

Designing and Making the Worlds Best Torque Instruments Since 1960

CHOOSING THE RIGHT TORQUE SENSOR

TOPICS COVERED

Determining Maximum Average Running Torque
Determining Probable Peak Torque
Accounting For Starting Conditions
Satisfying Accuracy Requirements
Avoiding EMI/Noise Errors
Specifying Input Power And Output Signals
Assuring Calibration Accuracy

S. HIMMELSTEIN AND COMPANY

CHOOSING THE RIGHT TORQUE SENSOR

Step 1. Find the Maximum Average Running Torque (MART).

The equation finds the maximum average running torque (**MART**). For *rpm*, use the **lowest speed** at which maximum rated power is developed.

$$\text{MART (lbf-in)} = [\text{Max Rated Horsepower}] \times [63025] / [\text{rpm}]$$

Step 2. Estimate the Probable Peak Torque (PPT).

Rotary machinery exhibits pulsating not smooth torque. Peak stress determines shaft capacity *not* stress duration (except for fatigue). To find a conservative¹ value of probable peak torque:

1. This procedure will select a conservatively sized sensor. Analytical techniques can derive a more precise value of peak torque. However, they are dependent on having exact values for *all* significant shaft network parameters -- seldom available.

Select the load service factor (**LSF**) from the following groups:

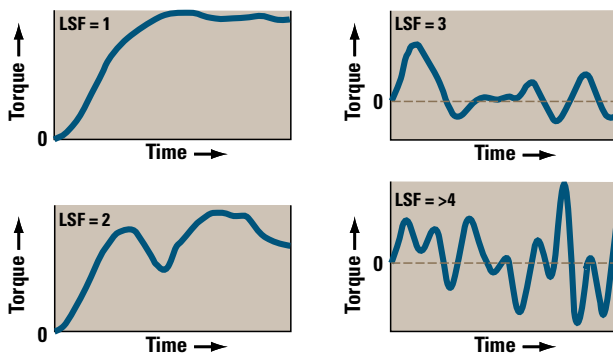
LSF = 1 for smooth, constant load devices; fans, can fillers, centrifugal blowers & liquid pumps, axial compressors, etc.

LSF = 2 for non-reversing, non-constant load or start/stop devices; extruders, hoists, conveyors, kilns, mixers, etc.

LSF = 3 for high variable shock or light reversing loads; crushers, hammer mills, single cylinder reciprocating pumps, tree barkers, vehicle drivelines, etc.

LSF = 4 → 6 for heavy to full torque reversals (need not cause reverse rotation) or with undamped torsional vibrations in the operating speed range; single and double acting reciprocating compressors, etc.

LSF (Load Service Factor) Torque Characteristics



Select the drive service factor (**DSF**) from the following groups:

DSF = 0 for smooth turbine, dc motor, or three phase ac motor except *variable frequency drives*.

DSF = 0.5 for gas engines with 8 or more cylinders, diesels with 10 or more cylinders, single phase ac motors.

DSF = 1 for 6 cylinder gas or 8 cylinder diesel engines, three phase variable frequency ac drives, etc.

DSF = 1.5 for 4 cylinder gas or 6 cylinder diesel engines and single phase variable frequency ac motors.

DSF = 2 → 4 for gas engines with less than 4 & diesels with less than 6 cylinders.

$$\text{Probable Peak Torque (PPT)} = (\text{MART}) \times ([\text{LSF}] + [\text{DSF}])$$

Select a sensor with **overload torque rating = > 2 X (PPT)**.

Step 3. Check Starting Conditions.

If the driver is an induction motor started across the line, *and* the load has high inertia, then verify the sensors' torque overload rating is at least *twice* the **motors' rated starting torque**. Alternately, use reduced voltage starting or limit motor current to *reduce* starting torque to the **PPT** calculated in step 1.

Step 4. Check For Extraneous Loads.

Any load, other than torque, is extraneous. Extraneous loads can be:

axial, i.e., the weight and thrust of a vertical pump.

radial, i.e., belt tension load.

bending, i.e., a pulley sensor with a non-centered pulley.

When such loads are expected, verify they are within the sensors ratings. If they are not, consider re-arranging the installation to isolate those loads or to make the installation more tolerant of them. For example, a floating flanged torque meter can handle many times the axial load of a foot-mounted shaft sensor. Pulley torque meters handle large radial and bending loads unacceptable to other types.

Step 5. Verify The Speed Rating by noting the sensor maximum operating speed.

Step 6. Verify Sensor Accuracy. The acceptable error (%) = > $[(\text{nonlinearity})^2 + (\text{hysteresis})^2 + (\text{non-repeatability})^2]^{0.5}$

Nonlinearity, hysteresis and non-repeatability are sensor errors (% of full scale). If the calculated error is too high, use a higher accuracy grade or two or more sensors (or dual range sensors) for the test range.

Step 7. Specify The Power Source. Select from vehicle battery, other dc power, ac carrier amplifier, or ac power line.

Step 8. Specify The Output Signal from among $\pm 5V$, $\pm 10V$, mV/V, or the 4-20 mA, 2-wire transmitter, or digital formats.

Step 9. Specify Noise Hardened Torquemeters when **EMI** is present. This should *always* be done when IGBT-based adjustable speed and/or vector drives are used. If needed, use a zero velocity speed pickup. See Bulletin 708 for details.

Step 10. Choose The Right Torque Sensor. Select a sensor with a suitable mechanical configuration, meeting these criteria:

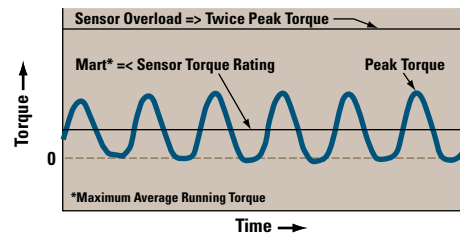
full scale = > MART (maximum average running torque)

overload = > 2 X PPT (probable peak torque)

overrange = > PPT (probable peak torque)

If an external data acquisition system is used, its overrange must also = > PPT.

The margin between PPT and sensor overload is needed to avoid fatigue failure; never plan to operate there.



Step 11. Verify The Torquemeter Is Accurately Calibrated And Meets Its Specifications.

Your assurance is that the makers' calibration laboratory is consistent with the sensor specification. That means its **Cal Lab has an independent, internationally recognized accreditation* with a best uncertainty less than the torquemeter error spec**. Clearly, it's absurd to certify performance higher than the Cal Labs' uncertainty – nonetheless, most competitors do and/or don't have lab accreditation.

*Himmelsteins' Torque Calibration Laboratory is accredited by NVLAP, an arm of the NIST, lab code 200487-0. Visit our website at www.himmelstein.com for a copy of the NVLAP Certificate and Accreditation Scope or, use the "Laboratory Accreditation" link at www.nist.gov

MCRT® SENSORS - MORE PERFORMANCE, RELIABILITY & CHOICE

MCRT® Sensor, Premium Standard Features

FEATURES ¹	ADVANTAGES	COMMENTS/BENEFITS
High strength, alloy steel shafts.	Superior sensor material, infinite fatigue life.	Large safety margins under dynamic conditions.
State-of-the-art foil strain gage sensing.	Precise static and dynamic response with excellent temperature gradient performance.	Refined over 50 years and dominant in precision weight and load measurement.
Low phase shift rotary transformers with unexcelled signal coupling performance.	Shielded coupling won't generate noise, wear, contaminants, is immune to oil & vibration.	Low noise, long life. No radio links, brushes, or complex rotating circuits subject to drift.
Non-ferrite rotary transformer construction.	No brittle parts subject to shock damage.	Highest safety margin for running/handling.
Unexcelled immunity to magnetic fields.	Unaffected by proximity to motor, generator and similar electric machinery magnetic fields.	Provides accurate, noise-free measurement and control of rotating electric machines.
Most models available <i>noise-hardened</i> against severe EMI from IGBT-based ASD's.	Provides accurate, noise-free data when used with modern, adjustable-speed drives (ASD's).	See Bulletin 708 and individual data sheets for availability of this feature.
Robust mechanical design and construction includes rigid rotor with large bearings.	Overload capacities from 2 to 10 times full scale rating handle high PPT/MART ratios.	Avoids unsupported rotor diaphragms. Optimized strength/sensitivity ratio.
Has both <i>static and dynamic response</i> .	Measures at any speed; 0 to ± maximum rpm. Can field dead weight calibrate.	Use one device to measure stall, average and peak-to-peak dynamic torques.
NIST traceable calibration done with 8 to 10 CW and 8 to 10 CCW loads. See Note 2.	Accuracy is assured with NVLAP accredited 10 oz.-inch to 4,000,000 lb.-inch calibrations.	Sensors have NVLAP approved Calibration Certificates documenting NIST traceability.

1. A few units have variations. See model specification for details.

2. Number of calibration steps are 8 (minimum) to 10, dependent on the sensor range and availability of calibration weights.

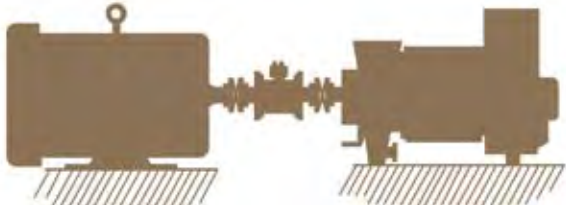
Choose An MCRT® Digital, mV/V Or DC Operated Torquemeter, Or A 4-20 mA, 2-Wire Transmitter

TYPE	SELECTION CRITERIA	MCRT® CHARACTERISTICS	COMMENTS/BENEFITS
mV/V Torquemeter	Excitation Power	3 kHz ±10% sinusoid @ 3-6 V rms, regulated.	Good noise immunity for long cables.
	Output Signal	1.5 to 4 mV/V rms, dependent on model.	Matches 3 kHz strain gage carrier amplifiers.
	Required Cabling	Multiple twisted and shielded wire pairs.	Complex cable needs reactive balance.
	Accuracy Grades	Standard and enhanced	Best accuracy <i>if calibrated with cable & amp.</i>
	Mechanical Styles	Shaft, flange, splined, pulley, roll, and wheel.	Widest choice of standard products.
DC Operated Torquemeter	Excitation Power	10.5 to 24V dc. Reverse polarity protected.	Unregulated sources include battery power.
	Output Signal	±5V & ±10V, filtered @ 1 & 500 or, 1100 Hz.	Noise tolerant signal needs no amplification.
	Required Cabling	Simple three conductor shielded cable.	Calibration and balance free of cable effects.
	Accuracy Grades	Standard and Enhanced.	NIST traceable calibration unaffected by cables.
	Mechanical Styles	Shaft, flange, splined, pulley, roll, and wheel.	Most popular styles are standard.
Digital Torquemeter	Excitation Power	11 to 24V dc. Reverse polarity protected.	Unregulated sources include battery power.
	Analog Output Signals	±5V or ±10V, user selectable.	Outputs Torque, Speed and Power (Option).
	Digital Output	RS232 Serial Port at 38,400 baud.	Fully-scaled engineering unit results.
	Digital Filters	0.1 to 200 Hz in eleven 1-2-5 steps.	User selectable through provided software.
	Accuracy Grades	Standard and Enhanced.	NIST traceable calibration unaffected by cables.
	Mechanical Styles	Shaft, flange, splined, pulley, roll, and wheel.	Most popular styles are standard.
Compact Digital	Excitation Power	10 to 15 Vdc.	Unregulated sources include battery power.
	Analog Output Signals	±5 or ±10 V, user selectable.	Outputs Torque.
	Digital Output	RS232	Fully scaled engineering unit results
	Digital Filters	0.1 to 200 HZ	User selectable through provided software.
	Accuracy Grades	Standard and Enhanced.	NIST traceable calibration unaffected by cables.
	Mechanical Styles	Keyed Shaft	Inventory of standard units for fast delivery.
Bearingless Digital	Excitation Power	10 to 26 Vdc @ 10 W max.	Unregulated sources.
	Analog Output Signals	±5V or ±10V, user selectable.	Outputs Torque.
	FM Output	10 ± 5 kHz, 20 ± 10 kHz, 40 ± 20 kHz	
	Digital Output	RS232/485.	Fully scaled engineering unit results.
	Digital Filters	0.1 to 3,000 Hz	User selectable through provided software.
	Accuracy Grades	Standard and Enhanced.	NIST traceable calibration unaffected by cables.
	Mechanical Styles	Flange.	Shortest installed length.
4-20 mA 2-wire Transmitter	Excitation Power	10 to 32 V dc. Reverse polarity protected.	Unregulated sources include battery power.
	Output Signal	4-20 mA @ 0 to 1100 ohms loop resistance.	Has greatest immunity to ambient cable noise.
	Required Cabling	Simple two wire loop has lowest installed cost.	Calibration and balance free of cable effects.
	Accuracy Grades	Standard and Enhanced.	NIST traceable calibration unaffected by cables.
	Mechanical Styles	Shaft and flange types standard, others special.	Most popular styles are standard.

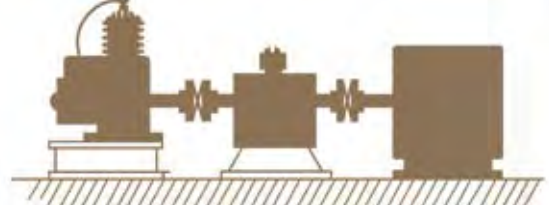
TORQUE SENSOR SELECTION EXAMPLES

Typical torque meter applications are illustrated. They demonstrate important selection principles and criteria discussed in this document. Space limitations prevent an exhaustive treatment. Refer to Himmelstein Product Specifications, Installation Manuals and

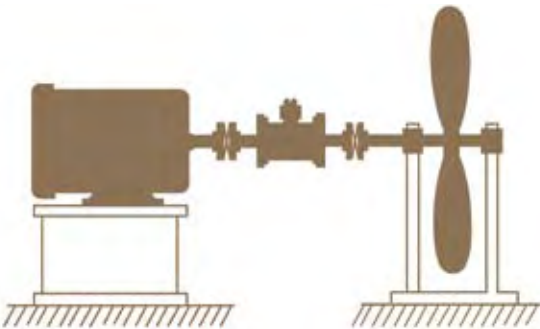
Technical Memoranda for additional details. You are encouraged to call if faced with a unique application or, should you need any help selecting a torque sensor. Our business is driven by solving your torque measurement and control problems.



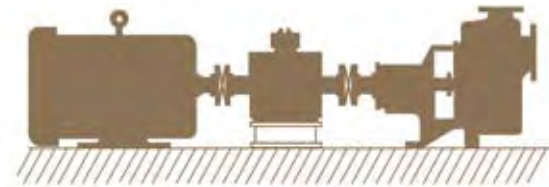
Induction Motor Driven Axial Compressor. The 250 HP compressor is driven at 1,750 rpm by a 3 phase, 250 HP induction motor. From Equation 1, $MART = 9,000$ lbf-in. Since service is stop/start, $LSF = 2$. DSF for the motor is 0. $PPT = 9,000 \times [2 + 0] = 18,000$ lbf-in. The sensors' overload rating = $> 36,000$ lbf-in. Since the torque signal will be used by the plant process computer 2,800 feet from the sensor, a 2-wire, 4-20 mA output format is desired. The compressor inertia is moderate and there are no significant extraneous loads. Choose either an MCRT[®] 39061X(12-3) or the 39007X(1-4).



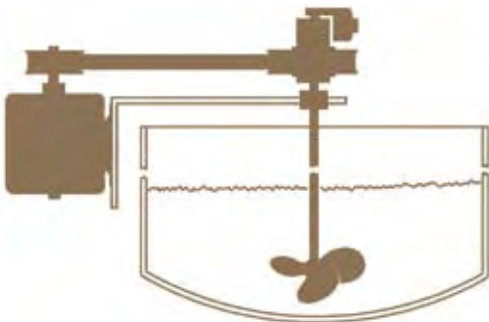
Single Cylinder Gas Engine Test Stand. A 12 HP at 2,600 rpm engine runs from 900 to 4,500 rpm. $MART = 291$ lbf-in. The absorber $LSF = 1$. A DSF of 4 should be used due to high peak to average torque ratio and probability of a torsional resonance occurring. Thus, $PPT = 291 \times [4 + 1] = 1,455$ lbf-in. The overload rating = $> 2,910$ lbf-in. Use an MCRT[®] 49703V(1-3); overload rating is 4,000 lbf-in, overrange is 1,500 lbf-in. With the filter at 200 hz and the output set to 10V at 1,000 lbf-in, data is instantaneous torque with 0.01% resolution. Set the filter to 1 Hz and set the 10V output to 300 lbf-in, data is average torque with 0.033% resolution.



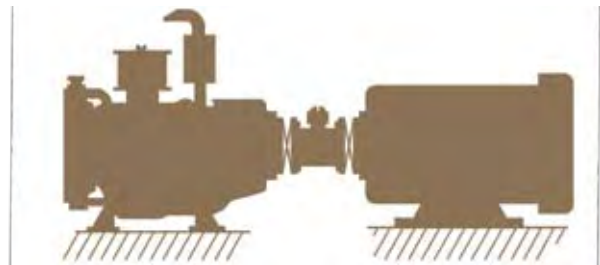
Induction Motor Driven Fan. A 15 HP, 875 rpm, 3 phase motor drives a 25" fan. From equation 1, $MART = 1,080$ lbf-in. From page 2, the $LSF = 1$ and $DSF = 0$. Thus, $PPT = 1,080 \times [1 + 0] = 1,080$ lbf-in; sensor overload = $> 2,160$ lbf-in. However, fan inertia is much greater than the motors'. When starting across the line, the sensor sees the *motor starting torque*; $3 \times MART$ or, 3,240 lbf-in. Thus, sensor overload rating = $> 6,480$ lbf-in, not 2,160 lbf-in. A flanged sensor handles thrust. Use either an MCRT[®] 39060X(2-3) or 49060V(2-3).



AC Motor Driven Centrifugal Water Pump. A 200 HP, variable frequency 3 phase drive runs the pump from 520 to 3,600 rpm. Using Equation 1 and 520 rpm, $MART = 24,240$ lbf-in. From page 2, $LSF = 1$ and $DSF = 1$; $PPT = 24,240 \times [1 + 1] = 48,480$ lbf-in. Thus, the sensor overload rating = $> 96,960$ lbf-in. Foot mounting is preferred for large sensors at higher speeds. No significant extraneous loads exist. Select an MCRT[®] 29007T(25-3) or 49007V(25-3). Both provide the needed immunity to EMI from the adjustable speed drive (ASD).



Belt Driven Mixer Assembly. The mixer is driven from 60 to 250 rpm. The dc, variable speed motor is rated ¼ HP. Belt tension is 350 pounds. From Equation 1, $MART = 262$ lbf-in at 60 rpm. From page 2, $LSF = 2$ and $DSF = 0.5$. Thus, $PPT = 262 \times [2 + 0.5] = 656$ lbf-in. The sensor overload = $> 1,313$ lbf-in. The belt loads are too high for shaft or flanged torque sensors. An MCRT[®] 3120TA(5-2) pulley torque meter handles 750 pound radial loads, and has the required measuring range and overload capacity (rated 2,500 lbf-in).



Diesel Engine Driven Generator. The 12 cylinder diesel is rated 1,080 HP at 1,800 rpm. From Equation 1, $MART = 37,815$ lbf-in. The variable load yields an $LSF = 2$, $DSF = 0.5$; see page 2. Thus $PPT = 37,815 \times [2 + 0.5] = 94,537$ lbf-in and overload capacity = $> 189,075$ lbf-in. No unusual extraneous load conditions exist. A flanged sensor is needed to save space. Select either an MCRT[®] 28070T(96-3), 29070T(48-3), 39070X(48-3) or 49070V(48-3) depending on desired output data format and accuracy requirements.

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