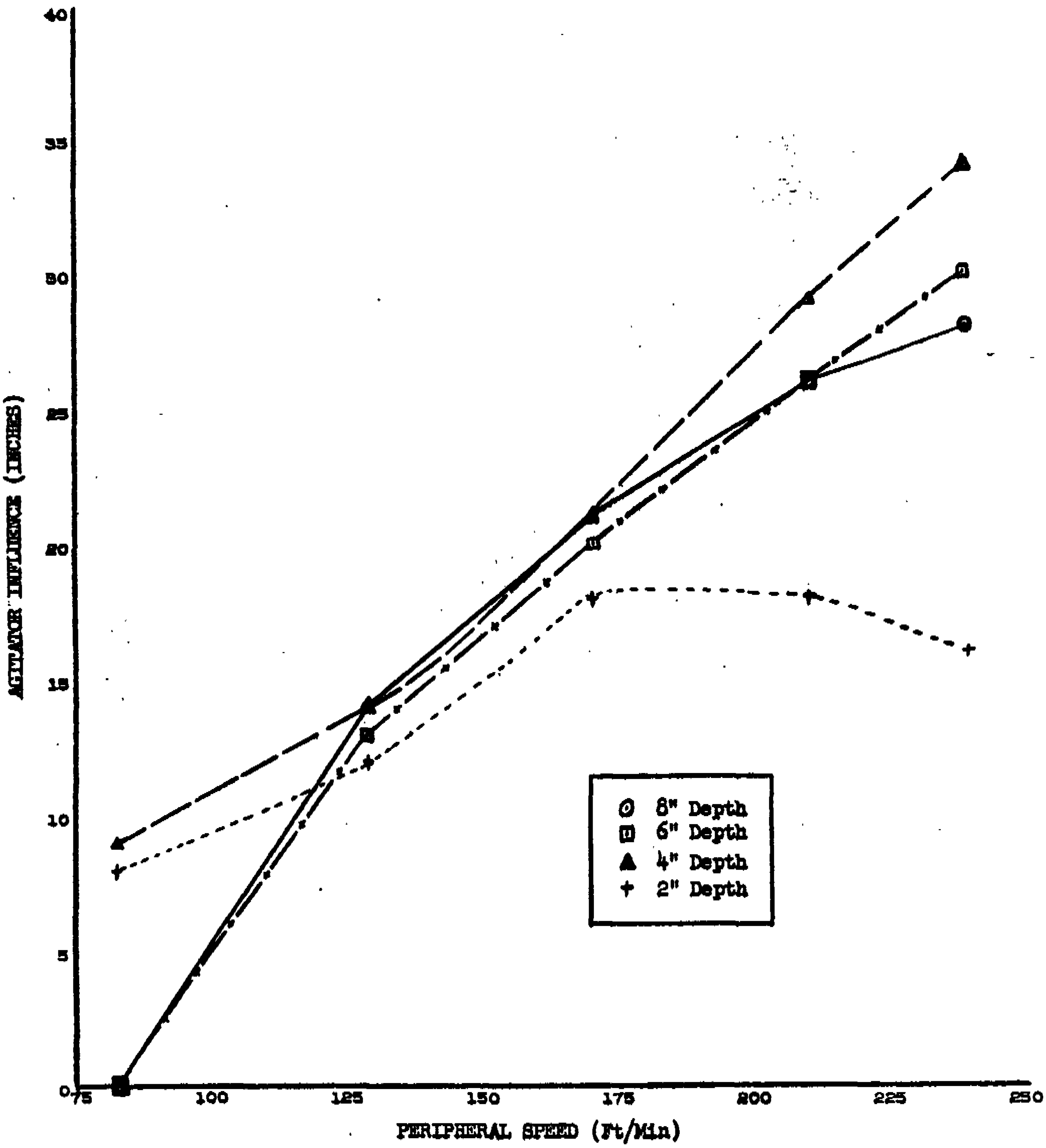

FIGURE 1 - C

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A.I. vs. PERIPHERAL SPEED FOR

VARIOUS DIAMETER IMPELLERS

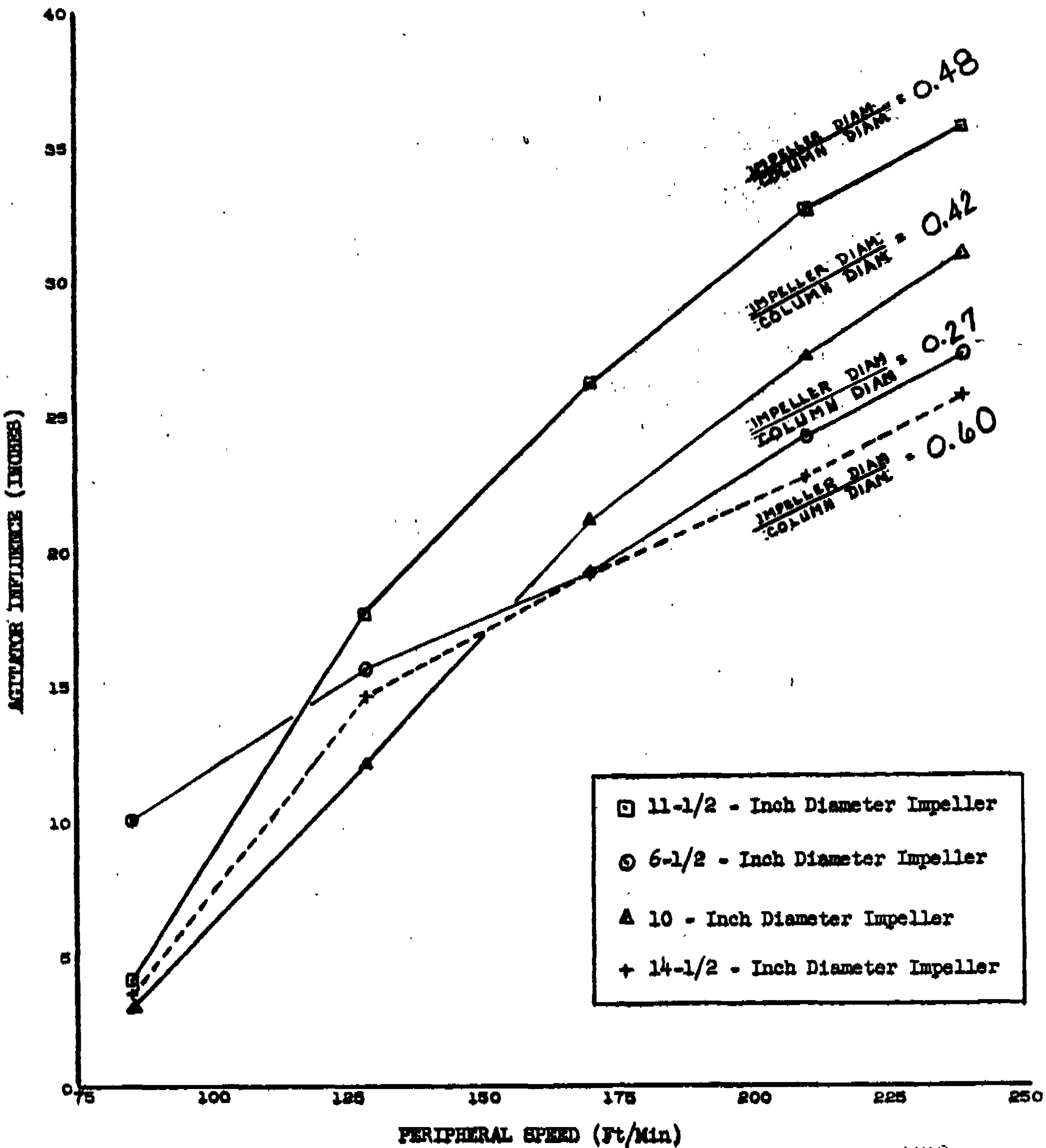

FIGURE 2

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EFFECT OF INCREASING NUMBER OF BLADES

10-INCH MIXCO IMPELLER, 4, 6, 8 BLADES

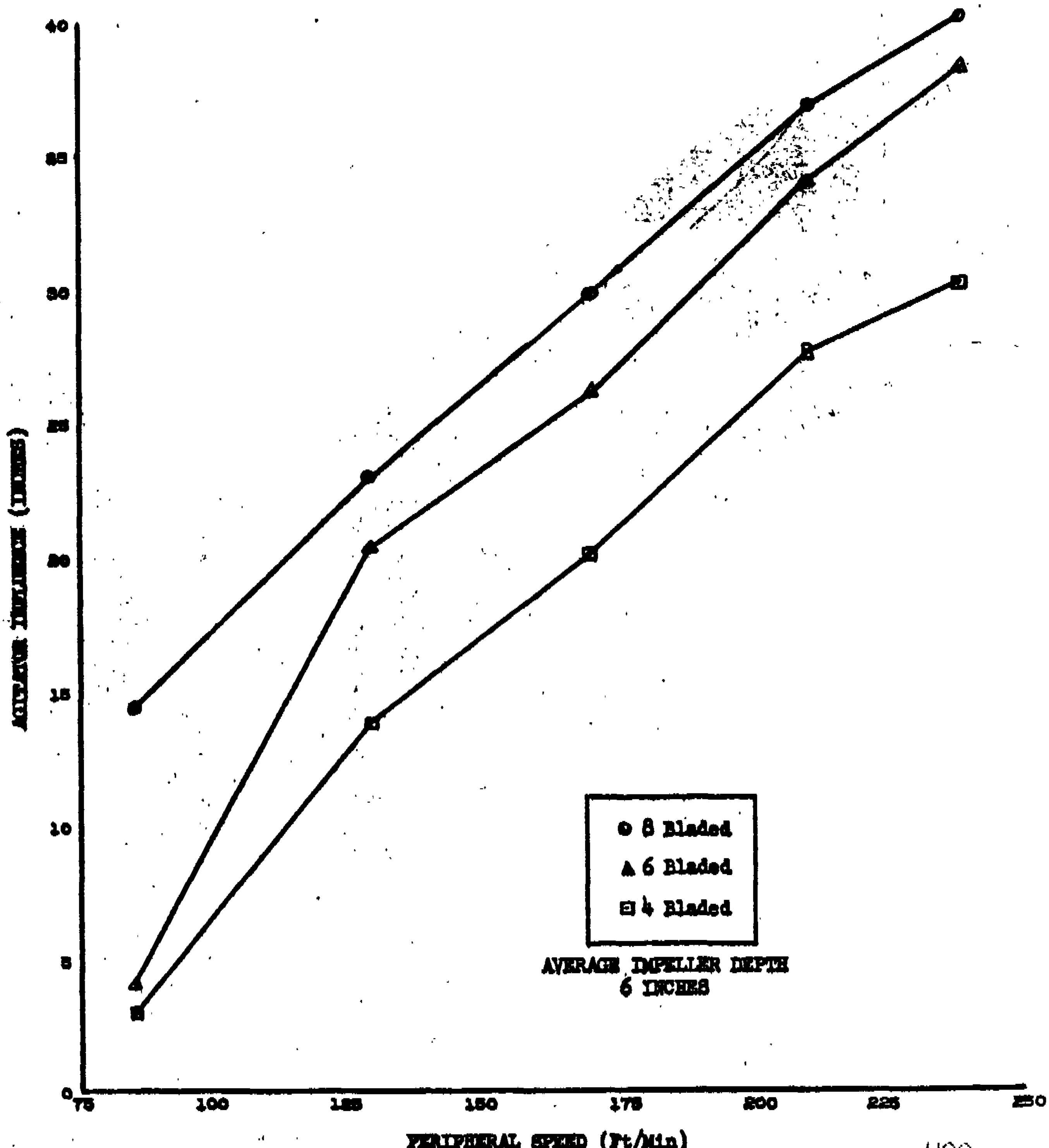

FIGURE 3

COMPARISON OF BAFFLE DESIGN

PERIPHERAL SPEED VS AGITATOR INFLUENCE

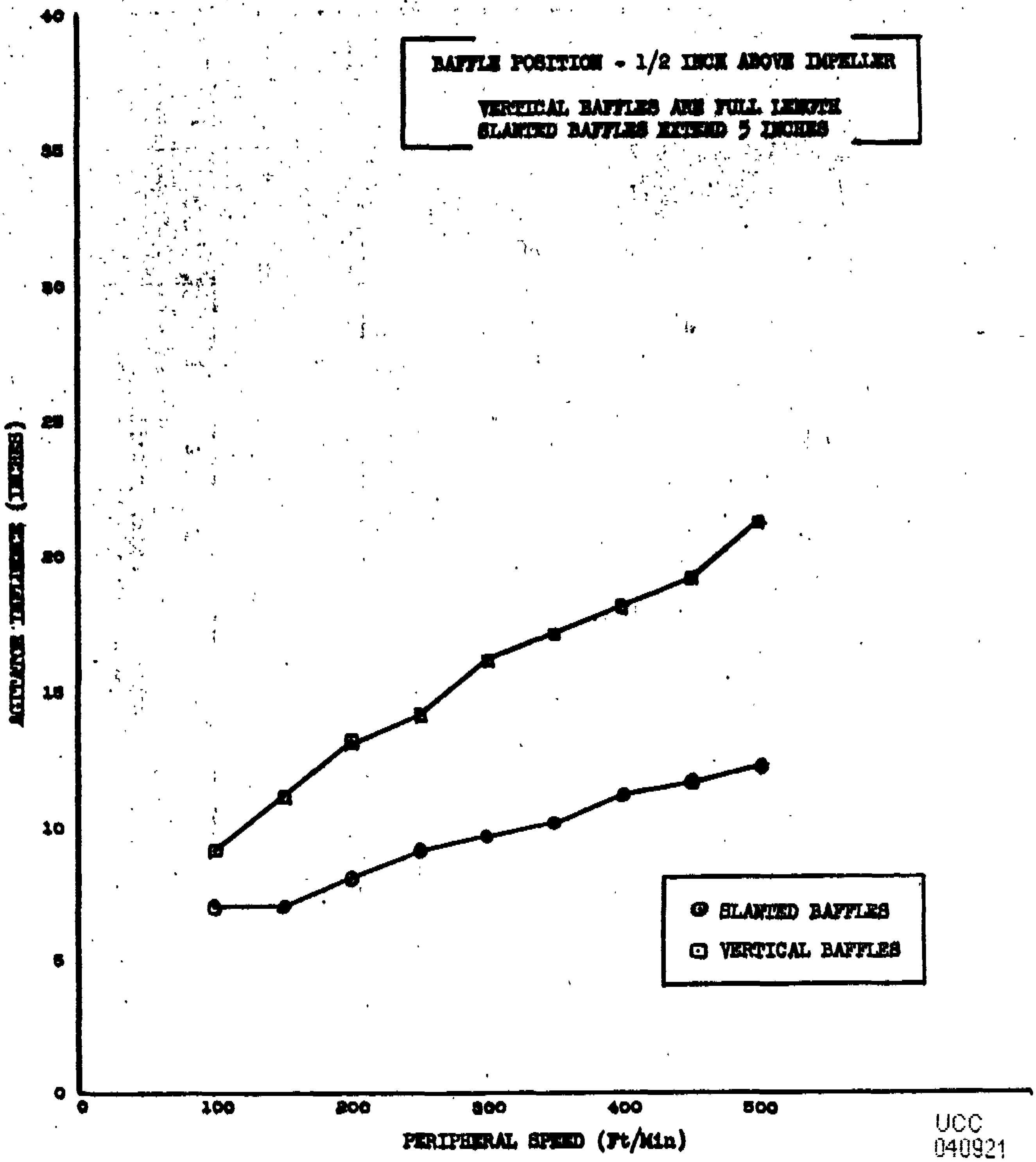

FIGURE 4

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BAFFLE EFFECT ON HEAT TRANSFER

HEIGHT VS TEMPERATURE

(30° BAFFLES)

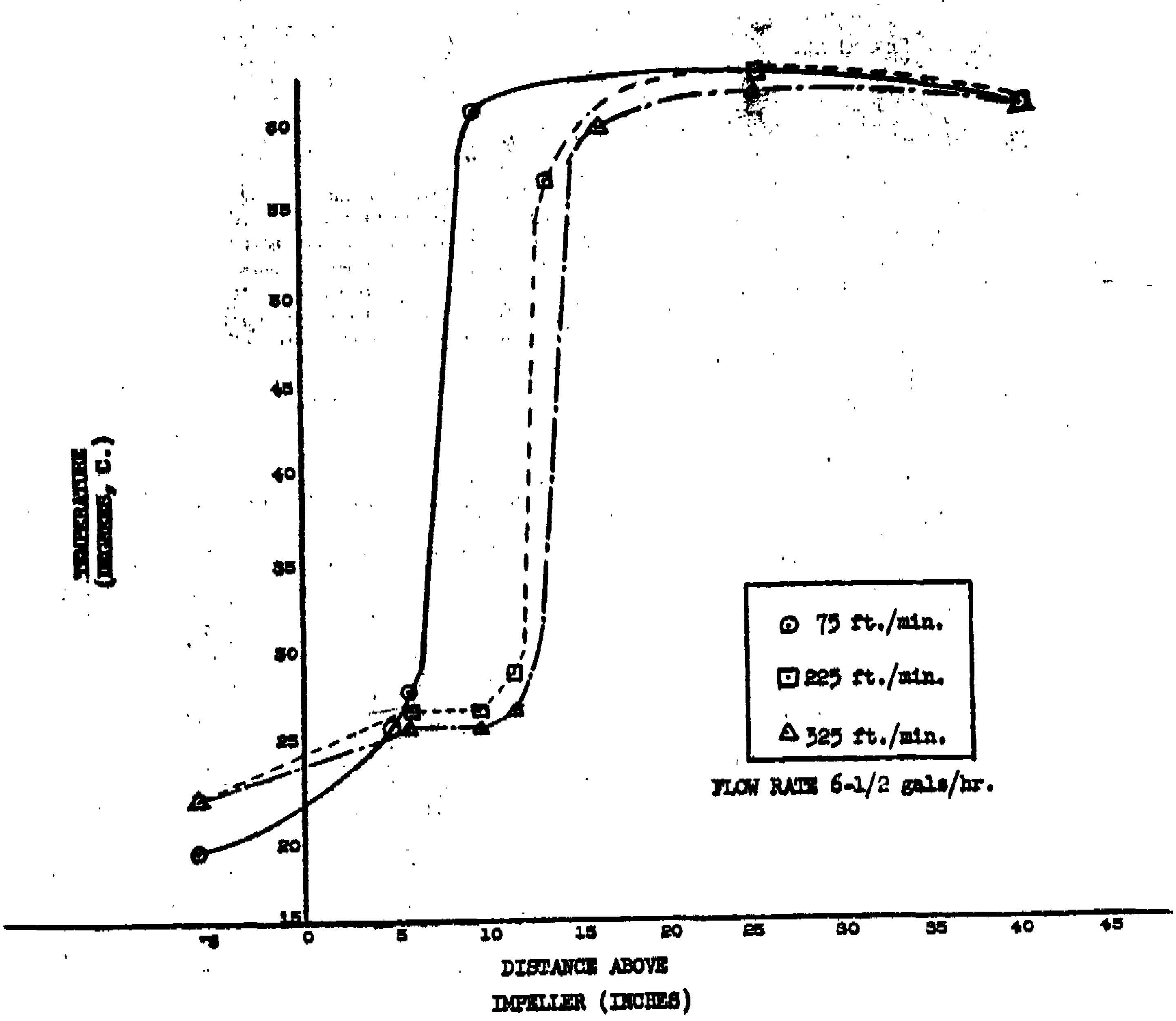

FIGURE 5-A

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BAFFLE EFFECT ON HEAT TRANSFER

HEIGHT VS. TEMPERATURE

(Slanted Baffles With Vertical Section)

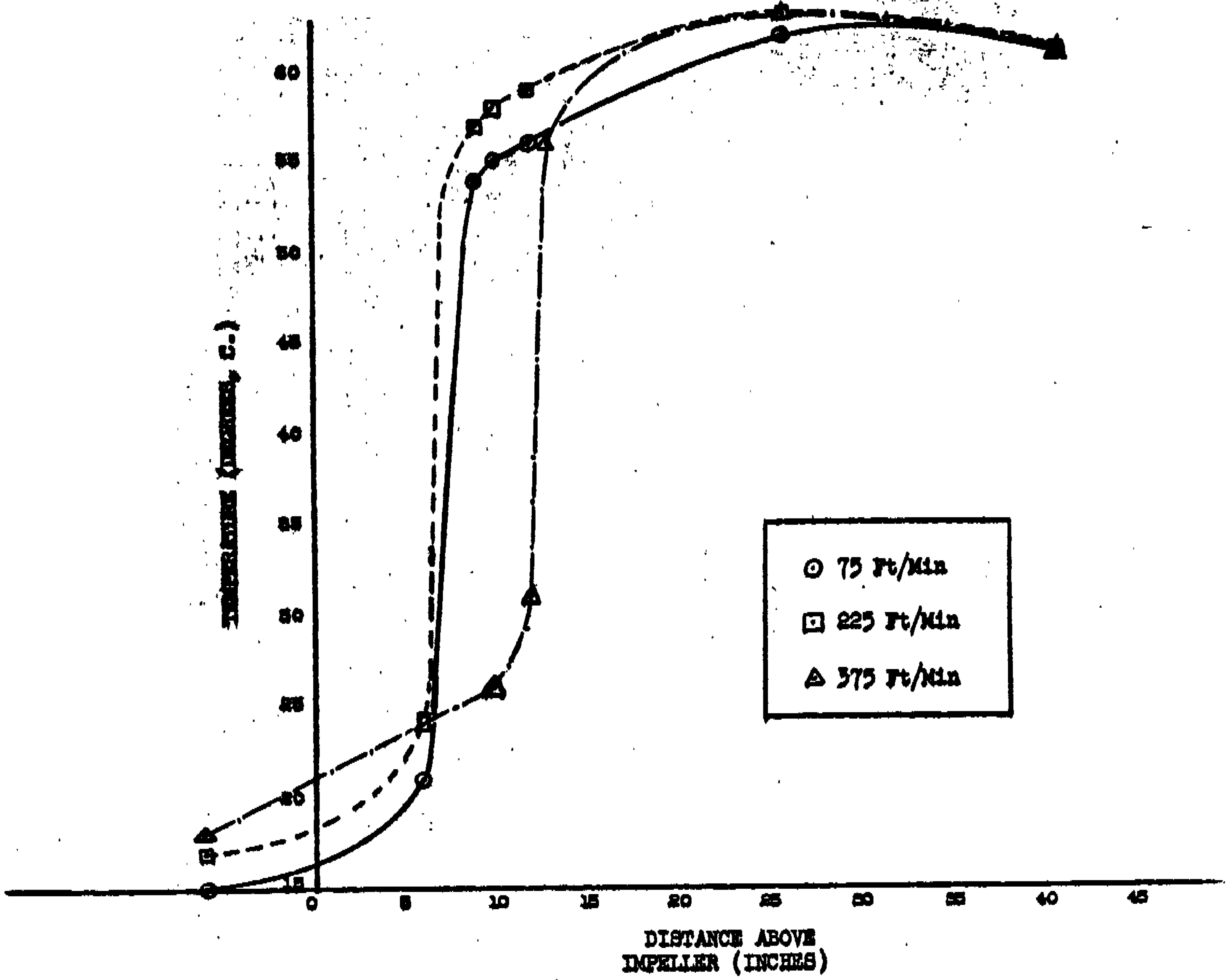

FIGURE 5 - B

BAFFLE EFFECT ON HEAT TRANSFER

HEIGHT VS TEMPERATURE

(Disk and Baffle Section - 2 Inches Above Impeller)

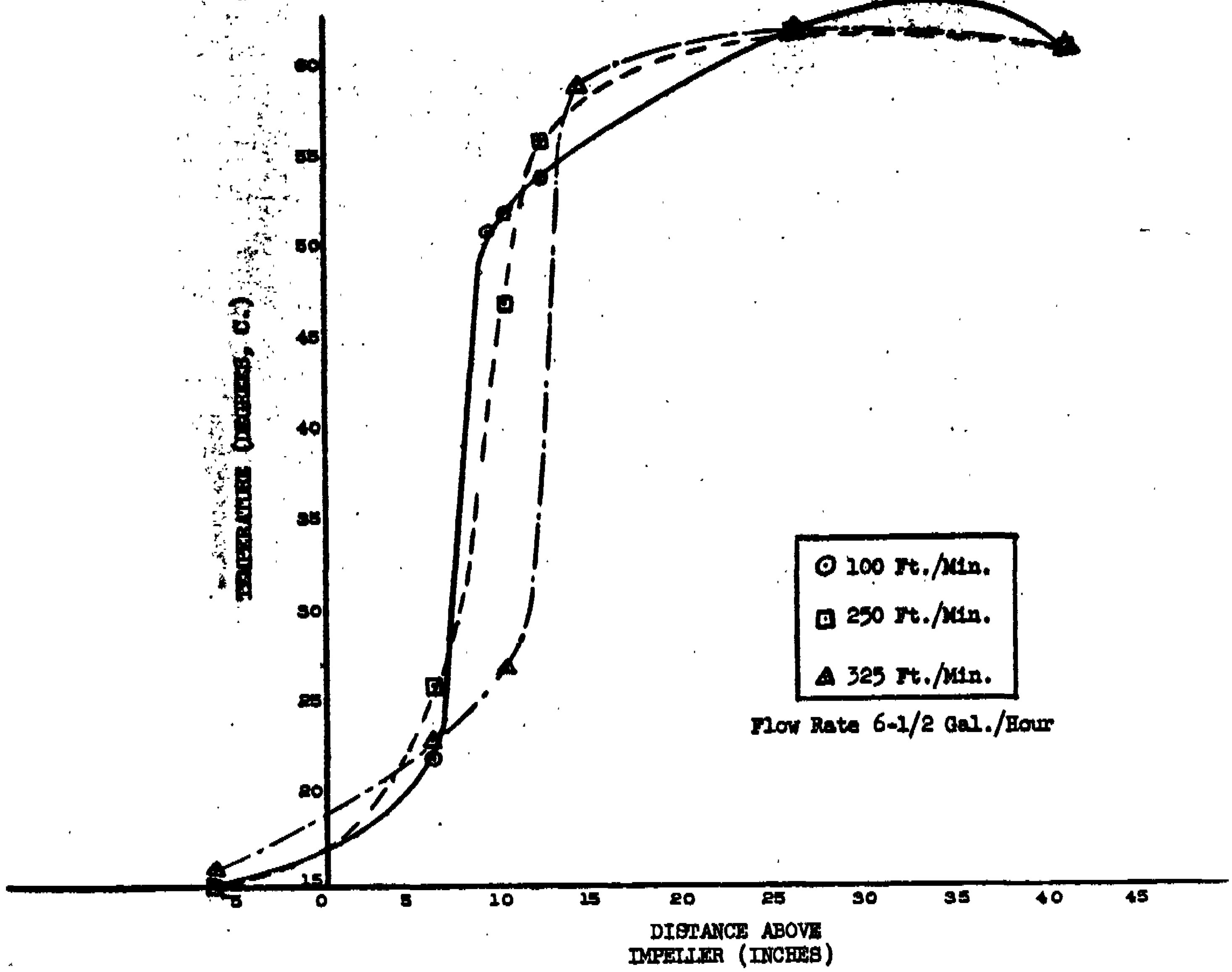

FIGURE 5-C

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BAFFLE EFFECT ON HEAT TRANSFER

HEIGHT VS TEMPERATURE

Disk - 2 Inches Above Impeller (No Baffles)

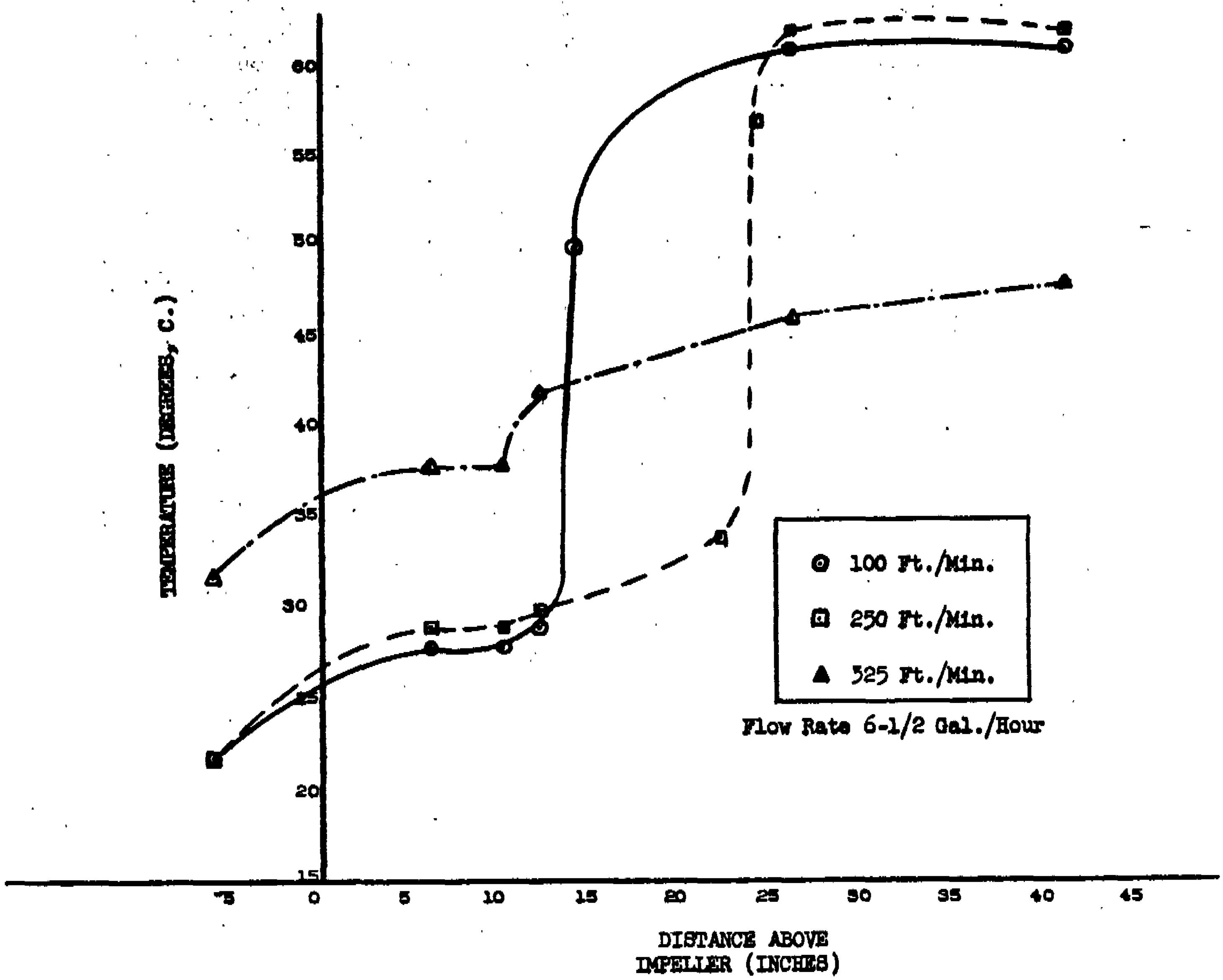

FIGURE 5-D

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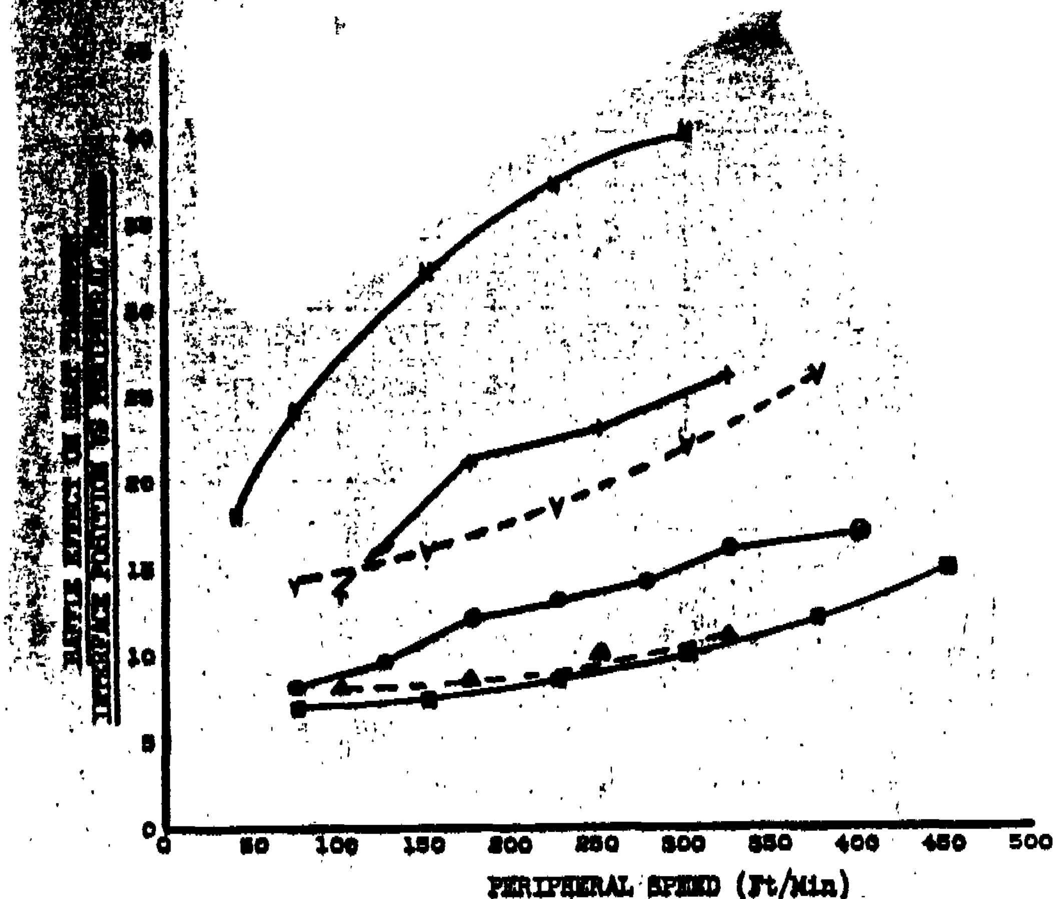
BAFFLE EFFECT ON HEAT TRANSFER

INTERFACE POSITION VS PERIPHERAL SPEED



N Impeller Alone (No Baffles or Disk)

V Vertical Baffles

+ Disk 2 Inches Above Impeller (No Baffles)

▲ 30° Baffles and Disk 2 Inches Above Impeller

⊕ 30° Baffles 2 Inches Above Impeller

▣ Slanted Baffles With Vertical Section

FIGURE 3-E

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EFFECT OF LOADING ON AGITATOR INFLUENCE

CONCENTRATION OF PELLETS VS. A.I.

TOTAL VOLUME - 20 LITERS

6" Diameter Column
4" Diameter, 3 bladed impeller
Speed - 290 ft/min.
Impeller - 8" below surface

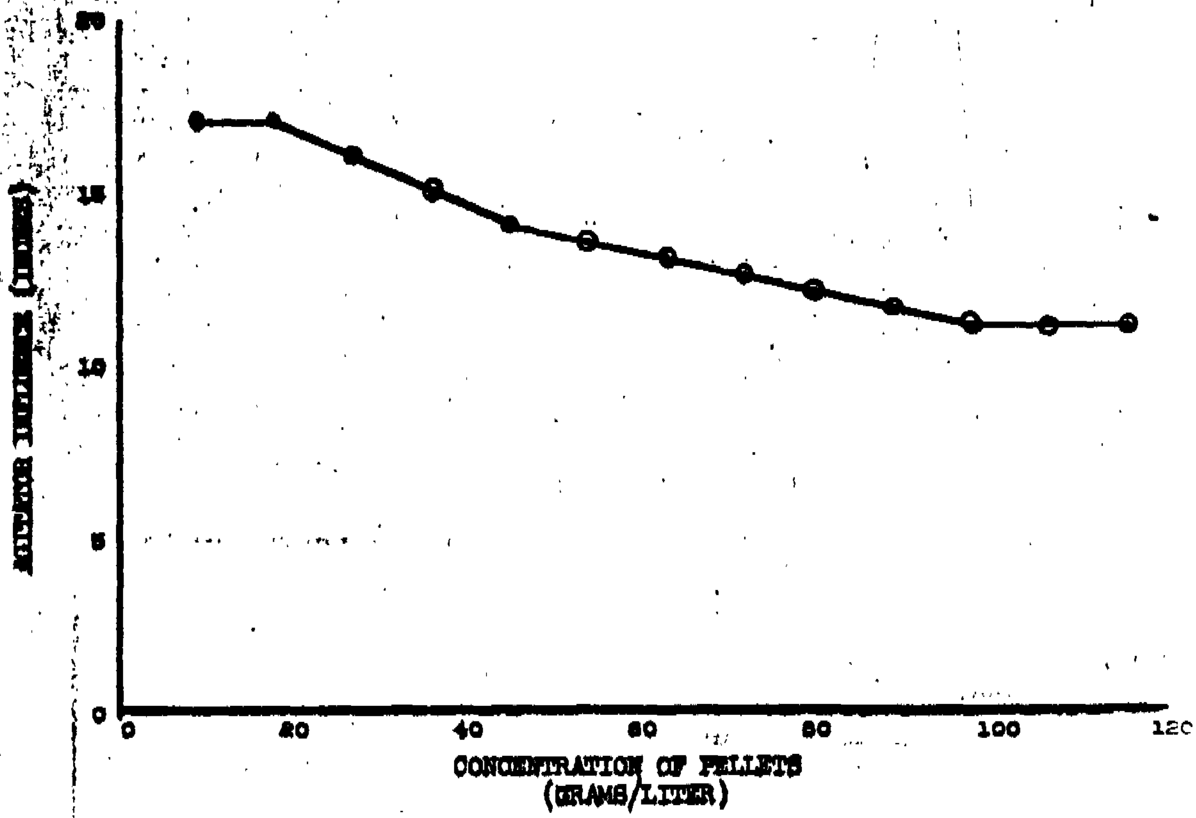

FIGURE 6

24-INCH DIAMETER GLASS COLUMN

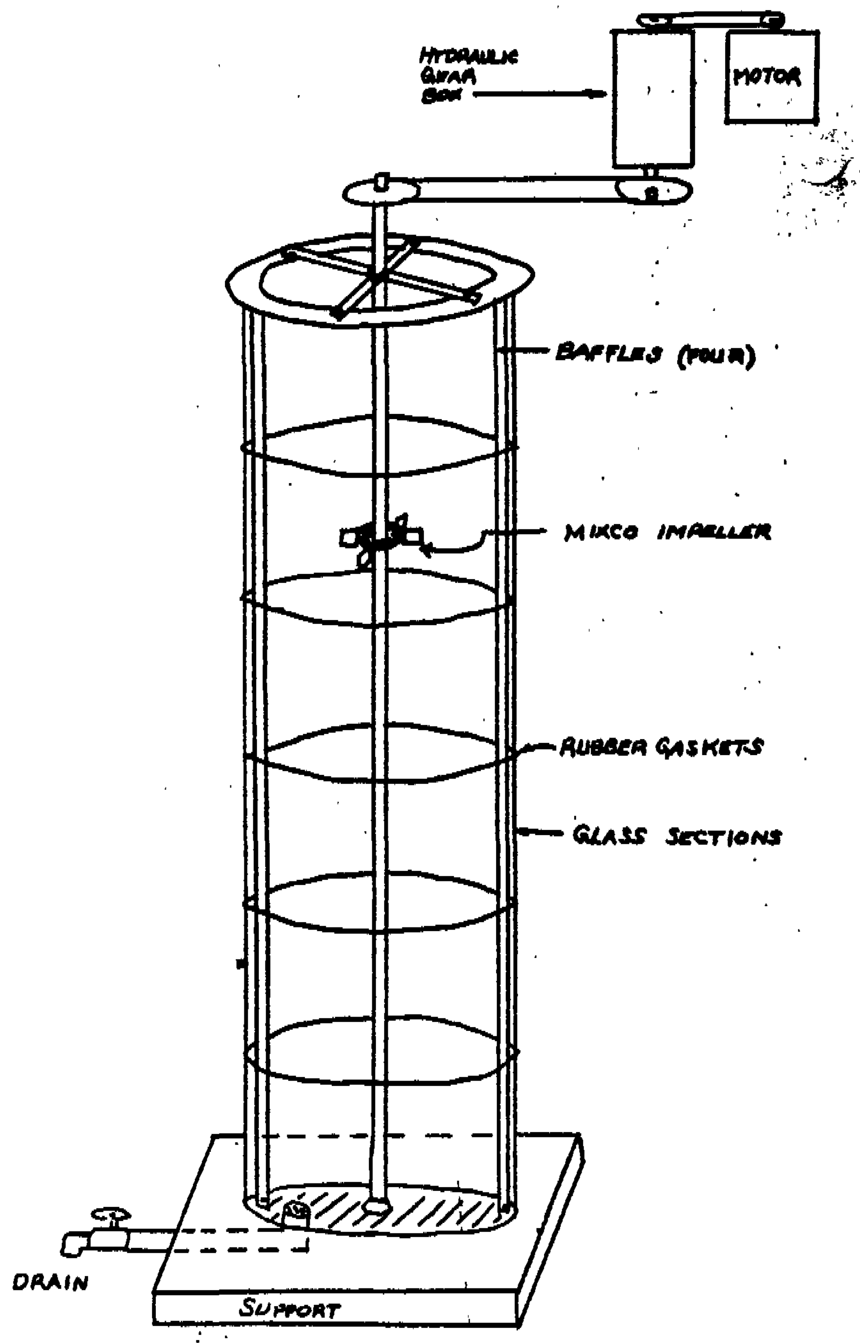

FIGURE 7-A

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6-INCH DIAMETER GLASS COLUMN

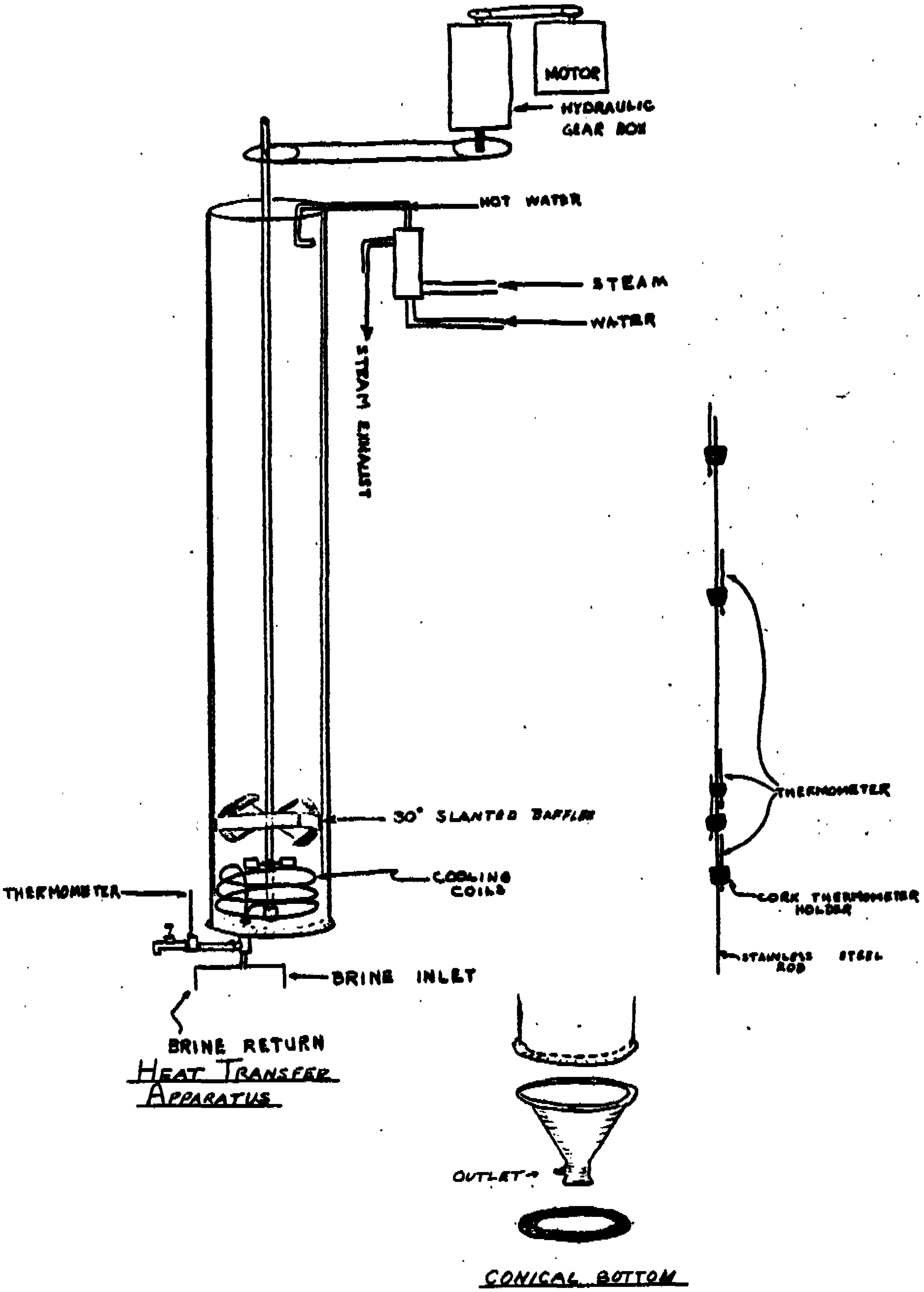

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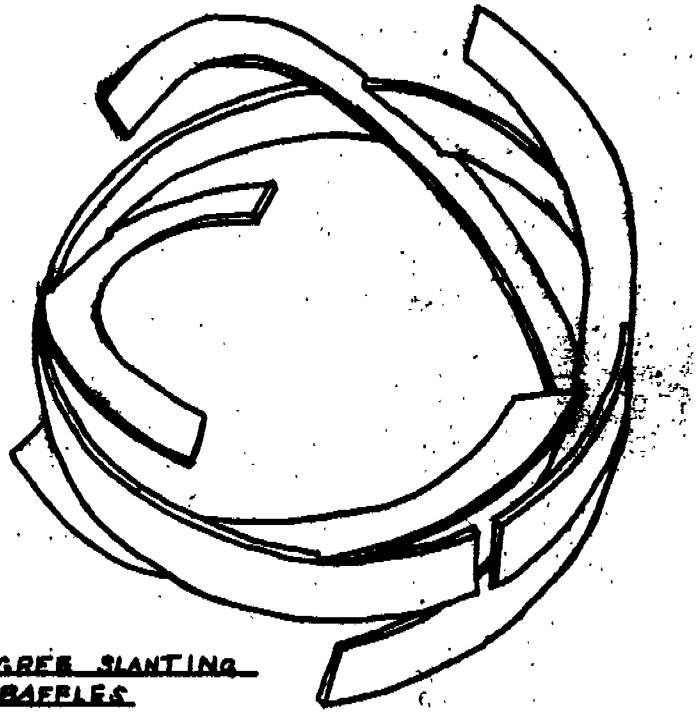
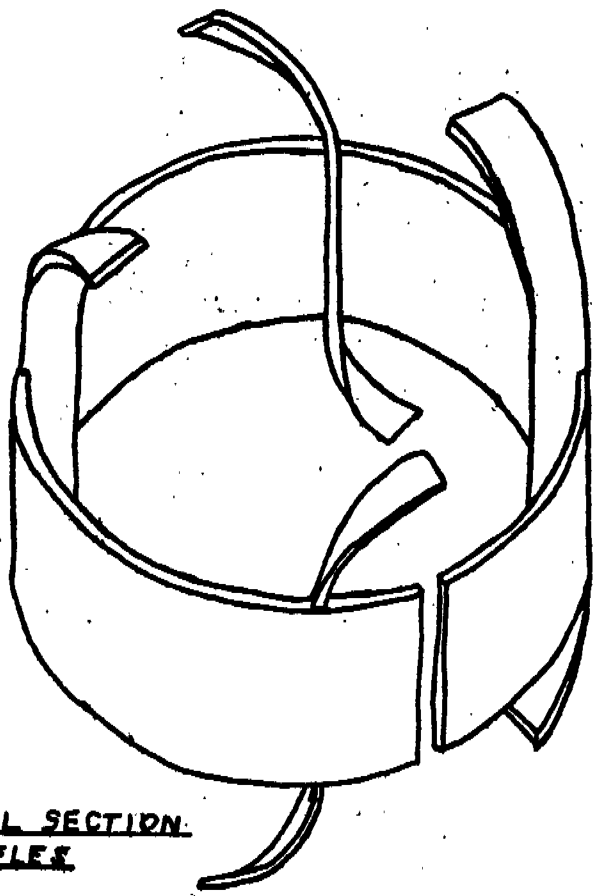
FIGURE 7-B

SLA[illegible] ED BAFFLE SECTIC 'S



30 DEGREE SLANTING BAFFLES



VERTICAL SECTION BAFFLES

FIGURE 8