Sample Calculation

Tandem Lifting and Tailing Lifting

Worked examples, including the load calculation at the tailing moment

Purpose. This document gives two worked examples for engineers preparing a lifting study: (A) a tandem lift of a horizontal module by two cranes, and (B) a tailing (upending) lift of a vertical vessel using a main crane and a tail crane. Part B shows in detail how the load is calculated at the tailing moment, when the tail crane first takes its share of the weight, and how those loads change as the vessel rotates to vertical.

All data are assumed for illustration. Crane capacities, factors and acceptance criteria must be replaced with the project lifting specification and the actual crane load charts.

1. Basis and Assumptions

Item	Value	Remark
Units	t, m	1 t = 1,000 kg (weights in tonnes-force)
Weight contingency factor	1.05	Covers weighing / estimating uncertainty
Dynamic amplification factor (DAF)	1.10	Applied to load and rigging
CoG tolerance	± 0.5 m	Along the longitudinal axis
Maximum crane utilisation	80 %	Of net chart capacity (typical tandem / tailing limit)
Rigging weights	Included	Added at the hook of the crane that carries them

Method: the load is treated as a rigid body in static equilibrium. Moments are taken about one lifting point to find the share carried by the other. Factors are then applied in the sequence: weight contingency, CoG tolerance, DAF, rigging.

2. Example A – Tandem Lift (Horizontal)

Two cranes lift a pipe-rack module horizontally, one crane at each lifting lug. Crane A is the heavier-loaded crane because the CoG is closer to lug A.

2.1 Input data

Parameter	Value	Symbol
Module weight	120.0 t	W
Module length	18.0 m	–
Lug A position (from end A)	2.0 m	–
Lug B position (from end A)	16.0 m	–
Lug spacing	14.0 m	S

Parameter	Value	Symbol
CoG position (from end A)	8.0 m	–
Distance CoG to lug A	6.0 m	a
Distance CoG to lug B	8.0 m	b
Rigging weight – Crane A / Crane B	2.0 t / 1.5 t	$W_{r,A}$ / $W_{r,B}$

2.2 Equations

Moments about lug B give the load on crane A, and moments about lug A give the load on crane B:

$$R_A = W \times b / S \qquad R_B = W \times a / S \qquad R_A + R_B = W$$

2.3 Calculation

Step 1 – Nominal static load share

R_A = 120 × 8.0 / 14.0 = 68.57 t R_B = 120 × 6.0 / 14.0 = 51.43 t (sum = 120.00 t ✓)

Step 2 – Apply weight contingency (1.05)

W = 120 × 1.05 = 126.0 t R_A = 126 × 8.0 / 14.0 = 72.00 t R_B = 126 × 6.0 / 14.0 = 54.00 t

Step 3 – CoG tolerance ± 0.5 m (take the worse case for each crane)

- CoG 0.5 m toward end A (a = 5.5, b = 8.5): R_A = 126 × 8.5 / 14 = 76.50 t, R_B = 49.50 t
- CoG 0.5 m toward end B (a = 6.5, b = 7.5): R_A = 126 × 7.5 / 14 = 67.50 t, R_B = 58.50 t

Design lug loads: Crane A = 76.50 t, Crane B = 58.50 t.

Step 4 – Apply DAF (1.10)

Crane A: 76.50 × 1.10 = 84.15 t Crane B: 58.50 × 1.10 = 64.35 t

Step 5 – Add rigging (× DAF) to obtain the hook load

Crane A: 84.15 + 2.0 × 1.10 = 86.35 t Crane B: 64.35 + 1.5 × 1.10 = 66.00 t

2.4 Crane check

Crane	Radius (m)	Net capacity (t)	Hook load (t)	Utilisation	Result
Crane A	20	150	86.35	57.6 %	OK
Crane B	18	100	66.00	66.0 %	OK

Both cranes are below the 80 % limit. Note that the two cranes carry unequal shares (about 57 % / 43 %), so each must be checked at its own radius with its own chart. During the lift the slew, travel and hoist of both cranes must be coordinated so the module stays level and the load share stays within the CoG envelope assumed above.

3. Example B – Tailing Lift (Upending a Vertical Vessel)

A vertical pressure vessel, transported and laid horizontally, is upended with two cranes. The main crane lifts the vessel by lugs near the top. The tail crane lifts the base (tail) lug and controls the rotation. The tail crane is gradually unloaded as the vessel approaches vertical, after which the main crane carries the full weight.

3.1 Input data

Parameter	Value	Symbol
Vessel dry weight	100.0 t	W
Vessel length	30.0 m	L
CoG height from base (tail end)	13.0 m	–
Main lifting lugs from base	24.0 m	–
Tail lug from base	1.5 m	–
Lug-to-lug distance	22.5 m	b
Distance main lug to CoG	11.0 m	a
Distance tail lug to CoG	11.5 m	c
Main rigging / tail rigging	3.0 t / 1.0 t	–

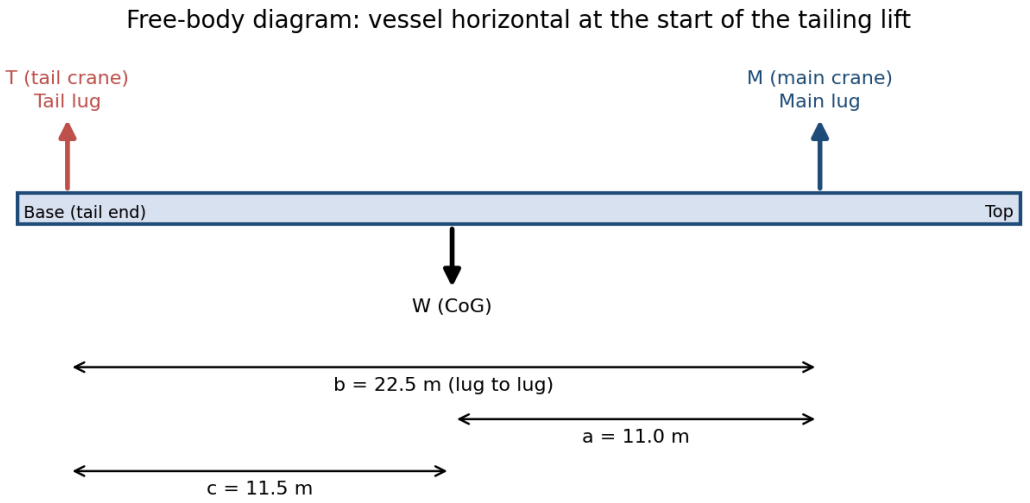


Figure 1 – Free-body diagram, vessel horizontal

3.2 Tailing moment: load split when the tail crane picks up

The tailing moment is the instant the tail lifts off its support and the tail crane takes its share. With the vessel horizontal and both lines vertical, the loads follow directly from moment equilibrium about each lug:

$$\Sigma M \text{ about main lug} = 0: \quad T \times b = W \times a \quad \rightarrow \quad T = W \times a / b$$

$$\Sigma M \text{ about tail lug} = 0: \quad M \times b = W \times c \quad \rightarrow \quad M = W \times c / b$$

$$T + M = W \quad \text{(vertical equilibrium check)}$$

The tail crane load equals the weight times the CoG distance from the main lug, divided by the lug spacing. The load is carried mainly by the crane on the side of the CoG that is closer to it.

Step 1 – Nominal static loads

T = 100 × 11.0 / 22.5 = 48.89 t M = 100 × 11.5 / 22.5 = 51.11 t (sum = 100.00 t ✓)

Step 2 – Apply weight contingency (1.05)

W = 100 × 1.05 = 105.0 t T = 105 × 11.0 / 22.5 = 51.33 t M = 105 × 11.5 / 22.5 = 53.67 t

Step 3 – CoG tolerance ± 0.5 m

- **Worst case for tail crane:** CoG moves toward the tail (a = 11.5 m): T = 105 × 11.5 / 22.5 = 53.67 t
- **Worst case for main crane:** CoG moves toward the top (c = 12.0 m): M = 105 × 12.0 / 22.5 = 56.00 t

Step 4 – Apply DAF (1.10)

T = 53.67 × 1.10 = 59.03 t M = 56.00 × 1.10 = 61.60 t

Step 5 – Add rigging (× DAF) to obtain the hook loads at the tailing moment

Tail crane hook load = 59.03 + 1.0 × 1.10 = 60.13 t

Main crane hook load = 61.60 + 3.0 × 1.10 = 64.90 t

Load case	Tail crane (t)	Main crane (t)	Comment
Nominal static	48.89	51.11	W = 100 t
With weight contingency	51.33	53.67	W = 105 t
Worst CoG case	53.67	56.00	± 0.5 m CoG
With DAF 1.10	59.03	61.60	–
Hook load incl. rigging	**60.13**	**64.90**	**Design at tailing moment**

3.3 Load during rotation (tail line inclined)

As the vessel rotates, the tail lug swings in toward the main hook while the tail crane tip stays in place, so the tail line becomes inclined. Let θ be the vessel angle from horizontal and α the angle of the tail line from vertical, leaning away from the main crane. Taking moments about the main lug:

$$T = W \times a \times \cos\theta \,/\, [\, b \times \cos(\theta - \alpha)\,]$$

$$\tan\alpha = (D - b\cos\theta) \,/\, (H + b\sin\theta)$$

Here D is the horizontal distance from the main hook axis to the tail crane tip, and H is the height of the tail crane tip above the main lug level. Assumed: D = 25.0 m, H = 20.0 m. The vertical and horizontal components of the tail line, and the resulting main line load, are:

$$T_v = T\cos\alpha \qquad T_h = T\sin\alpha \qquad M_v = W - T_v \qquad M = \sqrt{(M_v^2 + T_h^2)}$$

Worked check at θ = 60°

- Tail lug offset from main lug: horizontal b cos θ = 22.5 × 0.500 = 11.25 m; vertical drop b sin θ = 22.5 × 0.866 = 19.49 m
- α = atan[(25.0 − 11.25) / (20.0 + 19.49)] = atan(13.75 / 39.49) = 19.2°
- T = 100 × 11.0 × cos 60° / [22.5 × cos(60° − 19.2°)] = 550 / (22.5 × 0.7573) = 32.3 t
- T_v = 32.3 × cos 19.2° = 30.5 t; T_h = 32.3 × sin 19.2° = 10.6 t
- M_v = 100 − 30.5 = 69.5 t; M = √(69.5² + 10.6²) = 70.3 t

Results for all stages (static, unfactored, W = 100 t):

θ	α	Tail line T (t)	Main vertical (t)	Main horizontal (t)	Main line load (t)
0°	7.1°	49.27	51.11	6.11	51.48
30°	10.0°	45.05	55.63	7.83	56.18

θ	α	Tail line T (t)	Main vertical (t)	Main horizontal (t)	Main line load (t)
60°	19.2°	32.29	69.50	10.62	70.31
80°	26.6°	14.25	87.26	6.37	87.49
90°	–	0.00	100.00	0.00	100.00

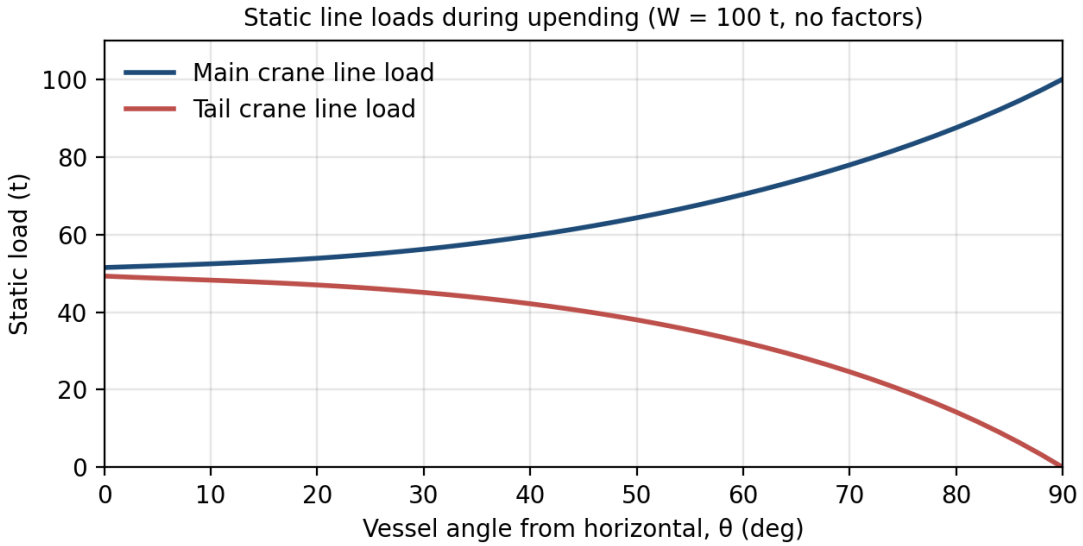


Figure 2 – Tail and main crane line loads versus vessel angle

Observations

- The tail crane load is highest at the start of the lift (about 49 t, at the tailing moment) and falls to zero as the vessel becomes vertical. Size the tail crane for the start of the lift.
- The main crane load rises from about 51 t to the full 100 t. The main crane governs at the end of the lift, so it must be checked at its final working radius.
- The horizontal component of the tail line must be resisted by the main line. The main crane should be allowed to boom or travel as needed so its line stays near the lug axis; avoid side loading.
- At θ = 0° the tail line is slightly inclined, so T is a little above T_v. Only the vertical component (48.89 t) takes part in the moment balance.
- The final transfer near vertical is sensitive to geometry. Control the tail line carefully so no sudden shock load reaches the main crane.

3.4 Factored crane check

Maximum main crane load occurs with the vessel hanging vertically: 105 × 1.10 + 3.0 × 1.10 = 118.80 t. Maximum tail crane load occurs at the tailing moment: 60.13 t (Section 3.2).

Crane	Radius (m)	Net capacity (t)	Hook load (t)	Utilisation	Result
Main crane (vertical hang)	24	160	118.80	74.3 %	OK
Tail crane (tailing moment)	18	90	60.13	66.8 %	OK

Both cranes are below the 80 % limit.

4. Notes and Limitations

- Capacities, radii, factors and the 80 % limit are examples only. Use the lifting specification of the project and the actual crane charts, with deductions for hook block, jib, auxiliary and wire rope as applicable.
- Not covered here: wind, ground bearing and crane pad checks, sling and shackle sizing at the real sling angles, lug and trunnion design, vessel shell local stresses at each stage, tail lug and tailing frame design, and clearance checks.
- In the tandem lift, both cranes must be designed for the load share at the CoG limits, not just for the nominal share. Many project standards also require a deration (for example 75 % of chart) or a load-share monitoring system.
- A detailed lift plan, a lift drawing for each stage, and review by a competent lifting engineer are required before any lift is carried out.