Table 1 of §1065.205–Recommended performance specifications for measurement instruments

Measurement Instrument	Measured quantity symbol	Complete System Rise time and Fall time	Recording update frequency	Accuracy[a]	Repeatability[a]	Noise[a]
Engine speed transducer	f_n	1 s	1 Hz means	2.0 % of pt. or 0.5 % of max.	1.0 % of pt. or 0.25 % of max.	0.05 % of max
Engine torque transducer	T	1 s	1 Hz means	2.0 % of pt. or 1.0 % of max.	1.0 % of pt. or 0.5 % of max.	0.05 % of max.
Electrical work (active-power meter)	W	1 s	1 Hz means	2.0 % of pt. or 0.5 % of max.	1.0 % of pt. or 0.25 % of max.	0.05 % of max
General pressure transducer (not a part of another instrument)	p	5 s	1 Hz	2.0 % of pt. or 1.0 % of max.	1.0 % of pt. or 0.50 % of max.	0.1 % of max
Atmospheric pressure meter used for PM-stabilization and balance environments	p_{atmos}	50 s	5 times per hour	50 Pa	25 Pa	5 Pa
General purpose atmospheric pressure meter	p_{atmos}	50 s	5 times per hour	250 Pa	100Pa	50 Pa
Temperature sensor for PM-stabilization and balance environments	T	50 s	0.1 Hz	0.25 K	0.1 K	0.1 K
Other temperature sensor (not a part of another instrument)	T	10 s	0.5 Hz	0.4 % of pt. K or 0.2 % of max. K	0.2 % of pt. K or 0.1 % of max. K	0.1 % of max
Dewpoint sensor for PM-stabilization and balance environments	T_{dew}	50 s	0.1 Hz	0.25 K	0.1 K	0.02 K
Other dewpoint sensor	T_{dew}	50 s	0.1 Hz	1 K	0.5 K	0.1 K
Fuel flow meter (Fuel totalizer in parentheses)	$\dot{m}$	5 s (N/A)	1 Hz (N/A)	2.0 % of pt. or 1.5 % of max.	1.0 % of pt. or 0.75 % of max.	0.5 % of max.
Total diluted exhaust meter (CVS) (With heat exchanger before meter)	$\dot{n}$	1 s (5 s)	1 Hz means (1 Hz)	2.0 % of pt. or 1.5 % of max.	1.0 % of pt. or 0.75 % of max.	1.0 % of max.
Dilution air, inlet air, exhaust, and sample flow meters	$\dot{n}$	1 s	1 Hz means of 5 Hz samples	2.5 % of pt. or 1.5 % of max.	1.25 % of pt. or 0.75 % of max.	1.0 % of max.
Continuous gas analyzer	x	5 s	1 Hz	2.0 % of pt. or 2.0 % of meas.	1.0 % of pt. or 1.0 % of meas.	1.0 % of max.
Batch gas analyzer	x	N/A	N/A	2.0 % of pt. or 2.0 % of meas.	1.0 % of pt. or 1.0 % of meas.	1.0 % of max.
Gravimetric PM balance	m_{PM}	N/A	N/A	See §1065.790	0.5 µg	N/A
Inertial PM balance	m_{PM}	5 s	1 Hz	2.0 % of pt. or 2.0 % of meas.	1.0 % of pt. or 1.0 % of meas.	0.2 % of max.

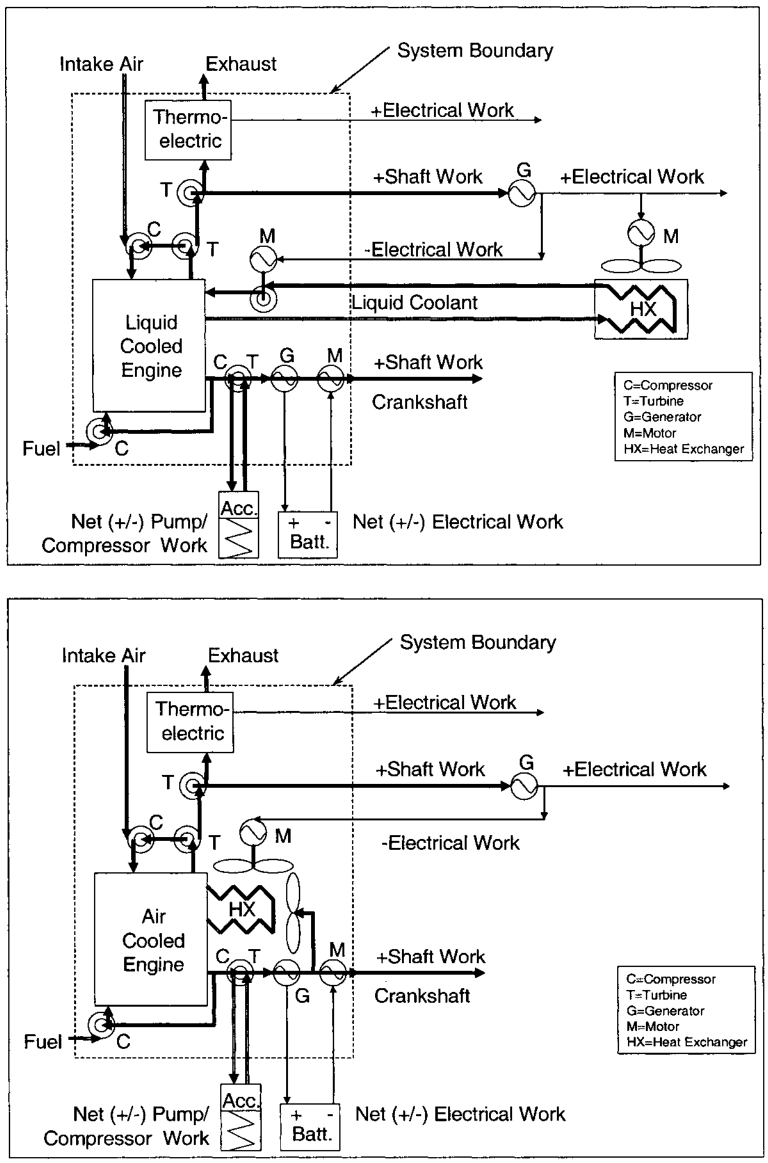
[a] Accuracy, repeatability, and noise are all determined with the same collected data, as described in §1065.305, and based on absolute values. "pt." refers to the overall flow-weighted mean value expected at the standard; "max." refers to the peak value expected at the standard over any test interval, not the maximum of the instrument's range; "meas" refers to the actual flow-weighted mean measured over any test interval.

MEASUREMENT OF ENGINE PARAMETERS AND AMBIENT CONDITIONS

§ 1065.210 Work input and output sensors.

(a) *Application*. Use instruments as specified in this section to measure work inputs and outputs during engine operation. We recommend that you use sensors, transducers, and meters that meet the specifications in Table 1 of § 1065.205. Note that your overall systems for measuring work inputs and outputs must meet the linearity verifications in § 1065.307. We recommend that you measure work inputs and outputs where they cross the system boundary as shown in Figure 1 of this section. The system boundary is different for air-cooled engines than for liquid-cooled engines. If you choose to measure work before or after a work conversion, relative to the system boundary, use good engineering judgment to estimate any work-conversion losses in a way that avoids overestimation of total work. For example, if it is impractical to instrument the shaft of an exhaust turbine generating electrical work, you may decide to measure its converted electrical work. In this case, divide the electrical work by an accurate value of electrical generator efficiency ($\eta<1$), or assume an efficiency of 1 ($\eta=1$), which would over-estimate brake-specific emissions. Do not underestimate the generator's efficiency because this would result in an under-estimation of brake-specific emissions. In all cases, ensure that you are able to accurately demonstrate compliance with the applicable standards.

Figure 1 of §1065.210: Work inputs, outputs, and system boundaries for liquid-cooled and air-cooled engines.



(b) *Shaft work.* Use speed and torque transducer outputs to calculate total work according to §1065.650.

(1) *Speed.* Use a magnetic or optical shaft-position detector with a resolution of at least 60 counts per revolution, in combination with a frequency

counter that rejects common-mode noise.

(2) *Torque.* You may use a variety of methods to determine engine torque. As needed, and based on good engineering judgment, compensate for torque induced by the inertia of accelerating and decelerating components connected to the flywheel, such as the drive shaft and dynamometer rotor. Use any of the following methods to determine engine torque:

(i) Measure torque by mounting a strain gage or similar instrument in-line between the engine and dynamometer.

(ii) Measure torque by mounting a strain gage or similar instrument on a lever arm connected to the dynamometer housing.

(iii) Calculate torque from internal dynamometer signals, such as armature current, as long as you calibrate this measurement as described in § 1065.310.

(c) *Electrical work.* Use a watt-hour meter output to calculate total work according to § 1065.650. Use a watt-hour meter that outputs active power (kW). Watt-hour meters typically combine a Wheatstone bridge voltmeter and a Hall-effect clamp-on ammeter into a single microprocessor-based instrument that analyzes and outputs several parameters, such as alternating or direct current voltage (V), current (A), power factor (pf), apparent power (VA), reactive power (VAR), and active power (W).

(d) *Pump, compressor or turbine work.* Use pressure transducer and flow-meter outputs to calculate total work according to § 1065.650. For flow meters, see § 1065.220 through § 1065.248.

§ 1065.215 Pressure transducers, temperature sensors, and dewpoint sensors.

(a) *Application.* Use instruments as specified in this section to measure pressure, temperature, and dewpoint.

(b) *Component requirements.* We recommend that you use pressure transducers, temperature sensors, and dewpoint sensors that meet the specifications in Table 1 of § 1065.205. Note that your overall systems for measuring pressure, temperature, and dewpoint must meet the calibration and verifications in § 1065.315.

(c) *Temperature.* For PM-balance environments or other precision temperature measurements over a narrow temperature range, we recommend thermistors. For other applications we recommend thermocouples that are not grounded to the thermocouple sheath. You may use other temperature sensors, such as resistive temperature detectors (RTDs).

(d) *Pressure.* Pressure transducers must be located in a temperature-controlled environment, or they must compensate for temperature changes over their expected operating range. Transducer materials must be compatible with the fluid being measured. For atmospheric pressure or other precision pressure measurements, we recommend either capacitance-type, quartz crystal, or laser-interferometer transducers. For other applications, we recommend either strain gage or capacitance-type pressure transducers. You may use other pressure-measurement instruments, such as manometers, where appropriate.

(e) *Dewpoint.* For PM-stabilization environments, we recommend chilled-surface hygrometers. For other applications, we recommend thin-film capacitance sensors. You may use other dewpoint sensors, such as a wet-bulb/dry-bulb psychrometer, where appropriate.

FLOW-RELATED MEASUREMENTS

§ 1065.220 Fuel flow meter.

(a) *Application.* You may use fuel flow in combination with a chemical balance of carbon (or oxygen) between the fuel, inlet air, and raw exhaust to calculate raw exhaust flow as described in § 1065.650, as follows:

(1) Use the actual value of calculated raw exhaust flow rate in the following cases:

(i) For multiplying raw exhaust flow rate with continuously sampled concentrations.

(ii) For multiplying total raw exhaust flow with batch-sampled concentrations.

(2) In the following cases, you may use a fuel flow meter signal that does