

# THE DESIGN AND CONSTRUCTION OF A FOLDING 60 FT. SELF SUPPORTING TOWER SYSTEM

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## Abstract

A system has been designed and constructed which allows a 60 ft. self supporting tower to be raised and lowered by means of a manually operated winch. An overview of the structural analysis and design of the cable system, gin pole, hinges, and winch foundation is given. The system has not only facilitated installation and maintenance but has also added considerably to the safety of these tasks.

## Hinged Tower System

The original consideration for constructing a hinged tower that could be easily raised and lowered was to facilitate some of our research projects. After having experience with the system, however, we have found other significant advantages. The first is safety. Working at the top of a tower has its dangerous moments even for experienced personnel, and the danger is certainly compounded for those working on a tower for the first time, as is often the case. The second is consumer acceptance which is, in many ways, closely associated with the first. If wind systems are ever to become as commonplace with the general populace as we all hope, then they are going to have to be easily and readily installed and maintained. Furthermore, in view of the present state of reliability of many systems now on the market, the capability of easily removing the entire system for major repairs or design changes is also a significant consideration.

In order to eliminate any guy wires, we chose a Unarco-Rohn 60 ft. SSV self-supporting tower for our analysis to determine if it was suitable for a hinged system. The following is an outline of some of the more pertinent analysis.

Various system configurations were considered before deciding on the one illustrated in Fig. 1.

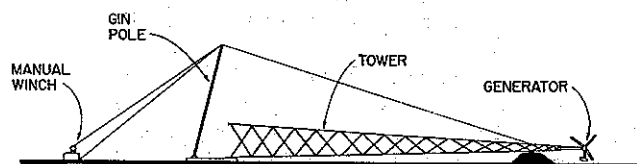


Fig. 1 Tower system configuration.

Two of the three legs are hinged at the foundation. The third leg, when in a vertical position, is attached to the same support as the base of the gin pole. One end of a cable of fixed length is attached to an eyebolt at the top of the gin pole; the other end is attached to the tower at a distance of about 50 ft. by means of a sling and shackle. A snatch block is attached to another eyebolt at the top of the gin pole in order to double the cable to the manual winch. Increasing the mechanical advantage, in this way, makes the effort necessary to turn the winch more reasonable.

As the winch is turned, the gin pole rotates about its base and the tower is pulled into a vertical position. Two short cables are also used to keep the gin pole from being pulled to either side. These cables go from the top of the gin pole to eyebolts positioned near the edge of the foundation. The winch has its own separate foundation.

## Design Analysis

Cables and Gin Pole. In order to calculate the forces, the weight distribution and total torque about the point of rotation must be determined. This information is given in Fig. 2.

Tower. Since we are using the tower in a way the manufacturer did not consider in determining the design criteria, it is important to carefully examine the forces on the tower components during raising or lowering the system. Here we will consider only the case when the tower is being supported in a near horizontal position since this is when the forces are a maximum. Fig. 7 shows the results of the loading-shear-moment calculations for the cable attached at the 50 ft. point of the tower.

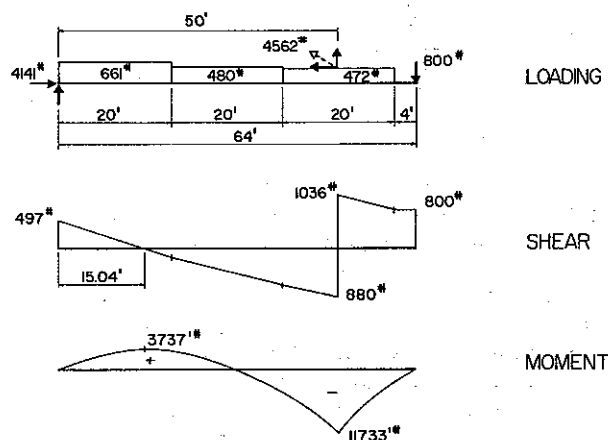


Fig. 7 Loading-shear-moment diagram.

Note that the applied forces on the tower are 4562 lbs. due to the tension in the cable, and the reaction forces of the hinges of 4141 lbs. horizontally and 497 lbs. vertically. The maximum shear of 1036 lbs. occurs at the lifting point and is well below the allowable shear of 15,400 lbs. for even a single 2 in. diameter standard pipe leg.

The moment diagram shows that the bottom half of the tower is bowed concave upward giving a positive moment with a maximum of 3737 ft. lbs. The top half is bowed concave downward giving a negative moment with a maximum of 11,733 ft. lbs. This type of analysis was repeated for various positions of attaching the lifting cable in order to determine the optimum position. The resulting maximum moments for both the positive and negative regions are plotted in Figure 8.

Taking into account the varying spread of the legs, the maximum force in a leg as a function of the tower lifting point was calculated and graphed in Fig. 9. All points on the graph are well below conservatively calculated values for the allowable compression and tension of 18 kips and 22 kips, respectively.

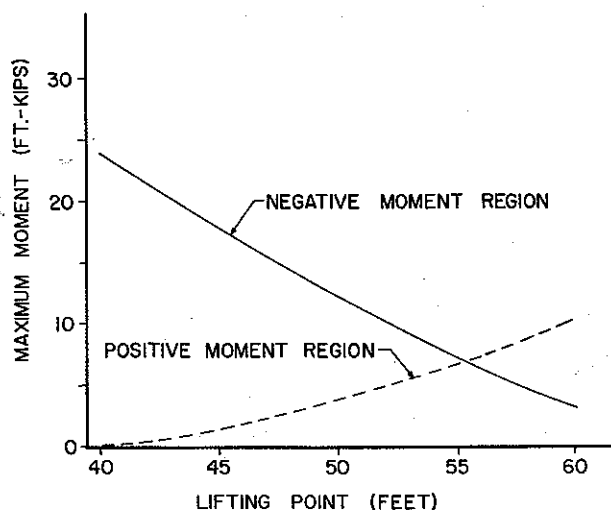


Fig. 8 The effect of lifting point on the maximum moment in the tower structure.

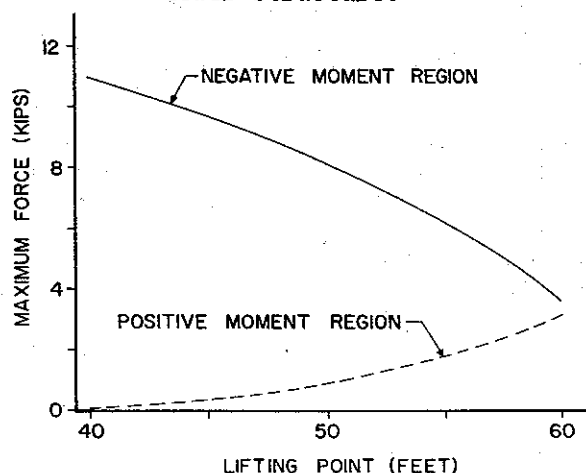


Fig. 9 The effect of lifting point on the maximum force in the tower structure.

It is also important to examine the forces in the immediate area of the lifting force. Since there is little lateral strength in the pipe leg, we can consider all the force at the lifting point being exerted on the supporting struts. The worst possible case is diagrammed in Fig. 10 (where only 3 of the 4 struts are shown). When the force exerted by the cable is perpendicular to the plane formed by the two struts going to the left in the figure, then the force is equally divided between the two remaining struts. Thus each strut must support a tension of 2.1 kips. An analysis of the strut, weld and bolt showed that the limiting factor is the 4.1 kips allowable shear in the 0.5 inch bolt attaching the strut to the leg.