Appendix A – Stability of Powered Industrial Trucks

A-1. **Definitions**

The following definitions help to explain the principle of stability:

Center of gravity: the point on an object at which all the object's weight is concentrated. For symmetrical loads, the center of gravity is in the middle of the load.

Counterweight: the weight that is built into the PIT's basic structure and is used to offset the load's weight and to maximize the vehicle's resistance to tipping over.

Fulcrum: the PIT's axis of rotation when it tips over.

Grade: the slope of a surface, which is usually measured as the number of feet of rise or fall over a hundred-foot horizontal distance (the slope is expressed as a percent).

Lateral stability: a PIT's resistance to overturning sideways.

Line of action: an imaginary vertical line through an object's center of gravity.

Load center: the horizontal distance from the load's edge (or the fork's or other attachment's vertical face) to the line of action through the load's center of gravity.

Longitudinal stability: the PIT's resistance to overturning forward or rearward.

Moment: the product of the object's weight times the distance from a fixed point (usually the fulcrum). In the case of a powered industrial PIT, the distance is measured from the point at which the PIT will tip over to the object's line of action. The distance is always measured perpendicular to the line of action.

Track: the distance between the wheels on the same axle of the PIT.

Wheelbase: the distance between the centerline of the vehicle's front and rear wheels.

A-2. **General**

A-2.1. Determining the stability of a PIT is simple once a few basic principles are understood: the PIT's wheelbase, track and height; the load weight distribution; and the counterweight location (if so equipped).

A-3. **Basic Principles**

A-3.1. Whether an object is stable depends on the object's moment at one end of a system being greater than, equal to, or smaller than the object's moment at the system's other end. This principle can be seen in the way a seesaw or teeter-totter works, that is, if the product of the load and distance from the fulcrum (moment) is equal to the moment at the device's other end, the device is balanced, and it will not move. However, if there is a greater moment at one end of the device, the device will try to move downward at the end with the greater moment.

A-3.2. The longitudinal stability of a counterbalanced powered industrial PIT depends on the vehicle's moment and the load's moment. In other words, if the mathematical product of the load moment (the distance from the front wheels, the approximate point at which the vehicle would tip forward) to the load

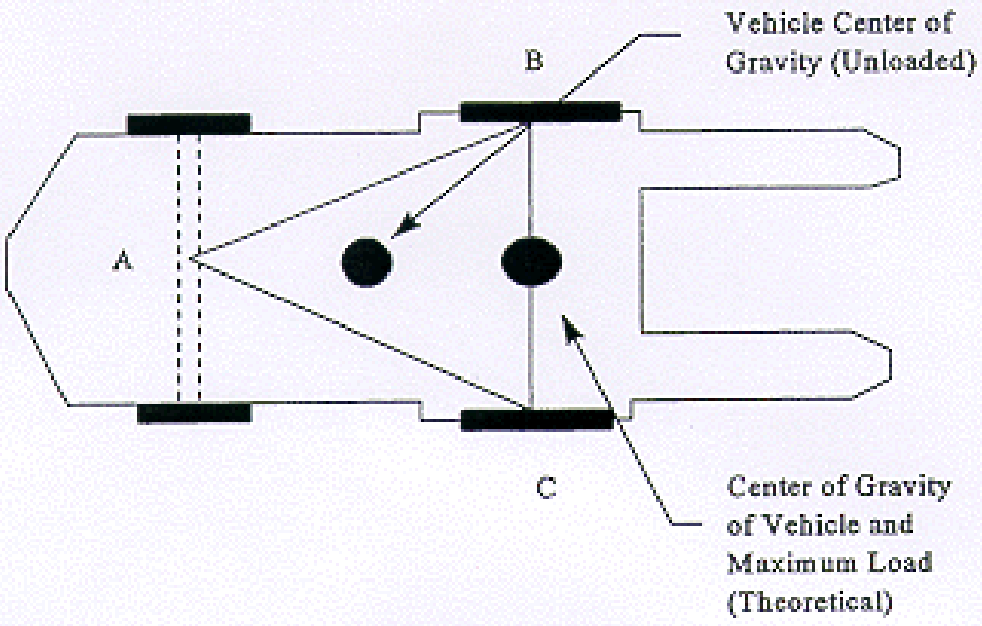
center of gravity times the load's weight is less than the vehicle's moment, the system is balanced and will not tip forward. However, if the load's moment is greater than the vehicle's moment, the greater load-moment will force the PIT to tip forward.

A-4. **The Stability Triangle**

A-4.1. The “Stability Triangle”, used in most stability discussions, demonstrates stability simply.

A-4.2. Almost all counterbalanced PITs have a three-point suspension system, that is, the vehicle is supported at three points. This is true even if the vehicle has four wheels. The PIT's steer axle is attached to the PIT by a pivot pin in the axle's center. When the points relate to imaginary lines, this three-point support forms a triangle called the stability triangle. Figure 1 depicts the stability triangle.

Figure 1.



Notes:

1. When the vehicle is loaded, the combined center of gravity (CG) shifts toward line B-C. Theoretically the maximum load will result in the CG at the line B-C. In actual practice, the combined CG should never be at line B-C.
2. The addition of additional counterweight will cause the truck CG to shift toward point A and result in a truck that is less stable laterally.

Photo from the Occupational Health and Safety Administration (OSHA)

A-4.3. When the vehicle's line of action, or load center, falls within the stability triangle, the vehicle is stable and will not tip over. However, when the vehicle's line of action or the vehicle/ load combination falls outside the stability triangle, the vehicle is unstable and may tip over. (See Figure 2.)

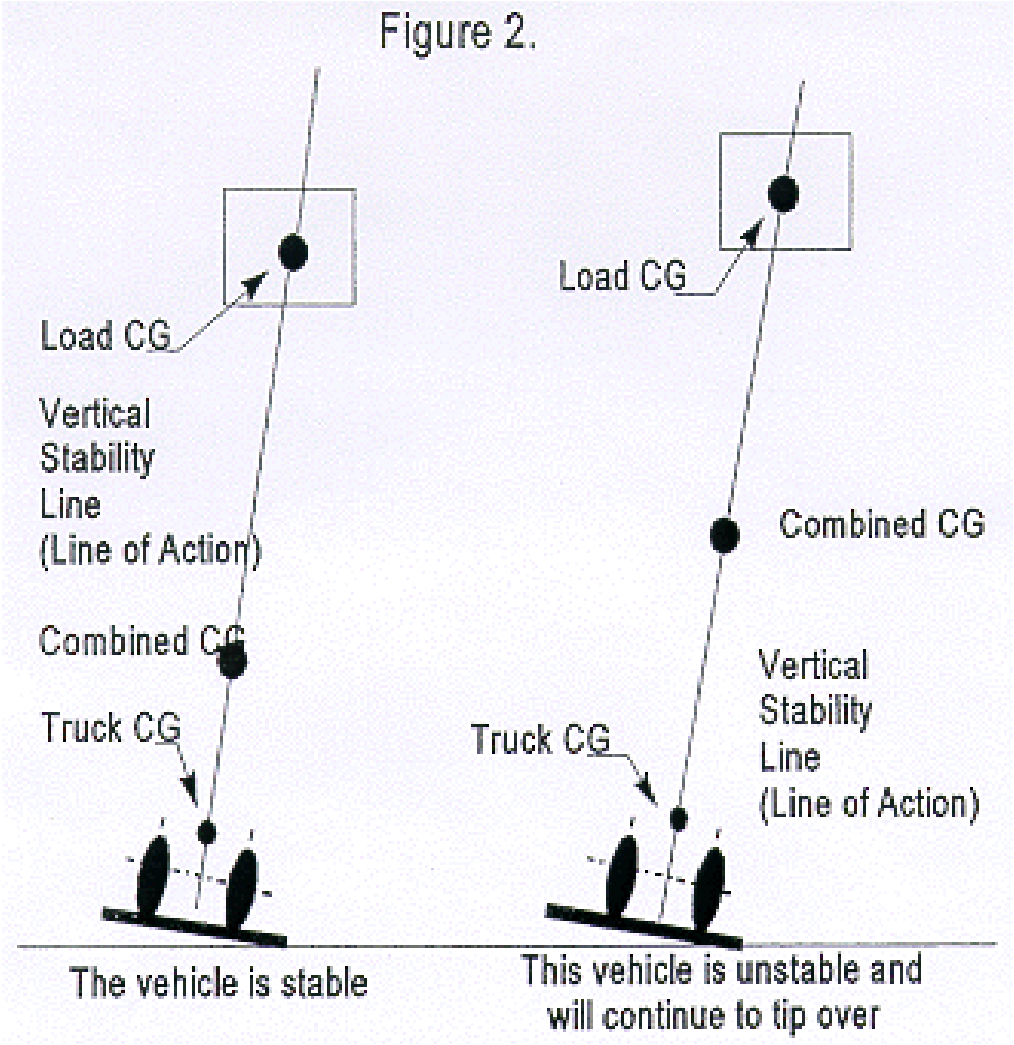


Photo from the Occupational Health and Safety Administration (OSHA)

A-5. **Longitudinal Stability**

A-5.1. The axis of rotation when a PIT tips forward is the front wheels' points of contact with the pavement. When a PIT tips forward, the PIT will rotate about this line.

A-5.2. To determine the maximum safe load-moment, the PIT manufacturer normally rates the PIT at a maximum load at a given distance from the front face of the forks. The specified distance from the front face of the forks to the line of action of the load is commonly called the load center.

A-5.3. Although the true load-moment distance is measured from the front wheels, this distance is greater than the distance from the front face of the forks. Calculating the maximum allowable load-moment using the load-center distance always provides a lower load-moment than the PIT was designed to handle.

A-6. **Lateral Stability**

A-6.1. The PIT’s lateral stability is determined by the line of action's position (a vertical line that passes through the combined PIT's and load's center of gravity) relative to the stability triangle. When the PIT is

not loaded, the PIT"s center of gravity location is the only factor to be considered in determining the PIT's stability.

A-6.2. Factors that affect the PIT's lateral stability include the load's placement on the PIT, the height of the load above the surface on which the vehicle is operating, and the vehicle's degree of lean.

A-7. **Dynamic Stability**

A-7.1. The weight's transfer and the resultant shift in the center of gravity due to the dynamic forces created when the PIT is moving, braking, cornering, lifting, tilting, and lowering loads, etc., are important stability considerations.

A-7.2. When determining whether a load can be safely handled, the operator should exercise extra caution when handling loads that cause the PIT to approach its maximum design characteristics.