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RIGGING HISTORY OF THE MILLSTONE II STEAM GENERATOR REPLACEMENT PROJECT

WATERFORD, CONNECTICUT

Millstone Nuclear Power Station

Unit 2 is the tall building just to the right of the stack

SCOPE OF WORK:

In early 1990, Fluor Daniel (FD) was awarded a contract to remove and replace two steam generators at the Millstone Nuclear Power plant located at Waterford, Connecticut. The contract specified that all design had to be completed so that the above would happen during a 60 day outage in July 1992. The tubes in the steam generators were leaking contaminated water into the bay above the allowable tolerance. Steam generators have two separate water systems running thru them. One is a closed system were water is circulated thru the tubes of the steam generators, out thru the reactor and back thru the steam generators. Of course, this water is contaminated with radiation. The other water system draws water from the bay and circulates it thru the steam generators to cool them and then goes back into the bay. The problem is that after a 20 to 30 year life, the tubes in the steam generators start to get pin holes in them and leak contaminated water into the cooling water. Thus, killing the fish in the bay. See figure 1 of an ISOMETRIC view that shows the cut line on the steam generators, the location of the two steam generators relative to each other and the reactor down between them. Also between the two steam generators is a refueling pool for the reactor (not shown in the drawing).

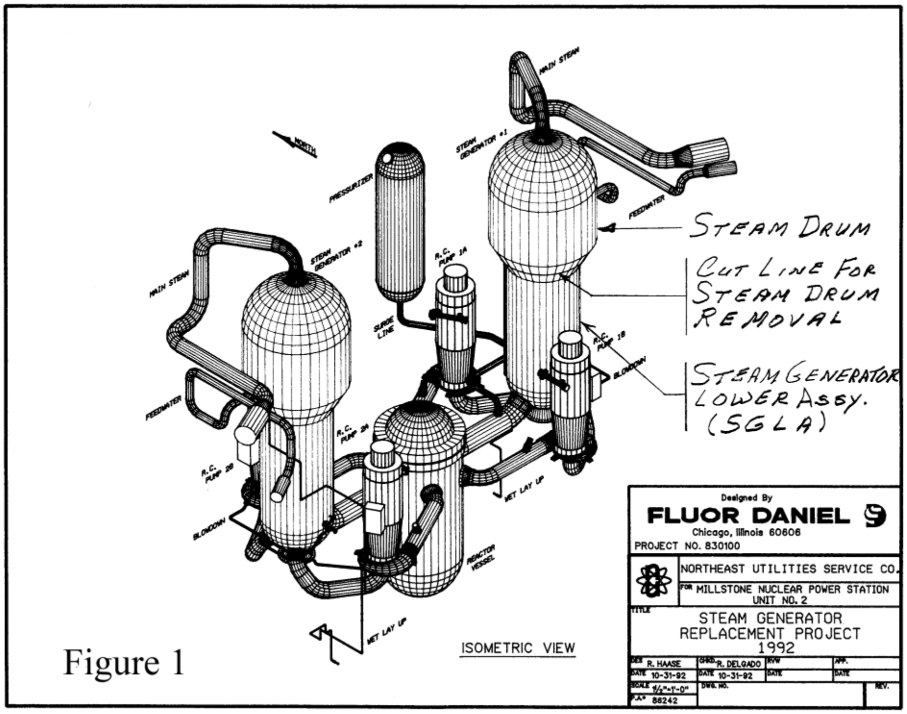

Figure 1

NORTHEAST UTILITY ENGINEERS:

THEIR PROPOSED METHOD:

The Northeast Utility (NU) engineers had already made some rigging studies and determined a feasible way to remove/install the two steam generators.   As the diameter (ϕ) of the top part of the steam generators called the steam drums (SD) had a 22’ ϕ and the equipment hatch was 19’ ϕ, they decided to make a cut on the cone section such that the maximum ϕ of the cone section on the lower part of the steam generator called the steam generator lower assembly (SGLA) was 18’.

This would allow the SD to be lifted off the SGLA, up out of the block house, turned upside down and set in a stand next to the refueling pool. Figure 2 shows the SD being lifted out of the block house.

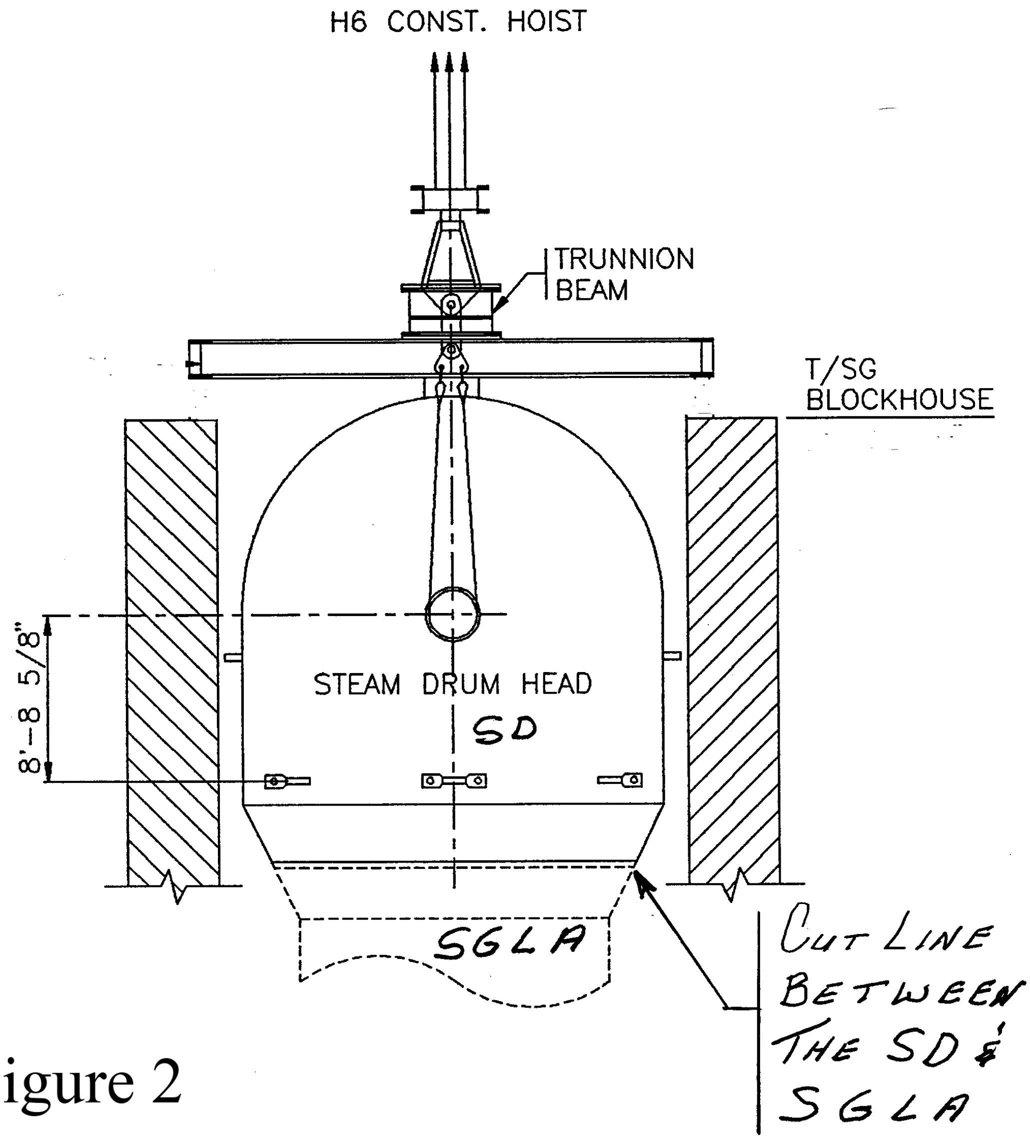

Figure 2

Figure 3 shows the SD setting in a stand next to the refueling pool in the inverted position so that its tubes can be replaced.

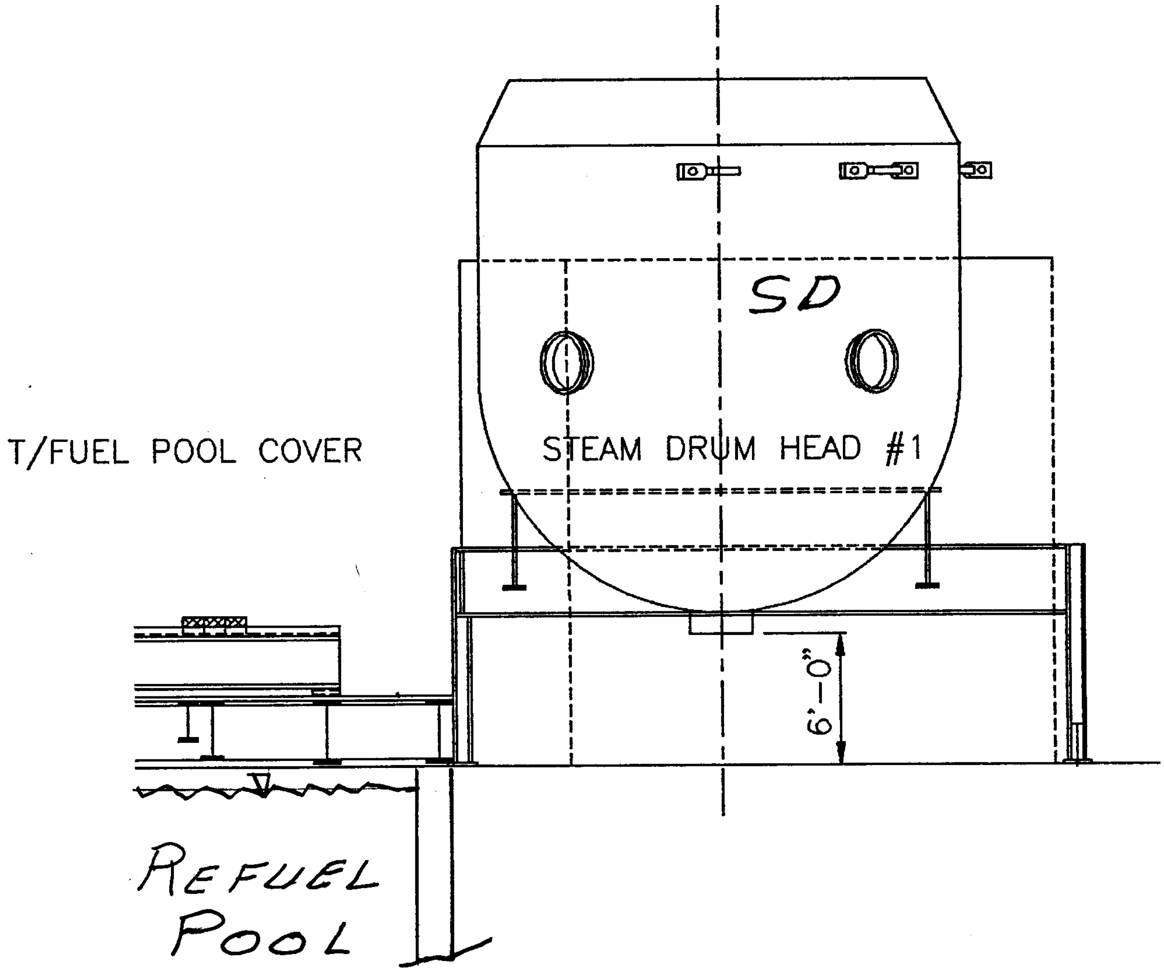

Figure 3

The maximum 18' ϕ cut would allow the cone section of the SGLA to be pulled up between the polar girders to give additional height clearance between the bottom stand and the top of the block house. It would also allow the SGLA to be moved out through the equipment hatch.

They calculated that a 5" thick steel top hat would have to be welded over the exposed tubes of the SGLA to cut down on the radiation after the steam drums were removed. The total weight of the old SGLA's was then calculated at 380 tons. They knew that the polar crane did not have near enough capacity to lift this weight nor did it have the height required to lift the SGLA out of the block house. They contacted the Reliance Company in Phoenix and contracted with them to furnish their 650 ton H6 hoist to run on top of the polar girders. It was set up so that lifting by the H6 hoist was done on one end of the polar girders only, so it only had to trolley from that end out to the middle of the span. Figure 4 shows NU's proposed method of lifting the SGLA by the H6 hoist up out of the block house with the top hat and cone section up between the polar girders.

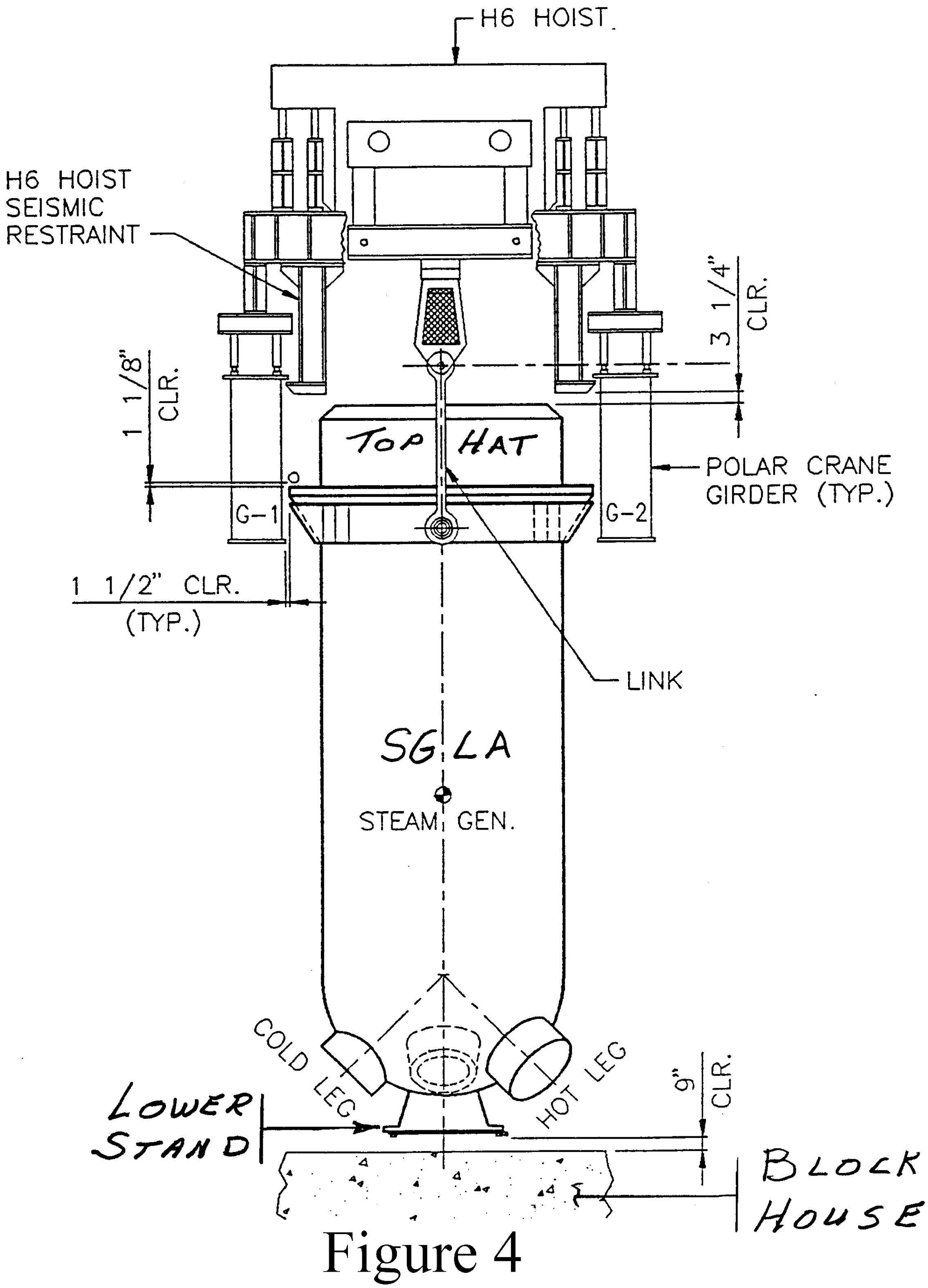

Figure 4

NU also found that additional trucks were needed at that end of the polar girders to carry the increased load. This design would be part of Fluor Daniel's Structural Engineer Department's scope of work. Figure 5 shows their design for adding the extra trucks.

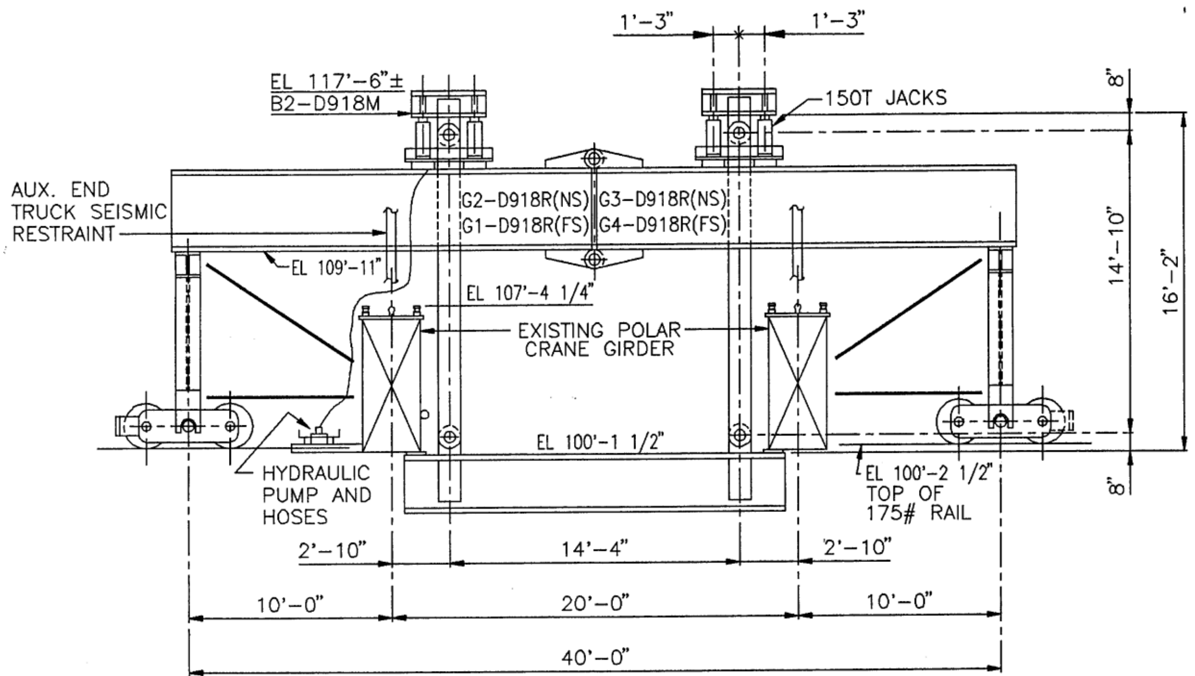

Figure 5

Another important aspect of FD's scope of work was to design heavy steel mats to cover over the refueling pool located between the two steam generators. NU's engineers proposed that the SGLA's would be down ended/up ended on these pool covers. Theses pool covers would also provide sort of a dance floor where a lot of activity would occur during the 60 day outage when the steam generators would be changed out, ie, items would be laid down on them for refurbishing, a 45 ton crane would be located on them, etc. Figure 6 shows the SGLA's being down ended on the fuel pool covers per NU's proposed method.

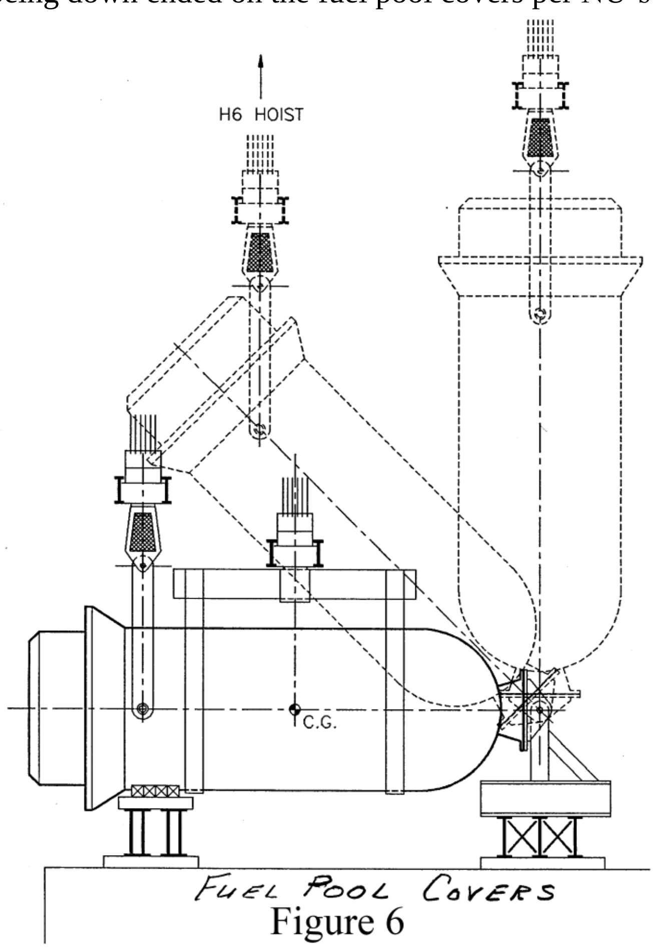

Figure 6

The NU proposed procedure called for the SGLA to then be lifted in the horizontal (IPP), moved around the pressurized block house and lowered down to the equipment hatch floor level. Figure 7 shows this maneuver.

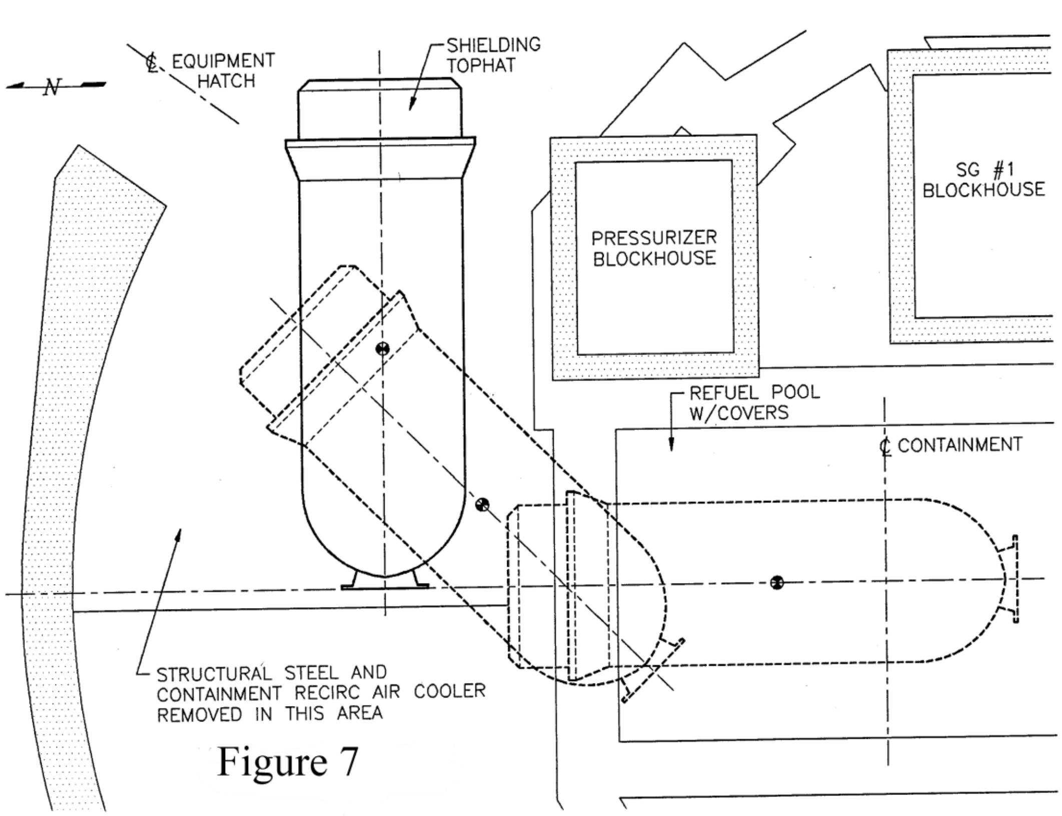

Figure 7

The SGLA would then be trolleyed outward and lowered until the top hat end would rest on a saddle positioned on rails in the equipment hatch and the stand end would rest on a saddle positioned on **hard point steel**. The H6 would then be unhooked and the rigging to handle the SGLA in the horizontal would be removed. The H6 would then be hooked to the lower stand and would carry the lower end of the SGLA as it was being pulled out of containment by pull jacks. Figure 8 shows these two maneuvers.

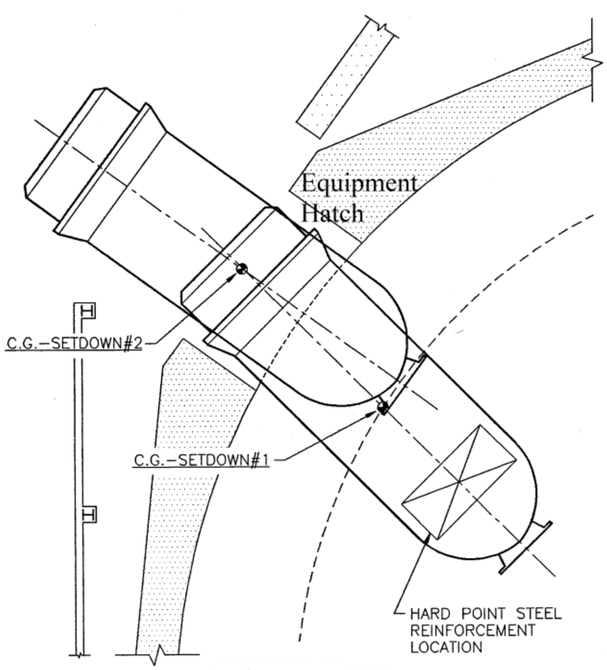

Figure 8

The problem with this scheme was that there was no “hard point steel”. At that location, there were three subterranean floors of stairs, diamond plated floor coverings, etc, not anything to support one half the weight of the SGLA. So this became the number 1 priority for the 1990 outage, ie, design, fabricate, and ship the hard point steel to Waterford, design modifications to the existing steel to accept the hard point steel, and then to install it during the above outage.

As the old steam drums were fabricated by Babcock & Wilcox (B&W), NU issued them a contract to furnish the two new SGLA’s and the trunnion bands needed to lift the two old ones and the two new ones.

FLUOR DANIEL STRUCTURAL ENGINEERS:

FLUOR DANIEL’S CHICAGO DESIGN OFFICE:

The engineering design was assigned to FD’s Chicago office. The major portion of the design was assigned to their Structural Department, ie, the structural modifications and the rigging. The FD Construction Manager (CM) at the NU site was from the Daniel side of FD and did not believe the FD Rigging Department had anything of value to offer. He and the Project Manager in the FD Chicago office felt that as the NU engineers had a proposed method for removing and replacing the steam generators, that all the Structural Department had to do was fill in the details. So they should be able to handle the entire project rigging needs, with help from Reliance’s Rigging Department.

PREPERATIONS FOR THE 1990 OUTAGE:

The first order of business for the FD Structural Department was to get ready for the 20 day outage in July 1990. The following items were top priority.

1. Design the hard point steel, get it fabricated and shipped to Waterford.
2. Design the modifications of the floor plate, stairs, etc. to make room for the hard point steel.
3. Make sure that Reliance had inspected, repaired, operated and test loaded the H6 hoist in Phoenix to make sure that it was working fine. Then dis-assemble it and ship it to Waterford in time for it to be moved into the containment building and installed on the polar girders.
4. Identify any other activity that needed to be taken care of before or during that outage.

During the 1990 outage, the hard point steel was installed as planned at a total design/fabricated/installed cost of $1,000,000. Reliance was not so lucky with their operation. They just barely managed to get the H6 into containment, mounted it up on the polar girders and got the seismic restraints installed when they ran out of time. NU was very disappointed with Reliance and with FD for their performance during the outage. They insisted that the FD CM be replaced and Reliance’s role be limited to issues with the H6 hoist.

FLUOR DANIEL RIGGING ENGINEERS:

PREPERATIONS FOR THE 1991 OUTAGE:

As soon as the new FD CM was up to speed, he could tell that the structural department was behind on the rigging design. He was from the Fluor side of FD and had used our rigging engineering department many times. He immediately asked that two FD rigging engineers be assigned to the project to assume responsibility for all rigging design/operations, starting in January 1991 at the Chicago office and then going to the field in May to get ready for the 20 day outage in July. Bob Poirier and I arrived the same day and started reviewing the rigging procedures and drawings that the structural department were working on or had already completed. We found that the following major items needed to be revised:

1. The device that was proposed for down ending the SGLA on the pool covers was too high, ie, the H6 didn't have enough head room to lift the SGLA lower stand over the device. This device was already designed. But, it became a moot point when item 2 below was implemented.
2. In reviewing the current 60 day outage schedule for removing the two old SGLA's and installing the two new ones, we were concerned that there were not enough rigging operations listed nor not near enough time allowed for all of the rigging operations. We then went thru the printout of the schedule and added rigging operations and changed the durations to ones we felt were more realistic. This was based on our rigging experience, but as we did not have any nuclear rigging experience, we had one of our field superintendents who had a lot of nuclear experience look at it also. FD's field personnel were using a very sophisticated scheduling program, so we went to the lead scheduler and had him enter our revised rigging operations and durations to see how they fit with the other field activities for the outage. He then printed out a copy so we could see the results. The printout showed that we were beyond the 60 days allotted for the outage, due to many interferences with other critical path activities, especially those taking place on the pool covers and polar crane usage.

   With this in mind, we decided to see if there was another way to take the SGLA's out of containment. After pouring over all of the containment drawings, we decided that it would be feasible to lift a SGLA out of the block house, bridge the polar girders until the SGLA was in line with the equipment hatch, lower it down, hook a tailing assembly to the lower stand via a flange lug, down end it and pull it out of the containment building with pull jacks. We went over our proposed scheme very carefully before we presented it to the CM because 1) The $1,000,000 hard point steel would not be used and 2) as we did not have a tailing assembly, we would have to design & fabricate one at what we estimated was a $250,000 cost. When the CM saw that this scheme would shorten up the schedule and free up the pool covers 100 % of the time for other operations, he decided that the cost would be worth it. As you can imagine, he had to be a super salesman to sell this scheme to the NU Management, the FD Project Manager and the FD VP sponsoring the job because a lot of time and money had been spent on the other scheme. But in the end, they all agreed to it.

   This is the method that we used and is shown in the presentation #18 Removing A Steam Generator. Also, see presentation #19 Tailing Assembly For Steam Generator Removal that pictorially shows the details of the tailing assembly. By the way, the total cost of the tailing assembly was under $250,000. Now for the design details concerning the special tailing assembly. Bob Poirier and I conceptualized it and designed it. We started with a 600-ton crawler transporter rented from Lampson. We then designed a pocket framed out of W36 beams that was welded to a 1.75" thick x 10' ϕ plate. This plate was pin connected to the 11' ϕ turntable of the transporter so it could swivel. We designed a counterweight frame out of W36 beams that mounted on top of the pocket. We placed 120 tons of concrete counterweights on the frame. Down in the pocket of the frame and directly over the center of the turntable, we mounted a sheave nest made up of twelve 30" ϕ sheaves. The sheave nest was welded to the 1.75" x 10' ϕ plate. On the top rear of the counterweight frame, we attached a rectangular frame made up of W12 beams. The 12" frame was pinned to the 36" frame at the back end. We mounted a power unit with a hydraulic pump on the 12" frame near the back and a hydraulic winch at the front. We attached a hydraulic cylinder to the side of the front end of the 12" fame so that the frame could pivot from side to side around the pin at the back. The reason for the ability of the frame to move side to side was this:

   The horizontal distance from the centerline of the hydraulic winch mounted on the 12" frame to the stationary diverter sheave next to the sheave nest was 7'. The required distance for correct spooling on the winch was approximately 30'. So we chose to use a hydraulic ram to move the front end of the frame and the hydraulic winch as required so that the 1 1/8" ϕ winch line would spoon correctly. Both the spooling of the wire and the cylinder worked great. We designed the hydraulic cylinder so that it worked at about 25 % of capacity. The **Hanna Hydraulics Company** fabricated the cylinder for us.

Note in the presentation showing the details of the tailing assembly that there were two control handles for the operator located on the counterweight frame. One handle was to control the movement of the 12" frame side to side and the other handle was to control the hydraulic winch. A parabolic mirror was located such that the operator could see which way to move the 12" frame so the winch would spool correctly, without being in harm's way.

We next designed an 800 ton fulcrum stand equipped with eight 100 ton Hillman rollers under it. We then designed a 46' stinger beam that had a sheave nest made up of twelve 30" ϕ sheaves welded to the top end and on the bottom end it had a special tip with the 6" ϕ spherical bearing mounted in it. The rear end of the stinger beam with the sheave nest was placed directly over the sheave nest in the counterweight frame. The fulcrum stand was connected to the stinger beam 20' from the sheave nest. Two 8" ϕ pipe struts pin connected to both the counterweight frame and the fulcrum stand kept the fulcrum stand in place. We then designed a flange lug that pinned to the spherical bearing and would bolt to the lower nozzle on the SGLAs.

Note in the presentation for the steam generator removal that when the tip of the stinger beam was lowered down to the bottom of the equipment hatch in guiding the SGLAs out, that the sheave nest on the other end was high in the air, meaning that a lot of wire rope was let out from the hydraulic winch. With the slow winch speed and 24 parts of line, the movement of the tip of the stinger beam was slow and smooth.

As a side note, things did not always go according to the plan. The actual rigging operations in containment were controlled by Work Order packages. Every operation had to have one and if things did not go according to the WO, then the operation was stopped by QC, the rigging crew sent back to the change room to get out of their protective clothing and we started making the changes to the WO. We soon found out that we shouldn't write them to tight or we would be in danger of having something not go according to the plan and have the work stopped. One example was when Bob designed the fulcrum stand, we decided that we needed a guide rail to keep it in line with the centerline coming out of the equipment hatch, so we had a 1" half round bar stock tack welded to the steel plate leading from the equipment hatch and made a 1" radius at both ends of the fulcrum stand as guide slots. We didn't want to walk the tailing assembly on the steel plate but the structural department insisted that it be laid down over the poured concrete to spread out the load. When we were down ending the first old SGLA out of containment, we evidently didn't line up the fulcrum guide slots with the half round bar to good because just as the SGLA was in the horizontal and we were walking the tail assembly back, the fulcrum stand locked up against the guide rail and the tracks on the Lampson transporter started to slip on the steel plate. I wanted to throw some dirt between the tracks and the plate to increase the friction but no, QC said that the WO did not allow it. So we sent the crew to the change shack and proceeded to change the WO so that we could scarf the half round off the steel plate. Two hours later after changing the WO, getting it signed by half a dozen people and scarfing off the half round bar, we were able to complete moving the SGLA out of the containment building. We should have realized that once the load was on the fulcrum stand it was not going to veer off course. And it didn't. We just made sure in the future that we took a little more time in lining it up along the centerline.

3. The NU engineers had decided early on that the polar crane could not be tied up solely with the heavy lifts and had to be used as efficiently as possible during the outage, ie, the polar crane hooks could be used anywhere in containment and the piggy-backed H6 would just go along for the ride unless needed for a heavy lift. To make sure that this happened while dealing with the SD's, they proposed fabricating a square lifting frame made up of two jacking beams that would be supported by four hydraulic cylinders located on the four corners of the block houses. Slings would run down from the frame around existing trunnions on the SD and back up to the frame. The hydraulic cylinders would be extended until

the required force was obtained to keep the SD from settling and interfering with the cutting equipment. When the girth cut was completed, the polar crane would be centered over the SD, the spreader bar from the H6 would be hooked to the frame and would lift the SD out of the block house where it would be rolled 180° and set down in a special designed stand for tube refurbishing. Two lifting frames would be required, one for each SD. The above procedure was reversed when setting the SD's back into the block house and welding them to the new SGLA's. Figure 9 & photo 1 shows this procedure. Note the Electric Pedestal Crane (EPC) with the red 8' offset tip boomed down so the SD could be swung over it.

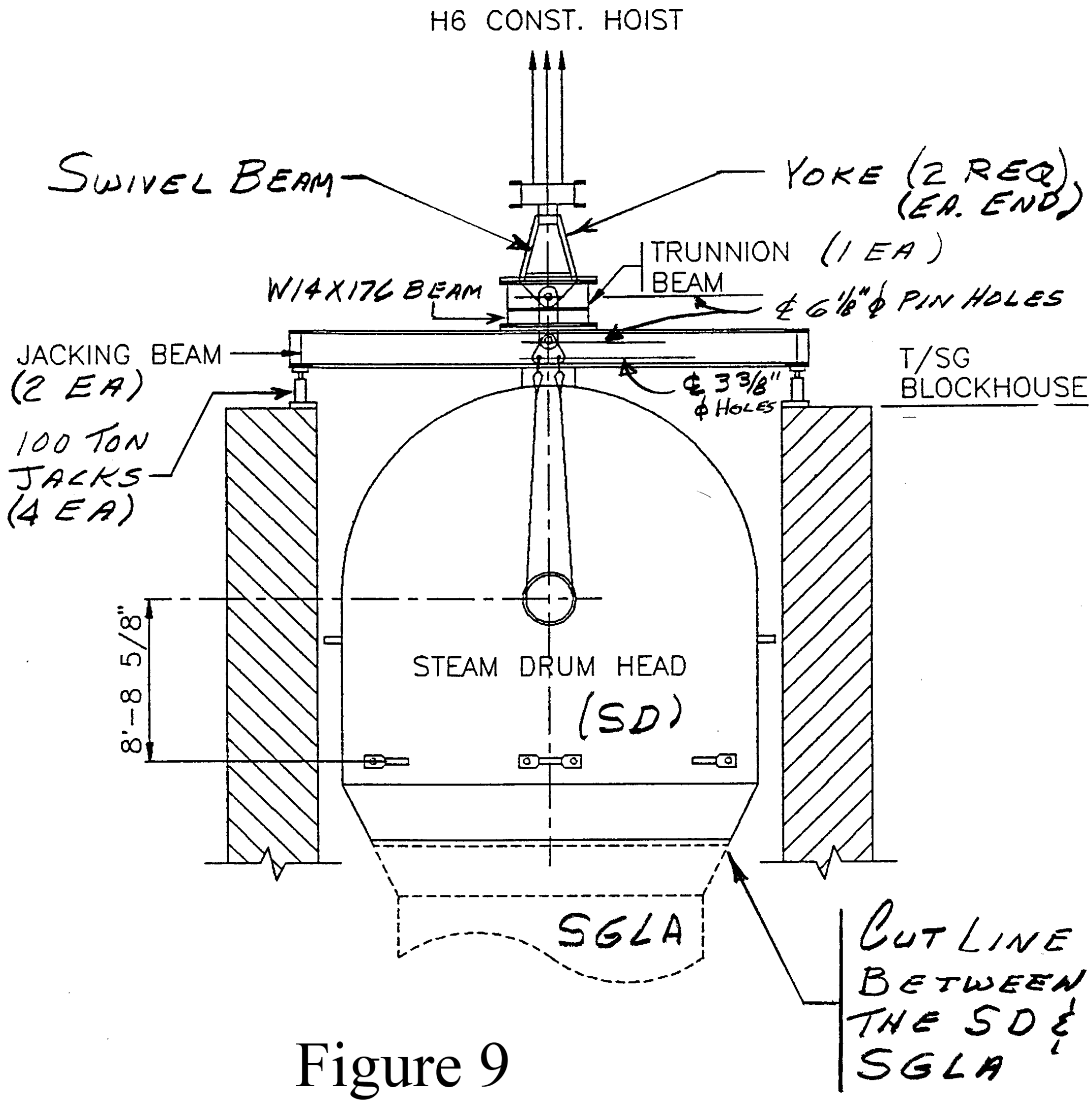

Figure 9

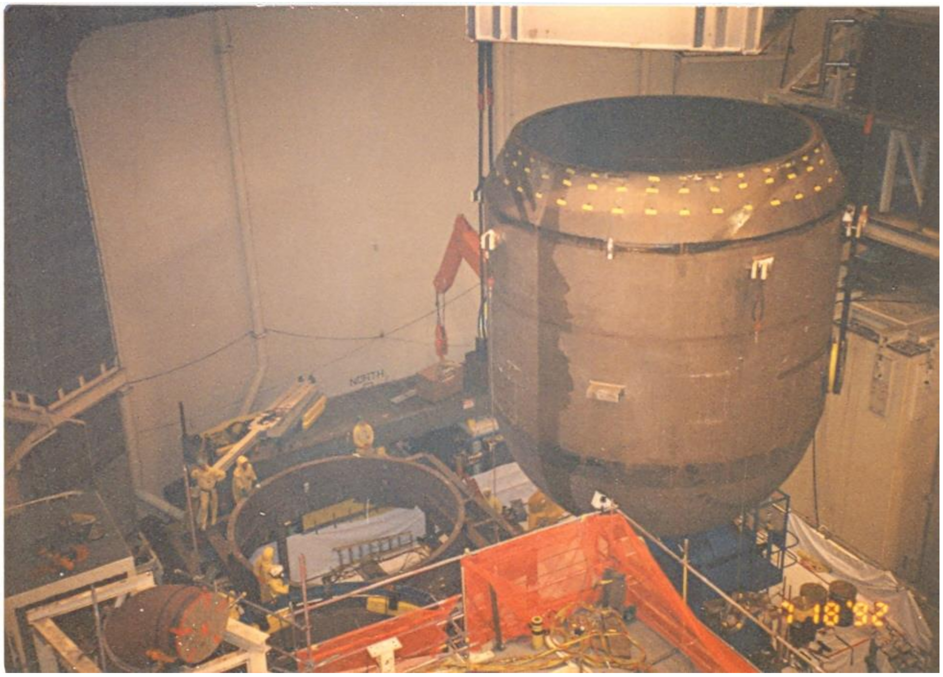

Photo 1

In reviewing the procedure for this operation, we noticed that the hydraulic cylinders that were proposed by the structural department had 60 tons of capacity and 4” of stroke. The weight of the old SD was estimated at 175 tons and the refurbished weight would be 210 tons. This meant that the jacks would be working at about 88% of capacity when holding the refurbished SD for the new girth weld. Also, having only 4” of stroke would not even take the stretch out of the doubled lift slings. We decided to change the procedure as follows:

a. Use four 100 ton jacks with 18” of stroke
b. Weld square steel posts at each of the four corners of the frame that would allow vertical movement but would restrict horizontal movement
c. Provide a large assortment of 12” square shims of various thicknesses that would be used to shim up under the frame at each corner when the calculated pressure was obtained. Also provide extra shims to be used under the cylinders if more stroke was required. More stroke was not required

We used the above changes and wrote the procedure around them. The actual holding of the SD’s with the hydraulic cylinders while the girth cuts and welds were made worked very well. We had good control maintaining the required gap and was able to adjust it very easily.

4. The procedure called for a 45 ton RT hydraulic Grove crane to be placed on the pool covers to be used as a general hook crane. We did not like the idea of a noisy internal combustion engine running 24 hours a day in the containment building even if the exhaust could be piped outside. Also, the 45 ton Grove crane took up a lot of space on the pool covers.

We did some research and found that Allied Systems Company from Portland, OR made electric pedestal cranes (EPC). We sent them our specifications which included a request for a 8’ tip offset at 75° from the centerline of the boom. They said the capacity for a straight tip was 45 tons but the offset tip reduced the capacity to 42 tons. They said that the cost to design, fabricate, test and ship to Waterford by late June 1992 would be approximately $250,000. We ran this request by the CM and he agreed to buy it based on our estimate that the resale value would be approximately 75% of the original cost.

The first items that were moved into the containment building at the start of the 1992 outage were the pool covers. Next was the EPC. We bolted and welded it to the pool covers and as they were so heavy due to being designed for down ending the SGLA's, we didn't even need extra counterweight. After this crane was installed, it was worked 24 hours a day for the full 60 day outage. See figure 10 that shows the drawing from Allied Systems that they provided to FD. Note that it shows the 8' offset tip.

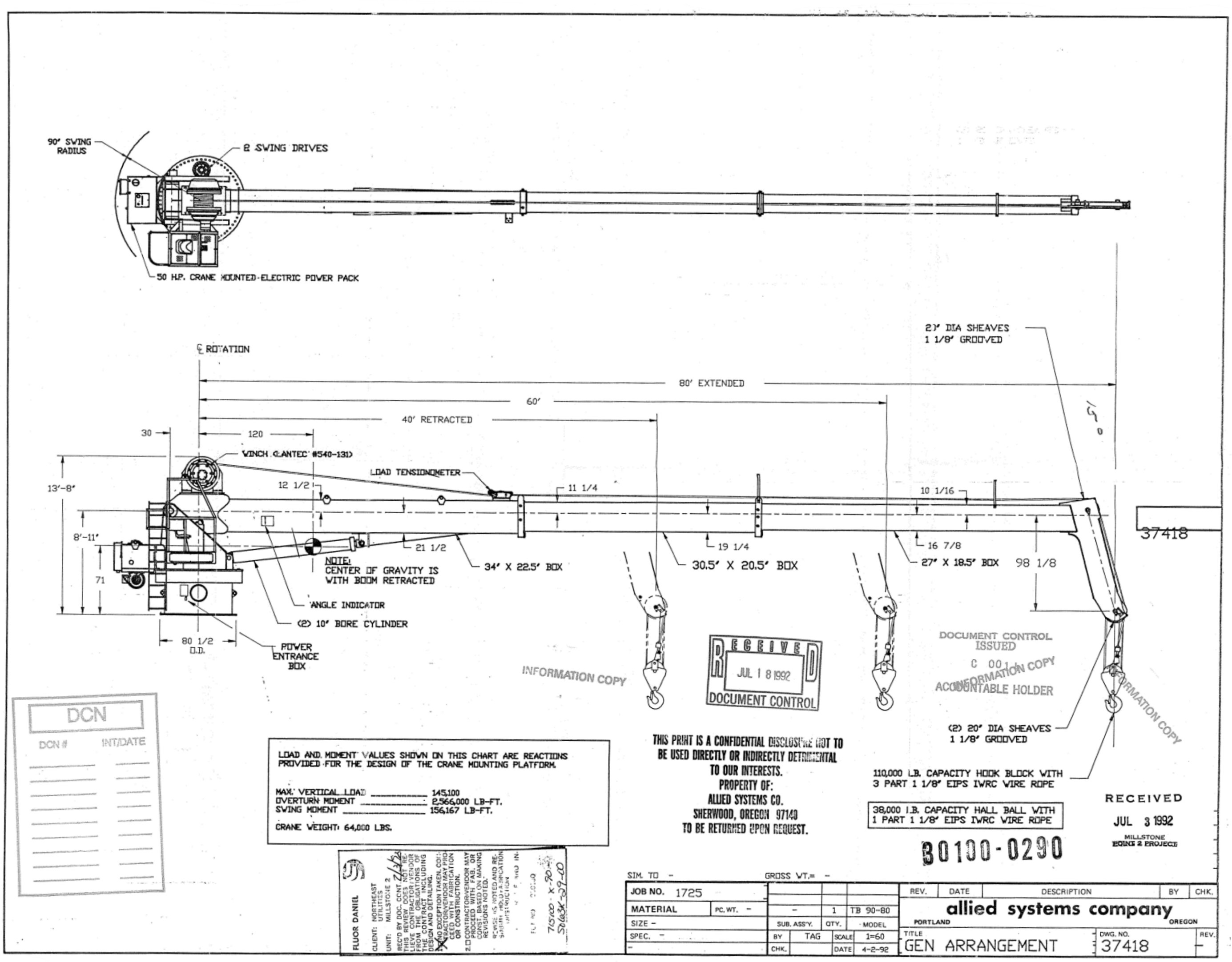

Figure 10

See photo 2 to see the EPC boomed down on the pool covers so a SGLA could be swung over it. The red boom section contains the 8' offset tip.

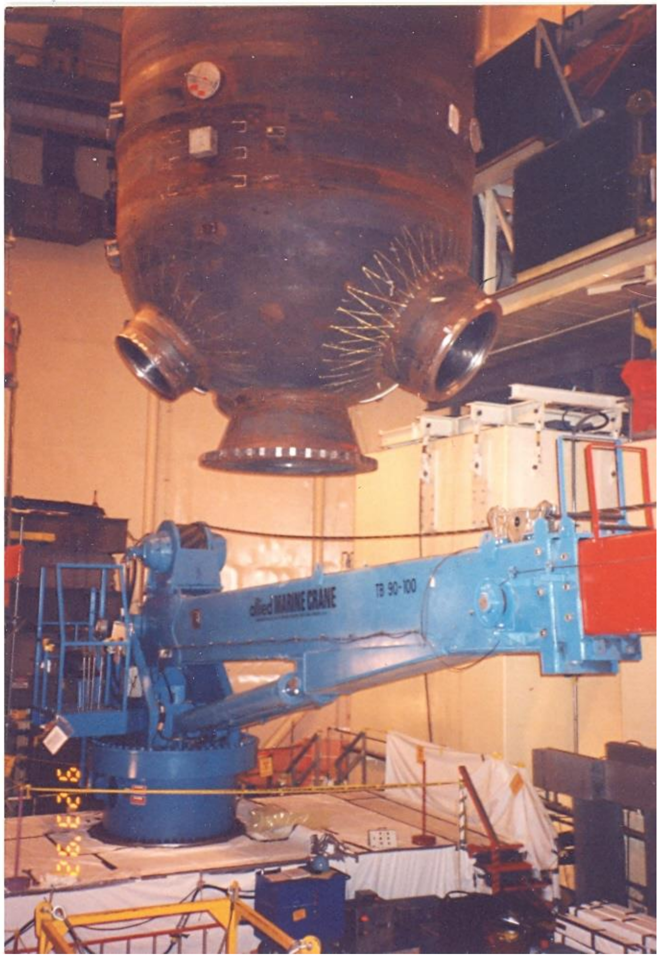

Photo 2

When the End Of Job report came out, it was voted as the most valuable piece of equipment on the job by NU and FD personnel.

As a side note, a contractor in the USA bought the EPC for 90% of the original cost. One day, a co-worker and I were talking to him and he made the statement that to make the EPC more useful and efficient, he had an 8’ offset tip fabricated for the boom. I thought long and hard before commenting on his remark, because when I was with Jake’s Crane & Rigging, he had broken his word and lied to me, costing Jake’s about $10,000. So I debated in my mind, do I say something or keep quite. After several nanoseconds, I decided that it was time to put him on the spot and I said “I know for a fact that you did not have the 8’ tip fabricated because I was at Millstone II and was involved in developing the specifications for the EPC and one of the items listed was for the 8’ offset tip. That ended our conversation and I haven’t spoken to the man since. The moral of this story is you shouldn’t brag about something if it isn’t the truth and you don’t know who you are talking to.

5. This item did not have anything to do with the structural department’s procedures, but when we went to the field for the 1991 outage, we noticed a lot of crated and boxed material being handled by small cranes and fork lifts that wouldn’t reach all the way under the wider crates. We decided that one big fork lift would replace a lot of this equipment and do it easier and smoother. We contacted the Taylor Fork Lift Company and got the specs for their 35 ton fork lift. As the fork lift had 8’ tines or forks, we made a rough design for a set of 14’ forks that would slip over the 8’ forks. We then asked Taylor if we bought the fork lift if they would develop a capacity chart for 7’ measured from the mast and include the ratings on one plaque along with the chart for 4’. They said they would be glad to, so we again went to the CM and laid out our recommendation with an estimate of a 75% resale.

He agreed to buy the forklift and with a copy of the capacity chart in hand, we finalized our design of the 14' forks. Shortly after the 1991 outage, the brand new bright red 35 ton fork lift arrived at the site. We installed the 14' forks, load tested them and put the fork lift to work. Of course, it was dubbed "big red" and proved to be extremely valuable offloading wide crates, boxes, equipment and even delivering them into the equipment hatch for the full year before and during the 1992 outage. In the End Of Job report, it was listed as the second most valuable piece of equipment on the job. As big red was in almost perfect running order, it was resold at 95% of original cost. See photo 3 that shows Big Red moving equipment into the containment building.

Photo 3

RIGGING DESIGN:

During the 1991 outage, Bob and I spent a considerable amount of time in the containment building measuring and doing layouts to support our proposed method of removing the SGLA's from the containment building. When we were sure that our initial assumptions were correct, we were ready to begin the rigging design in earnest for the 1992 outage. As neither one of us was a registered professional engineer (PE) we had to have our calculations signed off by the head of the structural department in Chicago, who was registered in Connecticut. We decided that with so much design ahead of us with about one year to finish it, that we would each do design work, have a structural engineer check our work and then have the head of the structural department sign off on the calculations. We decided to split up the design work as follows:

Review of the Reliance Beam	Bob
Design of the yokes for the above beam	Bob
Design of the large eye bars	Kent
Design of the flange lug for the SGLA lower stand	Bob
Design of the counterweight carrier for the tailing assembly	Kent
Design of the fulcrum stand for the tailing assembly	Bob
Design of the stinger beam for the tailing assembly	Kent
Design of the work platform around and between the SD's	Kent
Design of the rigging for the jacking frame for the SD's	Bob
Design of the jacking system for the SD's	Kent

Design of other smaller lifts	Bob & Kent
Writing Request For Quotes (RFQ's) for fabrication of rigging gear, ie, eye bars, flange lug, frames, jacking system, slings, etc.	Bob & Kent
Writing RFQ's for all purchased/rented rigging related equipment, ie, EPC, Big Red, Lampson transporter, etc.	Bob & Kent
Writing load testing procedures for all of the above equipment	Bob & Kent
Writing RFQ's for the load testing of above equipment*	Bob & Kent
Evaluating all RFQ's from a technical stand point	Bob & Kent
Writing WO packages for all rigging operations in containment	Bob & Kent

*All lifting equipment, except the tailing assembly, was shipped from the fabricators to Coordinated Equipment in Wilmington, CA to be load tested. The tailing assembly was load tested on site. See photo 4 to see one of the large eye bars being load tested.

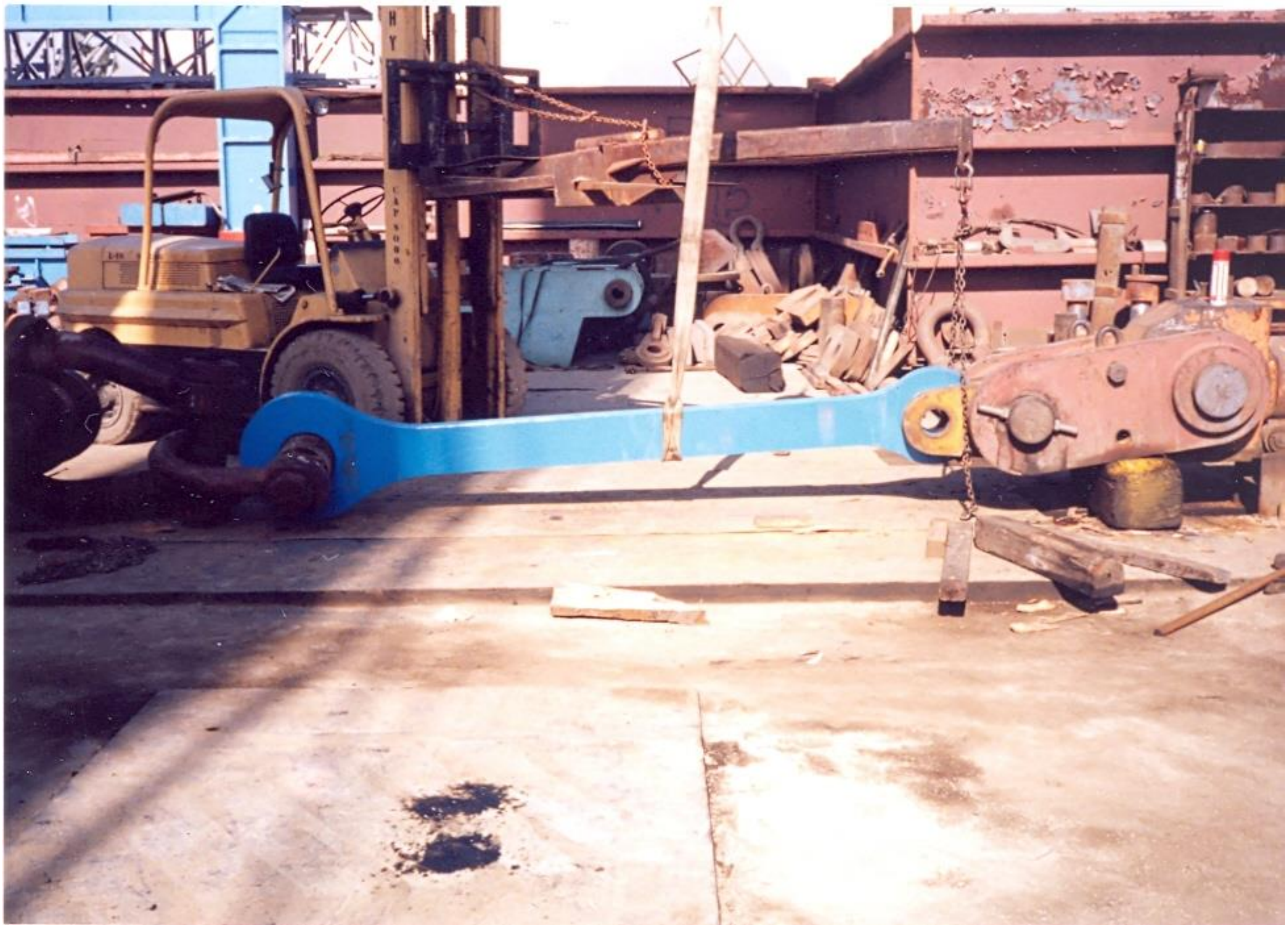

Photo 4

See photo 5 to see the Reliance beam and yokes being load tested.

Photo 5

SUMMARY:

The purpose of this presentation is threefold:

1. To show that rigging concepts and procedures must first be well thought out and developed before design even starts. If they are not, then the designs will probably have to be revised or scrapped altogether.
2. To show the amount of rigging engineering design involved in a Steam Generator change out.
3. To set the stage for showing the actual calculations for several of the above designs, ie, to show the methods, steps & requirements involved in rigging design for nuclear application. For example:

    a. Design of the large eye bars for lifting the SGLA's
    b. Design of the stinger beam for the down ending assembly
    c. Design of the temporary work platforms for the steam drums

    See presentations # 20, 21 & 22 for the above designs.

THE END