**Heavy Movable Structures, Inc.**

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# *Emergency Repair of a 7 Million Pound Swing Span (I-Street Bridge Center Bearing Repairs)*

by


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and
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# Emergency Repair of a 7 Million Pound Swing Span

(I-Street Bridge Center Bearing Repairs)

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LOCATION: I-STREET BRIDGE - SACRAMENTO, CA

OWNER: SOUTHERN PACIFIC LINES

## INTRODUCTION:

The I-Street Bridge is located in Sacramento, CA and crosses the Sacramento River (see Photo 1). This double-deck bridge has a double-track railway on the lower deck and a two-lane roadway with two sidewalks on the upper deck. The movable portion of the bridge is a 390'-3" long center bearing swing span weighing approximately 7 million pounds. Original construction was completed in 1911.

Otis Hovey discusses various aspects of this swing span (referred to as the "Sacramento River Bridge") in several locations in his classic "Movable Bridges - Volumes One and Two". One such commentary of particular interest follows:

> Hovey reports that up to the time of printing (1926), "The heaviest swing bridge in the United States is the double-track, double-deck, center-bearing span of the Southern Pacific Company across the Sacramento River, at Sacramento, California. ......... An attempt was first made to design a rim-bearing turntable to carry this great weight, but the available vertical distance of 8 ft. 4 3/4 in., from base of rail to masonry at the center pier was so small that no method of designing a satisfactory distributing system and drum was found." vol 1 p. 40 [1]

To this date, the I-Street Bridge remains one of the heaviest, (if not the heaviest), center-bearing swing spans in the United States. The limited vertical distance between top of rail and top of masonry was accommodated by design of a center bearing that is set mostly below the top of pier. The masonry encases the lower pivot casting, three piece spherical disk set, and the oil box (see Figure 1).

## TURNING DIFFICULTIES ENCOUNTERED:

On Sunday, June 2, 1996 at 2:15 PM, the I-Street Bridge was opened to pass a boat. The bridge operator noticed a loud grinding and popping noise throughout the opening process. While closing the bridge, the noise was still present. The bridge stopped approximately three feet short of the final closed position and would not close completely after four attempts. The temperature that afternoon was near 105 degrees making the effect of thermal expansion significant. It was suspected that the bridge may have become hung-up on something. Upon investigation, it was noticed that on the east end of the roadway, the pedestrian sidewalk retainer plates had been binding. Grease was applied to the retainer plates to aid in closing. No other areas showed signs of binding and all machinery appeared to be in good order. Because of the noise reported by the operator throughout the opening and closing process, the oil in the center lens assembly was topped off. Lastly, the drive pinion

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[1]Hovey, O.E., "Movable Bridges - In Two Volumes," New York: John Wiley & Sons, Inc., 1926

gears and ring gear were inspected and none were found to broken or jammed with foreign debris. It was then decided to make an attempt at opening and closing the bridge. Immediately upon opening, the popping and grinding sounds were heard in the center of the bridge. Further investigation showed that the noises were indeed coming from the center lens assembly. An attempt was then made to close the bridge, but full closure was not obtained in the automatic sequence mode. The operator overrode the controls and manually brought the bridge to the closed position. The closing time was approximately 5:35 PM.

The following morning, the lower drain valve on the lens assembly was opened to verify that the lens had been receiving oil. When the valve was opened, a small amount of water and very thick, dirty oil came out. The drain was then cleaned out and ten gallons of fresh oil were back filled through the drain in an attempt to get some lubrication to the lens. With this lubrication and a cooler ambient temperature, an opening was attempted to see if the problem had been resolved. At one quarter open, the bridge was stopped as the noise persisted. The bridge was then closed and it was decided that the lens must be removed and inspected.

## PREPARATION TO REMOVE LENSES:

Returning this span back to operation as quickly as possible was very important. The longest lead item would be the phosphor bronze disk of the lens assembly should it need replacement. The original disk was detailed on the shop drawings as 52 inches in diameter and 6 inches thick at the center. The bearing stress (pressure) on the projected area is approximately 3,300 PSI. A casting of bronze ASTM B22 alloy 913 was ordered immediately and was to be delivered within two weeks. In the meantime, concrete around the center bearing assembly had to be removed, a jacking plan developed and let for bidding, and possible bearing rehab options explored.

In order to access and repair damage, concrete encasing the center bearing assembly had to be removed. It was determined that an area of 14 feet by 8 feet of concrete that was 2 feet deep (approximately 7 cubic yards after accounting for the volume of the center pivot assembly) had to be removed (see Photo 2). This would provide sufficient working space to remove the oil box and the three disk lens assembly for inspection and repair. Southern Pacific personnel began this work immediately.

Jacking of the swing span required consideration of jack location, load distribution, interfering members, and stabilization of the span during jacking. A jacking plan was established utilizing primary jacking under the three center cross girders and secondary jacking under the end floor beams. The successful bidder for jacking was Rigging International with C. H. Bull providing the jacks and operations expert. Center jacking utilized twelve jacks of: 565 ton capacity, 3.1 inch stroke, and 12 inch diameter piston rod. End jacking utilized four jacks of 300 ton capacity with two jacks at each end floorbeam. Highway end dams would interfere with jacking of the swing span and were removed. Temporary plates that could be easily removed for jacking were installed across the roadway and sidewalk breaks. To stabilize the span during jacking two weldments were fabricated and installed at the center pier for restraint in longitudinal and transverse directions (see Photo 3). Rotational guides were installed at each end of the swing span (see Photo 4).

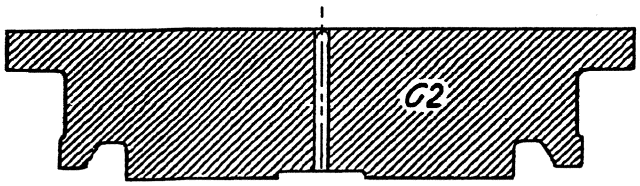
## INITIAL JACKING AND REMOVAL OF PIVOT LENS ASSEMBLY:

Jacking to remove the pivot lens assembly was scheduled for June 14, 1996. A twelve hour window was obtained, beginning at 9:15 PM. Before work began, a safety/organizational meeting was held. In order to remove the oil box, the bridge had to be raised 4-1/4 inches, however, the jacks only had a three inch stroke. The bridge was jacked 1-3/4 inches, set down on shims, and the jacks were reset. Throughout jacking, height was closely monitored at several locations, and by 10:50 PM the bridge was raised 4-1/4 inches and set on supporting shims.

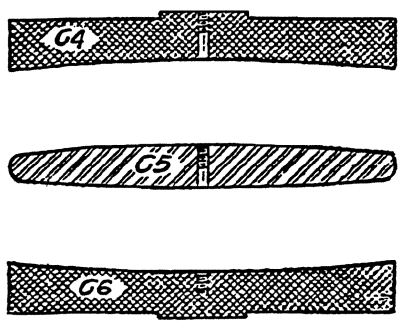
Removal of the oil box revealed the highly contaminated condition of the pivot lens assembly (see Photo 5). Inspection of the oil box halves (each weighing approximately 3,400 pounds) showed that the top disk of the lens assembly was in hard contact with the inside wall of the oil box.

The lens assembly was then removed. The top and bottom steel disks each weigh approximately 4,140 pounds and the center bronze disk weighs approximately 2,630 pounds making the three lens assembly weight almost 11,000 pounds. A steel slide rail assembly had been fabricated ahead of time to aid in removal and installation of the lens assembly (see Photo 6). It could be seen that the bottom steel disk was rotating on the base pivot casting producing distortion of the counterbore and boss as well as heavy scoring and galling. Temporary shim plates were stacked in the center pivot cavity in a criss-cross fashion to a height of 17-1/4 inches. The oil box was reinstalled around the new shim stack and the jacking procedure reversed. By 3:15 AM the bridge was ready to run rail and vehicular traffic.

## EVALUATING CONDITION OF THE PIVOT LENS ASSEMBLY:



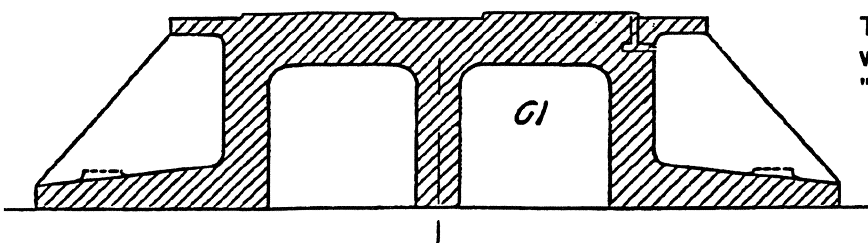

Top pivot casting, C2, surfaces were all in "mint" condition.




The top steel lens, C4, was in generally good condition with nc defects to the top, but the convex surface had light galling anc the central circular half of the contact surface was dry.

The center bronze lens, C5, had scoring on both surfaces with bronze particles and hardened lubricant in the oil grooves. After cleaning, deep scoring was evident in the center portion and a band of discolored bronze was revealed towards the oul half of the wear surface (see Photo 7).

The bottom steel lens, C6, was galled on the top surface with bronze "burn" marks. The bottom was deeply galled to 1/4 inc deep and the centering boss was worn on the edges.




The top surface of the lower pivot casting, C1, was deeply galled and the counterbore or "inkwell" was worn and distorted.

There was concern that the steel lenses were case hardened, and if the concave wear surfaces were remachined, the hardness spread between the mating surfaces would be insufficient. Initial machining of the steel lenses did not indicate surface hardening. Hardness testing was performed on the bronze and steel lenses. Bronze surface hardness was 212 BHN and the steel lenses averaged 242 BHN. This difference in hardness, although relatively low was determined to be adequate.

The center bronze disk had some deep scoring and areas of moderate porosity from the original casting process. However, it was determined that the existing piece could be remachined and reused. This would help in getting the bridge back in service according to the June 30th deadline established by the Coast Guard, but presented the problem of how to make-up the loss in height due to machining.

## REHABILITATION DESIGN:

Two significant problems had to be addressed in redesign of the center pivot assembly. First, as previously mentioned, there would be losses in the height of the assembly due to material removal required to clean-up all three disks. Secondly, the fit between the lower steel disk boss and the lower pivot casting counterbore had been destroyed. The boss/counterbore fit is what locates and holds the lower disk captive.

A plan was developed to install a new shim between the lower steel disk and the lower pivot casting. This shim would address both the assembly height problem and provide a new counterbore for centering the assembly (see Figure 2). The new shim thickness would be a minimum of 1/2 inch, but the final thickness would be held until final machining of the other components was complete. The new shim would be fixed to the lower pivot casting with snug fit dowels that were field drilled. The boss on the existing lower steel lens would be machined to the first clean diameter. The new shim plate would have a locating hole to accommodate the new boss. Also included in the new design were four "edge" dowels that would aid in keeping the lower steel disk in place and restrict rotation.

The spherical radii of the existing lenses were obtained from shop drawings. The radii of the steel disks were both 15' 3" and the radii of the bronze surfaces were 15' 0". In order to improve the load distribution by increasing the load area, radii of the steel disks were changed to 15' 2".

## MACHINING AND PREPARATION FOR REINSTALLATION:

Stewart Tool Company, Inc. located in Rancho Cordova, CA was selected to perform the required machining. They had the capacity and sophisticated equipment required to produce the spherical surfaces on the 52 inch diameter lenses. Two cutting passes were made on each surface of the bronze to clean-up the surfaces. In order to keep as much of the bronze material as possible, some surface imperfections were left "as-is". The oil grooves were recut to obtain the original 3/8 inch depth, all edges were given generous radii, and the wear surfaces were polished to a mirror finish. The upper and lower steel disks had their outer edges rounded to a 1/2 inch radius and their wear surfaces polished to a mirror finish. The lower steel disk also had its bottom resurfaced to remove the scoring, the boss was refinished, and four slots were machined on the outside diameter for the "edge dowels" (see Photo 8).

Final Thicknesses of Lenses:

| | | |
|---|---|---|
| Top Steel Lens | 5.405" | at center |
| Center Bronze Lens | 5.850" | at center |
| Bottom Steel Lens | 5.370" | at center |
| TOTAL THICKNESS | 16.625" | at center |

The new shim plate was machined to 1/2 inch thick yielding a total assembly height of 17-1/8 inches. Undersized holes were drilled in the new shim plate for the center and edge dowels.

Drill bits, reamers, dowels and special low clearance mag drills were obtained and prepared by Stewart Tool Co., Inc. for field drilling, reaming and installation of the dowels into the lower pivot casting. The three lenses were solvent cleaned, pre-lubricated, and shrink-wrapped. Four short angle pieces were tack-welded to the circumference of the assembly for transit and installation (see Photo 9).

## INSTALLATION OF THE REFURBISHED PIVOT LENS ASSEMBLY:

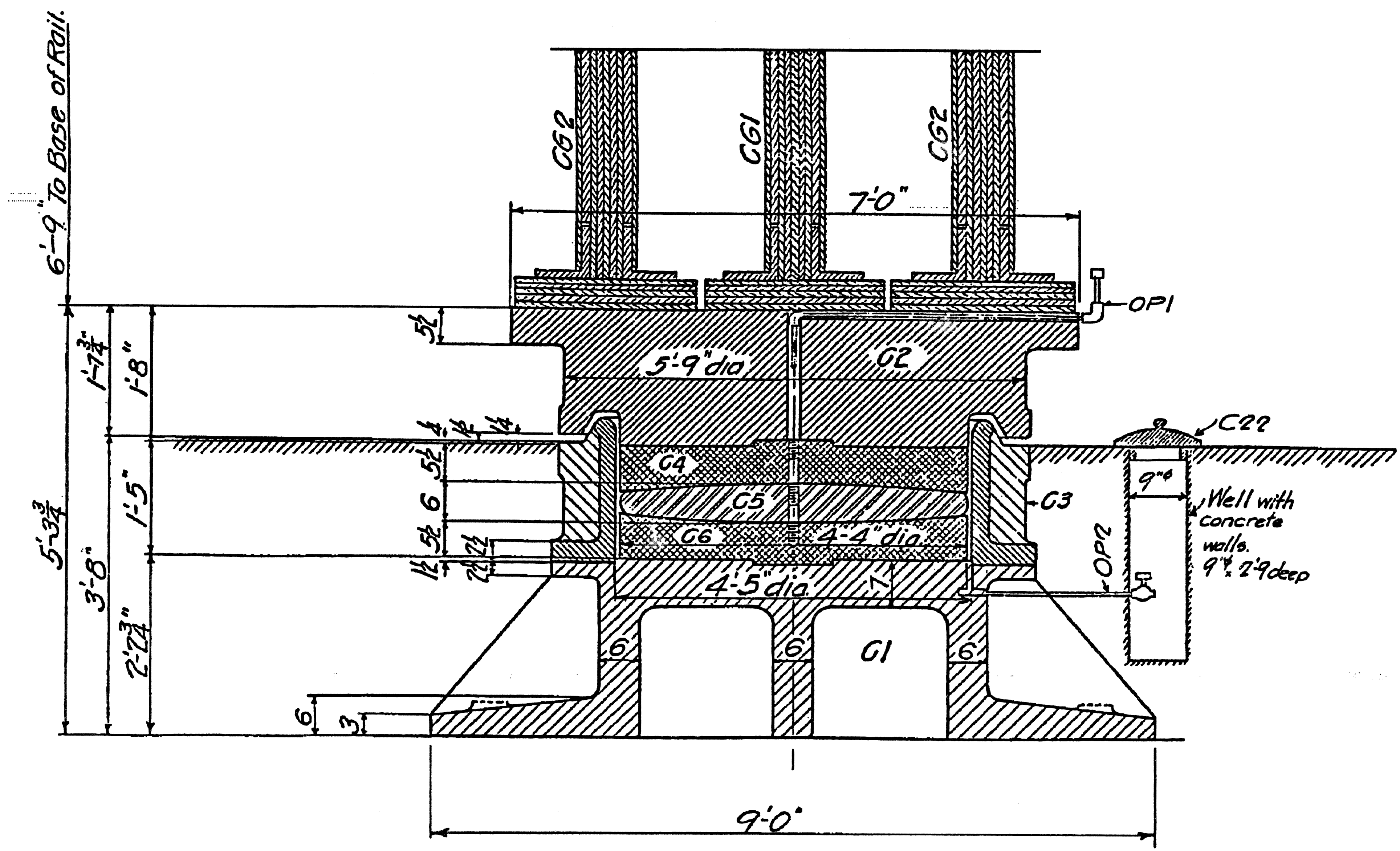
All machining to the three piece lens assembly was finished on June 26, 1996 and the assembly was delivered to the bridge at 2 PM. A 12 hour work window starting at 8 PM that evening had been established ahead of time. The swing span was raised 4.25 inches using the jacking procedure previously detailed. The oil box was removed and the temporary shim stack removed from the center bearing cavity. The lower pivot casting was cleaned and high spots removed by hand grinding. The new shim plate was then centered on the base pivot casting and the dowel holes were drilled and reamed. The shim plate was removed, burrs from drilling were ground smooth, the area was thoroughly cleaned, and the shim plate was doweled in place using the center dowels only (see Photo 10). All eight center dowels obtained a very nice light driving fit.

Installation of the three-piece lens assembly (weighing nearly 11,000 pounds) was accomplished using teflon strips to slide on to prevent damaging the machined surfaces. The assembly was then positioned for installation of the edge dowels. The edge dowels were installed and the assembly lowered onto the bottom pivot casting. Strap angles that had been tack welded onto the outside diameters of the steel lenses were ground off and the top steel lens was jacked up to seat in the upper pivot casting (see Photo 11). The area was thoroughly cleaned and gasket sealant was applied to the oil box to prevent oil leakage (see Photo 12). The oil box was filled wtih fresh oil.

Lowering of the span was performed as detailed previously with the exception that the transverse and longitudinal guides were cut away when the span was within 1/4 inch of seating on the new lens assembly. This allowed the lens assembly to "self-center". After checking wedges, centering latches, and conley joints, the bridge was ready to run rail traffic by 7 AM.

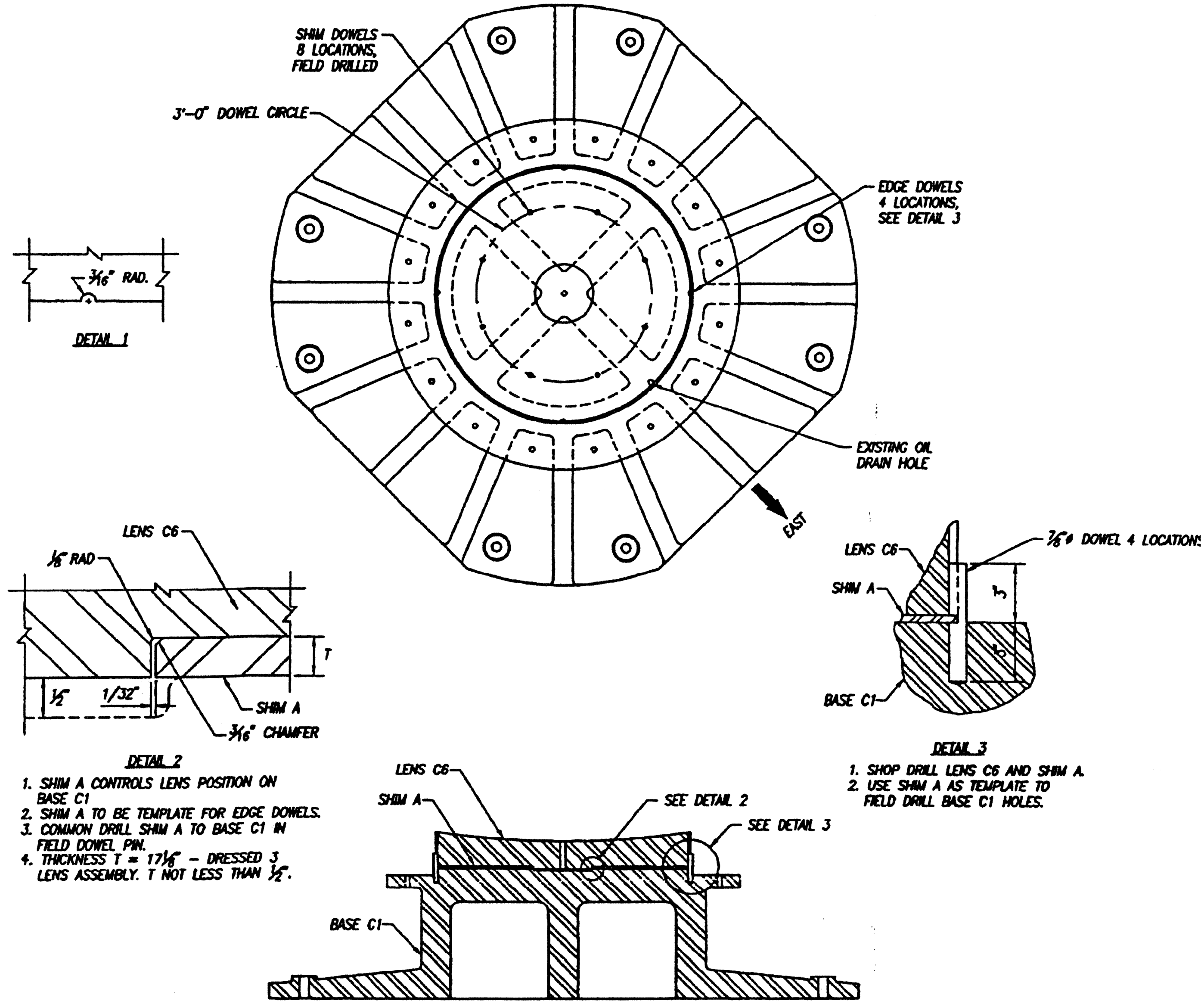
## TURNING THE SPAN:

In preparation to begin turning the span, all four rack/pinion meshes were checked and the oil level in the center bearing was verified. On June 28, 1996 the span was operated. Initial openings were in small increments as the rack/pinion meshes were closely monitored. Several normal opening and closing cycles were then performed without any problems. Noises from the center bearing assembly were completely eliminated.




SECTION OF CENTER.

Figure 1



SHIM DOWELS 8 LOCATIONS, FIELD DRILLED
3'-0" DOWEL CIRCLE
EDGE DOWELS 4 LOCATIONS, SEE DETAIL 3
EXISTING OIL DRAIN HOLE
EAST
3/16" RAD.
DETAIL 1
LENS C6
1/8" RAD
T
1/2"
1/32"
SHIM A
3/16" CHAMFER
DETAIL 2
1. SHIM A CONTROLS LENS POSITION ON BASE C1
2. SHIM A TO BE TEMPLATE FOR EDGE DOWELS.
3. COMMON DRILL SHIM A TO BASE C1 IN FIELD DOWEL PIN.
4. THICKNESS T = 17 1/8" - DRESSED 3 LENS ASSEMBLY. T NOT LESS THAN 1/2".
LENS C6
7/8"⌀ DOWEL 4 LOCATIONS
SHIM A
BASE C1
DETAIL 3
1. SHOP DRILL LENS C6 AND SHIM A.
2. USE SHIM A AS TEMPLATE TO FIELD DRILL BASE C1 HOLES.
LENS C6
SHIM A
SEE DETAIL 2
SEE DETAIL 3
BASE C1


Figure 2

**Photo 1 - I-Street Bridge of Sacramento, CA.**

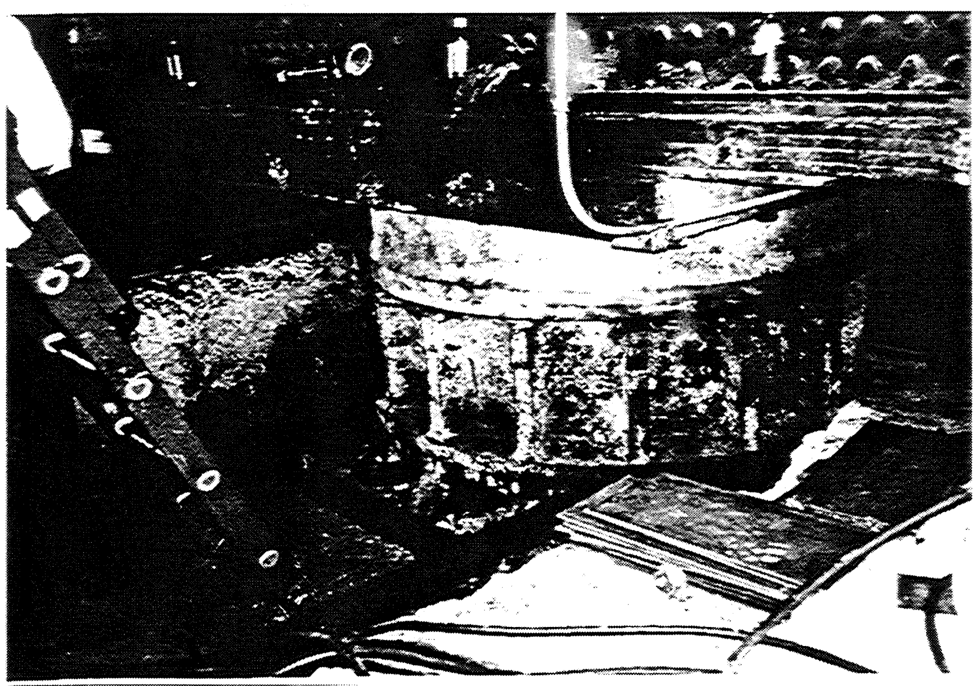


**Photo 2 - Area of concrete that had to be removed to access the center pivot assembly.**

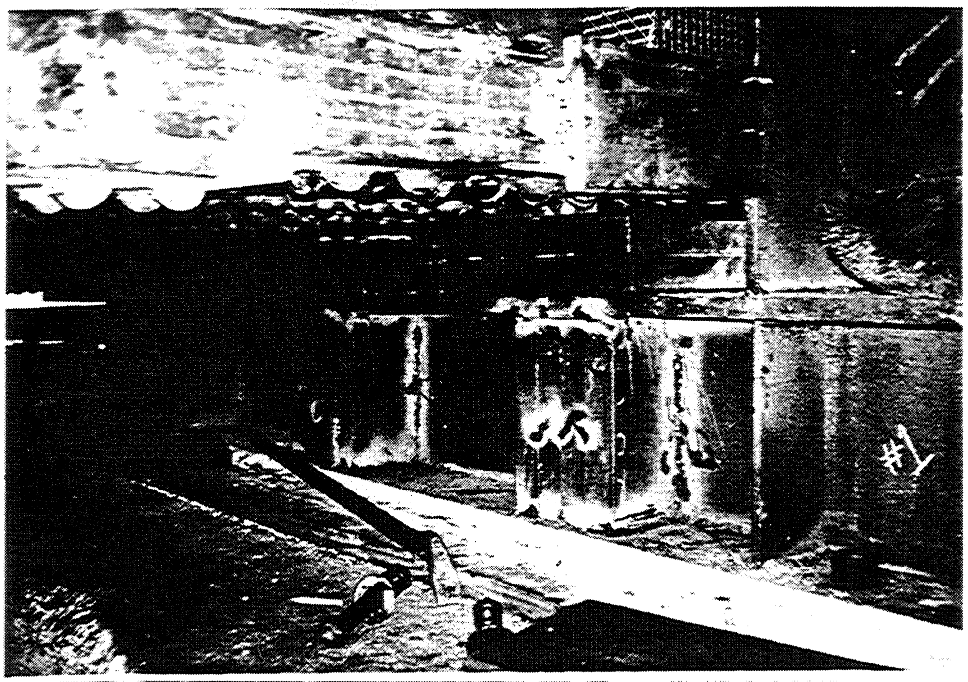


**Photo 3 - Temporary longitudinal and transverse restraints at center pier to stabilize and support swing span during jacking operation.**

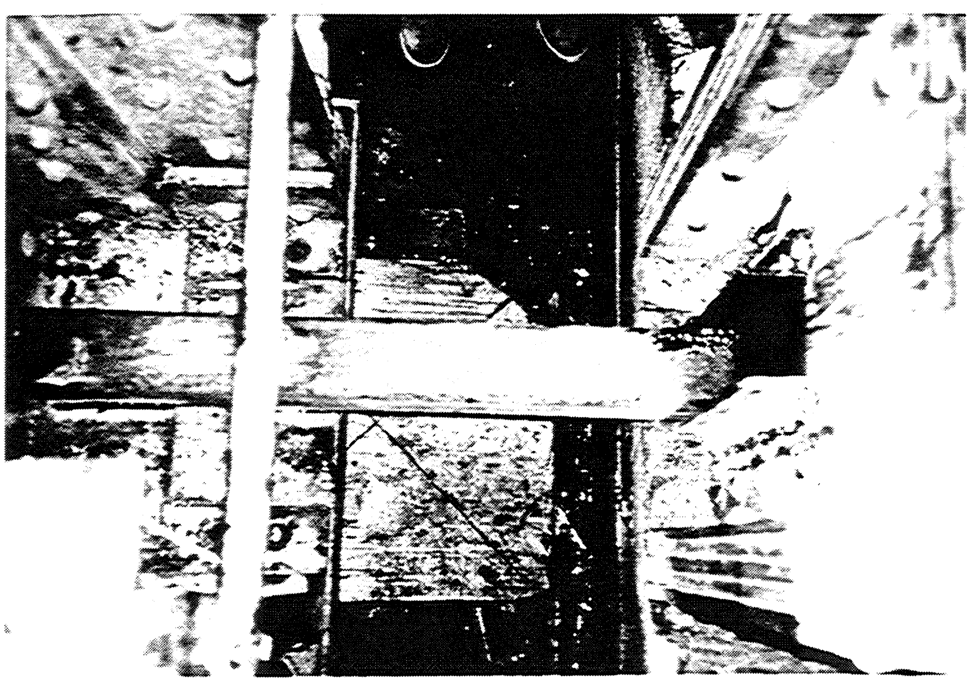


**Photo 4 - Rotational restraints at each end of swing span.**

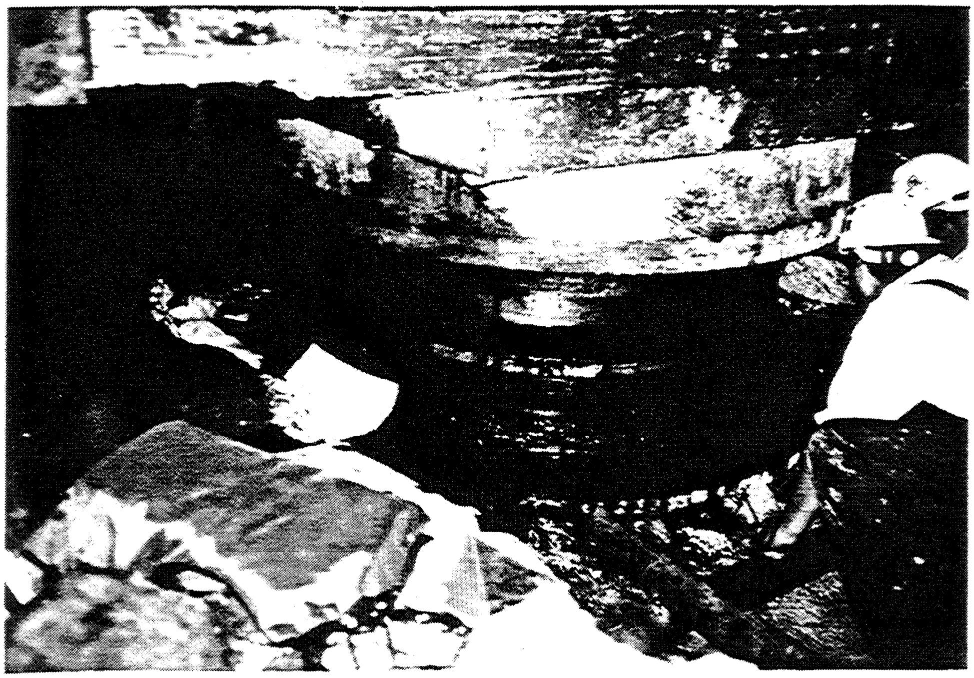


**Photo 5 - Half of oil box removed. Note the high level of contamination found inside. Also note that the top steel lens was "stuck" to the upper pivot casting.**

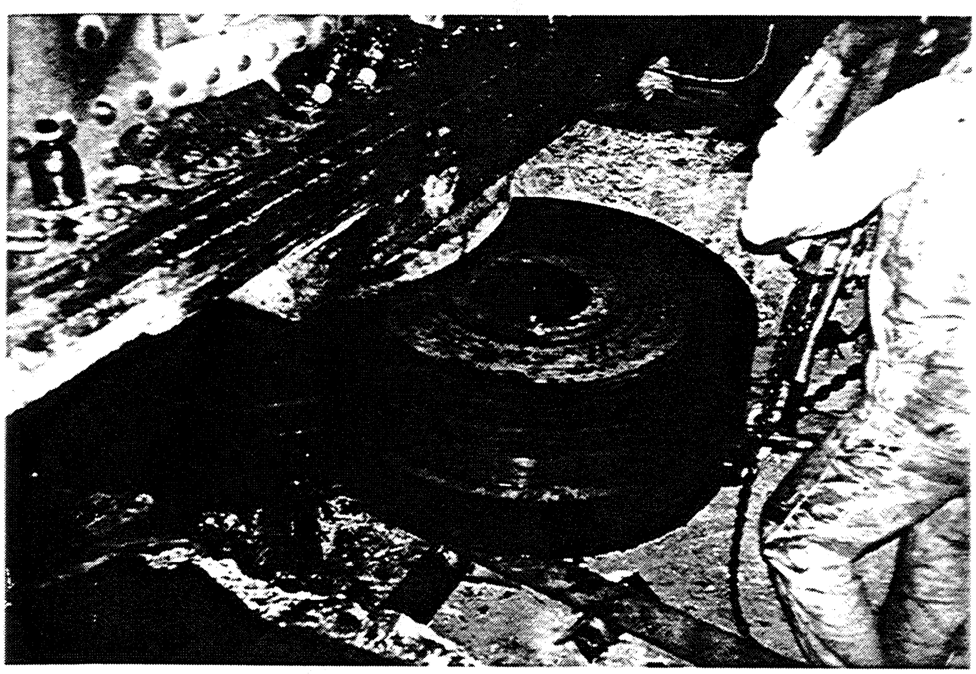


**Photo 6 - Removal of the pivot lens assembly. The top steel lens boss and top surface were in "mint" condition. Note the steel slide rail assembly for removal and installation of lens assembly.**

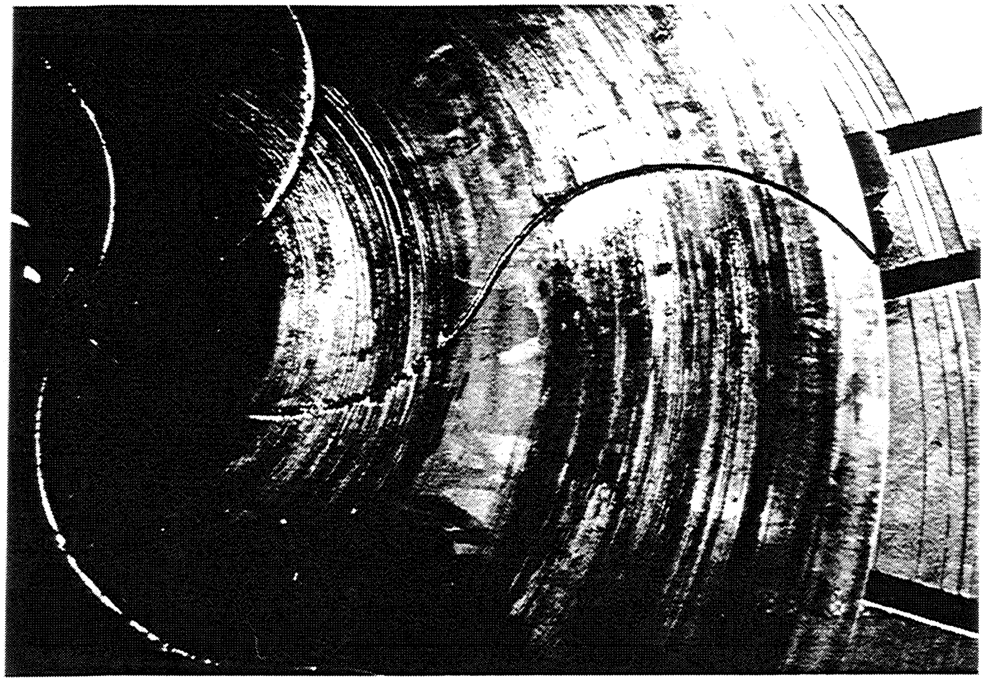


**Photo 7 - Top surface of bronze disk after cleaning.**

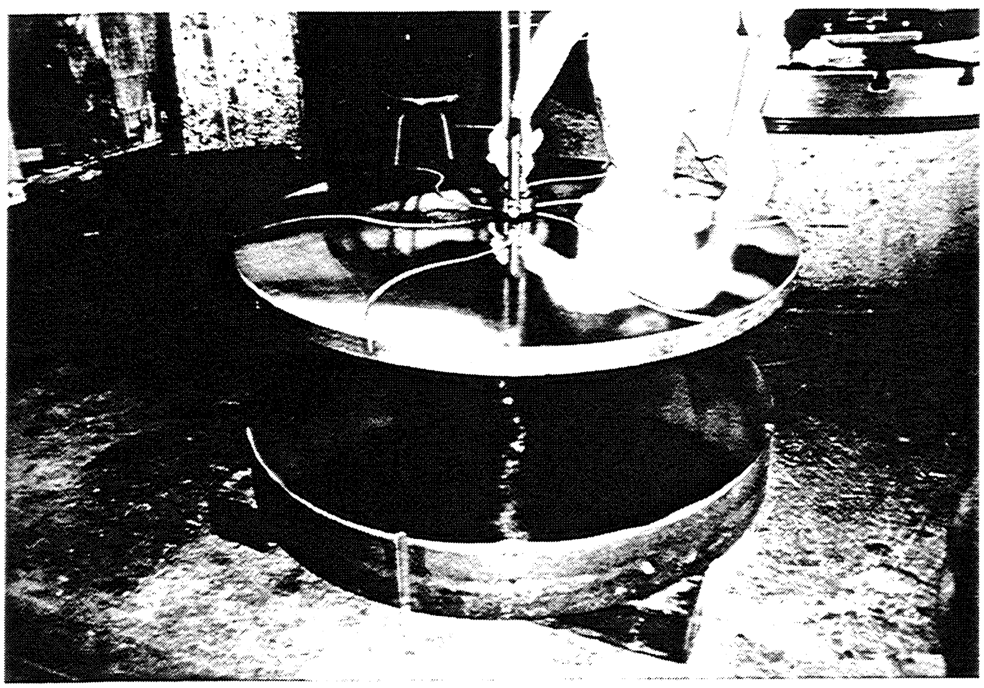


**Photo 8 - Bronze disk and bottom steel disk after remachining.**

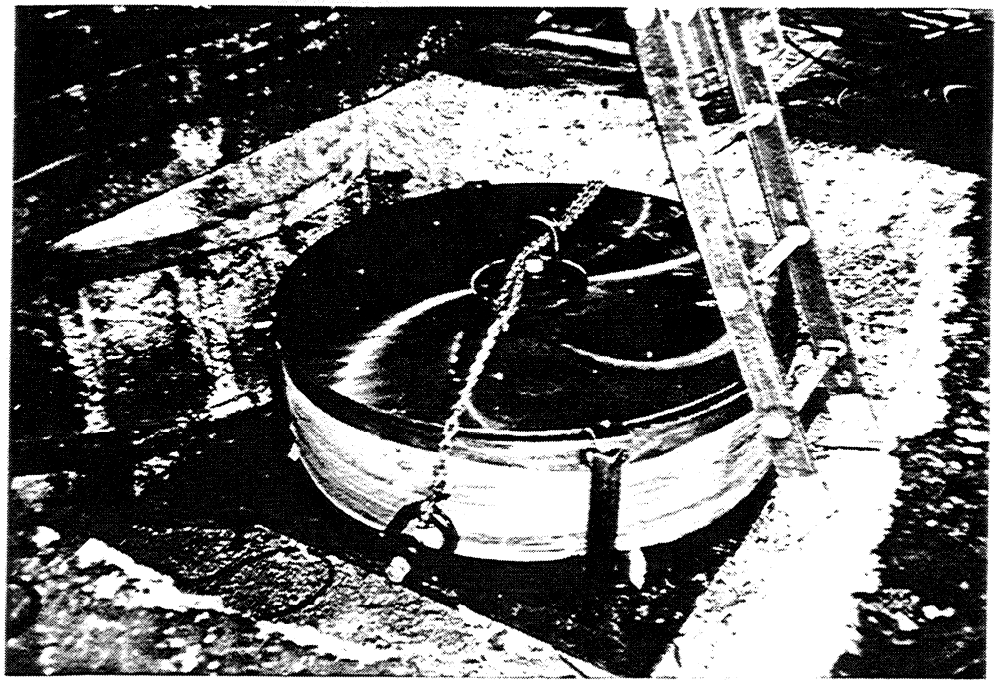


**Photo 9** - Three-piece lens assembly is shrink-wrapped and has angle tabs tack welded at four locations on the circumferance. The new shim plate rests on top.

**Photo 10** - The new 1/2" thick shim plate doweled to the lower pivot casting.

**Photo 11 - Top steel lens being seated in the upper pivot casting.**

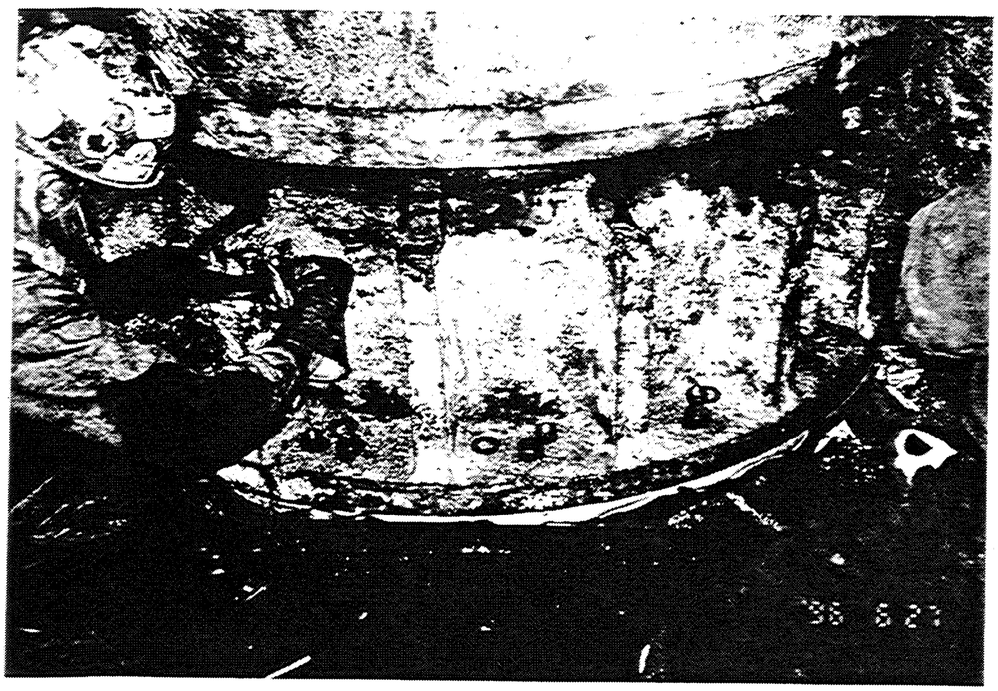


**Photo 12 - Oil box in place.**