

## § 1065.310

alignment in accordance with § 1065.650(c)(2)(i).

[73 FR 59326, Oct. 8, 2008, as amended at 75 FR 23039, Apr. 30, 2010]

### MEASUREMENT OF ENGINE PARAMETERS AND AMBIENT CONDITIONS

#### § 1065.310 Torque calibration.

(a) *Scope and frequency.* Calibrate all torque-measurement systems including dynamometer torque measurement transducers and systems upon initial installation and after major maintenance. Use good engineering judgment to repeat the calibration. Follow the torque transducer manufacturer's instructions for linearizing your torque sensor's output. We recommend that you calibrate the torque-measurement system with a reference force and a lever arm.

(b) *Recommended procedure.* (1) *Reference force quantification.* Use either a set of dead-weights or a reference meter such as strain gage or a proving ring to quantify the reference force, NIST-traceable within  $\pm 0.5\%$  uncertainty.

(2) *Lever-arm length quantification.* Quantify the lever arm length, NIST-traceable within  $\pm 0.5\%$  uncertainty. The lever arm's length must be measured from the centerline of the dynamometer to the point at which the reference force is measured. The lever arm must be perpendicular to gravity (i.e., horizontal), and it must be perpendicular to the dynamometer's rotational axis. Balance the lever arm's torque or quantify its net hanging torque, NIST-traceable within  $\pm 1\%$  uncertainty, and account for it as part of the reference torque.

(c) *Dead-weight calibration.* This technique applies a known force by hanging known weights at a known distance along a lever arm. Make sure the weights' lever arm is perpendicular to gravity (i.e., horizontal) and perpendicular to the dynamometer's rotational axis. Apply at least six calibration-weight combinations for each applicable torque-measuring range, spacing the weight quantities about equally over the range. Oscillate or rotate the dynamometer during calibration to reduce frictional static hysteresis. Determine each weight's force by multi-

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plying its NIST-traceable mass by the local acceleration of Earth's gravity (using this equation: force = mass · acceleration). The local acceleration of gravity,  $a_g$ , at your latitude, longitude, and elevation may be determined by entering position and elevation data into the U.S. National Oceanographic and Atmospheric Administration's surface gravity prediction Web site at [http://www.ngs.noaa.gov/cgi-bin/grav\\_pdx.prl](http://www.ngs.noaa.gov/cgi-bin/grav_pdx.prl). If this Web site is unavailable, you may use the equation in § 1065.630, which returns the local acceleration of gravity based on a given latitude. In this case, calculate the reference torque as the weights' reference force multiplied by the lever arm reference length (using this equation: torque = force · lever arm length).

(d) *Strain gage or proving ring calibration.* This technique applies force either by hanging weights on a lever arm (these weights and their lever arm length are not used as part of the reference torque determination) or by operating the dynamometer at different torques. Apply at least six force combinations for each applicable torque-measuring range, spacing the force quantities about equally over the range. Oscillate or rotate the dynamometer during calibration to reduce frictional static hysteresis. In this case, the reference torque is determined by multiplying the force output from the reference meter (such as a strain gage or proving ring) by its effective lever-arm length, which you measure from the point where the force measurement is made to the dynamometer's rotational axis. Make sure you measure this length perpendicular to the reference meter's measurement axis and perpendicular to the dynamometer's rotational axis.

[70 FR 40516, July 13, 2005, as amended at 73 FR 37305, June 30, 2008]

#### § 1065.315 Pressure, temperature, and dewpoint calibration.

(a) Calibrate instruments for measuring pressure, temperature, and dewpoint upon initial installation. Follow the instrument manufacturer's instructions and use good engineering judgment to repeat the calibration, as follows:

(1) *Pressure.* We recommend temperature-compensated, digital-pneumatic, or deadweight pressure calibrators, with data-logging capabilities to minimize transcription errors. We recommend using calibration reference quantities that are NIST-traceable within 0.5% uncertainty.

(2) *Temperature.* We recommend digital dry-block or stirred-liquid temperature calibrators, with data logging capabilities to minimize transcription errors. We recommend using calibration reference quantities that are NIST-traceable within 0.5% uncertainty. You may perform the linearity verification for temperature measurement systems with thermocouples, RTDs, and thermistors by removing the sensor from the system and using a simulator in its place. Use a NIST-traceable simulator that is independently calibrated and, as appropriate, cold-junction compensated. The simulator uncertainty scaled to temperature must be less than 0.5% of  $T_{\max}$ . If you use this option, you must use sensors that the supplier states are accurate to better than 0.5% of  $T_{\max}$  compared with their standard calibration curve.

(3) *Dewpoint.* We recommend a minimum of three different temperature-equilibrated and temperature-monitored calibration salt solutions in containers that seal completely around the dewpoint sensor. We recommend using calibration reference quantities that are NIST-traceable within 0.5% uncertainty.

(b) You may remove system components for off-site calibration. We recommend specifying calibration reference quantities that are NIST-traceable within 0.5% uncertainty.

[70 FR 40516, July 13, 2005, as amended at 73 FR 37305, June 30, 2008; 75 FR 23040, Apr. 30, 2010]

#### FLOW-RELATED MEASUREMENTS

##### § 1065.320 Fuel-flow calibration.

(a) Calibrate fuel-flow meters upon initial installation. Follow the instrument manufacturer's instructions and use good engineering judgment to repeat the calibration.

(b) You may also develop a procedure based on a chemical balance of carbon or oxygen in engine exhaust.

(c) You may remove system components for off-site calibration. When installing a flow meter with an off-site calibration, we recommend that you consider the effects of the tubing configuration upstream and downstream of the flow meter. We recommend specifying calibration reference quantities that are NIST-traceable within 0.5% uncertainty.

##### § 1065.325 Intake-flow calibration.

(a) Calibrate intake-air flow meters upon initial installation. Follow the instrument manufacturer's instructions and use good engineering judgment to repeat the calibration. We recommend using a calibration subsonic venturi, ultrasonic flow meter or laminar flow element. We recommend using calibration reference quantities that are NIST-traceable within 0.5% uncertainty.

(b) You may remove system components for off-site calibration. When installing a flow meter with an off-site calibration, we recommend that you consider the effects of the tubing configuration upstream and downstream of the flow meter. We recommend specifying calibration reference quantities that are NIST-traceable within 0.5% uncertainty.

(c) If you use a subsonic venturi or ultrasonic flow meter for intake flow measurement, we recommend that you calibrate it as described in § 1065.340.

##### § 1065.330 Exhaust-flow calibration.

(a) Calibrate exhaust-flow meters upon initial installation. Follow the instrument manufacturer's instructions and use good engineering judgment to repeat the calibration. We recommend that you use a calibration subsonic venturi or ultrasonic flow meter and simulate exhaust temperatures by incorporating a heat exchanger between the calibration meter and the exhaust-flow meter. If you can demonstrate that the flow meter to be calibrated is insensitive to exhaust temperatures, you may use other reference meters such as laminar flow elements, which