INTRODUCTION
TO
RIGGING ENGINEERING

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SLIDE SHOW INSTRUCTIONS

1. **The slides will automatically advance every 25 seconds**
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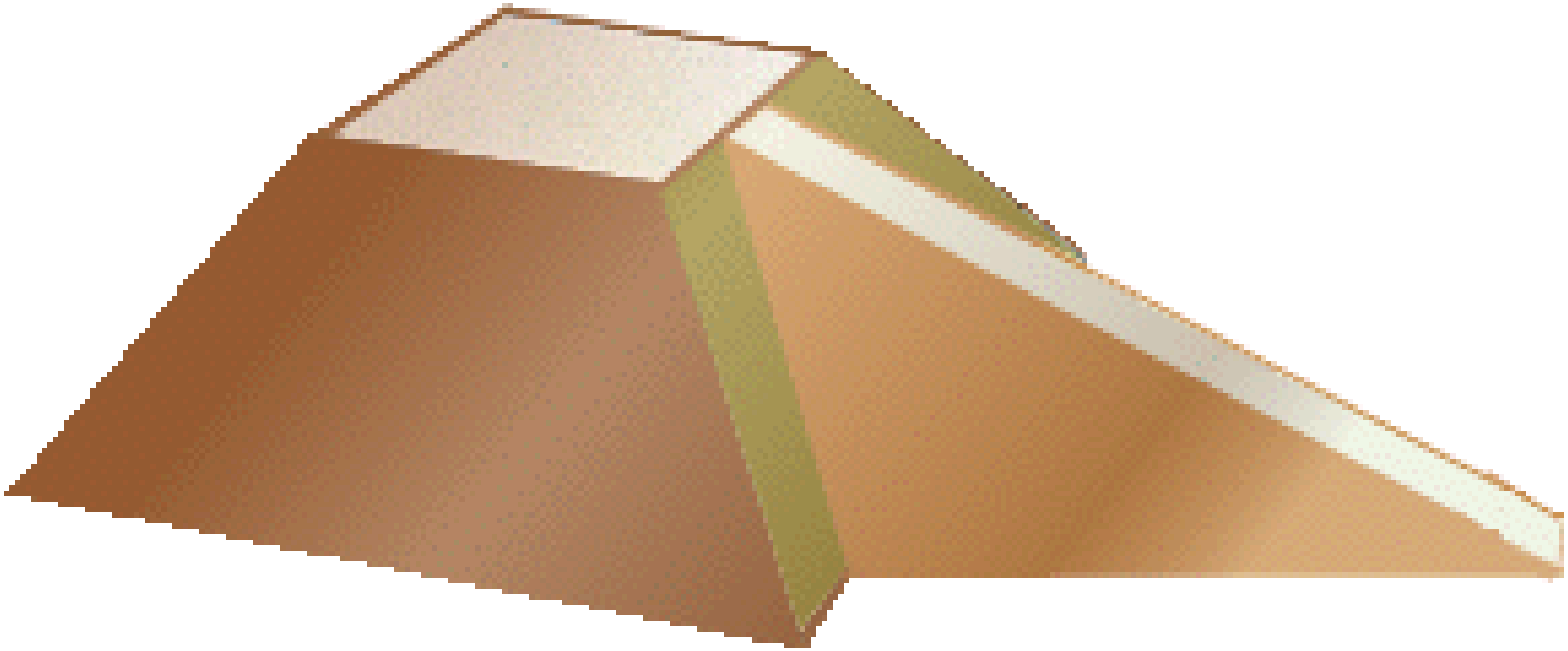
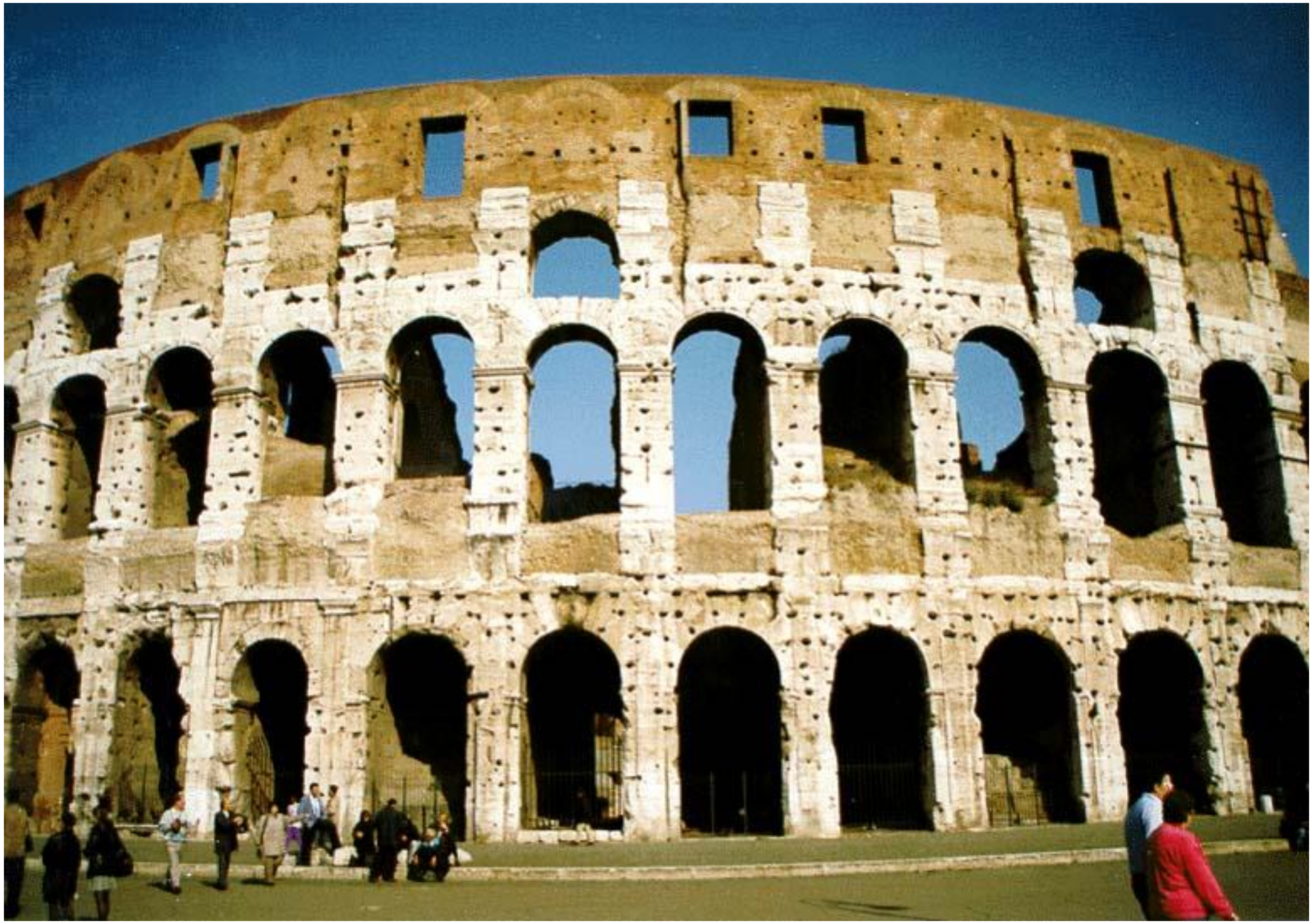
RIGGING:
Moving a block of stone up a ramp in the construction of a pyramid



RIGGING:
Building a coliseum



RIGGING:

Guying off the masts on wooden ships. The word "rigging" came from this type of work on wooden ships.

RIGGING:
Using block and tackle to hoist the sails

DEFINITION OF FIELD RIGGING

Field rigging is where the design & execution of the transportation and lifting on a project is done by the crane operators, riggers, rigging superintendents and area superintendents.

Until the late 1960's, most of the rigging done in the USA, and probably around the world, was done as Field Rigging.

There were a lot of accidents associated with field rigging. Thus the need for rigging engineering became apparent.

FIELD RIGGING

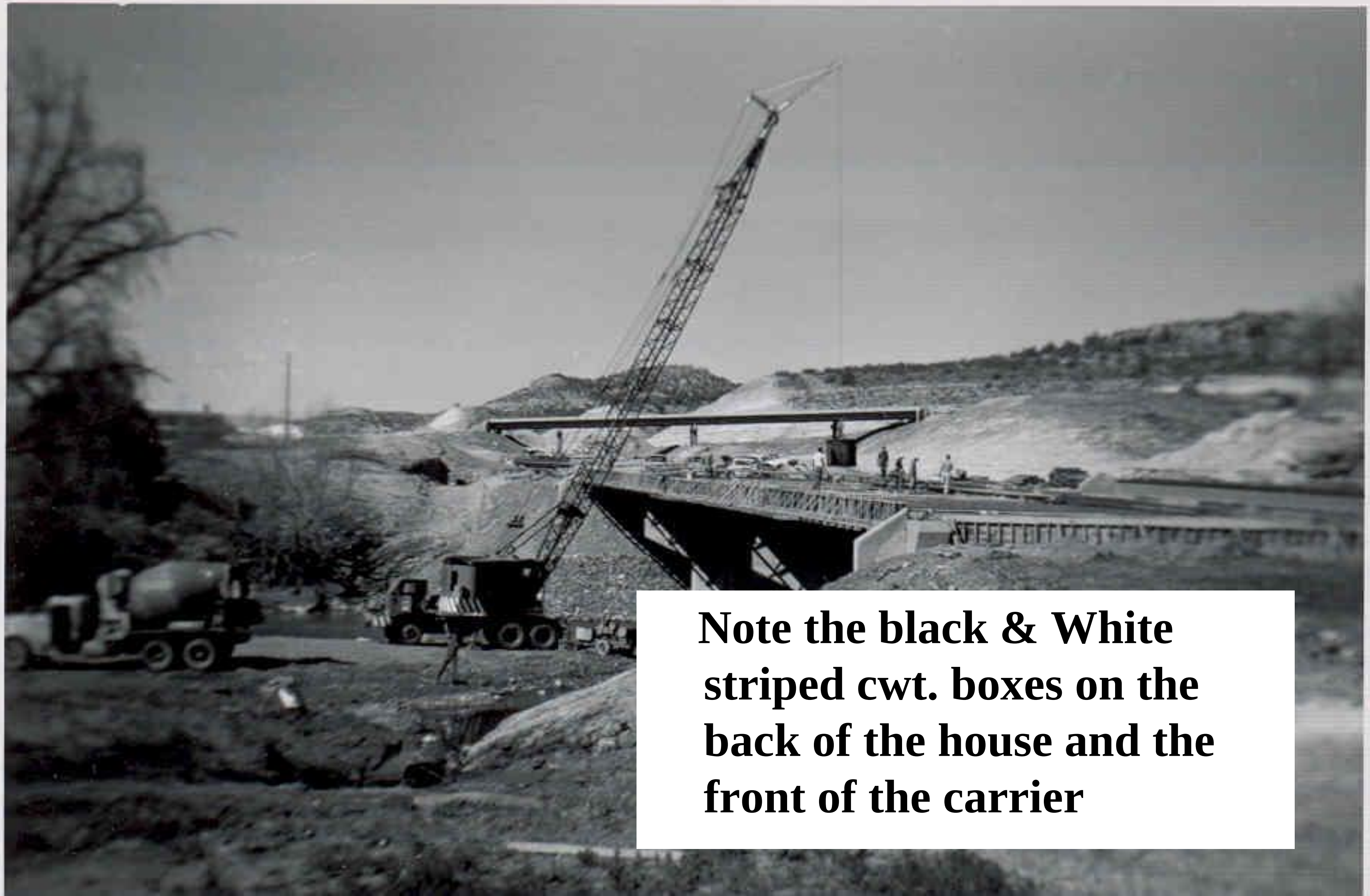
Personal account of bad field rigging

The first crane operator that I oiled for, fabricated and installed a counter weight box on the back of the house on a 20 ton crane and one on the front bumper of the carrier. Each box was then filled with 5.0 tons of metal punches. This increased the lifting capacity of the crane to somewhere between 25 and 30 ton.

The house of this crane was held on to the carrier by one hook roller in front and two in back.

This modification was not done with the approval of the crane manufacturer.

APR • 60



Note the black & White striped cwt. boxes on the back of the house and the front of the carrier

FIELD RIGGING (continued)

Personal account of bad field rigging

We later used this same modified 20 ton crane to set 48 ea. 20 ton pre-stressed beams. When erected, each beam set on one sliding and one fixed bearing plate. The crane operator stacked all 96 bearing plates on the counter weight box of the crane. This added about 2.5 tons of cwt to the 10 tons already in both cwt. boxes.

The hardest to reach beams were set first. Each time a beam was set, two bearing plates were removed from the cwt box. I can't believe that we never had a component failure, but it must have been because cranes were over designed in those days.

FIELD RIGGING: Setting 48 Prestressed Girders

Young Kent Goodman

RIGGING ACCIDENTS

Normally, rigging accidents are not caused by one factor alone.

If two or more negative factors line up in the same direction, then an accident is bound to happen. Murphy will make sure that it does.

Following are three examples of lifting accidents and the contributing factors.

FIELD RIGGING ACCIDENT # 1

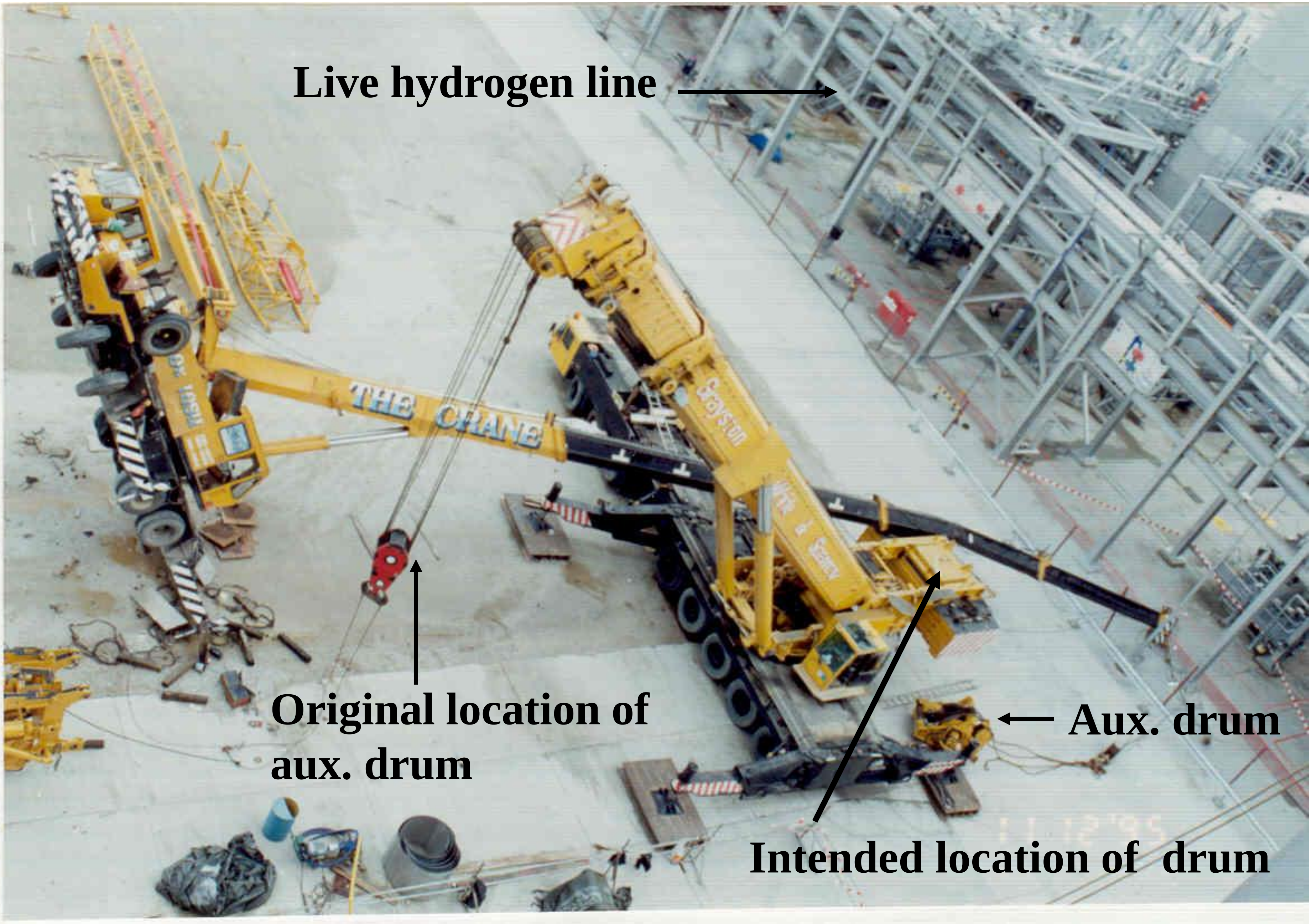
50 Te Crane turned over on top of a 400 Te crane during the installation of a luffing jib. One rigger was seriously injured

CONTRIBUTING FACTORS:

1. **The rigging crew partied late the night before the accident**
2. **The crew did not have a clear work plan**
3. **The crew thought the weight of the aux. drum assy. was 1 Te. It actually weighed 5 Te**
4. **The LMI of the 50 Te crane was inoperative due to a jumper wire installed by the operator**
5. **The radius of the 50 Te crane could have been reduce by swinging the house of the 400 Te crane 180 degrees**

NOTE: Boom missed a live hydrogen line by about 1'

50 Te Crane turned over on 400 Te crane



FIELD RIGGING ACCIDENT # 2

BOOM DROPPED ON A LINKBELT LS-718 RINGER OWNED BY A HEAVY LIFT CONTRACTOR (HLC):

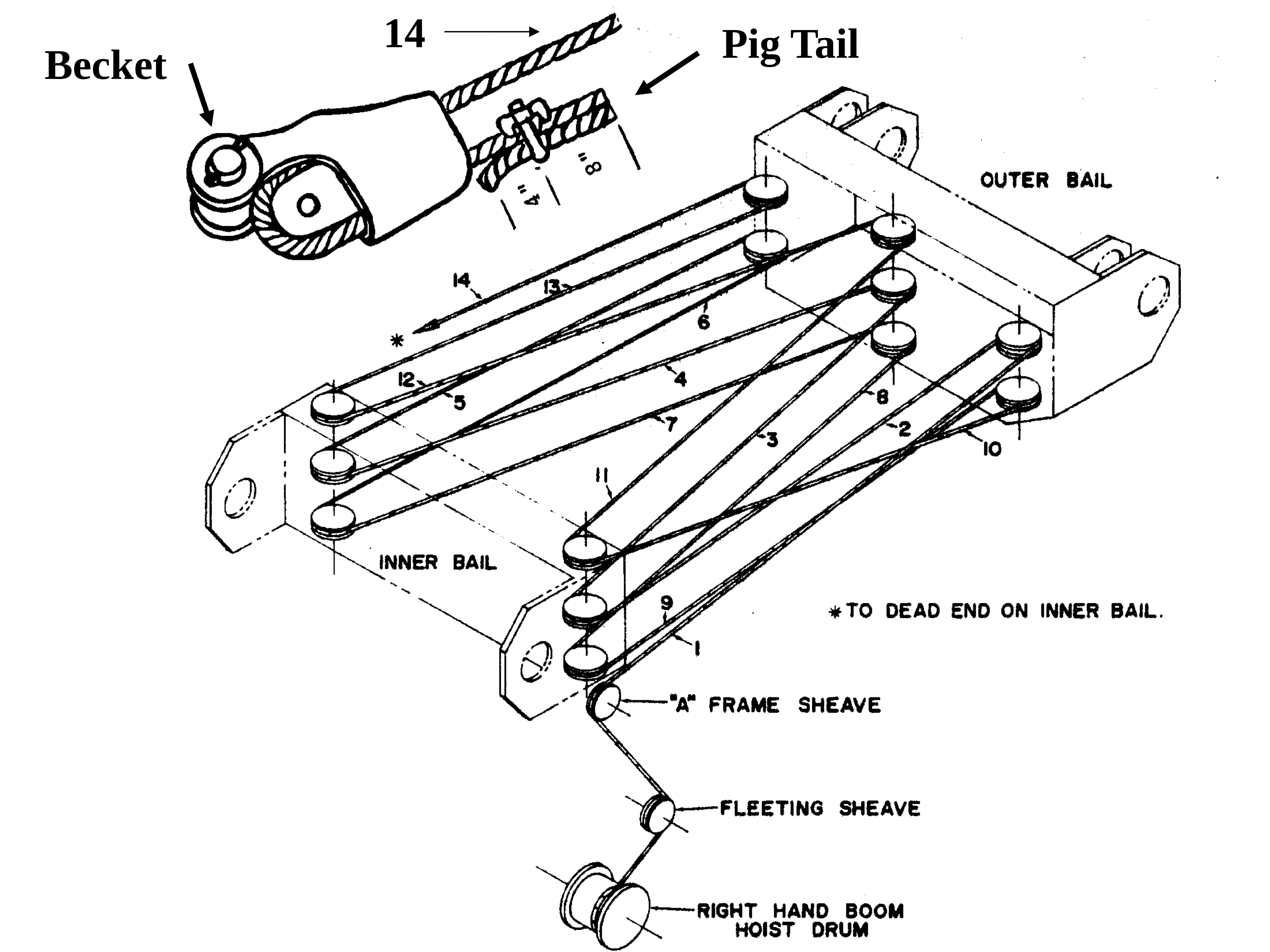
- The HLC was asked to make a long radius load test
- This was done to proof the assembly of the crane
- A 60 ton steam drum was used as a test weight
- A HRSG module was parked next to the crane
- Boom dropped before the test radius was reached
- No one was injured

CONTRIBUTING FACTORS:

a) The wrong Becket was used to dead-end the boom line

b) The erection crew was in a hurry to complete the assy. and did not install a cable clamp on the pig tail


VICON
360 ton Ringer crane accident



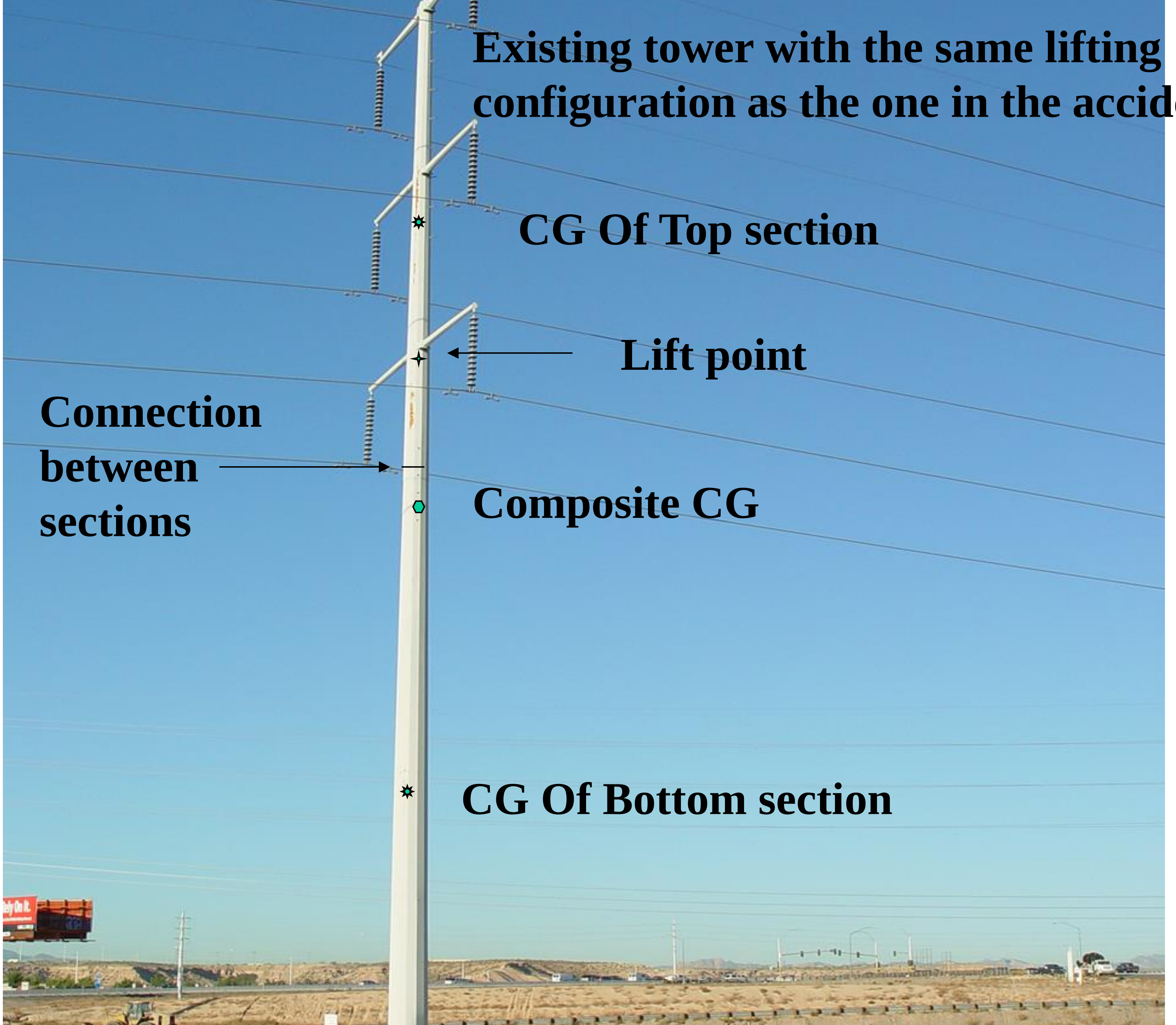
Becket
14
Pig Tail
4"
8"
OUTER BAIL
14
13
6
*
12
5
4
8
7
3
2
10
11
INNER BAIL
9
1
* TO DEAD END ON INNER BAIL.
"A" FRAME SHEAVE
FLEETING SHEAVE
RIGHT HAND BOOM HOIST DRUM

HRSG module parked in the wrong spot

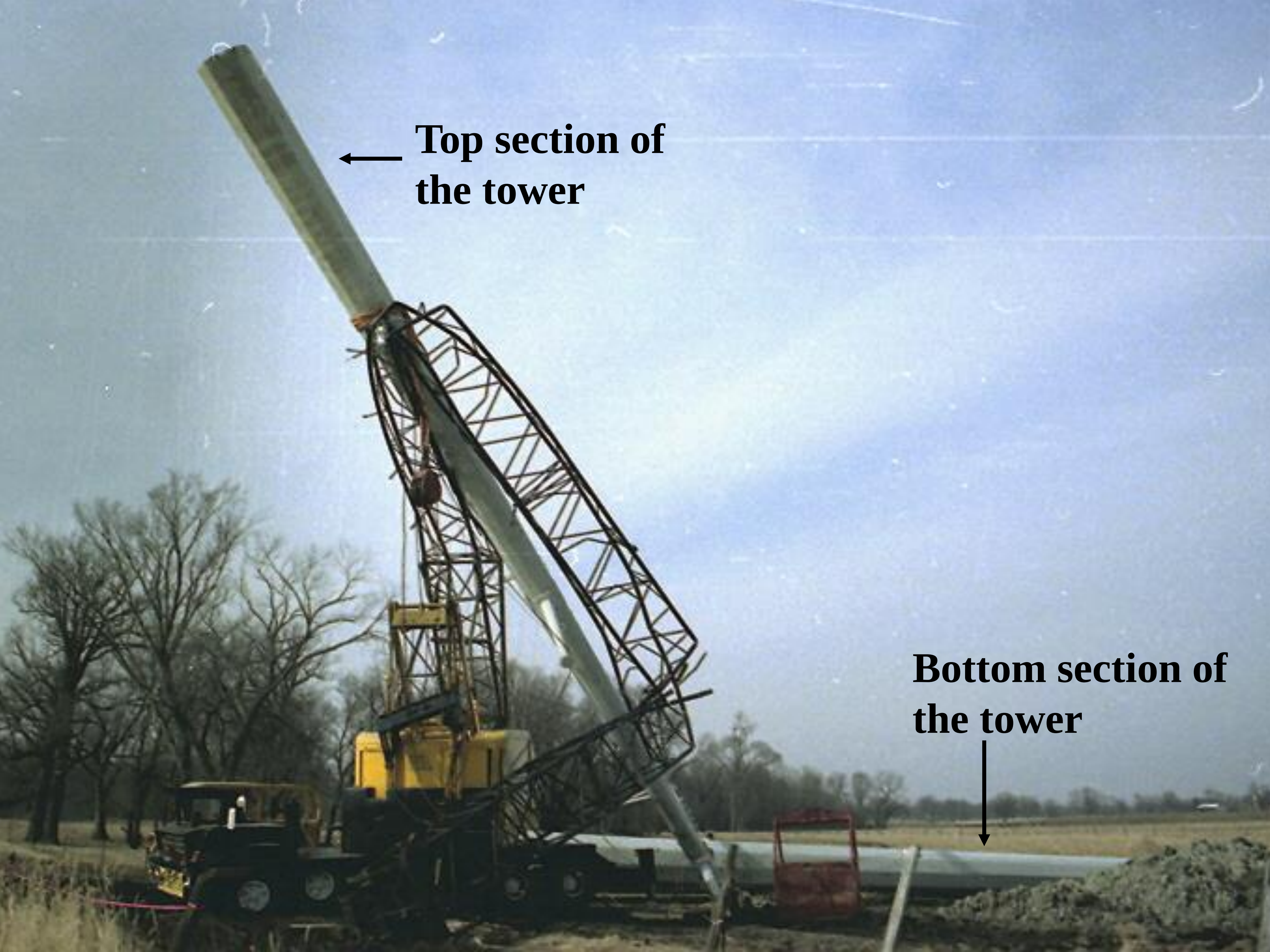
FIELD RIGGING ACCIDENT # 3

BOOM BUCKLED LIFTNG A TOWER:

1. A 125 ton truck crane was lifting a two section electrical transmission tower. The pick point was just above the connection
2. Just as it was upended, the the bottom section fell off, moving the location of the CG above the lift point
3. The top section did a 180 degree loop and twisted the boom off the crane. No one was injured
4. CONTRIBUTING FACTORS:
   a) The rigging crew relied on a pressed fit and friction to hold the two sections together.
   b) The sections should have been welded or bolted together



Existing tower with the same lifting configuration as the one in the accident
CG Of Top section
Lift point
Connection between sections
Composite CG
CG Of Bottom section


Top section of
the tower
Bottom section of
the tower

FIELD RIGGING Vs Rigging Engineering

Now days, the <u>heavy lifts</u> on projects are classified as "Engineered Lifts" which requires the expertise of a Rigging Engineer and the design and development process is called "Rigging Engineering".

The remaining lifts on the project are classified as "Field to Rig", and these lifts are performed by field rigging personnel as discussed earlier.

QUALIFICATIONS OF A RIGGING ENGINEER

1. Must be a graduate engineer from an accredited four year program.
2. Must have received a minimum two years training in a Contractor's recognized and structured rigging program.
3. Proficient in steel and timber design
4. Proficient in stress analysis
5. Has the experience and knowledge to design, evaluate, plan, oversee and estimate transportation and lifting activities during any phase of a project.
6. Must have practical experience with lifting equipment such as cranes, jacking systems, skidding, rolling, trailers, etc.

RIGGING ENGINEERS

Rigging Engineers (RE) usually choose one of two areas of expertise:

1. RE's in the first area work for Engineering Procurement Construction (EPC) companies. They are responsible for the rigging design and handling of the heavy lifts from the fabrication shop to the foundations at the site.

   Their work starts at the same time as home office engineering starts, about 1.5 years before field construction starts. This much lead time is required to complete the necessary rigging steps that must fit together for the heavy lifts to be completed.

   There are less than 100 RE's in this area in the world.

RIGGING ENGINEERS (Cont.)

2. RE's in the second area of expertise work for Heavy Lift Contractors (HLC) and their responsibilities start when EPC contracts are issued with a scope of work that says something like "Assume care, custody and control of the vessel at the dock, move it to the site and set it on the foundation. Provide all equipment, supervision, rigging drawings, etc, that are required".

   All of the HLC rigging drawings are reviewed and approved by the EPC Rigging Engineers.

   There are more than 5,000 RE's in this area of expertise in the world.

PURPOSE OF RIGGING ENGINEERING

Support Project, Engineering and the field Construction staff in the safe and economical transportation from the fabrication shop and installation of all heavy plant equipment with the smallest amount of RISK possible.

SERVICES PROVIDED TO PROJECT

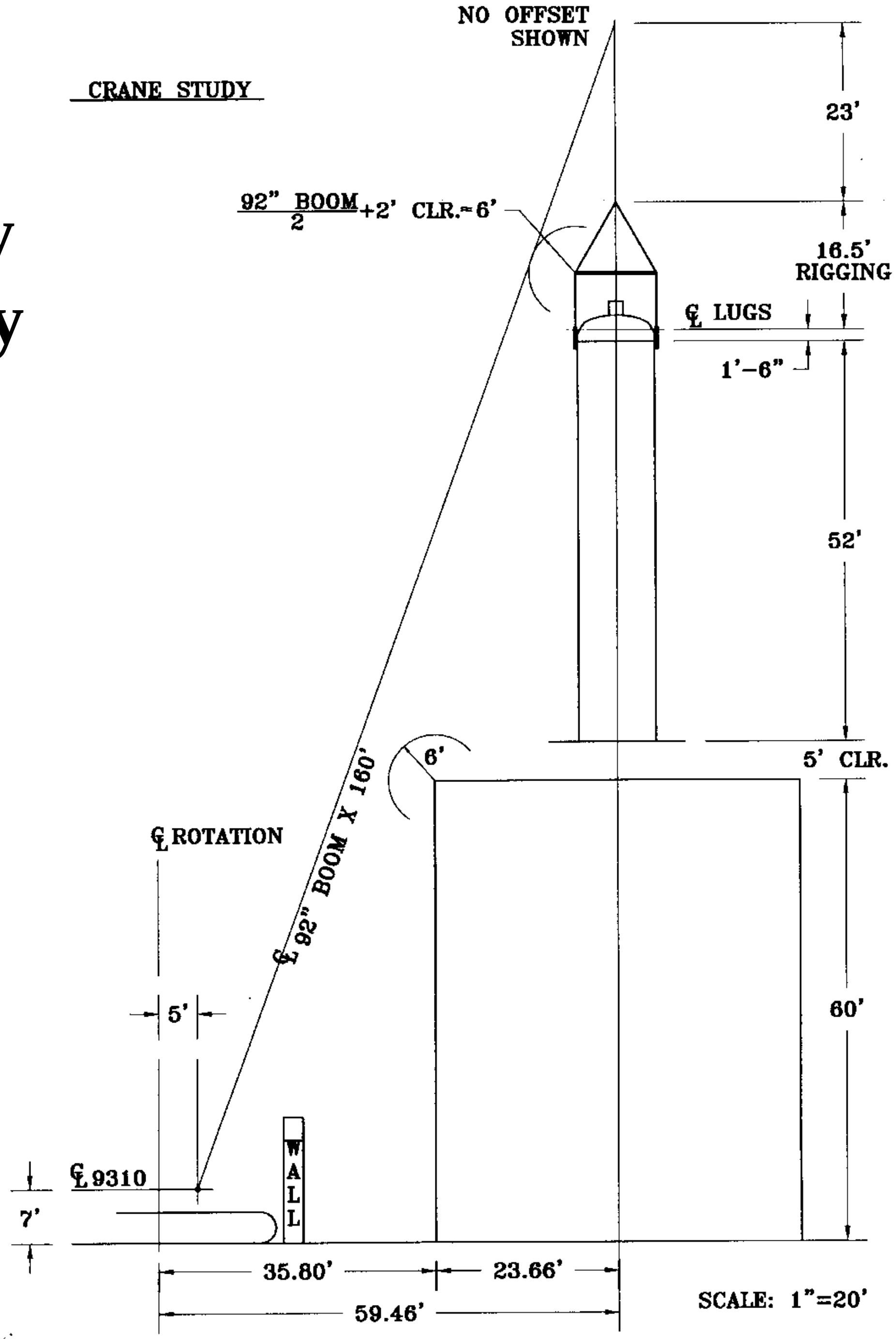
- Heavy transport and lifting studies
- Preliminary plot plan review (Constructability)
- Preliminary cost estimate for heavy transportation and lifts

SERVICES PROVIDED TO PROJECT: Continued

- Rigging input for the Request For Quotes (RFQ's) for heavy lift & transportation equipment
- Technical evaluation of RFQ's
- Transport and lifting equipment recommendations to construction management
- Note: The above happens up to 1.5 years before field construction starts on a project

Preliminary Crane Study (Typical)

Minimum head room required = 21'

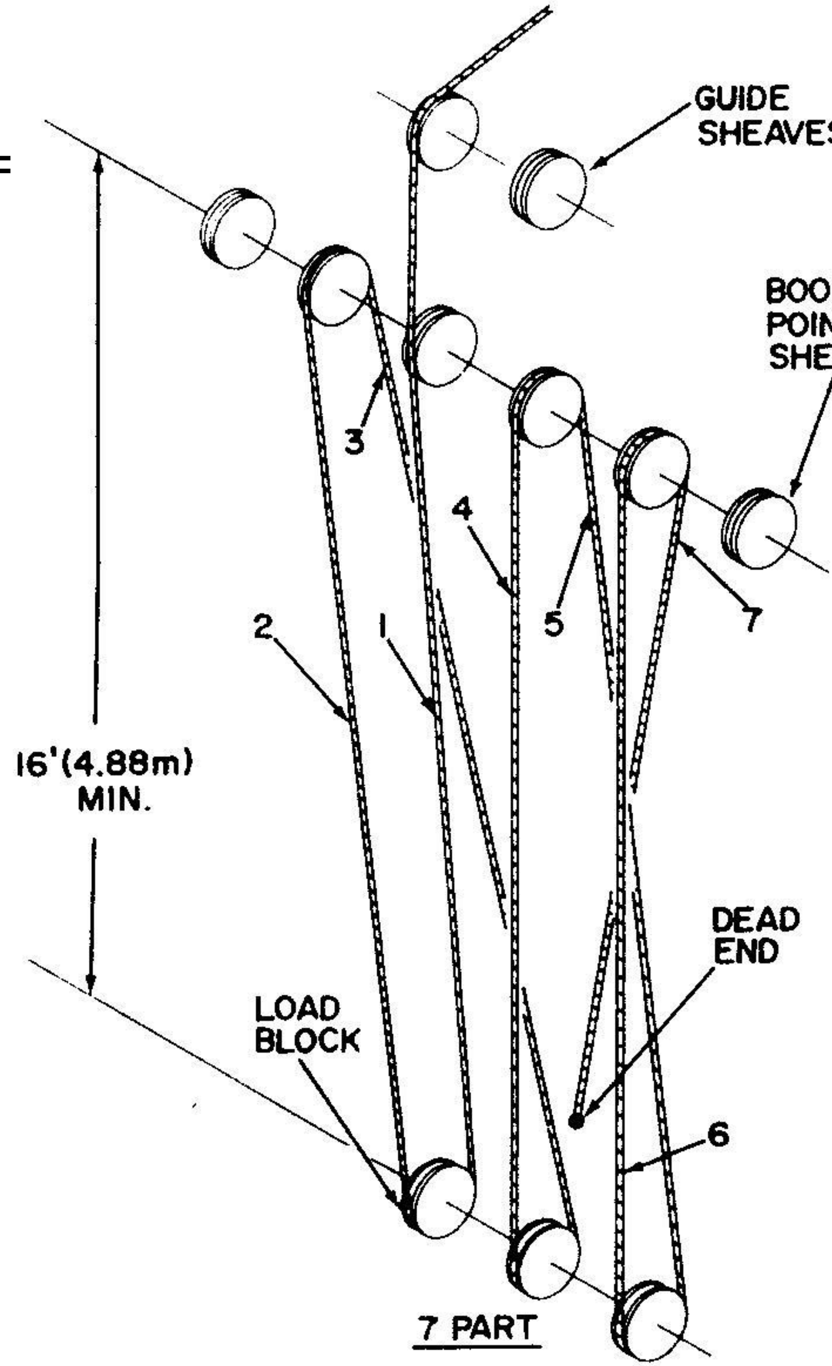


TALKING POINTS

- Boom Clr. = 2'
- Vertical Clr. = 5'
- Two-Block = 16'
- Radius is the name of the game
- 80% Chart

Minimum two-block distance = 16'

Based on a max. fleet angle Of 2.9 degrees



Minimum head room required = 16' + 5' down to bearing on the hook = 21'

This is a reeving diagram, not a lacing diagram

CONSTRUCTABILITY

A soon as the Process Engineers and Piping Engineers have developed a plot plan and the Vessels Engineers have preliminary vessel outline drawings, the Rigging Engineers start doing Crane Studies. Following is a typical constructability example.

The Rigging Engineer's crane studies showed that to set the heavy vessels for this project, an 800 Te crane would be required. The crane would have to be set up three times and there would be many HOLDS, ie, equipment and structures that couldn't be set until after the heavy vessels were erected.

The Rigging Engineer's then made crane studies to see what would be required to eliminate the "holds" as this project was on a fast track.

Their studies showed that a 1,200 Te crane could be used to set all of the heavy vessels from one set up if the following changes to the plot plan were made:

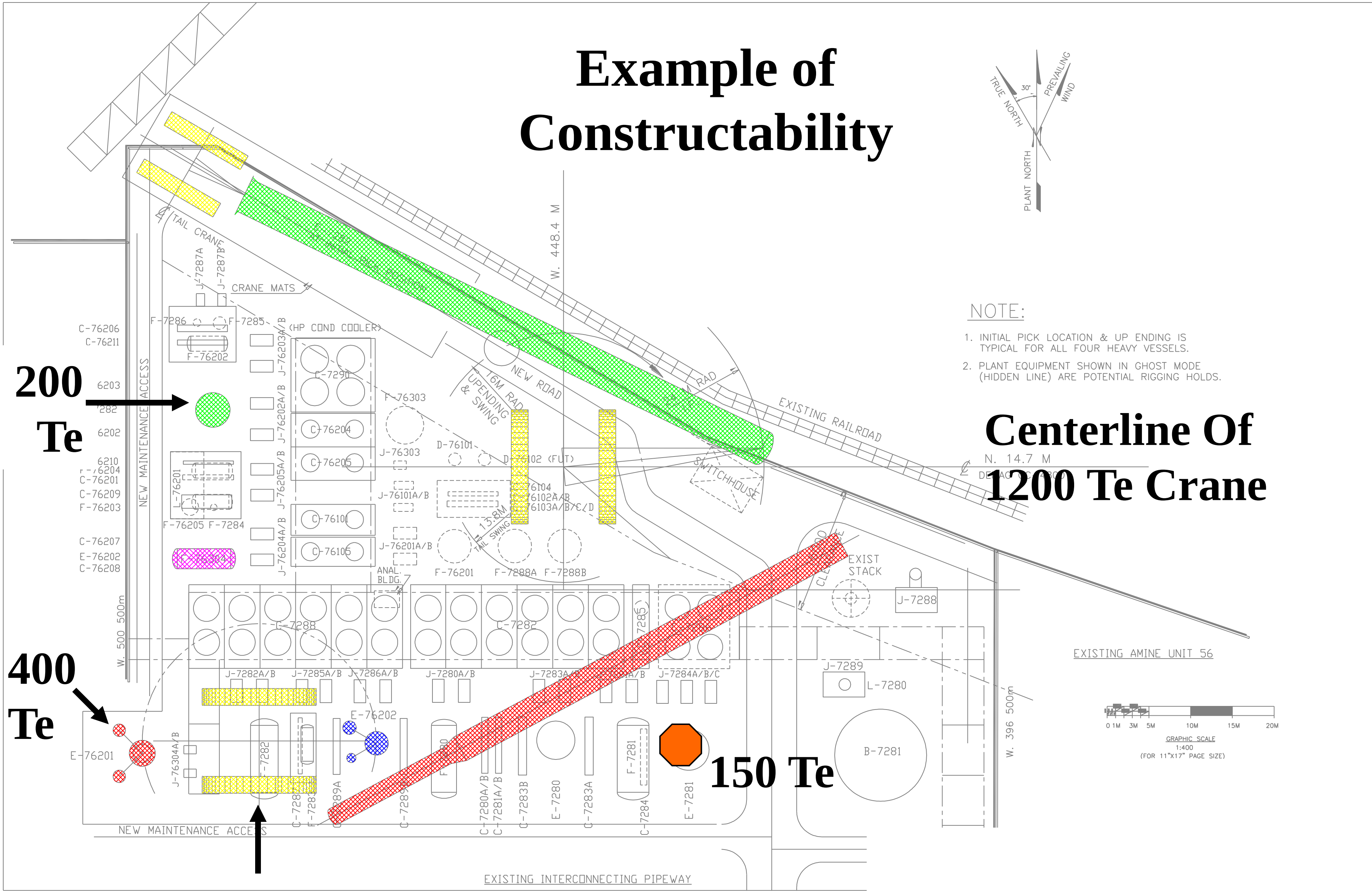
Constructability Continued:

1. Move the 400 ton vessel to the location of the 200 ton vessel
2. Move the 200 ton vessel to the location of the 150 ton vessel
3. Move the 150 ton to the original location of the 400 ton vessel
4. Construct a lift pad for the 1,200 Te crane by driving piles and pouring a concrete cap over them. The pump foundations in the lift pad area could be poured as soon as the heavy vessels were set

The Process Engineers looked at the requested changes, found that they didn't effect the process, so they approved the changes

The Cost and Scheduling Engineers said that by eliminating all of the HOLDS except the pump foundations, it would save almost two months off the schedule and about $4,500,000

Example of Constructability



800 Te Crane set up, typical three places

SERVICES PROVIDED TO ENGINEERING

- **Lift attachment design**
- **Local stress analysis due to forces from lugs**
- **Squad check reviews**
  - **a. Lift attachment review of Vendor's design**
  - **b. Review of Vendor's method of erection**
- **Provide dimensions and ground bearing pressures for the heavy lift cranes & trailers**

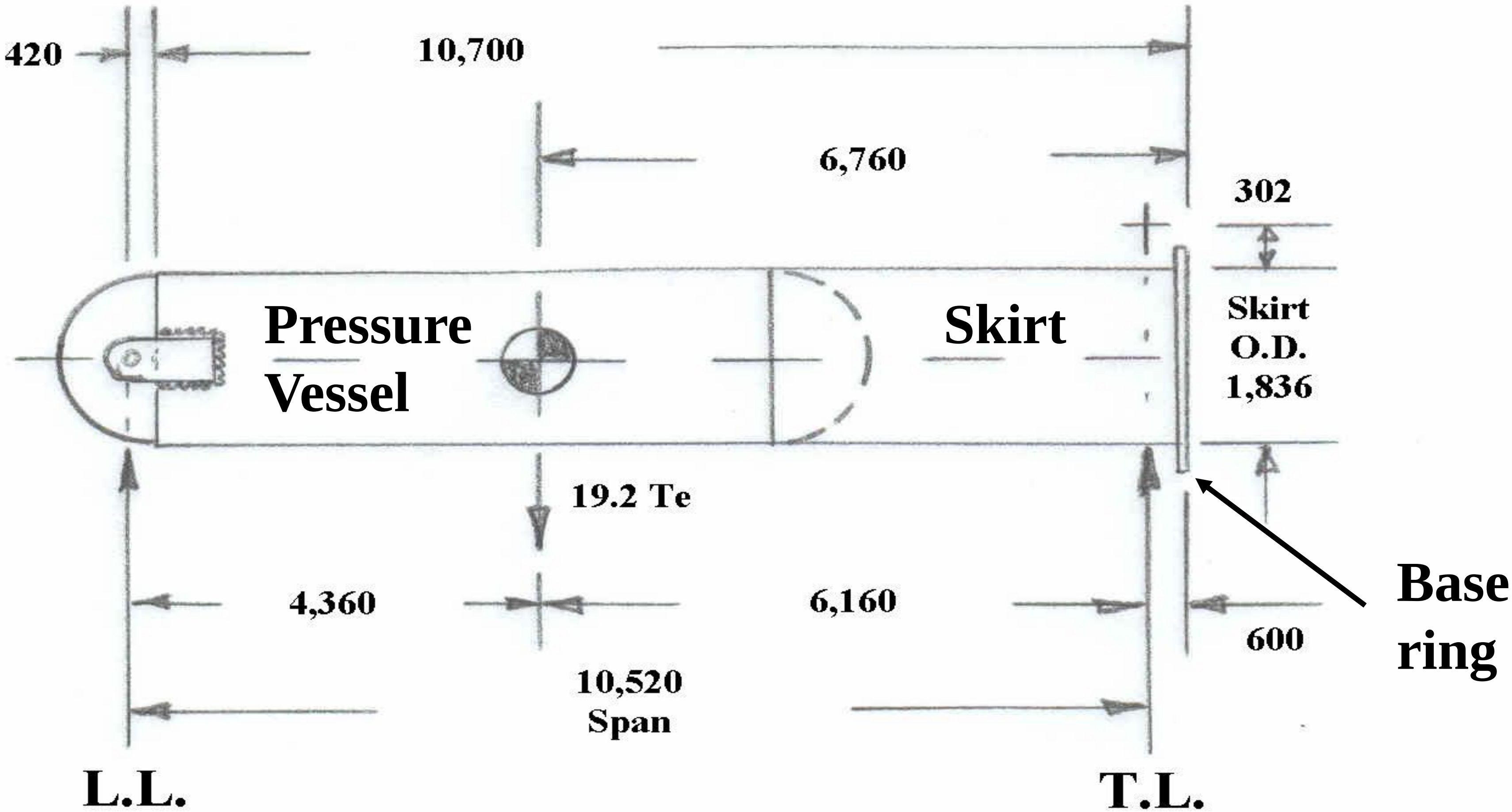
SERVICES PROVIDED TO CONSTRUCTION

- Rigging studies
- Interference drawings (showing all holds)
- Rigging drawings
- Field support
  - Route or transportation surveys
  - Lifting surveys
  - Lift supervision

LIFT ATTACHMENT DESIGN

1. Lifting lugs (pad eye, top head, cone)
2. Side lugs
3. Trunnions
4. Flange lugs
5. Equalizer beams
6. One Point Pick Device (OPPD)
7. Side hitch plates
8. Tail lugs and base ring reinforcement
9. Spreader bars
10. Tie downs

Some examples of each follow.



VERTICAL VESSEL

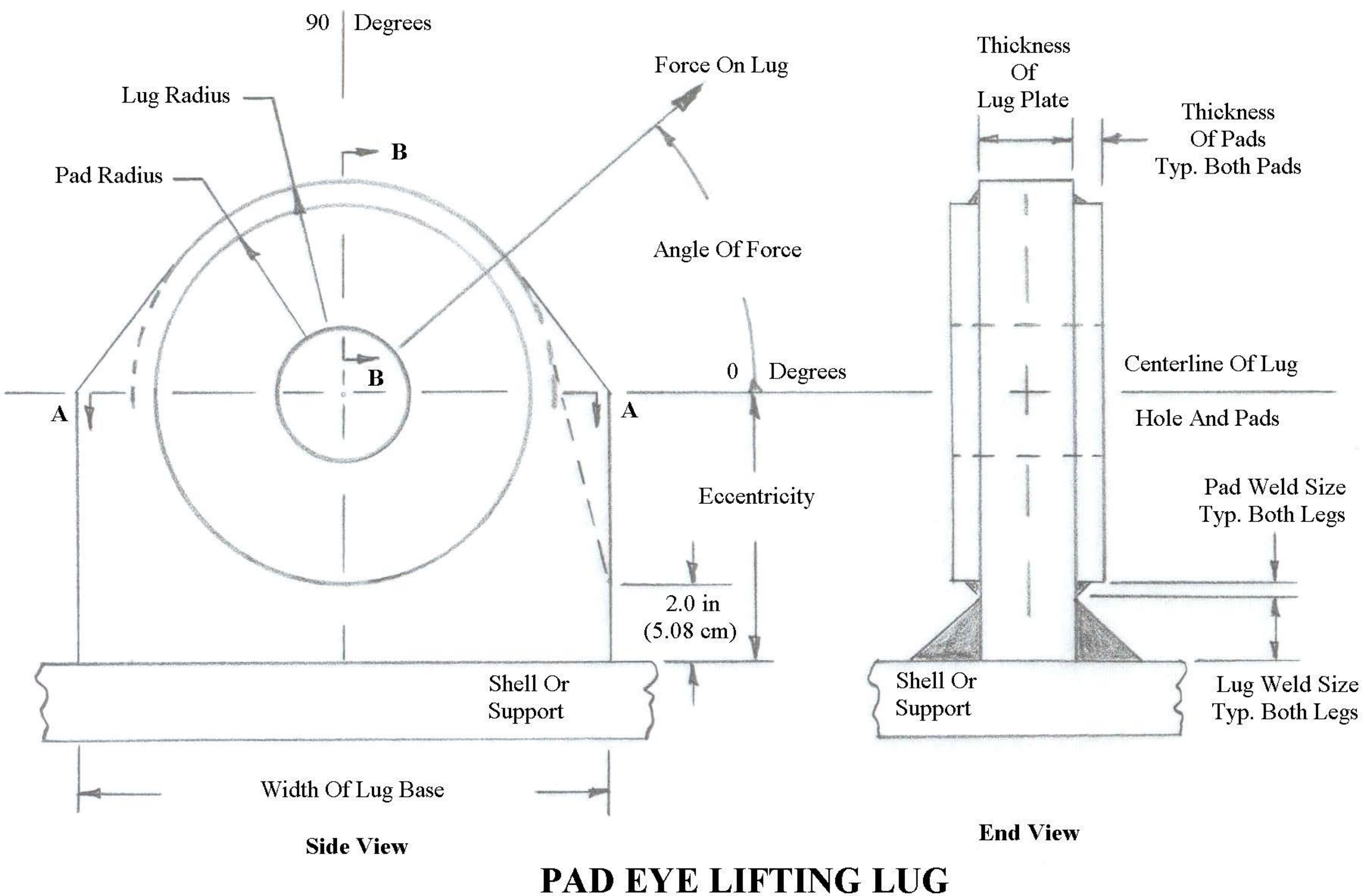
In the Initial Pick Position (IPP)

PAD EYE LIFTING LUGS

1. Used extensively by the field in fabrication work. Also used as tail lugs, lifting lugs, etc.
2. Attached to a vessel or structure by two parallel butt welds
3. End area and bearing stress is based on the full force applied on the centerline of the lug (at 90 degrees per the following sketch)
4. The combined bending stress of the lug plate and the lug weld is based on the horizontal and vertical components of the force

DISADVANTAGES:

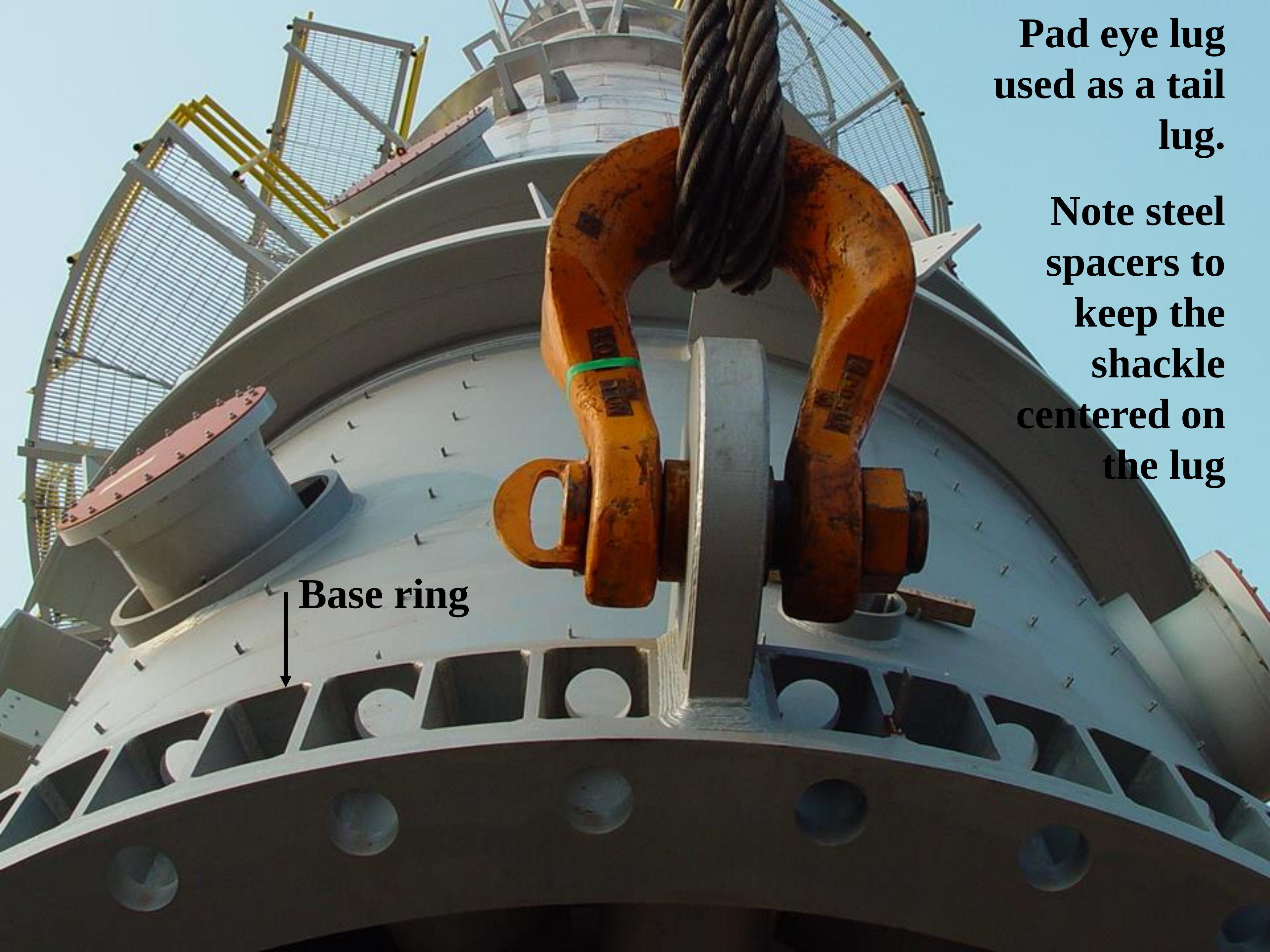
a. The welding and QC for the butt welds is very critical
b. Has little resistance to side loading, ie, the compression weld acts as a hinge and the tension weld has to carry all of the load



NOTES:

1. Section A-A: Area Across Pin Hole
2. Section B-B: Area Past Pin Hole
3. Sections not shown

Typical Pad Eye Lifting Lug


Pad eye lug used as a tail lug.
Note steel spacers to keep the shackle centered on the lug
Base ring

770 ton (700 Te) Reactor With Two Pad Eye Lugs For Lifting

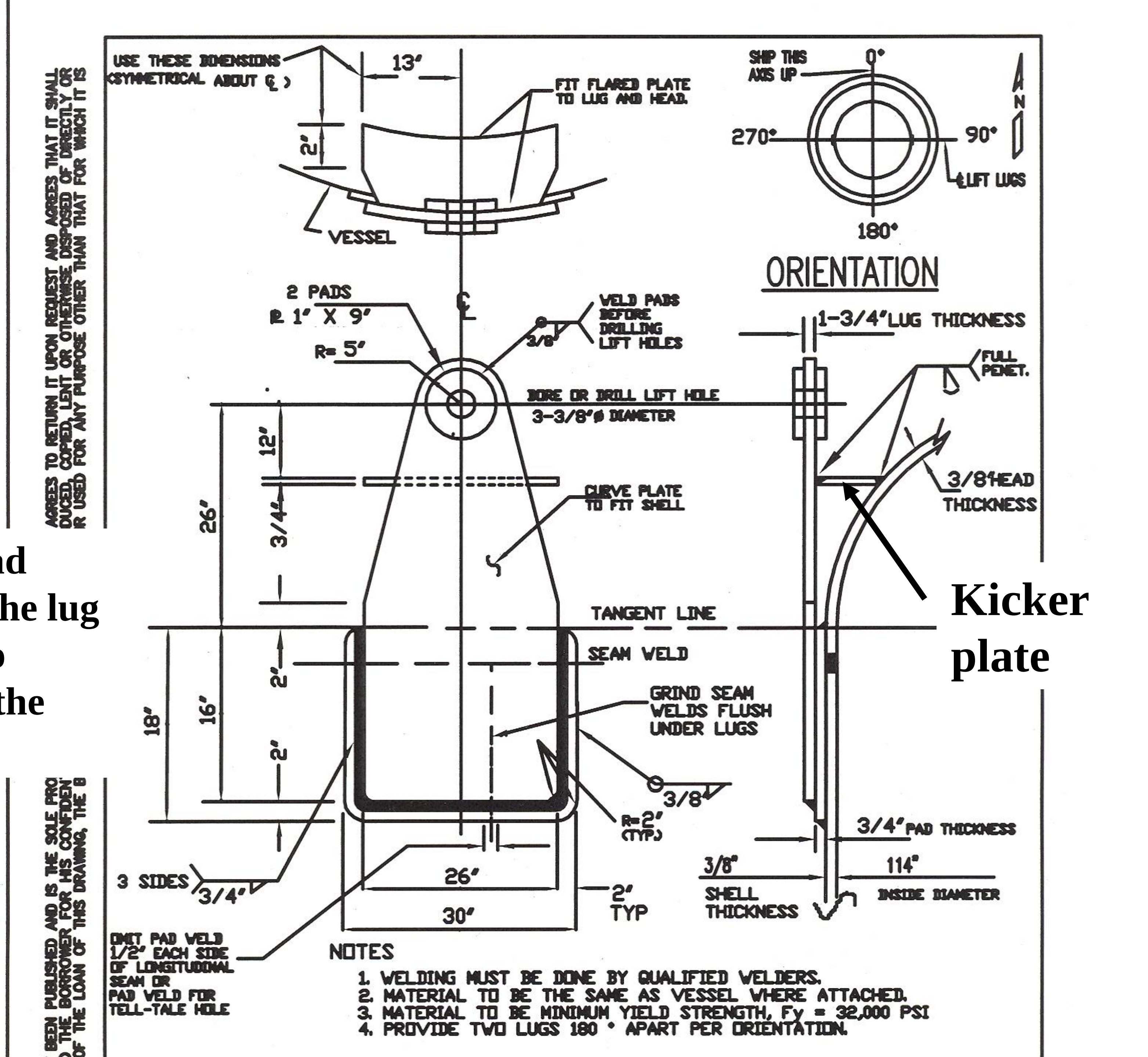
Top Head & Cone Lug Design

1. Most economical of all lifting lugs to design, fabricate and install
2. End area, bearing and combined stress of the lug plate and weld calculated the same as for pad eye lugs
3. Attached to the shell with a three sided weld
4. Easy to analyze the local shell stresses. If the weld size is less than the thickness of the shell, the shell is not overstressed at the tangent line
5. Safer to use than trunnions as the slings can't jump off

DISADVANTAGES:

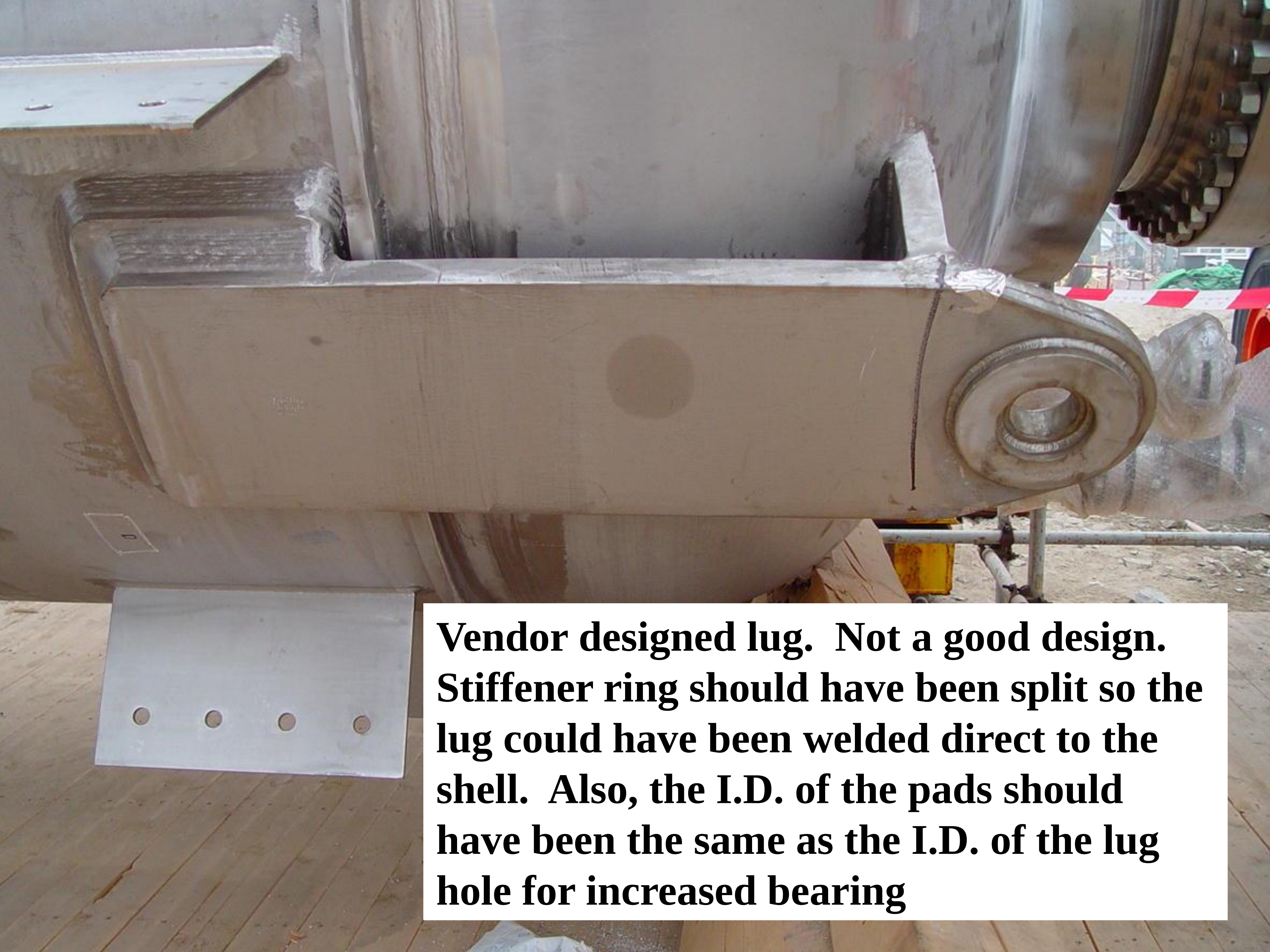
1. Bending in the shell can be a problem for long vessels
2. Harder to unhook the rigging than with trunnions

TYPICAL TOP HEAD LUG DRAWING

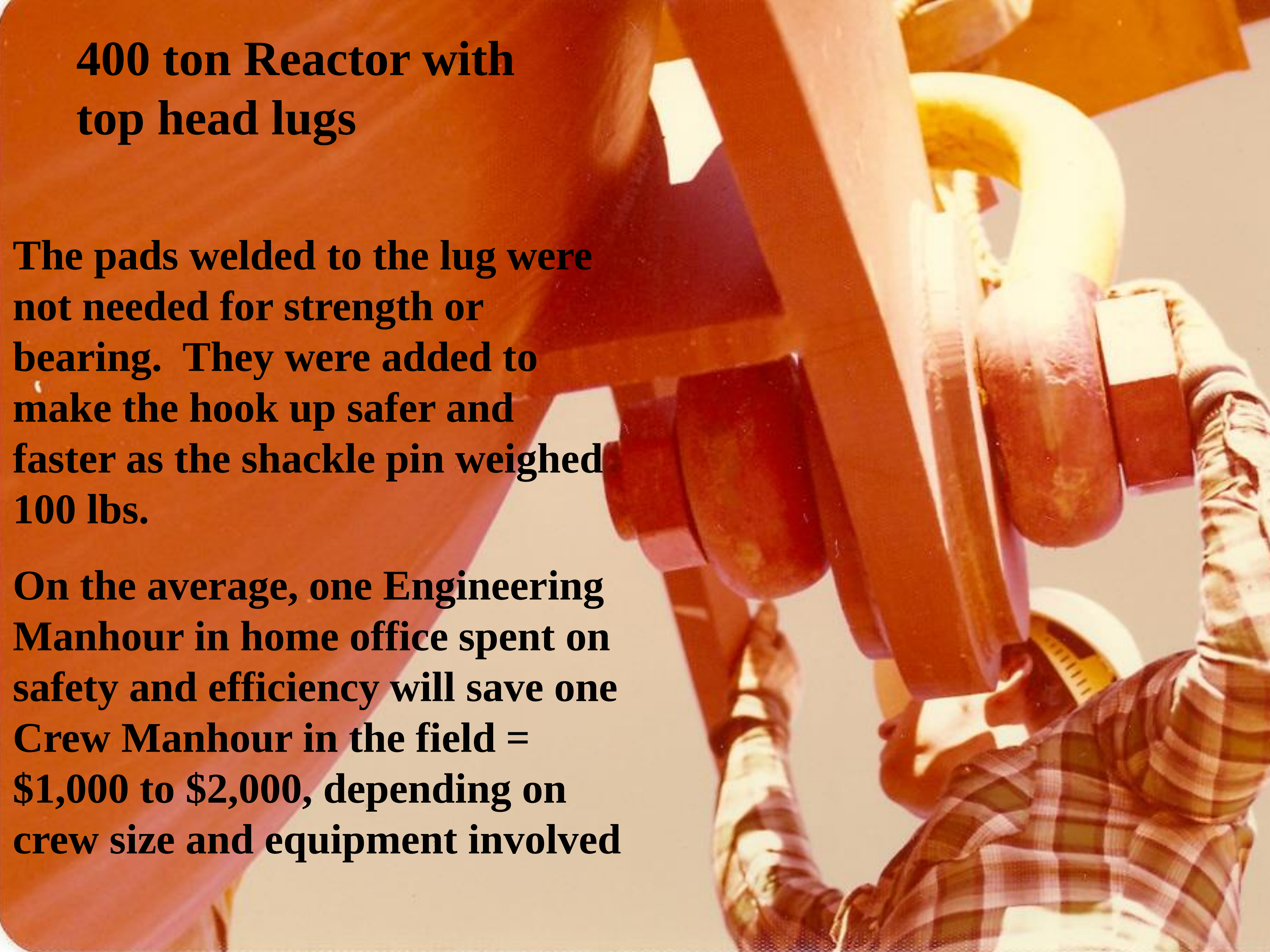


Note the ¾" pad used between the lug and the shell to accommodate the ¾" lug weld

Kicker plate



Vendor designed lug. Not a good design. Stiffener ring should have been split so the lug could have been welded direct to the shell. Also, the I.D. of the pads should have been the same as the I.D. of the lug hole for increased bearing

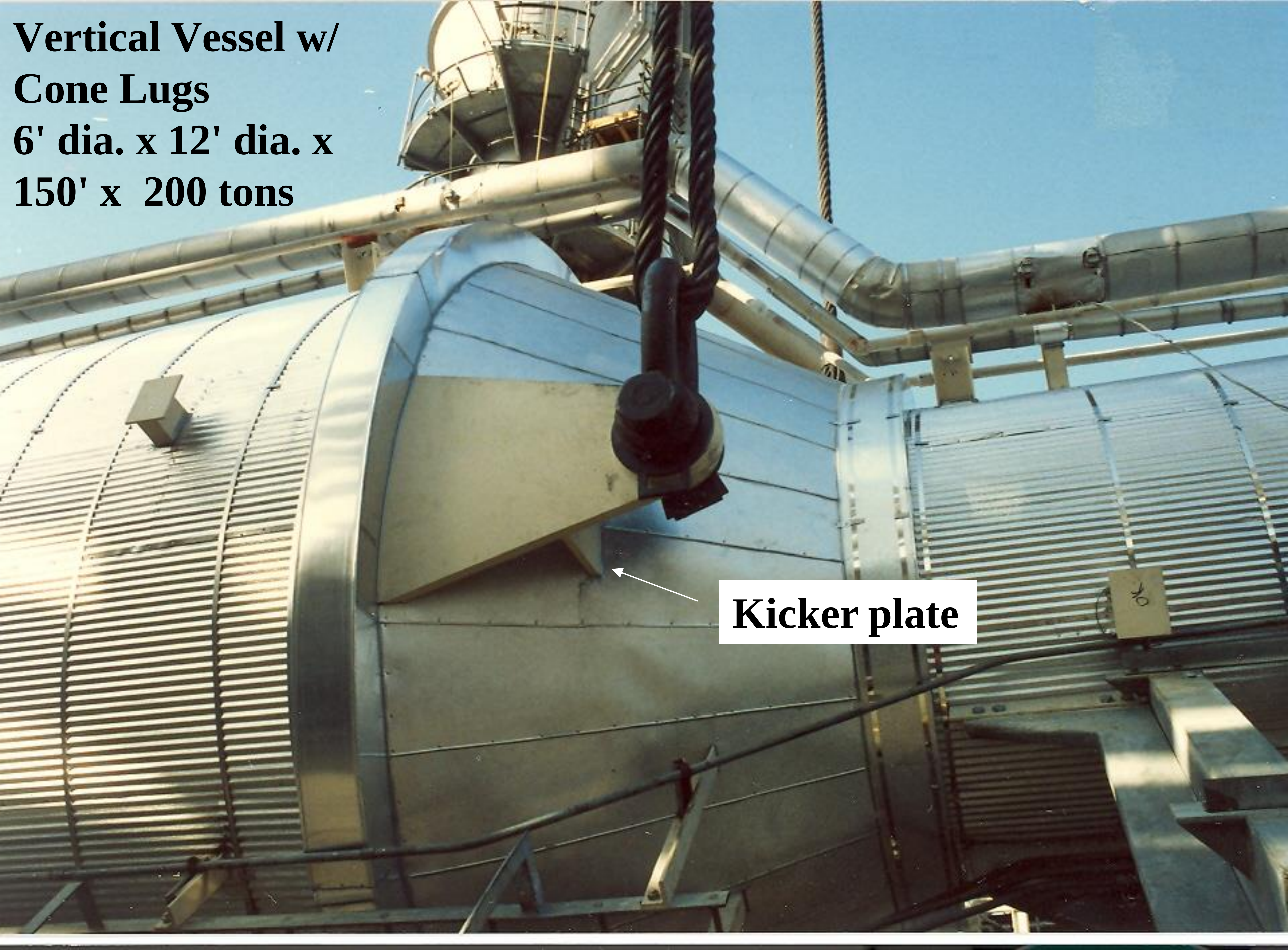


400 ton Reactor with top head lugs

The pads welded to the lug were not needed for strength or bearing. They were added to make the hook up safer and faster as the shackle pin weighed 100 lbs.

On the average, one Engineering Manhour in home office spent on safety and efficiency will save one Crew Manhour in the field = $1,000 to $2,000, depending on crew size and equipment involved

Vertical Vessel With Top Head Lugs


Vertical Vessel w/
Cone Lugs
6' dia. x 12' dia. x
150' x 200 tons
Kicker plate


Over shot line
Davit

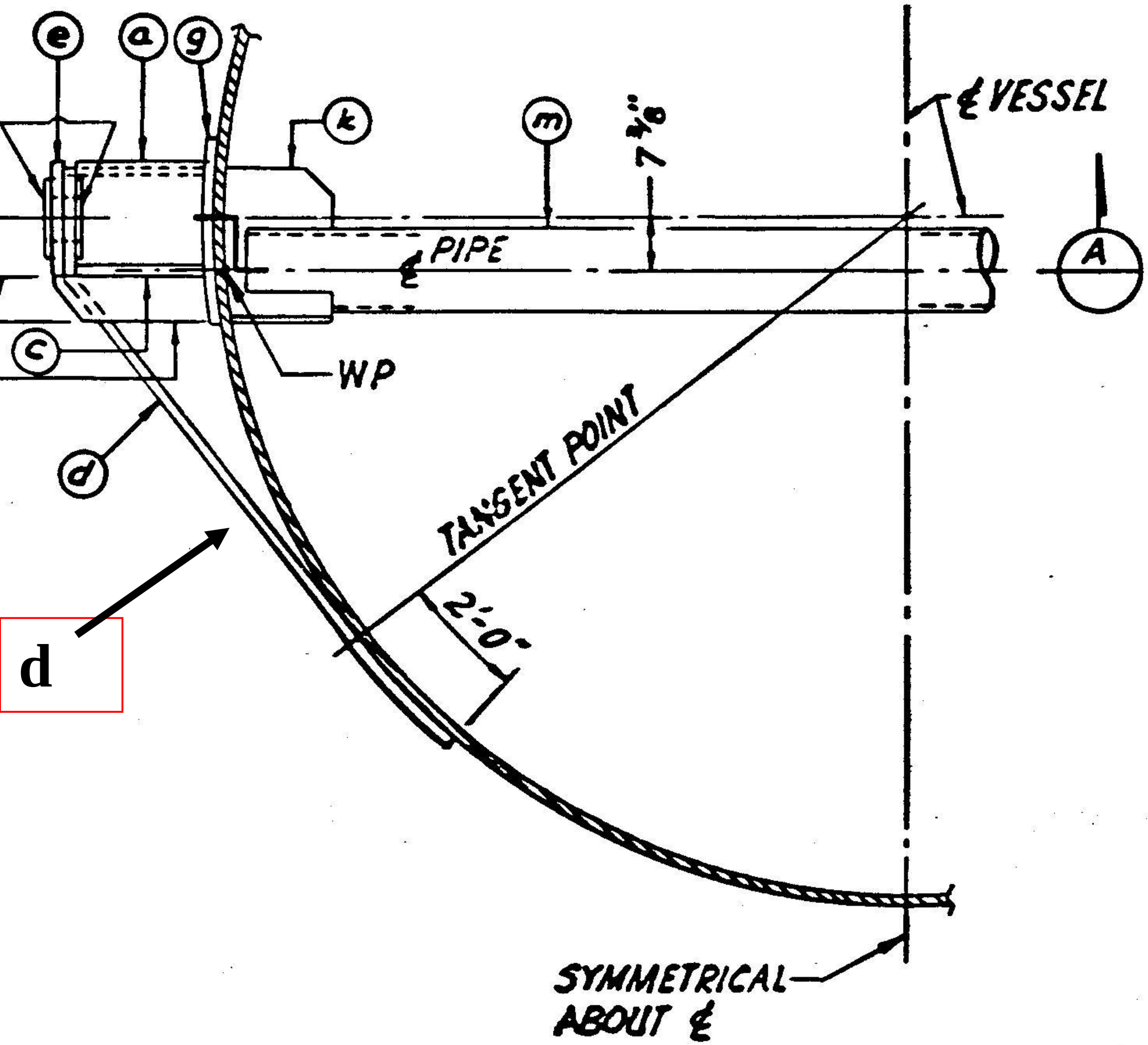
Slings need to be long enough so that the spreader bar will clear the over shot line during up ending

SIDE LUGS

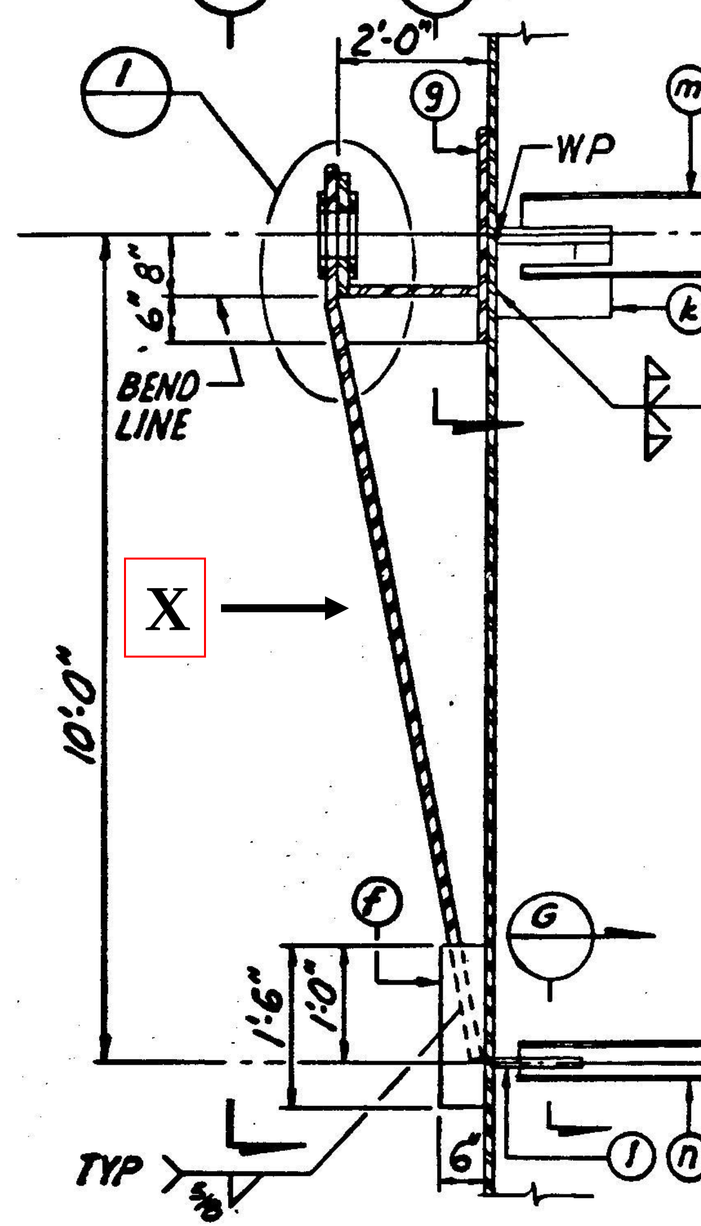
1. **Side lugs are used in cases where the use of top head lugs would cause over stressing of the shell due to buckling or bending**
2. **The transverse plates or straps carry the IPP load. See "d" in the left hand sketch**
3. **The Longitudinal plates or straps carry the full weight of the vessel when it is in the vertical position. See "X" in the right hand sketch**
4. **A compression & tension pipe are used inside the vessel to reduce bending**
5. **End area, bearing and combined stress of the lug plate and weld calculated the same as for pad eye lugs**

DISADVANTAGES:

a. **Costly to design, fabricate, cut out and remove after erection**

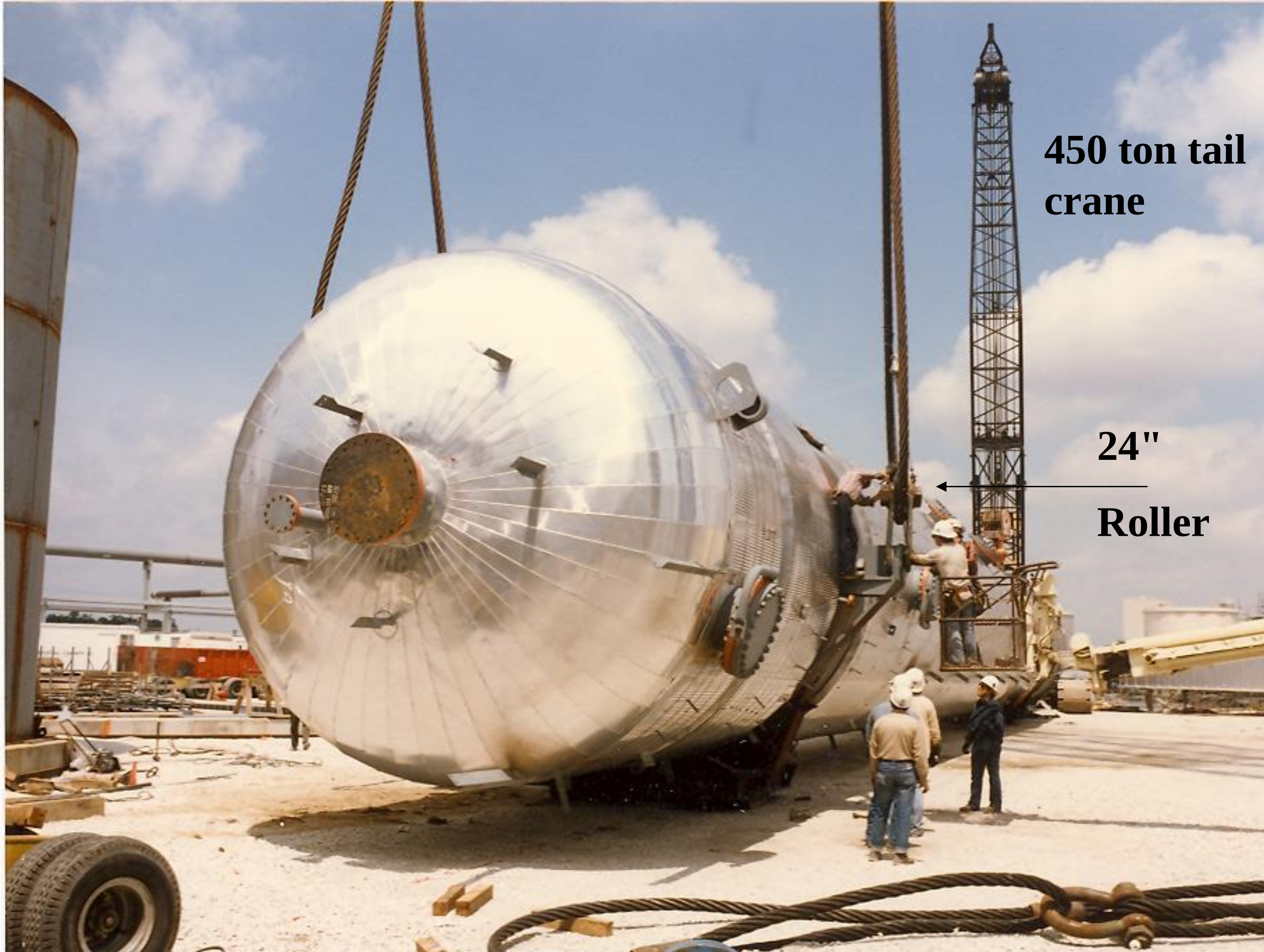


Vessel In Horizontal Position



Vessel In Vertical Position


450 ton Vertical Vessel With Side Lugs
Doubled 4.5" dia. sling
Roller with a 24" tread dia., two links & two 6" dia. pins


450 ton tail crane
24"
Roller

SWL OF A 4.5" DIA. SLING

Tension in the inclined portion of the slings = 485 kips

Breaking strength of a 4.5" dia**. EIPS wire rope** = 1,775 kips

SWL of a 4.5" dia **sling** with 100% efficiency

= 1775/safety factor of 5 = 355 kips

Efficiency of the swaged fitting at the eye = 90%

Efficiency of the slings bent over the ends of

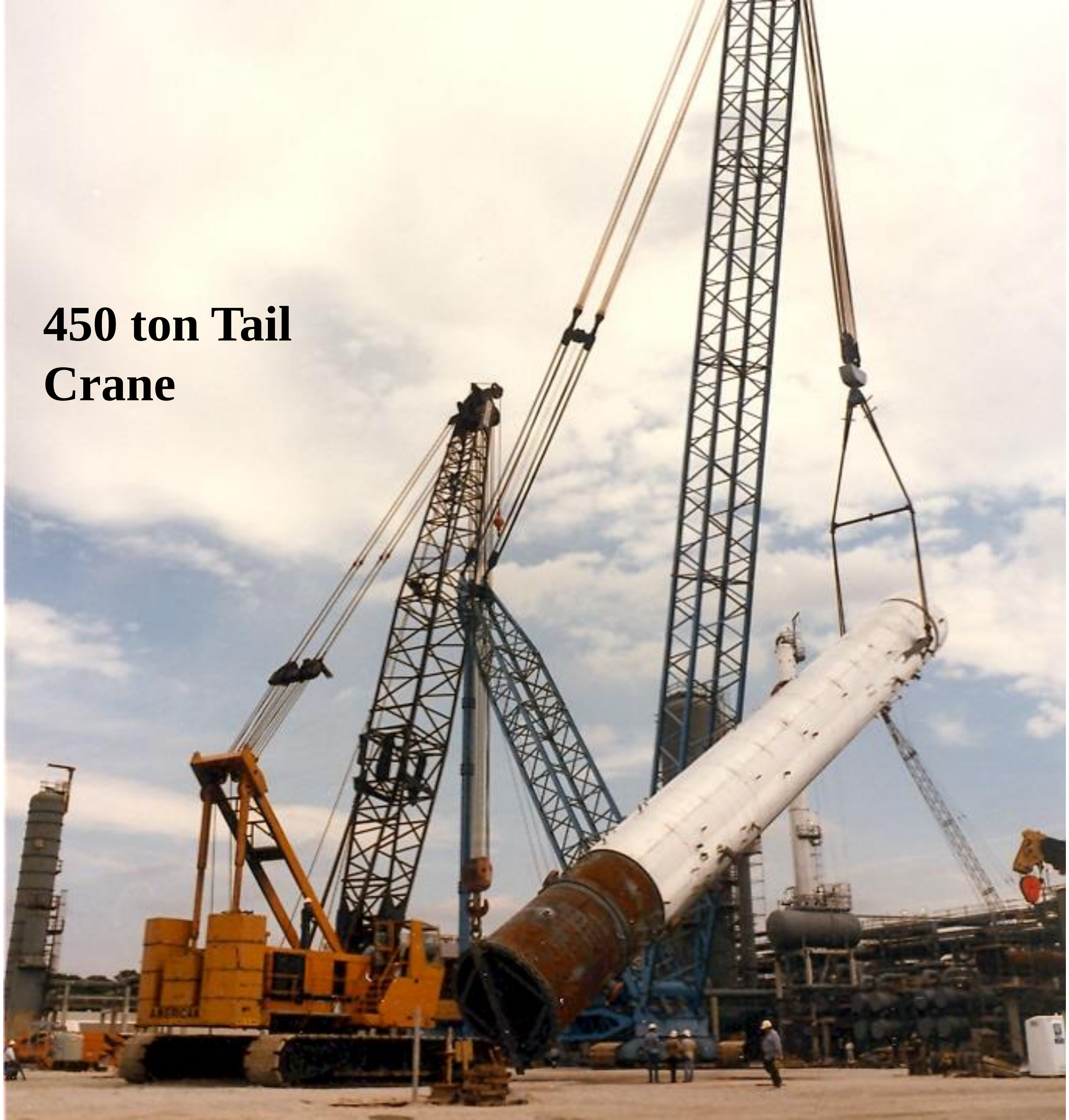
the spreader bar = 85%

Efficiency of the slings bent around the 24" rollers = 78%

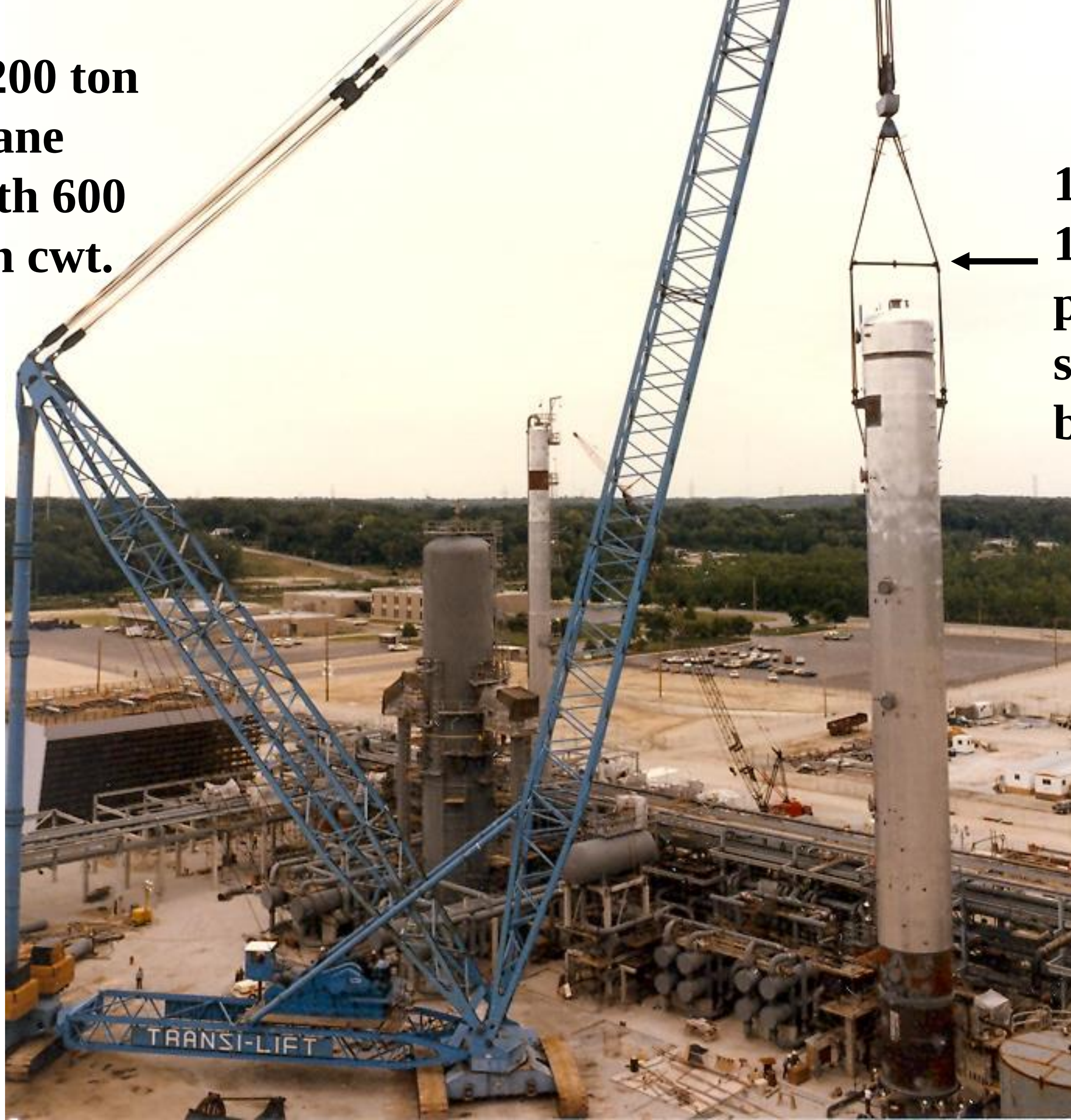
NOTE: Use the lowest efficiency as they do not all occur in the same place.

SWL of the sling is 355*0.78*2 parts = 554 kips

554 > 485, therefore a doubled 4.5" dia. sling is okay


450 ton Tail
Crane

1,200 ton crane with 600 ton cwt.



10"dia. x 16' XXS pipe spreader bar

Crane on mats

Lampson LTL-1200 Transilift

1.	Monthly rental: (**1987 Rental**) 7 mo.*	$275,000	**$1,925,000**
2.	Mob and demob costs:		
	Move in and out	$300,000	
	Assembly-disassembly.	$350,000	**$650,000**
		TOTAL	**$2,575,000**

1. Assemble time, 5,000 straight time hours: six weeks
2. Dis-assemble time: four weeks.
3. Assembly cranes required: Two 230 ton crawlers
4. Transportation of crane components: **130 truck loads each way**

TRUNNIONS

1. **Trunnions are used in cases where the use of top head lugs would cause over stressing of the shell in long vessels due to buckling or bending**

2. **They are used almost exclusively in Europe in place of top head lugs. Their use is gaining popularity in the USA**

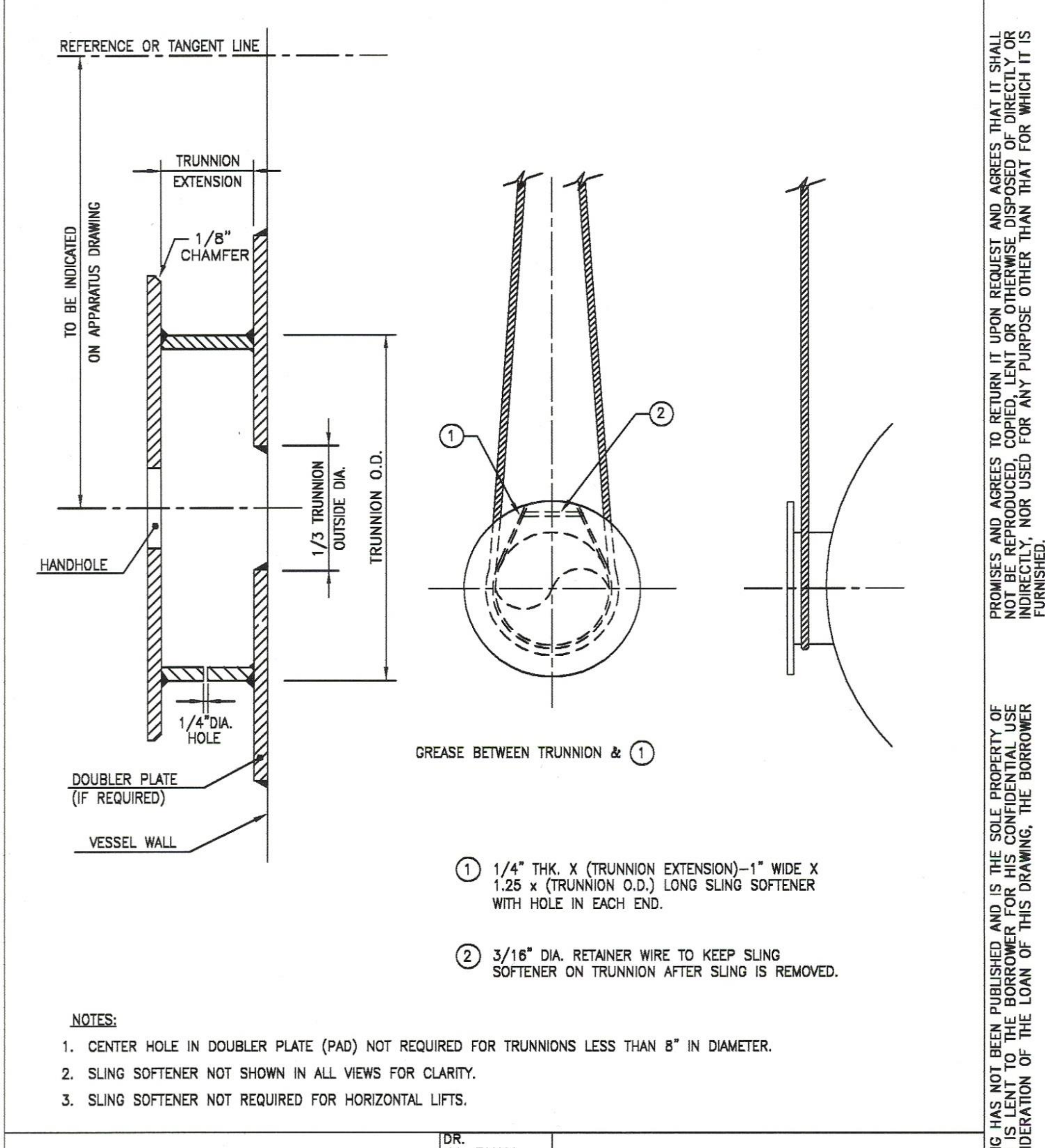
3. **They are easy to hook up to and unhook from**

DISADVANTAGES:

a. **The design, fabrication and installation is quite complex, sort of like trying to install lugs on the sides of an empty Pepsi can without deforming it**

b. **Not as safe as lugs with pin holes as the slings can jump off**

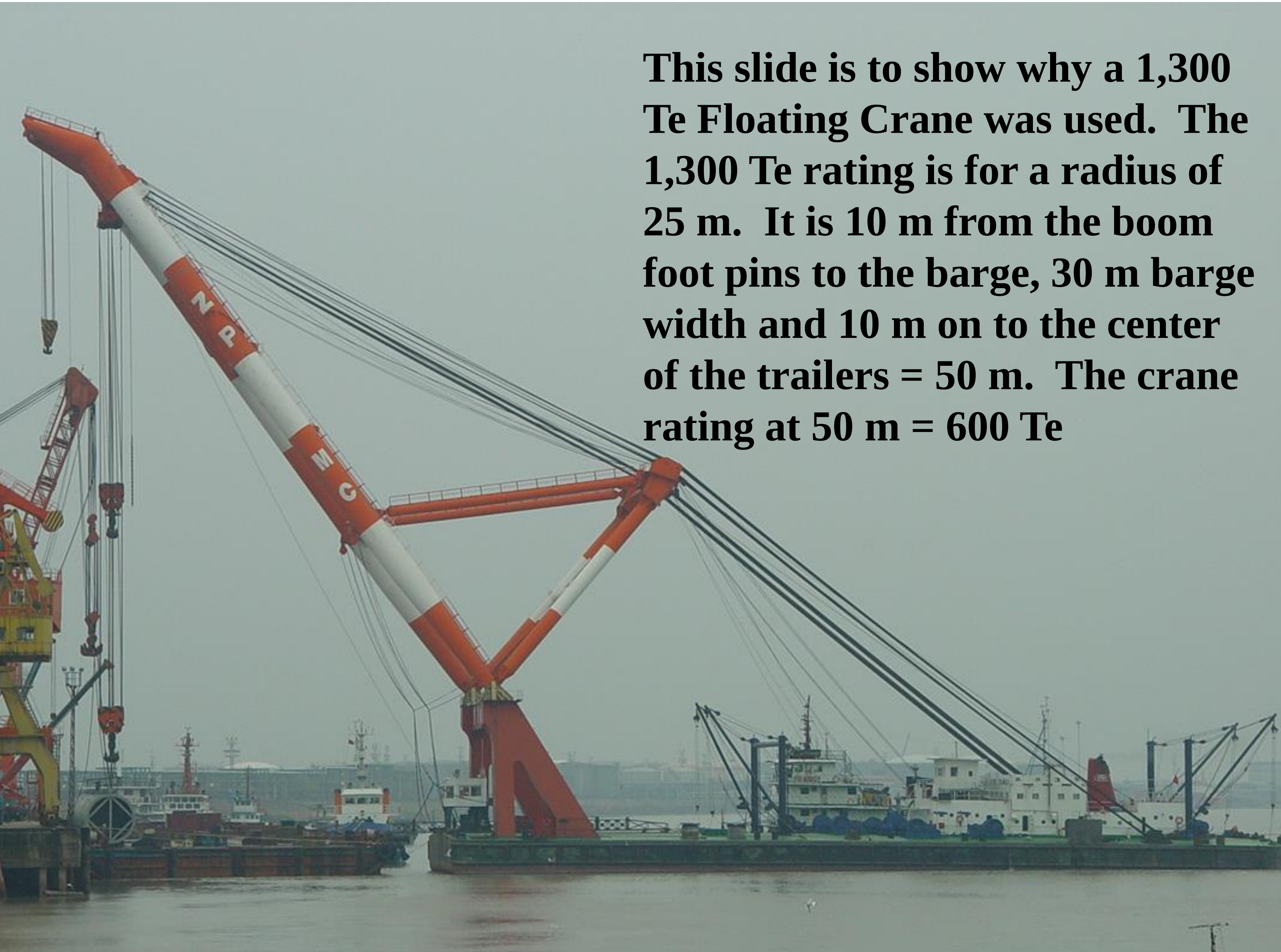
TYPICAL TRUNNION DRAWING



Vertical vessel with trunnions and tail lug.

Dimensions:
6 m x 94 m x 360 Te
20' x 308' x 396 tons

This slide is to show why a 1,300 Te Floating Crane was used. The 1,300 Te rating is for a radius of 25 m. It is 10 m from the boom foot pins to the barge, 30 m barge width and 10 m on to the center of the trailers = 50 m. The crane rating at 50 m = 600 Te



FLANGE LUG DESIGN

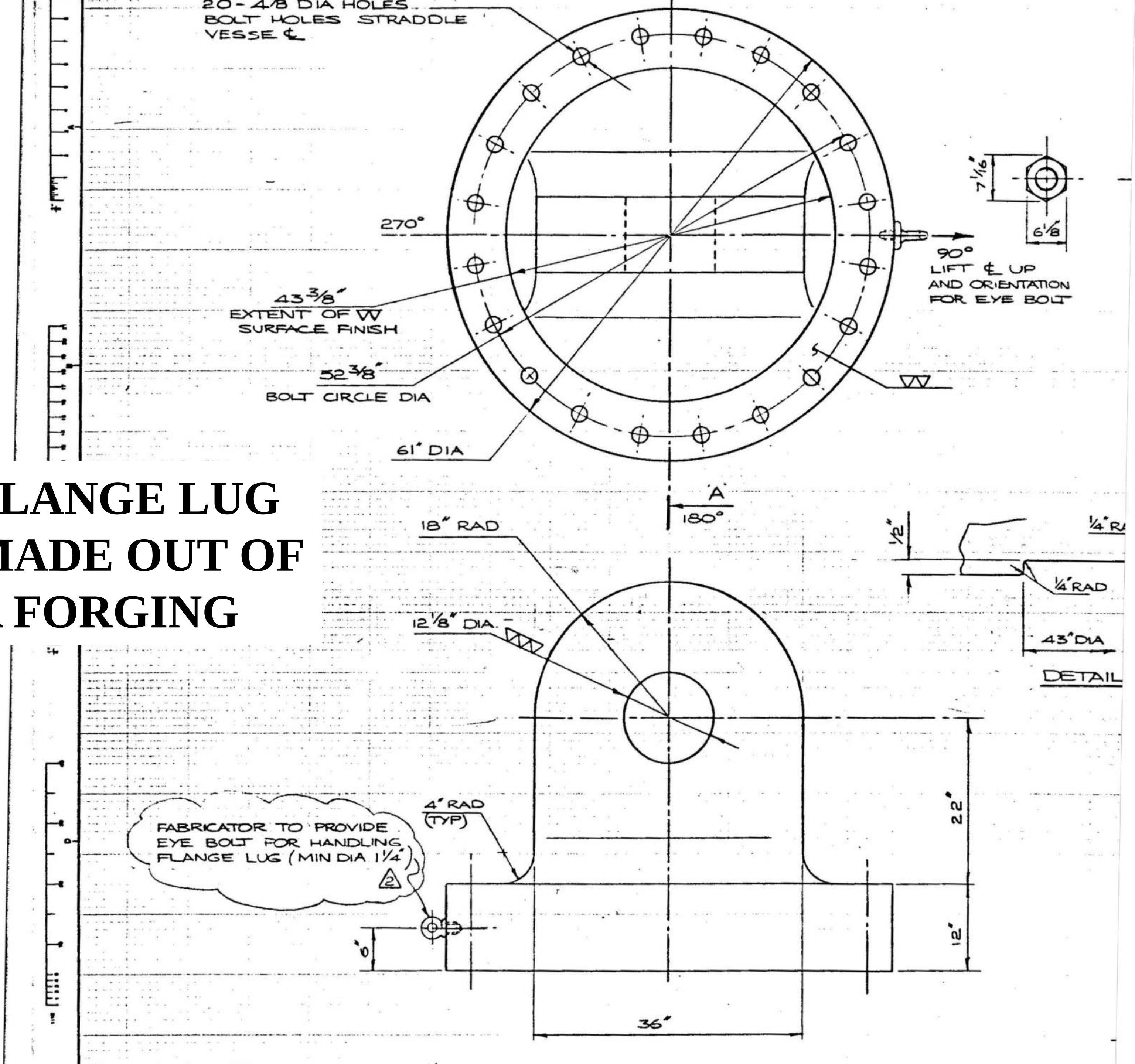
Made From A Weldment:

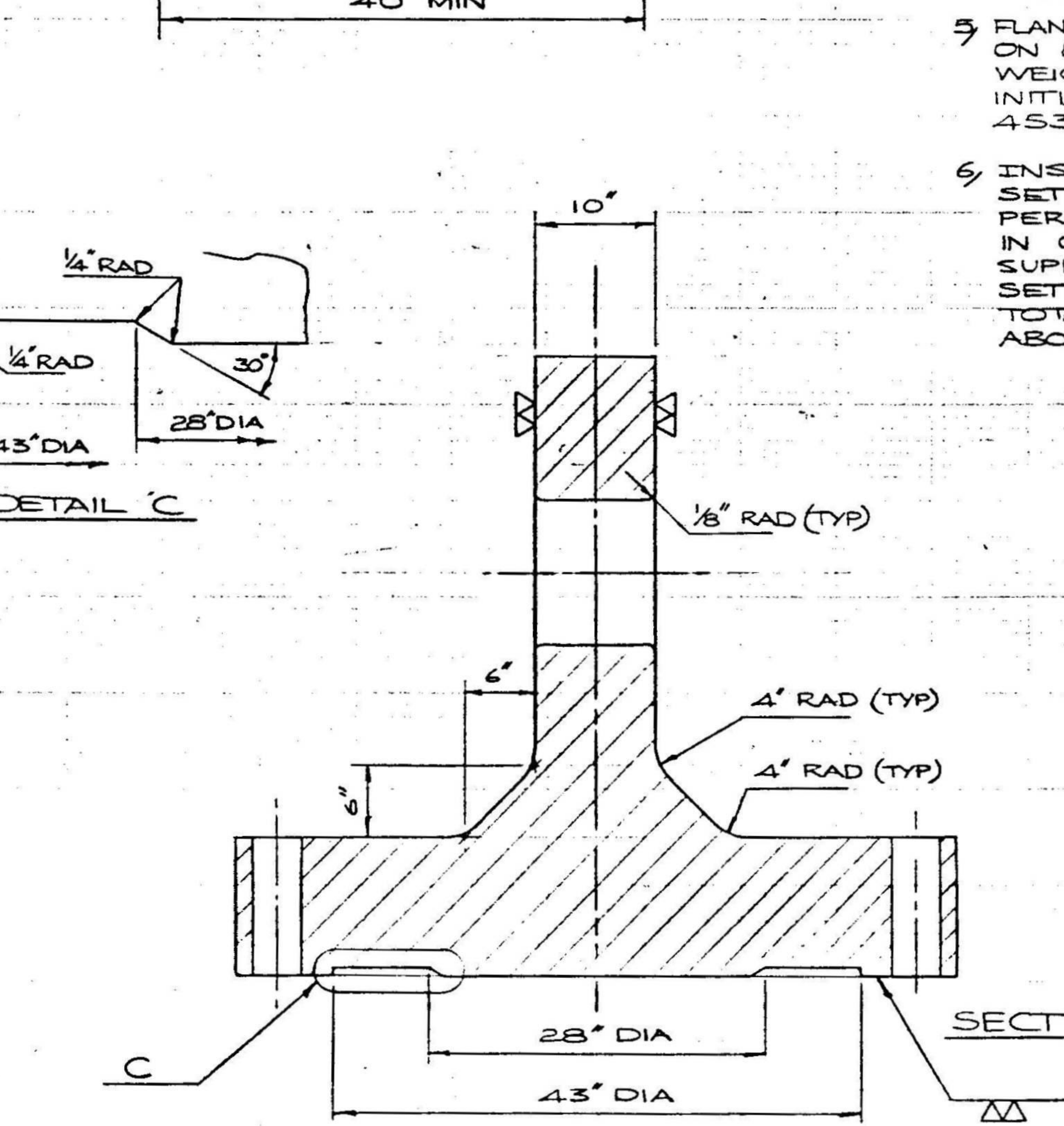
A base plate is fabricated that matches the bolt pattern on the reactor's top nozzle. A lug plate is welded to the base plate and gussets are installed to provide side stability, and weld length.

Made From A Forging:

A molten piece of metal that is larger than the specified size of the lug is mechanically pounded or compressed to a specific density to eliminate all voids. The forging is then machined to the final design dimensions. As there are no welds, this type of lug is superior and safer than one made from a weldment. The only down side is that the cost is approximately 2 times more, ie, if a weldment costs $3.00/lbs then a forging would cost about $6.00/lb. The flange lug shown on the drawing weighed 6,900 lbs. & cost about $42,000.00 to fabricate.

FLANGE LUG MADE OUT OF A FORGING

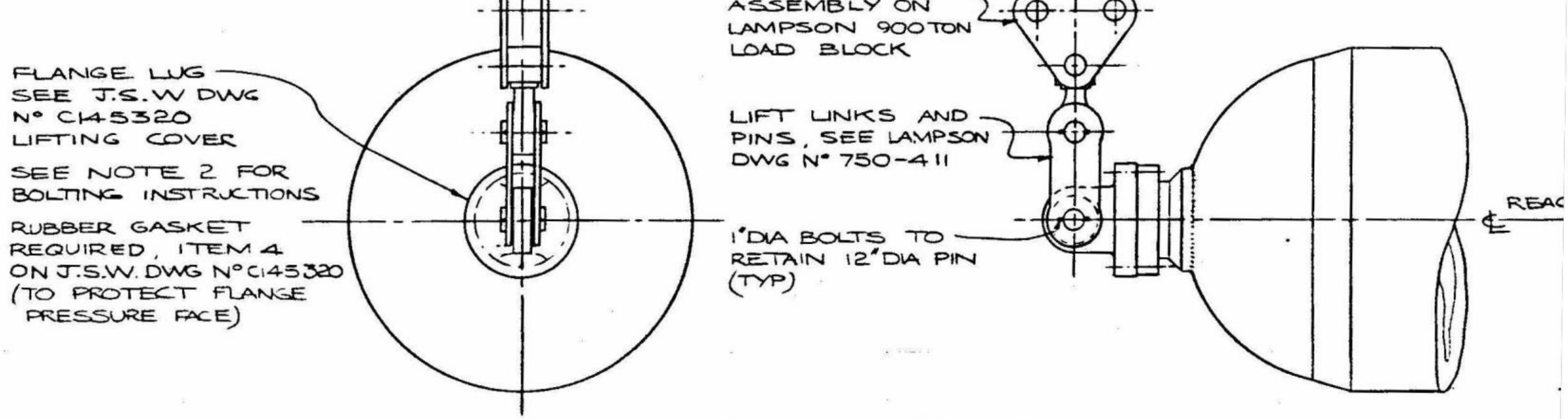




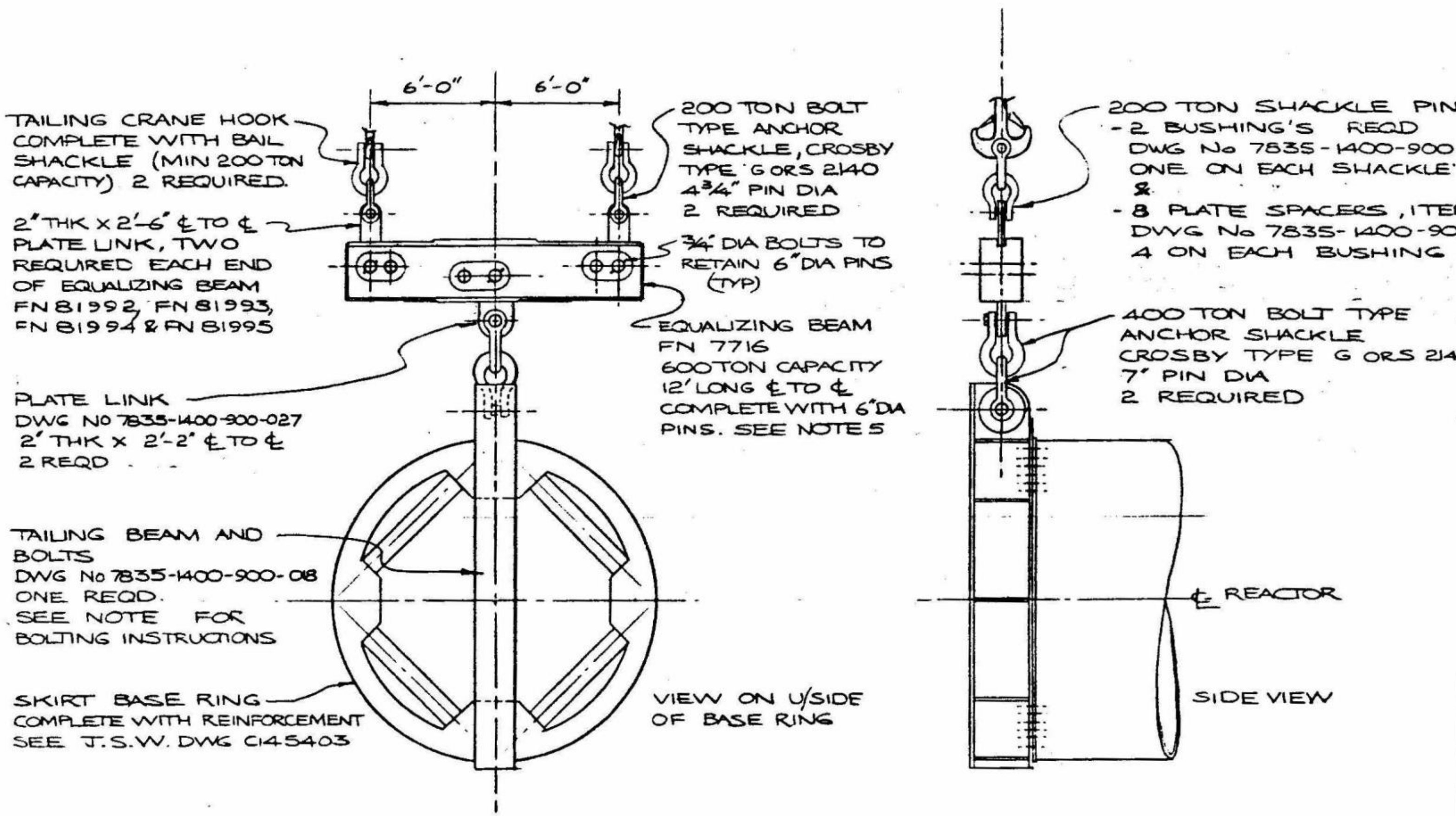
SECTION A-A

5. FLANGE LUG DESIGN BASED ON 830 TONS VESSEL WEIGHT. ESTIMATED INITIAL PICK LOADING 453 TONS (1 TON = 2000 LBS)

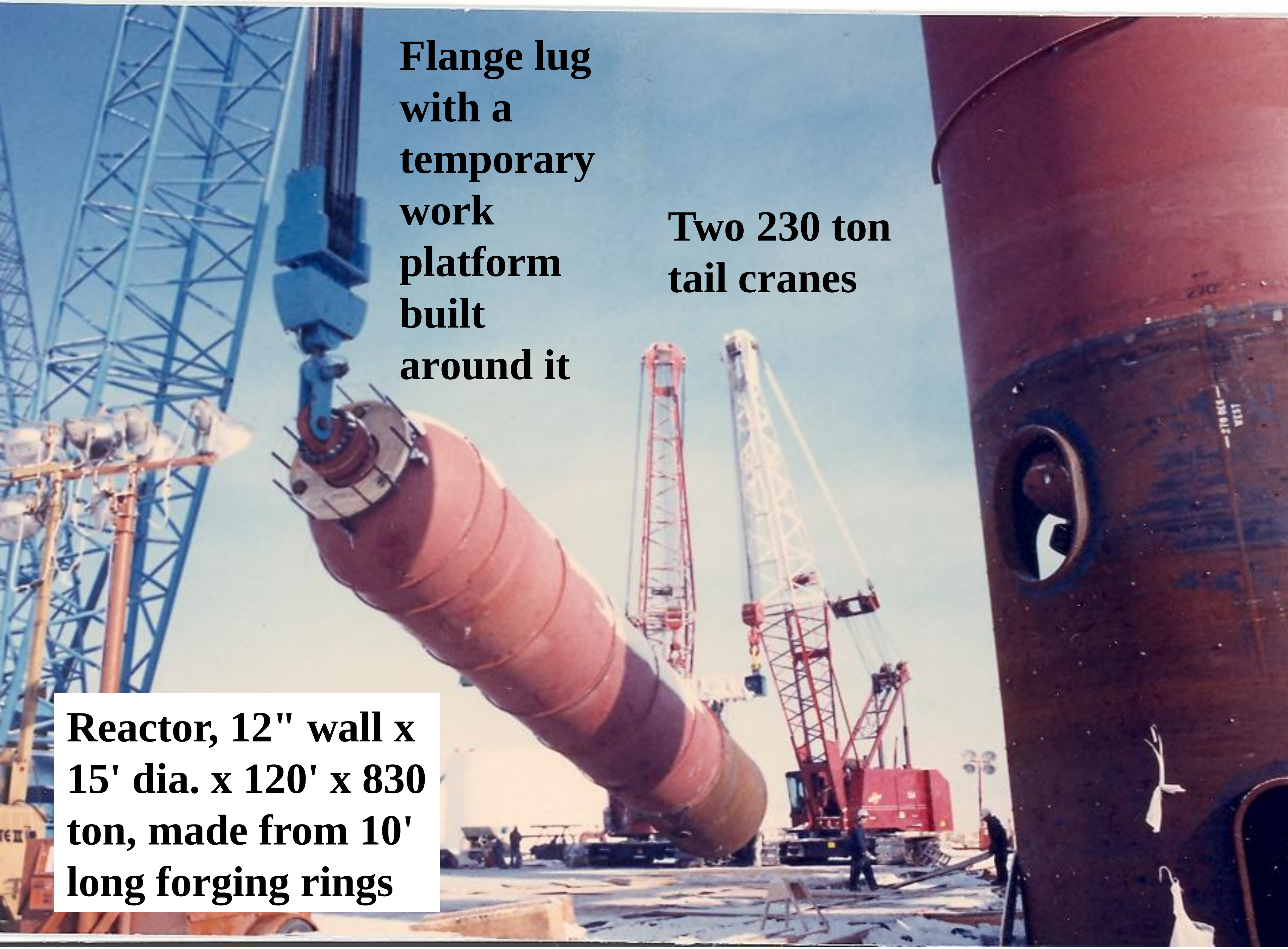
6. INSTEAD OF ONE COMPLETE SET OF ERECTION BOLTS PER VESSEL AS SPECIFIED IN ORIGINAL P.O., PLEASE SUPPLY TWO COMPLETE SET OF ERECTION BOLTS TOTAL AS PER NOTE 4 ABOVE.



TOP HEAD HOOK-UP



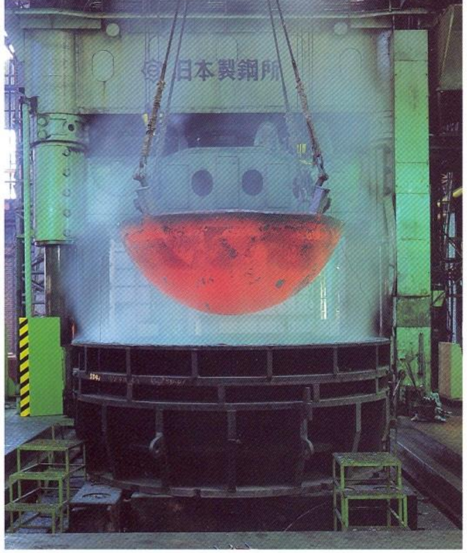
TAILING HOOK-UP


Flange lug with a temporary work platform built around it
Two 230 ton tail cranes
Reactor, 12" wall x 15' dia. x 120' x 830 ton, made from 10' long forging rings

Making a 12" wall x 15' dia. x 10' ring from a forging


12" wall x 15' dia. x 10' long ring made out of a forging

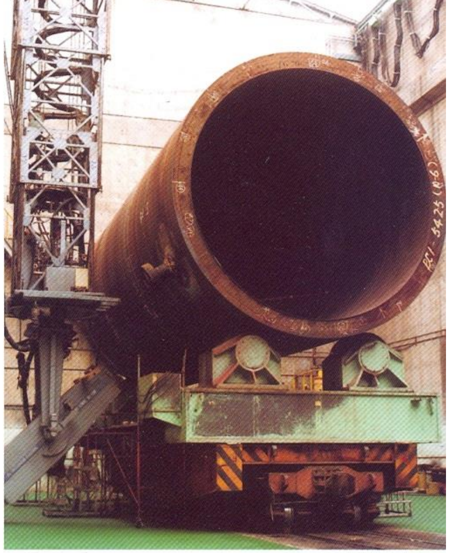
Forging a head



Hot forming of one piece head

Hydraulic bending press	6,000t and others	······3
Bending roll	···	······1

Welding 10' rings together

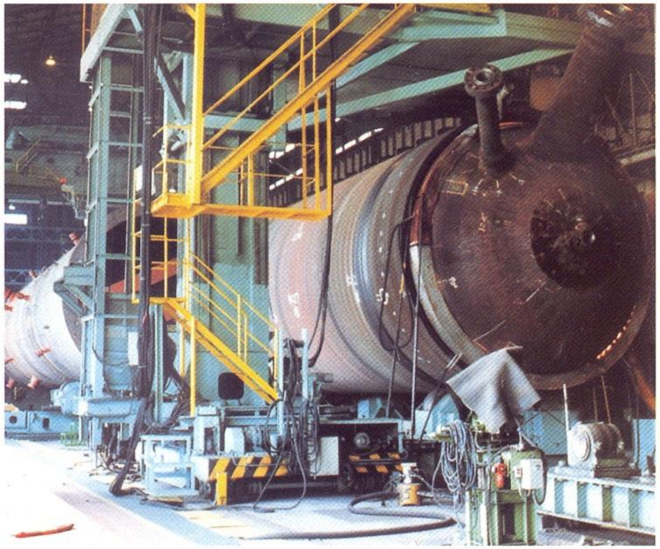


Radiographic examination

Radiographic examination apparatuses

Isotope	60 Co, 50Ci and others	·······················3
X-ray	5mA	···6
Linac	12MeV, 2000R/min at 1m, and 4MeV	···3

Welding on a head

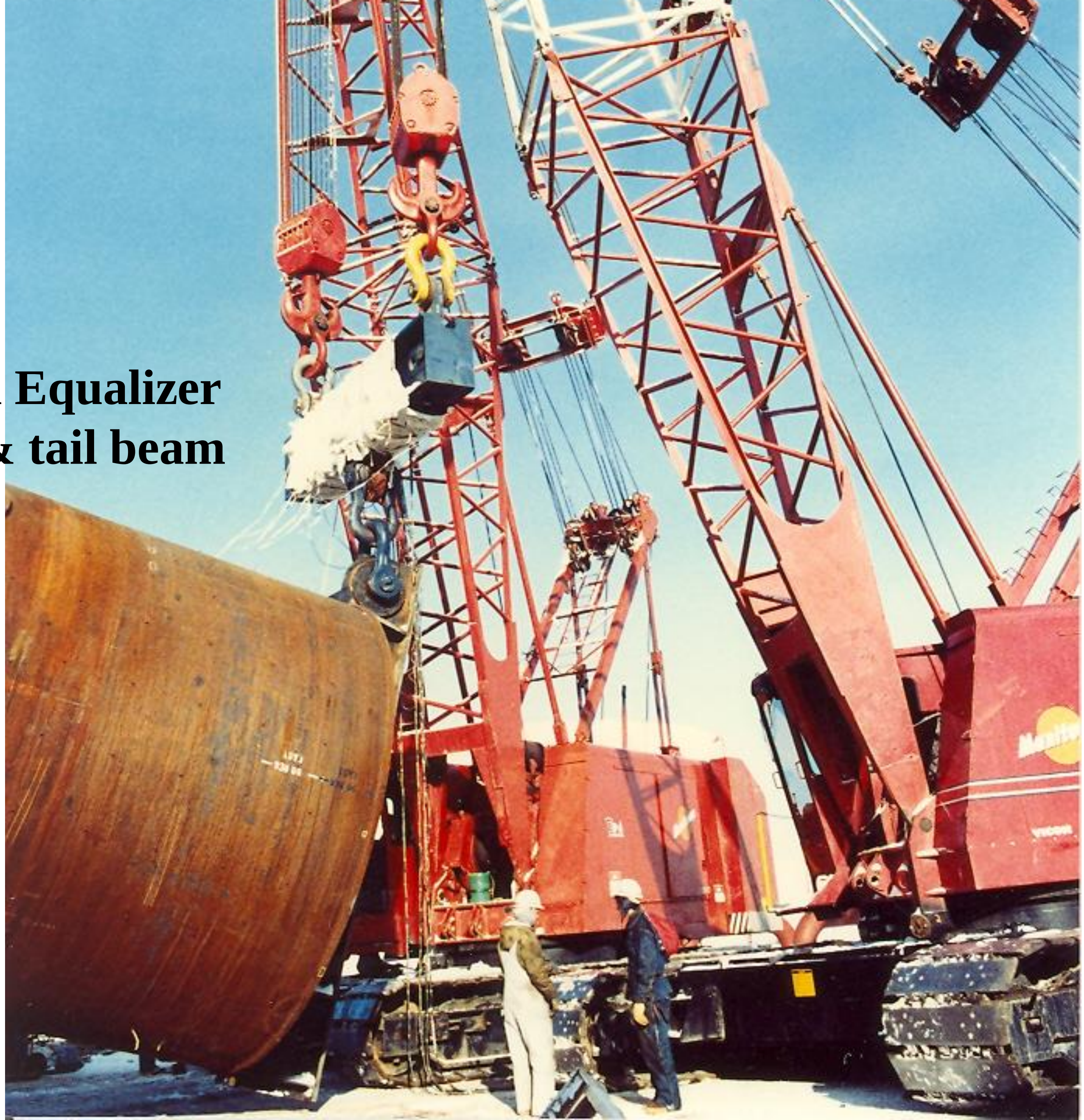


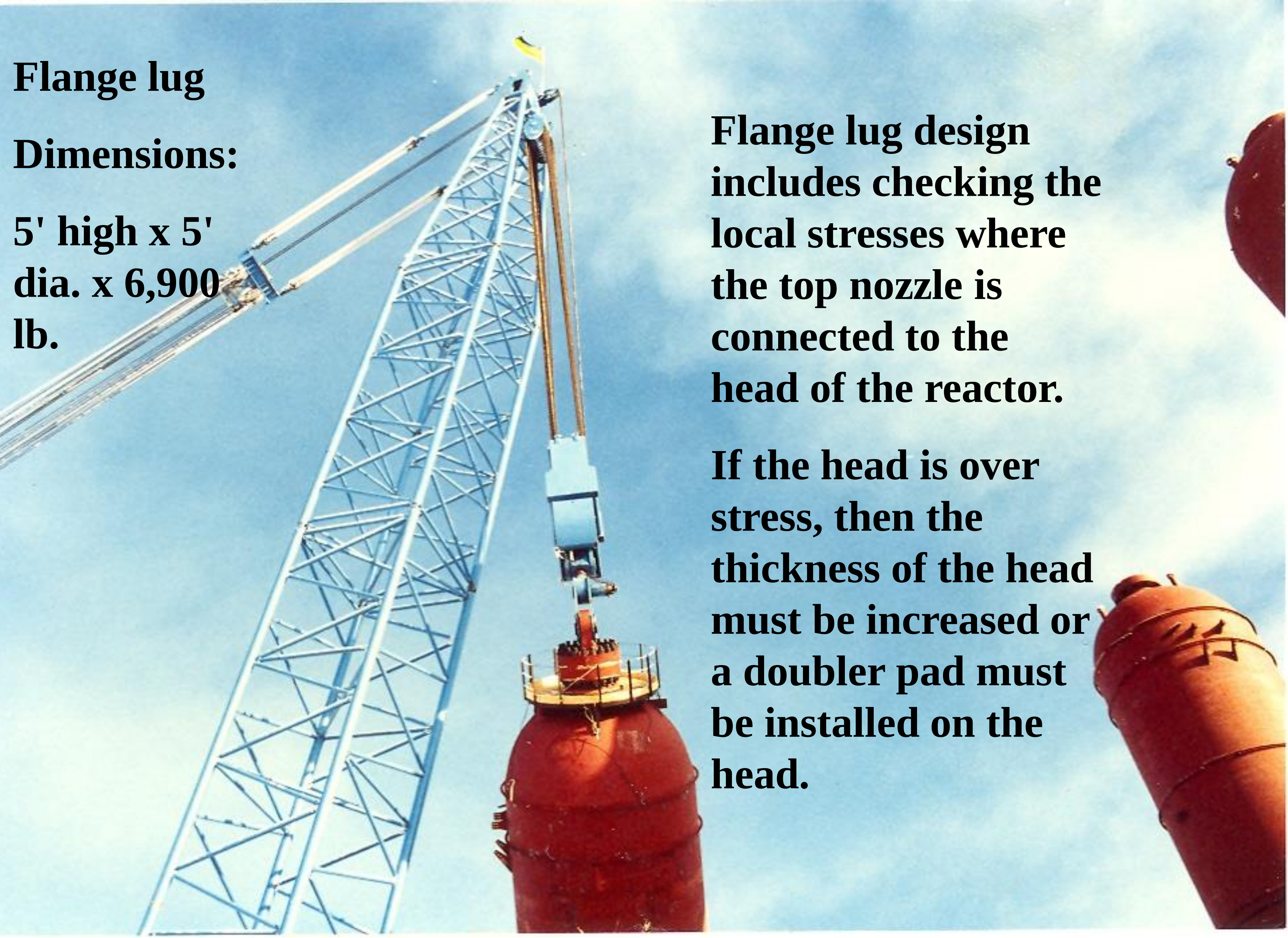
Circumferential seam welding of shell

Fabrication shops

	Floor area (M²)	Handling Capacity (Metric-tons)
No.2 Welding shop	10,407	100
No.4 Welding shop	11,740	1,200

600 ton Equalizer beam & tail beam





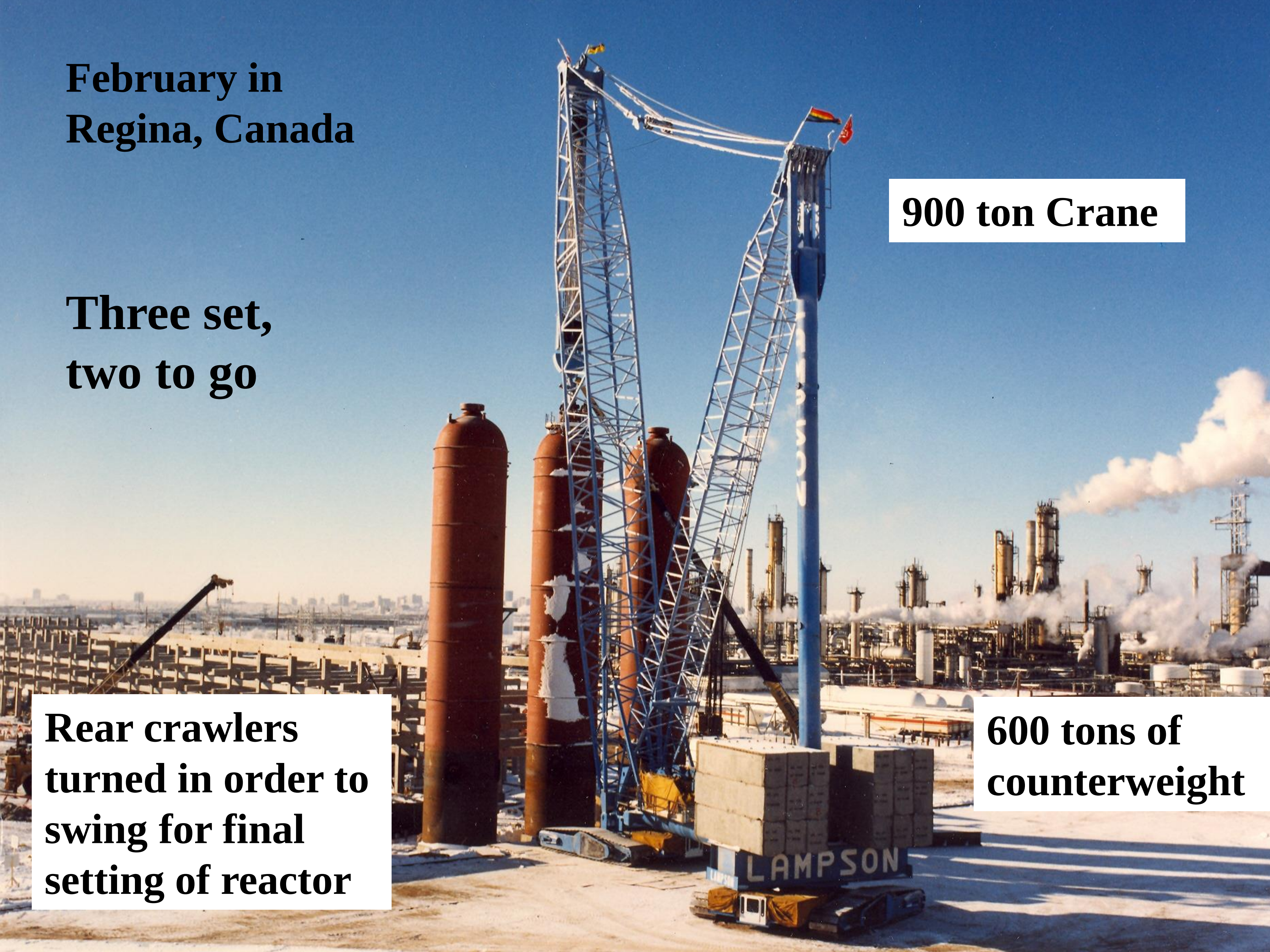
Flange lug

Dimensions:

5' high x 5' dia. x 6,900 lb.

Flange lug design includes checking the local stresses where the top nozzle is connected to the head of the reactor.

If the head is over stress, then the thickness of the head must be increased or a doubler pad must be installed on the head.

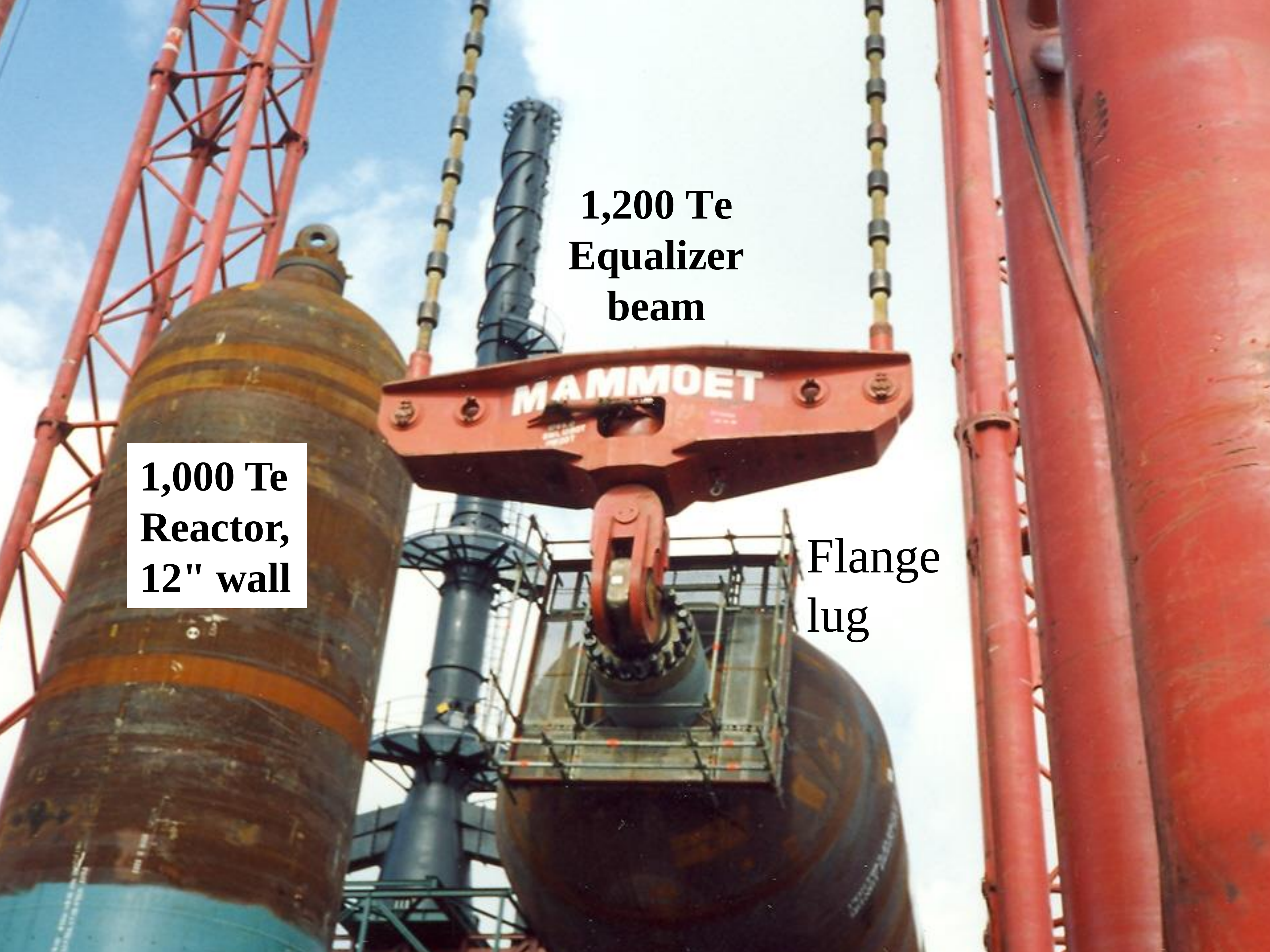

February in
Regina, Canada
Three set,
two to go
900 ton Crane
Rear crawlers
turned in order to
swing for final
setting of reactor
600 tons of
counterweight
LAMPSON

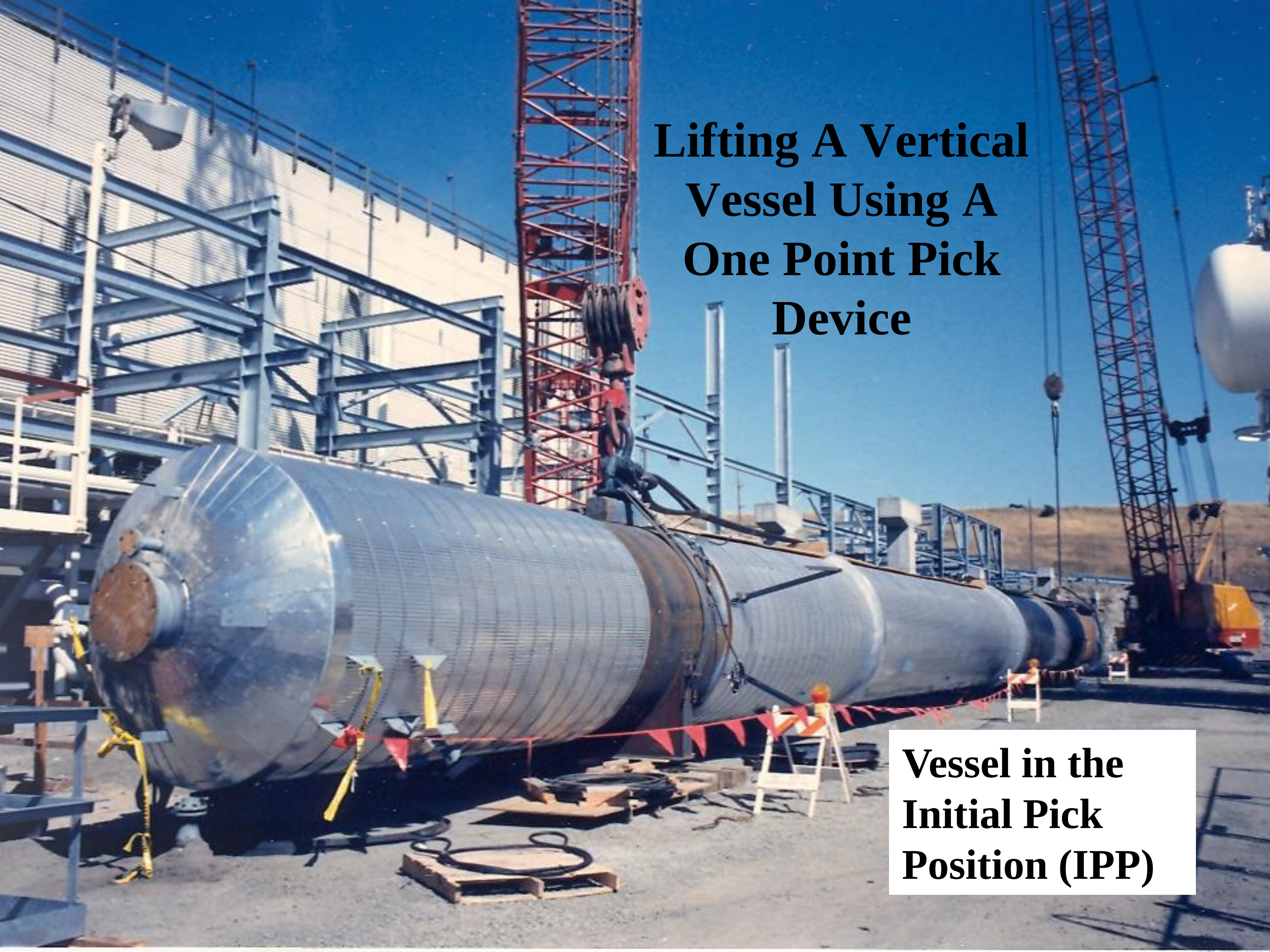
EQUALIZER BEAM

The main purpose of an equalizer beam is to ensure that the percentage of the load shared by each crane will not change during the erection of the piece of equipment.

This is accomplished by designing the beam so that the pin holes are all on the centerline of the beam. This way, when the beam gets out of level, the distances between the holes are still proportionately the same. If all the pin holes are not on the centerline of the beam, then the beam is not a true equalizer beam. To quote a fellow RE, "this means that some equalizer beams are more equal than others".

Usually, there are two pin holes at each end and two at the center of the beam. This enables the Rigging Engineer to rig up the beam so that the cranes will share the load in a 50-50, 40-60 or a 30-70 percent ratio.


1,200 Te Equalizer beam
1,000 Te Reactor, 12" wall
Flange lug
MAMMOET


Lifting A Vertical Vessel Using A One Point Pick Device
Vessel in the Initial Pick Position (IPP)

REASONS FOR USING A ONE POINT PICK DEVICE

1. **A tall vertical vessel can be erected using a crane with a short boom that doesn’t have to reach over the vessel.**
2. **A lifting lug doesn't have to be welded to the vessel**
3. **The rigging is fairly easy to install.**

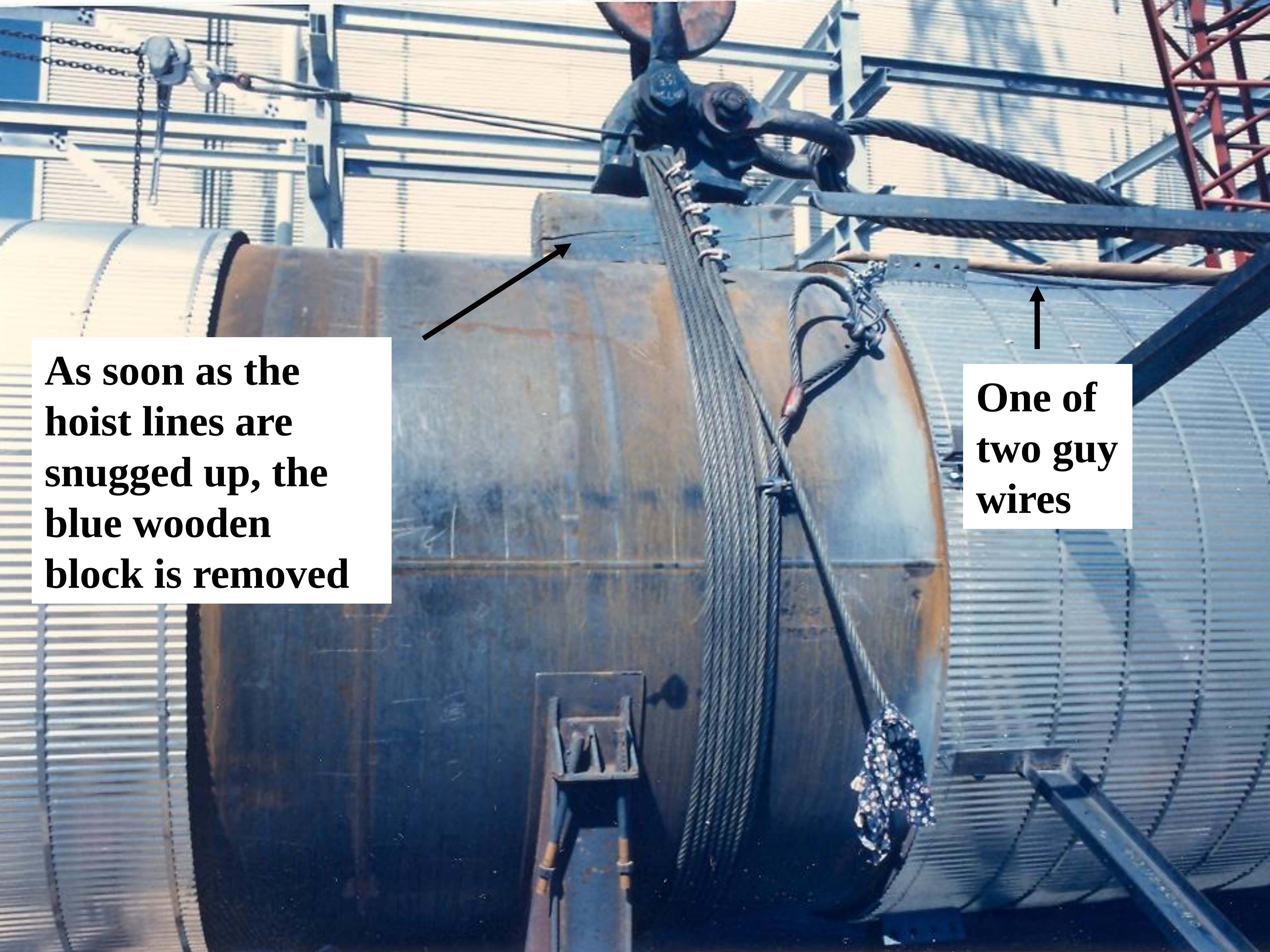
    a. Place a wooden block on the shell to position the OPPD so the load block won't interfere with the shell during upending

    b. Wrap the wire rope lashing thru the OPPD and around the shell with sufficient wraps to handle the initial pick load

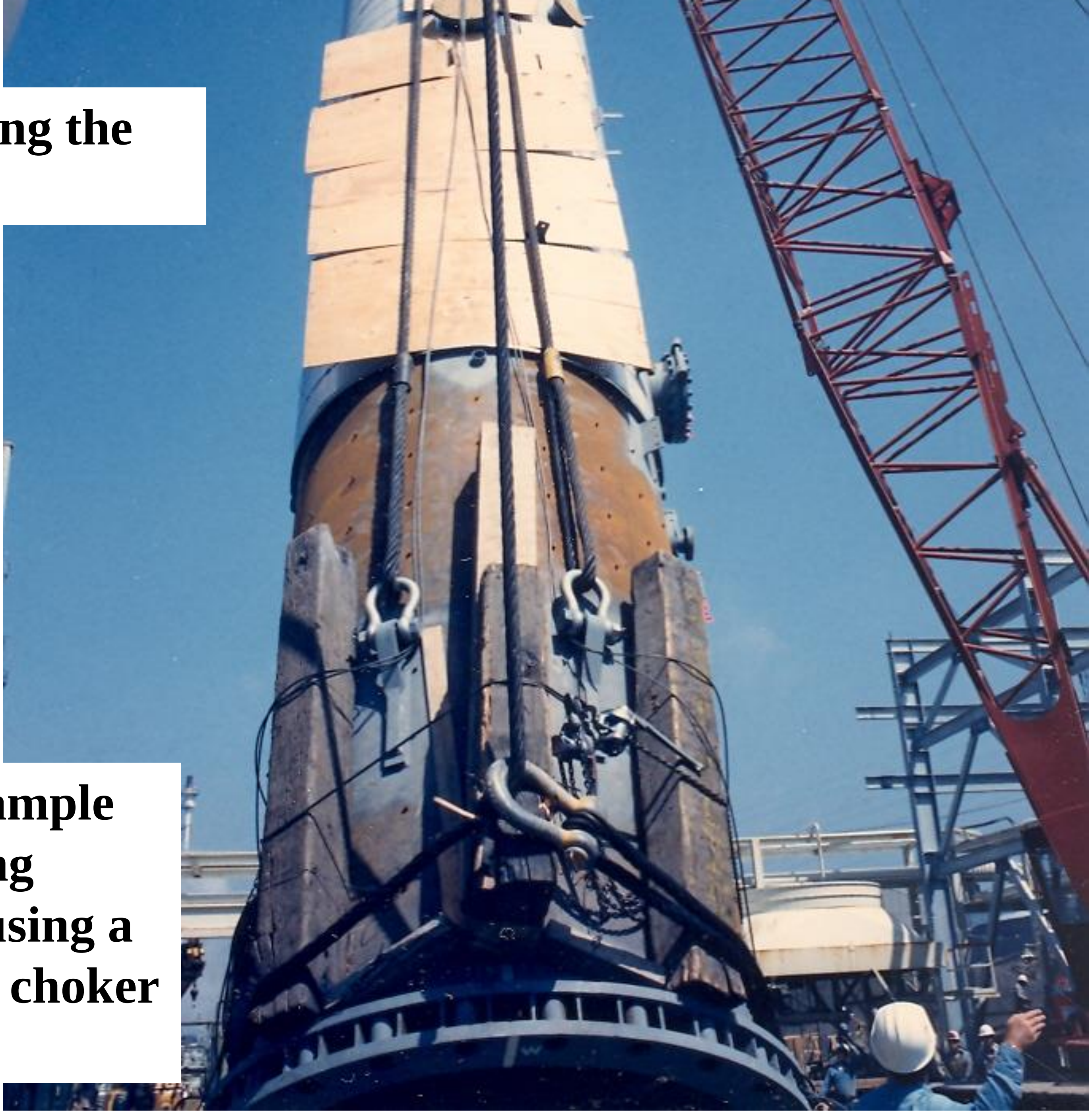
    c. Weld stirrups on the skirt of the vessel

    d. Connect the boot straps to the OPPD and the stirrups

    e. Use six tirfors to plumb the vessel after upending

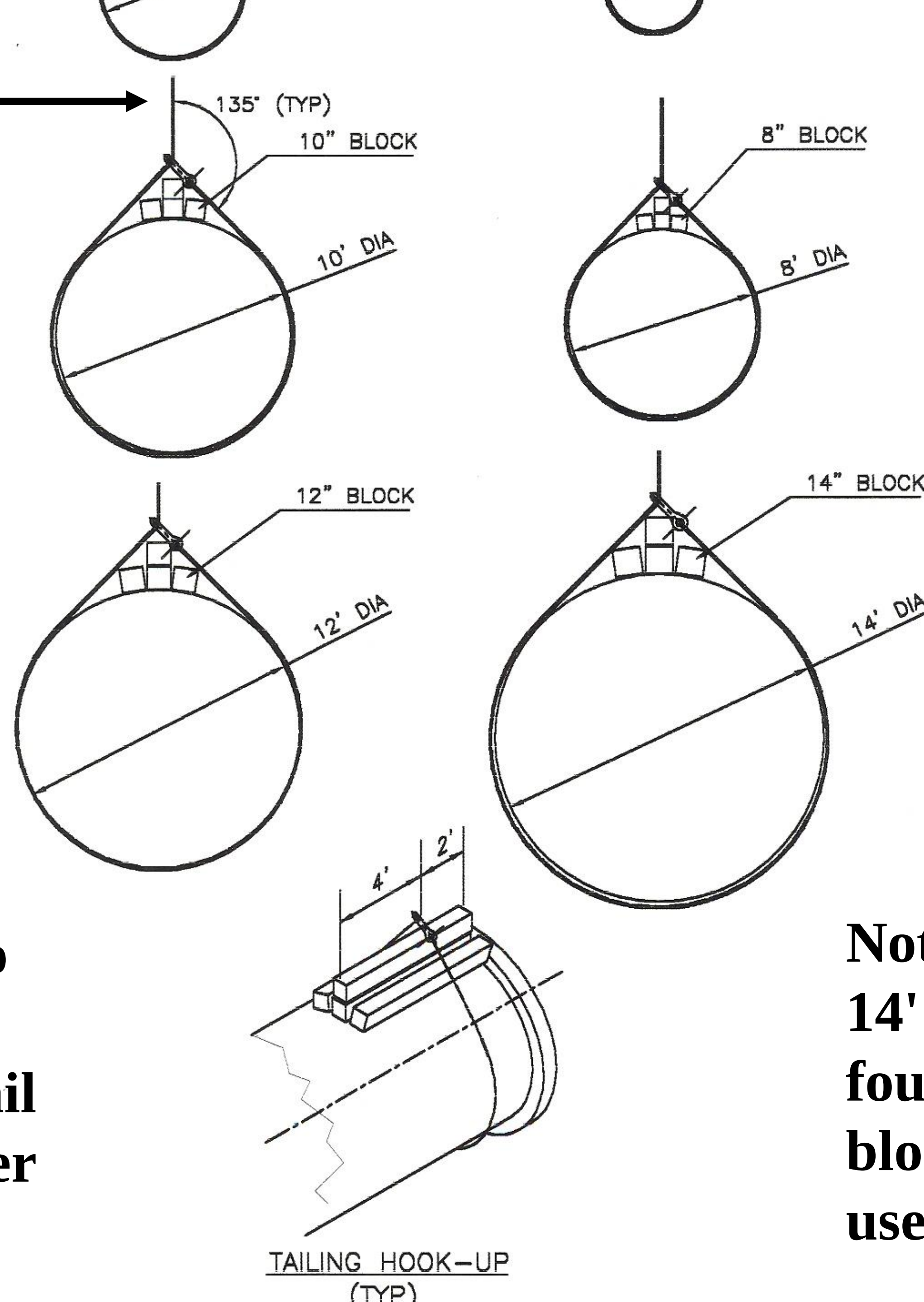

As soon as the hoist lines are snugged up, the blue wooden block is removed
One of two guy wires

Up ending the vessel



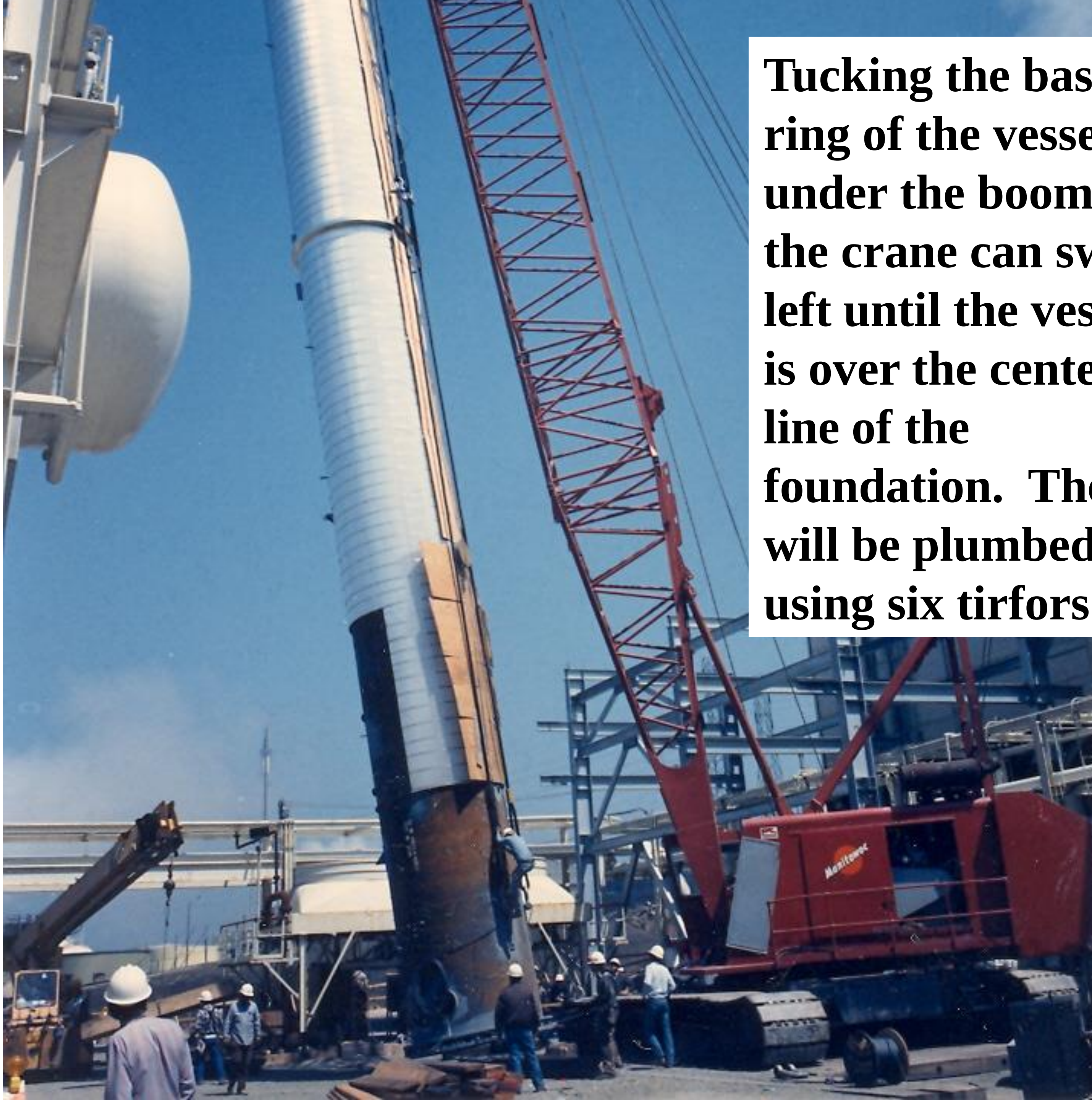
Good example of a tailing hookup using a sling in a choker Hitch

135 Degrees (Typical)

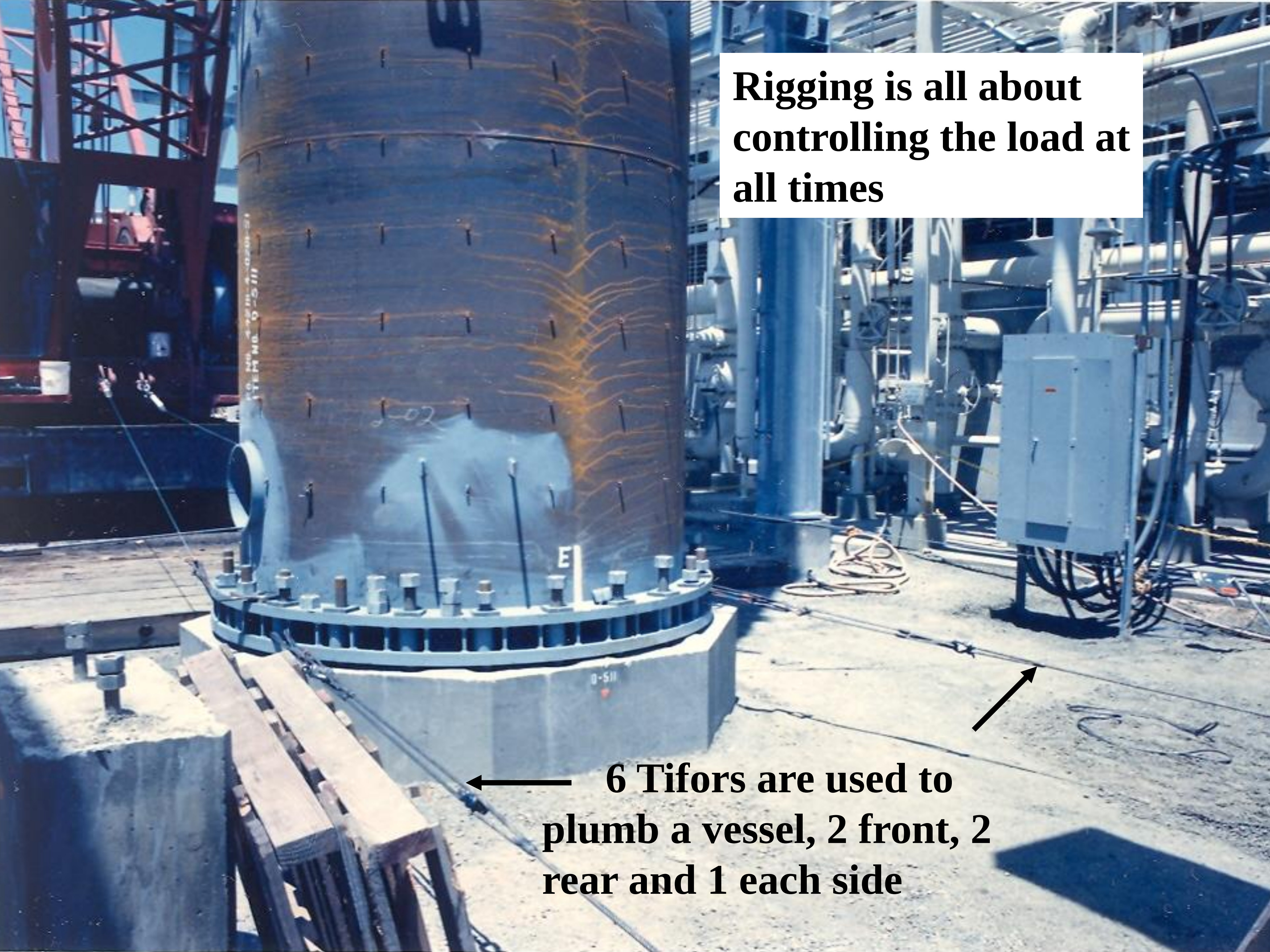


Skirt and base ring stresses do not have to be analyzed if a tail sling in a choker hitch is used

Note that for a 14' dia. skirt, four 14" wooden blocks must be used, etc



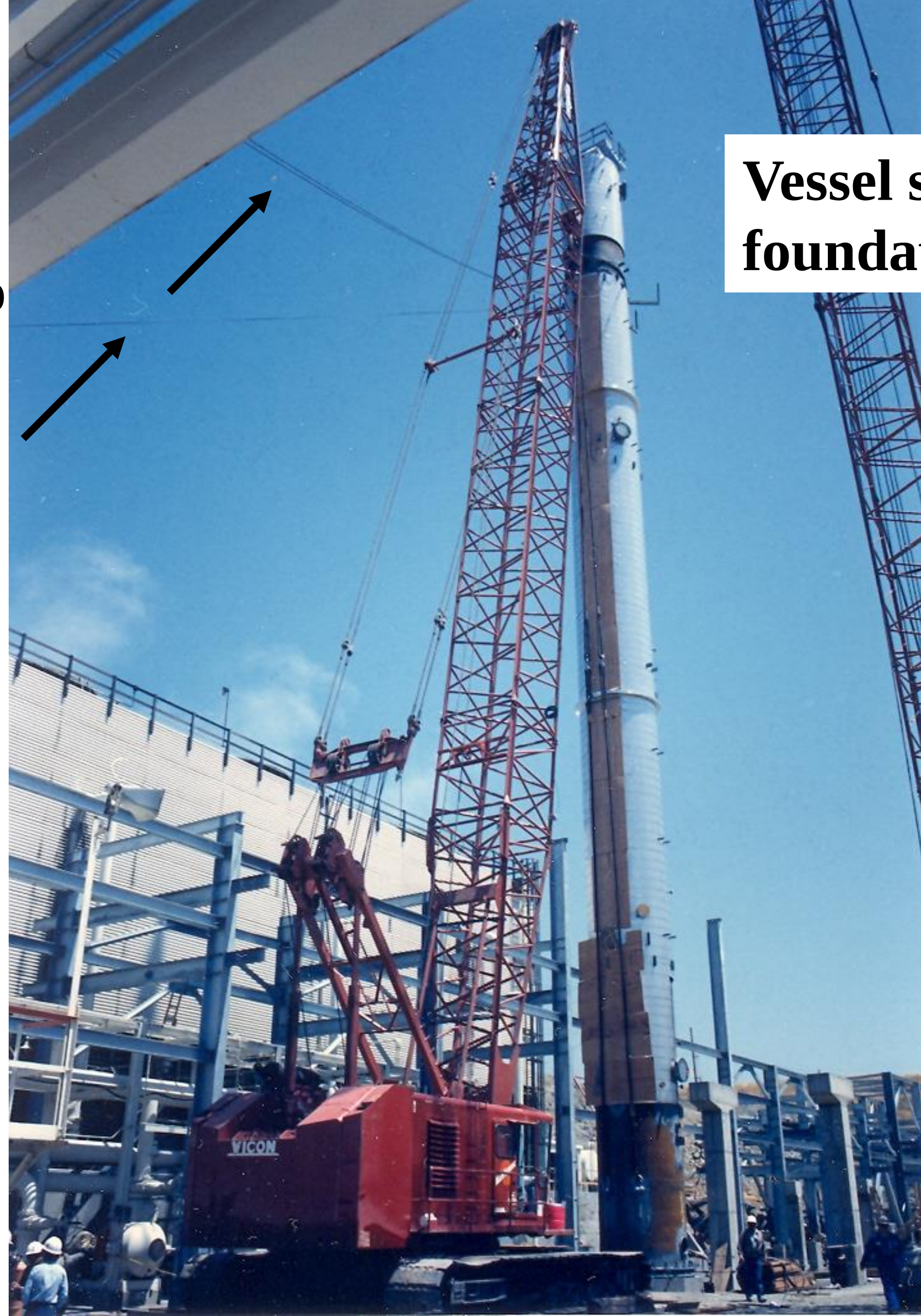
Tucking the base ring of the vessel under the boom so the crane can swing left until the vessel is over the center line of the foundation. Then it will be plumbed using six tirfors



Rigging is all about controlling the load at all times

6 Tifors are used to plumb a vessel, 2 front, 2 rear and 1 each side

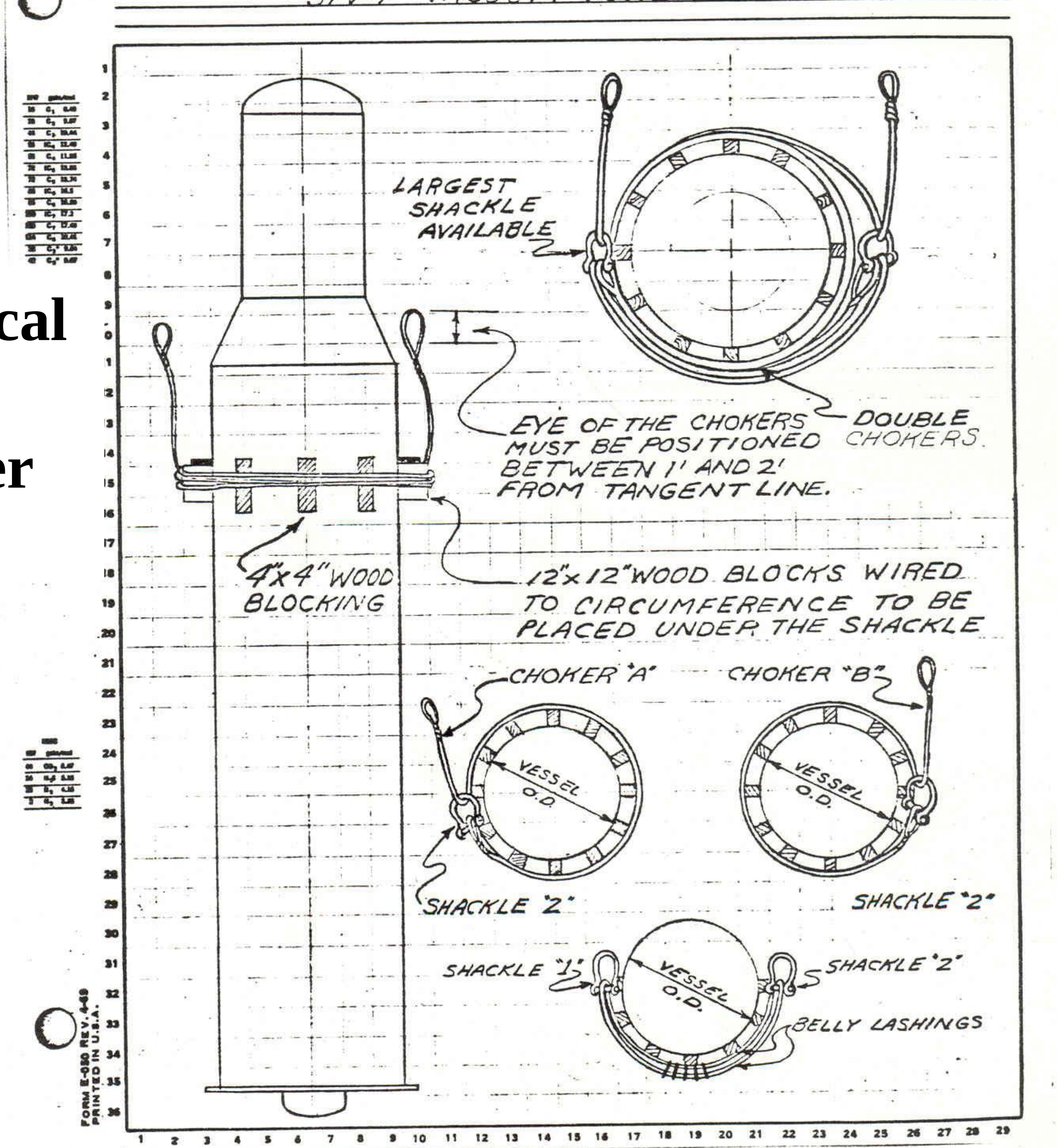
The two guy wires are used to keep the hook centered under the boom tip sheaves during plumbing of the vessel



Vessel set on foundation

Lifting a vertical vessel using double choker hitches

This type of hitch is used when there are no lugs on the vessel. It is labor intensive to hook up

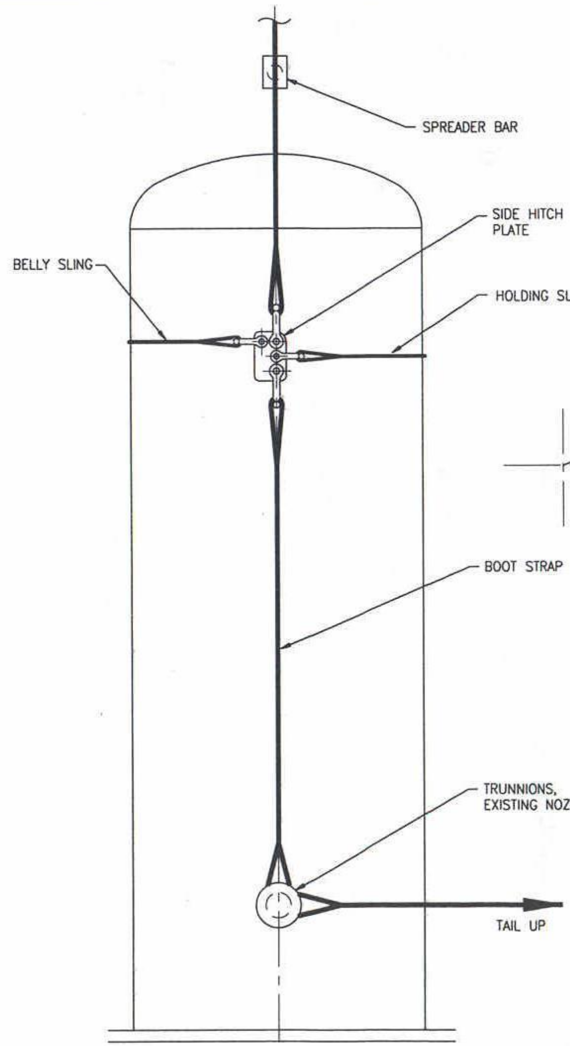


SIDE HITCH PLATE

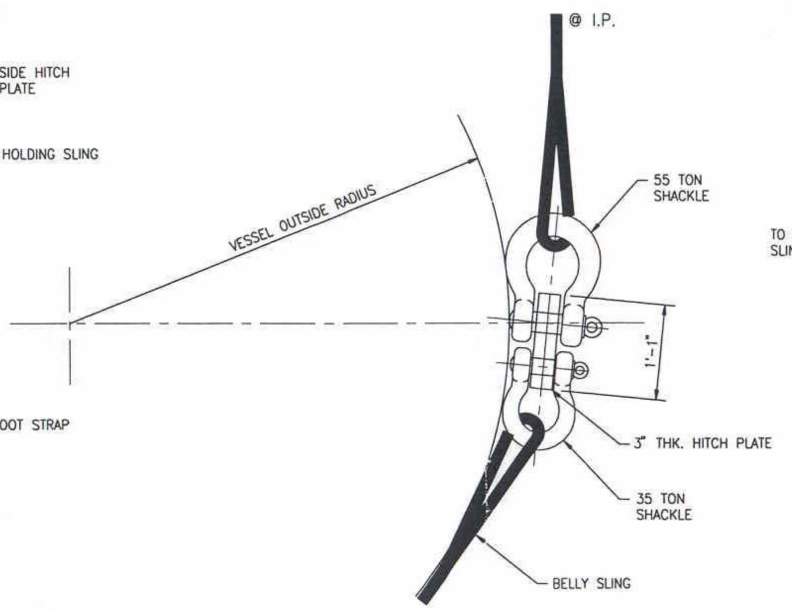
1. **The side hitch plate was designed to replace the Double Choke Method for lifting vessels that do not have lifting lugs on them**
2. **It is usually used to lift off the top sections of tall vessels that have become too corroded to be in service. This means that it is not safe to weld on lugs either**
3. **The boot straps can be hooked to existing nozzles, new lugs, etc**
4. **Easy to install. Assemble everything on the hook, swing it into place around the vessel and hook up the holding sling. Sort of like a woman putting on her bra.**

   Then hook up the boot straps to the nozzles or lugs at the base of the section and the vessel is ready to lift. The belly sling handles the IPP load and the boot straps handle the set load.

Side Hitch Plate

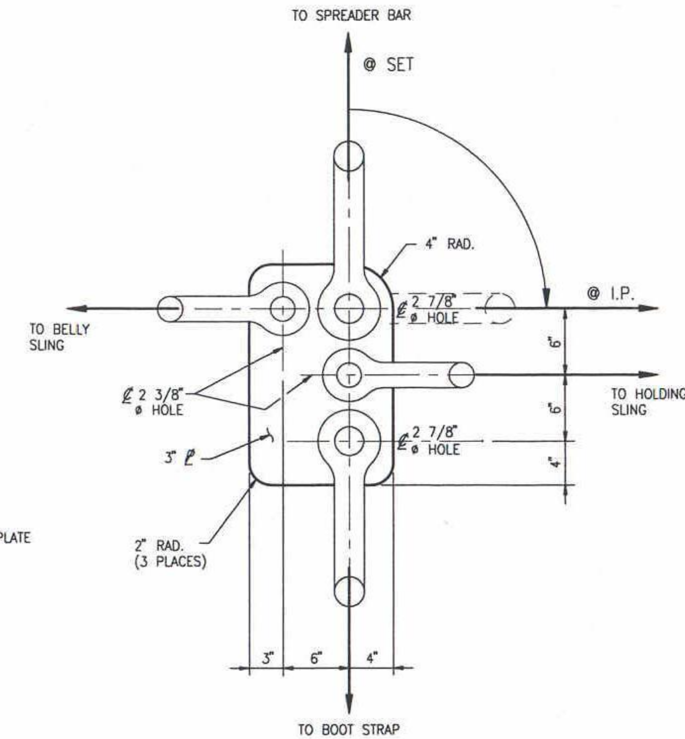


ELEVATION



PARTIAL VIEW AT I.P.

SIDE HITCH PLATE



SIDE HITCH PLATE DETAIL

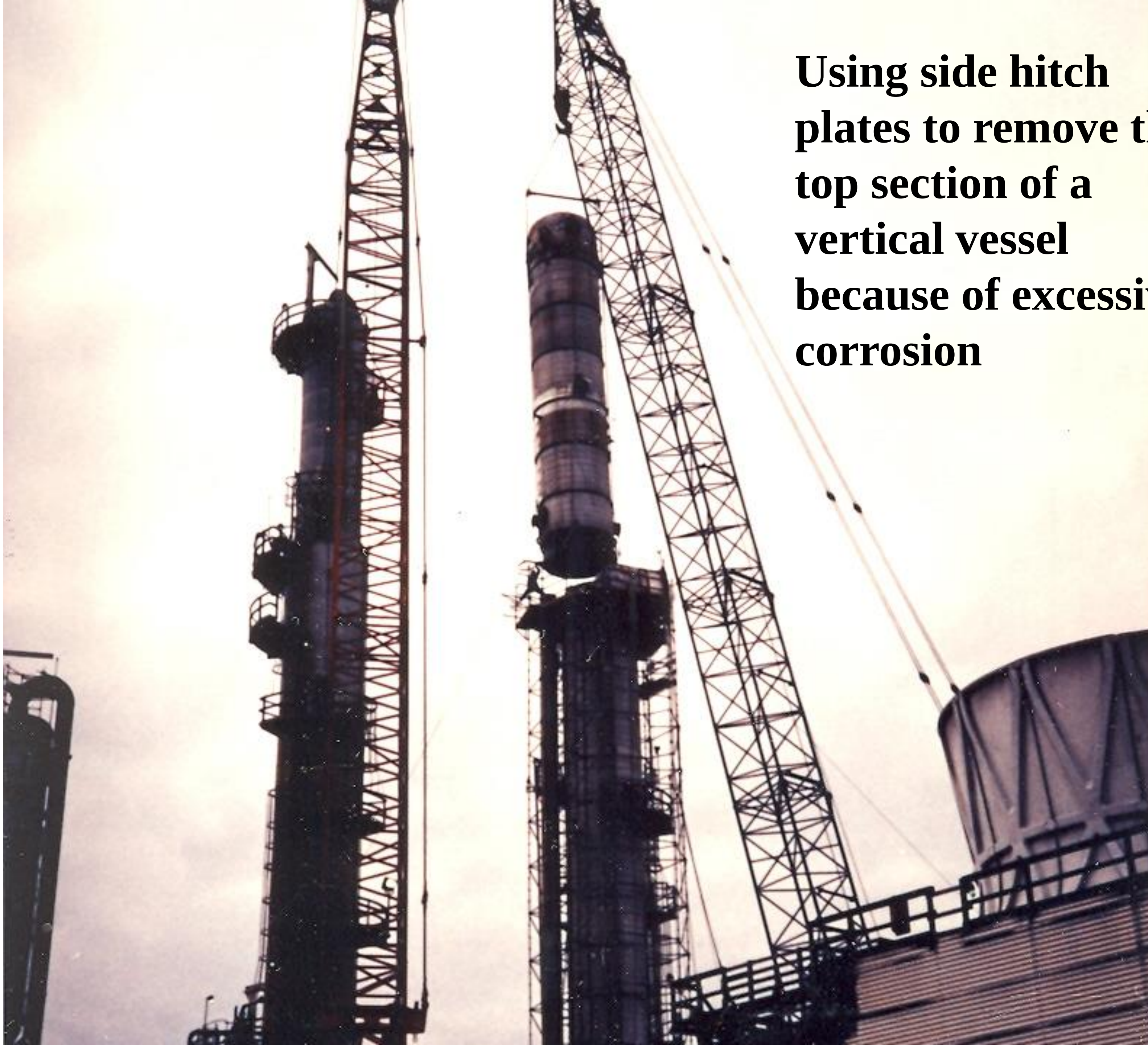
CAPACITY: 50 TONS PER HITCH PLATE

FABRICATION NOTES:

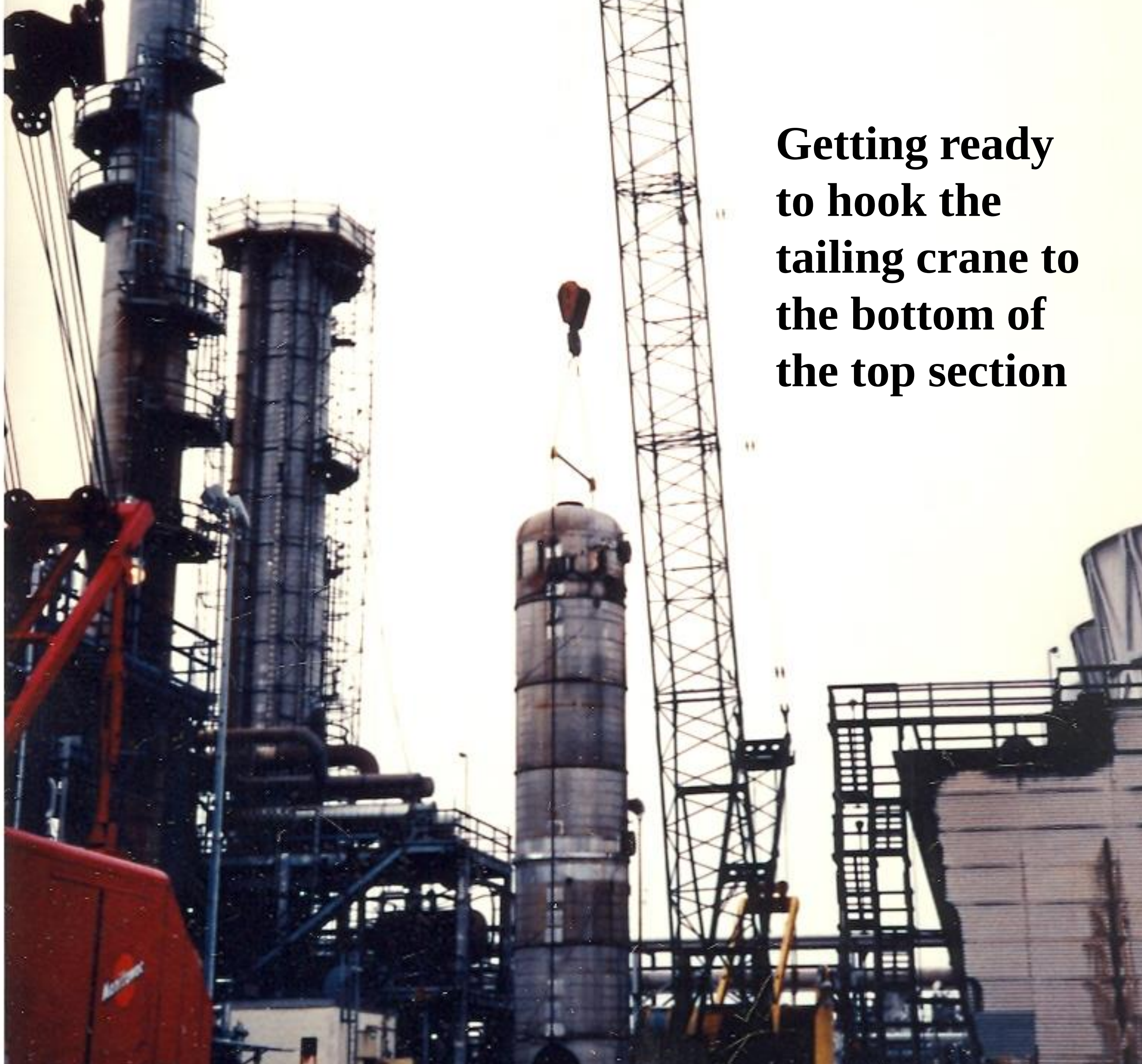
1. ALL WORK SHALL CONFORM TO AISC SPECIFICATION FOR DESIGN, FABRICATION, AND ERECTION OF STRUCTURAL STEEL BUILDINGS.
2. ALL MATERIAL SHALL BE A36 (36,000 PSI MINIMUM YIELD STRENGTH.)
3. SHOP TO APPLY TWO (2) COATS OF ZINC CHROMATE PRIMER, AND ONE (1) COAT OF ENAMEL (YELLOW).
4. DO NOT SCALE THIS DRAWING.

FIELD NOTES:

1. SOFTEN SHELL AS REQUIRED.
2. CONTACT THE RIGGING GROUP TO VERIFY THE STRUCTURAL STRENGTH OF EXISTING NOZZLES PROPOSED FOR ANCHORING BOOT STRAPS OR FOR TRUNNION, STIRRUP, OR LUG DESIGN.
3. LIFT SLINGS & BOOT STRAP SLINGS MUST BE DESIGNED FOR A 5:1 SAFETY FACTOR BASED ON THE TOTAL VESSEL WEIGHT.
4. THE BELLY SLING & HOLDING SLING MUST BE DESIGNED FOR A 5:1 SAFETY FACTOR BASED ON THE INITIAL PICK LOAD (I.P.).
5. A SPREADER BAR MUST BE USED FOR ERECTION.

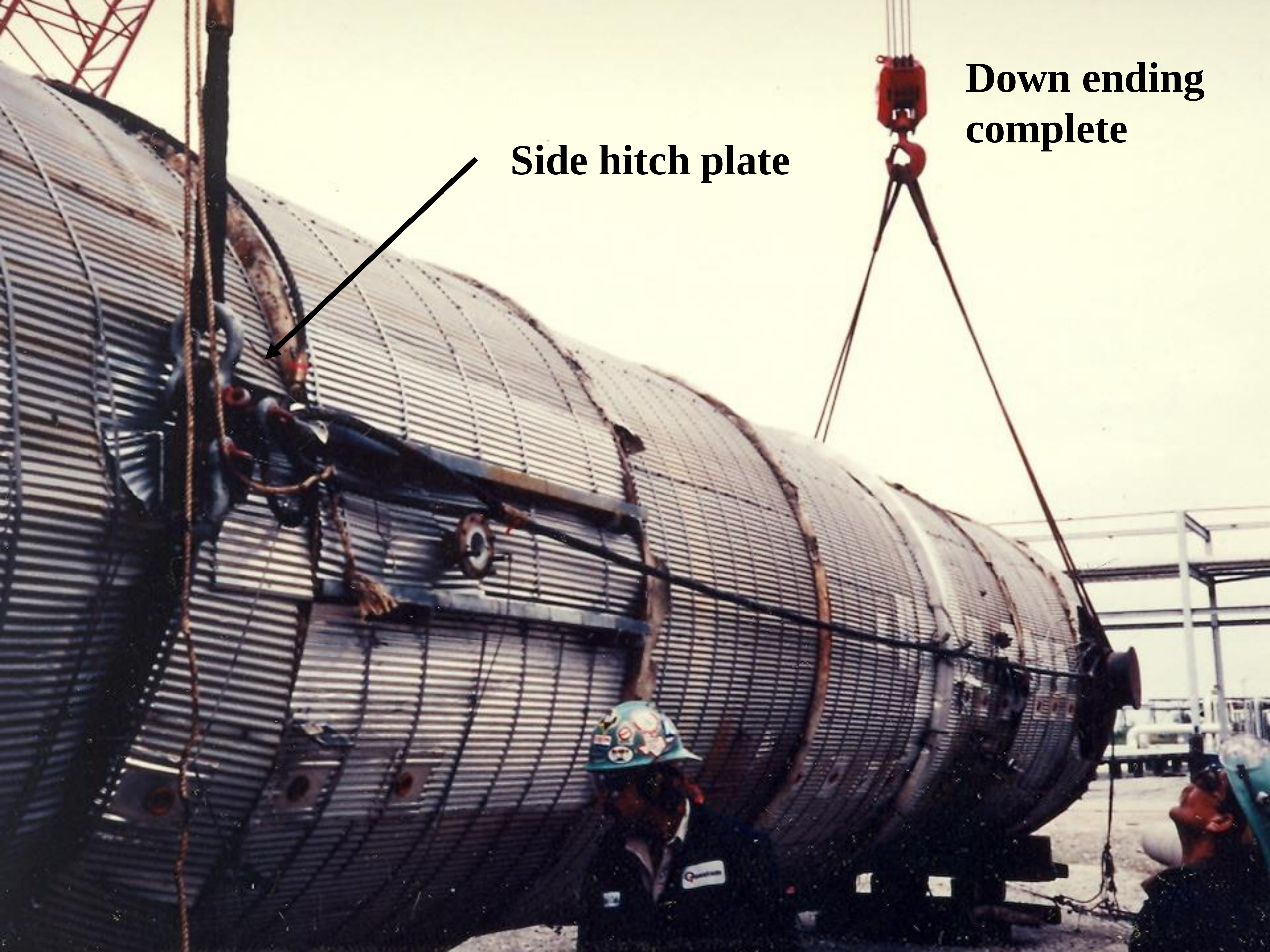


Using side hitch plates to remove the top section of a vertical vessel because of excessive corrosion



Getting ready to hook the tailing crane to the bottom of the top section

Down ending the top section


Down ending
complete
Side hitch plate

BASE RING REINFORCEMENT

1. **When a tail lug is to be used to tail a vertical vessel, the base ring stresses must be analyzed**

2. **Lifting the bottom of a vertical vessel with just a tail lug is called a one point support. The resulting tailing force causes the base ring to deflect in an egg shaped fashion. If the base ring deflects to much, it will be overstressed in bending**

3. **If the base ring is overstressed in a one point support, then an internal or external beam must be used to reduce the stresses. This is called a two point support. The resulting tailing force causes the base ring to deflect in an up side down pear shaped fashion. If the base ring deflects to much, it will be over stressed in bending**

4. **If the base ring is overstressed in a two point support, then diamond shaped reinforcement must be used to reduce the stresses. This is called a four point support.**

BASE RING REINFORCEMENT Continued:

5. **Using a four point support always works and will eliminate the over stressing of the base ring**

6. **Deciding whether to use an internal or external beam depends on it usage, i.e., if there are similar vessels to be tailed up, then an external tail beam would be used that bolts to the base plate of each of the vessels. If there is only one vessel to tail up, an internal beam would be welded inside the base plate.**

COMMENT:

a. **It should be pointed out that for each type of support, the Rigging Engineer would try to make it work by increasing the thickness or by decreasing the I.D. of the base plate. If that didn't work, then the RE would go to the next higher type support, i.e., from a one point to a two point support.**

Vertical vessel with tail lug and internal base ring reinforcement, 4 point support

Vertical vessel with external tailing beam in a 4 point support

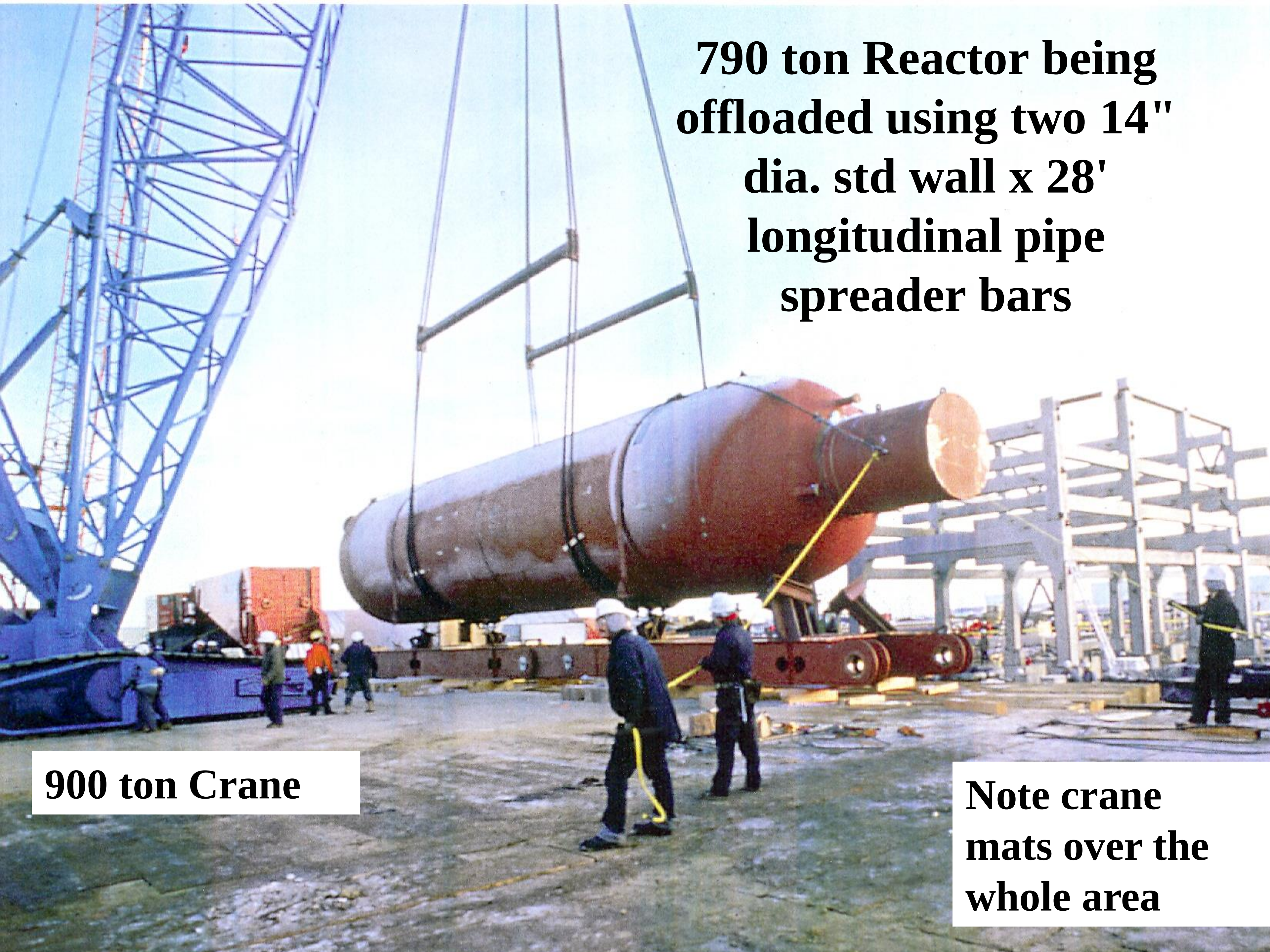
Vertical vessel with twin tailing beams

SPREADER BARS

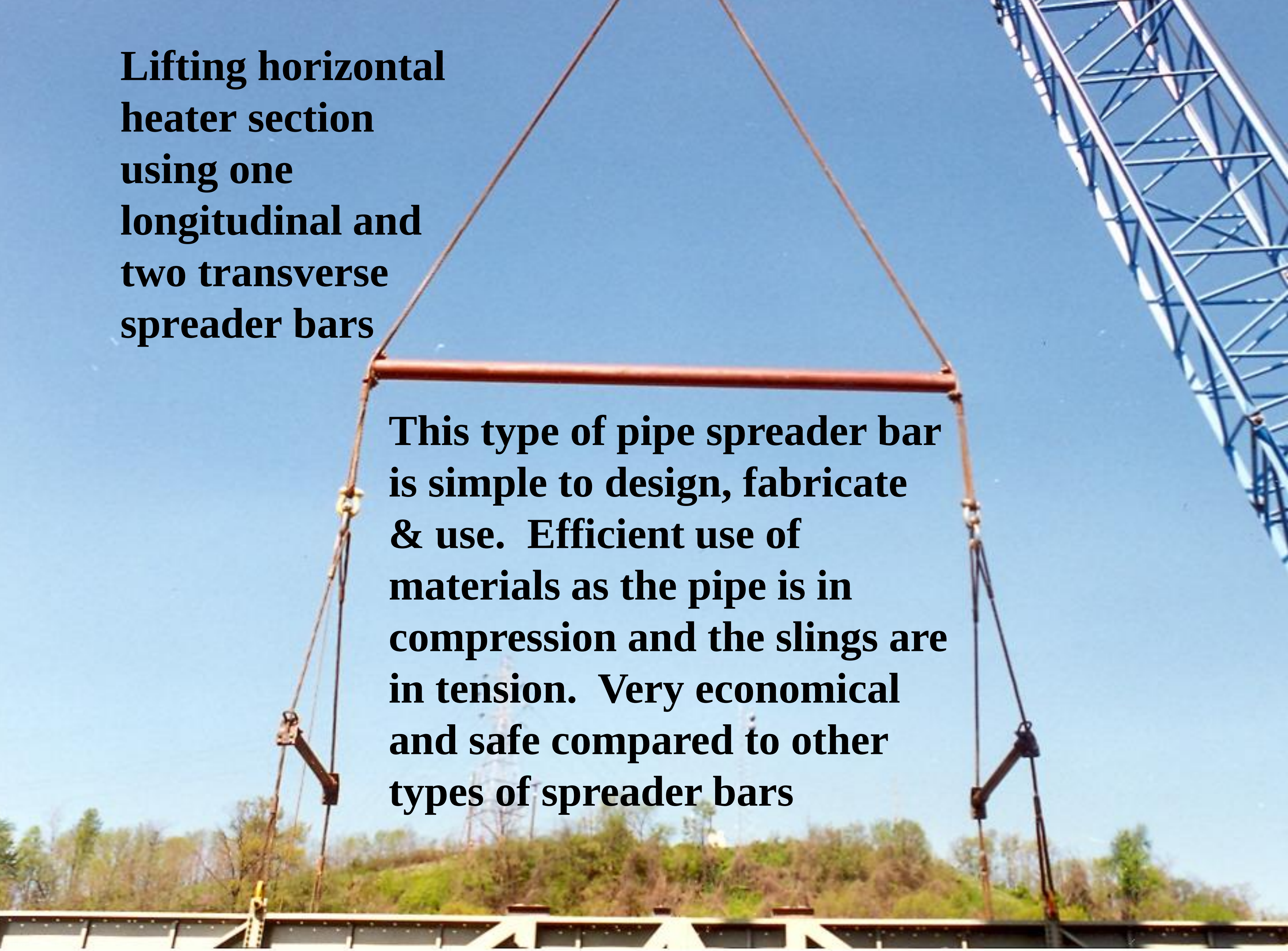
Unlike equalizer beams where the object is to keep the same percentage of load on each crane through out the lift, spreader bars are used to keep the lifting slings from side loading the lifting lugs, tail beams, crushing equipment, etc.

Spreader bars should be designed so that there is zero bending due to the influence of the lifting slings.

Lifting the tail end of a vertical vessel with a spreader bar

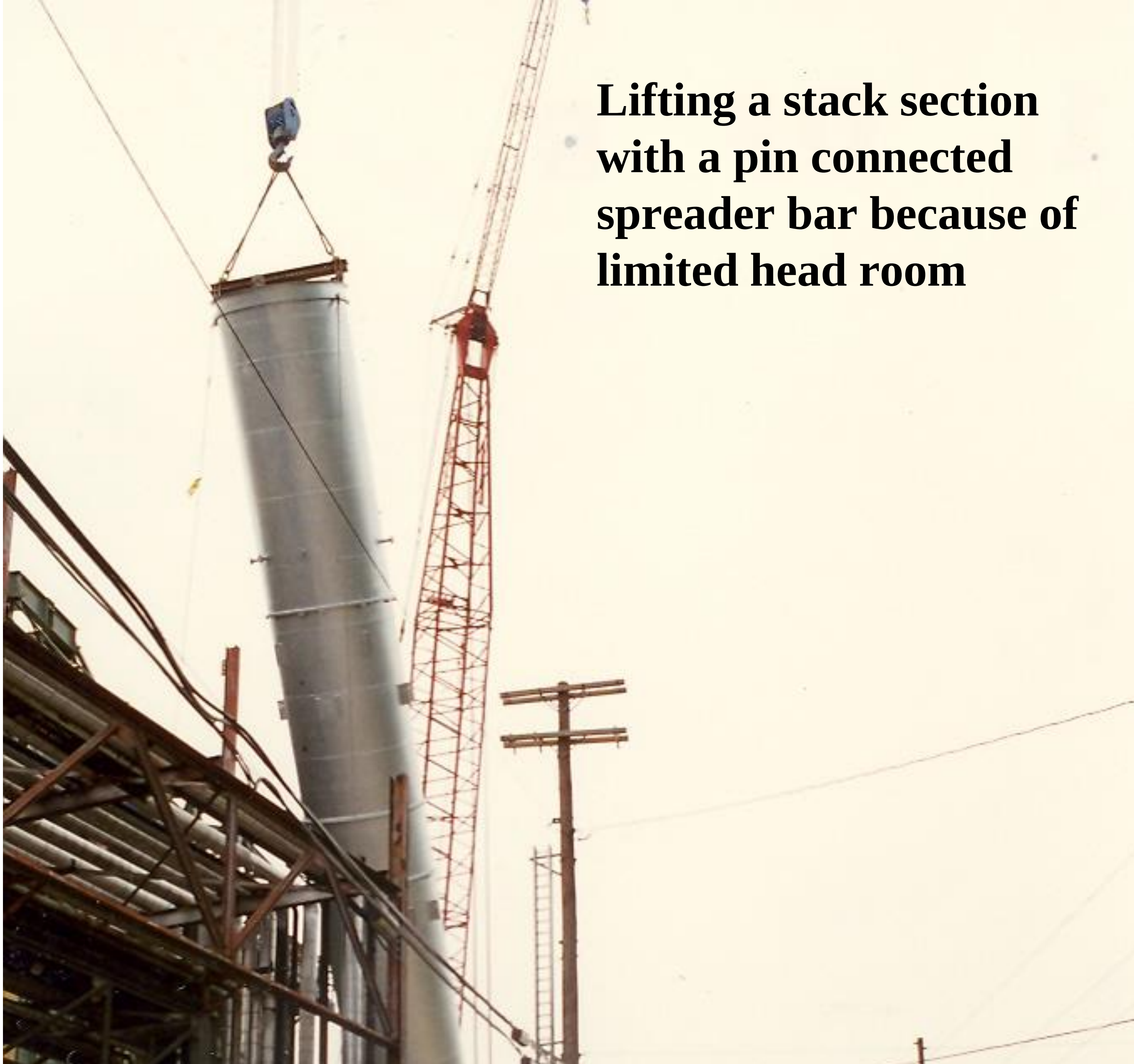

790 ton Reactor being offloaded using two 14" dia. std wall x 28' longitudinal pipe spreader bars
900 ton Crane
Note crane mats over the whole area

Lifting horizontal heater section using multi-spreader bars



Lifting horizontal heater section using one longitudinal and two transverse spreader bars

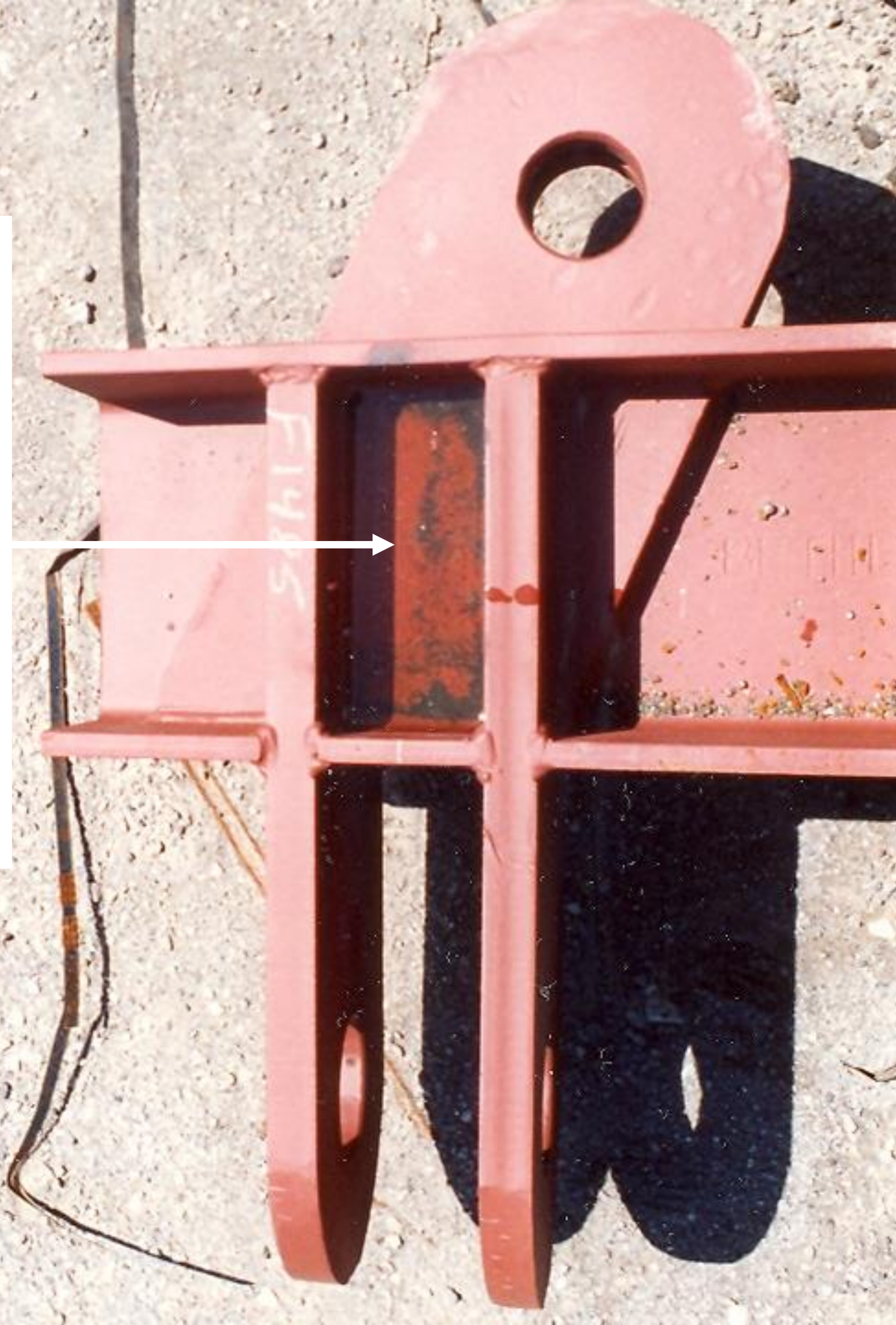
This type of pipe spreader bar is simple to design, fabricate & use. Efficient use of materials as the pipe is in compression and the slings are in tension. Very economical and safe compared to other types of spreader bars



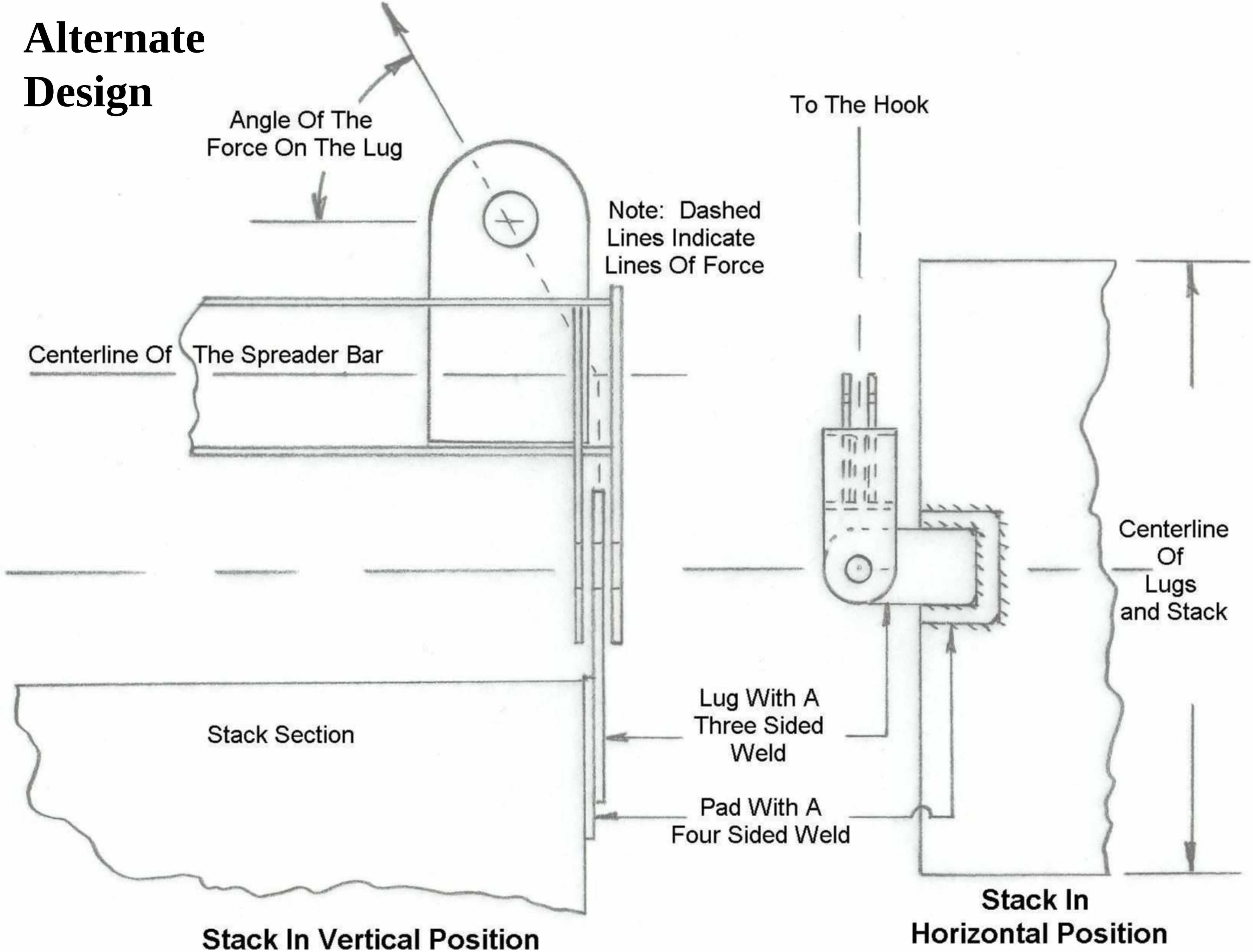
Lifting a stack section with a pin connected spreader bar because of limited head room

Actual spreader bar used for the stack lift

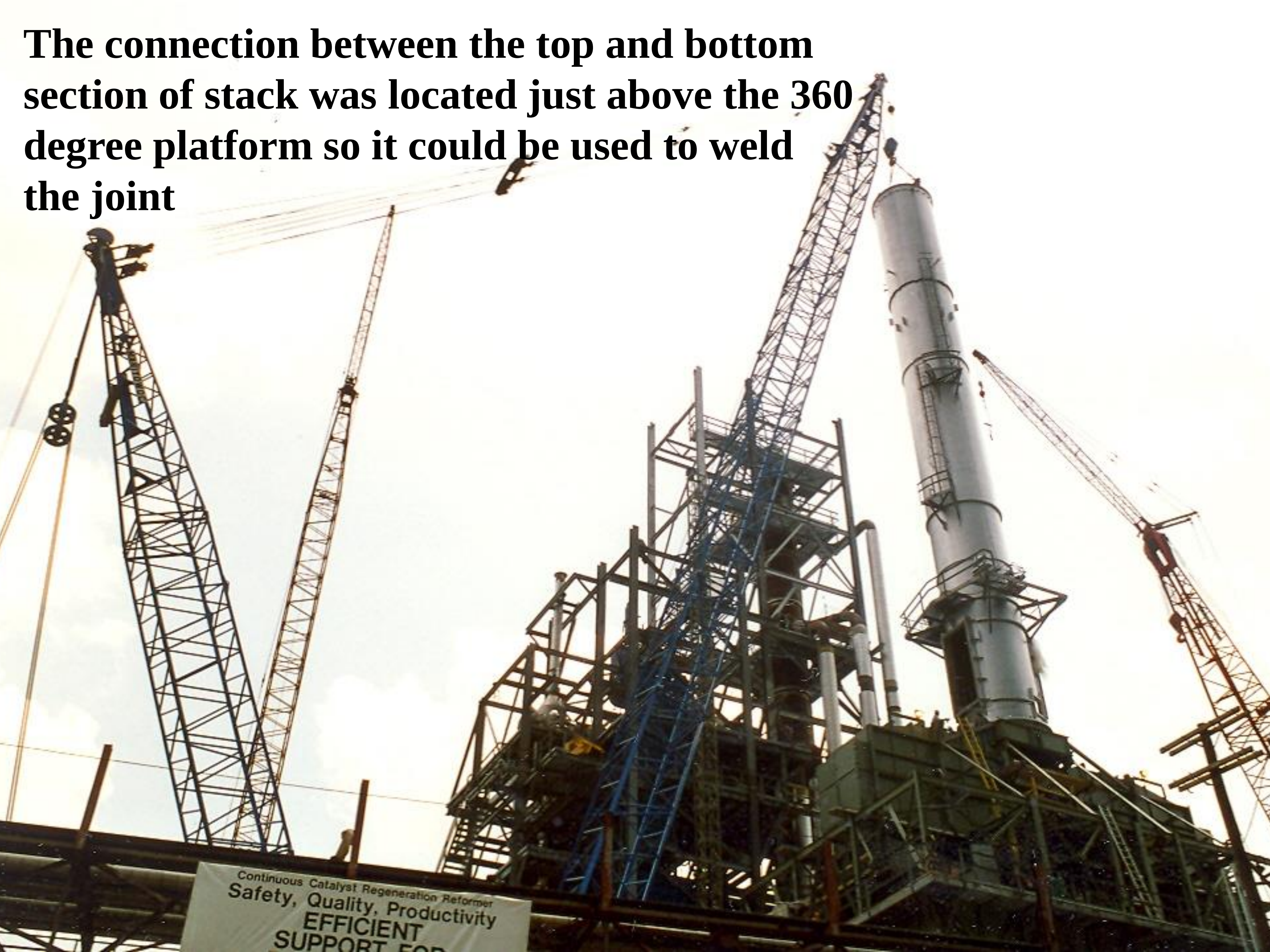
This bar was designed for zero moment due to the influence of the slings because the lines of force intersect at the centerline of the beam

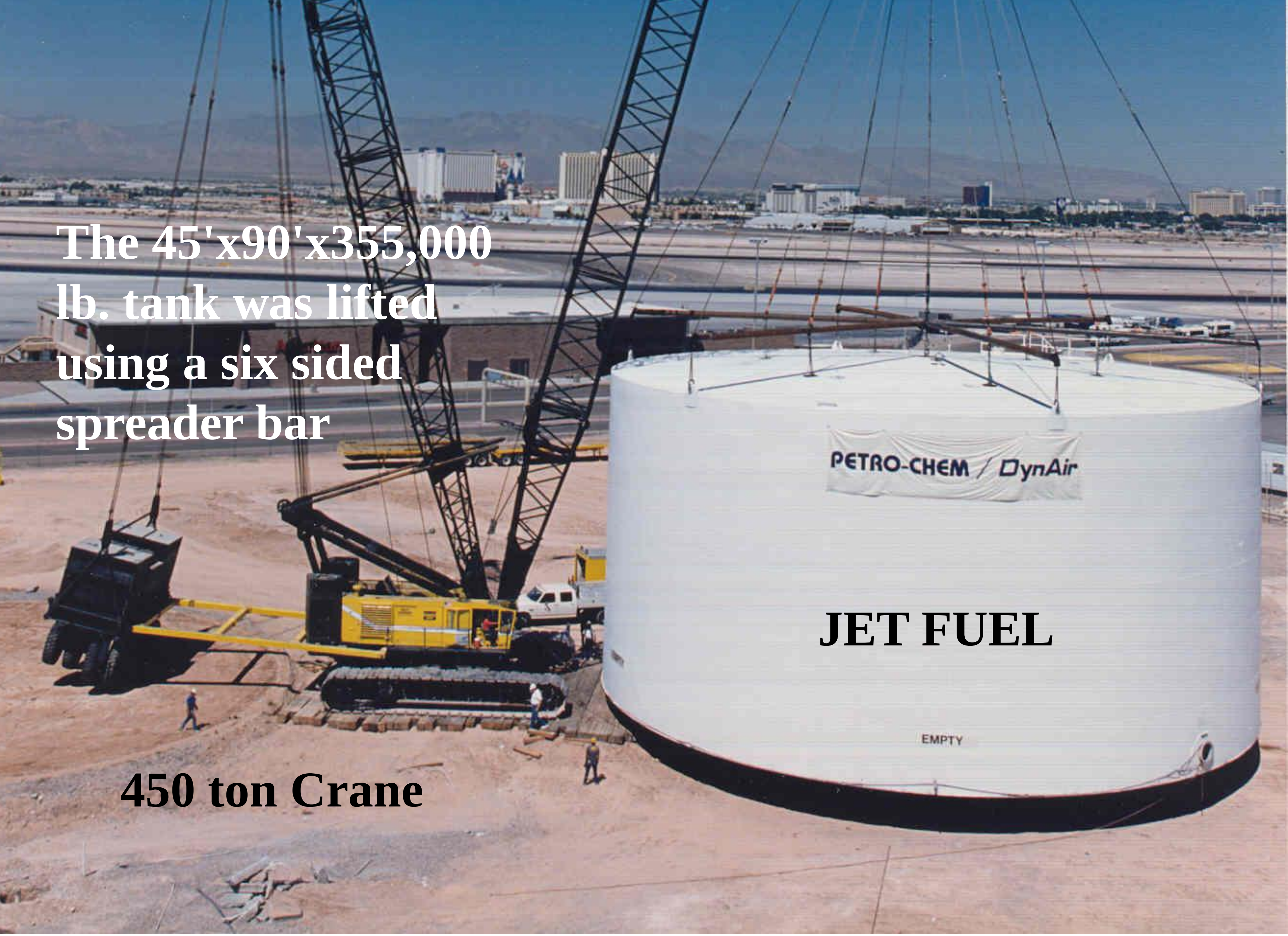


Alternate Design



The connection between the top and bottom section of stack was located just above the 360 degree platform so it could be used to weld the joint




The 45'x90'x355,000 lb. tank was lifted using a six sided spreader bar
PETRO-CHEM / DynAir
JET FUEL
EMPTY
450 ton Crane

200 Te HRSG Modules

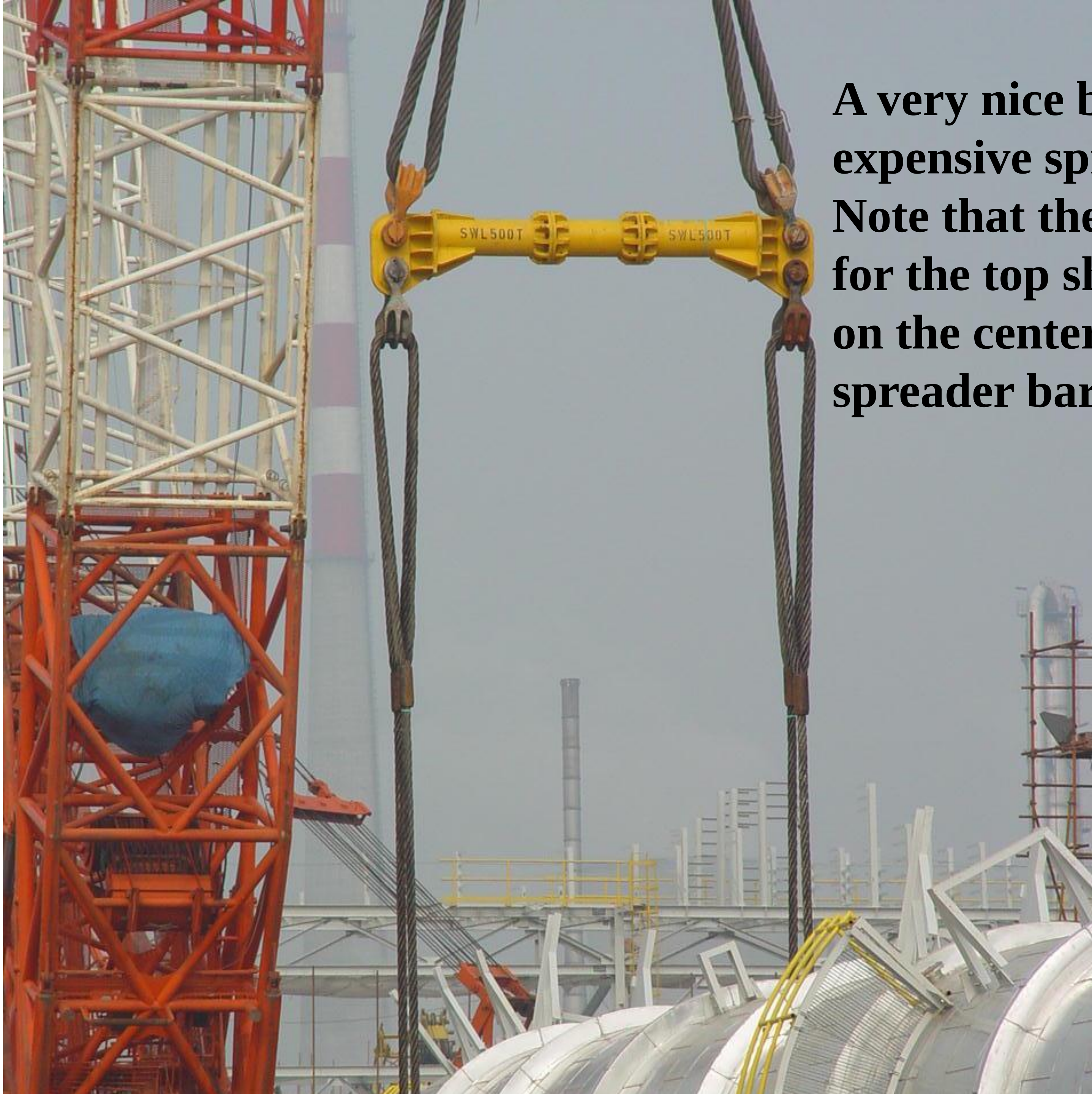
This is the most common type of spreader bar used in construction. Most Engineers don't know how to properly design it and the field is even worse in using it

This type of spreader bar has lugs top & bottom


国石化集团第二
设公司
服务
SCC OF SINOPEC SUPPLY
COMPLEX


A very complicated & expensive spreader bar to design, fabricate & use


A two point
support for the
base ring

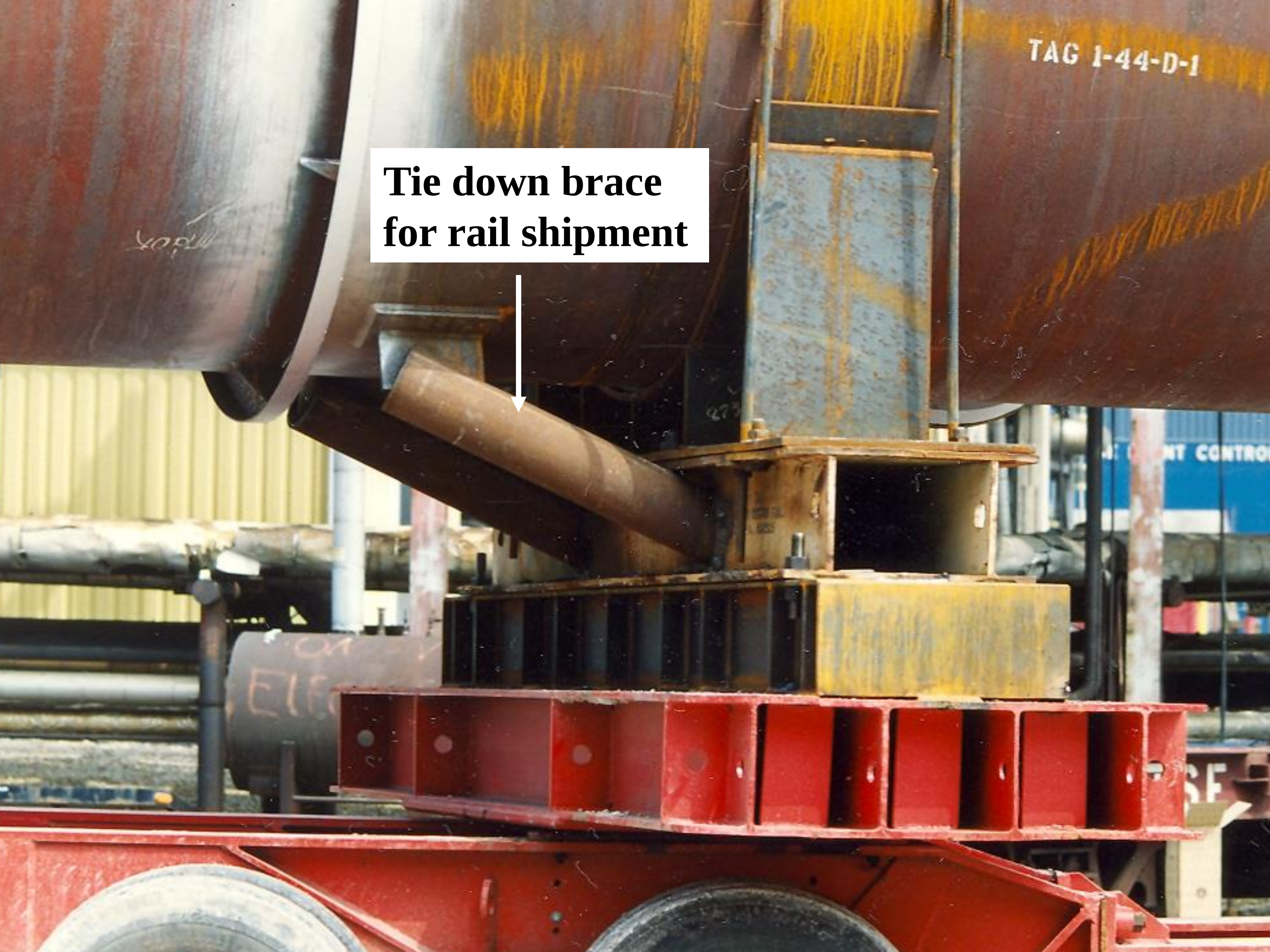


A very nice but expensive spreader bar. Note that the pin holes for the top shackles are on the centerline of the spreader bar

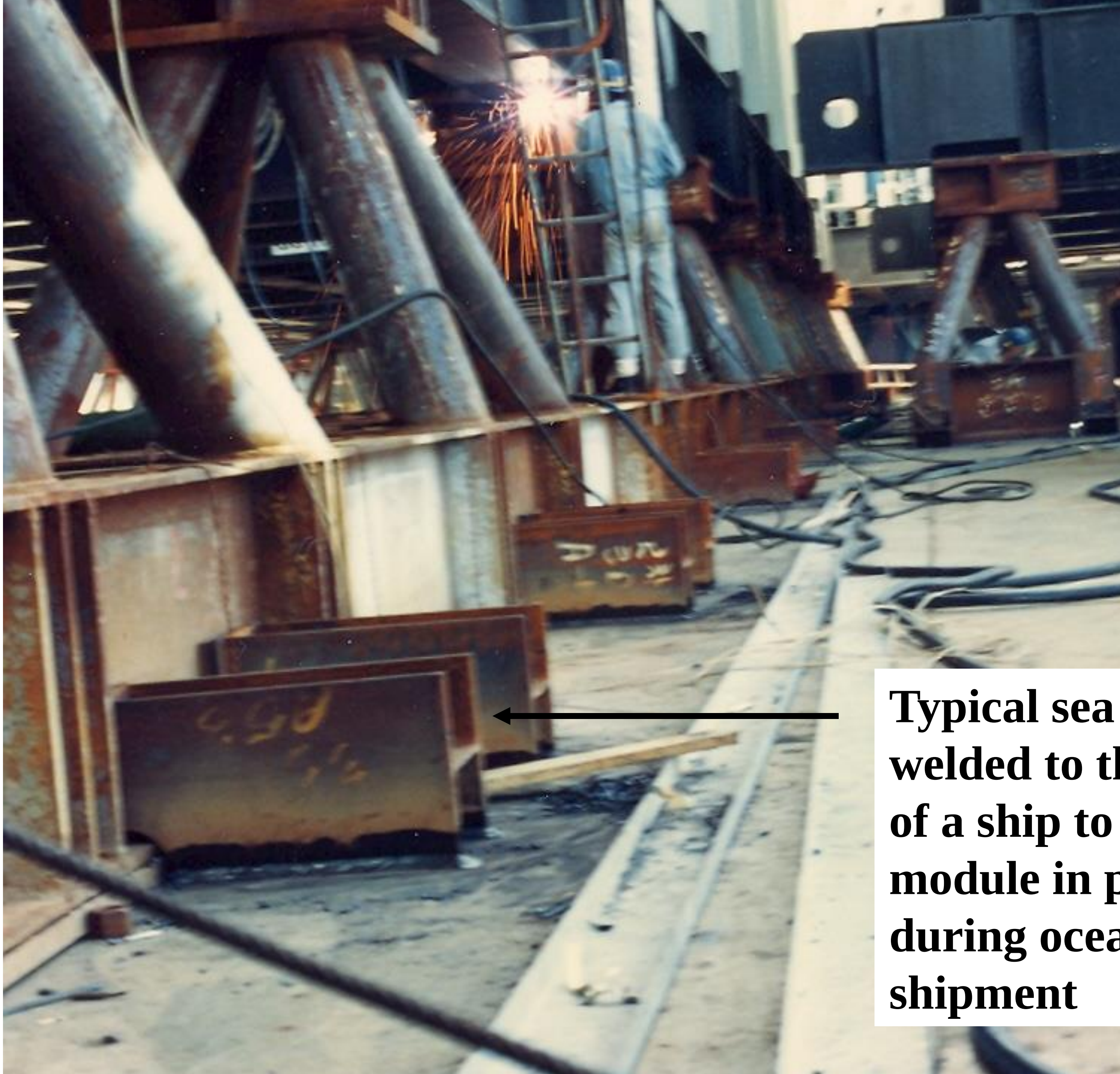
TIE DOWNS

Equipment being transported must be tied down or lashed to the trailer, railcar or ship deck so that it can not move in transit. The tie downs must be designed for the transportation forces involved. The types of tie downs range from:

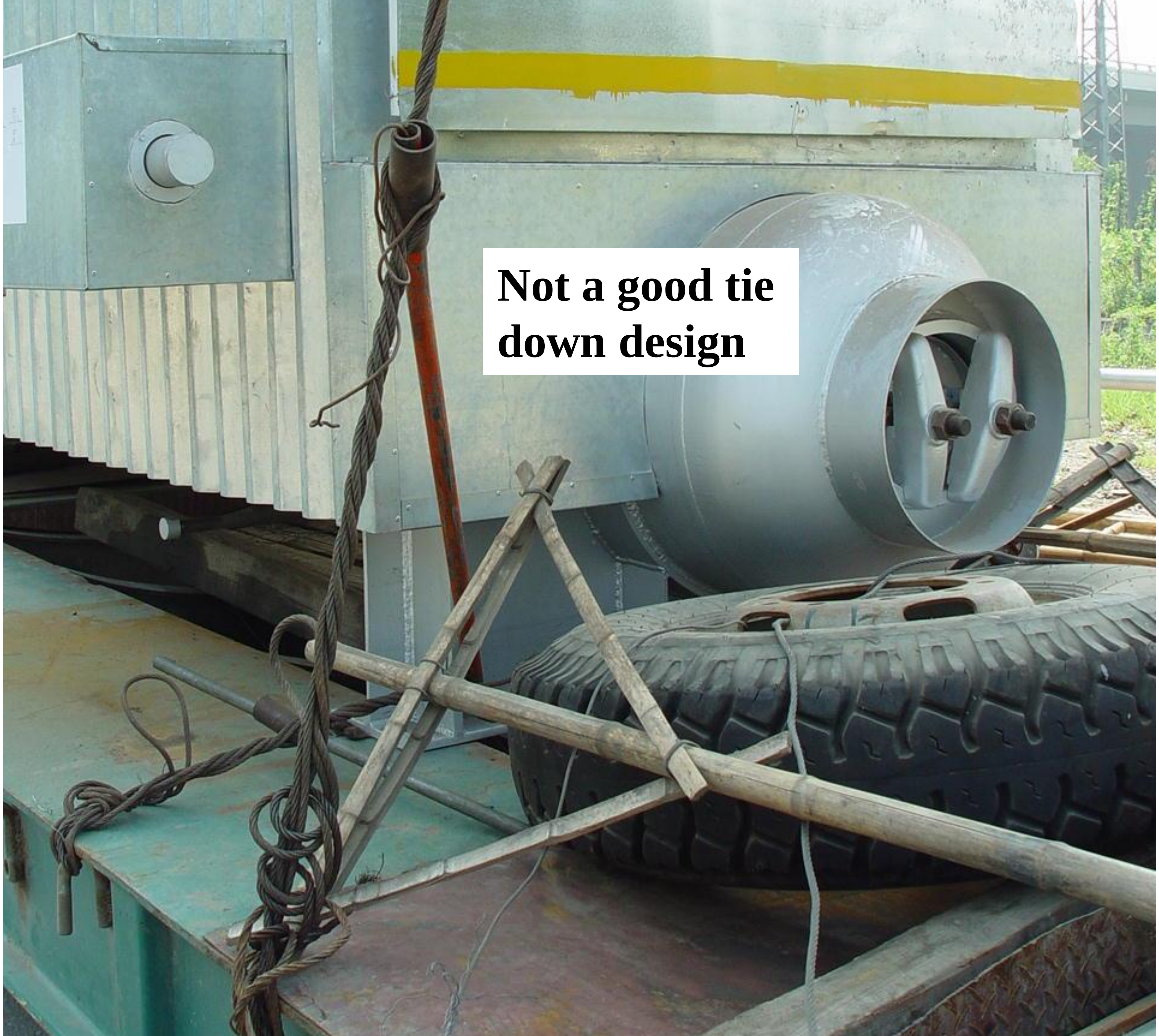
1. **Simple chains and boomers for a load being transported on a float or lowboy**
2. **Pipe bracings to keep a vessel centered on the saddles and bolsters during shipment on a rail car**
3. **Pad eye lugs and slings for lashing a vessel to the deck of a barge**
4. **Sea fasteners welded to the deck of a ship to keep a module from moving horizontally or vertically**


Tie down brace
for rail shipment
TAG 1-44-D-1


Lashing a vessel to a
barge deck



Typical sea fastener welded to the deck of a ship to hold a module in place during ocean shipment


Not a good tie down design

QUIZZES

AND

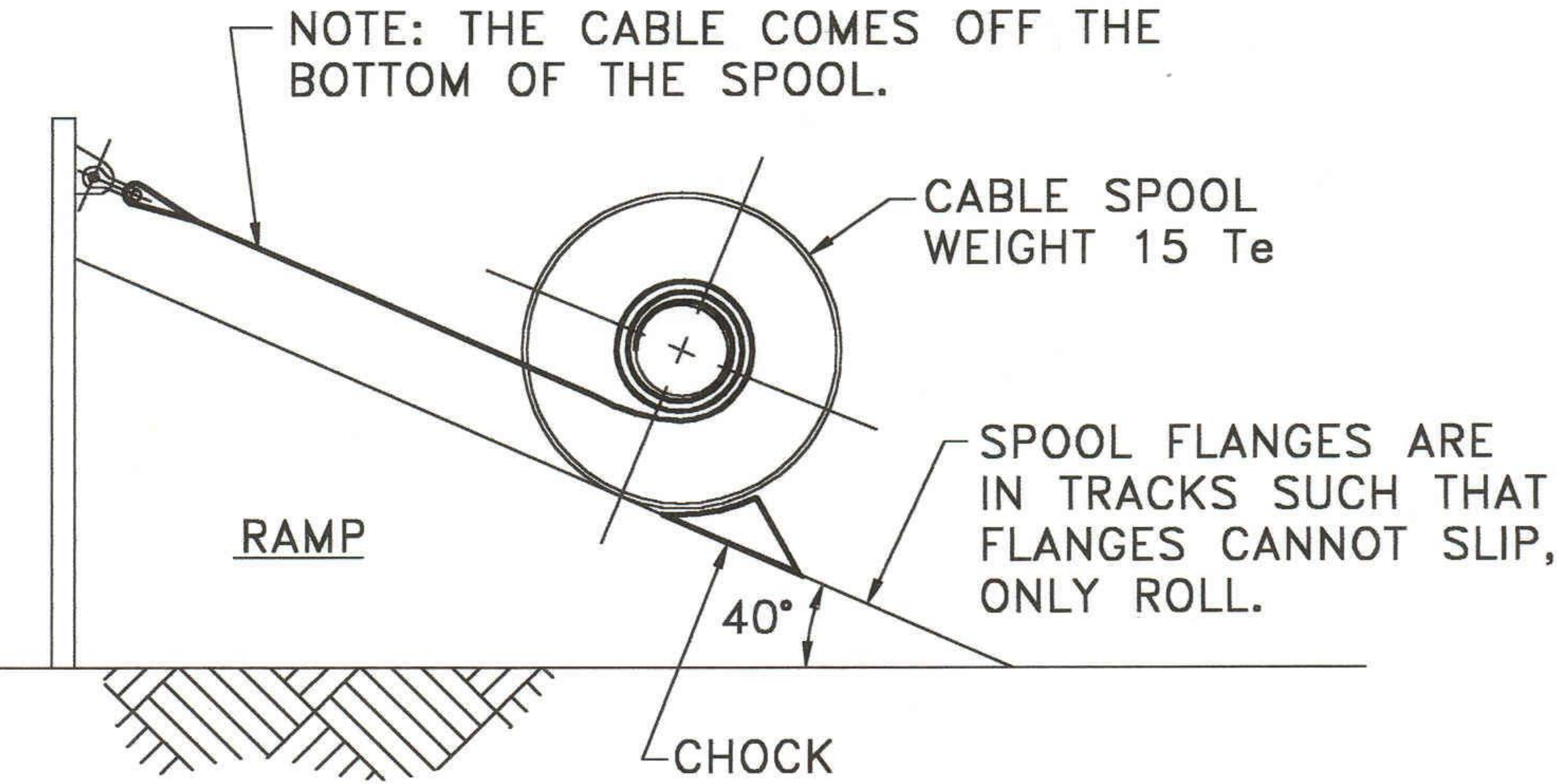
MODELS

Models are great. They don't have to look exactly like the item being lifted. They just have to have the same relationship between the weight, the CG and the pick points as the item being lifted or moved.

QUIZ 1

If the chock is removed, will the spool roll down the ramp?

YES _______ NO_________



ANSWER TO RIGGING QUIZ No. 1

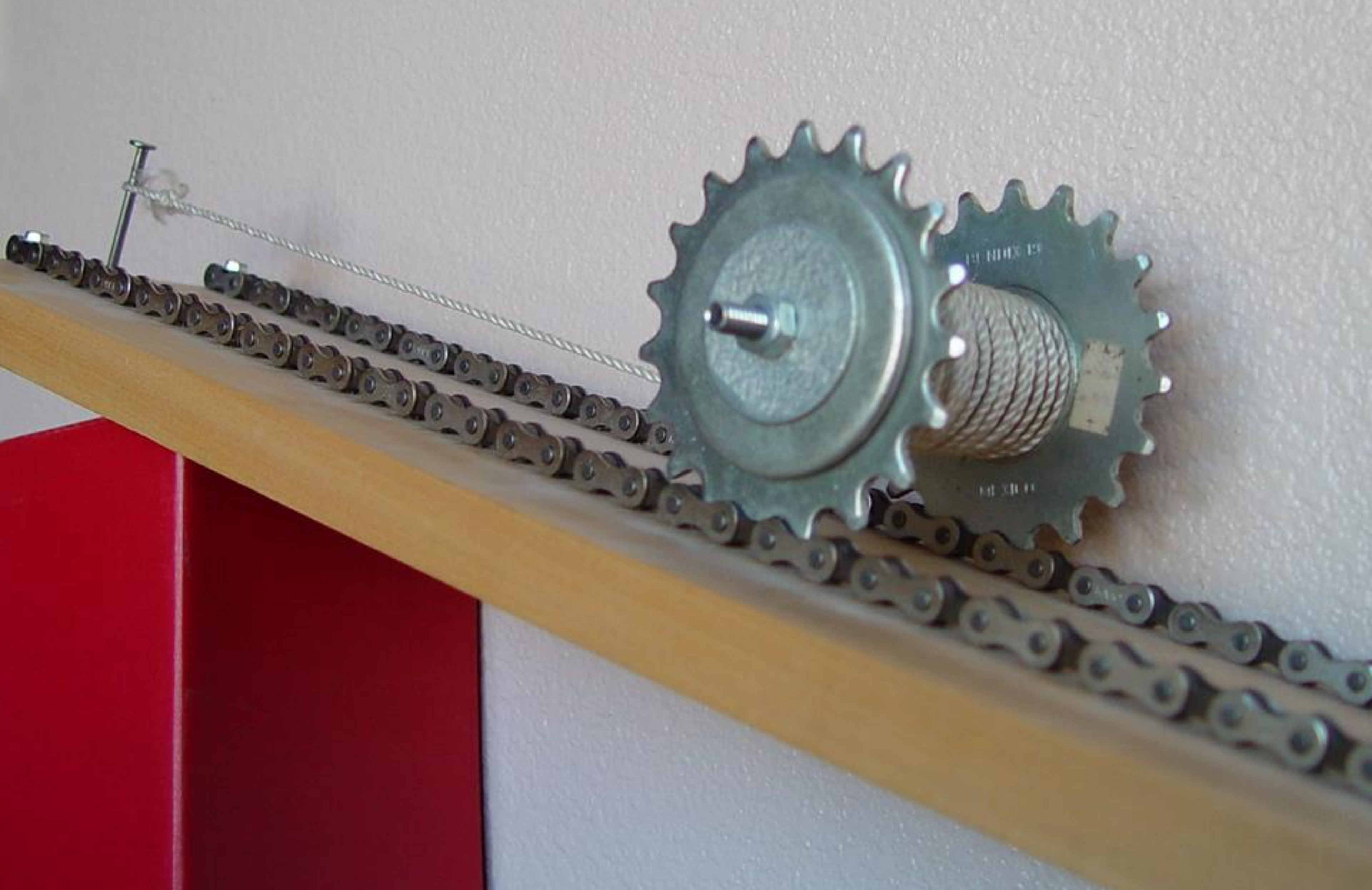
No, the spool will not roll as shown, because the radius from it's centerline to the outer layer of cable is less than the outside radius of the flanges. Imagine the spool rolling through 90 degrees from its present position. If 90 degree arcs for the cable and flanges are laid out parallel to the ramp, it can be seen that the resulting centerline positions of the spool at the end of each arc are not in the same place along the ramp.

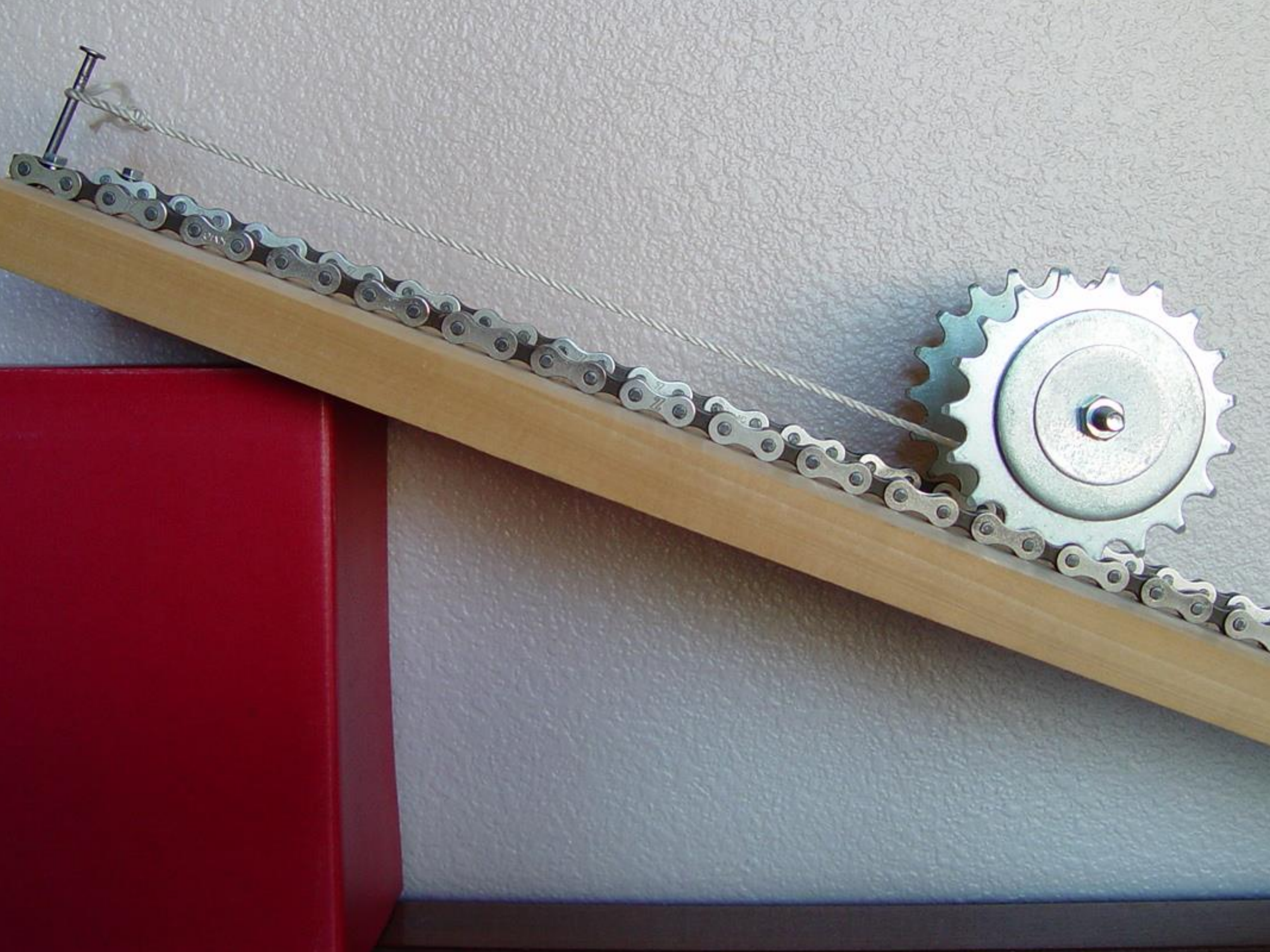
If the spool was full of cable, then the radii would be the same and the spool would start to roll when the chock was removed. As the radius of the cable decreased due to cable being payed out, the spool would come to a stop on the ramp. This is assuming that the safe working load of the cable and the back stop where strong enough to resist the resulting momentum of the spool.

Note that the weight of the spool and cable nor the angle of the ramp have nothing to do with whether the spool will roll or not.

To prove to your self that the spool will not roll, place a reel of cable, a spool of electrical wire, or a yo-yo on a flat surface and start to slowly unwind it. Note that as the spool is unwinding, the end of the cable/string is slowly following along behind the spool. If someone stands on the end of the cable, the flanges on the spool have to be slipped in order to continue unwinding the cable.

Model of a spool similar to quiz 1





QUIZ 2

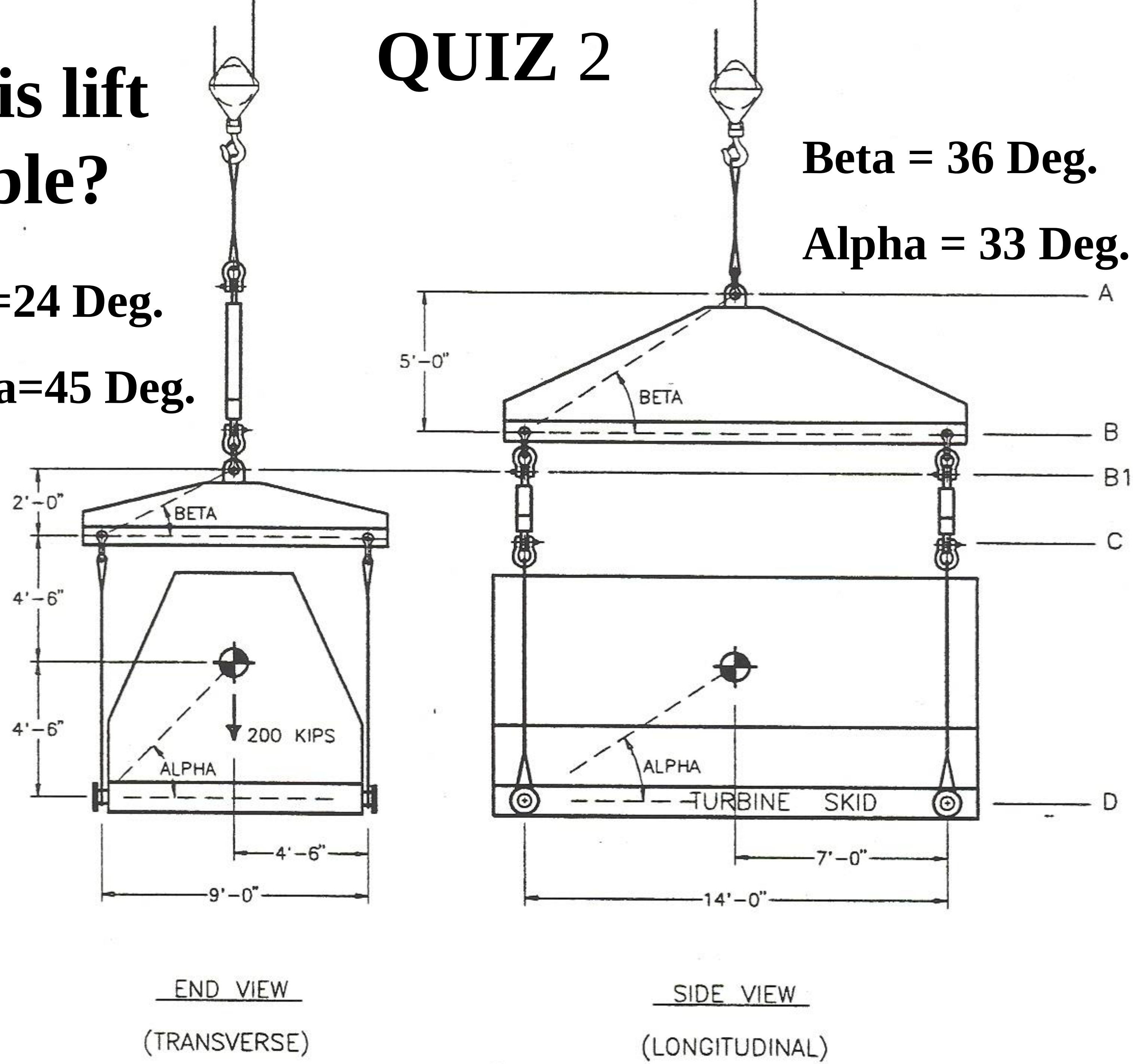
Is this lift stable?

Beta=24 Deg.

Alpha=45 Deg.

Beta = 36 Deg.

Alpha = 33 Deg.



ANSWER TO RIGGING QUIZ No. 6

The answer is no, this is not a safe lift. It is unstable against tipping in the transverse direction and borderline stable against tipping in the longitudinal direction.

This is because the angle Alpha below the center of gravity (CG) in the transverse direction is 45 degrees, and the angle Beta at the spreader bar is approximately 24 degrees. In order to be stable, Beta must be greater than Alpha.

For the longitudinal direction, angle Alpha is 32.75 degrees and angle Beta at the spreader bar is approximately 35 degrees. As Beta is greater than Alpha, theoretically, it is stable.

To better understand why the angle Beta at the spreader bar (or slings if they are being used above the spreader bar) must be larger than the corresponding angle Alpha at the CG in both the transverse and longitudinal direction, consider the following. Assume that the pick point "B1" in the transverse direction is actually located at "C" and centered between the shackle points. If the CG was located directly under the hook and could be kept there, then the load would be stable. But the location of the CG for a load is hard to calculate and is usually off by at least several inches to a foot. During lifting, dynamics of the lift, wind, different lengths of rigging, etc., tend to also shift the location of the CG. Therefore, if the CG is not under the hook as the load is lifted, the offset CG will cause the load to rotate away from the hook, and in so doing, the spreader bar and the skid platform will form a parallelogram as they rotate from the horizontal. As there is no resisting force against overturning or tipping, the spreader bar and skid platform will continue rotating into a more acute parallelogram until the slings bear up against the sides of the turbine. If the trunnions were located outside of the turbine frame, then the skid would turn up side down.

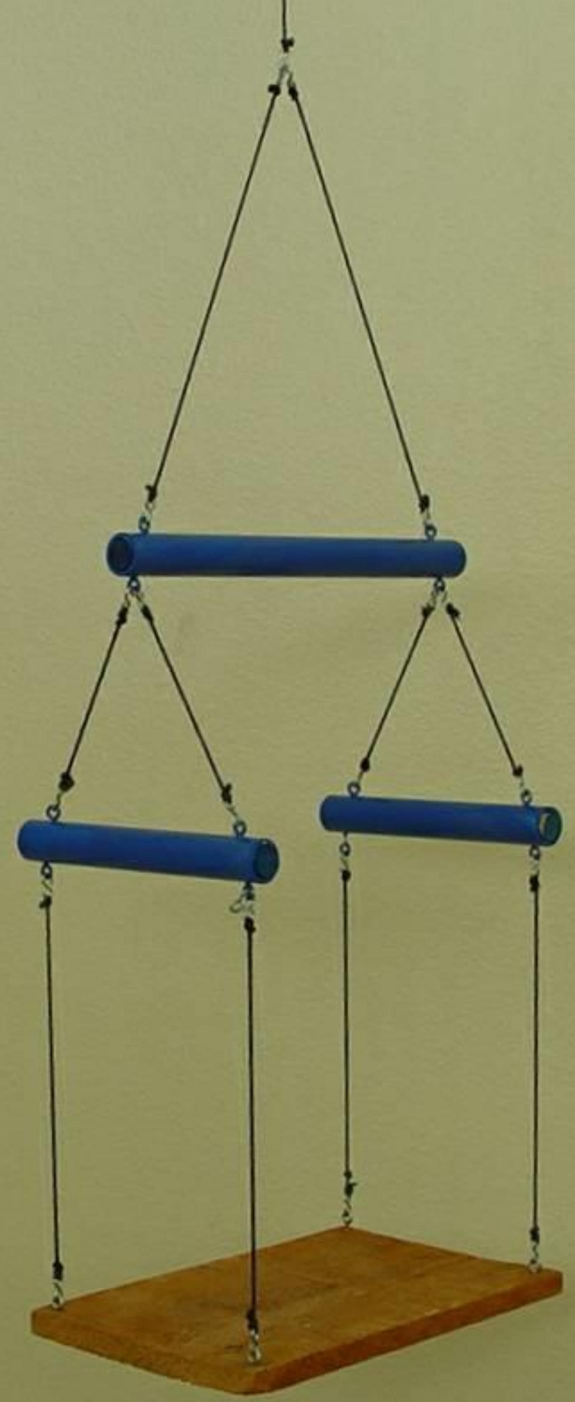
ANSWER TO RIGGING QUIZ No. 6, Continued

Consider one more situation where the skid is being lifted in the transverse direction without spreader bars, but with slings attached at the trunnions on the "D" line and connected to the pick points or hooks at a point below the CG. Also assume that there is no interference between the inclined slings and the turbine housing. As in the example above, there is no resisting force against overturning as the CG is located above the pick points or hooks & the skid is therefore unstable. Now, if the slings are lengthened until the pick points are above the CG, they provide a resisting force against overturning and the load will be stable.

So whether the slings are connected to the tunnnions and run directly to the hook, or they start at the spreader bar and go to the pick points or hooks, they must form an angle Beta that is greater than the angle Alpha at the CG. If the CG is not centered between the skid pick points, then both Alpha angles in the transverse and both Alpha angles in the longitudinal must be computed and compared with the corresponding Beta angles.

Now the most often asked question is how much greater must angle Beta be than angle Alpha. Theoretically and on paper, if Beta is as great as say one degree larger than Alpha, the lift should be stable. But due to the dynamics of lifting, the CG location not always being know accurately, the slings not always matched for length, etc, it is recommended that Beta be at least 20 degrees larger than Alpha. In most cases this will be conservative but safe.

AN EXAMPLE SIMILAR TO QUIZ 2



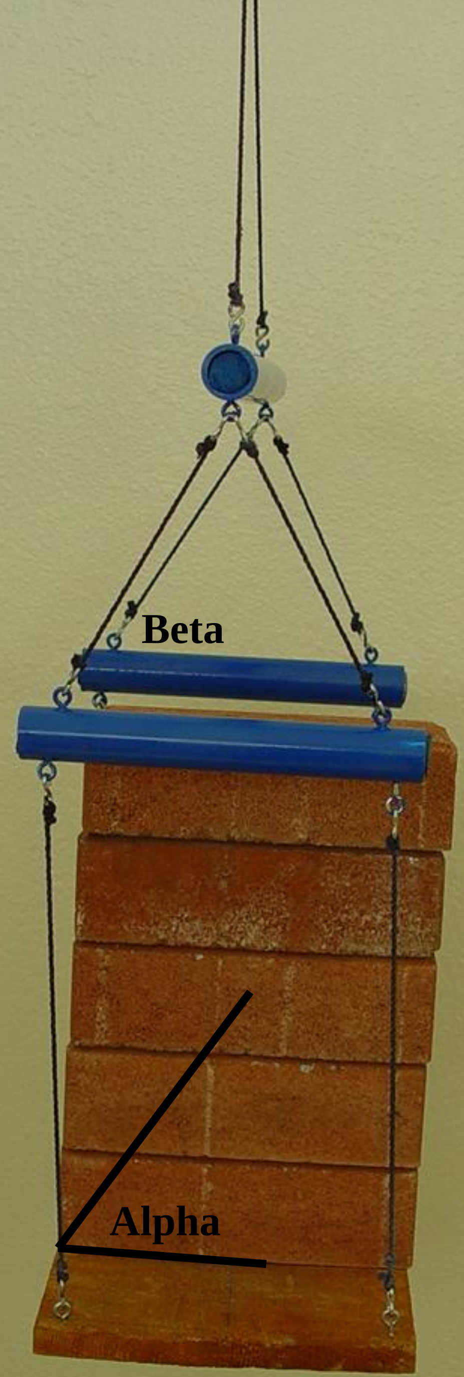
All it took to construct this model was a piece of board, string, one inch dia. PVC, screw eyes and S hooks.

The angle "Beta" between the slings and the transverse spreader bars is approx. 60 deg.

The angle "Alpha" is approx. 49 degrees for four bricks

Note that the load of four bricks is stable

Angle "Beta" is approx. 60 degrees



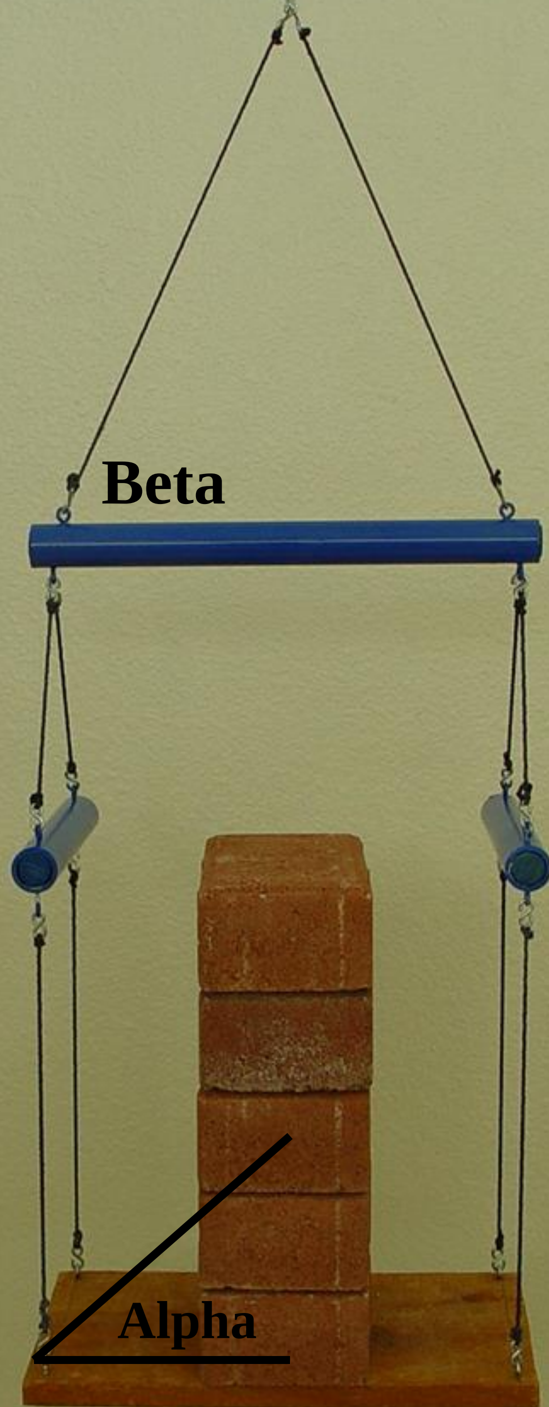
The angle "Alpha" for five bricks is approx. 60 degrees, the same as "Beta"

Note that the board and the spreader bars are starting to form a parallelogram and that the load of bricks is unstable and is about to roll over.

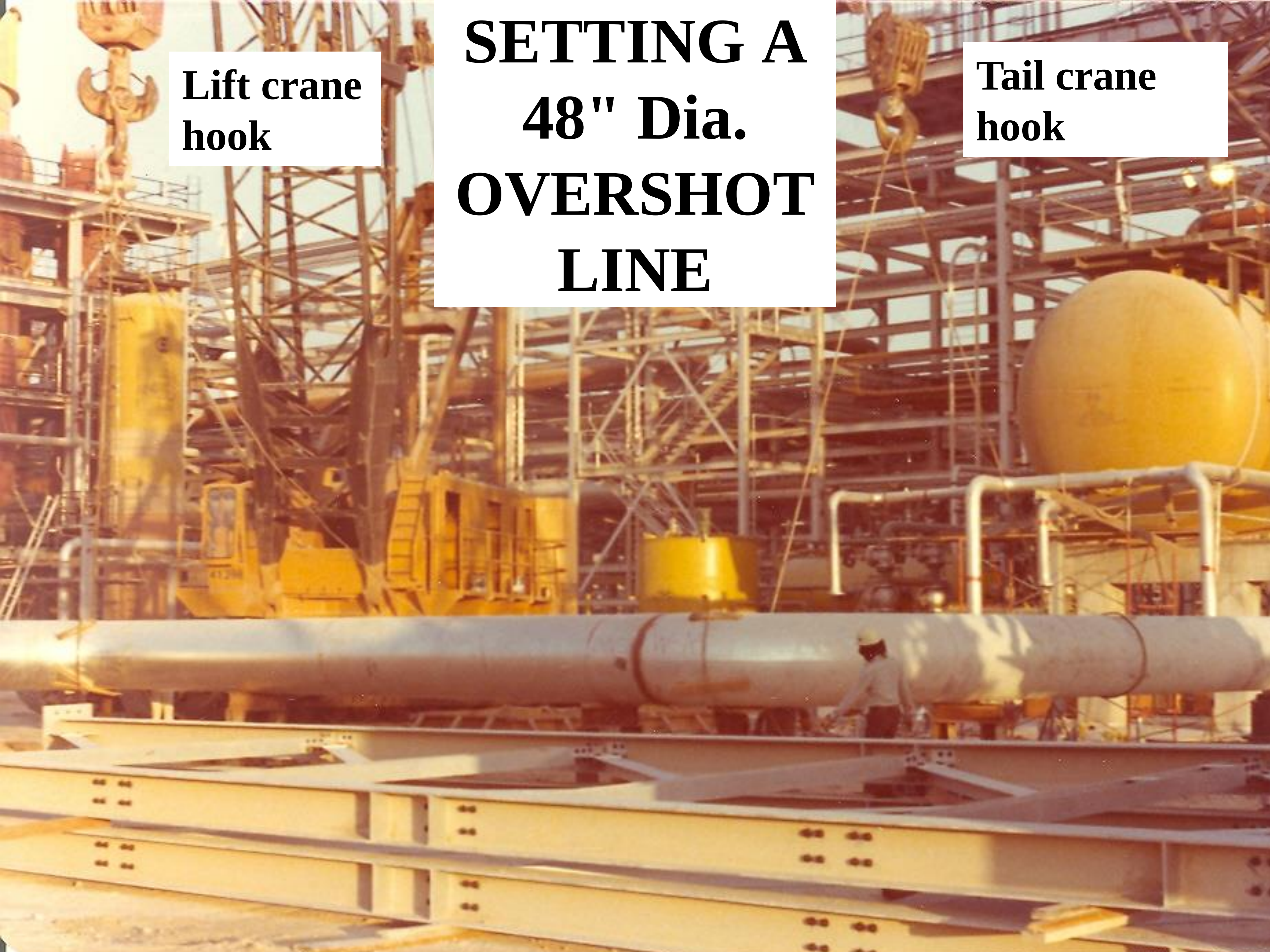
A load of six bricks will roll over either way, depending on how the bricks are stacked

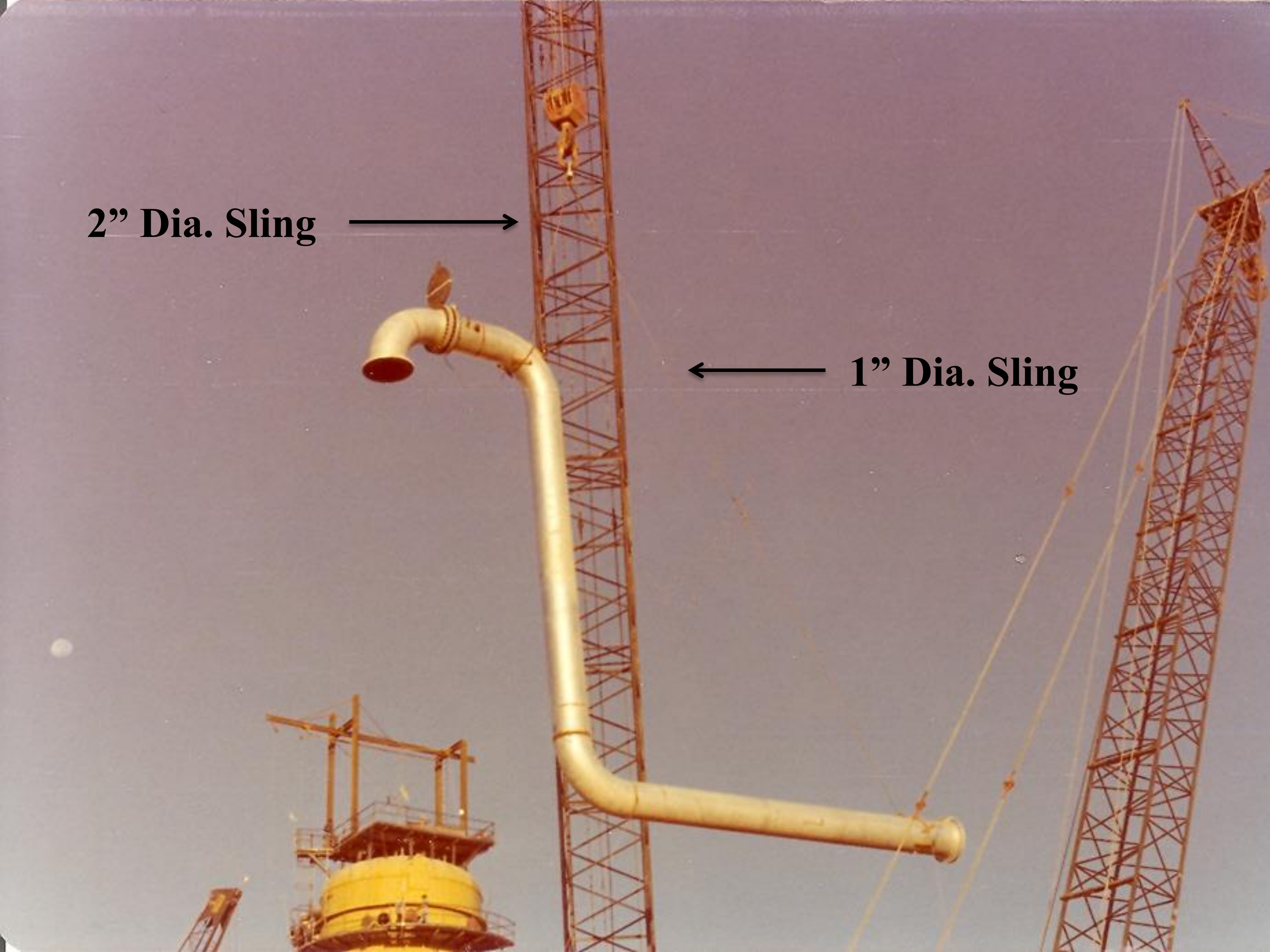
The angle "Beta" between the slings and the longitudinal spreader bar is approx. 65 deg.

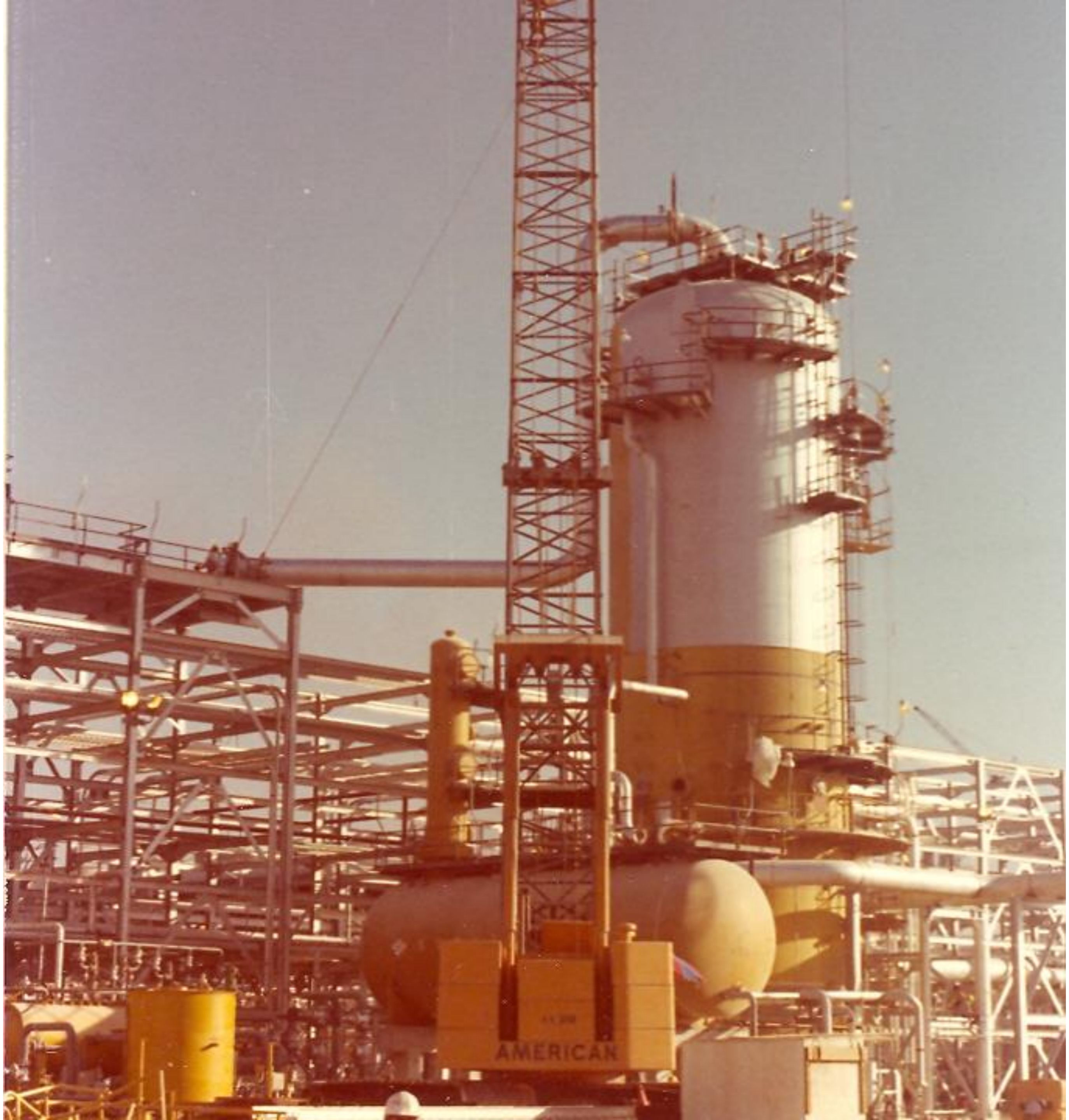
The angle "Alpha" for five bricks is approx. 47 degrees



Note that the load of five bricks is stable in the longitudinal direction


SETTING A 48" Dia. OVERSHOT LINE
Lift crane hook
Tail crane hook


2" Dia. Sling
1" Dia. Sling


AMERICAN

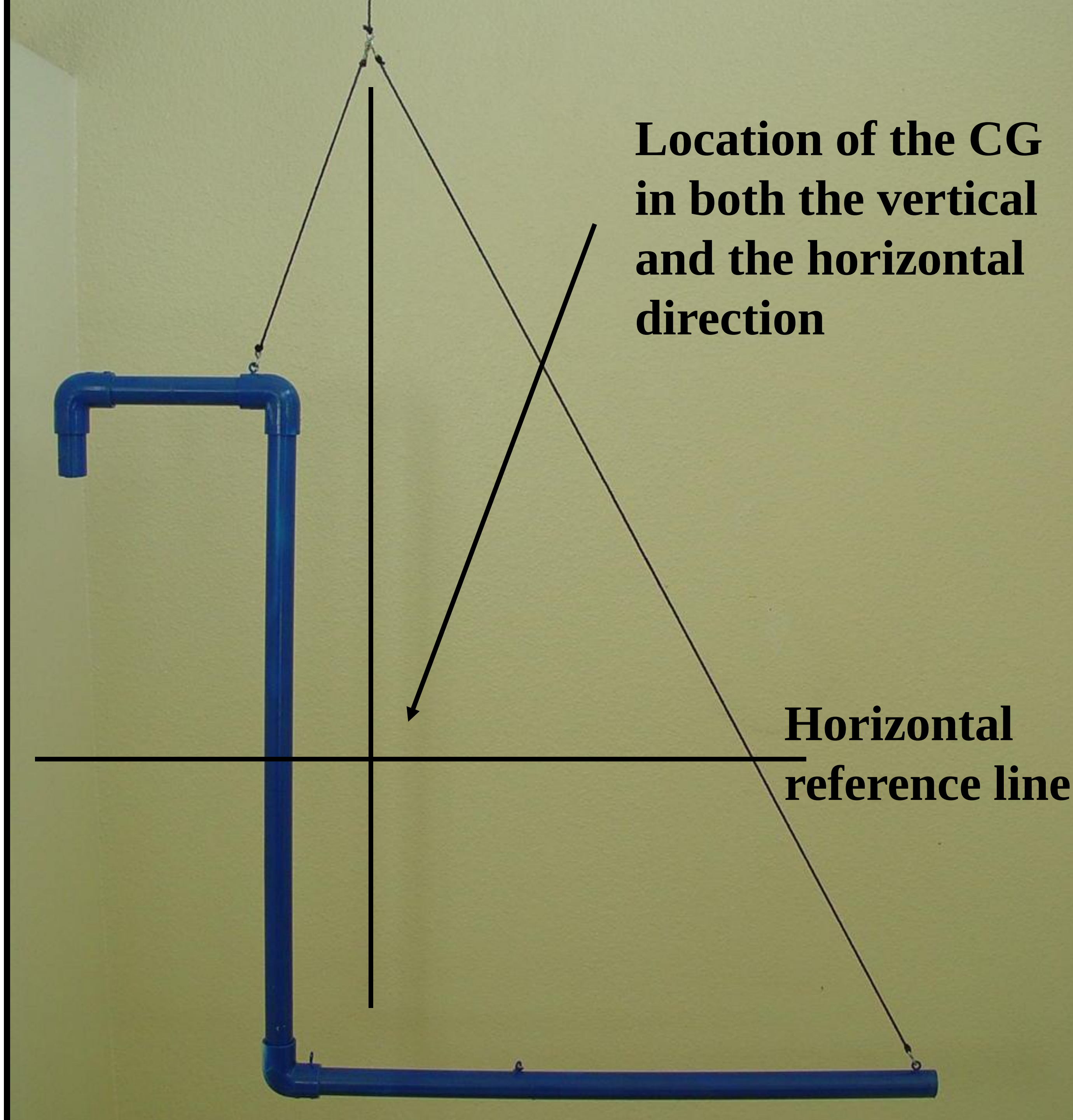
STEPS FOR DESIGNING THE RIGGING HOOKUP FOR A 48" DIA. PIPE SPOOL

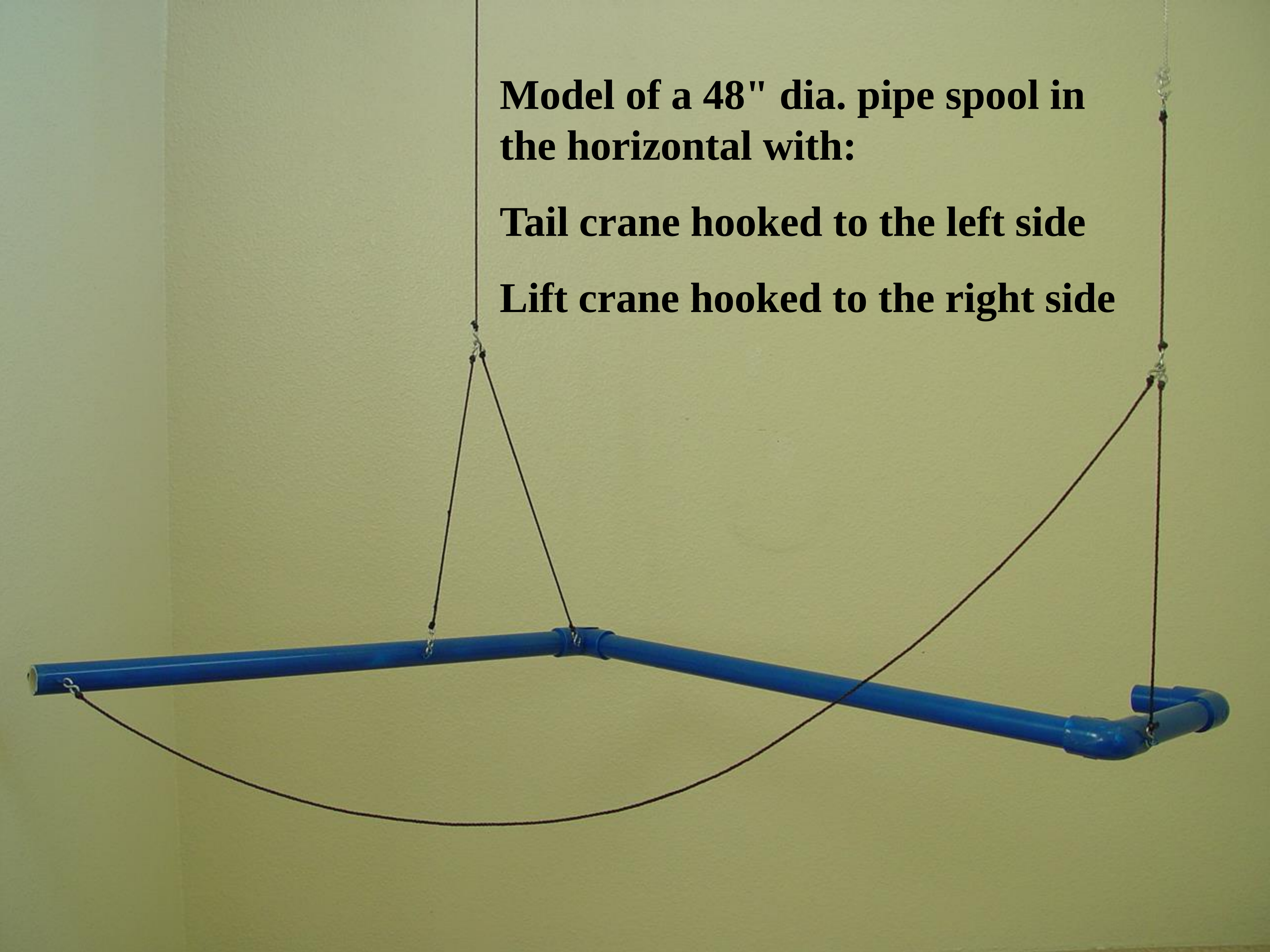
1. Calculate the weight and the location of the CG in both the vertical and horizontal directions

2. Lay the pipe spool out to scale in the vertical with the bottom run level. Run a sling from the right end up at a 60 degree angle until it crosses the vertical reference line of the CG. This intersection point is bearing on the lift crane hook. Run a sling down from the hook to the 90 degree elbow. Calculate the vertical reactions at the base of each sling. Size the slings, 2" dia. EIPS for the left and 1" dia. IPS for the right

3. With the pipe spool laying in the horizontal, calculate the vertical reactions around the vertical reference line of the CG. These reactions can be used to size the tailing slings and to determine the location of their pick points so the pipe spool can be floated in the horizontal without falling off the pipe stands

Model of a 48" dia. pipe spool in the vertical with the bottom run level




Model of a 48" dia. pipe spool in the horizontal with:
Tail crane hooked to the left side
Lift crane hooked to the right side

FINÉ