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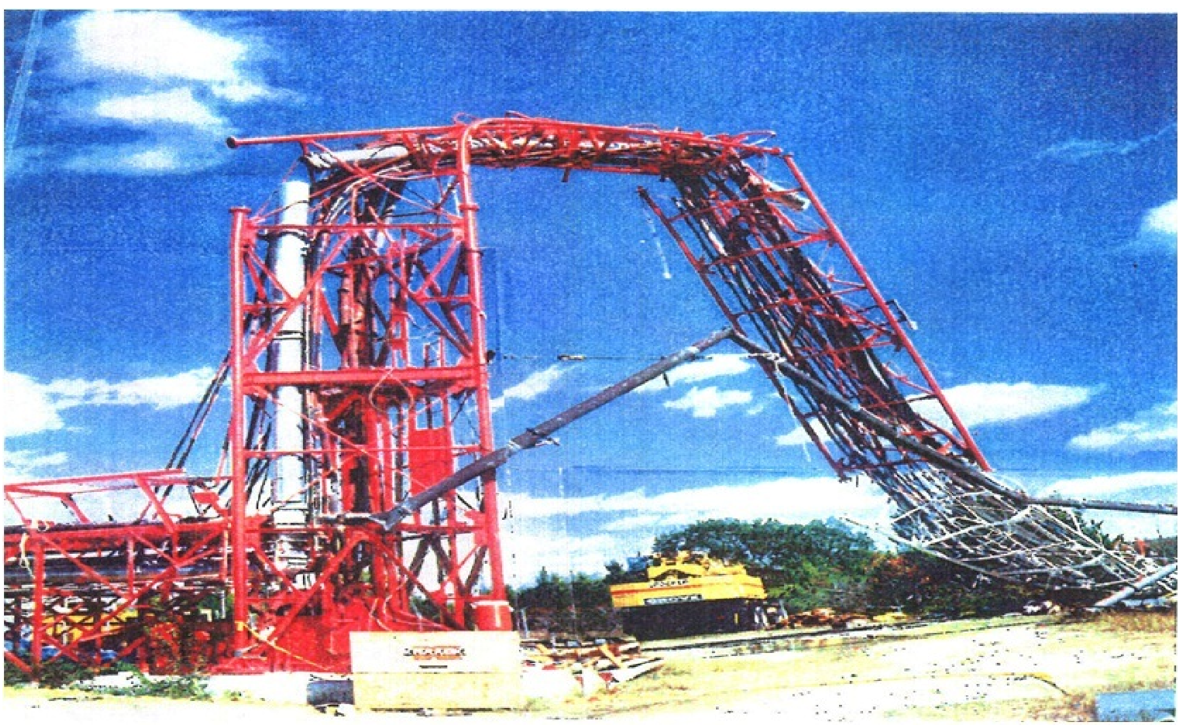
U.S. Department of Labor
Occupational Safety and Health Administration
Directorate of Construction

March 1997



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March 1997

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1.0 EXECUTIVE SUMMARY

A 1462 feet high antenna tower in Cedar Hill, Texas collapsed on October 12, 1996 killing three workers who were engaged in "jumping" a ginpole near the top of the tower to replace an existing television antenna which was mounted at the top of the tower with a new antenna. The workers fell with the falling sections of the tower and were believed to have been killed as they hit the ground. The tower was constructed in 1969 and was in a good state of repair. Prior to the accident, the structural design of the tower was examined by a consultant at the request of the TV Operating Station and was found to be in compliance with the applicable codes.

Mr. Henry Slagle, Safety Engineer of the Dallas Area Office arrived at the scene of the accident within two hours of the incident and took photographs and video of the site, and obtained a detailed account of the incident. Officials from the Regional Administrator's Office and other OSHA personnel assisted the Dallas Area Office in examining the remnants of the tower, interviewing eyewitnesses and taking field measurements.

The Directorate of Construction, National OSHA Office was contacted by the Regional Office to provide engineering assistance to the Area Office to determine the cause of the collapse. A structural engineer from the Office of Engineering, Directorate of Construction visited the site to observe the collapsed pieces and to collect relevant information and documents to conduct the evaluation and structural analyses of the tower.

Based on eyewitness statements, observation of the collapsed structural members of the tower, structural analyses of the tower under various loading conditions, the Occupational Safety and Health Administration concludes that:

1. The structural design of the KXTX antenna tower was adequate to resist the loads imposed upon it by the old antenna, standby antenna, four FM antennas, the new and old wave guides, transmission lines, cables and other appurtenances. The tower meets the EIA-222-E structural design criteria at 70 mph wind speed concurrent with the loads described above. A few of the diagonals were over stressed but were within the acceptable range and were well below the limit state values.

2. With the additional load of the ginpole and track assembly which was positioned on the SE face of the tower, the stresses in the members were determined to be within allowable values at the wind speed of 15 mph. The center of gravity of the ginpole was assumed to be well below the top of the track.

3. On the day of the accident, the ginpole was being "jumped" in an unsafe and unacceptable manner exposing the employees to danger which could result in deaths because the track was only tied to the tower at the top plate only. The bottom of the track was not anchored to the tower.

4. The ginpole and track assembly as configured on the tower with the attached jump line and load line was an acceptable system provided the center of gravity (c.g.) of the assembly was kept low. When the c.g. approaches the elevation of the top of the track and moves above it, the final orientation of the track and ginpole assembly after it reaches equilibrium under varying influence of the gravity and lateral loads cannot be predicted. At higher locations of the c.g. the assembly undergoes large rotations creating undue forces for the system. The ginpole and the track would have been a stable system even at relatively higher elevations of the c. g. provided the bottom of the track was also anchored to the tower, as originally intended.

5. The unpredictability of the ginpole and track assembly at higher elevations of the e.g. arises out of the following:

   (a) The track is subjected to unsymmetrical loads because of the configuration of the ginpole and its supports.

   (b) The assembly of the ginpole and track is subjected to lateral loads.

   (c) The track is anchored to the tower at the top only.

6. We believe that the most likely scenario of the collapse of the tower occurred in the following manner. As the e.g. of the ginpole was moved higher and higher above the top of the track, the ginpole and track assembly was subjected to large rotation and finally fall of the ginpole. At higher degrees of rotation, the wire ropes anchoring the track to the tower were subjected to a greater force due to ever increasing eccentricity of the weight of the ginpole. The greater force resulted in higher stresses in the members of the tower Section 8 in excess of their capacities. The failure of the diagonals and the horizontal strut where the track was anchored would precipitate the failure of other members. This would result in the gradual collapse of the tower.

   Other possible scenarios of failure, however, could not be conclusively ruled out.

The above conclusions are based on the premise that there are no deficiencies in the materials of the tower components. The results of the laboratory tests were not available at the time of completion of this report.

2.0 ACCIDENT DESCRIPTION

2.1 Accident:

On October 12, 1996, a 1462 feet high antenna tower at Cedar Hill, Texas (about 20 miles south of Dallas, TX), owned by Lin Television collapsed killing three employees of Doty-Moore Tower Services who were raising a gin pole near the top of the tower to replace an existing antenna with a new antenna. The collapse occurred about 10:30 A.M. on Saturday. The employees fell with the falling sections of the tower and are believed to have been killed as they hit the ground. A Safety Engineer from the Dallas Area Office arrived at the accident site in two hours of the accident. See Fig. 1 thru 14 for accident related photographs.

2.2 History of the tower:

The tower was originally designed and fabricated by Dresser-Ideco Corporation and was believed to have been erected about 1969. No structural changes or modifications have been reportedly made to the tower since then. The tower was designed for the then prevailing standard EIA RS-22-C, 65 PSF wind loads with no ice. The tower was constructed for the Double Day Broadcasting Company and was later sold to the Continental Broadcasting. In June 1994, Lin Television of 4, Richmond Square, Providence, Rhode Island, 02906, purchased the tower from the Continental Broadcasting. Lin Television owns and operates the KXAS Channel *5* in Dallas, TX. It also operates the KXTX Channel 39 which is owned by a different organization. On the top of the tower, the antenna for the KXTX Channel 39 TV station was mounted and on the side, antennas for four FM radio stations were attached at varying heights. In addition, it is equipped with wave guides, cables, transmission wires, etc. See discussion later for a list of antennas, dishes and reflectors.

2.3 Description of the tower:

The tower was triangular in plan with each side equal to 9 feet and rose 1462' above the ground. The tower comprising 50 prefabricated sections bolted together at splice joints with high strength bolts. Except for the section # 1 and 2 at the very top and the section # 41 near the bottom, all sections were typically 30' high. The segments are identified as #1 at the top with the numbers going down to *#50* at the base. The tower had seven levels of guys with three guys at each level at 120 degrees apart. There were in total 21 guys anchored at six locations. The top four levels of guys # 7,6,5 and 4 were anchored at the exterior anchors. The bottom three levels of guys # 3,2 and 1 were anchored at the interior anchors. The exterior anchors were placed at 1105', 1045’ and 1147’ in the NE, NW and in S directions respectively from the tower. The interior anchors were placed at 528’, 516’ and 549’ in the NE, NW and S directions respectively from the center of the tower. The guys were located at the following elevations. The size of the guy wires and the segments they were attached to are indicated below:

Guy No.	Elevations of attachments	Wire Rope size	Tower Section
7	1440-7 ¼"	1 ½"	# 2
6	1207'-7 ¼"	1 $^{9}/_{16}$ "	# 10
5	987'-7 ¼"	1 ½"	# 17
4	777'-7 ¼"	1 $^{7}/_{16}$"	# 24
3	567'-7 ¼"	1 $^{7}/_{16}$"	# 31
2	367'-7 ¼"	1 $^{9}/_{16}$"	# 38
1	188'-6"	1 $^{3}/_{8}$"	# 44

The guy anchors were placed at different elevations with respect to the tower base.

The typical section of the tower is shown in Fig. 15. The legs of the tower consisted of solid round members. The diameter varied from 5 ¼” to 3 ¼”. The diagonals were solid bars of 5/8” to 1 3/8” in diameter. Horizontal angles consisted of two angles placed back to back. The size was approximately 2 ½ X 2 X 1/4”. For exact size, see Fig. 16 thru 19. The following were the yield strengths of the tower members.

Legs	90 ksi
Diagonals	50 ksi
Horizontals	36 ksi

At the location of the guy wire attachments, two channels were placed at the horizontal member instead of the two angles. The typical connections of the horizontal and diagonals with the vertical legs were made of a ½” thick gusset plate shop welded to the solid member legs. The horizontal and diagonal members were then bolted with two 7/8” bolts. For typical connection details, see Fig. 20, 21. The connection at the splice of the sections consisted of 1 1/4” flange plates shop welded to the solid round members of the legs and bolted together with 7/8” dia. bolts.

At the top of the tower was placed a 52’ high RCA-TFU-28 antenna for the KXTX-TV Channel 39. This antenna was scheduled to be replaced by a new DiElectric TFU31E antenna during the current activity. See Fig. 29 for a view of the antenna tower.

The following is a list of antennas, reflectors and dishes attached to the tower as per the field inspection of July 10, 1995 as conducted by Doty Moore Tower Services.

Height	Name
85'	Ornni Antenna
270'	6' Grid Dish
297'	8' solid Dish
350'	Two way Yaggi
380'	10' gid dish
470'	8' HP Dish
500'	9' HP Dish
520'	1 Bay Antenna
917'	Two Way Antenna
1095'	14 Bay FM Antenna
1295'	4 Bay FM Antenna
1367'	6 Bay FM Antenna
1425'	8' Grid Dish plus Two Way Antenna
1445'	Two Bay FM Antenna
1462'	RCA TFU 28 slot Antenna

2.4 CONTRACTOR'S SCOPE OF WORK:

At the request of the Lin Television Inc., Doty Moore submitted a proposal on February 6, 1996 to:

Install a standby antenna
Connect the antenna to an existing unused 6 1/8" transmission line
Remove RCA antenna
Install a new Dielectric antenna
Remove 8" transmission line

Install a new DTW- 1500 wave guide.
Remove the standby antenna and 6 1/8” transmission line from the KXTX tower and install them on KXAS tower.

The Lin Television by its Purchase order C-10066 authorized the erector to proceed with the work on or around March 11, 1996. Subsequently, The KXTX tower contracted with the Malouf Engineering Intl., Inc. of 1702 N. Collins Blvd., Suite 203, Richardson, Texas to conduct a structural evaluation of the existing tower for the loads of the new antenna, the standby antenna (assumed to be at a height of 1247’) and new wave guides and other cables, etc. The Malouf Engineering conducted structural analyses to determine whether or not the tower meets the requirements of the ANSI/TIA/EIA 222-E.

During our interview with the President, Malouf Engineering on December 10, 1996, it was learned that the structural model of the tower for the structural analysis was not developed by the Malouf Engineers but by a former structural consultant, Alpha Tower Design, now out of business. Malouf obtained the model of the tower from them when Alpha Tower was getting out of business and had used it in its earlier analyses in 1994 and 1995. The earlier analyses were done at the request of KXTX TV station to determine the adequacy of the tower for change in antenna load and compliance with the EIA specifications 222-C. Malouf also stated that he assumed without verifying that the model he obtained from alpha Tower was in fact the as built tower.

The structural analysis conducted by Malouf Engineering was based on the premise that the tower is properly maintained without any structural deficiencies. The program is based on a static analysis of a beam column theory supported on a nonlinear spring constants at the guy locations. Standard three wind directions are considered, i.e., face, apex and parallel wind.

Their analyses indicated, as mentioned in their report of June 1, 1996 that the tower meets the provisions of the ANSI/EIA 222-E and the stresses are in the acceptable range. They, however, recommended that the new wave guide be placed in the inside of the tower which was in fact done.

At the request of the KXTX TV an inspection of the tower was conducted by Doty-Moore Tower Services and a report was prepared by them on July 10, 1995. The report indicated that the tower was generally in a good structural condition. Only one structural deficiency was noted in the report of a “bent diagonal rod 3rd section above the 4th guy level bay 3”. There were other non structural deficiencies noted but they were not considered highly significant. The report stated that there were no observed signs of unusual stress or vibration. The vertical alignment of the tower was also checked with two transit setup at 90 degrees. The amount of deviation from the true vertical ranged from 0 to 1 1/4”. The tensions in the guys were also measured and found to be within the acceptable range of 2-5%.

2.5 METHOD OF ERECTION:

The primary task of the erector was to remove the existing antenna at the top of the tower, 1462’ above the ground and safely transport it to the ground. The new antenna was then to be raised and mounted at the top of the tower. The top of the new antenna had to be raised about 56’ above the top of the tower to make the connections with the tower top plate. Transporting the antenna by a helicopter has proven to be dangerous in the past and is not favored by the industry. So, the erector decided to fast raise a built-up column like structure (called ginpole) similar to a crane boom along the side of the tower by means of a track and extend the gin pole some 75’ above the top of the tower. The ginpole would then be secured to the tower. By means of a wire rope passing over the top block of the ginpole, the new antenna would be slowly raised until the antenna base would be at the same level of the tower top plate and then connections will be made. This method of raising a ginpole by means of a track and fastening it to the tower and then employing the gin pole to pull the antenna up the tower is a well accepted practice in the industry. See Fig. 27 for the assembly of the ginpole and the track on the tower.

At the time of the accident, the contractor was raising the ginpole on the SE face of the tower with the top of the ginpole still in the range of 140’-125’ below the top of the tower. As stated above, the top of the ginpole was eventually going to be raised some 75’ above the tower. Raising the ginpole with a track is a complex and slow operation. Once the ginpole is raised to the desired elevation and fastened to the tower, raising the new antenna becomes a relatively simpler task. The following is a description of the manner in which the erector proceeded to raise or “jump” the ginpole.

The ginpole used in this project was a 30”x30” built up column composed of four pieces of approximately 25’ each. The pieces were connected with high strength bolts. The erector obtained the ginpole and the track sometime in 1989 from a former tower contractor who was placed in a Chapter 11 bankruptcy case. The ginpole was made up of five pieces each 25’ long enabling the user to vary the lengths of the ginpole. In this project only four pieces were used to make a 100’ long section. The top section of the ginpole is a tapered section with a block attached at the top called the “rooster head”. The rooster head could be rotated 360 degrees. The ginpole had two angles welded to them so that the ginpole could slide in the track. The bottom piece of the ginpole was equipped with two blocks for the wire rope connection with the track. The ginpole was reportedly used by the contractor in several tower servicing contracts in the past with success.

The track used in this project was a T shaped structure. The original track purchased by the erector reportedly consisted of three pieces, two horizontal plates to be placed at the top and bottom, and a central vertical member. The erector did not use the bottom plate in this project. So, the track could only be fastened to the tower at the top, See Fig. 21 and 22.

The jumping of the ginpole involves three wire ropes each connected to a separate drum of the winch hoist. The three rope lines are the tag lines, load line and the jump line. The tag line is used to guide the objects being raised from striking the tower. The load line is the line used to raise the track and the jump line is employed to raise the ginpole. The three lines are attached to three drums.

Tag line	5/16” dia. wire rope
Load line	½” dia. 6x36 (BS=11.ST)
Jump line	½” dia. wire rope 6x19 IWRC (BS= 11.5 T)

The employees first installed a block near the top of the tower by reaching thru the elevator located in the middle of the tower. The tag line was then carried thru the center of the tower and placed over the block. By means of the tag line, a second wire rope which would function as the load line was pulled up the tower. These two lines were used to raise the ginpole. The ginpole was raised in two pieces. The top piece (about 50’ long) was first raised and fastened to the tower followed by the bottom piece also 50’ long. The two segments were then connected. The load line was then employed to raise the track which was then fastened to the tower at about the bottom of the ginpole. The load line was then removed from the top block of the tower and placed over the rooster head of the ginpole. By means of the load line, the track was moved up and fastened at a height of about 1267’. Then the jump line was installed. The jump line went over the block located at the left hand of the top track plate and passed over the bottom blocks of the ginpole and then over the block located at the right side of the track top plate. The jump line went in the reverse order over the blocks located at the ginpole and was fastened at the dead end at the track top plate. The ginpole was then unfastened from the tower and was supported by the track only. The load line which passed through the sheave supported at the top of the gin pole was held by two counter weights (total weight = 1800 pounds) and attached to the tag line by a free wheel. The ginpole was then ready to be jumped by sliding through the track by tensioning the jump line.

On October 12, 1996, three employees, Dana Campbell “Doc” who was the foreman, Joe Kelly, Jr., and Michael Stinson were at the tower near the track to jump the ginpole. The operator at the winch was Terry Schrader who was in communication with the foreman through the radio contact. Based on the interview statements of the winch operator, the jumping process started rather well. After a brief period in which the ginpole was raised by an unknown amount, the foreman instructed the winch operator to lower the ginpole a little. The winch operator reportedly complied with the request and shortly thereafter the foreman asked the winch operator to jump the ginpole as fast as he wanted to. Moments later, the foreman frantically called the hoist operator to come down on the load, and the ginpole started to fall and the collapse of the tower occurred soon thereafter. See Fig. 28 for location of the bodies and the ginpole after the accident.

An eyewitness to the collapse provided a statement two days after the accident which indicated that she observed the ginpole to be in a vertical position aligned with the tower legs. Then she noticed that the ginpole leaned toward the right by about 10-15 degrees and then it came back to the vertical position. Her line of sight was about 55 degrees off the perpendicular to the southeast face of the tower, so the reported angle of 10-15 degrees could have been much higher. Thereafter she observed the ginpole to be climbing up for a distance equal to “one to one and one half times the distance between the triangular bracing section”. Then she said that the ginpole fell off the tower in “slow motion” with the top rotated about 25 degrees toward the NE. The ginpole moved downward to the northeast and disappeared. The tower, seconds later, collapsed when” the white top of the tower sank into the upper most orange segment, which sank into the next white section”. She continued - after several segments had telescoped downward, the lowest white segment that I could see wavered, bent about 3/4 of the distance down its height, drew its top load down toward my left.”

2.6 Description of the collapsed segments:

Fig. 23 shows the location of various tower segments as found on the ground following the collapse. Almost all separations occurred at the joint where the two 30’ sections were bolted together. The two bottom sections 50 and 49 were the only sections standing vertically. There were numerous separations in the tower as indicated by x-x on Fig. 16 thru 19. Section *5* thru 8 were the most twisted section on the ground. The track remained anchored to the section No. 8, though the track was fractured at a plane just below the bottom of the top plate. For field measurement of Section 8, see Fig. 26. The long vertical piece of the track suffered permanent deformations. The gin pole was found almost parallel to the NE guy, the top of the ginpole facing toward the tower base. Except for the deformation sustained by the angle near the junction of the bottom and the second section from the bottom, the ginpole was not significantly damaged. The angle which had sustained the deformation rides on the track while jumping. Besides, there were distinct signs of rubbing by wire rope near the damaged angle.

Out of the 21 guy wires, six were broken. The following identifies the fractured guy wires. The guy wires are numbered from bottom to the top, e.g., No.1 is the lowest guy wire and No. 7 is the top most guy wire.

# 1 NW fractured	13′-8" from the top
#*t* 2 NW fractured	28 to 42′ from the top
# 3 NW fractured	45′-9" from the top
# 4 NW fractured	*52’* from the top
# 6 S fractured	9-3" from the top
# 5 S fractured	6-8" from the top.

All other guy wires were intact. The # 5 NE guy wire rope was found to have suffered abrasion for a length of 377′ starting at about 68′ from the top. Calculations indicate that the abrasion of the wire rope ended where the bottom of the ginpole was located on the ground, See. Fig. 24.

The body of the foreman was found near the NE inner guy anchor location. The bodies of the other two workers were found on the roof of the transmitter building near the section No. 5.

During the field measurements after the collapse, it was discovered that the jump line wire rope was fractured at a number of places and their total length added up to about 1583’. Considering that the hoist was located about 213′ from the lower block on the tower and given the fact that the track was anchored at a height of 1237′ from the block, the bottom of the gin pole was determined to be about 33’ below the top of the track. This will place the center of gravity of the gin pole about 20’ above the track. Notes from the field also revealed that the jump line from the dead end at the track top plate was fractured at about 31′-10" and the other end of the jump line was found to be jammed in the ginpole bottom sheaves. This would indicate a strong possibility that at the time of the accident, the top of the ginpole was about 70′ above the top of the track

3.0 STRUCTURAL ANALYSIS:

The structural analyses consisted of three parts. The first part dealt with the tower's structural design to independently determine whether or not it met the design criteria of the industry standard EIA-222-E. This was undertaken to rule out any structural deficiency in the tower. The second part examined the tower with the additional load of the ginpole and track assembly placed on the SE face of the tower with the prevailing wind on the day of the accident. The objective of this analysis was to determine whether or not the tower section members were over stressed by the ginpole and track assembly at low elevations of the center of gravity of the ginpole. The third part consisted of examining the stability of the ginpole and track assembly during the jumping process and to determine whether or not the assembly was rendered unstable at higher elevations of the center of gravity of the ginpole and track assembly. It also determined the stresses in the tower legs and other tower members at large rotations of the ginpole.

Part I

A three dimensional finite element program based on stiffness matrix was used to model and analyze the structure. The program recognizes large displacements and large rotations of the members whose shears and moments are computed in deformed positions. The guys are modeled by three dimensional, geometrically nonlinear finite element cable stiffness elements. The tower is divided into elements corresponding roughly to a tower segment and the truss freedoms of each element are then reduced and transformed to equivalent beam type elements and then assembled into a tower stiffness matrix. The program reduces compression in slender diagonals instead of eliminating them completely which produces a much more realistic distribution of forces in the structure. This program was written, developed and run by Dr. Hugh Bradburn, Head of the Department of Civil Engineering, University of South Carolina, Columbia, SC.

The members' properties of the tower were taken from the original structural drawing No. 32596 prepared by Dresser-Ideco, the original designer. It was assumed that the drawing reflected the as-built conditions and no thorough verification of the member sizes and properties were done except at isolated locations. The member sizes used in this analysis compared favorably with those of the recent analysis performed by the Malouf Engineering Co. except for the diagonal members which Malouf assumed to be larger than what was shown on the drawings. In addition, Malouf Engineering assumed a higher yield strength of 90 ksi instead of 50 ksi. In any event, as will be discussed later, the conclusions and findings of this investigation will not be significantly affected.

The wind speed was taken as 70 mph and the resulting wind pressure was uniformly applied for the entire height, as recommended by the EIA standard. Wind was applied in three directions, the North, South and the East to determine the best combination to produce the maximum stresses. The load and sizes of the antennas, dishes, etc. were obtained from the manufacturers and the TV station. All antennas were assumed to be mounted on the north face facing Dallas and were assumed at the center of the north face. Any deviation in the exact location of the appurtenances on the north face will not be significant in our analysis. Ice was not considered in the analysis as is the practice in the Dallas area. The allowable capacities of the members were derived from the allowable stress design (ASD) method of the AISC (American Institute of Steel Construction), current edition.

The result of the analyses indicated that under 70 mph wind pressure and with the loads listed above, the member stresses were below the allowable stresses except for some diagonal members whose stresses were above the allowable stresses but fell in the acceptable range. It may be noted that these are the allowable stresses and not the ultimate strength values which are approximately 1.7 times larger than the allowable values. The tower meets the design criteria of the standard EIA-222-E. A comparison of the actual stresses against the allowable stresses is provided in Appendix A.

Part II

The tower was subjected to an additional load of the ginpole and the track assembly. The ginpole weighed 10,600 and the track about 500 pounds. In addition, the load line was attached to a couple of headache balls, both weighing 1800 pounds. The load line went over the rooster head of the ginpole. In calculating the tension of the four part jump lines, a 10% friction was considered at every sheave. The dead load of the jump and the load lines were also considered. The tower was also subjected to a horizontal force at the locations of the blocks near the bottom of the tower to serve the load and jump lines. All other loads and the physical properties of the members were the same as in the Part I analysis. The load lines which were attached to the headache balls were assumed to be plumb. The prevailing wind speed was obtained from the Dallas Fort Worth and the Love Field airports. Based on the review of the data, a wind speed of 15 mph was applied for the entire height of the tower.

The results of the analyses indicated that the member stresses were well within the allowable stresses and none of the members were over stressed.

Part III

This part dealt with the stability of the track and the ginpole. The ginpole and the track were weaved together by the jump line wire rope. One end was anchored to the track top plate and the other end through a block attached at the tower base was connected to the hoist drum, See Fig. 25. In addition the load line went over the rooster head sheave and the two headache balls were attached to it. A separation between the tower and the headache balls was maintained by the tag line. As the ginpole is raised by tensioning the jump line, the force in each part of the jump line varies depending upon the friction and also the acceleration of the jump. In addition, a lateral load is applied due to the presence of wind.

The above is a complex arrangement in which the track continuously seeks equilibrium under different forces in each part of the jump line and under varying elevations of the c.g. of the ginpole track assembly during the jumping operation, and also under the wind load. Under each set of conditions, the track attempts to arrive at a stable position where all the forces would be in equilibrium. The orientation of the track, i.e., the angle it makes with the tower does not remain constant. In fact under every variation, the orientation changes. The primary reason for this phenomena is the fact that the track is anchored at the top only and the bottom is free to rotate and displace. It may be noted that the track would not be plumb during the jumping operation because the forces applied to the track are not symmetrical and a lateral load is applied over the ginpole/track assembly. However, if the track was anchored at both the top and bottom, the plumbness would be assured.

In the equilibrium analyses of the track and gin assembly, a number of assumptions were made:

1. The jump and load lines are plumb.
2. The ginpole weighs about 10,000 pounds
3. The track weighs about 467 pounds.
4. The load and jump lines weigh about 1200 pounds.
5. The headache ball weighs 1800 pounds.
6. The friction between the tower and the track is ignored.
7. The track top member is 6 feet wide.
8. The inclined length of the wire rope sling is 4’-6”.
9. The wind force acts at the center of gravity of the ginpole and track assembly.

There were six variables in the equilibrium equations: the angle the left sling of the track makes with the tower, similar angle of the left sling, the angle of rotation of the track and ginpole, the force in the left sling, the force in the right sling, and the location of the center of gravity of the ginpole. A solution of the equations of equilibrium was obtained under different conditions. Tables 1 and 2 indicating the magnitude of rotation of the ginpole and the forces in the right and left slings are provided. In the appendix are the plots indicating the variables under varying conditions.

Tabulation of angle of rotation of ginpole (φ), wind force in kips (w), force in kips in the left sling (L) and the force in kips in the right sling (R) under different coefficient of friction. The location of the c.g. is taken with respect to the top of the track. Negative value indicates location below the top of the track.

This table is valid for the center of gravity near the top of the track which results in low angle of rotations. This table is not valid for high elevations of the center of gravity.

TABLE 1

location of e.g.	w (kips)	coefficient of friction	φ (degrees)	L (kips)	R (kips)
0	0	.4	+6 degrees	17	5
0	0	.3	+6	16.5	5
0	0	.2	+5.5	15.5	5
5'	-1.	.4	+5	14.	7.
5'	-0.8	.4	+4.5	14	7
5'	-0.6	.4	+4	15	7
5'	-0.4	.4	+4	15	7
5'	-0.2	.4	+4	15	7
0'	+.2	.4	+5	16	6
0'	+.4	.4	+4.5	16	5.5
0'	+.6	.4	+3.5	16	7
0'	+.8	.4	+3.25	15.5	6
0'	+1.0	.4	+2.5	12	10

The following table is applicable for large rotations:

TABLE 2

Location of the c.g.	w	Coefficient of Friction	φ	L	*R*
0	0	.4	68.5 degrees	45	30
0	0	.3	68.5	45	30
0	0	.2	68.5	43	30
-20'	1.0	.4	70	90	80
-20'	0	.4	-70	75	90
-20'	-1.0	.4	-70	80	90

A review of the tables and plots indicate the following:

* When the c.g. of the system is near the top of the track, the forces in the wire slings supporting the track do not significantly vary due to change in friction between the wire rope and the sheaves.

* The forces due to the wind at low speed do not significantly influence the forces in the track slings.

* As the c.g. rises from below the track to near the top of the track, the rotation of the ginpole increases but remains essentially in the low range of *2.5* to 6 degrees.

* As the c.g. rises above the track, a different phenomena takes place and the assembly tends to undergo large rotations. The assembly seeks equilibrium under varying loads and could rotate clockwise or counterclockwise. For example, if the c.g., is raised 20’ above the track, the system reaches equilibrium at a rotation of approximately 70 degrees with large forces in the left and right slings of the track.

* The ginpole is sensitive to horizontal force at the top of the ginpole at higher elevations of the c.g. of the ginpole.

The tower was reanalyzed for the forces imposed upon it in the event the ginpole undergoes large rotations at higher elevations of the center of gravity of the assembly. It was determined that the tower structural member’s stresses are well within the allowable values even at the high degree of rotation except for the strut at the location where the track is anchored to the tower. At the junction of the wire sling supporting the track, there are double horizontal angles spanning between the tower legs and two diagonals 7/8" diameter. The diagonals are capable of resisting little compressive force due to its mink al stiffness and the double angles is capable of a maximum compressive force of 35 kips with the load factor and reduction factor of one. With the buckling of the strut and the refusal of the diagonals to take additional loads, the tower legs are severely overstressed beyond their capacities.

For the above analysis, a general purpose three dimensional finite element analysis program, STAAD III was used to model the tower section between the guy level 6 and the top of the tower. To the model, two joint loads were applied at the SE face of the tower at the location where the track was anchored and member stresses were determined. The forces in the diagonals and the horizontal struts were exceeding their limit state values determined by the LRFD method of the American Institute of Steel Construction. Therefore the joint loads were reduced to about 25% until certain diagonal members were overstressed beyond their limit state values. Those diagonal members were then eliminated and an additional 28% of the load was applied which then resulted in the failure of the horizontal strut. The remaining force was then applied at the two joints to evaluate the tower leg stresses which were determined to be well above their capacity and hence the failure.

The shear rupture strength of the top plate of the track was also considered. The hole size in the 3/4" top plate was 1 1/4" and the diagonal edge distance was determined to be 2.2". The ultimate tensile strength of A-36 steel varies from 58 to 80 ksi. Therefore the rupture shear strength varies from 57 to 80 Kips with an average value of 68 Kips.

The wire sling of the track which anchored the track to the tower was measured to be of an average diameter of 0.916" having an approximate breaking strength of more than 100 kips. However, in the sling there were two shackles and one hook. Imprinted on the shackles were allowable loads of 8 ½ and 6 ½ tons and the allowable load on the hook was imprinted to be 4 ½ tons. The weakest link in the sling was therefore the hook with an estimated ultimate strength of 60 to 70 kips.

4.0 CONCLUSIONS:

Based upon the above, we conclude that:

1. The structural design of the KXTX antenna tower was adequate to resist the loads imposed upon it by the old antenna, standby antenna, four FM antennas, the new and old wave guides, transmission lines, cables and other appurtenances. The tower meets the EIA-222-E structural design criteria at 70 mph wind speed concurrent with the loads described above. A few of the diagonals were over stressed but were within the acceptable range and were well below the limit state values.

2. With the additional load of the ginpole and track assembly which was positioned on the SE face of the tower, the stresses in the members were determined to be within allowable values at the wind speed of 15 mph. The center of gravity of the ginpole was assumed to be well below the top of the track.

3. On the day of the accident, the ginpole was being “jumped” in an unsafe and unacceptable manner exposing the employees to danger which could result in deaths because the track was only tied to the tower at the top plate only. The bottom of the track was not anchored to the tower.

4. The ginpole and track assembly as configured on the tower with the attached jump line and load line was an acceptable system provided the center of gravity (c.g.) of the assembly was kept low. When the c.g. approaches the elevation of the top of the track and moves above it, the final orientation of the track and ginpole assembly after it reaches equilibrium under varying influence of the gravity and lateral loads cannot be predicted. At higher locations of the c.g. the assembly undergoes large rotations creating undue forces for the system. The ginpole and the track would have been a stable system even at relatively higher elevations of the c.g. provided the bottom of the track was also anchored to the tower, as originally intended.

5. The unpredictability of the ginpole and track assembly at higher elevations of the c.g. arises out of the following:

   (a) The track is subjected to unsymmetrical loads because of the configuration of the ginpole and its supports.

   (b) The assembly of the ginpole and track is subjected to lateral loads.

   (c) The track is anchored to the tower at the top only.

6. We believe that the most likely scenario of the collapse of the tower occurred in the following manner. As the c.g. of the ginpole was moved higher and higher above the top of the track, the ginpole and track assembly was subjected to large rotation and finally fall of the ginpole. At higher degrees of rotation, the wire ropes anchoring the track to the tower were subjected to a greater force due to ever increasing eccentricity of the weight of the ginpole. The greater force resulted in higher stresses in the members of the tower Section 8 in excess of their capacities. The failure of the diagonals and the horizontal strut where the track was anchored would precipitate the failure of other members. This would result in the gradual collapse of the tower.

   Other possible scenarios of failure, however, could not be conclusively ruled out.

The above conclusions are based on the premise that there are no deficiencies in the materials of the tower components. The results of the laboratory tests were not available at the time of completion of this report.

Figures

General View of the Collapsed Tower.

Figure 1

A view of the collapsed tower

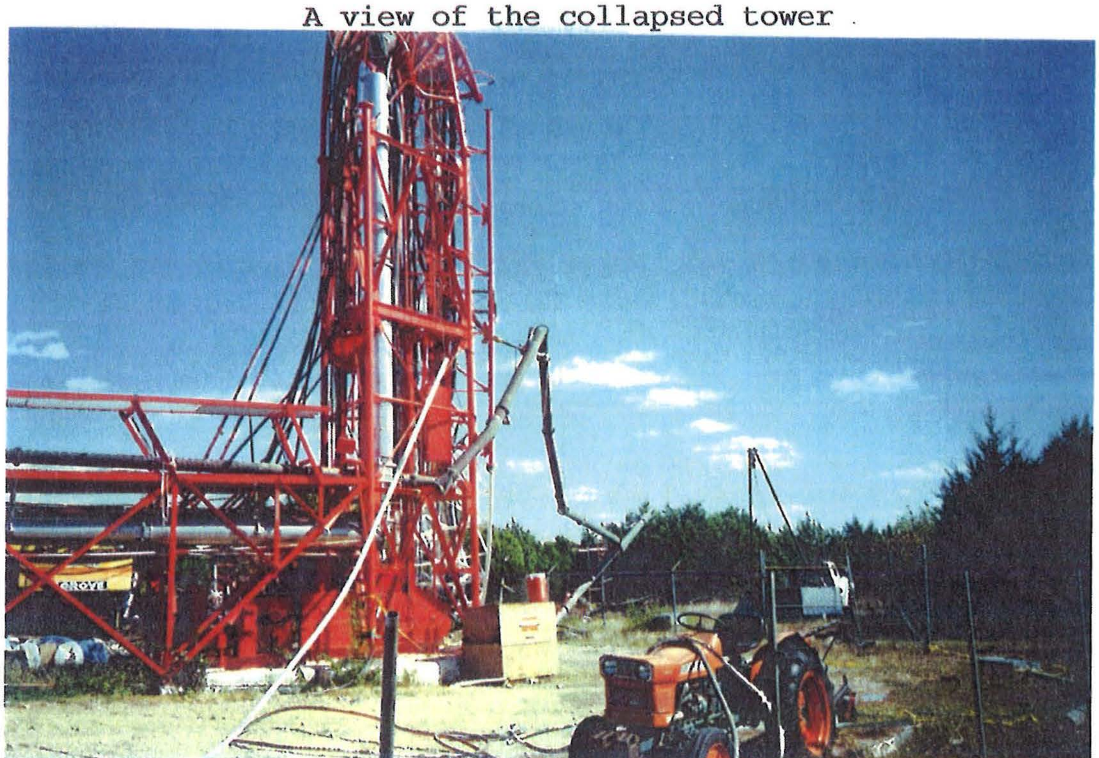
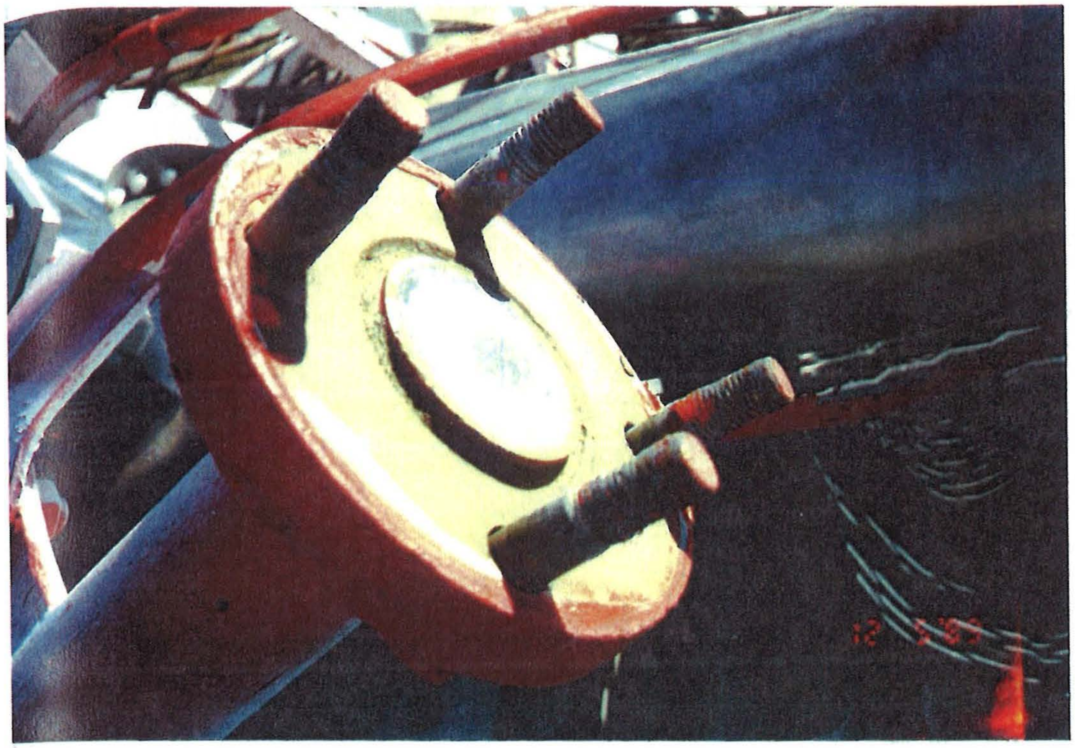


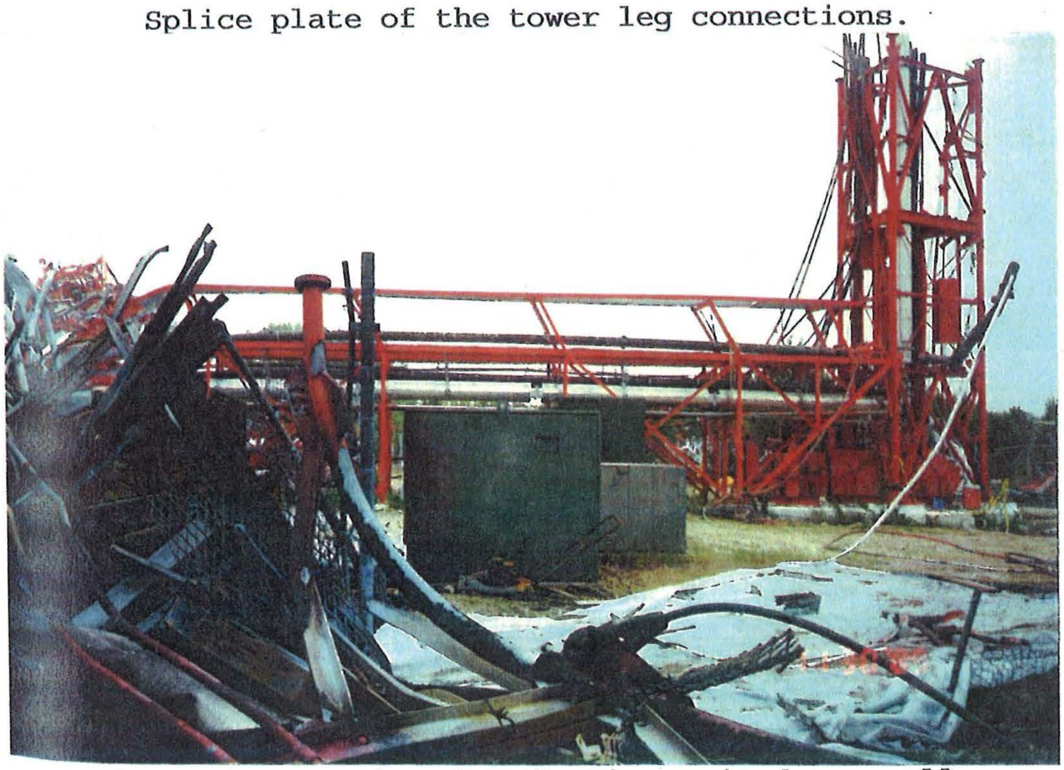
Figure 2

General view of the collapsed tower sections.

Figure 3



Splice plate of the tower leg connections.



The bottom section (30' long) remained generally intact during the collapse.

Figure 4

Scene of the collapsed tower. Part of the tower fell over the transmission building. Section #8 with the track attached to it was found on the roof.

Remnants of the tower on the ground.

Figure 5

Views showing typical connection of the diagonal and horizontal struts to the tower legs.

Figure 6

A connection of tower members at the guy locations.

Figure 7

Photographs showing the track top plate attached to the Section 8.

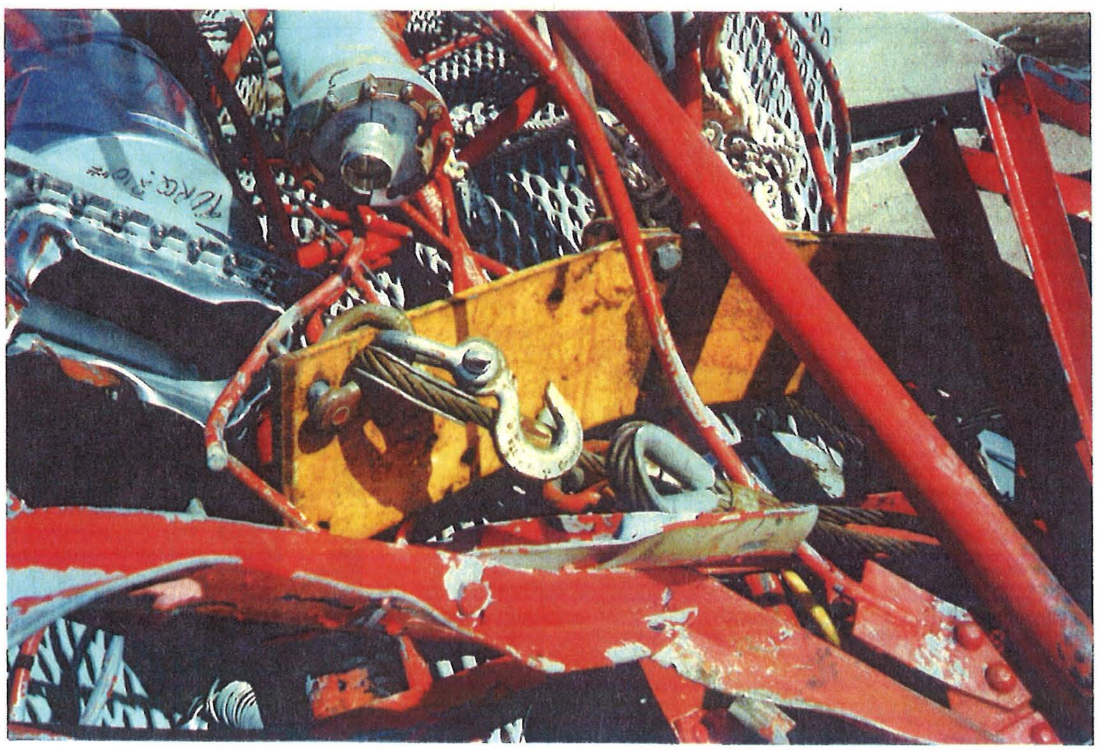
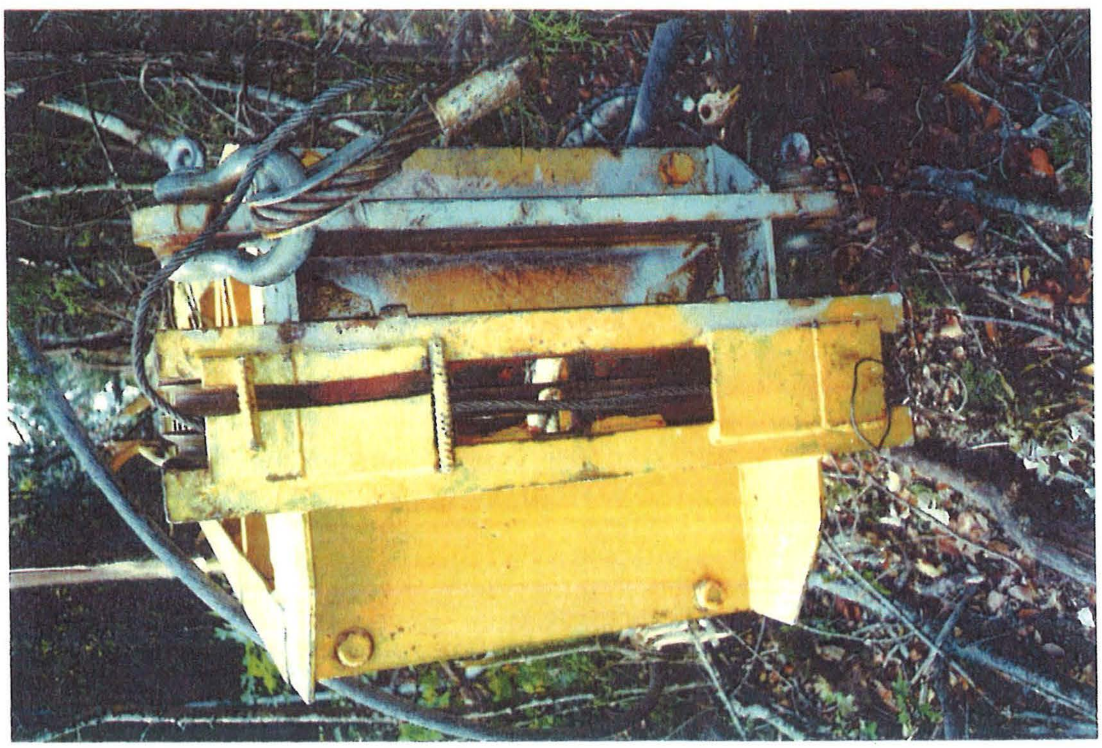


Figure 8

Views showing the load line, jump line and tag line with drums.

Figure 9



Views showing the bottom of the ginpole.

Figure 10

Views showing the ginpole.

Figure 11

View showing the ginpole after the collapse.

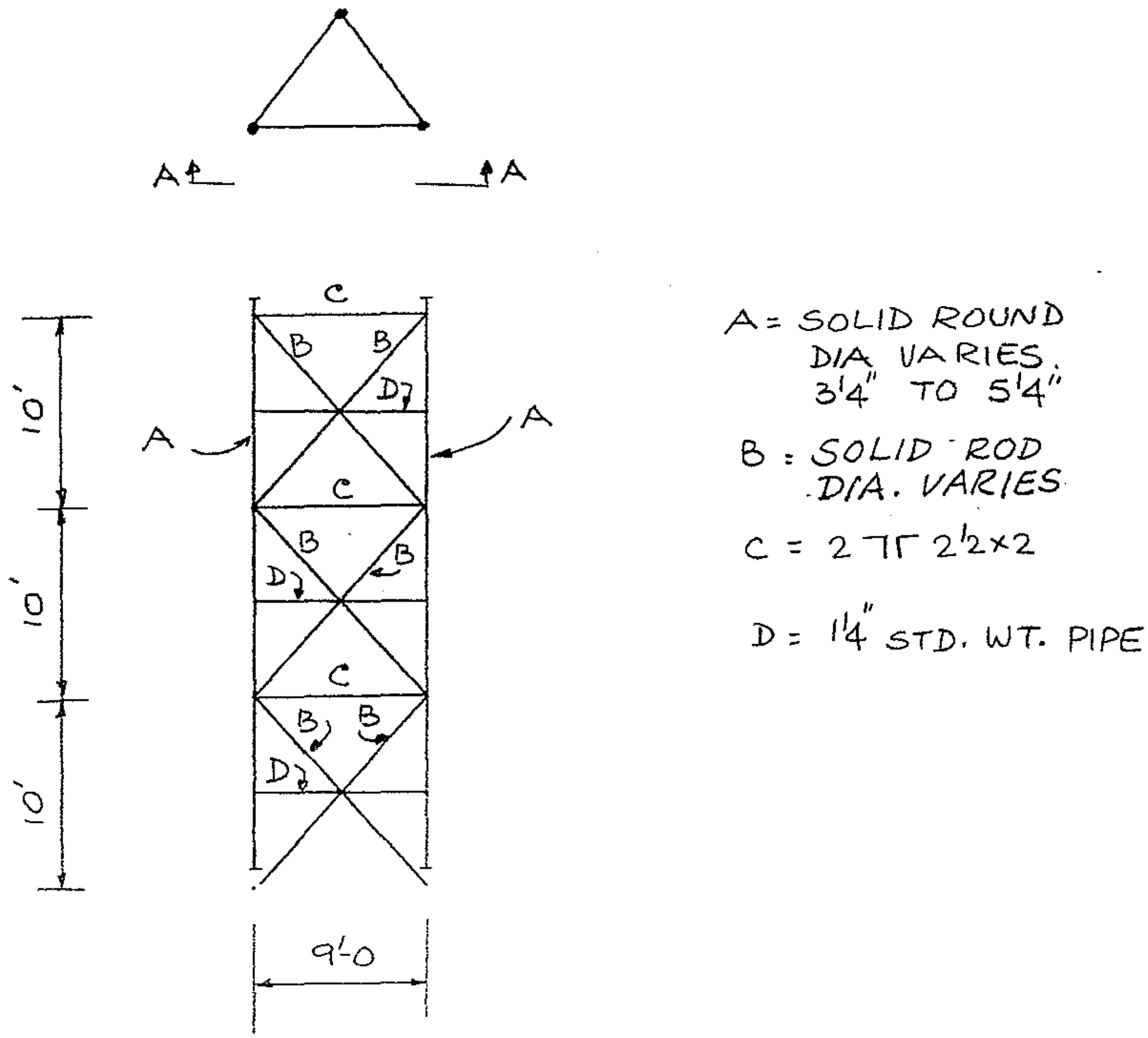
Figure 12

Views showing the deformed angle of the ginpole which slides in the track.

Figure 13

Views of the new antenna proposed to replace the old antenna.

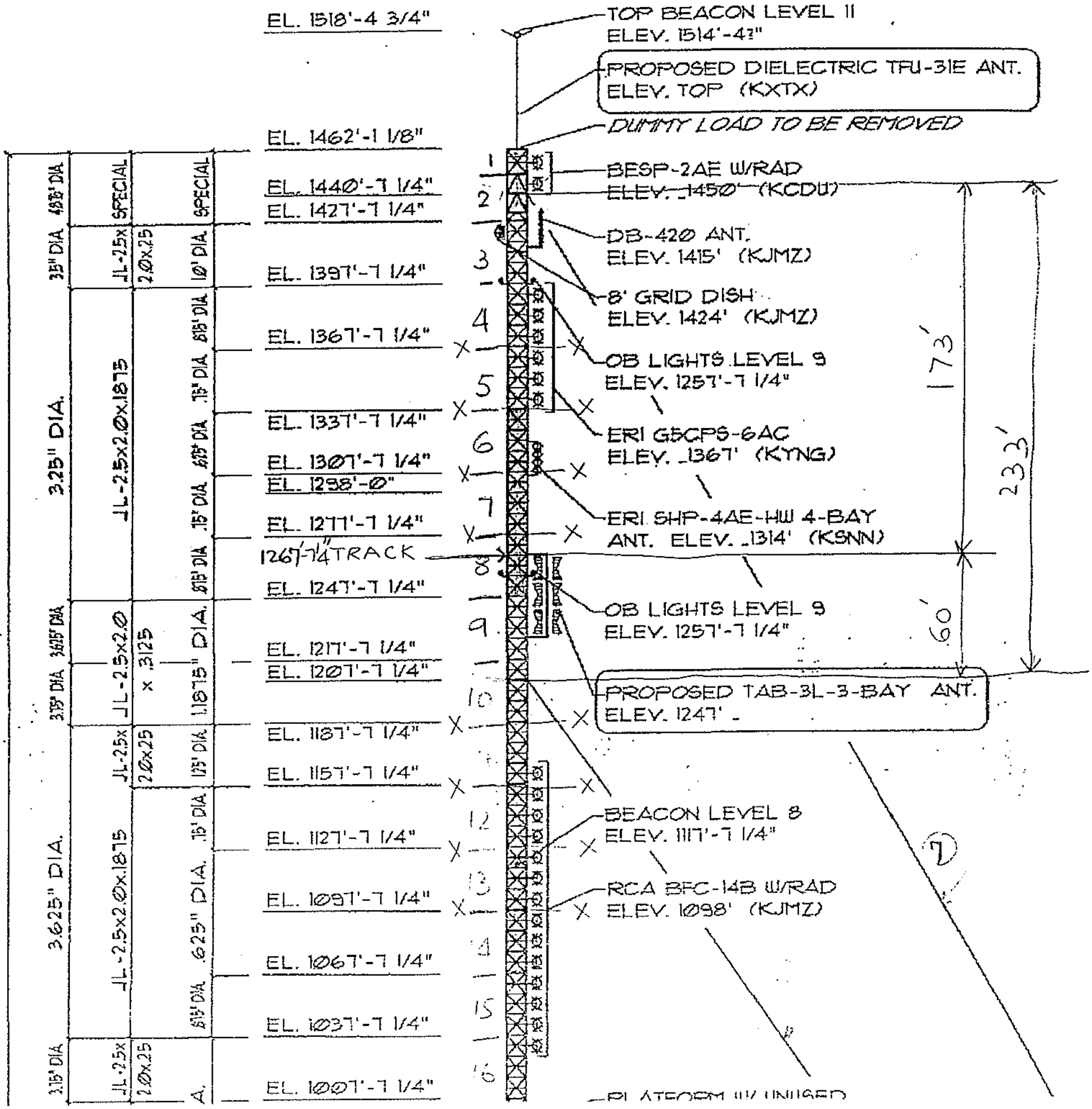
Figure 14



ELEVATION (TYP.) A-A

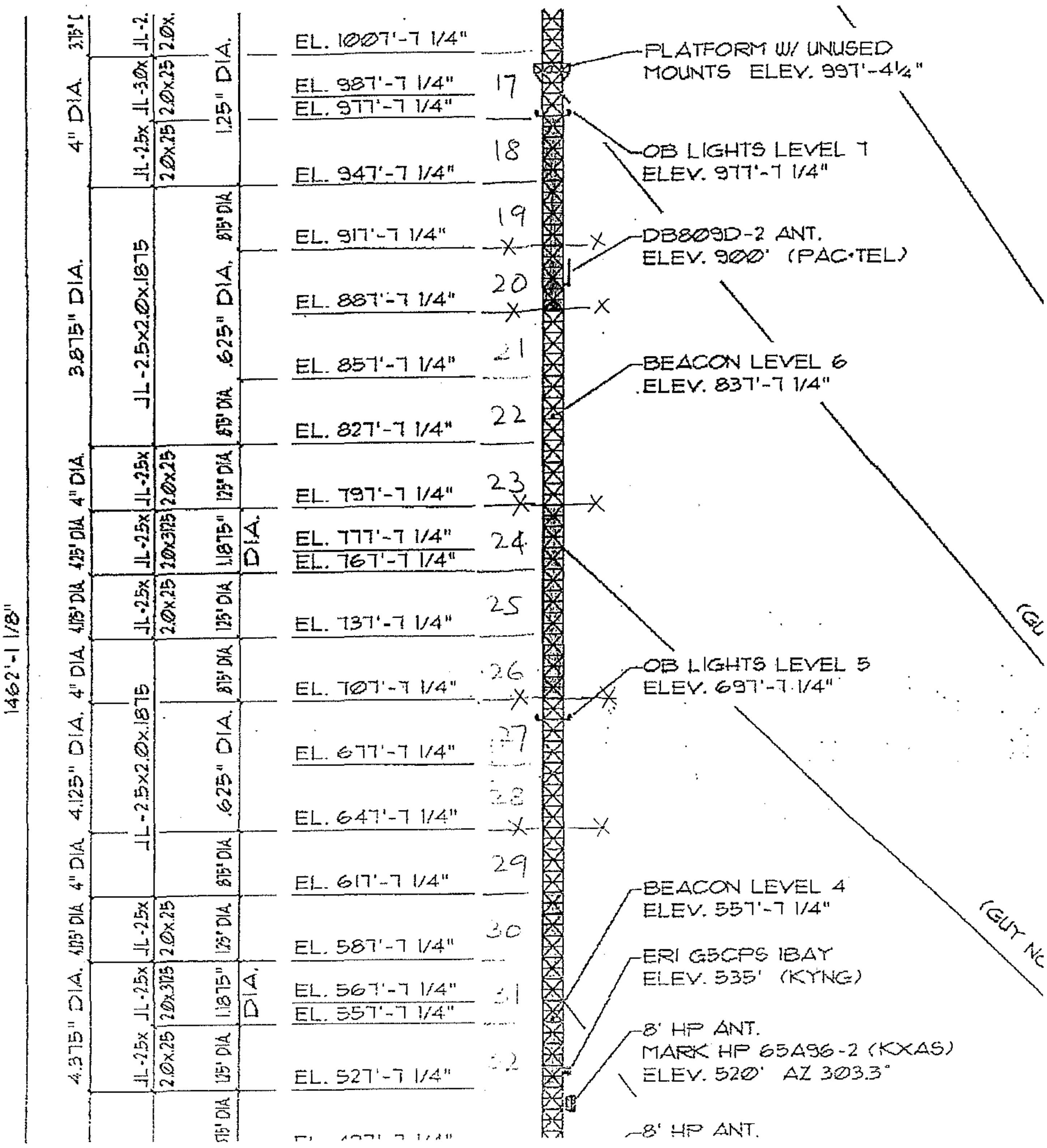
TYPICAL TOWER SECTION

Fig. 15



X-X = SEPARATION AFTER COLLAPSE

Fig 16



EL. 1007'-7 1/4"
EL. 987'-7 1/4"
EL. 977'-7 1/4"
EL. 947'-7 1/4"
EL. 917'-7 1/4"
EL. 887'-7 1/4"
EL. 857'-7 1/4"
EL. 827'-7 1/4"
EL. 797'-7 1/4"
EL. 777'-7 1/4"
EL. 767'-7 1/4"
EL. 737'-7 1/4"
EL. 707'-7 1/4"
EL. 677'-7 1/4"
EL. 647'-7 1/4"
EL. 617'-7 1/4"
EL. 587'-7 1/4"
EL. 567'-7 1/4"
EL. 557'-7 1/4"
EL. 527'-7 1/4"
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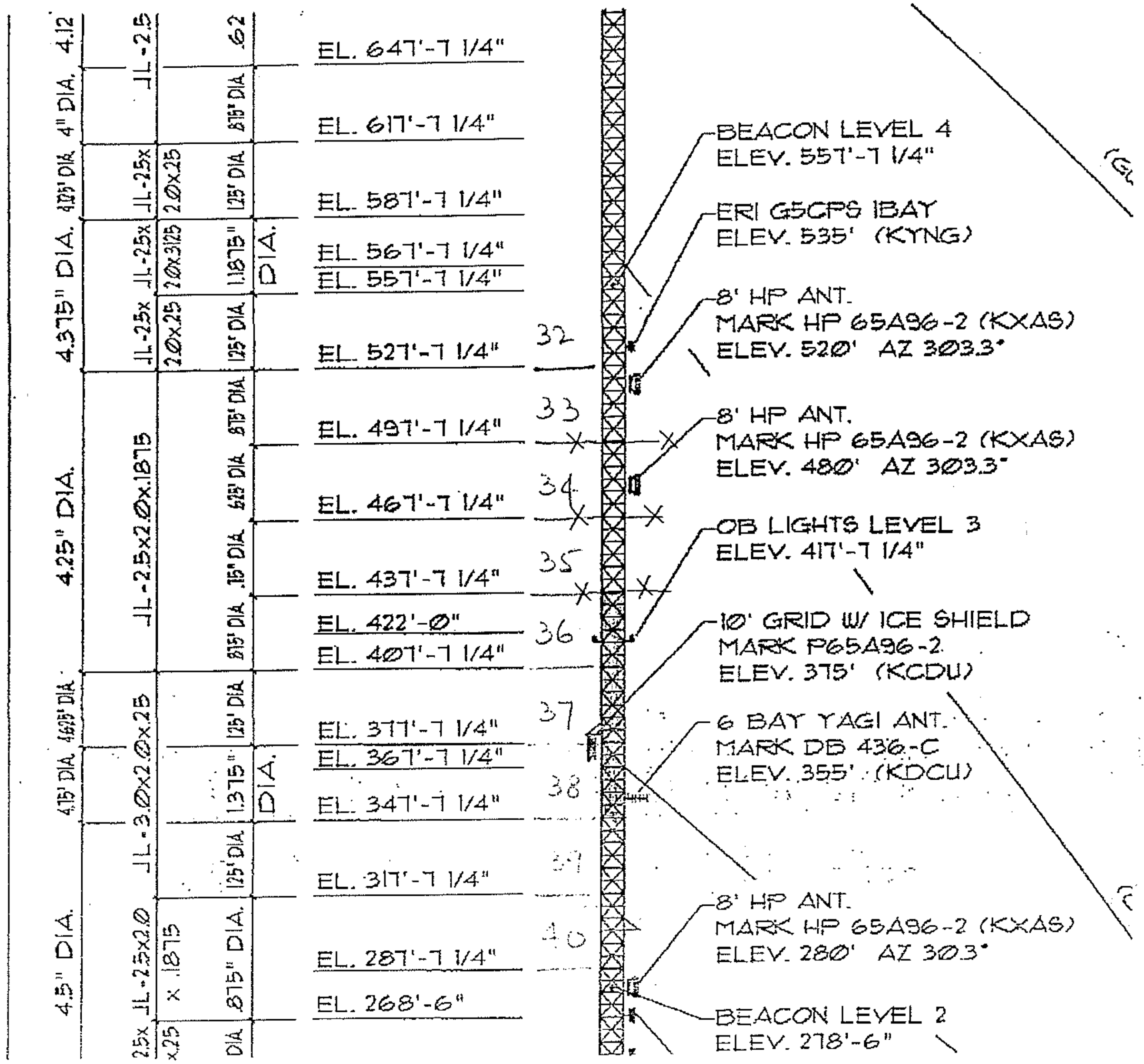
PLATFORM W/ UNUSED MOUNTS ELEV. 997'-4 1/4"
OB LIGHTS LEVEL 7 ELEV. 977'-7 1/4"
DB809D-2 ANT. ELEV. 900' (PAC-TEL)
BEACON LEVEL 6 ELEV. 837'-7 1/4"
OB LIGHTS LEVEL 5 ELEV. 697'-7 1/4"
BEACON LEVEL 4 ELEV. 557'-7 1/4"
ERI G5CPS IBAY ELEV. 535' (KYNG)
8' HP ANT. MARK HP 65A96-2 (KXAS) ELEV. 520' AZ 303.3°
8' HP ANT.
(GUY NO
1462'-1 1/8"
4" DIA.
3.875" DIA.
4" DIA.
4.125" DIA.
4" DIA.
4.375" DIA.
JL-2.5x2.0x.1875
JL-3.0x 2.0x.25
JL-2.5x 2.0x.25
1.25" DIA.
.625" DIA.
1.1875" DIA.

Fig. 17


4.12
4" DIA.
4.375" DIA.
4.25" DIA.
4.5" DIA.
JL-2.5
JL-2.5x2.0x.1875
JL-3.0x2.0x.25
DIA.
EL. 647'-7 1/4"
EL. 617'-7 1/4"
EL. 587'-7 1/4"
EL. 567'-7 1/4"
EL. 557'-7 1/4"
EL. 527'-7 1/4"
EL. 497'-7 1/4"
EL. 467'-7 1/4"
EL. 437'-7 1/4"
EL. 422'-0"
EL. 407'-7 1/4"
EL. 377'-7 1/4"
EL. 367'-7 1/4"
EL. 347'-7 1/4"
EL. 317'-7 1/4"
EL. 287'-7 1/4"
EL. 268'-6"
32
33
34
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36
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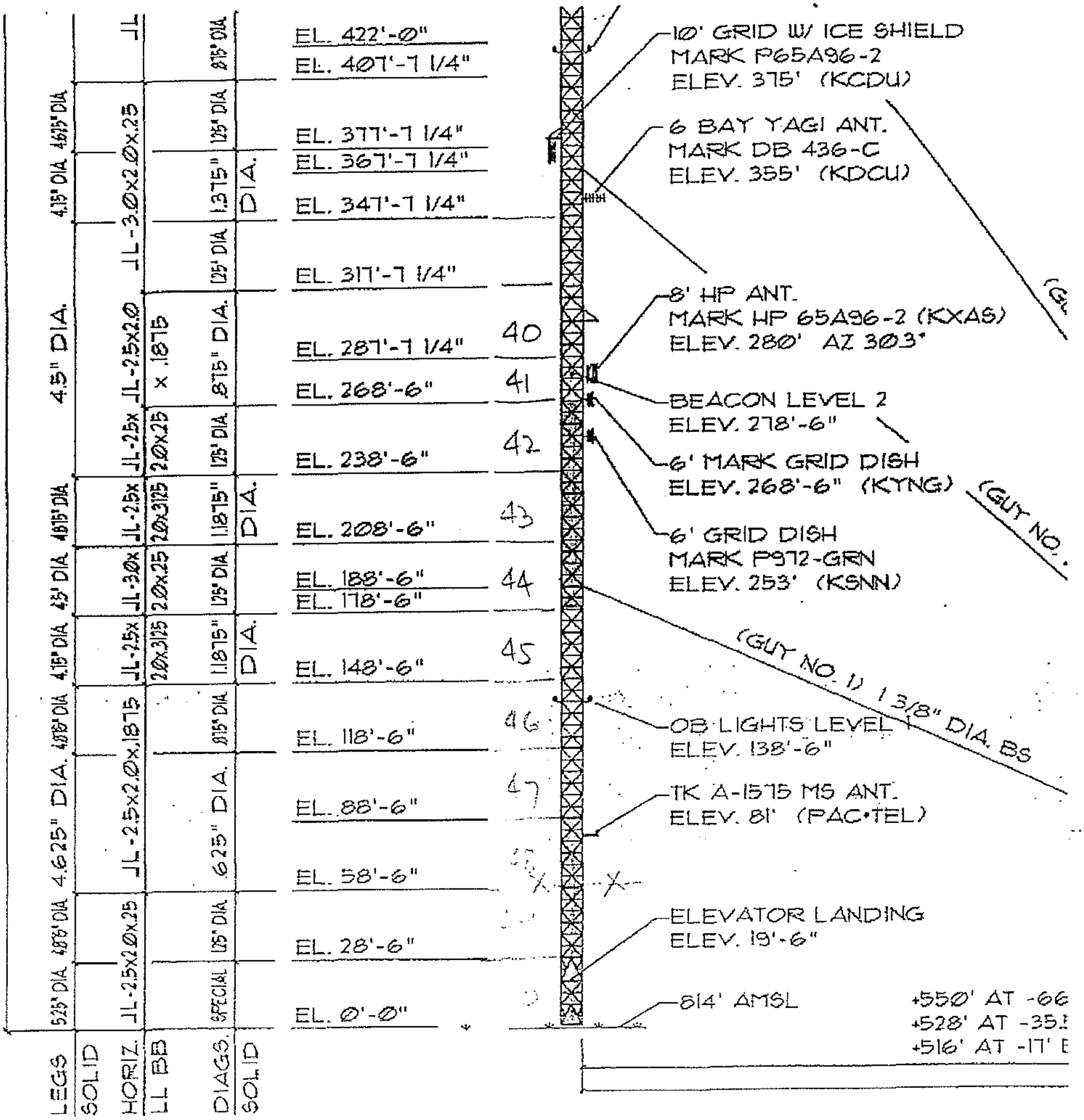
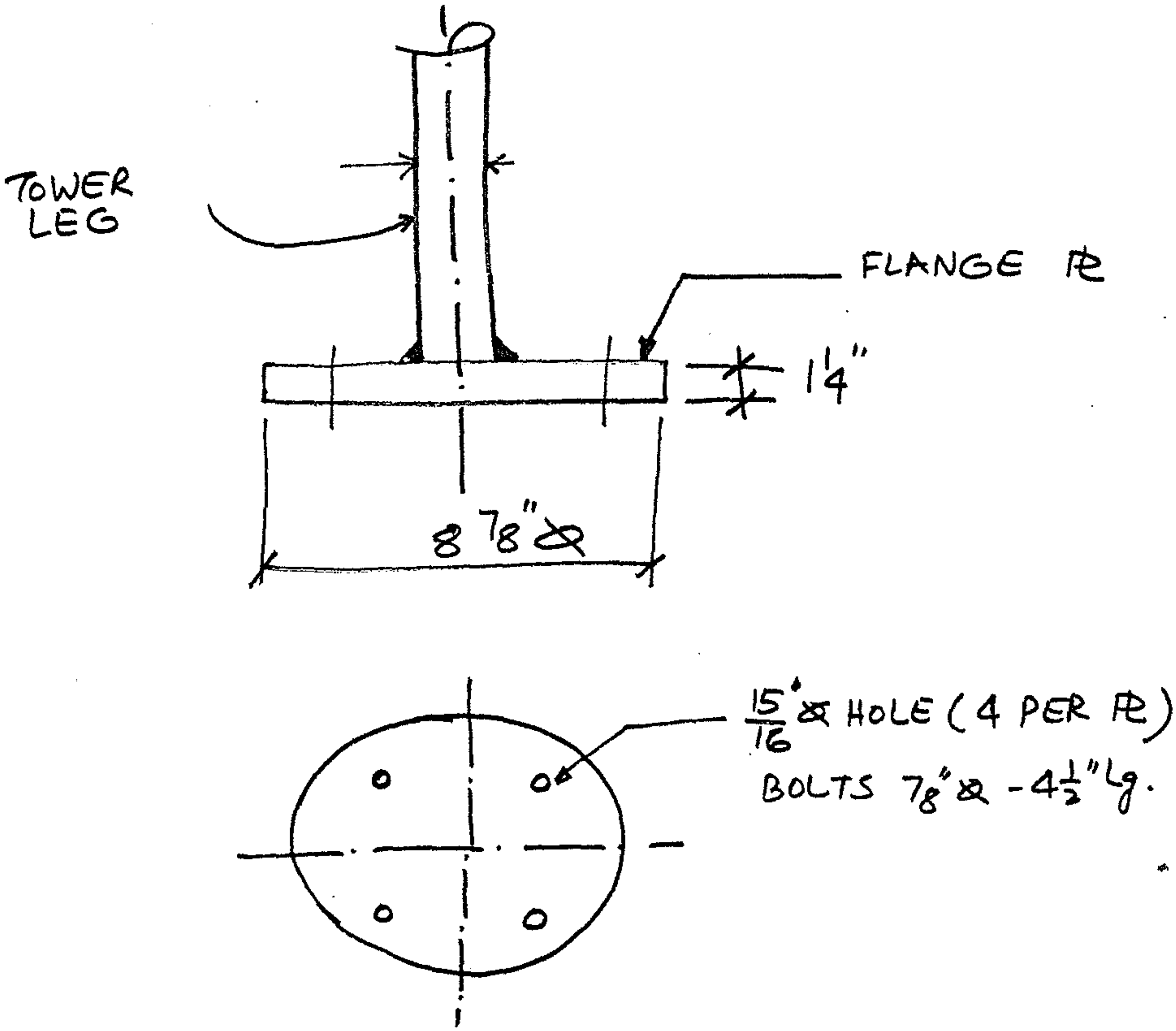
38
40
BEACON LEVEL 4
ELEV. 557'-7 1/4"
ERI G5CPS 1BAY
ELEV. 535' (KYNG)
8' HP ANT.
MARK HP 65A96-2 (KXAS)
ELEV. 520' AZ 303.3°
8' HP ANT.
MARK HP 65A96-2 (KXAS)
ELEV. 480' AZ 303.3°
OB LIGHTS LEVEL 3
ELEV. 417'-7 1/4"
10' GRID W/ ICE SHIELD
MARK P65A96-2
ELEV. 375' (KCDU)
6 BAY YAGI ANT.
MARK DB 436-C
ELEV. 355' (KDCU)
8' HP ANT.
MARK HP 65A96-2 (KXAS)
ELEV. 280' AZ 303°
BEACON LEVEL 2
ELEV. 278'-6"

Fig. 18



HORIZ. CHANNELS AT GUY PULLOFFS NOT SHOWN

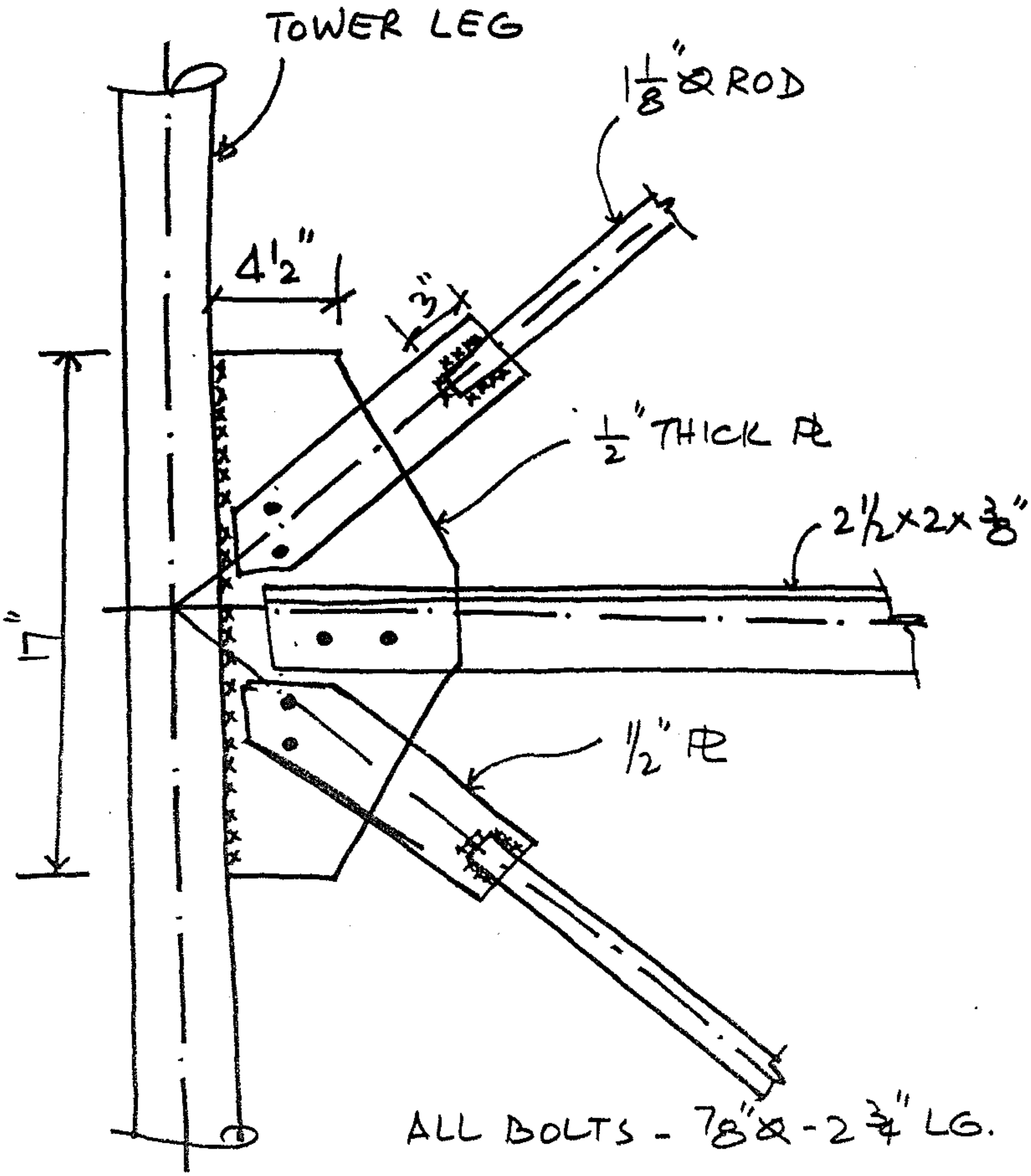
Fig. 19



TYPICAL DETAIL OF LEG CONNECTION

NTS.

Fig. 20



TYPICAL CONNECTION DETAIL

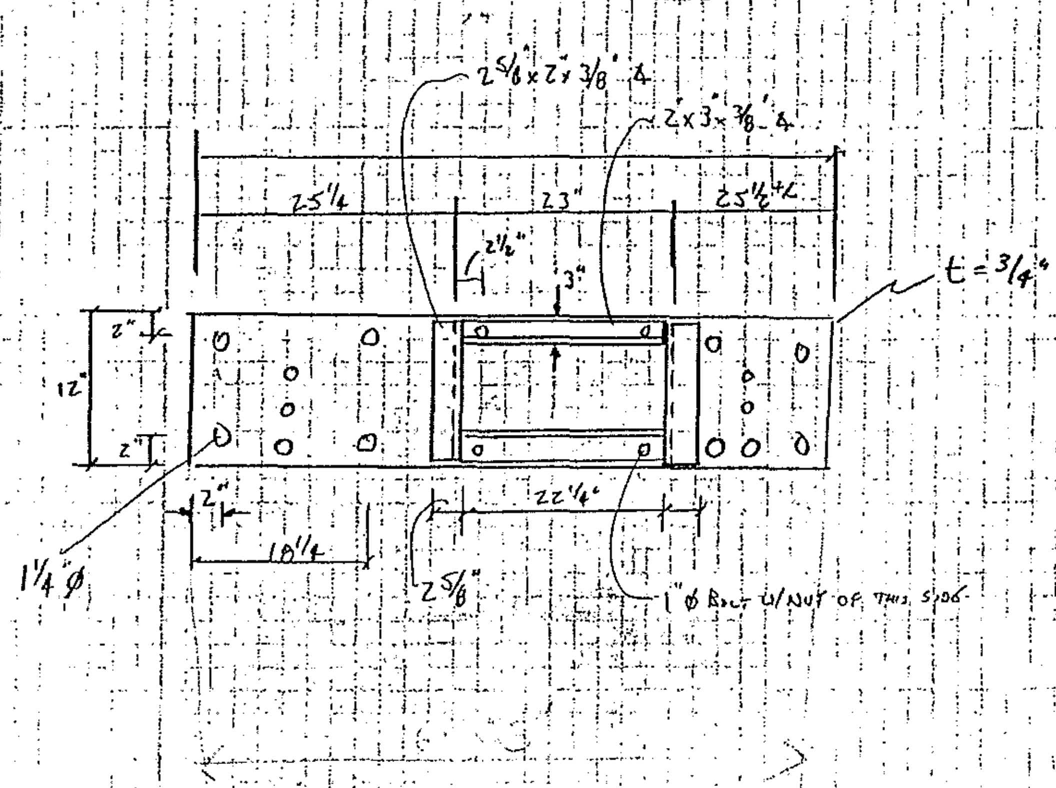
Fig. 21

MORRIS ENGINEERING COMPANY

MEI

SUBJECT

DATE 10/17/96
BY SED
SHEET 1 OF 4
MEI NO.



Jump Track Mounting Plate
Preliminary Dimensions
Fig. 2

8131 LBJ Frwy. Suite 360, Dallas, Texas 75251 Phone (972) 669-3171, Fax: (972) 669-2986

MORRIS ENGINEERING COMPANY

MEI

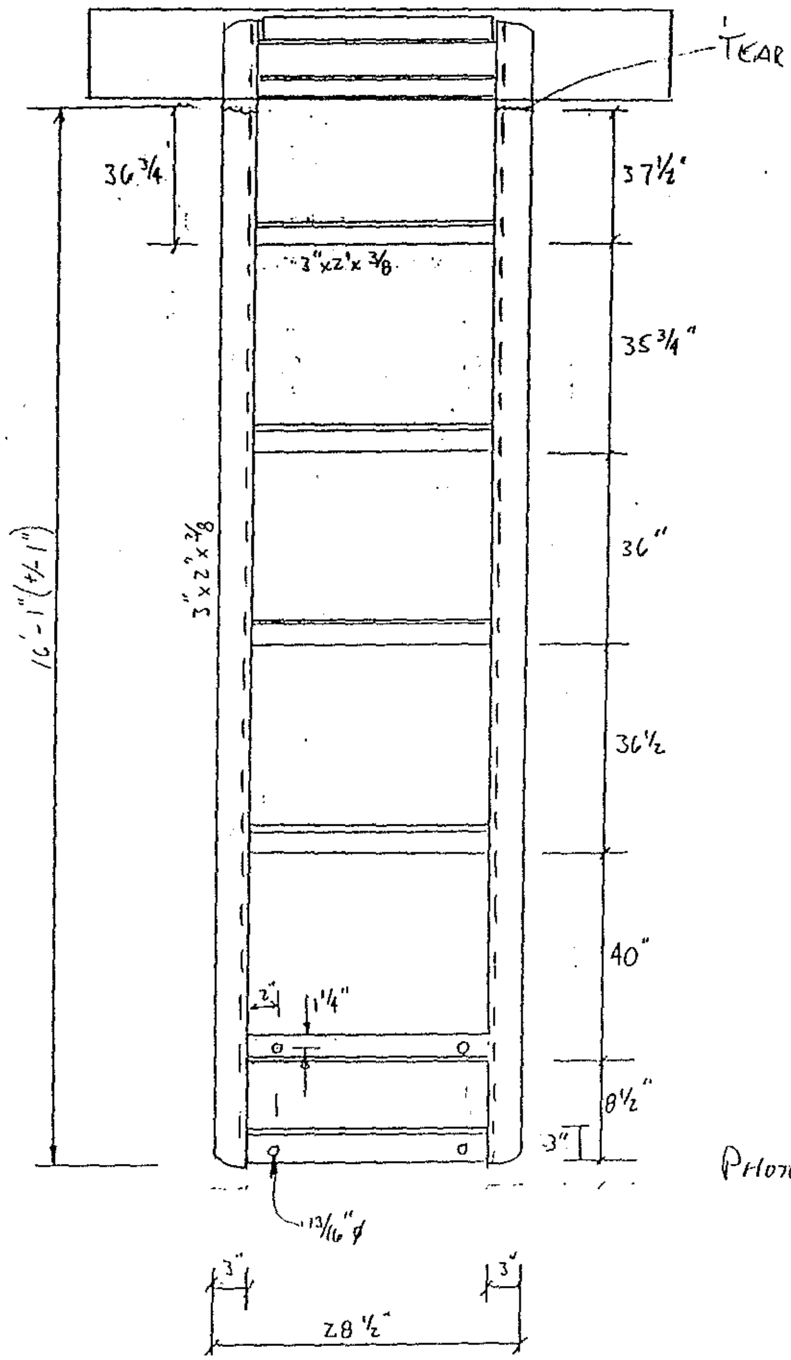
DATE 10/15/96

BY Jed Isen

SUBJECT Jump Track Assembly

SHEET 4 OF 4

MEI NO.



Photos 32 - 37

Jump Track Assembly

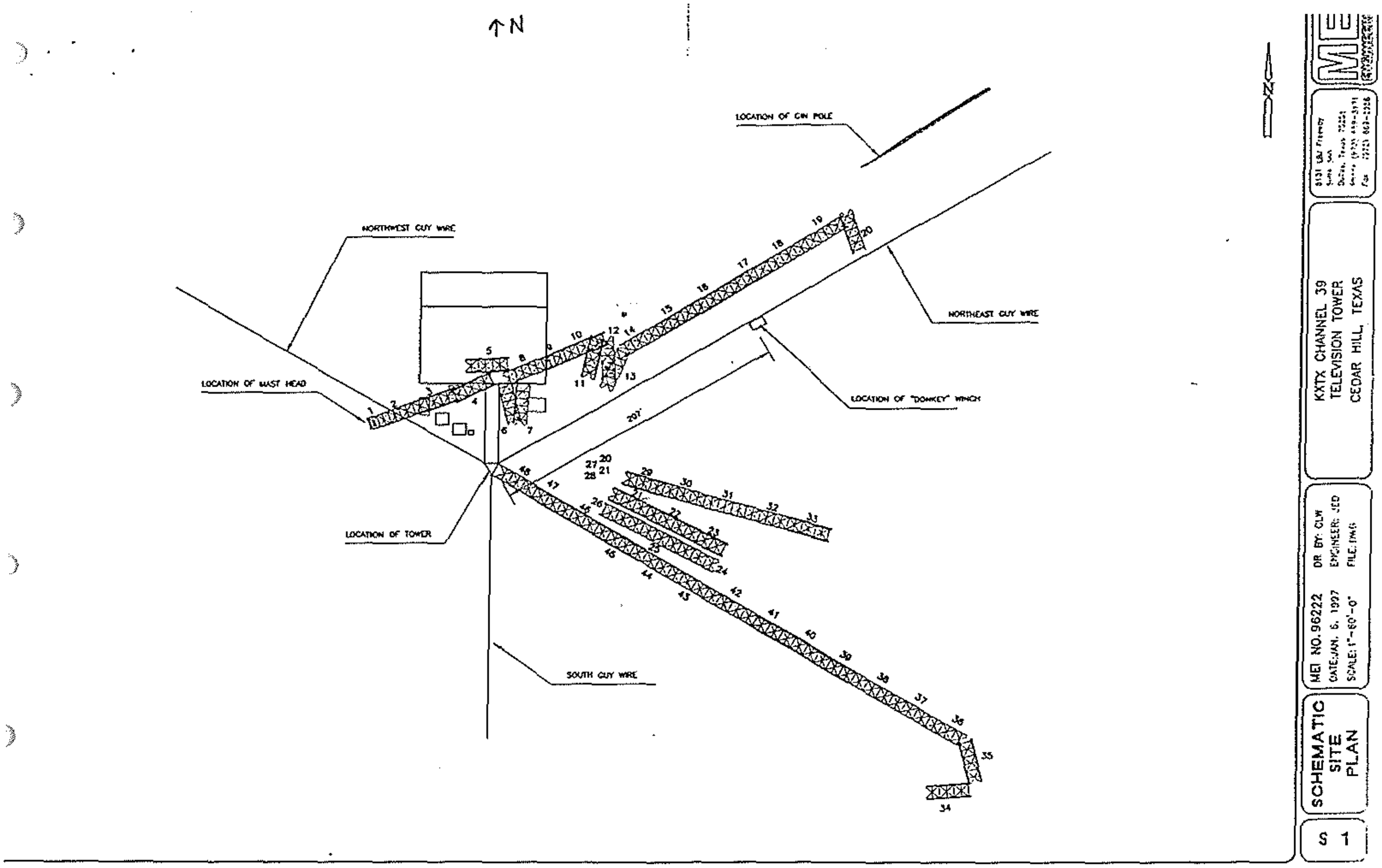
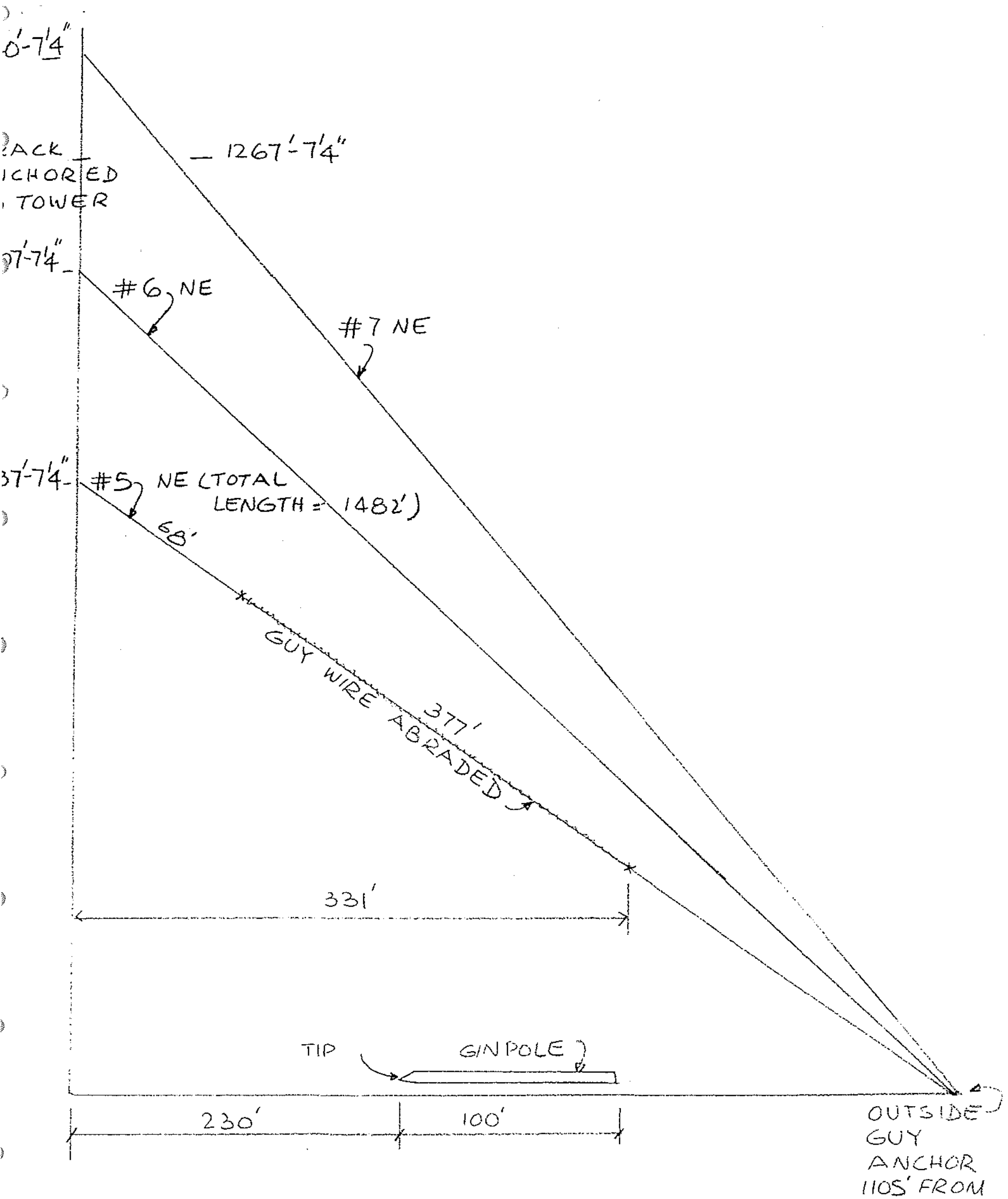
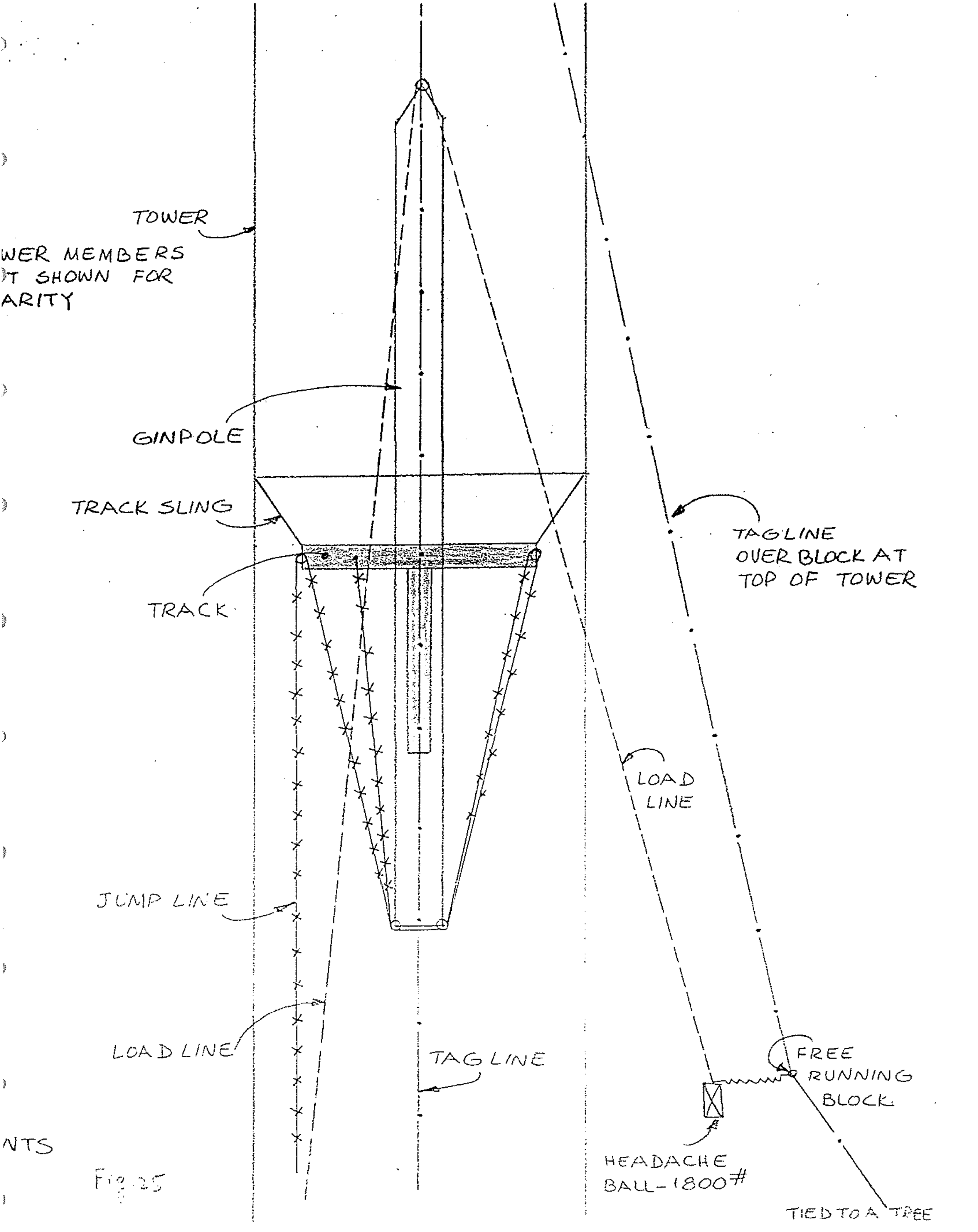

↑N
LOCATION OF GIN POLE
NORTHWEST GUY WIRE
NORTHEAST GUY WIRE
LOCATION OF MAST HEAD
LOCATION OF "DONKEY" WINCH
LOCATION OF TOWER
SOUTH GUY WIRE
207'
KXTX CHANNEL 39
TELEVISION TOWER
CEDAR HILL, TEXAS
MEI NO. 96222
DATE: JAN. 6, 1997
SCALE: 1"-60'-0"
DR BY: CLW
ENGINEER: JED
FILE: TMG
SCHEMATIC
SITE
PLAN
S 1

Fig. 23



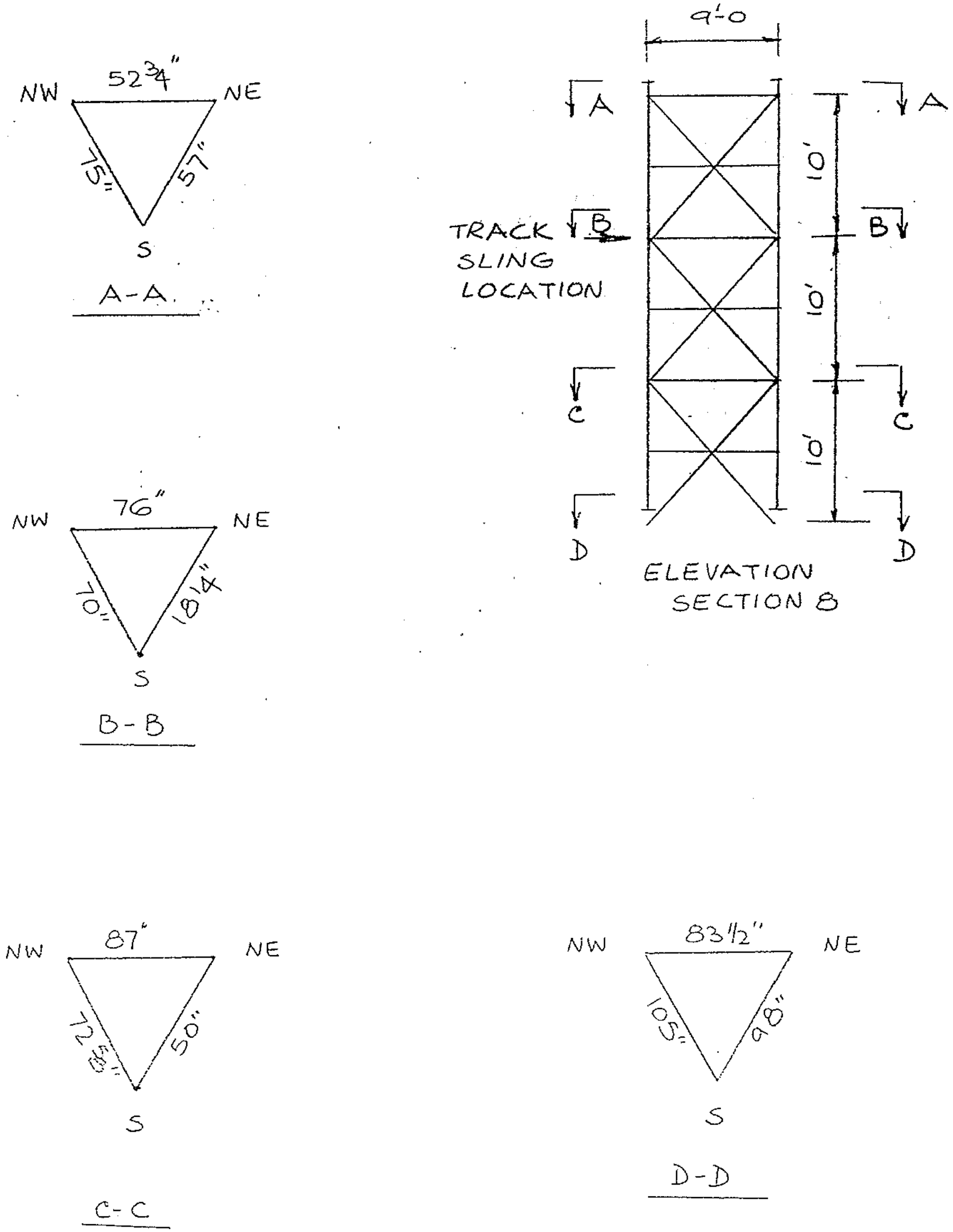
0'-7¼"
RACK
ANCHORED
TOWER
1267'-7¼"
07'-7¼"
#6 NE
#7 NE
37'-7¼"
#5 NE (TOTAL LENGTH = 1482')
68'
GUY WIRE ABRADED
377'
331'
TIP
GINPOLE
230'
100'
OUTSIDE GUY ANCHOR 1105' FROM ℄ OF TOWER

Fig 24



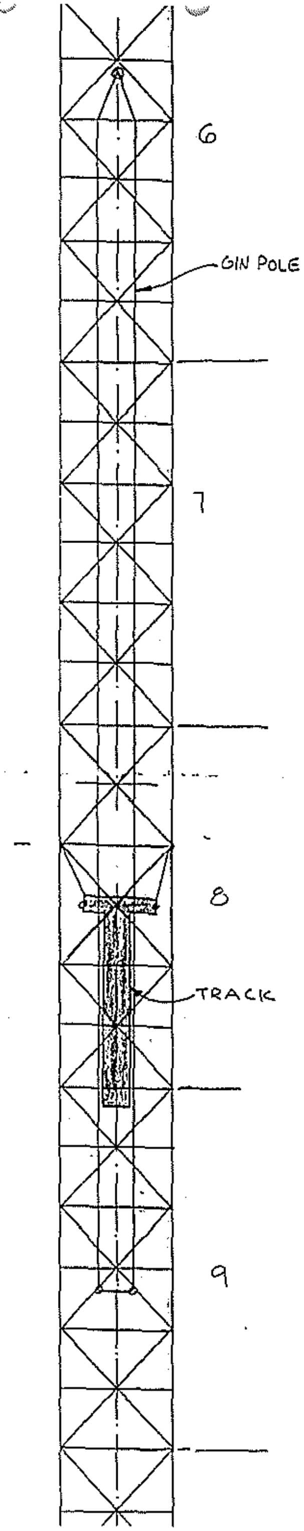
TOWER
WER MEMBERS
T SHOWN FOR
ARITY
GINPOLE
TRACK SLING
TRACK
TAGLINE
OVER BLOCK AT
TOP OF TOWER
LOAD
LINE
JUMP LINE
LOAD LINE
TAG LINE
FREE
RUNNING
BLOCK
HEADACHE
BALL-1800#
TIED TO A TREE
NTS

Fig 25



FIELD MEASUREMENT OF SECTION 8
AFTER TOWER COLLAPSE

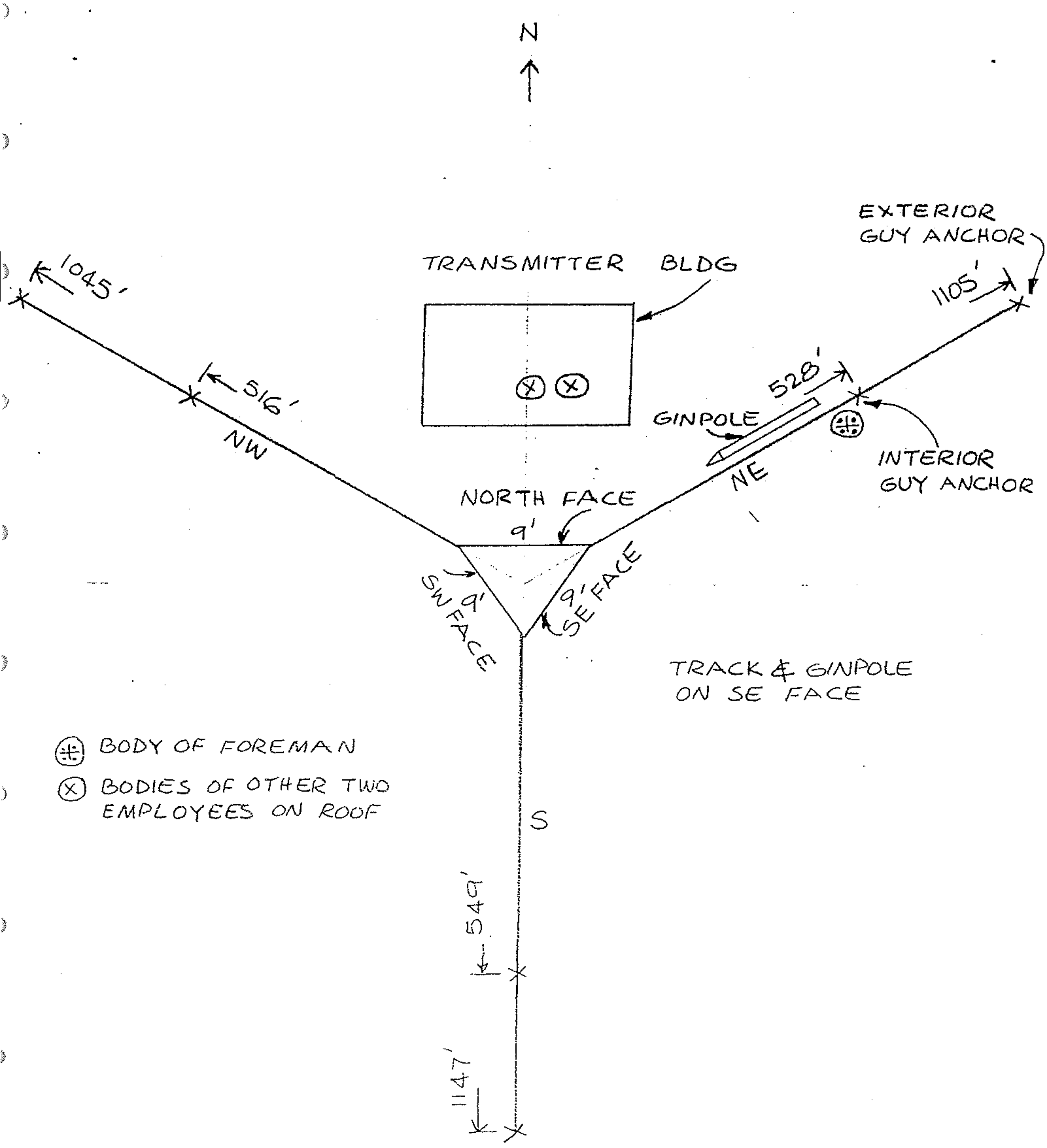
Fig. 26



1267'-7¼"

ELEVATION SHOWING TRACK & GINPOLE. JUMP LINE NOT SHOWN FOR CLARITY.

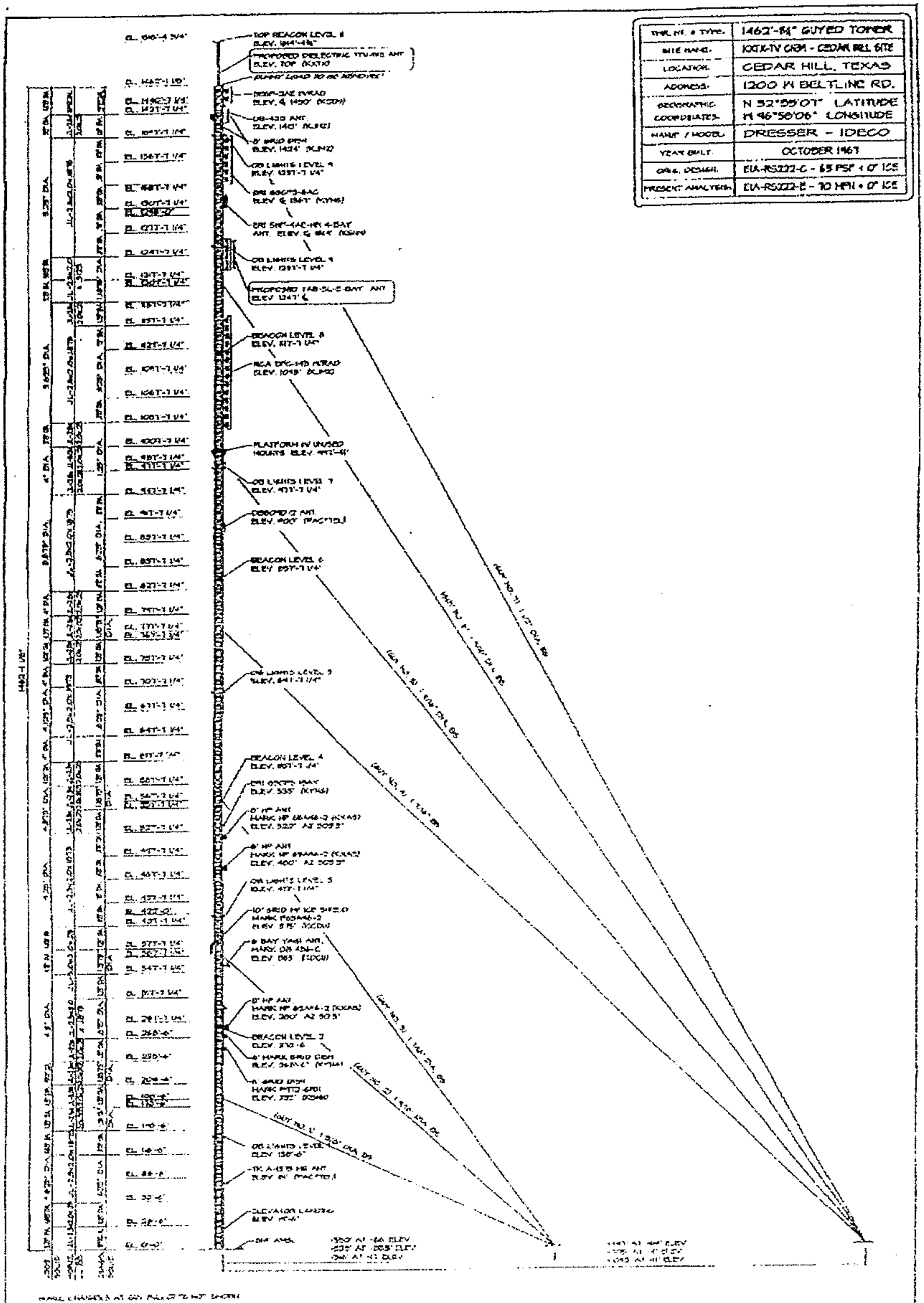
Fig. 27



PLAN

NTS

Fig. 28



96-026A

TOWER ELEVATION
1462' ± GUYED TOWER
KXTX - TV CH 39

MALOUF • ENGINEERING • INTERNATIONAL, INC.

STRUCTURAL ENGINEERING CONSULTANTS

Fig. 29

Appendix A

A.2 Analysis Results for 15 mph Wind + Track & Gin Pole Loads

A.2.1 Results for Approximate Loads

Leg Loads (Kips) 15 mph Wind

SECTION JHB DWG	SIZE	Fy Ksi	Max. Ld Kips	Dir	Allow. Ld Kips
1-3 50	R 5.25	90	303	2	876
4 49	R 4.625	95	295	2	659
5 48	R 4.625	95	290	2	659
6 47	R 4.625	95	286	2	659
7 46	R 4.625	95	282	2	659
8 45	R 4.75	95	278	3	707
9 44	R 5	95	277	3	776
10 43	R 4.625	95	262	1	659
11 42	R 4.5	95	258	1	613
12 41	R 4.5	95	254	3	613
13 40	R 4.5	95	253	3	613
14 39	R 4.5	95	252	1	613
15 38	R 4.75	95	253	1	707
16 37	R 4.625	95	230	1	659
17 36	R 4.25	95	224	1	524
18 35	R 4.25	95	218	1	524
19 34	R 4.25	95	214	1	524
20 33	R 4.25	95	213	1	524
21 32	R 4.375	95	215	1	568
22 31	R 4.375	95	216	1	568
23 30	R 4.125	95	188	1	482
24 29	R 4	95	181	1	441
25 28	R 4.125	95	179	1	482
26 27	R 4.125	95	178	1	482
27 26	R 4	95	176	1	441
28 25	R 4.125	95	172	1	482
29 24	R 4.25	95	170	1	524
30 23	R 4	95	148	1	441
31 22	R 3.875	95	149	1	401
32 21	R 3.875	95	148	1	401
33 20	R 3.875	95	146	1	401
34 19	R 3.875	95	143	1	401
35 18	R 4	95	138	1	441
36 17	R 4	95	135	1	441
37 16	R 3.75	95	106	1	363
38 15	R 3.625	95	105	1	327
39 14	R 3.625	95	103	2	327
40 13	R 3.625	95	103	2	327
41 12	R 3.625	95	102	2	327
42 11	R 3.625	95	99	2	327
43 10	R 3.75	95	95	2	363
44 9	R 3.625	95	70	3	327
45 8	R 3.25	95	74	3	225
46 7	R 3.25	95	66	3	225
47 6	R 3.25	95	63	3	225
48 5	R 3.25	95	59	3	225
49 4	R 3.25	95	54	3	225
50 3	R 3.5	95	47	3	292
51 2	R 4.125	50	38	3	352
52 1	R 4.875	36	3	2	116

Diagonal Loads (Kips)15 mph Wind

SECTION JHB DWG	SIZE	Fy Ksi	Max. Ld Kips	Dir	Allow. Ld Kips
1-3 50	See Special Table				
4 49	R 1	50	1.3	1	23.6
5 48	R 5/8	50	1.2	1	9.2
6 47	R 5/8	50	.4	1	9.2
7 46	R 7/8	50	.3	2	18.0
8 45	R 1 1/8	50	.5	2	29.8
9 44	R 1 1/4	50	1.9	1	36.8
10 43	R 1 1/8	50	1.6	1	29.8
11 42	R 1	50	1.4	1	23.6
12 41	R 7/8	50	.3	2	18.0
13 40	R 7/8	50	.6	2	18.0
14 39	R 1 1/4	50	.7	2	29.8
15 38	See Special Table				
16 37	R 1 1/4	50	1.4	1	36.8
17 36	R 7/8	50	1.5	1	18.0
18 35	R 3/4	50	.6	1	13.3
19 34	R 5/8	50	.8	2	9.2
20 33	R 3/4	50	1.3	2	13.3
21 32	R 1	50	1.8	2	23.6
22 31	R 1 1/8	50	2.2	2	29.8
23 30	R 1	50	1.4	3	23.6
24 29	R 7/8	50	1.0	1	18.0
25 28	R 5/8	50	.8	1	9.2
26 27	R 5/8	50	.6	1	9.2
27 26	R 7/8	50	.9	1	18.0
28 25	R 1	50	1.2	2	23.6
29 24	R 1 1/8	50	2.2	1	29.8
30 23	R 1	50	1.9	1	23.6
31 22	R 7/8	50	1.4	1	18.0
32 21	R 5/8	50	.5	1	9.2
33 20	R 5/8	50	.5	2	9.2
34 19	R 7/8	50	.8	2	18.0
35 18	R 1	50	1.2	3	23.6
36 17	R 1 1/8	50	2.1	1	29.8
37 16	R 1	50	1.4	3	23.6
38 15	R 7/8	50	1.1	2	18.0
39 14	R 5/8	50	.9	2	9.2
40 13	R 5/8	50	.6	1	9.2
41 12	R 3/4	50	.9	2	13.3
42 11	R 1	50	1.3	3	23.6
43 10	R 1 1/8	50	4.6	2	29.8
44 9	R 1 1/8	50	4.5	2	29.8
45 8	R 7/8	50	3.6	2	18.0
46 7	R 3/4	50	1.7	1	13.3
47 6	R 5/8	50	1.6	1	9.2
48 5	R 3/4	50	1.5	2	13.3
49 4	R 7/8	50	1.8	2	18.0
50 3	R 1	50	2.1	2	23.6
51 2	See Special Table				
52 1	See Special Table				

Strut Loads (Kips)15 mph Wind

SECTION JHB DWG	SIZE	Fy Ksi	Max. Ld Kips	Dir	Allow. Ld Kips
1-3 50	See Special Table				
4 49	2L2-1/2x2x 1/4	36	-.7	1	22
5 48	3/16	36	-.8	1	16
6 47	3/16	36	-.3	1	16
7 46	3/16	36	0		16
8 45	5/16	36	0		29
9 44	3x2x 1/4	36	13.6	1	23
10 43	2-1/2x2x5/16	36	-.8	1	29
11 42	1/4	36	-.6	1	22
12 41	3/16	36	0		16
13 40	3/16	36	0		16
14 39	3x2x 1/4	36	0		23
15 38	1/4	36	15.3	1	23
16 37	1/4	36	-.5	1	23
17 36	2-1/2x2x 3/16	36	-.8	1	16
18 35	3/16	36	-.2	1	16
19 34	3/16	36	-.5	2	16
20 33	3/16	36	-.9	2	16
21 32	1/4	36	-1.3	2	22
22 31	5/16	36	10.1	1	29
23 30	1/4	36	-.8	3	22
24 29	3/16	36	-.6	1	16
25 28	3/16	36	-.5	1	16
26 27	3/16	36	-.4	1	16
27 26	3/16	36	-.5	2	16
28 25	1/4	36	-.7	2	22
29 24	5/16	36	13.9	1	29
30 23	1/4	36	-1.2	1	22
31 22	3/16	36	-.7	1	16
32 21	3/16	36	-.3	1	16
33 20	3/16	36	-.4	2	16
34 19	3/16	36	-.3	2	16
35 18	1/4	36	-.8	3	22
36 17	5/16	36	13.8	1	29
37 16	1/4	36	-.8	2	22
38 15	3/16	36	-.7	2	16
39 14	3/16	36	-.5	2	16
40 13	3/16	36	-.5	1	16
41 12	3/16	36	-.6	1	16
42 11	1/4	36	-.9	3	22
43 10	5/16	36	13.7	3	29
44 9	5/16	36	-3.0	2	29
45 8	3/16	36	-5.0	3	16
46 7	3/16	36	-1.2	1	16
47 6	3/16	36	-1.0	1	16
48 5	3/16	36	-1.0	2	16
49 4	3/16	36	-1.2	2	16
50 3	1/4	36	-1.3	2	22
51 2	See Special Table				
52 1	See Special Table				

Special Table - Diagonal Loads (Kips) 15 mph Wind

SECTION JHB DWG	SIZE	Fy Ksi	Max. Ld Kips	Dir	Allow. Ld Kips
1 50	L2-1/2x2x1/4	36	-4.5	1	12.8
2 50	R 1-1/2	50	6.1	1	53.0
3 50	L2-1/2x2x1/4	36	-5.1	1	8.6
15-1 38	R 1-1/4	50	1.0	2	29.8
15-2 38	R 1-3/8	50	1.7	2	44.5
15-3 38	R 1-3/8	50	2.0	1	44.5
51-1 2	L2x2x1/4	36	-1.1	2	4.1
51-2 2	L3-1/2x3x1/4	36	-1.8	2	6.4
51-3 2	L3-1/2x3x1/4	36	-.6	1	6.4
52 41	L2x2x1/4	36	.4	1	3.3

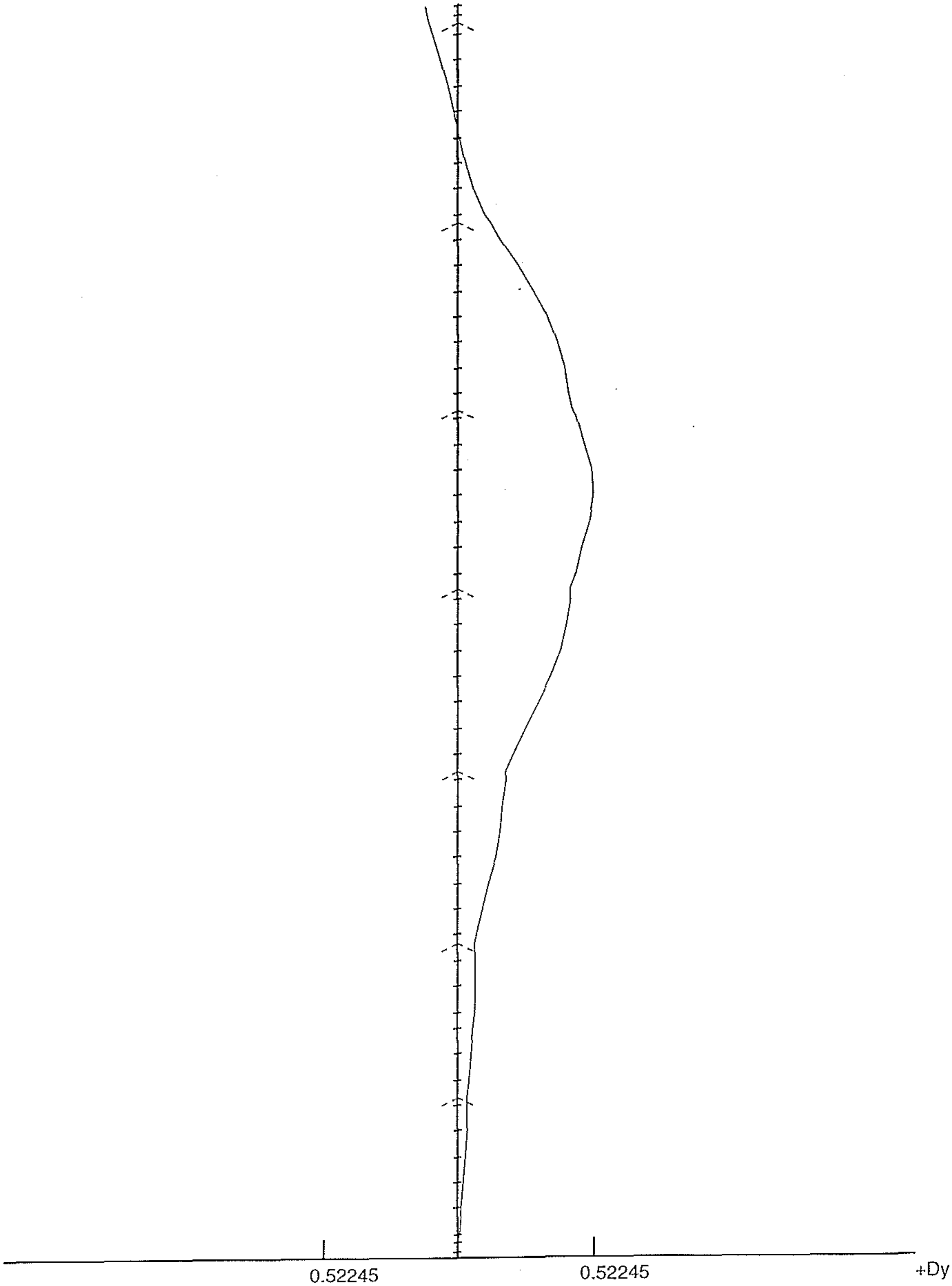
Special Table - Strut Loads (Kips) 15 mph Wind

SECTION JHB DWG	SIZE	Fy Ksi	Max. Ld Kips	Dir	Allow. Ld Kips
1 50	L2-1/2x2x1/4	36	-4.0	1	14.0
2 50	8C11.5	36	-2.0	1	16.9
3 50	L2x2x1/4	36	3.4	3	7.3
51-1 2	9C13.4	36	-.8	2	60.2
51-2 2	9C13.4	36	12.2	2	60.2
51-3 2	9C13.4	36	-.4	1	60.2
52 41	L2x1-1/2x3/16	36	-.2	1	.8

A.2.1.4 Displacement and Moment Diagrams

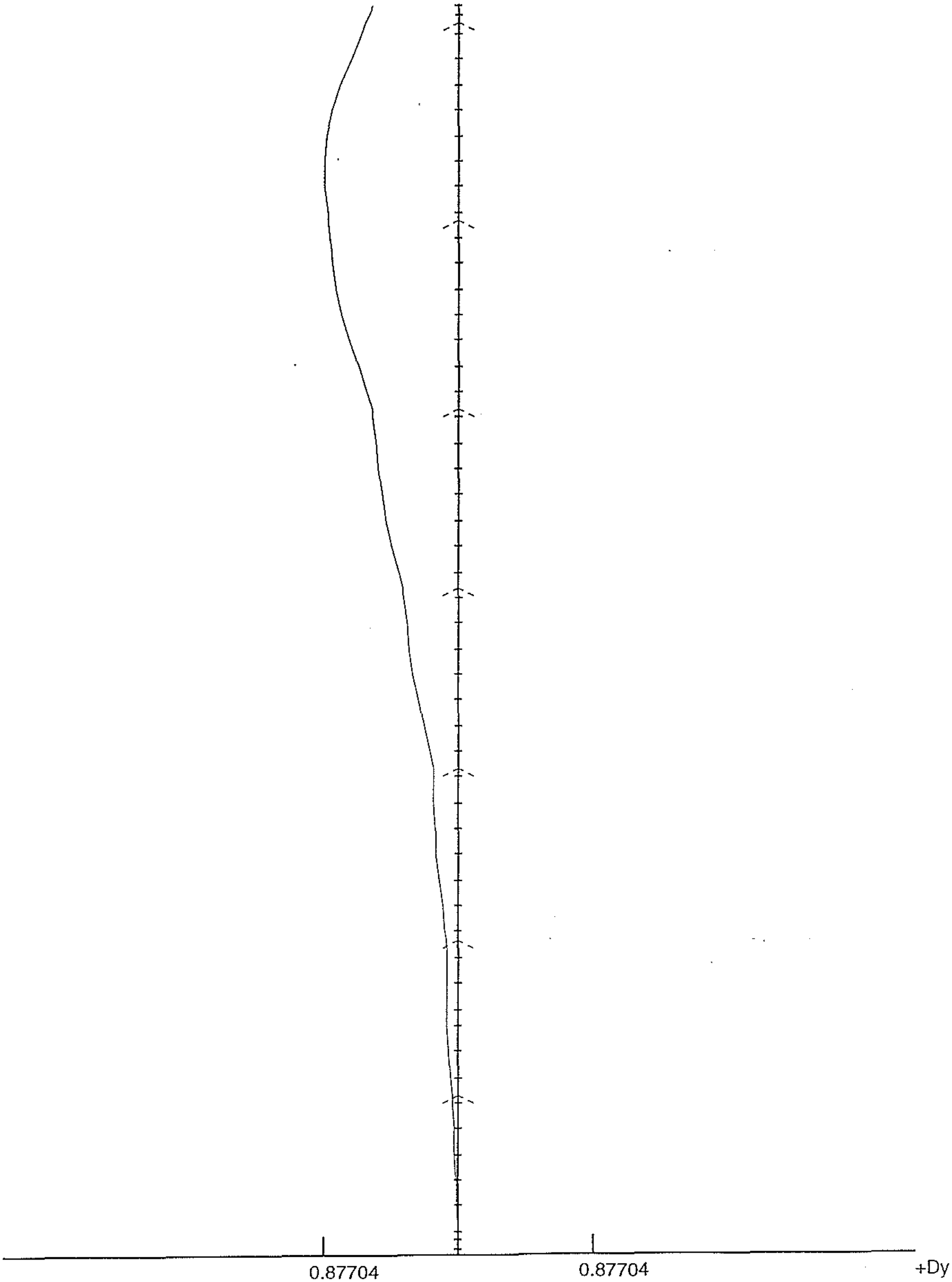
1500' CEDAR HILL TOWER(OSHA/AYUB), AYUB.DAT 19-DEC-96

Wind Direction - 1



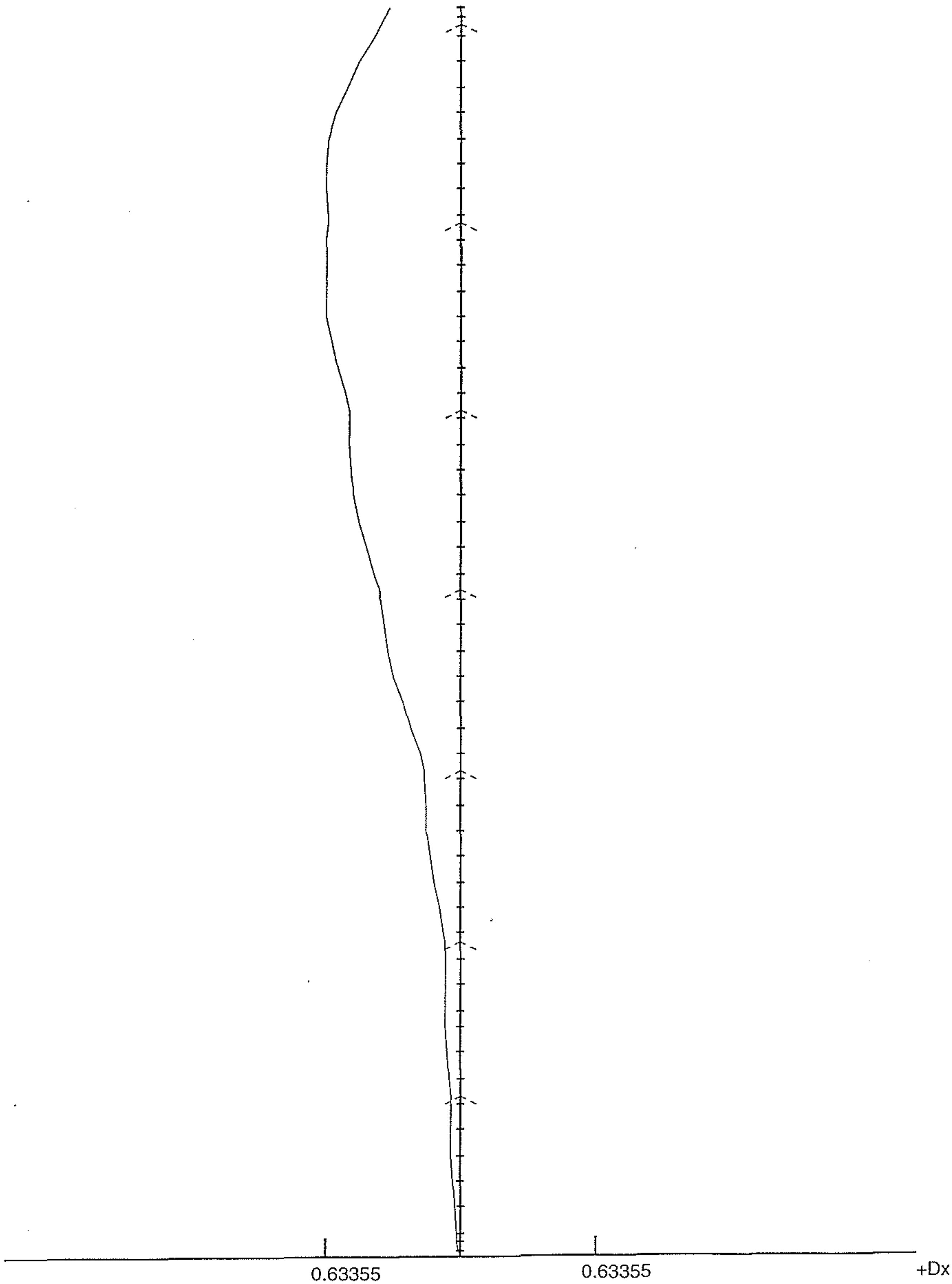
1500' CEDAR HILL TOWER(OSHA/AYUB), AYUB.DAT 19-DEC-96

Wind Direction - 2



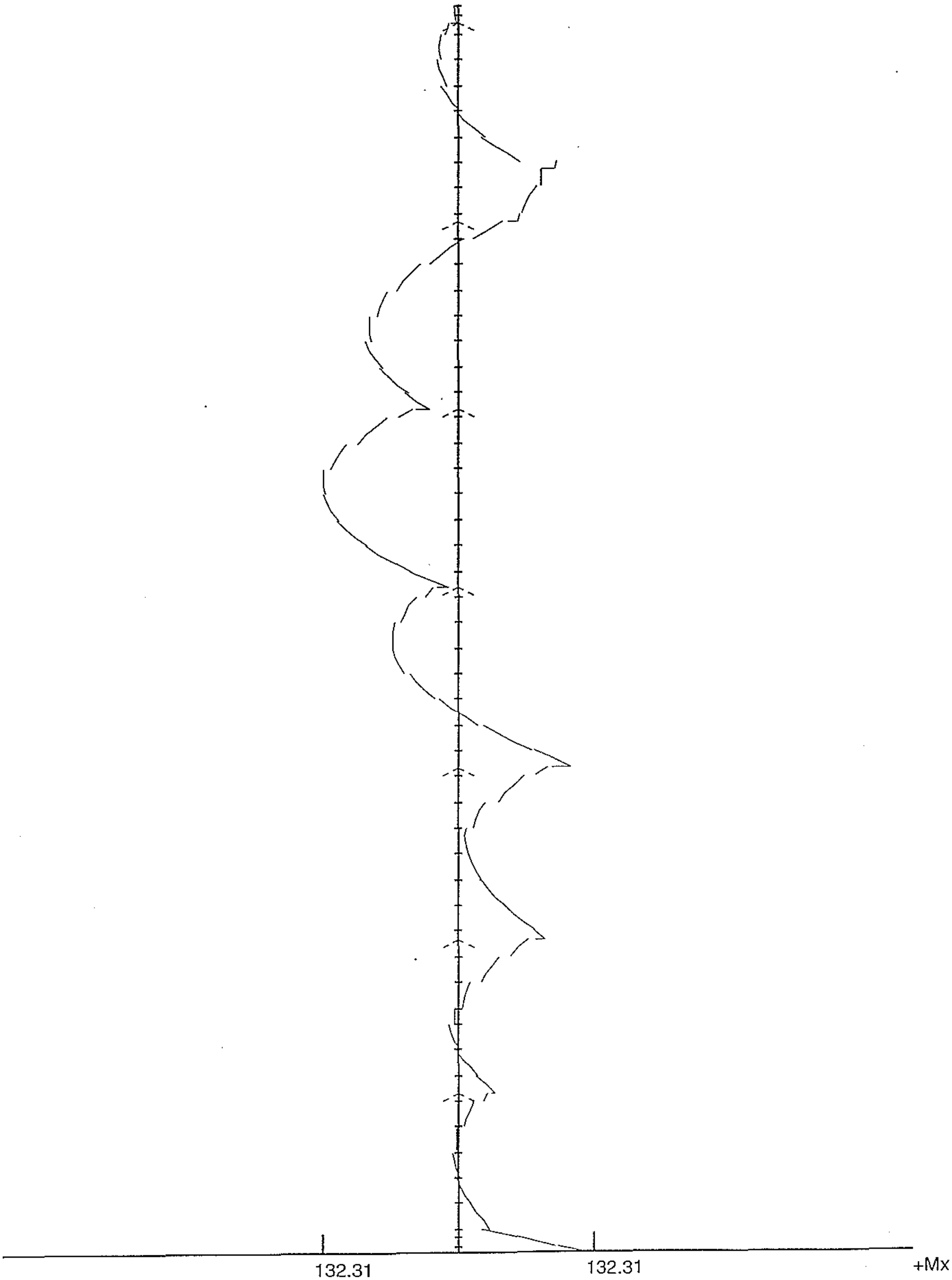
1500' CEDAR HILL TOWER(OSHA/AYUB), AYUB.DAT 19-DEC-96

Wind Direction - 3



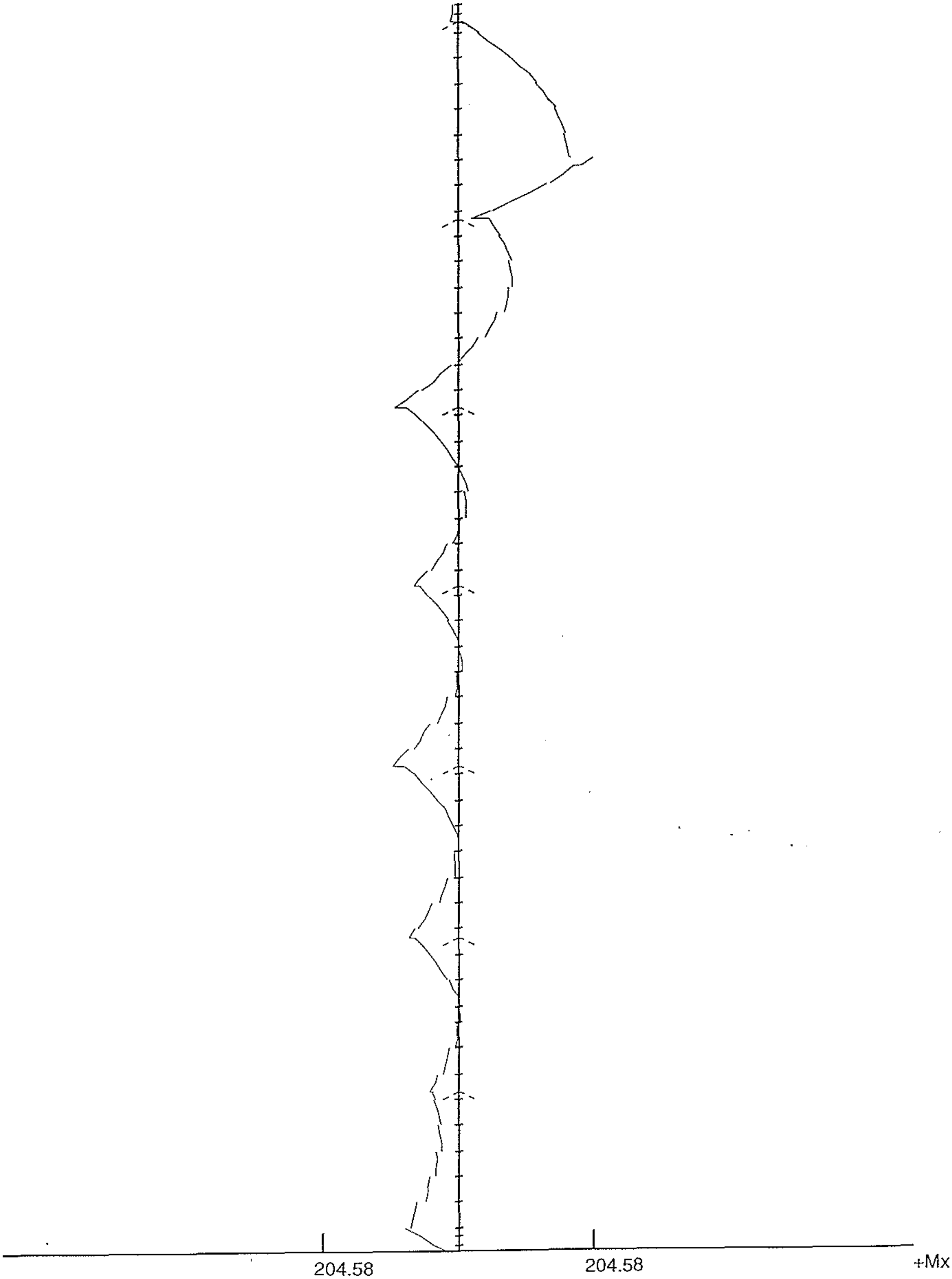
1500' CEDAR HILL TOWER(OSHA/AYUB), AYUB.DAT 19-DEC-96

Wind Direction - 1



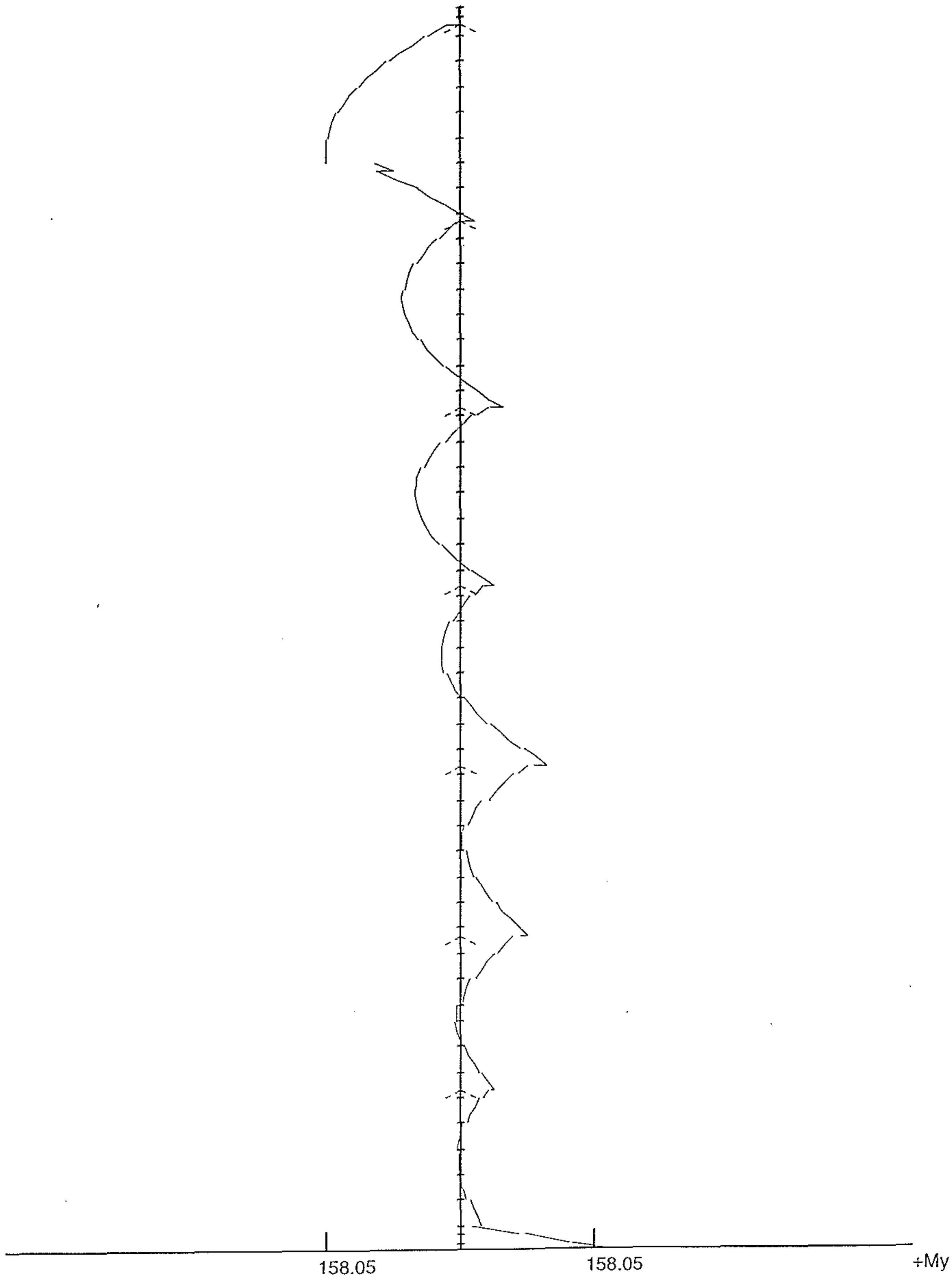
1500' CEDAR HILL TOWER(OSHA/AYUB), AYUB.DAT 19-DEC-96

Wind Direction - 2



1500' CEDAR HILL TOWER(OSHA/AYUB), AYUB.DAT 19-DEC-96

Wind Direction - 3



A.2.2 Results for Track and Gin Pole Rotated 70 deg Loads

A.2.2.1 Maximum Member Forces - Summary Table

Leg Loads (Kips) 15 mph Wind

SECTION JHB DWG	SIZE	Fy Ksi	Max. Ld Kips	Dir	Allow. Ld Kips
1-3 50	R 5.25	90	339	2	876
4 49	R 4.625	95	332	2	659
5 48	R 4.625	95	327	2	659
6 47	R 4.625	95	322	2	659
7 46	R 4.625	95	319	2	659
8 45	R 4.75	95	315	1	707
9 44	R 5	95	314	1	776
10 43	R 4.625	95	299	1	659
11 42	R 4.5	95	294	1	613
12 41	R 4.5	95	291	1	613
13 40	R 4.5	95	290	1	613
14 39	R 4.5	95	290	1	613
15 38	R 4.75	95	291	1	707
16 37	R 4.625	95	268	1	659
17 36	R 4.25	95	261	1	524
18 35	R 4.25	95	255	1	524
19 34	R 4.25	95	252	1	524
20 33	R 4.25	95	251	1	524
21 32	R 4.375	95	253	1	568
22 31	R 4.375	95	254	1	568
23 30	R 4.125	95	226	1	482
24 29	R 4	95	220	2	441
25 28	R 4.125	95	220	1	482
26 27	R 4.125	95	219	1	482
27 26	R 4	95	216	1	441
28 25	R 4.125	95	213	1	482
29 24	R 4.25	95	211	2	524
30 23	R 4	95	189	1	441
31 22	R 3.875	95	188	1	401
32 21	R 3.875	95	185	1	401
33 20	R 3.875	95	182	1	401
34 19	R 3.875	95	178	1	401
35 18	R 4	95	173	1	441
36 17	R 4	95	168	2	441
37 16	R 3.75	95	144	2	363
38 15	R 3.625	95	149	2	327
39 14	R 3.625	95	150	2	327
40 13	R 3.625	95	150	2	327
41 12	R 3.625	95	149	2	327
42 11	R 3.625	95	145	2	327
43 10	R 3.75	95	140	2	363
44 9	R 3.625	95	112	2	327
45 8	R 3.25	95	113	2	225
46 7	R 3.25	95	96	3	225
47 6	R 3.25	95	85	3	225
48 5	R 3.25	95	75	3	225
49 4	R 3.25	95	64	3	225
50 3	R 3.5	95	52	3	292
51 2	R 4.125	50	40	3	352
52 1	R 4.875	36	3	2	116

Diagonal Loads (Kips)15 mph Wind

SECTION JHB DWG	SIZE	Fy Ksi	Max. Ld Kips	Dir	Allow. Ld Kips
1-3 50	See Special Table				
4 49	R 1	50	1.1	1	23.6
5 48	R 5/8	50	1.2	1	9.2
6 47	R 5/8	50	.3	1	9.2
7 46	R 7/8	50	.3	2	18.0
8 45	R 1 1/8	50	.5	2	29.8
9 44	R 1 1/4	50	1.3	1	36.8
10 43	R 1 1/8	50	1.4	1	29.8
11 42	R 1	50	1.4	1	23.6
12 41	R 7/8	50	.3	2	18.0
13 40	R 7/8	50	.6	2	18.0
14 39	R 1 1/4	50	.7	2	29.8
15 38	See Special Table				
16 37	R 1 1/4	50	.9	1	36.8
17 36	R 7/8	50	1.5	1	18.0
18 35	R 3/4	50	.6	1	13.3
19 34	R 5/8	50	.5	1	9.2
20 33	R 3/4	50	1.2	2	13.3
21 32	R 1	50	1.7	2	23.6
22 31	R 1 1/8	50	2.0	2	29.8
23 30	R 1	50	1.3	3	23.6
24 29	R 7/8	50	1.0	1	18.0
25 28	R 5/8	50	.8	1	9.2
26 27	R 5/8	50	.8	3	9.2
27 26	R 7/8	50	1.0	3	18.0
28 25	R 1	50	.9	2	23.6
29 24	R 1 1/8	50	1.8	1	29.8
30 23	R 1	50	1.5	1	23.6
31 22	R 7/8	50	1.1	1	18.0
32 21	R 5/8	50	.5	3	9.2
33 20	R 5/8	50	.5	3	9.2
34 19	R 7/8	50	.8	3	18.0
35 18	R 1	50	1.3	3	23.6
36 17	R 1 1/8	50	3.9	3	29.8
37 16	R 1	50	3.3	3	23.6
38 15	R 7/8	50	3.3	3	18.0
39 14	R 5/8	50	3.2	3	9.2
40 13	R 5/8	50	3.1	3	9.2
41 12	R 3/4	50	2.9	3	13.3
42 11	R 1	50	2.7	3	23.6
43 10	R 1 1/8	50	12.0	3	29.8
44 9	R 1 1/8	50	12.0	3	29.8
45 8	R 7/8	50	11.0	3	18.0
46 7	R 3/4	50	4.2	2	13.3
47 6	R 5/8	50	4.4	3	9.2
48 5	R 3/4	50	4.6	3	13.3
49 4	R 7/8	50	4.8	3	18.0
50 3	R 1	50	5.1	3	23.6
51 2	See Special Table				
52 1	See Special Table				

Strut Loads (Kips)15 mph Wind

SECTION JHB DWG	SIZE	Fy Ksi	Max. Ld Kips	Dir	Allow. Ld Kips
1-3 50	See Special Table				
4 49	2L2-1/2x2x 1/4	36	-.5	1	22
5 48	3/16	36	-.8	1	16
6 47	3/16	36	-.2	1	16
7 46	3/16	36	0		16
8 45	5/16	36	0		29
9 44	3x2x 1/4	36	13.6	1	23
10 43	2-1/2x2x5/16	36	-.5	1	29
11 42	1/4	36	-.6	1	22
12 41	3/16	36	0		16
13 40	3/16	36	0		16
14 39	3x2x 1/4	36	0		23
15 38	1/4	36	15.2	2	23
16 37	1/4	36	-.4	1	23
17 36	2-1/2x2x 3/16	36	-.7	1	16
18 35	3/16	36	-.2	1	16
19 34	3/16	36	-.4	3	16
20 33	3/16	36	-.7	2	16
21 32	1/4	36	-1.0	2	22
22 31	5/16	36	10.0	3	29
23 30	1/4	36	-.4	1	22
24 29	3/16	36	-.3	1	16
25 28	3/16	36	-.5	1	16
26 27	3/16	36	-.6	3	16
27 26	3/16	36	-.6	3	16
28 25	1/4	36	-.5	3	22
29 24	5/16	36	13.8	1	29
30 23	1/4	36	-.7	3	22
31 22	3/16	36	-.5	3	16
32 21	3/16	36	-.3	3	16
33 20	3/16	36	-.2	2	16
34 19	3/16	36	-.4	1	16
35 18	1/4	36	-.8	1	22
36 17	5/16	36	14.0	3	29
37 16	1/4	36	-2.2	3	22
38 15	3/16	36	-2.2	3	16
39 14	3/16	36	-2.2	3	16
40 13	3/16	36	-2.1	3	16
41 12	3/16	36	-2.0	3	16
42 11	1/4	36	-1.9	3	22
43 10	5/16	36	14.3	3	29
44 9	5/16	36	-8.0	3	29
45 8	3/16	36	-76.0	3	16
46 7	3/16	36	-2.8	3	16
47 6	3/16	36	-3.1	3	16
48 5	3/16	36	-3.2	3	16
49 4	3/16	36	-3.3	3	16
50 3	1/4	36	-3.3	3	22
51 2	See Special Table				
52 1	See Special Table				

Special Table - Diagonal Loads (Kips) 15 mph Wind

SECTION JHB DWG	SIZE	Fy Ksi	Max. Ld Kips	Dir	Allow. Ld Kips
1 50	L2-1/2x2x1/4	36	-4.4	1	12.8
2 50	R 1-1/2	50	5.9	1	53.0
3 50	L2-1/2x2x1/4	36	-5.0	1	8.6
15-1 38	R 1-1/4	50	.9	2	29.8
15-2 38	R 1-3/8	50	1.2	2	44.5
15-3 38	R 1-3/8	50	1.7	1	44.5
51-1 2	L2x2x1/4	36	-2.4	3	4.1
51-2 2	L3-1/2x3x1/4	36	-4.0	3	6.4
51-3 2	L3-1/2x3x1/4	36	-.7	1	6.4
52 41	L2x2x1/4	36	.5	1	3.3

Special Table - Strut Loads (Kips) 15 mph Wind

SECTION JHB DWG	SIZE	Fy Ksi	Max. Ld Kips	Dir	Allow. Ld Kips
1 50	L2-1/2x2x1/4	36	-4.0	1	14.0
2 50	8C11.5	36	-1.9	1	16.9
3 50	L2x2x1/4	36	3.4	3	7.3
51-1 2	9C13.4	36	-1.8	3	60.2
51-2 2	9C13.4	36	12.7	3	60.2
51-3 2	9C13.4	36	-.4	1	60.2
52 41	L2x1-1/2x3/16	36	-.2	1	.8

Appendix B

A.3 Analysis Results for 70 mph Wind

A.3.1 Maximum Member Forces - Summary Table

Leg Loads (Kips) 70 mph Wind

SECTION JHB DWG	SIZE	Fy Ksi	Max. Ld Kips	Dir	Allow. Ld Kips
1-3 50	R 5.25	90	604	1	876
4 49	R 4.625	95	559	1	659
5 48	R 4.625	95	516	1	659
6 47	R 4.625	95	490	1	659
7 46	R 4.625	95	494	1	659
8 45	R 4.75	95	526	1	707
9 44	R 5	95	541	1	776
10 43	R 4.625	95	482	1	659
11 42	R 4.5	95	440	1	613
12 41	R 4.5	95	433	1	613
13 40	R 4.5	95	475	1	613
14 39	R 4.5	95	539	1	613
15 38	R 4.75	95	593	3	707
16 37	R 4.625	95	535	1	659
17 36	R 4.25	95	427	1	524
18 35	R 4.25	95	350	3	524
19 34	R 4.25	95	353	3	524
20 33	R 4.25	95	338	3	524
21 32	R 4.375	95	401	1	568
22 31	R 4.375	95	431	1	568
23 30	R 4.125	95	333	1	482
24 29	R 4	95	307	1	441
25 28	R 4.125	95	323	1	482
26 27	R 4.125	95	318	1	482
27 26	R 4	95	303	1	441
28 25	R 4.125	95	284	1	482
29 24	R 4.25	95	321	1	524
30 23	R 4	95	244	1	441
31 22	R 3.875	95	281	1	401
32 21	R 3.875	95	293	1	401
33 20	R 3.875	95	287	1	401
34 19	R 3.875	95	270	1	401
35 18	R 4	95	239	1	441
36 17	R 4	95	245	2	441
37 16	R 3.75	95	195	3	363
38 15	R 3.625	95	233	1	327
39 14	R 3.625	95	255	1	327
40 13	R 3.625	95	254	1	327
41 12	R 3.625	95	245	1	327
42 11	R 3.625	95	219	1	327
43 10	R 3.75	95	178	1	363
44 9	R 3.625	95	126	1	327
45 8	R 3.25	95	169	2	225
46 7	R 3.25	95	215	2	225
47 6	R 3.25	95	232	2	225
48 5	R 3.25	95	231	2	225
49 4	R 3.25	95	217	2	225
50 3	R 3.5	95	173	2	292
51 2	R 4.125	50	96	2	352
52 1	R 4.875	36	9	1	116

Diagonal Loads (Kips) 70 mph Wind

SECTION JHB DWG	SIZE	Fy Ksi	Max. Ld Kips	Dir	Allow. Ld Kips
1-3 50	See Special Table				
4 49	R 1	50	16.2	3	23.6
5 48	R 5/8	50	12.2	3	9.2
6 47	R 5/8	50	8.0	3	9.2
7 46	R 7/8	50	5.7	1	18.0
8 45	R 1 1/8	50	9.1	3	29.8
9 44	R 1 1/4	50	18.7	3	36.8
10 43	R 1 1/8	50	16.6	3	29.8
11 42	R 1	50	8.6	3	23.6
12 41	R 7/8	50	4.7	3	18.0
13 40	R 7/8	50	12.2	3	18.0
14 39	R 1 1/4	50	21.0	3	29.8
15 38	See Special Table				
16 37	R 1 1/4	50	32.9	3	36.8
17 36	R 7/8	50	24.5	3	18.0
18 35	R 3/4	50	16.5	3	13.3
19 34	R 5/8	50	6.3	3	9.2
20 33	R 3/4	50	14.5	3	13.3
21 32	R 1	50	26.3	3	23.6
22 31	R 1 1/8	50	36.2	3	29.8
23 30	R 1	50	30.3	3	23.6
24 29	R 7/8	50	20.5	3	18.0
25 28	R 5/8	50	9.7	3	9.2
26 27	R 5/8	50	7.9	3	9.2
27 26	R 7/8	50	19.0	3	18.0
28 25	R 1	50	30.3	3	23.6
29 24	R 1 1/8	50	38.1	3	29.8
30 23	R 1	50	31.3	3	23.6
31 22	R 7/8	50	20.2	3	18.0
32 21	R 5/8	50	9.6	3	9.2
33 20	R 5/8	50	9.9	3	9.2
34 19	R 7/8	50	21.4	3	18.0
35 18	R 1	50	32.5	3	23.6
36 17	R 1 1/8	50	40.5	3	29.8
37 16	R 1	50	35.2	3	23.6
38 15	R 7/8	50	25.1	3	18.0
39 14	R 5/8	50	13.8	3	9.2
40 13	R 5/8	50	4.6	3	9.2
41 12	R 3/4	50	15.9	3	13.3
42 11	R 1	50	27.1	3	23.6
43 10	R 1 1/8	50	34.7	3	29.8
44 9	R 1 1/8	50	30.7	3	29.8
45 8	R 7/8	50	23.1	3	18.0
46 7	R 3/4	50	15.0	3	13.3
47 6	R 5/8	50	6.6	2	9.2
48 5	R 3/4	50	9.6	3	13.3
49 4	R 7/8	50	19.2	3	18.0
50 3	R 1	50	27.0	3	23.6
51 2	See Special Table				
52 1	See Special Table				

Strut Loads (Kips) 70 mph Wind

SECTION JHB DWG	SIZE	Fy Ksi	Max. Ld Kips	Dir	Allow. Ld Kips
1-3 50	See Special Table				
4 49	2L2-1/2x2x 1/4	36	-10	3	22
5 48	3/16	36	-7	3	16
6 47	3/16	36	-5	3	16
7 46	3/16	36	-3	3	16
8 45	5/16	36	-5	1	29
9 44	3x2x 1/4	36	-13	3	23
10 43	2-1/2x2x5/16	36	-10	3	29
11 42	1/4	36	-5	3	22
12 41	3/16	36	-4	3	16
13 40	3/16	36	-9	3	16
14 39	3x2x 1/4	36	-13	3	23
15 38	1/4	36	-22	3	23
16 37	1/4	36	-21	3	23
17 36	2-1/2x2x 3/16	36	-15	3	16
18 35	3/16	36	-10	3	16
19 34	3/16	36	-3	3	16
20 33	3/16	36	-12	3	16
21 32	1/4	36	-18	3	22
22 31	5/16	36	-23	3	29
23 30	1/4	36	-19	3	22
24 29	3/16	36	-13	3	16
25 28	3/16	36	-5	3	16
26 27	3/16	36	-7	3	16
27 26	3/16	36	-14	3	16
28 25	1/4	36	-22	3	22
29 24	5/16	36	-22	3	29
30 23	1/4	36	-20	3	22
31 22	3/16	36	-13	3	16
32 21	3/16	36	-5	3	16
33 20	3/16	36	-9	3	16
34 19	3/16	36	-16	3	16
35 18	1/4	36	-23	3	22
36 17	5/16	36	-26	3	29
37 16	1/4	36	-22	3	22
38 15	3/16	36	-16	3	16
39 14	3/16	36	-8	3	16
40 13	3/16	36	-5	3	16
41 12	3/16	36	-13	3	16
42 11	1/4	36	-20	3	22
43 10	5/16	36	-22	3	29
44 9	5/16	36	-20	3	29
45 8	3/16	36	-15	3	16
46 7	3/16	36	-9	3	16
47 6	3/16	36	-4	3	16
48 5	3/16	36	-9	3	16
49 4	3/16	36	-14	3	16
50 3	1/4	36	-17	3	22
51 2	See Special Table				
52 1	See Special Table				

Special Table - Diagonal Loads (Kips) 70 mph Wind

SECTION JHB DWG	SIZE	Fy Ksi	Max. Ld Kips	Dir	Allow. Ld Kips
1 50	L2-1/2x2x1/4	36	-13.9	3	12.8
2 50	R 1-1/2	50	18.7	3	53.0
3 50	L2-1/2x2x1/4	36	-14.4	3	8.6
15-1 38	R 1-1/4	50	22.1	3	29.8
15-2 38	R 1-3/8	50	24.7	3	44.5
15-3 38	R 1-3/8	50	35.5	3	44.5
51-1 2	L2x2x1/4	36	-13.7	3	4.1
51-2 2	L3-1/2x3x1/4	36	-23.4	3	6.4
51-3 2	L3-1/2x3x1/4	36	-3.4	1	6.4
52 41	L2x2x1/4	36	2.3	1	3.3

Special Table - Strut Loads (Kips) 70 mph Wind

SECTION JHB DWG	SIZE	Fy Ksi	Max. Ld Kips	Dir	Allow. Ld Kips
1 50	L2-1/2x2x1/4	36	-12.7	3	14.0
2 50	8C11.5	36	-6.2	3	16.9
3 50	L2x2x1/4	36	-11.4	3	7.3
51-1 2	9C13.4	36	-9.9	3	60.2
51-2 2	9C13.4	36	32.0	2	60.2
51-3 2	9C13.4	36	-2.5	2	60.2
52 41	L2x1-1/2x3/16	36	-1.05	1	.8

Appendix C

A.4 Track & Gin Pole Analysis

A.4.1 Equilibrium Analysis

A.2.1.1 Maximum Member Forces - Summary Table

A.4.2 Computer Program

$a := 4.5 \quad b := 6 \quad c := 4.5 \quad d := 9 \quad i := \begin{pmatrix}1\\0\\0\end{pmatrix} \quad j := \begin{pmatrix}0\\1\\0\end{pmatrix} \quad k := \begin{pmatrix}0\\0\\1\end{pmatrix}$

$W := 11.06 \quad \mu := .4 \quad f := 1 \quad w := 0$

$ll := .25$

$q := \dfrac{4.21}{11.06} \quad p := \dfrac{(1+\mu)}{4}$

$a10 := \dfrac{i - \sqrt{3}\cdot j}{3} \quad b10 := i \quad c10 := \dfrac{i + \sqrt{3}\cdot j}{3}$

$ca := i\cdot a10 \quad ct := i\cdot c10$

$\alpha := \operatorname{acos}(ca) \quad \theta := \operatorname{acos}(ct)$

$a1(\Delta) := i\cdot\cos(\alpha+\Delta) - j\cdot\sin(\alpha+\Delta)$

$b1(\Delta) := i\cdot\cos(\Delta) + j\cdot\sin(\Delta)$

$c1(\Delta) := i\cdot\cos(\theta-\Delta) + j\cdot\sin(\theta-\Delta)$

$e1(\Delta) := -k \times b1(\Delta)$

$F(s,t,u,v,x) := -v\cdot a1(s) + x\cdot c1(u) - W\cdot(1 + p\cdot(1+q) + q)\cdot j + w\cdot i + ll\cdot i$

$f1(s,t) := -p\cdot W\cdot(a\cdot a1(s) + f\cdot e1(t)) \times j$

$f2(s,t,h) := (a\cdot a1(s) + .5\cdot b\cdot b1(t) + h\cdot e1(t)) \times (w\cdot i - W\cdot j)$

$f3(s,t,g) := (a\cdot a1(s) + .5\cdot b\cdot b1(t) - g\cdot e1(t)) \times (ll\cdot i - q\cdot W\cdot j)$

$f4(s,t,u,v) := v\cdot(a\cdot a1(s) + b\cdot b1(t)) \times c1(u)$

$M(s,t,u,v,g,h) := f1(s,t) + f2(s,t,h) + f3(s,t,g) + f4(s,t,u,v)$

Given

$d = a\cdot a1(\Delta\alpha)\cdot i + b\cdot b1(\Delta\beta)\cdot i + c\cdot c1(\Delta\theta)\cdot i$

$0 = a\cdot a1(\Delta\alpha)\cdot j + b\cdot b1(\Delta\beta)\cdot j + c\cdot c1(\Delta\theta)\cdot j$

$F(\Delta\alpha,\Delta\beta,\Delta\theta,L,R)\cdot i = 0$

$F(\Delta\alpha,\Delta\beta,\Delta\theta,L,R)\cdot j = 0$

$M(\Delta\alpha,\Delta\beta,\Delta\theta,R,g,h)\cdot k = 0$

$h + g = 50.39$

$sol(\Delta\alpha,\Delta\beta,\Delta\theta,L,R,g,h) := \operatorname{Find}(\Delta\alpha,\Delta\beta,\Delta\theta,L,R,g)$

A.4.3 Equilibrium Analysis Results

A.4.3.1 Plots Showing the Effect of Varying Friction - Equilibrium position 1

$N := 23 \quad hstart := 45 \qquad ans_0 := sol(.01, .01, .01, 1, 1, 1, hstart) \qquad \mu = 0.4$

$i := 1..N \quad h_0 := hstart \qquad w = 0$

$h_i := h_{i-1} - 2$

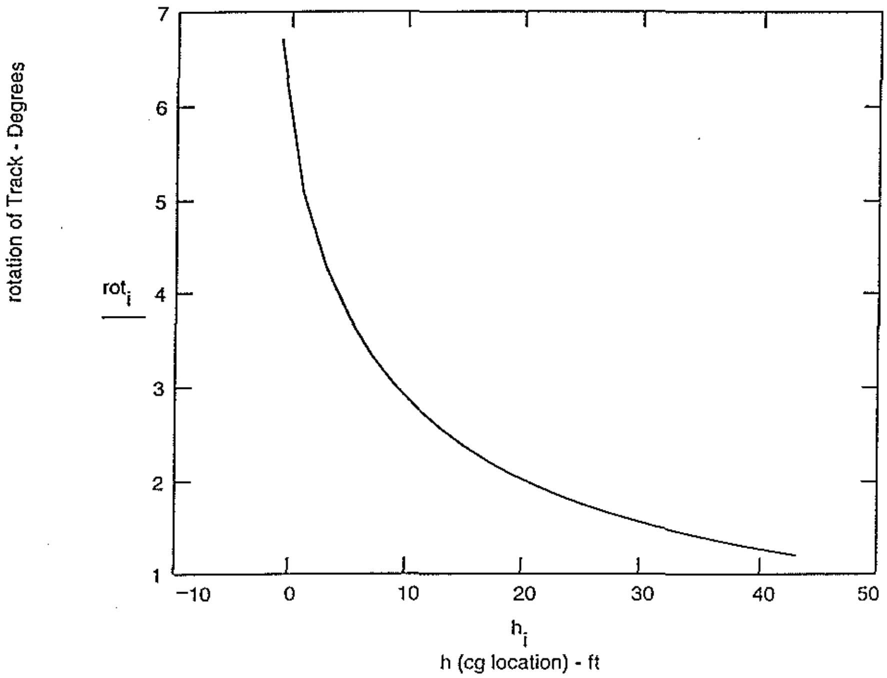
$ans_i := sol\left[\left(ans_{i-1}\right)_0, \left(ans_{i-1}\right)_1, \left(ans_{i-1}\right)_2, \left(ans_{i-1}\right)_3, \left(ans_{i-1}\right)_4, \left(ans_{i-1}\right)_5, h_i\right]$

$rot_i := \left(ans_i\right)_1 \cdot \frac{180}{\pi}$

$\left(ans_N\right)_0 \cdot \frac{180}{\pi} = 12.1627$

$\left(ans_N\right)_1 \cdot \frac{180}{\pi} = 6.7096$

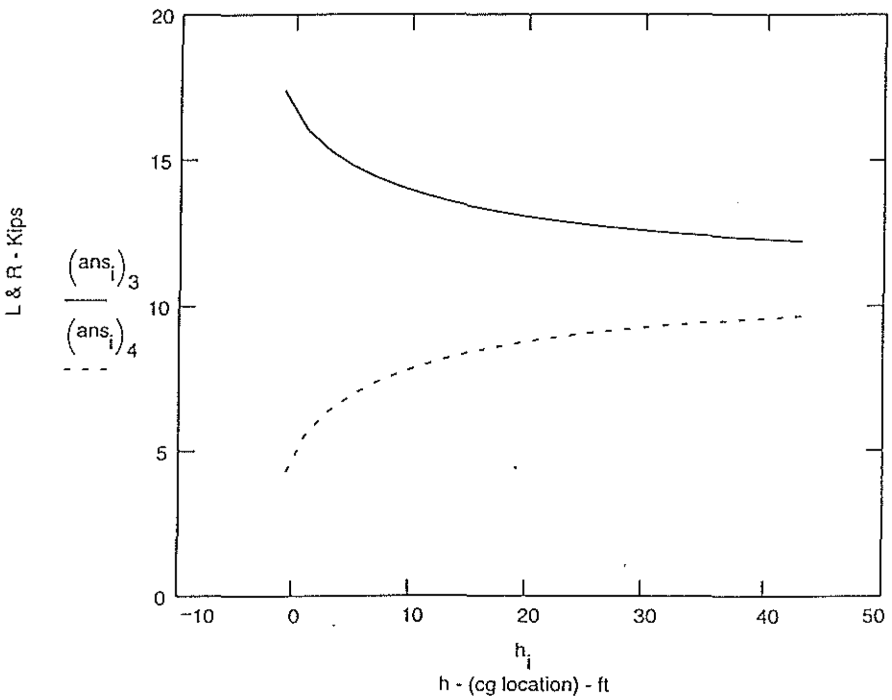
$\left(ans_N\right)_2 \cdot \frac{180}{\pi} = 13.7989$



Rotation vs h(cg location)

$\left(ans_N\right)_3 = 17.3851$

$\left(ans_N\right)_4 = 4.0314$



Forces L & R vs h (cg location)

$N := 23 \quad hstart := 45 \qquad ans_0 := sol(.01, .01, .01, 1, 1, 1, hstart) \qquad \mu = 0.3$

$i := 1..N \quad h_0 := hstart \qquad w = 0$

$h_i := h_{i-1} - 2$

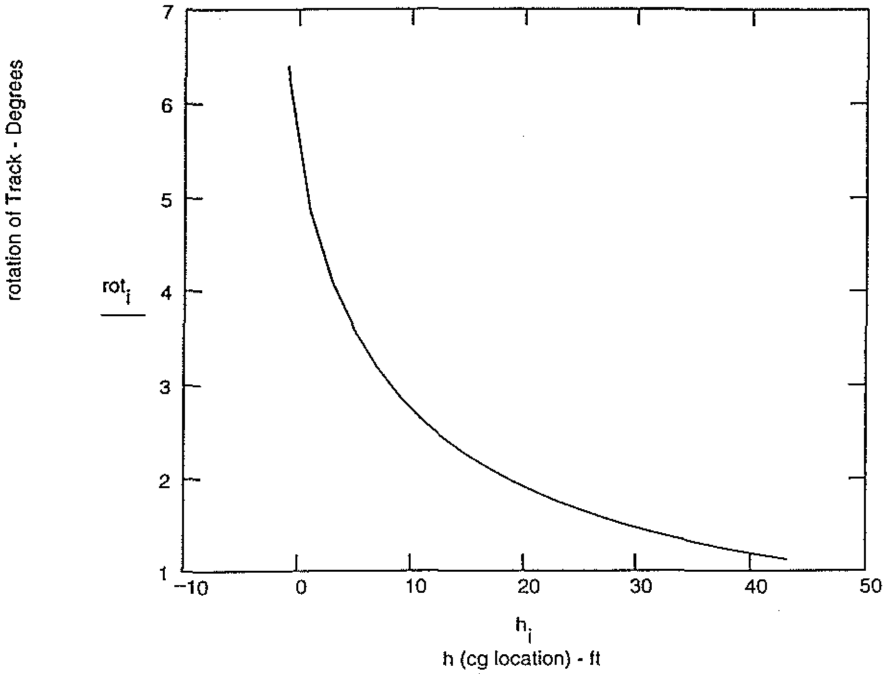
$ans_i := sol\left[(ans_{i-1})_0, (ans_{i-1})_1, (ans_{i-1})_2, (ans_{i-1})_3, (ans_{i-1})_4, (ans_{i-1})_5, h_i\right]$

$rot_i := (ans_i)_1 \cdot \frac{180}{\pi}$

$(ans_N)_0 \cdot \frac{180}{\pi} = 11.6579$

$(ans_N)_1 \cdot \frac{180}{\pi} = 6.3909$

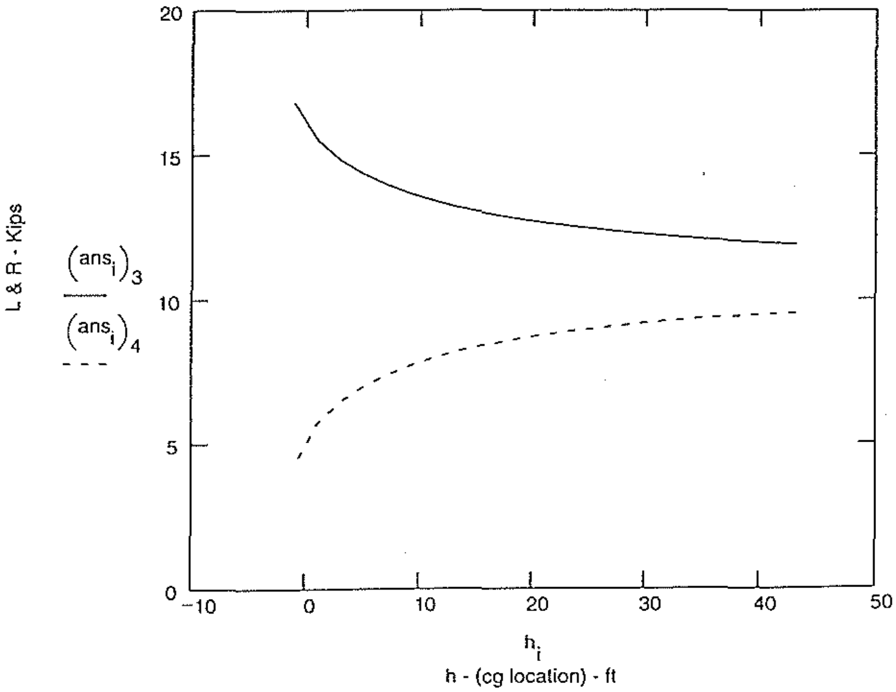
$(ans_N)_2 \cdot \frac{180}{\pi} = 13.1449$



Rotation vs h(cg location)

$(ans_N)_3 = 16.8164$

$(ans_N)_4 = 4.2413$



Forces L & R vs h (cg location)

$N := 23 \quad hstart := 45 \qquad ans_0 := sol(.01, .01, .01, 1, 1, 1, hstart) \qquad \mu = 0.2$

$i := 1..N \quad h_0 := hstart \qquad w = 0$

$h_i := h_{i-1} - 2$

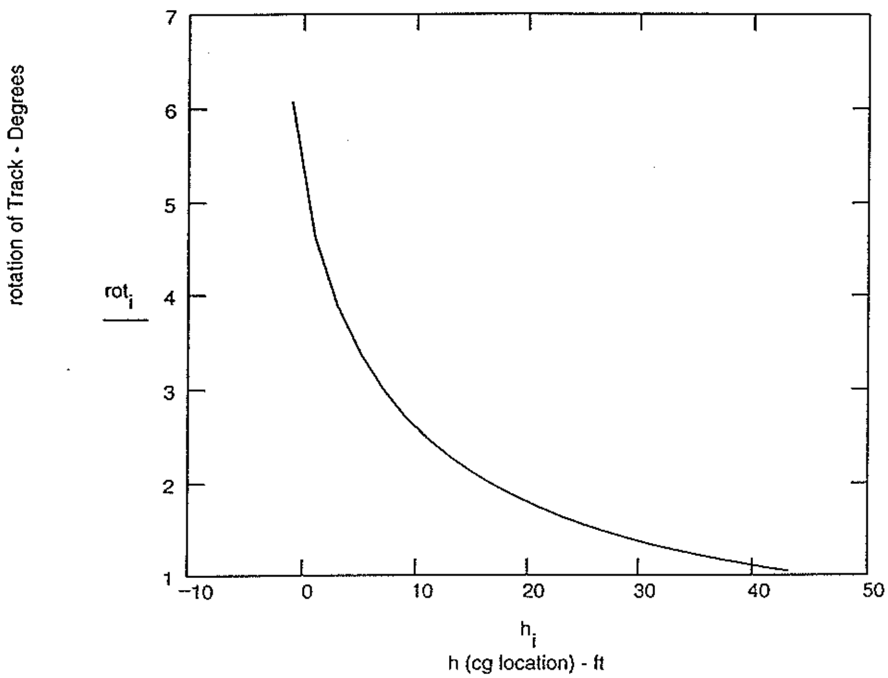
$ans_i := sol\left[(ans_{i-1})_0, (ans_{i-1})_1, (ans_{i-1})_2, (ans_{i-1})_3, (ans_{i-1})_4, (ans_{i-1})_5, h_i\right]$

$rot_i := (ans_i)_1 \cdot \frac{180}{\pi}$

$(ans_N)_0 \cdot \frac{180}{\pi} = 11.1276$

$(ans_N)_1 \cdot \frac{180}{\pi} = 6.0618$

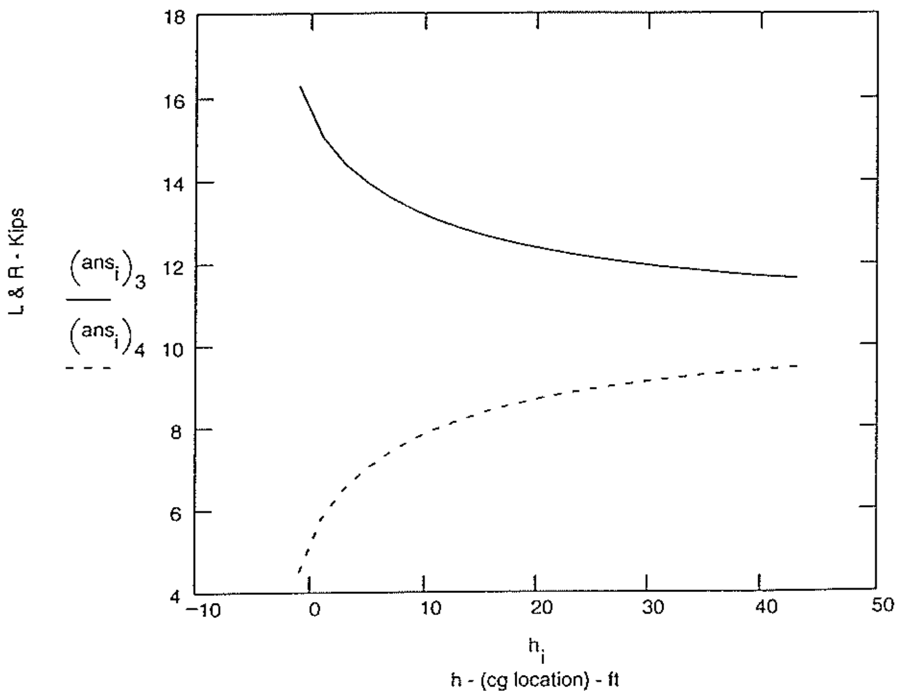
$(ans_N)_2 \cdot \frac{180}{\pi} = 12.4676$



Rotation vs h(cg location)

$(ans_N)_3 = 16.2421$

$(ans_N)_4 = 4.4552$



Forces L & R vs h (cg location)

A.4.3.2 Plots Showing the Effect of Varying Friction - Equilibrium position 2

$N := 50 \quad hstart := 2 \qquad ans_0 := sol(-26\cdot deg, 70\cdot deg, 104\cdot deg, 80, 60, 50, hstart) \qquad \mu = 0.4$

$i := 1..N \qquad h_0 := hstart \qquad w = 0$

$h_i := h_{i-1} - .5$

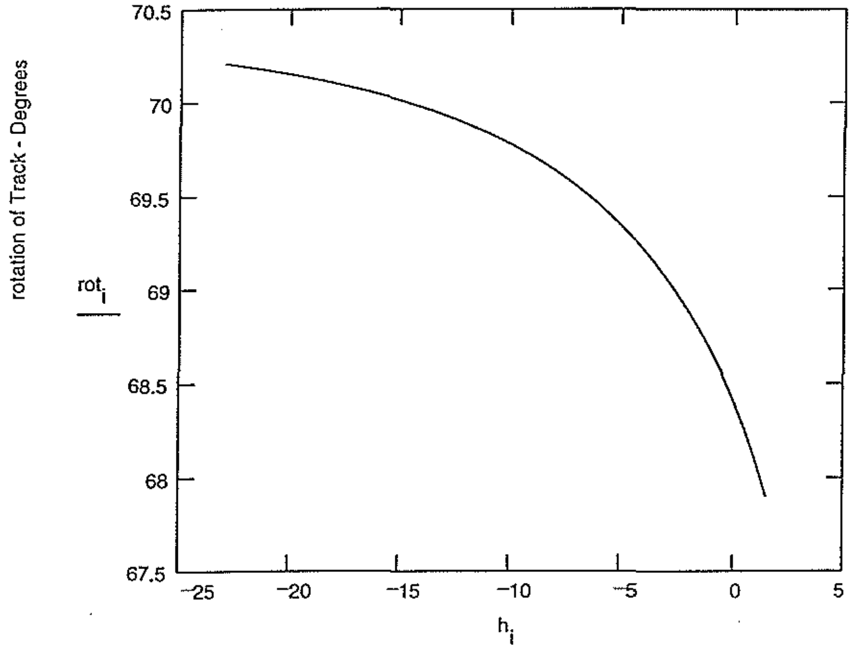
$$ans_i := sol\left[\left(ans_{i-1}\right)_0, \left(ans_{i-1}\right)_1, \left(ans_{i-1}\right)_2, \left(ans_{i-1}\right)_3, \left(ans_{i-1}\right)_4, \left(ans_{i-1}\right)_5, h_i\right]$$

$$rot_i := \left(ans_i\right)_1 \cdot \frac{180}{\pi}$$

$$\left(ans_N\right)_0 \cdot \frac{180}{\pi} = -26.6917$$

$$\left(ans_N\right)_1 \cdot \frac{180}{\pi} = 70.2062$$

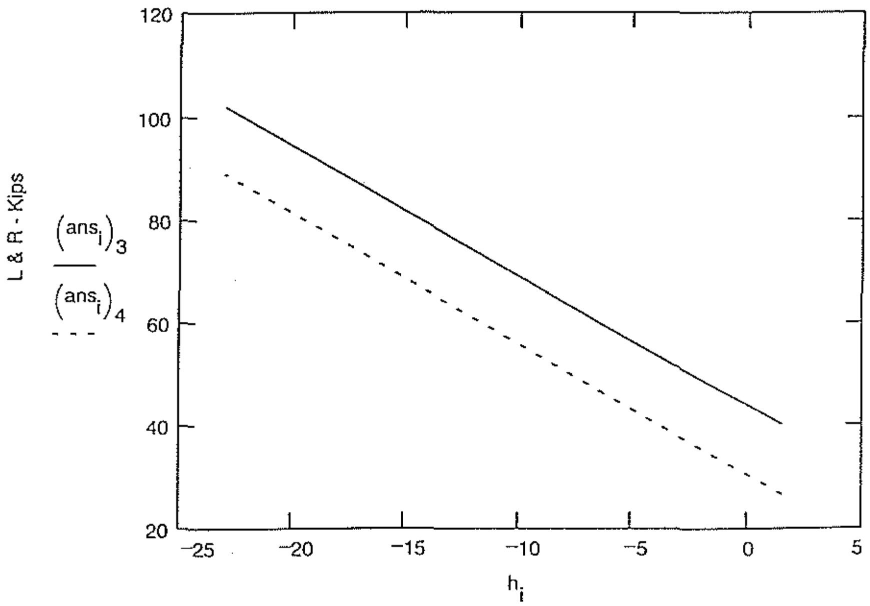
$$\left(ans_N\right)_2 \cdot \frac{180}{\pi} = 104.7193$$



Rotation vs h(cg location)

$$\left(ans_N\right)_3 = 101.7589$$

$$\left(ans_N\right)_4 = 88.7358$$



Forces L & R vs h (cg location)

$N := 50 \quad hstart := 2 \qquad ans_0 := sol(-26\cdot deg, 70\cdot deg, 104\cdot deg, 80, 60, 50, hstart) \qquad \mu = 0.3$

$i := 1 .. N \quad h_0 := hstart \qquad w = 0$

$h_i := h_{i-1} - .5$

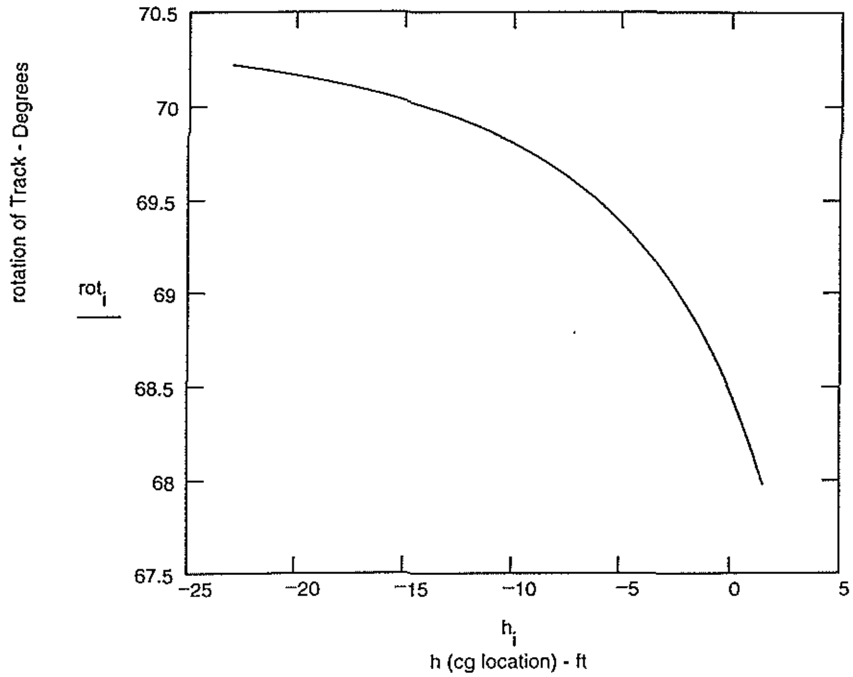
$ans_i := sol\left[\left(ans_{i-1}\right)_0, \left(ans_{i-1}\right)_1, \left(ans_{i-1}\right)_2, \left(ans_{i-1}\right)_3, \left(ans_{i-1}\right)_4, \left(ans_{i-1}\right)_5, h_i\right]$

$rot_i := \left(ans_i\right)_1 \cdot \frac{180}{\pi}$

$\left(ans_N\right)_0 \cdot \frac{180}{\pi} = -26.7791$

$\left(ans_N\right)_1 \cdot \frac{180}{\pi} = 70.2175$

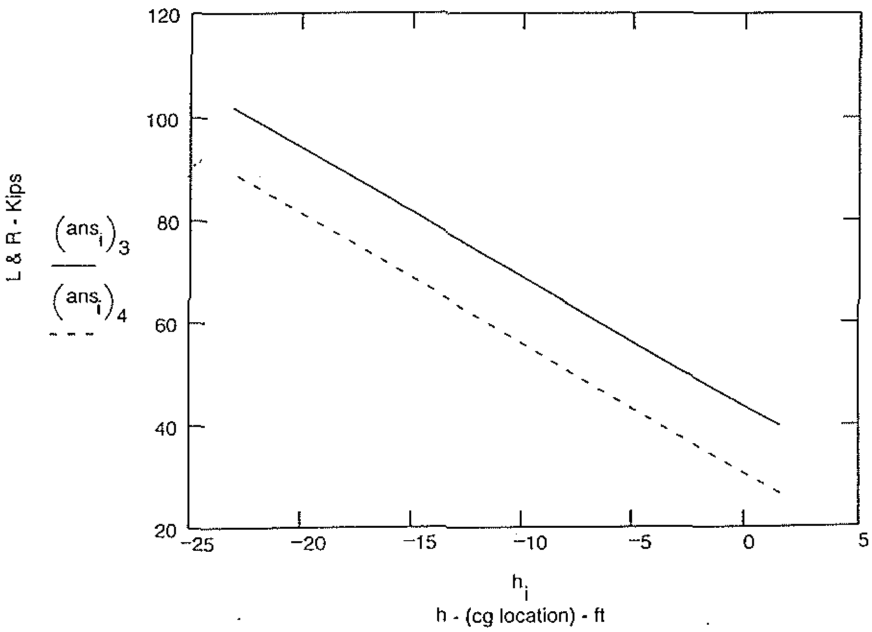
$\left(ans_N\right)_2 \cdot \frac{180}{\pi} = 104.8017$



Rotation vs h(cg location)

$\left(ans_N\right)_3 = 101.5477$

$\left(ans_N\right)_4 = 88.7681$



Forces L & R vs h (cg location)

$N := 50 \quad hstart := 2 \qquad ans_0 := sol(-26\cdot deg, 70\cdot deg, 104\cdot deg, 80, 60, 50, hstart) \qquad \mu = 0.2$

$i := 1..N \quad h_0 := hstart \qquad w = 0$

$h_i := h_{i-1} - .5$

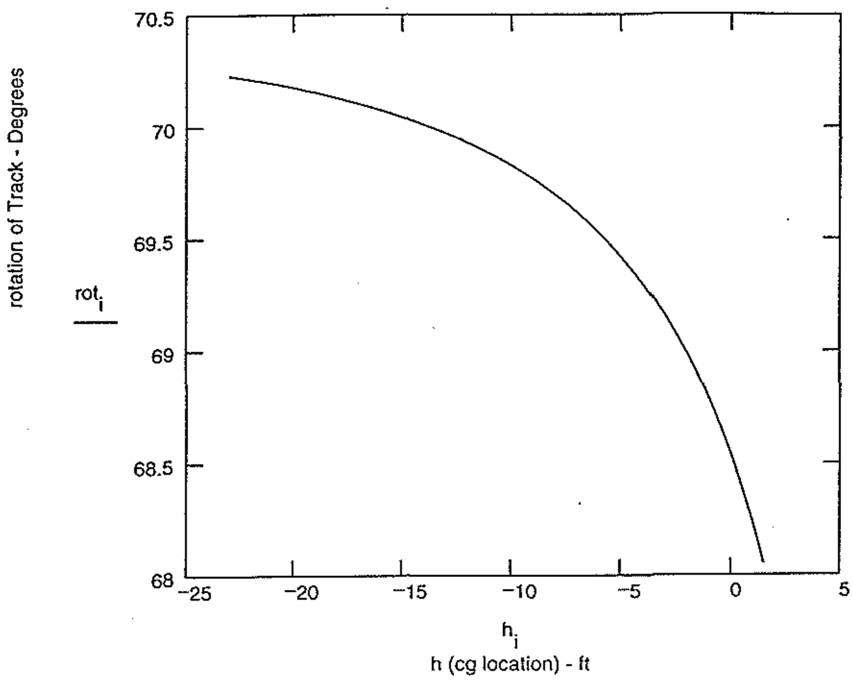
$ans_i := sol\left[(ans_{i-1})_0, (ans_{i-1})_1, (ans_{i-1})_2, (ans_{i-1})_3, (ans_{i-1})_4, (ans_{i-1})_5, h_i\right]$

$rot_i := (ans_i)_1 \cdot \frac{180}{\pi}$

$(ans_N)_0 \cdot \frac{180}{\pi} = -26.8666$

$(ans_N)_1 \cdot \frac{180}{\pi} = 70.2285$

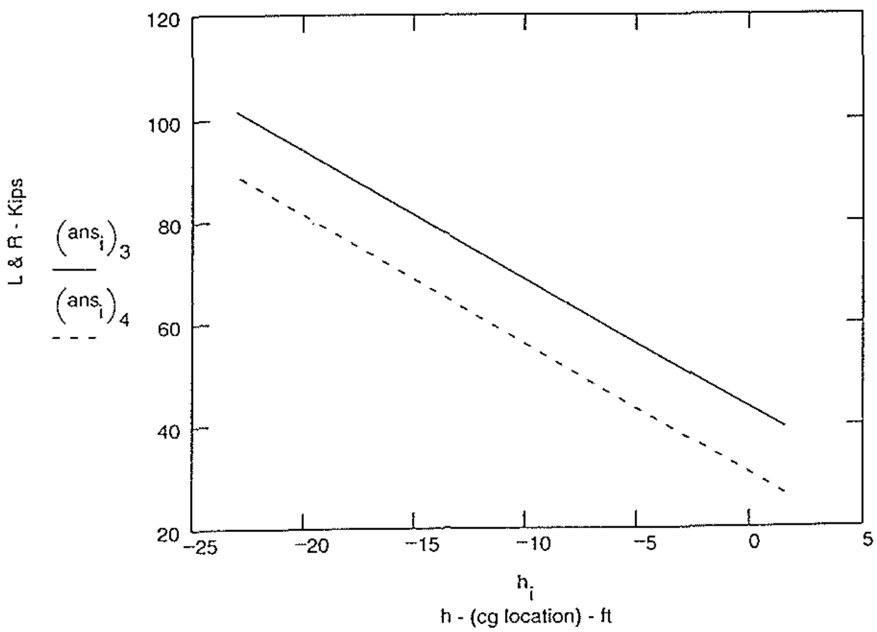
$(ans_N)_2 \cdot \frac{180}{\pi} = 104.8843$



Rotation vs h(cg location)

$(ans_N)_3 = 101.3367$

$(ans_N)_4 = 88.8004$



Forces L & R vs h (cg location)

A.4.3.3 Plots Showing the Effect of Varying Wind Load - Equilibrium position 1

$N := 22 \quad hstart := 45 \qquad ans_0 := sol(.01, .01, .01, 1, 1, 1, hstart) \qquad \mu = 0.4$

$i := 1..N \quad h_0 := hstart \qquad w = -1$

$h_i := h_{i-1} - 2$

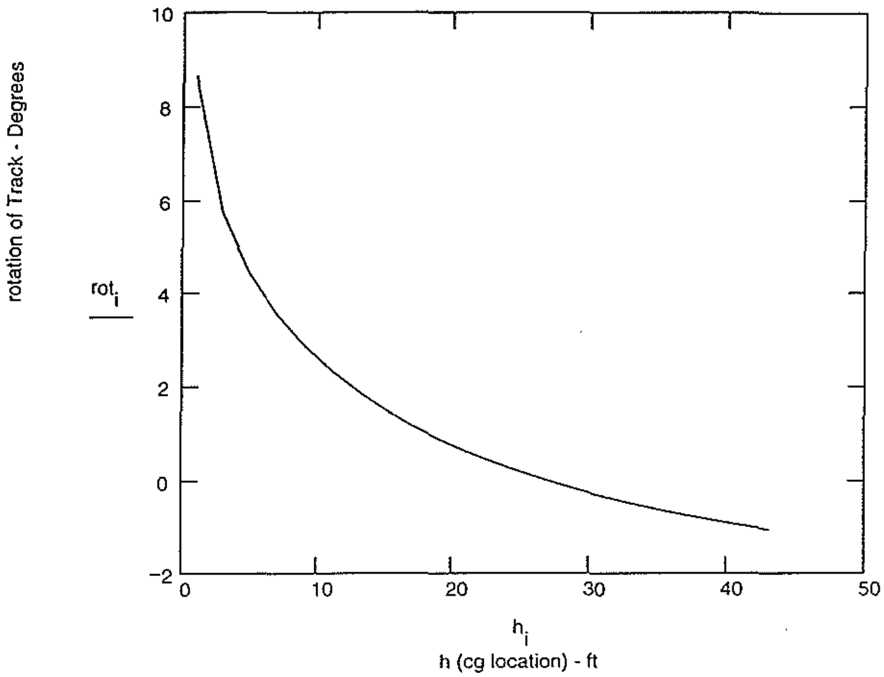
$$ans_i := sol\left[(ans_{i-1})_0, (ans_{i-1})_1, (ans_{i-1})_2, (ans_{i-1})_3, (ans_{i-1})_4, (ans_{i-1})_5, h_i\right]$$

$$rot_i := (ans_i)_1 \cdot \frac{180}{\pi}$$

$$(ans_N)_0 \cdot \frac{180}{\pi} = 15.0321$$

$$(ans_N)_1 \cdot \frac{180}{\pi} = 8.6408$$

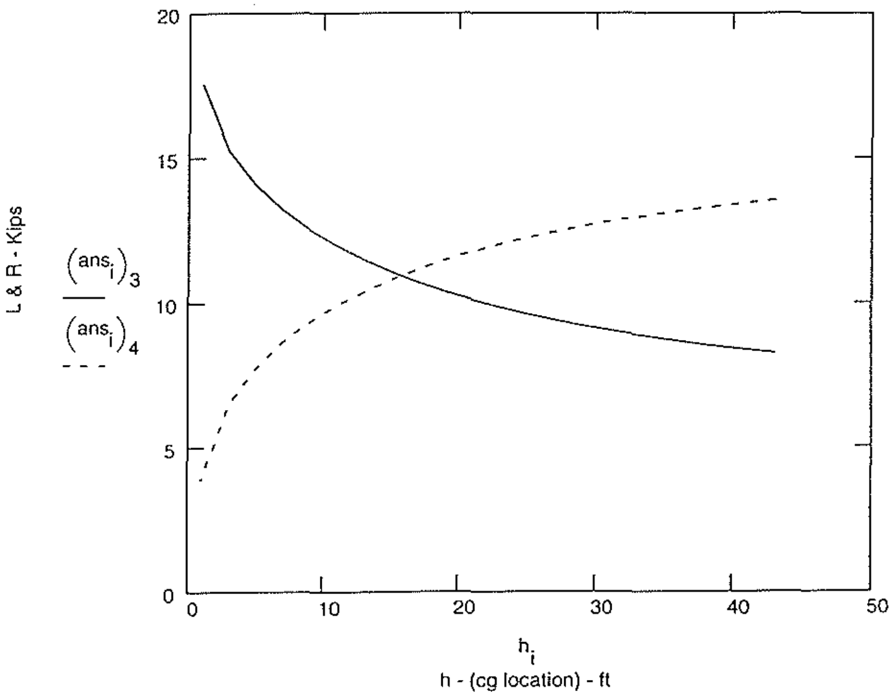
$$(ans_N)_2 \cdot \frac{180}{\pi} = 17.7146$$



Rotation vs h(cg location)

$$(ans_N)_3 = 17.5578$$

$$(ans_N)_4 = 3.903$$



Forces L & R vs h (cg location)

$N := 22 \quad hstart := 45 \qquad ans_0 := sol(.01, .01, .01, 1, 1, 1, hstart) \qquad \mu = 0.4$

$i := 1..N \quad h_0 := hstart \qquad w = -0.8$

$h_i := h_{i-1} - 2$

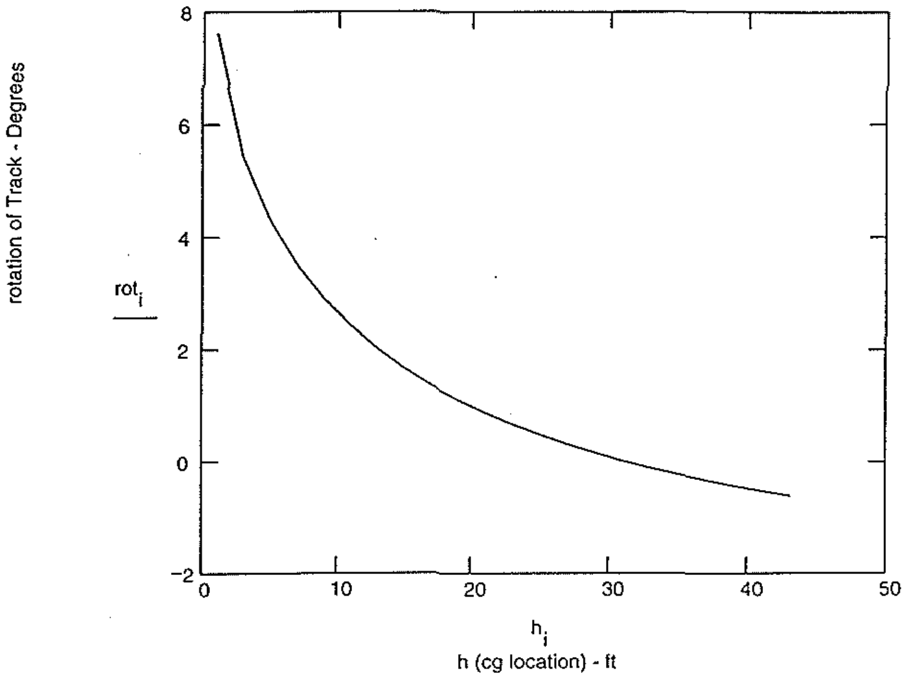
$ans_i := sol\left[(ans_{i-1})_0, (ans_{i-1})_1, (ans_{i-1})_2, (ans_{i-1})_3, (ans_{i-1})_4, (ans_{i-1})_5, h_i\right]$

$rot_i := (ans_i)_1 \cdot \frac{180}{\pi}$

$(ans_N)_0 \cdot \frac{180}{\pi} = 13.5456$

$(ans_N)_1 \cdot \frac{180}{\pi} = 7.6125$

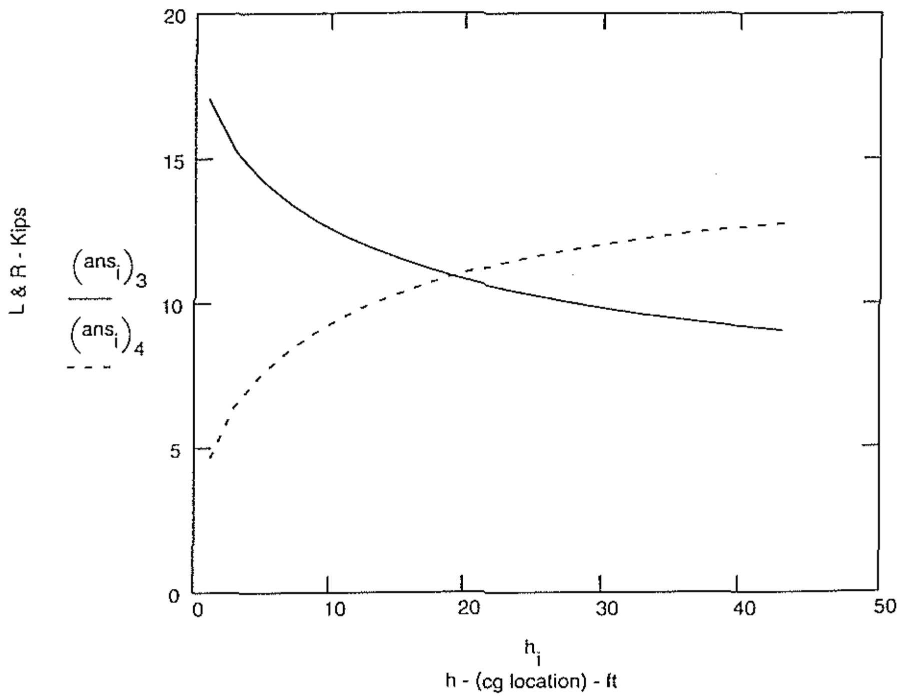
$(ans_N)_2 \cdot \frac{180}{\pi} = 15.641$



Rotation vs h(cg location)

$(ans_N)_3 = 17.0627$

$(ans_N)_4 = 4.4534$



Forces L & R vs h (cg location)

$N := 22 \quad hstart := 45 \qquad ans_0 := sol(.01, .01, .01, 1, 1, 1, hstart) \qquad \mu = 0.4$

$i := 1 .. N \quad h_0 := hstart \qquad w = -0.6$

$h_i := h_{i-1} - 2$

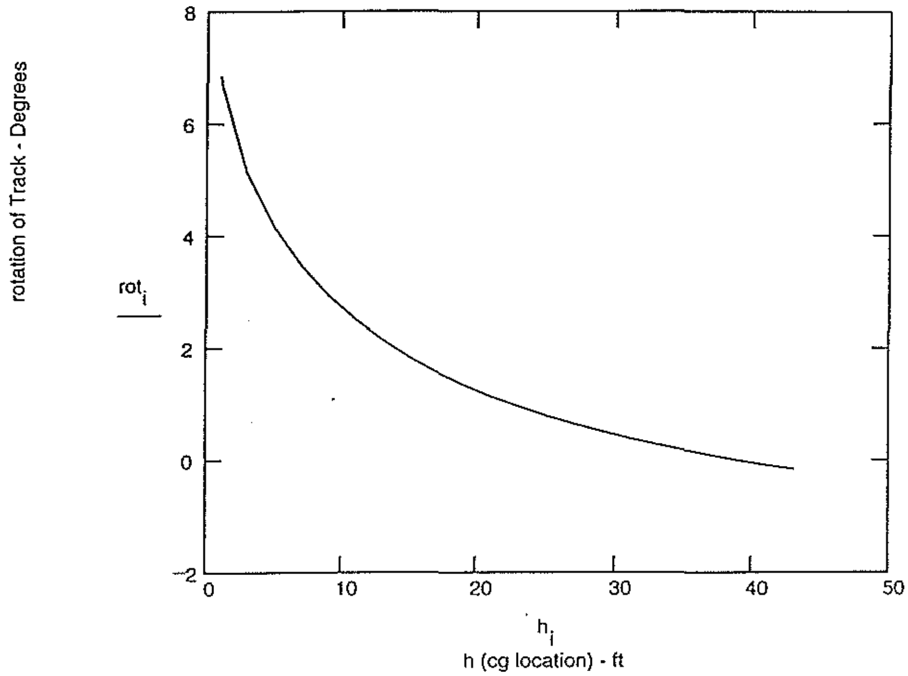
$ans_i := sol\left[(ans_{i-1})_0, (ans_{i-1})_1, (ans_{i-1})_2, (ans_{i-1})_3, (ans_{i-1})_4, (ans_{i-1})_5, h_i\right]$

$rot_i := (ans_i)_1 \cdot \frac{180}{\pi}$

$(ans_N)_0 \cdot \frac{180}{\pi} = 12.376$

$(ans_N)_1 \cdot \frac{180}{\pi} = 6.8458$

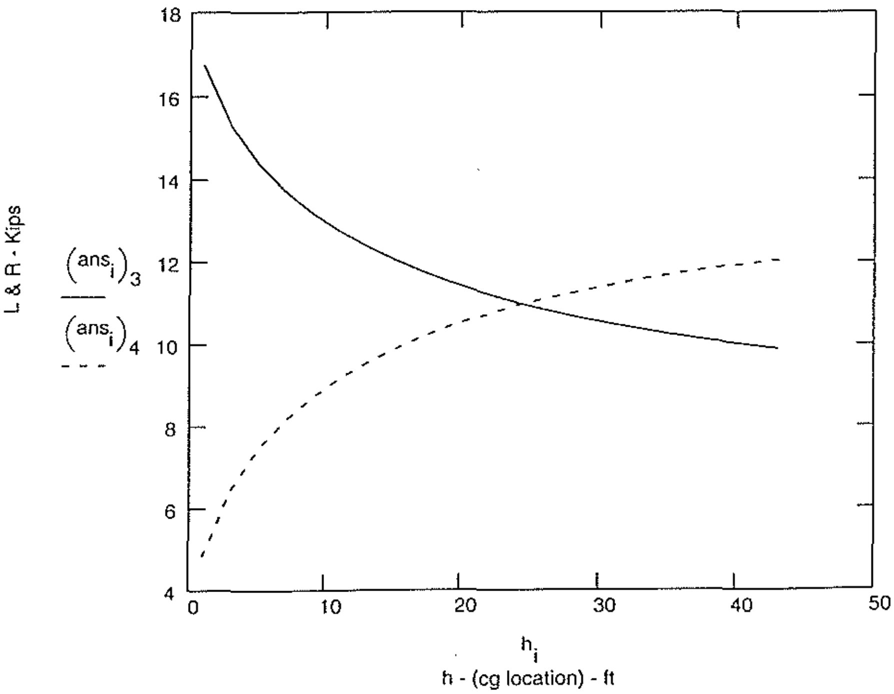
$(ans_N)_2 \cdot \frac{180}{\pi} = 14.078$



Rotation vs h(cg location)

$(ans_N)_3 = 16.7228$

$(ans_N)_4 = 4.8233$



Forces L & R vs h (cg location)

$N := 22 \quad hstart := 45 \qquad ans_0 := sol(.01, .01, .01, 1, 1, 1, hstart) \qquad \mu = 0.4$

$i := 1..N \quad h_0 := hstart \qquad w = -0.4$

$h_i := h_{i-1} - 2$

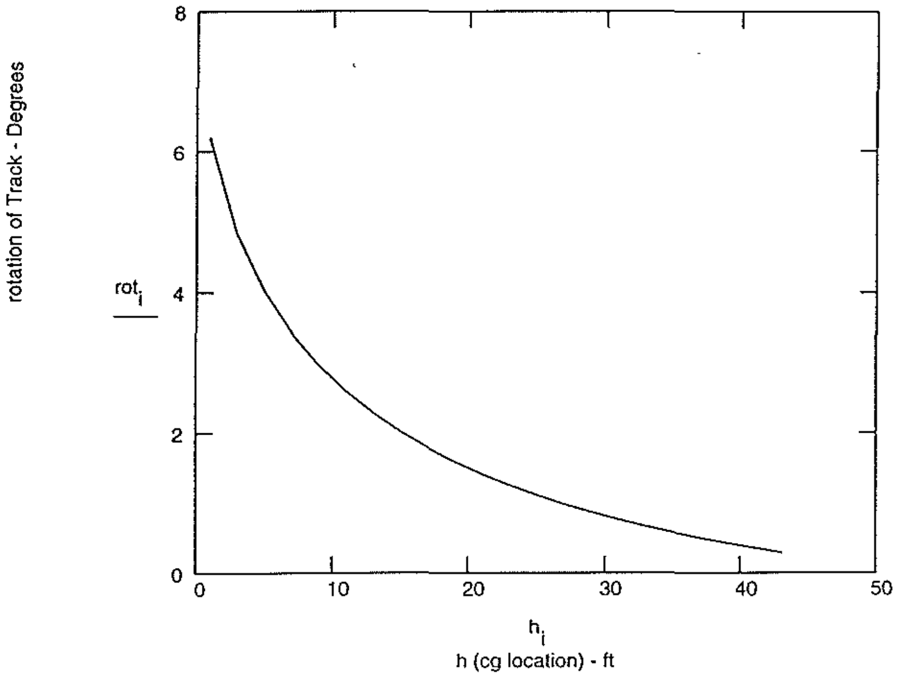
$ans_i := sol\left[(ans_{i-1})_0, (ans_{i-1})_1, (ans_{i-1})_2, (ans_{i-1})_3, (ans_{i-1})_4, (ans_{i-1})_5, h_i\right]$

$rot_i := (ans_i)_1 \cdot \frac{180}{\pi}$

$(ans_N)_0 \cdot \frac{180}{\pi} = 11.3423$

$(ans_N)_1 \cdot \frac{180}{\pi} = 6.1944$

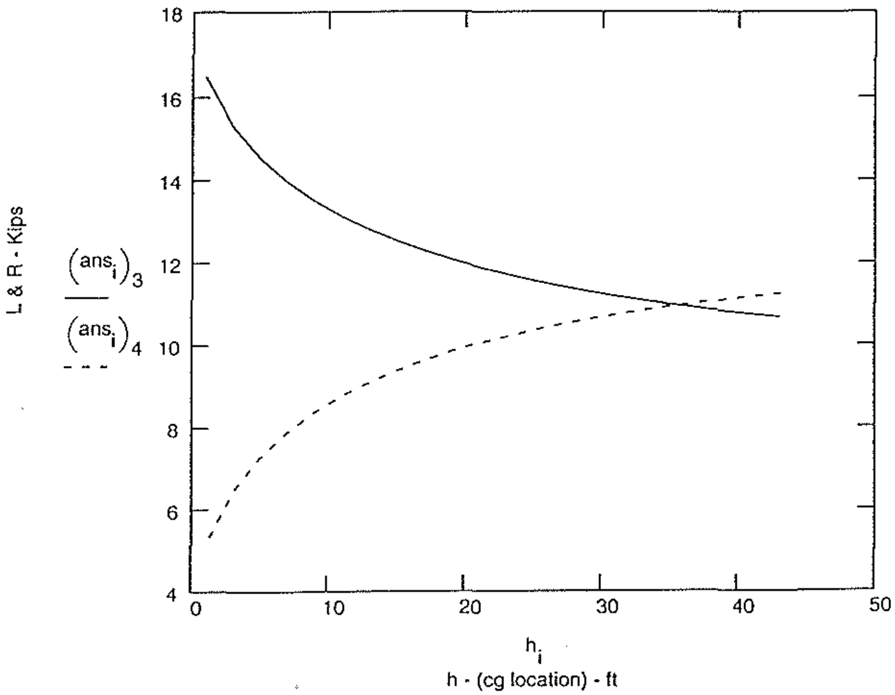
$(ans_N)_2 \cdot \frac{180}{\pi} = 12.7405$



Rotation vs h(cg location)

$(ans_N)_3 = 16.4524$

$(ans_N)_4 = 5.1147$



Forces L & R vs h (cg location)

$N := 22 \quad hstart := 45 \qquad ans_0 := sol(.01, .01, .01, 1, 1, 1, hstart) \qquad \mu = 0.4$

$i := 1 .. N \quad h_0 := hstart \qquad w = -0.2$

$h_i := h_{i-1} - 2$

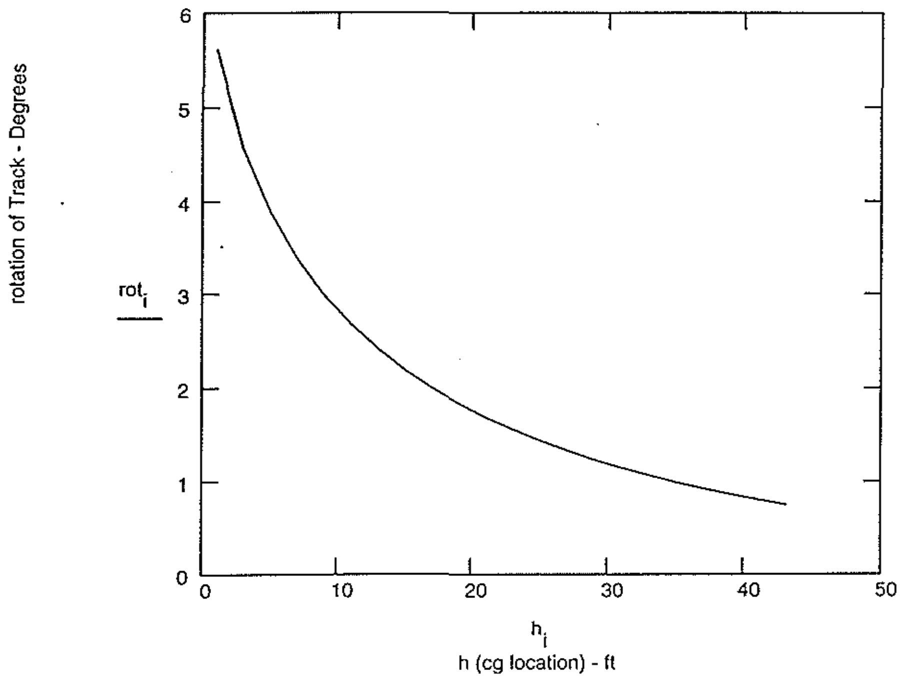
$$ans_i := sol\left[(ans_{i-1})_0, (ans_{i-1})_1, (ans_{i-1})_2, (ans_{i-1})_3, (ans_{i-1})_4, (ans_{i-1})_5, h_i\right]$$

$$rot_i := (ans_i)_1 \cdot \frac{180}{\pi}$$

$$(ans_N)_0 \cdot \frac{180}{\pi} = 10.3875$$

$$(ans_N)_1 \cdot \frac{180}{\pi} = 5.6115$$

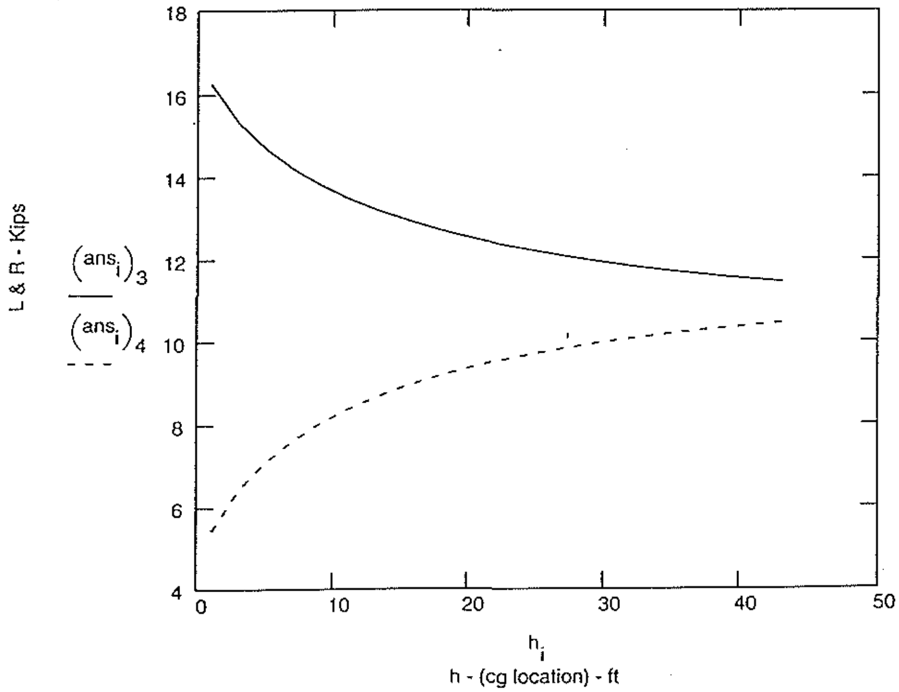
$$(ans_N)_2 \cdot \frac{180}{\pi} = 11.5382$$



Rotation vs h(cg location)

$$(ans_N)_3 = 16.2239$$

$$(ans_N)_4 = 5.3601$$



Forces L & R vs h (cg location)

$N := 23 \quad hstart := 45 \qquad ans_0 := sol(.01, .01, .01, 1, 1, 1, hstart) \qquad \mu = 0.4$

$i := 1..N \quad h_0 := hstart \qquad w = 0.2$

$h_i := h_{i-1} - 2$

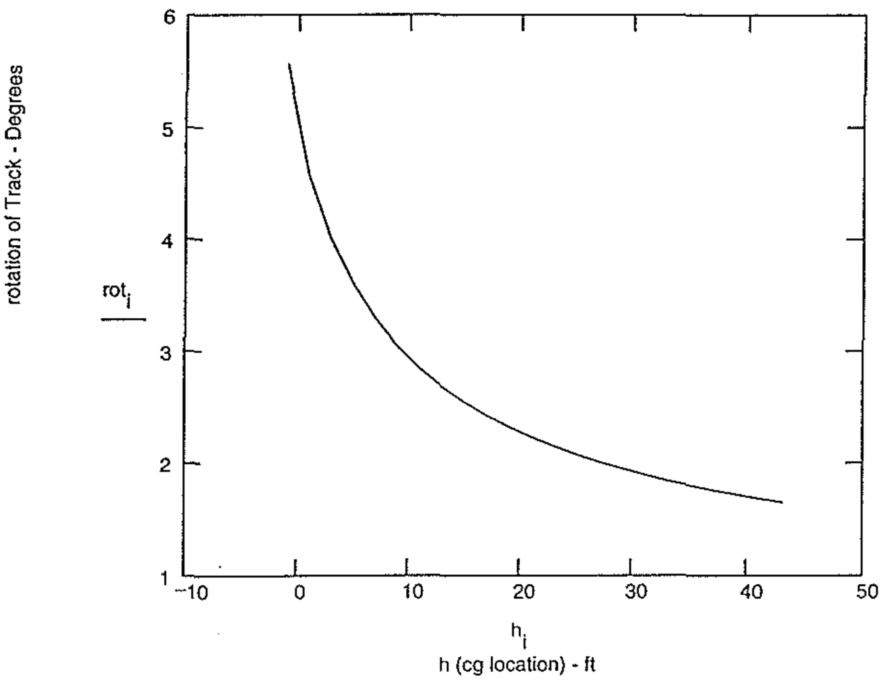
$ans_i := sol\left[(ans_{i-1})_0, (ans_{i-1})_1, (ans_{i-1})_2, (ans_{i-1})_3, (ans_{i-1})_4, (ans_{i-1})_5, h_i\right]$

$rot_i := (ans_i)_1 \cdot \frac{180}{\pi}$

$(ans_N)_0 \cdot \frac{180}{\pi} = 10.3083$

$(ans_N)_1 \cdot \frac{180}{\pi} = 5.5638$

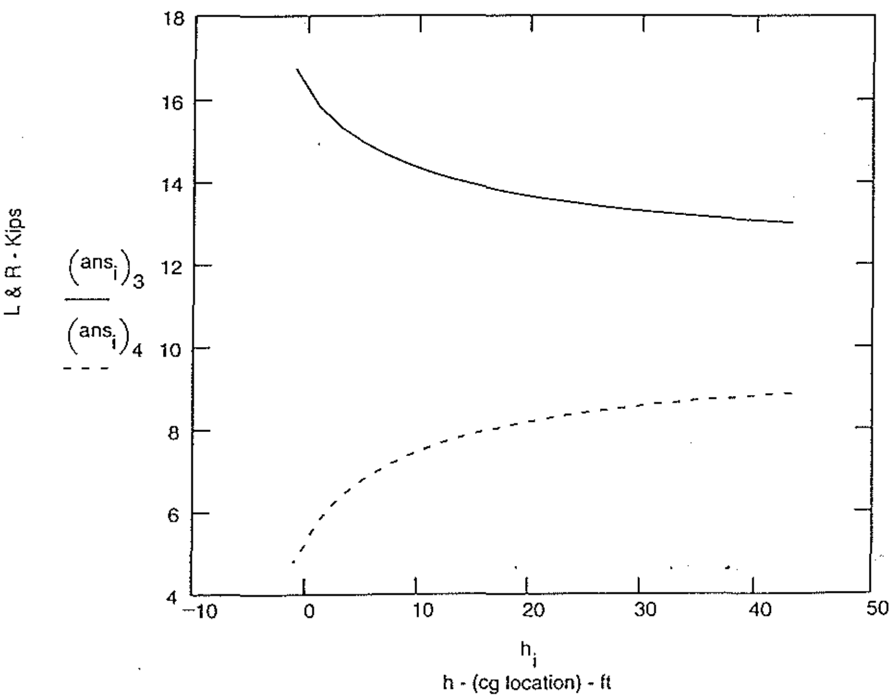
$(ans_N)_2 \cdot \frac{180}{\pi} = 11.4398$



Rotation vs h(cg location)

$(ans_N)_3 = 16.716$

$(ans_N)_4 = 4.7924$



Forces L & R vs h (cg location)

$N := 23 \quad hstart := 45 \qquad ans_0 := sol(.01, .01, .01, 1, 1, 1, hstart) \qquad \mu = 0.4$

$i := 1..N \quad h_0 := hstart \qquad w = 0.4$

$h_i := h_{i-1} - 2$

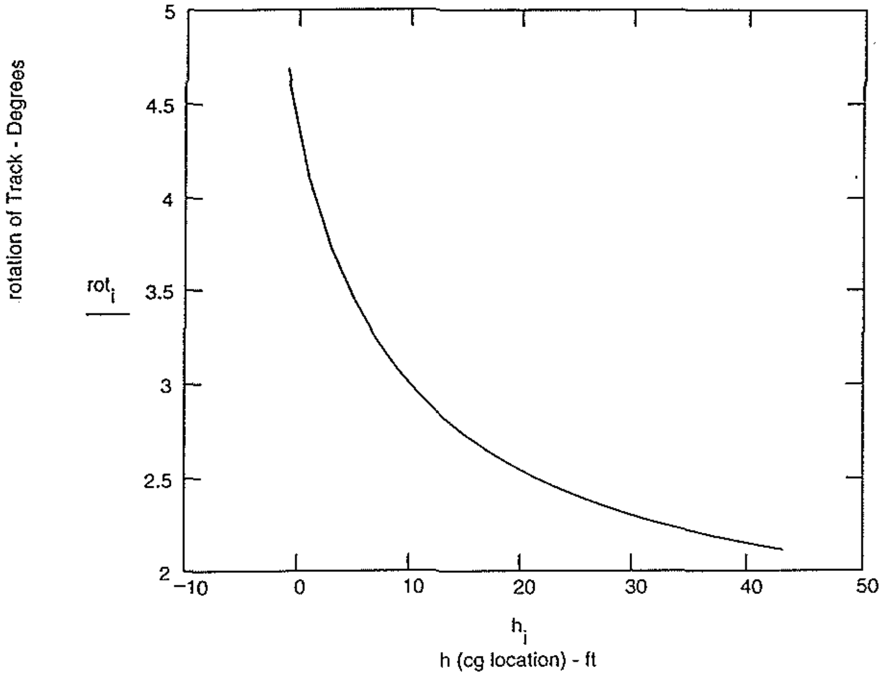
$ans_i := sol\left[(ans_{i-1})_0, (ans_{i-1})_1, (ans_{i-1})_2, (ans_{i-1})_3, (ans_{i-1})_4, (ans_{i-1})_5, h_i\right]$

$rot_i := (ans_i)_1 \cdot \frac{180}{\pi}$

$(ans_N)_0 \cdot \frac{180}{\pi} = 8.8136$

$(ans_N)_1 \cdot \frac{180}{\pi} = 4.6845$

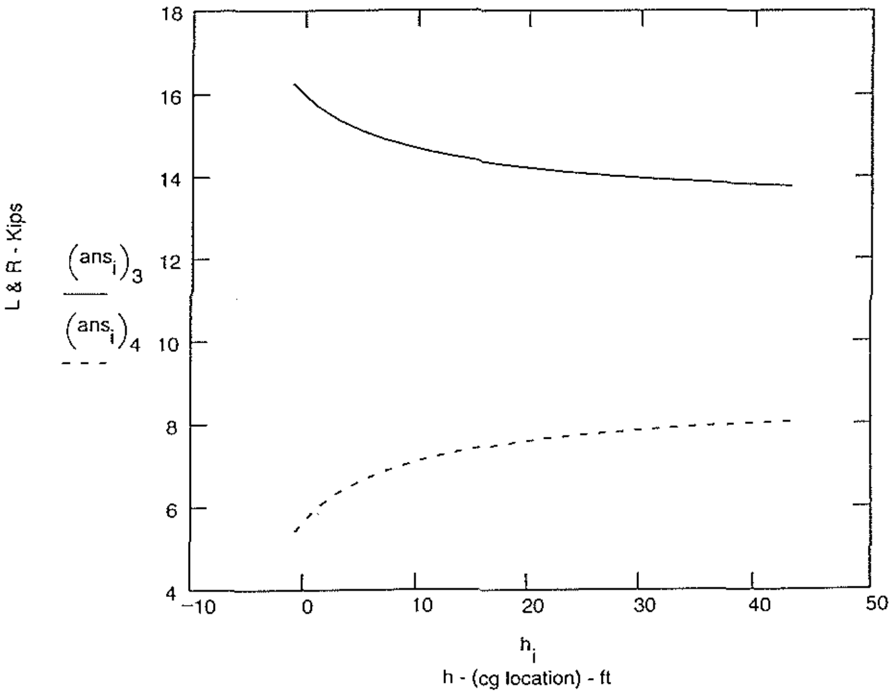
$(ans_N)_2 \cdot \frac{180}{\pi} = 9.6187$



Rotation vs h(cg location)

$(ans_N)_3 = 16.2212$

$(ans_N)_4 = 5.3477$



Forces L & R vs h (cg location)

$N := 25 \quad hstart := 45 \qquad ans_0 := sol(.01, .01, .01, 1, 1, 1, hstart) \qquad \mu = 0.4$

$i := 1..N \quad h_0 := hstart \qquad w = 0.6$

$h_i := h_{i-1} - 2$

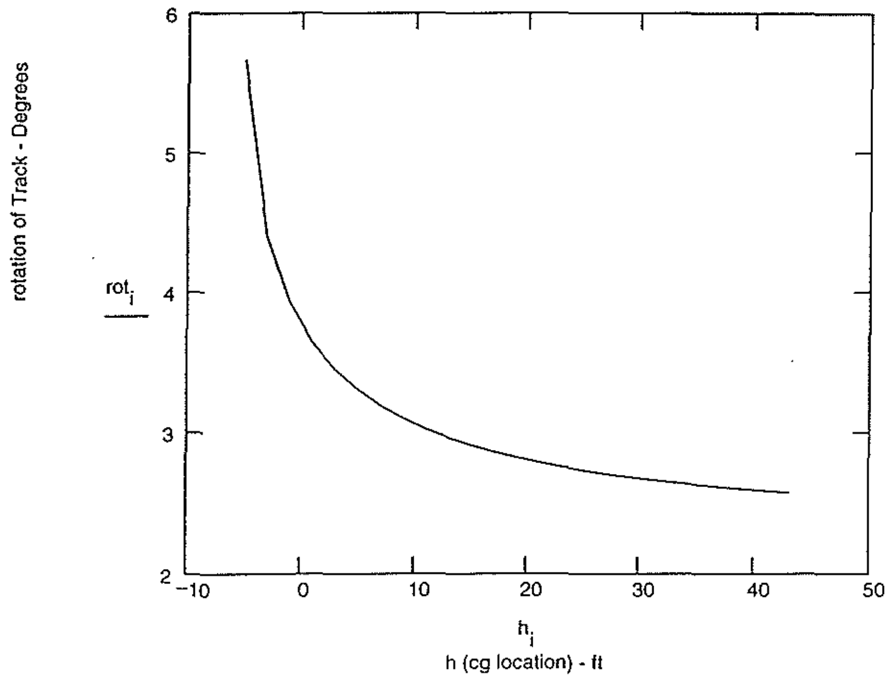
$ans_i := sol\left[(ans_{i-1})_0, (ans_{i-1})_1, (ans_{i-1})_2, (ans_{i-1})_3, (ans_{i-1})_4, (ans_{i-1})_5, h_i \right]$

$rot_i := (ans_i)_1 \cdot \frac{180}{\pi}$

$(ans_N)_0 \cdot \frac{180}{\pi} = 10.4766$

$(ans_N)_1 \cdot \frac{180}{\pi} = 5.6651$

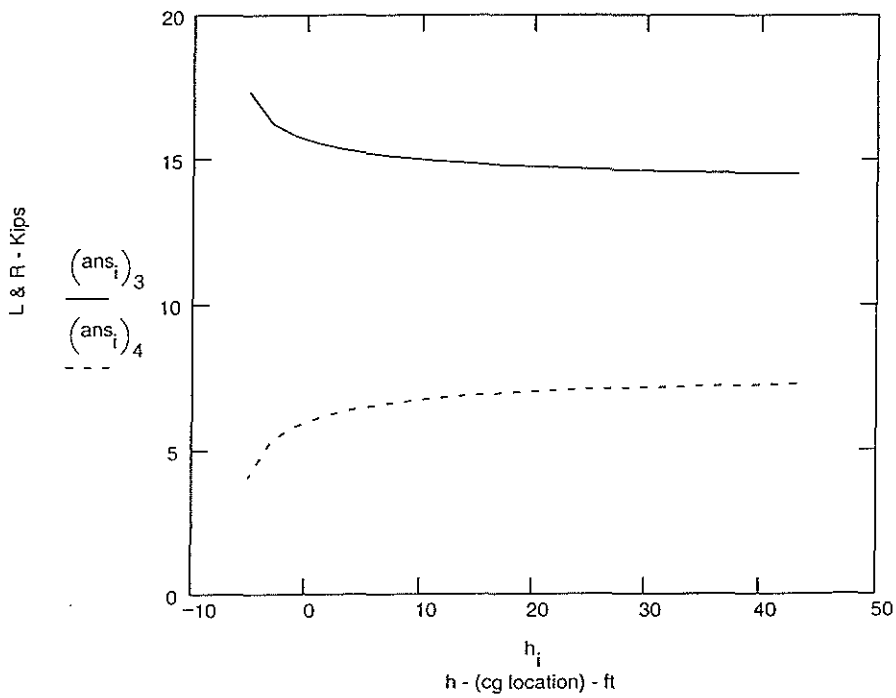
$(ans_N)_2 \cdot \frac{180}{\pi} = 11.6491$



Rotation vs h(cg location)

$(ans_N)_3 = 17.3329$

$(ans_N)_4 = 4.0823$



Forces L & R vs h (cg location)

$N := 27 \quad hstart := 45 \qquad ans_0 := sol(.01, .01, .01, 1, 1, 1, hstart) \qquad \mu = 0.4$

$i := 1..N \quad h_0 := hstart \qquad w = 0.8$

$h_i := h_{i-1} - 2$

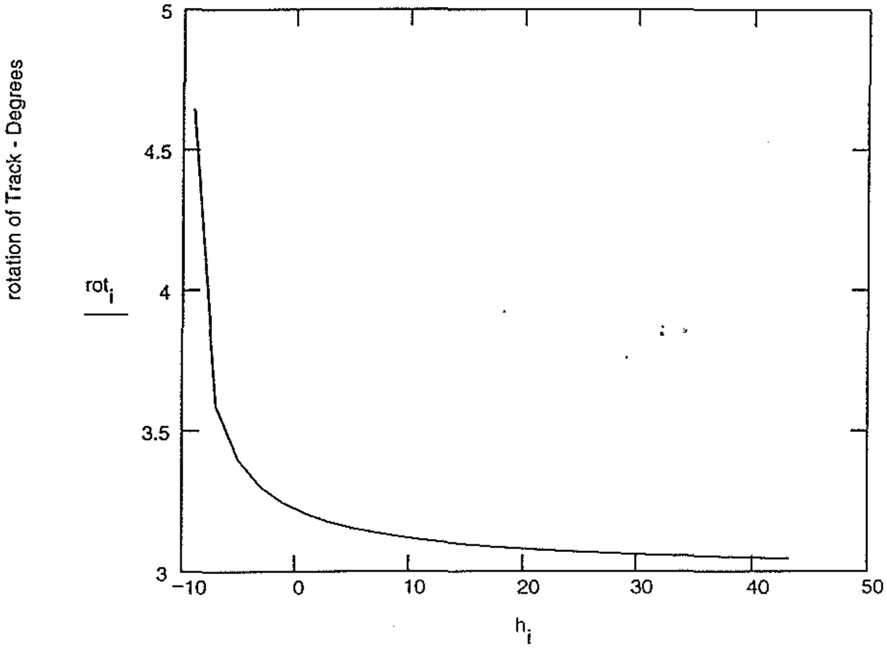
$$ans_i := sol\left[(ans_{i-1})_0, (ans_{i-1})_1, (ans_{i-1})_2, (ans_{i-1})_3, (ans_{i-1})_4, (ans_{i-1})_5, h_i\right]$$

$$rot_i := (ans_i)_1 \cdot \frac{180}{\pi}$$

$$(ans_N)_0 \cdot \frac{180}{\pi} = 8.7559$$

$$(ans_N)_1 \cdot \frac{180}{\pi} = 4.645$$

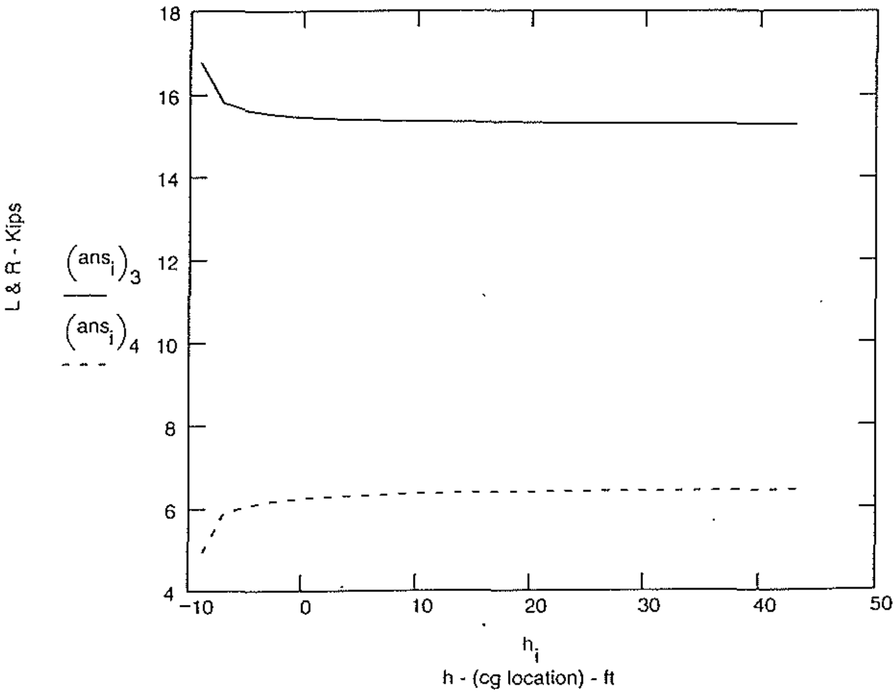
$$(ans_N)_2 \cdot \frac{180}{\pi} = 9.5462$$



Rotation vs h(cg location)

$$(ans_N)_3 = 16.7383$$

$$(ans_N)_4 = 4.7663$$



Forces L & R vs h (cg location)

$N := 28 \quad hstart := 45 \qquad ans_0 := sol(.01, .01, .01, 1, 1, 1, hstart) \qquad \mu = 0.4$

$i := 1 .. N \quad h_0 := hstart \qquad w = 1$

$h_i := h_{i-1} - 2$

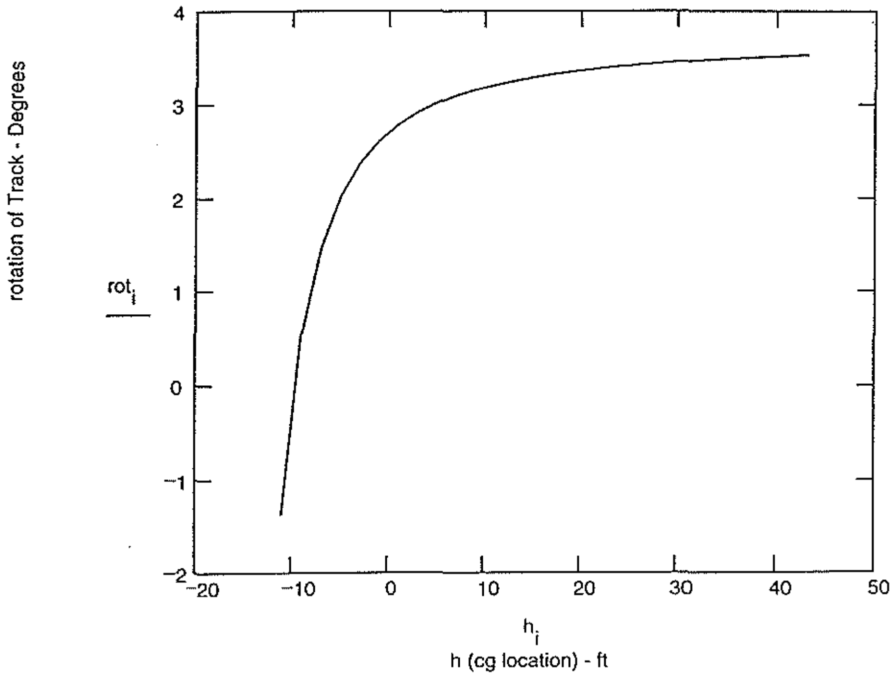
$ans_i := sol\left[(ans_{i-1})_0, (ans_{i-1})_1, (ans_{i-1})_2, (ans_{i-1})_3, (ans_{i-1})_4, (ans_{i-1})_5, h_i\right]$

$rot_i := (ans_i)_1 \cdot \dfrac{180}{\pi}$

$(ans_N)_0 \cdot \dfrac{180}{\pi} = -2.7902$

$(ans_N)_1 \cdot \dfrac{180}{\pi} = -1.3795$

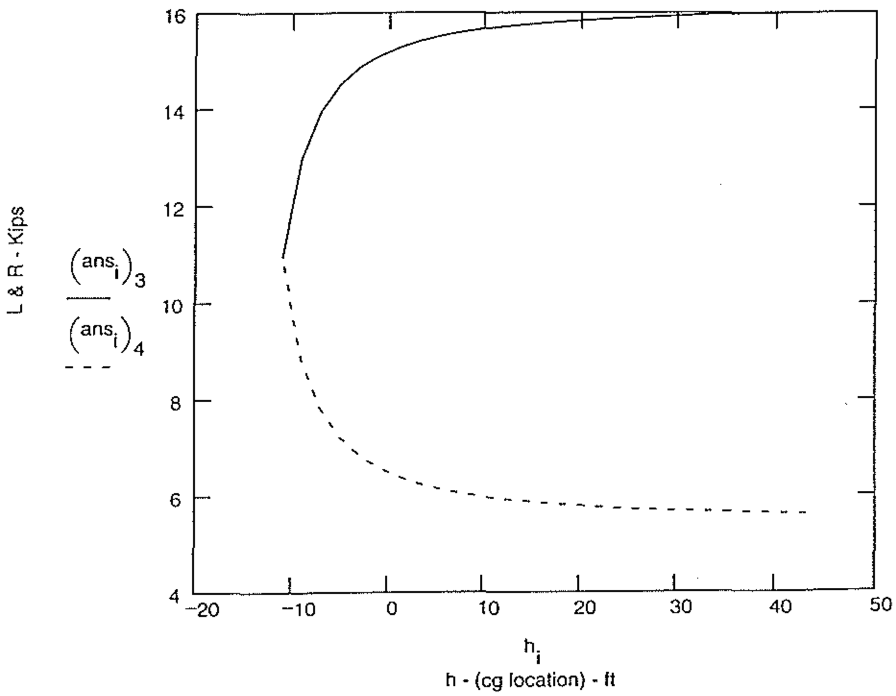
$(ans_N)_2 \cdot \dfrac{180}{\pi} = -2.7198$



Rotation vs h(cg location)

$(ans_N)_3 = 10.9597$

$(ans_N)_4 = 10.9358$



Forces L & R vs h (cg location)

A.4.3.4 Plots Showing the Effect of Varying Wind Load - Equilibrium position 2

$N := 50 \quad hstart := 2 \qquad ans_0 := sol(-26\cdot deg, 70\cdot deg, 104\cdot deg, 80, 60, 50, hstart) \qquad \mu = 0.4$

$i := 1..N \quad h_0 := hstart \qquad w = 1$

$h_i := h_{i-1} - .5$

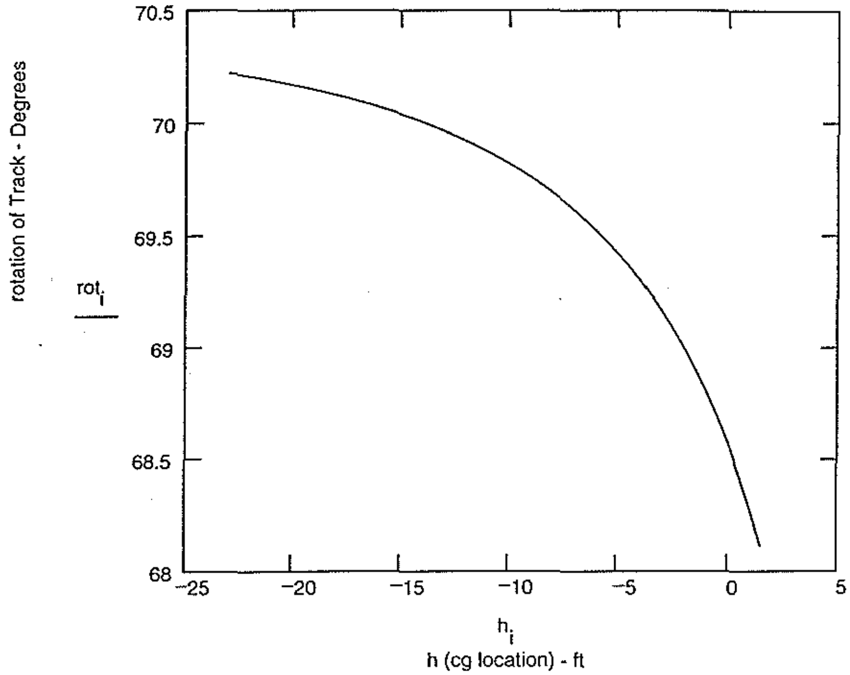
$ans_i := sol\left[(ans_{i-1})_0, (ans_{i-1})_1, (ans_{i-1})_2, (ans_{i-1})_3, (ans_{i-1})_4, (ans_{i-1})_5, h_i\right]$

$rot_i := (ans_i)_1 \cdot \frac{180}{\pi}$

$(ans_N)_0 \cdot \frac{180}{\pi} = -26.8171$

$(ans_N)_1 \cdot \frac{180}{\pi} = 70.2223$

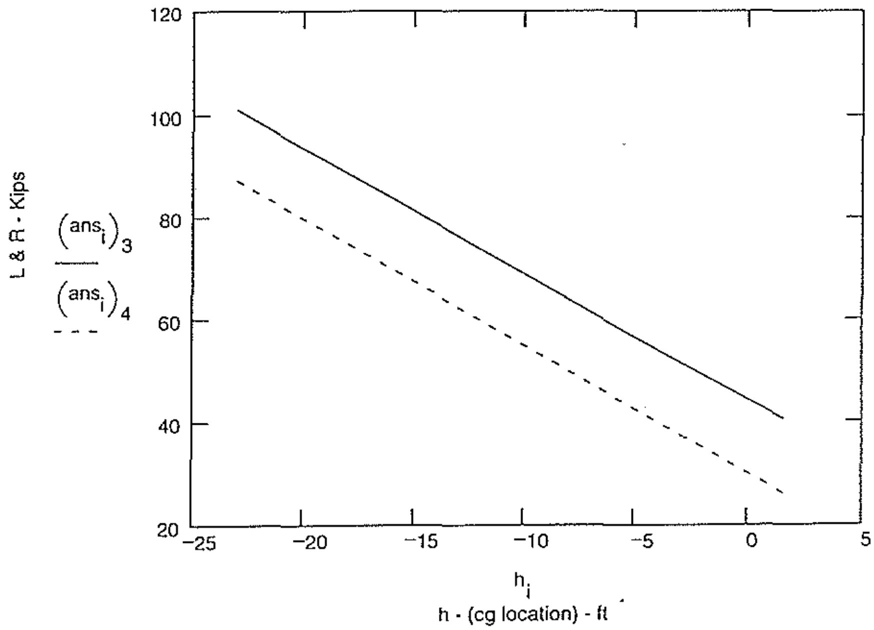
$(ans_N)_2 \cdot \frac{180}{\pi} = 104.8376$



Rotation vs h(cg location)

$(ans_N)_3 = 100.7759$

$(ans_N)_4 = 86.9764$



Forces L & R vs h (cg location)

$N := 50 \quad hstart := 2 \qquad ans_0 := sol(-104 \cdot deg, -70 \cdot deg, 26 \cdot deg, 80, 60, 50, hstart) \qquad \mu = 0.4$

$i := 1..N \quad h_0 := hstart \qquad w = 0$

$h_i := h_{i-1} - .5$

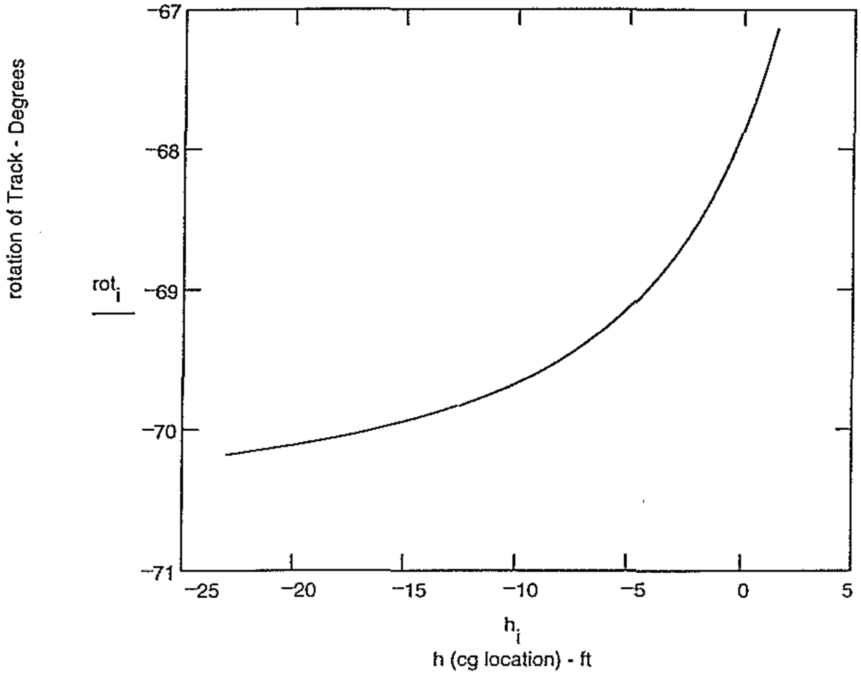
$ans_i := sol\left[\left(ans_{i-1}\right)_0, \left(ans_{i-1}\right)_1, \left(ans_{i-1}\right)_2, \left(ans_{i-1}\right)_3, \left(ans_{i-1}\right)_4, \left(ans_{i-1}\right)_5, h_i\right]$

$rot_i := \left(ans_i\right)_1 \cdot \frac{180}{\pi}$

$\left(ans_N\right)_0 \cdot \frac{180}{\pi} = -104.5281$

$\left(ans_N\right)_1 \cdot \frac{180}{\pi} = -70.1794$

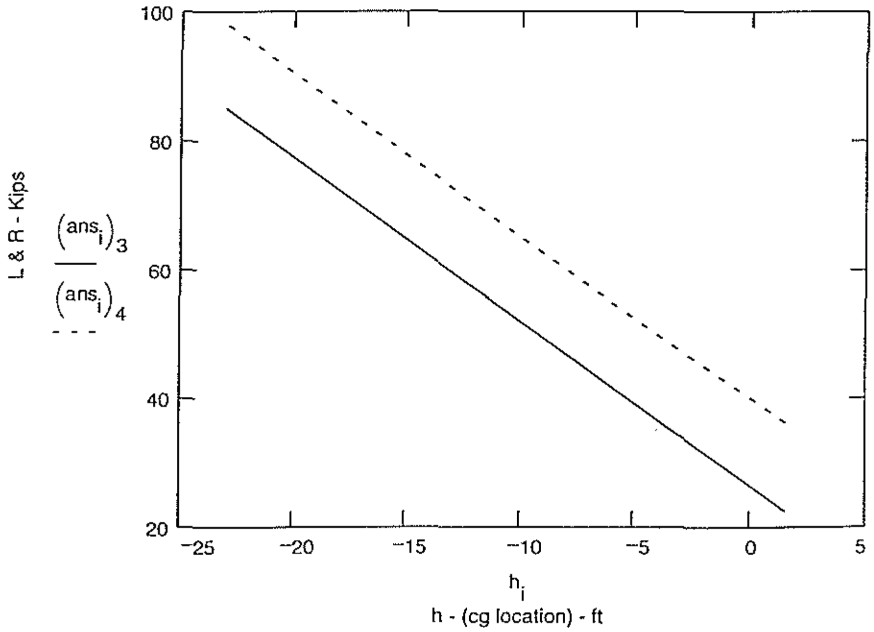
$\left(ans_N\right)_2 \cdot \frac{180}{\pi} = 26.4887$



Rotation vs h(cg location)

$\left(ans_N\right)_3 = 84.9947$

$\left(ans_N\right)_4 = 98.0234$



Forces L & R vs h (cg location)

$N := 50 \quad hstart := 2 \qquad ans_0 := sol(-104 \cdot deg, -70 \cdot deg, 26 \cdot deg, 80, 60, 50, hstart) \qquad \mu = 0.4$

$i := 1..N \qquad h_0 := hstart \qquad\qquad w = -1$

$h_i := h_{i-1} - .5$

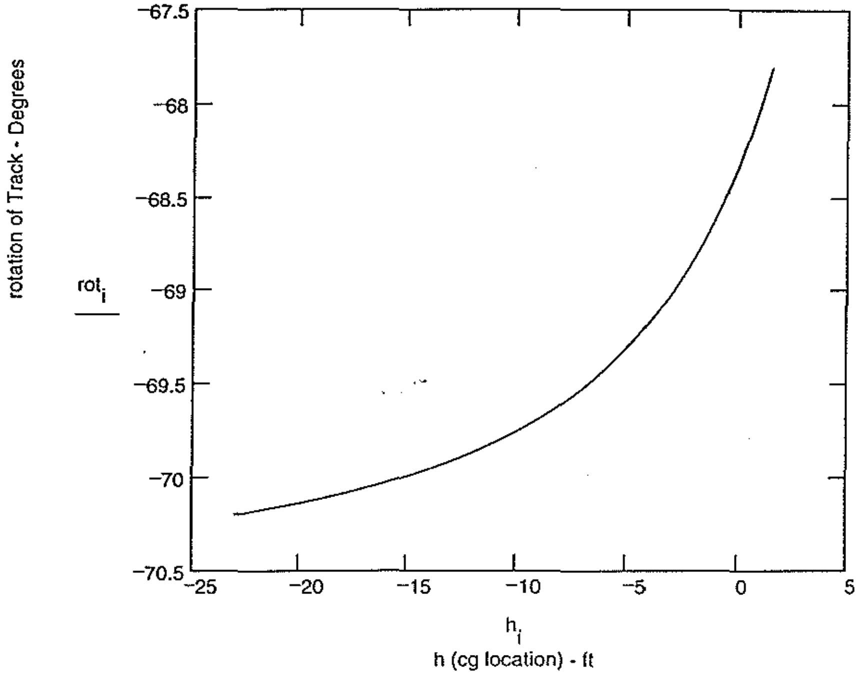
$ans_i := sol\left[(ans_{i-1})_0, (ans_{i-1})_1, (ans_{i-1})_2, (ans_{i-1})_3, (ans_{i-1})_4, (ans_{i-1})_5, h_i\right]$

$rot_i := (ans_i)_1 \cdot \frac{180}{\pi}$

$(ans_N)_0 \cdot \frac{180}{\pi} = -104.6837$

$(ans_N)_1 \cdot \frac{180}{\pi} = -70.2013$

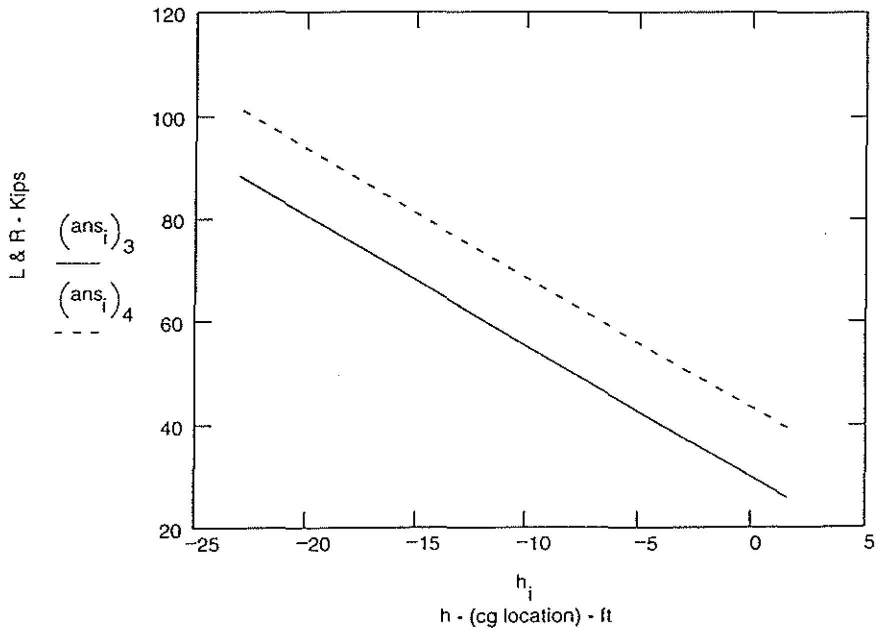
$(ans_N)_2 \cdot \frac{180}{\pi} = 26.6539$



Rotation vs h(cg location)

$(ans_N)_3 = 88.0172$

$(ans_N)_4 = 101.0413$



Forces L & R vs h (cg location)

A.4.4 Plots Showing the Effect of Varying Horizontal Component of Load Line Force - Equilibrium position 2

$N := 28 \quad hstart := 45 \qquad ans_0 := sol(.01, .01, .01, 1, 1, 1, hstart) \qquad \mu = 0.4$

$i := 1..N \quad h_0 := hstart \qquad w = 0$

$h_i := h_{i-1} - 2 \qquad ll = 0.25$

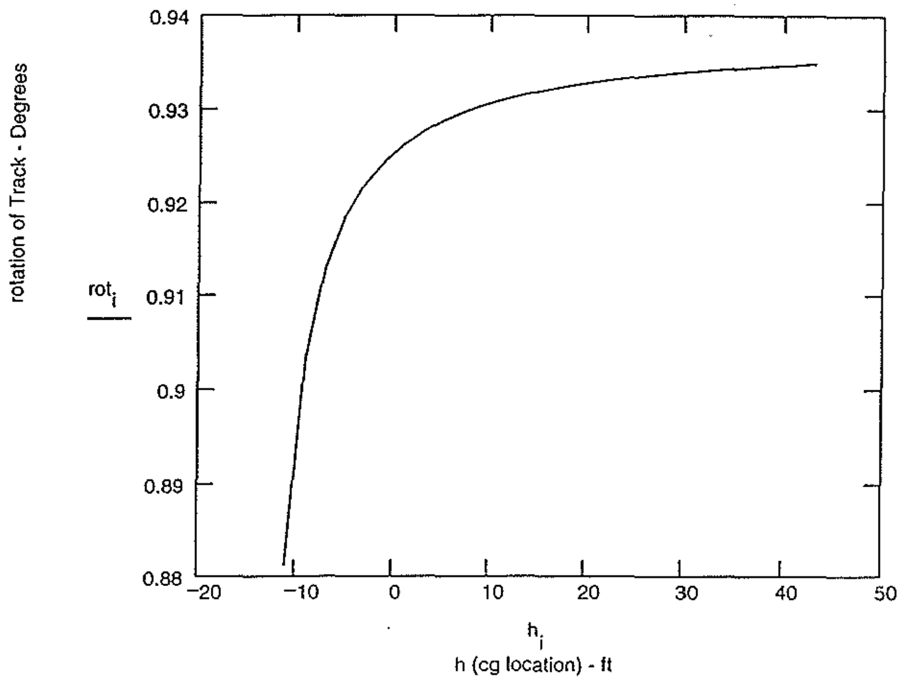
$ans_i := sol\left[(ans_{i-1})_0, (ans_{i-1})_1, (ans_{i-1})_2, (ans_{i-1})_3, (ans_{i-1})_4, (ans_{i-1})_5, h_i\right]$

$rot_i := (ans_i)_1 \cdot \frac{180}{\pi}$

$(ans_N)_0 \cdot \frac{180}{\pi} = 1.747$

$(ans_N)_1 \cdot \frac{180}{\pi} = 0.8812$

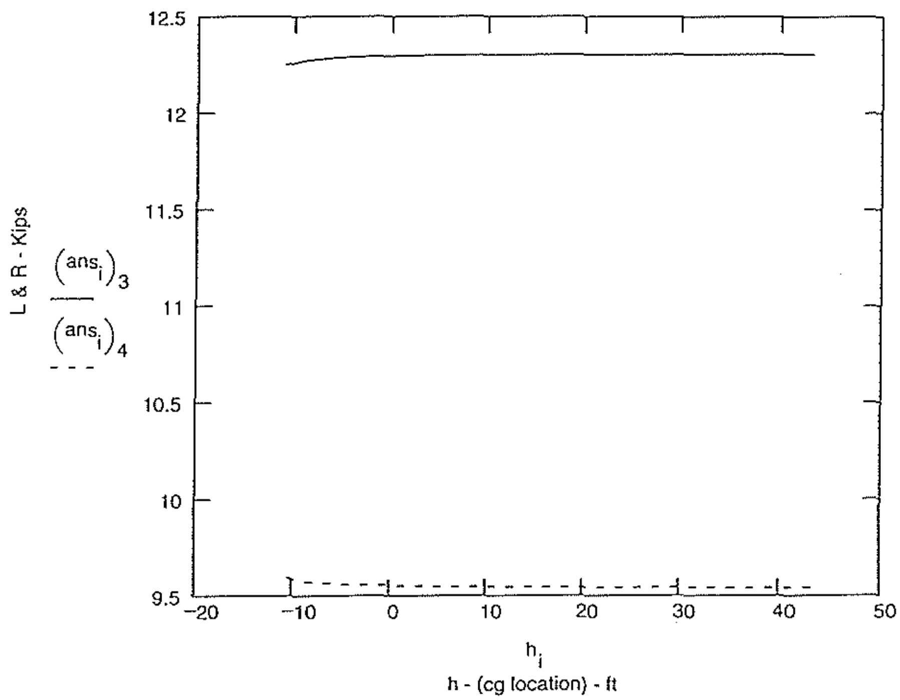
$(ans_N)_2 \cdot \frac{180}{\pi} = 1.7757$



Rotation vs h(cg location)

$(ans_N)_3 = 12.2485$

$(ans_N)_4 = 9.5999$



Forces L & R vs h (cg location)

$N := 50 \quad hstart := 2 \qquad ans_0 := sol(-104 \cdot deg, -70 \cdot deg, 26 \cdot deg, 80, 60, 50, hstart) \qquad \mu = 0.4$

$i := 1..N \qquad h_0 := hstart \qquad w = 0$

$h_i := h_{i-1} - .5 \qquad ll = 0.25$

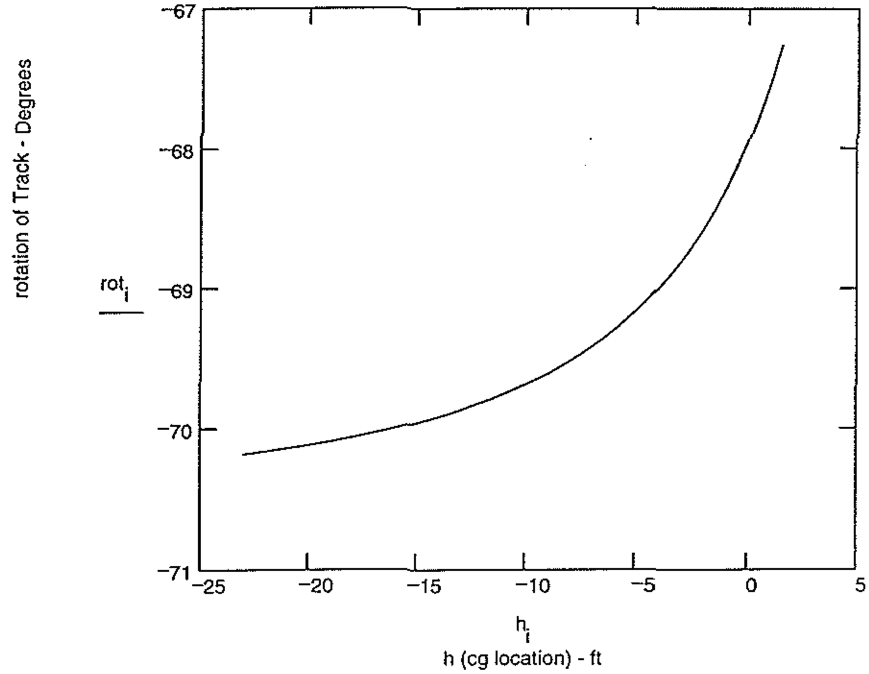
$ans_i := sol\left[(ans_{i-1})_0, (ans_{i-1})_1, (ans_{i-1})_2, (ans_{i-1})_3, (ans_{i-1})_4, (ans_{i-1})_5, h_i \right]$

$rot_i := (ans_i)_1 \cdot \frac{180}{\pi}$

$(ans_N)_0 \cdot \frac{180}{\pi} = -104.5386$

$(ans_N)_1 \cdot \frac{180}{\pi} = -70.1809$

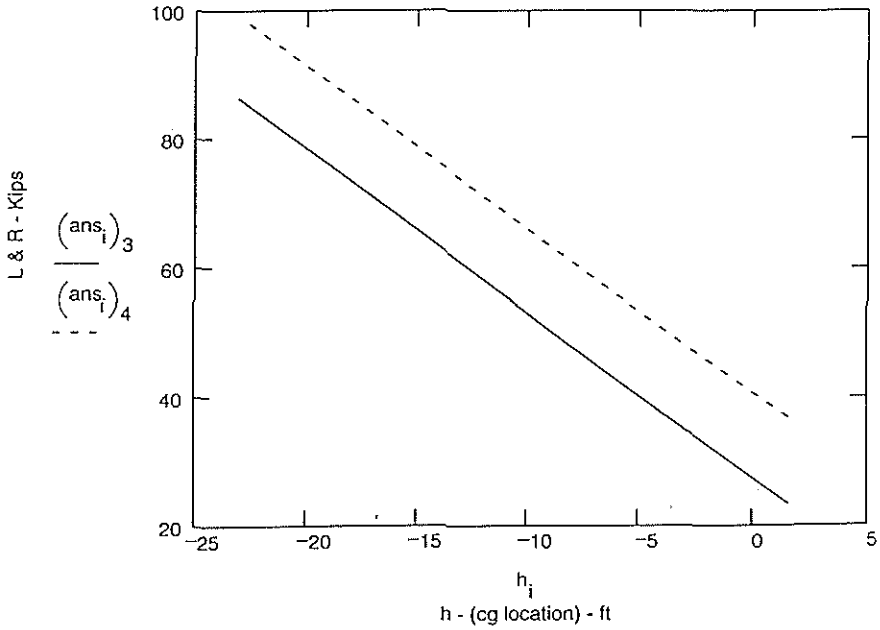
$(ans_N)_2 \cdot \frac{180}{\pi} = 26.4998$



Rotation vs h(cg location)

$(ans_N)_3 = 86.1913$

$(ans_N)_4 = 99.0246$



Forces L & R vs h (cg location)

A.5 Antenna Loads

The following antenna loading configuration was considered

NO	ELEVATION - FT	ANTENNA DESCRIPTIOM
1	1462	RCA TFU28 DAS Slot
2	1416-1434	DB-410
3	1422	8' Grid Dish
4	1342-1392	ERI G5CPS 6B FM
5	1298-1328	ERI G5CPS 4B FM
6	1037-1167	RCA BFC-14B FM /w Radome
7	896-906	Pactel DB-809D
8	530-540	ERI G5CPS 1B FM
9	520	8' High Performance Dish
10	480	8' High Performance Dish
11	377	10' Grid Dish
12	280	8' High Performance Dish
13	267	6' Grid Dish
14	213	6' Grid Dish

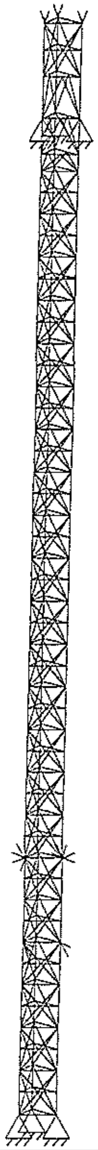
Appendix D

SELFWEIGHT Y -1.0

LN= 2 MN/ELEM

STRUCTURE DATA

TYPE = SPACE
NJ = 300
NM = 741
NE = 0
NS = 6
NL = 2
XMAX= 108.0
YMAX= 3054.0
ZMAX= 93.5



J=300,M=741

UNIT INC POU

S T A A D P O S T - P L O T (REV: 21.0W)

DATE: MAR 20, 1997

TITLE: - ANTENNA TOWER IN TEXAS (ANTENNA1)

TOWER MODEL

SELFWEIGHT Y -1.0

LN= 2 MN/ELEM

STRUCTURE DATA

TYPE = SPACE

NJ = 300

NM = 741

NE = 0

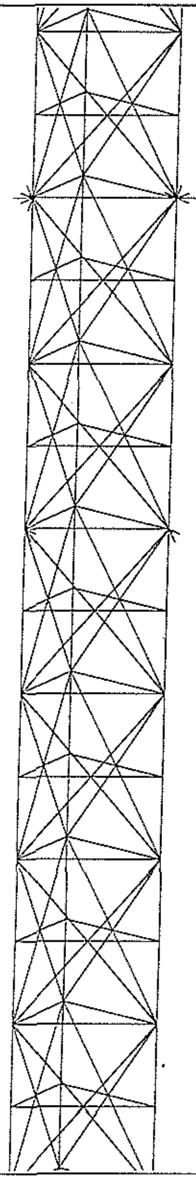
NS = 6

NL = 2

XMAX= 108.0

YMAX= 3054.0

ZMAX= 93.5



J=300,M=741

UNIT INC POU

S T A A D P O S T - P L O T (REV: 21.0W)

DATE: MAR 20, 1997

TITLE: - ANTENNA TOWER IN TEXAS (ANTENNA1)

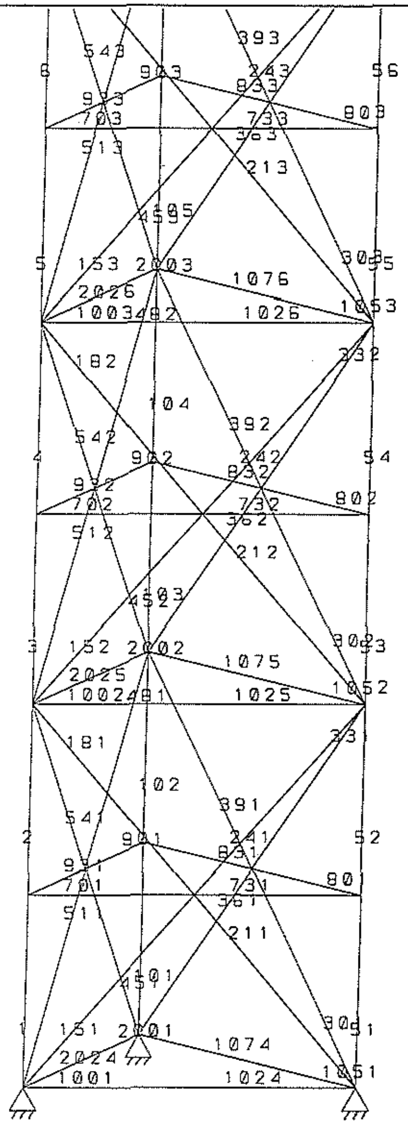
TOWER SECTION
(NEAR THE LOCATION OF GINPOLE SUPPORT)

SELFWEIGHT Y -1.0

LN= 2 MN/ELEM

STRUCTURE DATA

TYPE = SPACE
NJ = 300
NM = 741
NE = 0
NS = 6
NL = 2
XMAX= 108.0
YMAX= 3054.0
ZMAX= 93.5



J=300, M=741

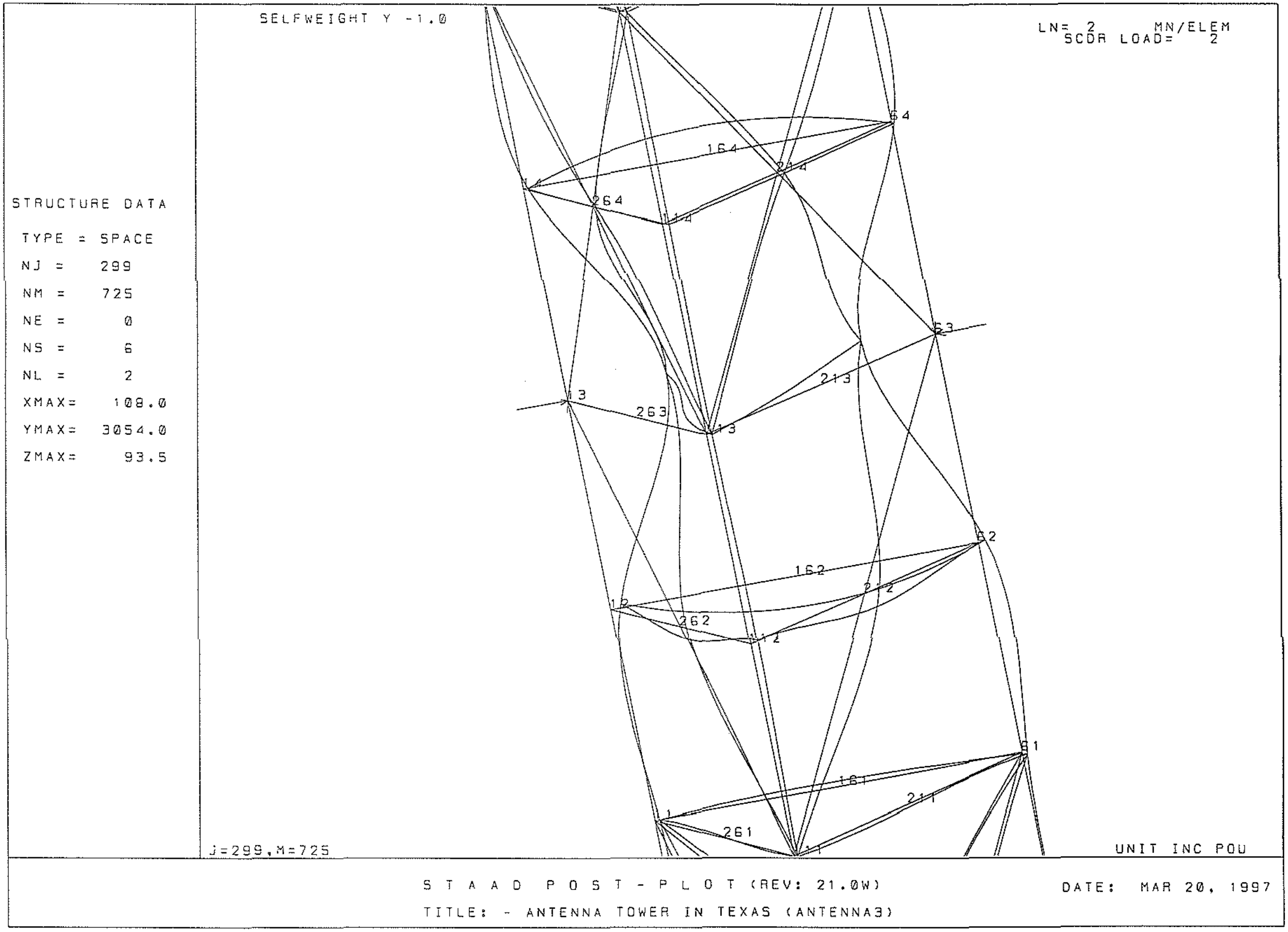
UNIT INC POU

S T A A D   P O S T - P L O T (REV: 21.0W)

DATE: MAR 20, 1997

TITLE: - ANTENNA TOWER IN TEXAS (ANTENNA1)

TOWER BASE (with member numbers)



TOWER DEFLECTED SHAPE

(AFTER THE BUCKLING OF DIAGONAL AND STRUCT MEMBERS)