

MONITORING OF ARCH DAMS

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INTRODUCTION

The design procedure for arch dams is now well established and involves extensive analytical and model studies in which many simplifying assumptions are made to enable the real and complex structure to be treated as a mathematical or structural model. Despite these simplifications there is substantial evidence indicating that the design methods used result in structures whose stresses and deflections agree well with calculated values. The evidence has been obtained by extensive instrumentation and observation on a number of dams with varying valley shape and foundation conditions, the results showing clearly that reasonable agreement exists between prototype behaviour and that predicted in the design. Most of the important contributions in this field have come from the United States Bureau of Reclamation (U.S.B.R.), the Laboratório Nacional de Engenharia Civil (L.N.E.C.), Portugal, and the Istituto Sperimentale Modelli e Strutture (I.S.M.E.S.), Italy.

In view of this advanced state of the art it is considered that instrumentation to check in detail the stressed state of the dam is not warranted in the case of a structure whose size is well within the limit of international experience. Not only are such studies costly involving as they must complementary studies of the elastic, creep and shrinkage properties of the concrete but considerable resources are required for their proper and thorough execution.

Where the safety control of the dam is the prime objective it is considered sufficient to monitor only the overall pattern of deformation of the dam and foundation, which, to some extent at least, forms a gross check on its stressed state.

The Hydro-Electric Commission, Tasmania, has 28 dams in service or under construction all of which have been built since 1945.

The number of each type is as follows:-

Earth	4 (including one under construction)
Rockfill	8 (either central or sloping core)
Gravity	3
Prestressed	2
Buttress	1
Faced Rockfill	6 (including one under construction)
Arch	4 (including one under construction)

Monitoring of all these dams is carried out, the extent and frequency being dependent on the size and type of dam and the length and history of service behaviour.

Because of the fairly rapid increase in the number of dams being monitored (18 since 1960) the Commission considered it necessary to centralise all records on its dams and for this purpose formed the Safety of Dams Unit within the Civil Design Division in 1971. This Unit is now responsible for collating and documenting in detail the complete history of each dam and for co-ordinating, assessing and presenting the results of all monitoring observations on dams in service.

This paper describes the types and methods of measurement made on three arch dams and presents the results of some observations. The instrumentation which will be installed in Gordon Dam, now under construction, is also given.

#### TYPES OF MEASUREMENT

A very good reference on what measurements should be made on an arch dam is the I.C.O.L.D. publication entitled

"General Considerations Applicable to Instrumentation  
for Concrete Dams"

written by the Committee on Observation of Dams and Models under chairman, Professor G. Oberti. This paper not only describes the types and methods of measurement and the purpose for which they are made but also gives an indicative list of the instruments available commercially and the companies which manufacture them.

The type of measurements made on the Commission's arch dams are

- (i) absolute horizontal and vertical displacement of points on the dam and foundation.
- (ii) differential displacement of the dam and foundation with respect to a vertical line consisting of a pendulum (or plumb bob) wire.
- (iii) differential displacement of points in the foundation with reference to a simple alignment provided by a tensioned tape or a steel rod anchored at one end.
- (iv) rotation with reference to a horizontal plane
- (v) strain deformation
- (vi) contraction joint gap
- (vii) temperature
- (viii) uplift or pore pressure
- (ix) leakage

#### METHODS OF MEASUREMENT AND INSTRUMENT DETAILS

##### 1) Surveying

Detailed description of the survey procedures used in the Commission in obtaining both absolute and relative displacements have been described by Jenkins and Funnell - ref (1).

They include:-

Base Line measurement using 200ft. long invar tapes standardised at the National Standards Laboratory, Sydney, every 2 or 3 years.

Triangulation observations for which a Wild T3 centesimal theodolite is used having an absolute accuracy of approximately  $\pm 3$  centesimal seconds (or  $\pm 1$  sexagesimal second). The overall accuracy of deflection measurements is considered to be  $\pm 0.002$  ft.

Collimation survey using Galileo adjustable targets and the Wild T3 theodolite as the collimating instrument. The absolute error in the measured deflections is approximately  $\pm 0.005$  ft. per 1000 ft. length of observation distance.

Precise levelling for which a Zeiss Ni 2 automatic level is normally used. A Zeiss Ni 1 is used for work of very high precision.

For lengths of run from 500 to 10,000 ft. and the number of set-ups from 8 to 80 per run the average misclose from an analysis of 94 runs was 0.004 ft. with a maximum of 0.015 ft.

Co-ordinometer measurements using a Galileo optical co-ordinometer to measure the movement of a suspended or inverted pendulum wire with reference to the co-ordinometer base. It provides direct measurement of the x and y components of movement to an accuracy of  $\pm 0.02$  mm, although the actual error is influenced by the stability of the pendulum wire at the time of measurement.

Rotation with respect to a horizontal plane is measured with an instrument called a clinometer. With a base length of 1 m the accuracy is  $\pm 2$  seconds of arc. Both Huggenberger and Galileo clinometers are used.

An electrical clinometer produced by Kyowa (CKE-33A) has a least reading of  $\pm 8$  seconds. This instrument may be used if telemetering of the measurement is required.

## 2) Measurement of Differential Displacement of Points in the Foundation

Two methods are used. The first involves measuring the change in length between the dead end of a drill hole and its collar by means of a rock compression gauge which consists of a steel rod anchored at the dead end and free to move relative to the rock at the collar. The movement is measured either by vernier callipers relative to a reference point anchored to the rock or by a Kyowa (CJ-12G) joint meter fixed to the rock at one end and attached to the steel rod at the other end. Accuracy is approximately  $\pm 0.001$  inch.

In the second method the change in length along an adit is measured by a tensioned tape anchored at one end and supported at intermediate measuring stations spaced at 10 to 20 ft. intervals. Accuracy is approximately  $\pm 0.02$  inch.

## 3) Measurement of Strain, Joint Gap and Temperature

Strain is measured by a Carlson type strain meter (Kyowa CS-25E) which has a gauge length of 250mm and a least reading of  $4 \times 10^{-6}$  units of strain.

Contraction joint gap movements are measured by the Kyowa CJ-12G joint meter. Gauge length is 260mm; range is 12mm for tension and 0.7mm for compression; least reading is 0.04mm.

Both the above meters also provide measurement of temperature to an accuracy of  $\pm 1^{\circ}\text{C}$ . Greater accuracy ( $\pm 0.3^{\circ}\text{C}$ ) is obtained from the Kyowa CTS-100N resistance thermometer.

The electrical conductors for these instruments are embedded directly in the concrete and are routed to multiple switch boxes (Kyowa NS-F series) located in the dam galleries. The maximum number of channels is 66 per box.

#### 4) Measurement of Pore Pressure

Pore pressures (or uplift pressures) have not been measured at any of the 3 existing arch dams. However, at Gordon Dam the effectiveness of the grout and drainage curtains in the steep, high abutments will be measured by monitoring pore pressures within the foundations. The Kyowa pore pressure meter (CP-N series) will be used by sealing them within specially located drill holes. This is an electrical instrument which measures the deformation of a diaphragm due to change in pore pressure by means of a strain meter.

#### 5) Measurement of Leakage

This is done either by channelling the water from a number of drain holes to a V-notch weir or by timing the discharge from a single hole into a calibrated container.

### RESULTS OF MEASUREMENTS

#### 1) Clark Dam

##### a) Description

Clark Dam is a constant radius structure located in the central part of the state on the Derwent River. Originally, when completed in 1949, the dam had a height of 200 ft. and a crest length of 1100 ft. Base thickness is 75 ft. In 1966 its height was increased to 221 ft. by the construction of a prestressed concrete cantilever wall on the original crest. Storage volume was thereby increased by some 70%.

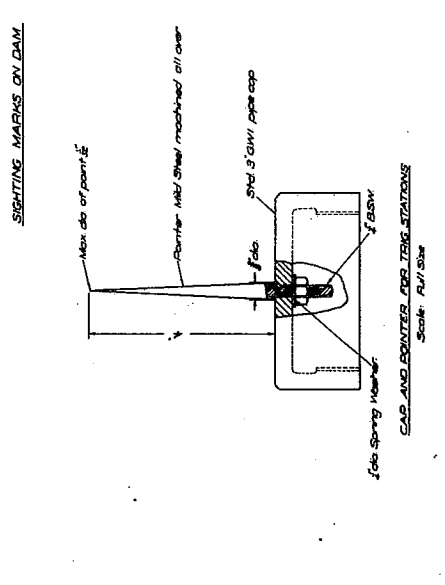
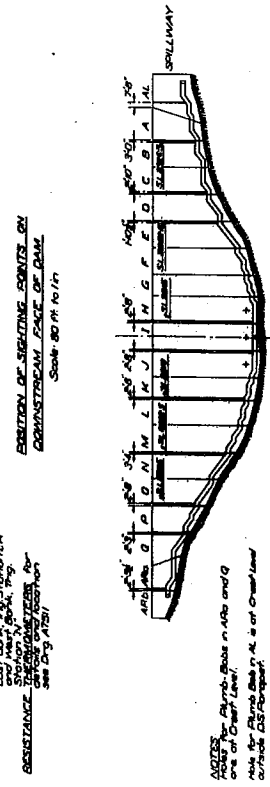
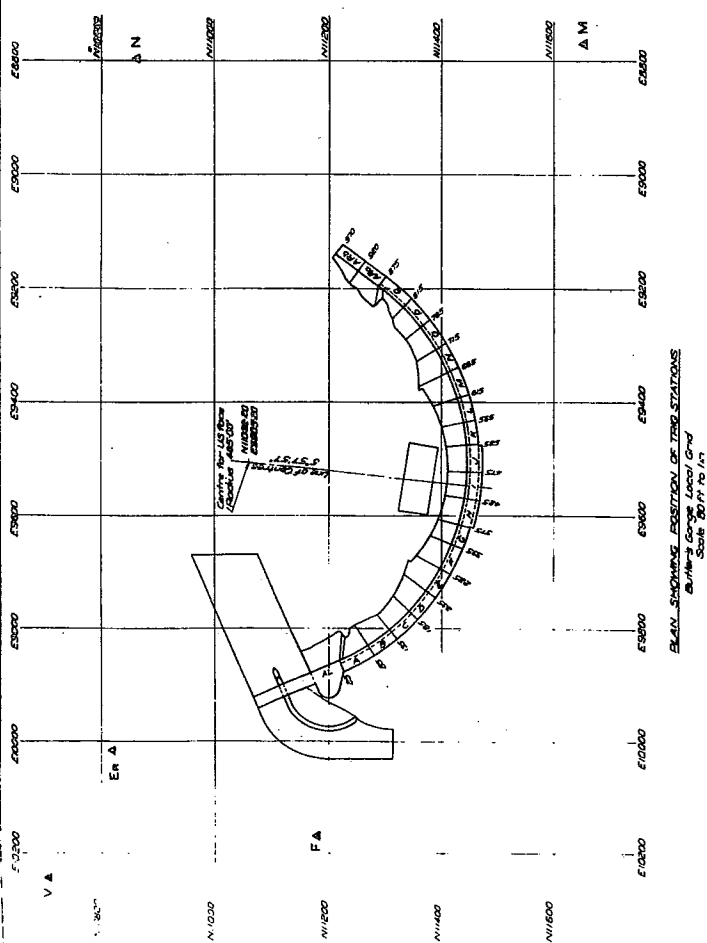
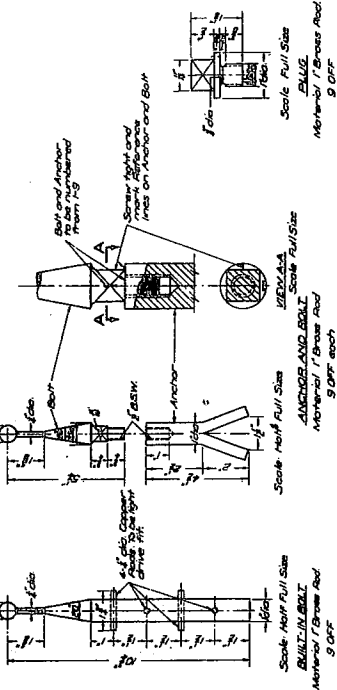
##### b) Instrumentation

The location of survey targets is shown in fig 1.

**LOCATION OF TIE STATIONS AND SECTION AND ELEVATION OF LINES**

Station	Section	Elevation
V	VER	870.00
E	ER	870.00
F	ER	870.00
M	M	870.00
N	N	870.00

1. Concrete pillars fixed with leveling screws at all stations for "N" tie stations.  
 2. Stations A and E are for use as observation points and are fixed in permanent position.  
 3. Stations V, F, M and N are for use as reference points.



THE HYDRO-ELECTRIC COMMISSION, TAIWAN

**CLARK DAM**

**DEFLECTION MEASUREMENTS**

**INSTALLATION OF EQUIPMENT**

**AB579**

NO.	DATE	BY	CHKD.
1	1954.10.15	W. S. ...	...
2	1954.10.15	W. S. ...	...
3	1954.10.15	W. S. ...	...
4	1954.10.15	W. S. ...	...
5	1954.10.15	W. S. ...	...
6	1954.10.15	W. S. ...	...
7	1954.10.15	W. S. ...	...
8	1954.10.15	W. S. ...	...
9	1954.10.15	W. S. ...	...
10	1954.10.15	W. S. ...	...

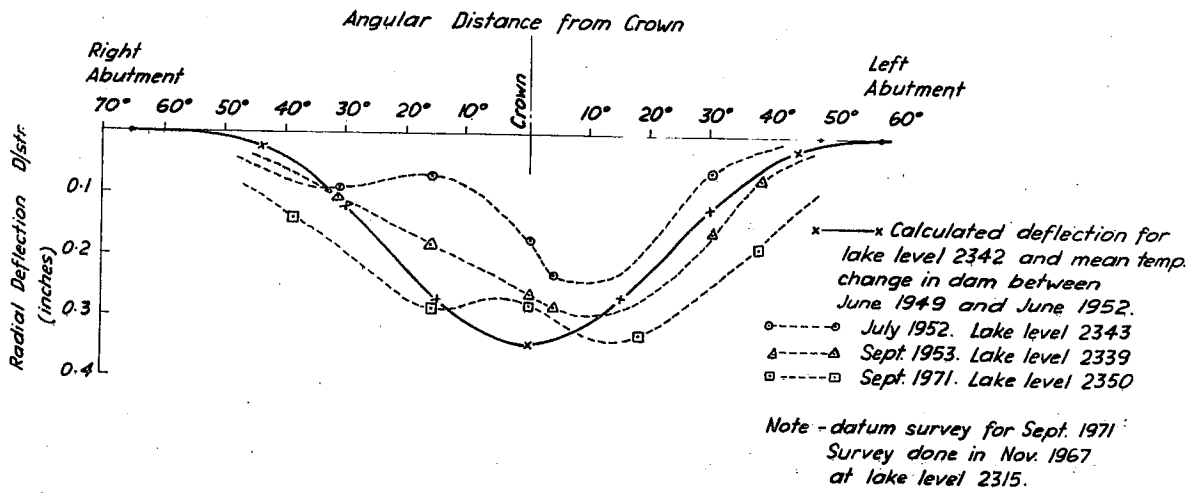


Fig. 2 - CLARK DAM - Radial Deflection of Crest Arch

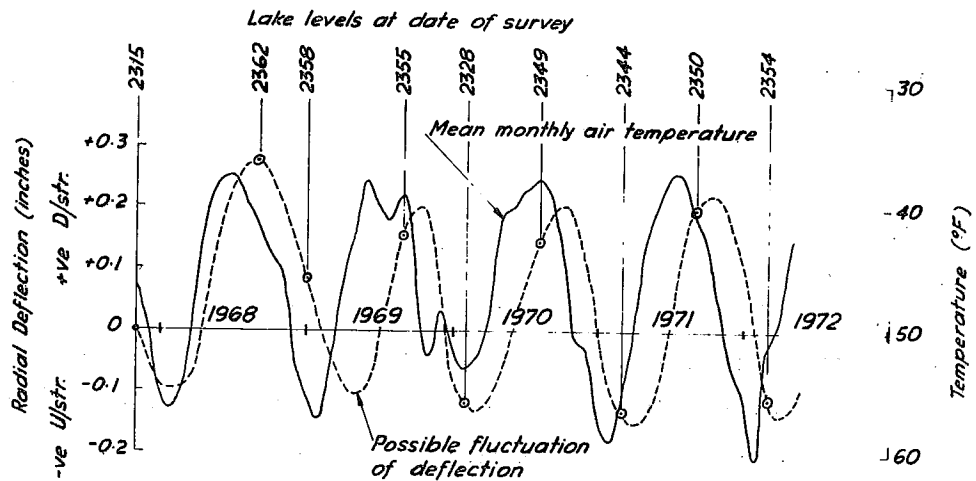


Fig. 3 - CLARK DAM - Radial Deflection at Centre of Crest.

Also shown are the locations of the pendulum shafts - however, due to poor installation of the pipes forming the shafts resulting in deviations from the vertical of almost half the pipe diameter the pendulums were not installed. In addition a number of resistance thermometers were embedded in 4 blocks of the dam and gap gauges were installed across contraction joints to control joint grouting operations.

c) Results

The reservoir (Lake King William) was filled between 1949 and 1952. Deflection surveys carried out in July 1952 and September 1953, have been described by Thomas (2). The measured radial deflections obtained from those two surveys, the survey in September, 1971 and the calculated deflection curves are shown in fig 2. The asymmetry of the measured deflection curve was ascribed to differential temperature between the two abutments.

No further measurements were made until the dam height was increased. At that time it was found necessary to modify the triangulation scheme used in the original surveys.

The new datum survey was carried out in November, 1967 when the lake was at SL 2315. Since then two surveys have been done each year. Fig 3 shows the radial deflection at the centre of the crest for the various surveys, the corresponding water level and the plot of mean monthly air temperature. The correlation with temperature is obvious and masks any influence of varying water load.

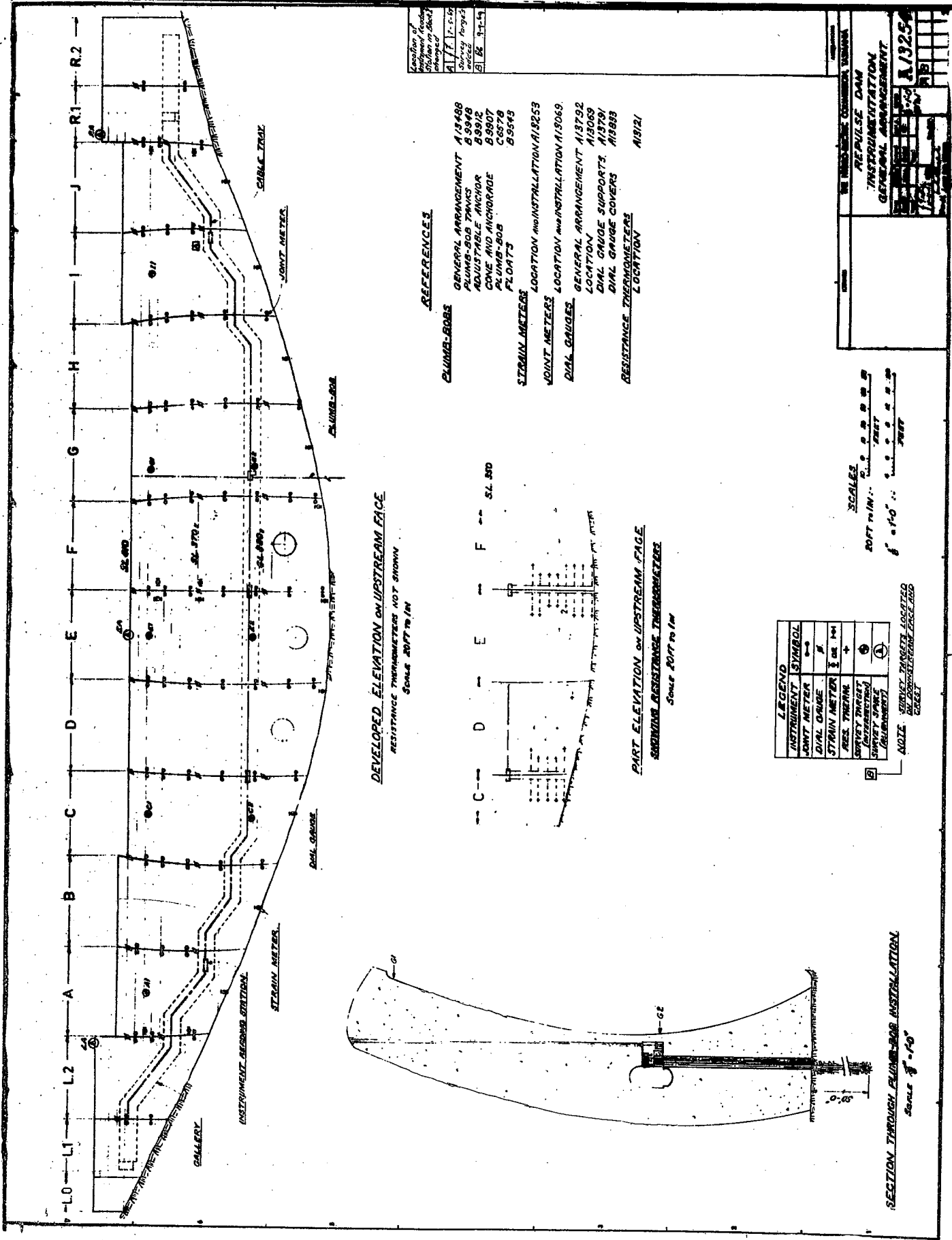
2) Repulse Dam

a) Description

Repulse is a cupola shaped dam, 139 ft. high, 679 ft. crest length and with thickness varying from 30 ft. at the base to 20 ft. at the crest. The dam is located on the Derwent River about 50 miles north west of Hobart. It was completed in 1968.

b) Instrumentation

The general arrangement of the instrumentation is shown in fig 4.



**DEVELOPED ELEVATION ON UPSTREAM FACE**

RESISTANCE THERMOMETERS NOT SHOWN  
SCALE 20 FT TO 1 IN

**REFERENCES**

- PLUMB-BOBS**
  - GENERAL ARRANGEMENT A13488
  - PLUMB-BOB TANKS B9948
  - ADJUSTABLE ANCHOR B9912
  - CONE AND ANCHORAGE B9907
  - PLUMB-BOB C6578
  - FLOATS B9543
- STRAIN METERS**
  - LOCATION AND INSTALLATION A13253
- JOINT METERS**
  - LOCATION AND INSTALLATION A13069
- DIAL GAUGES**
  - GENERAL ARRANGEMENT A13732
  - LOCATION A13069
  - DIAL GAUGE SUPPORTS A13731
  - DIAL GAUGE COVERS A13883
- RESISTANCE THERMOMETERS**
  - LOCATION A13121

**PART ELEVATION ON UPSTREAM FACE**

SHOWING RESISTANCE THERMOMETERS  
SCALE 20 FT TO 1 IN

INSTRUMENT	SYMBOL
JOINT METER	⊕
DIAL GAUGE	⊖
STRAIN METER	⊕
RES. THERM.	⊕
SAFETY TARGET (INTERSECTION)	⊕
SURVEY SPARK (REFERENCE)	⊕

NOTE: SAFETY TARGET LOCATED ON DOWNSTREAM FACE

**SCALES**  
20 FT TO 1 IN  
6" = 10' = 100'

Location of Instrument Facing Direction of Section

A	1-1-10
B	1-1-10
C	1-1-10
D	1-1-10
E	1-1-10
F	1-1-10
G	1-1-10
H	1-1-10
I	1-1-10
J	1-1-10
K	1-1-10
L	1-1-10
M	1-1-10
N	1-1-10
O	1-1-10
P	1-1-10
Q	1-1-10
R	1-1-10

REVISIONS

NO.	DATE	DESCRIPTION
1	1-1-10	REVISIONS
2	1-1-10	REVISIONS
3	1-1-10	REVISIONS
4	1-1-10	REVISIONS
5	1-1-10	REVISIONS
6	1-1-10	REVISIONS
7	1-1-10	REVISIONS
8	1-1-10	REVISIONS
9	1-1-10	REVISIONS
10	1-1-10	REVISIONS

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Fig. 4

The system consists of:-

- 7 survey targets for triangulation observations
- 3 collimation targets - one at the crest centre and one on each thrust block
- 1 suspended and 2 inverted pendulums located in G block
- 122 joint meters + 58 dial guage measuring stations also used to measure joint gaps
- 36 strain meters
- 27 thermometers

### c) Results

The strain meters were installed as single instruments and not in rosettes. Their purpose was to obtain some indication of vertical stresses around the base and of vertical and horizontal stresses near crest level. No results of any real value were obtained from them.

The datum survey was carried out in February, 1968 just prior to filling the dam in early March, 1968. Radial deflection at the centre of the dam 10 ft. below crest level, is shown in fig 5 together with mean monthly air temperature and the mean temperature of the crown cantilever. It may be seen that very little change in mean temperature occurred during filling so that the corresponding deflection is due almost entirely to the water load.

In fig 6 the deflection due to the first filling is compared with the calculated deflection due to water load only for the crest arch, the crown cantilever and the G block cantilever. The calculated deflection was obtained by trial load analysis using a value of 5 for the ratio of elastic modulus of concrete to foundation and an elastic modulus for concrete of  $3 \times 10^6$  lb/in<sup>2</sup>. The measured deflection was only 40% of that calculated indicating a considerably greater foundation modulus than that adopted.

Also shown in fig 6 are the calculated deflection curves for water load plus a 9°F temperature rise and water load plus an 8°F temperature fall, the range in deflection for the 17°F change in temperature being 0.59 inches. The measured ranged in deflection for a 12°F change in mean temperature of the crown cantilever has been 0.37 inches.

Comparison between the co-ordinometer measurements on the pendulums and the triangulation surveys shows a maximum difference of inches in the radial direction - fig 7.

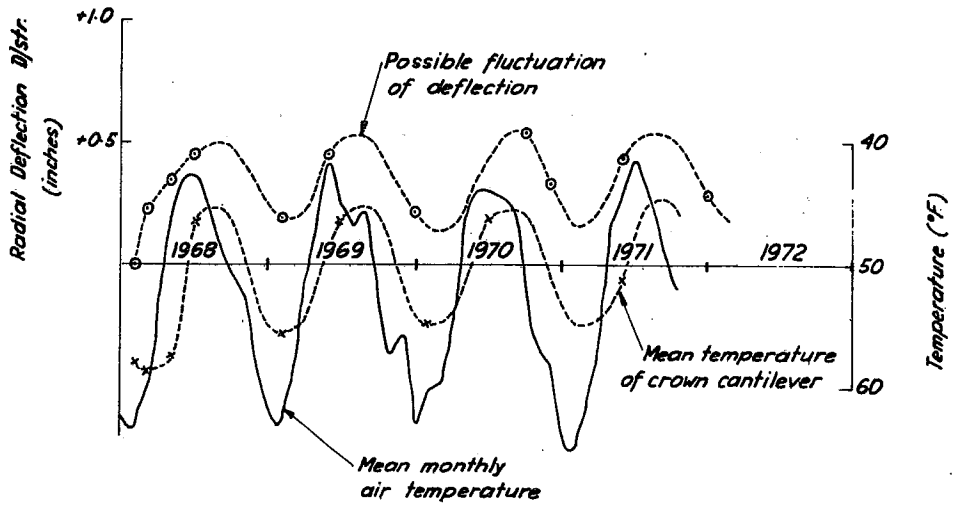


Fig. 5 - REPULSE DAM - Radial Deflection at Centre of Crest

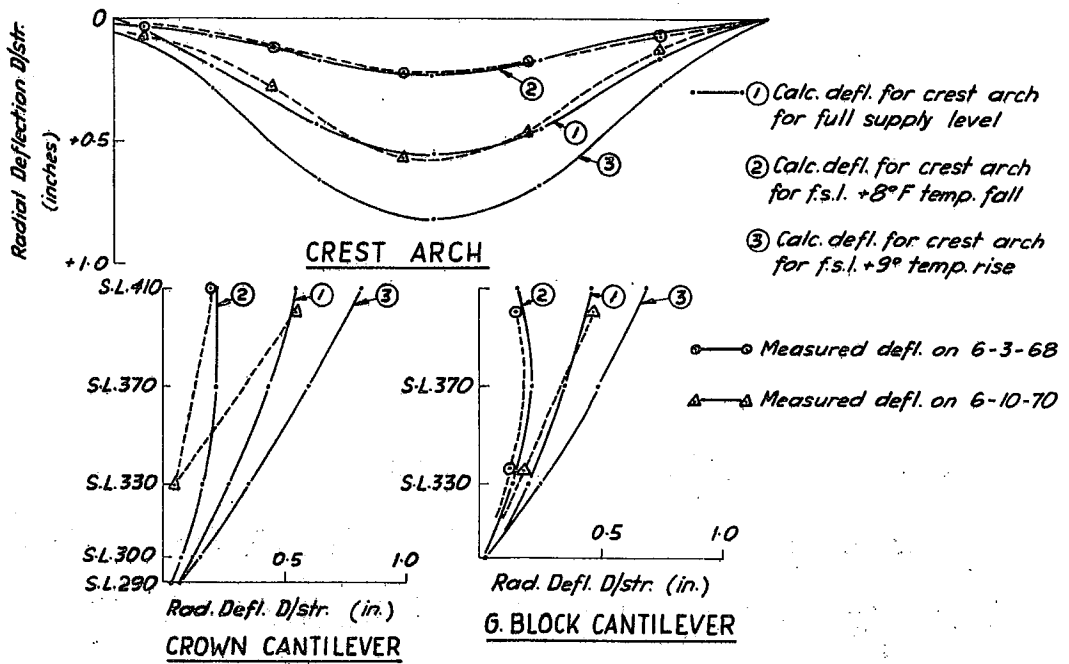
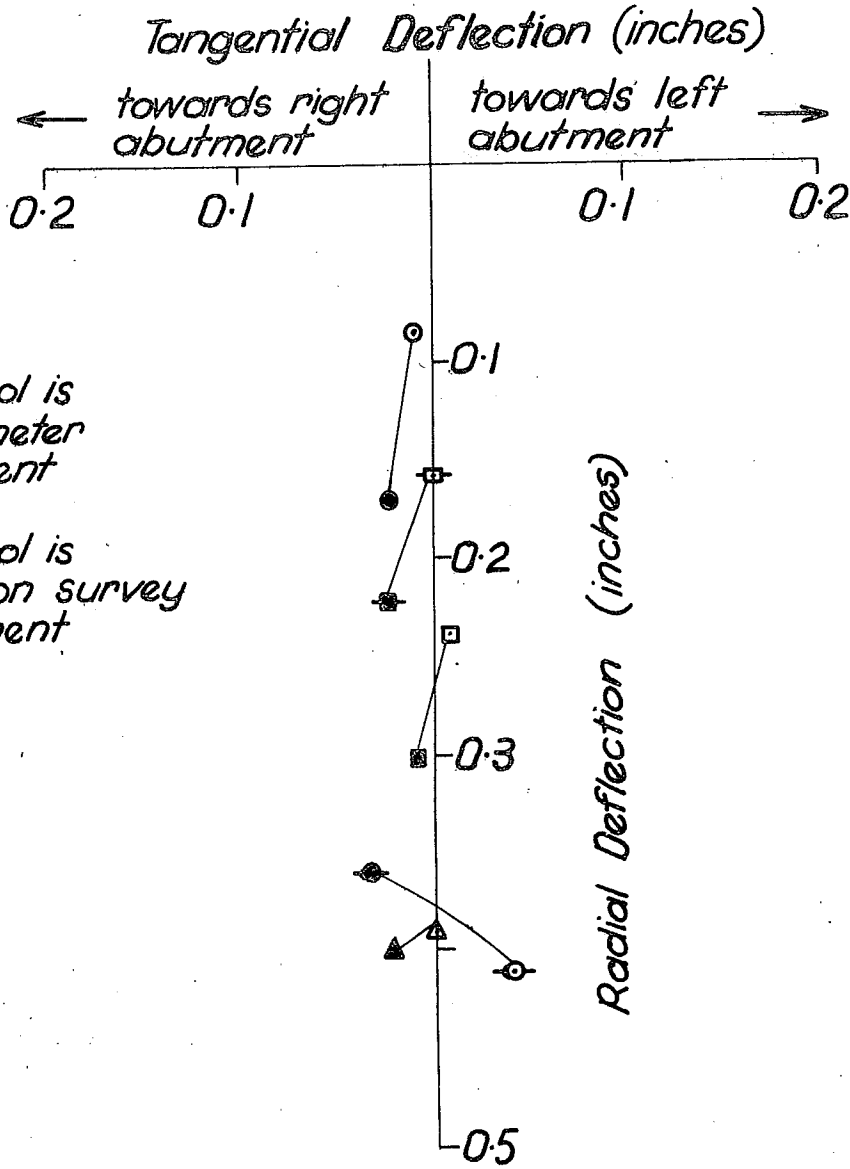


FIG. 6 - REPULSE DAM - Radial Deflection of Crest Arch and Two Cantilevers



Open symbol is  
co-ordinometer  
measurement

Solid symbol is  
triangulation survey  
measurement

- ) 6-3-68
- ) 16-5-68
- △) 4-7-68
- ) 9-6-71
- ) 13-1-72

Fig 7 - REPULSE DAM  
Comparison of Co-ordinometer and  
Triangulation Survey Measurements  
for Target G1.

3) Devils Gate Dama) Description

Devils Gate is a thin cupola shaped dam 275 ft. high and 440 ft. crest length, with thickness varying from 17 ft. at the base to 9 ft. at the crest. The dam is located on the Forth River in the north of the state 20 miles south of Devonport. It was completed in 1969.

b) Instrumentation

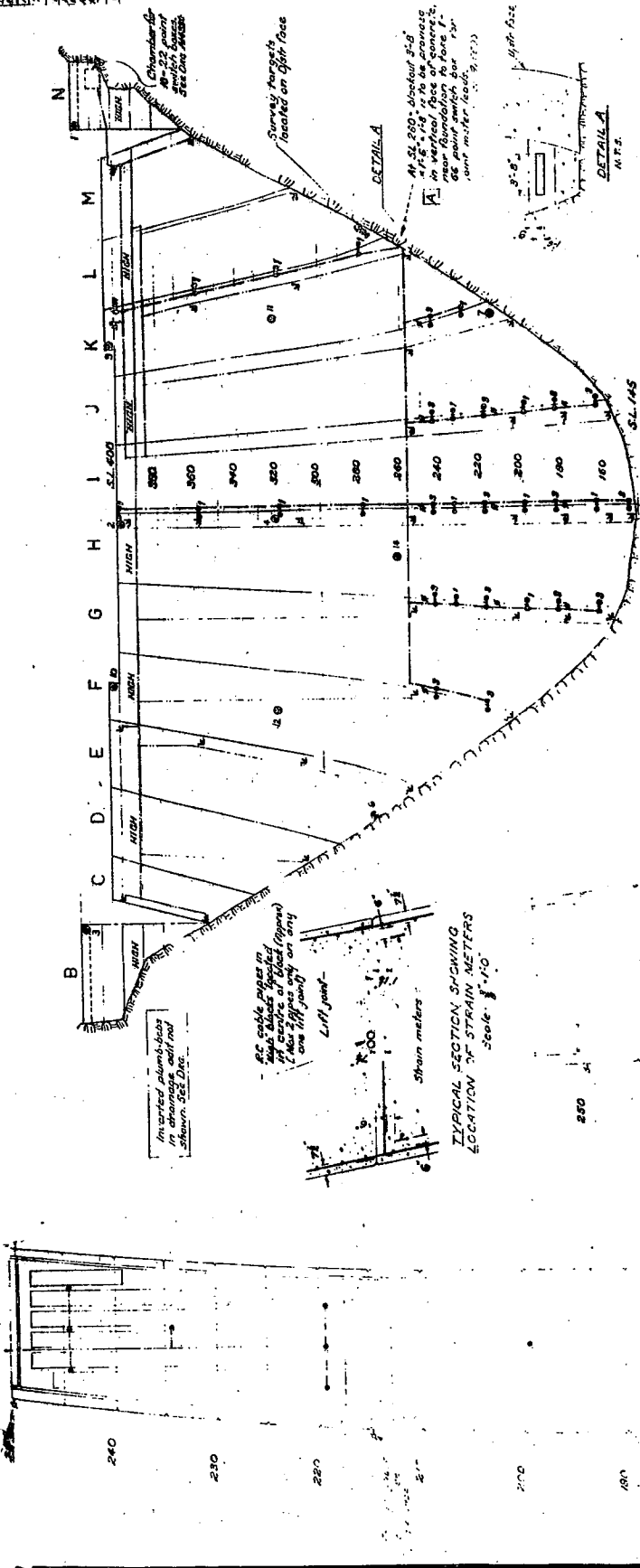
Because of the pronounced vertical curvature of the dam it was only possible to grout the lower one third of the contraction joints and this limitation introduced a high temperature load on the dam. Under the combined loading of own weight plus water load plus temperature load the analysis indicated that significant tensile stresses would occur in several locations. These were the extrados foundation region where both arch and cantilever stresses were in the range 150 to 300 lb/in<sup>2</sup> and the cantilever extrados at the top of the grouted zone where calculated cantilever tensions were in the range 150 to 200 lb/in<sup>2</sup>. It was decided to accept these tensions and to instrument the dam with strain meters to obtain an indication of whether the distribution of stresses was generally in accord with the design.

Fig 8 shows the instrumentation system installed and consisting of:-

- 12 survey targets for triangulation observations
- 70 strain meter rosettes of 3 meters each
- 61 joint meters (plus 22 dial gauge measuring stations for joint gap measurements)

No pendulums were installed because of the pronounced vertical curvature. In addition to the above and not shown in fig 8 two adits in a low modulus zone in the left abutment were instrumented to measure foundation deformation. In the adit at SL 350 there are 3 rock compression gauges of 50 ft. length, one in the radial direction and two in the tangential direction, and tape gauges along the 115 ft. length of adit which is approximately in the radial direction. In the adit at SL 284 there are 5 rock compression gauges each 50 ft. long. Two of these are in the vertical direction, two are in the horizontal tangential direction and one in the horizontal radial direction.

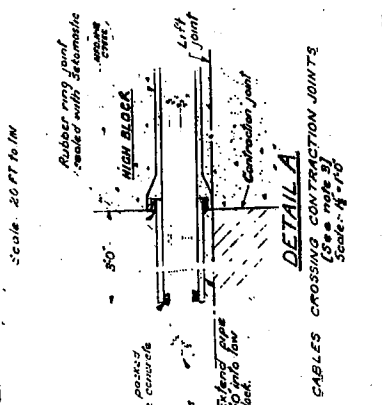
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CHECKED BY	J. H. ...
SCALE	1" = 20 FT
PROJECT	DEVILS GATE DAM
NO.	114733



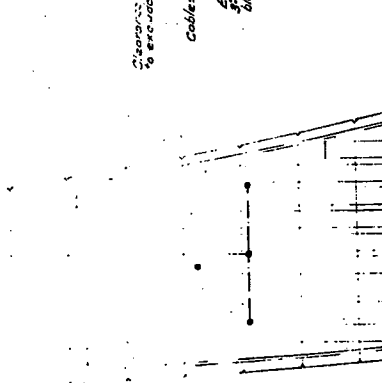
**DEVELOPED ELEVATION ON UPSTREAM FACE**  
Scale: 20 FT TO 1 IN

- NOTES**
1. POSITION OF JOINT METERS (Carbon Type Gages)
    - a. Where there are three gages, space the joint meter about 12 in.
    - b. Where there are two gages, space the joint meter about 18 in.
    - c. Where there is only one gage, as in (H) above, space the gage 18 in. from either end of the meter length of a 4 ft panel.
  2. POSITION OF STRAIN METERS (Carbon Type Gages)
    - a. Gages are on the line of centers.
    - b. Blocks E, F, G and I are 1.5 ft from center. See elevation on detail A.
    - c. Strain gages are near to the base joint as possible.
  3. Cables
    - a. Cables 5" x 1/16" B.C. cables with rubber ring joints across high blocks of SL 235, 21, 390 and SL 235.
    - b. Allow approx. 70 or 85 cables through each 4 ft panel.
    - c. One cable placed at each center of face. See detail A.
  4. Mark of section showing exact location of cables and cables are to be unpeeped and forwarded to E.C.D.

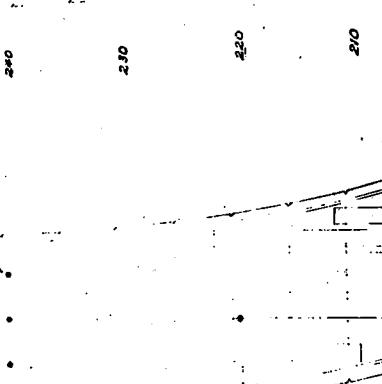
**DEVELOPED ELEVATION ON UPSTREAM FACE**  
Scale: 20 FT TO 1 IN



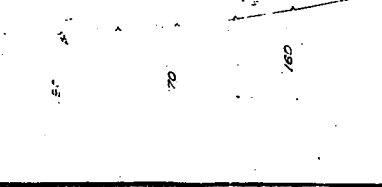
**DEVELOPED ELEVATION ON UPSTREAM FACE**  
Scale: 20 FT TO 1 IN



**DEVELOPED ELEVATION ON UPSTREAM FACE**  
Scale: 20 FT TO 1 IN



**DEVELOPED ELEVATION ON UPSTREAM FACE**  
Scale: 20 FT TO 1 IN



DATE	1/14/52
BY	J. H. ...
CHECKED BY	J. H. ...
SCALE	1" = 20 FT
PROJECT	DEVILS GATE DAM
NO.	114733

**LEGEND**

INSTRUMENT SYMBOL	
JOINT METER	○
STRAIN METER	○
DIAL GAUGE	○
SURVEY TARGET	○

**SCALES**

200 FT TO 1 IN	1" = 20 FT
100 FT TO 1 IN	1" = 10 FT
50 FT TO 1 IN	1" = 5 FT
25 FT TO 1 IN	1" = 2 FT 6 IN

Fig. 8

c) Results

The reservoir (Lake Barrington) was filled between 26th July and 4th September, 1969.

Strain measurements were converted to stresses using a single value of Young's modulus and without any allowance for creep and shrinkage. The presence of the tension zones in the extrados foundation region and across the extrados at the top of the grouted zone was confirmed. The results also indicated that the whole of the downstream face is in compression.

The deflection at the centre of the crest is shown in fig 9 together with a correlated mean monthly air temperature. It will be noted that there is virtually no lag between the mean monthly temperature and the temperature movement of the dam and this is to be expected in such a thin structure.

The calculated deflections, due to water load, of the arch at SL 400 (crest) and SL 310 are shown in fig 10 together with the maximum and minimum measured deflections obtained to date. The same information for the crown cantilever is shown in fig 11. The mean temperature and temperature gradients in the crown cantilever are shown in fig 12 for the date of the datum survey and 3 subsequent dates. Because of the temperature changes that took place during filling it is not possible at this stage to determine the deflection due to the water load alone. When a few more deflection surveys have been carried out with simultaneous measurement of temperature distribution it will be possible to determine the separate contribution of water and temperature loading statistically.

The tangential deflection of both point 5 on the right abutment and point 6 on the left abutment has gradually increased to about  $\frac{1}{8}$ th inch in the 3 years since filling. Smaller foundation deformation was obtained from the rock compression gauges in the left abutment at about the same level as point 6, results being in the range zero to  $\frac{1}{16}$  inch.

GORDON DAM1) Description

Gordon Dam will be a double curvature structure 460 ft. high with a thickness of 50 ft. at the base reducing to 9 ft. at the crest. The crest length will be 625 ft.

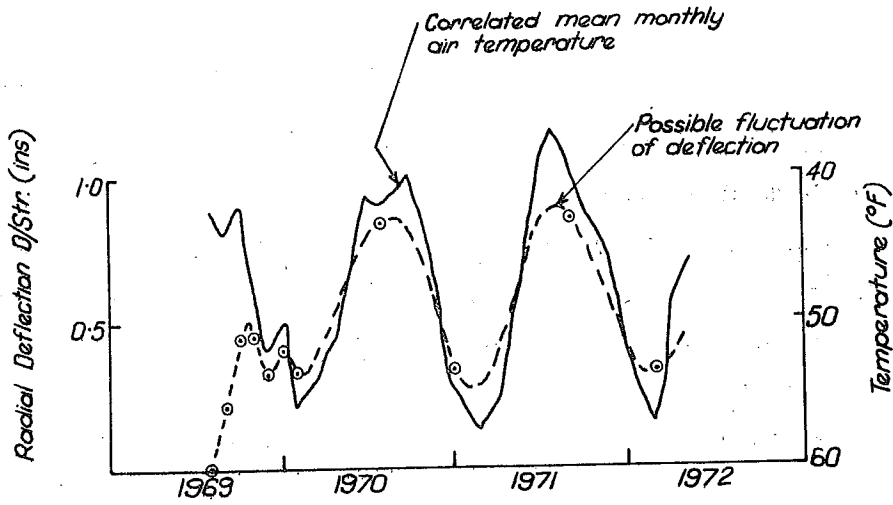


Fig 9 - DEVILS GATE DAM - Radial Deflection at Centre of Crest

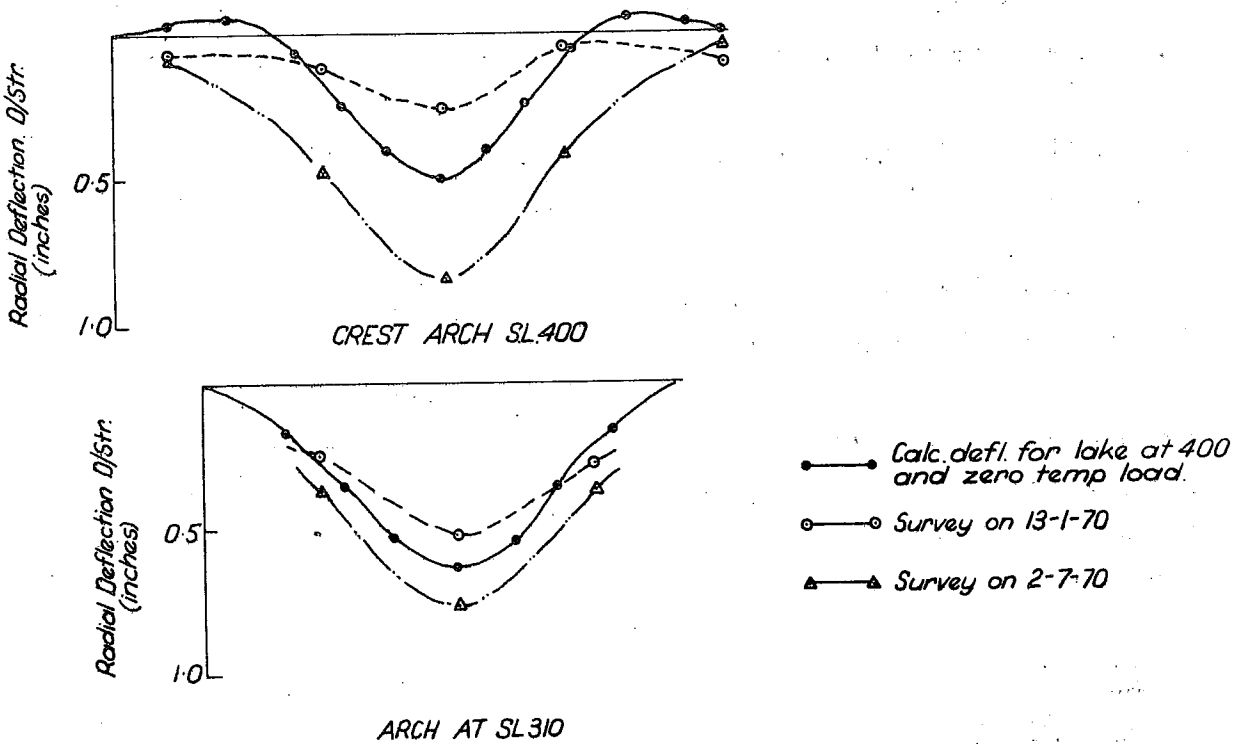


Fig 10 - DEVILS GATE DAM - Radial Deflection of Two Arches

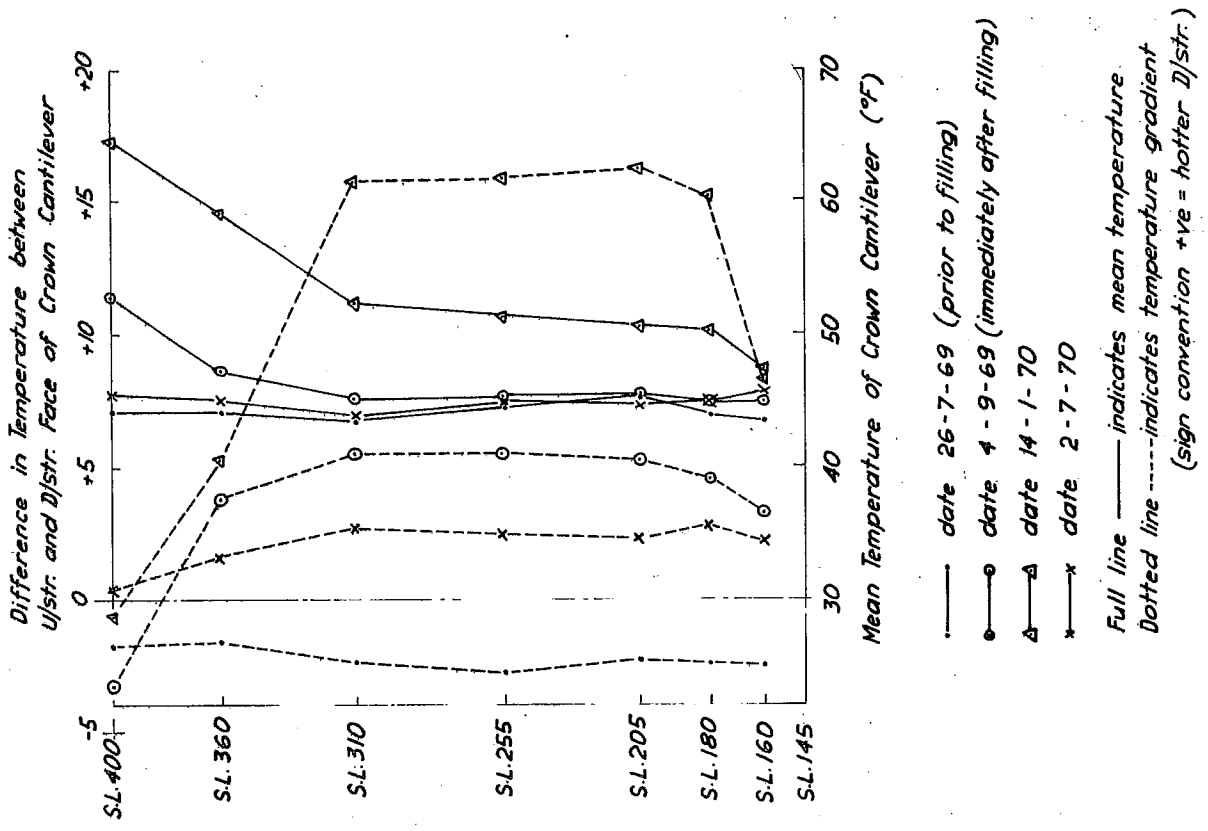


FIG. 12 - DEVILS GATE DAM  
Temperature of Crown Cantilever

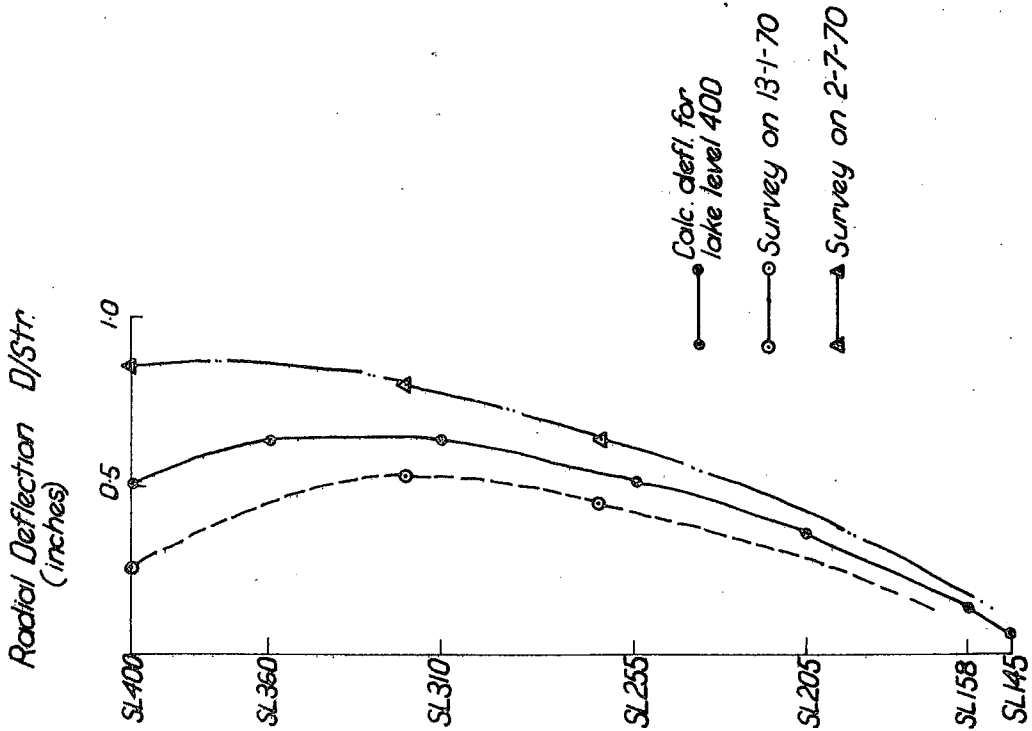


Fig 11- DEVILS GATE DAM  
Radial Deflection of  
Crown Cantilever

The dam is under construction at the present time in the south west region of the state. Concrete construction is in progress and approximately 10% of the 200,000 yd<sup>3</sup> of concrete has been placed.

2) General

Design studies for the dam were extensive and included:-

trial load analysis with radial and tangential adjustment

structural model tests at the Commission's Civil Engineering Laboratory and at L.N.E.C., Portugal

3 dimensional finite element analysis by Professor Zienkiewicz at University of Swansea

The agreement between all studies was in general excellent and showed that no tensions were present for the combined loading of own weight plus water load and that with temperature load added tensile stresses greater than 150 lb/in<sup>2</sup> were present in only three very localised areas.

The reservoir, Lake Gordon, and the adjacent Lake Pedder with a combined storage of 12 million acre feet will constitute a very large crustal load of  $1.4 \times 10^{10}$  tons. The possibility of increased seismic activity in the region due to this load was considered real and various seismic and related projects have been undertaken to monitor seismic events. These include:-

Extension of the 12 years old state seismic net into the south-west area

Installation of several micro-earthquake stations in the region

Precise repeat levelling and trilateration

In addition several strong motion instruments will be located at the dam.

3) Instrumentation

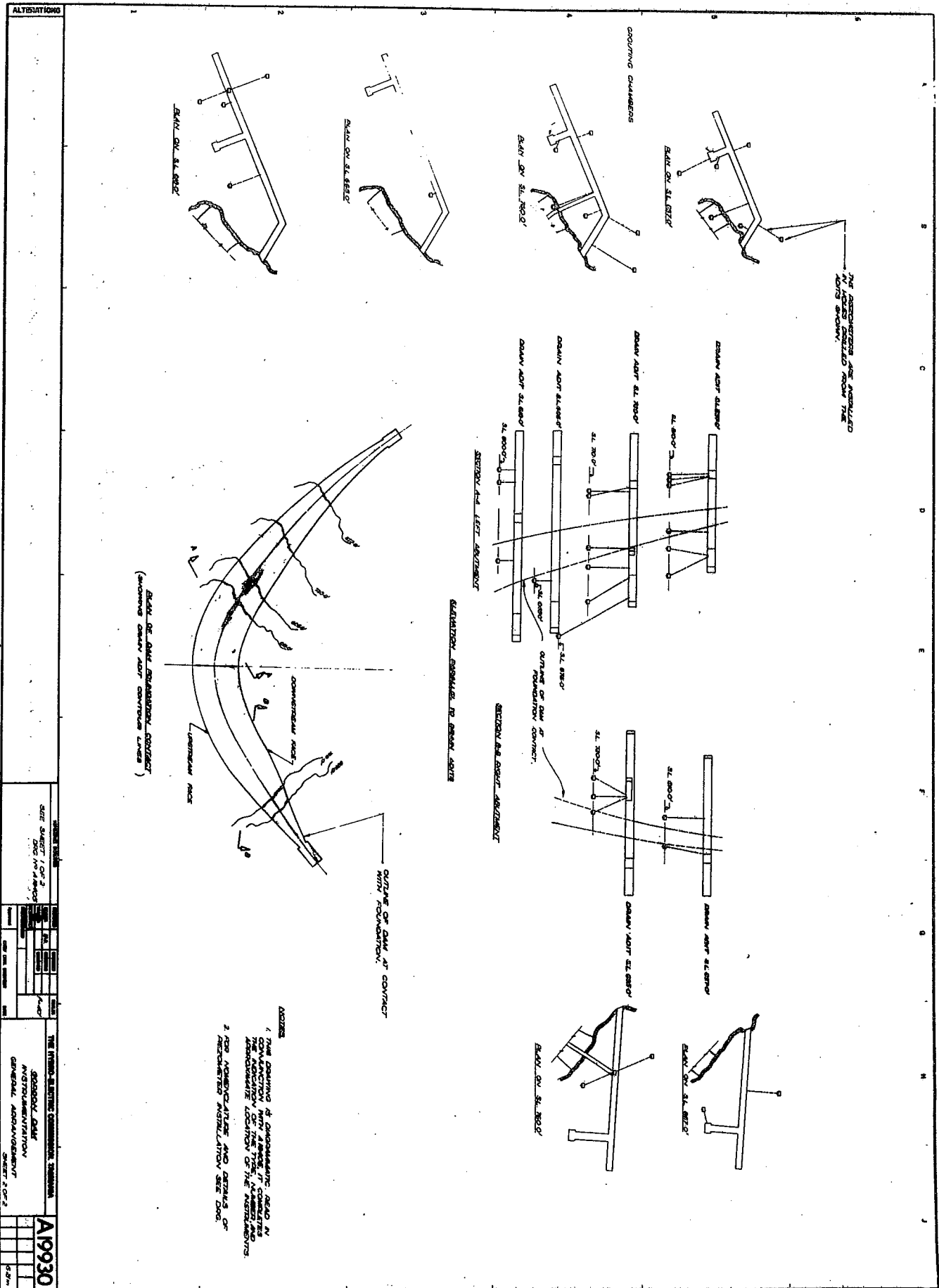
As mentioned above considerable work is involved in first instrumenting to measure strains and then in calculating stress from measured strain in concrete. In addition to the cost of instrumentation there is the cost of the necessary creep studies and of applying the laboratory data to measured strains in order to compute stress. Work on Repulse and Devils Gate showed that credible stress values would not be obtained without making the correct allowance for creep. In view of the cost and resources required for this work and because of the satisfactory state of calculated stress under all loading conditions it was decided not to install any strain meters but simply to monitor the deformations of the dam and foundation as a whole.

The instrumentation which will be installed in the dam is shown in figs 13 to 18 and consists of

- 23 survey targets (fig 15)
- 3 suspended and 3 inverted pendulums (fig 15). The suspended pendulums will hang from a suspension point at SL 905, pass through intermediate measuring chambers at SL 760 and terminate near the base of the dam. The inverted pendulums will be anchored 50 to 80 ft. below the foundation surface in cased 7 in. dia. drill holes and extend to the same chambers in which the suspended pendulums are terminated.
- 18 clinometer positions fig 13 of 1 in. base length, generally in orthogonal pairs to measure rotation in the radial and tangential directions.
- 150 joint meters, fig 13 and 16
- 30 resistance thermometers fig 17
- 32 piezometers fig 14
- 18 rock compression meters fig 14 and 18
- 1 MO2 accelerograph fig 13
- 4 Wilmot seismoscopes fig 13

In order to increase the accuracy of triangulation deflection surveys and reduce the time required to carry out each survey the Commission has placed on order a Kern Mekometer.



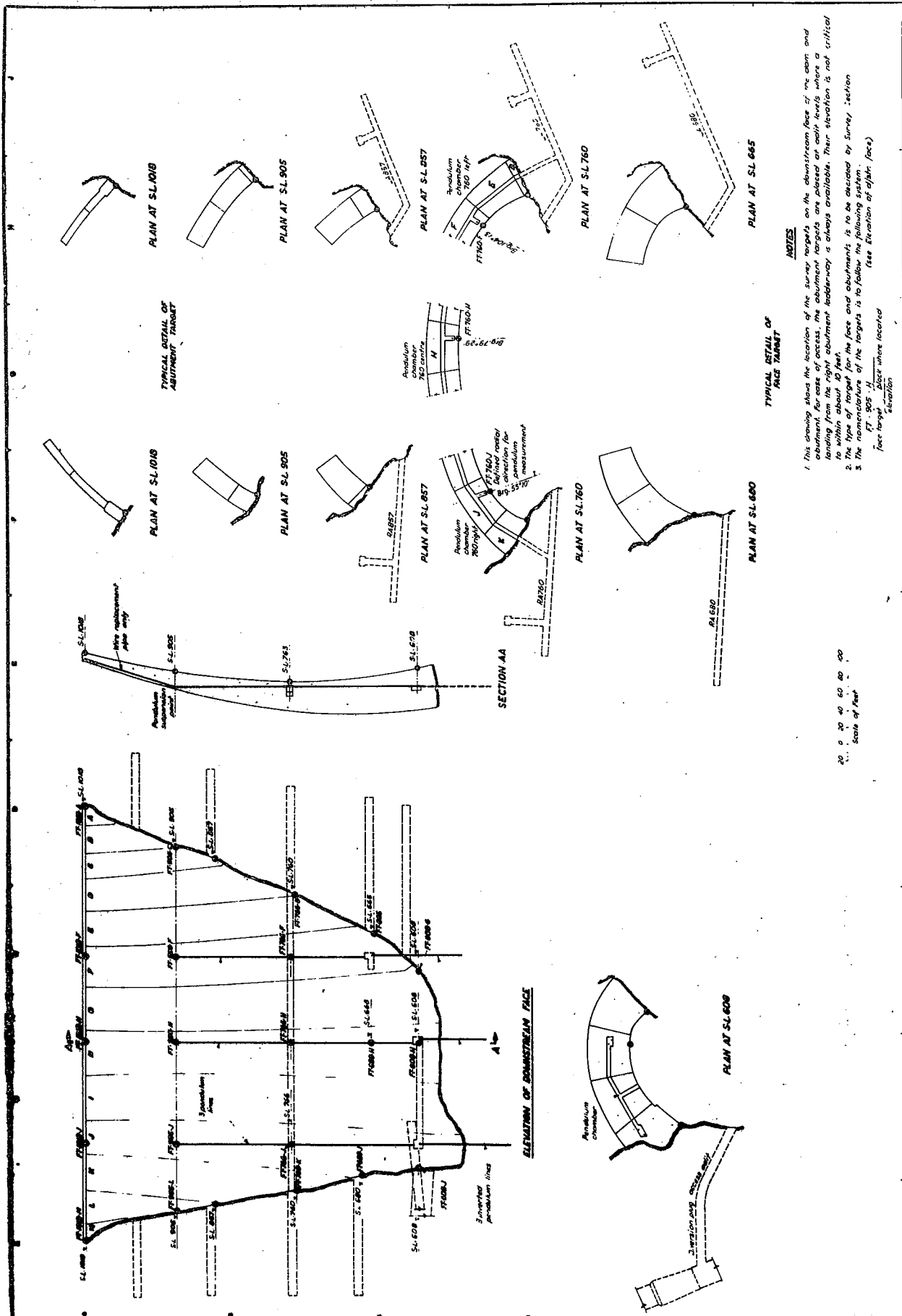


ALTERATIONS

DATE SHEET 1 OF 2  
DWC No. 41807

THE FEDERAL BUREAU OF INVESTIGATION  
GENERAL INVESTIGATIVE DIVISION  
GENERAL ADMINISTRATION  
SHEET 1 OF 2

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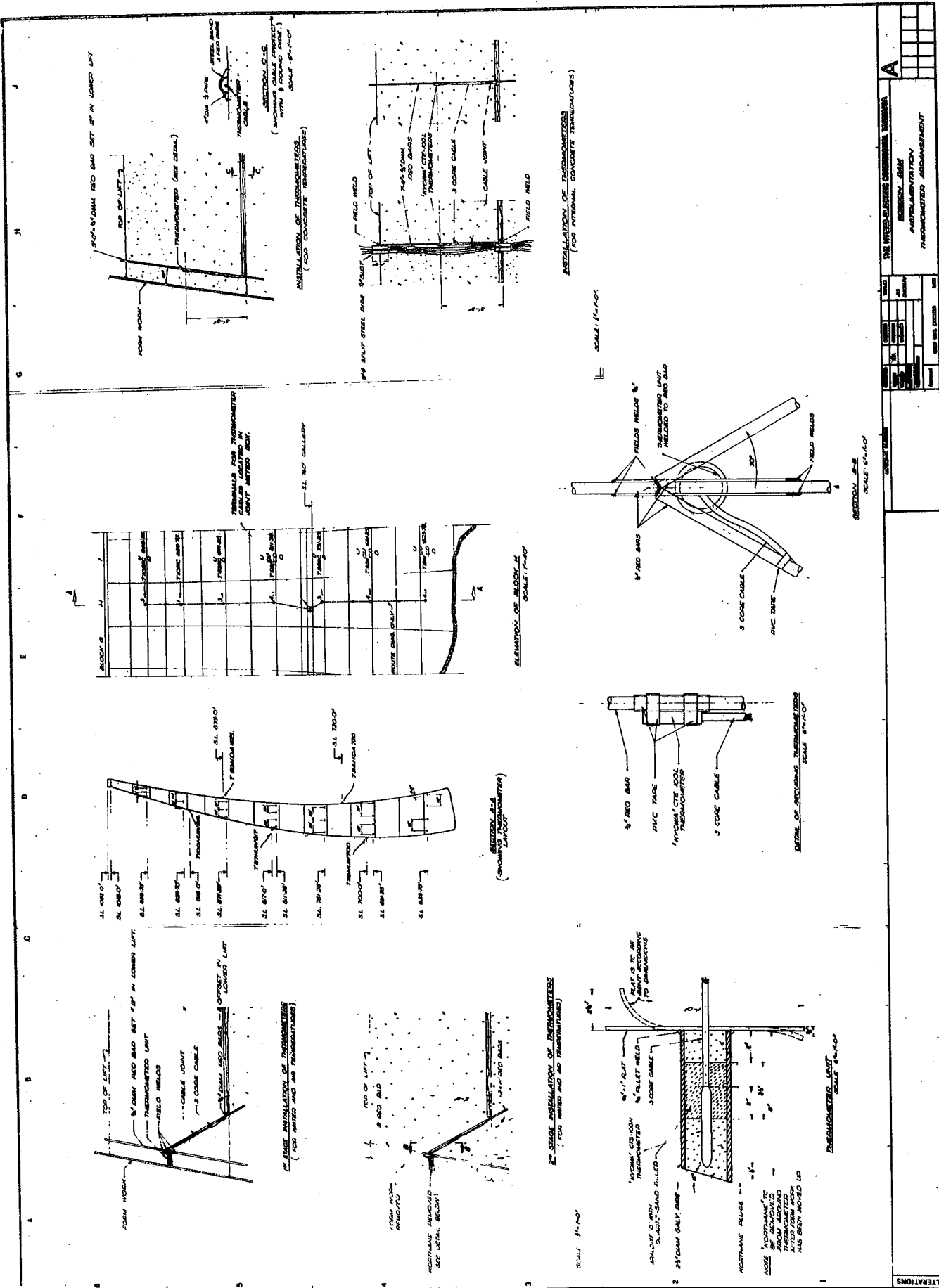
**NOTES**

1. This drawing shows the location of the survey targets on the downstream face of the dam and abutment. For ease of access, the abutment targets are placed at odd levels where a landing from the right abutment ladder-way is always available. Their elevation is not critical to within about 10 feet.
2. The type of target for the face and abutments is to be decided by Survey Section.
3. The nomenclature of the targets is to follow the following system:  
 (a) 'SL' - Station where located  
 (b) 'Face' - Face where located  
 (c) 'Target' - Target

Scale of Feet  
 0 10 20 30 40 50 60 70 80

THE HYDRO-ELECTRIC COMMISSION, TASMANIA <b>GORDON DAM</b> INSTRUMENTATION GENERAL ARRANGEMENT. SHEET 3 OF 3	
PROJECT NO. 4076 DRAWING NO. 4540 SCALE 1/4" = 1'	A20008





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THE HYDRO-ELECTRIC CORP. THERMOMETER  
 INSTRUMENTATION  
 THERMOMETER ARRANGEMENT

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SCALE: 3/4"=1'-0"

SCALE: 3/4"=1'-0"

SCALE: 3/4"=1'-0"

SCALE: 3/4"=1'-0"

SCALE: 3/4"=1'-0"

SCALE: 3/4"=1'-0"

SCALE: 3/4"=1'-0"

SCALE: 3/4"=1'-0"

SCALE: 3/4"=1'-0"



This is a direct distance measuring instrument of a high order of accuracy. Experience with the 3 or 4 instruments which exist in England and Switzerland shows the accuracy to be within  $\pm 0.1 \text{ mm} = 3$  parts per million of the site distance. Thus over a site distance of 300m the accuracy would be  $\pm 1 \text{ mm}$ .

Also under investigation at the present time is the possibility of obtaining measurements from the pendulums by means of electrical transducers. This is part of an overall proposal to telemeter measurements from a selected group of instruments either to Hobart or to the Gordon underground powerstation. The object of the proposal is to provide a more effective safety control procedure at considerably reduced cost during the life of the dam.

#### 4.) Assessment of Results

As stated above monitoring of Clark, Repulse and Devils Gate Dams is carried out two times per year. Assessment of the results consists of comparison with calculated values to see that measured deflections are of the right order and comparison of the seasonal observations to see that the expected temperature dependent fluctuations occur. The assessment is qualitative and is not capable of detecting whether an apparent anomaly is due to the particular loading conditions at the time of measurement or whether it is due to some unexpected phenomenon.

For Gordon Dam it is intended to use the measurements to establish empirically, by statistical methods, the response of the dam to the fluctuations of load, both water and thermal. When a correlation has been established detection of an abnormality will be an easier task, and the assessment of the safety of the structure will be soundly based on a variation from an observed repeatable pattern. This method of safety control is used extensively in Portugal - (3) and (4) and Italy (5).

#### CONCLUDING REMARKS

The monitoring of an arch dam for safety control requires systematic observation of the deflections of the structure and its foundation during construction and reservoir filling and throughout its life. Where possible two or three different methods of measurement should be employed to give greater overall confidence in the results.

Only by comparison between parallel sets of measurements can a systematic error in any one method be detected.

The deflection of the dam during filling is dependent on the increase in water load, the change in temperature and also creep, if the filling rate is slow. Subsequently, if the lake level remains essentially unchanged, deflection will fluctuate with temperature and increase asymptotically due to creep. Determination of the separate components of deflection due to water load, temperature and creep is of importance in assessing the results in order to find out whether an apparent anomaly is due to the specific loading conditions at the time or whether it is due to some unexpected phenomenon. The separate contribution of the various load parameters may be found simply by statistical methods. It is proposed to carry out this form of quantitative assessment on observations of Gordon Dam.

REFERENCES

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- (4) Marazio, A., - "Analisi statistiche sul comportamento di una grande diga nei primi anni di esercizio" - L'Energia Elettrica, No. 4, 1965.