TECHNICAL PUBLICATION

UPPER REAR STEAM DRUM REPLACEMENT AT WISCONSIN ELECTRIC POWER COMPANY'S PORT WASHINGTON STATION UNITS 2, 3, & 4

by

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Wisconsin Electric Power Company

Presented at the
Canadian Electric Association
Spring Meeting
Vancouver, British Columbia
March 29 - April 2, 1992

RST-101

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ABSTRACT

As the average age of operating utility steam generators increases, more and more steam drums and major headers will experience bore hole ligament cracking. This may be due in part to thermal fatigue and cycling operation, as well as normal aging of the steam generating equipment.

Methodology for assessing the severity of steam drum cracks has been in place for several years. Part of the assessment process is the inspection and mapping/replication of cracks. This phase is essential to the analytical evaluation of the drum shell. Repair or replacement recommendations/decisions result from these evaluations.

Problems associated with the physical replacement of a steam drum represent the final hurdles and must be addressed separately to accommodate the physical differences at each unit. Management of the safety, economic and scheduling issues related to multiple unit facilities also presents significant challenges.

This paper describes a current project employing engineering and construction innovation to solve the many challenges of steam drum replacement on adjacent units.

INTRODUCTION

The focus of this paper is Wisconsin Electric Power Company's (**WE**) five (5) unit Coal-fired power plant in Port Washington, Wisconsin. Initial operation of the units at this plant was from 1935 to 1950. The design electrical output capacity of each unit is 80 megawatts. Discovery of severe circumferential cracks in the upper rear steam drums has necessitated the reduction of operating pressures for Units 2 through 4 and the retirement of Unit #5.

Beginning in 1983 **WE** contracted outside consultants to perform examination and analysis of the drum cracks for units 2,3, &4. Riley Stoker Corporation (**RSC**) with Failure Analysis Associates(R) (FaAA) presently has the responsibility for the continued assessment of the drum cracks. This procedure is done on an approximately annual basis to determine the condition of cracks. Any enlarging or expansion of the cracks results in further pressure reductions of the units as the remedial solution.

Continued reduction of operating levels of the unit was not an acceptable solution. Therefore, **WE** issued a Request for proposal (RFP) in October 1987. The RFP described the work as Upper Rear Steam Drum Replacement on Units 2, 3, 4 and 5. Included with the RFP was a detailed technical specification. It outlined the material, labor, and field requirements of the project. The specification featured a proposed rigging plan for drum removal through the roof of each unit. This plan evolved from an earlier Engineering Study done by a consultant. **WE** left the evaluation of this plan to the discretion of each bidder.

Riley submitted (Nov '87) a Proposal for the replacement of the Upper Rear Steam Drums. In this submittal, **RSC** informed **WE** that the approach to this project would be innovative and aggressive. Instead of removing and replacing equipment through the roof, **RSC** proposed to transport the drums on a track system on the back end of the units through the coal bays and south wall of Unit 5 (see **Figure 4**). The proposed scheme offered the maximum safety for a project of this magnitude.

Negotiations resulted in a letter of intent with Wisconsin Electric in April of 1988 contingent upon **WE** obtaining all necessary approvals and permits.

Wisconsin Electric initially filed an application in July 1987 with the Public Service Commission of Wisconsin (PSCW) for the authority to renovate Units 1 through 5 at their Port Washington Power Plant. Subsequently, Wisconsin Electric became involved in several federal regulatory and jurisdictional proceedings and decisions regarding whether the proposed maintenance project would constitute a "source modification" under the provisions of the Clean Air Act. An air pollution control permit for Port Washington Power Plant was received in September 1990. In December 1990, the PSCW gave Wisconsin Electric approval to proceed with the renovation maintenance project.

In August 1990, **WE** requested an updated Proposal. The only major change to the specification was the elimination of Unit #5 from the scope of work due to retirement of this unit. Following PSCW approval and negotiations with Riley, a contract was awarded to Riley in December of 1990.

The scheduled nine (9) month unit #3 outage began September 1991. Structural work required prior to removal of drum began in April of 1991. Six (6) days ahead of schedule, on October 30, 1991, the old, 70 ton, upper rear steam drum was moved 10'-4½" east from its boiler position to the newly installed, Riley-designed track system.

DRUM INSPECTION

The original design of the boilers at Wisconsin Electric Power Company's Port Washington Plant are 3-drum Sterling cycle design, each about 660,000 pph steam output.

First evidence of bore hole and ligament cracking in the drum shell was discovered during a routine plant availability study inspection. Visual examination revealed the cracks. Dye penetrant, radiographic, and magnetic particle examination confirmed them. The most significant cracking appeared in the upper rear steam drum of Unit #5. However, examination confirmed cracking existed within the drums of Units #2, #3 and #4 as well.

Since discovery of the cracking in 1984, routine examinations of the upper rear steam drums have been conducted by **WE** personnel, the OEM, consultants, and other boiler manufacturers. The cracks are predominantly oriented in the circumferential direction between tube bore holes. The cracks originate on the internal surface of the upper rear steam drum within the boiler bank ligament field, as shown in **Figures 1 and 2**. This cracking has propagated into the thickness of the drum and/or into the tube bore holes. The drums are made of SA-204 GR. B carbon steel.

Introduction of feedwater supply to the boilers is through nozzles located at quarter points along the upper rear steam drums. Drum inspections continue to verify that most cracking is contained within the tube ligament field between the feedwater nozzles. This is a significant point. Units #2, #3, and #4, which do not have economizers, all exhibit drum cracking. Unit #1, which has an economizer, does not have drum cracking.

A considerable amount of data with respect to the extent and propagation of drum cracking has been collected during scheduled drum inspections. In many instances, the cracks originating from the boiler bank tube bore holes extend down the bore holes from the internal drum surface before disappearing behind the flared tube roll, see **Figure 3.** Drum inspections over the past several years and subsequent evaluations have generally led to the conclusion that the cracking is a result of thermal fatigue which is coupled with corrosion and exacerbated by the cycling of the unit with introduction of feedwater. It has also been agreed that the growth rate of the cracking in the upper rear steam drums has slowed to a very low or negligible growth rate.

The number of cracks, the branching which has occurred in the cracks, and the interpretation of results have all become part of an assessment program addressing the relative soundness of the drum. The basic characteristics of the current drum assessment program at the Port Washington Plant consists of the following:

- Drum inspection: Detailed visual inspection of the internal drum surface. This requires the removal of all parts (drum internals, feedwater distribution troughs) which may conceal the extent of cracking.

- Acquisition of data: Mapping of all crack parameters, with specific location and orientation about the ligament field, bore holes, length, and depth measurements of the cracks.

- Surface replication: Performing replication and documentation of specific cracks judged to be most critical. We use the size of the crack, the joining of several cracks in a specific ligament, and the relationship of the extent of cracking with respect to a closely-spaced ligament field as the criteria for consideration.

- Assessment of data: Modified area replacement and ligament efficiency calculations are performed to show the severity of the cracking. To further substantiate the results, a fracture mechanics/finite element study is performed.

Based on the results of the data assessment, the utility program has set the following course of action:

- Continued operation of the unit at reduced pressure with the establishment of a crack growth monitoring program.

- Review of plant operating procedures including the control of drum feedwater temperature, water chemistry, and control of cyclic operation which causes frequent fluctuations in feedwater temperature.

- Replacement of the drum

In addition, the utility program to mitigate the feedwater induced thermal stresses on the new drums include the following:

- Redesign of the drum internal feedwater distribution system.

- Installation of deaerators including start-up steam supply.

- Continued review of plant operating procedures.

ACQUISITION OF DATA

Initial evaluations by the boiler OEM included a series of ligament calculations considering the crack areas. The method assessed the effect of the cracking with respect to the maximum allowable working pressure of the upper rear steam drum. This technique was the basis of **WE**'s assessment on the continued operation of the units. This technique is still used today. Reducing the maximum allowable working pressure for Port Washington Units #2, #3, and #4, and the ultimate replacement of the upper rear steam drums were the results of the continued data acquisition and evaluation.

Data is acquired using a current-injection measurement probe method employing a TSI model CC-800B instrument with a model MPL-4 probe. Both the length and depth of individual cracks are measured. This allows us to: 1) estimate projected crack areas; 2) qualify the depth of cracking; and 3) monitor crack growth. In the areas where multiple cracking exists, the intersecting crack areas are conservatively summed. For consistency, crack depth measurements are monitored on the circumferential ligament cracks which had been measured during previous drum inspections, with the results compared. Data was obtained not only from ligament areas known to have cracks, but also from any areas of the ligament field where additional cracking was found.

SURFACE REPLICATION

The repeatability of the measurements, increases in crack branching, and effects of corrosion have made the assessment of cracking increasingly more difficult. The current injection probe measurements represent a subjective accumulation of data to be compared with previous crack data.

During the Spring 1991 inspection, an additional recommendation regarding the monitoring and measurement of significant cracks was presented by **RSC** to better define the crack growth rate within the upper rear steam drums. The replication process is used to get metallographic prints of specific cracks, to better define the crack growth rate within the upper rear steam drums. Specific cracks are selected based on their relative contribution to the overall drum assessment in the derating process. After the macro-replica is taken, the image is enlarged and a point count taken of the crack area. At the next inspection, the replication can be repeated and the point count retaken. By comparing the replicas, the crack growth rate can be measured.

The macro-replica technique is judged to be a more quantifiable technique than the collection and comparison of data by the current probe injection method. Although fewer replicas are taken compared to the number of cracks measured by the injection probe, a more accurate estimate of crack growth can be made. This program will continue to collect data by both methods.

ASSESSMENT OF DATA

The method used to check the effects of circumferential cracking is the comparison of the area replacement and the ligament efficiency technique. The ASME Boiler and Pressure Vessel Code, Section I establishes this criteria. The crack-like penetrations in the drum shell are accounted for by the exclusion of the areas created by the cracks from the original drum metal available in ligament calculations. It is important to note that the cracking is primarily in the circumferential direction, which allows for an adjustment of the "F" factor in paragraph PG-33, Section I, to compensate for the variation in pressure stress from the longitudinal to circumferential direction. If the ligament contains several cracks, the areas of the cracks in that specific ligament are summed and the comparison of crack areas is made. If the area required is larger than the compensation available or the cracking is significant, then a revised ligament efficiency is considered in calculating the revised maximum allowable working pressure for the drum.

In addition to performing a comparative analysis under the ASME Section I Boiler Code, fracture mechanics and finite element evaluations are also undertaken to substantiate the results made by the area replacement and ligament efficiency calculations. These higher order analytical techniques increase the confidence level regarding the size of the crack that could be present without the occurrence of unstable crack growth. Fracture mechanics is used to set up a recommended reinspection interval of the drum ligament crack areas.

Evaluation techniques employing area replacement, ligament efficiency, finite element, and fracture mechanics represent conservative estimates in determining the derated maximum allowable working pressure of the upper rear steam drums. As the crack measurement data accumulates and the amount of crack branching which is partially obscured by corrosion increases, the evaluation program becomes more difficult.

The continued reduction in the maximum allowable working pressure of the upper rear steam drums and the subsequent decrease of the unit generating capacity has now made it more economical to replace the drums. A drum replacement program is now under way at Port Washington Power Plant.

WE'S BID EVALUATION

Riley design features resulting in favorable bid evaluation by **WE** are as follows:

1. Reduced drum shell thickness from 5 to 3-7/8", which minimizes thermal stress for cycling operation and upgrading of drum material.

2. Redesign of the internal feedwater distribution and baffle system.

3. Swaged tube connection into new drum - facilitating tube installation.

4. Riley assuming responsibility of tube seat repair in existing drums.

REMOVAL/INSTALLATION CONCEPT

Riley's decision to explore an alternate procedure of drum removal/replacement rather than the method proposed in the RFQ resulted in the following monetary and safety considerations:

- The proposed method in the RFQ, see **Figure 4**, entailed removal of two suspension level main steel girders on each unit. This method requires installation of a massive temporary boiler support system before removal of the girders.

- Transport of the old and new drums across the building roof would require substantial reinforcement of the existing roof steel. The weights of the gantry frame, a pedestal crane and the rolling drum are factors considered in the associated reinforcement calculations.

- The roof opening over each unit would require temporary removable cover assemblies for weather protection and access. Restoration of the roof following completion of the project is also a requirement.

- The requirement for a large capacity crane to facilitate installation (and later dismantling) of the roof track, gantry frame and the pedestal crane resulted in substantial additional costs for this equipment.

Following an in-depth review of the Port Washington Plant layout, Riley chose an erection plan which optimized both safety and economy (see **Figure 5**). Additionally, minimal plant disruption and minimal weather exposure evolved as benefits of the plan. Features of the Riley drum replacement plan include:

- Reinforcement and redesign of the upper rear drum access platform. A permanent channel track system for Units 2 through 5 to accommodate north-south roller movement of the 70 ton drum(s), See **Figure 6**.

- Installation of four (4) temporary monorail beams, in an east-west direction, complete with hydraulic jacking rods on rollers to facilitate:
  • Raising each drum off its present support
  • Rolling the drum eastward to a position directly over the new track system
  • Lowering the drum into saddle supports on Hilman rollers for southerly movement out of the building, see **Figure 8**.

- Installation of sliding fire doors. Openings made in the concrete partition wall between each coal bay and adjacent unit permit movement of the drums through the coal bays. The sliding fire door isolates each coal bay from adjacent units when drum transport is complete.

- Installation of a permanent track system in the coal bays. This track is an extension of the walkway track system and permits continuous roller (drum) movement to the outrigger outside of the building.

- Re-design of the leveling conveyor assembly in each coal bay for rapid disconnect/connect reduces down time of this equipment which is in the direct path of drum movement.

- Installation of a steel structure (outrigger) attached to the outside of the plant on the south wall, see **Figure 7**. This structure includes:
  • Moveable tracks which are a continuation of the track system from inside the building
  • Overhead steel above the tracks suspends (2) 75 ton block sets (stationary and traveling) for lowering the drum to ground level and subsequent disposal.

Installation of the new drums uses the same outside structure, track system and hydraulic jacks/rollers with the procedure reversed compared to drum removal.

Several factors directly related to this unique procedure of drum removal and reinstallation influenced Wisconsin Electric's award of a material and labor contract to Riley Stoker. The Riley plan resulted in the lowest risk to plant operations and structural modifications. It also provided a number of other significant benefits to **WE**:

- In-plant movement of the drums through the south side of the building versus the roof resulted in intact boiler steel and building roof steel for the life of the project.

- Drum removal/installation sequence uses a combination of hydraulic jacking, saddle rollers and hoist/blocks for effective, safe movement of heavy loads.

- The design of upper rear drum access platform incorporates reinforced steel as the track system. This design is permanent with moveable grating inserts installed in the track channels for immediate use as an access platform when not used for drum or material transport. Also, the width of

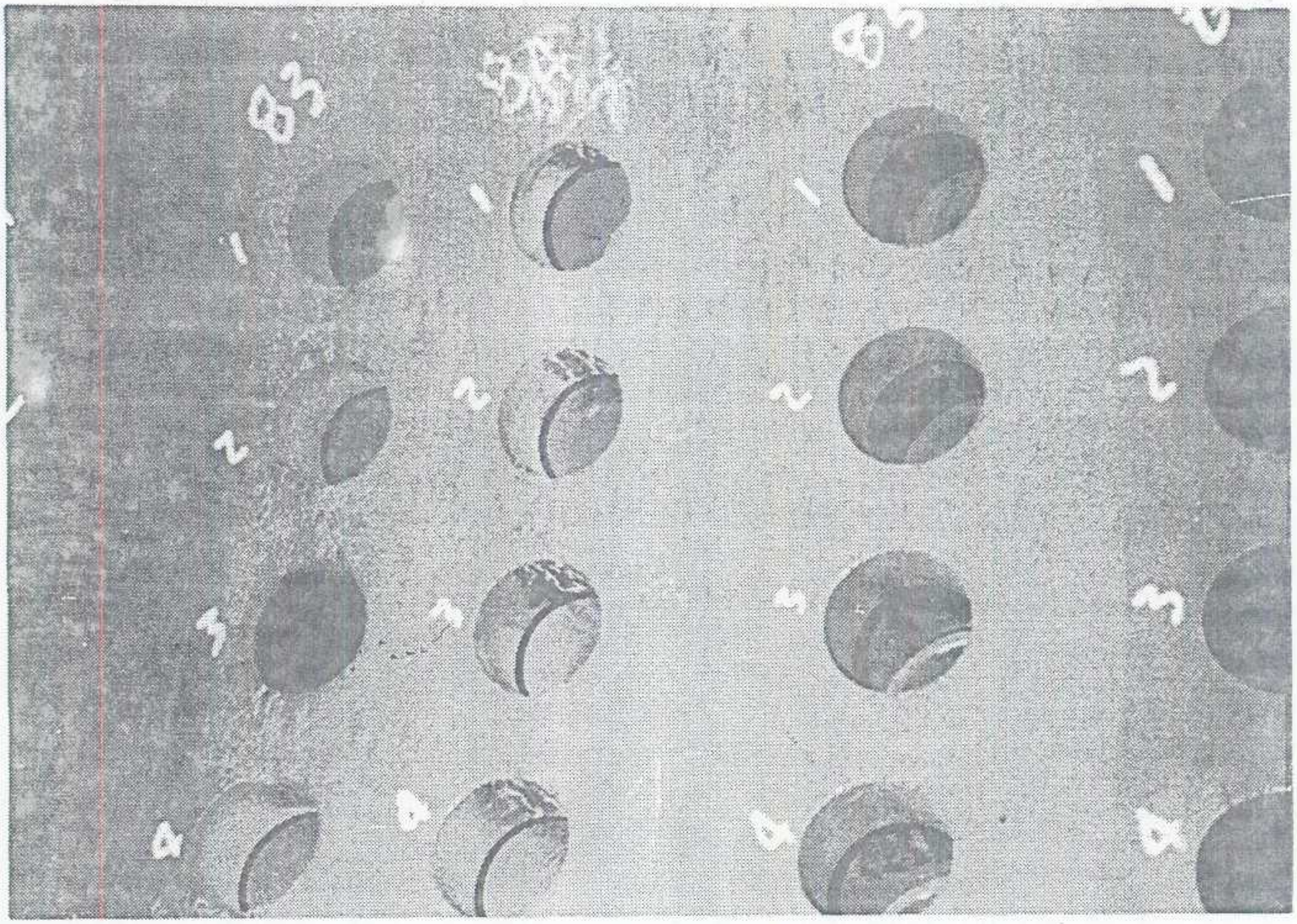

Figure 1

Upper rear steam drum circumferential bore hole arrangement. Photograph illustrates the tube bore hole cracking.

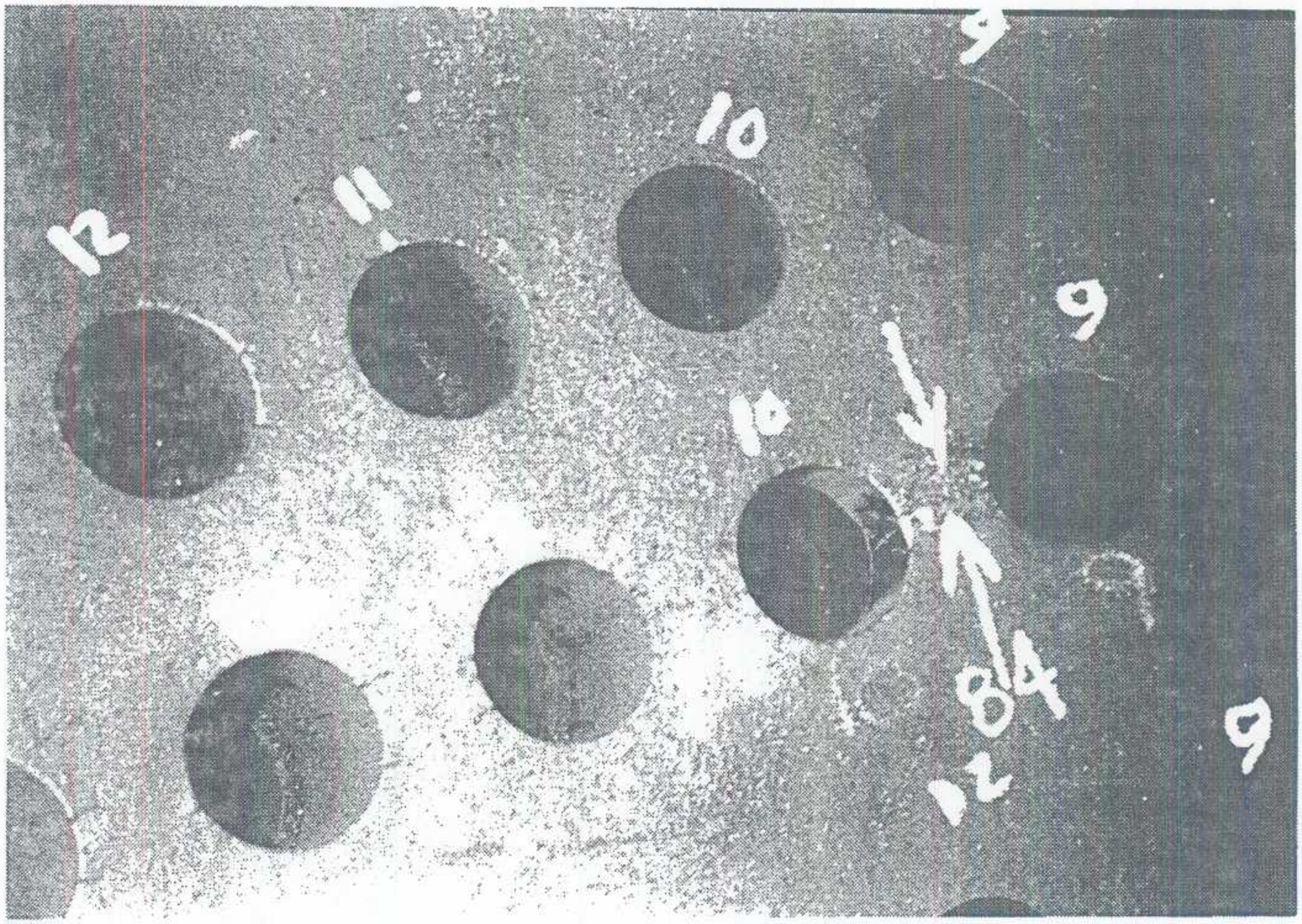

Figure 2

Ligament cracking between tube bore holes and propagation of cracking into shell

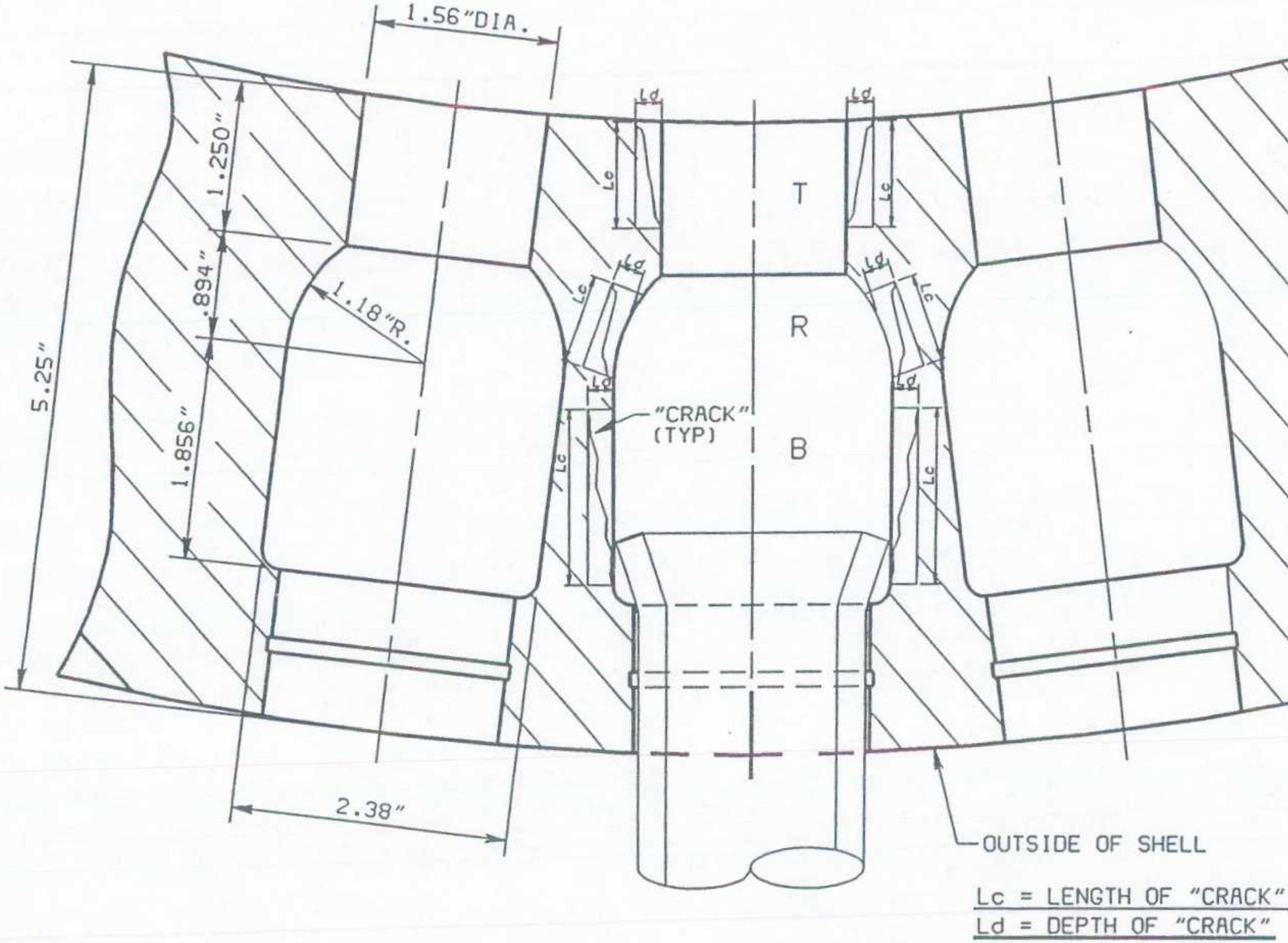
1.56"DIA.
1.250"
.894"
1.18"R.
5.25"
1.856"
Ld
Lc
T
R
B
"CRACK"
(TYP)
2.38"
OUTSIDE OF SHELL
Lc = LENGTH OF "CRACK"
Ld = DEPTH OF "CRACK"

FIGURE 3

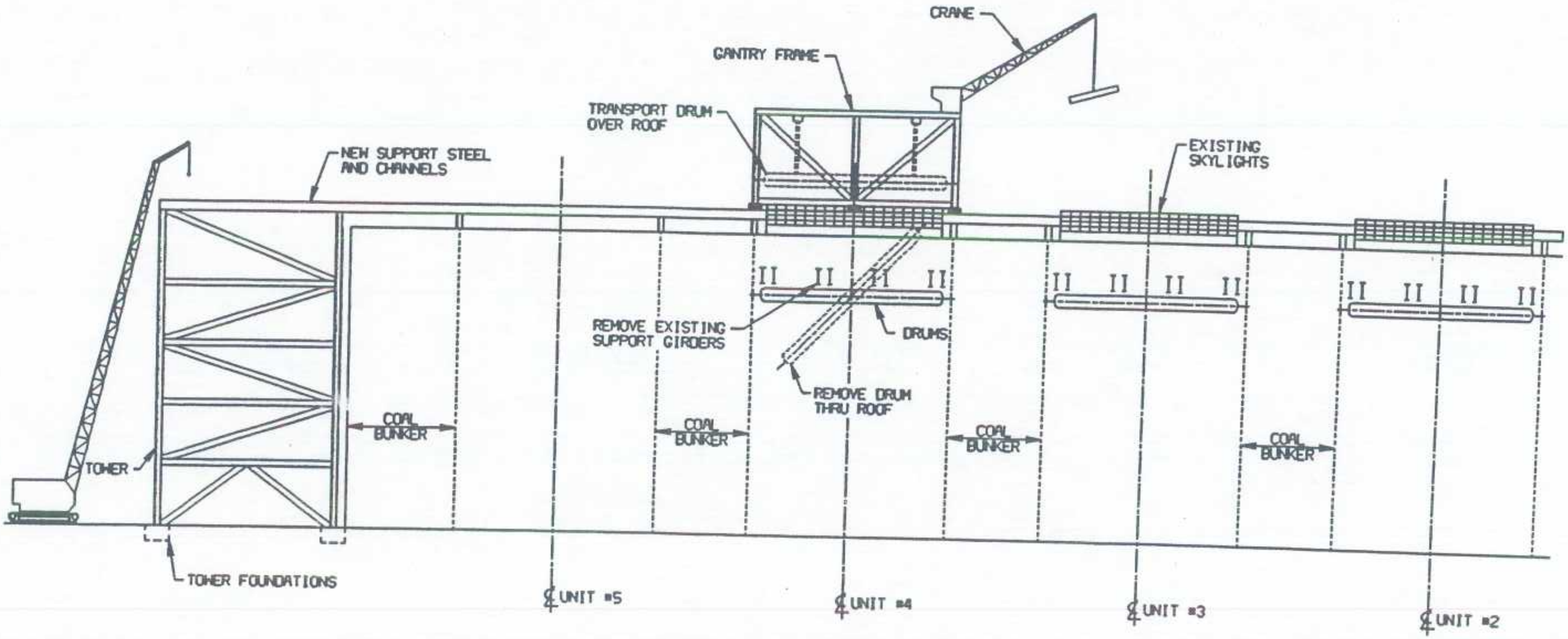

FIGURE #4

INITIAL RFQ RECOMMENDATION
FOR REMOVING DRUMS

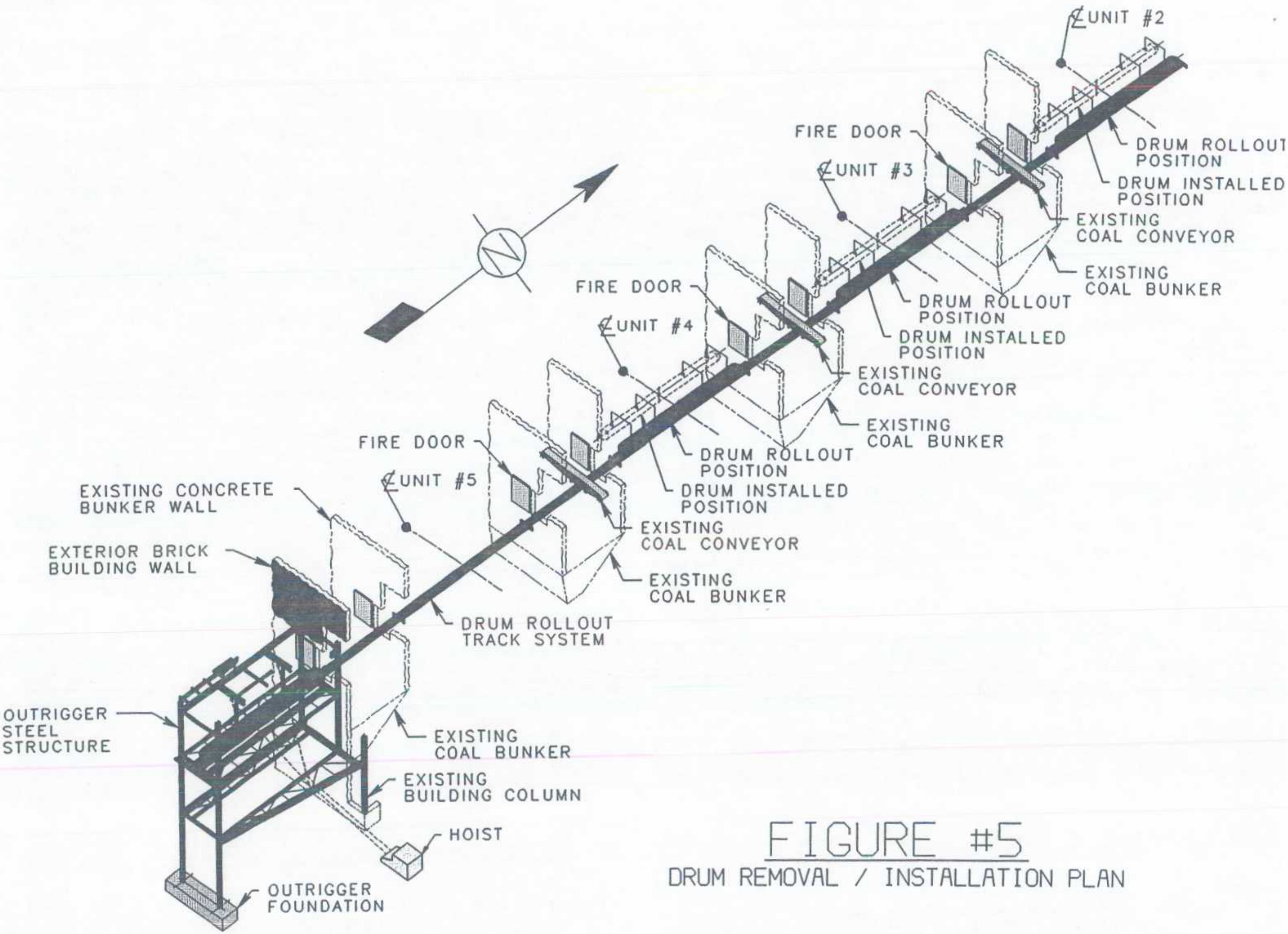

FIGURE #5

DRUM REMOVAL / INSTALLATION PLAN

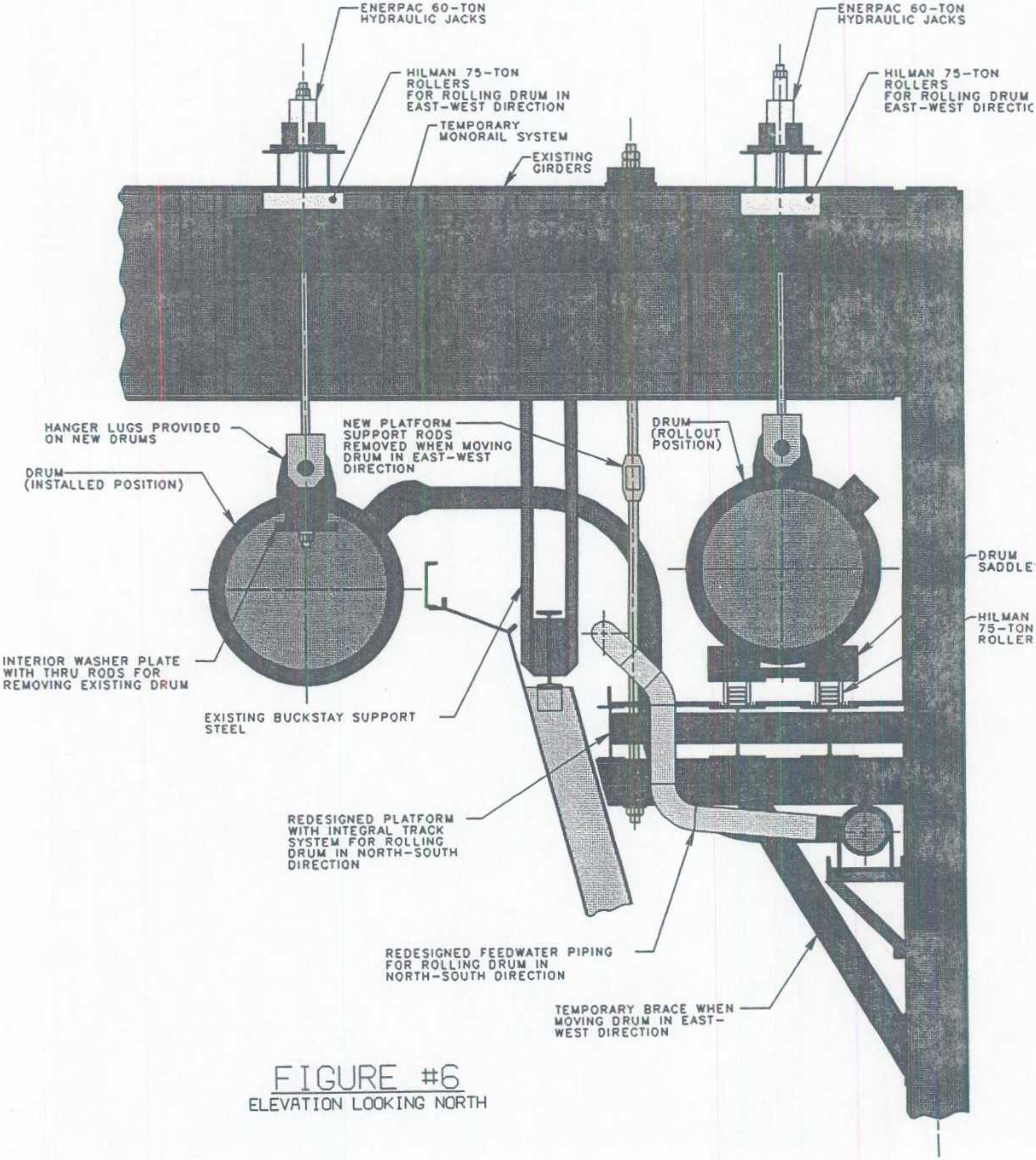

FIGURE #6

ELEVATION LOOKING NORTH

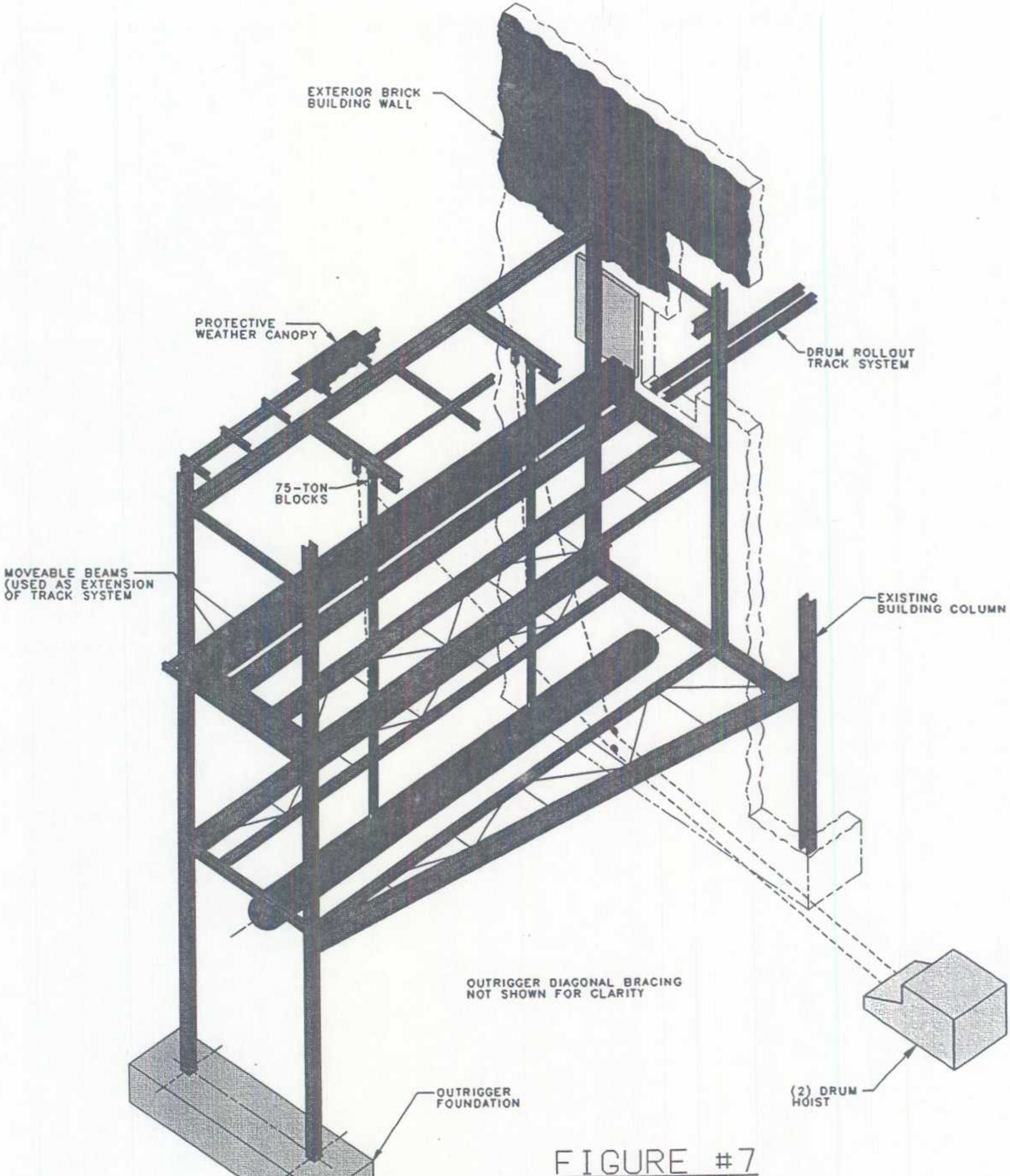

FIGURE #7
OUTRIGGER STEEL
FOR LOWERING & RAISING DRUMS