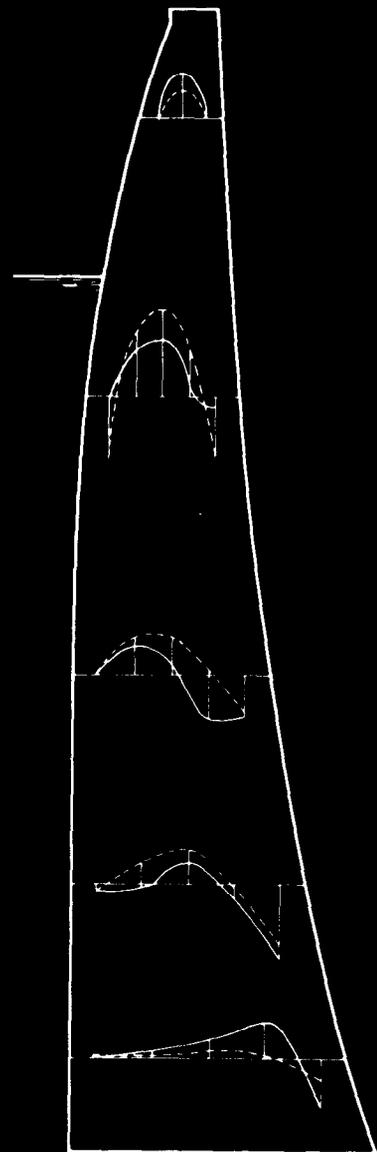


Comparison of Analytical and Structural Behavior Results for Flaming Gorge Dam

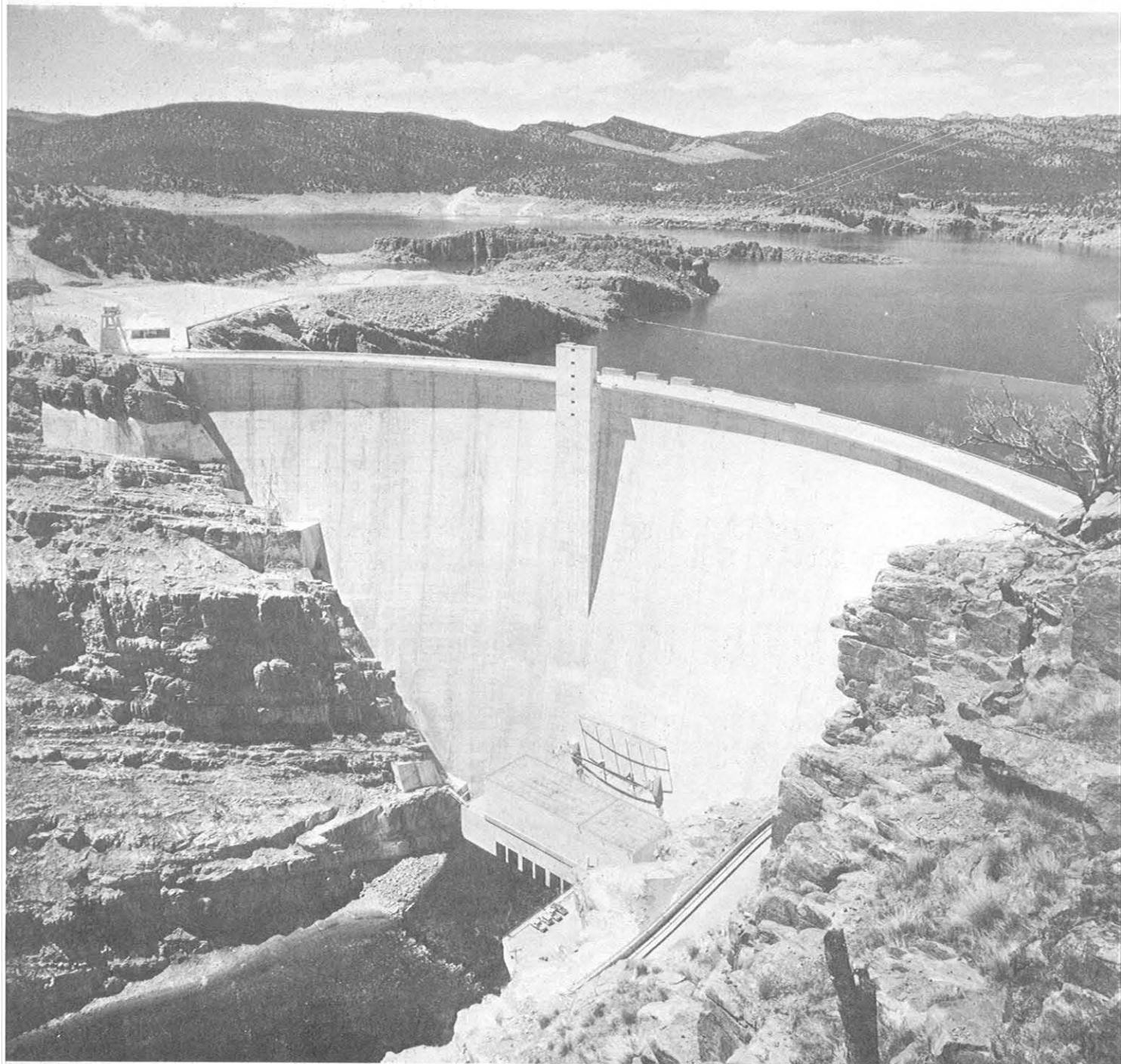


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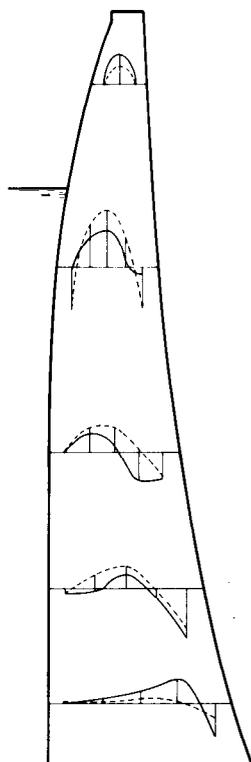
RESEARCH REPORT NO. 14

*United States Department of the
INTERIOR*

Bureau of Reclamation



Flaming Gorge Dam



Comparison of Analytical and Structural Behavior Results for Flaming Gorge Dam

Dams Branch
Division of Design
Office of Chief Engineer

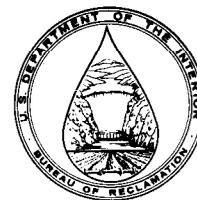


UNITED STATES DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, *Secretary*

BUREAU OF RECLAMATION

FLOYD E. DOMINY, *Commissioner*



In its assigned function as the Nation's principal natural resource agency, the Department of the Interior bears a special obligation to assure that our expendable resources are conserved, that renewable resources are managed to produce optimum yields, and that all resources contribute their full measure to the progress, prosperity, and security of America, now and in the future.

First Printing: 1968

UNITED STATES GOVERNMENT PRINTING OFFICE
WASHINGTON: 1968

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, or the Chief Engineer, Bureau of Reclamation, Attention 841, Denver Federal Center, Denver, Colo. 80225. Price 30 cents.

Preface

Engineers concerned with the safety of concrete arch dams should be reasonably certain that the structure will behave during operation as predicted by the analysis. For more than 30 years the Bureau of Reclamation has instrumented large concrete arch dams.

The two principal reasons for instrumentation are: (1) to obtain information which can be used to detect abnormal behavior of the structure, and (2) to obtain measurements which can be used to evaluate the effectiveness of the analysis method and the reliability of assumptions.

In line with the second reason, the purpose of the investigation reported in this publication is to demonstrate the efficacy of the trial-load method and the reliability of assumptions used for the design of Flaming Gorge Dam. Comparisons were made between measured and computed data. Changes in concrete stresses and deflections of the dam were compared for conditions at two periods of time.

The initial period, from October 9, 1963, to March 26, 1964, was used for the comparison of deflections and stresses due to seasonal temperature variation. Since reservoir and tailwater elevations did not change appreciably during this period, results show the effects of seasonal temperature variation alone. This permits an evaluation of the temperature assumptions used in the trial-load analysis, as well as the effects of temperature on movements and stresses in the dam.

The differences in structural behavior results for the second period, from March 26, 1964, to March 6, 1966, indicate the deflection and stress changes due

to reservoir water level fluctuations. The tailwater elevation remained constant during this period. Differences in temperature of the concrete between the two dates were small.

Because of the length of time covered by this study, the effects of concrete creep were introduced into the trial-load analysis by reducing the modulus of elasticity for the concrete. This study, which shows the effects of reservoir water level fluctuation on movement and stresses in the dam, gives an indication that the assumption made to include the effects of concrete creep is reasonably accurate.

Good agreement was obtained between the results from the trial-load analysis and those obtained from structural behavior measurements.

This report was prepared by Milton A. Kramer and Louis H. Roehm under the general direction of L. R. Scrivner and G. C. Rouse. These structural engineers are on the staff of the Chief Engineer, Bureau of Reclamation, Denver, Colo. Drawings were prepared by F. L. Dockhorn.

Included in this publication is an informative abstract and list of descriptors, or key words, and "identifiers." The abstract was prepared as part of the Bureau of Reclamation's program of indexing and retrieving the literature of water resources development. The descriptors were selected from the *Thesaurus of Descriptors*, which is the Bureau's standard for listing of key words.

Other recently published Water Resources Technical Publications are listed on the inside back cover of this report.

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Introduction

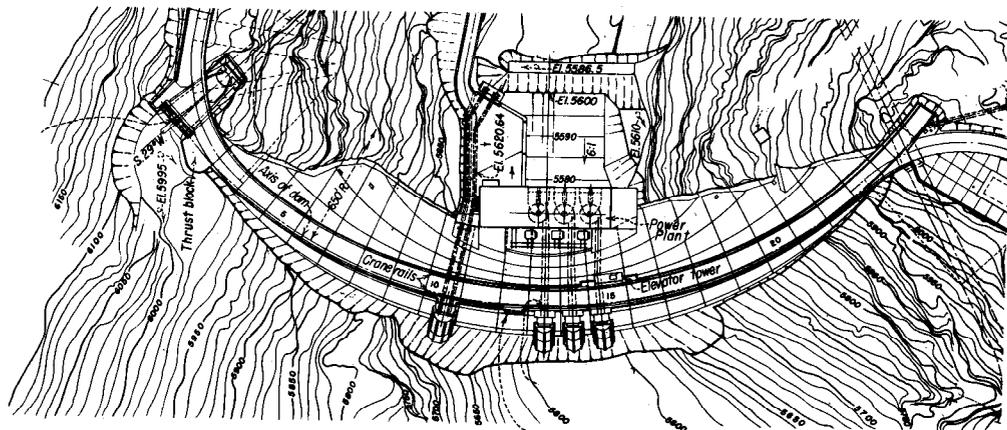
This report presents comparisons of results from trial-load analyses and structural behavior measurements for two loading conditions on Flaming Gorge Dam. Stresses and deflections from the analytical studies are compared with the results of measured data for each loading condition.

Flaming Gorge Dam is a concrete arch structure with an axis radius of 650 feet. The height of the dam above the lowest excavation for the foundation is 502 feet. The length of the crest is approximately 1,180 feet. A plan, elevation, and sections of Flaming Gorge Dam are shown on figure 1. The dam is on the Green River near Dutch John, Utah.

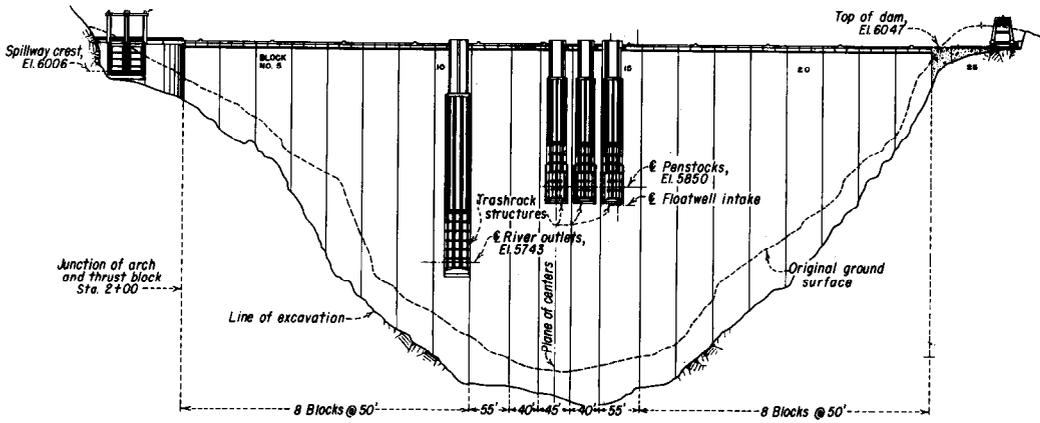
During the year, the dam is subjected to both daily and seasonal temperature variations. The period from October 9, 1963, to March 26, 1964, was selected for

the investigation of the effects of seasonal temperature change. The reservoir water surface and tailwater surface remained very nearly constant at elevations 5932 and 5600, respectively. This loading condition permits an investigation of temperature effects on the dam.

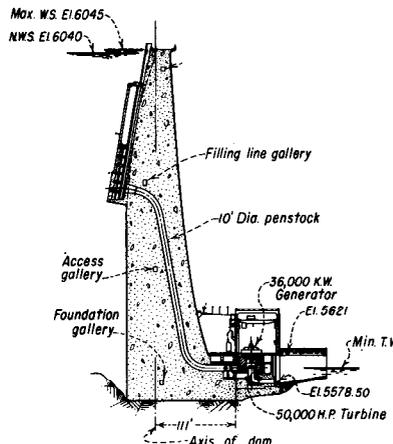
The period from March 26, 1964, to March 6, 1966, was selected to investigate the effect of a rise in reservoir water level from elevation 5932 to elevation 6000. Although the change in water surface elevation occurred during the early part of the 2-year period, the later date was selected to eliminate as nearly as possible the effects of temperature change of concrete from the study. The tailwater surface remained constant at elevation 5600 throughout this period.



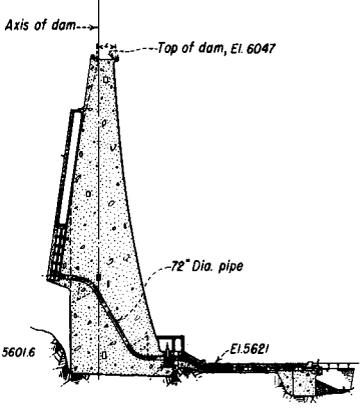
PLAN



UPSTREAM ELEVATION
(DEVELOPED ALONG AXIS OF DAM)



SECTION THRU POWER PLANT
(AT PLANE OF CENTERS)



SECTION THRU OUTLET WORKS



Figure 1.—Flaming Gorge Dam—Plan, elevation, and sections.

Data for Trial-Load Analyses

Data used in the trial-load analyses of Flaming Gorge Dam are as follows:

- a. Top of dam, elevation 6047.
- b. Base of dam, elevation 5555.
- c. Reservoir water surface assumed constant at elevation 5932 for the period of October 9, 1963, through March 26, 1964.
- d. Reservoir water surface raised to elevation 6000 during the early part of the 2-year period after March 26, 1964, and maintained at that elevation through March 6, 1966.
- e. Modulus of elasticity for short-time loading of concrete, 4.0×10^6 pounds per square inch.
- f. Modulus of elasticity for concrete under a sustained loading for the 2-year period March 26, 1964, to March 6, 1966, 3.0×10^6 pounds per square inch.
- g. Sustained modulus of elasticity for abutment rock on the left side, 2.0×10^6 pounds per square inch.
- h. Sustained modulus of elasticity for abutment rock on the right side and at the base of the dam, 1.0×10^6 pounds per square inch.
- i. Poisson's ratio for concrete, 0.20.
- j. Poisson's ratio for abutment rock, 0.04.
- k. Coefficient of thermal expansion for concrete, 5.0×10^{-6} per degree Fahrenheit.
- l. Unit weight of concrete, 150 pounds per cubic foot.
- m. Unit weight of water, 62.5 pounds per cubic foot.
- n. Tailwater surface remained constant at elevation 5600 throughout the period covered by these studies.
- o. Effects of silt, ice load, and earthquake are not included.
- p. Contraction joints grouted to elevation 6047. Two joints, one near each abutment, remain open above elevation 6000.
- q. Temperatures used in the analyses were recorded at strain meter and stress meter locations for each of the three dates selected.

Previous studies¹ indicate a lower modulus of elasticity for the abutment rock on the right side of the

dam. Bureau laboratory tests indicate an average value of about 1.5×10^6 pounds per square inch for all rock specimens tested. However, values for the modulus of elasticity in approximately the directions of resultant forces were not obtainable for many of the specimens on the right side of the dam and those available are, in general, lower than the values for the left side specimens. The values obtained near the base of the dam are also lower. Therefore, moduli of elasticity of 2.0×10^6 pounds per square inch for the left abutment rock and 1.0×10^6 pounds per square inch for the right abutment and base rock were assumed. Bureau laboratory results show that a modulus of elasticity of approximately 4.0×10^6 pounds per square inch might be expected for the concrete over a relatively short loading period such as exists between October 9, 1963 and March 26, 1964. However, tests of Flaming Gorge Dam concrete, for sustained loading over a 2-year period, table I, show a modulus of approximately 3.0×10^6 pounds per square inch. Thus, the change in deflections and stresses between March 26, 1964 and March 6, 1966, reflects not only a rise in the reservoir water level but also a change in the modulus of elasticity due to the effects of concrete creep for concrete under sustained loading.

Table I.—MODULUS OF ELASTICITY FOR CONCRETE UNDER SUSTAINED LOAD

[Laboratory tests of Flaming Gorge Dam concrete]

Age of concrete ¹ (days)	Loaded age (days)	Modulus of elasticity $\times 10^6$ psi
367	2	4.6
375	10	4.0
430	65	3.7
585	120	3.4
745	280	3.3
802	437	3.2
968	603	3.1
1,122	757	3.1

¹ Age of concrete at the time of initial loading was 1 year.

¹ Numbers designate literature cited in the "Bibliography" at the end of this report.

Trial-Load Analyses

The trial-load method of analysis² assumes the dam to be divided into a system of horizontal and vertical elements, each system occupying the entire volume of the dam and independent of the other. The loads applied to the dam are divided between these elements in such a way that geometrical continuity is attained throughout. Three displacements and three rotations may be satisfied in steps called adjustments. The radial deflections of the elements are brought into agreement by a radial adjustment. The tangential adjustment accounts for the tangential movements and may include vertical displacements and rotation about the radius. Rotations about the tangential and vertical axes are accounted for in the twist adjustment. The effects of vertical displacements and rotation about the radius are usually found to be small and were not included in these studies.

Tangential and rotational agreements are accomplished by introducing internal self-balancing tangential and twist loads at points common to the horizontal and vertical elements. The effects of foundation movement caused by the loaded dam are included.

The trial-load method is limited to a linear temperature variation from upstream to downstream face. Therefore, the measured temperatures, which may not vary linearly, must be represented by an equivalent linear temperature gradient. Stresses in these analyses are corrected for the variations of the recorded temperatures from the assumed gradient.

An electronic computer was used to perform the trial-load analyses of Flaming Gorge Dam for loading conditions which existed on each of the three dates selected.

Stresses and deflections were determined for seasonal temperature variations by using the temperature differences between October 9, 1963, and March 26, 1964. The results represent the effects of a temperature change from seasonal maximum to seasonal minimum.

Stresses and deflections for the rise in reservoir water level are changes from March 26, 1964, to March 6, 1966.

Instrumentation

To study the effects of loads, instruments of various types have been installed in concrete dams. Flaming Gorge Dam has been instrumented to provide structural behavior information.

Location of Instruments

Field measurements at Flaming Gorge were made using six types of structural behavior apparatus: strain meters,³ stress meters,³ joint meters,³ resistance thermometers,³ plumbines,⁴ and triangulation targets.⁴ Locations of this equipment are shown in figures 2 and 3.

The instruments embedded in Flaming Gorge Dam are: 912 strain meters, 61 stress meters, 116 joint meters, and 32 thermometers. Strain meter groups are embedded in 10 cantilever elements located in Blocks 3, 5, 7, 9, 10, 13, 16, 17, 19, and 22, respectively. "No-stress" strain meters used to measure autogeneous growth of the concrete are also located in the same 10 cantilever elements.

Thermometers were installed in a grid pattern in Block 13. The spacing is about 50 feet vertically by about 20 feet horizontally.

At elevation 5670, Block 13, 6 stress meters were embedded around strain meter Group 12, 2 meters each in Directions 1, 2, and 3, as shown in figure 4. At elevation 5880, 20 stress meters were embedded in the axial direction, 5 meters each in Blocks 7, 10, 16, and 19. At elevation 6000, 35 stress meters were embedded in the axial direction, 5 meters each in Blocks 3, 7, 10, 13, 16, 19, and 22.

Joint meters were embedded across contraction joints at all elevations where strain meters or stress meters are located. At elevation 5760 and below, 3 joint meters were installed across each joint. At elevations 5880 and 6000, 2 joint meters were installed across each joint.

Two systems for measuring deflections were provided. The first consists of three plumbines located in 12-inch-diameter wells extending from the top of the dam to near the foundation in Blocks 8, 14, and 18 (see figure 2).

The second system consists of a grid of 42 targets located on the downstream face of the dam. Triangu-

lation measurements were made on the targets from four piers. No triangulation measurements were made on October 9, 1963, and March 6, 1966; therefore, only deflection measurements obtained from plumbines are reported.

Reading of Instruments

Readings from strain meters, stress meters, joint meters, and thermometers were begun immediately following their embedment and were continued on an increasing time scale until readings were taken bi-weekly. Plumbline readings were taken weekly. During the period of this study, all instruments were read on a weekly or biweekly schedule.

At each scheduled reading, a test set¹ which is basically a Wheatstone bridge, is used to obtain values of resistance ratio, reverse ratio, and resistance sum for each strain meter, stress meter, and joint meter. Resistance thermometers require only a resistance sum reading.

Plumbline deflections were obtained using a 20-power microscope. A micrometer slide is attached to the microscope. Four readings are taken for each mounting position, two each for the target and for the plumbline. Graduation of the lead screw knob provides for micrometer readings to the nearest 0.0001 inch.

Analysis of Data

Before a comparison between measured and analytical results can be made, the measured data must be reduced to values of temperature, stress, and deflection. The methods and computer programs used to reduce the instrument data to temperature, stress, and deflection are completely described.^{1,5,6,7} These programs can be used to reduce these types of data for any structural behavior installation.

The calculation of stress from strain in concrete involves the concept of the "creep surface." Concrete is a material which exhibits changing elastic properties with increasing age and deformation of the concrete under constant load. The Bureau of Reclamation laboratory has been making creep tests on concrete for over 20 years.^{8,9,10,11} To describe the changing elastic properties of concrete, an equation was developed using

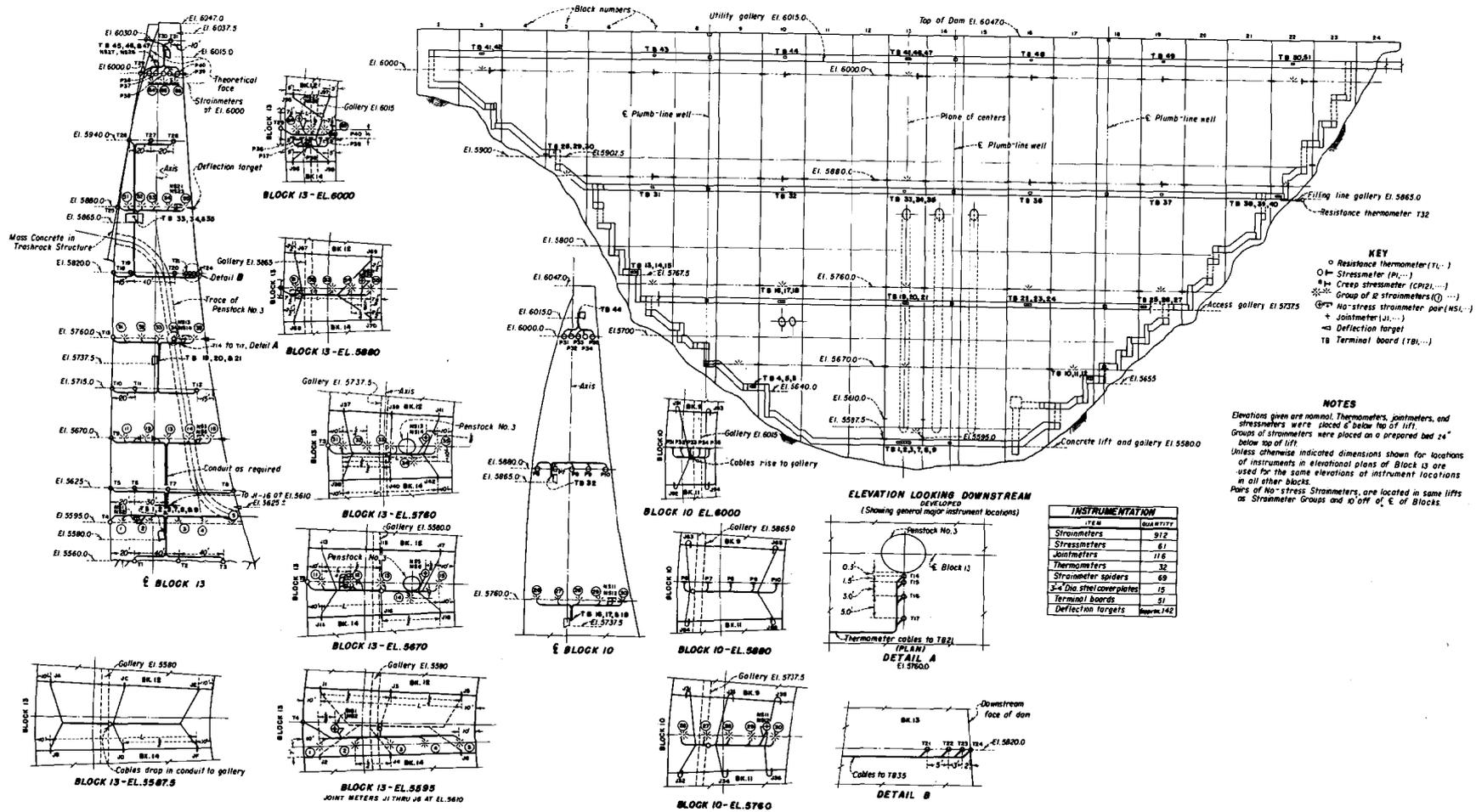


Figure 2.—Layout of structural behavior instruments—Blocks 10 and 13.

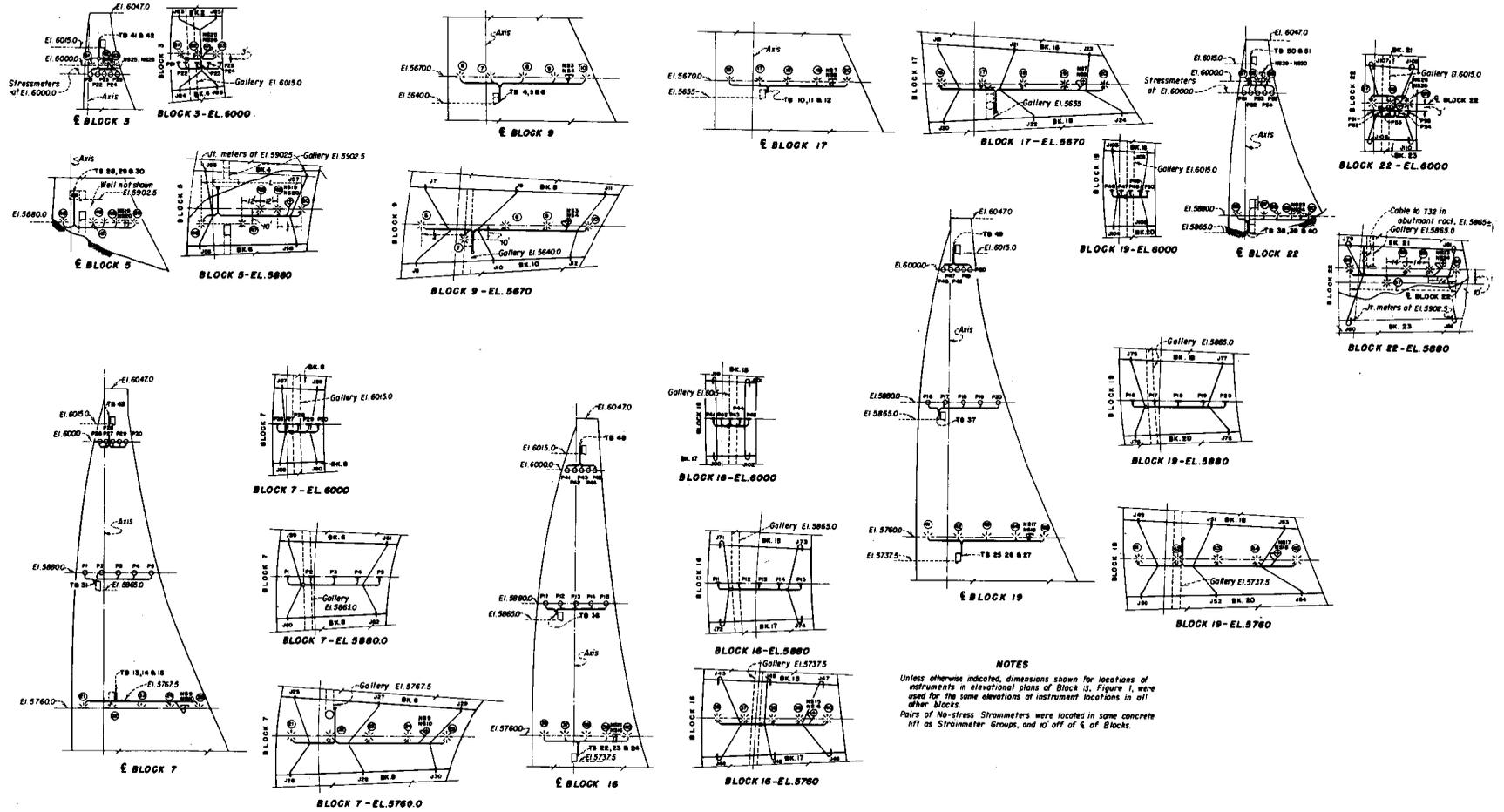


Figure 3.—Layout of structural behavior instruments—Blocks 3, 5, 7, 9, 16, 17, 19, and 22.

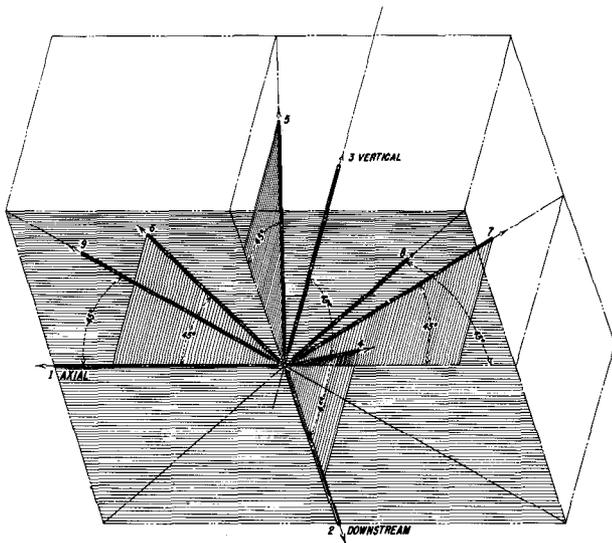


Figure 4.—Orientation of strain meter group.

data obtained from Bureau of Reclamation laboratory tests. A detailed description of the equation is given in Reference 5.

The following table shows the modulus of elasticity and some of the creep data obtained from laboratory tests on Flaming Gorge concrete. Creep strain is as-

sumed to be directly proportional to stress. The maximum stress applied to the test cylinders was 600 psi.

Table II.—ELASTIC AND CREEP DATA—
FLAMING GORGE CONCRETE

Concrete age at loading time (days)	Modulus of elasticity $\times 10^6$ psi at loading time	Creep strain $\times 10^{-6}$ in./in./psi loaded for 200 days
7	2.8	0.31
28	3.5	0.15
90	3.9	0.09
367	4.6	0.07
730	4.6	(1)

¹ No creep tests for this age of concrete.

A computer program was written to compute the best fit surface using the elastic and creep data from laboratory tests.^{1,5} The equation expresses the laboratory data in a form which can be used by the computer to calculate stress from strain meter data.

Bureau laboratory tests indicated a Poisson's ratio of approximately 0.20 for Flaming Gorge concrete.

Comparison of Analytical and Measured Data

Seasonal Temperature Change

Radial deflection changes due to the seasonal temperature variation are shown graphically in figure 5. Deflections from the trial-load study and measured deflections are shown at the plumbline locations.

Agreement between radial deflections for the trial-load study and measured deflections is good. The maximum difference between the radial deflections from the analytical study and measured radial deflections is approximately 0.11 inch. The comparison indicates the moduli of elasticity for abutment rock and concrete are correct and the linear temperature assumption used in the trial-load study does not appreciably affect the radial deflections.

Table III lists the measured and computed radial deflections at the top of the dam, elevation 6047 and elevation 6000. The maximum radial deflection is 0.88 inch for the measured data and 0.91 inch for the trial-load study.

Table III. — SEASONAL TEMPERATURE CHANGE—COMPARISON OF TRIAL-LOAD ANALYSIS RADIAL DEFLECTIONS AND MEASURED RADIAL DEFLECTIONS

Block	Elevation	Radial deflections (inches)	
		Trial-load	Measured
8	6047	0.60	0.64
14	6047	0.91	0.88
18	6047	0.68	0.69
8	6000	0.49	¹ 0.62
14	6000	0.76	¹ 0.83
18	6000	0.55	¹ 0.60

¹ Measured deflections are at elevation 6015.

Measured tangential movement changes are toward the left abutment. The trial-load study indicates movement toward the left abutment in Block 8 and toward the right abutment in Block 18. Although the tangential movements are small, the differences between ana-

lytical results and measured data shown in figure 5 indicate a movement of the abutments toward the left in the lower part of the dam. This may have been caused by a movement of foundation jointing as a temperature drop caused the dam to deflect downstream for the first time. Later measurements show tangential movements consistent with trial-load results.

Horizontal and vertical stress changes are shown in figures 6, 7, and 8. Stress distributions from the structural behavior measurements are represented by solid lines and those from the analytical study are shown as dashed lines. Stresses from the trial-load study were corrected for the deviations of measured temperatures from the assumed linear temperature gradient. A modulus of elasticity for concrete of 4.0×10^6 pounds per square inch and an assumed 100-percent restraint were used for this correction. A representative linear stress distribution for the analytical study is shown with the corrected stresses at elevation 5880 on Block 19 in figure 6. The seasonal temperature changes, along with the assumed linear temperature distributions, are shown adjacent to the meter locations.

Horizontal arch stresses are shown in figures 6 and 7 at meter locations along the horizontal arch elements. The comparison between measured arch stresses and the trial-load analysis stresses is good. At elevation 5670 near the downstream face, the measured data indicate stress changes of 340 psi, 310 psi, and 280 psi. At the same locations, the trial-load analysis indicated stress changes of 340 psi, 375 psi, and 305 psi. The maximum measured arch stress change at elevation 5760 was 320 psi in Blocks 13 and 16 near the downstream face. The trial-load analysis indicated stress changes of 340 psi and 350 psi, respectively. At elevation 5880, the measured data indicated stress changes of 230 psi increase to 300 psi decrease. The trial-load analysis indicated stress changes of 275 psi increase to 300 psi decrease at elevation 5880.

As shown in figure 8, the comparison between many of the measured vertical stresses and similar trial-load analysis stresses is good. At elevation 5670 near the downstream face, the measured data shows stress

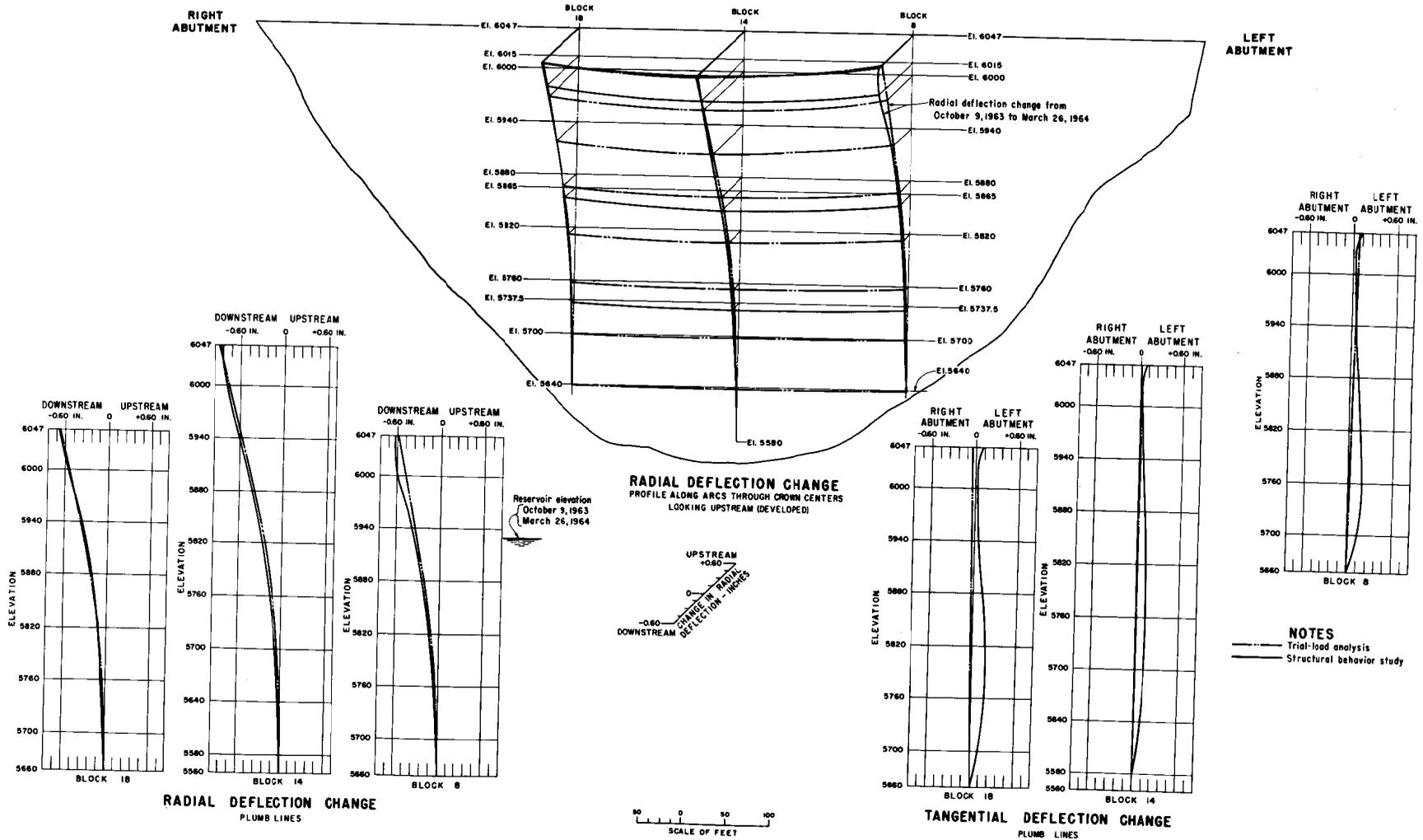


Figure 5.—Deflection change at plumb lines, October 9, 1963, to March 26, 1964.

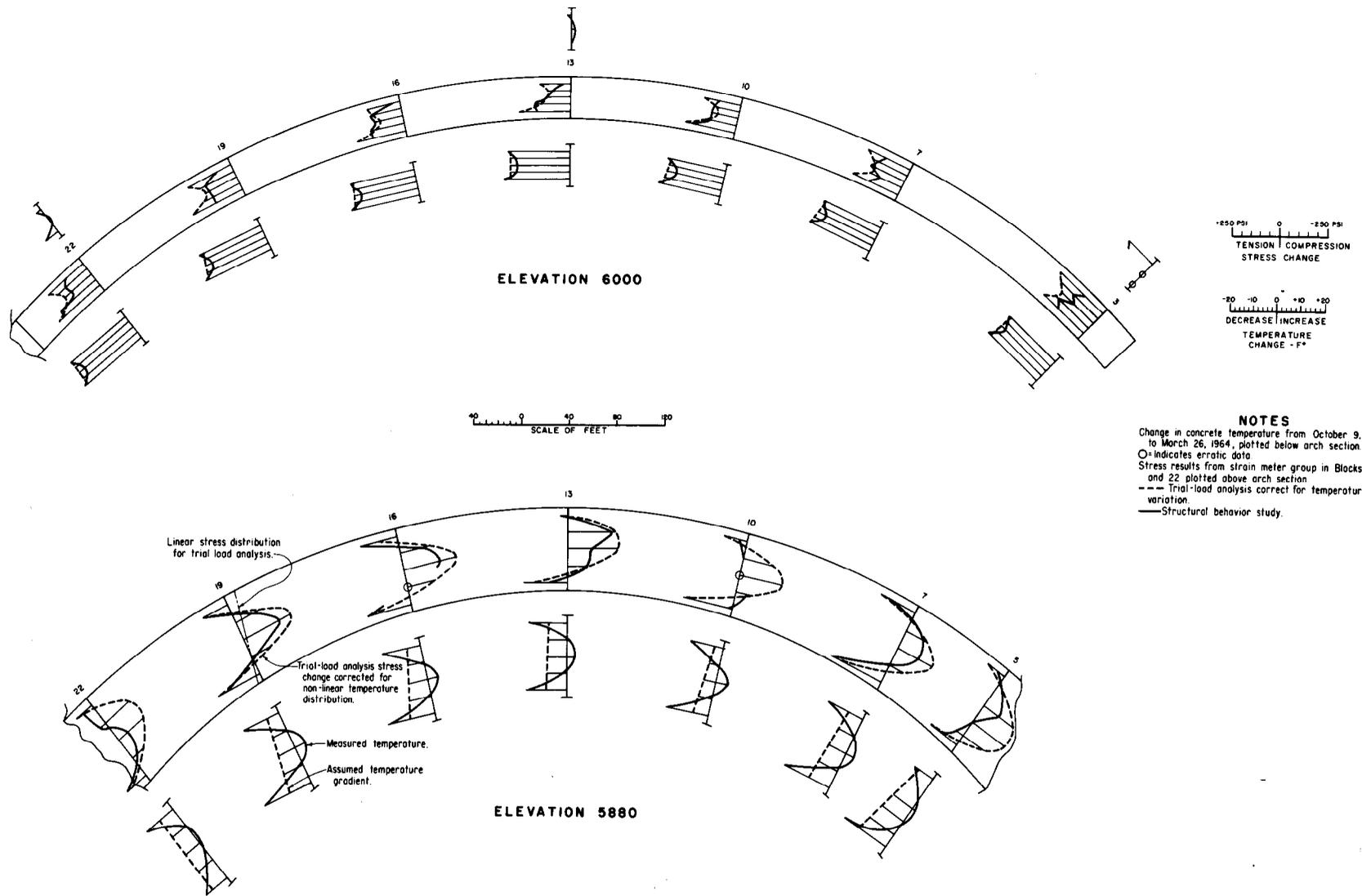


Figure 6.—Arch stress change and concrete temperature change—Elevations 5880 and 6000—October 9, 1963, to March 26, 1964.

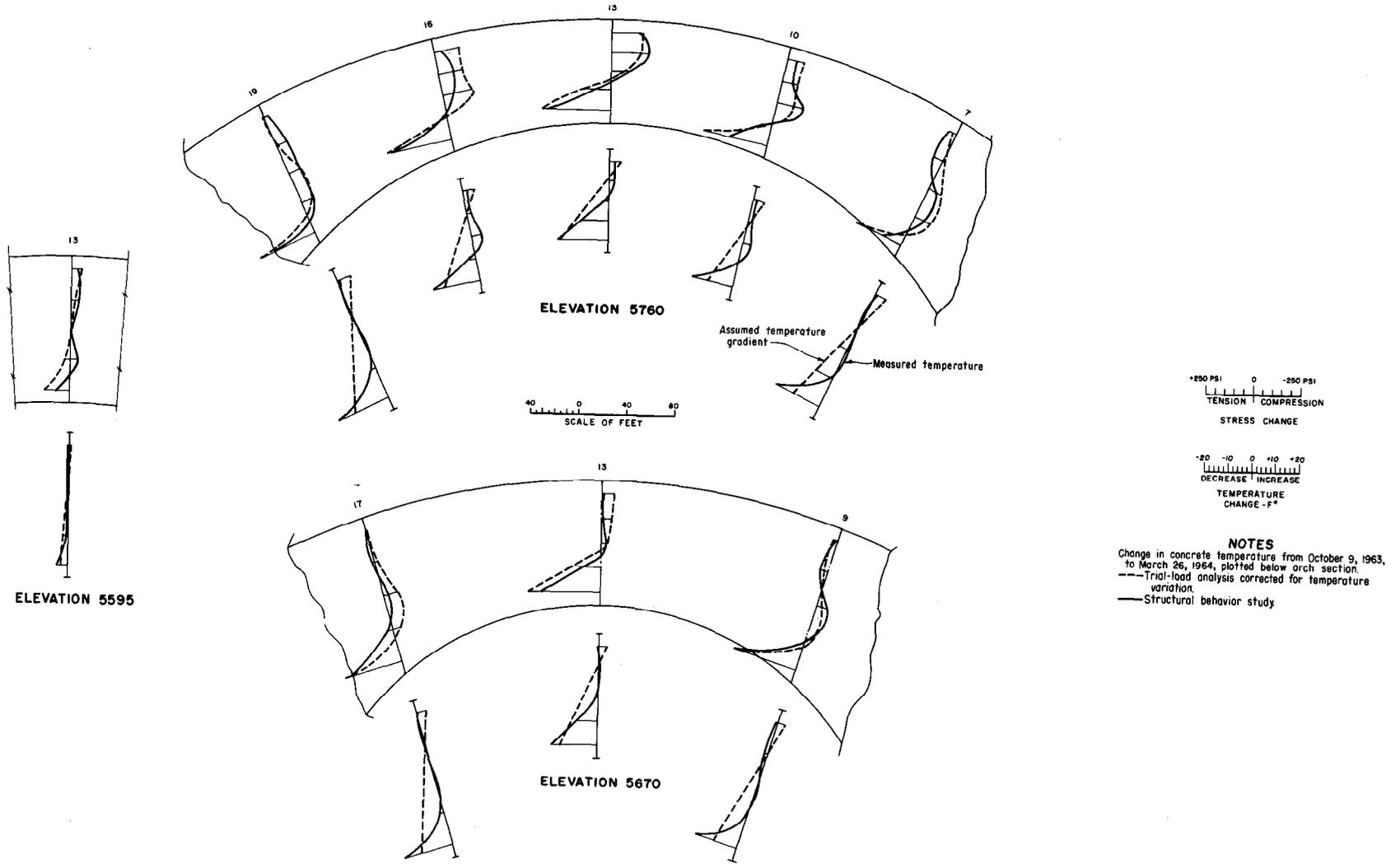


Figure 7.—Arch stress change and concrete temperature change—Elevations 5595, 5670, and 5760—October 9, 1963, to March 26, 1964.

changes of 190 psi, 200 psi, and 230 psi, at Blocks 9, 13, and 17, respectively. The trial-load analysis indicates stress changes of 190 psi, 175 psi, and 220 psi at the same locations. Stress changes indicated by the analytical study and the measured data are not in good agreement in some instances, particularly in the vertical elements.

The assumption of 100-percent restraint for the temperature correction of the vertical stresses from the trial-load analysis appears to be high for the points located in the interior of the dam. As may be noted in the figures, some of the meters were indicating erratic data.

Reservoir Water Level Fluctuation

Radial deflection changes for a variation in reservoir water level are shown in figure 9. Deflections from the trial-load study and measured deflections are compared at the plumblines locations.

Agreement between deflections for analytical results and measured data is very close. The maximum difference between computed and measured radial deflections is 0.07 inch. The comparison indicates the moduli of elasticity for concrete and abutment rock used in this analysis are approximately correct.

Table IV shows the measured and computed radial deflections at elevations 6047 and 6000. The maximum measured radial deflection is 0.74 inch and the maximum computed radial deflection is 0.69 inch.

The comparisons of tangential deflection changes are shown at plumblines locations in figure 9. Unlike the

Table IV.—RESERVOIR WATER LEVEL FLUCTUATIONS—COMPARISON OF TRIAL-LOAD ANALYSIS RADIAL DEFLECTIONS AND MEASURED RADIAL DEFLECTIONS

Block	Elevation	Radial deflections (inches)	
		Trial-load	Measured
8	6047	0.34	0.38
14	6047	0.69	0.74
18	6047	0.44	0.51
8	6000	0.31	¹ 0.37
14	6000	0.65	¹ 0.71
18	6000	0.40	¹ 0.48

¹ Measured deflections are at elevation 6015.

previous comparison of tangential deflections, the analytical results and measured data are very close. The maximum difference between the tangential deflections for the trial-load study and measured deflections is 0.064 inch.

Horizontal and vertical stress changes are shown in figures 10, 11, and 12. As for the previously discussed study, the stresses from the trial-load analysis were corrected for the variations of measured temperatures from the linear temperature gradients, assuming 100-percent restraint. A modulus of elasticity for concrete of 4.0×10^6 pounds per square inch was used because of the relatively short period over which temperature changes occur. The changes of measured temperatures and assumed linear temperature distributions are shown adjacent to the meter locations.

Horizontal arch stresses are shown at meter locations on the horizontal arch elements in figures 10 and 11.

The comparison between measured and computed arch stresses is good. At elevation 5670 near the downstream face, the measured data indicate stress changes of 80 psi and 130 psi at Blocks 17 and 9 respectively. The trial-load analysis indicates stress changes of 41 psi and 100 psi at the same locations. At elevation 5760, the measured arch stress changes vary from 260 psi increase to 20 psi decrease. The trial-load analysis indicated stress changes of 143 psi increase to 6 psi increase. At elevation 5880, measured arch stress changes vary from 290 psi to 20 psi. The trial-load analysis indicated stress changes of 245 psi to 69 psi.

Vertical cantilever stress changes are shown at the locations of meters on the vertical cantilever elements in figure 12. The comparison between analytical results and measured data is good. At elevation 5670 near the downstream face, the measured data show stress changes of 110 psi at Blocks 9 and 17. Trial-load results indicate stress changes of 94 psi at Block 9 and 65 psi at Block 17.

In general, the agreement between stress changes from the trial-load study and the measured data is not as close for this loading condition as it was for the seasonal temperature change. However, the longer period covered by this loading condition may allow the effect of concrete creep on stresses existing prior to October 9, 1963, to influence the stress changes indicated by the measured data. This effect was not included in the trial-load analysis.

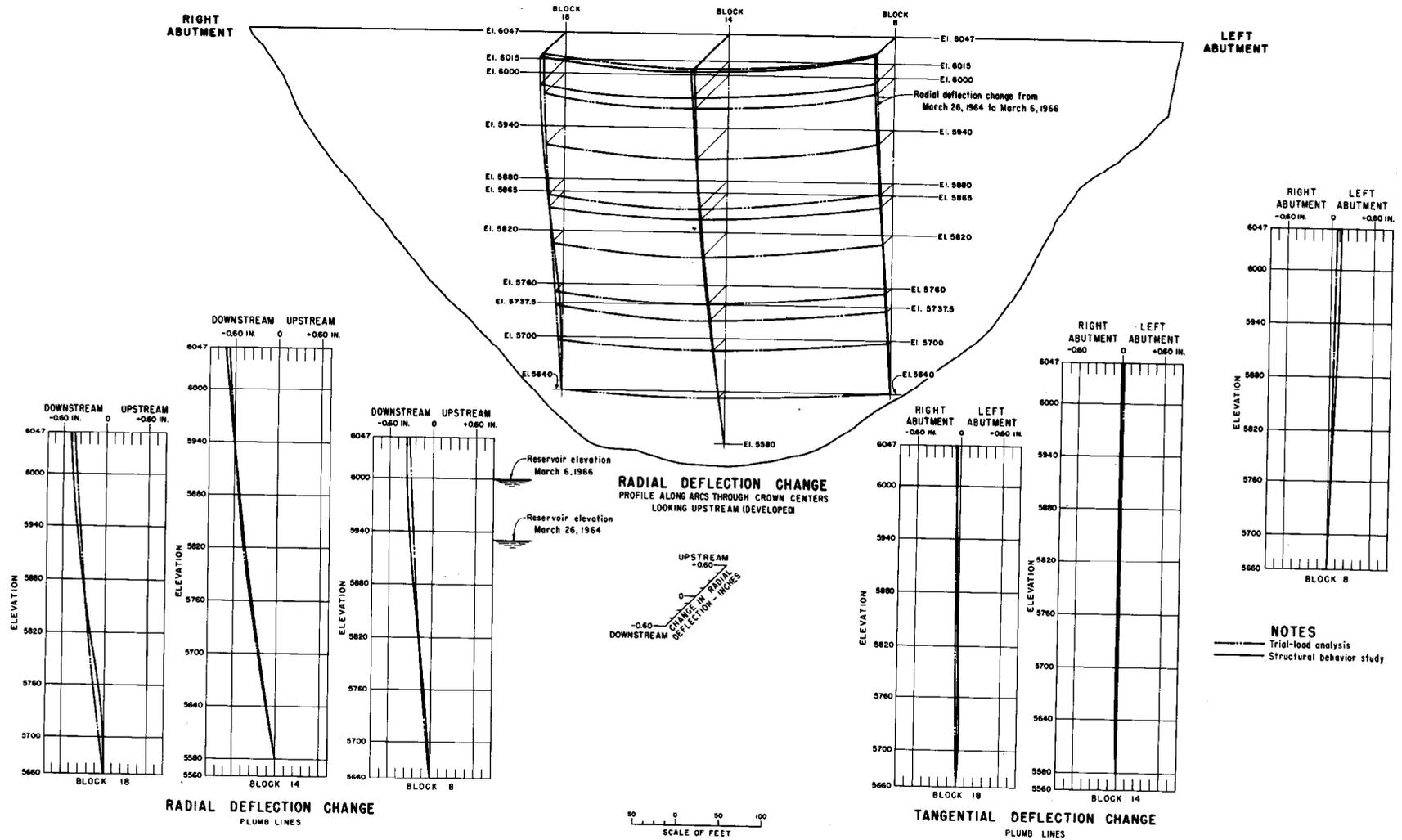


Figure 9.—Deflection change at plumb lines—March 26, 1964, to March 6, 1966.

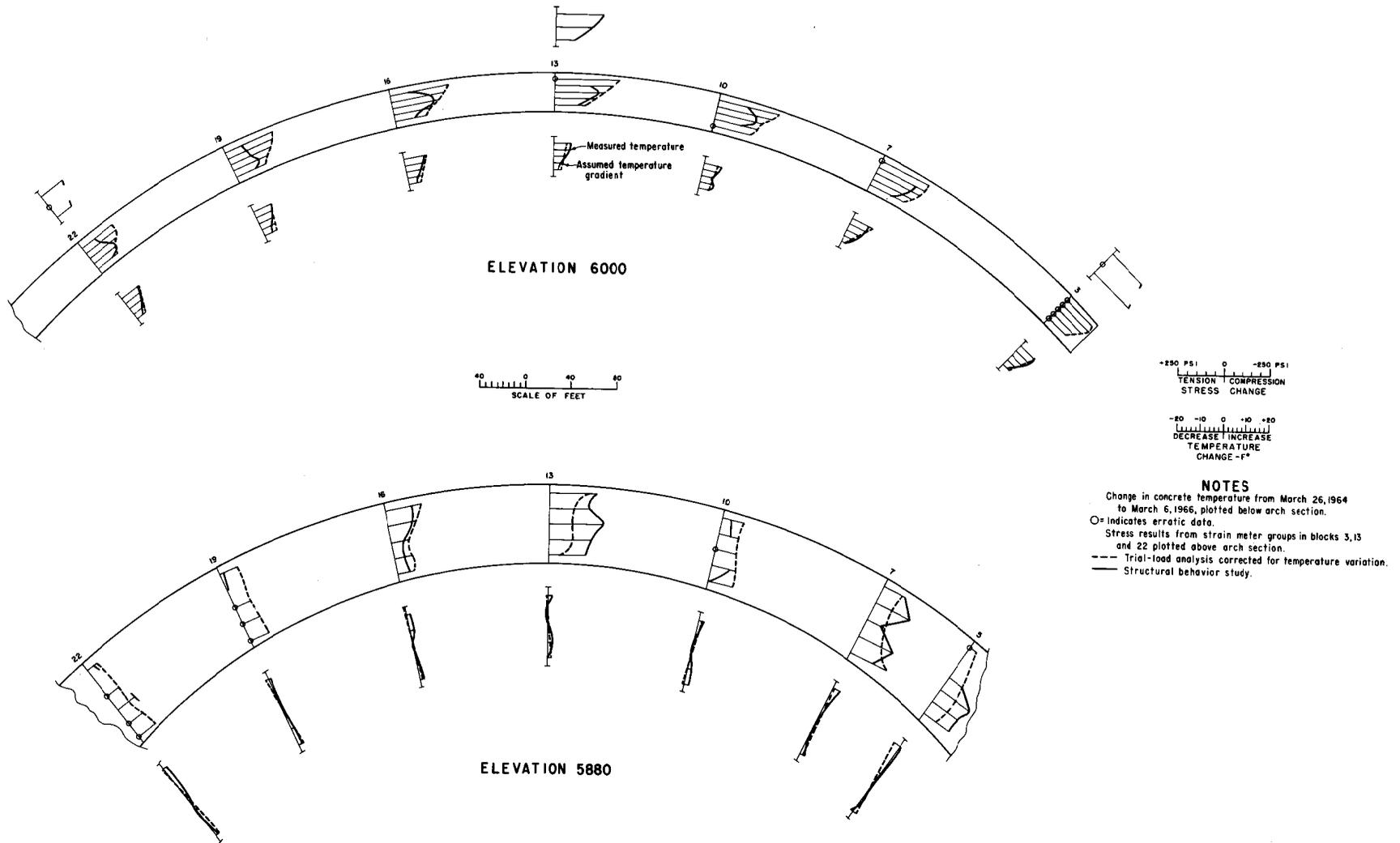


Figure 10.—Arch stress change and concrete temperature change—Elevations 5880 and 6000—March 26, 1964, to March 6, 1966.

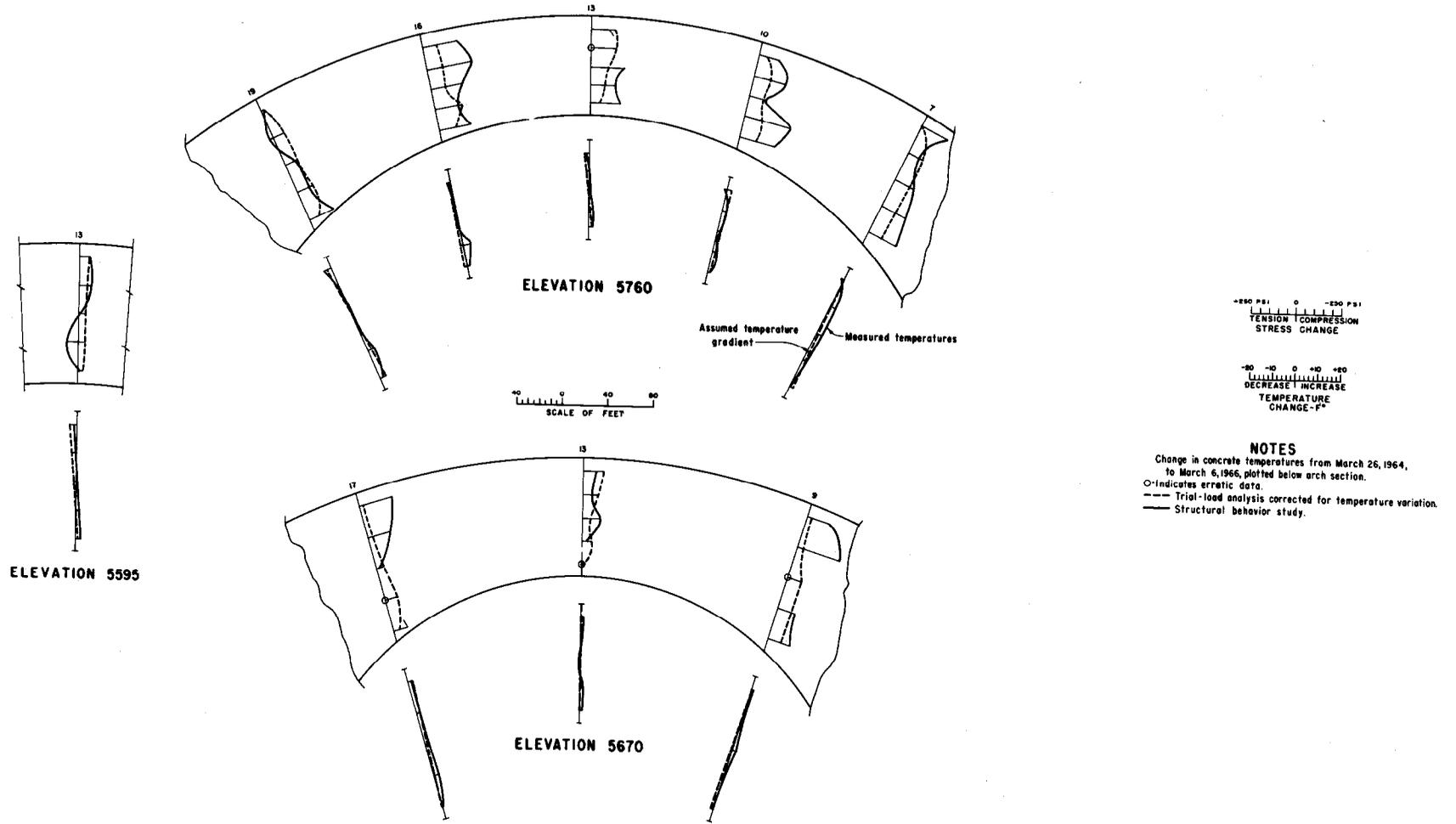


Figure 11.—Arch stress change and concrete temperature change—Elevations 5595, 5670, and 5760—March 26, 1964, to March 6, 1966.

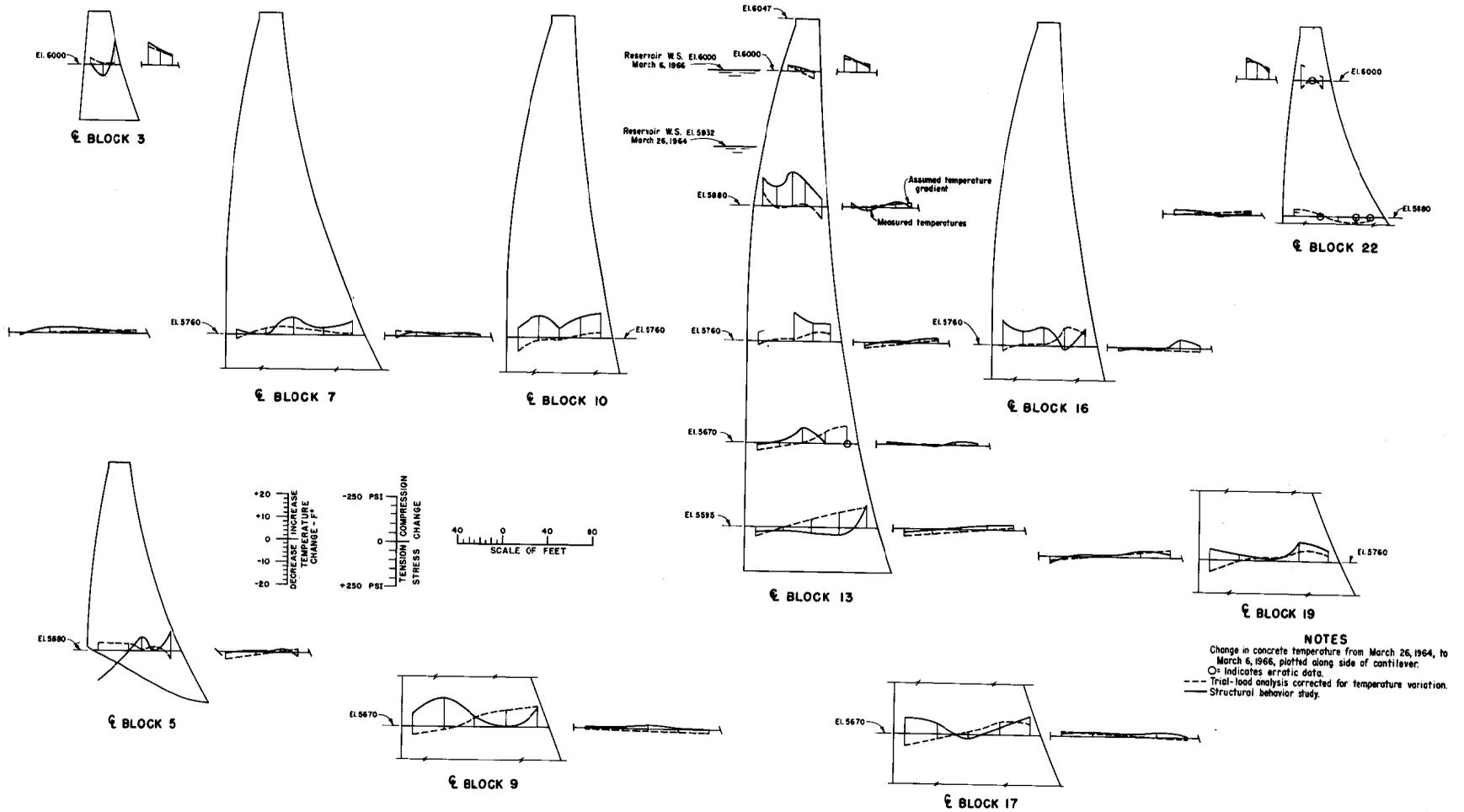


Figure 12.—Vertical stress change and concrete temperature change—March 26, 1964, to March 6, 1966.

Conclusions

The following conclusions were reached as a result of the comparison of structural behavior data and the trial-load analyses for the two loading conditions:

1. The linear temperature variation assumed for the trial-load analyses gives excellent deflection agreement. The resulting linear stress distributions from the trial-load analyses must be corrected for the differences between linear temperature distributions and measured temperatures. The comparison indicates that the assumption of 100-percent restraint was reasonable for horizontal stresses but high for the correction of vertical stresses.

2. The excellent agreement between the trial-load radial deflections and measured radial deflections for both loading conditions indicates the ratio of the assumed moduli of elasticity for abutment rock to the modulus of elasticity for concrete was correct. The radial deflection agreement for the 2-year period indi-

cates the sustained modulus of elasticity for concrete including the effect of concrete creep is correct.

3. Measured tangential deflections indicate greater movements than the trial-load analysis for October 9, 1963, to March 26, 1964. Tangential deflection agreement for the change between March 26, 1964, and March 6, 1966, is very good. Between October 9, 1963, and March 26, 1964, the dam deflected downstream for the first time. These results indicate inelastic behavior of the abutment rock during this period.

4. As shown in figures 5 and 9, seasonal temperature changes produce slightly greater deflections of Flaming Gorge Dam than the change of reservoir water surface from elevation 5932 to elevation 6000. The trial-load studies show 0.91 inch and 0.69 inch, respectively. Measured results show 0.88 inch and 0.74 inch.

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Abstract

Efficacy of the trial-load method and reliability of assumptions used in the design and analysis of concrete arch dams can best be demonstrated by comparison of analytical results with deflections and stresses from structural behavior measurements for an actual dam. Instruments that indicate length change, temperature, and deflection were installed in Flaming Gorge Dam. Readings from these instruments were recorded at scheduled intervals. An electronic computer was used to reduce the data to stresses, temperatures, and deflections. Stress and deflection changes were determined for two incremental loadings. Changes from October 9, 1963 to March 26, 1964, show the effects of seasonal temperature variation. Reservoir water and tailwater levels remained essentially constant during this period. The changes from March 26, 1964 to March 6, 1966, are the effects of a rise in reservoir

water level. Average concrete temperatures were approximately the same for both dates and the tailwater level remained constant over the entire period. Using an electronic computer, trial-load analyses were made for the same incremental loadings. Comparisons of stress changes and deflection changes for each loading increment are presented. Agreement between analytical studies by the trial-load method and structural behavior results is very close.

DESCRIPTORS—*arch dams/ *concrete dams/ stress analysis/ deflection/ dam design/ instrumentation/ strain measurement/ computers/ measuring instruments/ thermal stress/ data collection systems/ *structural behavior/ plumblines/ temperature/ creep/ elasticity modulus.

IDENTIFIERS—Flaming Gorge Dam, Utah/ Utah/ trial-load method.

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