*F/T* **Transducer**

# Six-Axis
# Force/Torque Transducer

## Installation and Operation Manual

Document # 9620-05-Transducer Section
June 2014

***Engineered Products for Robotic Productivity***
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# Forward

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## FCC Compliance - Class A

This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

## CE Conformity CE

### CTL Transducers

This device complies with EMC Directive 89/336/EEC and conforms to the following standards: EN50081-1:1992, EN50082-1:1992, CISPR 22:1993 (EN55022:1994), IEC 1000-4-2:1995, IEC 1000-4-3:1995, IEC 1000-4-4:1995

### DAQ Transducers

This device complies with EMC Directive 89/336/EEC and conforms to the following standards: EN55011:1998, ANSI C63.4:1992, EN61000-4-2:1995, EN61000-4-3:1995, EN61000-4-4:1995, EN61000-4-6:1995.

### Net F/T Transducers

This device complies with EMC Directive 2004/108/EC and conforms to the following standards: EN61326:1997+A1:1998+A2:2000,EN55022:1998_A1:2000+A2:2003, EN61000-4-2:1995+A1:1998+A2:2001, EN61000-4-3:2000, EN61000-4-4:2004, EN610000-4-5:1995+A1:1996, EN61000-4-6:1996+A1:2001, EN61000-4-8:1995, EN61000-4-11:2001.

### TWE Transducers

This device complies with EMC Directive 89/336/EEC and conforms to the following standards: EN50081-1:1992, EN50082-1:1992, CISPR 22:1993 (EN55022:1994), IEC 1000-4-2:1995, IEC 1000-4-3:1995, IEC 1000-4-4:1995

***Aside***

Please read the manual before calling customer service. Before calling, have the following information available:

1. Serial number (e.g., FT01234)
2. Transducer model (e.g., Nano17, Gamma, Theta, etc.)
3. Calibration (e.g., US-15-50/S, SI-65-6/S, etc.)
4. Accurate and complete description of the question or problem
5. Computer and software information. Operating system, PC type, drivers, application software and other relevant information about your configuration.

If possible, have access to the F/T system when calling.

## How to Reach Us

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# Table of Contents

# Glossary of Terms

| Terms | Conditions |
|---|---|
| Accuracy | See *Measurement Uncertainty*. |
| Compound Loading | Any load that is not purely in one axis. |
| CTL | Denotes transducers and systems that use the F/T Controller interface. |
| DAQ | Denotes transducers and systems that use the data acquisition interface. |
| FS | **F**ull-**S**cale. |
| F/T | **F**orce and **T**orque. |
| Fxy | The resultant force vector comprised of components Fx and Fy. |
| Hysteresis | A source of measurement caused by the residual effects of previously applied loads. |
| IFPS | **I**nter**F**ace/**P**ower **S**upply box. |
| IP60 | Ingress Protection rating 60 designates protection against dust. |
| IP65 | Ingress Protection rating 65 designates protection against water spray. |
| IP68 | Ingress Protection rating 68 designates submergibility in fresh water, in this case to a depth of 10 meters. |
| LabVIEW | A graphical programming environment created for data acquisition tasks by National Instruments. |
| Maximum Single-Axis Overload | The largest amount of pure load (not compound loading) that the transducer can withstand without damage. |
| MAP | **M**ounting **A**dapter **P**late. The transducer plate that attaches to the fixed surface or robot arm. |
| Measurement Uncertainty | The maximum expected error in measurements, as specified on the calibration certificate. |
| Mux Box | The component that contains transducer electronics for transducers that are too small to house them. |
| NI | **N**ational **I**nstruments Corporation, the owner of the *National Instruments* and *LabVIEW* trademarks. (www.ni.com) |
| Overload | The condition where more load is applied to the transducer than it can measure. This will result in saturation. |
| PC Card | A small computer card for use in most laptop computers. |
| PCMCIA Card | See *PC Card*. (*PCMCIA* has been renamed *PC Card* by its standards organization). |
| Point of Origin | The point on the transducer from which all forces and torques are measured. |
| PS | **P**ower **S**upply box. |
| Quantization | The process of converting a continuously variable transducer signal into discrete digital values. Usually used when describing the change from one digital value to the next. |
| Resolution | The smallest change in load that can be measured. This is usually much smaller than accuracy. |
| Saturation | The condition where the transducer or data acquisition hardware has a load or signal outside of its sensing range. |
| Sensor System | The entire assembly consisting of parts from transducer to controller. |
| TAP | **T**ool **A**dapter **P**late. The transducer surface that attaches to the load to be measured. |
| TWE | Denotes transducers that require user-amplification and data acquisition. |
| Tool Transformation | A method of mathematically shifting the measurement coordinate system resulting in a translated origin and/or rotated axes. |
| Transducer | The component that converts the sensed load into electrical signals. |
| Txy | The resultant torque vector comprised of components Tx and Ty. |
| Visual Basic | A Microsoft programming environment for developing Windows®-based applications. |

# 1. Safety

## 1.1 General

The customer should verify that the transducer selected is rated for the maximum loads and moments expected during operation. Refer to transducer specifications in *Section 4—Transducer Specifications* of this manual or contact ATI for assistance. Particular attention should be paid to dynamic loads caused by robot acceleration and deceleration. These forces can be many times the value of static forces in high acceleration or deceleration situations.

## 1.2 Explanation of Warnings

The warnings included here are specific to the product(s) covered by this manual. It is expected that the user heed all warnings from the robot manufacturer and/or the manufacturers of other components used in the installation.

**DANGER:** Notification of information or instructions that if not followed will result in death or serious injury. The notification provides information about the nature of the hazardous situation, the consequences of not avoiding the hazard, and the method for avoiding the situation.

**WARNING:** Notification of information or instructions that if not followed could result in death or serious injury. The notification provides information about the nature of the hazardous situation, the consequences of not avoiding the hazard, and the method for avoiding the situation.

**CAUTION:** Notification of information or instructions that if not followed could result in moderate injury or will cause damage to equipment. The notification provides information about the nature of the hazardous situation, the consequences of not avoiding the hazard, and the method for avoiding the situation.

**ATTENTION, NOTE, or NOTICE:** Notification of specific information or instructions about maintaining, operating, installation, or setup of the product that if not followed could result in damage to equipment. The notification can emphasize but is not limited to specific grease types, good operating practices, or maintenance tips.

## 1.3 Precautions

**DANGER:** Do not attempt to disassemble the transducer. This will damage the instrumentation.

**DANGER:** Do not probe any openings in the transducer. This will damage the instrumentation.

**DANGER:** Take care to prevent excessive forces or moments from being applied to the transducer during handling or installation. The small Nano series is easily overloaded during rough handling and may be damaged.

# 2. Installing the Transducer

This section will provide information on the environment, transducer IP rating, mounting the transducer, and routing the transducer cable.

## 2.1 Transducer Environment

To ensure proper operation, the IP rating of the transducer must match or exceed the transducer's environment. Unless otherwise specified, a transducer has no special IP protection. In this case, the transducer may be used only in benign environments with no dust, debris, liquids, or sprays. Refer to the *Accuracy over Temperature Section* of the *F/T Transducer Installation and Operation Manual (9620-05-Transducer Section)* for information on the transducer's temperature performance.

**CAUTION:** Damage to the outer jacketing of the transducer cable could enable moisture or water to enter an otherwise sealed transducer. Ensure the cable jacketing is in good condition to prevent transducer damage.

**NOTICE:** Transducers may react to exceptionally strong and changing electro-magnetic fields, such as those produced by magnetic resonance (MRI) imaging machines.

**NOTICE:** Transducers without an IP protection may exhibit a small offset in readings when exposed to strong light.

## 2.2 Mounting the Transducer

There are two different mounting methods for transducers. The first method has a fixed bolt pattern on the tool side of the transducer and a removable adapter plate on the mounting (robot or other device) side. The adapter plate needs to be removed from the transducer and machined with the mounting bolt pattern to match the robot or other device. If your device covers the mounting fasteners used to connect the transducer, you will not be able to use the removable adapter plate alone. If this is the case a user designed interface plate will be needed between the transducer and the robot or other device. Refer to *Section 2.2.1—Interface Plate Design* for more details. Refer to *Section 2.2.2—Mounting the Transducer with a Removable Mounting Adapter Plate.*

The second method is for transducers with non-removable adapter plates with fixed bolt patterns on both the tool and mounting sides of the transducer (Nano, Mini, IP-rated and some Omega transducers). This type may require a user designed interface plate to attach the transducer to the robot or other device. Refer to *Section 2.2.1—Interface Plate Design* for more details. Refer to *Section 2.2.3—Mounting the Transducer with a Non-removable Adapter Plate.*

**CAUTION:** Do not remove any fasteners or disassemble transducers without a removable adapter plate, these include Nano, Mini, IP-rated, and some Omega transducers. This will cause irreparable damage to the transducer and **void the warranty**. Leave all fasteners in place and do not disassemble the transducer.

Refer to the product drawings in *Section 4—Transducer Specifications* to determine if the adapter plate is removable for our transducer. Mount the transducer to a structure with sufficient mechanical strength. Not doing so can lead to sub-optimum performance.

### 2.2.1 Interface Plate Design

Interface plates may be required between the robot or other device and the transducer and between the transducer and the tooling. If the robot, other device, or tooling covers the mounting fasteners for the transducer an interface plate will be required. Custom interface plates are available from ATI upon request.

There are two types of mounting adapter plate (robot side). Small transducers such as Nano, Mini, IP-rated and some Omega transducers the mounting adapter plate is factory installed and should not be removed or machined. The mounting interface plate will have to be machined with the corresponding bolt pattern and dowel locations, refer to the drawings in *Section 4—Transducer Specifications*.

Larger transducers have a removable mounting adapter plates, refer to *Section 2.2.2—Mounting the Transducer with a Removable Mounting Adapter Plate* for more information. Machine the mounting interface plate to match the bolt pattern and dowel hole in the removable mounting adapter plate.

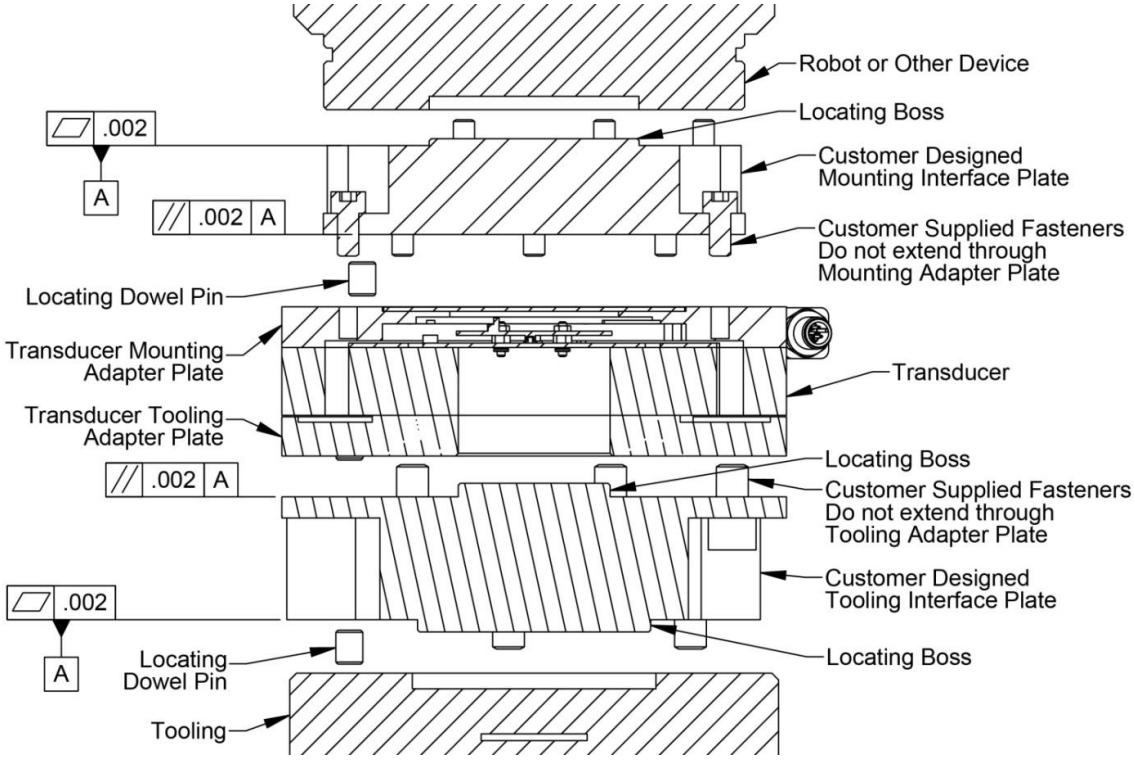
The transducer tooling adapter plate is factory-installed and the bolt circle is shown with the transducer in *Section 4—Transducer Specifications*. Most large F/T tool adapters follow the ISO 9409-1 mounting pattern. Machine the tooling interface plate to attach to this bolt circle.

**CAUTION:** Your tool may only touch the tool adapter plate. If your tool touches any other part of the transducer, it will not properly sense loads.

If the customer chooses to design and build an mounting or tooling interface plate, the following should be considered:

- The interface plate should be designed to include bolt holes for mounting, dowel pins, and a boss for accurate positioning on the robot or other devices and to the adapter plate. These locating features should orient the X and Y axis of the Transducer to the X and Y axis of the robot.
- The thickness of the interface plate must be great enough to provide the necessary thread engagement for the mounting fasteners.
- Mounting fasteners must not be too long. They should not extend through the adapter plate to avoid interference with the electronics inside the transducer. Refer to *Section 4—Transducer Specifications* for thread depth, mounting patterns, and other details.
- The interface plate must be properly designed to provide rigid mounting for the transducer. The interface plate should not distort under maximum sensor range of the transducer. Refer to *Section 4—Transducer Specifications* for specifications.
- The interface plate design must provide a flat and parallel mounting surface for the transducer. Refer to *Figure 2.1*.

**Figure 2.1—Interface Plate Design Specification**



### 2.2.2 Mounting the Transducer with a Removable Mounting Adapter Plate

Check to see if when mounting the transducer to the robot or other device you will have access to the mounting screws for attaching the transducer. If not, a user designed interface plate will be needed on one or both sides of the transducer, refer to *Section 2.2.1—Interface Plate Design* for details in designing an interface plate before continuing with this procedure.

Remove the power to the transducer.

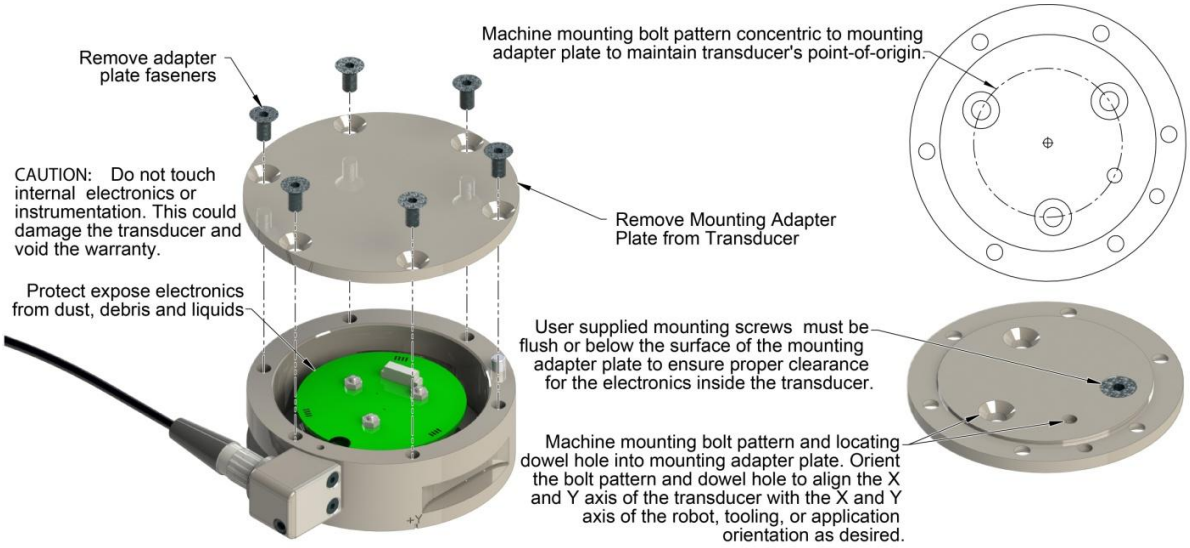
Remove all mounting fasteners from the mounting adapter plate and set aside.

> **CAUTION:** Do not touch internal electronics or instrumentation. This could damage the transducer and void the warranty. When the adapter plate is removed protect the exposed electronics from dust, debris, liquids, and other foreign objects.

Remove the adapter plate from the transducer. Machine the mounting bolt pattern from the robot, interface plate, or other device into the removable adapter plate. Make sure the bolt pattern and dowel hole orient the X and Y axis of the transducer with the X and Y axis of the robot.

> **CAUTION:** Mounting fasteners should not extend into the transducer beyond the adapter plate surface. This could cause damage to the internal electronics. When machining the removable adapter plate, make sure the heads of the fasteners are flush or below the surface of the

**Figure 2.2—Removable Adapter Plate**




If the customer supplied interface plate is required, mount the interface plate to the robot or other device. Note: Use fasteners with pre-applied adhesive or apply Loctite® to the mounting fasteners.

Mount removable adapter plate to the robot, other device, or interface plate using customer supplied fasteners. If fasteners do not have pre-applied adhesive, apply Loctite® to the fasteners. **Note**: Make sure the adapter plate orients the transducer so that the connector is at the appropriate location to route the cabling properly. Refer to *Section 2.3—Routing the Transducer Cable.*

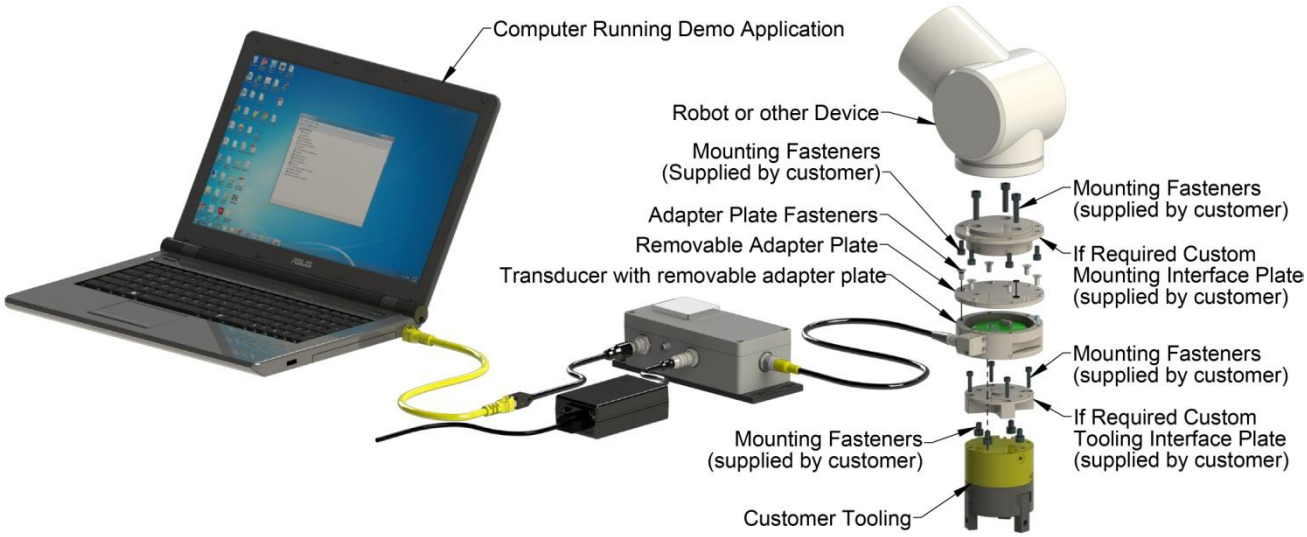
Attach the transducer to the removable adapter plate, hand tighten fasteners.

Connect power to the transducer and wait until demo application displays load data when applying force on the transducer.

**CAUTION:** Do not exceed the transducer's overload ratings. Smaller transducers can easily be irreparably damaged by apply small loads using tools (moment arm increases applied loads) when mounting the transducer. Always monitor the transducer using the demo application for gage saturation errors during installation. Stop applying force to the transducer and wait until the error clears to continue installation. If error does not clear, it may indicate loss of power or the overload value has been exceeded.

Tighten the fasteners mounting the transducer to the removable adapter plate. Monitor the demo application for gage saturation errors. If an error is displayed stop applying the force to the transducer and wait until the error clears before continuing installation.

**Figure 2.3—Monitor Load during Installation (Net F/T System Shown)**




**CAUTION:** Do not use fasteners that will exceed the customer interface depth specified on for the transducer. Using longer fasteners will penetrate the body of the transducer and damage the electronics, voiding the warranty. Use fasteners that provide the customer interface depth specified for the transducer. Refer to the transducer drawing.

**NOTICE:** The tool may not touch any other part of the transducer except the tool mounting surface. If the tool touches any other part of the transducer it will not properly sense loads. Make sure the tool mounts to the tool mounting surface and does not touch any other part of the transducer.

If the customer supplied tooling interface plate is required, mount the interface plate to the tooling. Note: Use fasteners with pre-applied adhesive or apply Loctite® to the mounting fasteners.

Attach the customer tooling or tooling interface plate to the transducer with customer supplied fasteners, the transducer provides a mounting pattern on the tool side of the transducer. If fasteners do not have pre-applied adhesive, apply Loctite® to the fasteners. Monitor the demo application for gage saturation errors. If an error is displayed stop applying the force to the transducer and wait until the error clears before continuing installation.

### 2.2.3 Mounting the Transducer with a Non-removable Adapter Plate

**CAUTION:** Do not attempt to drill, tap, machine, or otherwise modify or disassemble the transducer. This could damage the transducer and will void the warranty. Use the mounting bolt pattern provided to attach the transducer to the robot or other device and to mount the tool to the transducer. See the transducer drawings for details.

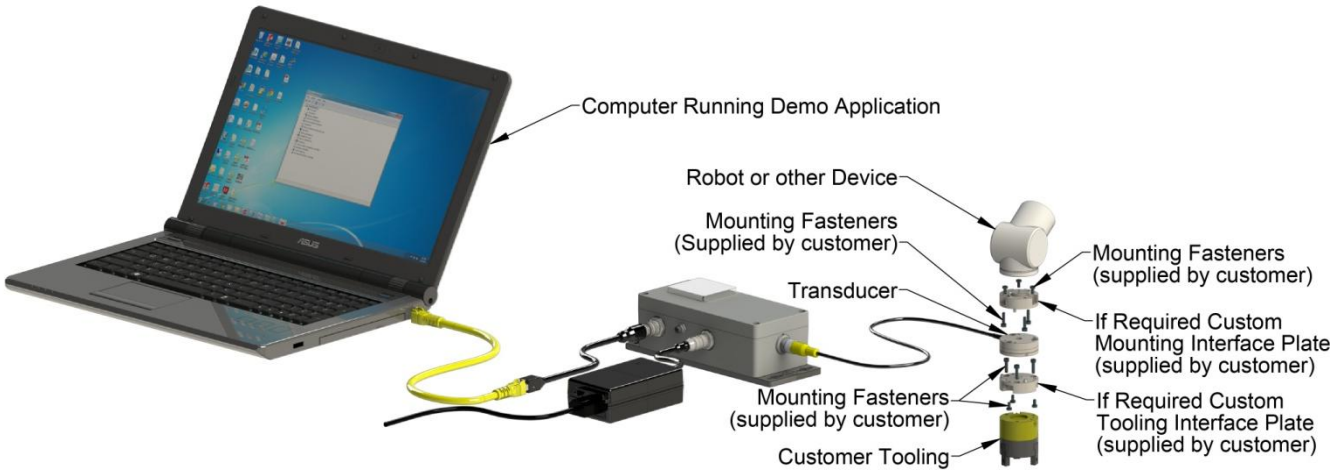
**CAUTION:** Do not use fasteners that will exceed the customer interface depth specified on for the transducer. Using longer fasteners will penetrate the body of the transducer and damage the electronics, voiding the warranty. Use fasteners that provide the customer interface depth specified for the transducer. Refer to the transducer drawing.

**CAUTION:** Do not exceed the single-axis overload value of the transducer. Smaller transducers can easily be irreparably damaged by apply small loads using tools (moment arm increases applied loads) when mounting the transducer. Always monitor the transducer using the demo application for gage saturation errors during installation. Stop applying force to the transducer and wait until the error clears to continue installation. If error does not clear, it may indicate loss of power or the overload value has

If the customer supplied interface plate is required, mount the interface plate to the robot or other device. Note: Use fasteners with pre-applied adhesive or apply Loctite® to the mounting fasteners.

Mount transducer to user-designed interface plate, directly to the robot, or other device with customer supplied fasteners. If fasteners do not have pre-applied adhesive, apply Loctite 222® to the fasteners. Monitor the demo application for gage saturation errors. If an error is displayed stop applying the force to the transducer and wait until the error clears before continuing installation.

**Figure 2.4— Monitor Load during Installation (Net F/T System Shown)**




**NOTICE:** The tool may not touch any other part of the transducer except the tool mounting surface. If the tool touches any other part of the transducer it will not properly sense loads. Make sure the tool mounts to the tool mounting surface and does not touch any other part of the transducer.

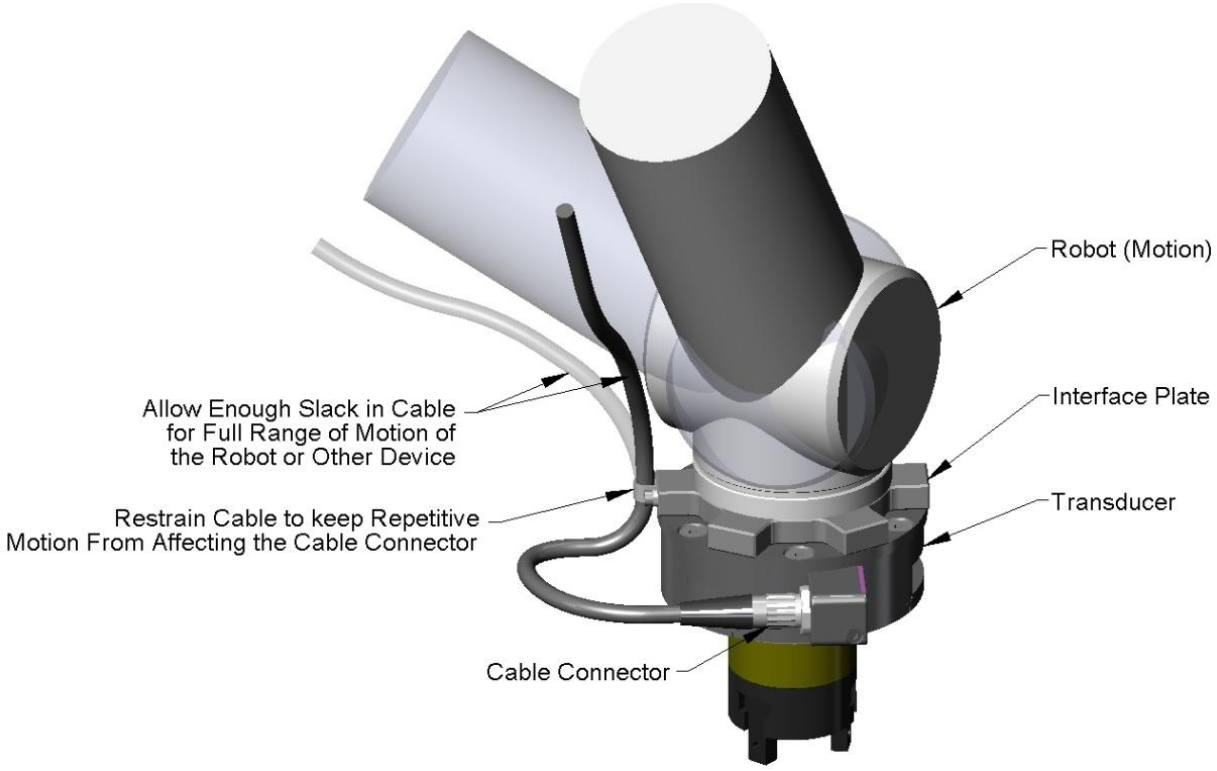
If the customer-supplied tooling interface plate is required, mount the interface plate to the tooling. Note: Use fasteners with pre-applied adhesive or apply Loctite® to the mounting fasteners.

Attach the customer tooling or tooling interface plate to the transducer with customer supplied fasteners, the transducer provides a mounting pattern on the tool side of the transducer. If fasteners do not have pre-applied adhesive, apply Loctite® to the fasteners. Monitor the demo application for gage saturation errors. If an error is displayed stop applying the force to the transducer and wait until the error clears before continuing installation.

## 2.3 Routing the Transducer Cable

The transducer can be used in a variety of applications that will affect how best to route the cable and determine the proper bending radius to use. Some applications will allow the transducer and the cable to remain in a static condition. Some applications require the transducer to be in a dynamic condition that requires the cable to be subjected to repetitive motion. It is important not to expose the transducer cable connectors to this repetitive motion, and properly restrain the cable close to the transducer connection.

**Figure 2.5**—Restrain Transducer Cable Close to Cable Connector

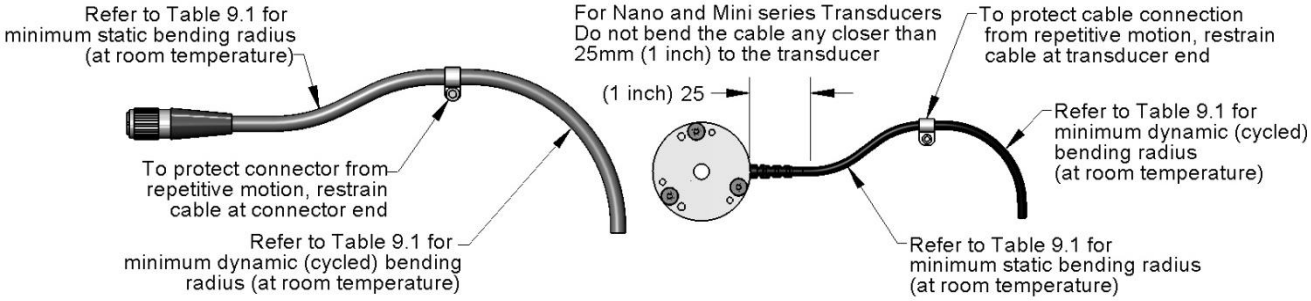



**CAUTION:** Do not subject the transducer cable connector to the repetitive motion of the robot or other device. Subjecting the connector to the repetitive motion will cause damage to the connector. Restrain the cable close to the connector to keep the repetitive motion of the robot from affecting the cable connector.

**CAUTION:** When routing cables do not bend less than the minimum bending radius required, refer to *Table 9.1* for minimum bending radius. The cable will fail due to fatigue from the repetitive motion. Make sure when routing the cable that the minimum dynamic bending radius is exceeded.

**CAUTION:** Do not stress or over bend the transducer cable, especially where it is attached to the transducer. This is particularly important on the Nano and Mini series of transducers. For these transducers, do not bend the cable any closer than 25mm (1 inch) to the transducer. Sharp bends must be avoided as they can damage the cable and transducer and will void the warranty.

**Figure 2.6—Transducer Cable Bending Radius**




| Table 9.1—Transducer Cable Bending Radius | | | | | |
|---|---|---|---|---|---|
| **Cable Type** | **Cable Dia. (mm)** | **Static Bending Radius (at room temperature)** | | **Dynamic Bending Radius (at room temperature)** | |
| | | **mm** | **inch** | **mm** | **inch** |
| 9105-TW | 3.2 | 16 | 0.63 | 32 | 1.26 |
| 9105-C3 | 4.4 | 22 | 0.87 | 44 | 1.73 |
| 9105-CM | 4.4 | 22 | 0.87 | 44 | 1.73 |
| 9105-CW | 4.4 | 22 | 0.87 | 44 | 1.73 |
| 9105-CT | 6.1 | 30.5 | 1.20 | 61 | 2.40 |
| 9105-C | 3.2 | 16 | 0.63 | 32 | 1.26 |
| | 4.4 | 22 | 0.87 | 44 | 1.73 |
| | 6.1 | 30.5 | 1.20 | 61 | 2.40 |
| | 10.0 | 50 | 1.97 | 100 | 3.94 |
| 9105-C-MTR | 8.4 | 42 | 1.65 | 84 | 3.31 |
| 9105-C-MTS | 8.4 | 42 | 1.65 | 84 | 3.31 |
| 9105-CF-MTR 9105-CF-MTS | 8.5 | 42.5 | 1.67 | 85 | 3.35 |
| **Note:** Temperature will affect cable flexibility, ATI recommends increasing the minimum dynamic bending radius for lower temperatures. | | | | | |

The transducer cable must be routed so that it is not stressed, pulled, kinked, cut, or otherwise damaged throughout the full range of motion. See the accompanying system manual for the transducer cable interfacing. If the desired application results in the cable rubbing, then use a **loose** plastic spiral wrap for protection.

**CAUTION:** Be careful not to crush the cable by over tightening tie wraps or walking on the cable, since this may damage the cable.

**CAUTION:** Cables on the Nano and Mini transducers are permanently attached to the transducer and cannot be disconnected. Do not attempt to disassemble these transducers, this will damage the transducer and void the warranty. Do not attempt to replace the cable. Contact ATI service for assistance.

**CAUTION:** Nano and Mini integral cables and cables of the 9105-C-H type must not subject the transducer end connection to more than 10 lbf (45 N) of side-to-side or pull force or permanent damage will result.

**CAUTION:** Larger transducers have removable cables. Do not attempt to disconnect these transducer cables by pulling on the cable itself or the connector boot; this can damage your system.

# 3. Topics

## 3.1 Accuracy over Temperature

Typical gain errors introduced over temperature for F/T transducers with hardware temperature compensation are listed below. These changes in sensitivity are independent of the transducer's rated accuracy at room temperature; the two accuracy ratings must be added to find an overall estimated accuracy at a certain temperature. This overall accuracy assumes that the unloaded and loaded measurements were taken at the same temperature. Drift error over temperature is not compensated and varies with each transducer. For best results, a reference reading should be taken or bias function executed at the current temperature before applying the load of interest.

**Table 3.1—Error Introduced Over Temperature for Non-Gamma Transducers**

| Deviation from 22°C | Typical Gain Error |
|---|---|
| ± 5°C | 0.1% |
| ± 15°C | 0.5% |
| ± 25°C* | 1% |
| ± 50°C* | 5% |

*Note: Deviation is bounded by transducer operational limits in Table 3.3.

**Table 3.2—Error Introduced Over Temperature for Gamma Transducers**

| Deviation from 22°C | Typical Gain Error |
|---|---|
| ± 5°C | 0.1% |
| ± 15°C | 0.5% |
| ± 25°C* | 1.5% |
| ± 50°C* | 7% |

*Note: Deviation is bounded by transducer operational limits in Table 3.3.

## 3.2 Tool Transformation Effects

All transducer working specifications pertain to the factory point-of-origin only. This includes the transducer's range, resolution, and accuracy. The transducer working specifications at a customer-applied point-of-origin will differ from those at the factory point-of-origin.

## 3.3 Environmental

The F/T system is designed to be used in standard laboratory or light-manufacturing conditions. Transducers with an IP60 designation are able to withstand dusty environments, those with an IP65 designation are able to withstand dusty environments and wash down, and those with an IP68 designation are able to withstand dusty environments and fresh-water immersion to a specified depth. Transducers without IP65 or IP68 designation may be used in environments with up to 95% relative humidity, non-condensing.

**Table 3.3—Transducer Temperature Ranges**

| Transducer Model Series | Storage | Operation | Units |
|---|---|---|---|
| 9105-TIF Transducer | -25 to +85 | -25 to +85 | °C |
| 9105-TW Transducer | -40 to +100 | -40 to +100 | °C |
| 9105-TW-…-H Transducer | -25 to +85 | -25 to +85 | °C |
| 9105-T Transducer | -20 to +80 | 0 to +70 | °C |
| 9105-NET Transducer | -40 to +85 | -40 to +85 | °C |

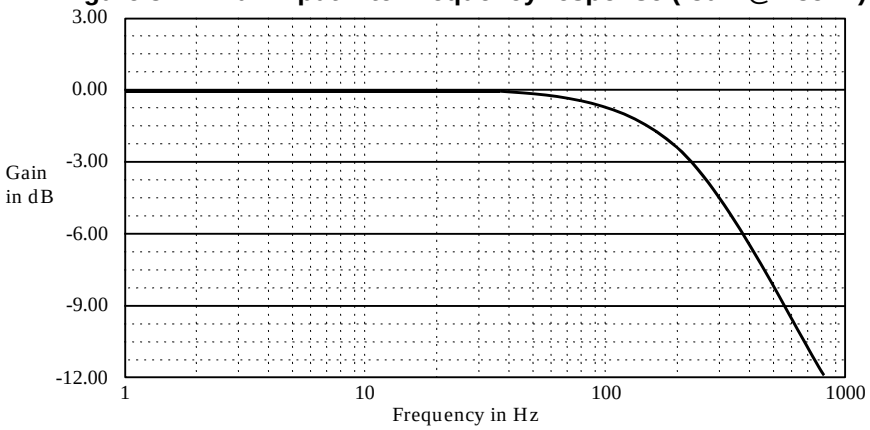
**Note:** These temperature ranges specify the storage and operation ranges in which the transducer can survive without damage. They do not take accuracy into account.

## 3.4 Mux Transducer Input Filter Frequency Response

Note: Mux transducers are only used in 9105-CTL, 9105-CON, and 9105-CTE systems.

The input filter used in 9105-T transducers and in the Mux box is used to prevent aliasing. This filtering is not used in 9105-TIF (DAQ) or our TWE transducers.

**Figure 3.1—Mux input filter frequency response (-3dB @ 235Hz)**



### 3.5 Transducer Strain Gage Saturation

The F/T sensor's strain gages are optimally placed to share information between the forces and torques applied to the sensor. Because of this sharing, it is possible to saturate the transducer with a complex load that has components below the rated load of the sensor. However, this arrangement allows a greater sensing range and resolution.

> **CAUTION:** When any strain gage is saturated or otherwise inoperable, **all transducer F/T readings are invalid.** Therefore, it is vitally important to monitor for these conditions.

## 4. Transducer Specifications

### 4.1 Notes

#### 4.1.1 About CTL Calibration Specifications

*CTL* refers to F/T systems that use the F/T Controller. Transducers used in these systems either have a 9105-T-*x* model transducer or include a Mux Box. The output resolution of CTL systems is different from other systems. CTL systems also provide analog voltage outputs that represent each of the six axes. CTL transducers have their own calibration specification listings because of these differences.

#### 4.1.2 Complex Loading Graph Description

The graphs in the sections for each transducer may be used to estimate a sensor's range under complex loading. Each page represents one sensor body with either English or Metric units. The top graph represents combinations of forces in the X and/or Y directions with torques about the Z-axis. The bottom graph represents combinations of Z-axis forces with X- and/or Y-axis torques. The graphs contain several different calibrations, distinguished by line weight.

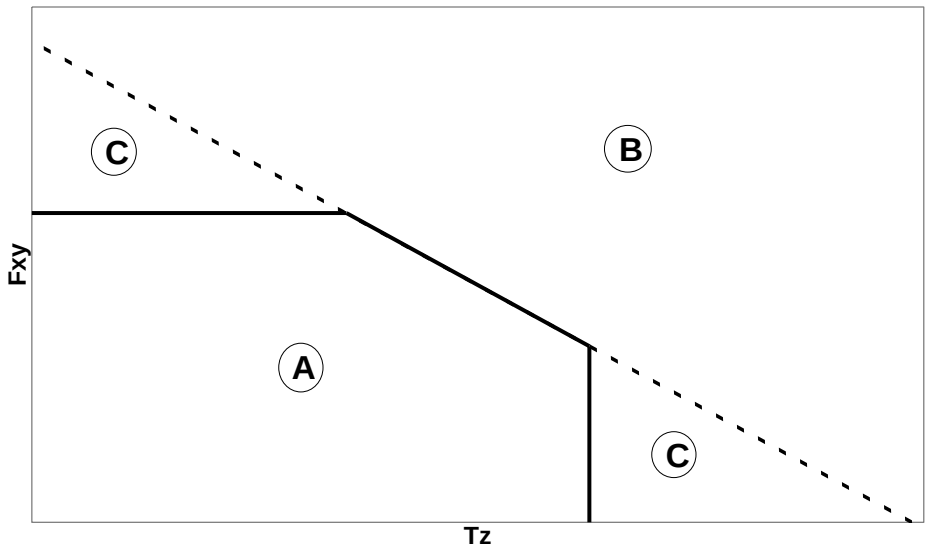
The sample graph shown in *Figure 4.1* shows how operating ranges can change with complex loading. The labels indicate the following regions:

A. Normal operating region. You can expect to achieve rated accuracy in this region.

B. Saturation region. Any load in this region will report a gage saturation condition.

C. Extended operating region. In this region, the sensor will operate correctly, but the full-scale accuracy is not guaranteed.

**Figure 4.1—Complex loading sample graph**



## 4.2 Nano17 Titanium

### 4.2.1 Calibration Specifications (excludes CTL calibrations)

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz | Tx,Ty | Tz | Fx,Fy | Fz | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| US-1.8–0.4 | 1.8 lbf | 3.15 lbf | 0.4 lbf-in | 0.4 lbf-in | 1/3400 lbf | 1/2720 lbf | 7/92800 lbf-in | 1/18560 lbf-in |
| US-3.6–0.8 | 3.6 lbf | 6.3 lbf | 0.8 lbf-in | 0.8 lbf-in | 1/1700 lbf | 1/1360 lbf | 7/46400 lbf-in | 1/9280 lbf-in |
| US-7.2–1.6 | 7.2 lbf | 12.6 lbf | 1.6 lbf-in | 1.6 lbf-in | 1/850 lbf | 1/680 lbf | 7/23200 lbf-in | 1/4640 lbf-in |
| | SENSING RANGES | | | | RESOLUTION | | | |

**Metric Calibrations (SI)**

| Calibration | Fx,Fy | Fz | Tx,Ty | Tz | Fx,Fy | Fz | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| SI-8–0.05 | 8 N | 14.1 N | 50 Nmm | 50 Nmm | 1/682 N | 1/682 N | 3/364 Nmm | 5/728 Nmm |
| SI-16–0.1 | 16 N | 28.2 N | 100 Nmm | 100 Nmm | 1/341 N | 1/341 N | 3/182 Nmm | 5/364 Nmm |
| SI-32–0.2 | 32 N | 56.4 N | 200 Nmm | 200 Nmm | 1/171 N | 1/171 N | 3/92 Nmm | 5/184 Nmm |
| | SENSING RANGES | | | | RESOLUTION | | | |

*These system resolutions quoted are the effective resolution after dropping eight counts of noise. The effective resolution can be improved with filtering. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.*

### 4.2.2 CTL Calibration Specifications

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz | Tx,Ty | Tz | Fx,Fy | Fz | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| US-1.8–0.4 | 1.8 lbf | 3.15 lbf | 0.4 lbf-in | 0.4 lbf-in | 1/1700 lbf | 1/1360 lbf | 7/46400 lbf-in | 1/9280 lbf-in |
| US-3.6–0.8 | 3.6 lbf | 6.3 lbf | 0.8 lbf-in | 0.8 lbf-in | 1/850 lbf | 1/680 lbf | 7/23200 lbf-in | 1/4640 lbf-in |
| US-7.2–1.6 | 7.2 lbf | 12.6 lbf | 1.6 lbf-in | 1.6 lbf-in | 1/425 lbf | 1/340 lbf | 7/11600 lbf-in | 1/2320 lbf-in |

**Metric Calibrations (SI)**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| SI-8–0.05 | 8 N | 14.1 N | 50 Nmm | 50 Nmm | 1/341 N | 1/341 N | 3/182 Nmm | 5/364 Nmm |
| SI-16–0.1 | 16 N | 28.2 N | 100 Nmm | 100 Nmm | 2/341 N | 2/341 N | 3/91 Nmm | 5/182 Nmm |
| SI-32–0.2 | 32 N | 56.4 N | 200 Nmm | 200 Nmm | 2/171N | 2/171 N | 3/46 Nmm | 5/92Nmm |
| | SENSING RANGES | | | | RESOLUTION | | | |

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz† | Tx,Ty, Tz | Fx,Fy | Fz† | Tx,Ty, Tz |
|---|---|---|---|---|---|---|
| US-1.8–0.4 | ±.18 lbf | ±.315 lbf | ±.04 lbf-in | 0.18 lbf/V | 0.315 lbf/V | 0.04 lbf-in/V |
| US-3.6–0.8 | ±.36 lbf | ±.63 lbf | ±.08 lbf-in | 0.36 lbf/V | 0.63 lbf/V | 0.08 lbf-in/V |
| US-7.2–1.6 | ±.72 lbf | ±1.26 lbf | ±.16 lbf-in | 0.72 lbf/V | 1.26 lbf/V | 0.16 lbf-in/V |

**Metric Calibrations (SI)**

| | | | | | | |
|---|---|---|---|---|---|---|
| SI-8–0.05 | ±.8 N | ±1.41 N | ±5 Nmm | 0.8 N/V | 1.41 N/V | 5 Nmm/V |
| SI-16–0.1 | ±1.6 N | ±2.82 N | ±10 Nmm | 1.6 N/V | 2.82 N/V | 10 Nmm/V |
| SI-32–0.2 | ±3.2 N | ±5.64 N | ±20 Nmm | 3.2 N/V | 5.64 N/V | 20 Nmm/V |
| | Analog Output Range | | | Analog ±10V Sensitivity‡ | | |

**Counts Value**

| Calibration | Fx, Fy, Fz | Tx, Ty, Tz | Fx, Fy, Fz | Tx, Ty, Tz |
|---|---|---|---|---|
| US-1.8–0.4 / SI-8–0.05 | 54400 / lbf | 371200 / lbf-in | 1280 / N | 256 / Nmm |
| US-3.6–0.8 / SI-16–0.1 | 27200 / lbf | 185600 / lbf-in | 640 / N | 128 / Nmm |
| US-7.2–1.6 / SI-32–0.2 | 13600 / lbf | 82800 / lbf-in | 320 / N | 64 / Nmm |
| **Tool Transform Factor** | .0022 in/lbf | | 0.0375 mm/N | |
| | Counts Value – Standard (US) | | Counts Value – Metric (SI) | |

*CTL resolutions are typical. System resolutions quoted are the effective resolution after dropping eight counts of noise. The effective resolution can be improved with filtering. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.*

‡ *±5V Sensitivity values are double the listed ±10V Sensitivity values.*

### 4.2.3 Nano17 Titanium Physical Properties

**Standard (US)**

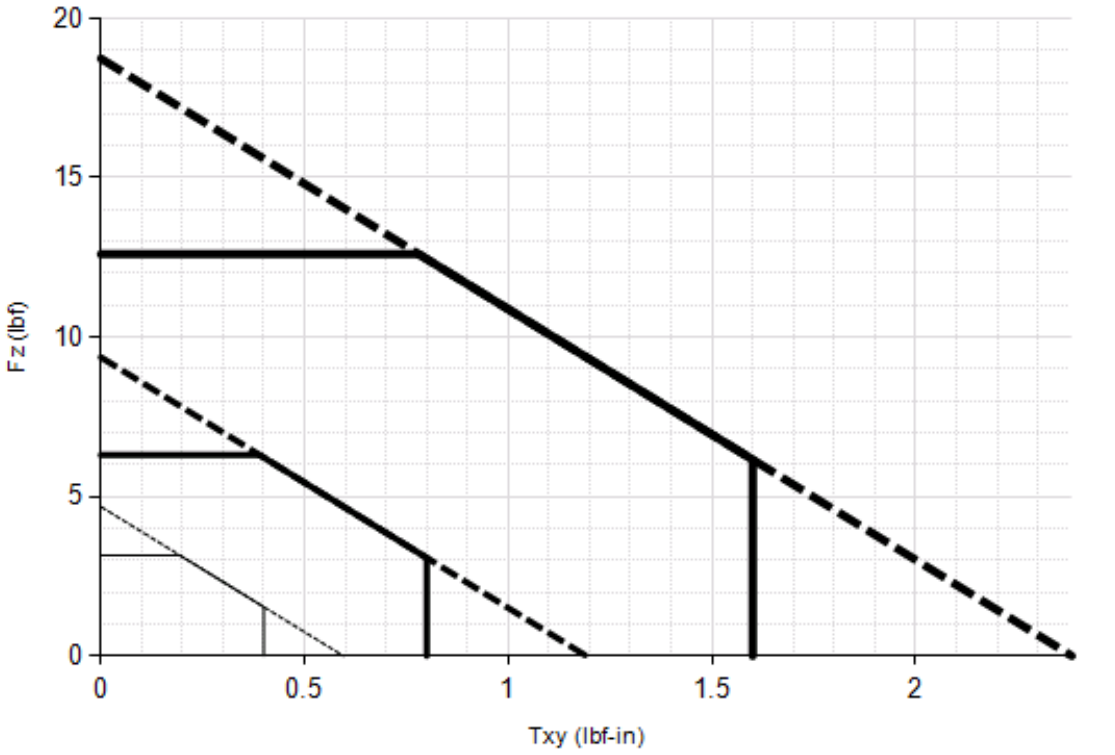
| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±35 lbf |
| Fz | ±70 lbf |
| Txy | ±8.9 lbf-in |
| Tz | ±10 lbf-in |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $2.7x10^4$ lb/in |
| Z-axis force (Kz) | $3.8x10^4$ lb/in |
| X-axis & Y-axis torque (Ktx, Kty) | $1.2x10^3$ lbf-in/rad |
| Z-axis torque (Ktz) | $2.0x10^3$ lbf-in/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 3000 Hz |
| Fz, Tx, Ty | 3000 Hz |
| **Physical Specifications** | |
| Weight* | 0.0223 lb |
| Diameter* | 0.669 in |
| Height* | 0.571 in |

**Metric (SI)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±160 N |
| Fz | ±310 N |
| Txy | ±1 Nm |
| Tz | ±1.2 Nm |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $4.8x10^6$ N/m |
| Z-axis force (Kz) | $6.6x10^6$ N/m |
| X-axis & Y-axis torque (Ktx, Kty) | $1.4x10^2$ Nm/rad |
| Z-axis torque (Ktz) | $2.2x10^2$ Nm/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 3000 Hz |
| Fz, Tx, Ty | 3000 Hz |
| **Physical Specifications** | |
| Weight* | 0.0101 kg |
| Diameter* | 17 mm |
| Height* | 14.5 mm |

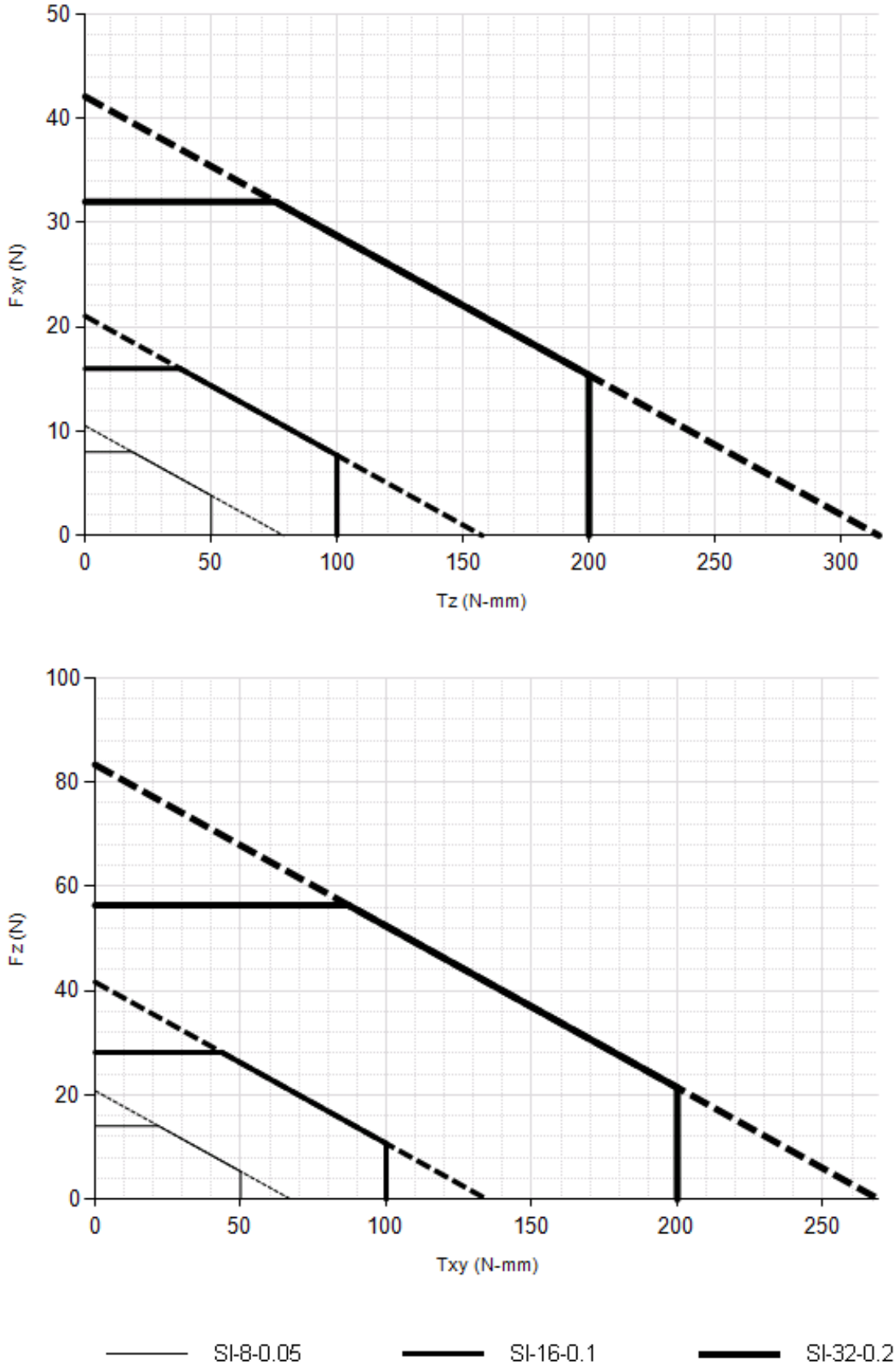
** Specifications include standard interface plate.*

### 4.2.4 Nano17 Titanium (US Calibration Complex Loading)

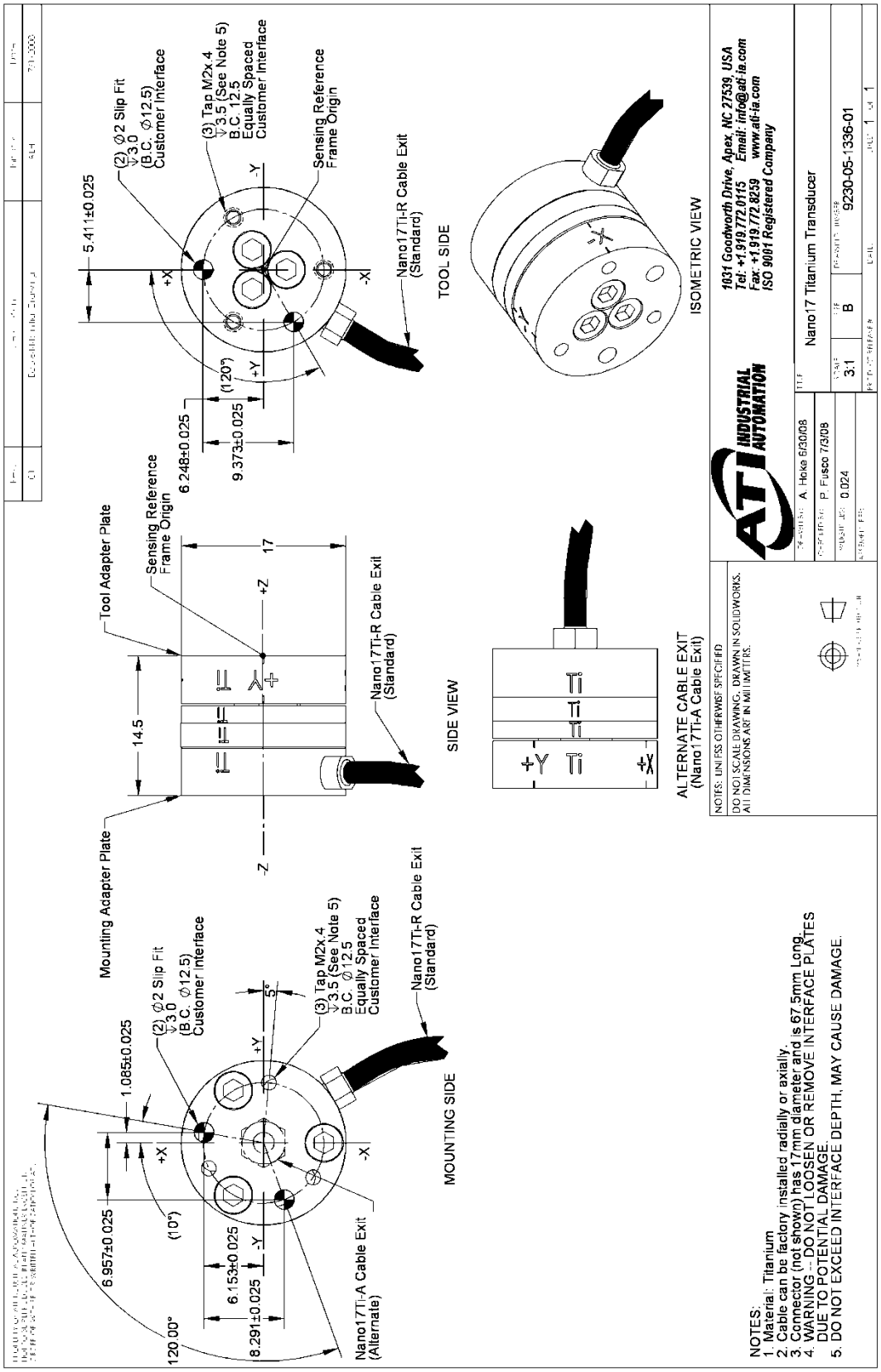




US-1.8-0.4 US-3.6-0.8 US-7.2-1.6

### 4.2.5 Nano17 Titanium (SI Calibration Complex Loading)



### 4.2.6 Nano17 Titanium Transducer Drawing



## 4.3 Nano17 (Includes IP65/IP68 Versions)

### 4.3.1 Calibration Specifications (excludes CTL calibrations)

> ***Note:***
>
> The outer body of the IP65 and the IP68 versions of the Nano17 are electrically floating from the rest of the system. If the transducer signal has additional noise, it may be necessary to electrically connect the transducer body to the case of the F/T system.

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz | Tx,Ty | Tz | Fx,Fy | Fz | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| US-3–1 | 3 lbf | 4.25 lbf | 1 lbf-in | 1 lbf-in | 1/1280 lbf | 1/1280 lbf | 1/8000 lbf-in | 1/8000 lbf-in |
| US-6–2 | 6 lbf | 8.5 lbf | 2 lbf-in | 2 lbf-in | 1/640 lbf | 1/640 lbf | 1/4000 lbf-in | 1/4000 lbf-in |
| US-12–4 | 12 lbf | 17 lbf | 4 lbf-in | 4 lbf-in | 1/320 lbf | 1/320 lbf | 1/2000 lbf-in | 1/2000 lbf-in |
| | SENSING RANGES | | | | RESOLUTION | | | |

**Metric Calibrations (SI)**

| Calibration | Fx,Fy | Fz | Tx,Ty | Tz | Fx,Fy | Fz | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| SI-12–0.12 | 12 N | 17 N | 120 Nmm | 120 Nmm | 1/320 N | 1/320 N | 1/64 Nmm | 1/64 Nmm |
| SI-25–0.25 | 25 N | 35 N | 250 Nmm | 250 Nmm | 1/160 N | 1/160 N | 1/32 Nmm | 1/32 Nmm |
| SI-50–0.5 | 50 N | 70 N | 500 Nmm | 500 Nmm | 1/80 N | 1/80 N | 1/16 Nmm | 1/16 Nmm |
| | SENSING RANGES | | | | RESOLUTION | | | |

*These system resolutions quoted are the effective resolution after dropping eight counts of noise. The effective resolution can be improved with filtering. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.*

### 4.3.2 CTL Calibration Specifications

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz | Tx,Ty | Tz | Fx,Fy | Fz | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| US-3–1 | 3 lbf | 4.25 lbf | 1 lbf-in | 1 lbf-in | 1/640 lbf | 1/640 lbf | 1/4000 lbf-in | 1/4000 lbf-in |
| US-6–2 | 6 lbf | 8.5 lbf | 2 lbf-in | 2 lbf-in | 1/320 lbf | 1/320 lbf | 1/2000 lbf-in | 1/2000 lbf-in |
| US-12–4 | 12 lbf | 17 lbf | 4 lbf-in | 4 lbf-in | 1/160 lbf | 1/160 lbf | 1/1000 lbf-in | 1/1000 lbf-in |
| | SENSING RANGES | | | | RESOLUTION | | | |

**Metric Calibrations (SI)**

| Calibration | Fx,Fy | Fz | Tx,Ty | Tz | Fx,Fy | Fz | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| SI-12–0.12 | 12 N | 17 N | 120 Nm | 120 Nmm | 1/160 N | 1/160 N | 1/32 Nmm | 1/32 Nmm |
| SI-25–0.25 | 25 N | 35 N | 250 Nmm | 250 Nmm | 1/80 N | 1/80 N | 1/16 Nmm | 1/16 Nmm |
| SI-50–0.5 | 50 N | 70 N | 500 Nmm | 500 Nmm | 1/40 N | 1/40 N | 1/8 Nmm | 1/8 Nmm |
| | SENSING RANGES | | | | RESOLUTION | | | |

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz | Tx,Ty, Tz | Fx,Fy | Fz | Tx,Ty, Tz |
|---|---|---|---|---|---|---|
| US-3–1 | ±3 lbf | ±4.25 lbf | ±1 lbf-in | 0.3 lbf/V | 0.425 lbf/V | 0.1 lbf-in/V |
| US-6–2 | ±6 lbf | ±8.5 lbf | ±2 lbf-in | 0.6 lbf/V | 0.85 lbf/V | 0.2 lbf-in/V |
| US-12–4 | ±12 lbf | ±17 lbf | ±4 lbf-in | 1.2 lbf/V | 1.7 lbf/V | 0.4 lbf-in/V |
| | Analog Output Range | | | Analog ±10V Sensitivity‡ | | |

**Metric Calibrations (SI)**

| Calibration | Fx,Fy | Fz | Tx,Ty, Tz | Fx,Fy | Fz | Tx,Ty, Tz |
|---|---|---|---|---|---|---|
| SI-12–0.12 | ±12 N | ±17 N | ±120 Nmm | 1.2 N/V | 1.7 N/V | 12 Nmm/V |
| SI-25–-0.25 | ±25 N | ±35 N | ±250 Nmm | 2.5 N/V | 3.5 N/V | 25 Nmm/V |
| SI-50–0.5 | ±50 N | ±70 N | ±500 Nmm | 5 N/V | 7 N/V | 50 Nmm/V |
| | Analog Output Range | | | Analog ±10V Sensitivity‡ | | |

**Counts Value**

| Calibration | Fx, Fy, Fz | Tx, Ty, Tz | Fx, Fy, Fz | Tx, Ty, Tz |
|---|---|---|---|---|
| US-3–1 / SI-12–0.25 | 5120 / lbf | 32000 / lbf-in | 1280 / N | 256 / Nmm |
| US-6–2 / SI-25–0.25 | 2560 / lbf | 16000 / lbf-in | 640 / N | 128 / Nmm |
| US-12–4 / SI-50–0.5 | 1280 / lbf | 8000 / lbf-in | 320 / N | 64 / Nmm |
| **Tool Transform Factor** | 0.0016 in/lbf | | 0.05 mm/N | |
| | Counts Value – Standard (US) | | Counts Value – Metric (SI) | |

*CTL resolutions are typical. System resolutions quoted are the effective resolution after dropping eight counts of noise. The effective resolution can be improved with filtering. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.*

‡ *±5V Sensitivity values are double the listed ±10V Sensitivity values.*

### 4.3.3 Nano17 Physical Properties

**Standard (US)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±56 lbf |
| Fz | ±110 lbf |
| Txy | ±14 lbf-in |
| Tz | ±16 lbf-in |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $4.7x10^4$ lb/in |
| Z-axis force (Kz) | $6.5x10^4$ lb/in |
| X-axis & Y-axis torque (Ktx, Kty) | $2.1x10^3$ lbf-in/rad |
| Z-axis torque (Ktz) | $3.4x10^3$ lbf-in/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 7200 Hz |
| Fz, Tx, Ty | 7200 Hz |
| **Physical Specifications** | |
| Weight* | 0.02 lb |
| Diameter* | 0.669 in |
| Height* | 0.571 in |

**Metric (SI)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±250 N |
| Fz | ±480 N |
| Txy | ±1.6 Nm |
| Tz | ±1.8 Nm |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $8.2x10^6$ N/m |
| Z-axis force (Kz) | $1.1x10^7$ N/m |
| X-axis & Y-axis torque (Ktx, Kty) | $2.4x10^2$ Nm/rad |
| Z-axis torque (Ktz) | $3.8x10^2$ Nm/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 7200 Hz |
| Fz, Tx, Ty | 7200 Hz |
| **Physical Specifications** | |
| Weight* | 0.00907 kg |
| Diameter* | 17 mm |
| Height* | 14.5 mm |

** Specifications include standard interface plate.*

### 4.3.4 Nano17 IP65/IP68 Physical Properties

**Standard (US)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±56 lbf |
| Fz | ±110 lbf |
| Txy | ±14 lbf-in |
| Tz | ±16 lbf-in |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $4.7x10^4$ lb/in |
| Z-axis force (Kz) | $6.5x10^4$ lb/in |
| X-axis & Y-axis torque (Ktx, Kty) | $2.1x10^3$ lbf-in/rad |
| Z-axis torque (Ktz) | $3.4x10^3$ lbf-in/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 2200 Hz |
| Fz, Tx, Ty | 2200 Hz |
| **Physical Specifications** | |
| Weight* | 0.09 lb |
| Diameter* | 0.79 in |
| Height* | 0.873 in |

**Metric (SI)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±250 N |
| Fz | ±480 N |
| Txy | ±1.6 Nm |
| Tz | ±1.8 Nm |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $8.2x10^6$ N/m |
| Z-axis force (Kz) | $1.1x10^7$ N/m |
| X-axis & Y-axis torque (Ktx, Kty) | $2.4x10^2$ Nm/rad |
| Z-axis torque (Ktz) | $3.8x10^2$ Nm/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 2200 Hz |
| Fz, Tx, Ty | 2200 Hz |
| **Physical Specifications** | |
| Weight* | 0.0408 kg |
| Diameter* | 20.1 mm |
| Height* | 22.2 mm |

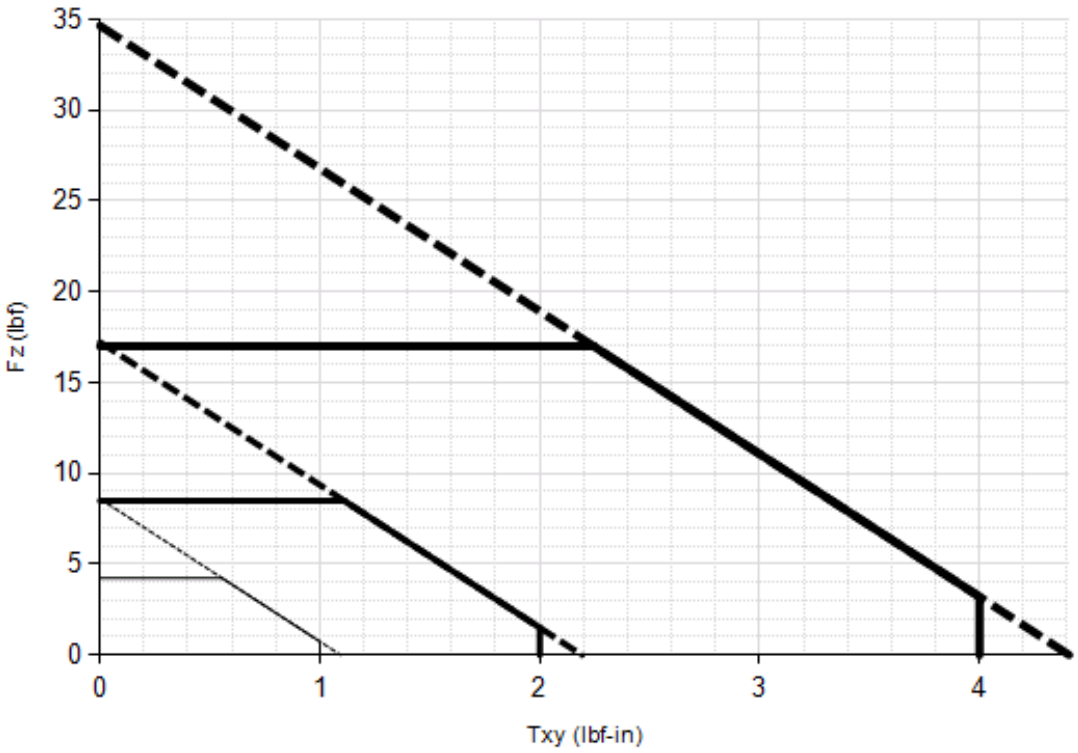
** Specifications include standard interface plate.*

**CAUTION:**
**IP68 Nano17 Fz as a Function of Submersion Depth:**

When submerged, IP68 transducers exhibit a decrease in Fz range related to the submersion depth. This loss is the result of pressure-induced preloading on the transducer. The preload can be masked by biasing the transducer at the depth prior to applying the load to be measured. The following estimates are for room temperature fresh water at sea level.

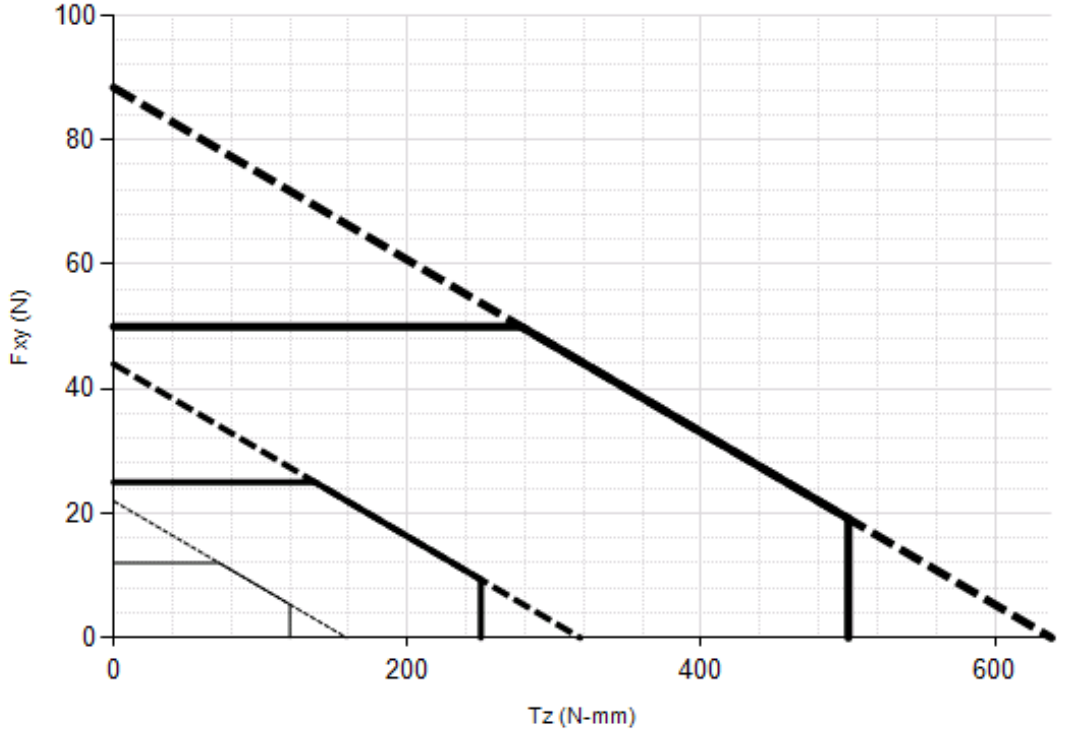
| ***IP68 Nano17*** | **US** | **Metric** |
|---|---|---|
| Fz preload at 4m depth | 2.01 lb | 8.93 N |
| Fz preload at other depths | -0.15 lb/ft × depthInFeet | -2.23 N/m × depthInMeters |

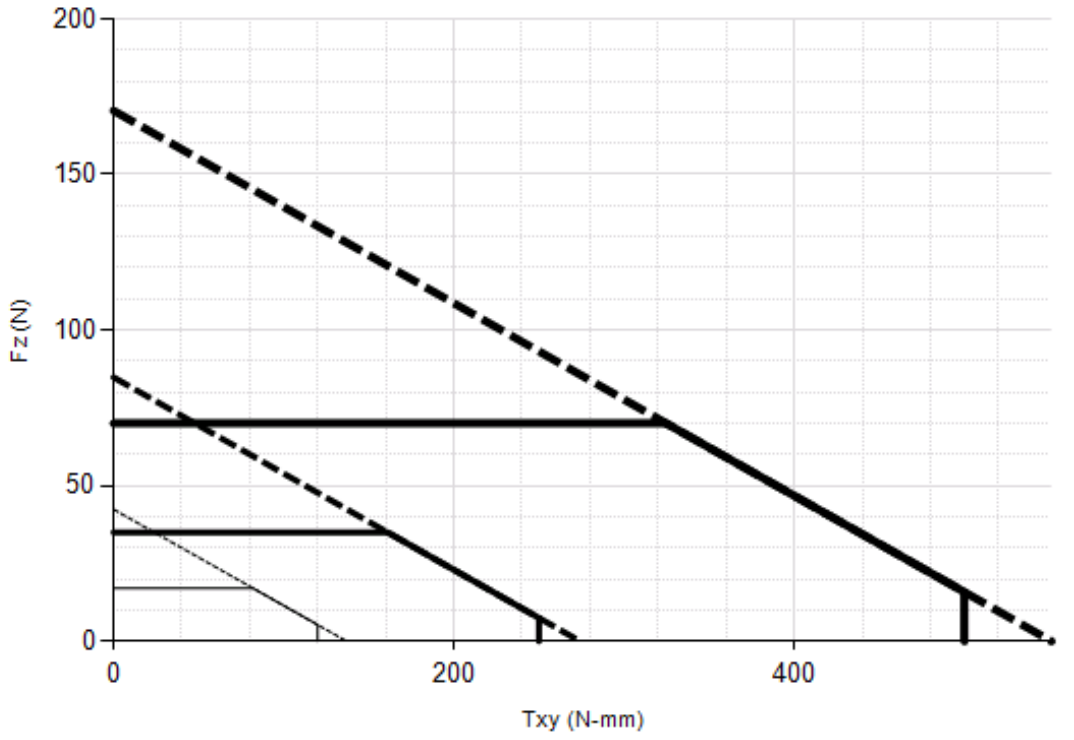
### 4.3.5 Nano17 (US Calibration Complex Loading)


US-3-1 US-6-2 US-12-4

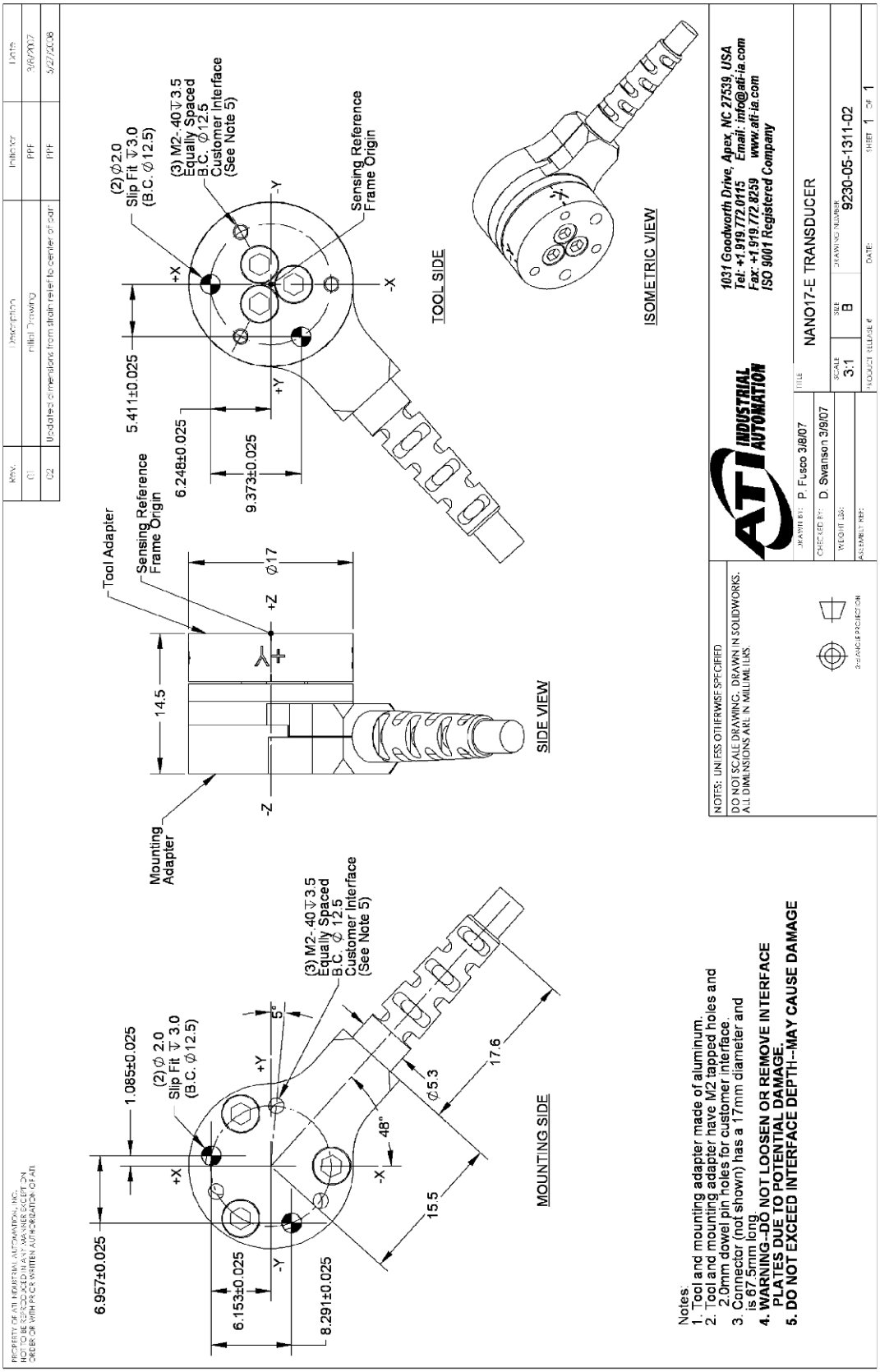
### 4.3.6 Nano17 (SI Calibration Complex Loading)



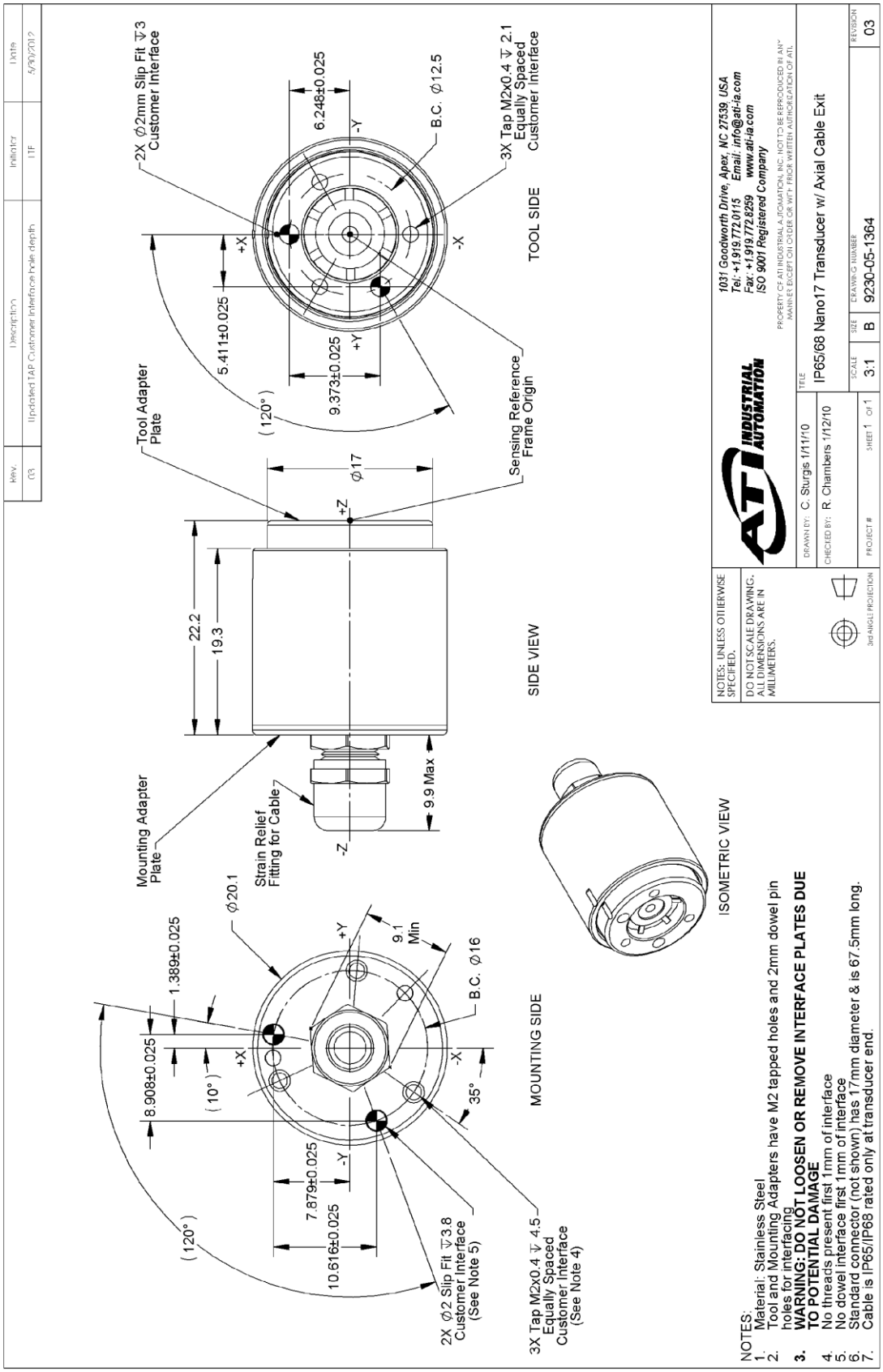




SI-12-0.12 SI-25-0.25 SI-50-0.5

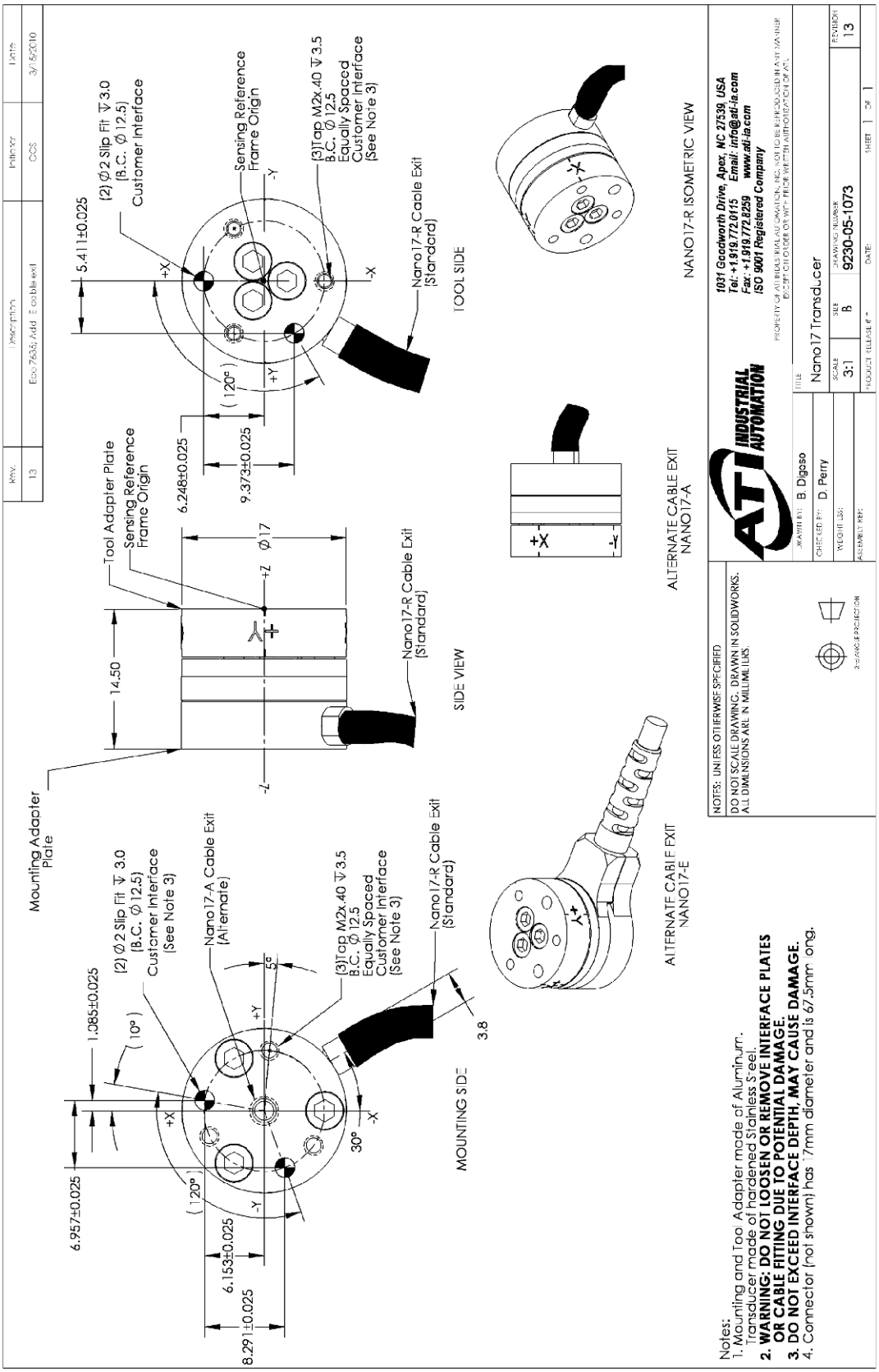
### 4.3.7 Nano17-E Transducer Drawing



### 4.3.8 Nano17 IP65/IP68 Transducer with Axial Cable Exit Drawing



### 4.3.9 Legacy Nano17 Transducer Drawing



## 4.4 Nano25 (Includes IP65/IP68 Versions)

### 4.4.1 Calibration Specifications (excludes CTL calibrations)

> ***Note:***
>
> The outer body of the IP65 and the IP68 versions of the Nano25 are electrically floating from the rest of the system. If the transducer signal has additional noise, it may be necessary to electrically connect the transducer body to the case of the F/T system.

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz | Tx,Ty | Tz | Fx,Fy | Fz | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| US-25–25 | 25 lbf | 100 lbf | 25 lbf-in | 25 lbf-in | 1/224 lbf | 3/224 lbf | 1/160 lbf-in | 1/320 lbf-in |
| US-50–50 | 50 lbf | 200 lbf | 50 lbf-in | 30 lbf-in | 1/112 lbf | 3/112 lbf | 1/80 lbf-in | 1/160 lbf-in |
| | SENSING RANGES | | | | RESOLUTION | | | |

**Metric Calibrations (SI)**

| Calibration | Fx,Fy | Fz | Tx,Ty | Tz | Fx,Fy | Fz | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| SI-125–3 | 125 N | 500 N | 3 Nm | 3 Nm | 1/48 N | 1/16 N | 1/1320 Nm | 1/2640 Nm |
| SI-250–6 | 250 N | 1000 N | 6 Nm | 3.4 Nm | 1/24 N | 1/8 N | 1/660 Nm | 1/1320 Nm |
| | SENSING RANGES | | | | RESOLUTION | | | |

*These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.*

### 4.4.2 CTL Calibration Specifications

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz | Tx,Ty | Tz | Fx,Fy | Fz | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| US-25–25 | 25 lbf | 100 lbf | 25 lbf-in | 25 lbf-in | 1/112 lbf | 3/112 lbf | 1/80 lbf-in | 1/160 lbf-in |
| US-50–50 | 50 lbf | 200 lbf | 50 lbf-in | 30 lbf-in | 1/56 lbf | 3/56 lbf | 1/40 lbf-in | 1/80 lbf-in |
| | SENSING RANGES | | | | RESOLUTION | | | |

**Metric Calibrations (SI)**

| Calibration | Fx,Fy | Fz | Tx,Ty | Tz | Fx,Fy | Fz | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| SI-125–3 | 125 N | 500 N | 3 Nm | 3 Nm | 1/24 N | 1/8 N | 1/660 Nm | 1/1320 Nm |
| SI-250–6 | 250 N | 1000 N | 6 Nm | 3.4 Nm | 1/12 N | 1/4 N | 1/330 Nm | 1/660 Nm |
| | SENSING RANGES | | | | RESOLUTION | | | |

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz | Tx,Ty, Tz | Fx,Fy | Fz | Tx,Ty, Tz |
|---|---|---|---|---|---|---|
| US-25–25 | ±25 lbf | ±100 lbf | ±25 lbf-in | 2.5 lbf/V | 10 lbf/V | 2.5 lbf-in/V |
| US-50–50 | ±50 lbf | ±200 lbf | ±50 lbf-in | 5 lbf/V | 20 lbf/V | 5 lbf-in/V |
| | Analog Output Range | | | Analog ±10V Sensitivity‡ | | |

**Metric Calibrations (SI)**

| Calibration | Fx,Fy | Fz | Tx,Ty, Tz | Fx,Fy | Fz | Tx,Ty, Tz |
|---|---|---|---|---|---|---|
| SI-125–3 | ±125 N | ±500 N | ±3 Nm | 12.5 N/V | 50 N/V | 0.3 Nm/V |
| SI-250–6 | ±250 N | 1000 N | ±6 Nm | 25 N/V | 100 N/V | 0.6 Nm/V |
| | Analog Output Range | | | Analog ±10V Sensitivity‡ | | |

**Counts Value**

| Calibration | Fx, Fy, Fz | Tx, Ty, Tz | Fx, Fy, Fz | Tx, Ty, Tz |
|---|---|---|---|---|
| US-25–25 / SI-125–3 | 896 / lbf | 1280 / lbf-in | 192 / N | 10560 / N |
| US-50–50 / SI-250–6 | 448 / lbf | 640 / lbf-in | 96 / Nm | 5280 / Nm |
| **Tool Transform Factor** | 0.007 in/lbf | | 0.18182 mm/N | |
| | Counts Value – Standard (US) | | Counts Value – Metric (SI) | |

***Note***: *Applying moments beyond ±30 lbf-in (±3.4Nm) in Tz can cause hysteresis and permanent zero-point change in the Nano25 (applies to all versions of the Nano25).*

*CTL resolutions are typical. System resolutions quoted are the effective resolution after dropping eight counts of noise. The effective resolution can be improved with filtering. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.*

† *For IP68 version see caution on physical properties page.*

‡ *±5V Sensitivity values are double the listed ±10V Sensitivity values.*

### 4.4.3 Nano25 Physical Properties

**Standard (US)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±520 lbf |
| Fz | ±1600 lbf |
| Txy | ±380 lbf-in |
| Tz | ±560 lbf-in |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $3.0 \times 10^5$ lb/in |
| Z-axis force (Kz) | $6.3 \times 10^5$ lb/in |
| X-axis & Y-axis torque (Ktx, Kty) | $5.7 \times 10^4$ lbf-in/rad |
| Z-axis torque (Ktz) | $8.1 \times 10^4$ lbf-in/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 3600 Hz |
| Fz, Tx, Ty | 3800 Hz |
| **Physical Specifications** | |
| Weight* | 0.14 lb |
| Diameter* | 0.984 in |
| Height* | 0.85 in |

**Metric (SI)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±2300 N |
| Fz | ±7300 N |
| Txy | ±43 Nm |
| Tz | ±63 Nm |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $5.3 \times 10^7$ N/m |
| Z-axis force (Kz) | $1.1 \times 10^8$ N/m |
| X-axis & Y-axis torque (Ktx, Kty) | $6.5 \times 10^3$ Nm/rad |
| Z-axis torque (Ktz) | $9.2 \times 10^3$ Nm/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 3600 Hz |
| Fz, Tx, Ty | 3800 Hz |
| **Physical Specifications** | |
| Weight* | 0.0634 kg |
| Diameter* | 25 mm |
| Height* | 21.6 mm |

** Specifications include standard interface plate.*

### 4.4.4 Nano25 IP65/IP68 Physical Properties

**Standard (US)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±520 lbf |
| Fz | ±1600 lbf |
| Txy | ±380 lbf-in |
| Tz | ±560 lbf-in |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $3.0x10^5$ lb/in |
| Z-axis force (Kz) | $6.3x10^5$ lb/in |
| X-axis & Y-axis torque (Ktx, Kty) | $5.7x10^4$ lbf-in/rad |
| Z-axis torque (Ktz) | $8.1x10^4$ lbf-in/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 3400 Hz |
| Fz, Tx, Ty | 3500 Hz |
| **Physical Specifications** | |
| Weight* | 0.3 lb |
| Diameter* | 1.1 in |
| Height* | 1.08 in |

**Metric (SI)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±2300 N |
| Fz | ±7300 N |
| Txy | ±43 Nm |
| Tz | ±63 Nm |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $5.3x10^7$ N/m |
| Z-axis force (Kz) | $1.1x10^8$ N/m |
| X-axis & Y-axis torque (Ktx, Kty) | $6.5x10^3$ Nm/rad |
| Z-axis torque (Ktz) | $9.2x10^3$ Nm/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 3400 Hz |
| Fz, Tx, Ty | 3500 Hz |
| **Physical Specifications** | |
| Weight* | 0.136 kg |
| Diameter* | 28 mm |
| Height* | 27.5 mm |

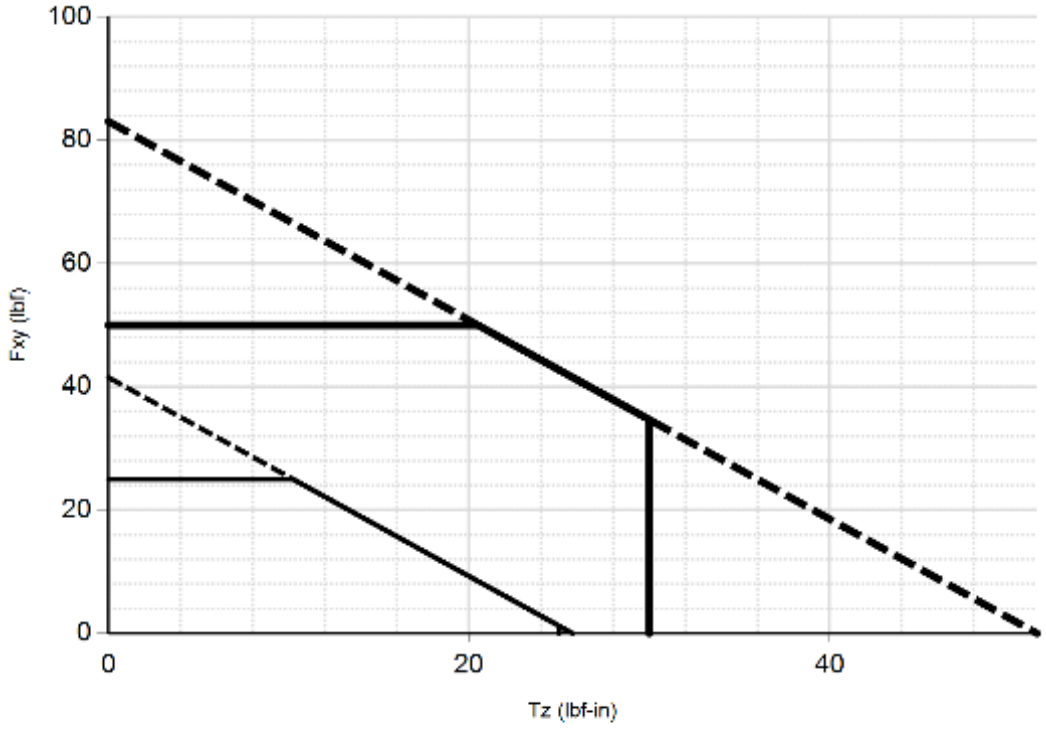
** Specifications include standard interface plate.*

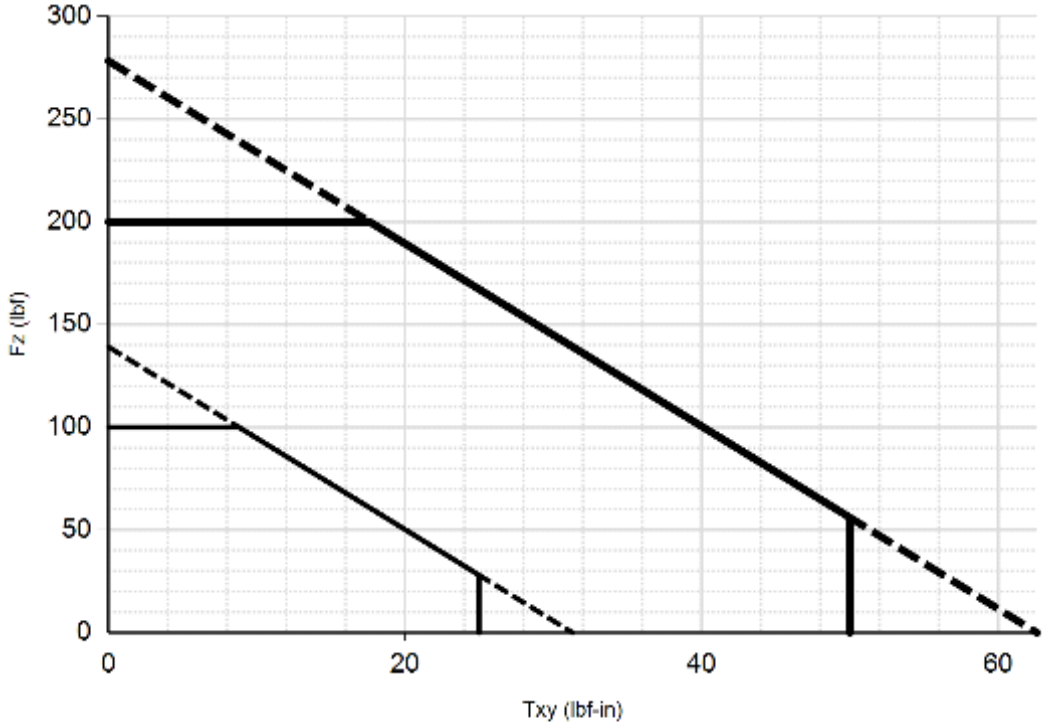
**CAUTION:**
**IP68 Nano25 Fz as a Function of Submersion Depth:**

When submerged, IP68 transducers exhibit a decrease in Fz range related to the submersion depth. This loss is the result of pressure-induced preloading on the transducer. The preload can be masked by biasing the transducer at the depth prior to applying the load to be measured. The following estimates are for room temperature fresh water at sea level.

| ***IP68 Nano25*** | **US** | **Metric** |
|---|---|---|
| Fz preload at 4m depth | 4.33 lb | 19.3 N |
| Fz preload at other depths | -0.33 lb/ft × depthInFeet | -4.81 N/m × depthInMeters |

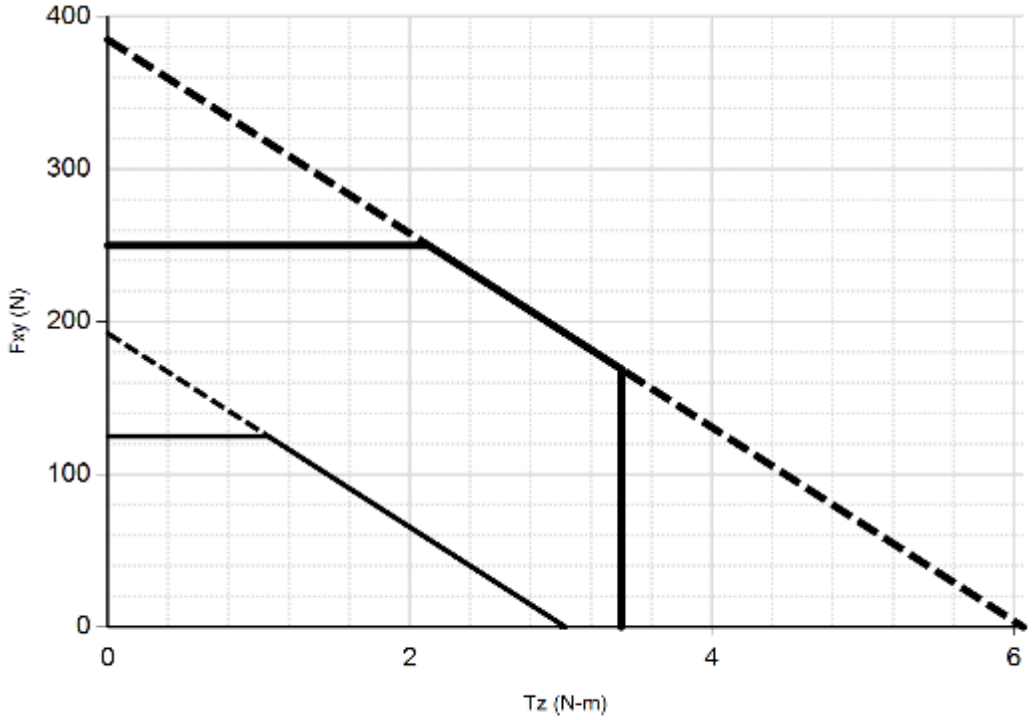
### 4.4.5 Nano25 (US Calibration Complex Loading) (Includes IP65/IP68 Versions)

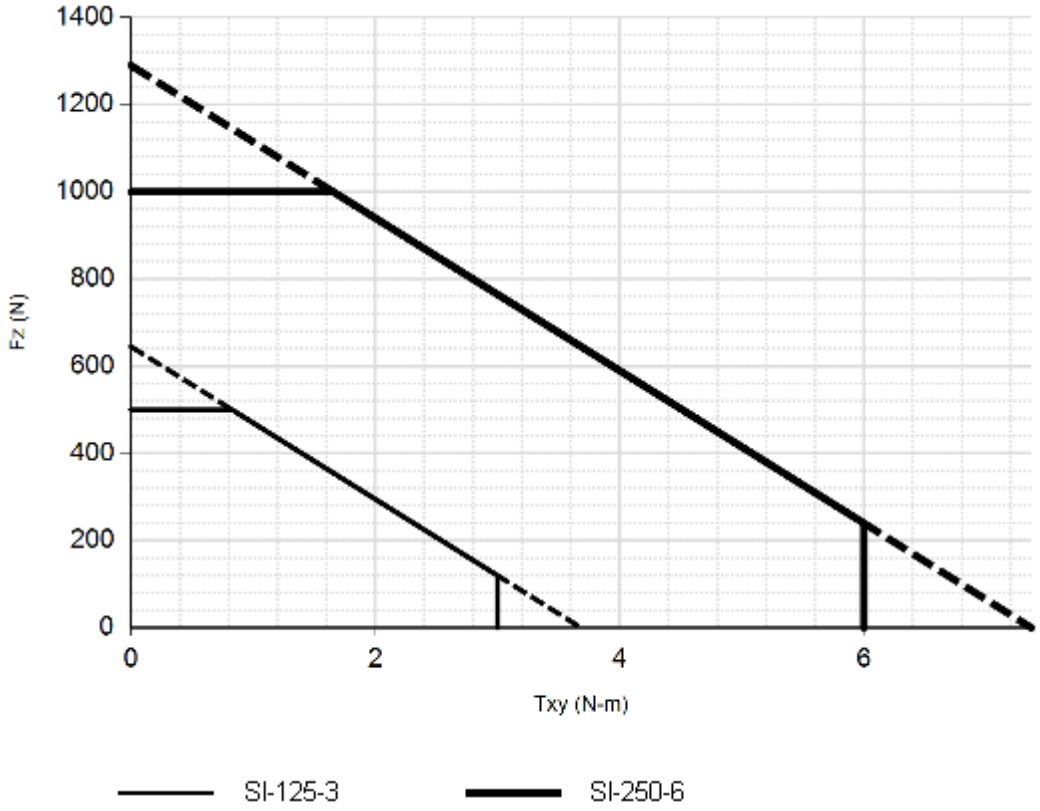


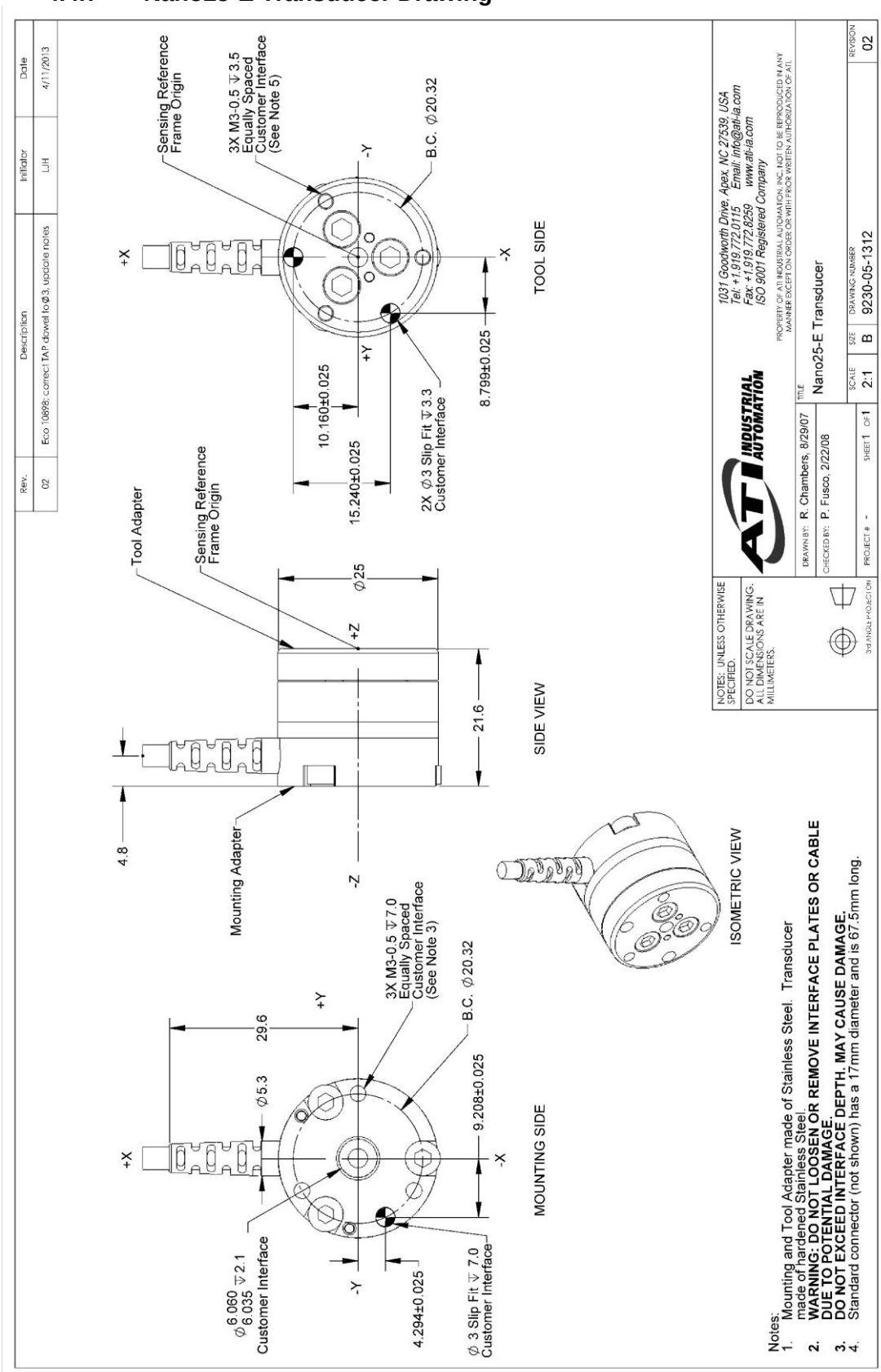

US-25-25 US-50-50

### 4.4.6 Nano25 (SI Calibration Complex Loading) (Includes IP65/IP68 Versions)

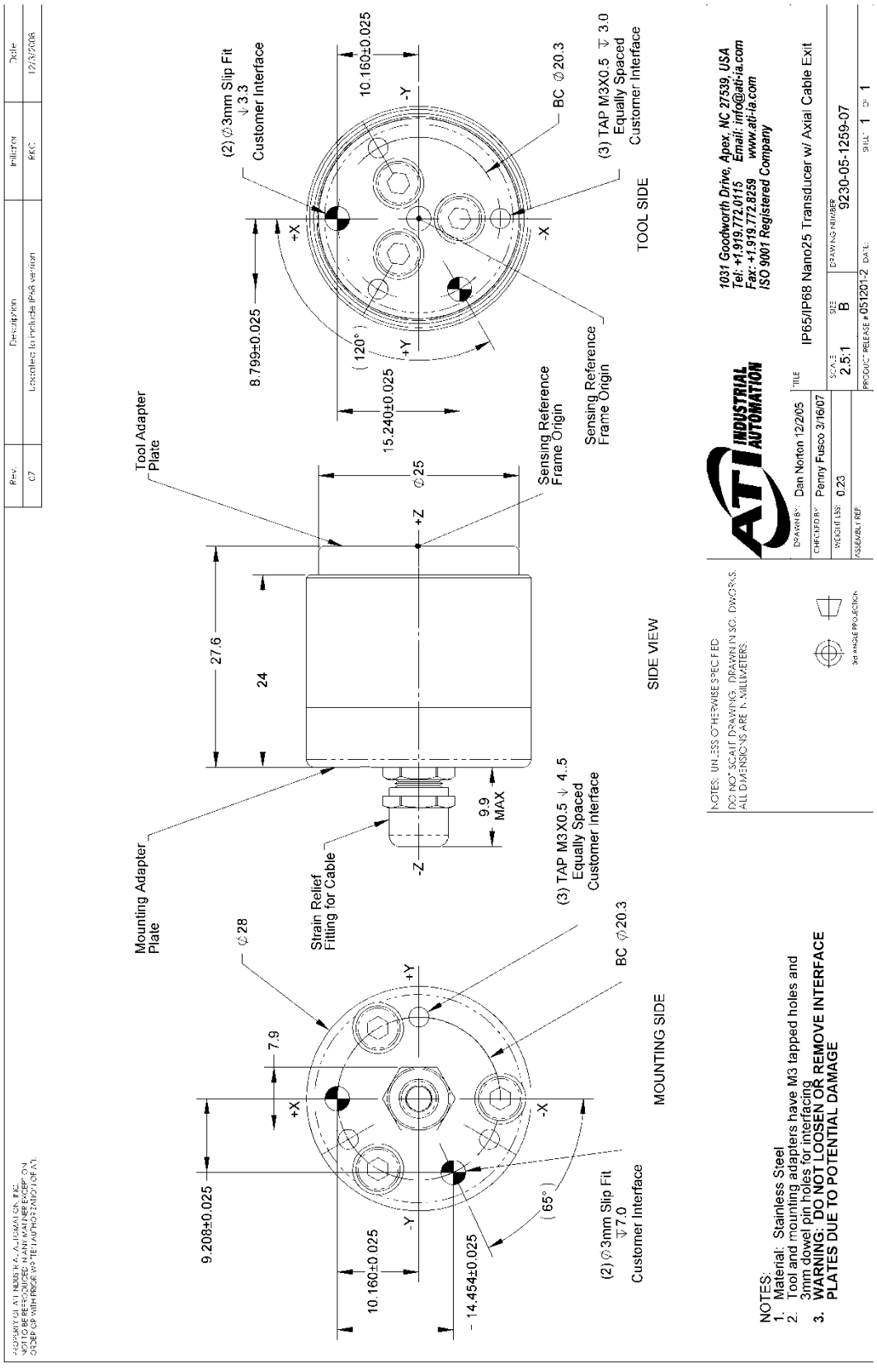


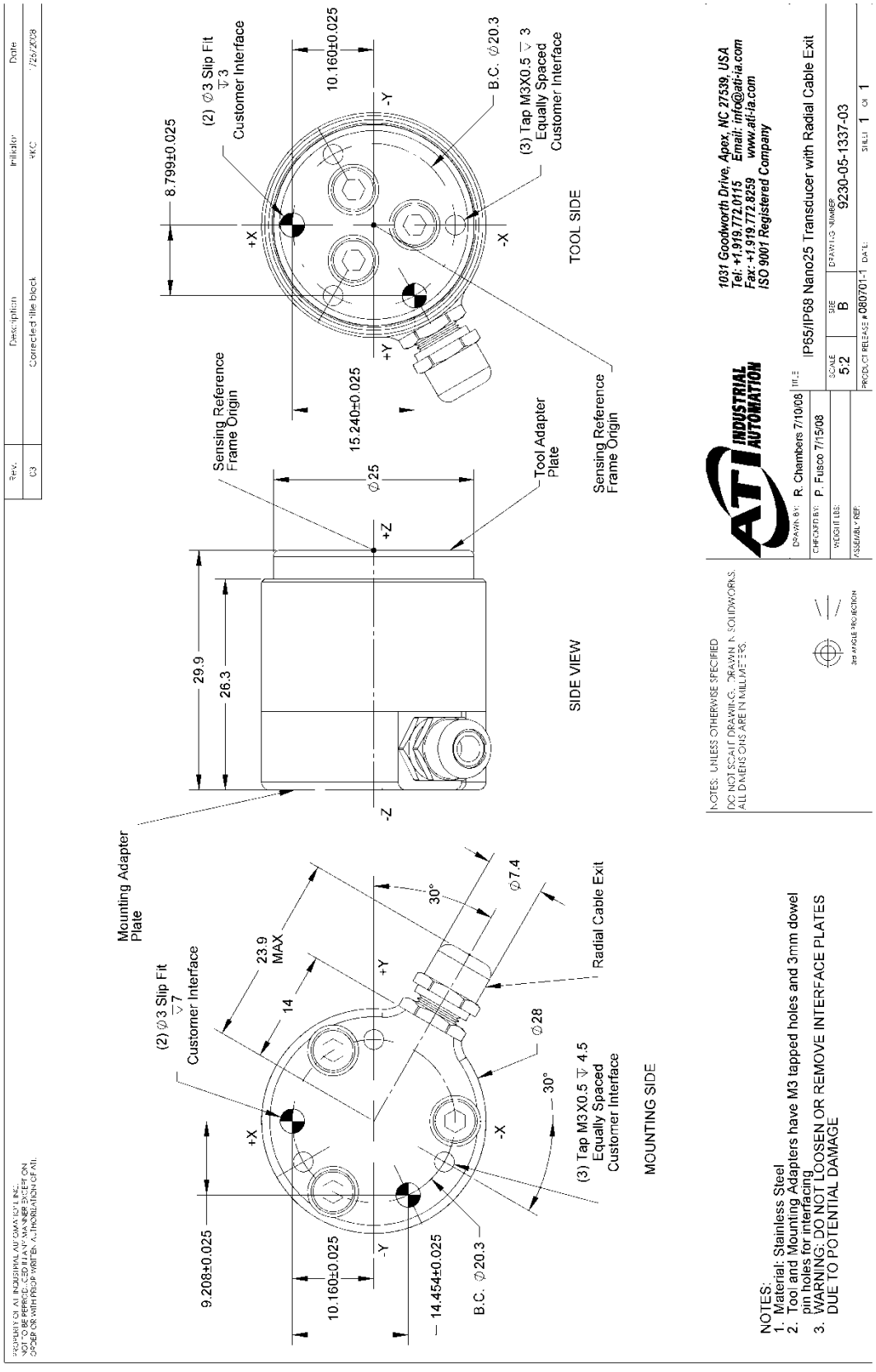
### 4.4.7 Nano25-E Transducer Drawing



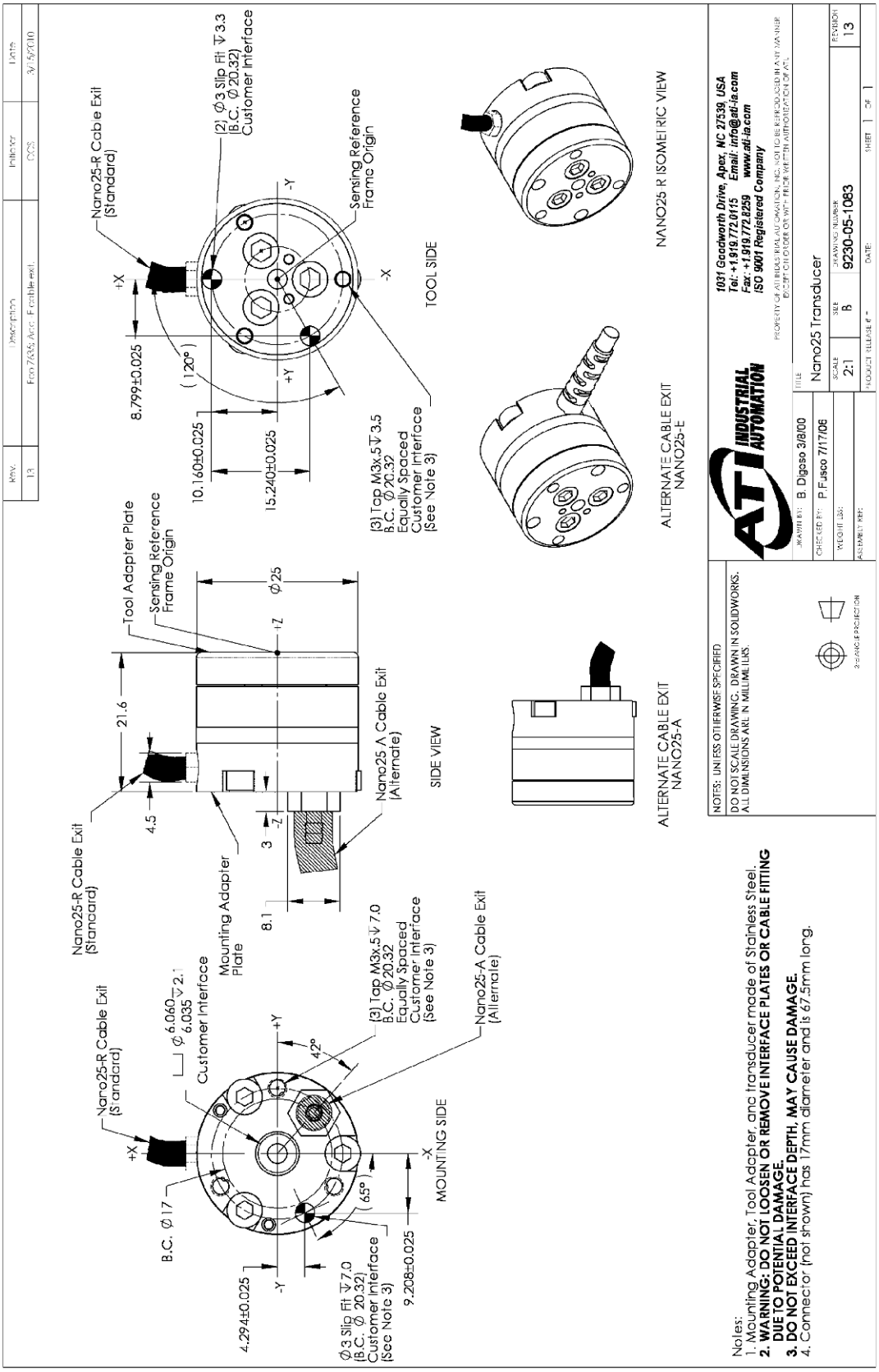
### 4.4.8 Nano25 IP65/IP68 Transducer with Axial Cable Exit Drawing



### 4.4.9 Nano25 IP65/IP68 Transducer with Radial Cable Exit Drawing



### 4.4.10 Legacy Nano25 Transducer Drawing



## 4.5 Nano43

### 4.5.1 Calibration Specifications (excludes CTL calibrations)

> ***Note:***
>
> The outer body of the Nano43 is electrically floating from the rest of the system. If the transducer signal has additional noise, it may be necessary to electrically connect the transducer body to the case of the F/T system.

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz | Tx,Ty | Tz | Fx,Fy | Fz | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| US-2-1 | 2 lbf | 2 lbf | 1 lbf-in | 1 lbf-in | 1/2320 lbf-in | 1/2320 lbf-in | 1/4640 lbf-in | 1.4640 lbf-in |
| US-4–2 | 4 lbf | 4 lbf | 2 lbf-in | 2 lbf-in | 1/1160 lbf | 1/1160 lbf | 1/2320 lbf-in | 1/2320 lbf-in |
| US-8–4 | 8 lbf | 8 lbf | 4 lbf-in | 4 lbf-in | 1/580 lbf | 1/580 lbf | 1/1160 lbf-in | 1/1160 lbf-in |
| | SENSING RANGES | | | | RESOLUTION* | | | |

**Metric Calibrations (SI)**

| Calibration | Fx,Fy | Fz | Tx,Ty | Tz | Fx,Fy | Fz | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| SI-9-0.125 | 9 N | 9 N | 125 Nmm | 125 Nmm | 1/512 N | 1/512 N | 1/40 Nmm | 1/40 Nmm |
| SI-18–0.25 | 18 N | 18 N | 250 Nmm | 250 Nmm | 1/256 N | 1/256 N | 1/20 Nmm | 1/20 Nmm |
| SI-36–0.5 | 36 N | 36 N | 500 Nmm | 500 Nmm | 1/128 N | 1/128 N | 1/10 Nmm | 1/10 Nmm |
| | SENSING RANGES | | | | RESOLUTION* | | | |

* *DAQ resolutions are typical for a 16-bit data acquisition system.*

*These system resolutions quoted are the effective resolution after dropping eight counts of noise. The effective resolution can be improved with filtering. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.*

### 4.5.2 CTL Calibration Specifications

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz | Tx,Ty | Tz | Fx,Fy | Fz | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| US-2-1 | 2 lbf | 2 lbf | 1 lbf-in | 1 lbf-in | 1/1160 lbf | 1/1160 lbf | 1/2320 lbf-in | 1/2320 lbf-in |
| US-4–2 | 4 lbf | 4 lbf | 2 lbf-in | 2 lbf-in | 1/580 lbf | 1/580 lbf | 1/1160 lbf-in | 1/1160 lbf-in |
| US-8–4 | 8 lbf | 8 lbf | 4 lbf-in | 4 lbf-in | 1/290 lbf | 1/290 lbf | 1/580 lbf-in | 1/580 lbf-in |
| | SENSING RANGES | | | | RESOLUTION | | | |

**Metric Calibrations (SI)**

| Calibration | Fx,Fy | Fz | Tx,Ty | Tz | Fx,Fy | Fz | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| SI-9-0.125 | 9N | 9 N | 125 Nmm | 125 Nmm | 1/256 N | 1/256 N | 1/20 Nmm | 1/20 Nmm |
| SI-18–0.25 | 18 N | 18 N | 250 Nmm | 250 Nmm | 1/128 N | 1/128 N | 1/10 Nmm | 1/10 Nmm |
| SI-36–0.5 | 36 N | 36 N | 500 Nmm | 500 Nmm | 1/64 N | 1/64 N | 1/5 Nmm | 1/5 Nmm |
| | SENSING RANGES | | | | RESOLUTION | | | |

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz | Tx,Ty, Tz | Fx,Fy | Fz | Tx,Ty, Tz |
|---|---|---|---|---|---|---|
| US-2-1 | | | | | | |
| US-4–2 | ±4 lbf | ±4 lbf | 2 lbf-in | 0.4 lbf/V | 0.4 lbf/V | 0.2 lbf-in/V |
| US-8–4 | ±8 lbf | ±8 lbf | ±4 lbf-in | 0.8 lbf/V | 0.8 lbf/V | 0.4 lbf-in/V |
| | Analog Output Range | | | Analog ±10V Sensitivity‡ | | |

**Metric Calibrations (SI)**

| Calibration | Fx,Fy | Fz | Tx,Ty, Tz | Fx,Fy | Fz | Tx,Ty, Tz |
|---|---|---|---|---|---|---|
| SI-9-0.125 | | | | | | |
| SI-18–0.25 | ±18 N | ±18 N | ±250 Nmm | 1.8 N/V | 1.8 N/V | 25 Nmm/V |
| SI-36–0.5 | ±36 N | ±36 N | ±500 Nmm | 3.6 N/V | 3.6 N/V | 50 Nmm/V |
| | Analog Output Range | | | Analog ±10V Sensitivity‡ | | |

**Counts Value**

| Calibration | Fx, Fy, Fz | Tx, Ty, Tz | Fx, Fy, Fz | Tx, Ty, Tz |
|---|---|---|---|---|
| US-2-1 / SI-9-0.125 | | | | |
| US-4–2 / SI-18–0.25 | 4640 / lbf | 9280 / lbf-in | 1024 / N | 80 / Nmm |
| US-8–4 / SI-36–0.5 | 2320 / lbf | 4640 / lbf-in | 512 / N | 40 / Nmm |
| **Tool Transform Factor** | 0.005 in/lbf | | 0.128 mm/N | |
| | Counts Value – Standard (US) | | Counts Value – Metric (SI) | |

*CTL resolutions are typical. System resolutions quoted are the effective resolution after dropping eight counts of noise. The effective resolution can be improved with filtering. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.*

‡ *±5V Sensitivity values are double the listed ±10V Sensitivity values.*

### 4.5.3 Nano43 Physical Properties

**Standard (US)**

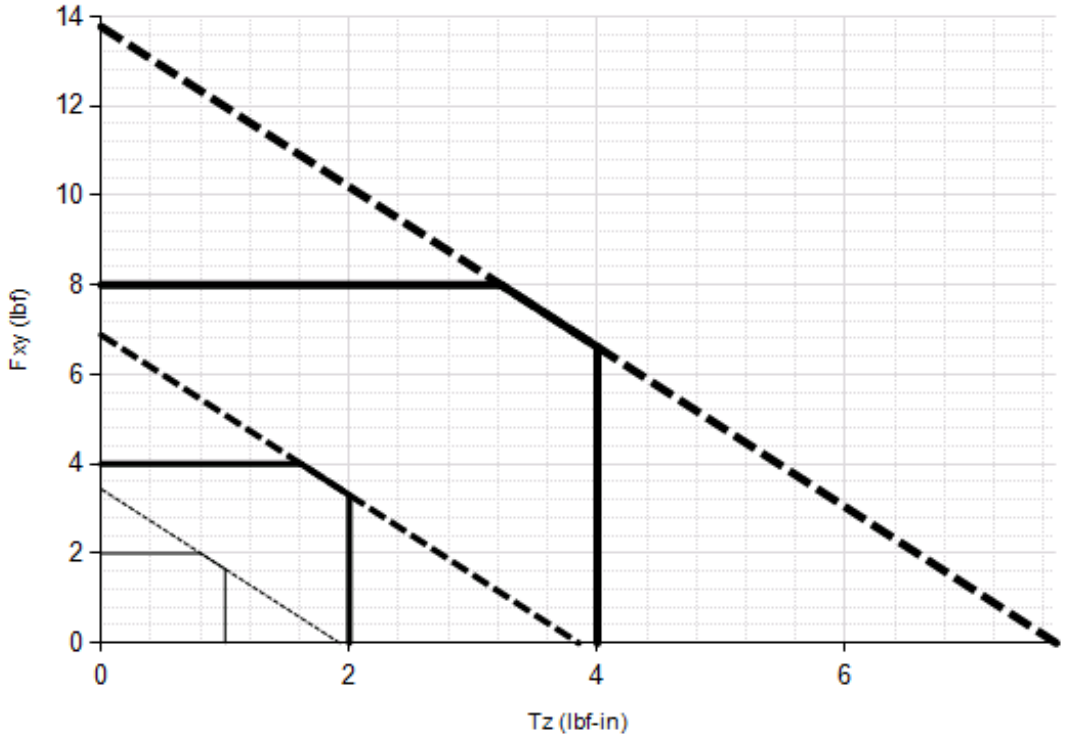
| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±68 lbf |
| Fz | ±86 lbf |
| Txy | ±29 lbf-in |
| Tz | ±41 lbf-in |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $2.9x10^4$ lb/in |
| Z-axis force (Kz) | $2.9x10^4$ lb/in |
| X-axis & Y-axis torque (Ktx, Kty) | $6.8x10^3$ lbf-in/rad |
| Z-axis torque (Ktz) | $1.0x10^4$ lbf-in/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 2800 Hz |
| Fz, Tx, Ty | 2300 Hz |
| **Physical Specifications** | |
| Weight* | 0.0854 lb |
| Diameter* | 1.69 in |
| Height* | 0.454 in |

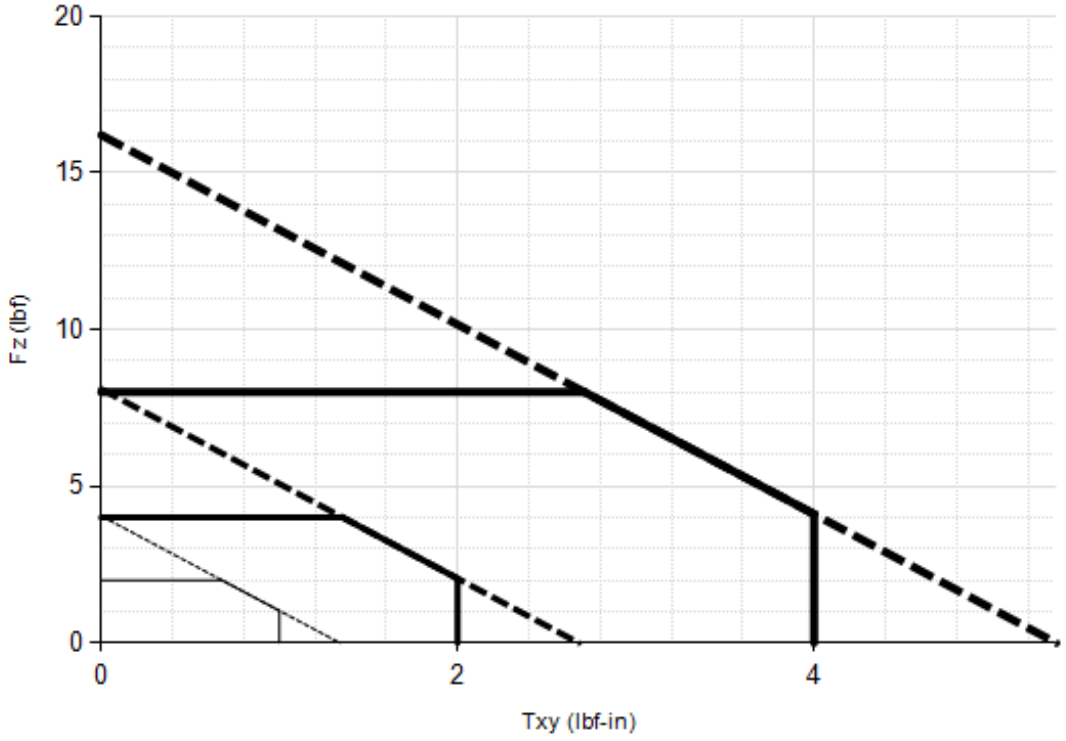
**Metric (SI)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±300 N |
| Fz | ±380 N |
| Txy | ±3.2 Nm |
| Tz | ±4.6 Nm |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $5.2x10^6$ N/m |
| Z-axis force (Kz) | $5.2x10^6$ N/m |
| X-axis & Y-axis torque (Ktx, Kty) | $7.7x10^2$ Nm/rad |
| Z-axis torque (Ktz) | $1.1x10^3$ Nm/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 2800 Hz |
| Fz, Tx, Ty | 2300 Hz |
| **Physical Specifications** | |
| Weight* | 0.0387 kg |
| Diameter* | 43 mm |
| Height* | 11.5 mm |

** Specifications include standard interface plate.*

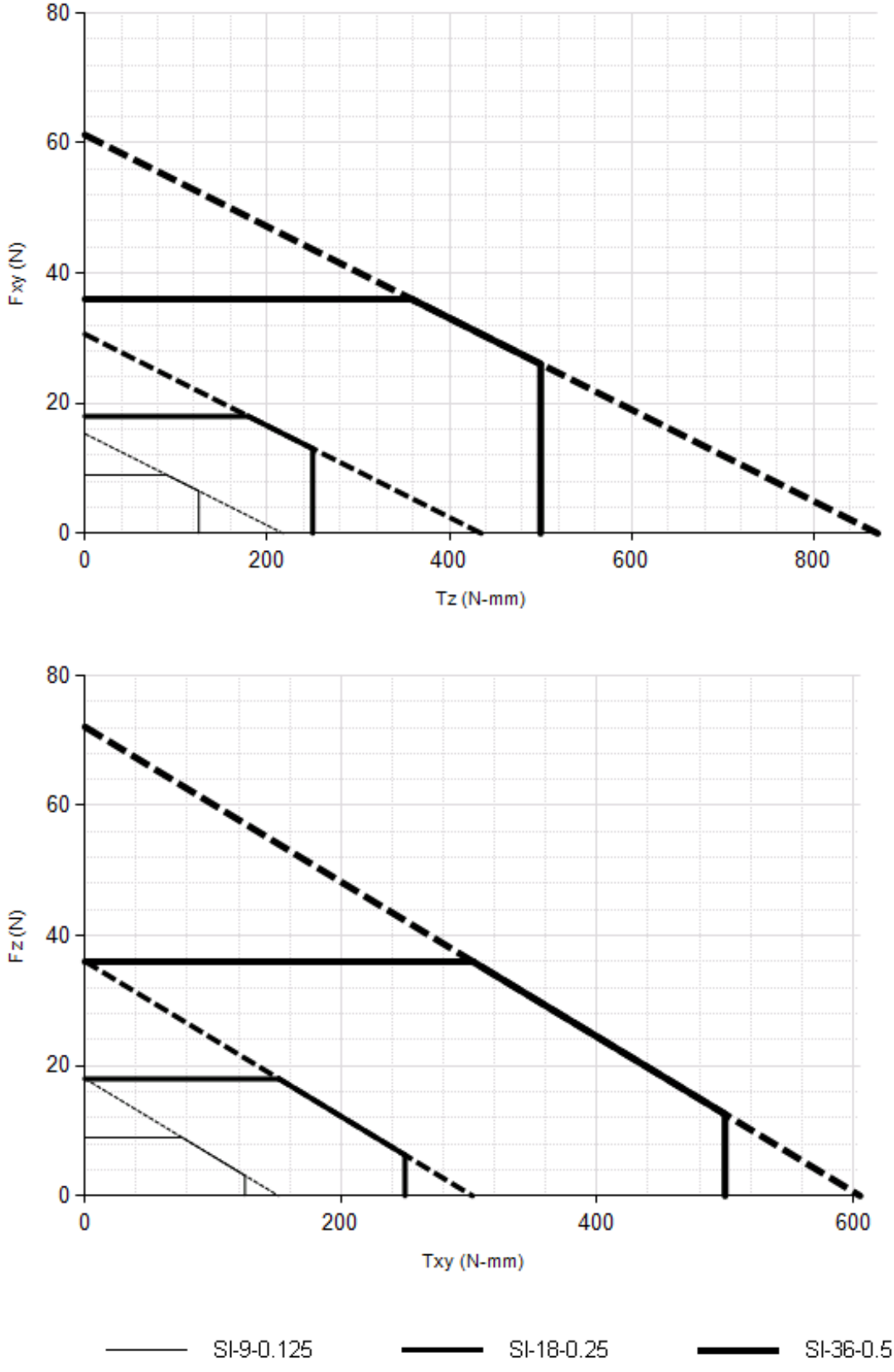
### 4.5.4 Nano43 (US Calibration Complex Loading)



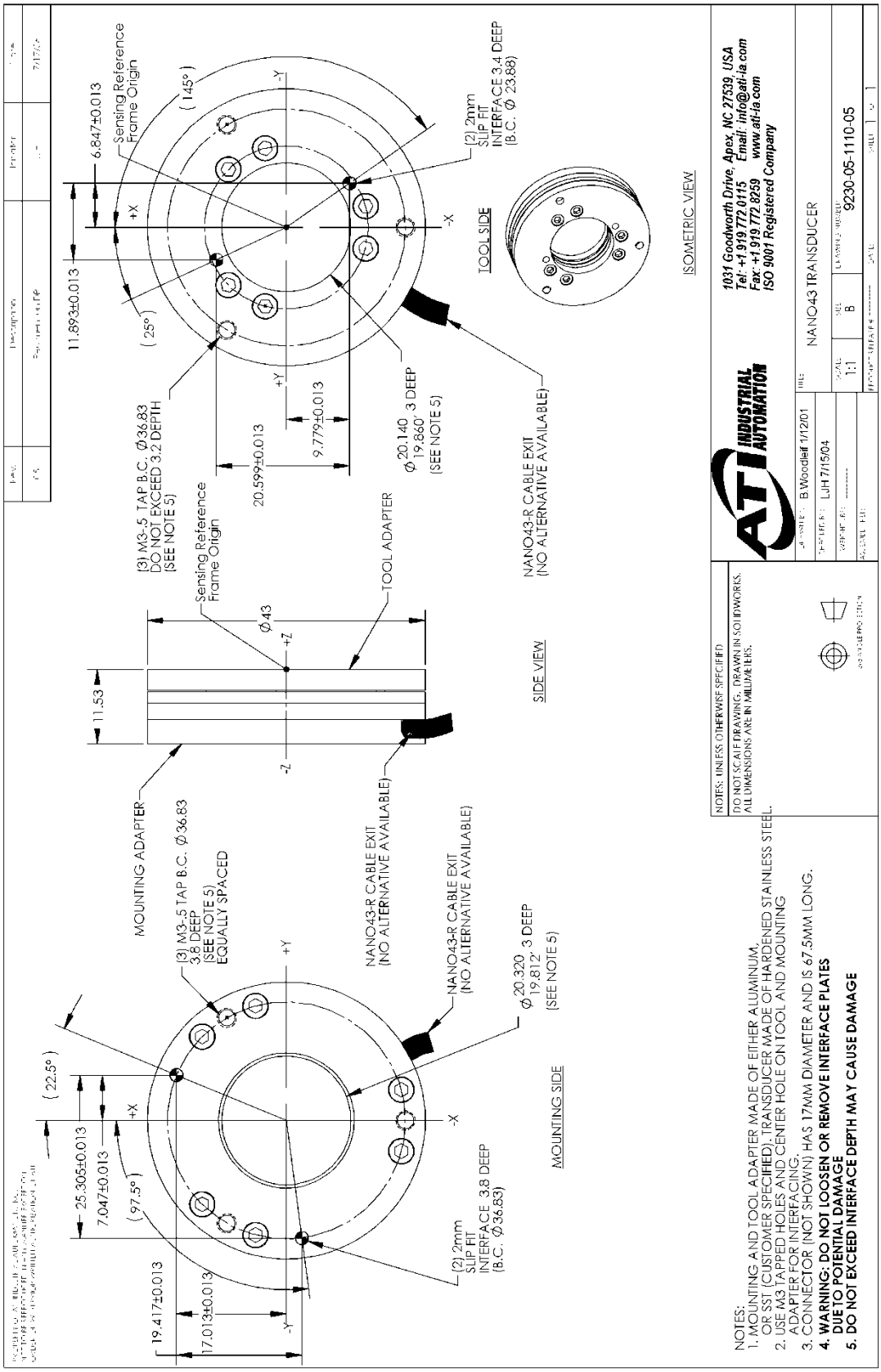




US-2-1 US-4-2 US-8-4

### 4.5.5 Nano43 (SI Calibration Complex Loading)



### 4.5.6 Nano43 Transducer Drawing



## 4.6 Mini27 Titanium

### 4.6.1 Calibration Specifications (excludes CTL calibrations)

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz | Tx,Ty | Tz | Fx,Fy | Fz | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| US-10–18 | 10 lbf | 20 lbf | 18 lbf-in | 10 lbf-in | 1/400 lbf | 3/400 lbf | 1/400 lbf-in | 1/800 lbf-in |
| US-20–36 | 20 lbf | 40 lbf | 36 lbf-in | 20 lbf-in | 1/200 lbf | 3/200 lbf | 1/200 lbf-in | 1/400 lbf-in |
| | SENSING RANGES | | | | RESOLUTION* | | | |

**Metric Calibrations (SI)**

| Calibration | Fx,Fy | Fz | Tx,Ty | Tz | Fx,Fy | Fz | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| SI-40–2 | 40 N | 80 N | 2 Nm | 1 Nm | 3/200 N | 3/100 N | 3/8000 Nm | 1/4000 Nm |
| SI-80–4 | 80 N | 160 N | 4 Nm | 2 Nm | 3/100 N | 3/50 N | 134000 Nm | 1/2000 Nm |
| | SENSING RANGES | | | | RESOLUTION* | | | |

* *DAQ resolutions are typical for a 16-bit data acquisition system.*

*These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.*

### 4.6.2 CTL Calibration Specifications

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz | Tx,Ty | Tz | Fx,Fy | Fz | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| US-10–18 | 10 lbf | 20 lbf | 18 lbf-in | 10 lbf-in | 1/200 lbf | 3/200 lbf | 1/200 lbf-in | 1/400 lbf-in |
| US-20–36 | 20 lbf | 40 lbf | 36 lbf-in | 20 lbf-in | 1/100 lbf | 3/100 lbf | 1/100 lbf-in | 1/200 lbf-in |
| | SENSING RANGES | | | | RESOLUTION* | | | |

**Metric Calibrations (SI)**

| Calibration | Fx,Fy | Fz | Tx,Ty | Tz | Fx,Fy | Fz | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| SI-40–2 | 40 N | 80 N | 2 Nm | 1 Nm | 3/100 N | 3/50 N | 3/4000 Nm | 1/2000 Nm |
| SI-80–4 | 80 N | 160 N | 4 Nm | 2 Nm | 3/50 N | 3/25 N | 3/2000 Nm | 1/1000 Nm |
| | SENSING RANGES | | | | RESOLUTION* | | | |

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz† | Tx,Ty, Tz | Fx,Fy | Fz† | Tx,Ty, Tz |
|---|---|---|---|---|---|---|
| US-10–18 | ±5 lbf | ±15 lbf | ±10 lbf-in | 0.5 lbf/V | 1.5 lbf/V | 1 lbf-in/V |
| US-20–36 | ±10 lbf | ±30 lbf | ±20 lbf-in | 1 lbf/V | 3 lbf/V | 2 lbf-in/V |
| | Analog Output Range | | | Analog ±10V Sensitivity‡ | | |

**Metric Calibrations (SI)**

| Calibration | Fx,Fy | Fz† | Tx,Ty, Tz | Fx,Fy | Fz† | Tx,Ty, Tz |
|---|---|---|---|---|---|---|
| SI-40–2 | ±20 N | ±60 N | ±1 Nm | 2 N/V | 6 N/V | 0.1 Nm/V |
| SI-80–4 | ±40 N | ±120 N | ±2 Nm | 4 N/V | 12 N/V | 0.2 Nm/V |
| | Analog Output Range | | | Analog ±10V Sensitivity‡ | | |

**Counts Value**

| Calibration | Fx, Fy, Fz | Tx, Ty, Tz | Fx, Fy, Fz | Tx, Ty, Tz |
|---|---|---|---|---|
| US-1–18 / SI-40–2 | 3200 / lbf | 3200 / lbf-in | 800 / N | 32000 / Nm |
| US-20–36 / SI-80–4 | 1600 / lbf | 1600 / lbf-in | 400 / N | 16000 / Nm |
| **Tool Transform Factor** | 0.01 in/lbf | | 0.25 mm/N | |
| | Counts Value – Standard (US) | | Counts Value – Metric (SI) | |

*CTL resolutions are typical. System resolutions quoted are the effective resolution after dropping eight counts of noise. The effective resolution can be improved with filtering. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.*

‡ *±5V Sensitivity values are double the listed ±10V Sensitivity values.*

### 4.6.3 Mini27 Titanium Physical Properties

**Standard (US)**

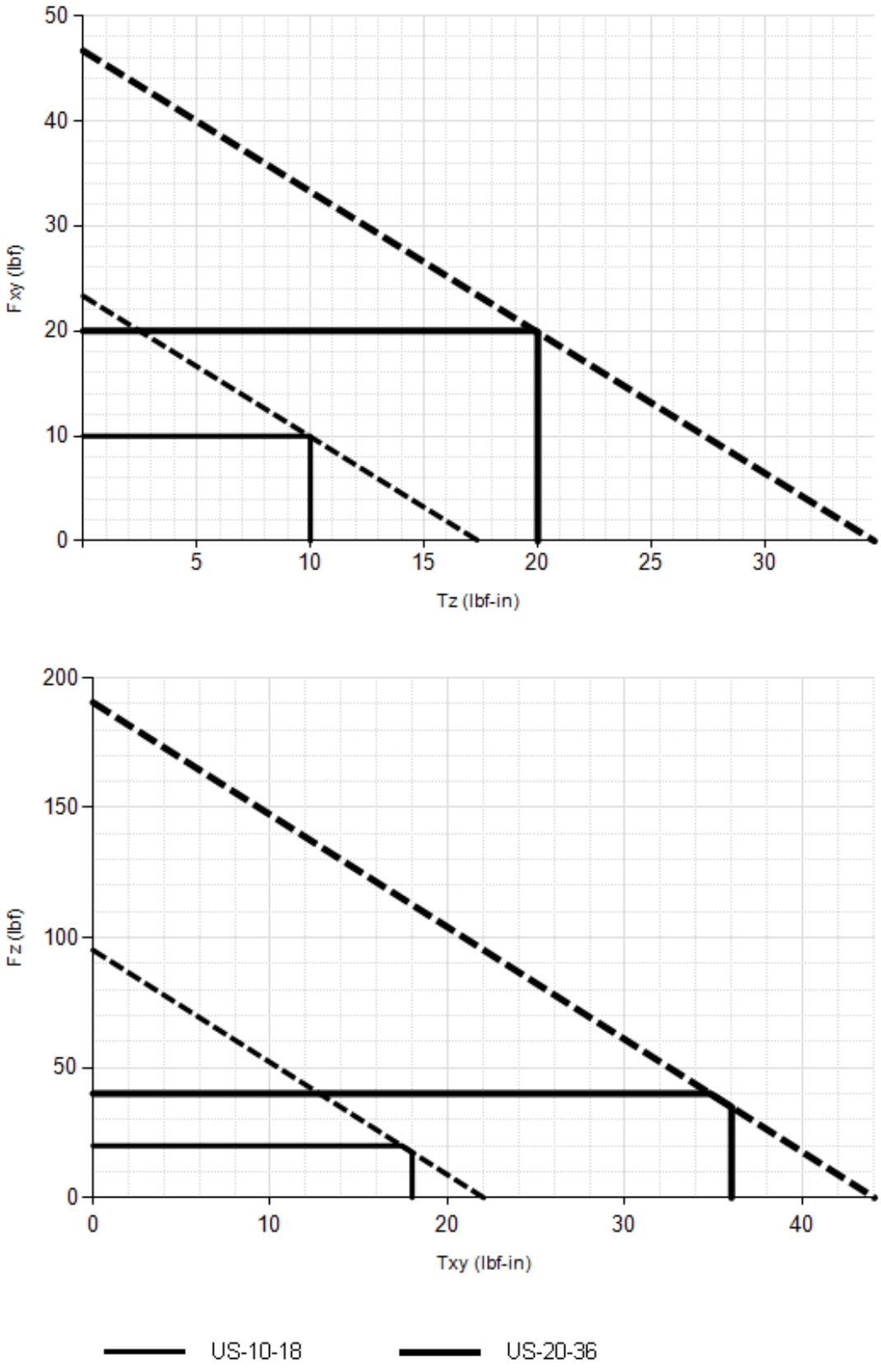
| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±330 lbf |
| Fz | ±1000 lbf |
| Txy | ±270 lbf-in |
| Tz | ±360 lbf-in |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $1.8x10^5$ lb/in |
| Z-axis force (Kz) | $3.6x10^5$ lb/in |
| X-axis & Y-axis torque (Ktx, Kty) | $4.0x10^4$ lbf-in/rad |
| Z-axis torque (Ktz) | $5.8x10^4$ lbf-in/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | |
| Fz, Tx, Ty | |
| **Physical Specifications** | |
| Weight* | 0.0736 lb |
| Diameter* | 1.06 in |
| Height* | 0.715 in |

**Metric (SI)**

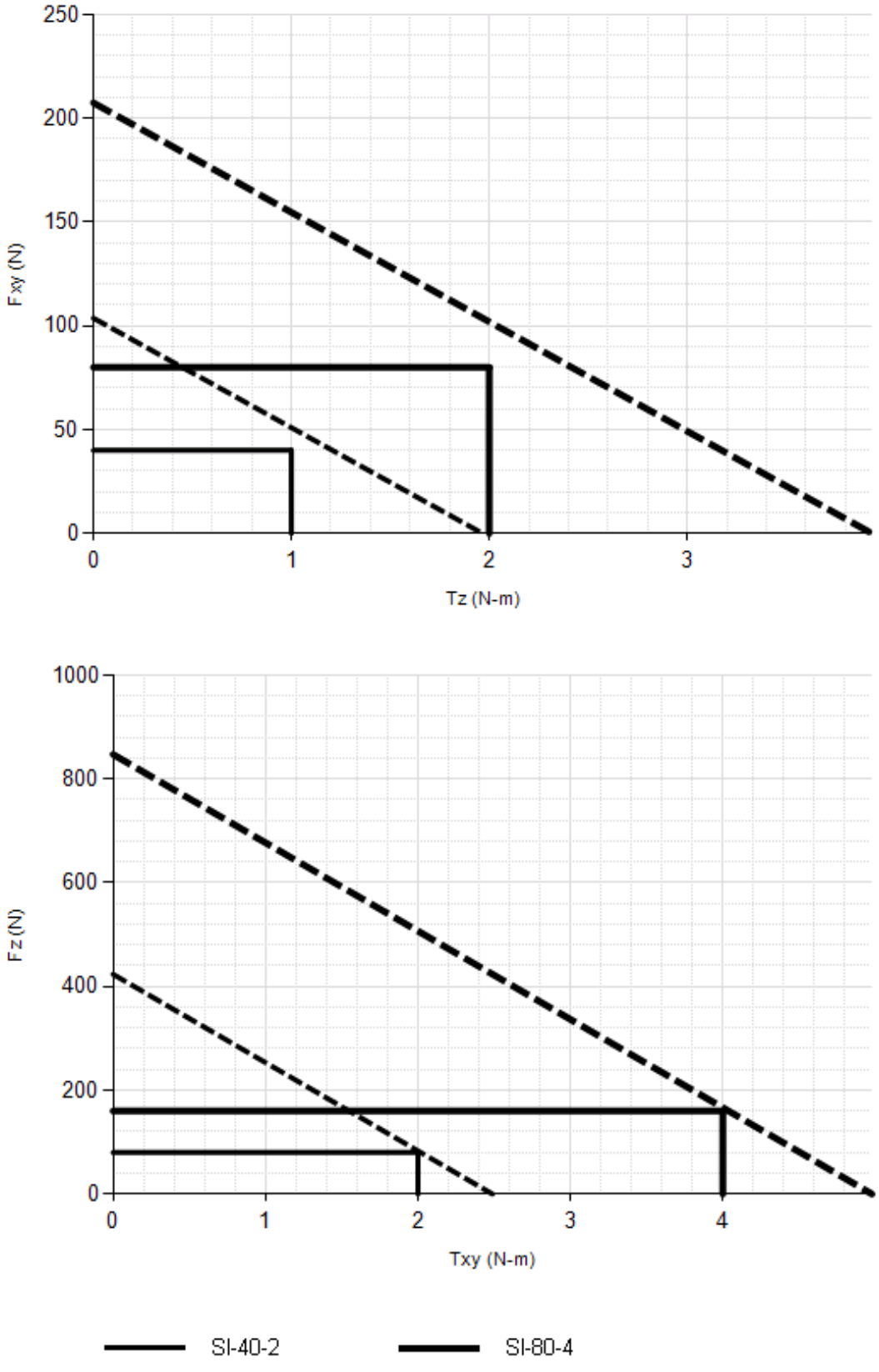
| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±1500 N |
| Fz | ±4600 N |
| Txy | ±30 Nm |
| Tz | ±40 Nm |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $3.1x10^7$ N/m |
| Z-axis force (Kz) | $6.4x10^7$ N/m |
| X-axis & Y-axis torque (Ktx, Kty) | $4.5x10^3$ Nm/rad |
| Z-axis torque (Ktz) | $6.5x10^3$ Nm/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | |
| Fz, Tx, Ty | |
| **Physical Specifications** | |
| Weight* | 0.0334 kg |
| Diameter* | 27 mm |
| Height* | 18.2 mm |

** Specifications include standard interface plate.*

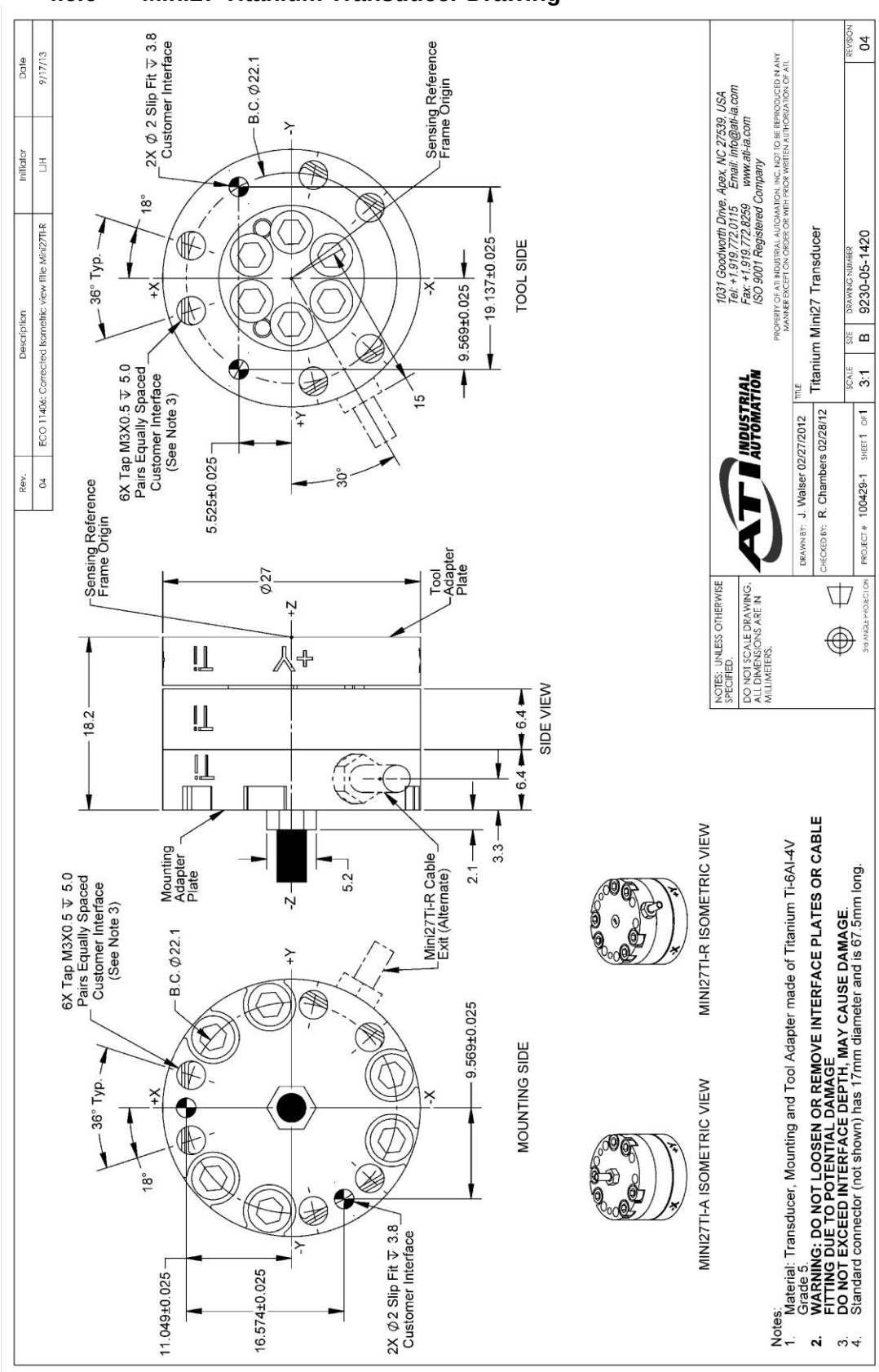
### 4.6.4 Mini27 Titanium (US Calibration Complex Loading)



### 4.6.5 Mini27 Titanium (SI Calibration Complex Loading)



### 4.6.6 Mini27 Titanium Transducer Drawing



## 4.7 Mini40 (Includes IP65/IP68 Versions)

### 4.7.1 Calibration Specifications (excludes CTL calibrations)

**Standard Calibration (US)**

| Calibration | Fx,Fy | Fz | Tx,Ty | Tz | Fx,Fy | Fz | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| US-5–10 | 5 lbf | 15 lbf | 10 lbf-in | 10 lbf-in | 1/800 lbf | 1/400 lbf | 1/800 lbf-in | 1/800 lbf-in |
| US-10–20 | 10 lbf | 30 lbf | 20 lbf-in | 20 lbf-in | 1/400 lbf | 1/200 lbf | 1/400 lbf-in | 1/400 lbf-in |
| US-20–40 | 20 lbf | 60 lbf | 40 lbf-in | 40 lbf-in | 1/200 lbf | 1/100 lbf | 1/200 lbf-in | 1/200 lbf-in |
| | SENSING RANGES | | | | RESOLUTION* | | | |

**Metric Calibration (SI)**

| Calibration | Fx,Fy | Fz | Tx,Ty | Tz | Fx,Fy | Fz | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| SI-20–1 | 20 N | 60 N | 1 Nm | 1 Nm | 1/200 N | 1/100 N | 1/8000 Nm | 1/8000 Nm |
| SI-40–2 | 40 N | 120 N | 2 Nm | 2 Nm | 1/100 N | 1/50 N | 1/4000 Nm | 1/4000 Nm |
| SI-80–4 | 80 N | 240 N | 4 Nm | 4 Nm | 1/50 N | 1/25 N | 1/2000 Nm | 1/2000 Nm |
| | SENSING RANGES | | | | RESOLUTION* | | | |

** DAQ resolutions are typical for a 16-bit data acquisition system.*

*These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.*

### 4.7.2 CTL Calibration Specifications

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz | Tx,Ty | Tz | Fx,Fy | Fz | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| US-5–10 | 5 lbf | 15 lbf | 10 lbf-in | 10 lbf-in | 1/400 lbf | 1/200 lbf | 1/400 lbf-in | 1/400 lbf-in |
| US-10–20 | 10 lbf | 30 lbf | 20 lbf-in | 20 lbf-in | 1/200 lbf | 1/100 lbf | 1/200 lbf-in | 1/200 lbf-in |
| US-20–40 | 20 lbf | 60 lbf | 40 lbf-in | 40 lbf-in | 1/100 lbf | 1/50 lbf | 1/100 lbf-in | 1/100 lbf-in |
| | SENSING RANGES | | | | RESOLUTION | | | |

**Metric Calibrations (SI)**

| Calibration | Fx,Fy | Fz | Tx,Ty | Tz | Fx,Fy | Fz | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| SI-20–1 | 20 N | 60 N | 1 Nm | 1 Nm | 1/100 N | 1/50 N | 1/4000 Nm | 1/4000 Nm |
| SI-40–2 | 40 N | 120 N | 2 Nm | 2 Nm | 1/50 N | 1/25 N | 1/2000 Nm | 1/2000 Nm |
| SI-80–4 | 80 N | 240 N | 4 Nm | 4 Nm | 1/25 N | 2/25 N | 1/1000 Nm | 1/1000 Nm |
| | SENSING RANGES | | | | RESOLUTION | | | |

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz† | Tx,Ty, Tz | Fx,Fy | Fz† | Tx,Ty, Tz |
|---|---|---|---|---|---|---|
| US-5–10 | ±5 lbf | ±15 lbf | ±10 lbf-in | 0.5 lbf/V | 1.5 lbf/V | 1 lbf-in/V |
| US-10–20 | ±10 lbf | ±30 lbf | ±20 lbf-in | 1 lbf/V | 3 lbf/V | 2 lbf-in/V |
| US-20–40 | ±20 lbf | ±60 lbf | ±40 lbf-in | 2 lbf/V | 6 lbf/V | 4 lbf-in/V |
| | Analog Output Range | | | Analog ±10V Sensitivity‡ | | |

**Metric Calibrations (SI)**

| Calibration | Fx,Fy | Fz† | Tx,Ty, Tz | Fx,Fy | Fz† | Tx,Ty, Tz |
|---|---|---|---|---|---|---|
| SI-20–1 | ±20 N | ±60 N | ±1 Nm | 2 N/V | 6 N/V | 0.1 Nm/V |
| SI-40–2 | ±40 N | ±120 N | ±2 Nm | 4 N/V | 12 N/V | 0.2 Nm/V |
| SI-80–4 | ±80 N | ±240 N | ±4 Nm | 8 N/V | 24 N/V | 0.4 Nm/V |
| | Analog Output Range | | | Analog ±10V Sensitivity‡ | | |

**Counts Value**

| Calibration | Fx, Fy, Fz | Tx, Ty, Tz | Fx, Fy, Fz | Tx, Ty, Tz |
|---|---|---|---|---|
| US-5–10 / SI-20–1 | 3200 / lbf | 3200 / lbf-in | 800 / N | 32000 / Nm |
| US-10–20 / SI-40–2 | 1600 / lbf | 1600 / lbf-in | 400 / N | 16000 / Nm |
| US-20–40 / SI-80-4 | 800 / lbf | 800 / lbf-in | 200 / N | 8000 / Nm |
| **Tool Transform Factor** | 0.01 in/lbf | | 0.25 mm/N | |
| | Counts Value – Standard (US) | | Counts Value – Metric (SI) | |

*CTL resolutions are typical. System resolutions quoted are the effective resolution after dropping eight counts of noise. The effective resolution can be improved with filtering. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.*

‡ *±5V Sensitivity values are double the listed ±10V Sensitivity values.*

### 4.7.3 Mini40 Physical Properties

**Standard (US)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±180 lbf |
| Fz | ±530 lbf |
| Txy | ±170 lbf-in |
| Tz | ±180 lbf-in |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $6.1x10^4$ lb/in |
| Z-axis force (Kz) | $1.2x10^5$ lb/in |
| X-axis & Y-axis torque (Ktx, Kty) | $2.5x10^4$ lbf-in/rad |
| Z-axis torque (Ktz) | $3.6x10^4$ lbf-in/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 3200 Hz |
| Fz, Tx, Ty | 4900 Hz |
| **Physical Specifications** | |
| Weight* | 0.11 lb |
| Diameter* | 1.57 in |
| Height* | 0.482 in |

**Metric (SI)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±810 N |
| Fz | ±2400 N |
| Txy | ±19 Nm |
| Tz | ±20 Nm |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $1.1x10^7$ N/m |
| Z-axis force (Kz) | $2.0x10^7$ N/m |
| X-axis & Y-axis torque (Ktx, Kty) | $2.8x10^3$ Nm/rad |
| Z-axis torque (Ktz) | $4.0x10^3$ Nm/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 3200 Hz |
| Fz, Tx, Ty | 4900 Hz |
| **Physical Specifications** | |
| Weight* | 0.0499 kg |
| Diameter* | 40 mm |
| Height* | 12.2 mm |

** Specifications include standard interface plate.*

### 4.7.4 Mini40 IP65/IP68 Physical Properties

**Standard (US)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±180 lbf |
| Fz | ±530 lbf |
| Txy | ±170 lbf-in |
| Tz | ±180 lbf-in |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $6.1x10^4$ lb/in |
| Z-axis force (Kz) | $1.2x10^5$ lb/in |
| X-axis & Y-axis torque (Ktx, Kty) | $2.5x10^4$ lbf-in/rad |
| Z-axis torque (Ktz) | $3.6x10^4$ lbf-in/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 1400 Hz |
| Fz, Tx, Ty | 1300 Hz |
| **Physical Specifications** | |
| Weight* | 0.6 lb |
| Diameter* | 2.1 in |
| Height* | 0.83 in |

**Metric (SI)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±810 N |
| Fz | ±2400 N |
| Txy | ±19 Nm |
| Tz | ±20 Nm |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $1.1x10^7$ N/m |
| Z-axis force (Kz) | $2.0x10^7$ N/m |
| X-axis & Y-axis torque (Ktx, Kty) | $2.8x10^3$ Nm/rad |
| Z-axis torque (Ktz) | $4.0x10^3$ Nm/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 1400 Hz |
| Fz, Tx, Ty | 1300 Hz |
| **Physical Specifications** | |
| Weight* | 0.272 kg |
| Diameter* | 53.3 mm |
| Height* | 21.1 mm |

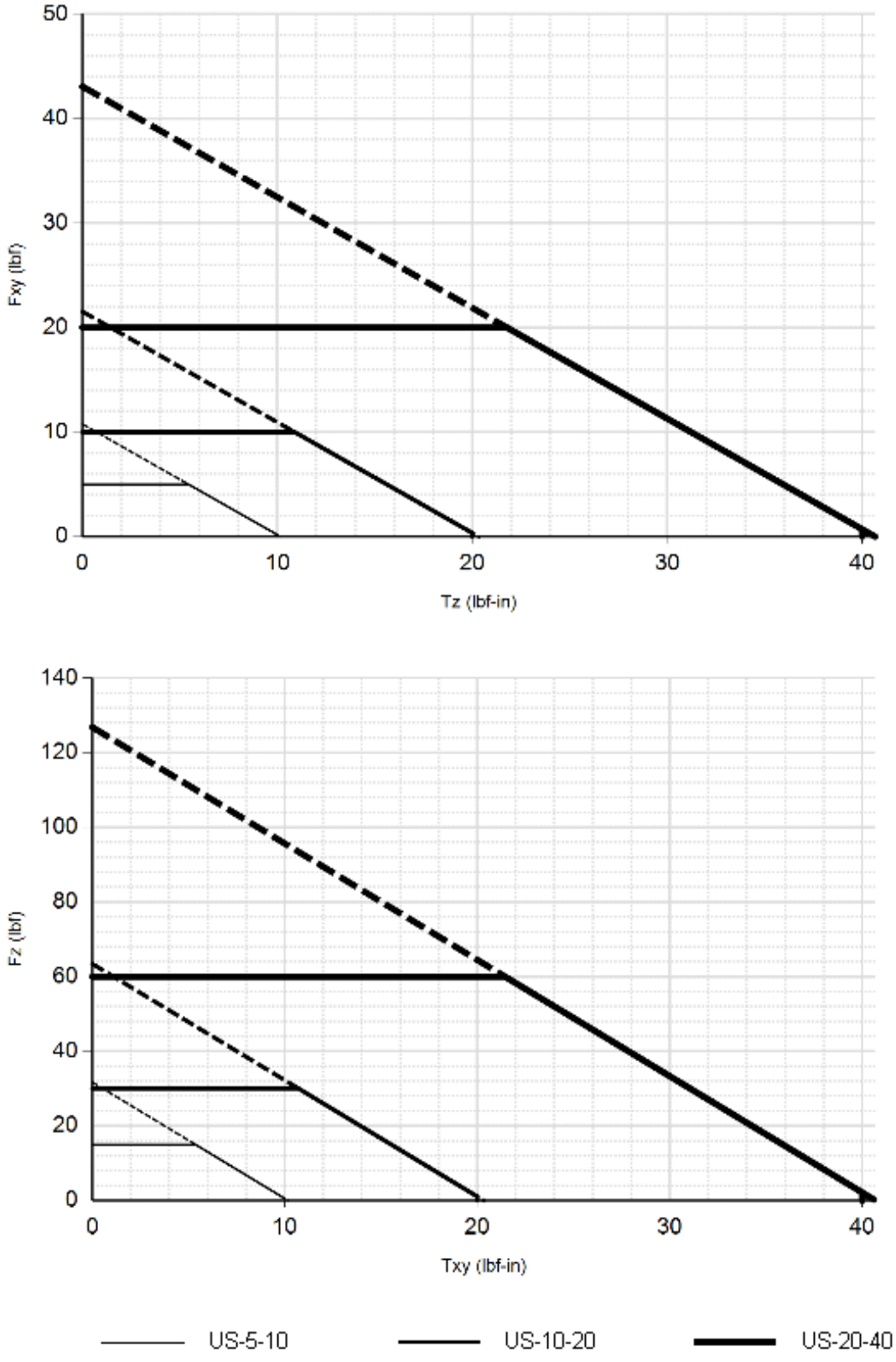
** Specifications include standard interface plate.*

**CAUTION:**
**IP68 Mini40 Fz as a Function of Submersion Depth:**

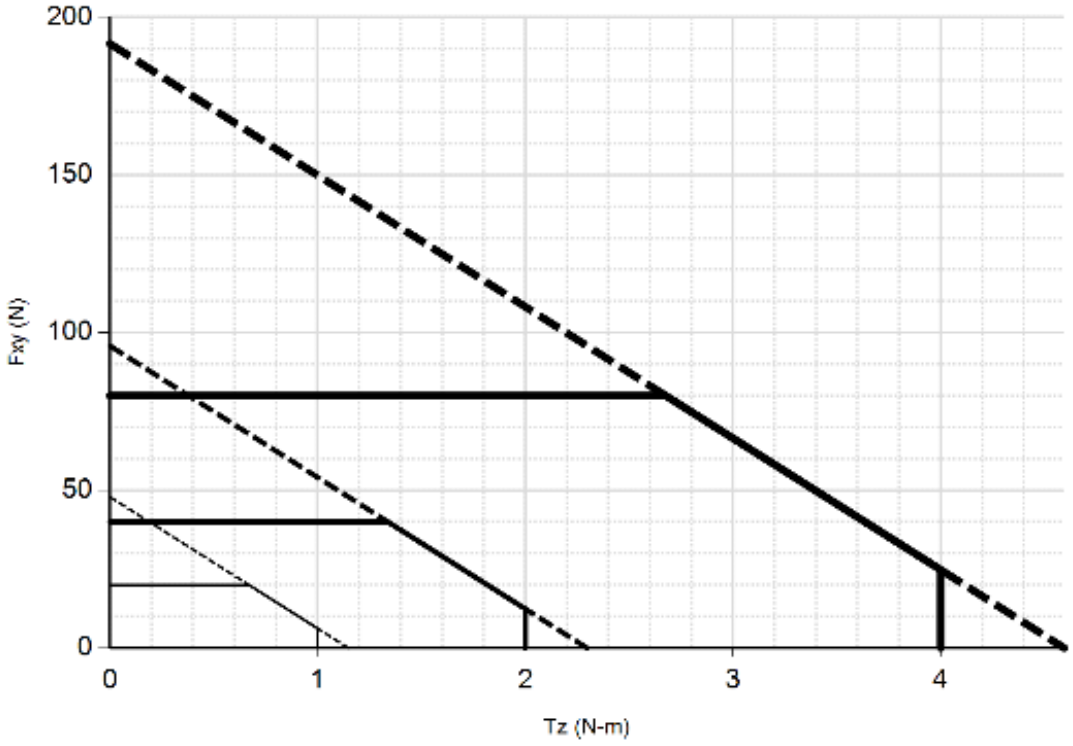
When submerged, IP68 transducers exhibit a decrease in Fz range related to the submersion depth. This loss is the result of pressure-induced preloading on the transducer. The preload can be masked by biasing the transducer at the depth prior to applying the load to be measured. The following estimates are for room temperature fresh water at sea level.

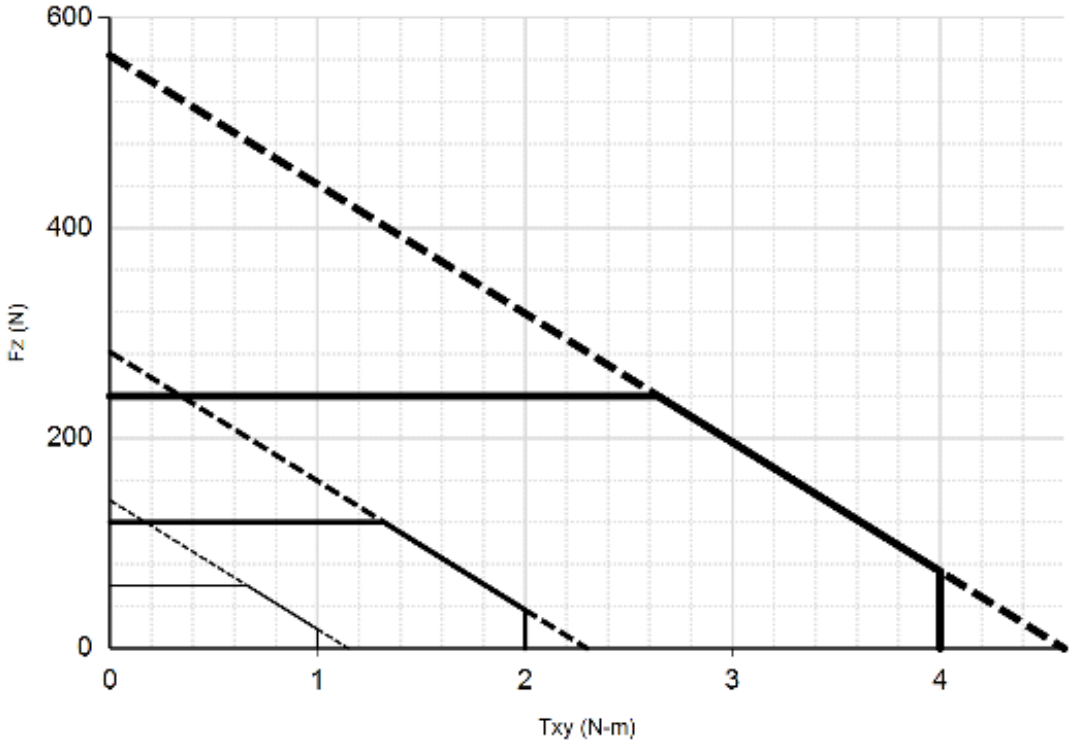
| ***IP68 Mini40*** | **US** | **Metric** |
|---|---|---|
| Fz preload at 4m depth | 17.0 lb | 75.5 N |
| Fz preload at other depths | -1.29 lb/ft × depthInFeet | -18.9 N/m × depthInMeters |

### 4.7.5 Mini40 (US Calibration Complex Loading)



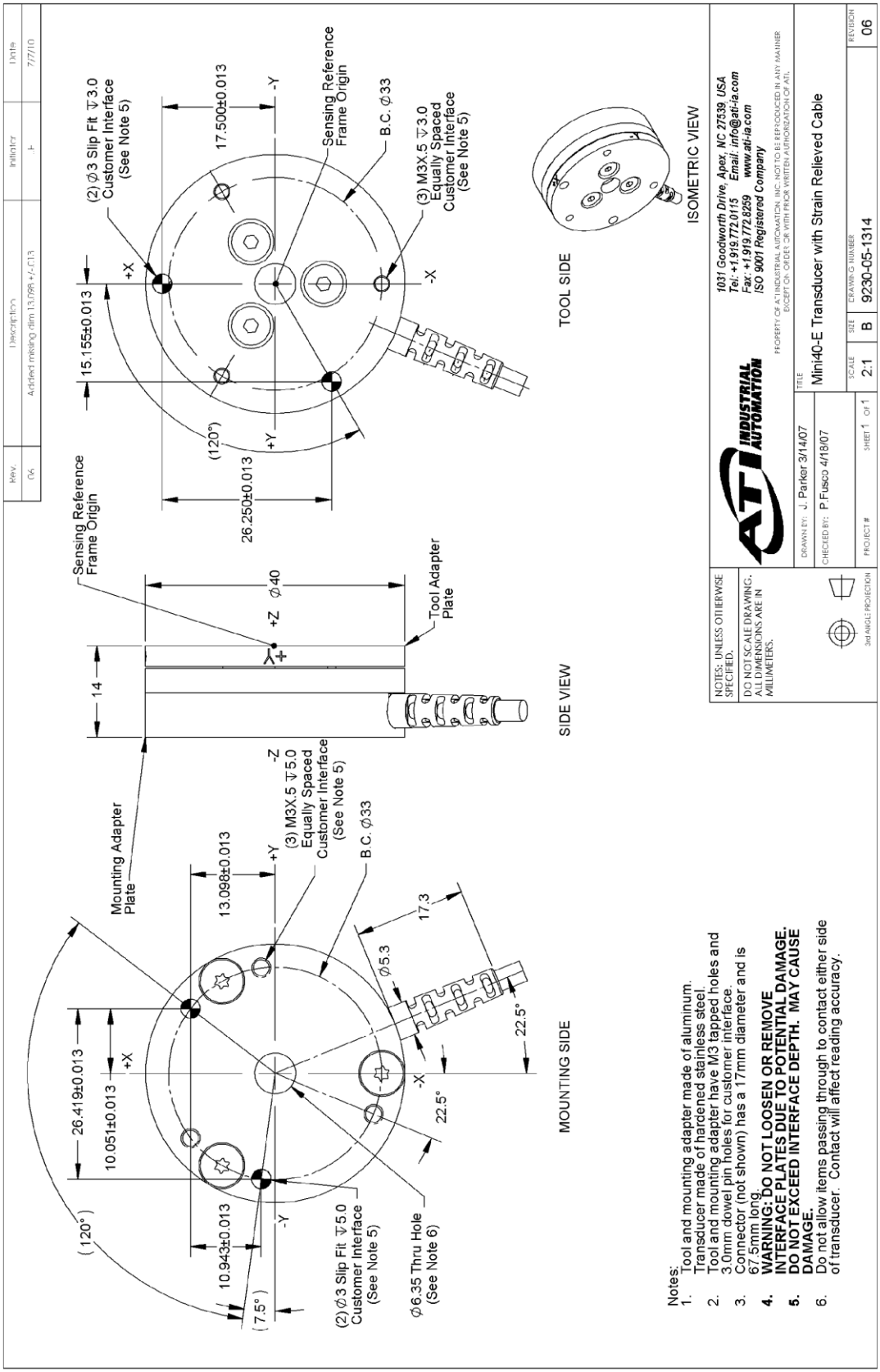
### 4.7.6 Mini40 (SI Calibration Complex Loading)



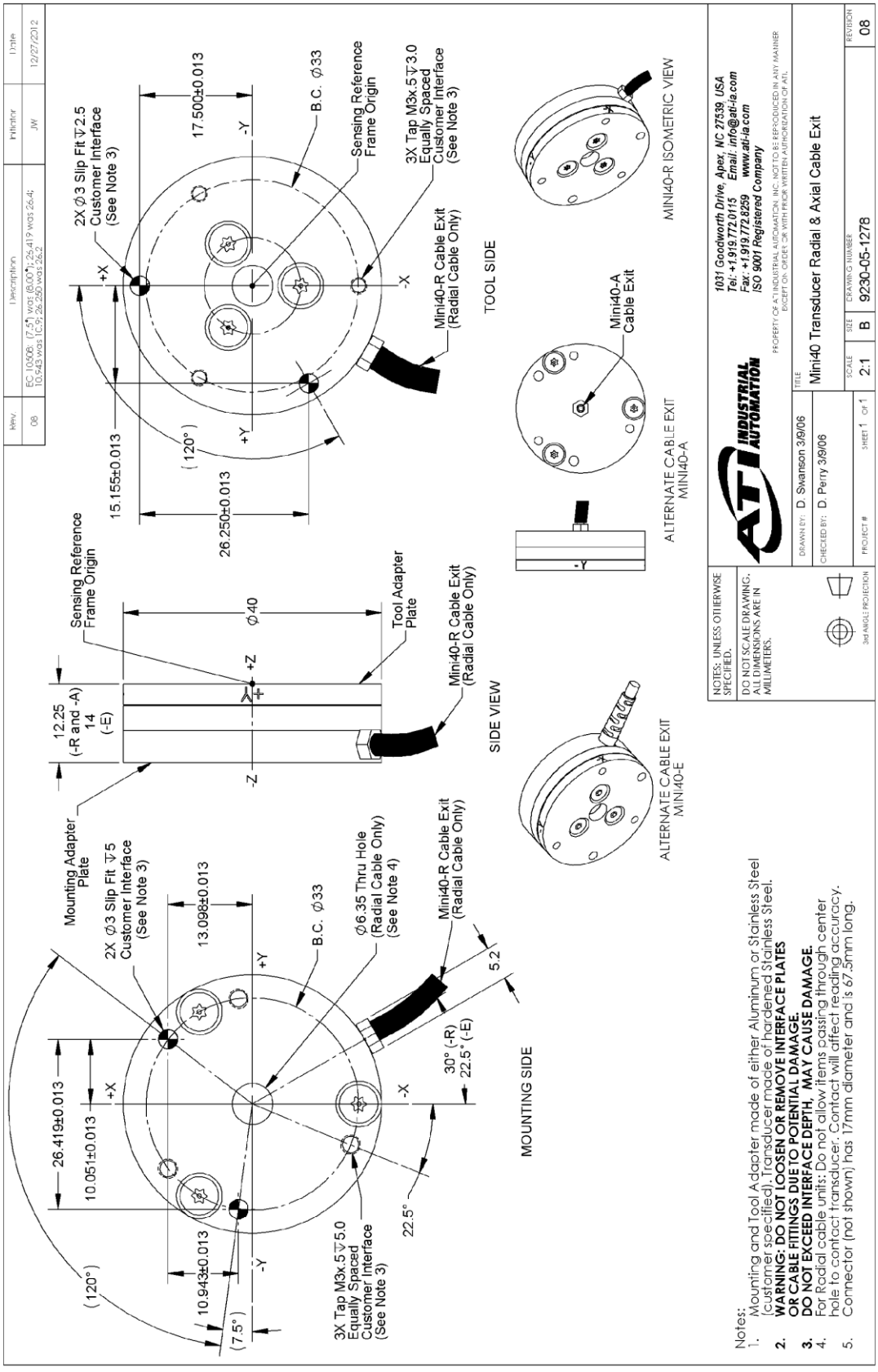




SI-20-1 SI-40-2 SI-80-4

### 4.7.7 Mini40-E Transducer Drawing



### 4.7.8 Legacy Mini40 Transducer Drawing



## 4.8 Mini45 Titanium

### 4.8.1 Calibration Specifications (excludes CTL calibrations)

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz | Tx,Ty | Tz | Fx,Fy | Fz | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| US-15-25 | 15 lbf | 15 lbf | 25 lbf-in | 25 lbf-in | 3/800 lbf | 1/160 lbf | 1/300 lbf-in | 1/400 lbf-in |
| US-30–50 | 30 lbf | 60 lbf | 50 lbf-in | 50 lbf-in | 3/400 lbf | 1/80 lbf | 1/150 lbf-in | 1/200 lbf-in |
| US-60–100 | 60 lbf | 120 lbf | 100 lbf-in | 100 lbf-in | 3/200 lbf | 1/40 lbf | 1/75 lbf-in | 1/100 lbf-in |
| | SENSING RANGES | | | | RESOLUTION* | | | |

**Metric Calibrations (SI)**

| Calibration | Fx,Fy | Fz | Tx,Ty | Tz | Fx,Fy | Fz | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| SI-60-3 | 60 N | 120 N | 3 Nm | 3 Nm | 1/60 N | 7/240 N | 3/8000 Nm | 1/3200 Nm |
| SI-120–6 | 120 N | 240 N | 6 Nm | 6 Nm | 1/30 N | 7/120 N | 3/4000 Nm | 1/1600 Nm |
| SI-240-12 | 240 N | 480 N | 12 Nm | 12 Nm | 1/15 N | 7/60 N | 3/2000 Nm | 1/800 Nm |
| | SENSING RANGES | | | | RESOLUTION* | | | |

** DAQ resolutions are typical for a 16-bit data acquisition system.*

*These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.*

### 4.8.2 CTL Calibration Specifications

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz | Tx,Ty | Tz | Fx,Fy | Fz | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| US-15-25 | 15 lbf | 30 lbf | 25 lbf-in | 25 lbf-in | 3/400 lbf | 1/80 lbf | 1/150 lbf-in | 1/200 lbf-in |
| US-30–50 | 30 lbf | 60 lbf | 50 lbf-in | 50 lbf-in | 3/200 lbf | 1/40 lbf | 1/75 lbf-in | 1/100 lbf-in |
| US-60–100 | 60 lbf | 120 lbf | 100 lbf-in | 100 lbf-in | 3/100 lbf | 1/20 lbf | 2/75 lbf-in | 1/50 lbf-in |
| | SENSING RANGES | | | | RESOLUTION | | | |

**Metric Calibrations (SI)**

| Calibration | Fx,Fy | Fz | Tx,Ty | Tz | Fx,Fy | Fz | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| SI-60-3 | 60 N | 120 N | 3 Nm | 3 Nm | 1/30 N | 7/120 N | 3/4000 Nm | 1/1600 Nm |
| SI-120–6 | 120 N | 240 N | 6 Nm | 6 Nm | 1/15 N | 7/60 N | 3/2000 Nm | 1/800 Nm |
| SI-240-12 | 240 N | 480 N | 12 Nm | 12 Nm | 2/15 N | 7/30 N | 3/1000 Nm | 1/400 Nm |
| | SENSING RANGES | | | | RESOLUTION | | | |

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz† | Tx,Ty, Tz | Fx,Fy | Fz† | Tx,Ty, Tz |
|---|---|---|---|---|---|---|
| US-15-25 | ±30 lbf | ±60 lbf | ±40 lbf-in | 3 lbf/V | 6 lbf/V | 4 lbf-in/V |
| US-30–50 | ±60 lbf | ±120 lbf | ±80 lbf-in | 6 lbf/V | 12 lbf/V | 8 lbf-in/V |
| US-60–100 | ±120 lbf | ±240 lbf | ±160 lbf-in | 12 lbf/V | 24 lbf/V | 16 lbf-in/V |
| | Analog Output Range | | | Analog ±10V Sensitivity‡ | | |

**Metric Calibrations (SI)**

| Calibration | Fx,Fy | Fz† | Tx,Ty, Tz | Fx,Fy | Fz† | Tx,Ty, Tz |
|---|---|---|---|---|---|---|
| SI-60-3 | ±145 N | ±290 N | ±5 Nm | 14.5 N/V | 29 N/V | 0.5 Nm/V |
| SI-120–6 | ±290 N | ±580 N | ±10 Nm | 29 N/V | 58 N/V | 1 Nm/V |
| SI-240-12 | ±580 N | ±1160 N | ±20 Nm | 58 N/V | 116 N/V | 2 Nm/V |
| | Analog Output Range | | | Analog ±10V Sensitivity‡ | | |

**Counts Value**

| Calibration | Fx, Fy, Fz | Tx, Ty, Tz | Fx, Fy, Fz | Tx, Ty, Tz |
|---|---|---|---|---|
| US-15-25 / SI-60-3 | 640 / lbf | 704 / lbf-in | 128 / N | 6016 / Nm |
| US-30-50 / SI-120-6 | 320 / lbf | 352 / lbf-in | 64 / N | 3008 / Nm |
| US-60-100 / SI-240-12 | 160 / lbf | 176 / lbf-in | 32 / N | 1504 / Nm |
| **Tool Transform Factor** | 0.009091 in/lbf | | 0.21277 mm/N | |
| | Counts Value – Standard (US) | | Counts Value – Metric (SI) | |

*CTL resolutions are typical. System resolutions quoted are the effective resolution after dropping eight counts of noise. The effective resolution can be improved with filtering. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.*

‡ *±5V Sensitivity values are double the listed ±10V Sensitivity values.*

### 4.8.3 Mini45 Titanium Physical Properties

**Standard (US)**

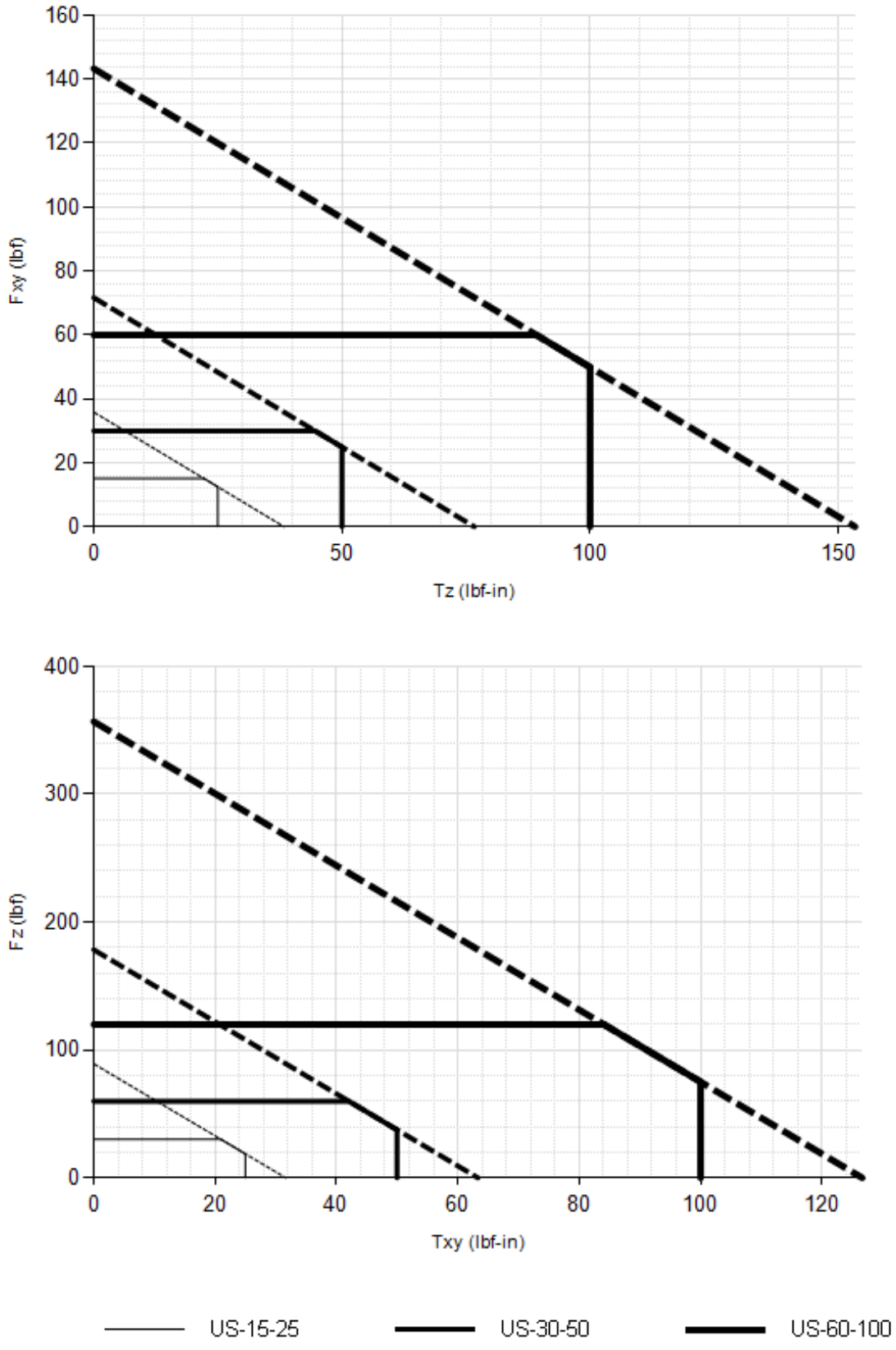
| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±670 lbf |
| Fz | ±1400 lbf |
| Txy | ±590 lbf-in |
| Tz | ±720 lbf-in |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $2.5x10^5$ lb/in |
| Z-axis force (Kz) | $3.3x10^5$ lb/in |
| X-axis & Y-axis torque (Ktx, Kty) | $8.6x10^4$ lbf-in/rad |
| Z-axis torque (Ktz) | $1.8x10^5$ lbf-in/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 5800 Hz |
| Fz, Tx, Ty | 4600 Hz |
| **Physical Specifications** | |
| Weight* | 0.22 lb |
| Diameter* | 1.77 in |
| Height* | 0.69 in |

**Metric (SI)**

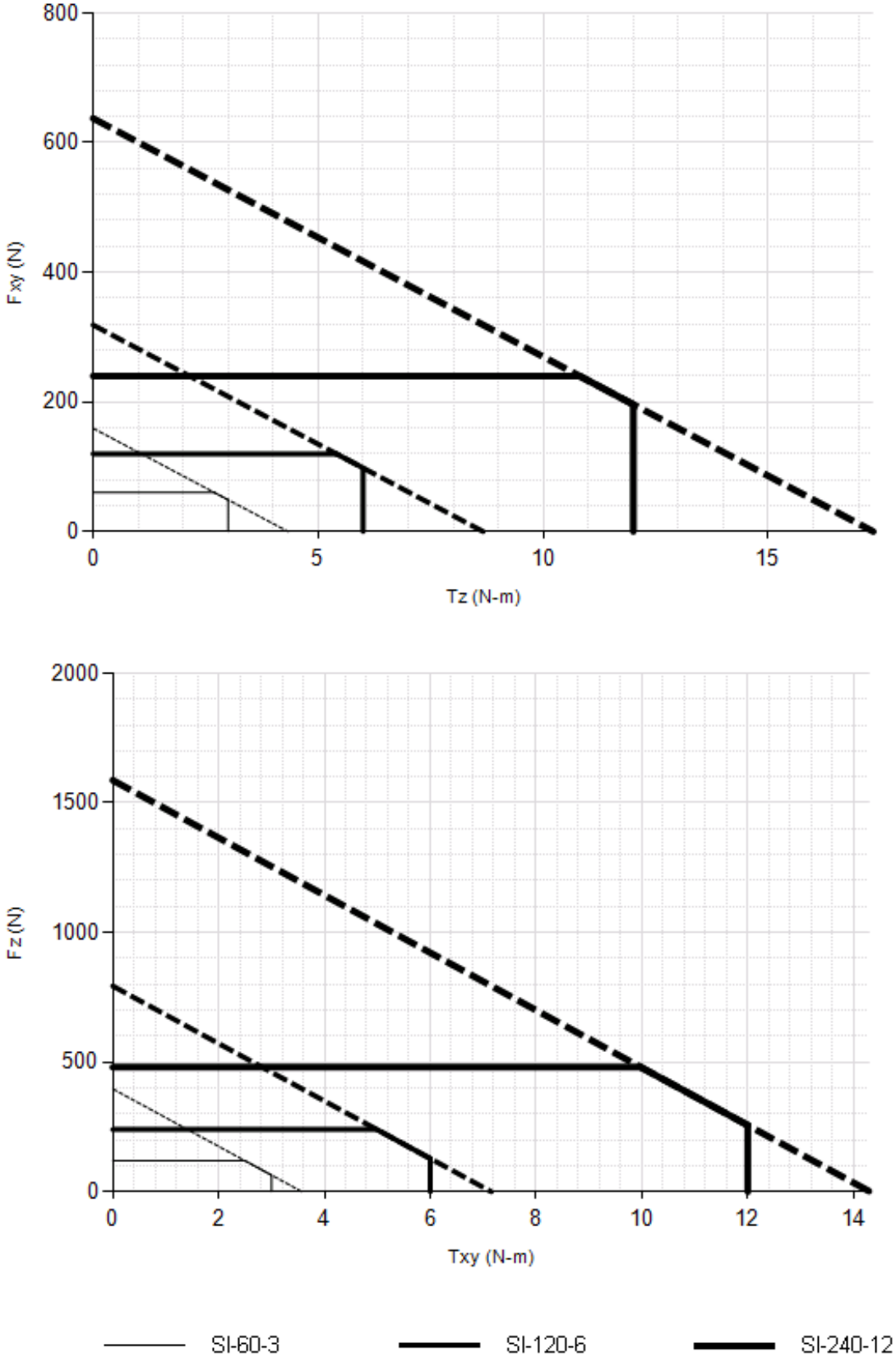
| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±3000 N |
| Fz | ±6400 N |
| Txy | ±67 Nm |
| Tz | ±81 Nm |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $4.3x10^7$ N/m |
| Z-axis force (Kz) | $5.7x10^7$ N/m |
| X-axis & Y-axis torque (Ktx, Kty) | $9.7x10^3$ Nm/rad |
| Z-axis torque (Ktz) | $2.0x10^4$ Nm/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 5800 Hz |
| Fz, Tx, Ty | 4600 Hz |
| **Physical Specifications** | |
| Weight* | 0.0998 kg |
| Diameter* | 45 mm |
| Height* | 17.5 mm |

** Specifications include standard interface plates.*

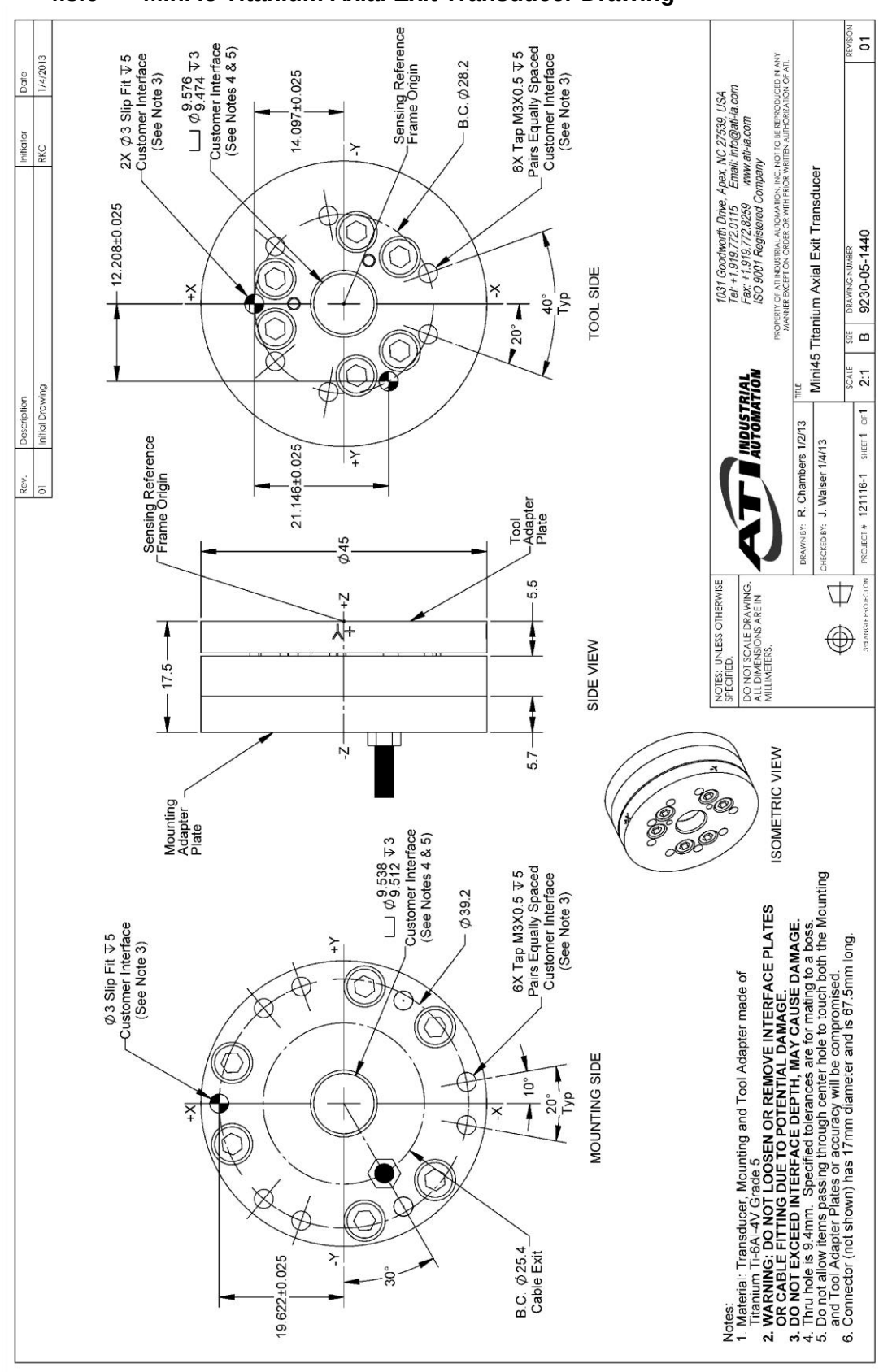
### 4.8.4 Mini45 Titanium (US Calibration Complex Loading)



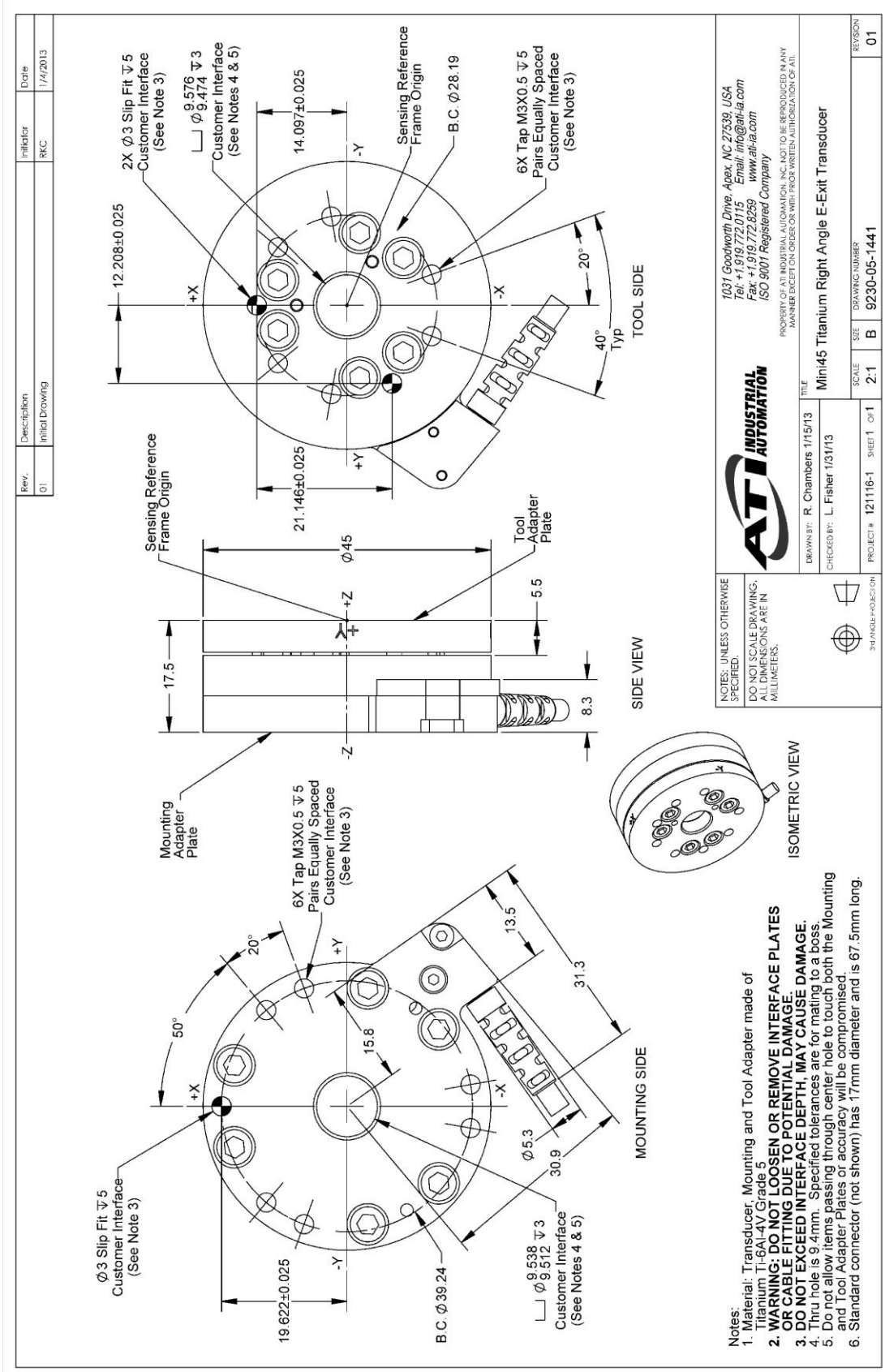
### 4.8.5 Mini45 Titanium (SI Calibration Complex Loading)



### 4.8.6 Mini45 Titanium Axial Exit Transducer Drawing



### 4.8.7 Mini45 Titanium Right Angle E-Exit Transducer Drawing



## 4.9 Mini45 (Includes IP65/IP68 versions)

### 4.9.1 Calibration Specifications (excludes CTL calibrations)

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz | Tx,Ty | Tz | Fx,Fy | Fz | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| US-30-40 | 30 lbf | 60 lbf | 40 lbf-in | 40 lbf-in | 1/80 lbf | 1/80 lbf | 1/88 lbf-in | 1/176 lbf-in |
| US-60–80 | 60 lbf | 120 lbf | 80 lbf-in | 80 lbf-in | 1/40 lbf | 1/40 lbf | 1/44 lbf-in | 1/88 lbf-in |
| US-120–160 | 120 lbf | 240 lbf | 160 lbf-in | 160 lbf-in | 1/20 lbf | 1/20 lbf | 1/22 lbf-in | 1/44 lbf-in |
| | SENSING RANGES | | | | RESOLUTION* | | | |

**Metric Calibrations (SI)**

| Calibration | Fx,Fy | Fz | Tx,Ty | Tz | Fx,Fy | Fz | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| SI-145–5 | 145 N | 290 N | 5 Nm | 5 Nm | 1/16 N | 1/16 N | 1/752 Nm | 1/1504 Nm |
| SI-290–10 | 290 N | 580 N | 10 Nm | 10 Nm | 1/8 N | 1/8 N | 1/376 Nm | 1/752 Nm |
| SI-580–20 | 580 N | 1160 N | 20 Nm | 20 Nm | 1/4 N | 1/4 N | 1/188 Nm | 1/376 Nm |
| | SENSING RANGES | | | | RESOLUTION* | | | |

** DAQ resolutions are typical for a 16-bit data acquisition system.*

*These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.*

### 4.9.2 CTL Calibration Specifications

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz | Tx,Ty | Tz | Fx,Fy | Fz | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| US-30–40 | 30 lbf | 60 lbf | 40 lbf-in | 40 lbf-in | 1/40 lbf | 1/40 lbf | 1/44 lbf-in | 1/88 lbf-in |
| US-60–80 | 60 lbf | 120 lbf | 80 lbf-in | 80 lbf-in | 1/20 lbf | 1/20 lbf | 1/22 lbf-in | 1/44 lbf-in |
| US-120–160 | 120 lbf | 240 lbf | 160 lbf-in | 160 lbf-in | 1/10 lbf | 1/10 lbf | 1/11 lbf-in | 1/22 lbf-in |
| | SENSING RANGES | | | | RESOLUTION | | | |

**Metric Calibrations (SI)**

| Calibration | Fx,Fy | Fz | Tx,Ty | Tz | Fx,Fy | Fz | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| SI-145–5 | 145 N | 290 N | 5 Nm | 5 Nm | 1/8 N | 1/8 N | 1/376 Nm | 1/752 Nm |
| SI-290–10 | 290 N | 580 N | 10 Nm | 10 Nm | 1/4 N | 1/4 N | 1/188 Nm | 1/376 Nm |
| SI-580–20 | 580 N | 1160 N | 20 Nm | 20 Nm | 1/2 N | 1/2 N | 1/94 Nm | 1/188 Nm |
| | SENSING RANGES | | | | RESOLUTION | | | |

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz† | Tx,Ty, Tz | Fx,Fy | Fz† | Tx,Ty, Tz |
|---|---|---|---|---|---|---|
| US-30–40 | ±30 lbf | ±60 lbf | ±40 lbf-in | 3 lbf/V | 6 lbf/V | 4 lbf-in/V |
| US-60–80 | ±60 lbf | ±120 lbf | ±80 lbf-in | 6 lbf/V | 12 lbf/V | 8 lbf-in/V |
| US-120–160 | ±120 lbf | ±240 lbf | ±160 lbf-in | 12 lbf/V | 24 lbf/V | 16 lbf-in/V |
| | Analog Output Range | | | Analog ±10V Sensitivity‡ | | |

**Metric Calibrations (SI)**

| Calibration | Fx,Fy | Fz† | Tx,Ty, Tz | Fx,Fy | Fz† | Tx,Ty, Tz |
|---|---|---|---|---|---|---|
| SI-145–5 | ±145 N | ±290 N | ±5 Nm | 14.5 N/V | 29 N/V | 0.5 Nm/V |
| SI-290–10 | ±290 N | ±580 N | ±10 Nm | 29 N/V | 58 N/V | 1 Nm/V |
| SI-580–20 | ±580 N | ±1160 N | ±20 Nm | 58 N/V | 116 N/V | 2 Nm/V |
| | Analog Output Range | | | Analog ±10V Sensitivity‡ | | |

**Counts Value**

| Calibration | Fx, Fy, Fz | Tx, Ty, Tz | Fx, Fy, Fz | Tx, Ty, Tz |
|---|---|---|---|---|
| US-30–40 / SI-145–5 | 640 / lbf | 704 / lbf-in | 128 / N | 6016 / Nm |
| US-60–80 / SI-290–10 | 320 / lbf | 352 / lbf-in | 64 / N | 3008 / Nm |
| US-120–160 / SI-580–20 | 160 / lbf | 176 / lbf-in | 32 / N | 1504 / Nm |
| **Tool Transform Factor** | 0.009091 in/lbf | | 0.21277 mm/N | |
| | Counts Value – Standard (US) | | Counts Value – Metric (SI) | |

*CTL resolutions are typical. System resolutions quoted are the effective resolution after dropping eight counts of noise. The effective resolution can be improved with filtering. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.*

‡ *±5V Sensitivity values are double the listed ±10V Sensitivity values.*

### 4.9.3 Mini45 Physical Properties

**Standard (US)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±1100 lbf |
| Fz | ±2300 lbf |
| Txy | ±1000 lbf-in |
| Tz | ±1200 lbf-in |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $4.2x10^5$ lb/in |
| Z-axis force (Kz) | $5.6x10^5$ lb/in |
| X-axis & Y-axis torque (Ktx, Kty) | $1.5x10^5$ lbf-in/rad |
| Z-axis torque (Ktz) | $3.1x10^5$ lbf-in/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 5600 Hz |
| Fz, Tx, Ty | 5400 Hz |
| **Physical Specifications** | |
| Weight* | 0.202 lb |
| Diameter* | 1.77 in |
| Height* | 0.618 in |

**Metric (SI)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±5100 N |
| Fz | ±10000 N |
| Txy | ±110 Nm |
| Tz | ±140 Nm |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $7.4x10^7$ N/m |
| Z-axis force (Kz) | $9.8x10^7$ N/m |
| X-axis & Y-axis torque (Ktx, Kty) | $1.7x10^4$ Nm/rad |
| Z-axis torque (Ktz) | $3.5x10^4$ Nm/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 5600 Hz |
| Fz, Tx, Ty | 5400 Hz |
| **Physical Specifications** | |
| Weight* | 0.0917 kg |
| Diameter* | 45 mm |
| Height* | 15.7 mm |

** Specifications include standard interface plates.*

**CAUTION:**
**IP68 Mini45 Fz as a Function of Submersion Depth:**

When submerged, IP68 transducers exhibit a decrease in Fz range related to the submersion depth. This loss is the result of pressure-induced preloading on the transducer. The preload can be masked by biasing the transducer at the depth prior to applying the load to be measured. The following estimates are for room temperature fresh water at sea level.

| ***IP68 Mini45*** | **US** | **Metric** |
|---|---|---|
| Fz preload at 4m depth | 17.0 lb | 75.5 N |
| Fz preload at other depths | -1.29 lb/ft × depthInFeet | -18.9 N/m × depthInMeters |

### 4.9.4 Mini45 IP65/IP68 Physical Properties

**Standard (US)**

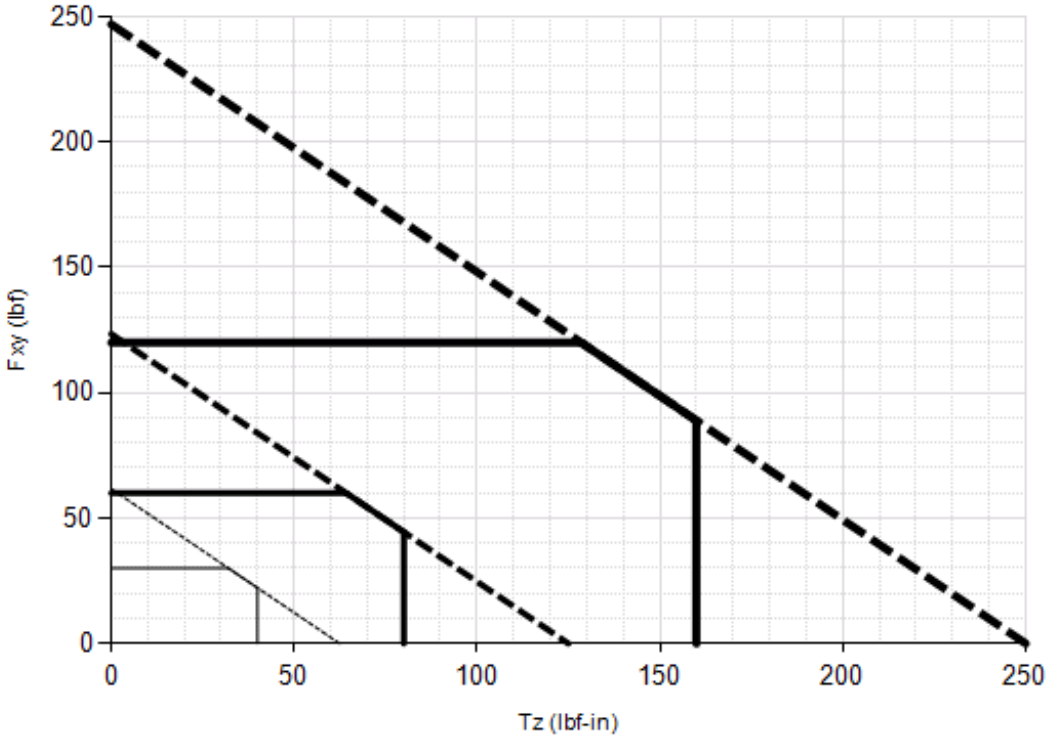
| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±1100 lbf |
| Fz | ±2300 lbf |
| Txy | ±1000 lbf-in |
| Tz | ±1200 lbf-in |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $4.2 \times 10^5$ lb/in |
| Z-axis force (Kz) | $5.6 \times 10^5$ lb/in |
| X-axis & Y-axis torque (Ktx, Kty) | $1.5 \times 10^5$ lbf-in/rad |
| Z-axis torque (Ktz) | $3.1 \times 10^5$ lbf-in/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 5200 Hz |
| Fz, Tx, Ty | 4200 Hz |
| **Physical Specifications** | |
| Weight* | 0.861 lb |
| Diameter* | 2.28 in |
| Height* | 0.988 in |

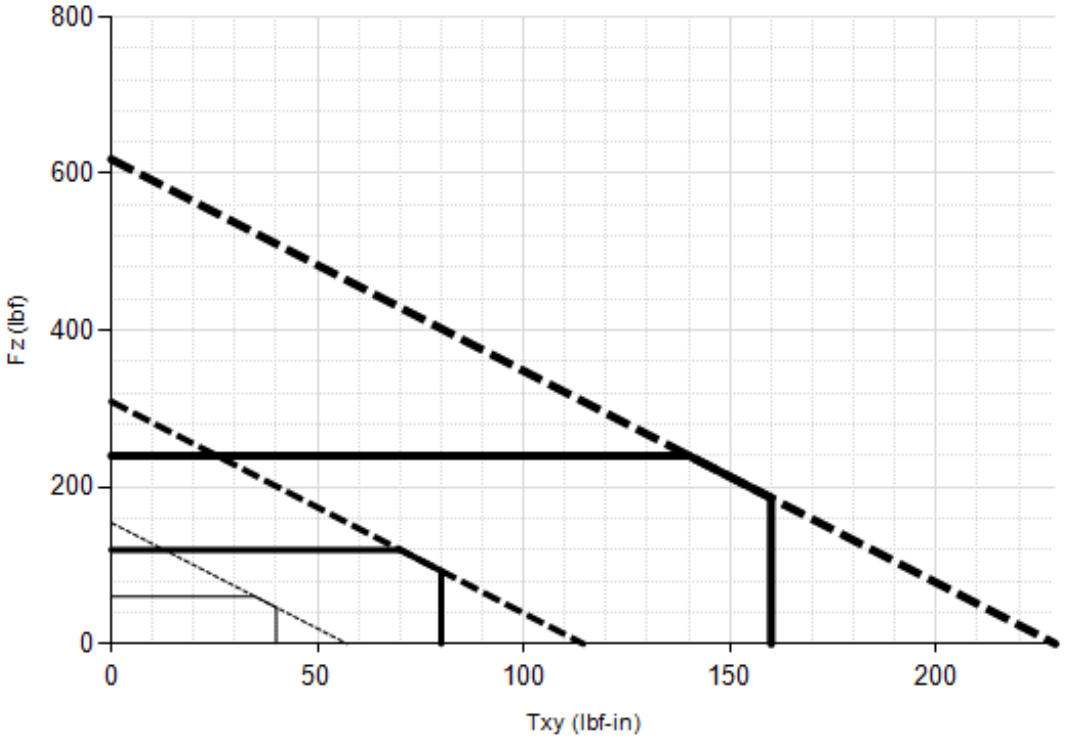
**Metric (SI)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±5100 N |
| Fz | ±10000 N |
| Txy | ±110 Nm |
| Tz | ±140 Nm |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $7.4 \times 10^7$ N/m |
| Z-axis force (Kz) | $9.8 \times 10^7$ N/m |
| X-axis & Y-axis torque (Ktx, Kty) | $1.7 \times 10^4$ Nm/rad |
| Z-axis torque (Ktz) | $3.5 \times 10^4$ Nm/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 5200 Hz |
| Fz, Tx, Ty | 4200 Hz |
| **Physical Specifications** | |
| Weight* | 0.391 kg |
| Diameter* | 57.9 mm |
| Height* | 25.1 mm |

** Specifications include standard interface plates.*

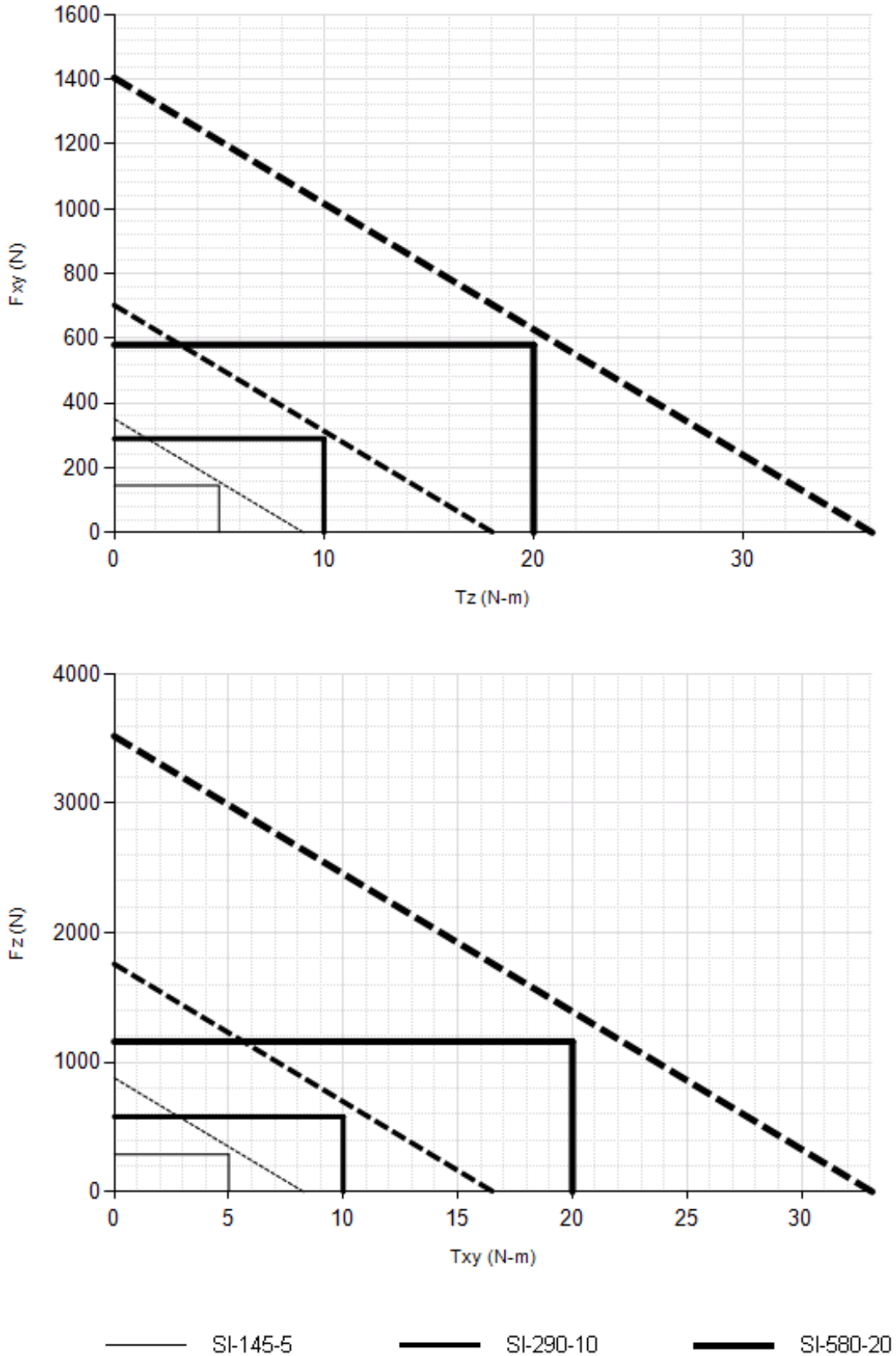
### 4.9.5 Mini45 (US Calibration Complex Loading)



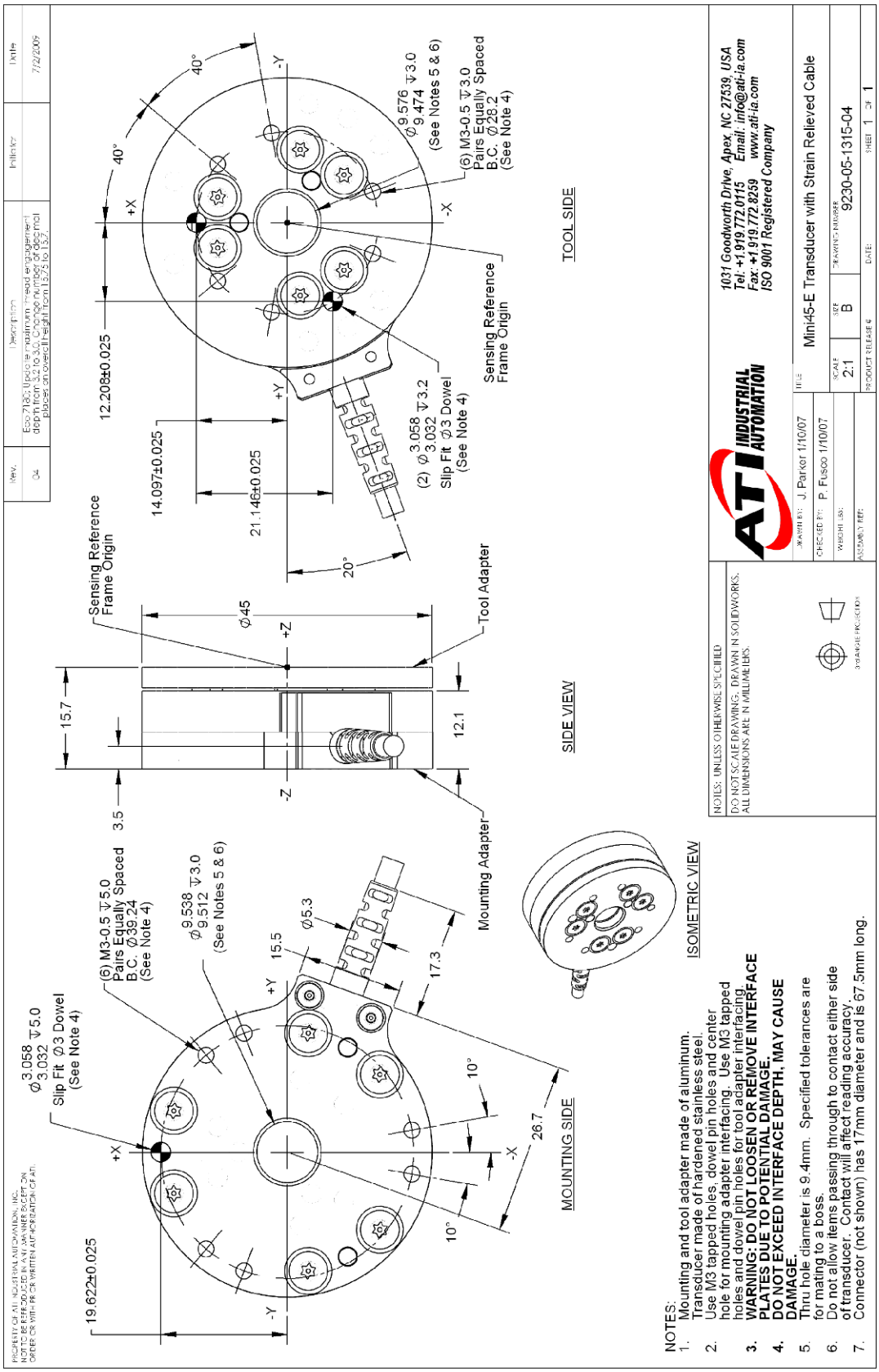




US-30-40 US-60-80 US-120-160

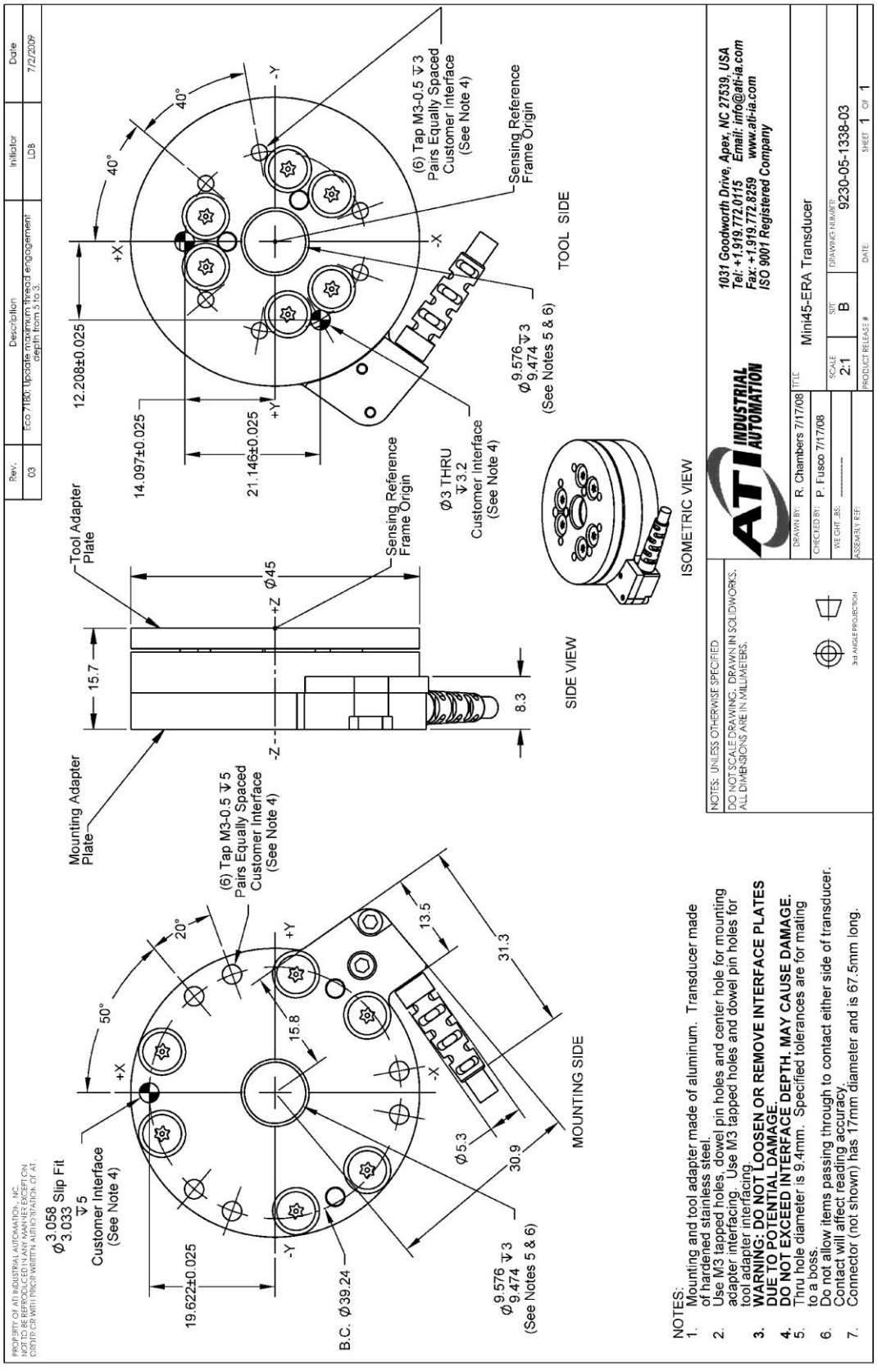
### 4.9.6 Mini45 (SI Calibration Complex Loading)



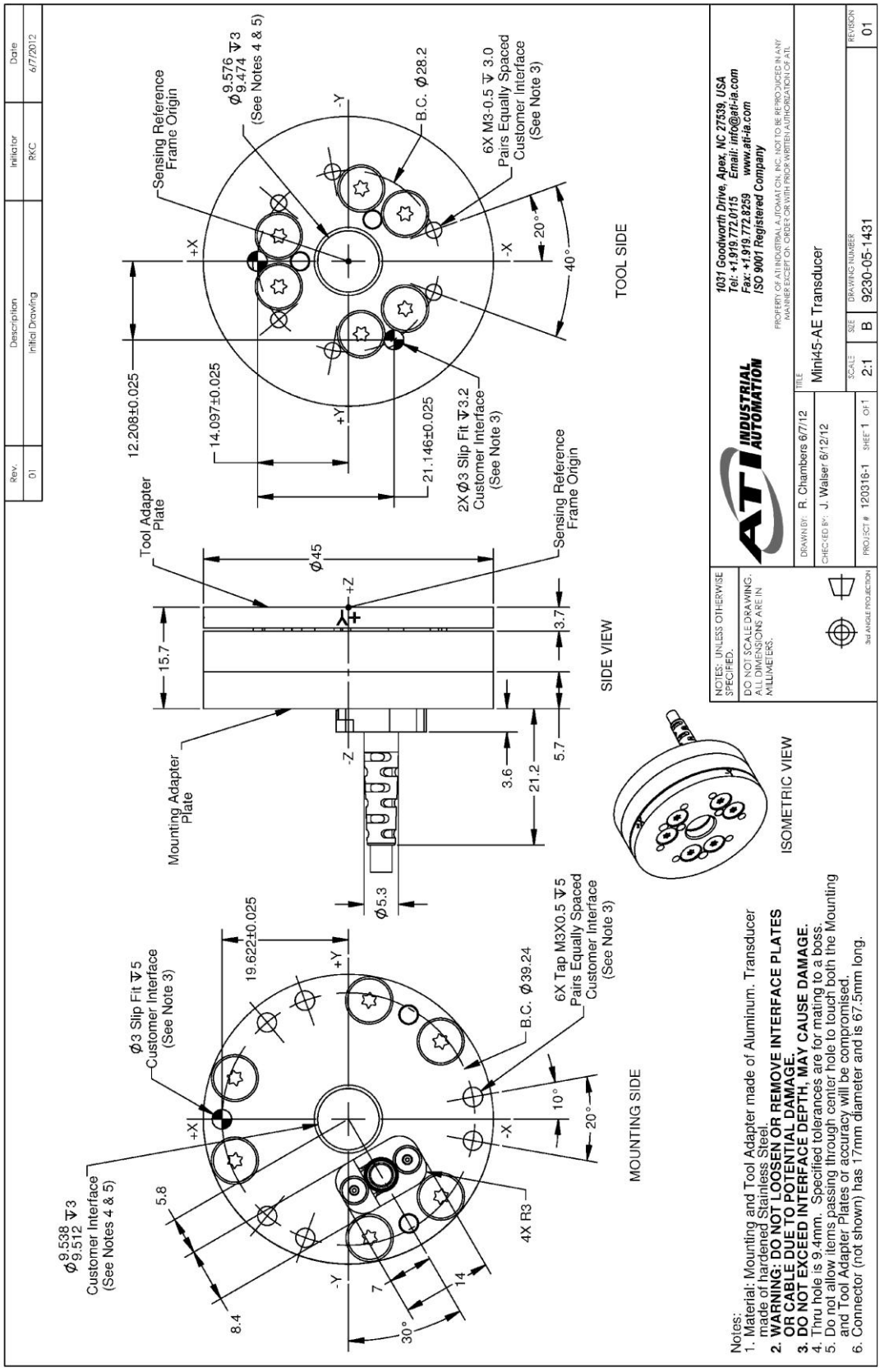
### 4.9.7 Mini45-E Transducer Drawing



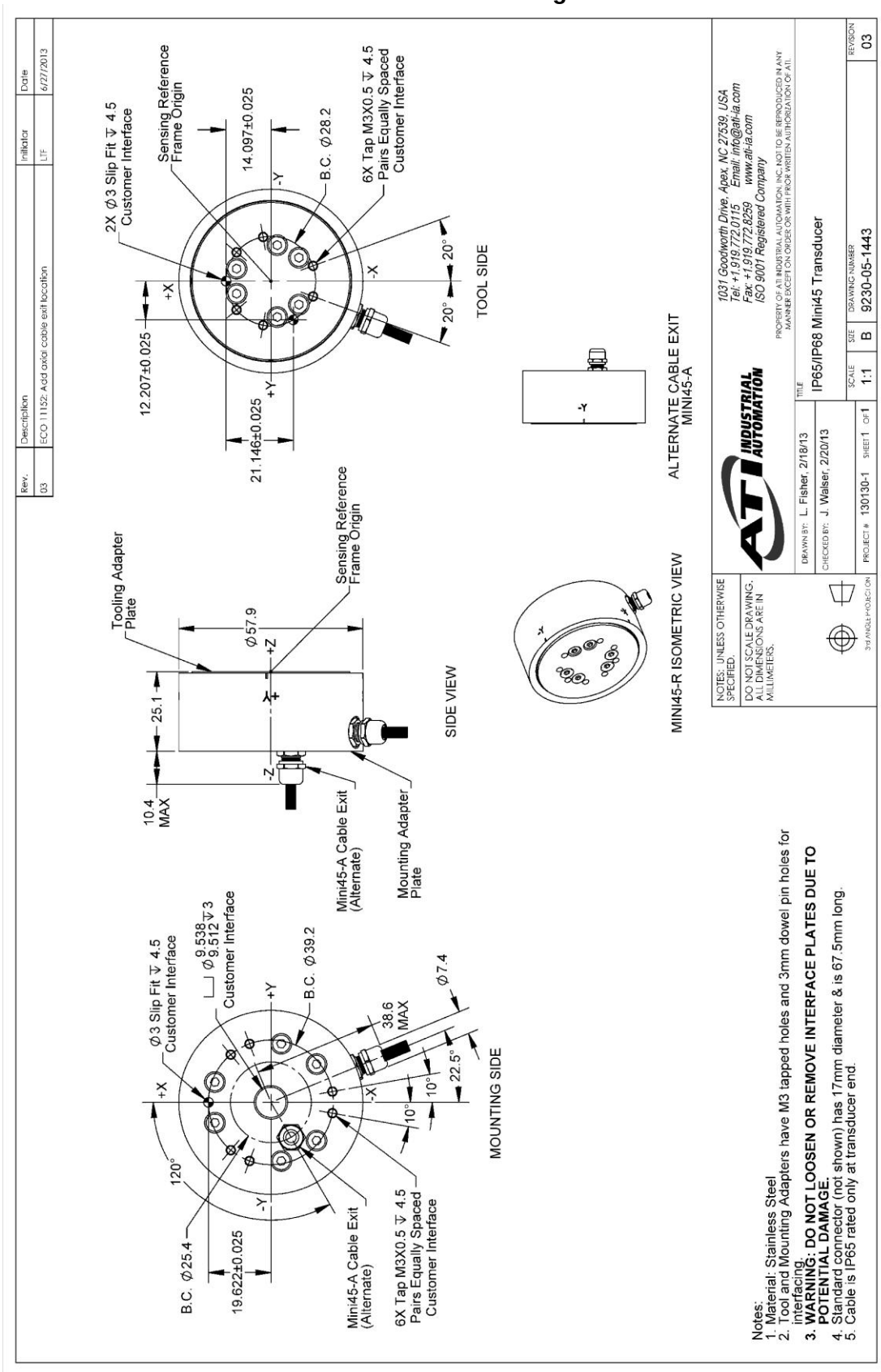
### 4.9.8 Mini45-ERA Transducer Drawing



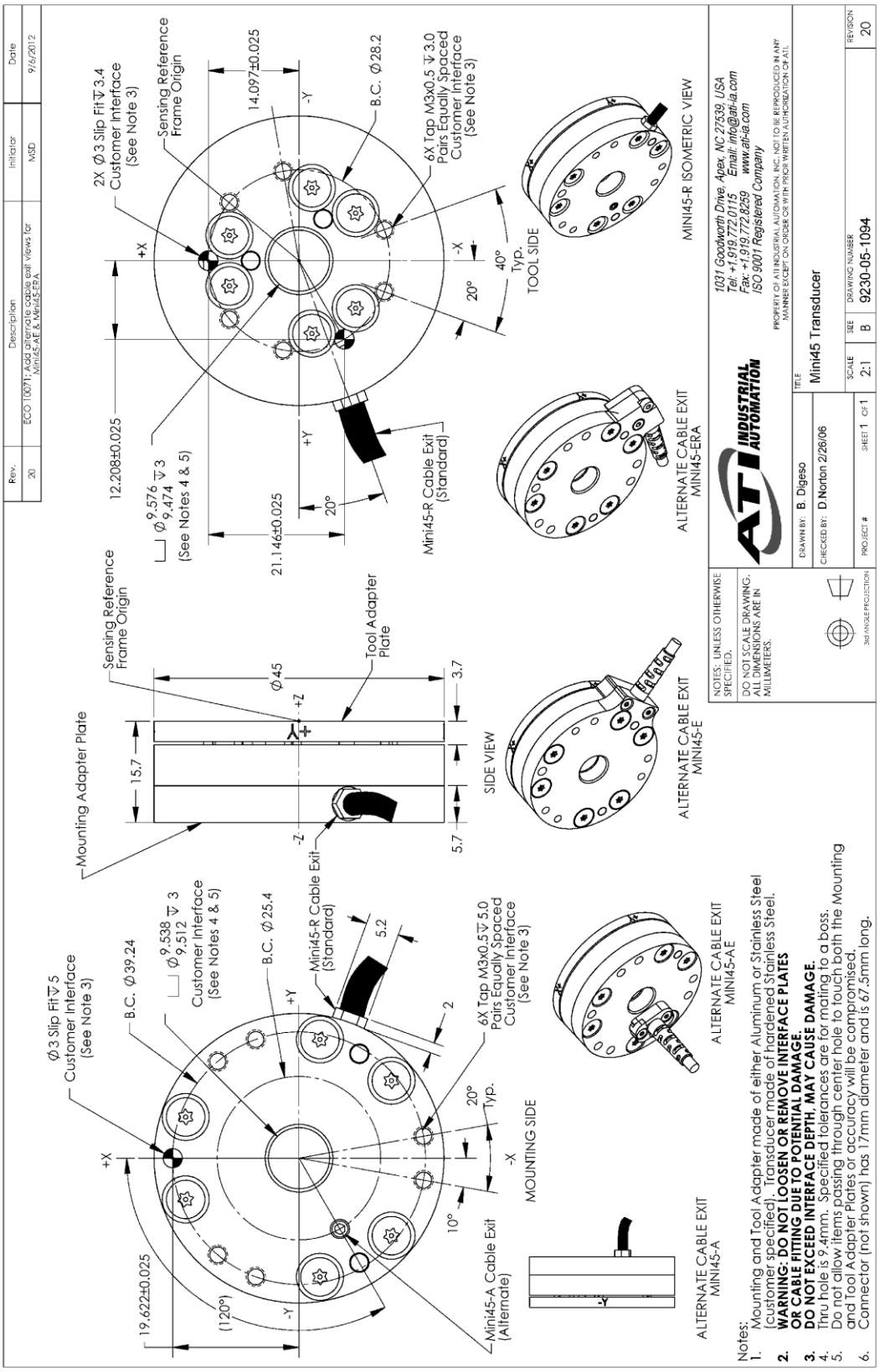
### 4.9.9 Mini45-AE Transducer Drawing



### 4.9.10 Mini45 IP65/IP68 Transducer Drawing



### 4.9.11 Legacy Mini45 Transducer Drawing



## 4.10 Mini58 (Includes IP60/IP65/IP68 Versions)

### 4.10.1 Calibration Specifications (excludes CTL calibrations)

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz† | Tx,Ty | Tz | Fx,Fy | Fz† | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| US-150-250 | 150 lbf | 375 lbf | 250 lbf-in | 250 lbf-in | 1/28 lbf | 3/56 lbf | 1/24 lbf-in | 1/40 lbf-in |
| US-300-500 | 300 lbf | 750 lbf | 500 lbf-in | 500 lbf-in | 1/14 lbf | 3/28 lbf | 1/12 lbf-in | 1/20 lbf-in |
| US-600-1000 | 600 lbf | 1500 lbf | 1000 lbf-in | 1000 lbf-in | 1/7 lbf | 3/14 lbf | 1/6 lbf-in | 1/10 lbf-in |

**Metric Calibrations (SI)**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| SI-700-30 | 700 N | 1700 N | 30 Nm | 30 Nm | 1/6 N | 1/4 N | 1/200 Nm | 1/320 Nm |
| SI-1400-60 | 1400 N | 3400 N | 60 Nm | 60 Nm | 1/3 N | 1/2 N | 1/100 Nm | 1/160 Nm |
| SI-2800–120 | 2800 N | 6800 N | 120 Nm | 120 Nm | 3/4 N | 1 N | 1/50 Nm | 1/80 Nm |
| | SENSING RANGES | | | | RESOLUTION* | | | |

* *DAQ resolutions are typical for a 16-bit system.*

*These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.*

### 4.10.2 CTL Calibration Specifications (Includes IP60/IP65/IP68 Version)

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz† | Tx,Ty | Tz | Fx,Fy | Fz† | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| US-150-250 | 150 lbf | 375 lbf | 250 lbf-in | 250 lbf-in | 1/14 lbf | 3/28 lbf | 1/12 lbf-in | 1/20 lbf-in |
| US-300-500 | 300 lbf | 750 lbf | 500 lbf-in | 500 lbf-in | 1/7 lbf | 3/14 lbf | 1/6 lbf-in | 1/10 lbf-in |
| US-600-1000 | 600 lbf | 1500 lbf | 1000 lbf-in | 1000 lbf-in | 2/7 lbf | 3/7 lbf | 1/3 lbf-in | 1/5 lbf-in |

**Metric Calibrations (SI)**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| SI-700-30 | 700 N | 1700 N | 30 Nm | 30 Nm | 1/3 N | 1/2 N | 1/100 Nm | 1/160 Nm |
| SI-1400-60 | 1400 N | 3400 N | 60 Nm | 60 Nm | 2/3 N | 1 N | 1/50 Nm | 1/80 Nm |
| SI-2800–120 | 2800 N | 6800 N | 120 Nm | 120 Nm | 1 1/2 N | 2 N | 1/25 Nm | 1/40 Nm |
| | SENSING RANGES | | | | RESOLUTION | | | |

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz† | Tx,Ty, Tz | Fx,Fy | Fz† | Tx,Ty, Tz |
|---|---|---|---|---|---|---|
| US-150-250 | ±150 lbf | ±375 lbf | ±250 lbf-in | 15.0 lbf/V | 37.5 lbf/V | 25.0 lbf-in/V |
| US-300-500 | ±300 lbf | ±750 lbf | ±500 lbf-in | 30 lbf/V | 75 lbf/V | 50 lbf-in/V |
| US-600-1000 | ±600 lbf | ±1500 lbf | ±1000 lbf-in | 60 lbf/V | 150 lbf/V | 100 lbf-in/V |

**Metric Calibrations (SI)**

| | | | | | | |
|---|---|---|---|---|---|---|
| SI-700-30 | ±700 N | ±1700 N | ±30 Nm | 70 N/V | 170 N/V | 3 Nm/V |
| SI-1400-60 | ±1400 N | ±3400 N | ±60 Nm | 140 N/V | 340 N/V | 6 Nm/V |
| SI-2800–120 | ±2800 N | ±6800 N | ±120 Nm | 280 N/V | 680 N/V | 12 Nm/V |
| | Analog Output Range | | | Analog ±10V Sensitivity‡ | | |

**Counts Value**

| Calibration | Fx, Fy, Fz | Tx, Ty, Tz | Fx, Fy, Fz | Tx, Ty, Tz |
|---|---|---|---|---|
| US-150-250 / SI-700-30 | 448 / lbf | 960 / lbf-in | 96 / N | 6400 / Nm |
| US-300-500 / SI-1400-60 | 224 / lbf | 480 / lbf-in | 48 / N | 3200 / Nm |
| US-600-1000 / SI-2800-120 | 112 / lbf | 240 / lbf-in | 16 / N | 1600 / Nm |
| **Tool Transform Factor** | See Tool Transform Factor table | | | |
| | Counts Value – Standard (US) | | Counts Value – Metric (SI) | |

**Tool Transform Factor**

| Calibration | US (English) | SI (Metric) |
|---|---|---|
| US-150-250 / SI-700-30 | 0.00467 in/lbf | 0.150 mm/N |
| US-300-500 / SI-1400-60 | 0.00467 in/lbf | 0.150 mm/N |
| US-600-1000 / SI-2800-120 | 0.00467 in/lbf | 0.150 mm/N |

*CTL resolutions are typical. System resolutions quoted are the effective resolution after dropping eight counts of noise. The effective resolution can be improved with filtering. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.*

*† For IP68 version see caution on physical properties page.*
*‡ ±5V Sensitivity values are double the listed ±10V Sensitivity values.*

### 4.10.3 Mini58 Physical Properties

**Standard (US)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±4800 lbf |
| Fz | ±11000 lbf |
| Txy | ±5300 lbf-in |
| Tz | ±7100 lbf-in |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $1.4x10^6$ lb/in |
| Z-axis force (Kz) | $2.1x10^6$ lb/in |
| X-axis & Y-axis torque (Ktx, Kty) | $9.3x10^5$ lbf-in/rad |
| Z-axis torque (Ktz) | $1.8x10^6$ lbf-in/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 3000 Hz |
| Fz, Tx, Ty | 5700 Hz |
| **Physical Specifications** | |
| Weight* | 0.76 lb |
| Diameter* | 2.28 in |
| Height* | 1.18 in |

**Metric (SI)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±21000 N |
| Fz | ±48000 N |
| Txy | ±590 Nm |
| Tz | ±800 Nm |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $2.5x10^8$ N/m |
| Z-axis force (Kz) | $3.7x10^8$ N/m |
| X-axis & Y-axis torque (Ktx, Kty) | $1.1x10^5$ Nm/rad |
| Z-axis torque (Ktz) | $2.0x10^5$ Nm/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 3000 Hz |
| Fz, Tx, Ty | 5700 Hz |
| **Physical Specifications** | |
| Weight* | 0.345 kg |
| Diameter* | 58 mm |
| Height* | 30 mm |

** Specifications include standard interface plates.*

### 4.10.4 Mini58 IP60 Physical Properties

**Standard (US)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±4800 lbf |
| Fz | ±11000 lbf |
| Txy | ±5300 lbf-in |
| Tz | ±7100 lbf-in |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $1.4 \times 10^6$ lb/in |
| Z-axis force (Kz) | $2.1 \times 10^6$ lb/in |
| X-axis & Y-axis torque (Ktx, Kty) | $9.3 \times 10^5$ lbf-in/rad |
| Z-axis torque (Ktz) | $1.8 \times 10^6$ lbf-in/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | |
| Fz, Tx, Ty | |
| **Physical Specifications** | |
| Weight* | 1.15 lb |
| Diameter* | 3.23 in |
| Height* | 1.42 in |

**Metric (SI)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±21000 N |
| Fz | ±48000 N |
| Txy | ±590 Nm |
| Tz | ±800 Nm |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $2.5 \times 10^8$ N/m |
| Z-axis force (Kz) | $3.7 \times 10^8$ N/m |
| X-axis & Y-axis torque (Ktx, Kty) | $1.1 \times 10^5$ Nm/rad |
| Z-axis torque (Ktz) | $2.0 \times 10^5$ Nm/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | |
| Fz, Tx, Ty | |
| **Physical Specifications** | |
| Weight* | 0.522 kg |
| Diameter* | 82 mm |
| Height* | 36.2 mm |

** Specifications include standard interface plates.*

### 4.10.5 Mini58 IP65/IP68 Physical Properties

**Standard (US)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±4800 lbf |
| Fz | ±11000 lbf |
| Txy | ±5300 lbf-in |
| Tz | ±7100 lbf-in |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $1.4 \times 10^6$ lb/in |
| Z-axis force (Kz) | $2.1 \times 10^6$ lb/in |
| X-axis & Y-axis torque (Ktx, Kty) | $9.3 \times 10^5$ lbf-in/rad |
| Z-axis torque (Ktz) | $1.8 \times 10^6$ lbf-in/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | |
| Fz, Tx, Ty | |
| **Physical Specifications** | |
| Weight* | 1.77 lb |
| Diameter* | 2.58 in |
| Height* | 1.48 in |

**Metric (SI)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±21000 N |
| Fz | ±48000 N |
| Txy | ±590 Nm |
| Tz | ±800 Nm |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $2.5 \times 10^8$ N/m |
| Z-axis force (Kz) | $3.7 \times 10^8$ N/m |
| X-axis & Y-axis torque (Ktx, Kty) | $1.1 \times 10^5$ Nm/rad |
| Z-axis torque (Ktz) | $2.0 \times 10^5$ Nm/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | |
| Fz, Tx, Ty | |
| **Physical Specifications** | |
| Weight* | 0.804 kg |
| Diameter* | 65.4 mm |
| Height* | 37.6 mm |

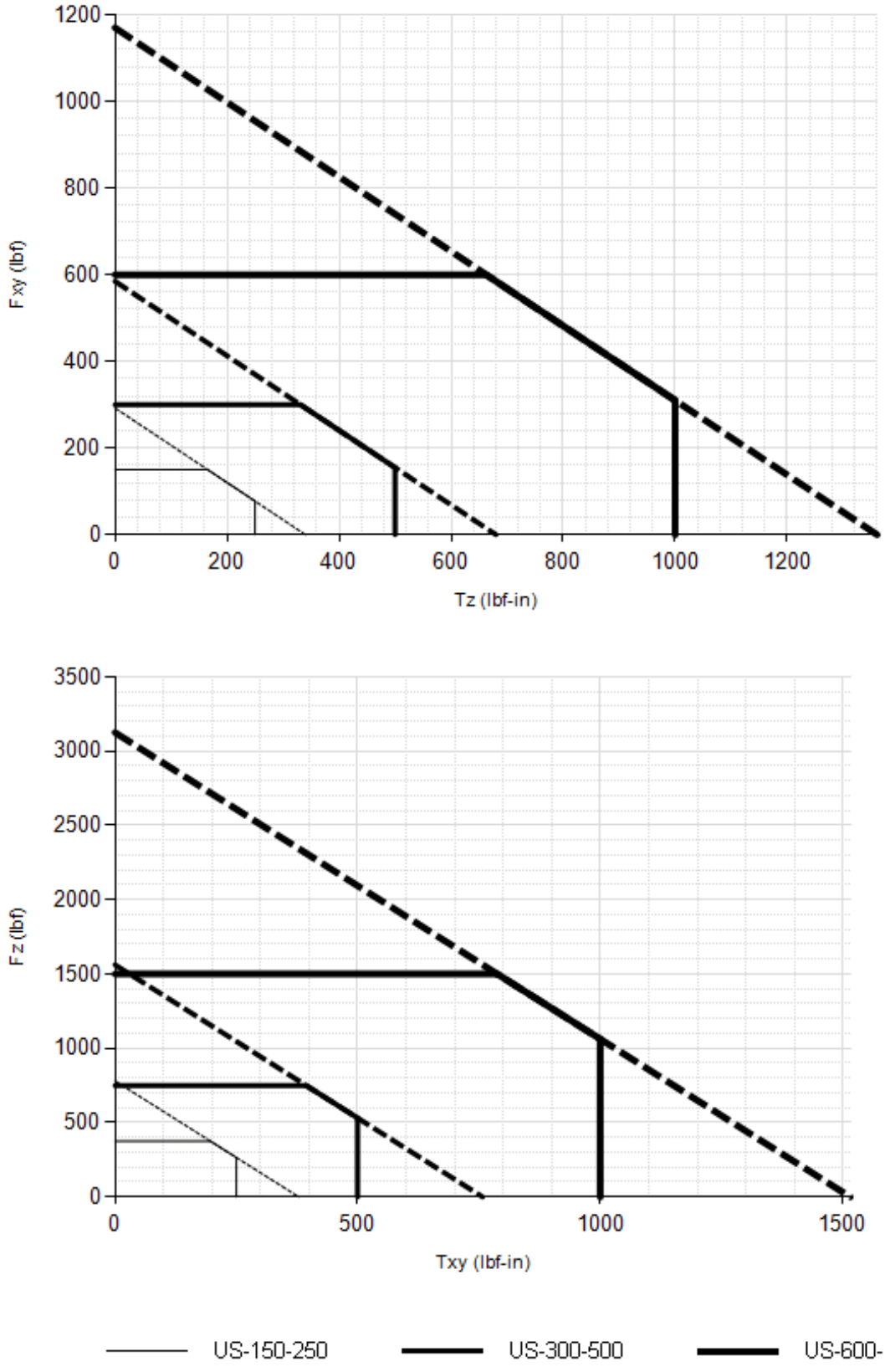
** Specifications include standard interface plates.*

**CAUTION:**
**IP68 Mini58 Fz as a Function of Submersion Depth:**

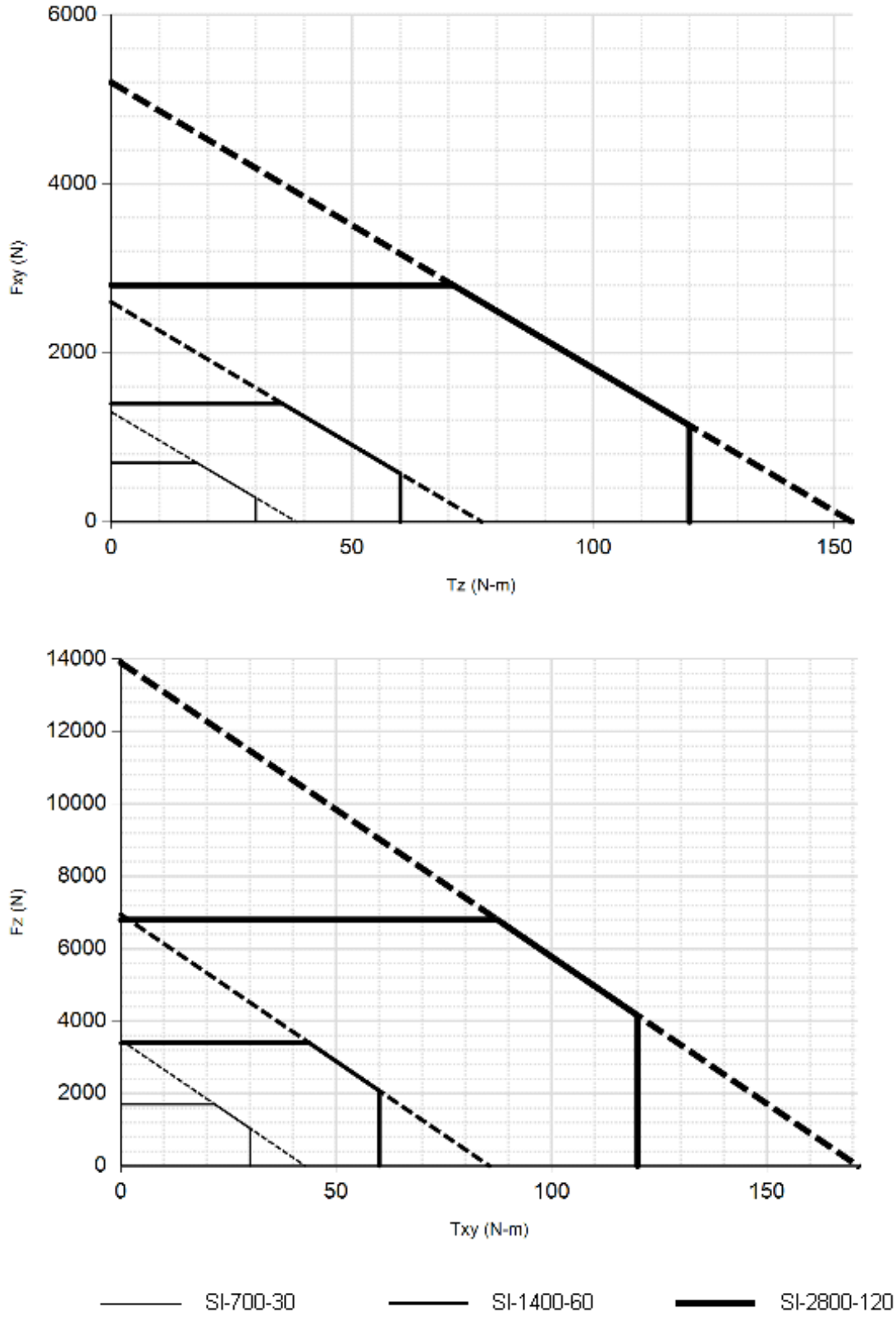
When submerged, IP68 transducers exhibit a decrease in Fz range related to the submersion depth. This loss is the result of pressure-induced preloading on the transducer. The preload can be masked by biasing the transducer at the depth prior to applying the load to be measured. The following estimates are for room temperature fresh water at sea level.

| ***IP68 Mini58*** | **US** | **Metric** |
|---|---|---|
| Fz preload at 4m depth | 24.3 lb | 108 N |
| Fz preload at other depths | -1.86 lb/ft × depthInFeet | -27.1 N/m × depthInMeters |

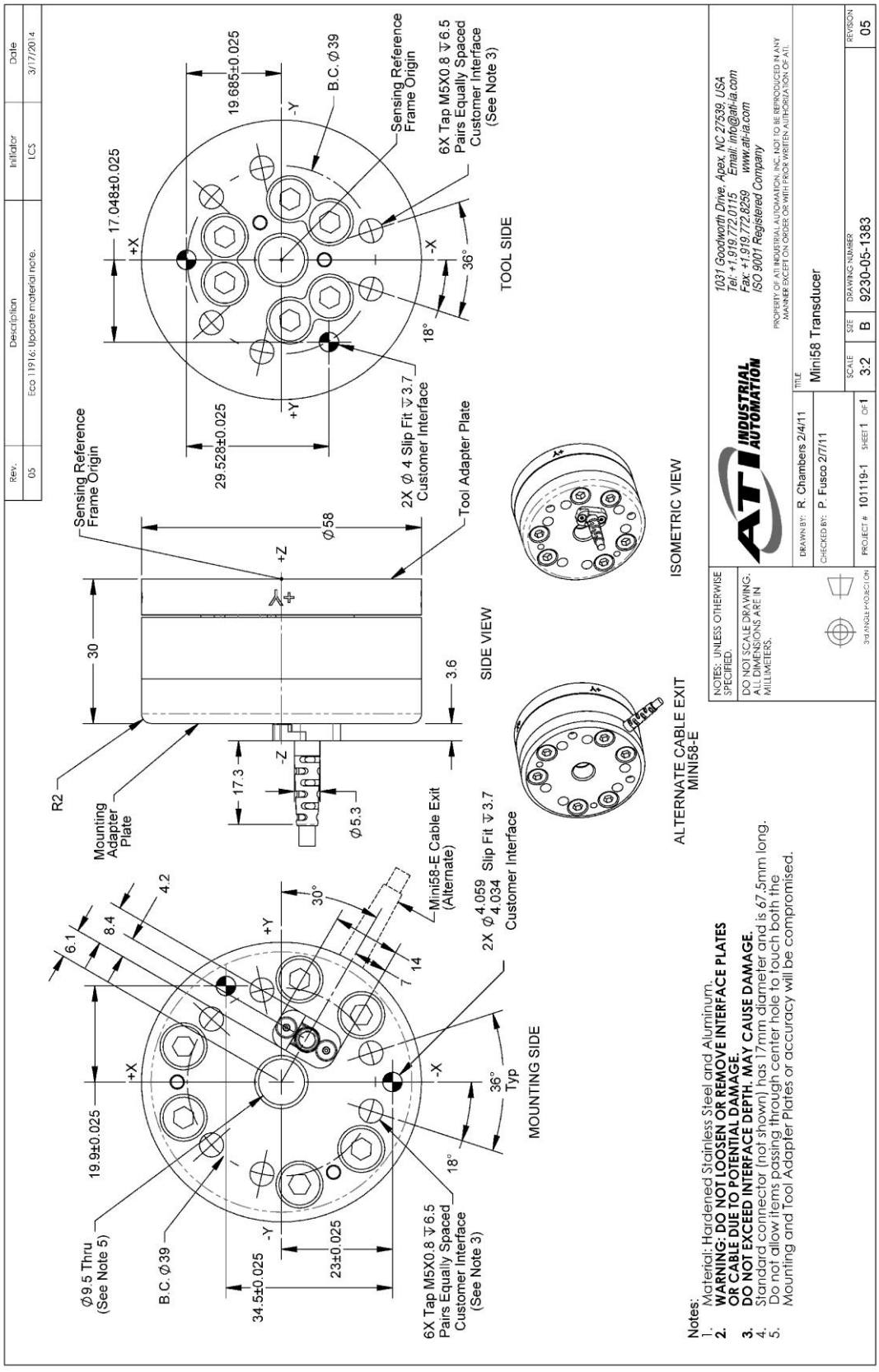
### 4.10.6 Mini58 (US Calibration Complex Loading) (Includes IP60/IP65/IP68 Version)



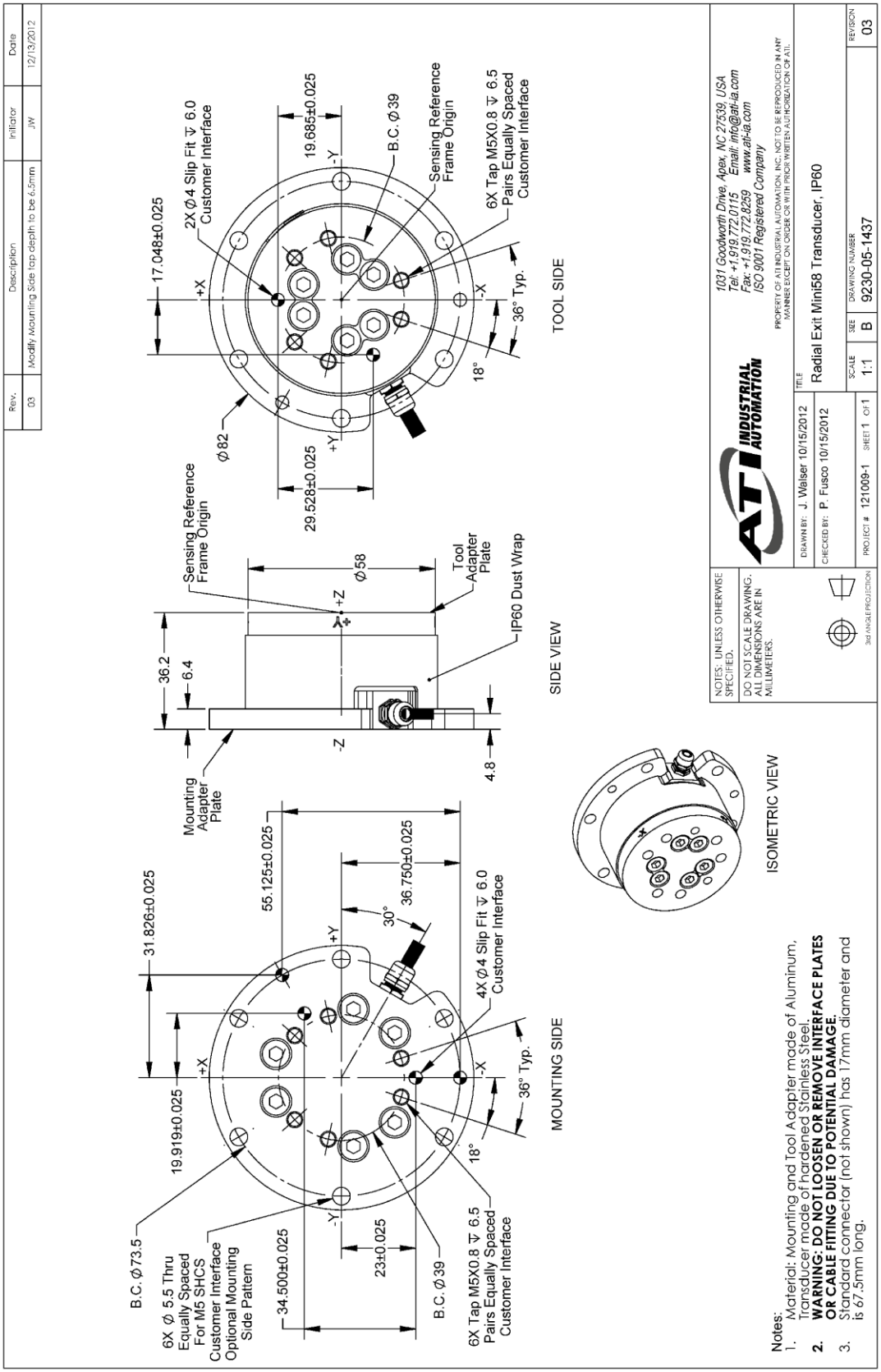
### 4.10.7 Mini58 (SI Calibration Complex Loading) (Includes IP60/IP65/IP68 Versions)



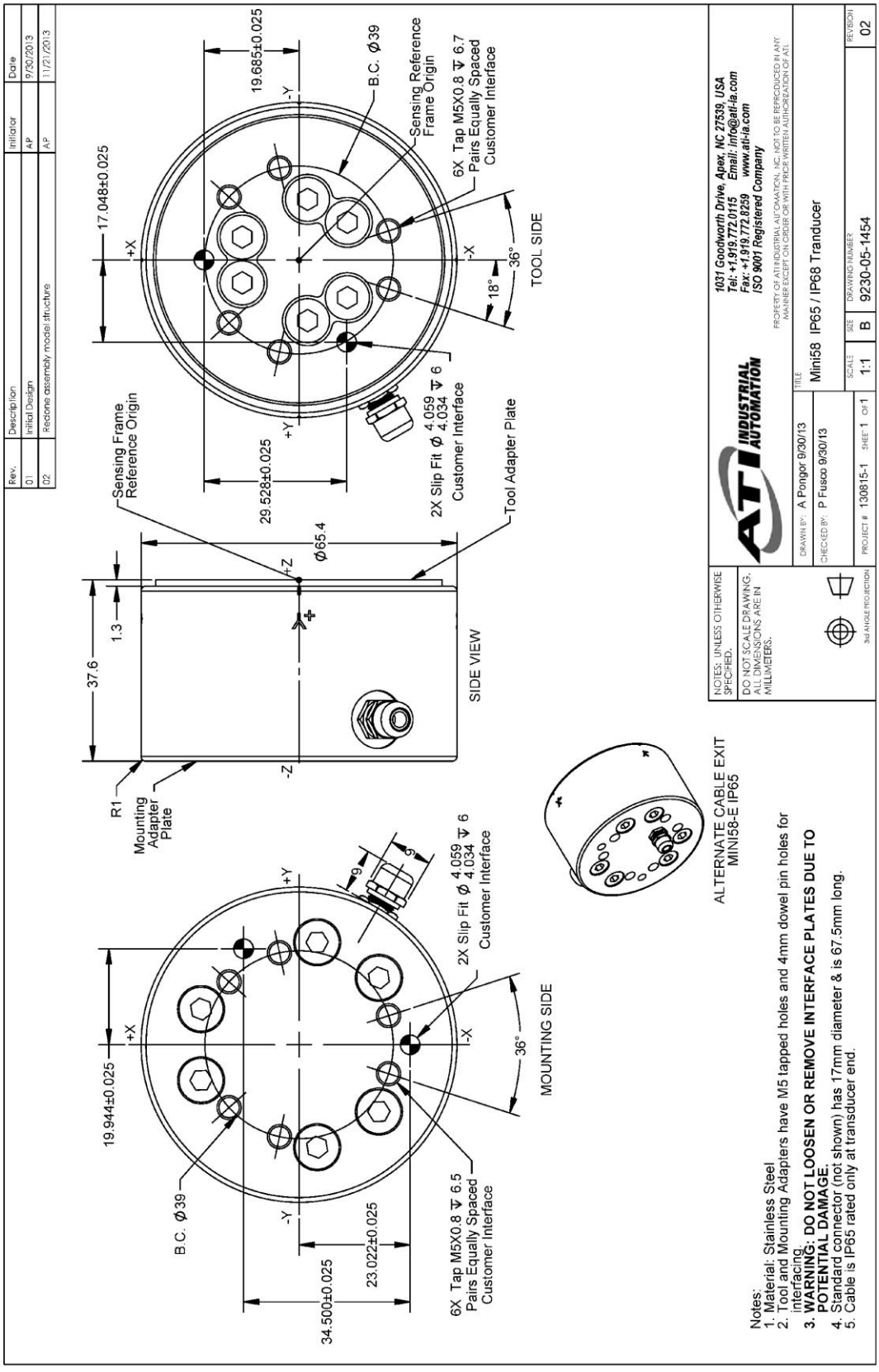
### 4.10.8 Mini58 Transducer Drawing



### 4.10.9 Mini58 IP60 Transducer Drawing



### 4.10.10 Mini58 IP65/IP68 Transducer Drawing



## 4.11 Mini85

### 4.11.1 Calibration Specifications (excludes CTL calibrations)

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz† | Tx,Ty | Tz | Fx,Fy | Fz† | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| US-105-185 | 105 lbf | 210 lbf | 185 lbf-in | 185 lbf-in | 1/52 lbf | 7/260 lbf | 5/168 lbf-in | 1/48 lbf-in |
| US-210-370 | 210 lbf | 420 lbf | 370 lbf-in | 370 lbf-in | 5/128 lbf | 3/64 lbf | 5/84 lbf-in | 1/24 lbf-in |
| US-420-740 | 420 lbf | 840 lbf | 740 lbf-in | 740 lbf-in | 5/64 lbf | 3/32 lbf | 5/42 lbf-in | 1/12 lbf-in |

**Metric Calibrations (SI)**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| SI-475-20 | 475 N | 950 N | 20 Nm | 20 Nm | 9/112 N | 3/28 N | 5/1496 Nm | 7/2992 Nm |
| SI-950-40 | 950 N | 1900 N | 40 Nm | 40 Nm | 9/56 N | 3/14 N | 5/748 Nm | 7/1496 Nm |
| SI-1900–80 | 1900 N | 3800 N | 80 Nm | 80 Nm | 9/28 N | 3/7 N | 5/374 Nm | 7/748 Nm |
| | SENSING RANGES | | | | RESOLUTION* | | | |

* *DAQ resolutions are typical for a 16-bit system.*

*These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.*

### 4.11.2 CTL Calibration Specifications

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz† | Tx,Ty | Tz | Fx,Fy | Fz† | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| US-105-185 | 105 lbf | 210 lbf | 185 lbf-in | 185 lbf-in | 1/26 lbf | 7/130 lbf | 5/84 lbf-in | 1/24 lbf-in |
| US-210-370 | 210 lbf | 420 lbf | 370 lbf-in | 370 lbf-in | 5/64 lbf | 3/32 lbf | 5/42 lbf-in | 1/12 lbf-in |
| US-420-740 | 420 lbf | 840 lbf | 740 lbf-in | 740 lbf-in | 5/32 lbf | 3/16 lbf | 5/21 lbf-in | 1/6 lbf-in |

**Metric Calibrations (SI)**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| SI-475-20 | 475 N | 950 N | 20 Nm | 20 Nm | 9/56 N | 3/14 N | 5/748 Nm | 7/1496 Nm |
| SI-950-40 | 950 N | 1900 N | 40 Nm | 40 Nm | 9/28 N | 3/7 N | 5/374 Nm | 7/748 Nm |
| SI-1900–80 | 1900 N | 3800 N | 80 Nm | 80 Nm | 9/14 N | 6/7 N | 5/187 Nm | 7/374 Nm |
| | SENSING RANGES | | | | RESOLUTION | | | |

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz† | Tx,Ty, Tz | Fx,Fy | Fz† | Tx,Ty, Tz |
|---|---|---|---|---|---|---|
| US-105-185 | ±105 lbf | ±210 lbf | ±185 lbf-in | 10.5 lbf/V | 21 lbf/V | 18.5 lbf-in/V |
| US-210-370 | ±210 lbf | ±420 lbf | ±370 lbf-in | 21 lbf/V | 42 lbf/V | 37 lbf-in/V |
| US-420-740 | ±420 lbf | ±840 lbf | ±740 lbf-in | 42 lbf/V | 84 lbf/V | 74 lbf-in/V |

**Metric Calibrations (SI)**

| | | | | | | |
|---|---|---|---|---|---|---|
| SI-475-20 | ±475 N | ±950 N | ±20 Nm | 47.5 N/V | 95 N/V | 2 Nm/V |
| SI-950-40 | ±950 N | ±1900 N | ±40 Nm | 95 N/V | 190 N/V | 4 Nm/V |
| SI-1900–80 | ±1800 N | ±38000 N | ±80 Nm | 190 N/V | 380 N/V | 8 Nm/V |
| | Analog Output Range | | | Analog ±10V Sensitivity‡ | | |

**Counts Value**

| Calibration | Fx, Fy, Fz | Tx, Ty, Tz | Fx, Fy, Fz | Tx, Ty, Tz |
|---|---|---|---|---|
| US-105-185 / SI-475-20 | 1040 / lbf | 1344 / lbf-in | 448 / N | 11968 / Nm |
| US-210-370 / SI-950-40 | 512 / lbf | 672 / lbf-in | 224 / N | 5984 / Nm |
| US-420-740 / SI-1900-80 | 256 / lbf | 336 / lbf-in | 112 / N | 2992 / Nm |
| **Tool Transform Factor** | See Tool Transform Factor table | | | |
| | Counts Value – Standard (US) | | Counts Value – Metric (SI) | |

**Tool Transform Factor**

| Calibration | US (English) | SI (Metric) |
|---|---|---|
| US-105-185 / SI-475-20 | 0.00774 in/lbf | 0.374 mm/N |
| US-210-370 / SI-950-40 | 0.00762 in/lbf | 0.374 mm/N |
| US-420-740 / SI-1900-80 | 0.00762 in/lbf | 0.374 mm/N |

*CTL resolutions are typical. System resolutions quoted are the effective resolution after dropping eight counts of noise. The effective resolution can be improved with filtering. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.*

*† For IP68 version see caution on physical properties page.*
*‡ ±5V Sensitivity values are double the listed ±10V Sensitivity values.*

### 4.11.3 Mini85 Physical Properties

**Standard (US)**

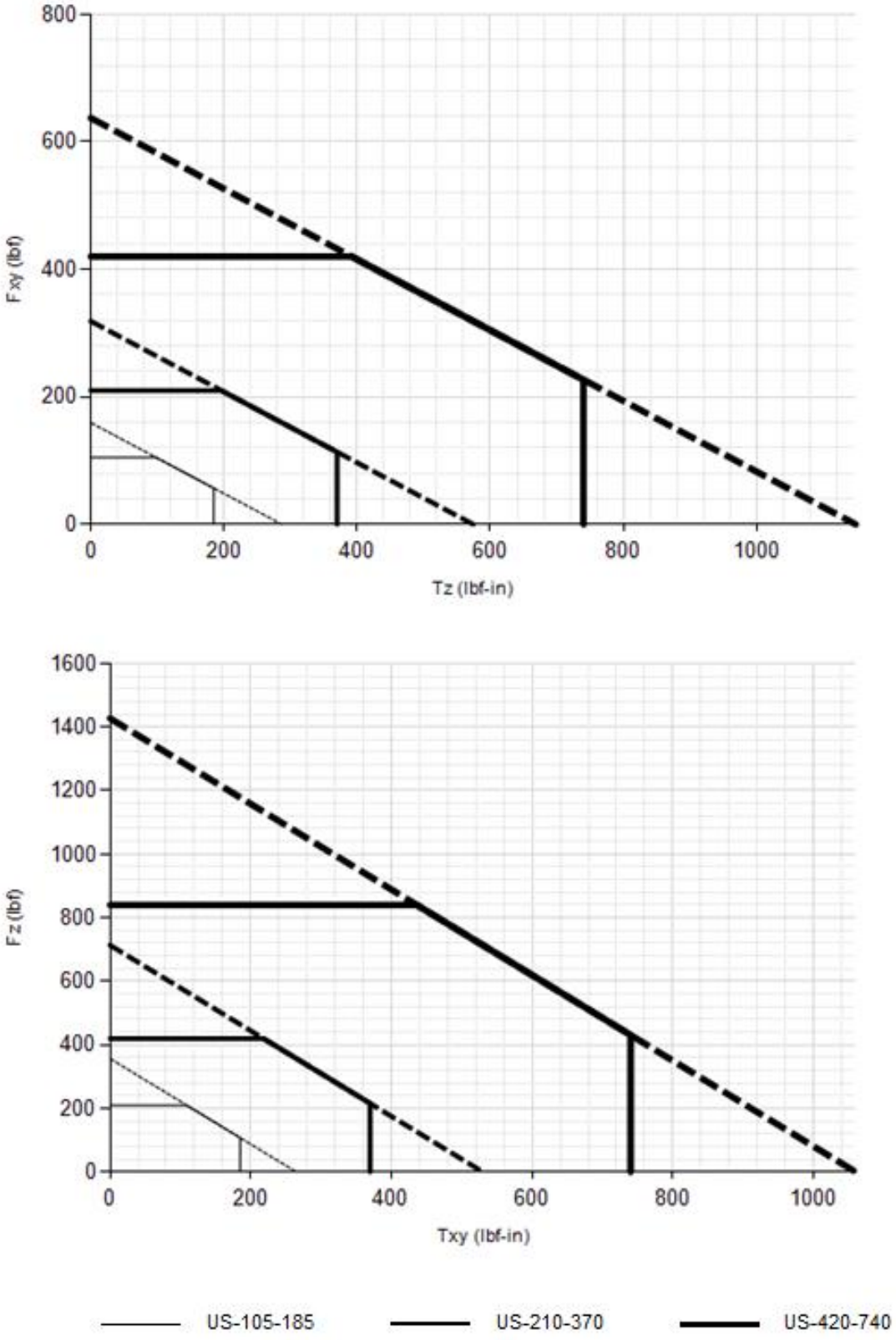
| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±2800 lbf |
| Fz | ±6100 lbf |
| Txy | ±4400 lbf-in |
| Tz | ±5400 lbf-in |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $4.4 \times 10^5$ lb/in |
| Z-axis force (Kz) | $6.8 \times 10^5$ lb/in |
| X-axis & Y-axis torque (Ktx, Kty) | $7.2 \times 10^5$ lbf-in/rad |
| Z-axis torque (Ktz) | $1.2 \times 10^6$ lbf-in/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 2400 Hz |
| Fz, Tx, Ty | 3100 Hz |
| **Physical Specifications** | |
| Weight* | 1.4 lb |
| Diameter* | 3.35 in |
| Height* | 1.17 in |

**Metric (SI)**

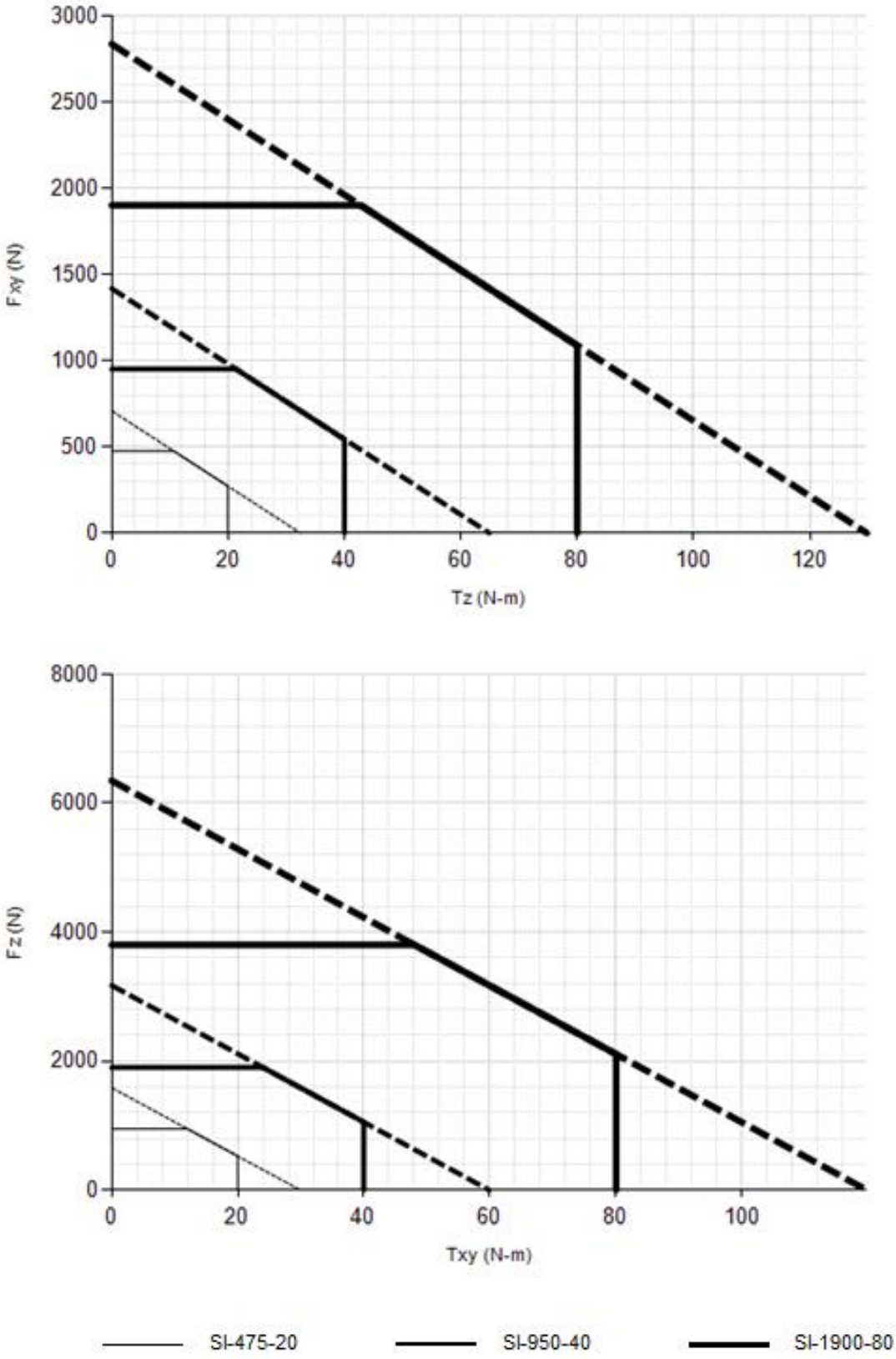
| | |
|---|---|
| Fxy | ±13000 N |
| Fz | ±27000 N |
| Txy | ±500 Nm |
| Tz | ±610 Nm |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $7.7 \times 10^7$ N/m |
| Z-axis force (Kz) | $1.2 \times 10^8$ N/m |
| X-axis & Y-axis torque (Ktx, Kty) | $8.1 \times 10^4$ Nm/rad |
| Z-axis torque (Ktz) | $1.3 \times 10^5$ Nm/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 2400 Hz |
| Fz, Tx, Ty | 3100 Hz |
| **Physical Specifications** | |
| Weight* | 0.635 kg |
| Diameter* | 85.1 mm |
| Height* | 29.8 mm |

** Specifications include standard interface plates.*

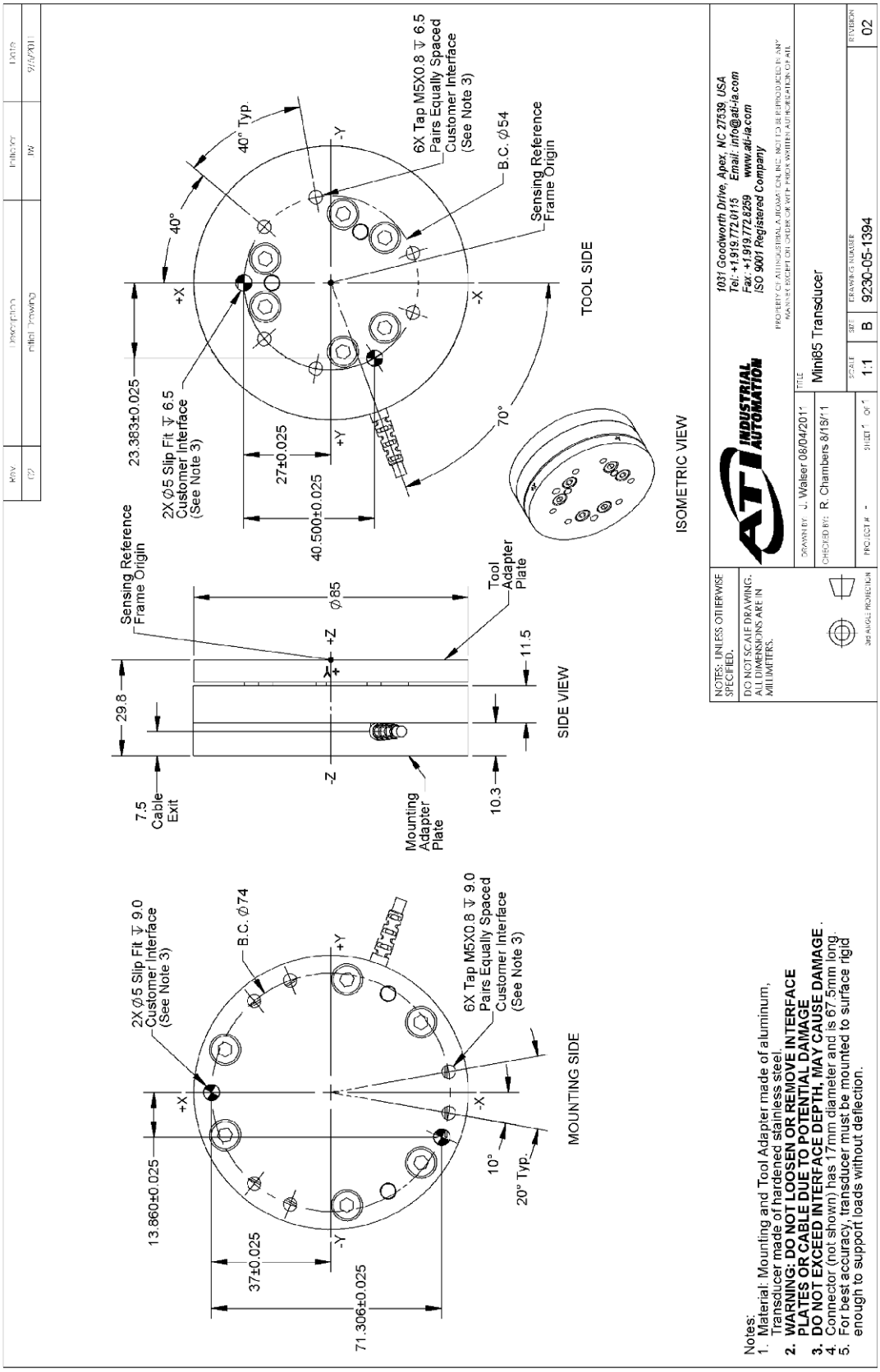
### 4.11.4 Mini85 (US Calibration Complex Loading)



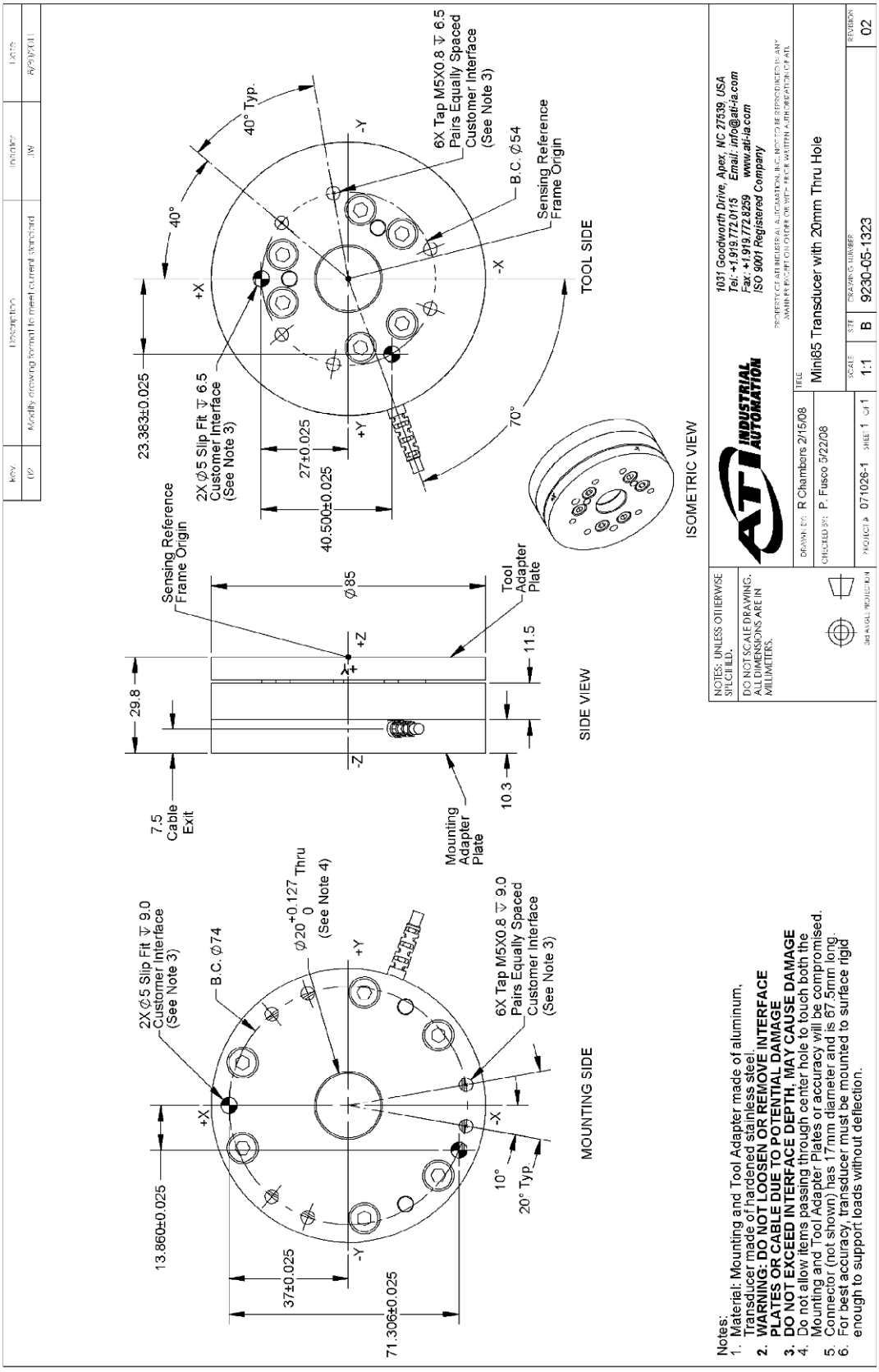
### 4.11.5 Mini85 (SI Calibration Complex Loading)



### 4.11.6 Mini85-E Transducer Drawing



### 4.11.7 Mini85 Transducer with 20mm Through-Hole Drawing



## 4.12 Gamma (Includes IP60/IP65/IP68 Versions)

### 4.12.1 Calibration Specifications (excludes CTL calibrations)

**Standard (US)**

| Calibration | Fx,Fy | Fz | Tx,Ty | Tz | Fx,Fy | Fz | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| US-7.5–25 | 7.5 lbf | 25 lbf | 25 lbf-in | 25 lbf-in | 1/640 lbf | 1/320 lbf | 1/320 lbf-in | 1/320 lbf-in |
| US-15–50 | 15 lbf | 50 lbf | 50 lbf-in | 50 lbf-in | 1/320 lbf | 1/160 lbf | 1/160 lbf-in | 1/160 lbf-in |
| US-30–100 | 30 lbf | 100 lbf | 100 lbf-in | 100 lbf-in | 1/160 lbf | 1/80 lbf | 1/80 lbf-in | 1/80 lbf-in |
| | SENSING RANGES | | | | RESOLUTION* | | | |

**Metric Calibrations (SI)**

| Calibration | Fx,Fy | Fz | Tx,Ty | Tz | Fx,Fy | Fz | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| SI-32–2.5 | 32 N | 100 N | 2.5 Nm | 2.5 NM | 1/160 N | 1/80 N | 1/2000 Nm | 1/2000 Nm |
| SI-65–5 | 65 N | 200 N | 5 Nm | 5 Nm | 1/80 N | 1/40 N | 10/13333 Nm | 10/13333 Nm |
| SI-130–10 | 130 N | 400 N | 10 Nm | 10 Nm | 1/40 N | 1/20 N | 1/800 Nm | 1/800 Nm |
| | SENSING RANGES | | | | RESOLUTION* | | | |

** DAQ resolutions are typical for a 16-bit data acquisition system.*

*These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.*

### 4.12.2 CTL Calibration Specifications (Includes IP60/IP65/IP68 Versions)

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz | Tx,Ty | Tz | Fx,Fy | Fz | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| US-7.5–25 | 7.5 lbf | 25 lbf | 25 lbf-in | 25 lbf-in | 1/320 lbf | 1/160 lbf | 1/160 lbf-in | 1/160 lbf-in |
| US-15–50 | 15 lbf | 50 lbf | 50 lbf-in | 50 lbf-in | 1/160 lbf | 1/80 lbf | 1/80 lbf-in | 1/80 lbf-in |
| US-30–100 | 30 lbf | 100 lbf | 100 lbf-in | 100 lbf-in | 1/80 lbf | 1/40 lbf | 1/40 lbf-in | 1/40 lbf-in |

**Metric Calibrations (SI)**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| SI-32–2.5 | 32 N | 100 N | 2.5 Nm | 2.5 Nm | 1/80 N | 1/40 N | 1/1000 Nm | 1/1000 Nm |
| SI-65–5 | 65 N | 200 N | 5 Nm | 5 Nm | 1/40 N | 1/20 N | 5/3333 Nm | 5/3333 Nm |
| SI-130–10 | 130 N | 400 N | 10 Nm | 10 Nm | 1/20 N | 1/10 N | 1/400 Nm | 1/400 Nm |
| | SENSING RANGES | | | | RESOLUTION | | | |

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz† | Tx,Ty, Tz | Fx,Fy | Fz† | Tx,Ty, Tz |
|---|---|---|---|---|---|---|
| US-7.5–25 | ±7.5 lbf | ±25 lbf | ±25 lbf-in | 0.75 lbf/V | 2.5 lbf/V | 2.5 lbf-in/V |
| US-15–50 | ±15 lbf | ±50 lbf | ±50 lbf-in | 1.5 lbf/V | 5 lbf/V | 5 lbf-in/V |
| US-30–100 | ±30 lbf | ±100 lbf | ±100 lbf-in | 3 lbf/V | 10 lbf/V | 10 lbf-in/V |

**Metric Calibrations (SI)**

| | | | | | | |
|---|---|---|---|---|---|---|
| SI-32–2.5 | ±32 N | ±100 N | ±2.5 Nm | 3.2 N/V | 10 N/V | 0.25 Nm/V |
| SI-65–5 | ±65 N | ±200 N | ±5 Nm | 6.5 N/V | 20 N/V | 0.5 Nm/V |
| SI-130–10 | ±130 N | ±400 N | ±10 Nm | 13 N/V | 40 N/V | 1 Nm/V |
| | Analog Output Range | | | Analog ±10V Sensitivity‡ | | |

**Counts Value**

| Calibration | Fx, Fy, Fz | Tx, Ty, Tz | Fx, Fy, Fz | Tx, Ty, Tz |
|---|---|---|---|---|
| US-7.5–25 / SI-32–2.5 | 2560 / lbf | 2560 / lbf-in | 640 / N | 8000 / Nm |
| US-15–50 / SI-65–5 | 1280 / lbf | 1280 / lbf-in | 320 / N | 5333.33 / Nm |
| US-30–100 / SI-130–10 | 640 / lbf | 640 / lbf-in | 160 / N | 3200 / Nm |
| **Tool Transform Factor** | See Tool Transform Factor table | | | |
| | Counts Value – Standard (US) | | Counts Value – Metric (SI) | |

**Tool Transform Factor**

| Calibration | US (English) | SI (Metric) |
|---|---|---|
| US-7.5–25 / SI-32–2.5 | 0.01 in/lbf | 0.8 mm/N |
| US-15–50 / SI-65–5 | 0.01 in/lbf | 0.6 mm/N |
| US-30–100 / SI-130–10 | 0.01 in/lbf | 0.y h5 mm/N |

*CTL resolutions are typical. System resolutions quoted are the effective resolution after dropping eight counts of noise. The effective resolution can be improved with filtering. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.*

† *For IP68 version see caution on physical properties page.*
‡ *±5V Sensitivity values are double the listed ±10V Sensitivity values.*

### 4.12.3 Gamma Physical Properties

**Standard (US)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±280 lbf |
| Fz | ±930 lbf |
| Txy | ±700 lbf-in |
| Tz | ±730 lbf-in |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $5.2 \times 10^4$ lb/in |
| Z-axis force (Kz) | $1.0 \times 10^5$ lb/in |
| X-axis & Y-axis torque (Ktx, Kty) | $9.3 \times 10^4$ lbf-in/rad |
| Z-axis torque (Ktz) | $1.4 \times 10^5$ lbf-in/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 1400 Hz |
| Fz, Tx, Ty | 2000 Hz |
| **Physical Specifications** | |
| Weight* | 0.562 lb |
| Diameter* | 2.97 in |
| Height* | 1.31 in |

**Metric (SI)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±1200 N |
| Fz | ±4100 N |
| Txy | ±79 Nm |
| Tz | ±82 Nm |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $9.1 \times 10^6$ N/m |
| Z-axis force (Kz) | $1.8 \times 10^7$ N/m |
| X-axis & Y-axis torque (Ktx, Kty) | $1.1 \times 10^4$ Nm/rad |
| Z-axis torque (Ktz) | $1.6 \times 10^4$ Nm/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 1400 Hz |
| Fz, Tx, Ty | 2000 Hz |
| **Physical Specifications** | |
| Weight* | 0.255 kg |
| Diameter* | 75.4 mm |
| Height* | 33.3 mm |

** Specifications include standard interface plates.*

### 4.12.4 Gamma IP60 Physical Properties

**Standard (US)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±280 lbf |
| Fz | ±930 lbf |
| Txy | ±700 lbf-in |
| Tz | ±730 lbf-in |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $5.2 \times 10^4$ lb/in |
| Z-axis force (Kz) | $1.0 \times 10^5$ lb/in |
| X-axis & Y-axis torque (Ktx, Kty) | $9.3 \times 10^4$ lbf-in/rad |
| Z-axis torque (Ktz) | $1.4 \times 10^5$ lbf-in/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 1200 Hz |
| Fz, Tx, Ty | 1200 Hz |
| **Physical Specifications** | |
| Weight* | 1.03 lb |
| Diameter* | 3.9 in |
| Height* | 1.56 in |

**Metric (SI)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±1200 N |
| Fz | ±4100 N |
| Txy | ±79 Nm |
| Tz | ±82 Nm |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $9.1 \times 10^6$ N/m |
| Z-axis force (Kz) | $1.8 \times 10^7$ N/m |
| X-axis & Y-axis torque (Ktx, Kty) | $1.1 \times 10^4$ Nm/rad |
| Z-axis torque (Ktz) | $1.6 \times 10^4$ Nm/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 1200 Hz |
| Fz, Tx, Ty | 1200 Hz |
| **Physical Specifications** | |
| Weight* | 0.467 kg |
| Diameter* | 99.1 mm |
| Height* | 39.6 mm |

** Specifications include standard interface plates.*

### 4.12.5 Gamma IP65 Physical Properties

**Standard (US)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±280 lbf |
| Fz | ±930 lbf |
| Txy | ±700 lbf-in |
| Tz | ±730 lbf-in |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $5.2 \times 10^4$ lb/in |
| Z-axis force (Kz) | $1.0 \times 10^5$ lb/in |
| X-axis & Y-axis torque (Ktx, Kty) | $9.3 \times 10^4$ lbf-in/rad |
| Z-axis torque (Ktz) | $1.4 \times 10^5$ lbf-in/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 1000 Hz |
| Fz, Tx, Ty | 970 Hz |
| **Physical Specifications** | |
| Weight* | 2.4 lb |
| Diameter* | 4.37 in |
| Height* | 2.06 in |

**Metric (SI)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±1200 N |
| Fz | ±4100 N |
| Txy | ±79 Nm |
| Tz | ±82 Nm |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $9.1 \times 10^6$ N/m |
| Z-axis force (Kz) | $1.8 \times 10^7$ N/m |
| X-axis & Y-axis torque (Ktx, Kty) | $1.1 \times 10^4$ Nm/rad |
| Z-axis torque (Ktz) | $1.6 \times 10^4$ Nm/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 1000 Hz |
| Fz, Tx, Ty | 970 Hz |
| **Physical Specifications** | |
| Weight* | 1.09 kg |
| Diameter* | 111 mm |
| Height* | 52.3 mm |

** Specifications include standard interface plates.*

### 4.12.6 Gamma IP68 Physical Properties

**Standard (US)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±280 lbf |
| Fz | ±930 lbf |
| Txy | ±700 lbf-in |
| Tz | ±730 lbf-in |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $5.2 \times 10^4$ lb/in |
| Z-axis force (Kz) | $1.0 \times 10^5$ lb/in |
| X-axis & Y-axis torque (Ktx, Kty) | $9.3 \times 10^4$ lbf-in/rad |
| Z-axis torque (Ktz) | $1.4 \times 10^5$ lbf-in/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 1250 Hz |
| Fz, Tx, Ty | 940 Hz |
| **Physical Specifications** | |
| Weight* | 4.37 lb |
| Diameter* | 4.37 in |
| Height* | 2.06 in |

**Metric (SI)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±1200 N |
| Fz | ±4100 N |
| Txy | ±79 Nm |
| Tz | ±82 Nm |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $9.1 \times 10^6$ N/m |
| Z-axis force (Kz) | $1.8 \times 10^7$ N/m |
| X-axis & Y-axis torque (Ktx, Kty) | $1.1 \times 10^4$ Nm/rad |
| Z-axis torque (Ktz) | $1.6 \times 10^4$ Nm/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 1250 Hz |
| Fz, Tx, Ty | 940 Hz |
| **Physical Specifications** | |
| Weight* | 1.98 kg |
| Diameter* | 111 mm |
| Height* | 52.3 mm |

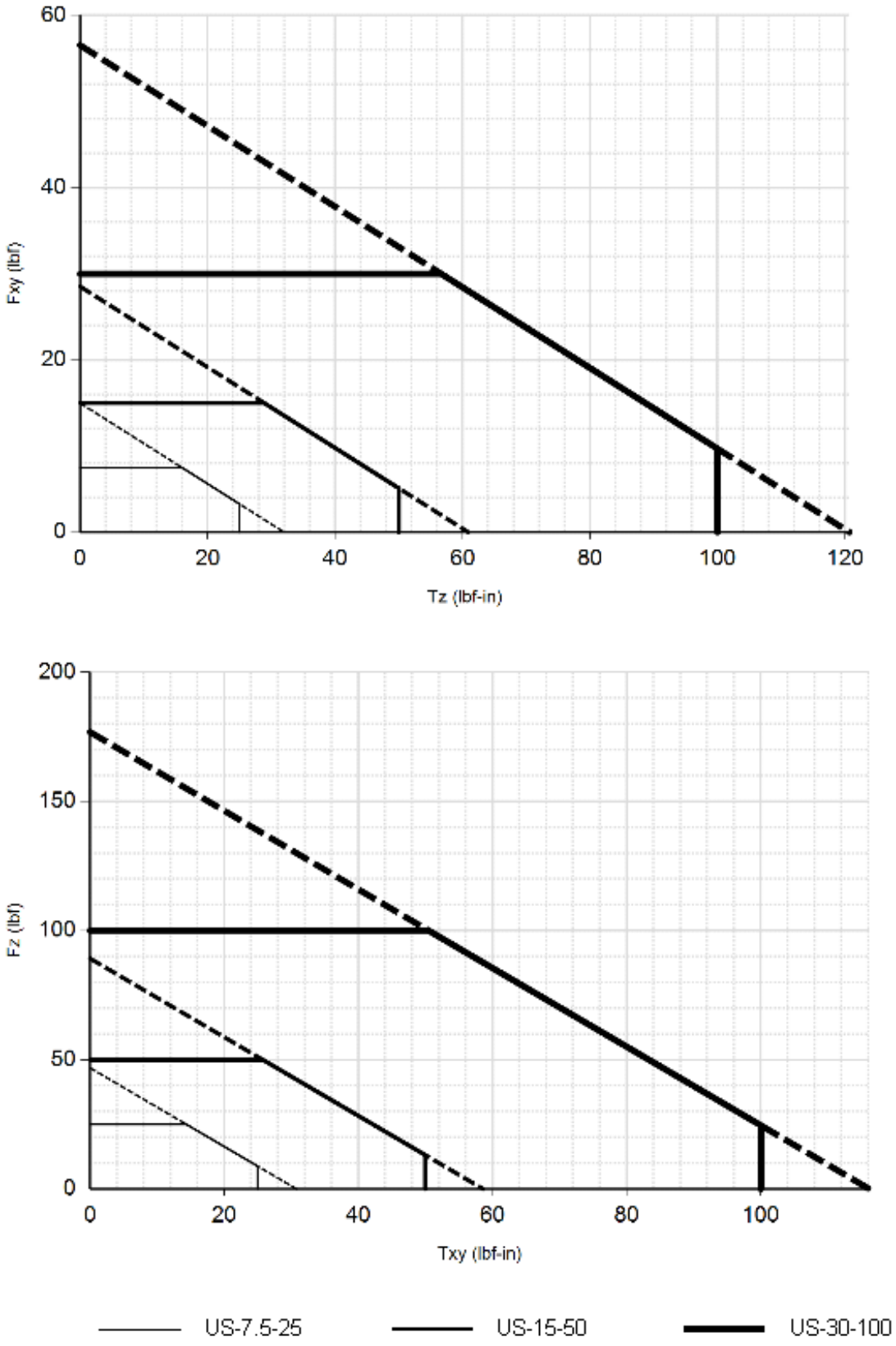
** Specifications include standard interface plates.*

**CAUTION:**
**IP68 Gamma Fz as a Function of Submersion Depth:**

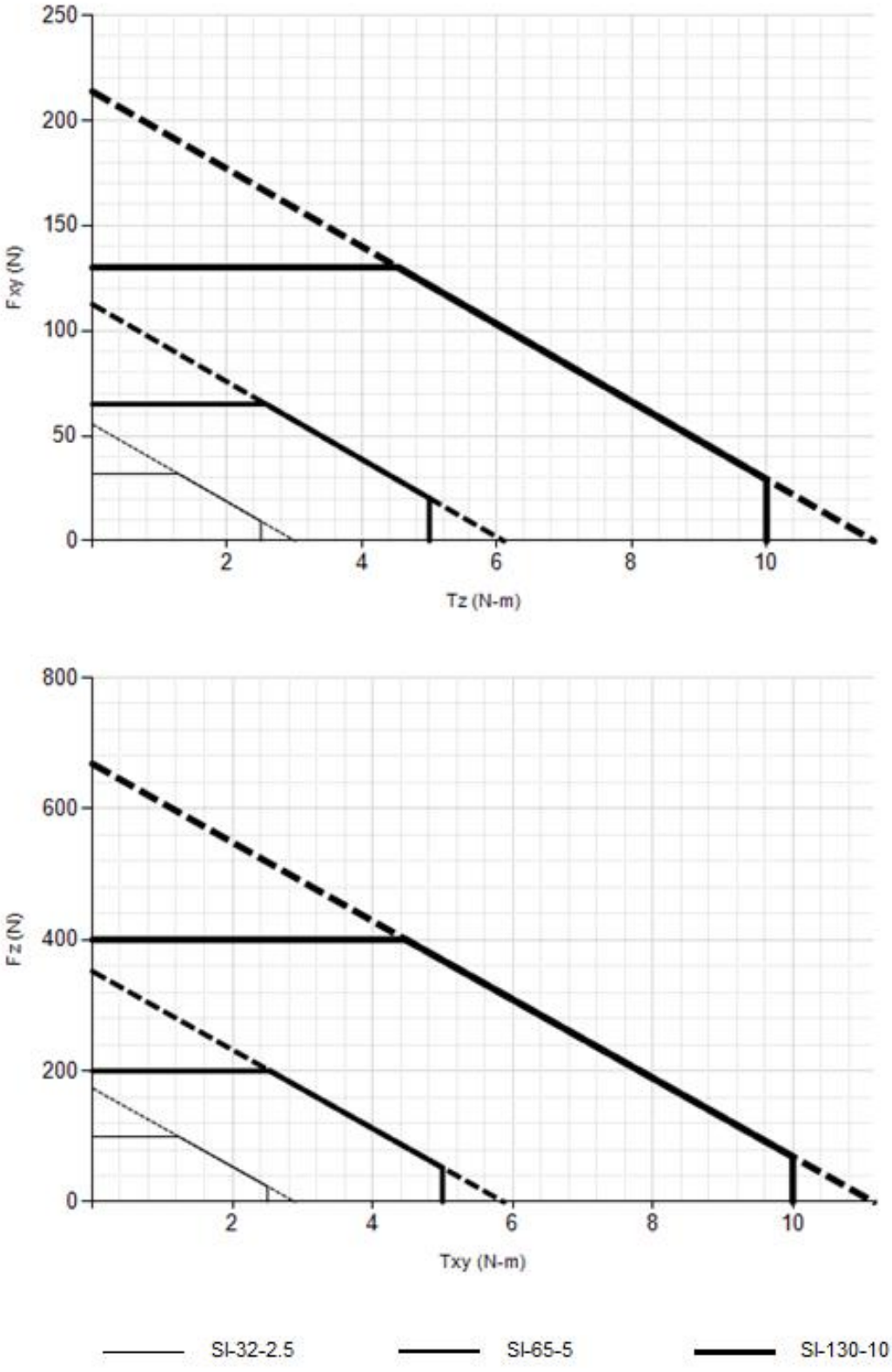
When submerged, IP68 transducers exhibit a decrease in Fz range related to the submersion depth. This loss is the result of pressure-induced preloading on the transducer. The preload can be masked by biasing the transducer at the depth prior to applying the load to be measured. The following estimates are for room temperature fresh water at sea level.

| ***IP68 Gamma*** | **US** | **Metric** |
|---|---|---|
| Fz preload at 4m depth | -42.9 lb | -191 N |
| Fz preload at other depths | -3.27 lb/ft × depthInFeet | -47.4 N/m × depthInMeters |

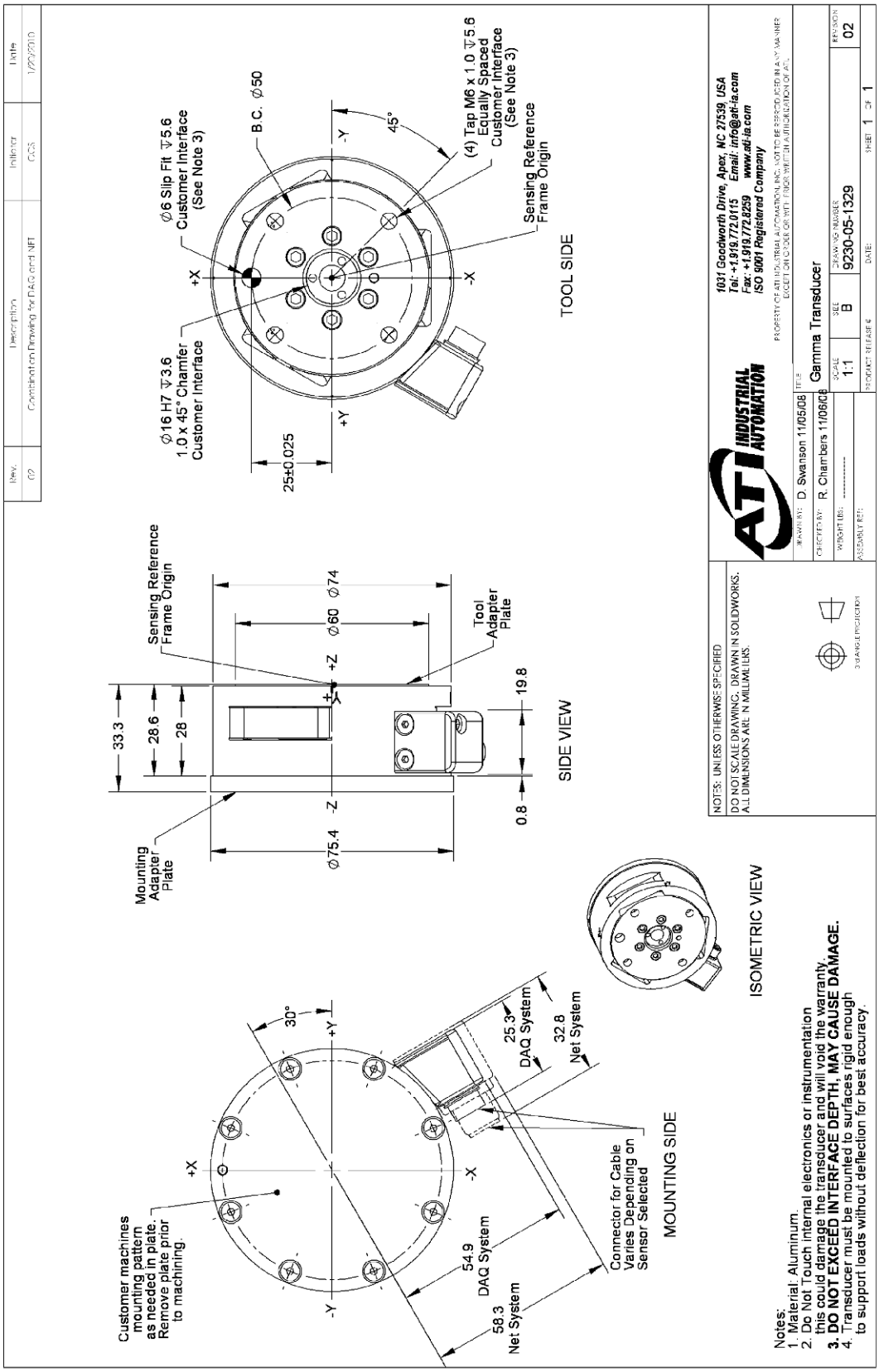
### 4.12.7 Gamma (US Calibration Complex Loading) (Includes IP60/IP65/IP68 Versions)



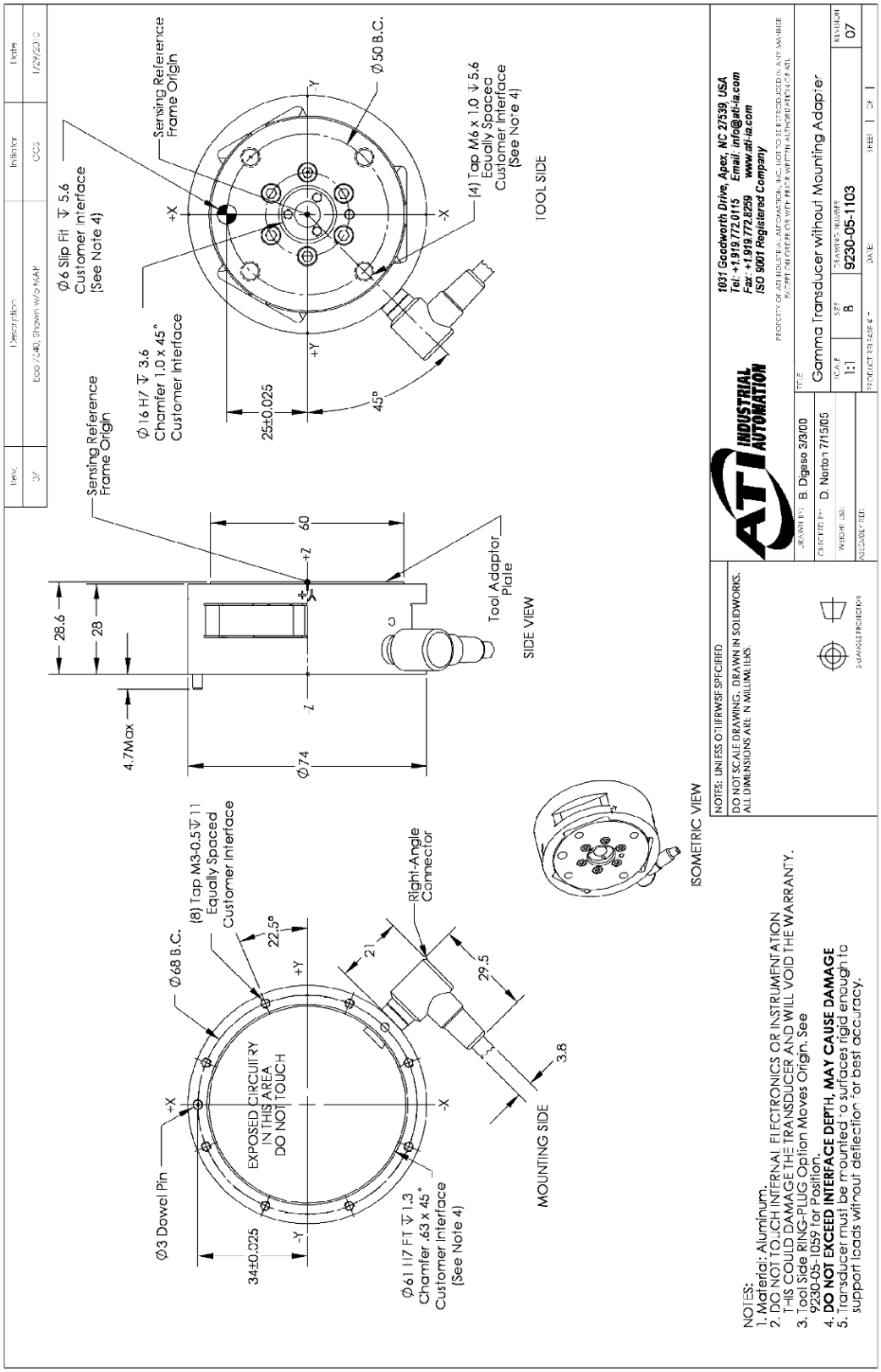
### 4.12.8 Gamma (SI Calibration Complex Loading) (Includes IP60/IP65/IP68 Versions)



### 4.12.9 Gamma DAQ/Net Transducer Drawing

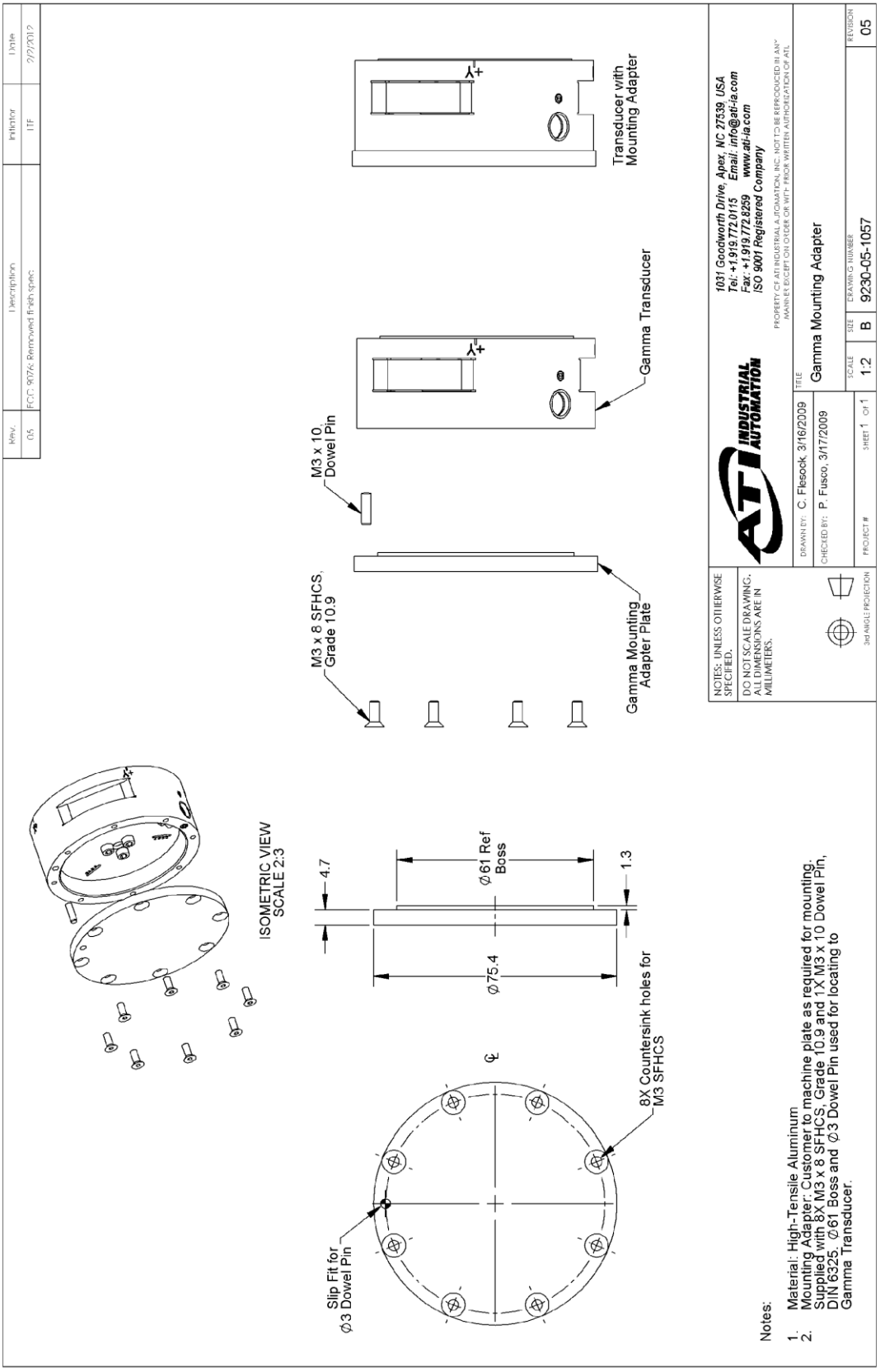


### 4.12.10 9105-T-Gamma Transducer without Mounting Adapter Drawing

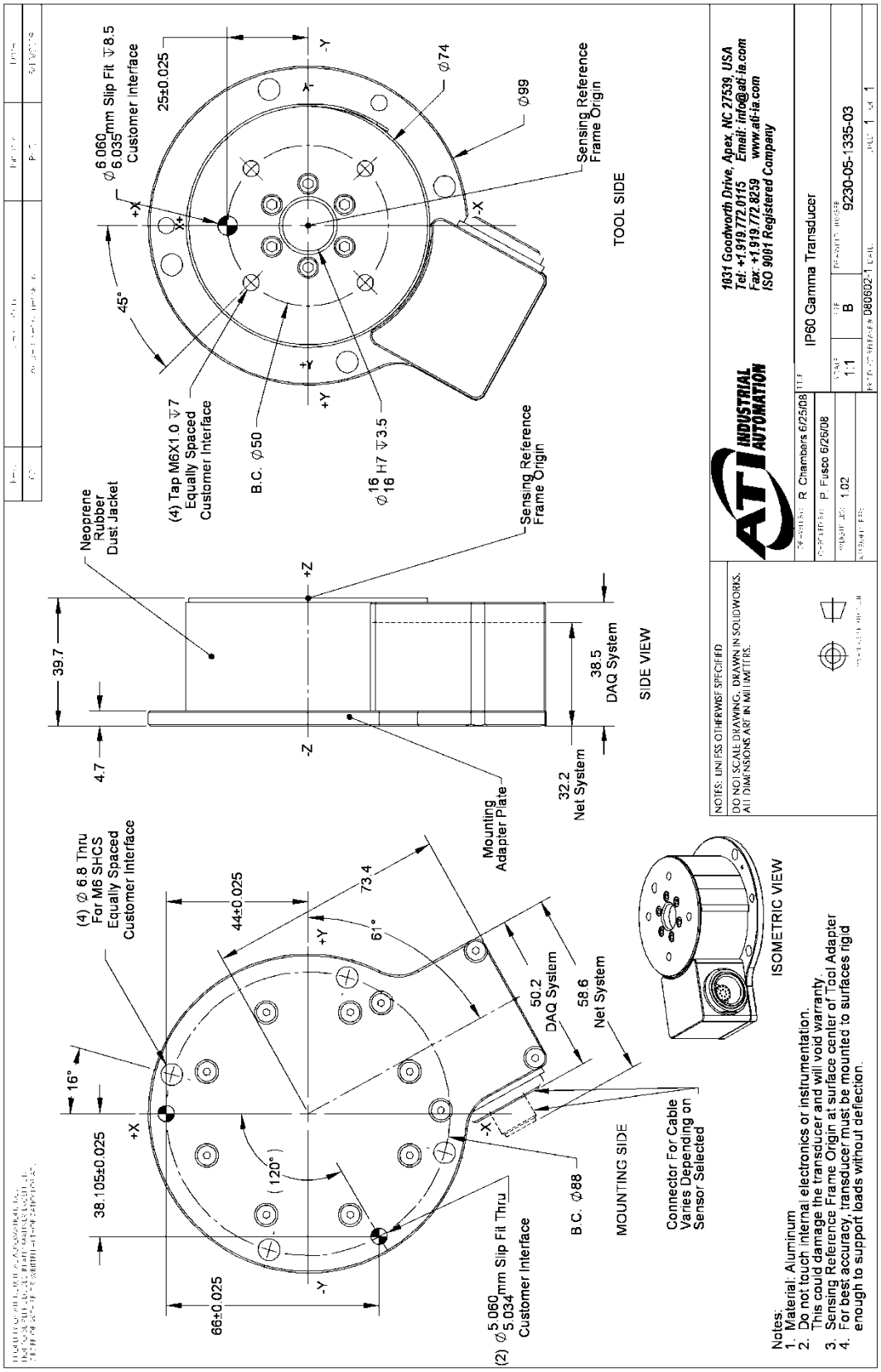



Note: Mux transducers are used in F/T Controller systems.

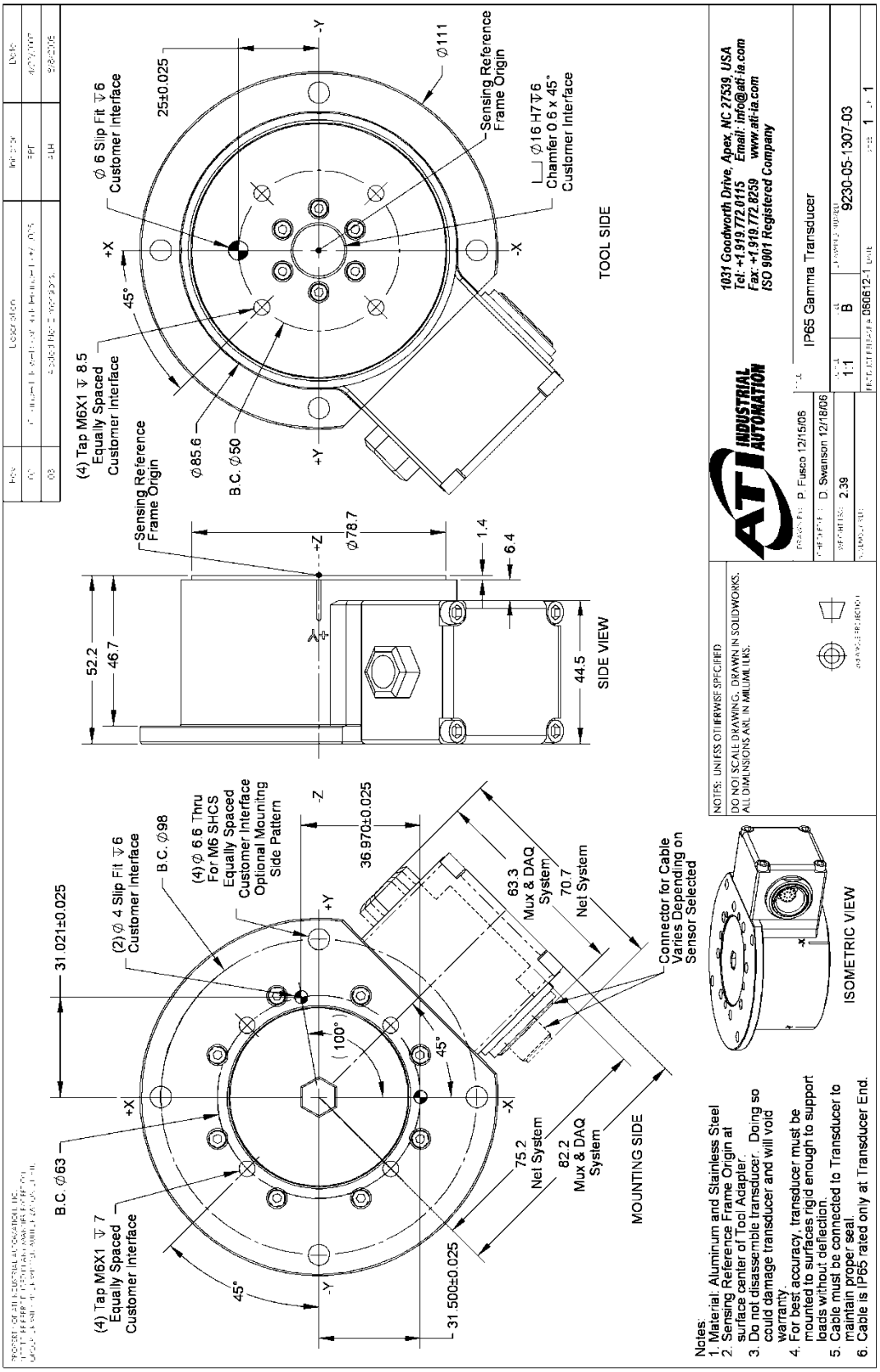
### 4.12.11 Gamma Mounting Adapter Plate Drawing



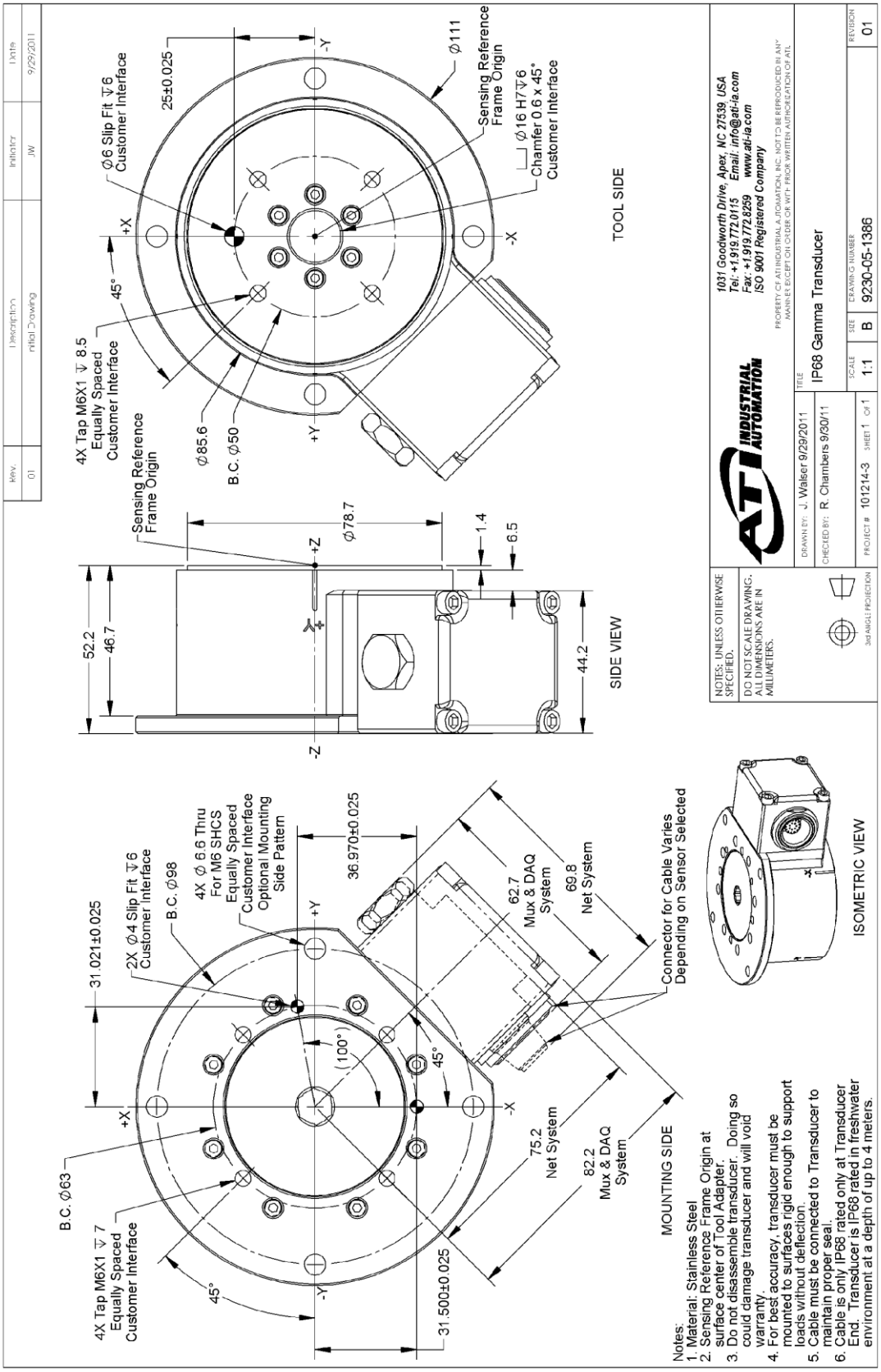
### 4.12.12 Gamma IP60 Transducer Drawing



### 4.12.13 Gamma IP65 Transducer Transducer



### 4.12.14 Gamma IP68 Transducer Drawing



## 4.13 Delta (Includes IP60/IP65/IP68 Versions)

### 4.13.1 Calibration Specifications (excludes CTL calibrations)

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz*** | Tx,Ty | Tz | Fx,Fy | Fz*** | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| US-50–150 | 50 lbf | 150 lbf | 150 lbf-in | 150 lbf-in | 1/128 lbf | 1/64 lbf | 3/128 lbf-in | 1/64 lbf-in |
| US-75–300 | 75 lbf | 225 lbf | 300 lbf-in | 300 lbf-in | 1/64 lbf | 1/32 lbf | 3/64 lbf-in | 1/32 lbf-in |
| US-150–600 | 150 lbf | 450 lbf | 600 lbf-in | 600 lbf-in | 1/32 lbf | 1/16 lbf | 3/32 lbf-in | 1/16 lbf-in |
| | SENSING RANGES | | | | RESOLUTION* | | | |

**Metric Calibrations (SI)**

| Calibration | Fx,Fy | Fz*** | Tx,Ty | Tz | Fx,Fy | Fz*** | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| SI-165–15 | 165 N | 495 N | 15 Nm | 15 Nm | 1/32 N | 1/16 N | 1/528 Nm | 1/528 Nm |
| SI-330–30 | 330 N | 990 N | 30 Nm | 30 Nm | 1/16 N | 1/8 N | 5/1333 Nm | 5/1333 Nm |
| SI-660–60 | 660 N | 1980 N | 60 Nm | 60 Nm | 1/8 N | 1/4 N | 10/1333 Nm | 10/1333 Nm |
| | SENSING RANGES | | | | RESOLUTION* | | | |

** DAQ resolutions are typical for a 16-bit data acquisition system.*

*These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.*

### 4.13.2 CTL Calibration Specifications (Includes IP60/IP65/IP68 Versions)

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz† | Tx,Ty | Tz | Fx,Fy | Fz† | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| US-50–150 | 50 lbf | 150 lbf | 150 lbf-in | 150 lbf-in | 1/64 lbf | 1/32 lbf | 3/64 lbf-in | 1/32 lbf-in |
| US-75–300 | 75 lbf | 225 lbf | 300 lbf-in | 300 lbf-in | 1/32 lbf | 1/16 lbf | 3/32 lbf-in | 1/16 lbf-in |
| US-150–600 | 150 lbf | 450 lbf | 600 lbf-in | 600 lbf-in | 1/16 lbf | 1/8 lbf | 3/16 lbf-in | 1/8 lbf-in |
| | SENSING RANGES | | | | RESOLUTION | | | |

**Metric Calibrations (SI)**

| Calibration | Fx,Fy | Fz† | Tx,Ty | Tz | Fx,Fy | Fz† | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| SI-165–15 | 165 N | 495 N | 15 Nm | 15 Nm | 1/16 N | 1/8 N | 1/264 Nm | 1/264 Nm |
| SI-330–30 | 330 N | 990 N | 30 Nm | 30 Nm | 1/8 N | 1/4 N | 10/1333 Nm | 10/1333 Nm |
| SI-660–60 | 660 N | 1980 N | 60 Nm | 60 Nm | 1/4 N | 1/2 N | 5/333 Nm | 5/333 Nm |
| | SENSING RANGES | | | | RESOLUTION | | | |

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz† | Tx,Ty, Tz | Fx,Fy | Fz† | Tx,Ty, Tz |
|---|---|---|---|---|---|---|
| US-50–150 | ±50 lbf | ±150 lbf | ±150 lbf-in | 5 lbf/V | 15 lbf/V | 15 lbf-in/V |
| US-75–300 | ±75 lbf | ±225 lbf | ±300 lbf-in | 7.5 lbf/V | 22.5 lbf/V | 30 lbf-in/V |
| US-150–600 | ±150 lbf | ±450 lbf | ±600 lbf-in | 15 lbf/V | 45 lbf/V | 60 lbf-in/V |
| | Analog Output Range | | | Analog ±10V Sensitivity‡ | | |

**Metric Calibrations (SI)**

| Calibration | Fx,Fy | Fz† | Tx,Ty, Tz | Fx,Fy | Fz† | Tx,Ty, Tz |
|---|---|---|---|---|---|---|
| SI-165–15 | ±165 N | ±495 N | ±15 Nm | 16.5 N/V | 49.5 N/V | 1.5 Nm/V |
| SI-330–30 | ±330 N | ±990 N | ±30 Nm | 33 N/V | 99 N/V | 3 Nm/V |
| SI-660–60 | ±660 N | ±1980 N | ±60 Nm | 66 N/V | 198 N/V | 6 Nm/V |
| | Analog Output Range | | | Analog ±10V Sensitivity‡ | | |

**Counts Value**

| Calibration | Fx, Fy, Fz | Tx, Ty, Tz | Fx, Fy, Fz | Tx, Ty, Tz |
|---|---|---|---|---|
| US-50–150 / SI-165–15 | 512 / lbf | 512 / lbf-in | 128 / N | 2112 / Nm |
| US-75–300 / SI-330–30 | 256 / lbf | 256 / lbf-in | 64 / N | 1066.67 / Nm |
| US-150–600 / SI-660–60 | 128 / lbf | 128 / lbf-in | 32 / N | 533.333 / Nm |
| **Tool Transform Factor** | 0.01 in/lbf | | 0.6 mm/N | |
| | Counts Value – Standard (US) | | Counts Value – Metric (SI) | |

*CTL resolutions are typical. System resolutions quoted are the effective resolution after dropping eight counts of noise. The effective resolution can be improved with filtering. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.*

*† For IP68 version see caution on physical properties page.*

‡ *±5V Sensitivity values are double the listed ±10V Sensitivity values.*

### 4.13.3 Delta Physical Properties

**Standard (US)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±840 lbf |
| Fz | ±2300 lbf |
| Txy | ±2500 lbf-in |
| Tz | ±3600 lbf-in |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $2.0 \times 10^5$ lb/in |
| Z-axis force (Kz) | $3.4 \times 10^5$ lb/in |
| X-axis & Y-axis torque (Ktx, Kty) | $4.6 \times 10^5$ lbf-in/rad |
| Z-axis torque (Ktz) | $8.1 \times 10^5$ lbf-in/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 1500 Hz |
| Fz, Tx, Ty | 1700 Hz |
| **Physical Specifications** | |
| Weight* | 2.01 lb |
| Diameter* | 3.72 in |
| Height* | 1.31 in |

**Metric (SI)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±3700 N |
| Fz | ±10000 N |
| Txy | ±280 Nm |
| Tz | ±400 Nm |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $3.6 \times 10^7$ N/m |
| Z-axis force (Kz) | $5.9 \times 10^7$ N/m |
| X-axis & Y-axis torque (Ktx, Kty) | $5.2 \times 10^4$ Nm/rad |
| Z-axis torque (Ktz) | $9.1 \times 10^4$ Nm/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 1500 Hz |
| Fz, Tx, Ty | 1700 Hz |
| **Physical Specifications** | |
| Weight* | 0.913 kg |
| Diameter* | 94.5 mm |
| Height* | 33.3 mm |

** Specifications include standard interface plates.*

### 4.13.4 Delta IP60 Physical Properties

**Standard (US)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±840 lbf |
| Fz | ±2300 lbf |
| Txy | ±2500 lbf-in |
| Tz | ±3600 lbf-in |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $2.0 \times 10^5$ lb/in |
| Z-axis force (Kz) | $3.4 \times 10^5$ lb/in |
| X-axis & Y-axis torque (Ktx, Kty) | $4.6 \times 10^5$ lbf-in/rad |
| Z-axis torque (Ktz) | $8.1 \times 10^5$ lbf-in/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 1100 Hz |
| Fz, Tx, Ty | 1100 Hz |
| **Physical Specifications** | |
| Weight* | 4 lb |
| Diameter* | 4.6 in |
| Height* | 1.85 in |

**Metric (SI)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±3700 N |
| Fz | ±10000 N |
| Txy | ±280 Nm |
| Tz | ±400 Nm |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $3.6 \times 10^7$ N/m |
| Z-axis force (Kz) | $5.9 \times 10^7$ N/m |
| X-axis & Y-axis torque (Ktx, Kty) | $5.2 \times 10^4$ Nm/rad |
| Z-axis torque (Ktz) | $9.1 \times 10^4$ Nm/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 1100 Hz |
| Fz, Tx, Ty | 1100 Hz |
| **Physical Specifications** | |
| Weight* | 1.81 kg |
| Diameter* | 117 mm |
| Height* | 47.1 mm |

** Specifications include standard interface plates.*

### 4.13.5 Delta IP65 Physical Properties

**Standard (US)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±840 lbf |
| Fz | ±2300 lbf |
| Txy | ±2500 lbf-in |
| Tz | ±3600 lbf-in |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $2.0 \times 10^5$ lb/in |
| Z-axis force (Kz) | $3.4 \times 10^5$ lb/in |
| X-axis & Y-axis torque (Ktx, Kty) | $4.6 \times 10^5$ lbf-in/rad |
| Z-axis torque (Ktz) | $8.1 \times 10^5$ lbf-in/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 880 Hz |
| Fz, Tx, Ty | 920 Hz |
| **Physical Specifications** | |
| Weight* | 3.91 lb |
| Diameter* | 4.96 in |
| Height* | 2.06 in |

**Metric (SI)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±3700 N |
| Fz | ±10000 N |
| Txy | ±280 Nm |
| Tz | ±400 Nm |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $3.6 \times 10^7$ N/m |
| Z-axis force (Kz) | $5.9 \times 10^7$ N/m |
| X-axis & Y-axis torque (Ktx, Kty) | $5.2 \times 10^4$ Nm/rad |
| Z-axis torque (Ktz) | $9.1 \times 10^4$ Nm/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 880 Hz |
| Fz, Tx, Ty | 920 Hz |
| **Physical Specifications** | |
| Weight* | 1.77 kg |
| Diameter* | 126 mm |
| Height* | 52.2 mm |

** Specifications include standard interface plates.*

### 4.13.6 Delta IP68 Physical Properties

**Standard (US)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±840 lbf |
| Fz | ±2300 lbf |
| Txy | ±2500 lbf-in |
| Tz | ±3600 lbf-in |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $2.0 \times 10^5$ lb/in |
| Z-axis force (Kz) | $3.4 \times 10^5$ lb/in |
| X-axis & Y-axis torque (Ktx, Kty) | $4.6 \times 10^5$ lbf-in/rad |
| Z-axis torque (Ktz) | $8.1 \times 10^5$ lbf-in/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 950 Hz |
| Fz, Tx, Ty | 960 Hz |
| **Physical Specifications** | |
| Weight* | 5.8 lb |
| Diameter* | 4 in |
| Height* | 2.06 in |

**Metric (SI)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±3700 N |
| Fz | ±10000 N |
| Txy | ±280 Nm |
| Tz | ±400 Nm |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $3.6 \times 10^7$ N/m |
| Z-axis force (Kz) | $5.9 \times 10^7$ N/m |
| X-axis & Y-axis torque (Ktx, Kty) | $5.2 \times 10^4$ Nm/rad |
| Z-axis torque (Ktz) | $9.1 \times 10^4$ Nm/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 950 Hz |
| Fz, Tx, Ty | 960 Hz |
| **Physical Specifications** | |
| Weight* | 2.63 kg |
| Diameter* | 102 mm |
| Height* | 52.2 mm |

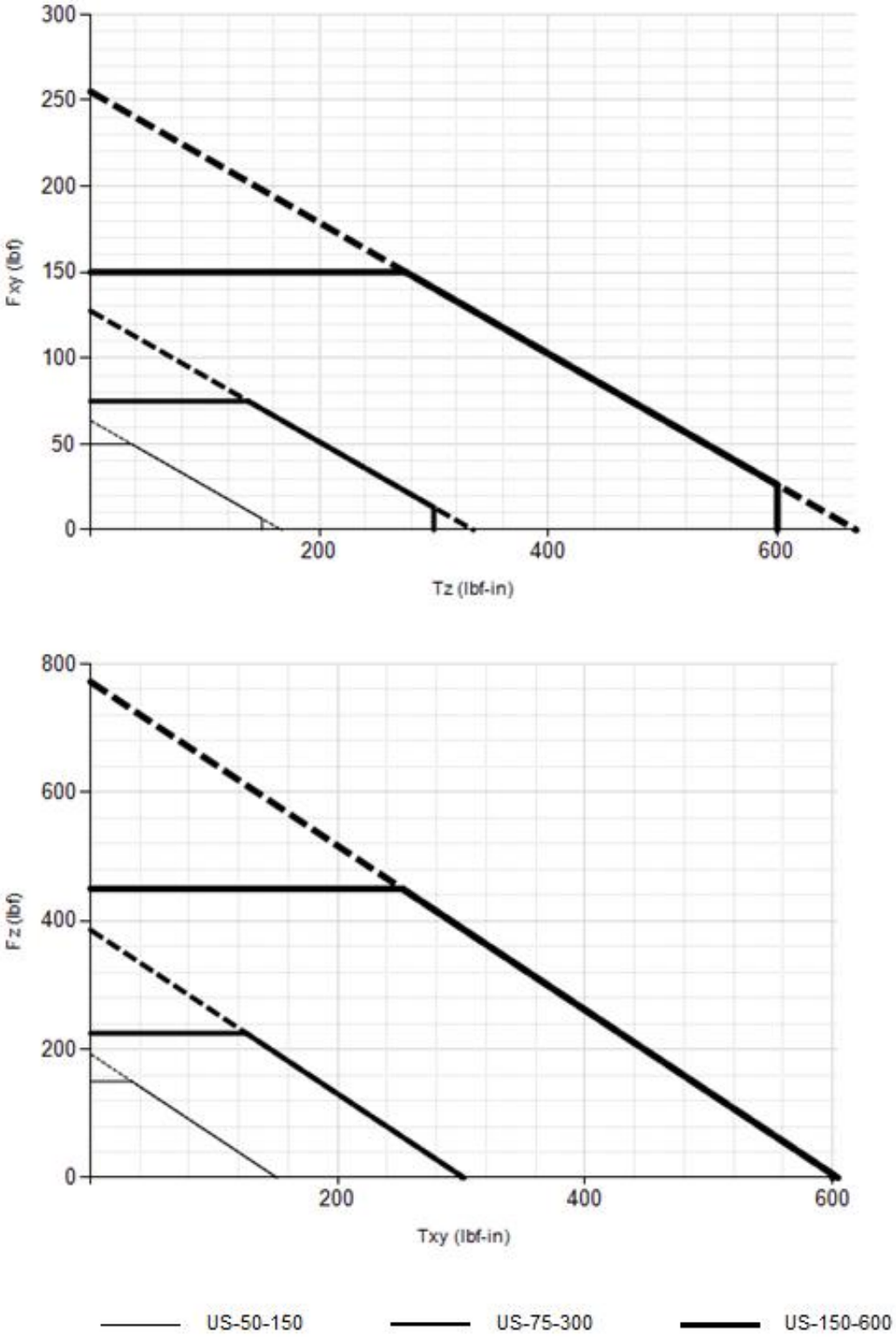
** Specifications include standard interface plates.*

**CAUTION:**
**IP68 Delta Fz as a Function of Submersion Depth:**

When submerged, IP68 transducers exhibit a decrease in Fz range related to the submersion depth. This loss is the result of pressure-induced preloading on the transducer. The preload can be masked by biasing the transducer at the depth prior to applying the load to be measured. The following estimates are for room temperature fresh water at sea level.

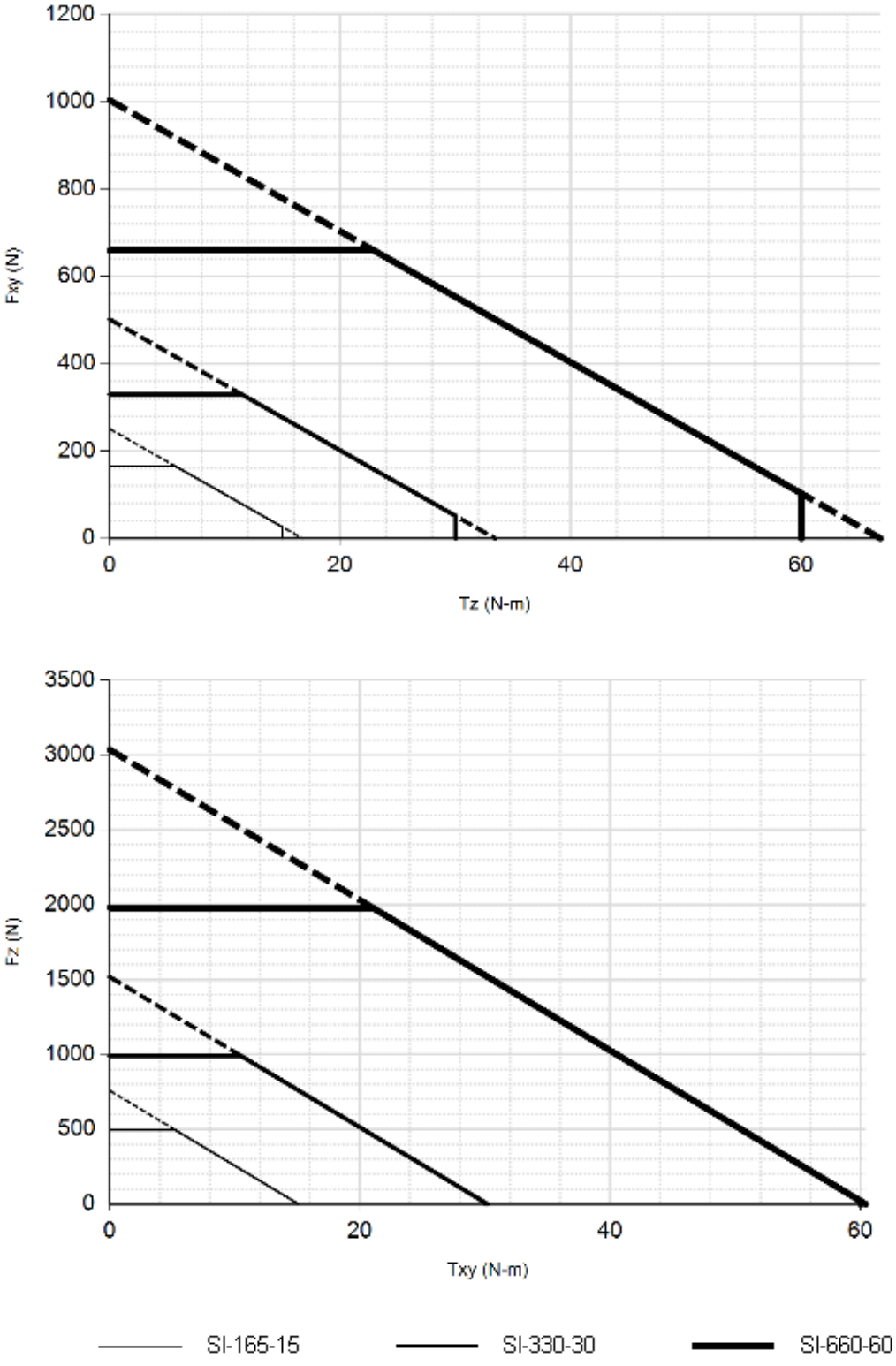
| ***IP68 Delta*** | **US** | **Metric** |
|---|---|---|
| Fz preload at 10m depth | 161 lb | 716 N |
| Fz preload at other depths | -4.9 lb/ft × depthInFeet | -72 N/m × depthInMeters |

### 4.13.7 Delta (US Calibration Complex Loading) (Includes IP60/IP65/IP68 Versions)



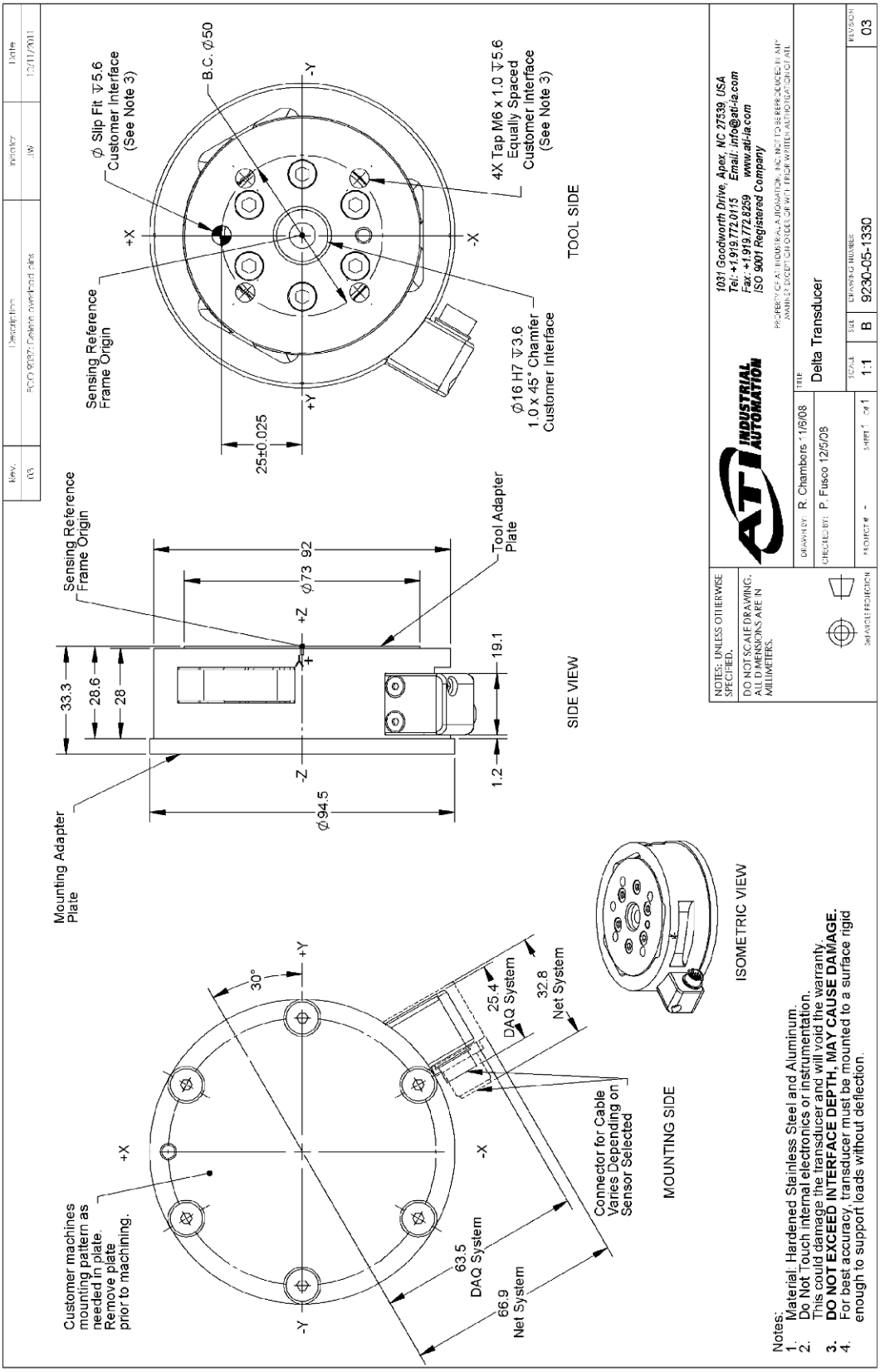

*** For IP68 version see caution on physical properties page.

### 4.13.8 Delta (SI Calibration Complex Loading) (Includes IP60/IP65/IP68 Versions)

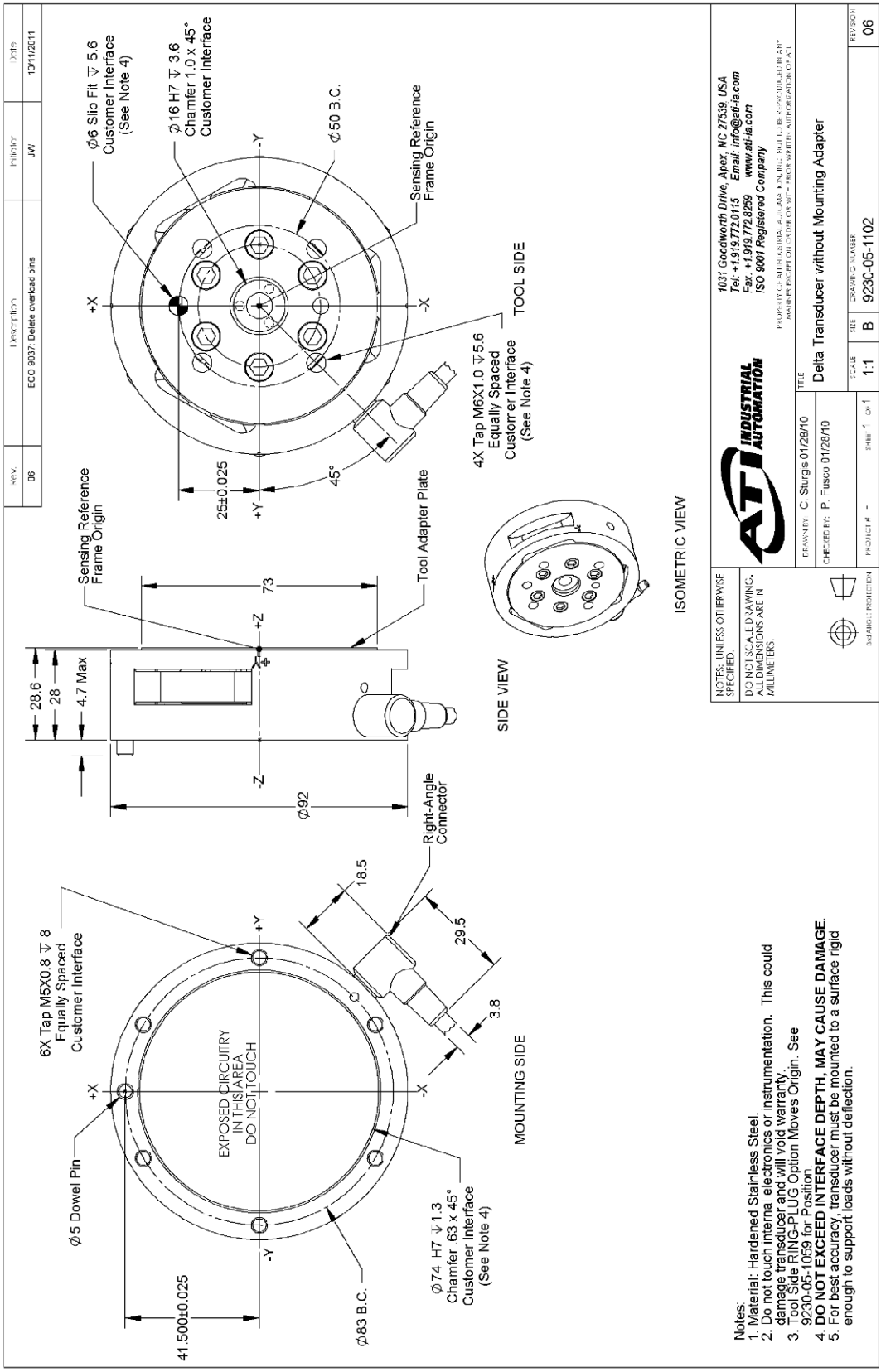



*** For IP68 version see caution on physical properties page.

### 4.13.9 Delta DAQ/Net Transducer Drawing

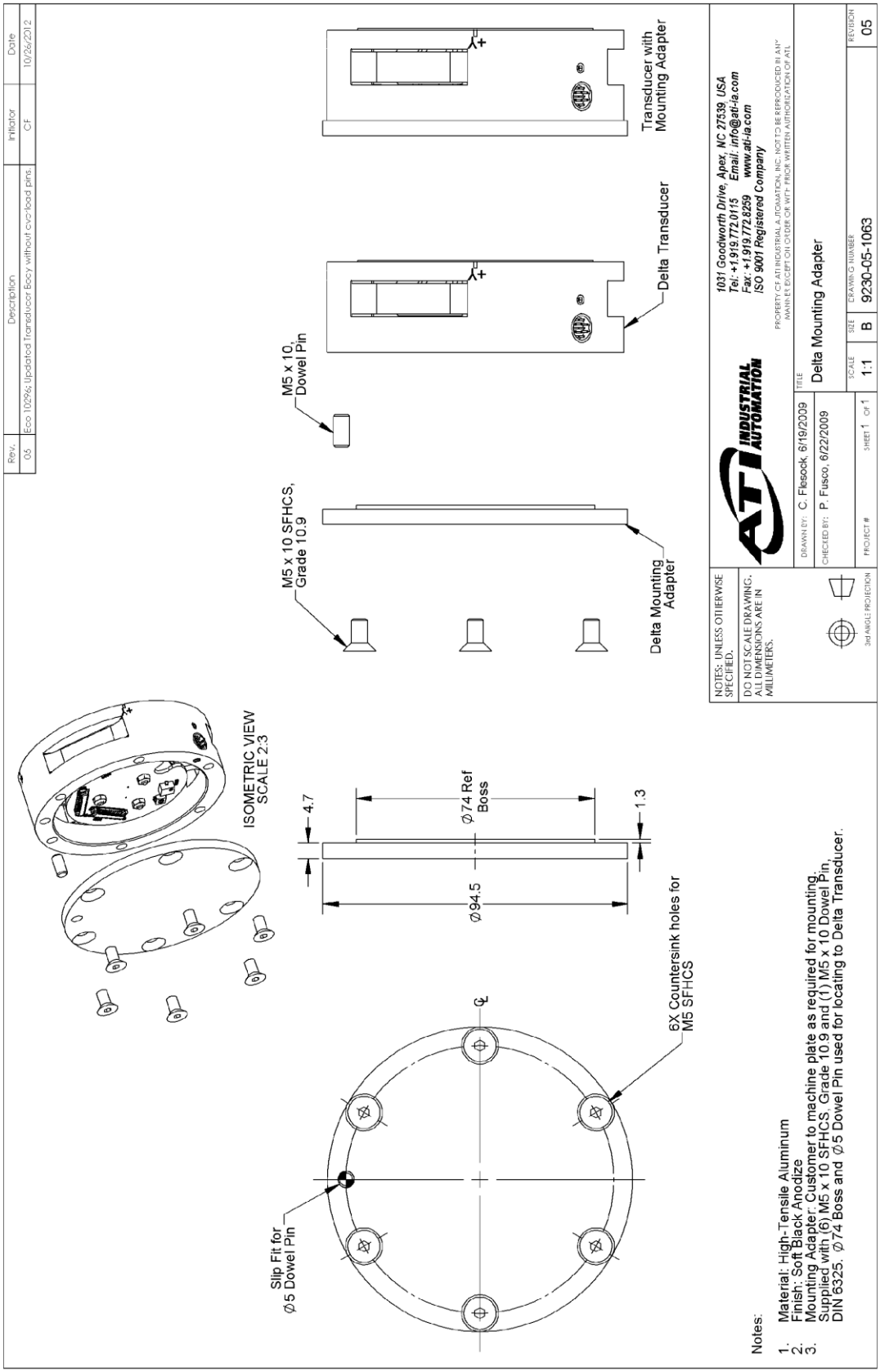


### 4.13.10 9105-T-Delta Transducer without Mounting Adapter Drawing

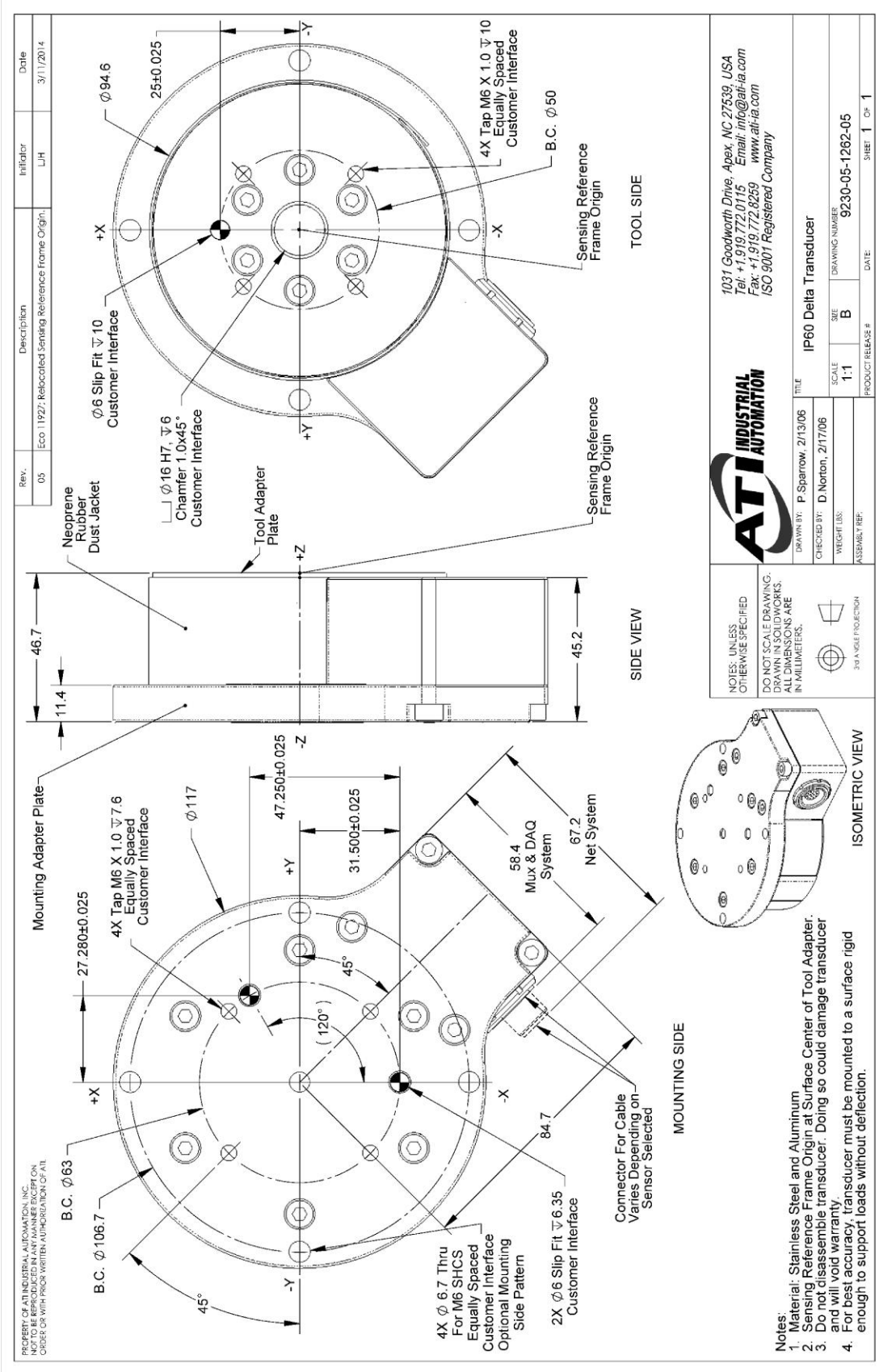



Note: Mux transducers are used in F/T Controller systems.

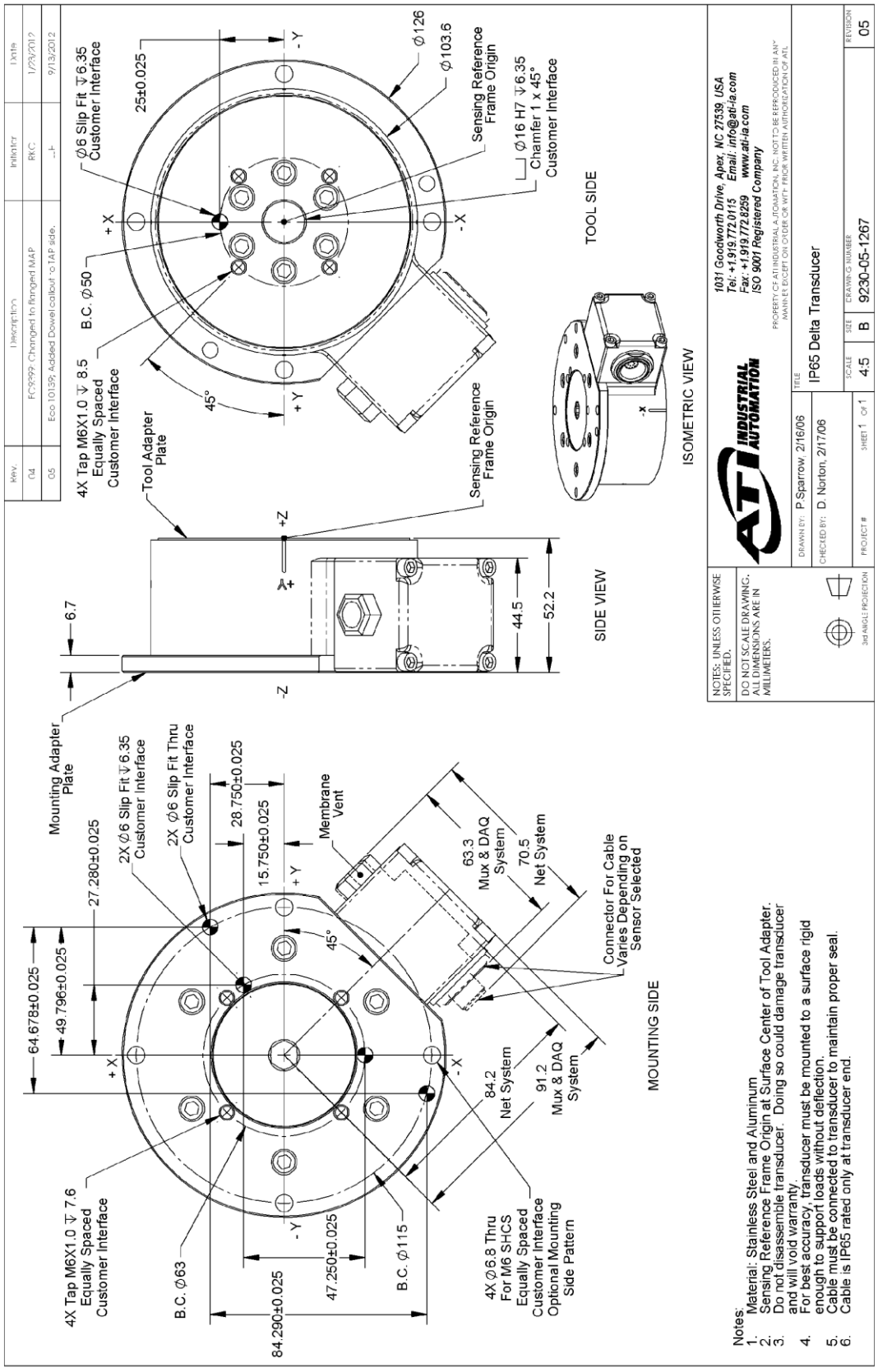
### 4.13.11 Delta Mounting Adapter Drawing



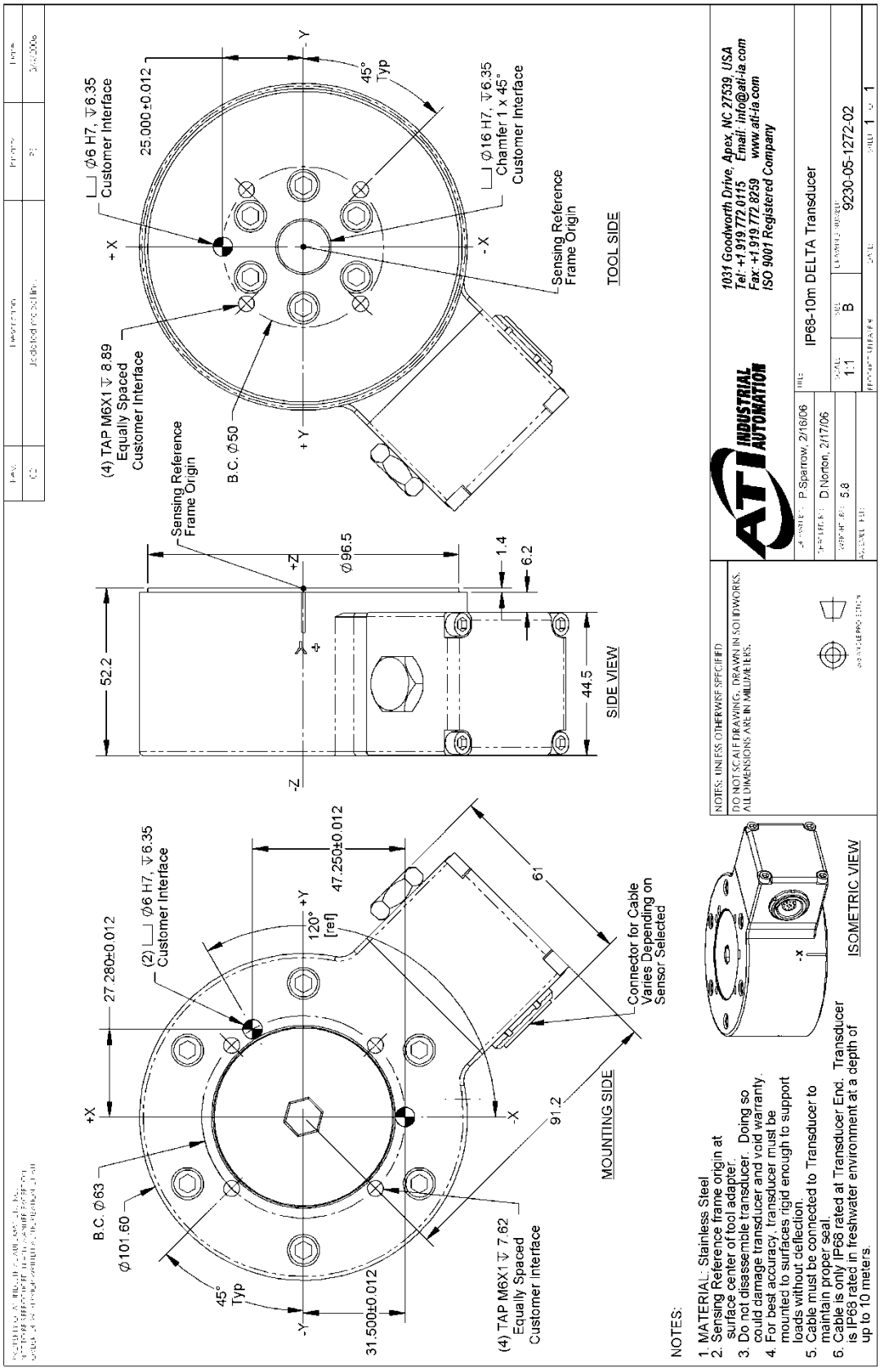
### 4.13.12 Delta IP60 Transducer Drawing



### 4.13.13 Delta IP65 Transducer Drawing



### 4.13.14 Delta IP68 Transducer Drawing



## 4.14 Theta (Includes IP60/IP65/IP68 Versions)

### 4.14.1 Calibration Specifications (excludes CTL calibrations)

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz*** | Tx,Ty | Tz | Fx,Fy | Fz*** | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| US-200–1000 | 200 lbf | 500 lbf | 1000 lbf-in | 1000 lbf-in | 1/32 lbf | 1/16 lbf | 1/8 lbf-in | 1/8 lbf-in |
| US-300–1800 | 300 lbf | 875 lbf | 1800 lbf-in | 1800 lbf-in | 5/68 lbf | 5/34 lbf | 5/16 lbf-in | 5/16 lbf-in |
| US-600–3600 | 600 lbf | 1500 lbf | 3600 lbf-in | 3600 lbf-in | 1/8 lbf | 1/4 lbf | 1/2 lbf-in | 1/2 lbf-in |
| | SENSING RANGES | | | | RESOLUTION* | | | |

**Metric Calibrations (SI)**

| Calibration | Fx,Fy | Fz*** | Tx,Ty | Tz | Fx,Fy | Fz*** | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| SI-1000–120 | 1000 N | 2500 N | 120 Nm | 120 Nm | 1/4 N | 1/4 N | 1/40 Nm | 1/80 Nm |
| SI-1500–240 | 1500 N | 3750 N | 240 Nm | 240 Nm | 1/2 N | 1/2 N | 1/20 Nm | 1/40 Nm |
| SI-2500–400 | 2500 N | 6250 N | 400 Nm | 400 Nm | 1/2 N | 1 N | 1/20 Nm | 1/20 Nm |
| | SENSING RANGES | | | | RESOLUTION* | | | |

** DAQ resolutions are typical for a 16-bit data acquisition system.*

*These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.*

### 4.14.2 CTL Calibration Specifications

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz† | Tx,Ty | Tz | Fx,Fy | Fz† | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| US-200–1000 | 200 lbf | 500 lbf | 1000 lbf-in | 1000 lbf-in | 1/16 lbf | 1/8 lbf | 1/4 lbf-in | 1/4 lbf-in |
| US-300–1800 | 300 lbf | 875 lbf | 1800 lbf-in | 1800 lbf-in | 5/34 lbf | 5/17 lbf | 5/8 lbf-in | 5/8 lbf-in |
| US-600–3600 | 600 lbf | 1500 lbf | 3600 lbf-in | 3600 lbf-in | 1/4 lbf | 1/2 lbf | 1 lbf-in | 1 lbf-in |

**Metric Calibrations (SI)**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| SI-1000–120 | 1000 N | 2500 N | 120 Nm | 120 Nm | 1/2 N | 1/2 N | 1/20 Nm | 1/40 Nm |
| SI-1500–240 | 1500 N | 3750 N | 240 Nm | 240 Nm | 1 N | 1 N | 1/10 Nm | 1/20 Nm |
| SI-2500–400 | 2500 N | 6250 N | 400 Nm | 400 Nm | 1 N | 2 N | 1/10 Nm | 1/10 Nm |
| | SENSING RANGES | | | | RESOLUTION | | | |

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz† | Tx,Ty, Tz | Fx,Fy | Fz† | Tx,Ty, Tz |
|---|---|---|---|---|---|---|
| US-200–1000 | ±200 lbf | ±500 lbf | ±1000 lbf-in | 20 lbf/V | 50 lbf/V | 100 lbf-in/V |
| US-300–1800 | ±300 lbf | ±875 lbf | ±1800 lbf-in | 30 lbf/V | 87.5 lbf/V | 180 lbf-in/V |
| US-600–3600 | ±600 lbf | ±1500 lbf | ±3600 lbf-in | 60 lbf/V | 150 lbf/V | 360 lbf-in/V |

**Metric Calibrations (SI)**

| | | | | | | |
|---|---|---|---|---|---|---|
| SI-1000–120 | ±1000 N | ±2500 N | ±120 Nm | 100 N/V | 250 N/V | 12 Nm/V |
| SI-1500–240 | ±1500 N | ±3750 N | ±240 Nm | 150 N/V | 375 N/V | 24 Nm/V |
| SI-2500–400 | ±2500 N | ±6250 N | ±400 Nm | 250 N/V | 625 N/V | 40 Nm/V |
| | Analog Output Range | | | Analog ±10V Sensitivity‡ | | |

**Counts Value**

| Calibration | Fx, Fy, Fz | Tx, Ty, Tz | Fx, Fy, Fz | Tx, Ty, Tz |
|---|---|---|---|---|
| US-200–1000 / SI-1000–120 | 128 / lbf | 64 / lbf-in | 32 / N | 320 / Nm |
| US-300–1800 / SI-1500–240 | 54.4 / lbf | 12.8 / lbf-in | 16 / N | 160 / Nm |
| US-600–3600 / SI-2500–400 | 32 / lbf | 16 / lbf-in | 16 / N | 80 / Nm |
| **Tool Transform Factor** | See Tool Transform Factor table | | | |
| | Counts Value – Standard (US) | | Counts Value – Metric (SI) | |

**Tool Transform Factor**

| Calibration | US (English) | SI (Metric) |
|---|---|---|
| US-200–1000 / SI-1000–120 | 0.02 in/lbf | 1 mm/N |
| US-300–1800 / SI-1500–240 | 0.0425 in/lbf | 1 mm/N |
| US-600–3600 / SI-2500–400 | 0.02 in/lbf | 2 mm/N |

*CTL resolutions are typical. System resolutions quoted are the effective resolution after dropping eight counts of noise. The effective resolution can be improved with filtering. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.*

*† For IP68 version see caution on physical properties page.*
*‡ ±5V Sensitivity values are double the listed ±10V Sensitivity values.*

### 4.14.3 Theta Physical Properties (Includes IP60/IP65/IP68 Versions)

**Standard (US)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±4500 lbf |
| Fz | ±11000 lbf |
| Txy | ±18000 lbf-in |
| Tz | ±18000 lbf-in |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $4.0 \times 10^5$ lb/in |
| Z-axis force (Kz) | $6.9 \times 10^5$ lb/in |
| X-axis & Y-axis torque (Ktx, Kty) | $3.0 \times 10^6$ lbf-in/rad |
| Z-axis torque (Ktz) | $4.7 \times 10^6$ lbf-in/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 680 Hz |
| Fz, Tx, Ty | 820 Hz |
| **Physical Specifications** | |
| Weight* | 11 lb |
| Diameter* | 6.1 in |
| Height* | 2.41 in |

**Metric (SI)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±20000 N |
| Fz | ±51000 N |
| Txy | ±2000 Nm |
| Tz | ±2000 Nm |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $7.1 \times 10^7$ N/m |
| Z-axis force (Kz) | $1.2 \times 10^8$ N/m |
| X-axis & Y-axis torque (Ktx, Kty) | $3.4 \times 10^5$ Nm/rad |
| Z-axis torque (Ktz) | $5.3 \times 10^5$ Nm/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 680 Hz |
| Fz, Tx, Ty | 820 Hz |
| **Physical Specifications** | |
| Weight* | 4.99 kg |
| Diameter* | 155 mm |
| Height* | 61.1 mm |

** Specifications include standard interface plates.*

### 4.14.4 Theta IP60 Physical Properties

**Standard (US)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±4500 lbf |
| Fz | ±11000 lbf |
| Txy | ±18000 lbf-in |
| Tz | ±18000 lbf-in |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $4.0 \times 10^5$ lb/in |
| Z-axis force (Kz) | $6.9 \times 10^5$ lb/in |
| X-axis & Y-axis torque (Ktx, Kty) | $3.0 \times 10^6$ lbf-in/rad |
| Z-axis torque (Ktz) | $4.7 \times 10^6$ lbf-in/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | |
| Fz, Tx, Ty | |
| **Physical Specifications** | |
| Weight* | 19 lb |
| Diameter* | 7.63 in |
| Height* | 2.91 in |

**Metric (SI)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±20000 N |
| Fz | ±51000 N |
| Txy | ±2000 Nm |
| Tz | ±2000 Nm |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $7.1 \times 10^7$ N/m |
| Z-axis force (Kz) | $1.2 \times 10^8$ N/m |
| X-axis & Y-axis torque (Ktx, Kty) | $3.4 \times 10^5$ Nm/rad |
| Z-axis torque (Ktz) | $5.3 \times 10^5$ Nm/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | |
| Fz, Tx, Ty | |
| **Physical Specifications** | |
| Weight* | 8.62 kg |
| Diameter* | 194 mm |
| Height* | 74 mm |

** Specifications include standard interface plates.*

### 4.14.5 Theta IP65/IP68 Physical Properties

**Standard (US)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±4500 lbf |
| Fz | ±11000 lbf |
| Txy | ±18000 lbf-in |
| Tz | ±18000 lbf-in |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $4.0 \times 10^5$ lb/in |
| Z-axis force (Kz) | $6.9 \times 10^5$ lb/in |
| X-axis & Y-axis torque (Ktx, Kty) | $3.0 \times 10^6$ lbf-in/rad |
| Z-axis torque (Ktz) | $4.7 \times 10^6$ lbf-in/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | |
| Fz, Tx, Ty | |
| **Physical Specifications** | |
| Weight* | 19.8 lb |
| Diameter* | 6.41 in |
| Height* | 2.95 in |

**Metric (SI)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±20000 N |
| Fz | ±51000 N |
| Txy | ±2000 Nm |
| Tz | ±2000 Nm |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $7.1 \times 10^7$ N/m |
| Z-axis force (Kz) | $1.2 \times 10^8$ N/m |
| X-axis & Y-axis torque (Ktx, Kty) | $3.4 \times 10^5$ Nm/rad |
| Z-axis torque (Ktz) | $5.3 \times 10^5$ Nm/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | |
| Fz, Tx, Ty | |
| **Physical Specifications** | |
| Weight* | 9 kg |
| Diameter* | 163 mm |
| Height* | 74.8 mm |

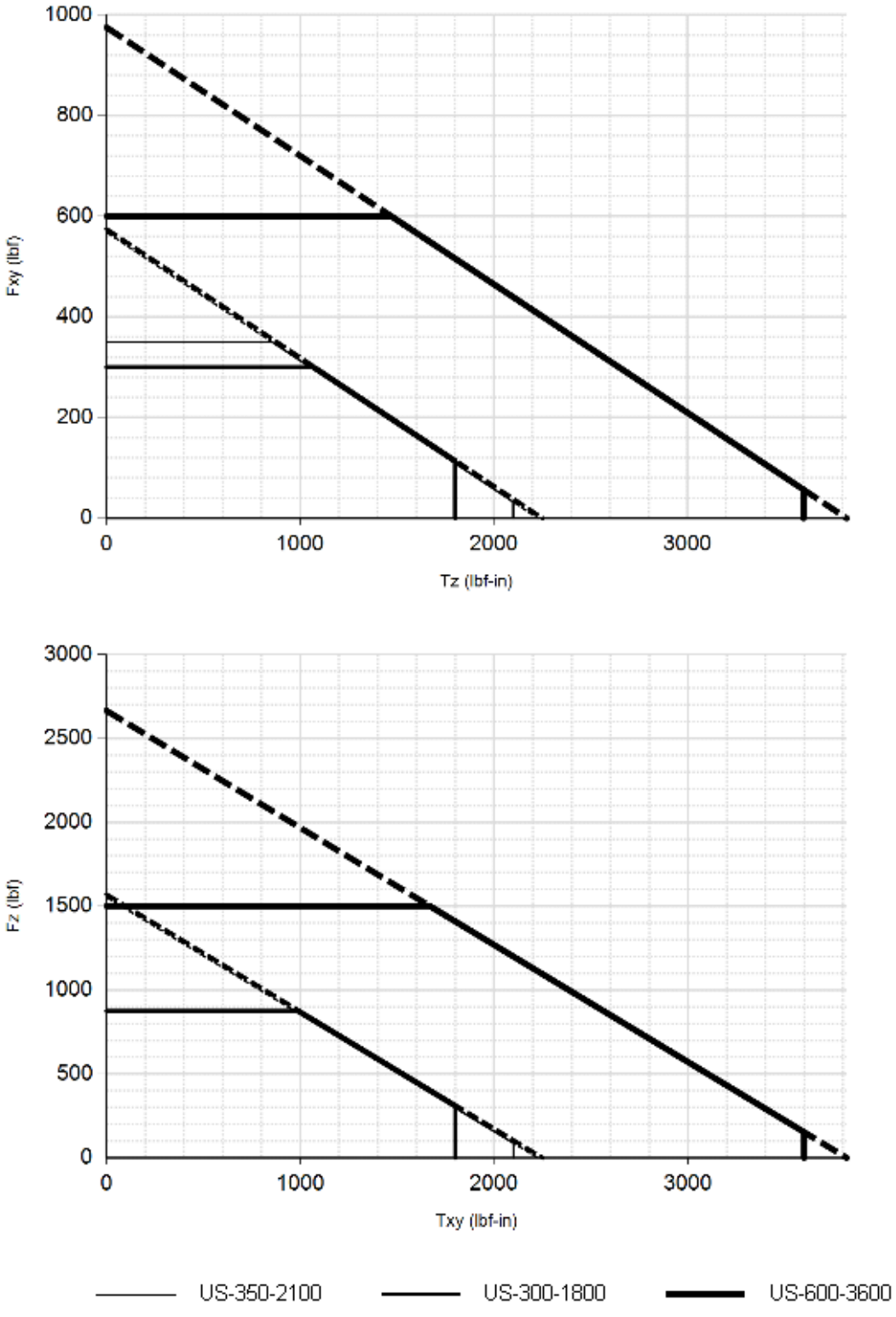
** Specifications include standard interface plates.*

**CAUTION:**
**IP68 Theta Fz as a Function of Submersion Depth:**

When submerged, IP68 transducers exhibit a decrease in Fz range related to the submersion depth. This loss is the result of pressure-induced preloading on the transducer. The preload can be masked by biasing the transducer at the depth prior to applying the load to be measured. The following estimates are for room temperature fresh water at sea level.

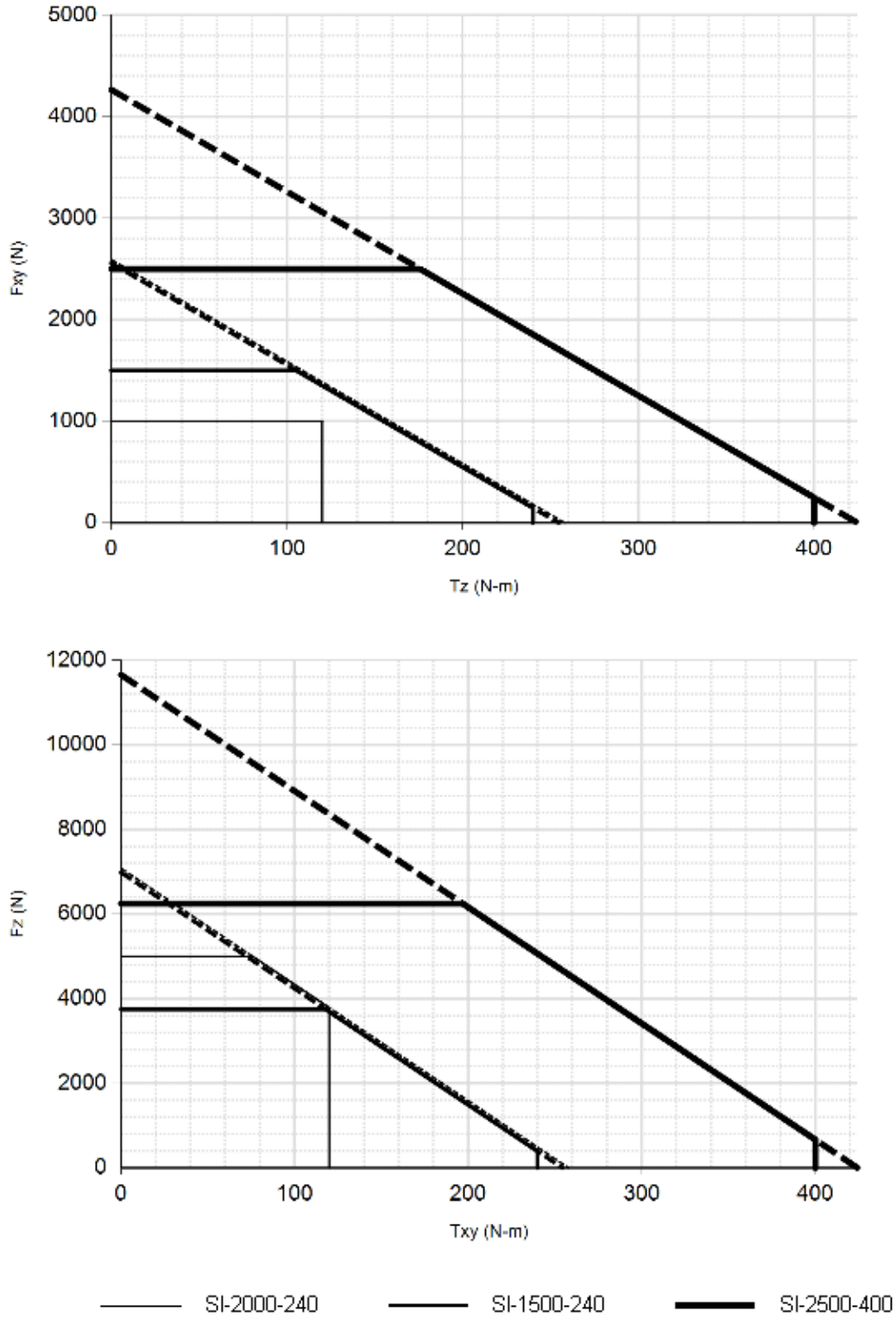
| ***IP68 Theta*** | **US** | **Metric** |
|---|---|---|
| Fz preload at 10m depth | 429 lb | 1907 N |
| Fz preload at other depths | -13 lb/ft × depthInFeet | -191 N/m × depthInMeters |

### 4.14.6 Theta (US Calibration Complex Loading) (Includes IP60/IP65/IP68 Versions)



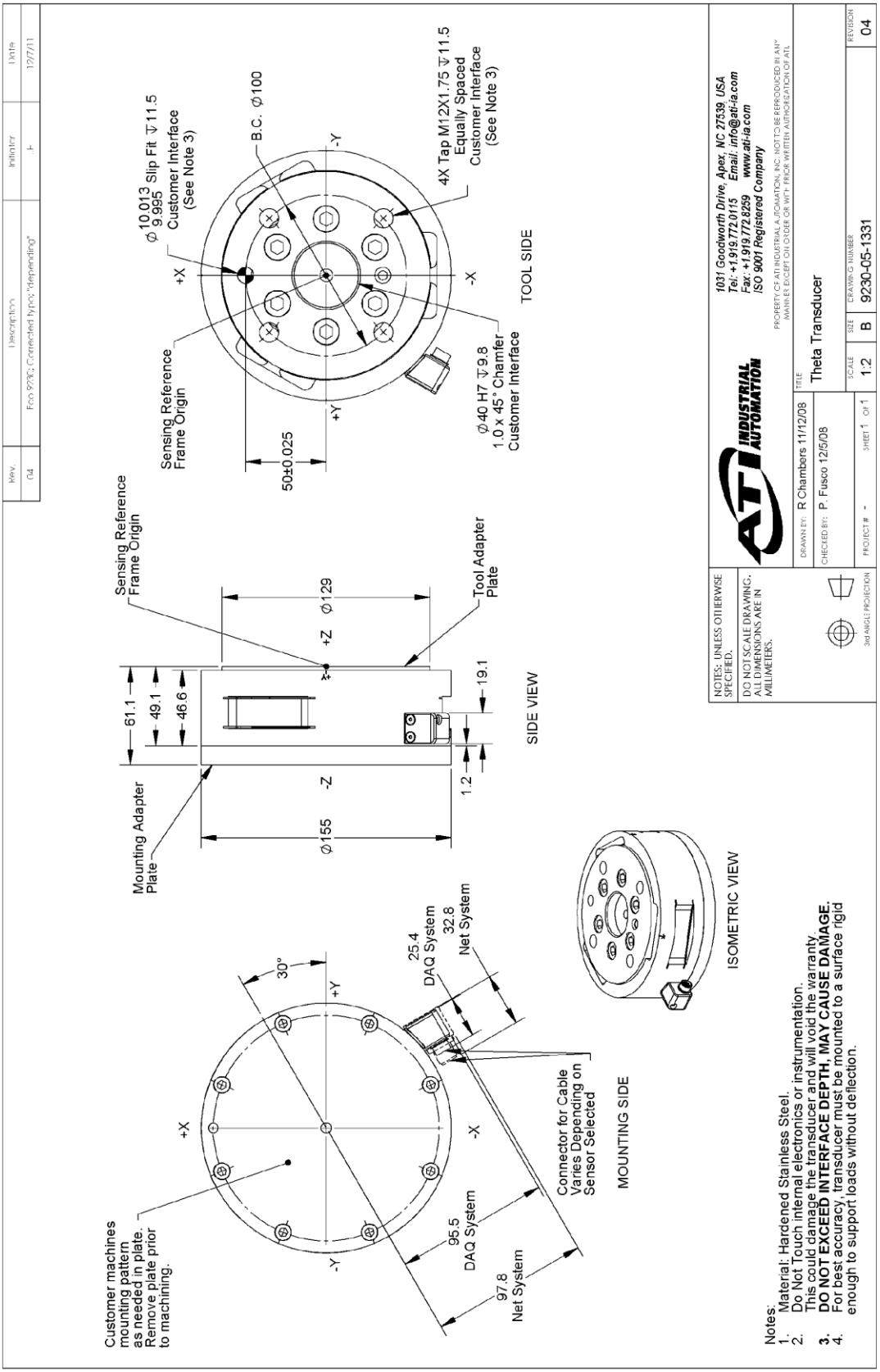

*** For IP68 version see caution on physical properties page.

### 4.14.7 Theta (SI Calibration Complex Loading) (Includes IP60/IP65/IP68 Versions)

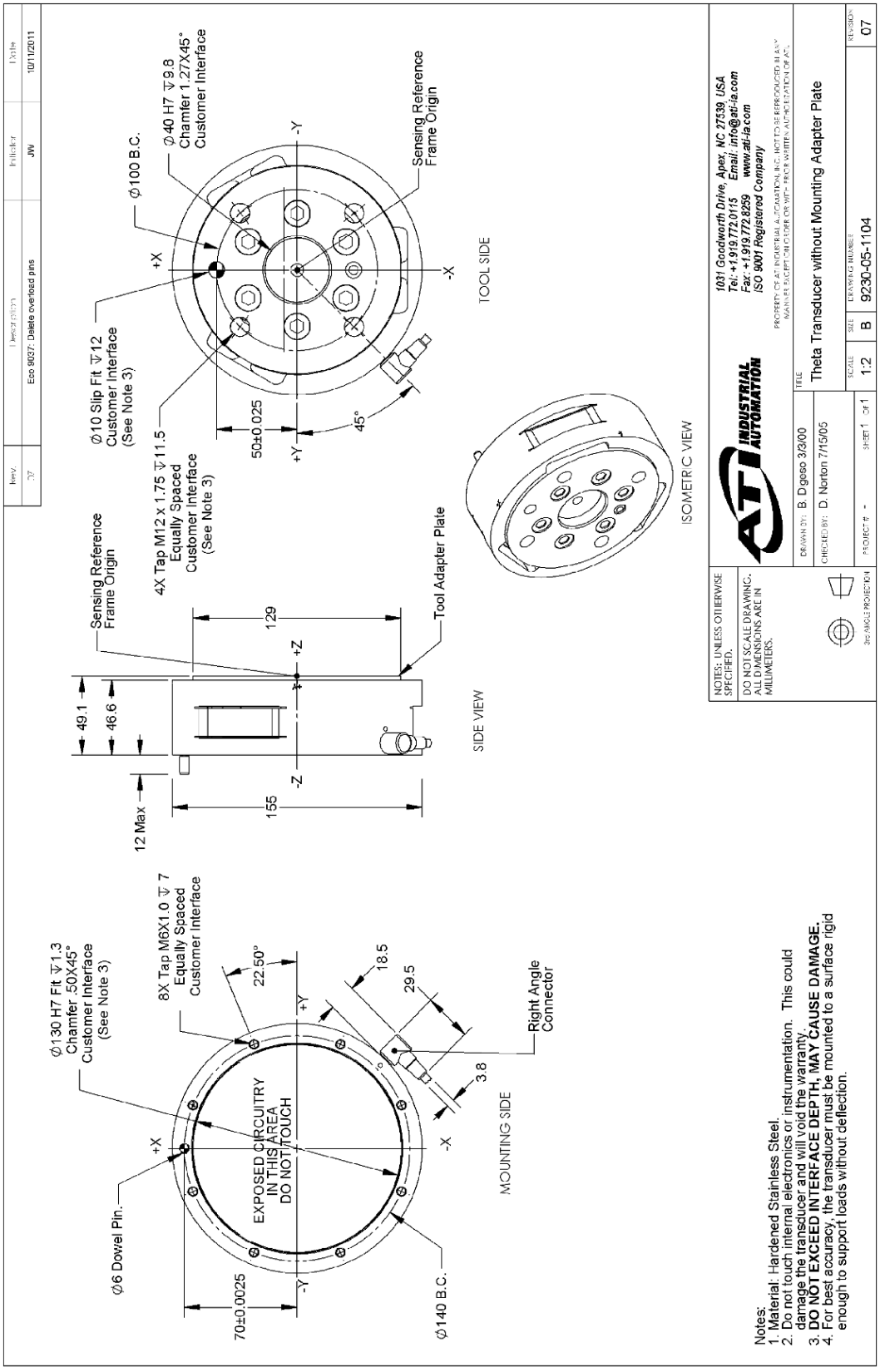



*** For IP68 version see caution on physical properties page.

### 4.14.8 Theta DAQ/Net Transducer Drawing

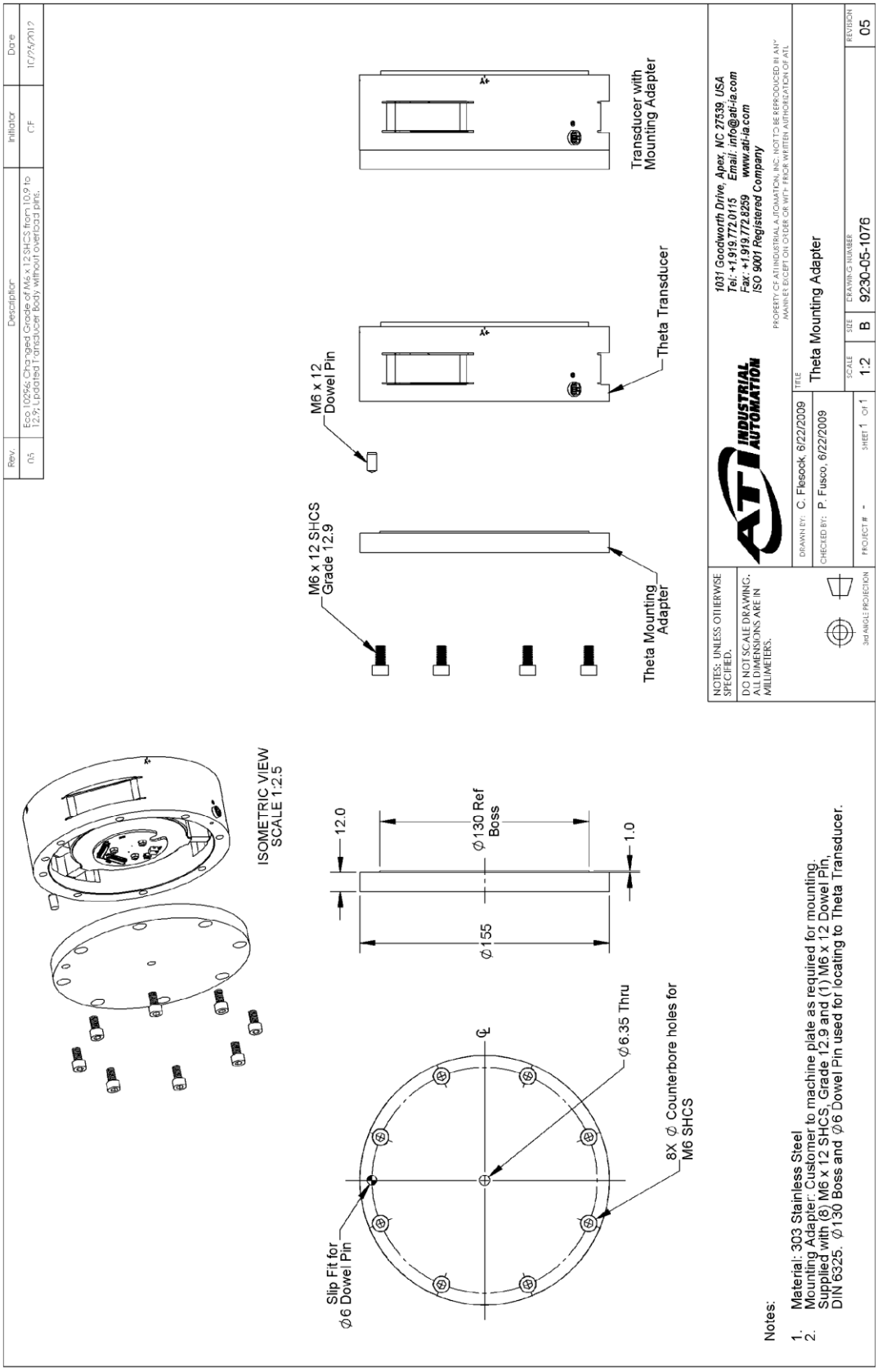


### 4.14.9 9105-T-Theta Transducer without Mounting Adapter Plate Drawing

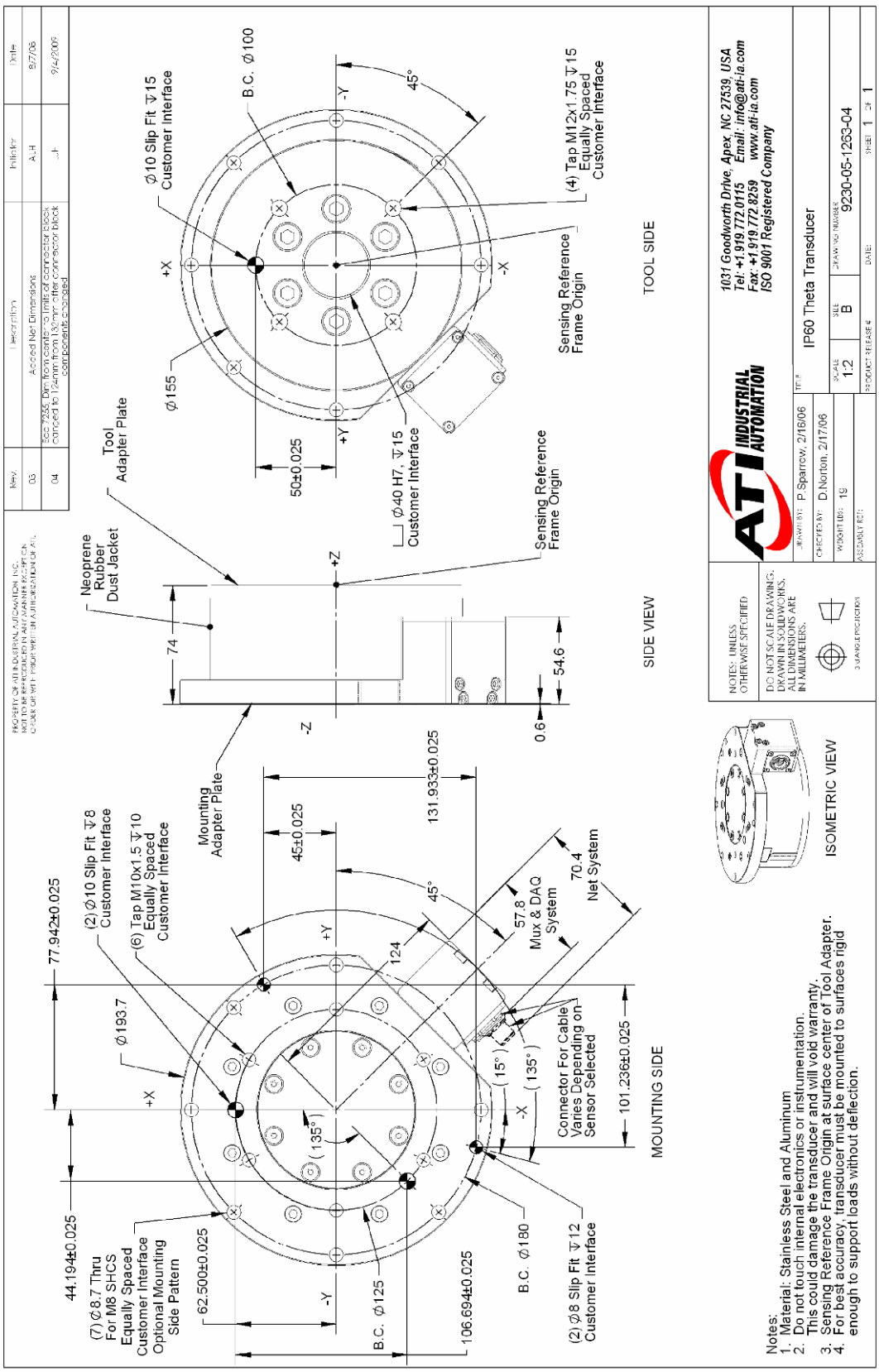



Note: Mux transducers are used in F/T Controller systems.

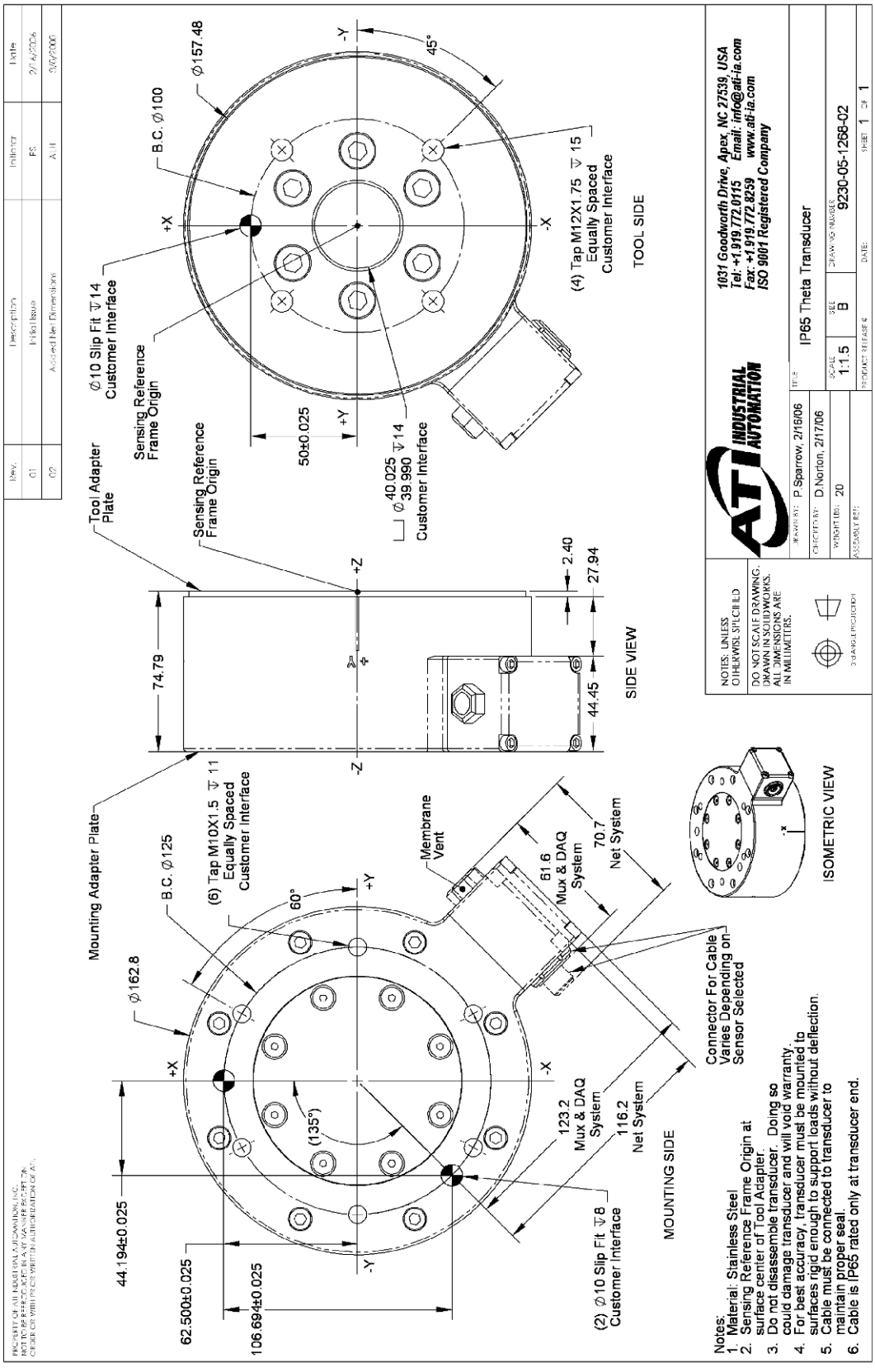
### 4.14.10 Theta Mounting Adapter Plate Drawing



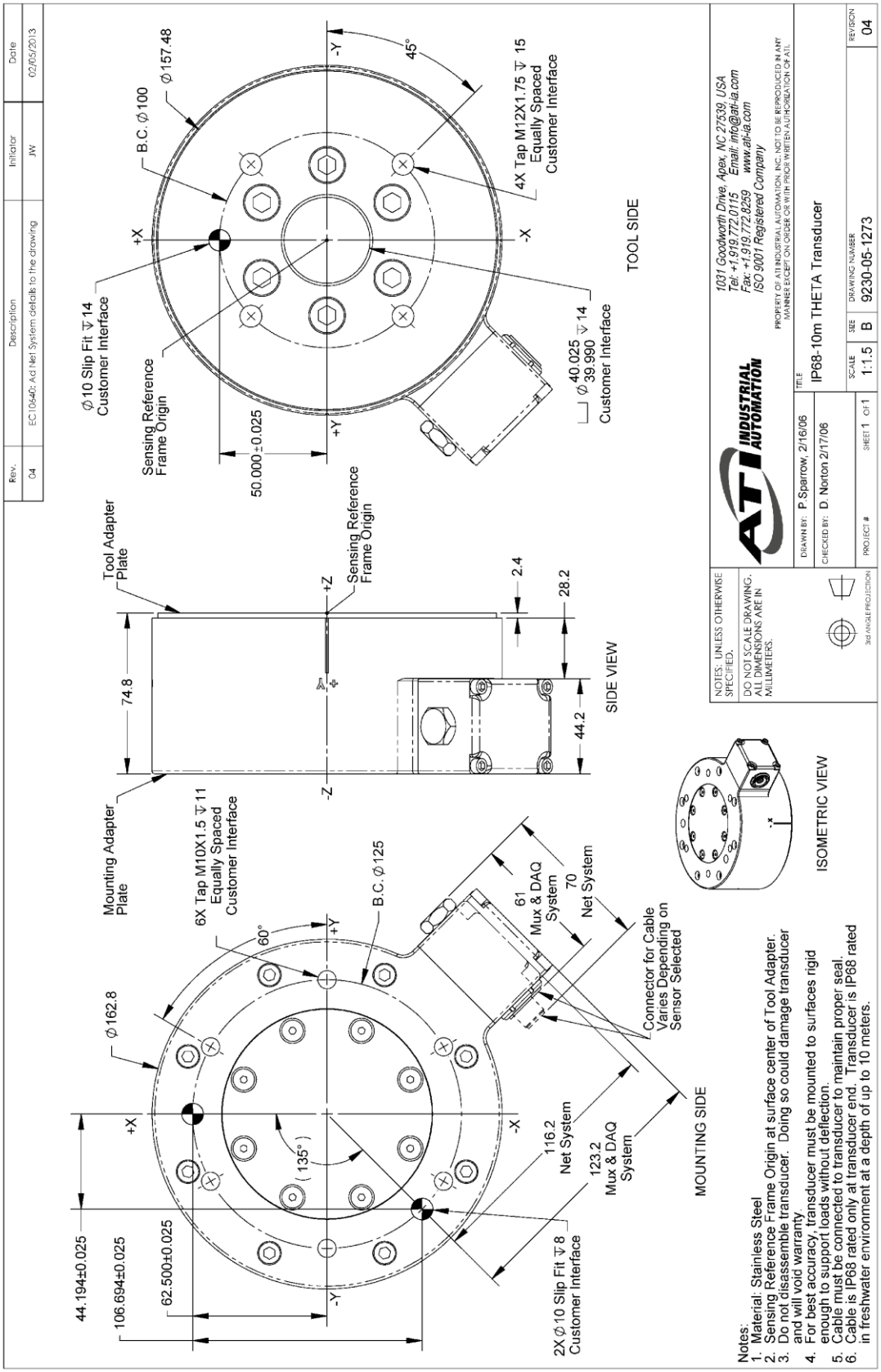
### 4.14.11 Theta IP60 Transducer Drawing



### 4.14.12 Theta IP65 Transducer Drawing



### 4.14.13 Theta IP68 Transducer Drawing



## 4.15 Omega85 (Includes IP60/IP65/IP68 Versions)

### 4.15.1 Calibration Specifications (excludes CTL calibrations)

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz† | Tx,Ty | Tz | Fx,Fy | Fz† | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| US-105-185 | 105 lbf | 210 lbf | 185 lbf-in | 185 lbf-in | 1/52 lbf | 3/130 lbf | 3/112 lbf-in | 1/48 lbf-in |
| US-210-370 | 210 lbf | 420 lbf | 370 lbf-in | 370 lbf-in | 5/128 lbf | 3/64 lbf | 3/56 lbf-in | 1/24 lbf-in |
| US-420-740 | 420 lbf | 840 lbf | 740 lbf-in | 740 lbf-in | 5/64 lbf | 3/32 lbf | 3/28 lbf-in | 1/12 lbf-in |

**Metric Calibrations (SI)**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| SI-475-20 | 475 N | 950 N | 20 Nm | 20 Nm | 1/14 N | 3/28 N | 5/1496 Nm | 7/2992 Nm |
| SI-950-40 | 950 N | 1900 N | 40 Nm | 40 Nm | 1/7 N | 3/14 N | 5/748 Nm | 7/1496 Nm |
| SI-1900–80 | 1900 N | 3800 N | 80 Nm | 80 Nm | 2/7 N | 3/7 N | 5/374 Nm | 7/478 Nm |
| | SENSING RANGES | | | | RESOLUTION* | | | |

* *DAQ resolutions are typical for a 16-bit system.*

*These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.*

**Note:**
The Omega85 does not support an on-board mux board, therefore it cannot be used with the F/T Controller. For Controller F/T systems we recommend the Mini85.

### 4.15.2 Omega85 IP60 Physical Properties

**Standard (US)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±2800 lbf |
| Fz | ±6100 lbf |
| Txy | ±4400 lbf-in |
| Tz | ±5400 lbf-in |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $4.4 \times 10^5$ lb/in |
| Z-axis force (Kz) | $6.8 \times 10^5$ lb/in |
| X-axis & Y-axis torque (Ktx, Kty) | $7.2 \times 10^5$ lbf-in/rad |
| Z-axis torque (Ktz) | $1.2 \times 10^6$ lbf-in/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 2100 Hz |
| Fz, Tx, Ty | 3000 Hz |
| **Physical Specifications** | |
| Weight* | 1.45 lb |
| Diameter* | 3.35 in |
| Height* | 1.32 in |

**Metric (SI)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±13000 N |
| Fz | ±27000 N |
| Txy | ±500 Nm |
| Tz | ±610 Nm |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $7.7 \times 10^7$ N/m |
| Z-axis force (Kz) | $1.2 \times 10^8$ N/m |
| X-axis & Y-axis torque (Ktx, Kty) | $8.1 \times 10^4$ Nm/rad |
| Z-axis torque (Ktz) | $1.3 \times 10^5$ Nm/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 2100 Hz |
| Fz, Tx, Ty | 3000 Hz |
| **Physical Specifications** | |
| Weight* | 0.658 kg |
| Diameter* | 85.1 mm |
| Height* | 33.4 mm |

** Specifications include standard interface plates.*

### 4.15.3 Omega85 IP65/IP68 Physical Properties

**Standard (US)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±2800 lbf |
| Fz | ±6100 lbf |
| Txy | ±4400 lbf-in |
| Tz | ±5400 lbf-in |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $4.4 \times 10^5$ lb/in |
| Z-axis force (Kz) | $6.8 \times 10^5$ lb/in |
| X-axis & Y-axis torque (Ktx, Kty) | $7.2 \times 10^5$ lbf-in/rad |
| Z-axis torque (Ktz) | $1.2 \times 10^6$ lbf-in/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | |
| Fz, Tx, Ty | |
| **Physical Specifications** | |
| Weight* | 4.2 lb |
| Diameter* | 3.65 in |
| Height* | 1.52 in |

**Metric (SI)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±13000 N |
| Fz | ±27000 N |
| Txy | ±500 Nm |
| Tz | ±610 Nm |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $7.7 \times 10^7$ N/m |
| Z-axis force (Kz) | $1.2 \times 10^8$ N/m |
| X-axis & Y-axis torque (Ktx, Kty) | $8.1 \times 10^4$ Nm/rad |
| Z-axis torque (Ktz) | $1.3 \times 10^5$ Nm/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | |
| Fz, Tx, Ty | |
| **Physical Specifications** | |
| Weight* | 1.91 kg |
| Diameter* | 92.7 mm |
| Height* | 38.7 mm |

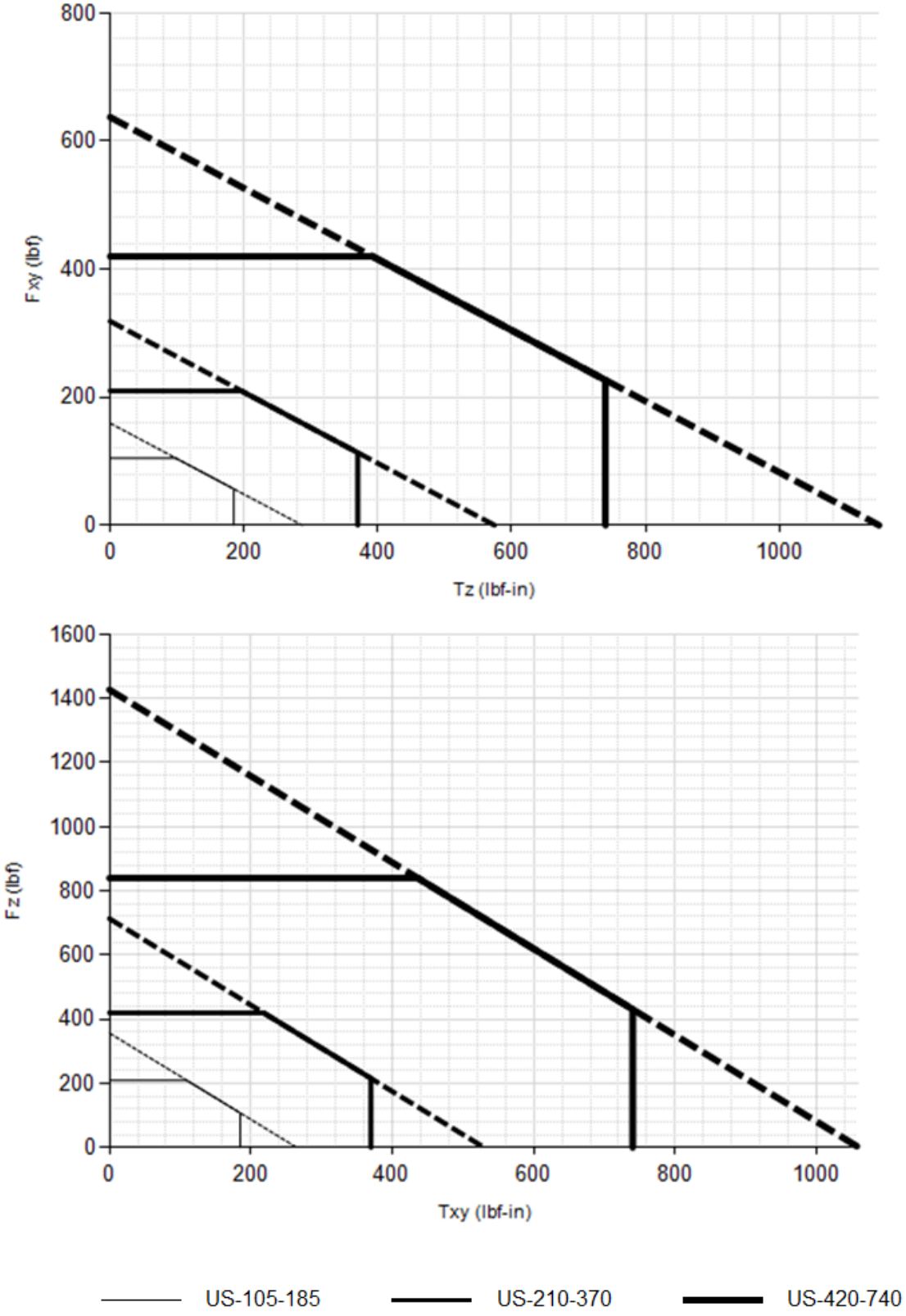
** Specifications include standard interface plates.*

**CAUTION:**
**IP68 Omega85 Fz as a Function of Submersion Depth:**

When submerged, IP68 transducers exhibit a decrease in Fz range related to the submersion depth. This loss is the result of pressure-induced preloading on the transducer. The preload can be masked by biasing the transducer at the depth prior to applying the load to be measured. The following estimates are for room temperature fresh water at sea level.

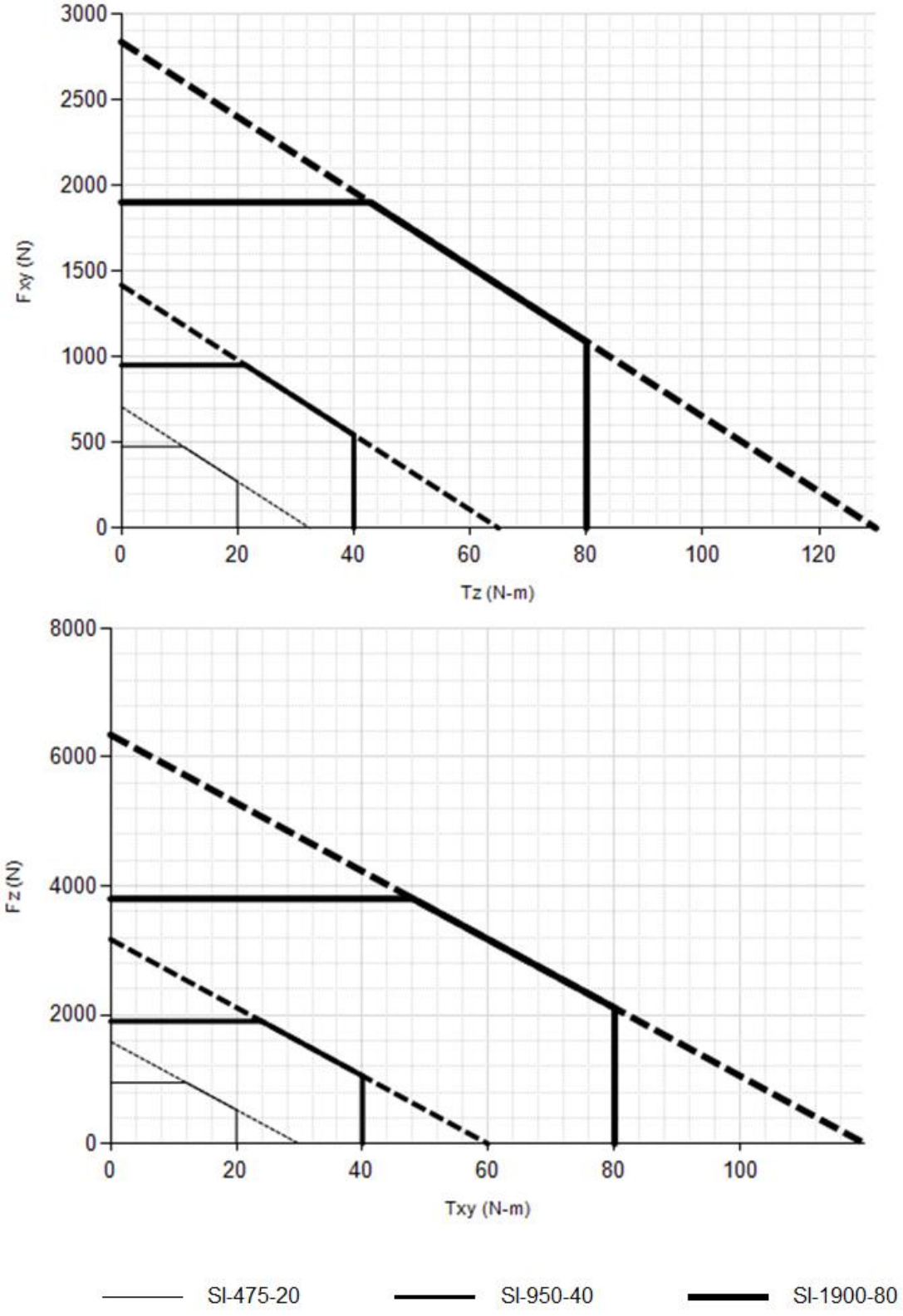
| ***IP68 Omega85*** | **US** | **Metric** |
|---|---|---|
| Fz preload at 10m depth | 128 lb | 570 N |
| Fz preload at other depths | -3.9 lb/ft × depthInFeet | -57 N/m × depthInMeters |

### 4.15.4 Omega85 (US Calibration Complex Loading) (Includes IP60/IP65/IP68 Versions)



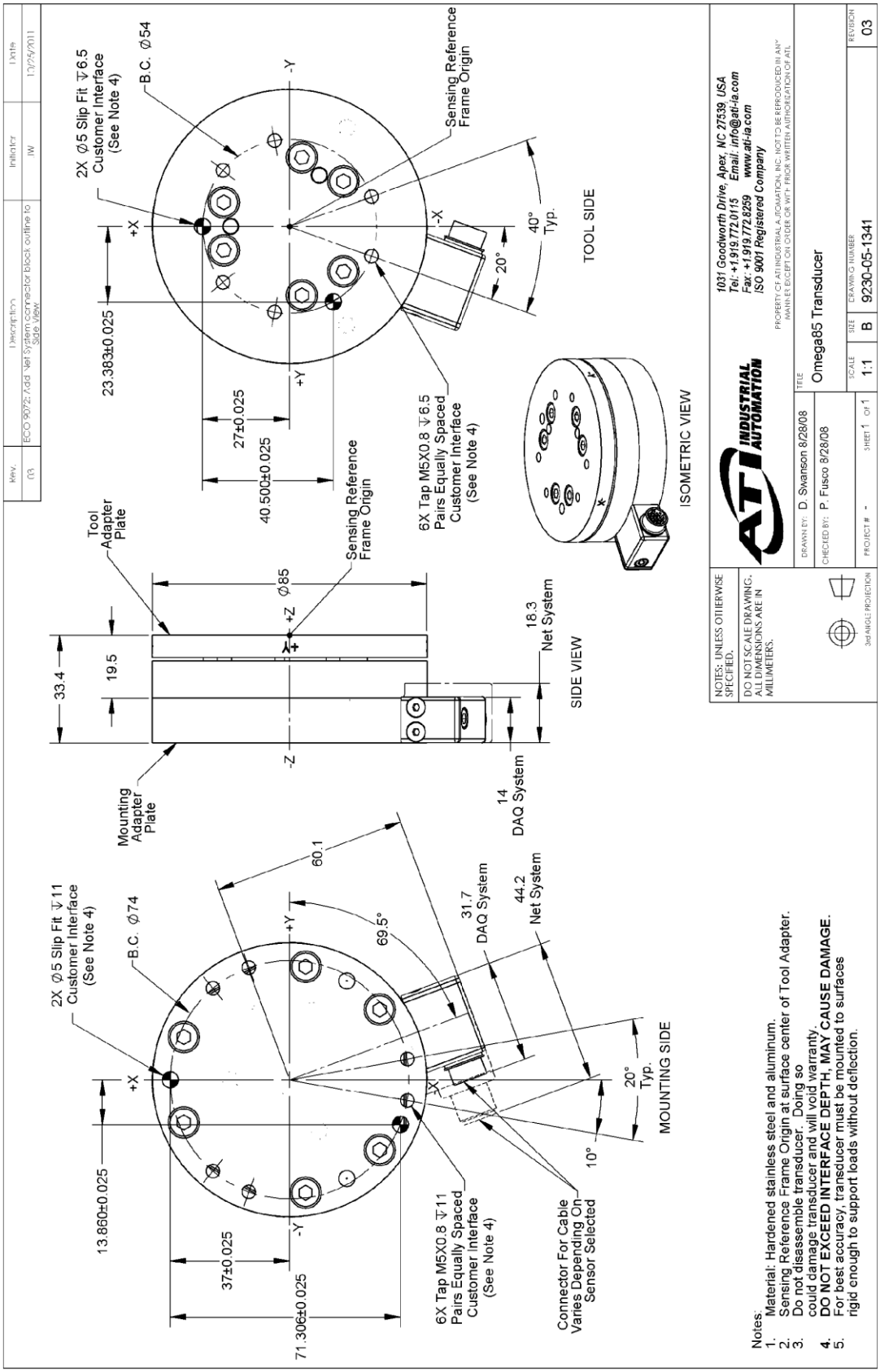

*** For IP68 version see caution on physical properties page.

### 4.15.5 Omega85 (SI Calibration Complex Loading) (Includes IP60/IP65/IP68 Versions)

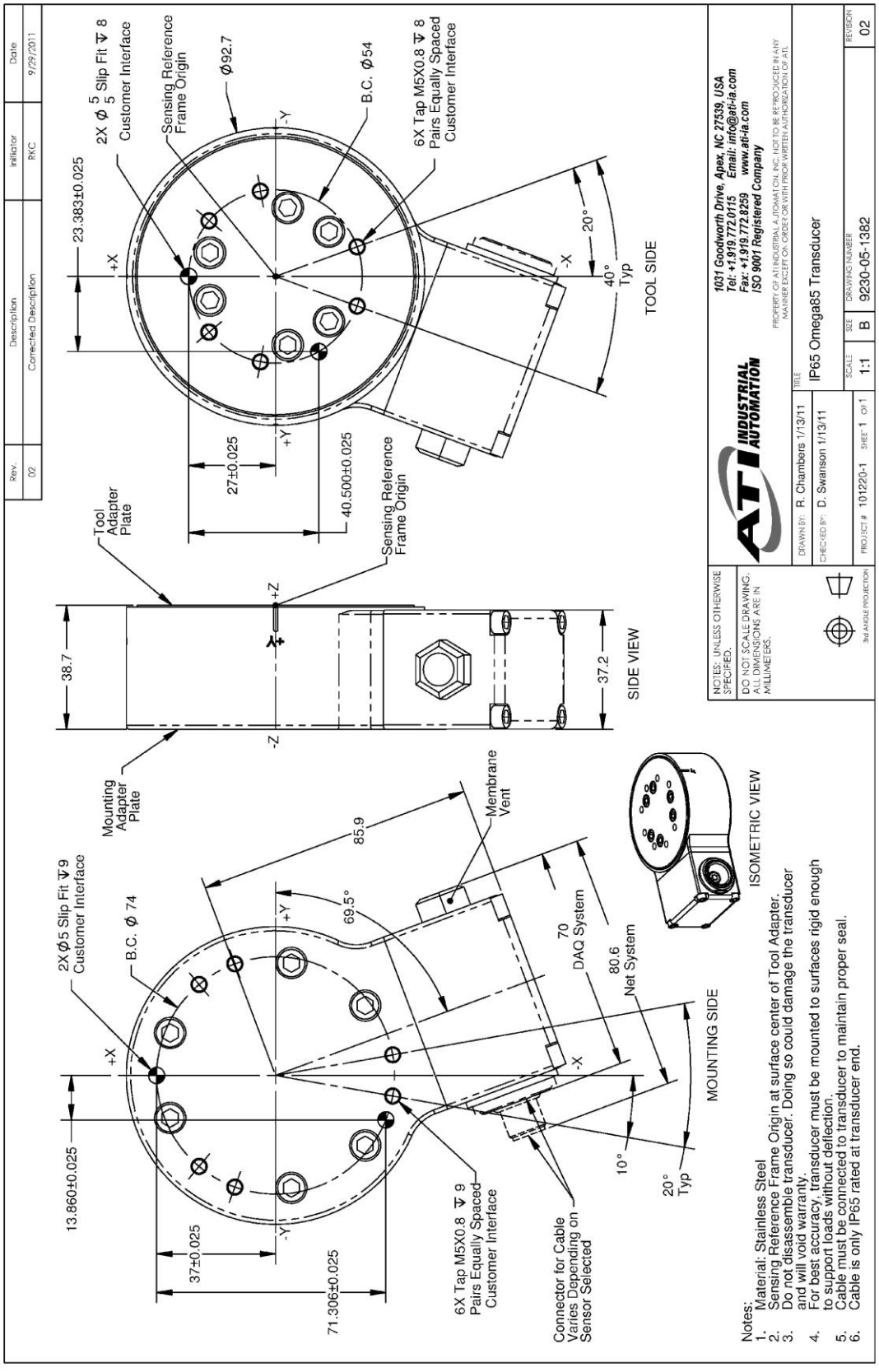



*** For IP68 version see caution on physical properties page.

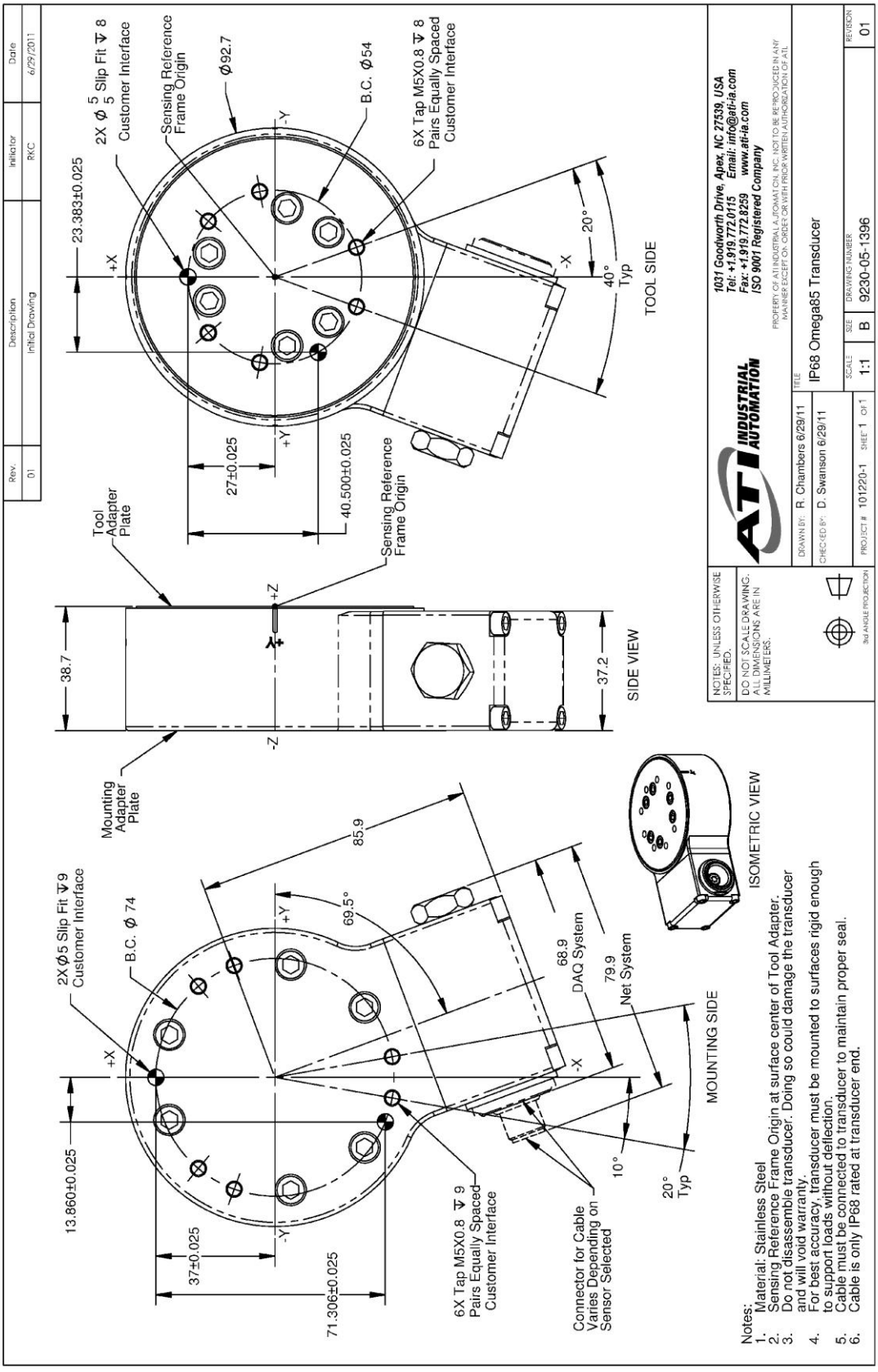
### 4.15.6 Omega85 Transducer Drawing



### 4.15.7 Omega85 IP65 Transducer Drawing



### 4.15.8 Omega85 IP68 Transducer Drawing



## 4.16 Omega160 (Includes IP60/IP65/IP68 Versions)

### 4.16.1 Calibration Specifications (excludes CTL calibrations)

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz† | Tx,Ty | Tz | Fx,Fy | Fz† | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| US-200–1000 | 200 lbf | 500 lbf | 1000 lbf-in | 1000 lbf-in | 1/32 lbf | 1/16 lbf | 1/8 lbf-in | 1/8 lbf-in |
| US-300–1800 | 300 lbf | 875 lbf | 1800 lbf-in | 1800 lbf-in | 5/68 lbf | 5/34 lbf | 5/16 lbf-in | 5/16 lbf-in |
| US-600–3600 | 600 lbf | 1500 lbf | 3600 lbf-in | 3600 lbf-in | 1/8 lbf | 1/4 lbf | 1/2 lbf-in | 1/4 lbf-in |

**Metric Calibrations (SI)**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| SI-1000–120 | 1000 N | 2500 N | 120 Nm | 120 Nm | 1/4 N | 1/4 N | 1/40 Nm | 1/80 Nm |
| SI-1500–240 | 1500 N | 3750 N | 240 Nm | 240 Nm | 1/4 N | 1/2 N | 1/20 Nm | 1/40 Nm |
| SI-2500–400 | 2500 N | 6250 N | 400 Nm | 400 Nm | 1/2 N | 3/4 N | 1/20 Nm | 1/20 Nm |
| | SENSING RANGES | | | | RESOLUTION* | | | |

* *DAQ resolutions are typical for a 16-bit system.*

*These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.*

### 4.16.2 CTL Calibration Specifications

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz† | Tx,Ty | Tz | Fx,Fy | Fz† | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| US-200–1000 | 200 lbf | 500 lbf | 1000 lbf-in | 1000 lbf-in | 1/16 lbf | 1/8 lbf | 1/4 lbf-in | 1/4 lbf-in |
| US-300–1800 | 300 lbf | 875 lbf | 1800 lbf-in | 1800 lbf-in | 5/34 lbf | 5/17 lbf | 5/8 lbf-in | 5/8 lbf-in |
| US-600–3600 | 600 lbf | 1500 lbf | 3600 lbf-in | 3600 lbf-in | 1/4 lbf | 1/2 lbf | 1 lbf-in | 1/2 lbf-in |

**Metric Calibrations (SI)**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| SI-1000-120 | 1000 N | 2500 N | 120 Nm | 120 Nm | 1/2 N | 1/2 N | 1/20 Nm | 1/40 Nm |
| SI-1500-240 | 1500 N | 3750 N | 240 Nm | 240 Nm | 1/2 N | 1 N | 1/10 Nm | 1/20 Nm |
| SI-2500-400 | 2500 N | 6250 N | 400 Nm | 400 Nm | 1 N | 1 1/2 N | 1/10 Nm | 1/10 Nm |
| | SENSING RANGES | | | | RESOLUTION | | | |

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz† | Tx,Ty, Tz | Fx,Fy | Fz† | Tx,Ty, Tz |
|---|---|---|---|---|---|---|
| US-200–1000 | ±200 lbf | ±500 lbf | ±1000 lbf-in | 20 lbf/V | 50 lbf/V | 100 lbf-in/V |
| US-300–1800 | ±300 lbf | ±875 lbf | ±1800 lbf-in | 30 lbf/V | 87.5 lbf/V | 180 lbf-in/V |
| US-600–3600 | ±600 lbf | ±1500 lbf | ±3600 lbf-in | 60 lbf/V | 150 lbf/V | 360 lbf-in/V |

**Metric Calibrations (SI)**

| | | | | | | |
|---|---|---|---|---|---|---|
| SI-1000–120 | ±1000 N | ±2500 N | ±120 Nm | 100 N/V | 250 N/V | 12 Nm/V |
| SI-1500–240 | ±1500 N | ±3750 N | ±240 Nm | 150 N/V | 375 N/V | 24 Nm/V |
| SI-2500–400 | ±2500 N | ±6250 N | ±400 Nm | 250 N/V | 625 N/V | 40 Nm/V |
| | Analog Output Range | | | Analog ±10V Sensitivity‡ | | |

**Counts Value**

| Calibration | Fx, Fy, Fz | Tx, Ty, Tz | Fx, Fy, Fz | Tx, Ty, Tz |
|---|---|---|---|---|
| US-200–1000 / SI-1000–120 | 128 / lbf | 64 / lbf-in | 32 / N | 320 / Nm |
| US-300–1800 / SI-1500–240 | 54.4 / lbf | 12.8 / lbf-in | 16 / N | 160 / Nm |
| US-600–3600 / SI-2500–400 | 32 / lbf | 16 / lbf-in | 16 / N | 80 / Nm |
| **Tool Transform Factor** | See Tool Transform Factor table | | | |
| | Counts Value – Standard (US) | | Counts Value – Metric (SI) | |

**Tool Transform Factor**

| Calibration | US (English) | SI (Metric) |
|---|---|---|
| US-200–1000 / SI-1000–120 | 0.02 in/lbf | 1 mm/N |
| US-300–1800 / SI-1500–240 | 0.0425 in/lbf | 1 mm/N |
| US-600–3600 / SI-2500–400 | 0.02 in/lbf | 2 mm/N |

*CTL resolutions are typical. System resolutions quoted are the effective resolution after dropping eight counts of noise. The effective resolution can be improved with filtering. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.*

*† For IP68 version see caution on physical properties page.*
*‡ ±5V Sensitivity values are double the listed ±10V Sensitivity values.*

### 4.16.3 Omega160 Physical Properties (Includes IP60 Version)

**Standard (US)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±3900 lbf |
| Fz | ±11000 lbf |
| Txy | ±15000 lbf-in |
| Tz | ±17000 lbf-in |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $4.0 \times 10^5$ lb/in |
| Z-axis force (Kz) | $6.8 \times 10^5$ lb/in |
| X-axis & Y-axis torque (Ktx, Kty) | $2.9 \times 10^6$ lbf-in/rad |
| Z-axis torque (Ktz) | $4.6 \times 10^6$ lbf-in/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 1300 Hz |
| Fz, Tx, Ty | 1000 Hz |
| **Physical Specifications** | |
| Weight* | 6 lb |
| Diameter* | 6.16 in |
| Height* | 2.2 in |

**Metric (SI)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±18000 N |
| Fz | ±48000 N |
| Txy | ±1700 Nm |
| Tz | ±1900 Nm |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $7.0 \times 10^7$ N/m |
| Z-axis force (Kz) | $1.2 \times 10^8$ N/m |
| X-axis & Y-axis torque (Ktx, Kty) | $3.3 \times 10^5$ Nm/rad |
| Z-axis torque (Ktz) | $5.2 \times 10^5$ Nm/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 1300 Hz |
| Fz, Tx, Ty | 1000 Hz |
| **Physical Specifications** | |
| Weight* | 2.72 kg |
| Diameter* | 157 mm |
| Height* | 55.9 mm |

** Specifications include standard interface plates.*

### 4.16.4 Omega160 IP65/IP68 Physical Properties

**Standard (US)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±3900 lbf |
| Fz | ±11000 lbf |
| Txy | ±15000 lbf-in |
| Tz | ±17000 lbf-in |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $4.0 \times 10^5$ lb/in |
| Z-axis force (Kz) | $6.8 \times 10^5$ lb/in |
| X-axis & Y-axis torque (Ktx, Kty) | $2.9 \times 10^6$ lbf-in/rad |
| Z-axis torque (Ktz) | $4.6 \times 10^6$ lbf-in/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 1200 Hz |
| Fz, Tx, Ty | 900 Hz |
| **Physical Specifications** | |
| Weight* | 16 lb |
| Diameter* | 6.5 in |
| Height* | 2.59 in |

**Metric (SI)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±18000 N |
| Fz | ±48000 N |
| Txy | ±1700 Nm |
| Tz | ±1900 Nm |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $7.0 \times 10^7$ N/m |
| Z-axis force (Kz) | $1.2 \times 10^8$ N/m |
| X-axis & Y-axis torque (Ktx, Kty) | $3.3 \times 10^5$ Nm/rad |
| Z-axis torque (Ktz) | $5.2 \times 10^5$ Nm/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 1200 Hz |
| Fz, Tx, Ty | 900 Hz |
| **Physical Specifications** | |
| Weight* | 7.26 kg |
| Diameter* | 165 mm |
| Height* | 65.9 mm |

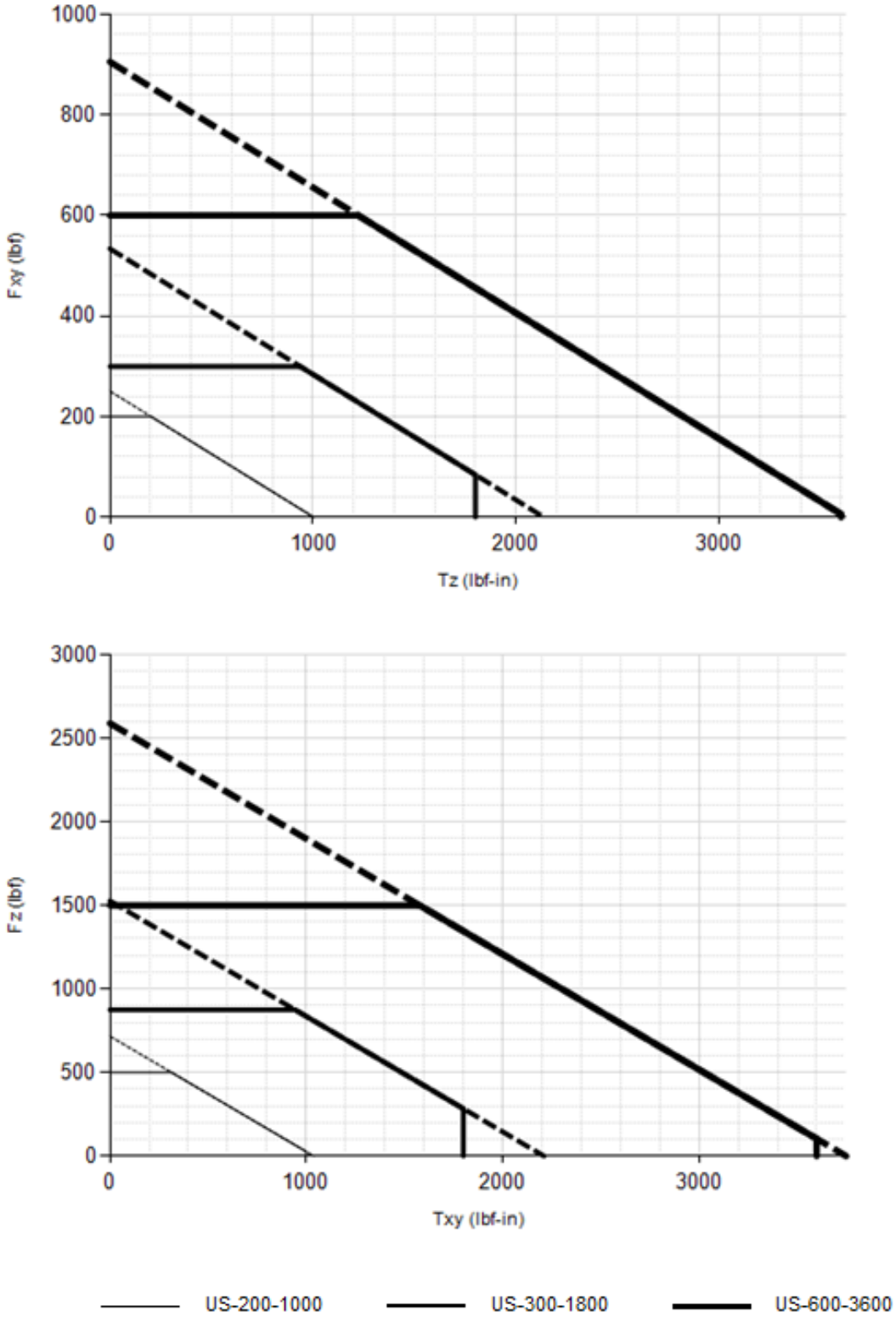
** Specifications include standard interface plates.*

**CAUTION:**
**IP68 Omega160 Fz as a Function of Submersion Depth:**

When submerged, IP68 transducers exhibit a decrease in Fz range related to the submersion depth. This loss is the result of pressure-induced preloading on the transducer. The preload can be masked by biasing the transducer at the depth prior to applying the load to be measured. The following estimates are for room temperature fresh water at sea level.

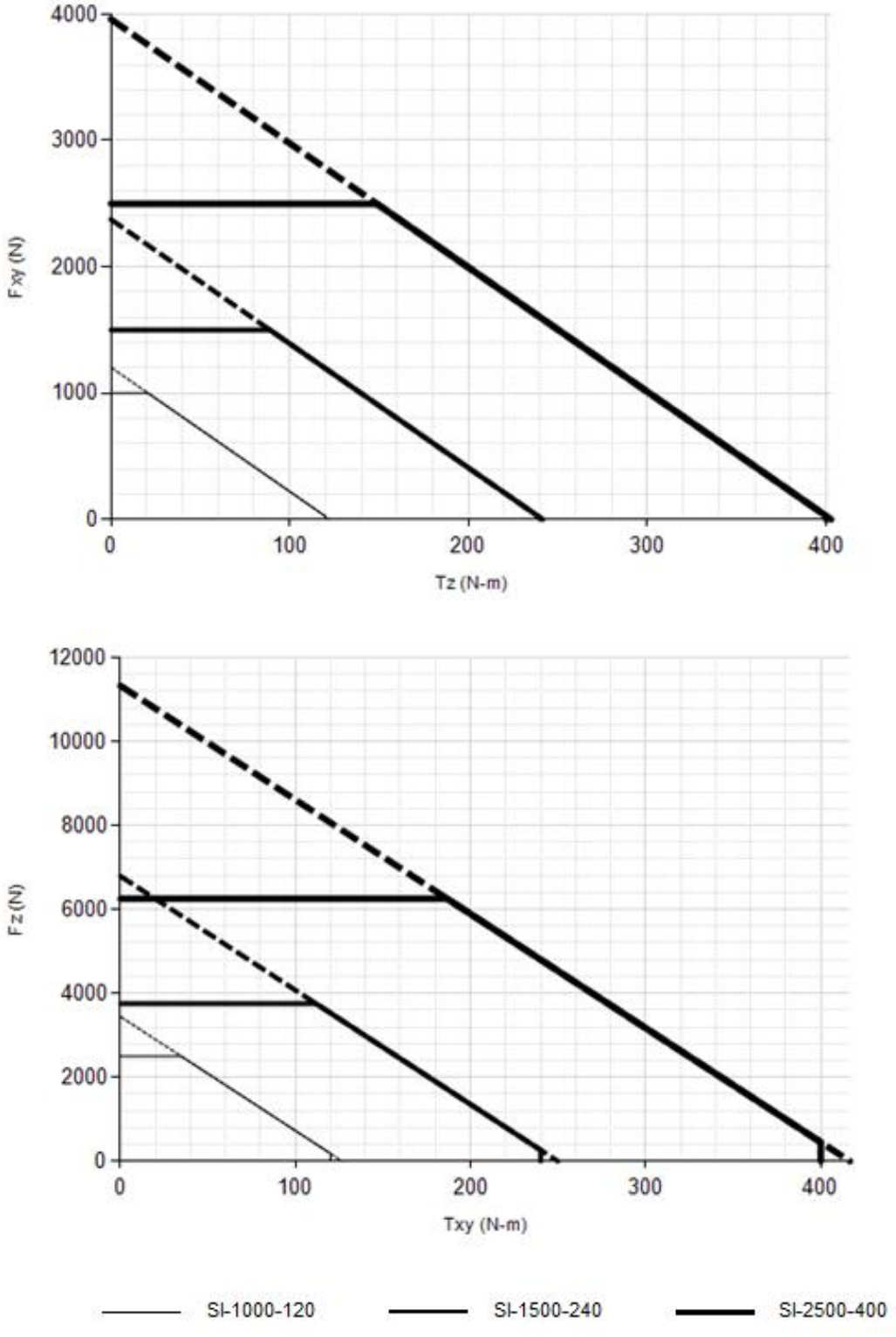
| ***IP68 Omega160*** | **US** | **Metric** |
|---|---|---|
| Fz preload at 10m depth | 429 lb | 1907 N |
| Fz preload at other depths | -13 lb/ft × depthInFeet | -191 N/m × depthInMeters |

### 4.16.5 Omega160 (US Calibration Complex Loading) (Includes IP60/IP65/IP68 Versions)



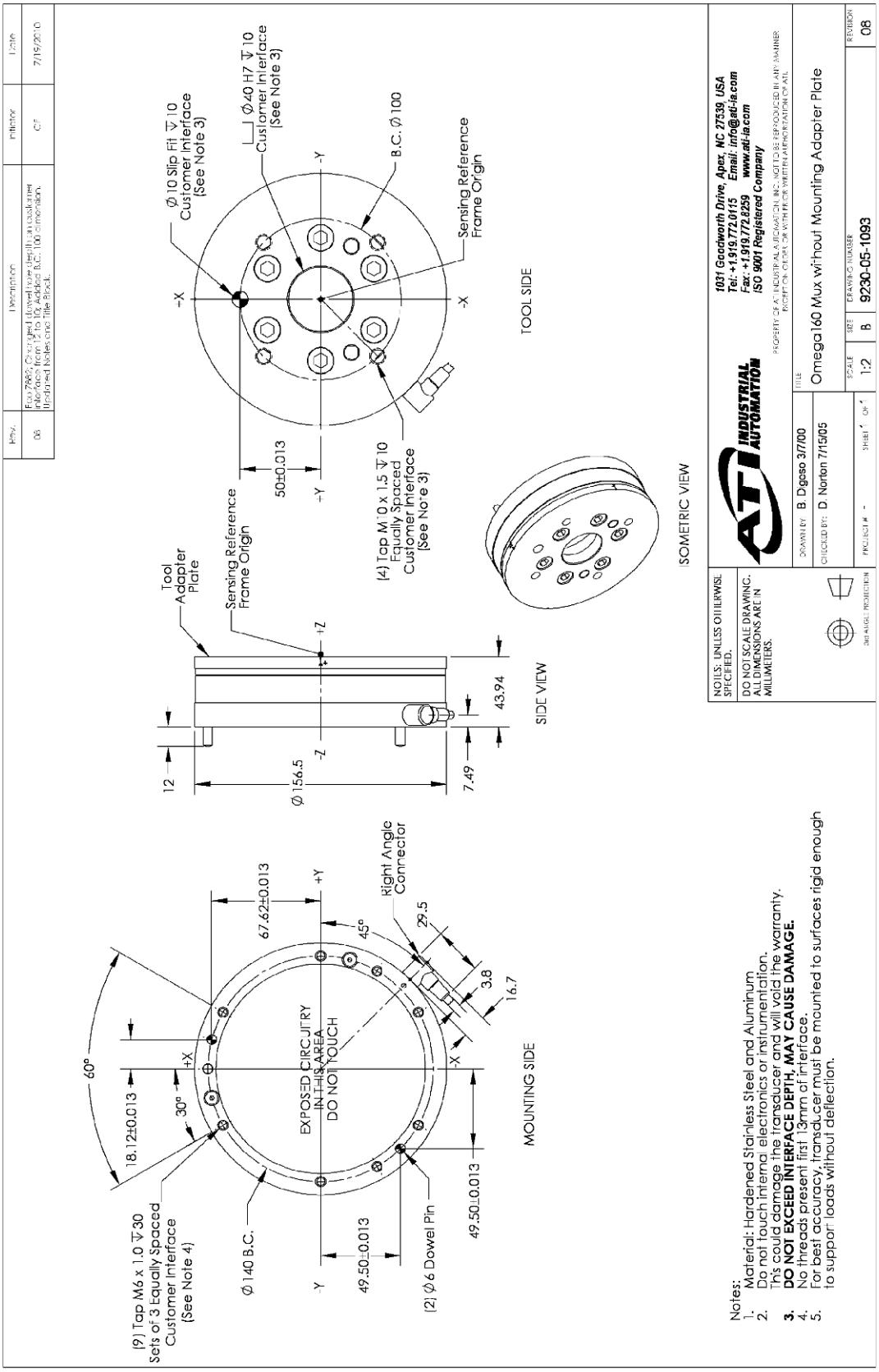

*** For IP68 version see caution on physical properties page.

### 4.16.6 Omega160 (SI Calibration Complex Loading) (Includes IP60/IP65/IP68 Versions)

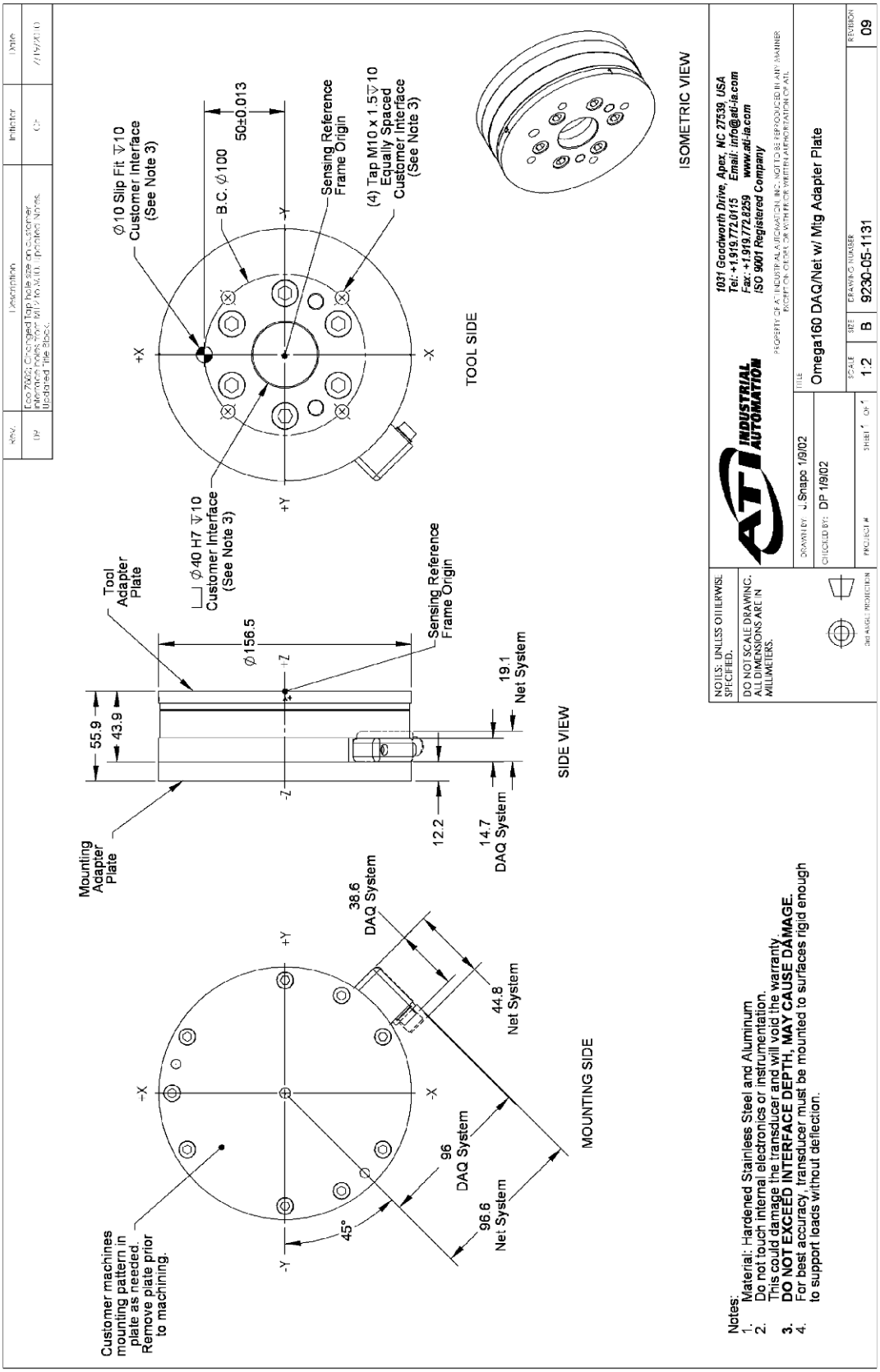



*** For IP68 version see caution on physical properties page.

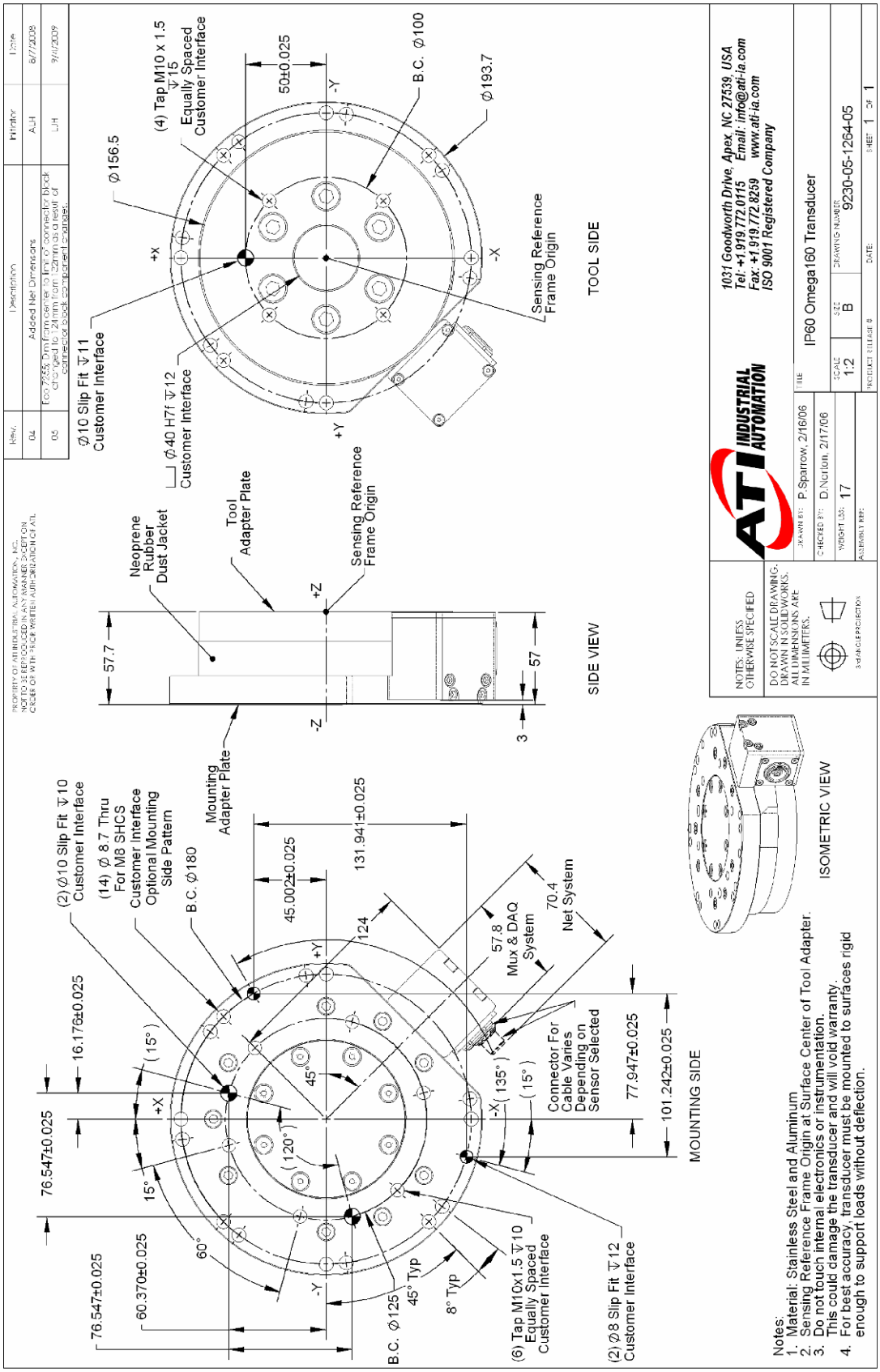
### 4.16.7 Omega160 Transducer without Mounting Adapter Plate Drawing



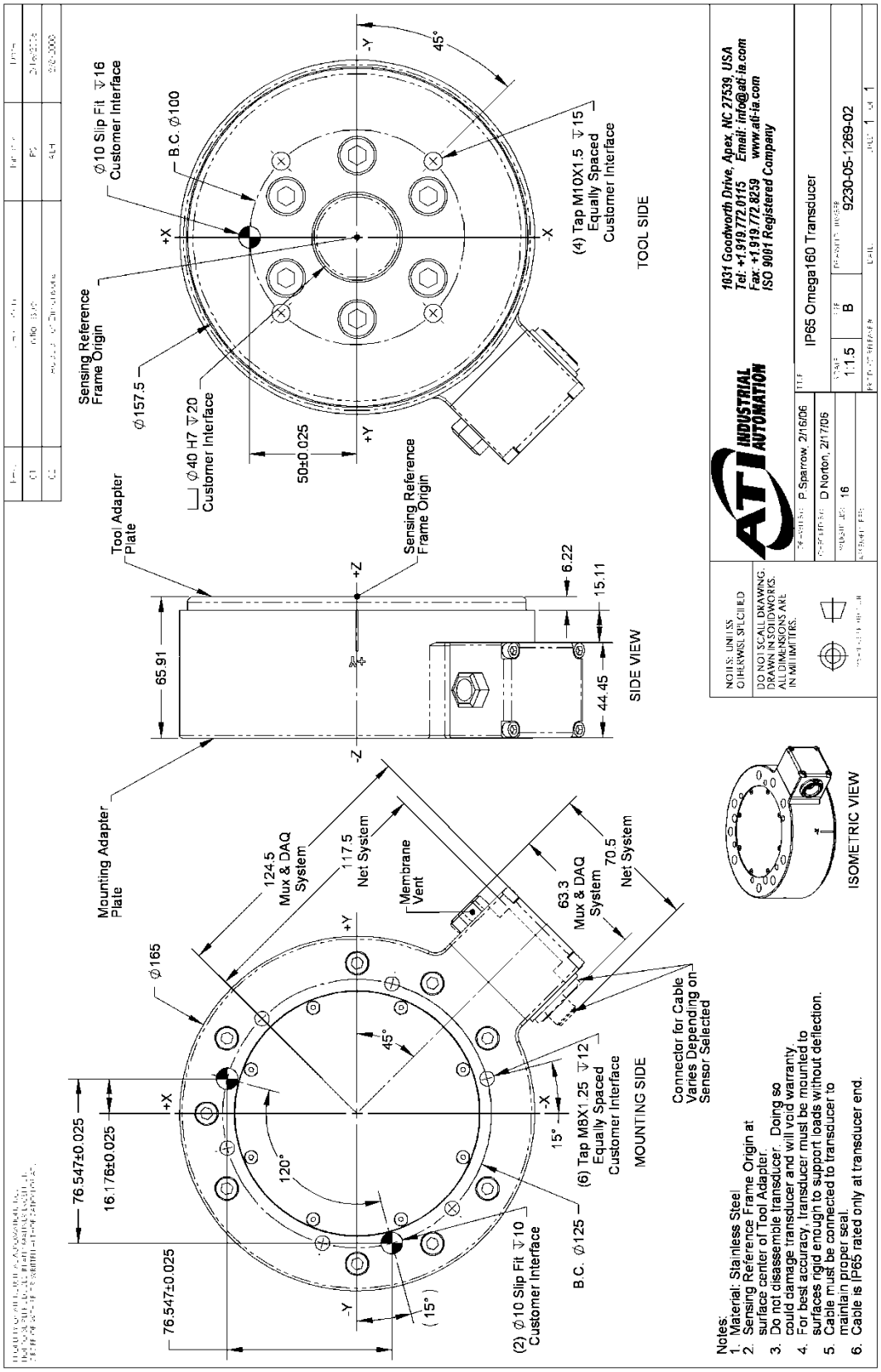
### 4.16.8 Omega160 DAQ/Net with Mounting Adapter Plate Drawing



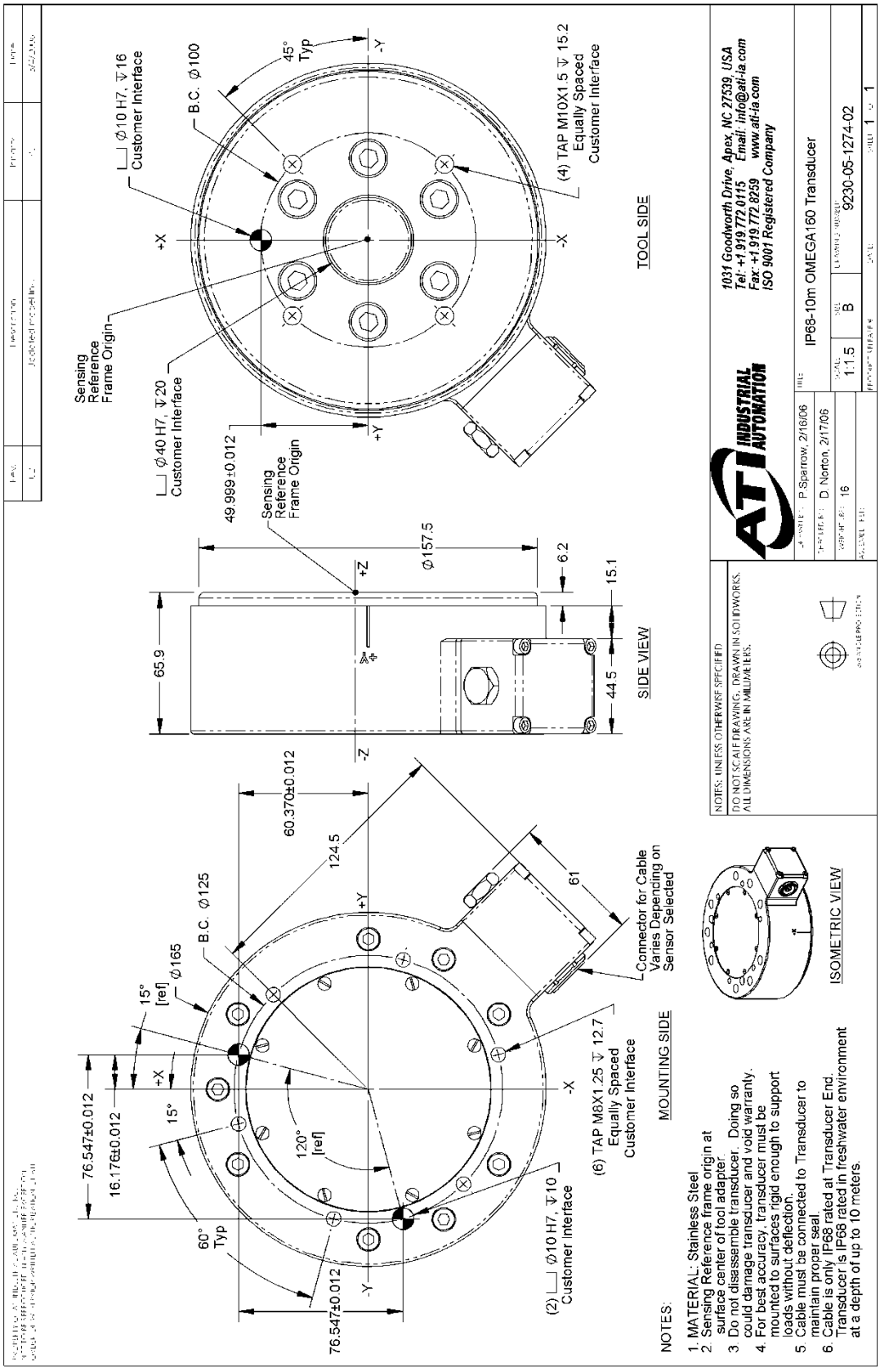
### 4.16.9 Omega160 IP60 Transducer Drawing



### 4.16.10 Omega160 IP65 Transducer Drawing



### 4.16.11 Omega160 IP68 Transducer Drawing



## 4.17 Omega190 (Includes IP60/IP65/IP68 Versions)

### 4.17.1 Calibration Specifications (excludes CTL calibrations)

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz† | Tx,Ty | Tz | Fx,Fy | Fz† | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| US-400-3000 | 400 lbf | 1000 lbf | 3000 lbf-in | 3000 lbf-in | 5/64 lbf | 5/32 lbf | 15/32 lbf-in | 5/16 lbf-in |
| US-800-6000 | 800 lbf | 2000 lbf | 6000 lbf-in | 6000 lbf-in | 5/32 lbf | 5/16 lbf | 15/16 lbf-in | 5/8 lbf-in |
| US-1600-12000 | 1600 lbf | 4000 lbf | 12000 lbf-in | 12000 lbf-in | 5/16 lbf | 5/8 lbf | 1 7/8 lbf-in | 1 1/4 lbf-in |

**Metric Calibrations (SI)**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| SI-1800-350 | 1800 N | 4500 N | 350 Nm | 350 Nm | 3/8 N | 3/4 N | 5/96 Nm | 5/144 Nm |
| SI-3600-700 | 3600 N | 9000 N | 700 Nm | 700 Nm | 3/4 N | 1 1/2 N | 5/48 Nm | 5/72 Nm |
| SI-7200-1400 | 7200 N | 18000 N | 1400 Nm | 1400 Nm | 1 1/2 N | 3 N | 5/24 Nm | 5/36 Nm |
| | **Sensing Ranges** | | | | **Resolution*** | | | |

* *DAQ resolutions are typical for a 16-bit data acquisition system.*

*These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.*

### 4.17.2 CTL Calibration Specifications

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz† | Tx,Ty | Tz | Fx,Fy | Fz† | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| US-400-3000 | 400 lbf | 1000 lbf | 3000 lbf-in | 3000 lbf-in | 5/32 lbf | 5/16 lbf | 15/16 lbf-in | 5/8 lbf-in |
| US-800-6000 | 800 lbf | 2000 lbf | 6000 lbf-in | 6000 lbf-in | 5/16 lbf | 5/8 lbf | 1 7/8 lbf-in | 1 1/4 lbf-in |
| US-1600-12000 | 1600 lbf | 4000 lbf | 12000 lbf-in | 12000 lbf-in | 5/8 lbf | 1 1/4 lbf | 3 3/4 lbf-in | 2 1/2 lbf-in |
| | SENSING RANGES | | | | RESOLUTION | | | |

**Metric Calibrations (SI)**

| Calibration | Fx,Fy | Fz† | Tx,Ty | Tz | Fx,Fy | Fz† | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| SI-1800-350 | 1800 N | 4500 N | 350 Nm | 350 Nm | 3/4 N | 1 1/2 N | 5/48 Nm | 5/72 Nm |
| SI-3600-700 | 3600 N | 9000 N | 700 Nm | 700 Nm | 1 1/2 N | 3 N | 5/24 Nm | 5/36 Nm |
| SI-7200-1400 | 7200 N | 18000 N | 1400 Nm | 1400 Nm | 3 N | 6 N | 5/12 Nm | 5/18 Nm |
| | SENSING RANGES | | | | RESOLUTION | | | |

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz† | Tx,Ty, Tz | Fx,Fy | Fz† | Tx,Ty, Tz |
|---|---|---|---|---|---|---|
| US-400-3000 | ±400 lbf | ±1000 lbf | ±3000 lbf-in | 40 lbf/V | 100 lbf/V | 25 lbf-in/V |
| US-800-6000 | ±800 lbf | ±2000 lbf | ±6000 lbf-in | 80 lbf/V | 200 lbf/V | 50 lbf-in/V |
| US-1600-12000 | ±1600 lbf | ±4000 lbf | ±12000 lbf-in | 160 lbf/V | 400 lbf/V | 100 lbf-in/V |
| | Analog Output Range | | | Analog ±10V Sensitivity‡ | | |

**Metric Calibrations (SI)**

| Calibration | Fx,Fy | Fz† | Tx,Ty, Tz | Fx,Fy | Fz† | Tx,Ty, Tz |
|---|---|---|---|---|---|---|
| SI-1800-350 | ±1800 N | ±4500 N | ±350 Nm | 180 N/V | 450 N/V | 35 Nm/V |
| SI-3600-700 | ±3600 N | ±9000 N | ±700 Nm | 360 N/V | 900 N/V | 70 Nm/V |
| SI-7200-1400 | ±7200 N | ±18000 N | ±1400 Nm | 720 N/V | 1800 N/V | 140 Nm/V |
| | Analog Output Range | | | Analog ±10V Sensitivity‡ | | |

**Counts Value**

| Calibration | Fx, Fy, Fz | Tx, Ty, Tz | Fx, Fy, Fz | Tx, Ty, Tz |
|---|---|---|---|---|
| US-400-3000 / SI-1800-350 | 153.6 / lbf | 307.2 / lbf-in | 32 / N | 230.4 / Nm |
| US-800-6000 / SI-3600-700 | 76.8 / lbf | 153.6 / lbf-in | 16 / N | 115.2 / Nm |
| US-1600-12000 / SI-7200-1400 | 38.4 / lbf | 76.8 / lbf-in | 8 / N | 57.6 / Nm |
| **Tool Transform Factor** | 0.005 in/lbf | | 1.3889 mm/N | |
| | Counts Value – Standard (US) | | Counts Value – Metric (SI) | |

*CTL resolutions are typical. System resolutions quoted are the effective resolution after dropping eight counts of noise. The effective resolution can be improved with filtering. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.*

*† For IP68 version see caution on physical properties page.*

*‡ ±5V Sensitivity values are double the listed ±10V Sensitivity values.*

### 4.17.3 Omega190 Physical Properties

**Standard (US)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±8000 lbf |
| Fz | ±25000 lbf |
| Txy | ±60000 lbf-in |
| Tz | ±60000 lbf-in |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $1.4x10^6$ lb/in |
| Z-axis force (Kz) | $2.1x10^6$ lb/in |
| X-axis & Y-axis torque (Ktx, Kty) | $1.4x10^7$ lbf-in/rad |
| Z-axis torque (Ktz) | $2.8x10^7$ lbf-in/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | |
| Fz, Tx, Ty | |
| **Physical Specifications** | |
| Weight* | 14 lb |
| Diameter* | 7.48 in |
| Height* | 2.2 in |

**Metric (SI)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±36000 N |
| Fz | ±110000 N |
| Txy | ±6800 Nm |
| Tz | ±6800 Nm |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $2.4x10^8$ N/m |
| Z-axis force (Kz) | $3.6x10^8$ N/m |
| X-axis & Y-axis torque (Ktx, Kty) | $1.5x10^6$ Nm/rad |
| Z-axis torque (Ktz) | $3.2x10^6$ Nm/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | |
| Fz, Tx, Ty | |
| **Physical Specifications** | |
| Weight* | 6.35 kg |
| Diameter* | 190 mm |
| Height* | 55.9 mm |

** Specifications include standard interface plates.*

### 4.17.4 Omega190 IP60 Physical Properties

**Standard (US)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±8000 lbf |
| Fz | ±25000 lbf |
| Txy | ±60000 lbf-in |
| Tz | ±60000 lbf-in |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $1.4x10^6$ lb/in |
| Z-axis force (Kz) | $2.1x10^6$ lb/in |
| X-axis & Y-axis torque (Ktx, Kty) | $1.4x10^7$ lbf-in/rad |
| Z-axis torque (Ktz) | $2.8x10^7$ lbf-in/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 1200 Hz |
| Fz, Tx, Ty | 1200 Hz |
| **Physical Specifications** | |
| Weight* | 31 lb |
| Diameter* | 9.37 in |
| Height* | 2.9 in |

**Metric (SI)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±36000 N |
| Fz | ±110000 N |
| Txy | ±6800 Nm |
| Tz | ±6800 Nm |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $2.4x10^8$ N/m |
| Z-axis force (Kz) | $3.6x10^8$ N/m |
| X-axis & Y-axis torque (Ktx, Kty) | $1.5x10^6$ Nm/rad |
| Z-axis torque (Ktz) | $3.2x10^6$ Nm/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 1200 Hz |
| Fz, Tx, Ty | 1200 Hz |
| **Physical Specifications** | |
| Weight* | 14.1 kg |
| Diameter* | 238 mm |
| Height* | 73.7 mm |

** Specifications include standard interface plates.*

### 4.17.5 Omega190 IP65/IP68 Physical Properties

**Standard (US)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±8000 lbf |
| Fz | ±25000 lbf |
| Txy | ±60000 lbf-in |
| Tz | ±60000 lbf-in |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $1.4 \times 10^6$ lb/in |
| Z-axis force (Kz) | $2.1 \times 10^6$ lb/in |
| X-axis & Y-axis torque (Ktx, Kty) | $1.4 \times 10^7$ lbf-in/rad |
| Z-axis torque (Ktz) | $2.8 \times 10^7$ lbf-in/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 1400 Hz |
| Fz, Tx, Ty | 980 Hz |
| **Physical Specifications** | |
| Weight* | 29 lb |
| Diameter* | 8.03 in |
| Height* | 2.94 in |

**Metric (SI)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±36000 N |
| Fz | ±110000 N |
| Txy | ±6800 Nm |
| Tz | ±6800 Nm |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $2.4 \times 10^8$ N/m |
| Z-axis force (Kz) | $3.6 \times 10^8$ N/m |
| X-axis & Y-axis torque (Ktx, Kty) | $1.5 \times 10^6$ Nm/rad |
| Z-axis torque (Ktz) | $3.2 \times 10^6$ Nm/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 1400 Hz |
| Fz, Tx, Ty | 980 Hz |
| **Physical Specifications** | |
| Weight* | 13.2 kg |
| Diameter* | 204 mm |
| Height* | 74.8 mm |

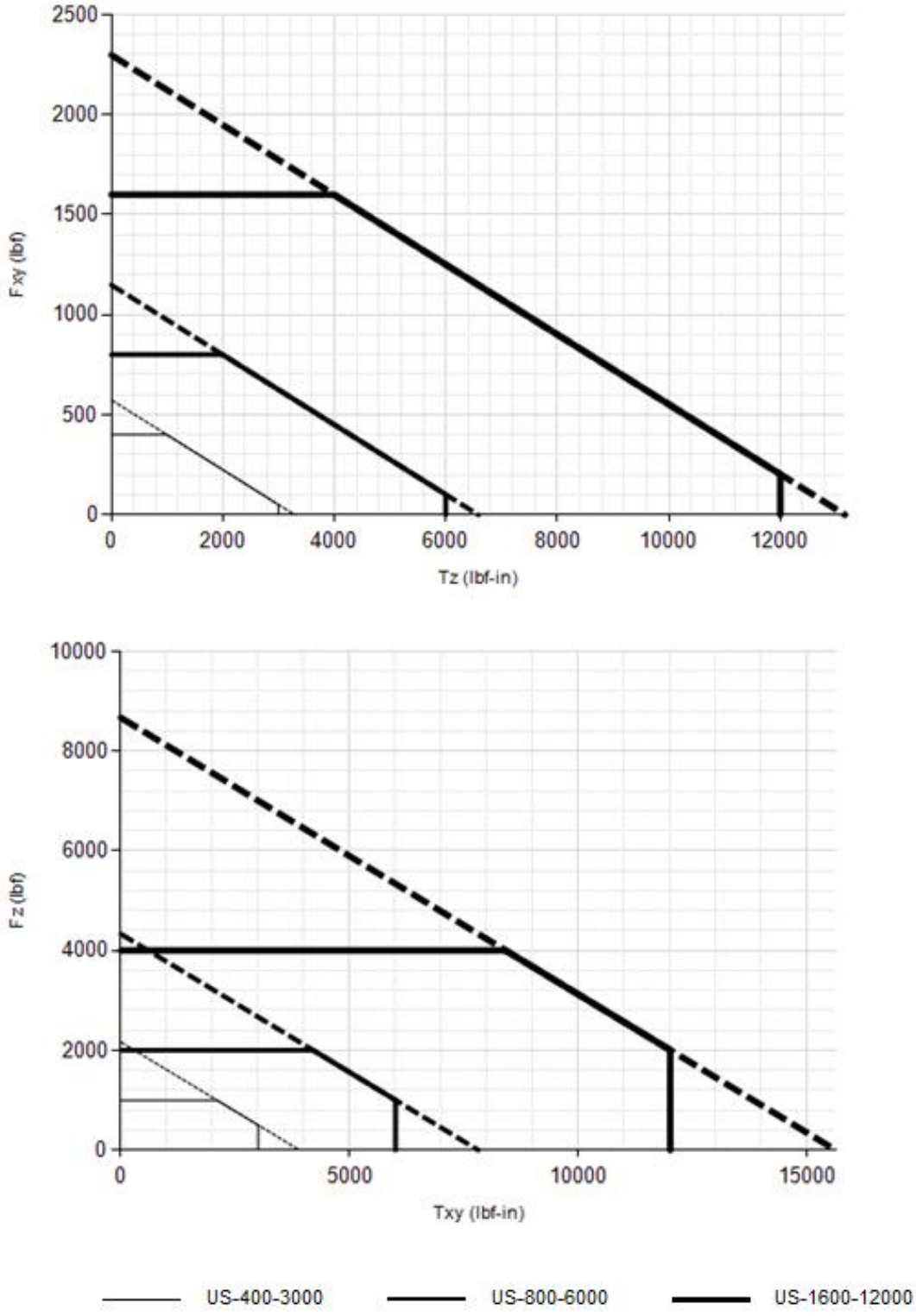
** Specifications include standard interface plates.*

**CAUTION:**
**IP68 Omega190 Fz as a Function of Submersion Depth:**

When submerged, IP68 transducers exhibit a decrease in Fz range related to the submersion depth. This loss is the result of pressure-induced preloading on the transducer. The preload can be masked by biasing the transducer at the depth prior to applying the load to be measured. The following estimates are for room temperature fresh water at sea level.

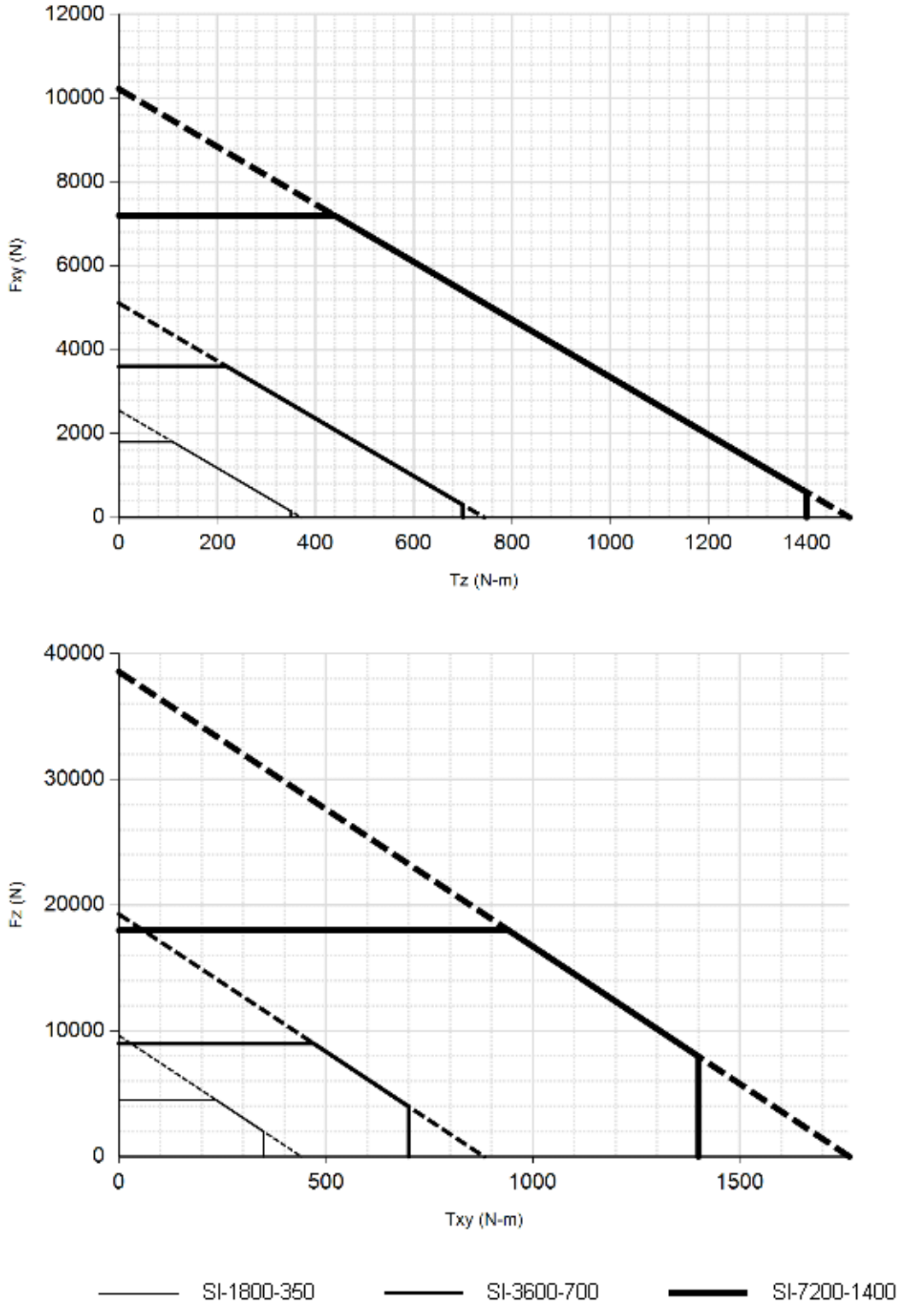
| ***IP68 Omega190*** | **US** | **Metric** |
|---|---|---|
| Fz preload at 10m depth | 661 lb | 2941 N |
| Fz preload at other depths | -20 lb/ft × depthInFeet | -294 N/m × depthInMeters |

### 4.17.6 Omega190 (US Calibration Complex Loading) (Includes IP60/IP65/IP68 Versions)



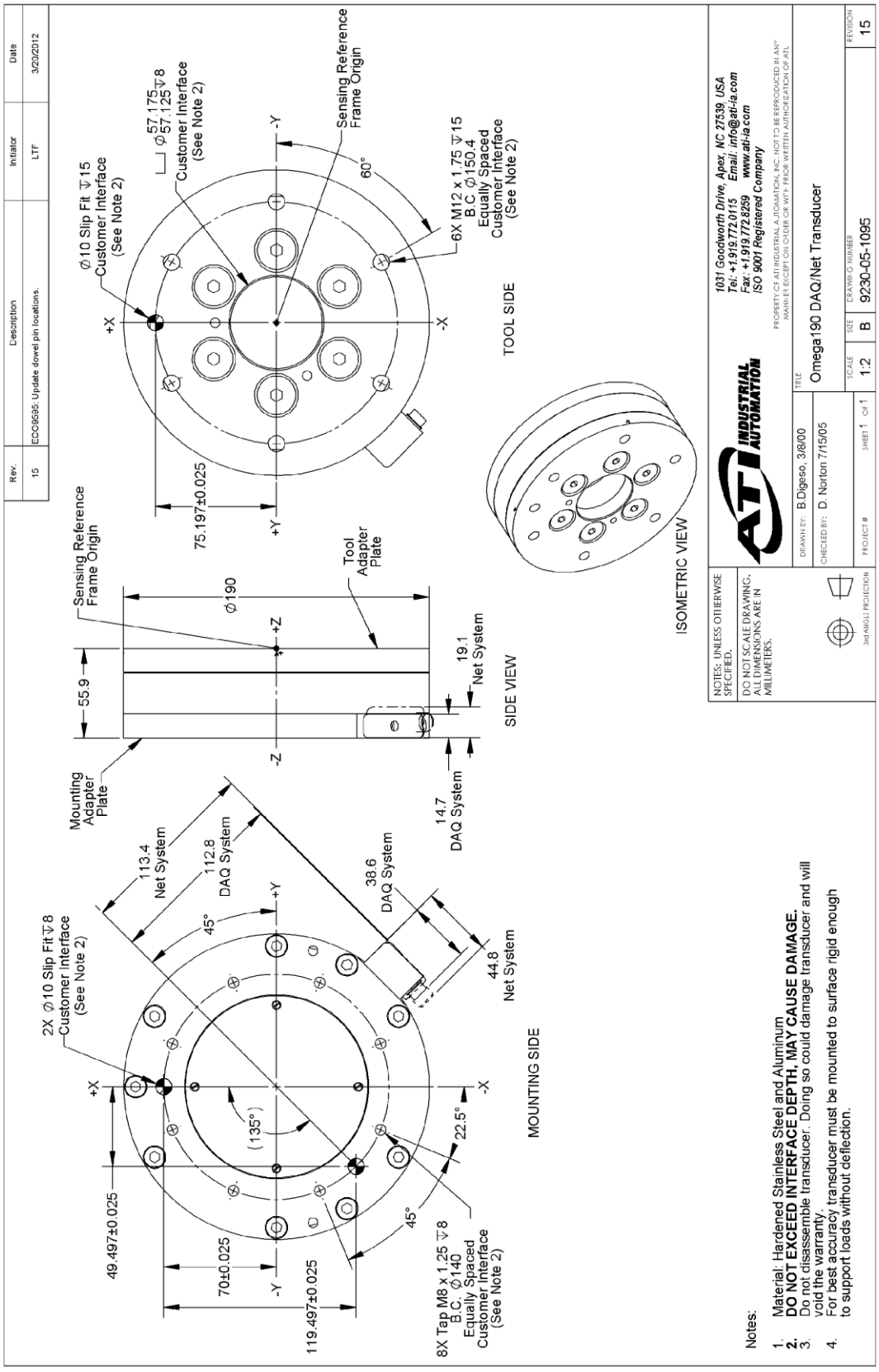

*** For IP68 version see caution on physical properties page.

### 4.17.7 Omega190 (SI Calibration Complex Loading) (Includes IP60/IP65/IP68 Versions)

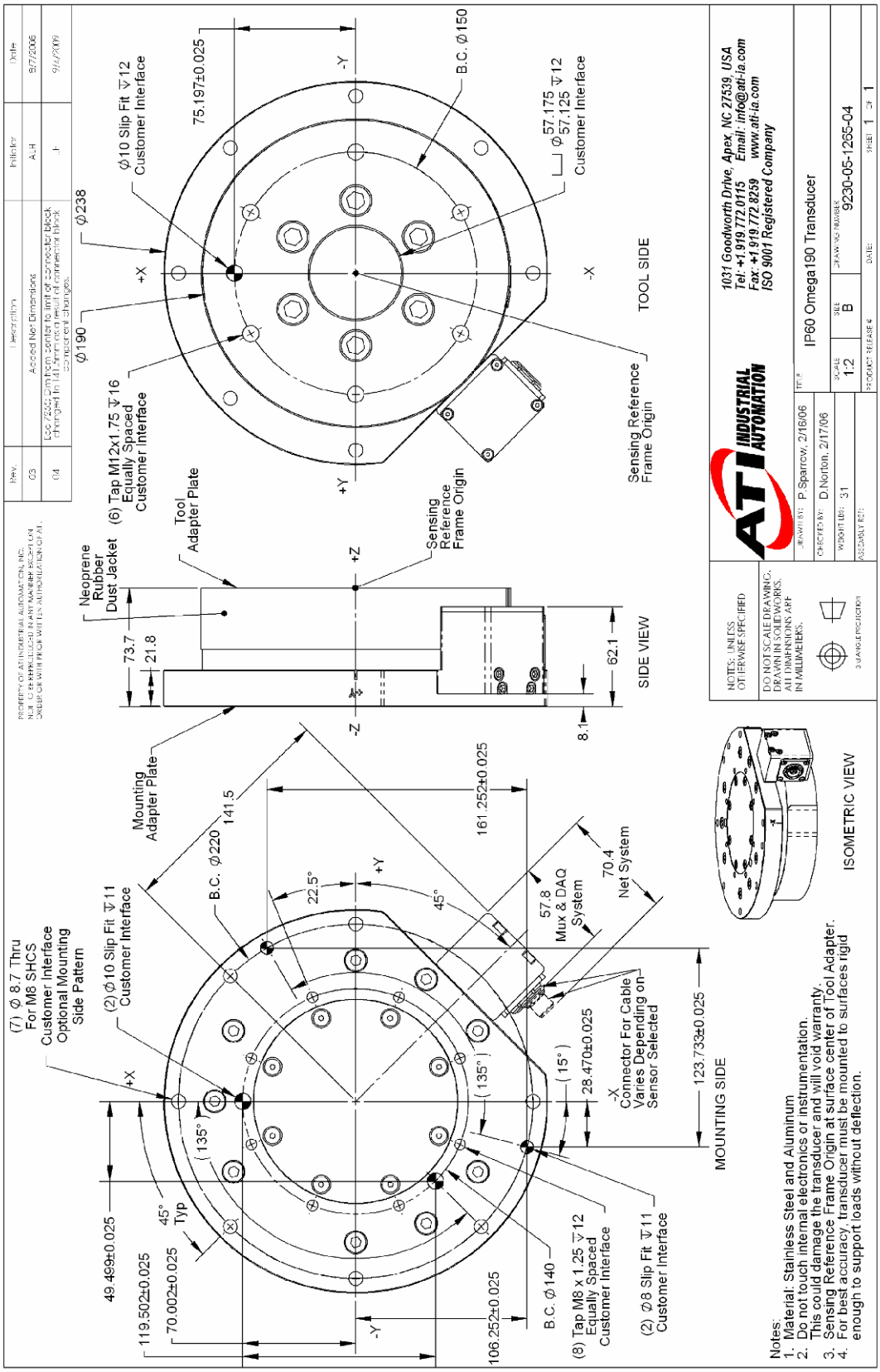



*** For IP68 version see caution on physical properties page.

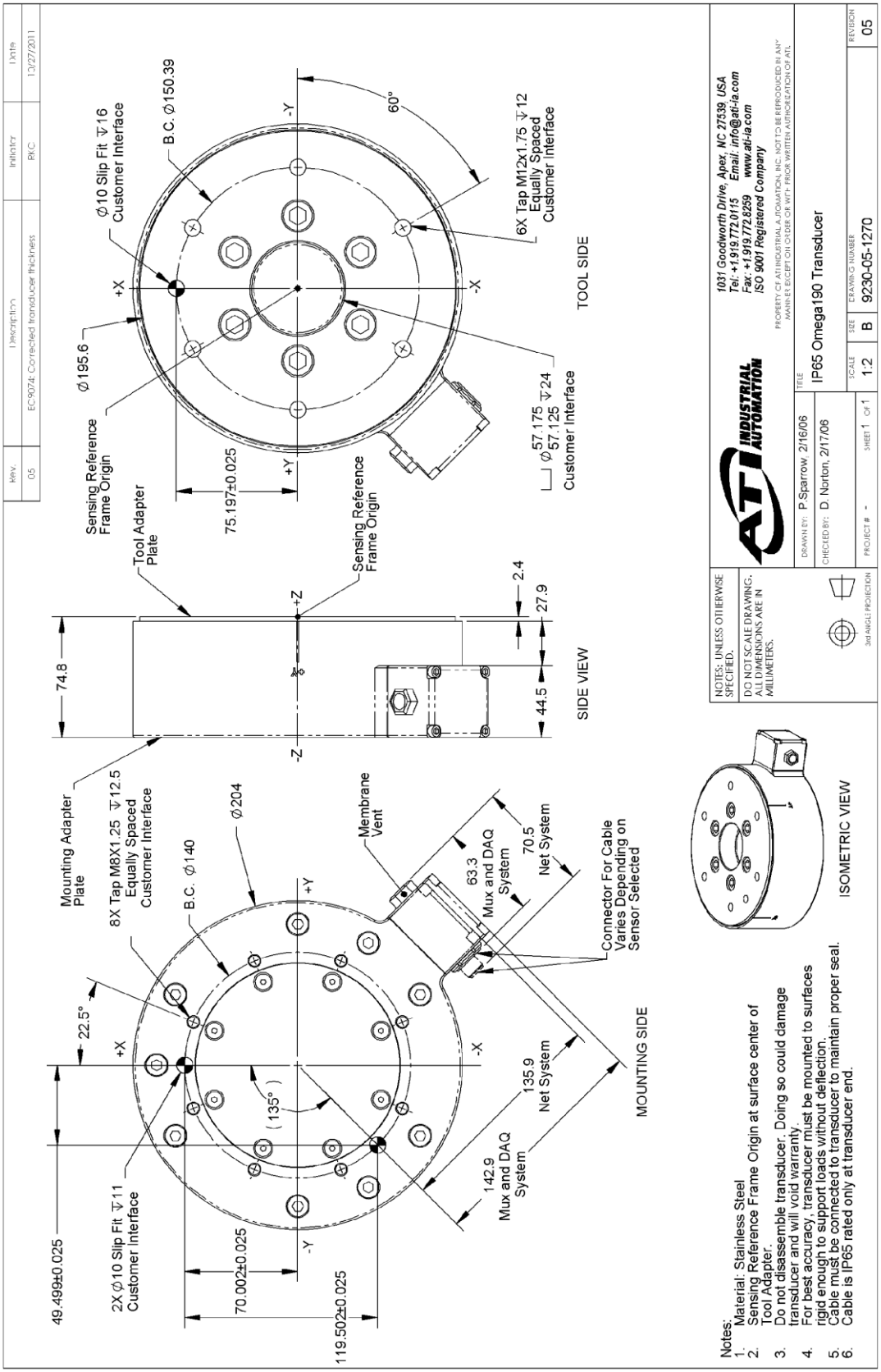
### 4.17.8 Omega190 DAQ/Net Transducer Drawing



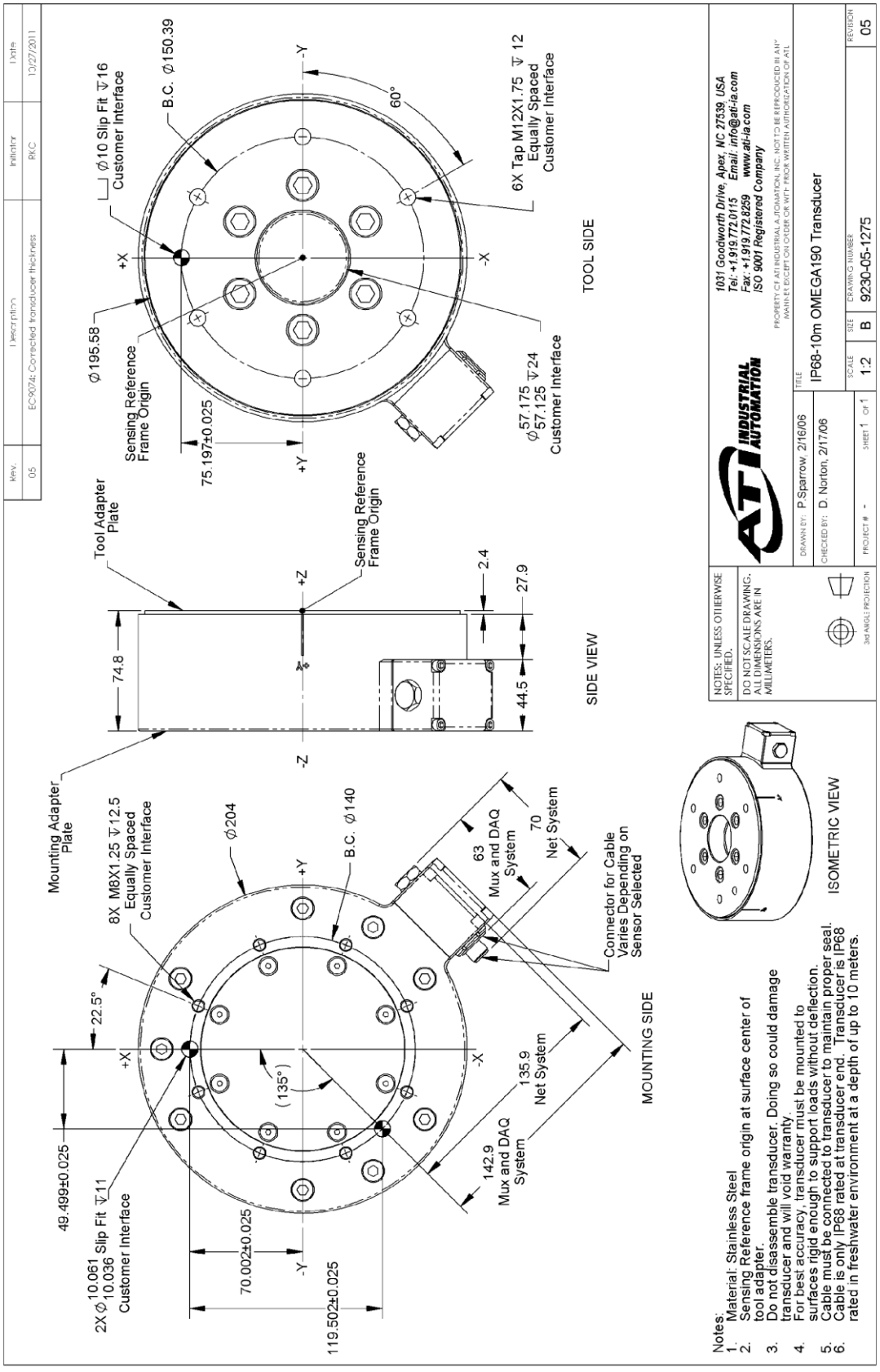
### 4.17.9 Omega190 IP60 Transducer Drawing



### 4.17.10 Omega190 IP65 Transducer Drawing



### 4.17.11 Omega190 IP68 Transducer Drawing



## 4.18 Omega250 (Includes IP60/IP65/IP68 Versions)

### 4.18.1 Calibration Specifications (excludes CTL calibrations)

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz*** | Tx,Ty | Tz | Fx,Fy | Fz*** | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| US-900–4500 | 900 lbf | 1800 lbf | 4500 lbf-in | 4500 lbf-in | 1/2 lbf | 1/2 lbf | 1 lbf-in | 1 lbf-in |
| US-1800–9000 | 1800 lbf | 3600 lbf | 9000 lbf-in | 9000 lbf-in | 1 lbf | 1 lbf | 2 lbf-in | 2 lbf-in |
| US-3600–18000 | 3600 lbf | 7200 lbf | 18000 lbf-in | 18000 lbf-in | 2 lbf | 2 lbf | 5 lbf-in | 5 lbf-in |
| | SENSING RANGES | | | | RESOLUTION* | | | |

**Metric Calibrations (SI)**

| Calibration | Fx,Fy | Fz*** | Tx,Ty | Tz | Fx,Fy | Fz*** | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| SI-4000–500 | 4000 N | 8000 N | 500 Nm | 500 Nm | 1 N | 2 N | 1/8 Nm | 1/8 Nm |
| SI-8000–1000 | 8000 N | 16000 N | 1000 Nm | 1000 Nm | 2 N | 4 N | 1/4 Nm | 1/4 Nm |
| SI-16000–2000 | 16000 N | 32000 N | 2000 Nm | 2000 Nm | 4 N | 8 N | 1/2 Nm | 1/2 Nm |
| | SENSING RANGES | | | | RESOLUTION* | | | |

** DAQ resolutions are typical for a 16-bit data acquisition system.*

*These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.*

### 4.18.2 CTL Calibration Specifications

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz*** | Tx,Ty | Tz | Fx,Fy | Fz*** | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| US-900–4500 | 900 lbf | 1800 lbf | 4500 lbf-in | 4500 lbf-in | 1 lbf | 1 lbf | 2 lbf-in | 2 lbf-in |
| US-1800–9000 | 1800 lbf | 3600 lbf | 9000 lbf-in | 9000 lbf-in | 2 lbf | 2 lbf | 5 lbf-in | 5 lbf-in |
| US-3600–18000 | 3600 lbf | 7200 lbf | 18000 lbf-in | 18000 lbf-in | 5 lbf | 5 lbf | 10 lbf-in | 10 lbf-in |
| | SENSING RANGES | | | | RESOLUTION | | | |

**Metric Calibrations (SI)**

| Calibration | Fx,Fy | Fz*** | Tx,Ty | Tz | Fx,Fy | Fz*** | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| SI-4000–500 | 4000 N | 8000 N | 500 Nm | 500 Nm | 2 N | 4 N | 1/4 Nm | 1/4 Nm |
| SI-8000–1000 | 8000 N | 16000 N | 1000 Nm | 1000 Nm | 4 N | 8 N | 1/2 Nm | 1/2 Nm |
| SI-16000–2000 | 16000 N | 32000 N | 2000 Nm | 2000 Nm | 8 N | 16 N | 1 Nm | 1 Nm |
| | SENSING RANGES | | | | RESOLUTION | | | |

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz† | Tx,Ty, Tz | Fx,Fy | Fz† | Tx,Ty, Tz |
|---|---|---|---|---|---|---|
| US-900–4500 | ±900 lbf | ±1800 lbf | ±4500 lbf-in | 90 lbf/V | 180 lbf/V | 450 lbf-in/V |
| US-1800–9000 | ±1800 lbf | ±3600 lbf | ±9000 lbf-in | 180 lbf/V | 360 lbf/V | 900 lbf-in/V |
| US-3600–18000 | ±3600 lbf | ±7200 lbf | ±18000 lbf-in | 360 lbf/V | 720 lbf/V | 1800 lbf-in/V |
| | Analog Output Range | | | Analog ±10V Sensitivity‡ | | |

**Metric Calibrations (SI)**

| Calibration | Fx,Fy | Fz† | Tx,Ty, Tz | Fx,Fy | Fz† | Tx,Ty, Tz |
|---|---|---|---|---|---|---|
| SI-4000–500 | ±4000 N | ±8000 N | ±500 Nm | .4 N/V | .8 N/V | .05 Nm/V |
| SI-8000–1000 | ±8000 N | ±16000 N | ±1000 Nm | .8 N/V | 1.6 N/V | .10 Nm/V |
| SI-16000–2000 | ±16000 N | ±32000 N | ±2000 Nm | 1.6 N/V | 3.2 N/V | .20 Nm/V |
| | Analog Output Range | | | Analog ±10V Sensitivity‡ | | |

**Counts Value**

| Calibration | Fx, Fy, Fz | Tx, Ty, Tz | Fx, Fy, Fz | Tx, Ty, Tz |
|---|---|---|---|---|
| US-900–4500 / SI-4000–500 | 8 / lbf | 4 / lbf-in | 4000 / N | 32000 / Nm |
| US-1800–9000 / SI-8000–1000 | 4 / lbf | 2 / lbf-in | 2000 / N | 16000 / Nm |
| US-3600–18000 / SI-16000-2000 | 2 / lbf | 1 / lbf-in | 1000 / N | 8000 / Nm |
| **Tool Transform Factor** | 0.02 in/lbf | | 1.25 mm/N | |
| | Counts Value – Standard (US) | | Counts Value – Metric (SI) | |

*CTL resolutions are typical. System resolutions quoted are the effective resolution after dropping eight counts of noise. The effective resolution can be improved with filtering. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.*

*† For IP68 version see caution on physical properties page.*

*‡ ±5V Sensitivity values are double the listed ±10V Sensitivity values.*

### 4.18.3 Omega250 Physical Properties (Includes IP60/IP65/IP68 Versions)

**Standard (US)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±37000 lbf |
| Fz | ±74000 lbf |
| Txy | ±180000 lbf-in |
| Tz | ±220000 lbf-in |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $2.4 \times 10^6$ lb/in |
| Z-axis force (Kz) | $3.2 \times 10^6$ lb/in |
| X-axis & Y-axis torque (Ktx, Kty) | $2.7 \times 10^7$ lbf-in/rad |
| Z-axis torque (Ktz) | $5.5 \times 10^7$ lbf-in/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 780 Hz |
| Fz, Tx, Ty | 770 Hz |
| **Physical Specifications** | |
| Weight* | 70 lb |
| Diameter* | 11.6 in |
| Height* | 3.74 in |

**Metric (SI)**

| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±160000 N |
| Fz | ±330000 N |
| Txy | ±21000 Nm |
| Tz | ±25000 Nm |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $4.2 \times 10^8$ N/m |
| Z-axis force (Kz) | $5.6 \times 10^8$ N/m |
| X-axis & Y-axis torque (Ktx, Kty) | $3.0 \times 10^6$ Nm/rad |
| Z-axis torque (Ktz) | $6.2 \times 10^6$ Nm/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | 780 Hz |
| Fz, Tx, Ty | 770 Hz |
| **Physical Specifications** | |
| Weight* | 31.8 kg |
| Diameter* | 295 mm |
| Height* | 94.9 mm |

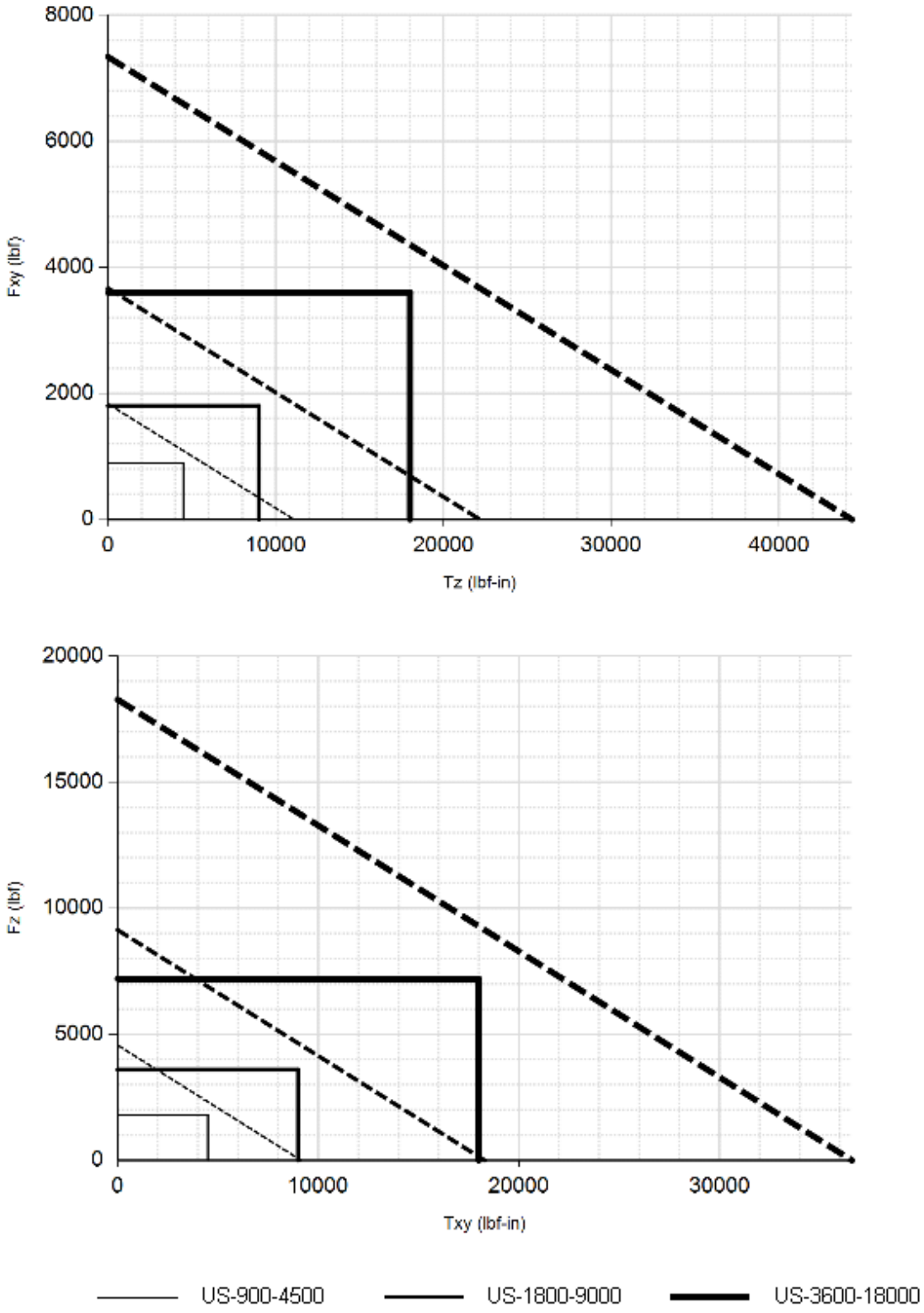
** Specifications include standard interface plates.*

**CAUTION:**
**IP68 Omega250 Fz as a Function of Submersion Depth:**

When submerged, IP68 transducers exhibit a decrease in Fz range related to the submersion depth. This loss is the result of pressure-induced preloading on the transducer. The preload can be masked by biasing the transducer at the depth prior to applying the load to be measured. The following estimates are for room temperature fresh water at sea level.

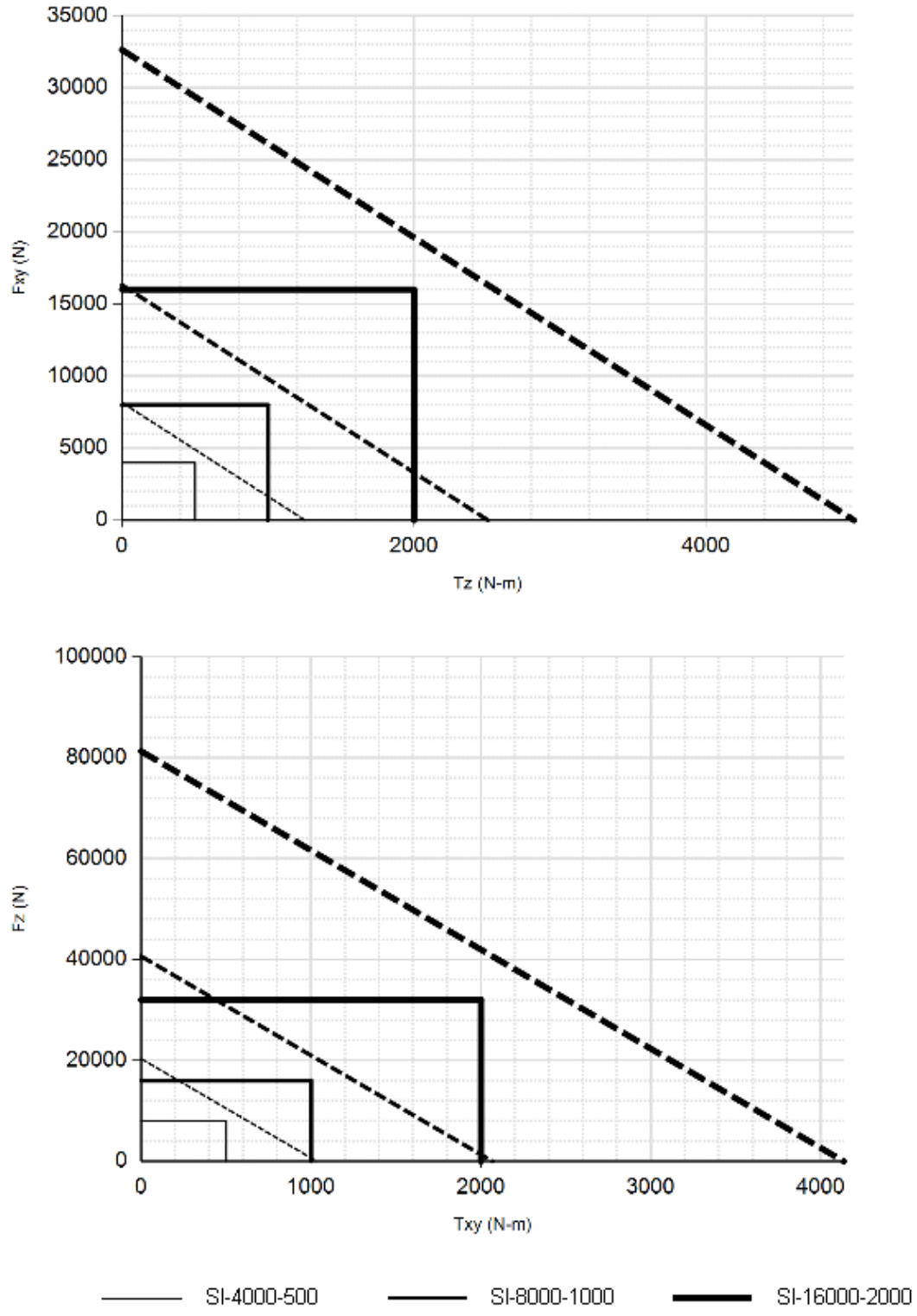
| ***IP68 Omega250*** | **US** | **Metric** |
|---|---|---|
| Fz preload at 10m depth | -1138 lb | -5061 N |
| Fz preload at other depths | -35 lb/ft × depthInFeet | -506 N/m × depthInMeters |

### 4.18.4 Omega250 (US Calibration Complex Loading) (Includes IP60/IP65/IP68 Versions)



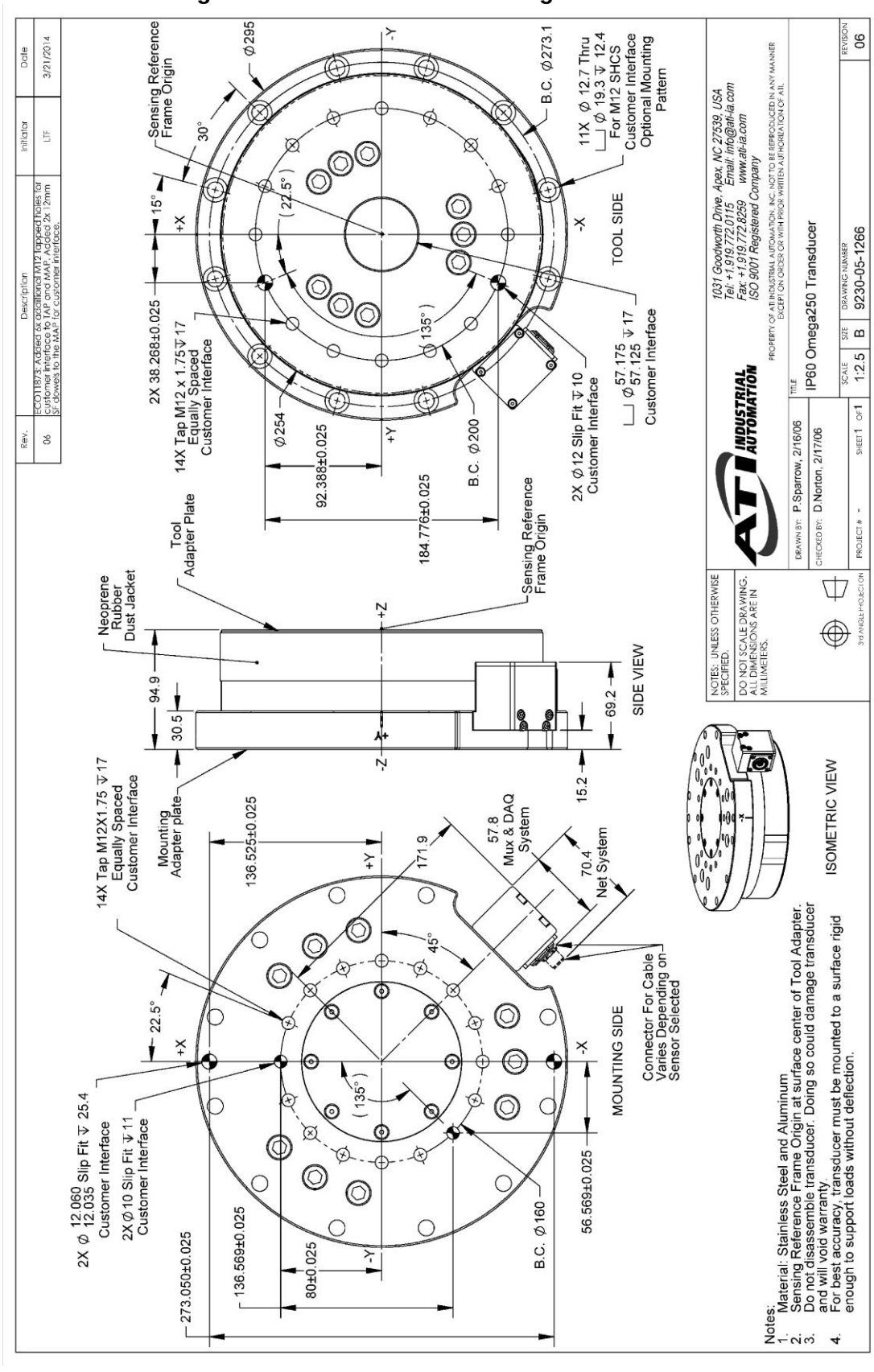

*** For IP68 version see caution on physical properties page.

### 4.18.5 Omega250 (SI Calibration Complex Loading) (Includes IP60/IP65/IP68 Versions)

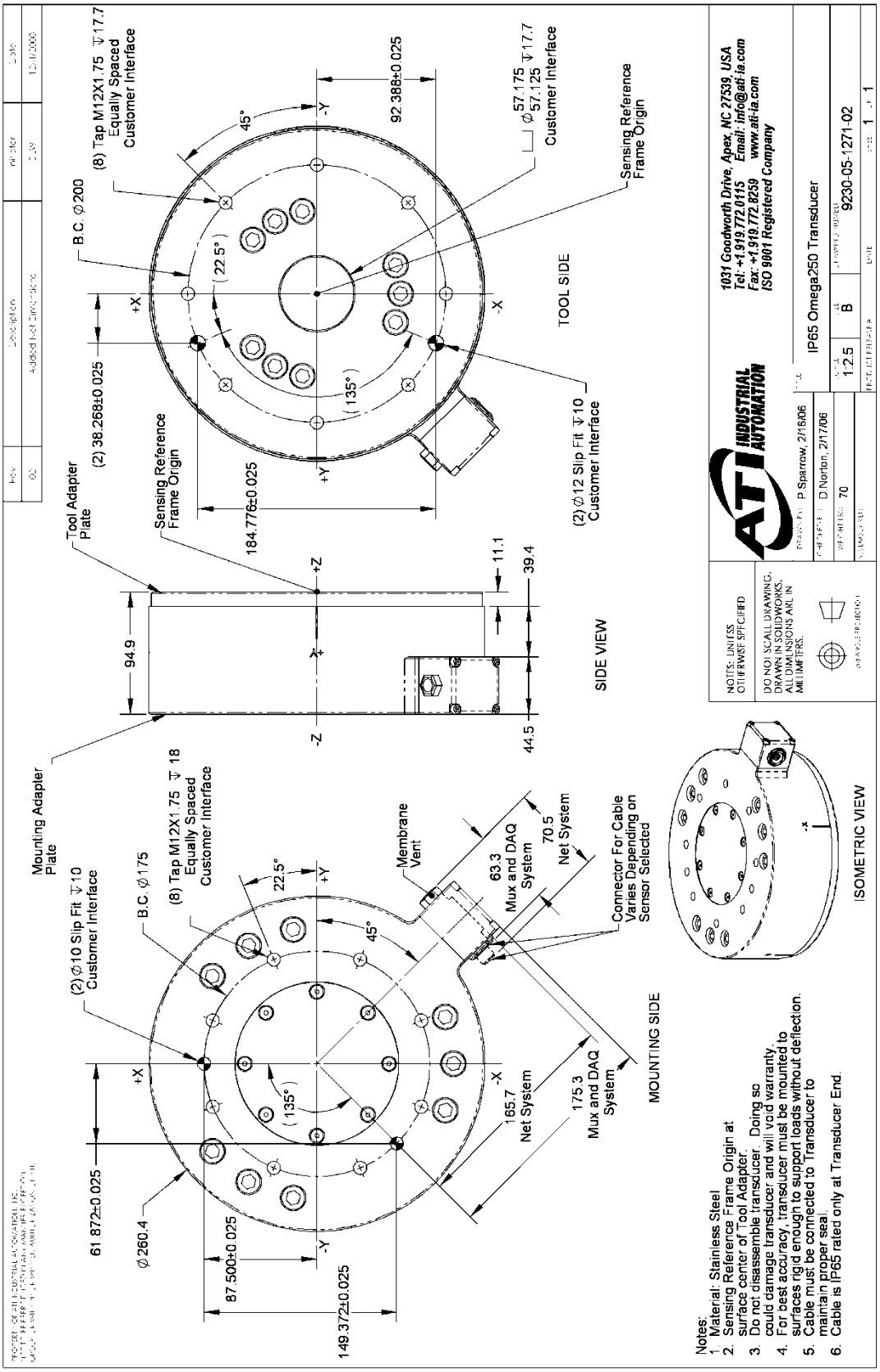



*** For IP68 version see caution on physical properties page.

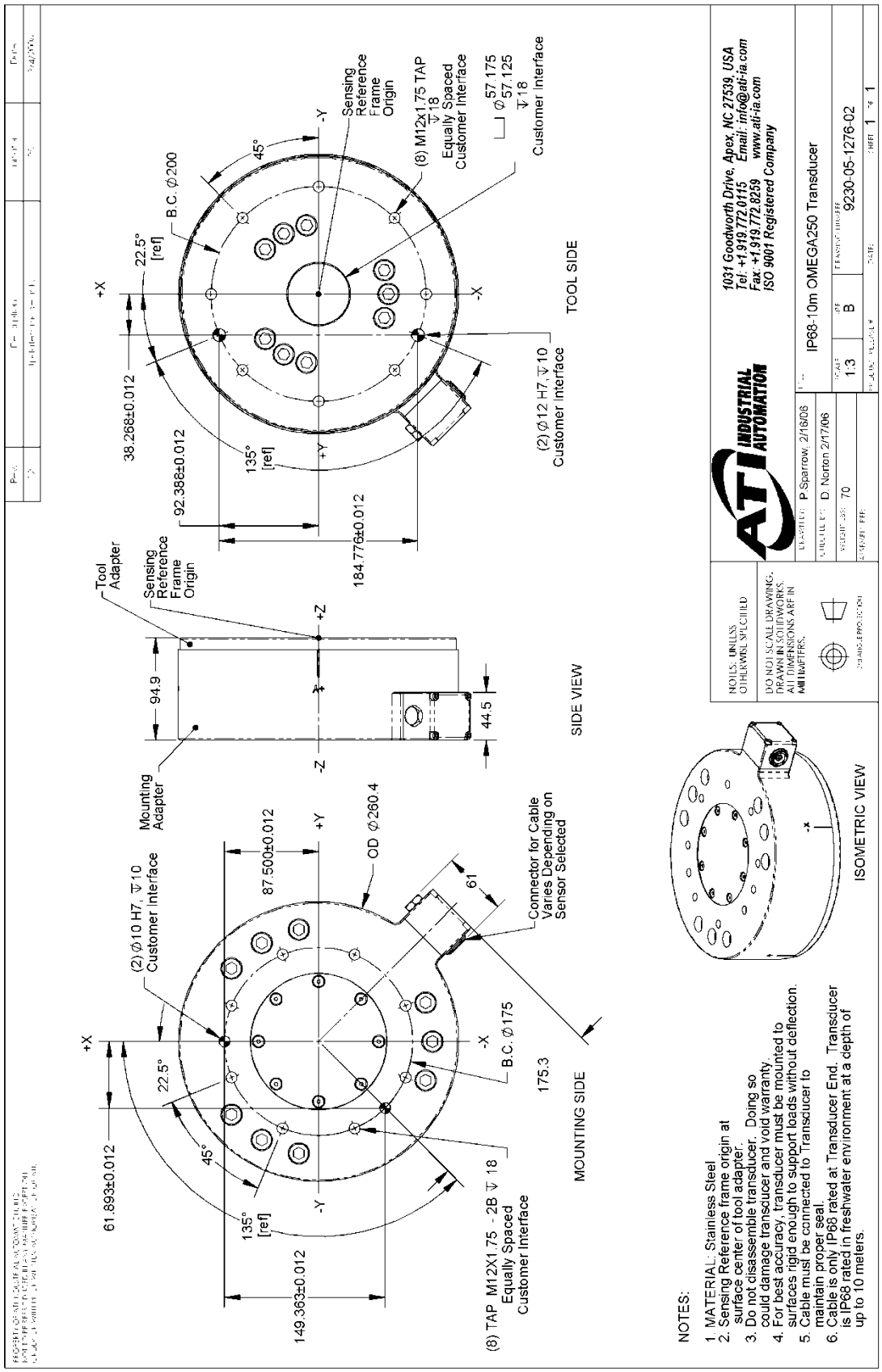
### 4.18.6 Omega250 IP60 Transducer Drawing



### 4.18.7 Omega250 IP65 Transducer Drawing



### 4.18.8 Omega250 IP68 Transducer Drawing



## 4.19 Omega331

### 4.19.1 Calibration Specifications (excludes CTL calibrations)

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz | Tx,Ty | Tz | Fx,Fy | Fz | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| US-2250–13000 | 2250 lbf | 5250 lbf | 13000 lbf-in | 13000 lbf-in | 1/2 lbf | 1 lbf | 3 3/4 lbf-in | 1 7/8 lbf-in |
| US-4500–26000 | 4500 lbf | 10500 lbf | 26000 lbf-in | 26000 lbf-in | 1 lbf | 2 lbf | 7 1/2 lbf-in | 3 3/4 lbf-in |
| US-9000–52000 | 9000 lbf | 21000 lbf | 52000 lbf-in | 52000 lbf-in | 2 lbf | 4 lbf | 15 lbf-in | 7 1/2 lbf-in |
| | SENSING RANGES | | | | RESOLUTION* | | | |

**Metric Calibrations (SI)**

| Calibration | Fx,Fy | Fz | Tx,Ty | Tz | Fx,Fy | Fz | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| SI-10000–1500 | 10 kN | 22 kN | 1.5 kNm | 1.5 kNm | 1/480 kN | 1/240 kN | 3/8000 kNm | 3/16000 kNm |
| SI-20000–3000 | 20 kN | 44 kN | 3 kNm | 3 kNm | 1/240 kN | 1/120 kN | 3/4000 kNm | 3/8000 kNm |
| SI-40000–6000 | 40 kN | 88 kN | 6 kNm | 6 kNm | 1/120 kN | 1/60 kN | 3/2000 kNm | 3/4000 kNm |
| | SENSING RANGES | | | | RESOLUTION* | | | |

** DAQ resolutions are typical for a 16-bit data acquisition system.*

*These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.*

### 4.19.2 CTL Calibration Specifications

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz | Tx,Ty | Tz | Fx,Fy | Fz | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| US-2250–13000 | 2250 lbf | 5250 lbf | 13000 lbf-in | 13000 lbf-in | 1 lbf | 2 lbf | 7 1/2 lbf-in | 3 3/4 lbf-in |
| US-4500–26000 | 4500 lbf | 10500 lbf | 26000 lbf-in | 26000 lbf-in | 2 lbf | 4 lbf | 15 lbf-in | 7 1/2 lbf-in |
| US-9000–52000 | 9000 lbf | 21000 lbf | 52000 lbf-in | 52000 lbf-in | 4 lbf | 8 lbf | 30 lbf-in | 15 lbf-in |
| | SENSING RANGES | | | | RESOLUTION | | | |

**Metric Calibrations (SI)**

| Calibration | Fx,Fy | Fz | Tx,Ty | Tz | Fx,Fy | Fz | Tx,Ty | Tz |
|---|---|---|---|---|---|---|---|---|
| SI-10000–1500 | 10 kN | 22 kN | 1.5 kNm | 1.5 kNm | 1/240 kN | 1/120 kN | 3/4000 kNm | 3/8000 kNm |
| SI-20000–3000 | 20 kN | 44 kN | 3 kNm | 3 kNm | 1/120 kN | 1/60 kN | 3/2000 kNm | 3/4000 kNm |
| SI-40000–6000 | 40 kN | 88 kN | 6 kNm | 6 kNm | 1/60 kN | 1/30 kN | 3/1000 kNm | 3/2000 kNm |
| | SENSING RANGES | | | | RESOLUTION | | | |

**Standard Calibrations (US)**

| Calibration | Fx,Fy | Fz | Tx,Ty, Tz | Fx,Fy | Fz | Tx,Ty, Tz |
|---|---|---|---|---|---|---|
| US-2250–13000 | ±2250 lbf | ±5250 lbf | ±13000 lbf-in | 225 lbf/V | 525 lbf/V | 1300 lbf-in/V |
| US-4500–26000 | ±4500 lbf | ±10500 lbf | ±26000 lbf-in | 450 lbf/V | 1050 lbf/V | 2600 lbf-in/V |
| US-9000–52000 | ±9000 lbf | ±21000 lbf | ±52000 lbf-in | 900 lbf/V | 2100 lbf/V | 5200 lbf-in/V |
| | Analog Output Range | | | Analog ±10V Sensitivity‡ | | |

**Metric Calibrations (SI)**

| Calibration | Fx,Fy | Fz | Tx,Ty, Tz | Fx,Fy | Fz | Tx,Ty, Tz |
|---|---|---|---|---|---|---|
| SI-10000–1500 | ±10 kN | ±22 kN | ±1.5 kNm | 1 kN/V | 2.2 kN/V | 0.15 kNm/V |
| SI-20000–3000 | ±20 kN | ±44 kN | ±3 kNm | 2 kN/V | 4.4 kN/V | 0.3 kNm/V |
| SI-40000–6000 | ±40 kN | ±88 kN | ±6 kNm | 4 kN/V | 8.8 kN/V | 0.6 kNm/V |
| | Analog Output Range | | | Analog ±10V Sensitivity‡ | | |

**Counts Value**

| Calibration | Fx, Fy, Fz | Tx, Ty, Tz | Fx, Fy, Fz | Tx, Ty, Tz |
|---|---|---|---|---|
| US-2250–13000 / SI-10000–1500 | 32 / lbf | 6.4 / lbf-in | 7680 / kN | 64000 / kNm |
| US-4500–26000 / SI-20000–3000 | 16 / lbf | 3.2 / lbf-in | 3840 / kN | 32000 / kNm |
| US-9000–52000 / SI-40000–6000 | 8 / lbf | 1.6 / lbf-in | 1920 / kN | 16000 / kNm |
| **Tool Transform Factor** | 0.05 in/lbf | | 1.2 mm/N | |
| | Counts Value – Standard (US) | | Counts Value – Metric (SI) | |

*CTL resolutions are typical. System resolutions quoted are the effective resolution after dropping eight counts of noise. The effective resolution can be improved with filtering. NOTE: Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.*

‡ *±5V Sensitivity values are double the listed ±10V Sensitivity values.*

### 4.19.3 Omega331 Physical Properties (Includes IP60/IP65/IP68 Versions)

**Standard (US)**

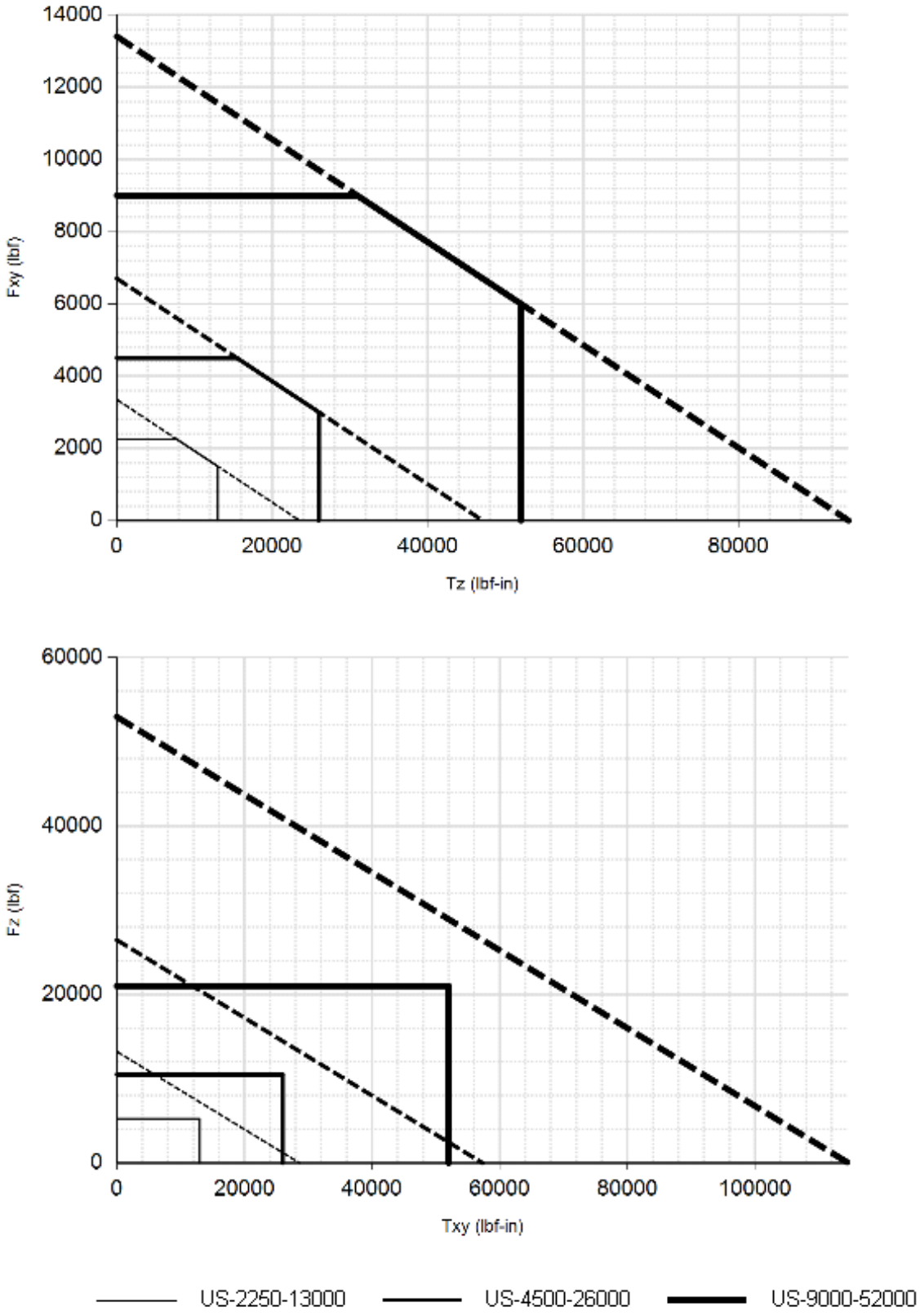
| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±58000 lbf |
| Fz | ±120000 lbf |
| Txy | ±280000 lbf-in |
| Tz | ±410000 lbf-in |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $6.9 \times 10^6$ lb/in |
| Z-axis force (Kz) | $7.3 \times 10^6$ lb/in |
| X-axis & Y-axis torque (Ktx, Kty) | $8.1 \times 10^7$ lbf-in/rad |
| Z-axis torque (Ktz) | $2.1 \times 10^8$ lbf-in/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | |
| Fz, Tx, Ty | |
| **Physical Specifications** | |
| Weight* | 104 lb |
| Diameter* | 13 in |
| Height* | 4.22 in |

**Metric (SI)**

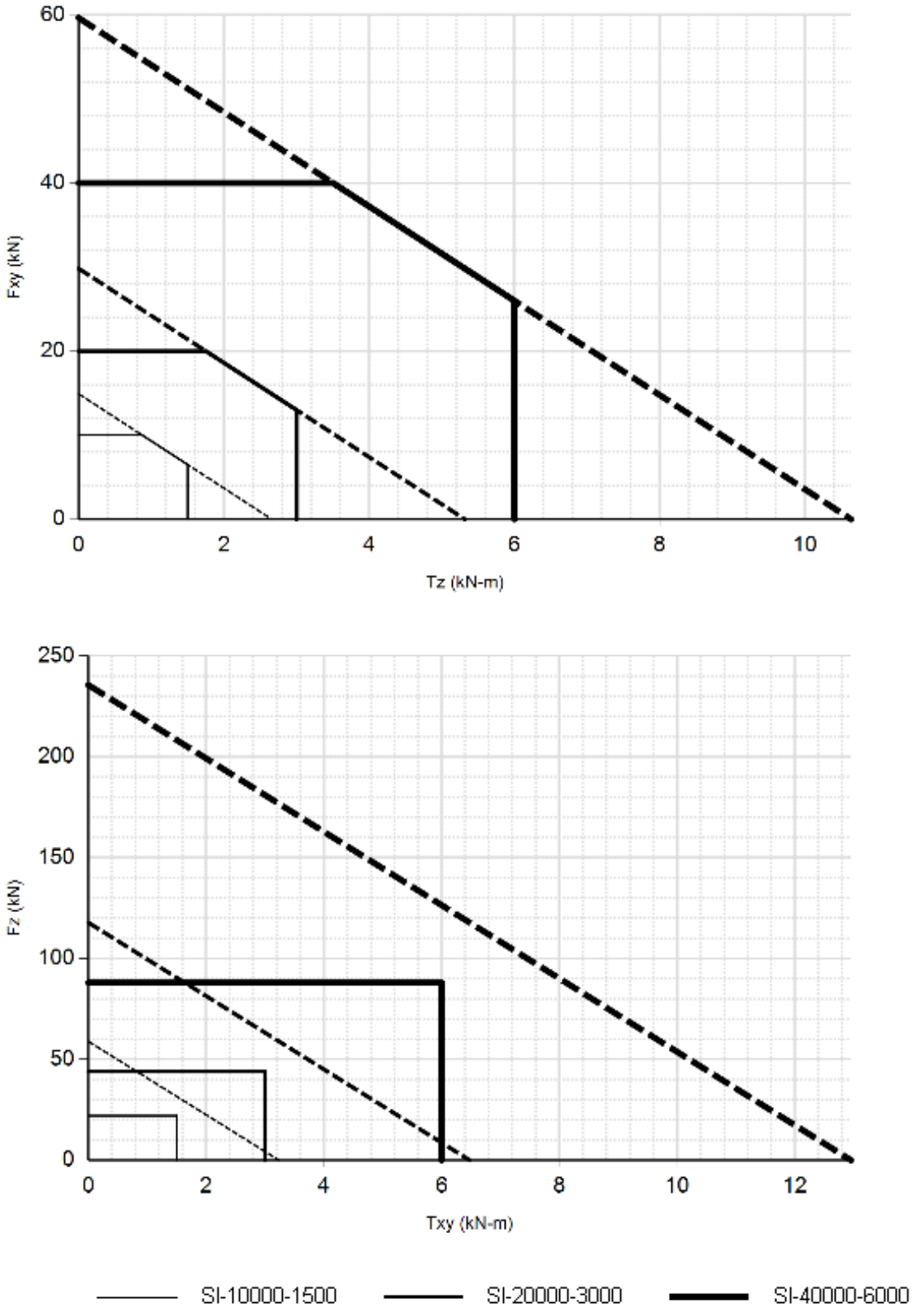
| | |
|---|---|
| **Single-Axis Overload** | |
| Fxy | ±260000 N |
| Fz | ±520000 N |
| Txy | ±32000 Nm |
| Tz | ±46000 Nm |
| **Stiffness (Calculated)** | |
| X-axis & Y-axis forces (Kx, Ky) | $1.2 \times 10^9$ N/m |
| Z-axis force (Kz) | $1.3 \times 10^9$ N/m |
| X-axis & Y-axis torque (Ktx, Kty) | $9.2 \times 10^6$ Nm/rad |
| Z-axis torque (Ktz) | $2.4 \times 10^7$ Nm/rad |
| **Resonant Frequency** | |
| Fx, Fy, Tz | |
| Fz, Tx, Ty | |
| **Physical Specifications** | |
| Weight* | 47 kg |
| Diameter* | 330 mm |
| Height* | 107 mm |

** Specifications include standard interface plates.*

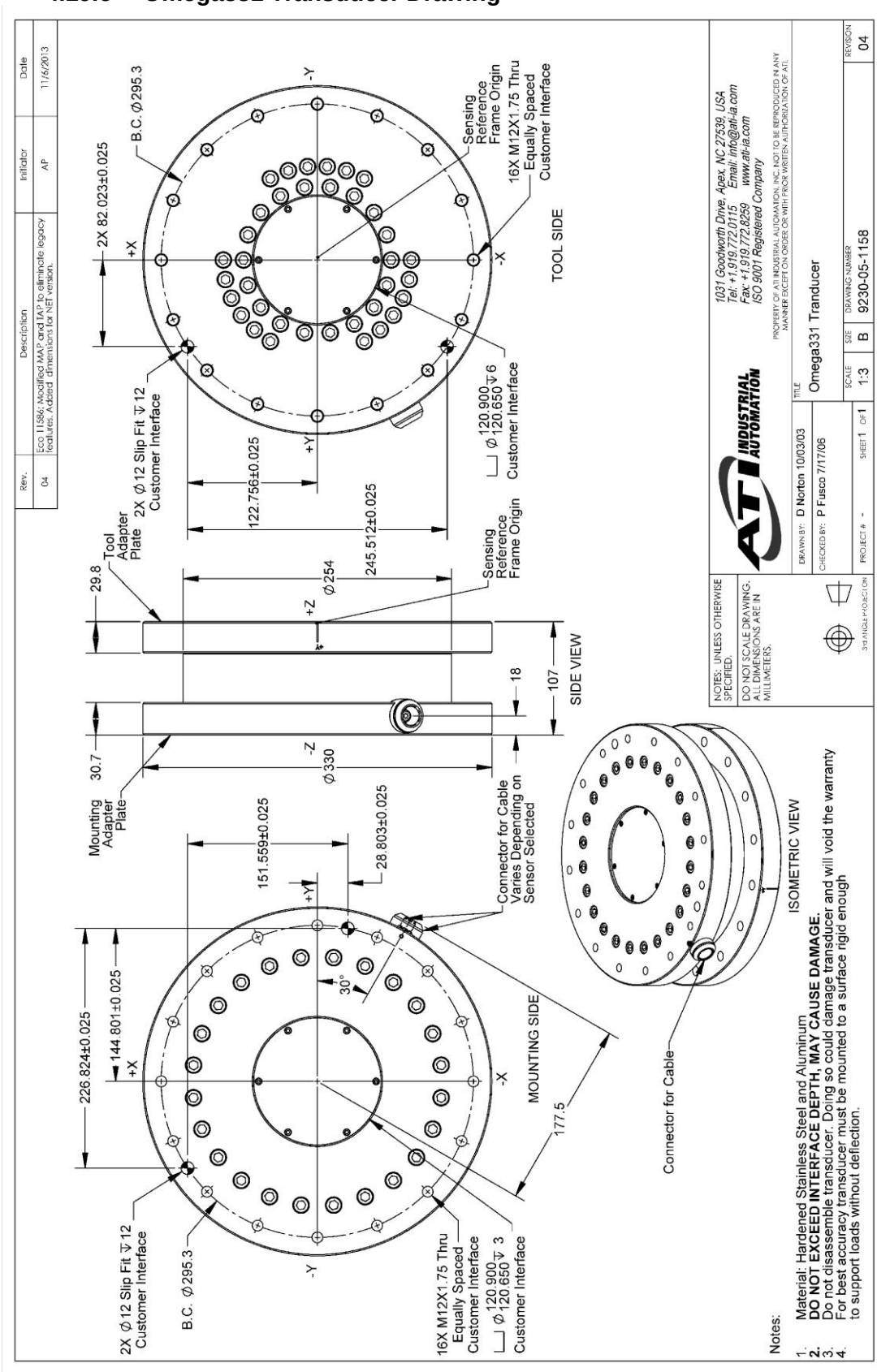
### 4.19.4 Omega331 (US Calibration Complex Loading)



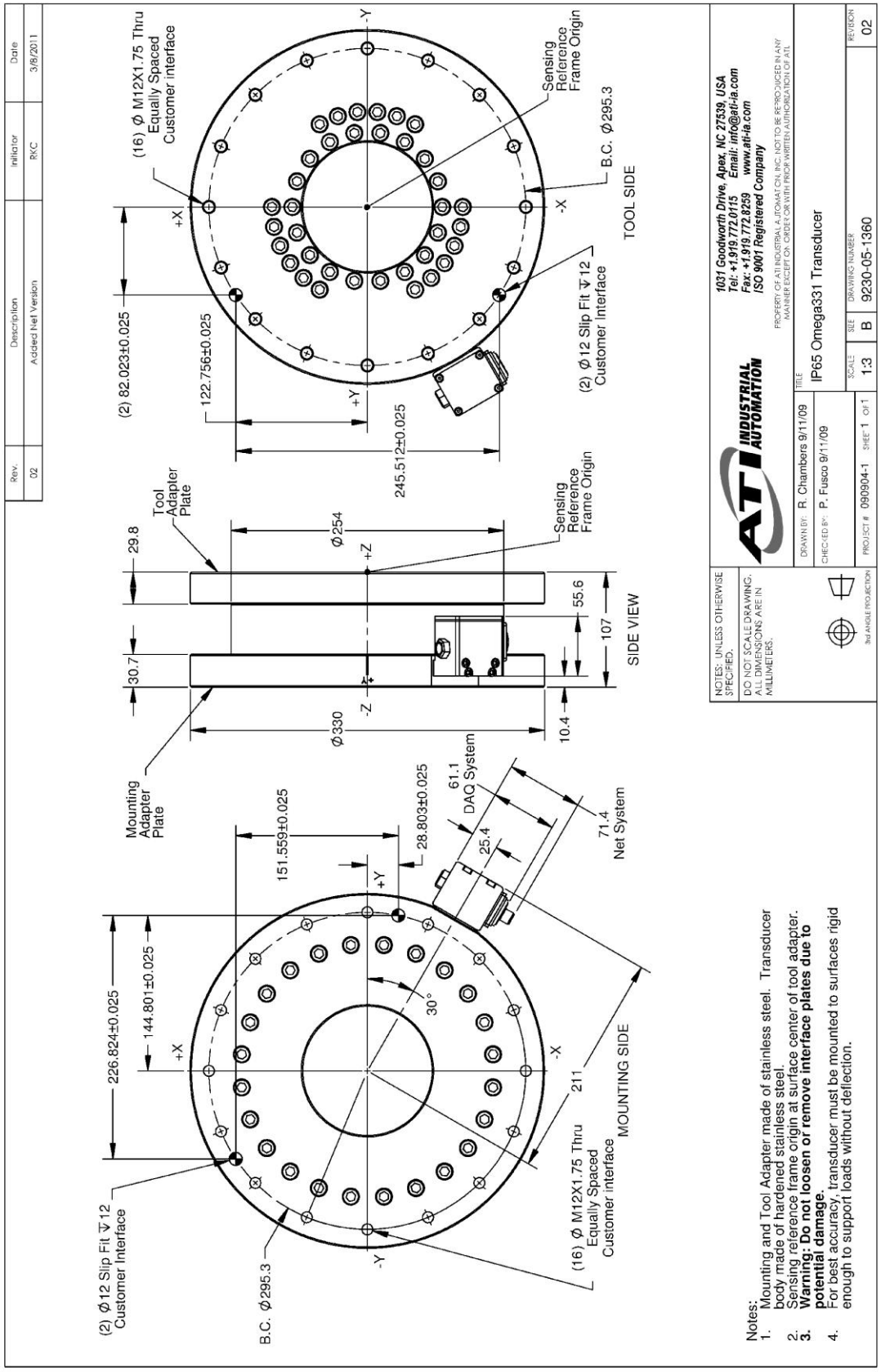
### 4.19.5 Omega331 (SI Calibration Complex Loading)



### 4.19.6 Omega331 Transducer Drawing



### 4.19.7 Omega331 IP65 Transducer Drawing



# 5. Advanced Topics

## 5.1 Reducing Noise

### 5.1.1 Mechanical Vibration

In many cases, perceived noise is actually a real fluctuation of force and/or torque, caused by vibrations in the tooling or the robot arm. Many F/T systems offer filtering or averaging that can smooth out noise. If this is not sufficient, you may want to add a digital filter to the application software.

### 5.1.2 Electrical Interference

Check the F/T's ground connections if you observe interference by motors or other noise-generating equipment.

Consider using averaging or filtering if sufficient grounding is not possible or does not reduce the noise.

## 5.2 Detecting Failures (Diagnostics)

### 5.2.1 Detecting Sensitivity Changes

Sensitivity checking of the transducer can also be used to measure the transducer system's health. This is done by applying known loads to the transducer and verifying the system output matches the known loads. For example, a transducer mounted to a robot arm may have an end-effector attached to it:

If the end-effector has moving parts, they must be moved in a known position. Place the robot arm in an orientation that allows the gravity load from the end-effector to exert load on many transducer output axes.

Record the output readings.

Position the robot arm to apply another load, this time causing the outputs to move far from the earlier readings.

Record the second set of output readings.

Find the differences from the first and second set of readings and use it as your sensitivity value.

Even if the values vary somewhat from sample set to sample set, they can be used to detect gross errors. Either the resolved outputs or the raw transducer voltages may be used (the same must be used for all steps of this process).

**CAUTION:** When any strain gage output is saturated or otherwise inoperable, **all transducer F/T readings are invalid**. Therefore, it is vitally important to monitor for these conditions.

## 5.3 Scheduled Maintenance

### 5.3.1 Periodic Inspection

For most applications, there are no parts that need to be replaced during normal operation. With industrial-type applications that continuously or frequently move the system's cabling, you should periodically check the cable jacket for signs of wear. These applications should implement the procedures discussed in *Section 5.2—Detecting Failures (Diagnostics)* to detect any failures.

Transducers that are not IP60, IP65, or IP68 rated must be kept free of excessive dust, debris, or moisture. IP60-rated transducers must be kept free of excessive moisture. Debris and dust should be kept from accumulating on or in a transducer.

### 5.3.2 Periodic Calibration

Periodic calibration of the transducer and its electronics is required to maintain traceability to national standards. Follow any applicable ISO-9000-type standards for

calibration. ATI Industrial Automation recommends annual recalibrations, especially for applications that frequently cycle the loads applied to the transducer.

## 5.4 Transducer Cabling

### 5.4.1 Calibrations

In many cases the transducer cable comprises part of the calibrated transducer. In these cases, changing the length or type of the cable can affect the calibration. Check with ATI Industrial Automation when making cabling changes to ensure your system's calibration will not be affected.

### 5.4.2 Cabling and Connectors

The transducer cables and connectors are not designed to be user serviceable. The high flex life stranding used in the cable is difficult to work with and will fail prematurely if improperly assembled.

However, there are special cases when customers find it necessary to temporarily remove the connector on a cable that is permanently attached to a transducer (such as found on the Nano and Mini series transducers). When reattaching the wires to the connector, it is vital that each conductor is encased in heat shrink tubing at the connection to prevent premature fatiguing of the mechanical connection. Also, any components contained in the connector must be reconnected exactly as found – failing to do so will impact system performance and accuracy.

Damage to the outer jacketing of the transducer cable could enable moisture or water to enter an otherwise sealed transducer. Ensure the cable jacketing is in good condition to prevent transducer damage.

## 5.5 A Word about Resolution

ATI's transducers have a three sensing beam configuration where the three beams are equally spaced around a central hub and attached to the outside wall of the transducer. This design transfers applied loads to multiple sensing beams and allows the transducer to increase its sensing range in a given axis if a counterpart axis has reduced.

The resolution of each transducer axis depends on how the applied load is spread among the sensing beams. The best resolution occurs in the scenario when the quantization of the gages is evenly distributed as load is applied. In the worst case scenario, the discrete value of all involved gages increases at the same time. The typical scenario will be somewhere between these two.

F/T resolutions are specified as *typical resolution*, defined as the average of the worst and best case scenarios. Because both multi-gage effects can be modeled as a normal distribution, this value represents the most commonly perceived, average resolution. Although this misrepresents the actual performance of the transducers, it results in a close (and always conservative) estimate.

## 6. Terms and Conditions of Sale

The following Terms and Conditions are a supplement to and include a portion of ATI's Standard Terms and Conditions, which are on file at ATI and available upon request.

ATI warrants to Purchaser that force torque sensor products purchased hereunder will be free from defects in material and workmanship under normal use for a period of one year from the date of shipment. This warranty does not cover components subject to wear and tear under normal usage or those requiring periodic replacement. ATI will have no liability under this warranty unless: (a) ATI is given written notice of the claimed defect and a description thereof within thirty (30) days after Purchaser discovers the defect and in any event not later than the last day of the warranty period; and (b) the defective item is received by ATI not later ten (10) days after the last day of the warranty period. ATI's entire liability and Purchaser's sole remedy under this warranty is limited to repair or replacement, at ATI's election, of the defective part or item or, at ATI's election, refund of the price paid for the item. The foregoing warranty does not apply to any defect or failure resulting from improper installation, operation, maintenance or repair by anyone other than ATI.

ATI will in no event be liable for incidental, consequential or special damages of any kind, even if ATI has been advised of the possibility of such damages. ATI's aggregate liability will in no event exceed the amount paid by purchaser for the item which is the subject of claim or dispute. ATI will have no liability of any kind for failure of any equipment or other items not supplied by ATI.

No action against ATI, regardless of form, arising out of or in any way connected with products or services supplied hereunder may be brought more than one year after the cause of action accrued.

No representation or agreement varying or extending the warranty and limitation of remedy provisions contained herein is authorized by ATI, and may not be relied upon as having been authorized by ATI, unless in writing and signed by an executive officer of ATI.

Unless otherwise agreed in writing by ATI, all designs, drawings, data, inventions, software and other technology made or developed by ATI in the course of providing products and services hereunder, and all rights therein under any patent, copyright or other law protecting intellectual property, shall be and remain ATI's property. The sale of products or services hereunder does not convey any express or implied license under any patent, copyright or other intellectual property right owned or controlled by ATI, whether relating to the products sold or any other matter, except for the license expressly granted below.

In the course of supplying products and services hereunder, ATI may provide or disclose to Purchaser confidential and proprietary information of ATI relating to the design, operation or other aspects of ATI's products. As between ATI and Purchaser, ownership of such information, including without limitation any computer software provided to Purchaser by ATI, shall remain in ATI and such information is licensed to Purchaser only for Purchaser's use in operating the products supplied by ATI hereunder in Purchaser's internal business operations.

Without ATI's prior written permission, Purchaser will not use such information for any other purpose or provide or otherwise make such information available to any third party. Purchaser agrees to take all reasonable precautions to prevent any unauthorized use or disclosure of such information.

Purchaser will not be liable hereunder with respect to disclosure or use of information which: (a) is in the public domain when received from ATI; (b) is thereafter published or otherwise enters the public domain through no fault of Purchaser; (c) is in Purchaser's possession prior to receipt from ATI; (d) is lawfully obtained by Purchaser from a third party entitled to disclose it; or (f) is required to be disclosed by judicial order or other governmental authority, provided that, with respect to such required disclosures, Purchaser gives ATI prior notice thereof and uses all legally available means to maintain the confidentiality of such information.