Project Report No. 80

ANGAT RIVER HYDROELECTRIC PROJECT
SPILLWAY HYDRAULIC DESIGN
ADDENDUM TO FINAL MEMORANDUM OF JULY 1963: CALIBRATION OF SPILLWAY WITH LOW CREST BLOCKS

by
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Projected for
NATIONAL POWER CORPORATION
Manila, Philippines

Consulting Engineers
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of the Philippines, Manila

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Introduction

This addendum reports the results of calibration tests on the partially completed Angat spillway. The study was based upon a memorandum by W. A. Waldorf, Harza Engineering Company, dated September 20, 1965 from which the following quotation is taken:

> It is contemplated for flood protection during construction of Angat Dam to hold the spillway crest blocks in a partially completed condition shown in the attached sketch. Piers will be carried to full height and it is probable that gates will be erected and maintained in the fully opened position during the flood season of 1966. The remainder of the spillway structure will be in the completed condition as shown on design drawings. . . . For purposes of flood routing studies a rating curve is desired for the partially completed spillway covering the range from El. 193 to El. 215. Maximum water surface for the construction design floods is El. 206+ as determined by routing the July 1962 flood using a computed rating curve. The additional range from El. 206 to El. 215 is desired for making check routings of higher floods. The spillway model may be used in its existing form without modifying the approach channel to the present shape of the right abutment. Photographs are desired of the flow over the crest and at the deflector for reservoir elevations 206, 210, and 215. No measurements are necessary other than those for the rating curve but any unusual features of flow throughout the spillway should be noted in the report.

The geometry of the uncompleted spillway crests is shown in Chart 1, which indicates that portions of the crest around the two piers will be uncompleted and left at different elevations. At the left pier the crest will be at elev. 193.0 m with an offset to 192.5 m while at the right pier the crest will be at elev. 198.5 m. The remainder of the crest of the structure will be completed to elev. 202.0 m. As suggested by the above quotation the spillway crest of the model previously used for tests of this structure was modified in accordance with Chart 1. The bed in the approach

channel leading to the spillway was reconstructed so that the bed level was at elev. 193.0 m in order to duplicate approximately the approach conditions to the spillway.

Photo 1 is an overall view of the spillway model showing the upper pool, spillway crest and chute, and the deflectors at the end of the chute. A closeup of the modified spillway crest from the downstream side is given in Photo 2. In this photo the relative heights of the various sections of the uncompleted spillway are shown. Inasmuch as it was proposed that if the gates were installed they would be maintained in the fully opened condition, no spillway gates were fitted in the model. The absence of the spillway gates made photographic observations of the flow more convenient.

Rating Curve for Partially Completed Spillway

The rating curve for the spillway crest was determined for reservoir elevations ranging from about 202 meters to 217 meters. The reservoir pool elevations were measured at a point 265 meters "prototype" upstream from the crest and in the reservoir proper. At the same time headwater elevations were determined at points 155 meters and 45 meters upstream from the crest in order to check the effect of the approach velocity. The rating curve relating spillway discharge to reservoir water level is shown in Chart 2. For purposes of comparison the rating for the completed spillway when the crest is at elev. 202 m is also plotted on the chart. The position of the two curves indicates that the headwater elevation for the partially completed crest configuration is approximately 3 meters lower than the corresponding headwater level for the completed crest for a range of discharges from 2000 to 6000 cubic meters per second. Below the 2000 cms discharge the difference increases from 3 meters to about 5 meters at a discharge of 500 cms. The reason for the greater difference at small discharges between the reservoir level for the uncompleted structure and the reservoir level for the completed structure is found in the shape of the crest. Since a portion of the crest is stopped at elev. 193.0 m a larger proportion of the small discharges is directed through this low section, while, as the discharge increases, more and more of the discharge is forced over the higher portions of the crest and the effect of the low section becomes less and less in terms of the total discharge.

Influence of the Geometry of the Uncompleted Structure upon the Flow Pattern in the Neighborhood of the Spillway Crest and Spillway Chute

During the course of the experiments photographic observations were made of the flow patterns approaching the spillway, the flow over the spillway, and through chute deflectors for various reservoir pool elevations.

Reservoir Pool Elevation 206.0 Meters. Photo 3 shows the flow pattern in the approach channel with the reservoir at elev. 206.0 m and the discharge 1600 cms. The streaks on the water surfaces are images of confetti introduced in the reservoir, and the length of the streaks represents the relative velocity. The flow pattern in this instance is relatively uniform with little evidence of separation at the entrance to the approach channel. Photo 4 is a view of the flow approaching the spillway from downstream. There is some concentration of the flow towards the left pier and the low crest section of the spillway. This concentration of the flow in the lower layers is well shown in Photo 5, which is a photograph of dye streaks formed on the bottom of the approach channel. The jets of water through the low portion spreading laterally to fill the individual chutes (Photo 4) initiate transverse waves in the chute downstream of the crest. They are reasonably well damped out, however, by the time flow reaches the deflectors so that the jets (Photo 6) leaving the deflectors are relatively smooth. It is also apparent from Photo 6 that for this reservoir level more water flows in the left end center chutes than in the right chute.

Reservoir Pool Elevation 210.0 Meters. When the reservoir pool is at elev. 210.0 m the discharge is 2900 cms. The flow pattern in the approach channel for this reservoir level as shown in Photo 7 is relatively uniform, although there appears to be a stronger separation at the left side of the entrance so that the streamlines tend to drift toward the right as the flow approaches the crest. Observations of dye streaks on the bed of the approach channel (Photo 8) showed a counteracting current approaching the low section of the spillway crest. This combination of secondary currents toward the right on the surface and toward the left near the bed suggests a weak helical flow in the approach channel. In Photo 9 taken from downstream and showing the flow approaching the spillway, the flow pattern approaching the crest is rather uniform and rectilinear. Because of the increased head on the

spillway the low portion of the crest has somewhat less influence on the overall flow distribution so that the transverse components of flow in the left and center chutes are considerably less distinct than for the lower reservoir level. The action of the deflectors in directing the flow downstream and the more uniform distribution of flow between the several chutes is shown in Photo 10.

Reservoir Pool Elevation 215.0 Meters. In Photo 11 taken of the approach channel with the reservoir pool at elev. 215.0 m and discharge of 5000 cms, the flow as delineated by the confetti streaks is quite uniform as it approaches the crest and there is little evidence of separation at the approach channel entrance. However, near the bed there is still a concentration of flow toward the low section of the spillway crest. This flow pattern delineated by dye streaks on the bed is shown in Photo 12. Some evidence of a drift of the surface flow toward the right bank is shown in Photo 13 which was taken from downstream and shows the flow approaching the spillway crest. With the discharge of 5000 cms and reservoir level at elev. 215.0 m, the influence of the non-uniform spillway crest is greatly lessened and the discharge in each of the spillway chutes is nearly the same. This is shown in Photo 14 which shows the flow leaving the spillway through the deflectors.

ACKNOWLEDGEMENT

The expert assistance of Mr. David J. Anderson in the performance of these calibration experiments and in the photographic observations of the flow patterns is acknowledged.

LIST OF PHOTOS

PHOTO 1 (Serial No. 136-54) This view of the model shows the overall geometry including a portion of the reservoir, the approach channel, the spillway and the spillway chute, as well as the deflectors and the river into which the spillway discharges. The scale of the model is 1:118.1.

PHOTO 2 (Serial No. 136-101) The model spillway crest was modified to conform to the partially completed prototype spillway structure. The portion of the crest near the left pier was at elev. 193.0 m with a lower downstream step at elev. 192.5 m. The portion near the right pier was at elev. 198.5 m, while the remainder of the crest which was completed was at elev. 202.0 m.

PHOTO 3 (Serial No. 136-106) The flow pattern in the approach channel for a discharge of 1600 cms and reservoir pool elev. 206.0 m is delineated by the confetti streaks. In this case the flow was relatively uniform with little or no separation at the approach channel inlet.

PHOTO 4 (Serial No. 136-107) The flow approaches the spillway crest, tending to concentrate in the low section of the spillway crest. The reservoir pool elevation is 206.0 m.

PHOTO 5 (Serial No. 136-123) The flow pattern near the bed of the approach channel, delineated by dye streaks, shows the concentration of the flow toward the low section of the spillway crest. This added flow increases further the discharge in the left and center chutes.

PHOTO 6 (Serial No. 136-108) For the reservoir pool elevation of 206.0 m most of the flow takes place in the left and center chutes. The flow is adequately deflected downstream into the center of the river.

PHOTO 7 (Serial No. 136-109) The flow pattern in the approach channel for a discharge of 2900 cms and reservoir pool elevation of 210.0 m is relatively uniform with only slight evidence of secondary current. The separation at the left bank is considerably greater than that at the right bank.

PHOTO 8 (Serial No. 136-125) The concentration of a bottom flow toward the low section of the spillway crest is made evident by dye streaks even for the relatively high reservoir pool elevation of 210.0 m.

PHOTO 9 (Serial No. 136-110) This photograph of the flow approaching the spillway taken from downstream shows a relatively uniform flow pattern without evidence of the secondary current.

PHOTO 10 (Serial No. 136-111) The deflectors are quite effective in directing the flow downstream into the river. Because of the higher reservoir pool elevation (210.0 m) the flow is somewhat more uniformly distributed among the three chutes.

PHOTO 11 (Serial No. 136-112) The flow pattern in the approach channel for the maximum discharge of 5000 cms when the reservoir pool elevation is 215.0 m is relatively uniform and smooth.

PHOTO 12 (Serial No. 136-126) A distinct concentration of flow near the approach channel bed toward the low section of the spillway crest occurs even for the maximum discharge of 5000 cms. The dye streaks show streamlines in this region.

PHOTO 13 (Serial No. 136-119) The view of the approach channel flow from the spillway crest shows a slight tendency for a secondary current to approach the right bank of the approach channel. In spite of this the flow over the crest and down the chute appears to be reasonably uniform and symmetrical.

PHOTO 14 (Serial No. 136-114) The flow through the spillway chutes is even more uniformly distributed than for the smaller discharges. The deflectors are effective in directing the jets downstream toward the center of the discharge channel.

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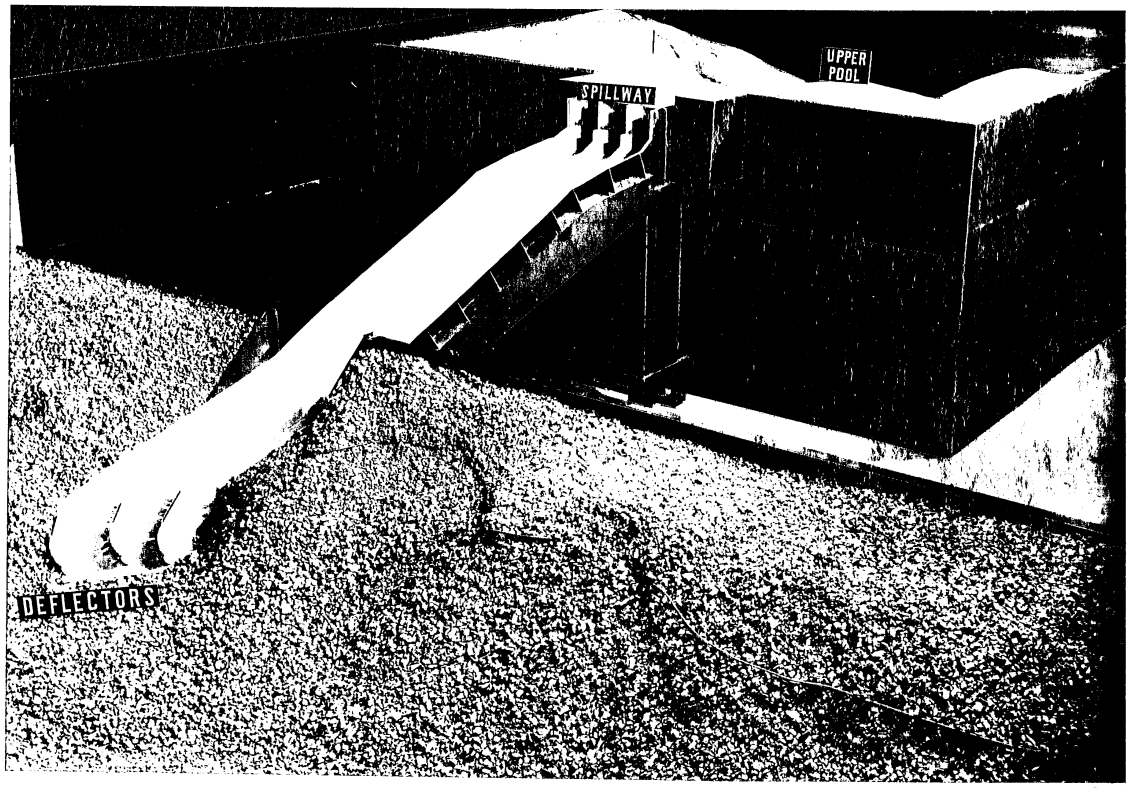
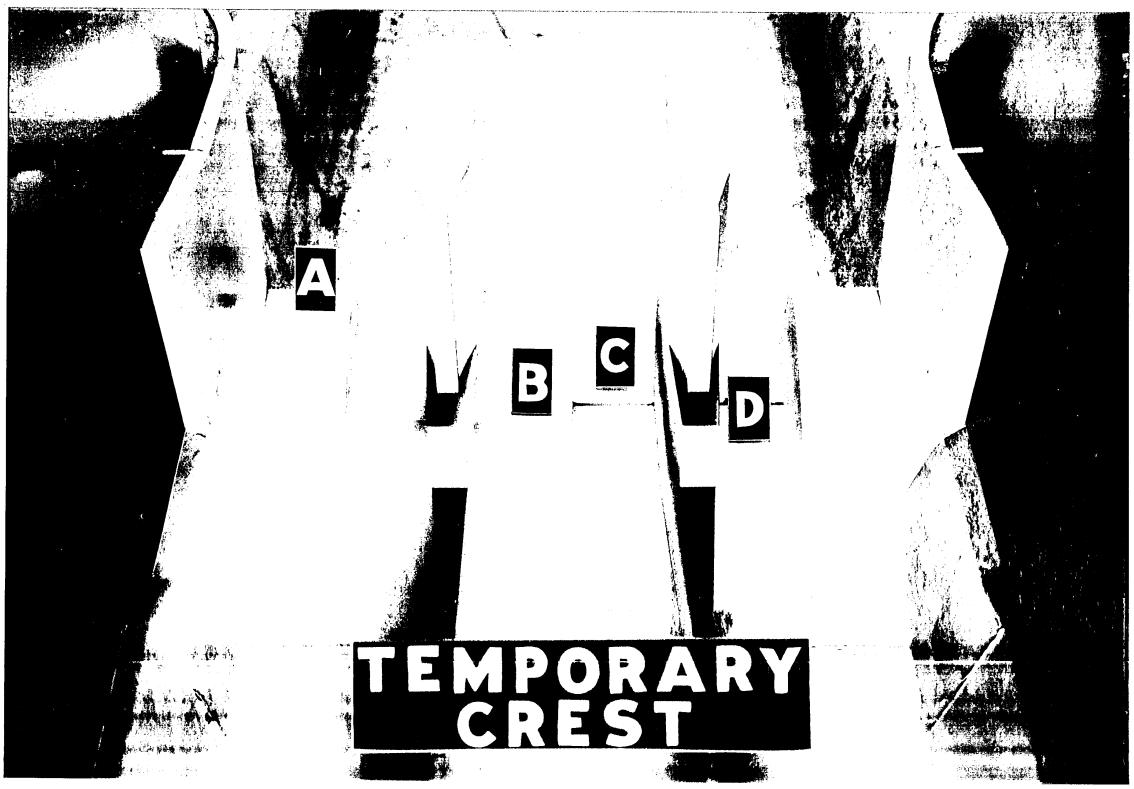


Photo 1



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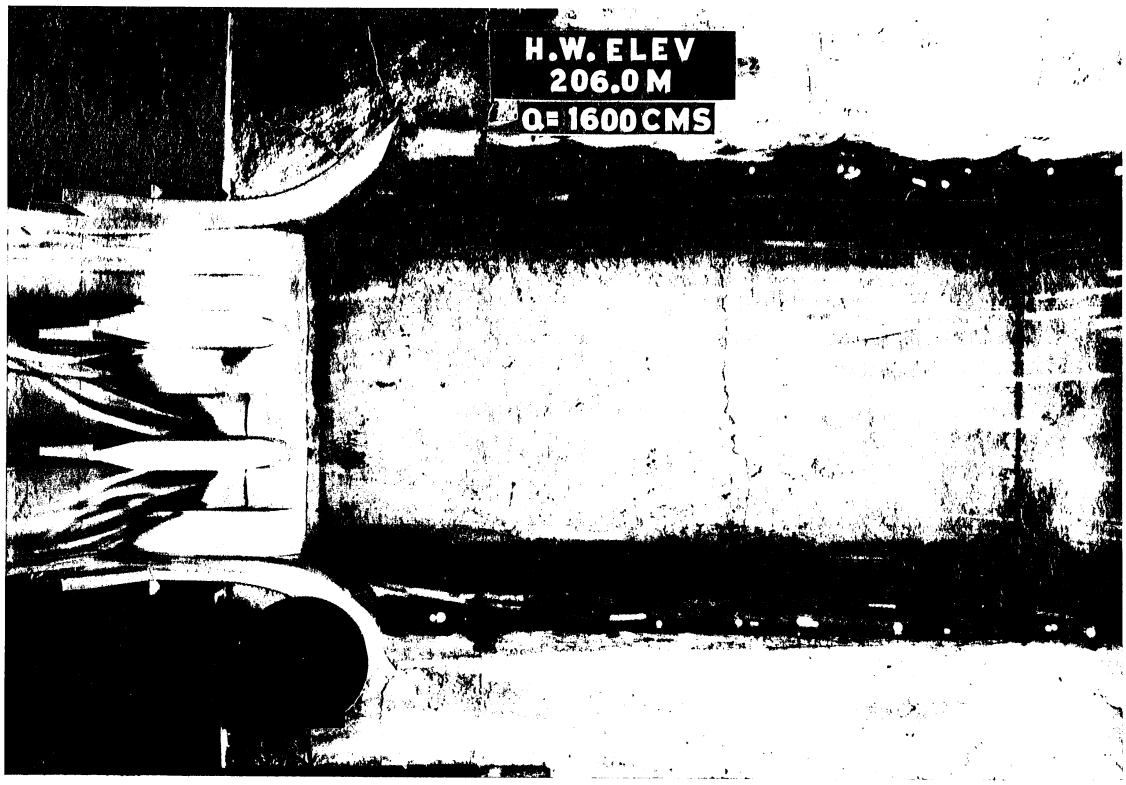
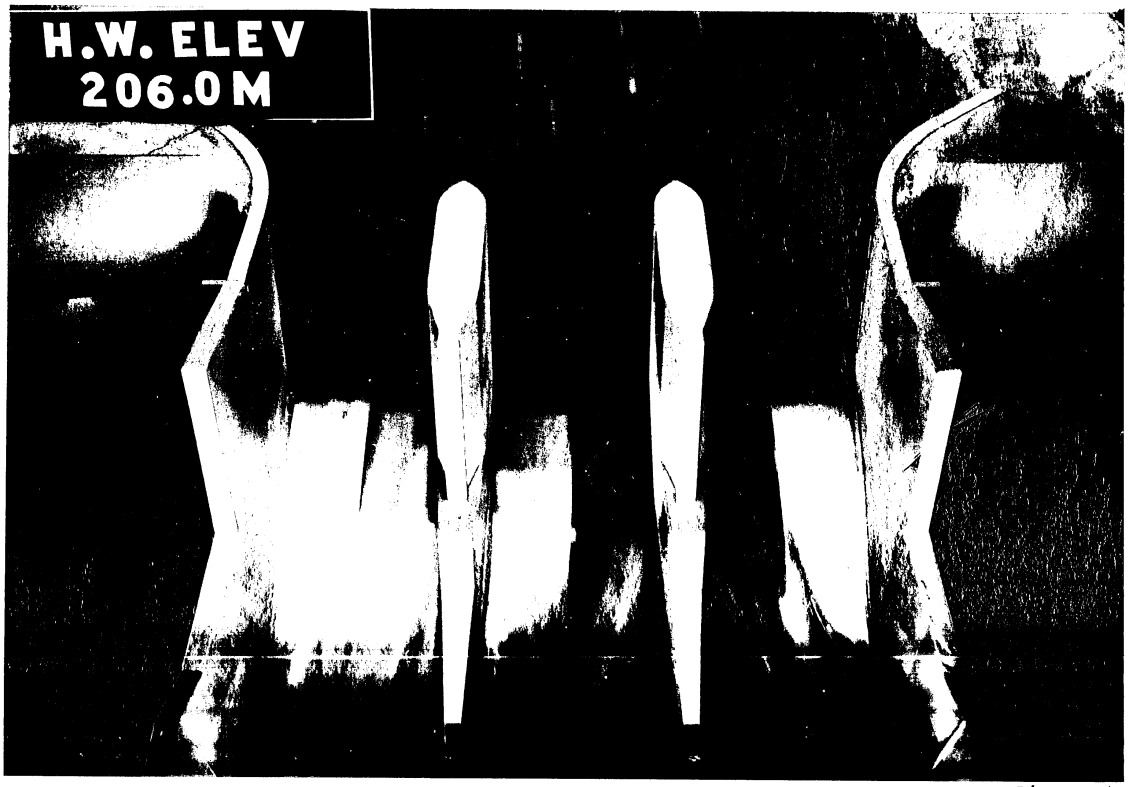


Photo 3



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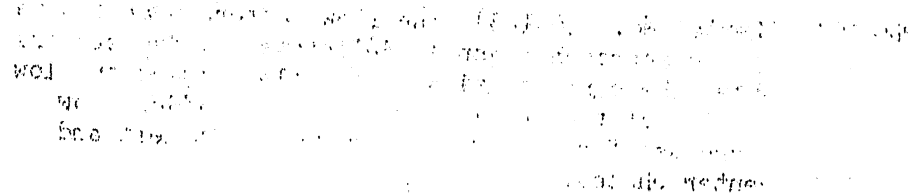

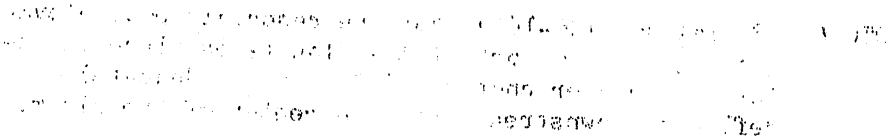

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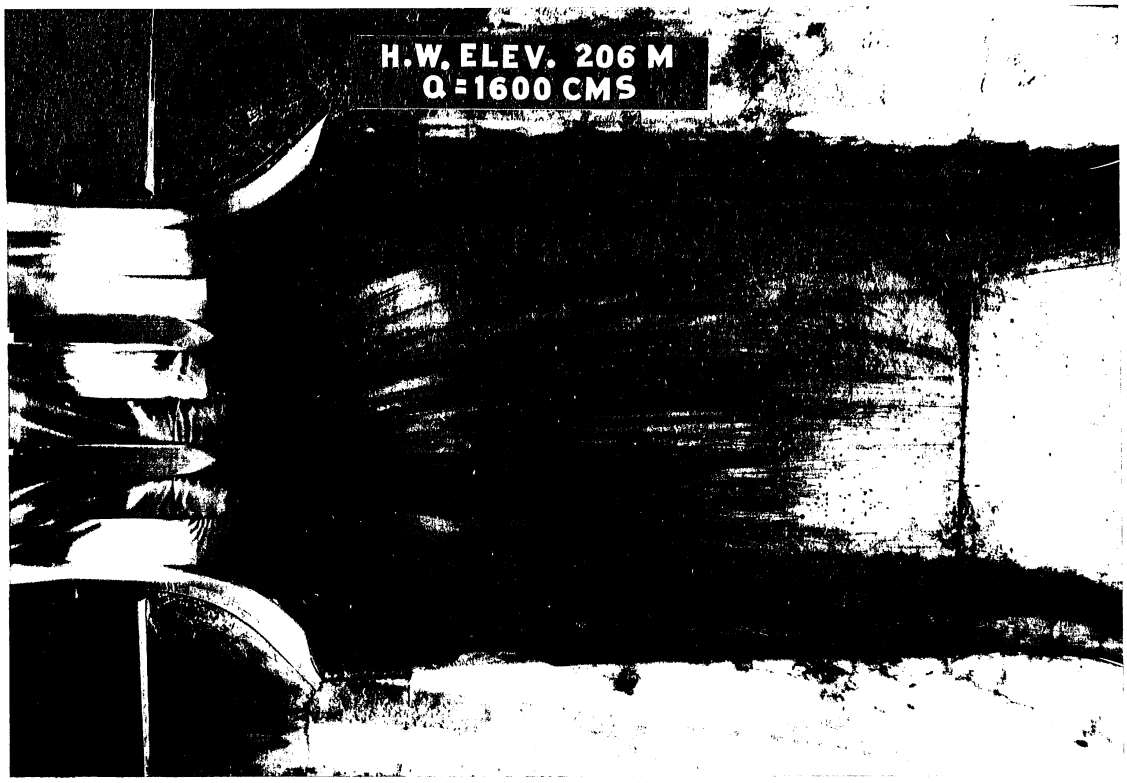

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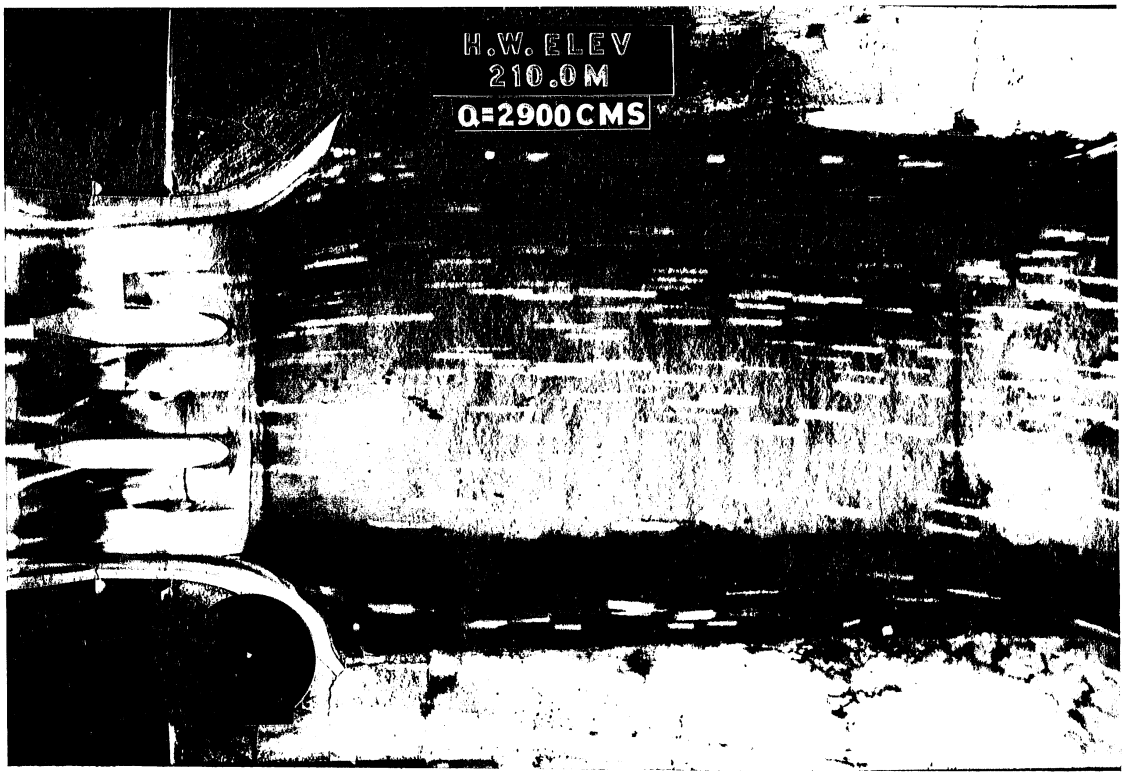
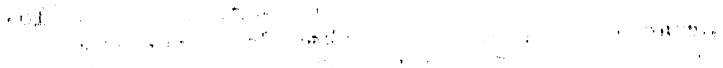


Photo 7

Photo 8



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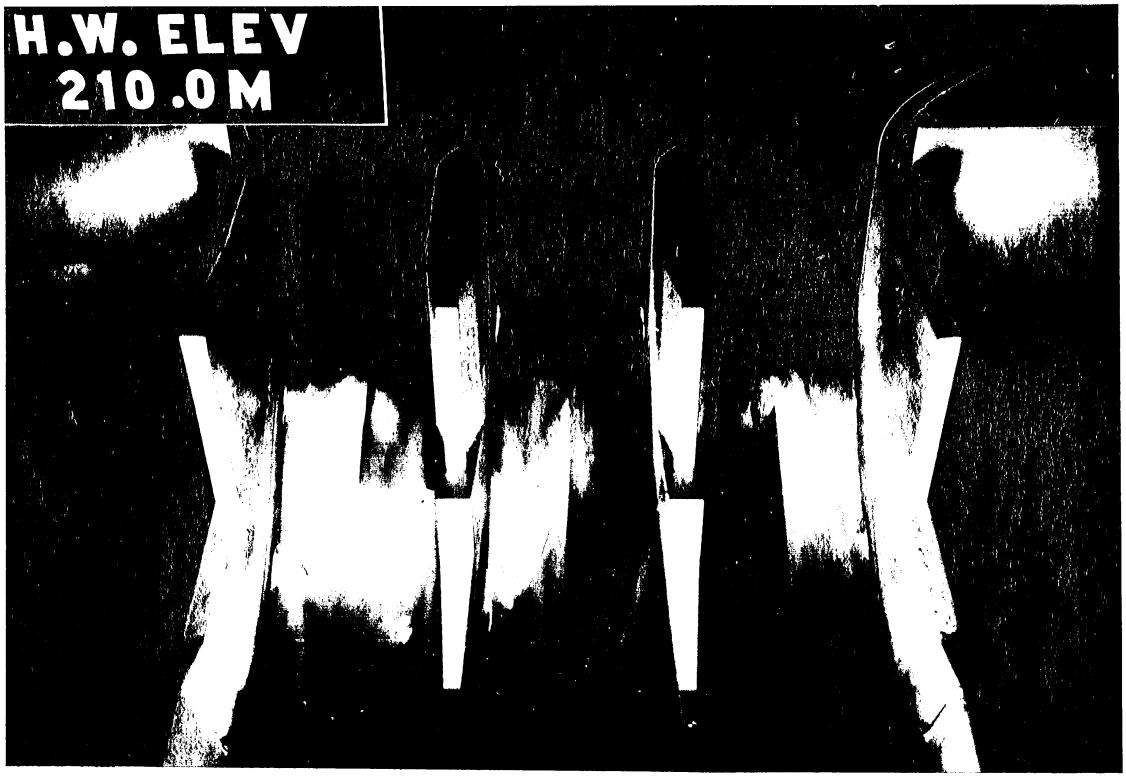
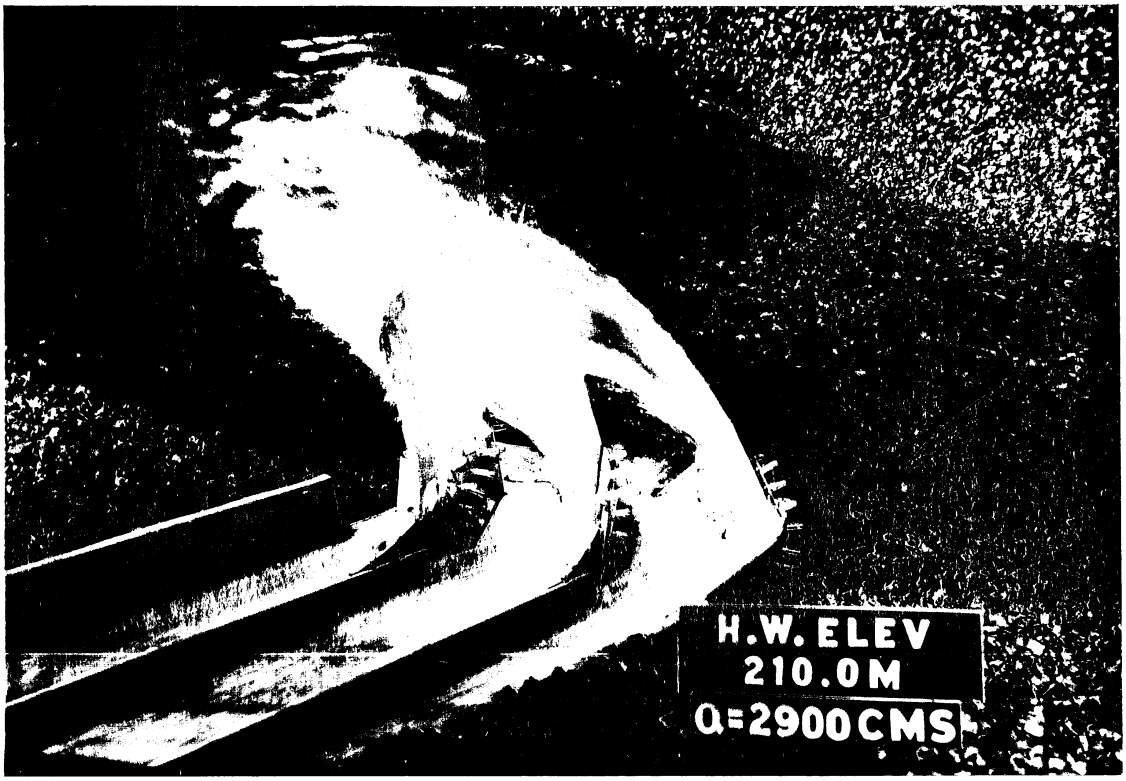


Photo 9



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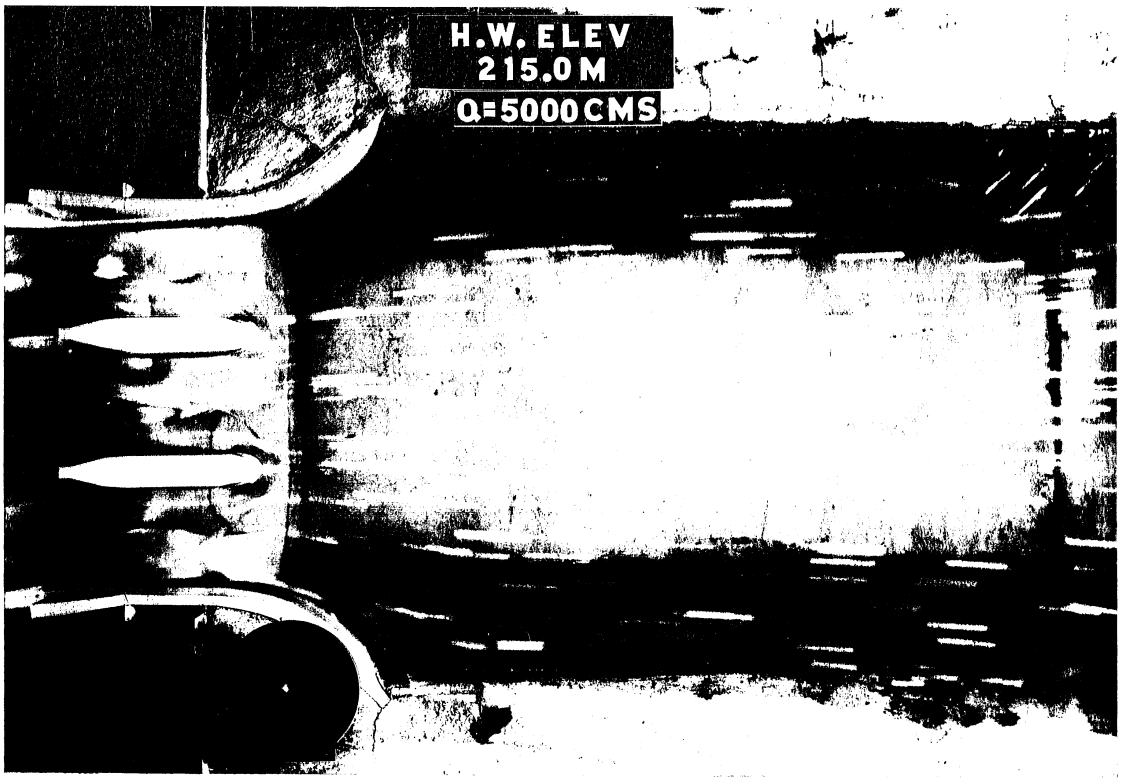
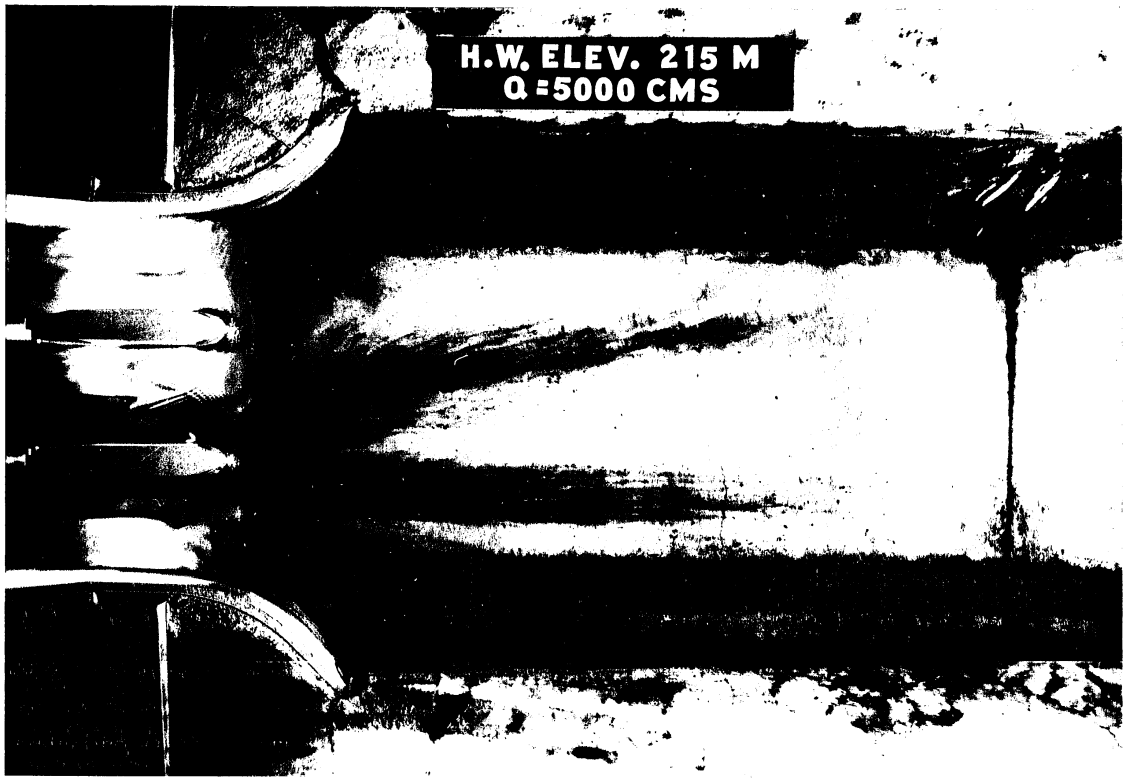


Photo 11



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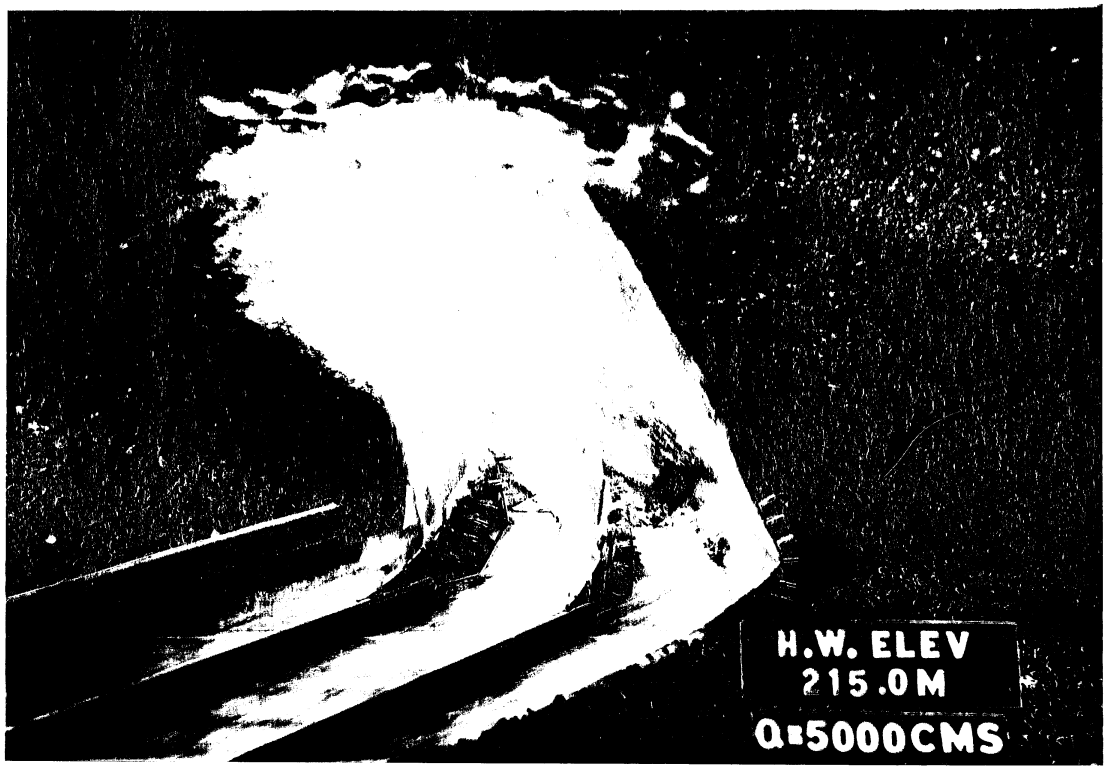
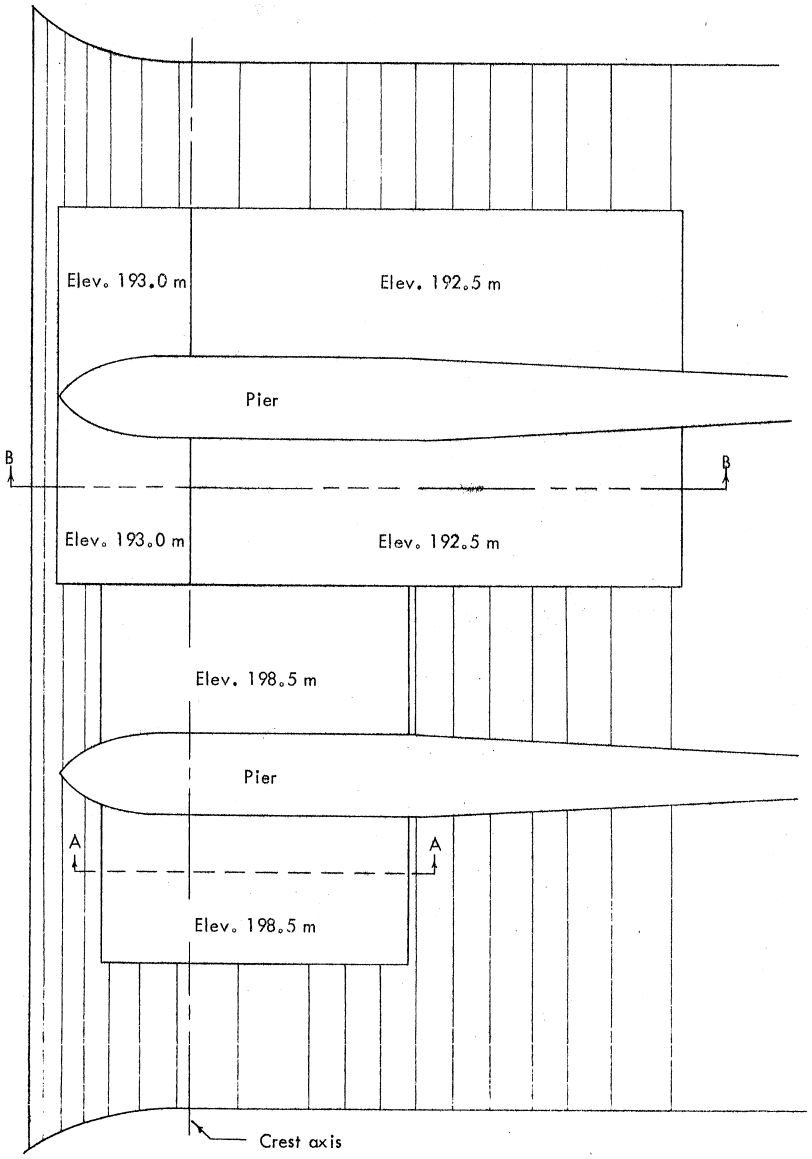
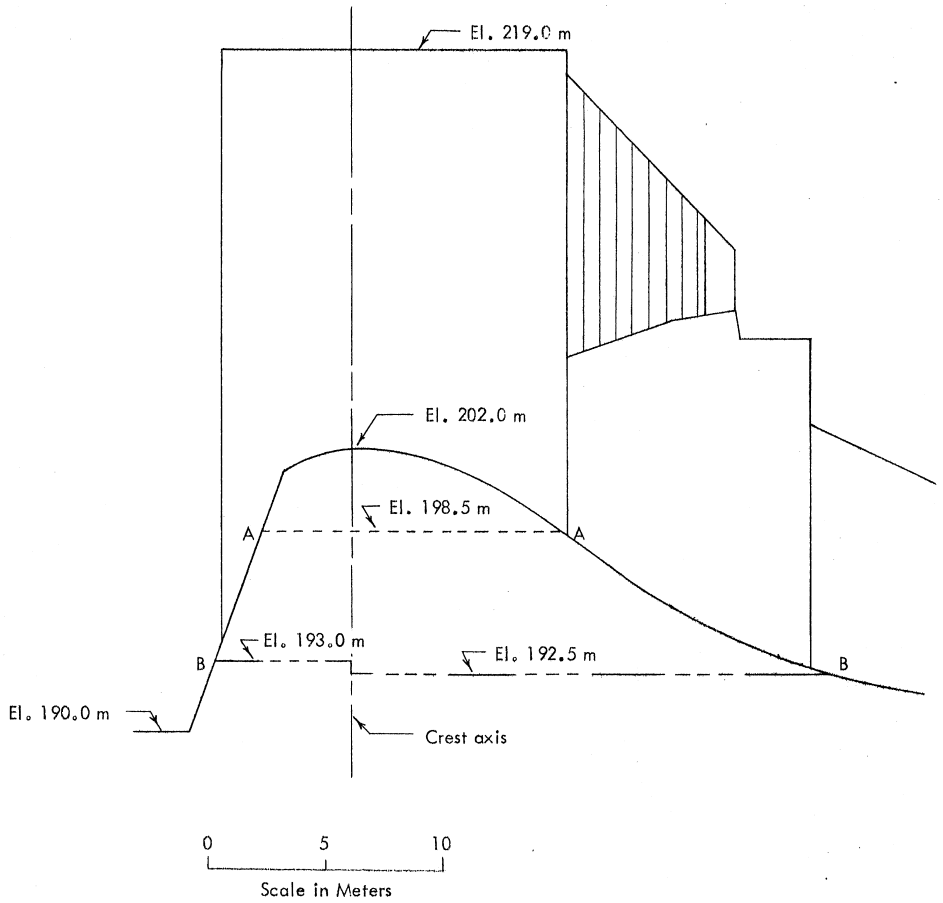


Photo 14

LIST OF CHARTS





CREST CONFIGURATION
Model Scale 1:118.1

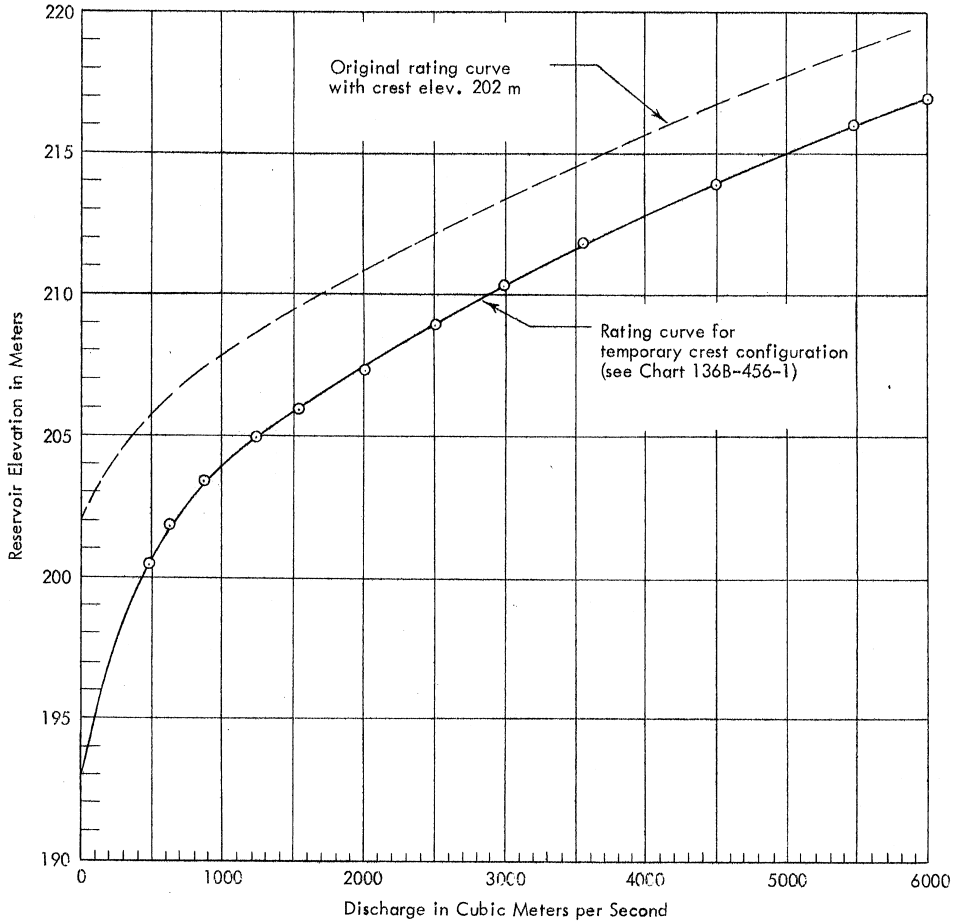
Note:

Information as to crest configuration taken from Harza drawing 260 SKC 1004 A. (260-F-52)

National Power Corporation; Manila, Philippines
ANGAT RIVER HYDROELECTRIC PROJECT
Harza Engineering Company, Chicago, Ill.
HYDRAULIC STUDIES
TEMPORARY CREST CONFIGURATION

SAINT ANTHONY FALLS HYDRAULIC LABORATORY
UNIVERSITY OF MINNESOTA

DRAWN DJA	CHECKED	APPROVED
SCALE	DATE 10-27-65	NO. 136B-456-1



Notes:

(1) Reservoir elevation determined 265 meters (prototype) upstream from crest.

(2) Original rating curve based on approach channel elevation of 190 meters.

SPILLWAY RATING CURVES
Approach Channel Elev. 190 m
Model Scale 1:118.1

National Power Corporation; Manila, Philippines
ANGAT RIVER HYDROELECTRIC PROJECT
Harza Engineering Company, Chicago, Ill.
HYDRAULIC STUDIES
TEMPORARY CREST CONFIGURATION

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DRAWN D.IA	CHECKED	APPROVED
SCALE	DATE 11-23-65	NO. 136B-456-2