6

TRAILERS AND TRUCK TRACTORS

6. Trailers and Truck Tractors

6.1 GENERAL

Transporting plant equipment with conventional truck and trailer is a common operation on a construction site. In some cases, its responsibilities have been taken too lightly and problems have occurred.

Movement by transport is generally made on a hauling unit of standard manufacture. In selecting a hauling unit, the following items of information must be known:

- Stability triangle of the load on the trailer has been checked.
- The weight of the piece is within the design capability of the hauling unit.
- The configuration and structure of the bed of the hauling unit mat accommodate the piece or pieces.
- Axle loadings do not exceed floor or access road limitations.
- Maneuverability of the hauling unit must be compatible with the access route.
- Assistance that may be required to negotiate grades has been obtained.
- Adequate clearances have been verified along the access route.

In addition, the following should be considered when determining the feasibility of transporting a capacity load on a trailer.

6.2 TRAILERS

The type of load being applied to the trailer must be determined. This load could be classified in one of the following categories:

- Point load
- Uniform or equally distributed load
- Uncoupled load, where the tractor has been removed and the trailer is supported on the loading wheels
- Off center load

- Drive-on load from the rear or over the side
- Braking shear
- Torsional loading
- Vibrational loading

The design of a trailer main frame usually is of the center beam design, where the main support beams are closely spaced down the canter of the trailer, or of the perimeter beams design, where the main support beam are located on the outside edge of the trailer bed.

Trailer manufacturers rate trailer capacity in different ways. Many manufacturers design and rate their trailers assuming that the load is spread evenly along the main deck. Some manufacturers rate their trailers based on a 17-foot long uniform load, while others use 8-foot uniform load. The distribution of the load imposed by the trailer is also an assumption made in design. This assumption also varies with the trailer manufacturer. However, in general, the design load distribution is based on 65 percent of the load to the rear wheels and 35 percent of the weight to the fifth-wheel pin.

6.3 TRUCK TRACTORS

The evaluation of the proper truck tractor for transporting heavy loads should include horsepower and tractive effort, front and rear axle rated capacity, fifth-wheel capacity, transmission reductions, and tire capacity.

6.3.1 Tractive Effort

Net tractive effort is defined as the torque or rim pull delivered to the tires at the ground. The following sections present the formulas for tractive effort.

6.3.2 Front and Rear Axle Capacities

A general purpose tractor will usually have a rear axle capacity at the ground of 44,000 pounds. To determine the allowable payload weight from the trailer, the complete tire weight of the tractor and trailer being supported on the tractor rear wheels at the ground must be subtracted from the capacity. For example, the tire weights of a conventional truck and trailer at the rear wheels is approximately 18,000 pounds. This tire weight subtracted from the capacity rating of the rear axle (44,000 pounds) leaves only 26,000 pounds of payload capacity. The attached sample tractor specification gives a rear axle capacity of 44,000 pounds for a general purpose tractor and 65,000 pounds capacity for the lowbed tractor. On a special heavy haul tractor, the rear axle capacity can be as high as 120,000 pounds. In addition, the front axle capacity should be checked, with special attention to the position of the fifth wheel and the weight transfer. See Figures 6.16-1 through 6.16-3 for typical tractor axle load distributions.

6.3.3 Tire Capacity

The weight being carried by each tire should be checked against the manufacturer's recommended loading. Sample manufacturer tire service loads and inflation tables are shown in Tables 6.17-1 through 6.17-3.

6.4 VEHICLE SPEED

Vehicle speed in miles per hour (m.p.h.) is the rolling radius of loaded driving tire multiplied by the engine r.p.m and divided by 168 times the overall gear reduction of the power train:

$$\text{m.p.h.} = \frac{\text{rDm x r}}{168 \text{ x R}}$$

Where:

168	is a factor
r.p.m	is the engine speed in revolutions per minute
R	is the overall gear reduction, including both axle and transmission
m.p.h.	is the vehicle speed in miles per hour
r	is the rolling radius of loaded driving tire

Example:
Find the speed of a vehicle where the engine speed is 1,292 r.p.m, the rolling radius of loaded driving tire is 19.2 inches, and the overall gear reduction is 15.9.

$$\text{m.p.h.} = \frac{1292 \text{ x } 19.2}{168 \text{ x } 15.9} = 9.3 \text{ miles per hour}$$

6.5 TRACTIVE EFFORT

The tractive effort is obtained by multiplying the corrected engine torque by the total ratio of power train by the efficiency of the power train, and dividing this product by the rolling radius of the driving tires.

$$TE = \frac{T \times R \times e \times C \times 12}{r} \quad \text{(pounds)}$$

Where:

T	is the gross engine torque in lb.-ft.
C	is a correction factor for engine torque to determine net torque available at the flywheel; generally 0.85.
R	is the overall gear reduction including both axle and transmission.
e	is the mechanical efficiency of the drive line; generally 0.85.
r	is the rolling radius of loaded driving tire in inches.
12	is a constant converting lb-ft to lb-in.

Example:
Find the tractive effort where the rolling radius of driving tires is 19.5 inches, the total ratio of power train is 52.9, and the gross engine torque is 606 lb-ft.

$$\frac{606 \times 52.9 \times 0.85 \times 0.85 \times 12}{19.5} = 14{,}253 \text{ pounds}$$

6.6 NET TRACTIVE EFFORT

Net tractive effort is tractive effort with an allowance made for rolling resistance:

$$\text{Net TE} = \text{Tractive Effort} - \frac{(RR)\ (DAW)}{100}$$

Where:

RR	is the rolling resistance (1.5% for concrete)
DAW	is the driving axle weight (30,000 pounds)

Example:

$$\text{Net TE} = 14{,}253 - \frac{(1.5)\ (30.000)}{100} = 13{,}803 \text{ pounds}$$

Net tractive effort divided by the coefficient of friction (0.6 for average dry surface) equals the ideal weight on the rear axles. In the example then:

$$\text{Ideal weight} = \frac{13.803}{0.6} = 23{,}000 \text{ pounds}$$

If the weight is appreciably less than this amount, the tires will skid before starting to pull the load.

6.7 OVERALL REDUCTION

A truck has the following specifications:

Main transmission	8051C	first gear ratio 6.25 to 1.00
Auxiliary transmission	834IG	low gear ratio 1.60 to 1.00
Rear axle	SQHD	ratio 5.29 to 1.00

The overall reduction of any given truck is the product of the first gear ratio in the main transmission, the low (underdrive) ratio in the auxiliary transmission, and the rear axle ratio. The overall reduction is derived as follows:

$$(6.25) \times (1.60) \times (5.29) = 52.9 \text{ to } 1$$

6.8 GRADEABILITY

Obviously, the tractive effort available at the wheels must be greater than the sum of the rolling resistances encountered. If this is not so, the transmission must be shifted to a lower gear to increase the tractive effort. The percentage of grade that can be negotiated is given by the formula:

$$G = \frac{1200 \text{ x } T \text{ x } e \text{ x } C \text{ x } R}{r \text{ x } GVW} - RR$$

Where:

1,200	is a constant expressing the percentage of grade and feet
T	is the gross engine torque in Ib.-ft
e	is the mechanical efficiency of the drive line, generally 0.85
C	is a correction factor for gross engine torque to determine net torque available at flywheel, generally 0.85
R	is the rolling radius of the loaded driving tire in inches
G.V.W.	is the gross vehicle weight in pounds
RR	is the rolling resistance expressed as a percentage

Example:

What percentage grade can be negotiated by a vehicle having a gross engine torque of 265 ft-lb, an overall gear reduction in high gear of 4.12 to 1, a tire rolling radius of 19.2 inches, and a gross vehicle weight of 30,000 lb?

$$G = \frac{1200 \text{ x } 265 \text{ x } 0.85 \text{ x } 0.85 \text{ x } 4.12}{19.2 \text{ x } 30{,}000} - 1.4 = 0.24\%$$

Where: RR is 1.4%

6.9 GROUND SPEED OF TRACK LAYING VEHICLE

The ground speed of a track laying vehicle is the engine speed in revolutions per minute times the circumference of the driving sprocket divided by 168 times 2 times 3.1416 times the overall gear reduction of the power train:

$$V = \frac{\text{rpm x C}}{\text{168 x 2 x 3.1416 x R}}$$

Where:

V	is the ground speed in m.p.h.
r.p.m	is the engine speed in revolutions per minute
C	is the circumference of the drive sprocket
Note:	C = N x L
N	is the number of teeth on the sprocket
L	is the length of links in inches
R	is the overall gear reduction

Example:
Find the ground speed in miles per hour where the engine speed is 1,800 r.p.m, the number of teeth on the sprocket is 41, the length of the link is 8 inches, and the total reduction of power train is 61 to 1.

C = 41 x 8 = 328 inches

and:

$$V = \frac{1800 \text{ x } 328}{168 \text{ x } 2 \text{ x } 3.1416 \text{ x } 61} = 9.2 \text{ m.p.h.}$$

6.10 ROAD ROLLING RESISTANCE

The road rolling resistance is the force required to push a vehicle over the surface on which it is rolling and may be expressed in several ways. One way is in terms of pounds resistance per thousand pounds of gross weight. Other methods are derived from this basic expression. The following are typical rolling resistances:

- Concrete, excellent 10 lb.
- Concrete, good 15 lb.
- Concrete, poor 20 lb.
- Asphalt, good 12 lb.
- Asphalt, fair 17 lb.
- Asphalt, poor 22 lb.
- Macadam, good 15 lb.
- Macadam, fair 22 lb.
- Macadam, poor 37 lb.
- Cobbles, ordinary 55 lb.
- Cobbles, poor 85 lb.
- Snow, 2 inches 25 lb.
- Snow, 4 inches 37 lb.
- Dirt, smooth 25 lb.
- Dirt, sandy 37 lb.
- Mud 37 lb. to 150 lb.
- Sand, level soft sand 60 lb. to 150 lb.
- Sand, dune 160 lb. to 300 lb.

Rolling resistance is the gross vehicle weight in pounds times the rolling resistance of the surface divided by 1,000:

$$RR = \frac{GVW \times R}{1\ 000}$$

Where:

RR	is the road rolling resistance in pounds
G.V.W.	is the gross vehicle weight in pounds
R	is the rolling resistance in pounds per thousand pounds of vehicle weight
1,000	is a constant to determine the number of thousand pounds in the vehicle

Example:
What is the rolling resistance of a vehicle having a gross weight of 7,000 pounds on poor asphalt?

$$RR = \frac{7000 \times 22}{1000} = 154 \text{ pounds}$$

Many formulas are arranged to use the resistances in the above table as a factor. To set the table data up in factor form, divide the resistance in pounds by 1,000:

$$Q = \frac{R}{1000}$$

Where:

Q	is the rolling resistance factor per pound of gross vehicle weight
R	is the rolling resistance in pounds per thousand pounds vehicle weight

Example:
What is the rolling resistance factor per pound of gross vehicle weight on good concrete?

$$Q = \frac{15}{1000} = 0.015$$

Another method of expressing road rolling resistance is in percent of grade. To express rolling resistance in percent of grade, multiply rolling resistance per thousand pounds vehicle by 100 and divide by 1,000.

$$\text{RR \% Grade} = \frac{R \times 100}{1000}$$

Where:

RR % grade	is the road rolling resistance in percent of grade
R	is the rolling resistance in pounds per thousand pounds vehicle weight
100	is a constant to express percent

Example:
What is the road rolling resistance expressed in percent of grade of a vehicle on good concrete?

$$\text{RR \% Grade} = \frac{15 \times 100}{1000} = 1.5\%$$

Typical Rolling Resistances for various types of road surfaces are listed in Table 6.10-1.

Table 6.10-1 Rolling Resistances for Various Road Surfaces

Type of Road Surface	Rolling Resistance (Percent)
Concrete and Asphalt	1.5
Hard Packed Dirt	2.5
Dry Dirt or Gravel	3
Soft Dirt	4
Wet Surface on Firm Base	4
Loose Sand or Gravel	10
Rutted and Soft Base	16

6.11 GRADES, SLOPES, AND GRADE RESISTANCE

Table 6.11-1 provides typical data for grade resistance for various grades and slopes.

Table 6.11-1 Grades, Slopes, and Grade Resistance

Grade[1]	Slope[2]	Grade resistance[3]
1	0°-34'	20
2	1°-9'	40
3	1°-43'	60
4	2°-17'	50
5	2°-52'	100
6	3°-26'	120
7	4°-0'	140
8	4°-34'	160
9	5°-9'	180
10	5°-43'	199
11	6°-17'	219
12	6°-51'	238
13	7°-24'	258
14	7°-58'	277
15	8°-32'	296
16	9°-5'	315
17	9°-39'	334
18	10°-12'	353
19	10°-45'	373
20	11°-19'	392
25	14°-2'	485
30	15°-17'	575
35	16°-42'	660
40	21°-48'	743
45	24°-14'	822
50	26°-34'	895
55	28°-49'	965
60	30°-58'	1,025
65	33°-1'	1,085
70	34°-59'	1,145
75	36°-52'	1,196
80	38°-40'	1,248
85	40°-22'	1,205
90	41°-59'	1,338
95	43°-32'	1,376
100	45°-0'	1,402

NOTES: (1) Grade is expressed in percent per 100 horizontal feet
(2) Slope is expressed in degrees and minutes per 100 horizontal feet
(3) Grade resistance is expressed in pounds of pull per ton to overcome grade resistance

6.12 TYPICAL TIRE LOADED RADIUS

Table 6.12-1 lists typical tire loaded Radius

Table 6.12-1 Typical Tire Loaded Radius

Size	Highway Tread	Off Highway Tread	Average Loaded Rolling Radius
9.00-20 (10x22.5)	19.0	19.2	19.50
10.00-20 (11x22.5) (18x19.5)	19.6	19.9	20.16
10.00-22 (11x24.5) (18x22.5)	20.7	20.8	21.15
11.00-20 (12x22.5) (19.5x19.5)	20.1	20.4	20.74
11.00-22 (12x24.5)	21.0	21.4	21.71
11.00-24	22.1	22.3	
12.00-20	20.8	21.2	
12.00-24	22.8	23.0	
14.00-24	24.3	25.3	

6.13 TYPICAL AXLE RATIOS

Typical axle ratios are listed in table 6.13-1.

Table 6.13-1 Typical Axle Ratios

Axle Model	Typical Ratios
R-140	3.70, 4.11, 4.33, 4.63, 5.29, 5.85, 6.14, 6.83, 7.40
R-170	3.70, 4.11, 4.33, 4.63, 4.88, 5.29, 5.85, 6.14, 6.83, 7.40
R-220	5.91, 6.38, 7.03, 7.79, 8.69, 9.71
R-230	4.11, 4.41, 4.77, 5.54, 5.91, 6.38, 6.51, 7.30, 7.79, 8.69, 9.71
U-200	5.91, 6.38, 7.03, 7.79, 8.69, 9.76
R-330 (Hi-Range)	4.41, 4.77, 5.54, 6.26, 7.09
R-330 (Lo-Range)	5.91, 6.38, 7.42, 8.38, 9.49
SLHD-SQHD	4.11, 4.44, 4.63, 4.88, 5.29, 5.83, 6.17, 6.83, 7.20, 7.80, 8.60
SSHD	4.11, 4.63, 5.29, 6.14, 6.83, 7.40
SLD-SLDD	4.68, 5.09, 5.56, 5.90, 6.41, 6.70, 7.00, 7.67, 8.43
SQD-SQDD	5.78, 6.44, 7.54, 8.31, 9.21
SRD-SRDD	5.78, 6.44, 7.54, 8.31, 9.21, 10.26
SUD-SUDD	7.24, 7.98, 9.00, 10.14, 11.08
SFD-SFDD 4640	8.08, 9.03, 10.16, 11.56
SQW	4.71, 5.67, 6.17, 6.80, 7.60, 8.20, 9.25
SPR-250	10.11

Note: Not all ratios listed are standard.

6.14 SAMPLE (UNIT)

6.14.1 Specifications — Lowbed Tractor

MODEL TYPE:	Conventional 6 x 4 heavy-duty construction type chassis.
DIMENSIONS:	Dimensions and weight distribution as shown in Figures 6.16-1 to 6.16-3.
ENGINE:	Detroit diesel model 8V71T, 75-mm injectors, 350 bhp (SAE) at 2,100 rpm, 990 lb.-ft. torque at 1,400 rpm, 568 cu. in. displacement, water cooled, 8 cylinder, V type, blower mounted turbo charger.
ENGINE EQUIPMENT:	Jacobs engine brake, oil cooler, flexible, aircraft type oil lines, full-flow oil filter, magnetic oil pan drain plug, dual fuel filters, cable operated engine shutdown, Bendix Westinghouse 12 cfm air compressor.
COOLING SYSTEM:	Surge tank dosed system type with radiator having 1,270 square inch frontal area, 4 7/16 inch thick core with 450 3/4-inch tubes in 5 rows, 11 fins per inch, 350 gallons per minute free flow, total cooling capacity of radiator core, top and bottom tanks 13.8 gallons, bolted top and bottom tanks, top tank baffled for deaeration. Full fan shroud.
ELECTRICAL SYSTEM:	85 mp Leece-Neville 2500 JB alternator. Two 12-volt Delco 1200 maintenance-free batteries rated at 475 cca each with 130 minimum reserve capacity; 24-volt starting system with automatic circuit breakers; 12-volt lighting system with automatic reset circuit breakers; oil and acid resistant plastic tape wrapped and tied harnesses with quick disconnect terminal blocks.
HOOD AND FENDERS:	Forward tilting, one piece, wide Unitglas hood and fenders; chrome outer radiator shell and chrome plated steel grill.
EXHAUST SYSTEM:	Single, vertical 5-inch exhaust with muffler and muffler guard. Exhaust to be cut level with cab top.
AIR CLEANER(S):	Dual 11-inch EBA dry type with filter restriction indicator, automatic moisture ejector, molded rubber sleeves, and stainless steel aircraft type clamps at all connections.

MAIN TRANSMISSION:	Fuller Model RT-1110, 10-speed twin countershaft, with a maximum torque capacity of 1,100 ft-lb 10 speeds forward and two speeds reverse; first gear ratio: 7.65 to 1, 10th gear ratio: 1 to 1. Single gear-shift lever with air operated range control.
AUXILIARY TRANSMISSION:	Fuller Model AT-1202A, 2-speed; 2.03 to 1 under-drive ratio and 1.00 to 1 direct drive ratio; Tulsa 830G5LU top mounted power tower winch drive.
CLUTCH:	Spicer angle spring 14-inch, 2-plate clutch with cushioned disk and dampened hub.
DRIVELINES:	1710 series with needlebearing universal joints; glide coated splines.
FRONT AXLE:	Timken Model FL931N, 18,000 lb. capacity at the ground, oil lubricated bearings, malleable steal hubs, 13 3/16-inch bolt circle with 1 inch wheel studs.
FRONT SUSPENSION:	Stacked spring, 24,000 lb. capacity with torque rods for front axle alignment.
STEERING SYSTEM:	Dual Seppard integral hydraulic power steering rated 20,000 lb. at the ground.
REAR AXLE(S):	Eaton Model 65DP planetary double reduction, load capacity 65,000 lb. at the ground, GCW rating 180,000 lb, 6.64 to 1 ratio, wide track, malleable hubs with 1-inch wheel studs on 13 3/16-inch bolt circle. Magnetic drain plug.
REAR AXLE SUSPENSION:	Kenworth Model KW6, 65,000 lb capacity.
SERVICE BRAKES:	Air operated S-Cam type 16 1/2 x 7 inches.
EMERGENCY/PARKING BRAKES:	MGM spring actuated air release type on both driving axles, high mounted for maximum ground clearance.
TIRES:	12:00 x 24 - 16 PR Goodyear hard rock lug, or equal (10 furnished).
WHEELS:	Steel disk wheels, 1-inch studs on 13 3/16 bolt circle (10 furnished).

FRAME:	Straight one-piece from front bumper to rear frame; 110,000 psi steel; 10 3/4 x 3 1/2 x 3/8 inch with full length insert, 27.3 $in.^3$ section modulus per rail, 3,102,000 lb. RBM per rail; crossmembers to be full depth steel, free fit bolted construction heat-treated flat washers under both bolt head and nut, nylon inserted lock nuts.
BUMPER:	Aluminum with heavy duty V-brace and center tow hook.
CAB:	Conventional style, composite fiberglass and aluminum construction with steel reinforcement for severe service conditions, mounted to frame with four rubber block vibration dampening shock mounts; bulkhead type aluminum doors fully sealed against air and dust hung from continuous, non-corrosive, piano-type hinges with bearing blocks top and bottom for additional support.
SEATS:	Driver: Bostrom West Coaster.
	Companion: Fixed, molded fiberglass with full back.
CAB FEATURES:	Windshield(s) and door windows tinted, heat absorbing laminated safety glass; 17 x 28 inch fixed rear cab window; safety window right door; left and right inside door locks; cowl vent with bug screen; fiberglass insulation in roof cab, doors, and rear panel; tilt-out instrument panel for full access to all instruments and circuit breakers; all instruments and switches individually back lighted.
ACCESSORIES:	Dual air-operated variable speed windshield wipers with separate motors and heavy-duty non-glare arms and parking control; windshield washers; cab dome light over each door; dual air horns; dual electric horns; cab mounted dual 6 x 16 inch rearview mirrors; single inside sun visor left side.
INSTRUMENTS & WARNING DEVICES:	Tachometer; speedometer with odometer in kilometers; ammeter; oil pressure, water temperature, air reservoir and application pressure gauges; high beam indicator; high water temperature, low oil, and air reservoir pressure warning lights; electric fuel gauge.
FUEL TANK(S):	Dual 55 gallon 22-inch diameter steel high mount.

LIGHTS:	Dual headlights; 5 ICC marker lights; directional signals with all flasher controlled lights fender mounted; dual stop and tail lights; back-up light.
SEVERE SERVICE ITEMS:	The following is a minimum list of additional items included for severe service. 1. Steel battery holddowns. 2. Heavy-duty forged aluminum 3-hole gussets on auxiliary transmission crossmember. 3. Steel fuel tank brackets and heavy-duty anchors for fuel tank straps. 4. Main transmission support springs. 5. Heavy-duty exhaust mounting brackets. 6. Steel tubular underbellhousing crossmember. 7. Steel front engine supports. 8. Steel flywheel housing.
TRACTOR EQUIPMENT:	Holland W-70-0 single oscillating heavy-duty fifth wheel with 31/2 inch king pin jaws; tractor kit complete with breakaway, hand control valve, 12-foot trailer air and light lines and hosetenna.
SPECIAL EQUIPMENT:	Integral cab guard and winch platform constructed of A53 schedule 40 seamless pipe and 6 x 6 x 1/2 inch angle base mounted on channel and bolted to truck frame; Braden model 50 winch rated at 100,000 lb line pull on first layer, 200 foot 1 inch cable, 2 feet of 1 inch tail chain with hook, air operated controls in cab and manual controls right side of winch installation; possom belly tool tray extending from winch mounting base to fifth wheel mounting angles; fifth wheel ramp from end of truck frame to fifth wheel mounting angles; full frame with 8 inch diameter tail roller.
PAINT:	Cab, chassis, and special equipment painted Wimbledon White.

6.15 SAMPLE (PROJECT)

6.15.1 Specific Unit Requirements - Tractor, General Purpose

DIMENSIONS:	Wheelbase, 230 inches; back of cab to end of frame, 222 inches.
ENGINE:	300 Horsepower minimum.
MAIN TRANSMISSION:	Fuller RT12515, 15-speed, twin countershaft, direct in 15th.
AUXILIARY TRANSMISSION:	None.
FRONT AXLE TYPE:	Non-driving.
REAR AXLE:	Operating conditions to be on highway; capacity at ground, 44,000 lb; G.C.W. capacity, 100,000 lb.
TIRES:	Front, 11:00 x 22, 16-ply hard rock rib; Rear, 11:00 x 22, 16-ply hard rock rib.
WHEELS:	8 x 22 inch steel; 10 hole, 11 1/4 inch bolt circle, 1 inch stud.
FRAME:	Class B.
FUEL TANK(S):	Two.
TRACTOR EQUIPMENT:	Holland FW-70-D single oscillating fifth wheel with 2 inch kingpin. 12 foot trailer air and light lines suspended from the headache rack by springs. Cab guard to be rectangular shape, 90 inches wide x 74 inches above frame rail. Perimeter to be 4 x 2 inch rectangular tubing with minimum of 3 horizontal cross bars. Bottom perimeter member to be 6 inches above truck frame. Headache rack mounted to angle, overlaid on frame and bolted through frame web, with bolt-in open storage box between angles with 6 inch sides and expanded metal bottom.

6.15.2 Specific Unit Requirements - Tractor, Lowbed/Winch

DIMENSIONS:	Wheelbase, 230"; Back of Cab to End of Frame, 222".
ENGINE:	400 Horsepower minimum.
MAIN TRANSMISSION:	Fuller RT-12515, 10-speed, twin countershaft, direct in 15th.
AUXILIARY TRANSMISSION:	Fuller AT1202, 2-speed, with top mounted P.T.O. for winch drive.
FRONT AXLE:	Non-driving.
REAR AXLE:	Operating conditions to be on/off highway; capacity at ground, 44,000 lbs.; G.C.W. 170,000 lbs.
TIRES:	Front, 11:00 x 22, 16 ply hard rock rib; Rear, 11:00 x 22, 16 ply hard rock rib.
WHEELS:	8.0" x 22" steel; 10 bole, 11 1/4" bolt circle for 1" studs.
FRAME:	Class C.
FUEL TANK(S):	Two.
TRACTOR EQUIPMENT:	Holland FW-70-0 single oscillating fifth wheel with 3 1/2" kingpin jaws. 12 foot trailer air and light lines suspended from the headache rack by springs.
SPECIAL EQUIPMENT:	Integral headache rack and winch platform constructed of A53 schedule 40 seamless pipe and 6" x 6" x 1/2" angle base mounted on channel and bolted to truck frame. Rear angle of winch to be secured by U-bolts around truck frame. Roller guides to be A53 schedule 40 seamless pipe. Winch to be rated 60,000 lbs. first layer on 8" diameter drum barrel, 31/4" diameter drum shaft. Oil cooled, fully adjustable automatic safety brake. 200 ft. 1" 6 x 31 IWRC cable, 2 ft. of 1" tail chain and hook. Air operated controls in cab and manual controls right side of winch installation. Tool tray constructed of A36 structural steel and expanded metal bottom extending from winch mounting base to 5th wheel mounting angles. Fifth wheel ramp from end of truck frame to fifth wheel mounting angles. Full frame width 8" diameter rail roller with removable spherical bushings; lube fittings for bushings. Entire tail roller assembly to be bolted to truck frame.

6.16 SAMPLE TRACTOR AXLE LOADINGS

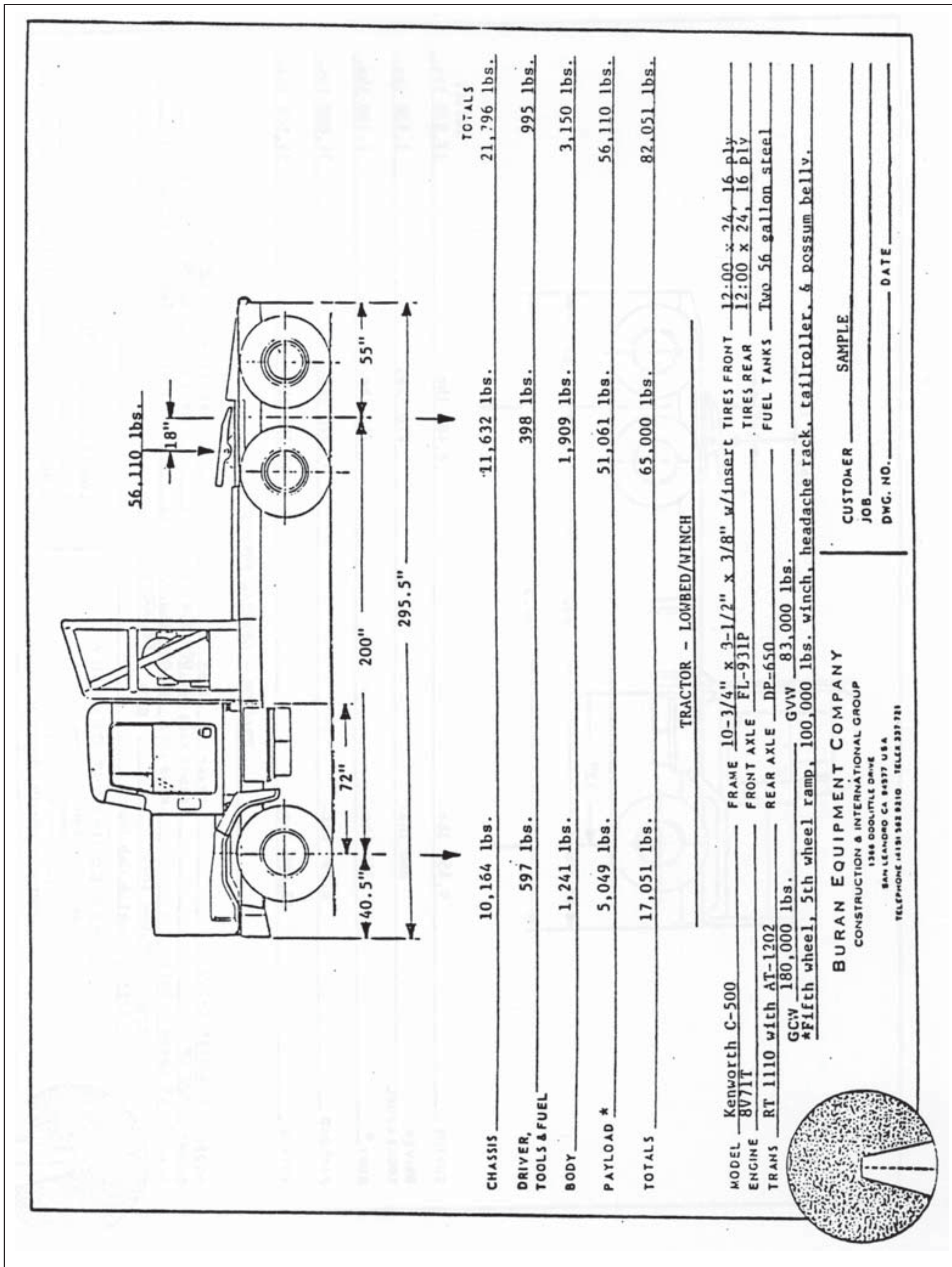


Figure 6.16-1 Tractor — Lowbed/Winch Sample

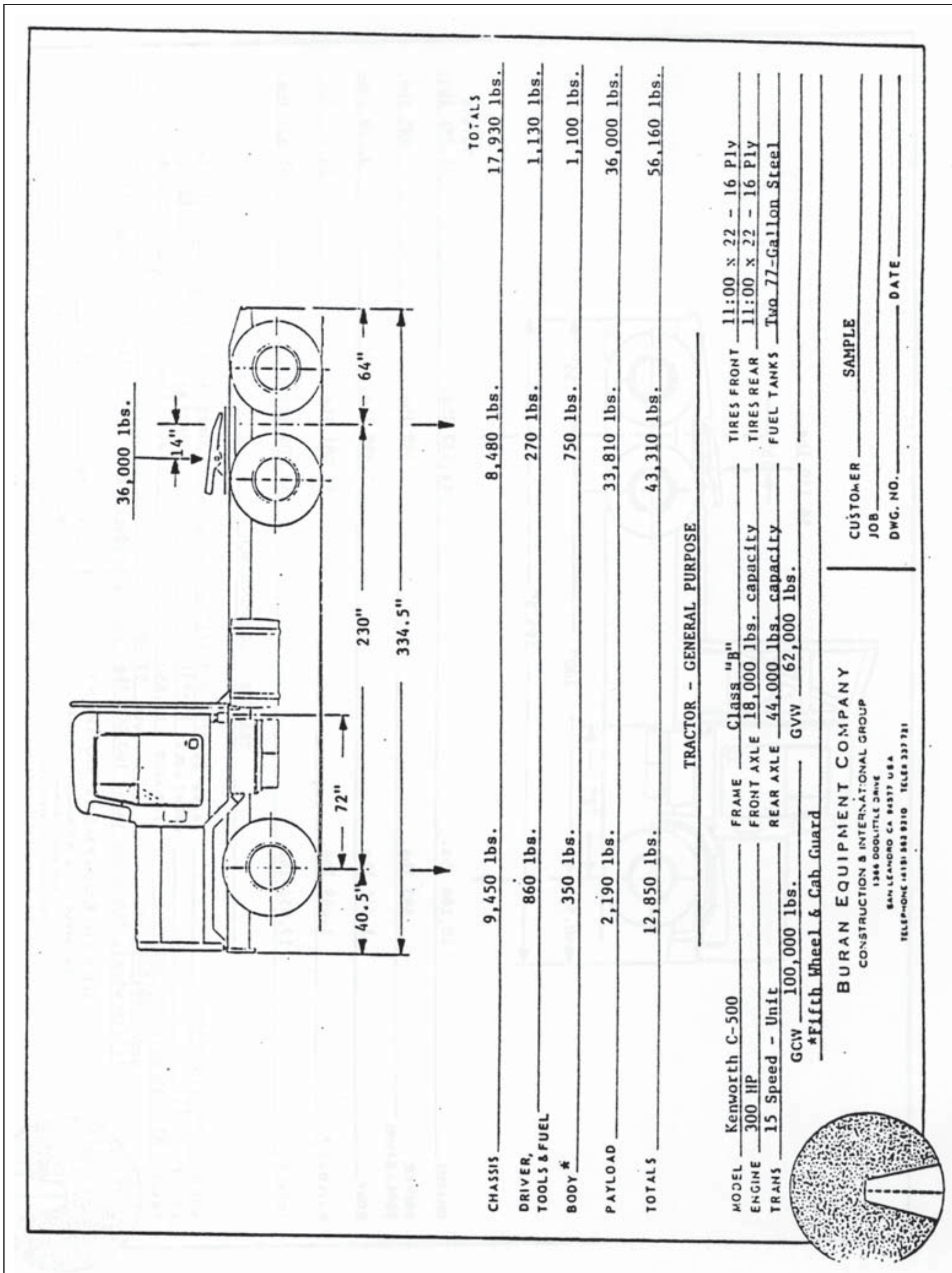


Figure 6.16-2 Tractor — General Purpose Sample

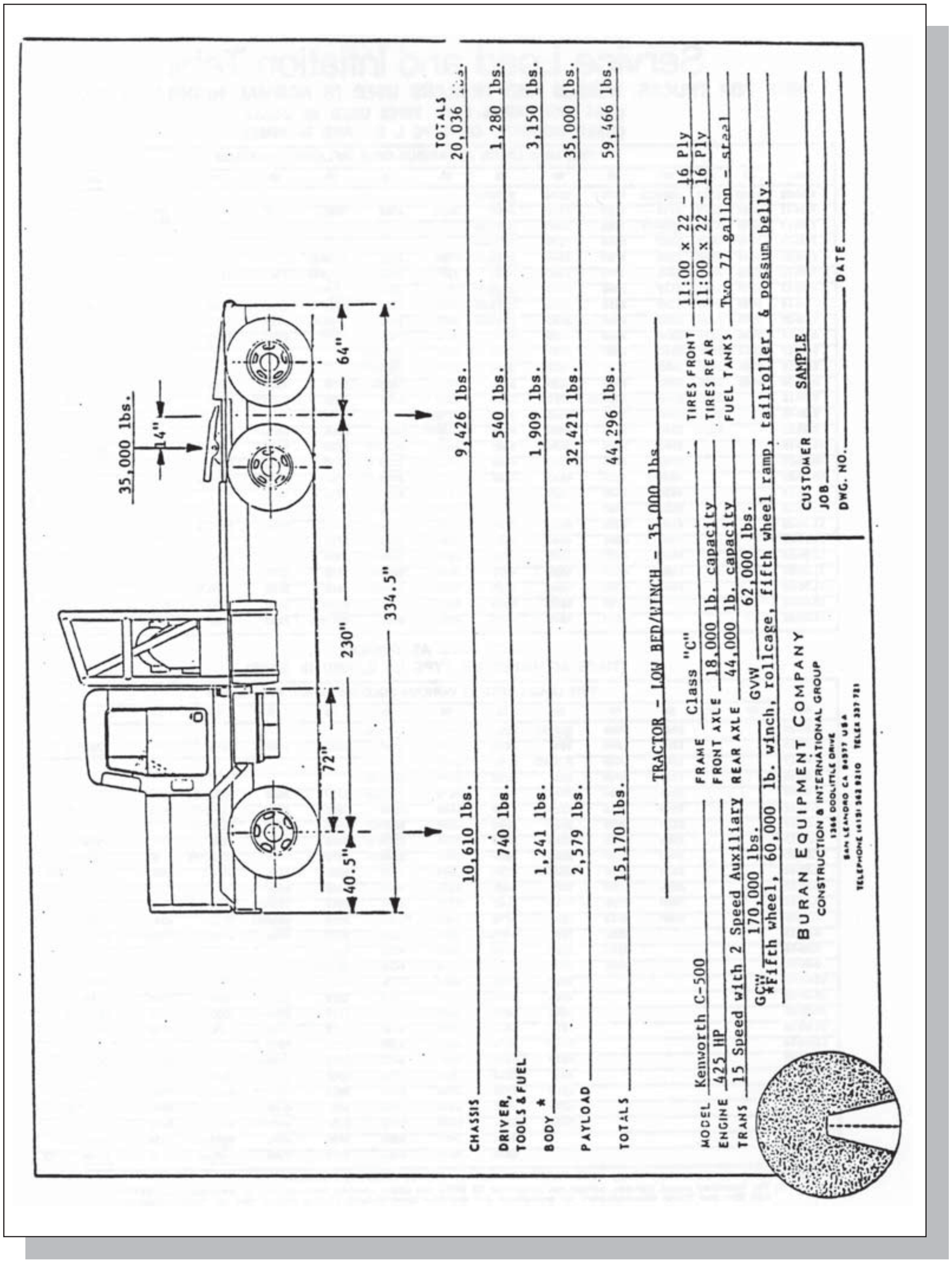


Figure 6.16-3 Tractor — Lowbed/Winch - 35,000 lbs. Sample

6.17 SAMPLE TIRE SERVICE LOAD AND INFLATION TABLES

Table 6.17-1 Service Load and Inflation Table

TIRES FOR TRUCKS, BUSSES AND TRAILERS USED IN NORMAL HIGHWAY SERVICE

(BIAS AND RADIAL PLY) TIRES USED AS DUALS
(TIRES MOUNTED ON TYPE I, II, AND III RIMS)

TIRE LOAD LIMITS AT VARIOUS COLD INFLATION PRESSURES

Size	40	45	50	55	60	65	70	75	80	85	90	95	100
6.50-20	1630	1750	1860(C)	1970	2070	2170(D)							
7.00-15	1510	1610	1720	1820	1910	2000	2090	2180	2260	2340	2420	2500(*F)	
7.00-17	1640	1760	1870(C)	1980	2080	2180(D)							
7.00-18	1710	1830	1950	2060	2170	2270(D)							
7.00-20	1840	1980	2100	2220	2340	2450(D)	2560	2660	2760(E)				
7.50-15	1700	1820	1940	2050	2160	2260	2360	2460	2550(E)	2640	2730	2820(*F)	
7.50-17	1850	1990	2110	2230	2350	2460(D)	2570	2680	2780(E)				
7.50-18	1920	2060	2190	2310	2430	2550(D)	2670	2780	2890	2990	3090	3190	3200(*G)
7.50-20	2070	2220	2350	2490	2620	2750(D)	2870	2990	3100(E)	3210	3320	3430(*F)	
8.25-15	2030	2170	2310	2440	2570	2700	2810	2930	3040	3150	3260(*F)	3360	3470(*G)
8.25-17	2220	2360	2510	2650	2790	2930	3060	3180(E)					
8.25-18	2280	2450	2600	2750	2900	3040	3170	3300(E)					
8.25-20	2460	2640	2800	2960	3120	3270	3410	3550(E)	3690	3820	3950(F)		
9.00-15		2590	2760	2920(D)	3070	3210	3360	3490	3630	3760(F)	3890	4010	4130(*G)
9.00-18		2910	3100	3270	3440	3610	3770(E)						
9.00-20		3120	3310	3510	3690	3870	4040(E)	4200	4360	4520(F)			
10.00-15			3140	3320	3490	3660	3830	3980(F)	4130	4280	4430(G)	4570	4710(*L)
10.00-20			3760	3970	4180	4380	4580	4760(F)	4950	5120	5300(G)		
10.00-22			4000	4230	4450	4660	4870	5070(F)	5260	5450	5640(G)		
11.00-15			3430	3630	3820	4000	4180	4350	4520	4680	4840	5000	5150(*H. *L)
11.00-18			3830	4060	4270	4470	4670	4860(F)					
11.00-20			4100	4330	4560	4780	4990	5190(F)	5390	5590	5780(G)		
11.00-22			4350	4600	4840	5080	5300	5520(F)	5730	5940	6140(G)		
11.00-24			4620	4890	5140	5390	5630	5860(F)	6090	6310	6520(G)		
11.50-20			4180	4420	4650	4870	5090	5290(F)	5500	5700	5890(G)		
11.50-22			4440	4700	4940	5180	5410	5630(F)	5850	6060	6270(G)		
12.00-20				4930	5190	5440	5680	5910	6140(G)	6360	6580	6790(*H)	
12.00-24				5550	5840	6120	6390	6650	6910(G)	7160	7410	7640(*H)	7870(*L)

NOTES:

1: Letters in parenthesis denote *load range* for which underscored Loads are maximum.

2: For restricted speed highway service not exceeding 50 MPH, the above loading ratings may be increased 9%. Important — consult rim and wheel manufacturers for availability and engineer specifications of rims and wheels for these applications.

Table 6.17-2 Service Load and Inflation Table

TIRES USED AS SINGLES

(TIRES MOUNTED ON TYPE I, II, AND III RIMS)

TIRE LOAD LIMITS AT VARIOUS COLD INFLATION PRESSURES													
Size	40	45	50	55	60	65	70	75	80	85	90	95	100
6.50-20			1860	2000	2120(C)	2250	2360	2470(D)					
7.00-15			1720	1840	1960	2070	2180	2280	2380	2490	2580	2670	2780(*F)
7.00-17			1870	2010	2130(C)	2260	2370	2490(D)					
7.00-18			1950	2090	2220	2350	2470	2590(D)					
7.00-20			2100	2260	2390	2530	2670	2790(D)	2920	3030	3150(*E)		
7.50-15			1940	2070	2210	2340	2460	2580	2690	2800	2910(*E)	3010	3110(*F)
7.50-17			2110	2270	2410	2540	2680	2800(D)	2930	3060	3170(*E)		
7.50-18			2190	2350	2500	2630	2770	2910(D)	3040	3170	3290	3410	3520(*G)
7.50-20			2360	2530	2680	2840	2990	3140(D)	3270	3410	3530(*E)	3660	3780(*F)
8.25-15			2310	2470	2630	2780	2930	3080	3200	3340	3470	3590	3720(*F. *G)
8.25-17			2510	2690	2860	3020	3180	3340	3490	3630(E)			
8.25-18			2600	2790	2960	3140	3310	3470	3610	3760(E)			
8.25-20			2800	3010	3190	3370	3560	3730	3890	4050(E)	4210	4350	4500(*F)
9.00-15				2950	3150	3330(D)	3500	3660	3830	3980	4140	4290(*F)	4430(*G)
9.00-18				3320	3530	3730	3920	4120	4300(E)				
9.00-20				3560	3770	4000	4210	4410	4610(E)	4790	4970	5150(*F)	
10.00-15					3580	3780	3980	4170	4370	4540(F)	4710	4880	5050(*G.*L)
10.00-20					4290	4530	4770	4990	5220	5430(F)	5640	5840	6040(*G)
10.00-22					4560	4820	5070	5310	5550	5780(F)	6000	6210	6430(*G)
11.00-15					3910	4140	4350	4560	4770	4960	5150	5340	5520(*H. *L)
11.00-18					4370	4630	4870	5100	5320	5540(F)			
11.00-20					4670	4940	5200	5450	5690	5920(F)	6140	6370	6590(*G)
11.00-22					4960	5240	5520	5790	6040	6290(F)	6630	6770	7000(*G)
11.00-24					5270	5570	5860	6140	6420	6680(F)	6940	7190	7430(*G)
11.50-20					4770	5040	5300	5550	5800	6030(F)	6270	6500	6710(*G)
11.50-22					5060	5360	5630	5910	6170	6420(F)	6670	6910	7150(*G)
12.00-20						5620	5920	6200	6480	6740	7000(G)	7250	7500(*H)
12.00-24						6330	6660	6980	7280	7580	7880(G)	8160	8450(*H. *L)

NOTES:

1: Letters in parenthesis denote load range for which underscored loads are maximum.

2: For restricted speed highway service not exceeding 50 MPH, the above loadingratings may be increased 9%. Important — consult rim and wheel manufacturers for availability and engineer specifications of rims and wheels for these applications.

Table 6.17-3 Service Load and Inflation Table

TIRES FOR FORK LIFT TRUCKS, MOBILE CRANES, SHOVELS, MINING CARS, FRONT END LOADERS AND DOZERS

MAXIMUM SPEED — 5 MILES PER HOUR

TABLE LP-1F

Tire Size	TIRE LOAD LIMITS AT VARIOUS COLD INFLATION PRESSURES													
	35	40	45	50	55	60	65	70	75	80	85	90	95	100
7.00-15	2410	2600	2790	2970	3140	3300	3460	3610	3760	3910	4050	4190	4320	4450 (12)
7.00-20	2940	3170	3410	3630	3840	4030	4230	4420	4600	4770	4950	5120	5280(10)	5440 (12)
7.50-10	1960	2120	2270	2410	2550	2690	2810	2940	3060	3180	3290	3400	3510(10)	3420 (12)
7.50-15	2710	2940	3150	3350	3540	3720	3900	4080	4240	4410	4560	4720(10)	4870	5020 (12)
7.50-18	3060	3310	3540	3770	3990	4190	4400	4590(8)	4780	4960	5140	5320(10)	5490	5660 (12)
7.50-20	3300	3570	3830	4070	4310	4530	4750	4960(8)	5160	5360	5550	5740(10)	5920	6110 (12)
8.25-15	3240	3500	3750	3990	4220	4440	4660	4860	5060	5260	5450	5630	5810	5990 (12)
8.25-18	3650	3940	4220	4490	4750	5000	5240	5470	5700	5920(10)				
8.25-20	3990	4240	4550	4840	5120	5380	5640	5890	6130	6370(10)	5500	6830	7040	7280 (12)
9.00-10	2630	2850	3050	3240	3430	3610	3780	3950	4110	4270(10)	4420	4580	4720	4860 (12)
9.00-15	3860	4170	4470	4750	5030	5290	5550	5790	6030	6260	6490	6710(12)		
9.00-20	4640	5020	5380	5720	6050	6370	6680	6970	7260	7530	7810	8070(12)		
10.00-15	4400	4750	5100	5420	5730	6030	6320	6600	6870	7140	7390	7650	7890(14)	
10.00-20	5260	5690	6090	6480	6860	7210	7560	7890	8220	8530	8840(12)	9140	9430(14)	
11.00-20	5740	6200	6650	7070	7480	7870	8250	8610	8970	9310(12)	9650	9980(14)		
12.00-20	6540	7070	7570	8060	8520	8960	9400	9810	10210	10610	10990(14)	11370	11730	12080 (16)
*12.00-24	7240(6)	7830	8390	8920(8)										
*13.00-24	8510(6)	9200	9880(8)	10490	11100	11670	12240	12780(12)	13300	13810	14310	14800(16)		
14.00-20	8980	9710	10400	11070	11710	12310	12910	13480	14030	14570	15100	15610	16110(18)	16800 (20)
*14.00-24	10020	10830(8)	11610	12350	13060	13740	14400(12)							
14.00-24	10020	10830	11610	12350	13060	13740	14400	15040	15650	16250	16840	17420	17970	18520 (20)
*16.00-24	13670	14780	15840	16850(12)										

TABLE LP-2

16.00-25	13120	14180	15200	16170	17100	17990	18860	19690	20500	21280	22050	22810	23530(24)	
18.00-25	16940	18320(12)	19630	20880	22090(16)	23230	24360	25440(20)	26470	27490(24)				
21.00-25	21810	23580	25270	28880(16)	28430	29900(20)	31350	32740(24)	34070	35380	36660(28)			
24.00-25	28170	30450	32640(18)	34720	36720	38620	40490(24)	42280	44010	45700(30)				
24.00-29	30170	32620	34980(18)	37180	39330	41370	43370(24)	45290	47140	48950(20)				
36.00-41	76650	82880	88820	94470	99930	105110	110190	115070	119770	124370	128870(48)			
36.00-51	84920	91820	98400	104670	110720	116450	122080	127490	132890(42)	137790	142780(50)	147660	152330	157000 (50)

*These tires used on S.D.C. rims.

NOTES: 1: For 10 MPH service, the above loads must be reduced 13% at the same inflation pressures.

2: For stationary service conditions, the above loads may be increased up to 57% with no increase in inflation.

7 TRANSPORTATION

7. Transportation

7.1 HEAVY HAULING AND TRANSPORTATION

This section discusses the transportation of heavy equipment, generally weighing 50 tons or more. To transport heavy plant equipment on the construction site or on public roads requires specialized land transporters. Various types of transporters include:

- Multi-axle hydraulic platform trailers
- Self-propelled multi-axle hydraulic platform trailers
- Low-bed/multi-axle transporters
- Crawler transporters
- Schnabel cars

7.1.1 Multi-Axle Hydraulic Platform Trailers

Multi-axle hydraulic platform trailers form the backbone of the world's fleet of heavy haul transporters. Manufacturers of this equipment include Scheurle, Goldhofer, Trabosa, Nicholas, and Cometto. Platform trailers must be towed and/or pushed by a separate tractor or series of tractors that are typically referred to as the prime mover(s).

A hydraulic platform trailer consists of a structural steel deck supported by an array of axle bogies. The axle bogie suspension is the heart of the hydraulic platform trailer. Each bogie is connected to the trailer deck and is supported by a linkage that consists essentially of a hydraulic cylinder or ram. All of these bogie cylinders are interconnected hydraulically. This hydraulic interconnection enables the deck of the trailer to be raised or lowered by pumping or draining fluid from the rams. Second, considering Pascal's law and applying his hydraulic principle to the interconnected hydraulic system, the transporter bogies will each support an equal load, regardless of where or how the load is applied to the deck of the transporter. This equalization means that the ground or bearing surface on which the transporter is traveling will see a uniform loading. The linkage and suspension are further refined to permit each bogie to tilt or pivot laterally, thus ensuring equal distribution to each tire. Each bogie swivels independently, allowing the transporter to be steered. An array of steering links enables the transporter to perform coordinated turns. Because of the large quantity of bogies, steering is hydraulically assisted. Steering input comes from the tow vehicle (prime mover) via a steel drawbar. Turning the drawbar actuates hydraulic cylinders that control the steering links, which, in turn, steer the bogies.

A feature typical to most hydraulic platform trailers is modularization. Depending on the manufacturer, the trailers come in modules of 2, 3, 4, 5, etc., axle lines (or files). Modules can be linked together longitudinally to create a trailer of virtually any length. In addition, the trailer modules can be linked together laterally to make double wide or even one and one-half wide platforms.

The actual hydraulic arrangement of the bogie cylinders must be statically determinate, which means that there must be three isolated hydraulic loops that correspond to a triangular support arrangement. This arrangement is referred to as the stability triangle or "three-point suspension." Usually, two lateral loops are located at the front of the trailer, and a single loop is located at the rear of the trailer. A four-loop system is possible but will not provide calculable or predictable loadings to the deck or supporting surface. The bogies within a particular loop are linked hydraulically; thus, Pascal's law applies and the bogies within that loop each see the identical load, regardless of bumps or potholes in the road. However, each of the three loops may not see the same load because of tilt, pitch, and the location of the payload's center of gravity. This must be determined with statics calculations. The three hydraulic loops allow the deck to be leveled. If the deck is tilting to one side, one of the lateral loops can be pumped up to extend the rams on that side and eliminate the tilt. If the deck is pitching toward the rear, the rear loop can be extended (or the two lateral loops in the front can be retracted).

The entire platform can be raised by extending the rams in each loop simultaneously. This feature, in many cases, eliminates the need for a lift crane for loading and offloading if temporary stands and outrigger beams are used under the payload.

Hydraulic power is supplied to the bogie rams and the steering rams from a power pack that consists of a pump, motor, reservoir, valving, and instrumentation. The power pack is manually operated, independent of the prime mover, and is typically mounted at the rear of the transporter.

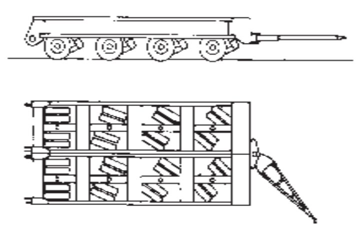
Information needed to develop a heavy haul transportation plan using hydraulic platform trailers includes the following:

- Weight and center of gravity of the equipment to be hauled
- Permissible equipment support location
- Maximum permitted axle load on supporting surface (road, bridge, etc.)
- Haul route grades
- Haul route turning radii
- Overhead and lateral clearances along the haul route

With this information, the haul planner can choose the proper transporter, transporter configuration, and prime movers.

Figure 7.1-1 16-Line Hydraulic Platform Trailer Hauling a HRSG Module

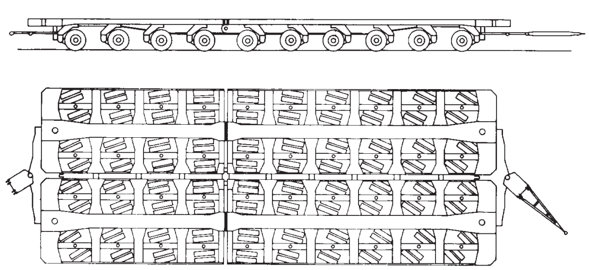
Constructions for Module Technic



Type K/100/4

Speed	50 kmh	20 kmh	5 kmh
Gross weight	80000	96000	112000 kg
Weight unladen, approx.	19500	19500	19500 kg
Payload capacity approx.	60500	76500	92500 kg
Axle pressure	4 x 20000	24000	28000 kg
Loading length			6350 mm
Loading width			3000 mm
Loading height		1250 ±	250 mm
Tires		32 fold	7.50–15

Figure 7.1-2 Single Wide, 4 Line Platform Trailer, Typical Data



Type K 150/6 and K 100/4
2 x 6 lines of axles and 2 x 4 lines of axles, longitudinally and transversally coupled

Speed	20 kmh	8 kmh	5 kmh
Gross weight	480000	500000	560000 kg
Weight unladen, approx.	80000	80000	80000 kg
Payload capacity	400000	420000	480000 kg
Axle pressure	20 x 24000	25000	28000 kg
Loading length			14950 mm
Loading width			6250 mm
Loading height		1075 mm ±	250 mm
Loading height, alternative		1250 mm ±	300 mm
Tires		160 fold	7.50–15

Figure 7.1-3 Double Wide, 10 Line Platform Trailer, Typical Data

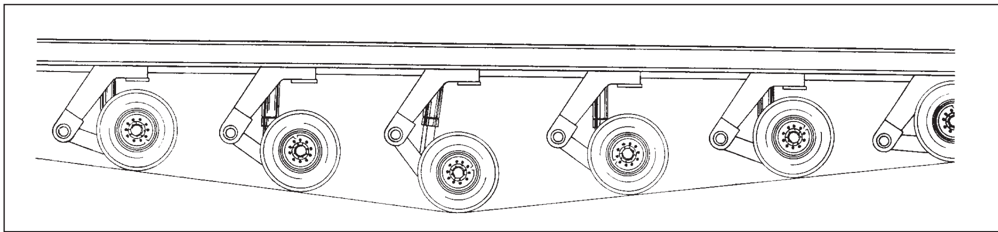


Figure 7.1-4 Platform trailer Hydraulic Suspension

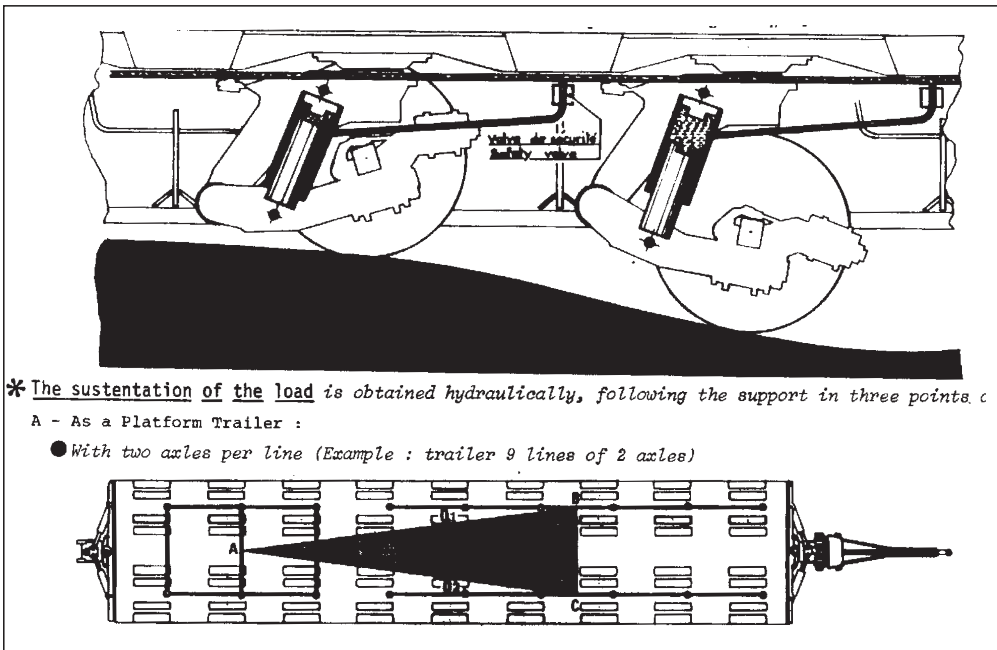


Figure 7.1-5 Platform Trailer Hydraulic Suspension and Stability Triangle

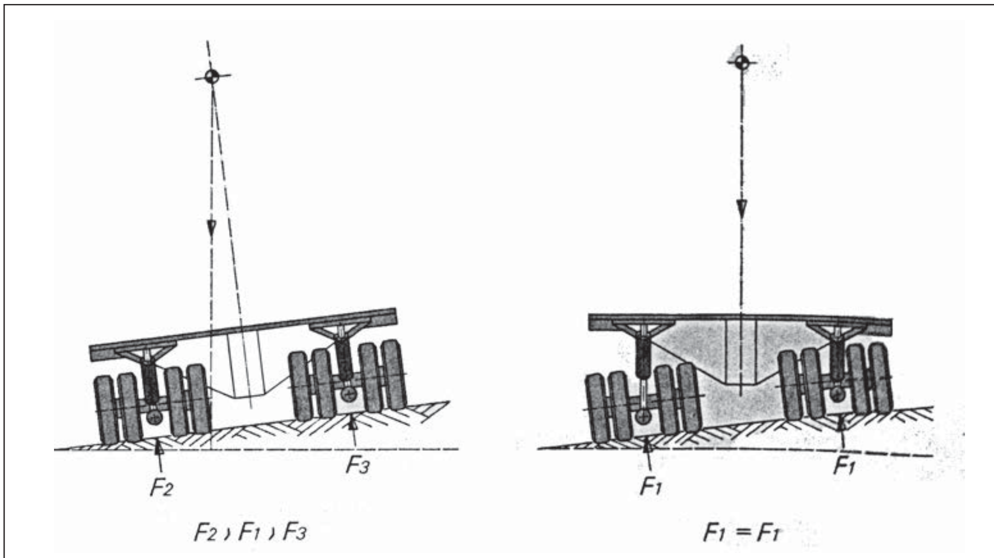


Figure 7.1-6 Self Leveling Capability

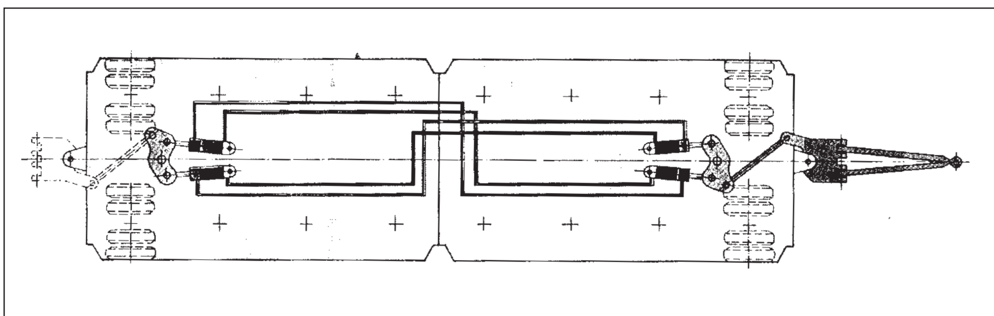


Figure 7.1-7 Hydraulic Steering Schematic

7.1.2 Self-Propelled, Multi-Axle Hydraulic Transporters

Multi-axle hydraulic platform trailers have traditionally required prime movers as tow vehicles. With recent advancements in technology, manufacturers have developed completely self-propelled transporters, eliminating the need for a tow vehicle. To increase maneuverability, these self-propelled transporters feature independent, 360-degree steering for all bogies. High maneuverability combined with a slightly greater capacity per axle line than a similar platform trailer make self-propelled transporters desirable for many transportation jobs. The only disadvantage when compared with towed platform trailers is the slower top speed. The theoretical top speed is limited by the capacity of the high torque hydraulic drive motors; whereas the top speed of towed trailers is limited by the prime mover speed. Practical factors such as stability, structural capacity of the deck, and dynamic effects play a major part in determining the overall haul speed.

Self-propelled transporters are modular and can be linked together longitudinally to create a transporter of any length. However, they do not necessarily need to be linked together. Transporter modules can be separated and placed at multiple payload support points. The individual transporter modules can then be linked electronically for uniform control of steering and movement.

The various figures in this section illustrate the versatility of self-propelled transporters for maneuverability and configuration flexibility. Up to one-half of the wheels in a transporter module can be powered drive wheels. These wheels provide superior tractive effort. With 360-degree steering and high traction, payloads can be positioned extremely accurately even in rugged or confined jobsites.

Figure 7.1-8 Scheuerle Self-Propelled Multi-Axle Hydraulic Transporter

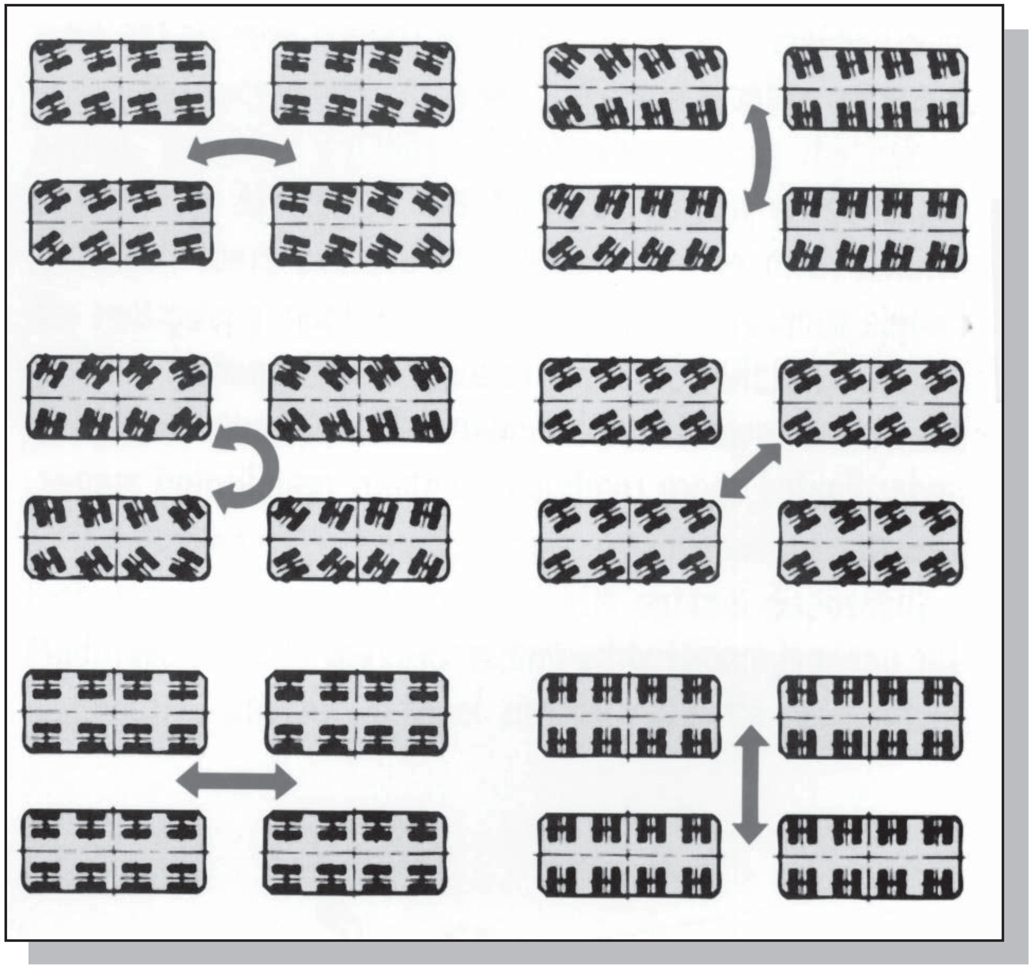
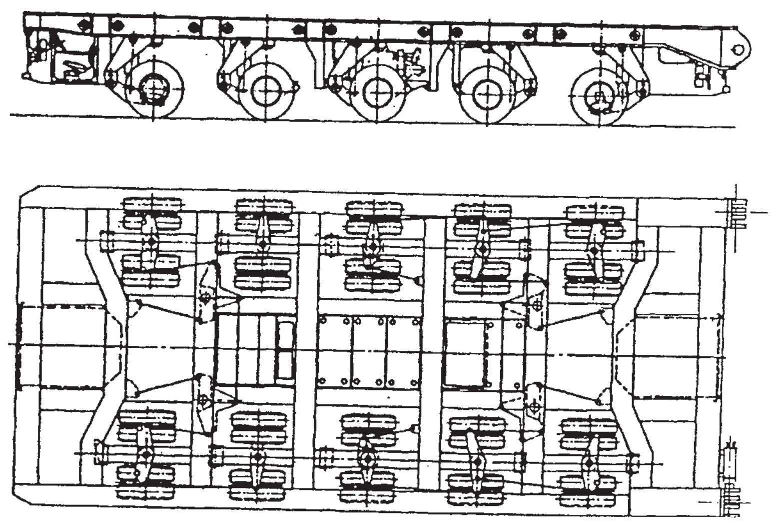


Figure 7.1-9 Examples of Steering Programs

Figure 7.1-10 KAMAG Self-Propelled Transporter

Figure 7.1-11 KAMAG Self-Propelled Transporters Hauling Module



Technical Data

Weights	techn.	max.
Gross weight	200 m/t	260 m/t
Unit weight	50 m/t	50 m/t
Payload capacity	150 m/t	210 m/t
Axle load	40 m/t	52 m/t

Dimensions		
Overall length		13.500 mm
Overall width		6.000 mm
Loading area, length		13.500 mm
Loading area, width		6.000 mm
Driving height		1.850 mm
Lift	+/–	350 mm
Inner turning radius		1.000 mm
Outer turning radius		10.000 mm

Speed		
empty, gradient	0,0 %	14,0 km/h
loaded, gradient	0,0 %	7,0 km/h
	9,5 %	1,5 km/h

Engine		
Type	Deutz	F8L 413F
Performance		174 kW
(at 2.500 rpm DIN 6271 B)		
Total tractive force		255 kN
Number of drive axles		3

Tires	
Number	40
Type	10.00 – 20 PR 16

Figure 7.1-12 Plan View and Technical Details of Typical Self-Propelled Platform Trailer

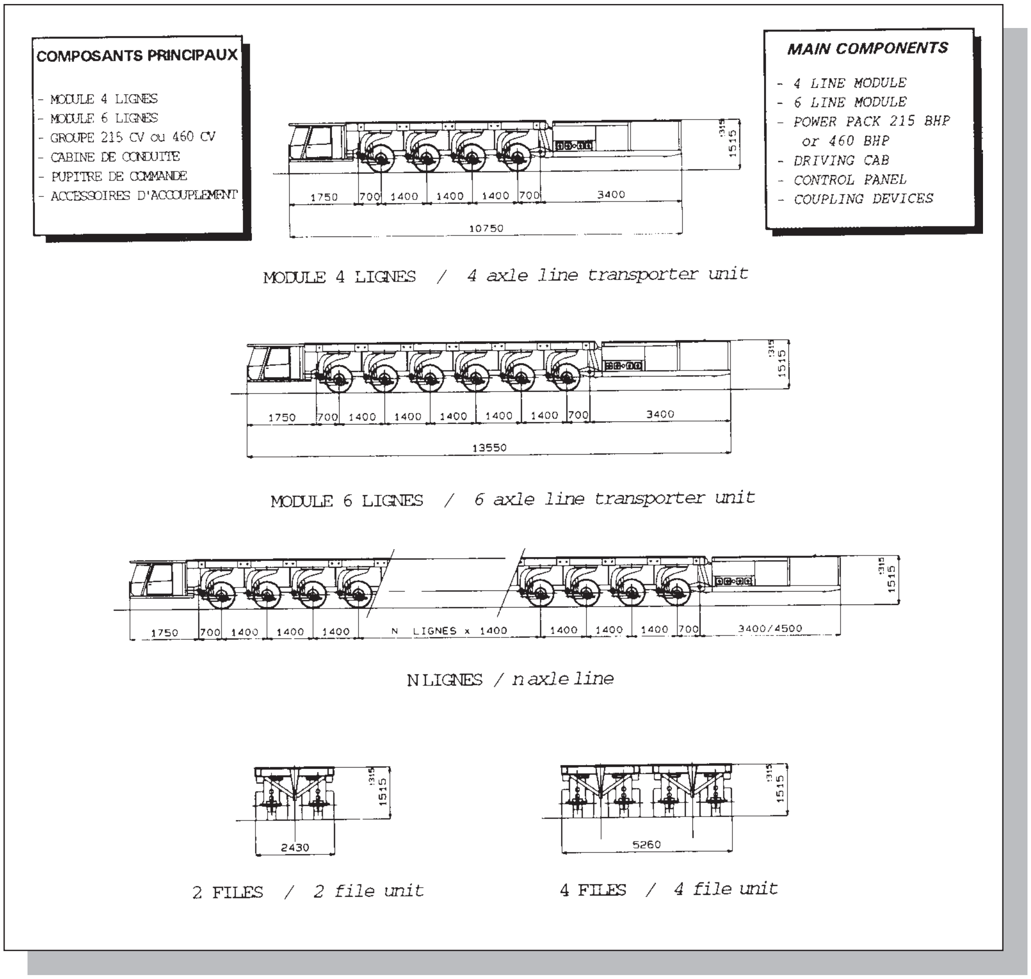


Figure 7.1-13 Four and Six Axle Self-Propelled Transporter Unit

7.1.3 Low-Bed/Multi-Axle Transporters

Low-bed/multi-axle transporters differ from hydraulic platform trailers in arrangement, performance, and suspension. Low-bed/multi-axle transporters rely on principles of statics to distribute load to the axles, whereas hydraulic platform trailers distribute the load to the axles with fluid (hydraulic oil) using Pascal's principle.

The load rests the low steel deck or bed (low-bed) of the transporter. The bed is generally low to the ground to keep the load center of gravity low, thus enhancing stability. The bed is outfitted with front and rear goosenecks that are supported by front and rear bogies. The bogies consist of a series (or stack) of distributor beams that distribute the load to a multitude of axles. The axle spacing and locations can be varied by changing the length and arrangement of the distributor beams. This variety allows the transporter to meet state and local highway permit requirements for axle loadings, which is sometimes difficult to achieve economically with platform trailers.

A variation of the low-bed concept is to replace the low-bed and goosenecks with horizontal girders. The load hangs from these girders, which are supported front and rear by the bogies. A disadvantage of low-bed/multi-axle transporters is generally their length and lack of maneuverability. The load sits in the middle of the transporter, and the axles and distributor beams extend forward and rearward. Thus, the overall length of the vehicle can remain reasonably short for compact loads, but, for long loads, such as refinery vessels, the overall transporter length can become unreasonable. The turning radius for these transporters is generally very large. Their use on anything other than major highways may be restricted due to sharp turns.

Figure 7.1-14 Goldhofer High Bridge Girder with self-propelled multi-axle trailers

7.1.4 Crawler Transporters

Crawler transporters were used extensively in the past. However, because of the lack of maneuverability and travel restrictions on paved roads, crawler transporters have limited applications. Crawler transporters consist of a structural steel platform mounted on top of a standard crawler crane carbody.

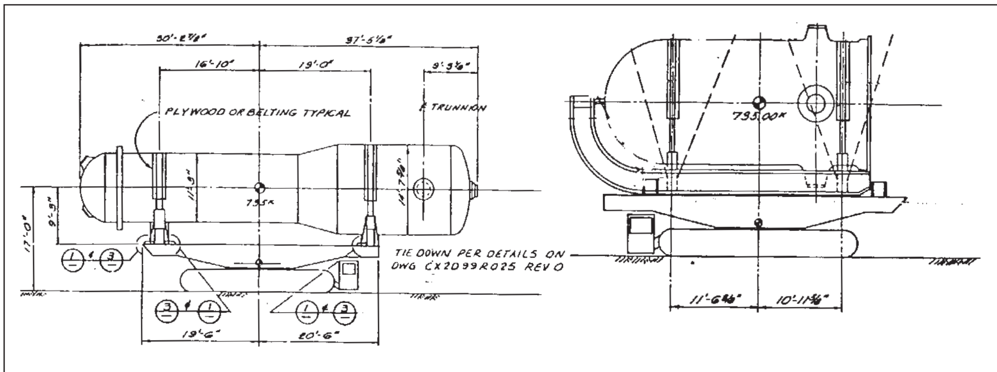


Figure 7.1-15 Crawler Transporter

7.1.5 Schnabel Cars

The Schnabel car configuration is suited for transporting heavy and bulky equipment via road or railroad. It offers unique advantages for keeping the center of gravity low to the ground, thus enhancing stability. This Schnabel arm consists of compression members at the top and tension members at the bottom. These members are pin connected to the vessel. In this manner, the Schnabel (or beak) arrangement uses the hauled equipment as a structural member to carry its own load. Equipment manufacturer such as General Electric and Westinghouse use Schnabel cars to transport generators, transformers, and other heavy, bulky equipment via rail.

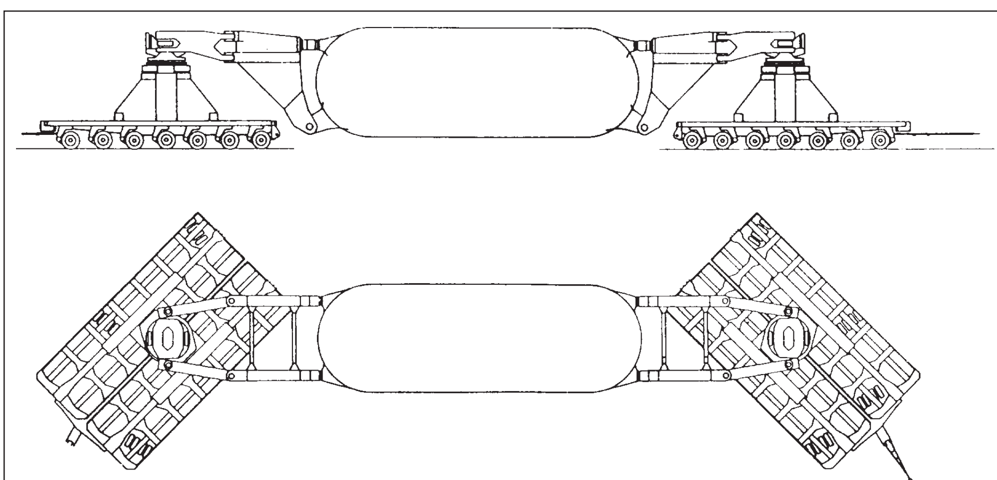


Figure 7.1-16 Schnabel Arrangement

7.2 LOAD STABILITY

Stability of heavy equipment being hauled on a trailer depends on the physical arrangement of the suspension system. When hauling, a trailer's axle configuration must be arranged to from a three-point, triangular suspension system. A three-point system is both stable and statically determinate.

For simplicity, consider a simple highway flatbed trailer. Two vertexes of the stability triangle are defined by the centers of the rear axle supports of the trailer. The third vertex lies along the centerline of the trailer and is located at what is commonly known as the kingpin. To add more axles, designers need to add distributor beams and additional king pins at each vertex to branch the load to sub-bogies (jeeps). The sub-bogies must also adhere to the three-point arrangement. For hydraulic platform trailers, a three-point suspension is achieved by isolating the hydraulic suspension into three independent loops, as is described in Section 7.1.1.

To determine the stability triangle for a loaded transporter, follow this procedure. First, draw a plan view of the transporter and an outline of the payload, including the location of its center of gravity. Identify the key suspension points that will form the vertex of the stability triangle. Connect these points with straight lines to form the stability triangle. Arrange the payload center of gravity so that it lies within the triangle; if it does not, your arrangement is unstable and will tip over. Draw the **shortest** line perpendicular to any side of the triangle through the payload center of gravity. Draw an elevation view of the transporter and payload. In the elevation view, draw this short line, which will be the side opposite the "**cant**" angle. The adjacent side is formed by the line thorough the center of gravity normal to the plane of the transporter deck. In practice, the stability of a hauled payload is acceptable as long as the cant angle does not exceed 5 degrees. This must account for roadway and site conditions such as superelevation, roadway camber, grade changes, dynamic effects in turns, and travel speed. In addition to the geometric limitations of the suspension, structural and mechanical limitations need to be considered if a load is allowed to tilt. Statics calculations are required to determine the tilted load distribution to each of the three suspension vertexes. The distribution will vary with center of gravity location and the amount of tilt. The forces must not subject the suspension components to excessive forces. For example, more load will shift to the "low" side of a tilted trailer and may overload the suspension on that side. Consequently the transporter must be de-rated when tilted.

To simplify the above procedure, many hydraulic platform trailer and transporter manufacturers have developed load stability charts. These charts are curves for different transporter configurations that give allowable transporter loads for various tilt angles and payload center of gravity heights. Figure 7.2-1 illustrates one of these curves for a Goldhofer trailer setup. Three items of information are needed; the chart is used to determine the fourth. Given the trailer arrangement, payload weight, and center of gravity height, the chart is used to determine the maximum tilt angle allowed. If the trailer arrangement, tilt angle, and center of gravity height are known, the chart is used to determine the heaviest payload.

Example 1
A contractor plans on using a single wide, 20-line transporter with a three-point suspension arrangement to haul a vessel that weighs 430 tons. The center of gravity of the vessel is 3 meters above the transporter deck. What is the maximum tilt angle that this transporter can safely negotiate?

Solution
From the chart, select the curve that represents 430 tons. Locate the center of gravity height of 3 meters along the vertical axis of the chart. Read the maximum tilt angle along the horizontal chart axis at the intersection of the 430-ton curve and the 3-meter line. This value is 5 degrees.

Example 2
Another vessel weighs 338 tons. With the same transporter from example 1, determine the maximum center of gravity height for transporting this vessel across the 5-degree slope.

Solution
There is no 338-ton curve on the chart; thus, we must use the 370-ton curve. (Interpolation between the curves is not recommended.) Reading the tilt angle of 5 degrees from the horizontal axis, it intersects the 370-ton curve at a load height of 5 meters.

For small amounts of tilt, a hydraulic platform transporter deck can be leveled as described earlier. Leveling the deck will equalize the load to each side of the transporter suspension, and the full, untilted, payload value can be used. For long hauls on public roads, this is usually not practical. Leveling is done manually and must be done with the transporter stopped or slowed down significantly.

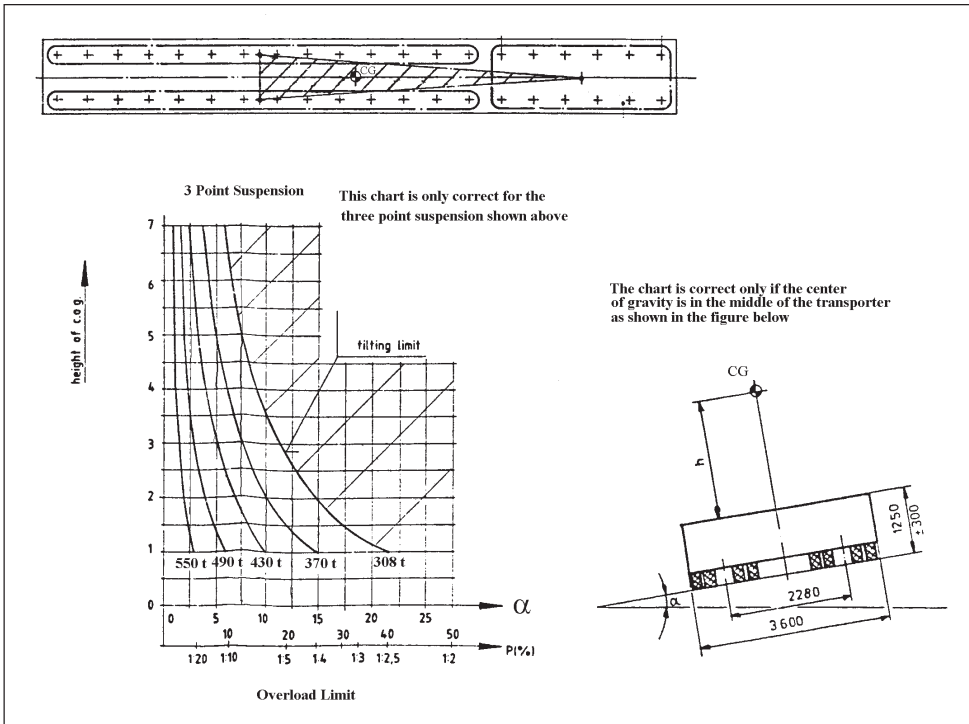


Figure 7.2-1 Load Capacity Reduction Due To Tilt

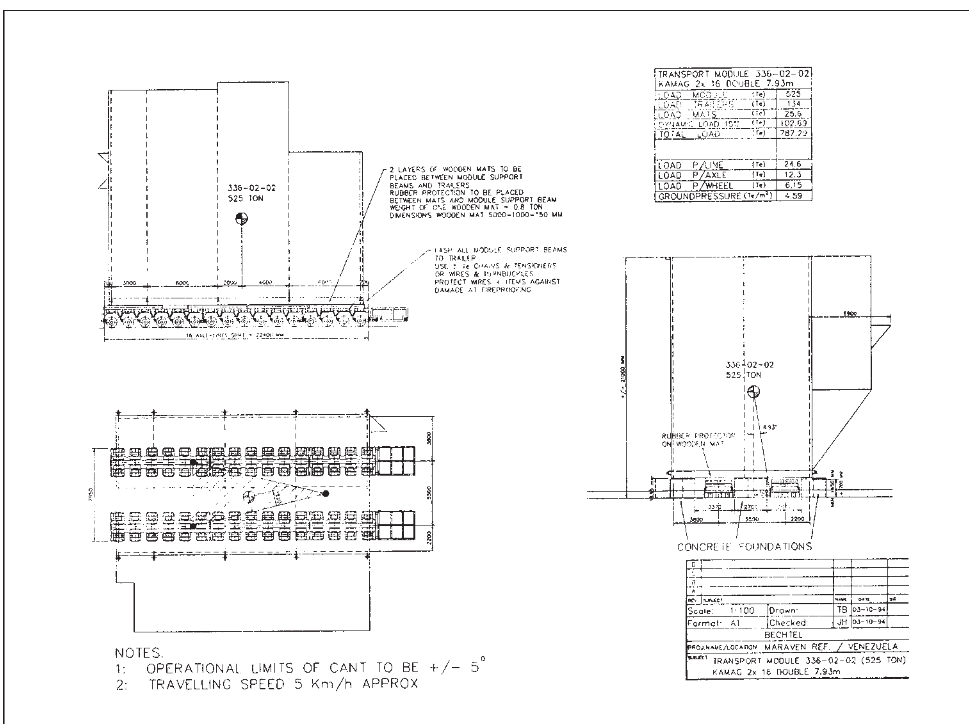


Figure 7.2-2 Cant Angle, Plan and Elevation Views

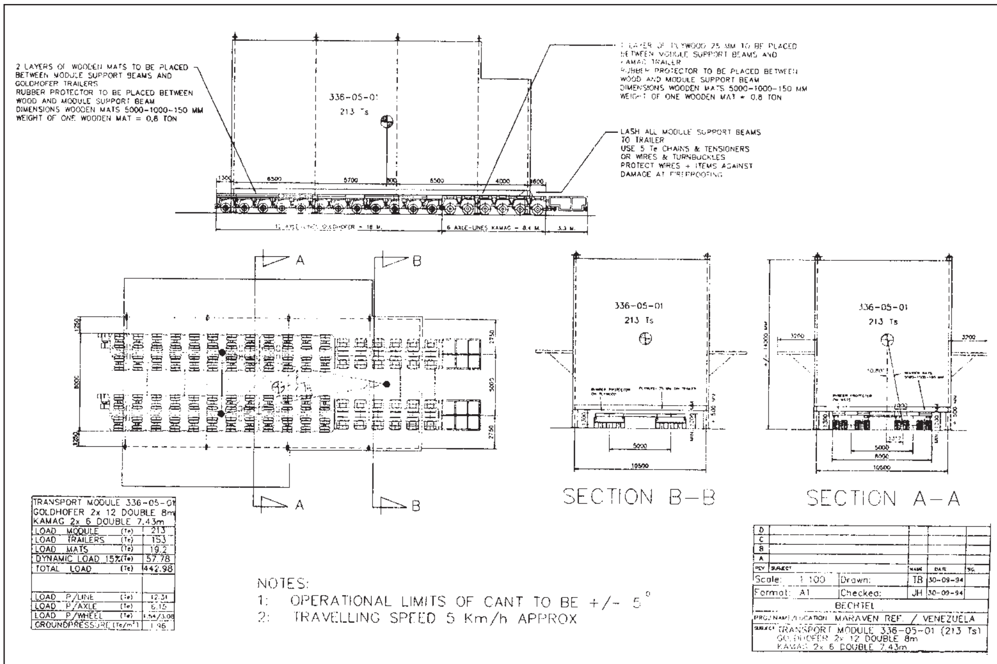


Figure 7.2-3 Cant Angle, Plan and Elevation Views

7.3 TRANSPORTER CAPACITY REDUCTION DUE TO SPEED

Hydraulic platform trailer payload capacity must be decreased as travel speed increases. Slower speeds offer larger capacities; faster speeds offer lower capacities. The primary reason for this reduction is, of course, dynamic effects. Impact loading is imparted to the transporter deck and suspension whenever the trailer hits a bump or discontinuity in the road. At high speeds, this impact force is greatly magnified. Figure 7.3-1 and the example below are manufacturer's data for a 4-line Scheurle trailer. Examination of the chart shows the significant decrease in capacity at high speeds.

Example

Payload capacity of a Scheurle 4 line, double wide trailer:
626 tons @ 20 km/hr
738 tons @ 5 km/hr

TECHNICAL DATA:

SPEED:	62 km/h	20 km/h	5 km/h	3 km/h
TOTAL WEIGHT:	48 t	96 t	108 t	120 t
WEIGHT UNLOADEN:	20 t	20 t	20 t	20 t
PAYLOAD:	28t	76t	88t	100t
AXLE LOAD:	4 x 12 t	4 x 24 t	4 x 28 t	4 x 30 t
TYRES:	32 x 7.50-15			
OVERALL LENGTH:	ca. 10825mm			
OVERALL WIDTH:	3000mm			
LOADING AREA:	3000 x 6420mm			
LOADING HEIGHT:	±300 1250mm			

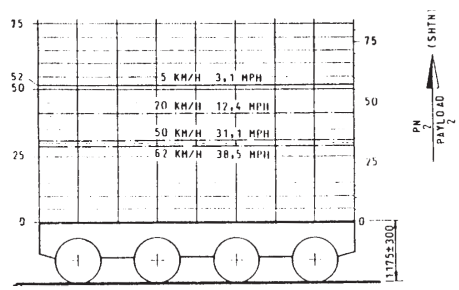


Figure 7.3-1

7.4 PAYLOAD SUPPORT LOCATIONS

Ideally, a hydraulic platform trailer's payload would be supported continuously along the length of the trailer's deck and apply a uniform load distribution. However, in most cases this ideal is impractical, and the payload is supported at two, three, or four discrete support points. Trailer manufacturers supply load charts, such as the one depicted in Figure 7.4-1, that show the permissible load capacities at various support locations along the length of the deck. For a two-point loading, the ideal support location is roughly at the quarter points. The permissible load decreases rapidly as the supports are moved closer to the center of the deck or as they are moved toward the ends of the deck. The reason is that the transporter deck consists of a longitudinal structural steel girder (or girders). The permissible loads at various locations are based on the structural capacity of the girder. Structurally, this is similar to a beam on an elastic foundation problem. The hydraulic suspension rams constitute the elastic foundation.

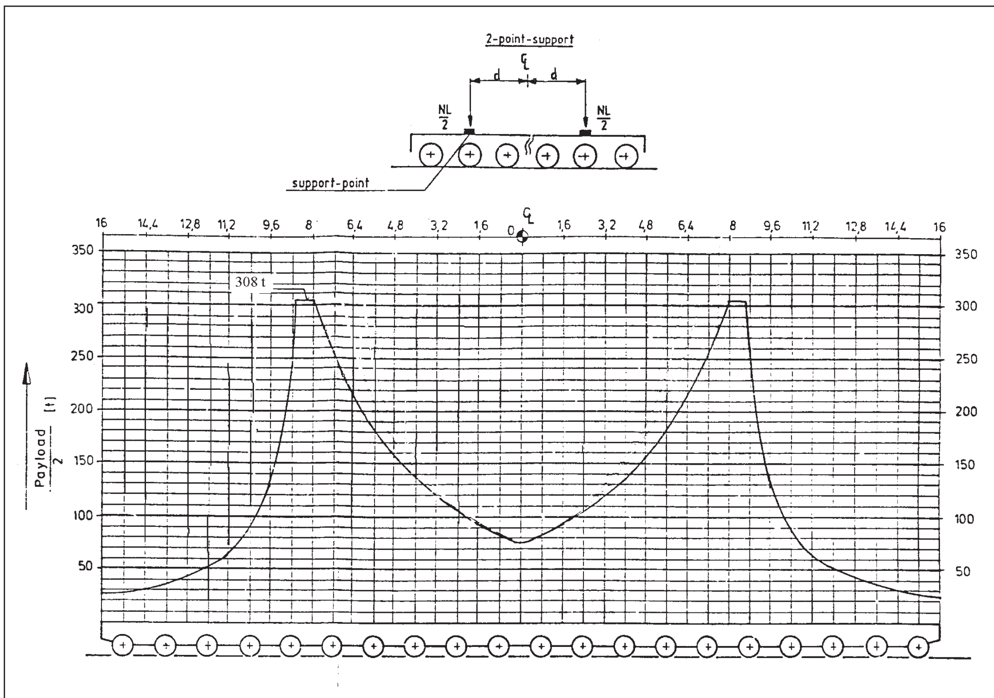


Figure 7.5-1 Allowable Loads For Various Deck Load Locations

7.5 WHEEL LOAD AND TIRE FOOTPRINT

Transporters and prime movers impart tire contact loads to their supporting surfaces. Tire bearing pressure information is required by the structural engineer and/or soils engineer for design or evaluation of ramps, short temporary bridges, culverts, and pavement. Many different tire widths and sizes are available on transporters. Generally, a tire's inflation pressure will be equal to its ground bearing pressure. The tire will squash the more it is loaded, thus increasing its bearing area proportionally. The load per unit area will remain constant. Figure 7.5-1 depicts bearing area curves for two different types of tires. Examine a given a tire width (type), wheel load, and inflation pressure on the chart. With this information, the bearing length can then be read from the horizontal axis.

Example

A contractor's transporter has four Continental 355/86-15 tires per axle, each with a width of 32 cm. The maximum axle load is 16 tons (4 tons per tire). The tires are inflated to 10 bar. Verify that the bearing pressure is equivalent to the tire inflation pressure.

Solution

From the graph, the longitudinal tire dimension is 12 cm at 10 bar inflation. This means that the bearing area is 12 cm x 32 cm = 384 cm^2. The load per tire is 16,000 kg/4 tires = 4,000 kg/tire. The ground bearing stress is 4,000 kg/384 cm^2 = 10.4 kg/cm^2 or approximately 10 bar.

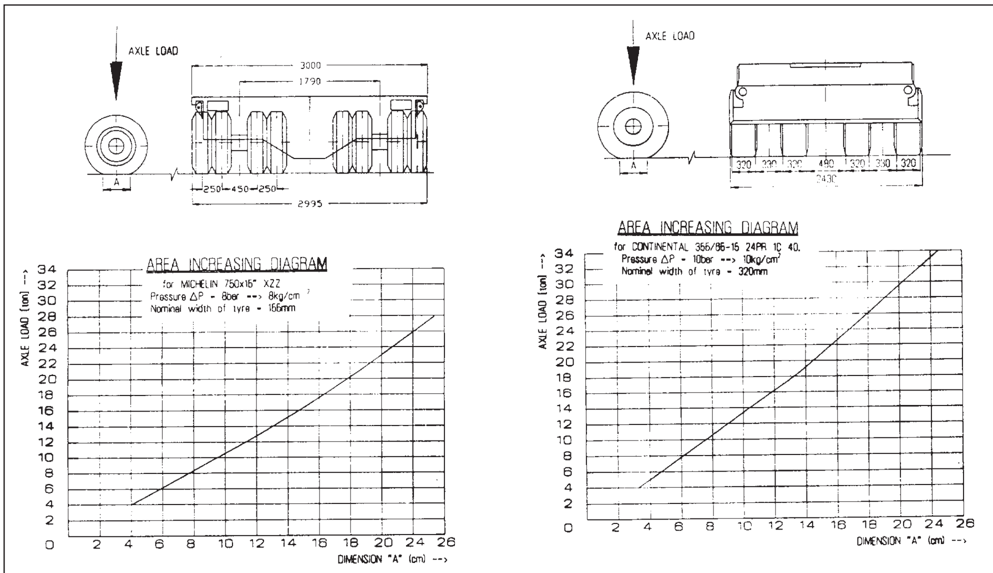


Figure 7.5-1 Tire Contact Area

8

BARGING

8. Barging

This section discusses the following:

- Barge selection requirements
- Barge loading arrangement drawings
- Draft, trim, list, ballast, and stability analysis
- Barge forces and motions; roll, pitch, and heave calculations
- Sea fastening
- Roll on and roll off operation

8.1 FLAT DECK BARGE SELECTION REQUIREMENTS

Size and nature of the cargo includes:

- Area of deck occupied by the cargo
- Room to place sea fastenings
- Height of cargo and its center of gravity
- Cargo concentration on the deck

Route of travel includes:

- Inland river, Great Lakes, intracoastal waterways, and oceans
- Minimum navigable depth on the route
- Minimum width and or height; coastal waterways width and overhead bridges

Nature of cargo may effect selection of barge, including:

- Marine shipment of hazardous materials are governed by the ANSI N14.24-1985.

Dead weight scale includes:

- Cargo capacity that a barge can support
- Draft of barge because of cargo weight

8.2 LOAD LINE CERTIFICATE

The load line certificate specifies the maximum allowable draft at which a barge can operate. The American Bureau of Shipping issues the load line certificate on behalf of the U.S. Coast Guard.

TF	Tropical Freshwater Freeboard
F	Freshwater Freeboard
T	Tropical Water Freeboard
S	Standard Summer Freeboard
W	Winter Freeboard
WNA	Winter North Atlantic Freeboard

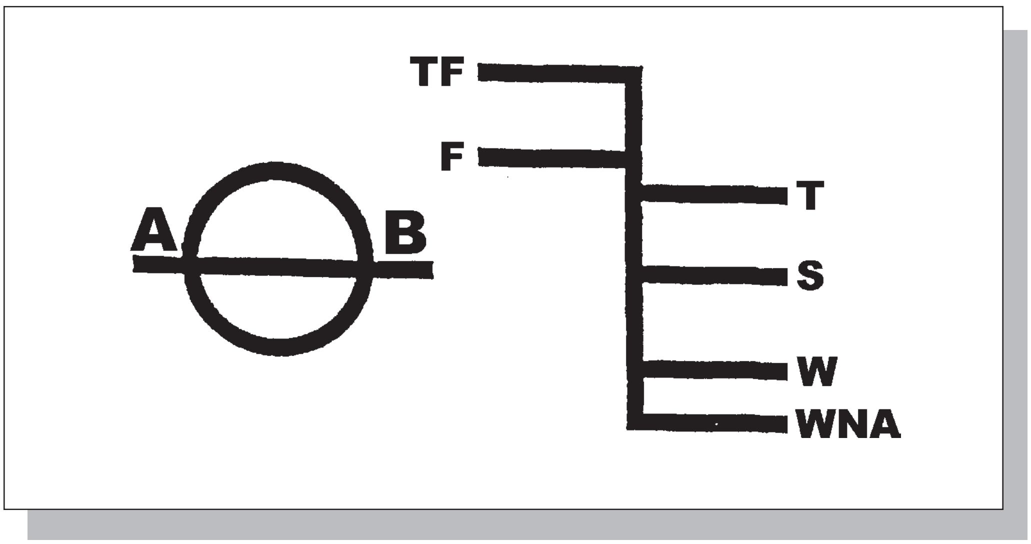


Figure 82-1 Load Line Markings

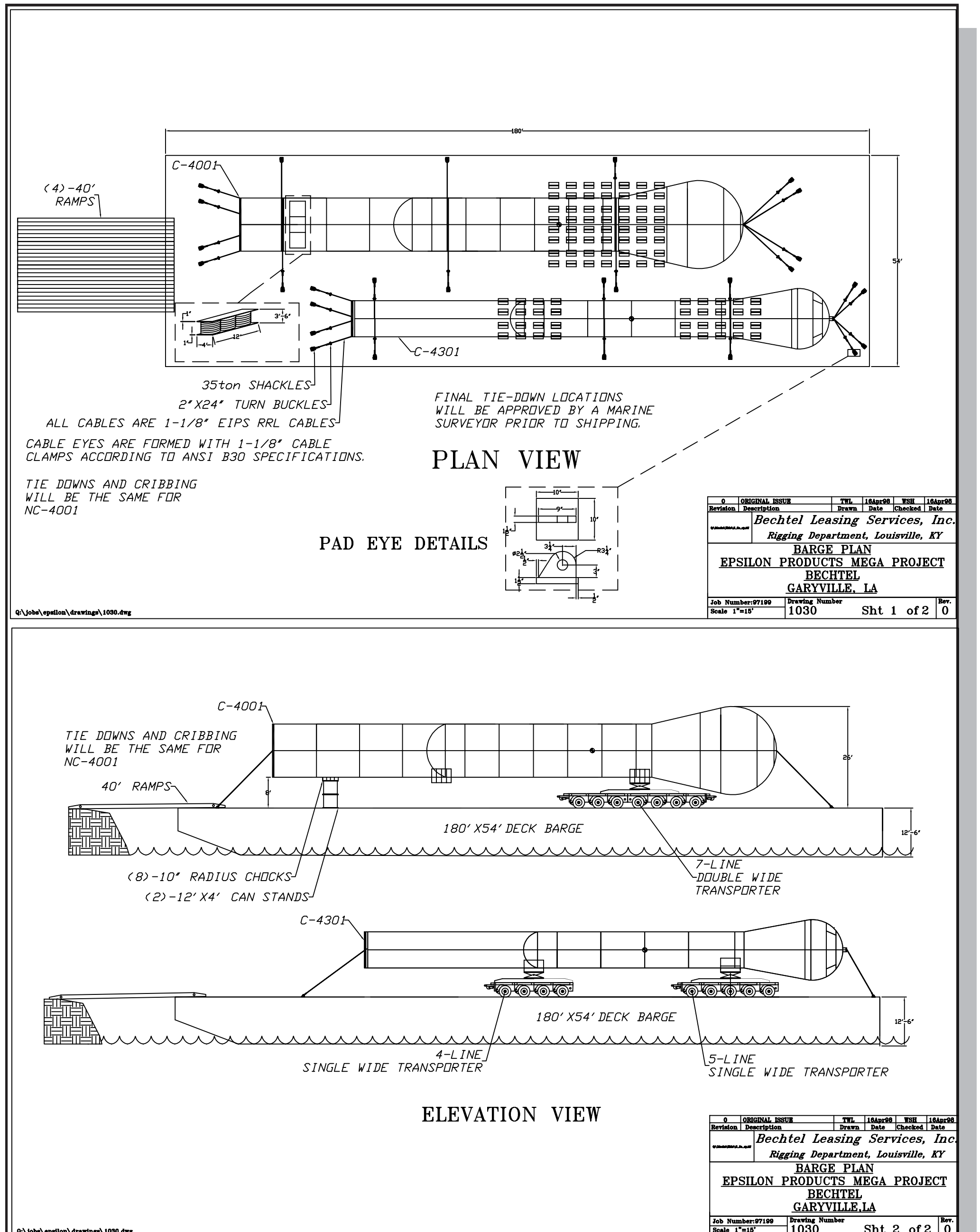


Figure 8.2-2 Barge Loading Arrangement

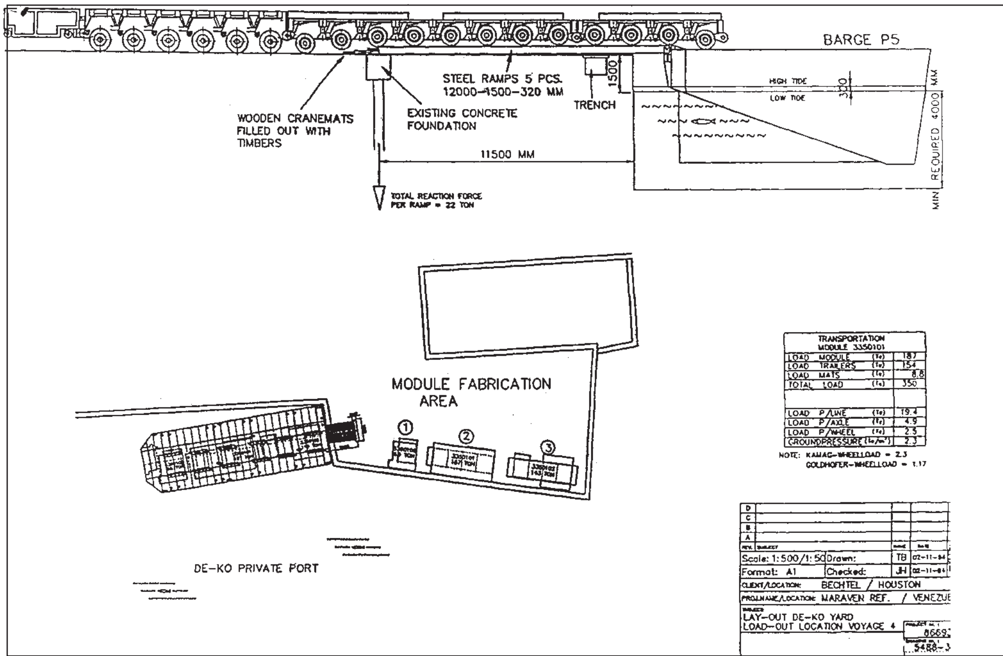


Figure 8.2-3

8.3 DRAFT AND TRIM

Draft includes the mean draft (measure near amidships), the forward draft (measured at bow), and the aft draft (measured at stern).

Trim includes the difference between forward and aft draft. Normally, the aft draft is greater for better towing and its called vessel is trimmed by the stern. Trim equal to ý percent to 1 percent of the barge's length is considered acceptable.

Computation of trim is a function of two quantities: trimming moment and moment to trim 1 inch (longitude distances from bow).

lcg = Longitudinal center of gravity of weight "w" in feet

LCB = Longitudinal center of buoyancy can be determined from hydrostatic curve or by calculation. Measured for bow locating center of gravity of the submerged volume of the barge.

W = Weights of individual items in long tons

D = Vessel displacement in long tons

Moment to trim 1 inch is a function of longitudinal metacentric height GML.

I_L = Moment of inertia of waterplace about transverse axis of barge in ft^4

$$LCG := \frac{\Sigma(lcg \cdot w)}{\Delta}$$

$$BM_L = \frac{I_L}{\Delta} \qquad I_L = \frac{B \cdot L_{WL}^3}{12} \qquad GM_T = KB + BM_T - KG \qquad MT1 := \frac{\Delta \cdot GM_L}{12 \cdot L}$$

Figure 8.3-1

8.4 LIST, TRANSVERSE ANGLE

The light weight (sum of barges, empty weight) of the barge is always on the longitudinal centerline as the center of buoyancy.
If the composite center of gravity of all loads on the barge is on the center, then the list is zero.
If the center of gravity of the loads is not on the center, then the eccentricity creates an angle to the side called list.

Transverse center of gravity (TCG):

$$TCG := \frac{\Sigma\,(tcg \cdot w)}{\Delta}$$

w = Weight of individual items in long tons
TCG = Transverse center of gravity of weights “w” in feet
Δ = Vessel displacement in long tons

The list angle:

$$\theta := \tan^{-1}\left(\frac{TCG}{GM}\right)$$

Figure 8.4-1

8.5 BALLAST REQUIREMENT

The water ballast is used to correct the barge floating condition. Ballast water can improve floating condition; however, it reduces speed or other functions.

Figure 8.5-1 shows that the wing tank is one-half full of water ballast. When the barge is level and in calm water, the center of gravity of ballast water is at the center of the tank. As the barge heels, the surface of ballast remains level; however, the center of gravity of liquid will shift to the side and this shift will affect the stability. U.S. Coast Guard 46 CFR 170, Subpart I, addresses the corrections to be made to the stability calculation to account for free surface effects. The procedure computes an effective rise in center of gravity of the barge. This will reduce values for GM and GZ because lateral shift of G for rectangular ballast compartments

To calculate the rise in G to a virtual position G' because of the free surface effect:

1 = Longitudinal dimension of the compartment

b = Transverse width of the compartment

= Displacement (volume) of the barge

r = Ratio of specific gravity of the liquid in the tank to the liquid in which the barge is floating.

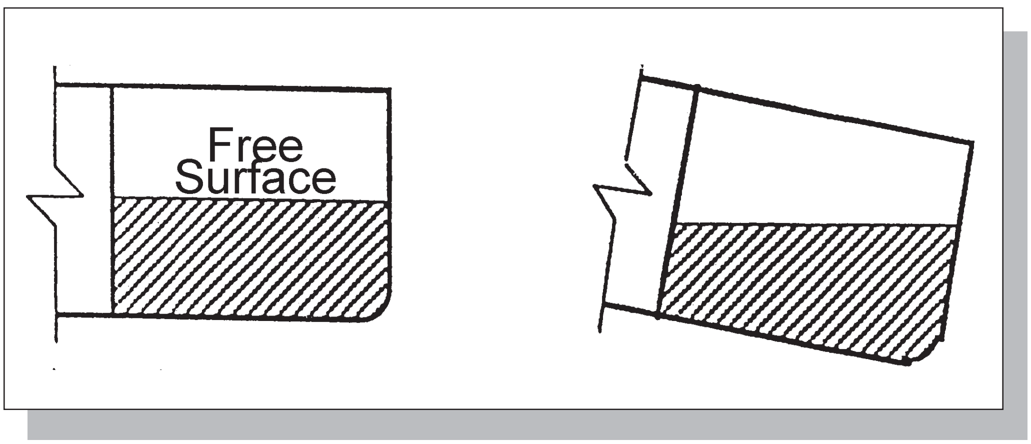


Figure 8.5-1

Ballast can increase draft, affect the center of gravity height of the laden barge, and reduce the value of GM (metacentric height) and the GZ (righting arm). The increase in draft will reduce the roll and pitch acceleration, which may reduce the cost of sea-fastening.

defined in U. S. Coast Guard publication 46 CFR 170 and 46 CFR 174. A barge tends to return to an upright position after being leaned by an outside force or measurement of the barge to resist capsizing. The number of different values needs to be computed by the naval architect or engineer to quantify the stability of the barge.
Initial stability or statical stability is the tendency of the barge to remain vertical in calm waters and return to vertical after having been displaced by a small angle of list, for example, 10 degrees.

Center of buoyancy B = Centroid of the submerged volume of the barge

Center of gravity G = Centroid of all weights on the laden barge, including the barge, ballast, and cargo weights

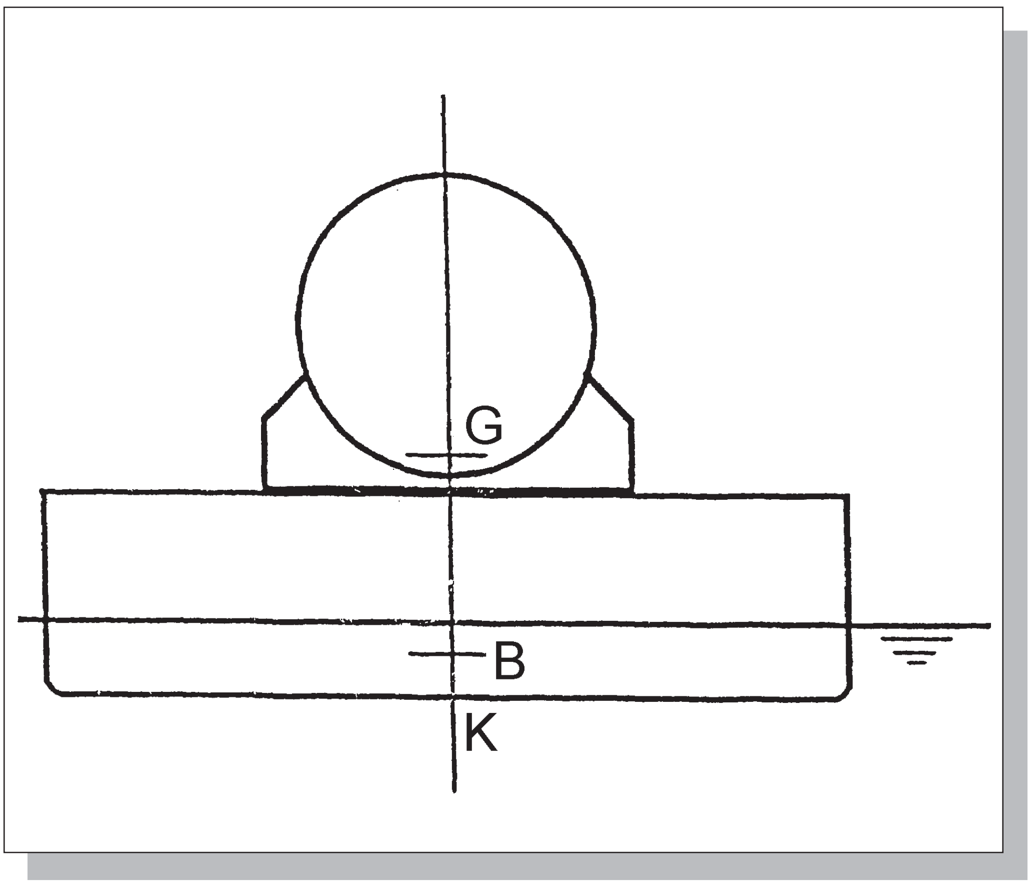


Figure 8.6-1

When the barge heels to starboard, the center of buoyancy shifts to the lower side, and if we draw a vertical line from B to intersect the barge centerline, we locate the transverse metacenter M.

Transverse metacenter is the point to which the center of gravity of the ship may rise and still possess positive stability.

As long as G is below M, the barge will return to vertical when listed by an outside force. GM is called metacentric height. Righting arm GZ = GM sin o horizontal distance between the vertical line from the center of gravity to when the line from metacenter to buoyancy.

Metacentric height:	GM	= KB + BM -KG
Righting arm:	GZ	= GM sin o horizontal distance between vertical line from the center of gravity to when the line from metacenter to buoyancy

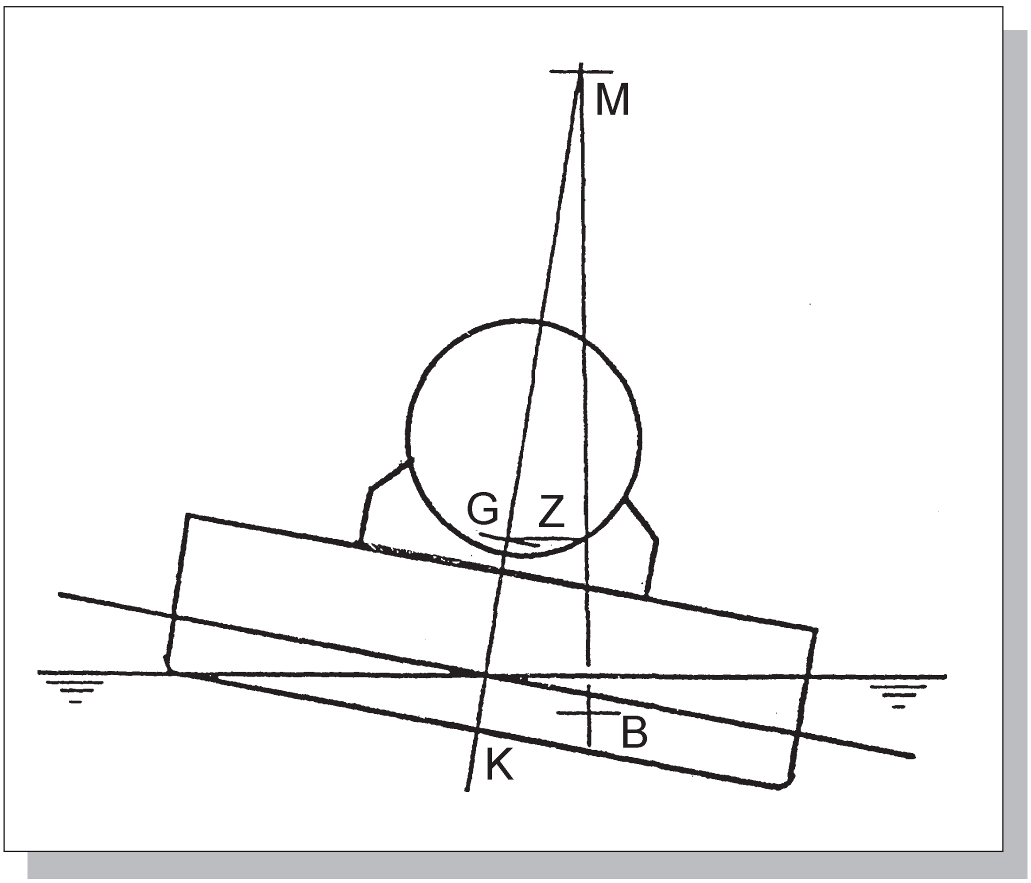


Figure 8.6-2

GZ is 0 when the barge is level; as the barge heels, GZ increases to maximum and then drops back to 0.

The righting arm curve shows that the maximum righting arm is about 10 feet and occurs at an angle of 25 degrees.

The area under the curve to this point is dynamic stability; it is approximately 170 feet-degrees. The angle that GZ returns to 0 is 72 degrees and is called the range of stability.

Items need to be computed when the stability of a barge is assessed.

1. Maximum righting arm
2. Angle of heel at which maximum righting arm is determined
3. Angle of heel when the righting arm becomes 0
4. Dynamic stability expressed in foot-degree

Righting Arm Curve

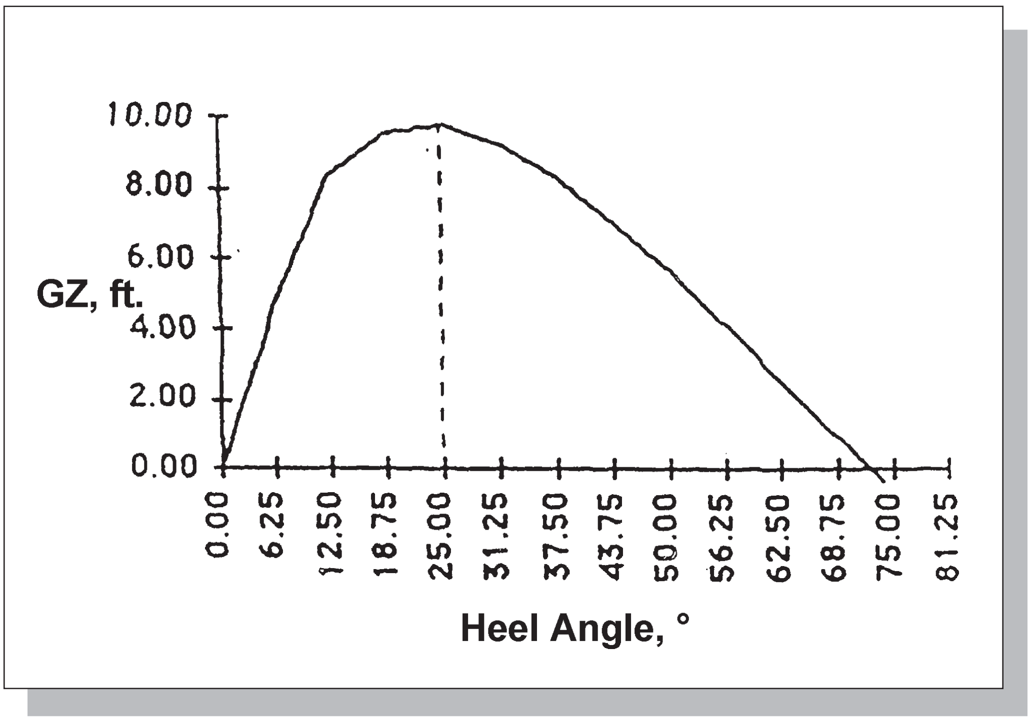


Figure 8.6-3

Displacement of barge Δ = total weight in metric tonnes (barge ~empty weight + weight of all cargo onboard).

Moment summation method is used to locate the center of gravity of the barge in 3D.

Vertical center of gravity: KG (always measured up from the keel)

Transverse center of gravity: TCG (measured relative to the longitudinal centerline)

Longitudinal center of gravity: LCG (measured from the bow)

Displacement of barge in terms of volume of water it displaces: $=\Delta * \rho$

Δ = Vessel displacement in long tons

P = 35.00 cubic feet per long ton for saltwater and 35.9 cubic feet for fresh water

T = Draft, determined from deadweight scale. Height of center of buoyancy: KB = 0.53 * T

It = Moment inertia of waterplane about longitudinal axis of the barge in ft^4

(L_{wl} = Length of waterline)

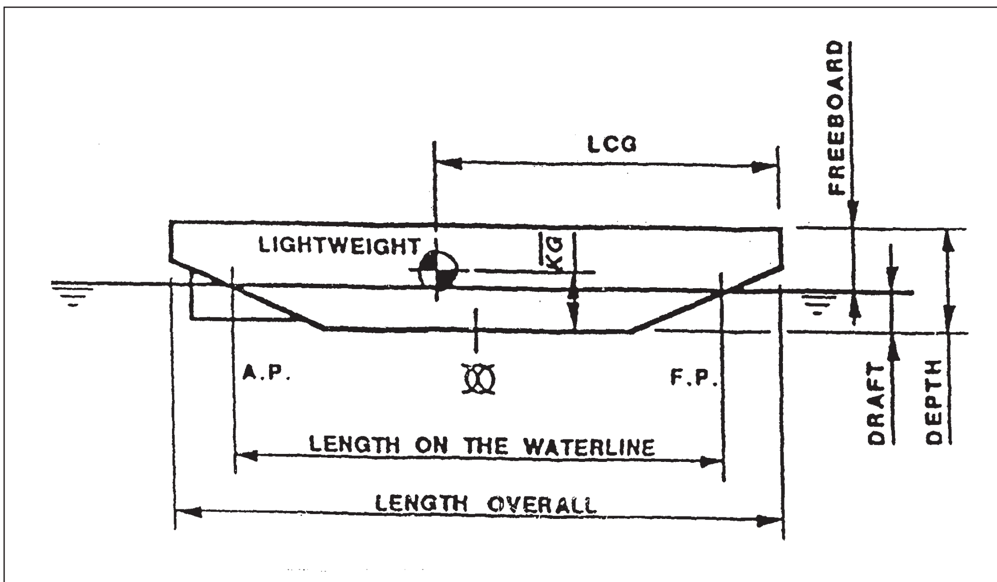


Figure 8.6-4

The righting arm GZ = GM x sin ø. The major effort to construct the righting arm curve is to locate the center of buoyancy for various angles of inclination. The objective is to locate the center of buoyancy in terms of y and z, and then the righting arm GZ = z x cos ø + y x sin ø - KG x sin ø.

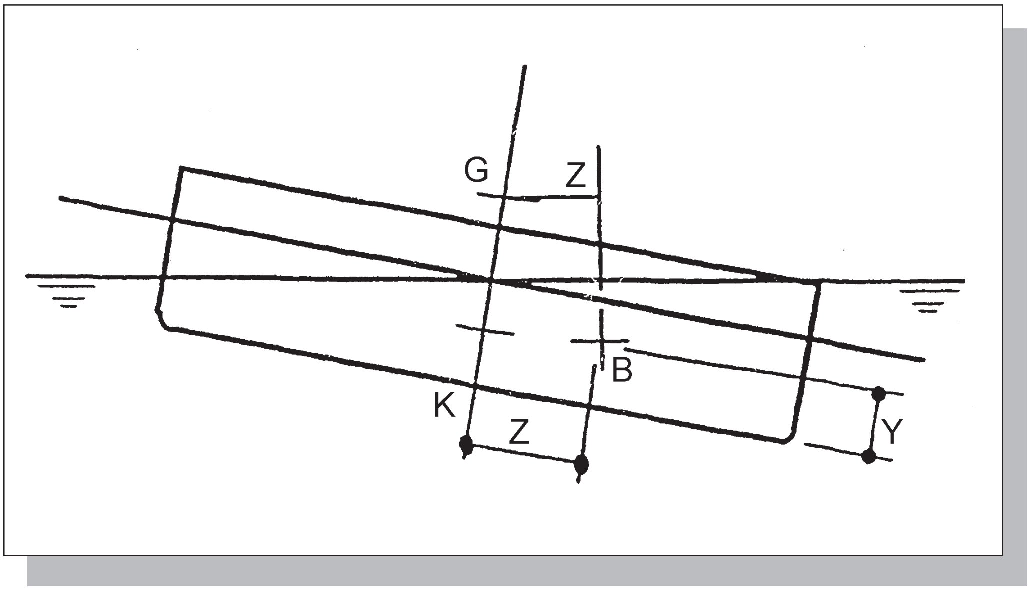


Figure 8.6-5 Heeled Center of Buoyancy

KM/B = CIT/12 CB (B/T) + CKB (T/B): This equation is plotted to show the relationship between the height of metacenter above the keel and the draft. B equals beam (width of barge).

The curve shown below includes the height of the center of buoyancy expressed as KB/B calculated for the Loveland barge 1721. The height of metacenter drops significantly as the draft increases.

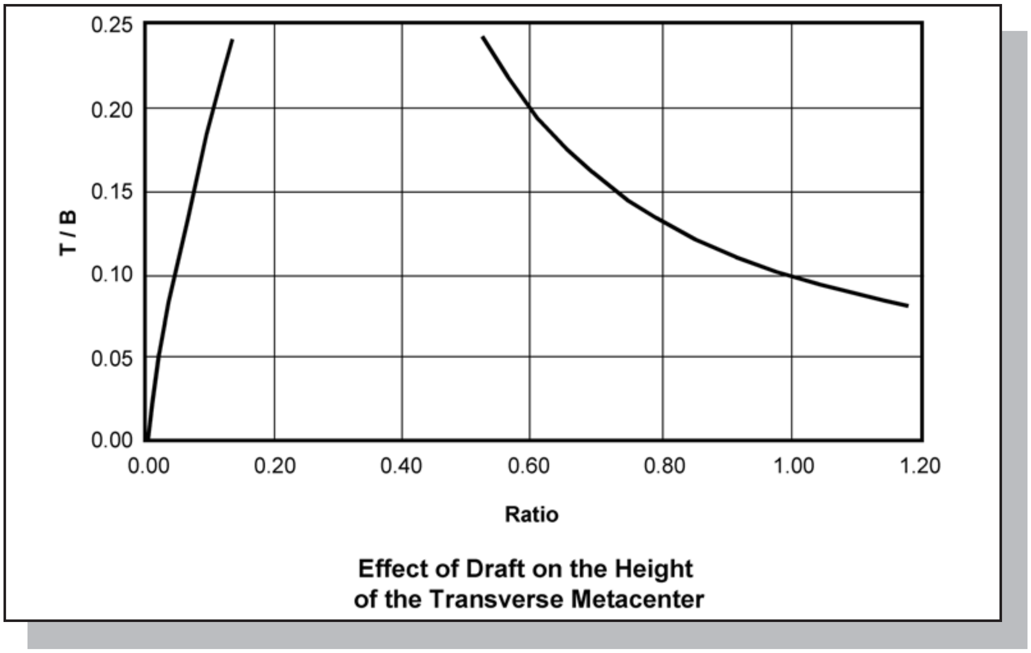


Figure 8.6-6 Effect of Draft on the Height of the Transverse Metacenter

Example:

Determine the height of the transverse metacenter; KM for the Loveland barge 1721 and barge Paul Bunyan using the curve. In both cases the mean draft is 5 feet.

Solution:

The beam for Loveland 1721 is 43'-6". The draft/beam ratio T/B is 0.115. Reading from the graph, the value for the KM/B equals 0.88. Therefore, KM equals 38.3 feet.

For Paul Bunyan, the beam is 54 feet; T/B is 0.093; curve KM/B is 1.04; therefore, the KM is 56.2†feet.

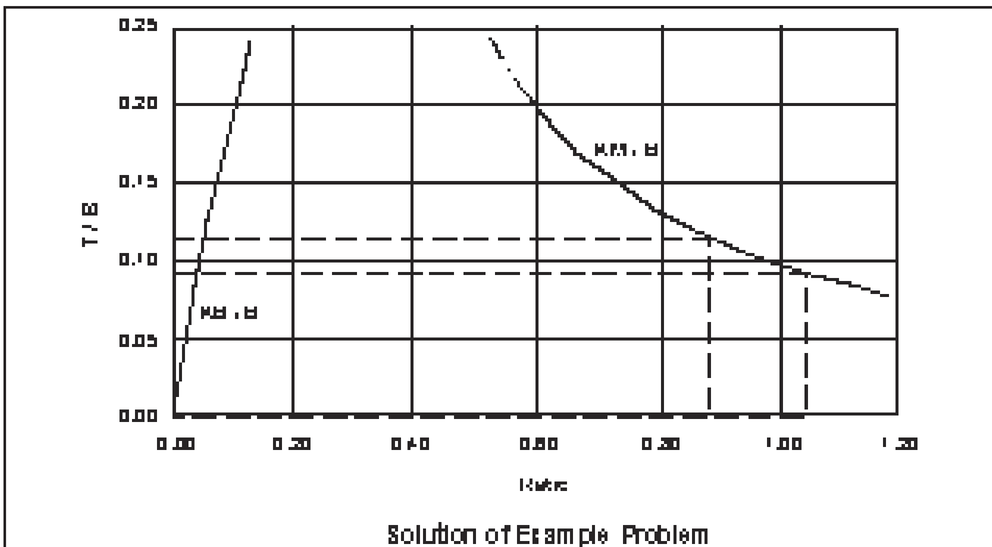


Figure 8.6-7 Solution of Example Problem

8.7 INTACT STABILITY REQUIREMENT

The Coast Guard requirements for stability are published in 46 CFR 170 through 174, Part 170. It establishes the requirement for all vessels, and Part 174 under Subpart B addresses requirements for the deck cargo barges. 46 CFR 170 defines various requirements in the construction of vessels. An ABS loadline certificate and classification assure that the barge meets or exceeds the requirements.

One calculation is defined in its part; the definition of initial stability is defined by the metacentric height GM:

Value of P varies with the 6 type of travel routes.

The minimum required is:

P for ocean service, Great Lakes, or service on exposed water $P = 0.005 + (L / 14{,}200)^2$ long tons/square feet

L = Length between perpendiculars in feet

A = Projected lateral area in square feet of the portion of the barge and deck cargo above the waterline

H = The vertical distance in feet from center of A to the center of underwater lateral area or approximately one-half of the draft

W = Displacement in long tons

T = 14 degrees or the angle of heel at which one-half of the freeboard to the deck edge is immersed, or whichever is less. Value of the P in the above equation relates to a wind speed of approximately 55 knots for ocean service, 45 knots for Great Lakes service, and 40 knots for protected waters.

Table 8.7-1 U.S. Coast Guard Table 174,020

Category (1)	Beam/Depth Ratio (2)	Draft/Depth Ratio (3)
A	3.00 to 3.74	Equal to or less than 0.70
B	3.75 to 3.99	Equal to or less than 0.72
C	4.00 to 4.49	Equal to or less than 0.76
D	4.50 to 6.00	Equal to or less than 0.80

8.8 DAMAGED STABILITY REQUIREMENT

The U.S. Coast Guard has no regulation that defines stability requirements in a damaged condition for deck barge cargo. ANSI N14.24-1985 requires determination of the stability analysis to assure that the vessel or cargo will not be lost. In this case, assumptions are made that one or more watertight compartments are damaged.

Two calculation methods are used: 1) Lost buoyancy method and 2) Added weight method. The water in the flooded compartment will increase weight and draft. If the flooded volume is not symmetrical, list and trim need to be calculated.

8.9 BARGE MOTION AND FORCES

Barge stability needs to be analyzed to assure that the barge will always return to an upright position after being moved away because of wind and wave forces. Six degrees of freedom of motion may occur. Three degrees are rotational—roll, pitch, and yaw—and three are linear. Among these six forces, roll, pitch, and heave are significant forces. The other three forces, surge, yaw and sway, are small and insignificant.

In practice for transportation of heavy equipment on a flat deck barge, two loading conditions of wave-induced motion forces are considered: 1) Beam seas (wave traveling cross the width of the barge) and 2)†Head seas (wave traveling along the length of the barge), and combines heave and pitch forces.

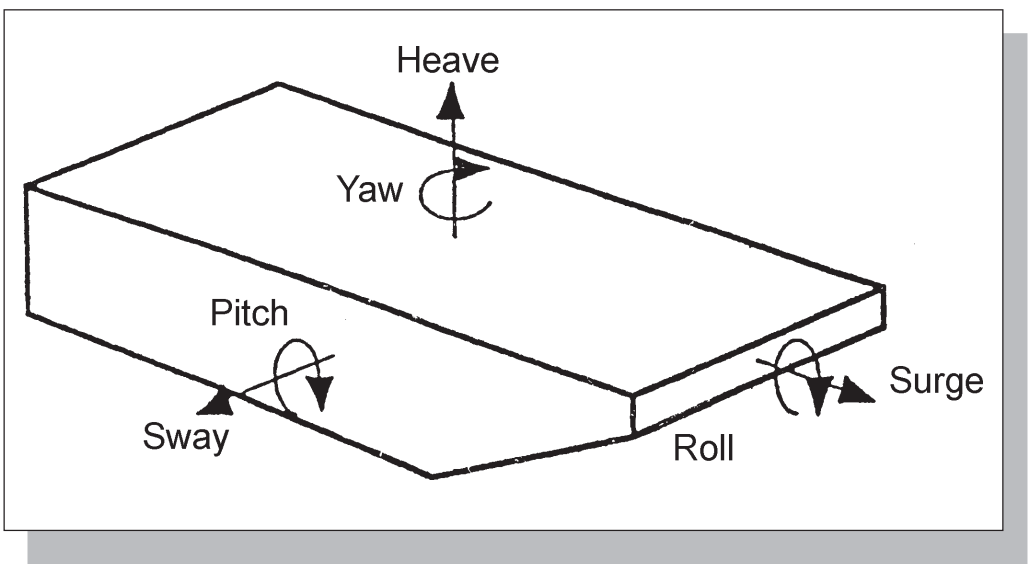


Figure 8.9-1

8.10 CALCULATION OF FORCES DUE TO ROLL

The barge will roll about on its longitudinal axis and roll at the period of the waves. The most severe motion will be when the period of waves is at or near the barge' s natural period.
Tr = N. natural period in roll

$$T_r = \frac{2 * \pi * kx}{\sqrt{g}} \sqrt{\frac{I + XA}{GM}} \qquad K_x = \sqrt{\frac{IX}{A}}$$

$$x_A = \frac{(B / T)^2}{100}$$

GM = Metacentric height
Kx = Radius of gyration of mass
XA = Added mass coefficient

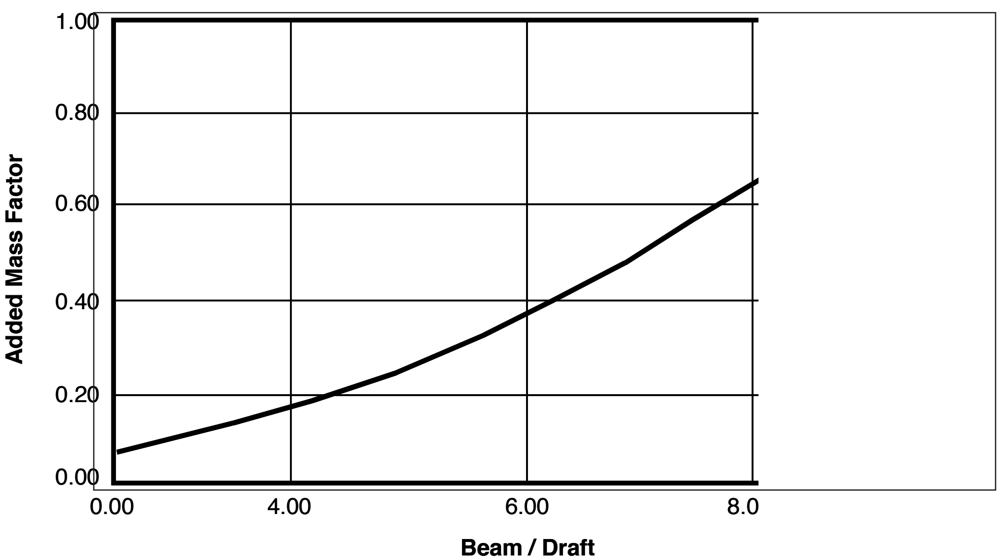


Figure 8.10-1

Having calculated the period of roll, we can determine the two roll forces that act on the cargo because of these motions: radial force and tangentially force.
Fr = Radial force, small in magnitude and ignored
Ft = Tangentially force

$$F_{Tp} = W^* \left(\frac{4 * \pi^2}{T_r^2} * \frac{Y}{g} * \frac{\phi * \pi}{180} + \sin(\phi) \right) \qquad F_{Tn} = W^* \left(\frac{4 * \pi^2}{T_r^2} \right.$$

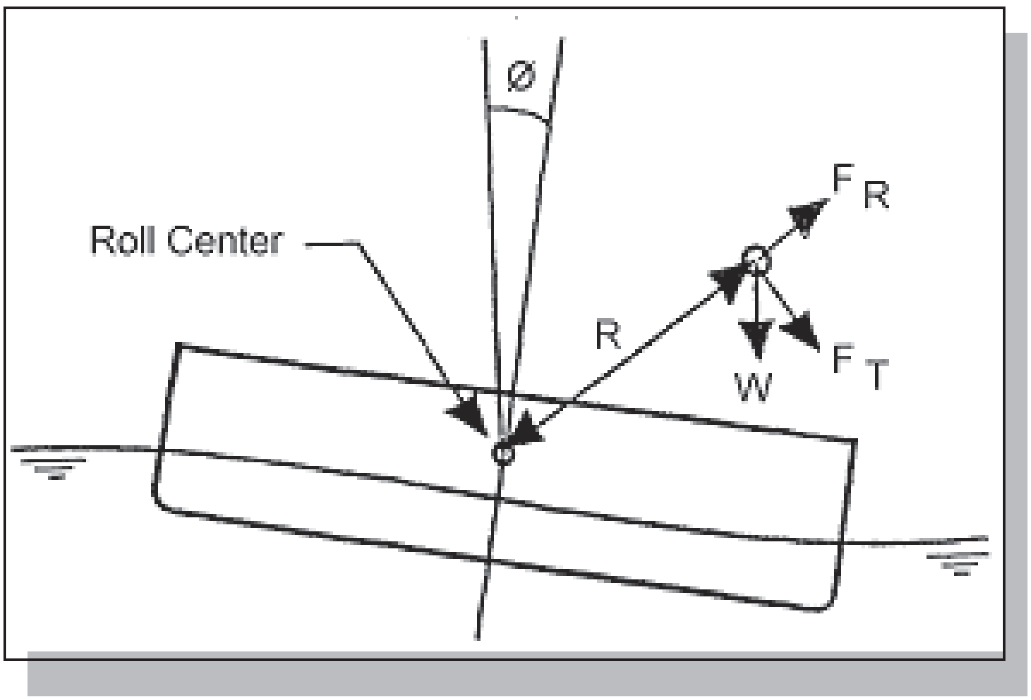


Figure 8.10-2

8.11 CALCULATION OF FORCES DUE TO PITCH

Computation of forces due to pitch requires the expression of various equations in terms of longitudinal rather than transverse.

$$T_P := \frac{2 \cdot \pi \cdot K_P}{\sqrt{g}}$$

GM_L = Metacentric height
Kz = Radius of gyration of mass
XA = Added mass coefficient assumed at 25% of vessel length

$$F_{(T_p)} = \circ W \cdot \left(\frac{4 \cdot \pi^2}{T_p{}^2} \cdot \frac{Y}{g} \cdot \frac{\phi \cdot \pi}{180} \cdot \sin(\phi) \right) \qquad F_{(T_n)} = \circ W \cdot \left(\frac{4 \cdot \pi^2}{T_p{}^2} \cdot \frac{x}{g} \cdot \frac{\phi \cdot \pi}{180} \cdot \cos(\phi) \right)$$

Pitch angle 0 = 4 deg. for protected waters
6 deg. at seas near coastlines
10 deg. in the open seas

8.12 CALCULATION OF FORCES DUE TO HEAVE

Vertical force is created due to heave. A barge in heave mode is like a suspended weight from a spring. The stiffness of the spring is a standard quantity in tons per inch immersion. The TIP value is based on number of long tons required to increase draft by 1 inch.

For saltwater $TPI := \frac{A_w}{420}$ For freshwater $TPI_{fw} = \frac{A_w}{431}$

Aw = Area of water plane in square feet

Th = Natural period in heave $T_h = 2 \cdot \pi \cdot \sqrt{\frac{\Delta \cdot (1 + x_A)}{12 \cdot g \cdot TPI}}$

XA = Added mass factor

Fh = Heave force up or down
Yh = Amplitude of heave in feet

$$F_h = \frac{TPI \cdot 12 \cdot Y_h}{\Delta \cdot (1 + x_A)} \cdot W$$

Δ = Displacement in long tons

W = Weight of cargo in long tons

Table 8.12-1 Annual Sea States in the Open Ocean, Northern Hemisphere

Sea State Number (1)	Significant Wave Height (Feet) (2)	Sustained Wind Speed (Knots) (3)	Percentage Probability (4)	Model Wave Period (Seconds) Range (5)	Model Wave Period (Seconds) Most Probable (6)	Wave Length (Feet) (7)
0-1	0.0 – 0.3	0 – 6	0.0	-	-	-
2	0.3 – 1.6	7 – 10	5.7	3 – 15	7	251
3	1.6 – 4.1	11 – 16	19.7	5 – 15.5	8	328
4	4.1 – 8.2	17 – 21	28.3	6 – 16	9	415
5	8.2 – 1.1	22 – 27	19.5	7 – 16.5	10	512
6	13.1 – 19.7	28 – 47	17.5	9 – 17	12	737
7	19.7 – 29.5	48 – 55	7.6	10 – 18	14	1,004
8	29.5 – 45.5	56 – 63	1.7	13 – 19	17	1,480
>8	>45.5	>63	0.1	18 – 24	20	2,048

Column 7 is calculated based on the relationship between the wave length Lw and the wave period Tw: $L_w = \frac{g}{2 \cdot \pi} \cdot T^2{}_w$

8.13 SEA FASTENING

Sea fastening considerations include:

- Layout of the barge deck and cargo on the barge
- How to load the barge—by crane or by multi-ton transport
- Ramps
- Load spreaders
- Area need for sea fastening

8.14 AREA NEEDED FOR SEA FASTENING

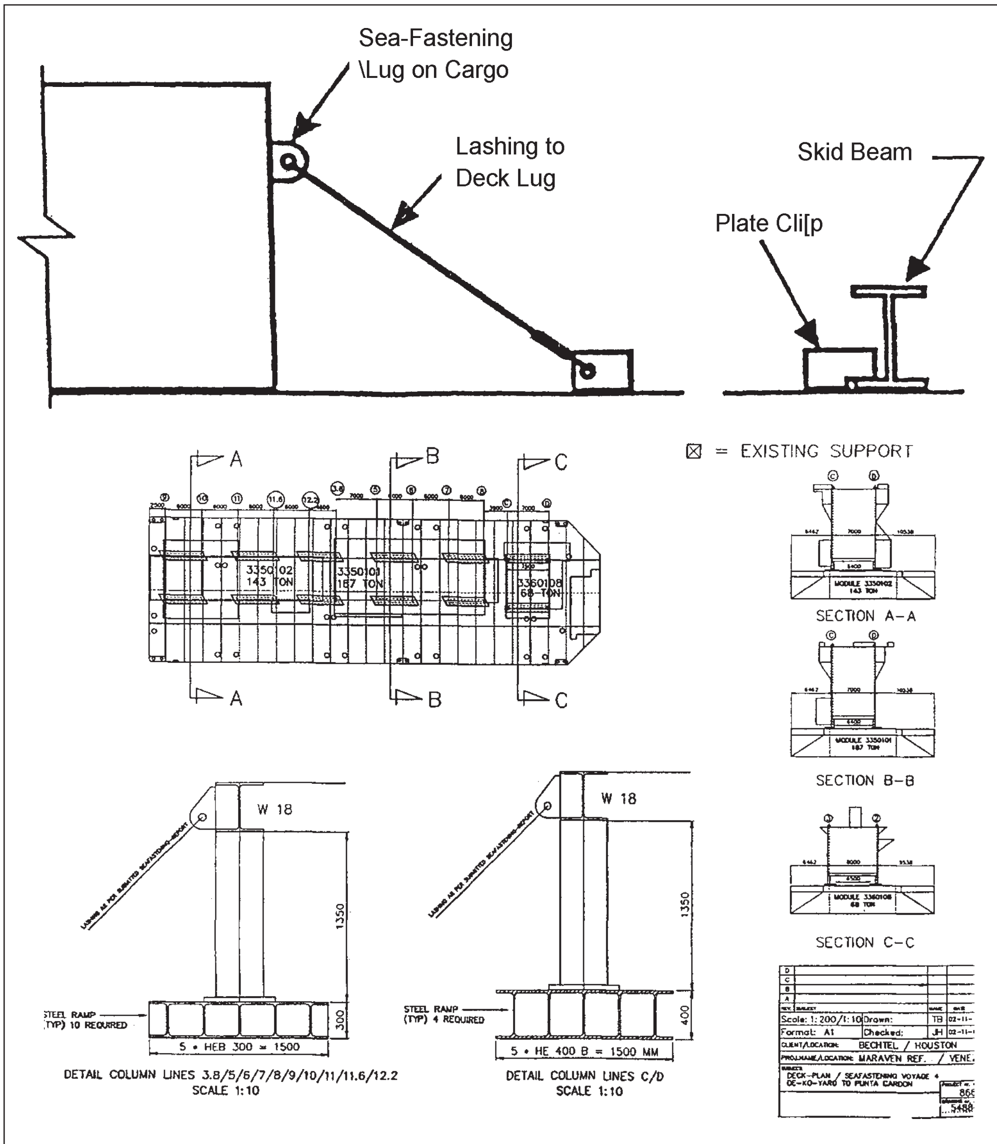
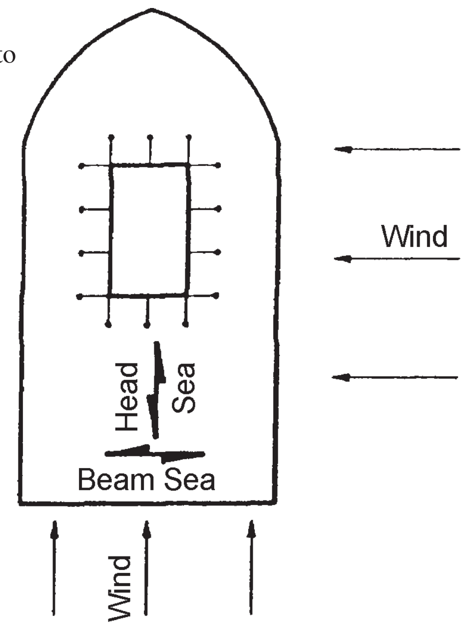


Figure 8.14-2

1. Vertical and horizontal acceleration due to head seas plus maximum wind condition at sea.



2. Vertical and horizontal acceleration due to beam seas plus maximum wind condition at sea.

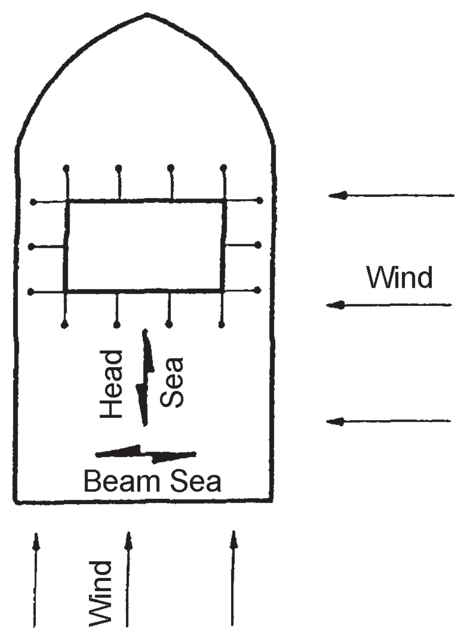


Figure 8.14-3 Sea Transport Condition and Design Horizontal Acceleration Factors

8.15 SEA TRANSPORT DESIGN CONDITION—U.S. COAST TO PUNTO FIJO

For head sea:

Vertical and horizontal acceleration plus maximum wind

DL + VAH + HAH + WL

For beam sea:

Vertical and horizontal acceleration plus maximum wind

DL + VAB + HAB + WL

In each equation:

Vertical acceleration (VAH) = .23 g due to head sea

Vertical acceleration (VAB) = .25 g due to beam sea

Horizontal acceleration (HAH) = varies (see chart) due to head sea

Horizontal acceleration (HAB) = varies (see chart) due to beam sea

Maximum wind at sea considered 92 mph (147 kph)

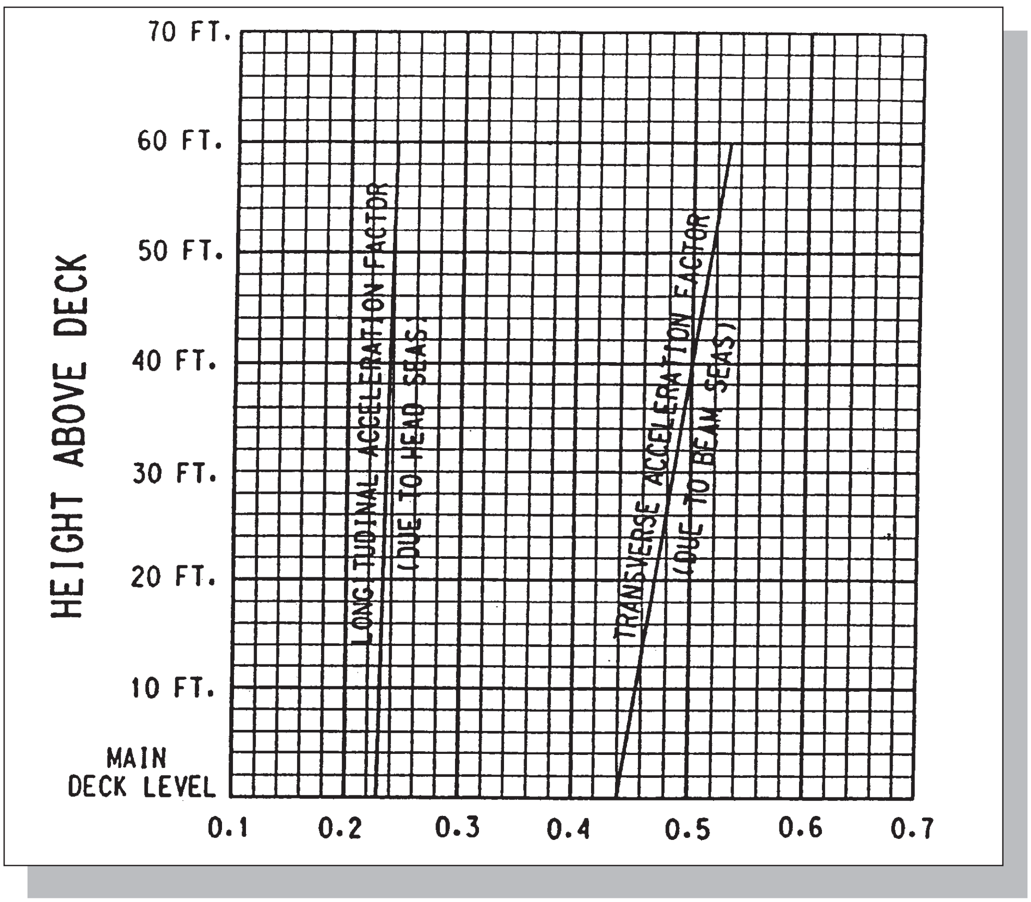


Figure 8.15-1 Design Horizontal Acceleration Factor (from United States to Punto Fijo)

Note: To be used for design of all unit C-1 modules

8.16 SEA TRANSPORT DESIGN CONDITION VENEZUELA TO PUNTO FIJO

For head sea:

Vertical and horizontal acceleration plus maximum wind

DL + VAH + HAH + WL

For beam sea:

Vertical and horizontal acceleration plus maximum wind

DL + VAB + HAB + WL

In each equation:

Vertical acceleration (VAH) = .12 g due to head sea

Vertical acceleration (VAB) = .20 g due to beam sea

Horizontal acceleration (HAH) = varies (see chart) due to head sea

Horizontal acceleration (HAB) = varies (see chart) due to beam sea

Maximum wind at sea considered 80 mph (128 kph)

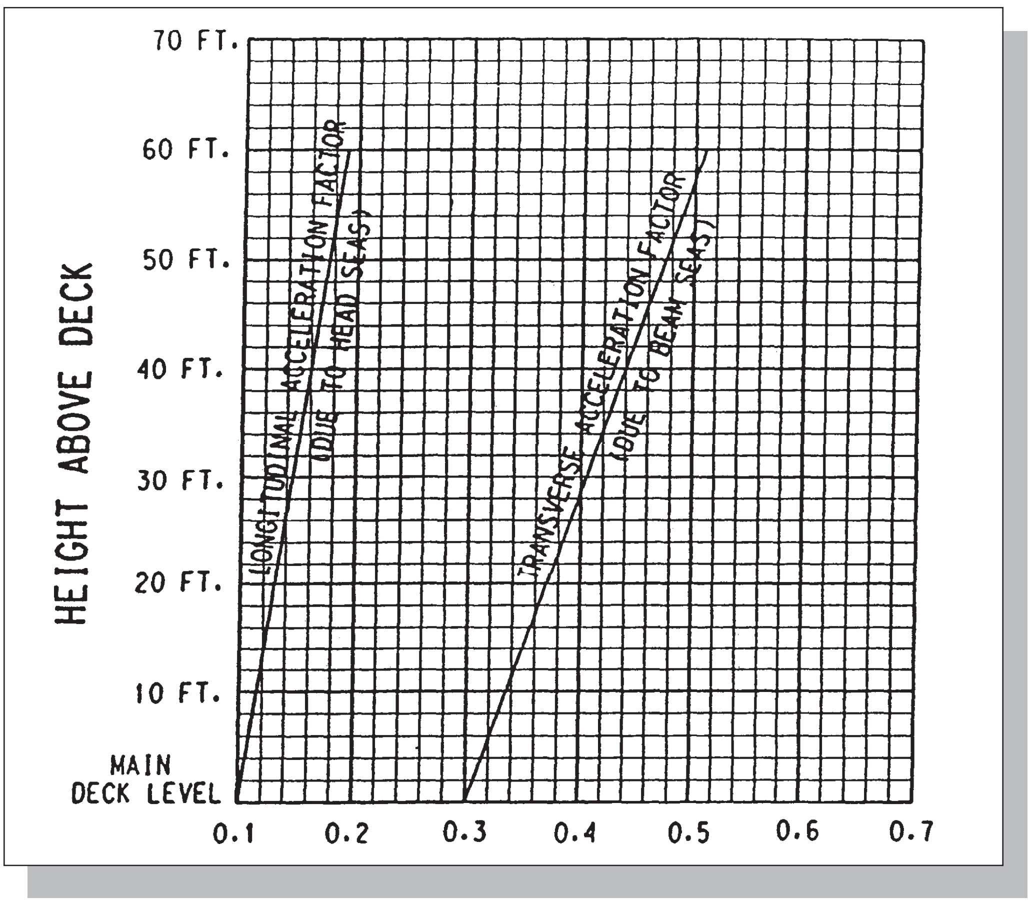


Figure 8.16-1 Design Horizontal Acceleration Factor (from Venezuela to Punto Fijo)

8.17 ROLL-ON AND ROLL-OFF OPERATION

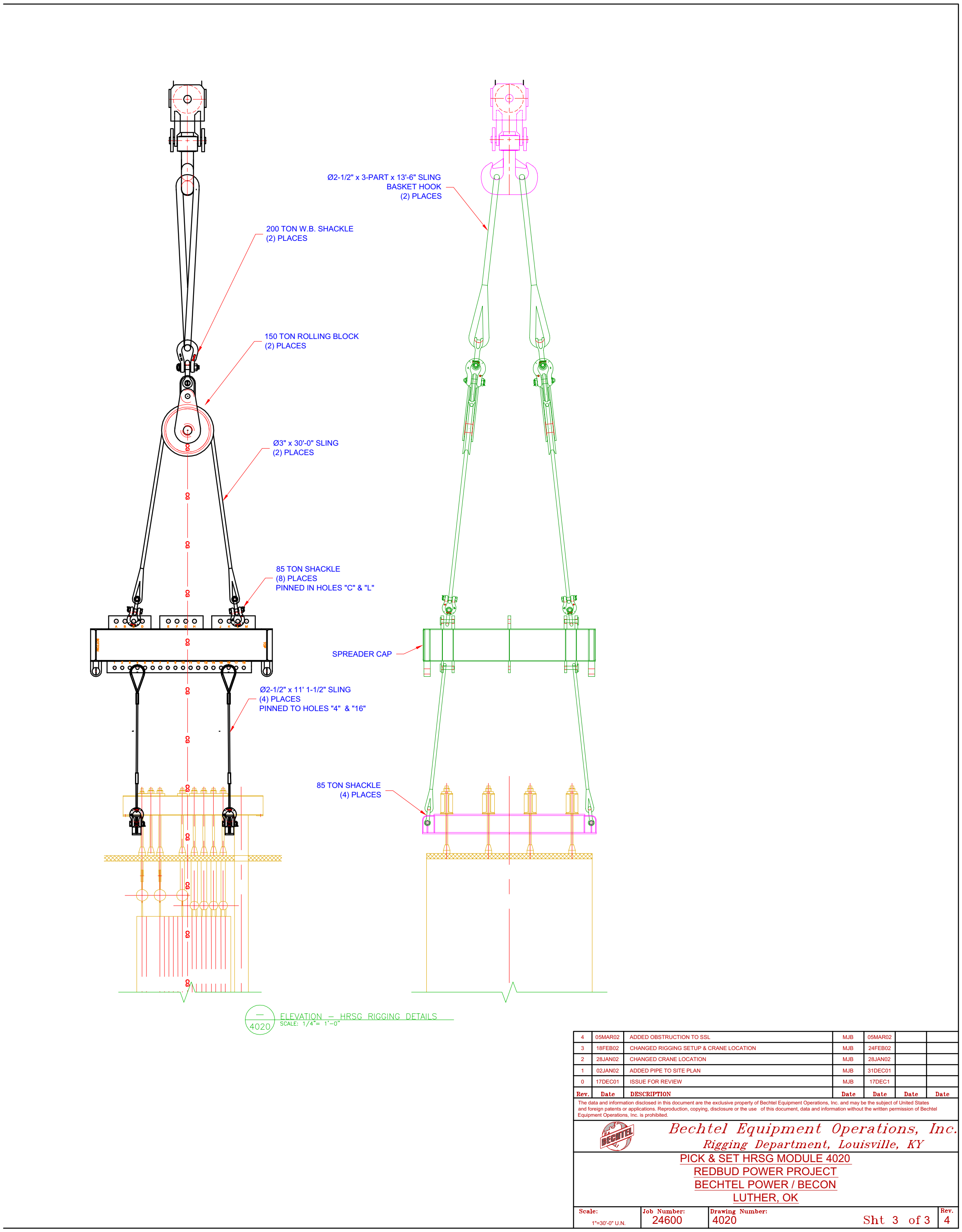
Roll-on and roll-off operation considerations include:

- Dock (sheet piling) structural load-supporting capacity
- Tide levels for roll-on or roll-off for a floating barge
- Ballast requirement
- Ramps, spanning bridge and its slope change because of load movement
- Water depth sufficient that the barge will not be grounded
- Water elevation data
- Barge deck and framing to support roll-on and roll-off loads

Figure 8.17-1

Figure 8.17-2

9 RIGGING PLANS AND DIAGRAMS



9. Rigging Plans

9.1 INTRODUCTION

Much of Bechtel's work includes heavy lifting (HL) and/or heavy hauling (HH). Skilled planning of these activities is vital to the safety and success of a project.

These activities are, by their nature, potentially high risk. To minimize this risk, it is essential that a competent person properly plan every HL and HH operation. In the Bechtel organization, the center of excellence for HL/HH activities is the Bechtel Equipment Operations (BEO) rigging department. It provides the competent persons.

The degree of planning involved will vary according to the complexity of the task. Typically, a rigging plan for a complex operation will need to include the following:

- An assessment of the risks involved in the particular operation
- A method statement to ensure that a system of work is in place to make sure that HL/HH operations are carried out safely
- Drawings fully illustrating the engineers' intent and relaying it in sufficient detail to those who conduct the work
- Special procedures in the form of written instructions
- Checks to be adopted
- Reference data, manufacturers' assembly instructions, capacity charts, and calculations

9.2 PURPOSES OF STUDIES

A rigging plan for a project commences with a study, a critical part of which is a drawing.

There are two main reasons for the preparation of any drawing:

- Investigate
- Inform

Investigative drawings are intended to investigate the practicality of a concept or the implications of a proposal and check details and interfaces. Together with calculations and technical data such as capacity charts, drawings allow the engineers to arrive at an informed conclusion. They are primarily working tools; they may demonstrate the impracticality of an idea and may never be issued. Selected investigative drawings will be worked up to the *inform* level.

Informative drawings are, as their name suggests, intended to inform and will be formally issued. They need to contain a minimum of information required to relay the engineers' intent to the targeted audience. The appearance and content of informative drawings need to be standardized as outlined in this section.

9.3 PRELIMINARY STUDIES

9.3.1 Timing

HL/HH haul considerations are vital to the execution strategy for major projects. Heavy and large items can have extremely long lead times in design and fabrication. Handling practicalities and cost are major considerations when envelope sizes and weights of critical items are specified. Obtaining the input of the HL/HH engineer and determining the HL/HH means at an early stage are critical to the execution strategy where abnormal items are concerned.

The equipment to handle extreme "abnormals" is not readily available and needs to be booked well in advance. Adequate time to plan and to mobilize is essential if the cost is to be minimized. (Short notice mobilization can be very expensive.)

The HL/HH investigation phase must be conducted in the initial project planning phase, well before full field mobilization.

9.3.2 Aims of Preliminary Studies

During the investigation phase, possible methods and equipment that could be used are investigated, and one or more solutions are recommended for adoption and development.

The aim of this phase is an overall scheme for the works to provide:

- A safe solution with risk minimized
- A method compliant with project requirements
- An efficient and cost-effective solution
- An optimized schedule with minimized jobhours expended

Advice as to how the requirements may be adjusted to aid greater efficiency and yield cost savings may also result. Noncompliant options may be offered.

9.3.3 Scope of HL/HH Activities

The scope of the activities involved will be determined in the inquiry and/or by negotiation and may include:

- Offloading from a barge, ship, or rail car
- Hauling to the site by public roads and/or site roads
- Offloading and temporary storage
- Reloading and transport to the lift or placing location
- Lifting activities (cranes, mast systems, gantries, gin poles, and strand jacks)
- Tailing
- Skidding and rolling
- Specialized transport
- Jacking works (jack and pack, climbing jacks, use of trailers, and cylinder jacking)

Associated activities not specifically covered under the remit of HL/HH but which would be handled using similar principles include:

- Barging
- Shipping
- Sea-fastening
- Load-in and load-out works
- Use of floating cranes
- Weighing

9.3.4 Drafting of the Technical Specification

At some stage in the life of the project, a technical specification for HL/HH activities must be defined. This project function is one in which BEO, as a center of excellence in HL/HH services, is mandated to assist where required. If no specification is forthcoming, the BEO may need to draft its understanding of the specification before any contract is accepted.

The aim of the technical specification is to provide information to sufficiently inform a bidder of a project's technical requirements, to disseminate critical information, to generally describe and inform, to provide a level basis for all bidders, and to eliminate ambiguity and minimize clarifications.

Typically, the technical specification:

- Defines plant location and local conditions
- Describes site road and rail links, quay and port locations, and restrictions and limitations

- Includes a site plan or plot plan
- Includes a specification of lifts, weights, sizes, center of gravity (vertical versus horizontal), etc.
- Defines the construction philosophy, and includes a draft (milestone) schedule
- Defines the extent of the working area, construction holds, no-go areas, services, and other restrictions
- Defines ground bearing pressure (GBP) and other permissible loadings
- Defines any operational restrictions (live plant, extreme weather, and remote location)
- Defines hand-over location by item (commencement of work)
- Defines conclusion of work (e.g., lifted on prepared foundation versus lifted, shimmed, aligned, leveled, bolted, or grouted)

The technical specification will not define everything that the engineer will need to conduct the work.

9.3.5 Information Gathering

9.3.5.1 Sources of Information

After the scope of the work and the aim of the outcome are determined, all of the information required to conduct the study and prepare the preliminary plan must be obtained. Development of an economical and efficient rigging plan requires obtaining as much information as possible early in the project.

Establishing an economical and efficient method will require information about the site, vendor equipment, and available lifting equipment. In the early days, information is typically sparse and a complete technical specification is unlikely at the stage of producing preliminary plans. This situation should improve as the project progresses. Before final plans are prepared or contracts are signed, a technical specification needs to be received from project team members or developed with them so that no ambiguity develops. (See preceding section.)

You will need to seek out the balance of the information as best as you can. Limited information such as general arrangement drawings, plot plans, and equipment specifications may be available through the project. The best way to obtain and extract information is to ask key project people, call vendors, or meet with the vendors' representatives. Later, more detailed vendor drawings and project steel and concrete drawings will be available with which to refine the rigging plan. A site visit may be required. Note that in a contractual situation, you will not be able to rely on any information gathered informally or from third parties. All critical information must be confirmed to you formally and should form part of any ensuing contract. For example, do not rely on hearsay for a weight where lift capacities are critical; do not accept "we have had cranes as big as that on there without mats before"; properly check out the ground bearing. Always err on the side of caution in direct inverse proportion to the quality of the information, particularly where a decision is critical. Poor information equals low safety factors.

The following subsections describe some of the key points to consider during all stages of lift planning and development.

9.3.5.2 Vendor's Equipment Drawing

A vendor's drawing shows the general arrangement of the item to be lifted, including any attached platforms, protruding pipes, and lifting lug locations.

The vendor's vessel drawing should indicate the shipping weight, erection weight, and center-of-gravity location. These data should be determined accurately and verified from sources such as the fabricators' drawings, checked computations, similar units previously handled, Bechtel Engineering Standards, and shipping weights. Whenever possible, obtain the scale weights before a unit arrives at the site. Check that the weight shown is the weight to be handled. Ask:

- Is insulation included?
- Are platforms and ladders fitted or not?
- Are containers empty or full? (Does the transformer weight include oil or not?)
- Does the shipping weight include saddles and supports?
- Is there any material hang-up inside?
- Are trays and packing fitted in exchangers?
- Has any equipment been added to an item since the drawing was made?

Beware of dismantling anything for several reasons. The information tends to be poor. Once you have the weight, you often cannot get rid of it again if it weighs too much. It will invariably weigh a lot more than you were told. You do not really know where the center of gravity is. Often, locked-in forces are free to act when the final fixing is released; you cannot always predict their magnitude or direction. Demolition does not attract the same importance as assembly and tends (wrongly) to be a less safe activity as a result. There is never the same money in taking something apart, whereas the work is, if anything, more exacting; thus, there is the tendency to minimize the cost and run capacities to the limit. Exercise extreme caution and use high safety factors.

Two inexpensive ways of verifying lift weights of vendor-supplied components are (1) to have the vendor call with the weight of the component that the shop crane indicates or (2) to check the truckers' scale weight. Regardless of the method used, lift weights should be verified before the lift. If the load is irregular, contact the vendor for recommendations on how to level the load during the lift. Be clear as to who is responsible for obtaining an accurate weight.

Regardless of any methods to determine the weight, the responsibility should in most cases lie with the entity you are working for. If it weighs too much, you can be sure that it will be your responsibility if you do not clarify this point.

The vendor's drawing will also show the purpose, location, and orientation of approved lifting lugs or lifting points. Often, the vendor will supply a sketch of the intended lift method, including sling locations and orientations. If the drawing appears ambiguous or if the lift planner identifies a better way of rigging the vessel, check back with the vendor for approval or clarification. Beware that lugs attached to a piece of equipment may be there for purposes other than lifting the entire vessel. Sometimes shop fabrication lugs will remain on the vessel after it leaves the shop. These lugs may be smaller than the approved erection lugs and will not be sufficient to lift the entire vessel. Never apply a greater load to a lift point than it was designed for or load it in a different direction than designed for. Although checking the adequacy of an item (and its lifting attachments) to withstand the loads imposed during lifting should not normally be part of BEO's remit, conduct some simple proving checks anyway as early as possible for your own peace of mind. It is not unknown for the load to fail during lifting.

In addition, check the physical size for the shackles and slings to be used. At times, a trainee may be assigned to this job and a lug that fits no known shackle may result. It can be changed if you identify the problem early enough.

If lugs are required but not provided, check with the vendor or a design engineer. Welding limitations or back-up stiffeners may be required such as with a thin-walled stack section.

9.3.5.3 Project Site Date

An overall site plan is necessary to plan equipment haul routes onto the site, to identify offloading and temporary storage areas, and to plan onsite hauling routes from the storage area to the lift location. Detailed plot plans are required to identify foundation locations and to select the optimum positions for the lift crane.

Ideally, where the schedule permits, the largest and heaviest items will be lifted and/or placed directly on arrival, eliminating temporary storage for these items. If this is not possible for schedule reasons or where dressing is involved, storage and dressing are ideally at the foundation, allowing direct lifting and placing at a later date.

9.3.5.4 Location of Utilities and Terrain Conditions

Underground utilities such as water and sewer lines, conduit banks, power and instrument cabling, ducts, and culverts must be located and avoided as far as possible when cranes or heavy loads are located or moved. Where this is not possible, the design engineer must structurally evaluate their capacity. Temporary bridging or layers of crane mats may be required to reduce stress levels.

Working space requirements for the assembly and operation of equipment must also be considered. For example, in addition to locating a crane, the space required to erect it and lay down its boom must be considered. This is usually not much of a problem for telescopic boom cranes, but for lattice boom truck and crawler cranes, ample room must be provided to lay out and assemble the full length of the boom on the ground. Once the boom is assembled and raised, the crane will have limited mobility, especially cranes with long boom lengths. The terrain that the crane must traverse from its assembly area to the lift location must also be considered. It must always be possible to render a crane safe in the event of high winds. Where the operating location of a crane prevents completely laying down its boom within a very short time, alternative plans must be made to support and secure the boom to make it safe.

9.3.5.5 Other Data

In addition to the overall site data, detailed project drawings for the building or unit are required. A plan of the building or unit in which the vessel or equipment must be set is necessary to determine lift height, pick and set radius, boom clearance, distance, and tail swing clearances.

9.3.6 Data Requirement Sheets

The following sheets are a"shopping list" of the technical information that you may require. Use them as applicable as a checklist. Add where necessary.

Item List

Description	Comments
Names of items	
Reference number	
Plant location	
Horizontal or vertical	
Dressed (Y/N)	
Envelope dimensions	
Receipt at?	
Manner of receipt (FAS/FOT, etc.)	
Delivery date	

Item Details (per Item)

Description	Comments
Item name/reference number	
Outline drawing	
Detail drawing with full dimensions	
Erection weight	Confirm before lifting
Center of gravity location	Confirm if possible
Lift attachment type and location	
Lift attachment detail	Check suitability of design and shackle fit

Base ring/support saddle detail	
Extent of dressing	
Platform drawings	

Receipt on Barge/Ship

Description	Comments
Quay layout	
Access and egress onto quay area	
Cross-section through quay/profile	
Quay height relative to datum	Only if ro-ro envisaged
Mean water height relative to datum	Only if ro-ro envisaged
Tidal range	Only if ro-ro envisaged
Tide tables	Only if ro-ro envisaged
Date of loading/load-out	Only if ro-ro envisaged
Location of piles/ground beams	
Loading on piled locations	
Loading generally on quay	
Crane rails on quay and loading	
Dredging plan	
Maximum size of barge/ship accommodated	
Maximum draft	
Mooring bollards location and load	
Craneage available	
Responsible port authority	
Physical restrictions	
Electric cables/voltage	
Charges for use	Is BEO responsible?
Barge/ship details, including cross-section	
Loading arrangement	
Unloading location on quayside	
Can ship/barge be turned?	

Receipt at Storage Area

Description	Comments
Location and layout	
Route in and out	
Intended location and orientation within area	
Strong points	
General permissible loading	

Available craneage	
Available labor	
Support arrangement	
Support height	If not on ground
Clearance width between supports	If at height

Receipt on Trailer

Description	Comments
Trailer type and configuration	
Trailer width and length	
Tractive arrangement, including drawbar	
Saddle numbers and locations	
Saddle drawings	
Orientation on trailer (plan and rotation)	
Transport height and width	
Transport drawing	
Lashing arrangements	
Handover location and orientation	
Jacking points if any	

Receipt on Rail Car

Description	Comments
Layout of rail spur	
Intended unloading location	
Operational restrictions imposed	
Permits required	
Craneage available	
Access from road	
General ground loading capacity	
Undergrounds	
Overheads	
Rail car detail	
Orientation on rail car (plan and rotation)	

Route Survey

Description	Comments
Intended route to site	
Public roads and/or private roads	
Map of route	
Envelope dimensions of load/transport	

Transport equipment turn characteristics	
Swept area, tightest turn	
Critical turns (measure/sketch their profile)	
Height restrictions, cables, and location/type	
Width restrictions, signs, etc.	
Street furniture to be removed	
Ramping required	
Culverts, drains, and other undergrounds	
Bridges, their design, and their carrying capacity	
Permit requirements and responsible authorities	
Time to obtain permits	
Statutory height/width/weight/axle load limits	
Alternative routings	
Photograph of route	

Site

Description	Comments
Site layout	
"North" location	
Plot plan with item locations	
Foundation details	
Installation elevations	
Intended "holds"	
Services locations	
Permissible GBP	
Structure details	
Any piled crane foundations?	
Routes on site	
Permit system	
Working hours	

Site Storage Area

Description	Comments
Location and layout	
Route in and out	
Intended location and orientation within area	
Strong points	
General permissible loading	
Available craneage	
Available labor	

9.3.7 Equipment and Method Selection

Having gathered all the necessary information and fully understanding what the job entails, the rigging engineer will investigate solutions and proceed to equipment and method selection.

9.3.7.1 Considerations

In doing so (together with colleagues), in addition to the technical aspects, the rigging engineer will need to consider the following as they apply:

- **Country**
  - Bechtel policy about the country
  - Existing alliances and affiliations
  - Completion
- **Site**
  - Site visit/offsite route survey
  - Ground conditions at site
  - Prevailing weather conditions
  - Quays and jetties that may be used
  - Laydown areas
  - Potential crane locations
  - Onsite routing
  - What the site and project personnel actually want (attempt to understand their preferences, prejudices, and requirements)
- **Equipment**
  - Equipment to be made available free issue (or could be by negotiation)
  - BEO equipment in locality
  - Equipment available locally
  - Local suppliers and their existing alliances, experience, and expertise
  - Costs of equipment of interest
  - Locally prevailing rates for equipment that BEO is to supply
- **Mobilization**
  - Possible routes for transport of equipment to site and limitations
  - Budget pricing for mobilization

  - Tax situation, particularly as regards to temporary import
  - Restrictions on age of equipment
  - Local laws on equipment, certification requirements, testing, etc.

- **Labor**
  - Scope of supply as regards labor
  - Availability of local labor
  - Rates of pay and benefits to be paid, holiday, and severance
  - Workers compensation and insurances
  - Agency rates
  - Labor employment laws
  - Accommodation type available and cost and related services
  - Laws on ex-patriates, visas, and the like
  - Ex-patriates' tax situation
  - Site working pattern (rotations, etc.)
  - Personnel transport type and cost
  - Air fare cost

These factors will often determine the practicality of one technical solution over another. Specifying a crane that cannot get to the site, using a high-intensity labor method in a high labor cost country, preparing a study where Bechtel does not want to work, and so on are not practical methods.

9.3.7.2 Brainstorming

Armed with full knowledge of what the job entails, country and site conditions, and equipment availability and cost, the rigging engineer needs to:

- Examine the critical items and together with engineering colleagues:
  - Consider conventional BEO possibilities (may be several)
  - Consider innovative solutions
  - Consider possible alliance partner solutions
  - Consider local solutions
  - Investigate competitors' options
- Examine the lesser items:
  - Determine the minimum equipment required for the lesser items
  - For lifting, investigate the numbers of crane locations and re-rigs required
  - Try to balance greater capacity versus speed and cost
- Look at the support equipment:
  - Determine what general support equipment is required

9.3.7.3 Selection of Lifting Means

After the site data and vessel information are known, crane or other lifting equipment selection may begin.

- Identify all the lifts to be investigated on the plot plan(s). If there are several and they are consecutive with the crane being relocated between them, consider joining all the plot plans together to obtain an overall picture of the site and where the items are on it.
- Identify the critical lifts driving the crane selection on the plot plan(s)
- Identify the underground services
- Identify the laydown areas and transport routes
- Identify no-go areas and live plant
- Locate any specially provided access and hard standing provided for cranes
- Make an initial assessment. Knowing the size and weight of the critical lifts, determine an approximate boom length and radius, and form an early assessment of the likely capacity of the crane required. Use the crane manufacturers' capacity charts as a reference. Information about lifting equipment is available through many sources, including the Bechtel Equipment Catalog, equipment manufacturer, or crane rental contractor.

- Decide the type of crane. Decide whether a crawler, ringer, or mobile is likely to be the best option, and try to identify a suitable type (or types) from the list of machines economically available for that project.
- Identify possible crane locations. Try to identify suitably clear areas in which to locate the cranes and lifting equipment
- Check out possible main lift crane(s):
  - These days, the assessment of the crane(s) best suited is mainly done by simulating the worst case(s) in AutoCAD using prepared blocks for the items and for the cranes (to the same scale as the plot, normally full size). By this means, the boom length actually required can be checked. A generous allowance for the rigging and hookblock must be allowed. The base ring and support saddles must clear the foundation by at least 600 mm (2 feet). Do not forget that slings do stretch some. In addition, when upending, do not forget that some tailing methods (J-skids and trailer tailing for example) may result in the tail being a considerable height in the air when vertical (often higher than the foundation).
  - Test your initial thoughts. Locate the crane in the area that you selected and orient it to the best advantage considering the surroundings and foundations and undergrounds; adjust it within available limits to obtain the best compromise of boom length and radius/capacity, while maintaining adequate clearance for the item to be lifted and the surroundings. You will often find that adding boom has little detrimental effect on capacity, whereas increasing radius quickly does. If this does not work, try a different machine.
  - If you do not have AutoCAD available, revert to tried and tested methods. Prepare a transparent overlay showing the selected crane in the plan and a second overlay showing the item. Both will be to the same scale as the plot. With these templates overlaid on the plot plan, determine where to best spot the crane(s) so that there will be the least amount of interference.
  - Having determined a likely radius in the plan, examine the elevation by similar means (using template overlays), and check clearances between the boom and the vessel and between the vessel and surrounding obstructions. Check capacity.
  - Whichever method is used, maintain clearances between the boom and the vessel and between the vessel and surrounding obstructions during all phases of the lift, including swinging, hoisting, and

booming. Minimum clearances should be indicated on the lift layout drawings. Similarly, clearances between the tail swing of the crane and any backmast and capacity-enhancing devices (Superlift, etc.) must be shown for all phases of the lift.

  – When examining cranes, try as far as possible to use common lift positions, do as much as possible from one location, and try to avoid changing the boom length too frequently.

- Consider alternative means:

  – When available, properly sized cranes usually provide the most economical lifting methods. There are a number of cases where this may not be so:

  * The project is in a remote location.
  * Labor is cheap.
  * Cranes are not available.
  * There is a long time between heavy lifts.
  * Something needs to be held at a height for a prolonged period.
  * The weight is extreme.
  * Lifts will occur inside buildings.
  * Space is too restricted to place a crane, and the design engineer cannot reposition other equipment or hold equipment foundations to provide adequate room.
  * The lift height is small.
  * The obvious solution requires moving in straight lines with a suspended load.
  * This is only one very heavy lift among a number of lighter items.
  * Only the hoisting means is required, e.g., lowering down a shaft or lifting within a load-carrying structure.

- In such cases, restrict the use of cranes to lesser lifts/support duties, and consider the following alternatives for the critical lifts:

  – **Portable hydraulic telescoping gantries**—These gantries are ideal for offloading equipment and work well for setting equipment on low pedestals. They can lift and carry, are set up very rapidly, are compact, and are easy to transport. The cost of such systems is low for their capacity. They do not require heavy support craneage to erect. However, the lift height is restricted and there is more labor content in building and transferring the rig. Movement of the rigs is conventionally unidirectional although the suspension can include cross-slide facilities. Where required, they can be used on elevated runways and the rigging can incorporate strand jacks or the like for greater hoisting range. Accessories such as turntables are available.

– **Strand jacks**—Strand jacks are hoisting devices. Each jack unit consists of two grip heads between which is fitted a double-acting hydraulic cylinder with hollow ram. A tendon, which is a bundle of approximately 3/4 inch wire strands, passes through the hollow body of the jack and the two grip heads. Each strand is gripped individually by collets seated in the upper and lower grip heads. As the jack is extended, the upper collets grip the strands, and the tendon is raised through the lower head. As the jack retracts, the lower grip head locks the tendon, and the upper head releases. In this manner, the tendon is pulled through the jack in a series of strokes. The lower end of the tendon terminates in a lug that is attached to the load. A range of capacities is available up to about 900Te/unit. Multiple units are normally used under central computer control.

A strand jack can be used horizontally as a heavy-duty linear winch for pulling a structure such as an offshore jacket along slide-ways for example. Conventionally, they are mounted on a load-carrying structure to raise or lower a load. Typical Bechtel uses include very heavy vessels or HRSGs.

– **Mast systems**—Mast systems typically are sectional lattice masts erected in pairs to the required height. They are spanned by a header beam on which is mounted the hoisting means. Strand jacks may be used for this; alternatives such as wire rope hoists or chain-link jacks (performing a similar function) exist. Masts of this type are load-carrying. There are systems working a climbing jack principle where the beam starts at low level and is raised by jacks either climbing the mast or pushing up from the base. In these cases, the mast is used to stabilize the jacking system and is lighter. In all cases, x-slide facilities and swivels can be fitted. Conventional rigging is used from the swivel hook. PSC masts use strand jacks and can be arranged to luff.

These systems largely replaced gin poles and are themselves being supplanted by the heaviest of cranes. However, they still have their place in specialized applications. Their main disadvantages are the time to erect, jobhours involved, support craneage required, need to guy (in most cases), foundations required, deadmen for the guys, and relatively slow lifting speed. Their advantages are high capacity and low capital cost for their capacity. They can be used in confined spaces and can hold loads for prolonged periods; their capacity depends less on height than a crane, and they can typically go to approximately 120 m. They are useful for mid-range lifts (approximately 400Te) in remote regions.

  - **Gin poles**—Gin poles are the precursor of the modern mast systems. They are sectional lattice masts erected in pairs to the required height and mounted on articulating bases. They use a header beam (mounted on articulating bearings). They use winches located at ground level as the hoisting means, with the lead lines led up the poles to sheave blocks suspended from the header beam. Gin poles are not used much now but are still favored in Japan. They do the job adequately and are relatively inexpensive. They have lesser capacity than modern mast systems generally and are slow to set up. They suffer all the other disadvantages. In some cases, they can be arranged to luff.
  - **Portable overhead gantries**—A number of companies have proprietary portable (rail-mounted) overhead gantries. These gantries use winches or alternative hoisting means and work well for setting equipment on high pedestals (35 to 110 feet).
  - **Other alternatives**—It may be possible in some cases to drive an item directly to its foundation; horizontal drums, slug catchers, and heavy pre-assembled units (PAUs) are candidates. The trailers can often be used to jack the piece up or down; alternatively, external jack and pack methods can be used where suitable jacking points exist.

- Consider delivery to the lift location:
  - Look at where the item to be lifted is to be lifted from, where will it be made available, or where can it be brought to. Trace the vessel's route over the plot plan and determine the best movements and location for the transporter, vessel, and crane(s). Determine how much space the delivery method will use; determine whether it will interfere with the lifting method. Can you keep to the roads or is it necessary to go onto the plot; is it necessary to drive over foundations; are any holds required?

- Consider tailing by crane:
    - When a piece needs to be upended, the tailing means need to be considered. In the vast majority of cases, using a crane is the obvious solution. Often a suitably rated crane will be on site for general site use and for placing smaller items.
    - Knowing the weight and location of the center of gravity, calculate the tail load. Preferably, do a spreadsheet run showing the load decay by angle of inclination. You can sometimes take advantage of this information to specify a lesser capacity crane.
    - Where possible, try to locate the main lift crane, the load, and the tail crane so that you can get the required movement of tail to head (or vice versa) without needing to move the tail crane. This approach might allow the use of a telescopic crane and may simplify setup and ground preparation. It is quicker and may be cheaper.
    - Ways to achieve this approach include:
    - * Locating the main lift crane to the side of the head of the item and slewing the head toward the tail crane using the main lift crane as the lift progresses. The tail crane basically holds the tail in a fixed location until the last few moments.
    - * Locating the tail crane to the side of the tail and slewing the tail toward the head as the lift progresses
    - * Booming out the tail crane as the tail load decays in line with the reducing capacity of the tail crane
    - * Booming out the main lift crane toward the tail crane within its capacity
    - * Combinations of all the above
- If the piece you are upending is long and you cannot get all the movement that you need from cranes in fixed locations, reduce the distance head to tail by some other means. The simplest way is to use a crawler crane at the tail; pick the tail and crawl to the head as the lift progresses, finally booming out as the load decays. It is possible, but not as preferable, to keep the tail fixed and crawl the head to the tail. Alternatively, you could consider one of the alternative methods such as J-skids or trailer tailing as described later.
- When designing a tailing arrangement, avoid side loading crane booms and/or avoid the load swinging into the boom when picked. This situation can happen if the suspension is not truly vertical above the lift points at the time when the item is lifted clear. The load

ideally needs to find its own position when picked without increasing or reducing lift radius (particularly on the tail crane). One way to achieve this approach is to have the tail crane alongside the tail at pick (rather than behind the tail) and to have the tail crane on free slew. Any movement along the length of the vessel will cause the tail crane to slew at the same radius, thus maintaining vertical suspension.

- Keeping the tail load over the side of a crawler crane is preferable to being over the corner or the front because the loads will be spread well along the length of one track, rather than being concentrated on the front pads. The tail can be brought in front of the crane toward the end of the operation to take advantage of the distance gained while slewing and to reduce the distance to be crawled (thus requiring preparation).
- Finally, keeping the crane to the side allows transport to be easily removed to the rear.
- Where cranes are not the answer for tailing, consider alternative tailing means:
  - **Hinged tail frames**—It is possible to provide a two-part hinge arrangement to support the tail, one part bolted to the base ring of the ring and the other mounted on skids or trailers. The hinge point needs to be on the centerline of the vessel (or above) to avoid the load moving to over-center as it is approaches the vertical. This point, of course, ends up being quite high, which may require longer crane booms and consequent loss of crane capacity. To minimize this situation, most designs incorporate two hinge points: one on which the tailing commences and a second that engages as the load approaches the vertical. This load transfer needs to be accommodated in the trailers or whatever else is used to support the frame. There are a number of proprietary designs, most of which are adjustable to cover a range of vessel sizes and weights.
  - **J-skids**—A J-shaped skid can be bolted to the base ring of a vessel. As upending progresses, the skid rolls on the profile of the J, constantly altering the point of contact and minimizing the support height. The profile of the J needs to be such that the center of gravity of the load being lifted never crosses the line of support of the tail. This profile would lead to the load moving to “over-center” and becoming unstable as it approaches the vertical. The J-skid needs to be mounted on skid rails/rollers or trailers, allowing it to be moved toward the main lift during upending. The skid needs to engage in the component on which it rolls, which is sometimes achieved by a type of rack arrangement of spigots and holes. Because the point of support is changing throughout the tailing while the tail load is also changing, the loading regime on whatever is supporting the skid is also changing, and its design needs to

reflect this change. If trailers are used, they will need to have the required capacity at all phases and to be adjusted through the movement.

- **Trailers**—Trailers can be a very convenient method of supporting a tailing frame. In most cases, heavy trailers are used to deliver the piece to the lift point, and then they can be used to support the tail during lifting. This approach is best if transport and lifting are within the brief of the same company. Probably, the trailers will require no more room than was used when they delivered the vessel, the ground preparation is the same, and the pressures relatively low. Self-propelled multi-axle trailers (SPMTs) are ideal for this approach because they can drive themselves in. The only adjustment that may be required is where the tail height for fitment of the frame is higher than that when it was delivered. Often, it needs to be lifted slightly. This lift can usually be achieved with the trailer hydraulics. On the face of it, the trailer will need to be sufficient to carry the tail load at pick. The line of application will not generally be central on the trailer and will change as the lift progresses; this change needs to be accounted for. Furthermore, a school of thought says that the trailer should be capable of taking the entire load. This theory is on the basis that there is a theoretical risk of the piece effectively balancing on the trailer on its hinge when vertical, with the crane doing nothing more than stabilizing it. In practice, there is usually so much spring in the system as to require the crane to be actually lowered off (with the piece vertical) to create this condition. Most designs use a cup arrangement for the hinge (rather than a pin); this arrangement allows the frame to be lifted clear as a direct continuation of the upending, avoiding this possibility.
- **Skid systems**—It is also possible to mount the tail frame on rails, supported through skid shoes using Teflon or the like. Alternatively, it may be mounted on Hilman rollers or similar. The tail will need to be winched in as the lift progresses. The rails need to be mounted on crane mats or other foundations and well leveled and aligned. The accuracy this approach requires, the complexity, potential hang ups at the rail joints and the need to transfer the tail weight onto this arrangement in the first place are significant disadvantages. It is relatively low cost and can work well when upending steam generators inside reactor buildings for example when the rails are mounted on concrete.

• Consider less critical lifts:

- Now consider the lesser lifts. Determine whether they can be sensibly made with the same crane as used for the critical lifts from the same positions. Determine whether it makes better sense to do the critical lifts and demobilize the largest crane thereafter. Determine whether the crane used for tailing the critical lifts should be used as the main lift crane for the less critical lifts (supplemented with a lesser crane). Determine whether masts will be used for the critical lifts; if so, determine whether the crane needed to build the system will be enough for the lesser lifts.

- Plan your strategy:
    - Having determined the most appropriate equipment to conduct the critical lifts and the lesser lifts, where to locate the equipment, how to make the lifts, and how to conduct the tailing, you should be in a position to rationalize your strategy. Define your thinking, and seek consensus to proceed to complete preliminary for one or more ideas.

9.3.8 General Considerations in Preliminary HL/HH Plans

In preparation of preliminary HH/HL plans, general considerations will include the size and weight of the pieces to be handled, the site and route conditions, the equipment available, possible multiple uses for the equipment, schedule impacts, and costs.

The plans will:

- Determine the possible handling means, i.e.:
    - Cranes (type and location)
    - Mast systems
    - Gantries
    - Trailers (type, numbers, etc.)

- Determine their impact on the pieces to be handled:

- Loads imposed at differing phases
- Possible interferences during handling
- Lift lug criteria
- Lashing and securing locations and loads
- Extent of dressing possible
- Omissions required
- Maximum weight possible
- Maximum size envelopes
- Stability of the load
- Stresses imposed

• Determine the impact on the surroundings:

- Equipment locations
- Swing radii
- Working areas required
- Sterilization and holds required
- Clearances to obstructions
- Loads and pressures imposed
- Civil works required
- Build position– Boom laydown direction (in operating location)
- Effects on undergrounds utilities
- Transport routes and modifications required
- Permit requirements
- Wind restrictions

• Determine the logistics schedule impacts, for example in lifting:

- Crane locations required
- How much can be done from each location
- The route between crane locations
- Holds required on plant and racks

The preliminary plans will consist of basic lift and haul studies supported by calculations and other data where required. Site investigations and route studies may be needed. Investigation with equipment suppliers and supporting data from them may be required.

9.3.9 Outcome

The outcome of the investigation phase should be:

- A recommended strategy
- Identification of type of equipment required
- Input to work up a preliminary schedule with a planner, leading to:
  - Durations of equipment required
  - With commercial personnel, draft costings
  - Clear direction about the impact of these activities on the surroundings
  - Clarified interfaces with others (what do we expect from them)
- Preliminary plan for the works in sufficient detail to explain the intent clearly to others and to identify the concerns and interfaces (See later sections for required level of detail.)
- Draft method statement where required to further explain the intent

9.3.10 Constructability Studies and Pre-Engineering

Constructability studies where HL/HH activities are involved are an example of preliminary (investigative) work where BEO involvement, on behalf of a project, is mandated. This work would typically occur at the project FEED stage, and BEO would be expected to advise the project on:

- Prior experience in similar cases and lessons learned
- Design of items to obtain best balance of progress versus construction equipment cost
- Latest developments in HL/HH technology
- Innovative concepts for HL/HH services
- Local availability of construction equipment
- Plant layout to minimize equipment requirements
- Scheduling to obtain maximum effective use of lift and haul equipment
- Maximizing lifts within information on the capacity of equipment readily available
- Cost of alternatives

9.3.11 Development

Selected preliminary studies will be expanded, refined, and changed as the job progresses and will eventually evolve into a fully detailed operational plan.

9.4 DEVELOPED STUDIES

9.4.1 Categories of Drawings

After the investigative phase has concluded and the way forward has been established, HL/HH rigging studies need to be prepared to sufficiently inform others (internally and externally). These studies are to be prepared to a level of detail appropriate to the purpose to which the study is to be put. Thus, it is very important to identify the purpose and the target recipients.

To assist in this effort, BEO has defined three categories of drawings (by purpose) and has tabulated the minimum content required for each category. This approach is intended to ensure that every drawing contains information appropriate to its purpose; it acts as a checklist for the engineer and is a common yardstick against which internal (and externally submitted) rigging drawings can be checked.

- **Category 1**—Category 1 is typically a preliminary study intended to check the viability of a concept, identify required equipment, check loadings, define working areas, suggest equipment locations, and check clearances. Its use is primarily for early planning, budget costing, etc., within BEO and Bechtel projects. It may be of sufficient detail for some bids and is aimed at commercial as well as technical personnel. The recipients are project engineers, planners and schedulers, operational personnel, costing engineers, and managers.
- **Category 2**—Category 2 is typically a more detailed feasibility study or a first run at a working proposal. It needs to be sufficiently detailed to fully explain the intentions and highlight points of concern, interfaces, and the like. It is aimed more at technical than commercial personnel—i.e., the project's engineers and site staff and BEO's operational personnel—premobilization. One or more drawings to this level (critical items) accompany more detailed bids.
- **Category 3**—Category 3 is a working drawing, intended for construction, containing all the detail necessary for field personnel to perform the works. The drawing must relay to the workers in the field ALL of the information necessary to properly execute the planned lift in a clear, unambiguous format. Relying solely on verbal instructions to guide the rigging superintendent is not acceptable. It documents the lift and provides all the necessary analysis; it is the blueprint binding all the parties involved to a common purpose. It is an integral part of the execution plan for the works. Engineers and project operational personnel are the key target.

All pertinent instructions should be in writing or sketched on the rigging drawing. In the event that the preparer of the drawing is not present, the rigging drawing should be a stand-alone document detailing how to perform the lift.

9.4.2 Information To Be Contained on Drawings

Establish with the person requiring the drawing which category of drawing you are producing and use the table as a guideline for the information it should contain. It will be checked against these criteria.

9.4.2.1 Lifting Studies

Description	Drawing Category 1	2	3
DRAWING UTILITIES			
Job description, client, job number, drawing number, revision number, date	☐	☐	☑
Site north	☐	☑	☑
Plan, elevations, end views	☐	☑	☑
Notes	☐	☑	☑
Limiting conditions	☐	☑	☑
MAIN LIFT CRANE(S)			
Crane manufacturer/model	☑	☑	☑
Crane configuration (boom and jib lengths and type), jib and/or boom angles as appropriate	☑	☑	☑
Leading dimensions of crane, tail swing radius	☑	☑	☑
Machine counterweight	☑	☑	☑
Crawler c/s, outrigger c/s as appropriate	☑	☑	☑
Superlift to be used, back mast radius, back mast length and type, tray or carriage	☑	☑	☑
Hoist block capacity	☐	☐	☑
Hoist line capacity and number of parts	☐	☐	☑
Two block minimum distance	☐	☑	☑
Other pertinent data	☐	☑	☑
MAIN CRANE LOCATION AND MOVEMENTS			
Erection location of crane and boom laydown direction, area required to build crane	☐	☐	☑
Crane location at all phases of the operations (x and y from plant reference such as foundation)	☑	☑	☑
Orientation of crane undercarriage referenced to site north	☑	☑	☑
Radius (hook to centerline of rotation at all phases)	☑	☑	☑
Path of load movement defined	☑	☑	☑
Zone of tail swing defined and affected zone	☐	☑	☑
Zone of Superlift swing defined	☐	☑	☑
Foundation holds required	☐	☐	☑
Extent of matting to be provided under crawler tracks or outrigger			

pads defined and referenced to crane	☐	☑	☑
Blocking required under ringers	☐	☑	☑
Crawler/outrigger loads and distributed pressures defined at all phases of the operations	☐	☑	☑
Site permissible GBP/ground preparation defined	☐	☑	☑

LOAD TO BE HANDLED

Reference number/description	☑	☑	☑
Reference to vendor/other drawing of item	☐	☐	☑
Erection weight of load, factor added as required	☑	☑	☑
Position of center of gravity	☑	☑	☑
Head load and tail loads at commencement of lift (and such other phases of the lift as are critical to the crane capacities)	☑	☑	☑
Location and type of lifting points	☐	☑	☑
Compatibility of lugs for intended rigging	☐	☐	☑
Extent of ladders, platforms, and weight	☐	☑	☑
Possible interference rigging to lift items at all phases of the lift	☐	☑	☑
Any temporary lift frames and the like and weight	☐	☑	☑
Delivery direction where appropriate	☐	☑	☑
Envelope required for transport equipment and checked for possible interference	☐	☐	☑
Location of any temporary supports and loadspreading grillages and checked for interference	☐	☐	☑

RIGGING

Shackle details (manufacturer, size, type, capacity, safe working load [SWL], pin size)	☐	☐	☑
Sling details (type, construction, eye type, length, diameter, material grade, SWL, and factor of safety)	☐	☐	☑
Spreader bar/beam (type and reference number assembly details, length and construction, capacity chart details, and SWL)	☐	☐	☑
Other rigging details as required	☐	☐	☑
Hook-up drawing	☑	☑	☑
Item reference numbers and test certification numbers	☐	☐	☑

LOAD TABLE(S)

Crane fixed weight items (hook blocks, hoist line, auxiliary blocks, and jib attachments)	☐	☑	☑
Rigging weights	☐	☑	☑
Load weight	☑	☑	☑
Load contingency factors as applicable	☐	☑	☑
Load ancillaries (ladders, platforms, contents, insulation, and fireproofing)	☐	☑	☑
Special considerations that apply (dynamic effects, suction, etc.)	☐	☑	☑
Total resulting lifted load	☑	☑	☑
Crane capacity at all phases	☑	☑	☑

Down rating factor for multiple crane lifts if applicable	☑	☑	☑
Percentage capacity	☑	☑	☑
Repeat load table data for all critical phases of the operation (i.e, pick, boom out, slew, place, etc.)	☐	☑	☑
TAILING			
Method to be used (crane/trailer/other)	☑	☑	☑
Details of tailing /frame attachment if any (type, method of attachment, capacity, references, and SWL)	☐	☐	☑
Crane details as main crane (as applies)	☐	☑	☑
Rigging details as head (as applies)	☐	☑	☑
Equipment reference numbers and certification number	☐	☐	☑
Trailer details as apply, type, number of axles, location referenced to base of vessel	☐	☑	☑
Tail height at commencement and completion	☐	☑	☑
OPERATION DETAILS			
Exclusion (working) zones	☐	☐	☑
Limiting wind speeds for operation	☐	☐	☑
Special operational restrictions (visibility, temperature, etc.)	☐	☐	☑
Restrictions on approach to power lines, rail lines, quay edges, live plant, etc.	☑	☑	☑
Restrictions on permitted slew angle	☑	☑	☑
Notes of any permits to be in place before commencement	☐	☐	☑
Plan showing load path, tail and superlift swing	☑	☑	☑
Elevation showing minimum clearances load and rigging to crane (particularly spreader) at all phases.	☑	☑	☑
Critical clearances load and rigging to surrounding plant	☐	☑	☑
Path of tail and tailing crane/trailer	☐	☑	☑
Elevation of load showing position at maximum height, clearance to head sheaves, and manufacturer’s minimum approach (consider height of tail method)	☑	☑	☑

9.4.2.2 Haul Studies

Description	**Drawing Category**		
	1	**2**	**3**
DRAWING UTILITIES			
Job description, client, job number, drawing number, revision number, date	☐	☑	☑
Plan, elevation, and end view	☐	☑	☑
PRIME MOVER			
Manufacturer/model	☐	☑	☑
Horsepower	☐	☐	☑
Nominal tractive effort	☐	☐	☑

Axle spacing	☑	☑	☑
Ballast carried	☐	☑	☑
Weight	☑	☑	☑
Leading dimensions	☑	☑	☑
Fifth wheel height	☑	☑	☑
Load carried on fifth wheel	☑	☑	☑
Axle loading	☑	☑	☑

TRAILER

Manufacturer and model number	☐	☑	☑
Type and configuration of trailers	☑	☑	☑
Leading dimensions	☑	☑	☑
Axle spacing	☐	☑	☑
Capacity of trailer as used	☑	☑	☑
Deck height	☑	☑	☑
Travel range of deck height (where applicable)	☑	☑	☑
Turning circle	☐	☑	☑
Drawbar length (where applicable)	☐	☐	☑

LOAD DETAILS

Reference number/description	☑	☑	☑
Reference to vendor/other drawing of item	☐	☐	☑
Transport weight of load	☑	☑	☑
Position of center of gravity	☑	☑	☑
Extent of ladders, platforms, weight	☑	☑	☑

LOAD ON TRAILER

Numbers and location of support saddles (where used)	☑	☑	☑
Saddle dimensions	☐	☑	☑
Orientation of load on trailer	☑	☑	☑
Location of load on trailer	☑	☑	☑
Support reactions on trailer deck	☐	☐	☑
Loadspreading materials required	☐	☑	☑
Lashing and securing arrangements	☐	☑	☑
Required ratings of all rigging materials	☐	☐	☑
Lashing points	☐	☑	☑
Protective materials where required	☐	☐	☑
Transport height and width	☑	☑	☑
Overall transport length	☑	☑	☑

LOAD TABLE

Self weight of trailer	☐	☑	☑
Weight of load carried by trailer	☐	☑	☑

Weight of saddles, turntables, beams, etc.	☐	☑	☑
Total weight carried by trailer	☐	☑	☑
Axle loads			
Wheel contact area and pressure	☐	☑	☑
"Shadow" (uniform) ground pressure imposed	☐	☑	☑
STABILITY			
Trailer hydraulic arrangement	☐	☑	☑
Support triangle (plan)	☐	☑	☑
Distance from center of gravity to support triangle	☐	☑	☑
Angle of stability on end view	☐	☑	☑
OPERATIONAL CONSTRAINTS			
Limiting traveling speed	☐	☐	☑
Limiting wind speeds for operation	☐	☐	☑
Special operational restrictions (visibility, temperature, etc.)	☐	☐	☑
Restrictions on approach to power lines, rail lines, quay edges, live plant, etc.	☐	☑	☑
Restrictions on cross fall, incline, radius	☐	☑	☑
Route study with required movements and clearances as necessary	☑	☑	☑

Checkers of drawings should use the above table as a guide when checking content. Any third-party drawing for a critical lift submitted to BEO should be checked against the Category 3 criteria. If necessary, send the criteria to those producing the drawing.

9.4.3 Preparation of Detailed Drawings

9.4.3.1 Views Required

Elevation

This view shows the relationship between the cranes and the vessel being lifted and should show all lifting attachments, as well as any structures that may cause interference. It should also show the minimum boom clearance and the clearance over foundation anchor bolts. All clearances encountered during the lift must be considered. In some cases, a boom cross section at the critical elevation will be needed to show the actual boom clearance. Include anything necessary to completely describe the lift.

Plan

This view shows the relationship of the centerline of rotation of the main lift cranes with the vessel at the initial pick and in the set positions. Include any structures adjacent to the lift. Also show any walkings or swings that must be done by the crane and the vessel's location part way through the swing, if applicable. At the set position, indicate any required rotation of the vessel and the final lug orientation. In the initial pick position, indicate which axis is up and the tailing crane to be used. Show the boom cross section at the elevation where clearance is at the minimum.

Detail of Rigging Arrangement

Show all attachments and slings exactly as they will be arranged. Show all dimensions and label all parts.

Detail of Tailing Arrangement

Provide any views necessary to show the hook-up in detail with all of the attachments to be used. Information should be just as comprehensive as the main lifting attachment. If the tailing load changes during the upending process, show the magnitude and position of the maximum value.

9.4.3.2 Refinement of Lift Equipment Selection

Having earlier established the type of equipment to be used, attempt to rationalize. Examine the actual manufacturer's capacity charts for that individual machine, and determine the most appropriate configurations in which to put the crane to optimize its use and capacity, not just on this lift but considering the project as a whole. Try to do as much as possible from one location before relocating. Try to identify one configuration that you can use to do the majority of the work; avoid too may boom changes. Note that there are often "special" duties for larger cranes that can be considered. Note also that cranes of a common denomination are not necessarily all the same. They can be equipped differently, have subtle differences in detail, or use a different boom. Do not rely on generic charts produced for publicity.

9.4.3.3 Below-the-Hook Rigging Requirements

Once a crane or lifting method has been identified, the next step is to select and design below-the-hook rigging gear. This gear may consist of any combination of slings, shackles, spreader bars, lifting beams, rigging plates, link plates, etc. Common shackle and sling sizes and capacities can be found in manufacturers' handbooks such as Crosby, Sling-Max, Lift-All, and others. Large capacity spreaders, lifting beams, and lifting plates are not usually off-the-shelf items but are custom built or rented from a specialized rigging company. BEO has developed strategic alliances with certain lifting and rental companies and can obtain heavy lift beams and bars economically. All lifting beams, spreader bars, and lifting plates need to be designed by a structural engineer and must meet ANSI requirements. Fabrication and subsequent use of these devices in the field without Engineering's approval are not acceptable. Check that your selected tackle fits the attachments designed. You would be surprised how often lift lugs are designed for no known shackle. Try to rationalize your rigging selection around a standard rigging loft that you intend to supply. That is, consider what rigging will be available and design around it as far as possible. Try to avoid changing the rigging for every lift.

Below-the-hook rigging will be arranged depending largely on the number and location of lift points (or lugs) on the vessel and the manner and direction in which they are allowed to be loaded. The simplest arrangement is for one lift point. Typically, however, there are two or more lifting points. These points must all be connected to the hook with slings, shackles, spreaders, or rigging plates. Choose slings, spreaders, and rigging plates so that all lift points are properly loaded and the load is stabilized. Avoid configurations where the slings are unequal and one or more slings can go slack (two-point). Consider the use of a lifting frame when multiple points are involved. Consider the ability of the load to be lifted in the intended manner and beware of excessive deflection. Consider how, in the field, to adjust the level of a load having an offset center of gravity (different in practice from that anticipated), particularly where lifts must be placed to very fine limits.

9.4.3.4 Lifting Attachments

In the majority of cases, vendors will have provided items to be lifted with suitable lugs or trunnions. Handling a vessel or piece of equipment should only be done at the approved lifting locations and support points. Check with the equipment vendor or design engineer to determine if any handling limitations of the vessel or equipment are not shown on drawings. Only load the lugs in the intended directions, and never overload them. Do not design a rigging arrangement that could result in loadings not intended or allowed for by the designer of the lift attachment.

If the vendor did not supply lift lugs and no alternative method exists, request design engineering to design them. Beware of welding anything to an item in the field, particularly a pressure vessel because it will probably have been heat treated. Use bolted-on attachments where possible, and check out the item to which you are bolting to ensure that it will be adequate. Allow for the changing magnitude and direction of forces (when tailing, for example). Only a qualified structural engineer should design all such attachments.

If the rigging plan is prepared sufficiently early, it should be possible for the vendor to incorporate lugs where best needed to suit the site situation. Good communication with the vendor is essential to make this approach work. When a lug is evaluated, both the lug itself and the portion of the equipment to which it is attached must be structurally adequate. Rarely does the lug itself fail. The structure to which the lug is attached usually is the cause of failure because its strength was not considered. For example, a 1/2 inch thick lug will easily tear right out of a 3/8 inch thick tank wall if back-up or support steel is not provided. Where lifting attachments need to be fitted to an item in the field, it should be done under the supervision of an engineer. An appropriate inspection regime must be established for any welds involved (note earlier comments). Be aware that a load test may be required in such a case, whereas an alternative arrangement such as choking a sling round a suitably strong member would probably not require it.

On the rigging drawing, lift lugs or attachments required for lifting, holdback, or tailing should be shown in plan and elevation. Add section views to show location and orientation. Details of the lug or attachments should be shown or reference made to a vendor or project drawing number. In the case of stacks and thin wall units, the location of the pick point may require reinforcement. This must be shown and in place before lifting. The diagram should note whether the lug attachment is field or shop installed, if removal is required, and the procedure for removal. Detailed information, including location and orientation of shop-installed lugs and attachments, should be furnished to the fabricator at the earliest possible date.

The angle of approach with respect to the hoisting equipment and the direction of the top, bottom, or end of a piece should be shown.

9.4.3.5 Tailing

The drawings need to include detail showing the tailing connection, indicating clearances, the type of connections, safe working loads of each component, and the factor of safety for the slings. Slings and hitches are described in Section 4 and provide more information on this subject. The use of lugs or fixtures for tailing should be considered and, in most cases, will provide for better control of the lift. If a tilt-up device is specified, consider the transfer onto the tail device, the method and required height, support during transfer, etc.

9.4.3.6 Ground Preparation

It is vital to establish a design figure for permissible ground-bearing pressure. If this is not forthcoming from the project/client, independent steps must be taken to verify the figure through testing. Lifts should be designed to minimize the imposed pressures during HL/HH operations. Using manufacturer’s information, load/pressure calculation software, and spreadsheets as applicable, calculate the loads and pressures imposed at the various phases of the lift. Then specify a suitable foundation arrangement. In the worst of cases, piling may be specified. In most cases, wooden/steel mats (located on prepared ground) are used to provide a firm operating surface and distribute the load. See the guidance provided in Section 3.9. Check to determine if special mat arrangements are needed to satisfy soil-bearing capacity requirements. The number and size of mats should be shown and a detailed layout drawn to avoid edge-loading of mats. The layout and design of required mats should be coordinated with design engineering.

9.4.3.7 Receipt of the Load

Define clearly on the rigging drawings the required manner in which the item to be lifted is to be received, including direction, orientation, rotation, height, saddles, and type and size of trailer. Necessary information should be furnished to the shipper or delivering agency for proper loading and delivery to eliminate reeling at the site.

9.4.3.8 Operational Procedures

In the case of complicated lifts, consider preparation of sequence drawings showing the intentions during the different phases of the lift, the movements to be made, the equipment radii and capacities, and the changing loads throughout.

In the case of straightforward lifts, show the path of the load through the phases of the lift, radii, and capacities.

9.5 FINAL RIGGING PLANS

9.5.1 Contents of Final Rigging Plans

A rigging plan is required for each lift of which the drawings are one part. The plan provides all the details required to execute the lift operation and includes required pre-lift inspection checklists, appropriate facility permits and clearances, operator qualifications, and, most important, rigging drawings and calculations.

Typically, plans for complex operations will be a dossier of information for each lift, including the following:

- An assessment of the risks involved in the particular operation
- Special procedures in the form of written instructions establishing a system of work ensuring that these HL/HH operations are carried out safely, including:
    - Rigging drawings fully illustrating the engineer's intent and relaying it in sufficient detail to those who are to conduct the work
    - Calculations
    - Method statements
    - Procedures
    - Pre-inspection checklists
- Reference data, including:
    - Manufacturers' equipment specifications
    - Capacity charts and so on
    - Guidelines on use and manuals
    - Manufacturers' assembly instructions
    - Machine checks
- Site data, including:

- Operators' qualifications
- Approvals as required
- Work permits and clearances

9.5.2 Lift Data Sheets

A data sheet MUST be completed for each and every lift. This sheet summarizes all the pertinent lift and crane data in a standard format. Sample lift data sheets are shown at the end of this section. The data sheets may be incorporated directly into the rigging drawings to eliminate paperwork.

The following sections describe the items included on the lift data sheets.

9.5.2.1 Lifted Piece Description and Reference Drawing

A short description of the piece to be lifted and a reference drawing or sketch are necessary. A reference drawing MUST be obtained and show equipment weight, center of gravity, dimensions, lift lug locations, and other important handling instructions.

9.5.2.2 Crane Configuration

All data that pertain to the configuration of the crane must be stated in the crane configuration. Different load charts apply to different crane configurations. The exact configurations of the crane must be documented explicitly. The crane operator must be assured that the crane is configured to perform the lift that the planner envisioned. Having a summary of the crane's configuration facilitates proper crane setup.

9.5.2.3 Crane's Fixed Weight

All items hanging from the boom point are considered part of the load and must be accounted for as part of the lifted load. Read the load chart notes to confirm. These items include the hook block, wire rope, auxiliary blocks, below-the-hook rigging, and boom attachments.

9.5.2.4 Piece Weight

The total weight of the unit or vessel to be lifted must be determined from the manufacturer's data, actual scale weights, and calculations. The piece weight should be verified independently using at least two of these methods. Do not wait until the piece is attached to the hook to scale it with the crane's load indicator. The crane's load indicator should be used only as a third check. The piece weight also includes the weight of any attachments such as lifting lugs (which in some instances may be substantial). Typically, manufacturers do not include lifting attachment weights in their published equipment weights. Water weight is another item that should not be overlooked. If the piece of equipment has been sitting outdoors for any amount of time, rainwater may accumulate in fins, refractory, and fiber insulation. Thus, water could account for an additional 5 to 10 percent of the weight and must be accounted for.

9.5.2.5 Total Weight To Be Lifted

The total weight to be lifted is the sum of the fixed weight and the piece weight.

9.5.2.6 Pick Capacity

The pick capacity is the capacity of the crane when it is picking up the piece of equipment from its initial position. This capacity is the chart value for the configuration described in the crane configuration portion of the data sheet. Crane load charts typically give capacities at 5 or 10 foot radius increments and usually do not correspond exactly to the actual pick radius. For example, suppose that a load is picked up at a 17 foot radius. Because the load chart only gives values for 15 feet and 20 feet radii, the correct chart value is the 20 feet radius, which would be the lower load value. In some circumstances, it may be acceptable to interpolate between chart values, but the general rule (and safest approach) is to use the lower load value. The data sheet has been set up to accommodate this situation.

9.5.2.7 Set Capacity

The set capacity is the capacity of the crane as it is setting the piece of equipment. This capacity may or may not be more critical than the pick capacity, but it is a situation that should be considered and evaluated. The set capacity is denoted as a percentage of the chart capacity and must be below 100 percent.

9.5.2.8 Clearances

Boom and obstruction clearances must be evaluated for each stage of a lift. Spreader bars and lift beams should be examined closely because they are typically as wide as the load and are the first items to interfere with the boom if the load is swiveled. Minimum clearances should be calculated and documented on the data sheet. The minimum sling safety factor is determined by dividing the known breaking strength rating for the sling wire used by the weight lifted times the governing efficiency factor. The minimum clearance from the rigging diagram should be stated here.

9.5.2.9 Two Crane Lifts

The data sheet for two crane lifts is similar to the one-crane sheets. The only difference is that there are two cranes and the piece weight must be divided. A static calculation or other rational procedure must be attached to the data sheet describing the basis for the load split.

9.5.3 Method Statement Policy

BEO recognizes its obligation to provide for a safe system of work in all its activities. Much of what it undertakes is potentially hazardous and the preparation of a written method statement for a task is an important tool in planning for a safe system of work in these cases. Before work begins, the task to be undertaken is assessed for size and complexity; if the task warrants it, a method statement is produced to an appropriate level of detail.

Bechtel's policy is to provide outline proposals for critical lifts and moves at a tender stage, including drawings, equipment ratings, and a brief method statement. This outline is developed post award into a working method statement that, on larger projects, will form part of the lift/transport manual for the project.

The method statement for a lift or move is a single document containing all of the instructions necessary to undertake the work in a safe manner. The method statements are designed to be clear and unambiguous, describing the work to be undertaken in logical sequence from start to completion. They cross reference the drawings for the work and any other standard procedures to be adopted. Limitations in the engineering and other particular points of note are highlighted. Any safety instructions and permit requirements are appended.

Standard tasks (such as erecting heavy cranes) have standard method statements. These are incorporated in the dossier/manual for the project.

The method statements are indexed for ease of reference and are marked with a date of preparation and a revision number. To keep them current, they are reviewed as often as is necessary and re-issued. Copies are issued to all concerned with the supervision of the operation, and the skilled operators are briefed from the copies.

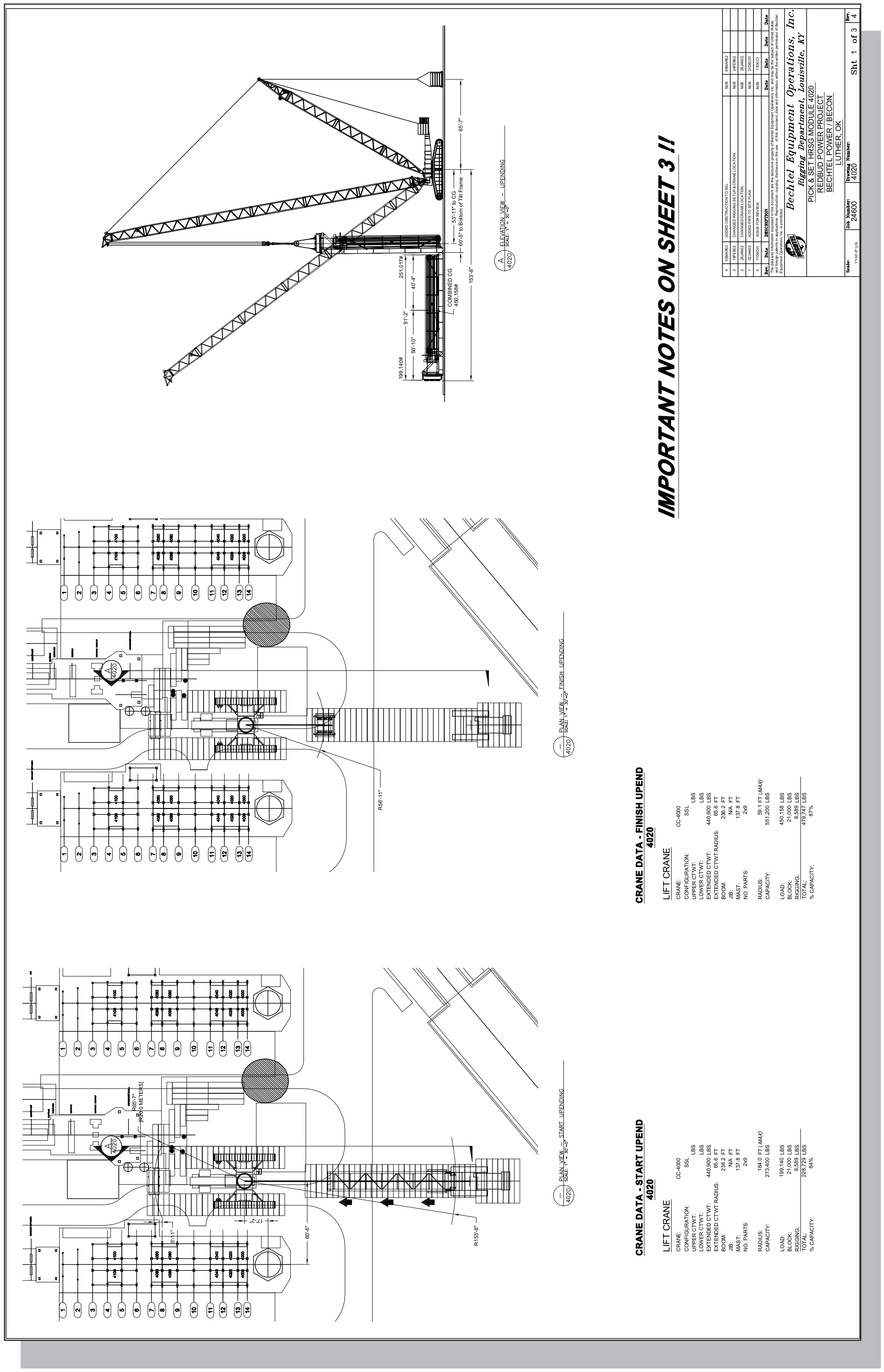
All involved are responsible for complying with the method statement. A person is appointed to police the operations, either the site manager or supervisor. On larger projects, a dedicated safety officer may be appointed and is tasked with overseeing compliance.

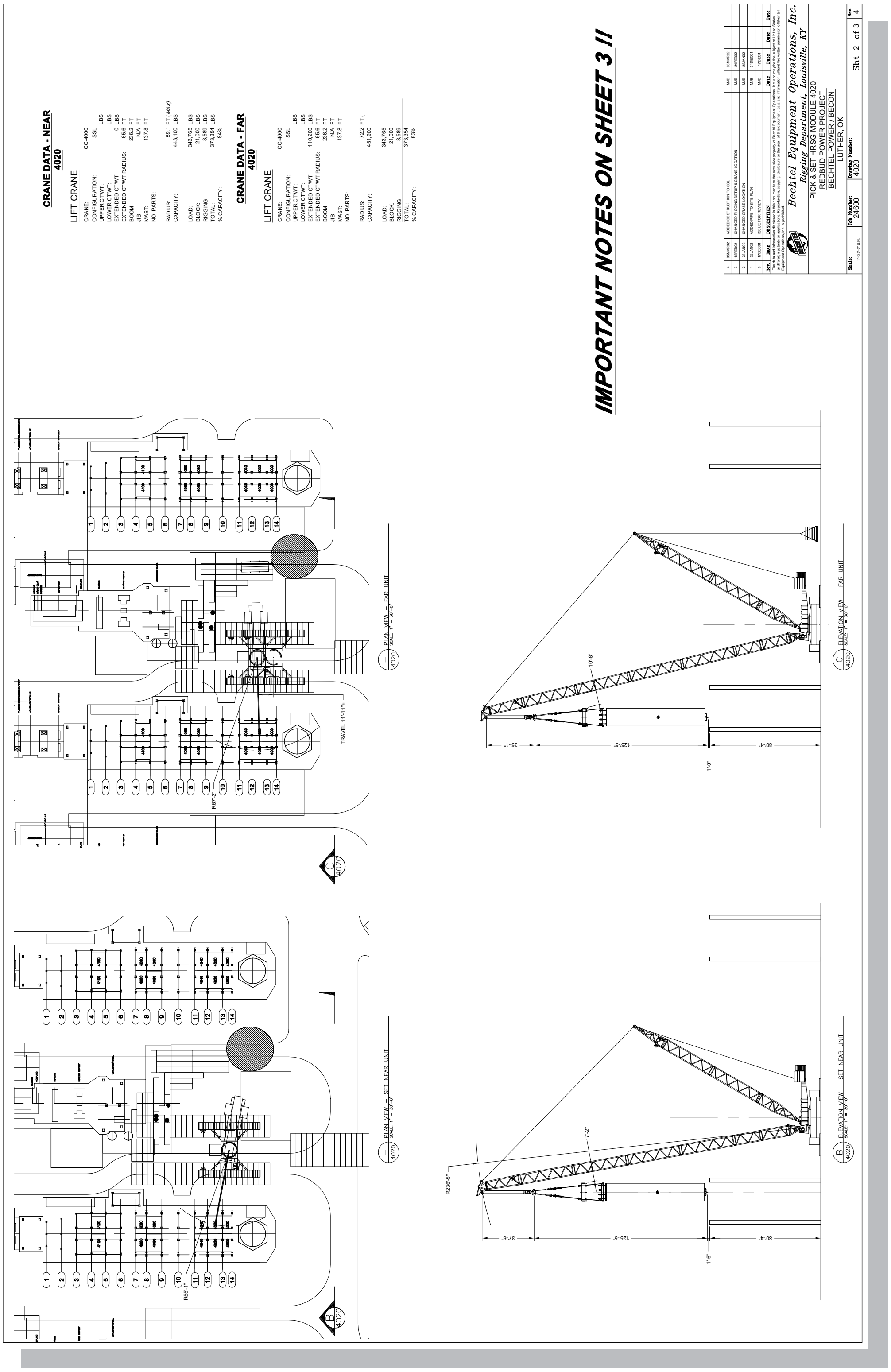
9.5.4 Project Lift Manual

On a large project where there are many lifts, the dossiers being the lift plans for each lift will be collated into one document, the lift manual. This is the definitive record of the work and an integral part of the quality assurance and control procedures.

9.6 EXAMPLES OF TYPICAL RIGGING DRAWINGS

The following detailed rigging drawings show the required level of detail:




CRANE DATA - NEAR
4020
LIFT CRANE
CRANE: CC-4000
CONFIGURATION: SSL
UPPER CT'WT: LBS
LOWER CT'WT: LBS
EXTENDED CT'WT: 0 LBS
EXTENDED CT'WT RADIUS: 65.6 FT
BOOM: 236.2 FT
JIB: N/A FT
MAST: 137.8 FT
NO. PARTS:
RADIUS: 59.1 FT (MAX)
CAPACITY: 443,100 LBS
LOAD: 343,765 LBS
BLOCK: 21,000 LBS
RIGGING: 8,589 LBS
TOTAL: 373,354 LBS
% CAPACITY: 84%
CRANE DATA - FAR
4020
LIFT CRANE
CRANE: CC-4000
CONFIGURATION: SSL
UPPER CT'WT: LBS
LOWER CT'WT: LBS
EXTENDED CT'WT: 110,200 LBS
EXTENDED CT'WT RADIUS: 65.6 FT
BOOM: 236.2 FT
JIB: N/A FT
MAST: 137.8 FT
NO. PARTS:
RADIUS: 72.2 FT (
CAPACITY: 451,900
LOAD: 343,765
BLOCK: 21,000
RIGGING: 8,589
TOTAL: 373,354
% CAPACITY: 83%
IMPORTANT NOTES ON SHEET 3 !!
4 05MAR02 ADDED OBSTRUCTION TO SSL MJB 05MAR02
3 18FEB02 CHANGED RIGGING SETUP & CRANE LOCATION MJB 24FEB02
2 28JAN02 CHANGED CRANE LOCATION MJB 28JAN02
1 02JAN02 ADDED PIPE TO SITE PLAN MJB 31DEC01
0 17DEC01 ISSUE FOR REVIEW MJB 17DEC1
Rev. Date DESCRIPTION Date Date Date Date
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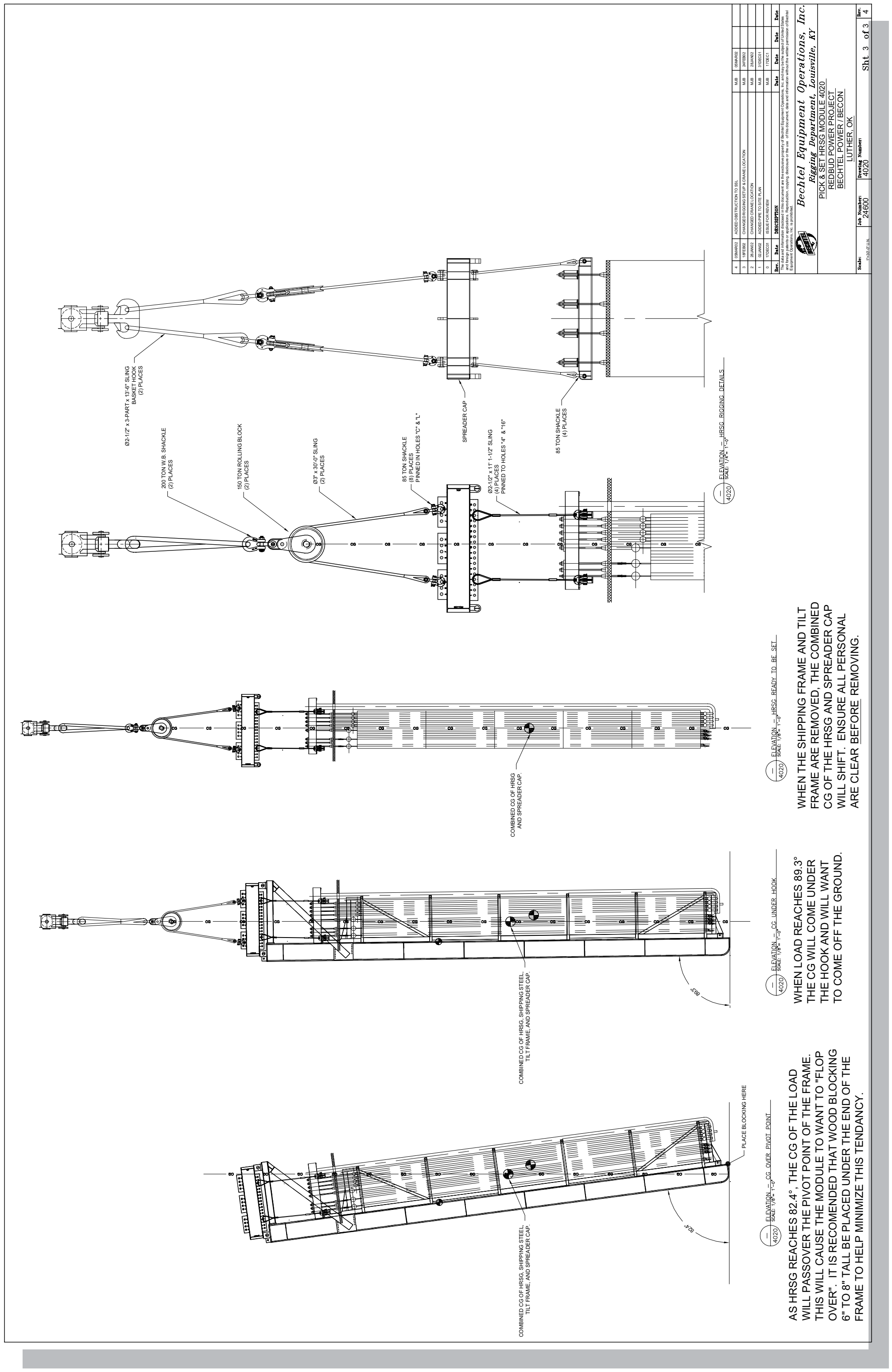
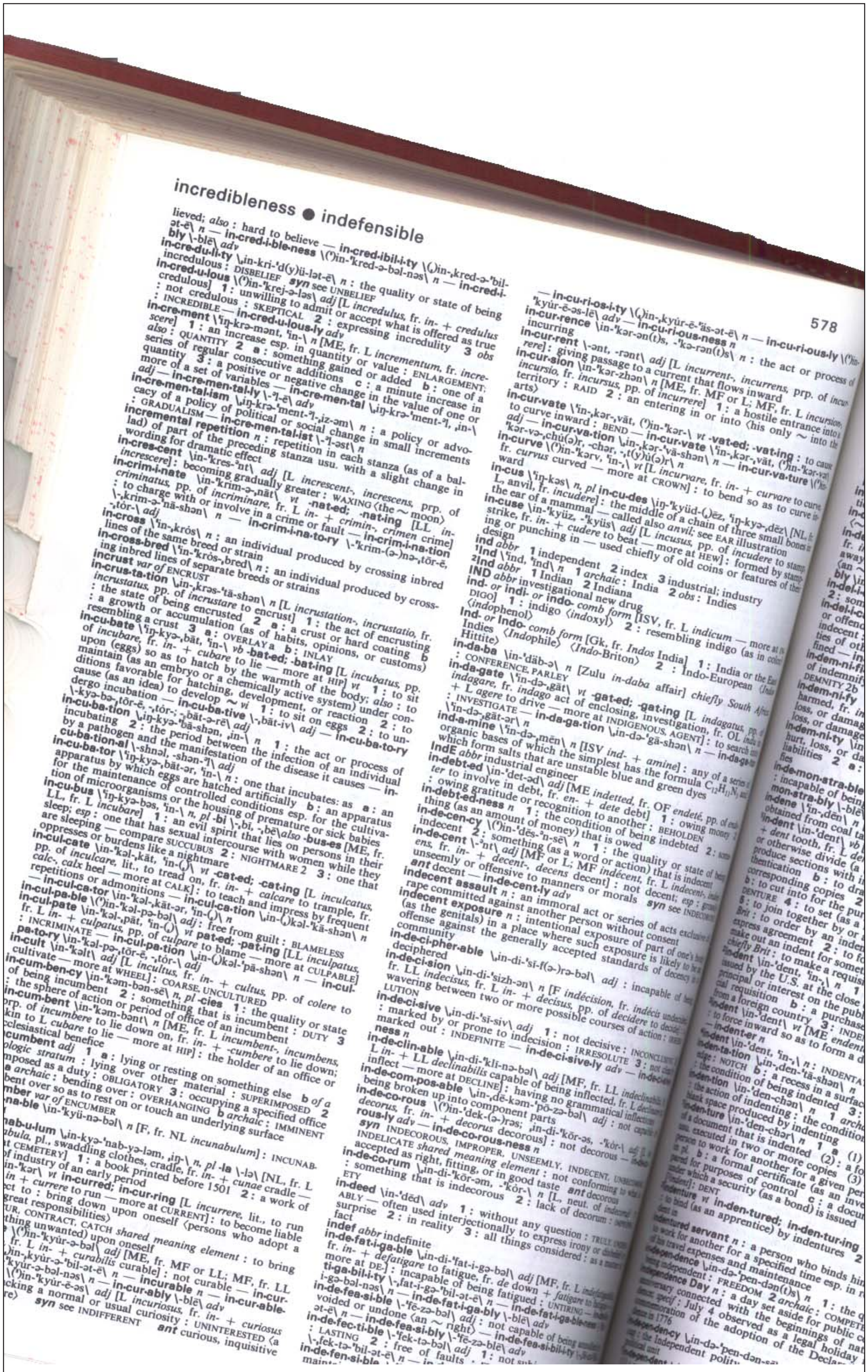
Bechtel Equipment Operations, Inc.
Rigging Department, Louisville, KY
PICK & SET HRSG MODULE 4020
REDBUD POWER PROJECT
BECHTEL POWER / BECON
LUTHER, OK
Scale: 1"=30'-0" U.N.
Job Number: 24600
Drawing Number: 4020
Sht 2 of 3
Rev. 4
PLAN VIEW – FAR UNIT
PLAN VIEW – SET NEAR UNIT
ELEVATION VIEW – FAR UNIT
ELEVATION VIEW – SET NEAR UNIT
TRAVEL 11'-11"±

VER 2.12.02


Bechtel Equipment Operations, Inc.
Rigging Department, Louisville, KY
PICK & SET HRSG MODULE 4020
REDBUD POWER PROJECT
BECHTEL POWER / BECON
LUTHER, OK
Job Number: 24600
Drawing Number: 4020
Sht 3 of 3
Rev 4
ELEVATION — HRSG RIGGING DETAILS
Ø2-1/2" x 3-PART x 13'-6" SLING BASKET HOOK (2) PLACES
200 TON W.B. SHACKLE (2) PLACES
150 TON ROLLING BLOCK (2) PLACES
Ø3" x 30'-0" SLING (2) PLACES
85 TON SHACKLE (5) PLACES PINNED IN HOLES "C" & "L"
SPREADER CAP
85 TON SHACKLE (4) PLACES
ELEVATION — HRSG READY TO BE SET
COMBINED CG OF HRSG AND SPREADER CAP
WHEN THE SHIPPING FRAME AND TILT FRAME ARE REMOVED, THE COMBINED CG OF THE HRSG AND SPREADER CAP WILL SHIFT. ENSURE ALL PERSONAL ARE CLEAR BEFORE REMOVING.
ELEVATION — CG UNDER HOOK
COMBINED CG OF HRSG, SHIPPING STEEL, TILT FRAME, AND SPREADER CAP
WHEN LOAD REACHES 89.3° THE CG WILL COME UNDER THE HOOK AND WILL WANT TO COME OFF THE GROUND.
ELEVATION — CG OVER PIVOT POINT
PLACE BLOCKING HERE
COMBINED CG OF HRSG, SHIPPING STEEL, TILT FRAME, AND SPREADER CAP
AS HRSG REACHES 82.4°, THE CG OF THE LOAD WILL PASSOVER THE PIVOT POINT OF THE FRAME. THIS WILL CAUSE THE MODULE TO WANT TO "FLOP OVER". IT IS RECOMENDED THAT WOOD BLOCKING 6" TO 8" TALL BE PLACED UNDER THE END OF THE FRAME TO HELP MINIMIZE THIS TENDANCY.

10

GLOSSARY



d.

10. Glossary

The following is a glossary of common rigging terms and expressions.

ABRASION - Surface wear on the wires of a wire rope.

ACCELERATION STRESS - Additional stress imposed on a wire rope due to increasing velocity of load.

ACCESSORY - A secondary part of assembly of parts which contributes to the overall function and usefulness of a machine.

A-FRAME - See Gantry.

A-FRAME DERRICK - A derrick in which the boom is hinged from a cross-member between the bottom ends of two upright members spread apart at the lower ends and joined at the top; the boom point secured to the junction of the side members, and the side members are braced or guyed from this junction point.

ALBERT'S LAY - Synonymous with Lang Lay.

ALTERNATE LAY - Lay of a wire rope in which the strands are alternately regular and Lang Lay.

ALTERNATIVE LAY - SPECIAL - A rope that has two Lang Lay strands alternating with one Regular Lay strand.

ANGLE INDICATOR (BOOM) - An accessory which measures the angle of the boom above the horizontal position.

AREA, METALLIC - Sum of the cross-sectional areas of individual wires in a wire rope or strand.

ATTACHMENT - Any other device that may be added as a complete unit or assembly.

AXIS OF ROTATION - The vertical line through the axis around which the crane superstructure rotates.

AXLE - The shaft or spindle about which a wheel revolves. On truck and wheel mounted cranes, it refers to an automotive type of axle assembly including housing, gearing, differential, bearings, and mounting appurtenances.

AXLE, LIVE - Driven axle.

AXLE, TAG - Non-powered rear axle (not driven); follows the drive axle.

AXLE, PUSHER - Non-powered rear axle, located ahead of the drive axle.

AXLE (BOGIE) - Two or more axles mounted in a frame so as to distribute the load between the axles and permit vertical oscillation of the wheels.

BACKHITCH GANTRY - A structural frame, located to the rear of the revolving superstructure and usually extending above the cab. Retractable means are usually available to lower the cab height for roadable convenience. Its purpose is to support the boom hoist's derricking system.

BACKSTAY - A guy used to support a boom or mast, or that section of a main cable, as on a suspension bridge, cableway, etc., leading from the tower to the anchorage.

BACKWARD STABILITY - Resistance to overturning of a crane in rearward direction.

BAIL - The U-shaped member of a shackle, socket or other fitting.

BAIL BLOCK - A block attached to a shovel or hoe dipper, through which rope line is reeved. Also referred to as a Padlock.

BALLAST - See Counterweight.

BAND BRAKE - Circular type of brake of an external contracting type, having a strap lined with heat and wear resistant friction material.

BARREL - The lagging or body portion of a rope drum.

BASE (MOUNTING) - The traveling base upon which the revolving superstructure is mounted, such as a car, truck, or crawler wheel platform.

BASE (ROTATING) - See Revolving Superstructure

BASE (TURNTABLE) - See Revolving Superstructure

BASKET DERRICK - A derrick without a boom, similar to a gin pole, with its base supported by ropes attached to corner posts or other parts of the structure. The base is at a lower elevation than its supports. The location of the base of a basket derrick can be changed by varying the length of the rope supports. The top of the pole is secured with multiple reeved guys to position the top of the pole.

BASKET HITCH - The sling configuration underneath a load used to form two parts of wire rope for lifting.

BASKET OF SOCKET - The conical portion of a socket into which a splayed rope end is inserted and secured with zinc.

BECKET - An anchor or tie-off point for the dead end of a live line.

BECKET LOOP - A loop of small rope or strand fastened to the end of a large wire rope to facilitate installation.

BENDING STRESS - Stress imposed on the wires of a wire rope by bending.

BOLSTER - Attachment to a trailer to support load, which can be fixed or can oscillate in one, two, or three directions.

BOOM - A timber, metal section or strut which is pivoted or hinged at the heel (lower end) at a location fixed in height on a frame, mast, or vertical member, with its point (upper end) supported by chains, ropes, or rods to the upper end of the frame, mast, or vertical member. A rope for raising and lowering the load is reeved through sheaves or a block at the boom point.

BOOM ANGLE - The angle above the horizontal position of the straight line, joining the centerline of the boom's foot pin and centerline of the boom's point load'hoist sheave pin.

BOOMCHORD - A main corner member of a lattice type boom.

BOOM HARNESS - See Boom Hoist Equalizer.

BOOM HOIST EQUALIZER - A block and sheave assembly in which the topping lift cable is reeved in such a way that the tensions in the boom support pendants are equal.

BOOM LACING - Structural truss members placed at angles to a lattice type boom and supporting the boom chords.

BOOM LENGTH - The straight line distance from the centerline of a boom's foot pin to centerline of a boom's point load'hoist sheave pin.

BOOM LINE - A wire rope used for supporting or operating the boom on derricks, cranes, drag lines, shovels, etc.

BOOM POINT - The outward end of the top section of the boom.

BOOM SECTION - Basic crane booms are usually in two sections, upper and lower. Such booms may be lengthened by insertion of one or more additional sections.

BOOM SPLICES - Splicing connections for sections of basic crane booms and additional sections, usually of the splice plate type, pin type or butt type.

BOOM STOP - A device used to limit the angle of the boom to the highest recommended boom angle.

BREAST DERRICK - A derrick without a boom. The mast consists of two side members spread farther apart at the base than at the top and tied together at the top and bottom by rigid members. The mast is prevented from tipping forward by guys connected to its top. The load is raised and lowered by ropes through a sheave or block secured to the top crosspiece.

BRIDGE SOCKET - Steel castings with baskets for securing rope ends and equipped with adjustable bolts. A closed type has Unbolt and an open type has two eyebolts and pin.

BRIDLE - See Boom Hoist Equalizer.

BRIDGE SLING - A two-part wire rope sling attached to a single-part line. The legs of the sling are spread to divide and equalize the load.

BRIGHT ROPE - Wire rope made of wires that are not coated with zinc or tin.

BUTT SECTION (INNER) - Portion of the boom that is hinged to the revolving deck.

CAB - A housing which covers the revolving superstructure, machinery, and operator's station. On a truck crane, there is a separate cab to cover the driver's station.

CABLE - A term loosely applied to wire ropes, wire strands, manila ropes and electrical conductors.

CABLE-LAID WIRE ROPE - A type of wire rope consisting of several wire ropes laid into a single wire rope. Example: 6 x 6 x 7 tiller rope.

CAR BODY - See Base Mounting.

CENTER PIN - Vertical pin or shaft which acts as a rotation centering device and connects to the revolving superstructure and base mounting.

CHOCKING - Used to keep round vessel from rolling and usually made of timber wedges.

CHASSIS - The framework of a vehicle including all parts necessary for its operation.

CHICAGO BOOM DERRICK - A boom which is attached to an outside upright member of the structure serving as the mast, and the boom is stepped into a fixed socket clamped to the upright. The derrick is complete with load, boom, and boom point swing line falls.

CHOKER - Sling hitch used to form a slip noose around the object to be moved or lifted.

CIRCUMFERENCE - Measured perimeter of a circle circumscribing the wires of a strand or the strands of a wire rope.

CLAMSHELL EQUIPMENT - Machines with clamshell attachments which are used to load material from stock piles, gondola cars, barges, and the like, or from virgin soil generally out of small area holes, deep trenches, or from below water. Orange peel bucket grapples and similar attachments are included in this classification.

CLASSIFICATION - Group or family of wire rope construction having common strengths and weights.

CLEVIS - See Shackle.

CLOSED SOCKET - Wire rope and fitting consisting of basket and bail made integral.

COIL - Circular bundle or wire rope not packed on a reel.

COMMON STRAND - Galvanized strand made of galvanized iron wire. See Grades, Strand.

CONICAL DRUM - Grooved hoisting drum of varying diameter.

CONSTRUCTION - Design of wire rope including number of strands, number of wires per strand and arrangement of wires in each strand.

CONTINUOUS BEND - Reeving of wire rope over sheaves and drums so that it bends in one direction, as opposed to reverse bend.

CORE - Core member of a wire rope about which the strands are laid. It may be fiber, a wire strand, or an independent wire rope.

COUNTERWEIGHT - Weight used to supplement the weight of the machine in providing stability for lifting working loads and usually attached to the rear of a revolving superstructure. Also called Ballast.

COVER WIRES - Outer layer of wires.

CRAWLER CHAIN - Chain used as the final drive to the crawler belt.

CRAWLER MOUNTING - Two continuous, parallel crawler belts, consisting of a series of tread shoes or links encompassing rollers and drive tumblers, supporting a base frame which houses the propelling mechanism, driven and controlled from a revolving superstructure.

CROSS LAY - A multiple layered rope or strand in which the lay of the inner wire layer is opposite to the lay of the outer layer.

CROSSOVER - See Boom Hoist Equalizer.

CROWD - Outward movement of the dipper stick in relation to its axis on the boom.

CUFFING - See Derricking.

CYLINDRICAL DRUM - Hoisting drum of uniform diameter.

DEAD MAN - Buried object in the ground used to secure guy wires.

DEFLECTION - (a) Sag of a rope in a span; usually measured at mid-span as the depth from the chord joining the tops of the two supports.

(b) Any deviation from a straight line.

DERRICK - An apparatus consisting of a mast or equivalent member, held at the head by guys or braces, with or without a boom, and used with a hoisting mechanism and operating ropes.

DERRICK BULLWHEEL - A horizontal ring or wheel which is fastened to the foot of a derrick for the purpose of turning the derrick by means of ropes leading from this wheel to a powered drum.

DERRICKING - Operation of changing the boom angle in a vertical plane. See Boom Hoist Equalizer.

DIAMETER - Distance measured across the center of a circle circumscribing the wires of a strand or the strands of a wire rope.

DIPPER - A material container rigidly attached to a machine. See Shovel Dipper and Hoe Dipper.

DOGS (PAWL AND RACHET) - Devices for locking the motion or movement of hoisting drums.

DRAGLINE EQUIPMENT - Machines with dragline attachments are generally used to excavate material from below the grade on which the machine is placed.

DRIVE TUMBLER - A roller with teeth or lugs which contacts matching recesses, lugs, or pins in the crawler belt.

DROMEDARY - Long wheelbase tractor using a body or container between the fifth wheel and cab.

DRUM (ROPE) - A rotating cylinder with side flanges on which rope used in machine operations is wrapped.

DUAL CROWD - A type in which the reaction from dead end of the hoist hitch is used to assist crowding of the dipper and where an independent crowding mechanism is also provided.

EFFICIENCY (SLING) - Percentage ratio of the measured breaking strength of a sling to the strength of the wire rope tested separately.

ELASTIC LIMIT - Limit of stress above which a permanent deformation takes place within the material.

ENDLESS ROPE - Rope whose two ends are spliced together.

EQUALIZING THIMBLES - Special type of fitting used as a component part of some wire rope slings.

EXTRA HIGH STRENGTH STRAND - A grade of galvanized or bright strand.

EYE OR EYE SPLICE - A loop, with or without a thimble, formed at the end of a wire rope.

FAIRLEAD - A device to guide wire rope for proper spooling.

FALL ROPE - Wire rope in the falls or tackle.

FIBER CORES (CENTERS) - Cords or rope made of vegetable or synthetic fiber used in center of wire rope (strand).

FIDDLE BLOCK - A block consisting of two sheaves in the same plane held in place by the same cheek plates.

FIFTH WHEEL - Circular metal plate secured to the chassis frame, which engages the trailer's kingpin, permitting trailer to pivot.

FITTING - Any accessory used as an attachment for wire rope.

FILLER WIRE - Small auxiliary wires in a strand for spacing and positioning other wires.

FLAG - Marker on a rope to designate position of load.

FLANGE LUG - Usually bolted to the top flange of a vessel for lifting.

FLAT ROPE - Wire rope made of parallel alternating right lay and left lay ropes, sewn together by relatively soft wires.

FLATTENED STRAND ROPE - A wire rope with either oval- or triangular-shaped strands which presents a flattened rope surface.

FLEET ANGLE - Angle between position of a rope at the extreme end wrap on a drum, and a line drawn perpendicular to the axis of the drum through the center of the nearest fixed sheave.

FLOATING HARNESS - See Boom Hoist Equalizer.

FOOT BEARING OR BLOCK (SILL BLOCK) - The lower support on which the derrick mast rotates.

G.C.W. - Gross combination weight. Total weight of a fully-equipped tractor, trailer, or trailers and payload.

G.T.W. - Gross train weight. Same as G.C.W.

G.V.W. - Gross vehicle weight. Total weight of fully-equipped truck and payload.

GALVANIZE - To coat with zinc to protect against corrosion.

GANTRY - (A FRAME) - A crane gantry is a structure mounted on the revolving superstructure of the machine to which the boom supporting ropes are attached.

GEAR RATIO, AXLE - Ratio of the speed of the propeller shaft to the speed of the rear axle shaft.

GEAR RATIO, TRANSMISSION - Ratio of the input shaft’s speed to the speed of the output shaft.

GEAR RATIO, SLOW - High numerical ratio, such as 9.00 to 1.00 (low speed).

GEAR RATIO, FAST - Low numerical ratio, such as 3.00 to 1.00 (high speed).

GIN POLE - Compression member guyed from the top and pinned or in a socket at its base; usually used in pairs. The load is raised and lowered by ropes reeved through sheaves and blocks at the top of the pole.

GIN POLE DERRICK - Single live gin pole with its guys arranged to permit leaning the pole in any direction. The load is raised and lowered by ropes reeved through sheaves or blocks at the top of the pole.

GLAD HANDS - A separable mechanical connector used to join air hoses when combination vehicles are coupled together.

GOOSENECK BOOM - A boom which has an integral upper section projecting at an angle longitudinal to the axis of the lower section.

GRADES, ROPE - Classification of wire rope by their breaking strengths. In order of increasing breaking strengths, they are:

- Iron
- Traction
- Mild Plow Steel
- Plow Steel
- Improved Plow Steel
- Extra Improved Plow Steel
- Double Extra Improved Plow Steel

GRADES, STRAND - Classification of strand by breaking strengths. In order of increasing breaking strengths, they are:

- Common
- Siemens Martin
- High Strength
- Extra-High Strength

A utilities grade strand is also made to meet special requirements.

GRADEABILITY - Percent grade that a vehicle will negotiate.

GROMMET - An endless wire rope made from one continuous length of strand or wire rope, layed upon itself six times to form a rope composed of seven parts of wire rope or strand.

GROOVED DRUM - Drum with a grooved surface to accommodate and guide the rope.

GROUSER - Projecting lugs attached to, or integral with, crawler tread shoes to provide additional traction.

GUDGEON PIN - A pin connecting the mast cap to the mast, allowing rotation of the mast.

GUY (LINE) - A rope used to steady or secure the mast or other member in the desired position.

GUY DERRICK - A fixed derrick consisting of a mast capable of being rotated, supported in a vertical position by guys, and a boom whose bottom end is hinged or pivoted to move in a vertical plane with a reeved rope between the head of the mast and boom point for raising and lowering the load.

HAMMER HEAD BOOM - A boom on which both the hoist and boom suspension lines are offset from the centerline of the boom for load clearance.

HAWSER - Wire rope, usually galvanized, used for towing or mooring vessels.

HELPER SPRING - Additional spring device permitting greater load on an axle.

HOE EQUIPMENT - Machines with hoe attachments are used to excavate hard or loose material from below the grade on which the hoe stands. Hoe equipment includes: a boom, a dipper arm mounted to rotate vertically about an axis on the boom, a dipper attached to the dipper arm, and hoe units.

HOOK BLOCK - Block with hook attached used in lifting service. It may have a single sheave for double or triple line, or multiple sheaves for four or more parts of line.

HOOK ROLLERS - Rollers which prevent the lifting of the turntable from the base.

IDLER - SHEAVE - Used to guide or support a rope.

IDLER ROLLER - Rollers of a tread belt mechanism which are not power driven.

IDLER TUMBLER - Large end roller of crawler belt mechanism at the opposite end of the drive tumbler which is not power driven.

IMPROVED PLOW STEEL ROPE - See Grades, Rope.

INDEPENDENT CROWD or POSITIVE CROWD - A type driven by either a cable or a chain — or a combination of both — from the reversing mechanism on a revolving superstructure.

INDEPENDENT BOOM HOIST, SWING, AND TRAVEL - A drive independent of all other functions.

INDEPENDENT WIRE ROPE CORE (IWRC) - Wire rope used as the core of a larger rope.

INNER WIRES - All wires of a strand except the surface or cover wires.

INTER-AXLE DIFFERENTIAL - A gear device equally dividing the power between axles and compensating for unequal tire diameters.

INTERNALLY LUBRICATED - Wire rope or strand having all wires coated with lubricant.

JIB or BOOM TIP EXTENSIONS - An extension attached to the boom head to provide added boom length for handling specified loads. The jib may be in line with the boom or may be offset.

LACING - See Boom Lacing; also method of reeving blocks.

LAGGING - Grooved drum spool shells.

LANG LAY ROPE - Wire rope in which the wires in the strands and the strands in the rope are laid in the same direction.

LATTICED BOOM - Boom of open construction with angular or tubular lacing between main corner members in the form of a truss.

LAY - Manner in which wires are helically laid into strands or strands into rope.

LEFT LAY -
(a) Strand - Strand in which the cover wires are laid in a helix having a left-hand screw.

(b) Rope - Rope in which the strands are laid in a helix having a left-hand pitch, similar to a left-hand screw.

LENGTH OF LAY - See Pitch.

LIFTING CAPACITY - See Rated Loads, Net Load, Practical Working Loads.

LIFTING LUG - Attachment used in lifting equipment.

LIVE ROLLER CIRCLE - An assembly of multiple swing rollers free to roll between a revolving superstructure and mounting.

LOAD - See Rated Load, Net Load and Practical Load.

LOAD BLOCK - See Hook Block.

LOAD BLOCK, LOWER - The assembly of sheaves, pins and frame suspended from the hoisting rope.

LOAD BLOCK, UPPER - The assembly of sheaves, pins and frame suspended from the boom by solid links or direct connection.

LOAD LINE - Another term for Hoist Line. In the lifting crane service it refers to the main hoist. The secondary hoist is referred to as a Whip Line.

LOAD MOMEMT INDICATOR (LMI) - A device, that when fitted to a crane, automaticly gives, within specified tolerance limits, a warning of the approach to the safe working load on the crane and a further warning when the safe working load has been exceeded.

LOCKED COIL STRAND - Smooth-surfaced strand composed of shaped wires laid in concentric layers around a center of round wires.

MAGNET EQUIPMENT - Machines with magnet attachments used to handle ferrous products in either the form of raw materials such as pig iron and scrap, or semi-finished billets, plates, and castings.

MAIN DRUMS - Main drums are used for lifting and lowering loads, to operate excavating attachments, and for other purposes. Two main drums and an operating mechanism usually are provided. Some manufacturers offer a third drum for special operations.

MARLINE SPIKE - Tapered steel pin used in splicing or inspecting wire rope.

MAST - Frame hinged at or near the boom hinge point and extending above the case for use in connection with supporting a boom.

LIVE MAST - Topping lift rope raises and lowers the mast. The boom is connected to the mast with pendants.

FIXED MAST - Mast is fixed in position with back hitch pendants to the gantry. The boom is raised and lowered by connecting the topping left reeving between the mast top and boom tip.

MAST CAP (SPIDER) - The fitting at the top of the mast or gin pole to which the guys are connected.

MATS - Supports or floats used for supporting machines on soft ground — usually of timber construction.

METALLIC CORES - See Wire Strand Core and Independent Wire Rope Core.

MILD PLOW - See Grades, Rope.

MOORING LINES - Galvanized wire rope — usually 6x12 or 6x24 — of spring lay construction, used for holding ships to docks.

NET LOAD - Net load is the weight of material that can be handled. It is determined by deducting the weight of the auxiliary load handling equipment such as hooks, hook blocks, slings, buckets, magnets, pile drive leads, etc. from the rated loads.

NON-PREFORMED - (NON. PREF.) - The wires and or strands are not shaped to the helical form they assume in the strand.

NON-ROTATING WIRE ROPE - 18x7 wire rope consisting of a 6x7 left lay and lay inner rope is covered by twelve 7-wire strands right lay regular lay.

NON-SPINNING WIRE ROPE - See Non-Rotating Wire Rope.

OPEN SOCKET - Wire rope fitting consisting of a Basket and two Ears with a pin.

OUTER WIRES - See Cover Wires.

OUTRIGGERS - Extendible arms attached to the mounting base, which rest on supports at the outer ends to increase stability.

PAY LOAD - See Net Load.

PEENING - Permanent distortion of outside wire in a rope caused by pounding.

PENDANTS - A supporting rope which maintains a constant distance between the points of attachments to the two components connected by the rope.

PINTLE HOOK - Coupling at the rear of a truck for the purpose of towing a trailer or other units.

PITCH - The distance parallel to the axis of the rope (or strand) in which a strand (or wire) makes one complete helical convolution about the core (or center). Also known as length of lay.

PITCH DIAMETER - Root diameter of drum, lagging or sheave, plus the diameter of the rope.

PITMAN ARM - Steering gear arm which attaches to drag link.

PLOW STEEL - See Grades, Ropes.

POWER CONTROLLED LOWERING - In the lifting crane service, some manufacturers offer Power Controlled Lowering by a reversing mechanism in the power train to one or more of the drums to provide a limited lowering speed and reduce demand on the drum brake.

PRACTICAL WORKING LOAD - Practical working load is that load established for the particular job by the equipment user with due allowance for operating conditions. These conditions include the supporting ground and other factors affecting stability, wind, hazardous surroundings, experience of personnel, etc.

PREFORMED STRAND - Strand in which the wires are permanently shaped before fabrication to the helical form they assume in the strand.

PREFORMED WIRE ROPE - Wire rope in which the strands are permanently shaped before fabrication to the helical form they assume in the wire rope.

PRESSED FITTING - A fitting in which a wire rope is attached, after insertion, by pressing the shank enclosing the rope. See Swaged Fitting.

PRESTRESSING - Stressing a wire rope or strand before use under such a tension and for such a time that the constructional strength is largely removed.

PROPORTIONAL BEAM - Beam used to proportion the load lifted to each crane in a two crane lift.

PUP - A short semitrailer used in combination with a dolly and another semitrailer to create a twin trailer.

PULL BLOCK - See Bail Block.

RADIUS OF LOAD - The horizontal distance from a projection of the axis of rotation to the supporting surface to the center of vertical hoist line or tackle with the load applied.

RATED LOAD (OF CRANE) - Rated loads at specified radii are the lesser of a specified percentage of tipping loads or the machine's structural competence as established by the manufacturer, and are the maximum loads at those radii covered by the manufacturer's warranty.

REEVING - A rope system where the rope travels around drums and sheaves.

REGULAR LAY ROPE - Wire rope in which the wires in the strands and the strands in the rope are laid in opposite directions.

RETARDER - An auxiliary speed reducing device. The retardation is generated by a moving vehicle.

REVERSE BEND - Reeving of a wire rope over sheaves and drums so that it bends in opposite directions.

REVERSE LAY - See Alternate Lay.

REVOLVING SUPERSTRUCTURE - The rotating frame and machinery located thereon, except the power plant, for operating the machine.

RIGHT LAY - (a) Strand - Strand in which the cover wires are laid in a helix having a right-hand pitch, similar to a right-hand screw.

(b) Rope - Rope in which the strands are laid in a helix having a right-hand pitch, similar to a right-hand screw.

RIM PULL - Actual amount of effort in pounds available at the point of contact of tire and road surface.

ROLLER PATH (OF CRANE) - The surface upon which run the rollers that support revolving superstructure. It may accommodate either cones or cylindrical rollers.

ROLLING RESISTANCE - Sum of the forces at the area of contact between a vehicle's tires and road surface acting against the direction of movement.

ROTATING BASE - See Revolving Superstructure.

SADDLE - Device to support round vessels, etc., which protects the shell and spreads out loads. A saddle can be used in place of chocking to keep a load from rolling.

SAFETY HOOK - A hook with a latch to prevent slings or load from accidentally slipping off the hook.

SAFE WORKING LOAD - The proper load in which the rope, shackle, etc. may carry as determined by manufacturers' data, tests, and applicable codes.

SPECIALIZED CARRIERS AND RIGGING ASSOCIATION (SC&RA) - An international association serving members engaged in the crane, rigging and oversize/overweight transportation industries.

SEALE - A strand construction having one size of cover wires with the same number of one size of wires in the inner layer and each layer having the same length and direction of lay. The most common construction is one center wire, nine inner wires.

SEIZE - To bind securely the end of a wire rope or strand with wire or strand.

SELF ERECTION RIGGING - Rope reeved through sheaves for the purpose of erecting the mast and boom. Does not carry any of the load under working conditions.

SHACKLE - A U-shaped fitting with a pin.

SHEARLEG DERRICK - A derrick without a boom and similar to a Breast Derrick. The mast, wide at the bottom and narrow at the top, is hinged at the bottom and has its top secured by a multiple-reeved guy to permit handling loads at various radii by means of load tackle suspended from the mast top.

SHEAVE - A grooved pulley for **use** with rope.

SIDE LOADING - A load applied at an angle to the vertical plane of the boom.

SILL - A member connecting the foot block and stiffleg, or a member connecting the lower ends of a double member mast.

SLINGS, BRAIDED - A very flexible sling composed of several individual wire ropes braided into a single sling.

SLIP TORQUE - Torque required to slip wheels.

SMOOTH FACED DRUM - Drum with a plain face, not grooved.

SOCKET - Type of wire rope fitting. See Bridge Sockets, Closed Sockets, Open Sockets, and Wedge Sockets.

SPIRAL GROOVE - Groove which follows the path of a helix around the drum as the thread of a screw.

SPLICING - Interweaving of two ends of ropes so as to make a continuous or endless length without appreciably increasing the diameter. Also, making a loop or eye in the end of a rope by tucking the ends of the strands.

SPREADER BAR - A member used to make slings vertical from the object lifted; theoretically, a compression member.

SPREADER BEAM - Same function as the Spreader Bar, but uses less headroom; a bending member.

STABILITY - The ability of a mobile machine to resist tipping; does not normally apply to a stationary mounting.

STANDING ROPE - See Guy Line.

STEEL CLADROPE - Rope with individual strands spirally wrapped with flat steel wire.

STIFFLEG - Rigid member supporting the mast at the head.

STIFFLEG DERRICK - A derrick similar to a guy derrick except that the mast is supported or held in place by two or more stiff members, called stifflegs, which are capable of resisting either tensile or compressive forces. Sills are generally provided to connect the lower ends of the stifflegs to the foot of the mast.

STIRRUP - The U-bolt or eyebolt attachment on a bridge socket.

STRAND - An arrangement of wires helically laid about an axis, or another wire or fiber center to produce a symmetrical section.

STRAND CENTER - See Centers.

STRAND CORE - See Cores.

STRUCTURAL COMPETENCE - The ability of the machine and its components to withstand the stresses imposed by applied loads.

SUSPENSION - Attaching parts, including springs, for securing an axle or axles to a chassis frame.

SWAGED FITTINGS - Fittings in which wire rope is inserted and attached by cold flowing method.

SWING - The function of revolving the superstructure of the machine.

SWING BEARING - A combination of rings with balls or rollers capable of sustaining radial, axial or overturning loads of the revolving superstructure.

SWING BRAKE - A swing brake is a friction device to hold the revolving superstructure in any desired position relative to the mounting.

SWING GEAR - External or internal gear with which a swing pinion on a revolving superstructure meshes to provide the swing motion.

SWING LOCK - A mechanical device to lock the revolving superstructure to the mounting in established positions.

SWING MECHANISM - The machinery involved in providing dual directional rotation of the revolving superstructure.

SWING RADIUS - The distance from the center of rotation to the hook of a freely suspended load.

SWING SPEED - The speed, in revolutions per minute, at which the revolving superstructure rotates.

TACKLE (HOIST) - Assembly of ropes and sheaves arranged for pulling.

TAG LINE - A rope used to prevent rotation of a load.

TAIL SWING - Distance from the center of rotation to the maximum rear extension of a revolving superstructure.

TANDEM DRIVE - Two axle drive combination.

THIMBLE - Grooved metal fitting to protect the eye of a wire rope.

THIRD DRUM - A third hoist drum in addition to two main hoist drums, often used in pile driving and as the whip line.

TINNED WIRE - Wire coated with tin.

TIPPING CONDITION - A machine is considered to be at the point of tipping when a balance is reached between the overturning moment of the load and the stabilizing moment of the machine when on a firm, level supporting surface.

TIPPING LOAD - Tipping load is the load producing a tipping condition at a specified radius. It includes the weights of hook,hook blocks, slings, etc., plus weight on the hook.

TIRE SIZES - These are specified by diameter of casing, diameter of wheel and ply rating, i.e., 9.00 x 20-10 ply is a 9-inch diameter casing on a 20-inch diameter wheel or rim, and is of 10-ply construction.

TORQUE CONVERTER - Hydraulic torque multiplier operating as a fluid coupling.

TOWER ATTACHMENT - A crane attachment adaptable to a basic crane machine. The attachment consists of a vertical tower with a working boom affixed to the upper part of the tower.

TRACTIVE EFFORT - The amount of force available at the driving tires of a vehicle.

TRAVEL MECHANISM - The machinery involved in providing travel.

TREAD SHOES - Hinged steel pads joined to form a continuous crawler belt which supports the machine.

TRUCK CRANE - Crane mounted on an independent engine-driven rubber-tire carrier.

TUMBLER - One of the large sprockets for a crawler belt. See Idler Tumbler and Drive Tumbler.

TURNBUCKLE - Device attached to wire rope for making limited adjustments in length. It consists of a barrel and right and left hand threaded bolts.

TWO BLOCK DISTANCE - Distance measured from boom point sheave pin to sheave pin of traveling (lower) blocks.

WARRINGTON - A strand construction in which one layer of wires, usually the outer, is composed of alternating large and small wires.

WEDGE SOCKET - Wire rope fitting in which the rope end is secured by a wedge.

WHEELBASE - Distance between centerlines of front and rear axles or to centerline of tandem axles.

WHIP LINE - Secondary hoist line. Also see Load Line.

WIRE - Single continuous length of metal, round or shaped, cold drawn from a rod.

WIRE ROPE - A plurality of strands laid helically around an axis or a core.

WORKING WEIGHT - Weight of machine in working order with complete front end equipment.

11

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  145-T Heart Lake Road
  Brampton, Ontario, Canada LGW 3K3

  (416) 451-9261

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- AMERICAN PECCO CORPORATION
  (See Morrow Crane)

- BIGGE CRANE AND RIGGING
  10700 Bigge St.
  San Leandro, CA 94577

  (510)-638-8100

  (Union wire rope sling handbook)

- BOB'S RIGGING & CRANE HANDBOOK
  Bob De Benedictis, Inc.
  6410 South Atlantic Avenue
  New Smyrna Beach, Florida 32169

  (904) 423-7759
  FAX: (904) 423-7573

- BRODERICK & BASCOM ROPE COMPANY
  Route 3
  Oak Grove Industrial Park
  P.O. Box 844
  Sedalia, Missouri 65302-0844

  (816) 827-3131

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  P. 0. Box 1920
  Denver, Colorado 80201

  DISTRICT OFFICE - 4067 Watts Street
  Emeryville, California 94608

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  Lima Division
  100-T
  North Michigan Street
  P.O. Box 7008
  South Bend, Indiana 46634

  (219) 239-0100

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  74 Victoria Street
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  10229 E. Independence Ave.
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- THE CROSBY GROUP
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  P.O. Box 3128
  Tulsa, Oklahoma 74101

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  P.O. Box 7010
  Charlotte, North Carolina 28241

  (704) 588-0510

- ENERPAC
  13000 W. Silver Silver Spring Road
  Butler, Wisconsin 53007

  (414)-781-6600

  (hydraulic jacking equipment)

- EKCO INSTRUMENTS LIMITED
  Priory Crescent
  Southend-on-Sea, Essex
  England SS26PS

  Telephone: Southend-on-Sea 330851

  (Ekco load guard indicator systems)

- ESCO CORPORATION
  144-146 West 18th Street
  New York, New York 10011

  (212) 242-2500

  (Swaged sleeves and sockets, rigging attachments, and swaging press)

- FMC CORPORATION
  200 E. Randolpi Drive
  Chicago, IL 60601

  (800) 621-4500

- GLG SYSTEMS, INC.
  11152 Condor Avenue
  Fountain Valley, California 92708

  (714) 549-4777

  (Load indicating units)

- GROVE MANUFACTURING COMPANY
  Division of Walter Kidde & Company, Inc.
  Shady Grove, Pennsylvania 17256

  (717) 597-8121

  (Grove hydraulic telescoping boom cranes)

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  P. 0. Box 554
  Milwaukee, Wisconsin 53201

  (P&H Cranes)

- HEEDE INTERNATIONAL, INC.
  One Greenwich Plaza
  Greenwich, Connecticut 06830

  (203) 661-9040

  (Hydraulic lift climbers)

- HILMAN, INC.
  2604 Atlantic Ave.
  Wall, New Jersey 07719

  (201) 449-9296

- I & I SLING, INC.
  2626 Market Street
  P.O. Box 2068
  Aston, Pennsylvania 19014

  (610) 485-8500 (Mark Coyle)
  FAX: (610) 494-5835

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- J & R ENGINEERING
  538 Oakland Avenue
  P.O. Box 447
  Mukwonago, Wisconsin 53149

  (262) 363-9660
  FAX: (262) 363-9620

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- JOHN CHATTILLON & SONS
  83-30 Kew Gardens Road
  Kew Gardens, New York 11415

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- KOEHRING
  Lorain Division
  Chattanooga, Tennessee 37405

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- LIEBHERR CRANE/SCHILLER INT.
  101 Eaton Street
  Hampton, VA 23669

  (757) 727-0700

- LIFTECH
  366 Grand Ave.
  Oakland, CA 94610

  (510)-832-5606

  (specialty rigging design)

- LIFT SYSTEMS
  205-42ST Street
  Moline, IL 61265

  (309)-765-9842

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- LIFTEX SLINGS, INC.
  204-T Railroad Drive
  Northampton Industrial Park
  Ivyland, Pennsylvania 18974

  (215) 322-9095

  (Nylon slings)

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  9609 Gayton Road, Suite 100
  Richmond, Virginia 23233-4904

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  300-T Marcus Blvd.
  Deer Park, New York 11729

  (516) 586-5100

  (Compulift crane warning systems)

- LUCKER MANUFACTURING COMPANY
  444 South Henderson Road
  King of Prussia, Pennsylvania 19406

  (215) 337-0444

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  2936 Fourteenth Avenue
  Kenosha, Wisconsin 53140

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  500 S. 16th Street
  Manitowoc, Wisconsin 54220

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- MARINO CRANE SERVICE
  25 Mill Street
  Middletown, CT 06457

  (860) 347-0827

- MARTIN-DECKER COMPANY
  1200-T Cypress Creek Road
  Cedar Park, Texas 78613

  (Martin Decker load indicating systems)

- MORROW CRANE
  3218 Pringle Rd. S.E.
  Salem, OR 97302

  (503)-585-5721

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- PADGETT INC.
  901 E. Fourth St.
  New Albany, IN 47150

  (812)-945-1299

  (specialty rigging steel fabrication)

- PEERLESS DIVISION
  Royal Industries
  18205 S. W. Boones Ferry Road
  P. 0. Box 447
  Tualatin, Oregon 97062

  (Trailers)

- PIASECKI AIRCRAFT CORPORATION
  Island Avenue, International Airport
  Philadelphia, Pennsylvania 19153

  (215) 365-2222

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- PREWITT ASSOCIATES 1634 N. Broadway
  Lexington, Kentucky 40505

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  Holland, Michigan 49423

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  P.O. Box 2038
  1100 East Second Street
  Pomona, California 91766

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- SHEAVE MASTER, INC.
  P.O. Box 736
  Addison, Texas 75001

  (214) 241-9191

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- SIKORSKY AIRCRAFT
  6900 Main Street
  Stratford, Connecticut 06601

  (203) 386-4000

  (Heavy lift helicopters)

- THE SKOOKUM COMPANY, INC.
  P. 0. Box 03099
  8524 N. Crawford Street
  Portland, Oregon 97203

  (503) 286-3627

  (Block and rigging equipment) Catalog No. SC76

- U.S. STEEL SUPPLY
  Division of United States Steel
  P.O. Box 368
  San Francisco, California 94101

  (415) 621-4988

  or P.O. Box 2489
  Houston, Texas 77001

  (713) 672-8351

  (Wire rope manufacturers)
  (Tiger Brand wire rope and slings)
  (Tiger Brand Wire Rope Engineering Handbook)

- VALLEY FORGE STEEL
  10702 Bigge St.
  San Leandro, CA 94577

  (510)-638-2929

  (specialty and rigging steel fabrication)

- VAN SEUMEREN, U.K.
  Coulson House
  15 Front St. West
  Bedlington
  Northumberland
  NE22 5TZ

  011-44-01670-820-881

- VEMCO INDUSTRIES, INC.
  305 South Acacia Street
  San Dimas, CA 90599-6745

  (909) 599-6745

  (Vibra Tension load indicators)

- VERSABAR, INC.
  1111 Engineers Rd.
  Belle Chase, LA 70037

  (504)-392-3200
  FAX: (504)-392-3211

- WEAR FLEX SLINGS
  Division MHS Limited
  6616 W. Irving Park Road
  Chicago, Illinois 60634

  (312) 736-3333

  (Nylon slings)

- WEIGHLOAD, INC.
  1049 South Mahaning Avenue
  Alliance, Ohio 44601

  (216) 823-7800

  (Load indicators, boom angle indicators)

- WILLY SCHEUERLE
  Fahrzeugfabrik
  D 7114 Pfederbach

  Telephone: Oehringen 07941/7031

  (Hydraulic platform trailers)

- WIRE ROPE INDUSTRIES OF CANADA LIMITED
  1611 40th Street
  Calgary, Alberta

  (403) 265-1541

  (Blue Strand Wire Rope Catalogue)

- <u>Wire Rope Sling Users Manual</u>

  Wire Rope Technical Board
  P.O. Box 849
  Stevensville, Maryland 21666

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