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CONTRACT REPORT K-[illegible]

GENERAL PURPOSE COMPUTER-AIDED ANALYSIS AND DESIGN OF TAINTER GATES

Volume II

PROCEDURAL MANUAL

by

[illegible]

[redacted]

[illegible]

Final Report

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Prepared for U. S. Army Engineer Division, Lower Mississippi Valley
P. O. Box 80, Vicksburg, Miss. 39180

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U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

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A step-by-step procedure is presented for analyzing and designing tainter gate hydraulic structures by a general purpose, structural analysis and design computer system. The ICES STRUDL II computer system is selected for use since it is the only general purpose, structural computer program that has all the necessary characteristics to perform the analysis and design. The method considers the effects of the hoisting cables, side seal friction, trunnion pin friction, and sidesway constraint limit. The STRUDL approach described herein
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20. ABSTRACT (Continued).

is arranged for maximum utility of the approach in a design office environment. Details of the theoretical formulation are presented in the companion report, Contract Report K-76-1, Volume I, "General Purpose Computer-Aided Analysis and Design of Tainter Gates; Theoretical Manual." The use of the FASTDRAW/2 interactive graphics system is also described in step-by-step detail. FASTDRAW/2 proves to be useful for displaying three-dimensional views of the tainter gate structure geometry for final check purposes but is not as useful for tainter gate geometry creation.

PREFACE

This report is the result of work performed under Contract No. DACW39-76-M-0869, dated September 3, 1975, and No. DACW39-76-M-2230, dated December 9, 1975, between U. S. Army Engineer Waterways Experiment Station (WES) and the author, Dr. Leroy Z. Emkin, Consulting Engineer, for development of a procedure to use Structural Design Language (STRUDL), a subsystem of the Integrated Civil Engineering System (ICES), for analysis and design of 3-girder tainter gates. The task was directed by the Automatic Data Processing Center (ADPC), Computer Analysis Branch (CAB), WES, as part of a project to furnish assistance to the sponsor, the Computer-Aided Structural Design (CASD) Committee of the U. S. Army Engineer Division, Lower Mississippi Valley (LMVD). The report is in two volumes, a theoretical and a procedural manual.

The author would like to thank Dr. N. Radhakrishnan, Special Technical Assistant to the Chief, ADPC, WES, who managed the project, Mr. W. A. Price III, Computer-Aided Structural Design Project Engineer, WES, Mr. D. R. Dressler, Chairman of the CASD Committee and Sponsor Representative, LMVD, and Mr. J. J. Smith, Structural Engineer, U. S. Army Engineer District, St. Louis, Missouri, for their expert advice and technical assistance during this study.

The task was under the general supervision of J. B. Cheek, Chief, CAB, and D. L. Neumann, Chief, ADPC. COL G. H. Hilt, CE, was Director of WES, and F. R. Brown was Technical Director.

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1. INTRODUCTION

A comprehensive formulation for the analysis and design of tainter gates by a general purpose structural analysis and design computer program (ICES STRUDL II (2,3,4)[1]) is presented in Reference (1). However, the STRUDL II procedures used were only suitable for the formulation process, and not well suited for use in a design office environment.

Consequently, it is the intent of this report to describe a recommended procedure for the STRUDL II analysis and design of tainter gates for use in the design office. In order to illustrate the approach, a specific tainter gate was considered in this study. It was the Clarence Cannon Re-Regulation Dam and Spillway Tainter Gate (6,7).

Only results of the formulation are presented herein. The reader is referred to Reference (1) for the theoretical details.

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[1] Numbers in parentheses refer to references in the REFERENCES Section.

2. THE ANALYSIS MODEL

2.1 Introduction

A typical tainter gate, as sketched in Fig. 1, is characterized by a skin plate to retain water, and vertical stiffening ribs, horizontal girders, strut arms, and a trunion girder, to support and stabilize the skin plate. In addition, hoisting cables are used to lift the gate on occasion to permit the flow of water. A complete and detailed description of the specific tainter gate considered in this study is shown in References (6) and (7).

2.2 Geometry and Topology Conditions

The geometry and topology of the Clarence Cannon Tainter Gate used for the recommended STRUDL II solution is shown in Figs. 2, 3, and 4.

The skin plate is modeled using plate bending-and-stretching finite elements. McAuto's PBS2 proprietary finite element (4) was selected as having good characteristics for such a model. The mesh size plays an important role in the accuracy of the analysis results. A very fine mesh would be necessary to accurately compute the stress distribution in the skin plate. However, such a fine mesh would lead to an excessively costly analysis due to the large number of elements and joints that would have to be processed. It was felt that an accurate calculation of the skin plate stresses was not necessary at first. Rather, it was decided to use a coarser mesh size which would at least retain a proper representation of the skin plate's stiffness effects on the rest of the tainter gate structure. After the analysis, another analysis could be performed, using a finer mesh size, in those regions where high stresses are indicated, or calculations similar to current

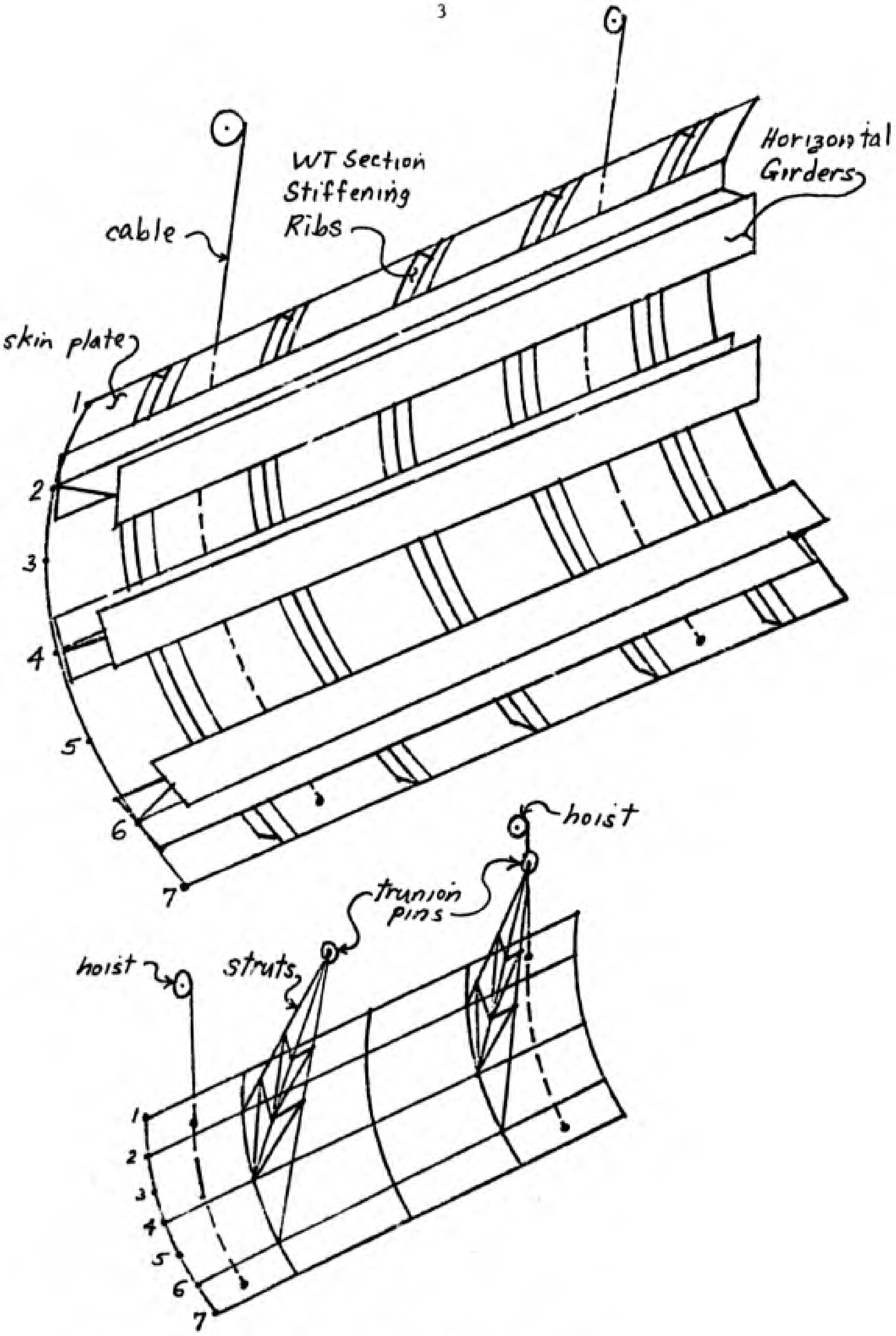


Figure 1. Typical Tainter Gate Configuration

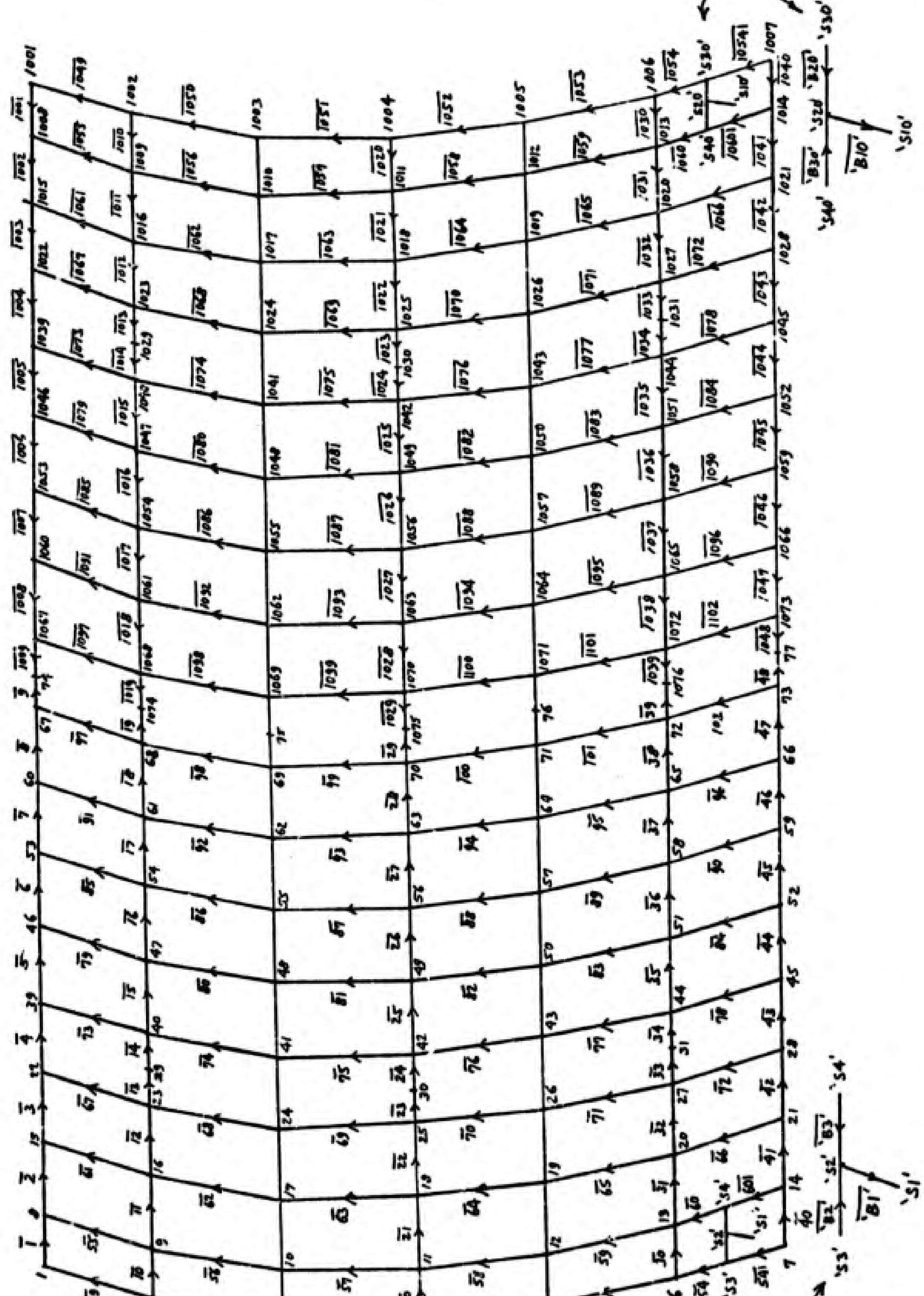


Figure 2. Member Incidences and Joints in Skin Plate of Clarence Cannon Tainter Gate STRUDL II Model

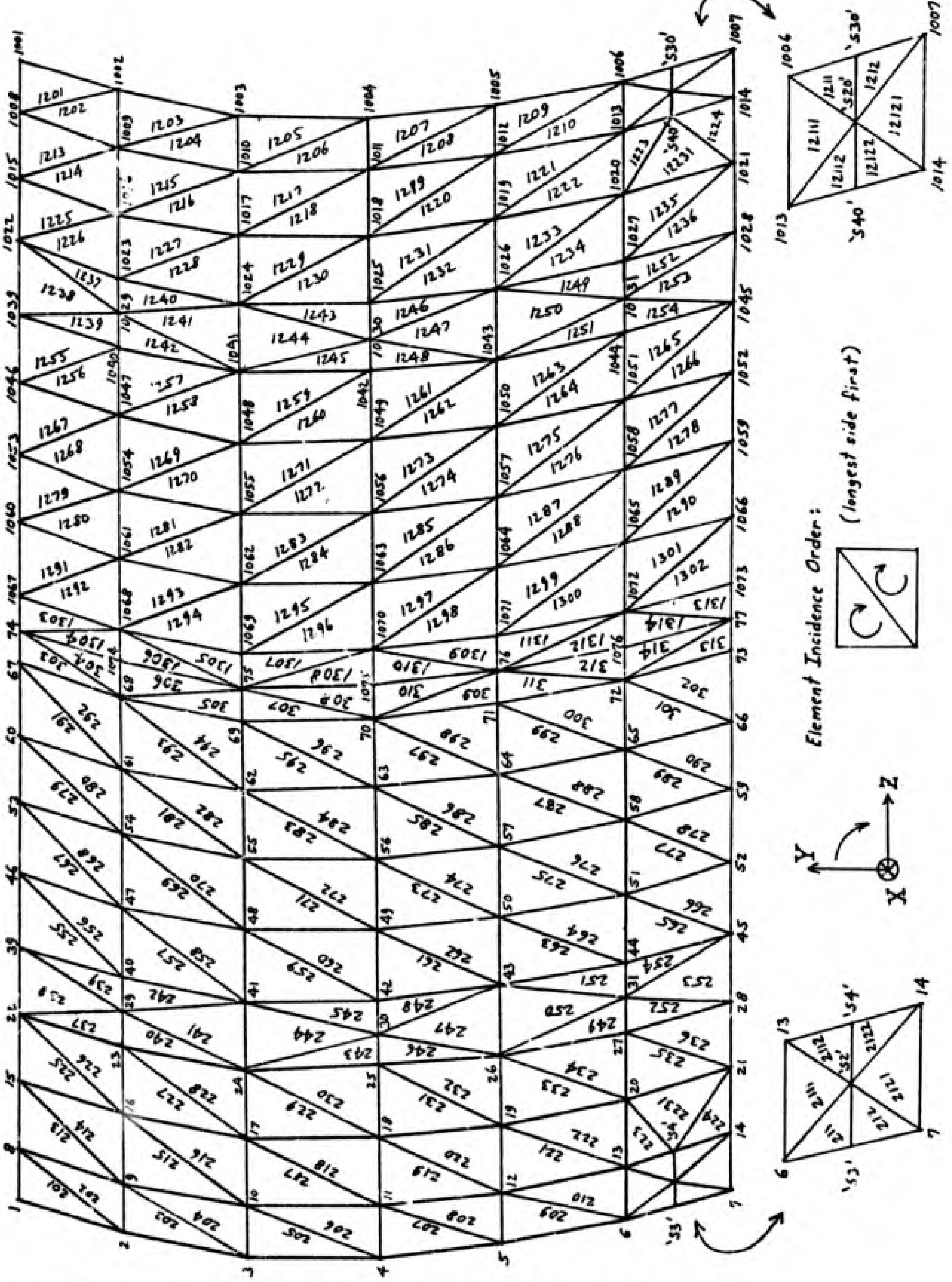


Figure 3. Element Incidences and Joints in Skin Plate of Clarence Cannon Tainter Gate STRUDL II Model

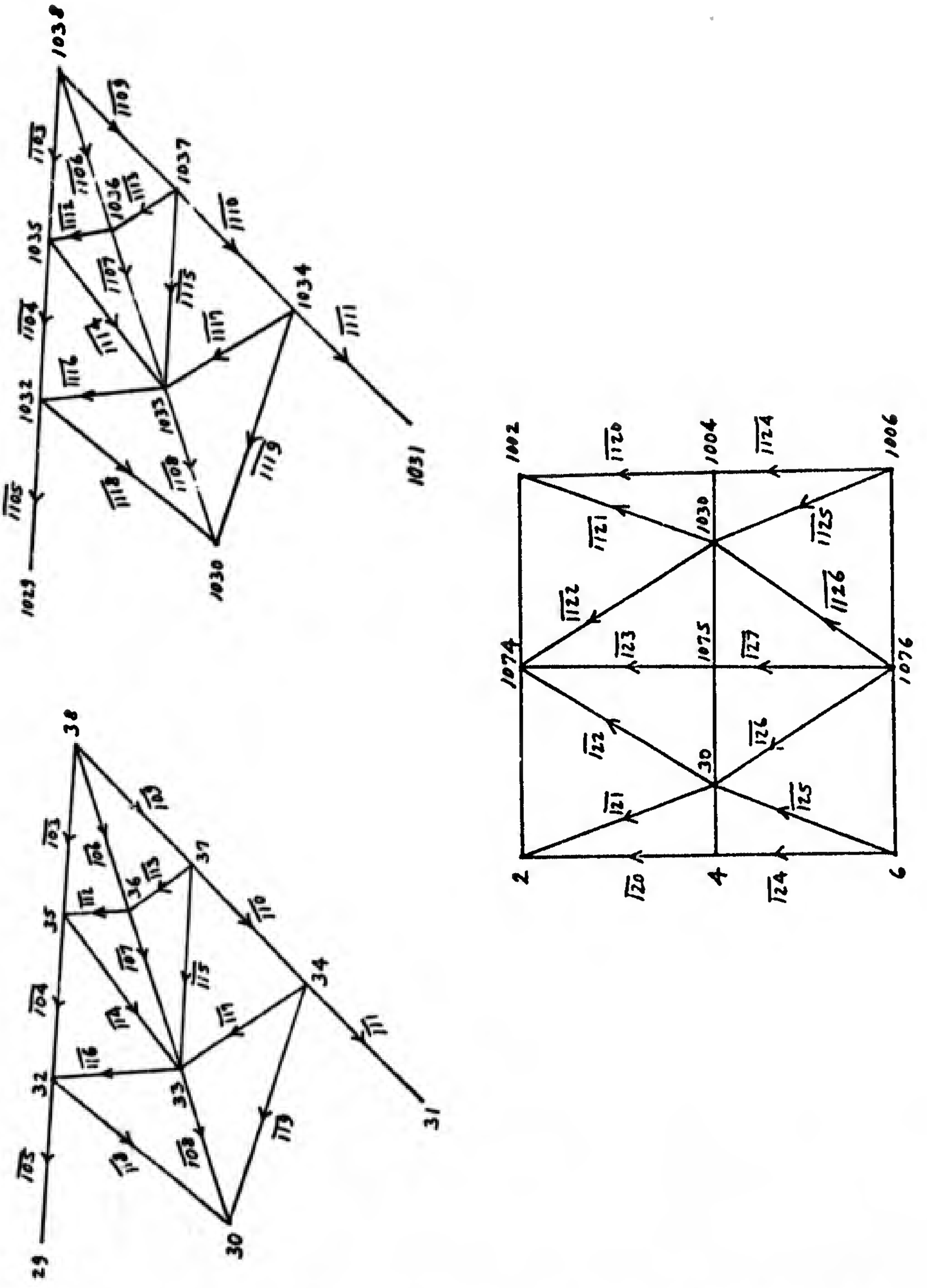


Figure 4. Member Incidences and Joints in Struts and Skin Plate Bracing System for Clarence Cannon Tainter Gate STRUDL II Model

Corps practice for computing skin plate stresses could be used. Fig. 3 shows the finite element incidences and joints in the skin plate of the Clarence Cannon Tainter Gate STRUDL II model. The difference in skin plate thickness near the cables and away from the cables are accounted for by changing the finite element thicknesses in the respective regions. Note the finer mesh size used in the region where the hoisting cable is attached to the skin plate (near joints 'S2' and 'S20'). It should also be noted that the finite element incidences were all input in a clockwise order (from global Y to global Z), and always started with the longer side first. This is recommended, but not required, by the McAuto STRUDL manual (4).

The main horizontal girders, stiffening ribs, and joints in the skin plate are shown in Fig. 2. The joints are located on the inside (downstream) face of the skin plate. Consequently, although the incidences of the member elements are in terms of these joints, the centroidal axes of the members do not pass through the joints. This condition must be modeled properly, since at some member ends, the eccentricity of the joint from the actual end of a member which is incident upon it is almost two feet. This is modeled using the STRUDL MEMBER ECCENTRICITIES command.

The members and joints in the struts and skin plate bracing system are shown in Fig. 4.

Rather than modeling the cable as a separate structural element, only its effect on the skin plate is modeled. At the connection of the cable to the skin plate, the cable is modeled either as a reaction component in the direction of the cable, i.e. in a direction which is tangent to the skin plate surface and in a vertical plane, or as a known applied force (in the case of the gate bound at the side seals). The value of this reaction, or the known applied force, is the cable force. This part of the cable effect is accounted for in the structural boundary condition cases as described in Section 2.5. In addition, the cable exerts a radial pressure on the skin plate over the length of contact between the cable and skin plate, and is equal to the value of the cable force divided by the radius of curvature of the skin plate (since the skin plate has a constant radius of curvature in a vertical plane). This part of the cable effect is modeled as an applied load as is shown in Fig. 5, and described in Section 2.6.

The connection of the hoisting cables to the skin plate is modeled by members 'B1', 'B2', 'B3', 'B10', 'B20', and 'B30', and by joints 'S1', 'S2', 'S3', 'S10', 'S20', and 'S30'. The cable connection points are at joints 'S1' and 'S10'. Members 'B1', 'B2', 'B3', 'B10', 'B20', and 'B30' are modeled with fictitiously high stiffnesses since it is only desired to transfer the equilibrium effect of the cable to the skin plate.

The calculation of the joint coordinates and other geometric characteristics is shown in Appendix A. The calculation of the coordinates of the points of support of the cable to the skin plate, and the points of tangency of the cable to the skin plate is shown in Appendix B. Member element beta angle and end eccentricity calculations and memeber properties are shown in Appendix C.

2.3 Design Loading Conditions

The specification of design loading conditions must recognize a variety of boundary conditions and geometric states of the gate. One is associated with the gate resting on the sill. Another is associated

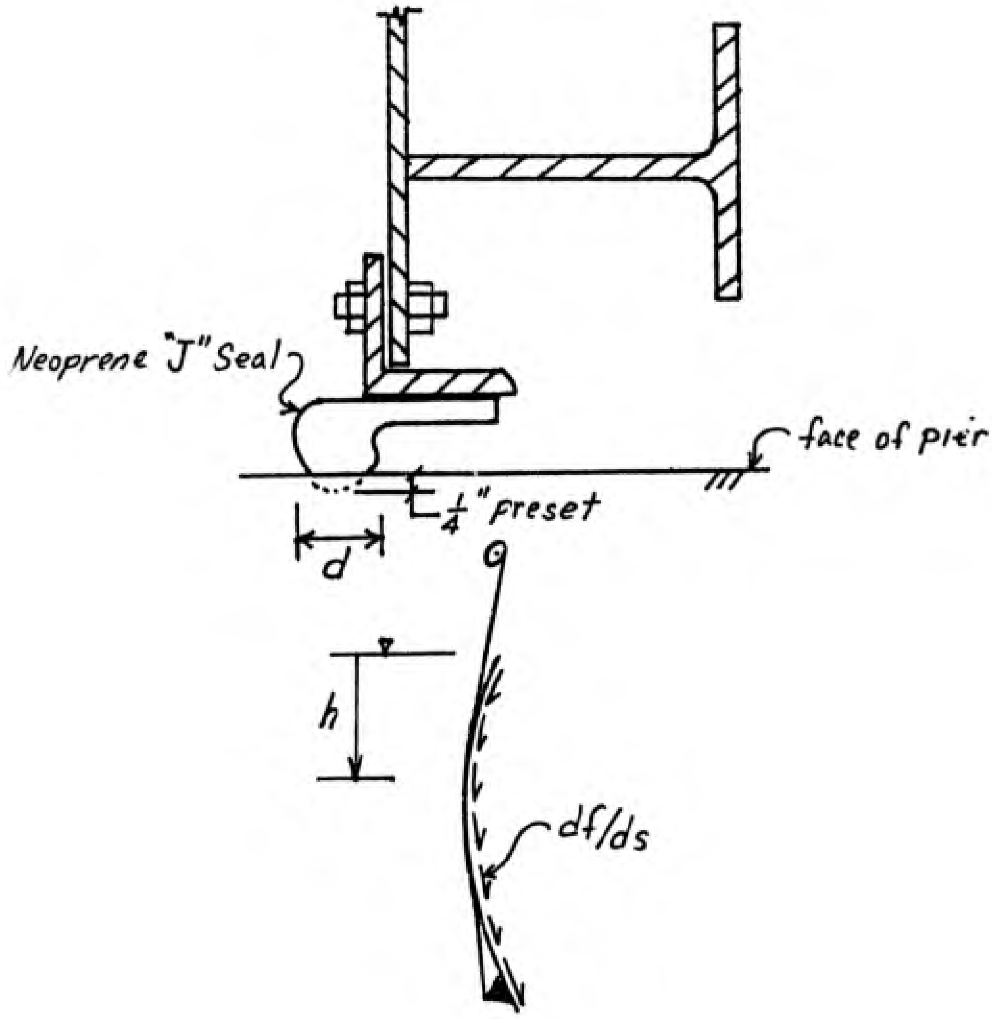


Figure 5. Neoprene Side Seal Friction Effect

with both cables lifting the gate, but the gate may be in any position from one in which it is just beginning to open, to one in which it is fully open. Another is associated with only one cable lifting the gate (i.e. one cable has broken), but the gate may again be in any position from just starting to open to fully open. In addition, for the one cable situation, lateral displacements of the gate may be large enough to cause the gate to touch the side pier walls which lead to another boundary condition. This is a non-linear behavior since it must be determined if the gate touches the side piers and if so (or if not), the boundary conditions may need to be changed. Another is associated with either one or two cables lifting the gate with the gate in any position, but in addition, the gate binds at the side seals and the force in the cable(s) increase to the maximum hoisting force that the hoisting motor can exert.

Considering this variety of gate states, it is clear that there are an infinite number of different loading conditions that could be used for design. It is, of course, the responsibility of the engineer and appropriate design specifications to select a finite number for actual use. For the specific gate used in this study, there were eight design loading conditions specified in the design notes (6) of the Clarence Cannon Re-Regulation Dam Tainter Gate Design. They were as shown in Table 1. It should be noted that the eighth loading, Loading Condition VIII, was not used in this study primarily because it was not considered to be worth the effort to recompute the gate geometry in view of the goal of this report to describe an analysis procedure to handle any gate geometry. Consequently, only Loading Conditions I - VII were

TABLE 1

Clarence Cannon Re-Regulation Dam Tainter Gate
Design Loading Conditions

Loading Condition I

a. Dead load of gate
b. Hydrostatic load. Water to top of gate, elevation 530.0 ft.
c. Hoist cables slack, gate resting on sill. All forces reacted by sill and trunions.
d. Normal Group I loading - no overstress permitted.

Loading Condition II

a. Dead load of gate
b. Hydrostatic load. Water to top of gate, elevation 530.0 ft.
c. Gate supported by both hoisting cables. All forces reacted by trunion pins and hoisting cables.
d. Gate strating to open. Friction factor of 0.3 at trunion pins and 0.5 at side seals.
e. Normal Group I loading - no overstress permitted.

Loading Condition III

a. Same as Loading Condition I plus wave loading.
b. Group II Loading - 1/3 overstress permitted.

Loading Condition IV

a. Dead load of gate
b. Hydrostatic load. Water at elevation 528.0 ft.
c. Impact load of 5 K/ft of gate width applied at elevation 528.0 ft.
d. Gate resting on sill. All forces reacted by sill and trunions.
e. Group II loading - 1/3 overstress permitted.

Loading Condition V

a. Dead load of gate
b. Hydrostatic load. Water at elevation 528.0 ft.
c. Impact load of 5 K/ft of gate width applied at elevation 528.0 ft.
d. Gate supported by both hoisting cables. All forces reacted by trunions and hoisting cables.
e. Gate starting to open. Friction factor of 0.3 at trunion pins and 0.5 at side seals.
f. Group II loading - 1/3 overstress permitted.

Loading Condition VI

a. Same as Loading Condition II, except all forces are reacted by trunions and only one hoisting cable.
b. Group III loading - 50% overstress permitted.

TABLE 1 - CONTINUED

Loading Condition VII (See Note 1) a. Same as Loading Condition II, except gate is assumed held down by friction and binding. Hoist cable load becoming 280% of normal cable tension due to development of maximum design torque in hoist. b. Group III loading - 50% overstress permitted.
Loading Condition VIII (See Note 2) a. Dead load of gate b. Gate wide open against stops. Bottom of gate at elevation 535.0 ft. c. Hoisting cable loads equal to 280% of normal maximum cable tension due to development of design torque in hoist. d. Gate supported by both hoisting cables. All forces reacted by trunions and hoisting cables. e. Group III loads - 50% overstress permitted.

Note 1: (a) It is assumed that Loading Condition II forces, including cable force F and trunion moment M, are developed prior to binding. (b) Binding occurs, after which an additional 1.8F and 0.0M are applied to the bound gate developing additional gate forces which are added to the Loading Condition II gate forces.

Note 2: Loading Condition VIII was not used in this study primarily because it was not considered to be worth the effort to recompute the gate geometry since the goal of this report was to describe an analysis procedure to handle any gate geometry.

considered. However, Loading Condition VIII would make an excellent case to analyze in order to test one's understanding of many of the concepts presented in this report.

2.4 Three Special Tainter Gate Characteristics

There are three special characteristics of tainter gate structures which require special attention. The first is associated with friction forces (df/ds) caused by the skin plate neoprene side seals, along the skin plate side edges, bearing against the side piers of the hyraulic channel (Fig. 5). This effect can be accounted for as an applied load as will be shown in Section 2.4.1.

The second special characteristic is associated with the effect of friction forces at the trunion pin locations providing resisting moments M (Fig. 6). This moment M is a function of the unknown resultant R of the global X and Y components of trunion pin reaction, as well as the Z component, as will be shown in Section 2.4.2.

The third special characteristic is associated with a situation when only one cable supports the gate. In this case, the gate experiences lateral deflections which may be large enough so that the gate will touch the side walls of the hydraulic channel. This is, of course, a non-linear behavior since, if the gate does in fact touch the side walls, the external boundary conditions must be changed to reflect the new side support and the analysis repeated. This procedure is described in Sections 2.4.3 and 3.

2.4.1 Side Seal Friction Effect

As was developed in the Theoretical Manual (1), the side seal friction force per unit length along the skin plate edge (df/ds) is

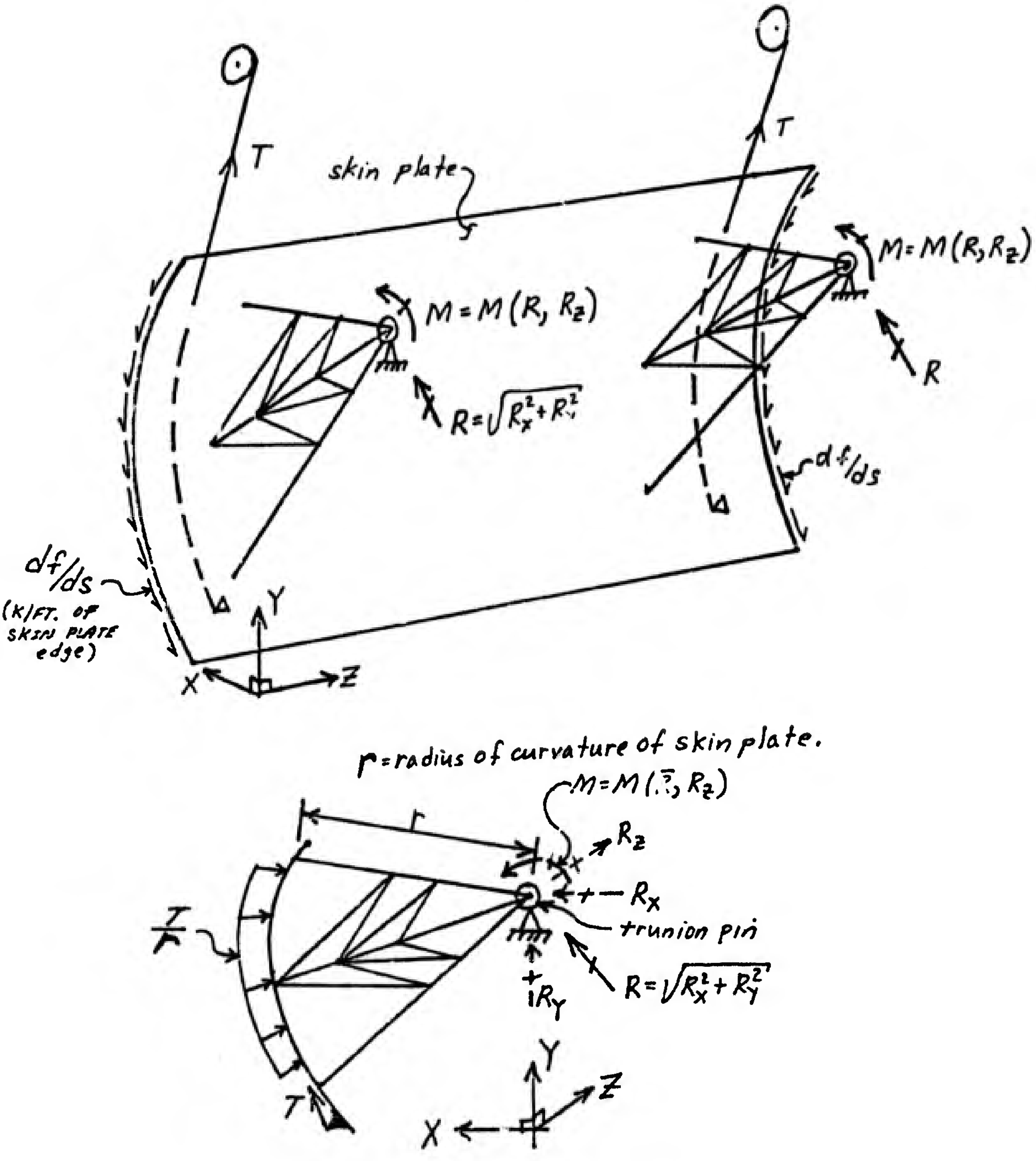


Figure 6. General Tainter Gate Computer Model

equal to

$$\frac{df}{ds} = (\mu_s k + 0.0624\mu_s dh) \text{ K/ft} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where μ_s = coefficient of side seal friction, k = normal force induced by the preset of the neoprene "J" seal, d = effective width of the "J" seal, and h = distance from top of the skin plate to the point in question (this is conservative for water levels below the top of the gate). For the Clarence Cannon Tainter Gate under consideration, μ_s = 0.5 (from Corps Manual (8) EM 1110-2-2702, pg. 18), k = 0.048 K/ft applied uniformly along the entire length of the skin plate edge and due to a neoprene "J" seal preset of 0.25 inch, and d = 2.25 in. = 0.1875 ft. So,

$$\frac{df}{ds} = (0.024 + 0.00585h) \text{ K/ft} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Note that df/ds is simply an externally applied force in a direction tangent to the skin plate side edges and opposite to the upward movement of the gate (Figs. 5 and 6).

2.4.2 Trunion Pin Friction Effect

Each trunion pin total reaction is composed of three global components, R_x, R_y, and R_z, which are parallel to the global X, Y, and Z axes as shown in Fig. 6. Components R_x and R_y lead to a resultant force R which exerts pressure directly on the trunion pins. This pressure leads to a friction force around the trunion pin which is statically equivalent to a resisting moment about the global Z axis and a resultant force in a direction perpendicular to R. Component R_z reacts through a trunion yoke on end bearing plates, exerting pressure which leads to a friction force that is only statically equivalent to a resisting moment.

Now, as was developed in the Theoretical Manual (1), the resultant trunion pin global reaction components, R_x, R_y, and R_z result in friction forces on the pin $P_{x'}$, $P_{y'}$, and M such that,

$$\left.\begin{aligned} P_{x'} &= 0.0 \\ P_{y'} &= \tfrac{2}{3}\mu_t \sqrt{R_x^2 + R_y^2} \\ M &= 0.7854\mu_t r_p \sqrt{R_x^2 + R_y^2} + \mu_t |R_z| r_p \end{aligned}\right\} \qquad \ldots\ldots\ldots\ldots(3)$$

where $P_{y'}$ is in a direction perpendicular to $R = \sqrt{R_x^2 + R_y^2}$, and where μ_t = coefficient of trunion pin friction, and r_p = trunion pin radius. For the Clarence Cannon Tainter Gate under consideration, $\mu_t = 0.3$ (from Corps Manual (8) EM 1110-2-2702), and $r_p = 5.0$ in. = 0.41667 ft. So,

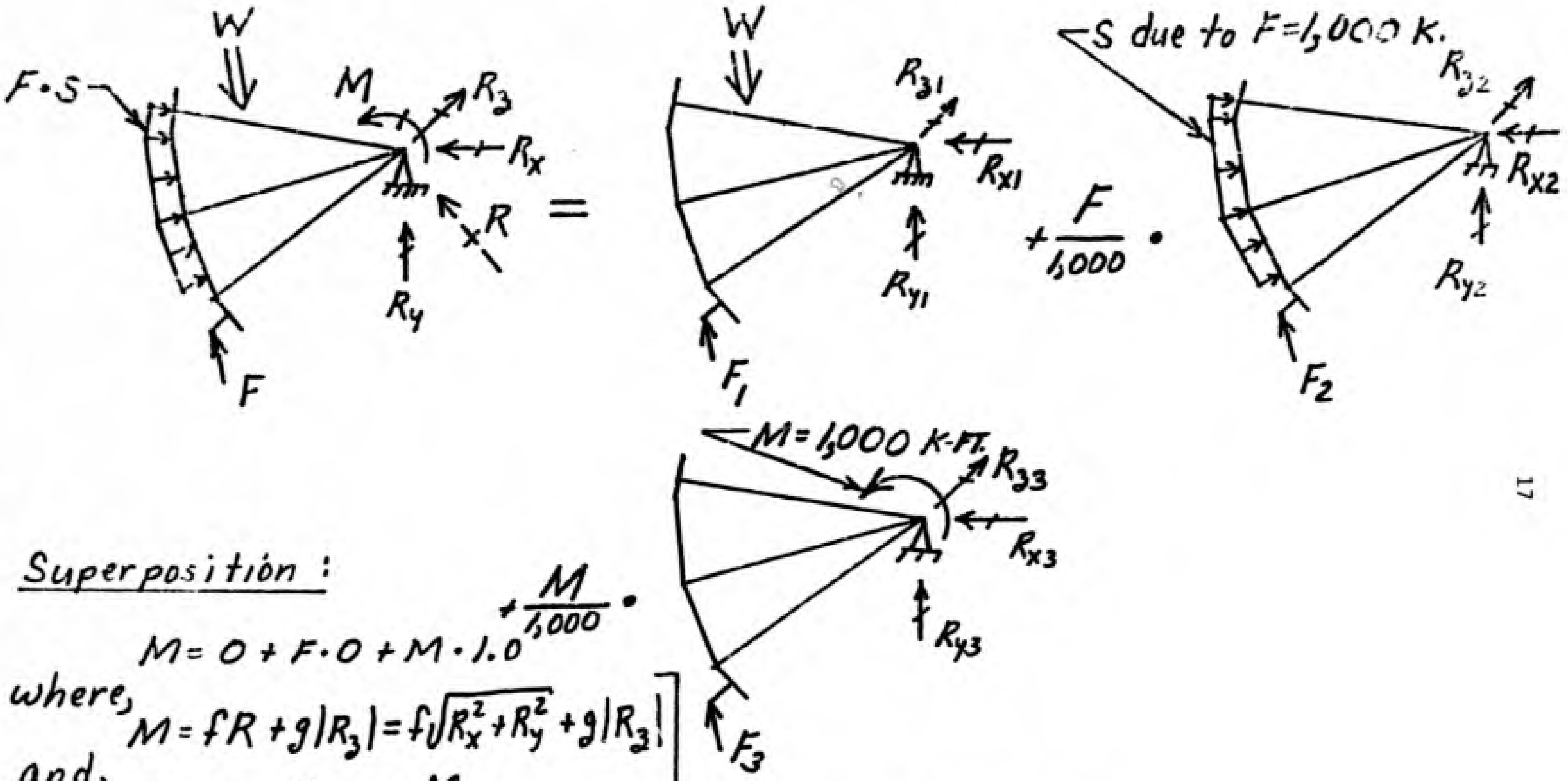
$$\left.\begin{aligned} P_{x'} &= 0.0 \\ P_{y'} &= 0.20\sqrt{R_x^2 + R_y^2} \\ M &= 0.098167\sqrt{R_x^2 + R_y^2} + 0.1250|R_z| \end{aligned}\right\} \qquad \ldots\ldots\ldots\ldots\ldots\ldots(4)$$

Now, the calculation of the trunion pin friction forces depends on whether the tainter gate is supported by two cables or only one cable. The procedure will be summarized next.

2.4.2.1 2-Cable Symmetrical Case

When the tainter gate is supported by two cables (design Loading Conditions II, V, and VII, see Table 1), it experiences completely symmetrical behavior. Consequently, only the symmetrical part of the trunion pin friction moment effect needs to be considered, i.e. only one trunion pin and one cable need be included in the calculation.

The Theoretical Manual (1) formulates the procedure required to compute the trunion pin friction moment M. Fig. 7 summarizes the equations that need to be solved for the Clarence Cannon Tainter Gate. The solution



Superposition :

$$M = 0 + F\cdot 0 + M\cdot 1.0$$

where, $M = fR + g|R_3| = f\sqrt{R_x^2+R_y^2} + g|R_3|$

and,

$$F = F_1 + \frac{F}{1,000}\cdot F_2 + \frac{M}{1,000}\cdot F_3$$

$$R_x = R_{x1} + \frac{F}{1,000}\cdot R_{x2} + \frac{M}{1,000}\cdot R_{x3}$$

$$R_y = R_{y1} + \frac{F}{1,000}\cdot R_{y2} + \frac{M}{1,000}\cdot R_{y3}$$

$$R_3 = R_{31} + \frac{F}{1,000}\cdot R_{32} + \frac{M}{1,000}\cdot R_{33}$$

Solve for F and M.

f, g = friction factors
r_p = trunion pin radius = 5" = .416667'

$f = 0.2356\ r_p = 0.098167$ ft.

$g = 0.30\ r_p = 0.1250$ ft.

Figure 7. 2-Cable Symmetrical Case

is actually performed by a supplied program, XFTWO, at the appropriate point in the STRUDL II structural analysis as described in Section 3. A listing of XFTWO is given in Appendix G. Example input to XFTWO for the STRUDL II analysis described in Section 3 is given in Appendix H.

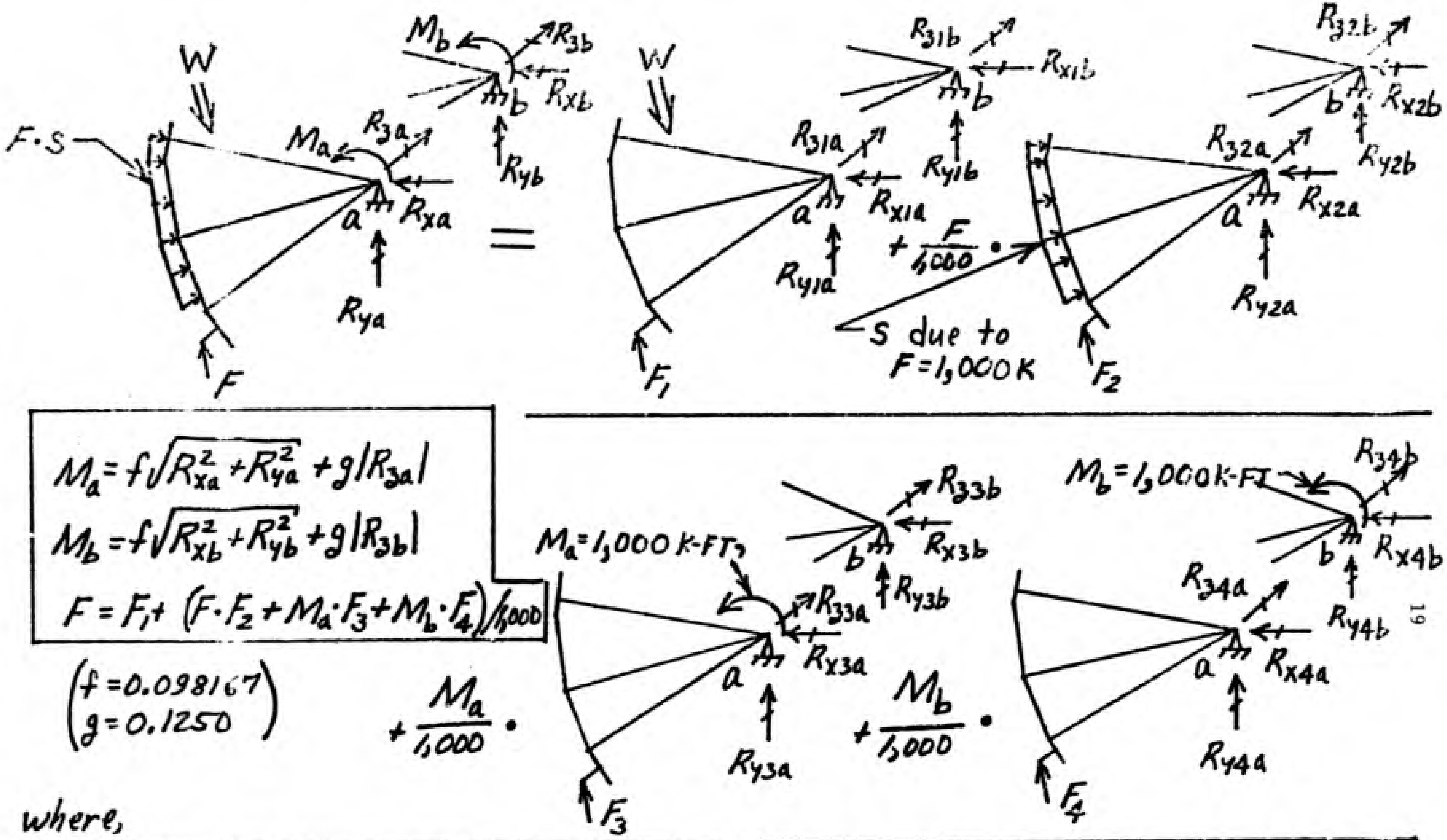
2.4.2.2 1-Cable Non-Symmetrical Case

When the tainter gate is supported by only one cable (design Loading Condition VI), it experiences non-symmetrical behavior. Consequently, trunion pin friction effects at both trunion pins in addition to the single supporting cable need to be considered in the analysis.

The Theoretical Manual (1) formulates the procedure required to compute the trunion pin friction moments M_a and M_b at each trunion pin. Fig. 8 summarizes the equations that need to be solved for the Clarence Cannon Tainter Gate. The solution is actually performed by a supplied program, XFONE, at the appropriate point in the STRUDL II structural analysis as described in Section 3. A listing of XFONE is given in Appendix G. Example input to XFONE for the STRUDL II analysis described in Section 3 is given in Appendix H.

2.4.3 Non-Linear Lateral Boundary Contact Problem

Since it is not known a-priori whether or not the tainter gate will make contact with the side pier walls while supported by only one hoisting cable, more than one analysis may be necessary. However, based upon the results of the initial STRUDL II analysis reported in the Theoretical Manual (1), it will first be assumed that the tainter gate does make contact with the side walls at joints 7 and 1001 (Fig. 2), so that the first analysis for the 1-cable case will include side support in addition to the other boundary conditions and loading conditions



$$M_a = f\sqrt{R_{xa}^2 + R_{ya}^2} + g|R_{3a}|$$

$$M_b = f\sqrt{R_{xb}^2 + R_{yb}^2} + g|R_{3b}|$$

$$F = F_1 + (F \cdot F_2 + M_a \cdot F_3 + M_b \cdot F_4)/1,000$$

$$\begin{pmatrix} f = 0.098167 \\ g = 0.1250 \end{pmatrix}$$

where,

$$R_{xa} = R_{x1a} + (FR_{x2a} + M_a R_{x3a} + M_b R_{x4a})/1,000$$

$$R_{ya} = R_{y1a} + (FR_{y2a} + M_a R_{y3a} + M_b R_{y4a})/1,000$$

$$R_{3a} = R_{31a} + (FR_{32a} + M_a R_{33a} + M_b R_{34a})/1,000$$

$$R_{xb} = R_{x1b} + (FR_{x2b} + M_a R_{x3b} + M_b R_{x4b})/1,000$$

$$R_{yb} = R_{y1b} + (FR_{y2b} + M_a R_{y3b} + M_b R_{y4b})/1,000$$

$$R_{3b} = R_{31b} + (FR_{32b} + M_a R_{33b} + M_b R_{34b})/1,000$$

Figure 8. 1-Cable Non-Symmetrical Case

(Load Group C - Table 4) associated with design Load Combination VI (Table 1).

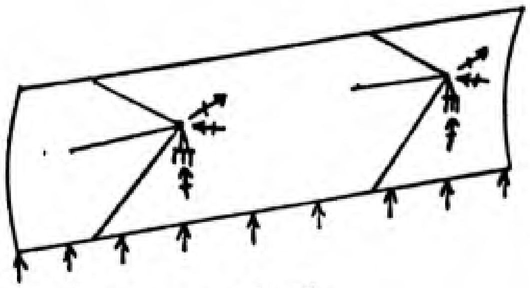
The results of this analysis are checked, and if the lateral reactions at the side supports are only in compression, then the tainter gate does in fact contact the side walls. However, if the lateral reactions at joints 7 and 1001 are in tension, then the gate does not contact the side walls, and another analysis is necessary where the side supports are removed. This procedure is described in Section 3. Only one analysis was necessary, since the gate does make contact with the side walls at joints 7 and 1001.

2.5 Structural Boundary Condition Cases

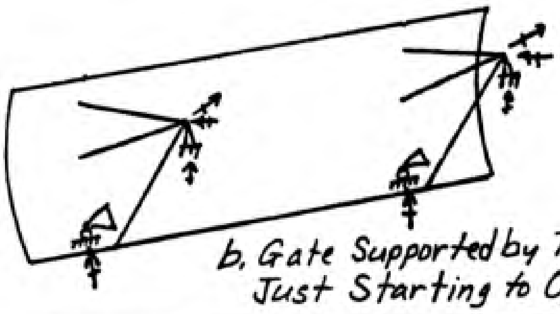
Referring to the seven design loading conditions used in this study, Loading Conditions I - VII in Table 1, it is clear that there are four distinct structural boundary condition cases. These cases are identified here as Load Groups, where a Load Group is defined as a set of independent loads applied to the structure with a particular set of boundary conditions. The boundary conditions associated with each of the four Load Groups are as follows:

Load Group A: gate resting on sill; translational force reactions in the global Y direction at each contact point with the sill; and translational force reactions in the global X, Y, and Z directions at each trunion pin (Fig. 9a).

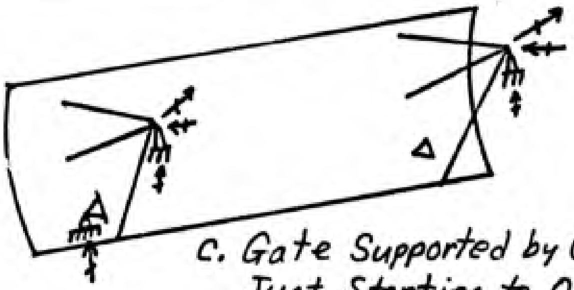
Load Group B: gate supported by two hoisting cables, just starting to open; single translational force reaction at both cable support points on skin plate, (to simulate cable effect at point of connection to skin plate), and in a direction which is tangent to skin plate; translational force reactions at each trunion pin in global X, Y, and



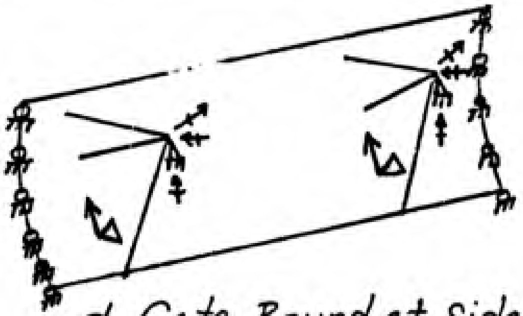
a. Gate on Sill



b. Gate Supported by Two Hoisting Cables Just Starting to Open



c. Gate Supported by One Hoisting Cable Just Starting to Open



d. Gate Bound at Side Seals

Figure 9. Boundary Condition Cases

Z directions (Fig. 9b).

Load Group C: gate supported by only one hoisting cable, just starting to open; translational force reactions at one cable support point on skin plate (to simulate one cable effect at point of connection to skin plate), and in a direction which is tangent to skin plate; translational force reactions at each trunion pin in global X, Y, and Z directions (Fig. 9c).

Load Group D: gate bound at side seals; effect of two hoisting cables at skin plate connections accounted for by applying known cable forces at both points of connection to skin plate; translational force reactions at each trunion pin in global X, Y, and Z directions; translational force reactions at side seals in directions which are tangent to skin plate edges and in a vertical plane (Fig. 9d).

It should be noted that Load Group C may be divided into two different cases. One is associated with the gate not experiencing sufficient lateral displacements to touch the side piers, and another is associated with the gate experiencing sufficiently large lateral displacements (0.25 inches for the specific gate used in this study), so that lateral supports must be added to the Load Group C boundary conditions.

The detailed specification of these boundary condition cases are described in Section 3.

2.6 Independent Loading Conditions by Load Group

Upon inspection of the seven design loading conditions considered in this study (see Table 1), it is seen that there are six distinct independent loading conditions which are (1) dead load of gate,

(2) hydrostatic load, water at elevation 530.0 ft., (3) hydrostatic load water at elevation 528.0 ft., (4) impact load at elevation 528.0 ft., (5) wave load, water at elevation 530.0 ft., and (6) 1.8 x cable force from design Loading Condition II. In addition, as was shwon in Section 2.4, the side seal friction effect may be considered as an applied loading condition. So, a seventh independent load is, (7) side seal friction. Also, as was shown in the Theoretical Manual (1), the trunion pin friction effect may be accounted for by a superposition technique which requires the application of two more independent loading conditions which are, (8) gate skin plate pressure due to a 1,000 K cable force, and (9) a 1,000 K-ft moment about the global Z axis applied at one or both trunion pins and in a direction which resists the upward movement of the gate. Finally, since Load Group C may be associated with the gate displacing laterally until it touches the side piers, after which it is restrained from further lateral movement at the points of contact, a tenth independent loading condition should be considered which is, (10) a specified lateral joint displacement (±0.25 inches for the specific gate considered in this study) applied at the joints which may be in contact with the side piers.

Although there are ten independent loading conditions which can be identified, it is not clear that these are the ones which are used in a structural analysis. In particular, there are also four boundary condition (Load Group) cases which were identified in Section 2.5, and most of these independent loading conditions are associated with two or more boundary condition cases. If an independent loading condition is associated with two boundary condition cases, for example, it generates two independent loading conditions for structural analysis purposes since, even though the applied loads are the same, different structural analysis results will be generated for the different boundary conditions. Consequently, it is necessary to identify the independent loading conditions in terms of their corresponding boundary condition cases to properly account for the actual number of independent loads.

For the specific gate under consideration in this study, there are twenty independent loading conditions which must be considered. Tables 2, 3, 4, and 5 summarize them. Details of the loading computations are shown in Appendix D.

2.7 Design Loading Combinations

Section 2.3 and Table 1 summarize the seven design loading conditions considered for the specific tainter gate used in this study. In Section 2.5, it was shown that these loading conditions are associated with four distinct boundary condition states, and in Section 2.6 and Tables 2, 3, 4, and 5, it was shown that there are a total of twenty independent loading conditions associated with these four boundary condition states. Also, the Theoretical Manual (1) demonstrates how the tainter gate final behavior is a superposition of cases involving forces identified in Figs. 7 and 8 as W, radial pressure due to a 1,000 K cable force, and a 1,000 K-ft moment, as well as combination factors F/1000 and M/1000. This Section will describe the formulation for combining the independent loading conditions to form the design loading combinations in such a way as to be consistent with the superposition required in the computation of cable force F and trunion pin friction moment M.

TABLE 2

Independent Loadings - Load Group A
Gate Resting on Sill

Independent Load Number	Independent Load Description
1	Dead load of gate structure
2	Hydrostatic load, water at top of gate, elevation 530.0 ft.
3	Wave load, elevation 530.0 ft.
4	Hydrostatic load, water at elevation 528.0 ft.
5	Impact load of 5 K/ft of gate width applied to gate skin plate at elevation 528.0 ft.

TABLE 3

Independent Loadings - Load Group B
Gate Supported by Two Cables, Just Starting to Open

Independent Load Number	Independent Load Description
6	Dead load of gate structure.
7	Hydrostatic load, water at top of gate, elevation 530.0 ft.
8	Hydrostatic load, water at elevation 528.0 ft.
9	Impact load of 5 K/ft of gate width applied to gate skin plate at elevation 528.0 ft.
10	Side seal friction in a direction resisting gate opening.
11	Skin pressure due to 1,000 K. cable force in both cables
12	1,000 K-ft trunion pin friction moment at both pins and in a direction resisting gate opening.

TABLE 4

Independent Loadings - Load Group C
Gate Supported by One Cable, Just Starting to Open

Independent Load Number	Independent Load Description
13	Dead load of gate structure.
14	Hydrostatic load, water at top of gate, elevation 530.0 ft.
15	Side seal friction in a direction resisting gate opening.
16	Skin pressure due to 1,000 K cable force in one cable.
17	1,000 K-ft trunion pin friction moment at one pin (joint 38 in gate under study) in a direction resisting gate opening.
18	1,000 K-ft trunion pin friction moment at one pin (joint 1038 in gate under study) in a direction resisting gate opening.
20	Joint displacement load, in gate under study, at joint 1001 = +0.25 inches, at joint 7 = -0.25 inches, to simulate part of lateral constraint provided by side pier walls.

TABLE 5

Independent Loadings - Load Group D
Gate Bound at Side Seals, Supported by Two Cables

Independent Load Number	Independent Load Description
19	Skin pressure due to 1,000 K. cable force in both cables, and 1,000 K. force at both points of connection of the cable to the skin plate in an upward direction and tangent to the skin plate.

First it should be noted that Corps design specifications, as taken from Reference (6), require that allowable stresses, computed from the 1970 American Iron and Steel Institute Specifications (9), are to be reduced by 83-1/3%. This is precisely equivalent to increasing all analysis element force results by the factor 1.0/0.83333 = 1.20. In addition, the Corps specifications permit three cases of stress design. One case permits no overstress. In this case, the combination factor applied to the independent load combinations would be 1.2 x 1.0 = 1.2. The second case permits a 1/3 overstress (i.e. computed stress may exceed allowable by 1/3 x allowable). In this case, the combination factor applied to the independent load combinations would be 1.2 x 1.0/(4/3) = 1.2 x 0.75. The third case permits a 50% overstress. In this case, the combination factor applied to the independent load combinations would be 1.2 x 1.0/(3/2) = 1.2 x 0.6667.

Now, in order to combine the independent loading conditions for tainter gate analysis, it must be recognized that for any one load combination, all the independent loading conditions involved must be associated with the same boundary condition case. That is, for any one loading combination, the independent loads must all be taken from either Table 2 or 3 or 4 or 5, depending on the required boundary conditions. Now, design loading conditions I, III, and IV (see Table 1), are associated with Load Group A, the gate resting on the sill (Table 2), and reacted by sill and trunion pins, and not involving any cable force or trunion pin friction moment. The required combinations are,

$$(I) = 1.2 \times (1 + 2)$$

$$(III) = 1.2 \times 0.75 \times (1 + 2 + 3) \qquad \ldots\ldots\ldots\ldots(5)$$

$$(IV) = 1.2 \times 0.75 \times (1 + 4 + 5) \qquad \ldots\ldots\ldots\ldots (5) \text{ cont.}$$

where the integer numbers are independent load numbers from Table 2. Note that design loads III and IV permit a 1/3 overstress as described in Table 1.

Design loading conditions II and V are associated with Load Group B, the gate supported by two cables, and the gate just starting to open (Table 3). Since these conditions must include the effects of the cable force F and trunion pin friction moment M, the combination of independent loads must be consistent with the formulation for computing F and M whereby a proper superposition of cases is required as represented by the Theoretical Manual (1) Eq. (29) and repeated here for reference,

$$Q = q_1 + \frac{F}{1000} q_2 + \frac{M}{1000} q_3 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

where Q may be interpreted as the design load combination force results, and therefore where q_1 = forces due to applied loads other than the effects of cable force F (i.e. forces due to W in Fig. 7, and independent loads 6, 7, 8, 9, and 10), q_2 = forces due to the effect of the radial skin pressure equivalent of a 1,000 K cable force (independent load 11), and q_3 = forces due to the effect of a 1,000 K-ft trunion pin friction moment (independent load 12). The required combinations are,

$$\left.\begin{aligned} (II) &= 1.2 \times (6 + 7 + 10 + \frac{F}{1000} \times 11 + \frac{M}{1000} \times 12) \\ (V) &= 1.2 \times 0.75 \times (6 + 8 + 9 + 10 + \frac{F}{1000} \times 11 + \frac{M}{1000} \times 12) \end{aligned}\right\} \ldots (7)$$

where the integer numbers are independent load numbers from Table 3, and F and M are the cable forces and trunion pin friction moments computed for the 2-cable symmetrical case by the computer program XFTWO (Appendix G) according to Theoretical Manual (1) Eq. (34). Note that a 1/3 overstress is permitted in design load condition V.

Design loading condition VI is associated with Load Group C, the gate supported by only one cable, and the gate just starting to open (Table 4). Since this condition must include the effects of cable force F, and trunion pin friction moments M_a and M_b, the combination of independent loads must be consistent with the formulation for computing F, M_a, and M_b for the 1-cable unsymmetrical case which requires a proper superposition of cases as represented by Theoretical Manual (1) Eq. (35) and repeated here for reference,

$$Q \approx q_1 + \frac{F}{1000} q_2 + \frac{M_a}{1000} q_3 + \frac{M_b}{1000} q_4 \quad \ldots\ldots\ldots\ldots\ldots (8)$$

where Q may be interpreted as the design load combination force results, and therefore where q_1 = forces due to applied loads other than the effects of cable force F (i.e. forces due to W in Fig. 8, and independent loads 13, 14, 15, and 20), q_2 = forces due to the effect of the radial skin pressure equivalent of a 1,000 K cable force in one cable (independent load 16), q_3 = forces due to the effect of a 1,000 K-ft trunion pin friction moment M_a in one trunion pin (independent load 17), and q_4 = forces due to the effect of a 1,000 K-ft trunion pin friction moment M_b in the other trunion pin (independent load 18).

Now, since this is the unsymmetrical design loading condition, before the required combination is shown, it must be noted that there are two possible states for this combination. One state is associated with the gate experiencing small enough lateral displacements so that the gate does not touch the side pier walls. This state involves independent loads 13 to 18 analyzed for Load Group C boundary conditions which do not include side wall constraints. The second state is associated with the gate experiencing sufficiently large lateral displacements so that the gate touches the side pier walls. This state involves independent loads 13 to 18 and 20 analyzed for Load Group C boundary conditions which include the side wall constraints. Each state must, of course, be investigated, and the one which occurs used for design. From the Theoretical Manual (1), the second state, i.e. with side wall constraints, occurred for the specific tainter gate considered in this study as described in Section 3. So, the two different possible combinations are,

$$(\mathrm{VI})_{\substack{\text{no side}\\ \text{wall}\\ \text{constraint}}} = 1.2(0.6667)(13 + 14 + 15 + \frac{F}{1000}(16) + \frac{M_a}{1000}(17) + \frac{M_b}{1000}(18)) \quad .....(9)$$

or,

$$(\mathrm{VI})_{\substack{\text{with side}\\ \text{wall}\\ \text{constraint}}} = 1.2(0.6667)(13 + 14 + 15 + 20 + \frac{F}{1000}(16) + \frac{M_a}{1000}(17) + \frac{M_b}{1000}(18)) \quad ....(10)$$

where the integer numbers are independent load numbers from Table 4, and F, M_a, and M_b are the cable force, and trunion pin friction moments computed for the 1-cable unsymmetrical case by the computer program XFONE (Appendix G) according to Theoretical Manual (1) Eq. (36). Note that a 50% overstress is permitted in this design condition.

Finally, design loading condition VII is associated with Load Group D, the gate bound at the side seals, and the gate supported by two cables (Table 5). This design load condition is specified to have the same load combination as design load II, but in addition, the force in the cable increases to a value of 280% of the cable force in design load II.

Consequently, this load condition first uses the same results as generated in design load II, and then adds the results of an analysis for an additional 180% of the design load II cable force applied to the gate with the side seals bound (Load Group D boundary conditions). The required combination is,

$$(\text{VII}) = 0.6667 \times (\text{II}) + 1.2 \times 0.6667 \times (1.8 \times \frac{F}{1000} \times 19) \ldots. (11)$$

where the integer number is an independent load number from Table 5, the (II) refers to design load combination II (see Eq. (7)), and F = the cable force used in design load combination II. Note that a 50% overstress is permitted in this design load condition.

Table 6 summarizes the required seven design load combinations considered for the specific tainter gate studied in this report.

2.8 Summary

This Section described the overall characteristics of the tainter gate analysis model. The geometric (joint coordinates) and topologic (member and element incidences) were described in Section 2.2 and Figs. 2, 3, and 4. Design loading conditions as specified by the Corps were described in Section 2.3 and Table 1. These loading conditions required the identification of four boundary condition cases, Section 2.5, each of which requires a separate analysis.

Section 2.4 described three special characteristics of the tainter gate which are the principal causes of difficulty in the computer analysis of tainter gates. These are the side seal friction effects, trunion pin friction effects, and non-linear lateral boundary contact problem. Side seal friction may be handled as an applied load, while the boundary contact problem may be handled by performing multiple

TABLE 6

Force Design Loading Combination Summary

Design Load Combination	Independent Load Combinations
I	$1.2 \times (1 + 2)$
II	$1.2 \times (6 + 7 + 10 + \frac{F}{1000} \times 11 + \frac{M}{1000} \times 12)$
III	$1.2 \times 0.75 \times (1 + 2 + 3)$
IV	$1.2 \times 0.75 \times (1 + 4 + 5)$
V	$1.2 \times 0.75 \times (6 + 8 + 9 + 10 + \frac{F}{1000} \times 11 + \frac{M}{1000} \times 12)$
VI (no side wall constraint)	$1.2 \times 0.6667 \times (13 + 14 + 15 + \frac{F}{1000} \times 16 + \frac{M_a}{1000} \times 17 + \frac{M_b}{1000} \times 18)$
VI (with side wall constraint)	$1.2 \times 0.6667 \times (13 + 14 + 15 + 20 + \frac{F}{1000} \times 16 + \frac{M_a}{1000} \times 17 + \frac{M_b}{1000} \times 18)$
VII	$0.6667 \times (II) + 1.2 \times 0.6667 \times (1.8 \times \frac{F}{1000} \times 19)$

Final Combination Factors for Recommended STRUDL II Runs:

II: $F = 24.871$ K, $M = 58.400$ K-ft
V: $F = 11.226$ K, $M = 58.963$ K-ft
VI: $F = 49.879$ K, $M_a = 60.453$ K-ft, $M_b = 56.323$ K-ft

analyses. However, as formulated in the Theoretical Manual (1), the trunion pin friction effect required a special procedure involving a superposition of actual applied and special loading conditions.

The Corps specified design loading conditions, required boundary conditions, and special loading conditions required by the formulation for trunion pin friction moment lead to the twenty independent loading conditions as summarized in Section 2.6 and Tables 2, 3, 4, and 5.

Finally, the design load combinations, which are linear combinations of the twenty independent loading conditions, are formed in such a way as to be consistent with the superposition of loads required by the trunion pin friction moment formulation, while at the same time resulting in the design loading conditions. The load combination factors F, M, M_a, and M_b are computed by the supplied FORTRAN programs XFTWO and XFONE. Table 6 summarizes the required combinations and final values of F, M, M_a, and M_b. Note that the cable force is represented by the value of F, while the trunion pin friction moments are represented by the values of M, M_a, and M_b.

Now, Section 3 describes the details of the recommended approach to analyzing and designing the tainter gate using STRUDL II, and incorporating the analysis model presented in this Section.

3. DETAILS OF THE RECOMMENDED STRUDL II ANALYSIS AND DESIGN PROCEDURE

3.1 Introduction

In order to use a general purpose computer program to perform an accurate structural analysis and design of the type of tainter gate under consideration, it must possess certain special and sophisticated capabilities including:

1. the ability to perform multiple analyses in the same computer run,

2. the ability to change the data base between the different analyses so that each analysis may be based on different boundary conditions, and/or loading conditons, etc.,

3. the ability to save on the computer, for any length of time, the status of a problem solution at any point, display results for engineering review, and subsequently continue the problem solution with a modified data base,

4. the ability to combine analysis results for different loading conditions used in the same analysis,

5. the ability to combine analysis results for different loading conditions used in several different analyses involving different boundary conditions,

6. the ability to include in the model description such special conditions as the eccentricity of the end of a member element from the joint center it connects to, the location of the shear center of a member element from its centroid, and others,

7. the ability to perform design of steel member elements according to AISC Specifications (9).

The only commercially available general purpose structural analysis and design computer program that has all of the above, and many more advanced capabilities is the STRUDL II subsystem (2,3). This program was used through the facilities of the McDonnell Automation Co. (4).

3.2 Overview of the Analysis and Design Approach

The general approach that is recommended to be followed to analyze and design tainter gates of the kind considered in this report (the Clarence Cannon Tainter Gate (6,7)) first involves describing the structure's geometry, topology, member and finite element properties, independent loading conditions, and boundary conditions in the first run. The analysis for Load Group A loading and boundary conditions (Table 2) is performed next. After verifying that the STRUDL input and results are good, the third run is performed. The third run includes the three analyses for Load Group B, C, and D (Tables 3, 4, and 5) loading and boundary conditions. The analysis for Load Group C (1-cable case) includes the lateral support condition and Loading 20 in the first Load Group C analysis. Although all four analyses could be performed in one run, it is felt that the first analysis should be run for one Load Group case to assure that all the input data and other conditions are correct.

The results of the two analysis runs are saved on the computer for future use by the STRUDL II SAVE command. The first three runs involve the use of extensive data base management facilities, which are only contained in the ICES STRUDL II computer system.

Following these STRUDL runs, the cable force F and trunion pin friction moment M for design Loading Conditions II and V are computed by program XFTWO, and the cable force F and trunion pin friction moments M_a and M_b for design Loading Condition VI were computed by program XFONE. Then, Loading Combinations I to VII are formed for member and element forces and reactions using the loading combinations as summarized in Table 6 where the combination factors are,

Design Load II: F = 24.871 K M = 58.400 K-ft
Design Load V: F = 11.226 K M = 58.963 K-ft
Design Load VI: F = 49.879 K M_a = 60.453 K-ft M_b = 56.323 K-ft

The input to XFTWO and XFONE used to compute these values of cable forces and trunion pin friction moments is shown in Appendix H.

Seven additional combinations were formed, D1 to D7, for displacements corresponding to design loads I to VII. The displacements are formed by dividing the displacements from design loads I to VII by the stress decrease and/or increase factors, since these factors are only applicable to stresses and not displacements. Table 7 summarizes the appropriate combinations.

The reaction results for Load Combination VI are checked next to verify that the lateral reactions at joints 7 and 1001 are in compression. If they are, then the side support boundary condition was correct, i.e. the tainter gate contacts the side walls for the 1-cable case. If not, the side supports would be removed, and the analysis and load combination procedures repeated for Load Group C and Loading Combination VI. For the case considered herein, the lateral reactions at joint 7 and 1001 are in compression, so no reanalysis is required.

Finally, STRUDL II is used to perform a design check on the member elements of the existing Clarence Cannon Tainter Gate. This is

TABLE 7

Displacement Combination Summary

Load Combination	Displacement Combination
D1	(I)/1.2
D2	(II)/1.2
D3	(III)/(1.2 x 0.75)
D4	(IV)/(1.2 x 0.75)
D5	(V)/(1.2 x 0.75)
D6	(VI)/(1.2 x 0.6667)
D7	(VII)/(1.2 x 0.6667)

followed by a complete design of all members for comparison with the original member sizes.

3.3 Recommended Step-by-Step STRUDL II Analysis and Design Procedure

A detailed description of the recommended STRUDL II analysis and design procedure is presented in this section. Although the specific commands used relate to the Clarence Cannon Tainter Gate (6,7), the philosophical approach is sound and general in nature, and may be applied to any tainter gate with similar characteristics. It is assumed that the reader is familiar with the language conventions and capabilities of STRUDL II (2,3). A complete listing of the STRUDL commands described below is given in Appendix E.

- -

Run 1: First STRUDL II run.

(1) Specify the complete structural geometry (joint coordinates), topology (member and element incidences), member and structural boundary conditions, material properties (including material weight density), member eccentricities, member beta angles, and member and element properties. It is important to note that any joint which will be a support joint during any of the subsequent analyses is defined as a SUPPORT joint from the start. Although this is not necessary, since a joint may be made a support joint at any later point in the STRUDL solution, it is considered to be a better and less error prone practice in the case under study.

(2) Request STRUDL PLOT's on the line printer to check the entire geometry and topology of the structure. Both member elements and finite elements can be displayed on the line printer with McAuto's STRUDL (4).

An alternative checking procedure is to use the McAuto FASTDRAW/2 (5) interactive graphics system to verify the geometry and topology. A description of how this is done, as well as how to generate and modify the geometry and topology of a tainter gate structure, is presented in Section 6.

(3) Request the total frame weight to be displayed using the STEEL TAKEOFF command. This output weight should be verified against the actual frame weight, since STRUDL will later be requested to automatically generate the frame dead weight to be used in the various Load Groups. Note that only frame member dead weights, which includes the effect of member eccentricities, are computed and output. Finite element dead weights are not automatically computed and must be input by the user.

(4) Request member lengths to be output to verify that member eccentricities are properly accounted for by STRUDL.

(5) Impose the structural boundary conditions at the trunion pins, joints 38 and 1038, by releasing the support restraint on the rotation about the global Z axis.

(6) Describe the Load Group A (Table 2) independent load conditions 1, 2, 3, 4, and 5, for the gate resting on sill case. Note that an automatic calculation of member dead loads is requested by the DEAD LOAD command, whereas the skin plate finite element dead loads are directly input.

(7) Describe the Load Group B (Table 3) independent load conditions 6, 7, 8, 9, 10, 11, and 12, for the gate supported by 2 cables case.

(8) Describe the Load Group C (Table 4) independent load

conditions 13, 14, 15, 16, 17, 18, and 20, for the gate supported by 1 cable case. Note that load 20 is associated with the 1/4 inch lateral side support clearance that joints 7 and 1001 are assumed to displace just prior to contacting the side pier walls. This will be verified following the generation of design load VI reactions at joints 7 and 1001.

(9) Describe the Load Group D (Table 5) independent load condition 19 for the gate supported by 2 cables and bound at side seals case.

(10) Issue a CHECK INPUT command which requests STRUDL to perform a data consistency check prior to analysis. This is advisable, since many data input errors may be detected during this check, and then they can subsequently be corrected prior to the first analysis.

(11) Issue a SAVE command to save the current status of the problem solution on the computer. This permits the current state of the problem solution to be reviewed offline before proceeding further.

```
SAVE 'GATE/CK1'
```

Note that the data value 'GATE/CK1' is an arbitrary file name of the file which stores the current state of the problem at the time the SAVE command is given, on the DD1 data set which is a permanent data set defined on a private CORPS 2314 disk pack (see Job Control Language in Appendix F).

Check results of first STRUDL run for input errors before proceeding.

Run 2: Restore the SAVE'd Run 1 file 'GATE/CK1' by,

```
STRUDL RESTORE 'GATE/CK1'
```

It should be noted that this RESTORE is non-destructive. This means that if the computer goes down during this run, or if an input error or any other condition causes the problem solution to terminate prematurely, the file associated with 'GATE/CK1' is not destroyed. The problem solution may again be RESTORE'd from the same file 'GATE/CK1' after the difficulty which caused premature termination is corrected.

(1) Describe the special boundary conditions consistent with Load Group A, the gate resting on the sill (Fig. 9(a)).

(2) Activate Load Group A independent loads 1, 2, 3, 4, and 5 (Table 2) using the LOAD LIST command, leaving all other defined loads (loads 6 thru 20) inactive. This has the effect that for any subsequent analysis, only loads 1 to 5 will be analyzed for the current boundary conditions.

(3) Perform a STIFFNESS ANALYSIS NJP 4 for the Load Group A case. The number of joint partitions (NJP) for analysis was specified as 4. This will increase the efficiency of the equation-solution-part of the stiffness analysis by partitioning the stiffness equations into 4 joints/partition.

(4) Output all reaction results. Other results, such as member and element forces and joint displacements are not output at this time since they are excessively voluminous and not considered to be useful at this point in the solution procedure.

(5) Save the current state of the problem solution.

```
SAVE 'GATE/CK2'
```

Note that a different file name is used here to save than the previous one. This is done so that if it is desired to return to this exact status of the problem solution, it can be done. This process of alternating SAVE file names from run to run is not absolutely necessary, but is recommended.

- -

Review results of Run 2, especially the reactions to verify that all boundary conditions for the gate on the sill case are correct.

- -

Run 3: Restore SAVE'd Run 2 file 'GATE/CK2' by,

STRUDL RESTORE 'GATE/CK2'

This run analyzes the tainter gate for the remaining Load Groups B, C, and D. In order to do this, the structural boundary conditions must, in each case, be modified using several of the STRUDL data base management facilities.

(1) In the STRUDL DELETIONS mode, delete the special boundary conditions associated with Load Group A. This returns released joints at the cable support joints and on the sill to fully fixed SUPPORT joints. Then, in the STRUDL ADDITIONS mode, completely release the joints on the sill to make them free joints, and release the two cable support joints ('S1' and 'S10') in such a way as to retain a single translational restraint in a direction which is tangent to the skin plate (see Appendix B and Fig. 9(b)).

(2) Activate Load Group B independent loads 6, 7, 8, 9, 10, 11, and 12, using the LOAD LIST command leaving all other loads inactive.

(3) Perform a STIFFNESS ANALYSIS NJP 4 for the Load Group B case, gate supported by two cables.

(4) Output all reaction results.

(5) Issue an intermediate SAVE command to save the results of the current analyses, and to protect against a premature machine failure during the next analysis.

```
SAVE 'GATE/CK1'
```

(6) In the DELETIONS mode, delete the boundary conditions for joint 'S10', one of the cable support points, and for joints 7 and 1001, the points assumed to contact the side pier walls. This returns these joints to fully fixed SUPPORT joints. Then, in the ADDITIONS mode, completely release joint 'S10' making it a free joint. This effectively leaves the tainter gate supported only at one support point, namely at joint 'S1' (Fig. 9(c)). Also, release joints 7 and 1001 in such a way as to retain a single translational restraint in the global Z direction. This simulates the lateral support which occurs when the gate is assumed to make contact with the side walls.

(7) Activate Load Group C independent loads 13, 14, 15, 16, 17, 18, and 20, using the LOAD LIST command leaving all other loads inactive.

(8) Perform a STIFFNESS ANALYSIS NJP 4 for the Load Group C case, gate supported by only one cable, with side support.

(9) Output all reaction results.

(10) Issue an intermediate SAVE command to save the results of the current analyses, and to protect against a premature machine failure during the next analysis.

```
SAVE 'GATE/CK1'
```

The current file 'GATE/CK1' is now replaced by the new file 'GATE/CK1'.

(11) In the DELETIONS mode, delete the boundary conditions for

joint 'S1', the remaining cable support point, and for all joints along both side edges. This returns these joints to fully fixed SUPPORT joints. Then, in the ADDITIONS mode, completely release joint 'S1' making it a free joint. This effectively leaves the tainter gate free from cable "support," permitting the application of a known cable force for the gate bound at side seals case. Also, release the joints along the side edges in such a way as to retain a single translational restraint at each side edge joint in a direction which is tangent to the skin plate side edges. This effectively binds the side seals to the side pier walls.

(12) Activate Load Group D independent load 19, using the LOAD LIST command leaving all other loads inactive. Load 19 is associated with the cables pulling on the former cable support joints ('S1' and 'S10') with a specified cable force as well as with the cable pressure on the skin plate.

(13) Perform a STIFFNESS ANALYSIS NJP 4 for the Load Group D case, gate bound at side seals, known cable force applied.

(14) Output all reaction results.

(15) Save the current state of the problem solution.

```
SAVE 'GATE/CK1'
```

- -

Review results of Run 3, especially the reactions from each of the three analyses for Load Groups B, C, and D, to verify that all boundary conditions for each analysis are correct.

Now, form the necessary combinations representing the results for loads W in Figs. 7 and 8, and output reactions for loads W and the 1,000 K cable force, and 1,000 K-ft trunion pin friction moments to be used to compute the actual values of cable force F and trunion pin friction moments M (Fig. 7), and M_a and M_b (Fig. 8) using FORTRAN programs XFTWO and XFONE respectively.

Run 4: Restore the SAVE'd Run 3 file 'GATE/CK1' by,

```
STRUDL RESTORE 'GATE/CK1'
```

(1) Activate all twenty independent loading conditions.

(2) Let load combination 101 be the results of the 2-cable structural analysis due to loads W in Fig. 7, and associated with design load II (Table 6). So, form load combination 101 by summing the analysis results for independent loads 6, 7, and 10 where load 101 = 6 + 7 + 10.

(3) Output reactions at joints 'S1' and 'S10' (cable support points), and joints 38 and 1038 (trunion pins), for loadings 101, 11, and 12.

(4) Output reactions at all previously defined support joints for loads 101, 11, and 12.

(5) Let load combination 102 be the results of the 2-cable structural analysis due to loads W in Fig. 7, and associated with design load V (Table 6). So, form load combination 102 by summing the analysis results for independent loads 6, 8, 9, and 10 where load 102 = 6 + 8 + 9 + 10.

(6) Output reactions at joints 'S1', 'S10', 38, and 1038 for loads 102, 11, and 12.

(7) Output reactions at all previously defined support joints for loads 102, 11, and 12.

(8) Let load combination 103 be the results of the 1-cable structural analysis due to loads W in Fig. 8, and associated with design load VI (Table 6). So, form load combination 103 by summing the analysis results

for independent loads 13, 14, 15, and 20 where load 103 = 13 + 14 + 15 + 20.

(9) Output reactions at joints 'S1', 38, and 1038 for loads 103, 16, 17, and 18.

(10) Output reactions at all previously defined support joints for loads 103, 16, 17, and 18.

(11) Save the current state of the problem solution.

```
SAVE 'GATE/CK2'
```

- -

Review results. Verify that non-zero reactions exist only at joints 'S1', 'S10', 38, and 1038 for loads 101, 102, 11, and 12, and that non-zero reactions exist only at joints 'S1', 38, and 1038 for loads 103, 16, 17, and 18.

- -

Using the reaction values at joints 'S1', 'S10', 38, and 1038 for loads 101, 11, and 12, compute F and M for the 2-cable case (for use in design loads II and VII) using the FORTRAN program XFTWO (Fig. 7 and Appendix H). The results for use in forming design loads II and VII (Table 6) were:

F = 24.8708 K, M = 58.3999 K-ft

(F = cable force, M = trunion pin friction moments at joints 38 and 1038)

- -

Using the reaction values at joints 'S1', 'S10', 38, and 1038 for loads 102, 11, and 12, compute F and M for the 2-cable case (for use in design load V) using FORTRAN program XFTWO (Fig. 7 and Appendix H). The results for use in forming design load V (Table 6) were:

F = 11.2262 K, M = 58.9627 K-ft

(F = cable force, M = trunion pin friction moments at joints 38 and 1038)

Using the reaction values at joints 'S1', 38, and 1038 for loads 103, 16, 17, and 18, compute F, M_a, and M_b for the 1-cable case (for use in design load VI) using FORTRAN program XFONE (Fig. 8 and Appendix H). The results for use in forming design load VI (Table 6) were:

$$F = 49.8795 \text{ K}, \quad M_a = 60.4530 \text{ K-ft}, \quad M_b = 56.3227 \text{ K-ft}$$

(F = cable force, M_a = trunion pin friction moment at joint 38, M_b = trunion pin friction moment at joint 1038)

Run 5: Restore the SAVE'd Run 4 file 'GATE/CK2' by,

```
STRUDL RESTORE 'GATE/CK2'
```

(1) Form design load combinations I, III, and IV (Table 6).

(2) Form design load combinations II and V (Table 6) using the values of F and M computed following Run 4.

(3) Form design load combination VII (Table 6) using load II results and the value of 1.8 x F of load II computed following Run 4.

(4) Form design load combination VI (Table 6) using the values of F, M_a, and M_b computed following Run 4.

(5) Form displacement combinations D1 to D7 (Table 7).

(6) Activate displacement combinations D1 to D7 using the LOAD LIST command for displacement result output.

(7) Output displacements for all joints for loads D1 to D7.

(8) Activate load combinations I to VII using the LOAD LIST command for force result output.

(9) Output reactions at all support joints for design loads I to VII.

(10) Output all member end forces for design loads I to VII.

(11) Output all finite element stresses for design loads I to VII. Reference (4) describes how to interpret these results.

(12) Output all finite element principal stresses for design loads I to VII. Note that a special McAuto command was used, since the formal STRUDL command was not available at the time of this writing.

(13) Save the current state of the problem solution.

```
SAVE 'GATE/CK1'
```

Review all results. Check equilibrium, displacements, etc. Verify that trunion pin friction moments in the cable supported cases are properly related to the trunion pin translational reactions R_x, R_y, and R_z by the equations in Figs. 7 and 8 (see Section 4).

Check lateral (global Z-direction) reactions at the side supports (joints 7 and 1001) for design load VI. The resulting reactions were in compression, which verified that the tainter gate did in fact make contact with the side pier walls as first assumed in Run 3, step no. 6. If these reactions were in tension, then the lateral restraint at joints 7 and 1001 would have had to be removed and the structure reanalyzed, F, M_a, and M_b recomputed, and load and displacement combinations VI and D6 reformed.

This completes the full analysis of the tainter gate.

The next STRUDL II run is used to CHECK the existing (input) Clarence Cannon Tainter Gate member sizes for satisfaction of the 1970 AISC (9) steel design code. The check is applied to all W-shape, angle-shape, and T-shape members for design load combination I to VII forces.

It should be noted that CHECK'ing can only be performed for member elements whose properties are represented by TABLE section sizes.

Before proceeding, it must be pointed out that a STRUDL II Design/Check difficulty exists which cannot be overcome in certain special circumstances. Consider the strut members 103 to 111, and 1103 to 1111 in Fig. 4. These members have lateral bracing at their ends for buckling considerations about their local y-axes (minor axis), but no lateral support, except at the trunion pin ends (joints 38 and 1038 in Fig. 4) of members 103, 106, 109, 1103, 1106, and 1109, and the skin plate ends of members 105, 108, 111, 1105, 1108, and 1111 for buckling considerations about their local z-axes (major axis). For example, members 103, 105, and 106 must be considered as three separate members when computing their minor axis buckling characteristics, but must be considered as one long member when computing their major axis buckling characteristics. Part of the problem may be accounted for by specifying an unbraced buckling length equal to the three-member length (see the 'LZ' parameter input in Run 6) for local z-axis buckling, while the local y-axis unbraced buckling length is allowed to be the actual length of each of the three members respectively. Now, the computation of C_m and C_b factors depend on the value of member end-moments. For the z-axis buckling, these moments should be at the ends of the three member length, i.e. at the trunion pin end and skin plate end, but modified for the presence of the gussett plates. However, STRUDL II only uses end moments at the real member ends, i.e. at the joints the member connects. Therefore, the C_m and C_b factors are not computed correctly for the strut members. Consequently, for these strut members, STRUDL can only be used to generate a code design or check which is approximate, but which must be verified using a more accurate hand check that accounts for the multi-member length for buckling about the local z-axis more correctly.

It should also be noted that gussett plates exist at the trunion pin and skin plate ends of the strut members 103 to 111. This reduces the unbraced length about the local z-axis by 2 feet at the skin plate end, and reduces the unbraced length about the local y-axis by 4 feet at the trunion pin ends. In addition, stress calculations for member design or checking should not be performed in the gussett plate regions. The SECTION command is used to control this.

In all cases, the member eccentricity effect is also included in the unbraced length calculation.

- -

Run 6: Restore the SAVE'd Run 5 file 'GATE/CK1' by,

STRUDL RESTORE 'GATE/CK1'

(1) In order to check members by the 1970 AISC code, certain design information is required, while other information is optional. This information, referred to as PARAMETERS, is described in References (3) and (4). PARAMETER values specified for this design CHECK were:

(a) 'CODE' 'SP69' ALL, the 1970 AISC code was requested.

(b) 'FYLD' 50.0 ALL, yield stress for all members.

(c) 'UNLCF' 0.0 MEMBERS 49 TO 102, 1049 TO 1102, unsupported length of compression flange = 0.0 for skin plate stiffening ribs.

(d) 'KY' 1.0 ALL BUT 1.2 MEMBERS 10 TO 39, 1010 TO 1039, 103 TO 119, 1103 TO 1119, effective length factors for named members about their local y-axes.

(e) 'KZ' 1.0 ALL BUT 1.2 MEMBERS 10 TO 39, 1010 TO 1039, 103 TO 119, 1103 TO 1119, effective length factors for named members about their local z-axes.

(f) 'LZ' 323.293 103 TO 105, 1103 TO 1105

'LZ' 322.942 106 TO 111, 1106 TO 1111, unbraced length of named members relative to local z-axis buckling and including member eccentricity and gussett plate (at skin plate end) effects on length.

(g) 'LY' 110.204 103,106,109,1103,1106,1109, unbraced length of named members relative to local y-axis buckling and including member eccentricity and gusset plate (at trunion pin end) effects on length.

(h) 'SDSWAYY' 'NO' ALL

'SDSWAYZ' 'NO' ALL BUT 'YES' MEMBERS 103 TO 111,1103 TO 1111,

no sidesway assumed for all members about their local y-axes for C_{my} calculations, and no sidesway assumed for all members about their local z-axes for C_{mz} calculations except for the strut arm members.

(i) 'TRACE' 4 ALL, specifies that only summary information for the critical load condition be printed for each member CHECK'd.

(2) A listing of all current design data was requested. This shows all current values of PARAMETERS, CONSTRAINTS, etc. to be used by the CHECK or SELECT commands.

(3) Print all current member and finite element properties for reference purposes.

(4) Points along members which are to be stress checked are specified by the SECTION command.

(5) Design or checking code specifications is costly on the computer. It is important to request them to be performed only for those loading conditions which are considered to be the design loading conditions. In this case, only design load combinations I to VII (Tables 1 to 6) need be considered. However, loads I to V and VII lead to perfectly symmetrical structural behavior, while load VI leads to unsymmetrical behavior. Therefore, only a symmetrical set of member elements were CHECK'ed for

loads I to V and VII, and all members were checked for load VI. So,

(a) Activate load VI by the LOAD LIST command.

(b) Request a code check on all members.

(c) Activate loads I to V and VII by the LOAD LIST command.

(d) Request a code check on the symmetrical set of members.

(e) Save the current state of the problem solution.

```
SAVE 'GATE/CK2'
```

- -

Review all results.

All members passed the 1970 AISC code check except the skin plate stiffening ribs (WT-shapes). Every stiffening rib member failed the code check. Although the remaining members passed the code check, it was obvious from the critical check conditions that many of these members were overdesigned.

Consequently, the next run will request STRUDL to perform a redesign of all L, W, and WT-shape members in the structure.

- -

Run 7: Restore the SAVE'd Run 6 file 'GATE/CK2' by,

```
STRUDL RESTORE 'GATE/CK2'
```

(1) By successively using the INACTIVE MEMBERS, ACTIVE MEMBERS, and STEEL TAKEOFF commands, the dead weight of the W, L, and WT-shape members are output.

(2) The code check procedures in the previous Run 6 did not require knowledge of the specific section table names, since each member section's name implied the table to which it belonged. However, for design purposes

the table name from which members are to be selected for design is required. Therefore, the PARAMETERS command is given and followed by,

```
'TBLNAM' 'STEELW'  10 TO 39, 1010 TO 1039, 103 TO 119,
     1103 TO 1119 $ W-Shapes
'TBLNAM' 'STEELL' 1 TO 9, 1001 TO 1009  $ L-Shapes
'TBLNAM' 'STEELWT' 49 TO 102, 1049 TO 1102, 541, 601, 10541,
     10601, 120 TO 127, 1120 TO 1122, 1124 TO 1126  $ WT-Shapes
```

(3) Print all current design data showing all current values of PARAMETERS, CONSTRAINTS, etc. to be used by the SELECT commands following.

(4) Since design load combination VI is not symmetrical, all members are designed for it. So, activate load VI using the LOAD LIST command, and then request design for all W-shape, L-shape, and WT-shape members respectively using the SELECT MEMBERS command. It should be noted that it is advised to design all the members of one shape before designing the members of another shape. This avoids continually changing tables each time a member is selected which would be very inefficient. Also note that the words 'COMBINED' and 'BEAM' only refer to the method used to select the starting section in a table for design purposes. They do not affect which code formulae are checked during the design which is instead a function of the state of the forces, etc. on a member.

(5) Following design, all member properties are output.

(6) The new dead weight of the designed members are output.

(7) All members must now be designed for the symmetrical design loads. So, activate design loads 'I', 'II', 'III', 'IV', 'V', and 'VII' using the LOAD LIST command, and then request design only for 1/2 of the

W, L, and WT-shape members on one symmetrical side of the structure, as well as the two WT shape members in the skin bracing system on the axis of symmetry, using the SELECT MEMBERS command successively.

(8) Output all member properties.

(9) The new dead weight of the designed members are output.

(10) All members are activated.

(11) Save the current state of the problem solution.

```
SAVE 'GATE/CK1'
```

Review all results.

As discussed in Section 4, most members designed are different in size within any group of sections (i.e. W, L, or WT-shape sections). This is not a cost effective specification for construction purposes. Consequently, it is necessary to impose certain constraints on the sizes to make them more uniform in size. Certain members were easy to adjust by inspection. These included all L-shape members, WT-shape members, and W-shape lacing members between the strut arms. However, the W-shape members in the horizontal girders had to be redesigned (Run 8) to satisfy an additional constraint on their nominal depths. By inspection, it was decided that the strut arms should be constrained to W14 shapes, and the horizontal girders should be constrained to W21 shapes (this could be smaller, but skin plate displacements were estimated to be too high if a smaller nominal depth than 21 inches were selected). Note that this could not be accomplished in the first design cycle (Run 7), since it was not known what depth members would be initially selected by the design procedures.

Now, in order to constrain the horizontal girder and strut arm member depths to W21 and W14 shapes, two procedures may be followed. The first involves specifying member depth constraints using the MEMBER CONSTRAINTS command to constrain the 'INT/YD' parameter (Reference 4, page 90) to be less than 20.0 in and greater than 19 in. for the W21 shape, and less than 13.5 in. and greater than 12.0 in. for the W14 shape. There is a potential danger in doing this, however. The problem emerges when STRUDL selects an initial trial section in a section table which has a depth larger than the depth constraint bounds. Since STRUDL only increments sections up the section table (to a larger size), it may not be able to satisfy the depth constraint. To avoid this situation, it is advised to use the second procedure to constrain depth.

The second procedure involves using the TABLE I subsystem to build new section tables that contain those sections which satisfy any specified constraint, such as nominal depth. This is done in the next Run by building two tables called 'W21' and 'W14'. There are several ways of doing this, as described in detail in Reference 4, pages 135-137. Example B.4 on page 137 of Reference 4 is followed herein. Note that at the end of the next Run, these two tables are deleted with the QDELETE command.

- -

Run 8: Build new section tables, and restore SAVE'd Run 7 file 'GATE/CK1' to continue design. First, build the new tables by,

```
TABLE 'W21/W14'
```

(1) Transfer all W21 sections from table 'STEELW' to table 'W21'

on the DD1 user data set (see STRUDL JCL in Appendix F).

(2) Order table 'W21' as required by STRUDL.

(3) Transfer all W14 sections from table 'STEELW' to table 'W14' on the DD1 user data set.

(4) Order table 'W14' as required by STRUDL.

(5) List tables 'W21' and 'W14'.

Now, restore Run 7 file 'GATE/CK1' by,

STRUDL RESTORE 'GATE/CK1'

(1) Output the current weight of the skin plate L-shape members, the skin plate WT-shape stiffening ribs, the skin plate WT-shape bracing members, the horizontal girder W-shape members, and the strut W-shape members on a symmetrical side of the frame, as well as the two skin plate WT-shape bracing members on the axis of symmetry.

(2) In the CHANGES mode, change the table names to 'W21' for members 10 to 39, and to 'W14' for members 103 to 111, and change the member section sizes for those members which were modified by inspection of the Run 7 design results. Return to ADDITIONS mode. Print all design data (PARAMETERS, CONSTRAINTS, etc.).

(3) Since the design results from Run 7 indicate that design load VI did not control any member design, only design loads 'I', 'II', 'III', 'IV', 'V', and 'VII' are activated by the LOAD LIST command.

(4) Request design of the horizontal girders (10 to 39) and strut arms (103 to 111).

(5) Modify the newly designed members, and their symmetrical counterparts, to impose size uniformity within any one horizontal girder or any one strut arm.

(6) Print all member properties to verify that all members are of the desired section sizes.

(7) Output the current dead weight of all L, WT, and W-shape members.

(8) Activate all members.

(9) Save the current state of the problem solution.

```
SAVE 'GATE/CK2'
```

(10) Delete temporary section tables 'W21' and 'W14'.

Review all results. Section 4 presents an evaluation of the results.

All designed members and their symmetric counterparts have new section sizes. If a reanalysis were desired based on the new sizes, all that is required is to repeat Run Numbers 2 through 5. Then, the existing member sizes can be checked based on the new analysis results by repeating Run Number 6.

This concludes the description of the complete recommended analysis and design procedure for tainter gates using ICES STRUDL II.

4. INTERPRETATION AND EVALUATION OF RESULTS

4.1 Verify Cable Force and Trunion Pin Friction Moment Effect

The reactions for design load combinations II, V, and VI (Table 6) include the cable force and trunion pin friction moments which must be consistent with the special superposition equations shown in Figs. 7 and 8. It is of interest to verify that this is in fact true.

4.1.1 F and M Check for 2-Cable Load Combination II

Load Combination II is a symmetrical case, so only the reactions at joints 'S1' and 38 need be checked. At joint 'S1' the reaction components output by STRUDL are,

$$R_{X,S1} = 16.405 \text{ K.}$$

$$R_{Y,S1} = 24.930 \text{ K.}$$

$$R_{Z,S1} = 0.0 \text{ K.}$$

Since load II has a load factor 1.2 applied to it, the cable force $F_{C,II}$, used to compare to F_{II} computed by program XFTWO for this case, is the resultant of $R_{X,S1}$, $R_{Y,S1}$, and $R_{Z,S1}$ all divided by 1.2. So,

$$\begin{aligned} F_{C,II} &= \sqrt{R^2_{X,S1} + R^2_{Y,S1} + R^2_{Z,S1}}\ /1.2 \\ &= \sqrt{(16.405)^2 + (24.930)^2 + 0^2}\ /1.2 \\ &= 29.843/1.2 \\ &= 24.870 \text{ K.} \end{aligned}$$

The cable force computed by XFTWO for Load II, F_{II}, following STRUDL Run 4 (Section 3.3) was,

$$F_{II} = 24.871 \text{ K.}$$

Since $F_{C,II} = F_{II}$, the result is consistent.

At trunion pin joint 38, the translation reaction components output by STRUDL are,

$$R_{X,38} = 520.600 \text{ K.}$$

$$R_{Y,38} = -251.628 \text{ K.}$$

$$R_{Z,38} = 106.412 \text{ K.}$$

In addition, the moment about the global Z-axis, i.e. the trunion pin friction moment, output is,

$$M_{Z,38} = 70.080 \text{ K-ft, Anti-clockwise}$$

These results must also be divided by the load factor 1.2 before comparing to the trunion pin friction moment M computed by program XFTWO. So,

$$R_{X,II} = R_{X,38}/1.2 = 433.833 \text{ K.}$$

$$R_{Y,II} = R_{Y,38}/1.2 = -209.690 \text{ K.}$$

$$R_{Z,II} = R_{Z,38}/1.2 = 88.677 \text{ K.}$$

$$M_{P,II} = M_{Z,38}/1.2 = 58.400 \text{ K-ft, Anti-clockwise}$$

According to Fig. 7, the trunion pin friction moment, M, must be related to $R_{X,II}$, $R_{Y,II}$, and $R_{Z,II}$ by,

$$M = f\sqrt{R_{X,II}^2 + R_{Y,II}^2} + g|R_{Z,II}|$$

where $f = 0.7854\mu_t r_p$, $g = \mu_t r_p$, $\mu_t = 0.3$, $r_p = 0.41667$ ft. So,

$$\begin{aligned} M &= 0.098167\sqrt{(433.833)^2 + (-209.690)^2} + 0.1250|88.677| \\ &= 47.302 + 11.085 \\ &= 58.387 \text{ K-ft, Anti-clockwise} \end{aligned}$$

Since $M \simeq M_{P,II} = 58.400$ K-ft, and also since XFTWO computed $M = 58.400$ K-ft following Run 4 (Section 3.3), then the result is consistent.

4.1.2 F and M Check for 2-Cable Load Combination V

Load Combination V is also symmetrical, so only the reactions at joints 'S1' and 38 need be checked where the STRUDL reaction components at joint 'S1' are,

$$R_{X,S1} = 5.553 \text{ K.}$$

$$R_{Y,S1} = 8.438 \text{ K.}$$

$$R_{Z,S1} = 0.0 \text{ K.}$$

The load factor applied to load V which must be divided out for comparison purposes is 1.2 x 0.75. So,

$$\begin{aligned} F_{C,V} &= \sqrt{R^2_{X,S1} + R^2_{Y,S1} + R^2_{Z,S1}}\ /(1.2 \times 0.75) \\ &= \sqrt{(5.553)^2 + (8.438)^2 + 0^2}\ /(1.2 \times 0.75) \\ &= 10.101/(1.2 \times 0.75) \\ &= 11.224 \text{ K.} \end{aligned}$$

The cable force computed by XFTWO for load V, F_V, following STRUDL Run 4 was,

$$F_V = 11.226 \text{ K.}$$

Since $F_{C,V} = F_V$, the result is consistent.

At trunion pin joint 38, the translation reaction components, and global Z-axis moment (trunion pin friction moment), output by STRUDL were,

$$R_{X,38} = 405.431 \text{ K.}$$

$$R_{Y,38} = -161.498 \text{ K.}$$

$$R_{Z,38} = 81.708 \text{ K.}$$

$$M_{Z,38} = 53.066 \text{ K-ft, Anti-clockwise}$$

These results must also be divided by the load factor 1.2 x 0.75. So,

$$R_{X,V} = R_{X,38}/(1.2 \times 0.75) = 450.479 \text{ K.}$$

$$R_{Y,V} = R_{Y,38}/(1.2 \times 0.75) = -179.442 \text{ K.}$$

$$R_{Z,V} = R_{Z,38}/(1.2 \times 0.75) = 90.787 \text{ K.}$$

$$M_{P,V} = M_{Z,38}/(1.2 \times 0.75) = 58.962 \text{ K-ft, Anti-clockwise}$$

But the trunion pin friction moment M must be,

$$M = 0.098167\sqrt{(450.479)^2 + (-179.442)^2} + 0.1250|90.787|$$

$$= 47.601 + 11.348$$

$$= 58.950 \text{ K-ft, Anti-clockwise}$$

Since $M \simeq M_{P,V} = 58.962$, and also since XFTWO computed M = 58.963 K-ft following Run 4, then the result is consistent.

4.1.3 F, M_a, and M_b Check for 1-Cable Load Combination VI

Load Combination VI with side wall constraints (Table 6) is unsymmetrical, so the reactions at joints 'S1', 38, and 1038 need to be checked. At joint 'S1' the reaction components output by STRUDL are,

$$R_{X,S1} = 21.928 \text{ K.}$$

$$R_{Y,S1} = 33.324 \text{ K.}$$

$$R_{Z,S1} = 0.0 \text{ K.}$$

The load factor applied to load VI is 1.2 x 0.6667. So,

$$F_{C,VI} = \sqrt{R_{X,S1}^2 + R_{Y,S1}^2 + R_{Z,S1}^2}\ /(1.2 \times 0.6667)$$

$$= \sqrt{(21.928)^2 + (33.324)^2 + 0^2}\ /(1.2 \times 0.6667)$$

$$= 39.891/(1.2 \times 0.6667)$$

$$= 49.862 \text{ K.}$$

The cable force computed by XFONE for load VI following Run 4 was,

$$F_{VI} = 49.879 \text{ K.}$$

Since $F_{C,VI} \simeq F_{VI}$, the result is consistent.

At trunion pin joints 38 and 1038, the translational reaction components and global Z-axis moment (trunion pin friction moments) output by STRUDL were,

$R_{X,38} = 359.154$ K.

$R_{Y,38} = -172.186$ K.

$R_{Z,38} = 74.103$ K.

$M_{Z,38} = 48.362$ K-ft, Anti-clockwise

$R_{X,1038} = 335.025$ K.

$R_{Y,1038} = -163.328$ K.

$R_{Z,1038} = -67.758$ K.

$M_{Z,1038} = 45.058$ K-ft, Anti-clockwise

These results must also be divided by the load factor 1.2 x 0.6667.

So,

$R_{X,VI,38} = R_{X,38}/(1.2 \times 0.6667) = 448.920$ K.

$R_{Y,VI,38} = R_{Y,38}/(1.2 \times 0.6667) = -215.222$ K.

$R_{Z,VI,38} = R_{Z,38}/(1.2 \times 0.6667) = 92.624$ K.

$M_{P,VI,a} = M_{Z,38}/(1.2 \times 0.6667) = 60.449$ K-ft, Anti-clockwise

and,

$R_{X,VI,1038} = R_{X,1038}/(1.2 \times 0.6667) = 418.760$ K.

$R_{Y,VI,1038} = R_{Y,1038}/(1.2 \times 0.6667) = -204.150$ K.

$R_{Z,VI,1038} = R_{Z,1038}/(1.2 \times 0.6667) = -84.693$ K.

$M_{P,VI,b} = M_{Z,1038}/(1.2 \times 0.6667) = 56.320$ K-ft, Anti-clockwise

But the trunion pin friction moments M_a and M_b must be,

$$M_a = .098167\sqrt{(448.920)^2 + (-215.222)^2} + 0.1250|92.624|$$

$$= 48.872 + 11.578$$

$$= 60.450 \text{ K-ft, Anti-clockwise}$$

$$M_b = 0.098167\sqrt{(418.760)^2 + (-204.150)^2} + 0.1250|-84.693|$$

$$= 45.733 + 10.587$$

$$= 56.320 \text{ K-ft, Anti-clockwise}$$

Since $M_a = M_{P,VI,a} = 60.449$ K-ft, and $M_b = M_{P,VI,b} = 56.320$ K-ft, and also since XFONE computed $M_a = 60.453$ K-ft and $M_b = 56.323$ K-ft following Run 4, then the results are consistent.

4.2 Final Trunion Pin Reactions

As was noted in Eqs. (3) and (4), the trunion pin friction moment is also associated with a resultant force, $P_{y'}$, acting in a direction perpendicular to the resultant of the trunion pin reaction components R_X and R_Y, and is equal to,

$$P_{y'} = \mu_t \frac{2}{3}\sqrt{R_X^2 + R_Y^2}$$

where $\mu_t = 0.3$ for the gate under consideration. So,

$$P_{y'} = 0.2\sqrt{R_X^2 + R_Y^2}$$

Now, using reaction components R_X and R_Y with the load factors divided out, the value of $P_{y'}$ for load cases II, V, and VI are,

$$P_{y',II} = .2\sqrt{(433.833)^2 + (-209.690)^2}$$
$$= 96.370 \text{ K.}$$

$$P_{y',V} = .2\sqrt{(450.479)^2 + (-179.442)^2}$$
$$= 96.981 \text{ K.}$$

$$P_{y',VI,38} = .2\sqrt{(448.920)^2 + (-215.222)^2}$$
$$= 99.569 \text{ K.}$$

$$P_{y',VI,1038} = .2\sqrt{(418.760)^2 + (-204.150)^2}$$
$$= 93.174 \text{ K.}$$

So, the final trunion pin reaction components consist of R_X, R_Y, R_Z, M, and $P_{y'}$ acting in a direction perpendicular to the resultant reaction $R = \sqrt{R_X^2 + R_Y^2}$.

4.3 STRUDL II Design/Check Difficulty

A difficulty exists which cannot be overcome in certain special situations. Consider the strut members 103 to 111, and 1103 to 1111 in Fig. 4. These members have lateral bracing at their ends for buckling considerations about their local Y-axes (minor axis), but no lateral support, except at the trunion pin ends (joints 38 and 1038 in Fig. 4) of members 103, 106, 109, 1103, 1106, and 1109, and the skin plate ends of members 105, 108, 111, 1105, 1108, and 1111 for buckling considerations about their local Z-axes (major axis). For example, members 103, 105, and 106 must be considered as three separate members when computing their minor axis buckling characteristics, but must be considered as one long member when computing their major axis buckling characteristics. Part of the problem may be accounted for by specifying an unbraced buckling length equal to the three member length (see 'LZ' parameter input in Run 6) for local Z-axis buckling. However, the computation of C_m and C_b factors depend on the value of member end-moments. For the Z-axis buckling, these moments should be at the ends of the three member length, i.e. at the trunion pin end and skin plate end. However, STRUDL II uses end moments at the real member ends, i.e. at the joints the member connects. Therefore, the C_m and C_b factors are not computed correctly for the strut members. Consequently, for these strut members, STRUDL can only be used to generate a code design or check which is approximate, but which must be verified using a more accurate hand check that accounts for the multi-member length for buckling about the local Z-axis.

Another problem with the struts is that there is a large gussett plate at the trunion pin end of the strut members. Consequently, checking or designing the strut members for moments and shears at the trunion pin end is too conservative. Strut sections should not be checked any closer to the trunion pin than at the edge of the gussett plates. This was specified by the SECTION command given in Run 6.

4.4 STRUDL II SAVE/RESTORE Commands

The STRUDL II SAVE/RESTORE feature is non-destructive. That is to say, if during a run which has been RESTORE'd, the computer goes down, or some command causes a premature termination prior to the next SAVE, the run that was RESTORE'd from is not destroyed and may be RESTORE'd again.

Furthermore, in the STRUDL runs described in Section 3 and listed in Appendix E, two SAVE file names were alternately used, 'GATE/CK1' and 'GATE/CK2'. The utility of this approach is best demonstrated by a simple example. Suppose a STRUDL run is SAVE'd using file name 'GATE/CK1'. The next run RESTORE'd 'GATE/CK1', executes, and SAVE's using file name 'GATE/CK2'. Now, the review of the last run determines certain errors which produced erroneous results. It is desired to rerun this last run, with the errors removed. All that is required is to RESTORE 'GATE/CK1' and execute again, but this time with the command errors corrected.

Although this procedure is not necessary, it is considered to be more convenient for the type of analysis and design procedures described herein.

4.5 CHECK/DESIGN Results

Following the complete analysis of the tainter gate in Run 5, STRUDL II was used to check the starting member sizes for satisfaction of the 1970 AISC (9) steel design code. The check was performed in Run 6 as described in Section 3.

All L and W shape members and WT-shape skin plate bracing members satisfied the code check, and, in fact, were shown to be very oversized in many cases. On the other hand, all WT-shape skin plate stiffening ribs failed the code check, and many by a considerable amount[2]. The total dead weight of the starting member L, WT, and W-shapes was 33.066 Kips (L-shapes = 0.494 Kips, WT-shapes = 11.763 Kips, and W-shapes = 20.809 Kips).

In Run 7, all L, WT, and W-shape members were designed by STRUDL for all seven design load combinations. The results of these designs are shown in Tables 8, 9, 10, 11, and 12. The unsymmetrical design load VI did not control the design of any member. In fact only design loads I, II, IV, and V were effective in controlling the design of all the members. The total dead weight of the designed members was 27.798 Kips (L-shapes = 0.182 Kips, WT-shapes = 14.020 Kips[2], and W-shapes = 13.594 Kips).

The L-shape members decreased in size by 0.312 Kips (63.2% reduction). The WT-shape members increased in size by 2.257 Kips (19.2% increase)[2]. The W-shape members decreased in size by 7.215 Kips (34.7% decrease). Finally, the total L, WT, and W-shape member weight decreased by 5.268 Kips or a 15.9% reduction in total weight.

Although this seems to be a substantial weight reduction, it is not realistic since there were many different section sizes selected with little uniformity. However, lack of uniformity is not cost effective from a fabrication and construction point of view. Consequently, STRUDL Run 8 was executed to provide for more uniformity in the W-shape horizontal girders, and the W-shape strut arm members. Uniformity and final design of the remaining members was provided either by inspection of the Run 7 design results, or by Appendix I hand design in the case of the WT-shape skin plate stiffeneing ribs.

---

[2] See Appendix I for further clarification of this eroneous result for the WT-shape skin plate stiffening ribs.

TABLE 8

Results of L-Shape Skin Plate Top Member Design
(Design is Symmetrical)

Member	Initial Size	STRUDL Design	Critical Condition	Final Selected Design Size *
1	L8x4x7/16	L3½x2½x¼	V	L6x3½x¼
2	do	L3½x2½x¼	IV	do
3	do	L3x2½x¼	IV	do
4	do	L4x3x¼	IV	do
5	do	L5x3½x¼	IV	do
6	do	L6x3½x¼	IV	do
7	do	L6x3½x¼	IV	do
8	do	L5x3½x¼	IV	do
9	do	L6x3½x¼	IV	do

* All L-shape skin plate members at top of skin plate the same size.

TABLE 9

Results of WT-Shape Skin Plate Stiffening Rib Design
(Design is Symmetrical)

Member	Initial Size	STRUDL Design *	Critical Condition	Final Selected Design Size **
49	WT7x17	WT9x20	V	WT7x17
50	do	WT9x17	V	do
51	do	WT9x17	II	do
52	do	WT9x20	II	do
53	do	WT10x22	I	do
54	do	WT9x17	I	do
541	do	WT6x11	I	do
55	do	WT10x22	V	do
56	do	WT9x17	V	do
57	do	WT9x17	II	do
58	do	WT10x22	II	do
59	do	WT10x22	I	do
60	do	WT10x22	I	do
601	do	WT6x9	I	do
61	do	WT10x24	V	do
62	do	WT9x20	V	do
63	do	WT9x20	II	do
64	do	WT10x22	II	do
65	do	WT10x22	I	do

Member	Initial Size	STRUDL Design *	Critical Condition	Final Selected Design Size **
66	do	WT10x22	I	do
67	do	WT12x27	IV	do
68	do	WT9x17	V	do
69	do	WT10x22	II	do
70	do	WT10x24	II	do
71	do	WT10x24	I	do
72	do	WT10x22	I	do
73	do	WT12x27	IV	do
74	do	WT10x22	V	do
75	do	WT10x22	II	do
76	do	WT10x24	II	do
77	do	WT10x24	II	do
78	WT7x17	WT10x24	I	WT7x17
79	WT7x15	WT10x27	V	WT7x15
80	do	WT10x22	V	do
81	do	WT10x22	II	do
82	do	WT10x22	II	do
83	do	WT10x22	I	do
84	do	WT10x22	I	do
85	do	WT10x24	V	do
86	do	WT10x22	V	do
87	do	WT10x22	II	do
88	do	WT10x22	II	do
89	do	WT10x22	II	do

Member	Inital Size	STRUDL Design *	Critical Condition	Final Selected Design Size **
90	do	WT10x22	I	do
91	do	WT10x24	V	do
92	do	WT10x22	V	do
93	do	WT9x20	II	do
94	do	WT10x22	II	do
95	do	WT10x22	II	do
96	do	WT10x22	I	do
97	do	WT10x24	V	do
98	do	WT10x22	V	do
99	do	WT9x20	II	do
100	do	WT10x22	II	do
101	do	WT10x22	II	do
102	WT7x15	WT9x20	I	WT7x15

---

* Based on STRUDL II design of the WT-shape skin plate stiffening ribs acting non-compositely with the skin plate.

** Based on Appendix I hand design of skin plate stiffening ribs acting compositely with the skin plate. Also, size uniformity retained for cost-effective design.

TABLE 10

Results of WT-Shape Skin Plate Bracing Design
(Design is Symmetrical)

Member	Initial Size	STRUDL Design	Critical Condition	Final Selected Design Size *
120	WT7x11	WT3x4	SLNDRNSS	WT4x5
121	do	WT3x4	do	do
122	do	WT3x4	do	do
123	do	WT3x4	do	do
124	do	WT3x4	do	do
125	do	WT3x4	TENSION	do
126	do	WT3x4	SLNDRNSS	do
127	do	WT4x5	TENSION	do

*All skin plate bracing members the same size.

TABLE 11

Results of W-Shape Horizontal Girder Design in Skin Plate
(Design is Symmetrical)

Member	Initial Size	STRUDL Design	Critical Condition	Final Selected Design Size *
10	W24x55	W6x8	II	W21x49
11	do	W12x19	V	do
12	do	W14x26	V	do
13	do	W12x40	V	do
14	do	W14x38	V	do
15	do	W12x31	V	do
16	do	W12x19	V	do
17	do	W12x16	IV	do
18	do	W12x19	IV	do
19	do	W12x16	IV	do
20	W24x76	W10x11	II	W21x62
21	do	W14x26	II	do
22	do	W14x43	II	do
23	do	W21x55	II	do
24	do	W24x61	II	do
25	do	W21x49	II	do
26	do	W14x30	II	do
27	do	W14x22	I	do
28	do	W14x26	I	do
29	do	W14x22	I	do

Member	Initial Size	STRUDL Design	Critical Condition	Final Selected Design Size *
30	do	W12x14	II	W21x68
31	do	W14x30	I	do
32	do	W18x45	II	do
33	do	W24x68	II	do
34	do	W24x68	II	do
35	do	W21x55	I	do
36	do	W18x35	I	do
37	do	W14x34	II	do
38	do	W18x35	II	do
39	do	W14x38	II	do

*Main horizontal girders (Fig. 2) selected so that same section size in any one level, but all three levels have the same nominal depth (W21) members.

TABLE 12

Results of W-Shape Strut Member Design
(Design is Symmetrical)

Member	Initial Size	STRUDL Design	Critical Condition	Final Selected Design Size *
103	W14x43	W14x38	V	W14x43
104	do	W12x40	V	do
105	do	W12x40	V	do
106	W14x78	W12x53	II	W14x61
107	do	W14x48	II	do
108	do	W21x55	II	do
109	do	W14x61	II	W14x68
110	do	W14x68	II	do
111	do	W18x60	I	do
112	W14x22	W6x8	II	W6x15
113	do	W6x8	II	do
114	do	W6x15	II	do
115	do	W6x15	SLNDRNSS	do
116	do	W6x8	do	do
117	do	W6x8	do	do
118	do	W6x15	do	do
119	do	W4x13	do	do

* To provide cost-effective section size uniformity.

Tables 8, 9, 10, 11, and 12 also summarize the final selected member sizes. The final dead weight of all L, WT, and W-shape members was 28.325 Kips (L-shapes = 0.225 Kips, WT-shapes = 10.656 Kips, and W-shapes = 17.444 Kips).

Compared to the original starting member sizes, the final design results changed as follows. The L-shape members decreased in size by 0.269 Kips (54.5% reduction). The WT-shape members decreased in size by 1.107 Kips (9.4% decrease). The W-shape members decreased in size by 3.365 Kips (16.2% decrease). Finally, the total L, WT, and W-shape member weight decreased by 4.741 Kips or a 14.3% decrease in total weight compared to the original starting member weight.

Weight results are summarized in Table 13.

4.6 Summary of Computer Costs

All computer runs were made on the computer facilities of the McDonnell Automation Co., St. Louis, Missouri.

Table 14 summarizes the cost for each STRUDL II run as well as the total cost for the recommended STRUDL II tainter gate analysis and design procedure. It should be noted that the structure analyzed and designed was a space structure with 161 joints, 262 member elements, 238 plate bending and stretching finite elements, 20 independent loading conditions, 7 design loading combinations for force design, 7 displacement combinations for displacement output, 4 structural analyses, 1 member design code check, and 2 member design cycles, in a total of 8 seperate STRUDL II runs.

The total computer cost was $3,447.

TABLE 13

Steel Dead Weights (Kips)

Shape	Original Sizes	First STRUDL II Design	Final Design
L-Shapes	0.494	0.182 (-63.2%)	0.225 (-54.5%)
WT-Shapes	11.763	14.020 (+19.2%)	10.656 (-9.4%)
W-Shapes	20.809	13.594 (-34.7%)	17.444 (-16.2%)
All L, WT, & W-Shapes	33.066	27.798 (-15.9%)	28.325 (-14.3%)

TABLE 14

Summary of Computer Costs

Run No.	Computer Cost ($)*	STRUDL Fee Unit Surcharge ($)*	Total Cost ($)*
1	246	--	246
2	282	61	343
3	1,129	182	1,311
4	191	--	191
5	605	--	605
6	225	26	251
7	276	72	348
8	144	8	152
TOTAL =	$3,098	$349	$3,447

*Rounded to the nearest dollar.

Space Frame: 161 joints
262 member elements
238 finite elements
20 independent loading conditions
7 design force combinations
7 displacement combinations
4 structural analyses
1 member design code check
2 member 1970 AISC Code design cycles
8 STRUDL II runs

5. SPECIAL ANALYSIS PROCEDURES

It is of interest to note how two special analysis procedures may be executed in STRUDL for tainter gate analysis. One is associated with temperature loadings, and the other is associated with a more refined finite element analysis in regions of high stress.

5.1 Temperature Problems

Two types of temperature effects may be accounted for in STRUDL. One is associated with temperature that causes pure axial strain in a member or finite element. This is due to a temperature change at the centroidal axis position of members, or midsurface plane of finite elements. The other is associated with a pure bending strain caused by a linear temperature variation from one side to another of a member element with zero temperature change at the centroidal axis, or from one face to another of a finite element with zero temperature change at the midsurface plane.

These may be included in any loading condition using the MEMBER TEMPERATURE LOADS command (2) for member elements, and the ELEMENT TEMPERATURE LOADS command (3,4) for finite elements.

5.2 Refined Finite Element Analysis

The finite element grid size used to model the skin plate is good to represent the skin plates' stiffening effect on the tainter gate structure, but is not too good for an accurate computation of the stress distribution in the skin plate. If it were desired to obtain a more accurate representation of the skin plate stresses in certain regions, the following procedures may be followed.

1. Use a much more refined finite element mesh from the start of the analysis. This is considered to be unjustifiably costly, especially since there are satisfactory hand analyses which can be performed for the tainter gate skin plate design(6).

2. If a more refined analysis were desired following a coarse mesh analysis, the region in question may be isolated as a separate structure, a fine finite element mesh established, any required loads applied, and, most importantly, displacement boundary conditions applied along the boundary of the region in question. These displacement boundary conditions are the displacements of the joints along the boundary of the region in question, which were computed in the coarse mesh analysis. This refined analysis should produce more reasonable skin plate stresses.

6. USE OF INTERACTIVE GRAPHICS, FASTDRAW/2

6.1 Introduction

The structural model of the tainter gate shown in Figures 2, 3, and 4 is fairly complex and not very regular. There are four major groupings of members, joints, and finite elements which are the skin plate member elements and joints (Figure 2), the skin plate finite elements and joints (Figure 3), and the strut and bracing members and joints (Figure 4).

The generation of the geometry of the tainter gate may be done in several ways for a STRUDL II Analysis, including (1) specifying all joint coordinates and element incidences in the STRUDL run as is shown in Appendix E, (2) using the automatic generation features of the ICES TOPOLOGY (10) subsystem, and (3) using the automatic generation features of McDonnell Automation's proprietory interactive graphics system FASTDRAW/2 (5).

This section describes how FASTDRAW/2 may be used to both display and generate the geometry of the tainter gate.

6.2 Display Existing Tainter Gate Geometry

The recommended STRUDL analysis and design procedure described in this report specified the geometry of the tainter gate as part of the input commands (Appendix E). In order to display this geometry on an interactive CRT (Cathode Ray Tube) screen using FASTDRAW/2, the following script may be used. It should be noted that more than one procedure to display the tainter gate is possible, as described in the FASTDRAW/2 manual (5), but only one is presented here. It should also be noted that it was not possible to obtain hard copy of the display screen for the following FASTDRAW/2 script. In order to see the results of the commands, this script should be executed at an interactive graphics terminal.

---

(1) The following job is run in a remote batch mode to load the joint coordinate, member incidences, element incidences, and element properties from a STRUDL input deck of cards into a file named "LZESRCE" on the McAuto SIGMA 9 Computer:

```
//name JOB (S,accnt,'LZEGATE/WES'),'name',MSGLEVEL=(1,1),
// LIM=(5,5,10),REGION=60K
//* SIG7sigaccnt   name    filename
//*PROCESS PRINT
//*FORMAT PR,DDNAME=SYSMSG,DEST=termid
//*FORMAT PR,DDNAME=SYSMSG,DEST=SIGB
//*FORMAT PR,DDNAME=DATA,CONTROL=SINGLE,DEST=SIGB
//*DATASET DDNAME=DATA
          STRUDL '___' '___'
          JOINT COORDINATES
                :
          MEMBER INCIDENCES
                :
          ELEMENT INCIDENCES
                :
          ELEMENT PROPERTIES
                :
          FINISH
//*ENDDATASET
//*ENDPROCESS
```

where,

name = your last name but less than or equal to eight alphanumeric characters beginning with an alphabetic character.

accnt = account number for use on the IBM computer assigned by McAuto.

sigaccnt = account number for use on the SIGMA 9 computer assigned by McAuto.

filename = file name which stores the STRUDL geometry data source (LZESRCE as described herein).

termid = terminal ID of the remote batch terminal from which the STRUDL source data is submitted.

This job will return a message to the remote batch terminal indicating no EXEC card used, and job not submitted to MAIN. This is normal, as the job was submitted to the SIGMA 9, not the IBM.

(2) The SIGMA 9 Computer is now dialed (1-800-325-8037) from an interactive graphics terminal, such as a Tektronix 4014 (large screen), and the terminal is loged on with:

Username, Usernumber, Password where Usernumber and Password are assigned by McAuto, and Usernumber is the same as sigaccnt used in step (1) above.

Now, in what follows, the characters #, *, >, and : are prompt characters requesting a user response.

---

(2) #CAT list the catalog of file names fo Usernumber.

(3) #OLD LZESRCE reference existing STRUDL source file generated from batch mode in Step (1) above.

(4) #EDIT enter the Edit mode.

(5) *FTO-9999,/STRUDL/ find and display the line where the string "STRUDL" appears.

n STRUDL ..... will appear where n is the line number.

(6) *DEO-m delete all information (JCL, etc.) on file from lines 0 to m where m=n-1.

(7) FTO-9999,/FINISH/ find and display the line where the string "FINISH" appears.

i FINISH will appear.

(8) *DEj-9999 delete all information on file from line j=i+1 to end of file line ≤ 9999.

(9) *END exit EDIT

(10) #SAVE file LZESRCE now only contains STRUDL source from the command STRUDL to the command FINISH inclusive.

(11) #FAS2 request entry into FASTDRAW/2.

(12) *BUILD GTEM FROM LZESRCE build the FASTDRAW model file name GTEM from existing STRUDL file LZESRCE

(13) :STRUDL response to "LANGUAGE" prompt indicating file LZESRCE is in STRUDL language.

(14) >TER request that any errors detected be displayed on CRT terminal

(15) *END exit FASTDRAW/2.

(16) #BYE log off.

At any future time, we may sign on again and use FASTDRAW/2 STRUDL model file "GTEM" to display the STRUDL model. Note that there are a large number of ways in which display may be made. See FASTDRAW/2 (5) manual for more details.

(17) Dial SIGMA 9 and Log on as in Step (2).

(18) #FAS2 request entry into FASTDRAW/2

(19) *USE GTEM requests FASTDRAW/2 to use existing file GTEM as the model file.

(20) *DISPLAY enter DISPLAY mode. Model file can only be displayed, not modified, in this mode. The *APPEND command would be used to modify model.

(21) :T14 terminal code response for a Tektronix 4014 (large screen) interactive graphics terminal.

(22) :NONE response to TABLET CODE prompt indicating no tablet to be used for command input.

(23) :0,0,0 response to request for θ_z, θ_y, and θ_x angles (see Appendix F, p. 87 of FASTDRAW/2 manual (5) for angle definition. The model file GTEM is displayed on the screen.

(24) >REORIENT -20,40,-15 the model file GTEM is displayed now in a new orientation.

(25) >PLANE cursor cross-hairs will appear. Select any three non-colinear points, where the first two points are oriented left to right on bottom of screen. For example, orient cursor over joints 7, 1007 1006, each time hitting any key except the carriage return key. The identified plane is displayed. 2D mode is entered.

(26) >PLANE 7,1007,1006 this will do the same display as in Step (25).

(27) >WINDOW cursor appears. Select any two points on the display. This forms a diagonal of a rectangular boundary on the 2-D display, within which the structure will be enlarged and displayed on the screen. The points selected do not have to be on the structure itself.

(28) >PAN slide the window over the current image. With cursor, select

one new point on plane displayed in Step (27), and this becomes the new center of a window for the display of Step (26). This point does not have to be on structure.

(29) >3D request 3-D mode.

(30) :0,90,0 model file GTEM is displayed. If this is not desired, hit the BREAK key.

(31) >DRAW E(201-314,1201-1314,2111,2112,2122,2121,12111,12112,12121, 12122) only the finite element skin plate elements named are displayed.

(32) >FULL the model begins being displayed. Hit BREAK key to stop.

(33) >REORIENT 0,0,0 the model begins being displayed. Hit BREAK key to stop.

(34) >DRAW M(103-119) only member elements 103 to 119 in strut are displayed.

(35) >DRAW M(1103-1119) members 1103-1119 in the other strut are displayed.

(36) >FULL as display begins, hit BREAK key.

(37) >REORIENT -20,40,-15 as display begins, hit BREAK key.

(38) >DRAW M(103-119,1103-1119) both struts are drawn.

(39) >END exit DISPLAY mode entered in Step (20).

(40) *END exit FASTDRAW/2 mode.

(41) #BYE Log Off.

There are many other options for displaying the model file. Refer to the FASTDRAW/2 Manual (5) for these options.

6.3 Create New Tainter Gate Geometry

Section 6.2 described a procedure to display the tainter gate geometry which was first prepared in card form for a STRUDL analysis, and then read into the SIGMA 9 computer at McAuto for processing by FASTDRAW/2. This Section describes how to create the tainter gate geometry directly using FASTDRAW/2 from a Tektronix 4014 interactive CRT graphics terminal, using the script of commands presented below. Unfortunately, during the preparation of this script, it was not possible to obtain a hard copy of the images which appeared on the CRT screen. However, if this script is followed, it would be obvious to the user the process being executed and the prompts displayed by FASTDRAW/2 which require user response.

---

(1) The SIGMA 9 computer is dialed, 1-800-325-8037, from an interactive graphics terminal, such as a Tektronix 4014 (large screen), and the terminal is Loged On with:

Username, Usernumber, Password

where Usernumber and Password are assigned by McAuto.

Now, in what follows, the characters #, *, >, and : are prompt characters requesting a user response. Sometimes they are preceeded by a prompt message. When the user runs the following script, these will be obvious. Also, a blank space or a comma may be used to separate input data.

It is important that the user have a copy of the FASTDRAW/2 (5) User Manual readily accessible as he proceeds through the script. It is also advised that the user first become familiar with terminal operation and

FASTDRAW/2 by displaying a more simple structure than the tainter gate and following the script outlined in Section 6.2.

When the cursor, cross-hairs, appear on the screen, they may be used to select points on the screen depending on which FASTDRAW/2 command is being used. After the cursor is positioned at a point, indicate this point by touching any key on the keyboard <u>except</u> the carriage return key. To exit the cursor mode, hit the carriage return key.

---

(2) #CAT list the catalog of file names for Usernumber.

(3) #FAS2 request entry into FASTDRAW/2.

Now the first model file to be created will consist of all joints in the skin plate and cable support points as shown in Fig. 10. Note that the joint and element names in Figs. 10, 11, and 12 correspond to the original joint names used in the actual STRUDL analysis (Aypendix E). However, FASTDRAW/2 currently assigns its own joint and element names as they are created. The user, at present, cannot modify these labels. Although this is a serious disadvantage of FASTDRAW/2, it is the author's understanding that the capability to modify labels consistent with the user's desires will be available in the near future. In what follows, the word "original" will refer to the labels in Figs. 10, 11, and 12, while FASTDRAW/2 labels will be different.

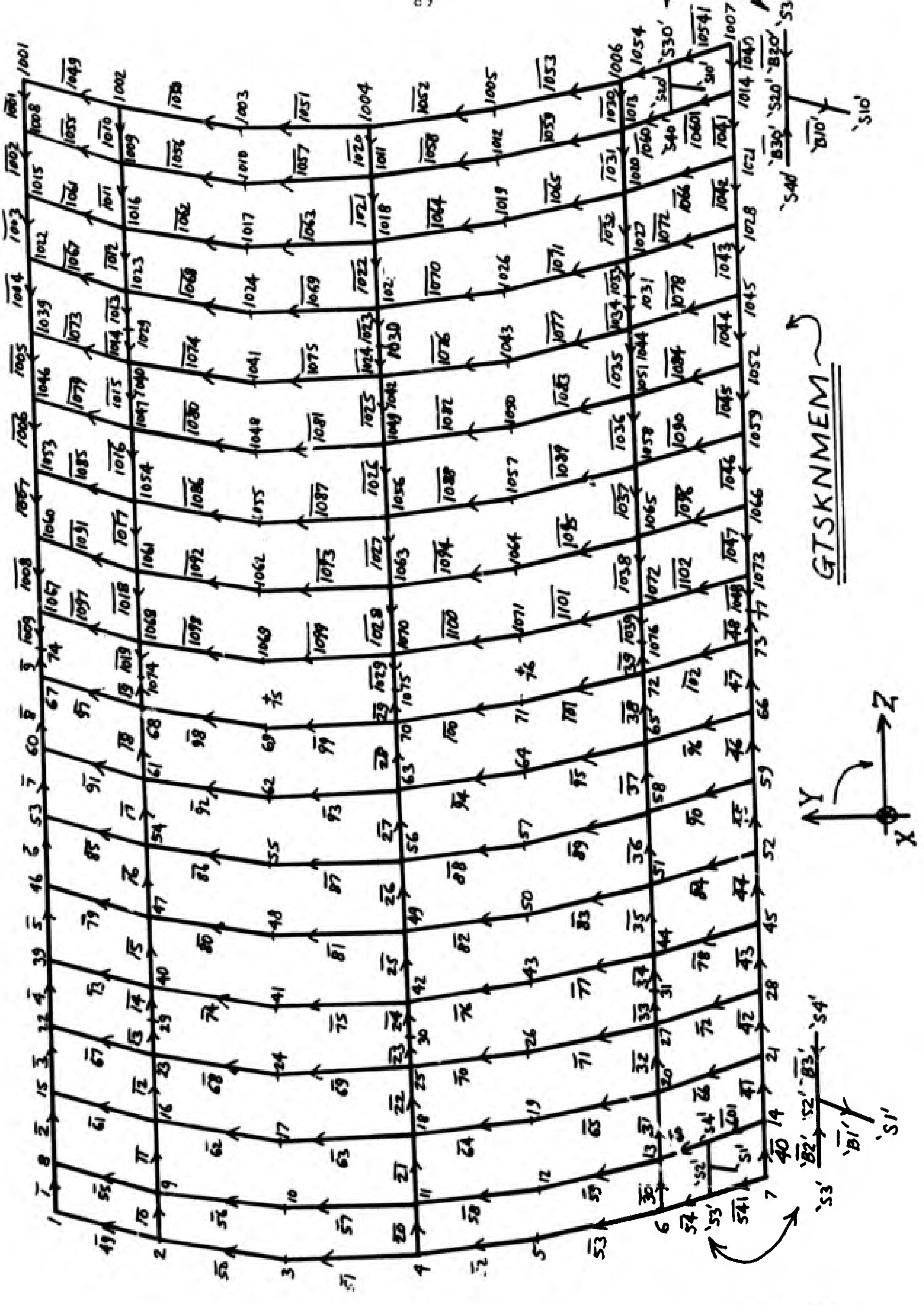


Figure 10. FASTDRAW/2 Member/Joint Creation Model (Joint and Member Names are 'Original' Names and are NOT FASTDRAW/2 Names)

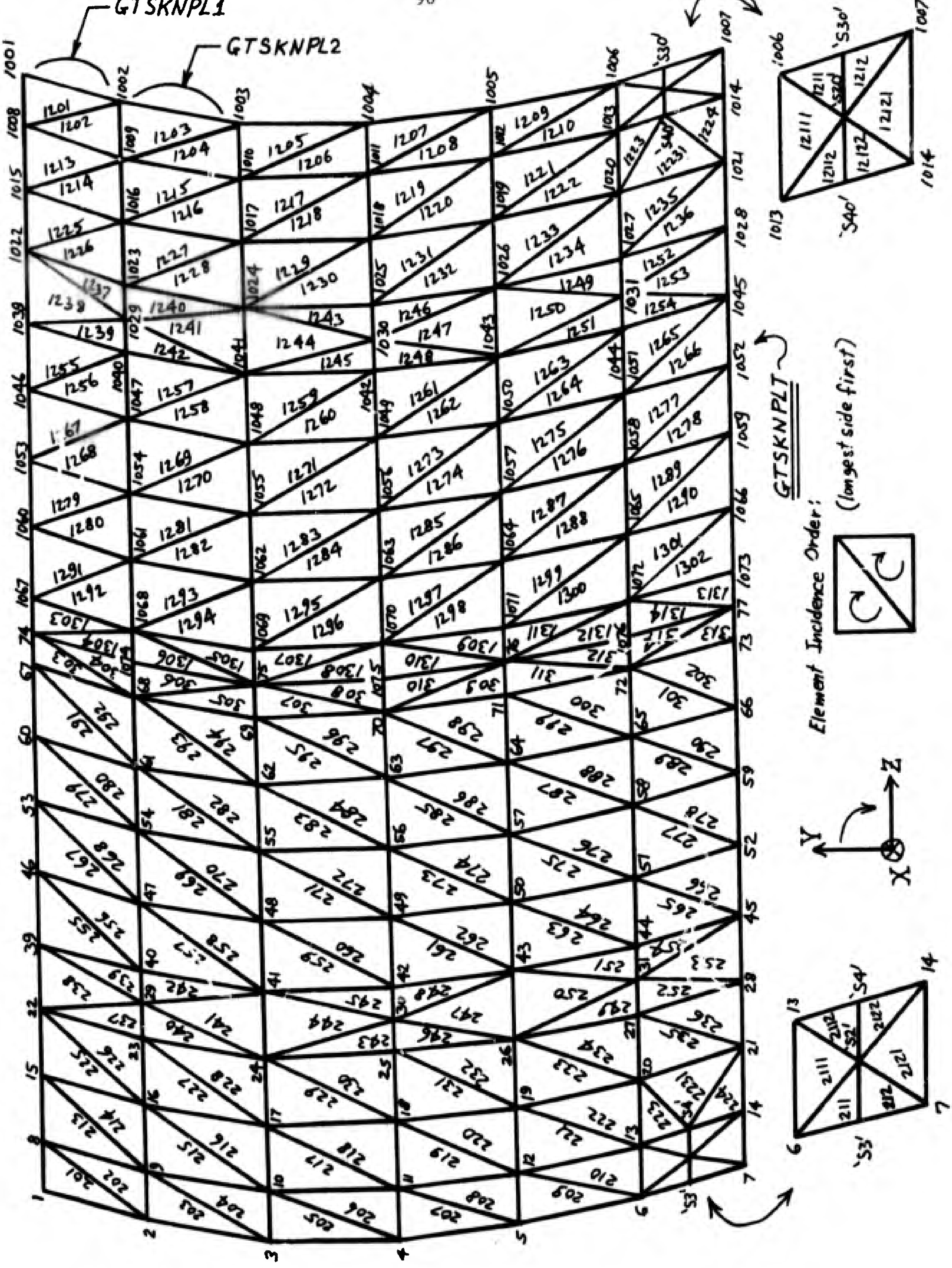


Figure 11. FASTDRAW/2 Finite Element Creation Model (Joint and Element Names are 'Original' Names and NOT FASTDRAW/2 Names)

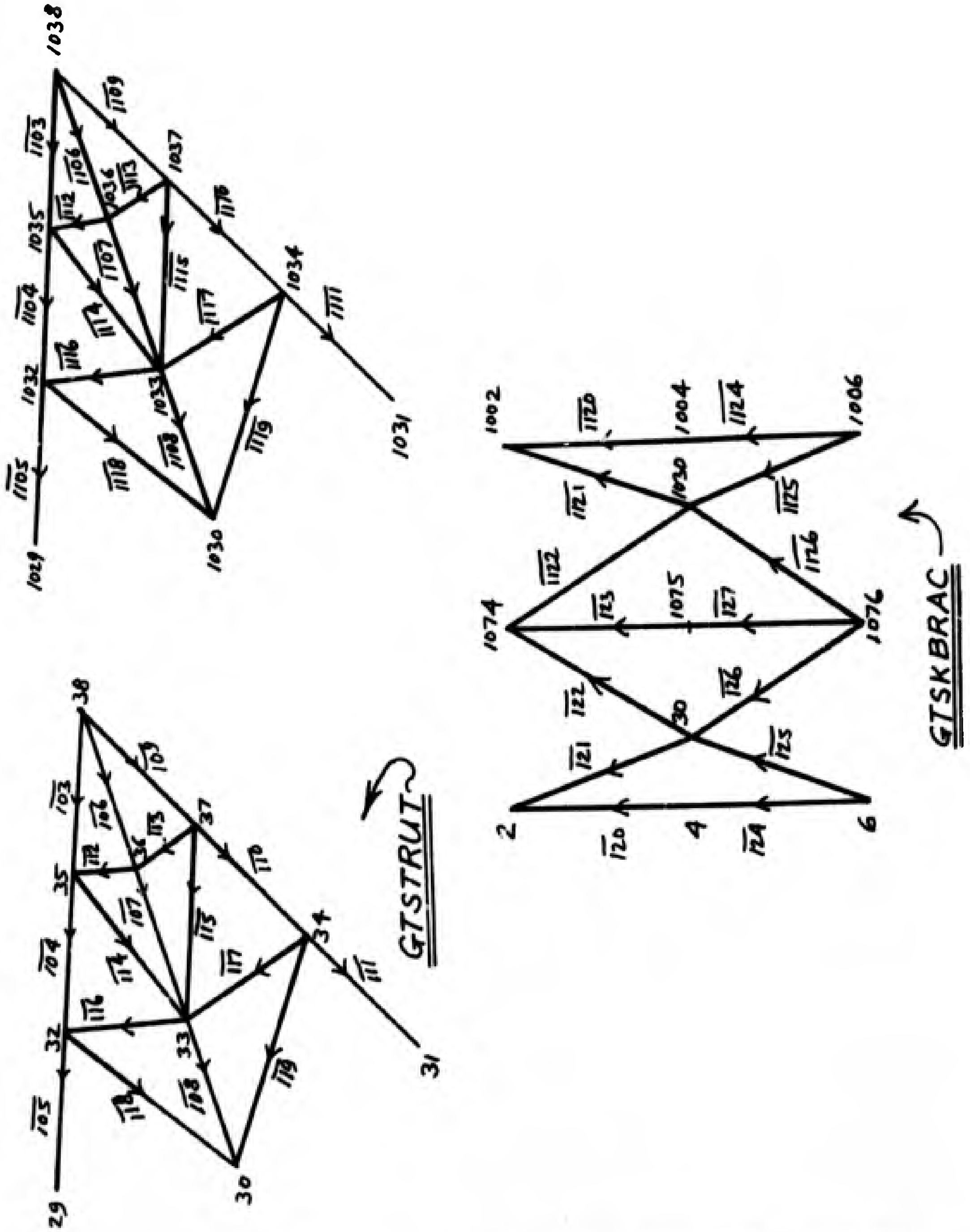


Figure 12. FASTDRAW/2 Strut/Brace Member Creation Model (Joint and Member Names are 'Original' Names and are NOT FASTDRAW/2 Names)

(4) *BUILD GTSKNPTS.FROM TABLET

Identify model file name GTSKNPTS which will contain skin plate and cable support joints, and which will be created from the TABLET, where TABLET can be the CRT screen (Step 7 below) or the terminal Tablet. This command automatically puts the user in the 2D mode.

(5) :STRUDL response to LANGUAGE prompt indicating that the file or files to be generated should be placed in the STRUDL II format when STORE'd at end (Step 141).

(6) :T14 terminal code response for a Tektronix 4014 (large screen) interactive graphics terminal. Enter TXX if a Tektronix 4010 or 4012 small screen terminal.

(7) :SCREEN indicates TABLET to be interpreted as the CRT screen for FASTDRAW/2 command input.

(8) :XY plane in which the current geometry model is to be created. This may be changed at any future time.

(9) :0.013 scale factor to fit model to be created on screen since actual tainter gate dimensions will be used.

(10) :200,-10,8 origin of current XY coordinate system.

(11) Cursor will appear and user prompted to locate three points defining positive XY axis Directions. Locate first point at lower left of screen, second point at lower right of screen, and third point at upper left of screen. This defines X-axis positive right and Y-axis positive up.

(12) >KEYIN indicates to FASTDRAW/2 that series of point coordinates are to be entered. Since current mode is 2D and in the XY plane, only X and Y coordinates need be entered. Also, since the origin of the current XY plane being displayed is at Z=8.0, all the Z coordinates of points to be entered are taken as Z=8.0.

(13) The user is now prompted with FASTDRAW/2 point labels, and must now respond with the X and Y coordinates. Note that original (Fig. 10) joint numbers are shown in parentheses to right for reference only.

```
1:359.399,372.          (1)
2:371.344,298.086       (2)
3:368.024,221.756       (3)
4:349.180,147.715       (4)
5:319.532,85.518        (5)
6:278.922,29.857        (6)
7:249.415,0.0           (7)
8:hit carriage return.
```

(14) >LABEL P displays FASTDRAW/2 point labels.

(15) >L NP place a FASTDRAW/2 geometry line (<u>not</u> a STRUDL member element) successively between points 1, 2, 3, 4, 5, 6, and 7. To do this, use cursor to identify point 1, then 2, then 3, 4, 5, 6, and 7. Then hit carriage return key to exit cursor mode.

(16) >LABEL E displays FASTDRAW/2 line labels 1 to 6.

(17) >PLANE Z=8.0 displays plane where Z=8.0.

(18) >TRANSLATE E(1-6) elements 1 to 6 will be translated to Z=22.5 one time. Respond to prompt as,

```
?Y  generate new points
:0,0,22.5  translate to Z=22.5
:1  translate onl  one time.
```

(19) >LAB P

(20) >LAB E

(21) >Translate E(7-12) elements 7-12 will be translated to Z=43.5, a distance of 21.0 inches in Z direction. Repeat this 21.0 inch translation process 15 times.

?Y

:0, 0, 43.5

:15

(22) >Lab P

(23) >Lab E

(24) >Translate E(97-102) translate elements 97-102 to Z=352.0 one time.

?Y

:0,0,352.0

:1

(25) > Lab P

(26) >Lab E

(27) > Delete E(1-108) delete all FASTDRAW/2 line elements 1-108 just created. This leaves only the points.

(28) >3D enter 3-D mode

(29) > 0, 60, 10 good 3-D viewing angle. The points in current model file are displayed.

(30) >KEYIN keyin X, Y, and Z coordinates of all additional skin plate and cable support joints not yet created. Original joint names are shown in parentheses for reference.

127: 359.399, 372., 180. (74)

128: 371.344, 298.086, 77.75 (29)

129: 371.344, 298.086, 180. (1074)

130: 371.344, 298.086, 282.25 (1029)

131: 368.024, 221.756, 180. (75)

132: 349.18, 147.715, 77.75 (30)

133: 349.18, 147.715, 180. (1075)

134: 349.18, 147.715, 282.25 (1030)

135: 319.532, 85.518, 180. (76)

136: 278.922, 29.857, 77.75 (31)

137: 278.922, 29.857, 180. (1076)

138: 278.922, 29.857, 282.25 (1031)

139: 249.415, 0.0, 180. (77)

140: 268.1174, 6.7175, 15.25 ('S1')

141: 262.4728, 12.3866, 15.25 ('S2')

142: 262.4728, 12.3866, 8.0 ('S3')

143: 262,4728, 12.3866, 22.50 ('S4')

144: 268.1174, 6.7175, 344.75 ('S10')

145: 262.4728, 12.3866, 344.75 ('S20')

146: 262.4728, 12.3866, 352.0 ('S30')

147: 262.4728, 12.3866, 337.5 ('S40')

148: hit carriage return

(31) > REDRAW displays current model file in current orientation.

(32) > WINDOW use cursor to locate ends of an imaginary diagonal of imaginary rectangle which bounds the lower left cable support point area to be magnified and displayed on the screen for checking purposes.

(33) > FULL redraw the full model file

(34) > WINDOW use cursor to identify lower right cable support point area to be magnified and displayed.

(35) > FULL

(36) > DEFINE defines the current created GTSKNPTS model file as a user defined "super element" which is stored in file GTSKNPTS. Respond to prompt as,

:N

:1 one definition point to be selected

Use cursor to identify original joint 1001 as to definition point.

Use cursor to identify original joint 1001 as the label point.

Hit carriage return in response to attribute prompt.

(37) >END model file GTSKNPTS is now defined and stored on the SIGMA9 computer under user account number usernumber for future use by FASTDRAW/2.

Now, the second model file, GTSKNMEM, will be created to contain all the STRUDL member elements and joints in the skin plate and at cable supports (Fig. 10)

(38) * BUILD GTSKNMEM FROM GTSKNPTS

Copy model file GTSKNPTS into model file GTSKNMEM. Although the same joint labels are used, this causes no problem since they are changed when building entire structure from these super elements at a later time.

(39) :MODEL response to LANGUAGE prompt.

(40) *APPEND FROM TABLET indicates user wishes to modify file GTSKNEM which is now a copy of file GTSKNPTS. FASTDRAW/2 enters 3D mode.

(41) :0, 90, 0 model file is displayed in this viewing angle.

(42) > EL1 generages a STRUDL member element between two successively identified points using the cursor. Hit carriage return to exit this mode. Now, generate all STRUDL member elements in the skin plate using the cursor.

(43) > WINDOW use cursor to window in on lower left cable support area.

(44) > EL1 generate lower left cable support members.

(45) > 3D

(46) :0, 90, 0 displays current model file.

(47) > WINDOW use cursor to window in on lower right cable support area.

(48) > EL1 generate lower right cable support members.

(49) > LAB M

(50) > LAB P

(51) > FULL

(52) > DEFINE to define model file GTSKNMEM.

:N

:4

Use cursor to identify original joints 7, 4, 1, and 1001 as the four definition points.

Use cursor to identify original joint 1001 as the label point

Hit carriage return in response to attribute prompt.

```
(53) > END
```

Now, the third model file, GTSKNPL1, will be created to contain all the STRUDL finite elements in the top row of the skin plate (Fig. 11).

---

(54) *BUILD GTSKNPL1 FROM GTSKNPTS

(55) :MODEL

(56) *APPEND FROM TABLET

(57) :0, 90, 0 model file is displayed.

(58) > EL3 generates a STRUDL PBS2 finite element between three successively identified points using the cursor. Use the cursor to generate all finite elements in top row on left of axis of symmetry.

(59) > PLANE use cursor to select three points (lower left, lower right, upper left) on plane just created in Step (58). This plane alone will now be displayed.

(60) > LAB E displays labels of all FASTDRAW/2 element labels displayed on screen.

(61) > ROTATE E (109-127) request a rotation of finite element plane about axis of symmetry to generate elements on right side. Respond,

:N

:2

Select original joints 1074 and 74 using cursor. This is axis of rotation.

:180 rotate 180°.

:1 rotate only one time. The new finite elements will be displayed.

(62) > 3D

(63) :0, 90, 0 current model file will be displayed.

(64) > SAVE intermediate save of file in case computer goes down.

(65) >DELETE use cursor to delete all points outside of this element plane. A previously defined definition point could not be deleted. This caused no problem and was not of concern.

(66) >REDRAW

(67) >PLANE same as Step (59).

(68) >DEFINE

:N

:3

Use cursor to identify original joints 2, 1, and 1001 as definition points.

Use cursor to identify original joint 1001 as the label point.

Hit carriage return in response to attribute prompt.

(69) >END

Now, the fourth model file, GTSKNPL2, will be created to contain all the STRUDL finite elements in the second row of the skin plate (Fig. 11).

```
(70) *BUILD GTSKNPL2 FROM GTSKNPTS

(71) :MODEL

(72) *APPEND FROM TABLET

(73) :0, 90, 0

(74) > EL3 generate STRUDL PBS2 finite elements in second row of skin plate

     to left of axis of symmetry.

(75) > PLANE selected three points in created plane with cursor.

(76) > LAB E

(77) > ROTATE E(109-127)

     :N

     :2

     Select original joints 75 and 1074 as rotation axis using cursor.

     :180

     :1

(78) > 3D

(79) :0, 90, 0

(80) > SAVE

(81) > DELETE use cursor to delete all points outside this element plane.

(82) > REDRAW

(83) > PLANE same as Step (75)

(84) > DEFINE

     :N

     :3

     Use  cursor to identify original joints 3, 2 and 1002 as definition points.
     Use cursor to identify original joint 1002 as the label point.
     Hit carriage return in response to attribute prompt.

(85) > END
```

Now, the fifth model file, GTSKNPLT, will be created using model files GTSKNPL1 and GTSKNPL2 to contain all the STRUDL PBS2 finite elements in the skin plate (Fig. 11).

---

(86) *BUILD GTSKNPLT FROM GTSKNPTS

(87) :MODEL

(88) *APPEND FROM TABLET

(89) :0, 90, 0

(90) > ELEMENT indicates that the STRUDL element menu on p. 73 of the FASTDRAW/2 manual (5) is to be modified to include the two super elements GTSKNPL1 and GTSKNPL2. Respond as follows,

:4, GTSKNPL1

:5, GTSKNPL2

:Hit carriage return, current model file is redrawn.

(91) > EL4 identify original joints 2, 1, and 1001 with cursor. Model file GTSKNPL1 will then be drawn in.

(92) > EL5 identify original joints 3, 2, and 1002 with cursor. Model file GTSKNPL2 will then be drawn in.

(93) > EL4 identify original joints 4, 3, and 1003 with cursor. Model file GTSKNPL1 will then be drawn in.

(94) > EL5 identify original joints 5, 4, and 1004 with cursor. Model file GTSKNPL2 will then be drawn in.

(95) > EL4 identify original joints 6, 5, and 1005 with cursor. Model file GTSKNPL1 will then be drawn in.

(96) > WINDOW in on bottommost level

(97) > EL3 generate each finite element in bottommost level successively using cursor.

(98) > FULL

(99) > SAVE

(100) > CONVERT E converts all joint coordinates of GTSKNPL1 and GTSKNPL2 to global GTSKNPLT coordinates and labels all new joints and elements just added.

(101) > DEFINE

:N

:4

Use cursor to identify original joints 7, 4, 1 and 1001 as the four definition points.

Use cursor to identify original joint 1001 as the label point.

Hit carriage return in response to attribute request.

(102) > END

Now the sixth model file, GTSTRUT, will be created (Fig. 12) directly from the screen.

---

(103) *BUILD GTSTRUT FROM TABLET

(104) :STRUDL

(105) Since 3D mode is desired, hit carriage return in response to plane, scale, and origin prompts. Then use cursor to locate axis anywhere on screen.

(106) > 3D enter 3D mode.

(107) :0, 0, 0

(108) > KEYIN the X, Y, and Z coordinates of joints in the strut are now keyed in. Original joint numbers are shown in parentheses.

1: 371.344, 298.086, 77.75 (29)
2: 349.180, 147.715, 77.75 (30)
3: 278.922, 29.857, 77.75 (31)
4: 0.0, 276., 15. (38)
5: 263.534, 291.674, 59.532 (32)
6: 247.805, 184.959, 59.532 (33)
7: 197.945, 101.318, 59.532 (34)
8: 155.725, 285.262, 41.315 (35)
9: 146.430, 222.203, 41.315 (36)
10: 116.967, 172.779, 41.315 (37)
11: Hit carriage return

(109) > 3D

(110) :0, 0, 0

(111) > EL1 use this command and cursor to locate all member elements in strut.

(112) > DEFINE

:N

:4

Use cursor to identify original joints 29, 30, 31, and 38 as the four definition points.

Use cursor to identify original joint 38 as the label point.

Hit carriage return in response to attribute request.

```
(113) > END
```

Now the seventh model file, GTSKBRAC, will be created (Fig. 12) directly from the screen.

---

(114) *BUILD GTSKBRAC FROM TABLET

(115) :STRUDL

(116) Repeat step (105)

(117) > 3D

(118) :0, 90, 0

(119) > KEYIN the X, Y, and Z coordinates of joints in the skin brace are now keyed in. Original joint numbers are shown in parentheses.

1: 371.344, 298.086, 8. (2)
2: 349.180, 147.715, 8. (4)
3: 278.922, 29.857, 8. (6)
4: 371.344, 298.086, 180. (1074)
5: 349.180, 147.715, 180. (1075)
6: 278.922, 29.857, 180. (1076)
7: 371.344, 298.086, 352. (1002)
8: 349.180, 147.715, 352. (1004)
9: 278.922, 29.857, 352. (1006)
10: 349.180, 147.715, 77.75 (30)
11: 349.180, 147.715, 282.25 (1030)
12: Hit carriage return

(120) > 3D

(121) :0, 90, 0

(122) > EL1 Use this command and cursor to locate all member elements in skin brace.

(123) > DEFINE

:N

:4

Use cursor to identify original joints 6, 4, 2, and 1002 as the four definition points.

Use cursor to identify original joint 1002 as the label point.

Hit carriage return in response to attribute request.

```
(124) > END
```

Now, the eighth model file, GTTNTRGT, will be created to contain all joints, members, and finite elements of the tainter gate using model files, GTSKNMEM, GTSKNPLT, GTSTRUT, and GTSKBRAC.

```
------------------------------------------------------------------------------

(125) *BUILD GTTNTRGT FROM GTSKNMEM

(126) :MODEL

(127) *APPEND FROM TABLET

(128) :0, 90, 0

(129) > ELEMENT

       :4, GTSKNPLT

       :5, GTSTRUT

       :6, GTSKBRAC

       :Hit carriage return, current model file will be redrawn.

(130) > EL6 identify original joints 6, 4, 2, and 1002 with cursor.  Mode file

       GTSKBRAC will then be drawn in.

(131) > KEYIN the X, Y, and Z coordinates of original joints 38 and 1038 are

       keyed into current model file on screen.

       J1: 0,276,15                                              (38)

       J2: 0, 276,345                                          (1038)

       J3: Hit carriage return.

(132) > EL5 identify original joints 29, 30, 31, and 38 with cursor.  Model

       file GTSTRUT will then be drawn in at one end of tainter gate.

(133) > EL5 identify original joints 1029, 1030, 1031, and 1038 with cursor.

       Model file GTSTRUT will then be drawn in at the other end of the tainter

       gate.

(134) > EL4 identify original joints 7, 4, 1 and 1001 with cursor.  Model file

       GTSKNPLT will then be drawn in.

(135) > SAVE

(136) > CONVERT E

(137) > 3D
```

(138) :0, 60, 10 observe and check model,

(139) > DEFINE

:Y FASTDRAW/2 will indicate that 500 elements and 166 points exist in current model file. However, 5 points will be unconnected since they could not be deleted (they were definition points) when building GTSKNPL1 and GTSKNPL2. This does not matter since the points were unconnected in those two model files and will be neglected in the subsequent STORE command in Step (141).

:4

Use cursor to identify original joints 7, 4, 1, and 1001 as the four definition points.

Use cursor to identify original joint 1001 as the label point.

Hit carriage return in response to attribute request.

(140) > END

(141) *STORE GTSTRGTE the current complete tainter gate model file, GTTNTRGT, is converted into STRUDL input commands for JOINT COORDINATES, MEMBER INCIDENCES, and ELEMENT INCIDENCES, and stored in STRUDL input file GTSTRGTE.

FASTDRAW/2 responds that 161 joints were generated, that 5 unconnected joints were neglected, and that 262 members and 238 elements were generated. This is exactly correct.

:N

(142) *END exit from FASTDRAW/2.

(143) #LIST GTSTRGTE list STRUDL II source input geometry file on screen for review. The word SUPPORT may be added to SUPPORT joints by EDIT'ing file GTSTRGTE.

It is desireable to also route file GTSTRGTE to a local line printer for a permanent copy for review.

---

(144) #HOST

(145) +PRINT

(146) :accnt,PRINT response to prompt, where accnt = McAuto IBM account number assigned by McAuto.

(147) :LZE/GATE response to prompt.

(148) Hit carriage return in response to next prompt.

(149) ?N response to next prompt.

(150) :terminalid respond with remote batch terminal ID to which output is to be directed.

(151) :132 response to prompt.

(152) :GTSTRGTE(NLN) response to file name and options response.

(153) :Hit carriage Return key in response to next file prompt.

(154) ?Y response to prompt.

(155) +END exit PRINT command.

(156) #BYE log off.

End of FASTDRAW/2 tainter gate geometry creation session.

These pages are blank; continue to page 119.

6.4 Evaluation of FASTDRAW/2 for Tainter Gate Geometry Display and Creation

The display of an existing tainter gate geometry input from computer cards, and the creation of a tainter gate geometry using FASTDRAW/2 (5) is described in Sections 6.2 and 6.3, respectively.

In regard to the display procedures, FASTDRAW/2 proved to be easy to use, as well as considerably powerful in its ability to display any part of, or the entire geometry in any orientation necessary for effective observation. In just a few hours, it was possible to display and review the entire structure and verify that the complete geometry was correct.

However, as described in Section 3, STRUDL Run 1, and Appendix E, a complete verification of the tainter gate geometry was performed using a series of STRUDL PLOT commands to display the geometry on the line printer. Although the precision of these line printer plots are not as good as the FASTDRAW/2 displays on the CRT screen they were sufficient for the verification of the geometry.

In regard to the creation of a tainter gate geometry, FASTDRAW/2 also proved to be considerably powerful, and easy to use once the philosophy of the system is mastered. It turns out that FASTDRAW has a great deal of versatility as long as the geometry to be created displays a moderate amount of regularity.

However, the tainter gate considered in this study (Figures 2, 3, and 4) does not display very much regularity. In fact, there is sufficient irregularity that it took an expert in the use of FASTDRAW approximately eight hours to create the tainter gate at an interactive terminal. It is estimated that it would take approximately fourteen to sixteen hours of effort to create the tainter gate geometry by someone who is less than an expert, but still thoroughly familiar with FASTDRAW. This is considered to be excessive and counterproductive. Worse than this, it is not possible to arbitrarily assign or change joint and element names using FASTDRAW. This is considered to be a serious disadvantage.

Therefore, in regard to tainter gate structures, it is recommended that creation of the geometry is performed directly in STRUDL through the use of the JOINT COORDINATE, MEMBER INCIDENCE, AND ELEMENT INCIDENCE commands. This should be followed by a complete display of the geometry using the STRUDL PLOT commands as shown in Appendix E. Only after this is done is it recommended that FASTDRAW/2 be used to display three-dimensional views of the geometry for final verification as described in Section 6.2. If geometry errors are found using FASTDRAW/2, corrections can be applied directly through FASTDRAW/2 using commands described in Section 6.3. However, since the original geometry was generated in computer card form, it is also recommended that corrections are applied directly to the input card deck. It is not recommended to use FASTDRAW/2 to create the tainter gate geometry.

7. CONCLUSIONS AND RECOMMENDATIONS

This report has demonstrated that the anlaysis and design of a tainter gate may be performed by a general purpose computer structural analysis and design program, and include the effect of cable supports, side seal friction, and trunion pin friction moments, provided the program embodies certain special characteristics. These include: (1) the ability to perform multiple analyses in the same computer run; (2) the ability to change the data base between the different analyses so that each analysis may be based on different boundary conditions, and/or loading conditions, etc.; (3) the ability to save on the computer, for any length of time, the status of a problem solution at any point, display results for engineering review, and subsequently continue the problem solution with a modified data base; (4) the ability to combine analysis results for different loading conditions used in the same analysis; (5) the ability to combine analysis results for different loading conditions used in several different analyses involving different boundary conditions; (6) the ability to include in the model description such special conditions as the eccentricity of the end of a member element from the joint center it connects to, the location of the shear center of a member element from its centroid, and others; and (7) the ability to perform design of steel member elements according to AISC Specifications (9).

The only commercially available general purpose structural analysis and design computer program that has all of these, and many more, advanced capabilities is the ICES STRUDL II subsystem (2,3).

The formulated analysis procedure for the tainter gate involves a superposition of results from a variety of different load cases, and even different boundary conditions. The linear combination factors for the superpositions are computed by solving highly non-linear systems of equations, as programmed in the supplied computer programs XFONE and XFTWO (Appendix G).

The finite element model used for the skin plate is a highly accurate representation of the skin plate stiffness effect on the tainter gate behavior. Although the stresses computed in the coarse mesh finite elements are not sufficiently accurate for design purposes, they are uniformly very low for the skin plate thickness used, and consequently, they justify a conclusion that the existing thickness is adequate from a strength point of view. If a reduction in thickness were desired, a more refined finite element grid size would be required, or the current Corps skin plate design technique could be used. If a more refined finite element analysis were desired, it is only necessary to select the more highly stressed portions of the skin plate based on the coarse grid analysis. break these regions up into finer mesh sizes, and then apply the appropriate external loads to these regions, as well as applying displacement boundary conditions using the displacement values along the region's boundary that were computed in the original coarse mesh analysis (Section 5.2).

However, based upon the discussion in Appendix I, it is recommended that a more convenient model of the skin plate and rib stiffening system be used than the finite element and rib model used in this study. The recommended model would simply consist of vertical ribs whose properties were the same as an equivalent composite section composed of the actual WT-shape rib section and an effective width of skin plate. This model would then be consistent with the composite section required for design purposes as shown in Appendix I.

The design of the frame L and W-shape members was successfully performed by STRUDL II. Not only were AISC Specifications satisfied, but member depth constraints and equating member sizes were also satisfied.

The design of the WT-shape members were not performed properly by STRUDL II since these members really behave compositely with the skin plate. Consequently, they must be designed by hand as discussed in Appendix I.

The final design of the tainter gate using STRUDL II to design the L and W-shape members, and using hand computations to design the WT-shape members acting compositely with the skin plate, led to a 14.3% (4.741 Kips) reduction in the tainter gate weight of steel. This is a significant result not only because of the large weight reduction, but also because the accuracy and reliability of the analysis and design results are at the same time much higher.

The total computer cost of $3,447 has proven STRUDL II to be a cost-effective tool for the complete analysis and design of tainter gate structures.

The use of FASTDRAW/2 proved to be desireable for three-dimensional displays of the tainter gate geometry for final check purposes, but not desireable for tainter gate geometry creation.

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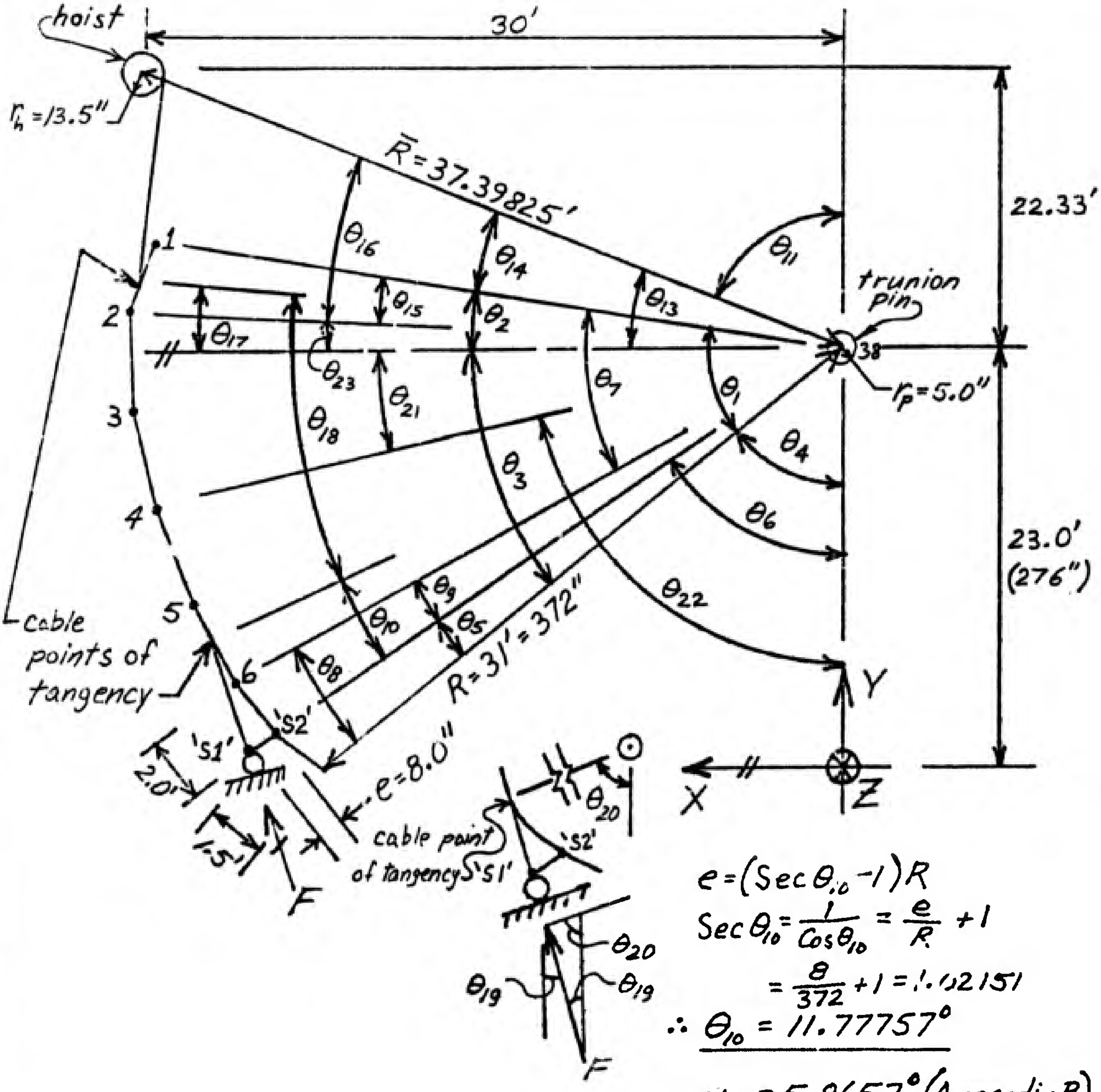
APPENDICES

APPENDIX A

Calculation of Joint Coordinate and Other Characteristic Geometry

This Appendix contains calculations for the relative angular positions of characteristic joints on the STRUDL structural model shown in Fig. 2, and the computations of joint coordinates.



$$e = (\operatorname{Sec}\theta_{10} - 1)R$$

$$\operatorname{Sec}\theta_{10} = \frac{1}{\operatorname{Cos}\theta_{10}} = \frac{e}{R} + 1$$

$$= \frac{8}{372} + 1 = 1.02151$$

$$\therefore \underline{\theta_{10} = 11.77757^\circ}$$

$$\underline{\theta_{17} = 5.8657^\circ} \text{ (Appendix B)}$$

Based on Corps Drawings (7) S-CC, 45/11 - 45/15:

$$\theta_1 = 11.5517 + 23.5764 + 21.2550 + 6.4689$$
$$= 62.8519^\circ$$

$$\theta_2 = 14.9553^\circ$$

$$\theta_3 = \theta_1 - \theta_2 = 47.8966^\circ$$

$$\theta_4 = 90 - \theta_3 = 42.1034^\circ$$

$$\theta_5 = \frac{1.5(360^\circ)}{2\pi R} = \frac{1.5(360)}{2\pi(31)} = 2.77238^\circ$$

$$\theta_6 = \theta_4 + \theta_5 = 44.87578^\circ$$

$$\theta_7 = 56.3831^\circ,\ \theta_8 = 6.4688^\circ,\ \theta_9 = 3.6964^\circ$$

$$\theta_{11} = \mathrm{Tan}^{-1}\frac{30}{22.33}$$

$$= 53.33846^\circ$$

$$\theta_{13} = 36.66154^\circ,\ \theta_{14} = 21.70624^\circ;\ \theta_{15} = 11.55167^\circ$$

$$\theta_{16} = \theta_{14} + \theta_{15} = 33.25791^\circ$$

$$\theta_{18} = 90 - \theta_6 - \theta_{10} + \theta_{17} = 39.21235^\circ$$

$$\theta_{19} = 90 - \theta_{20} = 33.34665^\circ$$

$$\theta_{20} = \theta_6 + \theta_{10} = 56.65335^\circ$$

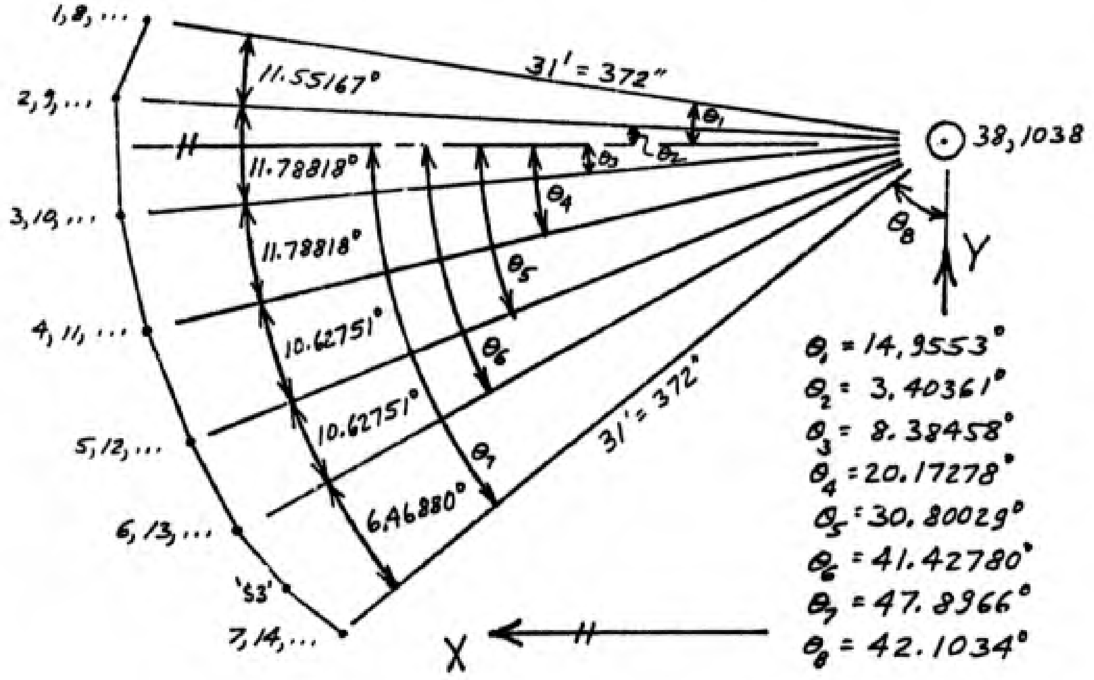
$$\theta_{21} = 20.17278^\circ$$

$$\theta_{22} = 90 - \theta_{21} = 69.82722^\circ$$

$$\theta_{23} = \theta_2 - \theta_{15} = 3.40363^\circ$$

Joints in skin plate: 1, 2, 3, . . . , 77, 1001, 1002, 1003, . . . , 1076

Angles measured in global X-Y plane:



$\theta_1 = 14.9553°$

$\theta_2 = 3.40361°$

$\theta_3 = 8.38458°$

$\theta_4 = 20.17278°$

$\theta_5 = 30.80029°$

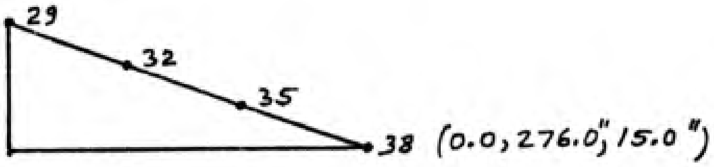
$\theta_6 = 41.42780°$

$\theta_7 = 47.8966°$

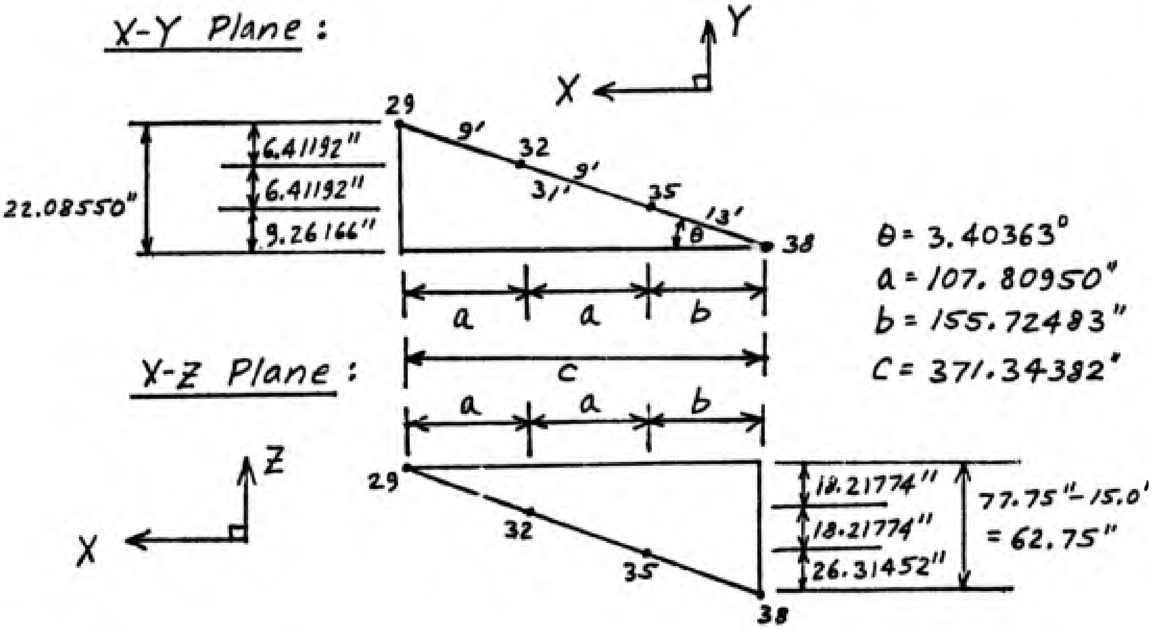
$\theta_8 = 42.1034°$

Joint i	$X = 372 \times \cos \theta_i$	$Y = 276 \pm 372 \times \sin \theta_i$	Z
1, 8, . . .	359.39941"	372.00032"	8.0", ., ., . . .
2, 9, . . .	371.34382"	298.08550"	8.0", ., ., . . .
3, 10, . . .	368.02392"	221.75616"	8.0", ., ., . . .
4, 11, . .	349.18039"	147.71494"	8.0", ., ., . . .
5, 12, . . .	319.53212"	85.51844"	8.0", ., ., . . .
6, 13, . . .	278.92192	29.85662"	8.0", ., ., . . .
7, 14, . . .	249.41508"	0.0"	8.0", ., ., . . .

Joints Along Top Strut Arm



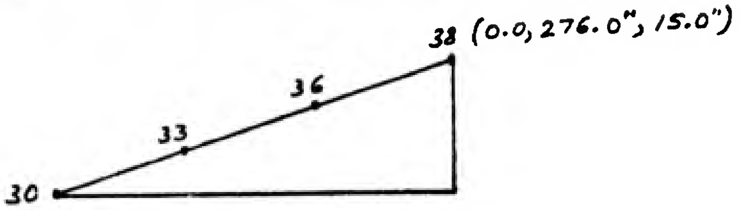
X-Y Plane :

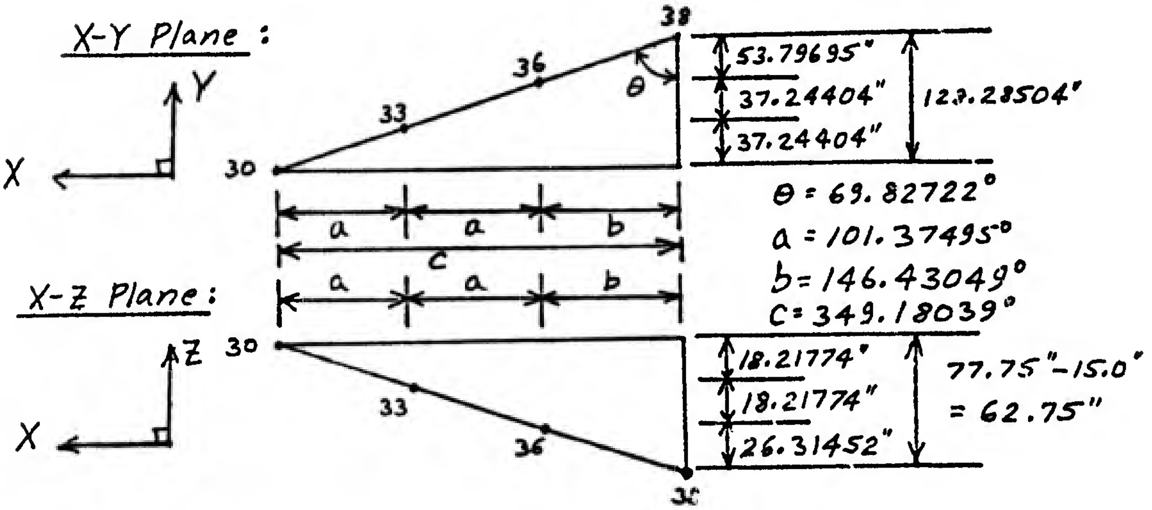


θ = 3.40363°
a = 107.80950"
b = 155.72483"
C = 371.34382"

Joint	X	Y	Z
38	0.0	276.0"	15.0"
35	155.72483"	285.26166"	41.31452"
32	263.53433"	291.67358"	59.53226"
29	371.34383"	298.08550	77.75"

Joints Along Middle Strut Arm:



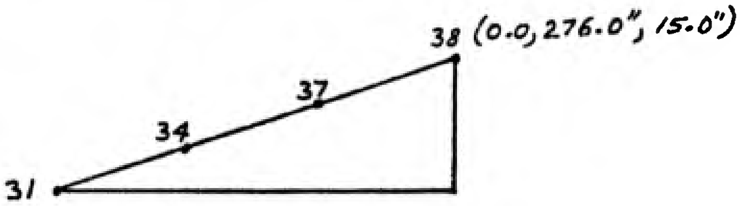


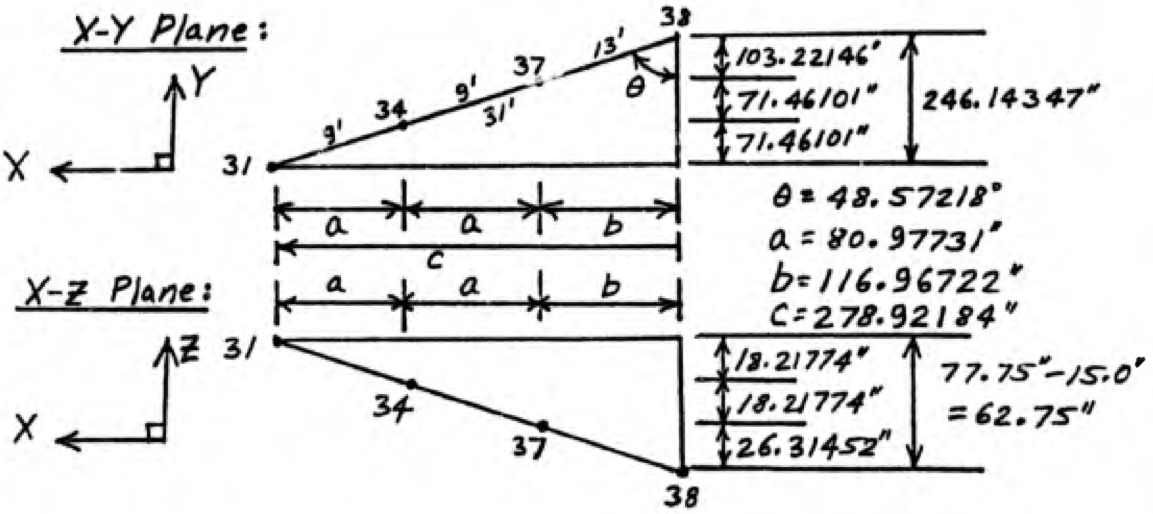
θ = 69.82722°
a = 101.37495°
b = 146.43049°
c = 349.18039°

77.75" − 15.0" = 62.75"

Joint	X	Y	Z
38	0.0	276.0"	15.0"
36	146.43049"	222.20305"	41.31452"
33	247.80544"	184.95901"	59.53226"
30	349.18039"	147.71497"	77.75"

Joints Along Bottom Strut Arm:



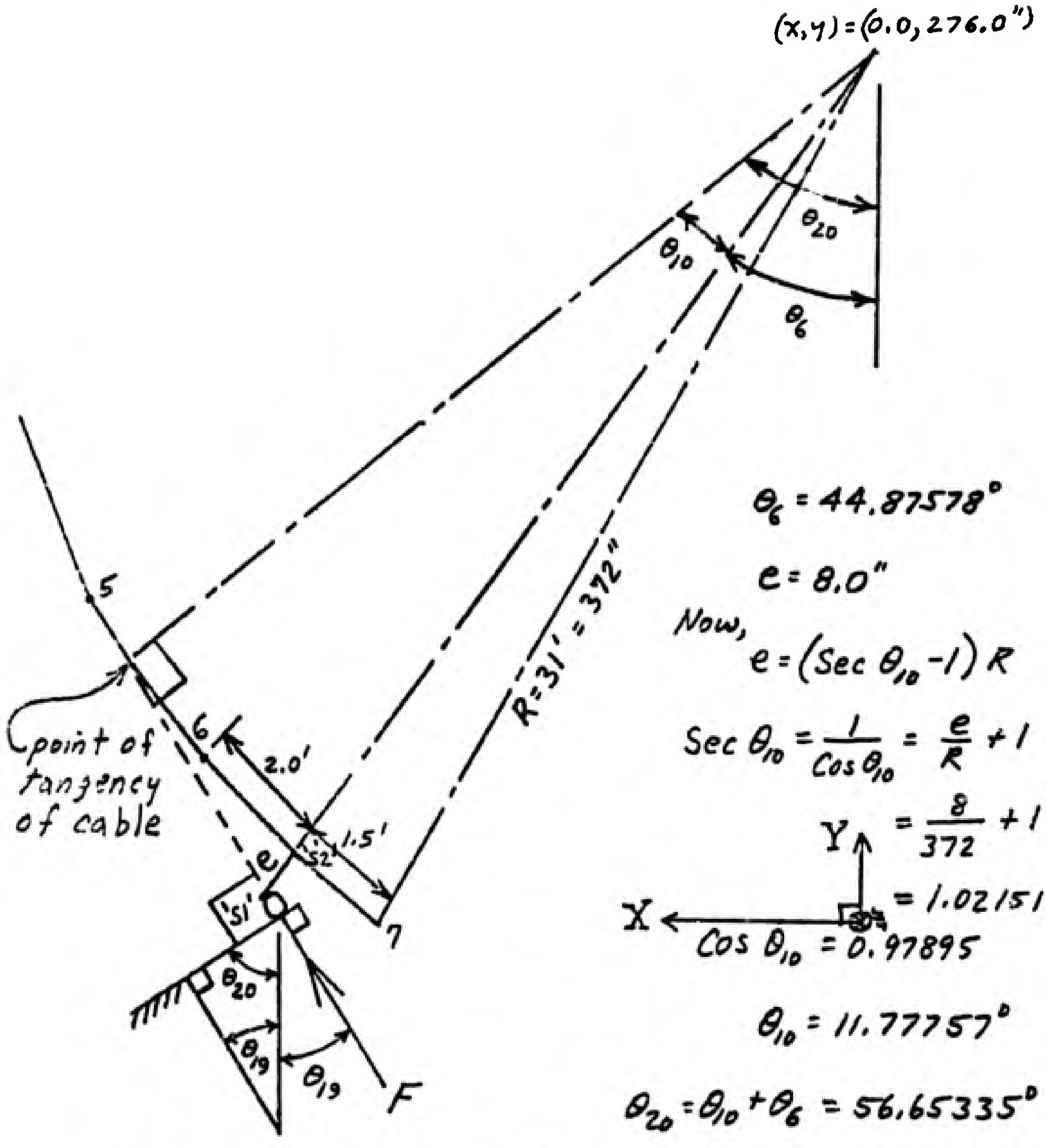


Joint	X	Y	Z
38	0.0	276.0"	15.0"
37	116.96722"	172.77854"	41.31452"
34	197.94453"	101.31753"	59.53226"
31	278.92184"	29.85652"	77.75"

APPENDIX B

Calculation of Cable Reaction Force F Direction and Support Points, and Cable Points of Tangency to the Skin Plate

This Appendix contains the calculations for the direction of the cable reaction force F at joints 'S1' and 'S10' in Fig. 2. This force acts in a direction whose line of action is tangent to the skin plate near the bottom of the skin plate. In addition, the calculation of the location of the points of tangency of the cable to the skin plate at the top and bottom of the skin plate are shown.



$\theta_6 = 44.87578^\circ$

$e = 8.0''$

Now,

$$e = (\operatorname{Sec}\theta_{10} - 1)R$$

$$\operatorname{Sec}\theta_{10} = \frac{1}{\operatorname{Cos}\theta_{10}} = \frac{e}{R} + 1$$

$$= \frac{8}{372} + 1$$

$$= 1.02151$$

$$\operatorname{Cos}\theta_{10} = 0.97895$$

$$\theta_{10} = 11.77757^\circ$$

$$\theta_{20} = \theta_{10} + \theta_6 = 56.65335^\circ$$

$$\underline{\underline{\theta_{19} = 90 - \theta_{20} = 33.34665^\circ}}$$

$x_{s_1} = 380 \operatorname{Sin}\theta_6 = 268.1174''$

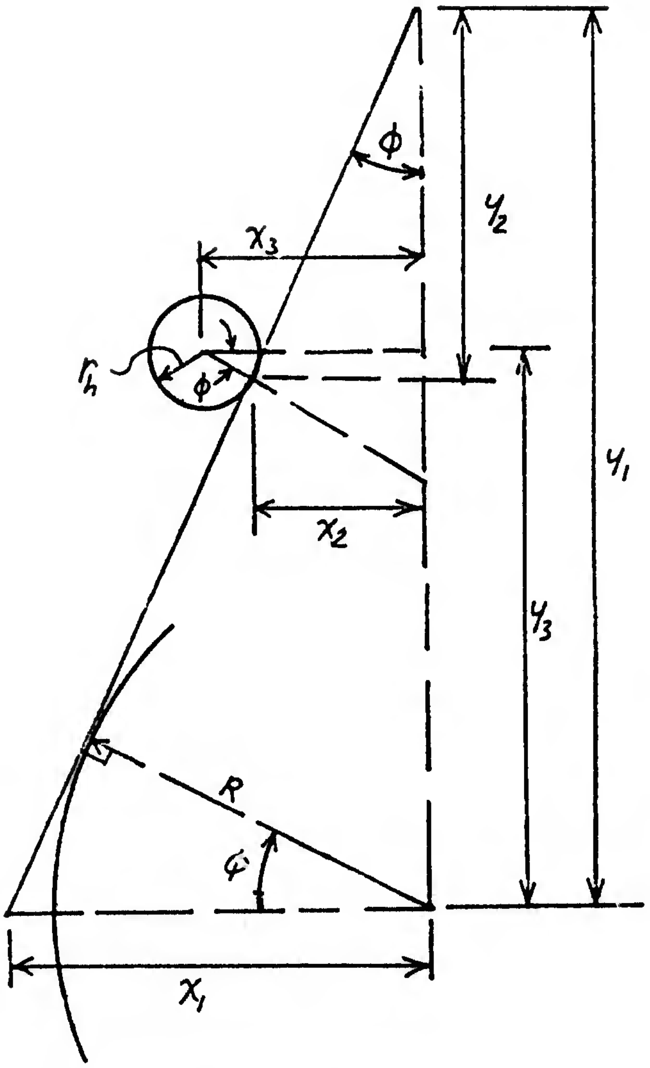
$y_{s_1} = 276 - 380 \operatorname{Cos}\theta_6 = 6.7175''$

$x_{s_2} = 372 \operatorname{Sin}\theta_6 = 262.4728''$

$y_{s_2} = 276 - 372 \operatorname{Cos}\theta_6 = 12.3866''$

$(x, y, z)_{'s1'} = (268.1174, 6.7175, 15.25)$; $(x, y, z)_{'s10'} = (x_{s1}, y_{s1}, 344.$

$(x, y, z)_{'s2'} = (262.4728, 12.3866, 15.25)$; $(x, y, z)_{'s20'} = (x_{s2}, y_{s2}, 344.$



$x_3 = 30' = 360'$

$y_3 = 22.33' = 267.96'$

$r_h = 13.5''$

$R = 31' = 372''$

$$x_2 = x_3 - r_h \cos\phi$$

$$x_1 = \frac{R}{\cos\phi}, \quad y_1 = \frac{R}{\sin\phi}, \quad y_2 = y_1 - y_3 + r_h \sin\phi$$

$$x_2/y_2 = x_1/y_1 \longrightarrow x_2 = x_1 \frac{y_2}{y_1} = \frac{\sin\phi}{\cos\phi}(y_1 - y_3 + r_h \sin\phi)$$

$$x_2 = \tan\phi\,(y_1 - y_3 + r_h \sin\phi) = \tan\phi\left(\frac{R}{\sin\phi} - y_3 + r_h \sin\phi\right)$$

$$x_3 - r_h \cos\phi = \tan\phi\left(\frac{R}{\sin\phi} - y_3 + r_h \sin\phi\right)$$

$$x_3 + \frac{\sin\phi}{\cos\phi} y_3 = r_h\left(\cos\phi + \frac{\sin^2\phi}{\cos\phi}\right) + \frac{R}{\cos\phi}$$

$$x_3 \cos\phi + y_3 \sin\phi = r_h + R$$

$$y_3 \sqrt{1-\cos^2\phi} = (r_h+R) - x_3\cos\phi$$

$$y_3^2(1-\cos^2\phi) = (r_h+R)^2 - 2x_3(r_h+R)\cos\phi + x_3^2\cos^2\phi$$

$$\underbrace{(x_3^2+y_3^2)}_{a}\cos^2\phi \underbrace{-2x_3(r_h+R)}_{b}\cos\phi + \underbrace{\left[(r_h+R)^2-y_3^2\right]}_{c} = 0$$

$$a\cos^2\phi + b\cos\phi + c = 0$$

$$a = x_3^2 + y_3^2 = (360^2 + 267.96^2) = 201,402.5616$$

$$b = -2x_3(r_h+R) = -2(360)(13.5+372) = -277,560.0$$

$$c = (r_h+R)^2 - y_3^2 = (13.5+372)^2 - (267.96)^2 = 76,807.6884$$

$$\cos\phi = \frac{-b \pm \sqrt{b^2-4ac}}{2a} = \frac{277,560.0 \pm \sqrt{1.516249282\times10^{10}}}{2(201,402.5616)}$$

$$= \frac{277,560.0 \pm 123,136.0744}{402,805.1232} = \begin{cases} 0.994764 \\ \cancel{0.383371} \end{cases}$$

$$\phi = \begin{cases} 5.8657^\circ \\ \cancel{67.4573^\circ} \end{cases}$$

So,

$$\underline{\underline{\phi = 5.8657^\circ}}$$

APPENDIX C

Calculations for Member Beta Angles, Member Eccentricities, and Member Properties

This Appendix contains the calculations of the STRUDL Beta angles for those members which have non-zero Beta angles. Also, the calculation of the non-zero eccentricities of member ends from joint centers they are incident upon are shown. Finally, member properties are summarized.

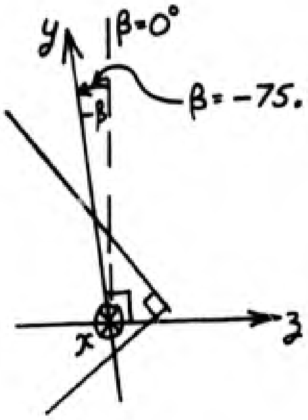
After joint coordinates and member incidences are specified, the Beta angles are the final geometric parameters which exactly orient the members in the structure with respect to the global reference frame.

Member eccentricities are required since the ends of many members are attached to joints at points which are not at the center of the specified joint locations.

BETA Angles and Properties

Members 1 TO 9: L8x4x7/16

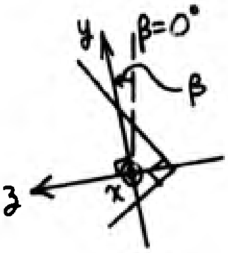
STRUDL Size = L80407



β = −75.0447° (from J.J. Smith, Corps St. Louis District)

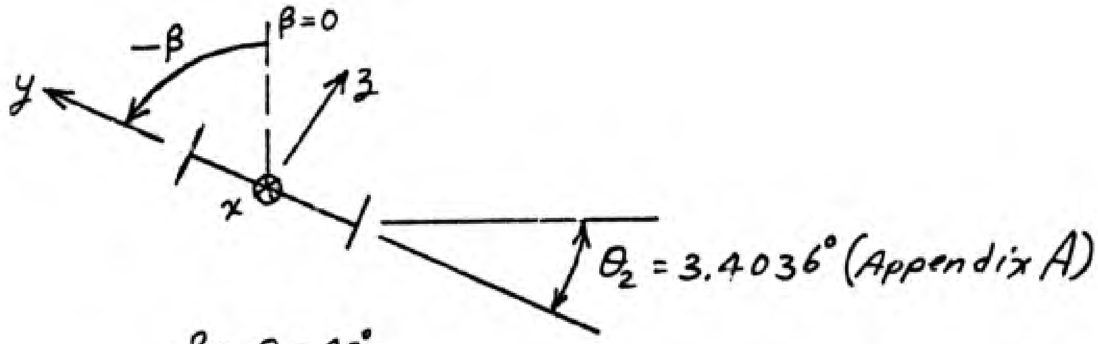
Members 1001 TO 1009: L8x4x7/16

STRUDL Size = L80407



β = +75.0447° (from J.J. Smith, Corps, St. Louis District)

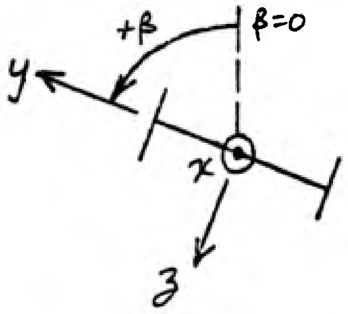
Members 10 TO 19: W24 x 55



$\beta = \theta_2 - 90°$

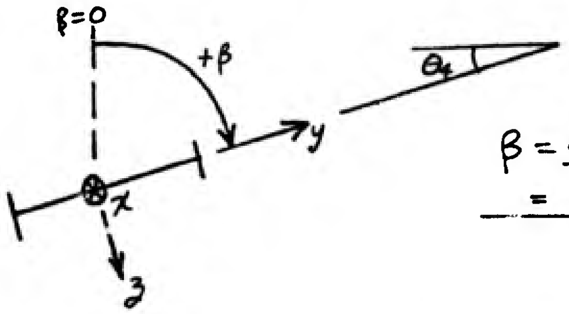
$\beta = -86.5964°$

Members 1010 TO 1019: W24 x 55



$\beta = +86.5964°$

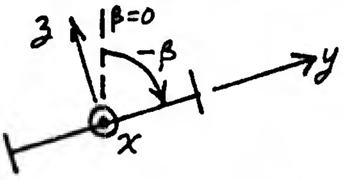
Members 20 TO 29: W24×76



$\theta_4 = 20.17278°$ (Appendix A)

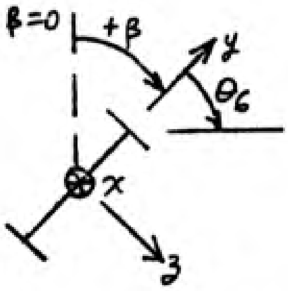
$\beta = 90 - \theta_4$
$= 69.82722°$

Members 1020 TO 1029: W24×76



$\beta = -69.82722°$

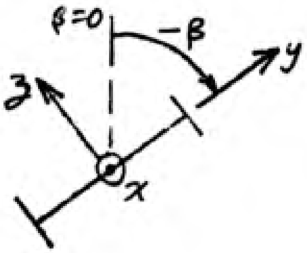
Members 30 TO 39: W24×76



$\theta_6 = 41.42780°$ (Appendix A)

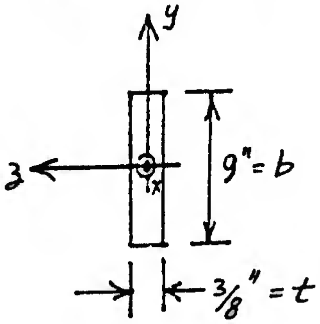
$\beta = 90 - \theta_6$
$= 48.5722°$

Members 1030 TO 1039: W24×76



$\beta = -48.5722°$

Members 40 TO 48, 1040 TO 1048:



$$\beta = 0^\circ$$

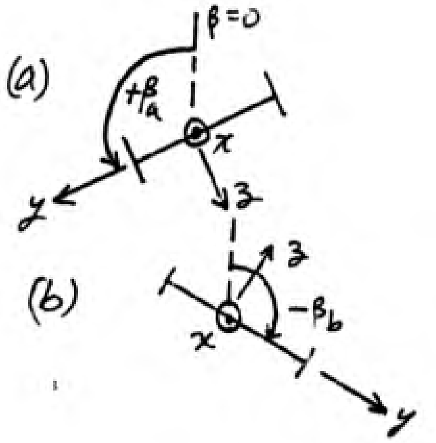
$$I_x = \frac{1}{3} b t^3 = 0.1582 \text{ in}^4.$$

$$I_y = \frac{b t^3}{12} = 0.0396 \text{ in}^4.$$

$$I_z = \frac{t b^3}{12} = 22.781 \text{ in}^4.$$

$$A_x = bt = 3.375 \text{ in}^2.$$

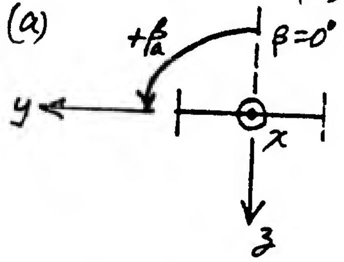
Members: (a) 103 TO 105
(b) 1103 TO 1105 } W14x43



$\beta_a = 90.57°$ (from J.J. Smith, Corps St. Louis District)

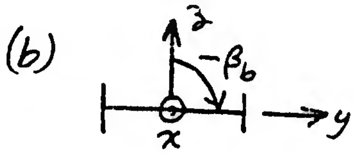
$\beta_b = -90.57°$

Members: (a) 106 TO 108
(b) 1108 TO 1108 } W14x78



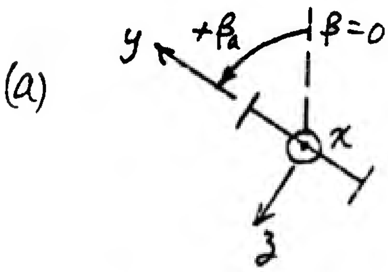
$\beta_a = 86.34°$

$\beta_b = -86.34°$

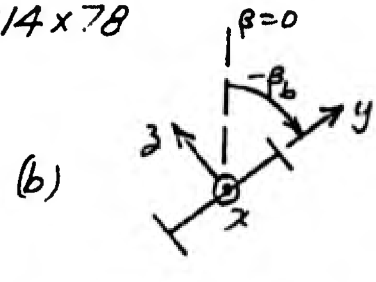


(from J.J. Smith, Corps St. Louis District)

Members: (a) 109 TO 111
(b) 1109 TO 1111 } W14x78



$\beta_a = 81.81°$



$\beta_b = -81.81°$

(from J.J. Smith, Corps St. Louis District)

Members $\left.\begin{array}{l} 49 \text{ TO } 78 \\ 1049 \text{ TO } 1078 \end{array}\right\} \text{WT7x17, } \beta = 0^\circ$

Members $\left.\begin{array}{l} 79 \text{ TO } 102 \\ 1079 \text{ TO } 1102 \end{array}\right\} \text{WT7x15, } \beta = 0^\circ$

Members $\left.\begin{array}{l} 120 \text{ TO } 127 \\ 1120 \text{ TO } 1122 \\ 1124 \text{ TO } 1126 \end{array}\right\} \text{WT7x11, } \beta = 0^\circ$

Now, from J.J. Smith, Corps St. Louis District:

Members $\left.\begin{array}{l} 112 \text{ TO } 119 \\ 1112 \text{ TO } 1119 \end{array}\right\} \text{W14x22}$

Members $\left.\begin{array}{l} 112, 113, 116, 117, \\ 1112, 1113, 1116, 1117 \end{array}\right\} \beta = 90.0^\circ$

Members:

114, $\beta = 81.69^\circ$

1114, $\beta = -81.69^\circ$

115, $\beta = 90.80^\circ$

1115, $\beta = -90.80^\circ$

118, $\beta = 79.24^\circ$

1118, $\beta = -79.24^\circ$

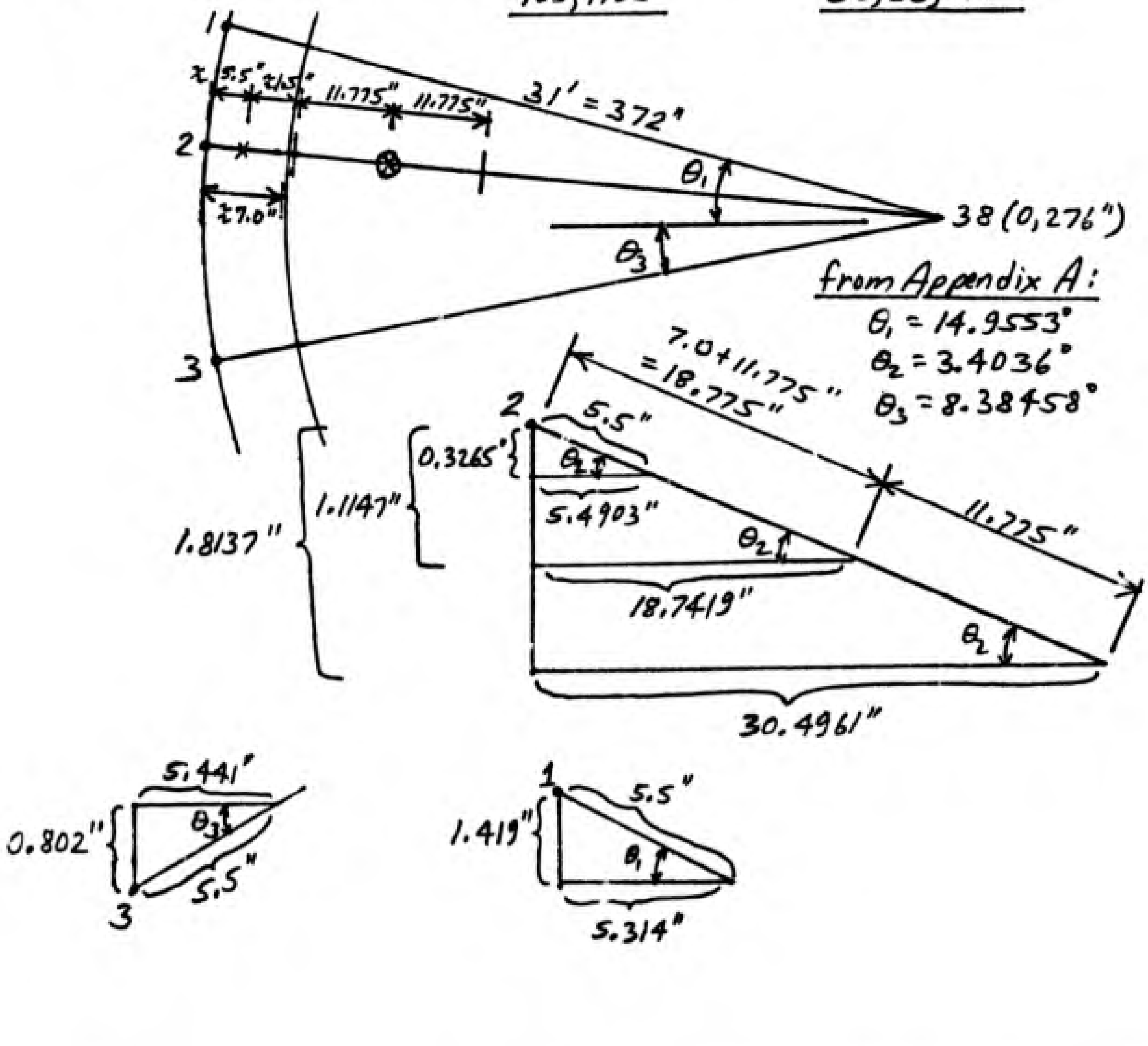
119, $\beta = 92.29^\circ$

1119, $\beta = -92.29^\circ$

Member Eccentricities

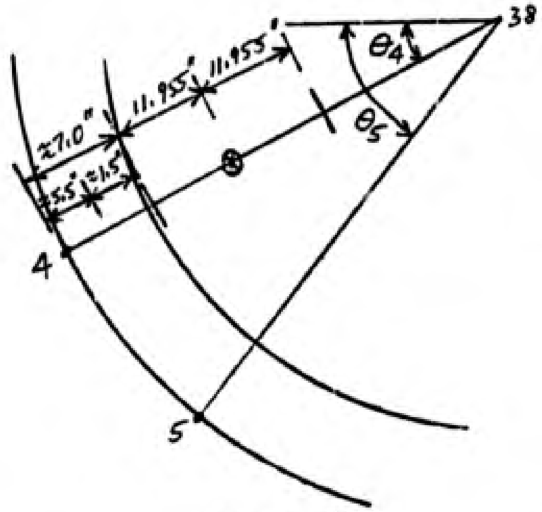
These are the distances from a joint to the end of a member measured parallel to the global X, Y, and Z axes. See listing in Appendix E for the use of the following data:

Members 10-19, 1010-1019, Verticals 49,55,...
105,1105 50,56,...



from Appendix A:
$\theta_1 = 14.9553°$
$\theta_2 = 3.4036°$
$\theta_3 = 8.38458°$

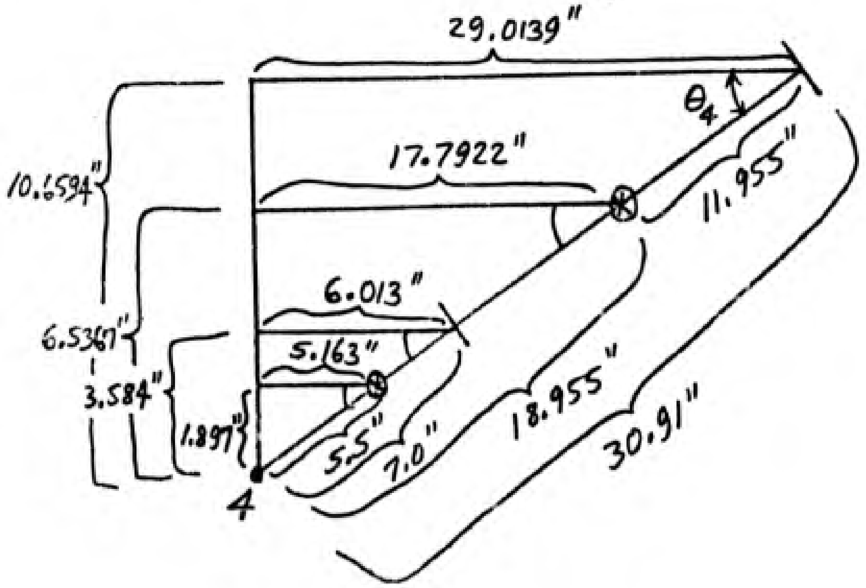
Members 20-29, 1020 TO 1029, Verticals 51, 57, ...
108, 1108 52, 58, ...

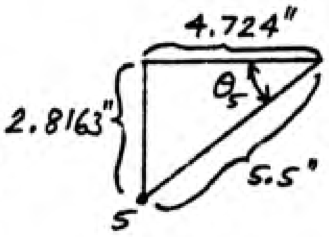


from Appendix A

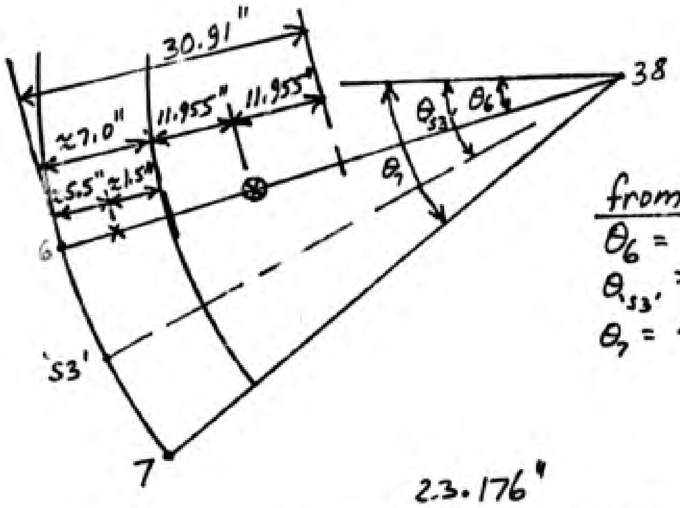
$\theta_4 = 20.17278°$

$\theta_5 = 30.80029°$

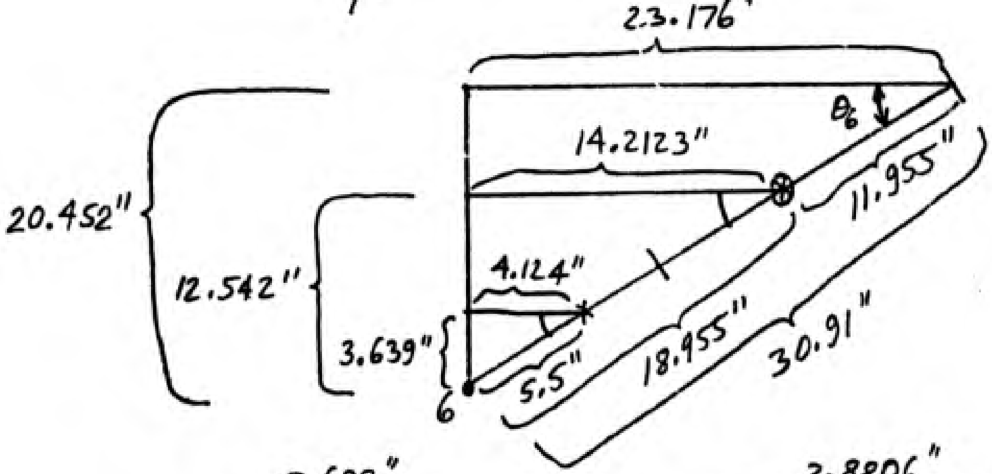


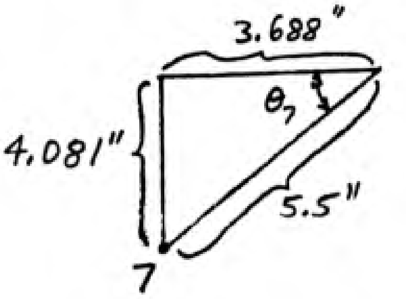


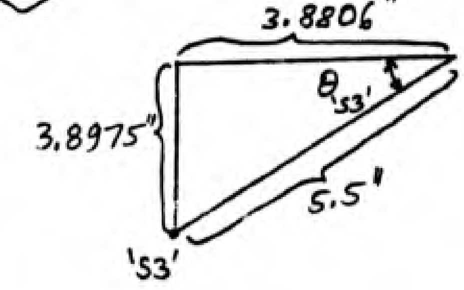
Members 30–39, 1030–1039, 111, 1111, Verticals 53, 59, ...
54, 60, ...
541, 601, ...
66, 72, ...



from Appendix A
$\theta_6 = 41.42780°$
$\theta_{53'} = 45.1242°$
$\theta_7 = 47.8966°$







APPENDIX D

Calculation of Independent Loading Conditions

The calculation of the independent loading conditions, some of which are contained in more than one Load Group, are shown in this Appendix.

LOAD GROUPS

Definition : A load group is a set of loads applied to the structure with a particular set of boundary conditions

Load Group A : Gate resting on sill.

Load Group B : Gate supported by two hoisting cables, just starting to open.

Load Group C : Gate supported by only one hoisting cable, just starting to open.

Load Group D : Gate bound at side seal, supported by two hoisting cables.

LOAD GROUP A

Gate Resting on Sill

Independent Load No.	Load Description
1.	Dead load of gate.
2.	Hydrostatic load, water at top of gate, elevation 530 ft.
3.	Wave load, elevation 530 ft.
4.	Hydrostatic load, water at elevation 528 ft.
5.	Impact load of 5 K/FT. of gate width applied at elevation 528 ft.

LOAD GROUP B
Gate Supported by Two Cables
Just Starting to Open

Independent Load No.	Load Description
6.	Dead load of gate.
7.	Hydrostatic load, water at top of gate, elevation 530 ft.
8.	Hydrostatic load, water at elevation 528 ft.
9.	Impact load of 5 K/FT. of gate width applied at elevation 528 ft.
10.	Side seal friction resisting gate opening.
11.	Skin pressure due to 1,000 K. cable force in each cable.
12.	1,000 K-FT trunion friction moment at each pin resisting gate opening.

LOAD GROUP C

Gate Supported by One Cable

Just Starting to Open

Independent Load No.	Load Description
13.	Dead load of gate.
14.	Hydrostatic load, water at top of gate, elevation 530 ft.
15.	Side seal friction resisting gate opening.
16.	Skin pressure due to 1,000 K. cable force in one cable.
17.	1,000 K-FT. trunion friction moment at one pin (at joint 38) resisting gate opening.
18.	1,000 K-FT. trunion friction moment at one pin (at joint 1038) resisting gate opening.
20.	Joint displacement load at joint 1001 = +0.25", and at joint 7 = -0.25" to simulate lateral constraint provided by side pier walls.

LOAD GROUP D

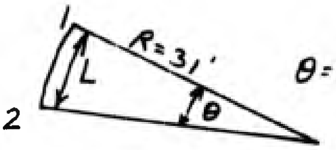
Gate Bound at Side Seal

Supported by Two Cables

Independent Load No.	Load Description
19.	Skin pressure due to 1,000 k. cable force in each cable.

Skin Plate Dead Loads

Between joint levels 1 and 2:



$\theta = 11.55167°$

$$L = \left(\frac{\theta}{360°}\right) 2\pi R = 6.25005 \text{ ft.}$$

In 14.5" width, $W_1 = (6.25005')\left(\frac{14.5''}{12}\right)\left(\frac{.75''}{12}\right)(490 \text{ lb/ft}^3)$

$= 231.2844$ lb.

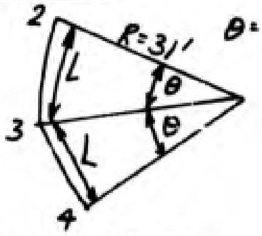
$\frac{W_1}{4} = 57.8211$ lb.

In 21" width, $W_2 = (6.25005')\left(\frac{21''}{12}\right)\left(\frac{.375''}{12}\right)(490 \text{ lb/ft}^3)$

$= 167.4818$ lb.

$\frac{W_2}{4} = 41.87045$ lb.

Between joint levels 2 and 3, and 3 and 4:



$\theta = 11.78818°$

$$L = \left(\frac{\theta}{360}\right) 2\pi R = 6.37802 \text{ ft.}$$

In 14.5" width, $W_3 = (6.37802')\left(\frac{14.5''}{12}\right)\left(\frac{.75''}{12}\right)(490 \text{ lb/ft}^3)$

$= 236.01993$ lb.

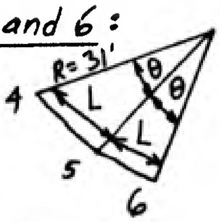
$\frac{W_3}{4} = 59.00498$ lb.

In 21" width, $W_4 = (6.37802')\left(\frac{21''}{12}\right)\left(\frac{.375''}{12}\right)(490 \text{ lb/ft}^3)$

$= 170.91098$ lb.

$\frac{W_4}{4} = 42.72775$ lb.

Between joint levels 4 and 5, and 5 and 6:



$\theta = 10.62751°$

$L = \left(\frac{\theta}{360°}\right) 2\pi R = 5.75004 \text{ ft.}$

In 14.5" width, $W_5 = (5.75004')\left(\frac{14.5''}{12}\right)\left(\frac{.75''}{12}\right)(490 \text{ lb/ft}^3)$

$= 212.78129 \text{ lb.}$

$\frac{W_5}{4} = 53.19532 \text{ lb.}$

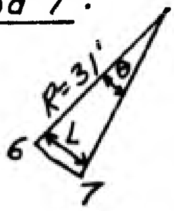
In 21" width, $W_6 = (5.75004')\left(\frac{21''}{12}\right)\left(\frac{.375''}{12}\right)(490 \text{ lb/ft}^3)$

$= 154.08300 \text{ lb.}$

$\frac{W_6}{4} = 38.52075 \text{ lb.}$

Between joint levels 6 and 7:

$\theta = 6.46880°$



$L = \left(\frac{\theta}{360°}\right) 2\pi R = 3.49996 \text{ ft.}$

In 14.5" width, $W_7 = (3.49996')\left(\frac{14.5''}{12}\right)\left(\frac{.75''}{12}\right)(490 \text{ lb./ft}^3)$

$= 129.51666 \text{ lb.}$

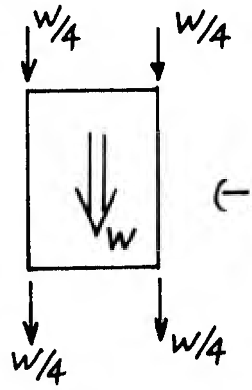
$\frac{W_7}{4} = 32.37917 \text{ lb.}$

In 21" width, $W_8 = (3.49996')\left(\frac{21''}{12}\right)\left(\frac{.375''}{12}\right)(490 \text{ lb./ft.}^3)$

$= 93.78793 \text{ lb.}$

$\frac{W_8}{4} = 23.44698 \text{ lb.}$

Assume each full panel skin plate dead load distributes $\frac{1}{4}W$ to each corner node as,



(−) Global Y joint loads.

So, for joints :

1, 1001 : $P = -(W_1/4) = -57.8211$ lb.

2, 1002 : $P = -(W_1/4 + W_3/4) = -116.82608$ lb.

3, 1003 : $P = -(W_3/4 + W_3/4) = -118.00996$ lb.

4, 1004 : $P = -(W_3/4 + W_5/4) = -112.20030$ lb.

5, 1005 : $P = -(W_5/4 + W_5/4) = -106.39064$ lb.

6, 1006 : $P = -(W_5/4 + W_7/4) = -85.57449$ lb.

7, 1007 : $P = -(W_7/4) = -32.37917$ lb.

8, 1008 : $P = -(W_1/4 + W_2/4) = -99.69155$ lb.

9, 1009 : $P = -(W_1/4 + W_2/4 + W_3/4 + W_4/4) = -201.42428$ lb.

10, 1010 : $P = -(W_3/4 + W_3/4 + W_4/4 + W_4/4) = -203.46546$ lb.

11, 1011 : $P = -(W_3/4 + W_4/4 + W_5/4 + W_6/4) = -193.44880$ lb.

12, 1012 : $P = -(W_5/4 + W_5/4 + W_6/4 + W_6/4) = -183.43214$ lb.

13, 1013 : $P = -(W_5/4 + W_6/4 + W_7/4 + W_8/4) = -147.54222$ lb.

14, 1014 : $P = -(W_7/4 + W_8/4) = -55.82615$ lb.

15, 22, 39, 46, 53, 60, 67, 1015, 1022, 1039, 1046, 1053, 1060, 1067 :

$$P = -(W_2/4 + W_2/4) = -83.74090 \text{ lb.}$$

16, 23, 40, 47, 54, 61, 68, 1016, 1023, 1040, 1047, 1054, 1061, 1068 :

$$P = -(W_2/4 + W_2/4 + W_4/4 + W_4/4) = -169.19640 \text{ lb.}$$

17, 24, 41, 48, 55, 62, 69, 1017, 1024, 1041, 1048, 1055, 1062, 1069 :

$$P = -(W_4/4 + W_4/4 + W_4/4 + W_4/4) = -170.91098 \text{ lb.}$$

18, 25, 42, 49, 56, 63, 70, 1018, 1025, 1042, 1049, 1056, 1063, 1070 :

$$P = -(W_4/4 + W_4/4 + W_6/4 + W_6/4) = -162.49700 \text{ lb.}$$

19, 26, 43, 50, 57, 64, 71, 1019, 1026, 1043, 1050, 1057, 1064, 1071 :

$$P = -(W_6/4 + W_6/4 + W_6/4 + W_6/4) = -154.08300 \text{ lb.}$$

20, 27, 44, 51, 58, 65, 72, 1020, 1027, 1044, 1051, 1058, 1065, 1072 :

$$P = -(W_6/4 + W_6/4 + W_8/4 + W_8/4) = -123.93546 \text{ lb.}$$

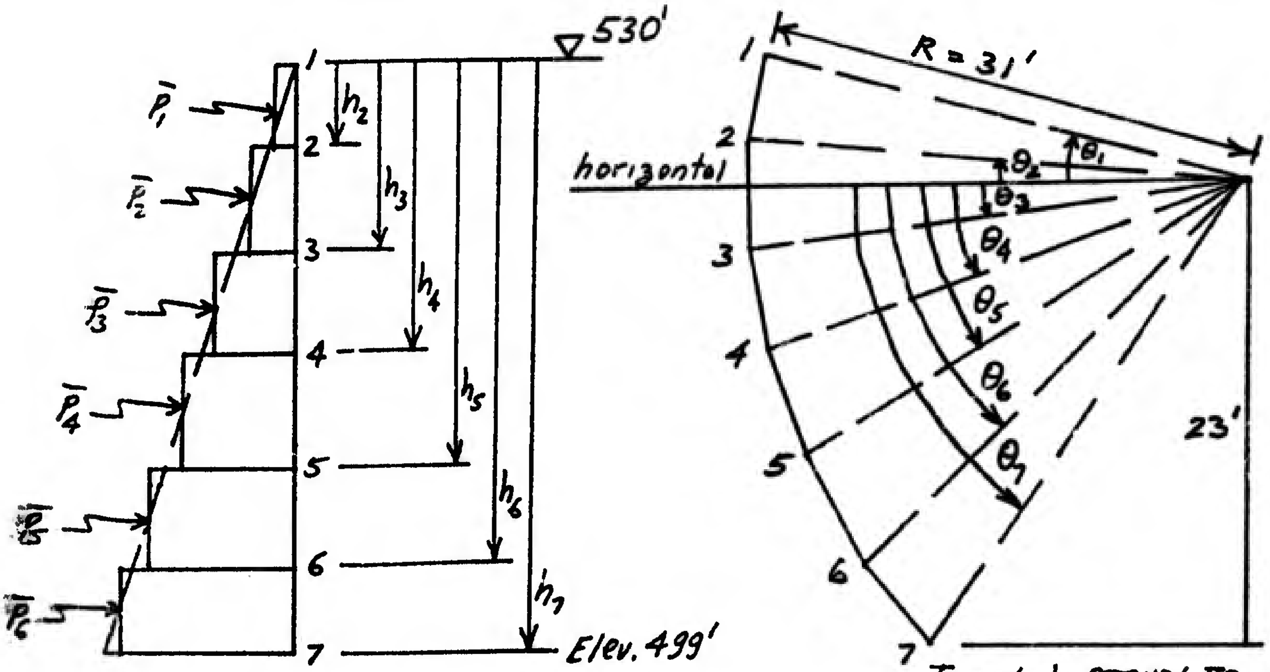
21, 28, 45, 52, 59, 66, 73, 1021, 1028, 1045, 1052, 1059, 1066, 1073 :

$$P = -(W_8/4 + W_8/4) = -46.89396$$

Total = 16,185.67248 lb.

Hydrostatic Load at Elevation 530 ft.

$\bar{P}_i$: Applied perpendicular to skin plate.



where:

$P_i = 0.0624 h_i$ K/FT²

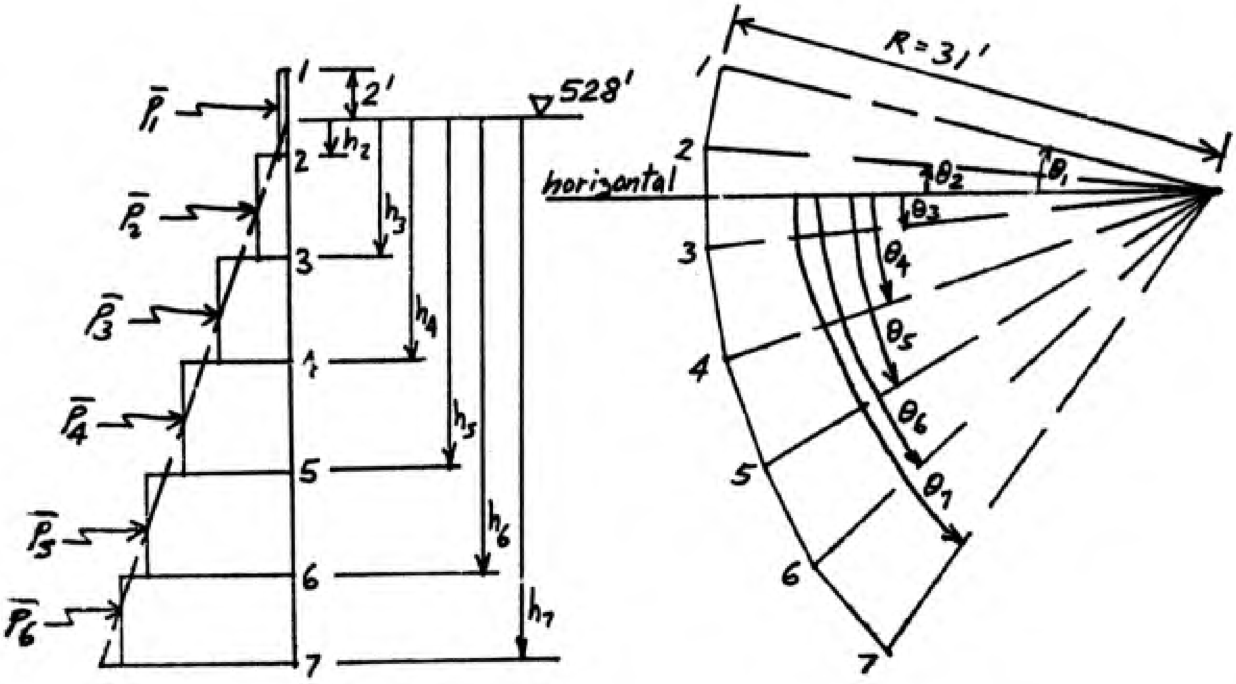
$\bar{P}_i = (P_i + P_{i+1})/2$ K/FT²

Input to STRUDL II

i	θ_i°	h_i (FT)	P_i (K/FT²)	$\bar{P}_i$ (K/FT²)
1	14.9553	0.0	0.0	0.1922
2	3.40363	6.160	0.3844	0.5828
3	8.38458	12.520	0.7812	0.9738
4	20.17278	18.690	1.1663	1.3280
5	30.80029	23.874	1.4897	1.6344
6	41.42780	28.512	1.7791	1.8568
7	47.8966	31.000	1.9344	—

Hydrostatic Load at Elevation 528 ft.

$\bar{P}_i$: Applied perpendicular to skin plate.



where:

$$P_i = 0.0624 h_i \ \text{K/FT}^2$$

$$\bar{P}_1 = \left(\frac{0+P_2}{2}\right)\left(\frac{h_2}{2+h_2}\right) \ \text{K/FT}^2$$

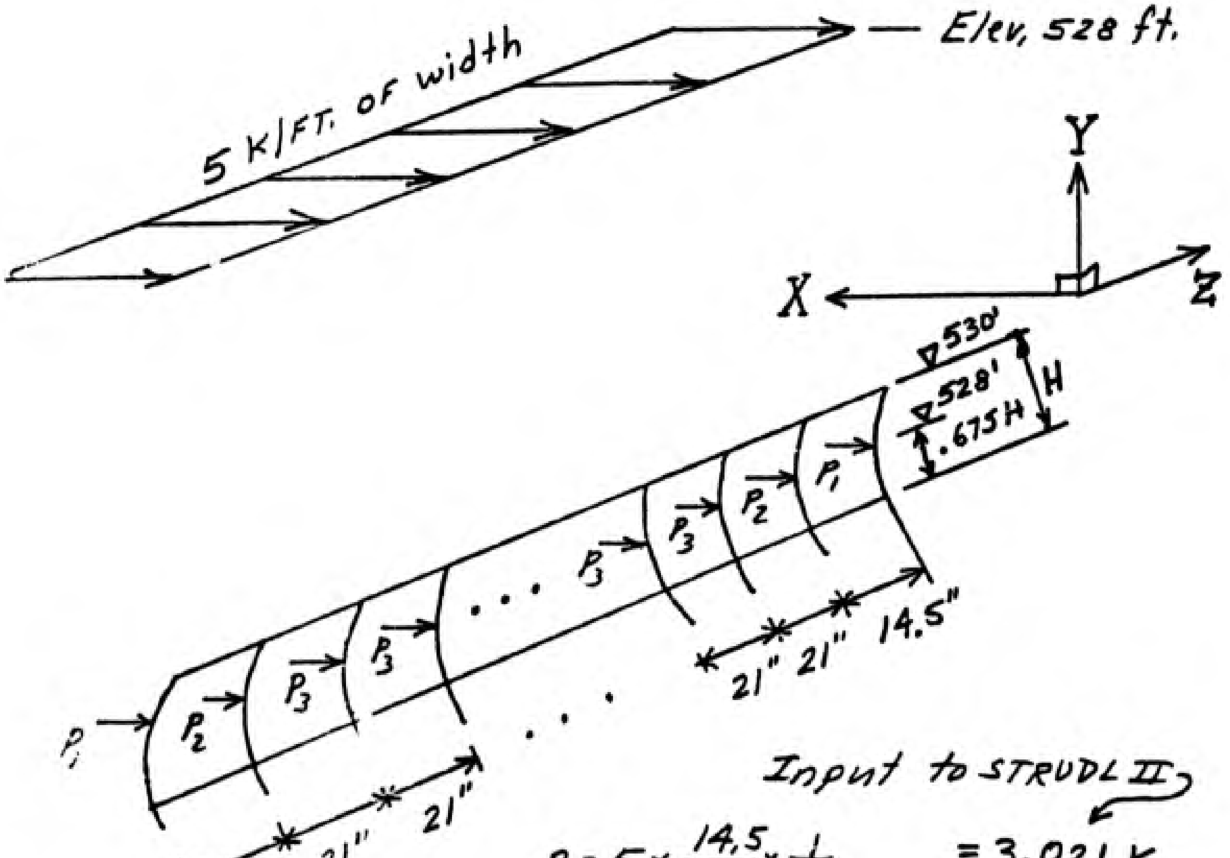
$$\bar{P}_i = (P_i + P_{i+1})/2 \ \text{K/FT}^2$$

$$(i = 2, 3, \cdots, 6)$$

i	θ_i°	h_i (FT.²)	P_i (K/FT.²)	$\bar{P}_i$ (K/FT.²)
1	14.9553	0.0	0.0	0.0877
2	3.40363	4.160	0.2596	0.4580
3	8.38458	10.520	0.6564	0.8490
4	20.17278	16.690	1.0415	1.2032
5	30.80029	21.874	1.3649	1.5096
6	41.42780	26.512	1.6543	1.7320
7	47.8966	29.0	1.8096	—

Impact Load at Elevation 528 ft.

Assume skin plate is flexible enough so that load is applied directly to vertical ribs as a concentrated load parallel to the global X-axis.



Input to STRUDL II

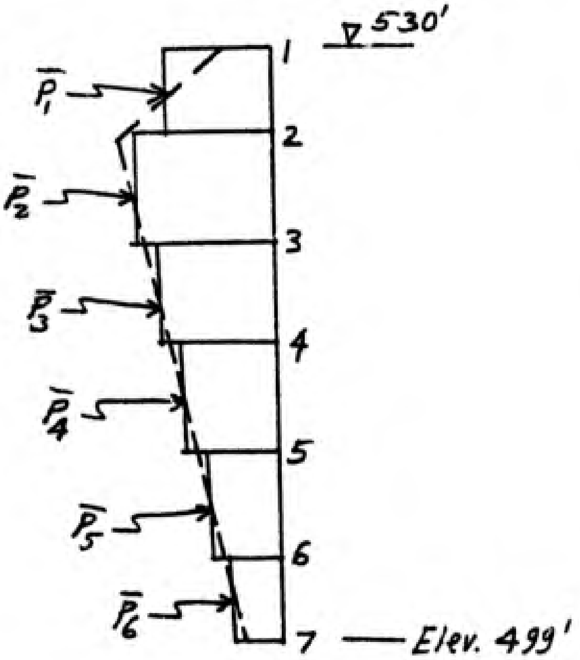
$P_1 = 5 \times \frac{14.5}{12} \times \frac{1}{2} = \underline{3.021}$ K.

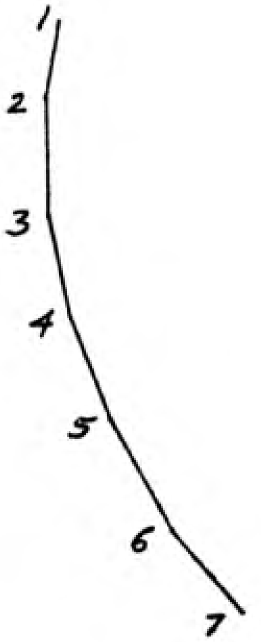
$P_2 = 5 \times \frac{14.5}{12} \times \frac{1}{2} + 5 \times \frac{21}{12} \times \frac{1}{2} = \underline{7.396}$ K.

$P_3 = 5 \times \frac{21}{12} = \underline{8.750}$ K.

Wave Loading at Elevation 530 ft.

$\bar{P}_i$: Applied perpendicular to skin plate.





Input to STRUDL II

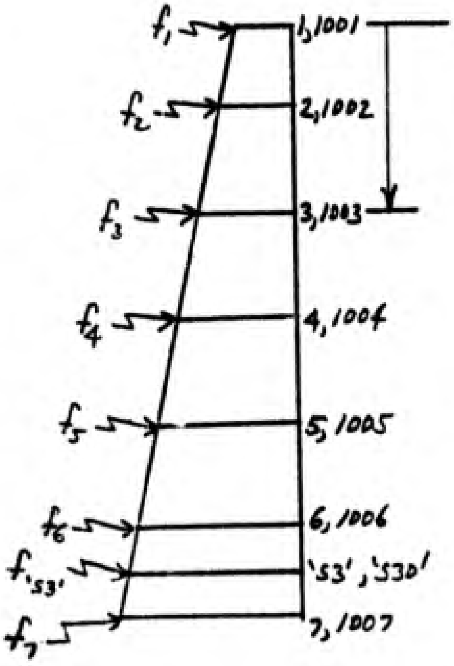
i	P_i (K/FT.²)	$\bar{P}_i$ (K/FT.²)
1	0.048	0.094
2	0.140	0.1268
3	0.1136	0.1008
4	0.088	0.0772
5	0.0664	0.0567
6	0.047	0.0420
7	0.037	—

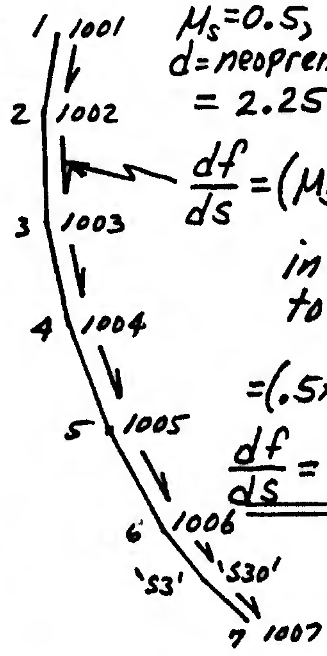
P_i taken from Re-Regulation Design Notes, Nov. 12, 1970, pg. 10.

$\bar{P}_i = (P_i + P_{i+1})/2$ K/FT.²

Side Seal Friction Resisting Gate Opening

(from "Hydraulic Structures Research Report," by Don Dressler, January 5, 1970)





$\mu_s = 0.5$, $k = 48\ \text{lb/ft.} = 0.048\ \text{K/FT.}$

d = neoprene J-seal diameter $= 2.25'' = 0.1875'$

$$\frac{df}{ds} = (\mu_s k + .0624 \mu_s d h)\ \text{K/FT.}$$

in a direction parallel to skin plate edge.

$$= (.5 \times .048 + .0624 \times .5 \times .1875 h)$$

$$\underline{\underline{\frac{df}{ds} = 0.024 + 0.00585 h\ \text{K/FT.}}}$$

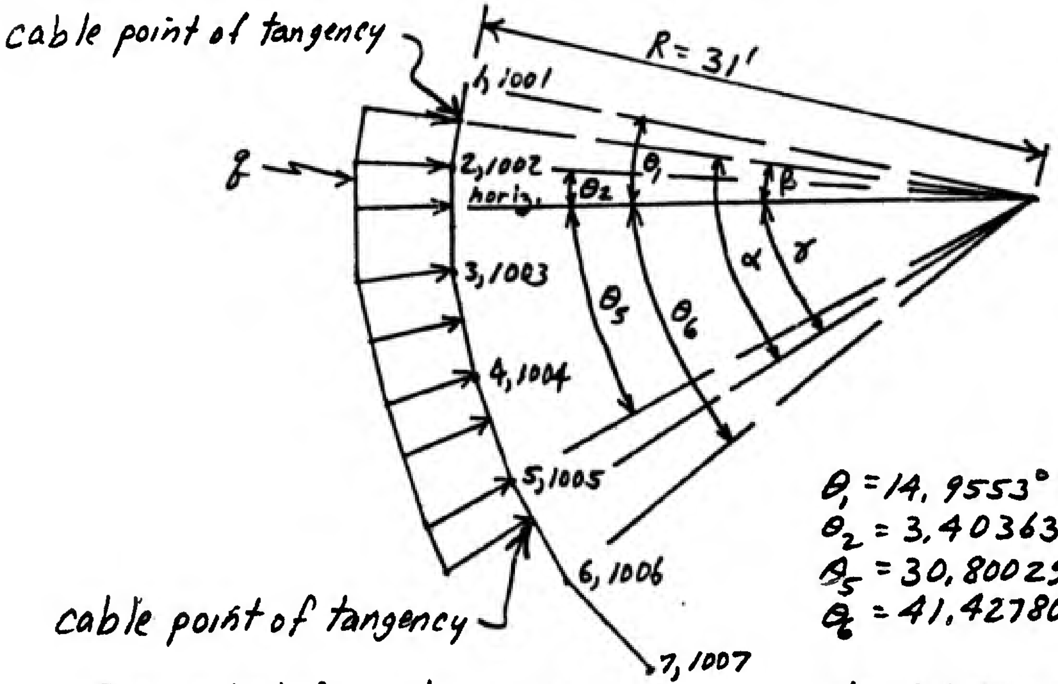
$$f_i = \left(\frac{df}{ds}\right)_i = 0.024 + 0.00585 h_i\ \text{K/FT.}$$

f_i applied parallel to edge member local x-axis at both edges of skin plate.

Input to STRUDL II

i	h_i (FT.)	f_i (K/FT.)
1	0.0	0.024
2	6.160	0.06004
3	12.520	0.09724
4	18.690	0.13334
5	23.874	0.16366
6	28.512	0.19080
'S3'	29.9678	0.1993
7	31.000	0.20535

Skin Pressure Due to 1,000 K. Cable Force



$\theta_1 = 14.9553°$
$\theta_2 = 3.40363°$
$\theta_5 = 30.80029°$
$\theta_6 = 41.42780°$

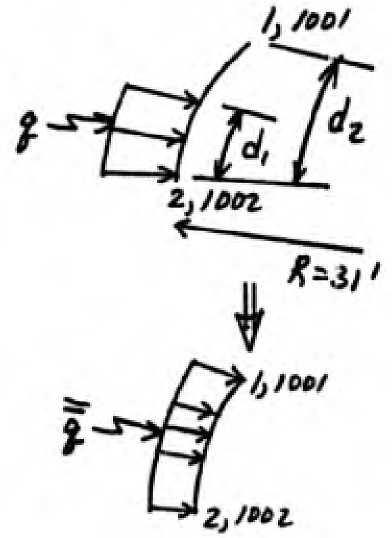
$\alpha = 39.21235°$
$\beta = 5.8657°$
$\gamma = 33.34665°$

$\bar{q}$ = radial force due to a 1,000 K. force in each cable.
$= T/R = \frac{1000K}{31\ FT.}$

q = radial pressure on a skin plate width $= 14.5" = w$
$= \bar{q}/w$
$= \frac{1000/(31 \times 12)}{14.5} = 0.18540\ k/in^2$ between joints 2-5, 1002-1005.
$= \underline{26.6976\ K/FT^2}.$

Now, in the region:

Between joints 1-2, and 1001 – 1002:



$$d_1 = \left(\frac{\beta-\theta_2}{360^\circ}\right)(2\pi R) = 1.33211 \text{ ft.}$$

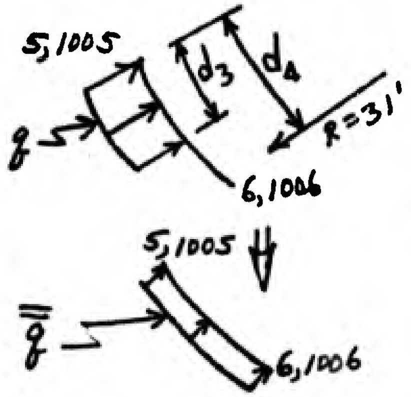
$$d_2 = \left(\frac{\theta_1-\theta_2}{360}\right)(2\pi R) = 6.25005 \text{ ft.}$$

$$\bar{\bar{q}} = q \times \frac{d_1}{d_2} = .18540\left(\frac{1.33211}{6.25005}\right)$$

$$= .03952 \text{ K/in}^2.$$

$$\bar{\bar{q}} = \underline{5.69088 \text{ K/FT}^2.}$$

Between joints 5-6, and 1005–1006:



$$d_3 = \left(\frac{\gamma-\theta_5}{360}\right)(2\pi R) = 1.37771'$$

$$d_4 = \left(\frac{\theta_6-\theta_5}{360}\right)(2\pi R) = 5.75004'$$

$$\bar{\bar{q}} = q \times \frac{d_3}{d_4} = .18540\left(\frac{1.37771}{5.75004}\right)$$

$$= .04442 \text{ K/in}^2.$$

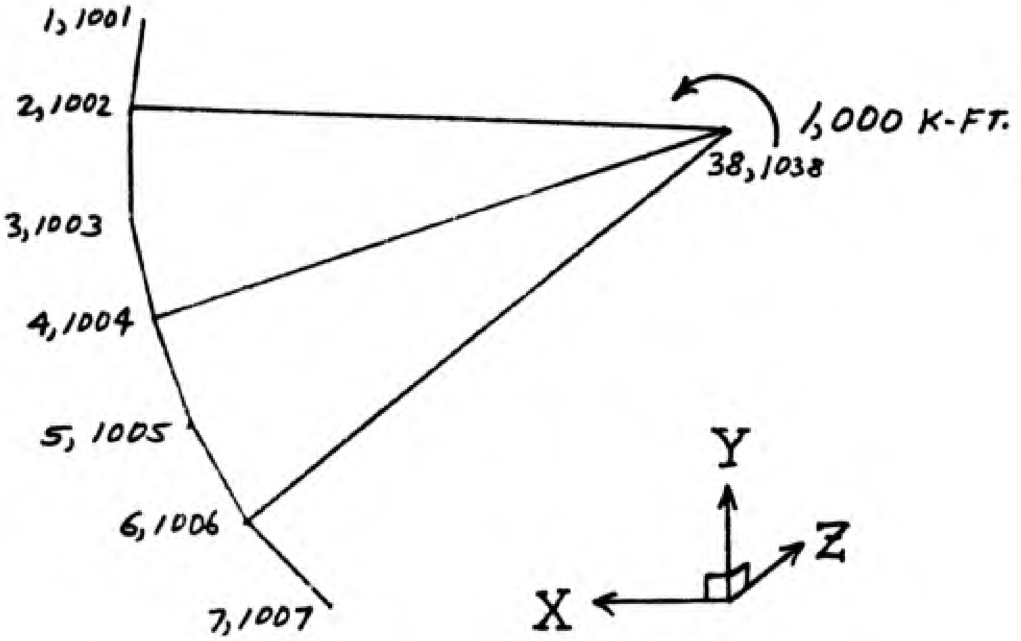
$$\bar{\bar{q}} = \underline{6.39648 \text{ K/FT}^2.}$$

Summary:

Apply to elements: Input to STRUDL II

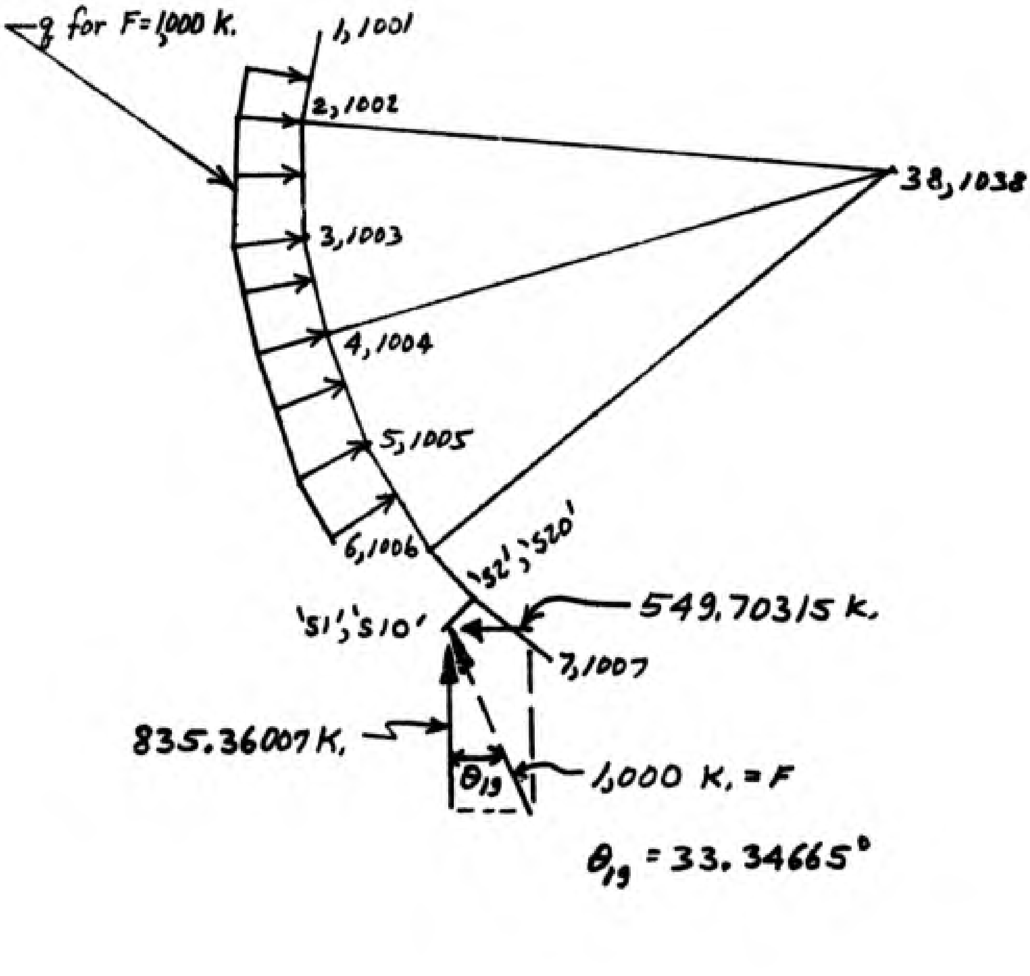
201, 202, 1201, 1202 ⟶ $\bar{\bar{q}} = 5.69088$ K/FT².
203 – 208, 1203 – 1208 ⟶ $q = 26.6976$ K/FT².
209, 210, 1209, 1210 ⟶ $\bar{\bar{q}} = 6.39648$ K/FT².

1,000 K-FT. Trunion Friction Moment Resisting Gate Opening

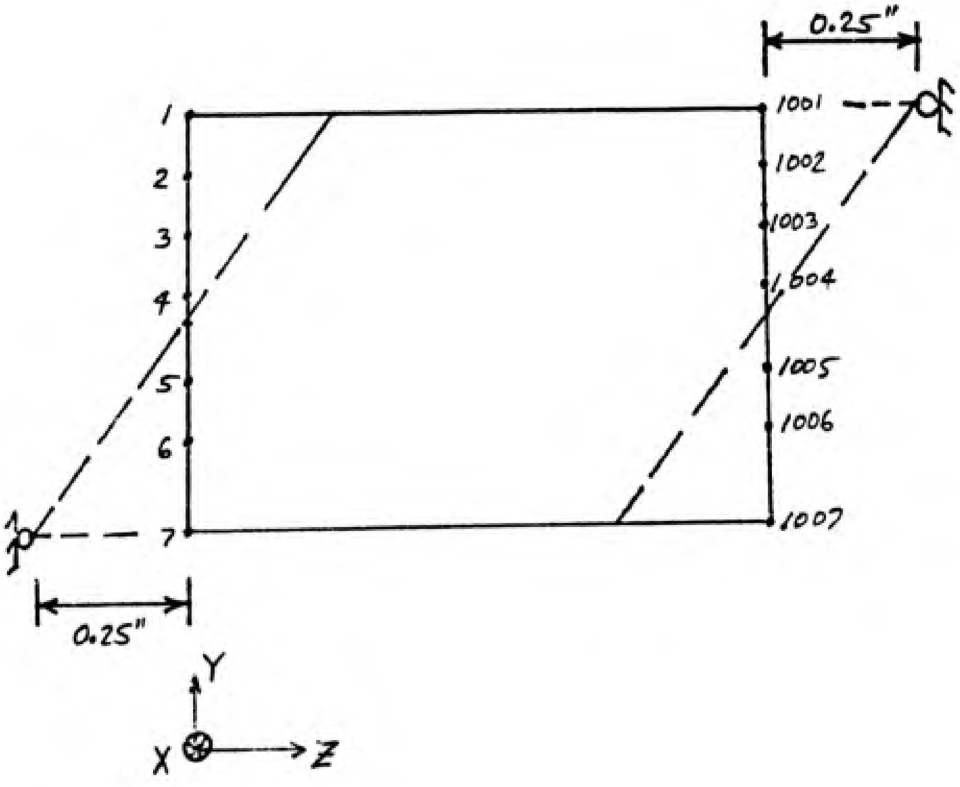


Gate Bound at Side Seal

1,000 K. Force in Each Cable



Lateral Joint Displacements Associated with Side Pier Support Constraint



FINAL DESIGN LOADING COMBINATIONS

(taken from: "Clarence Cannon Re-Regulation Dam Tainter Gate Design Notes", and Section 2.7)

Notes: In all cases, AISC allowable stresses are to be reduced by $83\frac{1}{3}\%$ or equivalently, increase <u>all</u> applied loads by $1/.833 = 1.20$. So,

a. When no overstress is permitted, load combination factor $= 1.2 \times 1.0 = \underline{1.2}$

b. When 1/3 overstress is permitted, load combination factor $= 1.2 \times \frac{1}{4/3} = \underline{1.2 \times 0.75}$

c. When 50% overstress is permitted, load combination factor $= 1.2 \times \frac{1}{3/2} = \underline{1.2 \times 0.6667}$

Loading Combination No.	Combination
I.	$1.2 \times (1+2)$
II.	$1.2 \times (6+7+10+11 \times .0248708+12 \times .0583999)$
III.	$1.2 \times (0.75 \times (1+2+3))$
IV.	$1.2 \times (0.75 \times (1+4+5))$
V.	$1.2 \times (0.75 \times (6+8+9+10+11 \times .0112262+12 \times .0589627))$
VI.	$1.2 \times (0.6667 \times (13+14+15+20+16 \times .0498795+17 \times .0604530$ $+18 \times .0563227))$
VII.	$1.2 \times (0.6667 \times (6+7+10+11 \times .0248708+12 \times .0583999$ $+19 \times 1.8 \times .0248708))$

APPENDIX E

Listing of Recommended STRUDL II Problem Solution Commands

Section 3.3 describes the step-by-step procedures used in the recommended STRUDL II analysis and design problem solution. A complete listing of the recommended STRUDL II commands for the analysis and design procedure which is suitable in a design office environment, and which is directly based upon the problem formulation summarized in this report, and presented in the Theoretical Manual (1), is contained in this Appendix.

```
1
    STRUDL 'LZEGATE' 'CLARENCE CANNON RE-REGULATION TAINTER GATE ANAL./DES., RUN 2'
    TIME BEGIN
    UNITS INCH KIPS DEGREES FAHRENHEIT
    TYPE SPACE FRAME
    $ -------------------------------------------------------------------------------
    JOINT COORDINATES
          1    359.399    372.000      0.000     SUPPORT
          2    371.344    298.086      0.000     SUPPORT
          3    368.024    221.756      0.000     SUPPORT
          4    349.180    147.715      0.000     SUPPORT
          5    319.532     85.518      0.000     SUPPORT
          6    278.922     29.857      0.000     SUPPORT
    'S3' 262.4728 12.3866 0.0       SUPPORT
          7    249.415      0.000      0.000     SUPPORT
    'S1' 268.1174 6.7175 15.25      SUPPORT
    'S2' 262.4728 12.3866 15.25
          8    359.399    372.000     22.500
          9    371.344    298.086     22.500
         10    368.024    221.756     22.500
         11    349.180    147.715     22.500
         12    319.532     85.518     22.500
         13    278.922     29.857     22.500
    'S4' 262.4728 12.3866 22.50
         14    249.415      0.000     22.500     SUPPORT
         15    359.399    372.000     43.500
         16    371.344    298.086     43.500
         17    368.024    221.756     43.500
         18    349.180    147.715     43.500
         19    319.532     85.518     43.500
         20    278.922     29.857     43.500
         21    249.415      0.000     43.500     SUPPORT
         22    359.399    372.000     64.500
         23    371.344    298.086     64.500
         24    368.024    221.756     64.500
         25    349.180    147.715     64.500
         26    319.532     85.518     64.500
         27    278.922     29.857     64.500
         28    249.415      0.000     64.500     SUPPORT
         29    371.344    298.086     77.750
         30    349.180    147.715     77.750
         31    278.922     29.857     77.750
         32    263.534    291.674     59.532
         33    247.805    184.959     59.532
         34    197.945    101.318     59.532
         35    155.725    205.262     41.315
         36    146.430    222.283     41.315
         37    116.967    172.779     41.315
         38      0.000    276.000     15.000     SUPPORT
         39    359.399    372.000     85.500
         40    371.344    298.086     85.500
         41    368.024    271.756     85.500
         42    349.180    147.715     85.500
         43    319.532     85.518     85.500
         44    278.922     29.857     85.500
         45    249.415      0.000     85.500     SUPPORT
         46    359.399    372.000    106.500
         47    371.344    298.086    106.500
         48    368.024    221.756    106.500
         49    349.180    147.715    106.500
         50    319.532     85.518    106.500
         51    278.922     29.857    106.500
         52    249.415      0.000    106.500     SUPPORT
1        53    359.399    372.000    127.500
```

```
--------------------------------------------------------------------
   54   371.344   298.086   127.500
   55   368.024   221.756   127.500
   56   349.180   147.715   127.500
   57   319.532    85.518   127.500
   58   278.922    29.857   127.500
   59   249.415     0.000   127.503    SUPPORT
   60   359.399   372.000   148.500
   61   371.344   298.086   148.500
   62   368.024   221.756   148.500
   63   349.180   147.715   148.500
   64   319.532    85.518   148.500
   65   278.922    29.857   148.500
   66   249.415     0.000   148.500    SUPPORT
   67   359.399   372.000   169.500
   68   371.344   298.086   169.500
   69   368.024   221.756   169.500
   70   349.180   147.715   169.500
   71   319.532    85.518   169.500
   72   278.922    29.857   169.500
   73   249.415     0.000   169.500    SUPPORT
   74   359.399   372.000   180.000
 1074   371.344   298.086   180.000
   75   368.024   221.756   180.000
 1075   349.180   147.715   180.000
   76   319.532    85.518   180.000
 1076   278.922    29.857   180.000
   77   249.415     0.000   180.000    SUPPORT
 1073   249.415     0.000   190.500
 1072   278.922    29.857   190.500
 1071   319.532    85.518   190.500
 1070   349.180   147.715   190.500
 1069   368.024   221.756   190.500
 1068   371.344   298.086   190.500
 1067   359.399   372.000   190.500    SUPPORT
 1066   249.415     0.000   211.500
 1065   278.922    29.857   211.500
 1064   319.532    85.518   211.500
 1063   349.180   147.715   211.500
 1062   368.024   221.756   211.500
 1061   371.344   298.086   211.500
 1060   359.399   372.000   211.500    SUPPORT
 1059   249.415     0.000   232.500
 1058   278.922    29.857   232.500
 1057   319.532    85.518   232.500
 1056   349.180   147.715   232.500
 1055   368.024   221.756   232.500
 1054   371.344   298.086   232.500
 1053   359.399   372.000   232.500    SUPPORT
 1052   249.415     0.000   253.500
 1351   278.922    29.857   253.500
 1050   319.532    85.518   253.500
 1049   349.180   147.715   253.500
 1048   368.024   221.756   253.500
 1047   371.344   298.086   253.500
 1046   359.399   372.000   253.500    SUPPORT
 1045   249.415     0.000   274.500
 1044   278.922    29.857   274.500
 1043   319.532    85.518   274.500
 1042   349.180   147.715   274.500
 1041   368.024   221.756   274.500
 1040   371.344   298.086   274.500
 1039   359.399   372.000   274.500    SUPPORT
 1038     0.000   276.000   345.000
 1037   116.967   172.779   318.685
 1036   146.430   222.203   318.685
 1035   155.725   265.262   318.685
--------------------------------------------------------------------
```

```
   1034   197.945   181.315   300.468
   1033   247.805   184.959   300.468
   1032   263.534   291.674   300.468
   1031   278.922    29.857   282.250
   1030   349.180   147.715   282.250
   1029   371.344   298.086   282.250
   1028   249.415     0.000   295.500     SUPPORT
   1027   278.922    29.857   295.500
   1026   319.532    85.518   295.500
   1025   349.180   147.715   295.500
   1024   368.024   221.756   295.500
   1023   371.344   298.086   295.500
   1022   359.399   372.000   295.500
   1021   249.415     0.000   316.500     SUPPORT
   1020   278.922    29.857   316.500
   1019   319.532    85.518   316.500
   1018   349.180   147.715   316.500
   1017   368.024   221.756   316.500
   1016   371.344   298.086   316.500
   1015   359.399   372.000   316.500
   1014   249.415     0.000   337.500     SUPPORT
  *S40* 262.4728 12.3866 337.50
   1013   278.922    29.857   337.500
   1012   319.532    85.518   337.500
   1011   349.180   147.715   337.500
   1010   368.024   221.756   337.500
   1009   371.344   298.086   337.500
   1008   359.399   372.000   337.500
  *S10* 268.1174 6.7175 344.75          SUPPORT
  *S20* 262.4728 12.3866 344.75
   1007   249.415     0.000   352.000     SUPPORT
  *S30* 262.4728 12.3856 352.00         SUPPORT
   1006   278.922    29.857   352.000     SUPPORT
   1005   319.532    85.518   352.000     SUPPORT
   1004   349.180   147.715   352.000     SUPPORT
   1003   368.024   221.756   352.000     SUPPORT
   1002   371.344   298.086   352.000     SUPPORT
   1001   359.399   372.000   352.000     SUPPORT
  $ --------------------------------------------------------------------------------
  MEMBER INCIDENCES
  $ SKIN PLATE HORIZONTAL BEAMS AND STIFFENING RIBS.
        1    1    8
        2    8   15
        3   15   22
        4   22   39
        5   39   46
        6   46   53
        7   53   60
        8   60   67
        9   67   74
     1001 1001 1008
     1002 1008 1015
     1003 1015 1022
     1004 1022 1039
     1005 1039 1046
     1006 1046 1053
     1007 1053 1060
     1008 1060 1067
     1009 1067   74
       10    2    9
       11    9   16
       12   16   23
       13   23   29
       14   29   40
       15   40   47
       16   47   54
```

```
  17   54   61
  18   61   68
  19   68 1074
1010 1002 1009
1011 1009 1016
1012 1016 1023
1013 1023 1029
1014 1029 1040
1015 1040 1047
1016 1047 1054
1017 1054 1061
1018 1061 1068
1019 1068 1074
  20    4   11
  21   11   18
  22   18   25
  23   25   30
  24   30   42
  25   42   49
  26   49   56
  27   56   63
  28   63   70
  29   70 1075
1020 1004 1011
1021 1011 1018
1022 1018 1025
1023 1025 1030
1024 1030 1042
1025 1042 1049
1026 1049 1056
1027 1056 1063
1028 1063 1070
1029 1070 1075
  30    6   13
  31   13   20
  32   20   27
  33   27   31
  34   31   44
  35   44   51
  36   51   58
  37   58   65
  38   65   72
  39   72 1076
1030 1006 1013
1031 1013 1020
1032 1020 1027
1033 1027 1031
1034 1031 1044
1035 1044 1051
1036 1051 1058
1037 1058 1065
1038 1065 1072
1039 1072 1076
  40    7   14
  41   14   21
  42   21   28
  43   28   45
  44   45   52
  45   52   59
  46   59   66
  47   66   73
  48   73   77
1040 1007 1014
1041 1014 1021
1042 1021 1028
1043 1028 1045
```

```
    1044 1045 1052
    1045 1052 1059
    1046 1059 1066
    1047 1066 1073
    1048 1073   77
   $ SKIN PLATE VERTICAL STIFFENING RIBS.
      49    2    1
      50    3    2
      51    4    3
      52    5    4
      53    6    5
   54 *53* 6
   541 7 *53*
      55    9    8
      56   10    9
      57   11   10
      58   12   11
      59   13   12
   60 *54* 13
   601 14 *54*
      61   16   15
      62   17   16
      63   18   17
      64   19   18
      65   20   19
      66   21   20
      67   23   22
      68   24   23
      69   25   24
      70   26   25
      71   27   26
      72   28   27
      73   40   39
      74   41   40
      75   42   41
      76   43   42
      77   44   43
      78   45   44
      79   47   46
      80   48   47
      81   49   48
      82   50   49
      83   51   50
      84   52   51
      85   54   53
      86   55   54
      87   56   55
      88   57   56
      89   58   57
      90   59   58
      91   61   60
      92   62   61
      93   63   62
      94   64   63
      95   65   64
      96   66   65
      97   68   67
      98   69   68
      99   70   69
     100   71   70
     101   72   71
     102   73   72
    1049 1002 1001
    1050 1003 1002
    1051 1004 1003
    1052 1005 1004
```

```
 1053 1006 1005
1054 *S30* 1006
10541 1007 *S30*
 1055 1009 1008
 1056 1010 1009
 1057 1011 1010
 1058 1012 1011
 1059 1013 1012
1060 *S40* 1013
10601 1014 *S40*
 1061 1016 1015
 1062 1017 1016
 1063 1018 1017
 1064 1019 1018
 1065 1020 1019
 1066 1021 1020
 1067 1023 1022
 1068 1024 1023
 1069 1025 1024
 1070 1026 1025
 1071 1027 1026
 1072 1028 1027
 1073 1040 1039
 1074 1041 1040
 1075 1042 1041
 1076 1043 1042
 1077 1044 1043
 1078 1045 1044
 1079 1047 1046
 1080 1048 1047
 1081 1049 1048
 1082 1050 1049
 1083 1051 1050
 1084 1052 1051
 1085 1054 1053
 1086 1055 1054
 1087 1056 1055
 1088 1057 1056
 1089 1058 1057
 1090 1059 1058
 1091 1061 1060
 1092 1062 1061
 1093 1063 1062
 1094 1064 1063
 1095 1065 1064
 1096 1066 1065
 1097 1068 1067
 1098 1069 1068
 1099 1070 1069
 1100 1071 1070
 1101 1072 1071
 1102 1073 1072
& STRUT SYSTEM OF MEMBERS.
103 38 35
104 35 32
105 32 29
106 38 36
107 36 33
108 33 30
109 38 37
110 37 34
111 34 31
112 36 35
113 37 36
114 35 33
115 37 33
```

```
116 33 32
117 34 33
118 32 30
119 34 30
1103 1038 1035
1104 1035 1032
1105 1032 1029
1106 1038 1036
1107 1036 1033
1108 1033 1030
1109 1038 1037
1110 1037 1034
1111 1034 1031
1112 1036 1035
1113 1037 1036
1114 1035 1033
1115 1037 1033
1116 1033 1032
1117 1034 1033
1118 1032 1030
1119 1034 1030
$ SKIN PLATE BRACE MEMBERS.
120 4 2
121 30 2
122 30 1074
123 1075 1074
1120 1004 1002
1121 1030 1002
1122 1030 1074
124 6 4
125 6 30
126 1076 30
127 1076 1075
1124 1006 1004
1125 1006 1030
1126 1076 1030
$ CABLE SUPPORT POINT SIMULATION MEMBERS ON SKIN PLATE.
'B1' 'S2' 'S1'
'B2' 'S3' 'S2'
'B3' 'S4' 'S2'
'B10' 'S20' 'S10'
'B20' 'S30' 'S20'
'B30' 'S40' 'S20'
$ ------------------------------------------------------------------------
ELEMENT INCIDENCES
  201    8    7    1
  202    2    8    9
  203    9    3    2
  204    3    9   10
  205   10    4    3
  206    4   10   11
  207   11    5    4
  208    5   11   12
  209   12    6    5
  210    6   12   13
211 6 'S2' 'S3'
2111 13 'S2' 6
2112 'S2' 13 'S4'
212 'S2' 7 'S3'
2121 7 'S2' 14
2122 14 'S2' 'S4'
  213   15    9    8
  214    9   15   16
  215   16   10    9
  216   10   16   17
  217   17   11   18
```

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     218    11    17    18
     219    18    12    11
     220    12    18    19
     221    19    13    12
     222    13    19    20
   223 20 *54* 13
   2231 20 21 *54*
   224 *54* 21 14
     225    22    16    15
     226    16    22    23
     227    23    17    16
     228    17    23    24
     229    24    18    17
     230    18    24    25
     231    25    19    18
     232    19    25    26
     233    26    20    19
     234    20    26    27
     235    27    21    20
     236    21    27    28
   237 22 29 23
   238 29 22 39
   239 29 39 40
   240 29 24 23
   241 24 29 41
   242 41 29 40
   243 24 30 25
   244 30 24 41
   245 30 41 42
   246 30 26 25
   247 26 30 43
   248 43 30 42
   249 26 31 27
   250 31 26 43
   251 31 43 44
   252 31 28 27
   253 28 31 45
   254 45 31 44
     255    46    40    39
     256    40    46    47
     257    47    41    40
     258    41    47    48
     259    48    42    41
     260    42    48    49
     261    49    43    42
     262    43    49    50
     263    50    44    43
     264    44    50    51
     265    51    45    44
     266    45    51    52
     267    53    47    46
     268    47    53    54
     269    54    48    47
     270    48    54    55
     271    55    49    48
     272    49    55    56
     273    56    50    49
     274    50    56    57
     275    57    51    50
     276    51    57    58
     277    58    52    51
     278    52    58    59
     279    60    54    53
     280    54    60    61
     281    61    55    54
     282    55    61    62
```

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    283   62   56   55
    284   56   62   63
    285   63   57   56
    286   57   63   64
    287   64   58   57
    288   58   64   65
    289   65   59   58
    290   59   65   66
    291   67   61   60
    292   61   67   68
    293   68   62   61
    294   62   68   69
    295   69   63   62
    296   63   69   70
    297   70   64   63
    298   64   70   71
    299   71   65   64
    300   65   71   72
    301   72   66   65
    302   66   72   73
  303 74 68 67
  304 68 74 1074
  1304 74 1068 1074
  1303 1068 74 1067
  305 68 75 69
  306 75 68 1074
  1306 1068 75 1074
  1305 75 1068 1069
  307 75 70 69
  308 70 75 1075
  1308 75 1070 1075
  1307 1070 75 1069
  309 70 76 71
  310 76 70 1075
  1310 1076 76 1075
  1309 76 1070 1071
  311 76 72 71
  312 72 76 1076
  1312 76 1072 1076
  1311 1072 76 1071
  313 72 77 73
  314 77 72 1076
  1314 1072 77 1076
  1313 77 1072 1073
    1291 1061 1067 1060
    1292 1067 1061 1068
    1293 1062 1068 1061
    1294 1068 1062 1069
    1295 1063 1069 1062
    1296 1069 1063 1070
    1297 1064 1070 1063
    1298 1070 1064 1071
    1299 1065 1071 1064
    1300 1071 1065 1072
    1301 1066 1072 1065
    1302 1072 1066 1073
    1279 1054 1060 1053
    1280 1060 1054 1061
    1281 1055 1061 1054
    1282 1061 1055 1062
    1283 1056 1062 1055
    1284 1062 1056 1063
    1285 1057 1063 1056
    1286 1063 1057 1064
    1287 1058 1064 1057
    1288 1064 1058 1055
```

```
    1289 1059 1065 1058
    1290 1065 1059 1066
    1267 1047 1053 1046
    1268 1053 1047 1054
    1269 1048 1054 1047
    1270 1054 1048 1055
    1271 1049 1055 1048
    1272 1055 1049 1056
    1273 1050 1056 1049
    1274 1056 1050 1057
    1275 1051 1057 1050
    1276 1057 1051 1058
    1277 1052 1058 1051
    1278 1058 1052 1059
    1255 1040 1046 1039
    1256 1046 1040 1047
    1257 1041 1047 1040
    1258 1047 1041 1048
    1259 1042 1048 1041
    1260 1048 1042 1049
    1261 1043 1049 1042
    1262 1049 1043 1050
    1263 1044 1050 1043
    1264 1050 1044 1051
    1265 1045 1051 1044
    1266 1051 1045 1052
   1237 1029 1022 1023
   1238 1029 1039 1022
   1239 1039 1029 1040
   1240 1024 1029 1023
   1241 1041 1029 1024
   1242 1029 1041 1040
   1243 1030 1024 1025
   1244 1030 1041 1024
   1245 1041 1030 1042
   1246 1026 1030 1025
   1247 1043 1030 1026
   1248 1030 1043 1042
   1249 1031 1026 1027
   1250 1031 1043 1026
   1251 1043 1031 1044
   1252 1029 1031 1027
   1253 1045 1031 1028
   1254 1031 1045 1044
      1225 1016 1022 1015
      1226 1022 1016 1023
      1227 1017 1023 1016
      1228 1023 1017 1024
      1229 1018 1024 1017
      1230 1024 1018 1025
      1231 1019 1025 1018
      1232 1025 1019 1026
      1233 1020 1026 1019
      1234 1026 1020 1027
      1235 1021 1027 1020
      1236 1027 1021 1028
      1213 1009 1015 1008
      1214 1015 1009 1016
      1215 1010 1016 1009
      1216 1016 1010 1017
      1217 1011 1017 1010
      1218 1017 1011 1018
      1219 1012 1018 1011
      1220 1018 1012 1019
      1221 1013 1019 1012
      1222 1019 1013 1020
```

```
1223 *S40* 1020 1013
12231 102. 1020 *S40*
1224 1021 *S40* 1014
 1201 1002 1008 1001
 1202 1008 1002 1009
 1203 1003 1009 1002
 1204 1009 1003 1010
 1205 1004 1010 1003
 1206 1010 1004 1011
 1207 1005 1011 1004
 1208 1011 1005 1012
 1209 1006 1012 1005
 1210 1012 1006 1013
1211 *S20* 1006 *S30*
12111 1006 *S20* 1013
12112 1013 *S20* *S40*
1212 1007 *S20* *S30*
12121 1014 *S20* 1007
12122 *S20* 1014 *S40*
$ ------------------------------------------------------------ ------------------------
EJECT
STATISTICS ALL BAR GRAPH
TIME PRINT
EJECT
PLOT FORMAT DATA MINIMUM
PLOT PLANE XY PROJECTION JOINTS 1 2 7
PLOT PLANE XY PROJECTION JOINTS 8 9 14
PLOT PLANE XY PROJECTION JOINTS 15 16 21
PLOT PLANE XY PROJECTION JOINTS 22 23 28
PLOT PLANE XY PROJECTION JOINTS 39 40 45
PLOT PLANE XY PROJECTION JOINTS 46 47 52
PLOT PLANE XY PROJECTION JOINTS 53 54 59
PLOT PLANE XY PROJECTION JOINTS 60 61 66
PLOT PLANE XY PROJECTION JOINTS 67 68 73
PLOT PLANE XY PROJECTION JOINTS 1067 1068 1073
PLOT PLANE XY PROJECTION JOINTS 1060 1061 1066
PLOT PLANE XY PROJECTION JOINTS 1053 1054 1059
PLOT PLANE XY PROJECTION JOINTS 1046 1047 1052
PLOT PLANE XY PROJECTION JOINTS 1039 1040 1045
PLOT PLANE XY PROJECTION JOINTS 1022 1023 1028
PLOT PLANE XY PROJECTION JOINTS 1015 1016 1021
PLOT PLANE XY PROJECTION JOINTS 1008 1009 1014
PLOT PLANE XY PROJECTION JOINTS 1001 1002 1007
PLOT PLANE YZ PROJECTION JOINTS 1 2 8
PLOT PLANE YZ PROJECTION JOINTS 2 3 9
PLOT PLANE YZ PROJECTION JOINTS 3 4 10
PLOT PLANE YZ PROJECTION JOINTS 4 5 11
PLOT PLANE YZ PROJECTION JOINTS 5 6 12
PLOT PLANE YZ PROJECTION JOINTS 6 7 13
PLOT FORMAT ORIENTATION NON STANDARD
PLOT PLANE XY PROJECTION JOINTS 29 30 38
PLOT PLANE XY PROJECTION JOINTS 30 38 31
PLOT PLANE XY PROJECTION JOINTS 1029 1030 1038
PLOT PLANE XY PROJECTION JOINTS 1030 1038 1031
PLOT FORMAT ORIENTATION STANDARD
PLOT PLANE YZ PROJECTION JOINTS 2 6 1006
PLOT PLANE YZ PROJECTION JOINTS 2 4 1004
PLOT PLANE YZ PROJECTION JOINTS 4 6 1006
PLOT PLANE XZ PROJECTION JOINTS 31 38 1031
PLOT FORMAT ORIENTATION NON STANDARD
PLOT PLANE XZ PROJECTION JOINTS 30 38 1030
PLOT PLANE XZ PROJECTION JOINTS 29 38 1029
PLOT FORMAT ORIENTATION STANDARD
PLOT PLANE XZ PROJECTION JOINTS *S1* *S2* *S3*
EJECT
TIME PRINT
```

```
$ --------------------------------------------------------------------------------
UNITS FEET LBS
CONSTANTS
DENSITY 490.0 ALL BUT 0.0 *B1* *B2* *B3* *B10* *B20* *B30*  $ LB/FT**3
UNITS INCH KIPS
CONSTANTS
E 29000.0 ALL
POISSON 0.15 ALL
BETA -75.0447 1 TO 9
BETA  75.0447 1001 TO 1009
BETA -86.5964 10 TO 19
BETA  86.5964 1010 TO 1019
BETA  69.8272 20 TO 29
BETA -69.8272 1020 TO 1029
BETA  48.5722 30 TO 39
BETA -48.5722 1030 TO 1039
BETA 90.57 103 TO 105
BETA -90.57 1103 TO 1105
BETA 86.34 106 TO 108
BETA -86.34 1106 TO 1108
BETA 81.81 109 TO 111
BETA -81.81 1109 TO 1111
BETA 90.0 112 113 116 117, 1112 1113 1116 1117
BETA 81.69 114
BETA -81.69 1114
BETA 90.80 115
BETA -90.80 1115
BETA 79.24 118
BETA -79.24 1118
BETA 92.29 119
BETA -92.29 1119
$ --------------------------------------------------------------------------------
MEMBER RELEASES
120 TO 127, 1120 TO 1122, 1124 TO 1126  START MOMENT X Y Z, END MOMENT Y Z
$ --------------------------------------------------------------------------------
MEMBER PROPERTIES PRISMATIC
40 TO 48, 1040 TO 1048  AX 3.375 IX 0.158 IY 0.0396 IZ 22.781
*B1* *B2* *B3* *B10* *B20* *B30*  AX 1000.0 IX 10000.0 IY 10000.0 IZ 10000.0
$ --------------------------------------------------------------------------------
MEMBER PROPERTIES TABLE *STEELW*
10 TO 19, 1010 TO 1019 TABLE *W24X55*
20 TO 39, 1020 TO 1039 TABLE *W24X76*
103 TO 105, 1103 TO 1105 TABLE *W14X43*
106 TO 111, 1106 TO 1111 TABLE *W14X78*
112 TO 119, 1112 TO 1119 TABLE *W14X22*
$ --------------------------------------------------------------------------------
MEMBER PROPERTIES TABLE *STEELL*
1 TO 9, 1001 TO 1009  TABLE *L80407*
$ --------------------------------------------------------------------------------
MEMBER PROPERTIES TABLE *STEELWT*
49 TO 78, 541 601, 1049 TO 1078, 10541 10601  TABLE *WT7X17*
79 TO 102, 1079 TO 1102  TABLE *WT7X15*
120 TO 127, 1120 TO 1122, 1124 TO 1126  TABLE *WT7X11*
$ --------------------------------------------------------------------------------
ELEMENT PROPERTIES
201 TO 212, 2111 2112 2121 2122, 1201 TO 1212, 12111 12112 12121 12122  -
          TYPE *PBS2* THICKNESS 0.75
213 TO 314, 1213 TO 1314, 2231 12231   -
          TYPE *PBS2* THICKNESS 0.375
$ --------------------------------------------------------------------------------
PRINT MEMBER PROPERTIES
$ --------------------------------------------------------------------------------
$ MEMBER LENGTHS BEFORE MEMBER ECCENTRICITIES SPECIFIED.
PRINT MEMBER LENGTHS
EJECT
$ --------------------------------------------------------------------------------
```

```
$ TOTAL FRAME WEIGHT (EXCLUDING SKIN PLATE) BEFORE ECCENTRICITIES SPECIFIED.
STEEL TAKEOFF
$ ------------------------------------------------------------------------------
MEMBER ECCENTRICITIES    $ INCHES
1 TO 9, 1001 TO 1009 GLOBAL START X -4.78 Y -2.141 END X -4.78 Y -2.141
10 TO 19, 1010 TO 1019  GLOBAL START X -18.7419 Y -1.1147   -
                               END X -18.7419 Y -1.1147
20 TO 29, 1020 TO 1029  GLOBAL START X -17.7922 Y 6.5367  -
                               END X -17.7922 Y 6.5367
30 TO 39, 1030 TO 1039  GLOBAL START X -14.2123 Y 12.542  -
                               END X -14.2123 Y 12.542
40 TO 48, 1040 TO 1048  GLOBAL START X 0.0 Y 4.5 END X 0.0 Y 4.5
$ RIBS.
49 55 61 67 73 79 85 91 97 1049 1053 1061 1067 1073 1079 1085 1091 1097  -
      GLOBAL START X -5.490 Y -0.327 END X -5.314 Y -1.419
50 56 62 68 74 80 86 92 98 1050 1056 1062 1068 1074 1080 1086 1092 1098  -
      GLOBAL START X -5.441 Y 0.802 END X -5.490 Y -0.327
51 57 63 69 75 81 87 93 99 1051 1057 1063 1069 1975 1081 1087 1093 1099  -
      GLOBAL START X -5.163 Y 1.897 END X -5.441 Y 0.802
52 58 64 70 76 82 88 94 100 1052 1058 1064 1070 1076 1082 1088 1094 1100  -
      GLOBAL START X -4.724 Y 2.816 END X -5.163 Y 1.897
53 59 65 71 77 83 89 95 101 1053 1059 1065 1071 1077 1083 1089 1095 1101  -
      GLOBAL START X -4.124 Y 3.639 END X -4.724 Y 2.816
54 60 1054 1060  GLOBAL START X -3.881 Y 3.898 END X -4.124 Y 3.639
541 601 10541 10601  GLOBAL START X -3.688 Y 4.081 END X -3.881 Y 3.898
66 72 78 84 90 96 102 1066 1072 1078 1084 1090 1096 1102   -
      GLOBAL START X -3.688 Y 4.081 END X -4.124 Y 3.639
$ STRUTS.
105 1105 GLOBAL START X 0.0 Y 0.0 END X -30.496 Y -1.814
108 1108 GLOBAL START X 0.0 Y 0.0 END X -29.014 Y 10.659
111 1111 GLOBAL START X 0.0 Y 0.0 END X -23.176 Y 20.452
$ STRUT BRACES.
118 119 1118 1119 GLOBAL START X 0.0 Y 0.0 END X -6.015 Y 3.584
$ ------------------------------------------------------------------------------
EJECT
$ ------------------------------------------------------------------------------
$ MEMBER LENGTHS AFTER MEMBER ECCENTRICITIES SPECIFIED.
PRINT MEMBER LENGTHS
EJECT
$ ------------------------------------------------------------------------------
$ TOTAL FRAME WEIGHT (EXCLUDING SKIN PLATE) AFTER ECCENTRICITIES SPECIFIED.
$ NOTE THAT SKIN PLATE WEIGHS 16185.67248 LBS.
STEEL TAKEOFF
$ ------------------------------------------------------------------------------
$ -----TRUNION PIN LOCATIONS-----------------------------------
JOINT RELEASES
38 1038 MOMENT Z
$ ------------------------------------------------------------------------------
UNITS LBS FEET
LOADING 1 'D.L. - GATE ON SILL'
$ FRAME MEMBER DEAD LOADS.
DEAD LOAD Y -1.0
$ SKIN PLATE DEAD LOAD, TOTAL = 16185.67248 LBS.
JOINT LOADS   $ LBS
1 1001 FORCE Y -57.8211
2 1002 FORCE Y -116.82608
3 1003 FORCE Y -118.00996
4 1004 FORCE Y -112.20030
5 1005 FORCE Y -106.39064
6 1006 FORCE Y -85.57449
7 1007 FORCE Y -32.37917
8 1008 FORCE Y -99.69155
9 1009 FORCE Y -201.42420
10 1010 FORCE Y -233.46546
11 1011 FORCE Y -193.44880
12 1012 FORCE Y -183.43214
```

```
13 1013 FORCE Y -147.54222
14 1014 FORCE Y -55.82615
15 22 39 46 53 60 67 1015 1022 1039 1046 1053 1060 1067  FORCE Y -83.74090
16 23 40 47 54 61 68 1016 1023 1040 1047 1054 1061 1068  FORCE Y -169.19640
17 24 41 48 55 62 69 1017 1024 1041 1048 1055 1062 1069  FORCE Y -170.91098
18 25 42 49 56 63 70 1018 1025 1042 1049 1056 1063 1070  FORCE Y -162.49700
19 26 43 50 57 64 71 1019 1026 1043 1050 1057 1064 1071  FORCE Y -154.08300
20 27 44 51 58 65 72 1020 1027 1044 1051 1058 1065 1072  FORCE Y -123.93546
21 28 45 52 59 66 73 1021 1028 1045 1052 1059 1066 1073  FORCE Y -46.89396
$ ------------------------------------------------------------------------------
UNITS KIPS FEET
LOADING 2 *HYDRO. ELEV. 530 FT - GATE ON SILL*
ELEMENT LOADS  $ K/FT**2
201 202 213 214 225 226 237 238 239 255 256 267 268 279 280 291 292 303 304  -
1303 1304 1291 1292 1279 1280 1267 1268 1255 1256 1237 1238 1239 1225 1226   -
   1213 1214 1201 1202   SURFACE FORCES LOCAL PZ -0.1922
203 204 215 216 227 228 240 241 242 257 258 269 270 281 282 293 294 305 306  -
   1305 1306 1293 1294 1281 1282 1269 1270 1257 1258 1240 1241 1242 1227 1228 -
   1215 1216 1203 1204   SURFACE FORCES LOCAL PZ -0.5928
205 206 217 218 229 230 243 244 245 259 260 271 272 283 284 295 296 307 308  -
   1307 1308 1295 1296 1283 1284 1271 1272 1259 1260 1243 1244 1245 1229 1230 -
   1217 1218 1205 1206   SURFACE FORCES LOCAL PZ -0.9738
207 208 219 220 231 232 246 247 248 261 262 273 274 285 286 297 298 309 310  -
1309 1310 1297 1298 1285 1286 1273 1274 1261 1262 1246 1247 1248 1231 1232   -
   1219 1220 1207 1208   SURFACE FORCES LOCAL PZ -1.3280
209 210 221 222 233 234 249 250 251 263 264 275 276 287 288 299 300 311 312  -
   1311 1312 1299 1300 1287 1288 1275 1276 1263 1264 1249 1250 1251 1233 1234 -
   1221 1222 1209 1210   SURFACE FORCES LOCAL PZ -1.6344
211 2111 2112 212 2121 2122 223 2231 224 235 236 252 253 254 265 266 277 278  -
   289 290 301 302 313 314 1313 1314 1301 1302 1289 1290 1277 1278 1265 1266  -
   1252 1253 1254 1235 1236 1223 12231 1224 1211 12111 12112   -
   1212 12121 12122   SURFACE FORCES LOCAL PZ -1.8565
$ ------------------------------------------------------------------------------
LOADING 3 *WAVE LOAD - GATE ON SILL*
ELEMENT LOADS  $ K/FT**2
201 202 213 214 225 226 237 238 239 255 256 267 268 279 280 291 292 303 304  -
1303 1304 1291 1292 1279 1280 1267 1268 1255 1256 1237 1238 1239 1225 1226   -
   1213 1214 1201 1202   SURFACE FORCES LOCAL PZ -0.094
203 204 215 216 227 228 240 241 242 257 258 269 270 281 282 293 294 305 306  -
   1305 1306 1293 1294 1281 1282 1269 1270 1257 1258 1240 1241 1242 1227 1228 -
   1215 1216 1203 1204   SURFACE FORCES LOCAL PZ -0.1268
205 206 217 218 229 230 243 244 245 259 260 271 272 283 284 295 296 307 308  -
   1307 1308 1295 1296 1283 1284 1271 1272 1259 1260 1243 1244 1245 1229 1230 -
   1217 1218 1205 1206   SURFACE FORCES LOCAL PZ -0.1008
207 208 219 220 231 232 246 247 248 261 262 273 274 285 286 297 298 309 310  -
1309 1310 1297 1298 1285 1286 1273 1274 1261 1262 1246 1247 1248 1231 1232   -
   1219 1220 1207 1208   SURFACE FORCES LOCAL PZ -0.0772
209 210 221 222 233 234 249 250 251 263 264 275 276 287 288 299 300 311 312  -
   1311 1312 1299 1300 1287 1288 1275 1276 1263 1264 1249 1250 1251 1233 1234 -
   1221 1222 1209 1210   SURFACE FORCES LOCAL PZ -0.0567
211 2111 2112 212 2121 2122 223 2231 224 235 236 252 253 254 265 266 277 278  -
   289 290 301 302 313 314 1313 1314 1301 1302 1289 1290 1277 1278 1265 1266  -
   1252 1253 1254 1235 1236 1223 12231 1224 1211 12111 12112   -
   1212 12121 12122   SURFACE FORCES LOCAL PZ -0.0420
$ ------------------------------------------------------------------------------
LOADING 4 *HYDRO., ELEV. 520 FT, GATE ON SILL*
ELEMENT LOADS  $ K/FT**2
201 202 213 214 225 226 237 238 239 255 256 267 268 279 280 291 292 303 304  -
1303 1304 1291 1292 1279 1280 1267 1268 1255 1256 1237 1238 1239 1225 1226   -
   1213 1214 1201 1202   SURFACE FORCES LOCAL PZ -0.0877
203 204 215 216 227 228 240 241 242 257 258 269 270 281 282 293 294 305 306  -
   1305 1306 1293 1294 1281 1282 1269 1270 1257 1258 1240 1241 1242 1227 1228 -
   1215 1216 1203 1204   SURFACE FORCES LOCAL PZ -0.4580
205 206 217 218 229 230 243 244 245 259 260 271 272 283 284 295 296 307 308  -
   1307 1308 1295 1296 1283 1284 1271 1272 1259 1260 1243 1244 1245 1229 1230 -
   1217 1218 1205 1206   SURFACE FORCES LOCAL PZ -0.8490
```

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 207 208 219 220 231 232 246 247 248 261 262 273 274 285 286 297 298 309 310  -
 1309 1310 1297 1298 1285 1286 1273 1274 1261 1262 1246 1247 1248 1231 1232    -
    1219 1220 1207 1208   SURFACE FORCES LOCAL PZ -1.2032
 209 210 221 222 233 234 249 250 251 263 264 275 276 287 288 299 300 311 312  -
    1311 1312 1299 1300 1287 1288 1275 1276 1263 1264 1249 1250 1251 1233 1234 -
    1221 1222 1209 1210   SURFACE FORCES LOCAL PZ -1.5096
 211 2111 2112 212 2121 2122 223 2231 224 235 236 252 253 254 265 266 277 278  -
    289 290 301 302 313 314 1313 1314 1301 1302 1289 1290 1277 1278 1265 1266  -
    1252 1253 1254 1235 1236 1223 12231 1224 1211 12111 12112   -
    1212 12121 12122   SURFACE FORCES LOCAL PZ -1.7320
$ ----------------------------------------------------------------------------
LOADING 5 'IMPACT, 5 K/FT OF GATE WIDTH AT 528 FT ELEV, GATE ON SILL'
MEMBER LOADS  $ KIPS
49 1049  FORCE X GLOBAL CONCENTRATED FRACT P -3.021 L 0.675
55 1055  FORCE X GLOBAL CONCENTRATED FRACT P -7.396 L 0.675
61 67 73 79 85 91 97 1097 1091 1085 1079 1073 1067 1061    -
     FORCE X GLOBAL CONCENTRATED FRACT P -8.750 L 0.675
$ ----------------------------------------------------------------------------
UNITS LBS FEET
LOADING 6 'D.L. - 2 CABLES'
$ FRAME MEMBER DEAD LOADS.
DEAD LOAD Y -1.0
$ SKIN PLATE DEAD LOAD, TOTAL = 16185.67248 LBS.
JOINT LOADS  $ LBS
1 1001 FORCE Y -57.8211
2 1002 FORCE Y -116.82608
3 1003 FORCE Y -118.00996
4 1004 FORCE Y -112.20033
5 1005 FORCE Y -106.39064
6 1006 FORCE Y -85.57449
7 1007 FORCE Y -32.37917
8 1008 FORCE Y -99.69155
9 1009 FORCE Y -201.42428
10 1010 FORCE Y -203.46546
11 1011 FORCE Y -193.44880
12 1012 FORCE Y -183.43214
13 1013 FORCE Y -147.54222
14 1014 FORCE Y -55.82615
15 22 39 46 53 60 67 1015 1022 1039 1046 1053 1060 1067  FORCE Y -83.74090
16 23 40 47 54 61 68 1016 1023 1040 1047 1054 1061 1068  FORCE Y -169.19640
17 24 41 48 55 62 69 1017 1024 1041 1048 1055 1062 1069  FORCE Y -170.91098
18 25 42 49 56 63 70 1018 1025 1042 1049 1056 1063 1070  FORCE Y -162.49700
19 26 43 50 57 64 71 1019 1026 1043 1050 1057 1064 1071  FORCE Y -154.88300
20 27 44 51 58 65 72 1020 1027 1044 1051 1058 1065 1072  FORCE Y -123.93546
21 28 45 52 59 66 73 1021 1028 1045 1052 1059 1066 1073  FORCE Y -46.89396
$ ----------------------------------------------------------------------------
UNITS KIPS FEET
LOADING 7 'HYDRO., ELEV. 530 FT. - 2 CABLES'
ELEMENT LOADS  $ K/FT**2
201 202 213 214 225 226 237 238 239 255 256 267 268 279 280 291 292 303 304  -
1303 1304 1291 1292 1279 1280 1267 1268 1255 1256 1237 1238 1239 1225 1226    -
   1213 1214 1201 1202   SURFACE FORCES LOCAL PZ -0.1922
203 204 215 216 227 228 240 241 242 257 258 269 270 281 282 293 294 305 306  -
   1305 1306 1293 1294 1281 1282 1269 1270 1257 1258 1240 1241 1242 1227 1228 -
   1215 1216 1203 1204   SURFACE FORCES LOCAL PZ -0.5828
205 206 217 218 229 230 243 244 245 259 260 271 272 283 284 295 296 307 308  -
   1307 1308 1295 1296 1283 1284 1271 1272 1259 1260 1243 1244 1245 1229 1230 -
   1217 1218 1205 1206   SURFACE FORCES LOCAL PZ -0.9738
207 208 219 220 231 232 246 247 248 261 262 273 274 285 286 297 298 309 310  -
1309 1310 1297 1298 1285 1286 1273 1274 1261 1262 1246 1247 1248 1231 1232    -
   1219 1220 1207 1208   SURFACE FORCES LOCAL PZ -1.3280
209 210 221 222 233 234 249 250 251 263 264 275 276 287 288 299 300 311 312  -
   1311 1312 1299 1300 1287 1288 1275 1276 1263 1264 1249 1250 1251 1233 1234 -
   1221 1222 1209 1210   SURFACE FORCES LOCAL PZ -1.6344
211 2111 2112 212 2121 2122 223 2231 224 235 236 252 253 254 265 266 277 278  -
   289 290 301 302 313 314 1313 1314 1301 1302 1289 1290 1277 1278 1265 1266  -
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   1252 1253 1254 1235 1236 1223 12231 1224 1211 12111 12112  -
   1212 12121 12122    SURFACE FORCES LOCAL PZ -1.8568
$ ---------------------------------------------------------------------
LOADING 8 'HYDRO., ELEV. 528 FT. - 2 CABLES'
ELEMENT LOADS   $ K/FT**2
201 202 213 214 225 226 237 238 239 255 256 267 268 279 280 291 292 303 304  -
1303 1304 1291 1292 1279 1280 1267 1268 1255 1256 1237 1238 1239 1225 1226  -
   1213 1214 1201 1202    SURFACE FORCES LOCAL PZ -0.0877
203 204 215 216 227 228 240 241 242 257 258 269 270 281 282 293 294 305 306  -
   1305 1306 1293 1294 1281 1282 1269 1270 1257 1258 1240 1241 1242 1227 1228 -
   1215 1216 1203 1204    SURFACE FORCES LOCAL PZ -0.4580
205 206 217 218 229 230 243 244 245 259 260 271 272 283 284 295 296 307 308  -
   1307 1308 1295 1296 1283 1284 1271 1272 1259 1260 1243 1244 1245 1229 1230 -
   1217 1218 1205 1206    SURFACE FORCES LOCAL PZ -0.8490
207 208 219 220 231 232 246 247 248 261 262 273 274 285 286 297 298 309 310  -
1309 1310 1297 1298 1285 1286 1273 1274 1261 1262 1246 1247 1248 1231 1232   -
   1219 1220 1207 1208    SURFACE FORCES LOCAL PZ -1.2032
209 210 221 222 233 234 249 250 251 263 264 275 276 287 288 299 300 311 312  -
   1311 1312 1299 1300 1287 1288 1275 1276 1263 1264 1249 1250 1251 1233 1234 -
   1221 1222 1209 1210    SURFACE FORCES LOCAL PZ -1.5096
211 2111 2112 212 2121 2122 223 2231 224 235 236 252 253 254 265 266 277 278  -
   289 290 301 302 313 314 1313 1314 1301 1302 1289 1290 1277 1278 1265 1266  -
   1252 1253 1254 1235 1236 1223 12231 1224 1211 12111 12112   -
   1212 12121 12122    SURFACE FORCES LOCAL PZ -1.7320
$ ---------------------------------------------------------------------
LOADING 9 'IMPACT, 5 K/FT OF GATE WIDTH AT 528 FT ELEV, 2 CABLES'
MEMBER LOADS   $ KIPS
49 1049  FORCE X GLOBAL CONCENTRATED FRACT P -3.021 L 0.675
55 1055  FORCE X GLOBAL CONCENTRATED FRACT P -7.396 L 0.675
61 67 73 79 85 91 97 1097 1091 1085 1079 1073 1067 1061   -
      FORCE X GLOBAL CONCENTRATED FRACT P -8.750 L 0.675
$ ---------------------------------------------------------------------
LOADING 10 'SIDE SEAL FRICTION - 2 CABLES'
MEMBER LOADS   $ K/FT PARALLEL TO MEMBER CENTROIDAL AXIS.
49 1049  FORCE X LINEAR WA -0.06004 WB -0.024
50 1050  FORCE X LINEAR WA -0.09724 WB -0.06004
51 1051  FORCE X LINEAR WA -0.13334 WB -0.09724
52 1052  FORCE X LINEAR WA -0.16366 WB -0.13334
53 1053  FORCE X LINEAR WA -0.19080 WB -0.16366
54 1054  FORCE X LINEAR WA -0.19930 WB -0.19080
541 10541  FORCE X LINEAR WA -0.20535 WB -0.19930
$ ---------------------------------------------------------------------
LOADING 11 'UNIT CABLE FORCE PRESSURE EFFECT, 1000K EACH CABLE-2 CABLES'
ELEMENT LOADS   $ K/FT**2
201 202 1201 1202            SURFACE FORCES LOCAL PZ -5.69088
203 TO 208, 1203 TO 1208     SURFACE FORCES LOCAL PZ -26.6976
209 210 1209 1210            SURFACE FORCES LOCAL PZ -6.39648
$ ---------------------------------------------------------------------
LOADING 12 'UNIT TRUNION FRICTION MOMENT, 1000 K-FT AT EACH PIN-2 CABLES'
JOINT LOADS   $ K-FT
38 1038  MOMENT Z -1000.0
$ ---------------------------------------------------------------------
UNITS LBS FEET
LOADING 13 'D.L. - 1 CABLE'
$ FRAME MEMBER DEAD LOADS.
DEAD LOAD Y -1.0
$ SKIN PLATE DEAD LOAD, TOTAL = 16185.67248 LBS.
JOINT LOADS   $ LBS
1 1001 FORCE Y -57.8211
2 1002 FORCE Y -116.82608
3 1003 FORCE Y -118.00996
4 1004 FORCE Y -112.20030
5 1005 FORCE Y -106.39064
6 1006 FORCE Y -85.97449
7 1007 FORCE Y -32.37917
8 1008 FORCE Y -99.69155
```

```
9 1009 FORCE Y -201.42424
10 1010 FORCE Y -203.46546
11 1011 FORCE Y -193.44880
12 1012 FORCE Y -193.43214
13 1013 FORCE Y -147.54222
14 1014 FORCE Y -55.82615
15 22 39 46 53 60 67 1015 1022 1039 1046 1053 1060 1067  FORCE Y -83.74098
16 23 40 47 54 61 68 1016 1023 1040 1047 1054 1061 1068  FORCE Y -169.19640
17 24 41 48 55 62 69 1017 1024 1041 1048 1055 1062 1069  FORCE Y -170.91098
18 25 42 49 56 63 70 1018 1025 1042 1049 1056 1063 1070  FORCE Y -162.49700
19 26 43 50 57 64 71 1019 1026 1043 1050 1057 1064 1071  FORCE Y -154.08300
20 27 44 51 58 65 72 1020 1027 1044 1051 1058 1065 1072  FORCE Y -123.93546
21 28 45 52 59 66 73 1021 1028 1045 1052 1059 1066 1073  FORCE Y -46.89396
$ ------------------------------------------------------------------------
UNITS KIPS FEET
LOADING 14 *HYDRO., ELEV. 530 FT. - 1 CABLE*
ELEMENT LOADS  $ K/FT**2
201 202 213 214 225 226 237 238 239 255 256 267 268 279 280 291 292 303 304  -
1303 1304 1291 1292 1279 1280 1267 1268 1255 1256 1237 1238 1239 1225 1226   -
   1213 1214 1201 1202   SURFACE FORCES LOCAL PZ -0.1922
203 204 215 216 227 228 240 241 242 257 258 269 270 281 282 293 294 305 306  -
   1305 1306 1293 1294 1281 1282 1269 1270 1257 1258 1240 1241 1242 1227 1228 -
   1215 1216 1203 1204   SURFACE FORCES LOCAL PZ -0.5828
205 206 217 218 229 230 243 244 245 259 260 271 272 283 284 295 296 307 308  -
   1307 1308 1295 1296 1283 1284 1271 1272 1259 1260 1243 1244 1245 1229 1230 -
   1217 1218 1205 1206   SURFACE FORCES LOCAL PZ -0.9738
207 208 219 220 231 232 246 247 248 261 262 273 274 285 286 297 298 309 310  -
1309 1310 1297 1298 1285 1286 1273 1274 1261 1262 1246 1247 1248 1231 1232   -
   1219 1220 1207 1208   SURFACE FORCES LOCAL PZ -1.3280
209 210 221 222 233 234 249 250 251 263 264 275 276 287 288 299 300 311 312  -
   1311 1312 1299 1300 1287 1288 1275 1276 1263 1264 1249 1250 1251 1233 1234 -
   1221 1222 1209 1210   SURFACE FORCES LOCAL PZ -1.6344
211 2111 2112 212 2121 2122 223 2231 224 235 236 252 253 254 265 266 277 278  -
   289 290 301 302 313 314 1313 1314 1301 1302 1289 1290 1277 1278 1265 1266  -
   1252 1253 1254 1235 1236 1223 12231 1224 1211 12111 12112   -
   1212 12121 12122   SURFACE FORCES LOCAL PZ -1.8565
$ ------------------------------------------------------------------------
LOADING 15 *SIDE SEAL FRICTION - 1 CABLE*
MEMBER LOADS  $ K/FT PARALLEL TO MEMBER CENTROIDAL AXIS.
49 1049  FORCE X LINEAR WA -0.06004 WB -0.024
50 1050  FORCE X LINEAR WA -0.09724 WB -0.06004
51 1051  FORCE X LINEAR WA -0.13334 WB -0.09724
52 1052  FORCE X LINEAR WA -0.16366 WB -0.13334
53 1053  FORCE X LINEAR WA -0.19080 WB -0.16366
54 1054  FORCE X LINEAR WA -0.19930 WB -0.19080
541 10541  FORCE X LINEAR WA -0.20535 WB -0.19930
$ ------------------------------------------------------------------------
LOADING 16 *UNIT CABLE FORCE PRESSURE EFFECT, 1000K - 1 CABLE*
ELEMENT LOADS  $ K/FT**2
201 202      SURFACE FORCES LOCAL PZ -5.69088
203 TO 208   SURFACE FORCES LOCAL PZ -26.69760
209 210      SURFACE FORCES LOCAL PZ -6.39648
$ ------------------------------------------------------------------------
LOADING 17 *UNIT TRUNION FRICTION MOMENT, 1000 K-FT, JOINT 38 - 1 CABLE*
JOINT LOADS  $ K-FT
38  MOMENT Z -1000.0
$ ------------------------------------------------------------------------
LOADING 18 *UNIT TRUNION FRICTION MOMENT, 1000 K-FT, JOINT 1038 - 1 CABLE*
JOINT LOADS  $ K-FT
1038  MOMENT Z -1000.0
$ ------------------------------------------------------------------------
LOADING 19 *UNIT CABLE FORCE, 1000K EACH CABLE, BOUND - 2 CABLES*
JOINT LOADS  $ KIPS
*S1* *S10*  FORCE X 549.70315,  Y 835.36007  $  GLOBAL COMPONENTS OF 1000 KIPS
ELEMENT LOADS  $ K/FT**2
201 202 1201 1202            SURFACE FORCES LOCAL PZ -5.69088
```

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203 TO 208, 1203 TO 1208      SURFACE FORCES LOCAL PZ -26.6976
209 210 1209 1210             SURFACE FORCES LOCAL PZ -6.39648
$ ------------------------------------------------------------------------------
UNITS INCH
LOADING 20 *1-CABLE SIDE SUPPORT 1/4 INCH CLEARANCE*
JOINT DISPLACEMENT  $ INCHES
1001 DISPLACEMENTS Z 0.250
   7  DISPLACEMENTS Z -0.250
$ ------------------------------------------------------------------------------
TIME PRINT
$ --------CHECK DATA FOR CONSISTANCY-------------------------------------------
CHECK INPUT
$ ------------------------------------------------------------------------------
TIME PRINT
QLIST 001
TIME PRINT
$ -----SAVE FOR REVIEW AND CHECKPOINT PURPOSES----------------------------------
SAVE *GATE/CK1*
FINISH
```

```
STRUDL RESTORE 'GATE/CK1'    $ 2
TIME BEGIN
QLIST DD1
$ ---------GATE RESTING ON SILL CASE---------------------------------------------
$ ---------LOADINGS 1, 2, 3, 4, 5------------------------------------------------
JOINT RELEASES
7 14 21 28 45 52 59 66 73    1073 1066 1059 1052 1045 1028 1021   -
          1014 1007  FORCE X Z,  MOMENT X Y Z
1 TO 6, 1001 TO 1006, 'S1' 'S10' 'S3' 'S30'  FORCE X Y Z, MOMENT X Y Z  $ FREE
$ -------------------------------------------------------------------------------
$ -----ANALYZE FOR GATE ON SILL CASE---------------------------------------------
LOAD LIST 1 2 3 4 5
DUMP TIME
STIFFNESS ANALYSIS NJP 4
TIME PRINT
UNITS KIPS FEET
OUTPUT DECIMAL 3
OUTPUT BY JOINT
LIST REACTIONS
TIME PRINT
$ -----SAVE RESULTS AND CHECKPOINT-----------------------------------------------
SAVE 'GATE/CK2'
FINISH
```

```
STRUDL RESTORE 'GATE/CK2'    $ 3
TIME BEGIN
QLIST DD1
$ -----GATE SUPPORTED BY TWO CABLES, JUST STARTINS TO OPEN-----------------------
$ -----LOADINGS 6, 7, 8, 9, 10, 11, 12- -----------------------------------------
$ ------------------------------------------------------------------------------
DELETIONS
JOINT RELEASES
'S1' 'S10'  $ SUPPORT
7 14 21 28 45 52 59 66 73    1073 1066 1059 1052 1045 1028 1021   -
     1014 1007   $ SUPPORT
ADDITIONS
JOINT RELEASES  $ DEGREES
7 14 21 28 45 52 59 66 73    1073 1066 1059 1052 1045 1028 1021   -
        1014 1007  FORCE X Y Z, MOMENT X Y Z  $ FREE
'S1' 'S10'  MOMENT X Y Z,  FORCE X Z,  THI -33.34665
$ -----ANALYZE FOR GATE SUPPORTED BY 2 CABLES-----------------------------------
LOAD LIST 6 7 8 9 10 11 12
TIME PRINT
STIFFNESS ANALYSIS NJP 4
TIME PRINT
UNITS KIPS FEET
OUTPUT DECIMAL 3
OUTPUT BY JOINT
LIST REACTIONS
$ ------------------------------------------------------------------------------
TIME PRINT
$ -----INTERMEDIATE SAVE TO PROTECT AGAINST MACHINE FAILURE---------------------
$ -----         OR SOME OTHER PROBLEM OCCURRING WHILE PROCESSING.---------------
SAVE 'GATE/CK1'
QLIST DD1
$ ------------------------------------------------------------------------------
TIME PRINT
EJECT
TIME BEGIN
$ -----GATE SUPPORTED BY ONE CABLE, SIDE SUPPORT, JUST STARTINS TO OPEN---------
$ -----LOADINGS 13 14 15 16 17 18 20--------------------------------------------
$ ------------------------------------------------------------------------------
DELETIONS
JOINT RELEASES
'S10'   $ SUPPORT
7 1001  $ SUPPORT
ADDITIONS
JOINT RELEASES
'S10'  FORCE X Y Z,  MOMENT X Y Z   $ FREE
7 1001  FORCE X Y  MOMENT X Y Z  $ SIDE SUPPORT
$ -----ANALYZE FOR GATE SUPPORTED BY 1 CABLE, WITH SIDE SUPPORT-----------------
LOAD LIST 13 14 15 16 17 18 20
TIME PRINT
STIFFNESS ANALYSIS NJP 4
TIME PRINT
UNITS KIPS FEET
OUTPUT DECIMAL 3
OUTPUT BY JOINT
LIST REACTIONS
$ ------------------------------------------------------------------------------
TIME PRINT
$ -----INTERMEDIATE SAVE TO PROTECT AGAINST MACHINE FAILURE---------------------
$ -----         OR SOME OTHER PROBLEM OCCURRING WHILE PROCESSING.---------------
SAVE 'GATE/CK1'
QLIST DD1
$ ------------------------------------------------------------------------------
TIME PRINT
```

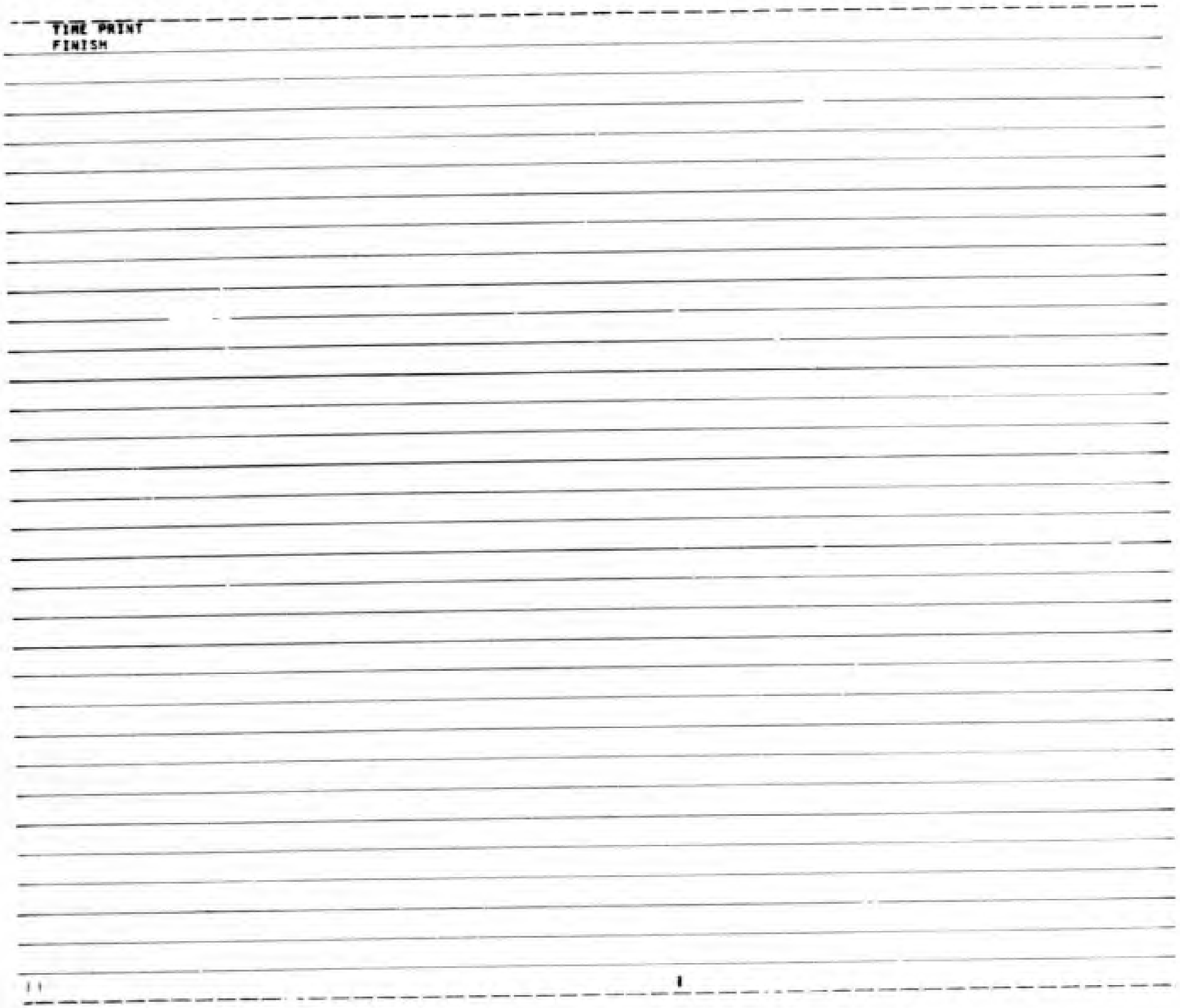
```
EJECT
TIME BEGIN
$ -----GATE BOUND AT SIDE SEAL PARALLEL TO SIDE SEAL----------------------------
$ -----LOADING 19---------------------------------------------------------------
DELETIONS
JOINT RELEASES
1 TO 7, 'S3', 1001 TO 1007, 'S30'  $ SUPPORT
'S1'  $ SUPPORT
ADDITIONS
JOINT RELEASES  $ DEGREES
'S1'  FORCE X Y Z,  MOMENT X Y Z  $ FREE
1, 1001  MOMENT X Y Z,  FORCE X Z,  TH1 14.9553
2, 1002  MOMENT X Y Z,  FORCE X Z,  TH1  3.4036
3, 1003  MOMENT X Y Z,  FORCE X Z,  TH1 -8.38458
4, 1004  MOMENT X Y Z,  FORCE X Z,  TH1 -20.17275
5, 1005  MOMENT X Y Z,  FORCE X Z,  TH1 -30.40029
6, 1006  MOMENT X Y Z,  FORCE X Z,  TH1 -41.42780
'S3' 'S30'  MOMENT X Y Z,  FORCE Y Z,  TH1 -45.12422
7, 1007  MOMENT X Y Z,  FORCE X Z,  TH1 -47.8966
$ ------------------------------------------------------------------------------
$ -----ANALYZE FOR GATE BOUND AT SIDE SEAL PARALLEL TO SIDE SEAL - 2 CABLES-----
LOAD LIST 1'
TIME PRINT
STIFFNESS ANALYSIS NJP 4
TIME PRINT
UNITS KIPS FEET
OUTPUT DECIMAL 3
OUTPUT BY JOINT
LIST REACTIONS
$ ------------------------------------------------------------------------------
TIME PRINT
$ -----SAVE RESULTS AND CHECKPOINT----------------------------------------------
SAVE 'GATE/CK1'
QLIST 001
TIME PRINT
$ ------------------------------------------------------------------------------
FINISH
```

```
STRUDL RESTORE 'GATE/CK1'     $ 4
TIME BEGIN
QLIST DD1
$ ---------------------------------------------------------------------------
UNITS KIPS FEET
OUTPUT BY JOINT
OUTPUT DECIMAL 8
$ -----ACTIVATE ALL LOADING CONDITIONS----------------------------------------
LOAD LIST 1 TO 20
$ -----FORM DESIGN LOADING CONDITIONS NECESSARY TO COMPUTE CABLE FORCE F AND
$ -----    TRUNION FRICTION MOMENT M ------------------------------------------
LOADING COMBINATION 101 'F AND M FOR II, 6+7+10'
COMBINE 101 6 1.0 7 1.0 10 1.0
LOADING LIST 101 11 12
LIST REACTIONS JOINTS 'S1' 'S10' 38 1038
LIST REACTIONS
$ ---------------------------------------------------------------------------
LOAD LIST 1 TO 20, 101
LOADING COMBINATION 102 'F AND M FOR V, 6+8+9+10'
COMBINE 102 6 1.0 8 1.0 9 1.0 10 1.0
LOAD LIST 102 11 12
LIST REACTIONS JOINTS 'S1' 'S10' 38 1038
LIST REACTIONS
$ ---------------------------------------------------------------------------
LOAD LIST 1 TO 20, 101, 102
LOADINP COMBINATION 103 'F AND " F3R VI, 13+14+15+20'
COMBINE 103 13 1.0 14 1.0 15 1.0 20 1.0
LOAD LIST 103 16 17 18
LIST REACTIONS JOINTS 'S1' 'S10' 38 1038
LIST REACTIONS
$ ---------------------------------  ----------------------------------------
TIME PRINT
$ -----SAVE RESULTS AND CHECKPOINT-------------------------------------------
SAVE 'GATE/CK2'
QLIST DD1
TIME PRINT
$ -----NOW, COMPUTE, OFFLINE, F AND M FOR USE ON LOAD COMBINATIONS II, V, VI,---
$ -----      AND VII---------------------------------------------------------
FINISH
```

```
STRUDL RESTORE 'GATE/CK2'     $ 5
TIME BEGIN
QLIST DD1
$ ------------------------------------------------------------------------------
$ -----ACTIVATE ALL LOADINGS----------------------------------------------------
LOAD LIST 1 TO 20, 101, 102, 103
$
$ -----FORM DESIGN LOADING COMBINATIONS-----------------------------------------
$ -----FOR CORPS DESIGN STRESSES, REDUCE AISC VALUES BY 83.3%, OR
$ -----    EQUIVALENTLY, INCREASE APPLIED LOADS BY 1/0.833 = 1.20 --------------
$
LOAD COMBINATION 'I' '1.2*(1+2)'
COMBINE 'I' 1 1.2 2 1.2
$
LOAD COMBINATION 'II' '1.2*(6+7+10+11*.0248708+12*.0583999)'
COMBINE 'II' 101 1.2 11 0.0298450 12 0.0700799
$
LOAD COMBINATION 'III' '1.2*(0.75*(1+2+3))'
LOAD LIST 1 TO 20, 101 TO 103, 'I' 'II'
COMBINE 'III' 'I' 0.75 3 0.90
$
LOAD COMBINATION 'IV' '1.2*(0.75*(1+4+5))'
COMBINE 'IV' 1 0.90 4 0.90 5 0.90
$
LOAD COMBINATION 'V' '1.2*(0.75*(6+8+9+10+11*.0112262+12*.0589627))'
COMBINE 'V' 102 0.90 11 0.0101036 12 0.0530664
$
LOAD COMBIN 'VI' '1.2*(0.667*(13+14+15+20+16*.0498795+17*.0604530+18*.0563227))'
COMBINE 'VI' 103 0.80 16 0.0399036 17 0.0403624 18 0.0450582
$
LOAD COMBIN 'VII' '1.2*(0.667*(6+7+10+11*.0248708+12*.0583999+19*.0447674))'
COMBINE 'VII' 'II' 0.66667 19 0.0358139
$
$ -----FORM COMBINATIONS FOR JOINT DISPLACEMENT RESULT OUTPUT--------------------
LOAD LIST 'I' 'II' 'III' 'IV' 'V' 'VI' 'VII'
LOAD COMBINATION 'D1' 'I' 0.8333333'
COMBINE 'D1' 'I' 0.8333333
LOAD COMBINATION 'D2' 'II' 0.8333333'
COMBINE 'D2' 'II' 0.83333333
LOAD COMBINATION 'D3' 'III' 1.1111111'
COMBINE 'D3' 'III' 1.1111111
LOAD COMBINATION 'D4' 'IV' 1.1111111'
COMBINE 'D4' 'IV' 1.1111111
LOAD COMBINATION 'D5' 'V' 1.1111111'
COMBINE 'D5' 'V' 1.1111111
LOAD COMBINATION 'D6' 'VI' 1.250'
COMBINE 'D6' 'VI' 1.250
LOAD COMBINATION 'D7' 'VII' 1.250'
COMBINE 'D7' 'VII' 1.250
$ -----OUTPUT DISPLACEMENT RESULTS-----------------------------------------------
LOAD LIST 'D1' 'D2' 'D3' 'D4' 'D5' 'D6' 'D7'
UNITS INCH KIPS
OUTPUT DECIMAL 5
OUTPUT BY LOADING
LIST DISPLACEMENTS
$ ------------------------------------------------------------------------------
$ -----ACTIVATE ALL DESIGN LOADING CONDITIONS FOR FORCE OUTPUT------------------
LOAD LIST 'I' 'II' 'III' 'IV' 'V' 'VI' 'VII'
UNITS KIPS FEET
OUTPUT DECIMAL 3
LIST REACTIONS
$
OUTPUT BY MEMBER
```

```
LIST FORCES ALL MEMBERS
LIST SECTION FORCES MEMBERS 49 55 61 67 73 79 85 91 97 1097 1091 1085 1079  -
                            1073 1067 1061 1055 1049   -
                            SECTION FRACTIONAL NS 3 0.0 0.675 1.0
$ -----FINITE ELEMENT RESULTS-------------------------------------------------------
LIST STRESSES
$ -----THE FOLLOWING COMMAND IS A NON SUPPORTED COMMAND BY MCAUTO AT PRESENT----
$ -----        FOR PRINCIPAL STRESSES IN THE PSS2 AND PBST FINITE ELEMENTS.-------
$ -----        HOWEVER, MCAUTO RECOMMENDED TO USE IT NOW ANYWAY.------------- ----
UNITS INCH KIPS
ABC/STRESSES
$
$ ------------------------------------------------------------------------------
TIME PRINT
$ -----SAVE RESULTS AND CHECKPOINT-----------------------------------------------
SAVE 'GATE/CK1'
GLIST DD1
TIME PRINT
FINISH
```

```
STRUDL RESTORE 'GATE/CK1'    $ 6
TIME BEGIN
QLIST DD1
OUTPUT DECIMAL 3
$ -----SET APPROPRIATE PARAMETERS FOR CHECKING PURPOSES-----------------------------
$ -----NOTE THAT FOR STRUT COLUMNS, MEMBERS 103-111,1103-1111, THE LOCAL
$ -----    Z-AXIS(MAJOR) UNBRACED LENGTH IS REDUCED BY 2 FT. AT THE SKIN
$ -----    PLATE END DUE TO THE PRESENCE OF GUSSET PLATES(SEE CORPS
$ -----    DRAWING DACW 43, 45/13, AND REDUCED BY THE MEMBER ECCENTRICITY
$ -----    NEAR THE SKIN PLATE ENDS(SEE PRINT OUT OF MEMBER LENGTHS AFTER
$ -----    ECCENTRICITY INPUT).
$ -----ALSO, STRUT COLUMNS 103,106,109,1103,1106,1109 ARE REDUCED IN
$ -----    LENGTH BY 4 FT. FOR MINOR AXIS BUCKLING DUE TO GUSSET PLATES
$ -----    AT TRUNION PIN ENDS(SEE CORPS DRAWING DACW 43, 45/12).
UNITS KIPS INCHES
PARAMETERS
    'CODE' 'SP69' ALL
    'FYLD' 50.0 ALL
    'UNLCF' 0.0 MEMBERS 49 TO 102, 1049 TO 1102  $  SKIN PLATE STIFFENING RIBS.
$ K = 1.0 FOR ALL MEMBERS EXCEPT HORIZONTAL GIRDERS AND STRUTS = 1.2.
    'KY' 1.0 ALL BUT 1.2 MEMB 10 TO 39, 1010 TO 1039, 103 TO 119, 1103 TO 1119
    'KZ' 1.0 ALL BUT 1.2 MEMB 10 TO 39, 1010 TO 1039, 103 TO 119, 1103 TO 1119
    'LZ' 323.293 103 TO 105, 1103 TO 1105  $ Z AXIS UNBRACED LENGTH,
$                      INCLUDES ECCENTRICITY AND GUSSET PLATE SHORTENING.
    'LZ' 322.942 106 TO 111, 1106 TO 1111  $ Z AXIS UNBRACED LENGTH,
$                      INCLUDES ECCENTRICITY AND GUSSET PLATE SHORTENING.
    'LY' 110.204  103,106,109,1103,1106,1109  $ Y-AXIS UNBRACED LENGTH,
$                    REDUCED 4 FT. FOR GUSSET PLATE AT TRUNION PIN END.
    'SDSWAYY' 'NO' ALL  $ ALL MEMBERS ASSUMED BRACED AGAINST MINOR AXIS
$          SIDESWAY FOR CMY CALCULATIONS.
    'SDSWAYZ' 'NO' ALL BUT 'YES' MEMBERS 103 TO 111, 1103 TO 1111
$      ALL MEMBERS ASSUMED BRACED AGAINST MAJOR AXIS SIDESWAY FOR CMZ
$         CALCULATIONS EXCEPT MEMBERS 103 TO 111, AND 1103 TO 1111.
    'TRACE' 4 ALL
$ ---------------------------------------------------------------------------
PRINT DESIGN DATA ALL MEMBERS
UNITS INCHES LBS
PRINT MEMBER PROPERTIES
SECTION FRACTIONAL NS 2 0.0 1.0  $  ALL MEMBERS BUT THE FOLLOWING
SECTION NS 2 48.0 158.2 MEMBERS 103 106 109 1103 1106 1109  $ INCHES
SECTION NS 2  0.0 55.56 MEMBERS 105 1105  $ INCHES
SECTION NS 2  0.0  55.2 MEMBERS 108 111 1108 1111  $ INCHES
SECTION FRACTIONAL NS 2 0.0 0.675 1.0 MEMBERS 49 55 61 67 73 79 85 91 97  -
          1097 1091 1085 1079 1073 1067 1061 1055 1049
$ -----ACTIVATE NON-SYMMETRICAL LOADING COMBINATION-------------------------------
LOAD LIST 'VI'
$ -----CHECK CODE FOR ALL MEMBERS TO BE CHECKED-----------------------------------
CHECK CODE MEMBERS 1 TO 9, 1001 TO 1009  $ L-SHAPE MEMBERS.
CHECK CODE MEMBERS 10 TO 39, 103 TO 119, 1010 TO 1039, 1103 TO 1119  $ W-SHAPES
CHECK CODE MEMBERS 49 TO 102, 120 TO 127, 1049 TO 1102, 1120 TO 1122,   -
                 1124 TO 1126  $ WT-SHAPE MEMBERS.
TIME PRINT
$ -----ACTIVATE SYMMETRICAL DESIGN LOADING COMBINATIONS---------------------------
LOAD LIST 'I' 'II' 'III' 'IV' 'V' 'VII'
$ -----CHECK ONLY 1/2 OF THE MEMBERS FOR SYMMETRICAL LOADS-----------------------
CHECK CODE MEMBERS 1 TO 9  $ L-SHAPE MEMBERS.
CHECK CODE MEMBERS 10 TO 39, 103 TO 119  $ W-SHAPE MEMBERS.
CHECK CODE MEMBERS 49 TO 102, 120 TO 127  $ WT-SHAPE MEMBERS.
$ ---------------------------------------------------------------------------
TIME PRINT
$ -----SAVE RESULTS AND CHECKPOINT-----------------------------------------------
SAVE 'GATE/CK2'
QLIST DD1
```


TIME PRINT
FINISH

```
STRUDL RESTORE 'GATE/CK2'  $ 7
TIME BEGIN
QLIST DD1
UNITS INCH KIPS
$ ----------------------------------------------------------------------------
$ DEAD WEIGHT OF W-SHAPE MEMBERS ONLY.
INACTIVE MEMBERS ALL
ACTIVE MEMBERS    -
        10 TO 39, 1010 TO 1039, 103 TO 119, 1103 TO 1119
STEEL TAKEOFF
$ ----------------------------------------------------------------------------
$ DEAD WEIGHT OF L-SHAPE MEMBERS ONLY.
INACTIVE MEMBERS ALL
ACTIVE MEMBERS    -
        1 TO 9, 1001 TO 1009
STEEL TAKEOFF
$ ----------------------------------------------------------------------------
$ DEAD WEIGHT OF WT-SHAPE MEMBERS ONLY.
INACTIVE MEMBERS ALL
ACTIVE MEMBERS    -
        49 TO 102, 1049 TO 1102, 541, 601, 10541, 10601   -
            120 TO 127, 1120 TO 1122, 1124 TO 1126
STEEL TAKEOFF
$ ----------------------------------------------------------------------------
$ DEAD WEIGHT OF ALL W, L, AND WT SHAPE MEMBERS.
INACTIVE MEMBERS ALL
ACTIVE MEMBERS          -
        10 TO 39, 1010 TO 1039, 103 TO 119, 1103 TO 1119    -
        1 TO 9, 1001 TO 1009            -
        49 TO 102, 1049 TO 1102, 541, 601, 10541, 10601    -
            120 TO 127, 1120 TO 1122, 1124 TO 1126
STEEL TAKEOFF
$ NOTE THAT SKIN PLATE WEIGHS 16.196 KIPS.
ACTIVE MEMBERS ALL
$ ----------------------------------------------------------------------------
PARAMETERS
    'TBLNAM' 'STEELW' 10 TO 39, 1010 TO 1039, 103 TO 119, 1103 TO 1119 $ W-SHAPES
    'TBLNAM' 'STEELL' 1 TO 9, 1001 TO 1009  $ L-SHAPE'
    'TBLNAM' 'STEELWT' 49 TO 102, 1049 TO 1102, 541, 601, 10541, 10601   -
                    120 TO 127, 1120 TO 1122, 1124 TO 1126  $ WT-SHAPES
PRINT DESIGN DATA
$ ALLOW UNCONSTRAINED DESIGN.  THEN REVIEW DESIGNED MEMBER SIZES AFTER SAVE.
$       SET APPROPRIATE NOMINAL DEPTH CONSTRAINTS, RESTORE AND REDESIGN
$       THOSE MEMBERS NOT SATISFYING THE NOMINAL DEPTH CONSTRAINT.
$ SECTION COMMAND SPECIFIED IN RUN NO. 6.
$ DESIGN ALL MEMBERS FOR NON-SYMMETRIC DESIGN LOAD VI.
LOAD LIST 'VI'
$ W-SHAPES.
SELECT MEMBERS 10 TO 39, 1010 TO 1039, 103 TO 119, 1103 TO 1119 WITH 'COMBINED'
$ L-SHAPES.
SELECT MEMBERS 1 TO 9, 1001 TO 1009 WITH 'SEAM'
$ WT-SHAPES.
SELECT MEMBERS 49 TO 102, 1049 TO 1102, 541,601,10541,10601, 120 TO 127  -
               1120 TO 1122, 1124 TO 1126  WITH 'SEAM'
PRINT MEMBER PROPERTIES ALL
$ ----------------------------------------------------------------------------
$ DEAD WEIGHT OF W-SHAPE MEMBERS ONLY.
INACTIVE MEMBERS ALL
ACTIVE MEMBERS    -
        10 TO 39, 1010 TO 1039, 103 TO 119, 1103 TO 1119
STEEL TAKEOFF
$ ----------------------------------------------------------------------------
$ DEAD WEIGHT OF L-SHAPE MEMBERS ONLY.
```

```
INACTIVE MEMBERS ALL
ACTIVE MEMBERS    -
        1 TO 9, 1001 TO 1009
STEEL TAKEOFF
$ ---------------------------------------------------------------------------
$ DEAD WEIGHT OF WT-SHAPE MEMBERS ONLY.
INACTIVE MEMBERS ALL
ACTIVE MEMBERS    -
        49 TO 102, 1049 TO 1102, 541, 601, 10541, 10601    -
            120 TO 127, 1120 TO 1122, 1124 TO 1126
STEEL TAKEOFF
$ ---------------------------------------------------------------------------
$ DEAD WEIGHT OF ALL W, L, AND WT SHAPE MEMBERS.
INACTIVE MEMBERS ALL
ACTIVE MEMBERS            -
        10 TO 39, 1010 TO 1039, 103 TO 119, 1103 TO 1119     -
        1 TO 9, 1001 TO 1009          -
        49 TO 102, 1049 TO 1102, 541, 601, 10541, 10601    -
            120 TO 127, 1120 TO 1122, 1124 TO 1126
STEEL TAKEOFF
$ NOTE THAT SKIN PLATE WEIGHS 16.186 KIPS.
ACTIVE MEMBERS ALL
$ ---------------------------------------------------------------------------
TIME PRINT
$ DESIGN SYMMETRIC PART OF STRUCTURE FOR THE SYMMETRIC DESIGN LOADS.
LOAD LIST *I* *II* *III* *IV* *V* *VII*
$ W-SHAPES.
SELECT MEMBERS 10 TO 39, 103 TO 119  WITH *COMBINED*
$ L-SHAPES.
SELECT MEMBERS 1 TO 9  WITH *BEAM*
$ WT-SHAPES.
SELECT MEMBERS 49 TO 102, 541,601, 120 TO 127  WITH *BEAM*
PRINT MEMBER PROPERTIES ALL
$ ---------------------------------------------------------------------------
$ DEAD WEIGHT OF 1/2 OF W-SHAPE MEMBERS ONLY.
INACTIVE MEMBERS ALL
ACTIVE MEMBERS    -
        10 TO 39, 103 TO 119
STEEL TAKEOFF
$ ---------------------------------------------------------------------------
$ DEAD WEIGHT OF 1/2 OF L-SHAPE MEMBERS ONLY.
INACTIVE MEMBERS ALL
ACTIVE MEMBERS    -
        1 TO 9
STEEL TAKEOFF
$ ---------------------------------------------------------------------------
$ DEAD WEIGHT OF 1/2 OF WT-SHAPE MEMBERS ON SYMMETRICAL SIDE ONLY.
INACTIVE MEMBERS ALL
ACTIVE MEMBERS    -
        49 TO 102, 541, 601, 120 121 122 124 125 126
STEEL TAKEOFF
$ ---------------------------------------------------------------------------
$ DEAD WEIGHT OF 1/2 OF ALL W, L, AND WT SHAPE MEMBERS ON SYMMETRICAL SIDE.
INACTIVE MEMBERS ALL
ACTIVE MEMBERS   -
        10 TO 39, 103 TO 119         -
        1 TO 9          -
        49 TO 102, 541, 601, 120 121 122 124 125 126
STEEL TAKEOFF
$ ---------------------------------------------------------------------------
$ DEAD WEIGHT OF TWO WT-SHAPE MEMBERS ON AXIS OF SYMMETRY.
INACTIVE MEMBERS ALL
ACTIVE MEMBERS    -
        123 127
STEEL TAKEOFF
$ NOTE THAT SKIN PLATE WEIGHS 16.186 KIPS.
```

```
ACTIVE MEMBERS ALL
$ --------------------------------------------------------------------------------
TIME PRINT
$ -----SAVE RESULTS AND CHECKPOINT------------------------------------------------
SAVE *GATE/CK1*
QLIST OD1
TIME PRINT
FINISH
```

```
TABLE *W21/W14*     $ 8
TRANSFER TABLE FROM *STEELW* SUBSYSTEM TO *W21* USER
TRANSFER ITEMS FROM *W21X142* TO *W21X44*
ORDER TABLE *W21*
ORDER BY INCREASING *AX*
ORDER TABLE *W21*
      ARRANGE *SY* ON *AX* WITH ID *AXSY*
      ARRANGE *SZ* ON *AX* WITH ID *AXSZ*
      ARRANGE *RY* ON *AX* WITH ID *AXRY*
      ARRANGE *RZ* ON *AX* WITH ID *AXRZ*
FILE TABLE
TRANSFER TABLE FROM *STEELW* SUBSYSTEM TO *W14* USER
TRANSFER ITEMS FROM *W14X730* TO *W14X22*
ORDER TABLE *W14*
ORDER BY INCREASING *AX*
ORDER TABLE *W14*
      ARRANGE *SY* ON *AX* WITH ID *AXSY*
      ARRANGE *SZ* ON *AX* WITH ID *AXSZ*
      ARRANGE *RY* ON *AX* WITH ID *AXRY*
      ARRANGE *RZ* ON *AX* WITH ID *AXRZ*
FILE TABLE
QLIST 001
OUTPUT PRINT TABLE *W21* ALL
OUTPUT PRINT TABLE *W14* ALL
EJECT
STRUDL RESTORE *GATE/CK1*  $ 8
TIME BEGIN
QLIST 001
UNITS INCH KIPS
$ -------------------------------------------------------------------------------
$ DEAD WEIGHT OF 1/2 OF L-SHAPE MEMBERS ON SYMMETRICAL SIDE.
INACTIVE MEMBERS ALL
ACTIVE MEMBERS 1 TO 9
STEEL TAKEOFF
$ -------------------------------------------------------------------------------
$ DEAD WEIGHT OF 1/2 OF WT-SHAPE SKIN PLATE STIFFENING RIBS ON SYMM. SIDE.
INACTIVE MEMBERS ALL
ACTIVE MEMBERS 49 TO 102, 541, 601
STEEL TAKEOFF
$ -------------------------------------------------------------------------------
$ DEAD WEIGHT OF 1/2 OF WT-SHAPE SKIN PLATE BRACING MEMBERS ON SYMM. SIDE.
INACTIVE MEMBERS ALL
ACTIVE MEMBERS 120 121 122 124 125 126
STEEL TAKEOFF
$ -------------------------------------------------------------------------------
$ DEAD WEIGHT OF TWO WT-SHAPE SKIN PLATE BRACING MEMBERS ON AXIS OF SYMMETRY.
INACTIVE MEMBERS ALL
ACTIVE MEMBERS 123 127
STEEL TAKEOFF
$ -------------------------------------------------------------------------------
$ DEAD WEIGHT OF W-SHAPE HORIZONTAL GIRDERS ON SYMMETRICAL SIDE.
INACTIVE MEMBERS ALL
ACTIVE MEMBERS 10 TO 39
STEEL TAKEOFF
$ -------------------------------------------------------------------------------
$ DEAD WEIGHT OF W-SHAPE STRUT MEMBERS ON SYMMETRICAL SIDE.
INACTIVE MEMBERS ALL
ACTIVE MEMBERS 103 TO 119
STEEL TAKEOFF
$ -------------------------------------------------------------------------------
$ CHANGE MEMBERS SIZES TO FINAL SELECTED DESIGN SIZE FOR THOSE MEMBERS
$     CHANGED BY INSPECTION.
CHANGES
```

```
PARAMETERS
     'TBLNAM' 'W21'  10 TO 39
     'TBLNAM' 'W14'  103 TO 111
MEMBER PROPERTIES TABLE 'STEELL'
1 TO 9, 1001 TO 1009  TABLE 'L60354'  $ L6X3-1/2X1/4
MEMBER PROPERTIES TABLE 'STEELWT'
49 TO 79, 541, 601, 1049 TO 1079, 10541, 10601  TABLE 'WT12X27'
80 TO 102, 1080 TO 1102  TABLE 'WT10X24'
120 TO 127, 1120 TO 1122, 1124 TO 1126  TABLE 'WT4X5'
MEMBER PROPERTIES TABLE 'STEELW'
112 TO 119, 1112 TO 1119  TABLE 'W6X15'
$ ---------------------------------------------------------------
ADDITIONS
$ ---------------------------------------------------------------
$ PARAMETERS AND SECTIONS SPECIFIED IN RUNS 6 AND 7 AND CHANGED IN THIS RUN.
PRINT DESIGN DATA ALL MEMBERS
$ FROM RUN 7 RESULTS, IT IS SEEN THAT DESIGN LOAD VI DOES NOT CONTROL ANY
$     MEMBER DESIGN.  SO, ONLY DESIGN FOR SYMMETRICAL DESIGN LOADS.
LOAD LIST 'I', 'II', 'III', 'IV', 'V', 'VII'
SELECT MEMBERS 10 TO 39 WITH 'COMBINED'
SELECT MEMBERS 103 TO 111 WITH 'COMBINED'
$ ---------------------------------------------------------------
$ ADJUST MEMBERS DESIGNED AND THEIR SYMMETRICAL COUNTERPARTS TO BE
$     UNIFORM IN SIZE.
TAKE MEMBERS 10 TO 19, 1010 TO 1019  AS LARGEST 'SZ' OF MEMBERS 10 TO 19
TAKE MEMBERS 20 TO 29, 1020 TO 1029  AS LARGEST 'SZ' OF MEMBERS 20 TO 29
TAKE MEMBERS 30 TO 39, 1030 TO 1039  AS LARGEST 'SZ' OF MEMBERS 30 TO 39
TAKE MEMBERS 103 TO 105, 1103 TO 1105 AS LARGEST 'AX' OF MEMBERS 103 TO 105
TAKE MEMBERS 106 TO 108, 1106 TO 1108 AS LARGEST 'AX' OF MEMBERS 106 TO 108
TAKE MEMBERS 109 TO 111, 1109 TO 1111 AS LARGEST 'AX' OF MEMBERS 109 TO 111
$ ---------------------------------------------------------------
PRINT MEMBER PROPERTIES ALL
$ ---------------------------------------------------------------
$ DEAD WEIGHT OF ALL L-SHAPE MEMBERS.
INACTIVE MEMBERS ALL
ACTIVE MEMBERS 1 TO 9, 1001 TO 1009
STEEL TAKEOFF
$ ---------------------------------------------------------------
$ DEAD WEIGHT OF ALL WT-SHAPE SKIN PLATE STIFFENING RIBS.
INACTIVE MEMBERS ALL
ACTIVE MEMBERS 49 TO 102, 541, 601, 1049 TO 1102, 10541, 10601
STEEL TAKEOFF
$ ---------------------------------------------------------------
$ DEAD WEIGHT OF ALL WT-SHAPE SKIN PLATE BRACING MEMBERS.
INACTIVE MEMBERS ALL
ACTIVE MEMBERS 120 TO 127, 1120 TO 1122, 1124 TO 1126
STEEL TAKEOFF
$ ---------------------------------------------------------------
$ DEAD WEIGHT OF ALL W-SHAPE HORIZONTAL GIRDERS.
INACTIVE MEMBERS ALL
ACTIVE MEMBERS 10 TO 39, 1010 TO 1039
STEEL TAKEOFF
$ ---------------------------------------------------------------
$ DEAD WEIGHT OF ALL W-SHAPE STRUT MEMBERS.
INACTIVE MEMBERS ALL
ACTIVE MEMBERS 103 TO 119, 1103 TO 1119
STEEL TAKEOFF
$ ---------------------------------------------------------------
$ DEAD WEIGHT OF ALL L, WT, AND W-SHAPE MEMBERS.
ACTIVE MEMBERS ALL
INACTIVE MEMBERS 40 TO 48, 1040 TO 1048
STEEL TAKEOFF
$ NOTE THAT SKIN PLATE WEIGHS 16.186 KIPS.
$ ---------------------------------------------------------------
ACTIVE MEMBERS ALL
TIME PRINT
```

```
$ ------SAVE RESULTS AND CHECKPOINT-------------------------------------------------
SAVE *GATE/CK2*
QLIST DD1
TIME PRINT
$ ------DELETE THE TEMPORARY TABLES *W21* AND *W14* FROM USER DATA SET DD1--------
QDELETE FILE FROM DD1 *W21*
QDELETE FILE FROM DD1 *W14*
QLIST DD1
TIME PRINT
FINISH
```

11

APPENDIX F

STRUDL Job Control Language

The Job Control Language (JCL) used to run the STRUDL runs at McDonnell Automation Co. are shown in this Appendix. It should be noted that the size of the DD1 data set on the private Corps pack VOL=SER=GAITTF must be large enough to store all SAVE'd files. Also, the DD4 data set must be large enough to store the STIFFNESS ANALYSIS generated data, as well as all other input/output data generated in a problem run. Guidelines for the size of these data sets are given in Reference (4).

1. JCL for Run 1

```
//name JOB (S,accnt,'LZEGATE/WES'),'EMKIN USAE8',MSGLEVEL=(1,1),
//   LIM=(60,300,100),REGION=300K
// EXEC STRUDL,PRI=300
//GO.DD1 DD UNIT=2314,DISP=(NEW,KEEP),DCB=(DSORG=DA,BLKSIZE=7288),
//   VOL=SER=GAITTF,SPACE=(TRK,(800,100)),DSN=SAVE.CLARCANN.WES.LZE2
//GO.FT05F001 DD *
QTITLE DEPTH 60
PAGE LINE 1
STRUDL '---'  '---'
       .
       .
       .
       .
       .
FINISH
/*
```

where,

name = any less-than-or-equal-to eight alphanumeric character string beginning with an alpha character.

accnt= an assigned account number

GAITTF = name of the Corps of Engineers WES 2314 disk pack used for this study.

SAVE.CLARCANN.WES.LZE2 = name of the file on disk pack GAITTF into which STRUDL SAVE files are placed.

Now, it should be noted that the values in the LIM, REGION, PRI, and SPACE parameters depend on the problem being solved and may be highly variable from problem to problem. Care should be taken when selecting these since they will effect the total cost of a computer run. Reference (4) should be consulted for guidelines.

2. JCL for all subsequent Runs following Run 1

Same as above, except change:

```
REGION=500K

DISP=(OLD,KEEP)
```

on JCL cards 2 and 4 respectively.

APPENDIX G

Descriptions and Listings of Programs XFTWO and XFONE

This Appendix describes the input requirements for computing F, M, M_a, and M_b by FORTRAN programs XFTWO and XFONE. In addition, listings of the compilations and output of programs XFTWO and XFONE are also included. See Appendix H for the input to these two programs for the initial STRUDL II run considered in this report.

INPUT to FORTRAN Program XFTWO

Program XFTWO is used to compute values of F and M for the 2-cable cases (Load Combinations II and V in the initial STRUDL II run considered in this report). The following assumes the user is familiar with standard FORTRAN FORMAT conventions.

Card 1: READ: MAX,TOL,XSTART

FORMAT(I10,2F10.3)

where,

MAX = maximum number of Newton-Raphson iteration cycles permitted to compute F and M to satisfy tolerance TOL.

TOL = convergence tolerence of Newton-Raphson iteration for the 2-cable case (0.01 is recommended).

XSTART = starting value of M (or X) in the Newton-Raphson iteration for the 2-cable case (1.0 is recommended).

Card 2: READ: F,G

FORMAT(2F10.3)

where,

F = friction factor f associated with resultant reaction $R = \sqrt{R_x^2 + R_y^2}$ in Fig. 7.

G = friction factor g associated with reaction component R_z in Fig. 7.

Card 3: READ: F1X,F1Y,RX1,RY1,RZ1

FORMAT(5F15.3)

where,

F1X,F1Y = average of the global X-direction and Y-direction reaction components respectively at cable support joints 'S1' and 'S10' for load combinations associated with the W forces in Fig. 7 (load 101 or 102 in initial STRUDL run)

RX1,RY1,RZ1 = average of the global X, Y, and Z-direction reaction components respectively, associated with the W load case in Fig. 7, at trunion pin joints 38 and 1038.

Card 4: READ: F2X,F2Y,RX2,RY2,RZ2

FORMAT(5F15.3)

where,

F2X,F2Y = same as F1X,F1Y, except for the load case associated with the application of the 1,000 k. cable force in Fig. 7 (load 11 in initial STRUDL II run) but divided by the factor 1,000.

RX2,RY2,RZ2 = same as RX1,RY1, RZ1, except for the 1,000 K. cable force case in Fig. 7, but also divided by the factor 1,000.

Card 5: READ: F3X,F3Y,RX3,RY3,RZ3

FORMAT(5F15.3)

where,

F3X,F3Y = same as F2X, F2Y, except for the load case associated with the application of the 1,000 K-ft moment at the trunion pins (load 12 in initial STRUDL II run), and also divided by a factor of 1,000.

RX3,RY3,RZ3 = same as RX2, RY2, RZ2, except for the 1,000 K-ft trunion pin moment case in Fig. 7, and also divided by a factor of 1,000.

INPUT to FORTRAN Program XFONE

Program XFONE is used to compute values of F, M_a, and M_b for the 1-cable case (Load Combination VI in the initial STRUDL II run considered in this report). The following assumes the user is familiar with standard FORTRAN FORMAT conventions.

Card 1: READ: MAX,TOL,X10,X20

FORMAT(I10,3F10.3)

where,

MAX = same as for XFTWO, but for F, M_a, and M_b

TOL = same as for XFTWO, but for F, M_a and M_b

X10 = starting value of M_a (or X_a) in the Newton-Raphson iteration for the 1-cable case (1.0 is recommended).

X20 = starting value of M_b (or X_b) in the Newton-Raphson iteration for the 1-cable case (1.0 is recommended).

Card 2: READ: F,G

FORMAT(2F10.3)

where,

F = friction factor f associated with resultant reaction $R = \sqrt{R_X^2 + R_Y^2}$ in Fig. 8.

G = friction factor g associated with reaction component R_Z in Fig. 8.

Card 3: READ: RX1A,RY1A,RZ1A,RX1B,RY1B,RZ1B,F1X,F1Y

FORMAT(8F10.3)

where,

RX1A,RY1A,RZ1A = global X, Y, and Z-direction reaction components at trunion pin joint 38 for load combination associated with W forces in Fig. 8 (load 103 in initial STRUDL II run).

RX1B,RY1B,RZ1B = same as RX1A, RY1A, RZ1A, except at trunion pin joint 1038.

F1X,F1Y = global X and Y-direction reaction components at cable support joint 'S1' for W load case in Fig. 8.

Card 4: READ: RX2A,RY2A,RZ2A,RX2B,RY2B,RZ2B,F2X,F2Y

FORMAT(8F10.3)

where,

RX2A,RY2A,RZ2A = global X, Y, and Z-direction reaction components at trunion pin joint 38 for 1,000 K. cable force load case in Fig. 8 (load 16 in initial STRUDL II run), but divided by a factor of 1,000.

RX2B,RY2B,RZ2B = same as RX2A, RY2A, RZ2A, except at trunion pin joint 1038.

F2X,F2Y = global X and Y-direction reaction components at cable support joint 'S1' for 1,000 K. cable force load case in Fig. 8, but divided by a factor of 1,000.

Card 5: READ: RX3A,RY3A,RZ3A,RX3B,RY3B,RZ3B,F3X,F3Y

FORMAT(8F10.3)

where,

RX3A,RY3A,RZ3A = same as RX2A,RY2A,RZ2A, except for the 1,000 K-ft trunion pin joint 38 moment load case in Fig. 8 (load case 17).

RX3B,RY3B,RZ3B = same as RX3A, RY3A, RZ3A, except at trunion pin joint 1038.

F3X,F3Y = same as F2X,F2Y, except for the 1,000 K-ft moment at joint 38 load case (load case 17).

Card 6: READ: RX4A,RY4A,RZ4A,RX4B,RY4B,RZ4B,F4X,F4Y

FORMAT(8F10.3)

where,

RX4A,RY4A,RZ4A = same as RX3A,RY3A,RZ3A, except for the 1,000 K-ft moment at joint 1038 load case (load case 18 in initial STRUDL II run).

RX4B,RY4B,RZ4B = same as RX4A,RY4A,RZ4A, except reactions are at trunion pin joint 1038.

F4X,F4Y = same as F2X,F2Y, except for the 1,000 K-ft moment at joint 1038 load case (load case 18).

Program XFTWO source and assembly listings are available separately as provided by Engineer Regulation ER 18-1-6 on request to:

Director
USAE Waterways Experiment Station
ATTN: WESKA
P. O. Box 631
Vicksburg, Mississippi 39180

Results of XFTWO

F and M for Use in Load Combination II and VII

```
MAX,TOL,XSTART=        100      .010     1.000

F,G=   .9816709E-01   .1250000E+00

F1X,F1Y,RX1,RY1,RZ1=    .1263494E+02   .1920077E+02   .4187177E+03  -.2041743E+03   .8588361E+02

F2X,F2Y,RX2,RY2,RZ2=  -.3797000E-04  -.5770100E-04   .6496910E+00  -.1506100E+00   .1144160E+00

F3X,F3Y,RX3,RY3,RZ3=    .1773500E-01   .2695000E-01  -.1773400E-01  -.2694700E-01   .8200000E-03

F1,F2,F3=     .2298502E+02    .6907334E-04    .3226194E-01
X,FF,RH,RV,RL,FUNC =   .100000E+01   .230189E+02   .433655E+03 -.207852E+03   .885182E+02 -.572727E+02
X,FF,RH,RV,RL,FUNC = -.100000E+01   .229543E+02   .433649E+03 -.207788E+03   .885091E+02 -.592683E+02
X,FF,RH,RV,RL,FUNC = 0.              .229866E+02   .433652E+03 -.207820E+03   .885136E+02 -.582705E+02
X,FF,RH,RV,RL,FUNC =   .200000E+01   .230511E+02   .433658E+03 -.207884E+03   .885227E+02 -.562749E+02
X,FF,RH,RV,RL,FUNC =   .300000E+01   .230834E+02   .433662E+03 -.207916E+03   .885272E+02 -.552771E+02
X,XM2,XM1,XP1,XP2=  .100000E+01 -.100000E+01 0.                .200000E+01   .300000E+01
HM2,HM1,HP1,HP2= -.592683E+02 -.582705E+02 -.562749E+02 -.552771E+02
FUNCP=   .997789E+00
K,H,HP,XOLD,XNEW,DIFF,TOL,FF=         1 -.572727E+02   .997789E+00   .100000E+01   .583996E+02   .573996E+02   .100000E-01   .230834E+02

X,FF,RH,RV,RL,FUNC =   .583996E+02   .248708E+02   .433840E+03 -.209693E+03   .887776E+02 -.254166E-03
X,FF,RH,RV,RL,FUNC =   .563996E+02   .248063E+02   .433834E+03 -.209629E+03   .887686E+02 -.199581E+01
X,FF,RH,RV,RL,FUNC =   .573996E+02   .248386E+02   .433837E+03 -.209661E+03   .887731E+02 -.998034E+00
X,FF,RH,RV,RL,FUNC =   .593996E+02   .249031E+02   .433844E+03 -.209725E+03   .887821E+02   .997526E+00
X,FF,RH,RV,RL,FUNC =   .603996E+02   .249354E+02   .433847E+03 -.209757E+03   .887866E+02   .199531E+01
X,XM2,XM1,XP1,XP2=  .583996E+02   .563996E+02   .573996E+02   .593996E+02   .603996E+02
HM2,HM1,HP1,HP2= -.199581E+01 -.998034E+00   .997526E+00   .199531E+01
FUNCP=   .997780E+00
K,H,HP,XOLD,XNEW,DIFF,TOL,FF=         2 -.254166E-03   .997780E+00   .583996E+02   .583999E+02   .254732E-03   .100000E-01   .249354E+02

8888888   RH,RV,RL,RT=   .433840E+03 -.209693E+03   .887776E+02   .481859E+03

8888888   MR,XNEW,FF=   .583999E+02   .583999E+02   .248708E+02
```

M=58.3999 k-ft

F=24.8708 k.

Results of XFTWO

F and M for Use in Load Combination V

```
MAX,TOL,XSTART=        100      .010     1.000

F,G=    .9816700E-01    .1250000E+00

F1X,F1Y,RX1,RY1,RZ1=    .5124974E+01    .7788200E+01    .4442340E+03  -.1760771E+03    .8955357E+02

F2X,F2Y,RX2,RY2,RZ2=  -.3797000E-04  -.5770100E-04    .6496910E+00  -.1586100E+00    .1144160E+00

F3X,F3Y,RX3,RY3,RZ3=    .1773500E-01    .2695000E-01  -.1773400E-01  -.2694700E-01    .8280000E-03

F1,F2,F3=    .9323166E+01    .6987334E-04    .3226194E-01
X,FF,RH,RV,RL,FUNC =   .100000E+01   .935607E+01   .450295E+03 -.177588E+03   .906249E+02 -.578457E+02
X,FF,RH,RV,RL,FUNC = -.100000E+01   .929155E+01   .450288E+03 -.177524E+03   .906158E+02 -.598417E+02
X,FF,RH,RV,RL,FUNC = 0.              .932381E+01   .450292E+03 -.177556E+03   .906204E+02 -.588437E+02
X,FF,RH,RV,RL,FUNC =   .200000E+01   .938834E+01   .450298E+03 -.177620E+03   .906294E+02 -.568477E+02
X,FF,RH,RV,RL,FUNC =   .300000E+01   .942060E+01   .450301E+03 -.177652E+03   .906339E+02 -.558497E+02
X,XM2,XM1,XP1,XP2=   .100000E+01 -.100000E+01 0.             .200000E+01   .300000E+01
HM2,HM1,HP1,HP2= -.598417E+02 -.588437E+02 -.568477E+02 -.558497E+02
FUNCP=   .997985E+00
K,H,HP,XOLD,XNEW,DIFF,TOL,FF=        1 -.578457E+02   .997985E+00   .100000E+01   .589625E+02   .579625E+02   .100000E-01   .942060E+01

X,FF,RH,RV,RL,FUNC =   .589625E+02   .112262E+02   .450482E+03 -.179447E+03   .908869E+02 -.279028E-03
X,FF,RH,RV,RL,FUNC =   .569625E+02   .111617E+02   .450475E+03 -.179382E+03   .908778E+02 -.199623E+01
X,FF,RH,RV,RL,FUNC =   .579625E+02   .111939E+02   .450479E+03 -.179414E+03   .908823E+02 -.998255E+00
X,FF,RH,RV,RL,FUNC =   .599625E+02   .112584E+02   .450485E+03 -.179479E+03   .908914E+02   .997697E+00
X,FF,RH,RV,RL,FUNC =   .609625E+02   .112907E+02   .450488E+03 -.179511E+03   .908959E+02   .199567E+01
X,XM2,XM1,XP1,XP2=   .589625E+02   .569625E+02   .579625E+02   .599625E+02   .609625E+02
HM2,HM1,HP1,HP2= -.199623E+01 -.998255E+00   .997697E+00   .199567E+01
FUNCP=   .997976E+00
K,H,HP,XOLD,XNEW,DIFF,TOL,FF=        2 -.279028E-03   .997976E+00   .589625E+02   .589627E+02   .279594E-03   .100000E-01   .112907E+02

$$$$$$$  RH,RV,RL,RT=   .450482E+03 -.179447E+03   .908869E+02   .494907E+03

$$$$$$$  MR,XNEW,FF=   .589627E+02   .589627E+02   .112262E+02
```

→M=58.9627 k-ft.   →F=11.2262 K.

216-225

Program XFONE source and assembly listings are available separately as provided by Engineer Regulation ER 18-1-6 on request to:

Director
USAE Wateways Experiment Station
ATTN: WESKA
P. O. Box 631
Vicksburg, Mississippi 39180

Results of XFONE

F, Ma, and Mb for Use in Load Combination VI

```
MAX,TOL,X10,X20=      100     .010     1.000    1.000

F,G=   .9816700E-01   .1250000E+00

RX1A,RY1A,RZ1A,RX1B,RY1,RZ1B,,F1X,F1Y=  .410390E+03 -.204000E+03  .857314E+02  .426994E+03 -.204334E+03 -.859911E+02
                                                                                                  .253433E+02  .385131E+02
RX2A,RY2A,RZ2A,RX2B,RY2B,RZ2B,F2X,F2Y=  .809816E+00 -.197003F-90  .142095E+00 -.160105E+00  .303000E-01  .277550E-01
                                                                                                 -.851000E-04 -.129450E-03
RX3A,RY3A,RZ3A,RX3B,RY3B,RZ3B,F3X,F3Y= -.200210E-01 -.268100E-01 -.120100E-02  .220600E-02 -.136450E-03 -.362770E-03
                                                                                                  .177370E-01  .269540E-01
RX4A,RY4A,RZ4A,RX4B,RY4B,RZ4B,F4X,F4Y= -.111920E-01  .301000E-02 -.200900E-02 -.654500E-02 -.307560E-01 -.121400E-02
                                                                                                  .177400E-01  .269590E-01

F1,F2,F3,F4=  .461035E+02  .154961E-03  .322664E-01  .322722E-01

****************************************************************************************************

X1,X2,FF,RHA,RVA,RLA,H1=  .100000E+01  .100000E+01  .461752E+02  .447752E+03 -.213120E+03  .922894E+02 -.592157E+02
X1,X2,FF,RHA,RVA,RLA,H1= -.100000E+01  .100000E+01  .461107E+02  .447740E+03 -.213054E+03  .922826E+02 -.612110E+02
X1,X2,FF,RHA,RVA,RLA,H1= 0.                         .100000E+01  .461430E+02  .447746E+03 -.213087E+03  .922860E+02 -.602134E+02
X1,X2,FF,RHA,RVA,RLA,H1=  .200000E+01  .100000E+01  .462075E+02  .447758E+03 -.213153E+03  .922928E+02 -.582181E+02
X1,X2,FF,RHA,RVA,RLA,H1=  .300000E+01  .100000E+01  .462398E+02  .447764E+03 -.213186E+03  .922962E+02 -.572204E+02
X1,X2,XM2,XM1,XP1,XP2=  .100000E+01  .100000E+01 -.100000E+01 0.              .200000E+01  .300000E+01
HM2,HM1,HP1,HP2,H1P= -.612110E+02 -.602134E+02 -.582181E+02 -.572204E+02  .997636E+00
K,H1,H1P=   1 -.592157E+02  .997636E+00
X1K,X1NEW,X2K,DIFF1,TOL,FF=  .100000E+01  .603561E+02  .100000E+01  .593561E+02  .100000E-01  .462398E+02

****************************************************************************************************

X1,X2,FF,RHA,RVA,RLA,H1=  .603561E+02  .100000E+01  .480907E+02  .448115E+03 -.215089E+03  .924903E+02 -.259686E-03
X1,X2,FF,RHA,RVA,RLA,H1=  .583561E+02  .100000E+01  .480262E+02  .448102E+03 -.215022E+03  .924835E+02 -.199551E+01
X1,X2,FF,RHA,RVA,RLA,H1=  .593561E+02  .100000E+01  .480585E+02  .448109E+03 -.215056E+03  .924869E+02 -.997887E+00
X1,X2,FF,RHA,RVA,RLA,H1=  .613561E+02  .100000E+01  .481230E+02  .448121E+03 -.215122E+03  .924937E+02  .997367E+00
X1,X2,FF,RHA,RVA,RLA,H1=  .623561E+02  .'00000E+01  .481553E+02  .448127E+03 -.215155E+03  .924971E+02  .199499E+01
X1,X2,XM2,XM1,XP1,XP2=  .603561E+02  .100000E+01  .583561E+02  .593561E+02  .613561E+02  .623561E+02
HM2,HM1,HP1,HP2,H1P= -.199551E+01 -.997887E+00  .997367E+00  .199499E+01  .997627E+00
K,H1,H1P=   2 -.259686E-03  .997627E+00
X1K,X1NEW,X2K,DIFF1,TOL,FF=  .603561E+02  .603563E+02  .100000E+01  .260304E-03  .100000E-01  .481553E+02

****************************************************************************************************

X1,X2,FF,RHB,RVB,RLB,H2=  .603563E+02  .100000E+01  .480967E+02  .419429E+03 -.202527E+03 -.846795E+02 -.553078E+02
X1,X2,FF,RHB,RVB,RLB,H2=  .603563E+02 -.100000E+01  .480262E+02  .419453E+03 -.202468E+03 -.846788E+02 -.573073E+02
X1,X2,FF,RHB,RVB,RLB,H2=  .603563E+02 0.                          .480585E+02  .419441E+03 -.202497E+03 -.846791E+02 -.563075E+02
X1,X2,FF,RHB,RVB,RLB,H2=  .603563E+02  .200000E+01  .481230E+02  .419418E+03 -.202556E+03 -.846798E+02 -.543081E+02
X1,X2,FF,RHB,RVB,RLB,H2=  .603563E+02  .300000E+01  .481553E+02  .419406E+03 -.202586E+03 -.846801E+02 -.533083E+02
X1,X2,XM2,XM1,XP1,XP2=  .603563E+02  .100000E+01 -.100000E+01 0.              .200000E+01  .300000E+01
HM2,HM1,HP1,HP2,H2P= -.573073E+02 -.563075E+02 -.543081E+02 -.533083E+02  .999736E+00
K,H2,H2P=   1 -.553078E+02  .999736E+00
X2K,X2NEW,X'',DIFF2,TOL,FF=  .100000E+01  .563224E+02  .603563E+02  .553224E+02  .100000E-01  .481553E+02

****************************************************************************************************

X1,X2,FF,RHB,RVB,RLB,H2=  .603563E+02  .563224E+02  .498764E+02  .418781E+03 -.204160E+03 -.846971E+02 -.323475E-03
X1,X2,FF,RHB,RVB,RLB,H2=  .603563E+02  .543224E+02  .498118E+02  .418805E+03 -.204101E+03 -.846964E+02 -.199977E+01
X1,X2,FF,RHB,RVB,RLB,H2=  .603563E+02  .553224E+02  .498441E+02  .418793E+03 -.204130E+03 -.846967E+02 -.100005E+01
```

```
X1,X2,FF,RHB,RVB,RLB,H2=  .603563E+02  .573224E+02  .499087E+02  .418770E+03 -.204189E+03 -.846974E+02  .999400E+00
X1,X2,FF,RHB,RVB,RLB,H2=  .603563E+02  .583224E+02  .499410E+02  .418758E+03 -.204219E+03 -.846977E+02  .199912E+01
X1,X2,XM2,XM1,XP1,XP2=  .603563E+02  .563224E+02  .543224E+02  .553224E+02  .573224E+02  .583224E+02
HM2,HM1,HP1,HP2,H2P= -.199977E+01 -.100005E+01  .999400E+00  .199912E+01  .999724E+00
K,H2,H2P=   2 -.323475E-03  .999724E+00
X2K,X2NEW,X1K,DIFF2,TOL,FF=  .563224E+02  .563227E+02  .603563E+02  .323564E-03  .100000E-01  .499410E+02
************************************************************************************************************************
************************************************************************************************************************
X1,X2,FF,RHA,RVA,RLA,H1=  .603563E+02  .563227E+02  .498764E+02  .448942E+03 -.215230E+03  .926285E+02 -.964451E-01
X1,X2,FF,RHB,RVB,RLB,H2=  .603563E+02  .563227E+02  .498764E+02  .418781E+03 -.204160E+03 -.846971E+02 -.227374E-12
X1K,X2K,H1,H2,TOL=  .603563E+02  .563227E+02 -.964451E-01 -.227374E-12  .100000E-01
************************************************************************************************************************
************************************************************************************************************************
X1,X2,FF,RHA,RVA,RLA,H1=  .603563E+02  .563227E+02  .498764E+02  .448942E+03 -.215230E+03  .926285E+02 -.964451E-01
X1,X2,FF,RHA,RVA,RLA,H1=  .583563E+02  .563227E+02  .498119E+02  .448929E+03 -.215164E+03  .926217E+02 -.209170E+01
X1,X2,FF,RHA,RVA,RLA,H1=  .593563E+02  .563227E+02  .498441E+02  .448935E+03 -.215197E+03  .926251E+02 -.109407E+01
X1,X2,FF,RHA,RVA,RLA,H1=  .613563E+02  .563227E+02  .499087E+02  .448948E+03 -.215263E+03  .926319E+02  .901183E+00
X1,X2,FF,RHA,RVA,RLA,H1=  .623563E+02  .563227E+02  .499410E+02  .448954E+03 -.215296E+03  .926352E+02  .189881E+01
X1,X2,XM2,XM1,XP1,XP2=  .603563E+02  .563227E+02  .583563E+02  .593563E+02  .613563E+02  .623563E+02
HM2,HM1,HP1,HP2,H1P= -.209170E+01 -.109407E+01  .901183E+00  .189881E+01  .997628E+00
K,H1,H1P=   1 -.964451E-01  .997628E+00
X1K,X1NEW,X2K,DIFF1,TOL,FF=  .603563E+02  .604530E+02  .563227E+02  .966744E-01  .100000E-01  .499410E+02
************************************************************************************************************************
************************************************************************************************************************
X1,X2,FF,RHA,RVA,RLA,H1=  .604530E+02  .563227E+02  .498795E+02  .448942E+03 -.215233E+03  .926288E+02 -.684850E-09
X1,X2,FF,RHA,RVA,RLA,H1=  .584530E+02  .563227E+02  .498150E+02  .448930E+03 -.215167E+03  .926220E+02 -.199526E+01
X1,X2,FF,RHA,RVA,RLA,H1=  .594530E+02  .563227E+02  .498473E+02  .448936E+03 -.215200E+03  .926254E+02 -.997628E+00
X1,X2,FF,RHA,RVA,RLA,H1=  .614530E+02  .563227E+02  .499118E+02  .448948E+03 -.215266E+03  .926322E+02  .997628E+00
X1,X2,FF,RHA,RVA,RLA,H1=  .624530E+02  .563227E+02  .499441E+02  .448954E+03 -.215299E+03  .926356E+02  .199526E+01
X1,X2,XM2,XM1,XP1,XP2=  .604530E+02  .563227E+02  .584530E+02  .594530E+02  .614530E+02  .624530E+02
HM2,HM1,HP1,HP2,H1P= -.199526E+01 -.997628E+00  .997628E+00  .199526E+01  .997628E+00
K,H1,H1P=   2 -.684850E-09  .997628E+00
X1K,X1NEW,X2K,DIFF1,TOL,FF=  .604530E+02  .604530E+02  .563227E+02  .684441E-09  .100000E-01  .499441E+02
************************************************************************************************************************
************************************************************************************************************************
X1,X2,FF,RHB,RVB,RLB,H2=  .604530E+02  .563227E+02  .498795E+02  .418781E+03 -.204160E+03 -.846970E+02  .355993E-04
X1,X2,FF,RHB,RVB,RLB,H2=  .604530E+02  .543227E+02  .498150E+02  .418805E+03 -.204100E+03 -.846964E+02 -.199941E+01
X1,X2,FF,RHB,RVB,RLB,H2=  .604530E+02  .553227E+02  .498473E+02  .418793E+03 -.204130E+03 -.846967E+02 -.999689E+00
Z1,X2,FF,RHB,RVB,RLB,H2=  .604530E+02  .573227E+02  .499118E+02  .418769E+03 -.204189E+03 -.846973E+02  .999760E+00
X1,X2,FF,RHB,RVB,RLB,H2=  .604530E+02  .583227E+02  .499441E+02  .418758E+03 -.204219E+03 -.846976E+02  .199948E+01
X1,X2,XM2,XM1,XP1,XP2=  .604530E+02  .563227E+02  .543227E+02  .553227E+02  .573227E+02  .583227E+02
HM2,HM1,HP1,HP2,H2P= -.199941E+01 -.999689E+00  .999760E+00  .199948E+01  .999724E+00
K,H2,H2P=   1  .355993E-04  .999724E+00
X2K,X2NEW,X1K,DIFF2,TOL,FF=  .563227E+02  .563227E+02  .604530E+02 -.356091E-04  .100000E-01  .499441E+02
************************************************************************************************************************
************************************************************************************************************************
X1,X2,FF,RHA,RVA,RLA,H1=  .604530E+02  .563227E+02  .498795E+02  .448942E+03 -.215233E+03  .926288E+02  .620810E-07
X1,X2,FF,RHB,RVB,RLB,H2=  .604530E+02  .563227E+02  .498795E+02  .418781E+03 -.204160E+03 -.846970E+02 0.
X1K,X2K,H1,H2,TOL=  .604530E+02  .563227E+02  .620810E-07 0.           .100000E-01
************************************************************************************************************************
************************************************************************************************************************
************************************************************************************************************************
```

```
**********************
$$$$$ RHA,RVA,RLA,RTA=  .448942E+03 -.215233E+03  .926288E+02  .497870E+03
$$$$$ RHB,RVB,RLB,RTB=  .418781E+03 -.204160E+03 -.846970E+02  .465896E+03

$$$$$ X1,X2=  .604530E+02  .563227E+02
**********************

$$$$$ MRA  =   .604530E+02 = Ma
$$$$$ MRB  =   .563227E+02 = Mb
$$$$$ FF   =   .498795E+02 = F

**********************
```

F = 49.8795 K., M_a = 60.4530 K-ft., M_b = 56.3227 K-ft.

APPENDIX H

Input to XFTWO and XFONE to Compute Values of F, M, M_a, and M_b Shown in Table 8

This Appendix shows the data values input to FORTRAN programs XFTWO and XFONE to compute values of F, M, M_a, and M_b shown in Table 6. The definition of variable names used and FORMAT of data is given in Appendix G. It is assumed that the reader is familiar with the FORTRAN FORMAT conventions.

F and M for Use in Design Load Combination II Using Program XFTWO

Reaction values for STRUDL II loading combinations 101, 11, and 12 are used, except that the values from loads 11 and 12 are first divided by 1,000. Also, since behavior is symmetrical, reaction values at joints 'S1' and 'S10', and joints 38 and 1038 respectively were averaged before inputting them.

So, data cards to XFTWO:

Card 1: MAX,TOL,XSTART in (I10,2F10.3) FORMAT

data: 100, 0.01, 1.0

Card 2: F,G in (2F10.3) FORMAT

data: 0.098167, 0.12500

Card 3: F1X,F1Y,RX1,RY1,RZ1 in (5F15.3) FORMAT
(load 101)

data: 12.634942, 19.200768, 418.717651, -204.174294, 85.883614

Card 4: F2X,F2Y,RX2,RY2,RZ2 in (5F15.3) FORMAT
(load (11)/1000)

data: -.000037970, -.000057701, .649691, -.158610, .114416

Card 5: F3X,F3Y,RX3,RY3,RZ3 in (5F15.3) FORMAT
(load (12)/1000)

data: .017735, .026950, -.017734, -.026947, .000828

Result: F = 24.8708 K., M = 58.3999 K-ft

F and M for Use in Design Load Combination V Using Program XFTWO

Reaction values for STRUDL II loading combinations 102, 11, and 12 are used, except that the values from loads 11 and 12 are first divided by 1,000. Also, since behavior is symmetrical, reaction values at joints 'S1' and 'S10', and joints 38 and 1038 respectively were averaged before inputting them.

So, data cards to XFTWO:

Card 1: same as for Load II

Card 2: same as for Load II

Card 3: F1X,F1Y,RX1,RY1,RZ1 in (5F15.3) FORMAT
(load 102)

data: 5.124974, 7.788200, 444.234009, -176.077103, 89.553574

Card 4: same as for Load II

Card 5: same as for Load II

Result: F = 11.2262 K., M = 58.9627 K-ft

F, M_a', and M_b for Use in Design Load Combination VI Using Program XFONE

Reaction values for STRUDL II loading combinations 103, 16, 17, and 18 are used, except that the values from loads 16, 17, and 18 are first divided by 1,000. Reaction values taken from joints 'S1', 38, and 1038. This case includes side support constraints.

So, data cards to XFONE:

Card 1: MAX,TOL,X10,X20 in (I10,3F10.3) FORMAT

data: 100, 0.01, 1.0, 1.0

Card 2: F,G, in (2F10.3) FORMAT

data: 0.098167, 0.12500

Card 3: RX1A,RY1A,RZ1A,RX1B,RY1B,RZ1B,F1X,F1Y in (8F10.3) FORMAT.
(load 103)

data: 410.389648, -204.000473, 85.731430, 426.997559, -204.333786, -85.991104, 25.343262, 38.513062

Card 4: RX2A,RY2A,RZ2A,RX2B,RY2B,RZ2B,F2X,F2Y in (8F10.3) FORMAT.
(load (16)/1000)

data: .809816, -.197003, .142095, -.160105, .038388, .027755 -.00008518, -.00012945

Card 5: RX3A,RY3A,RZ3A,RX3B,RY3B,RZ3B,F3X,F3Y in (8F10.3) FORMAT.
(load (17)/1000)

data: -.020021, -.026310, -.001201, .002286, -.00013645, -.00036277, .017737, .02695

Card 6: RX4A,RY4A,RZ4A,RX4B,RY4B,RZ4B,F4X,F4Y in (8F10.3) FORMAT.
(load (18)/1000)

data: -.011192, .003810, -.002089, -.006545 -.030756, -.001214, .017740, .026959

Result:

$F = 49.8795$ K.

$M_a = 60.4530$ K-ft

$M_b = 56.3227$ K-ft

APPENDIX I

Final Design of the WT-Shape Skin Plate Stiffening Ribs

The STRUDL II design of the WT-shape skin plate stiffening ribs, as shown in Table 9, led to eroneously large section sizes. This was due to the fact that STRUDL assumed these members to be acting as WT-shapes between the joints they connect. However, in reality, these members behave compositely with the skin plate. Consequently, their design must reflect this composite action, or be overly conservative as the STRUDL design shown in Table 9. Since STRUDL II design procedures cannot account for this case at the present time, these WT-shapes must be designed by hand.

Now, in order to determine the proper forces acting on the composite section, the WT-shape member end forces must be added to the skin plate finite element forces, and then reduced to equivalent forces acting at the centroid of the composite section. This is demonstrated in the following two critical rib member designs in Parts (A) and (B).

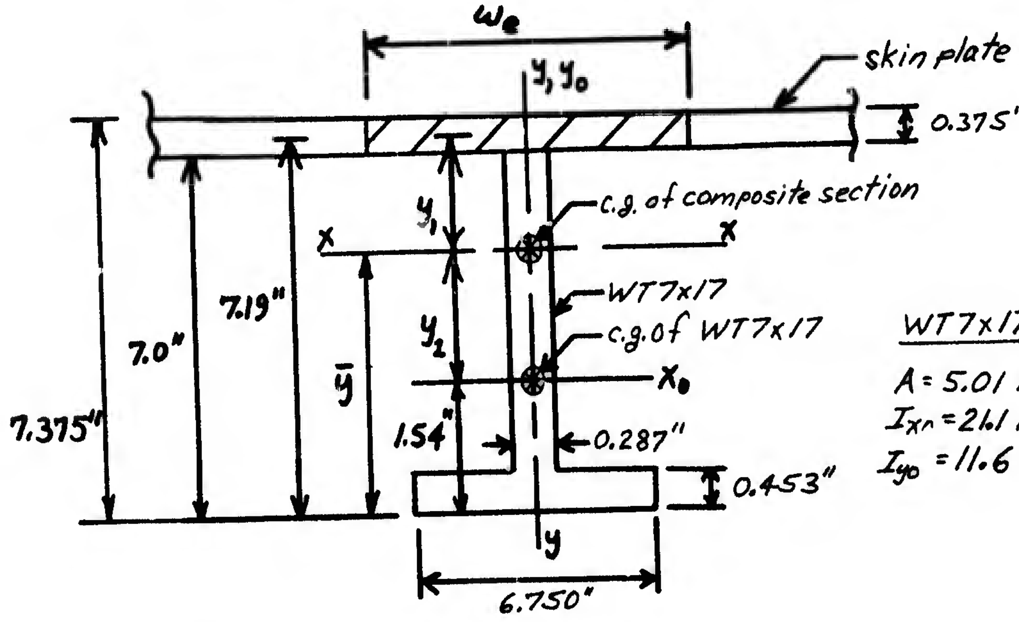
It should first be noted, however, that since composite action must be considered for design of the stiffening rib/skin plate system, then it would be more convenient to model this composite system for analysis purposes by replacing the rib/finite element structural model with an equivalent composite member model. This new model would consist of a system of vertical ribs whose properties are the same as an equivalent composite section composed of the actual WT-shape ribs acting compositely with an effective width of skin plate (see composite section property calculations in Parts (A) and (B) below). It is believed that this new model would lead to analysis results for which final design would not be any different from the design obtained using the rib/finite element model discussed in this report. Due to time and cost limitations, this was not considered in this report. However, it is the recommended structural model.

Part (A): Design of WT-Shape Member Numbers 49 to 78

As can be seen in Table 9, members 49 to 78 designed by STRUDL II as non-composite WT-shapes are much larger than their initial starting size of a WT7x17 section. However, it can be shown that the WT7x17 section is adequate if designed as a section acting compositely with the skin plate. This will be shown for member 73 at end joint 40 where a review of the STRUDL II output shows maximum forces acting, and associated with design load combination IV, for the group of members 49 to 78.

Note that this design check for member 73 is based in part on the Clarence Cannon Re-Reg Tainter Gate design computations(11) by J. J. Smith, September, 1974.

(A1) Compute Composite Section Properties of WT7x17 and Skin Plate



WT7x17

$A = 5.01 \text{ in}^2$

$I_{xo} = 21.1 \text{ in}^4$

$I_{yo} = 11.6 \text{ in}^4$

Section Properties

w_e = effective width of skin plate (by Corps EM 1110-2-2702)

$$= 1.5\sqrt{\frac{E}{F_y}}\, t = 1.5\sqrt{\frac{29{,}000}{50}}\,(.375)$$

$$w_e = 13.5''$$

$$\bar{y} = \frac{(13.5)(.375)(7.19) + (5.01)(1.54)}{(13.5)(.375) + 5.01} = \frac{44.11}{10.07}$$

$$= 4.38''$$

$$y_1 = 7.19 - 4.38 = 2.81''$$

$$y_2 = 4.38 - 1.54 = 2.84''$$

$$I_x = \frac{(13.5)(.375)^3}{12} + (13.5)(.375)(2.81)^2 + 21.1 + 5.01(2.84)^2$$

$$= .059 + 39.974 + 21.1 + 40.409$$

$$= 101.54 \text{ in}^4.$$

$$I_y = \frac{(.375)(13.5)^3}{12} + 11.6$$

$$= 76.887 + 11.6$$

$$= 88.487 \text{ in}^4.$$

$$A = (13.5)(.375) + 5.01$$

$$= 10.07 \text{ in}^2.$$

(A2) Material Properties

Skin Plate = A-441 steel
WT-Shape = A-441 steel
Group 1 Shape

$F_y = 50$ ksi.

(A3) Check Compactness and Compute F_{bx}

AISC, 1970, Section 1.5.1.4 :

¶(a) ok.

¶(b) $b/t = \frac{6.75/2}{.453} = 7.45$

$\frac{52.2}{\sqrt{F_y}} = \frac{52.2}{\sqrt{50}} = 7.38$

$b/t > \frac{52.2}{\sqrt{F_y}}$

∴ non-compact by ¶(b).

¶(c) not applicable

¶(d) $d/t = \frac{7.0 - .453}{.287} = 22.81$

This member has approximately zero axial force (see step (A5)).

So, allowable $d/t = \frac{412}{\sqrt{F_y}} = \frac{412}{\sqrt{50}} = 58.27$

$\therefore d/t = 22.81 < \text{allow. } d/t = 58.27$, ok.

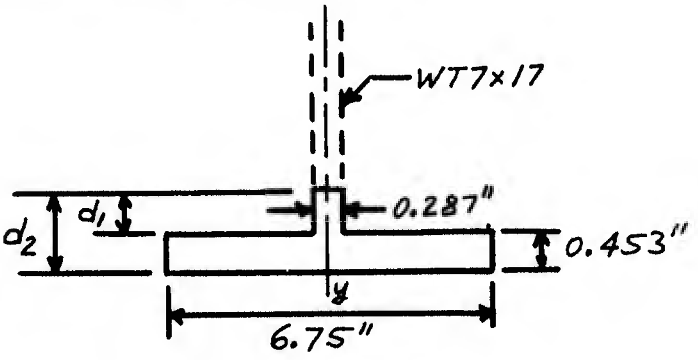
TP (e) $\frac{76.0\, b_f}{\sqrt{F_y}} = \frac{76(6.75)}{\sqrt{50}} = 72.55$

$\frac{20{,}000}{(d/A_f)F_y} = \frac{20{,}000}{\frac{7.375}{(6.75)(.453)}(50)} = 165.84$

$\therefore$ Allow. $\ell_u = 72.55''$

But $\ell_{u,73} = 73.8'' > 72.55''$, $\therefore$ non-compact by TP (e).

So, must use AISC Sect. 1.5.1.4.6a :



$d_1 = \frac{1}{3}(4.38 - .453) = 1.31''$

$d_2 = 1.31 + .453 = 1.76''$

$I_y = \frac{(.453)(6.75)^3}{12} + \frac{(1.31)(.287)^3}{12}$

$= 11.612 \text{ in}^4$

$A = (.453)(6.75) + (1.31)(.287)$
$= 3.434 \text{ in}^2$

$r_t = \sqrt{\frac{I_y}{A}} = \sqrt{\frac{11.612}{3.434}} = 1.839''$

$l_{u,73} = 73.8''$

So, $\frac{l_{u,73}}{r_t} = \frac{73.8}{1.839} = 40.13$

Now, take $C_b = 1.0$ (conservative)

$\therefore \sqrt{\frac{102 \times 10^3 C_b}{F_y}} = \sqrt{\frac{102 \times 10^3 \times 1.0}{50}} = 45.1$

and, $\frac{l_{u,73}}{r_t} = 40.13 < 45.1$

$\therefore F_{bx} = 0.6 F_y = 0.6(50)$
$= 30 \text{ ksi.}$

However, by Corps Specifications,
$F_{bx} = 0.833 \times (0.6 F_y)$

This is accounted for in the design loading combination IV formulation by applying the factor 1.0/0.833 (see STRUDL output or input in Appendix E)

So,

$F_{bx} = 0.6 F_y$

$\underline{\underline{F_{bx} = 30 \text{ ksi.}}}$

(A4) Compute F_{by}

$$F_{by} = 0.6\,F_y = 0.6(50)$$
$$= 30\ \text{ksi.}$$

However, by Corps Specifications,
$$F_{by} = 0.833 \times (0.6\,F_y)$$

This is accounted for in the design loading combination IV formulation by applying the factor 1.0/0.833 (see STRUDL output or input in Appendix E).

So, $F_{by} = 0.6\,F_y$

$$\underline{\underline{F_{by} = 30\ \text{ksi.}}}$$

(A5) Compute Forces on Composite Member 73 at Joint 40 for Loading Combination IV.

The STRUDL output indicates maximum moment for members 49 through 78 occurs at joint 40 end of member 73 for loading combination IV.

The design forces for this composite member at end joint 40 are composed of the member end forces at joint 40 plus the skin plate forces at joint 40 assumed to act over a full 21" width of plate (half the distance between adjacent ribs summed up). This is necessary to assure that all the forces are accounted for even though the effective skin plate width for design is taken as 13.5" in Step (A1).

Now, the axial force and bending moments in member 73 at joint 40 from the STRUDL analysis Run 5 for loading combination IV is :

$F_{73} = 24.7$ k. (compression)
$M_{x,73} = 27.96$ k-ft. (M_3 in STRUDL)
$M_{y,73} = 1.40$ k-ft. (M_y in STRUDL)

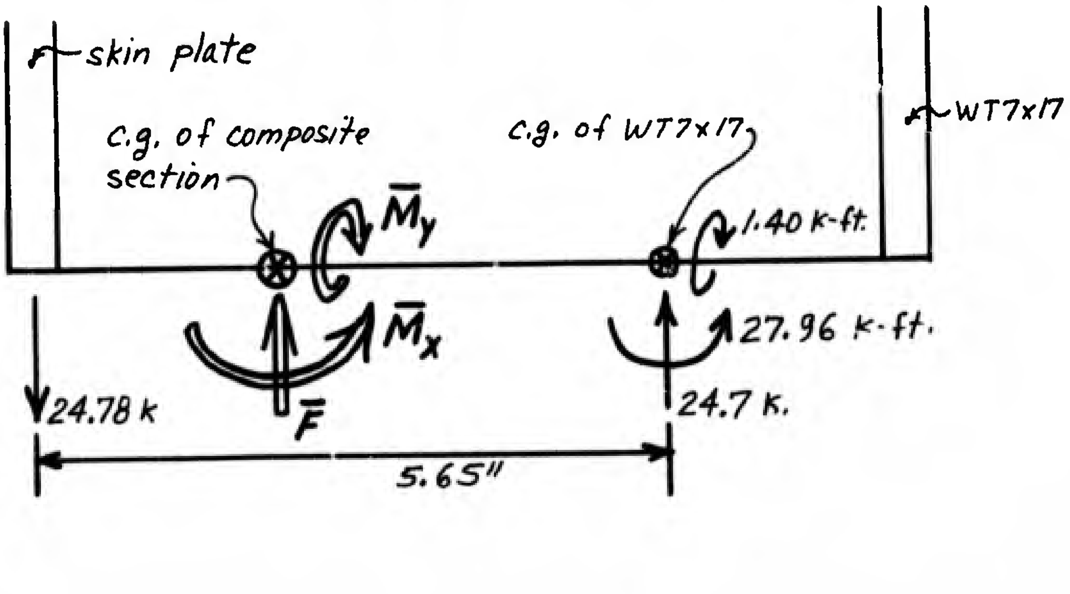
The in-plane forces for loading combination IV in the skin plate at joint 40, and parallel to member 73, is obtained by averaging the N_{YY} stress-resultants for all finite elements (nos. 239, 242, 255, 256, 257) incident on joint 40. So,

$$F_{plate} = 21\left[\frac{(N_{YY}^{239} + N_{YY}^{242} + N_{YY}^{255} + N_{YY}^{256} + N_{YY}^{257})\,\text{k/ft.} \times \frac{1}{12}}{5}\right]$$

$$= 21\left[\frac{(15.401 + 15.480 + 13.419 + 11.878 + 14.645)\frac{1}{12}}{5}\right]$$

$$= 21\,(1.180\ \text{k/in})$$

$= 24.78$ k., tension acting through the midplane of the skin plate at joint 40.



$$\bar{F} = 24.7 - 24.78 = 0.08\ k.$$
$$\approx 0.0\ k.$$
$$\bar{M}_y = 1.40\ k\text{-}ft.$$
$$\bar{M}_x = 27.96 + 24.7\left(\frac{5.65}{12}\right)$$
$$= 39.59\ k\text{-}ft.$$

Since $f_a/F_a < .15$, Use AISC Eq. (1.6-2):

$$\frac{f_a}{F_a} + \frac{f_{bx}}{F_{bx}} + \frac{f_{by}}{F_{by}} \le 1.0$$

$$f_a \approx 0$$
$$f_{bx} = \frac{(39.59 \times 12)(4.38)}{101.54}$$
$$= 20.49\ ksi.$$
$$f_{by} = \frac{(1.4 \times 12)(13.5/2)}{88.487}$$
$$= 1.28\ ksi.$$

So,
$$0 + \frac{20.49}{30} + \frac{1.28}{30} \overset{?}{\le} 1.0$$
$$0 + 0.68 + 0.04 = 0.73 < 1.0,\ \underline{\underline{ok}}$$

(A6) Result

The STRUDL design of the WT-shape stiffening rib indicated that the WT7x17 was inadequate. This was due to a design based on the WT-shape alone, and not accounting for the composite action with the skin plate.

However, after properly accounting for the composite action, it is seen that the WT7x17 is adequate after all!

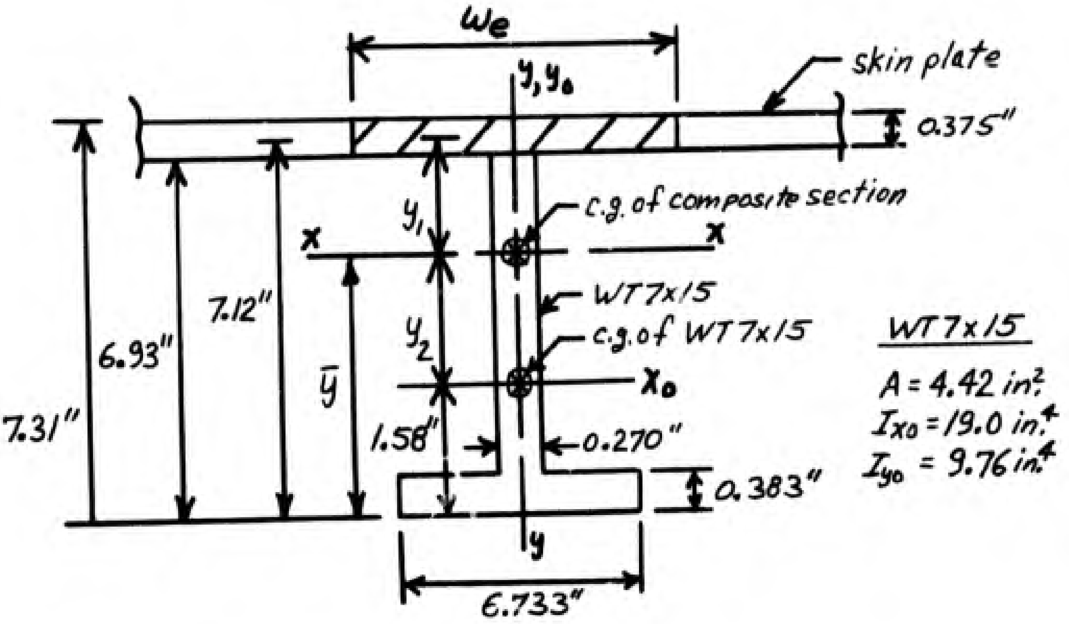
So, let all member numbers 49 to 78 and 1049 to 1078 = WT7x17 as originally designed by the Corps.

Part (B): Design of WT-Shape Member Numbers 79 to 102

As can be seen in Table 9, members 79 to 102 designed by STRUDL II as non-composite WT-shapes are much larger than their initial starting size of a WT7x15 section. However, it can be shown that the WT7x15 section is adequate if designed as a section acting compositely with the skin plate. This will be shown for member 79 at end joint 47 where a review of the STRUDL II output shows maximum forces acting, and associated with design load combination V, for the group of members 79 to 102.

Note that this design check for member 79 is based in part on the Clarence Cannon Re-Reg Tainter Gate design computations(11) by J. J. Smith, September, 1974.

(B1) Compute Composite Section Properties of WT7x15 and Skin Plate



Section Properties

w_e = effective width of skin plate
(by Corps EM 1110-2-2702)

$$= 1.5\sqrt{\frac{E}{F_y}}\,t = 1.5\sqrt{\frac{29{,}000}{50}}\,(.375)$$

$$w_e = 13.5''$$

$$\bar{y} = \frac{(13.5)(.375)(7.12)+(4.42)(1.58)}{(13.5)(.375)+4.42} = \frac{43.029}{9.483}$$

$$= 4.54''$$

$$y_1 = 7.12 - 4.54 = 2.58''$$
$$y_2 = 4.54 - 1.58 = 2.96''$$

$$I_x = \frac{(13.5)(.375)^3}{12} + (13.5)(.375)(2.58)^2 + 19.0 + 4.42(2.96)^2$$
$$= .059 + 33.698 + 19.0 + 38.726$$
$$= 91.48 \text{ in}^4.$$

$$I_y = \frac{(.375)(13.5)^3}{12} + 9.76$$
$$= 76.887 + 9.76$$
$$= 86.65 \text{ in}^4.$$

$$A = (13.5)(.375) + 4.42$$
$$= 9.48 \text{ in}^2.$$

(B2) Material Properties

Skin Plate = A-441 steel
WT-shape = A-441 steel
Group 1 Shape

$F_y = 50$ ksi.

(B3) Check Compactness and Compute F_{bx}

AISC, 1970, Section 1.5.1.4 :

¶(a) ok.

¶(b) $b/t = \frac{6.733/2}{.383} = 8.79$

$\frac{52.2}{\sqrt{F_y}} = \frac{52.2}{\sqrt{50}} = 7.38$

$b/t > \frac{52.2}{\sqrt{F_y}}$

$\therefore$ non-compact by ¶(b).

¶(c) not applicable

¶(d) $d/t = \frac{6.93 - .383}{.270} = 24.25$

This member is in tension (see Step (B5)).

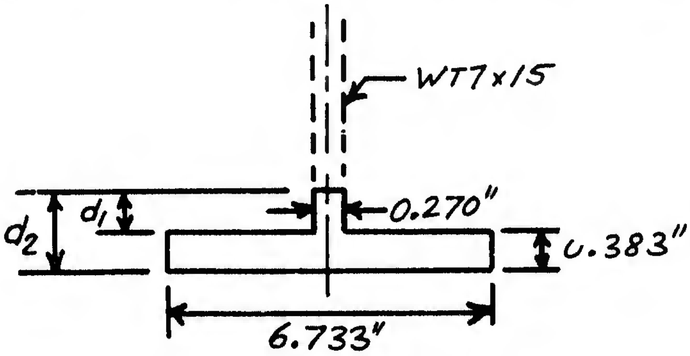
So, allowable $d/t = \frac{412}{\sqrt{F_y}} = \frac{412}{\sqrt{50}} = 58.27$

$\therefore d/t = 24.25 <$ allow. $d/t = 58.27$, ok.

$$\text{IP (e)} \quad \left.\begin{array}{l} \frac{76.0\, b_f}{\sqrt{F_y}} = \frac{76(6.733)}{\sqrt{50}} = 72.37 \\ \frac{20,000}{(d/A_f)F_y} = \frac{20,000}{\frac{7.31}{(6.733)(.383)}(50)} = 141.1 \end{array}\right\} \therefore \text{Allow. } l_u = 72.37''$$

But $l_{u,79} = 73.77'' > 72.37''$, $\therefore$ <u>non-compact by IP(e).</u>

So, must use AISC Sect. 1.5.1.4.6a :



$d_1 = \frac{1}{3}(4.54 - .383) = 1.39''$

$d_2 = 1.39 + .383 = 1.77''$

$I_y = \frac{(.383)(6.733)^3}{12} + \frac{(1.39)(.270)^3}{12}$

$= 9.744 \text{ in}^4$

$A = (.383)(6.733) + (1.39)(.270)$
$= 2.954 \ in^2$

$r_t = \sqrt{\frac{I_y}{A}} = \sqrt{\frac{9.744}{2.954}} = 1.82''$

$l_{u,79} = 73.77''$

So, $\frac{l_{u,79}}{r_t} = \frac{73.77}{1.82} = 40.53$

Now, take $C_b = 1.0$ (conservative)

$\therefore \sqrt{\frac{102 \times 10^3 C_b}{F_y}} = \sqrt{\frac{102 \times 10^3 \times 1.0}{50}} = 45.1$

and, $\frac{l_{u,79}}{r_t} = 40.53 < 45.1$

$\therefore F_{bx} = 0.6 F_y = 0.6(50)$
$= 30 \ ksi.$

However, by Corps Specifications,
$F_{bx} = 0.833 \times (0.6 F_y)$

This is accounted for in the design loading combination V formulation by applying the factor 1.0/0.833 (see STRUDL output or input in Appendix E)

So,

$F_{bx} = 0.6 F_y$

$\underline{\underline{F_{bx} = 30 \ ksi.}}$

(B4) Compute F_{by}

$$F_{by} = 0.6\,F_y = 0.6(50)$$
$$= 30\text{ ksi.}$$

However, by Corps Specifications,

$$F_{by} = 0.833 \times (0.6\,F_y)$$

This is accounted for in the design loading combination V formulation by applying the factor 1.0/0.833 (see STRUDL output or input in Appendix E).

So, $F_{by} = 0.6\,F_y$

$$\underline{\underline{F_{by} = 30\text{ ksi.}}}$$

(B5) Compute Forces on Composite Member 79 at Joint 47 for Loading Combination V

The STRUDL output indicates maximum moment for members 79 through 102 occurs at joint 47 end of member 79 for loading combination V.

The design forces for this composite member at end joint 47 are composed of the member end forces at joint 47 plus the skin plate forces at joint 47 assumed to act over a full 21" width of plate (half the distance between adjacent ribs summed up). This is necessary to assure that all the forces are accounted for even though the effective skin plate width for design is taken as 13.5" in Step (B1).

Now, the axial force and bending moments in member 79 at joint 47 from the STRUDL analysis Run 5 for loading combination V is :

$F_{79} = 18.631$ k, (compression)
$M_{x,79} = 23.794$ k-ft. (M_3 in STRUDL)
$M_{y,79} = 0.912$ k-ft. (M_y in STRUDL)

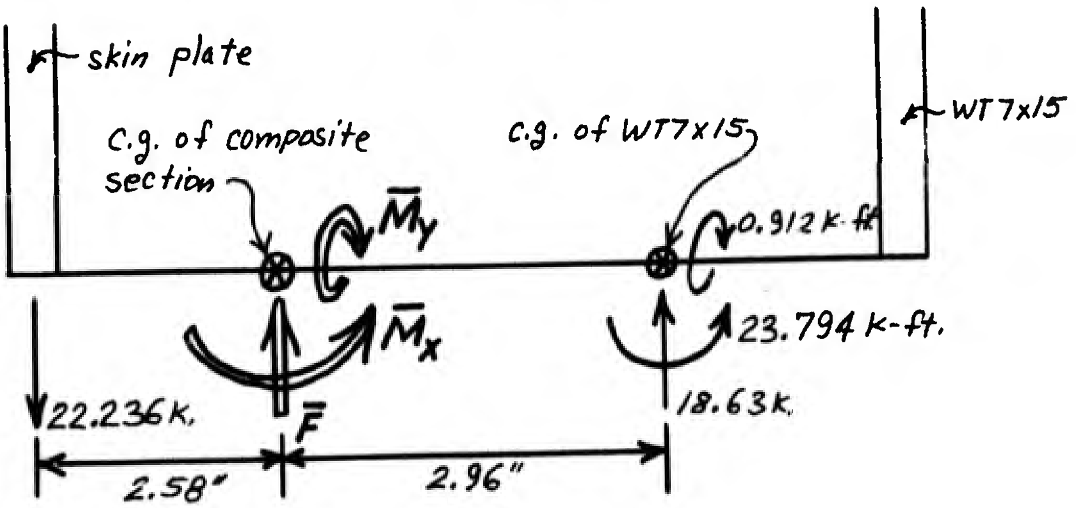
The in-plane forces for loading combination V in the skin plate at joint 47, and parallel to member 79, is obtained by averaging the N_{YY} stress-resultants for all finite elements (nos. 256, 257, 258, 267, 268, 269) incident on joint 47. So,

$$F_{plate} = 21 \left[\frac{(N_{YY}^{256} + N_{YY}^{257} + N_{YY}^{258} + N_{YY}^{267} + N_{YY}^{268} + N_{YY}^{269})\text{k/ft.} \times \frac{1}{12}}{6} \right]$$

$$= 21 \left[\frac{(12.060 + 14.723 + 14.200 + 10.894 + 9.955 + 14.406) \times \frac{1}{12}}{6} \right]$$

$$= 21 (1.059 \text{ k/in.})$$

$= 22.236$ k., tension acting through the midplane of the skin plate at joint 47.



$$\bar{F} = 22.236 - 18.63$$
$$= 3.606 \text{ K. (tension)}$$
$$\bar{M}_y = 0.912 \text{ k-ft.}$$
$$\bar{M}_x = 23.794 + 18.63\left(2.96 \times \tfrac{1}{12}\right) + 22.236\left(2.58 \times \tfrac{1}{12}\right)$$
$$= 23.794 + 4.595 + 4.781$$
$$= 33.170 \text{ k-ft.}$$

Since f_a is tension, use AISC Eq. (1.6-2) in the form:

$$\frac{f_{bx}}{F_{bx}} + \frac{f_{by}}{F_{by}} \leq 1.0$$

$$f_{bx} = \frac{(33.170 \times 12)(4.54)}{91.48}$$
$$= 19.75 \text{ ksi.}$$

$$f_{by} = \frac{(0.912 \times 12)(13.5/2)}{86.65}$$
$$= 0.85 \text{ ksi.}$$

So,

$$\frac{19.75}{30} + \frac{0.85}{30} \overset{?}{\leq} 1.0$$

$$0.66 + 0.03 = 0.69 < 1.0, \ \underline{\underline{\text{ok}}}$$

(B6) Result

The STRUDL design of the WT-shape stiffening rib indicated that the WT7x15 was inadequate. This was due to a design based on the WT-shape alone, and not accounting for the composite action with the skin plate.

However, after properly accounting for the composite action, it is seen that the WT7x15 is adequate after all!

So, let all member numbers 79 to 102 and 1079 to 1102 = WT7x15 as originally designed by the Corps.

In accordance with ER 70-2-3, paragraph 6c(1)(b), dated 15 February 1973, a facsimile catalog card in Library of Congress format is reproduced below.

Emkin, Leroy Z
General purpose computer-aided analysis and design of tainter gates, by Leroy Z. Emkin, Tucker, Georgia. Vicksburg, U. S. Army Engineer Waterways Experiment Station, 1976.
2 v. illus. 27 cm. (U. S. Waterways Experiment Station. Contract report K-76-1)
Prepared for U. S. Army Engineer Division, Lower Mississippi Valley, Vicksburg, Mississippi, under Contract Nos. DACW39-76-M-0869 and DACW39-76-M-2230.
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TA7.W34c no.K-76-1