Designation: E2883 – 13

Standard Guide for
Standard Guide for the Evaluation, and Calibration, Continuous Friction Measurement Equipment (CFME)[1]

This standard is issued under the fixed designation E2883; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide describes the evaluation and calibration of friction measurement systems which are known as Continuous Friction Measuring Equipment (CFMEs). The evaluation, and calibration processes; using the specialized equipment, instruments, pavement surfaces, trained personnel, and approved facilities; are performed using the procedures described below.

1.2 This guide is offered as a process to identify and quantify the variables that affect system performance, to minimize the effect of these variables, and to provide a means to relate CFMEs to reference skid measurement systems.

1.3 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. Some specific hazards statements are given in Section 7 on Hazards.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

E556 Test Method for Calibrating a Wheel Force or Torque Transducer Using a Calibration Platform (User Level)

E670 Test Method for Testing Side Force Friction on Paved Surfaces Using the Mu-Meter

E867 Terminology Relating to Vehicle-Pavement Systems

E1859 Test Method for Friction Coefficient Measurements Between Tire and Pavement Using a Variable Slip Technique

E1960 Practice for Calculating International Friction Index of a Pavement Surface

E2340 Test Method for Measuring the Skid Resistance of Pavements and Other Trafficked Surfaces Using a Continuous Reading, Fixed-Slip Technique

E2666 Practice for Correlations of Mu Values of Continuous Friction Measurement Equipment to Determine Maintenance Levels for Use at Airports

F377 Practice for Calibration of Braking/Tractive Measuring Devices for Testing Tires

F457 Test Method for Speed and Distance Calibration of Fifth Wheel Equipped With Either Analog or Digital Instrumentation

2.2 *Other Standards:*

BS 7941-1:2006 Method for measuring the skid resistance of pavement surfaces, Sideway-force Coefficient Routine Investigation Machine, SCRIM® (British Standard)

3. Terminology

3.1 *Definitions:*

3.1.1 *Calibration Platform, n*—a frictionless moving platform for applying a tractive force in the contact plane of a tire and associated means for measuring the applied horizontal and vertical force, also referred to as a "force plate." **E670**

3.1.2 *Field Test Center (FTC), n*—a facility with the needed test equipment, Reference Friction Measurement System (RFMS), test pavements and expertise to evaluate, calibrate and correlate CFME friction measurement systems. **E670**

3.1.3 *Horizontal Force, n*—a force in line with the direction of travel for fixed slip devices, perpendicular to direction of travel for side force devices. **E670**

3.2 Other terminology used in this guide conforms to the definitions in Terminology E867

4. Summary of Guide

4.1 There are three phases to this guide. Phase one records and reports the static and dynamic condition and accuracy of

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

the visiting system in an "As Arrived" condition with no changes being made. During phase two, each subsystem is evaluated and if necessary, adjusted to ensure compliance with tolerances outlined in Test Method E670, E1859, E2340 or other appropriate standards. Phase three is the final dynamic correlation between the visiting system and the RFMS.

4.2 The FTC personnel will calibrate the calibration platform or force plate used by the visiting equipment owner if provided.

4.3 A detailed report may be generated and presented to the equipment owner describing all static and dynamic test results.

5. Significance and Use

5.1 Friction characteristics of pavement surfaces are monitored by friction measurement systems, and the operating procedure for the use of these systems is found in Test Method E670, E1859, E2340 or other appropriate standards. However, mechanical or electronic system anomalies, over time, could result in measurement errors or inaccuracies. This requires that each of these systems be evaluated, calibrated and correlated on a regular basis.

5.2 This guide defines the process of ensuring that CFMEs produce consistent and accurate data and correlating the CFMEs to national benchmark RFMS.

6. Apparatus

6.1 *Reference Friction Measurement System (RFMS)*, a fixed slip type measurement system that meets the requirements of ASTM/FAA/FHWA, preferably the same type as the CFME(s) being calibrated: or a texture and low slip device.

6.2 *Five Test Pavements (pads),* with an asphalt, concrete or seal coat surface having a uniform high, medium, and low friction that spans the typical operating range and used to correlate multiple CFME systems. Pads with similar macro texture should be avoided. A recommended range of Mu for the low friction pad should be: one below 0.30, three medium friction pads between 0.30 and .0.50, and the high friction pad above 0.50. The length and width shall be suitable for the entire CFME system at the highest designated test speed. A suggested length and width is 300 ft (100 m) by 9 ft (3 m). The test surfaces shall be homogeneous, level, and free of contaminants and traffic. A nonpolishing surface is recommended. There shall be adequate space for the CFMEs to accelerate to the test speed and safely decelerate.

6.2.1 Facilities located with system manufacturers may not have test pads available, but should have identified pavements having Mu values similar to that noted in 6.2.

6.3 *One or Two Load Cells as needed,* calibrated annually and National Institute of Science and Technology (NIST) traceable, 1000 lb (4448 N) and 2000 lb (8900 N). Accuracy is required in accordance with Practice F377

6.4 *One or two Calibration Platforms as needed,* with digital instrumentation as described in Test Method E556 and calibrated in accordance with Practice F377. The top surfaces of the platforms are to be installed at the same height as the surrounding floor. Alternatively the unit may be raised above the floor to match the height of the platform with its associated equipment.

6.5 *One or two Calibration Platforms as needed,* lifting the test wheel. Alternatively the on board lifting devices may be used to lift the test wheel.

6.6 *Voltmeter, Oscilloscope, Strain Indicator,* and other test instruments capable of accurate measurement of voltages, and signals common in strain gauge instrumentation.

6.7 *Water Volume Measurement System;* to calibrate the water pumping ability of the water system, the following items are needed: a collector to capture all water pumped during a fixed time interval, a device to measure the volume of water pumped, and a stopwatch.

6.8 *Static Water Distribution Gauge (SDG),* a collector, set at floor level, which is divided into ten sections, eight sections of the device are 1/8 the width of the test tire and two sections, one on each side, that are one inch.; so that each section catches water from the water nozzle and feeds it into a separate reservoir and viewing allows the water nozzle distribution to be evaluated and photographed. See Appendix A for specifications of a suggested unit.

6.9 *Speed Measurement System,* to measure vehicle speed, ±0.1 mph (0.2 km/h). A fifth wheel calibrated to Test Method F457, precision GPS or precision radar is recommended.

6.10 *Precision Pressure Gauge* and air system are required for the calibration of tire pressure gauges. Gauges should have an accuracy of ±0.25 % full scale or better.

6.11 *Inclinometer,* with a measuring resolution of 1 minute.

6.12 *Force Plate Calibration Fixture,* a system, capable of developing a precise longitudinal and vertical force sufficient for the calibration of a calibration platform throughout its operating range as described in Practice F377.

NOTE 1—The following procedures (Sections 7, 8, 9 and 14) are for one test wheel, centered to vehicle/trailer width or on the driver"s side.

7. 'As Arrived' Data

7.1 Visiting systems, upon arrival, will be correlated[3] with the RFMS on five surfaces at the systems normal test speed and optionally at one to two additional test speeds. Twelve repeats should be run at the normal test speed. The visiting system and the RFMS should attempt to measure in the same lateral and longitudinal location for each pair of tests. The twelve repeats will be averaged and the mean, standard deviation, and confidence level will be reported, for each system, for each of the five surfaces. Repeatability should be reported and reproducibility if more than three of the same devices are tested (see C670). These values will be referred to as the "As Arrived Data."

[3] The correlation will depend on the end use. Manufacturers would use their standard device to correlate their devices; for airport maintenance, E2666 would be followed; calibrated CFME can be used with similar CFME. If a standard CFME and the CFME being calibrated have vastly different slip ratios, no correlation may be possible. The method used should be reported as well as any deviations where 7.1 cannot be followed.

8. Physical Measurements

8.1 Trailer Units

8.1.1 Physical measurements of the visiting system will be conducted and recorded in the "As Arrived" condition, before any changes are made. These measurements consist of checking and recording: test tire(s) type, manufacture, pressure(s), tire(s) wear level, water nozzle height, horizontal angle, and lateral position relative to tire centerline, nozzle width, for each nozzle used. If applicable, the distance from the center of the hitch ball to the floor, distance from the end of the nozzle to the trailer axle center, distance from the trailer axle center to the floor and the distance from the center of the hitch to the center of the trailer axle will be recorded. E670 has a reference to height of systems, but E2340 does not. On others, the water tank should be half full and the movement of the trailer unit shall not be more that 2 inches around the datum line having the trailer in a horizontal plane.

8.1.2 If applicable the angle of the trailer tongue and direction (up or down) along with the trailer lean angle, as well as number of tires, will be recorded.

8.1.3 Hitch height, above ground level, versus water load is measured and recorded at a full tank of water, a half tank and an empty tank.

8.1.4 The angular rotation of the force transducer(s) shall experience less than 1 degree with respect to its measuring plane. This may be measured on the calibration platform, during the "Static Force Evaluation and Calibration", using a precision inclinometer attached to the test wheel and operating the platform from 0 to the maximum horizontal force applicable to the particular CFME typically 80% of the vertical load.

8.1.5 Any changes to these measurements, to comply with the appropriate CFME standard, are to be made and recorded as "Final."

8.2 Vehicle Mounted Units

8.2.1 Physical measurements of the visiting system will be conducted and recorded in the "As Arrived" condition, before any changes are made. These measurements consist of: test tire(s) type, manufacture, pressure(s), tire(s) wear, level water nozzle height, horizontal angle, lateral position relative to tire centerline, and nozzle width (for each nozzle used).

8.2.2 Test wheel axle height, above ground level, versus water load is measured and recorded at a full tank of water, a half tank and an empty tank, as well as number of tires is recorded.

8.2.3 The angular rotation of the force transducer(s) shall experience less than 1 degree with respect to its measuring plane. This may be measured on the calibration platform, during the "Static Force Evaluation and Calibration", using a precision inclinometer attached to the test wheel and operating the horizontal platform force from 0 to the maximum horizontal force applicable to the particular CFME, typically 80% of maximum vertical load.

8.2.4 Any changes to these measurements, to comply with the appropriate CFME standard, are to be made and recorded as "Final."

9. Static Force Evaluation and Calibration

9.1 Determine that the calibration platform has been suitably calibrated within one year in accordance with Practice F377.

9.2 Drain or fill the water tank to obtain one-half tank of water onboard the friction measurement system.

9.3 Place the unit onto the calibration platform ensuring it is square and centered.

9.4 Set as appropriate, vehicle tire, trailer tire, air shock and test tire pressures to manufacturer specified pressures.

9.5 On trailer units with the platform floating, weigh and record the "As Arrived" weight of each test wheel. On vehicle mounted units weigh each test wheel with the test wheel lowered to the platform in test position. Any changes to these weights, after the "As Arrived" data runs, are recorded as "Final."

9.6 Reconnect truck and trailer and check trailer alignment on trailer units.

9.7 Apply external air and power as required to the visiting system.

9.8 Start the data system and go to the calibration screen, if available.

9.9 Record the "As Arrived" calibration values (for example: bias, zero, gain, shunt, or static) for the horizontal force and vertical force channels.

9.10 Make an "As Arrived" run, with the plate floating and the test wheel fixed; vary the horizontal force from 0 to 80% of normal vertical load in eight steps recording horizontal and vertical force from platform and the horizontal and vertical force from the CFME data system.

9.11 Adjust the data system to read forces directly and accurately from the wheel transducer with no computer correction, that is, reset the computer to a gain of 1 and offset of zero.

9.12 Set zero and span on the friction system vertical and horizontal force channels, if necessary, to match the calibration platform values at zero and full horizontal force and zero and full vertical force.

9.13 Measure horizontal force into vertical force cross talk by first recording vertical force on test wheel and plate with zero horizontal force. Compare the difference in vertical force value on the platform to the difference in vertical force value from the test wheel transducer while applying a midrange horizontal force. The difference between the change in the transducer force and platform force should be less than 1 % of the applied horizontal force. If not, rotate the wheel transducer or if applicable, adjust the hitch height, within manufacture"s limits.

9.14 With zero horizontal force applied, measure the vertical-into-horizontal cross talk by first recording the wheel transducer horizontal force at full vertical force. Reduce the vertical force midway between full load and zero and record the wheel transducer horizontal force again. The difference

between two horizontal transducer force values should be less than 1% of the vertical change. If not, rotate the wheel transducer or if applicable, adjust the hitch height slightly, within manufacture's limits.

9.15 If any mechanical changes were made, repeat steps 9.12, 9.13 and 9.14 until both axes exhibit a cross talk less than 1 %. Record the changes and new values.

9.16 On trailer units, add additional weights on the test wheel fender, evaluate the vertical force. Make three runs, in steps of approximately 50 lb (25 kg), or less, with an air jack under the test wheel axle, recording platform and system vertical force, with the last run being in the opposite direction to check for hysteresis which should be less than 1 % of the applied load. Nonlinearity should be less than 1 % of the applied load.

9.17 Using the air bearing platform, calibrate the friction measurement system vertical and horizontal force channels in accordance with the manufacturer's instructions.

9.18 If the calibration process indicates the overall system accuracy is outside of the manufacturer"s recommendations remedial action should be taken to bring the CFME within the limits. Suggested accuracy limits (applied vs. measured) are 1½ % of reading for full horizontal force range.

9.19 When finished, save the calibration values developed in the system computer. Record the horizontal and vertical force calibration shunt and other computed constants.

9.20 Print out the computer cycle time. Verify with graphical run data, if available or physical observation of events during the final correlation.

10. Tire Pressure Gauge Calibration

10.1 If the visiting system tire pressure gauge has not been calibrated within the last year, using the FTC pressure gauge calibrator, calibrate the visiting system tire pressure gauge by applying air pressure to the gauge at 5 psi (0.34 bar) intervals beginning at 10 psi (0.69 bar) and continuing throughout the range of the gauge (which should exceed the maximum tire pressures expected in the truck tires). Between 20 and 30 psi (1.4 to 2.1 bar) the interval should be in steps of 2 psi (0.14 bar) or less.

10.2 Record the results in the "As Arrived" column. Any changes in the gauge to bring it into agreement will require the above steps to be repeated and entered into the "Adjusted" column. The final accuracy of the gauge must be ±0.5 psi (±0.03 bar) between 20 and 30 psi (1.38 and 2.07 bar).

NOTE 2—The following sections require the selection of test speeds. 40 mph (64 km/h) is the primary test speed and one test speed below and one test speed above the primary speed need to be selected to evaluate the visiting system. Suggested test speeds are 20, 40 and 60 mph (32, 64 and 97 km/h) or 30, 40 and 50 mph (48, 64 and 80 km/h). The speed calibration, water calibration, and departure correlation are conducted at the three speeds selected. 20, 40, and 60 mph (32, 64 and 97 km/h) are the example speeds for the remainder of this document.

11. Speed and Distance Calibration

11.1 Evaluate the visiting system speed measurement system utilizing a calibrated speed measurement system such as a fifth wheel, radar gun, or high quality Global Positioning System. A fifth wheel is used for the example calibration device in steps 11.2 through 11.6.

11.2 Set vehicle/trailer tire and air shock pressures to user specified pressures (± 0.5 psi (± 0.03 bar)) at ambient temperature.

11.3 Operate the visiting system on the FTC facilities at 20, 40 and 60 mph (32, 64 and 97 km/h) as indicated on the reference readout and record the indicated digital vehicle speed. Repeat five times and report the average as the "As Arrived" speeds along with the arrival calibration values for speed and distance.

11.4 Calibrate the distance measurement by driving a surveyed course distance and following the friction measurement system manufacturer"s instructions for distance calibration.

11.5 If needed, make any manufacture recommended adjustments to the system to correct the system values to reference values, within ±1.5 % of the indicated reference speed or ±0.5 mph (±0.8 km/h), whichever is greater. Record the system calibration values, including calibration values for distance, left and right trailer wheel speed, and digital vehicle speed.

11.6 Operate the system at 20, 40, and 60 mph (32, 64 and 97 km/h) as indicated on the reference readout and record the indicated wheel speeds and the digital vehicle speed as applicable. Repeat five times and report the average as the "Final." Conduct a test at each of the three speeds and record the resultant test speed the computer reports. Also record the vehicle speedometer and tachometer indication at each of the three fifth wheel speeds.

12. Slip Ratio or Yaw Angle Verification

12.1 Slip Ratio

12.1.1 Where possible disconnect the drive to the test tire so that both the drive and driven tires rotate freely. If they cannot be disconnected, measure the rolling radius of each tire and a free rolling tire on the vehicle.

12.1.2 Place a reference mark on the tire"s sidewall and push the vehicle over a course of 50 feet and count the number of rotations of test tire and drive tire. Include the free rolling tire when the test tire and drive tire cannot be disconnected.

12.1.3 Reconnect the drive and repeat 12.2. Omit this step when the test tire cannot be disconnected from the drive tire.

12.1.4 Determine the slip ratio of the test tire and the drive tire and record the percent slip. If the slip is not within 2% of manufacture"s specification determine the problem and make repairs and then repeat slip verification tests.

12.1.5 For systems equipped with speed encoders on the test wheel and the vehicle, ensure the test wheel is inflated to the appropriate specification and measure the speed of the vehicle and the speed of the test wheel over a measured distance, and then calculate the slip ratio. If the slip is not within 2% of manufactures specification determine the problem and make repairs and then repeat slip verification tests.

12.2 Yaw Angle

12.2.1 On MuMeter devices measure the yaw angle and verify it is 7.5 ± 0.75 degrees.

12.2.2 On SCRIM® devices, measure the yaw angle and verify it is 20.0 ± 1.00 degrees.

12.2.3 On other side force devices, the yaw angle given by the manufacturer should be used.

13. Water Flow and Distribution

13.1 The water nozzle flow and distribution are calibrated on the ASTM water flow collector and the static distribution.

13.2 Set up and secure the truck and/or trailer for the water system calibration.

13.3 Either place the truck drive wheels on rollers or raised off the floor on jack stands.

13.4 Start the truck, bring the truck up to one of the test speeds, and activate the water system. When the speed is stable, simultaneously start the timer and slide the water flow collector under the nozzle. After filling the collector to the desired level, remove the collector, stop the timer and stop the truck wheels. Record the speed, time and amount of collected water and compute the "As Arrived" value in gallons per minute (L/min).

13.5 If the water flow rate is not within the allowable 10 % minimum and maximum in accordance with the applicable CFME standard, change pulleys, clean the system, or perform other maintenance on the water delivery system to bring the values into specification.

13.6 Repeat the 13.4 procedure three times at the test speed. Record the results as "Final" along with any service work performed.

13.7 With the flow collector removed, operate the truck and system at the test speed. Capture the water from the nozzle into the static distribution gauge until the outboard tubes show visible water. After each run label the menu board with: state, unit number, speed, run number and date then photograph to document the distribution of the water from the nozzle.

13.8 If the system is equipped with two test wheels and both nozzles are connected to the same pumping system, only an observation of the flow from the opposite side nozzle would need to be made to insure that no holes are blocked.

14. Force Plate Calibration

14.1 If a force plate is provided, along with the visiting friction measurement system that has not been calibrated within the last year, the force plate should be calibrated in accordance with Practice F377 standard procedures using the FTC Force Plate Calibration Fixture.

15. Final Testing and Reporting

15.1 Visiting systems, after any required adjustments, to bring them into compliance with the applicable CFME Test Method, will be tested again in accordance with 7.1. This will be done with the same type of tire used in the "As Arrived" Data, preferably from the same batch on each system, measuring in the same location of each surface. The twelve repeats will be averaged and the mean, standard deviation, and confidence level will be reported, for each system, for each of the five surfaces. Repeatability should be reported; and reproducibility is reported if more than three of the same device are tested. These values will be referred to as the "Final Data."

16. Documentation

16.1 Document the year, make, model, VIN and description of the system vehicle including type of water pump system and tank capacity. Document the system manufacturer, model, serial number, year of acceptance, and year of last update, if available. Record the type of data acquisition system along with current software revision number. Also record or photograph any other items of interest relating to the system, the operator(s), vehicle interior view showing data acquisition system, and the water distribution nozzle. Have the person responsible for the visiting system; provide information as to the owner of the system and address along with the names of the manager and operators.

17. Report

17.1 Provide the client with a report detailing the results of the evaluation and calibration of each of the sub systems, the results of the arrival and final correlations including the correlation equations, graphs, any repairs or adjustments made to the systems, photographs of the system, and any recommendations for improvements or adjustment to their data as determined by the correlation equations. List any subsystem that did not meet the requirements of the applicable Test Method. One copy of the report is placed in the FTC's permanent records and one copy is forwarded to the other FTC's

18. Frequency of System Correlation and Calibration

18.1 It is recommended that the visiting system be correlated and calibrated to Sections 1 through 17 of this guide once per year unless a major overhaul of the system has been performed.

18.2 A Field Calibration shall be performed prior to each use of the CFME in accordance with the manufacturer's instructions. A Certifying Calibration using a force plate shall be done once per year in accordance with the manufacturer's instructions.

APPENDIX

(Nonmandatory Information)

X1. Static Water Distribution Gauge

X1.1 Fig. X1.1

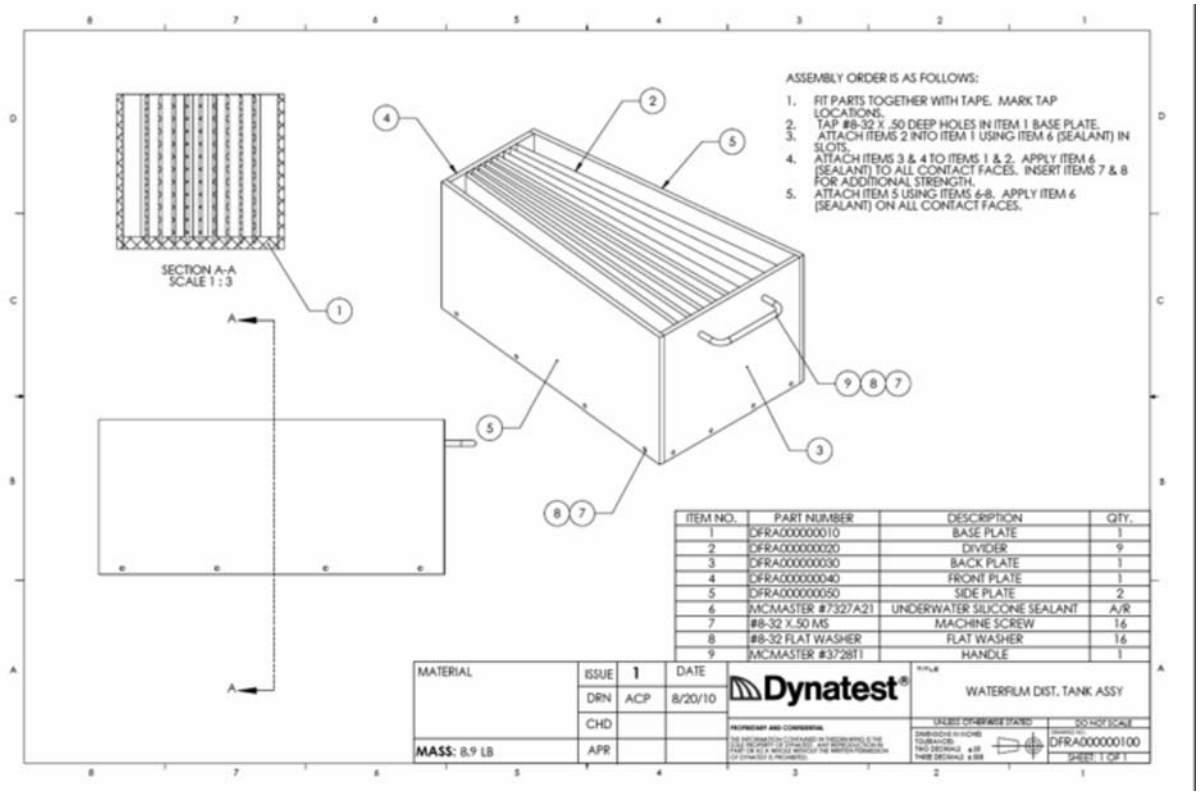

FIG. X1.1 Static Water Distribution Gauge