AMERICAN CONSULTING ENGINEERS COUNCIL'S

HEAVY MOVABLE STRUCTURES
MOVABLE BRIDGES AFFILIATE

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SESSION
WORKSHOP NOTES

Session (5-2)
"Gritty Grease Can Cause Big Problems",
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GRITTY GREASE CAN CAUSE BIG PROBLEMS
(or, What Can You Afford to Take For Granted On Your Movable Bridge?)

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A movable bridge in operation is an impressive sight. Members of the general public sometimes go out of their way to watch one operate. Conversely, the public also tends to take the operation of a movable bridge for granted as it faithfully opens on demand for their sailboat, or as it allows the train they ride or the car they drive to pass across unhindered on a daily basis, and experience an unpleasant surprise when a malfunction occurs.

Engineering minds appreciate the simplicity of the concept which allows a massive structure to move under precise control using compact, simple mechanisms and limited horsepower. This is made possible only by careful balancing and by keeping friction to a minimum. Engineers and operating personnel who are in charge of such a structure cannot afford to take it for granted, however. When a major problem occurs, tremendous expenses may result from consequential damages to the owner and to those he serves, adding to the expense of the repair itself. In addition to immediate economic consequences, political repercussions can include a decrease in public trust toward those providing goods and services who must depend on the bridge, leading to long term economic effects. The engineer and operator must be ever vigilant to detect and correct situations which may lead to problems, in addition to regular preventative maintenance. Contingency plans must also be put in place to minimize the effects of unforeseen problems.

The Amtrak vertical lift bridge over the Chicago River, 12 blocks south of Chicago's Union Station, is an example both of an undetected situation leading to a problem, and of a quick response and successful contingency plan. The size of the repair job in comparison to the limited inconvenience experienced by the public also speaks well of the cooperation and efficiency of the emergency team.

The Amtrak bridge was designed by Waddell and Harrington, and was built in 1913 for the Pennsylvania Railroad. Currently about 50 trains per day, including 12 commuter trains, utilize the structure when arriving or leaving the station. If the bridge cannot be used, each of these trains suffers a 20 - 30 minute detour. Up to 100 other trains daily, including 83 other commuter trains, can also be affected by the detouring trains passing over their routes. The problem is acute during rush hours, when trains are arriving or leaving the south side of Union Station within 4 minutes of each other.

The movable span, which supports the machinery house on the Amtrak vertical lift bridge, is a Pratt through-truss with double tracks, 273 ft. long. The span is raised and lowered using a system of up-haul and down-haul ropes attached to the channel side of the two 220 ft. high towers. Counterweights, suspended by ropes over sheaves at the top of each tower, balance the span on either end. Because the span is built on a skew across the river, and the counterweight ropes from each corner of the span require two sheaves each set (the ropes bending 90° at each location), vertical back legs are required for each tower (see Figure 1). This description and an early photographic print of this bridge are contained on pages 734 and 736 of Mr. Waddell's book, Bridge Engineering, which was published in 1925.

On the afternoon of June 14, 1988 the bridge operator found that he could not lower the span for a train movement after having raised for waterway traffic. When informed of the emergency, Amtrak immediately implemented their contingency plan for detouring trains to prepare for the impending rush hour and to bring in a team of specialists, the F.K. Ketler Company and heavy machinery specialist E.G. Todt, Inc., to restore the span to operation. It became evident that engineering assistance would be required, so Hazelet + Erdal, Inc. was called, based on their overall expertise in movable bridge design and troubleshooting.

It was determined that one or more bearings must have seized. Caps were first removed on suspected bearings for inspection purposes. Scored journals were noted on the south tower's southeast counterweight sheave trunnion at the west side bearing, and at the east side bearing for the northeast span sheave trunnion. Blasting shot in the lubricant was determined to be the culprit, having been found not only within the bearings, but also in a grease gun and in a pail of grease. Where did it come from? Shot blasting and painting of the span and lower parts of the towers had been done several months before. Could the grease container have been open to receive the contamination directly during the cleaning and painting operation? Why was the grease pail left open in any location?

With no time available for speculation, the team worked together to find a way to lower the span to allow rail traffic. A 200 ton high boom crane was brought to the site for the purpose of assisting the bridge machinery by lifting on the east end of the south counterweight at the same time that bridge power was to be applied to lower the span. In the mean time the damaged shaft journals were smoothed as much as possible on the exposed surfaces - the portions within the bearing bases were inaccessible. Heavy duty lubricant, normally used to lubricate railroad track switches, was spread by hand over the exposed journals. When everything was ready, with radio coordination between the bridge and crane operators and the workmen at the top of the south tower, the siezed bearings were broken loose and the span was slowly lowered about 15 feet, or one-third revolution of the sheaves, exposing another one-third of the journals. These, too, were smoothed and lubricated, and the 15 ft. lowering procedure repeated, this time without help from the crane. It was possible to fully seat the span after the procedure was done a third time. Trains began to move across the span midway through the evening rush hour on Thursday, June 16. Two days had elapsed.

This temporary solution, however, was unsatisfactory for the long term. The span had to be raised the following days to permit navigation, yet be available for rail traffic. While the span was temporarily successful in moving without assistance, permanent damage had occurred and operation was definitely not normal. It was questionable how long it would be before trouble would again develop. The damaged bushings had to be replaced.

Replacement of the bushings would be complicated (see Figure 2). The external static load on each sheave is delivered by horizontal and vertical rope tension. The vertical components of these loads are equal to the hanging weight of the portion of either the span or the counterweight supported by the ropes. A horizontal component is produced as rope tension is transmitted between the sheaves. The resultant, at approximately 45°, was incorporated into the original design for supporting the trunnions by splitting the bronze bushed pillow block bearings at 45°, perpendicular to this line of force. In order to lift the sheaves at the bearings, so that the bushings could be replaced, it would be best to remove this tension as much as possible so that only the weight of the ropes themselves, plus the weight of each sheave assembly, would be involved. It would also be necessary to use a special jacking arrangement so that the sheaves would move out at the 45° angle. To further complicate the situation, two different types of sheaves, one cast and one fabricated, were to be lifted, and the only support for the jacks was located *below* the thrust members *between* the bearings.

To remove the tension from the counterweight ropes, the counterweight was to be lifted and supported. Since these sixteen 2-1/4" diameter ropes would then sag between the sheaves, special supports would have to be built there for them. It was necessary to maintain operation of the bridge until the actual day of bushing replacement, however, so this support could not be completed until the latest possible time.

Meanwhile, the new bushings were to be manufactured across town, to be completed in approximately one week. It was decided to plan for their installation the weekend of June 25.

Work on the top of the tower and on the ground below continued all week. Several days were required to lower the counterweight support eye assemblies, which are threaded into large nuts for positioning and support. The screw threads on each eye lacked protective lubricant and had corroded over many years. Even after cleaning, heat had to be applied to the nuts, and hydraulic actuators had to be used to turn them a few degrees at a time. While this was being done, the rope supports between the sheaves were being put into place. Support frames were designed to stand on either side of the ropes without horizontal cross members upon which the ropes would bear until they were required. The cross members could then be installed in a short time. On the ground, beams and posts were fabricated for use in lifting the sheaves. The Engineers decided that the best method of jacking would be to support each sheave with a beam placed through the sheave between spokes ahead of the shaft and to jack against a second beam placed behind the shaft. In so doing the fixed support would become a pivot point and, with a little simultaneous movement of that pivot point, the shaft would move out at the required 45° angle. Support posts were to be set on the girder below by removing some of the lacing in the thrust member through which the post must pass. Careful measurements and calculation of loads were used in the design of these field fabricated members. W8x40# members were utilized to meet the requirements of strength, availability, and maximum envelope dimensions. Jacks of 100 ton capacity were to be used to lift the 15 ft. diameter sheaves.

Last minute preparations were accomplished Friday afternoon, June 24. All equipment to be used in the operation was lifted to the top of the tower.

Support of the counterweight and the ropes between the sheaves was not accomplished until late Saturday. As jacking was attempted on the first sheave Sunday, some unexpected deflection was experienced in the forward (span side) support through-beam. It was concluded that one aspect of the forces involved had been incompletely assessed, for as the weight of the counterweight was removed, the ropes shortened the amount they had originally stretched under load, causing sheave rotation toward the span. The deflection was determined to be of minor consequence in this case since no further loading in the direction of deflection would occur during jacking in this instance, and adequate safety factors had been incorporated into the design. Some time was lost in making this determination, however.

Once the preliminary work was accomplished, the actual replacement of the bushings took a short time, and was done successfully. The second sheave was lifted and its bushing replaced on Monday, June 27, using the same procedure. Bearings were rotated out of the bases using small hydraulic rams to push one end and "come-alongs" to pull the other end. The new bushings were more easily installed in the same manner.

Amtrak is to be commended for their well-planned response to the problem. They were able to successfully detour trains over other routes when required, with a minimum of inconvenience, and were able to assemble a cooperative team of experts to repair the problem in a minimum of time.

One purpose of this paper, however, is to emphasise the prevention of such a problem. With today's available technology, immediate confirmation of subtle changes observed, or even indications of problems which cannot be detected by our five senses, can be obtained.

State-of-the-art electrical systems used on new or retrofitted movable bridges today include programmable logic controllers (PLC's) for simplified operation with precise automatic control. In addition to control, however, a PLC allows the bridge to be provided with an automatic Data Acquisition System (DAS). A DAS can record each operation of the bridge, indicating date and time, including the operating sequence and any unusual characteristics within the system, for immediate and future reference. Unusual operating characteristics noted by the DAS can trigger warning statements displayed to the operator on a screen at the console, and can be recorded on an automatic print-out as well. If desired, the DAS can send this print-out automatically to a remote location for analysis by a supervisor. A DAS can warn of increased power being used, unequal torque requirements between portions of the mechanical operating system, over-speed, and unbalanced conditions on the movable span. Locations of trouble can be pinpointed in both the mechanical and electrical systems, and programmed automatic responses to unsafe conditions can be incorporated. If a DAS had been installed on the Amtrak bridge, the trouble should have been detected before seizure occurred.

When emergency situations occur, they should be used as opportunities to contemplate improving preventative measures. Taking advantage of current technology is certainly a good option to consider.

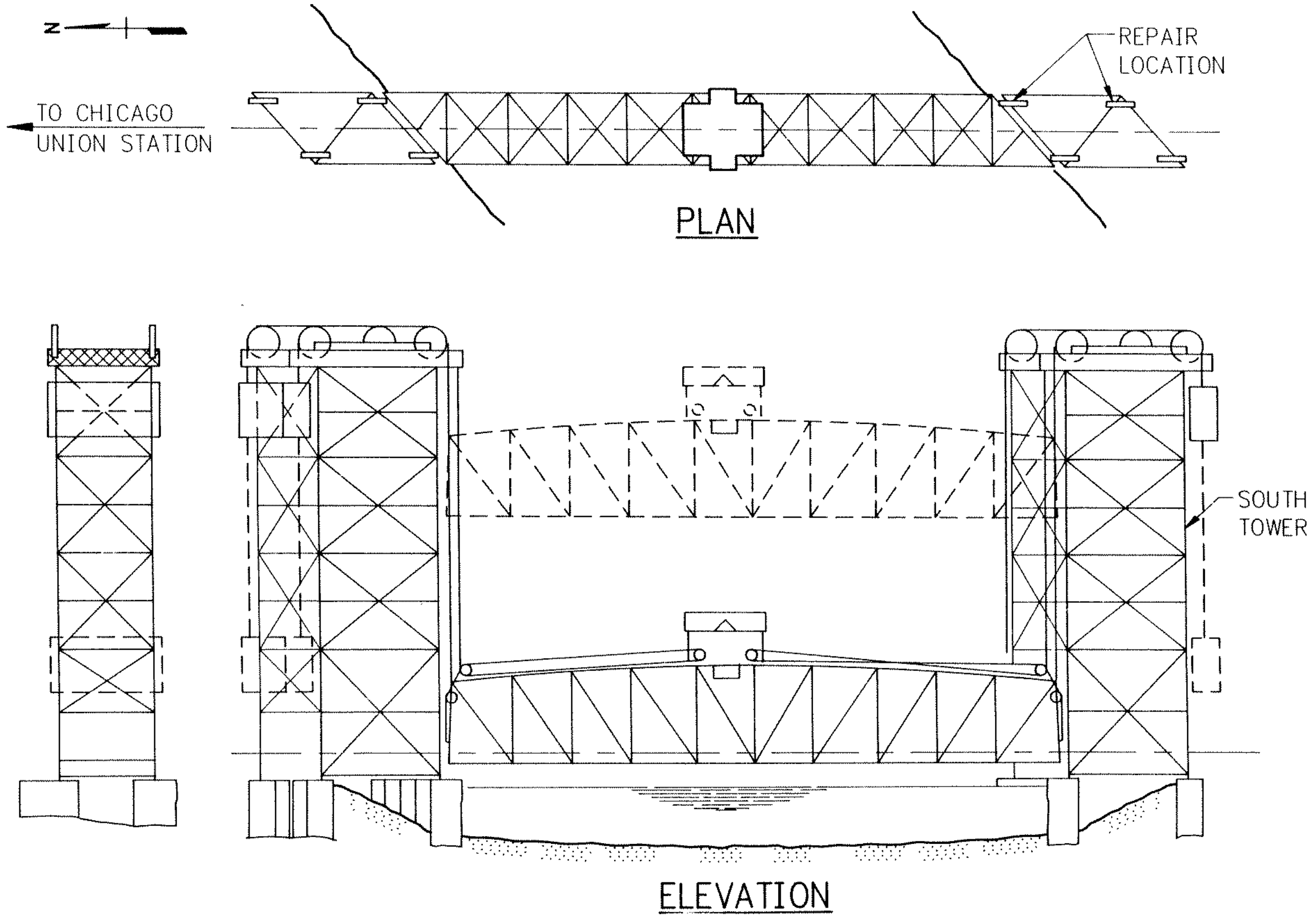

FIGURE 1 – AMTRAK VERTICAL LIFT BRIDGE ARRANGEMENT

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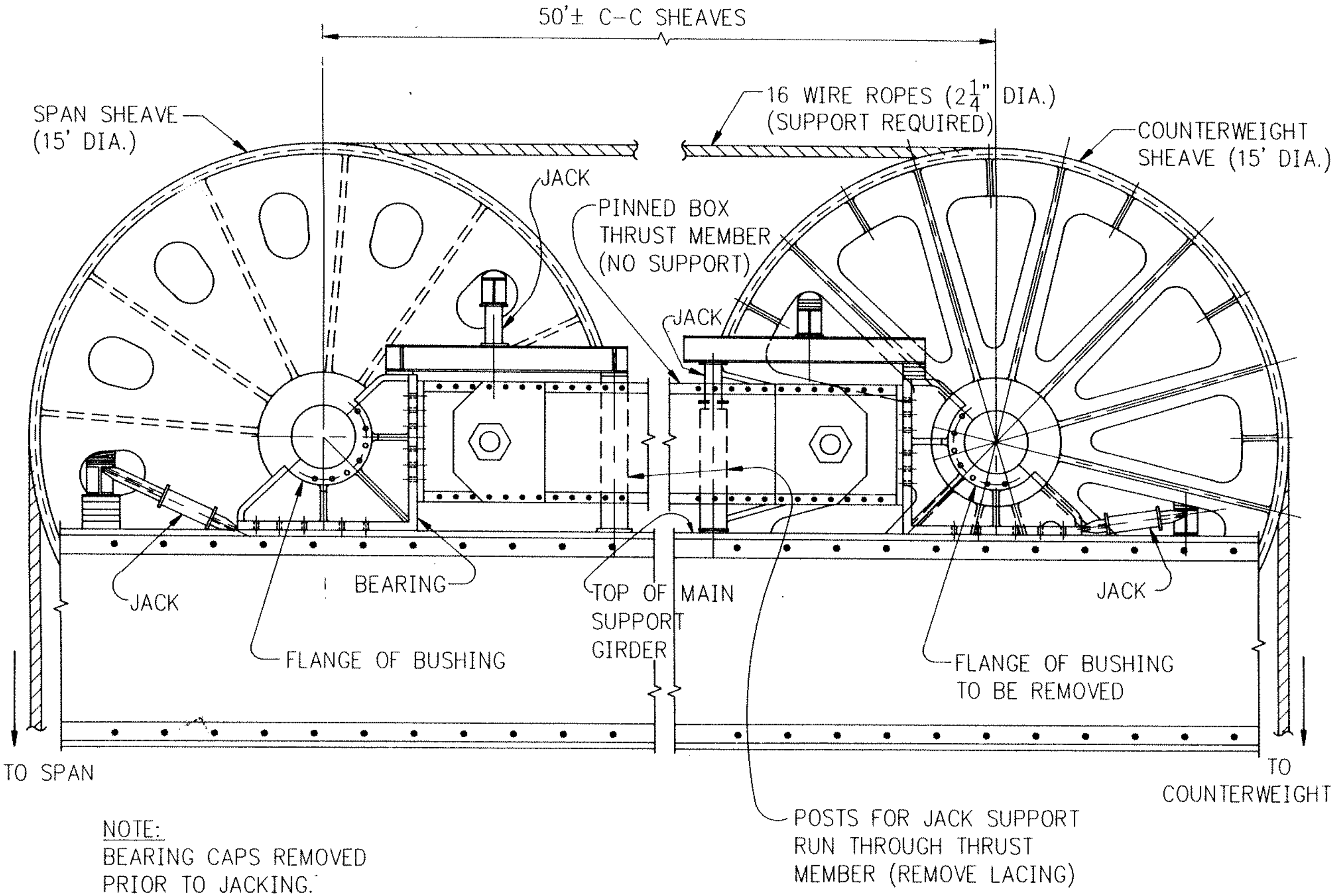

NOTE:
BEARING CAPS REMOVED
PRIOR TO JACKING.

FIGURE 2 – JACKING ARRANGEMENT

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