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

Measurement and Control Products Since 1960

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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.*

MART (lb-in) = [Max Rated Horsepower] X [63025] / [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 *conservative*[1] *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.

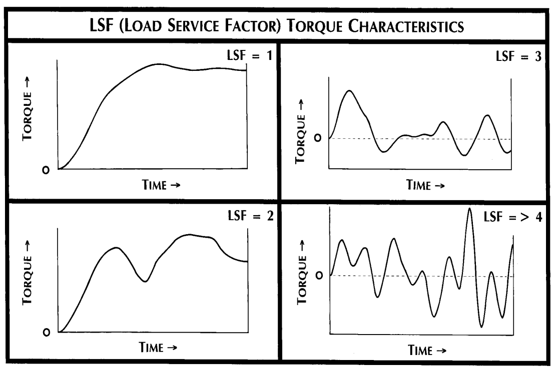
Select the *load service factor* (**LSF**) from the following groups:

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.



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.

Probable Peak Torque (PPT) = (MART) X ([LSF] + [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 torquemeter can handle many times the axial load of a foot mounted shaft sensor. Pulley torquemeters 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 (%) $=> [(\text{nonlinearity})^2 + (\text{hysteresis})^2 + (\text{nonrepeatability})^2]^{0.5}$
Nonlinearity, hysteresis and nonrepeatability are sensor errors (% of full scale). If the calculated error is too high, use a higher accuracy grade or two or more sensors for the test range.

Step 7. Specify The Power Source. Available choices are vehicle battery, other dc power, an ac carrier amplifier, or the ac power line.

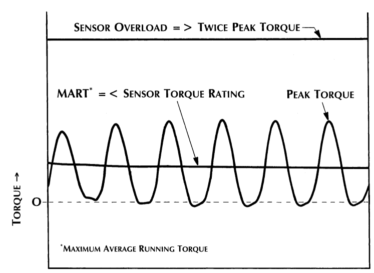
Step 8. Specify The Output Signal from among digital, ±5V, ±10V, mV/V, or the 4-20 mA, 2-wire transmitter formats.

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 suitable mechanical configuration*, from standard types meeting the above criteria. *The **sensor ratings should meet these criteria**:*

full scale => MART *(maximum average running torque)*
overload => 2 X PPT *(probable peak torque)*

Reserve the safety margin between the probable peak torque (PPT) and the sensors' overload rating for unexpected loads; <u>never plan to operate there</u>. See page 4 for examples.



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, 15-5PH[2] stainless shafts. Has excellent corrosion resistance.	Superior sensor material, infinite fatigue life. Better size tolerances and life than plating.	Greater safety margins under dynamic conditions. Smoother running shafting.
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[3] to magnetic fields.	Unaffected[3] 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 *noise-hardened*[3] 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 *static and dynamic response*.	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.
Choice of accuracy grades.	You get the accuracy you need; neither too little or too much.	Use a higher accuracy *with* a higher torque rating to create a higher overload capacity.
NIST traceable calibration done with 8 to 10^4 CW and 8 to 10^4 CCW loads.	Accuracy *is assured with NVLAP accredited*. 10 oz-in to 4,000,000 lb-in calibrations.	Sensors have NVLAP approved Calibration Certificates documenting NIST traceability.

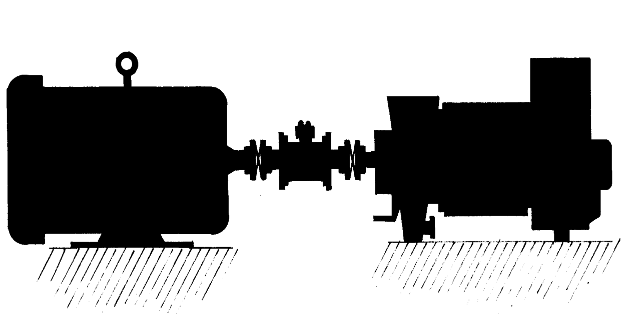
1. A few units have variations. See model specification for details.
2. AMS Grades 5658 or 5659, model dependent.
3. Greatest noise immunity is available in MCRT® Series 49000V and 48000V (equipped with Option G) noise hardened Torquemeters and in noise hardened MCRT® mV/V torquemeters supplied with Himmelstein cables and amplifiers.
4. 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	Precision, Enhanced, and Ultra-Precision.	Best accuracy *if calibrated with cable & amp.*
	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*.
	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.
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.

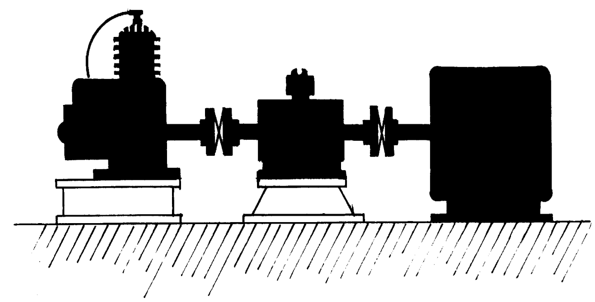
* Options

TORQUE SENSOR SELECTION EXAMPLES

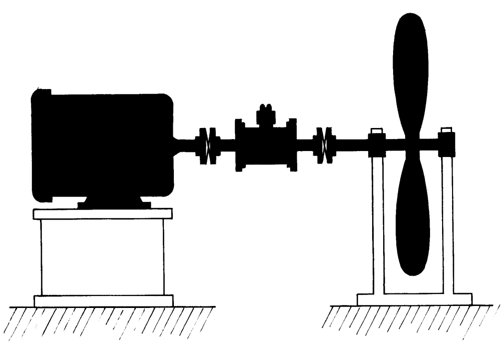
Typical torquemeter applications are illustrated. They demonstrate important selection principles and criteria discussed in this document. Space limitations prevent an exhaustive treatment. Refer to Himmelstein Product Specifications, Installation Manuals and Technical Memoranda for additional details. You are encouraged to call if faced with a unique application or, should you need any help selecting a torque sensor. Our business is solving your torque measurement and control problems.



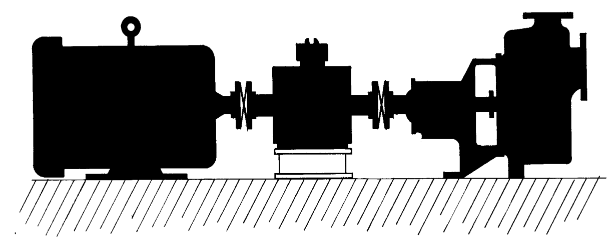
Induction Motor Driven Axial Compressor. The 250 HP compressor is driven at 1,750 rpm by a 3 phase, 250 HP induction motor. From Equation 1, MART = 9,000 lb-in. Since service is stop/start, the LSF = 2. DSF for the motor is 0. PPT = 9,000 X [2 + 0]= 18,000 lb-in. The sensors' overload rating = > 36,000 lb-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® 3961X(12-3) or the 3907X(1-4).



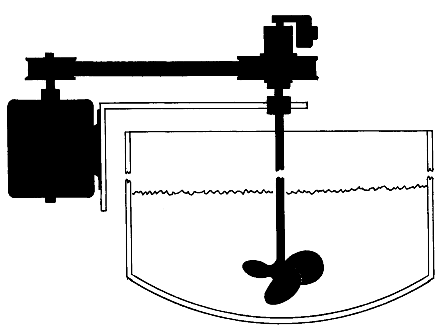
Single Cylinder Gas Engine Test Stand. The 12 HP at 2,600 rpm engine runs from 900 to 4,500 rpm. MART = 291 lb-in. The absorber LSF = 1. A DSF of 4 should be used because: the ratio of peak to average torque is very high and, a torsional resonance will probably occur at an operating speed. Thus, PPT = 291 X [4 + 1] = 1,455 lb-in. The sensors' overload rating = > 2,910 lb-in. Extraneous loads aren't a problem. Use an MCRT®59003(4-2) because the sensors' 4,000 lb-in overload rating will provide safe operation without compromising measurement accuracy.



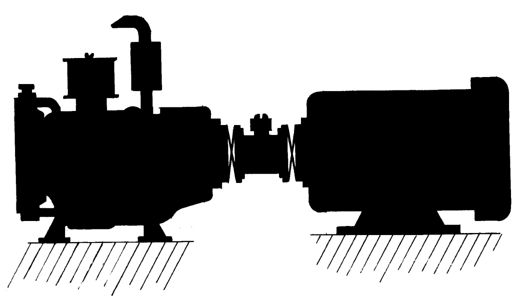
Induction Motor Driven Fan. A 15 HP, 875 rpm, 3 phase motor drives a 25" fan. From equation 1, MART = 1,080 lb-in. From page 2, the LSF = 1 and DSF = 0. Thus, PPT = 1,080 X [1 + 0] = 1,080 lb-in; sensor overload = > 2,160 lb-in. However, fan inertia is much greater than the motors'. When starting across the line, the sensor sees the *motor starting torque*; 3 X MART or, 3,240 lb-in. Thus, sensor overload rating = > 6,480 lb-in, not 2,160 lb-in. A flanged sensor handles thrust. Use either an MCRT®3960X(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 lb-in. From page 2, LSF = 1 and DSF = 1; PPT = 24,240 X [1 + 1] = 48,480 lb-in. Thus, the sensor overload rating = >96,960 lb-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 lb-in at 60 rpm. From page 2, LSF = 2 and DSF = 0.5. Thus, PPT = 262 X [2 + 0.5] = 656 lb-in. The sensor overload = > 1,313 lb-in. The belt loads are too high for shaft or flanged torque sensors. An MCRT®3120T(5-2) *pulley torquemeter* handles 750 pound radial loads, and has the required measuring range and overload capacity (rated 2,500 lb-in).



Diesel Engine Driven Generator. The 12 cylinder diesel is rated 1,080 HP at 1,800 rpm. From Equation 1, MART = 37,815 lb-in. The variable load yields an LSF = 2. DSF = 0.5; see page 2. Thus PPT = 37,815 X [2 + 0.5] = 94,537 lb-in and overload capacity = > 189,075 lb-in. No unusual extraneous load conditions exist. A flanged sensor is needed to save space. Select either an MCRT®26070T(96-3), 29070T(48-3), 3970X(48-3) or 49070V(48-3) depending on desired output data format and accuracy requirements.

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