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Hydraulic Excavator Lift Capacity Calculation and Test Procedure

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Submitted for Recognition as an American National Standard

SAE The Engineering Society For Advancing Mobility Land Sea Air and Space ®
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OFF-HIGHWAY MACHINERY STANDARD

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Ø HYDRAULIC EXCAVATOR LIFT CAPACITY CALCULATION AND TEST PROCEDURE

1. PURPOSE:

This standard provides a uniform method to calculate and a test procedure to validate hydraulic excavator lift capacity. It establishes definitions and specifies machine conditions for calculations in Section 1 and identifies the validating test procedure in Section 2.

2. SCOPE:

This standard applies to hydraulic excavators as defined in SAE J1057 and J1193.

3. DEFINITIONS:

3.1 Load: The external weight including the weight of the attaching equipment kilograms (pounds) applied at the lift point.

3.2 Lift Point: The location on the bucket or bucket linkage, specified by the manufacturer, to which a load may be attached for lifting purposes. If more than one lift point is provided, the one having greatest lift point radius shall be used for determining lift capacities. The lift point location(s) shall be identified on the rated lift capacity chart. See Figs. 1 and 2.

3.3 Lift Point Height: The vertical distance from the ground reference plane to the lift point. See Figs. 1 and 2.

3.4 Lift Point Radius: The horizontal distance from the axis of rotation to the vertical hoist line or tackle. See Figs. 1 and 2.

3.5 Rated Lift Bucket Position: The bucket attitude having a vertical line projected from the lift point, tangent, or as near tangent as the linkage allows, to the backside of the bucket. When the bucket linkage does not allow the load line to be tangent, the line may:

a. Hang free of the back of the bucket if the bucket cylinder is fully extended and the load line is adequately retained to the lift point. See Fig. 1.

b. Wrap the back of the bucket if the bucket cylinder is fully retracted and the load line of tackle does not come in contact with any sharp projection or edge. See Fig. 2.

3.6 Balance Point: When the moment acting to overturn the machine at a specific linkage position is equal to the moment of the machine available to resist overturning.

3.7 Tipping Load: When the load supported from the lift point at a specific linkage position achieves the balance point.

3.8 Rated Tipping Load: 75% of the tipping load at any specific linkage position.

3.9 Hydraulic Pressure:

a. Working Circuit Pressure - That nominal pressure applied to the specific circuit by the pump(s).

b. Holding Circuit Pressure - The maximum static pressure in a specific circuit, limited by a relief valve at a flow no greater than 10% of rated circuit flow.

3.10 Hydraulic Lift Capacity: The load that can be lifted from the lift point by the boom or arm cylinders with the bucket in the rated lift bucket position (paragraph 3.5) and the excavator physically restrained from tipping.

3.10.1 Boom Hydraulic Lift Capacity: The load that can be lifted by applying working circuit pressure to the boom cylinder(s) without exceeding holding circuit pressure in any other circuit.

3.10.2 Arm Hydraulic Lift Capacity: The load that can be lifted by applying working circuit pressure to the arm cylinder(s) without exceeding holding circuit pressure in any other circuit.

3.11 Rated Hydraulic Lift Capacity: 87% of the lesser of boom or arm hydraulic lift capacity at a specific linkage position (identified by lift point height and lift point radius).

3.12 Rated Lift Capacity: The smaller of either rated tipping load (3.8) or rated hydraulic lift capacity (3.11).

3.13 Maximum Radius Lift Capacity: The lift capacity determined in the same manner as rated lift capacity except that the bucket is positioned with the cutting edge vertical or as near vertical as the linkage allows. See Fig. 2. (Note: The hoist line or tackle is permitted to wrap smoothly round but should not be allowed to come in contact with any sharp projection on the back of the bucket.)

4. SECTION 1 - LIFT CAPACITY CALCULATIONS:

4.1 Tipping Load Calculations: A series of calculations at various linkage positions to determine the force generated by the boom and arm hydraulic lift capacities (as defined in 3.10.1 and 3.10.2) that achieves the balance point. Sufficient excavator linkage position calculations above and below the ground reference plane, over the ends and over the sides in the least stable position with the bucket in the rated lift bucket position must be obtained to develop a lift capacity chart. See Fig. 11.

Note: Tipping load calculations will use a "balance point" definition that includes the total moment of the machine available to resist overturning to achieve consistency in calculations. Previous definitions for tipping load such as:

"when all of the rollers leave the track"
"when the rollers on the opposite side leave the track"
"when one wheel leaves the ground"

shall not be used. These definitions are more test related, and since all tests measure the maximum overturning resisting force, the definitions should not be required.

4.1.1 Machine Configuration for Calculations:

4.1.1.1 Operating Mass: The mass of the base machine with standard equipment, or equipment specified by the manufacturer, operator (75 kg/165 lb), full fuel tank, full lubricating, hydraulic and cooling systems, and where provided, with empty bucket. This same mass is to be used for tool forces, range diagrams, and other standard specifications.

4.1.1.2 Permissible Variations: Because of the large number of attachment options and machine variations available, the manufacturer must publish revised lift capacity charts if these variations would decrease the machine rated lift capacity by more than 5%.

4.1.1.3 Lift capacities shall be calculated with the machine on a firm level supporting surface.

4.1.2 Calculations for the Balance Point for the End Tipping Line:

4.1.2.1 The tipping line to be used for balance point calculations over the front/rear of machines with crawler undercarriages shall be the centerline of support idlers or sprockets. See Fig. 4. (Note: The linkage shall be positioned over the front/rear in the least stable position for these calculations.)

4.1.2.2 The tipping line to be used for calculations over front/rear of machine with rubber-tired carrier mountings shall be the axle centerline, bogie axle centerline, or centerline of outrigger pad as shown in Figs. 5, 6, and 7.

4.1.2.3 Calculations shall be developed once with permanently mounted stabilizing devices in the retracted position and once with them applied in the most favorable position.

4.1.3 Calculations for Balance Point Point for Side Tipping Line:

4.1.3.1 The tipping line to be used for side tipping balance point calculations on machines with crawler undercarriages shall be defined by the pivot points between support rollers and track elements (such as links or guides) as shown in Fig. 3.

4.1.3.2 The tipping line to be used for calculations for the balance point of machines with rubber-tired carrier mountings shall be the center line of the tires at ground plane or midpoint between dual tires at ground reference plane when so equipped. See Figs. 3, 5, 6, and 7.

4.1.3.3 The tipping line for an excavator with oscillating axle shall be a line through the axle pivot point and one other rigid support point. See Figs. 3 and 7.

4.1.3.4 If ratings are based upon a blocked axle, this condition must be clearly defined on the lift capacity charts and diagrams. Other tipping lines used for side tipping calculations may pass through outrigger pads. See Figs. 3, 5, 6, and 7.

4.1.3.5 When defined through pivoted outrigger supports, the tipping line shall be at ground reference plane directly below the centerlines of the support-to-pad pivots. When defined through rigid outrigger pads, they shall be at ground reference plane through centroids of the pad ground contact areas. See Figs. 6 and 7.

4.2 Hydraulic Lift Capacity Calculations: A series of calculations at various linkage positions to determine the load that can be lifted at the lift point with the force generated by the boom and arm hydraulic lift capacity (as defined in 3.10.1 and 3.10.2). Sufficient excavator linkage position calculations shall be made above and below the ground reference plane to help develop a lift capacity chart. See Fig. 11.

5. SECTION 2 - VERIFICATION TESTING:

5.1 Test Site:

5.1.1 Dead Weight Test Site (Immovable Weight): A dead weight test site shall consist of a firm and level horizontal surface arranged so that a load cell can be connected between the lift point and the dead weight. The dead weight can be either a horizontal rail (Fig. 8) with a movable attachment device or a fixed point dead weight with the excavator moving to obtain the various linkage positions (Fig. 9).

5.1.2 Live Weight Test Site (Movable Weight): A live weight test site shall consist of a firm and level horizontal surface arranged so that a weight attached to the lift point can be moved without obstructing the limit of the excavator's tipping load or hydraulic capacity. The known mass of the movable weight shall replace the load cell during this test. See Fig. 10 for a typical test arrangement. The live weight shall be kept within 0.5 m/20 in of the ground reference plane from which it is raised by choosing an appropriate length load line.

5.2 Test Equipment:

5.2.1 A load cell of sufficient capacity (if a dead weight test site is used).

5.2.2 A weight of sufficient known mass (if a live weight test site is used).

5.2.3 A means of measuring the lift point position relative to the ground reference plane and the axis of rotation of the excavator.

5.2.4 A means of determining when the load line is tangent to the bucket at the lift point. When using the dead weight system, a means of indicating perpendicularity between the load line and the ground reference plane.

5.2.5 Means to monitor all hydraulic circuits which will be under pressure during the actual lift capacity verification.

5.2.6 Instrumentation accuracy should be ±2.5%.

5.3 Test Procedure:

5.3.1 The excavator shall be thoroughly cleaned and in normal working condition with fuel tanks filled to capacity and all other fluids at their prescribed levels.

5.3.2 The excavator shall be fitted with working equipment and counterweight as specified by the manufacturer for the calculated lift capacity chart being verified.

5.3.3 The hydraulic pressure shall be checked. This will include the working circuit pressure and the holding circuit pressure to ensure that the system is set at the manufacturer's recommended nominal published value. The system shall be at normal operating temperature for the test.

5.3.4 The test personnel are required to conduct the tests in a safe manner and should be acquainted with all operating instructions, operator's manuals, safety rules, etc., furnished by the manufacturer of the excavator and of the test equipment.

5.3.5 A means shall be provided for preventing the excavator from overturning during the test procedure.

5.4 Tests:

5.4.1 Tipping Load Measurements: Measurements shall be made at specific linkage positions to determine the verifying force values that achieve the balance point.

5.4.1.1 The tests for rubber-tired machines shall be conducted once with permanently mounted stabilizing devices in the retracted position and once with the permanently mounted stabilizing devices applied in the most favorable position.

5.4.1.2 Live Weight Test: No provisions are made to utilize a live weight method to determine the tipping load because of inherent dangers involved. However, the live weight will generally be of sufficient mass to allow it to serve as a dead weight at linkage positions approaching maximum reach. This will allow an adequate verification test to be conducted at facilities without a dead weight test system.

5.4.2 Hydraulic Lift Capacity Measurements: Measurements at specific linkage positions to verify lift capacity calculations.

5.4.2.1 Live Weight Test: The hydraulic lift capacity is the maximum measured force obtained by adjusting the linkage upward/outward until holding circuit pressure is reached in one circuit. The live weight shall be kept within 0.5 m/20 in of the ground reference plane by choosing an appropriate length load line. See Fig. 10.

5.4.3 The number of verifying points obtained for crawler and rubber-tired machines shall consist of a minimum of the following four points:

5.4.3.1 Tipping over the end and side. (Position the linkage over the end and the side to obtain tipping load points.)

5.4.3.2 Hydraulically limited lift capacity above and below the ground reference plane on which the excavator is located.

5.5 Verification Test Results: Measured lift forces, lift point heights and lift point radii for tipping loads and hydraulic lift capacities shall be recorded.

6. VALIDATION OF CALCULATED VALUES:

Lift capacity calculations shall be developed to compare to the measured values listed in 5.5. The measured values shall be a minimum of 95% of the calculated values. If not, the rated lift capacity chart shall be adjusted based on the correction factor determined by the measured values.

7. RATED LIFT CAPACITY CHART:

7.1 The rated lift capacity chart shall show the rated lift capacity at specific lift points (3.12). The chart shall note if the values are limited by hydraulic lift capacity.

7.2 The format for the rated lift capacity chart is shown in Fig. 11.

7.3 Rated lift capacity values shall be tabulated for intersections of the lift point with 1.5 m/5 ft or 2 m/10 ft vertically and horizontally spaced grid placed over the excavator's working range with bucket attitude maintained in the rated lift bucket position. The maximum and minimum lift radii may also be included even though not located in grid point. The origin of the grid shall be at the intersection of the ground reference plane and axis of rotation.

7.4 A rated lift capacity chart shall be mounted inside the excavator cab and legible from the control position.

The phi (Ø) symbol is for the convenience of the user in locating areas where technical revisions have been made to the previous issue of the report. If the symbol is next to the report title, it indicates a complete revision of the report.

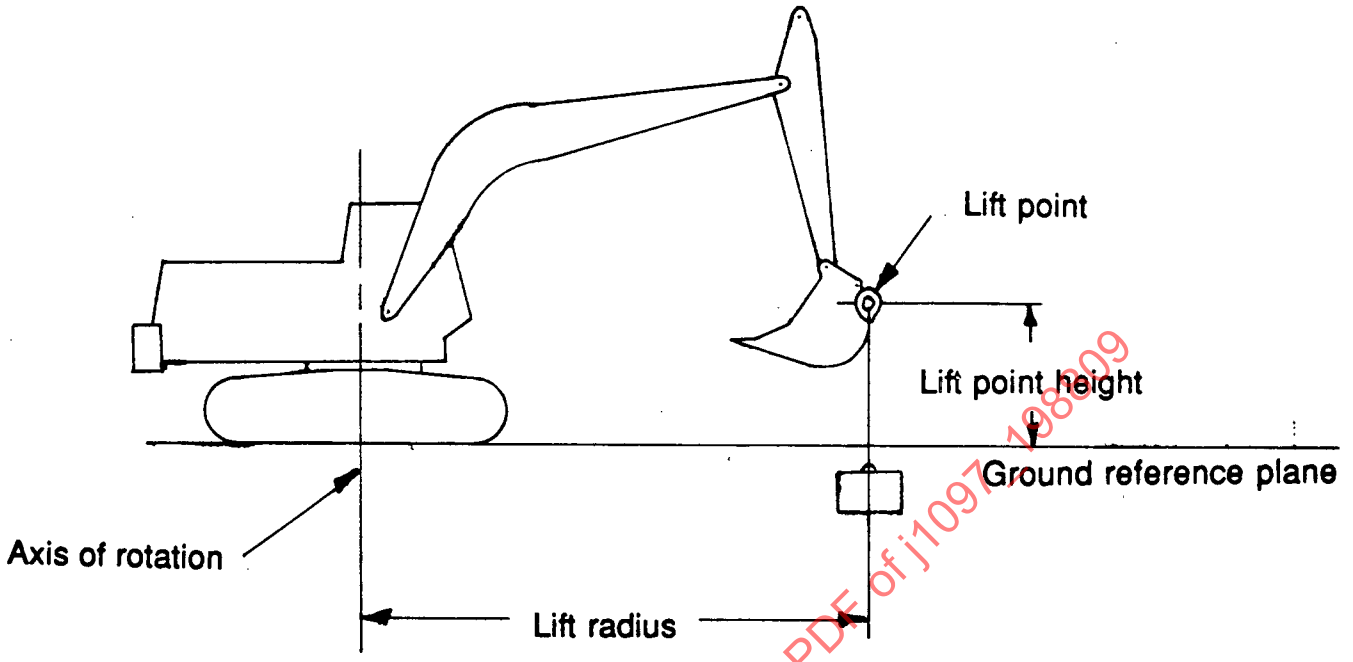

FIGURE 1

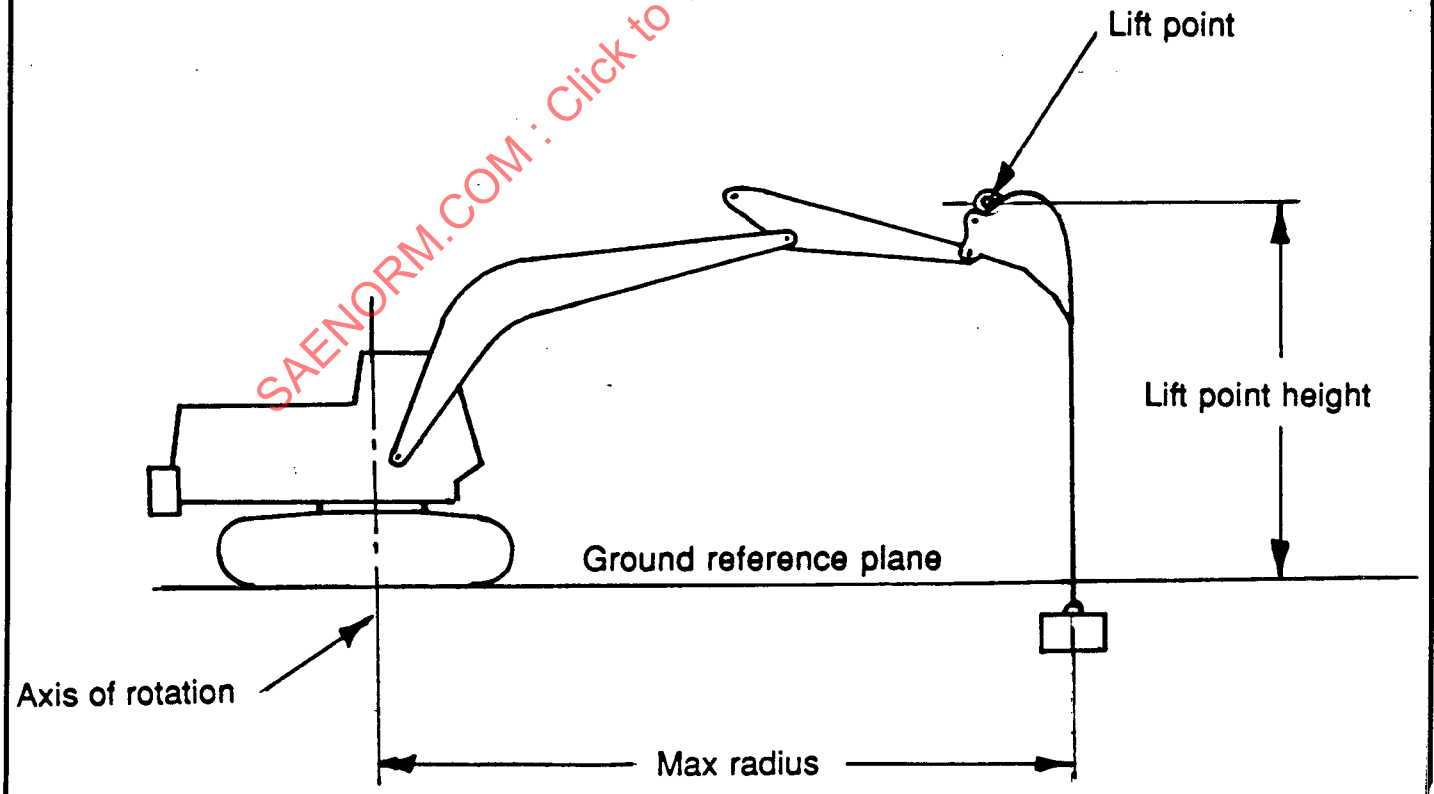

FIGURE 2

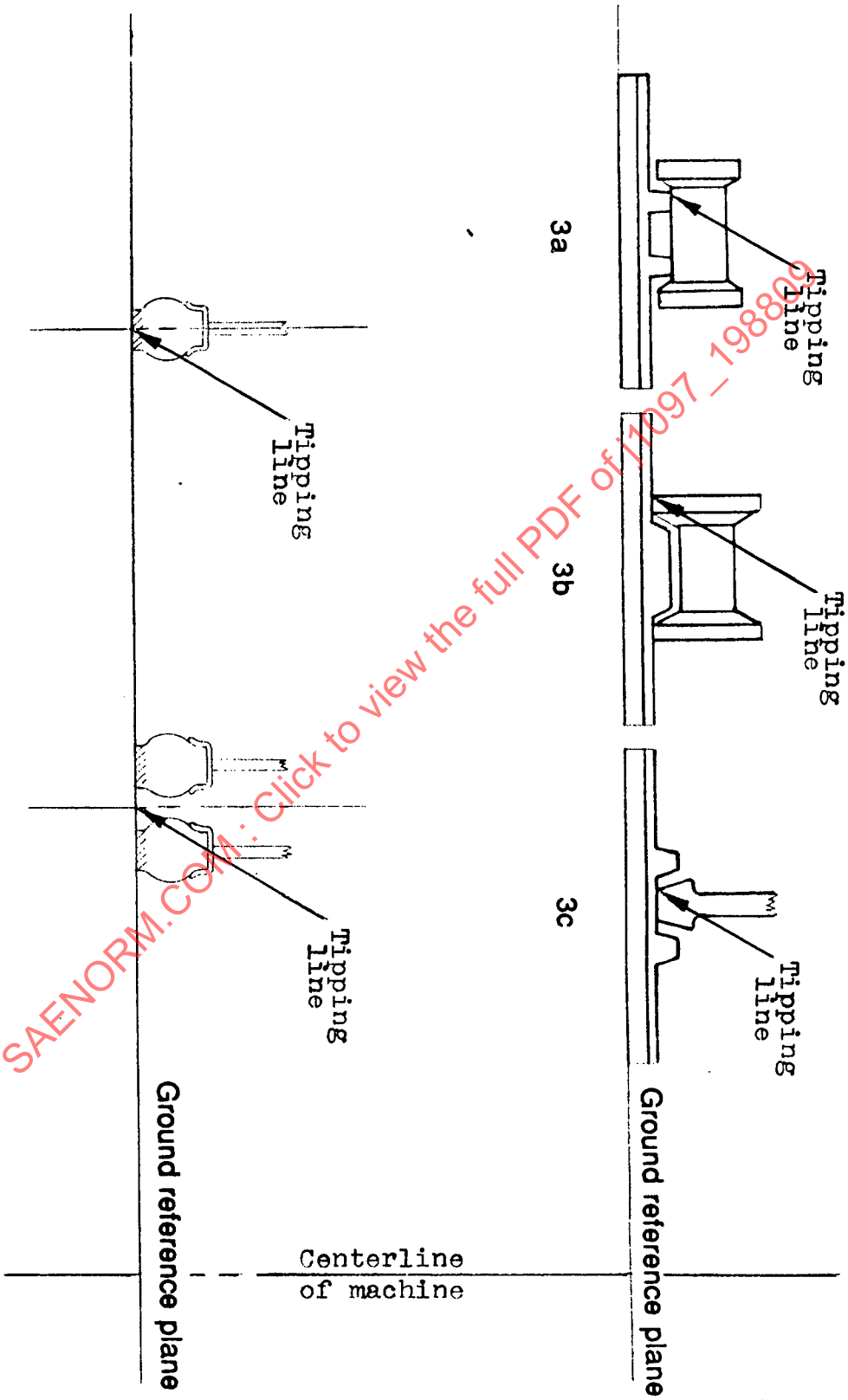

FIGURE 3

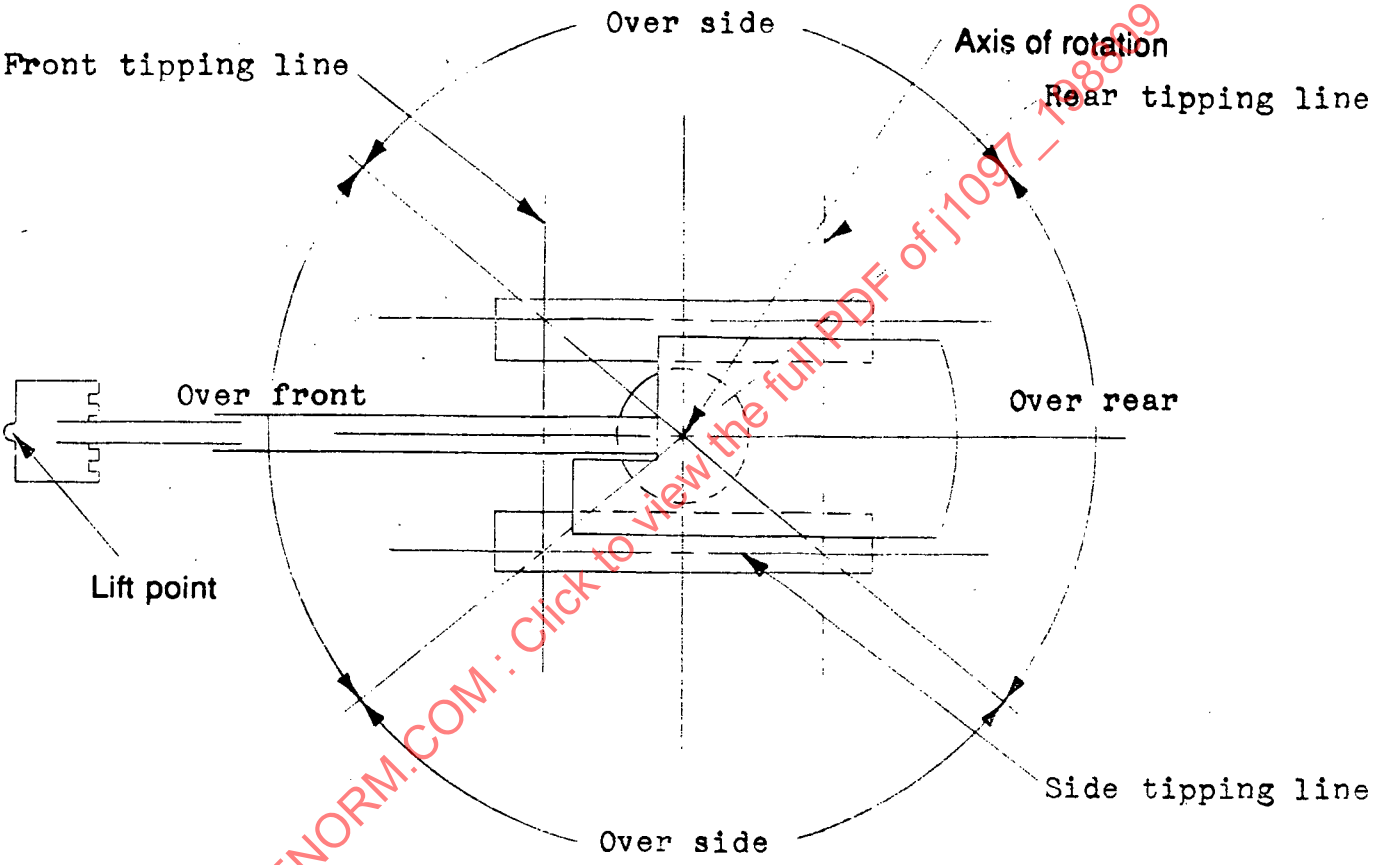

FIGURE 4 - Crawler Undercarriage

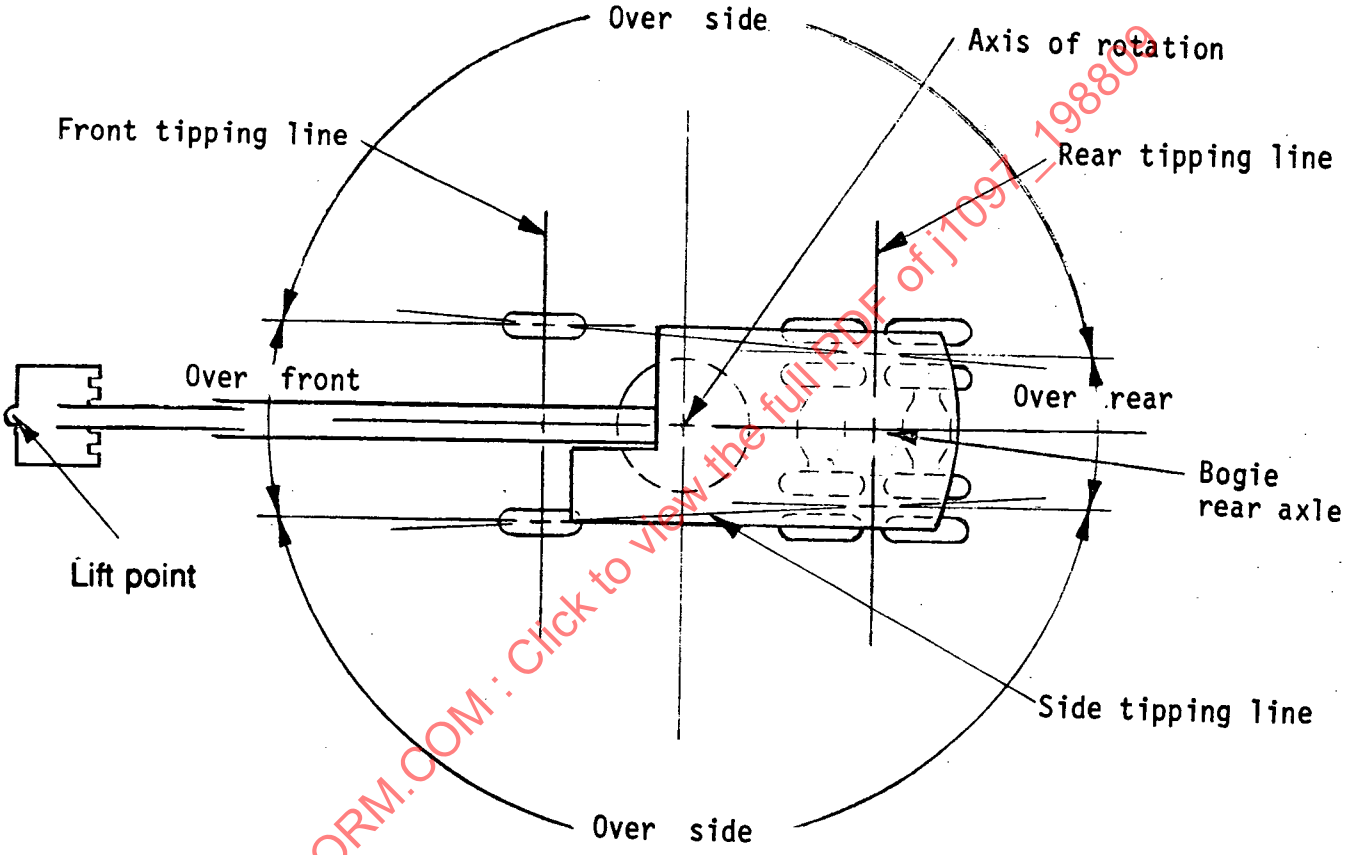

FIGURE 5 - Rubber-Tired Carrier, Rigid Axles

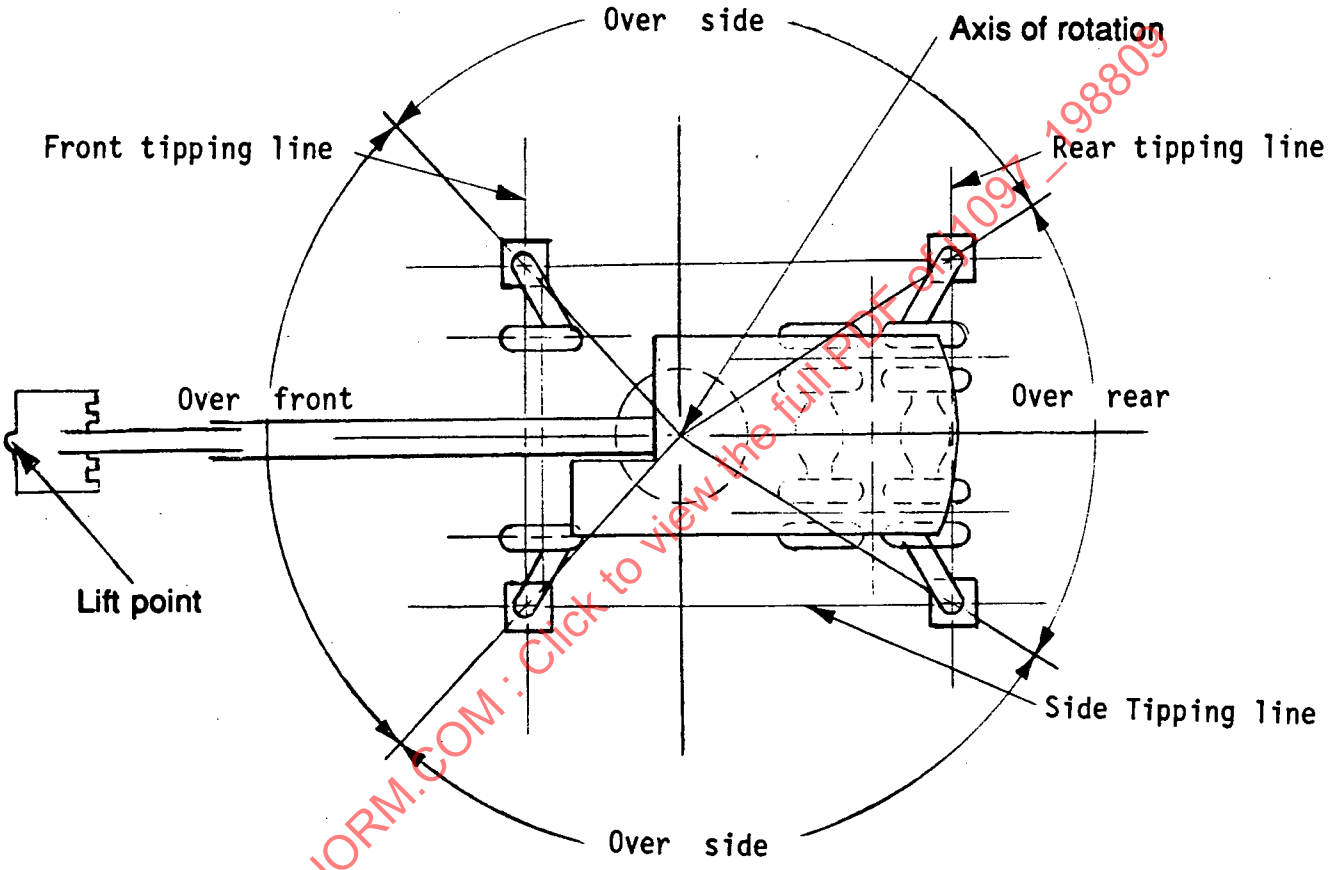

FIGURE 6 - Rubber-Tired Carrier, Front & Rear Outriggers

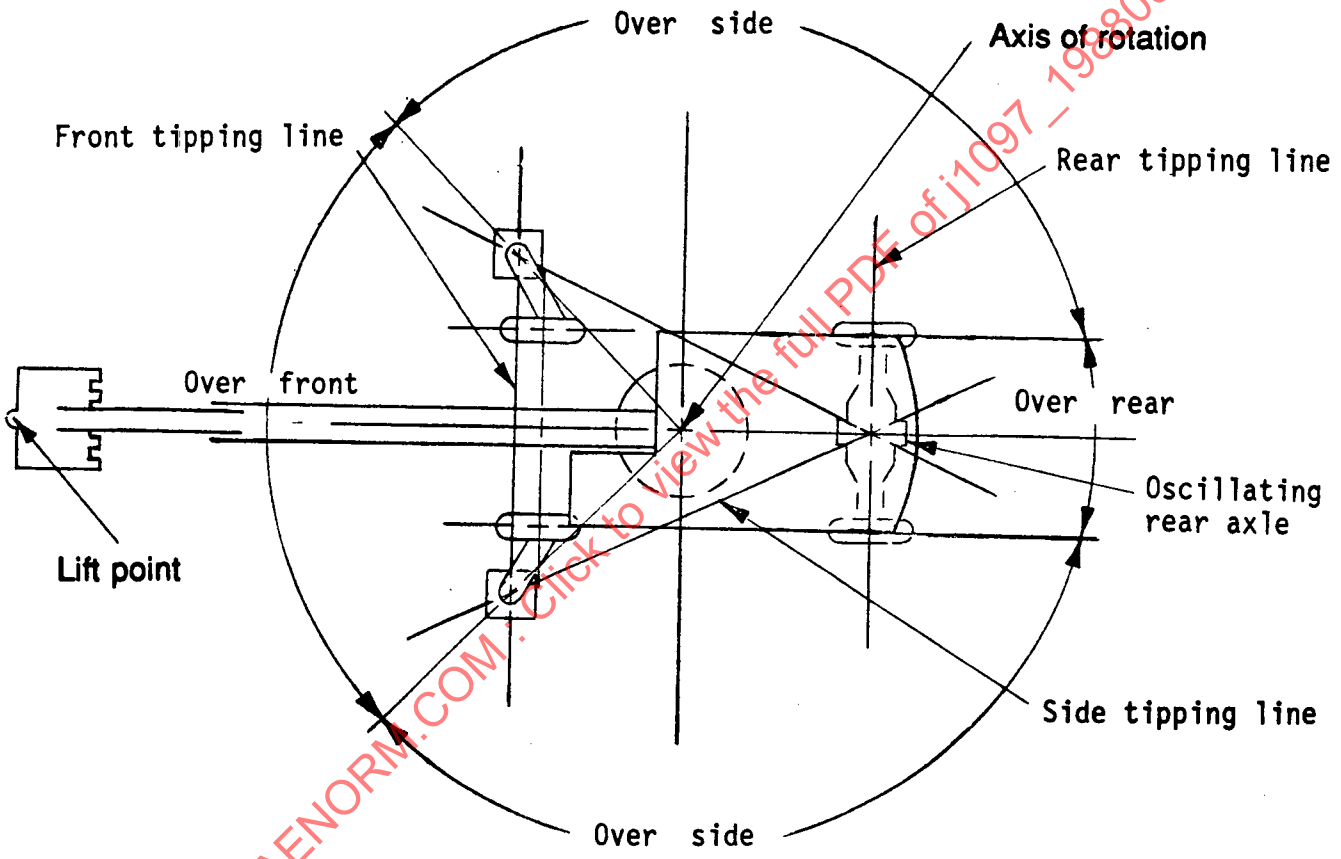

FIGURE 7 - Rubber-Tired Carrier, Front Outriggers, Rear Oscillating Axle

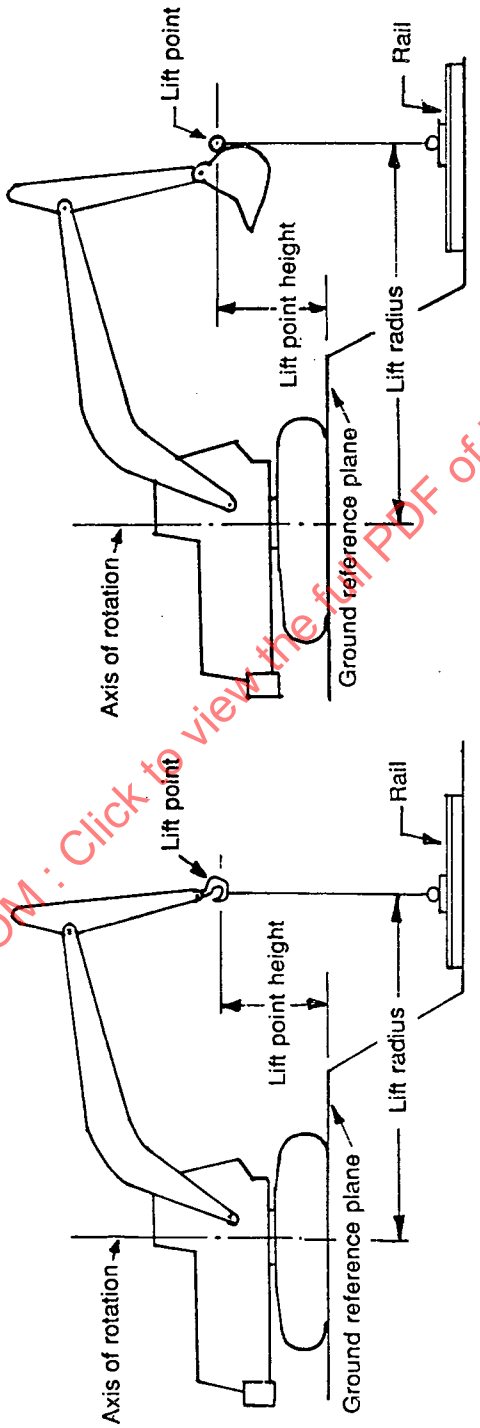

FIGURE 8 - Self Aligning Lift Facility

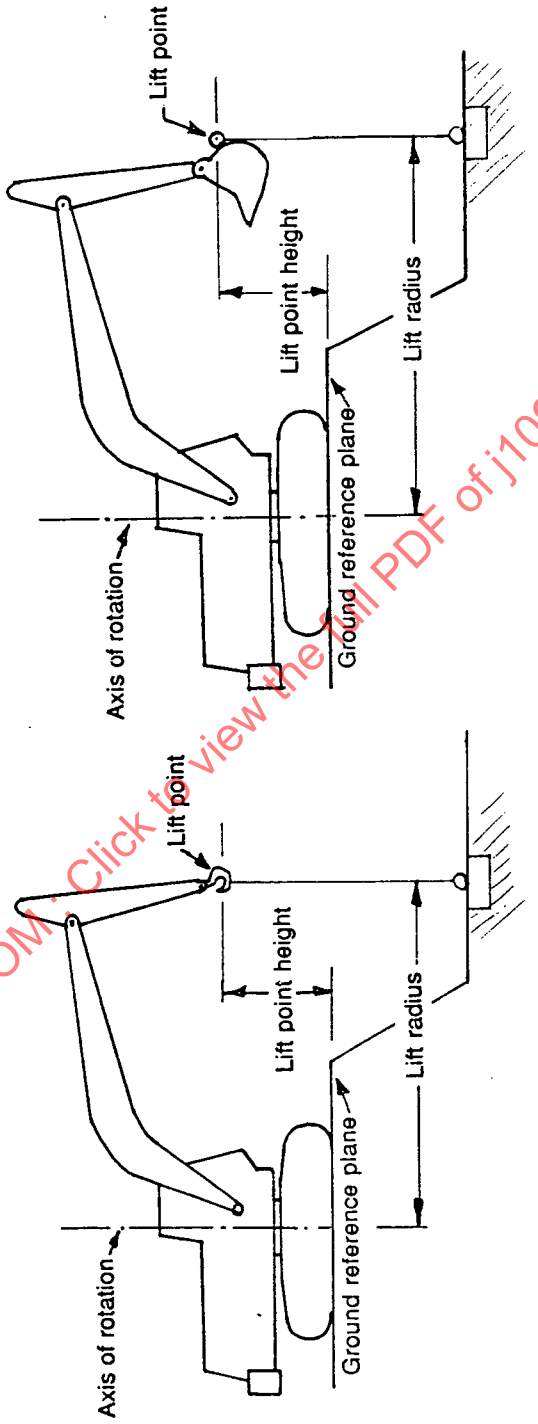

FIGURE 9 - Fixed Dead Weight