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Measurement of Quality in Two-Phase Flow Around Tube Bundles

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DISCLAIMER

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Operated for the U. S. Department of Energy
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Experiments have been conducted on probes for determining the secondary side quality within tube bundles which simulate the two-phase flow heat exchangers of pressurized water reactor plants. The testing was performed with a steam-water mixture of known quality flowing around unheated horizontal and vertical tubes. The probes operated by extracting low quality samples and indicating the bulk-stream's quality via relative concentrations of a chemical tracer. The parameter ranges tested were:

pressure	-	600 psia
mass velocity	-	50,000 to 355,000 $lb/hr\text{-}ft^2$
quality	-	0 to 0.67

The tests showed satisfactory probe performance for indicated qualities up to 0.25 for the vertical tube simulator and up to 0.40 for the horizontal tube simulator.

MEASUREMENT OF QUALITY IN TWO-PHASE FLOW AROUND TUBE BUNDLES

I. INTRODUCTION

The flow of two-phase mixtures of steam and water around tube bundles exists in heat exchanger systems where the region external to the tubes is permitted to achieve bulk boiling. One significant parameter for characterizing this two-phase flow is the local flowing quality (ratio of the mass flow rate of vapor to the total mass flow rate). To understand this complicated two-phase flow, it is essential that the local quality be known. However, in typical tests which model steam generators, the quality in the tube bundle region is not directly measured but must be calculated from semi-empirical correlations. Consequently, the need exists for employing an instrument (quality probe) which is capable of measuring the local two-phase flowing quality.

A survey of the literature on the subject of quality measurement identified a wide variety of probe designs. However, no proven device or technique was found which would provide for reasonably accurate measurement of quality under the constraints of a steam generator tube bundle. Potentially applicable ideas were determined in part from the literature survey and a series of brainstorming sessions. The studies of Kondic, References 1 and 2, reinforced a concept of using chemical tracers for quality determination and the possibility of a row-of-holes design for the probe tip. Works such as Jagota et al, Reference 3, strengthened the possibility that a porous material tip construction could lead to a successful probe design.

These ideas were used to formulate the design and construction of two new quality probes. This report presents the results of the proof-testing of these new probe designs.

II. TEST OBJECTIVES

The major objective of this test was to demonstrate the feasibility of quality probes in test sections simulating the tube bundle region of vertical tube and horizontal tube heat exchangers.

The secondary objectives of the tests were as follows:

1. Determine the feasibility of measuring tracer concentrations with an on-line analyzer vs. the atomic absorption technique.

2. Determine the range in values of tracer concentration suitable to satisfactory quality evaluation.

3. Determine the range in values of sample flow rate suitable to satisfactory quality determination.

4. Visually identify the two-phase flow pattern(s) existing in a simulated horizontal tube heat exchanger. The vertical tube simulator was not designed for flow visualization.

III. PROBES' PRINCIPLE OF OPERATION

The principles of operation of the quality probes and system described in this report are as follows:

1. Subcooled water is heated to provide a two-phase mixture of known quality.

2. This bulk-flow mixture of known quality flows into adiabatic test sections which simulate the geometry of a heat exchanger tube bundle region with vertical/horizontal tubes.

3. The probe is inserted into the bulk-flow stream.

4. Fluid from the bulk stream region enters the probe and is extracted for analysis. This within-probe fluid is termed the "sample flow".

5. The geometry of the probe(s) is designed to extract only samples of relatively low quality; i.e. nearly all-liquid samples. Capillary action provides the mechanism for this nearly all-liquid sampling.

6. A built-in orifice near the probe head provides pressure drop data on the extracted sample. This pressure drop is used to determine the quality of the extracted sample.

7. Any vapor in the extracted sample is condensed along the sample line by heat transfer to the surroundings.

8. The concentration of a tracer chemical in the condensed sample is determined by standard analyses.

9. A reference sample is extracted from the all-liquid region upstream of the quality probe. This location corresponds to the inlet to the heated section in the test described herein and the lower regions of the tube bundle in heat exchangers. The tracer concentration in this reference sample is determined by standard analyses.

10. The evaluated parameters of sample's quality, condensed sample concentration, and reference sample concentration are combined in a derivable expression to determine the probe-indicated value of quality in the bulk-flow stream.

IV. TEST EQUIPMENT

A. High Pressure Water System

Water was circulated within a high pressure loop which is shown schematically in Figures 1 and 2. Figure 1 is the configuration used in the test series with a vertical tube bundle simulator for the adiabatic test section. Figure 2 is the configuration used in tests with the horizontal tube simulator. The component maximum ratings of the loop are: pump - 120 psi head at 150 gal/min and pressurizer - 2500 psia at 650^{o}F. All piping is stainless steel.

B. Electrical Power

Two stages of a direct current generator were used for test section electrical power. The parallel connection of the two stages is rated at 1.6 MW at 16,000 amps.

C. Heated Test Section

As illustrated in Figure 1 and 2 a heated section was located upstream of the adiabatic simulator test section. This heated section was formed by connecting five tubes (347 SS - 0.750 inches O.D. x 0.083 inches wall thickness x 69.0 inches long heated length) in parallel. Electrical terminals were bolted to each tube to provide for nominally equal parallel electrical resistance heating of each tube. Each heated tube was covered with approximately 2-1/2 inches thick insulation of calcium-silicate fiberglass.

D. Vertical Tube Simulator

For the first series of tests, the adiabatic test section simulated the flow geometry within a vertical tube heat exchanger. This simulator, see Figure 3, was housed within a 2-1/2 inch Schedule 80 pipe of 316 stainless steel (2.490 inches I.D. x 36 inches long). This pipe was externally covered with approximately 2-1/2 inches of calcium-silicate fiberglass insulation. The tube bundle simulation, see Figure 4, was accomplished with three circular tubes (304 SS) and a "U" shaped filler bar (304 SS). The tubes were 0.500 inches O.D. on a triangular pitch of 0.750 inches. The ratio of hydraulic diameters of the "U"-half to the tube-half is 1.05. The ratio of the hydraulic diameters of the entire simulator to an infinite tube bundle is 0.96. Both ends of each tube were plug-sealed and supported by a flow distribution plate. No flow obstructions existed along the 36 inch length except for water thermocouples and the quality probe.

E. Horizontal Tube Simulator

For the second series of tests, the adiabatic test section simulated the flow geometry within a horizontal tube heat exchanger. This 316 SS simulator, see Figures 5, 6, and 7, consisted of a rectangular housing, cover plate, and an array of horizontal rods. The cut-out within the housing was four pitches, 3.376 inches, wide. The array of horizontal rods consisted of nine rows of 2.865 inch long rods. The four rods on each row were 0.563 inches O.D. and on a 0.844 inch triangular pitch. Half-section rods were used adjacent to the inner wall of the housing. Using the expression "4 x area/wetted perimeter" at the minimum flow area, the ratio of hydraulic diameters of the simulator to an infinite tube bundle was 0.91. The array of rods was weld-mounted onto a base plate. Leaf springs were used at each end of the base plate to aid in matching surfaces of the bare ends of the rods against the inner surface of the cover plate. A flow distribution plate was located upstream of the tube bundle. The cover plate, see Figure 8, was sealed against the housing with an O-ring of Ethylene Propylene Rubber. A 3-inch diameter opening in the cover plate was provided to permit visual observation of the flowing mixture. For the non-visual test runs, a 316 SS metal plug was used in the opening. For the visual test runs a transparent quartz window was used.

F. Row-of-Holes Quality Probe

As illustrated in Figure 9, the row-of-holes quality probe consists of the probe head, the orifice block and the attached tubing. All components are 304 stainless steel and assembled by welding. Figure 10 shows a photograph of a row-of-holes probe un-assembled components and a cut-away section after welding. The probe head, 0.134 inch O.D. x 0.106 inch I.D. has a rounded end and a single row of 8-0.025 inch diameter holes along the side. The orifice block includes an orifice, 0.013 inch diameter x 0.250 inches long, and a 0.025 inch diameter tap for sensing the upstream pressure. A set of three concentric tubes are attached downstream of the orifice.

A 0.025 inch diameter hole in the wall of the inner tube provides a tap for sensing the orifice's downstream pressure. Sample flow enters the probe head via the row-of-holes, passes through the orifice, and continues to flow within the center tube shown in Figure 9. The two annuli formed by the concentric tubes act to communicate the orifice's upstream and downstream pressures signals from the probe to outside the test section.

G. Sintered Metal Quality Probe

As illustrated in Figure 11, the sintered metal quality probe consists of the probe head, a connector piece, the orifice block, and the attached tubing. All components are 304 stainless steel and joined by welding. Figure 12 shows a photograph of a sintered metal probe in un-assembled components and a cut-away section after welding. The unassembled sintered metal probe head shown in Figure 12 is of slightly larger size and was not used in final assembly. The probe head, 0.125 inches O.D. x 0.061 inches I.D. x 0.509 inches long, is made of sintered stainless steel with a nominal pore size of 40 microns. The end of the probe head is sealed, i.e. non-porous. The open end of the probe head attaches to the connector piece which permits mating the probe head to the 0.134 inch O.D. orifice block. The orifice block, pressure taps, and the configuration of three concentric tubes consist of the same type of components as used for the row-of-holes probe.

H. Traversing Mechanism

A traversing mechanism, see photograph in Figure 13, was used to position the probe at desired location. This mechanism permits traversement by varying the insert depth of the probe into the test section and angle variation, i.e. rotation, with 180° of freedom. Graduation marks on the mechanism are used to set the probe to a known position. The traversing mechanism was un-insulated to promote steady-state conditions for heat loss in a practical time period.

I. Sampling Lines

As illustrated in Figure 1 for testing with the vertical tube simulator, the sample line extended out of the test section, through the drive mechanism through a series of instrumented heat exchangers which were insulated, and through a final heat exchanger. The fully condensed and cooled sample then passed through a flow metering orifice (0.013 inch diameter), and an on-line sodium-ion analyzer. A sample tap just preceding the analyzer was used to collect bottle samples. A similar sample line was used for the reference sample line extending from the inlet of the five heated tubes to the analyzer and bottle sampling tap.

As shown in Figure 2 for testing with the horizontal tube simulator, the sample line extended out of the test section, through the traversing mechanism and through an un-insulated heat exchanger. The fully condensed and cooled sample then passed through a flow metering rotameter and exited at the bottle sampling tap. A similar sample line was used for the reference sample line from the inlet of the five heated tubes to the bottle sampling tap.

J. Tracer Chemical

Sodium-ions from sodium-sulphate were used as the tracer chemical in this study.

K. Gas Safety

The sodium-ion analyzer used in the vertical tube tests required the use of a gas, dimethylamine, which is toxic and flammable. As a safety precaution for using the gas cylinder within the laboratory an absorption system was used. This system consisted of a pressure controlled automatic shutoff valve, a pressure controlled relief valve, and an absorption tank.

L. Instrumentation

Stainless steel sheathed chromel-alumel thermocouples were used for test section water temperature indication. One thermocouple was placed at the inlet and one at the exit of the heated section. Two water thermocouples were located within each of the adiabatic test sections above and below the probe location. Water thermocouples were also located at the loop flow metering orifices. Other water thermocouple locations for the vertical tube tests included the orifices on the sample lines, the instrumented heat exchanger, and at the cup inlet of the analyzer. For the horizontal tube tests, water thermocouples on the probe sample line were located downstream of the traversing mechanism and at the inlet to the rotameter.

Separate thermocouples were attached to the exit end of each of the five heated tubes to monitor possible critical heat flux conditions. Other thermocouples included the metal surface temperatures on the traversing mechanism and ambient air conditions. For the horizontal tube tests, thirteen thermocouples were attached along the probe line between the test section and the heat exchanger.

Loop pressure measurements included the system operating pressure with a 16 inch Bourdon type gage and the orifice pressure drops. Pressure differences were measured with differential pressure transducers. For the vertical tube tests, the measured pressure differentials included three differentials along the adiabatic test section, the difference between the bulk-flow and the probe-orifice upstream pressure, and the pressure drops across the probe's 0.013 inch orifice and the two sample line orifices. For the horizontal tube tests, the measured pressure differentials included seven differentials along the adiabatic test section, the differentials between the bulk flow and the probe-orifice upstream pressure, and the pressure drop across the probe's 0.013 inch orifice.

Electrical measurements consisted of the total generator supplied current and the voltage drop across each of the five heated tubes.

The loop water flow rate was measured with two orifices of the same size connected in series. The loop orifice diameters, in parallel flow legs, were 0.310 inches and 0.515 inches. For the vertical tube tests, the sample lines used 0.013 inch diameter orifices for flow rate indication. All flow rate orifices, i.e. all but the in-probe-head-orifices, were calibrated prior to quality probe testing. Weigh tanks were used for the loop orifice calibration and volumetric measurements were used for the sample line orifices.

Measurement of the sodium-ion concentrations was accomplished with two techniques. One was the selective ion electrode technique with a continuous on-line analyzer. The other was a flame technique with bottled samples and an atomic absorption analyzer. Both techniques of the on-line analyzer and bottle samples were used for the vertical tube tests. Only analysis of bottle samples was used for the horizontal tube tests.

An air operated injection pump with a graduated beaker was used to inject metered volumes of the tracer into the system. The injection tracer was a solution of sodium-sulphate at a nominal sodium concentration of one hundred parts per million.

A video-tape system was used for the selected visual tests on the horizontal tube simulator. This system included the camera, recorder, and monitor.

The data acquisition system included a 12 point recorder for test monitoring. An integrating digital voltmeter (IDVM) was used to measure all thermocouples, the generator current and voltage, pressure differential readings, and the on-line analyzer. These readings were automatically recorded on magnetic tape. The five critical heat flux (CHF) thermocouples were monitored by burn-out detectors and the IDVM for the horizontal tube tests. These CHF thermocouples were monitored only by burn-out detectors for the vertical tube tests.

V. TEST PROCEDURE

A. Simulator Flow Conditions

The operational procedure for the bulk flow conditions included the following steps:

1. establish steady-state loop conditions of pressure, flow rate, and inlet temperature to the five heated tubes

2. establish initial loop water chemistry conditions of

   - nominal pH : 6.5 to 7.5 (neutral)
   - oxygen content: less than 0.2 ppm
   - electrical resistivity: greater than 1.0 megohm-cm

3. inject the sodium-ions solution until the well mixed loop concentration achieved the desired nominal level. Runs were made at a nominal concentrations of 100 ppb and 1000 ppb.

4. set the electrical power to the five heated tubes at a level necessary to produce the desired steam quality within the simulated tube bundle.

B. Sample Flow Conditions

The general procedures used to operate the quality probes included the following steps:

1. set probe to the desired insertion mark

2. set the probe's sample flow rate to the desired value

3. for testing with the row-of-holes probe:

   (a) set the probe angle at +90° (row of holes directed up and away from the approaching bulk flow), and read the probe-orifice pressure drop

   (b) vary the angle and read the probe orifice pressure drop for:

   +45° - holes at 45° off vertical upward

   0° - holes horizontal; toward center rod for vertical tube tests; away from visual window for horizontal tube tests

   -45° - holes at 45° off vertical downward

   -90° - holes directed down and directly open to the approaching bulk flow

   (c) determine the angle corresponding to the minimum probe-orifice pressure drop; then re-set the probe angle to this optimum angle

4. extract sample fluid from the probe line and reference sample line by a) collecting in bottles, and b) flowing through the on-line analyzer

5. read/measure and record all data

For single phase tests, the electrical power was set to low or zero levels to yield the desired value of subcooling in the adiabatic simulator. These single phase runs serve as calibration runs for heat loss estimates and probe-orifice calibration.

Table I shows a list of data ranges tested. Shown are the bulk flow conditions of pressure, mass velocity and quality, and probe conditions of insert positions and sample flow rate.

C. Sodium-Ion Analysis

The procedures used for the on-line sodium-ion analyzer included a two point calibration for zero setting and slope setting. The details of this procedure were developed by extensive bench testing prior to the quality probe tests.

Bottle samples were collected for analysis of tracer concentration. The 500 ml polyethylene bottles were pre-conditioned by filling with a 10% solution of Hydrochloric acid and then storing them for a minimum of 48 hours. Then the bottles were thoroughly rinsed ten times with pure water. This procedure was used in order to reduce contamination and the corresponding data errors.

D. Data Reduction

A digital computer was used to reduce the measured temperatures and pressures to engineering units. All water properties were evaluated from Reference 4.

Loop water flow rates were evaluated as the numerical average of values calculated from the two orifices connected in series. All loop orifice constants were supplied by pre-test calibrations.

The test section's mass velocity was evaluated by dividing the flow rate by the simulated tube bundle's flow area: 0.01576 ft^2 for the vertical tube simulator, and 0.02236 ft^2 for the horizontal tube simulator. For the vertical tube tests, the sample line flow rates were measured by pre-calibrated orifices. For the horizontal tube tests, the sample line flow rates were measured by a pre-calibrated rotameter.

The water thermocouples within the adiabatic test sections were calibrated in-place against the saturation temperature. These calibrations were included in the final analysis of the data.

The total electrical power supplied by the five heated tubes was calculated as the product of the total generator current and an average voltage drop. This average voltage drop was the arithmetic average of the voltage drop measured on each of the five heated tubes. This total supplied power, the associated heat losses, and the measured inlet temperature to the five heated tubes were used with an energy balance to evaluate the quality within the adiabatic simulator.

The probe-indicated value of quality in the bulk-flow stream was evaluated from the expression

$$XTR = 1 - \frac{CI}{CII} (1 - XS),$$

where

XS is the sample's quality

CI is the sodium concentration in the reference sample extracted from the all-liquid region upstream of the five-heated tubes

CII is the sodium concentration in the fully condensed sample extracted by the probe

XTR is the probe-indicated quality of the bulk-flow stream

As detailed in Appendix A, this expression was derived using a one-dimensional species continuity equation on the tracer.

The values of sodium-ion concentration were evaluated by atomic absorption analysis of the bottle samples. The concentration values indicated by the on-line analyzer were judged to be in error due to excessive drift in the analyzer. This error was suspected but unconfirmed during actual testing. However, subsequent to the vertical tube simulator testing, the analyzer's drift was confirmed.

The quality of an extracted sample was evaluated using pressure drop characteristics of two-phase flow in the probe-orifice's 0.013 inch orifice. The two-phase flow was modeled with a slip ratio of 2.0 and the orifice constant was evaluated from liquid-only calibration runs. Details on this technique are given in Appendix A. It should be noted that the XS term is a relatively small correction, so that the measurement of bulk-flow quality is fairly insensitive to the assumptions involved in estimating XS.

VI. RESULTS AND DISCUSSION

A. Data Presentation

The experimental results of this test are shown in Tables 1-6. Tables 2-3 give detailed data with Tables 4-6 providing a summary of the data. Tables 2 and 4 are for the test series with the vertical tube simulator and the row-of-holes quality probe. Tables 3 and 5 are for the test series with the horizontal tube simulator and the row-of-holes quality probe. Tables 3 and 6 are for the test series with the horizontal tube simulator and the sintered metal quality probe.

The detailed data, Tables 2-3, are presented as follows: Column 1 gives the run number, an index for data sorting. Column 2 gives the operating pressure. Column 3 gives the average mass velocity of the bulk-flow in the simulator. Column 4 gives the fluid enthalpy within the adiabatic simulator. Column 5 gives the average of the bulk-flow's actual quality. Column 6 gives the sodium-ion concentration of the reference sample. Column 7 gives the identifier denoting a given transverse location of the probe within the simulator. Column 8 gives the angle orientation of the probe. Column 9 gives the probe's sample flow rate. Column 10 gives the probe's orifice pressure drop. Column 11 gives the quality of the extracted sample. Column 12 gives the sodium concentration of the probe's condensed sample. Column 13 gives the probe-indicated value of quality for the bulk-flow stream. Column 14 gives the difference in quality between the probe-indicated value and the bulk-flow's actual value.

The summarized data, Tables 4-6, are presented as follows: Column 1 gives the run number. Columns 2 and 3 give the bulk-flow stream average values of mass velocity and actual quality respectively. Column 4 gives the probe's reference mark for insert position (see Figure 4). Column 5 gives the quality of the extracted sample. Column 6 gives the probe's indicated value of quality in the bulk-flow stream. For comparison, Column 7 gives the quality difference between the probe's indicated value and the actual quality of the average bulk stream.

B. Vertical Tube Simulator and Row-of-Holes Probe

The data given in Table 2 and summarized in Table 4 were interpreted to determine the worthiness of the row-of-holes probe operating within the constraints of a test section simulating a vertical tube heat exchanger tube bundle. The trends and effects of other parameters were also examined.

1. Accuracy

Figure 14 shows a plot of the probe-indicated quality vs. the average actual quality. This plot infers both scatter and bias errors in the ability of the probe to measure the actual quality. As discussed in Appendix A, the error in actual quality was estimated to be less than ±0.01 quality. For indicated qualities from 0.05 to 0.25 the data show a scatter of approximately ±0.05, five percent quality, for most (33 out of 36) runs. Statistically, the 95%/95% tolerance interval for these data is +0.065 to -0.073; meaning that with 95 per cent confidence, 95 per cent of the data taken from an infinite population will fall within this interval. For indicated qualities above 0.25, the scatter becomes excessively greater than ±0.05, with a bias trend of indicated qualities being lower than actual qualities.

Causes of the bias and scatter are not known. However, future studies may consider several possibilities. An error analysis showed that the scatter for indicated qualities below 0.25 was approximately equally attributable to the errors inherent in concentration measurement and to evaluation of the sample quality. The concentration error may be significantly reduced by using the average value of multiple measurements of concentration on the same sample. The inherent errors in determination of the sample's quality may be reduced if additional calibration studies are made where mixtures of known quality are forced to flow through the probe's orifice. The bias of indicated qualities below actual qualities for indicated qualities above 0.25 may be due to concentration gradients which are not accounted for in the one-dimensional theory used to analyze the data, see Appendix A.

2. Mass velocity effects

Figure 15 shows a plot of the quality difference vs. the bulk-flow stream's average mass velocity. In general the differences at the low mass velocity, 50,000 $lb/hr\text{-}ft^2$, were scattered between ±0.05 quality and biased to less than -0.05. At the high mass velocity of 320,000 $lb/hr\text{-}ft^2$, the quality differences were generally scattered between ±0.05 quality. The reason for the bias exhibited at low mass velocity is not known. However, as indicated by Figure 14, this apparent mass velocity bias effect is not present for the range of indicated qualities below 0.25.

3. Sample's quality

As shown in Tables 2 and 4, the sample qualities for the row-of-holes probe with the vertical tube simulator were typically below 0.07 in value. Although zero quality, i.e. all liquid, samples were originally desired the sample qualities for runs where probe-indicated bulk qualities were below 0.25 were sufficiently low that errors from this source were acceptable. Runs 294 and 288 of Table 4 at 0.37 actual quality illustrate an uncertainty effect of high sample qualities. Run 294 with a sample quality of 0.106 shows a quality difference, indicated less actual, of -0.113. Run 288 with a sample quality of 0.013 shows a quality difference of only -0.068. The agreement between indicated and actual qualities for runs 264 and 252 of Table 4 was interpreted as coincidence since the sample's qualities, approximately 0.50, were considered to be known only to within ±0.20.

4. Profile trends

Figures 16 and 17 show plots of quality profiles for two series of runs. Each plot exhibits scatter with the average quality difference less than ±0.05. It is noted that different optimum angles were determined for the points on a given profile series.

5. Orientation effects

As shown in Table 2, changing the probe angle relative to the approaching flow usually results in a change in the quality of the extracted sample. As previously discussed the probe-angle was surveyed to determine the optimum angle corresponding to the minimum sample quality which was indicated by the minimum probe-orifice pressure drop for a given set of the other parameters. For most runs, the optimum angle corresponded to the row-of-holes aimed directly into (-90^{o}) the approaching flow or aimed directly opposite ($+90^{o}$) the approaching flow. For some runs, e.g. runs 331-336, effects of an angle at +90 deg (holes up) or the -90 deg (holes down) were approximately the same. For other runs, e.g. runs 69-74, only one angle, -90 deg as opposed to +90 deg, was the optimum. For some runs, e.g. runs 148-153, the sample's quality was virtually independent of probe angle. No trends on the dependency, if any, of optimum angle with bulk stream quality, probe insert position, or mass velocity were clearly interpretable.

6. Sample flow rate effects

Most test runs were conducted with a sample flow rate of approximately 3.0 lbm/hr. Some tests were conducted at sample flow rate of approximately 5.0 lbm/hr. The tests at 3.0 lb/hr typically showed the desirable feature of extracting samples of lower quality than did the tests at 5.0 lb/hr. This feature was observed early in the test program with a group of runs with all conditions except sample flow rate being nominally the same. For example, Table 2 shows the runs at 5.0 lbm/hr (runs 16, 17 and 18) to exhibit higher sample qualities then the runs at 3.0 lbm/hr (runs 21, 20 and 19).

7. Tracer concentration effects

As shown in Table 2, most (49 of 74) runs were conducted with a nominal reference concentration of sodium-ions at about 100 ppb. For comparison, some runs, e.g. runs 116-264, were made at a nominal concentration of about 1000 ppb (i.e. one part per million). These runs at 1000 ppb showed no clear advantage or disadvantage over the runs at 100 ppb with respect to accuracy. This trend of no clear difference was somewhat expected since the estimated error of approximately 5% of reading for the measurement of concentration by the atomic absorption technique applies to both 100 ppb and 1000 ppb solutions.

C. Horizontal Tube Simulator and Row-of-Holes Probe

The data given in Table 3 and summarized in Table 5 were interpreted to determine the feasibility of the row-of-holes probe operating within the constraints of a test section simulating a horizontal tube heat exchanger tube bundle. The trends and effects of other parameters were also examined.

1. Accuracy

Figure 18 shows a plot of the probe-indicated quality vs. the average actual quality. Similar to the vertical tube data discussed above, this plot shows both scatter and bias errors in the ability of the probe to measure the actual quality. For indicated qualities from 0.05 to 0.40 and tracer concentrations above 50 ppb the data show a scatter of approximately ±0.05, five per cent quality, for most (28 out of 35) runs. Statistically, the 95%/95% tolerance interval for these data is +0.072 to -0.110; meaning that with 95 per cent confidence, 95 per cent of the data taken from an infinite population will fall within this interval. For indicated qualities above 0.40, the bias trend of indicated qualities being lower than the actual qualities was exhibited. As with the vertical tube test series, an error analysis suggests that scatter for indicated qualities below 0.40 was due to both the inherent errors in the concentration measurements and in the sample's quality.

Although the causes of error bias are not fully known, future studies may examine several possibilities. The concentration errors could be reduced by multiple analyses of the same sample. The sample quality errors could be reduced by additional tests with known sample quality.

The bias for indicated qualities above 0.40 may be due to concentration gradients of the tracer in the liquid for a given quality. This cause is partially supported by comparing the apparent quality limits of the two tests; namely 0.25 quality for the vertical tube tests and 0.40 quality for the horizontal tube tests. Vertical flow past horizontal tubes should exhibit an enhanced mixing of the fluid compared to vertical flow past vertical tubes. Correspondingly, the existence of concentration gradients should be delayed to occur at higher qualities for the horizontal tube test compared to the vertical tube test.

The indicated bias may be due to actual quality gradients caused by disturbance of the bulk stream due to the presence of the probe. This would infer that for the tested low mass velocity, 50,000 lb/hr-ft^2, and at qualities above 0.40, either the vapor was disturbed to flow around the probe or that a relative surplus of liquid impinged onto the probe. In either case the indicated quality would be lower than the bulk-streams averaged actual quality.

2. Mass velocity effects

Figure 19 shows a plot of the quality difference (indicated less actual) vs. the bulk-flow stream's average mass velocity. For mass velocities of 140,000 lb/hr-ft^2 and above, the quality differences are generally scattered by approximately ±0.05 quality. Only at the low mass velocity of 50,000 lb/hr-ft^2 do the data show a significant bias of indicated quality below the actual. The reasons for this trend are unknown. As shown on Figure 18, the biased runs for indicated qualities above 0.40 were all at this low mass velocity of 50,000 lb/hr-ft^2. However, due to critical heat flux constraints on the five-heated tube arrangement, higher mass velocities could not be tested at the high actual qualities of nominally 0.53 and 0.65.

3. Sample's quality

As shown in Tables 3 and 5, the sample qualities for the row-of-holes probe with the horizontal tube simulator were generally below 0.07 for indicated qualities below 0.40. These sample qualities were considered sufficiently low to permit their being evaluated with reasonable accuracy by the technique of orifice pressure drop characteristics.

4. Profile trends

Figures 20, 21 and 22 show plots of quality profiles for three series of runs. At an average actual quality of 0.528, Figure 20 shows a bias with the indicated qualities typically about 0.1 quality below the actual. The approximately uniform bias exhibited in the profile plotted in Figure 20, suggests that if the bias is caused by probe disturbance of the bulk-flow stream, then this disturbance persists for all probe positions. Figures 21 and 22 show reasonable agreement between indicated and actual qualities. None of the profiles clearly indicate any pattern in profiles.

5. Orientation effects

As shown in Table 3, changing the probe angle relative to the approaching flow may result in a change in the quality of the extracted sample. For most cases, the optimum angle corresponded to the row-of-holes oriented directly opposite the approaching flow. The variations of probe-orifice pressure drop, i.e. an indirect measurement of sample's quality, with the probe angle was much less for tests with the horizontal tube simulator than for the previously discussed tests with the vertical tube simulator. This trend was considered reasonable since the tortuous path of vertical flow over horizontal tubes tends to preclude separated flow, i.e. annular flow, which occurs with vertical flow past vertical tubes.

6. Sample flow rate effects

Most tests were conducted with a sample flow rate of 3.0 lbm/hr. Some tests, i.e. run 155, were made at the lower flow rate of 2.0 lb/hr in order to possibly reduce the sample's quality while operating at high bulk qualities, i.e. 0.67 for run 155. However, this lower than ordinary sampling rate did not clearly reduce the samples quality to levels suitable for accurate determination of the sample's quality.

7. Tracer concentration effects

As shown in Table 3, most tests were conducted at a nominal reference concentration of sodium-ions at about 100 to 200 ppb. During one test series, runs 336-353, the reference concentration fell to below 50 ppb. These low concentration runs were judged as suspect data since the accuracy of concentration measurements is typically poorer at such low concentrations.

D. Horizontal Tube Simulator and Sintered Metal Probe

The data given in Table 3 (runs 385-403) and summarized in Table 6 were interpreted to determine the worthiness of the sintered metal probe operating within the constraints of a test section simulating a horizontal tube heat exchanger. Only a limited number of test runs were conducted due to available laboratory testing time. However the acquired data were sufficient to indicate trends and effects.

1. Accuracy

Figure 23 shows a plot of the indicated quality vs. the average actual bulk quality. Similar to the tested row-of-holes probe with the horizontal tube simulator, the scatter of approximately ± 0.05 quality was exhibited for indicated qualities below 0.40. For higher indicated qualities the indicated qualities were biased to significantly below the actual qualities.

2. Sample's quality

As shown in Tables 2 and 6, the sample qualities for the sintered metal probe were below 0.03 for all test conditions. These sample qualities are sufficiently low to permit reasonable accuracy in evaluation of the sample's quality for inclusion in the expression to evaluate the bulk-flow's quality. In general, the sample qualities extracted by the sintered metal probe were lower than the sample qualities extracted by the row-of-holes probe.

3. Orientation effects

The sintered metal surface is essentially a uniform distribution of many very small sampling holes. Correspondingly it was not necessary to rotate the probe to find some optimum angle as was done with the row-of-holes probe.

4. Plugging effects

The sintered metal probe's performances suggest its superiority over the row-of-holes probe with respect to extracting low quality samples and not requiring probe rotation. However, it is believed that simulation test results may be misleading since the bulk-flow stream was typically free of solids. It is believed that usage of a sintered metal probe in a system with the probability of suspended solids may render the sintered metal probe impractical due to plugging of the porous surface.

E. Visual Studies

A visual study was made during testing with the horizontal simulator and the sintered metal probe. This was accomplished by installing a quartz window in the adiabatic test section and monitoring the flow with a video-tape system. It was planned to determine the flow patterns of two-phase flow past horizontal tubes from the video recording. However, the recorded pictures were judged as too poor to interpret. The causes for poor resolution were considered to be a combination of three effects. First,the ends of the solid tubes were excessively bright which produced a poor contrast to reflections from "bubbles" in the flow. Second, the fluid velocity was too high relative to the frequency of video scans. This relative speed effect made it virtually impossible to actually "see" a bubble for more than one full screen scan of the recording system. Third, inspection by the naked eye suggested that the flow pattern was typically froth flow (a conglomerate of many small and non-coalesced bubbles) for most conditions of mass velocity and quality. As experienced by the author in a previous visual study, Reference 5, the images for froth flow are very difficult to interpret even with a high speed motion picture system.

The indicated existence of froth flow tends to support other data trends in suggesting that the flow was generally homogeneous with a normally uniform distribution of quality across the test section. However, the visual data were judged as insufficient to actually confirm this trend.

F. Operating Experiences

Pérformance of the quality probe tests employed a relatively new and unfamiliar technique and procedure. Correspondingly, some of the lessons learned deserve comment on guiding other quality probe users.

1. Probe rotation

It is necessary to rotate the row-of-holes in order to determine the optimum angle corresponding to minimum sample quality. This rotation should encompass the two stagnation points on the probe relative to the approaching flow.

2. Sample flow rate

The sample flow rate must be maintained constant at all times during a test. This is necessary to insure meaningful data from the rotation series. It is also important during an actual sampling run in which samples are collected since changes in flow rate could alter the quality of the sample being extracted and correspondingly the concentration of the collected sample.

3. Plugging

It is possible for the row-of-holes probe to become plugged. Plugging could occur at either - the row-of-holes, the orifice, or the pressure tap holes within the probe head. Plugging of the 0.013 inch diameter orifice holes did occur, after run number 365, with the horizontal tube simulator and the row-of-holes probe. This plugging was quickly resolved by simply applying back-pressure to the probe.

4. Concentration levels

The reference concentration level typically decreases with time. This follows since tracer-solutions are extracted by the probe line and the reference sampling line and the make-up water is typically pure, i.e. less than 5 ppb sodium concentration. This decrease can lead to excessively low concentration as experienced by runs 336-353 on the horizontal tube and row-of-holes probe test. These concentrations below 50 ppb were judged as suspect data due to excessive errors in concentration measurement. Correspondingly the nominal concentration should be frequently monitored and maintained at the desired level.

5. Chemical analysis

The use of an on-line analyzer for measurement of the probe-line and reference samples appears impractical due to excessive stabilization and calibration times. However, the use of an on-line analyzer would probably be satisfactory for continuous monitoring of a system's nominal concentration. The use of bottled samples which are later analyzed by the atomic absorption technique is satisfactory for the probe-line and reference samples. The inherent errors in the atomic absorption method may be reduced if the same sample is analyzed several times with recalibration of the analyzer each time.

6. Probe-orifice calibration

The technique of using the probe's orifice pressure drop characteristics requires that the orifice's constant be known for single phase flow. Correspondingly, calibration runs are required where liquid-only exists in the bulk-flow stream. Flow conditions with liquid-only at typical subcooling of 10 to 15°F were used in this test. This subcooling was considered to be sufficiently close to the saturation point while maintaining minimal subcooled voids. The frequency of orifice re-calibrations may depend on the particular probe and alkalinity conditions of the bulk stream. The relatively small orifice hole (0.013 inches) is sensitive to any surface changes as may occur when operating at a pH below 9.

7. Probe-orifice with two-phase flow

The probe orifices were never calibrated with two-phase flow of actually known quality. Such a calibration was judged as difficult due to the inherent errors of heat loss for a system operation at relatively low flow rates of 3.0 lb/hr. Correspondingly a relatively accurate two-phase calibration would require design and construction of rather elaborate equipment. The selected model based on a slip ratio of 2.0 was judged as sufficiently accurate for the extraction of low quality samples as experienced in this test.

VII. CONCLUSIONS

From interpretations of the data taken in this quality probe study and for the ranges of parameters tested the following major conclusions were made:

1. The tested row-of-holes quality probe is qualified for determination of steam quality within the tube bundle region of vertical tube heat exchangers for indicated qualities up to 0.25 and an accuracy limited to approximately ±0.05 quality.

2. The tested row-of-holes quality probe is qualified for determination of steam quality within the tube bundle region of horizontal tube heat exchangers for indicated qualities up to 0.40 and an accuracy limited to approximately ±0.05 quality.

3. The tested sintered-metal quality probe is qualified for determination of steam quality wi hin the tube bundle region of horizontal tube heat exchangers for indicated qualities up to 0.40 and an accuracy limited to approximately ±0.05 quality while operating at nominally solids-free conditions.

The following secondary conclusions were made:

1. An on-line analyzer for measuring tracer concentrations is impractical. However, such an analyzer would be feasible for monitoring a system's nominal concentration level. The technique of analysis by atomic absorption of collected bottle samples is satisfactory with respect to quality probe application. The inherent errors of this technique may be reduced if multiple measurements are made of the same sample with re-calibration after each case.

2. Results show satisfactory performance for sodium-ion concentrations at approximately 80 ppb and above. Unreliable results may be exhibited for concentration below 50 ppb.

3. Operation with the row-of-holes probe requires probe rotation. This requirement is necessary in order to determine the optimum angle which permits extracting samples of sufficiently low quality. Although most optimum angles in this test corresponded to the holes directly facing or directly opposing the approaching flow, probe rotation would be required for general use since the actual direction of flow may not be known. The sintered metal probe does not require probe rotation.

4. Operation at a nominal sample flow rate of 3.0 lb/hr is satisfactory for reasonable probe performance. Operation at higher sample flow rates may lead to excessive errors due to uncertainty in the sample's quality. Operation at lower flow rates may be impractical due to the requirement of maintaining steady-state conditions over the time required to fill a sample bottle.

5. The inherent errors in determination of the sample's quality may be reduced if additional tests are performed where samples of known quality are flowed through the probe orifice.

6. This study was only partially successful in determining the two-phase flow pattern of secondary side flow across a horizontal tube bundle. Although the identified flow pattern of froth flow was observed, the recorded data were inadequate to develop flow pattern maps.

TABLE I. List cf Tested Data Ranges

		Bulk-Flow Conditions					Probe Conditions	
Simulator Tube Orientation	Quality Probe	Pressure (psia)	Nominal Mass Velocity x 10^{-6} (lb/hr-ft^2)	Quality	Visual Data	Number of Runs	Number of Different Probe Insert Positions	Sample Flow Rate (lb/hr)
Vertical	row-of-holes	1200	0.2, 0.45	(subcooled)	no	11	2	3.0-9.0
Vertical	row-of-holes	600	0.05-0.35	(subcooled)	no	15	5	2.0-9.0
Vertical	row-of-holes	600	0.05	0.01-0.63	no	30	10	3.0, 5.0
Vertical	row-of-holes	600	0.10	0.07-0.63	no	10	3	3.0
Vertical	row-of-holes	600	0.19	0.09-0.40	no	9	5	3.0
Vertical	row-of-holes	600	0.31	0.10, 0.20	no	7	3	3.0
Horizontal	row-of-holes	1200	0.05, 0.45	(subcooled)	no	8	2	2.0-5.0
Horizontal	row-of-holes	600	0.05-0.45	(subcooled)	no	11	2	2.0-5.0
Horizontal	row-of-holes	600	0.05	0.07-0.67	no	23	6	2.0, 3.0
Horizontal	row-of-holes	600	0.15	0.08-0.44	no	13	7	3.0
Horizontal	row-of-holes	600	0.24	0.09-0.32	no	15	8	2.0, 3.0
Horizontal	row-of-holes	600	0.35	0.10, 0.18	no	4	2	3.0
Horizontal	sintered metal	1200	0.05	(subcooled)	yes	2	1	3.0
Horizontal	sintered metal	600	0.05, 0.35	(subcooled)	yes	2	1	3.0
Horizontal	sintered metal	600	0.05	0.06-0.66	yes	6	1	3.0
Horizontal	sintered metal	600	0.15	0.08-0.44	yes	4	1	3.0
Horizontal	sintered metal	600	0.24	0.10-0.30	yes	3	1	3.0
Horizontal	sintered metal	600	0.34	0.10, 0.20	yes	2	1	3.0

TABLE 2. Vertical Tube Simulator Test Results

SIMULATOR - VERTICAL TUBES
PROBE --- ROW-OF-HOLES

	BULK FLOW CONDITIONS AT PROBE LOCATION					PROBE SAMPLING CONDITIONS							
RUN NO.	PRES-SURE (PSIA)	MASS VELOCITY X 10-6 (LB/HR-FTSQ)	ENTHALPY (BTU/LB)	XB QUALITY	REFERENCE TRACER CONCEN-TRATION (PPB)	(1) PROBE --LOCATION-- INSERT	ANGLE	FLOW RATE (LB/HR)	ORIFICE PRESSURE DROP (PSI)	XS3 QUALITY OF SAMPLE	TRACER CONCEN-TRATION IN SAMPLE (PPB)	XBT TEST SECTION QUALITY VIA TRACER	QUALITY DIFFERENCE (XBT - XB)
1	1200	0.432	436.7	-0.237	288.	19.2	90	2.84	2.944	---	292.	---	---
2	1200	0.432	427.2	-0.236	78.	19.2	90	4.86	7.675	---	75.	---	---
3	1200	0.432	428.2	-0.235	65.	19.2	90	6.94	15.238	---	64.	---	---
4	1200	0.432	427.5	-0.236	75.	19.2	90	9.08	26.312	---	76.	---	---
5	1200	0.432	494.7	-0.126	19.	19.2	90	8.99	27.940	---	14.	---	---
6	1200	0.434	495.5	-0.125	14.	19.2	90	9.07	29.932	---	13.	---	---
7	1200	0.433	495.6	-0.125	12.	19.2	90	6.96	17.349	---	11.	---	---
8	1200	0.437	436.3	-0.123	61.	19.2	90	4.83	8.069	---	62.	---	---
9	1200	0.438	436.6	-0.123	62.	19.2	90	3.09	3.485	---	62.	---	---
10	600	0.336	457.2	-0.006	---	19.2	90	3.31	3.880	---	---	---	---
11	600	0.336	466.8	-0.007	---	19.2	90	4.52	7.452	---	---	---	---
12	600	0.336	467.0	-0.006	---	19.2	90	3.02	3.444	---	---	---	---
13	600	0.336	457.0	-0.006	---	19.2	90	5.00	8.949	---	---	---	---
14	600	0.336	457.0	-0.006	---	19.2	90	7.00	18.300	---	---	---	---
15	600	0.336	467.0	-0.006	---	19.2	90	9.04	35.769	---	---	---	---
16	600	0.051	580.1	0.148	78.	8.5	90	5.12	17.332	0.037	86.	0.127	-0.021
17	600	0.051	590.3	0.148	82.	14.5	90	5.02	22.877	0.069	88.	0.133	-0.016
18	600	0.051	582.3	0.151	71.	17.5	90	5.01	14.268	0.025	80.	0.135	-0.016
19	600	0.051	582.6	0.152	70.	17.5	90	3.00	3.673	0.003	81.	0.138	-0.013
20	600	0.051	584.1	0.154	72.	14.5	90	2.95	3.619	0.004	79.	0.092	-0.061
21	600	0.051	582.7	0.152	68.	8.5	90	2.95	3.509	0.002	80.	0.152	0.000

(1) See Figure 4 for description.

TABLE 2 (Continued)

SIMULATOR - VERTICAL TUBES
PROBE --- ROW-OF-HOLES

	BULK FLOW CONDITIONS AT PROBE LOCATION				PROBE SAMPLING CONDITIONS								
RUN NO.	PRESSURE (PSIA)	MASS VELOCITY X 10-6 (LB/HR-FTSQ)	ENTHALPY (BTU/LB)	XB QUALITY	REFERENCE TRACER CONCENTRATION (PPB)	(1) PROBE LOCATION INSERT	(1) PROBE LOCATION ANGLE	FLOW RATE (LB/HR)	ORIFICE PRESSURE DROP (PSI)	XS3 QUALITY OF SAMPLE	TRACER CONCENTRATION IN SAMPLE (PPB)	XBT TEST SECTION QUALITY VIA TRACER	QUALITY DIFFERENCE (XBT - XB)
22	600	0.050	731.6	0.355	---	14.5	90	3.00	7.945	---	---	---	---
23	600	0.050	731.6	0.355	---	14.5	45	3.00	4.918	---	---	---	---
24	600	0.050	731.6	0.355	---	14.5	0	3.00	3.988	---	---	---	---
25	600	0.050	731.6	0.355	---	14.5	-45	2.99	4.291	---	---	---	---
26	600	0.050	731.6	0.355	---	14.5	-90	2.99	4.264	---	---	---	---
27	600	0.050	732.6	0.356	70.	14.5	0	2.98	4.178	0.011	97.	0.286	-0.070
28	600	0.050	735.0	0.360	---	8.5	90	3.01	4.486	---	---	---	---
29	600	0.050	735.0	0.360	---	8.5	45	3.00	7.335	---	---	---	---
30	600	0.050	735.0	0.360	---	8.5	0	2.98	16.340	---	---	---	---
31	600	0.050	735.0	0.360	---	8.5	-45	3.02	15.039	---	---	---	---
32	600	0.050	735.0	0.360	---	8.5	-90	3.04	10.694	---	---	---	---
33	600	0.050	739.1	0.365	62.	8.5	90	2.94	4.043	0.010	89.	0.311	-0.055
34	600	0.050	584.0	0.153	---	14.5	90	2.84	3.802	---	---	---	---
35	600	0.050	584.0	0.153	---	14.5	45	2.96	3.889	---	---	---	---
36	600	0.050	584.0	0.153	---	14.5	0	2.96	3.883	---	---	---	---
37	600	0.050	584.0	0.153	---	14.5	-45	2.96	3.663	---	---	---	---
38	600	0.050	584.0	0.153	---	14.5	-90	2.96	3.776	---	---	---	---
39	600	0.050	586.7	0.157	57.	14.5	-45	3.02	3.804	0.003	65.	0.126	-0.031
40	600	0.050	587.0	0.157	---	8.5	90	3.01	3.779	---	---	---	---
41	600	0.050	587.0	0.157	---	8.5	45	3.01	4.497	---	---	---	---
42	600	0.050	587.0	0.157	---	8.5	0	3.01	5.487	---	---	---	---
43	600	0.050	587.0	0.157	---	8.5	-45	3.00	4.945	---	---	---	---
44	600	0.050	587.0	0.157	---	8.5	-90	3.01	4.638	---	---	---	---
45	600	0.051	582.5	0.151	99.	8.5	90	3.01	3.606	0.000	112.	0.116	-0.035
46	600	0.329	618.7	0.201	---	14.5	90	3.02	52.792	---	---	---	---
47	600	0.329	618.7	0.201	---	14.5	45	3.04	41.263	---	---	---	---
48	600	0.329	618.7	0.201	---	14.5	0	3.11	15.125	---	---	---	---
49	600	0.329	618.7	0.201	---	14.5	-45	3.12	5.242	---	---	---	---
50	600	0.329	618.7	0.201	---	14.5	-90	3.01	4.594	---	---	---	---

(1) See Figure 4 for description.

TABLE 2 (Continued)

SIMULATOR - VERTICAL TUBES
PROBE --- ROW-OF-HOLES

	BULK FLOW CONDITIONS --- AT PROBE LOCATION				PROBE SAMPLING CONDITIONS								
RUN NO.	PRESSURE (PSIA)	MASS VELOCITY X 10-6 (LB/HR-FTSQ)	ENTHALPY (BTU/LB)	XB QUALITY	REFERENCE TRACER CONCENTRATION (PPB)	(1) PROBE --LOCATION-- INSERT	ANGLE	FLOW RATE (LB/HR)	ORIFICE PRESSURE DROP (PSI)	XS3 QUALITY OF SAMPLE	TRACER CONCENTRATION IN SAMPLE (PPB)	XBT TEST SECTION QUALITY VIA TRACER	QUALITY DIFFERENCE (XBT - XB)
51	600	0.301	624.8	0.209	---	14.5	90	3.01	55.116	---	---	---	---
52	600	0.301	624.8	0.209	---	14.5	45	3.06	43.658	---	---	---	---
53	600	0.301	624.8	0.209	---	14.5	0	3.05	16.983	---	---	---	---
54	600	0.301	624.8	0.209	---	14.5	-45	3.08	4.771	---	---	---	---
55	600	0.301	624.8	0.209	---	14.5	-90	3.07	4.588	---	---	---	---
56	600	0.305	620.3	0.203	74.	14.5	-90	2.97	4.408	0.010	95.	0.229	0.026
57	600	0.305	620.2	0.203	---	8.5	90	2.97	19.346	---	---	---	---
58	600	0.305	620.2	0.203	---	8.5	45	2.95	32.635	---	---	---	---
59	600	0.305	620.2	0.203	---	8.5	0	2.95	47.467	---	---	---	---
60	600	0.305	620.2	0.203	---	8.5	-45	2.96	21.486	---	---	---	---
61	600	0.305	620.2	0.203	---	8.5	-90	2.96	8.621	---	---	---	---
62	600	0.305	621.3	0.204	69.	8.5	-90	2.99	8.457	0.065	83.	0.223	0.018
63	600	0.306	619.8	0.202	---	14.5	90	4.98	----	---	---	---	---
64	600	0.306	619.8	0.202	---	14.5	45	5.02	----	---	---	---	---
65	600	0.306	619.8	0.202	---	14.5	0	5.03	56.513	---	---	---	---
66	600	0.306	619.8	0.202	---	14.5	-45	5.01	13.505	---	---	---	---
67	600	0.306	619.8	0.202	---	14.5	-90	5.00	13.143	---	---	---	---
68	600	0.306	620.4	0.203	72.	14.5	-90	5.03	13.370	0.013	84.	0.154	-0.049
69	600	0.306	618.2	0.200	---	8.5	90	2.97	19.418	---	---	---	---
70	600	0.306	618.2	0.200	---	8.5	45	3.00	34.160	---	---	---	---
71	600	0.306	618.2	0.200	---	8.5	0	3.03	49.933	---	---	---	---
72	600	0.306	618.2	0.200	---	8.5	-45	3.03	21.654	---	---	---	---
73	600	0.306	618.2	0.200	---	8.5	-90	2.98	8.949	---	---	---	---
74	600	0.306	619.5	0.202	66.	8.5	-90	2.97	8.684	0.070	78.	0.213	0.011
75	600	0.335	460.6	-0.015	---	19.2	90	2.00	1.789	---	---	---	---
76	600	0.335	460.6	-0.015	---	19.2	45	3.02	3.805	---	---	---	---
77	600	0.335	460.6	-0.015	---	19.2	0	5.01	10.517	---	---	---	---
78	600	0.335	460.6	-0.015	---	19.2	-45	7.01	20.873	---	---	---	---
79	600	0.335	460.6	-0.015	---	19.2	-90	9.04	35.648	---	---	---	---

(1) See Figure 4 for description.

TABLE 2 (Continued)

SIMULATOR - VERTICAL TUBES
PROBE --- ROW-OF-HOLES

	BULK FLOW CONDITIONS --------- AT PROBE LOCATION --------				-----------PROBE SAMPLING CONDITIONS-----------								
RUN NO.	PRES-SURE (PSIA)	MASS VELOCITY X 10-6 (LB/HR-FTSQ)	ENTHALPY (BTU/LB)	XB QUALITY	REFERENCE TRACER CONCEN-TRATION (PPB)	(1) PROBE --LOCATION-- INSERT	ANGLE	FLOW RATE (LB/HR)	ORIFICE PRESSURE DROP (PSI)	KS3 QUALITY OF SAMPLE	TRACER CONCEN-TRATION IN SAMPLE (PPB)	XBT TEST SECTION QUALITY VIA TRACER	QUALITY DIFFERENCE (XBT - XB)
80	600	0.051	585.9	0.156	---	14.5	90	4.97	24.253	---	---	---	---
81	600	0.051	585.9	0.156	---	14.5	45	4.97	18.773	---	---	---	---
82	600	0.051	585.9	0.156	---	14.5	0	4.98	14.346	---	---	---	---
83	600	0.051	585.9	0.156	---	14.5	-45	4.98	13.065	---	---	---	---
84	600	0.051	585.9	0.156	---	14.5	-90	4.97	12.295	---	---	---	---
85	600	0.051	584.5	0.154	60.	14.5	-90	5.04	13.397	0.012	75.	0.210	0.056
86	600	0.051	727.2	0.349	---	14.5	90	4.96	62.957	---	---	---	---
87	600	0.051	727.2	0.349	---	14.5	45	5.00	48.706	---	---	---	---
88	600	0.051	727.2	0.349	---	14.5	0	4.98	19.655	---	---	---	---
89	600	0.051	727.2	0.349	---	14.5	-45	4.99	17.197	---	---	---	---
90	600	0.051	727.2	0.349	---	14.5	-90	4.98	15.984	---	---	---	---
91	600	0.051	725.2	0.346	62.	14.5	-90	4.78	15.037	0.027	82.	0.265	-0.082
92	600	0.051	726.8	0.348	---	8.5	90	2.85	4.454	---	---	---	---
93	600	0.051	725.8	0.348	---	8.5	45	2.82	8.797	---	---	---	---
94	600	0.051	726.8	0.348	---	8.5	0	2.80	13.032	---	---	---	---
95	600	0.051	726.8	0.348	---	8.5	-45	2.80	10.340	---	---	---	---
96	600	0.051	725.8	0.348	---	8.5	-90	2.86	7.478	---	---	---	---
97	600	0.051	730.5	0.353	63.	8.5	90	2.98	5.223	0.020	88.	0.298	-0.055
98	600	0.051	585.5	0.155	---	14.5	90	3.06	5.284	---	---	---	---
99	600	0.051	585.5	0.155	---	14.5	45	3.05	5.144	---	---	---	---
100	600	0.051	585.5	0.155	---	14.5	0	3.04	4.965	---	---	---	---
101	600	0.051	585.5	0.155	---	14.5	-45	3.07	4.982	---	---	---	---
102	600	0.051	585.5	0.156	---	14.5	-90	3.06	4.868	---	---	---	---
103	600	0.051	583.5	0.153	89.	14.5	-90	2.99	4.594	0.011	99.	0.110	-0.042
104	600	0.051	476.8	0.007	---	14.5	90	3.01	4.625	---	---	---	---
105	600	0.051	476.8	0.007	---	14.5	45	3.00	4.465	---	---	---	---
106	600	0.051	476.8	0.007	---	14.5	0	3.01	4.474	---	---	---	---
107	600	0.051	476.8	0.007	---	14.5	-45	2.94	4.334	---	---	---	---
108	600	0.051	475.8	0.007	---	14.5	-90	2.94	4.318	---	---	---	---
109	600	0.051	476.4	0.006	163.	14.5	-90	2.99	4.485	0.008	158.	-0.055	-0.061

(1) See Figure 4 for descrpition.

TABLE 2 (Continued)

SIMULATOR - VERTICAL TUBES
PROBE --- ROW-OF-HOLES

	BULK FLOW CONDITIONS --- AT PROBE LOCATION ---				PROBE SAMPLING CONDITIONS								
RUN NO.	PRESSURE (PSIA)	MASS VELOCITY X 10-6 (LB/HR-FTSQ)	ENTHALPY (BTU/LB)	XB QUALITY	REFERENCE TRACER CONCENTRATION (PPB)	(1) PROBE LOCATION INSERT	(1) PROBE LOCATION ANGLE	FLOW RATE (LB/HR)	ORIFICE PRESSURE DROP (PSI)	XS3 QUALITY OF SAMPLE	TRACER CONCENTRATION IN SAMPLE (PPB)	XBT TEST SECTION QUALITY VIA TRACER	QUALITY DIFFERENCE (XBT - XB)
110	600	0.051	477.2	0.008	---	8.5	90	3.00	4.497	---	---	---	---
111	600	0.051	477.2	0.008	---	8.5	45	3.03	5.885	---	---	---	---
112	600	0.051	477.2	0.008	---	8.5	0	3.04	4.783	---	---	---	---
113	600	0.051	477.2	0.008	---	8.5	-45	3.04	4.825	---	---	---	---
114	600	0.051	477.2	0.008	---	8.5	-90	3.04	4.712	---	---	---	---
115	600	0.051	477.2	0.008	155.	8.5	90	3.07	4.759	0.008	150.	-0.025	-0.032
116	500	0.051	581.0	0.149	---	0.5	90	3.07	4.598	---	---	---	---
117	500	0.051	581.0	0.149	---	0.5	45	3.08	4.524	---	---	---	---
118	500	0.051	581.0	0.149	---	0.5	0	3.07	4.533	---	---	---	---
119	500	0.051	581.0	0.149	---	0.5	-45	3.07	4.855	---	---	---	---
120	500	0.051	581.0	0.149	---	0.5	-90	3.06	5.468	---	---	---	---
121	500	0.051	582.1	0.151	1320.	0.5	45	2.88	3.993	0.002	1510.	0.127	-0.024
122	600	0.051	581.3	0.150	---	2.5	90	3.03	4.408	---	---	---	---
123	500	0.051	581.3	0.150	---	2.5	45	3.02	4.358	---	---	---	---
124	600	0.051	581.3	0.150	---	2.5	0	3.02	4.408	---	---	---	---
125	600	0.051	581.3	0.150	---	2.5	-45	3.01	4.795	---	---	---	---
126	500	0.051	581.3	0.150	---	2.5	-90	3.01	5.183	---	---	---	---
127	600	0.051	583.7	0.153	940.	2.5	45	3.01	4.333	0.001	1120.	0.161	0.008
128	600	0.051	587.0	0.158	---	5.5	90	2.98	4.465	---	---	---	---
129	600	0.051	587.0	0.158	---	5.5	45	3.07	4.581	---	---	---	---
130	600	0.051	587.0	0.158	---	5.5	0	3.03	4.695	---	---	---	---
131	600	0.051	587.0	0.158	---	5.5	-45	3.03	4.950	---	---	---	---
132	600	0.051	587.0	0.158	---	5.5	-90	3.04	5.551	---	---	---	---
133	600	0.051	583.2	0.152	900.	5.5	90	2.99	4.332	0.002	1030.	0.128	-0.025
134	600	0.051	455.0	-0.023	---	8.5	90	3.15	4.372	---	---	---	---
135	600	0.051	581.0	0.149	---	8.5	90	3.03	4.686	---	---	---	---
136	600	0.051	581.0	0.149	---	8.5	45	3.03	5.249	---	---	---	---
137	600	0.051	581.0	0.149	---	8.5	0	3.03	6.950	---	---	---	---
138	600	0.051	581.0	0.149	---	8.5	-45	3.03	6.578	---	---	---	---
139	600	0.051	581.0	0.149	---	8.5	-90	3.03	5.429	---	---	---	---
140	600	0.051	586.6	0.157	1770.	8.5	90	3.00	5.435	0.014	1990.	0.123	-0.034

(1) See Figure 4 for description.

TABLE 2 (Continued)

SIMULATOR - VERTICAL TUBES
PROBE --- ROW-OF-HOLES

RUN NO.	PRES-SURE (PSIA)	MASS VELOCITY X 10-6 (LB/HR-FTSQ)	ENTHALPY (BTU/LB)	XB QUALITY	REFERENCE TRACER CONCEN-TRATION (PPB)	(1) PROBE --LOCATION-- INSERT	ANGLE	FLOW RATE (LB/HR)	ORIFICE PRESSURE DROP (PSI)	XS3 QUALITY OF SAMPLE	TRACER CONCEN-TRATION IN SAMPLE (PPB)	XBT TEST SECTION QUALITY VIA TRACER	QUALITY DIFFERENCE (XBT - XB)
	BULK FLOW CONDITIONS AT PROBE LOCATION				PROBE SAMPLING CONDITIONS								
141	600	0.051	584.4	0.154	---	12.5	90	3.07	4.950	---	---	---	---
142	600	0.051	584.4	0.154	---	12.5	45	3.09	5.365	---	---	---	---
143	600	0.051	584.4	0.154	---	12.5	0	3.07	5.859	---	---	---	---
144	600	0.051	584.4	0.154	---	12.5	-45	3.07	5.228	---	---	---	---
145	600	0.051	584.4	0.154	---	12.5	-90	3.07	4.957	---	---	---	---
146	600	0.050	458.1	-0.019	---	11.5	90	3.04	3.472	---	---	---	---
147	600	0.050	589.0	0.160	1680.	11.5	90	3.00	3.764	0.005	1970.	0.152	-0.009
148	600	0.050	590.6	0.162	---	14.5	90	3.01	3.766	---	---	---	---
149	600	0.050	590.6	0.162	---	14.5	45	3.00	3.740	---	---	---	---
150	600	0.050	590.6	0.162	---	14.5	0	3.00	3.744	---	---	---	---
151	600	0.050	590.6	0.162	---	14.5	-45	3.00	3.690	---	---	---	---
152	600	0.050	590.6	0.162	---	14.5	-90	3.00	3.635	---	---	---	---
153	600	0.050	589.3	0.161	1340.	14.5	-90	3.01	3.654	0.003	1620.	0.175	0.015
154	600	0.050	587.2	0.158	---	20.5	90	3.05	3.695	---	---	---	---
155	600	0.050	587.2	0.158	---	20.5	45	3.05	4.151	---	---	---	---
156	600	0.050	587.2	0.158	---	20.5	0	3.05	5.140	---	---	---	---
157	600	0.050	587.2	0.158	---	20.5	-45	3.05	4.791	---	---	---	---
158	600	0.050	587.2	0.158	---	20.5	-90	3.05	4.334	---	---	---	---
159	600	0.050	589.8	0.161	2090.	20.5	90	3.19	3.957	0.001	2540.	0.178	0.017
160	600	0.050	590.2	0.162	---	26.5	90	3.02	3.473	---	---	---	---
161	600	0.050	590.2	0.162	---	26.5	45	3.02	3.466	---	---	---	---
162	600	0.050	590.2	0.162	---	26.5	0	3.02	3.585	---	---	---	---
163	600	0.050	590.2	0.162	---	26.5	-45	3.01	3.982	---	---	---	---
164	600	0.050	590.2	0.162	---	26.5	-90	3.01	4.169	---	---	---	---
165	600	0.050	590.1	0.162	1870.	26.5	45	3.06	3.532	0.000	2300.	0.187	0.025
166	600	0.050	588.8	0.160	---	28.5	90	2.97	3.387	---	---	---	---
167	600	0.050	588.8	0.160	---	28.5	45	3.04	3.430	---	---	---	---
168	600	0.050	588.8	0.160	---	28.5	0	3.03	3.557	---	---	---	---
169	600	0.050	588.8	0.160	---	28.5	-45	3.03	4.241	---	---	---	---
170	600	0.050	588.8	0.160	---	28.5	-90	3.03	4.568	---	---	---	---
171	600	0.050	585.6	0.158	1600.	28.5	90	3.05	3.518	0.000	1900.	0.158	0.002

(1) See Figure 4 for description.

TABLE 2 (Continued)

SIMULATOR - VERTICAL TUBES
PROBE --- ROW-OF-HOLES

	BULK FLOW CONDITIONS AT PROBE LOCATION				PROBE SAMPLING CONDITIONS								
RUN NO.	PRESSURE (PSIA)	MASS VELOCITY X 10-6 (LB/HR-FTSQ)	ENTHALPY (BTU/LB)	XB QUALITY	REFERENCE TRACER CONCENTRATION (PPB)	(1) PROBE --LOCATION-- INSERT	ANGLE	FLOW RATE (LB/HR)	ORIFICE PRESSURE DROP (PSI)	XS3 QUALITY OF SAMPLE	TRACER CONCENTRATION IN SAMPLE (PPB)	XBT TEST SECTION QUALITY VIA TRACER	QUALITY DIFFERENCE (XBT - XB)
172	600	0.050	453.7	-0.025	---	8.5	90	3.04	3.473	---	---	---	---
173	600	0.050	735.1	0.360	---	8.5	90	3.05	4.138	---	---	---	---
174	600	0.050	735.1	0.360	---	8.5	45	3.05	8.923	---	---	---	---
175	600	0.050	735.1	0.360	---	8.5	0	3.03	14.856	---	---	---	---
176	600	0.050	735.1	0.360	---	8.5	-45	3.03	13.818	---	---	---	---
177	600	0.050	735.1	0.360	---	8.5	-90	3.05	11.960	---	---	---	---
178	600	0.050	732.5	0.356	2060.	8.50	90	3.15	4.548	0.010	2720.	0.251	-0.106
179	600	0.050	728.0	0.350	---	14.5	90	2.99	6.838	---	---	---	---
180	600	0.050	728.0	0.350	---	14.5	45	3.00	4.690	---	---	---	---
181	600	0.050	728.0	0.350	---	14.5	0	2.99	3.942	---	---	---	---
182	600	0.050	728.0	0.350	---	14.5	-45	2.99	3.989	---	---	---	---
183	600	0.050	728.0	0.350	---	14.5	-90	2.99	4.173	---	---	---	---
184	600	0.050	730.4	0.353	1720.	14.5	0	2.99	4.139	0.011	2450.	0.306	-0.048
185	600	0.050	730.3	0.353	---	20.5	90	3.08	4.050	---	---	---	---
186	600	0.050	730.3	0.353	---	20.5	45	3.07	6.083	---	---	---	---
187	600	0.050	730.3	0.353	---	20.5	0	3.05	12.005	---	---	---	---
188	600	0.050	730.3	0.353	---	20.5	-45	3.04	10.677	---	---	---	---
189	600	0.050	730.3	0.353	---	20.5	-90	3.07	8.851	---	---	---	---
190	600	0.051	731.1	0.354	2300.	20.5	90	3.06	4.021	0.007	3300.	0.308	-0.047
191	600	0.306	458.2	-0.018	1760.	20.5	90	3.02	3.449	---	1760.	---	---
192	600	0.307	545.7	0.101	---	20.5	90	3.10	9.650	---	---	---	---
193	600	0.307	545.7	0.101	---	20.5	45	3.07	19.665	---	---	---	---
194	600	0.307	545.7	0.101	---	20.5	0	3.07	20.034	---	---	---	---
195	600	0.307	545.7	0.101	---	20.5	-45	3.10	8.119	---	---	---	---
196	600	0.307	545.7	0.101	---	20.5	-90	3.10	4.500	---	---	---	---
197	600	0.306	545.0	0.100	1350.	20.5	-90	3.12	4.670	0.013	1500.	0.112	0.012

(1) See Figure 4 for description.

TABLE 2 (Continued)

SIMULATOR - VERTICAL TUBES
PROBE --- ROW-OF-HOLES

RUN NO.	PRES-SURE (PSIA)	MASS VELOCITY X 10-6 (LB/HR-FTSQ)	ENTHALPY (BTU/LB)	XB QUALITY	REFERENCE TRACER CONCEN-TRATION (PPB)	(1) PROBE --LOCATION-- INSERT	ANGLE	FLOW RATE (LB/HR)	ORIFICE PRESSURE DROP (PSI)	XS3 QUALITY OF SAMPLE	TRACER CONCEN-TRATION IN SAMPLE (PPB)	XBT TEST SECTION QUALITY VIA TRACER	QUALITY DIFFERENCE (XBT - XB)
	BULK FLOW CONDITIONS AT PROBE LOCATION					PROBE SAMPLING CONDITIONS							
198	600	0.285	415.6	-0.077	---	14.5	90	2.95	3.105	---	---	---	---
199	600	0.306	458.7	-0.018	---	14.5	90	2.98	3.116	---	---	---	---
200	600	0.306	458.7	-0.018	---	14.5	45	2.96	3.193	---	---	---	---
201	600	0.306	458.7	-0.018	---	14.5	0	2.96	3.185	---	---	---	---
202	600	0.306	458.7	-0.018	---	14.5	-45	2.96	3.210	---	---	---	---
203	600	0.306	458.7	-0.018	---	14.5	-90	2.95	3.201	---	---	---	---
204	600	0.306	458.2	-0.018	1380.	14.5	90	3.02	3.135	---	1450.	---	---
205	600	0.307	543.0	0.097	---	14.5	90	3.06	31.362	---	---	---	---
206	600	0.307	543.0	0.097	---	14.5	45	3.10	25.702	---	---	---	---
207	600	0.307	543.0	0.097	---	14.5	0	3.16	10.709	---	---	---	---
208	600	0.307	543.0	0.097	---	14.5	-45	3.17	3.952	---	---	---	---
209	600	0.307	543.0	0.097	---	14.5	-90	3.18	3.832	---	---	---	---
210	600	0.307	542.6	0.097	740.	14.5	-90	2.94	3.293	0.005	820.	0.102	0.005
211	600	0.307	543.0	0.097	---	8.5	90	3.06	9.788	---	---	---	---
212	600	0.307	543.0	0.097	---	8.5	45	3.02	20.274	---	---	---	---
213	600	0.307	543.0	0.097	---	8.5	0	3.04	19.313	---	---	---	---
214	600	0.307	543.0	0.097	---	8.5	-45	3.05	7.702	---	---	---	---
215	600	0.307	543.0	0.097	---	8.5	-90	3.06	4.325	---	---	---	---
216	600	0.307	544.0	0.099	2060.	8.5	-90	3.00	4.208	0.017	2280.	0.112	0.014
217	600	0.100	462.0	-0.013	---	8.5	90	2.97	2.987	---	---	---	---
218	600	0.100	462.0	-0.013	---	8.5	45	2.98	3.141	---	---	---	---
219	600	0.100	462.0	-0.013	---	8.5	0	2.98	3.150	---	---	---	---
220	600	0.100	462.0	-0.013	---	8.5	-45	2.97	3.149	---	---	---	---
221	600	0.100	462.0	-0.013	---	8.5	-90	2.97	3.129	---	---	---	---
222	600	0.100	460.6	-0.015	1260.	8.5	90	2.90	2.972	---	1210.	---	---
223	600	0.100	528.2	0.077	---	8.5	90	3.03	3.737	---	---	---	---
224	600	0.100	528.2	0.077	---	8.5	45	3.04	4.159	---	---	---	---
225	600	0.100	528.2	0.077	---	8.5	0	3.03	4.852	---	---	---	---
226	600	0.100	528.2	0.077	---	8.5	-45	3.03	4.246	---	---	---	---
227	600	0.100	528.2	0.077	---	8.5	-90	3.03	3.700	---	---	---	---
228	600	0.100	530.8	0.081	2050.	8.5	-90	3.10	3.758	0.006	2190.	0.070	-0.011

(1) See Figure 4 for description.

TABLE 2 (Continued)

SIMULATOR - VERTICAL TUBES
PROBE --- ROW-OF-HOLES

RUN NO.	PRES-SURE (PSIA)	MASS VELOCITY X 10-6 (LB/HR-FTSQ)	ENTHALPY (BTU/LB)	XB QUALITY	REFERENCE TRACER CONCEN-TRATION (PPB)	(1) PROBE --LOCATION-- INSERT	ANGLE	FLOW RATE (LB/HR)	ORIFICE PRESSURE DROP (PSI)	XS3 QUALITY OF SAMPLE	TRACER CONCEN-TRATION IN SAMPLE (PPB)	XBT TEST SECTION QUALITY VIA TRACER	QUALITY DIFFERENCE (XBT - XB)
	BULK FLOW CONDITIONS -------- AT PROBE LOCATION --------				-----------PROBE SAMPLING CONDITIONS-----------								
229	600	0.100	529.0	0.078	---	14.5	90	2.98	3.882	---	---	---	---
230	600	0.100	529.0	0.078	---	14.5	45	2.98	3.794	---	---	---	---
231	600	0.100	529.0	0.078	---	14.5	0	2.98	3.649	---	---	---	---
232	600	0.100	529.0	0.078	---	14.5	-45	2.98	3.346	---	---	---	---
233	600	0.100	529.0	0.078	---	14.5	-90	2.98	3.279	---	---	---	---
234	600	0.100	526.2	0.075	1880.	14.5	-90	2.97	3.316	0.004	1940.	0.035	-0.040
235	600	0.101	525.3	0.073	---	20.5	90	3.02	3.415	---	---	---	---
236	600	0.101	525.3	0.073	---	20.5	45	2.98	3.640	---	---	---	---
237	600	0.101	525.3	0.073	---	20.5	0	2.98	4.192	---	---	---	---
238	600	0.101	525.3	0.073	---	20.5	-45	2.97	3.693	---	---	---	---
239	600	0.101	525.3	0.073	---	20.5	-90	2.97	3.549	---	---	---	---
240	600	0.100	523.7	0.071	1330.	20.5	90	3.07	3.484	0.003	1470.	0.098	0.027
241	600	0.100	460.1	-0.016	---	20.5	90	3.06	3.245	---	---	---	---
242	600	0.100	460.1	-0.016	---	20.5	45	3.07	3.248	---	---	---	---
243	600	0.100	460.1	-0.016	---	20.5	0	3.07	3.281	---	---	---	---
244	600	0.100	460.1	-0.016	---	20.5	-45	3.07	3.283	---	---	---	---
245	600	0.100	460.1	-0.016	---	20.5	-90	3.07	3.258	---	---	---	---
246	600	0.100	466.1	-0.008	1070.	20.5	90	3.01	3.245	---	1080.	---	---
247	600	0.101	922.6	0.616	---	20.5	90	3.07	40.178	---	---	---	---
248	600	0.101	922.6	0.616	---	20.5	45	3.07	36.153	---	---	---	---
249	600	0.101	922.6	0.616	---	20.5	0	2.88	69.052	---	---	---	---
250	600	0.101	922.6	0.616	---	20.5	-45	2.86	68.082	---	---	---	---
251	600	0.101	922.6	0.616	---	20.5	-90	2.71	74.947	---	---	---	---
252	600	0.101	930.5	0.627	1590.	20.5	45	3.07	39.482	0.438	2240.	0.601	-0.025
253	600	0.101	930.1	0.626	---	14.5	90	3.03	60.116	---	---	---	---
254	600	0.101	930.1	0.626	---	14.5	45	3.06	48.823	---	---	---	---
255	600	0.101	930.1	0.626	---	14.5	0	3.13	21.176	---	---	---	---
256	600	0.101	930.1	0.626	---	14.5	-45	3.09	10.619	---	---	---	---
257	600	0.101	930.1	0.626	---	14.5	-90	3.08	16.902	---	---	---	---
258	600	0.101	924.8	0.619	852.	14.5	-45	3.00	10.607	0.118	1516.	0.504	-0.115

(1) See Figure 4 for description.

TABLE 2 (Continued)

SIMULATOR - VERTICAL TUBES
PROBE --- ROW-OF-HOLES

	BULK FLOW CONDITIONS --- AT PROBE LOCATION					PROBE SAMPLING CONDITIONS							
RUN NO.	PRES-SURE (PSIA)	MASS VELOCITY X 10-6 (LB/HR-FTSQ)	ENTHALPY (BTU/LB)	XB QUALITY	REFERENCE TRACER CONCEN-TRATION (PPB)	(1) PROBE --LOCATION-- INSERT	ANGLE	FLOW RATE (LB/HR)	ORIFICE PRESSURE DROP (PSI)	XS3 QUALITY OF SAMPLE	TRACER CONCEN-TRATION IN SAMPLE (PPB)	XBT TEST SECTION QUALITY VIA TRACER	QUALITY DIFFERENCE (XBT - XB)
259	600	0.101	923.5	0.617	---	8.5	90	3.01	59.933	---	---	---	---
260	600	0.101	923.5	0.617	---	8.5	45	3.05	51.870	---	---	---	---
261	600	0.101	923.5	0.617	---	8.5	0	3.02	----	---	---	---	---
262	600	0.101	923.5	0.617	---	8.5	-45	2.94	----	---	---	---	---
263	600	0.101	923.5	0.617	---	8.5	-90	2.97	----	---	---	---	---
264	600	0.101	921.6	0.615	990.	8.5	45	3.03	50.265	0.541	1310.	0.653	0.038
265	600	0.100	457.6	-0.019	---	8.5	90	3.04	2.828	---	---	---	---
266	600	0.100	457.6	-0.019	---	8.5	45	3.04	3.112	---	---	---	---
267	600	0.100	457.6	-0.019	---	8.5	0	3.04	3.133	---	---	---	---
268	600	0.100	457.6	-0.019	---	8.5	-45	3.04	3.158	---	---	---	---
269	600	0.100	457.6	-0.019	---	8.5	-90	3.04	3.133	---	---	---	---
270	600	0.101	460.1	-0.016	256.	8.5	90	3.05	2.898	---	260.	---	---
271	600	0.100	597.1	0.171	---	8.5	90	3.05	3.038	---	---	---	---
272	600	0.100	597.1	0.171	---	8.5	45	3.05	8.037	---	---	---	---
273	600	0.100	597.1	0.171	---	8.5	0	3.05	8.702	---	---	---	---
274	600	0.100	597.1	0.171	---	8.5	-45	3.05	6.208	---	---	---	---
275	600	0.100	597.1	0.171	---	8.5	-90	3.05	3.968	---	---	---	---
276	600	0.101	597.1	0.171	232.	8.5	90	3.06	3.572	0.012	264.	0.132	-0.040
277	600	0.100	601.5	0.177	---	14.5	90	3.09	13.026	---	---	---	---
278	600	0.100	601.5	0.177	---	14.5	45	3.09	9.509	---	---	---	---
279	600	0.100	601.5	0.177	---	14.5	0	3.09	4.756	---	---	---	---
280	600	0.100	601.5	0.177	---	14.5	-45	3.09	3.447	---	---	---	---
281	600	0.100	601.5	0.177	---	14.5	-90	3.09	3.343	---	---	---	---
282	600	0.100	600.7	0.176	190.	14.5	-45	3.07	3.464	0.007	220.	0.143	-0.034
283	600	0.100	742.7	0.370	---	14.5	90	3.06	32.296	---	---	---	---
284	600	0.100	742.7	0.370	---	14.5	45	3.06	24.227	---	---	---	---
285	600	0.100	742.7	0.370	---	14.5	0	3.06	9.489	---	---	---	---
286	600	0.100	742.7	0.370	---	14.5	-45	3.06	4.197	---	---	---	---
287	600	0.100	742.7	0.370	---	14.5	-90	3.06	4.153	---	---	---	---
288	600	0.100	741.2	0.368	188.	14.5	-90	2.94	3.561	0.013	265.	0.308	-0.068

(1) See Figure 4 for description.

TABLE 2 (Continued)

SIMULATOR - VERTICAL TUBES
PROBE --- ROW-OF-HOLES

	BULK FLOW CONDITIONS AT PROBE LOCATION				PROBE SAMPLING CONDITIONS								
RUN NO.	PRES-SURE (PSIA)	MASS VELOCITY X 10-6 (LB/HR-FTSQ)	ENTHALPY (BTU/LB)	XB QUALITY	REFERENCE TRACER CONCEN-TRATION (PPB)	(1) PROBE --LOCATION-- INSERT	ANGLE	FLOW RATE (LB/HR)	ORIFICE PRESSURE DROP (PSI)	XS3 QUALITY OF SAMPLE	TRACER CONCEN-TRATION IN SAMPLE (PPB)	XBT TEST SECTION QUALITY VIA TRACER	QUALITY DIFFERENCE (XBT - XB)
289	600	0.100	739.4	0.366	---	8.5	90	3.06	8.423	---	---	---	---
290	600	0.100	739.4	0.366	---	8.5	45	3.06	20.480	---	---	---	---
291	600	0.100	739.4	0.366	---	8.5	0	3.06	33.948	---	---	---	---
292	600	0.100	739.4	0.366	---	8.5	-45	3.06	25.380	---	---	---	---
293	600	0.100	739.4	0.366	---	8.5	-90	3.06	14.940	---	---	---	---
294	600	0.100	740.6	0.367	181.	8.5	90	3.07	9.716	0.106	217.	0.254	-0.113
295	600	0.053	916.4	0.607	---	8.5	90	3.07	8.913	---	---	---	---
296	600	0.053	916.4	0.607	---	8.5	45	3.07	16.627	---	---	---	---
297	600	0.053	916.4	0.607	---	8.5	0	3.07	32.592	---	---	---	---
298	600	0.053	916.4	0.607	---	8.5	-45	3.07	35.521	---	---	---	---
299	600	0.053	916.4	0.607	---	8.5	-90	3.07	34.858	---	---	---	---
300	600	0.051	935.1	0.633	188.	8.5	90	3.06	7.779	0.077	300.	0.421	-0.212
301	600	0.051	934.4	0.632	---	14.5	90	3.06	21.837	---	---	---	---
302	600	0.051	934.4	0.632	---	14.5	45	3.06	15.669	---	---	---	---
303	600	0.051	934.4	0.632	---	14.5	0	3.06	5.851	---	---	---	---
304	600	0.051	934.4	0.632	---	14.5	-45	3.06	4.365	---	---	---	---
305	600	0.051	934.4	0.632	---	14.5	-90	3.06	4.466	---	---	---	---
306	600	0.051	931.5	0.628	172.	14.5	-45	2.94	3.724	0.014	261.	0.350	-0.278
307	600	0.194	537.9	0.090	---	14.5	90	3.09	21.730	---	---	---	---
308	600	0.194	537.9	0.090	---	14.5	45	3.09	18.105	---	---	---	---
309	600	0.194	537.9	0.090	---	14.5	0	3.09	6.622	---	---	---	---
310	600	0.194	537.9	0.090	---	14.5	-45	3.09	3.579	---	---	---	---
311	600	0.194	537.9	0.090	---	14.5	-90	3.09	3.524	---	---	---	---
312	600	0.194	538.0	0.091	136.	14.5	-90	3.10	3.327	0.001	153.	0.112	0.021
313	600	0.194	537.9	0.091	---	8.5	90	3.17	5.761	---	---	---	---
314	600	0.194	537.9	0.091	---	8.5	45	3.17	12.563	---	---	---	---
315	600	0.194	537.9	0.091	---	8.5	0	3.17	11.490	---	---	---	---
316	600	0.194	537.9	0.091	---	8.5	-45	3.17	5.733	---	---	---	---
317	600	0.194	537.9	0.091	---	8.5	-90	3.17	3.974	---	---	---	---
318	600	0.194	538.3	0.091	221.	8.5	-90	3.11	3.817	0.009	243.	0.098	0.007

(1) See Figure 4 for description.

TABLE 2 (Continued)

SIMULATOR - VERTICAL TUBES
PROBE --- ROW-OF-HOLES

RUN NO.	PRES-SURE (PSIA)	MASS VELOCITY X 10-6 (LB/HR-FTSQ)	ENTHALPY (BTU/LB)	XB QUALITY	REFERENCE TRACER CONCEN-TRATION (PPB)	(1) PROBE --LOCATION-- INSERT	ANGLE	FLOW RATE (LB/HR)	ORIFICE PRESSURE DROP (PSI)	XS3 QUALITY OF SAMPLE	TRACER CONCEN-TRATION IN SAMPLE (PPB)	XBT TEST SECTION QUALITY VIA TRACER	QUALITY DIFFERENCE (XBT - XB)
	BULK FLOW CONDITIONS -------- AT PROBE LOCATION --------					-----------PROBE SAMPLING CONDITIONS-----------							
319	600	0.194	456.0	-0.021	---	14.5	90	3.10	3.151	---	---	---	---
320	600	0.194	456.0	-0.021	---	14.5	45	3.10	3.117	---	---	---	---
321	600	0.194	456.0	-0.021	---	14.5	0	3.10	3.108	---	---	---	---
322	600	0.194	456.0	-0.021	---	14.5	-45	3.10	3.144	---	---	---	---
323	600	0.194	456.0	-0.021	---	14.5	-90	3.10	3.154	---	---	---	---
324	600	0.193	456.4	-0.021	192.	14.5	0	3.10	3.287	---	192.	---	---
325	600	0.194	612.6	0.193	---	14.5	90	3.05	32.857	---	---	---	---
326	600	0.194	612.6	0.193	---	14.5	45	3.05	23.469	---	---	---	---
327	600	0.194	612.6	0.193	---	14.5	0	3.05	9.570	---	---	---	---
328	600	0.194	612.6	0.193	---	14.5	-45	3.05	3.943	---	---	---	---
329	600	0.194	612.6	0.193	---	14.5	-90	3.05	3.742	---	---	---	---
330	600	0.194	611.6	0.191	188.	14.5	-90	3.05	3.706	0.013	221.	0.160	-0.031
331	600	0.194	611.4	0.191	---	8.5	90	3.04	8.770	---	---	---	---
332	600	0.194	611.4	0.191	---	8.5	45	3.04	16.444	---	---	---	---
333	600	0.194	611.4	0.191	---	8.5	0	3.04	29.033	---	---	---	---
334	600	0.194	611.4	0.191	---	8.5	-45	3.04	17.059	---	---	---	---
335	600	0.194	611.4	0.191	---	8.5	-90	3.04	8.396	---	---	---	---
336	600	0.195	610.6	0.190	157.	8.5	-90	3.04	8.412	0.093	205.	0.261	0.071
337	600	0.193	612.9	0.193	---	2.5	90	3.05	10.334	---	---	---	---
338	600	0.193	612.9	0.193	---	2.5	45	3.05	7.600	---	---	---	---
339	600	0.193	612.9	0.193	---	2.5	0	3.05	4.947	---	---	---	---
340	600	0.193	612.9	0.193	---	2.5	-45	3.05	4.310	---	---	---	---
341	600	0.193	612.9	0.193	---	2.5	-90	3.05	3.781	---	---	---	---
342	600	0.193	611.8	0.191	156.	2.5	-90	3.05	3.779	0.014	197.	0.219	0.028
343	600	0.194	610.2	0.189	---	20.5	90	3.04	30.618	---	---	---	---
344	600	0.194	610.2	0.189	---	20.5	45	3.04	67.239	---	---	---	---
345	600	0.194	610.2	0.189	---	20.5	0	3.04	52.456	---	---	---	---
346	600	0.194	610.2	0.189	---	20.5	-45	3.04	22.043	---	---	---	---
347	600	0.194	610.2	0.189	---	20.5	-90	3.04	11.711	---	---	---	---
348	600	0.194	610.6	0.190	148.	20.5	-90	3.05	6.918	0.068	182.	0.242	0.052

(1) See Figure 4 for description.

TABLE 2 (Continued)

SIMULATOR - VERTICAL TUBES
PROBE --- ROW-OF-HOLES

	BULK FLOW CONDITIONS --------- AT PROBE LOCATION --------				------------PROBE SAMPLING CONDITIONS------------								
RUN NO.	PRES-SURE (PSIA)	MASS VELOCITY X 10-6 (LB/HR-FTSQ)	ENTHALPY (BTU/LB)	XB QUALITY	REFERENCE TRACER CONCEN-TRATION (PPB)	(1) PROBE --LOCATION-- INSERT	ANGLE	FLOW RATE (LB/HR)	ORIFICE PRESSURE DROP (PSI)	XS3 QUALITY OF SAMPLE	TRACER CONCEN-TRATION IN SAMPLE (PPB)	XBT TEST SECTION QUALITY VIA TRACER	QUALITY DIFFERENCE (XBT - XB)
349	600	0.193	611.5	0.191	---	26.5	90	3.05	3.929	---	---	---	---
350	600	0.193	611.5	0.191	---	26.5	45	3.05	3.995	---	---	---	---
351	600	0.193	611.5	0.191	---	26.5	0	3.05	8.593	---	---	---	---
352	600	0.193	611.5	0.191	---	26.5	-45	3.05	10.024	---	---	---	---
353	600	0.193	611.5	0.191	---	26.5	-90	3.05	6.070	---	---	---	---
354	600	0.193	611.7	0.191	139.	26.5	90	3.06	4.141	0.020	169.	0.194	0.003
355	600	0.195	761.9	0.396	---	14.5	90	3.05	43.252	---	---	---	---
356	600	0.195	761.9	0.396	---	14.5	45	3.05	36.665	---	---	---	---
357	600	0.195	761.9	0.396	---	14.5	0	3.05	15.945	---	---	---	---
358	600	0.195	761.9	0.396	---	14.5	-45	3.05	5.525	---	---	---	---
359	600	0.195	761.9	0.396	---	14.5	-90	3.05	5.518	---	---	---	---
360	600	0.195	761.7	0.396	225.	14.5	-90	3.05	5.681	0.047	339.	0.368	-0.029
361	600	0.195	760.7	0.395	---	8.5	90	3.04	27.067	---	---	---	---
362	600	0.195	760.7	0.395	---	8.5	45	3.04	25.882	---	---	---	---
363	600	0.195	760.7	0.395	---	8.5	0	3.04	57.661	---	---	---	---
364	600	0.195	760.7	0.395	---	8.5	-45	3.04	50.907	---	---	---	---
365	600	0.195	760.7	0.395	---	8.5	-90	3.04	40.057	---	---	---	---
366	600	0.196	759.4	0.393	209.	8.5	45	3.04	23.223	0.303	270.	0.460	0.067
367	600	0.192	456.8	-0.020	196.	8.5	90	3.04	2.917	---	199.	---	---
368	1200	0.190	499.2	-0.119	191.	8.5	90	3.06	3.053	---	188.	---	---
369	1200	0.197	427.5	-0.236	187.	08.5	90	3.06	2.699	---	187.	---	---

(1) See Figure 4 for description.

TABLE 3. Horizontal Tube Simulator Test Results

SIMULATOR - HORIZONTAL TUBES
PROBE --- ROW-OF-HOLES

	BULK FLOW CONDITIONS --- AT PROBE LOCATION ---					PROBE SAMPLING CONDITIONS							
RUN NO.	PRESSURE (PSIA)	MASS VELOCITY X 10-6 (LB/HR-FTSQ)	ENTHALPY (BTU/LB)	XB QUALITY	REFERENCE TRACER CONCENTRATION (PPB)	(1) PROBE --LOCATION-- INSERT	ANGLE	FLOW RATE (LB/HR)	ORIFICE PRESSURE DROP (PSI)	XS2 QUALITY OF SAMPLE	TRACER CONCENTRATION IN SAMPLE (PPB)	XBT TEST SECTION QUALITY VIA TRACER	QUALITY DIFFERENCE (XBT - XB)
1	1200	0.419	412.8	-0.260	229.	22.5	-90	2.97	2.306	0.000	232.	0.013	0.272
2	1200	0.425	492.3	-0.130	225.	22.5	-90	2.97	2.395	0.000	231.	0.026	0.156
3	1200	0.050	498.0	-0.120	220.	22.5	-90	1.97	1.215	0.005	225.	0.027	0.147
4	1200	0.050	487.1	-0.138	226.	22.5	-90	2.98	-0.001	0.000	225.	-0.004	0.134
5	1200	0.050	495.1	-0.125	215.	22.5	-90	4.87	6.388	0.000	225.	0.044	0.170
6	1200	0.050	416.1	-0.254	208.	22.5	-90	4.87	6.650	0.000	208.	0.000	0.254
7	1200	0.050	416.8	-0.253	208.	22.5	-90	2.97	2.257	0.000	210.	0.010	0.263
8	1200	0.050	415.4	-0.255	200.	22.5	-90	1.96	1.141	0.000	195.	-0.026	0.230
9	600	0.051	459.8	-0.016	172.	22.5	-90	1.95	1.166	0.000	175.	0.017	0.033
10	600	0.051	459.2	-0.017	179.	22.5	-90	2.96	2.277	0.000	181.	0.011	0.028
11	600	0.051	459.5	-0.017	183.	22.5	-90	4.54	10.922	0.000	187.	0.021	0.038
12	600	0.050	519.8	0.066	---	22.5	90	2.96	2.623	---	---	---	---
13	600	0.050	519.8	0.066	---	22.5	45	2.96	2.721	---	---	---	---
14	600	0.050	519.8	0.066	---	22.5	0	2.96	2.761	---	---	---	---
15	600	0.050	519.8	0.066	---	22.5	-45	2.96	2.690	---	---	---	---
16	600	0.050	519.8	0.066	---	22.5	-90	2.96	2.651	---	---	---	---
17	600	0.050	520.1	0.066	172.	22.5	90	2.96	2.648	0.006	187.	0.085	0.019
18	600	0.050	519.9	0.066	---	15.5	90	2.96	2.582	---	---	---	---
19	600	0.050	519.9	0.066	---	15.5	45	2.96	2.562	---	---	---	---
20	600	0.050	519.9	0.066	---	15.5	0	2.96	2.581	---	---	---	---
21	600	0.050	519.9	0.066	---	15.5	-45	2.96	2.563	---	---	---	---
22	600	0.050	519.9	0.066	---	15.5	-90	2.96	2.555	---	---	---	---
23	600	0.050	520.2	0.066	170.	15.5	-90	2.96	2.405	-0.000	173.	0.017	-0.049

(1) See Figure 5 for description.

TABLE 3 (Continued)

SIMULATOR - HORIZONTAL TUBES
PROBE --- ROW-OF-HOLES

RUN NO.	PRESSURE (PSIA)	MASS VELOCITY X 10-6 (LB/HR-FTSQ)	ENTHALPY (BTU/LB)	XB QUALITY	REFERENCE TRACER CONCENTRATION (PPB)	(1) PROBE --LOCATION-- INSERT	ANGLE	FLOW RATE (LB/HR)	ORIFICE PRESSURE DROP (PSI)	XS2 QUALITY OF SAMPLE	TRACER CONCENTRATION IN SAMPLE (PPB)	XBT TEST SECTION QUALITY VIA TRACER	QUALITY DIFFERENCE (XBT - XB)
	BULK FLOW CONDITIONS	-------- AT PROBE LOCATION --------				-----------PROBE SAMPLING CONDITIONS-----------							
24	600	0.050	601.0	0.177	---	15.5	90	2.96	2.270	---	---	---	---
25	600	0.050	601.0	0.177	---	15.5	45	2.96	2.602	---	---	---	---
26	600	0.050	601.0	0.177	---	15.5	0	2.96	2.566	---	---	---	---
27	600	0.050	601.0	0.177	---	15.5	-45	2.96	2.585	---	---	---	---
28	600	0.050	601.0	0.177	---	15.5	-90	2.96	2.637	---	---	---	---
29	600	0.050	601.6	0.177	270.	15.5	90	2.96	2.520	0.002	320.	0.158	-0.019
30	600	0.050	606.5	0.184	---	22.5	90	2.95	2.899	---	---	---	---
31	600	0.050	606.5	0.184	---	22.5	45	2.95	2.967	---	---	---	---
32	600	0.050	606.5	0.184	---	22.5	0	2.95	3.531	---	---	---	---
33	600	0.050	606.5	0.184	---	22.5	-45	2.95	3.088	---	---	---	---
34	600	0.050	606.5	0.184	---	22.5	-90	2.95	2.982	---	---	---	---
35	600	0.050	606.7	0.184	262.	22.5	-90	2.95	2.802	0.009	307.	0.154	-0.030
36	600	0.051	685.5	0.292	---	22.5	90	2.95	2.991	---	---	---	---
37	600	0.051	685.5	0.292	---	22.5	45	2.95	4.092	---	---	---	---
38	600	0.051	685.5	0.292	---	22.5	0	2.95	5.070	---	---	---	---
39	600	0.051	685.5	0.292	---	22.5	-45	2.95	4.363	---	---	---	---
40	600	0.051	685.5	0.292	---	22.5	-90	2.95	3.977	---	---	---	---
41	600	0.050	685.7	0.292	247.	22.5	90	2.95	3.306	0.020	320.	0.244	-0.049
42	600	0.050	685.5	0.292	---	15.5	90	2.95	2.486	---	---	---	---
43	600	0.050	685.5	0.292	---	15.5	45	2.95	2.515	---	---	---	---
44	600	0.050	685.5	0.292	---	15.5	0	2.95	2.532	---	---	---	---
45	600	0.050	685.5	0.292	---	15.5	-45	2.95	2.602	---	---	---	---
46	600	0.050	685.5	0.292	---	15.5	-90	2.95	2.610	---	---	---	---
47	600	0.050	685.3	0.292	240.	15.5	90	2.95	2.513	0.003	310.	0.228	-0.064
48	600	0.050	770.8	0.409	---	15.5	90	2.95	2.187	---	---	---	---
49	600	0.050	770.8	0.409	---	15.5	45	2.95	2.007	---	---	---	---
50	600	0.050	770.8	0.409	---	15.5	0	2.95	2.042	---	---	---	---
51	600	0.050	770.8	0.409	---	15.5	-45	2.95	2.045	---	---	---	---
52	600	0.050	770.8	0.409	---	15.5	-90	2.95	2.078	---	---	---	---
53	600	0.050	772.5	0.411	230.	15.5	45	2.95	2.494	0.002	346.	0.336	-0.074

(1) See Figure 5 for description.

TABLE 3 (Continued)

SIMULATOR - HORIZONTAL TUBES

PROBE ---- ROW-OF-HOLES

	BULK FLOW CONDITIONS ---------- AT PROBE LOCATION ----------					------------PROBE SAMPLING CONDITIONS------------								
RUN NO.	PRESSURE (PSIA)	MASS VELOCITY X 10-6 (LB/HR-FTSQ)	ENTHALPY (BTU/LB)	XB QUALITY	REFERENCE TRACER CONCENTRATION (PPB)	PROBE (1) --LOCATION-- INSERT	ANGLE	FLOW RATE (LB/HR)	ORIFICE PRESSURE DROP (PSI)	XS2 QUALITY OF SAMPLE	TRACER CONCENTRATION IN SAMPLE (PPB)	XBT TEST SECTION QUALITY VIA TRACER	QUALITY DIFFERENCE (XBT - XB)
54	600	0.050	773.4	0.412	---	22.5	90	2.95	3.988	---	---	---	---
55	600	0.050	773.4	0.412	---	22.5	45	3.59	6.742	---	---	---	---
56	600	0.050	773.4	0.412	---	22.5	0	2.95	11.626	---	---	---	---
57	600	0.050	773.4	0.412	---	22.5	-45	2.95	8.666	---	---	---	---
58	600	0.050	773.4	0.412	---	22.5	-90	2.95	6.070	---	---	---	---
59	600	0.050	775.1	0.415	227.	22.5	90	2.96	4.187	0.038	333.	0.344	-0.070
60	600	0.051	460.9	-0.015	---	22.5	90	2.95	2.609	---	---	---	---
61	600	0.051	460.9	-0.015	---	22.5	45	2.95	2.615	---	---	---	---
62	600	0.051	460.9	-0.015	---	22.5	0	2.95	2.612	---	---	---	---
63	600	0.051	460.9	-0.015	---	22.5	-45	2.95	2.607	---	---	---	---
64	600	0.051	460.9	-0.015	---	22.5	-90	2.95	2.603	---	---	---	---
65	600	0.051	460.7	-0.015	203.	22.5	-90	2.95	2.440	0.000	205.	0.010	-0.025
66	600	0.050	859.5	0.530	---	02.0	90	2.95	2.583	---	---	---	---
67	600	0.050	859.5	0.530	---	02.0	45	2.95	2.993	---	---	---	---
68	600	0.050	859.5	0.530	---	02.0	0	2.95	3.906	---	---	---	---
69	600	0.050	859.5	0.530	---	02.0	-45	2.95	6.626	---	---	---	---
70	600	0.050	859.5	0.530	---	02.0	-90	2.95	9.454	---	---	---	---
71	600	0.050	858.1	0.528	201.	2.0	90	2.95	2.672	0.006	355.	0.437	-0.091
72	600	0.050	855.1	0.524	---	09.0	90	2.95	7.181	---	---	---	---
73	600	0.050	855.1	0.524	---	09.0	45	2.95	15.499	---	---	---	---
74	600	0.050	855.1	0.524	---	09.0	0	2.95	20.016	---	---	---	---
75	600	0.050	855.1	0.524	---	09.0	-45	2.95	15.629	---	---	---	---
76	600	0.050	855.1	0.524	---	09.0	-90	2.95	13.636	---	---	---	---
77	600	0.050	856.5	0.526	300.	09.0	90	2.95	7.687	0.107	455.	0.411	-0.114
78	600	0.050	855.9	0.525	---	15.5	90	2.94	2.815	---	---	---	---
79	600	0.050	855.9	0.525	---	15.5	45	2.94	3.131	---	---	---	---
80	600	0.050	855.9	0.525	---	15.5	0	2.94	3.148	---	---	---	---
81	600	0.050	855.9	0.525	---	15.5	-45	2.94	3.343	---	---	---	---
82	600	0.050	855.9	0.525	---	15.5	-90	2.94	4.878	---	---	---	---
83	600	0.050	854.4	0.523	270.	15.5	90	2.94	2.581	0.003	440.	0.388	-0.135

(1) See Figure 5 for description.

TABLE 3 (Continued)

SIMULATOR - HORIZONTAL TUBES
PROBE --- ROW-OF-HOLES

RUN NO.	PRES-SURE (PSIA)	MASS VELOCITY X 10-6 (LB/HR-FTSQ)	ENTHALPY (BTU/LB)	XB QUALITY	REFERENCE TRACER CONCEN-TRATION (PPB)	(1) PROBE --LOCATION-- INSERT	ANGLE	FLOW RATE (LB/HR)	ORIFICE PRESSURE DROP (PSI)	XS2 QUALITY OF SAMPLE	TRACER CONCEN-TRATION IN SAMPLE (PPB)	XBT TEST SECTION QUALITY VIA TRACER	QUALITY DIFFERENCE (XBT - XB)
	BULK FLOW CONDITIONS --------- AT PROBE LOCATION --------					------------PROBE SAMPLING CONDITIONS------------							
84	600	0.050	853.7	0.522	---	22.5	90	2.94	4.929	---	---	---	---
85	600	0.050	853.7	0.522	---	22.5	45	2.94	13.189	---	---	---	---
86	600	0.050	853.7	0.522	---	22.5	0	2.94	17.470	---	---	---	---
87	600	0.050	853.7	0.522	---	22.5	-45	2.94	12.876	---	---	---	---
88	600	0.050	853.7	0.522	---	22.5	-90	2.94	11.031	---	---	---	---
89	600	0.050	855.0	0.524	250.	22.5	90	2.94	6.452	0.083	405.	0.434	-0.089
90	600	0.050	857.0	0.525	---	29.5	90	2.95	2.455	---	---	---	---
91	600	0.050	857.0	0.525	---	29.5	45	2.95	2.924	---	---	---	---
92	600	0.050	857.0	0.525	---	29.5	0	2.95	3.080	---	---	---	---
93	600	0.050	857.0	0.525	---	29.5	-45	2.95	3.359	---	---	---	---
94	600	0.050	857.0	0.525	---	29.5	-90	2.95	4.281	---	---	---	---
95	600	0.050	857.9	0.527	205.	29.5	90	2.94	2.636	0.004	367.	0.443	-0.084
96	600	0.050	864.9	0.537	---	36.0	90	2.95	6.488	---	---	---	---
97	600	0.050	864.9	0.537	---	36.0	45	2.95	16.387	---	---	---	---
98	600	0.050	864.9	0.537	---	36.0	0	2.95	22.650	---	---	---	---
99	600	0.050	864.9	0.537	---	36.0	-45	2.95	14.370	---	---	---	---
100	600	0.050	864.9	0.537	---	36.0	-90	2.95	13.423	---	---	---	---
101	600	0.050	863.8	0.536	200.	36.0	90	2.95	6.566	0.084	327.	0.440	-0.096
102	600	0.050	860.0	0.530	---	43.0	90	2.95	2.218	---	---	---	---
103	600	0.050	860.0	0.530	---	43.0	45	2.95	2.792	---	---	---	---
104	600	0.050	860.0	0.530	---	43.0	0	2.95	3.159	---	---	---	---
105	600	0.050	860.0	0.530	---	43.0	-45	2.95	3.013	---	---	---	---
106	600	0.050	860.0	0.530	---	43.0	-90	2.95	4.641	---	---	---	---
107	600	0.050	862.1	0.533	190.	43.0	90	2.95	2.825	0.007	330.	0.428	-0.105
108	600	0.050	456.2	-0.021	---	22.5	90	2.95	2.366	---	---	---	---
109	600	0.050	456.2	-0.021	---	22.5	45	2.95	2.671	---	---	---	---
110	600	0.050	456.2	-0.021	---	22.5	0	2.95	2.670	---	---	---	---
111	600	0.050	456.2	-0.021	---	22.5	-45	2.95	2.656	---	---	---	---
112	600	0.050	456.2	-0.021	---	22.5	-90	2.95	2.555	---	---	---	---
113	600	0.050	455.9	-0.022	182.	22.5	90	2.94	2.503	0.000	180.	-0.011	0.010

(1) See Figure 5 for description.

TABLE 3 (Continued)

SIMULATOR - HORIZONTAL TUBES
PROBE --- ROW-OF-HOLES

	BULK FLOW CONDITIONS AT PROBE LOCATION					PROBE SAMPLING CONDITIONS							
RUN NO.	PRESSURE (PSIA)	MASS VELOCITY x 10-6 (LB/HR-FTSQ)	ENTHALPY (BTU/LB)	XB QUALITY	REFERENCE TRACER CONCENTRATION (PPB)	PROBE LOCATION(1) INSERT	PROBE LOCATION(1) ANGLE	FLOW RATE (LB/HR)	ORIFICE PRESSURE DROP (PSI)	XS2 QUALITY OF SAMPLE	TRACER CONCENTRATION IN SAMPLE (PPB)	XBT TEST SECTION QUALITY VIA TRACER	QUALITY DIFFERENCE (XBT - XB)
114	600	0.050	959.3	0.666	---	22.5	90	2.95	14.875	---	---	---	---
115	600	0.050	959.3	0.666	---	22.5	45	2.95	35.998	---	---	---	---
116	600	0.050	959.3	0.666	---	22.5	0	2.95	34.875	---	---	---	---
117	600	0.050	959.3	0.666	---	22.5	-45	2.95	33.624	---	---	---	---
118	600	0.050	959.3	0.666	---	22.5	-90	2.95	34.954	---	---	---	---
119	600	0.050	956.1	0.662	185.	22.5	90	2.95	18.007	0.283	305.	0.565	-0.097
120	600	0.051	953.2	0.658	---	22.5	90	1.95	3.649	---	---	---	---
121	600	0.051	953.2	0.658	---	22.5	45	1.95	7.351	---	---	---	---
122	600	0.051	953.2	0.658	---	22.5	0	1.95	10.081	---	---	---	---
123	600	0.051	953.2	0.658	---	22.5	-45	1.95	8.851	---	---	---	---
124	600	0.051	953.2	0.658	---	22.5	-90	1.95	8.273	---	---	---	---
125	600	0.050	959.3	0.666	280.	22.5	90	1.95	3.501	0.111	533.	0.533	-0.133
126	600	0.050	956.8	0.663	---	15.5	90	1.95	1.716	---	---	---	---
127	600	0.050	956.8	0.663	---	15.5	45	1.95	2.137	---	---	---	---
128	600	0.050	956.8	0.663	---	15.5	0	1.95	2.211	---	---	---	---
129	600	0.050	956.8	0.663	---	15.5	-45	1.95	2.417	---	---	---	---
130	600	0.050	956.8	0.663	---	15.5	-90	1.95	4.157	---	---	---	---
131	600	0.050	943.3	0.644	255.	15.5	90	1.95	1.654	0.027	505.	0.509	-0.136
132	600	0.050	944.1	0.645	---	15.5	90	2.95	3.328	---	---	---	---
133	600	0.050	944.1	0.645	---	15.5	45	2.95	4.050	---	---	---	---
134	600	0.050	944.1	0.645	---	15.5	0	2.95	5.716	---	---	---	---
135	600	0.050	944.1	0.645	---	15.5	-45	2.95	5.741	---	---	---	---
136	600	0.050	944.1	0.645	---	15.5	-90	2.95	10.524	---	---	---	---
137	600	0.050	942.0	0.642	235.	15.5	90	2.95	3.392	0.019	445.	0.482	-0.161
138	600	0.050	692.4	0.301	---	15.5	90	2.95	2.639	---	---	---	---
139	600	0.050	692.4	0.301	---	15.5	45	2.95	2.635	---	---	---	---
140	600	0.050	692.4	0.301	---	15.5	0	2.95	2.706	---	---	---	---
141	600	0.050	692.4	0.301	---	15.5	-45	2.95	2.664	---	---	---	---
142	600	0.050	692.4	0.301	---	15.5	-90	2.95	2.775	---	---	---	---
143	600	0.050	692.9	0.302	225.	15.5	45	2.94	2.698	0.004	290.	0.227	-0.075

(1) See Figure 5 for description.

TABLE 3 (Continued)

SIMULATOR - HORIZONTAL TUBES
PROBE --- ROW-OF-HOLES

	BULK FLOW CONDITIONS AT PROBE LOCATION				PROBE SAMPLING CONDITIONS								
RUN NO.	PRESSURE (PSIA)	MASS VELOCITY X 10-6 (LB/HR-FTSQ)	ENTHALPY (BTU/LB)	XB QUALITY	REFERENCE TRACER CONCENTRATION (PPB)	(1) PROBE LOCATION INSERT	(1) PROBE LOCATION ANGLE	FLOW RATE (LB/HR)	ORIFICE PRESSURE DROP (PSI)	XS2 QUALITY OF SAMPLE	TRACER CONCENTRATION IN SAMPLE (PPB)	XBT TEST SECTION QUALITY VIA TRACER	QUALITY DIFFERENCE (XBT - XB)
144	600	0.050	692.1	0.301	---	22.5	90	2.94	3.381	---	---	---	---
145	600	0.050	692.1	0.301	---	22.5	45	2.94	5.267	---	---	---	---
146	600	0.050	692.1	0.301	---	22.5	0	2.94	6.219	---	---	---	---
147	600	0.050	692.1	0.301	---	22.5	-45	2.94	5.337	---	---	---	---
148	600	0.050	692.1	0.301	---	22.5	-90	2.94	4.171	---	---	---	---
149	600	0.050	690.6	0.299	215.	22.5	90	2.94	3.372	0.018	280.	0.246	-0.053
150	600	0.050	963.3	0.671	---	22.5	90	1.94	4.017	---	---	---	---
151	600	0.050	963.3	0.671	---	22.5	45	1.94	8.330	---	---	---	---
152	600	0.050	963.3	0.671	---	22.5	0	1.94	12.199	---	---	---	---
153	600	0.050	963.3	0.671	---	22.5	-45	1.94	8.873	---	---	---	---
154	600	0.050	963.3	0.671	---	22.5	-90	1.94	9.069	---	---	---	---
155	600	0.050	959.6	0.665	200.	22.5	90	1.95	4.186	0.138	380.	0.546	-0.120
156	600	0.050	960.2	0.667	---	15.5	90	1.95	1.770	---	---	---	---
157	600	0.050	960.2	0.667	---	15.5	45	1.95	1.890	---	---	---	---
158	600	0.050	960.2	0.667	---	15.5	0	1.95	2.392	---	---	---	---
159	600	0.050	960.2	0.667	---	15.5	-45	1.95	2.545	---	---	---	---
160	600	0.050	960.2	0.667	---	15.5	-90	1.95	3.667	---	---	---	---
161	600	0.051	954.0	0.659	190.	15.5	90	1.95	1.811	0.033	395.	0.535	-0.124
162	600	0.149	455.2	-0.023	---	15.5	90	2.95	2.539	---	---	---	---
163	600	0.149	455.2	-0.023	---	15.5	45	2.95	2.790	---	---	---	---
164	600	0.149	455.2	-0.023	---	15.5	0	2.95	2.618	---	---	---	---
165	600	0.149	455.2	-0.023	---	15.5	-45	2.95	2.608	---	---	---	---
166	600	0.149	455.2	-0.023	---	15.5	-90	2.95	2.545	---	---	---	---
167	600	0.148	455.2	-0.022	207.	15.5	90	2.95	2.456	0.000	210.	0.014	0.037
168	600	0.149	533.0	0.083	---	15.5	90	2.94	2.648	---	---	---	---
169	600	0.149	533.0	0.083	---	15.5	45	2.94	2.668	---	---	---	---
170	600	0.149	533.0	0.083	---	15.5	0	2.94	2.740	---	---	---	---
171	600	0.149	533.0	0.083	---	15.5	-45	2.94	2.726	---	---	---	---
172	600	0.149	533.0	0.083	---	15.5	-90	2.94	2.696	---	---	---	---
173	600	0.149	531.6	0.082	217.	15.5	90	2.94	2.693	0.003	232.	0.068	-0.014

(1) See Figure 5 for description.

TABLE 3 (Continued)

SIMULATOR - HORIZONTAL TUBES
PROBE --- ROW-OF-HOLES

	BULK FLOW CONDITIONS --- AT PROBE LOCATION ---					PROBE SAMPLING CONDITIONS								
RUN NO.	PRESSURE (PSIA)	MASS VELOCITY X 10-6 (LB/HR-FTSQ)	ENTHALPY (BTU/LB)	XB QUALITY	REFERENCE TRACER CONCENTRATION (PPB)	(1) PROBE --LOCATION-- INSERT	ANGLE	FLOW RATE (LB/HR)	ORIFICE PRESSURE DROP (PSI)	XS2 QUALITY OF SAMPLE	TRACER CONCENTRATION IN SAMPLE (PPB)	XBT TEST SECTION QUALITY VIA TRACER	QUALITY DIFFERENCE (XBT - XB)
174	600	0.149	531.9	0.082	---	22.5	90	2.94	2.725	---	---	---	---
175	600	0.149	531.9	0.082	---	22.5	45	2.94	2.900	---	---	---	---
176	600	0.149	531.9	0.082	---	22.5	0	2.94	3.666	---	---	---	---
177	600	0.149	531.9	0.082	---	22.5	-45	2.94	3.064	---	---	---	---
178	600	0.149	531.9	0.082	---	22.5	-90	2.94	2.735	---	---	---	---
179	600	0.149	535.5	0.087	217.	22.5	90	2.94	2.939	0.010	227.	0.054	-0.034
180	600	0.150	623.3	0.207	---	22.5	90	2.95	14.382	---	---	---	---
181	600	0.150	623.3	0.207	---	22.5	45	2.95	22.007	---	---	---	---
182	600	0.150	623.3	0.207	---	22.5	0	2.95	40.427	---	---	---	---
183	600	0.150	623.3	0.207	---	22.5	-45	2.95	21.280	---	---	---	---
184	600	0.150	623.3	0.207	---	22.5	-90	2.95	14.808	---	---	---	---
185	600	0.149	622.7	0.206	215.	22.5	90	2.94	3.615	0.023	265.	0.207	0.001
186	600	0.146	628.0	0.214	---	15.5	90	2.95	2.425	---	---	---	---
187	600	0.146	628.0	0.214	---	15.5	45	2.95	2.696	---	---	---	---
188	600	0.146	628.0	0.214	---	15.5	0	2.95	8.040	---	---	---	---
189	600	0.146	628.0	0.214	---	15.5	-45	2.95	8.884	---	---	---	---
190	600	0.146	628.0	0.214	---	15.5	-90	2.95	----	---	---	---	---
191	600	0.150	623.6	0.209	215.	15.5	90	2.95	2.583	0.000	263.	0.183	-0.025
192	600	0.144	722.3	0.342	---	15.5	90	2.95	2.702	---	---	---	---
193	600	0.144	722.3	0.342	---	15.5	45	2.95	7.157	---	---	---	---
194	600	0.144	722.3	0.342	---	15.5	0	2.95	18.220	---	---	---	---
195	600	0.144	722.3	0.342	---	15.5	-45	2.95	22.852	---	---	---	---
196	600	0.144	722.3	0.342	---	15.5	-90	2.95	26.527	---	---	---	---
197	600	0.144	722.8	0.343	203.	15.5	90	2.94	2.700	0.003	300.	0.325	-0.018
198	600	0.144	718.4	0.337	---	22.5	90	2.94	7.477	---	---	---	---
199	600	0.144	718.4	0.337	---	22.5	45	2.94	26.266	---	---	---	---
200	600	0.144	718.4	0.337	---	22.5	0	2.94	30.257	---	---	---	---
201	600	0.144	718.4	0.337	---	22.5	-45	2.94	18.858	---	---	---	---
202	600	0.144	718.4	0.337	---	22.5	-90	2.94	14.265	---	---	---	---
203	600	0.143	717.0	0.335	197.	22.5	90	2.95	8.588	0.117	270.	0.356	0.021

(1) See Figure 5 for description.

TABLE 3 (Continued)

SIMULATOR - HORIZONTAL TUBES
PROBE --- ROW-OF-HOLES

RUN NO.	PRES-SURE (PSIA)	MASS VELOCITY X 10-6 (LB/HR-FTSQ)	ENTHALPY (BTU/LB)	XB QUALITY	REFERENCE TRACER CONCEN-TRATION (PPB)
	BULK FLOW CONDITIONS -------- AT PROBE LOCATION --------				
204	600	0.144	758.1	0.391	---
205	600	0.144	758.1	0.391	---
206	600	0.144	758.1	0.391	---
207	600	0.144	758.1	0.391	---
208	600	0.144	758.1	0.391	---
209	600	0.144	755.1	0.387	194.
210	600	0.152	779.9	0.421	---
211	600	0.152	779.9	0.421	---
212	600	0.152	779.9	0.421	---
213	600	0.152	779.9	0.421	---
214	600	0.152	779.9	0.421	---
215	600	0.152	778.0	0.418	189.
216	600	0.152	778.2	0.419	---
217	600	0.152	778.2	0.419	---
218	600	0.152	778.2	0.419	---
219	600	0.152	778.2	0.419	---
220	600	0.152	778.2	0.419	---
221	600	0.152	778.6	0.419	177.
222	600	0.152	777.1	0.417	---
223	600	0.152	777.1	0.417	---
224	600	0.152	777.1	0.417	---
225	600	0.152	777.1	0.417	---
226	600	0.152	777.1	0.417	---
227	600	0.145	796.6	0.444	168.
228	600	0.145	796.2	0.443	---
229	600	0.145	796.2	0.443	---
230	600	0.145	796.2	0.443	---
231	600	0.145	796.2	0.443	---
232	600	0.145	796.2	0.443	---
233	600	0.146	796.1	0.443	156.

RUN NO.	(1) PROBE --LOCATION-- INSERT	ANGLE	FLOW RATE (LB/HR)	ORIFICE PRESSURE DROP (PSI)	XS2 QUALITY OF SAMPLE	TRACER CONCEN-TRATION IN SAMPLE (PPB)	XBT TEST SECTION QUALITY VIA TRACER	QUALITY DIFFERENCE (XBT - XB)
	-----------PROBE SAMPLING CONDITIONS-----------							
204	02.0	90	2.95	3.098	---	---	---	---
205	02.0	45	2.95	8.347	---	---	---	---
206	02.0	0	2.95	20.852	---	---	---	---
207	02.0	-45	2.95	26.473	---	---	---	---
208	02.0	-90	2.95	32.584	---	---	---	---
209	02.0	90	2.95	3.256	0.014	300.	0.362	-0.025
210	09.0	90	2.95	12.019	---	---	---	---
211	09.0	45	2.95	29.177	---	---	---	---
212	09.0	0	2.95	31.506	---	---	---	---
213	09.0	-45	2.95	19.013	---	---	---	---
214	09.0	-90	2.95	19.142	---	---	---	---
215	9.0	90	2.95	10.456	0.165	274.	0.410	-0.008
216	15.5	90	2.95	2.665	---	---	---	---
217	15.5	45	2.95	12.697	---	---	---	---
218	15.5	0	2.95	29.784	---	---	---	---
219	15.5	-45	2.95	32.707	---	---	---	---
220	15.5	-90	2.95	37.769	---	---	---	---
221	15.5	90	2.95	3.143	0.010	287.	0.389	-0.030
222	22.5	90	2.95	13.616	---	---	---	---
223	22.5	45	2.95	34.788	---	---	---	---
224	22.5	0	2.95	38.282	---	---	---	---
225	22.5	-45	2.95	27.141	---	---	---	---
226	22.5	-90	2.95	20.345	---	---	---	---
227	22.5	90	2.95	14.326	0.224	241.	0.459	0.015
228	29.5	90	2.95	3.229	---	---	---	---
229	29.5	45	2.95	17.031	---	---	---	---
230	29.5	0	2.95	32.683	---	---	---	---
231	29.5	-45	2.95	38.544	---	---	---	---
232	29.5	-90	2.95	40.345	---	---	---	---
233	29.5	90	2.95	3.087	0.009	269.	0.425	-0.018

(1) See Figure 5 for description.

TABLE 3 (Continued)

SIMULATOR - HORIZONTAL TUBES
PROBE --- ROW-OF-HOLES

RUN NO.	PRES-SURE (PSIA)	MASS VELOCITY x 10-6 (LB/HR-FTSQ)	ENTHALPY (BTU/LB)	XB QUALITY	REFERENCE TRACER CONCEN-TRATION (PPB)	(1) PROBE --LOCATION-- INSERT	ANGLE	FLOW RATE (LB/HR)	ORIFICE PRESSURE DROP (PSI)	XS2 QUALITY OF SAMPLE	TRACER CONCEN-TRATION IN SAMPLE (PPB)	XBT TEST SECTION QUALITY VIA TRACER	QUALITY DIFFERENCE (XBT - XB)
	BULK FLOW CONDITIONS AT PROBE LOCATION					PROBE SAMPLING CONDITIONS							
234	600	0.147	790.7	0.435	---	36.0	90	2.96	10.343	---	---	---	---
235	600	0.147	790.7	0.435	---	36.0	45	2.96	28.072	---	---	---	---
236	600	0.147	790.7	0.435	---	36.0	0	2.96	29.498	---	---	---	---
237	600	0.147	790.7	0.436	---	36.0	-45	2.96	22.686	---	---	---	---
238	600	0.147	790.7	0.436	---	36.0	-90	2.96	18.158	---	---	---	---
239	600	0.147	793.4	0.433	131.	36.0	90	2.96	10.883	0.168	188.	0.407	-0.033
240	600	0.150	787.4	0.431	---	43.0	90	2.96	2.946	---	---	---	---
241	600	0.150	787.4	0.431	---	43.0	45	2.96	12.761	---	---	---	---
242	600	0.150	787.4	0.431	---	43.0	0	2.96	33.228	---	---	---	---
243	600	0.150	787.4	0.431	---	43.0	-45	2.96	37.536	---	---	---	---
244	600	0.150	787.4	0.431	---	43.0	-90	2.96	40.571	---	---	---	---
245	600	0.149	789.9	0.435	126.	43.0	90	2.96	3.131	0.008	200.	0.375	-0.059
246	600	0.150	456.5	-0.021	---	22.5	90	2.96	2.573	---	---	---	---
247	600	0.150	456.5	-0.021	---	22.5	45	2.96	2.595	---	---	---	---
248	600	0.150	456.5	-0.021	---	22.5	0	2.96	2.644	---	---	---	---
249	600	0.150	456.5	-0.021	---	22.5	-45	2.96	2.666	---	---	---	---
250	600	0.150	456.5	-0.021	---	22.5	-90	2.96	2.660	---	---	---	---
251	600	0.150	456.2	-0.021	108.	22.5	90	2.96	2.671	0.000	107.	-0.009	0.012
252	600	0.421	453.9	-0.026	---	15.5	90	2.96	2.710	---	---	---	---
253	600	0.421	453.9	-0.026	---	15.5	45	2.96	2.613	---	---	---	---
254	600	0.421	453.9	-0.026	---	15.5	0	2.96	2.565	---	---	---	---
255	600	0.421	453.9	-0.026	---	15.5	-45	2.96	2.672	---	---	---	---
256	600	0.421	453.9	-0.026	---	15.5	-90	2.96	2.636	---	---	---	---
257	600	0.421	455.2	-0.022	103.	15.5	0	2.96	2.667	0.000	103.	0.000	0.022
258	600	0.241	539.5	0.093	---	15.5	90	2.96	2.363	---	---	---	---
259	600	0.241	539.5	0.093	---	15.5	45	2.96	2.420	---	---	---	---
260	600	0.241	539.5	0.093	---	15.5	0	2.96	5.756	---	---	---	---
261	600	0.241	539.5	0.093	---	15.5	-45	2.96	6.180	---	---	---	---
262	600	0.241	539.5	0.093	---	15.5	-90	2.96	7.580	---	---	---	---
263	600	0.243	539.3	0.092	99.	15.5	90	2.96	2.616	0.000	108.	0.083	-0.009

(1) See Figure 5 for description.

TABLE 3 (Continued)

SIMULATOR - HORIZONTAL TUBES
PROBE --- ROW-OF-HOLES

RUN NO.	PRESSURE (PSIA)	MASS VELOCITY X 10-6 (LB/HR-FTSQ)	ENTHALPY (BTU/LB)	XB QUALITY	REFERENCE TRACER CONCENTRATION (PPB)	(1) PROBE --LOCATION-- INSERT	ANGLE	FLOW RATE (LB/HR)	ORIFICE PRESSURE DROP (PSI)	XS2 QUALITY OF SAMPLE	TRACER CONCENTRATION IN SAMPLE (PPB)	XBT TEST SECTION QUALITY VIA TRACER	QUALITY DIFFERENCE (XBT - XB)
	BULK FLOW CONDITIONS AT PROBE LOCATION					PROBE SAMPLING CONDITIONS							
264	600	0.241	538.8	0.092	---	22.5	90	2.96	3.083	---	---	---	---
265	600	0.241	538.8	0.092	---	22.5	45	2.96	3.833	---	---	---	---
266	600	0.241	538.8	0.092	---	22.5	0	2.96	6.627	---	---	---	---
267	600	0.241	538.8	0.092	---	22.5	-45	2.96	3.529	---	---	---	---
268	600	0.241	538.8	0.092	---	22.5	-90	2.96	3.111	---	---	---	---
269	600	0.242	536.1	0.088	98.	22.5	90	2.96	3.021	0.006	107.	0.090	0.002
270	600	0.243	629.2	0.215	---	02.0	90	2.96	2.859	---	---	---	---
271	600	0.243	629.2	0.215	---	02.0	45	2.96	7.416	---	---	---	---
272	600	0.243	629.2	0.215	---	02.0	0	2.96	19.785	---	---	---	---
273	600	0.243	629.2	0.215	---	02.0	-45	2.96	26.769	---	---	---	---
274	600	0.243	629.2	0.215	---	02.0	-90	2.96	25.695	---	---	---	---
275	600	0.240	629.9	0.216	95.	02.0	90	2.96	2.382	0.000	121.	0.215	-0.001
276	600	0.238	632.9	0.220	---	09.0	90	2.96	3.806	---	---	---	---
277	600	0.238	632.9	0.220	---	09.0	45	2.96	11.213	---	---	---	---
278	600	0.238	632.9	0.220	---	09.0	0	2.96	17.065	---	---	---	---
279	600	0.238	632.9	0.220	---	09.0	-45	2.96	5.715	---	---	---	---
280	600	0.238	632.9	0.220	---	09.0	-90	2.96	3.999	---	---	---	---
281	600	0.237	634.1	0.222	94.	09.0	-90	2.96	3.159	0.009	115.	0.190	-0.032
282	600	0.239	631.4	0.218	---	15.5	90	2.95	2.895	---	---	---	---
283	600	0.239	631.4	0.218	---	15.5	45	2.95	12.178	---	---	---	---
284	600	0.239	631.4	0.218	---	15.5	0	2.95	26.130	---	---	---	---
285	600	0.239	631.4	0.218	---	15.5	-45	2.95	25.936	---	---	---	---
286	600	0.239	631.4	0.218	---	15.5	-90	2.95	30.822	---	---	---	---
287	600	0.238	631.4	0.218	88.	15.5	-90	2.95	2.788	0.002	119.	0.262	0.044
288	600	0.238	631.8	0.219	---	22.5	90	2.95	4.233	---	---	---	---
289	600	0.238	631.8	0.219	---	22.5	45	2.95	14.153	---	---	---	---
290	600	0.238	631.8	0.219	---	22.5	0	2.95	19.135	---	---	---	---
291	600	0.238	631.8	0.219	---	22.5	-45	2.95	5.506	---	---	---	---
292	600	0.238	631.8	0.219	---	22.5	-90	2.95	4.049	---	---	---	---
293	600	0.239	630.8	0.217	83.	22.5	-90	2.95	4.180	0.029	103.	0.218	0.001

(1) See Figure 5 for description.

TABLE 3 (Continued)

SIMULATOR - HORIZONTAL TUBES
PROBE --- ROW-OF-HOLES

RUN NO.	PRES-SURE (PSIA)	MASS VELOCITY X 10-6 (LB/HR-FTSQ)	ENTHALPY (BTU/LB)	XB QUALITY	REFERENCE TRACER CONCEN-TRATION (PPB)	(1) PROBE --LOCATION-- INSERT	ANGLE	FLOW RATE (LB/HR)	ORIFICE PRESSURE DROP (PSI)	XS2 QUALITY OF SAMPLE	TRACER CONCEN-TRATION IN SAMPLE (PPB)	XBT TEST SECTION QUALITY VIA TRACER	QUALITY DIFFERENCE (XBT - XB)
	BULK FLOW CONDITIONS AT PROBE LOCATION					PROBE SAMPLING CONDITIONS							
294	600	0.238	631.1	0.218	---	29.5	90	2.96	2.256	---	---	---	---
295	600	0.238	631.1	0.218	---	29.5	45	2.96	10.286	---	---	---	---
296	600	0.238	631.1	0.218	---	29.5	0	2.96	23.905	---	---	---	---
297	600	0.238	631.1	0.218	---	29.5	-45	2.96	28.281	---	---	---	---
298	600	0.238	631.1	0.218	---	29.5	-90	2.96	31.349	---	---	---	---
299	600	0.237	632.2	0.219	76.	29.5	90	2.96	2.584	0.000	99.	0.232	0.013
300	600	0.237	632.3	0.219	---	36.0	90	2.96	3.152	---	---	---	---
301	600	0.237	632.3	0.219	---	36.0	45	2.96	12.807	---	---	---	---
302	600	0.237	632.3	0.219	---	36.0	0	2.96	19.028	---	---	---	---
303	600	0.237	632.3	0.219	---	36.0	-45	2.96	5.373	---	---	---	---
304	600	0.237	632.3	0.219	---	36.0	-90	2.96	4.114	---	---	---	---
305	600	0.236	638.6	0.229	71.	36.0	90	2.96	3.338	0.013	89.	0.212	-0.016
306	600	0.235	636.3	0.225	---	43.0	90	2.96	2.813	---	---	---	---
307	600	0.235	636.3	0.225	---	43.0	45	2.96	9.092	---	---	---	---
308	600	0.235	636.3	0.225	---	43.0	0	2.96	26.750	---	---	---	---
309	600	0.235	636.3	0.225	---	43.0	-45	2.96	33.678	---	---	---	---
310	600	0.235	636.3	0.225	---	43.0	-90	2.96	36.631	---	---	---	---
311	600	0.236	636.1	0.225	68.	43.0	90	2.97	2.254	0.000	87.	0.218	-0.006
312	600	0.236	455.0	-0.023	---	22.5	90	2.97	2.721	---	---	---	---
313	600	0.236	455.0	-0.023	---	22.5	45	2.97	2.718	---	---	---	---
314	600	0.236	455.0	-0.023	---	22.5	0	2.97	2.741	---	---	---	---
315	600	0.236	455.0	-0.023	---	22.5	-45	2.97	2.638	---	---	---	---
316	600	0.236	455.0	-0.023	---	22.5	-90	2.97	2.728	---	---	---	---
317	600	0.236	452.9	-0.026	57.	22.5	-45	2.96	2.582	0.000	56.	-0.018	0.008
318	600	0.239	538.0	0.091	---	22.5	90	2.96	2.949	---	---	---	---
319	600	0.239	538.0	0.091	---	22.5	45	2.96	3.890	---	---	---	---
320	600	0.239	538.0	0.091	---	22.5	0	2.96	6.360	---	---	---	---
321	600	0.239	538.0	0.091	---	22.5	-45	2.96	3.867	---	---	---	---
322	600	0.239	538.0	0.091	---	22.5	-90	2.96	2.927	---	---	---	---
323	600	0.238	541.8	0.096	58.	22.5	-90	2.95	2.902	0.004	65.	0.112	0.016

(1) See Figure 5 for description.

TABLE 3 (Continued)

SIMULATOR - HORIZONTAL TUBES
PROBE --- ROW-OF-HOLES

RUN NO.	PRESSURE (PSIA)	MASS VELOCITY X 10-6 (LB/HR-FTSQ)	ENTHALPY (BTU/LB)	XB QUALITY	REFERENCE TRACER CONCENTRATION (PPB)	(1) PROBE LOCATION INSERT	(1) PROBE LOCATION ANGLE	FLOW RATE (LB/HR)	ORIFICE PRESSURE DROP (PSI)	XS2 QUALITY OF SAMPLE	TRACER CONCENTRATION IN SAMPLE (PPB)	XBT TEST SECTION QUALITY VIA TRACER	QUALITY DIFFERENCE (XBT - XB)
	BULK FLOW CONDITIONS AT PROBE LOCATION					PROBE SAMPLING CONDITIONS							
324	600	0.239	543.0	0.097	---	15.5	90	2.95	2.690	---	---	---	---
325	600	0.239	543.0	0.097	---	15.5	45	2.95	2.919	---	---	---	---
326	600	0.239	543.0	0.097	---	15.5	0	2.95	6.527	---	---	---	---
327	600	0.239	543.0	0.097	---	15.5	-45	2.95	6.133	---	---	---	---
328	600	0.239	543.0	0.097	---	15.5	-90	2.95	5.958	---	---	---	---
329	600	0.239	542.4	0.097	57.	15.5	90	2.95	2.595	0.000	64.	0.109	0.013
330	600	0.225	701.4	0.313	---	15.5	90	2.95	3.712	---	---	---	---
331	600	0.225	701.4	0.313	---	15.5	45	2.95	15.404	---	---	---	---
332	600	0.225	701.4	0.313	---	15.5	0	2.95	34.633	---	---	---	---
333	600	0.225	701.4	0.313	---	15.5	-45	2.95	36.482	---	---	---	---
334	600	0.225	701.4	0.313	---	15.5	-90	2.95	39.798	---	---	---	---
335	600	0.222	709.0	0.323	52.	15.5	90	2.95	3.733	0.021	74.	0.312	-0.011
336	600	0.221	709.4	0.324	---	15.5	90	1.96	1.812	---	---	---	---
337	600	0.221	709.4	0.324	---	15.5	45	1.96	2.883	---	---	---	---
338	600	0.221	709.4	0.324	---	15.5	0	1.96	9.867	---	---	---	---
339	600	0.221	709.4	0.324	---	15.5	-45	1.96	10.135	---	---	---	---
340	600	0.221	709.4	0.324	---	15.5	-90	1.96	13.827	---	---	---	---
341	600	0.220	709.8	0.324	39.	15.5	90	1.96	1.797	0.028	62.	0.389	0.064
342	600	0.236	692.3	0.301	---	22.5	90	1.96	2.521	---	---	---	---
343	600	0.236	692.3	0.301	---	22.5	45	1.96	6.140	---	---	---	---
344	600	0.236	692.3	0.301	---	22.5	0	1.96	8.113	---	---	---	---
345	600	0.236	692.3	0.301	---	22.5	-45	1.96	2.839	---	---	---	---
346	600	0.236	692.3	0.301	---	22.5	-90	1.96	2.702	---	---	---	---
347	600	0.231	698.1	0.309	36.	22.5	-90	1.96	2.854	0.073	51.	0.346	0.037
348	600	0.230	700.0	0.312	---	22.5	90	2.97	6.512	---	---	---	---
349	600	0.230	700.0	0.312	---	22.5	45	2.97	22.443	---	---	---	---
350	600	0.230	700.0	0.312	---	22.5	0	2.97	27.372	---	---	---	---
351	600	0.230	700.0	0.312	---	22.5	-45	2.97	8.762	---	---	---	---
352	600	0.230	700.0	0.312	---	22.5	-90	2.97	6.041	---	---	---	---
353	600	0.230	699.2	0.311	34.	22.5	-90	2.97	6.078	0.065	53.	0.400	0.089

(1) See Figure 5 for description.

TABLE 3 (Continued)

SIMULATOR - HORIZONTAL TUBES
PROBE --- ROW-OF-HOLES

	BULK FLOW CONDITIONS AT PROBE LOCATION					PROBE SAMPLING CONDITIONS							
RUN NO.	PRESSURE (PSIA)	MASS VELOCITY X 10-6 (LB/HR-FTSQ)	ENTHALPY (BTU/LB)	XB QUALITY	REFERENCE TRACER CONCENTRATION (PPB)	(1) PROBE LOCATION INSERT	(1) PROBE LOCATION ANGLE	FLOW RATE (LB/HR)	ORIFICE PRESSURE DROP (PSI)	XS2 QUALITY OF SAMPLE	TRACER CONCENTRATION IN SAMPLE (PPB)	XBT TEST SECTION QUALITY VIA TRACER	QUALITY DIFFERENCE (XBT - XB)
354	600	0.345	613.7	0.194	---	22.5	90	2.96	4.102	---	---	---	---
355	600	0.345	613.7	0.194	---	22.5	45	2.96	15.394	---	---	---	---
356	600	0.345	613.7	0.194	---	22.5	0	2.96	19.597	---	---	---	---
357	600	0.345	613.7	0.194	---	22.5	-45	2.96	5.308	---	---	---	---
358	600	0.345	613.7	0.194	---	22.5	-90	2.96	3.959	---	---	---	---
359	600	0.355	601.7	0.176	181.	22.5	-90	1.96	1.948	0.035	216.	0.191	0.015
360	600	0.355	605.6	0.182	---	15.5	90	2.96	3.930	---	---	---	---
361	600	0.355	605.6	0.182	---	15.5	45	2.96	12.602	---	---	---	---
362	600	0.355	605.6	0.182	---	15.5	0	2.96	24.919	---	---	---	---
363	600	0.355	605.6	0.182	---	15.5	-45	2.96	24.144	---	---	---	---
364	600	0.355	605.6	0.182	---	15.5	-90	2.96	29.985	---	---	---	---
365	600	0.353	605.3	0.183	176.	15.5	90	2.95	3.978	0.026	211.	0.187	0.005
366	600	0.335	543.4	0.098	---	15.5	90	2.96	2.845	---	---	---	---
367	600	0.335	543.4	0.098	---	15.5	45	2.96	4.979	---	---	---	---
368	600	0.335	543.4	0.098	---	15.5	0	2.96	10.367	---	---	---	---
369	600	0.335	543.4	0.098	---	15.5	-45	2.96	9.531	---	---	---	---
370	600	0.335	543.4	0.098	---	15.5	-90	2.96	16.184	---	---	---	---
371	600	0.332	545.4	0.101	127.	15.5	90	2.96	2.623	0.005	145.	0.129	0.028
372	600	0.378	453.8	-0.024	---	22.5	90	2.96	2.305	---	---	---	---
373	600	0.331	545.4	0.099	---	22.5	90	2.96	2.860	---	---	---	---
374	600	0.331	545.4	0.099	---	22.5	45	2.96	4.900	---	---	---	---
375	600	0.331	545.4	0.099	---	22.5	0	2.96	9.203	---	---	---	---
376	600	0.331	545.4	0.099	---	22.5	-45	2.96	3.589	---	---	---	---
377	600	0.331	545.4	0.099	---	22.5	-90	2.96	2.997	---	---	---	---
378	600	0.332	544.7	0.099	113.	22.5	90	2.96	2.854	0.011	126.	0.113	0.014

(1) See Figure 5 for description.

TABLE 3 (Continued)

SIMULATOR - HORIZONTAL TUBES
PROBE --- ROW-OF-HOLES

RUN NO.	PRESSURE (PSIA)	MASS VELOCITY X 10-6 (LB/HR-FTSQ)	ENTHALPY (BTU/LB)	XB QUALITY	REFERENCE TRACER CONCENTRATION (PPB)	(1) PROBE --LOCATION-- INSERT	ANGLE	FLOW RATE (LB/HR)	ORIFICE PRESSURE DROP (PSI)	XS2 QUALITY OF SAMPLE	TRACER CONCENTRATION IN SAMPLE (PPB)	XBT TEST SECTION QUALITY VIA TRACER	QUALITY DIFFERENCE (XBT - XB)
	BULK FLOW CONDITIONS -------- AT PROBE LOCATION --------					-----------PROBE SAMPLING CONDITIONS-----------							
379	600	0.386	455.3	-0.022	---	22.5	90	2.96	2.652	---	---	---	---
380	600	0.386	455.3	-0.022	---	22.5	45	2.96	2.491	---	---	---	---
381	600	0.386	455.3	-0.022	---	22.5	0	2.96	2.546	---	---	---	---
382	600	0.386	455.3	-0.022	---	22.5	-45	2.96	2.562	---	---	---	---
383	600	0.386	455.3	-0.022	---	22.5	-90	2.96	2.554	---	---	---	---
384	600	0.385	455.3	-0.022	103.	22.5	45	2.96	2.365	0.000	104.	0.010	0.032

(1) See Figure 5 for description.

TABLE 3 (Continued)

SIMULATOR - HORIZONTAL TUBES
PROBE --- SINTERED METAL

RUN NO.	PRESSURE (PSIA)	MASS VELOCITY X 10-6 (LB/HR-FTSQ)	ENTHALPY (BTU/LB)	XB QUALITY	REFERENCE TRACER CONCENTRATION (PPB)	PROBE LOCATION (1) INSERT	PROBE LOCATION (1) ANGLE	FLOW RATE (LB/HR)	ORIFICE PRESSURE DROP (PSI)	XS2 QUALITY OF SAMPLE	TRACER CONCENTRATION IN SAMPLE (PPB)	XBT TEST SECTION QUALITY VIA TRACER	QUALITY DIFFERENCE (XBT - XB)
	BULK FLOW CONDITIONS AT PROBE LOCATION					PROBE SAMPLING CONDITIONS							
385	1200	0.050	496.2	-0.123	201.	22.5	-	2.99	1.968	0.000	203.	0.010	0.133
386	1200	0.051	417.3	-0.252	68.	22.5	-	2.98	1.200	0.000	68.	0.000	0.252
387	600	0.050	467.2	-0.006	159.	22.5	-	2.98	1.995	0.000	160.	0.006	0.012
388	600	0.050	518.8	0.064	157.	22.5	-	2.97	2.866	0.022	161.	0.046	-0.018
389	600	0.050	608.1	0.186	156.	22.5	-	2.97	3.049	0.027	176.	0.138	-0.049
390	600	0.050	695.8	0.306	155.	22.5	-	2.97	2.747	0.019	196.	0.224	-0.082
391	600	0.050	784.0	0.427	140.	22.5	-	2.97	2.918	0.023	220.	0.379	-0.048
392	600	0.050	867.2	0.540	145.	22.5	-	2.97	2.648	0.008	244.	0.410	-0.130
393	600	0.050	951.5	0.655	145.	22.5	-	2.97	2.585	0.007	271.	0.468	-0.187
394	600	0.152	532.4	0.083	132.	22.5	-	2.97	2.951	0.015	146.	0.109	0.026
395	600	0.151	619.0	0.201	130.	22.5	-	2.98	2.609	0.007	163.	0.208	0.007
396	600	0.150	719.2	0.338	124.	22.5	-	2.98	2.269	0.000	176.	0.295	-0.043
397	600	0.150	792.9	0.439	160.	22.5	-	2.98	3.623	0.030	256.	0.394	-0.045
398	600	0.240	543.8	0.099	153.	22.5	-	2.98	2.939	0.014	172.	0.123	0.025
399	600	0.239	612.0	0.192	150.	22.5	-	2.99	3.073	0.017	182.	0.190	-0.002
400	600	0.240	693.5	0.303	147.	22.5	-	2.99	3.147	0.019	206.	0.300	-0.003
401	600	0.339	614.3	0.195	143.	22.5	-	2.98	2.731	0.003	176.	0.190	-0.005
402	600	0.338	542.8	0.097	136.	22.5	-	2.98	2.733	0.003	154.	0.119	0.022
403	600	0.338	452.8	-0.026	133.	22.5	-	2.98	2.549	0.000	133.	0.000	0.026

(1) See Figure 5 for description.

TABLE 4. Summary of Quality Probe Test Results - Vertical Tube Simulator and Row-of-Holes Probe

Run No.	Average Bulk-Flow Conditions at 600 psia: Mass Velocity x 10^{-6} (lb/hr-ft^2)	Actual Quality XB	Probe's Reference Insert Position	Sample's Quality XS	Probe-Indicated Value of Bulk-Flow's Quality XTR	Quality Difference (XTR-XB)
115	.05	.008	8.5	.008	-.025	-.032
109	.05	.006	14.5	.008	-.055	-.061
21	.05	.152	8.5	.002	.152	.000
45	.05	.151	8.5	.000	.116	-.035
16	.05	.148	8.5	.037	.127	-.021
20	.05	.154	14.5	.004	.092	-.061
39	.05	.157	14.5	.003	.126	-.031
103	.05	.153	14.5	.011	.110	-.042
17	.05	.148	14.5	.069	.133	-.016
85	.05	.154	14.5	.012	.210	.056
19	.05	.152	17.5	.003	.138	-.013
18	.05	.151	17.5	.025	.135	-.016
121	.05	.151	0.5	.002	.127	-.024
127	.05	.153	2.5	.001	.161	.008
133	.05	.152	5.5	.002	.128	-.025
140	.05	.157	8.5	.014	.123	-.034
147	.05	.160	11.5	.005	.152	-.009
153	.05	.161	14.5	.003	.175	.015
159	.05	.161	20.5	.001	.178	.017
165	.05	.162	26.5	.000	.187	.025
171	.05	.156	28.5	.000	.158	.002
33	.05	.365	8.5	.010	.311	-.055
97	.05	.353	8.5	.020	.298	-.055
178	.05	.356	8.5	.010	.251	-.106
27	.05	.356	14.5	.011	.286	-.070
184	.05	.353	14.5	.011	.306	-.048
91	.05	.346	14.5	.027	.265	-.082
190	.05	.354	20.5	.007	.308	-.047
300	.05	.633	8.5	.007	.421	-.212
306	.05	.628	14.5	.014	.350	-.278
228	.10	.081	8.5	.006	.070	-.011
234	.10	.075	14.5	.004	.035	-.040
240	.10	.071	20.5	.003	.098	.027
276	.10	.171	8.5	.012	.132	-.040
282	.10	.176	14.5	.007	.143	-.034

TABLE 4 (Continued)

Run No.	Average Bulk-Flow Conditions at 600 psia: Mass Velocity x 10^{-6} (lb/hr-ft^2)	Average Bulk-Flow Conditions at 600 psia: Actual Quality XB	Probe's Reference Insert Position	Sample's Quality XS	Probe-Indicated Value of Bulk-Flow's Quality XTR	Quality Difference (XTR-XB)
294	.10	.367	8.5	.106	.254	-.113
288	.10	.368	14.5	.013	.300	-.068
264	.10	.615	8.5	.541	.653	.038
258	.10	.619	14.5	.118	.504	-.115
252	.10	.627	20.5	.438	.601	-.025
318	.19	.091	8.5	.009	.098	.007
312	.19	.091	14.5	.001	.112	.021
342	.19	.191	2.5	.014	.219	.028
336	.19	.190	8.5	.093	.261	.071
330	.19	.191	14.5	.013	.160	-.031
348	.19	.190	20.5	.068	.242	.052
354	.19	.191	26.5	.020	.194	.003
366	.20	.393	8.5	.303	.460	.067
360	.20	.396	14.5	.047	.368	-.029
216	.31	.099	8.5	.018	.112	.014
210	.31	.097	14.5	.005	.102	.005
197	.31	.100	20.5	.013	.112	.012
62	.31	.204	8.5	.065	.223	.018
74	.31	.202	8.5	.070	.213	.011
56	.31	.203	14.5	.010	.229	.026
68	.31	.203	14.5	.013	.154	-.049

TABLE 5. Summary of Quality Probe Test Results - Horizontal Tube Simulator and Row-of-Holes Probe

Run No.	Average Bulk-Flow Conditions at 600 psia: Mass Velocity $x\ 10^{-6}$ (lb/hr-ft^2)	Actual Quality XB	Probe's Reference Insert Position	Sample's Quality XS	Probe-Indicated Value of Bulk-Flow's Quality XTR	Quality Difference (XTR-XB)
23	.05	.066	15.5	.000	.017	-.049
17	.05	.066	22.5	.006	.085	.019
29	.05	.177	15.5	.002	.158	-.019
35	.05	.184	22.5	.009	.154	-.030
47	.05	.292	15.5	.003	.228	-.064
143	.05	.302	15.5	.004	.227	-.075
41	.05	.292	22.5	.020	.244	-.049
149	.05	.299	22.5	.018	.246	-.053
53	.05	.411	15.5	.002	.336	-.074
59	.05	.415	22.5	.038	.344	-.070
71	.05	.528	2.0	.006	.437	-.091
77	.05	.526	9.0	.107	.412	-.114
83	.05	.523	15.5	.003	.388	-.135
89	.05	.524	22.5	.084	.434	-.089
95	.05	.527	29.5	.004	.443	-.084
101	.05	.536	36.0	.084	.440	-.096
107	.05	.533	43.0	.007	.428	-.105
131	.05	.644	15.5	.027	.509	-.136
137	.05	.642	15.5	.019	.482	-.161
161	.05	.659	15.5	.033	.535	-.124
119	.05	.662	22.5	.284	.566	-.096
125	.05	.666	22.5	.111	.533	-.133
155	.05	.666	22.5	.138	.546	-.120
173	.15	.082	15.5	.003	.068	-.014
179	.15	.087	22.5	.010	.054	-.034
191	.15	.208	15.5	.000	.183	-.025
185	.15	.206	22.5	.023	.207	.001
197	.14	.343	15.5	.003	.325	-.018
203	.14	.335	22.5	.117	.356	.021
209	.14	.387	2.0	.014	.363	-.025
215	.15	.418	9.0	.145	.410	-.008
221	.15	.419	15.5	.010	.389	-.030
227	.15	.444	22.5	.225	.460	.015
233	.15	.443	29.5	.009	.425	-.018
239	.15	.439	36.0	.149	.407	-.033
245	.15	.435	43.0	.008	.375	-.059

TABLE 5 (Continued)

Run No.	Average Bulk-Flow Conditions at 600 psia: Mass Velocity x 10^{-6} (lb/hr-ft^2)	Average Bulk-Flow Conditions at 600 psia: Actual Quality XB	Probe's Reference Insert Position	Sample's Quality XS	Probe-Indicated Value of Bulk-Flow's Quality XTR	Quality Difference (XTR-XB)
263	.24	.092	15.5	.000	.083	-.009
329	.24	.097	15.5	.000	.109	.013
269	.24	.088	22.5	.006	.090	.002
323	.24	.096	22.5	.004	.112	.016
275	.24	.216	2.0	.000	.215	-.001
281	.24	.222	9.0	.009	.190	-.032
287	.24	.218	15.5	.002	.262	.044
293	.24	.217	22.5	.029	.218	.001
299	.24	.219	29.5	.000	.232	.013
305	.24	.228	36.0	.013	.212	-.016
311	.24	.225	43.0	.000	.218	-.006
335	.22	.323	15.5	.021	.312	-.011
341	.22	.324	15.5	.028	.389	.064
347	.23	.309	22.5	.073	.346	.037
353	.23	.311	22.5	.065	.400	.089
371	.33	.101	15.5	.005	.129	.028
378	.33	.099	22.5	.011	.113	.014
365	.35	.183	15.5	.026	.187	.005
359	.35	.176	22.5	.035	.192	.015

TABLE 6. Summary of Quality Probe Test Results - Horizontal Tube Simulator and Sintered Metal Probe

Run No.	Average Bulk-Flow Conditions at 600 psia: Mass Velocity x 10^{-6} (lb/hr-ft^2)	Average Bulk-Flow Conditions at 600 psia: Actual Quality XB	Probe's Reference Insert Position	Sample's Quality XS	Probe-Indicated Value of Bulk-Flow's Quality XTR	Quality Difference (XTR-XB)
388	.05	.064	22.5	.022	.047	-.018
389	.05	.186	22.5	.027	.138	-.049
390	.05	.306	22.5	.019	.224	-.082
391	.05	.427	22.5	.024	.379	-.048
392	.05	.540	22.5	.008	.410	-.130
393	.05	.655	22.5	.007	.468	-.187
394	.15	.083	22.5	.015	.109	.026
395	.15	.201	22.5	.007	.208	.007
396	.15	.338	22.5	.000	.295	-.043
397	.15	.439	22.5	.030	.394	-.045
398	.24	.099	22.5	.014	.123	.025
399	.24	.192	22.5	.017	.190	-.002
400	.24	.303	22.5	.019	.300	-.003
402	.34	.097	22.5	.003	.119	.022
401	.34	.195	22.5	.003	.190	-.005

FIGURE I. SCHEMATIC DIAGRAM OF HIGH PRESSURE LOOP FOR VERTICAL TUBE SIMULATOR QUALITY PROBE TESTS

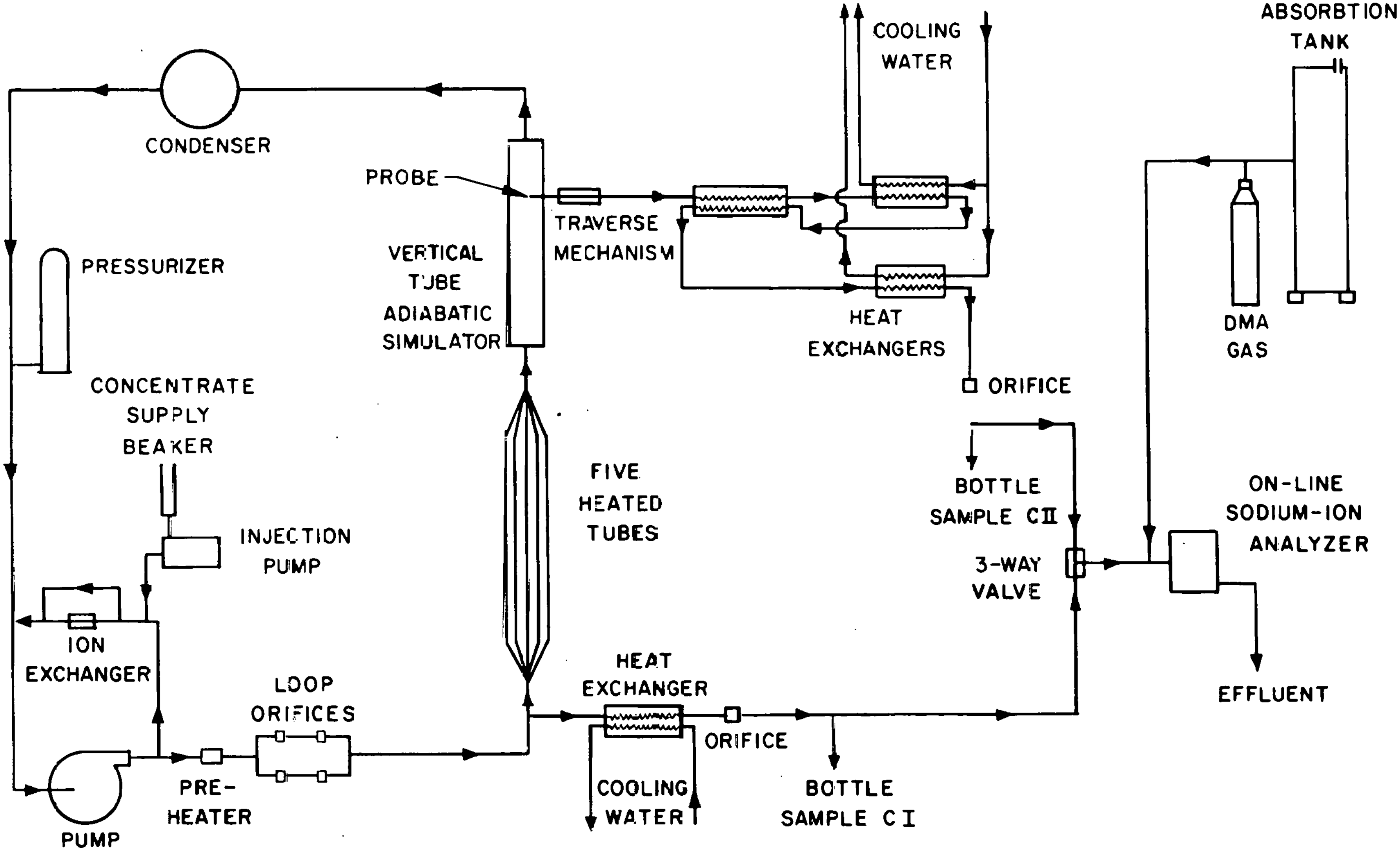


FIGURE 2. SCHEMATIC DIAGRAM OF HIGH PRESSURE LOOP FOR HORIZONTAL TUBE SIMULATOR QUALITY PROBE TESTS

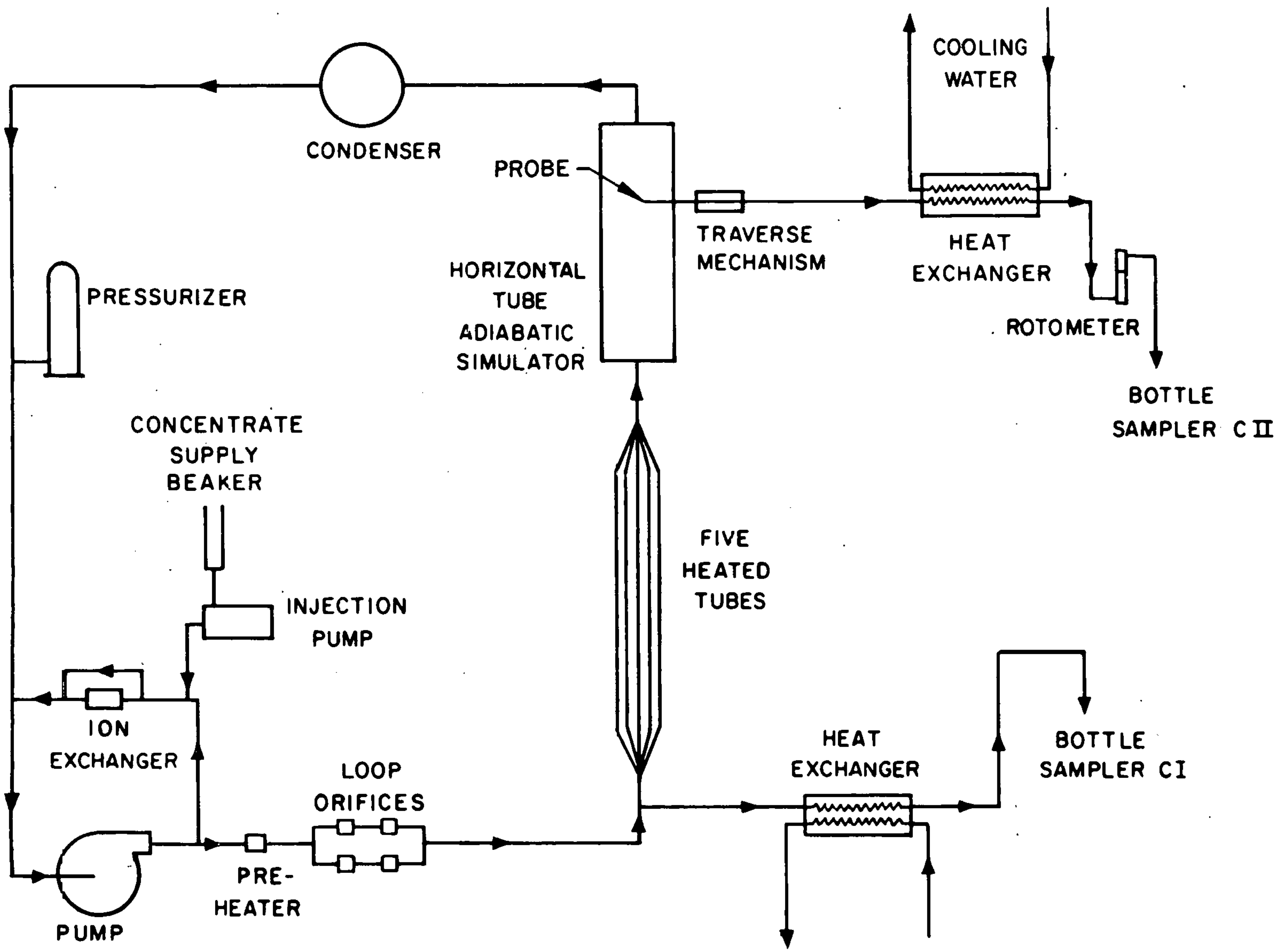


FIGURE 3. SCHEMATIC DIAGRAM OF TEST SECTION SIMULATING A VERTICAL TUBE HEAT EXCHANGER

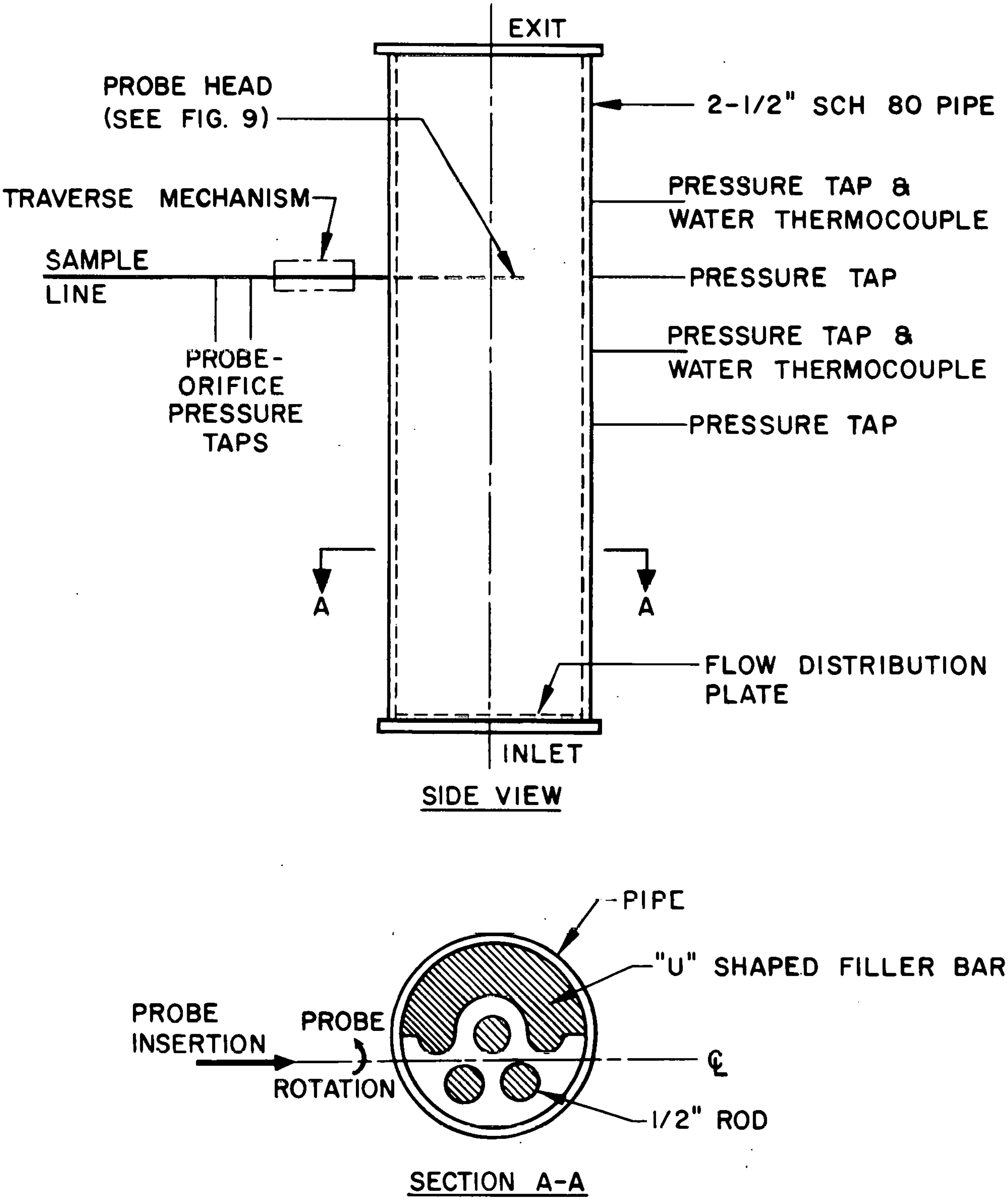
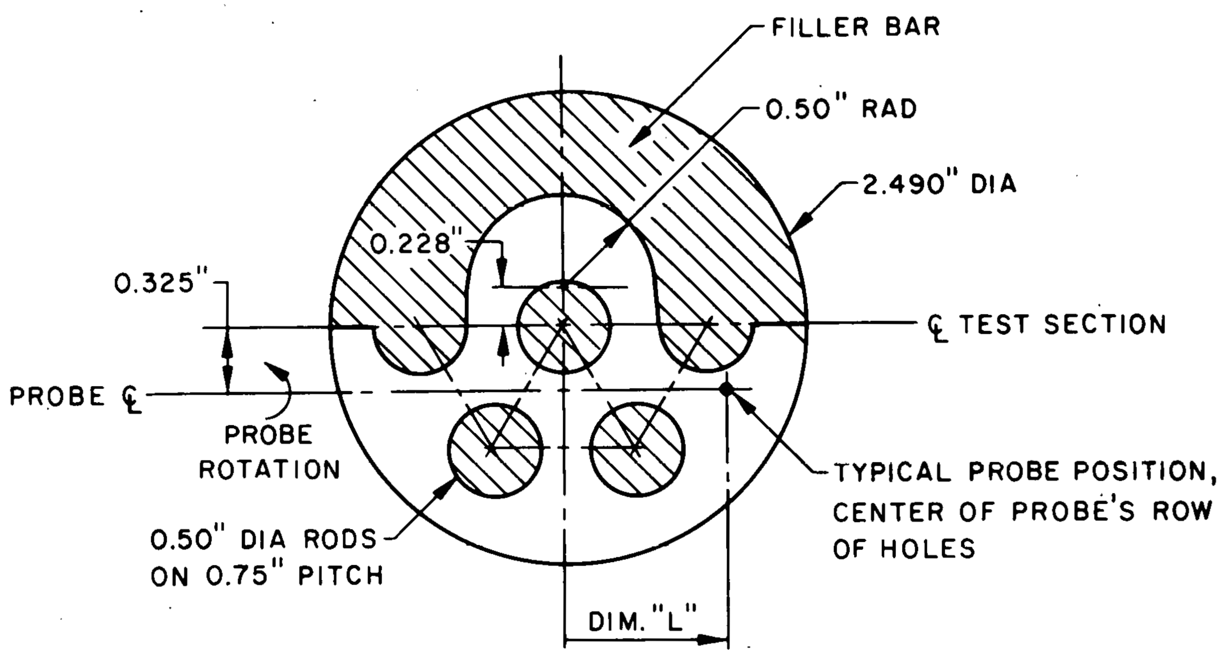


FIGURE 4. SKETCH OF VERTICAL TUBE SIMULATOR AND PROBE LOCATION DETAILS



SKETCH OF TEST SECTION CROSS SECTION

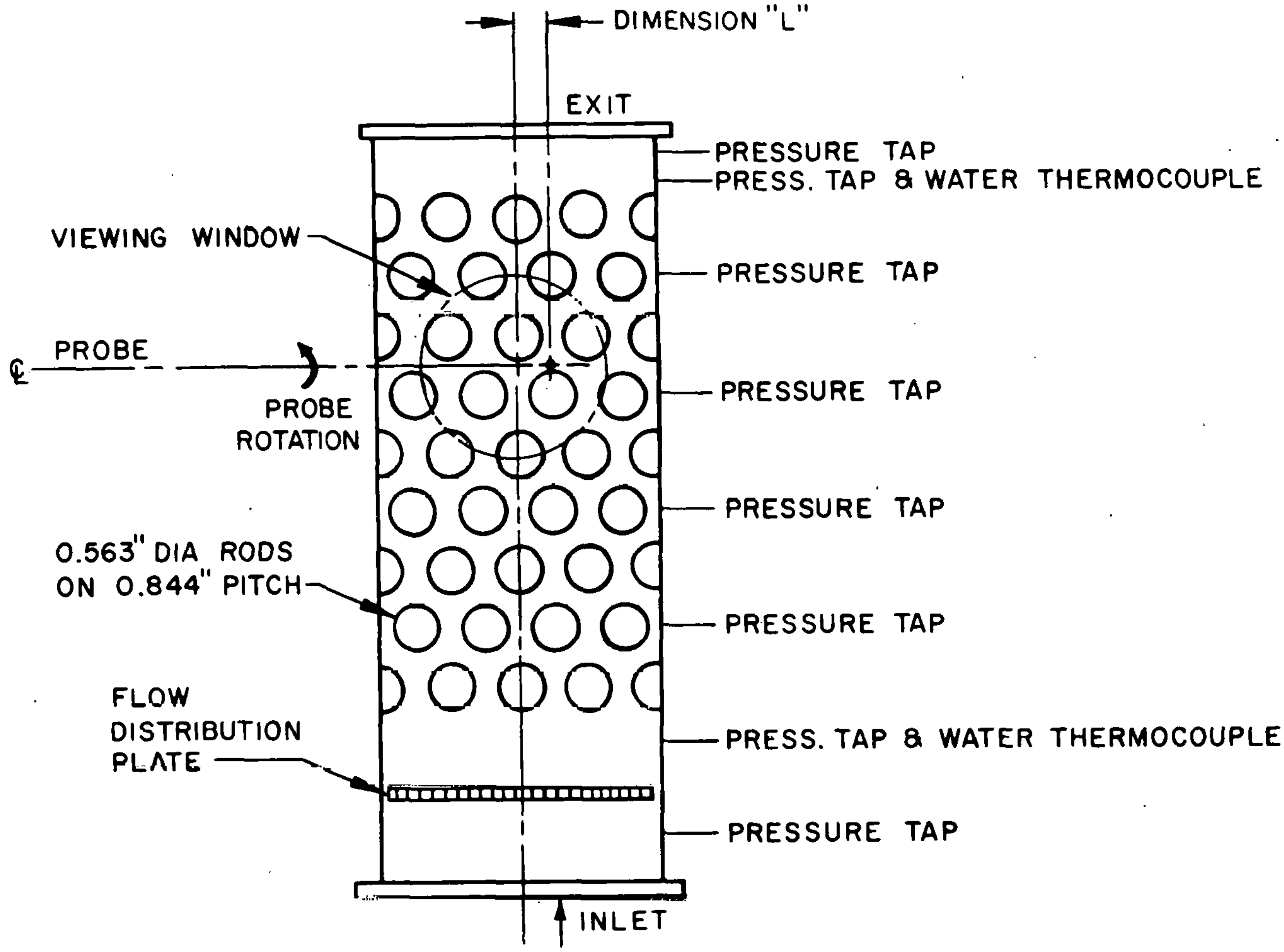
PROBE'S INSERT LOCATIONS

SYMBOL USED IN TABLE 2	DIMENSION "L" (INCHES)
0.5	0.875
2.5	0.750
5.5	0.563
8.5	0.375
12.5	0.125
14.5	0.000
17.5	-0.188
19.2	-0.294
20.5	-0.375
26.5	-0.750
28.5	-0.875

PROBE ANGLES

ANGLE (DEGREES)	ORIENTATION OF ROW-OF-HOLES
90	UP, AWAY FROM APPROACHING FLOW
45	UP, 45° OFF VERTICAL
0	HORIZONTAL, TOWARD CENTER ROD
-45	DOWN, 45° OFF VERTICAL
-90	DOWN, OPEN TO APPROACHING FLOW

FIGURE 5. SKETCH OF HORIZONTAL TUBE SIMULATOR AND PROBE LOCATION DETAILS



SKETCH OF TEST SECTION

PROBE'S INSERT LOCATIONS

SYMBOL USED IN TABLE 3	DIMENSION "L" (INCHES)
2.0	1.281
9.0	0.844
15.5	0.438
22.5	0.000
29.5	-0.438
36.0	-0.844
43.0	1.281

PROBE ANGLES

ANGLE (DEGREES)	ORIENTATION OF ROW-OF-HOLES
90	UP, AWAY FROM APPROACHING FLOW
45	UP, 45° OFF VERTICAL
0	HORIZONTAL, AWAY FROM VIEWING WINDOW
-45	DOWN, 45° OFF VERTICAL
-90	DOWN, OPEN TO APPROACHING FLOW

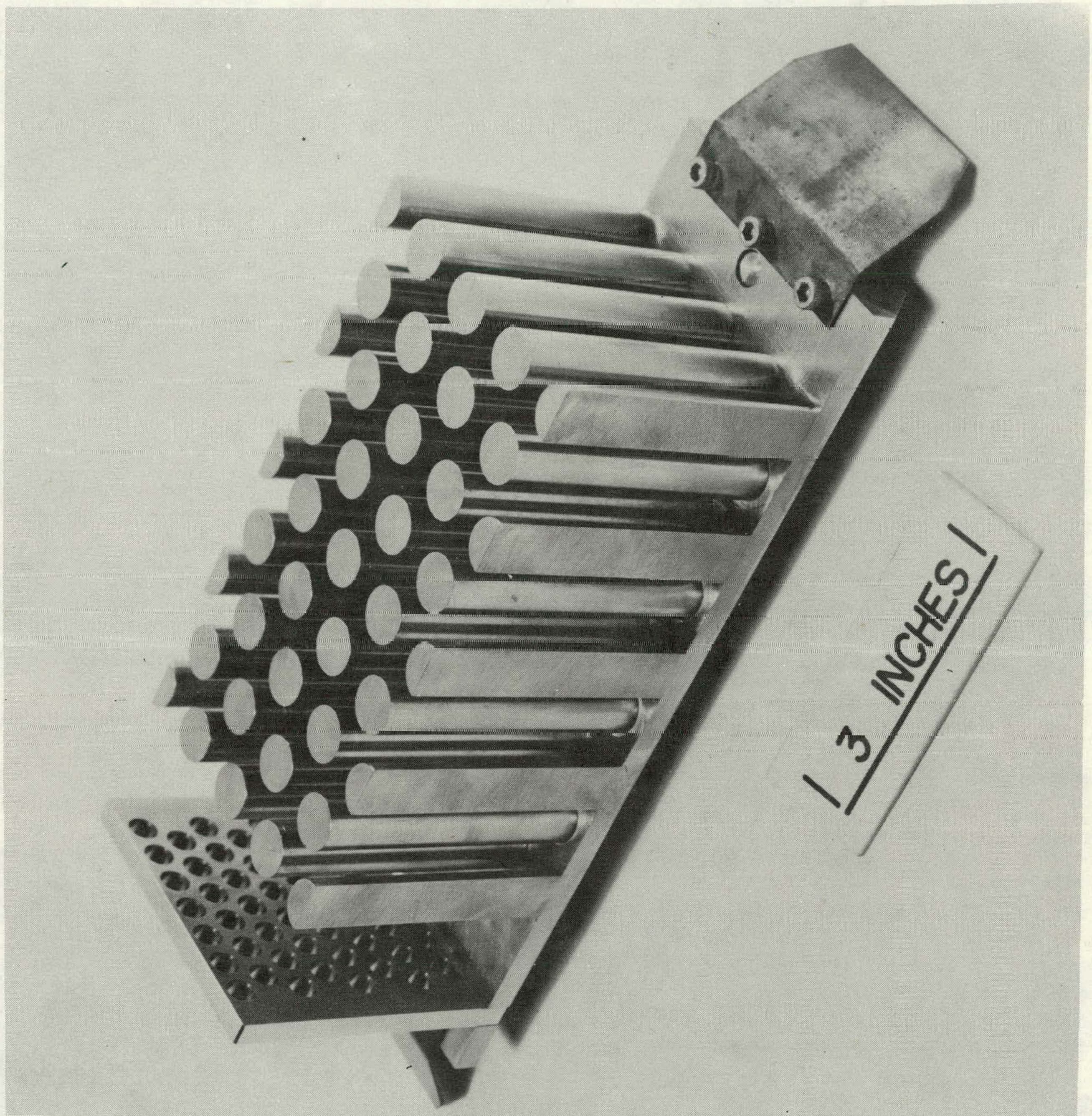


FIGURE 6. <u>Photograph of Horizontal Tube Bundle before Assembly</u>

Negative No. 52083-7

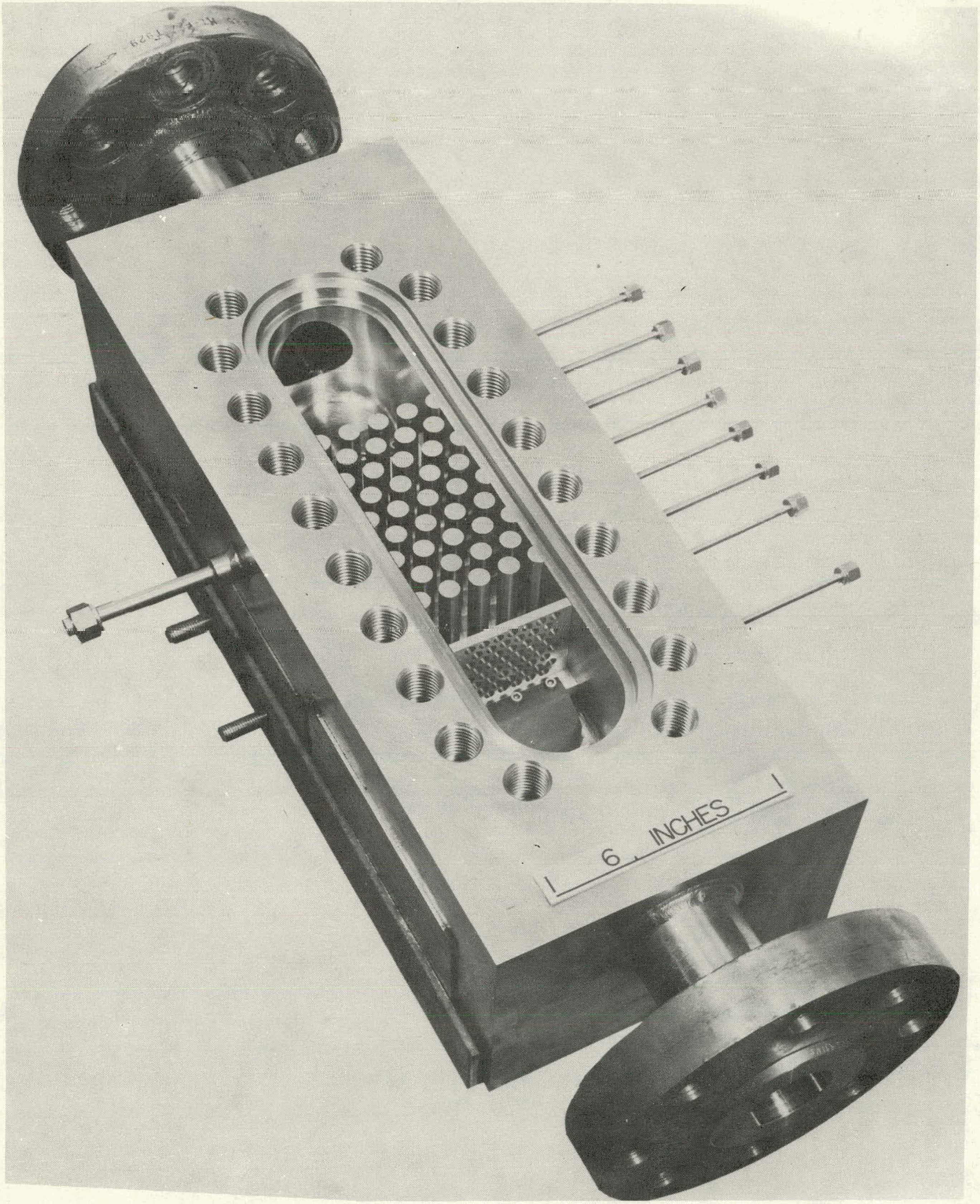


FIGURE 7. Photograph of Horizontal Tube Simulator before Attachment of Cover Plate

Negative No. 52083-1

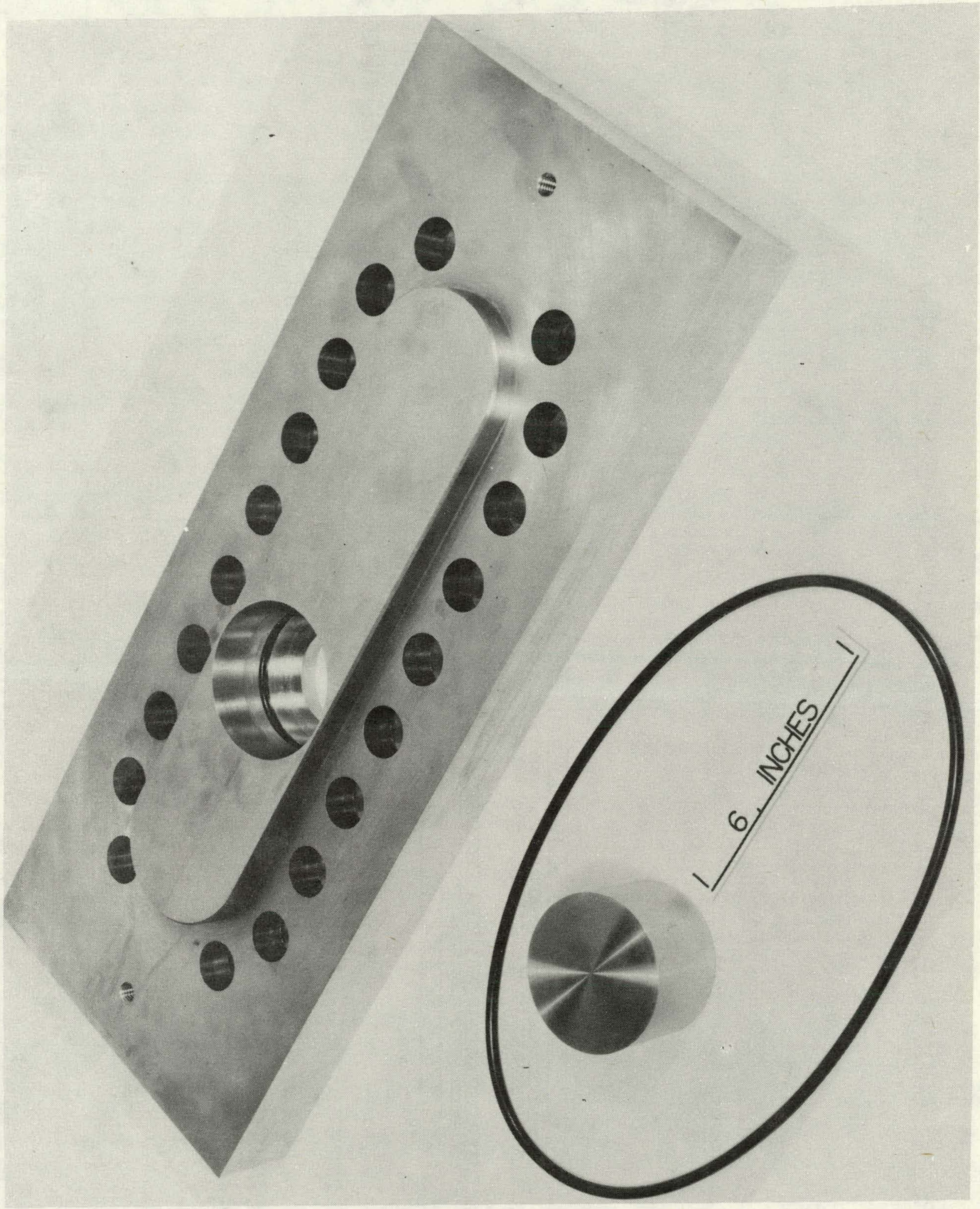
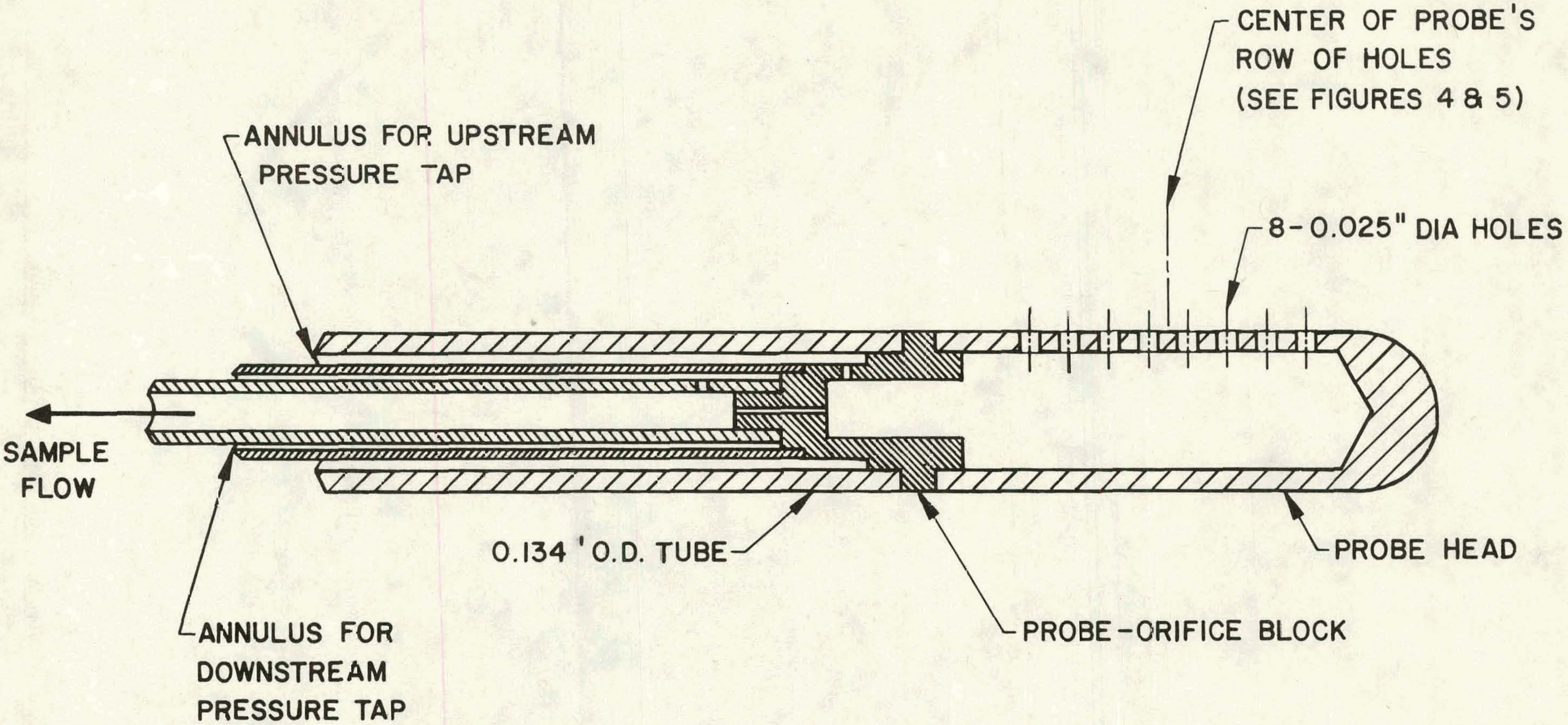


FIGURE 8. Photograph of Fluid Side of Cover Plate for Horizontal Tube Simulator and Metal-Plug Window

Negative No. 520835

FIGURE 9. CROSS-SECTIONAL SKETCH OF "ROW-OF-HOLES" QUALITY PROBE



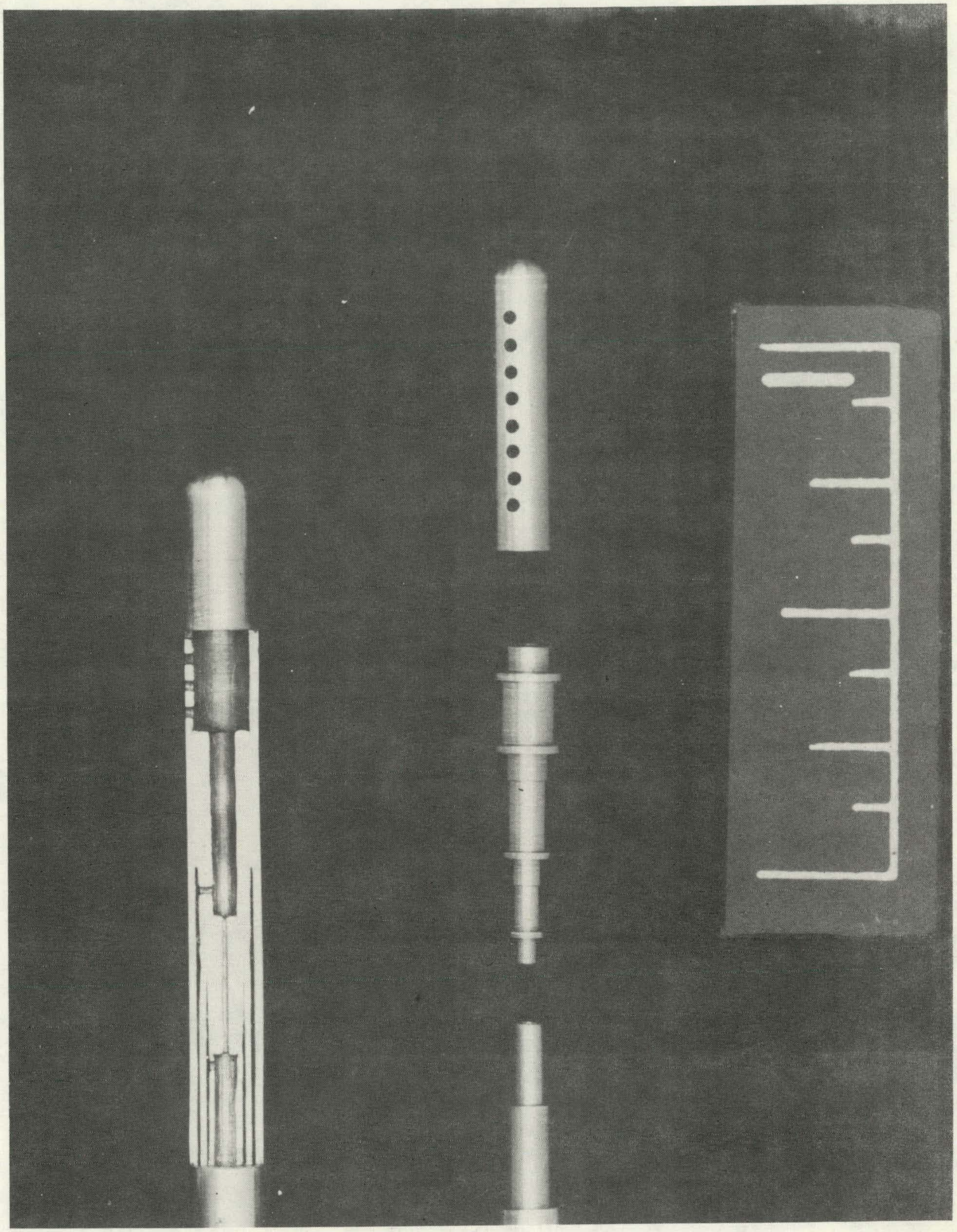
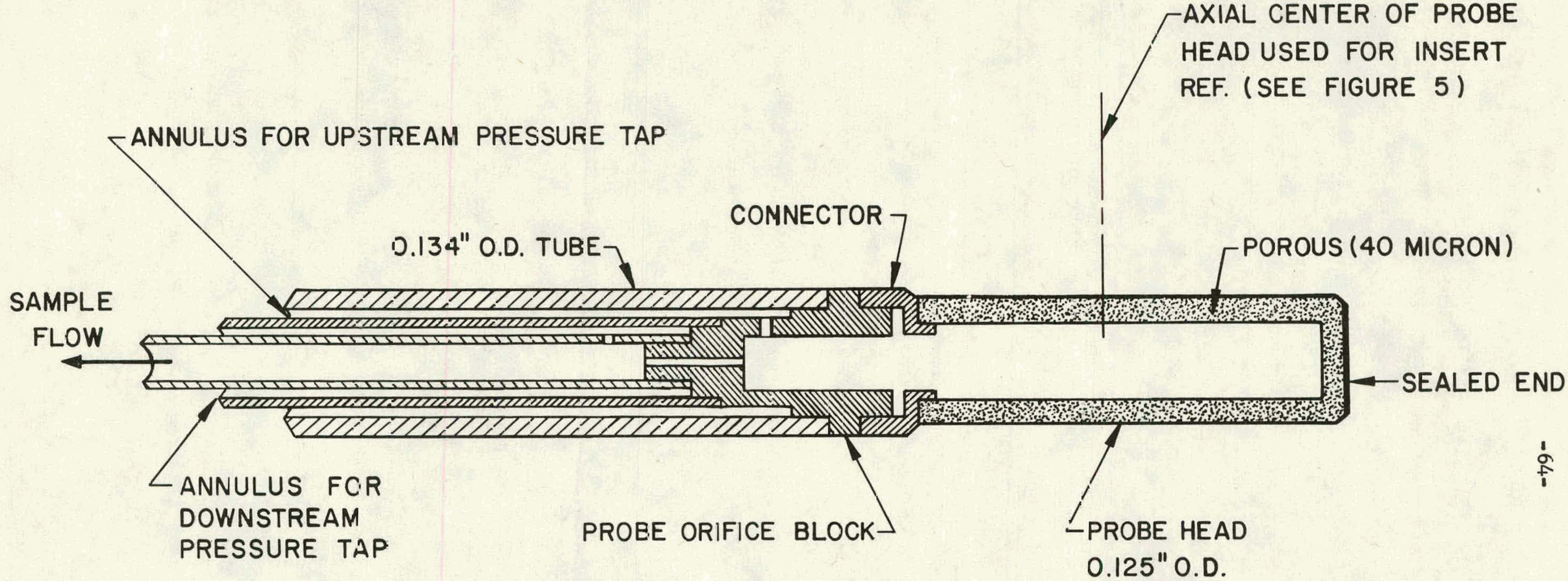


FIGURE 10. Photograph of Cross Section and Components of a Row-of-Holes Quality Probe

Negative No. 51678-3

FIGURE II. CROSS-SECTIONAL SKETCH OF "SINTERED METAL" QUALITY PROBE



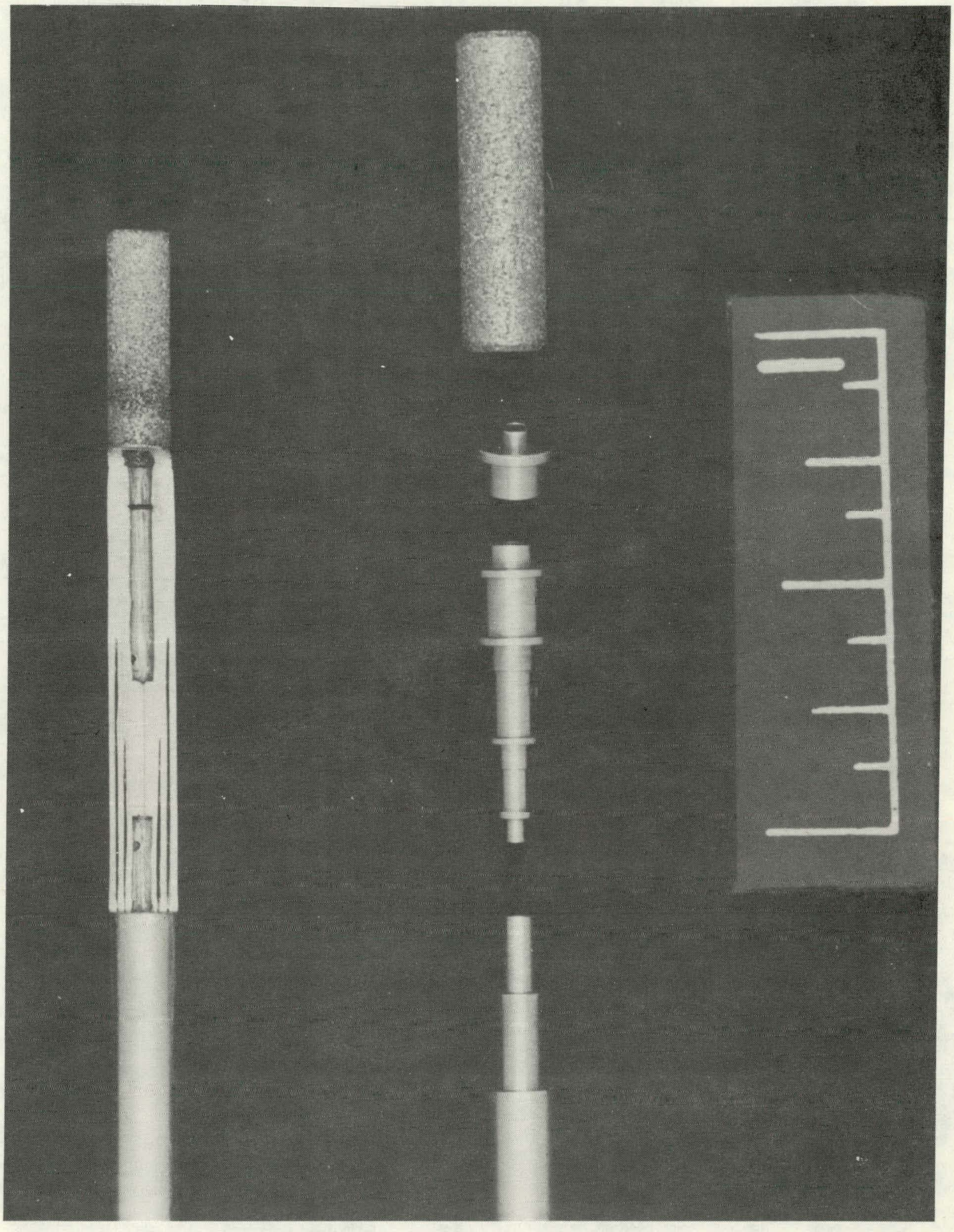


FIGURE 12. Photograph of Cross Section and Components of a Sintered Metal Quality Probe

Negative No. 51678-2

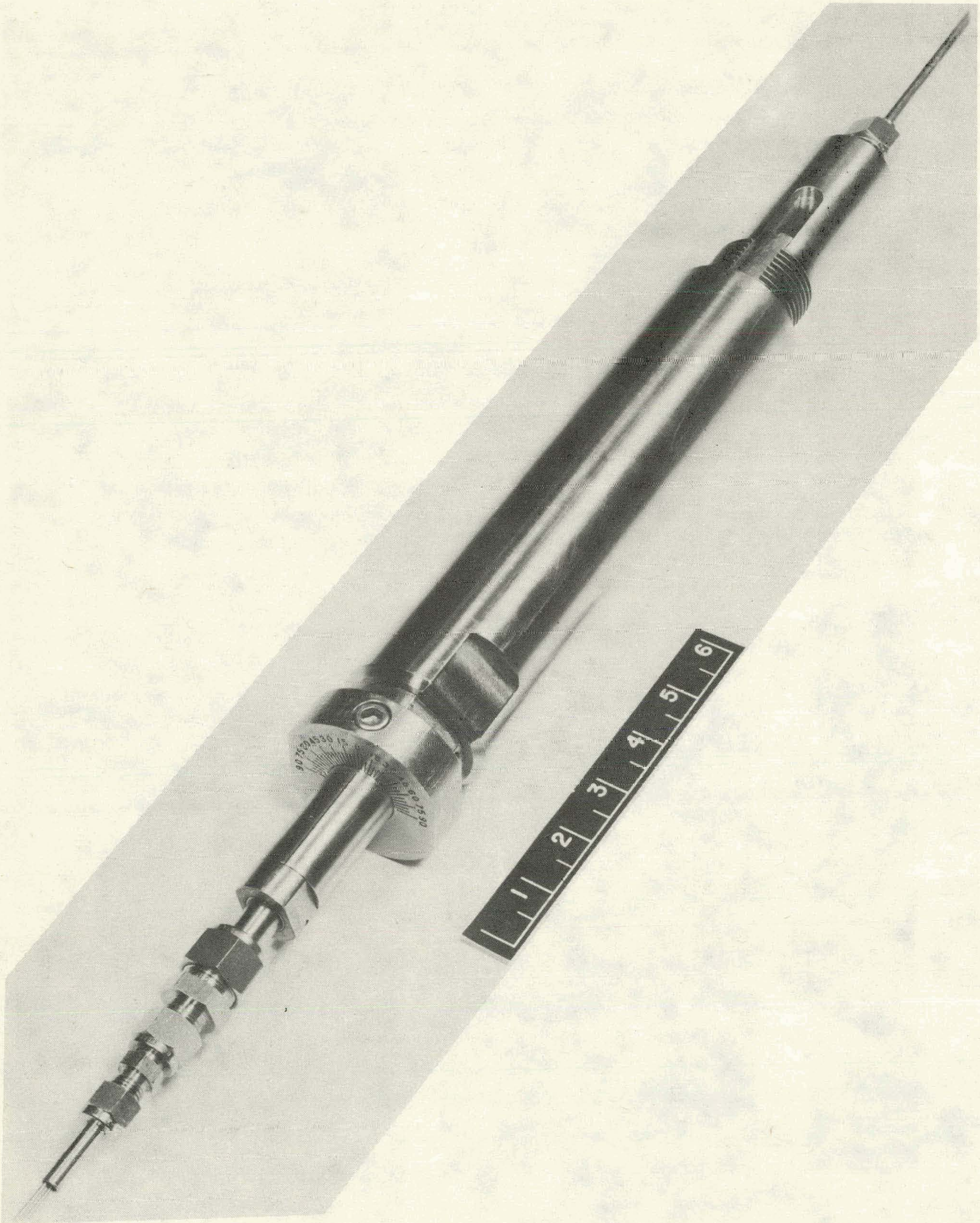


FIGURE 13. Photograph of Traversing Mechanism

Negative No. 50340-8

FIGURE 14. INDICATED QUALITY VS ACTUAL QUALITY

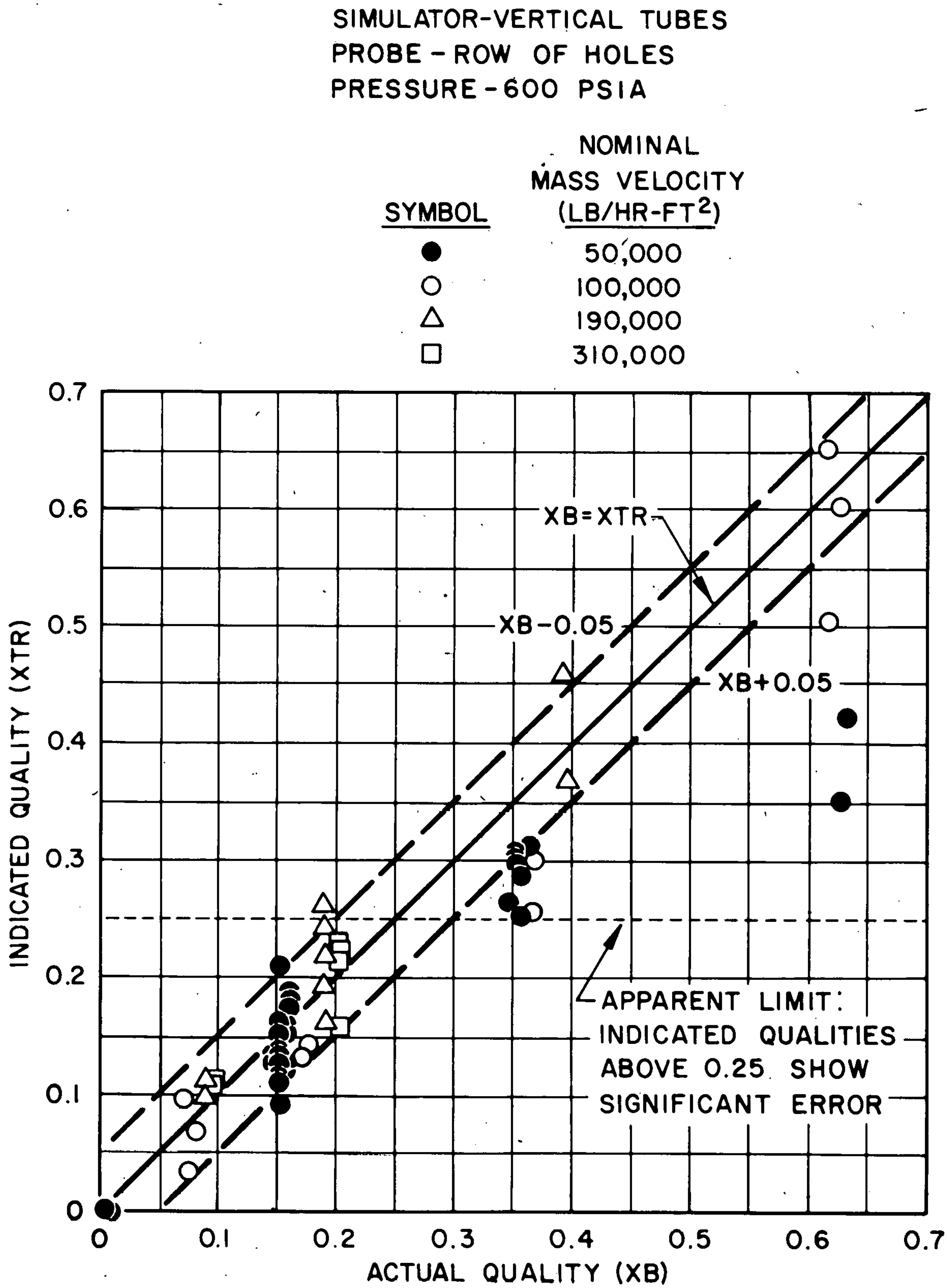


FIGURE 15. QUALITY ERROR VS MASS VELOCITY FOR VERTICAL TUBE SIMULATOR WITH ROW-OF-HOLES PROBE

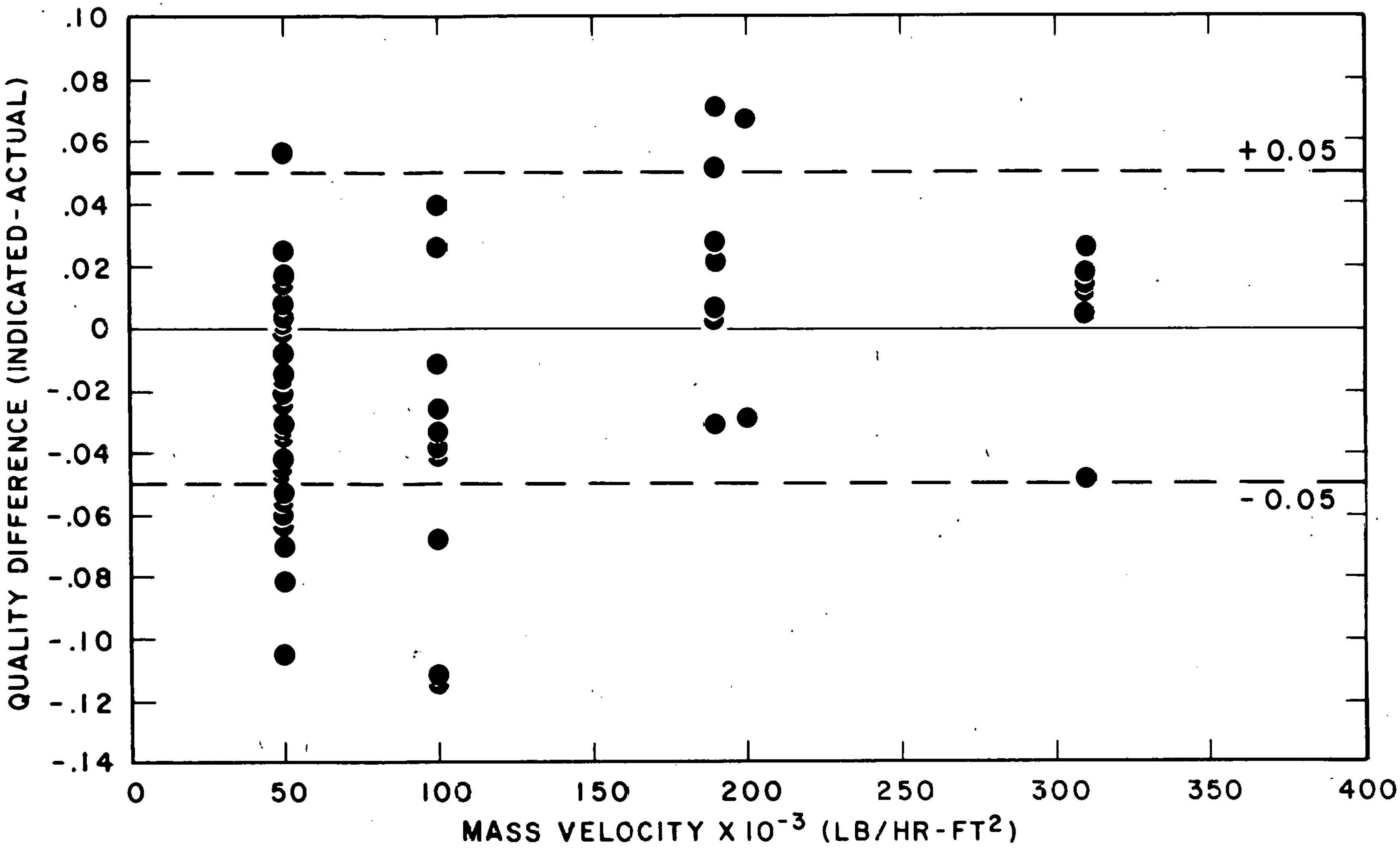


FIGURE 16. QUALITY PROFILE NO. 1

SIMULATOR - VERTICAL TUBES
PROBE - ROW-OF-HOLES
PRESSURE - 600 PSIA
MASS VELOCITY - 50,000 LB/HR-FT^2
NOMINAL QUALITY - 0.157
RUNS (TABLE 4) - 121, 127, 133, 140, 147, 153, 159, 165, 171

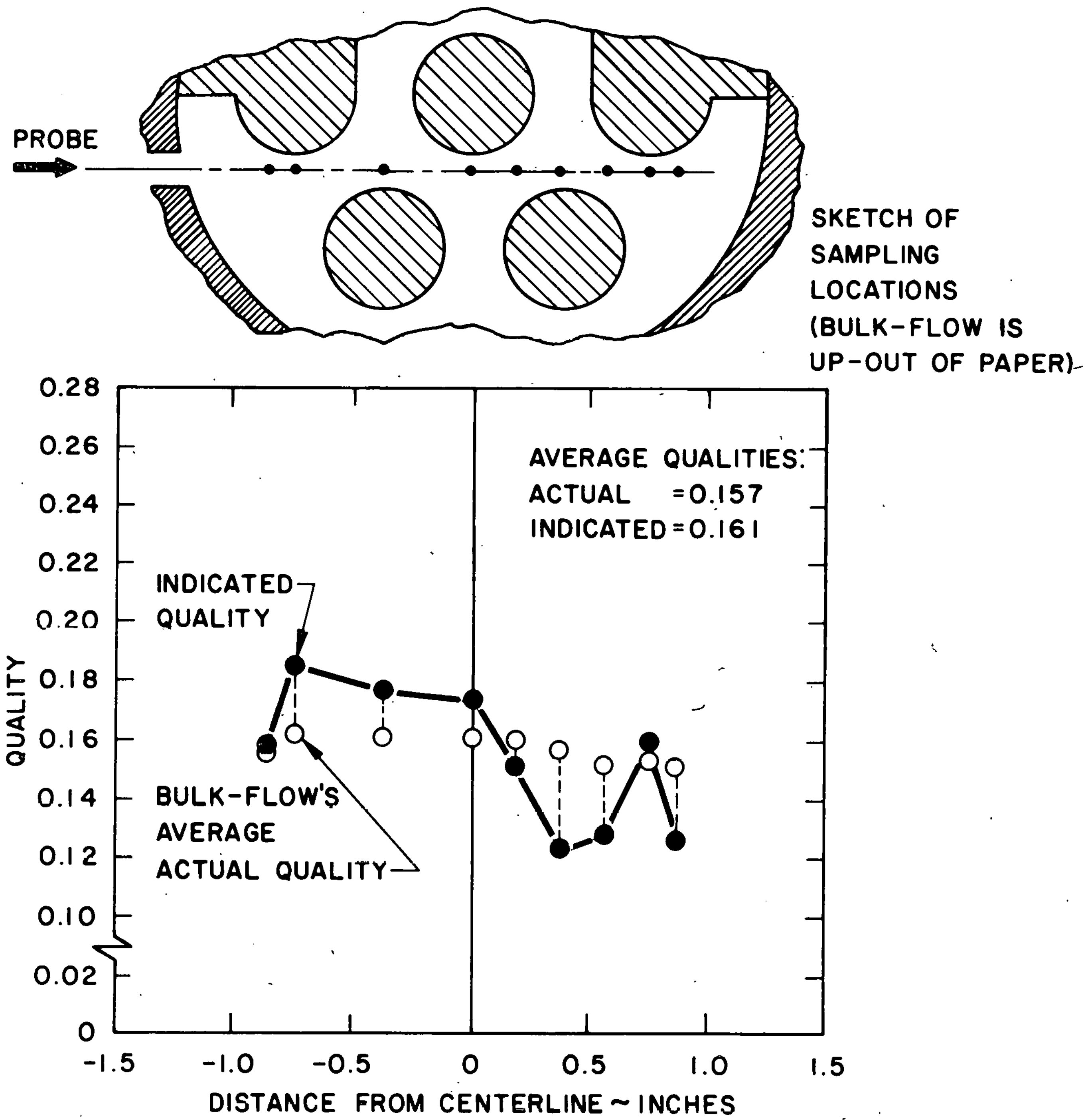
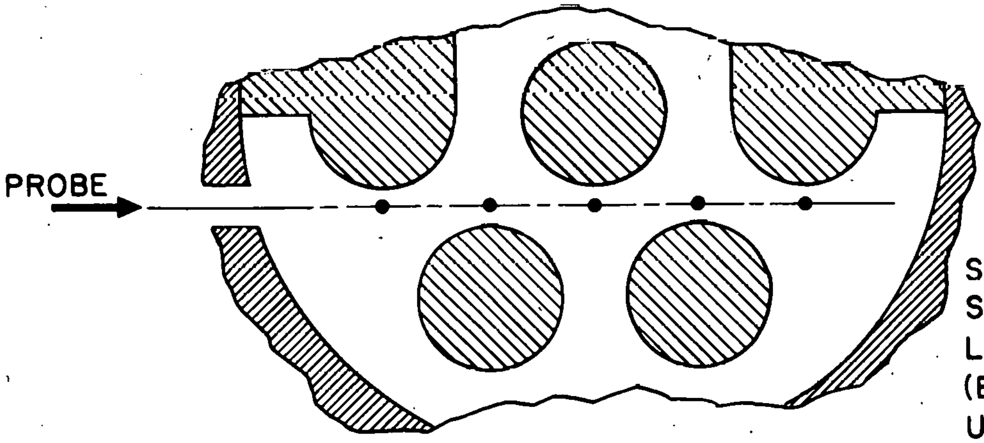


FIGURE 17. QUALITY PROFILE NO. 2

SIMULATOR - VERTICAL TUBES
PROBE - ROW-OF-HOLES
PRESSURE - 600 PSIA
MASS VELOCITY - 190,000 LB/HR-FT^2
NOMINAL QUALITY - 0.191
RUNS (TABLE 4) - 342, 336, 330, 348, 354



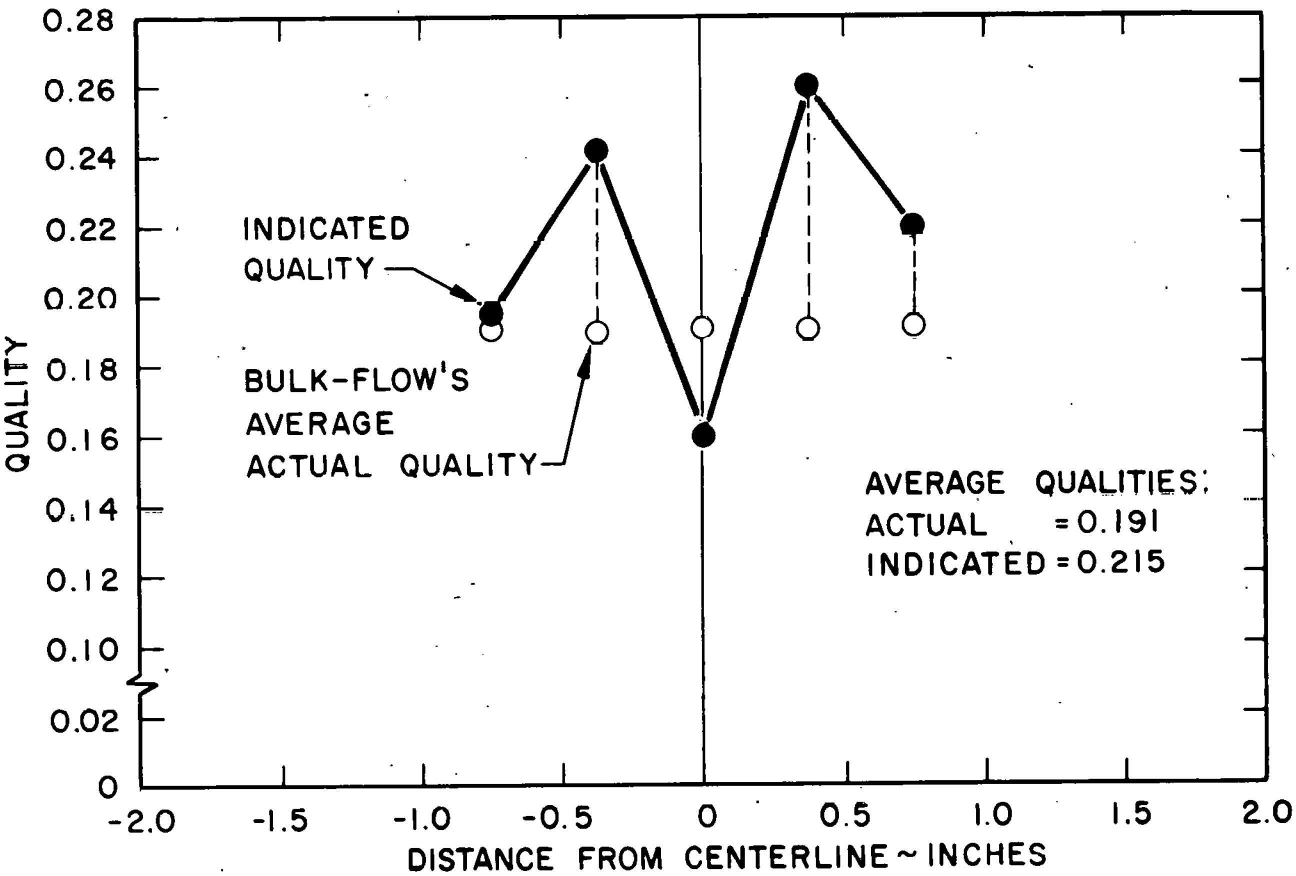


FIGURE 18. INDICATED QUALITY VS ACTUAL QUALITY

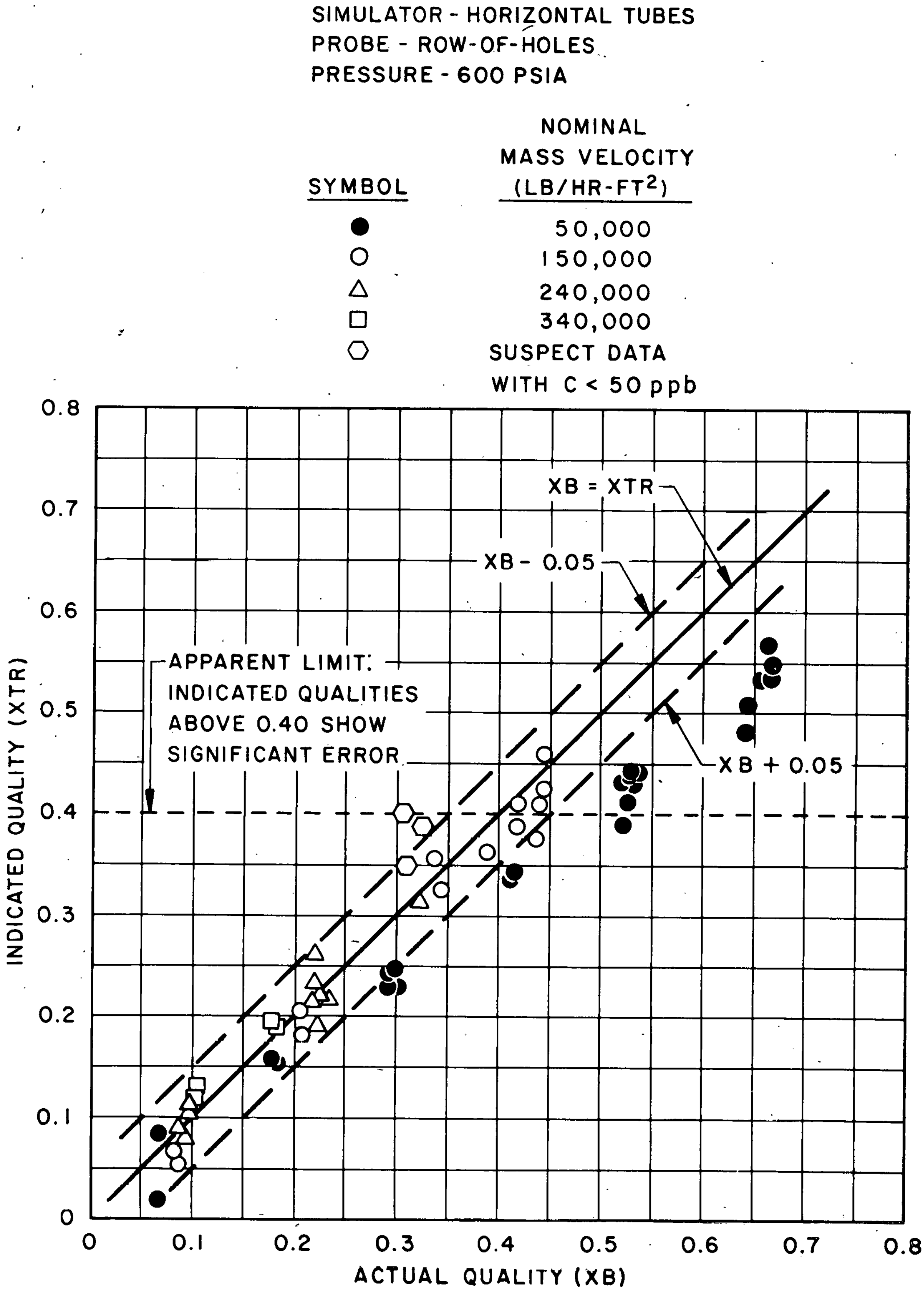


FIGURE 19. QUALITY ERROR VS MASS VELOCITY FOR HORIZONTAL TUBE SIMULATOR WITH ROW-OF-HOLES PROBE (○ SUSPECT DATA WITH CONCENTRATION < 50 ppb)

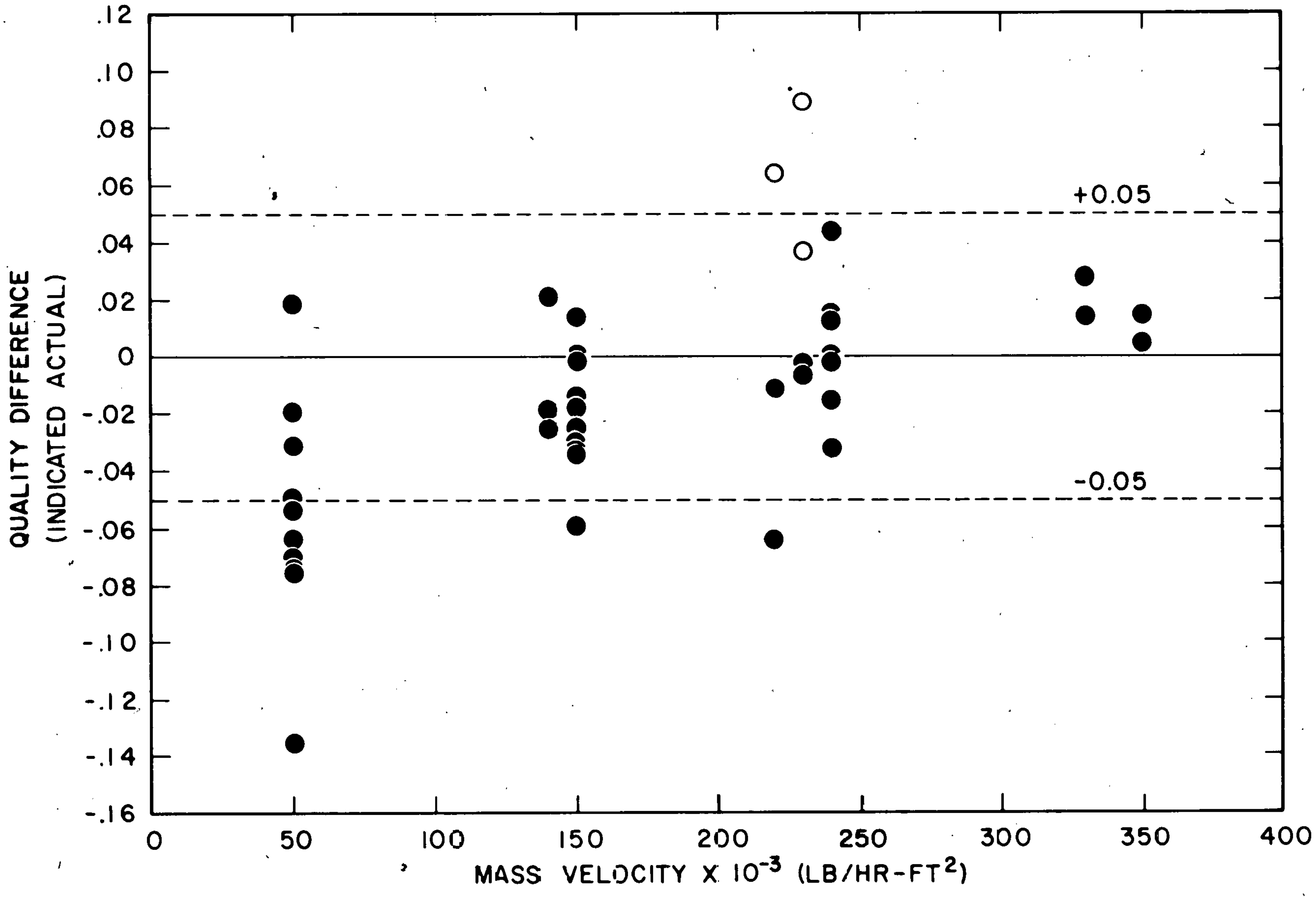


FIGURE 20. QUALITY PROFILE NO. 3

SIMULATOR - HORIZONTAL TUBES
PROBE - ROW-OF-HOLES
PRESSURE - 600 PSIA
MASS VELOCITY - 50,000 LB/HR-FT ^{2}
NOMINAL QUALITY - 0.528
RUNS (TABLE 5) - 71, 77, 83, 89, 95, 101, 107

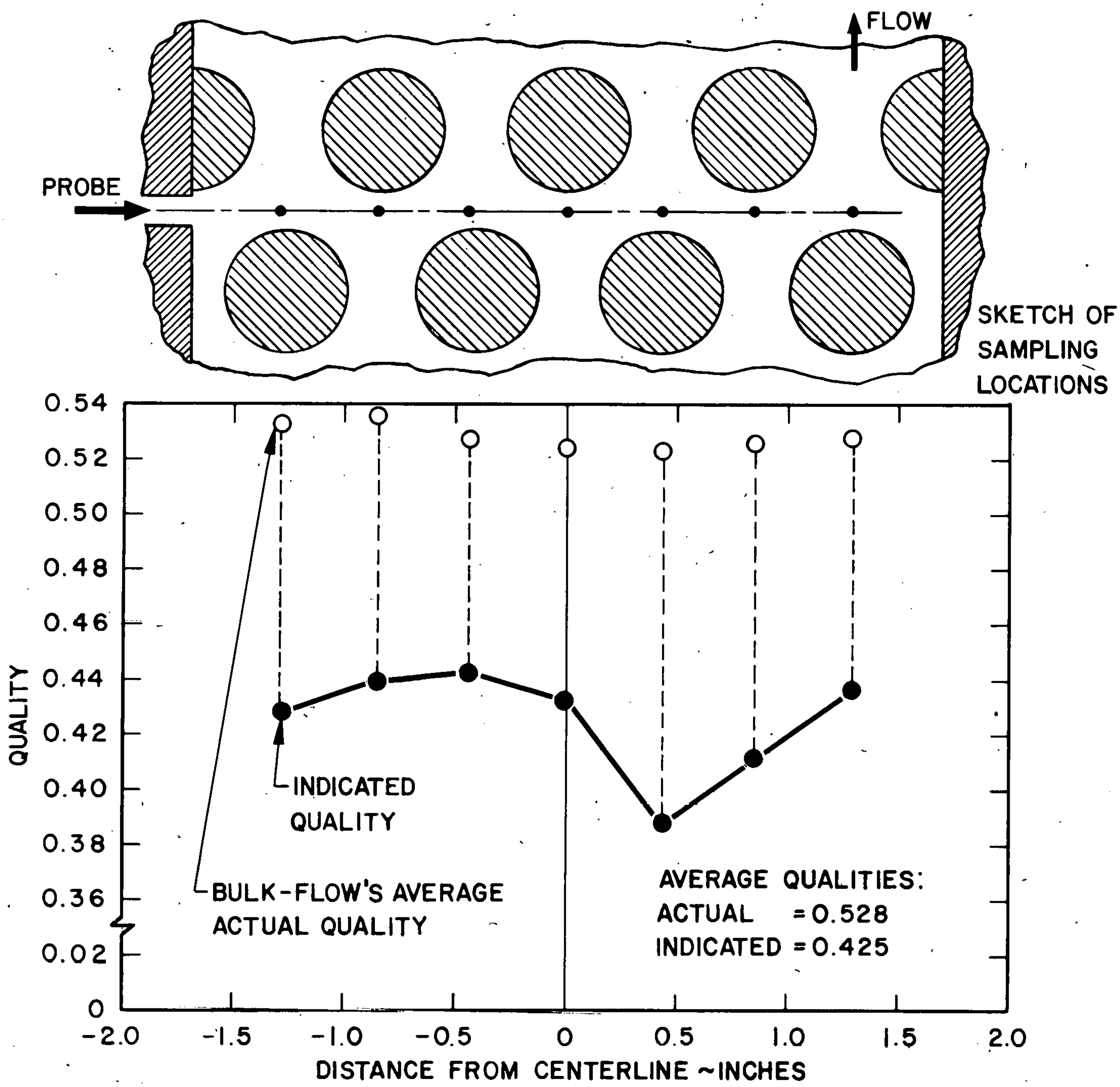


FIGURE 21. QUALITY PROFILE NO. 4

SIMULATOR - HORIZONTAL TUBES
PROBE - ROW-OF-HOLES
PRESSURE - 600 PSIA
MASS VELOCITY - 150,000 LB/HR-FT^2
NOMINAL QUALITY - 0.426
RUNS (TABLE 5) - 209, 215, 221, 227, 233, 239, 245

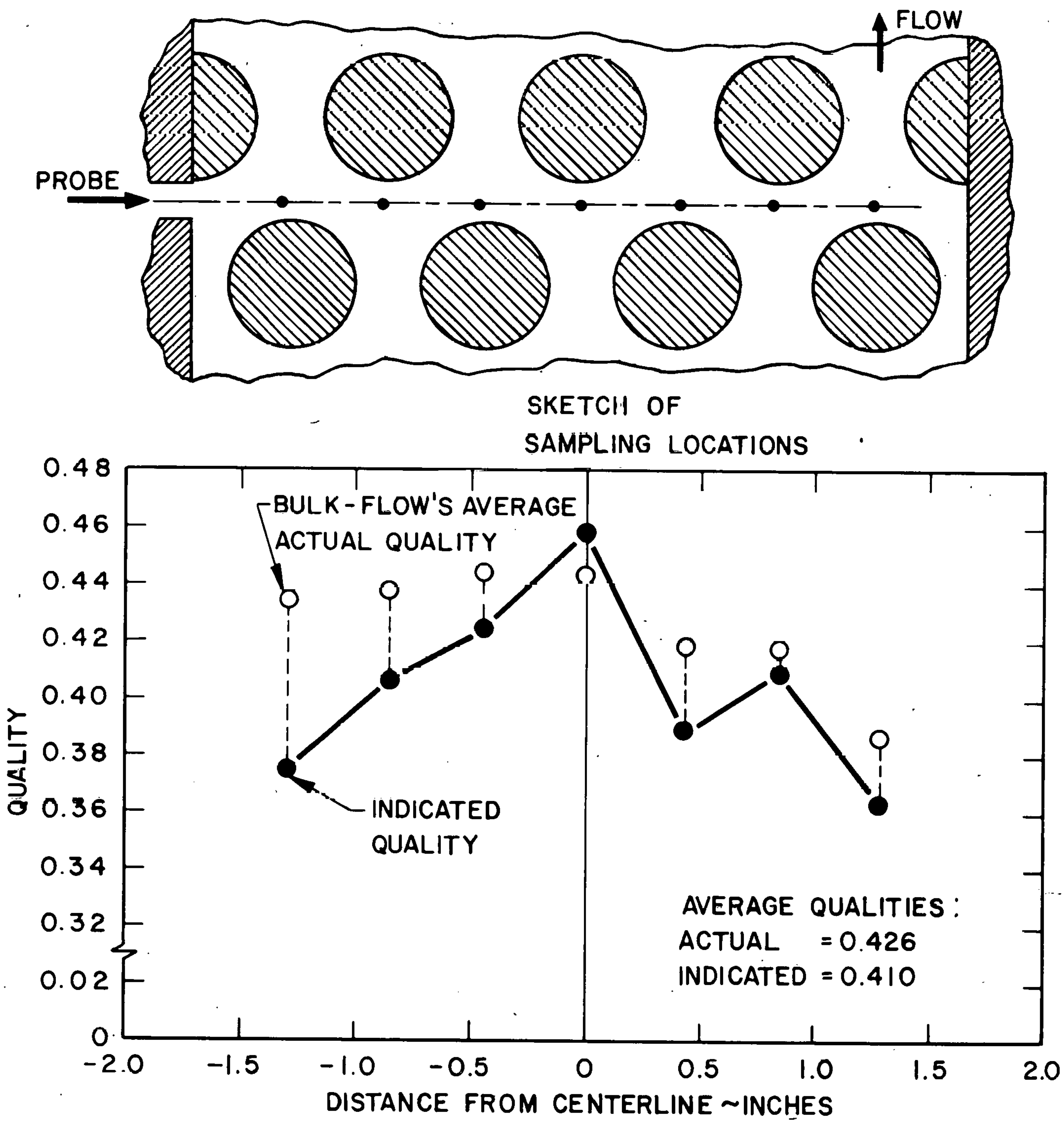
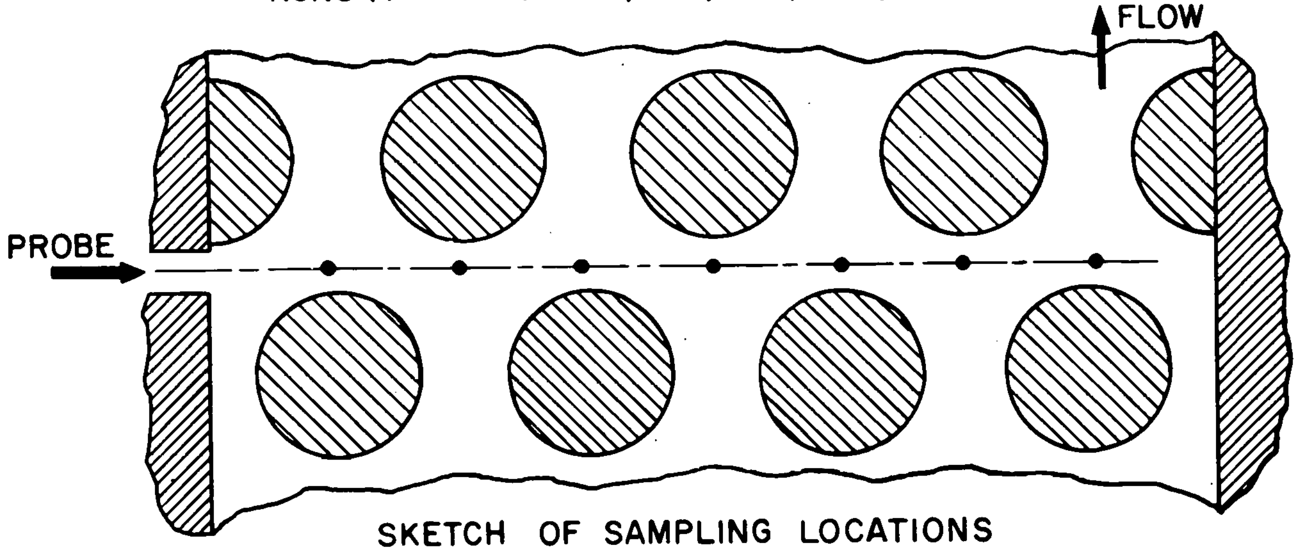


FIGURE 22. QUALITY PROFILE NO. 5

SIMULATOR - HORIZONTAL TUBES
PROBE - ROW-OF-HOLES
PRESSURE - 600 PSIA
MASS VELOCITY - 240,000 LB/HR-FT^2
NOMINAL QUALITY - 0.221
RUNS (TABLE 5) - 275, 281, 287, 293, 299, 305, 311



SKETCH OF SAMPLING LOCATIONS

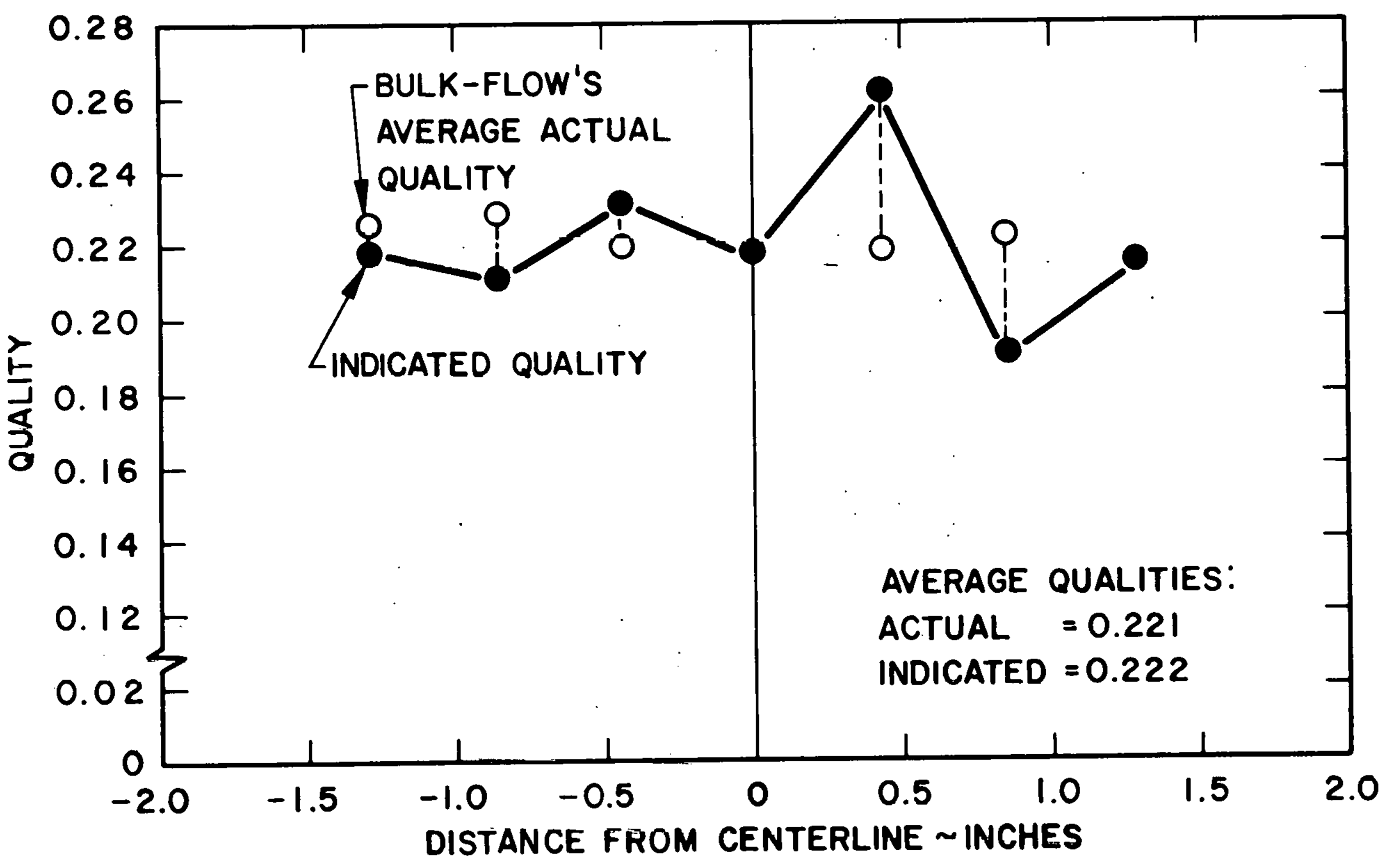
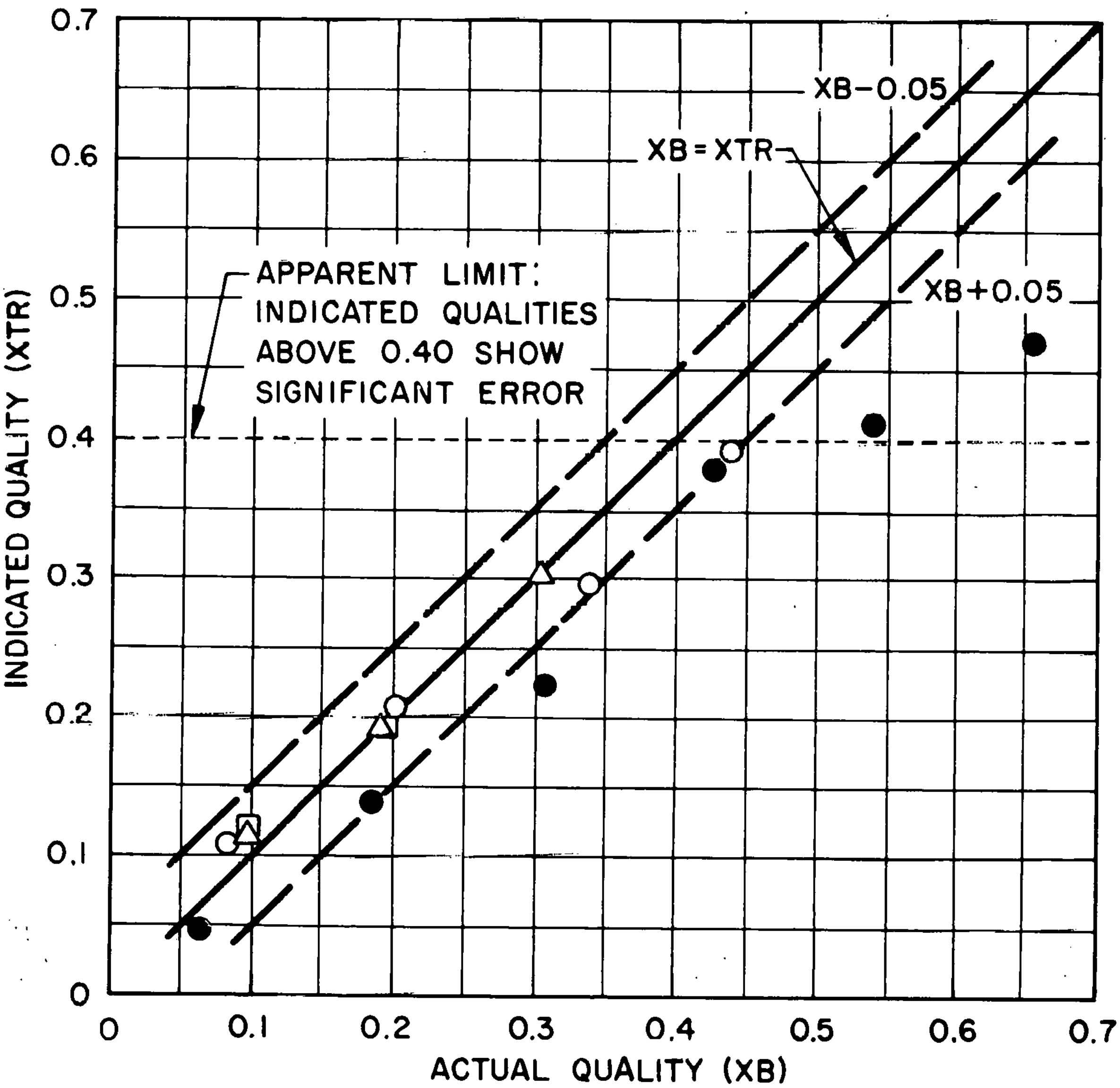


FIGURE 23. INDICATED QUALITY VS ACTUAL QUALITY

SIMULATOR-HORIZONTAL TUBES
PROBE-SINTERED METAL
PRESSURE-600 PSIA

SYMBOL	NOMINAL MASS VELOCITY (LB/HR-FT^2)
●	50,000
○	150,000
△	240,000
□	340,000



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DATA REDUCTION

1. Actual Quality of Bulk-Flow Stream

The actual quality of the bulk-flow was evaluated by performing an energy balance on a control volume. This control volume enveloped the five heated tubes and the unheated simulator up to the level of the quality probe. This balance was expressed as

$$(W)H_{in} + QE_{in} = (W)H_B + QL \qquad \text{(A-1)}$$

where

W = bulk flow rate (lb/hr)

H_{in} = enthalpy at inlet to the five heated tubes as evaluated at the operating pressure and the thermocouple-measured inlet-water temperature (Btu/lb)

QE_{in} = total power input from the five electrically heated tubes (Btu/hr)

H_B = average enthalpy of the bulk-flow at the probe level within the test section (Btu/lb)

QL = total heat loss along the five heated tubes and along the simulator up to the probe level (Btu/hr)

Single phase runs with subcooled exit water conditions were made to evaluate the heat losses. These runs included heated and unheated conditions, i.e. with and without applied electrical power at the five heated tubes.

For tests with the vertical tube simulator, the heat losses were estimated by the expression

$$QL_{VERT} = 51.2(TB - TA) + 4.31(TC - TA) \qquad \text{(A-2)}$$

where

TB = average water temperature along the five heated tubes (^{o}F)

TC = average water temperature along the section from the exit of the five heated tubes to the probe level (^{o}F)

TA = ambient room temperature (^{o}F)

For tests with the horizontal tube simulator, the heat losses were estimated by the expression

$$QL_{HORIZ} = 53.8(TD - TA) \quad \text{(A-3)}$$

where

TD = average of the five wall thermocouples used for CHF detection on the five heated tubes (^{o}F)

The estimated heat losses were typically low, below 25,000 Btu/hr, and corresponded to corrections in the bulk's actual quality of 0.04 and below.

The bulks quality was expressed by the equilibrium model of

$$X_B = \frac{H_B - H_f}{H_{fg}} \quad \text{(A-3)}$$

where

X_B = bulk-flow stream's actual quality

H_f = enthalpy of saturated liquid at the operating pressure (Btu/lb)

H_{fg} = latent heat of vaporization at the operating pressure (Btu/lb)

Combining Equations (A-1) and (A-3) gives the final expression

$$X_B = \frac{H_{in} + \frac{QE-QL}{W} - H_f}{H_{fg}} \quad \text{(A-4)}$$

which was used to evaluate the bulk-flow's actual quality. When the test section water is subcooled, Equation (A-4) gives a negative value of quality (e.g see Table 2, Column 5, Run No. 7).

The accuracy of the actual quality given in expression (A-4) was estimated to be better than ±0.01 quality. This value was based on an error analysis with ±5 psi operating pressure (saturation enthalpy terms), ±2^{o}F inlet temperature (inlet enthalpy), ±0.5 per cent error in flow rate (W), ±0.5 per cent error in the supplied power (QE), and ±20 per cent error in the small heat loss term (QL).

2. Expression for Relating Quality to Tracer Concentration

An expression for relating the qualities to tracer concentrations is derived by writing species mass balances for the tracer and the water. The assumptions for this analysis are:

1. steady-state; steady flow
2. no chemical reactions
3. the tracer substance is present only in the liquid-phase of a liquid-vapor mixture
4. one-dimensional flow in the simulator; tracer is uniformly distributed within the liquid of the liquid-vapor mixture at any cross section.

The following terms apply to this analysis:

CI - tracer concentration in the bulk-flow while the bulk-flow is all single phase liquid; i.e. upstream of heating such as the five heated tubes; a constant by assumptions no. 1 and 4.

CII - tracer concentration in an extracted sample after complete condensation of any vapor extracted with the sample

CB - tracer concentration in the liquid-phase of a two-phase mixture existing in the bulk-flow downstream of heating; a constant by assumptions 1 and 4.

XB - flowing quality of the two-phase bulk-flow stream; defined as $\frac{WBV}{WB}$

XS - flowing quality of the two-phase mixture entering the probe at the point of sampling; defined as $\frac{WSV}{WS}$

WB - mass flow rate of the bulk-fluid from which a sample is extracted

WBL - mass flow rate of liquid in the bulk-flow stream

WBV - mass flow rate of vapor in the bulk-flow stream

WBT - mass flow rate of tracer in the bulk-flow stream

WS - mass flow rate of the condensed sample

WSL - mass flow rate of liquid in the sample line at the point of sample extraction

WSV - mass flow rate of vapor in the sample line at the point of sample extraction

WST - mass flow rate of tracer in the sample line

The quality-concentration expression is derived from the following species mass balances

<u>bulk-flow stream</u>

water: $WB_{in} = WB_{out} = WBL_{out} + WBV_{out}$ (A-5)

tracer: $WBT_{in} = WBT_{out}$ (A-6)

From the definition of concentration and quality,

$$WBT_{in} = (CI)(WB_{in}) \quad \text{(A-7)}$$

$$WBT_{out} = (CB)(WBL_{out}),\ \text{or} \quad \text{(A-8)}$$

$$WBT_{out} = (CB)\,[(WB_{out})(1 - XB)] \tag{A-9}$$

Combining Equations (A-5) through (A-9) gives the relation

$$CB = (CI)\,(\frac{1}{1 - XB}) \tag{A-10}$$

<u>sample flow line</u>

water: $WS_{out} = WS_{in} = WSL_{in} + WSV_{in}$ (A-11)

tracer: $WST_{in} = WST_{out}$ (A-12)

From the definition of concentration and quality,

$$WST_{out} = (CII)\,(WS_{out}) \tag{A-13}$$

$$WST_{in} = (CB)\,[WSL_{in}],\text{ or} \tag{A-14}$$

$$WST_{in} = (CB)\,[(WS_{in})(1 - XS)] \tag{A-15}$$

Combining Equations (A-11) through (A-15) gives the relation

$$CB = (CII)\,(\frac{1}{1 - XS}) \tag{A-16}$$

Combining Equations (A-10) and (A-16) to eliminate the concentration term CB gives the relation

$$XB = 1 - (\frac{CI}{CII})(1 - XS) \tag{A-17}$$

The bulk's quality, XB, given in Equation (A-17) was interpreted as being the probe-indicated value of quality in the bulk-flow stream. It is noted that Equation (A-17) is valid for any value of the sample's quality, XS. Correspondingly, Equation (A-17) can be used to evaluate the probe's indicated quality of the bulk-flow stream provided that the sample's quality can be experimentally evaluated with reasonable accuracy.

3. <u>Sample's Quality by Orifice Characteristics</u>

The slip model for two-phase flow was expressed as

$$XS = \frac{1}{1 + \frac{1}{\gamma}\,(\frac{\rho_f}{\rho_g})\,(\frac{1-\alpha}{\alpha})} \tag{A-18}$$

where

XS = quality of the flowing mixture; e.g. the samples quality for this study ~ dimensionless

γ = slip ratio; velocity ratio of vapor to liquid ~ dimensionless

α = vapor fraction ~ dimensionless

ρ_f, ρ_g = saturation densities of liquid and vapor respectively ~ lb/ft^3

The effective density of the flowing two-phase mixture was expressed as

$$\bar{\rho} = \alpha (\rho_g) + (1 - \alpha) (\rho_f) \tag{A-19}$$

where

$\bar{\rho}$ is the effective density of the flowing two-phase mixture

Rearranging Equation (A-19) gives the expression

$$\left(\frac{1 - \alpha}{\alpha}\right) = \left(\frac{\bar{\rho} - \rho_g}{\rho_f - \bar{\rho}}\right) \tag{A-20}$$

This relation implies that if the effective density, $\bar{\rho}$, can be evaluated and a suitable value of slip-ratio is selected, then Equation (A-18) may be used to approximate the quality of an extracted sample.

The effective density, $\bar{\rho}$, was estimated using the pressure drop characteristics of the orifice built into the probe head. The orifice equation

$$DP = \frac{KW^2}{\rho} \tag{A-21}$$

where

DP = pressure drop ~ psi

W = flow rate ~ lb/hr

ρ = density of fluid flowing through the orifice ~ lb/ft^3

K = orifice constant ~ $(psi)(lb/ft^3)/(lb/hr)^2$

An orifice constant, KC, is evaluated as the constant K from Equation (A-21) from single phase calibration tests with slightly subcooled liquid in the bulk-flow stream. The orifice flow was typically turbulent flow with the orifice constant independent of Reynolds number. However, periodic single phase tests did show variations in the orifice constant with time. This time variation was interpreted as caused by chemistry effects from operating with a nominally neutral pH. The orifice constant denoted as KC represents the value interpolated from a plot of orifice constant K vs. time. These plots are shown in Figures A-1 and A-2.

For a two-phase mixture, the orifice characteristics were then approximated by the expression:

$$DPTP = \frac{(KC)\ W^2}{(\bar{\rho})\ (Y^2)} \qquad \text{(A-22)}$$

where:

DPTP = measured pressure drop during two-phase flow ~ psi

KC = orifice constant evaluated from all liquid calibration runs ~ $(psi)(lb/ft^3)/(lb/hr)^2$

W = flow rate of the condensed sample (lb/hr)

$\bar{\rho}$ = effective density of the flowing two-phase mixture ~ lb/ft^3

Y = expansion factor for the vapor ~ dimensionless

The expansion factor for two-phase mixtures was approximated by the expression

$$Y = 1.0 - (0.4219) \frac{(DPTP)}{(1.27)\ (P)} \ . \qquad \text{(A-23)}$$

This expression is based on Equation (7-16), page 191 of Reference 6. The factor 0.4219 is based on an orifice diameter ratio (β) of 0.013/0.047. The factor 1.27 is the ratio of specific heats (C_p/C_v) for vapor and the pressure (P) is the operating absolute pressure. The expansion factor was evaluated as 1.0 for liquid only flowing through the orifice. This method of using an expansion factor for two-phase mixtures is similar to that reported in the literature, i.e. Reference 7.

Rearranging Equation (A-22) gives the relation

$$\bar{\rho} = \frac{(KC)\ (W^2)}{(DPTP)\ (Y^2)} \qquad \text{(A-24)}$$

Substitution of Equation (A-20) into Equation (A-18) gives the relation

$$XS = \frac{1}{1 + (\frac{1}{\gamma})\ (\frac{\rho_f}{\rho_g})\ (\frac{\bar{\rho} - \rho_g}{\rho_f - \bar{\rho}})} \qquad \text{(A-25)}$$

The slip ratio, γ, used in this study was assumed to be a constant given by

$$\gamma = 2.0\ . \qquad \text{(A-26)}$$

Finally, using the slip ratio given in Equation (A-26) and the estimate of the effective mixture density evaluated using Equation (A-24), Equation (A-25) was used to estimate the sample's quality.

This technique for evaluating the sample's quality was not considered to be rigorous. However, it was judged to be suitable for the low quality samples achieved by the quality probe. The values of quality determined by using Equation (A-25) were checked by comparing estimates from a technique using a heat balance along the sample line and a previously published correlation for two-phase flow orifice characteristics.

A typical comparison of these techniques is as follows:

test - horizontal simulator and row-of-holes probe

run - run no. 209, given in Table 3

mass velocity - 144,000 $lb/hr\text{-}ft^2$

actual bulk quality (XB) - 0.387

term	Method of Evaluating Sample's Quality: Equation (A-25) $\gamma = 2.0$	Heat Balance	James* Correlation
sample quality (XS)	0.014	0.004	0.037
probe-indicated value of bulk quality (XTR)	0.364	0.356	0.377
quality difference (XTR-XB)	-0.025	-0.031	-0.010

* James Correlation, Reference 7, uses Equation (A-24) with the expression

$$\bar{\rho} = [XS^{1.5} (1/\rho_g - 1/\rho_f) + (1/\rho_f)]^{-1}.$$

FIGURE A-1. ORIFICE CONSTANT VS TIME

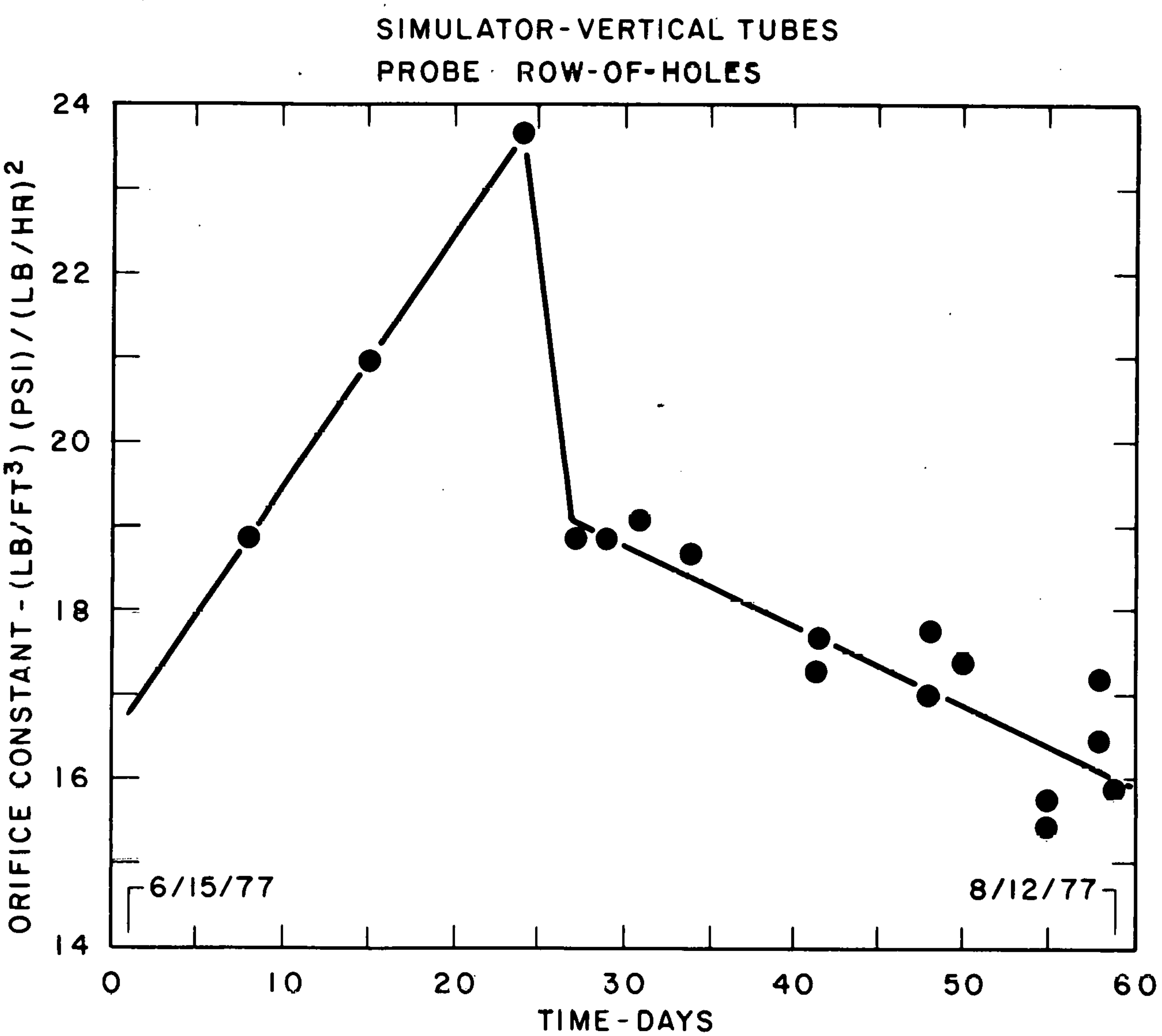

FIGURE A-2. ORIFICE CONSTANT VS TIME, SIMULATOR-HORIZONTAL TUBES