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SEISMIC QUALIFICATION ANALYSIS 150 TON SEMI-GANTRY CRANE PRIVATE FUEL STORAGE FACILITY SKULL VALLEY, UTAH

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CONTENTS

EXECUTIVE SUMMARY

A 150 ton semi-gantry crane is under design for the Private Fuel Storage Facility at Skull Valley, Utah. This crane will be used as part of the lifting operations for transferring sealed spent-fuel canisters to storage casks. Because of this handling of critical loads, the crane is classified as a Type I crane under the requirements of ASME NOG-1 for the construction of overhead and gantry cranes at nuclear facilities.

A seismic qualification analysis is carried out for the 150 ton semi-gantry crane in accordance with ASME-NOG-1 and the Stone and Webster Specifications 0599602-M001. A response spectrum analysis is used to calculate maximum stresses and forces in the structural components for the design response spectra given in terms of acceleration vs. frequency at 4% critical damping. The semi-gantry crane is supported on floor-mounted rails for the gantry legs and by rails on a support wall at the other end. These crane supports occur at substantially different elevations and thus will experience different lateral acceleration loads through the canister transfer building. A submodel for the support wall is developed and included in the analysis. This allows the appropriate accelerations at the wall support rails to develop from the input design response spectra at the bottom of the wall and the gantry legs. A static, lateral body force load is used to simulate the seismic response for the direction transverse to the bridge girders since slip of the bridge truck wheels on the rails will occur under these conditions. The response to these seismic loads is combined with the vertical static response and compared to allowable stresses as defined by ASME NOG-1.

Three trolley positions are evaluated; trolley at end of travel near the support wall, trolley at ¼ span near the gantry legs, and trolley at mid span. For each of these positions, a no load condition and loads on each of the main hoist and auxiliary hoist with both hook up and hook down positions are considered. The initial section sizes were modified based on preliminary seismic calculations. In all load cases using the adjusted section sizing, the calculated stresses are below the allowables for normal stress in tension and compression and for shear stress. A slack rope condition does not occur.

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INTRODUCTION

1.1 Description

The Private Fuel Storage Facility (PFSF) to be located on the Skull Valley Indian reservation in Utah will be constructed and operated by a consortium of nuclear utilities. The facility is designed for dry storage of spent fuel where sealed metal canisters containing spent-fuel assemblies are placed in concrete storage casks and stored on concrete slabs. A canister transfer building at the site will be used to offload transportation casks from a rail car or heavy haul trailer and transfer the sealed canisters to the storage casks. Two crane systems are under design to handle this transfer operation; a 200 ton overhead bridge crane, and a 150 ton semi-gantry crane. Since these cranes handle critical loads, they are classified as Type I cranes in accordance with ASME NOG-1 [1]. The cranes must be designed to remain in place and support the critical load during and after a safe shutdown earthquake (SSE). The cranes must also have single-failure-proof features such that any credible failure of a single component will not result in the loss of capability to stop and/or hold the critical load. The designs will be subject to review by the U. S. Nuclear Regulatory Commission (USNRC) for licensing as QA Category 1, Important to Safety.

This report documents the seismic qualification analysis for the initial design phase of the 150 ton semi-gantry crane. The seismic qualification analysis for the 200 ton overhead bridge crane is documented in a separate report. The semi-gantry crane, as illustrated in the Ederer Clearance Drawing, PA-2190, will have a main hoist with a capacity of 150 tons (maximum critical load) and an auxiliary hoist with a capacity of 25 tons. Ederer drawing D-36979 shows the initial design for the trolley arrangement. The design is for double bridge girders spanning 35 feet supported along one end on rails 55' above the building floor and with gantry legs mounted on rails at the other end. The bridge girders are welded plate box sections rigidly connected to box section end ties. On the wall supported end, the end tie attaches directly to the bridge trucks with pins to equalize the load to each truck. At the gantry end, the bridge girders are connected with a rigid end tie, which in turn is rigidly connected to the gantry legs. The gantry legs then connect through a load equalizing end tie to the bridge trucks at the floor. The gantry legs are also constructed of welded plate box sections which taper from the girder end tie connections to the equalizing sill connections. The bridge trucks are rigid box structures, each enclosing two 30" diameter wheels, connected with pins at each end of the equalizing sill. The bridge girders support rails along their centerlines with a 15 foot gage for the trolley. The structural skeleton for the trolley consists of 2 box section end trucks with 2 wheels each, which are rigidly connected at the midspan with a load beam or load girt. A deck plate across the top of the trucks and load girt is used for mounting the rope drums, hoist motors and brakes, the upper blocks, and other associated mechanical equipment. The trolley load girt is of welded plate box construction and directly supports the main hoist upper block reactions. The main hoist uses a 16 part reeving configuration allowing two independent wire ropes to wind simultaneously on the hoist drum. Each rope will support the lifted load with a force of 1/16 of the payload weight. The 25 ton auxiliary hoist uses a similar but 8 part reeving configuration. The main hoist uses a 1 3/8" diameter wire rope weighing 3.50 lbs. per foot. The main hoist drum is 59" in diameter providing 3.86 feet of hoist height per turn. This requires 14.6 turns for the full 56.5 foot lift height.

1.2 Objectives and Scope

The work reported herein is for the seismic qualification of the 150 ton semi-gantry crane and is carried out in accordance with the Stone and Webster Bid Specification 0599602-M001 [2] dated June 29, 1998, and with ASME NOG-1 [1]. The general requirements for such a seismic qualification of Type I overhead bridge cranes is well defined in ASME NOG-1, and the Stone and Webster specification further identifies specific requirements for the PFSF site. This report documents the analysis methods, modeling, and results used to meet these requirements for seismic qualification. The scope of this work is for initial detailed engineering in Phase I to support the NRC licensing application. For seismic qualification, this phase is for sizing of the structural skeleton of the crane system.

The S&W bid specification indicates that the analysis should be based on the design response spectra at the crane rails as provided in the specification. Thus, it is assumed in this work that the crane system is decoupled from the railway support system. The requirements in section NOG-4153.5 for evaluating decoupling are not part of the scope for this work.

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ANALYSIS PROCEDURE

2.1 Response Spectrum Analysis

The specifications for this seismic qualification requires that response spectrum analyses be performed for a specified set of load conditions. A response spectrum analysis is a well defined and industry standard procedure used to estimate the peak response for variables, such as displacement, stress, and reaction force, of a structural system subjected to a given base motion. In this case, the base motion is the design response spectrum given in terms of acceleration versus frequency at 4% of critical damping for 3 component directions at the building elevation supporting the crane railways. The basic assumptions for this type of analysis are that the response is linear and that it is relative to the base motion. The eigenmodes, frequencies, and modal participation factors are first extracted for the finite element model of the structural system. The peak modal response of the "generalized" variables in frequency space is calculated from the given input response spectrum (acceleration as a function of frequency and damping) and the modal participation factors. The corresponding peak physical response is then calculated for each natural frequency mode through the corresponding eigenvector. These peak physical responses for each natural mode are then combined to estimate the total peak response of the variable. Since the peak response in the different modes will not typically occur at the same time, the combination into a peak value is conservative. The method used to combine the individual modal response is the square root of the sum of the squares (SRSS) with the Ten Percent Method as described in USNRC Regulatory Guide 1.92 [3] for closely spaced modes. Modes are defined as closely spaced when the frequencies are within 10% of the lower value. The SRSS method is modified by adding twice the absolute value of the product of the peak modal response from each pair of such modes to the sum of the squares of all the modal peak values. Finally, these peak responses are combined for the different component directions using a square root of the sum of the squares combination. The resulting peak values from the seismic loads are then algebraically added to static values to compare with design allowables as specified in ASME NOG-1 for seismic qualification.

2.2 Software Qualification

The above procedure for response spectrum analysis is fully implemented in the ABAQUS/Standard general purpose finite element program [4]. This program is used extensively in the nuclear industry and is used for this work. The program allows input of 3 orthogonal base motion response spectrums and options for summing the modal contributions and the component contributions which are automatically calculated separately. The SRSS method for components and the SRSS with Ten Percent Rule for modal contributions are implemented and used. The rigid body type eigenmodes can also be calculated with this software. These modes give zero frequencies and can be excluded from the modal participation.

The ANATECH QA program requires that software be qualified for each individual QA project through verifications particular to the project's application of the software. To this end, example problems were tested with version 5.7 of ABAQUS to verify correct execution of the software and that the calculations for the response spectra procedure are correct.

2.3 Load Cases and Combinations

The load cases to evaluate for seismic qualifications are identified in ASME NOG-1 and require 3 different trolley locations (trolley at end of travel, trolley at ¼ of span, and trolley at midspan) with hook up and hook down at each position. For each hook position, the credible critical load must be applied, and, in addition, for each trolley position, the seismic loads are to be evaluated for no hook load. The Stone and Webster specification also requires that the above load cases be applied to both the main hoist and auxiliary hoist. For the semi-gantry crane, the trolley positions are not symmetric with respect to the midspan since the crane is supported by a wall on one end and by the gantry legs on the other end. The ¼ span trolley position must be evaluated relative to the trolley at end of travel in each direction to determine the trolley location that produces maximum stress for the site specific response spectra. The three trolley positions are likely to be trolley at wall end, trolley at midspan, and trolley at gantry leg end.

ASME NOG-1 specifies the boundary conditions to use on the finite element model for the seismic qualification calculations as referenced in Figure NOG-4154.3-1 and Table NOG-4154.3-1. One of these conditions is that an end wheel of the bridge trucks on each rail be restrained from motion along the rail direction. An exception to this requirement is taken with the argument that wheel slip along the rail will occur under seismic motion in this direction. Fixing these wheels is likely to artificially move the transverse bending type modes of the cranes down to frequencies with significantly more participation for the given loading. In these calculations, a lateral load will be included to account for a uniform acceleration of the crane along the rails due to wheel slippage. This lateral load is determined by multiplying the maximum vertical reaction load (static + seismic) by a coefficient of friction of 0.2. This lateral load is then applied as a static, uniform body force in the rail direction. Thus, the load combinations include the static vertical case, the wheel slip case for lateral seismic load along the bridge rails, and the vertical and lateral (transverse to bridge rails) seismic cases. Table 2-1 identifies the load cases required for this seismic qualification. In this table, the seismic load cases are identified as Hook Up, Hook Down, and Wheel Slip. Hook Up accounts for the vertical seismic component and the horizontal component transverse to the bridge rail using response spectrum analysis for the hook loaded and in the up position. The Hook Down case is identical except for the hook in the full down position. The Wheel Slip case accounts for seismic load in the horizontal direction along the bridge rails. Note that the seismic load cases, D_i, are the maximum values from combinations of the participating modes and the seismic components. Table 2-2 summarizes the load combinations for reporting, with the maximum of the combinations used for comparing to the design allowables. Note that the wheel slip, as a simulation of the lateral seismic load, is combined with the other seismic result using a square root of the sum of the square and this result added algebraically to the static vertical load.

2.4 Design Allowables

The allowable design criteria for the seismic qualification is established in Section NOG-4300 of ASME NOG-1. For the seismic qualification of the cranes at PFSF, the extreme environment conditions are considered. Because of the transition temperature requirements on fracture toughness at this site, A516, grade 70 steel (σ_y=38 ksi) is considered here for the structural skeleton of the semi-gantry crane. The maximum allowable stresses in structural steel members are defined as follows for the extreme environment loading:

	Tension	Compression	Shear
Specification	.9 σ_y	.9σ_y	.5σ_y
A516, Grade 70	34.2 ksi	34.2 ksi	19 ksi

Table 2-1. Load Cases for Semi-Gantry Crane

Loading	Trolley Position on Bridge		
	End	1/4 Span	Mid-Span
Static, No load			
Vertical	S_1	S_2	S_3
Static, Main hoist			
Hook load	S_4	S_5	S_6
Static, Auxiliary hoist			
Hook load	S_7	S_8	S_9
Seismic, No load	D_1	D_2	D_3
Wheel slip	W_1	W_2	W_3
Seismic, Main hoist			
Hook up	D_4	D_5	D_6
Hook down	D_7	D_8	D_9
Wheel slip	W_4	W_5	W_6
Seismic, Auxiliary hoist			
Hook up	D_{10}	D_{11}	D_{12}
Hook down	D_{13}	D_{14}	D_{15}
Wheel slip	W_7	W_8	W_9

Table 2-2. Load Combinations for Semi-Gantry Crane

Condition	Trolley Position on Bridge		
	End	¼ Span	Mid-Span
No load	$S_1+\left(D_1^2+W_1^2\right)^{1/2}$	$S_2+\left(D_2^2+W_2^2\right)^{1/2}$	$S_3+\left(D_3^2+W_3^2\right)^{1/2}$
Main Hoist			
Hook up	$S_4+\left(D_4^2+W_4^2\right)^{1/2}$	$S_5+\left(D_5^2+W_5^2\right)^{1/2}$	$S_6+\left(D_6^2+W_6^2\right)^{1/2}$
Hook down	$S_4+\left(D_7^2+\overline{W}_4^2\right)^{1/2}$	$S_5+\left(D_8^2+\overline{W}_5^2\right)^{1/2}$	$S_6+\left(D_9^2+\overline{W}_6^2\right)^{1/2}$
Auxiliary Hoist			
Hook up	$S_7+\left(D_{10}^2+W_7^2\right)^{1/2}$	$S_8+\left(D_{11}^2+W_8^2\right)^{1/2}$	$S_9+\left(D_{12}^2+W_9^2\right)^{1/2}$
Hook down	$S_7+\left(D_{13}^2+\overline{W}_7^2\right)^{1/2}$	$S_8+\left(D_{14}^2+\overline{W}_8^2\right)^{1/2}$	$S_7+\left(D_{15}^2+\overline{W}_9^2\right)^{1/2}$

Note: $\overline{W}_i$ is a factor of W_i as the ratio of total vertical force.

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ANALYSIS MODEL

3.1 Finite Element Mesh

The finite element mesh used for this seismic qualification of the semi-gantry crane for Phase I engineering is illustrated in Figure 3-1. This mesh shows the trolley at midspan along the bridge girders with the hook loaded and in the up position. Similar models are used for the other trolley positions and for hook up and down in each position. The model uses 3-node Timoshenko beam elements for the structural members. Plate elements are used to model a portion of the support wall. The basis of the modeling for the support wall is discussed in Section 3.5 for the Response Spectra Loads. The initial sizing of the structural cross sections for the members is shown in Figures 3-2 through 3-8. The neutral axis for each beam is computed from the cross-sections and located in space relative to the 100 foot elevation reference. Rigid links are used to offset from the beam neutral axis to a connection with another structural member. For example, the trolley wheels are supported on rails along the top of the bridge girder and the nodes representing these trolley wheels are offset from the girder neutral axis with a rigid link. This allows the correct spatial distribution of stiffness and mass for the model. The bridge trucks use pin connections to the equalizing sill beams. This connection is modeled with duplicate nodes, one connected with a rigid link to the bridge truck and the other connected with a rigid link to the neutral axis of the equalizing sill. The degrees of freedom at the duplicate nodes representing the pin are then constrained together while eliminating the rotational degree of freedom along the pin axis. This prevents moment transfer through the axis of the pin between the equalizing sill and bridge trucks. The two moments perpendicular to the pin axis are included in this connection. A rigid link also connects the neutral axis of the equalizing sill to the neutral axis of the bridge girders. Since the centerline of the bridge girder connects to the equalizing sill in line with the bridge truck pins, this rigid link aligns with the link connecting the equalizing sill neutral axis to the truck pin. The bridge girders connect to the equalizing sill which connects through the pins to the bridge trucks.

The gantry legs are tapered box sections rigidly attached to both the bridge girder and end tie at the top and to the equalizing sill at the bottom. Figure 3-8 shows the initial sizing of the gantry leg at the top. The section tapers in the major bending axis dimension to a web depth of 24" at the bottom. The two legs are connected together with horizontal and diagonal struts as shown in Figure 3-1. In the model, the gantry legs are broken into 8 segments along the length with stepped section properties for each segment. There are 4 beam elements in each segment with each element assigned section properties corresponding to the leg cross-section at the midpoint of the segment. The neutral axes of the beams align with the true neutral axis of the leg which tilts inward at the top and offsets from the neutral axis of the end tie. The end of the beam model for the gantry legs is connected with rigid links to both the neutral axis of the end tie and to the end of the bridge girder since the top of the gantry leg is physically attached to both components. The struts have section properties corresponding to a 8" diameter extra strong pipe (1/2" wall thickness).

The number of nodes and elements in the model is determined through an optimization study. The requirement in NOG-1 for sufficient dynamic degrees of freedom is when additional degrees of freedom in the model do not result in more than a 10% increase in response. The mesh optimization study used the model with trolley at midspan with hook up and increased the nodes and elements until the peak stresses in all structural members remained constant for the seismic loads. Figure 3-9 plots the results of this study showing the peak stress values for the different components as the factor on the number of elements in a baseline mesh is increased. The mesh shown in Figure 3-1 is the result of this study and contains 347 elements, 540 nodes, and 3237 degrees of freedom.

3.2 Section Properties and Mass Distribution

The response spectra analysis assumes linear response. For all structural members, an elastic modulus of 29E6 psi and Poisson's ratio of .318 are used. The beam section properties are computed from the cross-section shapes and input directly into the computer model. These section properties are summarized in Figure 3-2 through 3-8 for the initial sizing estimates of the sections. The gantry leg strut bracing uses an 8" extra strong pipe section. In addition to these structural sections, truss elements are used to model the hoist rope. The hoist uses a 16 part reeving configuration, and the area of the truss elements modeling the hoist rope is taken as 16 times the rope area, which is calculated at .766 in^2 using the rope manufacturer's formula for steel area of the 1 3/8" diameter core-wrapped rope. It is assumed that the reeving configuration for the rope acts like a single rope with an equivalent cross sectional area under dynamic conditions. This is consistent with the S & W Specification that the reeving system "provides true vertical lift, and is configured such that the hook block does not twist." The trolley deck plate is not included in the finite element model. As will be seen in the results, the highest stresses for the trolley skeleton are due to vertical loads and the deck plate contributes little to vertical bending in the load girt or trolley trucks. In addition, the deck plate is cut back to the load girt on the west end of the trolley for clearance with the main hoist drum.

The density of the material for each structural member is adjusted so that the weights approximate the Ederer estimates of component total weights shown on Drawing PA-2190. This accounts for diaphragms and stiffeners and equipment attached to the structural members. This density adjustment provides a uniform and consistent mass distribution to the nodes for these structural members. For these calculations, the north bridge girder with the trolley conductors and walkway weighs 28,000 lbs, and the south bridge girder with control panels and walkways weighs 31,000 lbs. The driver bridge truck weighs 5,500 lbs, and the idler bridge truck weighs 4,500 lbs. The upper equalizer sill weighs 3,500 lbs and the lower equalizing sill weighs 10,600 lbs. The gantry legs with upper end tie and struts weighs 27,300 lbs. The densities for the trolley trucks and load girt are adjusted so that the total trolley weight is 86,000 lbs. Here it is assumed that the total trolley weight is evenly distributed so that 2/3 of the weight is distributed to the trolley trucks and 1/3 is distributed to the trolley load girt. The total weight of the semi-gantry crane in the model is 225.4 kips.

A lumped mass for the 150 ton payload and 11,500 lb lower block is attached to the end of the hoist rope for the main hoist load cases. The weight of the spooled rope is lumped at the node in the middle of the load girt beam. For the main hoist, this is about 4000 lbs. For the hook down case, the weight of the extended rope is lumped half at the payload node and half at the load girt middle node. For the auxiliary hoist a 25 ton payload and 3300 lb lower block weight are modeled with a lumped mass at the appropriate heights for the hook up and hook down cases.

3.3 Hoist Configuration

In these models, for both the main and auxiliary hoist load cases, the hoist rope is connected directly to the middle of the trolley load girt beam. Thus, all the force from the payloads in the model is reacted by the load girt which in turn transfers the load to the middle of the trolley trucks. The actual connections and load paths in the crane system are more complex and the calculated stresses from the model are adjusted to account for the differences. The main hoist uses a 16 part reeving configuration in which 4 of the 16 ropes attach to the drum. The auxiliary hoist uses a similar 8 part reeving configuration with 2 of the 8 ropes attached to the drum. Therefore, in both cases, 25% of the calculated load will be taken by the drums and reacted through the bearings and gears directly into the trolley trucks. The upper block of the main hoist is mounted directly over the load girt, as modeled, so that the rope forces act directly through the centroid of the load girt. However, for the auxiliary hoist, the upper block must be offset from the load girt. Assuming the vertical hoist load is taken directly by the load girt, then an additional twisting moment is applied to the load girt. This delivers a concentrated bending moment to the trolley truck which is not modeled.

The calculated linear stresses in the trolley load girt and trolley trucks are factored to account for these modeling assumptions. Because the dominant loads in the load girt and trolley trucks are due to the vertical bending from the rope forces, simply supported beam free bodies can be used to calculate the adjustments. For both the main hoist and auxiliary hoist cases, the static and seismic stresses in the trolley load girt are reduced by 25% to account for the loads reacted to the trolley trucks through the drums. For the trolley trucks under loads on the main hoist, the load taken by the drum reduces the load transmitted through the load girt to the midspan of the trolley trucks. However, a moment is still induced into the trolley truck frame due to the moment on the hoist drum. From the statics calculation shown in Appendix A, the calculated stresses in the trolley trucks for the main hoist conditions can be reduced by 9%. For the trolley trucks under auxiliary hoist loading, an additional bending moment must be included in the stress due to the offset of the load block from the centerline of the trolley load girt. For this case, the calculated stresses must be increased by 43.7% as shown in Appendix A.

3.4 Boundary Conditions

With the exception of the bridge truck wheel restraint along the rail direction as discussed previously, the boundary conditions in the model are as specified in NOG-1. Figure 3-1 summarizes the boundary conditions. The bridge truck wheels at A and B are fixed in the vertical direction and in the direction perpendicular to the rails (x and z directions). The truck wheels at C and D are tied to the corresponding rail nodes at the top of the support wall and are free to move with the wall. This assumes that all transverse load is reacted by one set of wheels. All bridge truck wheels are free to move along the rails. This assumes that wheel slip occurs in this direction, and a static lateral load is included to account for this acceleration load. This case uses a friction force that is .2 times the total vertical wheel load (static + seismic forces). This lateral force is applied as a uniform body force in the direction along the rails with the wheels at A and C fixed in this direction for this load. For the seismic loads, the wheels are free to move along the rails to avoid mode shapes and frequencies that may be artificially induced by fixing two of the wheels in this direction.

In the model, the trolley wheels are tied to the rail nodes in the vertical direction and in the transverse direction (direction y in the model). The trolley wheels at E and F are tied to the rail nodes in the direction along the rail while the wheels at G and H are free to move in this direction. There are no restraints on rotations for the trolley or bridge truck wheels so that no moment can be transferred at any wheel connection.

3.5 Response Spectra Loads

The design response spectra as provided in the Stone and Webster specification are shown in Figure 3-10. The spectra is provided in terms of acceleration versus frequency for 4% damping at elevations 100' and 170' in the canister transfer building. The gantry legs are mounted on rails at elevation 100' while the other end of the semi-gantry crane is supported on rails at elevation 155' 3". The response spectrum analysis technique imposes displacement boundary conditions at support locations to extract mode shapes, frequencies and participation factors. The applied loads for the input response spectra then excite structural response that is relative to the imposed boundary conditions or support locations. In the ABAQUS implementation of the response spectrum analysis technique, only 1 response spectrum for each of 3 orthogonal directions may be input. Thus, different response spectra for support locations at different elevations in the model cannot be accommodated. One option is to impose the 170' response spectra at both the gantry legs and at the wall support as an envelope of the input spectra. This is typically very conservative since the east-west accelerations are much less at the gantry legs than higher up in the canister transfer building. The danger in this approach is that forcing equal acceleration loads at two different elevations may produce unrealistic results. A more consistent approach is to include the support wall in the model and apply the 100' acceleration spectra at the base of the wall and at the gantry leg support. The intent of the wall modeling is to allow the amplification of the spectra up the wall to develop naturally so that the bottom of the gantry legs are subjected to the accelerations at the 100' elevation and the bridge wheels on the support wall have accelerations more consistent with their elevations at 155'. Thus, the wall model can be constructed and calibrated to produce acceleration levels consistent with the spectra provided at 170' elevation when the 100' elevation spectra are applied at the base of the wall. This is accomplished by isolating the wall submodel and conducting steady state dynamic calculations for a range of frequencies while applying the given frequency dependent accelerations from the 100' elevation spectra at the base of the wall. First, the stiffness (wall thickness) and mass (density of the material) of the wall segment are adjusted so that its fundamental cantilever bending frequency matches the frequency where the peak acceleration occurs in the given response spectra. Using a modulus of 4.0E6 psi for the wall material, a wall thickness of 60" and a density corresponding to 75 lbs/ft^3 produce a fundamental bending frequency of 4.5 Hz. The simulated segment of the concrete wall must be relatively stiff compared to its mass to simulate the actual support wall structure in the canister transfer building. Note that the wall stresses are not considered (the wall is not being qualified in this analysis) so that these material adjustments are used to allow the wall submodel to deliver the correct accelerations to the bridge truck wheels. Since a segment of the continuous wall is modeled, boundary conditions are also included along the cut edges to simulate a continuous boundary. Figure 3-11 illustrates the modeling for the support wall. Because the input excitation at the fundamental frequency will cause very large accelerations at the top of the wall model, damping is needed to limit the accelerations at the top of the wall to that defined by the response spectra at 170' elevation. To this end, dashpots are attached at the top of the wall in the transverse bending direction, and the damping coefficient is adjusted until the calculated accelerations sufficiently represent those from the 170' elevation spectra. The behavior of the support wall submodel is illustrated in Figure 3-12. This figure plots the calculated lateral accelerations at the top of the wall vs. frequency compared to the design response spectra at 170' elevation.

The response of the wall model in the rail direction along the length of the wall is not important since wheel slip is assumed in this direction. In the vertical direction, a comparison of the response spectra for 100' and 170' show that very little amplification occurs in the canister transfer building for this direction. The fundamental frequency of the vertical extension mode for the wall submodel is 75 Hz, which is well outside the input frequencies of interest. Figure 3-13 shows the results of steady state dynamic frequency sweep calculations for the vertical direction in the wall using the 100' elevation vertical input accelerations at the base. Since the fundamental frequency is beyond the excitation frequency, the model simply transmits the input acceleration at the base to the top of the wall. To better match the vertical spectra provided at 170' elevation, the vertical component of the 170' input spectra will be used. These figures demonstrate that the wall submodel simulates the effects of the support wall by returning the acceleration levels vs frequency consistent with the 170' spectra at the top of the wall when the 100' spectra is input at the base of the wall.

Number of Elements: 371
Number of Nodes: 576
Number of DOF: 3453

Weight of Trolley = 86.0 K
Weight of Girders = 59.0 K
Weight of Bridge Trucks = 20.0 K
Wt of Upper Equalizing Sill = 3.5 K
Wt of Lower Equalizing Sill = 10.6 K
Weight of Gantry Legs = 25.9 K
Weight of Gantry End Tie = 1.8 K

Total Weight of Crane = 221.6 K

	Boundary Conditions		
Wheels	x	y	z
A	fix	--	fix
B	fix	--	fix
C	--	--	--
D	--	--	--

Trolley wheels at E & F are fully constrained to the rails. Wheels at G & H are constrained to the rails in y & z, but are free to roll along the rail in the x direction.

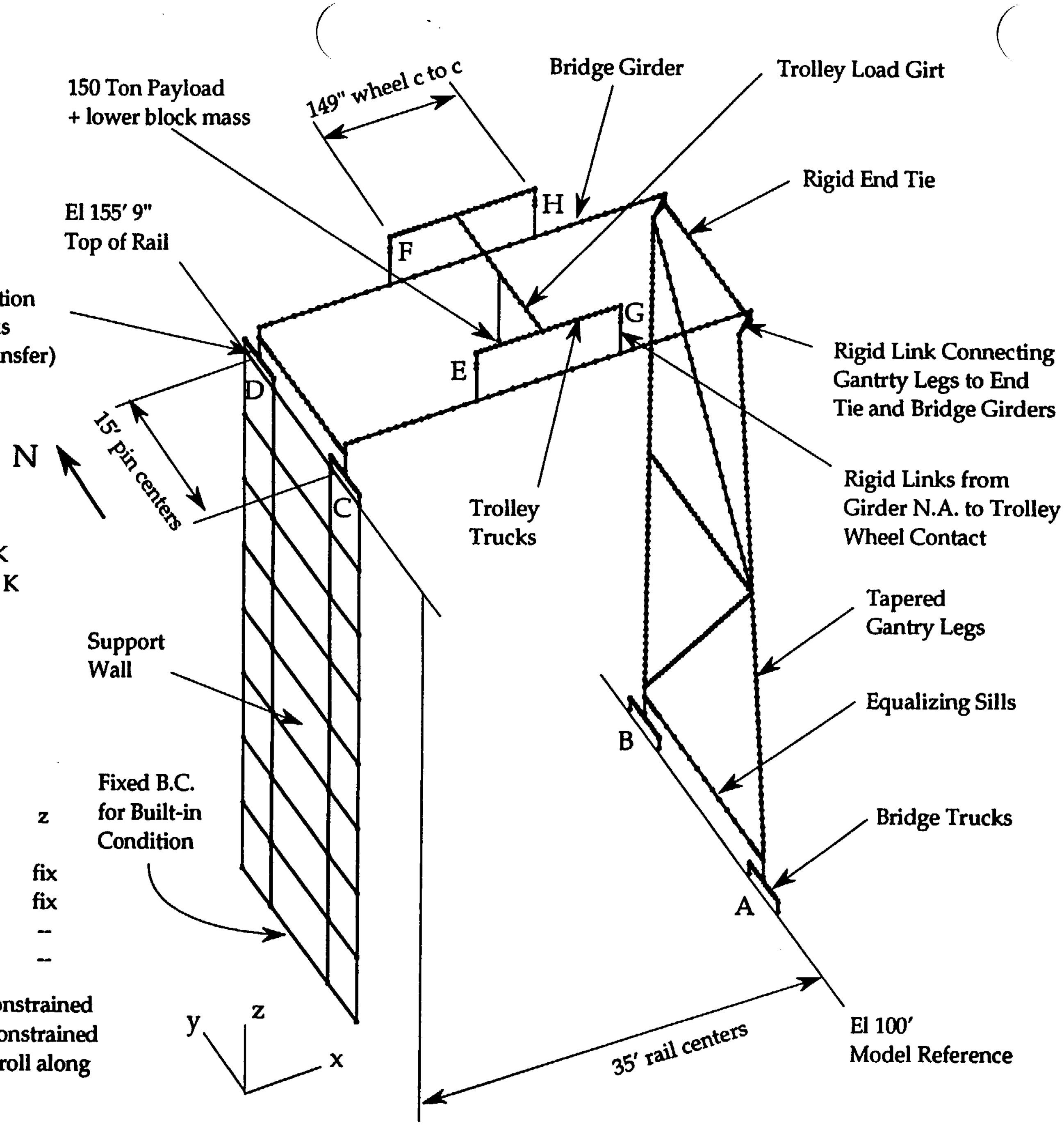

Figure 3-1. Seismic Model for 150 Ton Semi-Gantry Crane, Trolley at Midspan, Hook Up

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150 Ton Semi-Gantry Crane - Bridge Girders

wo	wi	tf	tw	H
30.00	26.25	0.750	0.375	78.00

Area	103.50	in^2		Length	420.00	in
Yc	39.75	in		Weight	12345	lb
Ixx	99429.19	in^4				
Iyy	13743.21	in^4				
J	35814.50	in^4				
Z	697.25	in				

	weight	density
	lb	lb/in^3
Sgirder	31000	0.71314
Ngirder	28000	0.64412

Longitudinal stiffeners on webs not included in section properties

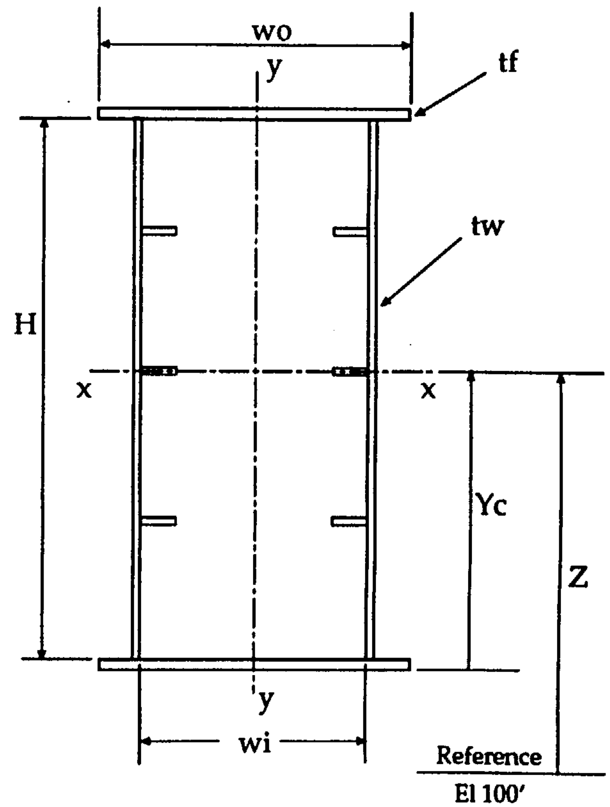


Figure 3-2. Initial Section Sizing for Bridge Girders

ANATECH

Linking Theory and Practice

16-Nov-98

150 Ton Semi-Gantry Crane - Trolley Trucks

wo	wi	tf	tw	H	tb
17.00	12.50	0.50	1.250	24.00	0.50

Area	75.38	in^2		Length	149.00
Yc	12.764	in		Weight	3190
Ixx	5182.27	in^4			
Iyy	3156.78	in^4			
J	4818.89	in^4			
Z	756.764	in		weight	density
				lb	lb/in^3
			Truck	28667	2.55249

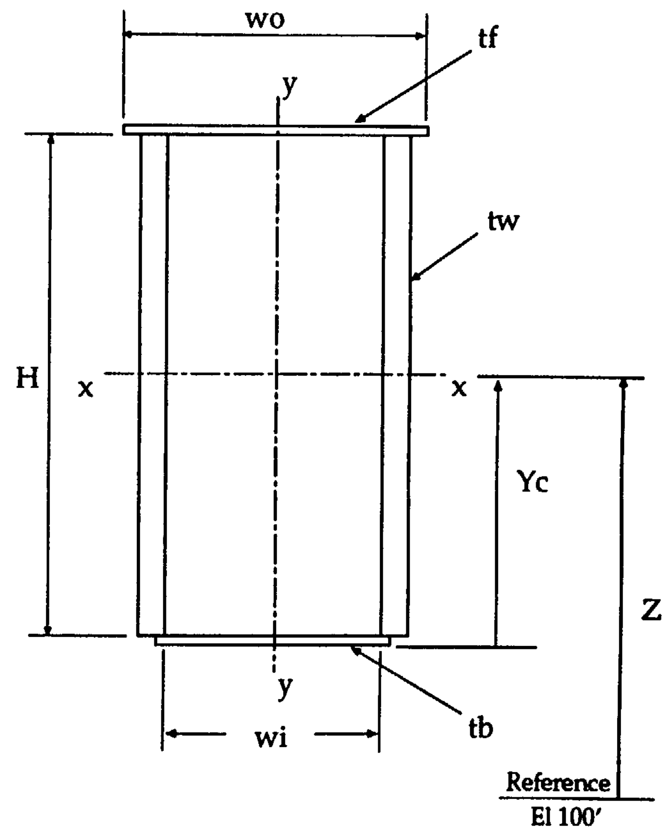


Figure 3-3. Initial Section Sizing for Trolley Trucks

150 Ton Semi-Gantry Crane - Trolley Load Girt

wo	wi	tf	tw	H
27.00	23.00	1.75	1.00	22.50

Area	139.50	in^2	Length	180.00
Yc	13.000	in	Weight	7131
Ixx	15815.53	in^4		
Iyy	12224.63	in^4		
J	17844.35	in^4		
Z	756	in		

	weight	density
	lb	lb/in^3
Total	28667	1.14164

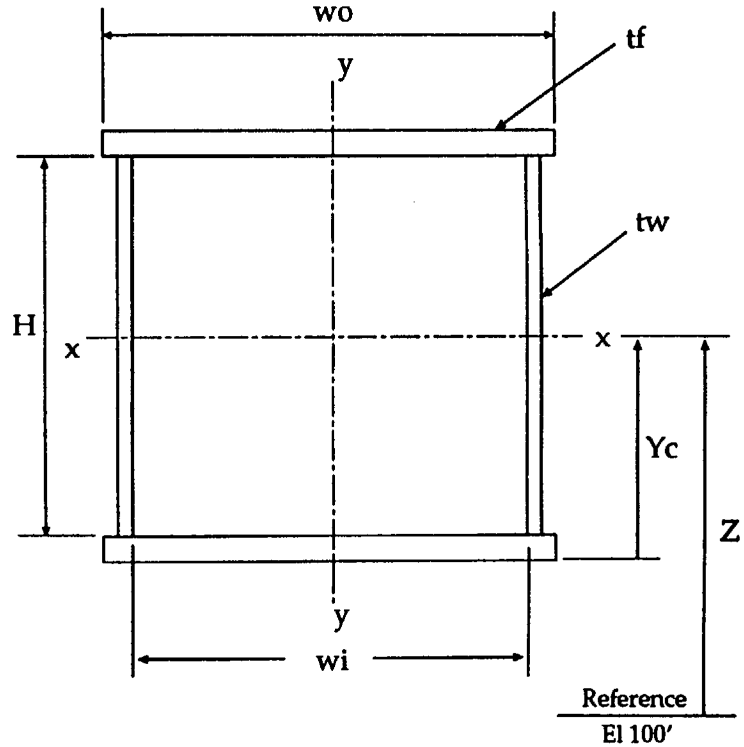


Figure 3-4. Initial Section for Trolley Load Girt

16-Nov-98

150 Ton Semi-Gantry Crane - Equalizing Sills

wo	wi	tf	tw	H	Pin
24.00	21.25	0.375	0.375	23.25	8.50

Area	35.44	in^2	LengthUp	180.00
Yc	12.00	in	WeightUp	1812
Ixx	3297.35	in^4	LengthLo	252.00
Iyy	2902.83	in^4	WeightLo	2536
J	4326.12	in^4		
Z	684.5	in (Upper)		
Z	45.5	in (Lower)		

	weight	density
	lb	lb/in^3
Upper	3500	0.54870
Lower	10800	1.20937

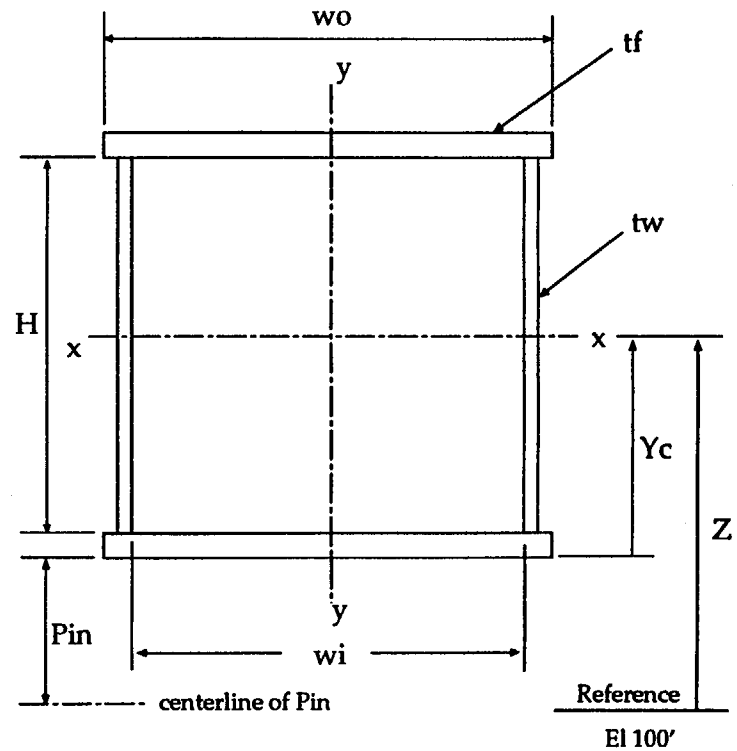


Figure 3-5. Initial Section Sizing for Equalizing Sills

ANATECH

Linking Theory and Practice

20-Nov-98

150 Ton Semi-Gantry Bridge Trucks

wo	wi	tf	tw	H
14.00	13.00	0.50	1.50	24.50

Area	87.50	in^2	Length	60.00
Yc	12.750	in	Weight	1491
Ixx	5864.32	in^4		
Iyy	4105.79	in^4		
J	5755.02	in^4		
Z	19.750	in (Lower)		
Z	658.750	in (Upper)		

	weight	density
	lb	lb/in^3
Driver	5500	1.04762
Idler	4500	0.85714

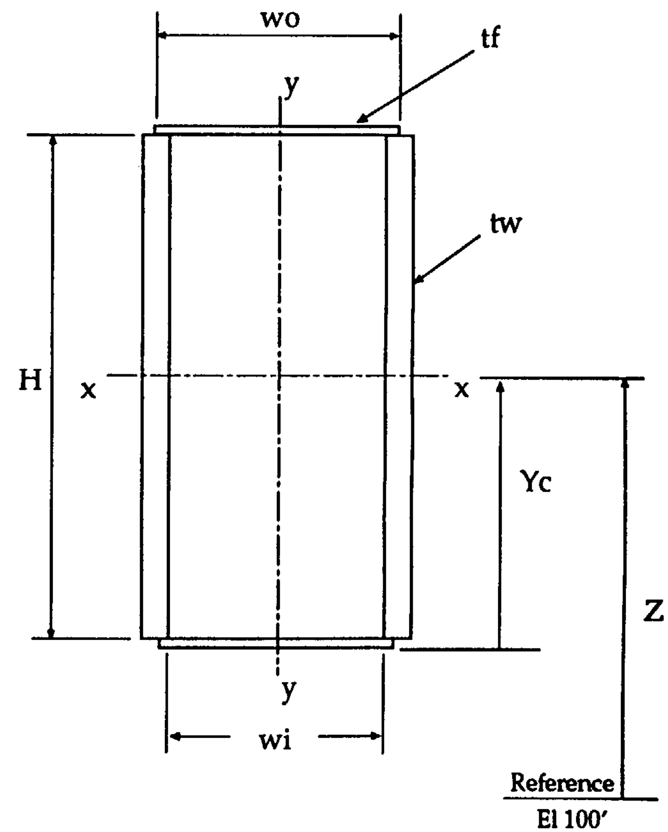


Figure 3-6. Initial Section Sizing for Bridge Trucks

150 Ton Semi-Gantry Crane - End Tie

wo	wi	tf	tw	H
24.00	21.25	0.375	0.375	24.00

Area	36.00	in^2	Length	180.00
Yc	12.375	in	Weight	1840
Ixx	3537.84	in^4		
Iyy	2968.59	in^4		
J	4530.07	in^4		
Z	669.875	in		

	weight	density
	lb	lb/in^3
Total	1840	0.28400

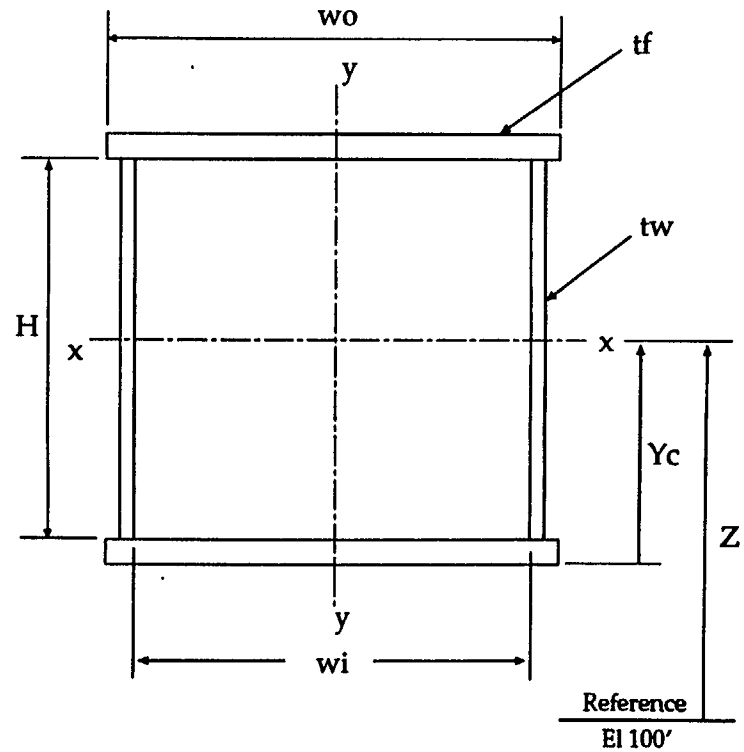
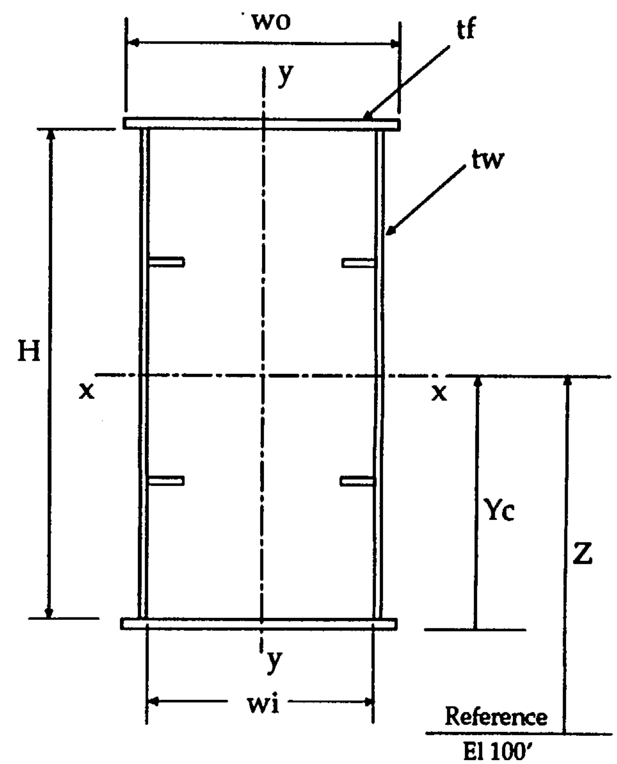


Figure 3-7. Initial Section Sizing for End Tie

150 Ton Semi-Gantry Crane - Gantry Legs at Top

wo	wi	tf	tw	H
24.00	21.25	0.500	0.375	48.00

Area	60.00	in^2		Length	420.00	in
Yc	24.50	in		Weight	7157	lb
Ixx	21026.00	in^4				
Iyy	5361.19	in^4				
J	12747.55	in^4				
Z	712.5	in		weight	density	
				lb	lb/in^3	
			LegWt	3550	0.14087	



Longitudinal stiffeners on webs not included in section properties

Figure 3-8. Initial Section Sizing for Gantry Leg at Top

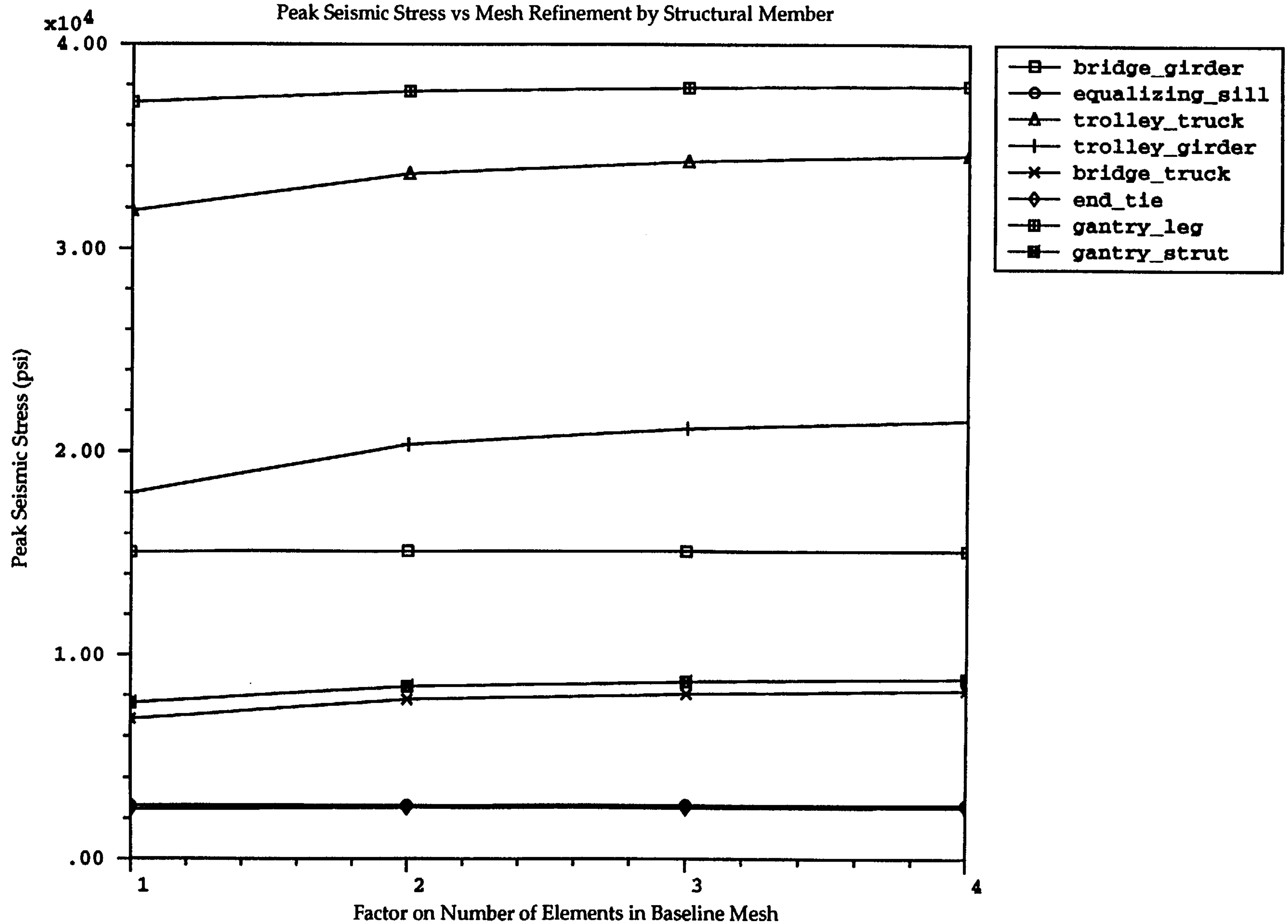


Figure 3-9. Mesh Refinement Study to Define Dynamic Degrees of Freedom

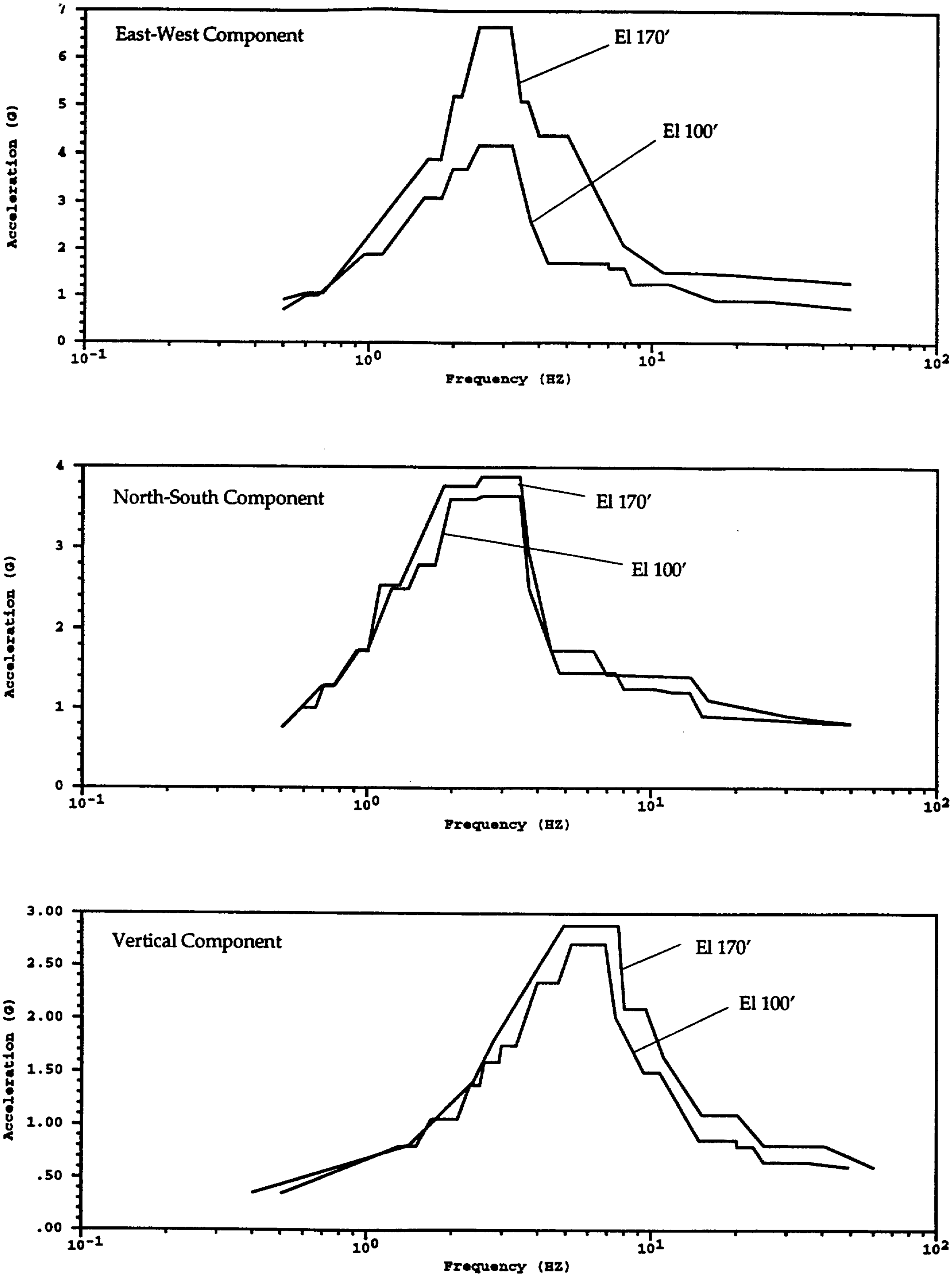


Figure 3-10. Design Response Spectra for Canister Transfer Building

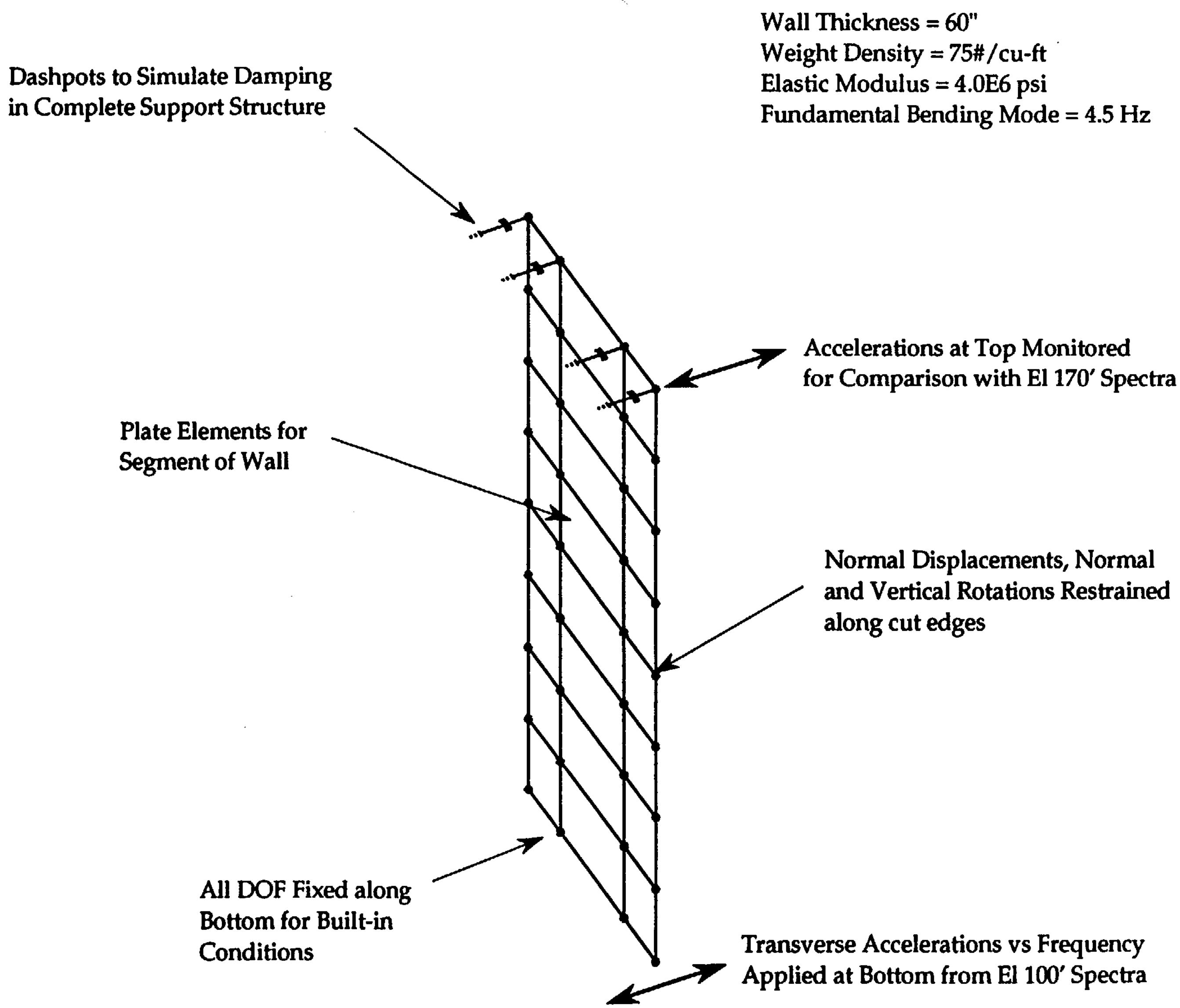


Figure 3-11. Support Wall Sub-Model

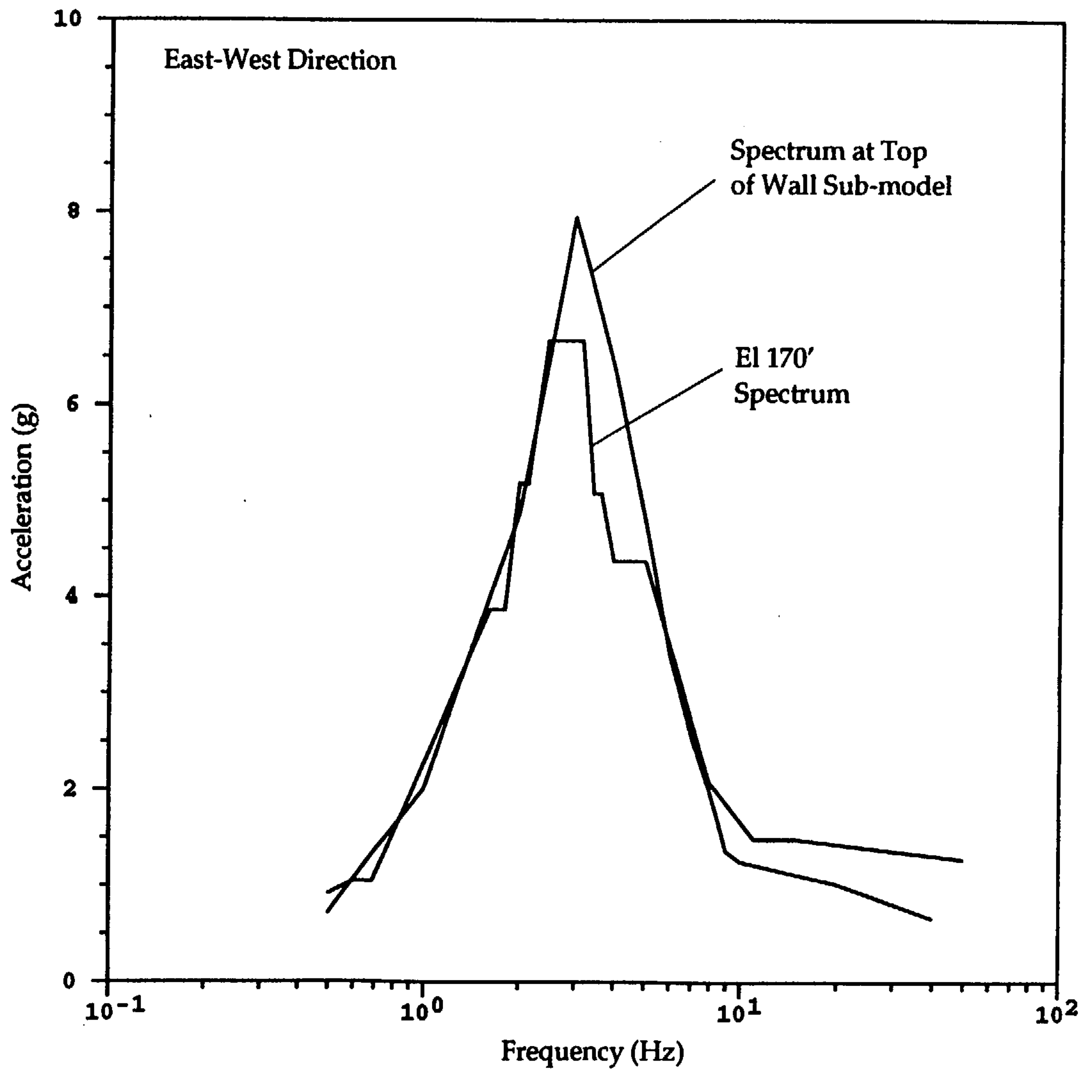


Figure 3-12. Wall Sub-Model Response Spectrum for East-West Direction

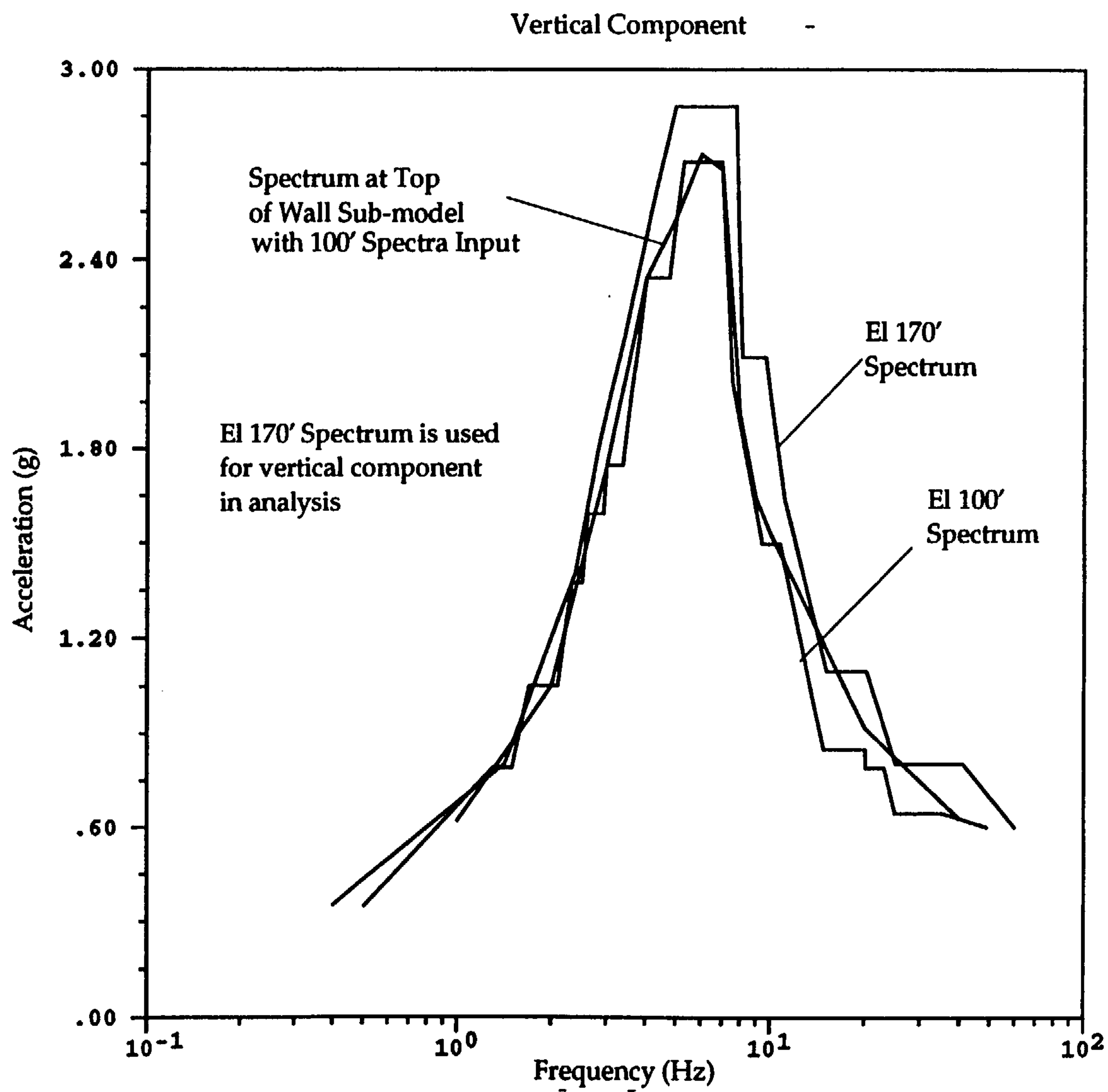


Figure 3-13. Wall Sub-Model Response Spectrum for Vertical Direction

4

ANALYSIS RESULTS

4.1 Preliminary Calculations

Preliminary calculations are first conducted to evaluate the performance of the model with the initial section sizing and to investigate the relative effects of the various parameters and load cases. Several tests are performed to evaluate the importance of the seismic components and the modal participation. The model with trolley at midspan and main hoist loaded in the hook up position is used for these test cases. By considering each seismic component separately, the loading that dominates the stress distribution for each structural member can be determined. Furthermore, by isolating the contribution of the fundamental mode in the stress combination, the importance of the modal participation can be determined. The following tables summarize the results of this investigation.

Peak Stresses (psi) due to Vertical Seismic Loads

		Vertical Seismic Load Component			
Member	Total Seismic Stress	All Modes		Mode 5 Only	
		Stress	% of Total	Stress	% of Vertical
Bridge Girder	14435	13000	90.0	12990	99.9
Equalizing Sill	2509	1900	75.7	1891	99.5
Trolley Truck	35893	35188	98.0	35180	99.9+
Trolley Load Girt	22144	21921	99.0	21919	99.9+
Bridge Truck	16413	7359	44.8	7343	99.8
End Tie	3871	3740	96.6	3495	93.4
Gantry Leg	25815	7886	30.5	7874	99.8
Gantry Strut	9940	2944	29.6	2054	69.8

Peak Stresses (psi) due to Lateral Seismic Loads

		Lateral e-w Seismic Load Component			
Member	Total Seismic Stress	All Modes		Mode 4 Only	
		Stress	% of Total	Stress	% of Lateral
Bridge Girder	14435	12674	87.8	12664	99.9
Equalizing Sill	2509	1625	64.8	1610	99.1
Trolley Truck	35893	9870	27.5	9861	99.9
Trolley Load Girt	22144	3134	14.2	3104	99.0
Bridge Truck	16413	14832	90.4	14811	99.9
End Tie	3871	1326	34.3	1311	98.9
Gantry Leg	25815	24592	95.3	24589	99.9
Gantry Strut	9940	9858	99.2	9817	99.6

In these tables, the total seismic value is that computed from all included modes and all components of load. The vertical and lateral components are then evaluated to find the % of the total stress caused by each component. Finally, only the contribution from the fundamental mode for the vertical or lateral component is evaluated to find the % of its contribution to the respective component from all modes. It is clear that the trolley trucks and trolley load girt stresses are dominated by the vertical loading so that the adjustments to stresses discussed in Section 3 are justified. The vertical loading has over 99% contributed from the fundamental vertical bending mode at 4.64 Hz for the trolley at midspan with hook up and loaded. The seismic loads in the bridge trucks, gantry legs, and gantry struts are dominated by the e-w lateral seismic component with the fundamental mode at 2.6 Hz providing 99% of the modal participation. These test cases indicate that the bridge girders develop significant loads from both vertical and lateral components. The vertical component develops stress near the midspan of the girder while the lateral load develops stresses near the end tie connections. These results also indicate that only a few modes need to be included to achieve the requirements for the number of modes in ASME NOG-1. However, because of the ease of including modes in these calculations, the first 41 modes (up to 50 Hz) are included in the complete seismic qualification analyses. At this level, the change in seismic stresses from including additional modes cannot be detected in the printouts.

The next step is to evaluate the effects of the trolley position on the seismic response. Since the semi-gantry crane is not symmetric, the trolley positions at each end may be more critical than the trolley at quarter span as specified in ASME NOG-1. Thus, preliminary calculations are performed for 4 different trolley positions; trolley at east end over gantry legs, trolley at quarter span between the gantry legs and midspan, trolley at midspan, and the trolley at end of travel over the wall support on the west end. For these cases, the main hoist is loaded with the hook up. Tables A-1 through A-4 in the Appendix summarize the peak dynamic stresses and the combination with static and wheel slip for the above cases, respectively. Comparing Tables A-1 and A-2 for the east end and east quarter span trolley positions shows that the dynamic response is very similar for these cases. The quarter span case has higher stresses for the bridge girders and gantry legs. The trolley truck and load girt stresses are slightly higher for the trolley at east end. However, the stresses for the trolley truck and load girt look to be governed by the trolley at west end (Table A-4). Therefore, the trolley positions used for the seismic qualification calculations are trolley at quarter span to the east, trolley at midspan, and trolley at end of travel to the west.

Next, an evaluation of the initial section sizing is performed by comparing the peak combined stress in each structural member with allowables for the preliminary calculations. For these calculations, the model was refined to increase the flanges on the trolley truck from .5" to 1.25" thick, the trolley rails are lowered by 1.5 inches to accommodate the taller trucks, and the height of the load girt webs are increased to match the increased depth of the trolley trucks. An error in the model was corrected to adjust the wall mounted rail elevation upward by 24" and the rail to rail distance reduced by 24" to match the clearance drawings. Finally, the 170' spectra vertical component was used in lieu of the 100' spectra vertical component, and some component weights are adjusted. Tables A-5 through A-7 summarize the results of these preliminary calculations to evaluate the initial section sizing. These tables indicate that the trolley trucks are still overstressed. This is attributed to the increased height of the bridge rail elevation and the use of the 170' vertical spectra for conservatism. Tables A-5 through A-7 also show that the trolley load girt and gantry legs are slightly overstressed. In addition, for the ¼ span load case, the end tie also develops stresses above the allowables. An evaluation of the section forces for the end tie indicate that this overstress is due to equal contributions of bending in the vertical and lateral directions. The section size are adjusted for the seismic qualifications based on these preliminary calculations. The flanges on the trolley trucks are increased to 2" thick which adds another 1.5" to the overall truck height. The webs of the trolley load girt are increased to 24" to match the increased truck sizes. Both the webs and flanges of the end tie are increased from .375" to .50". The section modulus for the gantry legs is also increased by increasing the width from 24" to 28". The bridge girders can be optimized somewhat since the preliminary calculations indicate that the peak stresses are within allowables for this extreme loading. The width is reduced from 30" to 28" and the depth from 78" to 72". Figures 4-1 through 4-8 document the final section sizes and properties used for the seismic qualification calculations.

4.2 Seismic Qualification Results

The model is adjusted to account for the section sizing as described above and documented in Figures 4-1 through 4-8, and all load cases are executed for the seismic qualification analyses. The results of the seismic qualification load cases and load combinations are summarized in Tables 4-1 through 4-15. The columns labeled Static are the static stresses due to gravity. The Dynamic column is the results from the response spectrum analysis for the vertical and horizontal (east-west) seismic loads. The Wheel Slip column accounts for the north-south horizontal seismic load. These tables show the maximum stresses and forces for the various structural members and connections for the different trolley locations and load on the main and auxiliary hoists. The maximum values of each structural member are itemized for the static vertical loads, the wheel slip simulation of the transverse seismic load, and the dynamic loads from the response spectra analysis. The combined value is computed using SRSS for the dynamic and wheel slip values and then algebraic summation with the static value. The trolley load girt stresses are reduced by 25% to account for the load reacted by the hoist drum. For the main hoist load cases, the trolley truck stresses are reduced by 9%, and for the auxiliary hoist load cases, the trolley truck stresses are increased by 43.7%. The forces at the bridge truck pins, the trolley wheels, and the bridge truck wheels are the maximum values found for any one of the respective components. For the main hoist load cases, the rope force is calculated from 1/16 of the maximum force computed in the truss element connecting the payload to the trolley load girt. For the auxiliary hoist load cases, the rope force is reported as 1/8 of the total force in the truss element. The dynamic rope force would need to exceed the static rope force before a slack rope condition would occur. For the main hoist load, the drum torque can be calculated by taking 4 times the rope force times the drum radius of 29.5". The drum torque for the auxiliary hoist can be calculated in a similar manner.

Trolley at West End

Figures 4-8 and 4-9 show the first 8 fundamental mode shapes and frequencies for the 150 ton semi-gantry crane with the trolley positioned at the west end of travel with a 150 ton load in the hook up position. The mode shapes are scaled for a maximum deflection of 50 inches. Tables 4-1 through 4-5 summarize the maximum response for the various load cases for the trolley at this position. The critical load case here is for the main hoist in the hook up position with a 150 ton load as shown in Table 4-2. The calculated normal stresses for the trolley load girt are at 98.6% of the allowable for this load combination. The trolley truck and gantry leg stresses are at 83.7 and 82.5% of allowables, respectively. All other components and all shear stresses are well within allowables. The no load and auxiliary hoist load cases show relatively small stresses with the largest stresses in the gantry legs at about 80% of allowables.

Trolley at ¼ Span

Figures 4-9 and 4-10 illustrate the lowest fundamental mode shapes and frequencies for the trolley positioned at ¼ of the span toward the gantry legs. These modes consider the main hoist loaded with the hook up. Tables 4-6 through 4-10 summarize the maximum response for all components for each load case for this trolley position. Again, the largest stresses occur for a 150 ton load on the main hoist with the hook in the fully up position. The trolley truck, trolley load girt, and gantry legs are the highest stressed at 96.3, 98.8, and 96.3% of allowable, respectively. The bridge girders are stressed to 80.5% of allowables. The hook down position for the main hoist has stresses at 92.8% of allowable for the gantry legs. All components for the no load and auxiliary hoist conditions are within allowables.

Trolley at Mid-span

Figure 4-11 and 4-12 illustrate the mode shapes and frequencies for the model with the trolley at midspan with the main hoist loaded and hook up. Tables 4-11 through 4-15 summarize the maximum response for the components for all load cases for this trolley position. The largest stresses for this trolley position is for the main hoist loaded and in the up position. Again the trolley trucks, trolley load girt, and gantry legs are the highest stressed at 92.7, 98.3, and 95.3% of allowables, respectively. For the hook down case, the gantry legs are the highest stressed at 87.9% of allowables. For the auxiliary hoist load cases, the gantry legs show stresses of 81.8% of allowable. All other structural members are well within allowables.

4.3 Summary of Results

Using the adjusted section sizes, all structural members show maximum combined stresses below the allowable of 90% of yield stress. The maximum stresses for the various components develop for different trolley positions and loading conditions. For all trolley positions, the 150 ton load on the main hoist with the hook in the up position is the worst load case. The hook down case typically shifts the fundamental vertical bending mode to a lower frequency, which is less excited by the design response spectrum. Figures 4-14 and 4-15 illustrate the first 8 fundamental modes for the trolley at midspan case to illustrate this frequency shift. The no load and auxiliary hoist load conditions typically develop stresses less than 60% of allowables except for the gantry legs, which are typically stressed to 80% of allowable. The bridge girders develop maximum stress for the trolley at midspan. The bridge trucks are more highly stressed for the trolley at the west end. All other components develop their maximum stress for the trolley at ¼ span toward the gantry legs. The maximum normal stresses for each structural member and the corresponding load combination are summarized as follows;

Member	Load Combination	Static (psi)	Dynamic (psi)	Wheel Slip (psi)	Combined (psi)	% of Allowable
Bridge Girder	Trolley at Midspan 150 Ton Load Hook Up	7069	21711	5559	29480	86.2
Equalizing Sill	Trolley at ¼ Span 150 Ton Load Hook Up	1779	5119	10644	13590	39.7
Trolley Truck	Trolley at ¼ Span 150 Ton Load Hook Up	7215	25488	3312	32918	96.3
Trolley Girder	Trolley at ¼ Span 150 Ton Load Hook Up	8213	25516	1991	33807	98.8
Bridge Truck	Trolley at End 150 Ton Load Hook Up	5749	19926	3701	26016	76.1
End Tie	Trolley at ¼ Span 150 Ton Load Hook Up	1275	17083	5206	19134	55.9
Gantry Leg	Trolley at ¼ Span 150 Ton Load Hook Up	5099	27579	3661	32920	96.3
Gantry Strut	Trolley at ¼ Span No Load Hook Up	1206	17251	3319	18773	54.9

An interesting observation is the performance of the end tie connecting the bridge girders at the top of the gantry legs. The preliminary calculations indicated an overstressed condition with the initial section sizing for the trolley at ¼ span. The seismic stresses were due to both vertical and lateral bending in roughly equal contributions. The end tie section sizing was adjusted accordingly by increasing both the flange and web thickness from .375" to .50". All load combinations with the final section sizes for all structural components now show much reduced stresses in the end tie with the maximum stress at 56% of allowable for the trolley at ¼ span. A test calculation is conducted to evaluate the performance of the initial section sizing of the end tie with the final section sizing of the other components. The test analysis uses the trolley at 1/4 span with the 150 ton main hoist load with the hook up. The section properties for the initial sizing of the end tie are used but no adjustments are done for the slight change in location of the neutral axis. The end tie seismic stresses increase by 70% consistent with the change in the section modulus. However, the stresses in the gantry legs and trolley trucks also increase for this test case. The seismic stress in the gantry legs increase by 2.2 % and in the trolley trucks by 8.6%, which will exceed the allowable in the trolley truck. Thus, while the end tie is "under stressed" in the current configuration, the stiffness tying the gantry legs and bridge girders together is needed to lower stresses in other critical components. If the end tie is returned to the initial sizing using .375" thick webs and flanges, the trolley trucks and possibly other components will need additional section sizing to meet stress allowables for the seismic loads. Increasing the end tie section for .5" flanges and webs is more efficient than increasing the sizes of the other components.

Table 4-1. Maximum Stresses For 150 Ton Semi-Gantry Crane
Trolley at West End, Main Hoist Hook Up, No Load

Member	Component	Static (psi)	Dynamic (psi)	Wheel Slip (psi)	Combined (psi)	% Allowable
Bridge Girder	Normal Stress	1881	11753	1505	13730	40.1
	Horizontal Shear	18	114	258	301	1.6
	Vertical Shear	582	1163	47	1746	9.2
Equalizing Sill	Normal Stress	842	1855	4838	6023	17.6
	Horizontal Shear	1	257	58	264	1.4
	Vertical Shear	161	84	219	396	2.1
Trolley Truck*	Normal Stress	1489	5324	1668	7067	20.7
	Horizontal Shear	10	120	123	182	1.0
	Vertical Shear	205	252	17	458	2.4
Trolley Girder**	Normal Stress	853	2766	956	3779	11.1
	Horizontal Shear	0	632	71	636	3.3
	Vertical Shear	162	157	18	320	1.7
Bridge Truck	Normal Stress	1852	15390	1863	17354	50.7
	Horizontal Shear	15	2618	245	2644	13.9
	Vertical Shear	359	640	269	1054	5.5
End Tie	Normal Stress	206	1307	1321	2065	6.0
	Horizontal Shear	0	136	29	140	0.7
	Vertical Shear	34	55	66	120	0.6
Gantry Leg***	Normal Stress	1506	25131	944	26655	77.9
	Lateral Shear	26	58	32	92	0.5
	Longitudinal Shear	12	975	5	988	5.2
Gantry Trusses	Normal Stress	1110	8673	2147	10045	29.4
	Horizontal Shear	1	314	0	315	1.7
	Vertical Shear	33	122	15	155	0.8

*Normal stress reduced by 9% for load reacted by drum to trolley wheels.
**Normal stress reduced by 25% for load reacted by drum to trolley wheels.
***Shear stress calculated using smallest cross-sectional area of leg.

Member	Component	Static (lbs)	Dynamic (lbs)	Wheel Slip (lbs)	Combined (lbs)
Rope Force	Axial Force	727	58	0	786
Truck Pins	Axial Force	1168	418250	13454	419634
	Horizontal Force	41	2039	46680	46765
	Vertical Force	57758	111830	32381	174182
Trolley Wheels	Longitudinal Force	40	241100	10173	241355
	Lateral Force	1328	15841	16381	24115
	Vertical Force	27378	33551	2247	61004
Bridge Wheels	Longitudinal Force	1312	230030	21424	232338
	Lateral Force	24674	0	29212	53886
	Vertical Force	31642	56006	23570	92405
Girder-to-Sill	Longitudinal Force	1404	409670	11405	411233
	Lateral Force	1749	10972	24852	28915
	Vertical Force	56047	111630	4497	167768
End-Tie-to-Girder	Longitudinal Force	1427	27644	742	29081
	Lateral Force	1070	4229	5566	8060
	Vertical Force	16420	80038	1600	96474

Table 4-2. Maximum Stresses For 150 Ton Semi-Gantry Crane
Trolley At West End, Main Hoist Hook Up, 150 Ton Load

Member	Component	Static (psi)	Dynamic (psi)	Wheel Slip (psi)	Combined (psi)	% Allowable
Bridge Girder	Normal Stress	5366	14721	2989	20387	59.6
	Horizontal Shear	119	351	513	740	3.9
	Vertical Shear	1825	4627	93	6452	34.0
Equalizing Sill	Normal Stress	1323	4264	9608	11835	34.6
	Horizontal Shear	0	257	115	282	1.5
	Vertical Shear	169	122	435	620	3.3
Trolley Truck*	Normal Stress	7449	20919	3312	28629	83.7
	Horizontal Shear	63	215	245	389	2.0
	Vertical Shear	824	2180	34	3004	15.8
Trolley Girder**	Normal Stress	8282	25367	1899	33719	98.6
	Horizontal Shear	0	632	142	648	3.4
	Vertical Shear	1215	3597	36	4813	25.3
Bridge Truck	Normal Stress	5749	19926	3701	26016	76.1
	Horizontal Shear	74	2625	486	2744	14.4
	Vertical Shear	1042	2542	535	3639	19.2
End Tie	Normal Stress	588	1724	2624	3727	10.9
	Horizontal Shear	4	135	58	151	0.8
	Vertical Shear	44	69	131	192	1.0
Gantry Leg***	Normal Stress	2456	25690	1874	28214	82.5
	Lateral Shear	33	89	63	142	0.7
	Longitudinal Shear	28	977	9	1006	5.3
Gantry Trusses	Normal Stress	1215	7276	4265	9649	28.2
	Horizontal Shear	1	264	1	264	1.4
	Vertical Shear	32	115	29	151	0.8

*Normal stress reduced by 9% for load reacted by drum to trolley wheels.
**Normal stress reduced by 25% for load reacted by drum to trolley wheels.
***Shear stress calculated using smallest cross-sectional area of leg.

Member	Component	Static (lbs)	Dynamic (lbs)	Wheel Slip (lbs)	Combined (lbs)
Rope Force	Axial Force	19478	3804	0	23281
Truck Pins	Axial Force	2682	418020	26721	421555
	Horizontal Force	245	3196	92711	93012
	Vertical Force	177050	444330	64313	626010
Trolley Wheels	Longitudinal Force	69	241110	20204	242025
	Lateral Force	8334	28035	32534	51281
	Vertical Force	108950	287430	4462	396415
Bridge Wheels	Longitudinal Force	6468	230670	42551	241030
	Lateral Force	72655	0	58018	130673
	Vertical Force	91352	222400	46812	318625
Girder-to-Sill	Longitudinal Force	3142	409450	22652	413218
	Lateral Force	11413	33640	49358	71145
	Vertical Force	175360	444200	8932	619650
End-Tie-to-Girder	Longitudinal Force	3181	46254	1474	49458
	Lateral Force	1391	4510	11055	13331
	Vertical Force	34462	104650	3178	139160

Table 4-3. Maximum Stresses For 150 Ton Semi-Gantry Crane
Trolley At West End, Main Hoist Hook Down, 150 Ton Load

Member	Component	Static (psi)	Dynamic (psi)	Wheel Slip (psi)	Combined (psi)	% Allowable
Bridge Girder	Normal Stress	5366	11697	2244	17276	50.5
	Horizontal Shear	119	191	385	549	2.9
	Vertical Shear	1825	2307	70	4133	21.8
Equalizing Sill	Normal Stress	1323	2607	7214	8994	26.3
	Horizontal Shear	0	257	86	272	1.4
	Vertical Shear	169	92	326	508	2.7
Trolley Truck*	Normal Stress	7449	9499	2487	17269	50.5
	Horizontal Shear	63	145	184	297	1.6
	Vertical Shear	824	984	25	1808	9.5
Trolley Girder**	Normal Stress	8282	11437	1426	19807	57.9
	Horizontal Shear	0	603	106	613	3.2
	Vertical Shear	1215	1598	27	2813	14.8
Bridge Truck	Normal Stress	5749	16600	2779	22580	66.0
	Horizontal Shear	74	2595	365	2694	14.2
	Vertical Shear	1042	1267	402	2371	12.5
End Tie	Normal Stress	588	1327	1970	2963	8.7
	Horizontal Shear	4	134	44	145	0.8
	Vertical Shear	44	65	98	162	0.9
Gantry Leg***	Normal Stress	2456	25087	1407	27582	80.7
	Lateral Shear	33	66	47	114	0.6
	Longitudinal Shear	28	970	7	998	5.3
Gantry Trusses	Normal Stress	1215	7599	3202	9461	27.7
	Horizontal Shear	1	284	1	285	1.5
	Vertical Shear	32	134	22	168	0.9

*Normal stress reduced by 9% for load reacted by drum to trolley wheels.
**Normal stress reduced by 25% for load reacted by drum to trolley wheels.
***Shear stress calculated using smallest cross-sectional area of leg.

Member	Component	Static (lbs)	Dynamic (lbs)	Wheel Slip (lbs)	Combined (lbs)
Rope Force	Axial Force	19478	1763	0	21240
Truck Pins	Axial Force	2682	414770	20063	417937
	Horizontal Force	245	2072	69612	69888
	Vertical Force	177050	221610	48289	403860
Trolley Wheels	Longitudinal Force	69	237160	15170	237714
	Lateral Force	8334	19142	24428	39369
	Vertical Force	108950	129760	3350	238753
Bridge Wheels	Longitudinal Force	6468	228040	31949	236735
	Lateral Force	72655	0	43563	116218
	Vertical Force	91352	110860	35149	207651
Girder-to-Sill	Longitudinal Force	3142	406170	17008	409668
	Lateral Force	11413	18368	37060	52776
	Vertical Force	175360	221460	6707	396922
End-Tie-to-Girder	Longitudinal Force	3181	31298	1107	34499
	Lateral Force	1391	4211	8301	10699
	Vertical Force	34462	83897	2386	118393

Table 4-4. Maximum Stresses For 150 Ton Semi-Gantry Crane
Trolley At West End, Auxiliary Hoist Hook Up, 25 Ton Load

Member	Component	Static (psi)	Dynamic (psi)	Wheel Slip (psi)	Combined (psi)	% Allowable
Bridge Girder	Normal Stress	2460	12490	1678	15062	44.0
	Horizontal Shear	35	153	288	361	1.9
	Vertical Shear	788	1483	52	2272	12.0
Equalizing Sill	Normal Stress	878	2328	5394	6753	19.7
	Horizontal Shear	0	256	64	264	1.4
	Vertical Shear	163	92	244	423	2.2
Trolley Truck*	Normal Stress	3913	10513	2937	14829	43.4
	Horizontal Shear	19	159	137	229	1.2
	Vertical Shear	307	458	19	765	4.0
Trolley Girder**	Normal Stress	2086	5672	1066	7857	23.0
	Horizontal Shear	0	774	80	779	4.1
	Vertical Shear	337	637	20	974	5.1
Bridge Truck	Normal Stress	2499	16223	2078	18855	55.1
	Horizontal Shear	25	2733	273	2771	14.6
	Vertical Shear	473	816	300	1342	7.1
End Tie	Normal Stress	270	1238	1473	2194	6.4
	Horizontal Shear	1	132	33	137	0.7
	Vertical Shear	36	68	73	135	0.7
Gantry Leg***	Normal Stress	1650	25769	1052	27440	80.2
	Lateral Shear	27	61	35	98	0.5
	Longitudinal Shear	15	991	5	1006	5.3
Gantry Trusses	Normal Stress	1125	7393	2394	8896	26.0
	Horizontal Shear	1	269	0	270	1.4
	Vertical Shear	32	131	16	164	0.9

*Normal stress increased by 43.7% to compensate for auxiliary hoist offset.
**Normal stress reduced by 25% for load reacted by drum to trolley wheels.
***Shear stress calculated using smallest cross-sectional area of leg.

Member	Component	Static (lbs)	Dynamic (lbs)	Wheel Slip (lbs)	Combined (lbs)
Rope Force	Axial Force	6667	4428	0	11095
Truck Pins	Axial Force	1346	435360	15002	436964
	Horizontal Force	75	2503	52051	52186
	Vertical Force	77560	142540	36107	224602
Trolley Wheels	Longitudinal Force	22	260320	11343	260589
	Lateral Force	2477	20966	18266	30284
	Vertical Force	40918	60349	2505	101319
Bridge Wheels	Longitudinal Force	2168	240110	23889	243463
	Lateral Force	32639	0	32573	65212
	Vertical Force	41554	71376	26282	117615
Girder-to-Sill	Longitudinal Force	1670	426840	12717	428699
	Lateral Force	3353	14612	27711	34680
	Vertical Force	75852	142360	5015	218300
End-Tie-to-Girder	Longitudinal Force	1718	29890	828	31619
	Lateral Force	1124	3864	6207	8435
	Vertical Force	19415	84559	1784	103993

Table 4-5. Maximum Stresses For 150 Ton Semi-Gantry Crane
Trolley At West End, Auxiliary Hoist Hook Down, 25 Ton Load

Member	Component	Static (psi)	Dynamic (psi)	Wheel Slip (psi)	Combined (psi)	% Allowable
Bridge Girder	Normal Stress	2460	12437	1620	15002	43.9
	Horizontal Shear	35	146	278	349	1.8
	Vertical Shear	788	1280	50	2069	10.9
Equalizing Sill	Normal Stress	878	2095	5206	6490	19.0
	Horizontal Shear	0	256	62	264	1.4
	Vertical Shear	163	93	236	416	2.2
Trolley Truck*	Normal Stress	3913	9741	2835	14059	41.1
	Horizontal Shear	19	154	133	222	1.2
	Vertical Shear	307	326	18	634	3.3
Trolley Girder**	Normal Stress	2086	4552	1029	6752	19.7
	Horizontal Shear	0	768	77	771	4.1
	Vertical Shear	337	402	19	740	3.9
Bridge Truck	Normal Stress	2499	16087	2006	18711	54.7
	Horizontal Shear	25	2728	264	2765	14.6
	Vertical Shear	473	704	290	1234	6.5
End Tie	Normal Stress	270	1247	1422	2161	6.3
	Horizontal Shear	1	134	32	139	0.7
	Vertical Shear	36	57	71	127	0.7
Gantry Leg***	Normal Stress	1650	25696	1015	27366	80.0
	Lateral Shear	27	60	34	96	0.5
	Longitudinal Shear	15	991	5	1006	5.3
Gantry Trusses	Normal Stress	1125	8125	2311	9572	28.0
	Horizontal Shear	1	302	0	303	1.6
	Vertical Shear	32	134	16	168	0.9

*Normal stress increased by 43.7% to compensate for auxiliary hoist offset.
**Normal stress reduced by 25% for load reacted by drum to trolley wheels.
***Shear stress calculated using smallest cross-sectional area of leg.

Member	Component	Static (lbs)	Dynamic (lbs)	Wheel Slip (lbs)	Combined (lbs)
Rope Force	Axial Force	6667	3148	0	9815
Truck Pins	Axial Force	1346	434650	14480	436237
	Horizontal Force	75	2148	50242	50363
	Vertical Force	77560	123060	34852	205460
Trolley Wheels	Longitudinal Force	22	259530	10949	259783
	Lateral Force	2477	20350	17631	29402
	Vertical Force	40918	42955	2418	83941
Bridge Wheels	Longitudinal Force	2168	239670	23059	242945
	Lateral Force	32639	0	31441	64080
	Vertical Force	41554	61606	25368	108179
Girder-to-Sill	Longitudinal Force	1670	426110	12275	427957
	Lateral Force	3353	14030	26748	33557
	Vertical Force	75852	122880	4841	198827
End-Tie-to-Girder	Longitudinal Force	1718	29706	799	31435
	Lateral Force	1124	4140	5991	8406
	Vertical Force	19415	83738	1722	103171

Table 4-6. Maximum Stresses For 150 Ton Semi-Gantry Crane
Trolley At 1/4-Span, Main Hoist Hook Up, No Load

Member	Component	Static (psi)	Dynamic (psi)	Wheel Slip (psi)	Combined (psi)	% Allowable
Bridge Girder	Normal Stress	2052	10351	2893	12800	37.4
	Horizontal Shear	12	135	174	232	1.2
	Vertical Shear	584	1198	38	1783	9.4
Equalizing Sill	Normal Stress	1029	2225	4920	6429	18.8
	Horizontal Shear	0	261	146	299	1.6
	Vertical Shear	168	87	152	343	1.8
Trolley Truck*	Normal Stress	1461	5267	1531	6947	20.3
	Horizontal Shear	6	115	114	168	0.9
	Vertical Shear	205	295	21	501	2.6
Trolley Girder**	Normal Stress	841	3050	921	4026	11.8
	Horizontal Shear	1	626	76	632	3.3
	Vertical Shear	162	197	18	360	1.9
Bridge Truck	Normal Stress	2374	15091	2544	17678	51.7
	Horizontal Shear	17	2562	416	2613	13.8
	Vertical Shear	468	677	481	1298	6.8
End Tie	Normal Stress	364	2363	2407	3737	10.9
	Horizontal Shear	0	133	37	138	0.7
	Vertical Shear	42	78	160	220	1.2
Gantry Leg***	Normal Stress	2211	24431	1692	26701	78.1
	Lateral Shear	31	88	40	127	0.7
	Longitudinal Shear	11	951	6	962	5.1
Gantry Trusses	Normal Stress	1206	17251	3319	18773	54.9
	Horizontal Shear	1	496	1	497	2.6
	Vertical Shear	32	109	15	142	0.7

*Normal stress reduced by 9% for load reacted by drum to trolley wheels.
**Normal stress reduced by 25% for load reacted by drum to trolley wheels.
***Shear stress calculated using smallest cross-sectional area of leg.

Member	Component	Static (lbs)	Dynamic (lbs)	Wheel Slip (lbs)	Combined (lbs)
Rope Force	Axial Force	727	66	0	793
Truck Pins	Axial Force	1764	418950	17664	421086
	Horizontal Force	152	2013	36125	36333
	Vertical Force	76611	118220	62615	210389
Trolley Wheels	Longitudinal Force	173	240160	10849	240578
	Lateral Force	817	15228	15167	22309
	Vertical Force	27371	39203	2730	66669
Bridge Wheels	Longitudinal Force	1513	225190	36429	229630
	Lateral Force	32297	0	42363	74660
	Vertical Force	41104	59221	42055	113738
Girder-to-Sill	Longitudinal Force	2482	410510	12491	413182
	Lateral Force	371	8125	16758	18995
	Vertical Force	27324	107460	3612	134845
End-Tie-to-Girder	Longitudinal Force	2483	31471	901	33967
	Lateral Force	1809	5038	11672	14522
	Vertical Force	32863	81265	5039	114284

Table 4-7. Maximum Stresses For 150 Ton Semi-Gantry Crane
Trolley At 1/4-Span, Main Hoist Hook Up, 150 Ton Load

Member	Component	Static (psi)	Dynamic (psi)	Wheel Slip (psi)	Combined (psi)	% Allowable
Bridge Girder	Normal Stress	6306	20275	6259	27525	80.5
	Horizontal Shear	68	616	376	790	4.2
	Vertical Shear	1757	4616	81	6374	33.5
Equalizing Sill	Normal Stress	1779	5119	10644	13590	39.7
	Horizontal Shear	1	312	316	445	2.3
	Vertical Shear	195	135	329	550	2.9
Trolley Truck*	Normal Stress	7215	25488	3312	32918	96.3
	Horizontal Shear	37	383	247	492	2.6
	Vertical Shear	824	2296	45	3121	16.4
Trolley Girder**	Normal Stress	8213	25516	1991	33807	98.8
	Horizontal Shear	4	731	165	753	4.0
	Vertical Shear	1215	3681	39	4896	25.8
Bridge Truck	Normal Stress	5830	19152	5504	25757	75.3
	Horizontal Shear	76	2847	901	3062	16.1
	Vertical Shear	1120	3441	1040	4714	24.8
End Tie	Normal Stress	1275	17083	5206	19134	55.9
	Horizontal Shear	2	556	79	564	3.0
	Vertical Shear	76	692	345	849	4.5
Gantry Leg***	Normal Stress	5099	27579	3661	32920	96.3
	Lateral Shear	69	314	87	395	2.1
	Longitudinal Shear	25	946	12	971	5.1
Gantry Trusses	Normal Stress	1612	10031	7179	13947	40.8
	Horizontal Shear	1	261	1	262	1.4
	Vertical Shear	34	111	32	150	0.8

*Normal stress reduced by 9% for load reacted by drum to trolley wheels.
**Normal stress reduced by 25% for load reacted by drum to trolley wheels.
***Shear stress calculated using smallest cross-sectional area of leg.

Member	Component	Static (lbs)	Dynamic (lbs)	Wheel Slip (lbs)	Combined (lbs)
Rope Force	Axial Force	19478	3858	0	23336
Truck Pins	Axial Force	5245	428130	38212	435077
	Horizontal Force	569	10510	78146	79418
	Vertical Force	190550	600470	135450	806107
Trolley Wheels	Longitudinal Force	585	247330	23468	249026
	Lateral Force	4869	50143	32810	64792
	Vertical Force	108960	303090	5905	412108
Bridge Wheels	Longitudinal Force	6687	249970	78803	268784
	Lateral Force	78235	0	91641	169876
	Vertical Force	98203	301050	90973	412698
Girder-to-Sill	Longitudinal Force	7210	418680	27020	426761
	Lateral Force	3003	24027	36252	46494
	Vertical Force	71012	189760	7814	260933
End-Tie-to-Girder	Longitudinal Force	7305	157310	1950	164627
	Lateral Force	3819	50188	25249	60000
	Vertical Force	98417	268140	10901	366778

Table 4-8. Maximum Stresses For 150 Ton Semi-Gantry Crane
Trolley At 1/4-Span, Main Hoist Hook Down, 150 Ton Load

Member	Component	Static (psi)	Dynamic (psi)	Wheel Slip (psi)	Combined (psi)	% Allowable
Bridge Girder	Normal Stress	6306	11775	4452	18894	55.2
	Horizontal Shear	68	183	268	393	2.1
	Vertical Shear	1757	2555	58	4313	22.7
Equalizing Sill	Normal Stress	1779	2281	7571	9686	28.3
	Horizontal Shear	1	259	225	344	1.8
	Vertical Shear	195	100	234	450	2.4
Trolley Truck*	Normal Stress	7215	11634	2356	19086	55.8
	Horizontal Shear	37	134	175	258	1.4
	Vertical Shear	824	971	32	1795	9.4
Trolley Girder**	Normal Stress	8213	12798	1416	21089	61.7
	Horizontal Shear	4	599	117	614	3.2
	Vertical Shear	1215	1707	28	2922	15.4
Bridge Truck	Normal Stress	5830	15147	3915	21475	62.8
	Horizontal Shear	76	2544	641	2700	14.2
	Vertical Shear	1120	1408	740	2710	14.3
End Tie	Normal Stress	1275	2570	3703	5782	16.9
	Horizontal Shear	2	132	56	145	0.8
	Vertical Shear	76	117	246	348	1.8
Gantry Leg***	Normal Stress	5099	26515	2604	31742	92.8
	Lateral Shear	69	133	62	215	1.1
	Longitudinal Shear	25	943	9	969	5.1
Gantry Trusses	Normal Stress	1612	8422	5106	11461	33.5
	Horizontal Shear	1	300	1	301	1.6
	Vertical Shear	34	67	23	104	0.5

*Normal stress reduced by 9% for load reacted by drum to trolley wheels.
**Normal stress reduced by 25% for load reacted by drum to trolley wheels.
***Shear stress calculated using smallest cross-sectional area of leg.

Member	Component	Static (lbs)	Dynamic (lbs)	Wheel Slip (lbs)	Combined (lbs)
Rope Force	Axial Force	19478	1880	0	21357
Truck Pins	Axial Force	5245	415810	27179	421942
	Horizontal Force	569	2482	55583	56207
	Vertical Force	190550	246290	96341	455013
Trolley Wheels	Longitudinal Force	585	236480	16692	237653
	Lateral Force	4869	17650	23337	34129
	Vertical Force	108960	128070	4200	237099
Bridge Wheels	Longitudinal Force	6687	223590	56050	237195
	Lateral Force	78235	0	65181	143416
	Vertical Force	98203	123190	64706	237353
Girder-to-Sill	Longitudinal Force	7210	407330	19218	414993
	Lateral Force	3003	10382	25785	30800
	Vertical Force	71012	121230	5558	192369
End-Tie-to-Girder	Longitudinal Force	7305	75334	1387	82652
	Lateral Force	3819	7621	17959	23328
	Vertical Force	98417	151870	7754	250485

Table 4-9. Maximum Stresses For 150 Ton Semi-Gantry Crane
Trolley At 1/4-Span, Auxiliary Hoist Hook Up, 25 Ton Load

Member	Component	Static (psi)	Dynamic (psi)	Wheel Slip (psi)	Combined (psi)	% Allowable
Bridge Girder	Normal Stress	2758	11648	3326	14872	43.5
	Horizontal Shear	21	186	200	295	1.6
	Vertical Shear	778	1539	43	2318	12.2
Equalizing Sill	Normal Stress	1153	3142	5656	7623	22.3
	Horizontal Shear	0	272	168	320	1.7
	Vertical Shear	173	135	175	393	2.1
Trolley Truck*	Normal Stress	3815	10566	2779	14741	43.1
	Horizontal Shear	11	153	131	213	1.1
	Vertical Shear	307	566	24	874	4.6
Trolley Girder**	Normal Stress	2065	6140	1058	8296	24.3
	Horizontal Shear	2	773	88	780	4.1
	Vertical Shear	337	714	21	1051	5.5
Bridge Truck	Normal Stress	2948	16057	2925	19269	56.3
	Horizontal Shear	27	2694	479	2764	14.5
	Vertical Shear	576	1016	552	1732	9.1
End Tie	Normal Stress	515	2826	2767	4470	13.1
	Horizontal Shear	0	140	42	146	0.8
	Vertical Shear	48	150	183	285	1.5
Gantry Leg***	Normal Stress	2691	25240	1945	28006	81.9
	Lateral Shear	34	123	46	165	0.9
	Longitudinal Shear	14	957	6	971	5.1
Gantry Trusses	Normal Stress	1274	7815	3815	9970	29.2
	Horizontal Shear	1	265	1	266	1.4
	Vertical Shear	32	79	17	113	0.6

*Normal stress increased by 43.7% to compensate for auxiliary hoist offset.

**Normal stress reduced by 25% for load reacted by drum to trolley wheels.

***Shear stress calculated using smallest cross-sectional area of leg.

Member	Component	Static (lbs)	Dynamic (lbs)	Wheel Slip (lbs)	Combined (lbs)
Rope Force	Axial Force	6667	4741	0	11408
Truck Pins	Axial Force	2342	436760	20305	439574
	Horizontal Force	221	4809	41526	42024
	Vertical Force	95524	177140	71980	286730
Trolley Wheels	Longitudinal Force	241	260090	12471	260630
	Lateral Force	1489	19856	17435	27913
	Vertical Force	40915	74964	3138	115945
Bridge Wheels	Longitudinal Force	2372	236730	41875	242777
	Lateral Force	39922	0	48698	88620
	Vertical Force	50582	88867	48343	151747
Girder-to-Sill	Longitudinal Force	3267	428290	14358	431798
	Lateral Force	721	11294	19264	23052
	Vertical Force	33524	119520	4152	153116
End-Tie-to-Girder	Longitudinal Force	3283	41909	1036	45205
	Lateral Force	2113	7989	13417	17728
	Vertical Force	43652	97367	5793	141191

Table 4-10. Maximum Stresses For 150 Ton Semi-Gantry Crane
Trolley At 1/4-Span, Auxiliary Hoist Hook Down, 25 Ton Load

Member	Component	Static (psi)	Dynamic (psi)	Wheel Slip (psi)	Combined (psi)	% Allowable
Bridge Girder	Normal Stress	2758	10840	3102	14033	41.0
	Horizontal Shear	21	157	186	265	1.4
	Vertical Shear	778	1272	40	2051	10.8
Equalizing Sill	Normal Stress	1153	2285	5274	6901	20.2
	Horizontal Shear	0	258	156	302	1.6
	Vertical Shear	173	90	163	359	1.9
Trolley Truck*	Normal Stress	3815	8963	2592	13145	38.4
	Horizontal Shear	11	143	122	200	1.1
	Vertical Shear	307	384	22	692	3.6
Trolley Girder**	Normal Stress	2065	4935	987	7097	20.8
	Horizontal Shear	2	762	82	768	4.0
	Vertical Shear	337	424	19	761	4.0
Bridge Truck	Normal Stress	2948	15810	2728	18992	55.5
	Horizontal Shear	27	2671	446	2735	14.4
	Vertical Shear	576	718	515	1459	7.7
End Tie	Normal Stress	515	2605	2580	4182	12.2
	Horizontal Shear	0	131	39	137	0.7
	Vertical Shear	48	76	171	235	1.2
Gantry Leg***	Normal Stress	2691	24849	1814	27606	80.7
	Lateral Shear	34	95	43	138	0.7
	Longitudinal Shear	14	961	6	975	5.1
Gantry Trusses	Normal Stress	1274	13366	3558	15105	44.2
	Horizontal Shear	1	408	1	408	2.1
	Vertical Shear	32	81	16	115	0.6

*Normal stress increased by 43.7% to compensate for auxiliary hoist offset.
**Normal stress reduced by 25% for load reacted by drum to trolley wheels.
***Shear stress calculated using smallest cross-sectional area of leg.

Member	Component	Static (lbs)	Dynamic (lbs)	Wheel Slip (lbs)	Combined (lbs)
Rope Force	Axial Force	6667	3220	0	9887
Truck Pins	Axial Force	2342	435390	18935	438144
	Horizontal Force	221	1958	38725	38995
	Vertical Force	95524	125370	67124	237733
Trolley Wheels	Longitudinal Force	241	258630	11630	259132
	Lateral Force	1489	18915	16259	26431
	Vertical Force	40915	50880	2926	91879
Bridge Wheels	Longitudinal Force	2372	234700	39050	240298
	Lateral Force	39922	0	45413	85335
	Vertical Force	50582	62790	45082	127880
Girder-to-Sill	Longitudinal Force	3267	426980	13389	430457
	Lateral Force	721	9642	17964	21110
	Vertical Force	33524	114190	3872	147780
End-Tie-to-Girder	Longitudinal Force	3283	34410	966	37707
	Lateral Force	2113	5676	12512	15852
	Vertical Force	43652	85110	5402	128933

Table 4-11. Maximum Stresses For 150 Ton Semi-Gantry Crane
Trolley At Mid-Span, Main Hoist Hook Up, No Load

Member	Component	Static (psi)	Dynamic (psi)	Wheel Slip (psi)	Combined (psi)	% Allowable
Bridge Girder	Normal Stress	2258	10245	2607	12830	37.5
	Horizontal Shear	7	95	211	239	1.3
	Vertical Shear	454	1142	48	1597	8.4
Equalizing Sill	Normal Stress	947	1923	5228	6517	19.1
	Horizontal Shear	1	261	124	290	1.5
	Vertical Shear	165	80	184	366	1.9
Trolley Truck*	Normal Stress	1425	5278	1696	6969	20.4
	Horizontal Shear	6	108	124	170	0.9
	Vertical Shear	204	259	22	464	2.4
Trolley Girder**	Normal Stress	834	2695	1059	3729	10.9
	Horizontal Shear	1	626	90	633	3.3
	Vertical Shear	162	163	18	326	1.7
Bridge Truck	Normal Stress	2002	15023	2480	17228	50.4
	Horizontal Shear	19	2546	386	2594	13.7
	Vertical Shear	395	633	349	1118	5.9
End Tie	Normal Stress	286	1567	1546	2488	7.3
	Horizontal Shear	1	134	12	135	0.7
	Vertical Shear	39	65	106	163	0.9
Gantry Leg***	Normal Stress	1929	24925	1219	26884	78.6
	Lateral Shear	29	63	34	101	0.5
	Longitudinal Shear	16	971	5	987	5.2
Gantry Trusses	Normal Stress	1163	15950	2586	17321	50.6
	Horizontal Shear	1	419	1	419	2.2
	Vertical Shear	32	256	15	288	1.5

*Normal stress reduced by 9% for load reacted by drum to trolley wheels.

**Normal stress reduced by 25% for load reacted by drum to trolley wheels.

***Shear stress calculated using smallest cross-sectional area of leg.

Member	Component	Static (lbs)	Dynamic (lbs)	Wheel Slip (lbs)	Combined (lbs)
Rope Force	Axial Force	727	54	0	782
Truck Pins	Axial Force	1650	418380	17602	420400
	Horizontal Force	97	2460	42406	42574
	Vertical Force	63984	110600	43737	182918
Trolley Wheels	Longitudinal Force	76	239820	12772	240236
	Lateral Force	726	14006	16445	22327
	Vertical Force	27317	34324	2837	61758
Bridge Wheels	Longitudinal Force	1645	223780	33765	227958
	Lateral Force	27201	0	31460	58661
	Vertical Force	34773	55354	30508	97977
Girder-to-Sill	Longitudinal Force	2144	409880	13191	412236
	Lateral Force	660	7114	20359	22226
	Vertical Force	39786	109680	4582	149562
End-Tie-to-Girder	Longitudinal Force	2169	28297	478	30470
	Lateral Force	1554	4168	7876	10465
	Vertical Force	25847	79995	2724	105888

Table 4-12. Maximum Stresses For 150 Ton Semi-Gantry Crane
Trolley At Mid-Span, Main Hoist Hook Up, 150 Ton Load

Member	Component	Static (psi)	Dynamic (psi)	Wheel Slip (psi)	Combined (psi)	% Allowable
Bridge Girder	Normal Stress	7069	21711	5559	29480	86.2
	Horizontal Shear	46	421	451	662	3.5
	Vertical Shear	1257	3396	102	4654	24.5
Equalizing Sill	Normal Stress	1458	3148	11146	13040	38.1
	Horizontal Shear	0	262	265	373	2.0
	Vertical Shear	183	150	393	604	3.2
Trolley Truck*	Normal Stress	7012	24423	3615	31700	92.7
	Horizontal Shear	34	312	264	442	2.3
	Vertical Shear	823	2292	46	3115	16.4
Trolley Girder**	Normal Stress	8168	25365	2258	33633	98.3
	Horizontal Shear	3	690	191	718	3.8
	Vertical Shear	1215	3675	38	4890	25.7
Bridge Truck	Normal Stress	4387	19453	5287	24546	71.8
	Horizontal Shear	89	2622	823	2838	14.9
	Vertical Shear	842	2525	743	3474	18.3
End Tie	Normal Stress	939	12775	3296	14132	41.3
	Horizontal Shear	3	592	26	596	3.1
	Vertical Shear	62	327	225	459	2.4
Gantry Leg***	Normal Stress	4325	28135	2599	32580	95.3
	Lateral Shear	48	133	73	199	1.0
	Longitudinal Shear	43	979	11	1022	5.4
Gantry Trusses	Normal Stress	1435	10884	5513	13636	39.9
	Horizontal Shear	1	264	1	265	1.4
	Vertical Shear	33	71	31	111	0.6

*Normal stress reduced by 9% for load reacted by drum to trolley wheels.

**Normal stress reduced by 25% for load reacted by drum to trolley wheels.

***Shear stress calculated using smallest cross-sectional area of leg.

Member	Component	Static (lbs)	Dynamic (lbs)	Wheel Slip (lbs)	Combined (lbs)
Rope Force	Axial Force	19478	3845	0	23322
Truck Pins	Axial Force	4876	425060	37528	431589
	Horizontal Force	405	8131	90411	91180
	Vertical Force	141980	440280	93249	592026
Trolley Wheels	Longitudinal Force	366	244840	27230	246716
	Lateral Force	4452	41163	35061	58523
	Vertical Force	108880	302470	6049	411410
Bridge Wheels	Longitudinal Force	7806	230410	71989	249200
	Lateral Force	58660	0	67074	125734
	Vertical Force	73869	220900	65044	304146
Girder-to-Sill	Longitudinal Force	5973	416440	28124	423362
	Lateral Force	4376	21891	43406	52990
	Vertical Force	112710	303530	9768	416397
End-Tie-to-Girder	Longitudinal Force	6054	110820	1020	116879
	Lateral Force	3120	22410	16793	31124
	Vertical Force	70959	200740	5808	271783

Table 4-13. Maximum Stresses For 150 Ton Semi-Gantry Crane
Trolley At Mid-Span, Main Hoist Hook Down, 150 Ton Load

Member	Component	Static (psi)	Dynamic (psi)	Wheel Slip (psi)	Combined (psi)	% Allowable
Bridge Girder	Normal Stress	7069	10149	3850	17924	52.4
	Horizontal Shear	46	108	312	376	2.0
	Vertical Shear	1257	1793	70	3051	16.1
Equalizing Sill	Normal Stress	1458	2217	7719	9489	27.7
	Horizontal Shear	0	262	184	320	1.7
	Vertical Shear	183	84	272	468	2.5
Trolley Truck*	Normal Stress	7012	10058	2504	17377	50.8
	Horizontal Shear	34	113	183	249	1.3
	Vertical Shear	823	969	32	1792	9.4
Trolley Girder**	Normal Stress	8168	11663	1564	19935	58.3
	Horizontal Shear	3	598	132	615	3.2
	Vertical Shear	1215	1600	27	2815	14.8
Bridge Truck	Normal Stress	4387	15408	3661	20224	59.1
	Horizontal Shear	89	2525	570	2678	14.1
	Vertical Shear	842	991	515	1959	10.3
End Tie	Normal Stress	939	1843	2283	3872	11.3
	Horizontal Shear	3	135	18	139	0.7
	Vertical Shear	62	88	156	241	1.3
Gantry Leg***	Normal Stress	4325	25660	1800	30048	87.9
	Lateral Shear	48	89	50	151	0.8
	Longitudinal Shear	43	971	7	1014	5.3
Gantry Trusses	Normal Stress	1435	10861	3818	12948	37.9
	Horizontal Shear	1	355	1	356	1.9
	Vertical Shear	33	74	22	110	0.6

*Normal stress reduced by 9% for load reacted by drum to trolley wheels.

**Normal stress reduced by 25% for load reacted by drum to trolley wheels.

***Shear stress calculated using smallest cross-sectional area of leg.

Member	Component	Static (lbs)	Dynamic (lbs)	Wheel Slip (lbs)	Combined (lbs)
Rope Force	Axial Force	19478	1759	0	21237
Truck Pins	Axial Force	4876	414900	25990	420589
	Horizontal Force	405	2581	62613	63071
	Vertical Force	141980	173370	64579	326987
Trolley Wheels	Longitudinal Force	366	236080	18858	237198
	Lateral Force	4452	14922	24281	32952
	Vertical Force	108880	127720	4189	236669
Bridge Wheels	Longitudinal Force	7806	221920	49855	235257
	Lateral Force	58660	0	46451	105111
	Vertical Force	73869	86744	45045	171612
Girder-to-Sill	Longitudinal Force	5973	406390	19477	412829
	Lateral Force	4376	8623	30060	35649
	Vertical Force	112710	155910	6765	268767
End-Tie-to-Girder	Longitudinal Force	6054	51362	706	57421
	Lateral Force	3120	5017	11630	15786
	Vertical Force	70959	111570	4022	182601

Table 4-14. Maximum Stresses For 150 Ton Semi-Gantry Crane
Trolley At Mid-Span, Auxiliary Hoist Hook Up, 25 Ton Load

Member	Component	Static (psi)	Dynamic (psi)	Wheel Slip (psi)	Combined (psi)	% Allowable
Bridge Girder	Normal Stress	3047	10697	2952	14144	41.4
	Horizontal Shear	13	112	239	277	1.5
	Vertical Shear	587	1386	54	1974	10.4
Equalizing Sill	Normal Stress	1032	2059	5919	7299	21.3
	Horizontal Shear	1	259	141	296	1.6
	Vertical Shear	168	82	209	392	2.1
Trolley Truck*	Normal Stress	3712	10342	3032	14489	42.4
	Horizontal Shear	10	134	140	204	1.1
	Vertical Shear	307	553	24	861	4.5
Trolley Girder**	Normal Stress	2051	5913	1199	8085	23.6
	Horizontal Shear	1	768	101	776	4.1
	Vertical Shear	337	721	20	1058	5.6
Bridge Truck	Normal Stress	2398	15841	2808	18486	54.1
	Horizontal Shear	30	2653	437	2719	14.3
	Vertical Shear	469	771	395	1336	7.0
End Tie	Normal Stress	395	1588	1750	2758	8.1
	Horizontal Shear	1	131	14	133	0.7
	Vertical Shear	43	62	119	177	0.9
Gantry Leg***	Normal Stress	2273	25667	1380	27977	81.8
	Lateral Shear	31	80	39	120	0.6
	Longitudinal Shear	20	983	6	1003	5.3
Gantry Trusses	Normal Stress	1208	7433	2928	9197	26.9
	Horizontal Shear	1	272	1	272	1.4
	Vertical Shear	32	82	17	116	0.6

*Normal stress increased by 43.7% to compensate for auxiliary hoist offset.
**Normal stress reduced by 25% for load reacted by drum to trolley wheels.
***Shear stress calculated using smallest cross-sectional area of leg.

Member	Component	Static (lbs)	Dynamic (lbs)	Wheel Slip (lbs)	Combined (lbs)
Rope Force	Axial Force	6667	4689	0	11356
Truck Pins	Axial Force	2186	435580	19931	438222
	Horizontal Force	148	2384	48015	48222
	Vertical Force	76931	134810	49523	220549
Trolley Wheels	Longitudinal Force	125	259330	14461	259857
	Lateral Force	1345	17665	18620	27011
	Vertical Force	40855	73223	3212	114148
Bridge Wheels	Longitudinal Force	2668	233100	38232	238883
	Lateral Force	32423	0	35622	68045
	Vertical Force	41262	67468	34543	117059
Girder-to-Sill	Longitudinal Force	2768	427140	14936	430169
	Lateral Force	1277	8975	23052	26015
	Vertical Force	51892	133080	5187	185073
End-Tie-to-Girder	Longitudinal Force	2814	35396	542	38214
	Lateral Force	1814	4823	8919	11954
	Vertical Force	33308	91219	3084	124579

Table 4-15. Maximum Stresses For 150 Ton Semi-Gantry Crane
Trolley At Mid-Span, Auxiliary Hoist Hook Down, 25 Ton Load

Member	Component	Static (psi)	Dynamic (psi)	Wheel Slip (psi)	Combined (psi)	% Allowable
Bridge Girder	Normal Stress	3047	10701	2815	14112	41.3
	Horizontal Shear	13	107	228	266	1.4
	Vertical Shear	587	1240	52	1828	9.6
Equalizing Sill	Normal Stress	1032	2168	5644	7078	20.7
	Horizontal Shear	1	262	134	295	1.6
	Vertical Shear	168	76	199	381	2.0
Trolley Truck*	Normal Stress	3712	8996	2891	13161	38.5
	Horizontal Shear	10	132	134	198	1.0
	Vertical Shear	307	362	23	670	3.5
Trolley Girder**	Normal Stress	2051	4493	1144	6688	19.6
	Horizontal Shear	1	762	97	769	4.0
	Vertical Shear	337	418	19	755	4.0
Bridge Truck	Normal Stress	2398	15737	2678	18361	53.7
	Horizontal Shear	30	2651	417	2714	14.3
	Vertical Shear	469	687	376	1252	6.6
End Tie	Normal Stress	395	1626	1669	2725	8.0
	Horizontal Shear	1	134	13	136	0.7
	Vertical Shear	43	71	114	177	0.9
Gantry Leg***	Normal Stress	2273	25433	1316	27740	81.1
	Lateral Shear	31	70	37	110	0.6
	Longitudinal Shear	20	985	5	1005	5.3
Gantry Trusses	Normal Stress	1208	14282	2792	15760	46.1
	Horizontal Shear	1	432	1	432	2.3
	Vertical Shear	32	136	16	169	0.9

*Normal stress increased by 43.7% to compensate for auxiliary hoist offset.
**Normal stress reduced by 25% for load reacted by drum to trolley wheels.
***Shear stress calculated using smallest cross-sectional area of leg.

Member	Component	Static (lbs)	Dynamic (lbs)	Wheel Slip (lbs)	Combined (lbs)
Rope Force	Axial Force	6667	3208	0	9875
Truck Pins	Axial Force	2186	434830	19005	437431
	Horizontal Force	148	2694	45784	46012
	Vertical Force	76931	120030	47222	205916
Trolley Wheels	Longitudinal Force	125	258400	13789	258892
	Lateral Force	1345	17326	17755	26153
	Vertical Force	40855	47923	3063	88876
Bridge Wheels	Longitudinal Force	2668	232910	36456	238414
	Lateral Force	32423	0	33967	66390
	Vertical Force	41262	60077	32938	109776
Girder-to-Sill	Longitudinal Force	2768	426370	14242	429376
	Lateral Force	1277	8596	21981	24879
	Vertical Force	51892	119040	4946	171035
End-Tie-to-Girder	Longitudinal Force	2814	31904	516	34722
	Lateral Force	1814	4611	8505	11488
	Vertical Force	33308	84674	2941	118033

150 Ton Semi-Gantry Crane - Bridge Girders

wo	wi	tf	tw	H
28.00	25.25	0.750	0.375	72.00

Area	96.00	in^2		Length	420.00	in
Yc	36.75	in		Weight	11451	lb
Ixx	78901.88	in^4				
Iyy	11609.28	in^4				
J	30462.92	in^4				
Z	697.25	in		weight	density	
				lb	lb/in^3	
Sx	2146.99	in^3	Sgirder	31000	0.76885	
Sy	829.23	in^3	Ngirder	28000	0.69444	

Longitudinal stiffeners on webs not included in section properties

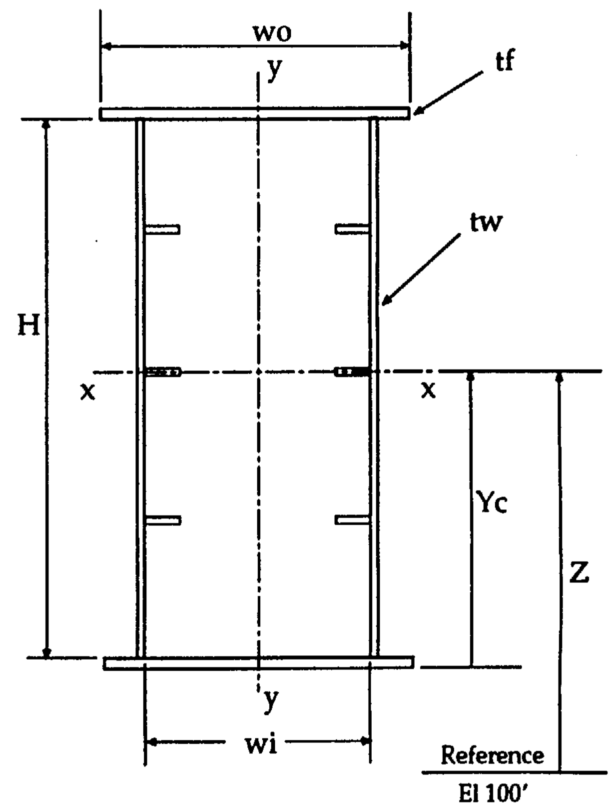


Figure 4-1. Final Section Sizing for Bridge Girders

150 Ton Semi-Gantry Crane - Trolley Trucks

wo	wi	tf	tw	H	tb
17.00	12.00	2.00	1.50	24.00	2.00

Area	133.00	in^2		Length	149.00
Yc	14.684	in		Weight	5628
Ixx	13723.07	in^4			
Iyy	4522.90	in^4			
J	10231.22	in^4			
Z	755.684	in		weight	density
				lb	lb/in^3
Sx	934.55	in^3	Truck	28667	1.44657
Sy	532.11	in^3			

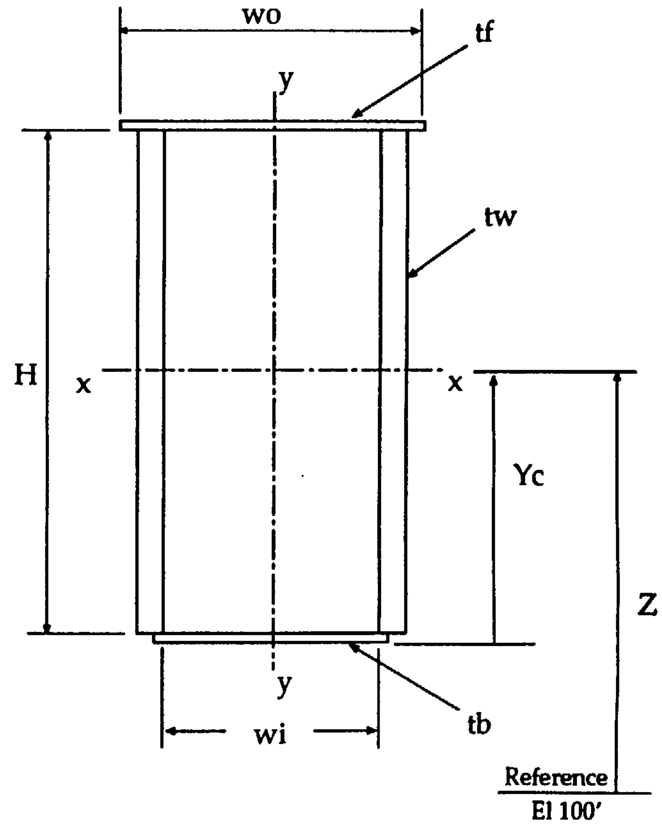


Figure 4-2. Final Section Sizing for Trolley Trucks

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150 Ton Semi-Gantry Crane - Trolley Load Girt

wo	wi	tf	tw	H
27.00	23.00	1.75	1.00	24.00

Area	142.50	in^2		Length	180.00
Yc	13.750	in		Weight	7285
Ixx	17992.97	in^4			
Iyy	12656.88	in^4			
J	19355.42	in^4			
Z	755.25	in			
				weight	density
Sx	1308.58	in^3		lb	lb/in^3
Sy	937.55	in^3	Total	28667	1.11761

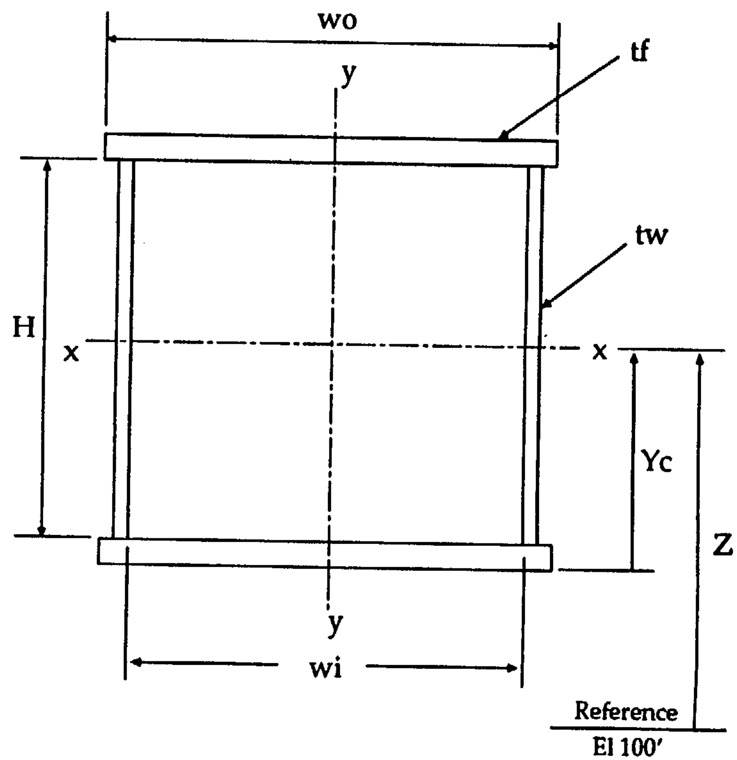

Figure 4-3. Final Section Sizing for Trolley Load Girt

30-Nov-98

150 Ton Semi-Gantry Crane - Equalizing Sills

wo	wi	tf	tw	H	Pin
24.00	21.25	0.375	0.375	23.25	8.50

Area	35.44	in^2	LengthUp	180.00
Yc	12.00	in	WeightUp	1812
Ixx	3297.35	in^4	LengthLo	252.00
Iyy	2902.83	in^4	WeightLo	2536
J	4326.12	in^4		
Z	708.5	in (Upper)		
Z	45.5	in (Lower)		

	weight	density
	lb	lb/in^3
Upper	3500	0.54870
Lower	10800	1.20937

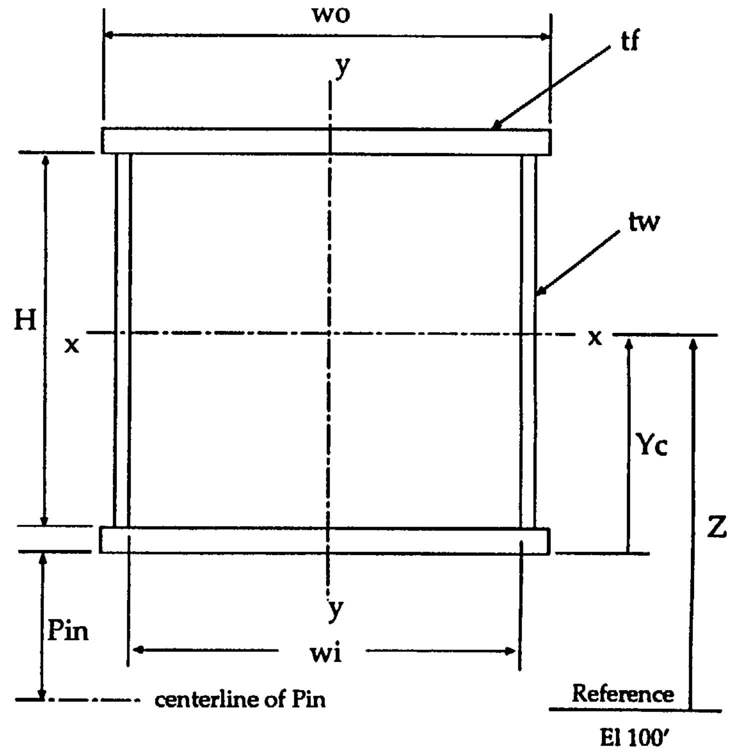

Figure 4-4. Final Section Sizing for Equalizing Sills

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150 Ton Semi-Gantry Bridge Trucks

wo	wi	tf	tw	H
14.00	13.00	0.50	1.50	24.50

Area	87.50	in^2	Length	60.00
Yc	12.750	in	Weight	1491
Ixx	5864.32	in^4		
Iyy	4105.79	in^4		
J	5755.02	in^4		
Z	19.750	in (Lower)		
Z	682.750	in (Upper)		

	weight	density
	lb	lb/in^3
Driver	5500	1.04762
Idler	4500	0.85714

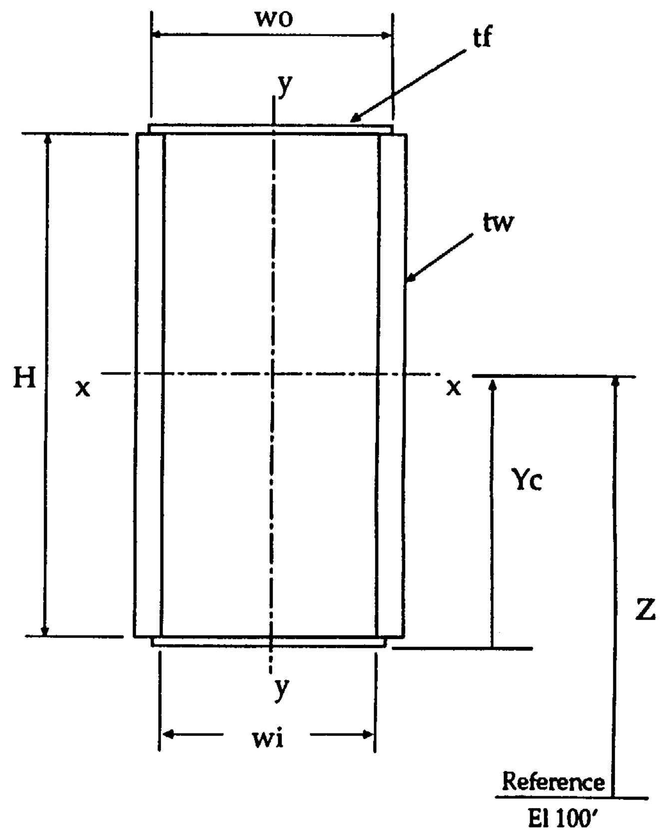

Figure 4-5. Final Section Sizing for Bridge Trucks

30-Nov-98

150 Ton Semi-Gantry Crane - End Tie

wo	wi	tf	tw	H
24.00	21.00	0.500	0.500	24.00

Area	48.00	in^2		Length	180.00
Yc	12.500	in		Weight	2454
Ixx	4754.00	in^4			
Iyy	3926.00	in^4			
J	6031.86	in^4			
Z	673.00	in			
				weight	density
Sx	380.32	in^3		lb	lb/in^3
Sy	327.17	in^3	Total	2454	0.28400

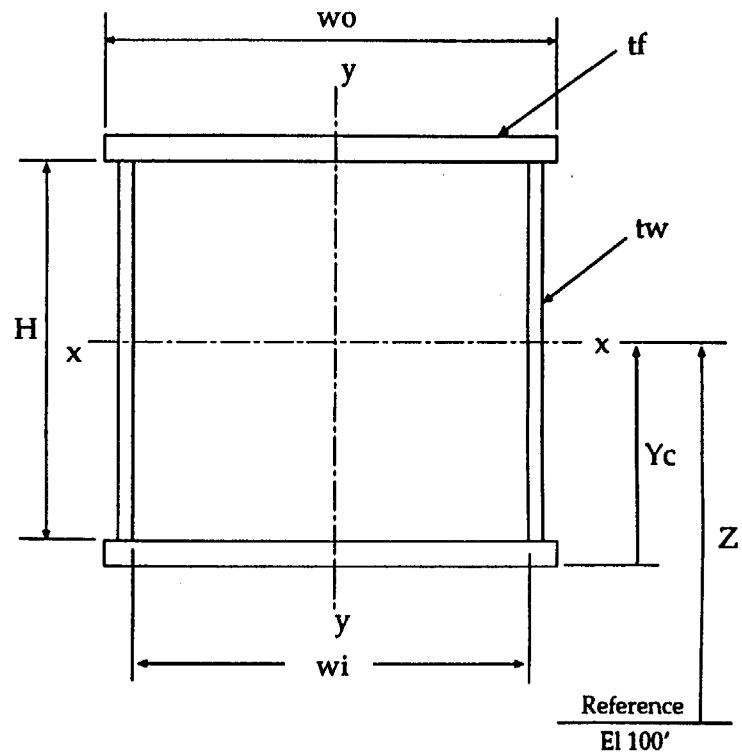

Figure 4-6. Final Section Sizing for End Tie

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150 Ton Semi-Gantry Crane - Gantry Legs at Top

wo	wi	tf	tw	H
28.00	25.25	0.500	0.375	48.00

Area	64.00	in^2		Length	600.00	in
Yc	24.50	in		Weight	9372.00	lb
Ixx	23378.33	in^4				
Iyy	7739.52	in^4				
J	17106.59	in^4				
				weight	density	
Sx	954.22	in^3		lb	lb/in^3	
Sy	552.82	in^3	LegWt	11872	0.35976	

Longitudinal stiffeners on webs not included in section properties
Leg section at bottom has same sizing but with 24" deep webs
Weight of diaphragms and stiffeners estimated at 2500 lbs per leg

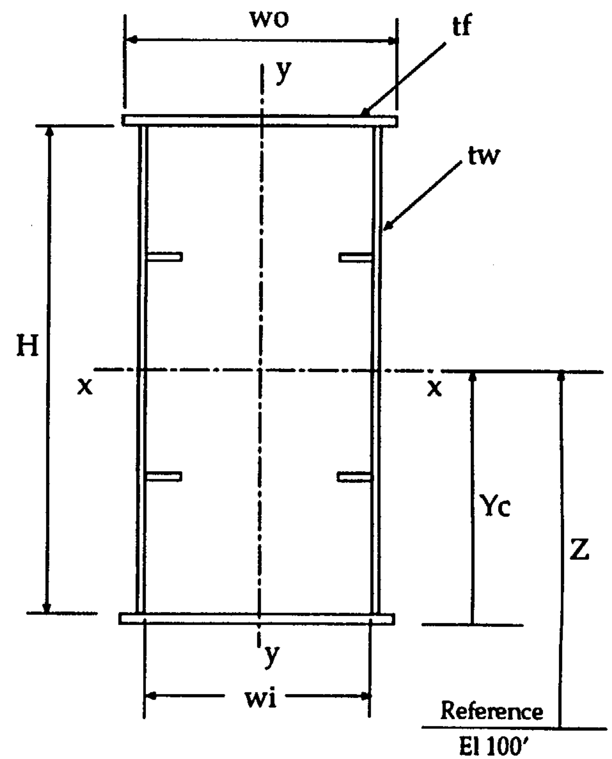


Figure 4-7. Final Section Sizing for Gantry Leg at Top

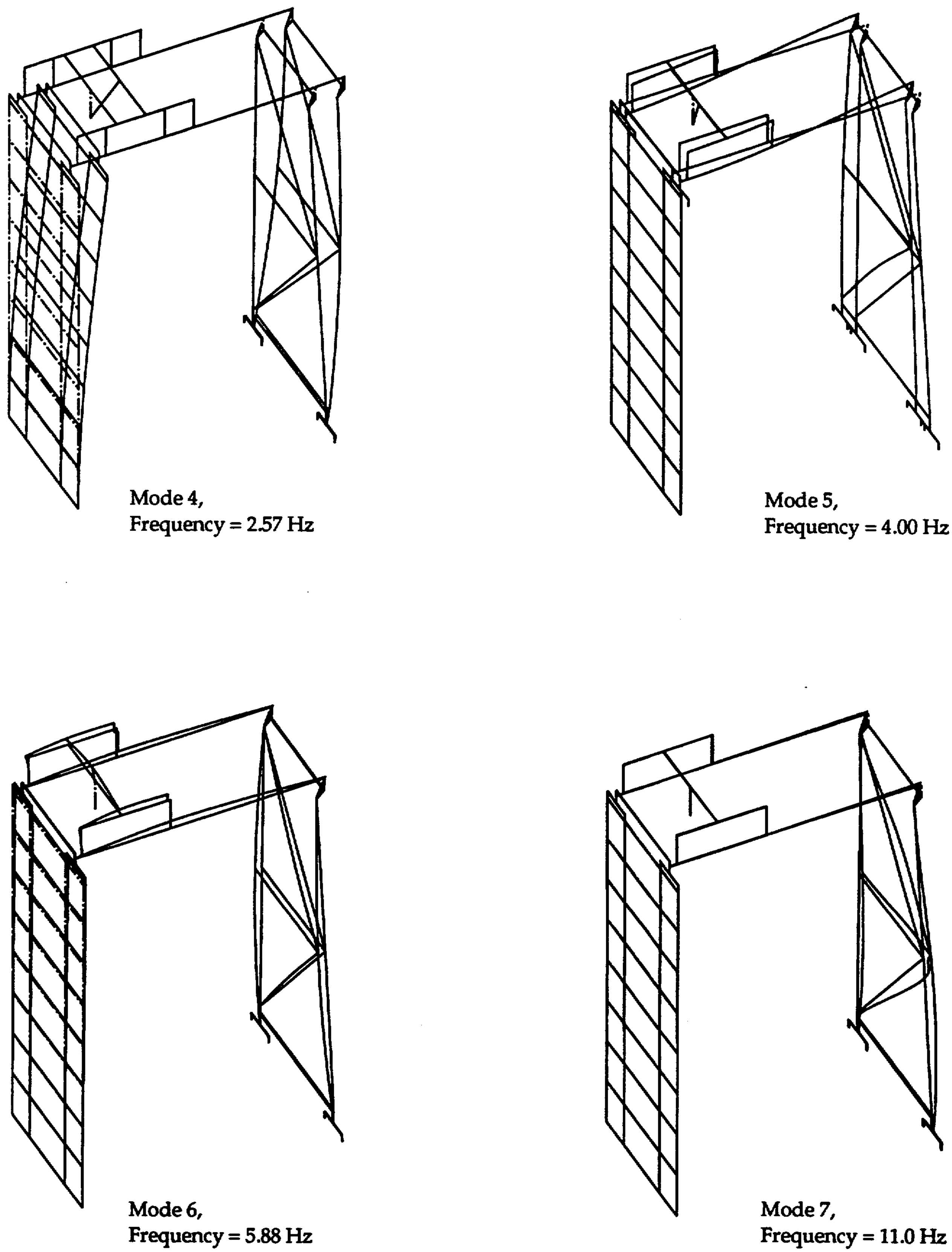


Figure 4-8. Trolley at West End, 150 Ton Load, Hook up, Fundamental Modes 4-7

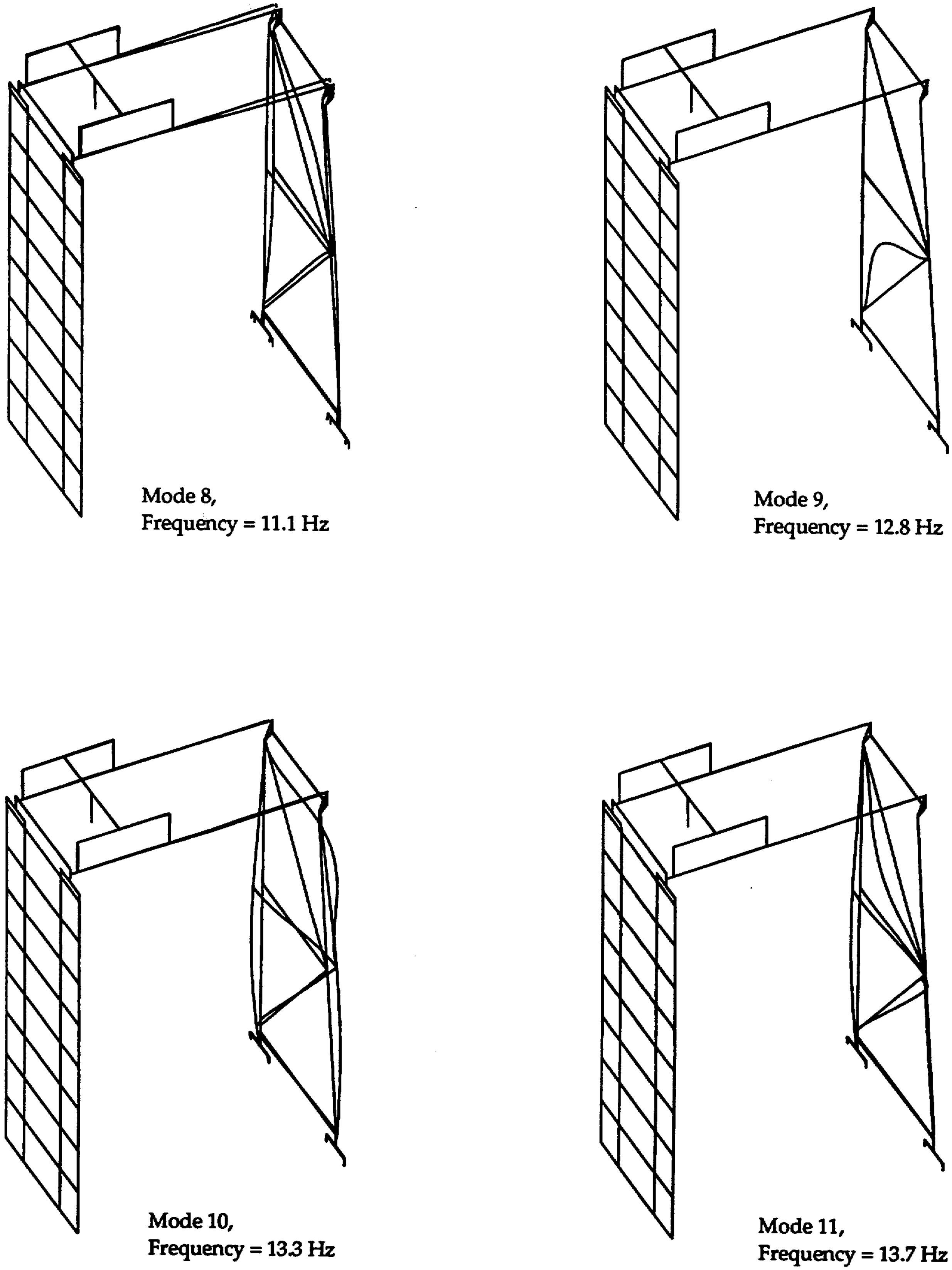


Figure 4-9. Trolley at West End, 150 Ton Load, Hook up, Fundamental Modes 8-11

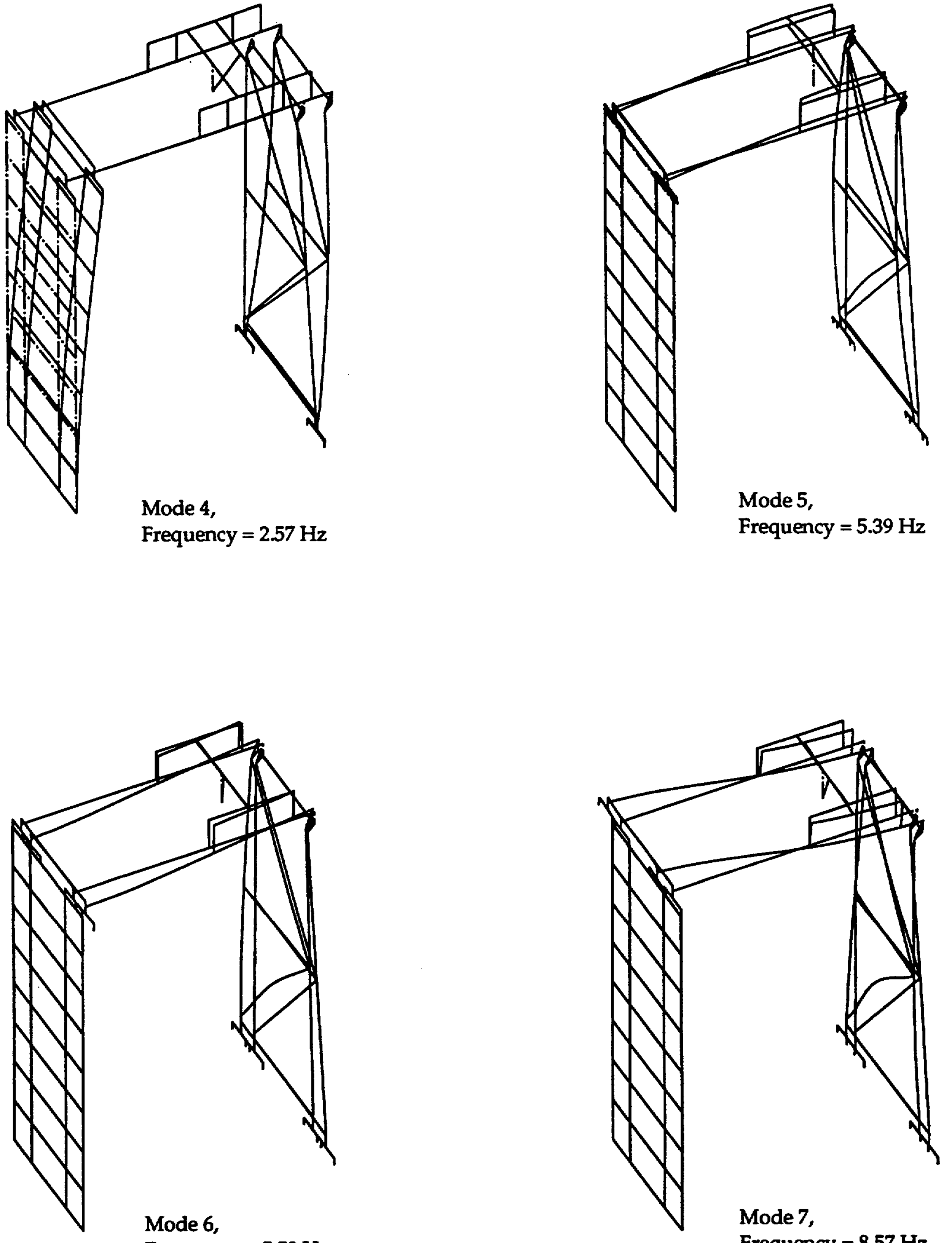
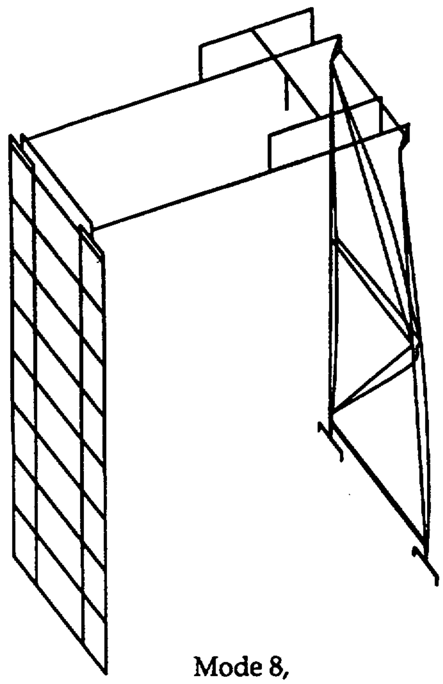
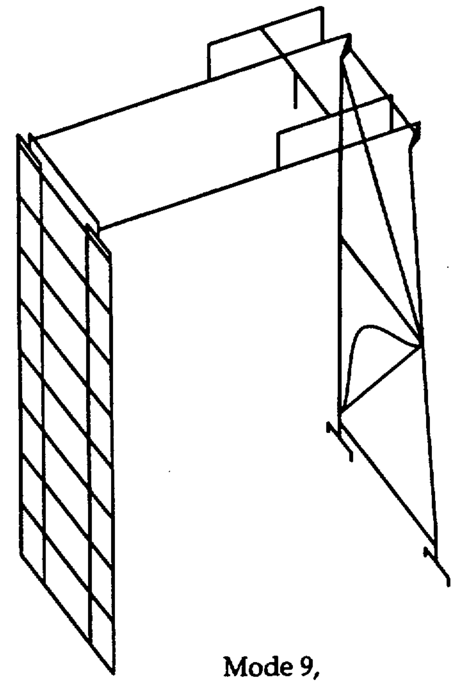


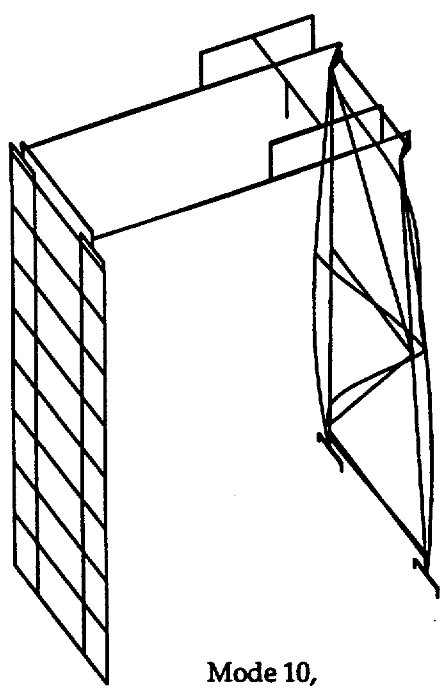
Figure 4-10. Trolley at Quarter Span, 150 Ton Load, Hook up, Fundamental Modes 4-7



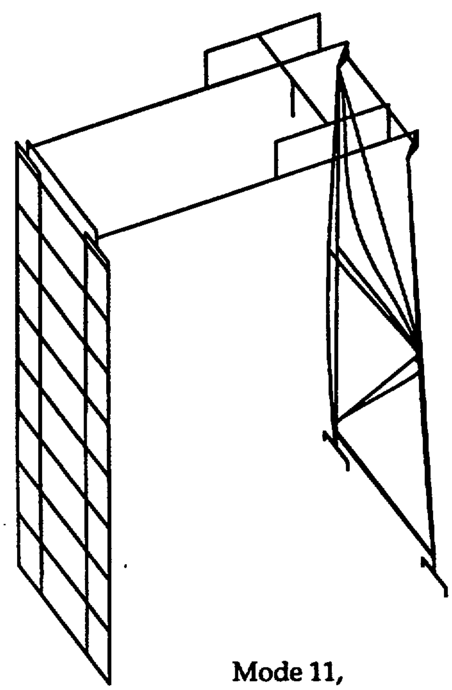
Mode 8,
Frequency = 11.0 Hz



Mode 9,
Frequency = 12.8 Hz

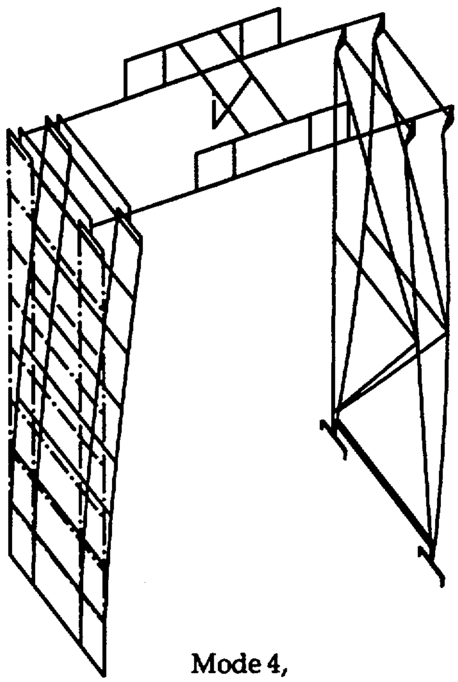


Mode 10,
Frequency = 13.2 Hz

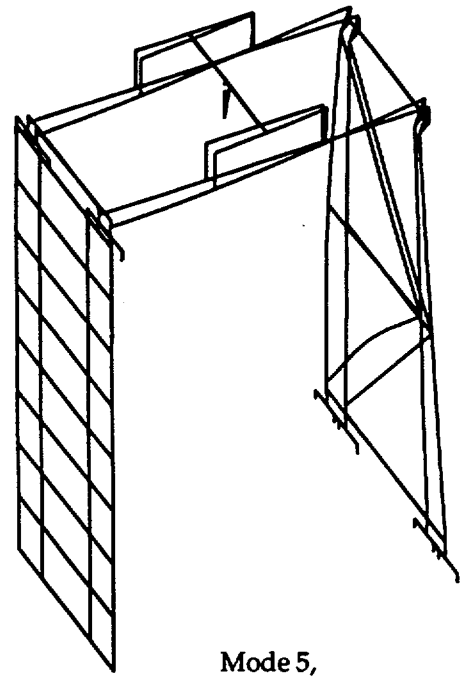


Mode 11,
Frequency = 13.7 Hz

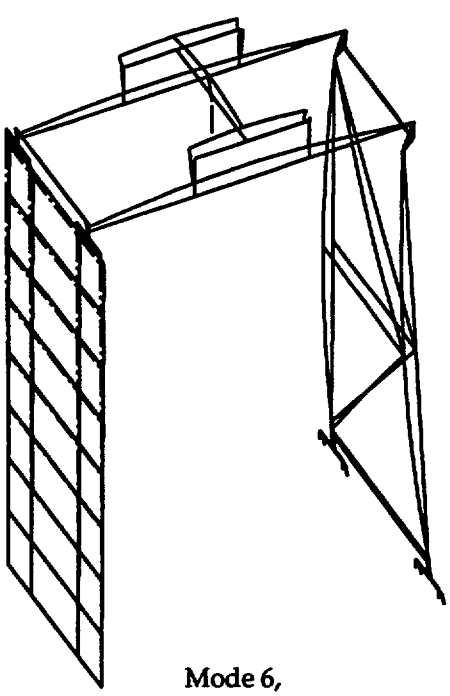
Figure 4-11. Trolley at Quarter Span, 150 Ton Load, Hook up, Fundamental Modes 8-11



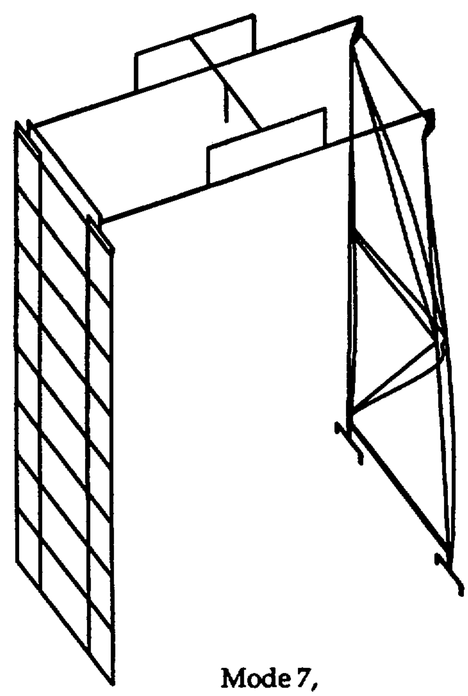
Mode 4,
Frequency = 2.57 Hz



Mode 5,
Frequency = 5.08 Hz



Mode 6,
Frequency = 5.25 Hz



Mode 7,
Frequency = 11.1 Hz

Figure 4-12. Trolley at Mid Span, 150 Ton Load, Hook up, Fundamental Modes 4-7

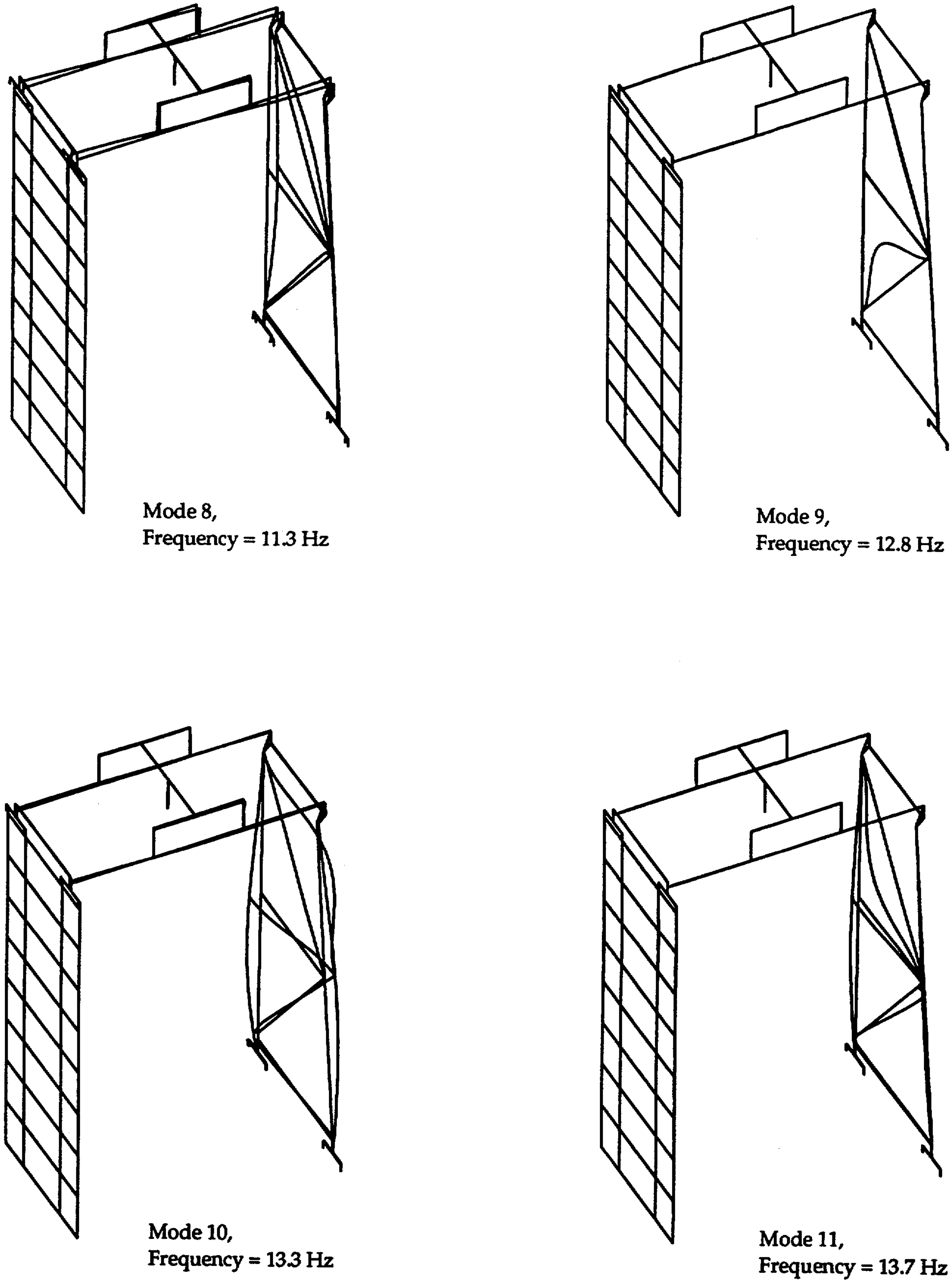
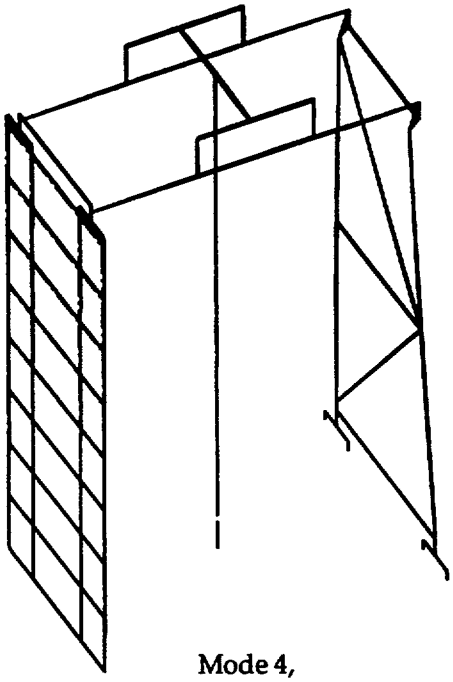
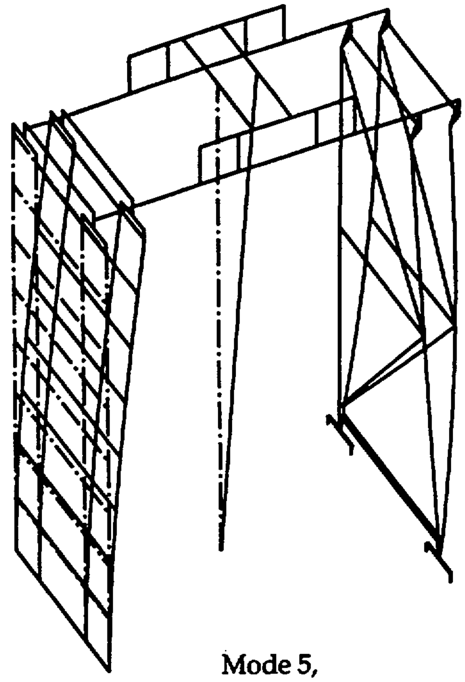


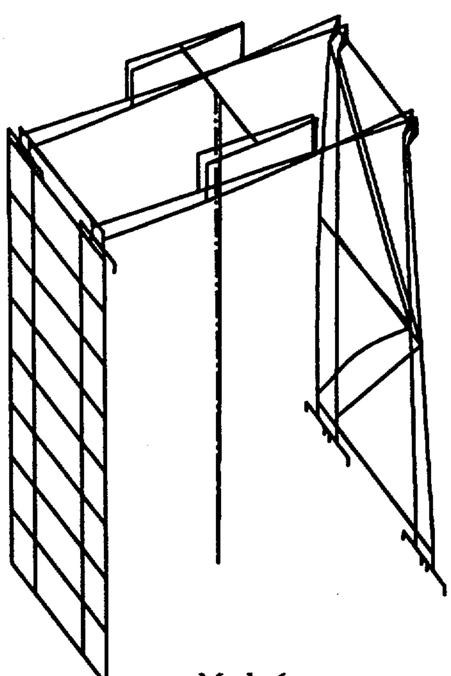
Figure 4-13. Trolley at Mid Span, 150 Ton Load, Hook up, Fundamental Modes 8-11



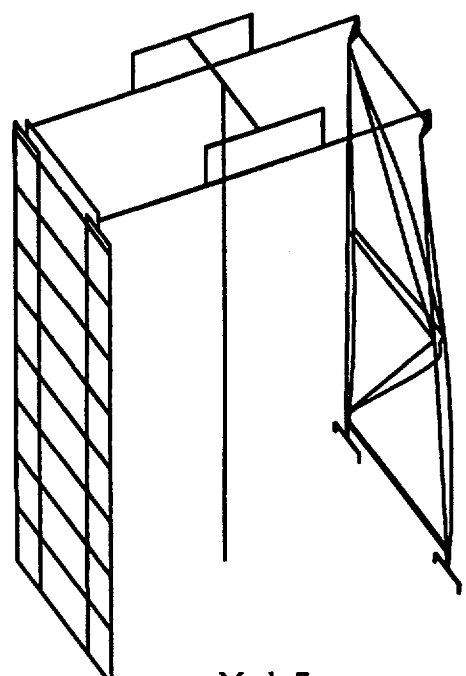
Mode 4,
Frequency = 2.35 Hz



Mode 5,
Frequency = 2.58 Hz



Mode 6,
Frequency = 5.09 Hz



Mode 7,
Frequency = 10.9 Hz

Figure 4-14. Trolley at Mid Span, 150 Ton Load, Hook Down, Fundamental Modes 4-7

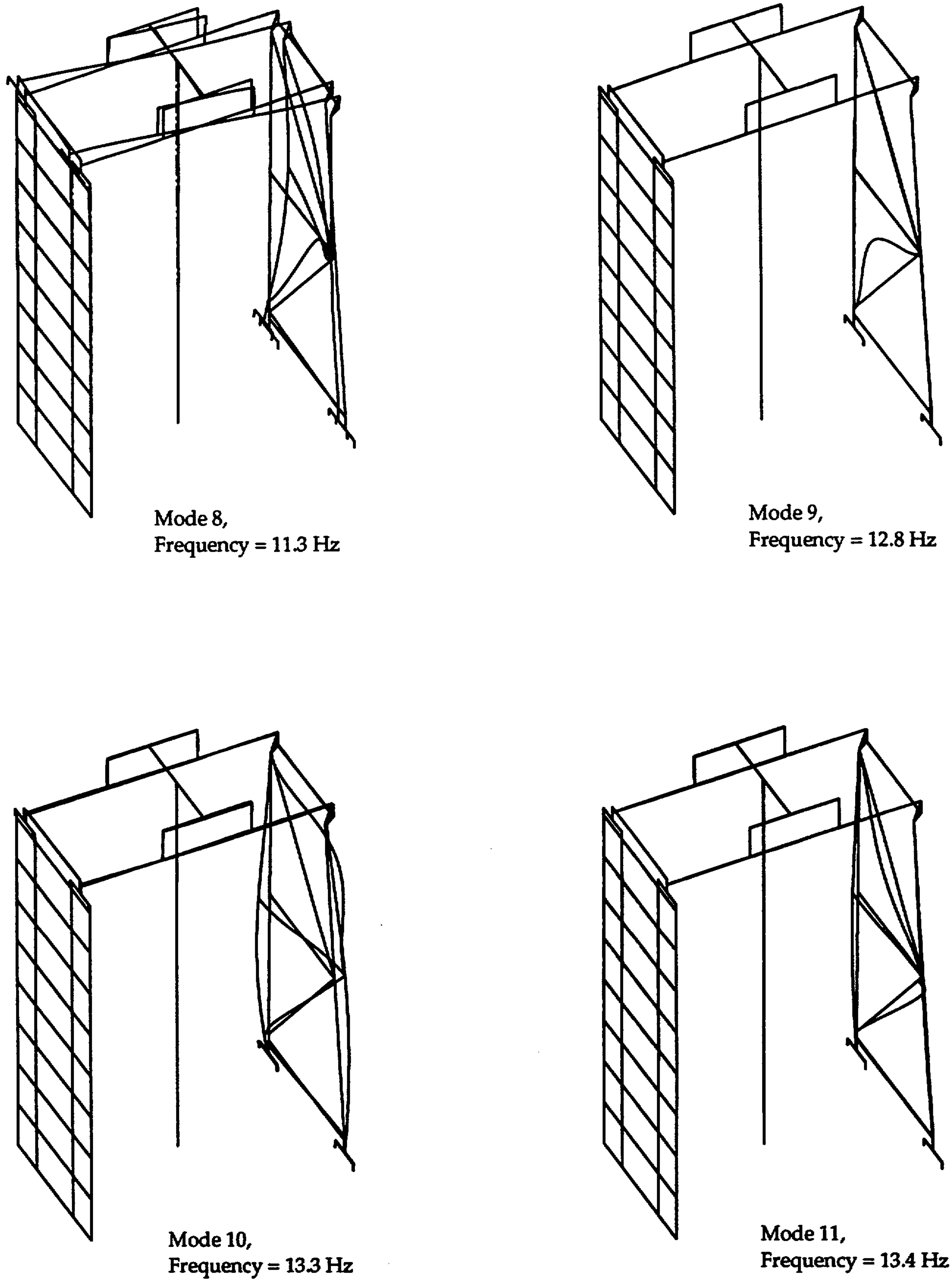


Figure 4-15. Trolley at Mid Span, 150 Ton Load, Hook Down, Fundamental Modes 8-11

5

SUMMARY AND CONCLUSIONS

A seismic qualification is carried out for the 150 ton semi-gantry crane in accordance with ASME NOG-1 and Stone and Webster Specification 0599602-M001. A support wall model is developed so that the 100' east-west response spectrum applied at the base of the wall will amplify to the acceleration spectrum given for the 170' elevation. The 170' elevation spectrum is used for the vertical component. Maximum response is calculated for the major structural components through response spectrum analyses using the acceleration response spectra for the crane elevation at the PFSF site. The response spectrum analysis uses the vertical and east-west horizontal seismic loads. A wheel slip condition is used to account for the north-south seismic component. These seismic stresses are combined through SRSS and added algebraically to the static stresses from gravity. The initial section sizing described in Section 3 is modified. Section 4 describes the adjusted section sizing and presents tables of maximum response for the structural members for all trolley positions and load cases. Using the adjusted section sizing, all calculated normal and shear stresses for all components are within allowables as defined in ASME NOG-1. A slack rope condition does not occur for any of the load combinations.

The response of the semi-gantry crane is found to be somewhat sensitive to the stiffness of the end tie connecting the bridge girders and the tops of the gantry legs. While the final sizing used for the end ties results in relatively low stresses in the end tie, use of smaller flanges and webs in the end tie will cause higher stresses in other crane structural members leading to over-stressed conditions. The stiffness of the final section sizing of the end tie is needed in the current crane configuration to limit stresses in other critical components.

Table 5-1 summarizes all the section forces for each structural component for the load combination causing the maximum stress in the component. For the specified load case, the location in the structural component is found where the peak stress occurs. All section forces in the component at this location for that load combination is extracted and summarized in the table. The Static values refer to section forces developed under gravity load. The Dynamic values report section forces developed from response spectra calculations considering vertical and east-west horizontal seismic load. The Wheel Slip values are section forces developed due to north-south horizontal seismic load in which slipping between the bridge truck wheels and the rails occur. Note that the total or Combined values for each section force is developed based on SRSS methods for the seismic components. Thus, the Combined section force values are valid for each section force type but cannot be used to compute total section stress through addition because of the nonlinear SRSS combinations. The identified section forces are consistent, that is they occur at the same place and combine to give the highest stresses in that component. They do not necessarily occur at the same time since they are extracted from the response spectra analysis that determined maximum values from the modal and component combinations. However, for subsequent detailed design in Phase II, such as sizing of stiffeners for buckling requirements, these section forces for each component represent the seismic requirements.

Revision D of Ederer drawing PA-2190, illustrated as Figure 5-1, and Revision B of Ederer drawing D-36979, illustrated as Figure 5-2, show the final dimensioning consistent with the revised section sizing used in the seismic qualification analysis.

Table 5-1. Maximum Responses For 150 Ton Semi-Gantry Crane Section Forces and Moments At High Stress Areas

Member	Loading	Axial Force (kips)	Lateral Force (kips)	Vertical Force (kips)	Vertical Moment (kip-ft)	Lateral Moment (kip-ft)	Twisting Moment (kip-ft)
Bridge Girder	Static	-4.2	0.0	6.5	-1205.3	19.9	-2.3
	Dynamic	119.7	9.9	85.5	3457.5	149.8	79.0
	Wheel Slip	28.1	-43.3	9.8	-93.3	-327.9	107.2
	Combined	127.1	44.4	92.6	4664.1	380.4	135.4
Equalizing Sill	Static	12.4	0.0	-6.9	32.7	0.0	-0.2
	Dynamic	14.7	11.1	4.3	64.4	49.4	9.2
	Wheel Slip	-41.9	11.2	-11.7	123.2	82.3	0.5
	Combined	56.8	15.7	19.3	171.7	96.0	9.4
Trolley Truck*	Static	0.0	4.9	78.8	-511.3	31.7	6.4
	Dynamic	77.2	48.9	240.5	1472.5	326.0	64.0
	Wheel Slip	23.5	-23.4	5.9	1.3	152.8	-42.9
	Combined	80.7	59.1	319.3	1983.8	391.8	83.4
Trolley Girder**	Static	-8.5	-0.6	-160.3	-882.1	-8.2	0.5
	Dynamic	26.9	56.2	502.4	2724.7	282.9	9.5
	Wheel Slip	13.6	23.5	-5.6	-33.0	-168.4	-5.8
	Combined	38.7	61.5	662.8	3607.0	337.5	11.7
Bridge Truck	Static	0.0	-6.5	88.0	-206.9	-15.0	-7.4
	Dynamic	1.5	203.3	222.2	516.7	487.6	247.9
	Wheel Slip	-56.3	40.9	-42.4	-32.0	-95.0	46.9
	Combined	56.3	213.9	314.2	724.5	511.8	259.7
End Tie	Static	-0.6	-0.1	3.7	34.2	-5.0	0.3
	Dynamic	29.6	26.7	33.2	296.6	198.4	3.7
	Wheel Slip	17.6	3.8	-16.6	-120.8	-28.0	-2.1
	Combined	35.1	27.1	40.8	354.5	205.4	4.5

Member	Loading	Axial Force (kips)	Major Axis Force (kips)	Minor Axis Force (kips)	Major Axis Moment (kip-ft)	Minor Axis Moment (kip-ft)	Twisting Moment (kip-ft)
Gantry Leg	Static	-184.0	-2.0	-0.9	-19.7	-19.3	-0.1
	Dynamic	547.7	4.5	27.8	1123.8	68.1	29.5
	Wheel Slip	-126.8	-0.1	0.5	-8.0	22.1	-3.7
	Combined	746.2	6.6	28.8	1143.5	90.9	29.9
Gantry Truss	Static	-2.6	0.0	0.4	-1.8	0.1	0.0
	Dynamic	6.8	5.8	1.0	5.8	31.0	2.0
	Wheel Slip	70.7	0.0	-0.4	-2.2	0.1	0.0
	Combined	73.6	5.9	1.5	8.0	31.1	2.0

*Vertical bending moment reduced by 9% for load reacted by drum to trolley wheels.

**Vertical bending moment reduced by 25% for load reacted by drum to trolley wheels.

Note that the Combined values for each section force is developed based on SRSS methods for the seismic components. The Combined values are valid for each section force type but should not be used to develop total section stress through addition.

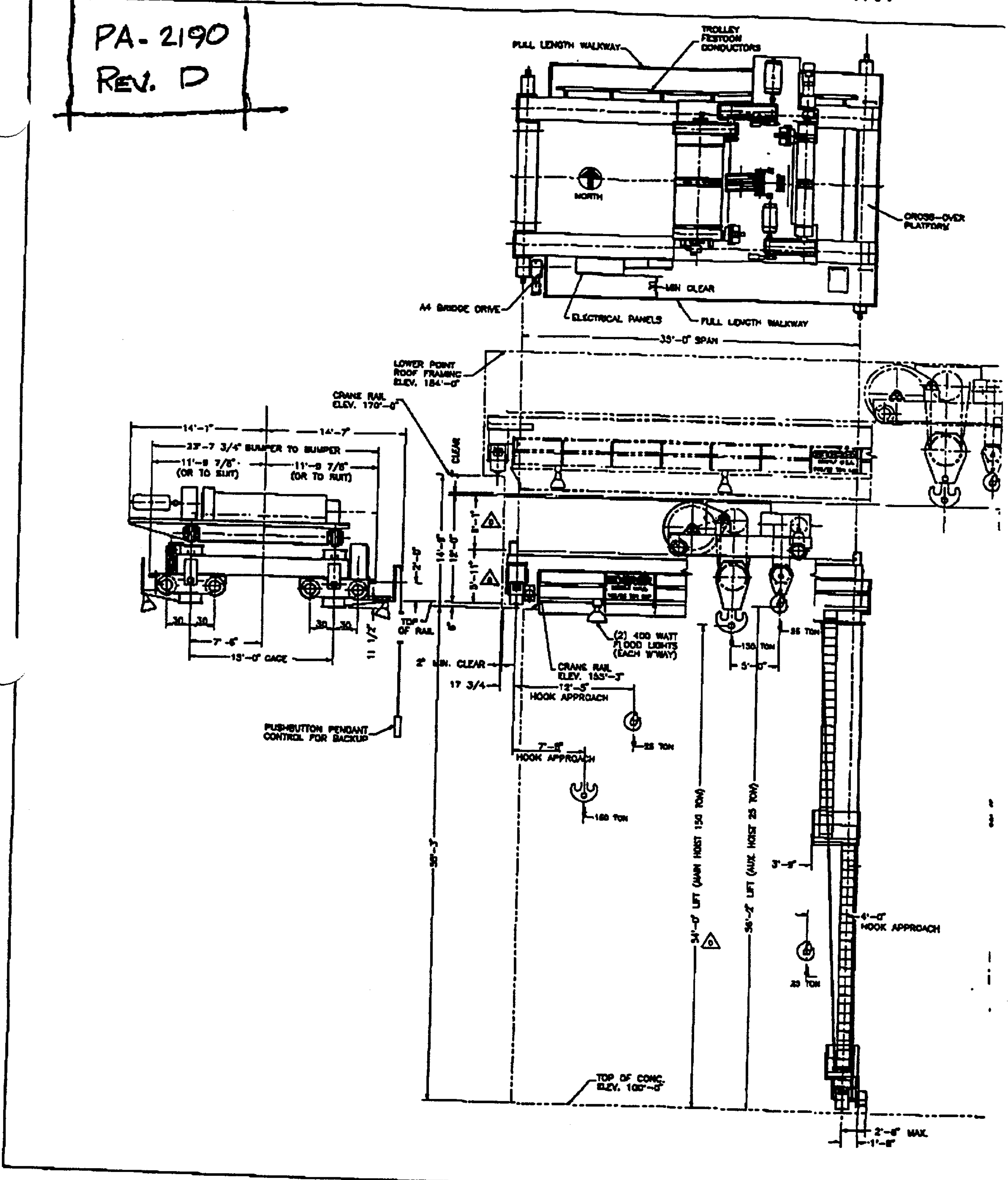


Figure 5-1. Final Dimensioning for Clearance Drawing PA-2190, Revision D

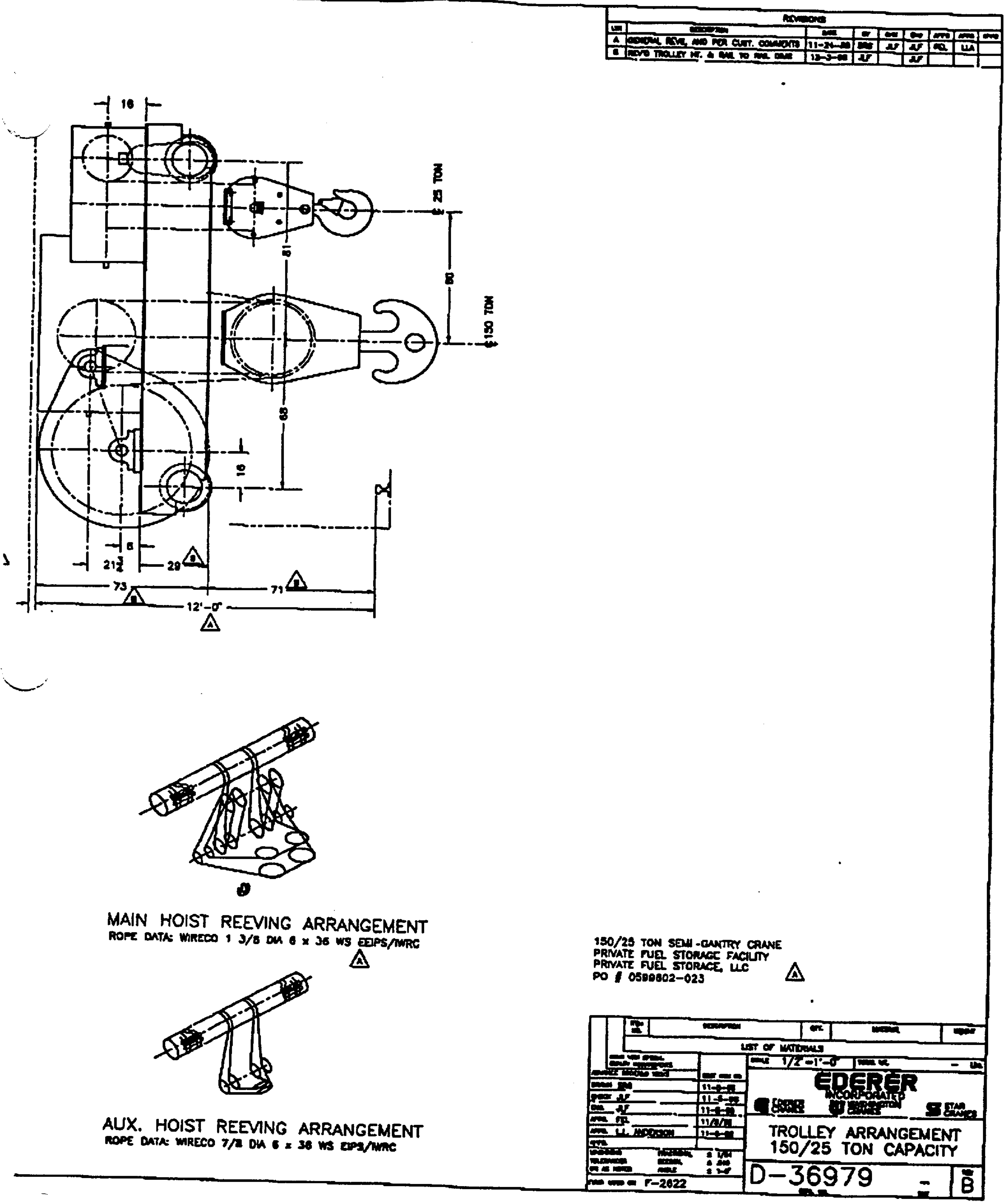


Figure 5-2. Final Dimensioning for Trolley Arrangement Drawing D-36979, Revision B

6

REFERENCES

1. "Rules for Construction of Overhead and Gantry Cranes," American National Standard, ASME NOG-1-1995, June 1995.

2. "Procurement Specification for Overhead Bridge Crane and Semi-Gantry Crane," Specification No 0599602-M001 (Rev 0), Stone and Webster as Engineer for Private Fuel Storage, LLC, June 29, 1998.

3. "Combining Modal Responses and Spatial Components in Seismic Response Analysis," U. S. Nuclear Regulatory Commission, Regulatory Guide 1.92, Revision 1, Feb. 1976.

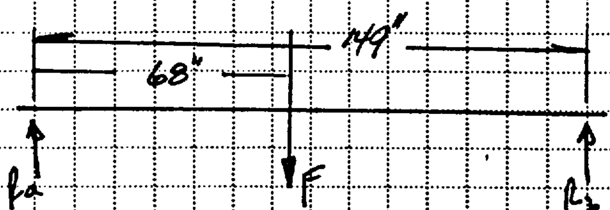
4. ABAQUS/Standard, Version 5.7, User Manual, Example Problem Manual, and Theory Manual, Hibbitt, Karlsson, & Sorensen, Inc., Pawtucket, RI, 1997.

APPENDIX A

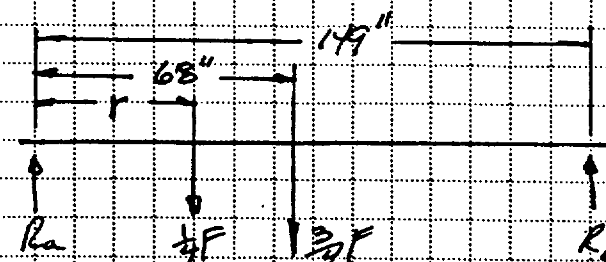
Determine Factor for Calculated Moments due to load reacted by hoist drum.

Ref: Ederer drwg D-36979 for Trolley Arrangement.

As modeled



Actual



Calculated Moment as modeled:

$R_b = \frac{68}{149} F = .456F$

$M_m = 68 \cdot F - (.456)(68)F = \underline{36.99 F}$

$r = \frac{1}{2}(\text{drum dia}) + 16'' \text{ offset}$
$= \frac{59}{2} + 16 = 45.5''$

"Actual" Moment:

$\Sigma M_{Ra}: \quad 149 R_b = 45.5(\frac{1}{4}F) + 68(\frac{3}{4}F) \qquad R_b = .42 F$

$M_a = 45.5(\frac{1}{4}F) + 68(\frac{3}{4}F) - (.42)(68)F = 33.82 F$

$\therefore$ Ratio $\frac{M_a}{M_m} = \frac{33.82}{36.99} = \boxed{.91}$

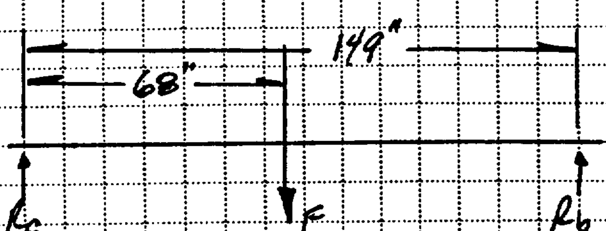
$\frac{33.909}{36.966} = \boxed{0.917}$ FW

EMB

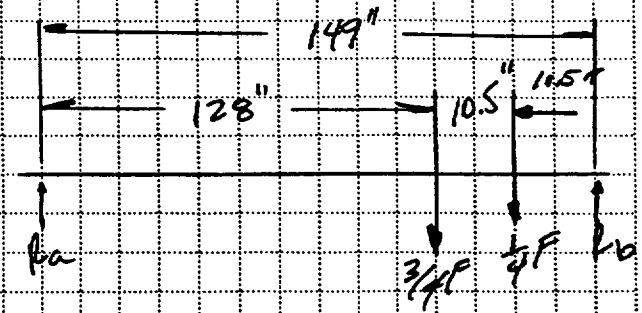
Determine Factor on Calculated Moments due to hoist offset and loads reacted by hoist drum:

Ref: Ederer drwg: D-36979 for Trolley Arrangement

As Modeled



"Actual"

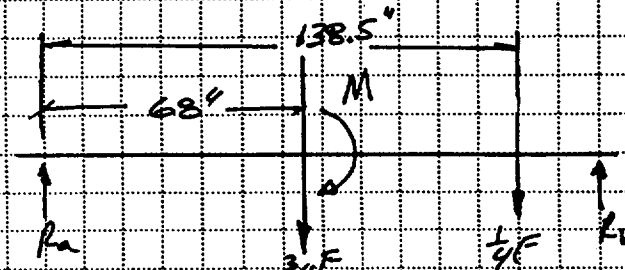


As Calculated Moment:

$R_b = \frac{68}{149} F = .456 F$

$M_M = 68F - 68(.456F) = 36.99 F$

"Actual" Moment:



$R_b(149) = 68(\frac{3}{4}F) + 138.5(\frac{1}{4}F) + 45F$

$R_b = .88 F$

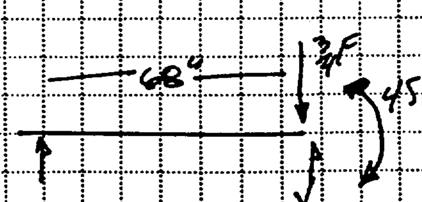
Auxiliary Hoist Offset applies moment to trolley truck through load girt:

$M = (128 - 68)\frac{3}{4}F = 45F$

$M_a = 68(\frac{3}{4}F) + 45F - (.63)F(68)$

$= 53.16 F$

Ratio $\frac{M_a}{M_M} = \frac{53.16}{36.99} =$ ~~1.49~~ 1.437



$V = \frac{3}{4}F - .12F = .63F$

E129

Table A-1. Maximum Stresses For 150 Ton Semi-Gantry Crane
Trolley At East End, Main Hoist Hook Up, 150 Ton Load
Wall At West End, Xbc East Fixed, Shock Input At 100'-0"

Member	Component	Static (psi)	Dynamic (psi)	Wheel Slip (psi)	Combined (psi)	% Allowable
Bridge Girder	Normal Stress	6106	12948	14182	25309	74.0
	Horizontal Shear	47	206	802	876	4.6
	Vertical Shear	1563	3729	209	5297	27.9
Equalizing Sill	Normal Stress	1424	2661	28668	30215	88.3
	Horizontal Shear	0	259	666	715	3.8
	Vertical Shear	107	94	1238	1348	7.1
Trolley Truck*	Normal Stress	15159	36089	10143	52645	153.9
	Horizontal Shear	50	243	944	1024	5.4
	Vertical Shear	1442	3212	147	4657	24.5
Trolley Girder**	Normal Stress	8843	22131	4423	31411	91.8
	Horizontal Shear	3	654	357	747	3.9
	Vertical Shear	1243	3028	74	4272	22.5
Bridge Truck	Normal Stress	5038	15358	13116	25234	73.8
	Horizontal Shear	44	2472	2160	3327	17.5
	Vertical Shear	1015	2214	1796	3867	20.4
End Tie	Normal Stress	1392	4892	15863	17992	52.6
	Horizontal Shear	3	151	413	443	2.3
	Vertical Shear	78	252	931	1043	5.5
Gantry Leg***	Normal Stress	5978	25823	6300	32558	95.2
	Lateral Shear	56	171	143	279	1.5
	Longitudinal Shear	80	851	46	933	4.9
Gantry Trusses	Normal Stress	2087	9865	17554	22223	65.0
	Horizontal Shear	1	263	3	264	1.4
	Vertical Shear	33	57	69	123	0.6

*Normal stress reduced by 12.5% for load reacted by drum to trolley wheels.
**Normal stress reduced by 25% for load reacted by drum to trolley wheels.
***Shear stress calculated using smallest cross-sectional area of leg.

Member	Component	Static (lbs)	Dynamic (lbs)	Wheel Slip (lbs)	Combined (lbs)
Rope Force	Axial Force	19461	3110	0	22570
Truck Pins	Axial Force	499	411630	86901	421202
	Horizontal Force	373	3409	177022	177428
	Vertical Force	176420	396220	242697	641062
Trolley Wheels	Longitudinal Force	358	241240	49863	246697
	Lateral Force	3778	18246	71762	77824
	Vertical Force	109070	242320	11046	351642
Bridge Wheels	Longitudinal Force	3923	222230	193335	298481
	Lateral Force	71896	0	160122	232018
	Vertical Force	91076	198190	160787	346285
Girder-to-Sill	Longitudinal Force	5129	403250	63310	413319
	Lateral Force	2209	10998	83321	86252
	Vertical Force	71852	164740	21622	238005
End-Tie-to-Girder	Longitudinal Force	5186	128950	6155	134283
	Lateral Force	4042	11134	43388	48836
	Vertical Force	91529	210060	17747	302337

Table A-2. Maximum Stresses For 150 Ton Semi-Gantry Crane
Trolley At 1/4-Span, Main Hoist Hook Up, 150 Ton Load
Wall At West End, Xbc East Fixed, Shock Input At 100'-0"

Member	Component	Static (psi)	Dynamic (psi)	Wheel Slip (psi)	Combined (psi)	% Allowable
Bridge Girder	Normal Stress	6106	13045	14084	25303	74.0
	Horizontal Shear	47	185	797	865	4.6
	Vertical Shear	1563	3513	207	5082	26.7
Equalizing Sill	Normal Stress	1424	2456	28471	30000	87.7
	Horizontal Shear	0	258	661	710	3.7
	Vertical Shear	107	84	1229	1339	7.0
Trolley Truck*	Normal Stress	15159	36044	10074	52584	153.8
	Horizontal Shear	50	241	937	1018	5.4
	Vertical Shear	1442	3219	146	4664	24.5
Trolley Girder**	Normal Stress	8843	22119	4393	31393	91.8
	Horizontal Shear	3	654	355	746	3.9
	Vertical Shear	1243	3032	74	4276	22.5
Bridge Truck	Normal Stress	5038	15503	13026	25287	73.9
	Horizontal Shear	44	2464	2145	3311	17.4
	Vertical Shear	1015	2085	1784	3760	19.8
End Tie	Normal Stress	1392	4566	15754	17794	52.0
	Horizontal Shear	3	153	411	441	2.3
	Vertical Shear	78	215	925	1028	5.4
Gantry Leg***	Normal Stress	5978	25934	6256	32656	95.5
	Lateral Shear	56	154	142	266	1.4
	Longitudinal Shear	80	857	45	938	4.9
Gantry Trusses	Normal Stress	2087	9897	17433	22134	64.7
	Horizontal Shear	1	264	3	265	1.4
	Vertical Shear	33	44	68	114	0.6

*Normal stress reduced by 12.5% for load reacted by drum to trolley wheels.
**Normal stress reduced by 25% for load reacted by drum to trolley wheels.
***Shear stress calculated using smallest cross-sectional area of leg.

Member	Component	Static (lbs)	Dynamic (lbs)	Wheel Slip (lbs)	Combined (lbs)
Rope Force	Axial Force	19461	3112	0	22573
Truck Pins	Axial Force	499	411310	86304	420766
	Horizontal Force	373	2638	175807	176200
	Vertical Force	176420	373080	241030	620587
Trolley Wheels	Longitudinal Force	358	241040	49521	246432
	Lateral Force	3778	18058	71269	77300
	Vertical Force	109070	242890	10970	352208
Bridge Wheels	Longitudinal Force	3923	221510	192007	297067
	Lateral Force	71896	0	159023	230919
	Vertical Force	91076	186630	159683	336696
Girder-to-Sill	Longitudinal Force	5129	402920	62876	412925
	Lateral Force	2209	9665	82749	85520
	Vertical Force	71852	172810	21474	245991
End-Tie-to-Girder	Longitudinal Force	5186	121240	6113	126580
	Lateral Force	4042	10479	43090	48388
	Vertical Force	91529	198620	17626	290930

Table A-3. Maximum Stresses For 150 Ton Semi-Gantry Crane
Trolley At Mid-Span, Main Hoist Hook Up, 150 Ton Load
Wall At West End, Xbc East Fixed, Shock Input At 100'-0"

Member	Component	Static (psi)	Dynamic (psi)	Wheel Slip (psi)	Combined (psi)	% Allowable
Bridge Girder	Normal Stress	6442	14435	12478	25523	74.6
	Horizontal Shear	34	119	944	985	5.2
	Vertical Shear	1155	2601	222	3765	19.8
Equalizing Sill	Normal Stress	1100	2509	29573	30779	90.0
	Horizontal Shear	0	257	552	609	3.2
	Vertical Shear	96	72	1415	1513	8.0
Trolley Truck*	Normal Stress	14940	35893	10412	52312	153.0
	Horizontal Shear	43	209	971	1036	5.5
	Vertical Shear	1441	3210	142	4654	24.5
Trolley Girder**	Normal Stress	8801	22144	4624	31422	91.9
	Horizontal Shear	1	655	369	754	4.0
	Vertical Shear	1243	3031	73	4275	22.5
Bridge Truck	Normal Stress	3779	16413	11926	24068	70.4
	Horizontal Shear	52	2450	1927	3169	16.7
	Vertical Shear	745	1554	1309	2777	14.6
End Tie	Normal Stress	1067	3871	11012	12739	37.2
	Horizontal Shear	3	163	213	272	1.4
	Vertical Shear	63	147	682	761	4.0
Gantry Leg***	Normal Stress	4297	25815	4455	30494	89.2
	Lateral Shear	40	120	118	209	1.1
	Longitudinal Shear	58	877	35	936	4.9
Gantry Trusses	Normal Stress	1900	9940	13670	18802	55.0
	Horizontal Shear	1	265	2	266	1.4
	Vertical Shear	33	46	67	114	0.6

*Normal stress reduced by 12.5% for load reacted by drum to trolley wheels.
**Normal stress reduced by 25% for load reacted by drum to trolley wheels.
***Shear stress calculated using smallest cross-sectional area of leg.

Member	Component	Static (lbs)	Dynamic (lbs)	Wheel Slip (lbs)	Combined (lbs)
Rope Force	Axial Force	19461	3108	0	22568
Truck Pins	Axial Force	304	410650	77549	418212
	Horizontal Force	249	2141	197065	197326
	Vertical Force	128130	278090	171841	455030
Trolley Wheels	Longitudinal Force	179	241400	51531	247017
	Lateral Force	3268	15741	73803	78731
	Vertical Force	109010	242150	10694	351396
Bridge Wheels	Longitudinal Force	4677	220210	172473	284390
	Lateral Force	52603	0	131968	184571
	Vertical Force	66889	139120	117128	248750
Girder-to-Sill	Longitudinal Force	3627	402240	57978	410024
	Lateral Force	3522	9851	97958	101974
	Vertical Force	119710	256990	22990	377726
End-Tie-to-Girder	Longitudinal Force	3659	89318	3808	93058
	Lateral Force	3166	8973	29783	34271
	Vertical Force	64359	150890	10631	215623

Table A-4. Maximum Stresses For 150 Ton Semi-Gantry Crane
Trolley At West End, Main Hoist Hook Up, 150 Ton Load
Wall At West End, Xbc East Fixed, Shock Input At 100'-0"

Member	Component	Static (psi)	Dynamic (psi)	Wheel Slip (psi)	Combined (psi)	% Allowable
Bridge Girder	Normal Stress	4789	14382	7846	21172	61.9
	Horizontal Shear	61	156	1158	1229	6.5
	Vertical Shear	1732	3774	206	5511	29.0
Equalizing Sill	Normal Stress	1117	3090	29183	30464	89.1
	Horizontal Shear	0	254	307	399	2.1
	Vertical Shear	84	56	1663	1748	9.2
Trolley Truck*	Normal Stress	15061	37177	10114	53589	156.7
	Horizontal Shear	58	213	956	1038	5.5
	Vertical Shear	1442	3317	112	4761	25.1
Trolley Girder**	Normal Stress	8845	23508	3958	32684	95.6
	Horizontal Shear	0	660	274	715	3.8
	Vertical Shear	1243	3190	75	4434	23.3
Bridge Truck	Normal Stress	5409	18300	9350	25959	75.9
	Horizontal Shear	36	2536	1266	2870	15.1
	Vertical Shear	1041	2184	1251	3558	18.7
End Tie	Normal Stress	673	1448	9228	10014	29.3
	Horizontal Shear	3	135	238	277	1.5
	Vertical Shear	45	76	511	562	3.0
Gantry Leg***	Normal Stress	2266	25099	3584	27620	80.8
	Lateral Shear	26	80	117	168	0.9
	Longitudinal Shear	30	884	27	914	4.8
Gantry Trusses	Normal Stress	1669	9945	11782	17087	50.0
	Horizontal Shear	1	265	1	266	1.4
	Vertical Shear	32	58	69	123	0.6

*Normal stress reduced by 12.5% for load reacted by drum to trolley wheels.
**Normal stress reduced by 25% for load reacted by drum to trolley wheels.
***Shear stress calculated using smallest cross-sectional area of leg.

Member	Component	Static (lbs)	Dynamic (lbs)	Wheel Slip (lbs)	Combined (lbs)
Rope Force	Axial Force	19461	3295	0	22756
Truck Pins	Axial Force	87	410840	56746	414828
	Horizontal Force	155	2278	220537	220703
	Vertical Force	181090	390730	133961	594146
Trolley Wheels	Longitudinal Force	34	242640	38277	245675
	Lateral Force	4388	15775	72724	78803
	Vertical Force	109090	250080	8478	359314
Bridge Wheels	Longitudinal Force	3198	227910	113319	257725
	Lateral Force	73648	0	146688	220336
	Vertical Force	93343	195510	112000	318661
Girder-to-Sill	Longitudinal Force	1735	402350	45864	406691
	Lateral Force	6320	16104	120119	127514
	Vertical Force	179420	390630	21282	570629
End-Tie-to-Girder	Longitudinal Force	1748	51527	3767	53412
	Lateral Force	1477	4038	22133	23976
	Vertical Force	30737	96277	7895	127337

Table A-5. Maximum Stresses For 150 Ton Semi-Gantry Crane
Trolley At West End, Main Hoist Hook Up, 150 Ton Load

Member	Component	Static (psi)	Dynamic (psi)	Wheel Slip (psi)	Combined (psi)	% Allowable
Bridge Girder	Normal Stress	4645	12929	2839	17882	52.3
	Horizontal Shear	98	292	470	652	3.4
	Vertical Shear	1698	4281	81	5980	31.5
Equalizing Sill	Normal Stress	1235	4001	9689	11718	34.3
	Horizontal Shear	0	256	132	289	1.5
	Vertical Shear	169	172	428	630	3.3
Trolley Truck*	Normal Stress	9960	28047	3770	38260	111.9
	Horizontal Shear	98	346	409	633	3.3
	Vertical Shear	1440	3824	55	5264	27.7
Trolley Girder**	Normal Stress	8567	26240	1791	34868	102.0
	Horizontal Shear	1	644	135	659	3.5
	Vertical Shear	1241	3680	34	4921	25.9
Bridge Truck	Normal Stress	5735	19880	3804	25976	76.0
	Horizontal Shear	66	2617	492	2729	14.4
	Vertical Shear	1022	2478	534	3557	18.7
End Tie	Normal Stress	649	2465	3555	4975	14.5
	Horizontal Shear	5	146	102	183	1.0
	Vertical Shear	45	94	151	223	1.2
Gantry Leg***	Normal Stress	2628	27580	2087	30287	88.6
	Lateral Shear	34	142	75	195	1.0
	Longitudinal Shear	23	1067	9	1090	5.7
Gantry Trusses	Normal Stress	1184	7229	4388	9641	28.2
	Horizontal Shear	1	360	1	361	1.9
	Vertical Shear	44	143	39	192	1.0

*Normal stress reduced by 12.5% for load reacted by drum to trolley wheels.
**Normal stress reduced by 25% for load reacted by drum to trolley wheels.
***Shear stress calculated using smallest cross-sectional area of leg.

Member	Component	Static (lbs)	Dynamic (lbs)	Wheel Slip (lbs)	Combined (lbs)
Rope Force	Axial Force	19478	3800	0	23277
Truck Pins	Axial Force	2392	427010	26860	430246
	Horizontal Force	278	4871	92419	92825
	Vertical Force	177610	443230	65177	625607
Trolley Wheels	Longitudinal Force	93	240890	18834	241718
	Lateral Force	7352	25938	31091	47842
	Vertical Force	108930	288300	4131	397260
Bridge Wheels	Longitudinal Force	5882	235180	44064	245154
	Lateral Force	72896	0	57554	130450
	Vertical Force	91642	221830	47768	318557
Girder-to-Sill	Longitudinal Force	2814	418420	22173	421821
	Lateral Force	10169	30229	48734	67517
	Vertical Force	175930	443150	8417	619160
End-Tie-to-Girder	Longitudinal Force	2844	42128	1794	45010
	Lateral Force	1568	6698	10873	14338
	Vertical Force	33905	100220	2837	134165

Table A-6. Maximum Stresses For 150 Ton Semi-Gantry Crane
Trolley At 1/4-Span, Main Hoist Hook Up, 150 Ton Load

Member	Component	Static (psi)	Dynamic (psi)	Wheel Slip (psi)	Combined (psi)	% Allowable
Bridge Girder	Normal Stress	5472	16617	6315	23249	68.0
	Horizontal Shear	52	986	381	1109	5.8
	Vertical Shear	1622	4223	82	5846	30.8
Equalizing Sill	Normal Stress	1722	11420	11691	18065	52.8
	Horizontal Shear	2	481	353	599	3.2
	Vertical Shear	193	379	368	721	3.8
Trolley Truck*	Normal Stress	9661	36583	4276	46493	135.9
	Horizontal Shear	52	1098	462	1243	6.5
	Vertical Shear	1440	4013	79	5454	28.7
Trolley Girder**	Normal Stress	8480	26332	2176	34901	102.0
	Horizontal Shear	5	998	183	1019	5.4
	Vertical Shear	1241	3765	40	5006	26.3
Bridge Truck	Normal Stress	5850	24131	6144	30751	89.9
	Horizontal Shear	71	3543	989	3749	19.7
	Vertical Shear	1105	4229	1058	5464	28.8
End Tie	Normal Stress	1358	41125	7240	43115	126.1
	Horizontal Shear	4	1535	161	1548	8.1
	Vertical Shear	79	1591	420	1725	9.1
Gantry Leg***	Normal Stress	5621	30543	4095	36437	106.5
	Lateral Shear	67	417	102	496	2.6
	Longitudinal Shear	16	1039	15	1055	5.6
Gantry Trusses	Normal Stress	1571	22523	7502	25311	74.0
	Horizontal Shear	1	357	4	359	1.9
	Vertical Shear	47	276	46	326	1.7

*Normal stress reduced by 12.5% for load reacted by drum to trolley wheels.
**Normal stress reduced by 25% for load reacted by drum to trolley wheels.
***Shear stress calculated using smallest cross-sectional area of leg.

Member	Component	Static (lbs)	Dynamic (lbs)	Wheel Slip (lbs)	Combined (lbs)
Rope Force	Axial Force	19478	3857	0	23334
Truck Pins	Axial Force	4906	465640	43559	472579
	Horizontal Force	668	21834	84963	88392
	Vertical Force	192310	753620	139730	958774
Trolley Wheels	Longitudinal Force	632	266810	25558	268664
	Lateral Force	3895	82696	35117	93738
	Vertical Force	108950	302880	5949	411888
Bridge Wheels	Longitudinal Force	6312	317850	88492	336251
	Lateral Force	78993	0	95932	174925
	Vertical Force	99118	378470	94720	489261
Girder-to-Sill	Longitudinal Force	6631	452340	31047	460035
	Lateral Force	2296	52183	39548	67772
	Vertical Force	70853	183840	8438	254887
End-Tie-to-Girder	Longitudinal Force	6717	162310	2775	169051
	Lateral Force	4379	107170	26115	114685
	Vertical Force	97378	261690	10161	359265

Table A-7. Maximum Stresses For 150 Ton Semi-Gantry Crane
Trolley At Mid-Span, Main Hoist Hook Up, 150 Ton Load

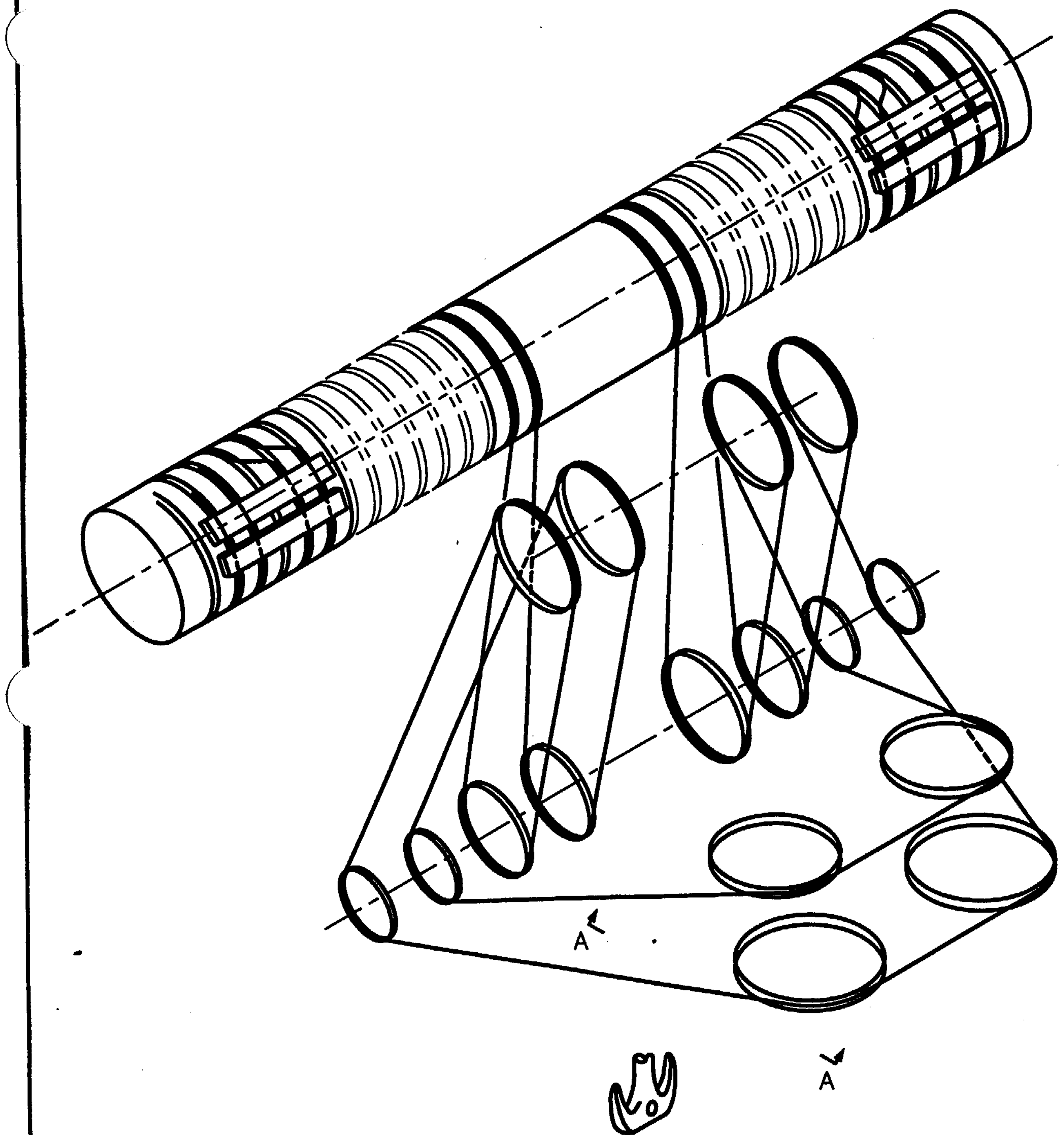
Member	Component	Static (psi)	Dynamic (psi)	Wheel Slip (psi)	Combined (psi)	% Allowable
Bridge Girder	Normal Stress	6136	18297	5031	25112	73.4
	Horizontal Shear	40	270	410	531	2.8
	Vertical Shear	1156	3057	88	4214	22.2
Equalizing Sill	Normal Stress	1400	2799	10980	12731	37.2
	Horizontal Shear	1	263	272	378	2.0
	Vertical Shear	182	124	386	588	3.1
Trolley Truck*	Normal Stress	9534	30615	4124	40425	118.2
	Horizontal Shear	56	381	439	637	3.4
	Vertical Shear	1439	3995	72	5435	28.6
Trolley Girder**	Normal Stress	8480	26342	2138	34909	102.1
	Horizontal Shear	3	663	182	691	3.6
	Vertical Shear	1241	3754	36	4995	26.3
Bridge Truck	Normal Stress	4402	18533	5277	23672	69.2
	Horizontal Shear	82	2558	806	2764	14.5
	Vertical Shear	832	2171	714	3117	16.4
End Tie	Normal Stress	1026	10000	4457	11974	35.0
	Horizontal Shear	5	471	79	483	2.5
	Vertical Shear	64	229	255	407	2.1
Gantry Leg***	Normal Stress	4389	29565	2765	34083	99.7
	Lateral Shear	48	149	83	219	1.2
	Longitudinal Shear	32	1065	11	1098	5.8
Gantry Trusses	Normal Stress	1398	9047	5418	11943	34.9
	Horizontal Shear	1	358	1	359	1.9
	Vertical Shear	45	81	40	136	0.7

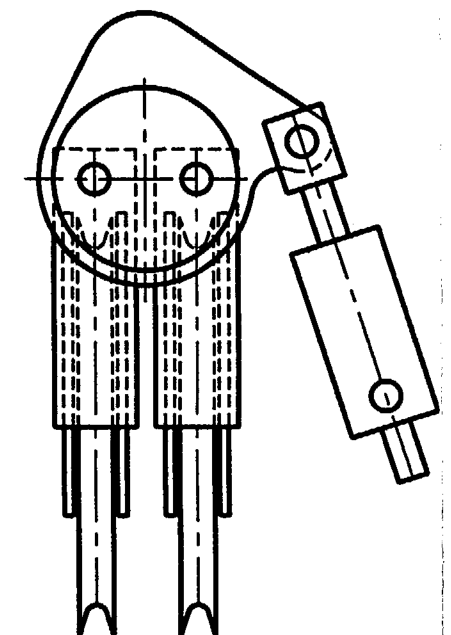
*Normal stress reduced by 12.5% for load reacted by drum to trolley wheels.
**Normal stress reduced by 25% for load reacted by drum to trolley wheels.
***Shear stress calculated using smallest cross-sectional area of leg.

Member	Component	Static (lbs)	Dynamic (lbs)	Wheel Slip (lbs)	Combined (lbs)
Rope Force	Axial Force	19478	3843	0	23321
Truck Pins	Axial Force	4375	429450	37478	435457
	Horizontal Force	475	4956	88589	89202
	Vertical Force	143450	387610	90857	541566
Trolley Wheels	Longitudinal Force	409	241810	25369	243546
	Lateral Force	4203	28710	33364	48219
	Vertical Force	108880	301470	5403	410398
Bridge Wheels	Longitudinal Force	7302	229950	72138	248302
	Lateral Force	59286	0	66154	125440
	Vertical Force	74627	194280	63883	279140
Girder-to-Sill	Longitudinal Force	5375	420800	27857	427096
	Lateral Force	4154	17204	42580	50078
	Vertical Force	113700	301250	9155	415089
End-Tie-to-Girder	Longitudinal Force	5434	102210	1589	107656
	Lateral Force	3444	12681	16168	23992
	Vertical Force	69936	190120	5120	260125

REVISIONS

LTR	DESCRIPTION	DATE	BY	CHK	ENG	APPD	APPD	APPD
A	ADD SECTION AA, & PROJECT DATA	11-5-98	SRS	JLF	JLF	FEL	LA	





A SECTION AA

APERTURE CARD

Also Available on Aperture Card

9902220118-01

150/25 TON SEMI-GANTRY CRANE
PRIVATE FUEL STORAGE FACILITY
PRIVATE FUEL STORAGE, LLC
PO # 0599602-023

REDUNDANT REEVING

TWO INDEPENDENT ROPES REEVED TO PROVIDE A TOTAL OF 16 PARTS. BOTH ENDS ANCHORED TO DRUM.

	ITEM NO.	DESCRIPTION	QTY.	MATERIAL	WEIGHT
C.I.		1 3/8 DIA WIRE ROPE	2	WIRECO 6 X 36 WS (EEIPS/IWRC)	

LIST OF MATERIALS

ITEMS WITH SPECIAL QUALITY REQUIREMENTS	14.4	SCALE NONE	TOTAL WT. LBS.
ADVANCE ORDERED ITEMS	COST ITEM NO.		
DRAWN RRM ESP, Inc.	10-13-98		
CHECK JLF	10-14-98		
ENG. JLF	10-14-98		
APPD. FEL	10-14-98		
APPD. L.L. ANDERSON	10-14-98		
APPD.			
MACHINING TOLERANCES OR AS NOTED	FRACTIONAL ± 1/64; DECIMAL ± .010; ANGLE ± 1-0"		
FIRST USED ON F-2622			

EDERER INCORPORATED

EDERER CRANES — WASHINGTON CRANES — STAR CRANES

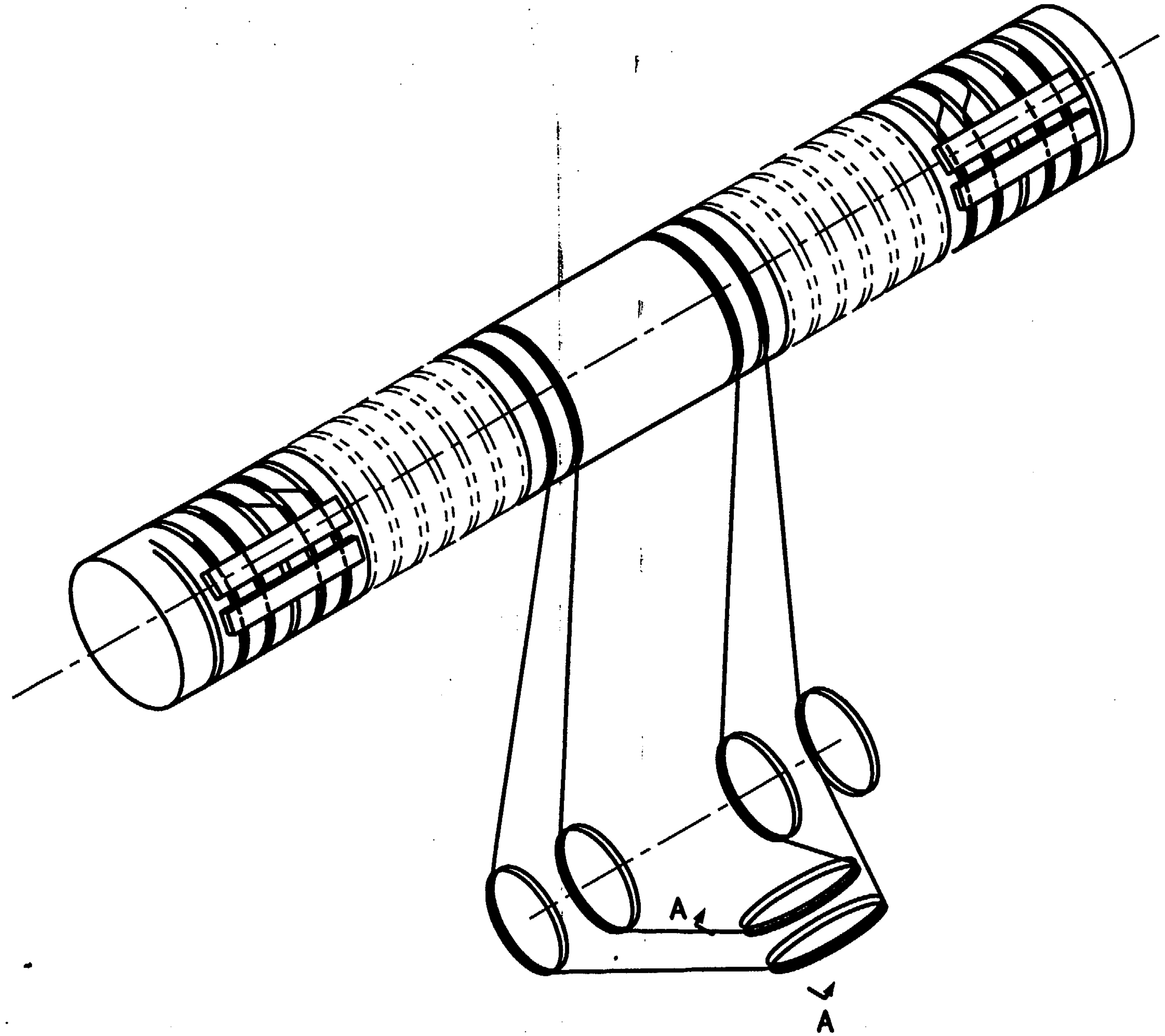
REEVING DIAGRAM
SIXTEEN PARTS (MAIN HOIST)

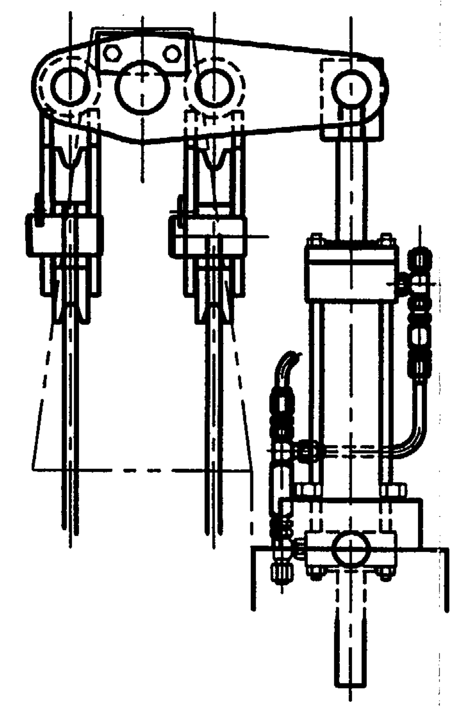
DWG. NO. B-36953 SHT – REV A

NOTES: NSR

1. SPF – A TEST SAMPLE OF ROPE TO BE PULLED TO FAILURE.
   MIN. TENSILE STRENGTH = 212,000 LBS.
   MIN. YIELD STRENGTH = 169,600 LBS. (2% OFF SET)
2. D.V. REQ'D.
3. USE SPECIFIED ROPE ONLY FOR REPLACEMENT, SUBSTITUTIONS SHOULD NOT BE MADE.

REVISIONS								
LTR	DESCRIPTION	DATE	BY	CHK	ENG	APPD	APPD	APPD
A	ADD SECTION AA, & PROJECT DATA	11-5-98	SRS	JLF	JLF	FEL	LA	





SECTION AA

APERTURE CARD

Also Available on Aperture Card

9902220118 .02

150/25 TON SEMI GANTRY CRANE
PRIVATE FUEL STORAGE FACILITY
PRIVATE FUEL STORAGE, LLC
PO # 0599602-023

REDUNDANT REEVING

TWO INDEPENDENT ROPES REEVED TO PROVIDE A TOTAL OF 8 PARTS. BOTH ENDS ANCHORED TO DRUM.

NOTES: NSR

1. SPF – A TEST SAMPLE OF ROPE TO BE PULLED TO FAILURE.
   MIN. TENSILE STRENGTH = 79,600 LBS.
   MIN. YIELD STRENGTH = 47,760 LBS. (2% OFF SET)
2. D.V. REQ'D.
3. USE SPECIFIED ROPE ONLY FOR REPLACEMENT, SUBSTITUTIONS SHOULD NOT BE MADE.

	ITEM NO.	DESCRIPTION	QTY.	MATERIAL	WEIGHT
C.I.		7/8 DIA. WIRE ROPE	2	WIRECO 6 X 36 WS (EIPS/IWRC)	

LIST OF MATERIALS

ITEMS WITH SPECIAL QUALITY REQUIREMENTS	20.4	
ADVANCE ORDERED ITEMS	COST ITEM NO.	
DRAWN	RRM ESP, Inc.	10-13-98
CHECK	JLF	10-14-98
ENG.	JLF	10-14-98
APPD.	FEL	10-14-98
APPD.	L.L. ANDERSON	10-14-98
APPD.		

MACHINING TOLERANCES OR AS NOTED		
FRACTIONAL	± 1/64	
DECIMAL	± .010	
ANGLE	± 1-0"	

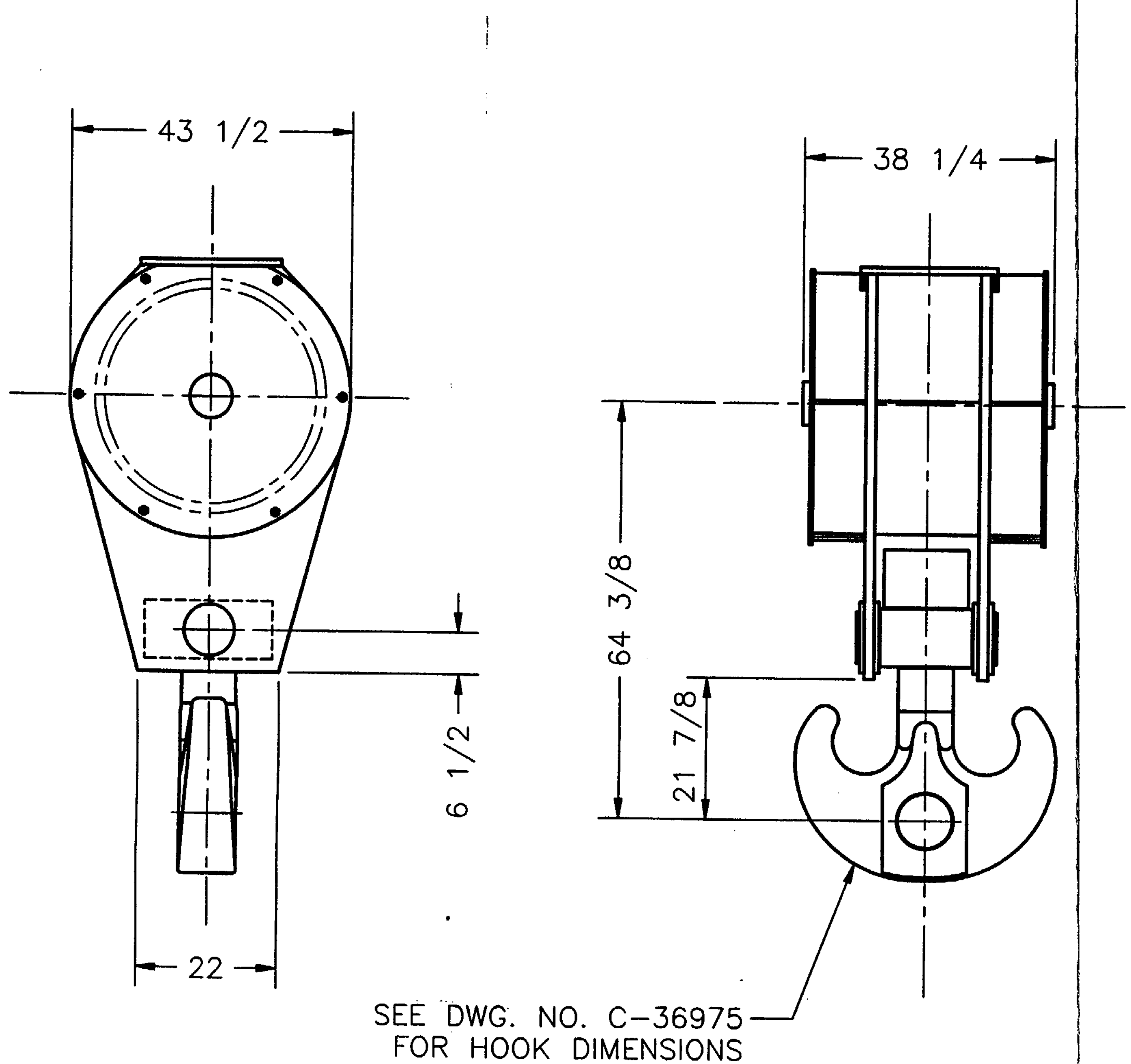
FIRST USED ON F-2622

SCALE NONE | TOTAL WT. LBS.

EDERER INCORPORATED
EDERER CRANES · WASHINGTON CRANES · STAR CRANES

REEVING DIAGRAM
EIGHT PARTS (AUX HOIST)

DWG. NO. B-36954 | SHT – | REV A



REVISIONS								
LTR	DESCRIPTION	DATE	BY	CHK	ENG	APPD	APPD	APPD
A	PER CUST. COMMENTS	11/17/98	JLF	SRS	JLF	RAS	LA:	

APERTURE CARD

Also Available on Aperture Card

9902220118 -03

A PRIVATE FUEL STORAGE FACILITY
P.O. NO. 0599602-023
150 TON SEMI-GANTRY CRANE

ITEM NO.	DESCRIPTION	QTY.	MATERIAL	WEIGHT

LIST OF MATERIALS

ITEMS WITH SPECIAL QUALITY REQUIREMENTS	0	SCALE NONE	TOTAL WT. — LBS.
ADVANCE ORDERED ITEMS	COST ITEM NO.		
DRAWN JLF	10/28/98		
CHECK FEL	10/29/98		
ENG. JLF	10/29/98		
APPD. FEL	10/29/98		
APPD. LLA	10/29/98		
APPD.			
MACHINING TOLERANCES OR AS NOTED	FRACTIONAL ± 1/64 DECIMAL ± .010 ANGLE ± 1-0°		
FIRST USED ON F-2622			

EDERER INCORPORATED
EDERER CRANES — WASHINGTON CRANES — STAR CRANES

MAIN HOIST BLOCK & HOOK DIMENSIONS

DWG. NO. B-37063 SHT — REV A

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