# TF Series

# Torque Flange Sensors

# User's Manual

DSPM Industria®
sensori & trasduttori
Via Paolo Uccello 4 - 20148 Milano
Tel +39 02 48 009 757 Fax +39 02 48 002 070 info@dspmindustria.it www.dspmindustria.it

## Purchase Record

Please record all model numbers and serial numbers of your Magtrol equipment, along with the general purchase information. The model number and serial number can be found on either a silver identification plate or white label affixed to each unit. Refer to these numbers whenever you communicate with a Magtrol representative about this equipment.

Model Number: ____________________________

Serial Number: ____________________________

Purchase Date: ____________________________

Purchased From: ____________________________



Second English Edition, revision H – November 2014

MAGTROL

# Safety Precautions

**WARNING! IN ORDER TO MINIMIZE RISKS, IT IS OF UTMOST IMPORTANCE TO RESPECT THE CURRENT SAFETY STANDARDS WHEN PLANNING, CONFIGURING AND OPERATING THE TORQUE MEASUREMENT DRIVE TRAIN.**

CAUTION: OPERATE THE TF SERIES TORQUE FLANGE SENSOR WITH GREAT CAUTION! THE SENSOR MAY BE IRREVERSIBLY DAMAGED IF IMPACTED MECHANICALLY (FALL), CHEMICALLY (ACIDS) OR THERMALLY (HOT AIR, VAPOR).

1. Make sure that all Magtrol electronic products are earth-grounded, to guarantee personal safety and proper operation.
2. Check line voltage before operating electronic equipment.
3. Make sure that all rotating parts are equipped with appropriate safety guards.

Note: Detailed information regarding safety guards can be found in *Section 2.6 – Protective Systems*.

4. Periodically check all connections and attachments.
5. Always wear protective glasses when working close to rotating elements.
6. Never wear a necktie or baggy clothes when standing close to rotating elements.
7. Never stand too close or bend over the rotating drive chain.

## QUALIFIED PERSONNEL

Persons in charge of installing and operating the TF Series Torque Flange Sensor must have read and understood this User's Manual, paying extra close attention to all safety-related information.

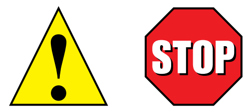
The TF Sensor is a high-precision product integrating the most recent measurement techniques. The sensor can give rise to residual dangers if used and manipulated in a non-compliant way by unqualified personnel.

This sensor must be handled by qualified personnel according to the technical requirements and the above-mentioned safety instructions. This is also true when using torque flange accessories.

## RESIDUAL HAZARDS

Sensor performance is only one element in torque measurement. Safety is of equal importance. There are possible residual hazards when operating rotating test equipment and it is the responsibility of the designer, the manufacturer and the user to minimize these hazards.

In addition to general safety precautions, residual hazards are highlighted in this manual by using the following symbols:




*Please read the Preface for a more detailed description of each symbol.*

## PROPER USE

The use of TF Series Torque Flange Sensors is exclusively restricted to torque and rotational speed measuring tasks and directly-related control and regulating tasks. Any further use shall be deemed to be improper.

For safe operation, the TF Sensor and its accessories may only be used according to the data and specifications given in this User's Manual. Safe operation can be guaranteed only when the sensor is correctly transported, stored, installed, mounted and used.

## MODIFICATIONS

The TF Torque Flange Sensor and its accessories may not be modified without the express consent of Magtrol. Magtrol is not be liable for any consequential damages resulting from unauthorized modifications.

# Revisions to This Manual

The contents of this manual are subject to change without prior notice.

## REVISION DATE

Second English Edition, revision H – November 2014

## TABLE OF REVISIONS

| Date | Edition | Change | Section(s) |
|---|---|---|---|
| 11/26/14 | 2nd edition, rev. H | Update Data Sheet | 1.2 |
| 10/24/14 | 2nd edition, rev. G | Remove TF209, TF210, TF211 and TF212 | throughout manual |
| 10/24/14 | 2nd edition, rev. G | Add TF309, TF310, TF311 and TF312 | throughout manual |
| 10/24/14 | 2nd edition, rev. G | All references to Torque 1.0 changed to Torque 7 | throughout manual |
| 10/24/14 | 2nd edition, rev. G | All references to 3410 changed to 3411 | throughout manual |
| 10/24/14 | 2nd edition, rev. G | Update Data Sheet | 1.2 |
| 07/04/11 | 2nd edition, rev. F | text concerning parasitic forces updated | 4.4 |
| 11/12/09 | 2nd edition, rev. E | New information about the cardan shaft was added in section 2.2.4.5. New information about radial forces, axial forces and dynamic limit was added to section 4.4. | 2.2.4.5, 4.4 |
| 06/18/09 | 2nd edition, rev. D | Changed values for TF 220 | 2.2.4.1 |
| 03/31/09 | 2nd edition, rev. C | Added (N/C for 5W conditioner) to pin 7 | 2.5.3.1 |
| 03/27/09 | 2nd edition, rev. B | 0.5 mm distance changed to 1.5 mm distance | 2.4.1 |
| 06/03/08 | 2nd edition, rev. A | New design for standard speed sensor | 1.2, 2.41 |
| 01/23/08 | Second Edition | Added TF 209 | throughout manual |
| 10/10/07 | First Edition, rev. A | Added high-temperature speed sensor information | 1.2, 2.4.2 |

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## 1. INTRODUCTION



## 2. INSTALLATION / CONFIGURATION



## 3. STARTUP



## 4. MEASUREMENT CONSIDERATIONS



## 5. OPERATING PRINCIPLES



## 6. TROUBLESHOOTING / MAINTENANCE

# Preface

## PURPOSE OF THIS MANUAL

This manual contains all the information required for the setup, connection and general use of Magtrol's Torque Flange Sensors of TF series. Please read this manual in its entirety before operating. Keep the manual in a safe place for quick reference whenever a question should arise.

## WHO SHOULD USE THIS MANUAL

This manual is intended for those who install Torque Flange Sensors on a bench test or to use it to determine the couple on a transmission chain. The operator is assumed to have the necessary technical training in mechanical engineering and electronics to enable him to install these Torque Flange Sensors.

## MANUAL ORGANIZATION

This section gives an overview of the structure of the manual and the information contained within it. Some information has been deliberately repeated in different sections of the document to minimize cross-referencing and to facilitate understanding through reiteration.

The structure of the manual is as follows:

Chapter 1: INTRODUCTION – Contains the technical data sheets for the Torque Flange Sensors of TF series, which describe the units and provide an overview of their possible applications.

Chapter 2: INSTALLATION/CONFIGURATION – Provides the information needed for the setup and connection of the Torque Flange Sensors.

Chapter 3: STARTUP – Give the instructions to start the system and adjust the zero of the measuring chain.

Chapter 4: MEASUREMENT CONSIDERATIONS – Describes the limits of measures.

Chapter 5: OPERATING PRINCIPLES – Contains information on lubrication procedures and provides recommendations for the calibration and checking of the measuring current and voltage.

Chapter 6: TROUBLESHOOTING/MAINTENANCE – Give the procedure to follow in case of breakdown of a Torque Flange Sensors TF.

## CONVENTIONS USED IN THIS MANUAL

The following symbols and type styles may be used in this manual to highlight certain parts of the text:

Note: This is intended to draw the operator's attention to complementary information or advice relating to the subject being treated. It introduces information enabling the correct and optimal function of the product.

Caution: This is used to draw the operator's attention to information, directives, procedures, etc. which, if ignored, may result in damage to the material being used. The associated text describes the necessary precautions to take and the consequences that may arise if these precautions are ignored.


**WARNING! THIS INTRODUCES DIRECTIVES, PROCEDURES, PRECAUTIONARY MEASURES, ETC. WHICH MUST BE EXECUTED OR FOLLOWED WITH THE UTMOST CARE AND ATTENTION, OTHERWISE THE PERSONAL SAFETY OF THE OPERATOR OR THIRD PARTY MAY BE AT RISK. THE READER MUST ABSOLUTELY TAKE NOTE OF THE ACCOMPANYING TEXT, AN D ACT UPON IT , BEFORE PROCEEDING FURTHER.**

# 1. Introduction

## 1.1 SYSTEM COMPONENTS

The complete TF Series torque measuring system consists of the following four primary components:

1. Measuring Flange with Signal Amplifier
2. HF Transmitter
3. Conditioner
4. Coaxial Cable (4 m)

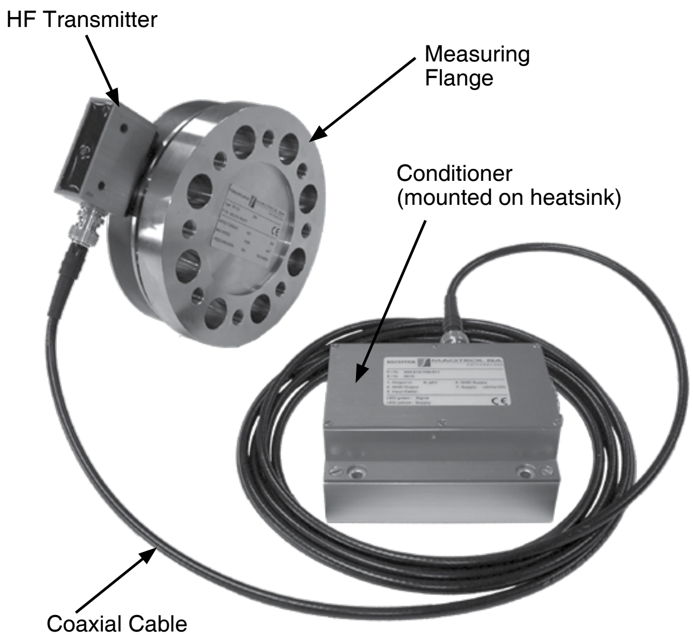



*Figure 1–1 TF Series Torque Flange Sensor Kit*

System options include the Speed Sensor and Conditioner, and the 3411 Display

### 1.1.1 MEASURING FLANGE

The measuring flange represents the rotor part of the torque sensor. It is made of steel and contains 4 strain gauges in full-bridge configuration, an amplifier, a low-pass filter and an A/D converter. It is fitted with an electromagnetic track around its circumference which acts as an antenna for sending telemetric transmissions to the HF transmitter and, ultimately, the conditioner.

### 1.1.2 HF TRANSMITTER

The high-frequency transmitter represents the stator part of the transducer. This transmitter receives the signal from the measuring flange and relays it to the conditioner.

### 1.1.3 Conditioner

The torque conditioner supplies power to the measuring flange, via the HF transmitter, and collects the torque signal measured by the system. To display measured values, the conditioner must be connected to a Magtrol 3411 Torque Display (see *Section 1.1.6 – Signal Processor/Display Unit*) or similar device.

| TF Model | Power | Mounting |
|---|---|---|
| TF 309 – TF 312<br>TF 213 – TF 217 | 1.5 W | Mounted on heatsink<br>(for heat dissipation) |
| TF 218 – TF 220 | 5 W | Mounted inside electronics module |

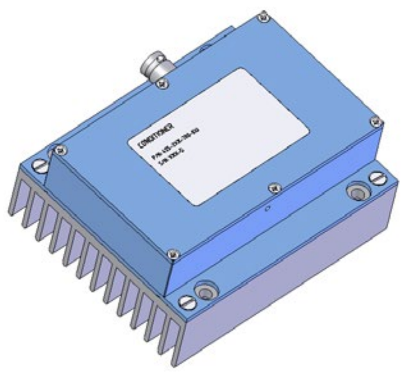


*Figure 1–2 Conditioner for TF 309 – TF 312 and TF 213 – TF 217 Torque Flange Sensors*

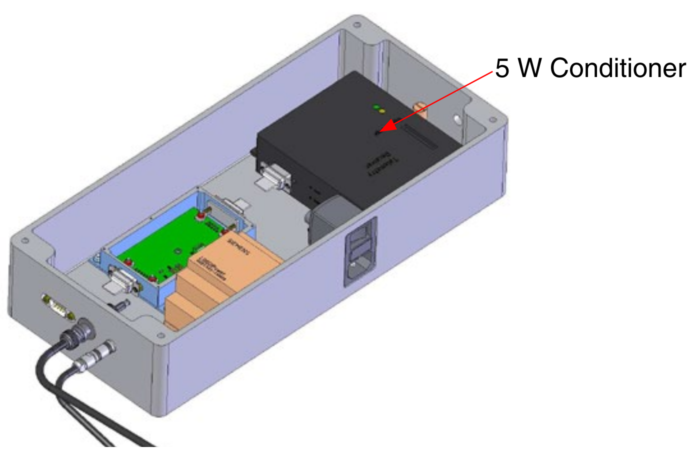



*Figure 1–3 Electronics Module for TF 218 – TF 220 Torque Flange Sensors*

### 1.1.4 Coaxial Cable

The shielded RG-58 coaxial cable between the HF transmitter and the conditioner has an impedance of 50 Ohms and is 4 meters long (8 m, 12 m, 16 m and 20 m cables are available as an option).

### 1.1.5 Speed Measurement Option

When ordered with the optional speed measurement capability, the TF Torque Sensor is fitted with a toothed rim with the speed sensor attached to the exterior (as shown in the figure below).

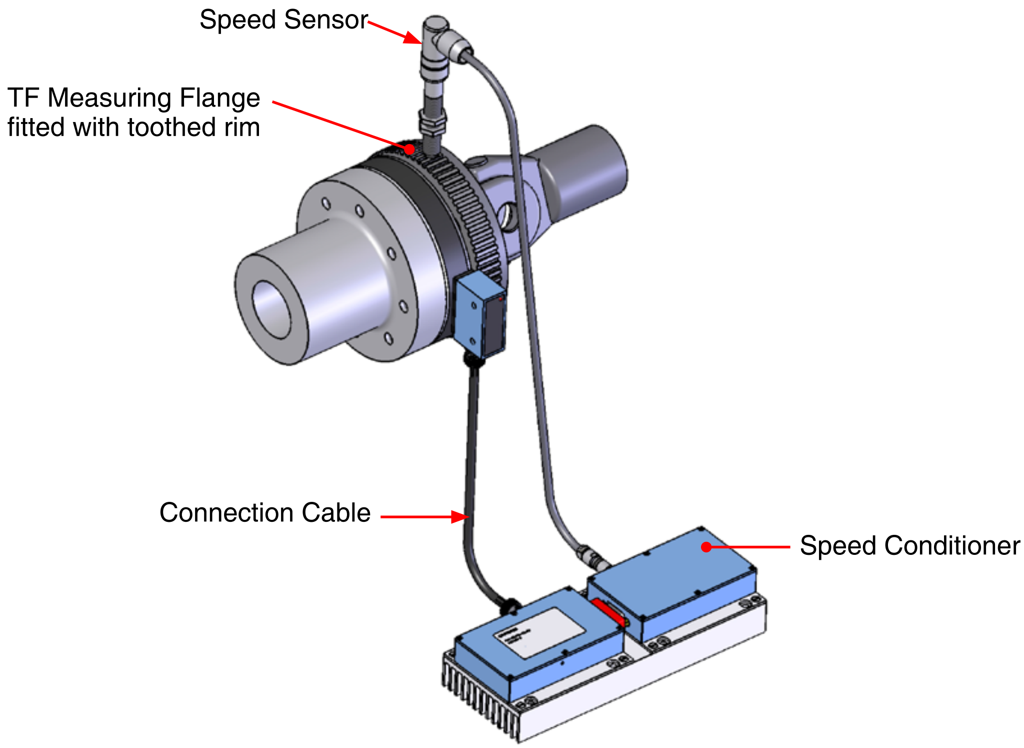



*Figure 1–4 Mounted TF Torque Flange Sensor with Speed Measurement Option*

### 1.1.6 Signal Processor/Display Unit

Available as a system option, Magtrol's 3411 Torque Display processes the torque and speed signals from the TF Sensor and displays the measured values and calculated power. For additional data processing, the unit has an Ethernet interface for connection to a PC and is delivered with Magtrol's Torque 7 Software.

Torque 7 is a user-friendly Windows® executable program, developed under LabVIEW™, used to automatically collect torque, speed and mechanical power data. The data can be printed, displayed graphically or quickly saved as a Microsoft® Excel spreadsheet.

*Figure 1–5 Model 3411 Torque Display*

## 1.2 DATA SHEET

# Couplemètre plat Série TF

## CARACTÉRISTIQUES

- Système de mesure complet comprenant :
  - Couplemètre avec amplificateur de signal
  - Transmetteur HF
  - Conditionneur
  - Câble coaxial 4 m
- Transmission sans contact du signal par télémétrie
- Couple : 50 N·m à 150 000 N·m (plus grand sur demande)
- Précision : 0,1% à 0,25% (0.05% optionel)
- Surcharge admissible : jusqu'à 200% (limite d'adhérence)
- Plage de mesure : 200%
- Surcharge de rupture : 400%
- Compact et facile à monter
- Grande rigidité en torsion
- Absence de roulements : sans usure ni maintenance
- Excellente immunité au bruit et résistance aux chocs
- Classe de protection : IP 42 (IP 54 option)
- Tension d'alimentation standard 24 V DC
- Capteur de vitesse (option) : mesure de la vitesse de rotation
- Utilisation à haute température : jusqu'à 125 °C (option)


*Couplemètre plat TF*

## DESCRIPTION

Grâce à sa conception, qui rend toute maintenance inutile du fait de l'absence de roulements, le couplemètre plat TF de Magtrol propose une solution compacte offrant de nombreux avantages. Sa grande rigidité en torsion permet de le monter directement sur l'axe de la machine ou sur la bride, évitant ainsi l'utilisation d'un accouplement sur un côté. Ceci permet un intégration aisée dans toute installation de mesure, tout en réduisant la taille et le coût.

Le couplemètre plat TF fait appel à un système de télémétrie pour transmettre avec grande précision les signaux provenant d'un pont de mesure à jauges de contrainte. Un amplificateur de signal embarqué conditionne le signal avant de le moduler à haute fréquence et de le transmettre par induction au conditionneur, via le transmetteur HF. Au niveau du conditionneur, ce signal numérique est transformé en une sortie analogique ±5 V DC. Un capteur à magnéto-résistances (option) permet de mesurer la vitesse de rotation et de la convertir en un signal TTL.

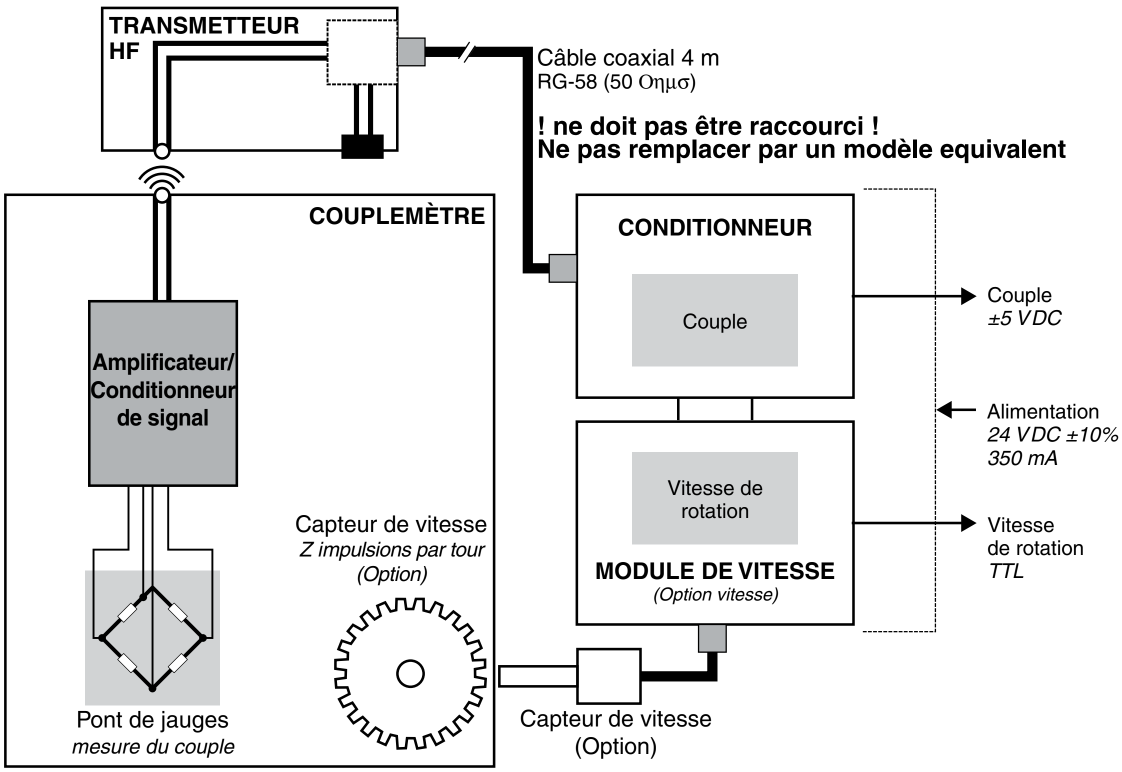
La transmission sans contact reste opérationnelle avec un espace de 5 mm entre l' antenne du couplemètre et le transmetteur HF et permet un désalignement radial ou axial entre ceux-ci. Un autre avantage du système est son innocuité aux interférences électromagnétiques – contrairement aux autres conceptions, le transmetteur HF ne doit pas faire le tour du capteur. De plus, un système de protection peut être monté sans causer d'interférences.

## APPLICATIONS

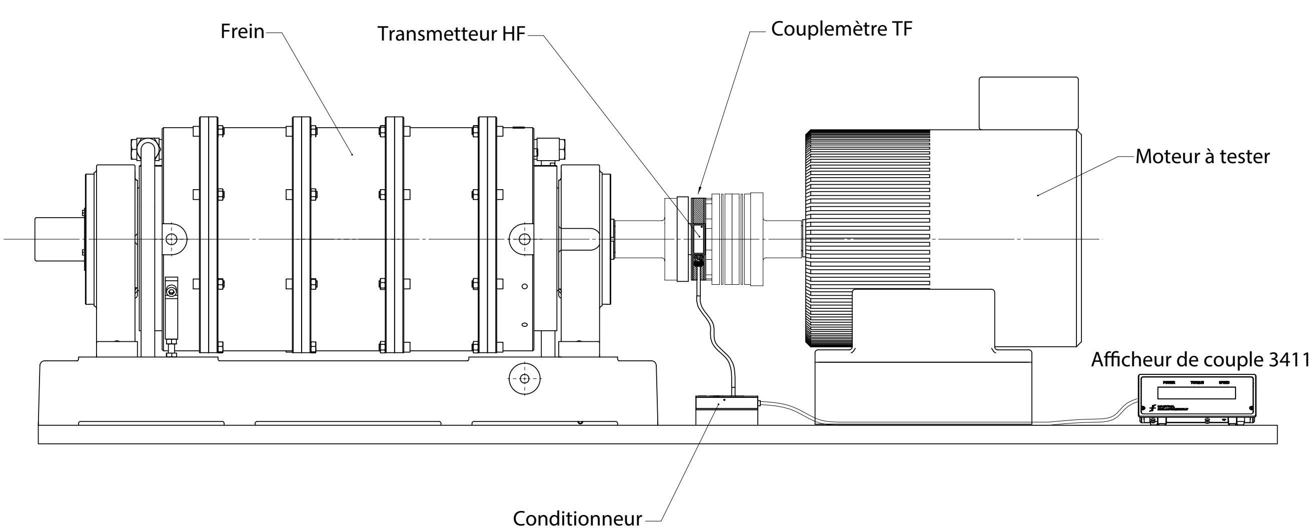
Le couplemètre plat TF permet de mesurer aussi bien les couples statiques que dynamiques sur des axes en rotation ou au repos. Ils peuvent être intégrés à des bancs de test pour moteurs à combustion et électriques ou de boîte à vitesse. Ils servent aussi à surveiller le couple dans des transmissions, des éoliennes, des turbines à gaz, des moteurs de bateau, etc.

# Diagrams TF

## BLOCK DIAGRAM




## CONFIGURATION DU SYSTÈME



# Spécifications TF

## CARACTÉRISTIQUES

| Modèle | | Couple nominal | Couple max. | Classe de précision | Vitesse de rotation max. | | Nombre de dents** | Rigidité en torsion | Déformation angulaire |
|---|---|---|---|---|---|---|---|---|---|
| | | N·m | % du C.N. | | TF $min^{-1}$ | TFHS $min^{-1}$ | Z | N·m/rad | ° |
| **TF 309** | | 20 | 200% | 0.1% | 17 000 | | 52 | 5,04 x $10^4$ | 0,023 |
| **TF 310** | **TFHS 310** | 50 | 200% | 0,1% | 17 000 | 20 000 | 52 | 7,20 × $10^4$ | 0,040 |
| **TF 311** | **TFHS 311** | 100 | 200% | 0,1% | 17 000 | 20 000 | 52 | 8,57 x $10^4$ | 0,067 |
| **TF 312** | **TFHS 312** | 200 | 200% | 0,1% | 17 000 | 20 000 | 52 | 1,06 × $10^5$ | 0,108 |
| **TF 213** | | 500 | 200% | 0,1% * | 13 000 | | 91 | 7,16 × $10^5$ | 0,040 |
| **TF 214** | | 1 000 | 200% | 0,1% * | 13 000 | | 91 | 9,55 × $10^5$ | 0,060 |
| **TF 215** | | 2 000 | 200% | 0,1% * | 10 000 | | 113 | 2,86 × $10^6$ | 0,040 |
| **TF 216** | | 5 000 | 200% | 0,1% | 8 000 | | 133 | 7,16 × $10^6$ | 0,040 |
| **TF 217** | | 10 000 | ‡ 150% | 0,1% | 8 000 | | 133 | 1,25 × $10^7$ | 0,046 |
| **TF 218** | | 20 000 | 200% | 0,20% – 0,25% | 3 000 | | 283 | 2,86 × $10^7$ | 0,040 |
| **TF 219** | | 50 000 | ‡ 180% | 0,20% – 0,25% | 3 000 | | 283 | 6,82 × $10^7$ | 0,042 |
| **TF 220** | | 100 000 | ‡ 180% | 0,25% – 0,30% | 3 000 | | 270 | 3,37 x $10^8$ | 0,017 |

| Modèle | Poids du couplemètre*** | Moment d'inertie |
|---|---|---|
| | kg | kg·m² |
| **TF 309** | 1,4 | 2,213 x $10^{-3}$ |
| **TF/TFHS 310** | 1,5 | 2,236 × $10^{-3}$ |
| **TF/TFHS 311** | 1,5 | 2,238 × $10^{-3}$ |
| **TF/TFHS 312** | 1,5 | 2,254 × $10^{-3}$ |
| **TF 213** | 3,3 | 7,803 × $10^{-3}$ |
| **TF 214** | 3,3 | 7,818 × $10^{-3}$ |
| **TF 215** | 5,2 | 1,868 × $10^{-2}$ |
| **TF 216** | 9,3 | 4,747 × $10^{-2}$ |
| **TF 217** | 9,3 | 4,706 × $10^{-2}$ |
| **TF 218** | 42,7 | 9,635 × $10^{-1}$ |
| **TF 219** | 43,3 | 9,724 × $10^{-1}$ |
| **TF 220** | 36,0 | 1,070 × $10^0$ |

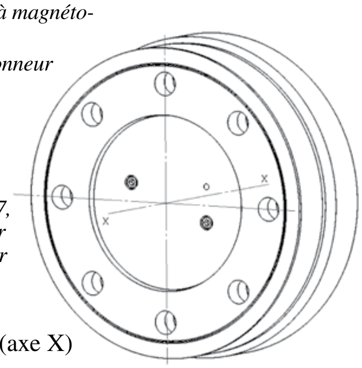
*Sur demande:*
- *Couple nominal plus grand, jusqu'à 150 000 N·m et plus*
- *Version haute vitesse*

* *Erreur Linéarité-hystérèse 0,05% sur demande*

** *Mesure de vitesse par capteur à magnéto-résistances sur demande.*

*** *Le transmetteur HF, le conditionneur et le module de récepteur et le conditionneur de signaux de vitesse de vitesse pèsent selon configuration de 0,8 à 2,8 kg en plus.*

‡ *La limite dynamique des TF217, TF219 et TF220 est donnée par la force limite transmissible par les vis de fixation.*



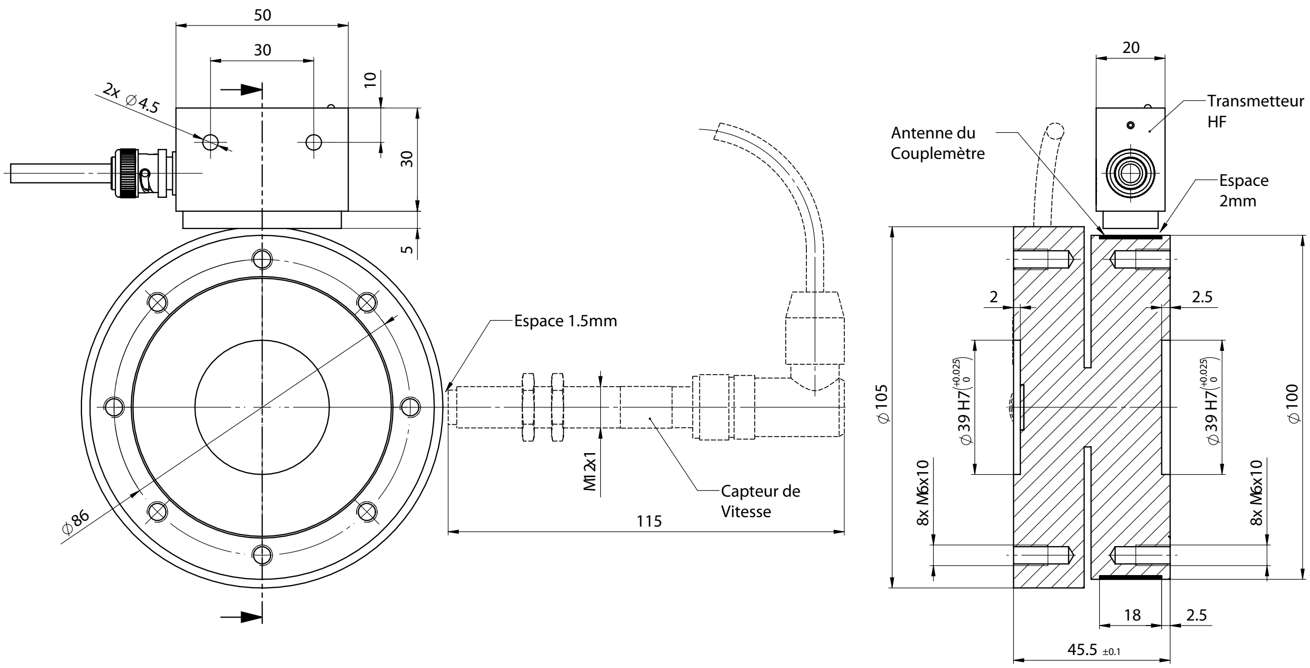
Moment d'inertie (axe X)

## VALEURS NOMINALES POUR TOUS LES CAPTEURS

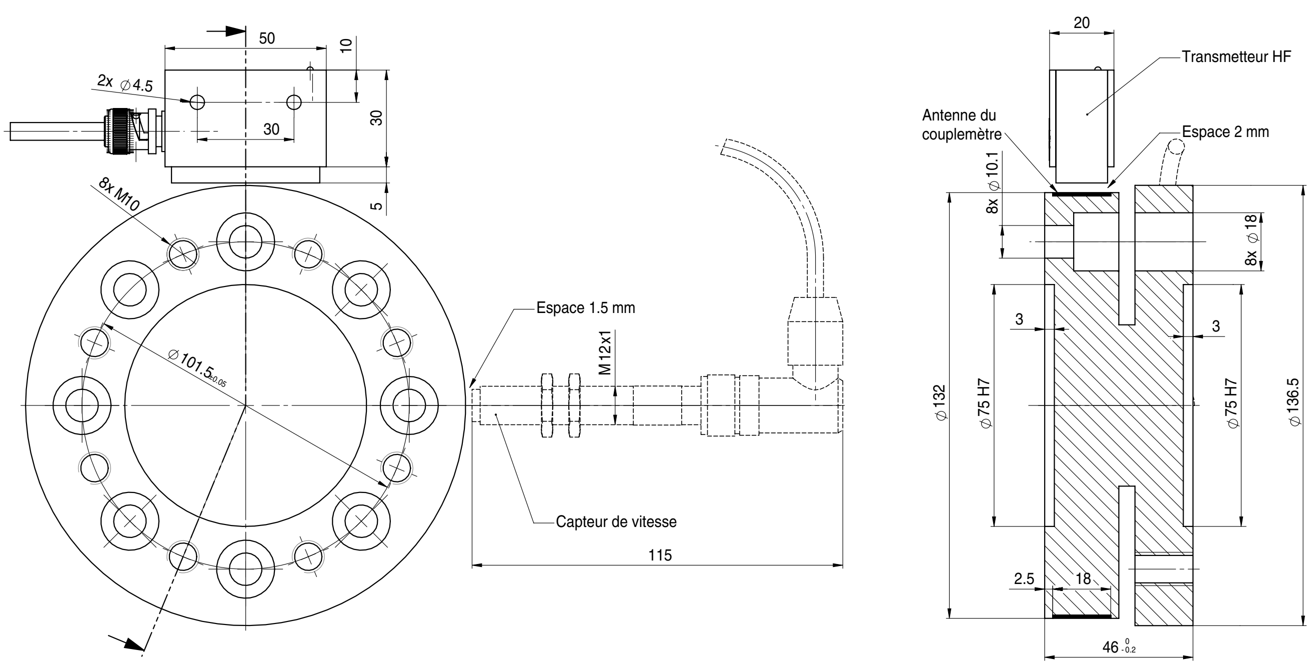
| **MESURE DU COUPLE** | |
|---|---|
| Couple dynamique maximum (valeur de crête, sans détérioration) | 400 % du couple nominal |
| **MESURE DE LA VITESSE (option)** | |
| Nombre de dents | Voir le tableau dans la rubrique caractéristiques |
| Capteur de vitesse | magneto-résistif |
| Vitesse minimale détectée | 0,5 $min^{-1}$ |
| **ENVIRONNEMENT** | |
| Température d'utilisation | +10 °C à +85 °C |
| Température de stockage | -25 °C à +85 °C |
| Température d'utilisation étandue (option) | -30 °C à +125 °C |
| Influence de la température sur le point zéro | 0,01 % / °C |
| Classe de protection | IP 42 (IP 54 en option) |
| **SIGNAUX D'ENTRÉE/SORTIE** | |
| Alimentation | 24 VDC ±10%, max 350 mA<br>TF 218, 219 et 220 :  100–240 VAC |
| Sortie du signal de couple (valeur nominale et maximum) | ±5 VDC/ ±10 VDC |
| Bande de fréquence du filtre | 0 à 1 kHz (-3 dB) / 5KHz optionnel |
| Sortie du signal de vitesse de rotation (option) | TTL / Z impulsions par tour |

# Dimensions du couplemètre		TF

## TF 309 À TF 312

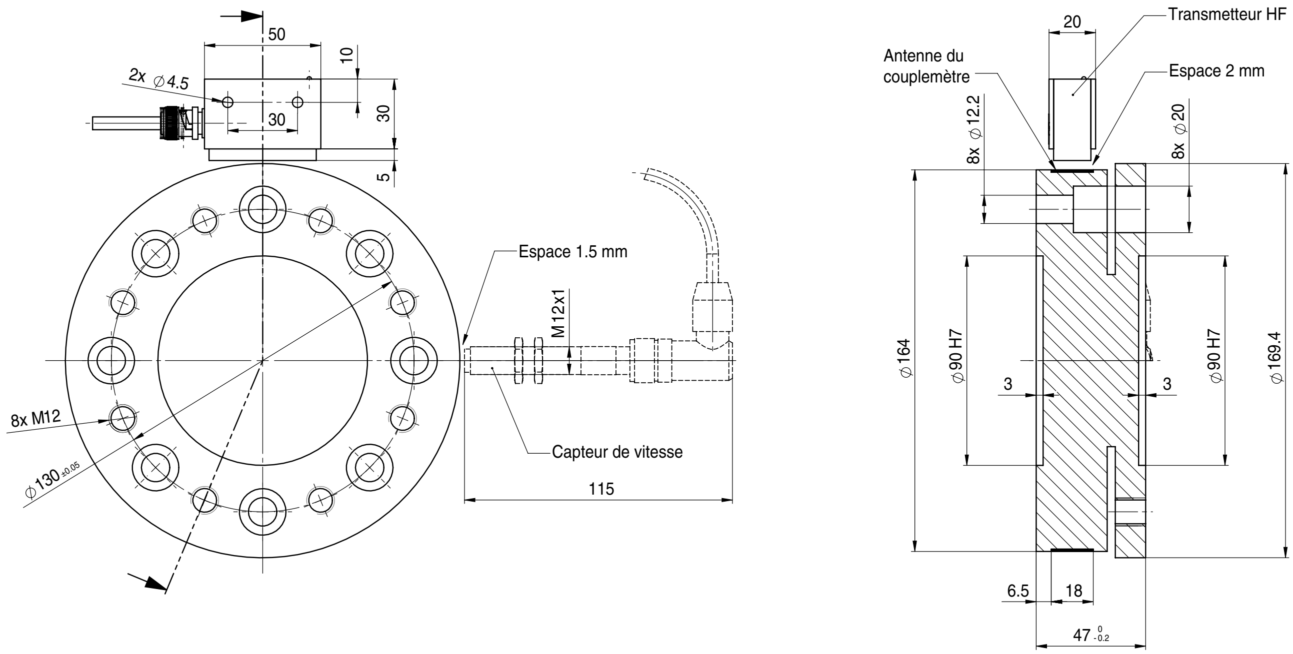



## TF 213 ET TF 214

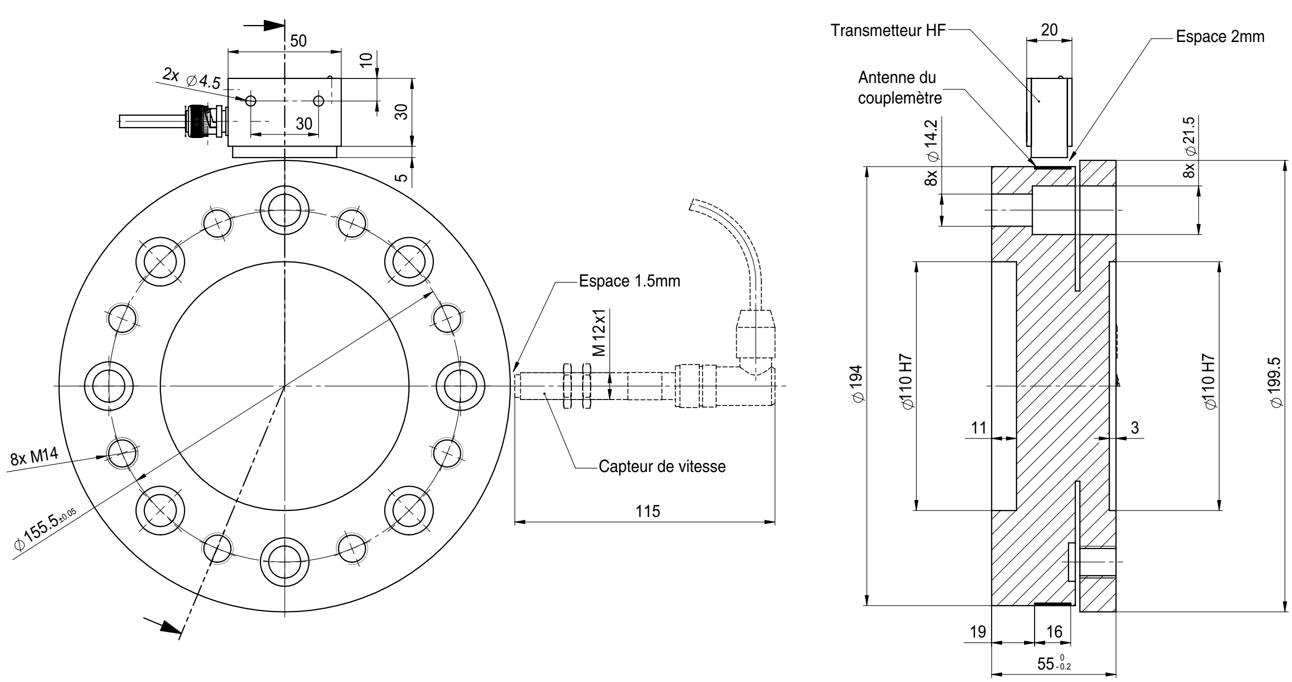


# Dimensions du couplemètre **TF**

## TF 215

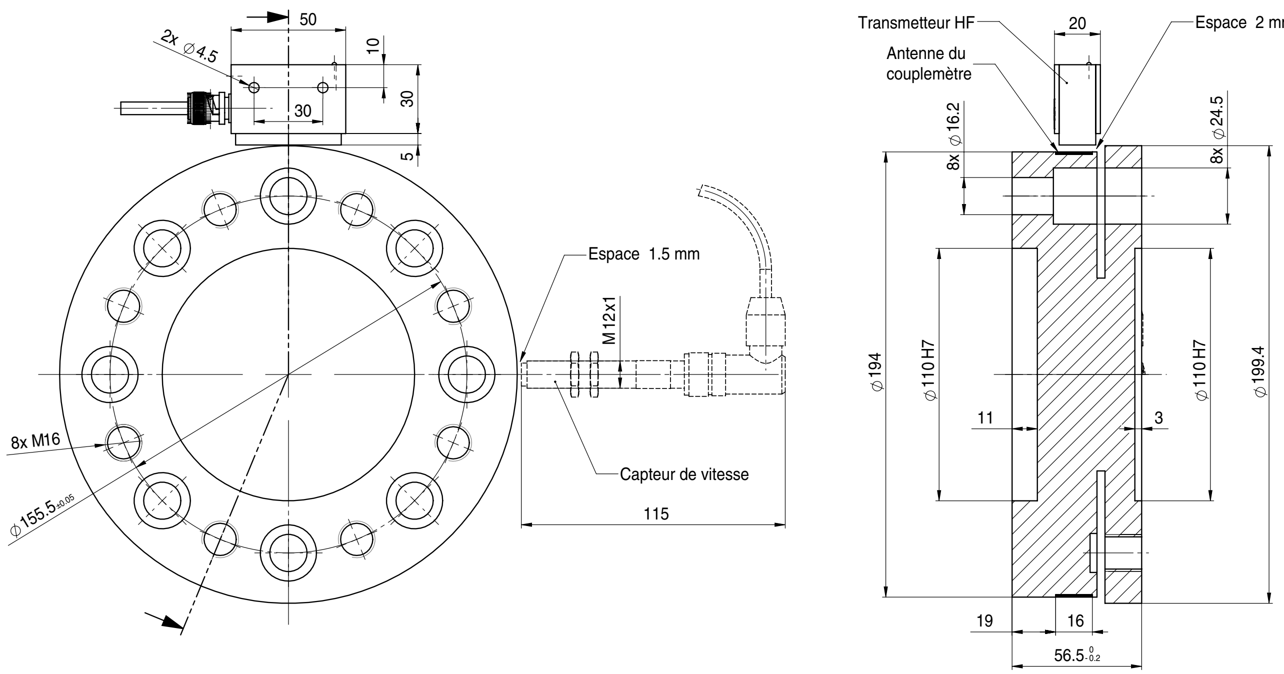



## TF 216

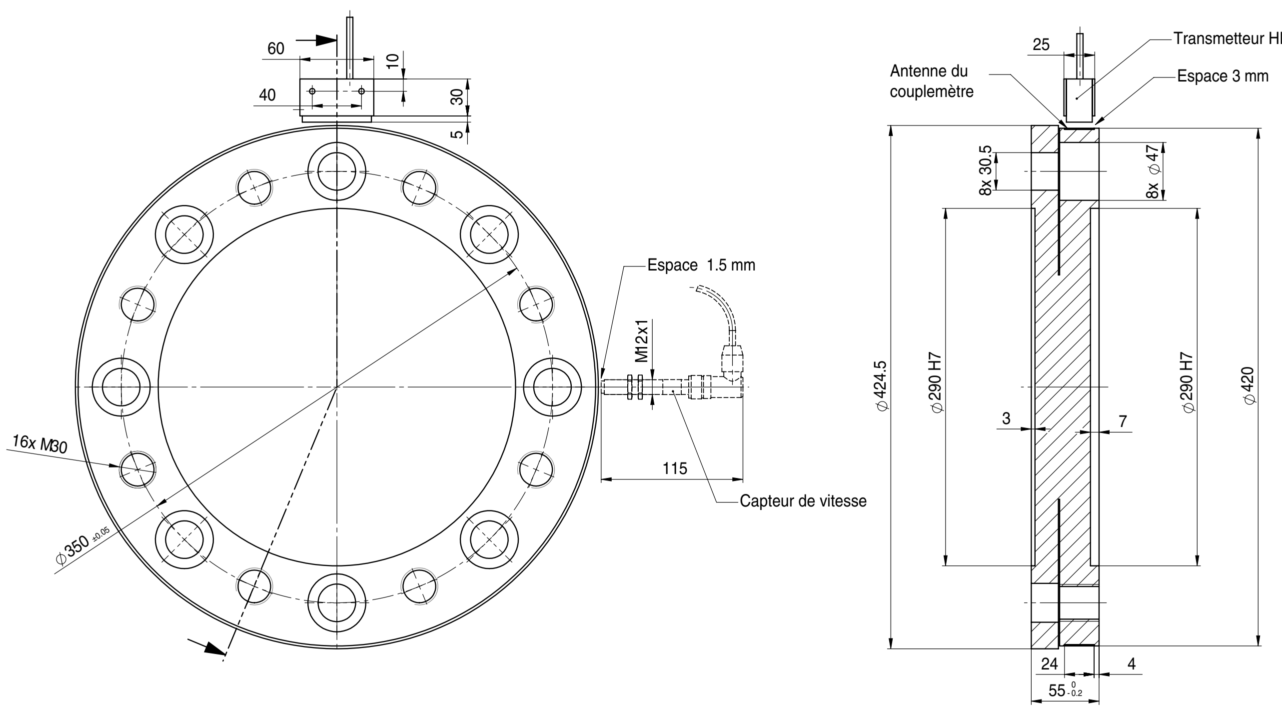


# Dimensions du couplemètre TF

## TF 217

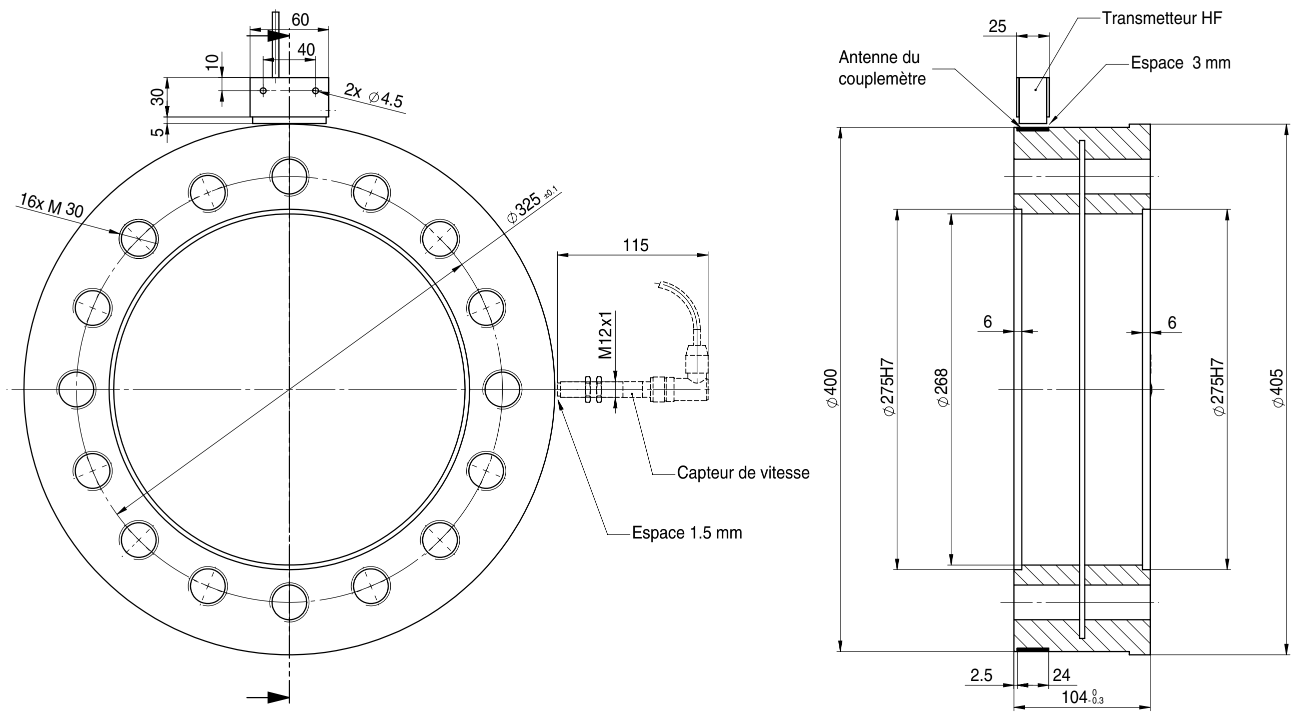



## TF 218 ET TF 219



# Dimensions du couplemètre TF

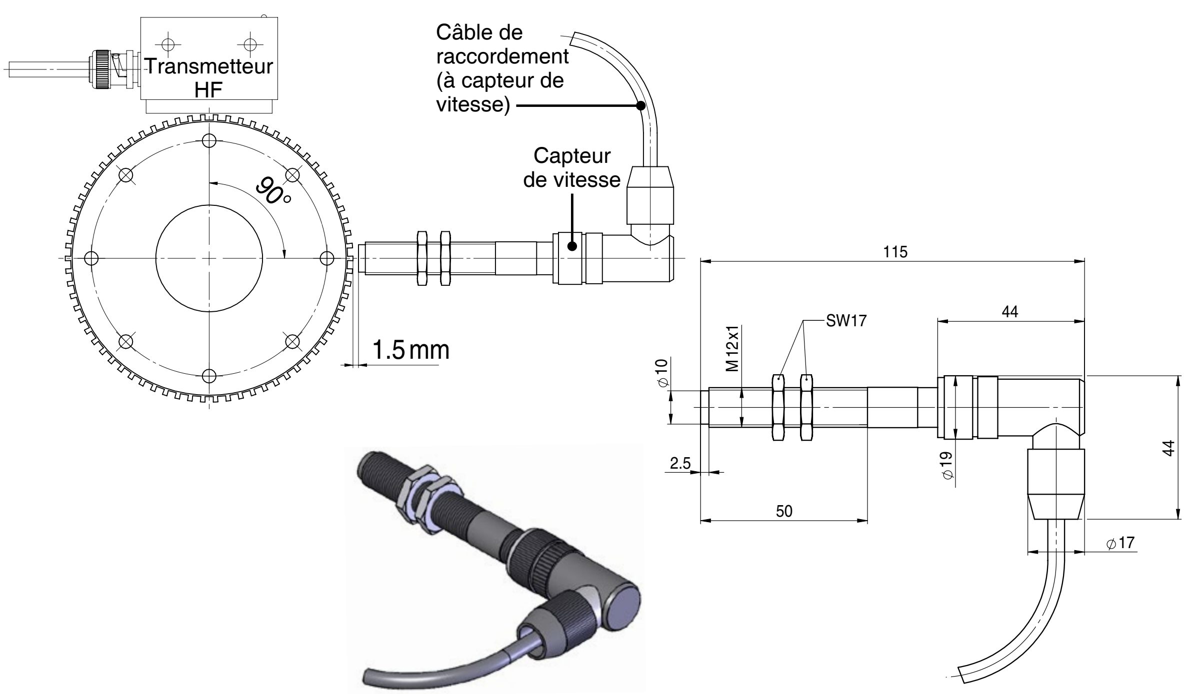
## TF 220



# Dimensions de capteur de vitesse **TF**

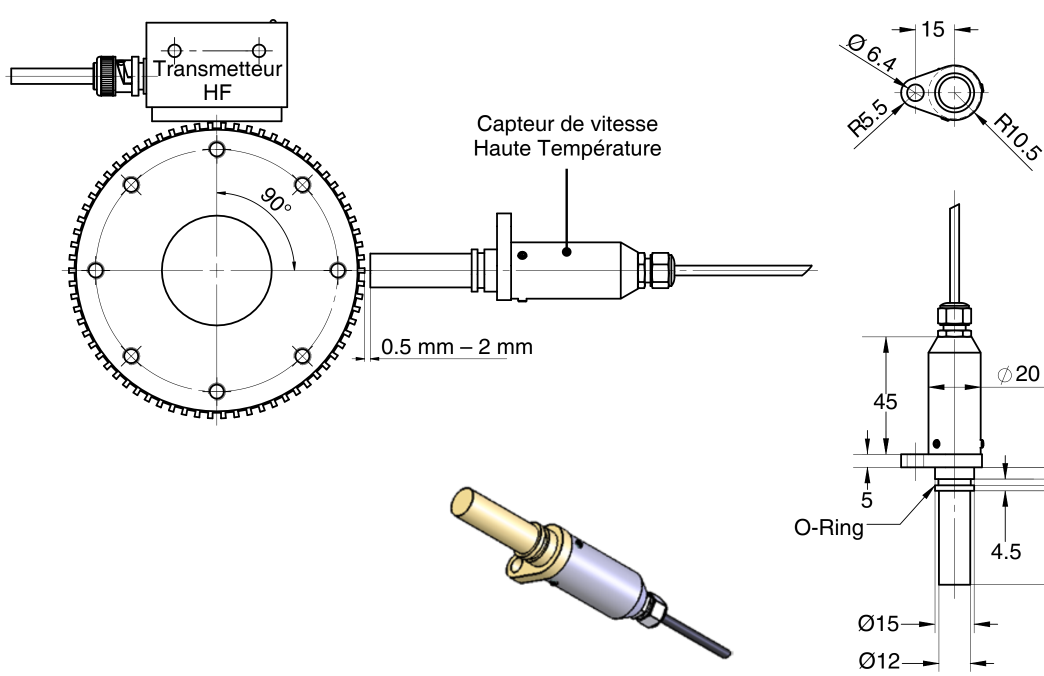
## CAPTEUR DE VITESSE STANDARD

Les capteurs de vitesse standards sont livrés avec les capteurs de couple plats TF commandés avec l'option de mesure de vitesse.




## CAPTEUR DE VITESSE HAUTE TEMPÉRATURE

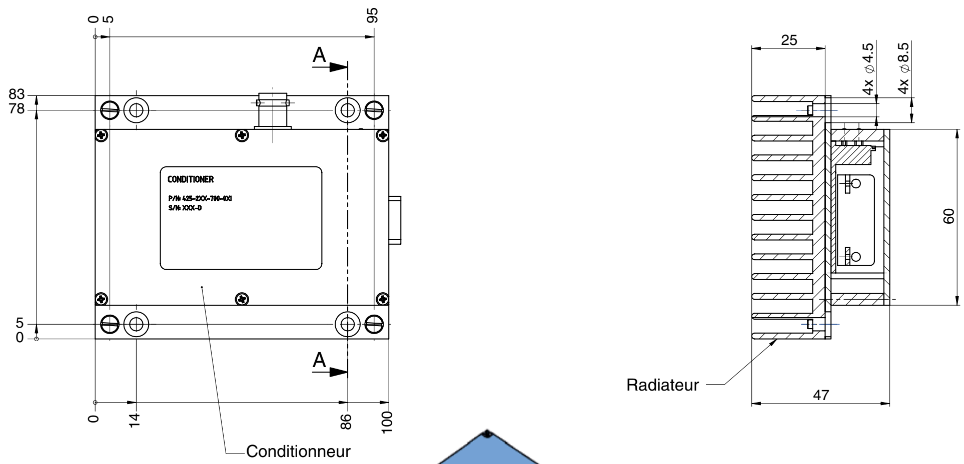
Les capteurs de vitesse haute-température sont livrés avec les capteurs de couple plats TF commandés avec les options de mesure de vitesse et de plage de température étendue (125 °C).

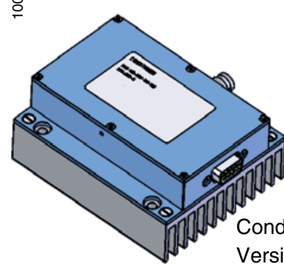


# Dimensions de conditionneur TF

## STANDARD

Pour TF 309 à TF 312 et TF 213 à TF 217

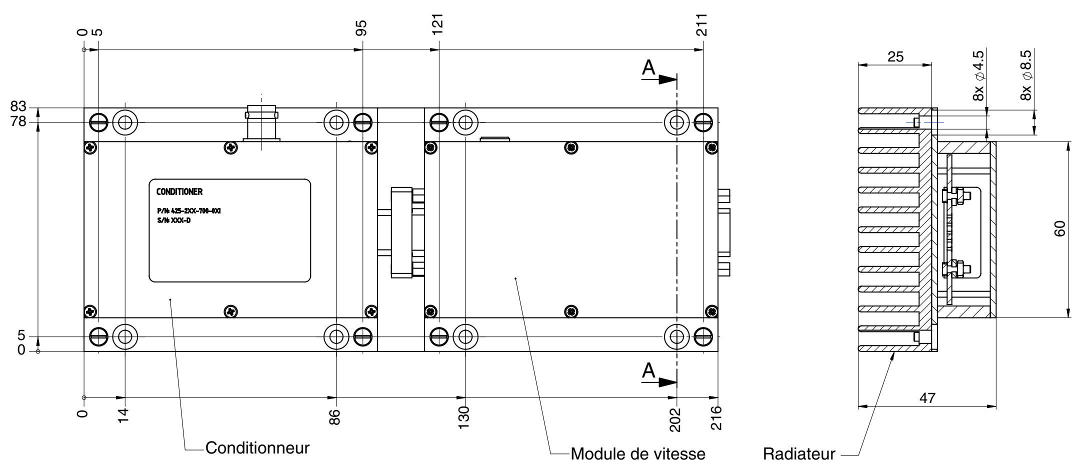


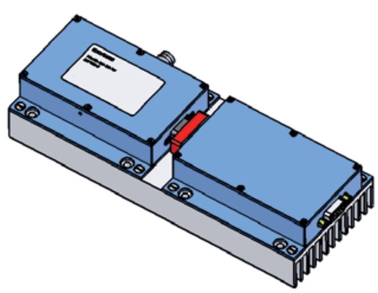



Conditionneur avec radiateur
Version standard

## AVEC OPTION VITESSE

Pour TF 309 à TF 312 et TF 213 à TF 217

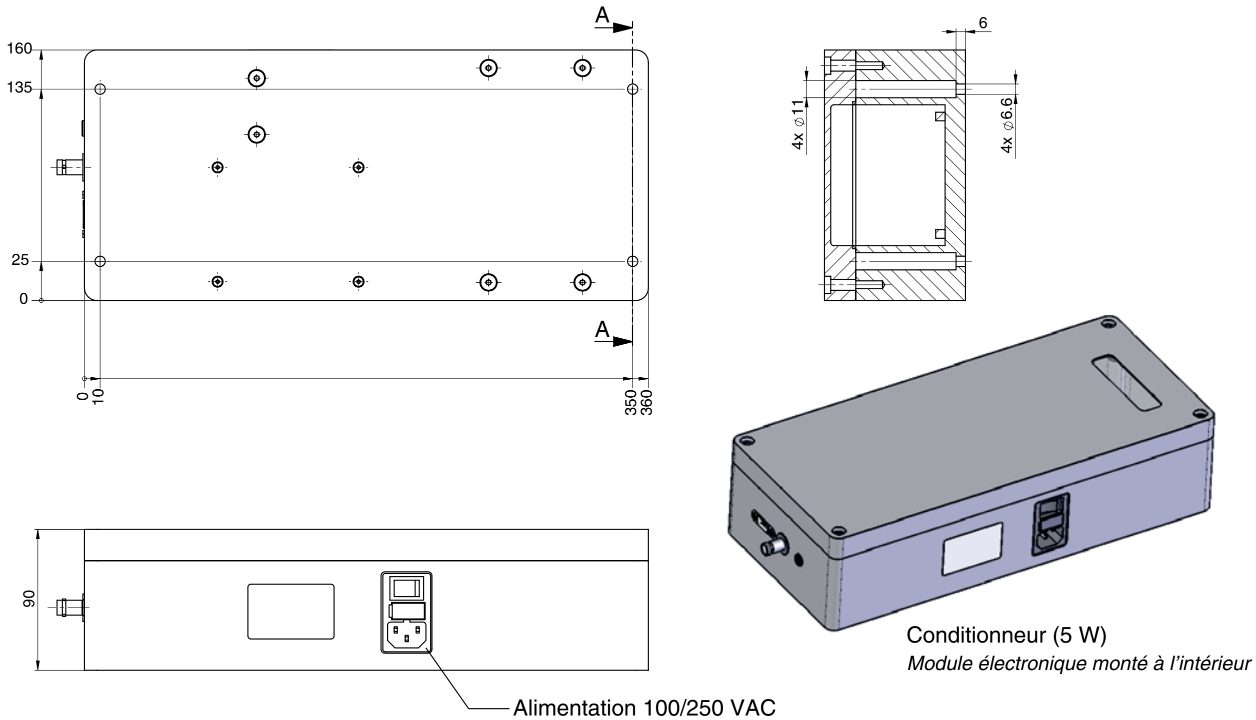


Conditionneur avec radiateur
Version vitesse

# Dimensions de conditionneur TF

## TF 218, TF 219 ET TF 220




Conditionneur (5 W)
*Module électronique monté à l'intérieur*

# Informations pour la commande TF

## OPTIONS ET INFORMATIONS POUR LA COMMANDE

**NUMÉRO DE COMMANDE : TF ☐☐☐ / 0 ☐ 1**

MODÈLE TF

| | |
|---|---|
| • Standard | 1 |
| • Avec mesure de vitesse | 2 |
| • Version haute température (125 °C) | 5 |
| • Haute température & mesure de vitesse | 6 |

## OPTIONS DU SYSTÈME

### Afficheur de couple modèle 3411

Magtrol propose l'afficheur de couple 3411. Il permet d'alimenter tous les couplemètres plats TF et d'afficher les valeurs de couple et de vitesse. Ses specifications comprennent:

- Mesure du couple en unités métriques, anglaises ou SI
- Affichage à fluorescence sous vide de grande dimension
- Fonction de test intégrée
- Indicateur de surcharge
- Fonction de tarage
- Connexion Ethernet
- Sorties pour les valeurs de couple et de vitesse de rotation
- Calibrage piloté par menu
- Inclus logiciel Magtrol Torque 7

### Logiciel de test Torque 7

Le logiciel de test Torque 7 de Magtrol, simple à utiliser, fonctionne sous Windows®. Il permet d'acquérir automatiquement des données de couple, de vitesse de rotation et de puissance, de les imprimer, de les représenter graphiquement et de les exporter dans un tableau Microsoft® Excel. Ce logiciel dispose également de fonctions standards d'acquisition de valeurs crêtes et de présentations graphiques combinées de courbes de mesure.

### Câbles de raccordement

**MODÈLE: ER 1 ☐☐ - 0 ☐**

EXTRÉMITÉ DU CÂBLE

| | |
|---|---|
| • Connecteur 14-PIN<br>*(Pour utilisation de l'afficheur 3411 ou du contrôleur DSP7001)* | 16 |
| • Bout libre | 17 |

LONGUEUR DU CÂBLE

| | |
|---|---|
| • 5 m | 1 |
| • 10 m | 2 |
| • 20 m | 3 |

### Accouplements

Pour votre couplomètre plat série TF, Magtrol propose les accouplements de la séries BSD Moduflex® 9200 ou à soufflet métallique de la série BKC.

Pour plus de détails, contacter votre office régional de vente.

# 2. Installation / Configuration

CAUTION: BEFORE COMPLETING THE ASSEMBLY AND MOUNTING, IT IS ADVISED TO FIRST POWER UP THE SYSTEM *(SEE SECTION 3.1)* IN ORDER TO CHECK THE SIGNAL TRANSMISSION.

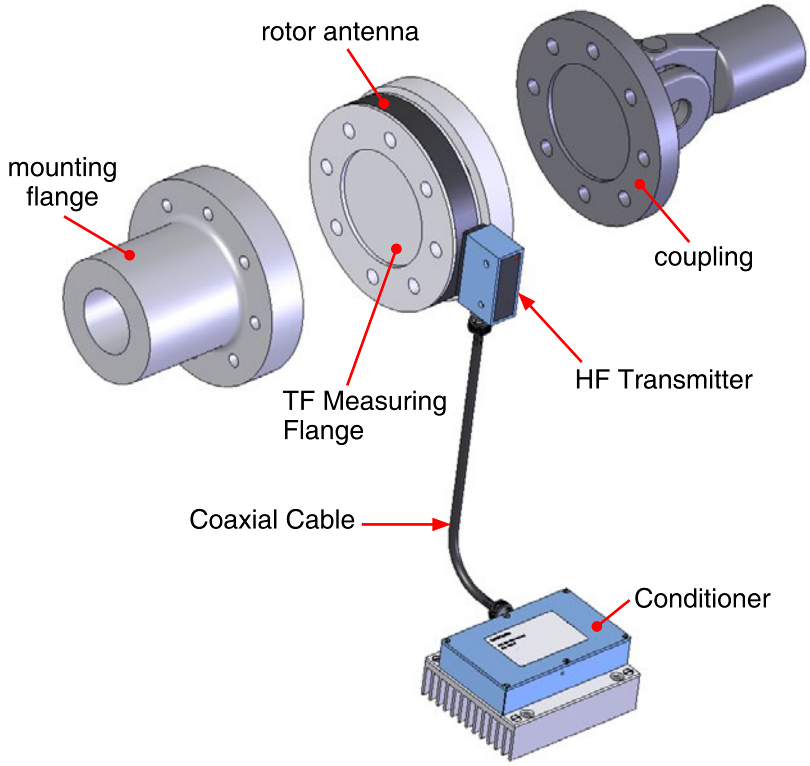



*Figure 2–1 Installation Overview*

## 2.1 INITIAL CLEANING

Prior to installing the TF Series Torque Flange Sensor, all contact surfaces including the measuring flange, coupling element and mounting flange must be carefully cleaned and degreased. This will guarantee optimal transmission of the measured torque signal.

Use a soft cloth lightly dampened with alcohol to avoid any abrasion. Be careful to prevent any alcohol from entering the flange or coming in contact with the rotor antenna during cleaning.

CAUTION: AVOID ANY USE OF OVERLY AGGRESSIVE SOLVENTS. THESE CAN DAMAGE THE ROTOR ANTENNA WHILE CLEANING. IF NECESSARY, ACETONE MAY BE USED (INSTEAD OF ALCOHOL) TO REMOVE ENCRUSTED DEPOSITS.

It is advised to clean all flange and coupling contact surfaces each time the drive train is reconfigured.

## 2.2 MEASURING FLANGE MOUNTING

### 2.2.1 Alignment

The TF Series Torque Flange Sensors are easy to install by design. However, it is important to achieve the best possible alignment of the various components of the measurement drive train. Angular and radial misalignments (as illustrated below) must be avoided.

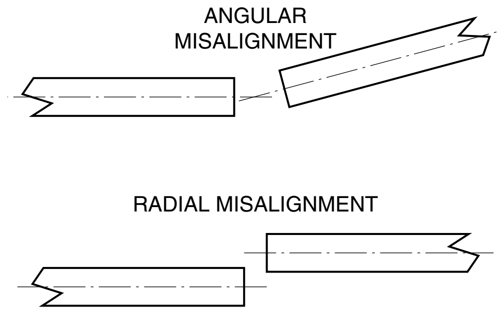



*Figure 2–2 Angular and Radial Misalignment*

The admissible angular and radial misalignment is 0.3° and 0.04 mm, respectively. By using proper couplings, modest misalignments can be compensated.

### 2.2.2 Coupling Selection

To avoid excessive extraneous loads, do not couple the driving elements directly to the driven part of the measuring chain by means of the measuring flange. A coupling is necessary.

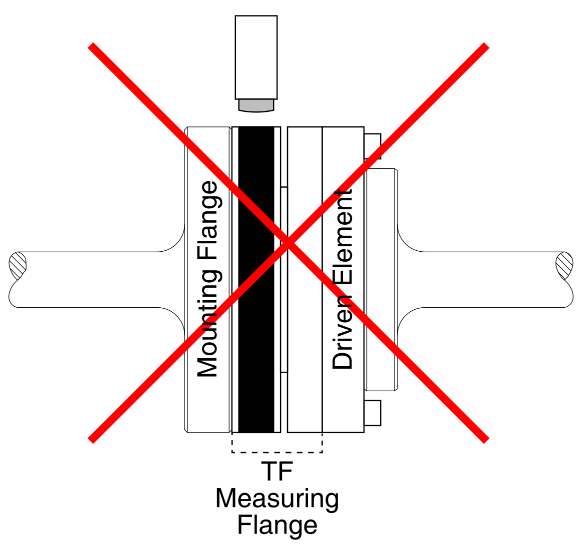



*Figure 2–3 Incorrect Mounting*

### 2.2.2.1 Couplings for Angular Misalignment

In case of a slight angular error, a one-piece lamella coupling, cardan shaft or bellows coupling may be used.

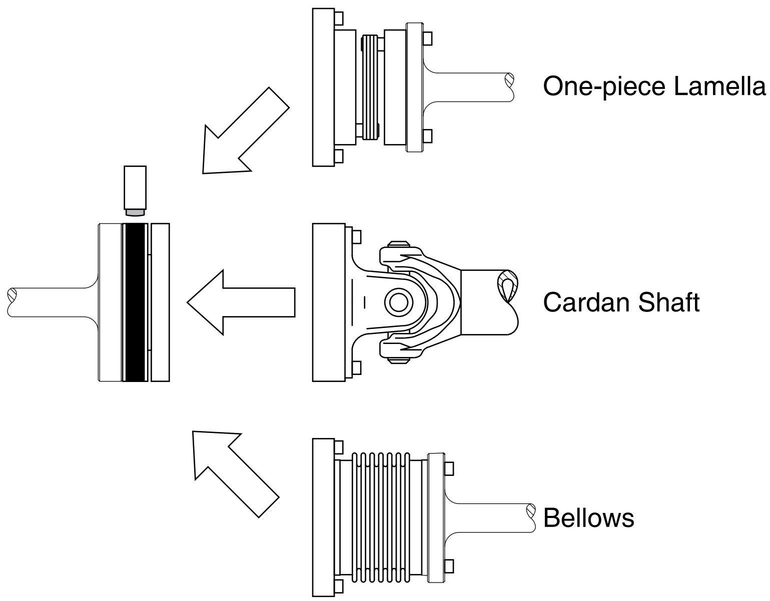



*Figure 2–4 Coupling Options for Angular Misalignment Correction*

### 2.2.2.2 Couplings for Radial Misalignment

If the shaft mounting shows a slight radial misalignment, a two-piece lamella coupling, double cardan shaft or bellows coupling may be used. These elements provide the system with two degrees of freedom in order to compensate for a slight radial misalignment.

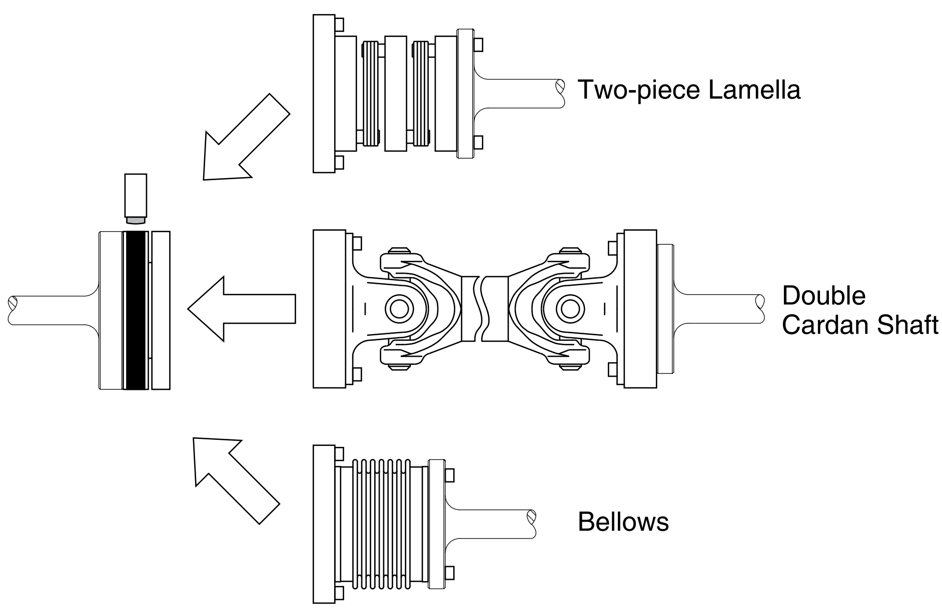



*Figure 2–5 Coupling Options for Radial Misalignment Correction*

### 2.2.3 Mounting Considerations

| Mounting Flange and Coupling Specifications | |
|---|---|
| Minimum Tensile Strength | 700 N/mm² |
| Minimum Hardness | 25 HRC |
| Roughness | Ra 1.6 |
| Minimum Face Flatness | 0.03 mm |
| Centering Tolerance Ø | g6 |

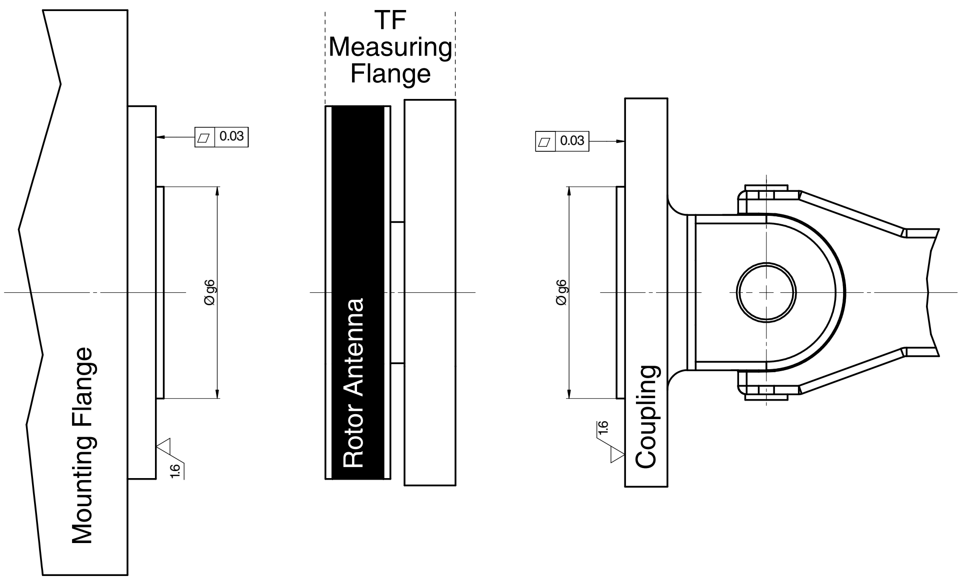



*Figure 2–6 Mounting Flange and Coupling Specifications*

- The mounting flange or coupling mounted on the same side as the rotor antenna must have a diameter equal to or smaller than the rotor antenna diameter.
- To achieve the best possible centering of the measuring flange, the mounting flanges and couplings should use a centering device with a g6 tolerance on the outside diameter as illustrated in *Figure 2–6 Mounting Flange and Coupling Specifications*.

  The measuring flange is fitted with a centering bore (tolerance H7) on each face.

Note: If the mounting flange is also fitted with a centering bore, an intermediate centering washer may be used (see *Figure 2–8 Mounted TF*).

- A minimum distance of 10 mm between the main body of the mounting flange and its center piece (as illustrated in *Figure 2–7 Measuring Flange Spacing*) is necessary to avoid any disturbance when transmitting the HF telemetry signal.

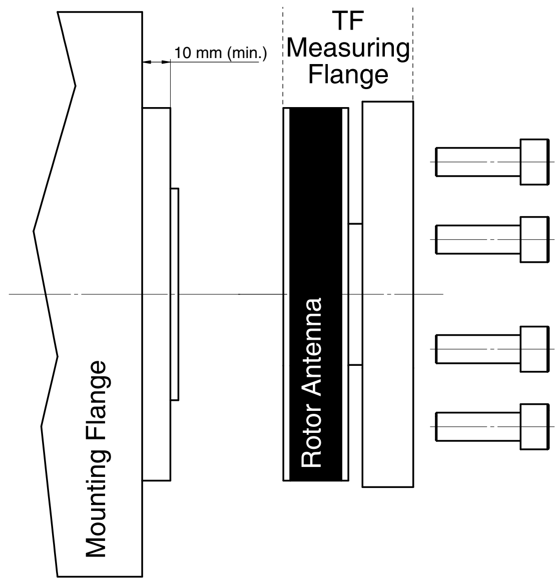



*Figure 2–7 Measuring Flange Spacing*

- Check the lengths of the screws and be sure to avoid any contact between the screws and the opposite part of the measuring flange (see *Figure 2–8 Mounted TF*).
- Ensure a 0.1 to 0.2 mm clearance between the centering hole of the measuring flange and the mounting flange centering washer.

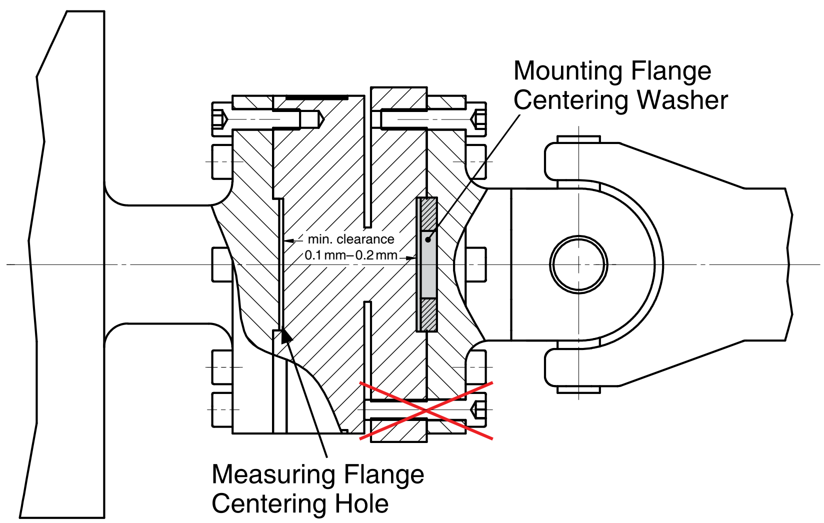



*Figure 2–8 Mounted TF*

## 2.2.4 Mounting Procedure

Since all TF Sensors are reversible, the component that is to be mounted on the same side as the measuring flange's rotor antenna must be mounted first. The options/mounting orders are as follows:

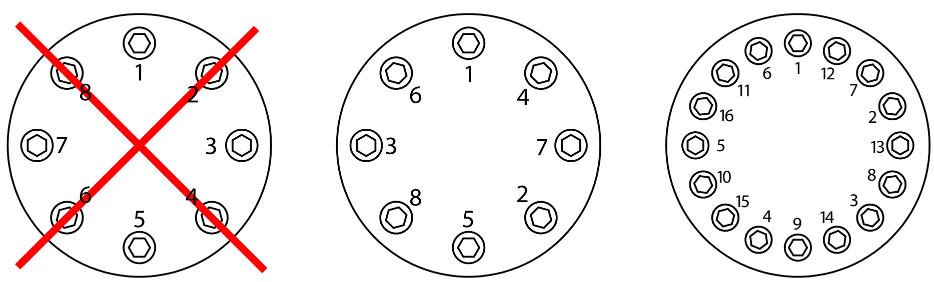
| Option | First Step | Second Step |
|---|---|---|
| A | Mounting Flange to Measuring Flange (see *Section 2.2.4.2)* | Coupling to Measuring Flange/Mounting Flange Assembly (see *Section 2.2.4.3)* |
| B | Coupling to Measuring Flange (see *Section 2.2.4.4)* | Mounting Flange to Measuring Flange/ Coupling Assembly to (see *Section 2.2.4.5)* |

### 2.2.4.1 Mounting Screws

The measuring flange must be mounted with 8.8/10.9/12.9 quality screws applying the specific fastening torque listed in the following table.

| TF Sensor Model | Fastening Screw Size | Screw Class | Fastening Torque [*N·m*] | |
|---|---|---|---|---|
| | | | Friction Coefficient μ = 0.10 | Friction Coefficient μ = 0.14 |
| **TF 309** | M6 | 8.8 | 9.0 | 11.3 |
| **TF 310** | | | | |
| **TF 311** | M6 | 10.9 | 13.2 | 16.5 |
| **TF 312** | | | | |
| **TF 213** | M10 | 10.9 | 63 | 79 |
| **TF 214** | | | | |
| **TF 215** | M12 | 10.9 | 108 | 137 |
| **TF 216** | M14 | 12.9 | 201 | 255 |
| **TF 217** | M16 | 12.9 | 309 | 395 |
| **TF 218** | M30 | 10.9 | 1 775 | 2 274 |
| **TF 219** | | | | |
| **TF 220** | M30 | 10.9 | 1775 | 2 274 |

The mounting screws must be tightened in the following order.



TF 309 – TF 312 &
TF 213 – TF 219

TF 220

*Figure 2–9 Screw Tightening Order*

Note: When faced with alternating loads, secure the screws in their threads with thread locker in order to avoid any loss of preload. Be sure to prevent the thread locker from spilling over.

### 2.2.4.2 Attaching the Mounting Flange to the Measuring Flange

Screw the measuring flange onto the mounting flange, firmly attaching it to the driving shaft, as shown in the figures below.

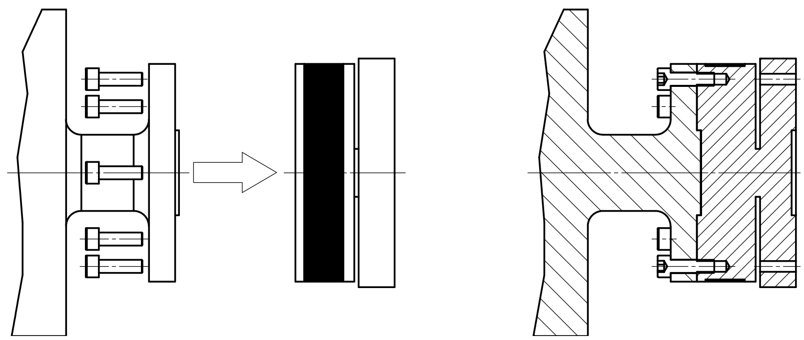


*Figure 2–10 Flange Mounting of TF 309 to TF 312 and TF 220 Sensors*

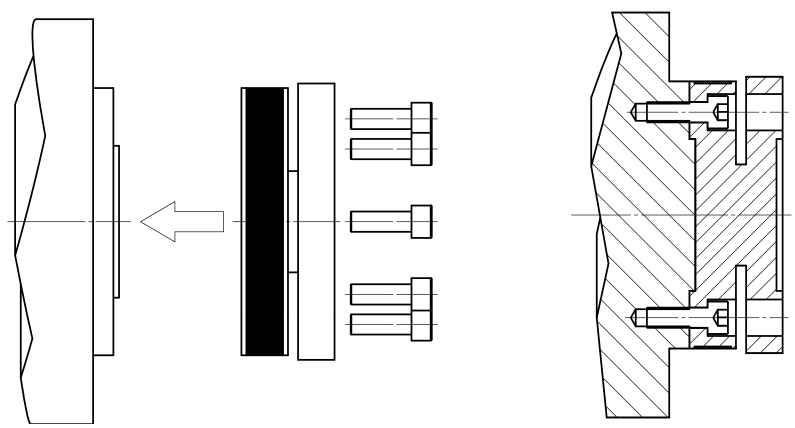


*Figure 2–11 Flange Mounting of TF 213 to TF 219 Sensors*

### 2.2.4.3 Attaching the Coupling to the Measuring Flange/Mounting Flange Assembly

Screw the single- or double-element coupling, or cardan shaft, onto the measuring flange.

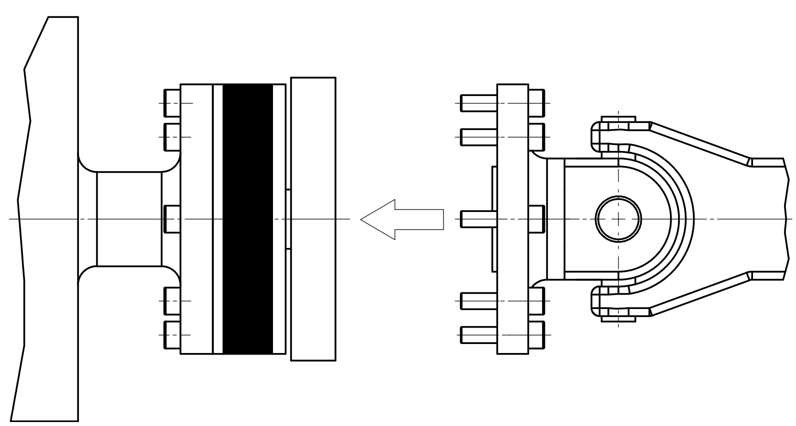


*Figure 2–12 Coupling Mounting to Measuring Flange/Mounting Flange Assembly*

### 2.2.4.4 Attaching the Coupling to the Measuring Flange

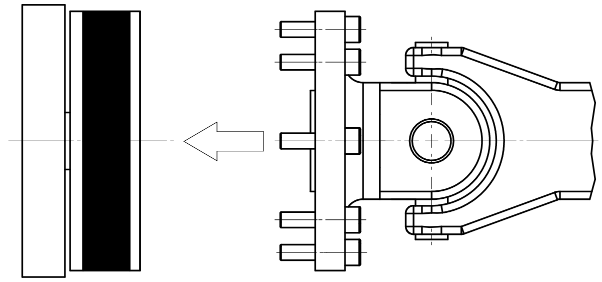


*Figure 2–13 Coupling Mounting to Measuring Flange (TF 309, 310, 311 and 220)*

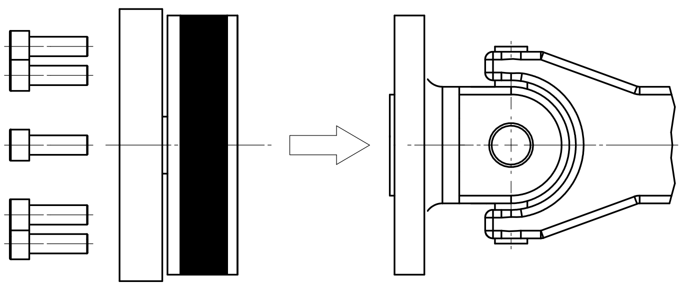


*Figure 2–14 Coupling Mounting to Measuring Flange (TF 213 – 219)*

### 2.2.4.5 Attaching the Mounting Flange to the Measuring Flange/Coupling Assembly

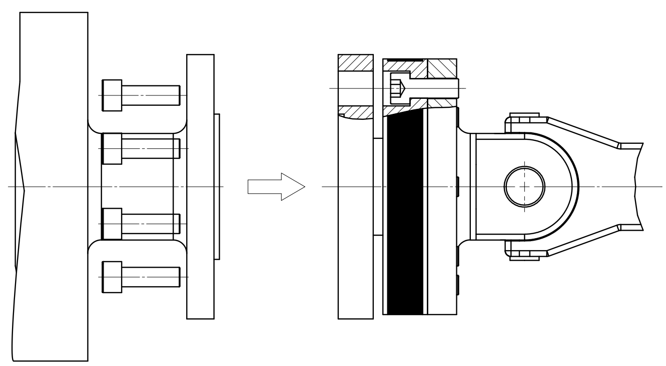


*Figure 2–15 Mounting Flange to Measuring Flange/Coupling Assembly*

Note: When using a cardan shaft, Magtrol recommends the latest generation of GKN series 687 cardan shafts with limited weight. Do not use the over weighted old cardan shafts. Proper mounting position of the cardan shaft is neccessary to ensure proper balancing. Standard applications using a cardan shaft should not exceed 1500-2000 rpm, depending on size and deflection angle.

## 2.3 HF TRANSMITTER MOUNTING

Mount the HF transmitter according to the following specifications:

- The HF transmitter must be perfectly centered (laterally) with the rotor antenna and also aligned with the measuring flange axis.
- A gap of 2 mm for TF 309 to TF 312 and TF 213 to TF 217 Sensors and 3 mm for TF 218 to TF 220 Sensors must be maintained between the HF transmitter and rotor antenna in order to guarantee the best possible signal transmission.
- The HF transmitter must be mounted onto a support which can be easily adjusted both horizontally and vertically. To prevent any disturbance of the transmitted signal, the support must be at least 10 mm away from the HF transmitter rim (see *Figure 2–16 HF Transmitter Installation*). The support must also be stable in order to prevent excessive vibrating of the HF transmitter and, consequently, avoid electromagnetic coupling problems between the rotor antenna and the HF transmitter.

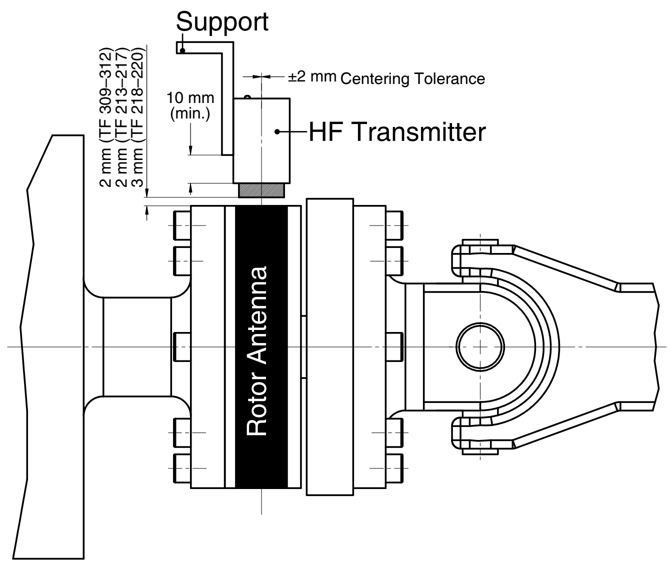



*Figure 2–16 HF Transmitter Installation*

## 2.4 SPEED SENSOR MOUNTING

If the TF Torque Flange Sensor is ordered with optional speed measurement capabilities, the HF Transmitter and the speed sensor must be mounted offset from each other with at least a 90° angle, as shown in *Figures 2–17* and *2–18*.

### 2.4.1 Standard Sensors

The speed sensor must be placed at a 1.5 mm distance from the measuring flange in order to optimize detection.

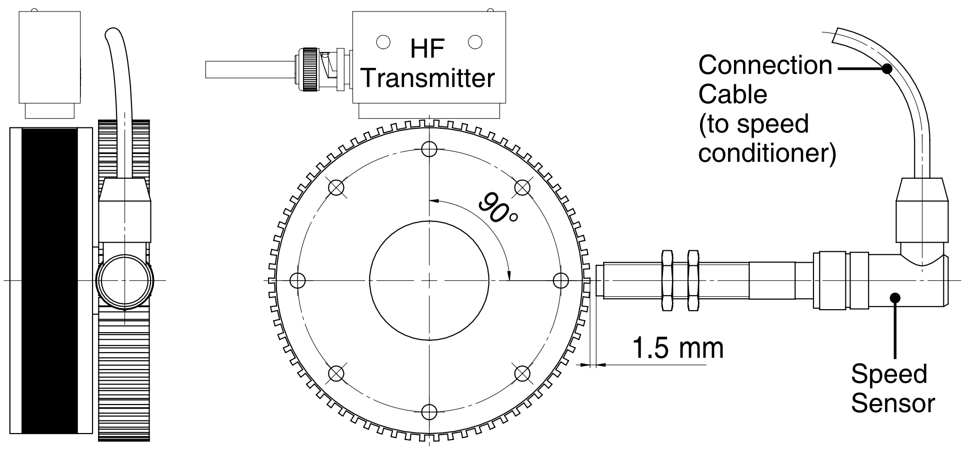



*Figure 2–17 Standard Speed Sensor Installation*

### 2.4.2 High-temperature Sensors

The high-temperature speed sensor, delivered with TF Torque Flange Sensors ordered with extended temperature range, must be placed at a 0.5 mm to 2 mm distance from the teeth with a 10° angle to optimize detection.

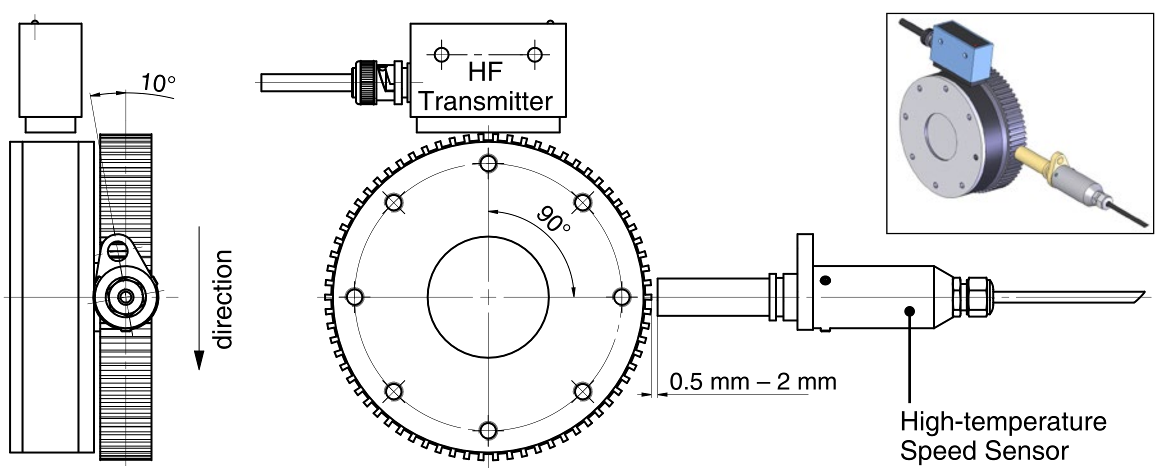



*Figure 2–18 High-temperature Speed Sensor Installation*

## 2.5 ELECTRICAL CONNECTIONS

Having installed the measuring flange and HF transmitter, only two electrical cables (three, with speed measurement option) need to be connected for the system to be operational.

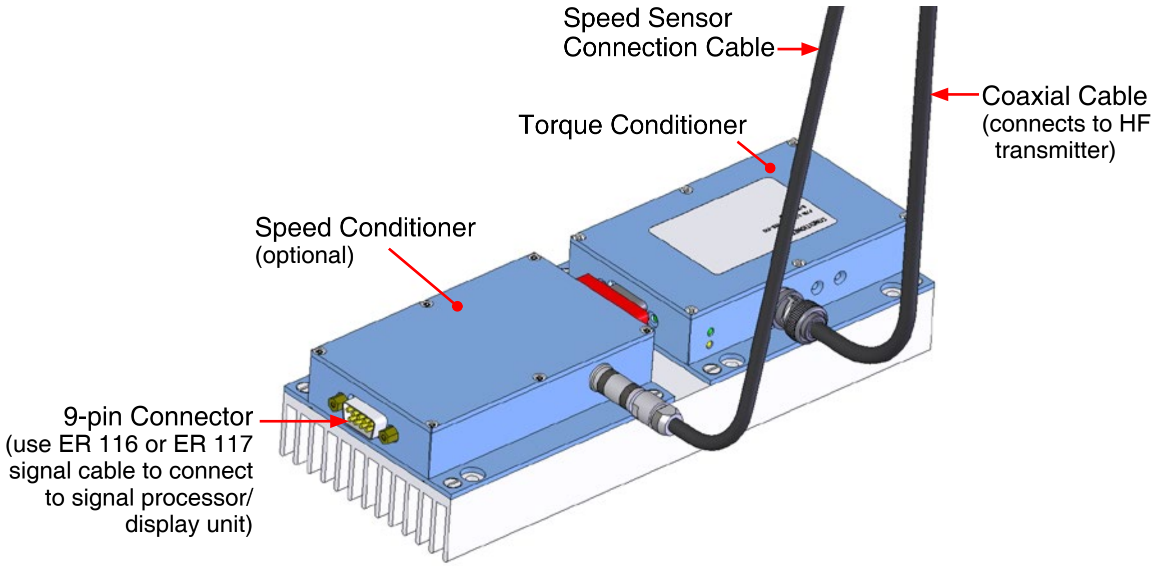



*Figure 2–19 Conditioner Connections*

Avoid running the ER-116/117 signal cable, coaxial cable and speed sensor connection cable through an environment which may be perturbed by electromagnetic fields. These cables should also not be run close to transformers, electric motors or motor drives. If running these TF Torque Flange Sensor cables through such environments cannot be avoided, a minimum distance of 2 feet from potentially perturbing components should be respected.

Ideally, these cables should be housed in steel conduit and connected to earth ground, to protect them as much as possible from electromagnetic perturbations.

### 2.5.1 Connecting the HF Transmitter to the Conditioner

CAUTION: NEVER SHORTEN THE COAXIAL CABLE. THE SYSTEM HAS BEEN TUNED IN ORDER TO OPTIMIZE THE HF TRANSMISSION USING THE COAXIAL CABLE'S ORIGINAL LENGTH (AS DELIVERED).

Connect the HF transmitter to the conditioner with the supplied coaxial cable, utilizing the dedicated connectors. (See *Figure 2–19 Conditioner Connections*.)

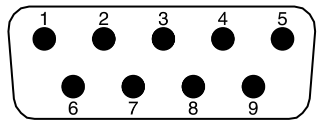
### 2.5.2 Connecting the (Optional) Speed Sensor to the Speed Conditioner

Connect the speed sensor to the speed conditioner with the supplied connection cable, utilizing the dedicated connectors. (See *Figure 2–19 Conditioner Connections*.)

### 2.5.3 Connecting the Conditioner to a Signal Processor/Display Unit

#### 2.5.3.1 Conditioner Connector

For connection to a signal processor/display unit such as a Magtrol 3411 Torque Display or DSP7001 Controller, the conditioner is equipped with a 9-pin D-sub connector.




1. Torque signal (-5 to +5 VDC)
   (-10 to +10 VDC for 200%)
2. Torque signal grounding 0 VDC
3. Calibration signal
4. N/C
5. Power supply grounding 0 VDC
6. TTL speed signal (*with speed measurement option*)
7. Power supply 24 VDC (±10%) (N/C for 5W conditioner)
8. N/C
9. N/C

*Figure 2–20 Conditioner Connector Pin Configuration*

#### 2.5.3.2 Signal Cables

Magtrol offers two cable options for connecting the TF Torque Flange Sensor to a signal processor/ display unit *(sold separately)*.

| Cable Model | Connectors | |
|---|---|---|
| | On Conditioner Side | On Display Side |
| ER 116 | 9-pin D-sub connector | 14-pin Centronics connector |
| ER 117 | 9-pin D-sub connector | none (only pigtail wires) |

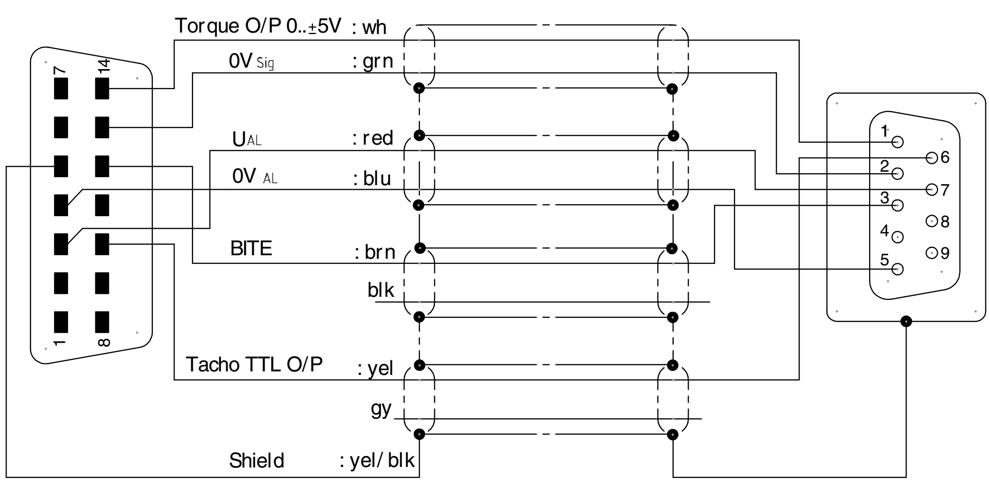



*Figure 2–21 ER 116 Cable Configuration*

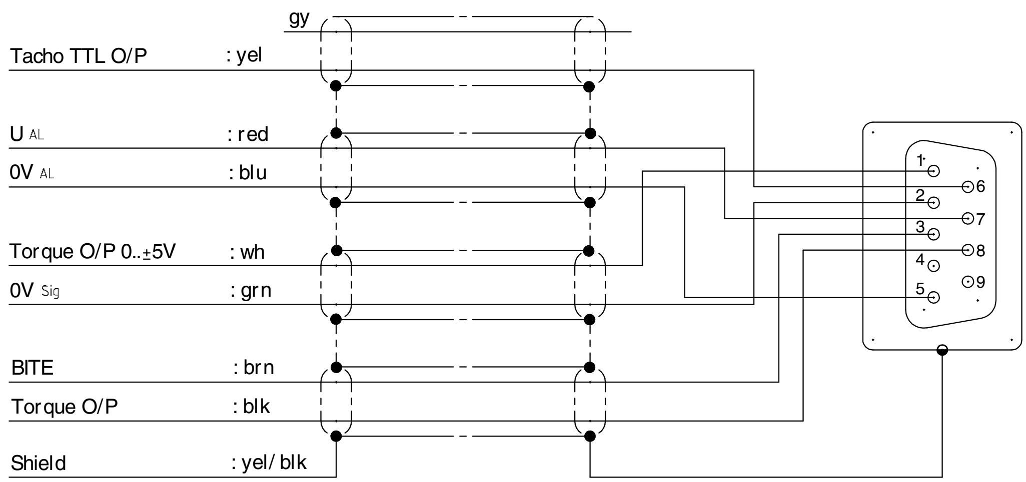



*Figure 2–22 ER 117 Cable Configuration*

## 2.6 PROTECTIVE SYSTEMS

**WARNING! ALL ROTATING PARTS MUST BE FITTED WITH A PROTECTIVE SYSTEM TO ENSURE THAT THE USER, AS WELL AS ALL OTHER SURROUNDING PEOPLE AND OBJECTS, WILL NOT BE INJURED OR DAMAGED AS A RESULT OF THE DRIVE ELEMENT BECOMING BLOCKED, A TORQUE OVERLOAD, OR ANY OTHER POTENTIAL PROBLEM.**

The following precautions concerning protective equipment of the drive train must be observed:

- Protective elements must prevent access to moving parts (during test).
- Protective elements must cover all parts which can cause crushing or cutting, and protect against projections of parts having become loose.
- Avoid attaching protective elements to rotating parts.
- A minimum space of at least 12 mm should be maintained between rotating parts and protective elements.

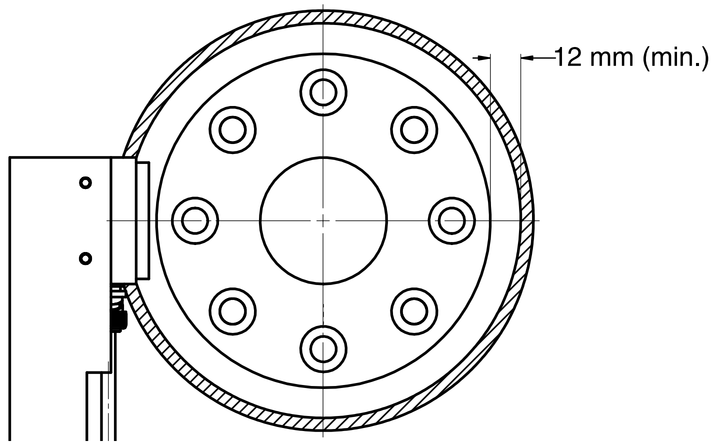



*Figure 2–23 Spacing Between Flange and Guard*

*Figure 2–24* shows a good example of a protective system. All parts of the bench are accessible, but the cover prevents any risk to the user when closed.

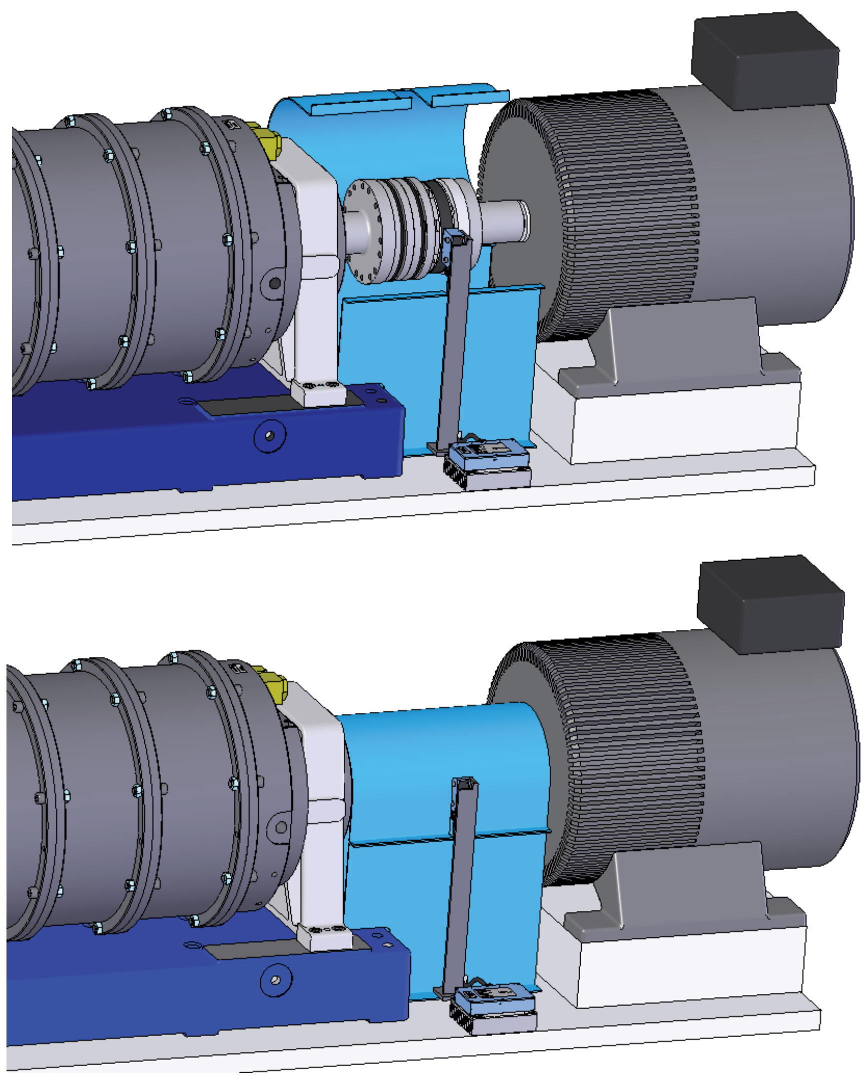


*Figure 2–24 Example of Protective System*

# 3. Startup

## 3.1 POWERING UP THE SYSTEM

1. Switch the system on (power up).
2. Check that all LEDs are illuminated. (If this is not the case, refer to *Section 6.2 – LED Indicators*).

| LED | Indicates |
|---|---|
| Yellow | Conditioner is powered up. |
| Green | Conditioner receives a (return) signal.<br>Data transmission is OK. |
| Red | HF transmitter is powered up. |

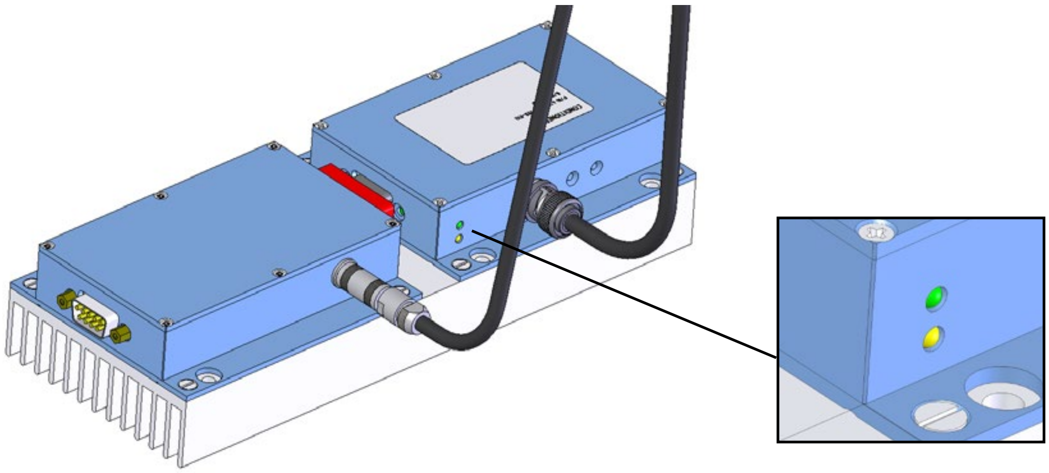


*Figure 3–1 Green and Yellow LEDs*

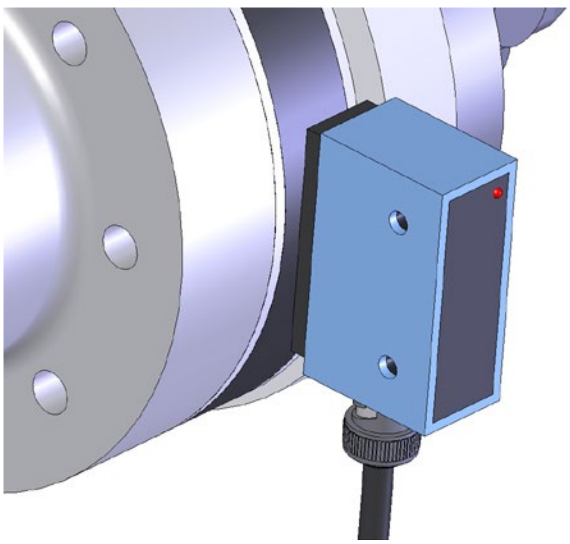


*Figure 3–2 Red LED*

## 3.2 OFFSET AND GAIN

Offset and gain of TF Series Torque Flange Sensors are calibrated before delivery. However the zero (offset) may have drifted slightly after mounting the measuring flange (surface flatness, fastening torque of the screws, parasitic forces).

If necessary, proceed as follows:

1. Completely unload the measuring chain (no force should be applied to the TF Sensor).
2. Adjust the torque output signal by means of the "Offset" potentiometer placed inside the conditioner in order to obtain a zero value for the torque (0 N·m = 0.000 V).

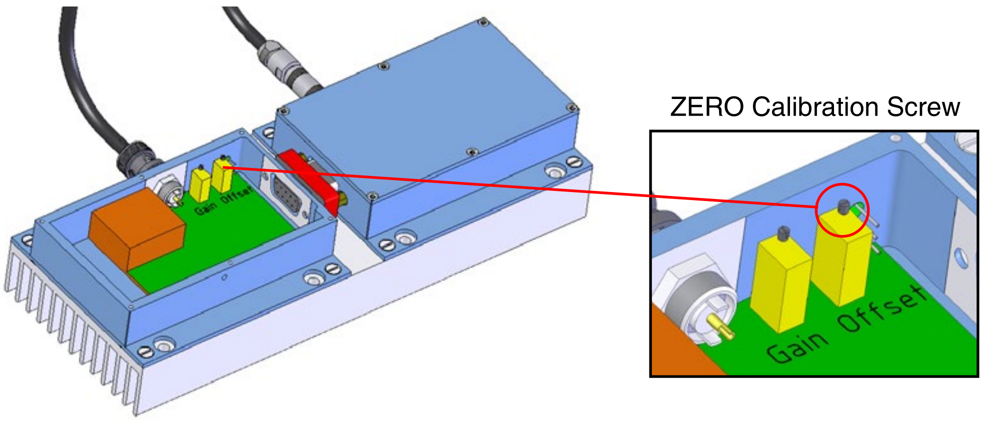



*Figure 3–3 Zero Calibration of 1.5 W Conditioner (TF 309–312 and TF 213–217 Sensors)*

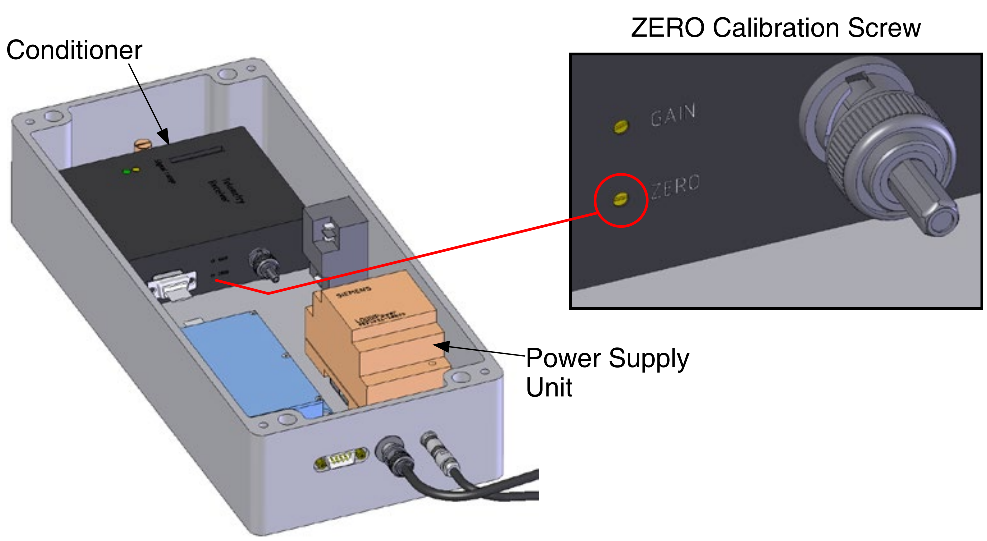



*Figure 3–4 Zero Calibration 5 W Conditioner (TF 218 to TF 220 Sensors)*

CAUTION: NEVER TOUCH THE "GAIN" ADJUSTMENT SCREW. IT IS ONLY USED AFTER A CONDITIONER REPLACEMENT OR REPAIR.

# 4. Measurement Considerations

| | |
|---|---|
| Caution: | When performing static measurements, it is possible to go beyond nominal torque and toward the torque limit which causes plastic deformation. When exceeding the nominal torque, any extraneous loads such as axial, shearing and bending forces must be avoided. |

## 4.1 DYNAMIC TORQUE

Static and dynamic measurements differ from one another by the evolution of torque over time. A constant torque produces static measurements, whereas varying torques can only be determined by dynamic measurement. TF Torque Flange Sensors have been designed to measure both static and dynamic torque.

## 4.2 DETERMINING THE NATURAL FREQUENCY OF A DRIVE TRAIN

| | |
|---|---|
| Caution: | Critical rotational speeds as well as natural frequencies have to be taken into consideration in order to avoid resonances and possible overloading of the TF torque flange sensor. |

In order to determine the dynamic torque and frequency response, and to prevent any damage to the system, it is necessary to calculate the natural frequency of the drive train's torsional oscillations.

The drive train is considered a combination of torsion springs with intermediate flywheel masses. In the TF Sensor, the deformation area of the measuring flange is the weakest link in the rotating measuring chain and is subject to torsional vibrations. A good approximation of the dominant torsional resonant frequency is given in the following formula:

$$f_0 = \frac{1}{2\pi}\sqrt{C_t \frac{J_1 + J_2}{J_1 \cdot J_2}}$$

| | |
|---|---|
| $f_0$ | System natural frequency [Hz] |
| $C_t$ | Torsional stiffness of the flange [N·m/rad] |
| $J_1$ | Moment of inertia (driving element + mounting flange + ½ measuring flange) [kg·m²] |
| $J_2$ | Moment of inertia (driven element + cardan shaft + ½ measuring flange) [kg·m²] |

A more detailed analysis of the dynamic system response may require the study of publications on structural mechanics. However, the following simplified model of a drive train can often be used.

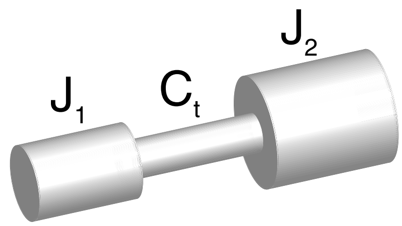



*Figure 4–1 Simplified Physical Drive Train Model*

Note: The natural torsional frequency of the drive train is lower due to the presence of the TF Torque Flange Sensor. The system's own natural frequency must then be recalculated to determine the influence of the TF Sensor.

The torsion spring describes the behavior of the measuring flange deformation zone. The torsional stiffness values ($C_t$) are indicated in the data sheet in *Section 1.2*. Both moments of inertia ($J_1$ and $J_2$) are generated by the two deformation areas and can be calculated by adding the moment of inertia of each individual element. The moment of inertia of the flange is also indicated in the data sheet. Consult with the suppliers of the couplings, driving element(s) and driven element(s) in order to obtain details on moment of inertia of the other drive train components.

The natural torsional frequency ($f_0$) determines the response of the torque measuring system and helps to determine whether rapid variations may influence the measuring system or whether the torque is amplified or damped by the drive train dynamics. The transfer curve is shown in *Figure 4–2* for various quality factor values (Q), depending on the torsional system damping factor. The graph charts the factor by which the torque will be amplified, depending on the frequency of the torsional oscillations.

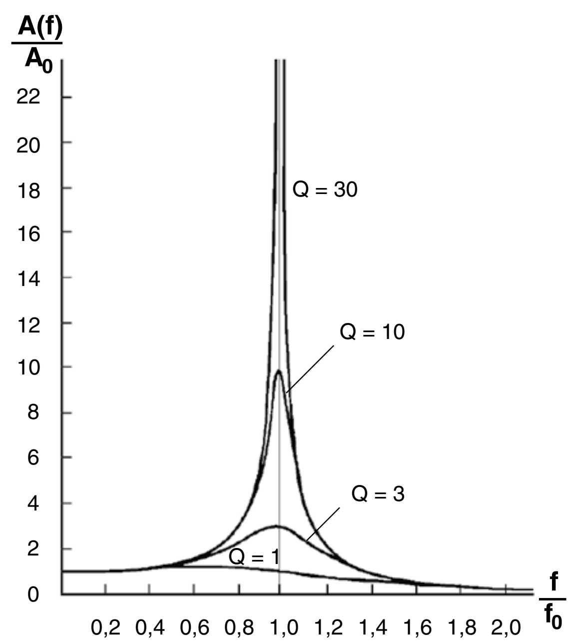



*Figure 4–2 Drive Train Transfer Curve*

Example:

Let us assume a natural frequency $f_0$ of 1000 Hz and a quality factor Q=10. A dynamic torque around 900 Hz (close to the natural frequency) would be read by the TF torque flange sensor and amplified by a factor of approximately 6. It is important to note that this amplification is not electrical but mechanical. The risk of overloading the TF Sensor is therefore real.

☞ Note: In practice, the system will be configured and used so as never to get close to the natural frequency of the measuring chain. The Q value must, if possible, be "1". For this reason, the drive train torsional oscillation frequency must be below ~0.5 $f_0$.

## 4.3 MAXIMUM DYNAMIC AMPLITUDE

The dynamic peak-to-peak amplitude must not exceed 400% of the nominal torque of the TF Torque Flange Sensor. This is even true with alternating loads. This amplitude must remain within -200% $M_{nominal}$ and +200% $M_{nominal}$ as shown in the graph below.

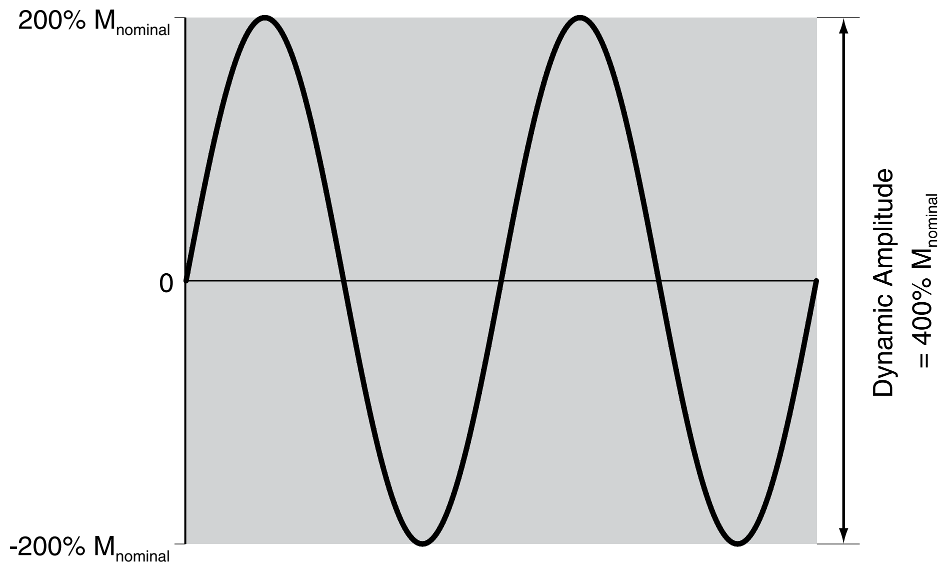



*Figure 4–3 Admissible Dynamic Load*

## 4.4 PARASITIC FORCES

CAUTION: NEVER EXCEED ADMISSIBLE LIMITS OF TORSIONAL MOMENTUM, AXIAL OR RADIAL FORCES. THE PARASITIC FORCES ARE TO BE AVOIDED AT MOST

If the TF Torque Flange Sensor is improperly installed, parasitic forces can act in both radial and axial directions on the sensor.

Radial forces generate torsional momentum on the TF Sensor which alters its center of gravity. The resulting imbalance will periodically load the TF sensor proportional to the rotational speed. The influence of this load increases with rotational speed.

Axial or radial forces, misalignment or unbalance will distort the measuring precision of the sensor. Modulation of axial or radial forces under rotation may cause an anticipated fatigue of the sensor and shorten its life time.

Note: The values provided in the table are dynamic limits. The dynamic limit could be much lower depending on the speed of application, balancing quality, alignment and vibrations.

The following table lists the admissible forces and torque which can be applied to the TF Series Torque Flange Sensors without damage.

| Model | Nominal Torque | Limit Torque | Rupture Torque | Bending Torque | Admissible Axial Force | Admissible Radial Force |
|---|---|---|---|---|---|---|
| | *N·m* | *N·m (150%–200% $M_{nominal}$)* | *N·m (400% $M_{nominal}$)* | *N·m* | *N* | *N* |
| **TF 309** | 20 | 40 | 80 | 8 | 800 | 400 |
| **TF 310** | 50 | 100 | 200 | 10 | 1,000 | 500 |
| **TF 311** | 100 | 200 | 400 | 15 | 1,200 | 600 |
| **TF 312** | 200 | 400 | 800 | 20 | 1,500 | 1,000 |
| **TF 213** | 500 | 1,000 | 2,000 | 125 | 3,750 | 3,750 |
| **TF 214** | 1,000 | 2,000 | 4,000 | 300 | 7,500 | 7,500 |
| **TF 215** | 2,000 | 4,000 | 8,000 | 600 | 15,000 | 15,000 |
| **TF 216** | 5,000 | 10,000 | 20,000 | 1,500 | 37,500 | 37,500 |
| **TF 217** | 10,000 | 15,000 | 40,000 | 3,000 | 75,000 | 75,000 |
| **TF 218** | 20,000 | 40,000 | 80,000 | 6,000 | 140,000 | 140,000 |
| **TF 219** | 50,000 | 90,000 | 200,000 | 17,000 | 200,000 | 200,000 |
| **TF 220** | 100,000 | 200,000 | 400,000 | 35,000 | 400,000 | 400,000 |

## 4.5 TEMPERATURE COMPENSATION

TF Series Torque Flange Sensors are temperature-compensated in their operating range of 20 °C and 85° C in a balanced-temperature environment where the temperature on each face of the measuring flange is the same. When mounted between a warm and a cold element, the TF Sensor displays variations of measuring accuracy. Mounting the TF Sensor in an environment with a thermal gradient between the flange faces must be avoided.

# 5. Operating Principles

## 5.1 TELEMETRY PRINCIPLE

Signal transmission between static and rotating components has always been plagued with technical problems. Magtrol's TF Series Torque Flange Sensors provide an interesting solution by using telemetry for signal transmission.

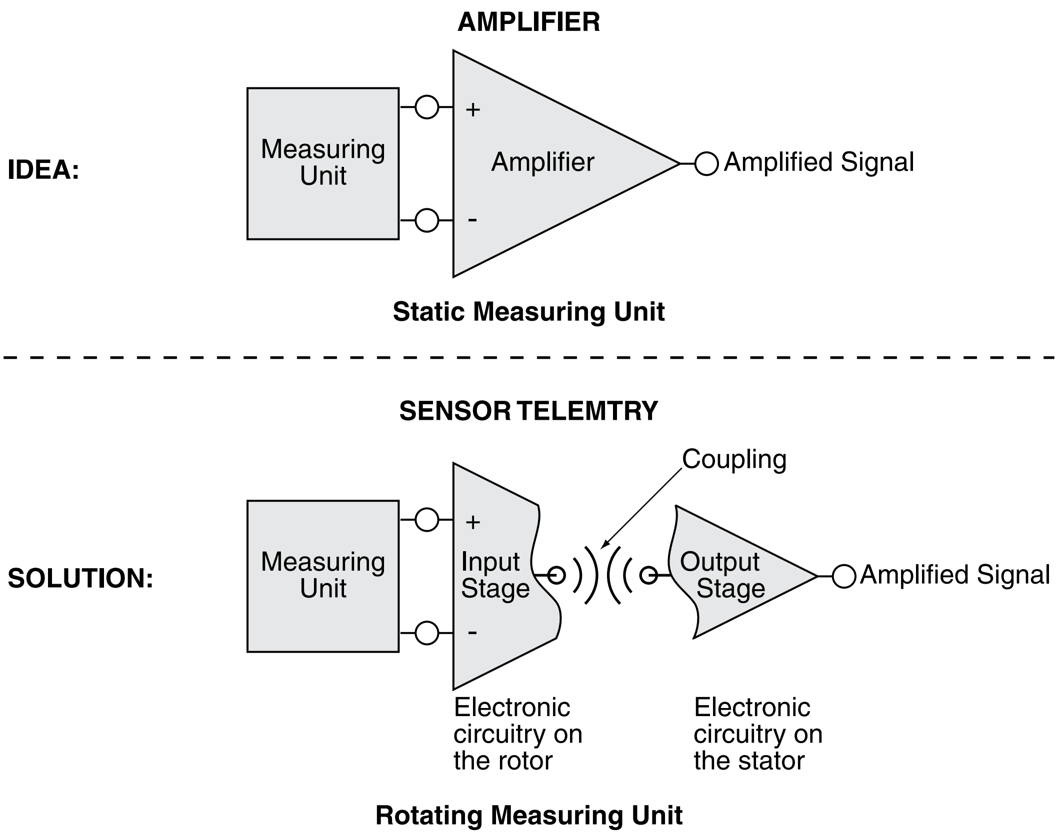



*Figure 5–1 Telemetry Principle Applied to TF Torque Flange Sensors*

## 5.2 SIGNAL TRANSMISSION

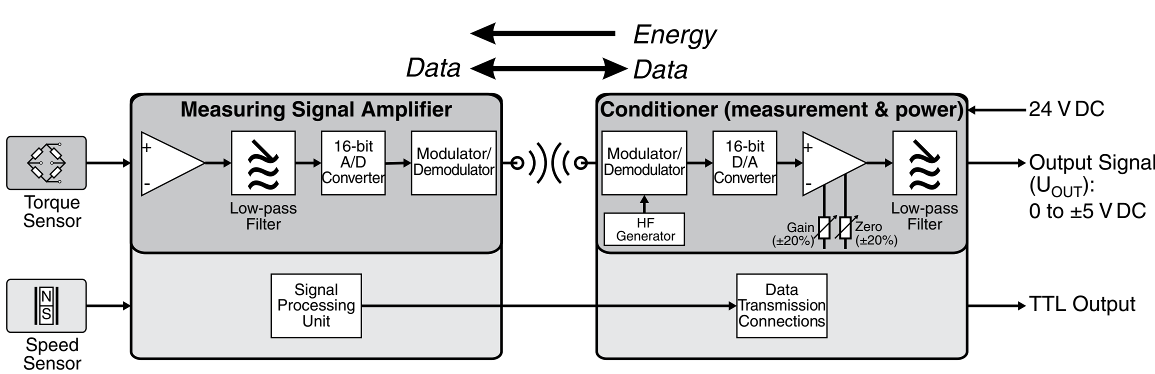



*Figure 5–2 Signal Transmission Block Diagram*

### 5.2.1 Measuring Flange to Conditioner

The torque signal is generated by strain gauges in a full-bridge configuration that are glued onto the inside of the measuring flange. This system has proven its efficiency and reliability over many decades with high measurement accuracy.

The signal delivered by the measuring flange is first amplified, and then sent to a low-pass filter before being digitalized with 16-bit resolution. Afterwards, the signal is modulated for transmission on an HF carrier wave (13.56 MHz). All this is carried out in the electronic module located inside the rotor. The measured signal is then transmitted by induction to the HF transmitter and finally demodulated by the conditioner.

### 5.2.2 Conditioner to Measuring Flange

A similar procedure is also used on the conditioner side which transmits the supply voltage (24 V) as well as the remote calibration signal to the rotor.

### 5.2.3 Speed Sensor to Speed Conditioner

Using the magnetoresistor principle, the (optional) speed sensor delivers a signal to the speed conditioner with a frequency proportional to the rotational speed.

# 6. Troubleshooting / Maintenance

## 6.1 DISMOUNTING THE MEASURING FLANGE

When dismounting the measuring flange from the drive train, make sure that all mounting screws are removed including those which are not visible from outside.

CAUTION: NEVER USE THE MEASURING FLANGE FOR LEVERAGE WHEN DISMOUNTING THE SENSOR.

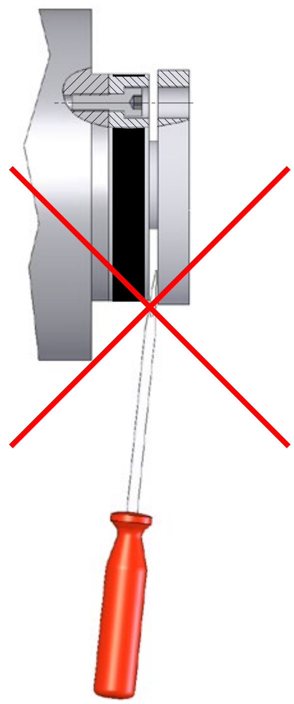


*Figure 6–1 Improper Dismounting*

## 6.2 LED INDICATORS

| LED Color | If NOT illuminated | Recommendation |
|---|---|---|
| Yellow | Power supply problem. | Check conditioner power supply:<br>TF 309 – TF 312<br>TF 213 – TF 217: 24 V DC (stabilized) 350 mA min.<br>TF 218 –TF 220: 220 V AC |
| | The conditioner is defect. | Return conditioner to Magtrol. |
| Red | HF transmitter power supply problem. | Check conditioner power supply, HF transmitter connectors and cable. |
| | HF transmitter is defect. | Return HF transmitter to Magtrol. |
| Green | Signal transmission problem. | Check HF transmitter (see *Section 2.3 – HF Transmitter Mounting*). |
| | Measuring flange is defect. | Return entire torque flange sensor (with its conditioner and HF transmitter) to Magtrol. |

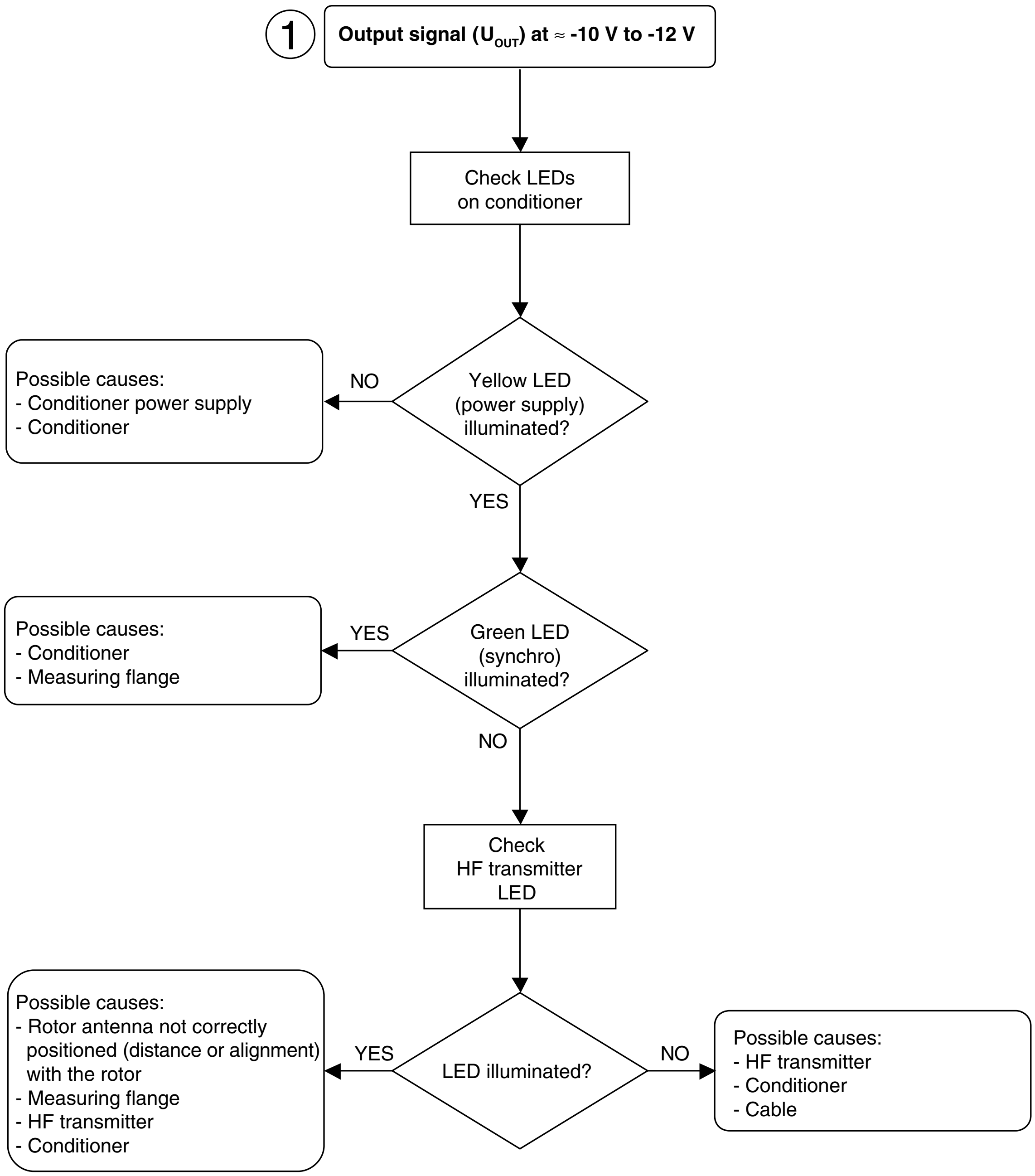
## 6.3 TROUBLESHOOTING

The following problems may occur with TF Series Torque Flange Sensors:

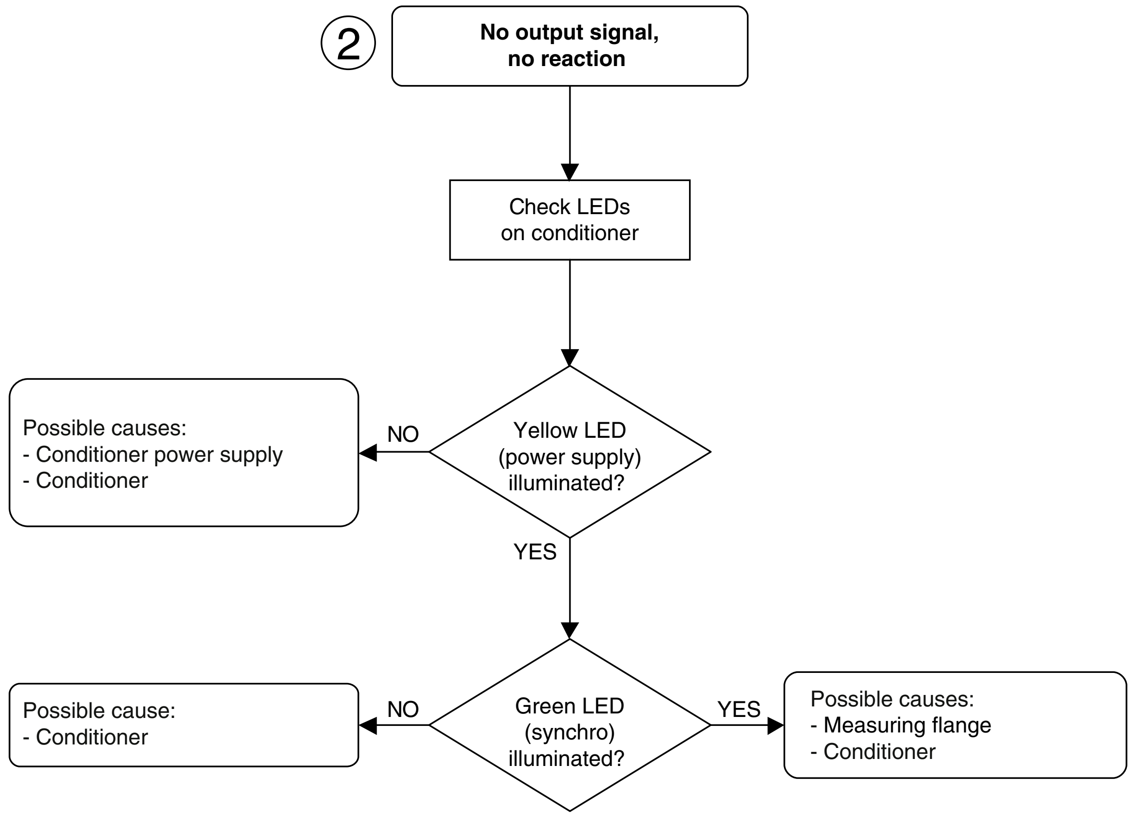
1. Output signal ($U_{out}$) remains between -10 V and -12 V
2. No output signal / no reaction
3. Signal is at ¾ of its nominal value (calibration value) when the measuring flange is unloaded, or the signal varies according to the load.
4. Unstable signal
5. "0" offset (signal behaves normally)

The possible causes of these problems are shown in the following flowcharts.

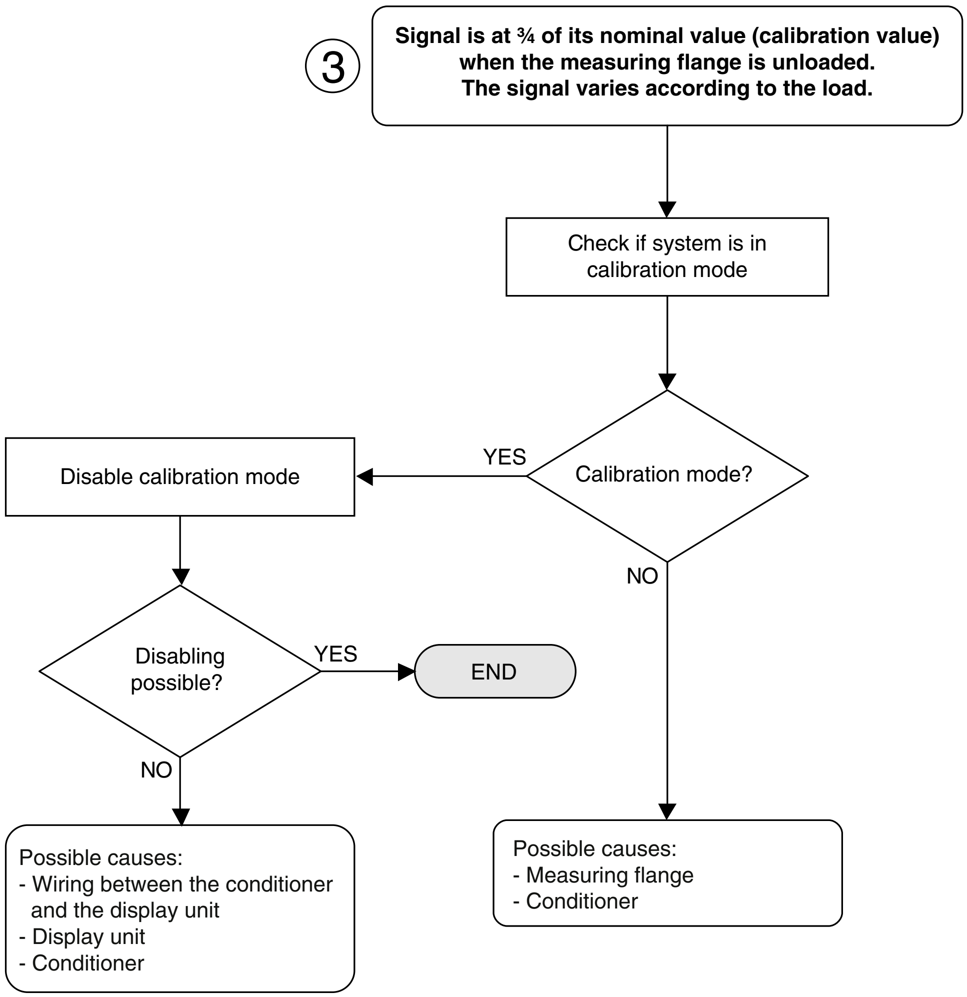
### 6.3.1 Output Signal Remains Between -10 V and -12 V



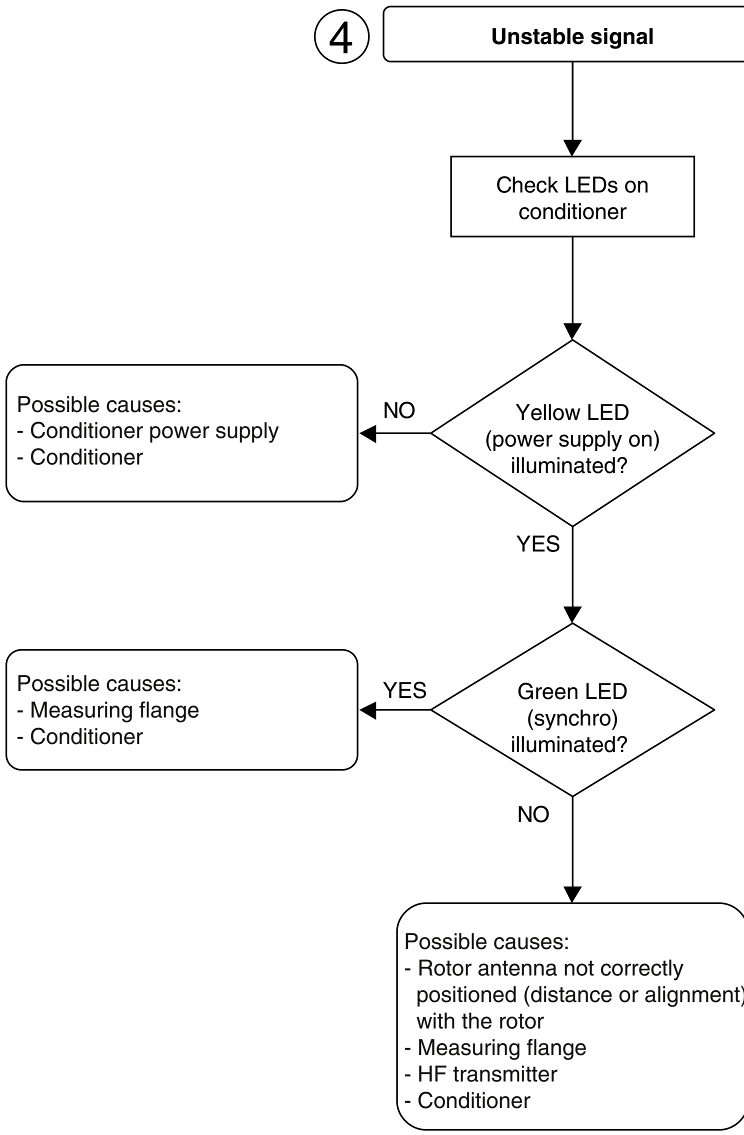
### 6.3.2 No Output Signal / No Reaction



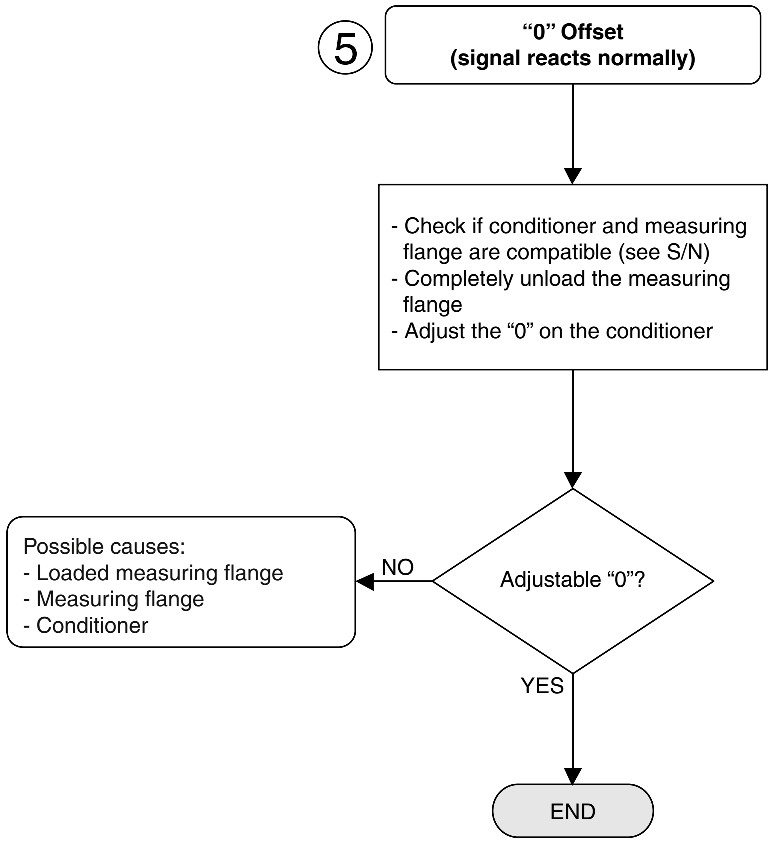
### 6.3.3 Signal at ¾ of its Nominal Value When Unloaded



### 6.3.4 Unstable Signal



### 6.3.5 "0" Offset with Normal Signal




☞ Note: If you require additional assistance, please contact Magtrol Customer Service.

## 6.4 REPAIR

In case of a defect, please refer to both the *Warranty* and *Service Information* located in the back of this manual.

CAUTION: MAINTENANCE MUST BE PERFORMED BY MAGTROL IN ORDER TO GUARANTEE FUTURE MEASURING ACCURACY.

### 6.4.1 DEFECT REPORT

To allow Magtrol to complete the work in the best possible time, it is imperative that the following information be documented and included with your return shipment:

- Model number, part number (P/N), serial number (S/N), order number and date of purchase
- Description of the defect and the conditions in which it appeared
- Description of the test bench (drawing, photographs, sketches, etc.)
- Description of the tested object (drawing, photographs, sketches, etc.)
- Description of the test cycle

### 6.4.2 RETURNING TO MAGTROL

1. Carefully pack the complete TF Torque Flange Sensor kit (including HF transmitter, conditioner and cable).
2. Include the defect report, as described in *Section 6.4.1*.
3. Follow the procedure outlined in the back of this manual under *Service Information – Returning Equipment to Magtrol SA (Switzerland).*

# Magtrol Limited Warranty

Magtrol, Inc. warrants its products to be free from defects in material and workmanship under normal use and service for a period of twenty-four (24) months from the date of shipment. Software is warranted to operate in accordance with its programmed instructions on appropriate Magtrol instruments. This warranty extends only to the original purchaser and shall not apply to fuses, computer media, or any other product which, in Magtrol's sole opinion, has been subject to misuse, alteration, abuse or abnormal conditions of operation or shipping.

Magtrol's obligation under this warranty is limited to repair or replacement of a product which is returned to the factory within the warranty period and is determined, upon examination by Magtrol, to be defective. If Magtrol determines that the defect or malfunction has been caused by misuse, alteration, abuse or abnormal conditions of operation or shipping, Magtrol will repair the product and bill the purchaser for the reasonable cost of repair. If the product is not covered by this warranty, Magtrol will, if requested by purchaser, submit an estimate of the repair costs before work is started.

To obtain repair service under this warranty, purchaser must forward the product (transportation prepaid) and a description of the malfunction to the factory. The instrument shall be repaired at the factory and returned to purchaser, transportation prepaid. **MAGTROL ASSUMES NO RISK FOR IN-TRANSIT DAMAGE.**

THE FOREGOING WARRANTY IS PURCHASER'S SOLE AND EXCLUSIVE REMEDY AND IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED OR IMPLIED, INCLUDING BUT NOT LIMITED TO ANY IMPLIED WARRANTY OF MERCHANTABILITY, OR FITNESS FOR ANY PARTICULAR PURPOSE OR USE. MAGTROL SHALL NOT BE LIABLE FOR ANY SPECIAL, INDIRECT, INCIDENTAL, OR CONSEQUENTIAL DAMAGES OR LOSS WHETHER IN CONTRACT, TORT, OR OTHERWISE.

## CLAIMS

Immediately upon arrival, purchaser shall check the packing container against the enclosed packing list and shall, within thirty (30) days of arrival, give Magtrol notice of shortages or any nonconformity with the terms of the order. If purchaser fails to give notice, the delivery shall be deemed to conform with the terms of the order.

The purchaser assumes all risk of loss or damage to products upon delivery by Magtrol to the carrier. If a product is damaged in transit, PURCHASER MUST FILE ALL CLAIMS FOR DAMAGE WITH THE CARRIER to obtain compensation. Upon request by purchaser, Magtrol will submit an estimate of the cost to repair shipment damage.

DSPM Industria®
sensori & trasduttori

Via Paolo Uccello 4 - 20148 Milano
Tel +39 02 48 009 757 Fax +39 02 48 002 070 info@dspmindustria.it www.dspmindustria.it