Manual of Petroleum Measurement Standards Chapter 2—Tank Calibration

Section 2.2B—Calibration of Upright Cylindrical Tanks Using the Optical Reference Line Method

ASTM D4738-88

ANSI/API MPMS CHAPTER 2.2B
FIRST EDITION, MARCH 1989

REAFFIRMED, JANUARY 2013

AMERICAN PETROLEUM INSTITUTE

Manual of Petroleum Measurement Standards Chapter 2—Tank Calibration

Section 2.2B—Calibration of Upright Cylindrical Tanks Using the Optical Reference Line Method

Measurement Coordination

ASTM D4738-88

ANSI/API MPMS CHAPTER 2.2B
FIRST EDITION, MARCH 1989

REAFFIRMED, JANUARY 2013

energy API
AMERICAN PETROLEUM INSTITUTE

Approved American National Standard ANSI

ASTM INTERNATIONAL
Standards Worldwide

SPECIAL NOTES

1. API PUBLICATIONS NECESSARILY ADDRESS PROBLEMS OF A GENERAL NATURE. WITH RESPECT TO PARTICULAR CIRCUMSTANCES, LOCAL, STATE, AND FEDERAL LAWS AND REGULATIONS SHOULD BE REVIEWED.

2. API IS NOT UNDERTAKING TO MEET THE DUTIES OF EMPLOYERS, MANUFACTURERS, OR SUPPLIERS TO WARN AND PROPERLY TRAIN AND EQUIP THEIR EMPLOYEES, AND OTHERS EXPOSED, CONCERNING HEALTH AND SAFETY RISKS AND PRECAUTIONS, NOR UNDERTAKING THEIR OBLIGATIONS UNDER LOCAL, STATE, OR FEDERAL LAWS.

3. INFORMATION CONCERNING SAFETY AND HEALTH RISKS AND PROPER PRECAUTIONS WITH RESPECT TO PARTICULAR MATERIALS AND CONDITIONS SHOULD BE OBTAINED FROM THE EMPLOYER, THE MANUFACTURER OR SUPPLIER OF THAT MATERIAL, OR THE MATERIAL SAFETY DATA SHEET.

4. NOTHING CONTAINED IN ANY API PUBLICATION IS TO BE CONSTRUED AS GRANTING ANY RIGHT, BY IMPLICATION OR OTHERWISE, FOR THE MANUFACTURE, SALE, OR USE OF ANY METHOD, APPARATUS, OR PRODUCT COVERED BY LETTERS PATENT. NEITHER SHOULD ANYTHING CONTAINED IN THE PUBLICATION BE CONSTRUED AS INSURING ANYONE AGAINST LIABILITY FOR INFRINGEMENT OF LETTERS PATENT.

5. GENERALLY, API STANDARDS ARE REVIEWED AND REVISED, REAFFIRMED, OR WITHDRAWN AT LEAST EVERY FIVE YEARS. SOMETIMES A ONE-TIME EXTENSION OF UP TO TWO YEARS WILL BE ADDED TO THIS REVIEW CYCLE. THIS PUBLICATION WILL NO LONGER BE IN EFFECT FIVE YEARS AFTER ITS PUBLICATION DATE AS AN OPERATIVE API STANDARD OR, WHERE AN EXTENSION HAS BEEN GRANTED, UPON REPUBLICATION. STATUS OF THE PUBLICATION CAN BE ASCERTAINED FROM THE API AUTHORING DEPARTMENT [TELEPHONE (202) 682-8000]. A CATALOG OF API PUBLICATIONS AND MATERIALS IS PUBLISHED ANNUALLY AND UPDATED QUARTERLY BY API, 1220 L STREET, N.W., WASHINGTON, D.C. 20005.

FOREWORD

Chapter 2.2B of the *Manual of Petroleum Measurement Standards* should be used in conjunction with API Standard 2550, *Measurement and Calibration of Upright Cylindrical Tanks*. Standard 2550 is currently being revised and will eventually be published as Chapter 2.2A of the *Manual of Petroleum Measurement Standards*.

API publications may be used by anyone desiring to do so. Every effort has been made by the Institute to assure the accuracy and reliability of the data contained in them; however, the Institute makes no representation, warranty, or guarantee in connection with this publication and hereby expressly disclaims any liability or responsibility for loss or damage resulting from its use or for the violation of any federal, state, or municipal regulation with which this publication may conflict.

Suggested revisions are invited and should be submitted to the director of the Measurement Coordination Department, American Petroleum Institute, 1220 L Street, N.W., Washington, D.C. 20005.

API/ASTM JOINT COMMITTEE ON STATIC PETROLEUM MEASUREMENT
WORKING GROUP ON TANK CALIBRATION

S. Sivaraman, Chairman
Exxon Research & Engineering Company
Florham Park, New Jersey

S. O. Aboulmagd
Arab Petroleum Pipelines Company (SUMED)
Alexandria, Arab Republic of Egypt

F. R. Conway
SGS Redwood Fluid and Gas Measurement Services
Deer Park, Texas

W. E. Dows III
Marathon Petroleum Company
Robinson, Illinois

V. J. Fabricatore
SGS Control Services Inc.
Redwood Petroleum and Petrochemical Division
Carteret, New Jersey

J. M. Johnson, Secretary
American Petroleum Institute
Washington, D.C.

H. S. Moore III
E. W. Saybolt & Company, Inc.
Pasadena, Texas

R. C. Morrell
Marine Consultant
Bartlesville, Oklahoma

D. Sauer
Charles Martin/Inspectorate
Pasadena, Texas

R. M. Sheppard
Buckeye Pipe Line Company
Emmaus, Pennsylvania

W. A. Thorpe
Petroleum Loss Prevention Company
Chester, New Jersey

W. K. Tkachuk
Shell Oil Company
Houston, Texas

B. J. Hampton, Technical Advisor
Citgo Petroleum Company
Lake Charles, Louisiana

CONTENTS

Chapter 2—Tank Calibration

SECTION 2B—CALIBRATION OF UPRIGHT CYLINDRICAL TANKS USING THE OPTICAL REFERENCE LINE METHOD

2.2B.1 Introduction

The optical reference line method (ORLM) is an alternative method to the manual tank strapping method (MTSM) for determining tank diameter. The primary difference between the ORLM and the MTSM is the procedure for determining tank diameter at shell courses other than the bottom course. The ORLM provides for measuring a reference diameter on the bottom course by manual strapping and measuring deviations in tank diameter at other predetermined horizontal and vertical stations by using an optical device. The other required special measurements, procedures, methods, and analytical tools for the development of a tank capacity table are identical to those stated in API Standard 2550.

2.2B.2 Scope

This standard describes measurement and calculation procedures for determining the diameters of upright welded (lap/butt) cylindrical tanks, or vertical cylindrical tanks, with a smooth outside surface and either floating or fixed roofs. This standard should be used in conjunction with API Standard 2550.

For external application of the ORLM on insulated tanks, the insulation must be removed. The ORLM may be used on the interior of the tank; however, when the reference circumference on the bottom course is established externally, the insulation at the bottom ring must be removed. This measurement shall conform to the procedures described in API Standard 2550.

Abnormally deformed tanks (that is, tanks that are dented or have other visible signs of damage) should be repaired before any calibration is undertaken.

2.2B.3 Definitions

The definitions listed in Chapter 1 and API Standard 2550 are applicable to this chapter. In addition, the definitions given in 2.2B.3.1 through 2.2B.3.7 apply to the ORLM.

2.2B.3.1 A *horizontal station* is a preestablished location in the horizontal plane at ground level along the tank circumference.

2.2B.3.2 A *vertical station* is a preestablished location in the vertical plane along the tank shell, corresponding to a given horizontal station.

2.2B.3.3 The *offset* is the measurement observed through an optical device on the horizontal scale of a traversing magnetic trolley at each vertical station.

2.2B.3.4 The *reference offset* is the measurement observed through an optical device on the horizontal scale of a traversing magnetic trolley at the vertical station on the bottom plate.

2.2B.3.5 The *reference circumference* is the circumference of a tank measured by the MTSM on the bottom ring.

2.2B.3.6 The *reference radius* is the reference circumference divided by 2π, where $\pi = 3.141593$.

2.2B.3.7 An *optical device* is an optical plummet or a theodolite equipped with a precision level.

2.2B.4 Referenced Publications

The following publications are referenced in this chapter:

API

Std 2550 *Measurement and Calibration of Upright Cylindrical Tanks* (ANSI/ASTM D 1220)

Manual of Petroleum Measurement Standards Chapter 1, "Vocabulary"

2.2B.5 Significance

Accurate tank circumference/radius measurements are critical in determinations of liquid volume. These measurements are influenced by both random errors associated with physical measurements and systematic errors associated with the particular device and/or procedure used. The combination of random and systematic errors has an impact on the overall precision, or accuracy, of any measurement. The ORLM is as precise as the MTSM and can be used as an alternative method of determining tank circumferences or diameters (radii).

2.2B.6 Equipment

The following equipment is required for the ORLM:

a. The equipment and apparatus described in API Standard 2550.

b. An optical device mounted on a tripod or an equivalent supporting device. The device should have a perpendicular line of vision (a 90-degree line of sight) and should have leveling fixtures along three different axes. The perpendicularity of the optical ray (or vertical reference line) shall be within 1 in 20,000 over the tank height.

c. A traversing magnetic trolley with a horizontal graduated scale (0.01-foot or 1-millimeter increments) used to measure the offset at different vertical stations. The magnetic trolley shall maintain its contact with the tank shell during the entire vertical traverse. The trolley shall be in good working order, and the zero on the scale shall be located closest to the tank shell. The numerical values etched on the scale shall be readable through the optical device. The scale's accuracy shall be verified against a master tape. The combined resolution of the scale and the optical device shall enable the operator to read the offset measurement to the nearest 0.005 foot (or 1 millimeter) at any given vertical station. (Since the minimum resolution of the metric scale is 1 millimeter, this system has a better overall resolution.)

2.2B.7 Optical Calibration Procedure

The step-by-step procedure described in 2.2B.7.1 through 2.2B.7.4 should be followed to measure deviations in the radius of a vertical storage tank by means of the ORLM.

2.2B.7.1 TANK STATUS BEFORE CALIBRATION

Before calibration, the tank shall have been filled at least once at its present location with liquid at least as dense as the liquid it is expected to contain. The usual hydrostatic test (for a period of approximately 24 hours) will usually satisfy this requirement. Any hydrostatic test should be performed in accordance with applicable construction and operating standards. Where possible, the liquid in the tank should be allowed to stand still for approximately 24 hours before calibration is performed. Other requirements for tank status are specified in API Standard 2550.

2.2B.7.2 PREPARATION

The minimum number of horizontal stations shall be selected in accordance with Table 1. Additional stations, beyond the minimum specified in Table 1, may be selected, but an even number of stations shall always be chosen. The stations shall be spaced as nearly equidistantly around the tank circumference as is possible. Figure 1 shows an example of the horizontal spacing.

Table 1—Tank Diameter Versus Minimum Number of Horizontal Stations

Tank Diameter		Minimum Number of Stations
Feet	Meters	
50	15	8
100	30	12
150	50	16
200	70	20
250	85	24
300	100	32
350	120	36

Horizontal stations shall be chosen to ensure that the vertical traverse of the trolley along the shell at any given station is at least 12 inches (300 millimeters) away from the vertical weld seam. The trolley shall be traversed at each horizontal station to ensure that there is no interference with the vertical weld seam. If there is interference, the horizontal station shall be relocated to eliminate the interference.

For the bottom ring, the preferred vertical station is (a) at 20 percent of the course height below the upper horizontal weld seam and (b) within the focal range of the optical instrument. If Criteria a and b conflict, the location will be dictated by the focal range of the equipment.

For any given horizontal station, at least two vertical stations shall be established for each ring, except for the bottom ring, as shown in Figure 2.

2.2B.7.3 INSTRUMENT VERIFICATION

The optical device should be leveled along three axes at each horizontal station. The perpendicularity of the optical ray or vertical reference line shall be verified as follows:

a. The magnetic trolley shall be moved all the way to the top of the tank, and the reading on the horizontal scale attached to the trolley shall be noted. The optical device shall not be permitted to move during this measurement.

b. The optical device shall be rotated 180 degrees about the vertical axis, and the reading on the horizontal scale shall again be noted. The optical device shall not be permitted to move during this measurement. The difference between the two measurements shall be within 1 in 20,000 over the total height of the tank. For example, if the tank height is 60 feet, the difference between the two measurements should be less than 0.003 foot. However, since the minimum resolution of the scale is 0.005 foot (or 1 millimeter), the acceptable difference between the two measurements is 0.005 foot (or 1 millimeter).

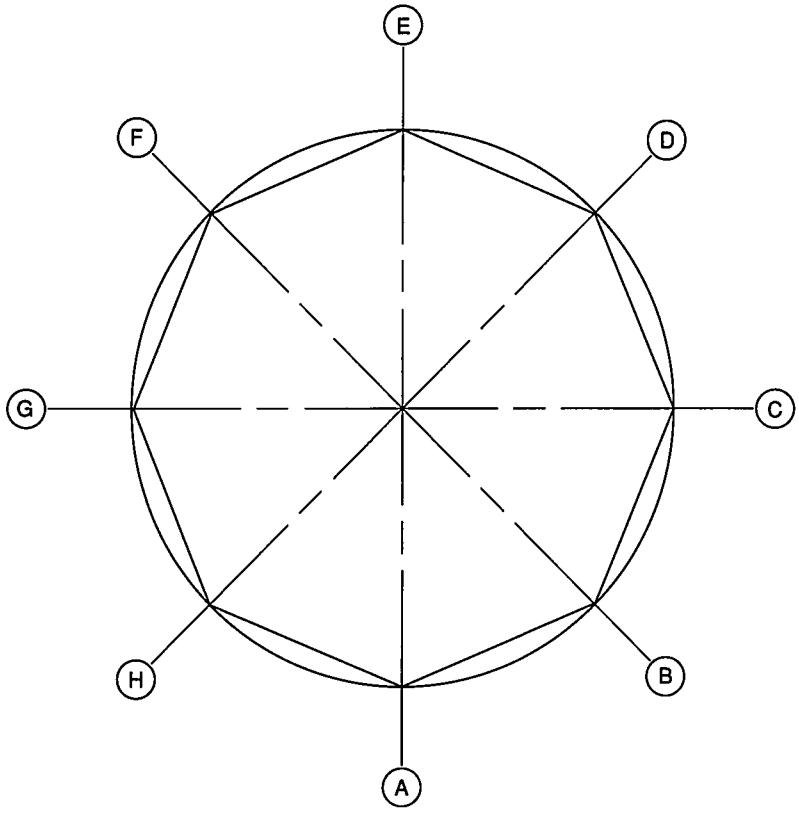


Figure 1—Tank Plan (Shown for Eight Horizontal Stations)

c. Steps a and b shall be repeated randomly at three horizontal stations (including the first station) during the course of the calibration.

2.2B.7.4 CALIBRATION PROCEDURES

The calibration measurements may be taken with any fill height of liquid in the tank. No transfer or mixing of the liquid shall occur during the calibration. The temperature and the relative density or API gravity of the liquid and the height of the liquid shall be recorded prior to the calibration procedure. Measurements shall proceed in the following manner:

a. The reference circumference shall be measured using a master tape. The reference circumference shall be measured at or very near the height of the first vertical station on the bottom ring (where the reference offset shall be measured as shown in Figure 2). The procedures given in API Standard 2550 shall be followed for the reference circumference measurement.
b. The optical device shall be verified as being in a stable position. At any given horizontal station, the device should not move or be disturbed during the traverse of the magnetic trolley from the bottom ring to the top.
c. The perpendicularity shall be verified (see 2.2B.7.3), and the reference offset (for example, Distance *a* in Figures 3 and 4) shall be measured from the first horizontal station.
d. The trolley shall be vertically traversed to the next predetermined vertical station in each ring, and the offset (for example, Distance *m* in Figures 3 and 4) shall be read. This procedure shall be repeated sequentially at each of the vertical stations.
e. After the offset in the topmost course is read, the trolley shall again be lowered to the bottom ring and the reference offset measurement shall be repeated. The initial and final reference offsets at each horizontal station shall be within 0.005 foot (or 1 millimeter) of each other. If the initial and final reference offsets for a horizontal station do not agree within 0.005 foot (or 1 millimeter), the procedure should be reinitiated, beginning with Step c.
f. Steps b–e shall be repeated for each horizontal station.
g. After the optical measurements around the tank are completed, the reference circumference measurement (Step a) shall be repeated using the same master tape. The initial and final readings shall agree within 0.005 foot (or 1 millimeter). If they do not agree, the

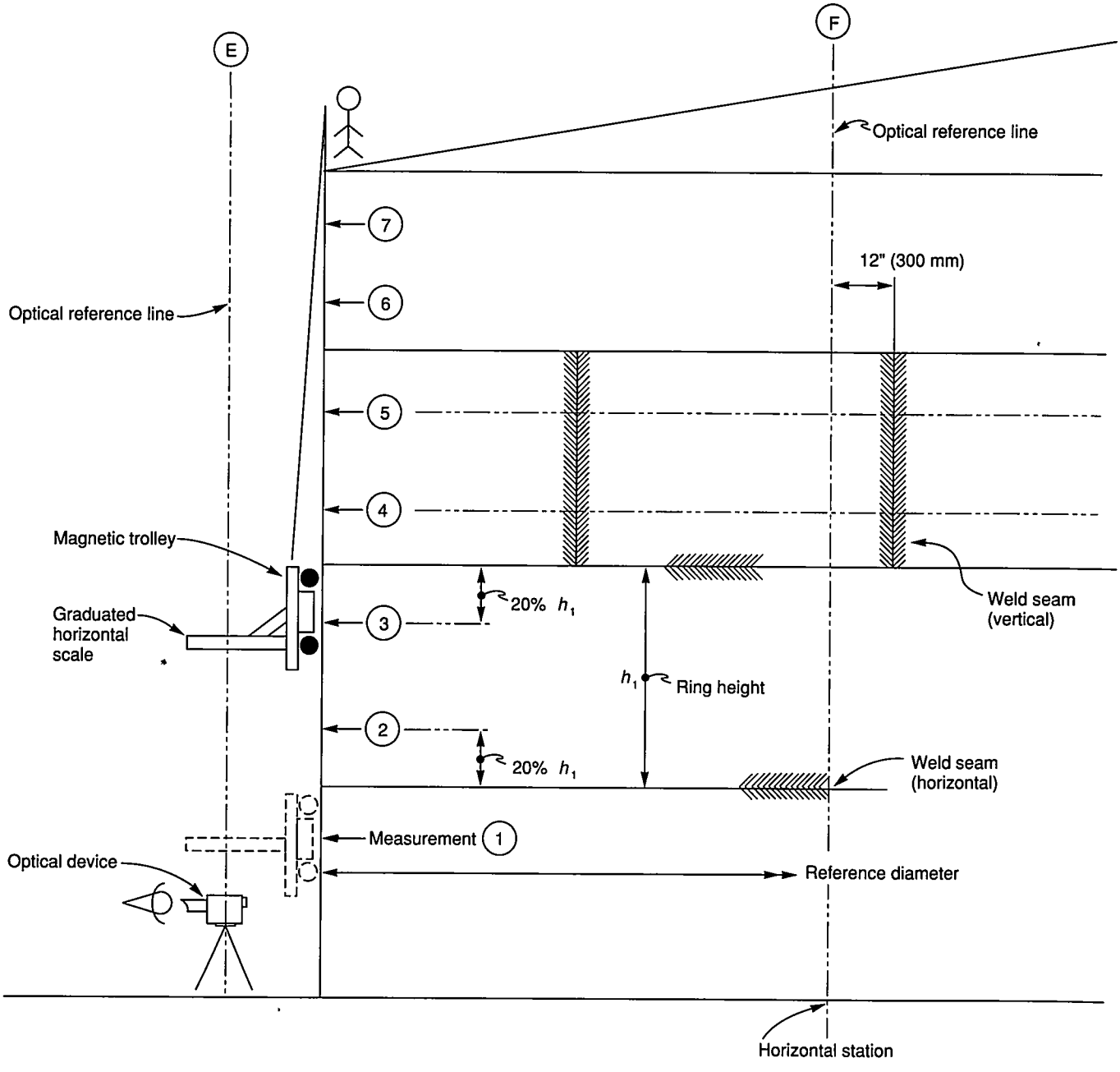


Figure 2—Tank Elevation

measurements shall be repreated from the beginning of the procedure.

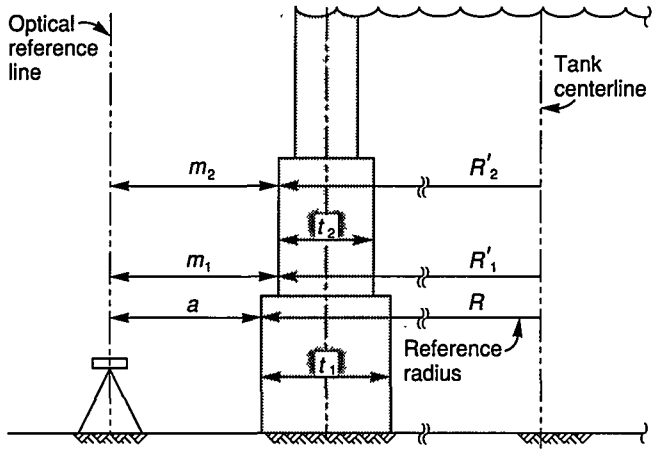
When the wind girder is located below the tank's maximum fill height, the tank circumference measurements above the wind girder shall be performed by the MTSM.

2.2B.8 Calculation Procedure

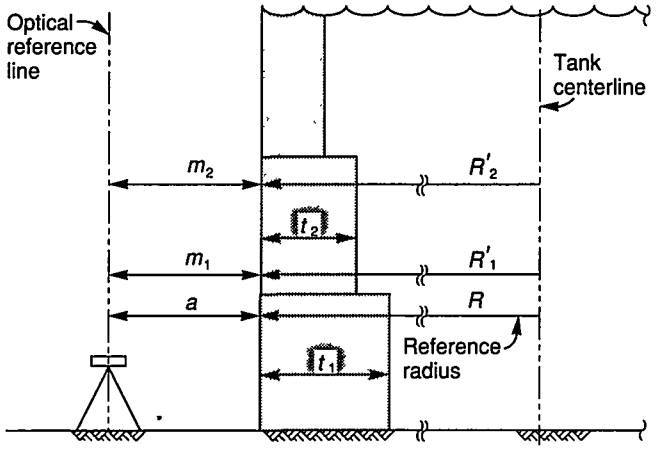
The calculation procedure to determine the radius of each ring from the offset measurements and the reference circumference measurement is presented in Figures 3 and 4. Once the ring radii are determined, the capacity table shall be developed in accordance with the procedures given in API Standard 2550.

2.2B.9 Development of Capacity Table

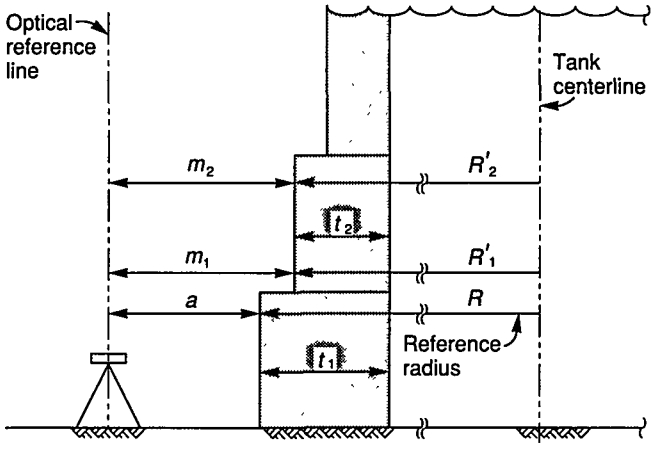
The ring circumferences/radii determined by the ORLM shall be used to develop the strapping table in accordance with the procedures given in API Standard 2550. All correction factors (for example, temperature and tilt) shall be considered, in accordance with API Standard 2550.



CENTERLINE FLUSH



OUTSIDE FLUSH



INSIDE FLUSH

Note: Using external measurement, the calculation to determine internal radius is performed as follows:

$$R'_1 + m_1 = R + a$$
$$R'_1 = R + a - m_1$$
$$= R - (m_1 - a)$$
$$= (C/2\pi) - (m_1 - a)$$

For n horizontal stations,

$$R'_1 = (C/2\pi) - [\Sigma(m_1 - a)]/n$$

Similarly,

$$R'_2 = (C/2\pi) - [\Sigma(m_2 - a)]/n$$

For the bottom ring,

$$R_i = R - t_1$$

For the bottom of the second ring,

$$R'_{1i} = R'_1 - t_2$$

For the top of the second ring,

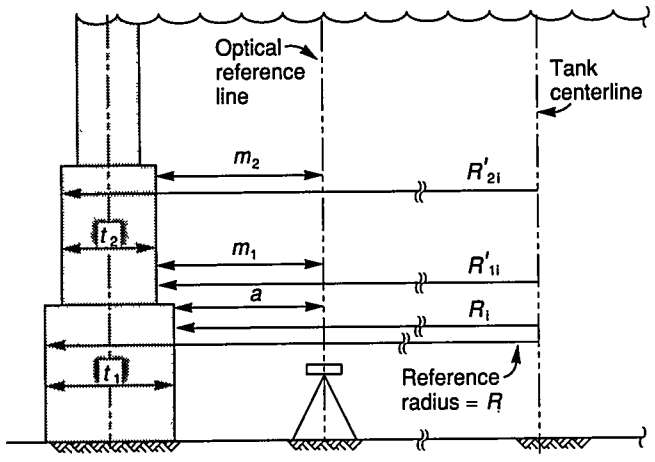
$$R'_{2i} = R'_2 - t_2$$

Where:

C = reference outer circumference.
R = reference outer radius (bottom ring) $= C/2\pi$.
R'_1, R'_2 = outer radii of second ring.
t_1, t_2 = ring thicknesses.
a = reference offset.
m_1, m_2 = individual ring offsets.
R_i = reference internal radius (bottom ring) $= R - t_1$.
R'_{1i} = internal radius (bottom of second ring).
R'_{2i} = internal radius (top of second ring).

A similar calculation shall be performed for all other rings.

Figure 3—Optical Reference Line Method: Determination of Internal Radius (External Measurement)



CENTERLINE FLUSH

Note: Using internal measurement, the calculation to determine internal radius is performed as follows:

$$R'_{1i} - m_1 = R_i - a$$
$$R'_{1i} = R_i + m_1 - a$$

For n horizontal stations,

$$R'_{1i} = [(C/2\pi) - t_1] + [\Sigma(m_1 - a)]/n$$

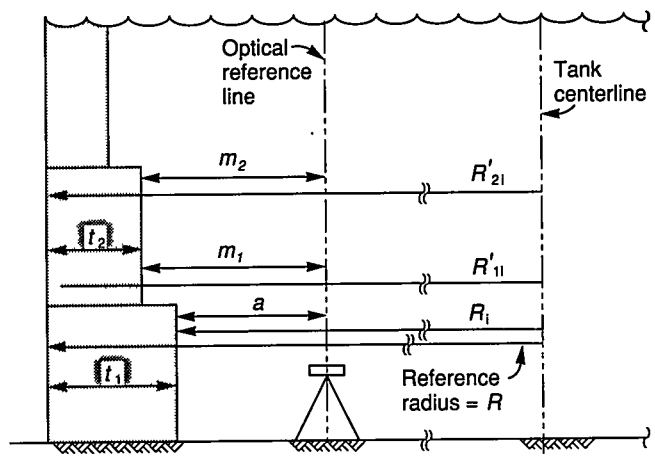
Similarly,

$$R'_{2i} = [(C/2\pi) - t_1] + [\Sigma(m_2 - a)]/n$$

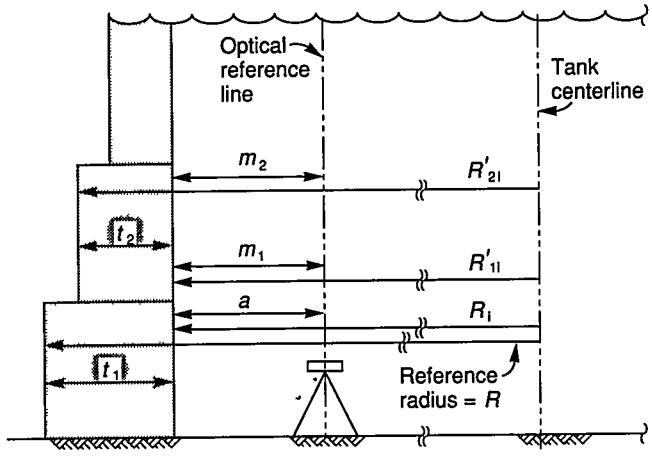
Where:

C = reference outer circumference.
R = reference outer radius (bottom ring) $= C/2\pi$.
t_1 = thickness of bottom ring.
R_i = reference internal radius (bottom ring) $= R - t_1$.
a = reference offset.
m_1, m_2 = individual ring offsets.
R'_{1i} = internal radius (bottom of second ring).
R'_{2i} = internal radius (top of second ring).

A similar calculation shall be performed for all other rings.



OUTSIDE FLUSH



INSIDE FLUSH

Figure 4—Optical Reference Line Method: Determination of Internal Radius (Internal Measurement)

Order No. 852-30023

1-1700—3/89—6C(5A)

American Petroleum Institute
1220 L Street, Northwest
Washington, D.C. 20005