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LABORATORIES, INC.

P. O. Box 1107, McMurray, PA 15317

FINAL TECHNICAL REPORT

AQUA-SHEAR Mixer Test Project - DOE Invention No. 522

Organization - ACT Laboratories, Inc.
875 S. Washington Road
Canonsburg, PA 15317

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INDEX

- I. Description of AQUA-SHEAR Mixer - DOE Invention No. 522
- II. Objective of Mixer Test Project
- III. Scope of Mixer Test Project - Two Stages
 - A. Liquid Feed Stream (Solvent)
 - B. Additive Feed (Solute)
- IV. Test Arrangement Description
- V. Primary Fluid Tests (Solvent Feed)
 - A. Solvents
 - B. Test Mixers
 - C. Test Description
 - D. Data Collection
 - E. Data Correlation
 - F. Graphic Representation of Test Data
 - G. Empirical Equation Development
- VI. Additive Feed Tests (Solute Feed)
 - A. Gaseous Additive
 - B. Powder Additive
- VII. Test Project Results
 - A. Primary Fluid Tests (Solvent Feed)
 - B. Additive Feed Tests (Solute Feed)
- VIII. Proposed Future Tests
 - A. Powder Mixing with High Viscosity Liquids
 - B. Pressurized Mixing
- IX. Executive Summary
- X. Exhibits:
 - Exhibit 1. - AQUA-SHEAR Mixer Flow Diagram
 - Exhibit 2. - Mixer Test Arrangement Flow Diagram and Test Operating Procedure
 - Exhibit 3. - Chart No. 1-AQUA-SHEAR Model Flood Flow Rates
 - Exhibit 4. - AQUA-SHEAR Mixer Model Selection Equations
 - Exhibit 5. - Graph No. 1 - Nozzle Coefficient of Discharge Versus Reynolds Number
 - Exhibit 6. - Graph No. 2 - Nozzle Coefficient of Discharge Versus Reynolds Number
 - Exhibit 7. - Empirical Equations - Discharge Coefficient, Reynolds Number
 - Exhibit 8. - Graph No. 3 - AQUA-SHEAR Mixer Aeration Capacity Graph
 - Exhibit 9. - Graph No. 4 - Additive Volume Ratio Flow Rate to Liquid Volume Flow Rate Versus Percentage Flood Flow
 - Exhibit 10.- Sample Calculation - Liquid Feed, Non-Aqueous, Model Selection
 - Exhibit 11.- Sample Calculation-Aeration Capacity
 - Exhibit 12.- Sample Calculation-Additive Feed Rate

I. Description of AQUA-SHEAR Mixer-DOE Invention No. 522

The AQUA-SHEAR Mixer is an instantaneous in-line continuous static mixer. Its application is for the addition and mixing of solid powders, slurries, liquids, or gases to a flowing liquid.

The liquid feed is divided into two equal streams which are directed through nozzles contained in each of the end caps of the mixing chamber. The opposing liquid streams collide in the center of the mixing chamber creating a zone of intense and concentrated turbulence.

Each of the end caps contain eight (8) identical nozzles equally spaced radially and circumferentially. These nozzles are angularly oriented to impart a rotary motion to the liquid streams. The end caps are identical so that when they are positioned geometrically opposed, the liquid streams issuing from the nozzles of each of the end caps are moving in the opposite rotational direction, i.e. one clockwise, one counterclockwise, as they collide in the center zone of the mixing chamber. (See Exhibit 1. - AQUA-SHEAR Mixer Flow Diagram).

Additives are introduced through a port located immediately above this zone which results in their instantaneous dispersion and mixing with the liquid feed. In particular, where the additive is a hard-to-wet powder, this instantaneous dispersion eliminates clumping and the formation of so called "Jelly Beans" or "Fish Eyes". Product solution is discharged through a port located directly below the mixing zone.

Each AQUA-SHEAR Mixer is provided with a yoke which equally divides the liquid feed stream, an additive feed pipe and a discharge pipe sized to insure continuity of flow.

It is essential to the operation of the AQUA-SHEAR Mixer that the liquid feed be uniform, i.e. non-pulsing. Although liquid flow rate may be varied within each Model's flow range, continuity of flow is required. Pumps supplying the liquid feed should therefore be of the centrifugal or gear type. Peristaltic or piston type pumps which produce pulsating non-uniform liquid feed are not compatible for use with the AQUA-SHEAR Mixer.

Normal operation of the AQUA-SHEAR Mixer is for applications where the product solution is discharged at or slightly above atmospheric pressure. In these cases, the flow pattern through the Mixer causes a negative pressure (suction) at the additive inlet port assisting the entry of the additive and in the case of additive powders reducing or totally eliminating "dusting" problems.

The AQUA-SHEAR Mixer can also be utilized efficiently in pressurized systems when positive additive force-feed systems are provided. Also, the AQUA-SHEAR Mixer may be furnished with a discharge outlet eductor which provides a positive discharge pressure of the product solution usually sufficient for routing to overhead storage tanks or to overcome pressure losses due to further process operations such as filtration, heat exchange, etc.

Since mixing operations are many and varied, it is necessary to determine operating conditions such as flows, temperature and pressure of the feed components. In addition, it is necessary to know the properties of the feed components such as viscosity, specific gravity, and in the case of solid additives, bulk density, flow characteristics, solubility etc.

II. Objective of Mixer Test Project

The objective of this test project is to collect controlled and measured operating data for the AQUA-SHEAR Mixer which can be correlated in a form to predict the performance of the Mixer for a variety of mixing applications, thereby reducing the need for field trial tests. Sufficient laboratory tests under varying operating conditions are to be conducted so that engineering application and design guides in the form of empirical equations, graphs, tables, or charts can be developed. This test project is limited to those applications where the feed stream is a liquid (the solvent) and the additive to be mixed with the liquid feed stream is air and a solid particulate, i.e. a powder (the solute). This test project is further limited in that the Mixer is operated so the product solution is discharged to atmosphere and the additive feed is not pressurized.

III. Scope of Mixer Test Project - Two Stages

A. Liquid Feed Stream (Solvent) Stage One

Stage One of this test project is confined to determining the flow characteristics of the Mixer with respect to the flow rate of the liquid feed stream and the resulting pressure loss across the Mixer for liquids of a range of viscosity and specific gravity. The maximum flow rate of the liquid feed stream will be measured. (The maximum flow rate of the liquid feed stream is defined as that flow rate, which when exceeded allows the liquid feed stream to enter the additive inlet port and is termed the Mixer Model Flood Flow Rate).

B. Additive Feed (Solute) - Stage Two

Stage Two of this test project is confined to deter-

mining and measuring the maximum additive powder feed rate to the Mixer with respect to the liquid feed flow rate. Mixing efficiency as related to liquid feed flow rate and additive feed rate will be evaluated by visual inspection of the mixing zone of the Mixer and by examination for homogeneity of samples of the Mixer effluent.

IV. Mixer Test Arrangement

The AQUA-SHEAR Mixer Test Arrangement is shown in Exhibit 2. - Mixer Test Arrangement Flow Diagram. Exhibit 2. includes the Mixer Test Arrangement Flow Diagram and Test Operating Procedure. This Mixer Test Arrangement is designed to permit the collection of operating data for both of the two stages of the Mixer Test Project, i.e. monitoring the liquid feed (solvent) and the additive feed (solute) rates.

V. Primary Fluid Tests (Solvent Feed)

- A. Solvent - The liquid feed test solutions (solvents) consisted of various concentrations of carboxymethyl-cellulose (CMC) in water, hereinafter referred to as CMC aqueous solutions. CMC is a polymer which when added to water increases the viscosity and slightly decreases the specific gravity of the resulting solution. All of the CMC aqueous solutions are Newtonian liquids (consistency of liquid is independent of shear stress). Twenty-nine (29) of these solutions, with viscosities ranging from 1 to 6,980 centipoise and specific gravities ranging from 1.0 to .95 were utilized as liquid feed solvents.
- B. Test Mixers - Two versions of the Model 400 AQUA-SHEAR Mixer were utilized for the Liquid Feed Tests. One of these contained .2500 inch diameter end cap nozzles. One of these contained .1875 inch diameter end cap nozzles.
- C. Test Description - Each test involved the pumping of a particular solvent through the mixer. Fifty-Eight (58) separate tests were conducted (Twenty-nine solvents, two nozzle sizes). The flow rate of solvent through the mixer was varied in order to cover the full flow range of the Mixer operating at atmospheric conditions, i.e. the Mixer outlet discharging to atmosphere. The maximum flow rate, the flood flow rate, was determined for each of the twenty-nine solvents. This flood flow rate is defined as that flow rate which, when exceeded, allows liquid to enter the additive inlet port (Exhibit 3, Chart No. 1.).
- D. Data Collection - For each solvent of a predetermined viscosity, flow rates were varied and the pressure drop

measured for each flow rate. Two (2) Model 400 AQUA-SHEAR Mixers were used for these tests. One contained .250 inch diameter nozzles. One contained .1875 inch diameter nozzles. Nozzle size, solvent flow rate, pressure drop, solvent viscosity and specific gravity were recorded. The flood flow rate for each solvent was also measured and recorded.

- E. Data Correlation - A preliminary analysis of the collected data indicated a relationship between Reynolds Number, N_{RE} & Mixer Nozzle Discharge Coefficient, C. A Reynolds Number and Mixer Discharge Coefficient were calculated for each of the test conditions, i.e. nozzle size, solvent flow rate, pressure drop, viscosity and specific gravity. Basic equations were used for these calculations. (See Exhibit 4.)
- F. Graphic Representation of Test Data - Graphs were prepared for Mixer Nozzle Coefficient of Discharge versus Reynolds Number for each solvent viscosity tested (See Exhibits 5. & 6.). These graphs indicate a straight line logarithmic function relationship between Mixer Nozzle Coefficient of Discharge and Reynolds Number for each solvent viscosity.
- G. Empirical Equation Development - The general form of the equation relating Mixer Nozzle Discharge Coefficient to Reynolds Number is as follows:

$$C = A + B \ln N_{RE} \quad (\text{Equation 3.})$$

A & B are constants which were determined from the test data. The Mixer Nozzle Discharge Coefficient and Reynolds Number test data were reduced using LOTUS 1-2-3. Plots were generated and linear regression (curve fitting) were performed using LOTUS Graphwriter. The deviation between the generated correlations and the test data was determined using LOTUS 1-2-3 and was in the range of 5%. Computer analysis of the test data indicated that A & B are essentially constant for three specific ranges of liquid solvent feed viscosity, namely: 1 to 60 centipoise; 60 to 230 centipoise; 230 to 6,980 centipoise. The General Equation (Equation 3. of Exhibit 7.) was used to formulate Equations 4., 5., & 6. by incorporating the test determined values of the three viscosity ranges. These three equations permit the calculation of the pressure drop (loss) of the liquid solvent feed stream through the Mixer for a specific nozzle size when the solvent flow rate, viscosity, and specific gravity are known.

VI. Additive Feed Tests (Solute Feed)

A. Gaseous Additive

1. Solvent - Water
2. Gaseous Additive - Air
3. Test Mixer - Model 300 AQUA-SHEAR Mixer, 9/64" diameter nozzles.
4. Test Description - Water was pumped through the Mixer and discharged to atmosphere. Water volume flow rates were varied and the rate of air volume induced was measured for each water volume flow rate. These tests were conducted to determine the volume rate of air induced as related to the water flow rate through the Mixer when the Mixer is discharging to atmosphere. Water flow through the Mixer produces a negative pressure (suction) at the additive inlet port. The degree of suction is related to water volume flow rate. The velocity of the air entering the additive port was measured using a hot wire anemometer. The volume flow rate of air induced for each water flow rate was calculated based on the measured air velocity and flow area of the additive inlet port.
5. Data Collection - Water volume flow rates were varied from 0 to 39 GPM. For each water volume flow rate the rate of air volume induced was measured and recorded.
6. Data Correlation - A preliminary analysis of the data collected indicated a distinct operating range of water flow rate. Below 10 GPM, or about 25% of full water flow rate, erratic behavior was noted, i.e. pulsating flow which resulted in inconsistent and non-uniform air induction. The maximum volume flow rate of air induced occurred at a water volume flow rate of 15 GPM or about 38% of full water flow rate. The data collected for water flow rates from 38% to 100% of full flow indicated an inversely proportional relationship between water flow rate and induced air flow rate. The data collected for water flow rates from 25 to 38% of full water flow indicated a directly proportional relationship between water flow rate and induced air flow rate.
7. Graphic Representation of Test Data - A graph was prepared of the ratio of volume flow rate of air induced to the volume flow rate of water versus the percentage of Mixer flood water flow rate (See Exhibit 8.) This graph permits the determination of the volume flow rate of air induced for various Mixer volume flow rates of water.

B. Powder Additive

1. Solvent - Water
2. Powder Additives - Pearl Starch, bulk density - 43 lb./cu.ft.; Starch, bulk density - 25 lb./cu.ft.
3. Test Mixer - Model 300 AQUA-SHEAR Mixer, 3/16 inch diameter nozzles.
4. Test Description - Water was pumped through the

- Mixer. The water flow rate was varied and the starch additive introduced was measured for each water flow rate. These tests were conducted to determine the maximum powder additive feed rate for two types of starch as related to the water flow rate when the water-starch solution is discharged to atmosphere. The powder additive feed rates were measured for the full operating range of Mixer water flow rates.
5. Data Collection - Water flow rates were varied from 0 to 39 GPM. For each water flow rate, the corresponding maximum rate of powder additive introduced was measured and recorded.
 6. Graphic Representation of Test Data - The ratio of powder additive volume flow rate to liquid volume flow rate was plotted versus the percentage of the Mixer flood liquid volume flow rate (See Exhibit 9.)

VII. Test Project Results

- A. Primary Fluid Tests (Solvent Feed) - The primary fluid tests resulted in the development of engineering application guides in the form of graphs (Exhibits 5. & 6.) & equations (Exhibits 4. & 7.) These application guides simplify the selection of the appropriate AQUA-SHEAR Mixer model based on the liquid feed (solvent) properties and flow conditions. For most industrial mixing applications, the liquid feed rate and pressure are specified and the viscosity and specific gravity of the feed liquid are known. With this specified information, the appropriate AQUA-SHEAR Mixer and nozzle size can be selected utilizing these engineering application guides. Exhibit 10. is a sample calculation utilizing these guides for Mixer selection.
- B. Additive Feed Tests (Solute Feed)
 1. Gaseous Additive (Air) - The gaseous additive feed tests resulted in the development of an engineering guide in the form of a graph (Exhibit 8). This graph allows for the determination of the amount of air induced by the mixer as related to the liquid feed rate. Exhibit 11. is a sample calculation utilizing this graph to determine the induced air flow rate as related to the liquid feed rate for a particular AQUA-SHEAR Mixer model.
 2. Powder Additive (Starch) - The powder additive feed tests resulted in the development of an engineering guide in the form of a graph (Exhibit 9.). This graph permits the determination of the amount of a powder (starch) as a function of the liquid feed rate related to the bulk density of the powder additive. Exhibit 12. is a sample calculation utilizing this graph to determine the maximum amount of powder additive which can be introduced for a specific liquid feed volume flow rate.

VIII. Proposed Future Tests

- A. Powder Mixing with High Viscosity Liquids - Many mixing applications require the mixing of powders with a viscous liquid. The degree of mixing which can be achieved is a function of the turbulence of the liquid into which the powder is being introduced. Tests designed to measure mixing efficiency and liquid turbulence in the Mixer would be desirable in order to develop engineering guides for these applications. The scope of such tests is indeterminate at this time due to the mixing process involved which is based on liquid turbulence. Turbulence, by definition, is a violent, irregular, random or disorderly motion. Therefore prediction of mixing efficiency for many particular applications will be based on the analysis of empirical data. It is possible that chaos mathematics may be of value in classifying and generalizing this data.
- B. Pressurized Mixing - Many mixing applications require the mixing of a powder with a pressurized liquid. All AQUA-SHEAR Mixer tests conducted to date have been limited to applications where the product solution is discharged essentially to atmosphere, i.e. a storage tank. In such cases the additive feed powder is not pressurized and the liquid feed flow rate and pressure is limited so that the liquid does not enter the additive feed port. This limitation of liquid feed flow rate and pressure restricts the degree of liquid turbulence and therefore limits mixing efficiency. Tests designed to measure mixing additive feed rates with relation to liquid flow rates would be desirable in order to develop engineering guides for pressurized system applications.

IX Executive Summary (Economic Future Potential of Technology)

The AQUA-SHEAR Mixer Test Project - DOE Invention No. 522 test results indicate the versatility of the mixer for a variety of mixing applications. These tests demonstrated the mixer's capability to mix additive powders with liquids having a wide range of viscosities.

Three difficult to disperse and hard-to-wet-powders were utilized as test additives. Instantaneous mixing was observed without the formation of lumps or generation of dust commonly encountered with other mixing techniques.

These features of the AQUA-SHEAR mixing technology offer distinct advantages for numerous mixing applications. In addition, the low power consumption, as shown by the relatively low liquid flow pressure loss during the mixing process, is evidence of high mixing efficiency.

The market for mixing powder additives with a liquid is currently dominated by batch type mixers which consist of a liquid holding tank equipped with motor driven impellers, paddles, turbines, or agitators. The AQUA-SHEAR Mixer has the potential to be a viable alternative and to gain a significant share of this market for several reasons: lower cost of equipment; reduced operational cost due to energy and process material savings; size advantage; continuous process operation minimizing "down time" (labor savings).

The AQUA-SHEAR Mixer can also be used in conjunction with a batch mixer process. Oftentimes batch mixer operations require the addition of several powders to a liquid batch. When one of these additives is difficult to disperse and "hard-to-wet", the AQUA-SHEAR Mixer can be utilized to prepare this particular solution prior to its introduction into the batch tank. It is expected that an appreciable niche market exists for this application.

Other markets include the neutralization of mine acid waste discharge, preparation of oil well drilling "mud", and municipal water treatment. All of these mixing applications involve powder additives which by their inherent properties are not readily dispersed or wetted. Current methods used are not energy efficient and often result in wastage due to unreacted additive material.

The AQUA-SHEAR Mixer can be utilized to mix additive powders with a liquid in a pressurized system. Several installations have been made for this application and the size of this market is probably substantial. However, to date no testing of the mixer to determine its design limitations have been conducted in this area.

The annual worldwide market for mixing applications with future potential for the AQUA-SHEAR mixing technology, exclusive of various niche markets, is estimated at approximately \$900,000,000. With a market of this magnitude, and the aforementioned advantages, it is expected that the AQUA-SHEAR mixing technology will be widely utilized and that its broad acceptance will be primarily limited by marketing capability restraints associated with a new technology.

Report Submitted By:

Donald R. Foltz

Donald R. Foltz
Executive Vice President

Date: 9-15-93

X. EXHIBITS

Exhibit 1.

AQUA-SHEAR MIXER FLOW DIAGRAM

Operating Description

The liquid feed stream (solvent) is divided into two equal streams (1/2 flow). Each of these two liquid streams enter the Mixer at opposite ends. Each stream is directed through a plate containing nozzles which are angularly oriented to impart a rotary motion to the two entering liquid streams. The rotary motion of one stream is clockwise and opposed to the counterclockwise motion of the other stream. As the two streams collide in the center of the mixing chamber an intense zone of liquid turbulence is created. The solid particulate additive (solute) is introduced at the additive inlet port located directly above the interface of the collision of the two opposing liquid streams. This results in the instantaneous dispersion and mixing of the additive. The solution of solvent and additive discharges through a port located directly below the interface of the two opposing liquid streams.

Exhibit 2.

AQUA-SHEAR Mixer Test Arrangement

Flow Diagram

Test Operating Procedure

1. All valves Closed, Pump C off, Powder Feeder D off.
2. Fill Powder Hopper E with solute.
3. Open Valve V-1, Fill Tank A, Close Valve V-1.
4. Open Valves V-2 & V-3.
5. Start Pump C and pump solvent through Mixer F into Tank B. Measure and record solvent flow rate and pressure at Mixer F. Stop Pump C when Tank A is empty.
6. Close Valve V-2 and open Valve V-5.
7. Start Pump C and circulate solvent through Valve V-5, Pump C, Valve V-3, and Mixer F into Tank B.
8. Start Powder Feeder D and add predetermined weight of solute to reach desired solvent solution viscosity.
9. Stop Powder Feeder D, recirculate solvent solution until solution is homogeneous (uniform consistency). Stop Pump C. Draw liquid sample from Tank B and measure viscosity and specific gravity.
10. Close Valve V-3, open Valve V-4, start Pump C and transfer solution to Tank A. Stop Pump C after all of solution is transferred to Tank A.
11. Close Valves V-4 and V-5 and open Valves V-2 and V-3
12. Start Pump C and transfer solution from Tank A through Mixer F into Tank B. Measure solution flow rate and solution pressure drop through Mixer F.
13. Draw solution sample from Tank B and check viscosity and specific gravity. Record.
14. Repeat steps 10-13, increasing flow each time until full flow is reached and measure and record flow rate and pressure drop for each flow increment.
15. Repeat steps 7-14 for each solution concentration.

Exhibit 3.

Chart No. 1

AQUA-SHEAR Mixer Model Flood Flow Rates (Gallons per Minute, GPM)

Liquid Feed Viscosity (Centipoise)*	Model Number						
	200	300	400	600	800	1000	1400
1.0	13.0	39.0	69.0	188	362	940	1,837
2.0	12.7	38.2	67.5	184	354	920	1,798
4.6	12.3	36.7	65.0	177	341	887	1,733
8.5	11.9	35.6	63.0	172	331	861	1,682
10	11.8	35.4	62.7	171	329	855	1,671
20	11.4	34.2	60.5	165	318	827	1,616
40	11.0	33.0	58.4	159	306	796	1,555
60	10.7	32.1	56.7	155	299	777	1,518
80	10.5	31.4	55.5	151	291	757	1,479
100	10.3	30.9	54.6	149	287	746	1,458
120	10.2	30.5	54.0	147	283	736	1,438
150	10.0	30.1	53.2	145	279	725	1,417
200	9.8	29.4	52.0	142	273	710	1,387
300	9.5	28.5	50.4	137	264	686	1,340
380	9.3	27.8	49.2	134	258	671	1,311
500	9.0	27.0	47.7	130	250	650	1,270
635	8.6	25.8	45.7	125	241	627	1,225
718	8.3	25.0	44.2	120	231	601	1,174
852	8.0	23.9	42.3	115	221	575	1,124
1,030	7.4	22.3	39.4	107	206	536	1,047
1,200	6.9	20.7	36.6	100	193	502	981
1,430	6.5	19.4	34.3	93.5	180	468	914
1,660	6.1	18.2	32.2	87.8	169	439	858
1,950	5.5	16.6	29.3	79.8	154	400	782
2,640	4.8	14.5	25.7	70.0	135	351	686
3,190	4.3	13.0	23.0	62.7	121	315	616
4,640	3.3	9.9	17.5	47.7	91.9	239	467
5,190	3.0	9.0	16.0	43.6	84.0	218	426
6,980	2.2	6.6	11.7	31.9	61.4	160	313

*Interpolate to estimate Flood Flow Rates between listed viscosities

Exhibit 4.

AQUA-SHEAR MIXER MODEL SELECTION EQUATIONS

Equation No. 1.:

$$\text{Reynolds Number, } N_{RE} = \frac{197.39QS}{\mu d}$$

Equation No. 2

$$\text{Nozzle Discharge Coefficient, } C = \frac{Q}{477.44 d^2 \sqrt{\Delta P/S}}$$

Nomenclature:

- N_{RE} = Reynolds Number, Dimensionless.
 C = Nozzle Discharge Coefficient, Dimensionless.
 Q = Total Liquid Feed Volume Flow Rate, Gal. Per Min. (GPM).
 S = Liquid Feed Specific Gravity (referred to water), Dimensionless.
 μ = Liquid Feed Viscosity, Centipoise.
 ΔP = Pressure Loss Across Mixer, Pounds Force per Sq.In. (PSI).
 d = Nozzle Diameter, Inches.

GRAPH No.1. - NOZZLE COEFFICIENT OF DISCHARGE VS. REYNOLDS NUMBER FOR VARIOUS LIQUID VISCOSITIES

GRAPH No.2. - NOZZLE COEFFICIENT OF DISCHARGE VS. REYNOLDS NUMBER FOR VARIOUS LIQUID VISCOSITIES

Exhibit 7.

EMPIRICAL EQUATIONS - DISCHARGE COEFFICIENT, REYNOLDS NUMBER

Equation No. 3., General:

$$C = A + B \ln N_{RE}$$

Equation No. 4., Viscosity Range 1 to 60 centipoise:

$$C = .425 - .0116\mu + (.0377 + .00191\mu) \ln N_{RE}$$

Equation No. 5., Viscosity Range 60 to 230 centipoise:

$$C = -.946 + 1.58 \ln \mu + (.161 - .000054\mu) \ln N_{RE}$$

Equation No. 6., Viscosity Range 230 to 6,980 centipoise:

$$C = -.560 + .0851 \ln \mu + (.0607 + .0162 \ln \mu) \ln N_{RE}$$

Graph No. 3 - AQUA-SHEAR Mixer Aeration Capacity Graph
(Discharge to atmospheric pressure operation)

Percentage of Mixer Flood Liquid Flow Rate, (%)

GRAPH NO. 4 ADDITIVE VOLUME FLOW RATE TO LIQUID VOLUME FLOW RATE RATIO VERSUS PERCENTAGE FLOOD FLOW

EXHIBIT 9.

AQUA-SHEAR MIXER - Sample Calculation - Liquid Feed, Non-Aqueous, Model Selection

Determine: Pressure Loss Across Mixer, ΔP , PSI

Given: Liquid Feed Rate, $Q = 37.0$ GPM
 Liquid Feed Viscosity, $\mu = 300$ Centipoise
 Liquid Feed Specific Gravity, $S = .95$
 Available Operating Pressure, $= 20$ PSIG

Solution: 1.) From Chart No. 1., Model 400 is selected (for liquid viscosity of 300 Centipoise, specified Liquid Feed Rate of 37 GPM is near to but below the Model 400 Flood Flow Rate of 50.4 GPM).

 2.) Use smallest nozzle size (Diameter, $d = .1875$ inches) for trial calculation of Pressure Loss Across Mixer.

 3.) Calculate Nre using Equation No. 1:

$$Nre = \frac{197.39QS}{\mu d} = \frac{(197.39)(37)(.95)}{(300)(.1875)}$$

$$Nre = 123.35$$

 4.) Use Graph No. 2. and enter horizontal axis at 123.35; project vertical line to intersect 300 Centipoise viscosity curve; project horizontal line from intersection to vertical axis and read Nozzle Discharge Coefficient, $C = .68$.

 5.) Calculate Pressure Loss Across Mixer using Equation No. 2:

$$C = \frac{Q}{477.44d^2 \sqrt{\Delta P/S}}$$

$$.68 = \frac{37}{(477.44)(.1875)^2 \sqrt{\Delta P/.95}}$$

$$\Delta P = 9.98 \text{ PSI} = \text{Pressure Loss Across Mixer}$$

 6.) Since the calculated pressure loss of 9.98 PSI does not exceed the Available Operating Pressure of 20 PSIG, Model 400 AQUA-SHEAR Mixer with .1875 inch diameter nozzles is proper selection.

Exhibit 11.

AQUA-SHEAR MIXER - Sample Calculation, Aeration Capacity

Given: Std. Model 400
 Liquid Feed - Water
 Actual Liquid Feed Flow Rate - 48.3 GPM = Q

Determine: Air Flow induced in std. cubic feed per min. (SCFM) = F

Solution: 1. Use Chart No. 1 to determine flood flow (69 GPM).
 2. Calculate % of flood flow:
 $48.3/69 \times 100 = 70\%$
 3. Enter Graph No. 3, Aeration Capacity Graph, on
 horizontal axis at 70%.
 4. Project vertical line upward to intersect curve.
 5. Project horizontal line from intersection to vertical
 axis, ratio of air flow rate induced to liquid flow
 rate, F/Q.
 6. $F/Q = .0623$
 7. Multiply Q times F/Q:
 $48.3 \times .0623 = 3.01$ SCFM of air induced at water
 flow rate of 48.3 GPM.

Note: If actual liquid flow rate is equal to the mixer flood flow rate,
 no air is induced.

Exhibit 12.

AQUA-SHEAR Mixer Sample Calculation - Additive Feed Rate

Data:

Standard Model 400 AQUA-SHEAR Mixer
Water Flow Rate - 40 GPM
Material Additive - Pearl Starch (maize)
Bulk Density Material Additive - 43 lb. per cu.ft.
Water Viscosity - 1.0 Centipoise

Determine:

Maximum feed rate of additive

Graphical Solution (Graph No. 4.):

1. Flood Flow of Model 400 = 69 GPM water (Chart No. 1)
2. Percentage Flood Flow = $\frac{40}{69} \times 100 = 58\%$
3. Enter horizontal axis of Graph 4. at 58%
4. Project vertically to intersect starch, bulk density = 43 lb./ft³ curve
5. Project from point of intersection to vertical axis. Ratio of Additive
Volume Flow Rate to Liquid Volume Flow Rate = .31
6. Additive Volume Flow Rate = 40 x .31 = 12.40 GPM
7. 12.40 GPM = 12.4/7.481 = 1.66 cu.ft. starch per min.

END

DATE
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