NSS RPV Removal Study
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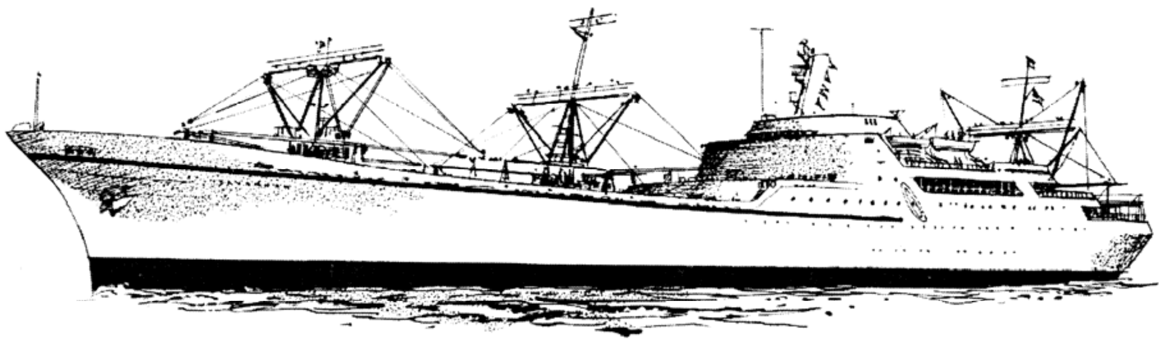
Revision 0



REACTOR PRESSURE VESSEL (RPV) REMOVAL STUDY For The NUCLEAR SHIP (N/S) SAVANNAH

CONTRACT No.: DTMA1C05013

Prepared for

U.S. Department of Transportation
Maritime Administration
Office of Ship Operations

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1.0 INTRODUCTION

The single most difficult task or sub-project associated with the N/S SAVANNAH decommissioning is the physical intact removal of the RPV and head. This is assuming that no Greater Than Class C (GTCC) Waste is removed from the reactor pressure vessel (RPV). The control rod drives (CRD) and CRD structures are also assumed to be removed before the RPV and head are to be removed.

The RPV, head, internals, rigging equipment and shielded shipping container are expected to weigh approximately 175 tons. While this is not an excessively large lift for marine cranes, the lift complexity is exacerbated by the following conditions:

- The lift comprises nuclear material. Although this lift is not required to be in compliance with the single failure proof requirements of NUREG 0612, ‘Control of Heavy Loads at Nuclear Power Plants’, the increased safety and sensitivity of the material is noteworthy.

- A significant set-back of a typical shore side crane in order to clear the reactor hatch deck railings. This is required due to the ship side wall extending vertically approximately 52' from the waterline. This requires significantly more capacity and ballast.

- Large spatial requirements (free water and working depth) for barge mounted crane service and associated tug maneuvering.

- The RPV will have to be moved to a stable, flat location and set vertically in the shielded shipping container approximately 25' high with an annular clearance of approximately 4" when hoisted from the N/S SAVANNAH.

- The loaded shielded shipping container may have to be rotated from the vertical to the horizontal position and then loaded in the horizontal position to the dockside transporter.

- Most waterfront quays which provide adequate depth for the mooring of the N/S SAVANNAH may not be structurally qualified for the weight of the rigging and off loaded material (concentrated crane, ballast, RPV, shipping can and rigging gear).

The RPV, head, and the shielded shipping container is within the weight capacity limits of typical large marine and land cranes at appropriate stand-off distances. It therefore should be lifted and handled as a unit without the reopening of the RPV. The three classes of cranes that can accomplish this function are:

1. Dry-dock bridge cranes (the only known commercial crane of this type in the mid-Atlantic region is located at Newport News Shipyard)
2. Seaborne (permanent barge mounted) floating cranes with twin shear-leg derricks
3. On-site assembled heavy lift derrick boom cranes

Bigge Power Constructors assisted WPI by consulting on the crane and lifting configuration options for removal of the RPV from the N/S SAVANNAH. Bigge surveyed the vessel and compartments in the area of the RPV space and Hold 4 (immediately forward of the RPV space). They also analyzed the range of crane capabilities that are located on the Atlantic seaboard where the vessel is located or to which it could reasonably be towed or trucked and erected.

The principal parameters used in this evaluation were as follows. **The following information is preliminary and should not be used for engineering calculations.**

A. Ship

1.	Beam at RPV hatch	78'
2.	RPV hatch coaming height above waterline	59'
3.	RPV hatch crane interferences from RPV hatch deck	64'
4.	Hold 4 intermediate deck system and bulkheads exterior to the RPV space	50'
5.	Containment Vessel (CV)/support cradle design clearance	18'
6.	Length, over all	595'

7.	Length, bow to CV centerline	300'
8.	Draft (before lift)	22'
9.	Draft (after lift)	21'
10	Ship stability during lift	Assumed to be unchanged

B. RPV, vessel internals, control rod blades, head and head mounted control rod drive (CRD) structure

1.	Weight (with rigging and CRD structure)	160 tons
2.	Weight (with rigging and w/o CRD structure)	135 tons
3.	Height (with rigging and CRD structure)	44'
4.	Height (with rigging and w/o CRD structure)	36'
5.	Maximum diameter w/o shield tank components	11'
6.	Head flange outside diameter	11'
7.	Vessel shell outside diameter	10'

C. Shielded shipping container

1.	Weight on hook (including rigging)	33 tons
2.	Height	24.5'
3.	Diameter	11.33'

There are many technical and equipment options that can be applied to the removal tasks of the N/S SAVANNAH. These tasks include removing the RPV from the ship, handling it during the packaging for transport and disposal, and loading it on the vehicle (heavy duty rail car). The factors to which the handling decisions are most sensitive in the case of the N/S SAVANNAH are as follows.

- Adequacy of navigable open water adjacent to a pier or quay of sufficient length to support barge mounted high capacity cranes. The cranes will have to be in a "T" configuration with the barge standing off of the breasted ship approximately 400'. The pier usable length will have to be approximately 1000' to permit shifting the ship forward or aft to clear the barge.

- Adequacy of loading capacities of the piers or quays on which a shore-side crane can be placed. The crane can not exceed the capacities of the support piles, berms or quayside earth fill and reinforcements

- Local area conditions (demographics, river or vehicular traffic, etc.) that can affect success and schedule

- National security

- Regulatory (USNRC, USCG, etc.) requirements

- Availability of RPV transportation systems away from the removal point

- Risk/benefit considerations

The options for removal of the RPV from the N/S SAVANNAH that were considered are as follows:

- Vertical removal by means of a fixed gantry or dry-dock spanning bridge crane located (footed) ashore. The crane would reach the centerline of the ship with access to a pier or shore side rail siding. The crane must have sufficient lift height to fully remove the RPV vessel free of the ship. If a tracked vehicle is utilized, the crane would be located on a reinforced berm or quay.

- Vertical removal with a single or twin boom floating shear-leg derrick crane permanently mounted to a barge. The ship would be inboard of the crane barge and adjacent to the pier.

- Horizontal removal with a dockside or overhead gantry crane. This would be accomplished by cutting an approximately 13' wide pathway to the pier above C deck. The pathway would traverse through the containment vessel, bulkhead walls, the collision barrier system and the concrete shielding. Alternatively, it could traverse directly into hold 4 and then through a vertical open-top hole cut in the side of the ship from A deck to the C deck.

All vertical lift options assume that hold 4 would be used for placement of a shielded shipping container for the RPV and head during preparations. This would minimize the RPV/head time spent in air during the transfer. This may not be the optimum transition plan for the RPV removal and packaging.

In the case of the second option, the shielded shipping container may be on the ship's deck or a supporting structure on the foredeck of the floating barge. The CRD's and above RPV penetrations structures could be removed in the shielded shipping container. The RPV would be in hold 4 or in the CV prior to removal from the containment vessel

In the case of the option for lifting with a shore-side assembled-on-site high capacity tractor crane, two types of cranes were considered. These included derricks that can be placed on a quay or wide pier with the ship breasted off of the pier; or the crane base set back from the vertical shipside the necessary distance to clear the boom over the ship rail at the reactor hatch deck and still reach the ship centerline. The typical problem with this arrangement is the fact that if a quay or pier is used to support the crane, it may not be structurally safe with the combined concentrated (on the track surface) weight of the crane, body, running rigging, crane ballast and the carried load.

All vertical and horizontal removal options assumed that the empty RPV shield tank and lead belt line shielding would be removed or cut away from the RPV prior to lifting. This will leave an unimpaired vertical lift of the RPV and head through the cupola for vertical removal sequences. For horizontal removal options, the requirements for moving the RPV laterally would include traveling through the following equipment:

1. neutron shield tank;
2. lead shielding;

3. the pier side steam generator;
4. containment vessel;
5. collision barriers (concrete and redwood)
6. N/S SAVANNAH's superstructure

The remaining attachments between the RPV and the N/S SAVANNAH include two primary loop inlet lines, two primary loop outlet lines, and the structural welds to the support frame on the bottom of the RPV vessel. The structural welds may be cut at the attachment points. The loop inlets/outlets (hot legs/cold legs) penetrations may be cut with an ID cutting machine and temporarily capped at the vessel wall.

All bulk RPV insulation is assumed to be off the RPV during the lift. However, the RPV must be prepared for transfer to the shielded shipping container in accordance with industrial safety requirements.

A limited survey of eastern seaboard heavy capacity cranes revealed there are many of each category available with the exception of high-capacity dry-dock bridge cranes. The categories of interest include shipyard bridge cranes, fixed shore side rail cranes, portable tractor crawler cranes and floating barge heavy lift cranes. While a wheeled tractor or field assembled track crane could be erected on the site, it is improbable that a pier or earthen shore side site could be qualified to take the focused weight of the ballast, RPV and shielded shipping container.

In the case of floating cranes and depending on the crane and location, the ship could be brought to the crane, or the crane to the ship. The seaboard from Jacksonville to Philadelphia was reviewed. Similar crane capability, although nor surveyed, is known to exist up the Atlantic seaboard to South Maine and at ports in the Gulf of Mexico.

Although nothing could be learned about its availability or features, the optimum dry-dock spanning crane would be the Newport News Shipbuilding modular erection high-capacity crane (No. 12). This crane, seen on the Newport News skyline prominently at the yards, could easily lift the N/S SAVANNAH RPV free of the containment RPV, free of hold 4, into the shielded shipping container and onto a heavy duty rail car. It is also possible to move the ship beyond the east coast ports/facilities (i.e., to the gulf coast where similar facilities are located), but typical representative regional crane assessment was not in the assessment scope.

The most technically promising and possibly safest and least cost RPV removal crane will be a heavy-lift (twin boom) shear leg luffing derrick permanently mounted on a customized barge, like the Charleston Giant, ported out of Charleston, SC (see Figure 1). If of adequate capacity, these barge mounted cranes can lift the RPV (with or without the CRD structure intact) over the side of the ship. It can then be placed on a load spreader structure on the foredeck of the derrick barge. It could also be placed in hold 4 of the N/S SAVANNAH. In this sequence, the derrick only booms in and the load line is maintained perpendicular to the ship centerline. The ship can then be shifted forward about 300' or aft about 400' and the barge crane winched into the pier side. There, the RPV can be set on a rotating frame that is mounted on a wheeled transporter. This would permit left-right movement and to keep the load under the center of the lifting system on the pier. The RPV will then be picked up in a four-point lift with a short-boom heavy capacity crane. It will then be set on a transporter or rail car. If a transporter is used to take the RPV to a rail loading location, the crane can typically be used to transfer the RPV to the rail car.

This evolution will require several pieces of rigging equipment which permit the RPV to be raised from the CV and through the cupola. It would also have to be rotated from the vertical to the horizontal position, all in an As-Low-As-Reasonably-Achievable (ALARA) manner.

There are several disadvantages of this lift sequence. It may take several days to accomplish. It requires a minimum of a 600' pier. It also requires approximately 300' of unobstructed navigable water at least approximately 15' deep in general and approximately 25' under the NS SAVANNAH keel adjacent to the pier. This would still require that the ship be moved out of the mooring to bring the RPV to the pier for rotating and loading. The pier and/or moorings would have to be approximately 1000' long to provide room to shift the ship aft and out of the crane barge path if the ship could not be moved from the pier.

With the RPV removed, the remaining lifts from the CV can be made with other standard cranes. The steam generators would be cut at the down comers and risers. Each steam drum and heat exchanger/mud drum could be taken out in two lifts per side. The pressurizer would be taken out next with the RPV shielding lead and neutron shield tank taken as convenient. This would constitute all of the major lifts from the containment RPV via the cupola requiring a special crane. The remaining lifts could be made with a wheeled pier side crane and/or a deck mounted 10 ton jib crane mounted on the RPV hatch deck.

There are also other east coast graving dock gantry cranes which have sufficient capacity to lift the RPV from the containment, although not with the control rod drive structure intact on the RPV. The use of a dry-dock for removal is expected to be substantially more expensive than the rental of a luffing, shear leg derrick unless dry-docking at that time in the decommissioning schedule is required for other reasons and the other work scheduled permits .

A RPV lift safety analysis and vessel stability evaluation will have to be prepared for the RPV removal. A 125% of maximum load test lift will be required. This will not be a single-failure-proof lift. The analysis must show that, in the event of rigging failure, the harbor or environs will not be contaminated either from airborne or water contamination. The effects of any such contamination also have to be shown to produce negligible/acceptable consequences to the environment. The analysis may use the ship, pier and the barge structures, as well as materials specifically designed to reduce the impact of damage in the event of failure during the lift.

Rigging for the lift requires standard equipment. A single point center,100 degree rotation cable lift with attachment to 2 or 3 RPV studs at 180 or 120 degree locations on the head flange is assumed. If necessary, the number of head studs in place can be increased. It is reported that only 6 studs remain in the RPV flange securing the RPV head at this time.

A single point lift with the ship trimmed and ballasted to a dead level condition will assure that the RPV can be lifted off the support pads and through the cupola opening vertically.

The head and RPV flange have at least 1' of radial clearance in the cupola, and the RPV has at least 1.5' of clearance.

Any RPV removal sequence will require some ship modifications that must be restored. Where these are more than cosmetic, such a cutting a horizontal path out of the containment RPV, the restoration must be properly engineered and in all cases, the restoration cost must be considered. This is especially sensitive since the ship could be in a disrupted condition for several weeks, even requiring that it be in a dry-dock for an extended period of time, until it could be safely floated again. Even then, the restoration work must be done in the same physical space as the remaining decommissioning work which would increase the cost of the decommissioning related work.

RECOMMENDATION

Due to the substantial uniqueness of the N/S SAVANNAH RPV removal versus all other activities related to decommissioning, the RPV removal warrants special consideration. The general decommissioning can be accomplished pier side with aboard ship lift capabilities. The RPV removal will require 25' of water depth to permit both forward and aft movement of the ship or floating crane. It will also require unobstructed 12' width of water outboard of the pier. In addition, 400' plus any safety margin will be required for the floating barge, breasting barge ship and tugboat maneuvering room. This may be a very select location which is not at all conducive to the general ship decommissioning activities.

The RPV removal site must also be very sensitive to rail or truck transportation routing to the selected disposal site. If a combination of services (truck off of the pier and then rail to the disposal site) is selected, an intermediate RPV transfer point must be provided.

WPI recommends that the RPV removal be accomplished with an overhead bridge crane of sufficient unmodified capacity. An acceptable alternative is a twin or single boom shear leg luffing derrick in a harbor location that is convenient to the luffing derrick and the ship, and in which other local ship and barge transit is minimized.

The RPV removal should be considered as a stand-alone project within the general decommissioning project. It may be advantageous to accomplish it in a separate location from the general decommissioning. It could also be designated as an integral task within the decommissioning if done in the same location as the ship decommissioning.

FIGURES AND TABLES

Typical heavy lift crane equipment configurations and lifting capacities are presented and described in the following figures.

Figure 1 is a sketch of the layout of a typical twin boom shear leg derrick (the key dimensions equal those of the Charleston Giant) that could be employed to remove the RPV from the N/S SAVANNAH containment, load it in the shielded shipping can on the pier or quay or in hold 4, rotate it to the horizontal position, and load it on a transporter.

Figure 2 is a typical Liebherr LR 1750 assemble-on-site very heavy capacity crawler crane configuration which would be rigged with a movable ballast and single stiff leg mast. This boom arrangement would include about 253' of boom and 115' of offset from the ship centerline, and would produce 555,000 pounds of lifting capacity.

Figures 3, 4 & 5 provides the tabulated basis for the capacity of this rigging arrangement.

Figure 6 provides the “footprint” for the LR 1750. This indicates that the crane tracks occupy a space of about 40' by 35'. However, the assembly area would be approximately 100' by 100' plus crane space. The maneuvering would involve 90 degree turning space with a circle of about 55'. This is an important constraint in considering the locations at which such a crane system can be erected.

Figure 1

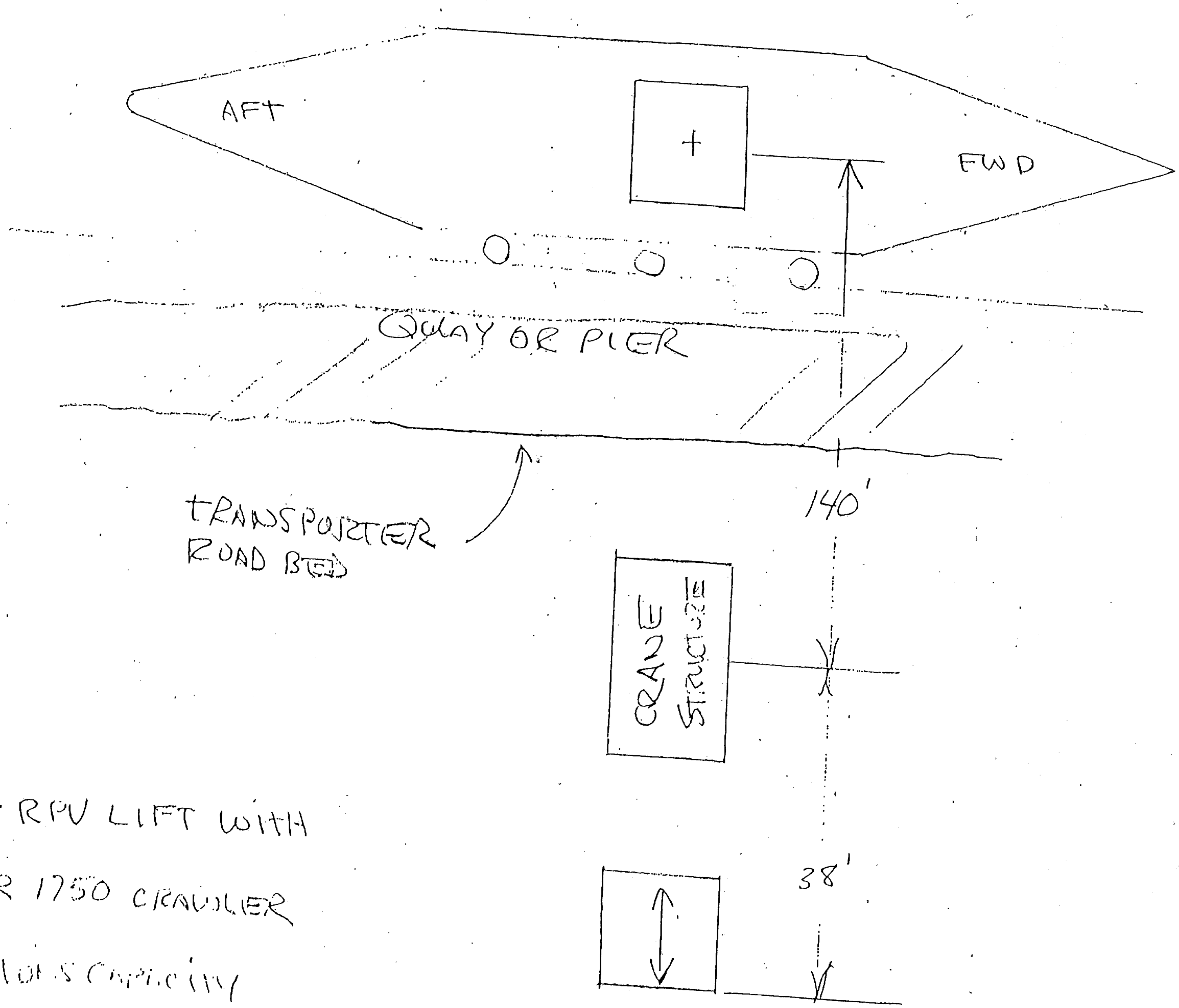

FIGURE 1

NS SAVANNAH RPV LIFT WITH
LIEBHERR LR 1750 CRAWLER
CRANE, ~ 400 TONS CAPACITY

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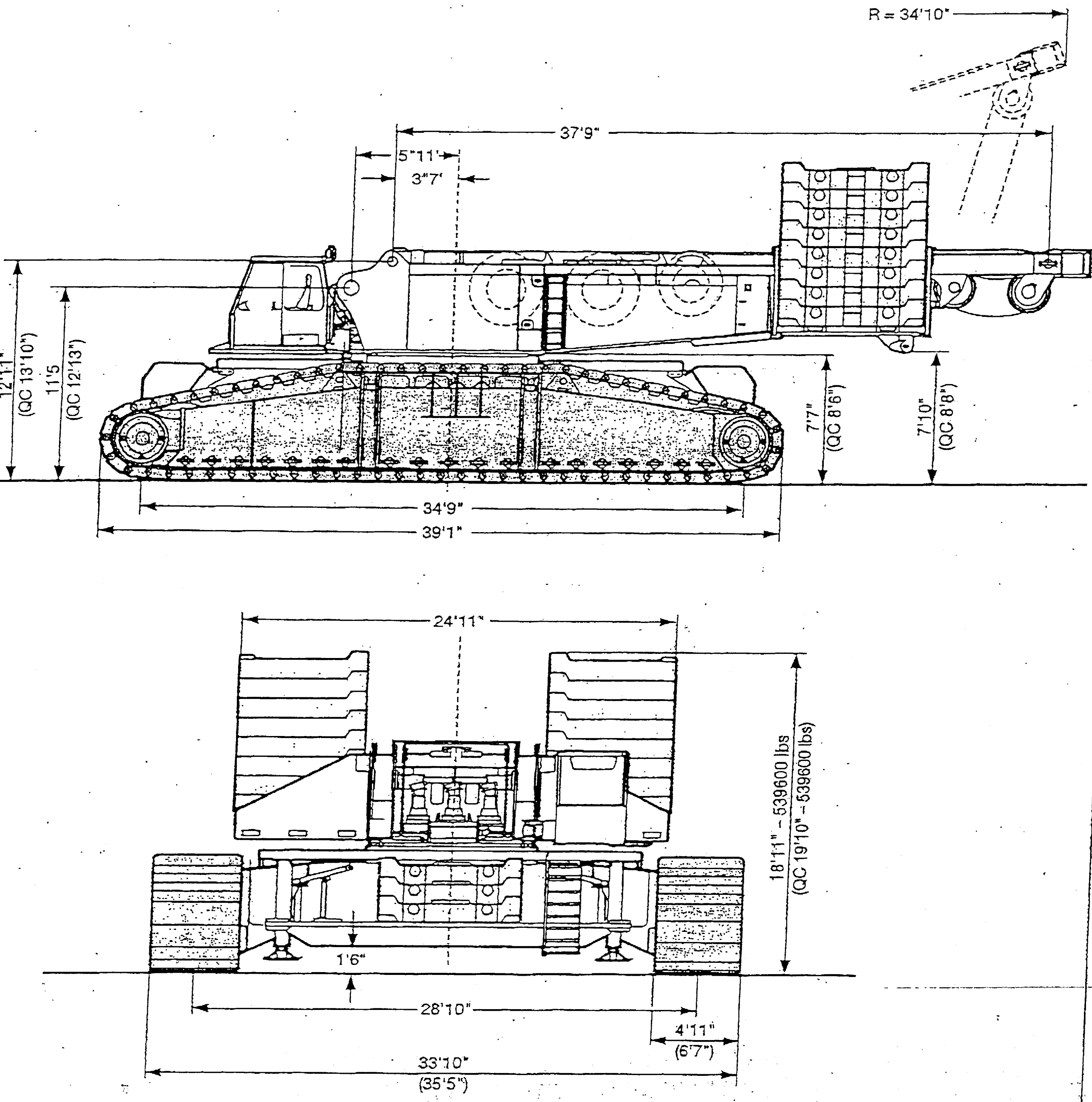
Figure 2 P. 4

Dimensions.
Encombrement.

LR 1750

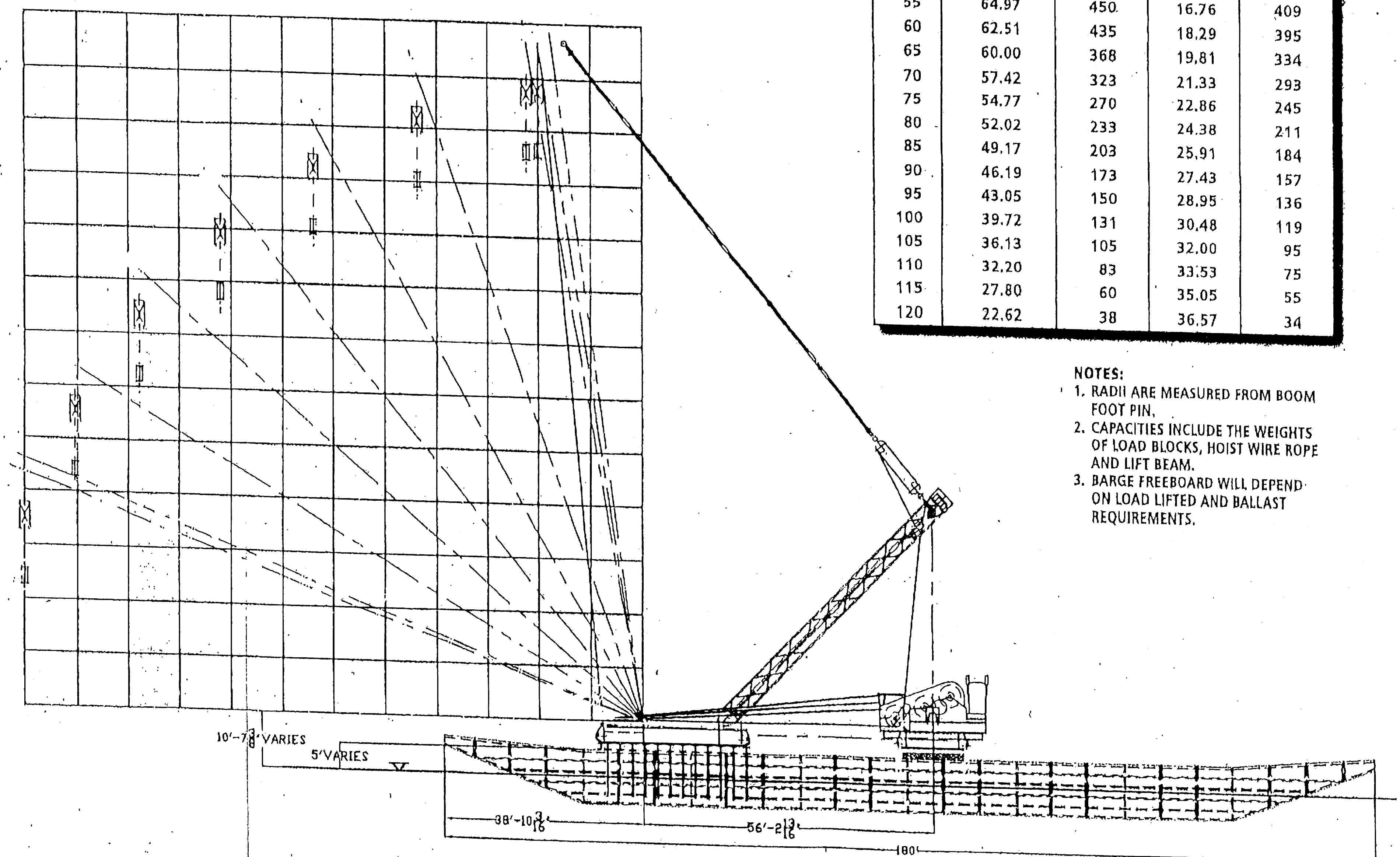


QC = Quick Connection

Figure 3

Figure 3

TWIN BOOM LUFFING DERRICK LOAD CHART



RADIUS FEET	BOOM ANGLE DEGREES	CAPACITY TONS	RADIUS METERS	CAPACITY TONNES
20	81.15	450	6.10	409
25	78.91	450	7.62	409
30	76.66	450	9.14	409
35	74.38	450	10.67	409
40	72.08	450	12.19	409
45	69.75	450	13.72	409
50	67.38	450	15.24	409
55	64.97	450	16.76	409
60	62.51	435	18.29	395
65	60.00	368	19.81	334
70	57.42	323	21.33	293
75	54.77	270	22.86	245
80	52.02	233	24.38	211
85	49.17	203	25.91	184
90	46.19	173	27.43	157
95	43.05	150	28.95	136
100	39.72	131	30.48	119
105	36.13	105	32.00	95
110	32.20	83	33.53	75
115	27.80	60	35.05	55
120	22.62	38	36.57	34

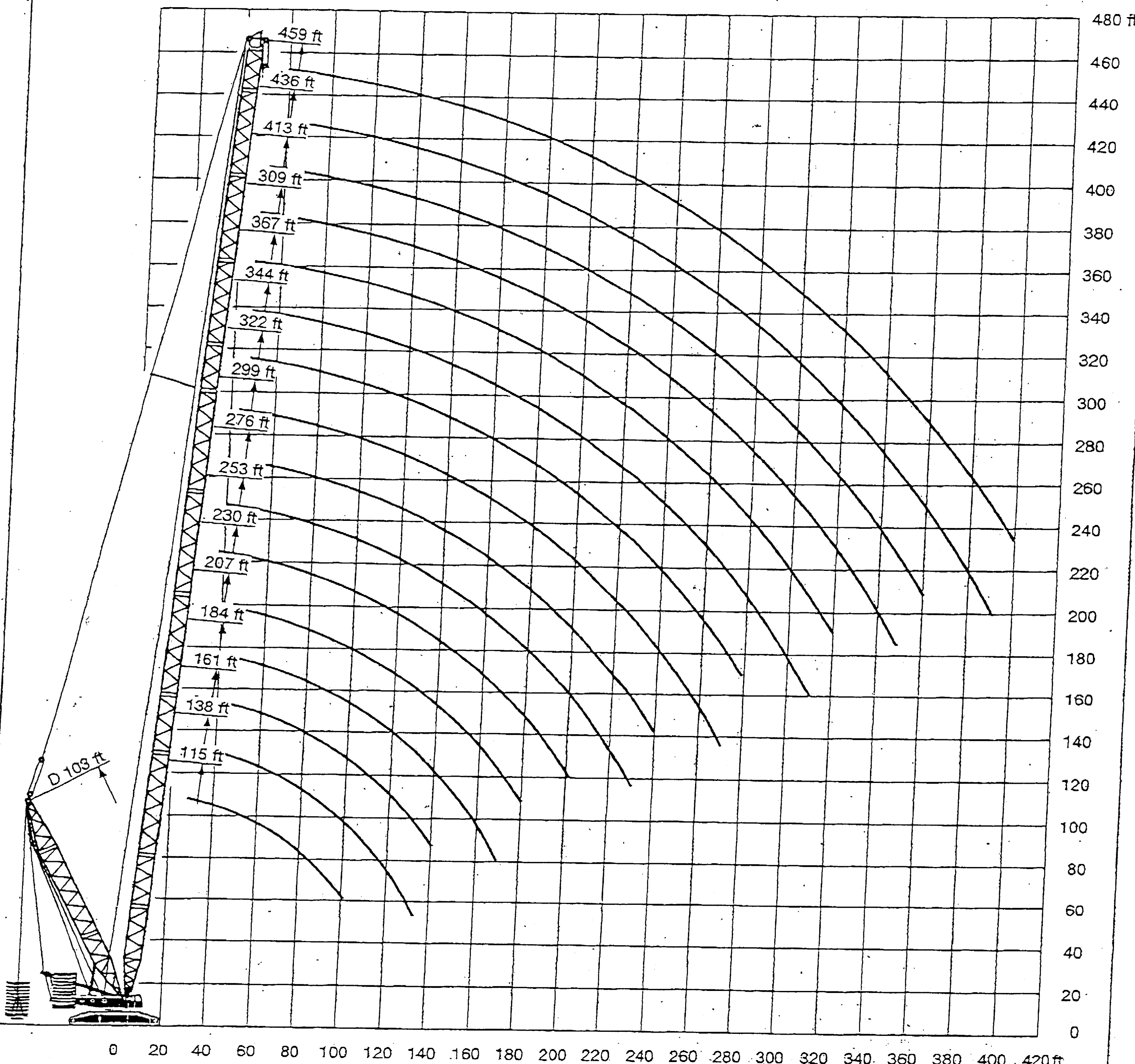
NOTES:

1. RADII ARE MEASURED FROM BOOM FOOT PIN.
2. CAPACITIES INCLUDE THE WEIGHTS OF LOAD BLOCKS, HOIST WIRE ROPE AND LIFT BEAM.
3. BARGE FREEBOARD WILL DEPEND ON LOAD LIFTED AND BALLAST REQUIREMENTS.

Lifting heights on SDB/BW boom/ derrick combination.
Hauteur de levage en configuration SDB/BW.

Figure 4

LR 1750



Lifting capacities on SDB/BW boom/ derrick combination.
Forces de levage en configuration SDB/BW.

Figure 5

LR 1750

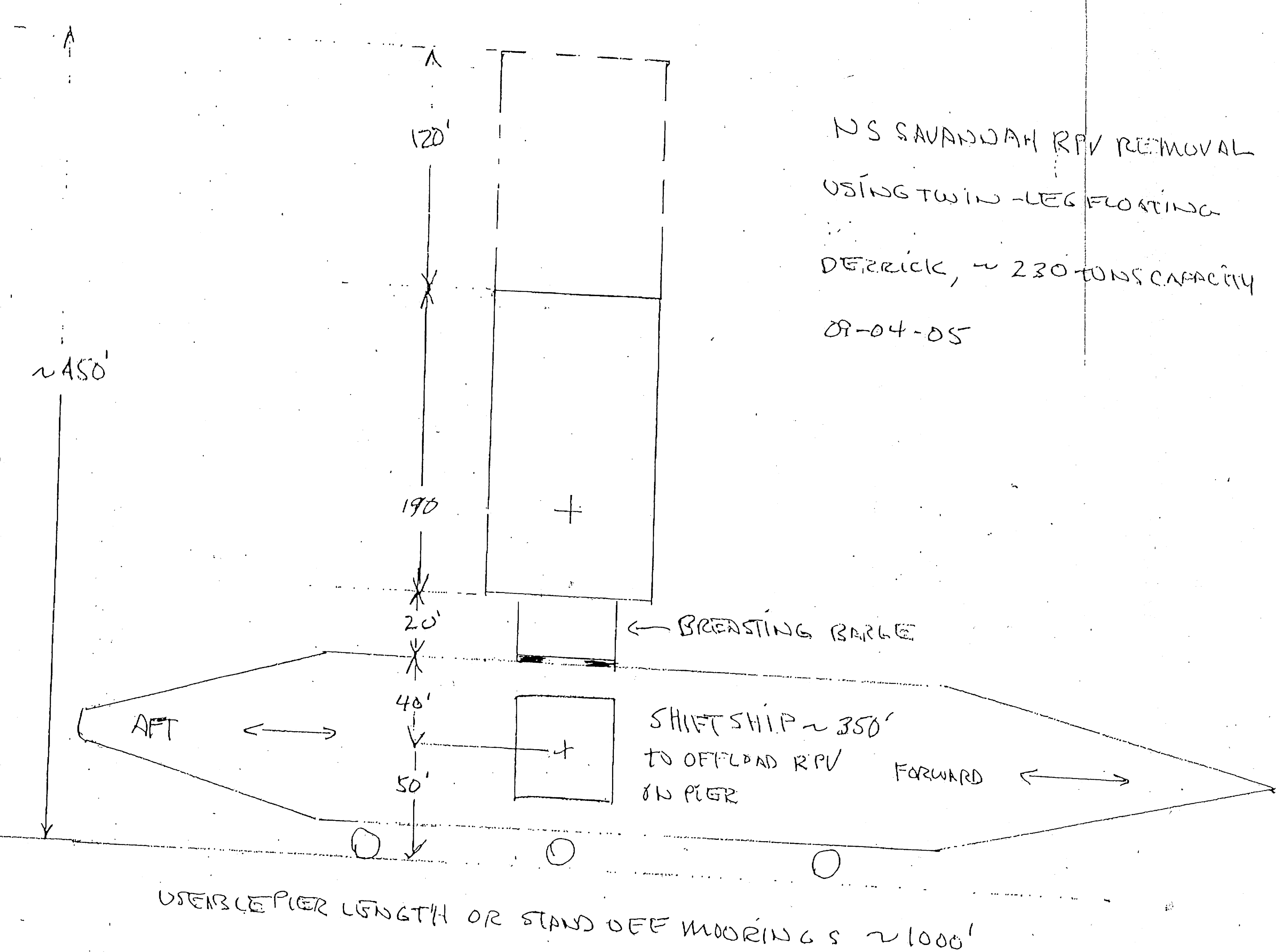
S 115 ft – 459 ft | D 103 ft | 360° | 484000 lbs | B BW max 881000 lbs x 65'7" | 209200 lbs

ft	115 ft	138 ft	161 ft	184 ft	207 ft	230 ft	253 ft	276 ft	299 ft	322 ft	344 ft	367 ft	390 ft	413 ft	436 ft	459 ft	ft
23	1653																23
24	1653																24
26	1653																26
28	1612	1575	1537														28
30	1568	1536	1499	1459													30
32	1530	1500	1464	1429													32
34	1492	1465	1430	1399	1232	1043											34
36	1456	1432	1398	1368	1231	1042											36
38	1422	1399	1369	1338	1230	1041	890	763									38
40	1390	1367	1339	1308	1219	1039	889	762	658	568							40
45	1316	1295	1268	1241	1141	1036	887	761	656	567							45
50	1250	1230	1205	1181	1075	1001	886	759	655	566	485	423	368				50
55	1189	1171	1146	1125	1014	955	873	758	653	564	483	422	367	317	272	231	55
60	1124	1118	1091	1071	959	906	847	756	652	563	481	422	366	316	272	230	60
65	1024	1069	1041	1021	909	861	807	752	651	562	479	421	366	315	271	229	65
70	928	989	988	964	864	819	770	730	648	561	476	421	365	315	271	229	70
75	844	916	923	900	822	780	736	704	638	558	474	420	364	314	270	228	75
80	768	846	857	837	784	745	704	676	622	554	471	420	363	314	270	227	80
85	698	783	809	789	749	716	674	649	604	545	469	419	363	313	269	227	85
90	641	724	758	754	720	689	646	624	588	532	467	419	362	312	269	226	90
95	589	668	710	714	689	663	621	598	566	519	462	418	361	312	268	225	95
100	539	616	663	674	655	638	596	570	540	506	456	417	361	311	268	224	100
105		571	618	635	622	610	569	543	516	492	447	415	360	310	266	224	105
110		531	576	599	591	582	543	517	493	471	437	414	356	309	263	223	110
115		494	538	563	561	555	517	493	472	452	425	410	352	308	261	222	115
120		458	504	529	532	529	493	470	451	433	411	403	348	306	258	221	120
125		423	474	497	505	505	469	450	431	415	394	390	344	304	255	218	125
130		385	445	467	478	481	449	433	412	398	379	373	340	302	253	216	130
135			418	442	453	459	431	418	397	382	365	359	335	299	251	215	135
140			391	419	428	436	414	402	383	367	352	346	328	296	249	213	140
150				376	386	394	382	373	357	342	326	321	311	289	244	209	150
160				335	350	355	352	345	332	319	303	299	289	278	238	206	160
170				297	317	324	324	320	309	299	283	278	269	260	232	202	170
180					287	297	299	295	288	279	266	261	253	243	226	198	180
190						272	276	273	267	261	250	245	238	228	217	192	190
200						247	254	253	248	243	234	230	223	214	206	187	200
210							233	234	230	227	219	216	210	201	194	183	210
220							214	217	214	211	205	202	197	189	183	173	220
230							195	200	199	197	192	190	184	178	172	163	230
240								184	185	184	179	177	172	167	161	153	240
250									171	171	168	165	160	157	151	143	250
260									158	159	157	155	146	147	141	135	260
270									145	148	146	144	136	137	133	126	270
280										136	136	134	128	128	124	118	280
290											126	125	120	120	116	111	290
300											116	116	113	112	108	103	300
310											107	107	105	104	97.5	96.5	310
320												98.5	97	96	88.5	89.5	320
330													89	88.5	82	82.5	330
340													81.5	81.5	75.5	76	340
350													74	74.5	69.5	69.5	350
360														67.5	64	63.5	360
370															58.1	57.5	370
380															52.4	51.6	380
390															46.3	46	390
400																40.4	400

Lifting capacities above 1320 kips only with additional equipment
Forces de levage plus de 1320 kips seulement avec équipement supplémentaire

TAB 128463 / 128052 / 128048

Figure 6


NS SAVANNAH RPV REMOVAL
USING TWIN-LEG FLOATING
DERRICK, ~ 230 TONS CAPACITY
09-04-05
~450'
120'
190
20'
40'
50'
BREASTING BARGE
AFT
SHIFT SHIP ~ 350'
TO OFFLOAD RPV
ON PIER
FORWARD
USEABLE PIER LENGTH OR STAND OFF MOORINGS ~1000'