INTENDED USE AND APPLICATIONS

Mechanical power transmission installations frequently require the use of torque measurement for system control and analysis. The uses of torque measurement are limitless. By measurement of other related parameters, high-accuracy system analysis and control is possible. A random sampling of torque transducer applications follow.

Power requirements: Input torque and speed to a device can give indications of the power required to drive the device, i.e. pumps, generators, gear boxes, machine tools, and drive trains.

Component efficiencies: Input and output work measurement of a system, such as input speed and torque and output speed and torque, give an indication of a component's or system's efficiency. Clutches, universal joints, brakes, transmissions, motors, and engines are routinely evaluated in this manner.

Process control: Changes in input or output power or component efficiencies often are the best (or only) "clue" to a process going out of control. Automatic systems can use "feedback" or "limit" techniques to correct or halt a faulty process. These techniques are used in gear lapping, tire grading, and textile weaving. Torque required to turn a fastener is becoming increasingly important.

Dynamic effects: Direct measurement of dynamic torque in actual systems can be made, which include acceleration effects. Dynamic range may be limited by system frequency response.

Physical properties: Determination of polar moments of inertia, torsional spring constants, bearing friction, and windage losses can be made using torque measurement techniques.

Torque measuring devices of high reliability and precision have become key tools to the analysis and control of mechanical power transmission. Complex systems can be separated into functional blocks that are analyzed as individual components and to their effect on the total mechanism. The selection of a torque measuring system, while often dictated by physical and environmental constraints, must be made with an understanding of the system torque, why it is being measured, and the torque measurement method being used.

See Appendix H - Typical applications of in-line torque sensors, page 20.

GENERAL DESCRIPTION

Torque sensors

In-line shaft torque sensors usually consist of a shaft, appropriately instrumented, placed between the driving power source and the loading mechanism. These sensors are based upon measuring torsional windup (angular deflection or strain) of a shaft under the applied torque. (See Appendix A - Torque and torque shaft principle on page 12 for further information on the subject of torque).
Strain gages
The Honeywell Model 1800 Series torque transducers (formerly known as Lebow) use resistance foil strain gage sensors designed to measure the torque transmitted through a rotating shaft. (See Appendix B - Strain gage torque transduction on page 12 for more information on the functioning of a transducer).

Rotary transformers
Input and output signals are transferred to and from the rotating shaft by means of rotary transformers. There are no brushes, slip rings, or other such devices incorporated in its design. Due to its unique design, the transformer coupling (signal transfer) is not adversely affected by shaft end-play, angular position of the shaft, or rotation, thereby eliminating any requirement for critical alignment of the internal components. (See Appendix C - Torque signal transmission on page 13 for the theory of operation of rotary transformer).

Bearings
The shaft is supported in the housing by means of precision ball bearings. The bearings determine the speed rating of the unit, and in general, follow the bearing manufacturer’s recommendations. Honeywell’s Model 1800 Series standard torque transducers are fitted with grease-filled bearings. Higher speed units can be provided by Honeywell which are designed for air-oil-mist lubrication. Maintenance is reduced to a minimum because the bearings are the only point of contact between the rotating and stationary members of the torque transducer. (See Appendix D - Bearing life on page 14 for more detailed information on bearings and bearing life). (See Appendix G - on Page 19 for more detailed information on the lubrication of bearings).

Compensation
Passive temperature compensation networks have been incorporated in both the strain gage circuitry and the rotary transformer system to automatically correct the torque readings for operating temperature variations.

Electrical connections
Electrical connections are made by means of standard “MS” type receptacles (mating connectors are furnished). Optionally, Honeywell can supply a cable assembly consisting of the above connector, and a high quality shielded cable terminated with pigtail leads or a connector of the customer’s choice.

Other features
Other features of the Honeywell Model 1800 Series torque transducers include a 60-tooth speed pickup gear, double-keyed input and output shafts, and balancing collars.

Optional features include a threaded magnetic speed sensor, zero velocity speed sensor, foot mounting plate, dynamic balancing and models with higher magnetic-field immunity.

Honeywell can also supply these transducers with many other features designed to meet a specialized application.

For other general features including dimensions and specifications, the user is referred to the outside dimensional drawing supplied with this particular unit.

MECHANICAL SET UP
Floating mount (housing unsupported)
When mounted with the housing unsupported, a good quality, “single-flex” coupling should be used on each end of the torque shaft to connect it to your drive and loading devices. Each “single-flex” coupling will compensate for angular misalignment only. Two “single-flex” couplings must be used to compensate for parallel misalignment.

All standard torque sensors in this series are provided with precision ground shaft diameters, and double keyways on each end of the shaft. Any coupling used should be sized to achieve a light press or slip fit on the shaft. Install a full length key in each keyway provided. The keys can be made from commercially available key stock, and should be precision fitted.

In-line mounting requires that the housing assembly be restrained from rotating. The housing is provided with tapped holes for mounting a restraining strap, that should be relatively flexible. Woven wire straps or light nylon webbing are acceptable.

Fixed mount (housing supported)
When installing your torque sensor with the foot-mount option, it is recommended that a “double-flex” coupling be installed on each end of the torque shaft. “Double-flex” couplings will compensate for both angular and parallel misalignment.

After proper alignment is verified, at least two dowel pin holes should be drilled through the foot-mount plate into the surface below. Installation of the dowel pins will aid in realignment should the torque sensor be removed and reinstall at a later date.
The same precision coupling fitting requirements outlined in the floating-mount instructions apply. Foot mounting requires that the torque shaft be aligned as well as possible with the driving and loading devices. Ideally, alignment should be within 0.001 inches per inch of the shaft diameter. Consult coupling manufacturers for selection of the best couplings for your application. (See below for further information on coupling considerations and selection).

**BENDING MOMENT LOADS**

Precautions should be taken when Honeywell rotating-shaft torque sensors are used for an application which requires that they be driven or loaded directly by a belt, chain, or gear-power transfer system. These systems can induce high bending loads in the shaft and may lead to premature transformer shaft and/or bearing failure.

Where these drive systems are required, the pulleys, sprockets, or gears should be mounted on a jackshaft assembly, coupled to the shaft of the torque sensor with a flexible coupling. This will allow the bearings of the jackshaft assembly to carry all bending loads and transfer only torque loads to the shaft of the torque sensor. Figure 2 shows a torque sensor in this application.

**Figure 2. Torque sensor with flexible couplings**

**COUPLING CONSIDERATIONS AND SELECTION**

Honeywell's Model 1800 Series of in-line shaft torque sensors are provided with precision ground shaft ends with double keyways on each end. Any coupling used should be sized to achieve a light press to slip-fit condition. Heavy press fits are to be avoided, as the shaft may be damaged during pressing operations.

In rotating torque transducer installations, the type of coupling used is very important. Rapid changes in torque, if they are to be measured, will require mechanical transfer between shafts without damping or deformation. This is especially important in those situations where torsional vibrations are part of the measurement and peak torques may exceed by many times the static torque value.

Though offered in many variations, couplings may be classified under one of the following three categories:

**Flexible** - These couplings obtain their flexibility from the rolling or sliding of mating parts, usually require lubrication and include such types as: gear, spindle, chain, grid, and U-joint. Thin metallic discs or diaphragms also provide flexibility in these couplings. These types do not need lubrication.

**Elastomeric** - These couplings obtain their flexibility from stretching or compressing a resilient material (rubber, plastic, etc.). Some sliding or rolling may take place, but these actions are minimal and do not enhance to the coupling's flexibility. They do not require lubrication.

**Miscellaneous** - This group derives their flexibility from a combination of previously listed mechanisms and includes pin and bushing, slider block, and spring types. Lubrication is required with many of these designs.

The installation of the coupling should be such that no radial forces other than the coupling weight are present. Couplings that will apply end thrust to the torque transducer should be avoided. Metal expands with an increase in temperature and should not be ignored when selecting a coupling. The torque transducer is a highly precise measuring device and should not be employed as a simple mechanical transmission element.

Angular and/or parallel misalignment in shafts may be compensated for by use of the proper coupling. (See Appendix E - Effects of misalignment of a torque sensor on page 14). However, the use of couplings does not eliminate the need for proper initial setup and alignment of the two shafts. Some couplings may induce heavy bending loads if shaft alignment is not closely maintained. The main function of a coupling is to compensate for a small initial misalignment, and for any gradual, minor variations in alignment which might occur over time as the result of normal operation.
Torsional stiffness required in a coupling will be determined by test parameters. If test parameters dictate the measurement of torque peaks, then a torsionally “stiff” coupling may be required. If test parameters dictate measurement of average torque, a torsionally “soft” coupling may be required.

Basic factors to consider when selecting a coupling are:

1. How much torque will it transmit?
2. Is the shaft engagement positive or will the coupling loosen and slip?
3. How much misalignment will the coupling tolerate?
4. Does it require lubrication and maintenance?
5. Is it easily installed and removed?
6. Must the machine be disassembled for installation and removal?
7. Will the coupling operate under adverse conditions?
8. At what speed will the coupling be operating?
9. Will the coupling withstand the inertia of the system?
10. What is the anticipated service life?
11. What is the cost?
12. How easy is it to disconnect to measure transducer no load zero?

(See Appendix F - Couplings and suppliers on page 16).

**ELECTRICAL SET UP**

Wiring schematics are supplied in this manual for use with certain commonly used instruments. The appropriate schematic is to be followed when connecting the instrument cable to the mating connector supplied with each torque transducer. For instruments not covered in this manual, consult the factory.

Use only a high quality shielded cable with shielded and twisted pairs for electrical connections. A continuous cable run is preferred (as opposed to a run consisting of a series of interconnected shorter cable assemblies) to reduce the possibility of poor connections and mis-wiring of shields. Honeywell cable number 7200-81-XX* (*replace XX with length in feet, i.e., 10, 25, 50, 100) is recommended for runs up to 100 feet. Note: 7200-81-XX is constructed of color coded Belden 8163.

All soldering should be done with a good quality 60/40 rosin core solder, using a 30-50 watt soldering iron. Avoid overheating, since in doing so, the insulation may be damaged. Clean all connections thoroughly with a rosin solvent after completion of soldering. Check all connections for continuity and correct “clocking.” Check the resistance between adjacent pins of the cable, with the cable disconnected. (Reading should be at least 5000 mOhm).

These instructions are to be used in conjunction with the pertinent instrument manual instructions supplied by the instrument manufacturer.

**GROUNDING AND SHIELDING**

All installations require the torque sensor housing to be grounded. Figure 3 shows four ways to ground the transducer/instrument/frame combination.
Ground transducer housing by wiring in configuration A, B, or C.
Use #22 (or larger) single conductor wire.

A. If transducer is foot mounted (to a metal frame), ground frame.
B. If transducer is shaft mounted (floating), ground transducer and frame to same point.
C. If transducer is shaft mounted, or foot-mounted to a non-metallic frame (or one which will not become grounded), ground transducer to instrument.
D. Instrument will normally be connected to earth-ground through third prong on power cord. (If more than one instrument is used in system, it may be desirable to establish separate ground circuits).

WIRING DIAGRAMS

The 1800 Series torque sensors are supplied with the receptacle wired for a 5-pin configuration. For the most accurate calibration transfer, the Model 7927 calibrator should be used between the torque sensor and instrument. A cable equivalent to Belden (8163) is recommended for optimum results.
The wiring diagrams in Figures 4, 5, and 6 show the transducer receptacle wiring and the instrument termination wiring for the instruments most commonly used in conjunction with the Honeywell Model 1800 Series torque sensors. Honeywell can supply the Model 7927 calibrator and the indicated cable assemblies as optional accessories at additional cost. Figure 7 shows the wiring used with the Model 7927 shunt calibration reference.

**Figure 4. Daytronic 9000 Series indicator wiring diagram**

**Figure 5. Daytronic 3000 Series indicator wiring diagram**

**Figure 6. Model 7927 shunt calibration reference wiring**
CALIBRATION

Factory Calibration
As a measurement device, traceability must be provided to equate the torque read-out signal of a transducer to a relative load. This is accomplished by the use of a static torsional load applied to the structure with lever arm and weights or a reference load cell. Adjustments in the reference instrumentation permit setting a zero indication with no load and a span reading with full rated torque. Intermediate load readings are observed, allowing the linearity and hysteresis characteristics of the unit to be determined.

User Calibration
To maintain the highest possible transducer accuracy, the calibration should be checked periodically with weights and a lever arm. The purpose is to look for changes in output when the same lever arm and weight are used for the test. Therefore, precision weights are not required.

In the field, a user may calibrate the installed torque transducer with the available instrumentation. The use of a lever arm and weights is not feasible or practical in some instances. Generally, a simulated signal equivalent to a torsional load is used to calibrate the instrumentation. With strain gage devices, the shunting of the gage in one leg of the Wheatstone Bridge by a resistor of considerably higher value is used. When the resistor circuit is closed, a bridge unbalance occurs that can be looked upon as a synthetic controlled strain. To insure traceability, the selection of the shunt resistor is made at the same time of the transducer’s final factory calibration.

Due to the isolation of the bridge from the stationary instrumentation in rotary transformers, common shunting techniques are not possible on the shaft.

This has led to the development of reference or dummy bridges on the stationary housing which could be shunted to create an electrical signal imbalance to enable user calibration of these devices. The problems of the early reference bridge is two fold:

1. They require “locked in” torque be removed from the shaft, and
2. The accuracy was degraded as torque sensor zero shifts with use. The amount of electrical imbalance was determined with original transducer zero and has no way to compensate span for changing transducer zero.

These problems have led to the development of the Model 7927 shunt calibration reference. The Model 7927 references an electrical imbalance when shunted from its own zero which is in actuality a “star bridge” or true zero. It allows the user to achieve calibration to a high degree of accuracy. It also allows the user to check for instrument drift during a test without always removing "locked in" torque from the torque sensor.

INSTALLATION OF THE MODEL 7927 SHUNT CALIBRATION REFERENCE
The Model 7927 shunt calibration reference is a circuit which provides an excellent means for calibrating a read-out instrument in conjunction with a Honeywell Model 1800 Series torque transducer. It consists of a precision star bridge and a two-position rotary switch which allows the star bridge to be switched to either the calibration mode or the run mode.

The Model 7927 shunt calibration reference can be used free of any mechanical support in the interconnect cable or it can be mounted behind a console panel if the panel is modified as shown in Figure 8.
USER CALIBRATION WITH MODEL 7927-102 AND DAYTRONIC MODEL 3278

NOTE: Torque transducer housing must be grounded prior to attempting this procedure. Review the Daytronic manuals before proceeding.

Preparation:
1. Ensure there is no “locked in” torque on the torque transducer shaft by breaking coupling loose on one end of the transducer.
2. Remove the cover from the Model 3278 and install the calibration resistor on the main circuit board (R78) and slide cover back on but do not fasten.
3. Connect the Model 7927 directly to the Model 3278 and to the Model 1800 through an interconnect cable.
4. Set the Model 7927 switch to “Run” and turn power “ON”.

Calibration:
1. Set the Model 7927 switch to “Run”, turn Model 3278 Power “ON”.
2. Adjust the “C Balance Control” and adjust zero while pressing the “Null” button to obtain minimum output reading.
3. Readjust the Model 3278 front panel Balance (fine and coarse) controls so display reads zero.
4. Set the switch on the Model 7927 to “CAL” position. The display will now indicate the difference between “true” zero and the torque transducer zero. This could be used to keep track of the transducer “zero balance” and will signify its condition.
5. Re-zero the display using the 3278 front panel balance controls, or subtract this reading (Being careful of sign) from the “+CAL” reading of step 6.
6. Press and hold the “+CAL” button and set the display to read the clockwise calibration value for this transducer by using the front panel “SPAN” controls.
7. Release the “+CAL” button and the display should return to zero. If it does not, repeat steps 4 and 5 until both values are stable and repeatable and then continue.
8. Press and hold the “-CAL” button and set the display to read the counter clockwise calibration value using symmetry adjustment P85 inside Model 3278. Refer to the Model 3278 manual for location of this adjustment.
9. Release “-CAL” button and the display should return to zero.
10. Set the Model 7927 to “RUN”.
11. Re-zero using the front panel balance controls, if necessary.

USER CALIBRATION WITH MODEL 7927-103 AND DAYTRONIC MODEL 9178A/9530A

NOTE: Torque transducer housing must be grounded prior to attempting this procedure. Review the Daytronic manuals before proceeding.

Preparation:
1. Ensure there is no “locked in” torque on the torque transducer shaft by breaking coupling loose on one end of the transducer.
2. Remove the 9178A module from the 9000 panel and install the calibration resistor on the main circuit board in place of any existing calibration resistor and reinstall the module.
3. Remove the front panel of the 9178A module by removing the two screws in the upper corners. Connect the Model 7927 directly to the Model 9000 and to the Model 1800 through an interconnect cable.

Calibration:
1. Set the Model 7927 switch to “Run” and turn power “ON”.
2. Readjust the “C Balance Control” to obtain minimum output reading.
3. Adjust the Model 9178A front panel Balance (fine and coarse) controls so display reads zero.
4. Set the switch on the Model 7927 to “CAL” position. The display will now indicate the difference between “true” zero and the torque transducer zero. This could be used to keep track of the transducer “zero balance” and will signify its condition.
5. Re-zero the display using the 9178A front panel balance controls, or subtract this reading (Be careful of sign) from the “+CAL” reading of step 6.
6. Press and hold the “+CAL” button and set the display to read the clockwise calibration value for this transducer by using the front panel “SPAN” controls.
7. Release the “+CAL” button and the display should return to zero. If it does not, repeat steps 4 and 5 until both values are stable and repeatable and then continue.
8. Press and hold the “-CAL” button and set the display to read the counter clockwise calibration value using symmetry adjustment R6 (-SPAN) inside the Model 9178A. Refer to the Model 9178A manual for location of this adjustment.
9. Release “-CAL” button and the display should return to zero.
10. Remove TARE value and set the Model 7927 to “RUN”.
11. Re-zero using the front panel balance controls, if necessary.
MODEL 1800 OPERATION CHECKLIST

Check to see that:

___ 1. Proper couplings have been selected for the application.

___ 2. Couplings have been installed and system has been aligned to comply with coupling manufacturer’s specifications.

___ 3. A restraining cable or strap has been installed to prevent the housing from rotating if the transducer is not foot-mounted.

___ 4. Safety shields have been installed.

___ 5. Transducer housing has been grounded in some manner such as a separate wire, restraining strap, or through mechanical fixturing. (Lightly touch hand to housing, if reading changes at all, the housing is not properly grounded).

___ 6. Proper calibration resistor has been installed in or on the instrument.

___ 7. Instrument has been properly spanned.

___ 8. Shunt calibration reference (7927) is in the “Run” position.

___ 9. All mounting bolts are tight.

___ 10. The splines (if your unit has them) have been lubricated.

___ 11. Does the measuring range contain a torsional or bending resonant mode?

___ 12. Is bearing maintenance procedure being followed?
SPECIFICATIONS AND DATA

MODEL_____________________________ S/N_____________________________ CALIBRATION DATE_____________________________

MODEL_____________________________ S/N_____________________________

SPECIFICATIONS:
RATED CAPACITY .................................................................................................................................
RPM ...........................................................................................................................................................
SIGNAL SENSOR ................................................................................................................................. 4 arm bonded strain gage bridge
BRIDGE RESISTANCE ............................................................................................................................ 350 Ohms nominal
MAXIMUM BRIDGE EXCITATION ............................................................................................................. 1 to 10 Vac RMS **
COMPENSATED TEMPERATURE RANGE ............................................................................................ 70 °F to 170 °F
USABLE TEMPERATURE RANGE ............................................................................................................ -20 °F to 170 °F
*EFFECT OF TEMPERATURE ON ZERO .................................................................................................. ±0.001 % of rated cap/°F
*EFFECT OF TEMPERATURE ON OUTPUT ........................................................................................... ±0.001 % of reading/°F
NON-LINEARITY ................................................................................................................................. ±0.____% or rated cap.

*Within compensated temperature range.

ELECTRICAL CONNECTIONS
Receptacle: MS-3102A-14S-5P or PTO2E-10-6P
Mating Connector: MS-3106E-14S-5S or PTO6W-10-6S

Pins
A (-) and D (+) SIGNAL___________________________Ohms dc
B (+) and C (-) EXCITATION______________________Ohms dc

CALIBRATION:
The Model 7927 contains a star network which can be switched into the circuit in place of the torque transducer. When the precision calibration resistor mounted on the readout instrument is switched across the star, a signal is produced which is equivalent to an applied torque. The resistor and torque values are shown below. These values are valid only when used with a high input impedance readout instrument.

TORQUE VALUE

_____________________________CW (+) ____________________________K Ohms
_____________________________CCW (-) ____________________________K Ohms

**The above calibration data is accurate only at 3.2768 KHz excitation.
MAINTENANCE
It is recommended that maintenance be performed at our factory. The only customer maintenance required in the field is bearing lubrication. See Appendix G for lubrication of bearings - page 19.

RETURN PROCEDURE
Call or write the Honeywell Test and Measurement Service Department for a Return Materials Authorization (RMA) number or generate an RMA number online at http://measurementsensors.honeywell.com. Take care to package all material to prevent shipping damage. All transportation charges must be prepaid.

Please include a letter or report outlining the defect or complaint, as well as a description of how the device was being used. Also, give the name, telephone number, and complete mailing address of the person(s) acquainted with the equipment being serviced so we can contact them if necessary.

We will advise you of price (if applicable) and delivery of the repaired/replaced device within five days of receipt of the device.

OTHER PRODUCTS AND SERVICES AVAILABLE
Load cell calibration service - up to 200,000 lb tension or compression. Standards traceable to NBS.
Torque calibration service - lever arm system up to 1,500,000 in-lb. Standards traceable to NBS.
Custom strain gaging for force, pressure, or torque.
Complete systems to monitor force or torque.
Special sensors to meet unusual size or environmental conditions.
APPENDIX A - TORQUE AND TORQUE SHAFT PRINCIPLE

Torque

Torque is generally defined as the cause which tends to produce rotation in a body. The simplest form of torque is that referred to as “moment of force” which is that torque produced by a force acting tangential to a body at a given distance (Figure 9).

Figure 9. Moment of force

\[ T = F \times d \]

\( T \) = Torque
\( F \) = Force
\( d \) = Distance

A second form of torque is that caused by two equal but opposite forces that are displaced from one another by a given distance. This torque is referred to as a “couple”, and differs from the “moment of force” in the respect that its effect on a body is independent of any physical measurement or position of lines of action (Figure 10).

Figure 10. Torque couple

\[ T = F \times d \]

\( T \) = Torque
\( F \) = Force
\( d \) = Distance

A third form of torque is that produced by a negative or positive angular acceleration. This torque is dependent upon the rotational axis of the acceleration and the inertia of that body about the axis (Figure 11).

Figure 11. Negative or positive angular acceleration

\[ T = J \times \alpha \]

\( T \) = Torque
\( J \) = Inertia
\( \alpha \) = Angular Acceleration

Torque shaft principle

In most cases, torque measuring transducers are based on the calculated torsional windup of a physical structure and a method of relating this angular displacement to torque. A torque shaft can be described as a torsional spring having a spring constant expressed in units such as in-lbs/radian or in-lbs/degree (Figure 12.)

Figure 12. Torque shaft

Since the torque sensor is a torsional spring, it will react as a “spring-mass” resonant system with the applied system inertia acting as the “mass”. The relationship of this resonant frequency to measuring frequency must be considered in specifying the proper transducer. It is generally best to obtain the stiffest torque measuring device within the physical and resolution requirements of the system.

APPENDIX B - STRAIN GAGE TORQUE TRANSDUCTION

The method of converting the induced torque on the specimen shaft to a usable signal for read-out can be accomplished using strain gage torque transduction.

The use of electrical resistance strain gages, bonded on a torque sensitive element, provides a highly accurate, reliable torque measuring device. The strain gage itself is a simple reliable device which consists of a foil grid that deforms in the same manner as the structure to which it is bonded. Gage resistance is proportional to the gage deformation and, in turn, the loading of the structure. The maximum tensile and compressive strains on a shaft subjected to torsion are along 45° helices. Gages are bonded to coincide with the lines of maximum strain and are connected in a four arm Wheatstone Bridge (Figure 13).

A Wheatstone Bridge is used because it has the property of giving a relatively large voltage output for a very small change in leg resistance. A “full” Wheatstone Bridge is used because it will be giving the largest output, maintain the best achievable linearity and is the easiest to compensate for undesirable environmental effects.
The bridge circuit acts as an adding and subtracting device that measures these strains while compensating for extraneous loads and temperature sensitivity. By application of a known voltage across two opposite (A & C) corners of the bridge, shaft deformation will cause a resistive unbalance in the bridge and a proportional change in the potential across the adjacent (B & D) corners. When used with commercially available strain gage conditioning instrumentation, torque measuring systems with better than .1% accuracy are obtainable.

APPENDIX C - TORQUE SIGNAL TRANSMISSION

When In-Line Torque Transducers are used in applications where the sensing element is not rotating, connection with the required instrumentation is direct. In cases where the sensing element is rotating as a part of a dynamic system, a method of signal transmission must be provided.

Rotary Transformers: In-Line Shaft Torque Sensors often utilize the maintenance advantages of rotary transformers for signal transfer. Rotating transformers differ from conventional transformers only in that either the primary or secondary winding is rotating. One Transformer is used to transmit the ac bridge supply voltage to the strain gage bridge, and a second transformer is used to transmit the torque signal. Thus, there is no direct contact between rotating and stationary elements of the sensor.

A pair of concentrically wound coils, one coil rotating beside or within the stationary coil, comprise the transformer. The coils are mutually enclosed within a high permeability structure, thereby, concentrating the magnetic fields produced and increasing transformer efficiency. A gap is provided in the magnetic structure to allow a support member for the inner rotating coil (Figure 14). Since there is no relative movement of any part of the magnetic path, this geometry provides freedom from the effects of “run-out”.

As with any transformer system, use of alternating current (ac) excitation is mandatory. Carrier Amplifier systems, which supply an ac excitation to the bridge and produce a direct current (dc) voltage from the ac signal returned, are commonly used. These instruments use carrier frequencies of 1 kHz to 25 kHz typical. Optimum results are achieved when using the Honeywell Model 7541 strain gage transducer Indicator with rotary transformer torque sensors. (Figure 15 illustrates the internal construction of this type of Torque Sensor).
APPENDIX D - BEARING LIFE

Even if a bearing is properly mounted, adequately lubricated, protected from foreign matter and not subject to extreme operating conditions, it can ultimately fail. Under ideal conditions, the repeated stresses developed in the contact areas between the bearings and the raceway will eventually result in the fatigue of the material. Fatigue is considered to be a spalling or pitting of an area of 0.01 in² (6.5 mm²) in any of the bearing components.

In most applications, the fatigue life is the maximum useful life of a bearing. Bearing manufacturers have developed a statistical relationship to establish a rated life, referred to as the L₁₀ or Lᵱᵣ₁₀ for each type of bearing. The L₁₀ life is defined as the number of operating revolutions that 90% of a given group of identical bearings will endure before the onset of “contact fatigue”. Lᵱᵣ₁₀ has the same definition except the parameters are operating hours at a given RPM. The L₁₀ or Lᵱᵣ₁₀ ratings are based upon ideal operating conditions.

Fatigue life assumes the application of a constant, stationary radial load as established by the manufacturer. Since fatigue life is inversely proportional to the 3 power of the applied load a reduction of the applied load by a factor of 2 will increase the statistical bearing life by a factor of 10. In most applications the bearings will be subjected to loads less that the established rated loads and in which case extended bearing life should be expected.

Speed ratings of Honeywell rotating torque sensors, unless brush contact limited, are based upon L₁₀ life of 15,000 hours. That is: if the life of a bearing system used in Honeywell rotating torque sensors, on a statistical basis, should last at least 15,000 hours if operated at maximum speed. This rating is based on light bearing loads; light loads defined as not exceeding 33% of bearing load rating at speed of operation, and under ideal conditions. The life of a bearing system at any other lower RPM may be approximated by the relation.

\[
\text{Bearing life (Hrs.)} = 15,000 \left( \frac{\text{RPM for an L₁₀ life of 15,000 hrs.}}{\text{actual RPM}} \right)
\]

*Not to exceed 30,000 hours

The L₁₀ life rating of bearings is subject to being modified by the lubrication technique used. Most bearings supplied by Honeywell include a grease pack lubrication system, in which case the bearings should not be operated for more than 200 - 300 hours continuous at rated speed. At 40% of rated speed this increases to approximately 600 hours. An air-oil option available on most models should be used if the above values are exceeded, in which case the bearings should provide reasonable service up to 2000 hours of continuous use at rated speed.

Because the parameters used by bearing manufacturers to establish bearing life or rated speed vary, it is impossible to provide a simple expression for the purpose of determining these values. If there are any questions, the factory should be consulted.

APPENDIX E - EFFECTS OF MISALIGNMENT OF A TORQUE TRANSDUCER

All Torque Transducers contain an element which undergoes an angular displacement upon the application of a torque about a prescribed axis. A signal is generated or read by measuring this angular displacement and relating it back to the applied torque which created it.

One of the advantages of a Strain Gage Torque Sensor is the fact that the angular displacement required to generate a usable signal is extremely small; typically less than a half degree at rated capacity of the transducer. This torsional stiffness of the transducer is important to consider when dynamic testing is contemplated because it directly affects the frequency response of the system. It also plays a large role in determining the effects of applying a torque to the transducer along an axis not corresponding to the transducers sensitive axis.

In order to visualize how the torsional stiffness of the transducer affects the “off-axis” loading sensitivity, imagine a reaction torque sensor which is infinitely rigid to forces or moments in any axis except the sensing axis. When a torque is applied to the transducer about its sensitive axis, the transducer will undergo an angular displacement proportional to the applied torque. (See Figure 16). A strain gage network inside the transducer gives a signal to this angular deflection.

Figure 16. Angular displacement proportional to applied torque
Now assume that the torque is applied to the transducer through a rigid shaft that is bearing supported as in Figure 17. As long as the shaft axis corresponds to the torque sensitive axis, the transducer still will be displaced through an angle and the transducer will read the correct value of applied torque.

Figure 17. Torque applied through supported bearing

Now assume that this same rigid shaft has its axis displaced by a distance “d” with respect to the torque sensitive axis as in Figure 18.

Figure 18. Axis displaced by distance

Applying a torque “t” to the shaft in this case will not cause an angular displacement of the sensor. The only effect of this torque is to produce reaction forces as shown in Figure 19. The transducer output will be \( q \).

Figure 19. Reaction forces

Assume now that the input shaft is displaced as in the previous example but in this case we have resilient bearing supports which allow the shaft to move in a direction perpendicular to the shaft axis. (See Figure 20). In this case, if no loads are imposed on the input shaft by the bearings, the sensor will indicate the correct torque. However, the input shaft axis will be translated through an angle of \( q \) degrees and a distance of \( d \times q \).

Figure 20. Shaft moving perpendicular to shaft axis

Another possibility exists for analysis and that is the shaft and bearing supports are again rigid; but the sensor has no side load stiffness. This case is identical to the previous one except you must now imagine the face of the transducer moving when a torque is applied (i.e.: the sensitive axis would be displaced through a distance of \( d \times q \)).

All of these examples are extremely hypothetical and the real problem of “off-axis” loading is a combination of each condition. In general, it can be seen that the following factors minimize the torque measuring errors due to off-axis loading:

1. High torsional stiffness in the sensor.
2. Close alignment of axis.
3. Low side load stiffness in either the sensor (or preferably in the torque input system).

The third factor is most readily obtained by adding flexible couplings in the system.
APPENDIX F - COUPLINGS - DESCRIPTION

The following discussion is meant to be an overview of the various coupling types available. Eaton does not recommend use of any one coupling type or coupling Manufacturer.

**Roller Chain**
Low cost, high-torque coupling tolerant of small misalignment. Consists of two sprockets, each attached to a different shaft, wrapped in the same roller chain. The sprockets are keyed or splined to the shafts.

Clearance between chain and sprockets allows angular misalignment in the range of $\frac{1}{3}^\circ$ to $1 \frac{1}{2}^\circ$ parallel misalignment of about 0.010 in., and end float in the range of 0.020 to 0.070 in.

The chain is installed or replaced easily without disturbing either shaft, and the coupling is torsionally rigid. Operation is often noisy, lubrication is required. At high speeds a cover is needed to retain lubricant.

The double-roller version allows a more compact installation (because it has an additional line of tensile plates), but the single-roller type provides slightly more end-float tolerance.

**Nylon Chain**
Identical to roller chain in principle, but with chain links and pins made of nylon or acetal instead of steel. Requires no oil or grease and thus can be used in food-processing and textile machinery. Can also be used in corrosive environments.

This type is the quietest of all chain couplings, but can carry only light loads and is not tolerant of shock. Angular misalignments of $\frac{1}{2}^\circ$ per sprocket engagement are allowed, as is 0.005 in parallel misalignment and 3/32-in. end float.

**Silent chain**
Intended for heavy-duty drives, with ratings up to 3,000 hp at 1,800 rpm. The coupling is similar in operation to the roller-chain coupling, but uses silent chain wrapped around two wide sprockets.

These couplings can take $1^\circ$ to $2^\circ$ misalignment, parallel misalignment of 2 % of chain pitch, and end play of 1/8 to 1 in.

Bore sizes range from 3/8 to 8 in with torque rated according to the shaft that fits the maximum bore of the hub. Operating speeds go as high as 5,000 rpm.

**Sliding disc**
Intended for low-speed, high-torque drives with minor misalignments. Two facing slotted flanges, attached to the shafts, are keyed together by a disc having projections that fit into the slots. There is enough clearance to allow sliding movement between disc and flanges.

This permits a small diameter for a given torque rating. But overall length is somewhat greater than that of other types. The shafts must be moved for repair or replacement of the coupling.

Allowable misalignments are $\frac{1}{2}^\circ$ angular, 1/16 to 1/4 in parallel, and endplay of 3/32 to 1/2 in.
Model 1800 In-line Torque Sensor

Sliding block
Similar in principle to the sliding-disc type, but capable of withstanding greater angular misalignment (up to 3°).

![Sliding block image]

Flanges with C-shaped jaws are connected to the shafts and engage a common square block that rides between them. The block is normally made from a self-lubricating metal or plastic. The coupling accepts parallel misalignment up to 10% of shaft dia. and takes end float of 1/32 to ¼ in.

Spring
Available in capacities ranging from instrument sizes to couplings capable of transmitting 240 hp. Needs no lubrication. Runs at speeds of 6,000 rpm. Allowable misalignments are 4° angular and 1/8 in. parallel.

Flexible link
Tangential links of spring steel connect driving and driven members. The links are placed in crossed pairs, one in tension and the other in compression. The coupling is torsionally rigid, yet permits shaft misalignment and high-speed operation.

Schmidt
Torsional forces are transferred through a series of plates by mechanical linkages while allowing great translation of the rotating axis of each plate. Input and output axis can be displaced one plate diameter or more.

![Schmidt coupling image]

Elastomeric Flex Members

Compression
Made in a variety of designs. All basically employ resilient plates or spacers that serve as a compression cushion between metal elements connected to the shafts. The resilient member may be a disc containing holes that accept metal pegs on the facing coupler plate (as illustrated), or it may be a shaped spacer riding between interleaved lugs on the facing coupler plates somewhat akin to the principle of the sliding-disc coupler.

![Elastomeric flex members image]

The resilient member is either rubber, neoprene-impregnated fiber, or polyurethane. Capacity ratings range from 500 hp per 100 rpm, with speeds up to 6,500 rpm. General benefits of all elastomeric couplings include vibration isolation, accommodation of misalignment, and long service life without maintenance.
Shear
Two facing coupler plates are capped and joined with a resilient annular element shaped and constructed somewhat like an automobile tire (as illustrated). In a variation of this principle, resilient spacers are attached to both faces of the coupler plates. In both types, misalignment and torsional shock loads are absorbed by shear deflection in the resilient element. The shear version deflects more underload compared to the compression version, thus the shear type absorbs impact better.

Flexible sleeve coupling
Two flanges with internal teeth engage a flexible sleeve with external teeth. The couplings have high torsional flexibility and are tolerant of shock and vibration. Allowable shaft misalignment is 1°; allowable axial displacement is ¼ in to ¾ in.

Rubber block
This coupling utilizes rubber in compression. The rubber blocks are installed in cavities formed by internal sleeve blades, external hub blades and two end closures. The cavities and rubber block configurations are designed to provide combinations of properties - such as high load carrying capacity and shock absorption, or low torsional stiffness for torsional vibration attenuation, and in either case, selective vibration damping properties. Capacities range from 10 to over 20,000 hp at 100 rpm with misalignment capacities of 1° angular, 1/16 in to 1/4 in parallel offset and 1/16 in to 1/2 in axial - depending upon size and operating speed.

APPENDIX G - LUBRICATION OF BEARINGS
(NOT APPLICABLE ON SPECIAL 1600s)

Maintenance On Grease Lubricated Bearings
Typically the grease used in the bearings on this device is Esso Andok B because it has long life with excellent channeling characteristics and low torque (after being run in) at all speeds. The grease is basically a Sodium Soap with Mineral Oil. The grease has a tendency to dry out with age, however, the lubricity can be restored and prolonged by adding 2 drops of Coray-100 Additive with a #27 Hypo-oiler after the first two years and two drops each year thereafter until either 5000 hours of use or 5 years elapsed time is reached. At that time the device should be returned to the factory to have the old grease removed and new grease installed.

Figure 21. Hypo-oiler

Procedure to add the Coray-100 Additive:
1. Assemble Hypo-oiler - See Figure 21.
2. Remove Lubrication Tube Caps
3. **CAUTION**: Hold bottom portion of fitting with appropriate wrench to prevent tube from rotating.
4. Place two drops of Coray-100 down each tube.
5. Reinstall the lubrication tube caps.

Figure 22. Location of lubrication tubes

Grease Lubrication
To grease a new ungreased Transducer, an air cylinder, Figure 23, is used to inject a measured amount of grease into a new bearing before it is used following this procedure.

1. Fill solenoid through the greased Fitting with grease until some grease comes out of the lubrication tube fitting.
2. Remove lubrication cap. **CAUTION**: Do not allow bottom portion of fitting to turn.
3. Screw the air cylinder onto the lubrication tube of the Transducer and apply 35 psi of air to the air cylinder and rotate the shaft of the Transducer slowly.
4. Replace cap on Lubrication Tube.

Figure 23. Air cylinder

NOTE: There are two lubrication tubes on each Rotary Transducer. See Figure 22.

Air-Oil-Mist Lubrication
Lubrication fittings are provided at each end of the torque sensor housing, adjacent to the bearings, for the introduction of the air-oil-mist. The atomized oil is carried by low pressure air to the inside of the bearing where it condenses on the moving parts of the bearing and drains to the outside of the housing. A portion of the mixture can be seen emerging from the bearing in foot mounted or shaft suspended torque sensors. Flange mounted Sensors should be installed so that the oil drain slot in the flange face is at the bottom and is unrestricted.

Because of the extreme efficiency of the air-oil-mist lubrication, very small quantities of air and oil are required. An air pressure setting of 5 psi to 10 psi and an oil control opening of 1.5 in to 3.5 in turns is normally adequate for the two bearings in the Torque Sensor. In general, the air-oil-mist device should be installed according to the manufacturer's recommendations. The air flow rate may be increased for greater cooling effect at high ambient temperatures.
CAUTION: Too great an oil blow rate may cause an increase in housing temperature because of “channeling” in the bearing groove, where the balls must push aside the excess liquid oil.

A high grade spindle oil with a viscosity of 500 s.s.u. (Saybolt Seconds Universal) at 100°F is recommended for the bearings supplied in the Torque Sensor.

Caution: Do not use an ambient temperature of less than 45°F.

* Stuart Warner Model: Alemite #385650

APPENDIX H - TYPICAL APPLICATIONS OF IN-LINE TORQUE TRANSDUCERS

- Testing of Speedometer Cables
- Testing of Blowers
- Testing of Small Motors, Pumps and Fans
- Evaluation of Clutch and Brake System
- “4” Square Dynamometer
- Testing Hydraulic Pumps
- Engine Dynamometer
- Chassis Dynamometer
- Checking Gear Box Efficiencies
CERTIFICATE OF CALIBRATION AND TRACEABILITY
This is to certify that the products described herein meet the specifications and performance requirements described in this application sheet. Test reports and other pertinent information are on file and available for inspections by your representative and/or U.S. Government representative upon request.

Calibration was performed with a test system in compliance with ANSI/NCSL Z540-1-1994 utilizing a reference load cell and/or dead weights and an electronic indicator. The test system was within current calibration requirements at the time of the test and is traceable to the National Institute of Standards Technology.

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