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APPLICATIONS OF ULTRASONIC ENERGY

PROGRESS REPORT NO. 11
Covering Period from August 1, 1958
to September 30, 1958

AEROPROJECTS INCORPORATED
WEST CHESTER, PENNSYLVANIA

Contract No. AT (30-1)-1836

October 1958

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NYO 7932
Metallurgy and Ceramics

APPLICATIONS OF ULTRASONIC ENERGY

Progress Report No. 11

for August-September 1958

by

Aeroprojects Incorporated

ABSTRACT

Continuous aqueous precipitation of thorium oxalate was accomplished using impinging jet streams of the reactants in an ultrasonically activated zone. Evaluation of the influence on resultant particle size was obtained through photomicrographs and centrifugal sedimentation size analysis. Log probability plots showed a significant decrease in particle size and a narrowing of the size distribution for the ultrasonically prepared material as compared to the control.

Leaching of a cesium-bearing alumina waste with 0.01 N nitric acid in the presence of vibratory energy was less effective at a frequency of 800 kc than at 20 kc. The effect of treatment time, power level, and ratio of leach liquid to waste was investigated with a 20-kc "fixed-bed" treatment vessel. Leaching efficiency was increased at the higher power levels and the same efficiency maintained when the ratio of waste to acid was increased. Intermittent treatment may be effective, with promise for further equipment economies.

Several liquid additive aerosols were evaluated in the ultrasonic agglomeration of KCl aerosol, a simulant for radioactive particulates in calciner off-gas. Silicone oils of several viscosities and two liquid surfactants produced essentially the same degree of agglomeration as the glycerine-water mixture previously used. Development of a larger unit for field test was initiated.

Studies of ultrasonic coalescence in stabilized kerosene-water emulsions led to the conclusion that a longer exposure time is indicated. Therefore fabrication was undertaken on a new annular treatment vessel which will permit a twofold increase in treatment time at the same linear velocity previously found to be near optimum.

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SECTION I

ULTRASONIC CONTROL OF CRYSTAL SIZE DURING AQUEOUS PRECIPITATION

PURPOSE AND SCOPE

Control of the particle size and particle size range of the thorium oxide used in HRT blanket slurries is highly desirable. With certain thorium oxide slurries, erosive action and plugging in regions of low-velocity flow in experimental loops are observed; these difficulties may be alleviated by using submicron particles and/or narrow size distributions of the thorium oxide. Work at ORNL (Ref. 1) has indicated that the size distribution of thorium oxide is influenced by that of the thorium oxalate prior to calcination.

Application of ultrasonic energy during the batch precipitation of thorium oxalate from thorium nitrate and oxalic acid has shown promise in producing small, rounded particles of thorium oxalate with a narrow size distribution, and the effect of chemical and ultrasonic treatment parameters has been investigated with various precipitation techniques (Ref. 2). Preliminary evaluation of the precipitates was conducted by microscopic examination and extended to particle size measurements using sedimentation techniques. Subsequently selected conditions may be used to prepare quantities of thorium oxalate having a specified size and distribution, which can then be converted by calcination to thorium oxide for further evaluation.

HIGHLIGHT DEVELOPMENTS

Previous reports have described experimentation with varied techniques for ultrasonic precipitation of thorium oxalate from thorium nitrate and oxalic acid on a batch treatment basis. Current efforts have been concentrated on jet precipitation of thorium oxalate under ultrasonic influence on a continuous-flow basis.

This technique involved the use of two fine streams, one of 0.5 M thorium nitrate solution and the other of 1.0 M oxalic acid solution, each of which flowed through the 0.012-inch-orifice-diameter jet at a controlled rate of 10 milliliters per minute. At equal flow rates, the concentrations used provided the stoichiometric quantities required for precipitation of the thorium oxalate. The jet streams were adjusted normal to each other at the bottom of an annulus 1/4-inch wide, having an outside diameter of 2-1/2 inches and a volume of 100 milliliters. This annular volume was activated at 20 kc by transducers driven with 1500 watts from a motor-alternator. The mixed streams were allowed to flow annularly to the opposite side of the vessel and thence to overflow through an outlet tube. Figure 1 shows the insert which was contained in an activated cylindrical zone 2-1/2 inches in diameter by 2-1/2 inches deep. The inner wall of this insert was air-backed and cooled by a water spray.

At the beginning of each test run, the annulus was filled with 100 milliliters of water, ultrasonic energy was applied, and the flow rates of the oxalic acid and thorium nitrate solutions were adjusted. During each 5-minute period of the run, 100 milliliters of product was collected through the outlet tube (B of Figure 1) at the top of the annulus. Each run consisted of eight 100-milliliter samples and hence continued for 40 minutes. Control runs were made in the same apparatus under the same conditions but without ultrasonic activation.

Each sample was diluted with an equal volume of distilled water, allowed to stand for 8 to 12 hours, filtered, washed, and dried in an oven at 105°-110°C. Dried thorium oxalate particles from each sample were then suspended in 0.005 M tetrasodium pyrophosphate solution and examined microscopically for particle-size evaluation. In addition, dispersions of thorium oxalate in trichloroethylene were prepared for particle-size analysis by means of a centrifugal sedimentation technique developed by Whitby (Ref. 3).

Representative photomicrographs of ultrasonic and control specimens (Figure 2) are difficult to interpret and show little apparent difference in particle sizes. However, results of the Whitby particle-size analysis, plotted in the log-probability charts of Figures 3 and 4, reveal the effectiveness of the ultrasonic treatment. The geometric mean of the particle-size distribution (on a weight basis) has been reduced from the control value of approximately 2.6 microns to approximately 1.5 microns, and calculations indicate a corresponding reduction in the geometric standard deviation from 1.85 to 1.45. Furthermore, with this technique no particles larger than 4 microns were detected in the ultrasonic samples, while the control samples showed particles as large as 10 microns. It is estimated that particles aggregating as much as 0.5 percent of the total mass can be detected in any size range. Thus the comparative data determined by the Whitby technique establish an advantage for ultrasonic treatment, not only in a smaller mean particle size but also in a narrower size-distribution range.

It is believed that, by changing the flow rate and/or concentrations of the solutions as well as the ultrasonic intensity level, it should be possible to obtain a wide variety of particle size distributions.

FUTURE WORK

The results from earlier representative test samples sent to ORNL for particle-size determinations by neutron activation analysis have been received, and these results will be compared with data from the Whitby analyses.

Additional jet precipitation studies will be carried out in ultrasonic cavitation fields, using varied ultrasonic and chemical parameters.

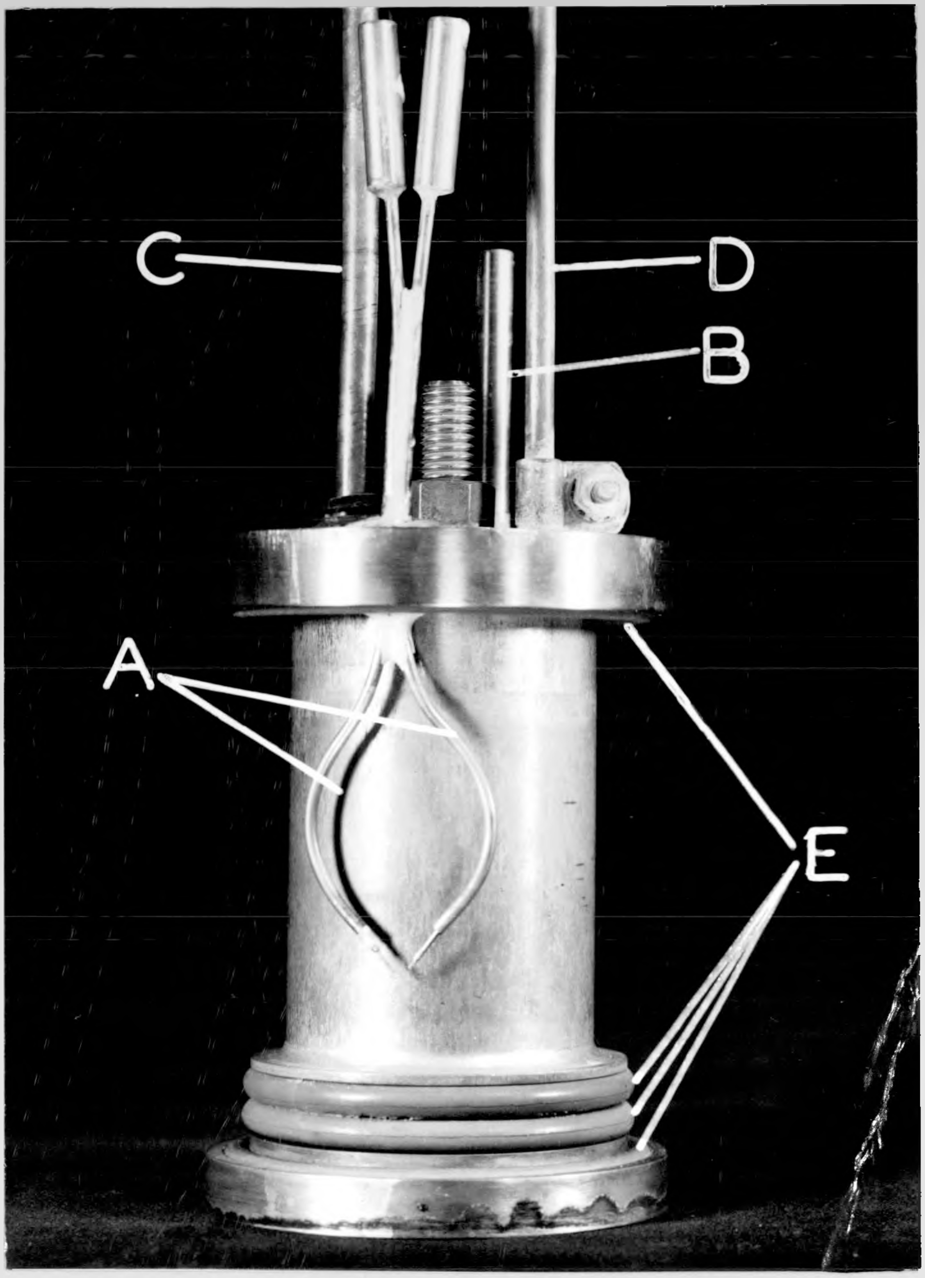
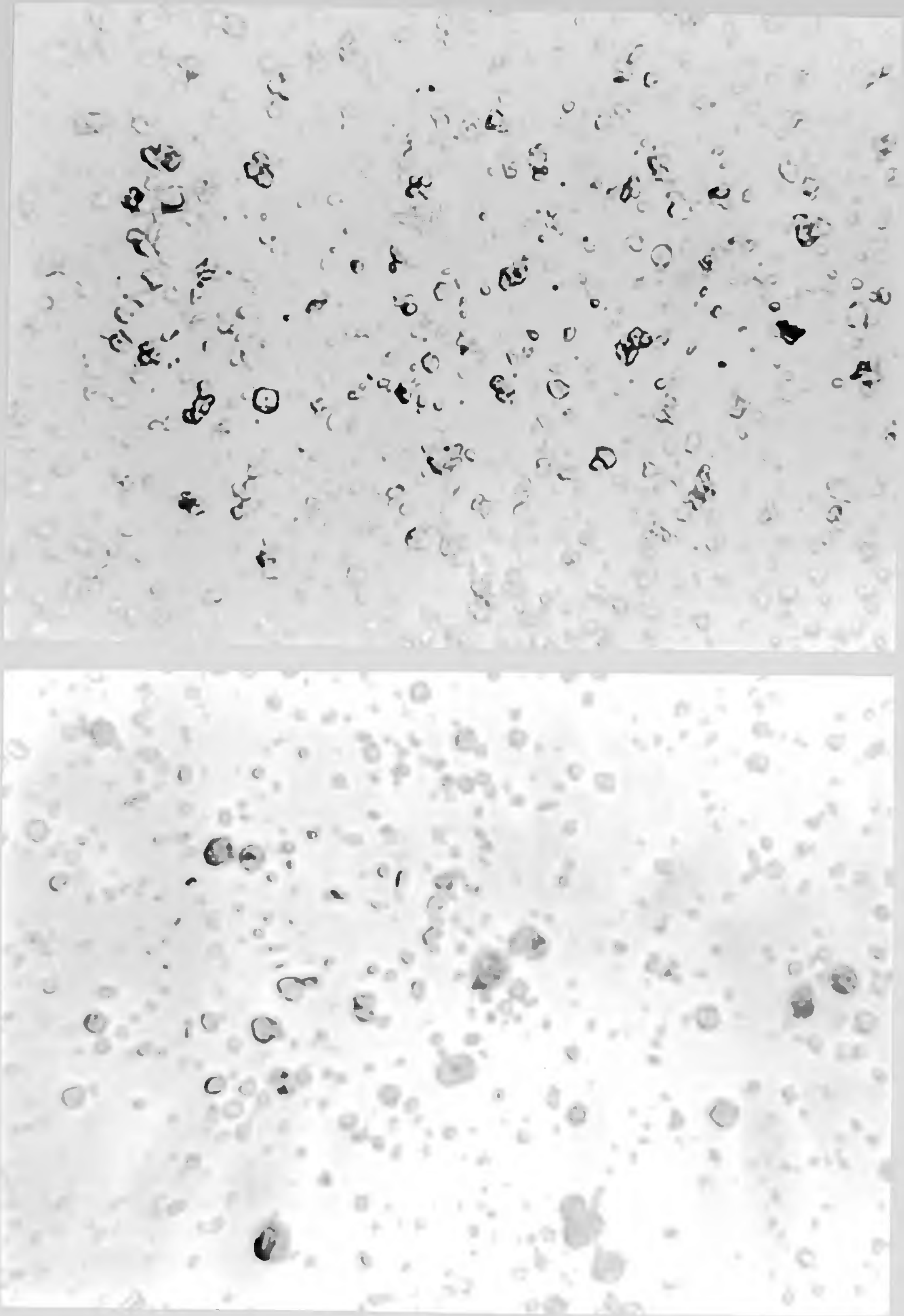


Figure 1

INSERT FOR JET PRECIPITATION OF THORIUM OXALATE
IN CYLINDRICAL HUB

A. Jet stream feed tubes
B. Outlet tube
C. Inlet for water cooling spray
D. Water outlet
E. Silicone O-ring seals

Mixing zone: Below feed tube orifices



a. Control

b. Ultrasonic

Figure 2

PHOTOMICROGRAPHS OF THORIUM OXALATE PARTICLES IN
0.005 M TETRASODIUM PYROPHOSPHATE SOLUTION
(Magnification: 1120X)

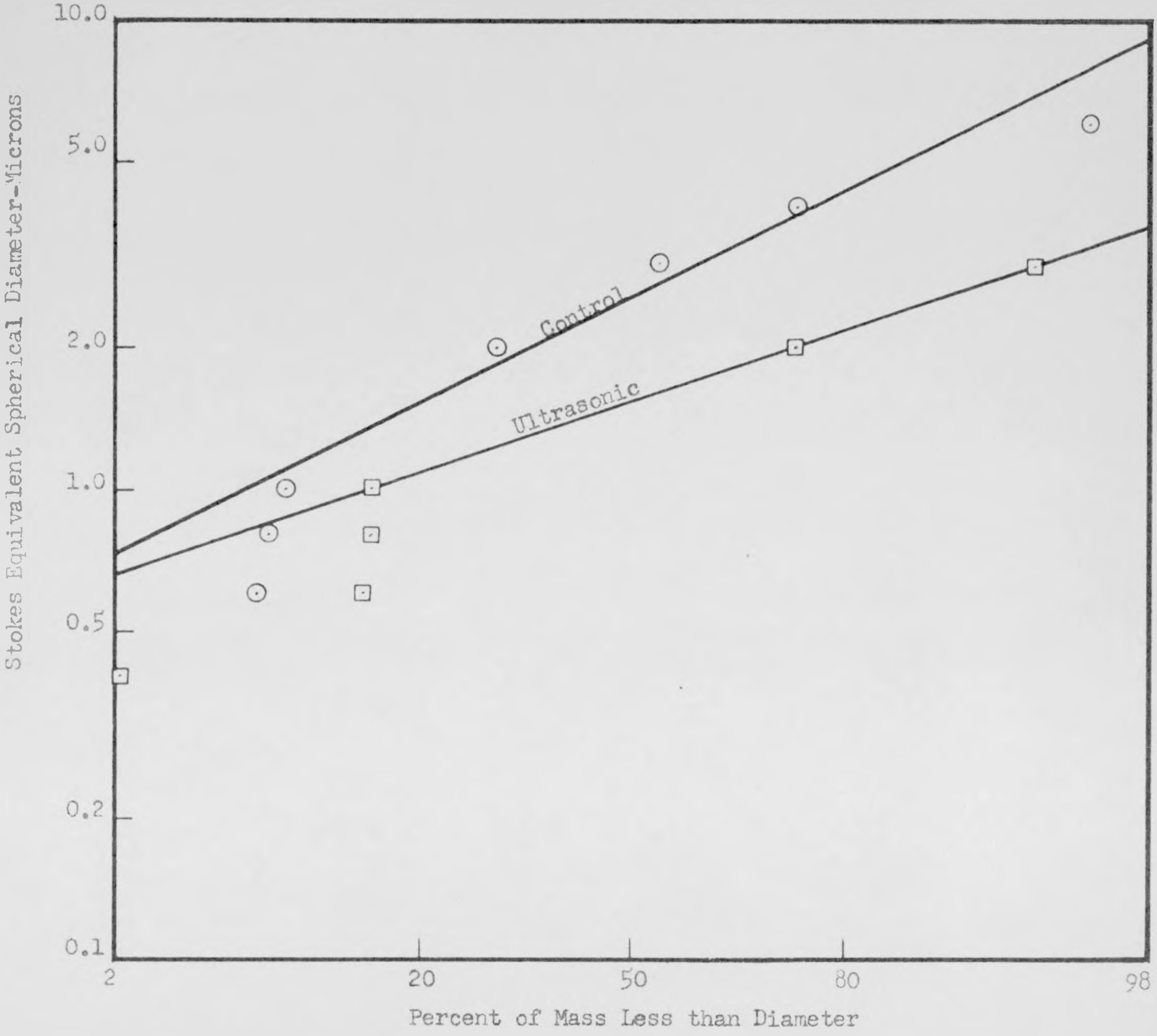


Figure 3

PARTICLE-SIZE DISTRIBUTION BY WHITBY CENTRIFUGE TECHNIQUE

FOR THORIUM OXALATE JET-PRECIPITATED WITH AND WITHOUT ULTRASONIC INFLUENCE

Reagents: 0.5 M Thorium Nitrate Solution
1.0 M Oxalic Acid Solution
Flow Rate: 10 ml/min for each solution
Ultrasonic Power Level: 1500 watts to transducer
Samples Taken: 5-10 minutes after start

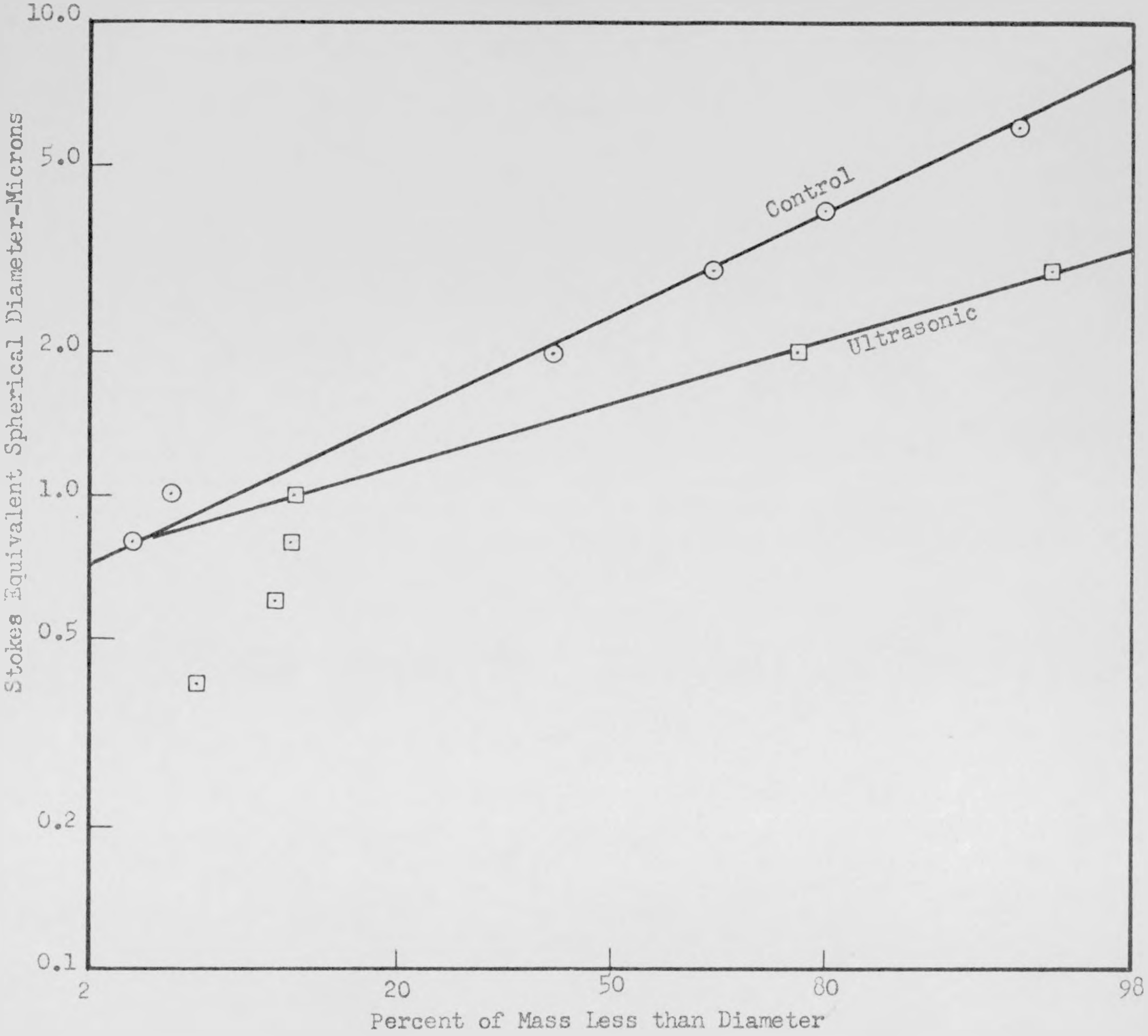


Figure 4

PARTICLE-SIZE DISTRIBUTION BY WHITBY CENTRIFUGE TECHNIQUE
FOR THORIUM OXALATE JET-PRECIPITATED WITH AND WITHOUT ULTRASONIC INFLUENCE

Reagents: 0.5 M Thorium Nitrate Solution
0.1 M Oxalic Acid Solution
Flow Rate: 10 ml/min for each solution
Ultrasonic Power Level: 1500 watts to transducer
Samples Taken: 30-35 minutes after start

SECTION II

ULTRASONIC LEACHING IN AQUEOUS SOLUTION

PURPOSE AND SCOPE

Calcined wastes from the nitric acid dissolution of fuel element materials contain considerable amounts of fission products; of particular interest are cesium-137 and strontium-90. Removal of these elements by a quick leaching process would simplify the cooling and storage problems and permit disposal of the other materials by simple burial. Present methods require large volumes of leaching liquid with long exposure time and do not remove as much as is desired for safe storage or disposal.

This program was undertaken to determine the feasibility and effectiveness of applying vibratory energy during the leaching of simulated aluminum-nitrate-type wastes containing various fission products. The earlier investigations of this program (Ref. 4) have shown the effectiveness of ultrasonic treatment in reducing the time required and increasing the percent fission product removed.

HIGHLIGHT DEVELOPMENTS

High-Frequency Ultrasonic Leaching in "Fixed-Bed" Vessel

Previous experiments (Ref. 5) had indicated accelerated leaching in a "fixed-bed" ultrasonic treatment vessel operating at a frequency of 20 kc. To evaluate the effect of frequency, several tests were made in an 800-kc "fixed-bed" vessel assembled from available components (Figure 5). Calcined cesium waste and 0.01 N nitric acid solution were placed in the 3-inch-diameter cylinder, the lower end of which was closed with a thin Mylar membrane, which is essentially transparent to ultrasonic energy. The vibratory output of an 800-kc barium titanate wafer, which was driven with 225 electrical watts input, was transmitted through a 1/2-inch layer of transformer oil, through the Mylar film, and into the treatment vessel. Mild stirring was supplied.

After 4 hours of ultrasonic treatment, only 25-30 percent of the cesium had been transferred to the leaching liquor. Since this was less than had been obtained in other vessels operating at 20 kc, no further work was done at the higher frequency.

"Fixed-Bed" Leaching at 20 KC

Further tests were conducted with the 20-kc "fixed-bed" vessel previously described to investigate the effect of treatment time, power level, and volume of leaching liquid.

Several runs were made using 5 grams of cesium waste and 300 milliliters of 0.01 N nitric acid solution, with intermittent application of ultrasonic energy at 50 watts input to the transducer. The results of two tests are shown in Figure 6. The data for Curve A were obtained using an ultrasonic cycle of 15 minutes on and 15 minutes off, with samples taken for analysis at the end of every hour. At the end of 5 hours, the leaching liquid was allowed to remain in contact with the waste for 3 additional hours with no applied ultrasonics; the percent leached was doubled in this 3-hour period. The data of Curve B were obtained with an ultrasonic cycle of 15 minutes on and 30 minutes off. During the first few hours, the curve was not essentially different from Curve A. The effect after longer periods of time should be investigated.

Additional runs were made in the same equipment and using the same quantities of calcined waste and nitric acid solution. However, in this case the transducer power was increased to 100 watts and was applied continuously. The leaching efficiency was greatly increased, 48 percent of the cesium being removed in 5 hours compared with 16-18 percent with intermittent treatment at 50 watts. The ultrasonic energy was shut off after 7 hours of treatment and the liquid remained in contact with the waste for an additional 15 hours; by this time 93 percent of the cesium activity had been removed from the waste, constituting the best results obtained in the "fixed-bed" vessel to date. Data from this test are plotted in Figure 7, along with comparable data obtained in earlier tests (Ref. 6) at the lower power level of 50 watts.

In another run under the same conditions (100 watts power), 3 hours of continuous ultrasonic application removed somewhat less beta activity, but 3 additional hours of standing with no ultrasonics resulted in 70 percent leaching (see Curve B of Figure 8).

The ratio of waste to acid was then increased by using 10 grams of calcined waste and only 200 milliliters of nitric acid solution. Ultrasonic treatment was applied for 2 hours at the further increased power level of 200 watts; during this time 20 percent of the cesium was removed. The nitric acid solution was then replaced with 200 milliliters of fresh solution and the treatment continued for an additional 2 hours, with 15 percent more of the activity being removed. These data are plotted in Figure 8 (Curve A) for comparison with results obtained in the previous test at lower power. It appears that the same leaching efficiency can be maintained under both conditions, and the advantages of using smaller quantities of leaching liquid warrant further investigation.

FUTURE WORK

Additional studies will be carried out using the converging-coupler vessel, with which good results had previously been obtained in short treatment periods (Ref. 7), to evaluate the effect of ultrasonic treatment for time periods in excess of 8 hours.

Additional tests will be designed to evaluate further increases in the ratio of calcined waste to leaching liquid.

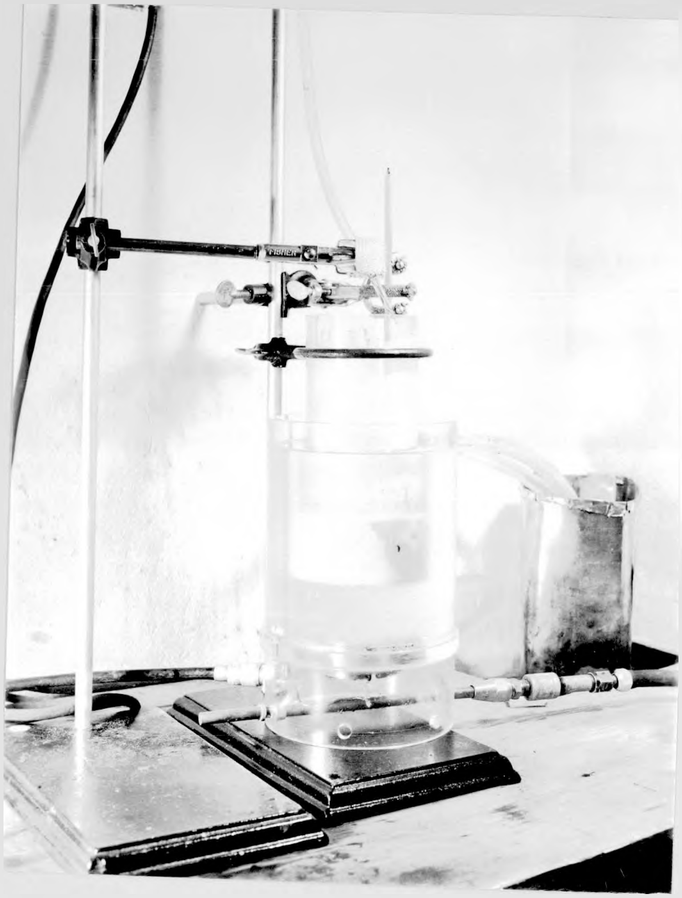


Figure 5

800-KC "FIXED-BED" ULTRASONIC TREATMENT VESSEL
USED FOR EXPERIMENTAL LEACHING OF CALCINED CESIUM WASTE

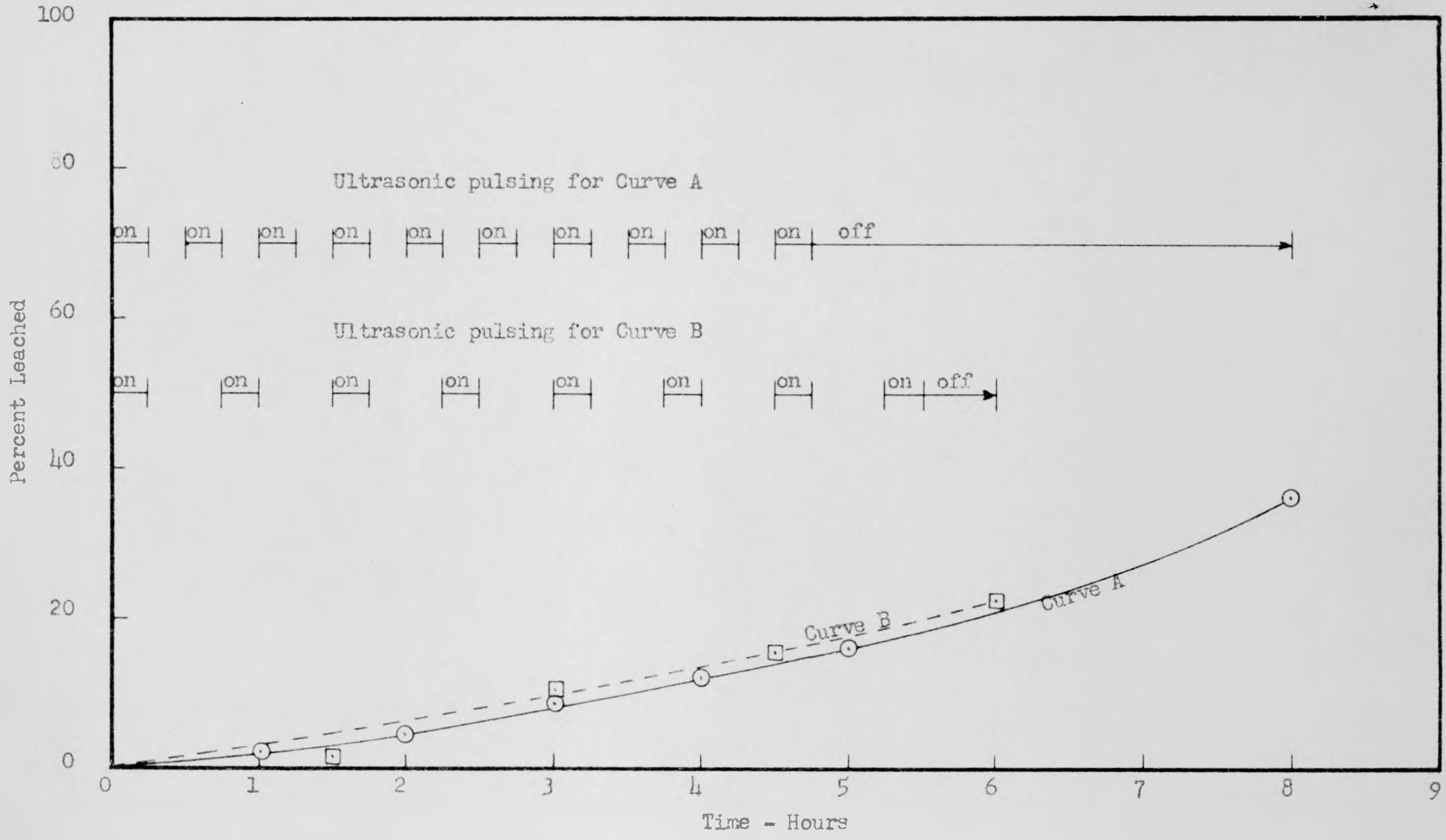


Figure 6

LEACHING OF CESIUM WASTE WITH 0.01 N NITRIC ACID SOLUTION
WITH INTERMITTENT ULTRASONIC TREATMENT IN "FIXED-BED" VESSEL

Materials: 5 grams Cesium Waste
300 ml HNO_3 Solution
Ultrasonic Frequency: 20 kc
Power Level: 50 watts

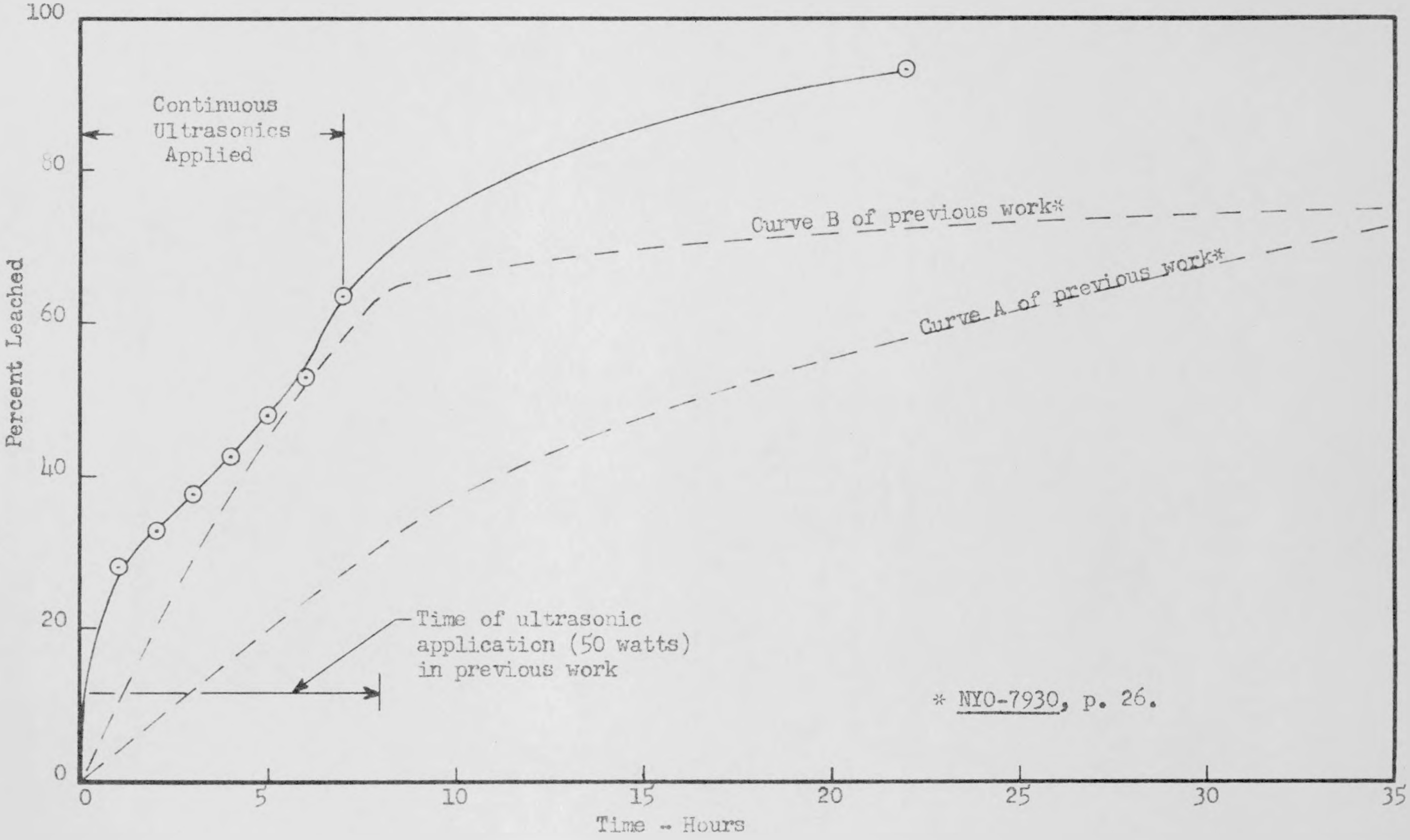


Figure 7

LEACHING OF CESIUM WASTE WITH 0.01 N NITRIC ACID SOLUTION

WITH CONTINUOUS ULTRASONIC TREATMENT IN "FIXED-BED" VESSEL

Materials: 5 grams Cesium Waste
300 ml HNO_3 Solution
Ultrasonic Frequency: 20 kc
Power Level: 100 watts

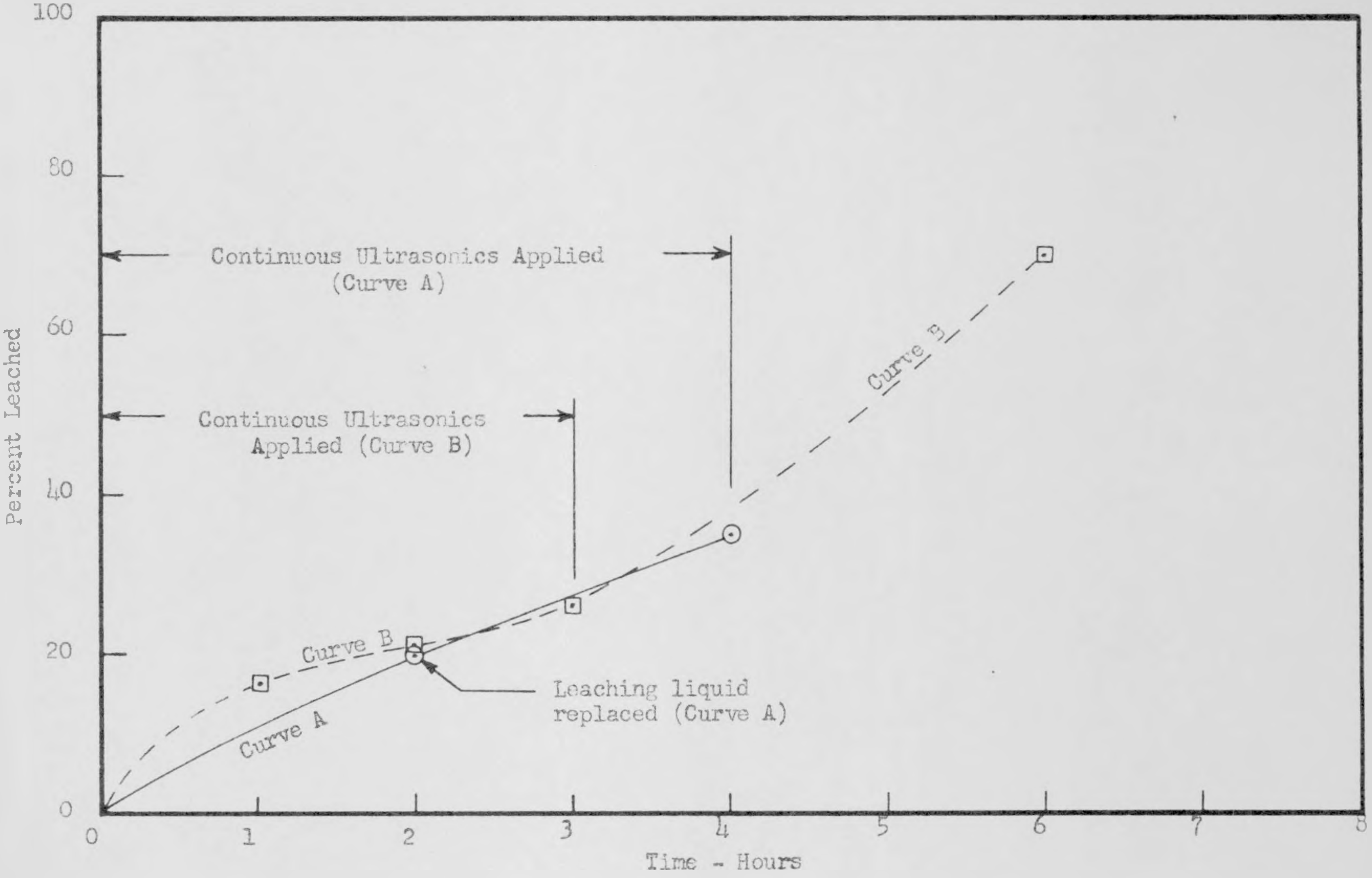


Figure 8

LEACHING OF CESIUM WASTE WITH 0.01 N NITRIC ACID SOLUTION

WITH CONTINUOUS ULTRASONIC TREATMENT IN "FIXED-BED" VESSEL

	Curve A	Curve B
Materials:	10 g Cesium Waste + 200 ml HNO_3	5 g Cesium Waste + 300 ml HNO_3
Frequency:	20 kc	20 kc
Power:	200 watts	100 watts

SECTION III

ULTRASONIC COALESCENCE IN GASEOUS AND LIQUID SYSTEMS

PURPOSE AND SCOPE

Coalescence in Gaseous Systems

Off-gas streams from calcined aqueous waste in the reprocessing of spent aluminum- and zirconium-based fuels contain polydispersed aerosols with highly radioactive particles too small to be removed efficiently by conventional air cleaners such as cyclones, bag filters, and scrubbers. However, such devices could be utilized effectively if the widely separated particles could be coalesced to larger size. A potential method of achieving such coalescence is the creation of an ultrasonic standing-wave field in the aerosol of interest and a concomitant increase in collision frequency through the use of a high concentration of additive aerosol whose particles are in an effective size range.

The present investigation is therefore designed to examine the feasibility of this approach, to evaluate physical and acoustical configurations for such ultrasonic agglomerating systems, and to establish practical methods whereby coalescence and subsequent collection of the particles can be accomplished.

Coalescence in Liquid Systems

The fine dispersions which lead to efficient extraction and leaching frequently result in very stable emulsions or suspensions. The use of ultrasonic standing-wave fields in the agglomeration of stable suspensions has been shown to be feasible (Ref. 8, 9). The purpose of this phase of the investigation is to establish the parameters which are important in the treatment of moderate volumes of liquids in continuous-flow systems. A typical use of this type of treatment might be in breaking interface emulsions which form in pulse columns. The emulsion might be led out from the column, treated ultrasonically, and the two separated phases returned to the column at an appropriate point.

HIGHLIGHT DEVELOPMENTS

Coalescence in Gaseous Systems

The previous progress report (Ref. 10) described ultrasonic agglomeration experiments with glycerine-water additives to increase coalescence in potassium chloride aerosols. These studies indicate that collection efficiency of airborne particles improves with large volumes of additive, with low flow rates, and with combined lower frequency-higher intensity treatment.

Exploratory experiments with other additives have been carried out to investigate the influence on ultrasonic coalescence in gaseous systems of such physical properties of the additive aerosol as density, particle size, surface tension, and dielectric constant. Silicone oils* of varying viscosity and several surfactants have been used to date. The apparatus, shown schematically in Figure 9 (the same as that previously used), consisted of a 2-1/2-inch-diameter Plexiglas tube with two Hartmann whistles operating in opposition at either end, the test cell in which the aerosols were generated, vacuum pumps to draw the aerosol through the tube, pre-impingers to collect particles smaller than 5 microns (Ref. 11), and all-glass impingers to collect all particles which pass through uncoalesced and hence are not readily collectible.

In each experiment, potassium chloride was aerosolized in the test cell from 200 milliliters of a 1-weight-percent aqueous solution and 300 milliliters of the selected additive aerosol used. Under optimum flow rates, the quantity of unagglomerated potassium chloride that passes through the tube and collects in the all-glass impingers is so small as to be difficult to evaluate by the analytical techniques employed (Ref. 11). Hence, the aerosol was drawn through the Plexiglas tube at 0.4 cubic foot per minute, although previous experience has indicated that lower velocities produce better collision efficiencies.

1. Silicone Oils as Additive Aerosols

Experimental studies were made using additive aerosols varying in viscosity from 1 to 100 centistokes. The particle size distributions for these oils were estimated by stirred sedimentation and Feather analysis, which is a rapid, reliable method developed at Aeroprojects for determining particle size of a non-evaporating aerosol as it exists immediately after generation. From aerosol sedimentation curves, in which the percent of the mass airborne is plotted as a function of time after atomization, the constituent classes of the size distribution are resolved by application of the Feather technique (Ref. 12). The results obtained for the silicone oils, together with those for glycerine-water solution for comparison, are shown in Table I.

Applying the theory of Brandt, Freund, and Hiedemann (Ref. 13) as previously discussed (Ref. 14) leads to the conclusion that optimum coalescence at a frequency in the vicinity of 20 kc appears to occur in the particle size range of 2-10 microns. Smaller particles follow the vibratory motion of the gas, while larger particles tend to fall out before they can be agglomerated by sonic means. The data of Table I show that the 1-centistoke material produces an aerosol of markedly

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* Dow Corning Series 200.

different characteristics from those of the higher viscosity materials, because of its low but appreciable vapor pressure at room temperature. This aerosol is composed predominantly of very small particles (< 3 microns) with a smaller percentage in the effective size range. Thus collection efficiency would be expected to be lower with this material, since coalescence into collectible-size material would require low-probability, multiparticle collision.

Agglomeration tests were made with each of the additives listed in Table I at frequencies of 13.5 kc and 21.5 kc, three replicates being made under each set of conditions. Examination of the results, presented in Table II, shows that at the frequency of 13.5 kc potassium ion collection efficiency was good (> 89 percent) except in the case of the 1-centistoke material, in accord with the considerations noted above. With additive aerosols in the viscosity range of 5-100 centistokes, collection efficiency at 13.5 kc generally decreased with increasing viscosity. The same trend was observed with a frequency of 21.5 kc at lower intensity, but in this case there appeared to be a stronger interaction between larger additive particle size and lower collection. The lower frequency-higher intensity condition was more effective under all conditions.

2. Liquid Surfactants as Additive Aerosols

Further experiments were designed to study the effectiveness of ionic and non-ionic liquid surfactants as additive aerosols. The initial experiments included two surfactants, both of which promote oil-in-water emulsification: (1) BCO,* an amphoteric agent, and (2) Tween 20,** a non-ionic agent.

The apparatus and techniques were essentially the same as described above, 300 milliliters of surfactant being used for each test. Only the lower frequency and higher intensity were used, since these conditions had produced better coalescence with the silicone oils. Three ultrasonic tests were made with the BCO and one with the Tween 20. In addition, an agglomeration test was made using each of these surfactant additive aerosols but without ultrasonic application.

The results obtained with the two surfactants, summarized in Table III, show no substantial differences. Furthermore, comparison of Tables II and III reveals no large differences among the various additives studied to date.

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* E. I. du Pont de Nemours & Co., Wilmington, Del. (30 percent active solids in water solution).

** Atlas Powder Company, Wilmington, Del. (100 percent active).

3. Studies with Larger Glass Coalescence Tube

Effort has been continued to establish the general geometrical limitations of size and shape of coalescence apparatus which might be suitable for field test purposes. The major objectives are (a) improved ultrasonic sources and (b) equipment capable of treating larger volumetric flow rates. Figure 10 shows current apparatus. The tube (A) for coalescence is glass, 14 feet long and with an inner diameter of 6 inches. Standing waves are generated by Hartmann whistles (B) mounted on steel frames (C) with parabolic reflectors (D) at either end of the tube. In this tube, as in the smaller Plexiglas tube, Mylar film is used to channel the aerosols through the standing-wave field (see Figure 9). A specially designed, sensitive, probe-type microphone (E) in the tube is attached to an analyzer (F) where frequency and intensity are registered during tuning. Aerosol from the test cell (G) is drawn through the glass tube by a vacuum pump metered by six all-glass impingers (H) with pre-impingers (I of Figure 11). Non-coalesced particles that do not fall out in the agglomerating tube, if readily collectible in cyclone collectors (i.e., greater than 5 microns in diameter), are removed by the pre-impinger. The impingers collect that portion of the potassium chloride which has coalesced sufficiently in the apparatus.

To evaluate the performance of the 6-inch-diameter glass tubular array, an experiment was conducted with Du Pont BCO as the additive aerosol, and the results compared with those from experiments with the 2-1/2-inch Plexiglas tube. The basic experimental techniques were the same as those used in previous experiments. Potassium chloride aerosol was generated from a 1-weight-percent aqueous solution in the test cell, the BCO was added in quantities of 300 milliliters, and the aerosol was drawn through the glass tube at 2.4 cubic feet per minute, which is four times the volume flow rate of the smaller Plexiglas tube, thus providing the same linear velocity in both tubes. A frequency of 14.5 kc was used, and the flow of aerosol through the standing-wave field was continued for sixty minutes.

The data from the experiment are summarized in Table IV, along with comparable data from Table III (obtained with the 2-1/2-inch-diameter Plexiglas tube). Since the 6-inch-diameter glass tube was more than three times as long as the 2-1/2-inch-diameter tube, superior performance was anticipated because of the greater coalescence length. Greater fall-out was observed in the non-ultrasonic control, but difficulties were experienced in the ultrasonic tests, and the acoustical performance of the larger tube with both whistles operating was observed to be poor. The collection efficiency for both tubes was approximately 90 percent. Earlier experiments have established that sharply defined standing waves accomplish more complete coalescence; hence, efforts to develop a good wave pattern in the larger tube should indicate its superiority.

Further study of the geometry of the array is necessary to determine the tube length and diameter effects on ultrasonic coalescence.

Coalescence in Liquid Systems

Additional emulsion coalescence experiments were carried out in the annular standing-wave vessel previously described (Ref. 15). This treatment apparatus consisted of a cylindrical barium titanate transducer contained in and bonded to an aluminum sheath. Radial vibrations transmitted by the aluminum sheath into the emulsion being treated were reflected by an outer cylinder to establish a standing-wave pattern. Two reflectors were used in the current work: a steel cylinder with an inside diameter of 15.8 centimeters, and an aluminum cylinder with an inside diameter of 11.45 centimeters.

The emulsion which was used in these experiments was the same as that used previously, i.e., a gelatin-stabilized kerosene-in-water emulsion containing approximately 1 volume percent kerosene. This emulsion was pumped through the vessel at a predetermined flow rate and the effluent material collected. It had previously been observed (Ref. 15) that multiple passes of the emulsion through the annular standing-wave vessel resulted in improved emulsion breaking. Therefore, after the first pass the equipment was cleaned, and the effluent material was pumped through the vessel for second and third passes.

The data for these experiments, presented in Table V, show that better emulsion breaking is obtained for lower linear velocities in the annulus of the treatment vessel. This observation confirms previously reported data (Ref. 15) in which linear velocities of 3 centimeters per minute resulted in an effluent material containing 0.2 percent kerosene while linear velocities of 5 centimeters per minute gave effluent emulsions containing 0.4 percent kerosene. The efficiencies of emulsion breaking reported in Table V were not as good as those reported previously and are believed to be related to tuning and other assignable apparatus difficulties. The effluent material from experiments at a linear velocity of 3 centimeters per minute resulted in 0.4 to 0.5 percent kerosene in the effluent from the first pass through the vessel. At a linear velocity of 5 centimeters per minute, the kerosene content of the effluent was 0.7 to 0.9 percent.

In every case, additional treatment of the emulsion resulted in further emulsion breaking. During the course of this work, it was also noted qualitatively that an emulsion once treated by the ultrasonic equipment broke more rapidly under a gravity field than did an emulsion which had not received ultrasonic treatment. The fact that better emulsion breaking is obtained in multiple passes through the apparatus suggests that longer treatment time at low linear velocities should be beneficial.

The vessel used in the above experiments employed a cylindrical transducer 6 inches long. In order to increase the treatment time, a new annular treatment vessel was fabricated with a transducer length of 12 inches (Figure 12). Three stainless steel reflectors, having inside diameters of 4.99, 6.08, and 8.02 inches, have been designed for this treatment vessel.

To achieve the same linear velocity in the annulus for these three reflectors, it is obvious that quite different volume rates of flow are required. In order to make the disturbance of the flow pattern on injection and removal of material contant from one reflector to another, the entrance ports are in the form of perforated tubes, the area of the perforations being proportional to the cross-sectional area of the annulus. Thus, the emulsion should enter and leave the annulus at the same velocity regardless of which reflector is being used. Two new coupler configurations will be used in the new treatment vessel. One of these consists of aluminum foil coated with a pressure-sensitive adhesive. The other coupler is a thick aluminum sheath which will be bonded to the transducer with soft solder.

FUTURE WORK

Coalescence in Gaseous Systems

Future work will include the following: exploratory experiments extending the evaluation of additive aerosol properties; studies of techniques for more precise analysis of the percent coalescence to permit operation at optimum efficiency; and modification of the geometry and further investigation of the effectiveness of the 6-inch-diameter tube in treating large volumes of gas.

Coalescence in Liquid Systems

The experimental program will continue with the major emphasis on the new standing-wave vessel. The study of the effect of a larger transducer should indicate whether it is preferable to use a longer treatment time or several short treatment times with a quiescent period between treatments. The maximum usable linear velocity in the annulus will be determined. The effects of diameter of reflector will be evaluated to determine the maximum depth of treatment through the emulsion phase.

Table I

PARTICLE-SIZE DISTRIBUTION OF LIQUID ADDITIVE AEROSOLS OF VARYING VISCOSITY

Material	w/o Less Than*				
	10 µ	8 µ	5 µ	4 µ	3 µ
5 cs Glycerine-Water	48	36	22	17	-
1 cs Silicone Oil	--	~95	~88	85	80
5 cs Silicone Oil	--	76	62	47	--
10 cs Silicone Oil	--	68	45	35	--
25 cs Silicone Oil	--	40	28	21	--
50 cs Silicone Oil	--	48	31	23	--
100 cs Silicone Oil	--	34	25	20	15

Table II

ULTRASONIC AGGLOMERATION OF POTASSIUM CHLORIDE SOLID AEROSOL WITH SILICONE OIL ADDITIVE AEROSOLS

Aerosol Flow Rate: 0.4 cfm
Additive Aerosol Volume: 300 ml
Normal Peak Intensity: 167 db at 13.5 kc
159 db at 21.5 kc

Additive Aerosol	Viscosity (cs)	w/o Particles* 8-4µ (Estimated)	Average % Collectible KCl (in Tube and BP)	
			at 13.5 kc	at 21.5 kc
Silicone Oil	1	10	65.1	48.6
Silicone Oil	5	29	94.2	91.6**
Silicone Oil	10	33	95.8	89.5
Silicone Oil	25	19	93.2	71.4
Silicone Oil	50	25	89.2	78.7
Silicone Oil	100	14	90.7	65.7
Glycerine-Water	5	19	98.2	87.0

* Weight percent in size range noted of 300 cc of additive passed through nozzle for atomization.

**Sonic intensity approximately 165 db for several tests in this series.

Table III

AGGLOMERATION OF POTASSIUM CHLORIDE SOLID AEROSOL WITH SURFACTANT ADDITIVE AEROSOL UNDER ULTRASONIC AND NON-ULTRASONIC CONDITIONS

Aerosol Flow Rate: 0.4 cfm
Additive Aerosol Volume: 300 ml
Ultrasonic Frequency: 13-14 kc
Ultrasonic Intensity: 167 db

Surfactant	Frequency	% Collectible KCl (in Tube and BP)	Average Percent Collectible
Du Pont BCO (Amphoteric)	(Non-Ultrasonic)	26.3	26.3
	13	88.1	
	13	89.9	
	14	93.8	90.6
Atlas Tween 20 (Non-ionic)	(Non-Ultrasonic)	18.3	18.3
	13.5	90.8	90.8

Table IV

COMPARISON OF ULTRASONIC COALESCENCE OF POTASSIUM CHLORIDE AEROSOL IN TWO EXPERIMENTAL ARRAYS

Additive Aerosol Used: BCO 35% Solids*

Inner Diameter of Tube (inches)	Frequency (kc)	No. of Whistles Operating	Observed Quality of Standing Waves	Percent Collectible KCl	Average Percent Collectible KCl
6	Non-Ultrasonic	0	---	64.9	64.9
2-1/2	Non-Ultrasonic	0	---	26.3	26.3
6	14	2**	Weak**	92.5	
6	14.5	2**	Weak**	87.2	89.8
6	14	2**	Weak**	90.1	
2-1/2	13	2		88.1	
	13	2		89.9	90.6
	14	2		93.8	
6	14	1 (with reflector)	Good	89.2	89.2

* Product of Du Pont de Nemours & Co.
** Difficulties observed in tuning Hartmann whistles.

Table V

ULTRASONIC AGGLOMERATION OF KEROSENE-WATER EMULSION

Frequency: 429 kc
Power: 400 watts
Transducer Diameter: 9.0 cm

Reflector Diameter (cm)	Emulsion Flow Rate (ml/min)	Linear Velocity (cm/min)	Initial Kerosene Concentration (Vol. %)	Effluent Kerosene Concentration (Vol. %)	Remarks
15.8	276	3	1.2	0.4	First Pass
				0.3	Second Pass
				0.2	Third Pass
15.8	276	3	1.2	0.5	First Pass
				0.3	Second Pass
				0.2	Third Pass
15.8	460	5	1.2	0.7	First Pass
				0.6	Second Pass
				0.5	Third Pass
15.8	460	5	1.2	0.9	First Pass
				0.7	Second Pass
				0.4	Third Pass
15.8	460	5	1.2	0.9	First Pass
				0.7	Second Pass
				0.5	Third Pass
11.45	205	5	1.1	0.3	First Pass
				0.2	Second Pass
				0.1	Third Pass

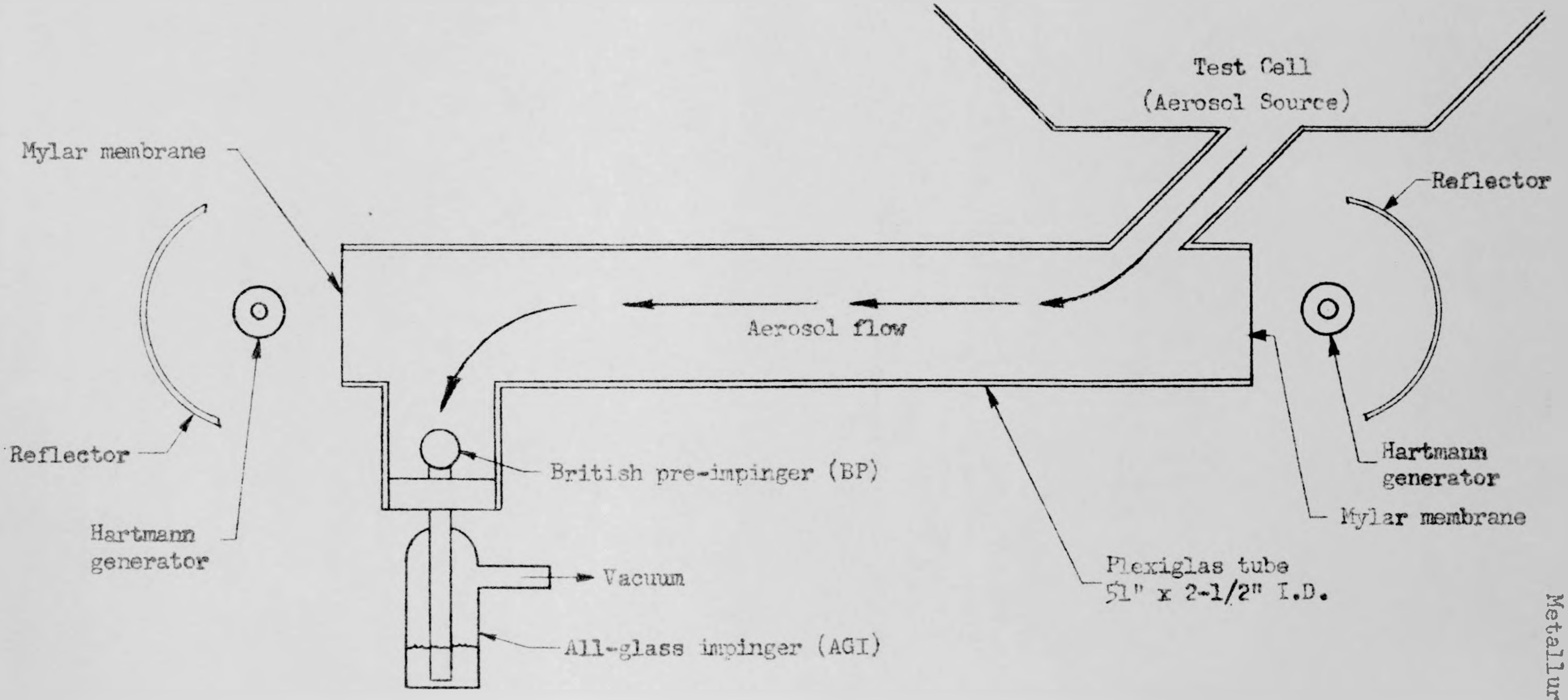
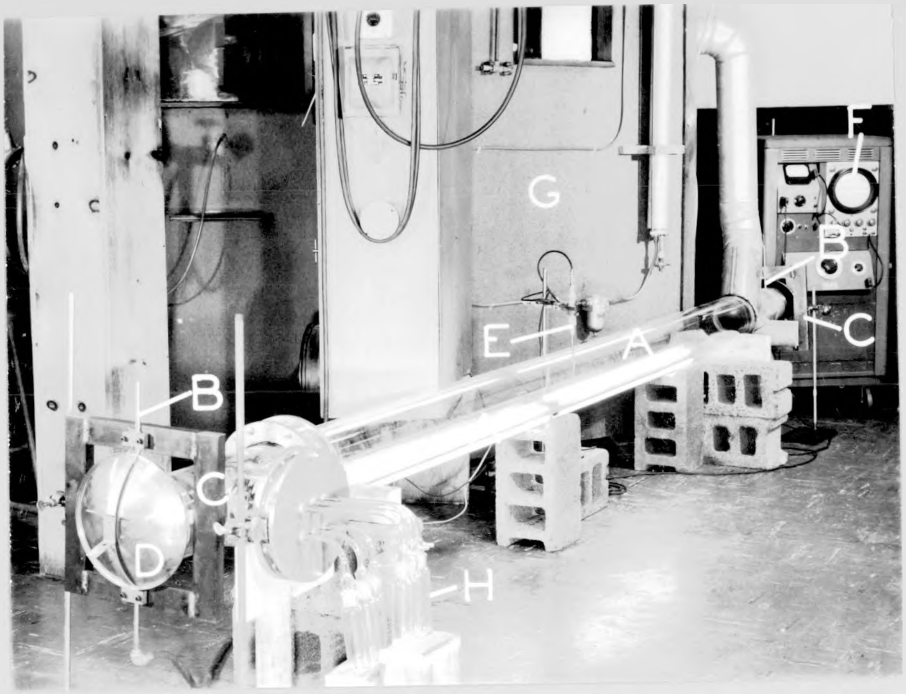


Figure 9

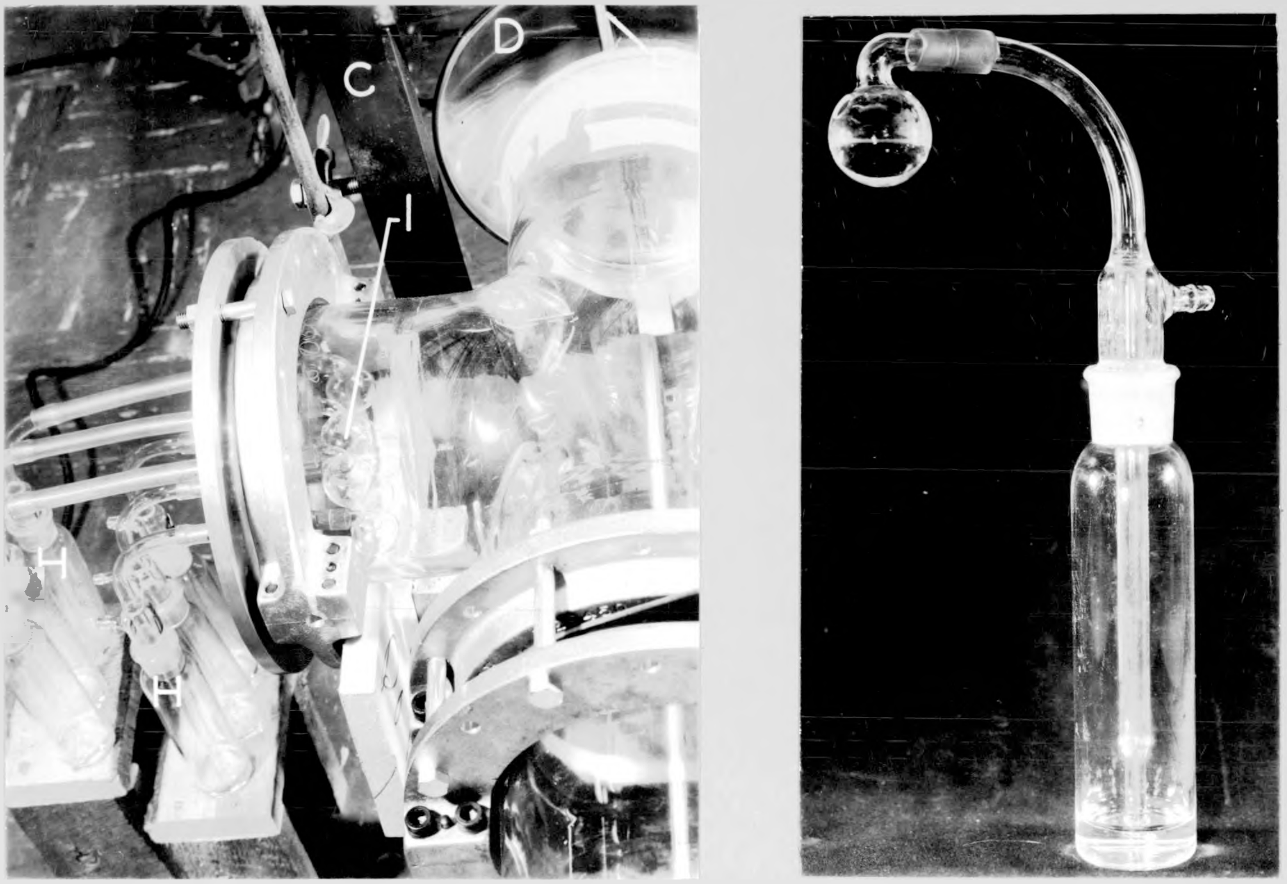
APPARATUS EMPLOYED FOR EVALUATION OF ULTRASONIC AGGLOMERATION
(Schematic)



A.	Glass coalescence tube Length: 14 feet Inner diameter: 6 inches	E.	Probe-type microphone
B.	Hartmann whistle	F.	Frequency analyzer
C.	Steel frame for Hartmann whistle	G.	Test cell
D.	Parabolic reflector for Hartmann whistle	H.	All-glass impingers
		I.	British pre-impinger (see Figure 11)

Figure 10

EXPERIMENTAL APPARATUS FOR ULTRASONIC COALESCENCE IN AEROSOLS



a. Impinger Assembly Attached to 6-Inch Diameter Coalescence Tube

b. Close-up of an All-Glass Impinger with British Pre-Impinger

Figure 11

ALL-GLASS IMPINGER WITH BRITISH PRE-IMPINGER

(Components as identified in Figure 2)

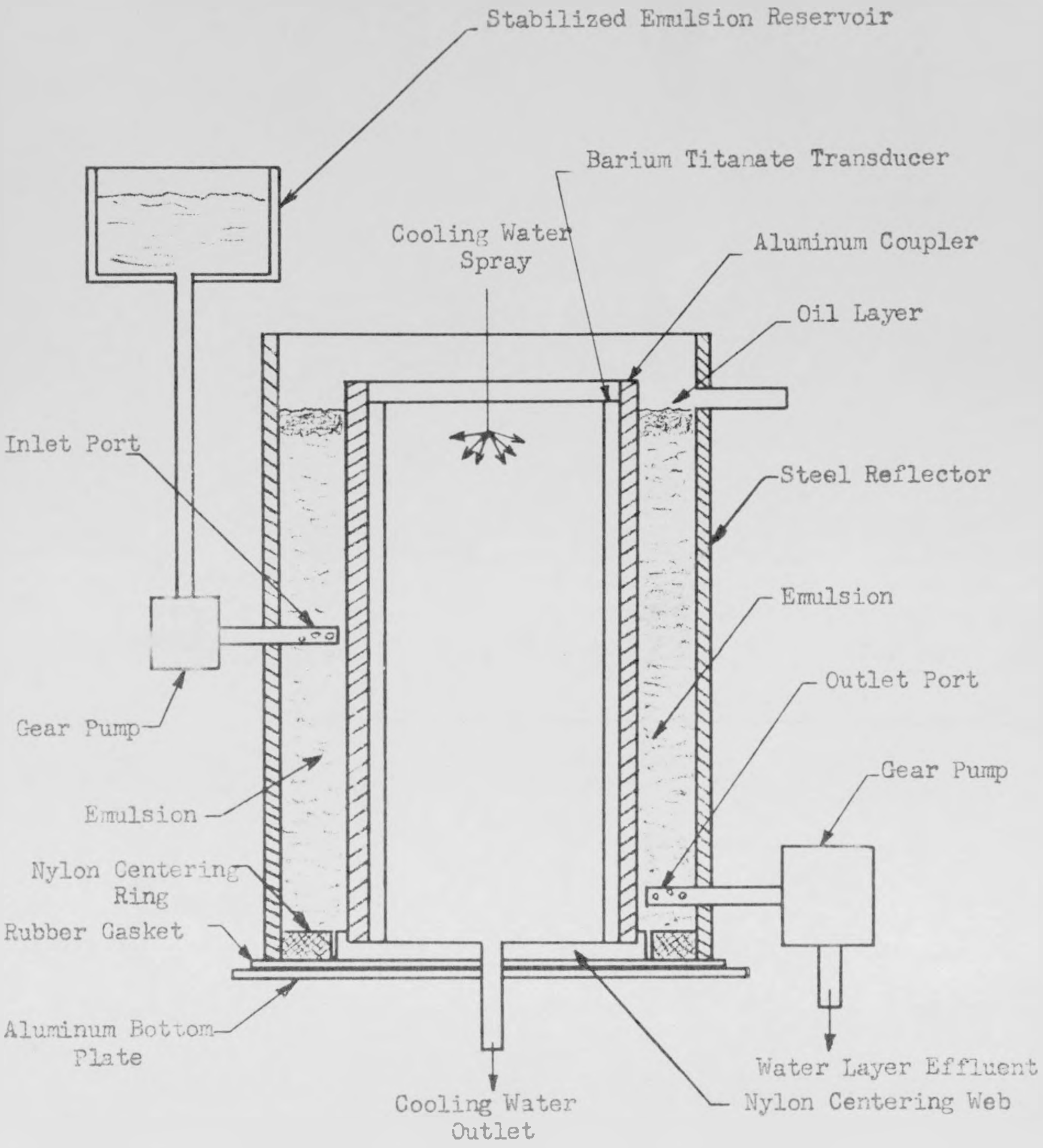


Figure 12

SCHEMATIC DIAGRAM OF ANNULAR

STANDING-WAVE VESSEL FOR EMULSION BREAKING

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