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WORKSHOP NOTES

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"Repair of Counterweight Trunnion Bearing"

THAMES RIVER BRIDGE
COUNTERWEIGHT TRUNNION REPAIR

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I have been given the opportunity today to discuss the partial rehabilitation of two very large counterweight trunnion bearings on a Scherzer Heel Trunnion Bascule Span. The movable bridge is owned by The National Railroad Passenger Corporation (AMTRAK) and carries both passenger and freight trains over the Thames River. The west end of the bridge is in New London, CT and the east end is in Groton, CT. The bridge was built by the American Bridge Company and construction was completed in 1917. The movable span is approximately 180 ft. long with a clear channel width of 150 ft.

In early June of 1990, shortly after I began working for Amtrak, I was asked to investigate "loud noises" which appeared to be coming from the counterweight trunnions, at the Thames River movable bridge, during operation. I will discuss the investigation and all of the work which followed in order to rehabilitate the counterweight trunnion bearings. All aspects of this project will be covered including:

1. the initial inspection/investigation.
2. preparation of design and specifications.
3. finding contractors capable of meeting the demands of the job and the bid process.
4. shop testing of the machining method and procedure verification.
5. the actual field work.

During the time which I am discussing this project I will be showing overhead transparencies (figures 1-10 at the end of this text) to better demonstrate the nature of the work which was accomplished. At the end of my presentation I will show color slides which were taken during the field work portion of this project.

In June of 1990 shortly after starting work for Amtrak I was asked to travel to Amtrak's Thames River bridge to investigate loud noises which were apparently emanating from the counterweight trunnion bearing on the south side of the movable span. A partial elevation and partial plan view of the bridge can be seen in Figure 1 at the end of the text. The machinery which powers the movable span is located above the railroad between and just below the two counterweight trunnion bearings. The operating struts are pin connected at the lower counterweight link pin and are pulled back towards the west approach span by the rack pinions; one on each side of the operating machinery. This causes the lift span to rotate about the main trunnion as the counterweight rotates about the counterweight trunnion and the interior angles in the parallelogram change.

A partial view of the counterweight truss can be seen in Figure 2 at the end of the text. The relative location of the machinery house and the operating strut can be seen in this figure. The counterweight trunnion bearings are 35-1/2" in diameter and approximately 38" long. The journals are effectively a 35-1/2" diameter cylinder with a bore through the center which accommodates the 20" diameter counterweight trunnion shaft. This assembly is bolted between the two sets of laminated plates which make up a portion of the counterweight truss on each side of the movable span. When the span rotates the counterweight truss, trunnion shaft and journal were designed to rotate as a unit in the bronze bushing in the bearing base. The bearing cap is babbitt lined. The counterweight trunnion can be seen in Figure 3.

Over the years this bridge has had several owners and maintenance at times has been less than adequate. Although, since Amtrak has been responsible for maintenance of the bridge, the maintenance has been good. Unfortunately, the poor maintenance practices of the past undoubtedly led to the problems which were found with this bearing.

It was Thursday afternoon, June 7th, 1990, when I arrived at the bridge and began the investigation. Due to the design of the bearing, access for inspection is very limited. Two partial openings were made while I was standing adjacent to the south counterweight trunnion bearing. Extremely loud noises emanated from this bearing and the entire movable span shuddered with each noise. A crack was observed at the top of the lomus nut which is used to secure the axial position of the counterweight trunnion shaft. The laminated plates had moved away from the side of the journal cylinder. Some of the bolts which pass through the journal cylinder were broken and one stud (Figure 4) which had been installed during a previous repair attempt had fallen out of the hole in which it was installed. In addition to the noise, relative movement could be seen between the bearing journal and the structural steel. This could be readily viewed at the interface of the laminated plates and the journal cylinder. The inspection of this interface was made possible as a result of the missing stud.

On Friday morning shortly after my arrival at Amtrak's New London, CT. Headquarters, Amtrak's structural supervisor received a phone call from the Thames River bridge operator. The operator explained that the bridge had just been closed after an opening and that during the closing the bearing noises were louder than usual. At the point during the operation where the bridge contacts the air buffers the motor amperage went to full scale and the bridge closed with a tremendous bang. At this time the bridge was taken out of service to river traffic indefinitely, pending further investigation.

During the following days an in-depth inspection of the counterweight bearing was conducted. The following is a brief account of the inspection:

Day 1 Friday June 8, 1990

1. The drive train was inspected for obvious problems. Nothing unusual was discovered.

2. The main speed reducer was inspected visually after removing the inspection cover. No failed parts were discovered although excessive wear in the form of pitting was found on the final reduction gear. This type of wear is typically a result of an overload condition.

3. Milt Stafford, a Consulting Engineer who specializes in movable bridge machinery was contacted and arrangements were made for him to be on site Saturday morning.

4. Paul Blair, a consultant from A.G. Litchenstein was contacted and arrived at the bridge site at noon.

5. The north half of the split bearing cap for the counterweight trunnion bearing was removed. There was no significant visual damage to the journal and the grease was ample and appeared to be free of contaminants.

6. Removal of the north lomus nut on the south counterweight trunnion began.

Day 2 Saturday, June 9, 1990

1. Milt Stafford arrives at bridge at 11:30 a.m.

2. Lomus nut removal complete at 1:00 pm. It took over twelve hours continuous work to remove lomus nut.

3. A decision was made to shim between the laminated structural steel plates and the bottom of the counterweight trunnion to fill the void which existed. This void was created as a result of wear on the trunnion shaft, the laminated steel plates or a combination of wear on both parts. Figure 5 shows the area where shims were added.

4. Measurements for shims were taken and fabrication began at a local machine shop.

5. Personnel from the Electric Boat Division of General Dynamics performed U.T. tests to the counterweight trunnions and checked the top half of the journal for cracks with eddy current. No defects were found.

Sunday, June 10, 1990

1. Installed shim. The shim was fit by hand using blueing and hand grinding to obtain the best possible fit.

2. The U.S. Coast guard provided Amtrak with a Borescope to perform a partial inspection of the journal and bushing on both counterweight trunnions. The only available access into the bushing is through the 3/8" diameter grease grooves.

3. Some pitting and scoring was found during the inspection but

nothing was found to indicate that the bearing had failed.

4. The bearing was flushed with kerosene and new grease was applied.

Monday, June 11, 1990

1. Lomus nut reinstalled.

2. Bridge tested at 6 p.m.

3. The noise at the bearing during operation was considerably less, however bridge maintenance personnel indicated that the noise was less severe during cooler temperatures and the temperature had dropped significantly since the bridge had been out of service. Therefore, we could not be sure if the addition of the shim had been a help or if the noise reduction was due to the temperature drop.

4. After discussing the situation with the U.S. Coast Guard it was decided that the bridge would be left on a limited opening schedule of 4 openings per day until further repairs could be made. The normal opening frequency for this bridge during the summer months is 10-12 openings per day.

During the period of June 13-July 11, 1990 alternative repair procedures were investigated and a position paper was presented to Amtrak's upper management for a final decision. One alternative was to design and install new bearings. Due to a U.S. naval submarine base located up river no extended construction outages could be obtained and therefore a temporary system to operate the movable span would be required during construction. The estimated cost to replace the bearings and provide a temporary operating system was $8.6 million. The second alternative presented was to remove the existing 2-1/4" bolts, enlarge the bolt holes, and install 3" diameter high strength bolts as a temporary repair so that additional alternatives could be investigated. The estimated cost of installing the new bolts in both trunnions was $300,000.00.

The recommendation was to replace the existing 2-1/4" bolts with high strength bolts so that a more permanent solution could be investigated including the possibility of constructing a new vertical lift span to replace the existing span. Amtrak's management agreed with the recommendations of the position paper. A detail of the proposed bolt replacement can be seen in Figure 6.

The proposed repair procedure would require some very difficult field machining. All machining had to be done from the inboard end of the bearings due to limited access at the opposite end. The process required machining through 45" of various materials including the high strength stud, cold rolled steel bolt and cast steel bearing journal with virtually no allowable drift. The new bolts which were installed can be seen in Figure 7. The shoulders on the bolt were left approximately .010" oversize during manufacturing so that each bolt could be individually fit to the machined holes. The machined hole would be required to have a 63 microinch finish or better, and the fit at the bolt shoulders was specified as .001" interference to .002" loose (LT-4). To obtain this fit would require very accurate machining. Since access was severely limited on the outboard side of the bearing, the bolt was designed so that it could be held and tightened from the inboard end of the bearing.

After discussing the intended repairs with the Coast Guard a final agreement was reached in which Amtrak was granted two separate 92 hour outages to replace the eight bolts in each of the counterweight trunnion bearings. One outage was used to work on each of the trunnion bearings. The 92 hour periods started at 3:00 pm on Monday and ended at 11:00 am on Friday.

Now all that was needed was to find a company capable of doing this work. The special bolts were ordered prior to bidding the contract in order to expedite the project. Amtrak opted to go with the big names in field machining: General Electric, Westinghouse and Dresser Rand. Of these companies, only Dresser Rand felt that the 92 hour time limit could not be met. The other two companies, Westinghouse and General Electric, indicated that 92 hours was sufficient to complete the required work.

A specification was written which described the expected results of the field machining and bolt installation in detail. The actual method of bolt removal, hole enlargement and bolt installation would be determined by the contractor and approved by Amtrak. The contract was put out for bid with bids being due by August 24th, 1990, less than 3 months after the initial investigation. No bids were received. Discussions with each of the bidders followed and the bid date was extended. Still no bids were received.

The list of bidders was then expanded to include Reed and Reed Incorporated and Continental Field Machining. Finally, after having bid the job several times, Amtrak was able to award the contract on November 29th, 1990 to Reed and Reed Contractors for $425,000.00 or more than $26,00.00 per bolt. The only other bid ever received was from Continental Field Machining at $460,000.00.

Within the next few weeks a repair method was submitted by Reed and Reed. They had decided to use a trepanning arrangement to remove the old bolt and increase the diameter of the hole all in one operation. Trepanning is basically a method of drilling in which a self guided head with replaceable cutters is used to drill holes with very high length to diameter ratios. This method of drilling leaves a core behind. The core in this case was approximately 1-3/8" in diameter. Leaving a core reduces the amount of metal which has to be machined and therefore speeds up the drilling process.

A custom made jig was developed to perform the trepanning operation. The jig was designed so that the required precision alignment would only have to be done one time on each counterweight trunnion.

The jig consisted of two-2" thick steel plates connected parallel to each other by 4-3" diameter steel shafts and cross bracing. Each of the 2" plates was machined with a hole pattern which matched the hole pattern of the bolts in the bearing. This pattern was based on shop drawings and field verification. The final position of each hole to be machined could be adjusted using bearings mounted in eccentric housings. 1/8" and 1/4" eccentric bearing housings were made in addition to the concentric housings. These bearings supported the boring bar to which the cutter was mounted. The boring bar was powered by a 20 horsepower hydraulic motor and shaft mounted speed reducer.

A piano wire arrangement was used to align the jig to a bore which exists in the center of the counterweight trunnion. The system was set up so that the machined holes would be within .010" of parallel over the length of the bolts. It was not possible to be sure that the bolts would be parallel to the bore through the center of the trunnion. The path of drilling had to be monitored closely during actual drilling. Figure 8 and 9 show the trepanning jig and the method of alignment.

The replaceable cutter and the cutter head can be seen in Figure 10. The cutter has 3 separate cutting surfaces to reduce the chip size. Cutting fluid is forced at a rate of 70 gallons per minute through the hollow boring bar between the inside diameter of the hollow boring bar and the outside diameter of the core. The high cutting fluid velocity aids in the breaking of chips and flushes the chips out of the drilled hole around the outside diameter of the boring bar.

The extreme flow rate of cutting fluid required that a collection system be developed. This turned out to be one of the more trying aspects of this job. Since there is always the potential for leakage into the river a water soluble biodegradable cutting fluid was selected.

Although the specification did require that the contractor complete the drilling of one hole on a test basis there was no provision for shop testing in the contract. Amtrak was able to convince the contractor that a shop test was in their best interest in order to properly verify the hole quality and machining time. It was made very clear in the contract that if the first hole drilled on the bridge was not successful there would be no further drilling.

The shop testing proved to be very worthwhile. The size of the hydraulic power unit was increased from 10 to 20 HP during the shop test. Also it was found that a 63 micro inch finish could not be obtained at the anticipated cutting speed (approximately 200 rpm). This brought about a slight change in the machining procedure. It was decided that the first cut would be made to a diameter of 2.940" followed by a reaming cutter which would remove an additional .050" on diameter and produce a better finish. The reamer was followed by a hone to produce the desired 63 microinch surface finish.

After several shop tests the contractor was able to produce a hole through a piece of steel 45" long at the proper diameter and surface finish in a time which indicated that eight bolts could be machined and replaced with new bolts in the 92 hour period. The shop test was approved and the operation taken to the bridge site.

The first test hole was drilled successfully in the north counterweight trunnion March 26, 1991.

The 92 hour closure was scheduled for the following week.

Everything started out fine. We were even able to get started about 1-1/2 hours early due to poor (rainy) weather conditions keeping the mariners off of the river. With the exception of working for several days with virtually no sleep, things were progressing quite well up through the drilling of 5 holes in addition to the test hole. The most challenging aspect to this point was the containment of the cutting fluid. At 70 gallons per minute even a small opening caused a large loss of fluid. Slowly all the leaks in the bearing were contained. The seventh hole turned out to be a nightmare. The manufacturer of the cutters had sent cutters which were the wrong size. This caused the cutter head to bind in the holes and make it appear as though we were not able to cut through the steel. It was seventeen long hours before it was realized that the cutters were not the proper size. The manufacturer was notified and they agreed to rush a shipment of additional cutters. When the cutters arrived we found out that they were also the wrong size. It was already too late to make the Friday deadline. A decision was made to use the old worn cutters of the proper size and literally plow our way through the seventh hole. Fortunately the safety factor in design was sufficient to allow operation with 7 of the 8 bolts in place.

The bridge was put back in service Saturday at 3:30 pm with only seven of 8 bolts installed. This was 28-1/2 hours behind the intended schedule.

Changes would have to be made prior to starting the south side. The south side looked as though it would be more difficult due to the fact that we would have to drill through the A449 high strength studs which had been installed during a previous repair attempt. An attempt was made to remove the studs prior to the drilling operation using a hydraulic torque wrench. A torque of 11,000 ft.-lbs. was applied to the studs and still the studs could not be removed.

Both the Coast Guard and the contractor provided Amtrak with relief. The contractor agreed to provide two complete machining crews and the Coast Guard agreed to extend the scheduled outage to 120 hours. All of the cutters were individually measured prior to the outage. The outage would start at midnight Sunday and end midnight Friday. One of the problems encountered during the machining of the north side was damage to the guide bar for which the contractor had no spare. Amtrak insisted that the contractor have a spare guide bar for this next outage.

Like the previous outage, bad weather was again on our side as it allowed us to get a jump on the outage. The contractor was able to start constructing the fluid collection system late Sunday afternoon. Everything went well during this outage. The anticipated problems in drilling through the A449 high strength studs proved to be of little difficulty during actual machining. Each of the bolts was installed and tightened as intended and the additional crew allowed everyone to get sufficient rest. Everything having gone well put us ahead of schedule and the south trunnion was completed by 5:30 pm on Thursday. This was 30 1/2 hours ahead of our 120 hour scheduled outage. The bridge was put back in service and the bearing was quiet during operation.

The last hole on the north counterweight trunnion bearing was drilled on Friday and the repair was complete.

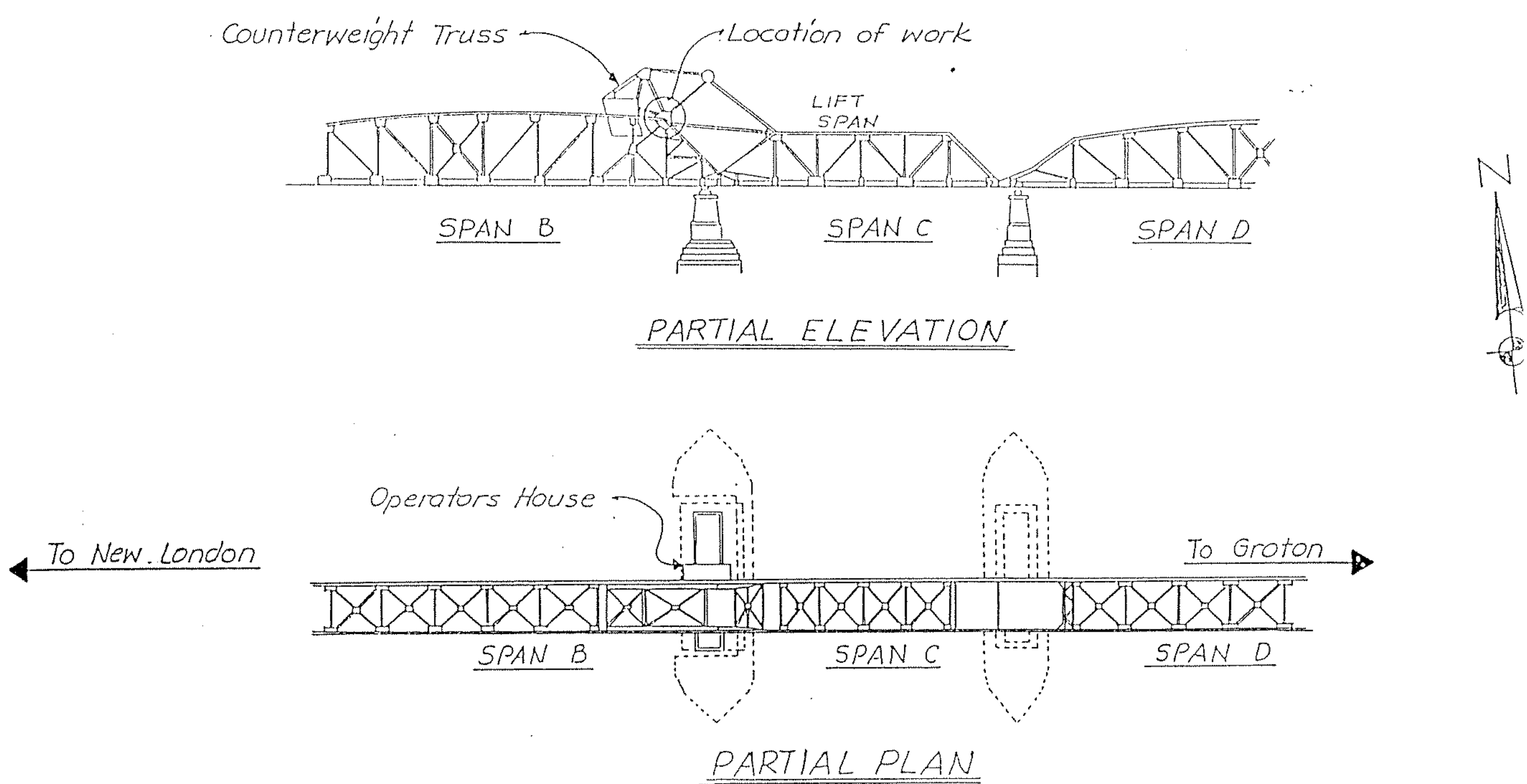

Counterweight Truss
Location of work
LIFT SPAN
SPAN B
SPAN C
SPAN D
PARTIAL ELEVATION
Operators House
To New. London
To Groton
SPAN B
SPAN C
SPAN D
PARTIAL PLAN
N

FIGURE 1

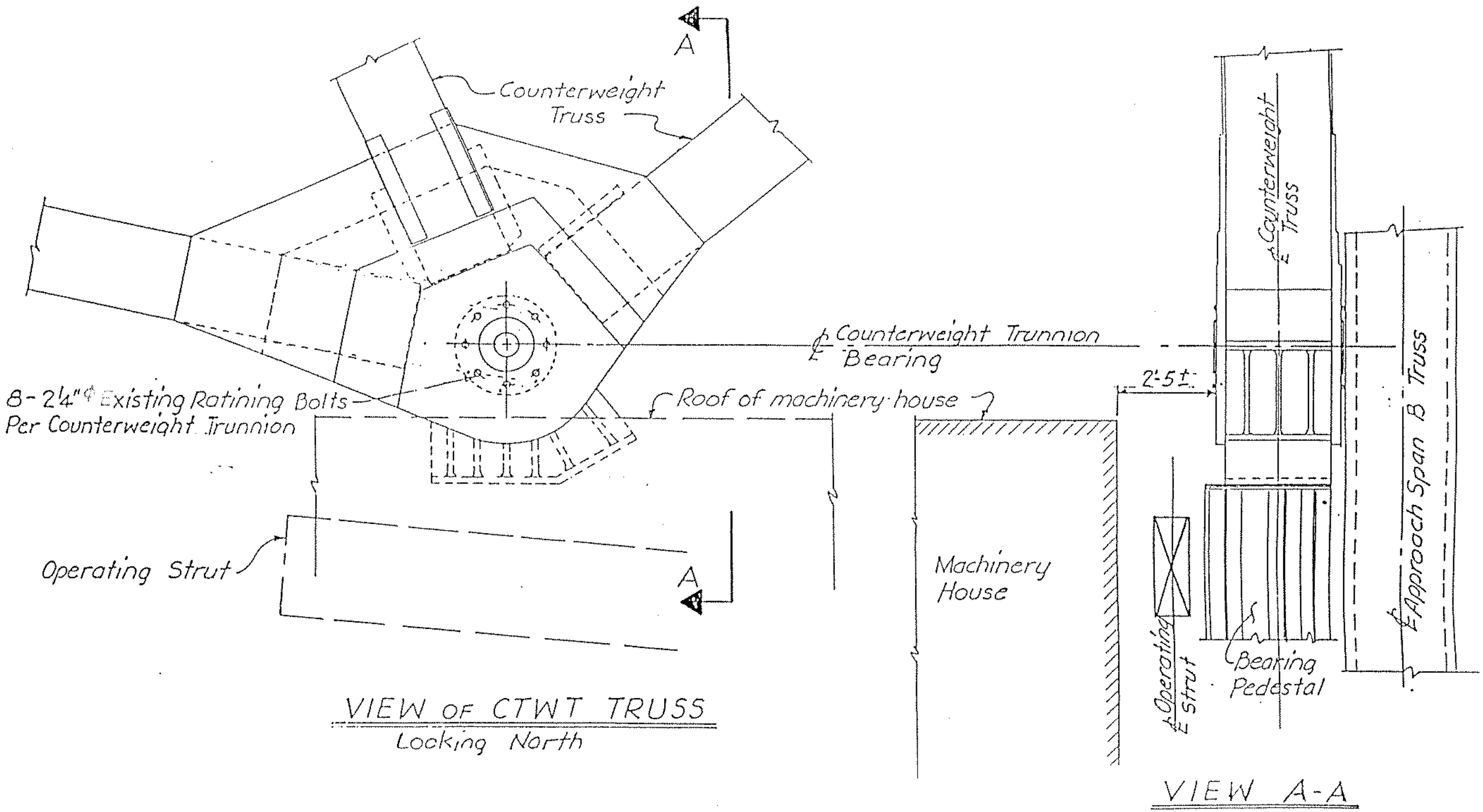
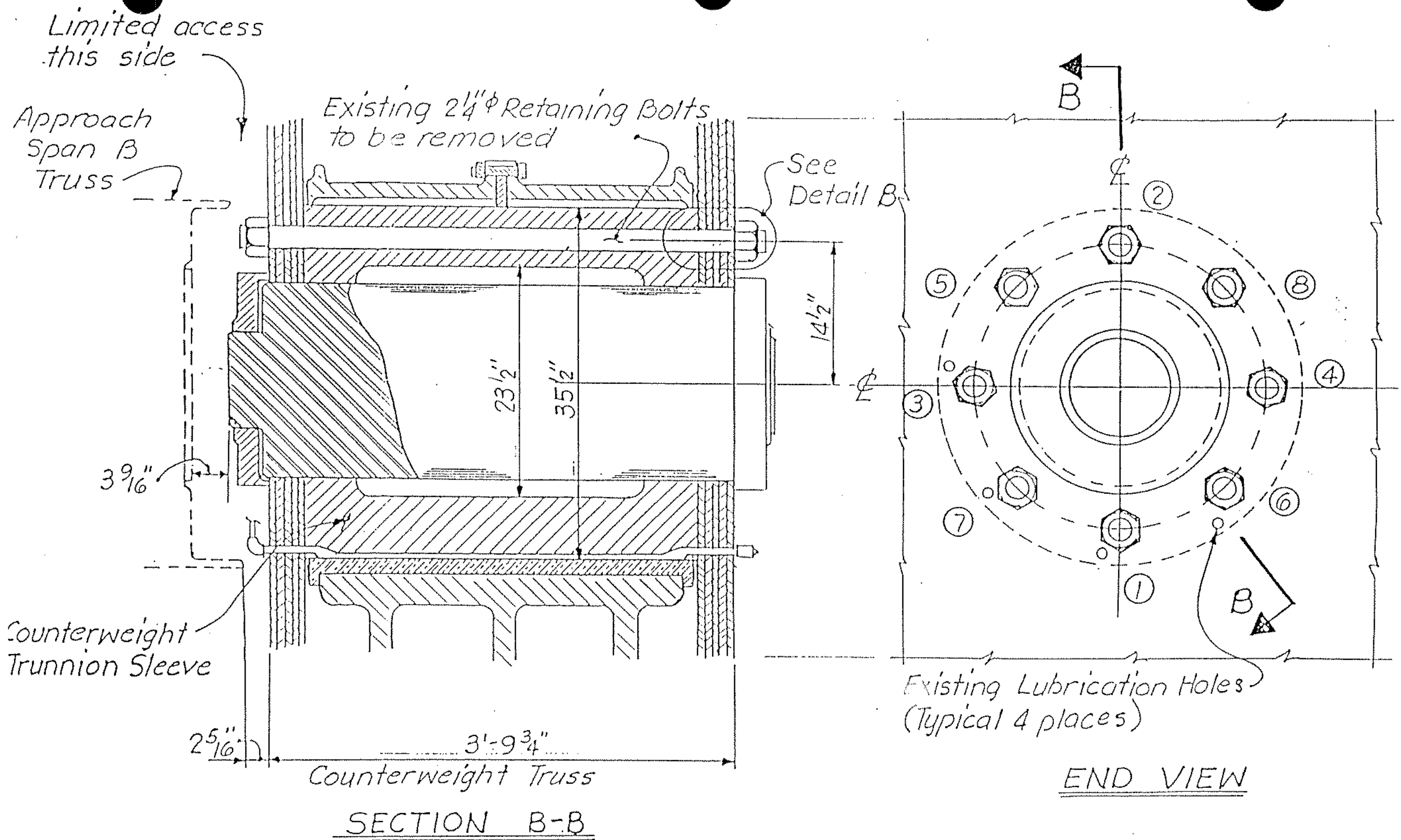
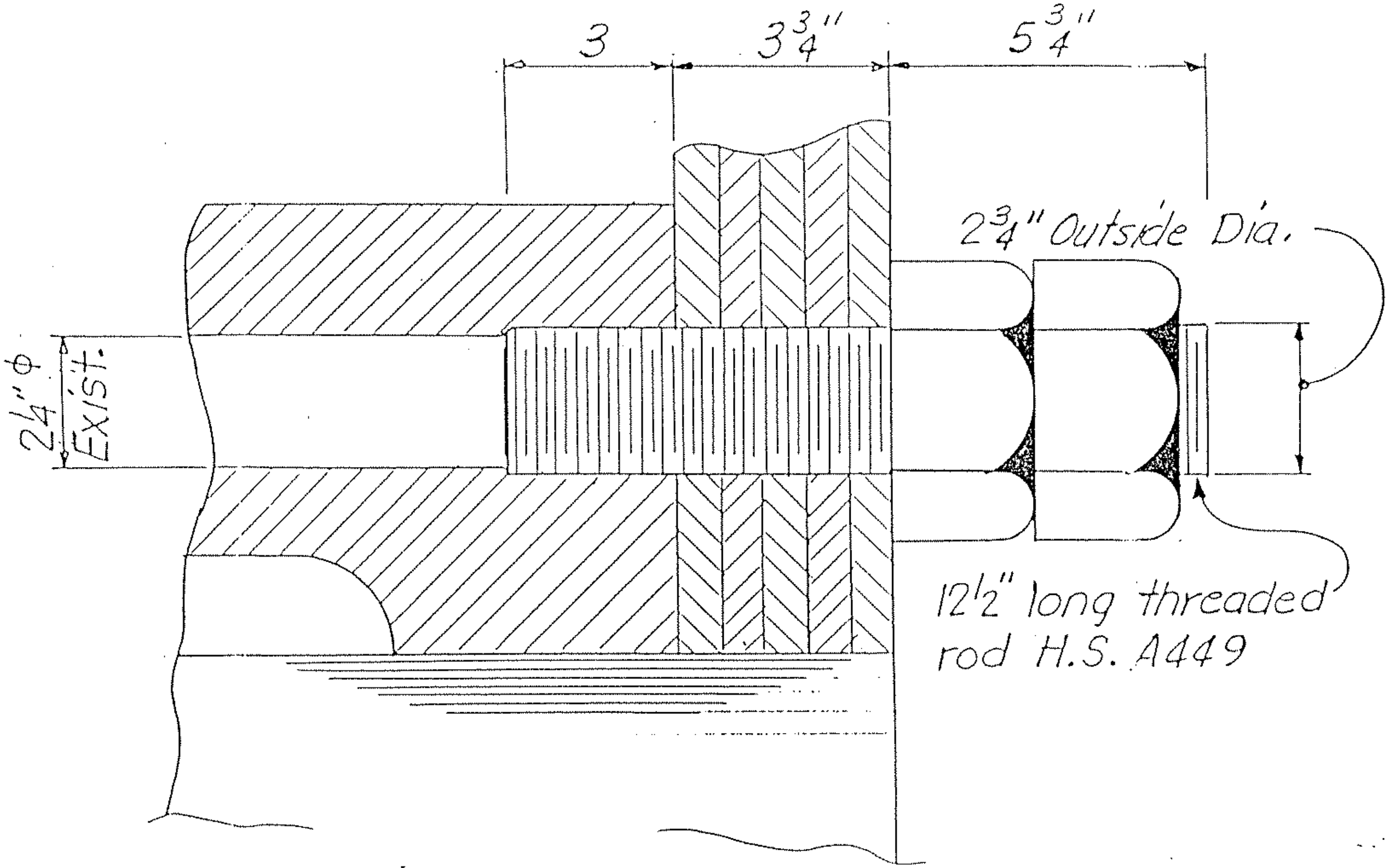

Counterweight Truss
A
A
8-2¼"ϕ Existing Ratining Bolts Per Counterweight Trunnion
Operating Strut
℄ Counterweight Trunnion Bearing
Roof of machinery house
Machinery House
2'-5±
℄ Counterweight Truss
℄ Approach Span B Truss
℄ Operating strut
Bearing Pedestal
VIEW OF CTWT TRUSS
Looking North
VIEW A-A

FIGURE 2



EXISTING COUNTERWEIGHT TRUNNION

FIGURE 3



DETAIL B

FIGURE 4

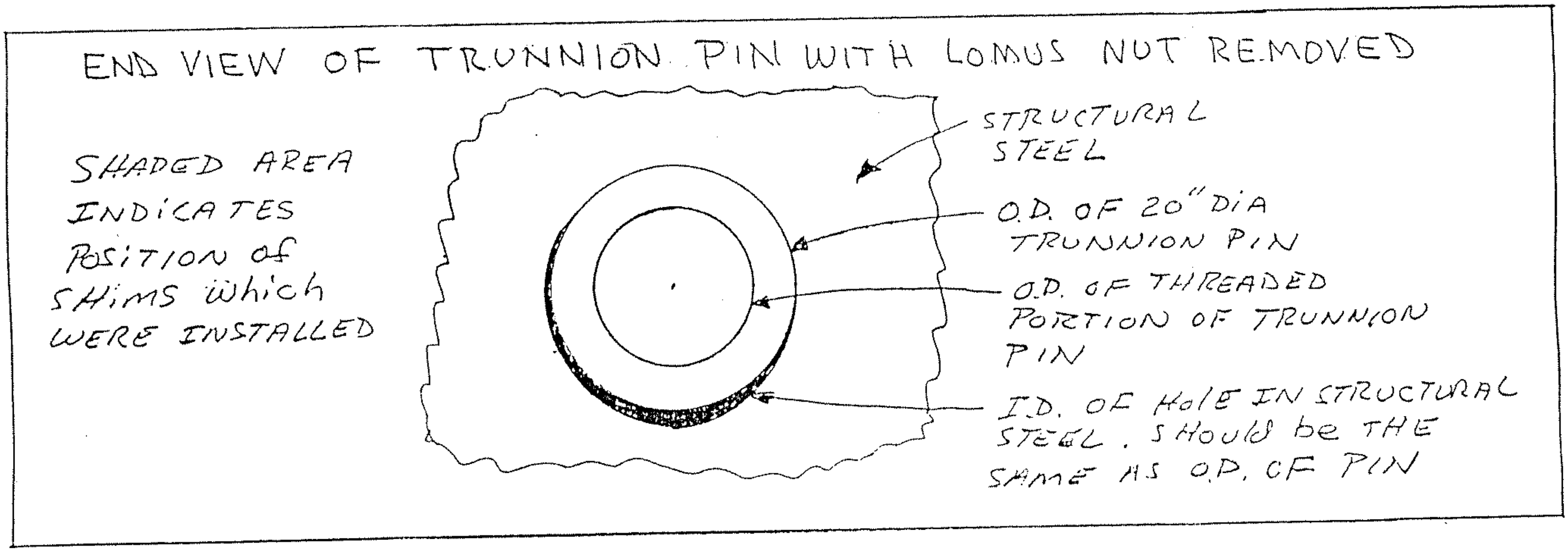

END VIEW OF TRUNNION PIN WITH LOMUS NUT REMOVED
SHADED AREA INDICATES POSITION OF SHIMS WHICH WERE INSTALLED
STRUCTURAL STEEL
O.D. OF 20" DIA TRUNNION PIN
O.D. OF THREADED PORTION OF TRUNNION PIN
I.D. OF HOLE IN STRUCTURAL STEEL. SHOULD BE THE SAME AS O.D. OF PIN

FIGURE 5

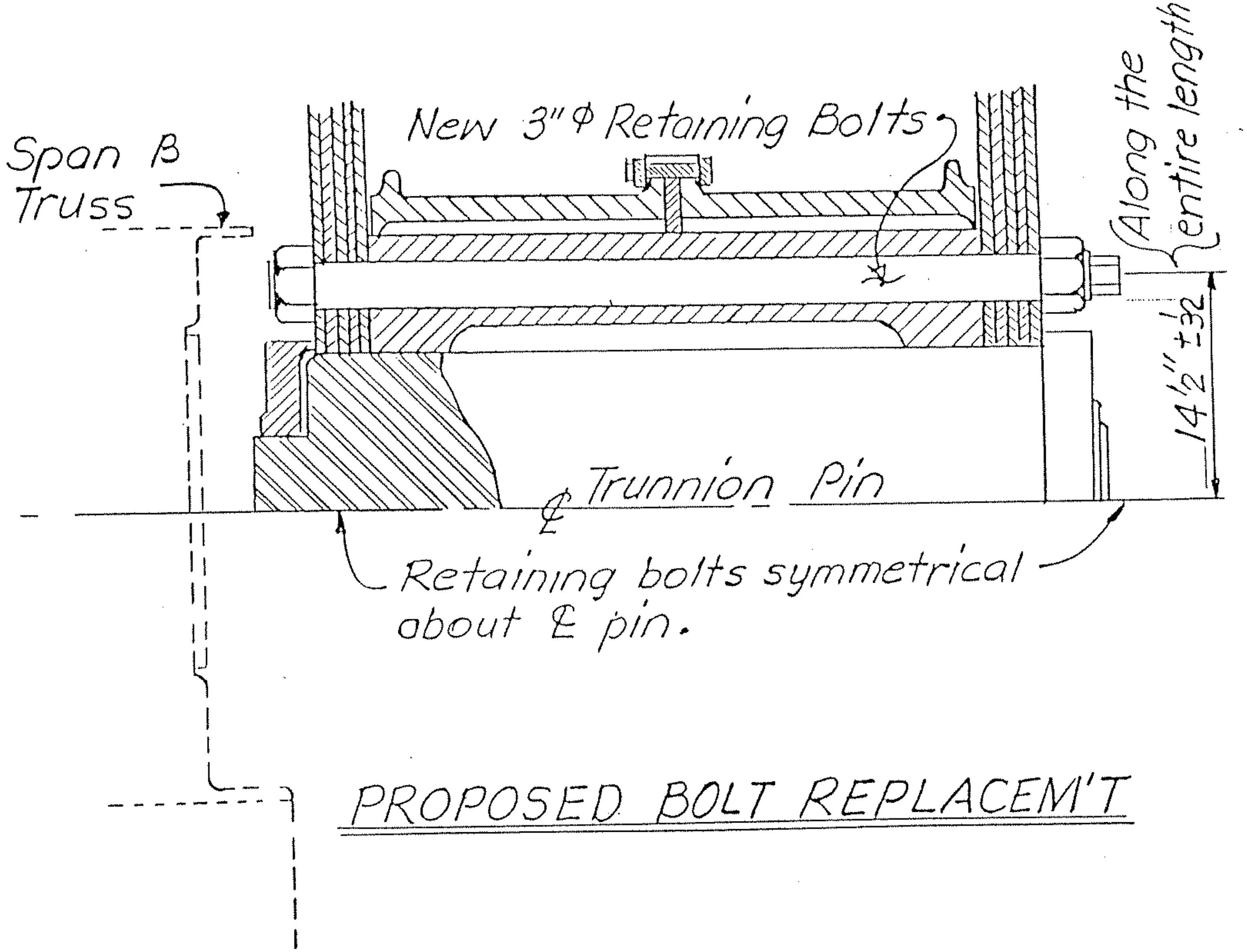

Span B
Truss
New 3"φ Retaining Bolts
Along the
entire length
$14\frac{1}{2}'' \pm \frac{1}{32}$
℄ Trunnion Pin
Retaining bolts symmetrical
about ℄ pin.
PROPOSED BOLT REPLACEM'T

FIGURE 6

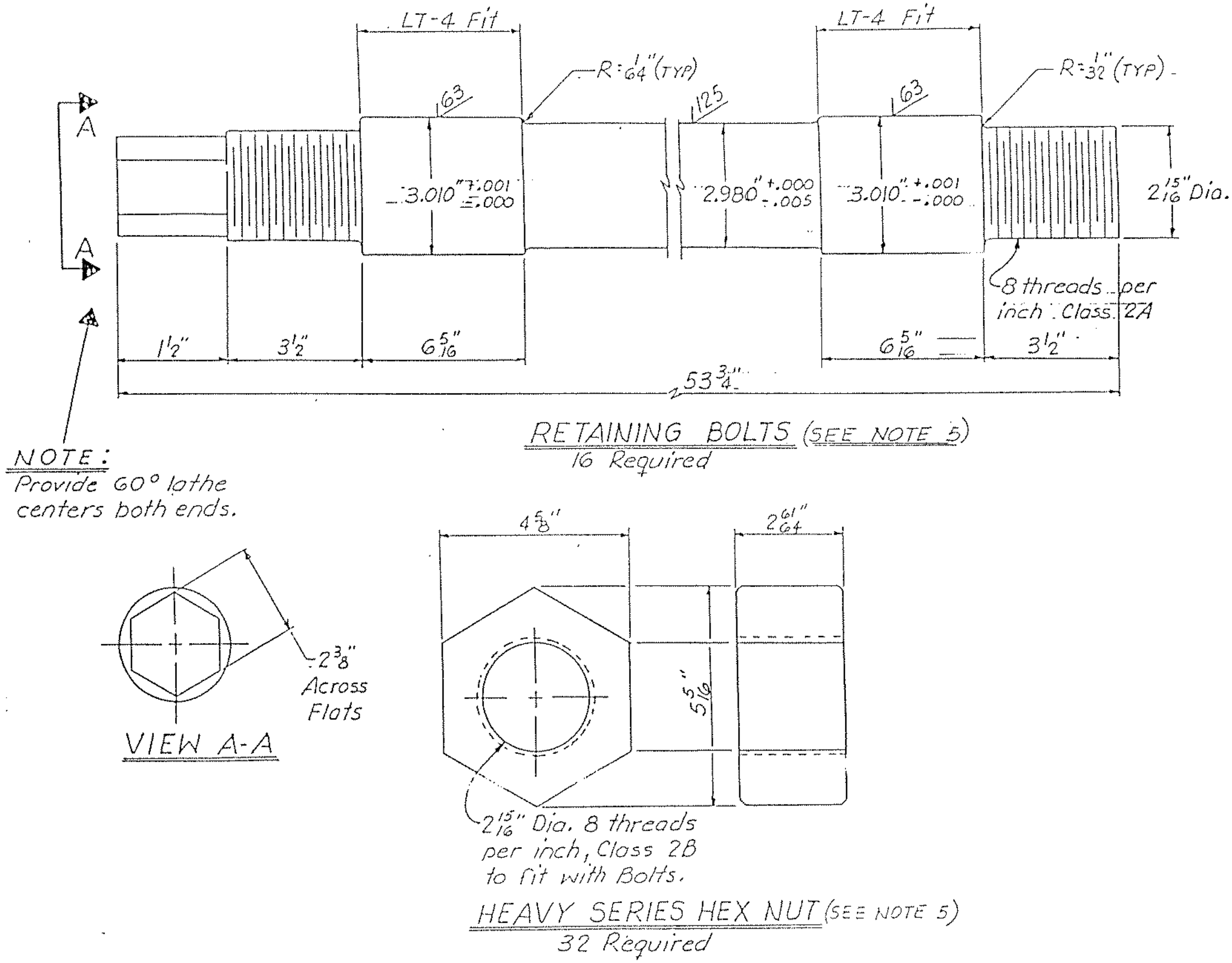
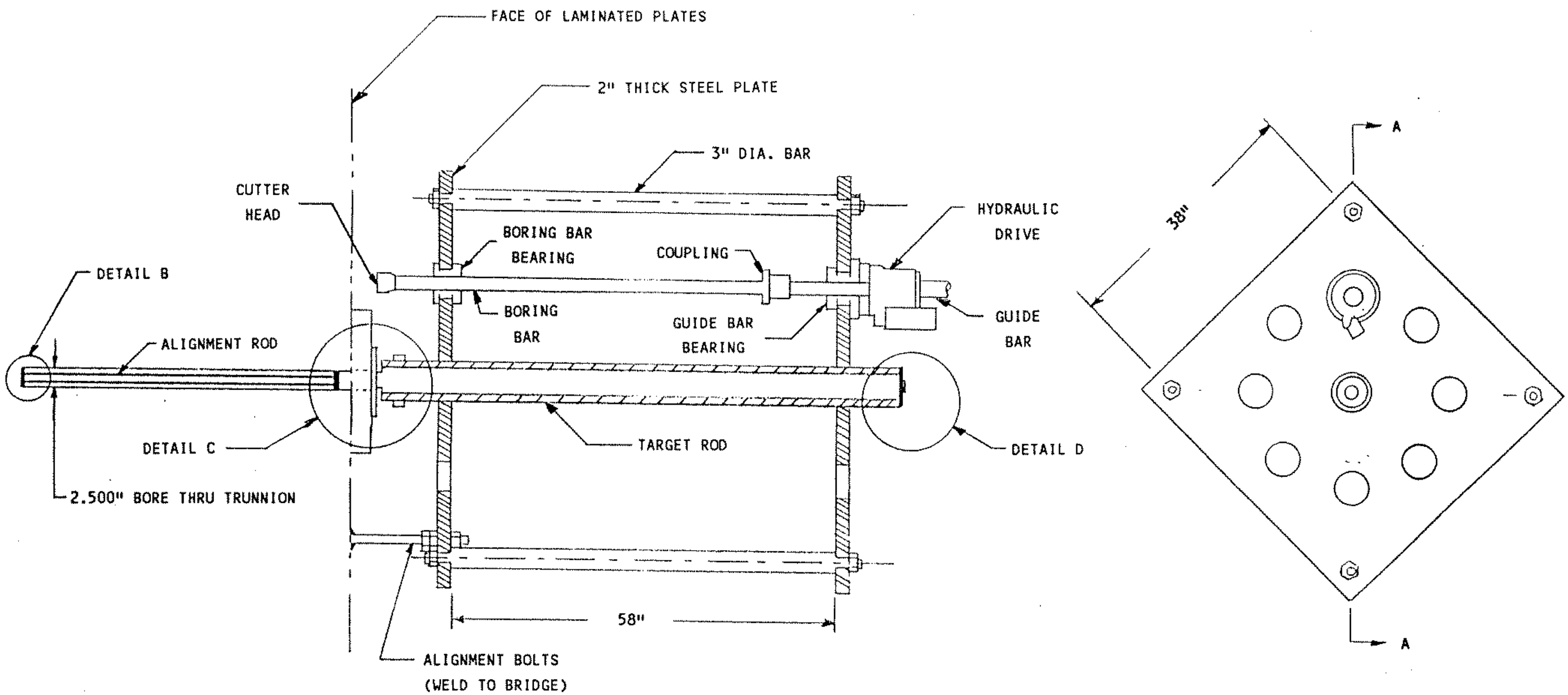

LT-4 Fit
R: 1/64" (TYP)
R: 1/32" (TYP)
63
125
3.010" +.001 -.000
2.980" +.000 -.005
2 15/16" Dia.
8 threads per inch Class 2A
1 1/2"
3 1/2"
6 5/16"
53 3/4"
A
A
RETAINING BOLTS (SEE NOTE 5)
16 Required
NOTE:
Provide 60° lathe centers both ends.
2 3/8" Across Flats
VIEW A-A
4 5/8"
2 61/64"
5 5/16"
2 15/16" Dia. 8 threads per inch, Class 2B to fit with Bolts.
HEAVY SERIES HEX NUT (SEE NOTE 5)
32 Required

FIGURE 7

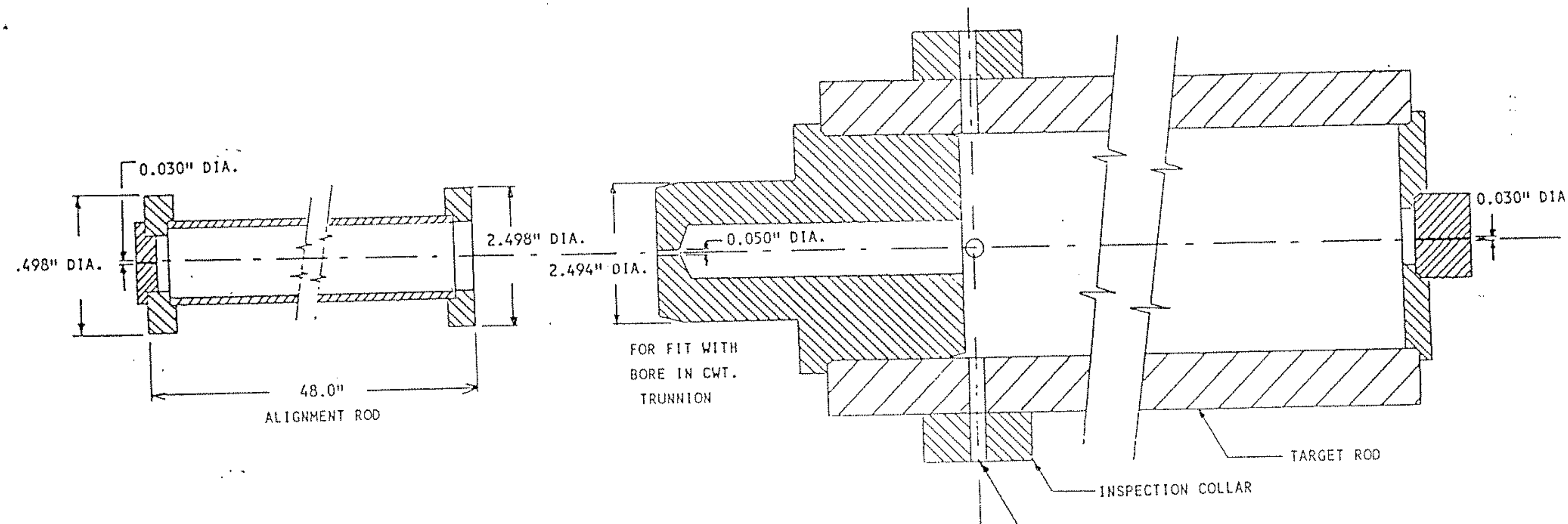


SECTION A-A

FIGURE 8

TREPANNING UNIT

ASSEMBLY VIEW



DETAIL B

DETAIL C

DETAIL D

NOTE: .030" DIA. HOLES THROUGH
NON CONDUCTIVE MATERIAL
FOR .030" DIA. PIANO WIRE

FIGURE 9

TREPANNING UNIT
TARGET DETAILS

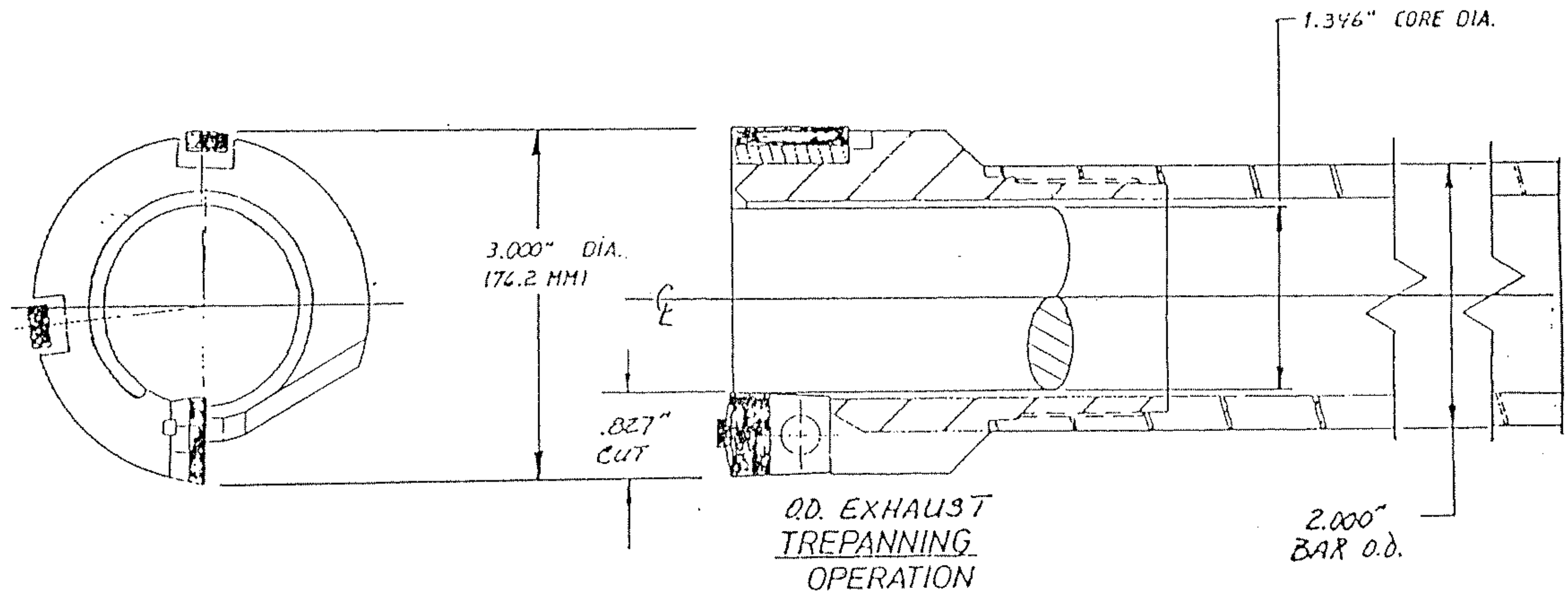

1.346" CORE DIA.
3.000" DIA.
(76.2 MM)
.827" CUT
O.D. EXHAUST TREPANNING OPERATION
2.000" BAR O.D.

FIGURE 10