

Investigation of the September 4, 2003, Collapse of the 1000-foot High TV Antenna Tower in Huntsville, Alabama

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REPORT

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Report Prepared by
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Description of the Tower

The 1,000 ft. high guyed tower at Huntsville, AL was originally designed and fabricated by Stainless, Inc., and was erected in 1976. The design of the tower conformed to the then E1A/222-C standard. The tower is currently owned by SpectraSite Broadcast Group (SBG) and is leased to the TV station WAAY, Huntsville, AL. The tower, consisting of 39 sections, is triangular with each side measuring approximately 7 feet. The tower is supported by a pinned base and six levels of guy wires at equal intervals to the top of the tower, see Figures 1 & 2. Each section is 25 ft high except for the very base and top sections.

In 1983, WAAY-TV 31, the-then owner of the tower, requested Stainless to reexamine the tower for additional equipment to be placed on the tower. Stainless performed a structural analysis and recommended modifications to the tower. Among the recommended modifications were installing horizontal sub-bracings in selected bays, replacing one guy wire, and replacing selected tension rods. The modifications, as recommended, were carried out in 1983. The 1983 structural analysis also conformed to the EJA/ 222-C standard.

In 2002, SpectraSite Broadcast Group (SBG), the new owner of the tower, asked Stainless, a subsidiary of SBG since 1999, to re-analyze the tower for a new HDTV antenna and additional equipment. A structural analysis was performed for the new loads, identified as condition 2, to conform to EIA/TIA standard 222-F. As a result of the analysis, modifications to the tower were recommended in a report (AL-0140E). Erection drawings were prepared, detailing the extent of work to be performed. See Figure 3 for locations of new horizontal braces.

SBG issued an internal work order on March 6, 2002 to Dotty Moore Tower Services, also a subsidiary of SBG, to perform modifications to the tower. The work consisted of:

- Install horizontal braces at the junction of the diagonals in 31 bays in tower sections T12 thru T15, T15, T24, T26 and T28.
- Remove existing top 14 ft. of the tower and replace it with a new 6 ft. tower section.
- Replace existing guy wires at the 6th level with new guy wires.
- Adjust guy tensions

Description of the collapse:

Work began about three weeks before the incident. The first item to be completed was the installation of new horizontal braces on the tower sections described above. It could not be completely ascertained whether new horizontal braces were added to section T28. During the modifications in 1983, the erection crew inadvertently installed braces in section T26 instead of T25. Therefore, the present crew had to remove the 1983 braces from T26 and install them at their correct location, T25. However, due to lack of new bolts, the crew postponed the removal of the 1983 braces for section T26. At the

time of the incident, section T26 had old 1983 braces and T25 had no new braces.

A week before the incident, the crew positioned a track, weighing approximately 1,200 pounds and a 30"x30"x160' gin pole, weighing approximately 16,000 pounds, on one face of the tower as a means to hoist the new antenna to the top of the tower. The gin pole was furnished with a rooster head, weighing approximately 3,000 pounds, at its head. At the time of the incident, the track was located on section T8 with the gin pole projecting approximately 96 feet above the track to section T4. The bottom of the gin pole was supported in a "wire basket" located in section T11. The gin pole was also provided with safety chokers located in section T6.

The gin pole was originally obtained by Dotty Moore Services from Kline Towers of Columbia, SC. It is believed that the track was also furnished by Kline. There were three rope lines running, known as jump line, load line and tag line see Figure 4. The purpose of the jump line (7/8" wire rope) attached to the track and the bottom of the gin pole is to raise the gin pole. The objective is to raise the gin pole well above the top of the tower so that the new antenna could be hoisted from the rooster head attached to the top of the gin pole and fastened to the top section of the tower. The purpose of the load line (7/8" wire rope) that went through a block located in the third section from the top of the tower, T3, is to slide the track upwards and to hoist miscellaneous pieces of material. A "headache" ball weighing approximately 1,500 pounds was also attached to the load line. The tag line (1/4" wire rope) going over a block near the top of the tower is meant to keep the materials being hoisted on the load line away from the face of the tower.

All three lines (i.e., load, jump and tag lines) were operated by the hoist equipment containing three winches, one for each line. The bottom block for the load line was attached to one leg of the tower, approximately 35 feet above the tower base. The attachment was made at the top of section T38, a few inches below the top splice flange plates. The load line running between the winch and the load line block attached to one of the tower legs made an angle of approximately 60 degrees from the face of the tower and did not coincide with the center of gravity of the tower.

At the time of the incident, the crew was attempting for the first time to raise the track by using the load line. Eyewitness statements indicated that on the day of the incident the winch operator raised the track a few inches but was immediately advised by the crew on the tower to lower it back down. A few minutes later, the winch operator was advised to try again to raise the track. The winch operator applied tension to the load line and the tower suddenly collapsed, with the failure beginning near the base of the tower.

Figure 5 indicates the approximate orientation of the collapsed tower on the ground. Sections T38 thru T22 collapsed approximately vertically down over the base. Sections

T22 thru T15 fell away from the base, approximately in a straight line. At the end of T15, there was a 180 degree fold and the remaining tower T14 thru T1 also fell approximately in a straight line towards the base.

The crew consisted of five workers. At the time of the incident, three were located on the tower and two on the ground. Two workers were positioned a few feet above the top of the track at the top of the section TB. One worker was located near the middle of the section T6. All three workers on the tower died during the collapse. The two workers, including the winch operator, survived because the tower fell away from the hoist (winch) equipment.

The photographs of the collapsed tower on the ground are shown in figures 6 thru 25.

Structural Analysis:

An independent structural analysis was conducted to determine:

1. Whether the structural design of the tower met the industry standards
2. Whether the tower was capable of supporting additional loads of gin pole, track, blocks and wire ropes etc.
3. Whether the loads applied to the tower at the time of the incident produced forces in excess of the tower's capacity.
4. The potential cause of the collapse.

The structural analysis was performed by Dr. Hugh Bradbum of the Department of Civil Engineering, University of South Carolina who has developed a proprietary finite element program to analyze guyed antenna towers. The results of his program have been tested and verified against industry standards and have been found to be conforming. The finite element 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, producing a much more realistic distribution of forces in the structure.

The member properties of the tower were derived from the original drawings prepared by Stainless (Report No. 2566), Stainless report 2566-2 of July 28, 1983 and Stainless report of November 15, 1983. Information was also derived from SpectraSite drawings AL-0140 and AL 1040E of February 25, 2002. Gin pole details were provided by the contractor who did the construction.

The structural analysis indicated that the forces in the tower under the loads that existed on the tower before the latest modifications to the tower were undertaken provided an adequate factor of safety in accordance with the industry standards. The tower was found to be conforming to the TIA/EIA 222-F standard. The tower was also determined

to be capable of supporting additional loads that were placed on the tower during the current modifications, i.e., gin pole, track, blocks and the wire ropes for the three lines.

The use of gin pole and track is common in the tower industry to raise new antennas and other loads. As the tower is designed to withstand wind and ice, and the stresses are kept below the allowable levels, the structural design of the tower generally provides an adequate factor of safety, even under the additional loads of gin poles, track, rooster head, headache ball, wire ropes, etc. The loads described above are gravity loads. However, the tower is sensitive to lateral loads due to wind and other sources. It was discovered that the block for the load line was not attached to any independent concrete block or tower footing but to one of the legs of the tower, at a height of 35 feet above the base. The tension in the load line would result in flexural stresses in the tower sections between the base and the upper guy level for tower which must be investigated to determine if a proper factor of safety could be maintained. Additionally, the load line running between the winch and the block that was fastened to one of the tower legs produced an angle of approximately 60 degrees to the tower face, thus creating eccentricity and torsional forces to the tower. If the load line was coincidental to the center of gravity of the tower, the tension would not produce torsional forces. It would only produce flexural forces.

Structural analyses were done to determine the level of tension that could be applied in the load line to cause a failure of the tower. Three loads were considered in the load line, i.e., 10,000, 15,000 and 20,000 pounds, and then the resulting forces in the tower members were compared with their ultimate capacities. At 10,000 pounds, the tower would not fail but the factor of safety was significantly compromised. A force of 15,000 pounds would result in the tower failure as a large number of members near the first guy level above the base were stressed above their ultimate capacities. Overstressing of a large number of members near the bottom-most guy level would result in the failure beginning near the bottom, as was reported by the eyewitness statements. The load line wire rope (7/8" dia.) and the winch were capable of withstanding a force of this magnitude.

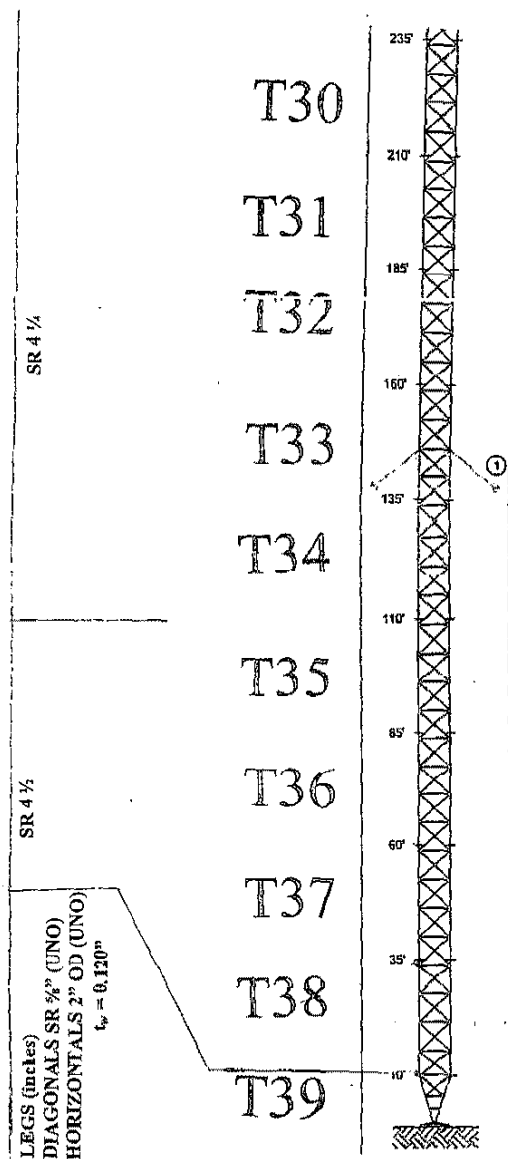
Eyewitnesses also stated that the crew was barely able to raise the track in its first attempt on the day of the incident. The operator raised the track a few inches and was immediately advised by the crew on the tower to bring it back. It is believed that there was a potential obstruction in the path of the track which went unnoticed by the two workers positioned a few feet above the track. On the next attempt, the winch is suspected of having exerted a larger force to the load line, creating a larger torsional force to the tower and leading to the collapse of the tower. After the incident, a steel angle was observed projecting from the face of the tower that could have caused a potential obstruction. In fact, the angle observed was severely deformed see figures 24 & 25.

Structural analysis also indicated that if the load line between the hoist (winch) and the tower was coincidental to the center of gravity of the tower, the tower would not have failed under the load line force of 15,000 pounds.

Conclusions:

Based on the above, the following conclusions are reached

1. The tower was determined to be structurally capable of supporting its loads, the loads of the appurtenances placed on it, the code-prescribed wind loads, and the loads of the ginpole, track, and wire ropes of the three lines i.e., load, jump and tag lines.
2. The contractor fastened the load line block to one of the tower legs at a height of 35 feet above the base, instead of to an independent concrete block or footings, thus subjecting the tower to forces that could compromise the structural integrity of the tower. The contractor did not conduct a structural analysis to determine the safe load that could be applied to the load line to maintain an adequate factor of safety of the tower.
3. The contractor placed a hoist (winch) at a location that produced eccentricity between the load line (running between the hoist and the load line block fastened to the tower) and the center of gravity of the tower. The eccentricity produced torsional forces on the tower when tension was applied to the load line by the hoist (winch). The contractor did not perform a structural evaluation of the tower to determine the maximum tension in the load line that could be safely applied.
4. Minutes before the incident, the crew experienced difficulty in raising the track, possibly due to obstructions in the path of the vertical movement of the track. A possible obstruction, observed after the collapse, was a steel angle projecting from the face of the tower, a few inches above the track.
5. The most likely cause of the collapse of the tower was the excessive force on the order of 15,000 pounds applied to the load line, possibly to overcome the obstruction described in # 4 above, by the hoist operator in raising the track.
6. It was determined that a force of 15,000 pounds in the load line, in the configuration as it existed, will produce tower failure. An eccentric force of 10,000 pounds would not cause the tower to collapse but would significantly reduce the factor of safety against failure.
7. If the load line running between the hoist (winch) and the load line block (fastened to the tower) was placed in a manner that coincided with the center of gravity of the tower, the tower would have been able to support a concentric load of 15,000 pounds.
8. Wind was not a factor in the collapse.



LOADING CONDITION 2

TOWER ELEVATION

FIGURE 3 (SHEET 1 OF 3)

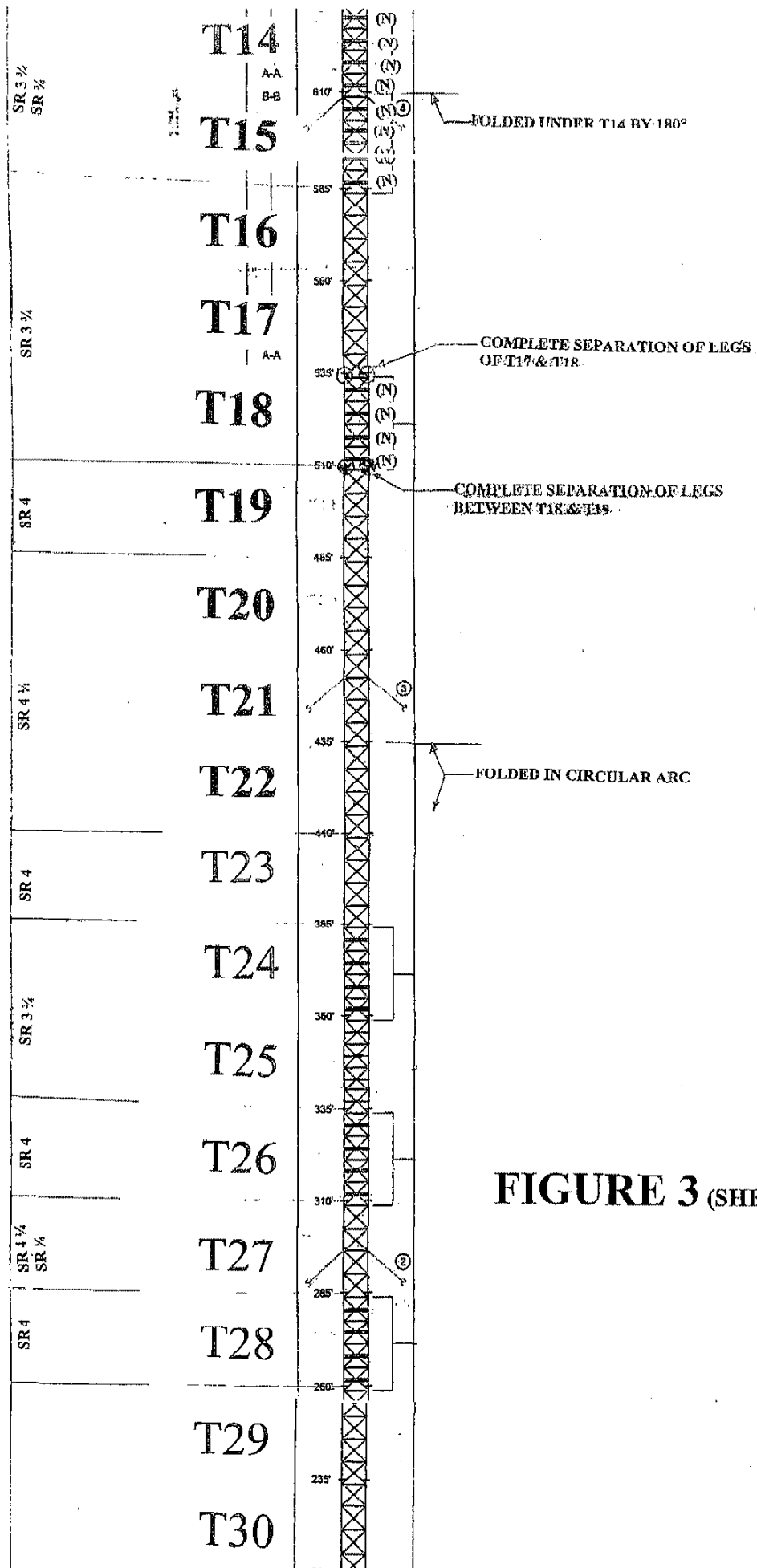


FIGURE 3 (SHEET 2 OF 3)

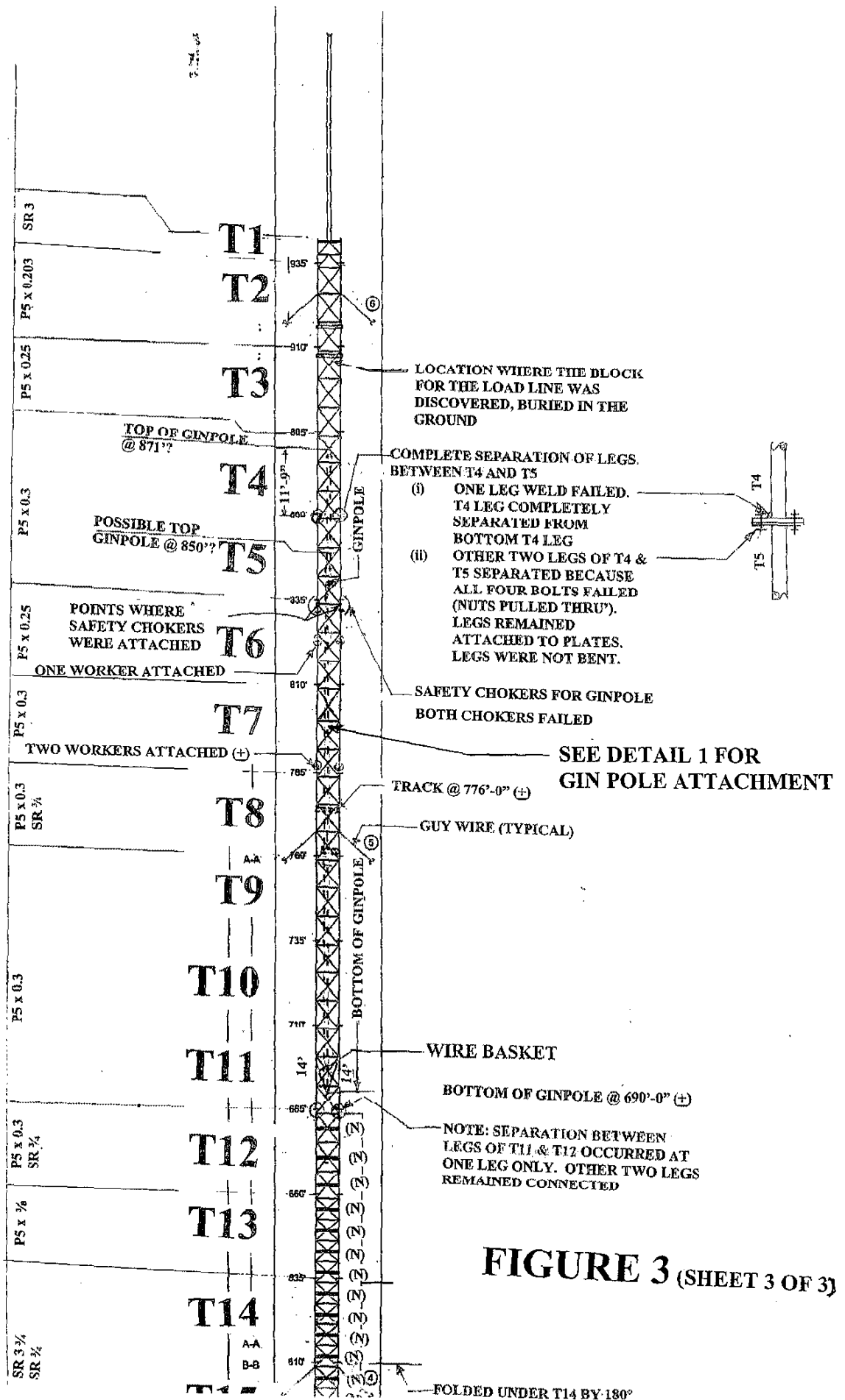
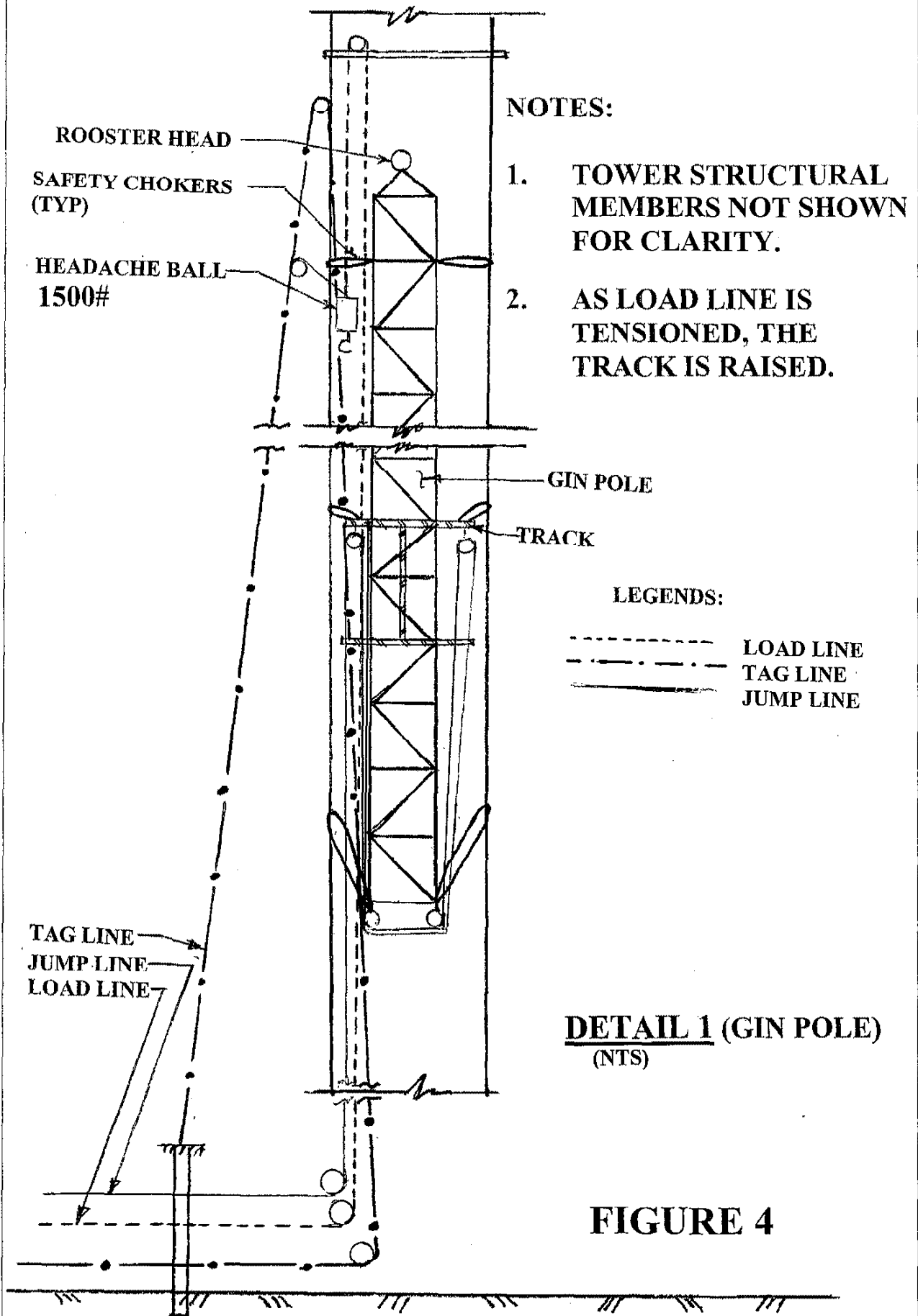


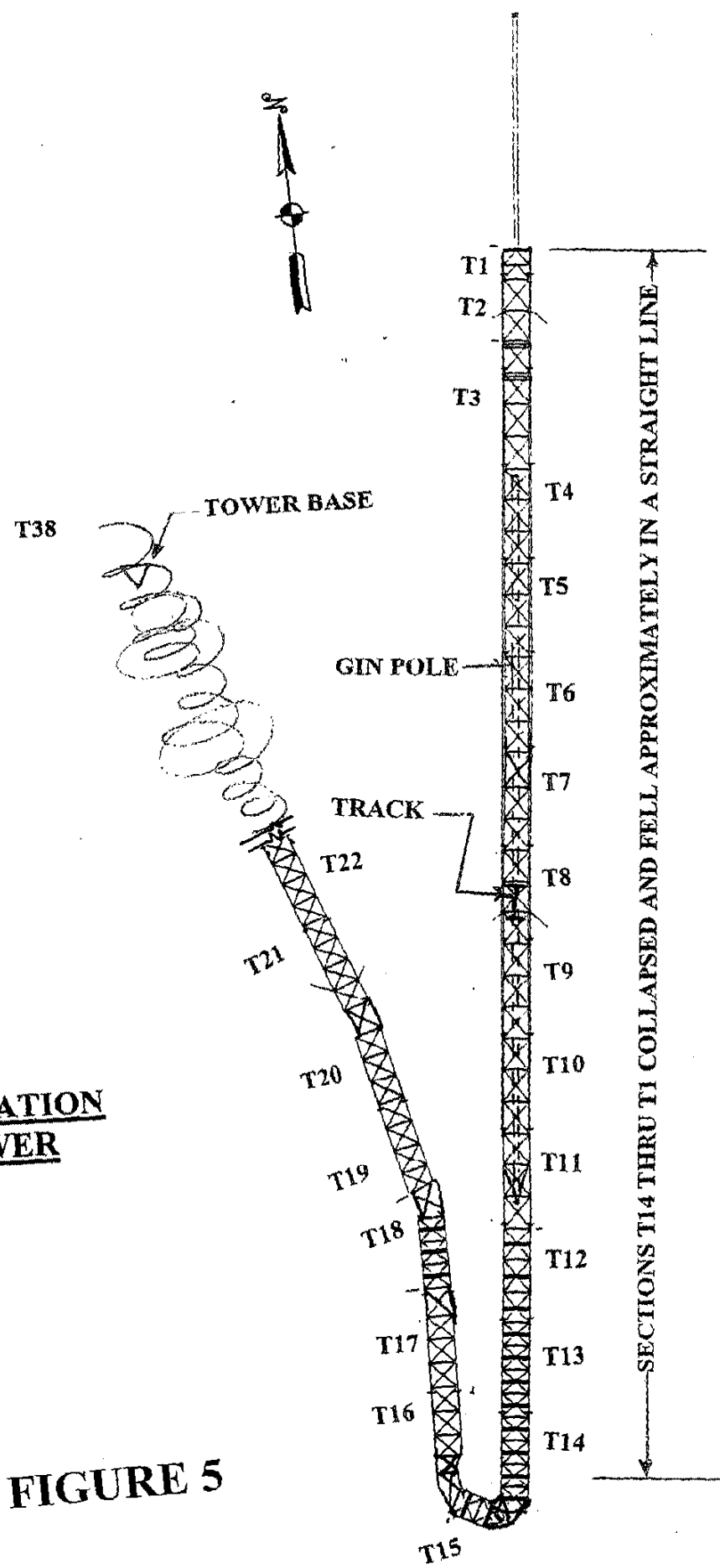
FIGURE 3 (SHEET 3 OF 3)



HOIST
3 WINCHES

APPROXIMATE LOCATION
OF COLLAPSED TOWER

FIGURE 5



SPECTRASITE BROADCAST GROUP

A Division of SpectraSite Communications, Inc.



SpectraSite

TOWER ID# AL-0140 , FCC# 1041008

SITE NAME: Huntsville 1008

ADDRESS: 1000 Monte Sano Blvd.

FOR TOWER LEASING INFORMATION CONTACT:

Collocation Management Department @

1-866-44 TOWER (44 88937)

www.SpectraSite.com

EMERGENCY CONTACT:

1-877-750-9592

FIGURE 6

Typical failure at splice joints of lower sections



FIGURE 7

A view of the collapsed gin pole.

FIGURE 8



FIGURE 9

A view of the track (yellow) and
the gin pole (red)



FIGURE 10

Top member of the track
(yellow) and the gin pole (red)

