HYDRAULIC MODEL STUDIES OF THE INTAKE AND SUCTION TUBES FOR HAVASU PUMPING PLANT

CENTRAL ARIZONA PROJECT, ARIZONA

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16. ABSTRACT
Hydraulic model studies were performed to assure satisfactory flow conditions through the intake channel, intake structure, and suction tubes for Havasu Pumping Plant, Arizona. The six units of the pumping plant will lift a total of 85 m^3/s (3,000 ft^3/s), 244 metres (m) (800 ft). The main objectives of the model study were: (1) to maintain uniform flow in the intake channel and, therefore, minimize sedimentation and trash buildup; (2) to eliminate vortices that might draw air into the suction tubes and cause rough pump operation and problems with rising bubbles in the discharge line; (3) to establish uniform, nonswirling flow at the pump eye and thus establish the best and most efficient approach flow conditions for the pump; and (4) to minimize head loss through the intake structure and suction tubes. In addition, two suction tube intake designs were studied in an attempt to minimize the structure size. The model was built to a 1:9.39 scale and included 45.7 m (150 ft) of intake channel, the entire intake structure, one correctly modeled suction tube, piping for the other five units, and trashracks for one unit. Flow conditions were generally acceptable except for vortex formation at units without trashracks. The trashracks acted as flow straighteners and eliminated the vortex problem.

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UNITED STATES DEPARTMENT OF THE INTERIOR * BUREAU OF RECLAMATION

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PURPOSE

These studies were made to aid in developing a satisfactory intake structure and suction tube design for the Havasu Pumping Plant, Arizona.

APPLICATION

The results of these studies are generally applicable only to structures with intake and suction tube designs similar to those studied. However, these studies may be useful in initial evaluations of other pump intake structures. Two sizes of suction tube intakes and gate sections were studied. Therefore, this report may give general guidance to the sizing of future suction tube intakes.

RESULTS

1. It was found that uniform distribution of operating units resulted in the best flow conditions in the intake channel and in the immediate vicinity of the suction tube intakes. Uneven distribution of operating units created large back eddies in the approach channel flow and caused severe vortex tendencies at the intakes.

2. The main source of vortex action at the suction tube intakes was the flow separation and rotational flow created when water moving along the face of the piers turned into the suction tube intake (fig. 12). The vortex actions thus created were strongest from the minimum water surface elevation of 134.1 metres (m) (400 ft) to a water surface elevation of 135.0 m (443 ft). The vortex strength reduced to a very weak tendency at elevation 135.6 m (445 ft). Between elevations 135.6 and 137.2 m (445 and 450 ft) (maximum water surface elevation), the vortex action was generally weak and posed no cause for concern.

3. The modification shown in figure 14 was to reduce the size of the flow separation and therefore reduce the vortex strength. It was not successful.

4. Placement of the trashracks on the intakes in all cases reduced the vortex strength at the intakes when the water surface elevation

was below 135.6 m (445 ft). This was because the trashracks functioned as flow straighteners and reduced rotation. In all cases, when the trashracks were in place, no vortices were observed with sufficient strength to draw air into the suction tubes.

5. For all operating conditions observed (including various combinations of operating units, water surface elevations, intake shapes, and both with and without the trashracks in place), the flow conditions throughout the suction tubes were found to be satisfactory. In the cylindrical or barrel section of the suction tube, the flow distribution was fairly uniform, with only very small angular velocity components. Similar satisfactory flow conditions were observed at the pump eye where the greatest velocities were approximately 106 percent of the average velocity and the greatest angular velocity was approximately 10° from axial. (This was quite rare; the vast majority of the data had less than 5° variation from axial flow.)

6. Head loss data indicated that the loss coefficient for the entire suction tube was approximately 0.09 based on the pump eye velocity head. The loss coefficient for the intake, gate section, transition, and 2.9 m (9.4 ft) of the barrel was found to be 0.008 and the loss coefficient for the remainder of the suction tube is 0.082. For a discharge of 14.2 m^3/s (500 ft^3/s) through a prototype suction tube, the corresponding head losses would be 0.49 m (1.60 ft) of water for

the total suction tube, 0.04 m (0.14 ft) for the upper portion of the suction tube, and 0.45 m (1.46 ft) for the lower portion. As can be seen, losses through the upper portion of the suction tube are small compared to those for the total suction tube. In conjunction with this, it was found that variations in the inlet shape or the presence of trashracks did not noticeably affect the head loss.

7. Both the square suction tube inlet and the rectangular suction tube inlet (fig. 10) yielded satisfactory hydraulic performance. The resulting flows for the two intakes (both in the intake channel and in the suction tube) were indistinguishable from each other.

INTRODUCTION

Havasu Pumping Plant is one feature of the Central Arizona project (fig. 1). The CAP (Central Arizona project) is a complex project the objective of which is to supplement and stabilize the water supplies of Maricopa, Pinal, and Pima Counties of central Arizona. It is also hoped that CAP will satisfy the growing water needs of these areas until the year 2000. Maricopa, Pinal, and Pima Counties not only contain the rapidly expanding metropolitan areas of Phoenix and Tucson, but also contain extensive established agricultural areas. For over three decades, central Arizona's natural water supply has been out of balance with total water demands, and the agricultural economy in particular has flourished and declined in direct relationship to the adequacy of water resources. Massive overpumping of ground-water reserves has been necessary to balance the yearly supply-demand relationship. The current overdraft on the underground basins of over 2.46 cubic dekametres (2 million acre-feet) per year is causing ground-water levels to decline at an average annual rate of 2.4 to 3.0 metres (8 to 10 ft) and consequently is also causing serious land subsidence. The importation of Colorado River water through construction of the CAP will be a great step towards reducing this annual overdraft and stabilizing ground-water levels.

The water will initially be lifted 244 metres (800 ft) from the Colorado River at Lake Havasu to the portal of Buckskin Mountains

Figure 1. - Location map.

Tunnel. After passing through the 10.5-km (6.5-mi) long tunnel, the flow enters Granite Reef Aqueduct and is transported to storage reservoirs near the use area. The maximum discharge for this system is 85.0 m^3/s (3,000 ft^3/s).

The initial 244-m (800-ft) vertical lift will be accomplished by Havasu Pumping Plant (fig. 2), the subject of this report. Havasu Pumping Plant will have six pump units, each with a maximum discharge capacity of 14.2 m^3/s (500 ft^3/s). The pumping plant will withdraw water from Lake Havasu through an intake channel. Because of the possibility of unsatisfactory flow conditions in the intake channel (fig. 3), in the intake structure (figs. 3 and 4), or in the suction tubes (fig. 4), a hydraulic model study of these elements was initiated. The four objectives of the study were:

1. Maintain uniform flow in the intake channel in the immediate vicinity of the pumping plant for all operating conditions. Uniform flow minimizes sedimentation and trash buildup that can result from back eddies and no-flow zones.

2. Eliminate all vortices that might draw air into the suction tubes. Air passing through the pumps would create rough operation and vibrations. The air could also cause problems as it rises and expands in the pump discharge lines.

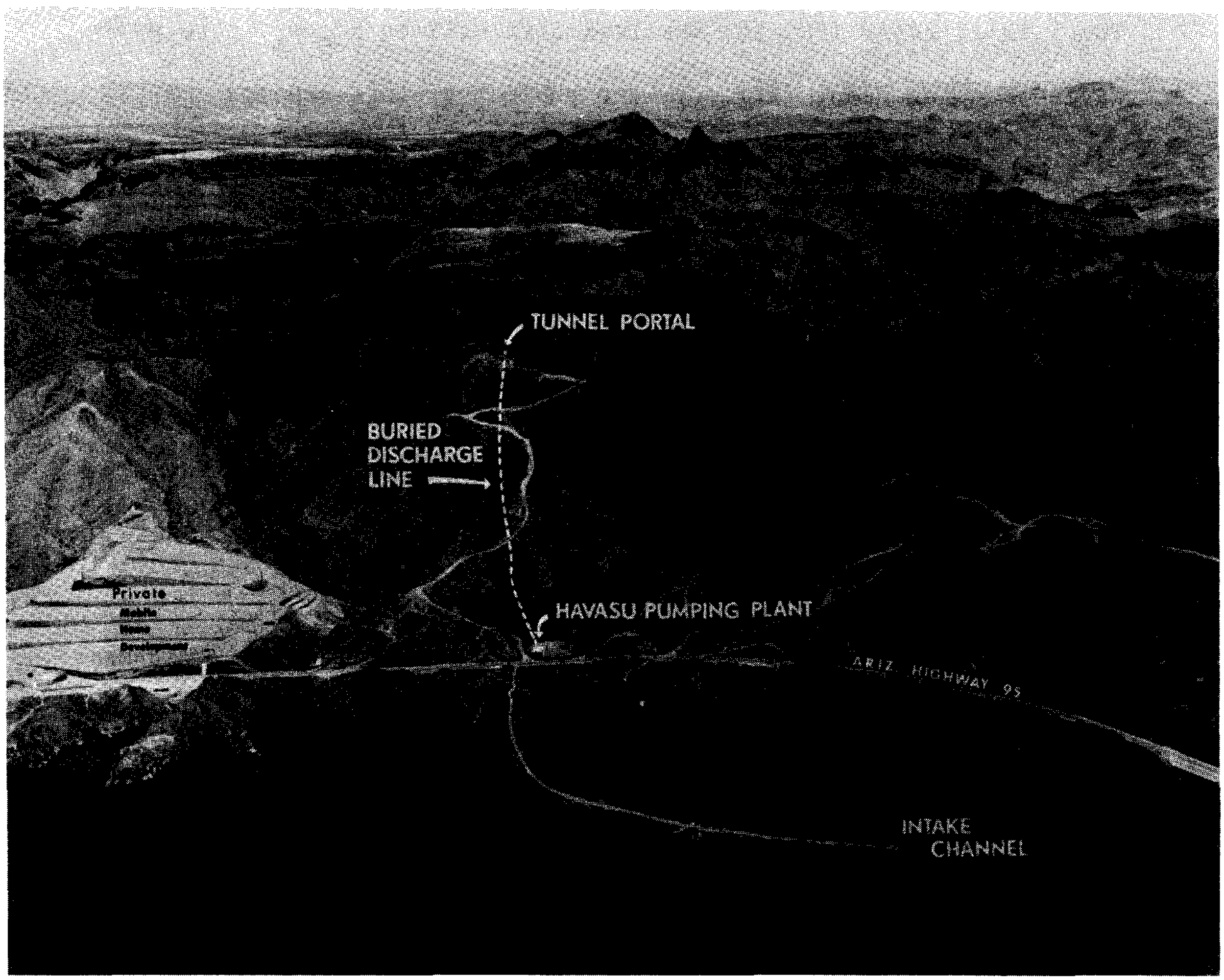


Figure 2. - Havasu Pumping Plant. Photo P344-300-12523

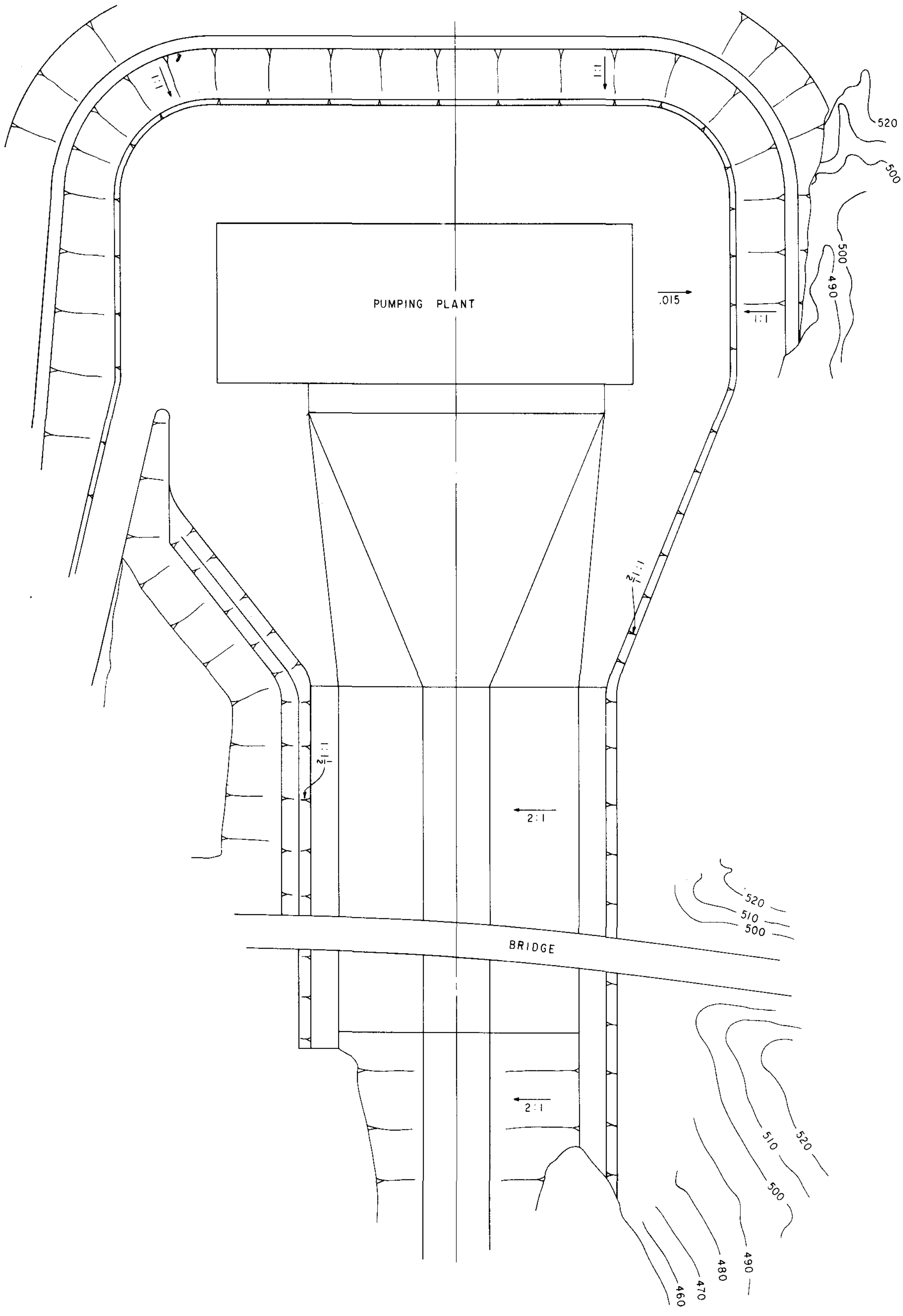


Figure 3. - Plan view of pumping plant and intake channel.

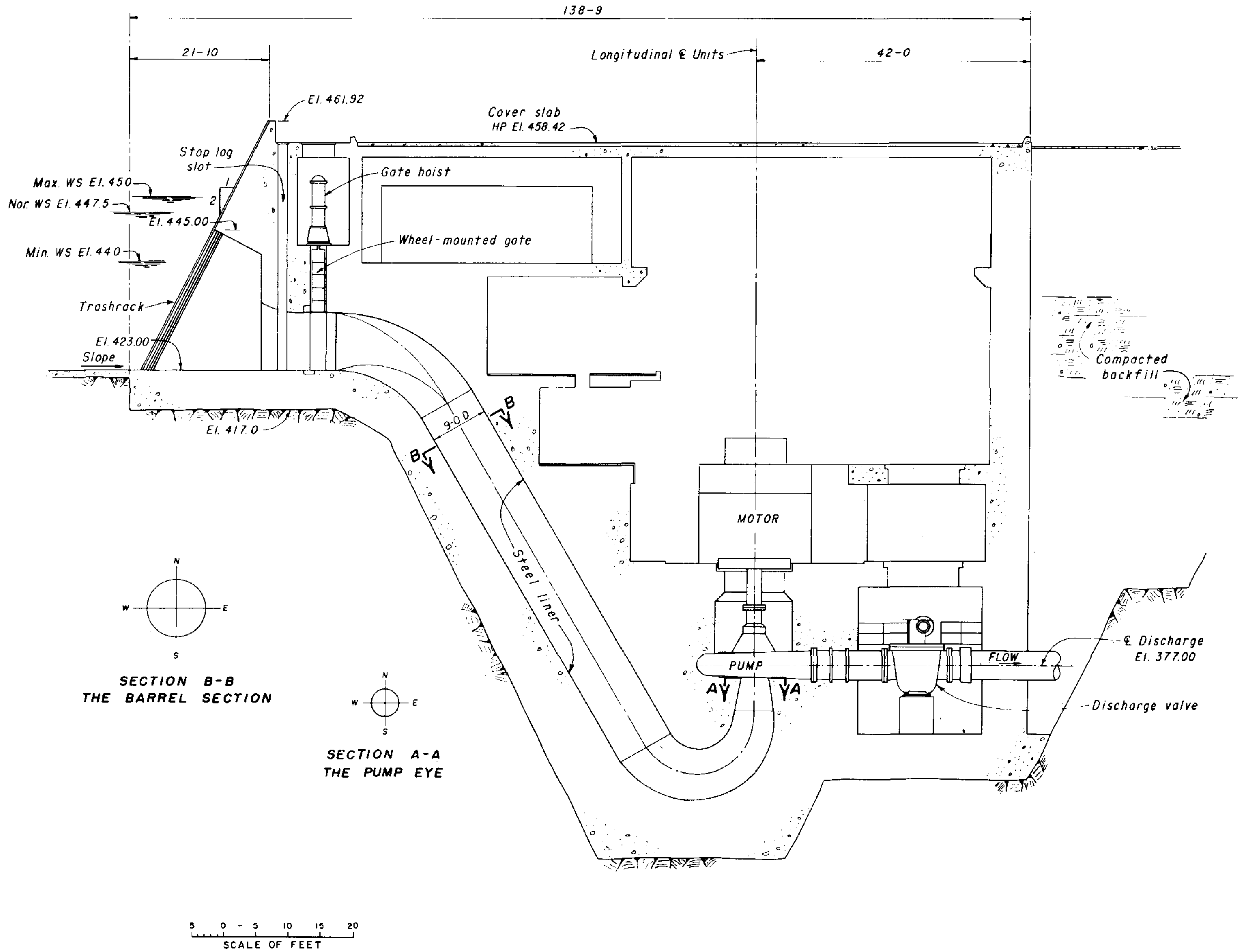


Figure 4. - Typical section of suction tube and pump.

3. Establish uniform, nonswirling flow at the pump eye. The pumps are designed for, and thus operate most efficiently with, uniform intake flow conditions.

4. Minimize head loss through the intake structure and suction tubes. This can be tied directly to the overall efficiency of the system and, therefore, to the power demands of the system. By meeting the combined third and fourth objectives, the power usage of the system should be minimized.

Dimensions used in this report, unless otherwise stated, refer to the prototype structure.

THE MODEL

Four factors were considered in the selection of the model scale. These were:

1. Maximize the diameter of the model pump eye. This is done to minimize the effects of flow disturbances caused by velocity probes inserted at the section. These disturbances could cause inaccuracies in the velocity profile data.

2. Maintain maximum discharge below the capacity of the laboratory pumps.

3. Limit the model size to fit the available laboratory floor space.

4. Select the model size so that standard plastic stock could be used in the model suction tube.

When these four criteria were considered, a model scale of 1:9.39 was selected. The 2.7-m (9-ft) diameter barrel or cylindrical section of the suction tube was modeled with 292-mm (11.5-in) inside-diameter plastic pipe (fig. 5). The 1.32-m (4.333-ft) prototype pump eye diameter was modeled as 141 mm (5.537 in). The maximum total prototype discharge of 85.0 m^3/s (3,000 ft^3/s) was modeled by a discharge of 0.31 m^3/s (11.1 ft^3/s). The model contained one correctly modeled suction tube and gate section. The other five units had piping and simplified gate sections which enabled the withdrawal of correctly modeled discharges (fig. 6). The modeled suction tube and gate section were movable and were tested at various unit locations. The model was constructed so that alternate gate sections and upper suction tube transitions could be tested. The upper suction tube transition is the one between the gate section and the barrel portion of the tube. The intake model also contained the intake structure and a portion

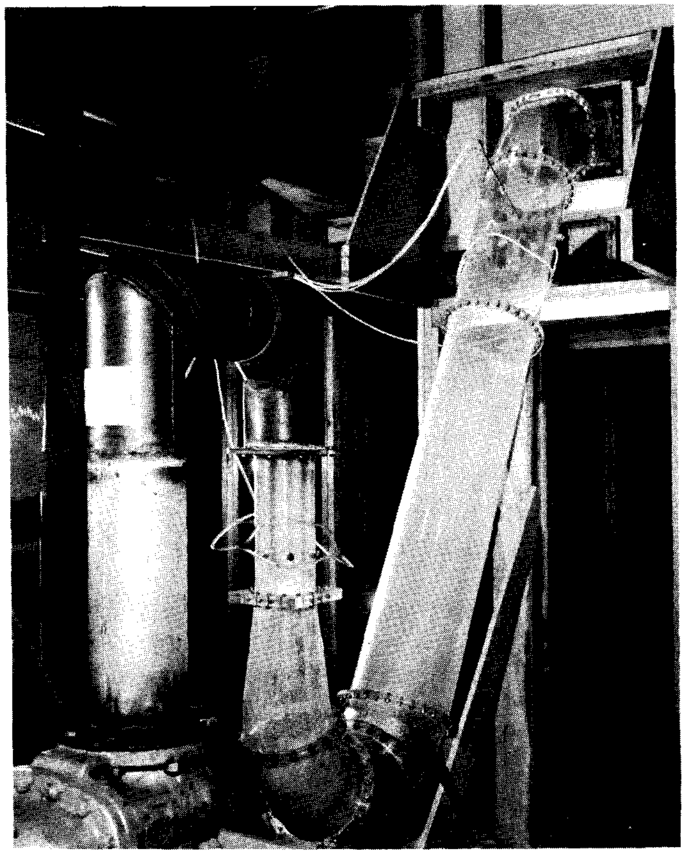


Figure 5. - Model suction tube. Photo P344-D-77307

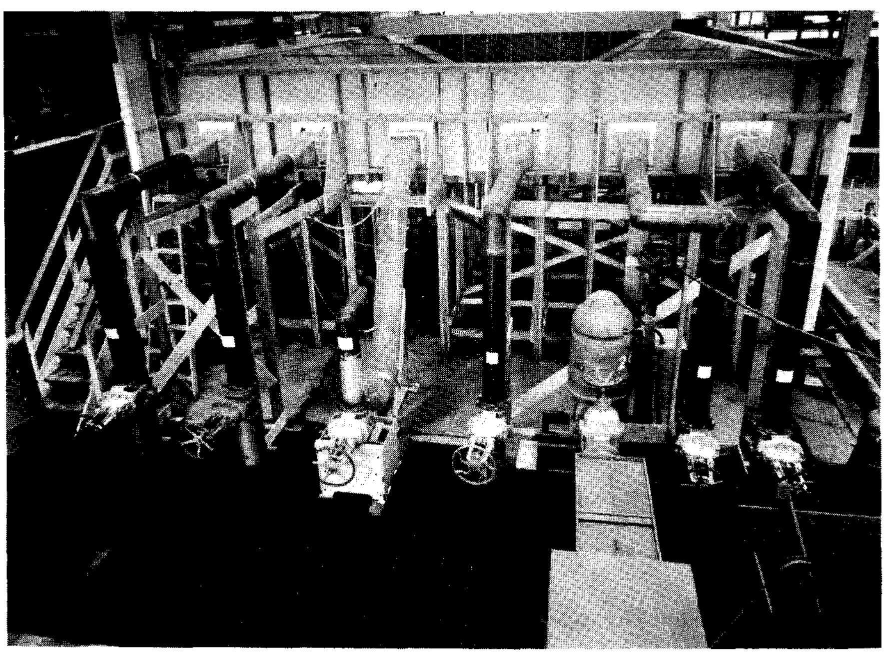


Figure 6. - Model release piping. Photo P344-D-77308

of the channel (figs. 7 and 8). All of the channel transition and approximately 30.5 m (100 ft) of the trapezoidal channel were included. The trashrack was modeled for one intake. All discharges were measured with venturi meters. The suction tube was modeled in plastic, the gate section in sheet metal, and the intake structure and channel in plywood and concrete.

The model was constructed so that both intake channel and suction tube flows could be studied under many operating conditions. All units could be operated independently and the channel water surface could be set at any desired elevation.

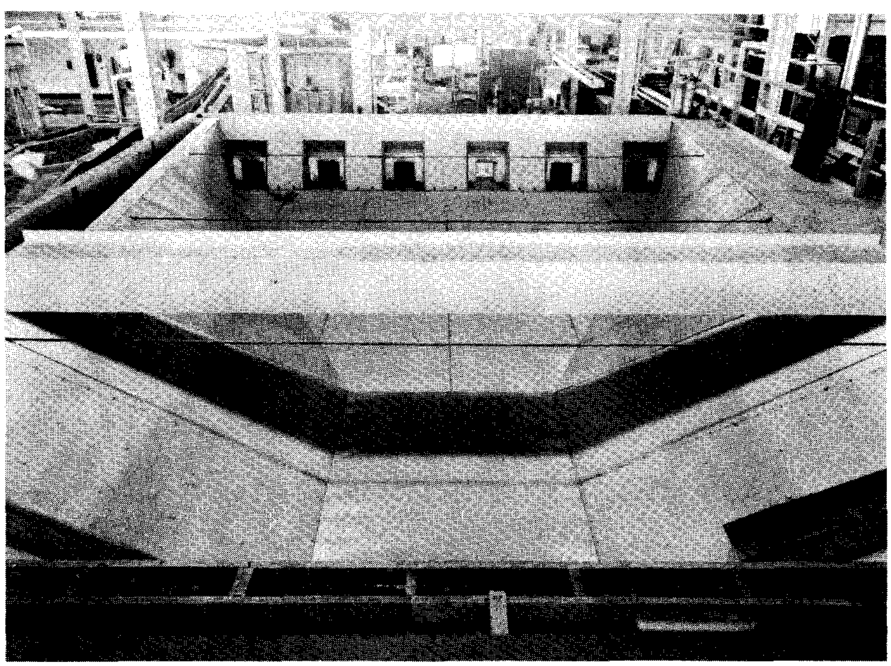


Figure 7. - Model intake channel. Photo P344-D-77309

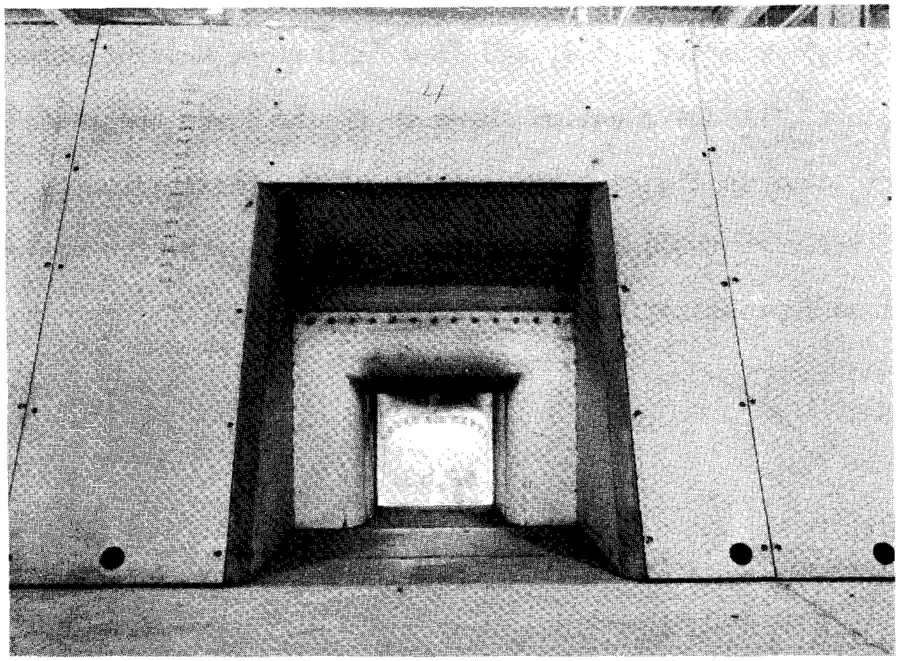


Figure 8. - Model suction tube intake. Photo P344-D-77310

THE INVESTIGATION

Each unit was calibrated so that it could be independently operated. Verification of flow conditions in the approach channel followed the calibration. For verification, the model was set up with all six units operating at maximum discharge. Pigmy and midget current meters were used to obtain velocity traverses at stations 3.1 m (10 ft) upstream from the end of the trapezoidal channel and 19.8 m (65 ft) upstream from the base of the intake structure face. The velocity profile was modified by the use of screening, which created resistance against high-velocity flows, and flow deflectors which redirected the flows, until the distribution shown in figure 9 was obtained. The contours shown in figure 9 are a ratio of the local velocity to the average velocity through the section. This distribution was considered to be representative of prototype conditions.

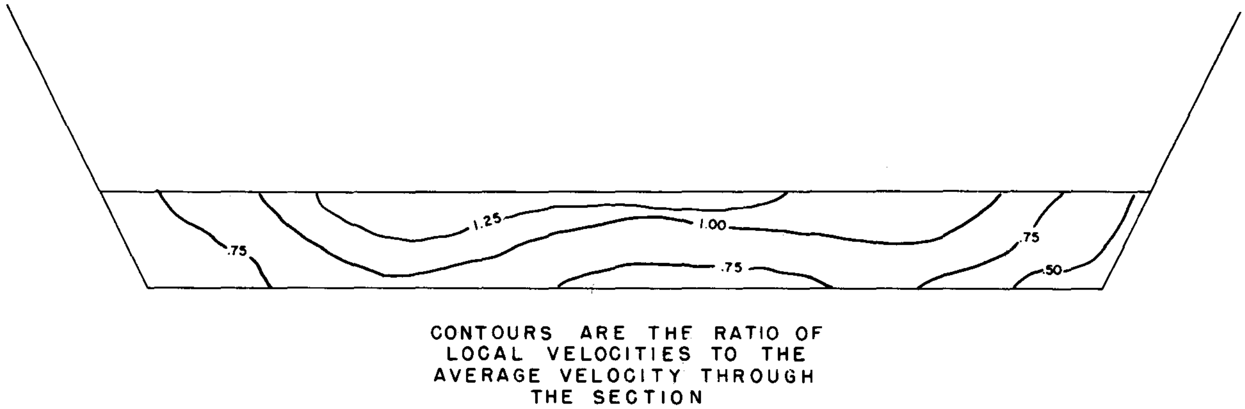


Figure 9. - Intake channel velocity distribution.

Unit 4 Suction Tube

Approach flow. - Evaluation of flow in the approach channel for various operational conditions followed. Two factors were considered. The first was the general flow pattern in the approach channel between the end of the trapezoidal channel and the intake structure. This included evaluation of strong directional flows, no-flow areas, and areas with large eddies. The second factor considered was the vortex action that occurred at individual intakes. The vortex action was evaluated only at the unit with the correctly modeled gate section and suction tube. In considering vortex tendencies, the main concern was with intensity and whether the vortices might pull air into the suction tube. The effect of the trashracks on these vortices was also considered.

The modeled suction tube was initially placed at unit 4 (the fourth unit from the left looking in the direction of flow). It was studied at that section with both a square cross-section intake and a rectangular cross-section intake (fig. 10). All possible operational conditions were considered, including various units operating in combination with unit 4 over the full range of possible water surface elevations. The more significant of these conditions were studied in detail. Video tapes were made of both the general channel flow patterns and the vortex tendencies. Through the use of the video tapes, the various flow conditions were evaluated and compared. The most severe flow concentrations and back eddies occurred in the approach channel for very unsymmetrical combinations of operating units (such as units 4, 5, and 6 operating together). Generally, reverse eddies occurred in front of all nonoperating units (fig. 11). If the nonoperating unit was bordered by operating units, the reverse eddy area was small (unit 3, fig. 11). But if the bordering units were also nonoperating, then more extensive eddies were noted (units 5 and 6, fig. 11). In some cases (such as units 1, 2, and 4 operating together), a strong shearing action would occur between the strong directional flow

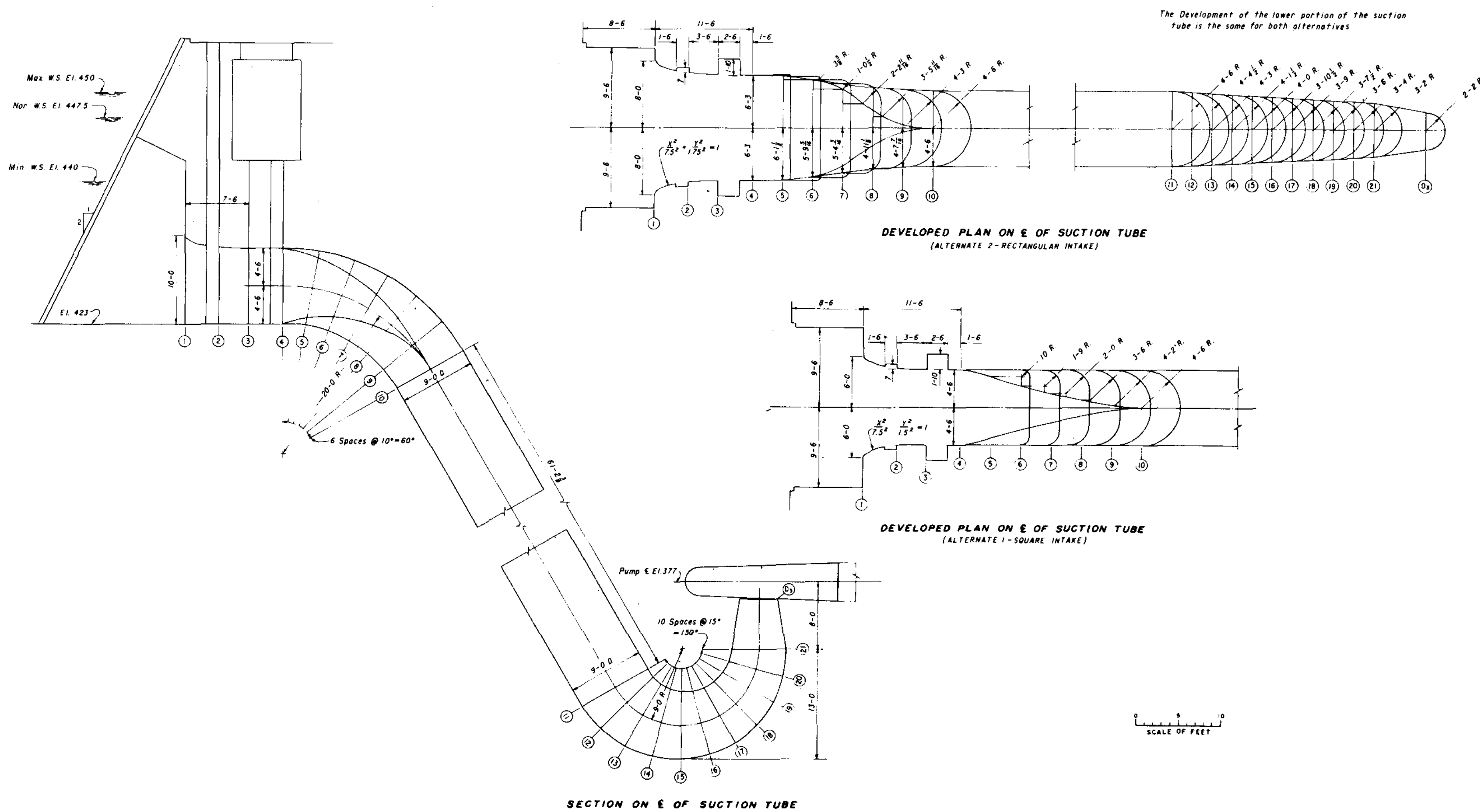


Figure 10. - Alternate suction tube designs.

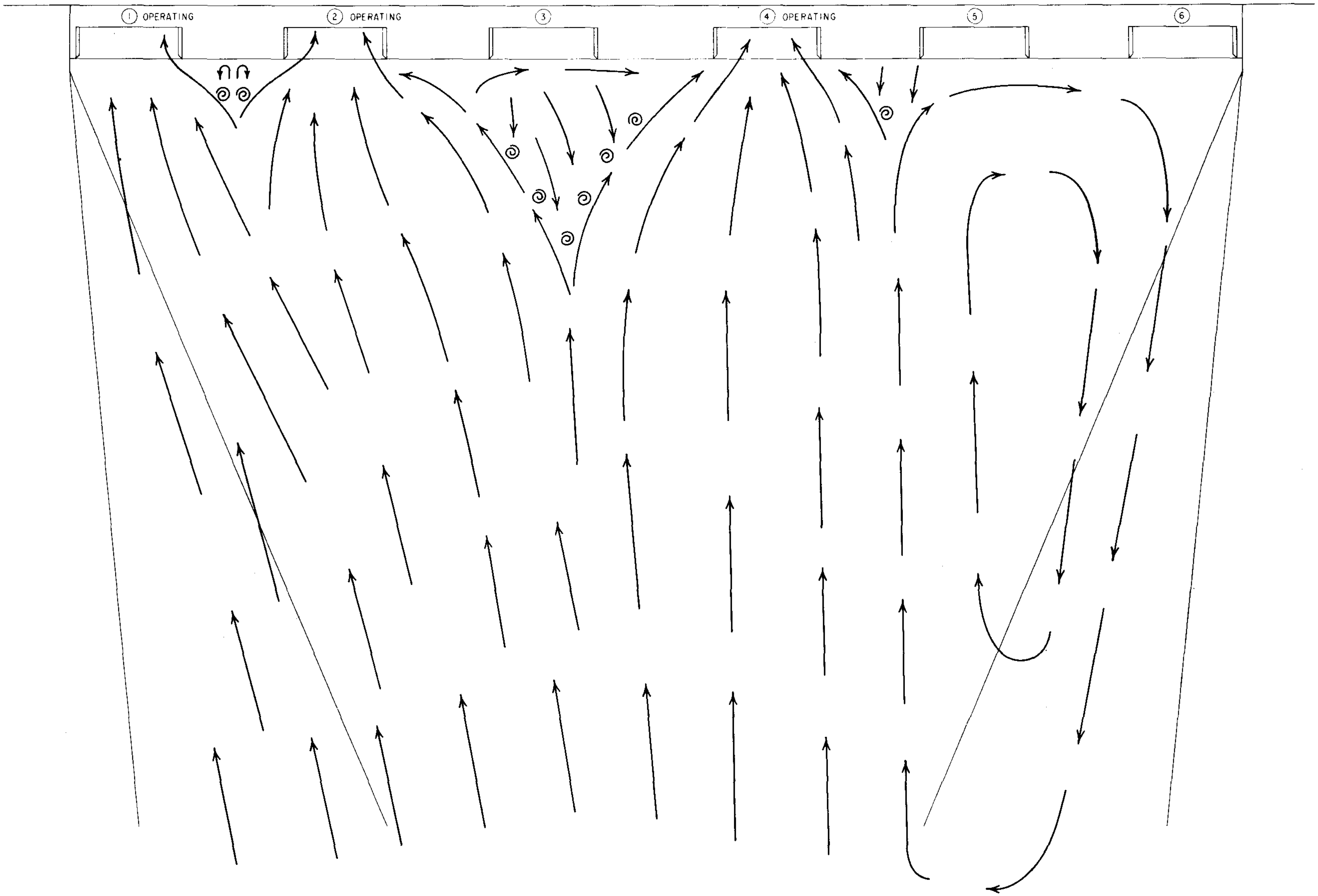


Figure 11. - Channel flow patterns (units 1, 2, and 4 operating).

entering an intake and the reverse eddy area in front of the bordering nonoperating unit (such as between units 3 and 4 in fig. 11). This shearing action created small dimple-like vortices which dissipated as they moved toward the intake (fig. 12). Generally, the best intake channel flow conditions were when the operating units were as uniformly distributed as possible.

Vortex action. - Simultaneous with observations of the intake channel flow conditions, vortex action at the intake to the unit with the modeled suction tube was studied. Generally, the most severe vortex action occurred at the minimum water surface elevation, 134.1 m (440 ft). At this level the water surface is 1.5 m (5 ft) below the top of the intake (fig. 4) and the beveled corners of the piers between the units have a maximum effect on the surface flow. Strong currents moved along the face of the piers toward the open intakes and once past the piers, turned into the intakes (fig. 12). The momentum established as the flow moved along the pier face caused a flow separation at these corners, and eddies formed between the intake flow and the pier walls. This swirling flow in turn led to the formation of vortices. It should be noted that the most severe vortices observed under any condition had only intermittent formation of strong, organized cores. Only occasionally did these cores develop sufficient strength to draw air into the suction tube. Vortices of this strength were never observed when the

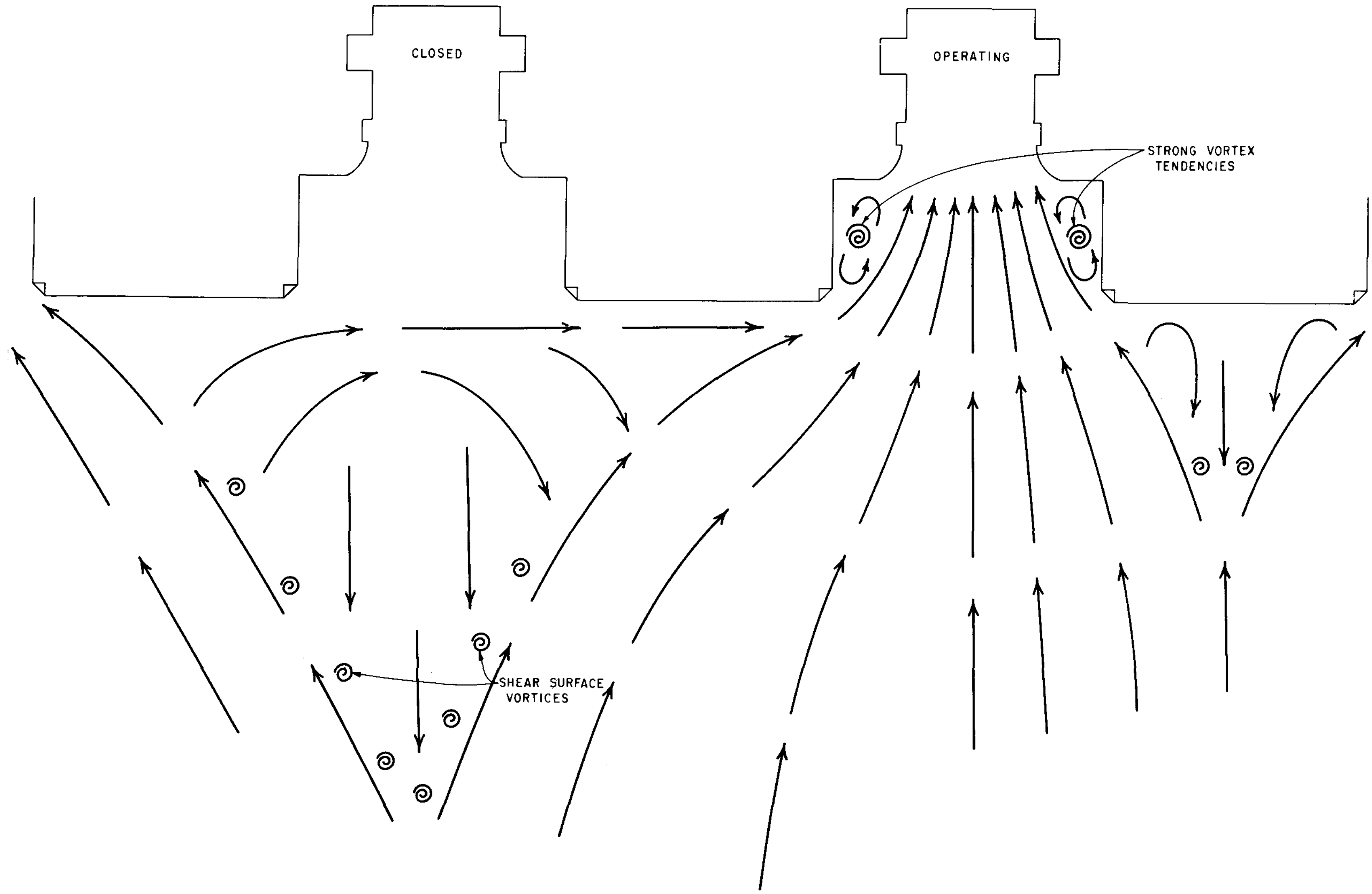


Figure 12. - Flow patterns at interior intake.

trashracks were in place (fig. 13). The trashracks significantly reduced vortex intensity by acting as flow straighteners and breaking

Figure 13. - Intake with trashrack. Photo P344-D-77311

up tight swirls. These swirls were replaced by large, rather mild eddies. To further improve flow conditions, an attempt was made to reduce the amount of dead area created by the flow separation at the intake. The sidewall modification shown in figure 14 was installed and tested at unit 4. No significant improvement in flow conditions was noted either with or without the trashrack in place.

The vortex intensity was less at higher water surfaces in all cases, for two primary reasons. First, the submergence of the intake is greater and, in general, this can be expected to reduce vortex strength.

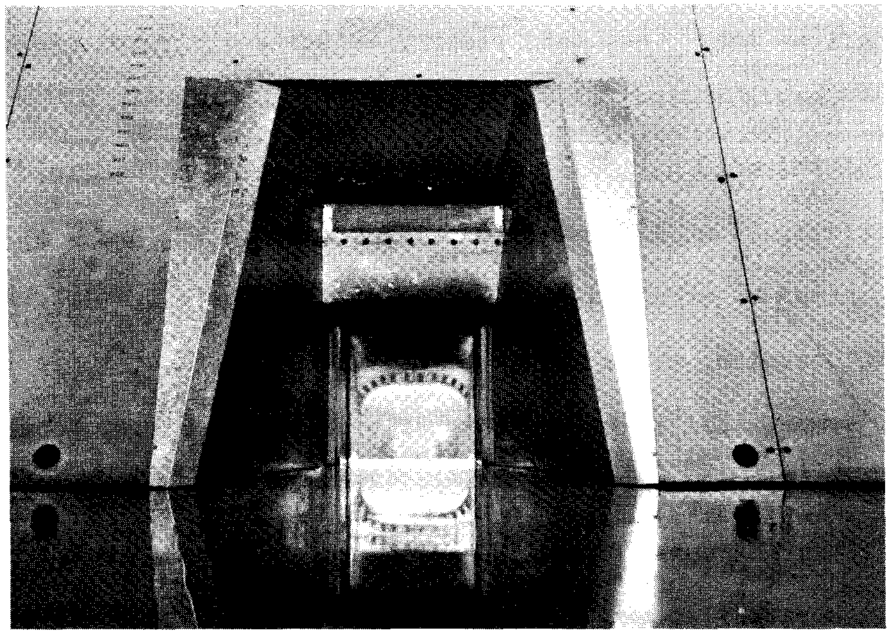


Figure 14. - Intake modification. Photo P344-D-77312

Second, as the water surface rises, the recessed intake has less effect on the surface flow pattern. The surface reverse eddy area created by the flow separation is consequently reduced as the water surface rises from elevation 134.1 m (440 ft) to elevation 135.6 m (445 ft) and is eliminated for water surfaces above elevation 135.6 m. The strongest vortices observed when the water surface was above elevation 135.6 m consisted of shallow surface dimples with fairly disorganized circulation cores. These vortices pose minimal threat of developing air-entraining cores.

When evaluation of surface flow conditions was completed, study of flow inside the unit 4 suction tube was started. It was thought that approach flow conditions might affect the velocity distribution in the suction tube. For this reason, velocity distributions were evaluated with two very different approach flow conditions. The two conditions selected were unit 4 operating alone at the maximum water surface elevation of 137.2 m (450 ft) and units 1, 2, and 4 operating at the minimum water elevation surface of 134.1 m (400 ft). When unit 4 is operating alone at the maximum water surface, there is low-velocity symmetrical approach flow, with only weak vortex tendencies. The vortices displayed shallow surface dimples with weak and disorganized circulation cores. Conversely, the flow conditions for units 1, 2, and 4 operating at the minimum water surface elevation were unsymmetrical, relatively high-velocity approach flows with strong vortex tendencies. The unsymmetrical approach flows were created by the strong, direct approach flow toward units 1 and 2 and the no-flow areas in front of units 5 and 6. As indicated in figure 11, the flow tends to approach unit 4 from the left (looking in the direction of flow). Unit 3 was closed to maximize the flows along the face of the piers and, therefore, maximize flow separation and vortex intensity.

Suction tube flow. - Velocity distribution data were collected at two sections in the suction tube (fig. 5). The first section was in the barrel 1.4 m (4.7 ft) downstream from its upper end. Data were collected at this section using a 6.4-mm (1/4-in.) diameter pitot cylinder. The second section was the pump eye or the section at which the suction tube attaches to the pump casing. At this section, a 3.2-mm (1/8-in) diameter pitot cylinder was used. Data were taken both with and without the trashracks in place so that their significance could be evaluated. Data were also taken for both the square gate section (alternate 1) and the rectangular gate section (alternate 2).

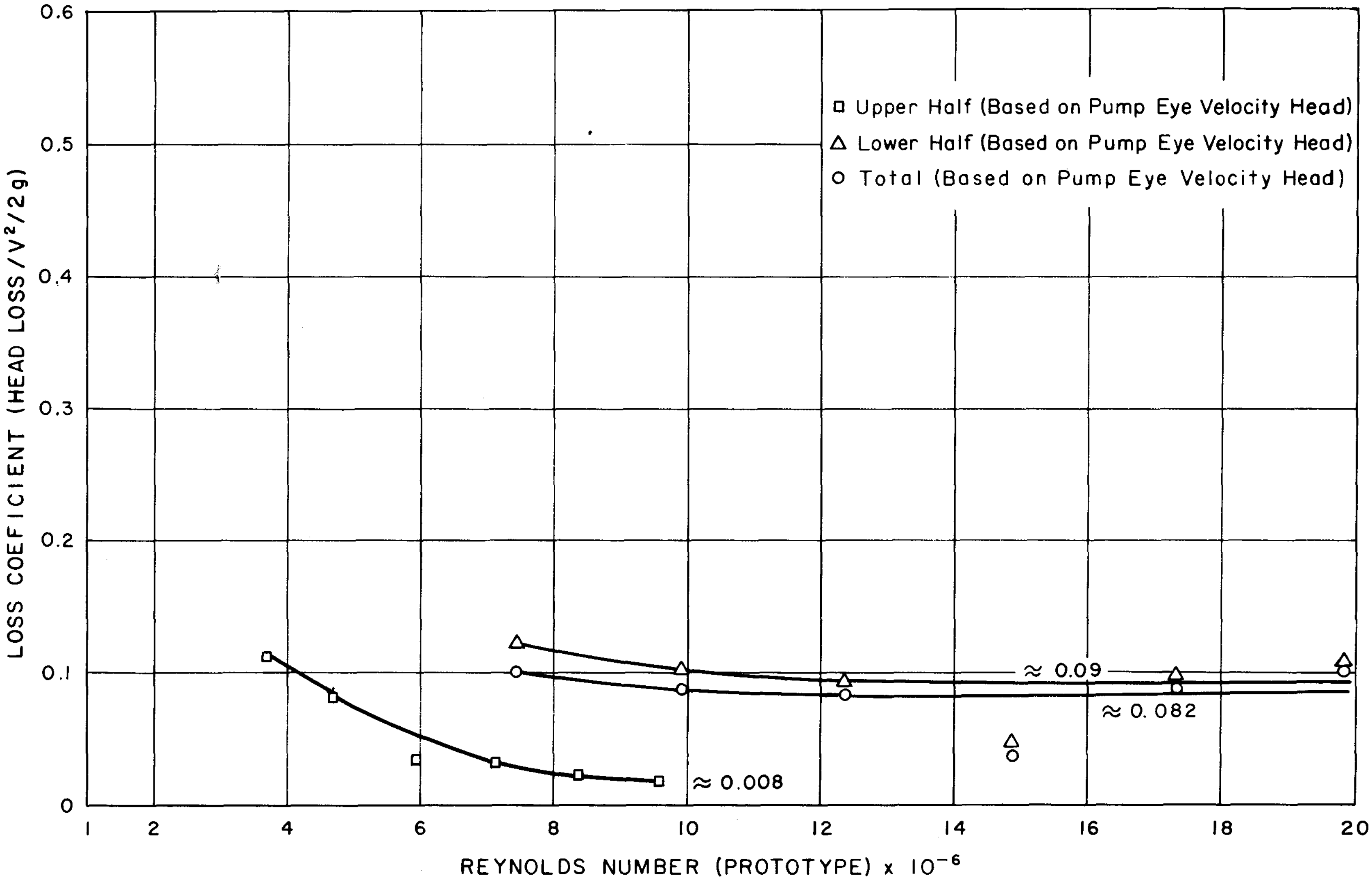
It was found that slightly higher velocities occurred near the sides of the barrel section and slightly lower velocities occurred near the top and bottom of the section (figs. A-1 through A-5). The highest velocities generally occurred in the middle of the section. These flow patterns can be attributed to two factors. The first is simply that the shear at the conduit wall forces the flow velocity at the boundary to zero. This would, therefore, tend to create a situation where the velocities in the center are higher than the velocities near the boundaries. The second contributing factor is that the incoming flow is constricted more at the sides than at either the top or the bottom. Not only is the vena contracta effect tending to constrict the flow, but the intake itself reduces in width from both sides. This would tend to cause higher velocity flow concentrations toward the sides of the barrel section. The highest velocities observed at the barrel section were approximately 108 percent of the average flow velocity through the section.

Good barrel section velocity distributions were observed for all conditions. Very little angular rotation about the suction tube axis was noted. In general, no distinct variations were detected between cases with and without trashracks, between cases with square or rectangular gate sections, or between cases with various approach flow conditions. Observed velocity distributions are shown in figures A-1 through A-5.

At the pump eye section a slightly skewed velocity distribution was noted for all flow conditions. Tests were run for the alternate 1 and alternate 2 intake gate sections, with and without the trashracks in place. As before, these runs were made with unit 4 operating alone at the maximum water surface elevation and with units 1, 2, and 4 operating at the minimum water surface elevation. In all cases, crescent-shaped higher-velocity areas occurred toward the sides of the section and toward the outside of the suction tube bend (figs. A-6 to A-13). Lower velocity areas were noted in a portion of the pump eye section that is toward the inside of the bend and that extends out toward the center of the section. Once again, no distinct variations could be detected between the various flow conditions and structures. Maximum observed velocities at the pump eye section were approximately 105 percent of the average flow velocity through the section. Rotation in the flow of up to 10° from axial was noted in some isolated cases but, in general, the observed rotation was less than 5°.

In summary, the observed flow conditions in the unit 4 suction tube were satisfactory. The flow was observed moving smoothly and continuously downstream. No separation zones, adverse eddy patterns, or detrimental swirling were noted. Flow conditions at the eye of the pump were relatively steady, uniform, and well directed.

Head loss. - The final consideration included in the evaluation of the unit 4 suction tube was head loss. Head loss data were collected for both the alternate 1 and 2 intakes. Data were also collected both with and without the trashracks in place. No clear distinction could be made between the alternate 1 and 2 data and between the data obtained either with or without trashracks. The head loss curves obtained are shown in figure 15. The curve for the upper portion of the suction tube shows head losses resulting between the reservoir and a point 2.87 m (9.4 ft) below the upper end of the barrel. The curve for the lower portion of the suction tube shows head loss from the point 2.87 m below the upper end of the barrel to the pump eye. It can be observed that the loss coefficient for the entire suction tube is approximately 0.09 based on the pump eye velocity head. This would translate to a head loss of 0.49 m (1.6 ft) of water in the prototype at the maximum discharge of 14.2 m^3/s (500 ft^3/s). The loss coefficient for the upper half of the suction tube at the pump eye was found to be approximately 0.008 and the loss coefficient for the lower half was found to be 0.082. The corresponding prototype head losses



HEAD LOSS DATA

Figure 15. - Head loss data.

at a discharge of 14.2 m^3/s (500 ft^3/s) are 0.04 and 0.45 m (0.14 and 1.46 ft) of water, respectively.

Unit 6 Suction Tube

With completion of testing at unit 4, the modeled suction tube was moved to the unit 6 position. Unit 6 was selected because it has very different approach flow conditions from those of unit 4. Unit 6 is an outside unit and, therefore, has approach flow from the front and one side. Units 2, 3, 4, and 5, the interior units, have approach flow from the front and both sides. The unit 6 location posed one problem. After the model had been constructed, an architectural change altered the slope of the trashrack surface from 1:4 to 1:2. The 1:2 slope trashrack surface was installed, but no change was made in the positioning of the channel transition. This caused an inaccurate modeling of the intersection between the trashrack surface and the intake channel. It was believed that the inaccuracy would have no effect on the hydraulic performance of the inside units, but would possibly affect the performance of units 1 and 6. Visual observations of the flow through unit 6 indicated the flow resulting in the inaccurate model should be more unsymmetrical than flow through a true model. This would result in worse flow conditions in the inaccurate model than in a true model with respect to both vortex formation tendencies and velocity distribution. Therefore, it was believed that if the inaccurate model showed satisfactory flow conditions, then the prototype should be assured of satisfactory hydraulic performance.

Because the alternate 1 intake was more nearly an optimum design, it was concluded that if flow conditions through it were found to be satisfactory, it would probably be used. It was also noted that both intakes had nearly identical hydraulic performance at the unit 4 position. For these reasons, it was decided that alternate 1 intake at the unit 6 position would be tested first and then the alternate 2 intake would be tested, if appropriate.

Approach flow and vortex action. - Studies were begun which were similar to, but briefer than, those at unit 4. Video tape and visual observations were made of surface approach flow conditions. Velocity distribution data were collected at the barrel and pump eye sections. Head losses were also considered. The vortex observations yielded results similar to those obtained at unit 4. The surface flow conditions for high water surface levels consisted of large eddy areas with intermittent dimples. Very little surface motion was observed in the middle water surface elevation range. Strong eddies with occasional strong vortices were noted near the minimum water surface elevation. Because of the very unsymmetrical approach flow conditions, the strongest eddying and vortex tendencies were always observed in the interior half of the intake. The configuration and intensity of the vortex action changed with various combinations of operating units. Unsymmetrical unit operation at relatively high channel discharges (such as units 1, 2, 3, 4, and 6, each operating at 14.2 m^3/s (500 ft^3/s) and at the minimum water surface) created the worst conditions. Without the trashracks in place, these conditions consisted of strong eddies on the left side of the intake (in the corner created by the pier) which intermittently organized into vortices strong enough to draw air bubbles into the suction tube (fig. 16). There was only minimal circulation on the right side of the intake (near the channel transition wall). With the trashrack in place, these surface flow conditions changed to a large general circulation over most of the intake with some intensified vortex formation. The vortex tendencies were stronger than at the interior intakes, but the trashrack still acted as a flow straightener and created satisfactory flow conditions. From these observations, it was concluded that with the trashracks in place no adverse surface flow conditions can be expected in the prototype.

Suction tube flow. - Velocity data were collected in the suction tube using the same procedure as before. Data were collected at both the pump eye and barrel sections with the reservoir at the minimum water surface elevation, both with and without the trashracks in place. Only the combination of units 1, 2, 3, 4, and 6 operating together (considered the worst approach condition) was

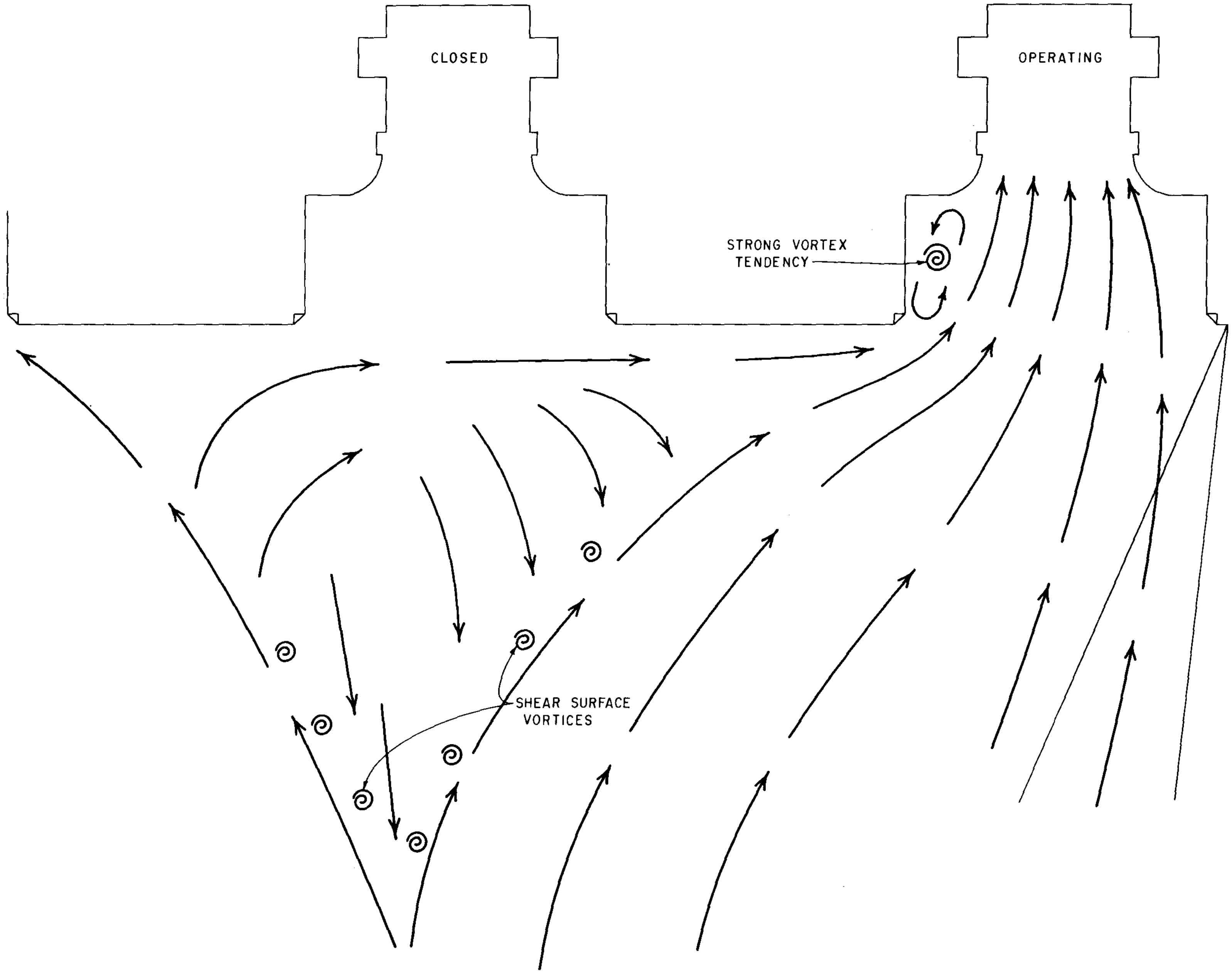


Figure 16. - Flow patterns at outside intake.

considered. The data (figs. A-14 through A-17) indicated velocity distributions very similar to those observed when the suction tube was at unit 4. These velocity distributions were considered to be satisfactory.

Head loss. - Finally, head loss was again considered. It was noted that the velocity distribution data indicated that the flows in the suction tube were the same at either unit 6 or 4. It was also noted that the data at unit 4 indicated that variations in the suction tube intake geometry or variations in the approach flow conditions had negligible effect on the total head loss from the channel to the pump. It was decided that the previous data (fig. 15) were representative; therefore, additional data were not required.

Because of its smaller size and the smaller gates that it would require, the square intake (alternate 1) was considered a more economical design. In addition, it was recognized that the rectangular intake (alternate 2) was, hydraulically, a more conservative design. It was concluded that if the square intake proved hydraulically satisfactory, the performance of the rectangular intake could also be considered hydraulically satisfactory. As has been stated, for the two intakes at the unit 4 location, no differences could be detected between the flow patterns, head losses, and vortex action. It was concluded, therefore, that both intake designs performed satisfactorily at the interior unit locations. Likewise, the square intake data collected at the unit 6 location indicates that either intake design should perform satisfactorily at the outside units. Because no adverse flow conditions were observed at the unit 6 location for the square intake, the model testing was considered complete.

APPENDIX

Contours indicate the ratio of the specific velocity at the location to the average velocity through the section.

APPENDIX

FIGURES

All figures show velocity distribution data either at the barrel or pump eye sections.

With the suction tube at the unit 4 location:

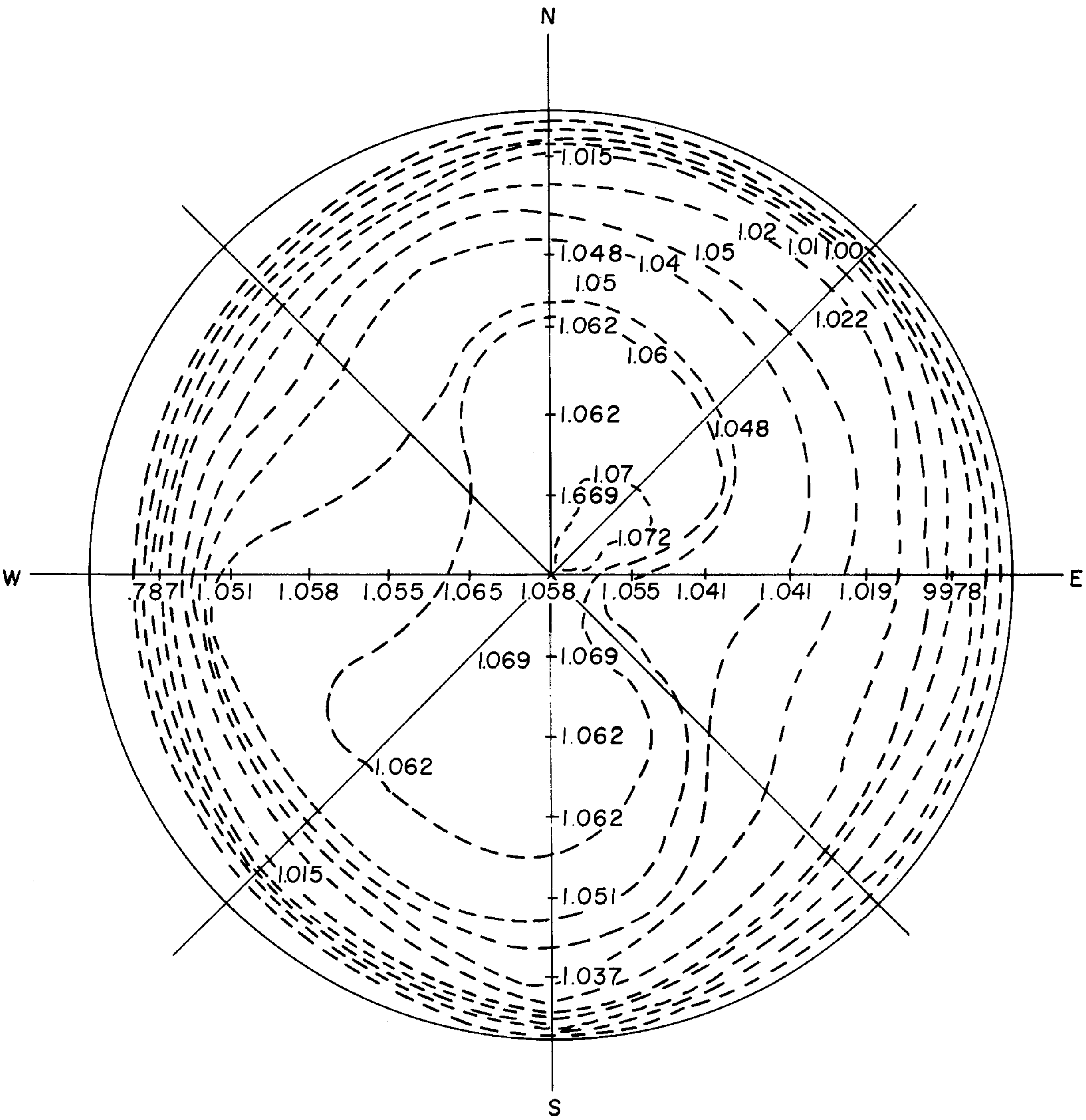


Figure A-1. - Unit 4 barrel section, unit 4 operating, 450 W.S., without trashrack, alternate 1.

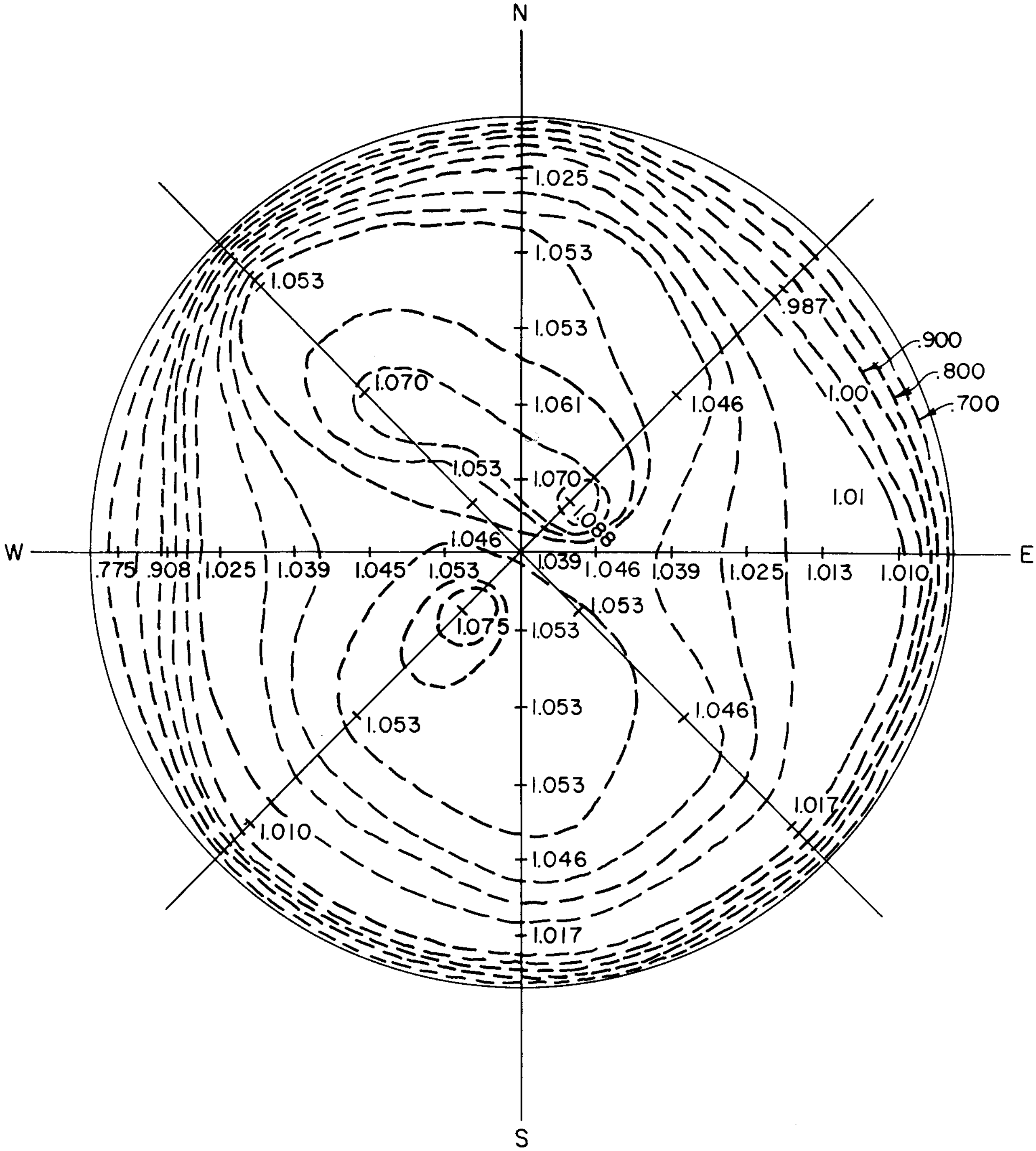


Figure A-2. - Unit 4 barrel section, units 1, 2, and 4 operating, 440 W.S., without trashrack, alternate 1.

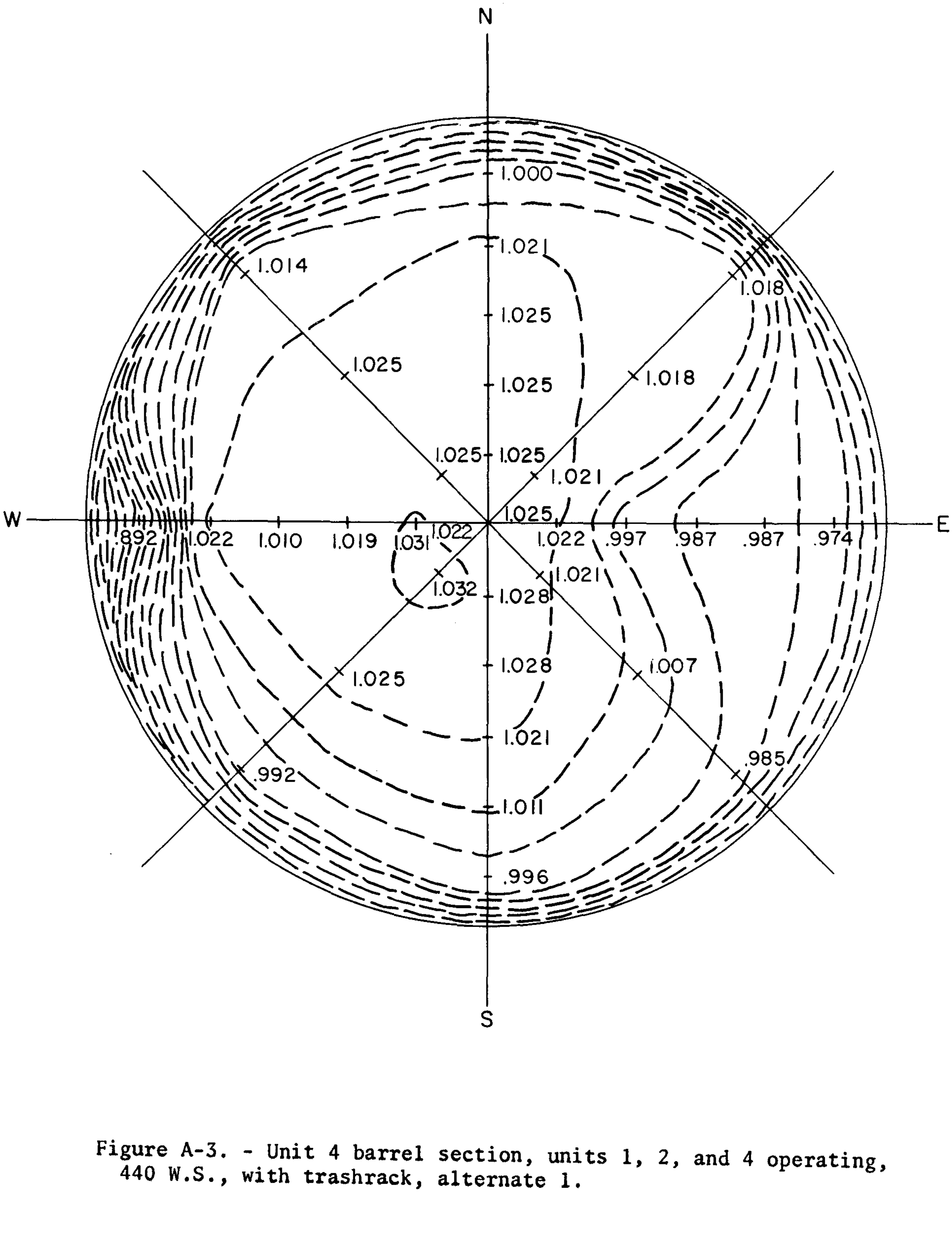


Figure A-3. - Unit 4 barrel section, units 1, 2, and 4 operating, 440 W.S., with trashrack, alternate 1.

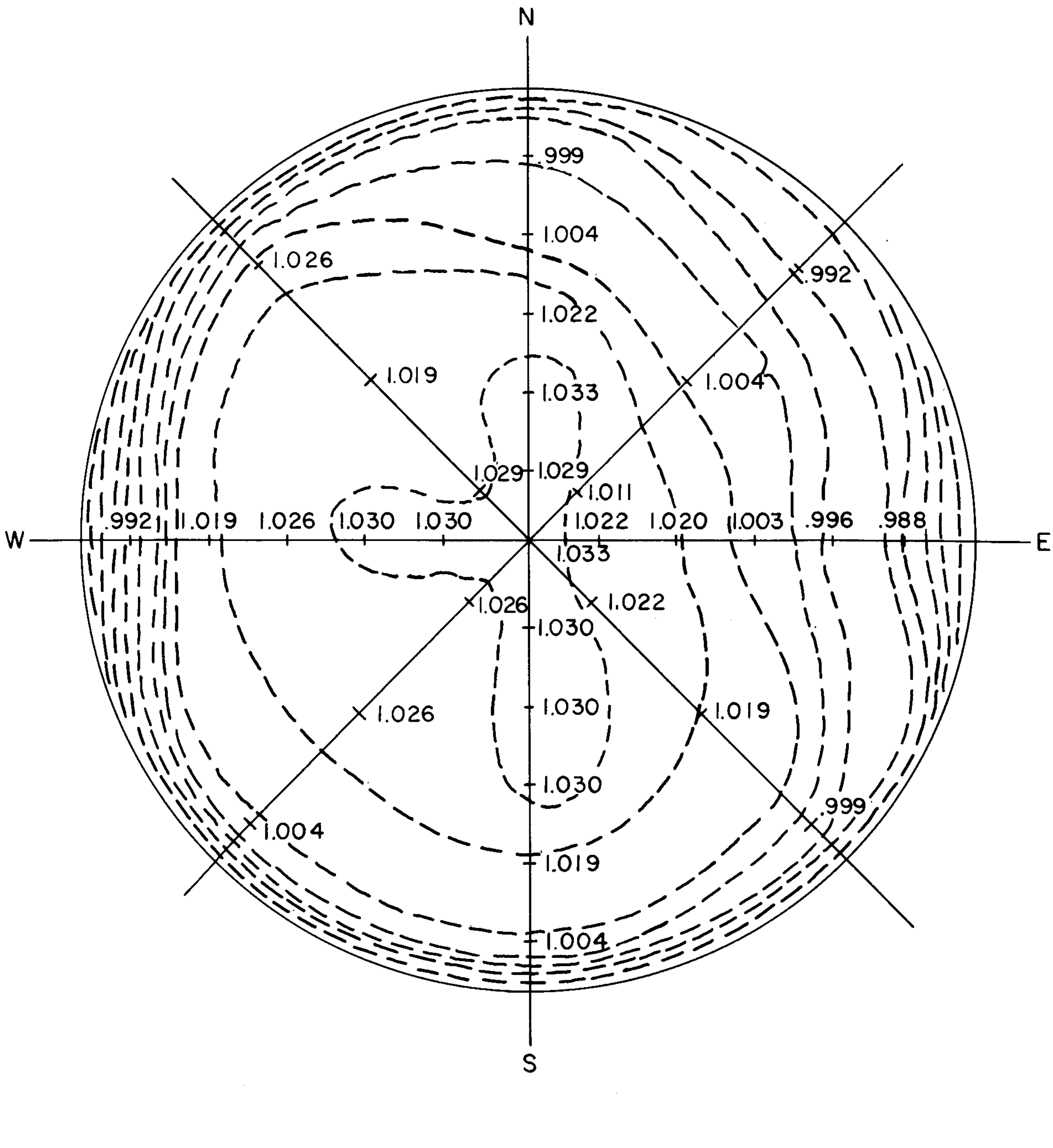


Figure A-4. - Unit 4 barrel section, unit 4 operating, 451 W.S., without trashrack, alternate 2.

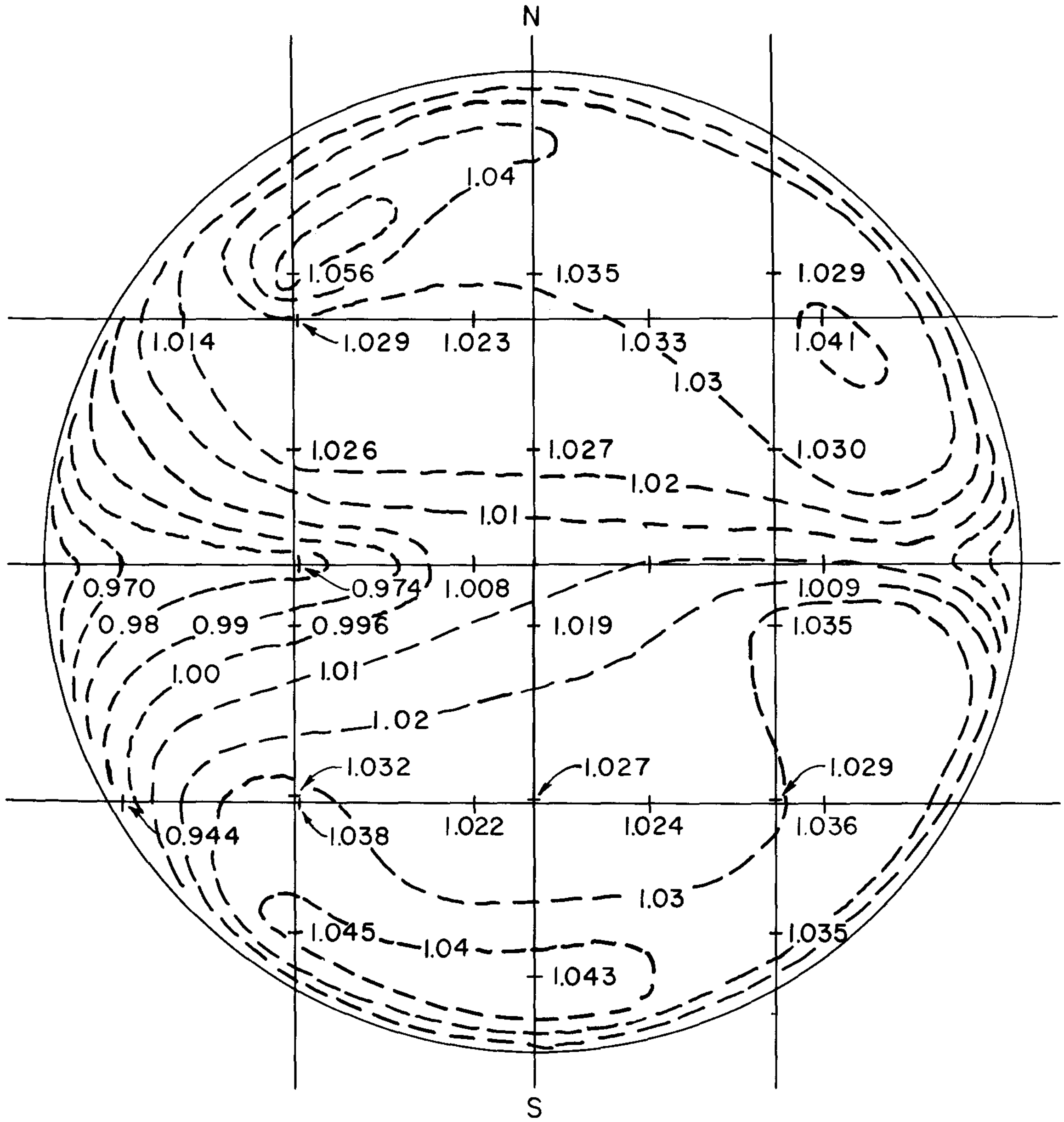


Figure A-7. - Unit 4 pump eye, unit 4 operating, 450 W.S., without trashrack, alternate 1.

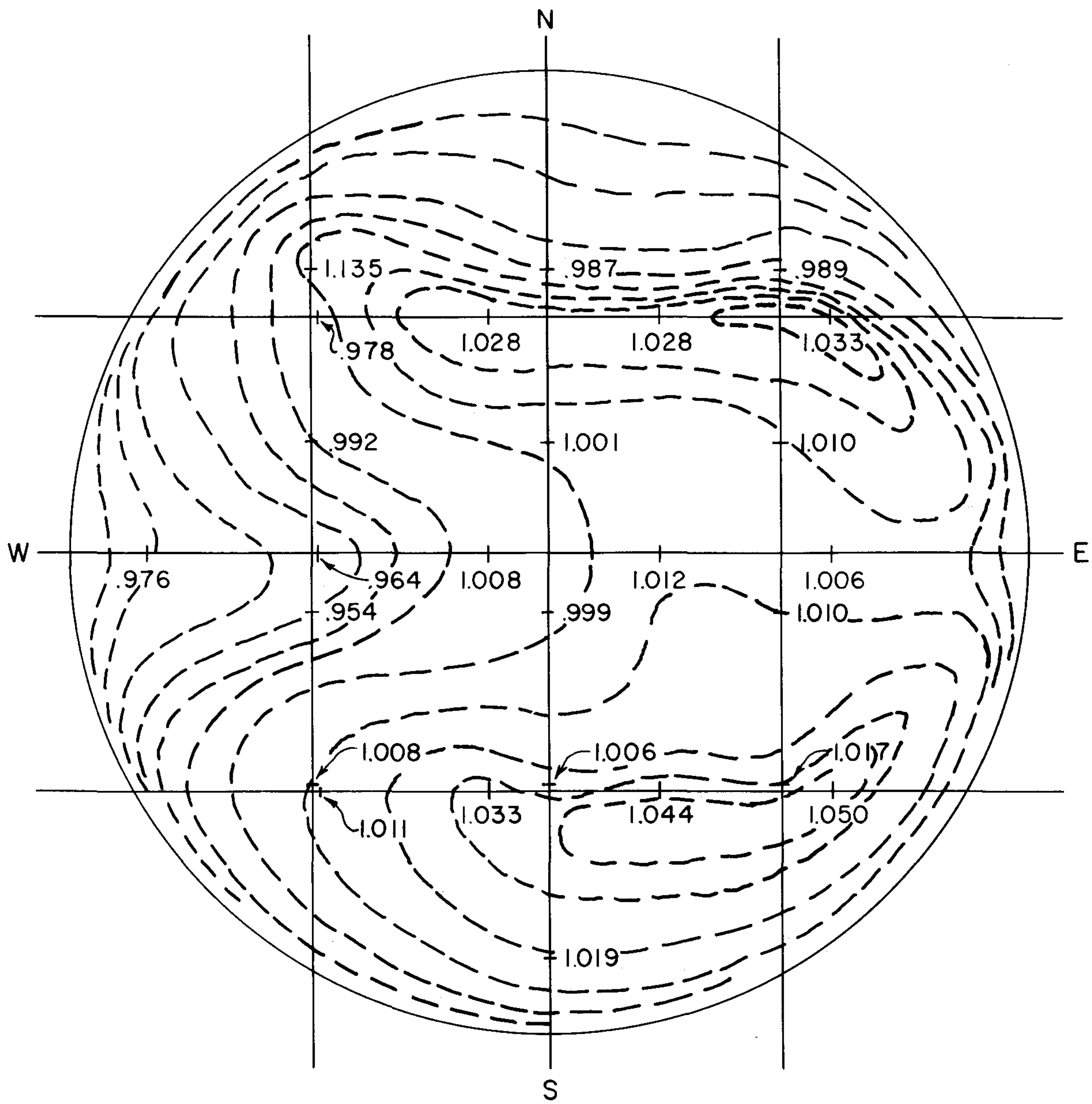


Figure A-8. - Unit 4 pump eye, units 1, 2, and 4 operating, 440 W.S., with trashrack, alternate 1.

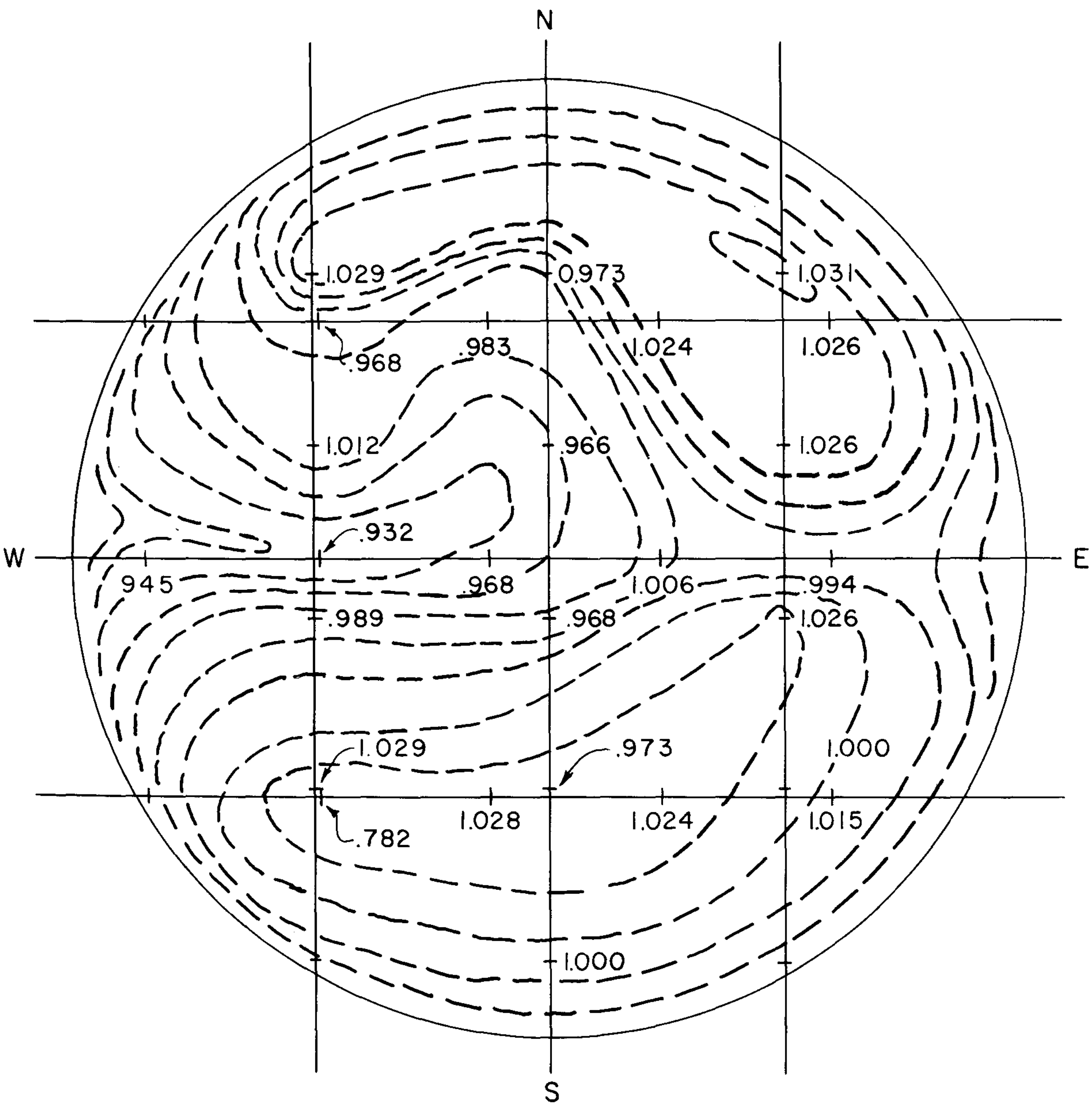


Figure A-9. - Unit 4 pump eye, unit 4 operating, 450 W.S., with trashrack, alternate 1.

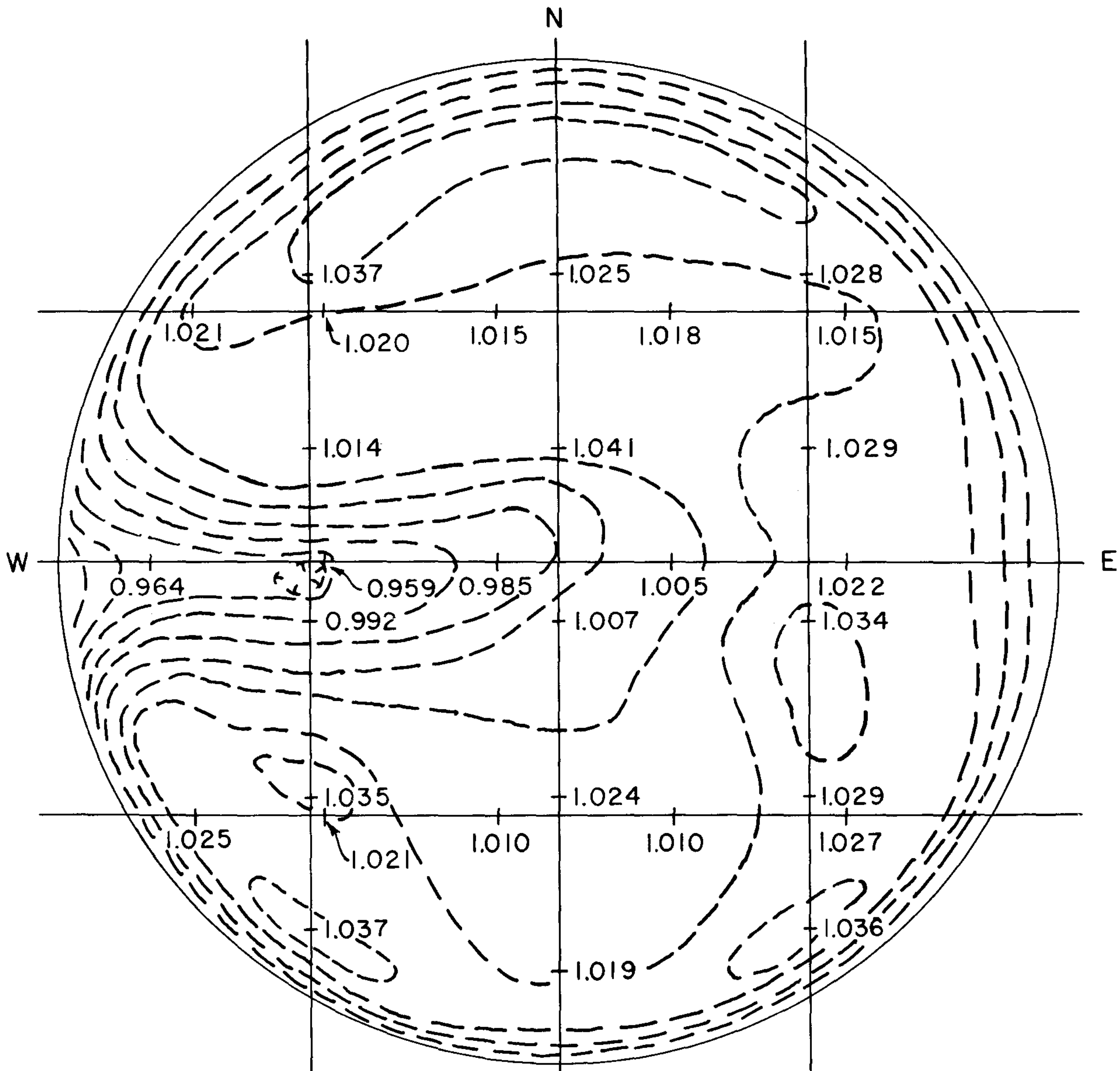


Figure A-10. - Unit 4 pump eye, unit 4 operating, 450 W.S., without trashrack, alternate 2.

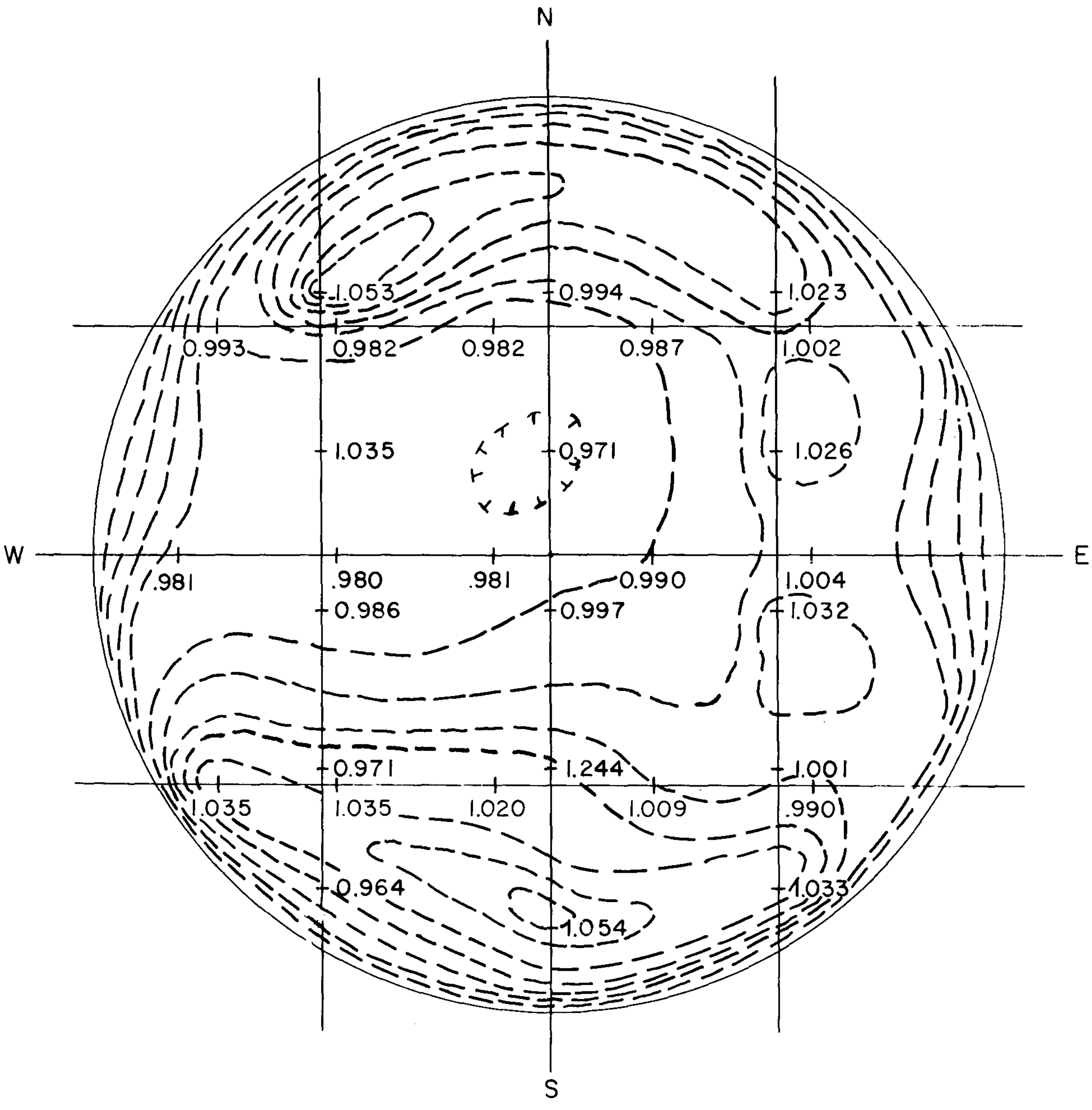


Figure A-11. - Unit 4 pump eye, unit 4 operating, 450 W.S., with trashrack, alternate 2.

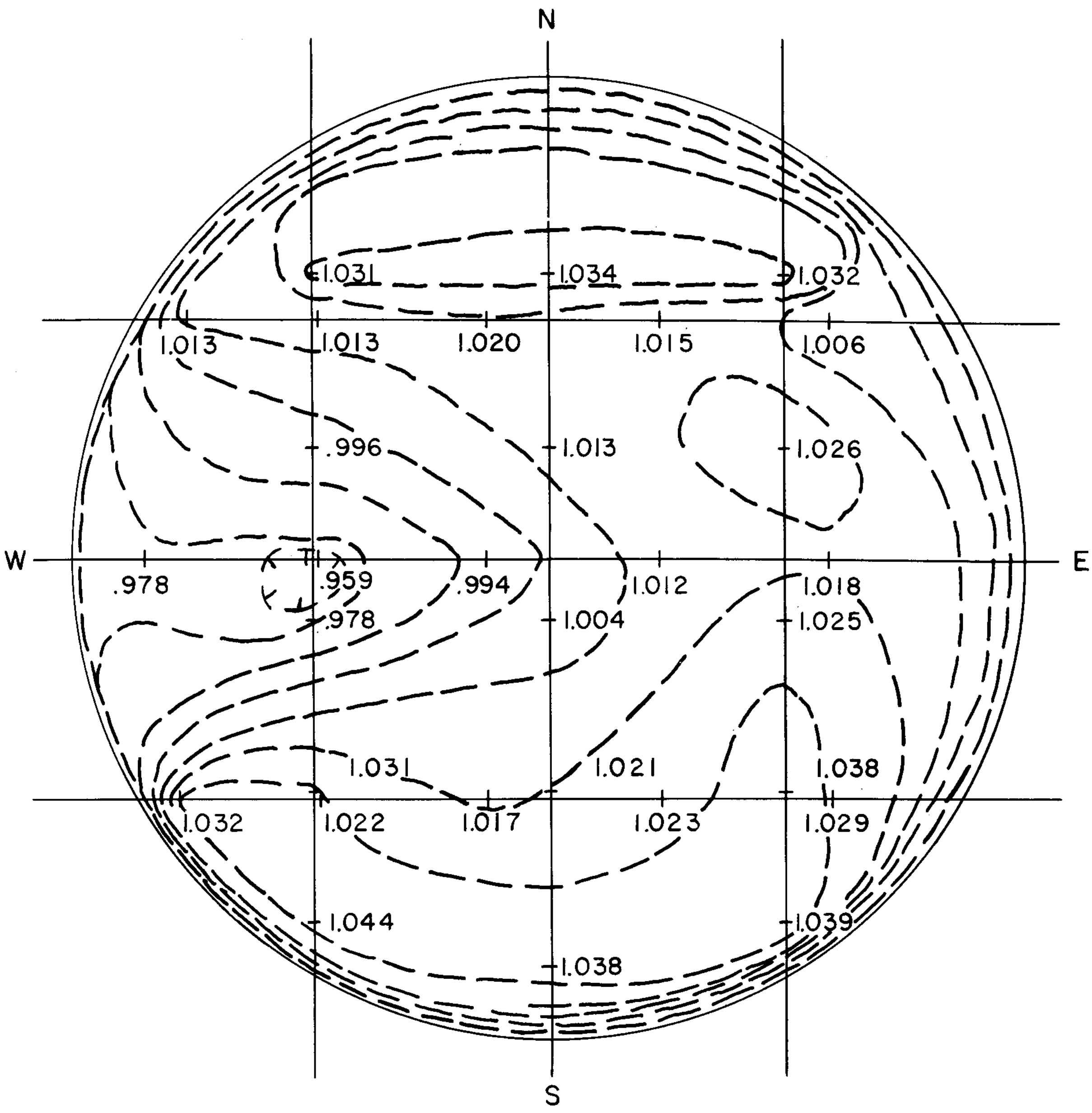


Figure A-12. - Unit 4 pump eye, units 1, 2, and 4 operating, 440 W.S., with trashrack, alternate 2.

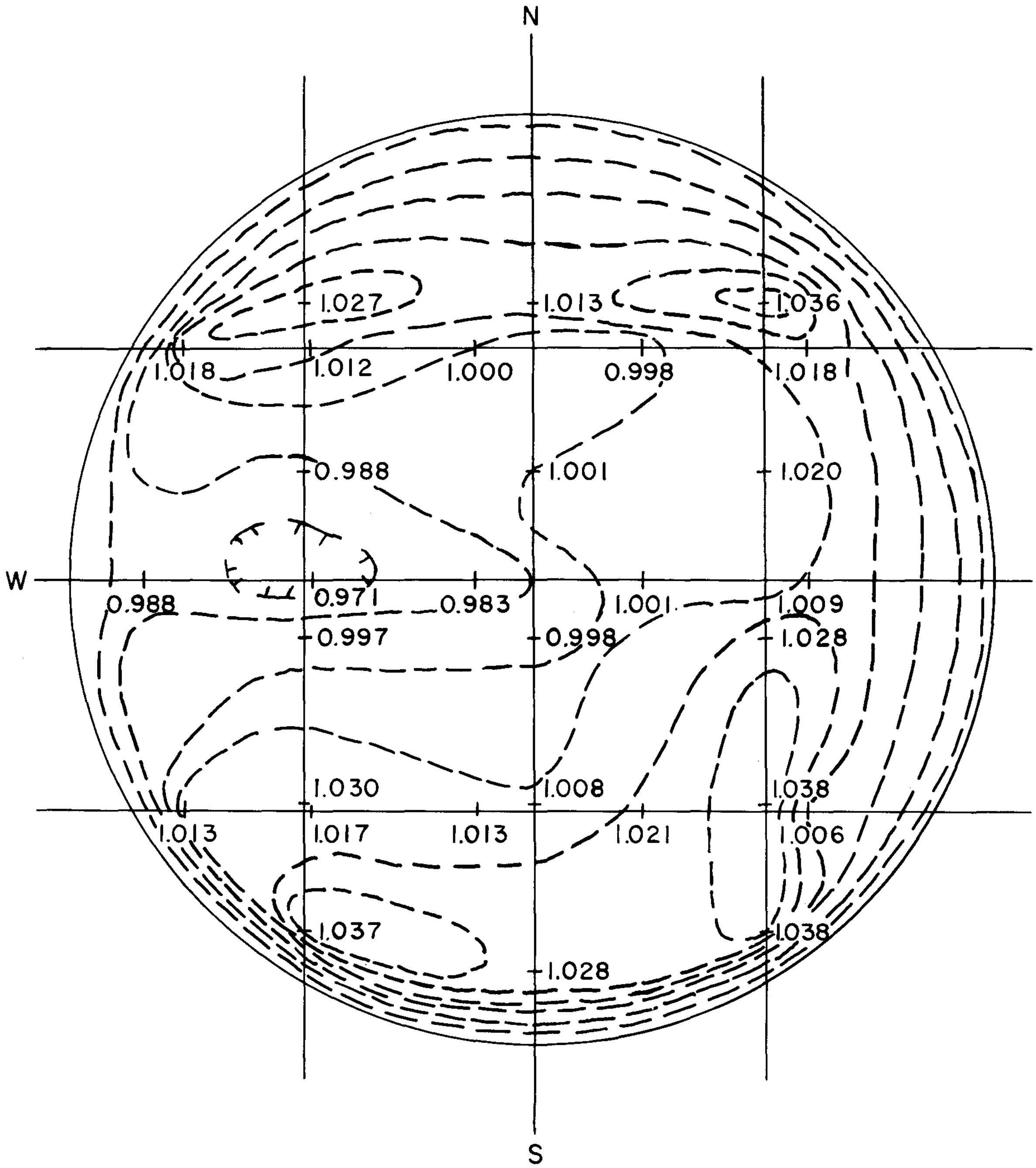


Figure A-13. - Unit 4 pump eye, units 1, 2, and 4 operating, 440 W.S., without trashrack, alternate 2.

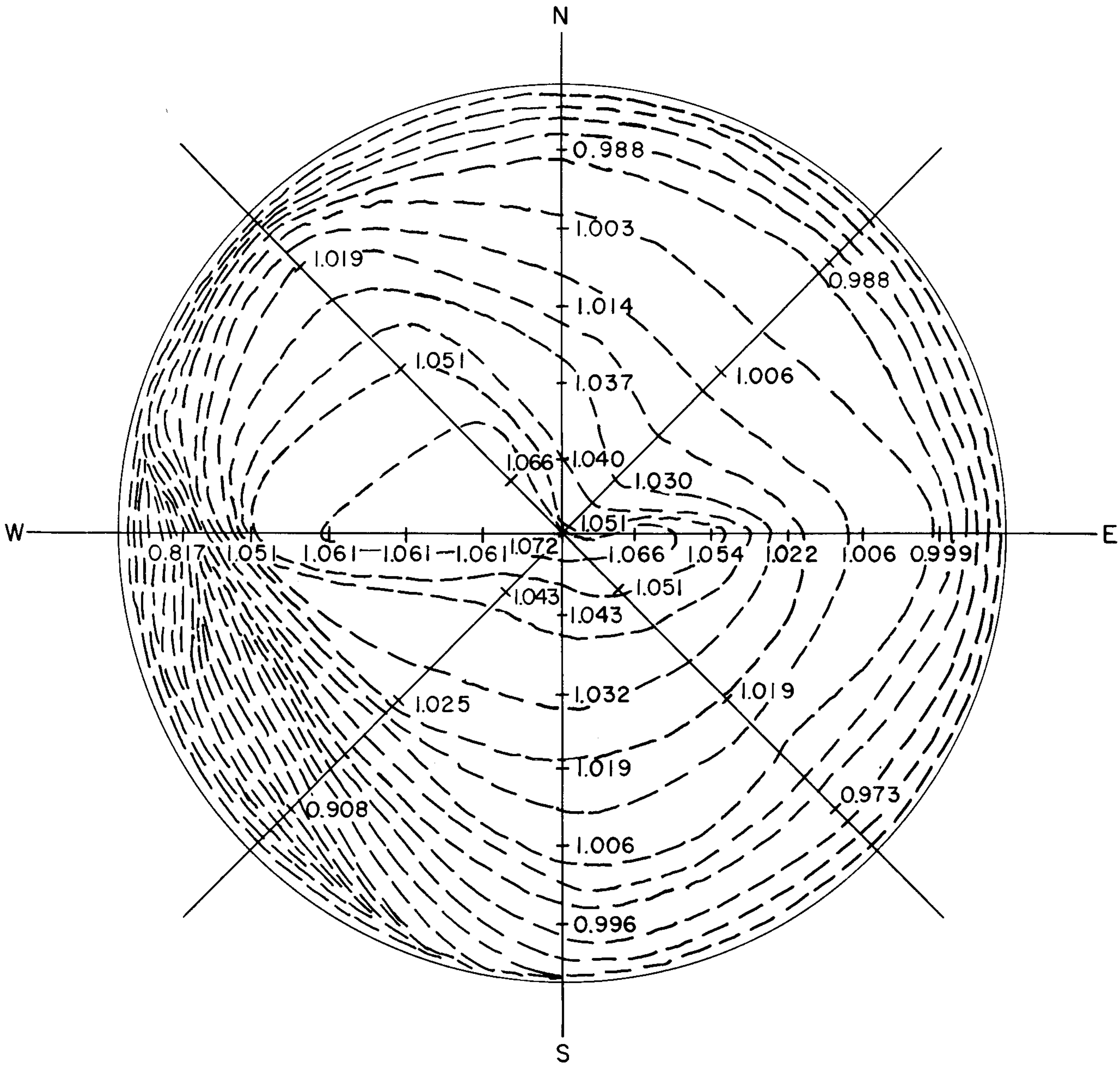


Figure A-14. - Unit 6 barrel section, units 1, 2, 4, and 6 operating, 439 W.S., without trashrack, alternate 1.

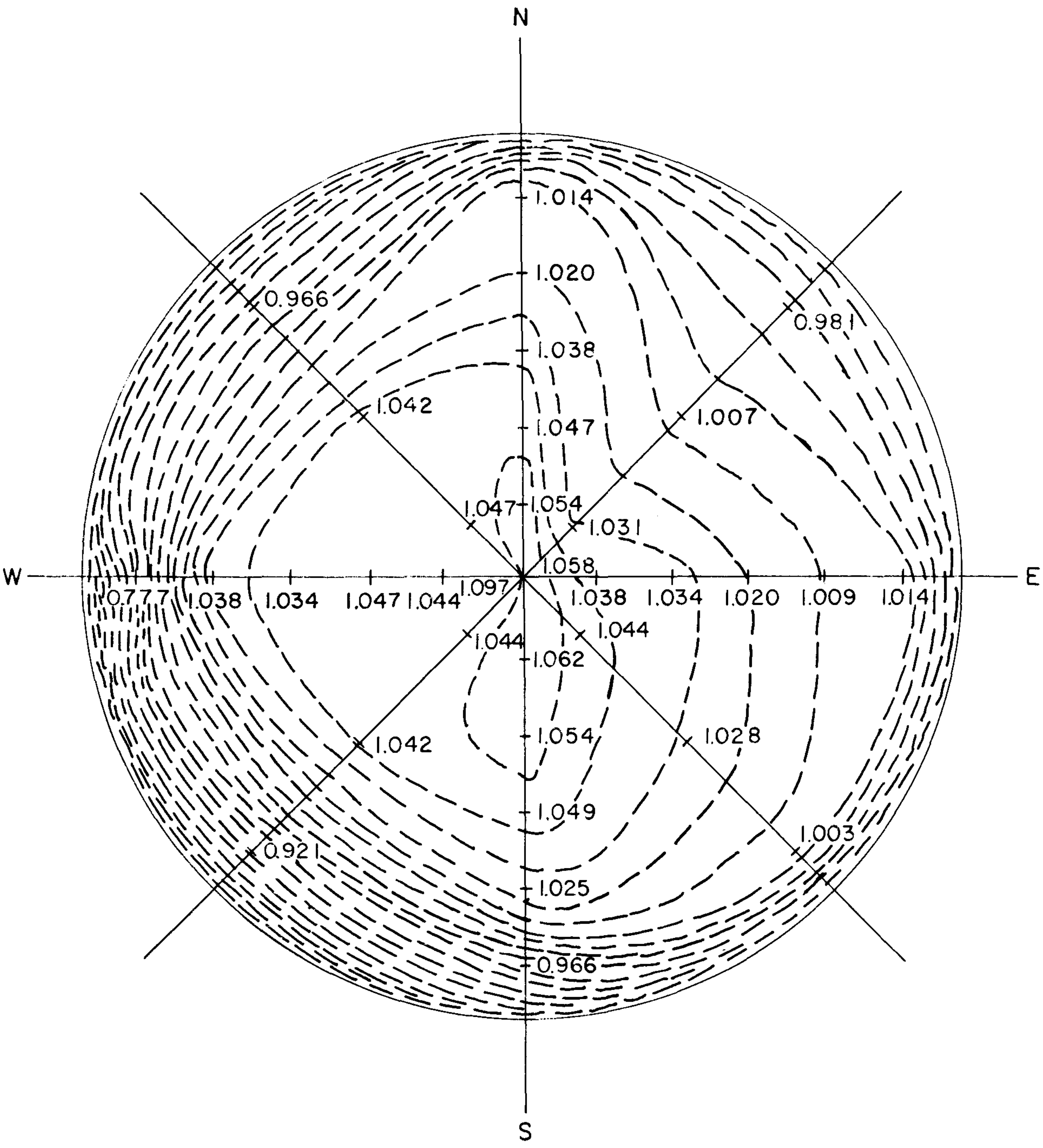


Figure A-15. - Unit 6 barrel section, units 1, 2, 3, 4, and 6 operating, 439 W.S., with trashrack, alternate 1.

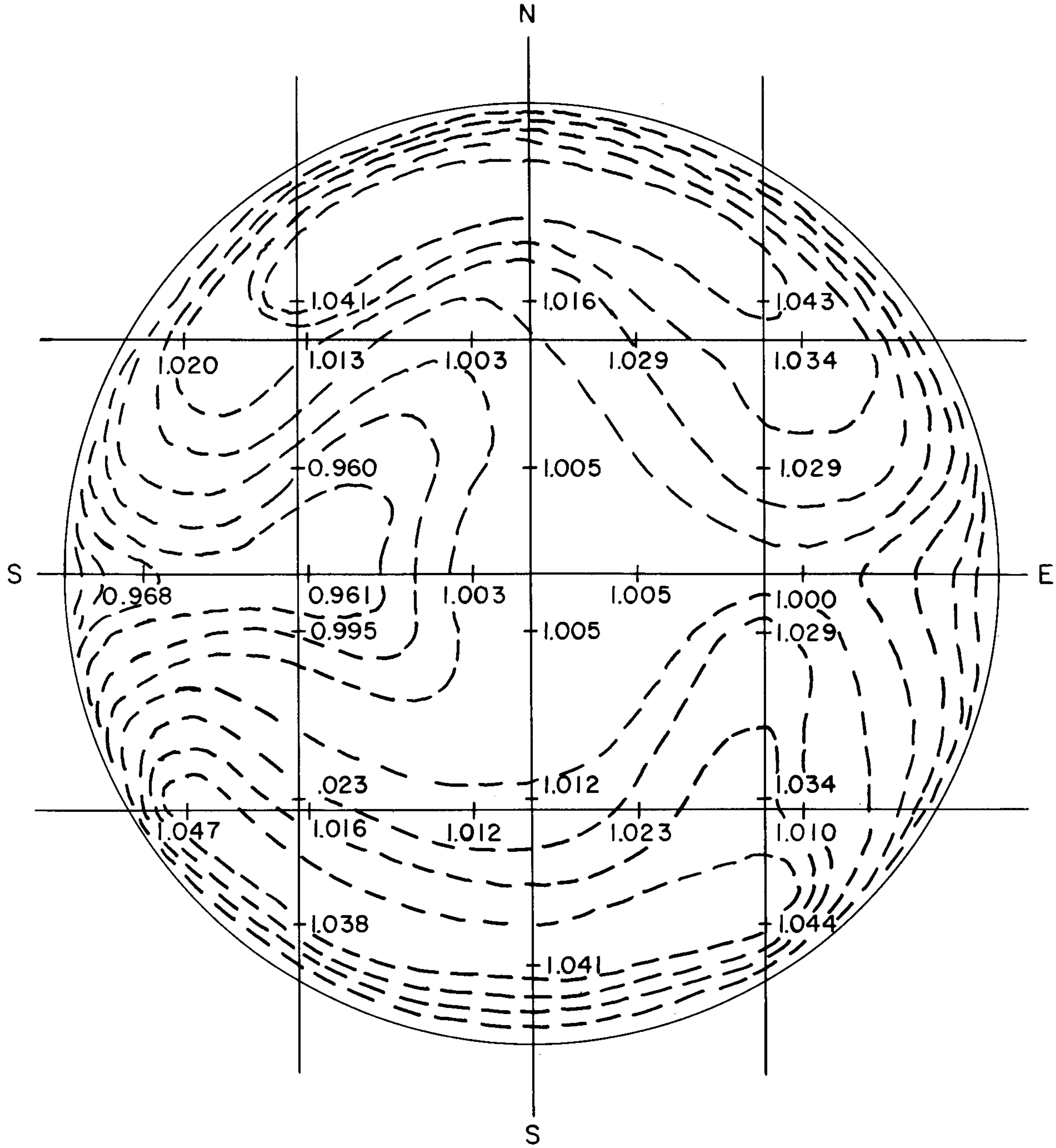


Figure A-16. - Unit 6 pump eye, units 1, 2, 3, 4, and 6 operating, 440 W.S., without trashrack, alternate 1.

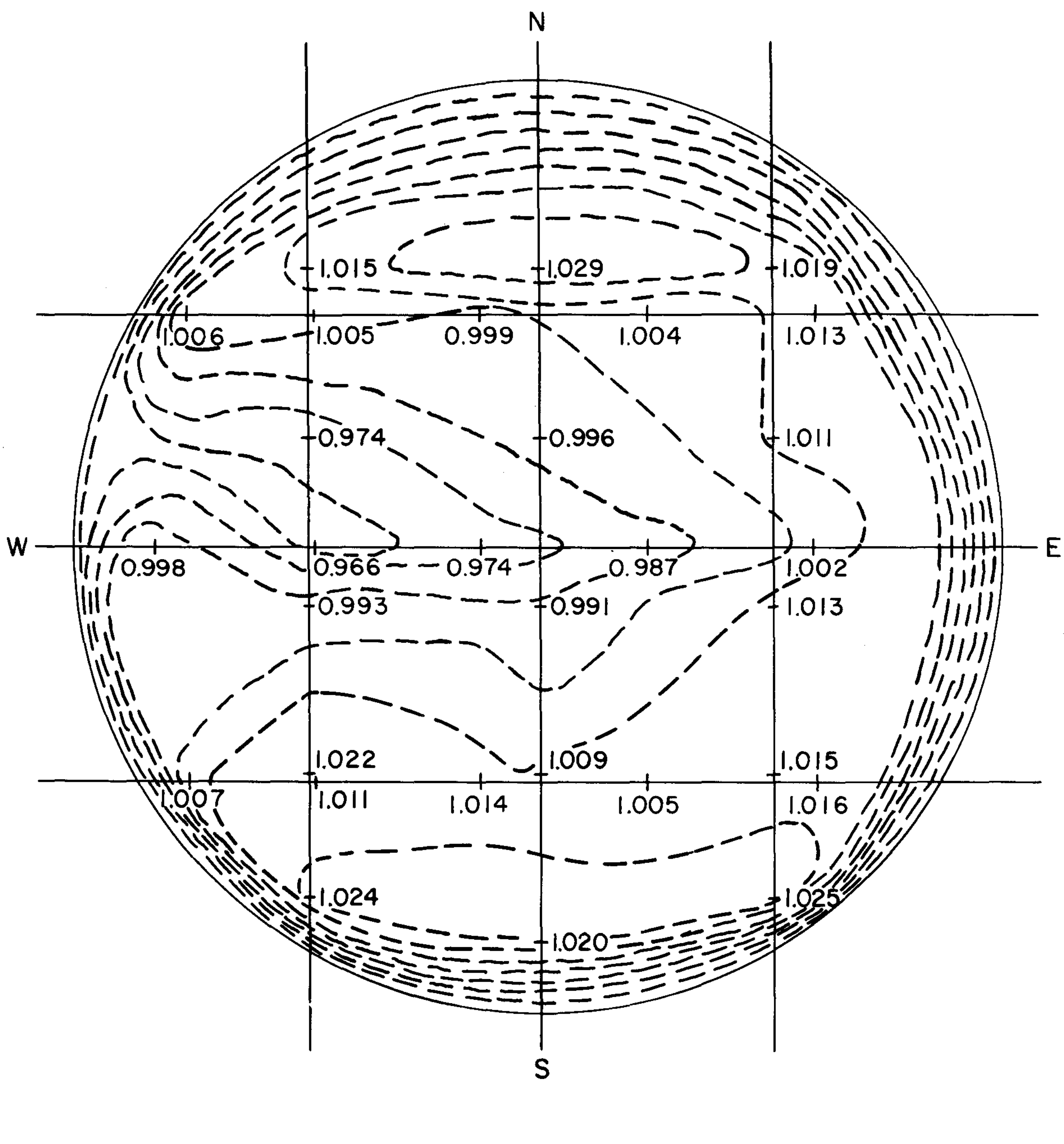


Figure A-17. - Unit 6 pump eye, units 1, 2, 3, 4, and 6 operating, 440 W.S., with trashrack, alternate 1.

GPO 837-894

ABSTRACT

Hydraulic model studies were performed to assure satisfactory flow conditions through the intake channel, intake structure, and suction tubes for Havasu Pumping Plant, Arizona. The six units of the pumping plant will lift a total of 85 m^3/s (3,000 ft^3/s), 244 metres (m) (800 ft). The main objectives of the model study were: (1) to maintain uniform flow in the intake channel and, therefore, minimize sedimentation and trash buildup; (2) to eliminate vortices that might draw air into the suction tubes and cause rough pump operation and problems with rising bubbles in the discharge line; (3) to establish uniform, nonswirling flow at the pump eye and thus establish the best and most efficient approach flow conditions for the pump; and (4) to minimize head loss through the intake structure and suction tubes. In addition, two suction tube intake designs were studied in an attempt to minimize the structure size. The model was built to a 1:9.39 scale and included 45.7 m (150 ft) of intake channel, the entire intake structure, one correctly modeled suction tube, piping for the other five units, and trashracks for one unit. Flow conditions were generally acceptable except for vortex formation at units without trashracks. The trashracks acted as flow straighteners and eliminated the vortex problem.

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GR-19-76
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Bur Reclam Rep GR-19, Div Gen Res, Oct 1976, Bureau of Reclamation, Denver, 56 p, 33 fig, append

DESCRIPTORS--/ hydraulic models/ *model studies/ pumping plants/ approach channels/ *entrances (fluid flow)/ intakes/ trashracks/ *velocity distribution/ *vortices/ *head losses/ design improvements
IDENTIFIERS--/ Havasu Pumping Plant, AZ

COSATI Field/Group: 13M COWRR: 1313.1

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