SAE International™ SURFACE VEHICLE RECOMMENDED PRACTICE

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Rating Lift Cranes on Fixed Platforms Operating in the Ocean Environment

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1. Scope—The scope of this SAE Recommended Practice is limited to cranes mounted on a fixed platform lifting loads from a vessel alongside. The size of the vessel is assumed not to exceed that of a work boat as defined in 3.14.

1.1 Purpose—The purpose of this document is to establish the design dynamic loads, the calculation procedures, and a load rating chart format for lift cranes operating in a variety of sea conditions.

2. References

2.1 Applicable Publications—The following publications form a part of the specification to the extent specified herein.

1. J. J. Meyers, C. H. Holm, and R. F. McAllister, "Handbook of Ocean and Underwater Engineering." McGraw-Hill Book Co., 1969.
2. Carley C. Ward, "Dynamic Vertical Forces on a Crane Loading (Unloading) a Floating Platform." Civil Engineering Laboratory Technical Memorandum TM 51-76-11 (September 1976).
3. Kenneth V. Johnson, "Theoretical Overload Factor Effect of Sea State on Marine Cranes." Offshore Technology Conference, Paper No. OTC 2584 (1976).
4. D. A. Davis and H. S. Zwibel, "The Motion of Floating Advanced Base Components in Shoal Water—A Comparison Between Theory and Field Test Data." Civil Engineering Laboratory Technical Note NH-1371.

3. Definitions

3.1 Significant wave height is the average of the highest one-third of the wave height population. Wave height is measured trough to crest.

3.2 Sea state is an indicator relating the height of the waves to sea conditions in relative terms.

3.3 Wave instrument reading as used on the load rating chart, indicates the value obtained from a wave buoy or a wave staff that relates to the sea conditions. The wave instrument reading can be analyzed to form the ratio of the average wave height to the average period ($\overline{H}/\overline{T}$).

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3.4 Surge is the fore and aft ship motion along the longitudinal axis through the center of gravity.

3.5 Sway is the athwart ship motion along the transverse axis through the center of gravity.

3.6 Heave is the vertical ship motion along the vertical axis through the center of gravity.

3.7 Roll is the angular ship motion about the longitudinal axis through the center of gravity.

3.8 Pitch is the angular ship motion about the transverse axis through the center of gravity.

3.9 Yaw is the angular ship motion about the vertical axis through the center of gravity.

3.10 Offlead is the percent slope from the vertical in the vertical plane of the boom, that locates the position of the load with respect to the tip of the boom.

3.11 Sidelead is the percent slope from the vertical normal to the vertical plane of the boom, that locates the position of the load with respect to the tip of the boom.

3.12 Dynamic rated load is the maximum load that can be lifted under specified dynamic conditions, without exceeding allowable strength limits.

3.13 Static rated load is the maximum load that can be lifted under normal land conditions, without exceeding allowable strength limits.

3.14 A typical work boat is a vessel of 180-ft length, 40-ft beam, and 1500-long-ton displacement.

4. Dynamic Load—The dynamic load being addressed is imposed on the crane at the time of the load lift off from the moving deck of the vessel alongside. Additionally, consideration is directed to the effects of the horizontal displacement in the plane of the boom and normal to the plane of the boom caused by surge and sway of the vessel.

After studying the motions of a workboat, it is assumed that the vertical motion follows the wave amplitude and that horizontal motions include sway, surge, and yaw, but exclude drift.

The vertical dynamic load, P (lb), that occurs when the lifted load W (lb) is directly under the boom tip is given by the equation:

$$P = W\left\{1 + \left[\frac{1k}{gW}(V_D + V_H)^2 + \left(\frac{A_D}{g}\right)^2\right]^{1/2}\right\} \quad \text{(Eq. 1)}$$

where:

g = Acceleration due to gravity (ft/s^2)
k = Vertical structural stiffness component with the load force at appropriate offlead (lb/ft)
V_D = Absolute value of velocity of the deck at the pick point (ft/s)
V_H = Absolute value of velocity of the load hook (ft/s)
A_D = Acceleration of the deck at pick point (ft/s^2). Refer to Reference 2.1.(2) for appropriate sign convention.

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If the pick point is assumed to coincide with the point of maximum wave downward velocity, then $A_D = 0$ and V_H and V_D are related by the sinusoidal wave equation and the constant line speed equation and Equation 1 reduces to:

$$W_D = P_{max} + \frac{m^2 k}{2} - \left[P_{max} m^2 k + \left(\frac{m^2 k}{2}\right)^2\right]^{1/2} \qquad \text{(Eq. 2)}$$

where:

W_D = Dynamic rated load
P_{max} = Maximum equivalent static force with offlead and sidelead that produces the maximum allowable load in any crane component

and

$$m = \frac{|V_H| + |V_D|}{\sqrt{g}}$$

or

$$m = 1.058 \frac{\overline{H}}{\overline{T}} \qquad \text{(Eq. 3)}$$

where:

m = Impact coefficient ($\sqrt{ft}$)
$\overline{H}$ = Average wave height (ft)
$\overline{T}$ = Average wave period (s)

The coefficient 1.058 in Equation 3 includes a 90% probability that the next wave will have a velocity less than $1.577\,\pi\,\overline{H}/\overline{T}$ (see Appendix A).

Implicit in Equation 2 are the dynamic effects of picking impact as well as sidelead and offlead effects. See Figure 1 for sidelead and offlead values. Equation 3 is to be used to calculate a series of values for m corresponding to values of $\overline{H}/\overline{T}$, such as those listed in Figure 2.

Wave Instrument Reading $\overline{H}/\overline{T}$ (ft/s)		0.25	0.46	0.80	1.17	1.61
	Static	Dynamic				
Off Lead (%)	0	6	8	12	16	22
Side Lead (%)	2	3	4	6	8	11

1. Alternatively, % offlead sidelead $= \dfrac{\text{(180 ft) (\% indicated)}}{\text{boom tip height above boat deck}}$

Minimum sidelead not to be less than 2%.

FIGURE 1—PERCENT OFFLEAD AND SIDELEAD[1]

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Manufacturer ____

Model ____________________ Boom Length ______100 ft______ S/N ____________________

Boom Foot to Sea Level Distance ______120 ft______

Static Conditions		Dynamic Conditions				
Wave Instrument Reading $\overline{H}/\overline{T}$ (ft/s)	0	0.25	0.46	0.80	1.17	1.61
Maximum Parts of Line to Clear Second Wave	Not appli-cable	7	6	5	4	3

Radius (ft)	Boom Angle (deg)	Static Rating (lb)	Dynamic Ratings for Four-Part Main Hoist Line 7/8 6 x 25 IWRC-EIPS				
25	78.5	90 000	72 000	56 000	42 900	30 500	
30	75.6	90 000	69 000	58 700	44 400	32 100	
40	69.6	90 000	67 900	56 600	41 900	30 700	
50	63.3	82 000	56 300	46 900	34 700	25 400	
Radius (ft)	**Boom angle (deg)**	**Static Rating (lb)**	**Dynamic Rating for One-Part Whip Hoist Line 7/8 6 x 25 IWRC-EIPS**				
25	80.1	22 700	18 900	16 900	16 300	13 900	11 500
30	76.1	22 700	19 000	17 000	16 300	14 000	11 600
40	70.3	22 700	18 900	16 900	16 200	13 900	11 500
50	64.0	22 700	18 400	16 500	15 800	13 400	11 000

FIGURE 2—MARINE CRANE RATING CHART FOR FIXED PLATFORM

5. Calculation Procedure

5.1 Calculate P_{max}—For each W_D that will be listed on the rating chart, each structural component of the crane is analyzed to find the value of P_{max} that could be applied to produce a maximum allowable load in a particular component. Appropriate offlead and sidelead factors are found in Figure 1. The allowable load in a particular component is determined by standard industry practice for land cranes contained in SAE J987 (structures) and SAE J959 (ropes).

5.2 Select P_{max}—For each W_D to be shown on the rating chart, a P_{max}, for each structural component of the crane is found, and the minimum value of P_{max} is selected. This will leave one P_{max} for each W_D.

5.3 Calculate k—For each W_D to be shown on the rating chart, and with appropriate offlead as shown on Figure 1, calculate the system springrate, k effective, at the load point. The term k is a function of load line, suspension line, A-frame, boom, and jib deflections under service load. Fewer components may be used in the determination of k as this will make the resulting ratings more conservative.

5.4 Calculate m—Using Equation 3, calculate the required values of m.

5.5 Calulate W_D—Using the P_{max}, k, and m values determined previously for each W_D to be shown, apply Equation 2 to calculate W_D.

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5.6 Calculate the Maximum Number of Parts of Line, N_ρ—Calculate the maximum number of parts of line, N_P: Using Equation 4, calculate the maximum number of parts of line that will permit the load to clear the second wave (see Appendix A).

$$N_P = \frac{V_L}{1.051 \frac{\overline{H}}{\overline{T}}} \quad \text{(Eq. 4)}$$

where:

N_P = Integer value of the right side of Equation 4 and represents the maximum parts of line required for the load to clear the second wave.

V_L = Hoist line speed (ft/s) when the rope is on the first layer of the drum. The coefficient 1.051 in Equation 4 includes a 90% probability that the next wave will have a velocity less than $1.577\,\pi\,\overline{H}/\overline{T}$.

6. ***Marine Crane Rating Chart Format***—A suggested format for a marine crane rating chart for fixed platforms is given in Figure 2. This format is suggested for use at the discretion of each manufacturer; some suggestions and comments regarding the content of this chart follow.

6.1 Each rating chart should be prepared for a fixed number of parts of load hoist line.

6.2 Each rating chart should also indicate ratings for a single part whipline.

6.3 The maximum parts of line that will permit the load to clear the second wave involves machinery parameters such as hoist capability and hoist line speed. It is advisable not to show ratings for cases in which the number of parts of line are not adequate for the load to clear the second wave.

6.4 The wave instrument reading, $\overline{H}/\overline{T}$, is a statistical description of the sea condition which is intended to be obtained from a wave recorder as described in 3.3. Note that $\overline{H}/\overline{T}$ is equal to 0.62 times the significant wave height in feet/average period in seconds.

7. ***Special Ratings***—This section describes procedures to be employed when it is necessary to obtain marine crane ratings for particular values of ship motion (vertical height, S, and period, T), sidelead, and offlead as specified by the user. In this case, the following procedure shall be applied:

7.1 The calculation of the dynamic rated load (W_D) from Equation 2 shall be based on a modified factor, m, given by:

$$m = 0.671 \frac{S}{T} \quad \text{(Eq. 5)}$$

7.2 The calculation of N_P from Equation 4 shall be given by:

$$N_P = \frac{V_L}{0.666 \frac{S}{T}} \quad \text{(Eq. 6)}$$

7.3 The remainder of the calculations are performed as outlined in Section 5.

PREPARED BY THE SAE CRANES AND LIFTING DEVICES TECHNICAL COMMITTEE

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APPENDIX A

BASIS OF EQUATIONS

A.1 In the usual practice of snatching a load from the deck of a heaving ship, the crane operator starts his hoist operation at the trough of a wave. On multipart line lifts, the hoist speed often cannot follow the wave and lift the load clear of the ship before the crest succeeding the trough. Because of the usual relationships between hoist speed and wave speed, the pickpoint will usually be while the ship is falling after the first crest. It will be assumed here that the pickpoint will be at maximum downward velocity of the ship.

Ship motion induced by wave action is a function of sea state, hull shape, and the displacement of the ship. The common work boat often used around fixed platforms is usually 1500 ton displacement or less. Smaller ships like this respond strongly to the sea, and it will be assumed (based on ship motion studies) that the vertical motion of the ship's rear quarter deck equals the vertical wave motion.

At the maximum velocity pickpoint ($\omega t = 3\pi/2$ from trough) the deck acceleration term in Equation 1 will disappear and

$$\frac{P}{W} = 1 + \frac{V_H + V_D}{\sqrt{g}}\sqrt{\frac{k}{W}} = 1 + m\sqrt{\frac{k}{W}} \qquad \text{(Eq. A1)}$$

At the pickpoint, the simultaneous solution of line displacement ($V_H t$) and wave displacement H $(1 - \cos \omega t)/2$ shows:

$$\frac{V_H + V_D}{\sqrt{g}} = \frac{H\pi}{T\sqrt{g}}\left(\frac{1 - \cos \omega t}{\omega t} - \sin \omega t\right) = m \qquad \text{(Eq. A2)}$$

Since $\omega t = 3\pi/2$ at the instant of lift off

$$m = \frac{3.808}{\sqrt{g}}\left(\frac{H}{T}\right) = 0.671\,\frac{H}{T} = 0.671\,q\,\frac{\bar{H}}{\bar{T}} \qquad \text{(Eq. A3)}$$

in dimensional units of $\sqrt{ft}$. The factor q is a probability parameter. If wave probability is 90% (see Figure A1), then q is 1.577 and

$$m = 0.671 \times 1.577\, \bar{H}/\bar{T} = 1.058\, \bar{H}/\bar{T} \qquad \text{(Eq. A4)}$$

The impact coefficient m in Equation A3 is a function of H/T, the wave height divided by wave period; but wave height and period are actually statistical functions of $\bar{H}$ and $\bar{T}$, the tabulated averages for any given sea state. The term 3.808 is dimensionless, while 0.671 is not. Note that $\bar{H}$ = 0.62 times the significant wave height.

The individual statistical functions of H/T are described in many References (e.g., section on *Sea Motion* in the "Handbook of Ocean and Underwater Engineering" in Reference 2.1.(1)). Both are usually described as Rayleigh or Weibull type skewed distributions and their interrelationship can be described on power spectral density plots. The statistical distribution of velocity is usually not shown. Analysis of test data, however, indicates that if the velocity probability density is considered as a normal (Gaussian) distribution symmetrical around $\bar{V}$, reasonable results will be obtained if the following assumptions are used:

$$\bar{V} = \frac{1}{N}\sum_{i=1}^{N} V_i \approx \pi\,\frac{\bar{H}}{\bar{T}} \qquad \text{(Eq. A5)}$$

$$(\overline{V^2}) = \frac{1}{N}\sum_{i=1}^{N} V_i^2 \approx 1.20(\bar{V})^2 \qquad \text{(Eq. A6)}$$

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where:

V_i is π H_i/T_i as obtained by the zero-up-crossing count method (see Reference 2.1.(1)). The velocity variance σ_V^2 is:

$$\sigma_V^2 = (\overline{V^2}) - (\overline{V})^2 = 0.20\pi^2(\overline{H}/\overline{T})^2 \quad \text{(Eq. A7)}$$

The H/T variance σ^2 and the standard deviation σ are:

$$\sigma^2 = 0.20\ (\overline{H}/\overline{T})^2 \quad \text{(Eq. A8)}$$

$$\sigma = 0.45\ (\overline{H}/\overline{T}) \quad \text{(Eq. A9)}$$

The number of standard deviations to give the cumulative probability P that H/T is less than q $\overline{H}/\overline{T}$ may be read from any normal distribution table, and factor q is calculated from:

$$q = 1 + 0.45\ n \quad \text{(Eq. A10)}$$

where:

n is the required number of standard deviations.

Equation A10 may be evaluated for various values of wave velocity probabilities P as shown in Figure A1.

P (%)	70	80	90	95	98	99
q	1.236	1.379	1.577	1.740	1.924	2.047

FIGURE A1—WAVE VELOCITY PROBABILITIES

Since wave velocity π H/T is proportional to H/T, one interpretation from Figure A1 may be, *there is a 90% probability that the next wave will have a velocity less than 1.577* π $\overline{H}/\overline{T}$. Another interpretation may be, *one wave in 100 may have a velocity of 2.047 times average velocity.*

A most important implication of Figure A1 has to do with overload potential and the fatigue considerations that could ensue. The calculation procedure outlined is intended to establish dynamic rated loads that will not, together with offlead and sidelead, cause stresses that exceed those permitted under static loading. The probability value used implies that 10% of the lifts could involve wave velocities higher than those provided for. However, when the joint probability of the coexistence of 100% rated load with full offlead and full sidelead is considered, the overload potential is far less than 10%.

It is most unlikely that all adverse factors will occur simultaneously, and it should not be construed that 10% of the lifts will exceed permitted stress levels if dynamic ratings are adhered to.

For more complete discourse on the derivation of the equations discussed herein, see References 2.1.(2) and 2.1.(3).

The sidelead and offleads shown in Figure 1 were determined after consideration of vessel surge and sway. The vessel surge and sway for the work boat were calculated using the ship motion computer program discussed in Reference 2.1.(4).

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