F/T Transducer

Six-Axis
Force/Torque Sensor System

Installation and Operation Manual

Document #: 9620-05-Transducer Section

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Foreword

ATI Industrial Automation, Inc. assumes no responsibility for any errors or omissions in this document. Users' critical evaluation is welcome to assist in the preparation of future documentation.

In consideration that ATI Industrial Automation, Inc. (ATI) products are intended for use with robotic and/or automated machines, ATI does not recommend the use of its products for applications wherein failure or malfunction of an ATI component or system threatens life or makes injury probable. Anyone who uses or incorporates ATI components within any potentially life threatening system must obtain ATI's prior consent based upon assurance to ATI that a malfunction of ATI's component does not pose direct or indirect threat of injury or death, and (even if such consent is given) shall indemnify ATI from any claim, loss, liability, and related expenses arising from any injury or death resulting from use of ATI components.

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

Note

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, SI-65-6, 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, be near the F/T system when calling.

How to Reach Us:

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Glossary

Term	Definition
Accuracy	See Measurement Uncertainty.
ActiveX Component	A reusable software component for the Windows applications.
Calibration	The act of measuring a transducer's raw response to loads and creating data used in converting the response to forces and torques.
Calibration Certificate	A statement that says the equipment measures correctly. These statements usually mean the equipment has been tested against national standards. The statements are produced as a result of calibration or re-calibration.
Compound Loading	Any load that is not purely in one axis.
Coordinate Frame	See Point of Origin
DAQ	Data Acquisition device.
DAQ F/T	An F/T Sensor System that uses industry standard data acquisition fasteners (usually computer cards) to convert the transducer signals into digital data.
DoF	Degrees of Freedom. See Six Degrees of Freedom.
Force	The push or pull exerted on an object.
FS	Full-Scale
F/T	Force and Torque.
F/T Controller	The electronics that connect to mux transducers.
Fxy	The resultant force vector comprised of components Fx and Fy.
Full-Scale Error	A measurement of sensing error. For example, if the calibrated measurement range of a sensor is 100 Newtons and the sensor is accurate to within 1 Newton, that sensor will have a Full-Scale Error of 1% (1% = 0.01 = 1 N / 100 N).
HTC	Fasteners Temperature Compensation. This is a method of improving the temperature performance of transducers. Usually this refers to span temperature compensation. Sometimes it also includes offset temperature compensation. HTC is better than STC.
Hysteresis	A source of measurement error caused by the residual effects of previously applied loads.
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.
Max. Single-Axis Overload	The largest amount of load in a single axis (all other axes are unloaded) that the transducer can withstand without damage.
MAP	Mounting Adapter Plate. The transducer's MAP attaches to the fixed surface or robot arm.
Measurement Uncertainty	The maximum expected error in measurements, as specified on the calibration certificate.
Moment	When something receives a torque, we say a moment is applied to it.
Mux	Short for multiplexer. F/T Controller Sensor Systems use mux electronics to interface to the transducer signals.

Term	Definition
Mux Box	A box that holds mux electronics for transducers that are too small for on-board electronics.
Net F/T	An F/T Sensor System that connects to the customer's monitoring equipment via Ethernet or CAN bus or DeviceNet.
NI	National Instruments Corporation, the owner of the National Instruments and LabVIEW trademarks. (www.ni.com) Maker of Data Acquisition Cards used by ATI in force sensors.
Offset Compensation	Correction of errors that change the zero point of a transducer's readings.
Overload	The condition where more load is applied to the transducer than it can measure. This will result in saturation.
Point of Origin	The point on the transducer from which all forces and torques are measured.
Quantization	The way the continuously variable transducer signal is converted into discreet digital values. Usually used when describing the change from one digital value to the next.
Reaction Torque	Torque applied that does not result in movement. Think of the twisting you attempt to put on a screw or bolt when it does not move. Our transducers sense reaction torque.
Re-calibration	The periodic verification of measurement equipment, like transducers, calipers and voltmeters, to prove it still measures correctly. The equipment may be adjusted if it doesn't measure correctly.
Resolution	The smallest change in load that can be measured. This is usually much smaller than accuracy.
Rotary Torque	Torque resulting in something moving. Generally this refers to the torque on things like drive shafts. Our transducers cannot sense rotational torque.
Saturation	The condition where the transducer or data acquisition fasteners has a load or signal outside of its sensing range.
Sensor System	The entire assembly consisting of parts from transducer to data acquisition card.
Six-axis Force/Torque Sensor	A device that measures the outputting forces and torques from all three Cartesian coordinates (x, y and z). A six-axis force/torque transducer is also known as a multi-axis force/torque transducer, multi-axis load cell, F/T sensor, or six-axis load cell.
Six Degrees of Freedom	Fx, Fy, Fz, Tx, Ty and Tz.
Span Compensation	Correction of errors that affect the sensitivity of a transducer.
STC	Software Temperature Compensation. A method of improving temperature performance of transducers. This method is not as good as HTC.
TAP	Tool Adapter Plate. The TAP part of the transducer is attached to the load that is to be measured.
Tool Transformation	Mathematically changing the measurement coordinate system by translating the origin and/or rotating the axes.
Torque	The measurement of force exerted on an object causing it to rotate.
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

The safety section describes general safety guidelines to be followed with this product, explanation of the notification found in this manual, and safety precaution that apply to the product. More specific notification are imbedded within the sections of the manual where they apply.

1.1 Explanation of Notifications

The notifications included here are specific to the product(s) covered by this manual. It is expected that the user heed all notifications 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.

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.

1.2 General Safety Guidelines

The customer should verify that the transducer selected is rated for maximum loads and moments expected during operation. Refer to transducer specifications in *Section 5—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.

1.3 Safety Precautions

CAUTION: Do not remove any fasteners or disassemble transducers without a removable mounting 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.

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

CAUTION: Do not exert excessive force on the transducer. The transducer is a sensitive instrument and can be damaged by applying force exceeding the single-axis overload values of the transducer and cause irreparable damage. Small Nano and Mini transducers can easily be overloaded during installation. Refer to the F/T Transducer manual (9620-05-Transducer Section) for specific transducer overload values.

2. Product Overview

A transducer is a device that measures the outputting forces and torques from all three Cartesian coordinates (x, y, and z). A six-axis force/torque transducer is also known as a multi-axis force/torque transducer, multi-axis load cell, F/T sensor, or six-axis load cell.

The ATI Multi-Axis Force/Torque Sensor system measures all six components of force and torque. The system consists of a transducer, shielded high-flex cable, and intelligent data acquisition system (Ethernet/DeviceNet interface or F/T controller). Force/Torque sensors are used throughout industry for product testing, robotic assembly, grinding, and polishing. In research, our sensors are used in robotic surgery, haptics, rehabilitation, neurology, and many others applications.

3. Installing the Transducer

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

3.1 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 *Section 4.1—Accuracy over Temperature* 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 electromagnetic fields, such as those produced by magnetic resonance imaging (MRI) machines.

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

3.2 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 3.2.1—Interface Plate Design* for more details. Refer to *Section 3.2.2—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 3.2.1—Interface Plate Design* for more details. Refer to *Section 3.2.3—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 5—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.

3.2.1 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 5—Transducer Specifications*.

Larger transducers have a removable mounting adapter plates, refer to *Section 3.2.2—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.

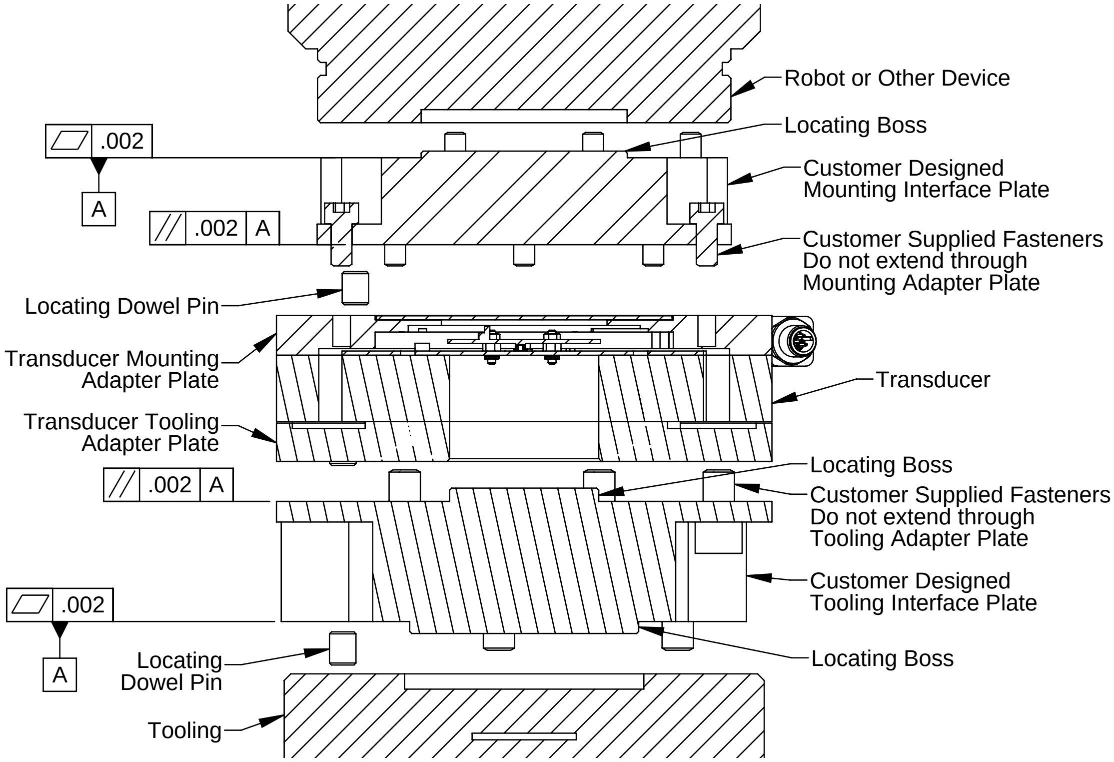
The transducer tooling adapter plate is factory installed and the bolt circle is shown with the transducer in *Section 5—Transducer Specifications*. Most large F/T tool adapters follow the ISO 9409-1 mounting pattern. Machine the tooling interface plate to attach to this bolt circle.

NOTICE: The tool may not contact any other part of the transducer except the tool mounting surface. If the tool contacts 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 contact any other part of the transducer.

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 5—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 5—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



3.2.2 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 3.2.1—Interface Plate Design* for details in designing an interface plate before continuing with this procedure.

1. Remove the power to the transducer.
2. Remove all mounting fasteners from the mounting adapter plate and set aside.

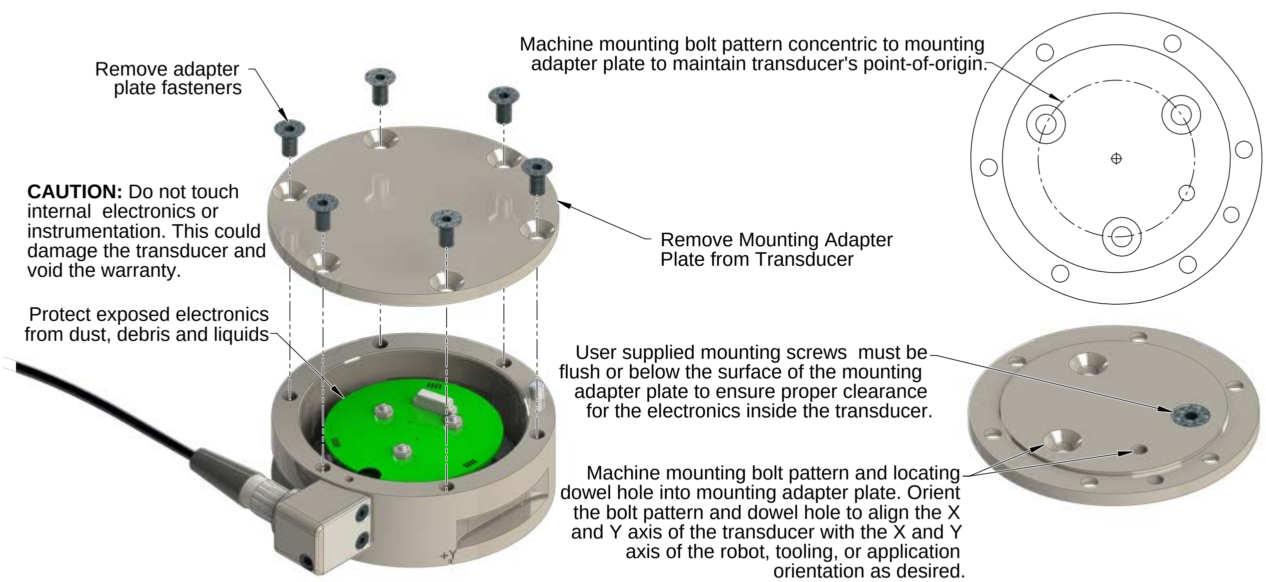
CAUTION: Do not touch internal electronics or instrumentation. This could damage the transducer and void the warranty. When the adapter plate is removed protect the exposed electronics from dust, debris, liquids, and other foreign objects.

3. 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.

NOTICE: Customers machining their own interface patterns should avoid concentrating all mounting features in the center of the adapter plate. A larger bolt circle will provide the most accurate readings as it will induce less bending in the plate.

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 adapter plate.

Figure 2.2—Removable Adapter Plate



4. 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 222® to the fasteners.

NOTICE: 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 3.3—Routing the Transducer Cable*.

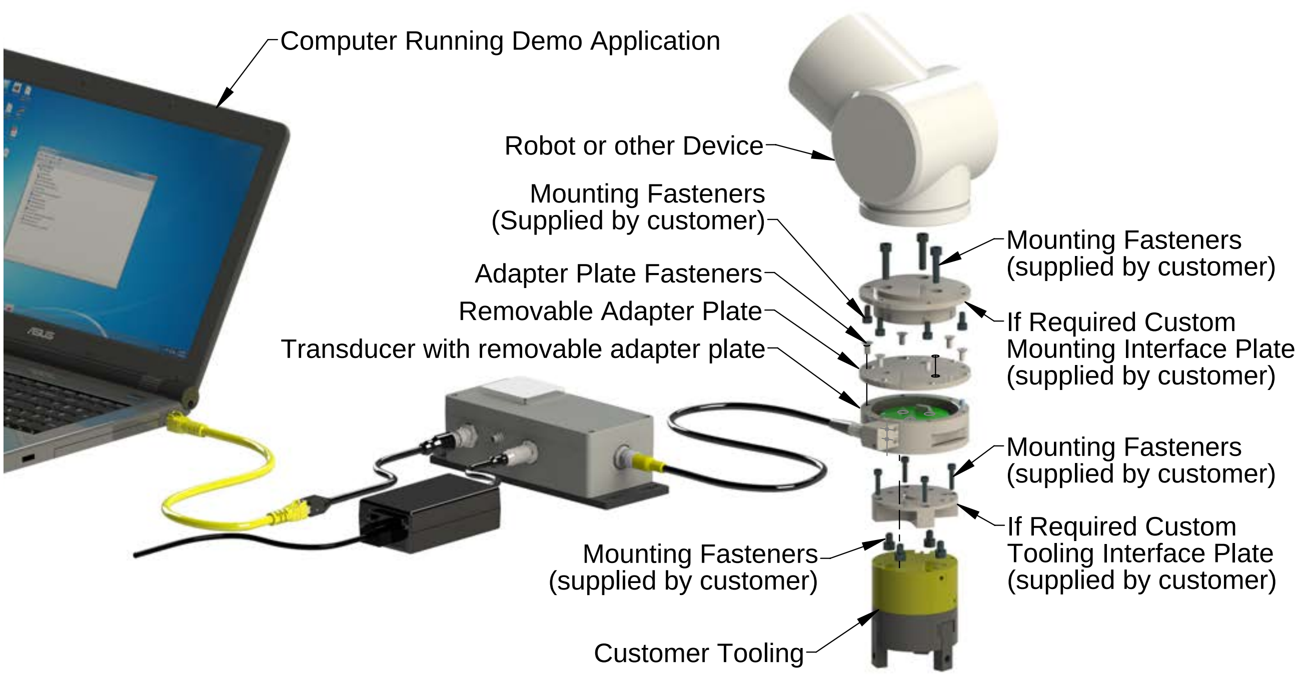
5. Attach the transducer to the removable adapter plate, hand tighten fasteners.

6. 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 applying 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.

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

Figure 2.3—Installing Transducers with Removable Mounting Adapter Plates



> **CAUTION:** Do not use fasteners that will exceed the customer interface depth specified 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 contact any other part of the transducer except the tool mounting surface. If the tool contacts 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 contact any other part of the transducer.

9. Monitor the demo application for gage saturation errors during installation. If an error is displayed stop applying the force to the transducer and wait until the error clears before continuing installation.
10. 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 222 to the fasteners.

3.2.3 Mounting the Transducer with a Non-removable Adapter Plate

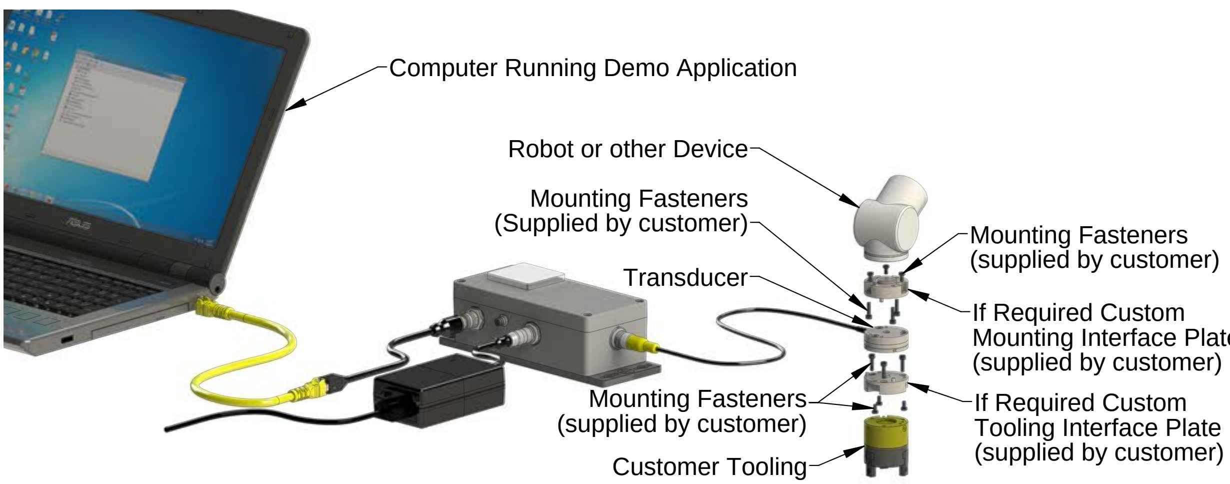
CAUTION: Do not attempt to drill, tap, machine, or otherwise modify or disassemble the transducer. This could damage the transducer and will void the warranty. Use the mounting bolt pattern provided to attach the transducer to the robot or other device and to mount the tool to the transducer. See the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

1. Monitor the demo application for gage saturation errors during installation. If an error is displayed stop applying the force to the transducer and wait until the error clears before continuing installation.
2. 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.

Figure 2.4—Installing Transducers with Non-removable Adapter Plates (Net F/T System Shown)



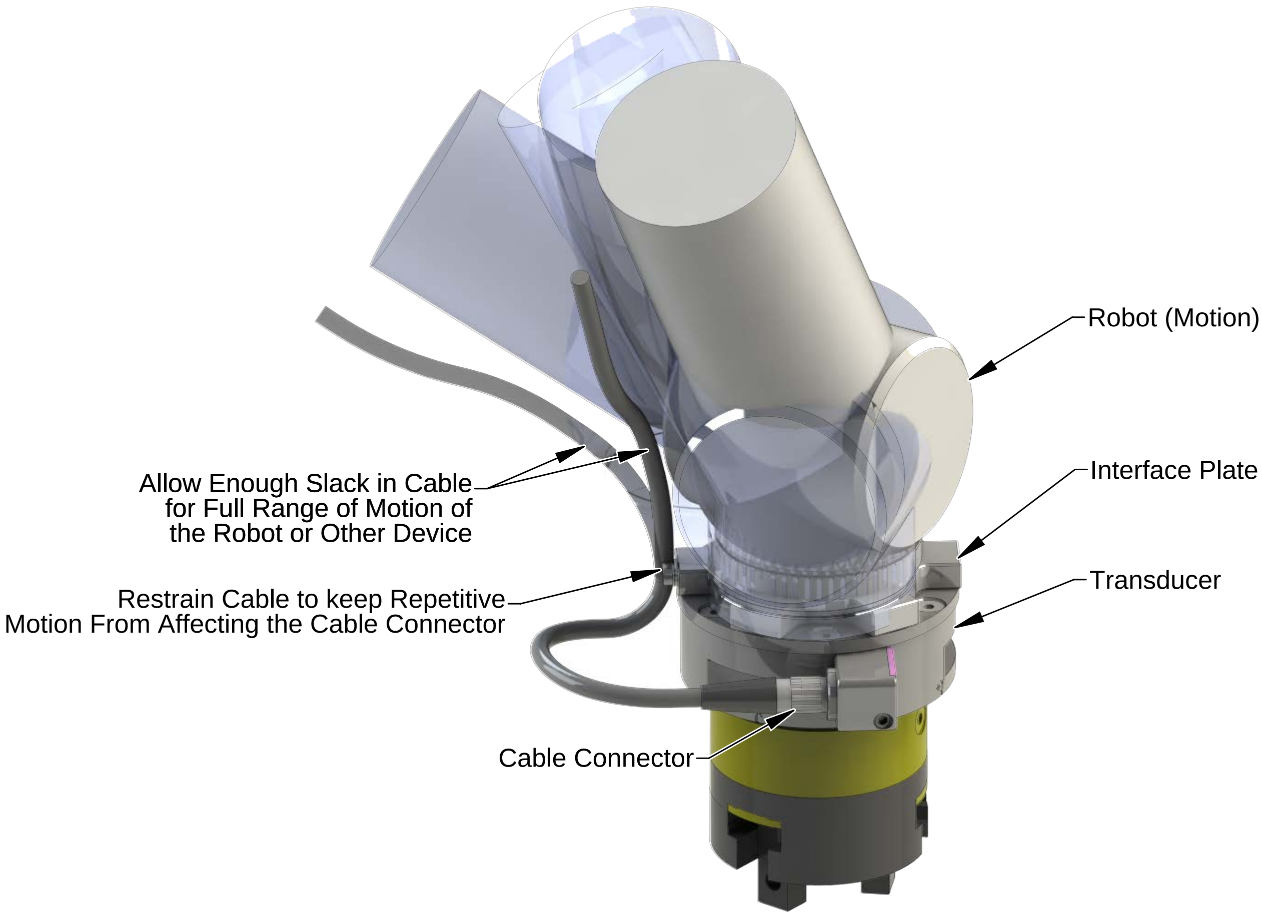
NOTICE: The tool may not touch any other part of the transducer except the tool mounting surface. If the tool touches any other part of the transducer it will not properly sense loads. Make sure the tool mounts to the tool mounting surface and does not touch any other part of the transducer.

3. Monitor the demo application for gage saturation errors during installation. If an error is displayed stop applying the force to the transducer and wait until the error clears before continuing installation.
4. 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 222 to the fasteners.

3.3 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 the cable to a smaller radius than the minimum bending radius specified in *Table 2.1*. The cable will fail due to fatigue from the repetitive motion. When routing the cable make sure the cable bends are larger then the minimum dynamic bending radius specified for the cable type.

⚠	**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 25 mm (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 Bending Radius

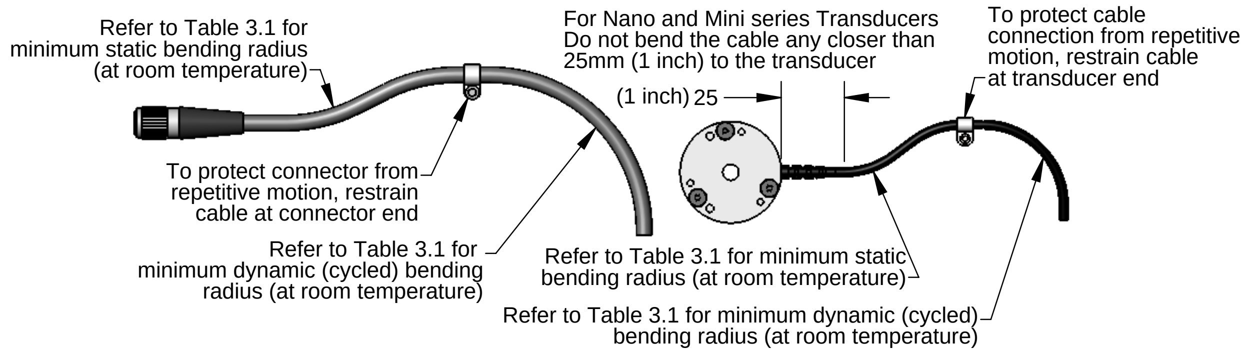


Table 2.1—Transducer Cable Bending Radius

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.

4. Topics

4.1 Accuracy over Temperature

Typical gain errors introduced over temperature for F/T transducers with fasteners 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]	1%
± 50°C[1]	5%

Note:
1. Deviation is bounded by transducer operational limits in *Section 4.3—Environmental*.

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]	1.5%
± 50°C[1]	7%

Note:
1. Deviation is bounded by transducer operational limits in *Section 4.3—Environmental*

4.2 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.

4.3 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 - Non-IP-Rated			
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.			

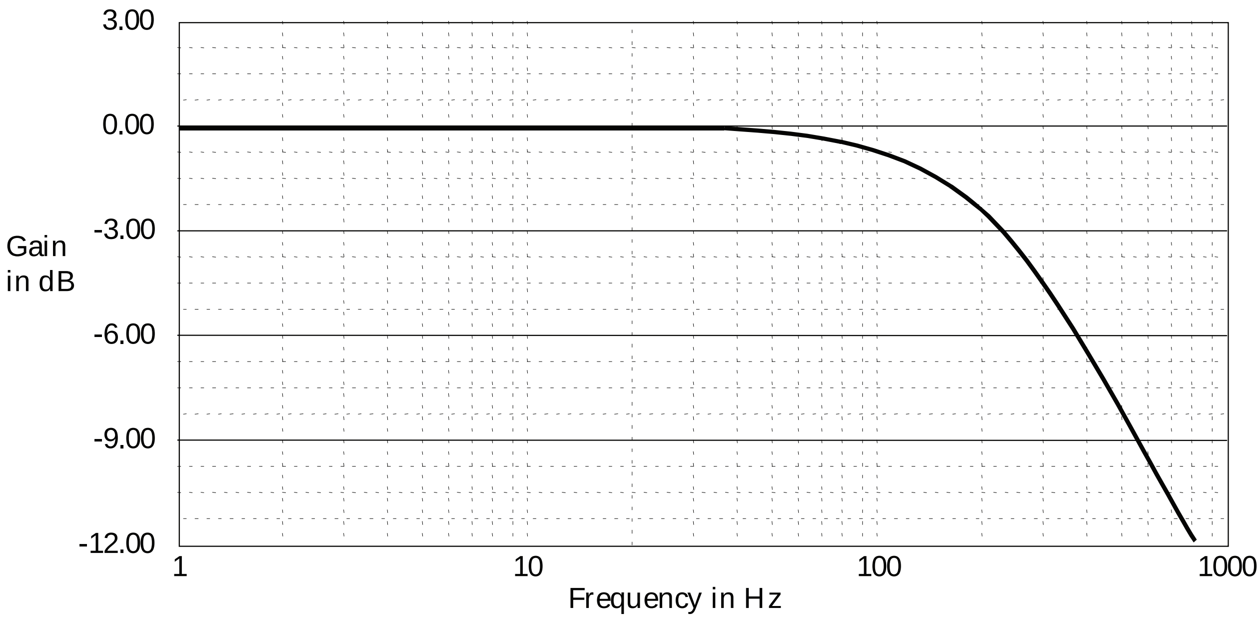
Table 3.4—Transducer Temperature Ranges - IP60, IP65, and IP68			
Transducer Model Series	**Storage**	**Operation**	**Units**
9105-TIF Transducer	-5 to +75	0 to +60	°C
9105-TW Transducer	-5 to +105	-5 to +105	°C
9105-T Transducer	-5 to +105	0 to +70	°C
9105-NET Transducer	-65 to +105	0 to +70	°C
Note: These temperature ranges specify the storage and operation ranges in which the transducer can survive without damage. They do not take accuracy into account.			

4.4 Mux Transducer Input Filter Frequency Response

NOTICE: 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)



4.5 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**. It is vitally important to monitor for these conditions.

5. Transducer Specifications

5.1 Notes

5.1.1 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.

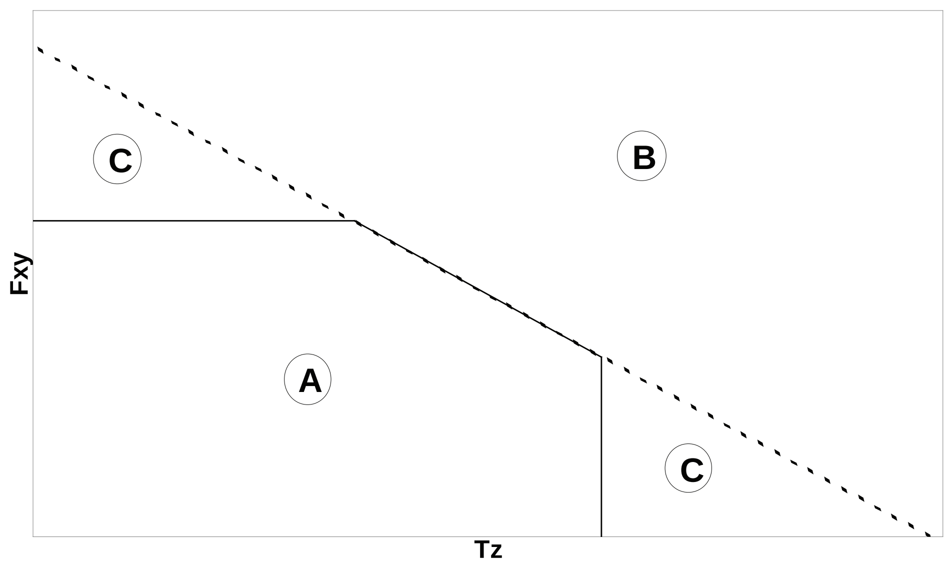
5.1.2 Complex Loading Graph Description

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



5.2 Nano17 Titanium

5.2.1 Nano17 Titanium Physical Properties

Table 4.1—Nano17 Titanium Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±35 lbf	±160 N
Fz	±70 lbf	±310 N
Txy	±8.9 inf-lb	±1 Nm
Tz	±10 inf-lb	±1.2 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	2.7×10^4 lb/in	4.8×10^6 N/m
Z-axis force (Kz)	3.8×10^4 lb/in	6.6×10^6 N/m
X-axis & Y-axis torque (Ktx, Kty)	1.2×10^3 lbf-in/rad	1.4×10^2 Nm/rad
Z-axis torque (Ktz)	2.0×10^3 lbf-in/rad	2.2×10^2 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	3000 Hz	3000 Hz
Fz, Tx, Ty	3000 Hz	3000 Hz
Physical Specifications		
Weight[1]	0.0223 lb	0.0101 kg
Diameter[1]	0.669 in	17 mm
Height[1]	0.571 in	14.5 mm

Note:
1. Specifications include standard interface plates.

5.2.2 Calibration Specifications (excludes CTL calibrations)

Table 4.2— Nano17 Titanium Calibrations (excludes CTL calibrations)[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Nano17 Titanium	US-1.8-0.4	1.8	3.15	0.4	0.4	1/3400	1/2720	7/92800	1/18560
Nano17 Titanium	US-3.6-0.8	3.6	6.3	0.8	0.8	1/1700	1/1360	7/46400	1/9280
Nano17 Titanium	US-7.2-1.6	7.2	12.6	1.6	1.6	1/850	1/680	7/23200	1/4640
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nmm)**	**Tz (Nmm)**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nmm)**	**Tz (Nmm)**
Nano17 Titanium	SI-8-0.05	8	14.1	50	50	1/682	1/682	3/364	5/728
Nano17 Titanium	SI-16-0.1	16	28.2	100	100	1/341	1/341	3/182	5/364
Nano17 Titanium	SI-32-0.2	32	56.4	200	200	1/171	1/171	3/92	5/184
		Sensing Ranges				**Resolution (DAQ, Net F/T)[3]**			

Notes:
1. These system resolutions quoted are the effective resolution after dropping eight counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. DAQ resolutions are typical for a 16-bit data acquisition system.

5.2.3 CTL Calibration Specifications

Table 4.3— Nano17 Titanium CTL Calibrations[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Nano17 Titanium	US-1.8-0.4	1.8	3.15	0.4	0.4	1/1700	1/1360	7/46400	1/9280
Nano17 Titanium	US-3.6-0.8	3.6	6.3	0.8	0.8	1/850	1/680	7/23200	1/4640
Nano17 Titanium	US-7.2-1.6	7.2	12.6	1.6	1.6	1/425	1/340	7/11600	1/2320
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nmm)**	**Tz (Nmm)**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nmm)**	**Tz (Nmm)**
Nano17 Titanium	SI-8-0.05	8	14.1	50	50	1/341	1/341	3/182	5/364
Nano17 Titanium	SI-16-0.1	16	28.2	100	100	2/341	2/341	3/91	5/182
Nano17 Titanium	SI-32-0.2	32	56.4	200	200	2/171	2/171	3/46	5/92
		Sensing Ranges				**Resolution (Controller)**			

Notes:

1. 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.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.

5.2.4 CTL Analog Output

Table 4.4— Nano17 Titanium Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Nano17 Titanium	US-1.8-0.4	±1.8	±3.15	±0.4	0.18	0.315	0.04
Nano17 Titanium	US-3.6-0.8	±3.6	±6.3	±0.8	0.36	0.63	0.08
Nano17 Titanium	US-7.2-1.6	±7.2	±12.6	±1.6	0.72	1.26	0.16
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty,Tz (Nmm)**	**Fx,Fy (N/V)**	**Fz (N/V)**	**Tx,Ty,Tz (Nmm/V)**
Nano17 Titanium	SI-8-0.05	±8	±14.1	±50	0.8	1.41	5
Nano17 Titanium	SI-16-0.1	±16	±28.2	±100	1.6	2.82	10
Nano17 Titanium	SI-32-0.2	±32	±56.4	±200	3.2	5.64	20
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

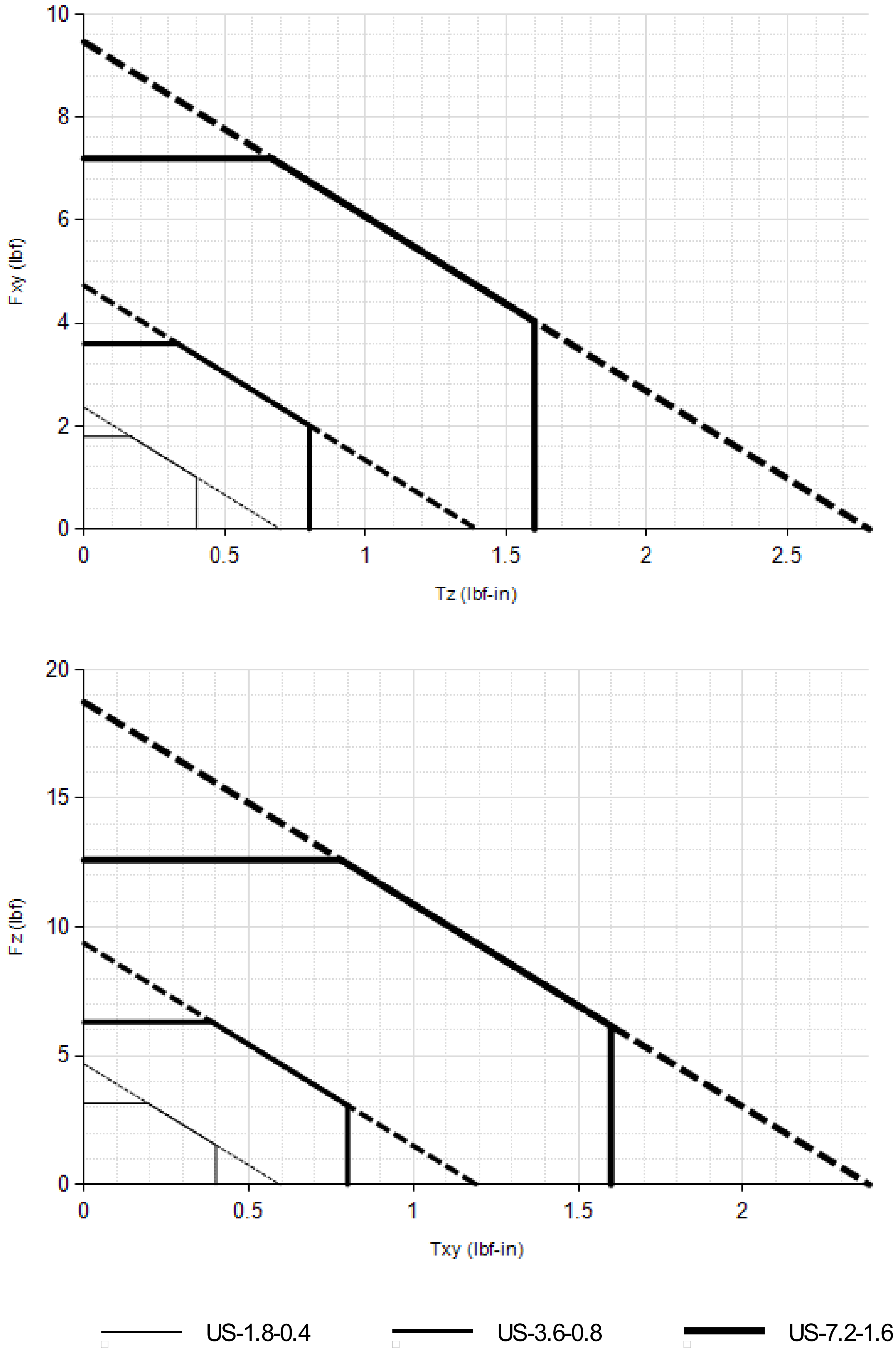
Notes:

1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.

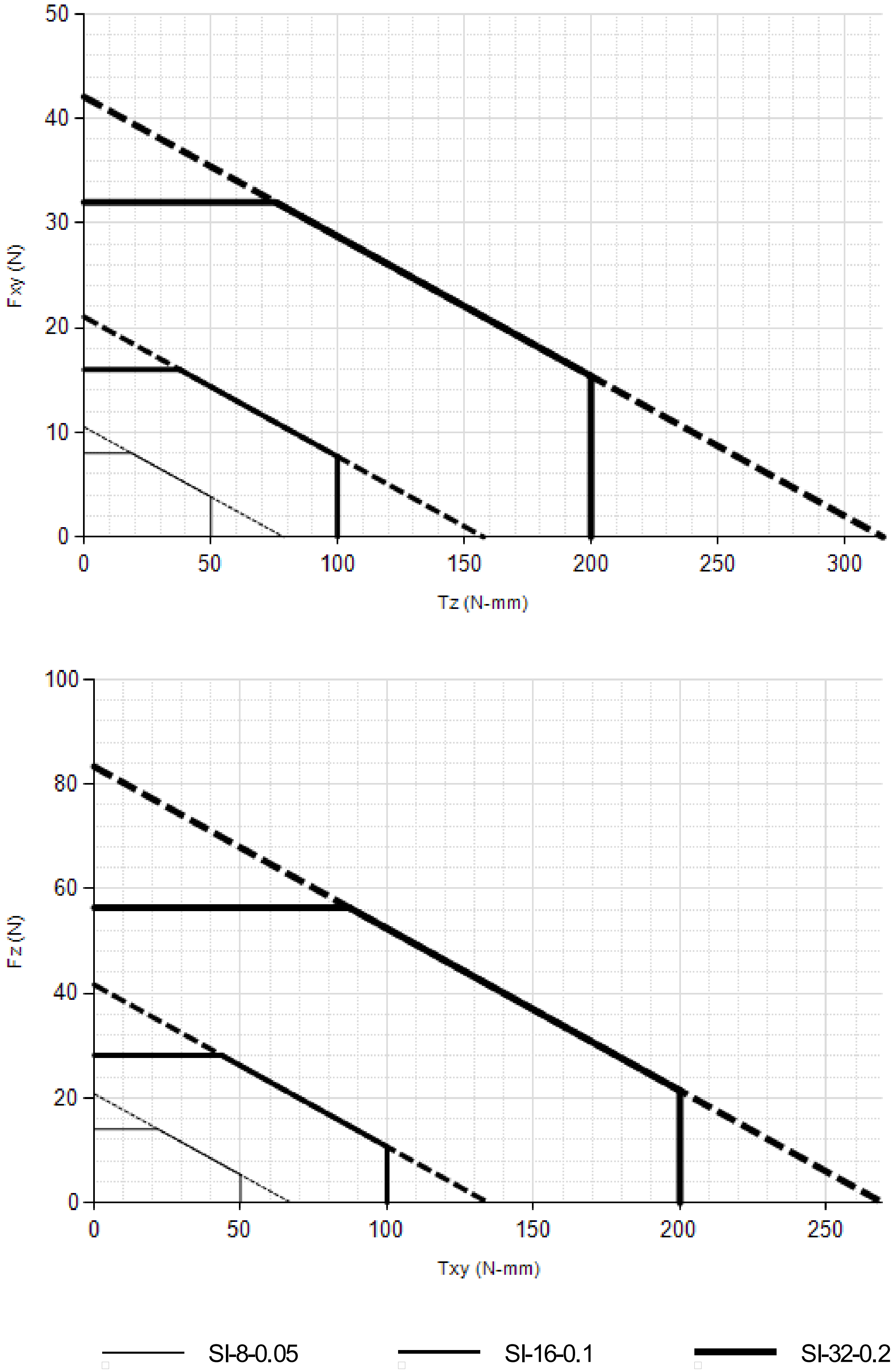
5.2.5 CTL Counts Value

Table 4.5—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ N)**	**Tx, Ty, Tz (/ Nmm)**
Nano17 Titanium	US-1.8–0.4 / SI-8–0.05	54400	371200	1280	256
Nano17 Titanium	US-3.6–0.8 / SI-16–0.1	27200	185600	640	128
Nano17 Titanium	US-7.2–1.6 / SI-32–0.2	13600	82800	320	64
Nano17 Titanium	Tool Transform Factor	0.0022 in/lbf		0.0375 mm/N	
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

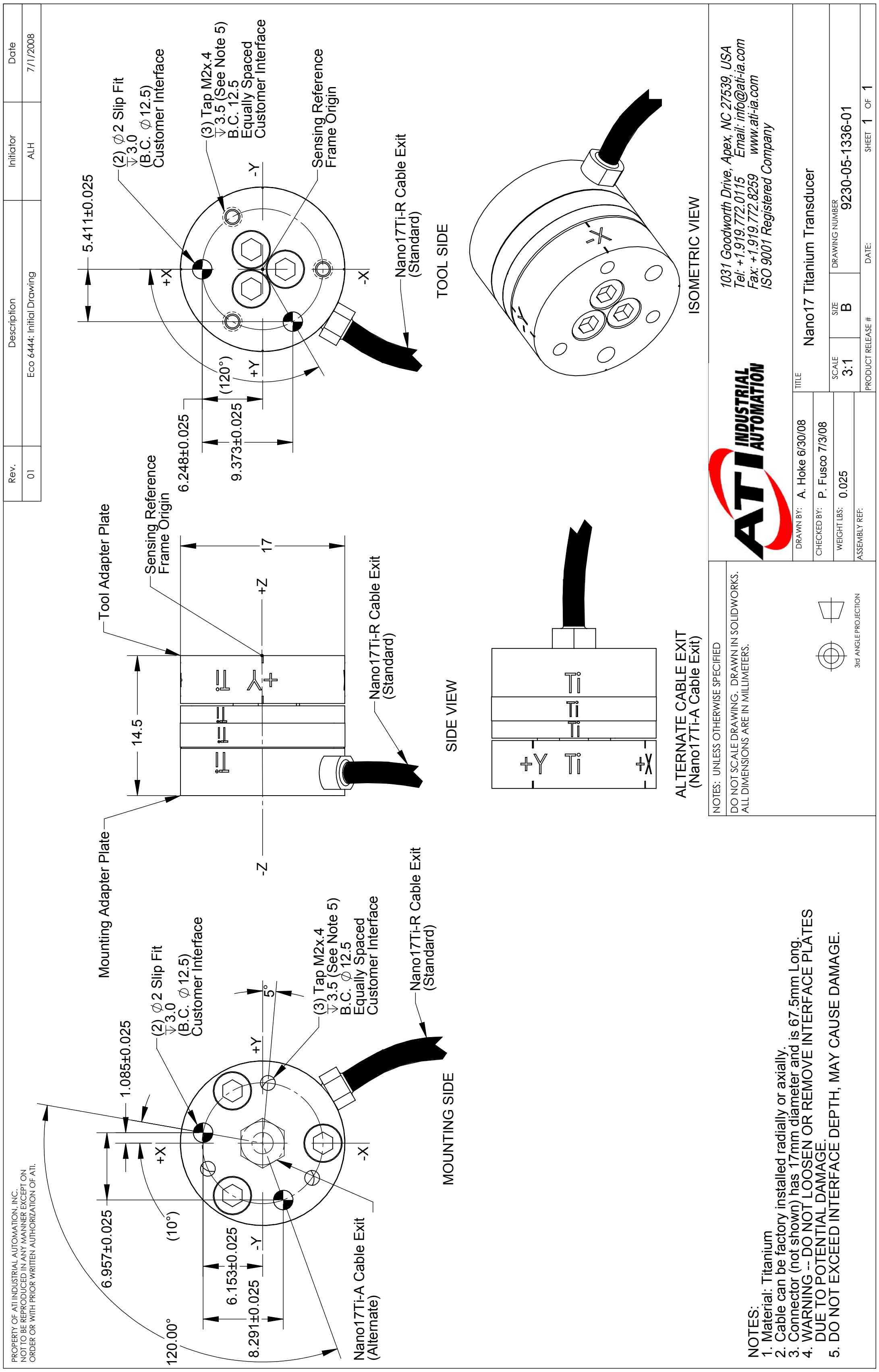
5.2.6 Nano17 Titanium (US Calibration Complex Loading)



5.2.7 Nano17 Titanium (SI Calibration Complex Loading)



5.2.8 Nano17 Titanium Transducer Drawing



5.3 Nano17 Specifications (Includes IP65/IP68 Versions)

5.3.1 Nano17 Physical Properties

Table 4.6—Nano17 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±56 lbf	±250 N
Fz	±110 lbf	±480 N
Txy	±14 inf-lb	±1.6 Nm
Tz	±16 inf-lb	±1.8 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	$4.7x10^{4}$ lb/in	$8.2x10^{6}$ N/m
Z-axis force (Kz)	$6.5x10^{4}$ lb/in	$1.1x10^{7}$ N/m
X-axis & Y-axis torque (Ktx, Kty)	$2.1x10^{3}$ lbf-in/rad	$2.4x10^{2}$ Nm/rad
Z-axis torque (Ktz)	$3.4x10^{3}$ lbf-in/rad	$3.8x10^{2}$ Nm/rad
Resonant Frequency		
Fx, Fy, Tz	7200 Hz	7200 Hz
Fz, Tx, Ty	7200 Hz	7200 Hz
Physical Specifications		
Weight[1]	0.02 lb	0.00907 kg
Diameter[1]	0.669 in	17 mm
Height[1]	0.571 in	14.5 mm
Note: 1. Specifications include standard interface plates.		

5.3.2 Nano17 IP65/IP68 Physical Properties

Table 4.7—Nano17 IP65/IP68 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±56 lbf	±250 N
Fz	±110 lbf	±480 N
Txy	±14 inf-lb	±1.6 Nm
Tz	±16 inf-lb	±1.8 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	$4.7x10^{4}$ lb/in	$8.2x10^{6}$ N/m
Z-axis force (Kz)	$6.5x10^{4}$ lb/in	$1.1x10^{7}$ N/m
X-axis & Y-axis torque (Ktx, Kty)	$2.1x10^{3}$ lbf-in/rad	$2.4x10^{2}$ Nm/rad
Z-axis torque (Ktz)	$3.4x10^{3}$ lbf-in/rad	$3.8x10^{2}$ Nm/rad
Resonant Frequency		
Fx, Fy, Tz	2200 Hz	2200 Hz
Fz, Tx, Ty	2200 Hz	2200 Hz
Physical Specifications		
Weight[1]	0.09 lb	0.0408 kg
Diameter[1]	0.79 in	20.1 mm
Height[1]	0.873 in	22.2 mm
Note: 1. Specifications include standard interface plates.		

CAUTION: 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.		
Submersion Depth		
IP68 Nano17	**US**	**Metric**
Fz preload at 4 m depth	2.01 lb	8.93 N
Fz preload at other depths	-0.15 lb/ft × depth In Feet	-2.23 N/m × depth In Meters

5.3.3 Calibration Specifications (excludes CTL calibrations)

Table 4.8— Nano17 Calibrations (excludes CTL calibrations)[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Nano17	US-3-1	3	4.25	1	1	1/1280	1/1280	1/8000	1/8000
Nano17	US-6-2	6	8.5	2	2	1/640	1/640	1/4000	1/4000
Nano17	US-12-4	12	17	4	4	1/320	1/320	1/2000	1/2000
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nmm)**	**Tz (Nmm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nmm)**	**Tz (Nmm)**
Nano17	SI-12-0.12	12	17	120	120	1/320	1/320	1/64	1/64
Nano17	SI-25-0.25	25	35	250	250	1/160	1/160	1/32	1/32
Nano17	SI-50-0.5	50	70	500	500	1/80	1/80	1/16	1/16
		Sensing Ranges				**Resolution (DAQ, Net F/T)[4]**			

Notes:

1. These system resolutions quoted are the effective resolution after dropping eight counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.
4. DAQ resolutions are typical for a 16-bit data acquisition system.

5.3.4 CTL Calibration Specifications

Table 4.9— Nano17 CTL Calibrations[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Nano17	US-3-1	3	4.25	1	1	1/640	1/640	1/4000	1/4000
Nano17	US-6-2	6	8.5	2	2	1/320	1/320	1/2000	1/2000
Nano17	US-12-4	12	17	4	4	1/160	1/160	1/1000	1/1000
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nmm)**	**Tz (Nmm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nmm)**	**Tz (Nmm)**
Nano17	SI-12-0.12	12	17	120	120	1/160	1/160	1/32	1/32
Nano17	SI-25-0.25	25	35	250	250	1/80	1/80	1/16	1/16
Nano17	SI-50-0.5	50	70	500	500	1/40	1/40	1/8	1/8
		Sensing Ranges				**Resolution (Controller)**			

Notes:
1. 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.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.

5.3.5 CTL Analog Output

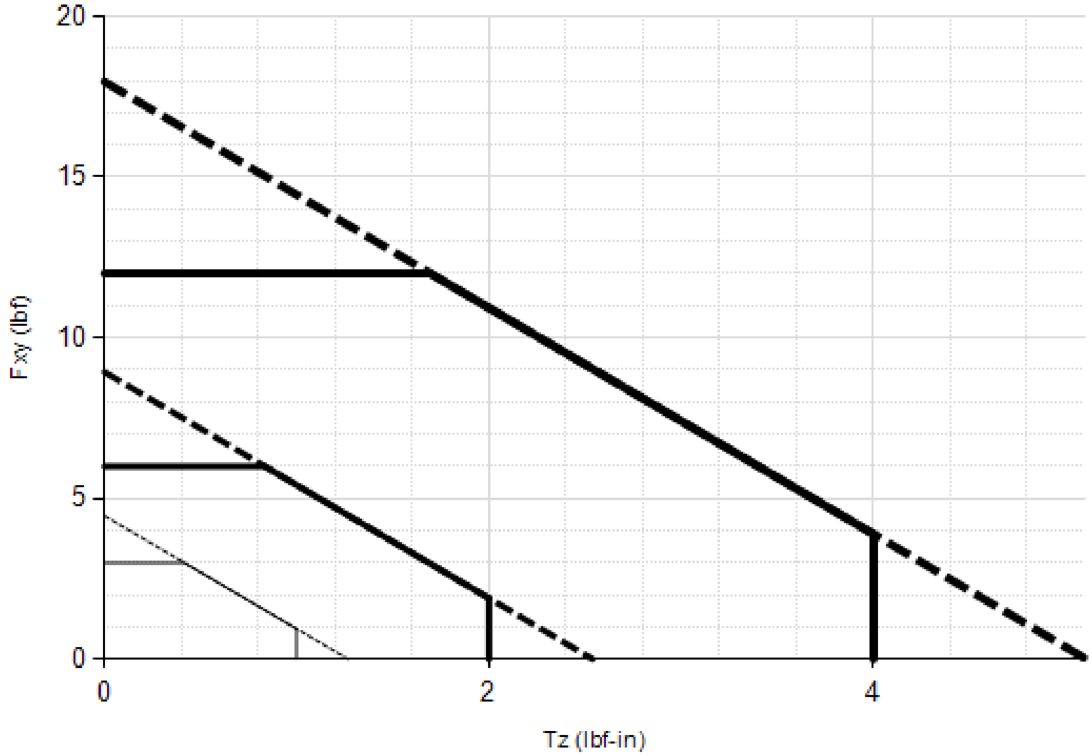
Table 4.10— Nano17 Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[2] (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz[2] (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Nano17	US-3-1	±3	±4.25	±1	0.3	0.425	0.1
Nano17	US-6-2	±6	±8.5	±2	0.6	0.85	0.2
Nano17	US-12-4	±12	±17	±4	1.2	1.7	0.4
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[2] (N)**	**Tx,Ty,Tz (Nmm)**	**Fx,Fy (N/V)**	**Fz[2] (N/V)**	**Tx,Ty,Tz (Nmm/V)**
Nano17	SI-12-0.12	±12	±17	±120	1.2	1.7	12
Nano17	SI-25-0.25	±25	±35	±250	2.5	3.5	25
Nano17	SI-50-0.5	±50	±70	±500	5	7	50
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

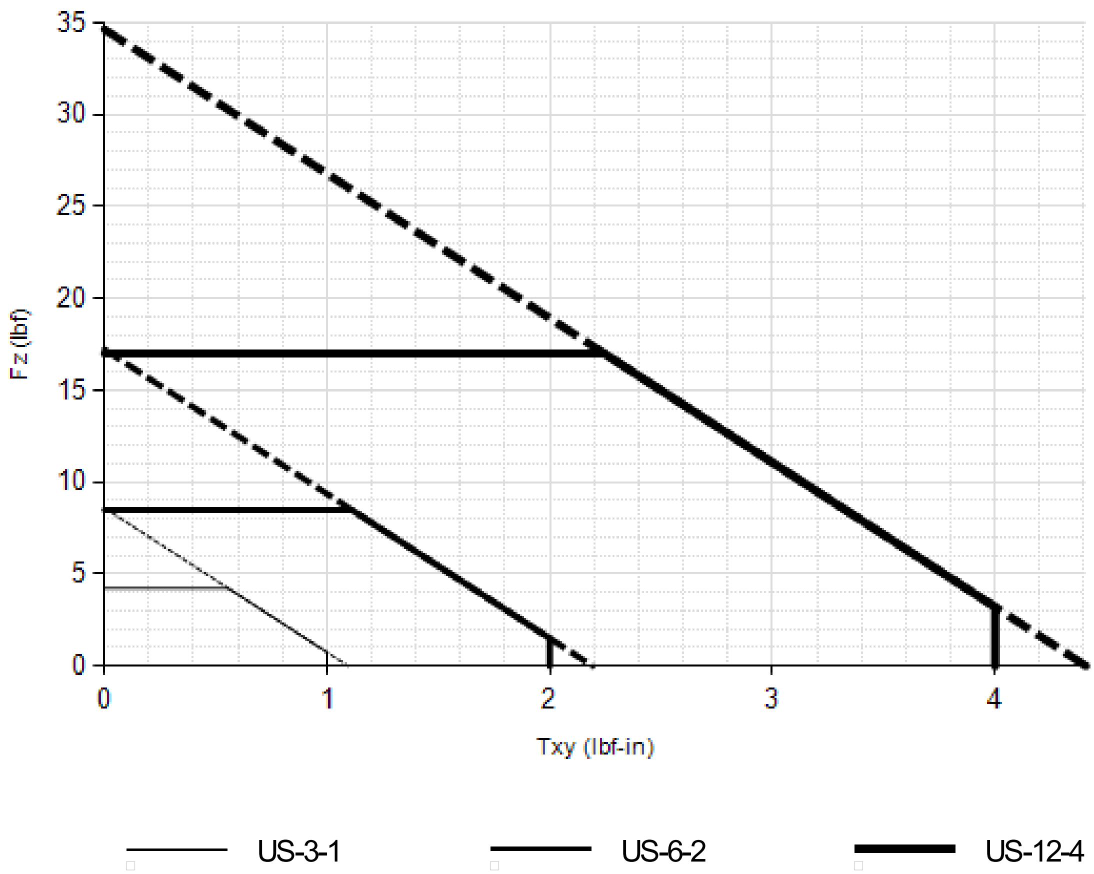
Notes:
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.
2. For IP68 version see caution on physical properties page.

5.3.6 CTL Counts Value

Table 4.11—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ N)**	**Tx, Ty, Tz (/ Nmm)**
Nano17	US-3–1 / SI-12–0.25	5120	32000	1280	256
Nano17	US-6–2 / SI-25–0.25	2560	16000	640	128
Nano17	US-12–4 / SI-50–0.5	1280	8000	320	64
Nano17	Tool Transform Factor	0.0016 in/lbf		0.05 mm/N	
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

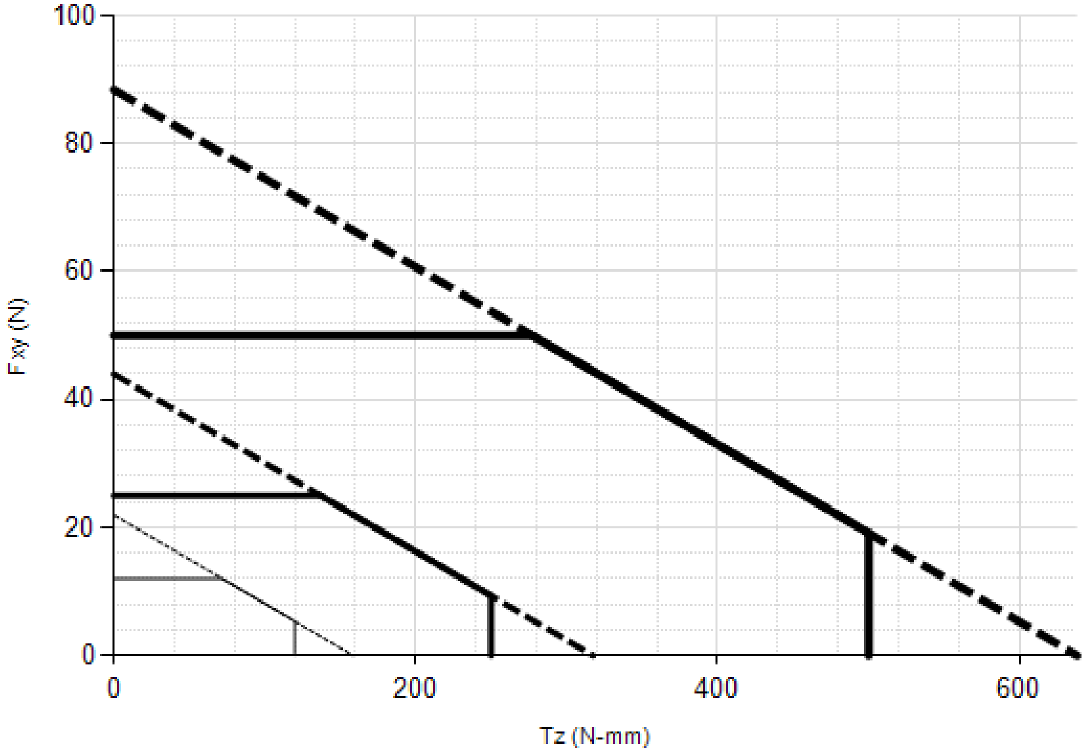
5.3.7 Nano17 (US Calibration Complex Loading)(Includes IP65/IP68)[1]

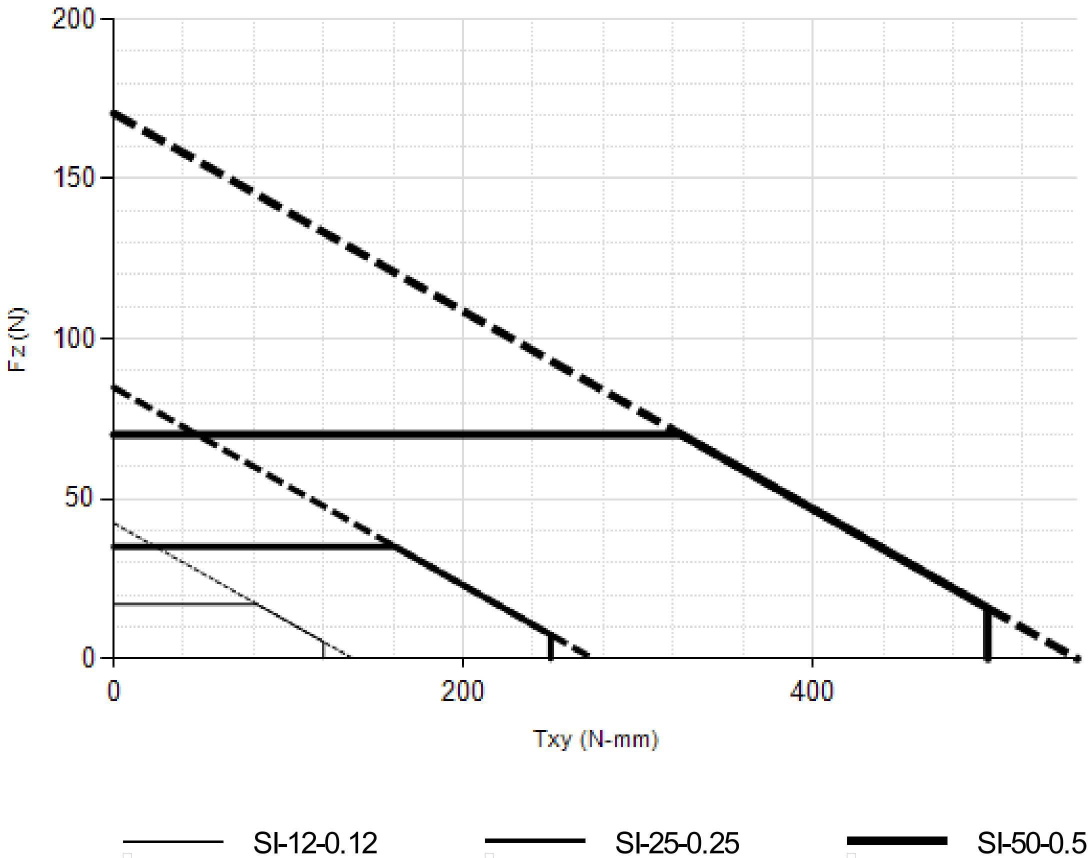




Note: 1. For IP68 version see caution on physical properties page.

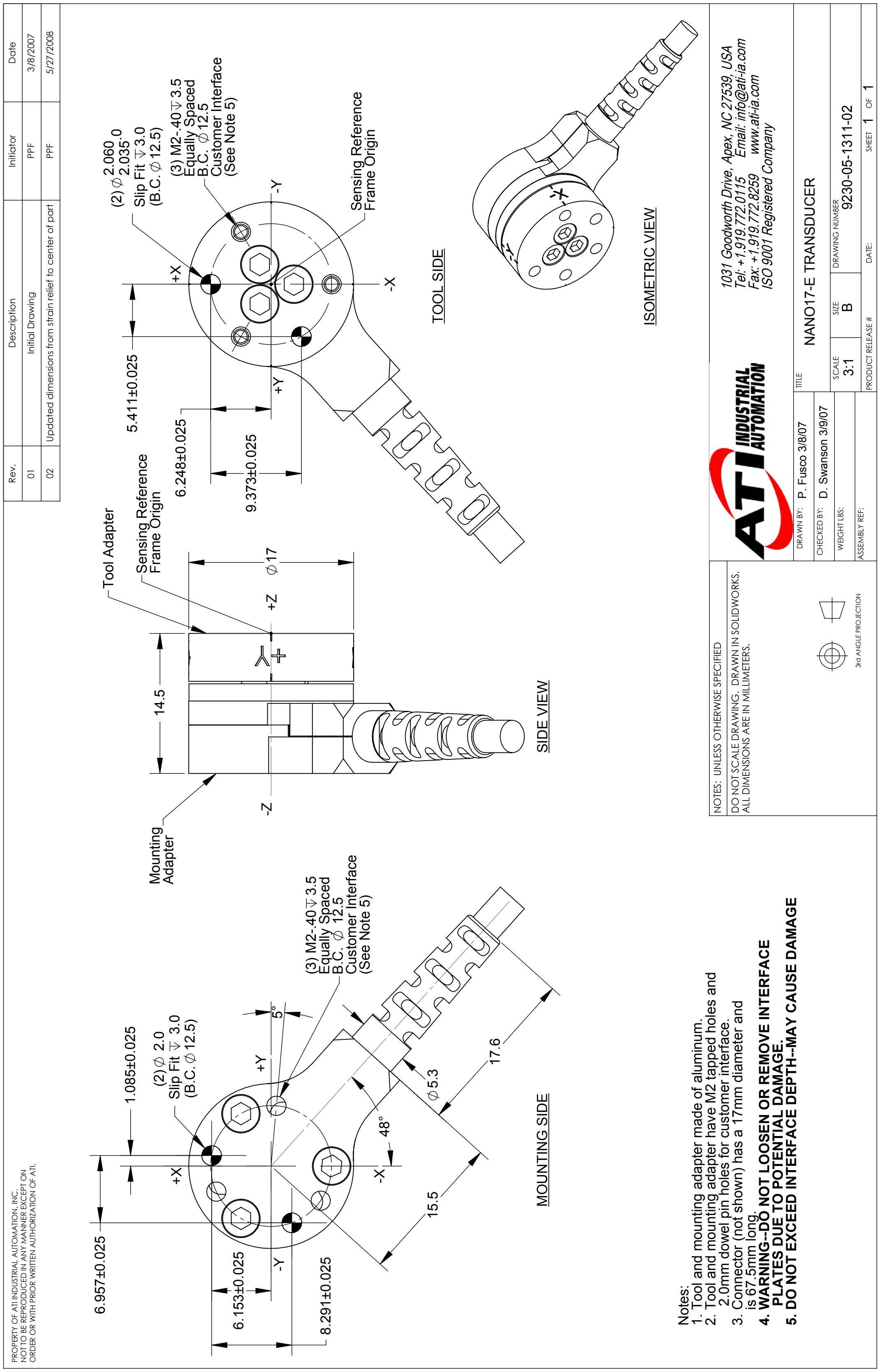
5.3.8 Nano17 (SI Calibration Complex Loading)(Includes IP65/IP68)[1]



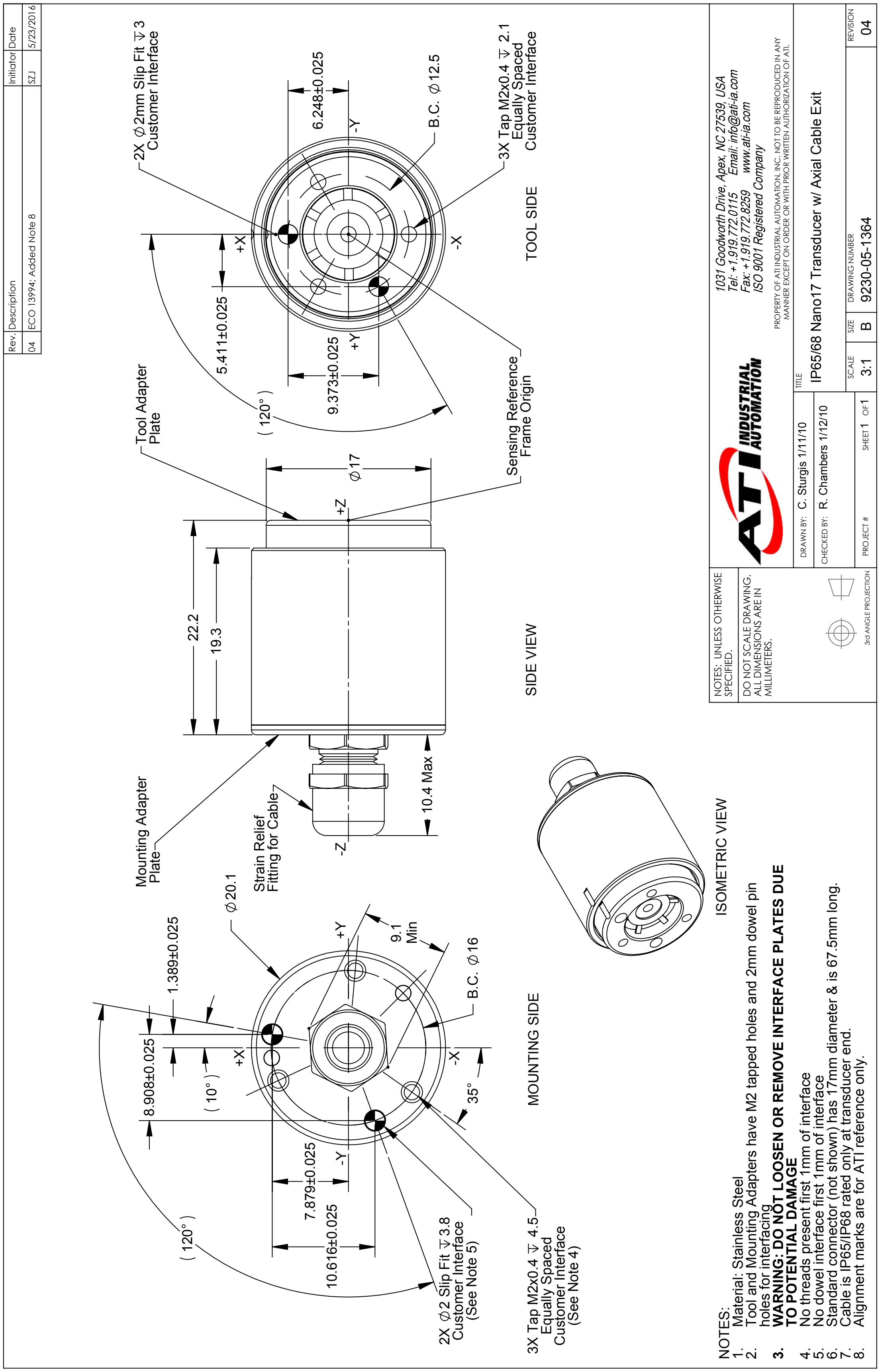


Note: 1. For IP68 version see caution on physical properties page.

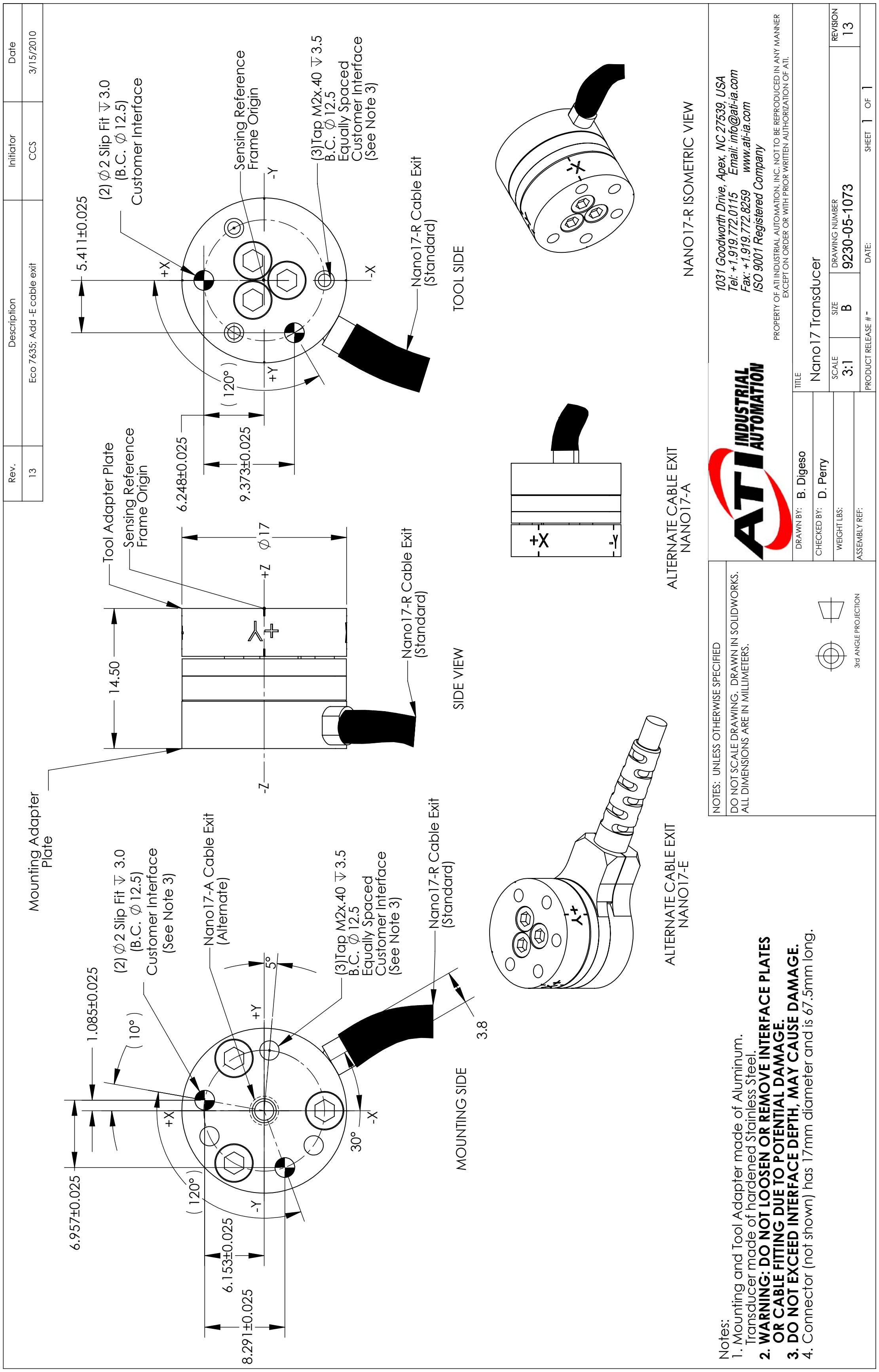
5.3.9 Nano17-E Transducer Drawing



5.3.10 Nano17 IP65/IP68 Transducer with Axial Cable Exit Drawing



5.3.11 Legacy Nano17 Transducer Drawing



5.4 Nano25 Specifications (Includes IP65/IP68 Versions)

5.4.1 Nano25 Physical Properties

Table 4.12—Nano25 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±520 lbf	±2300 N
Fz	±1600 lbf	±7300 N
Txy	±380 inf-lb	±43 Nm
Tz	±560 inf-lb	±63 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	3.0×10^5 lb/in	5.3×10^7 N/m
Z-axis force (Kz)	6.3×10^5 lb/in	1.1×10^8 N/m
X-axis & Y-axis torque (Ktx, Kty)	5.7×10^4 lbf-in/rad	6.5×10^3 Nm/rad
Z-axis torque (Ktz)	8.1×10^4 lbf-in/rad	9.2×10^3 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	3600 Hz	3600 Hz
Fz, Tx, Ty	3800 Hz	3800 Hz
Physical Specifications		
Weight[1]	0.14 lb	0.0634 kg
Diameter[1]	0.984 in	25 mm
Height[1]	0.85 in	21.6 mm

Note:
1. Specifications include standard interface plates.

5.4.2 Nano25 IP65/IP68 Physical Properties

Table 4.13—Nano25 IP65/IP68 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±520 lbf	±2300 N
Fz	±1600 lbf	±7300 N
Txy	±380 inf-lb	±43 Nm
Tz	±560 inf-lb	±63 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	3.0×10^5 lb/in	5.3×10^7 N/m
Z-axis force (Kz)	6.3×10^5 lb/in	1.1×10^8 N/m
X-axis & Y-axis torque (Ktx, Kty)	5.7×10^4 lbf-in/rad	6.5×10^3 Nm/rad
Z-axis torque (Ktz)	8.1×10^4 lbf-in/rad	9.2×10^3 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	3400 Hz	3400 Hz
Fz, Tx, Ty	3500 Hz	3500 Hz
Physical Specifications		
Weight[1]	0.3 lb	0.136 kg
Diameter[1]	1.1 in	28 mm
Height[1]	1.08 in	27.5 mm

Note:
1. Specifications include standard interface plates.

CAUTION: 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.

Submersion Depth		
IP68 Nano17	**US**	**Metric**
Fz preload at 4 m depth	4.33 lb	19.3 N
Fz preload at other depths	-0.33 lb/ft × depthInFeet	-4.81 N/m × depthInMeters

NOTICE: 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.

5.4.3 Calibration Specifications (excludes CTL calibrations)

Table 4.14— Nano25 Calibrations (excludes CTL calibrations)[1, 2, 4]

Sensor	(US) Standard Calibration	Fx,Fy (lbf)	Fz[3] (lbf)	Tx,Ty (lbf-in)	Tz (lbf-in)	Fx,Fy (lbf)	Fz[3] (lbf)	Tx,Ty (lbf-in)	Tz (lbf-in)
Nano25	US-25-25	25	100	25	25	1/224	3/224	1/160	1/320
Nano25	US-50-50	50	200	50	30	1/112	3/112	1/80	1/160
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Nano25	SI-125-3	125	500	3	3	1/48	1/16	1/1320	1/2640
Nano25	SI-250-6	250	1000	6	3.4	1/24	1/8	1/660	1/1320
		Sensing Ranges				**Resolution (DAQ, Net F/T)[5]**			

Notes:

1. These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.
4. 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).
5. DAQ resolutions are typical for a 16-bit data acquisition system.

5.4.4 CTL Calibration Specifications

Table 4.15— Nano25 CTL Calibrations[1, 2, 4]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Nano25	US-25-25	25	100	25	25	1/112	3/112	1/80	1/160
Nano25	US-50-50	50	200	50	30	1/56	3/56	1/40	1/80
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Nano25	SI-125-3	125	500	3	3	1/24	1/8	1/660	1/1320
Nano25	SI-250-6	250	1000	6	3.4	1/12	1/4	1/330	1/660
		Sensing Ranges				**Resolution (Controller)**			

Notes:

1. 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.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.
4. 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).

5.4.5 CTL Analog Output

Table 4.16— Nano25 Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[2] (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz[2] (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Nano25	US-25-25	±25	±100	±25	2.5	10	2.5
Nano25	US-50-50	±50	±200	±50	5	20	5
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[2] (N)**	**Tx,Ty,Tz (Nmm)**	**Fx,Fy (N/V)**	**Fz[2] (N/V)**	**Tx,Ty,Tz (Nm/V)**
Nano25	SI-125-3	±125	±500	±3	12.5	50	0.3
Nano25	SI-250-6	±250	±1000	±6	25	100	0.6
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

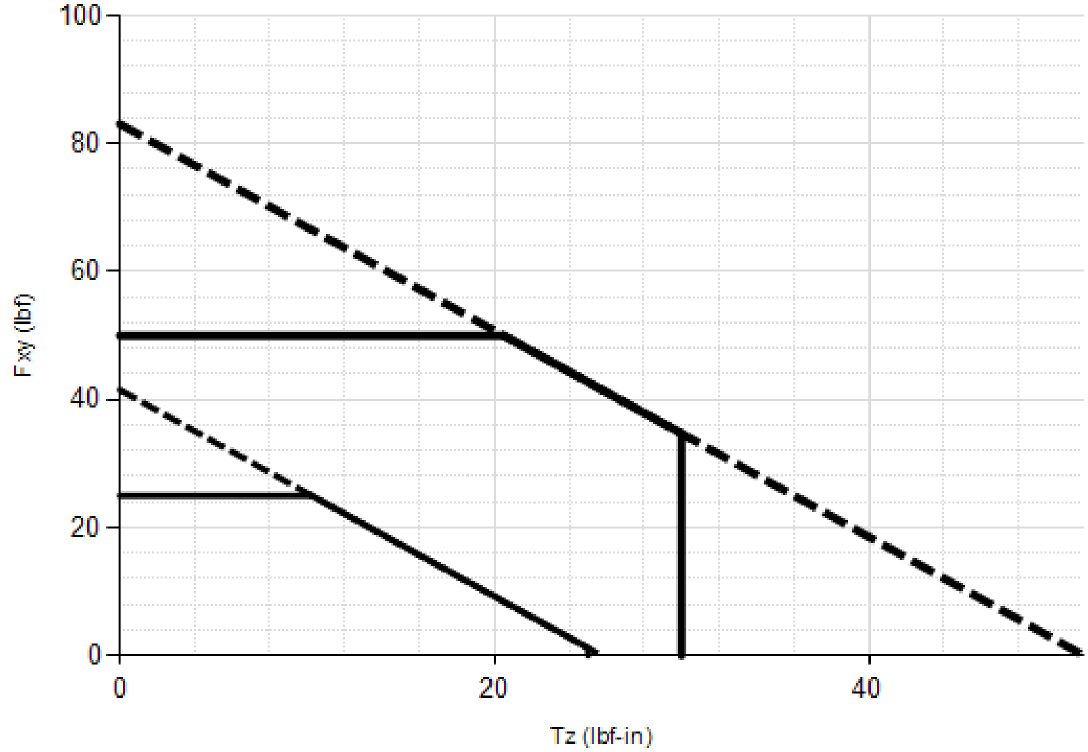
Notes:

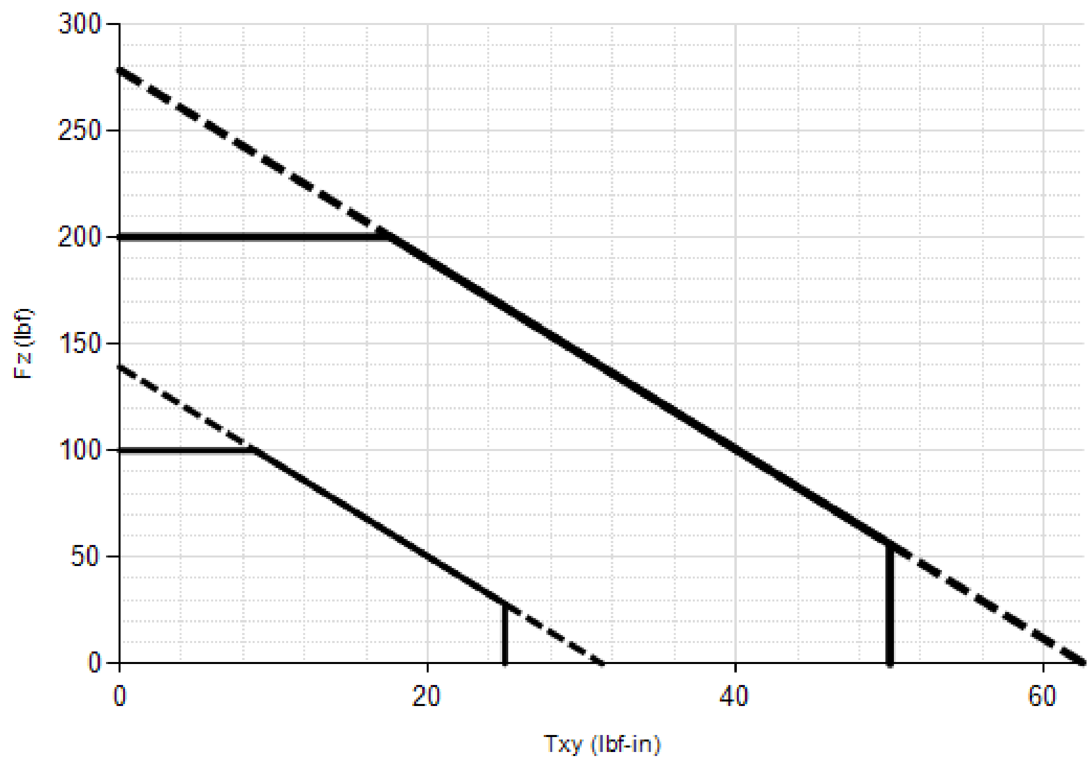
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.
2. For IP68 version see caution on physical properties page.

5.4.6 CTL Counts Value

Table 4.17—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz**	**Tx, Ty, Tz**
Nano25	US-25–25 / SI-125–3	896	1280	192 / N	10560 / N
Nano25	US-50–50 / SI-250–6	448	640	96 / Nm	5280 / Nm
Nano25	Tool Transform Factor	0.007 in/lbf		0.18182 mm/N	
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

5.4.7 Nano25 (US Calibration Complex Loading)(Includes IP65/IP68)[1]

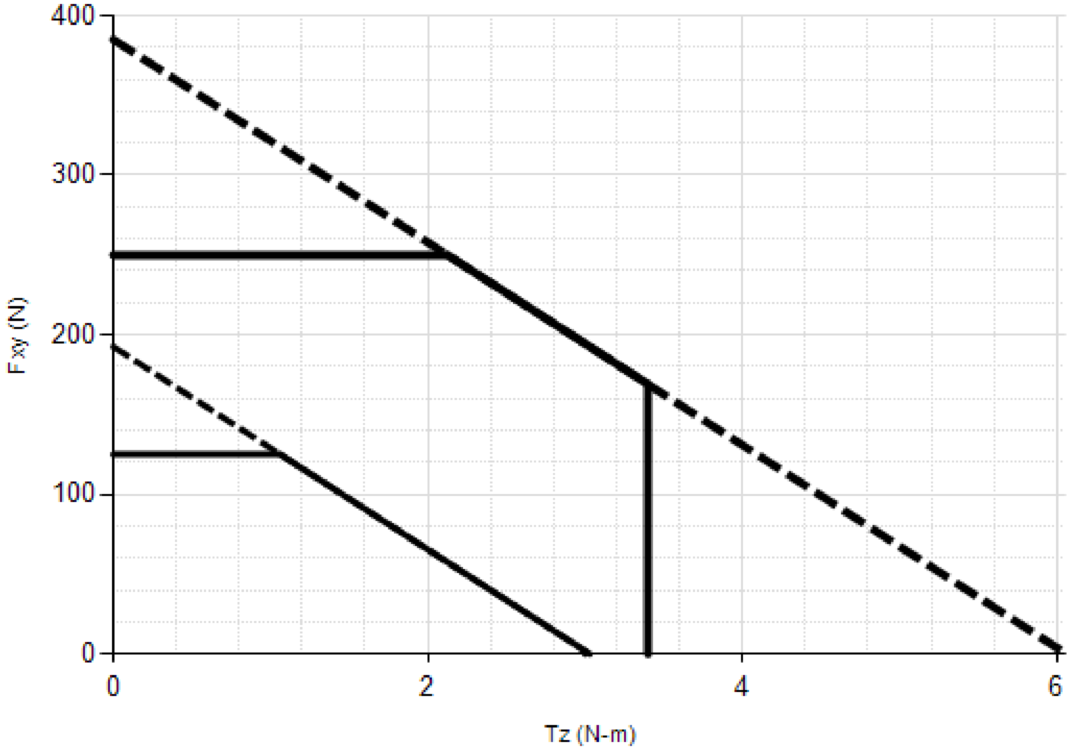


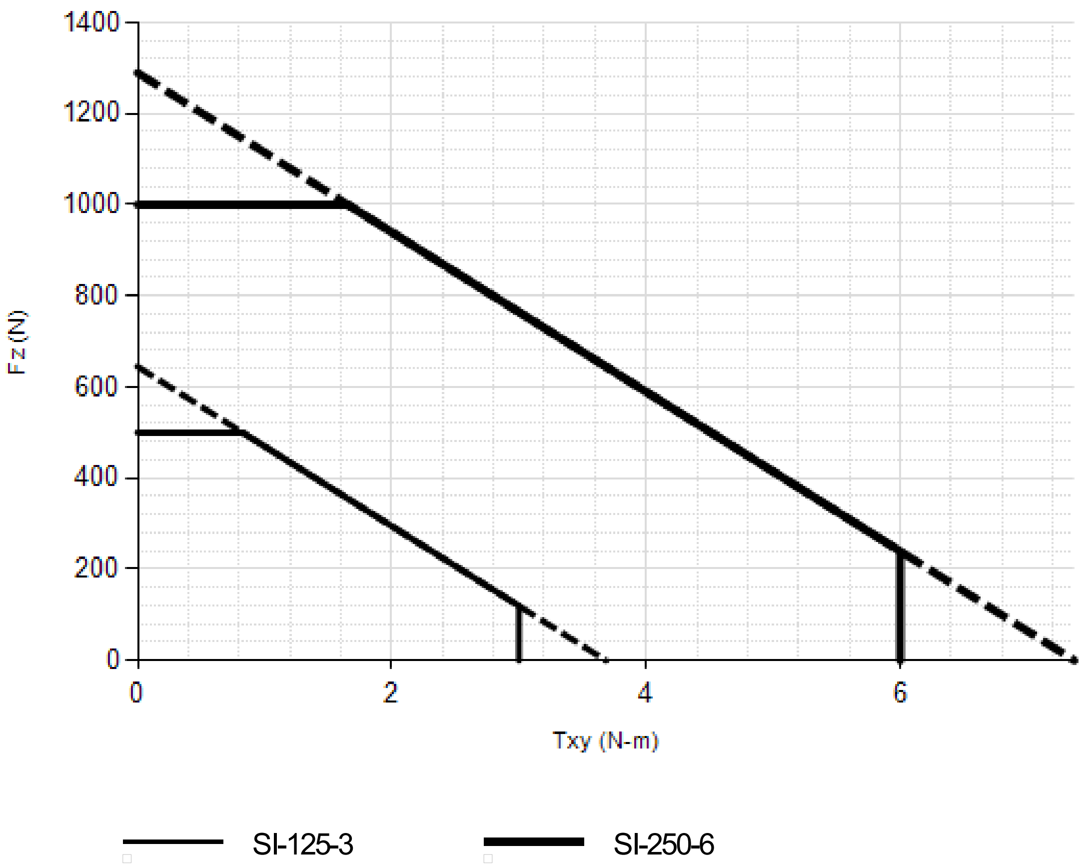


US-25-25 US-50-50

Note: 1. For IP68 version see caution on physical properties page.

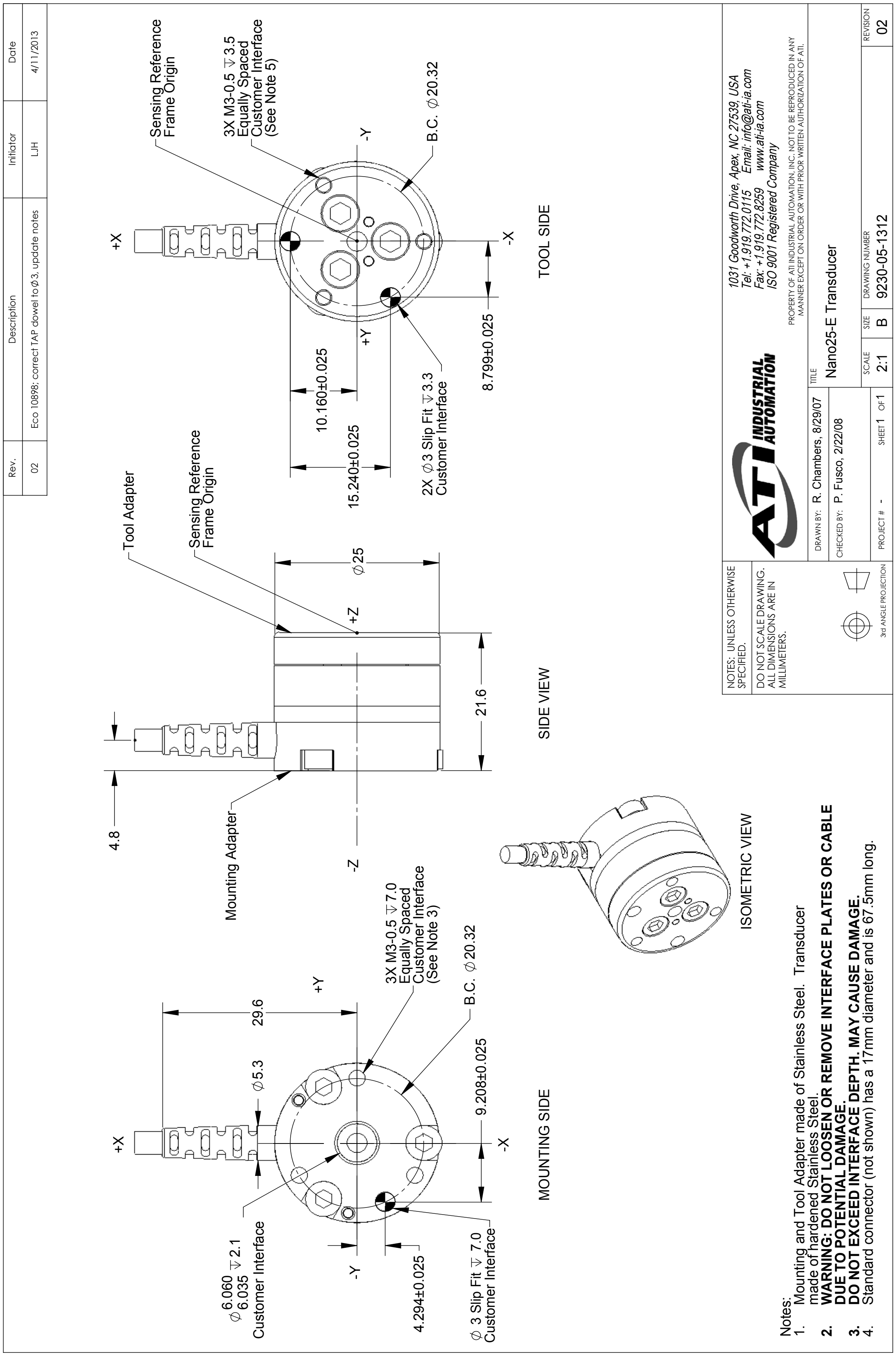
5.4.8 Nano25 (SI Calibration Complex Loading)(Includes IP65/IP68)[1]



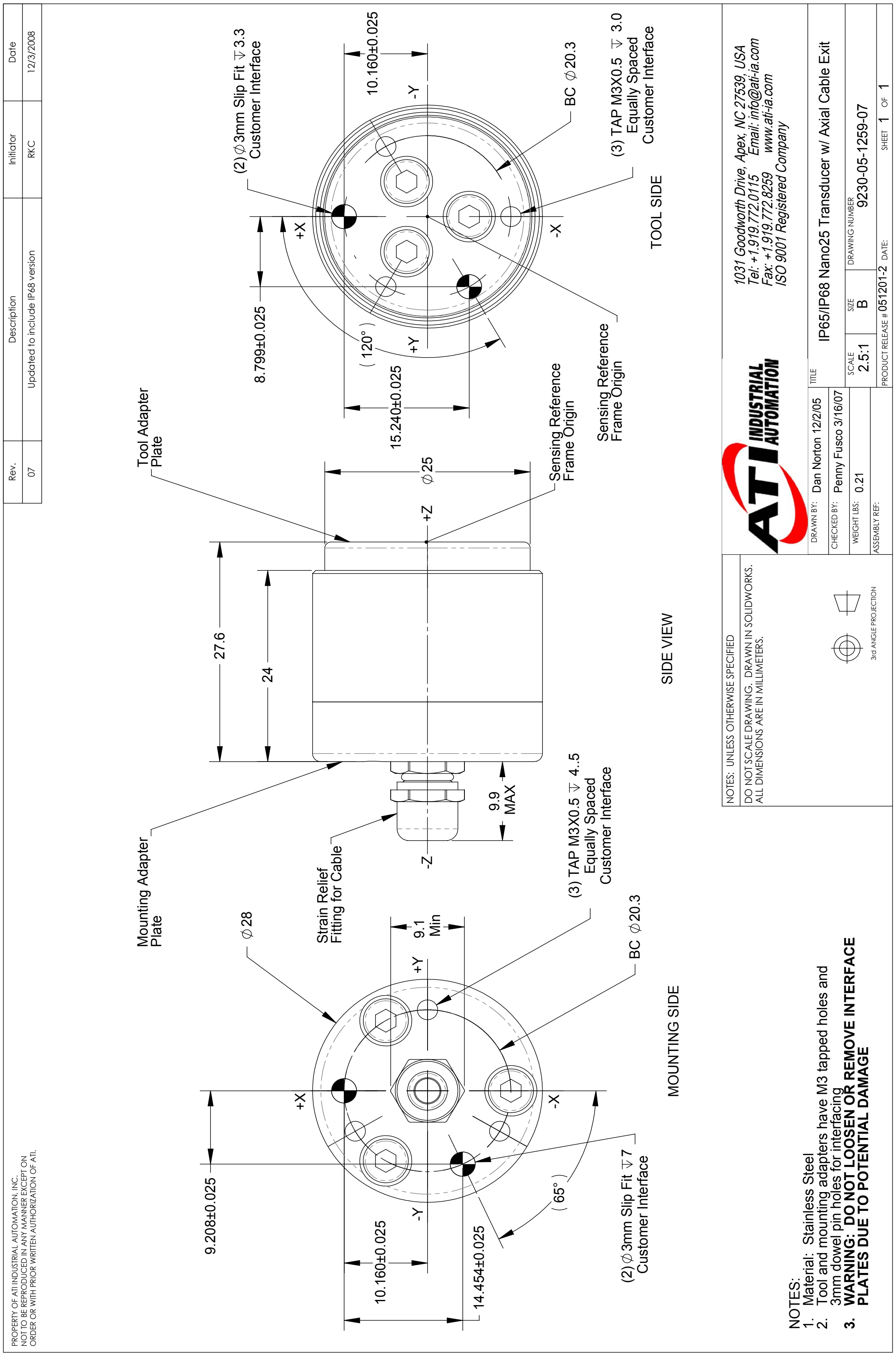


Note: 1. For IP68 version see caution on physical properties page.

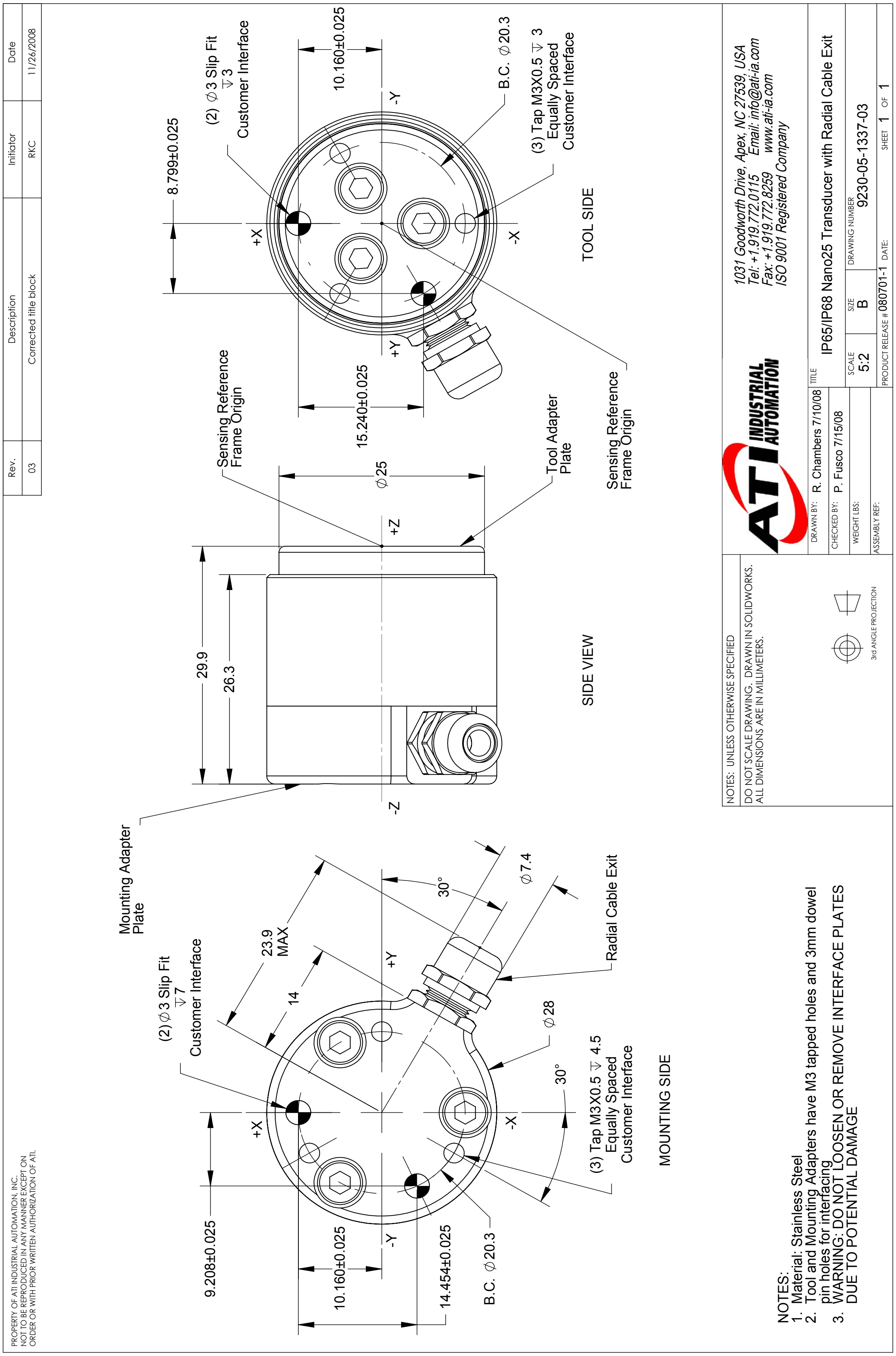
5.4.9 Nano25-E Transducer Drawing



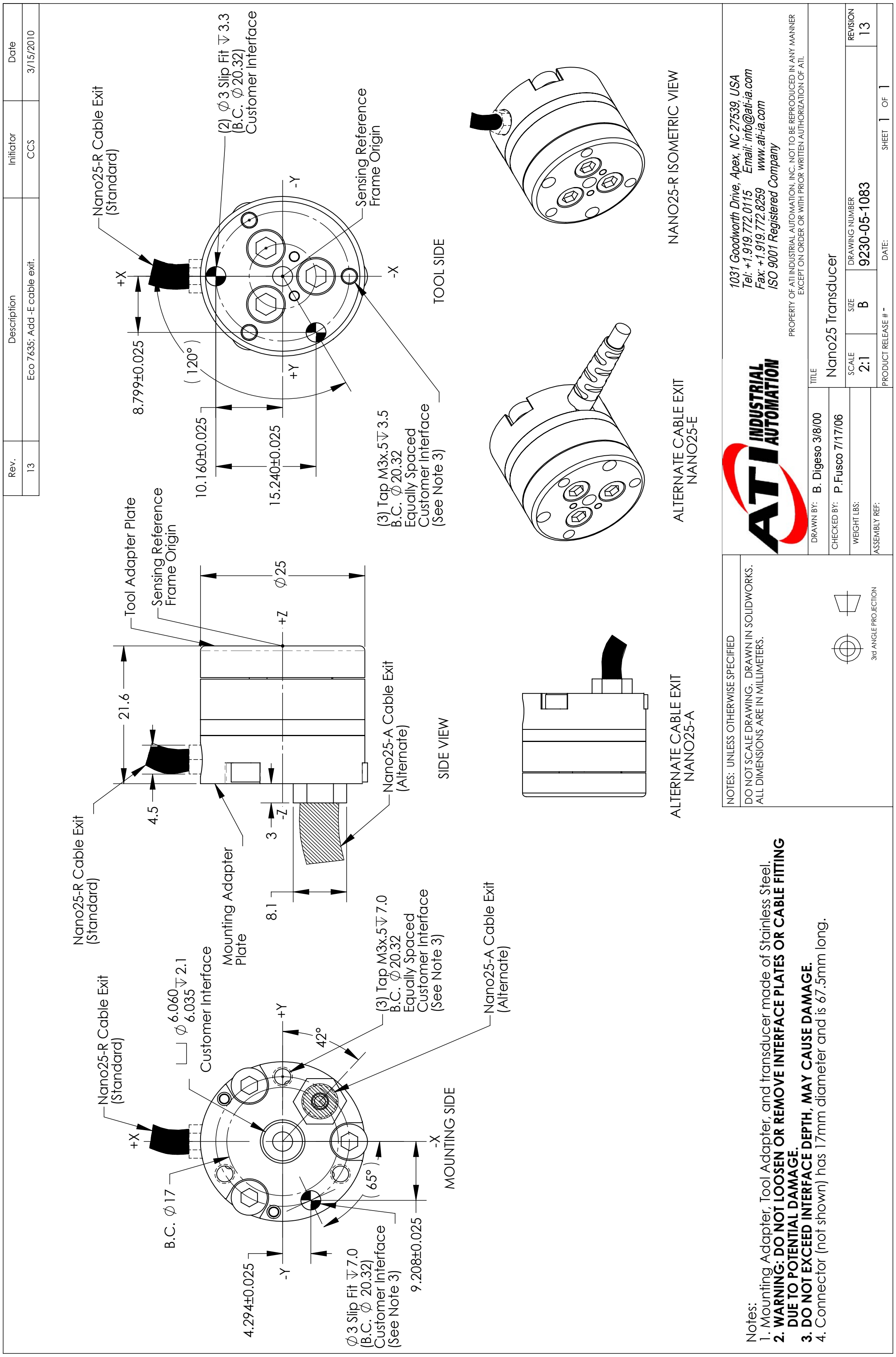
5.4.10 Nano25 IP65/IP68 Transducer with Axial Cable Exit Drawing



5.4.11 Nano25 IP65/IP68 Transducer with Radial Cable Exit Drawing



5.4.12 Legacy Nano25 Transducer Drawing



5.5 Nano43 Specifications

5.5.1 Nano43 Physical Properties

Table 4.18—Nano43 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±68 lbf	±300 N
Fz	±86 lbf	±380 N
Txy	±29 inf-lb	±3.2 Nm
Tz	±41 inf-lb	±4.6 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	2.9×10^4 lb/in	5.2×10^6 N/m
Z-axis force (Kz)	2.9×10^4 lb/in	5.2×10^6 N/m
X-axis & Y-axis torque (Ktx, Kty)	6.8×10^3 lbf-in/rad	7.7×10^2 Nm/rad
Z-axis torque (Ktz)	1.0×10^4 lbf-in/rad	1.1×10^3 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	2800 Hz	2800 Hz
Fz, Tx, Ty	2300 Hz	2300 Hz
Physical Specifications		
Weight[1]	0.0854 lb	0.0387 kg
Diameter[1]	1.69 in	43 mm
Height[1]	0.454 in	11.5 mm

Note:
1. Specifications include standard interface plates.

NOTICE: 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.

5.5.2 Calibration Specifications (excludes CTL calibrations)

Table 4.19— Nano43 Calibrations (excludes CTL calibrations)[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Nano43	US-2-1	2	2	1	1	1/2320	1/2320	1/4640	1/4640
Nano43	US-4-2	4	4	2	2	1/1160	1/1160	1/2320	1/2320
Nano43	US-8-4	8	8	4	4	1/580	1/580	1/1160	1/1160
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nmm)**	**Tz (Nmm)**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nmm)**	**Tz (Nmm)**
Nano43	SI-9-0.125	9	9	125	125	1/512	1/512	1/40	1/40
Nano43	SI-18-0.25	18	18	250	250	1/256	1/256	1/20	1/20
Nano43	SI-36-0.5	36	36	500	500	1/128	1/128	1/10	1/10
		Sensing Ranges				**Resolution (DAQ, Net F/T)[3]**			

Notes:
1. These system resolutions quoted are the effective resolution after dropping eight counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. DAQ resolutions are typical for a 16-bit data acquisition system.

5.5.3 CTL Calibration Specifications

Table 4.20— Nano43 CTL Calibrations[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Nano43	US-2-1	2	2	1	1	1/1160	1/1160	1/2320	1/2320
Nano43	US-4-2	4	4	2	2	1/580	1/580	1/1160	1/1160
Nano43	US-8-4	8	8	4	4	1/290	1/290	1/580	1/580
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nmm)**	**Tz (Nmm)**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nmm)**	**Tz (Nmm)**
Nano43	SI-9-0.125	9	9	125	125	1/256	1/256	1/20	1/20
Nano43	SI-18-0.25	18	18	250	250	1/128	1/128	1/10	1/10
Nano43	SI-36-0.5	36	36	500	500	1/64	1/64	1/5	1/5
		Sensing Ranges				**Resolution (Controller)**			

Notes:
1. 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.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.

5.5.4 CTL Analog Output

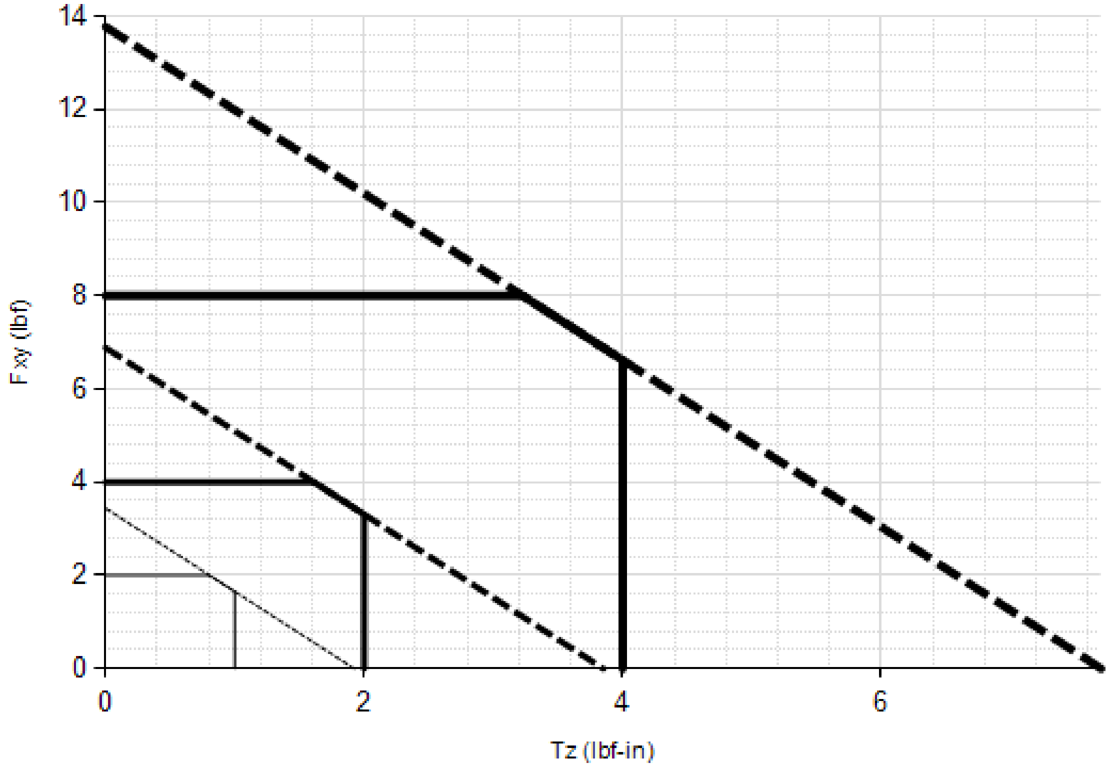
Table 4.21— Nano43 Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Nano43	US-2-1	N/A	N/A	N/A	N/A	N/A	N/A
Nano43	US-4-2	±4	±4	±2	0.4	0.4	0.2
Nano43	US-8-4	±8	±8	±4	0.8	0.8	0.4
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty,Tz (Nmm)**	**Fx,Fy (N/V)**	**Fz (N/V)**	**Tx,Ty,Tz (Nm/V)**
Nano43	SI-9-0.125	N/A	N/A	N/A	N/A	N/A	N/A
Nano43	SI-18-0.25	±18	±18	±250	1.8	1.8	25
Nano43	SI-36-0.5	±36	±36	±500	3.6	3.6	50
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

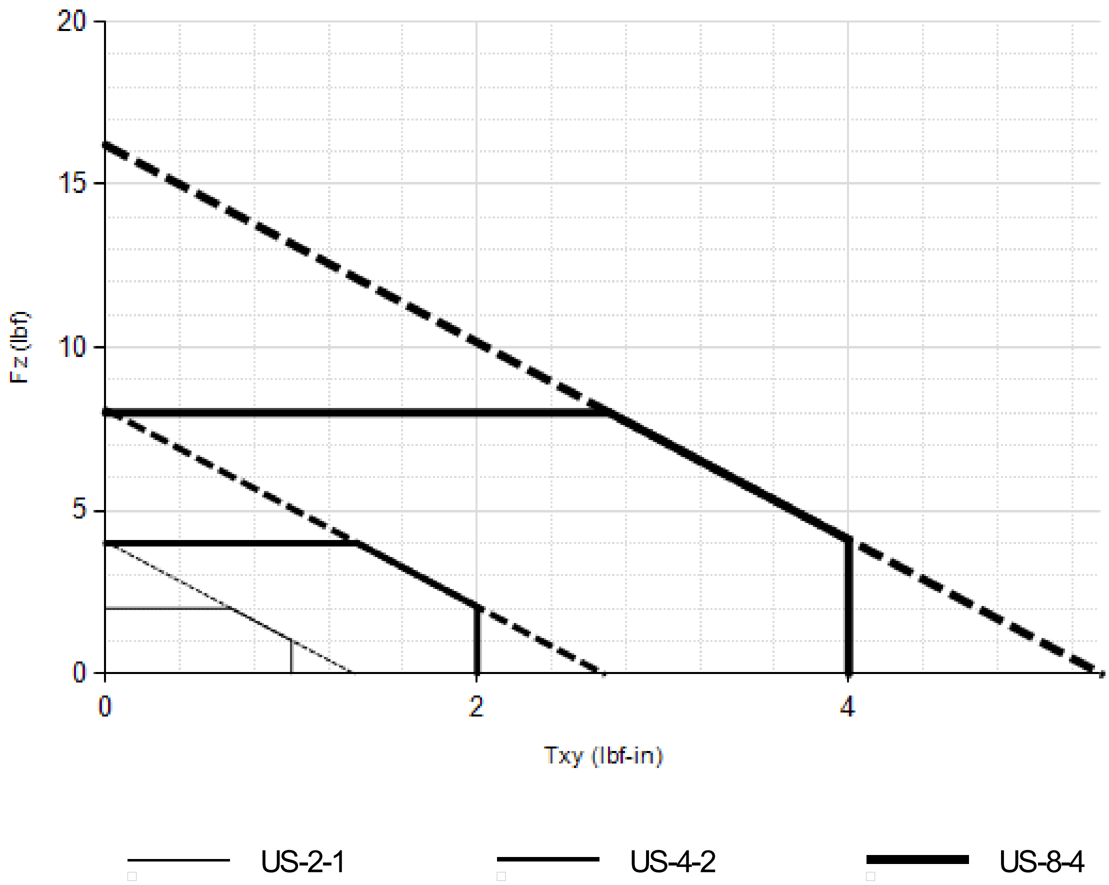
Notes:
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.

5.5.5 CTL Counts Value

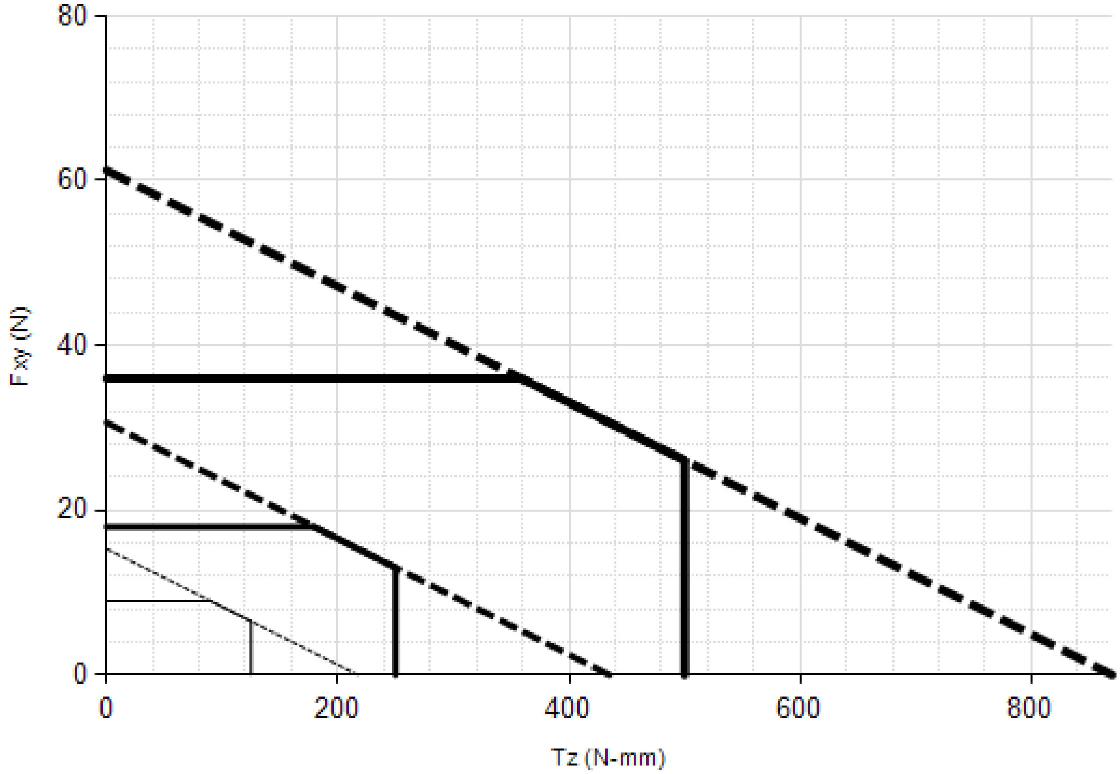
Table 4.22—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ N)**	**Tx, Ty, Tz (/ Nmm)**
Nano43	US-2-1 / SI-9-0.125	N/A	N/A	N/A	N/A
Nano43	US-4–2 / SI-18–0.25	4640	9280	1024	80
Nano43	US-8–4 / SI-36–0.5	2320	4640	512	40
Nano43	Tool Transform Factor	0.005 in/lbf		0.128 mm/N	
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

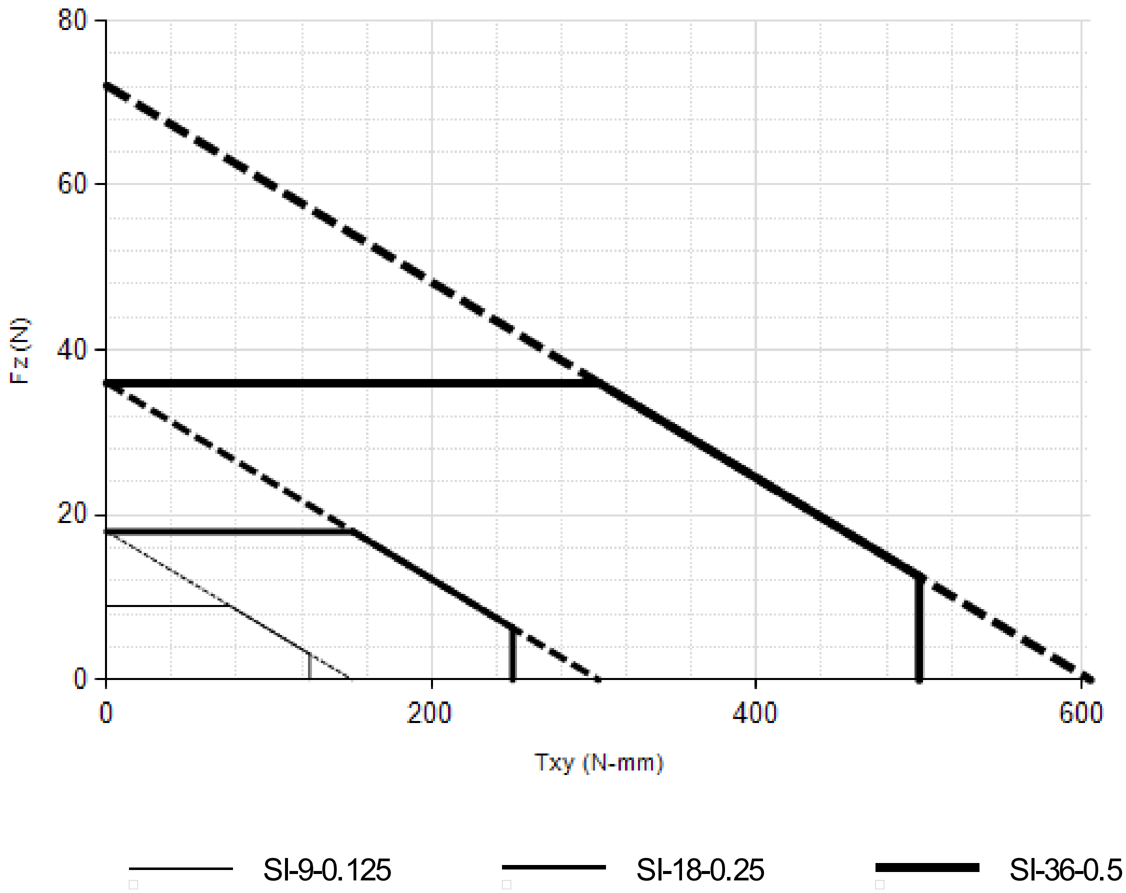
5.5.6 Nano43 (US Calibration Complex Loading)



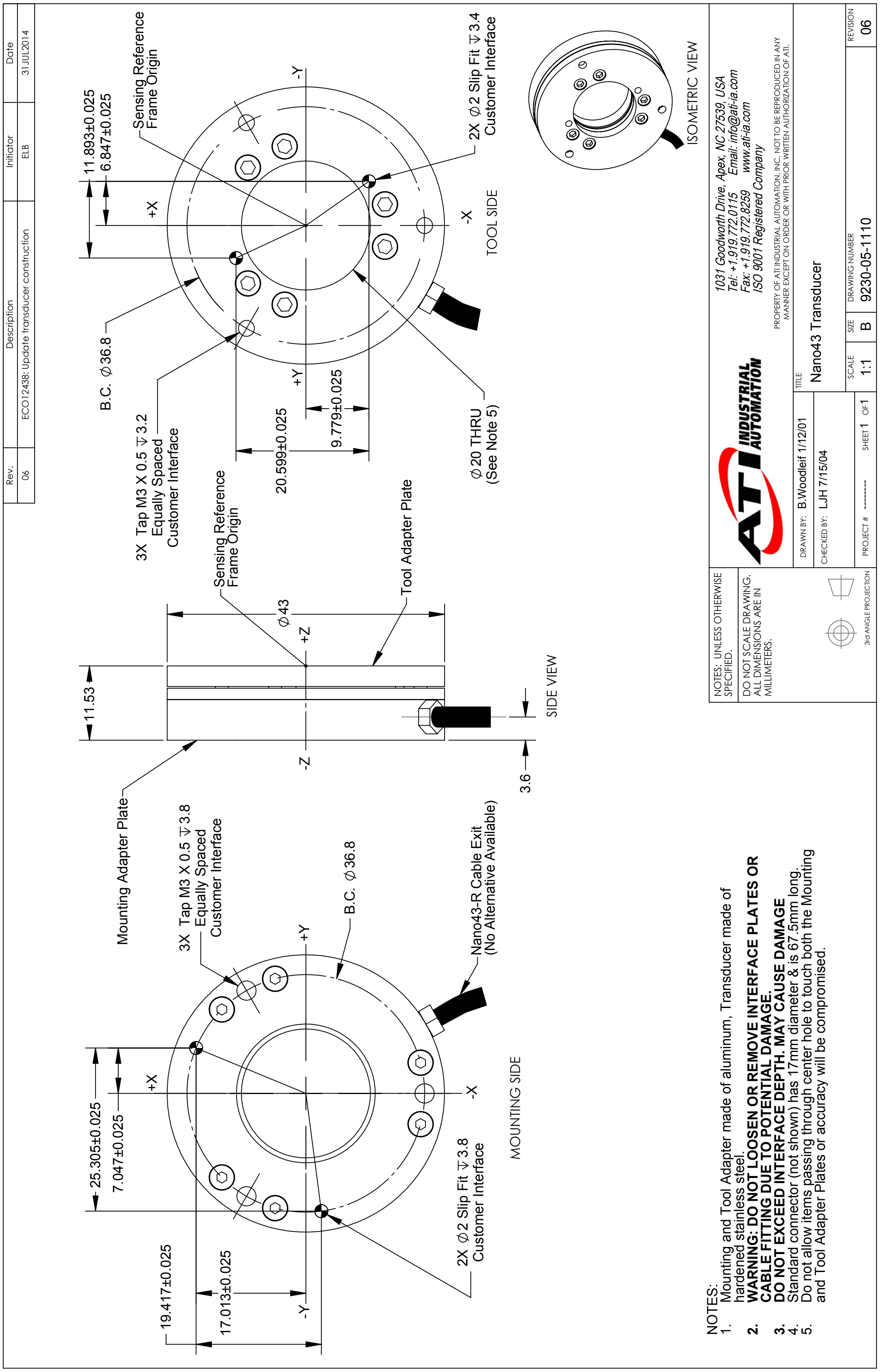


5.5.7 Nano43 (SI Calibration Complex Loading)





5.5.8 Nano43 Transducer Drawing



5.6 Mini27 Titanium Specifications

5.6.1 Mini27 Titanium Physical Properties

Table 4.23—Mini27 Titanium Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±330 lbf	±1500 N
Fz	±1000 lbf	±4600 N
Txy	±270 inf-lb	±30 Nm
Tz	±360 inf-lb	±40 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	$1.8x10^5$ lb/in	$3.1x10^7$ N/m
Z-axis force (Kz)	$3.6x10^5$ lb/in	$6.4x10^7$ N/m
X-axis & Y-axis torque (Ktx, Kty)	$4.0x10^4$ lbf-in/rad	$4.5x10^3$ Nm/rad
Z-axis torque (Ktz)	$5.8x10^4$ lbf-in/rad	$6.5x10^3$ Nm/rad
Resonant Frequency		
Fx, Fy, Tz	N/A	N/A
Fz, Tx, Ty	N/A	N/A
Physical Specifications		
Weight[1]	0.0736 lb	0.0334 kg
Diameter[1]	1.06 in	27 mm
Height[1]	0.715 in	18.2 mm

Note:
1. Specifications include standard interface plates.

5.6.2 Calibration Specifications (excludes CTL calibrations)

Table 4.24— Mini27 Titanium Calibrations (excludes CTL calibrations)[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Mini27 Titanium	US-10-18	10	20	18	10	1/400	3/400	1/400	1/800
Mini27 Titanium	US-20-36	20	40	36	20	1/200	3/200	1/200	1/400
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Mini27 Titanium	SI-40-2	40	80	2	1	3/200	3/100	3/8000	1/4000
Mini27 Titanium	SI-80-4	80	160	4	2	3/100	3/50	3/4000	1/2000
		Sensing Ranges				**Resolution (DAQ, Net F/T)[3]**			

Notes:
1. These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. DAQ resolutions are typical for a 16-bit data acquisition system.

5.6.3 CTL Calibration Specifications

Table 4.25— Mini27 Titanium CTL Calibrations[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Mini27 Titanium	US-10-18	10	20	18	10	1/200	3/200	1/200	1/400
Mini27 Titanium	US-20-36	20	40	36	20	1/100	3/100	1/100	1/200
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Mini27 Titanium	SI-40-2	40	80	2	1	3/100	3/50	3/4000	1/2000
Mini27 Titanium	SI-80-4	80	160	4	2	3/50	3/25	3/2000	1/1000
		Sensing Ranges				**Resolution (Controller)**			

Notes:

1. 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.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.

5.6.4 CTL Analog Output

Table 4.26— Mini27 Titanium Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Mini27 Titanium	US-10-18	±10	±20	±18	1	2	1.8
Mini27 Titanium	US-20-36	±20	±40	±36	2	4	3.6
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty,Tz (Nmm)**	**Fx,Fy (N/V)**	**Fz (N/V)**	**Tx,Ty,Tz (Nm/V)**
Mini27 Titanium	SI-40-2	±40	±80	±2	4	8	0.2
Mini27 Titanium	SI-80-4	±80	±160	±4	8	16	0.4
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

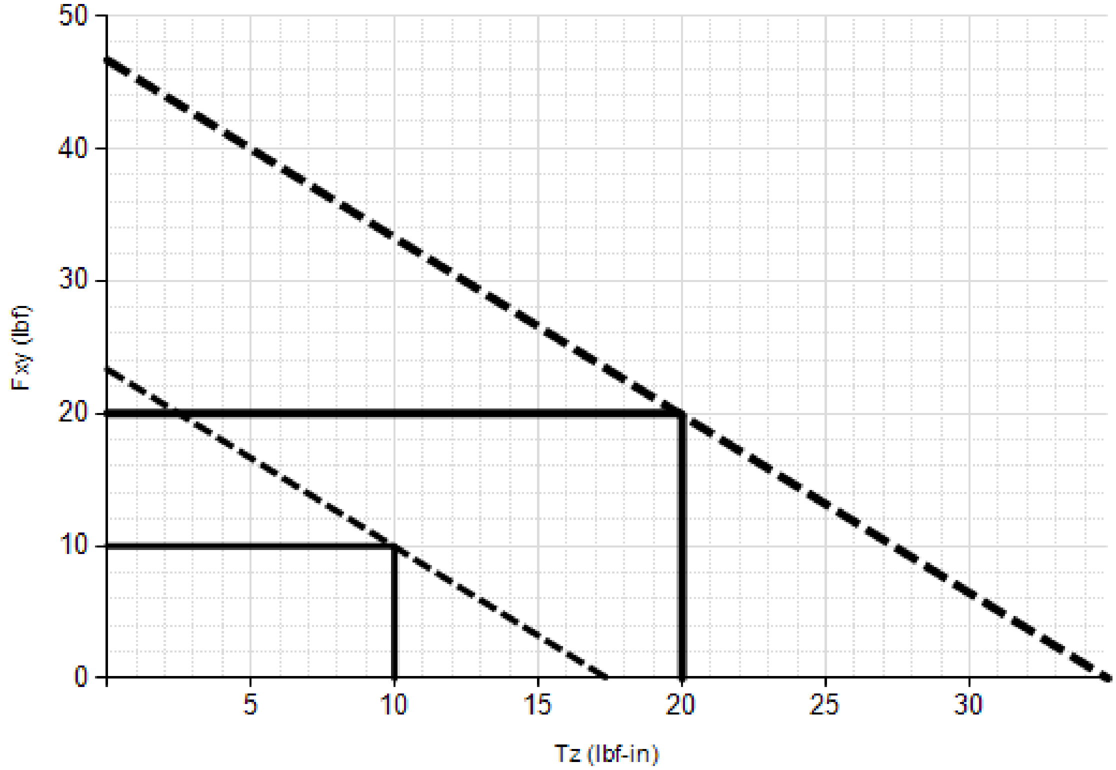
Notes:

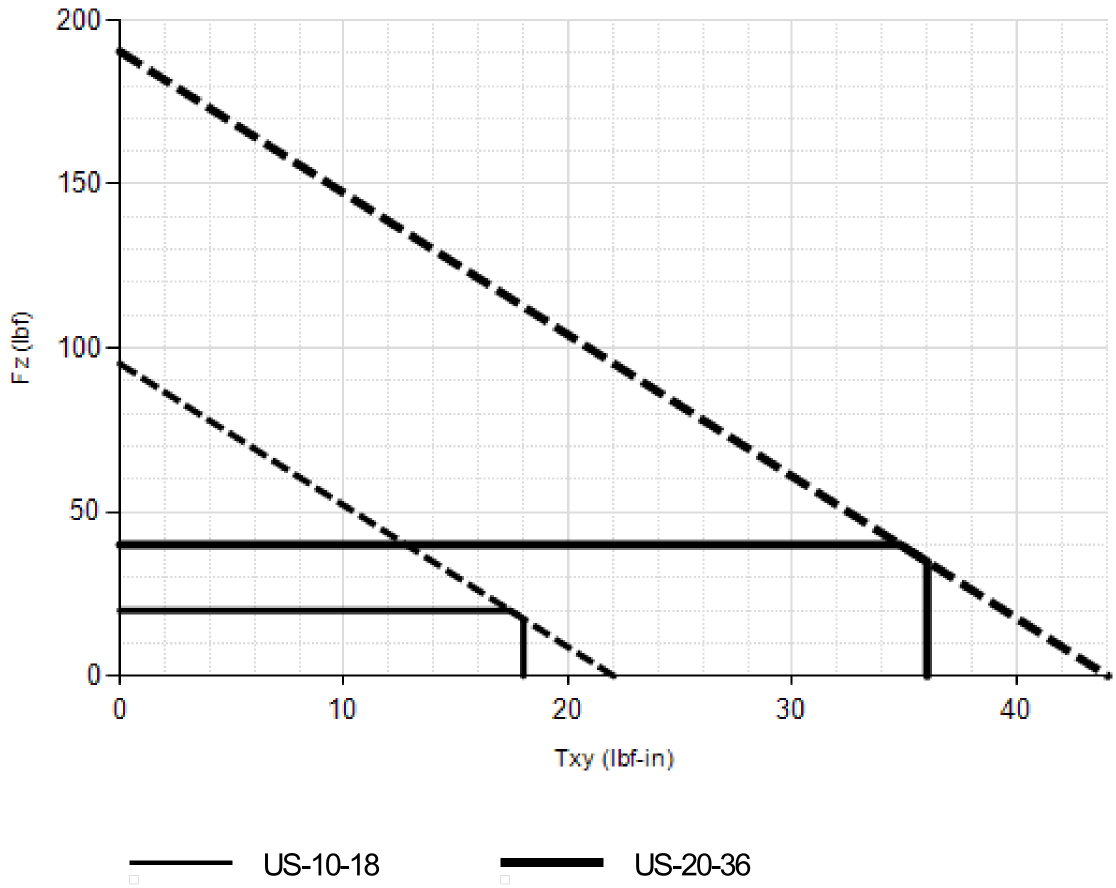
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.

5.6.5 CTL Counts Value

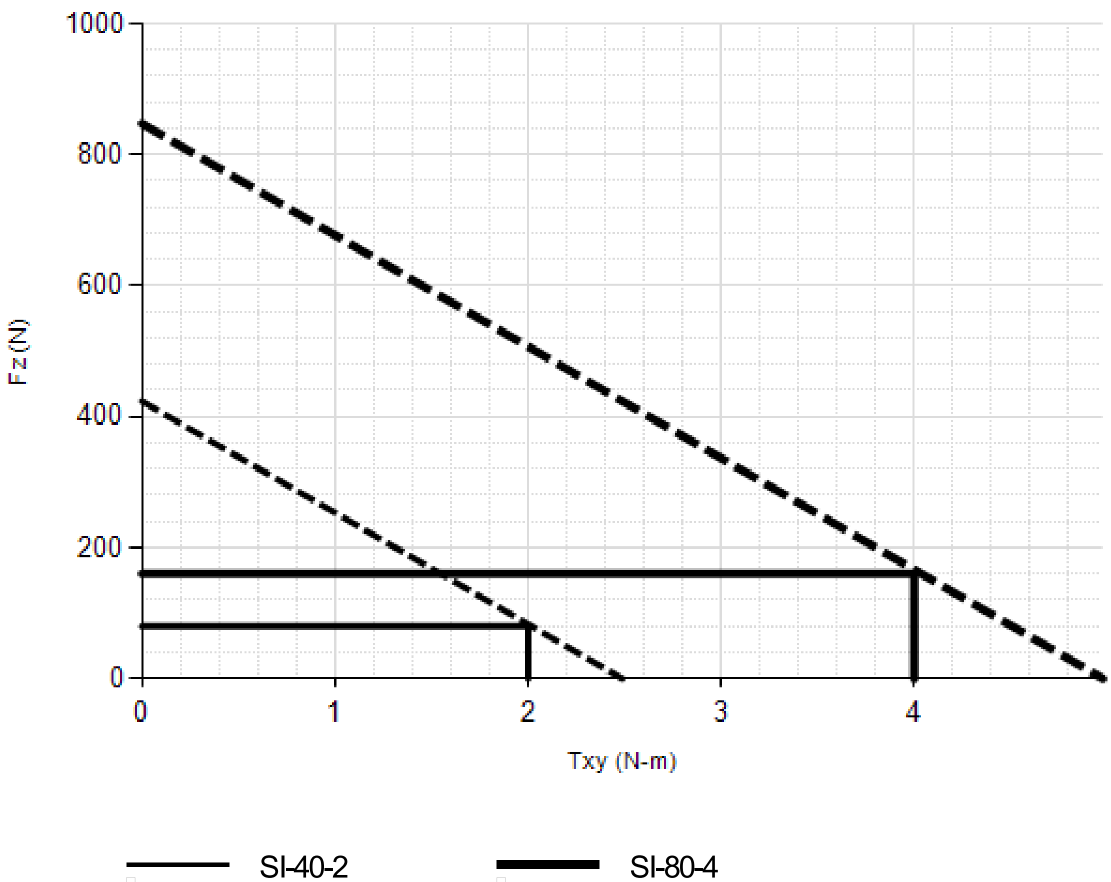
Table 4.27—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ N)**	**Tx, Ty, Tz (/ Nm)**
Mini27 Titanium	US-1–18 / SI-40–2	3200	3200	800	32000
Mini27 Titanium	US-20–36 / SI-80–4	1600	1600	400	16000
Mini27 Titanium	Tool Transform Factor	0.01 in/lbf		0.25 mm/N	
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

5.6.6 Mini27 Titanium (US Calibration Complex Loading)

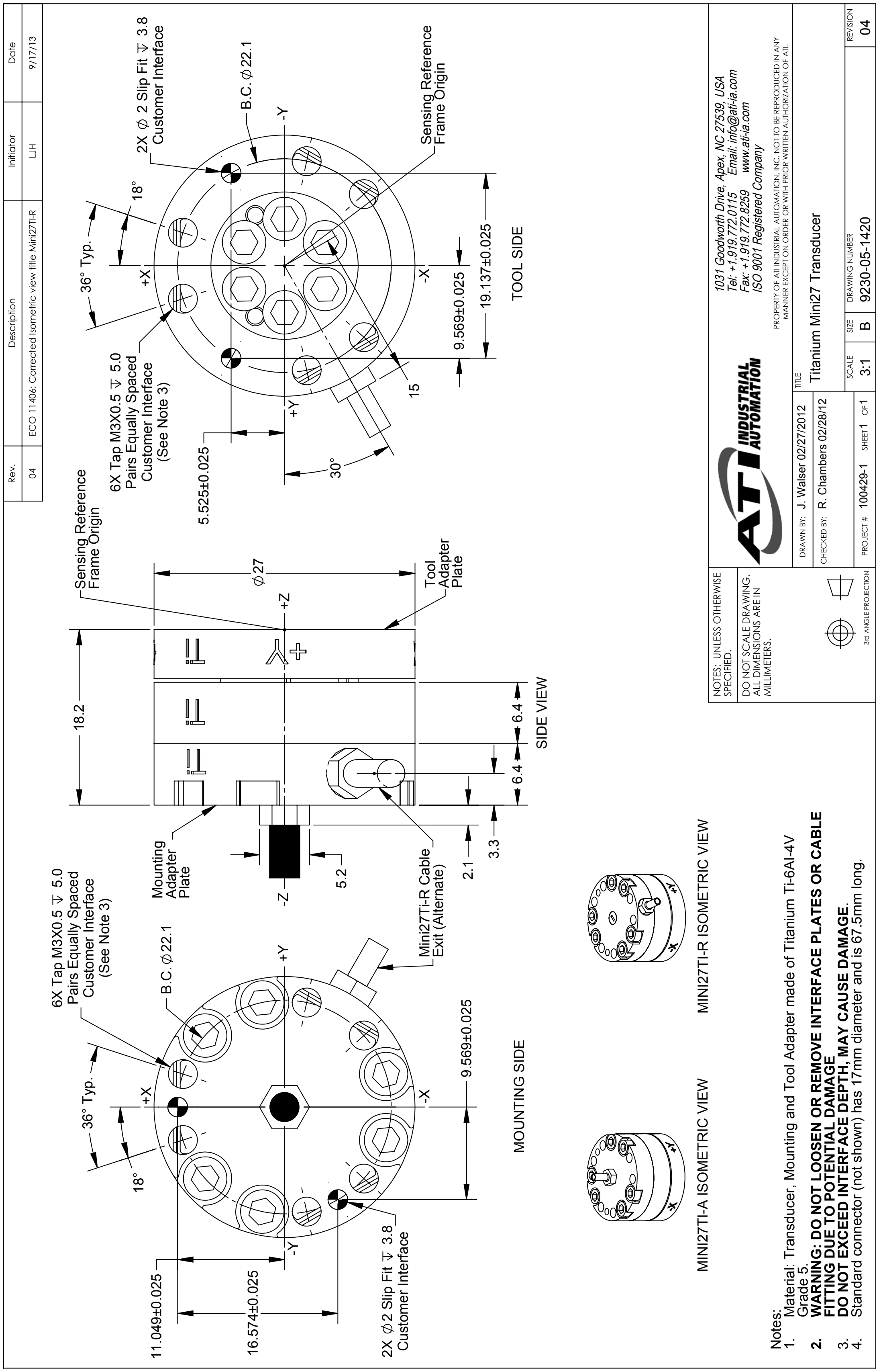




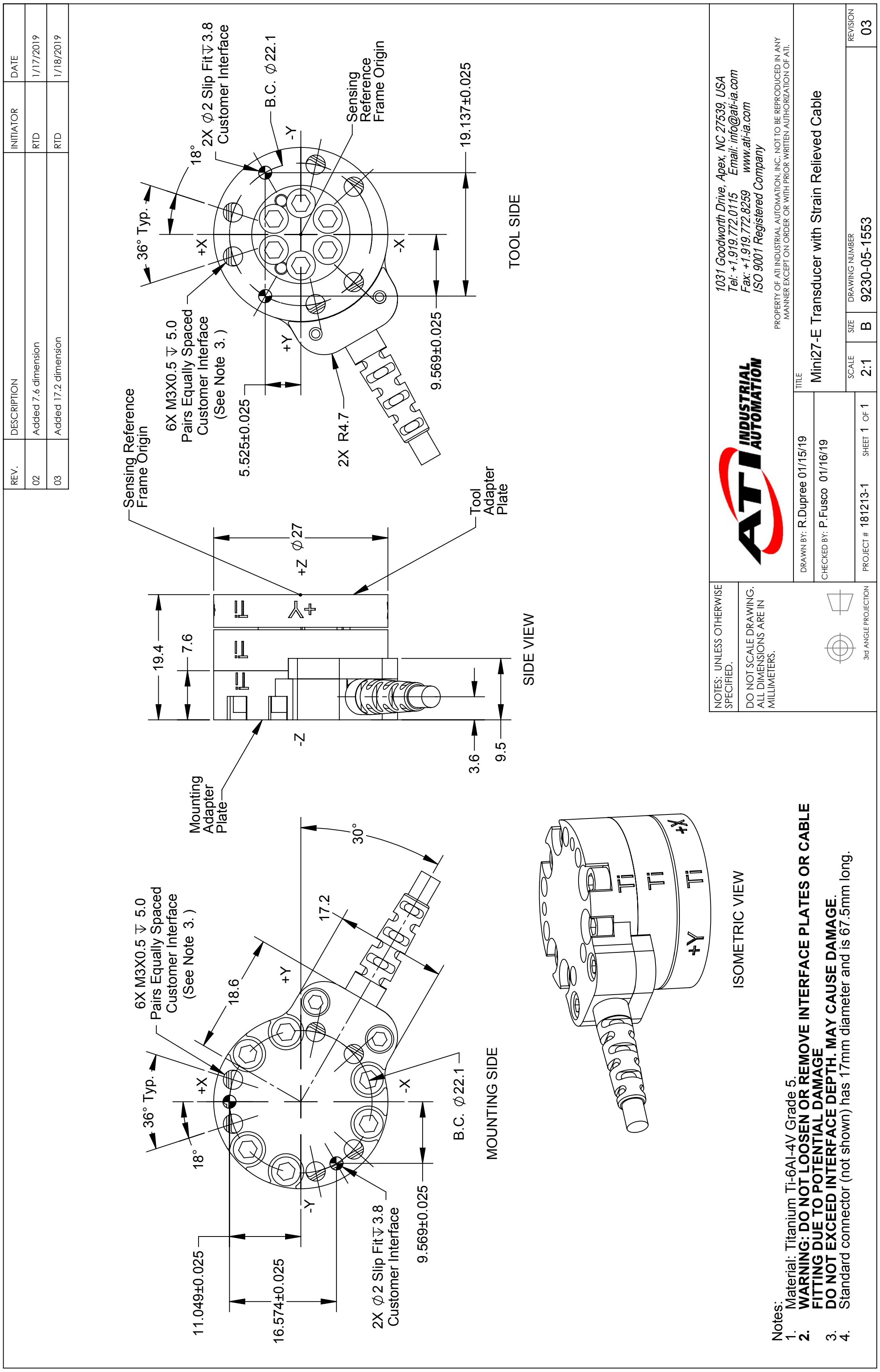
5.6.7 Mini27 Titanium (SI Calibration Complex Loading)



5.6.8 Mini27 Titanium Transducer Drawing



5.6.9 Mini27-E Titanium Transducer Drawing



5.7 Mini40 Specifications (Includes IP65/IP68 Versions)

5.7.1 Mini40 Physical Properties

Table 4.28—Mini40 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±180 lbf	±810 N
Fz	±530 lbf	±2400 N
Txy	±170 inf-lb	±19 Nm
Tz	±180 inf-lb	±20 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	$6.1x10^4$ lb/in	$1.1x10^7$ N/m
Z-axis force (Kz)	$1.2x10^5$ lb/in	$2.0x10^7$ N/m
X-axis & Y-axis torque (Ktx, Kty)	$2.5x10^4$ lbf-in/rad	$2.8x10^3$ Nm/rad
Z-axis torque (Ktz)	$3.6x10^4$ lbf-in/rad	$4.0x10^3$ Nm/rad
Resonant Frequency		
Fx, Fy, Tz	3200 Hz	3200 Hz
Fz, Tx, Ty	4900 Hz	4900 Hz
Physical Specifications		
Weight[1]	0.11 lb	0.0499 kg
Diameter[1]	1.57 in	40 mm
Height[1]	0.482 in	12.2 mm
Note: 1. Specifications include standard interface plates.		

5.7.2 Mini40 IP65/IP68 Physical Properties

Table 4.29—Mini40 IP65/IP68 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±180 lbf	±810 N
Fz	±530 lbf	±2400 N
Txy	±170 inf-lb	±19 Nm
Tz	±180 inf-lb	±20 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	$6.1x10^4$ lb/in	$1.1x10^7$ N/m
Z-axis force (Kz)	$1.2x10^5$ lb/in	$2.0x10^7$ N/m
X-axis & Y-axis torque (Ktx, Kty)	$2.5x10^4$ lbf-in/rad	$2.8x10^3$ Nm/rad
Z-axis torque (Ktz)	$3.6x10^4$ lbf-in/rad	$4.0x10^3$ Nm/rad
Resonant Frequency		
Fx, Fy, Tz	1400 Hz	1400 Hz
Fz, Tx, Ty	1300 Hz	1300 Hz
Physical Specifications		
Weight[1]	0.6 lb	0.272 kg
Diameter[1]	2.1 in	53.3 mm
Height[1]	0.83 in	21.1 mm
Note: 1. Specifications include standard interface plates.		

CAUTION: 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.

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

5.7.3 Calibration Specifications (excludes CTL calibrations)

Table 4.30— Mini40 Calibrations (excludes CTL calibrations)[1, 2]

Sensor	(US) Standard Calibration	Fx,Fy (lbf)	Fz[3] (lbf)	Tx,Ty (lbf-in)	Tz (lbf-in)	Fx,Fy (lbf)	Fz[3] (lbf)	Tx,Ty (lbf-in)	Tz (lbf-in)
Mini40	US-5-10	5	15	10	10	1/800	1/400	1/800	1/800
Mini40	US-10-20	10	30	20	20	1/400	1/200	1/400	1/400
Mini40	US-20-40	20	60	40	40	1/200	1/100	1/200	1/200
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Mini40	SI-20-1	20	60	1	1	1/200	1/100	1/8000	1/8000
Mini40	SI-40-2	40	120	2	2	1/100	1/50	1/4000	1/4000
Mini40	SI-80-4	80	240	4	4	1/50	1/25	1/2000	1/2000
		Sensing Ranges				**Resolution (DAQ, Net F/T)[4]**			

Notes:

1. These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.
4. DAQ resolutions are typical for a 16-bit data acquisition system.

5.7.4 CTL Calibration Specifications

Table 4.31— Mini40 CTL Calibrations[1, 2]

Sensor	(US) Standard Calibration	Fx,Fy (lbf)	Fz[3] (lbf)	Tx,Ty (lbf-in)	Tz (lbf-in)	Fx,Fy (lbf)	Fz[3] (lbf)	Tx,Ty (lbf-in)	Tz (lbf-in)
Mini40	US-5-10	5	15	10	10	1/400	1/200	1/400	1/400
Mini40	US-10-20	10	30	20	20	1/200	1/100	1/200	1/200
Mini40	US-20-40	20	60	40	40	1/100	1/50	1/100	1/100
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Mini40	SI-20-1	20	60	1	1	1/100	1/50	1/4000	1/4000
Mini40	SI-40-2	40	120	2	2	1/50	1/25	1/2000	1/2000
Mini40	SI-80-4	80	240	4	4	1/25	2/25	1/1000	1/1000
		Sensing Ranges				**Resolution (Controller)**			

Notes:
1. 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.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.

5.7.5 CTL Analog Output

Table 4.32— Mini40 Analog Output

Sensor	(US) Standard Calibration	Fx,Fy (lbf)	Fz[2] (lbf)	Tx,Ty,Tz (lbf-in)	Fx,Fy (lbf/V)	Fz[2] (lbf/V)	Tx,Ty,Tz (lbf-in/V)
Mini40	US-5-10	±5	±15	±10	0.5	1.5	1
Mini40	US-10-20	±10	±30	±20	1	3	2
Mini40	US-20-40	±20	±60	±40	2	6	4
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[2] (N)**	**Tx,Ty,Tz (Nm)**	**Fx,Fy (N/V)**	**Fz[2] (N/V)**	**Tx,Ty,Tz (Nm/V)**
Mini40	SI-20-1	±20	±60	±1	2	6	0.1
Mini40	SI-40-2	±40	±120	±2	4	12	0.2
Mini40	SI-80-4	±80	±240	±4	8	24	0.4
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

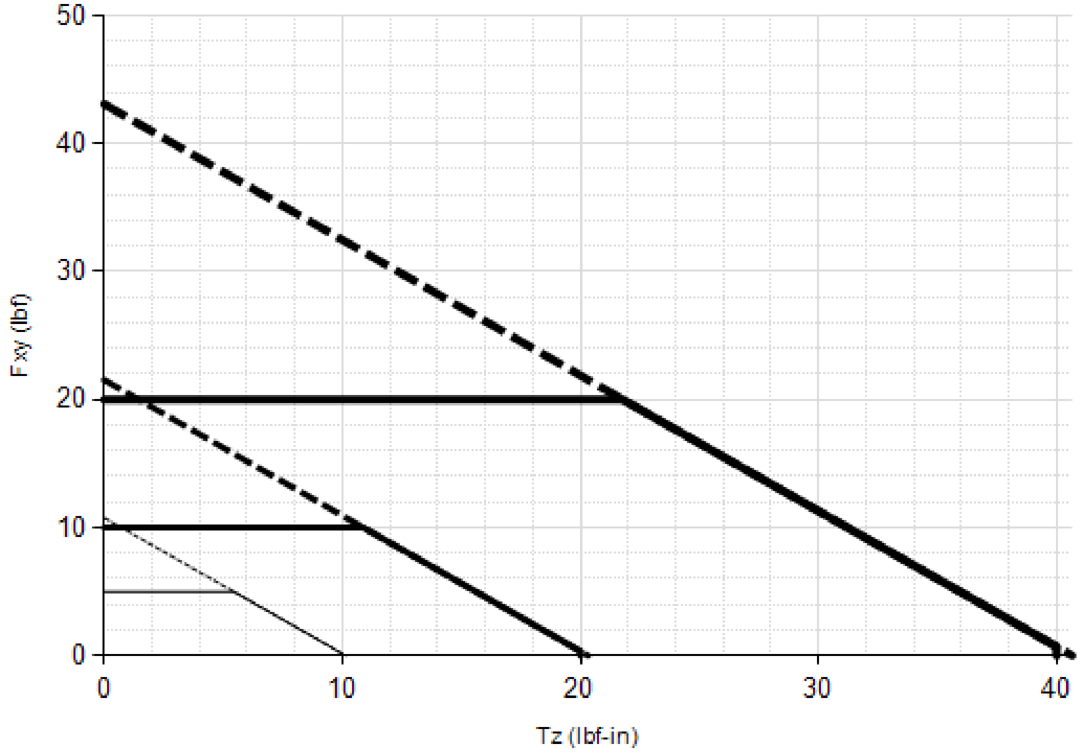
Notes:
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.
2. For IP68 version see caution on physical properties page.

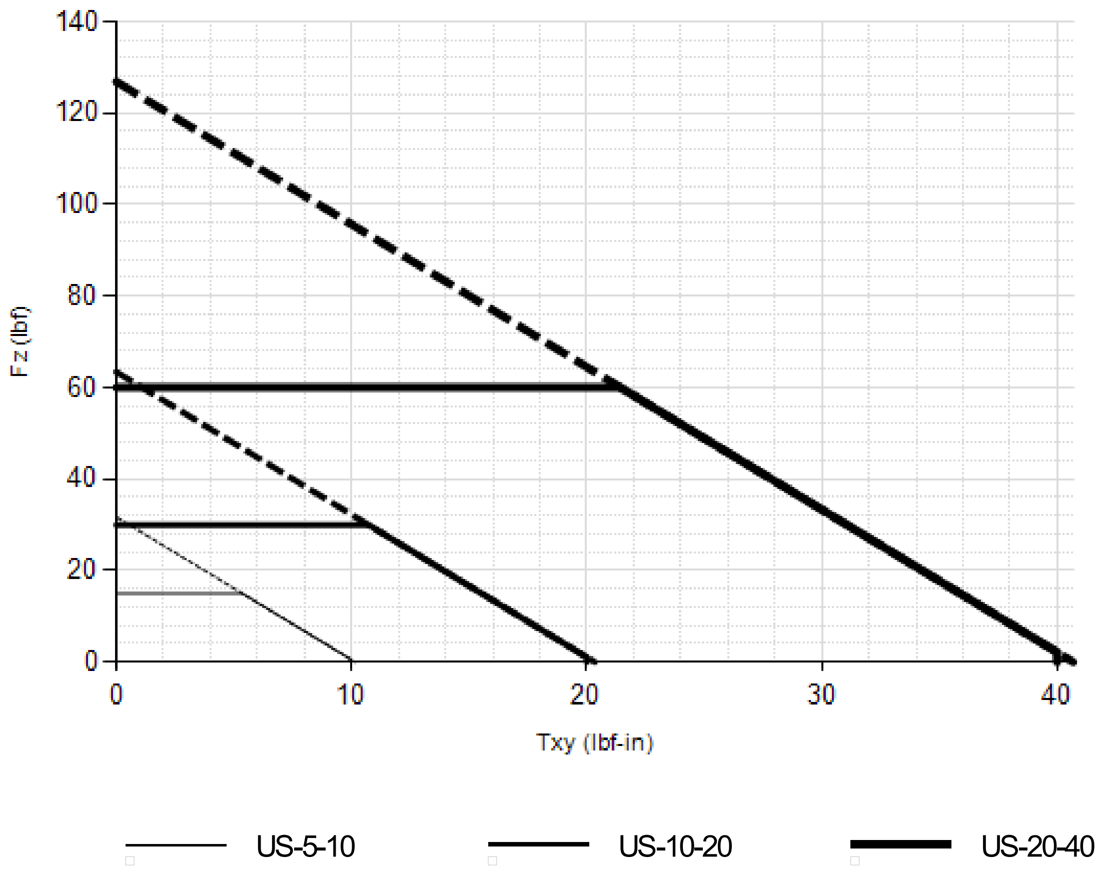
5.7.6 CTL Counts Value

Table 4.33—Counts Value

Sensor	Calibration	Fx, Fy, Fz (/ lbf)	Tx, Ty, Tz (/ lbf-in)	Fx, Fy, Fz (/ N)	Tx, Ty, Tz (/ Nm)
Mini40	US-5–10 / SI-20–1	3200	3200	800	32000
Mini40	US-10–20 / SI-40–2	1600	1600	400	16000
Mini40	US-20–40 / SI-80-4	800	800	200	8000
Mini40	Tool Transform Factor	0.01 in/lbf		0.25 mm/N	
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

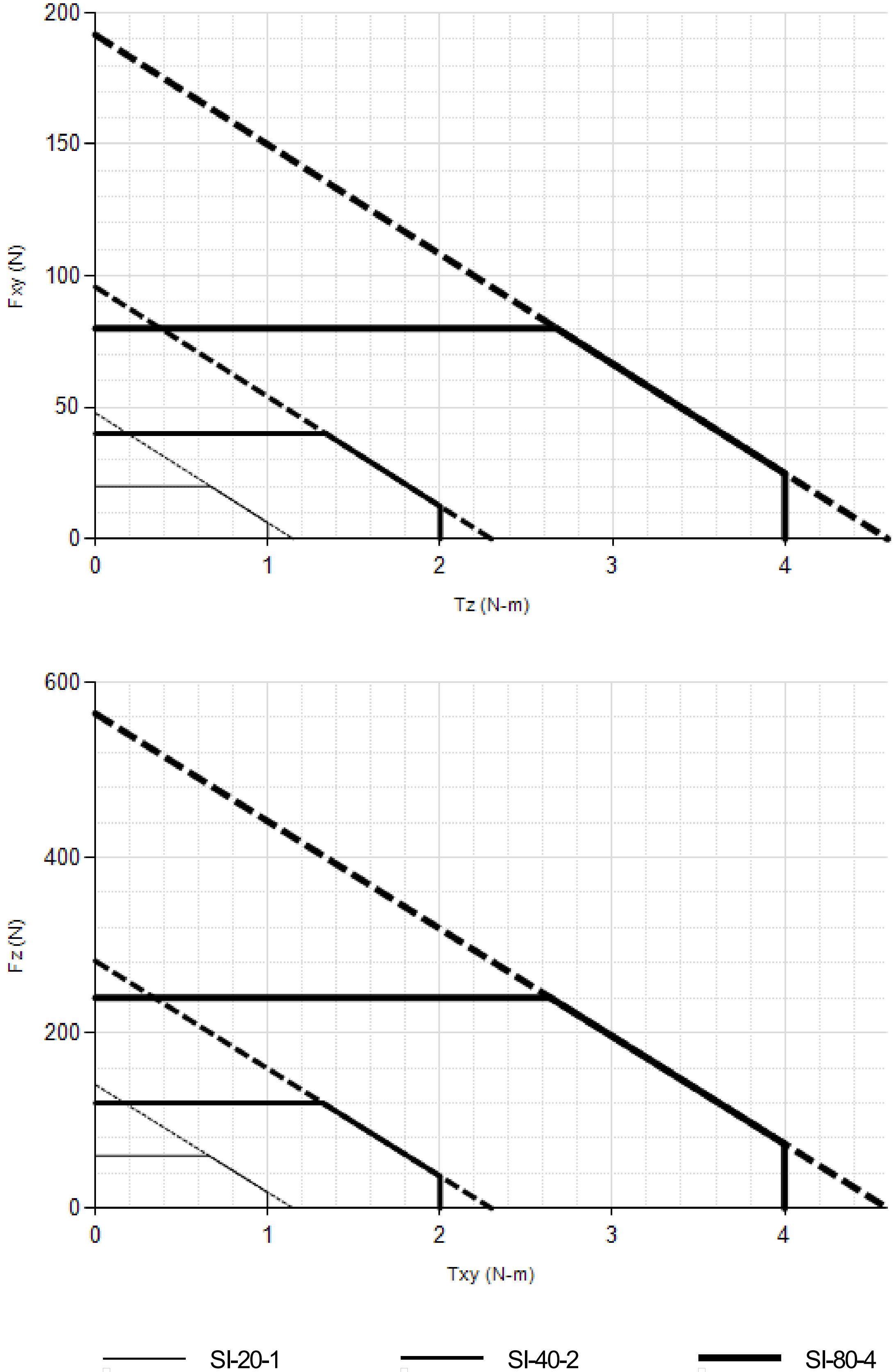
5.7.7 Mini40 (US Calibration Complex Loading)(Includes IP65/IP68)[1]





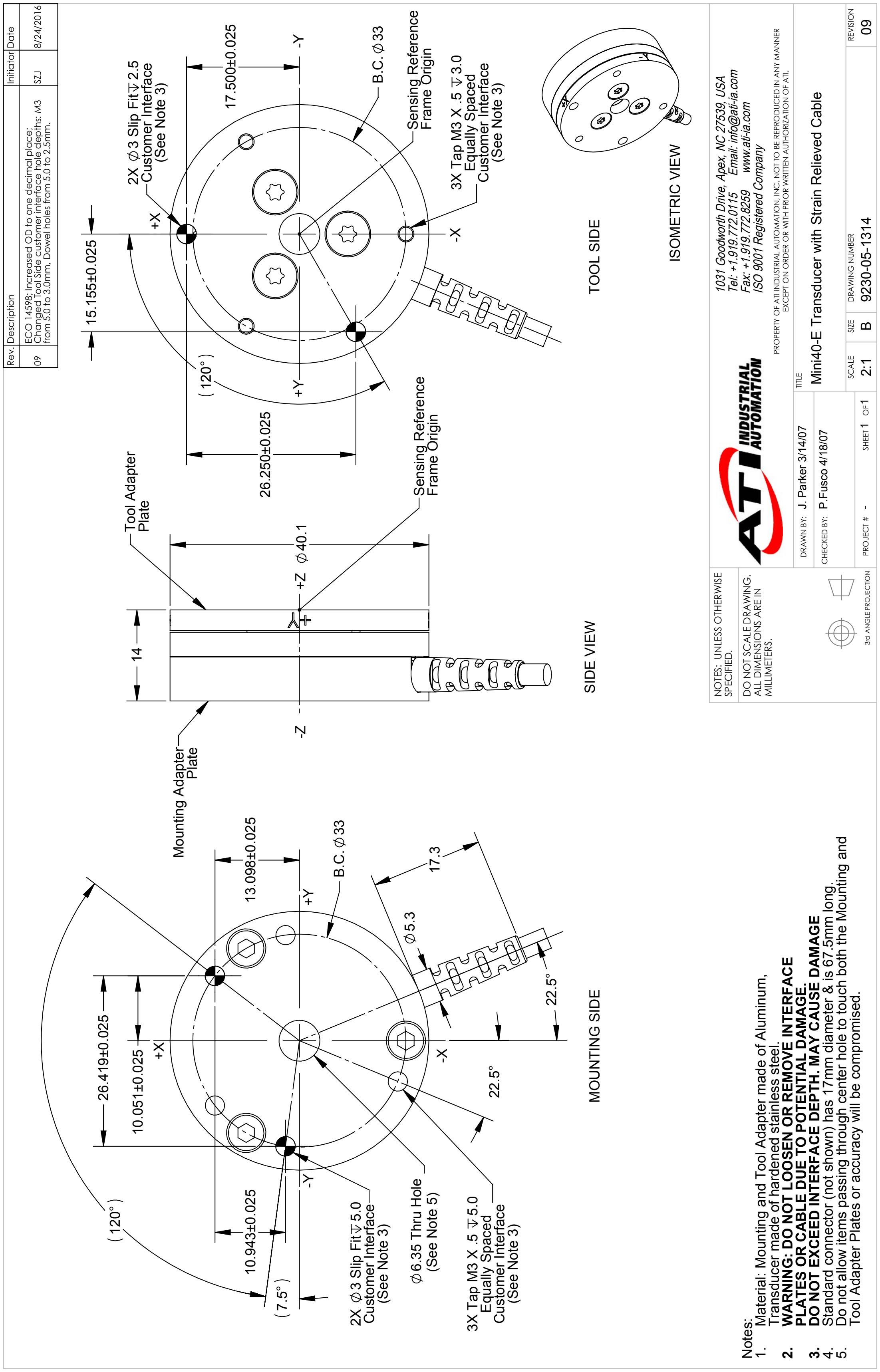
Note: 1. For IP68 version see caution on physical properties page.

5.7.8 Mini40 (SI Calibration Complex Loading)(Includes IP65/IP68)[1]

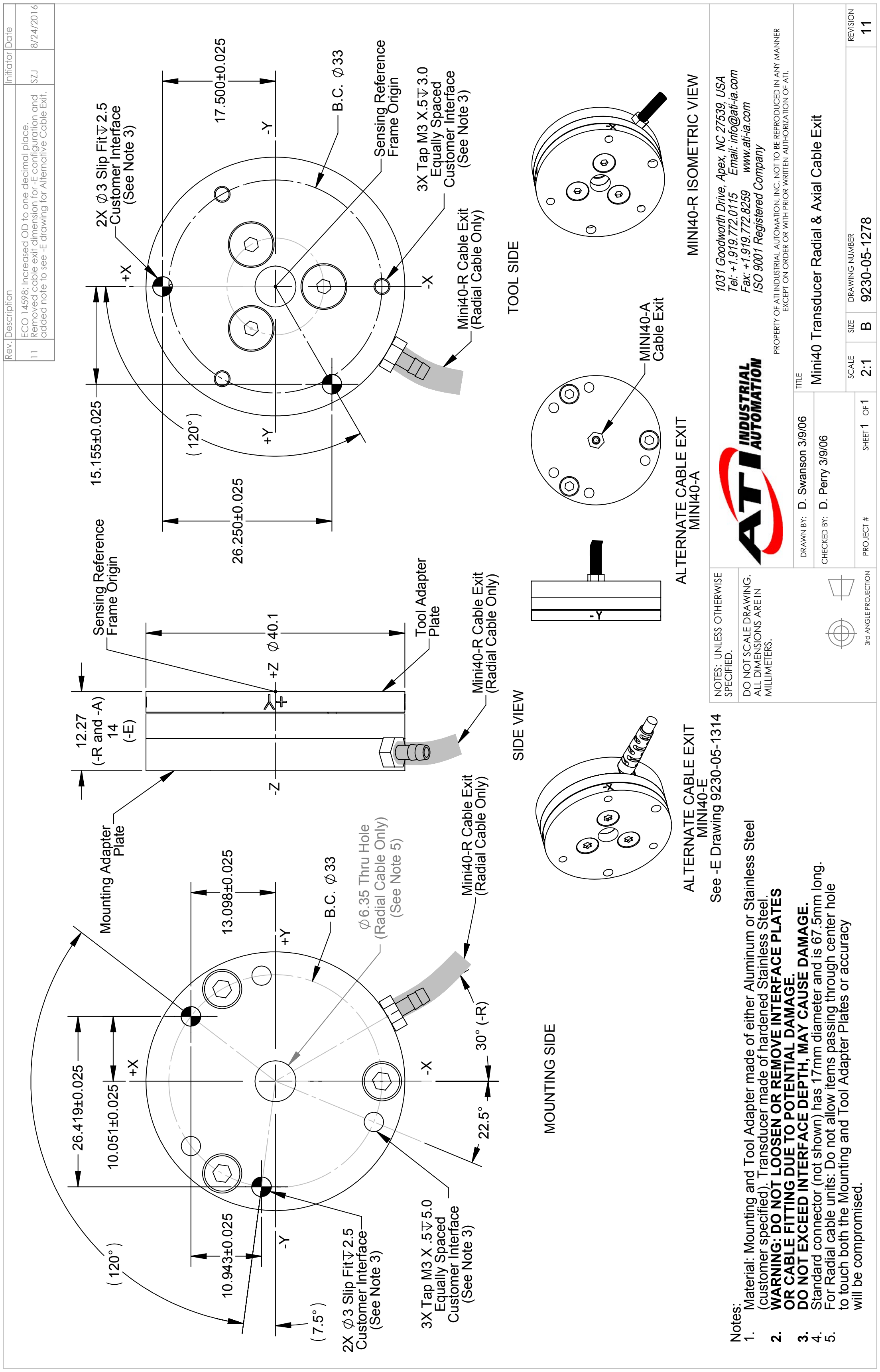


Note: 1. For IP68 version see caution on physical properties page.

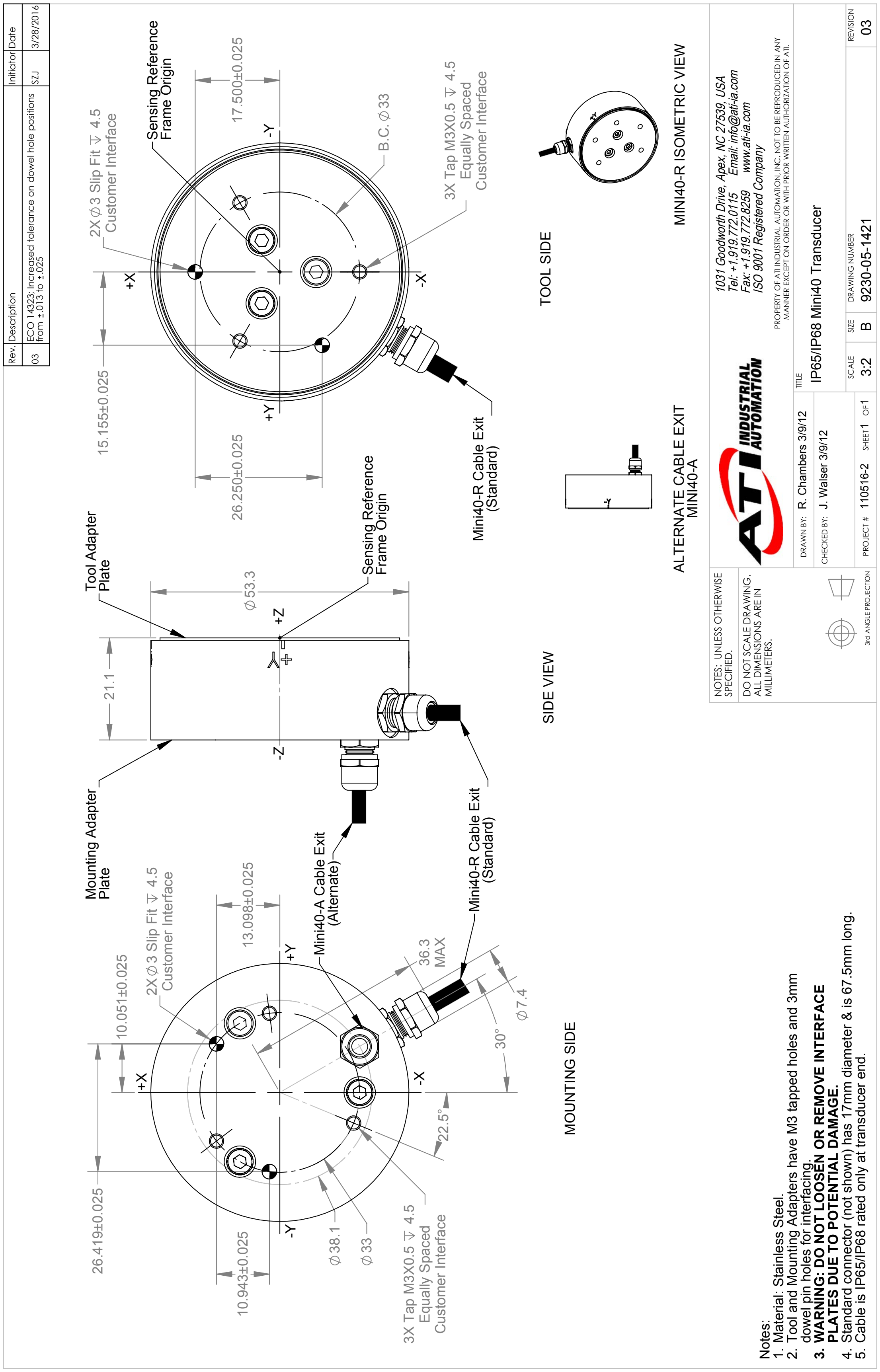
5.7.9 Mini40-E Transducer Drawing



5.7.10 Legacy Mini40 Transducer Drawing



5.7.11 Mini40 IP65/IP68 Transducer Drawing



5.8 Mini45 Titanium Specifications

5.8.1 Mini45 Titanium Physical Properties

Table 4.34—Mini45 Titanium Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±670 lbf	±3000 N
Fz	±1400 lbf	±6400 N
Txy	±590 inf-lb	±67 Nm
Tz	±720 inf-lb	±81 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	2.5×10^5 lb/in	4.3×10^7 N/m
Z-axis force (Kz)	3.3×10^5 lb/in	5.7×10^7 N/m
X-axis & Y-axis torque (Ktx, Kty)	8.6×10^4 lbf-in/rad	9.7×10^3 Nm/rad
Z-axis torque (Ktz)	1.8×10^5 lbf-in/rad	2.0×10^4 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	5800 Hz	5800 Hz
Fz, Tx, Ty	4600 Hz	4600 Hz
Physical Specifications		
Weight[1]	0.22 lb	0.0998 kg
Diameter[1]	1.77 in	45 mm
Height[1]	0.69 in	17.5 mm

Note:
1. Specifications include standard interface plates.

5.8.2 Calibration Specifications (excludes CTL calibrations)

Table 4.35— Mini45 Titanium Calibrations (excludes CTL calibrations)[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Mini45 Titanium	US-15-25	15	30	25	25	3/800	1/160	1/300	1/400
Mini45 Titanium	US-30-50	30	60	50	50	3/400	1/80	1/150	1/200
Mini45 Titanium	US-60-100	60	120	100	100	3/200	1/40	1/75	1/100
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Mini45 Titanium	SI-60-3	60	120	3	3	1/60	7/240	3/8000	1/3200
Mini45 Titanium	SI-120-6	120	240	6	6	1/30	7/120	3/4000	1/1600
Mini45 Titanium	SI-240-12	240	480	12	12	1/15	7/60	3/2000	1/800
		Sensing Ranges				**Resolution (DAQ, Net F/T)[3]**			

Notes:
1. These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. DAQ resolutions are typical for a 16-bit data acquisition system.

5.8.3 CTL Calibration Specifications

Table 4.36— Mini45 Titanium CTL Calibrations[1, 2]

Sensor	(US) Standard Calibration	Fx,Fy (lbf)	Fz (lbf)	Tx,Ty (lbf-in)	Tz (lbf-in)	Fx,Fy (lbf)	Fz (lbf)	Tx,Ty (lbf-in)	Tz (lbf-in)
Mini45 Titanium	US-15-25	15	30	25	25	3/400	1/80	1/150	1/200
Mini45 Titanium	US-30-50	30	60	50	50	3/200	1/40	1/75	1/100
Mini45 Titanium	US-60-100	60	120	100	100	3/100	1/20	2/75	1/50
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Mini45 Titanium	SI-60-3	60	120	3	3	1/30	7/120	3/4000	1/1600
Mini45 Titanium	SI-120-6	120	240	6	6	1/15	7/60	3/2000	1/800
Mini45 Titanium	SI-240-12	240	480	12	12	2/15	7/30	3/1000	1/400
		Sensing Ranges				**Resolution (Controller)**			

Notes:

1. 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.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.

5.8.4 CTL Analog Output

Table 4.37— Mini45 Titanium Analog Output

Sensor	(US) Standard Calibration	Fx,Fy (lbf)	Fz (lbf)	Tx,Ty,Tz (lbf-in)	Fx,Fy (lbf/V)	Fz (lbf/V)	Tx,Ty,Tz (lbf-in/V)
Mini45 Titanium	US-15-25	±15	±30	±25	1.5	3	2.5
Mini45 Titanium	US-30-50	±30	±60	±50	3	6	5
Mini45 Titanium	US-60-100	±60	±120	±100	6	12	10
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty,Tz (Nmm)**	**Fx,Fy (N/V)**	**Fz (N/V)**	**Tx,Ty,Tz (Nm/V)**
Mini45 Titanium	SI-60-3	±60	±120	±3	6	12	0.3
Mini45 Titanium	SI-120-6	±120	±240	±6	12	24	0.6
Mini45 Titanium	SI-240-12	±240	±480	±12	24	48	1.2
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

Note:

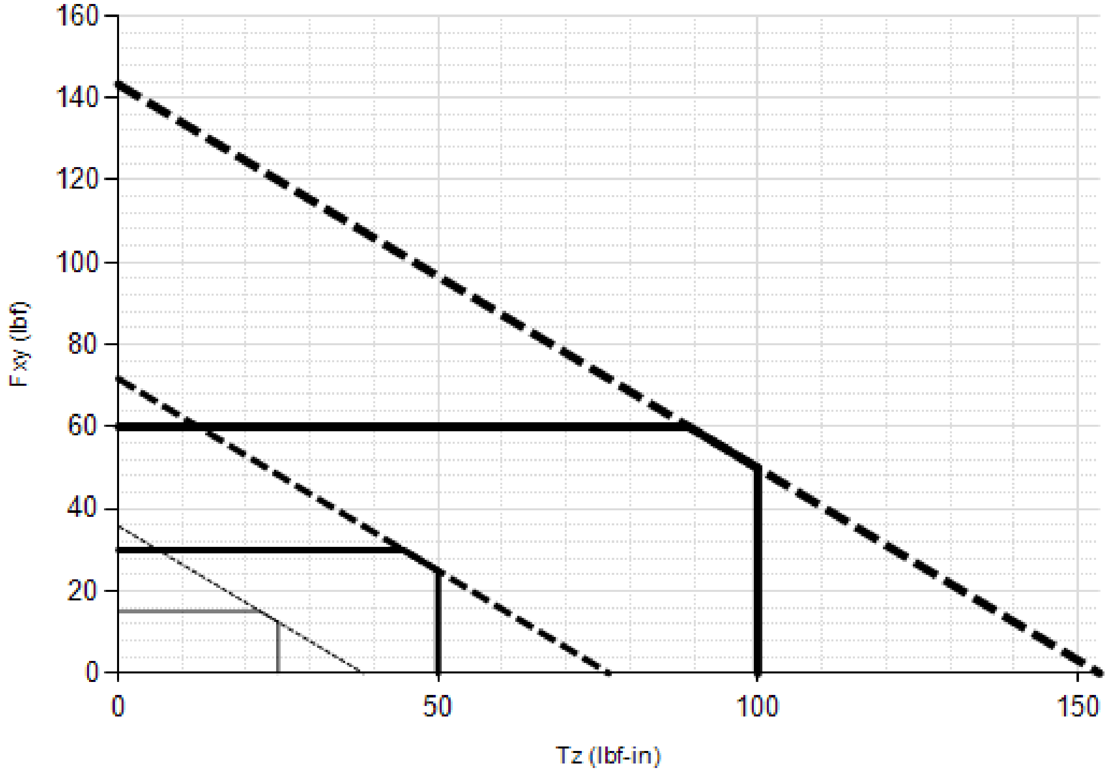
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.

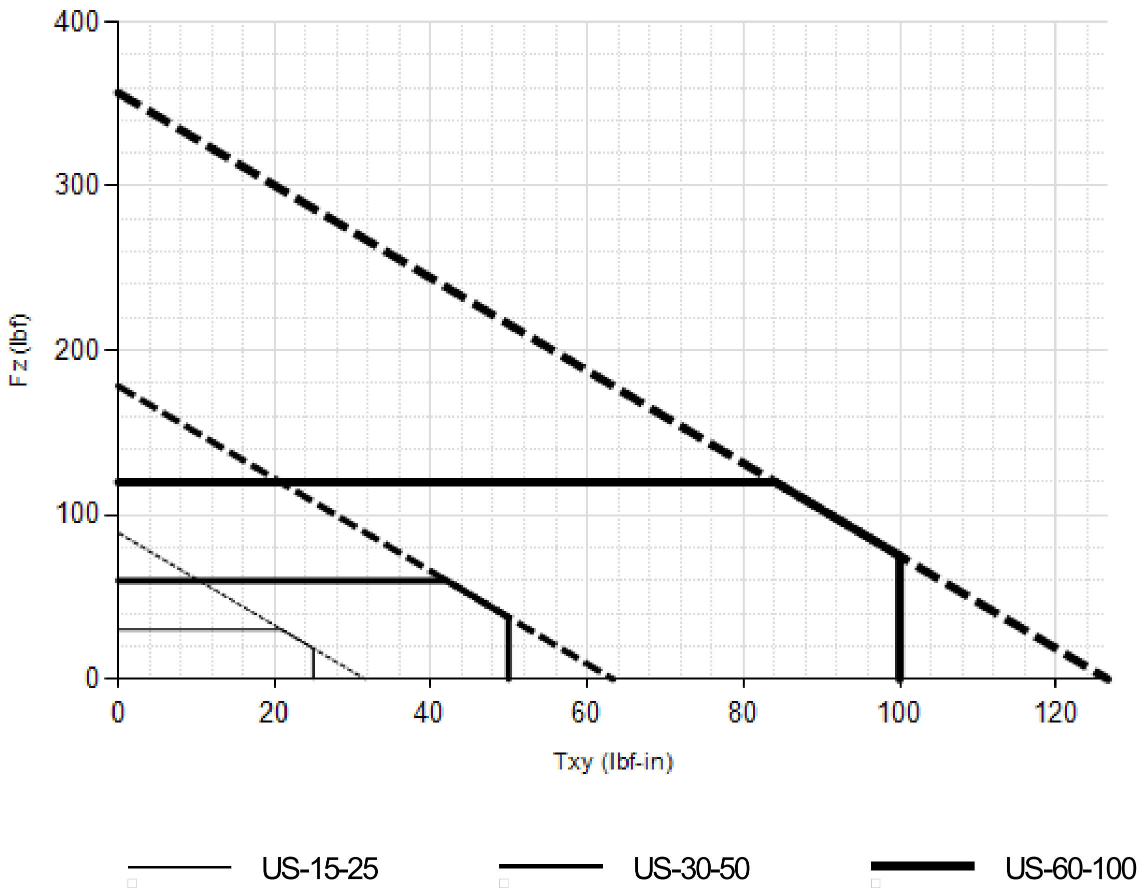
5.8.5 CTL Counts Value

Table 4.38—Counts Value

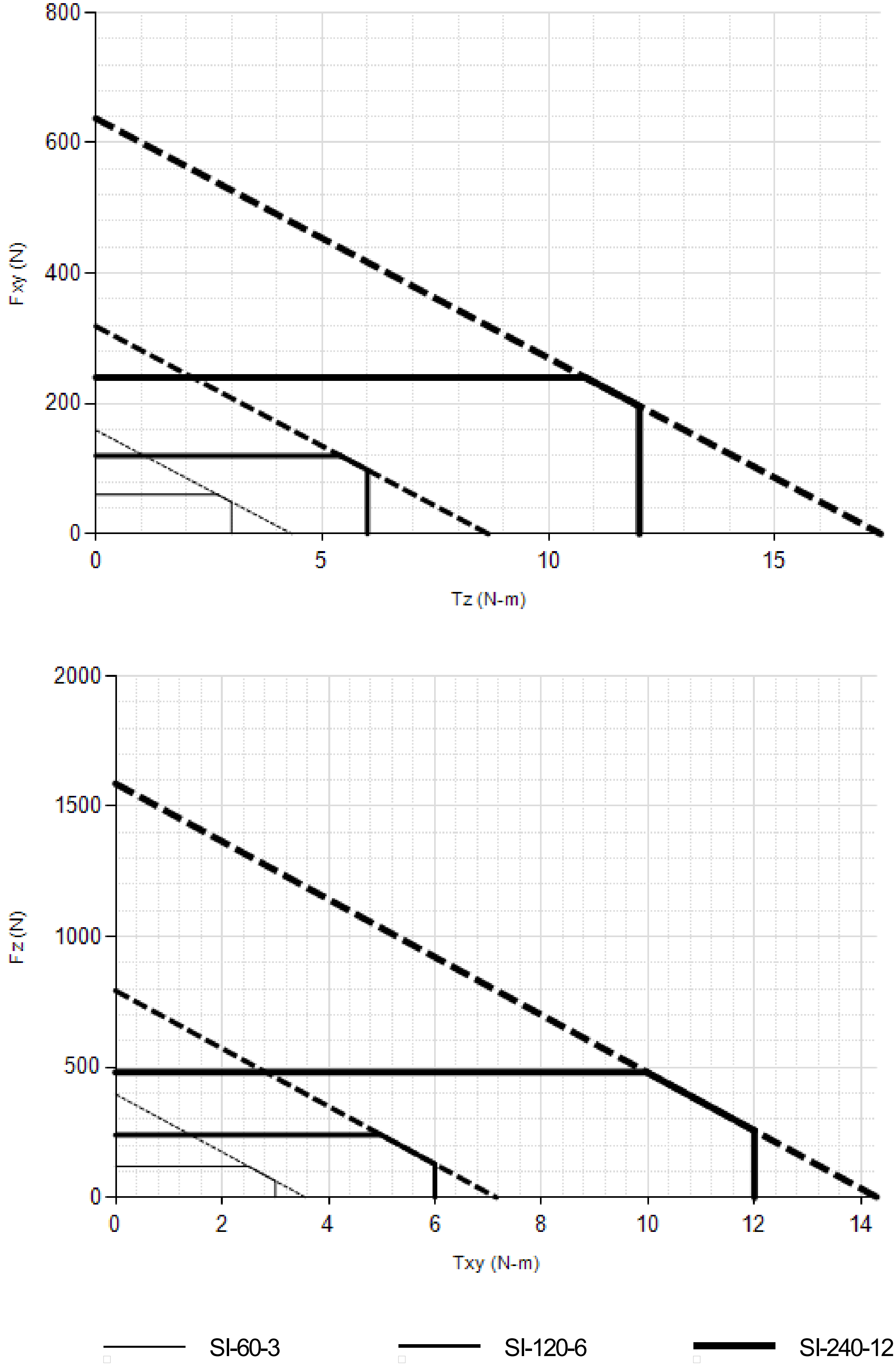
Sensor	Calibration	Fx, Fy, Fz (/ lbf)	Tx, Ty, Tz (/ lbf-in)	Fx, Fy, Fz (/ N)	Tx, Ty, Tz (/ Nm)
Mini45 Titanium	US-15-25 / SI-60-3	640	704	128	6016
Mini45 Titanium	US-30-50 / SI-120-6	320	352	64	3008
Mini45 Titanium	US-60-100 / SI-240-12	160	176	32	1504
Mini45 Titanium	Tool Transform Factor	0.009091 in/lbf		0.21277 mm/N	
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

5.8.6 Mini45 Titanium (US Calibration Complex Loading)

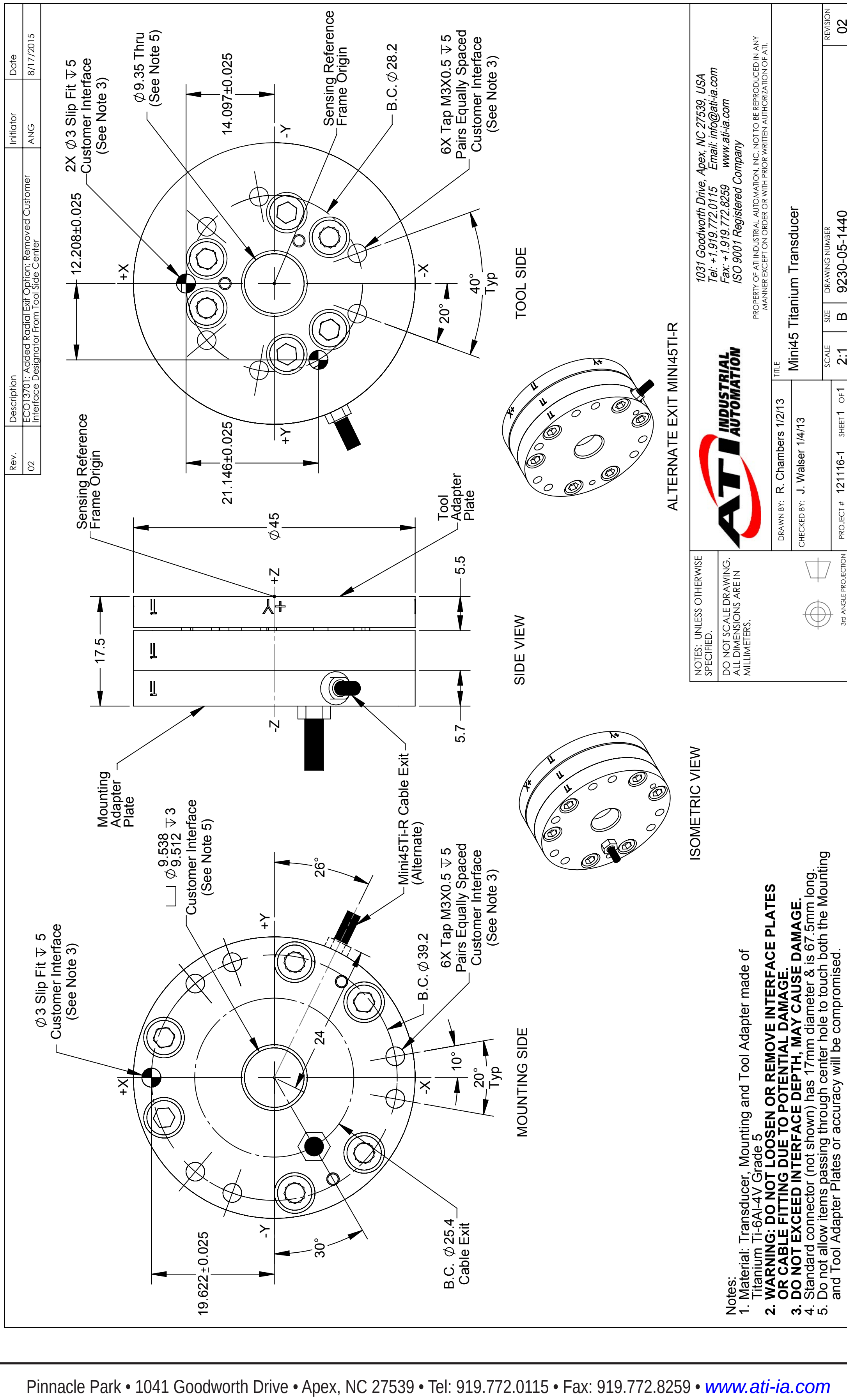




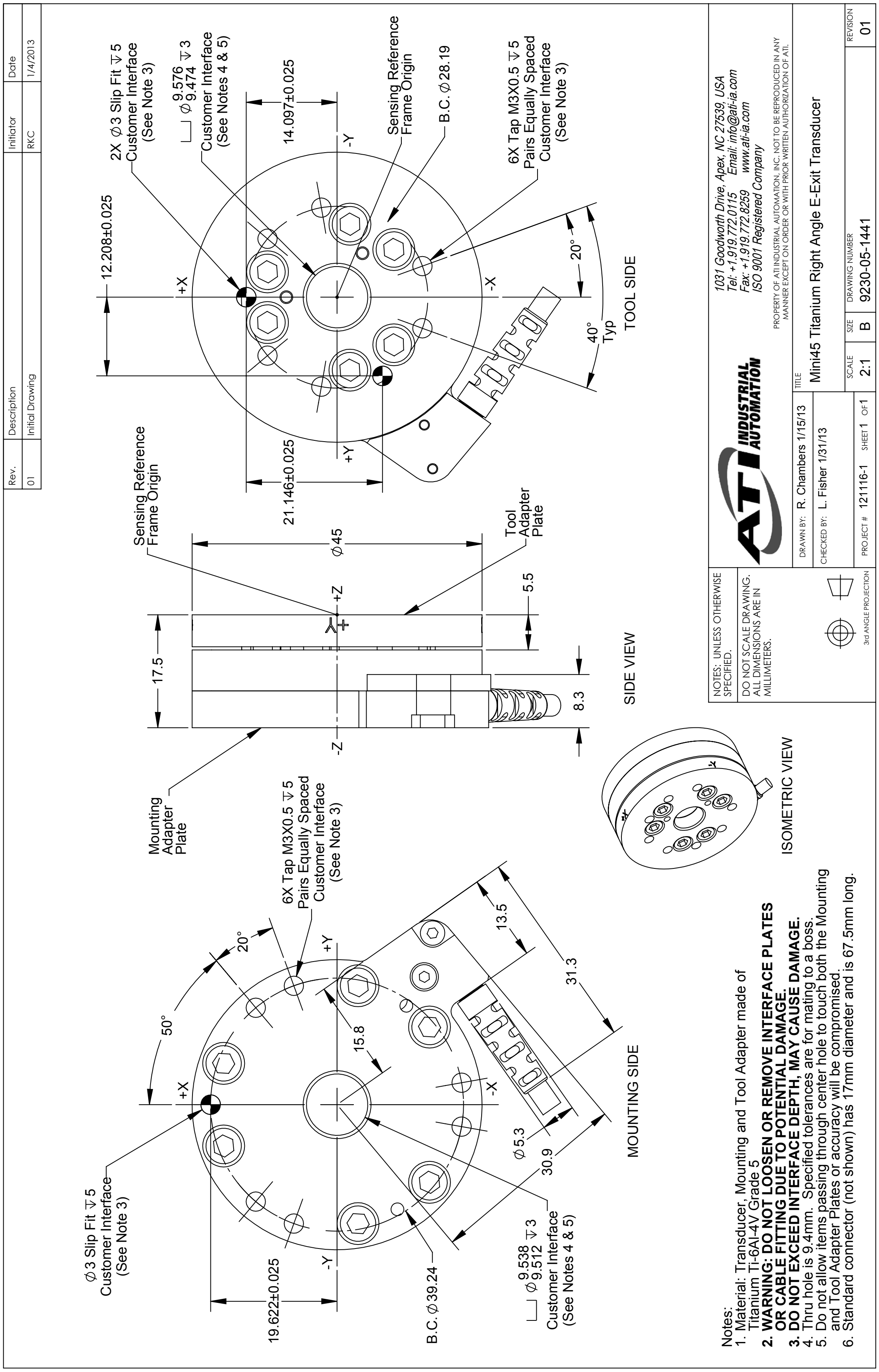
5.8.7 Mini45 Titanium (SI Calibration Complex Loading)



5.8.8 Mini45 Titanium Axial Exit Transducer Drawing



5.8.9 Mini45 Titanium Right Angle E-Exit Transducer Drawing



5.9 Mini45 Specifications (Includes IP65/IP68 Versions)

5.9.1 Mini45 Physical Properties

Table 4.39—Mini45 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±1100 lbf	±5100 N
Fz	±2300 lbf	±10000 N
Txy	±1000 inf-lb	±110 Nm
Tz	±1200 inf-lb	±140 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	4.2×10^5 lb/in	7.4×10^7 N/m
Z-axis force (Kz)	5.6×10^5 lb/in	9.8×10^7 N/m
X-axis & Y-axis torque (Ktx, Kty)	1.5×10^5 lbf-in/rad	1.7×10^4 Nm/rad
Z-axis torque (Ktz)	3.1×10^5 lbf-in/rad	3.5×10^4 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	5600 Hz	5600 Hz
Fz, Tx, Ty	5400 Hz	5400 Hz
Physical Specifications		
Weight[1]	0.202 lb	0.0917 kg
Diameter[1]	1.77 in	45 mm
Height[1]	0.618 in	15.7 mm
Note: 1. Specifications include standard interface plates.		

5.9.2 Mini45 IP65/IP68 Physical Properties

Table 4.40—Mini45 IP65/IP68 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±1100 lbf	±5100 N
Fz	±2300 lbf	±10000 N
Txy	±1000 inf-lb	±110 Nm
Tz	±1200 inf-lb	±140 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	4.2×10^5 lb/in	7.4×10^7 N/m
Z-axis force (Kz)	5.6×10^5 lb/in	9.8×10^7 N/m
X-axis & Y-axis torque (Ktx, Kty)	1.5×10^5 lbf-in/rad	1.7×10^4 Nm/rad
Z-axis torque (Ktz)	3.1×10^5 lbf-in/rad	3.5×10^4 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	5200 Hz	5200 Hz
Fz, Tx, Ty	4200 Hz	4200 Hz
Physical Specifications		
Weight[1]	0.861 lb	0.391 kg
Diameter[1]	2.28 in	57.9 mm
Height[1]	0.988 in	25.1 mm
Note: 1. Specifications include standard interface plates.		

CAUTION: 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.

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

5.9.3 Calibration Specifications (excludes CTL calibrations)

Table 4.41— Mini45 Calibrations (excludes CTL calibrations)[1, 2]

Sensor	(US) Standard Calibration	Fx,Fy (lbf)	Fz[3] (lbf)	Tx,Ty (lbf-in)	Tz (lbf-in)	Fx,Fy (lbf)	Fz[3] (lbf)	Tx,Ty (lbf-in)	Tz (lbf-in)
Mini45	US-30-40	30	60	40	40	1/80	1/80	1/88	1/176
Mini45	US-60-80	60	120	80	80	1/40	1/40	1/44	1/88
Mini45	US-120-160	120	240	160	160	1/20	1/20	1/22	1/44
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Mini45	SI-145-5	145	290	5	5	1/16	1/16	1/752	1/1504
Mini45	SI-290-10	290	580	10	10	1/8	1/8	1/376	1/752
Mini45	SI-580-20	580	1160	20	20	1/4	1/4	1/188	1/376
		Sensing Ranges				**Resolution (DAQ, Net F/T)[4]**			

Notes:

1. These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.
4. DAQ resolutions are typical for a 16-bit data acquisition system.

5.9.4 CTL Calibration Specifications

Table 4.42— Mini45 CTL Calibrations[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Mini45	US-30-40	30	60	40	40	1/40	1/40	1/44	1/88
Mini45	US-60-80	60	120	80	80	1/20	1/20	1/22	1/44
Mini45	US-120-160	120	240	160	160	1/10	1/10	1/11	1/22
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Mini45	SI-145-5	145	290	5	5	1/8	1/8	1/376	1/752
Mini45	SI-290-10	290	580	10	10	1/4	1/4	1/188	1/376
Mini45	SI-580-20	580	1160	20	20	1/2	1/2	1/94	1/188
		Sensing Ranges				**Resolution (Controller)**			

Notes:

1. 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.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.

5.9.5 CTL Analog Output

Table 4.43— Mini45 Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[2] (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz[2] (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Mini45	US-30-40	±30	±60	±40	3	6	4
Mini45	US-60-80	±60	±120	±80	6	12	8
Mini45	US-120-160	±120	±240	±160	12	24	16
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[2] (N)**	**Tx,Ty,Tz (Nm)**	**Fx,Fy (N/V)**	**Fz[2] (N/V)**	**Tx,Ty,Tz (Nm/V)**
Mini45	SI-145-5	±145	±290	±5	14.5	29	0.5
Mini45	SI-290-10	±290	±580	±10	29	58	1
Mini45	SI-580-20	±580	±1160	±20	58	116	2
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

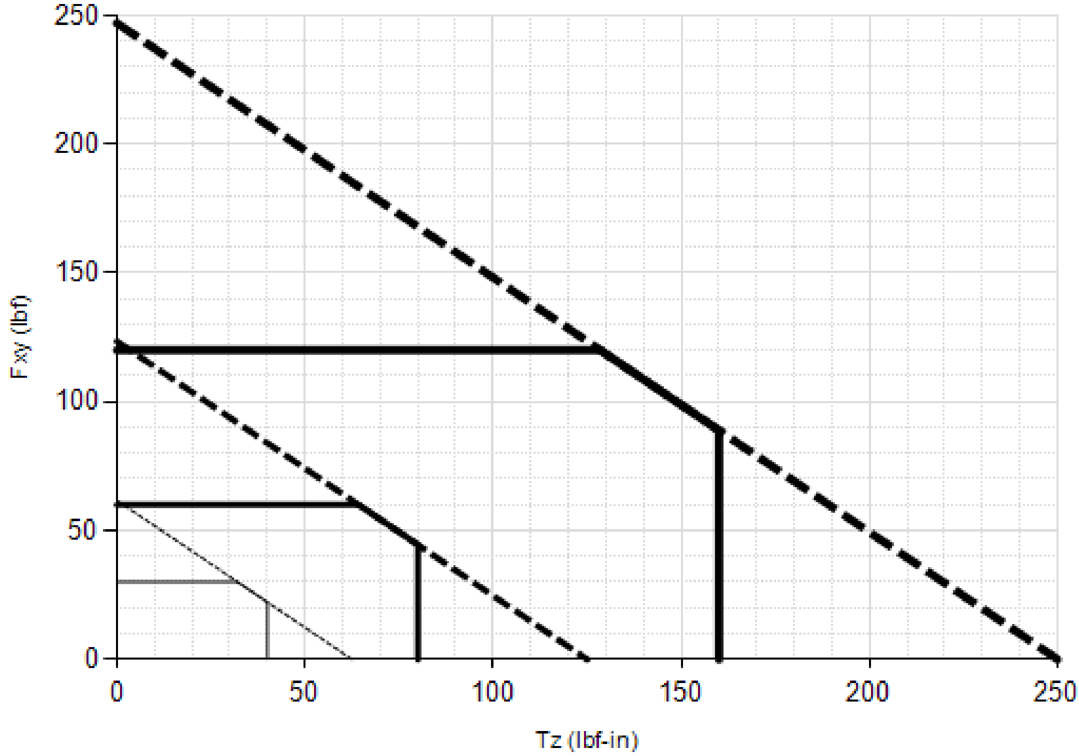
Notes:

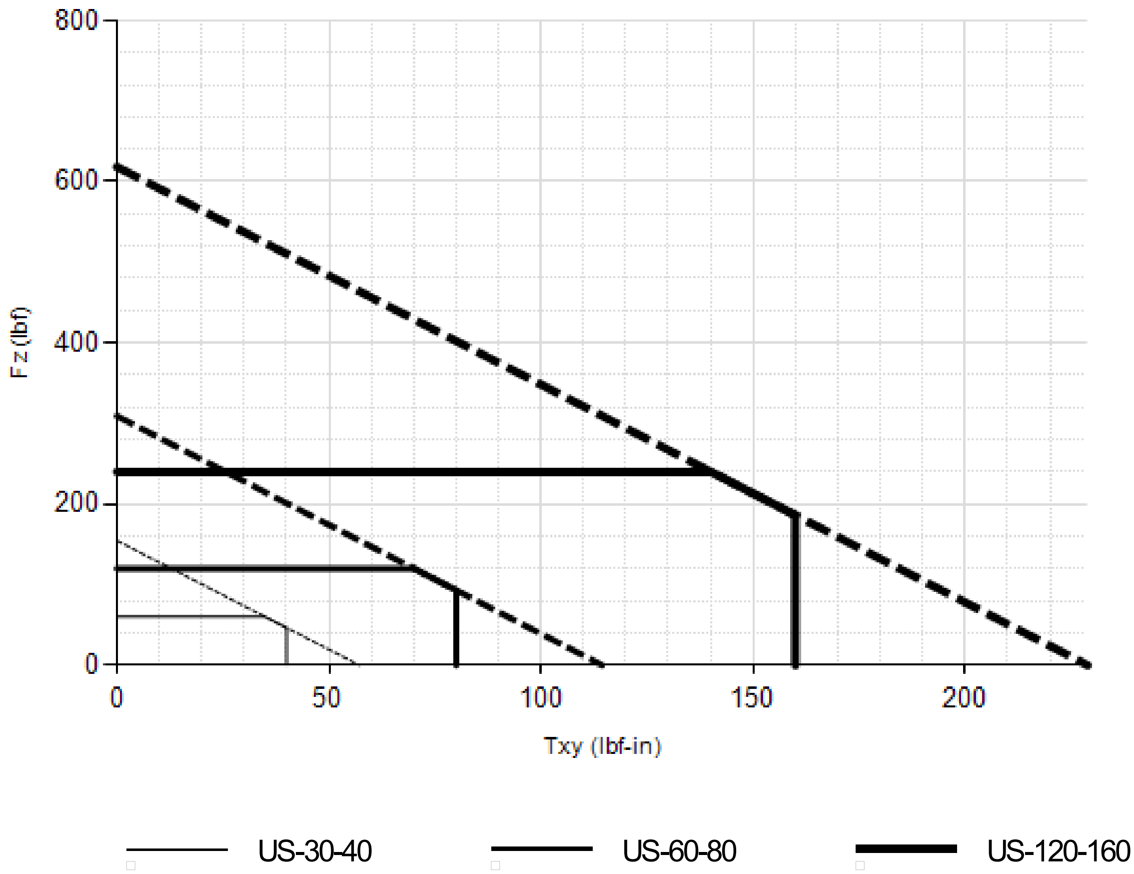
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.
2. For IP68 version see caution on physical properties page.

5.9.6 CTL Counts Value

Table 4.44—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ N)**	**Tx, Ty, Tz (/ Nm)**
Mini45	US-30–40 / SI-145–5	640	704	128	6016
Mini45	US-60–80 / SI-290–10	320	352	64	3008
Mini45	US-120–160 / SI-580–20	160	176	32	1504
Mini45	Tool Transform Factor	0.009091 in/lbf		0.21277 mm/N	
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

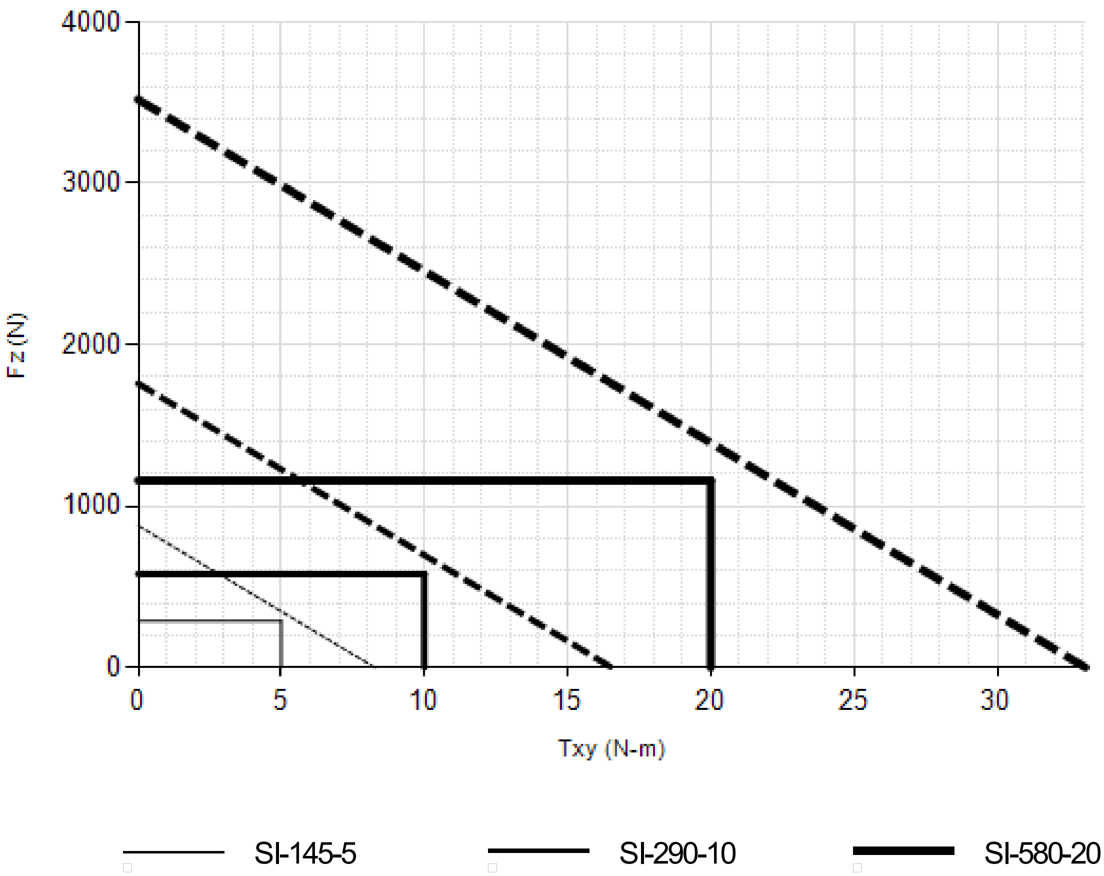
5.9.7 Mini45 (US Calibration Complex Loading)(Includes IP65/IP68)[1]





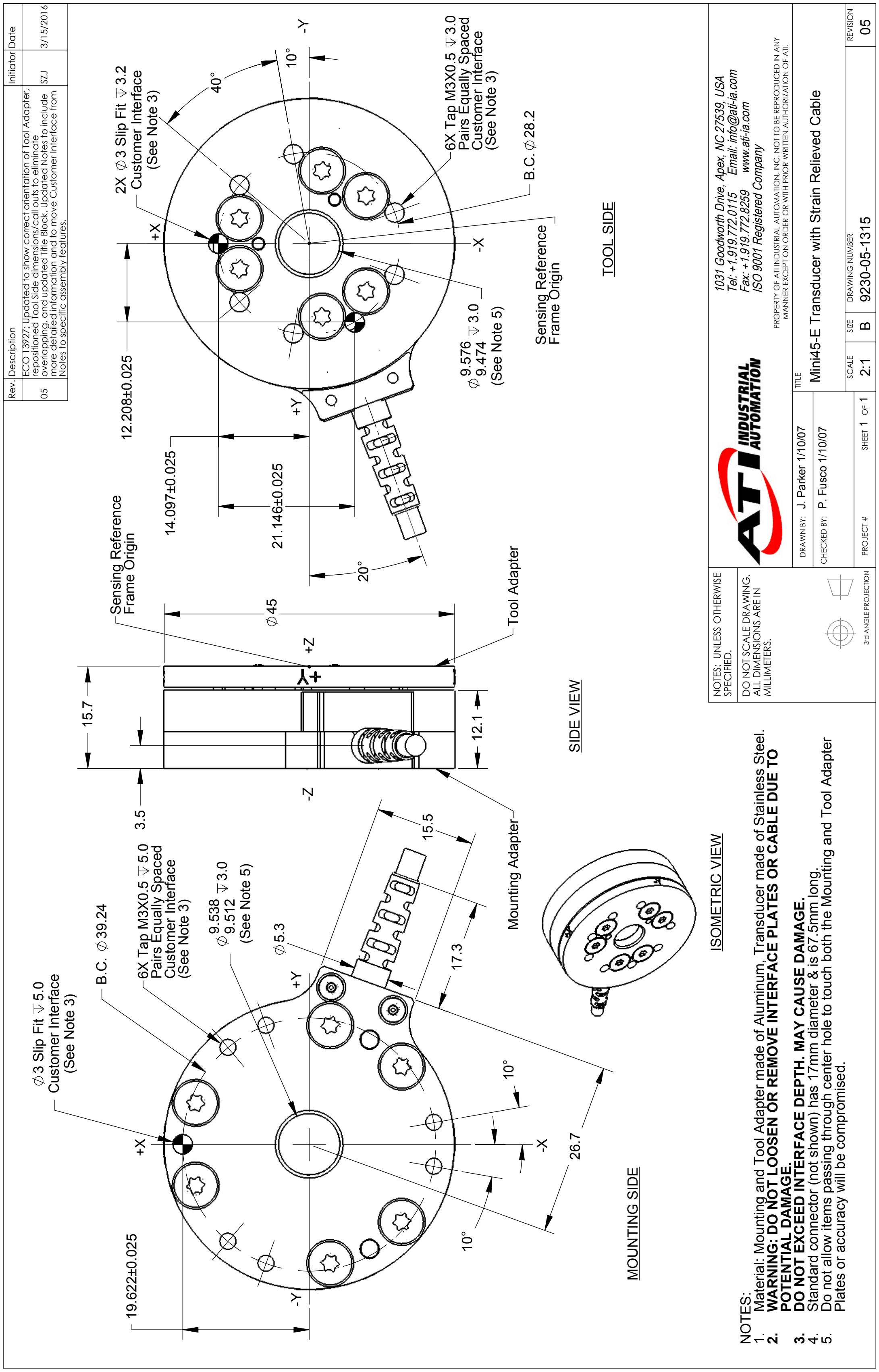
Note: 1. For IP68 version see caution on physical properties page.

5.9.8 Mini45 (SI Calibration Complex Loading)(Includes IP65/IP68)[1]

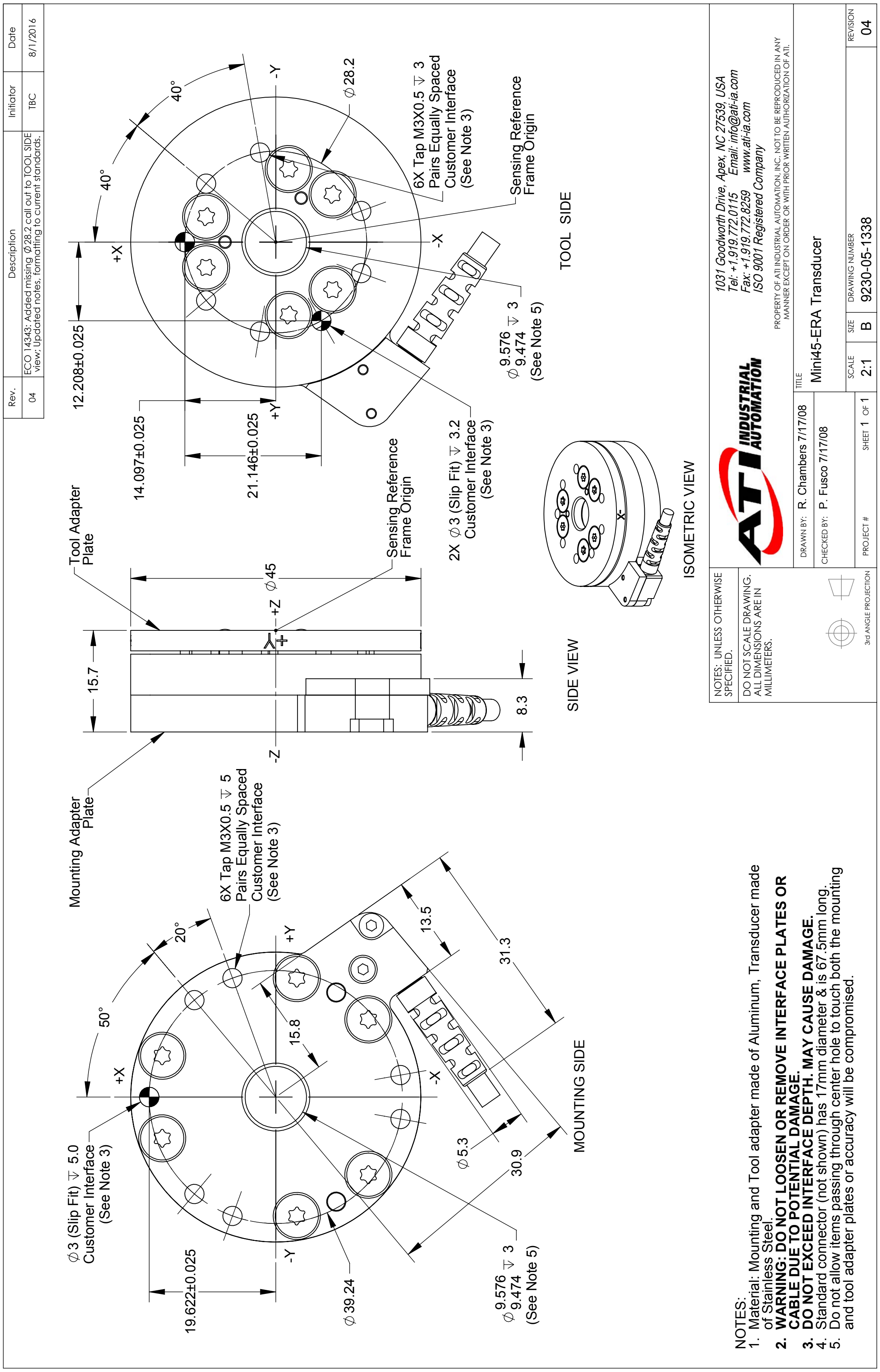


Note: 1. For IP68 version see caution on physical properties page.

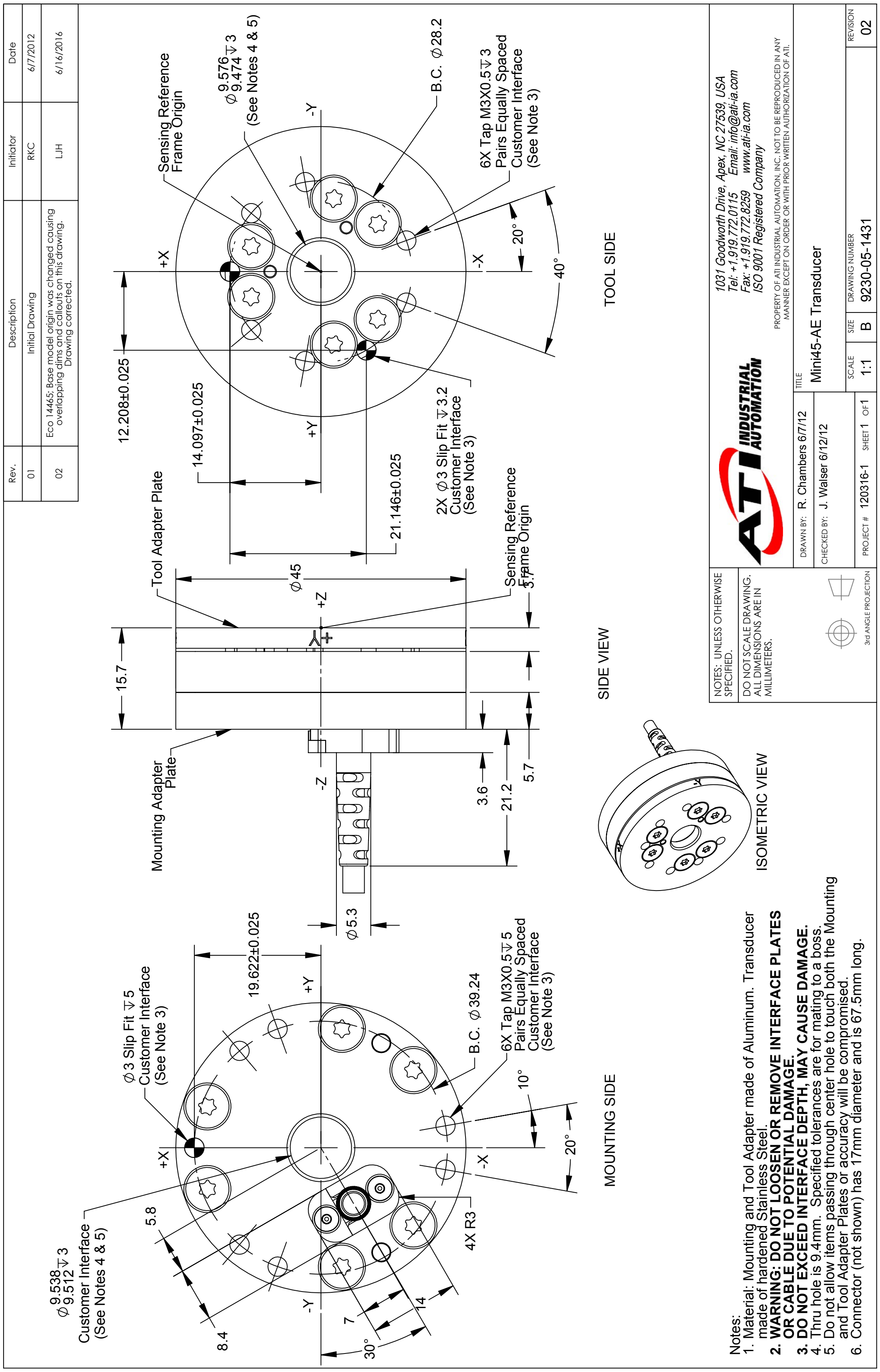
5.9.9 Mini45-E Transducer Drawing



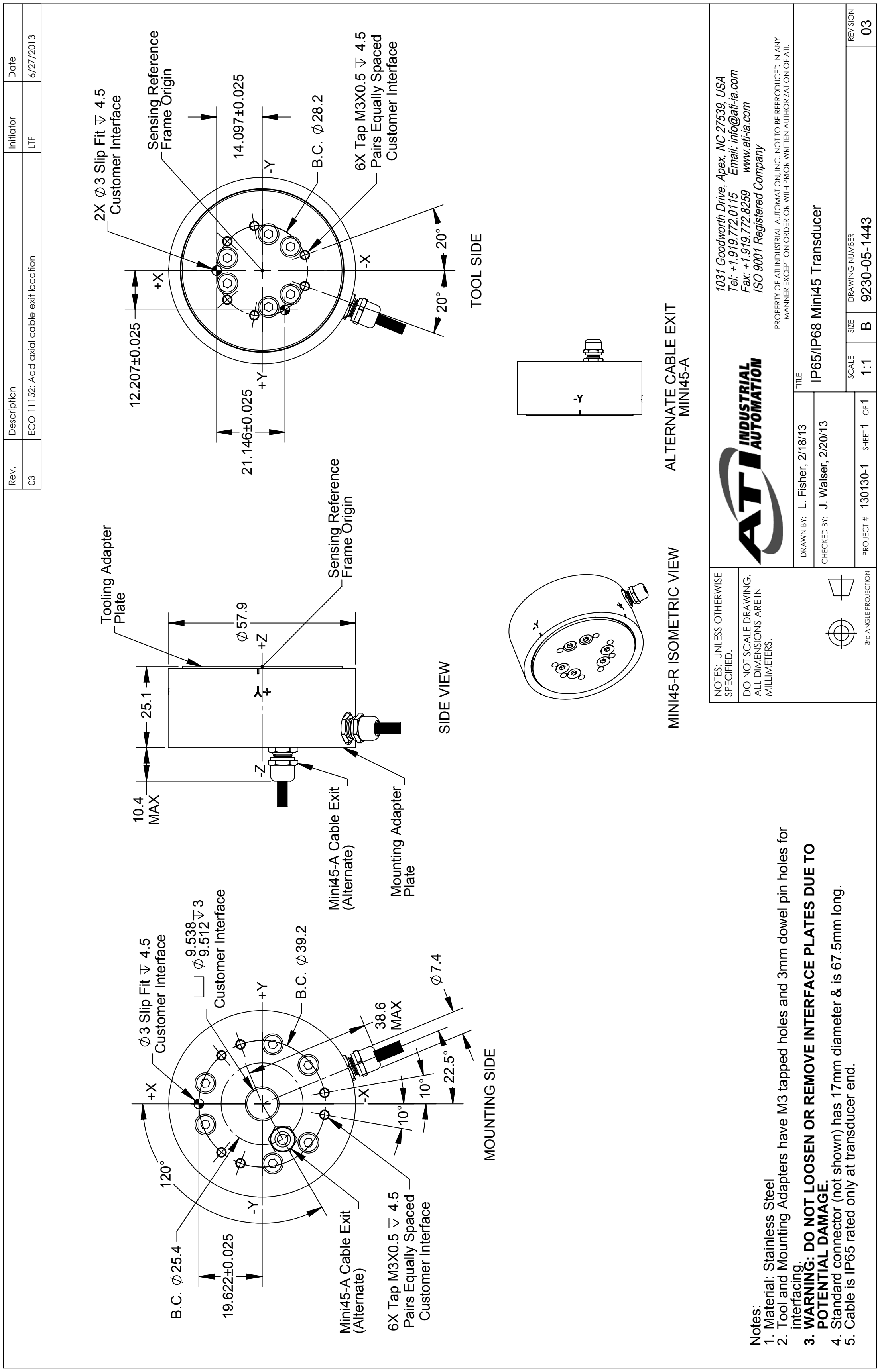
5.9.10 Mini45-ERA Transducer Drawing



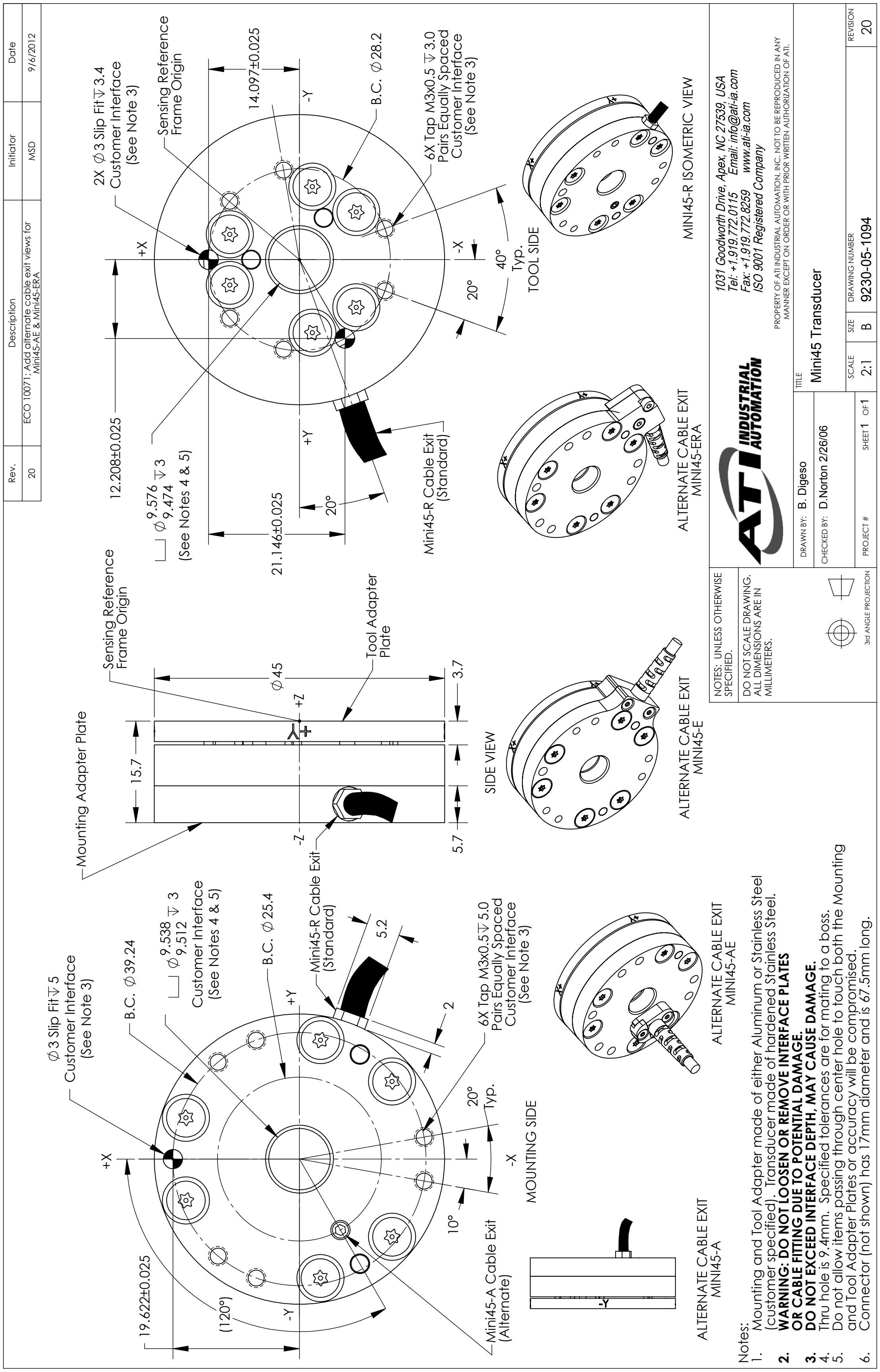
5.9.11 Mini45-AE Transducer Drawing



5.9.12 Mini45 IP65/IP68 Transducer Drawing



5.9.13 Legacy Mini45 Transducer Drawing



5.10 Mini58 Specifications (Includes IP60/IP65/IP68 Versions)

5.10.1 Mini58 Physical Properties

Table 4.45—Mini58 Physical Properties

Single-Axis Overload	(US) Standard Units	(SI) Metric Units
Fxy	±4800 lbf	±21000 N
Fz	±11000 lbf	±48000 N
Txy	±5300 inf-lb	±590 Nm
Tz	±7100 inf-lb	±800 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	1.4×10^6 lb/in	2.5×10^8 N/m
Z-axis force (Kz)	2.1×10^6 lb/in	3.7×10^8 N/m
X-axis & Y-axis torque (Ktx, Kty)	9.3×10^5 lbf-in/rad	1.1×10^5 Nm/rad
Z-axis torque (Ktz)	1.8×10^6 lbf-in/rad	2.0×10^5 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	3000 Hz	3000 Hz
Fz, Tx, Ty	5700 Hz	5700 Hz
Physical Specifications		
Weight[1]	0.76 lb	0.345 kg
Diameter[1]	2.28 in	58 mm
Height[1]	1.18 in	30 mm

Note:
1. Specifications include standard interface plates.

5.10.2 Mini58 IP60 Physical Properties

Table 4.46—Mini58 IP60 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±4800 lbf	±21000 N
Fz	±11000 lbf	±48000 N
Txy	±5300 inf-lb	±590 Nm
Tz	±7100 inf-lb	±800 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	1.4×10^6 lb/in	2.5×10^8 N/m
Z-axis force (Kz)	2.1×10^6 lb/in	3.7×10^8 N/m
X-axis & Y-axis torque (Ktx, Kty)	9.3×10^5 lbf-in/rad	1.1×10^5 Nm/rad
Z-axis torque (Ktz)	1.8×10^6 lbf-in/rad	2.0×10^5 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	N/A	N/A
Fz, Tx, Ty	N/A	N/A
Physical Specifications		
Weight[1]	1.15 lb	0.522 kg
Diameter[1]	3.23 in	82 mm
Height[1]	1.42 in	36.2 mm
Note: 1. Specifications include standard interface plates.		

5.10.3 Mini58 IP65/IP68 Physical Properties

Table 4.47—Mini58 IP65/IP68 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±4800 lbf	±21000 N
Fz	±11000 lbf	±48000 N
Txy	±5300 inf-lb	±590 Nm
Tz	±7100 inf-lb	±800 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	1.4×10^6 lb/in	2.5×10^8 N/m
Z-axis force (Kz)	2.1×10^6 lb/in	3.7×10^8 N/m
X-axis & Y-axis torque (Ktx, Kty)	9.3×10^5 lbf-in/rad	1.1×10^5 Nm/rad
Z-axis torque (Ktz)	1.8×10^6 lbf-in/rad	2.0×10^5 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	N/A	N/A
Fz, Tx, Ty	N/A	N/A
Physical Specifications		
Weight[1]	1.77 lb	0.804 kg
Diameter[1]	2.58 in	65.4 mm
Height[1]	1.48 in	37.6 mm
Note: 1. Specifications include standard interface plates.		

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

5.10.4 Calibration Specifications (excludes CTL calibrations)

Table 4.48— Mini58 Calibrations (excludes CTL calibrations)[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Mini58	US-150-250	150	375	250	250	5/112	1/16	1/20	7/240
Mini58	US-300-500	300	750	500	500	5/56	1/8	1/10	7/120
Mini58	US-600-1000	600	1500	1000	1000	5/28	1/4	1/5	7/60
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Mini58	SI-700-30	700	1700	30	30	1/6	7/24	9/1600	1/320
Mini58	SI-1400-60	1400	3400	60	60	1/3	7/12	9/800	1/160
Mini58	SI-2800-120	2800	6800	120	120	3/4	1 1/4	9/400	1/80
		Sensing Ranges				**Resolution (DAQ, Net F/T)[4]**			

Notes:
1. These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.
4. DAQ resolutions are typical for a 16-bit data acquisition system.

5.10.5 CTL Calibration Specifications

Table 4.49— Mini58 CTL Calibrations[1, 2]

Sensor	(US) Standard Calibration	Fx,Fy (lbf)	Fz[3] (lbf)	Tx,Ty (lbf-in)	Tz (lbf-in)	Fx,Fy (lbf)	Fz[3] (lbf)	Tx,Ty (lbf-in)	Tz (lbf-in)
Mini58	US-150-250	150	375	250	250	5/56	1/8	1/10	7/120
Mini58	US-300-500	300	750	500	500	5/28	1/4	1/5	7/60
Mini58	US-600-1000	600	1500	1000	1000	5/14	1/2	2/5	7/30
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Mini58	SI-700-30	700	1700	30	30	1/3	7/12	9/800	1/160
Mini58	SI-1400-60	1400	3400	60	60	2/3	1 1/6	9/400	1/80
Mini58	SI-2800-120	2800	6800	120	120	1 1/2	2 1/2	9/200	1/40
		Sensing Ranges				**Resolution (Controller)**			

Notes:
1. 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.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.

5.10.6 CTL Analog Output

Table 4.50— Mini58 Analog Output

Sensor	(US) Standard Calibration	Fx,Fy (lbf)	Fz[2] (lbf)	Tx,Ty,Tz (lbf-in)	Fx,Fy (lbf/V)	Fz[2] (lbf/V)	Tx,Ty,Tz (lbf-in/V)
Mini58	US-150-250	±150	±375	±250	15	37.5	25
Mini58	US-300-500	±300	±750	±500	30	75	50
Mini58	US-600-1000	±600	±1500	±1000	60	150	100
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[2] (N)**	**Tx,Ty,Tz (Nm)**	**Fx,Fy (N/V)**	**Fz[2] (N/V)**	**Tx,Ty,Tz (Nm/V)**
Mini58	SI-700-30	±700	±1700	±30	70	170	3
Mini58	SI-1400-60	±1400	±3400	±60	140	340	6
Mini58	SI-2800-120	±2800	±6800	±120	280	680	12
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

Notes:
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.
2. For IP68 version see caution on physical properties page.

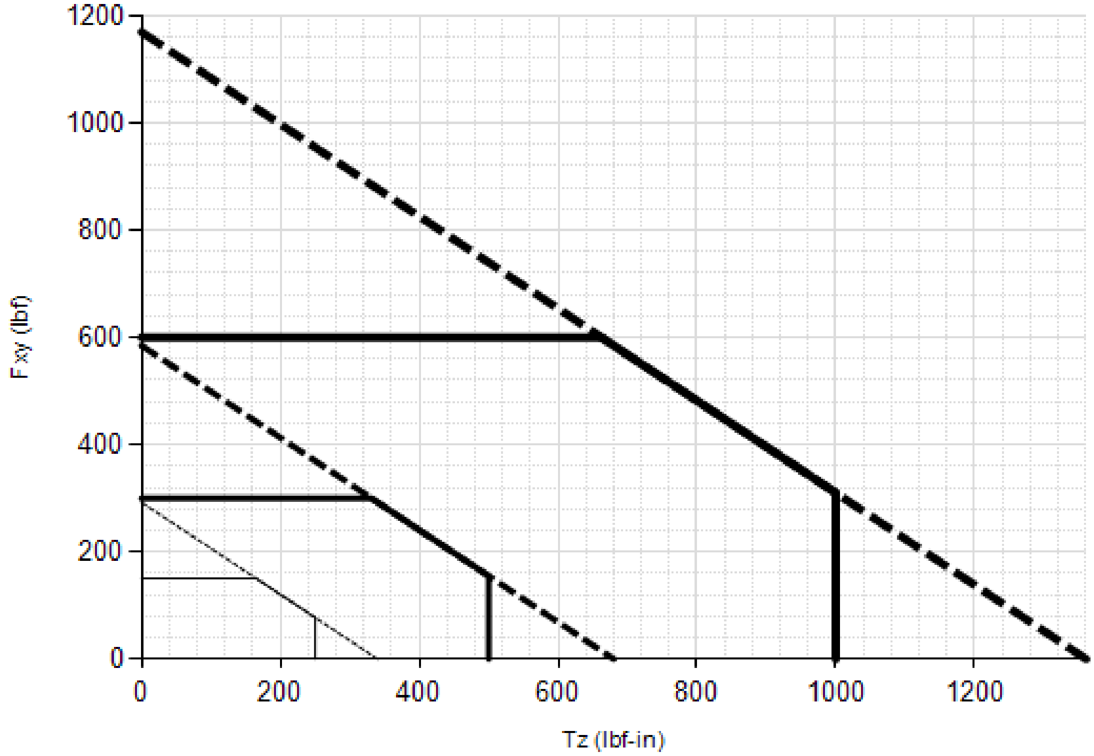
5.10.7 CTL Counts Value

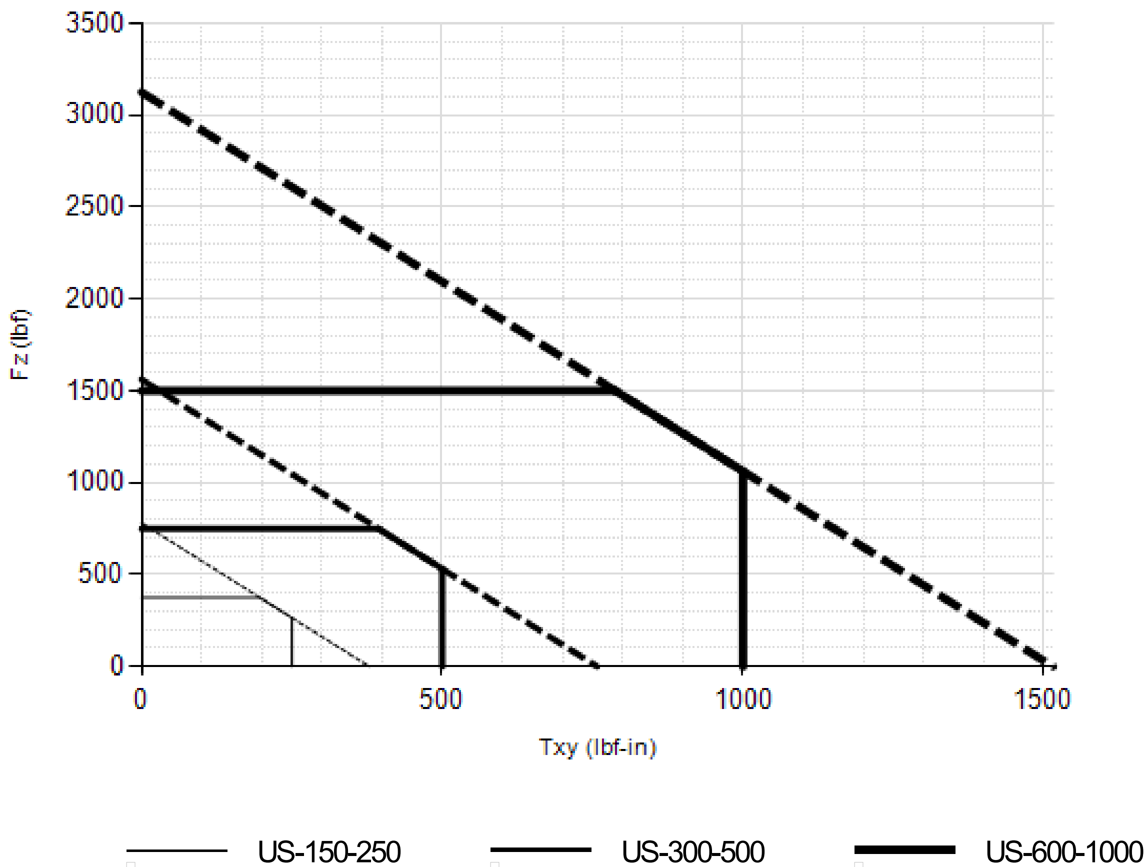
Table 4.51—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ N)**	**Tx, Ty, Tz (/ Nm)**
Mini58	US-150-250 / SI-700-30	448	960	96	6400
Mini58	US-300-500 / SI-1400-60	224	480	48	3200
Mini58	US-600-1000 / SI-2800-120	112	240	16	1600
Mini58	Tool Transform Factor	See Tool Transform Factor table			
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

5.10.8 Tool Transform Factor

Table 4.52—Tool Transform Factor			
Sensor	**Calibration**	**US (English)**	SI (Metric)
Mini58	US-150-250 / SI-700-30	0.00467 in/lbf	0.150 mm/N
Mini58	US-300-500 / SI-1400-60	0.00467 in/lbf	0.150 mm/N
Mini58	US-600-1000 / SI-2800-120	0.00467 in/lbf	0.150 mm/N

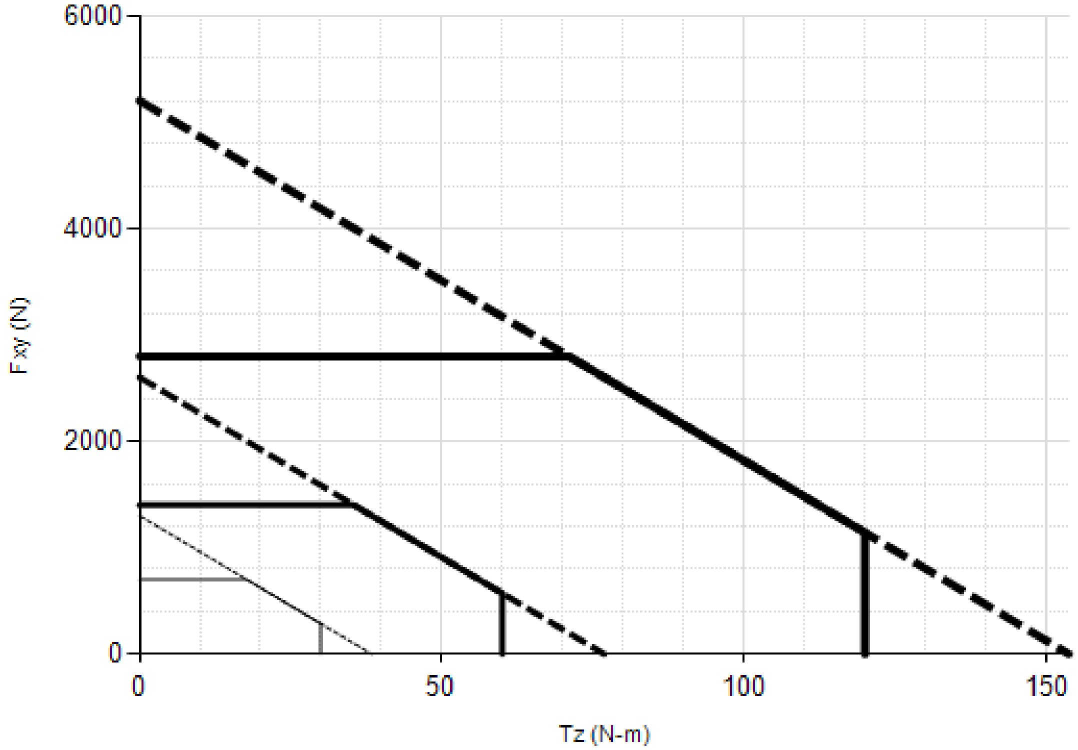
5.10.9 Mini58 (US Calibration Complex Loading)(Includes IP60/IP65/IP68)[1]

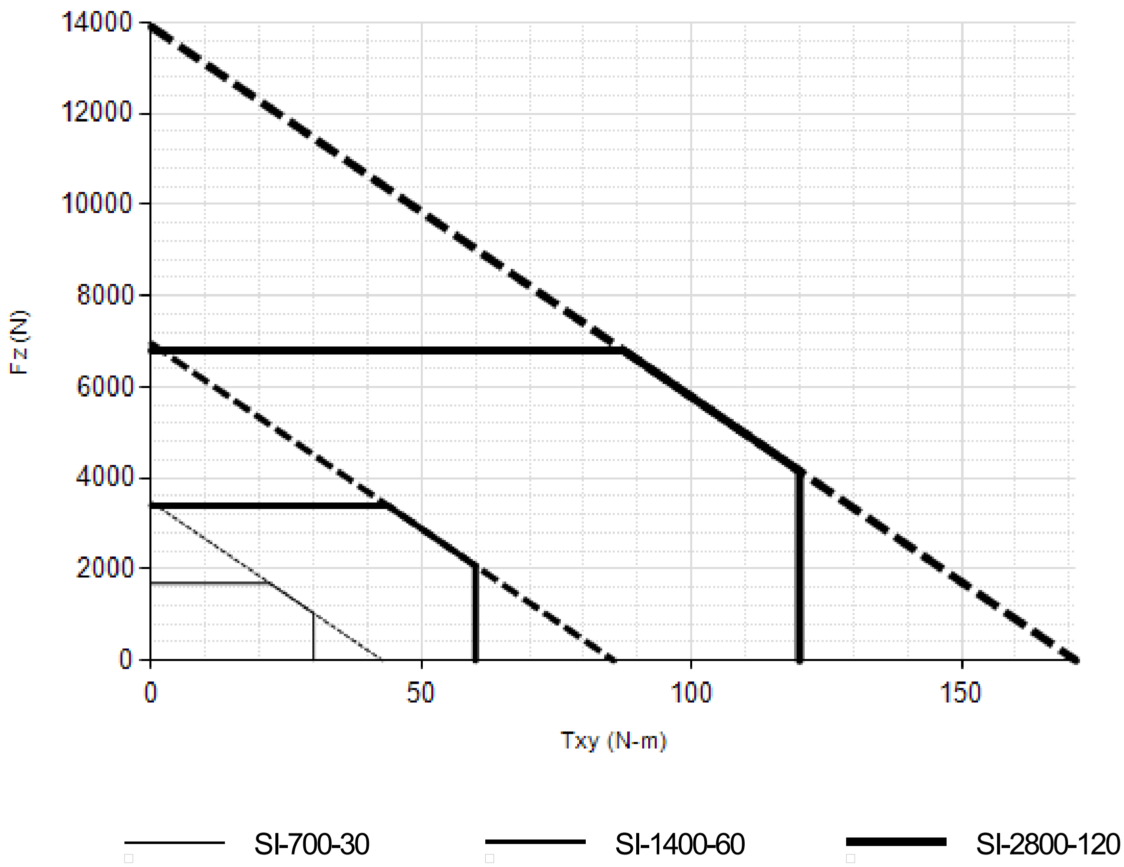




Note: 1. For IP68 version see caution on physical properties page.

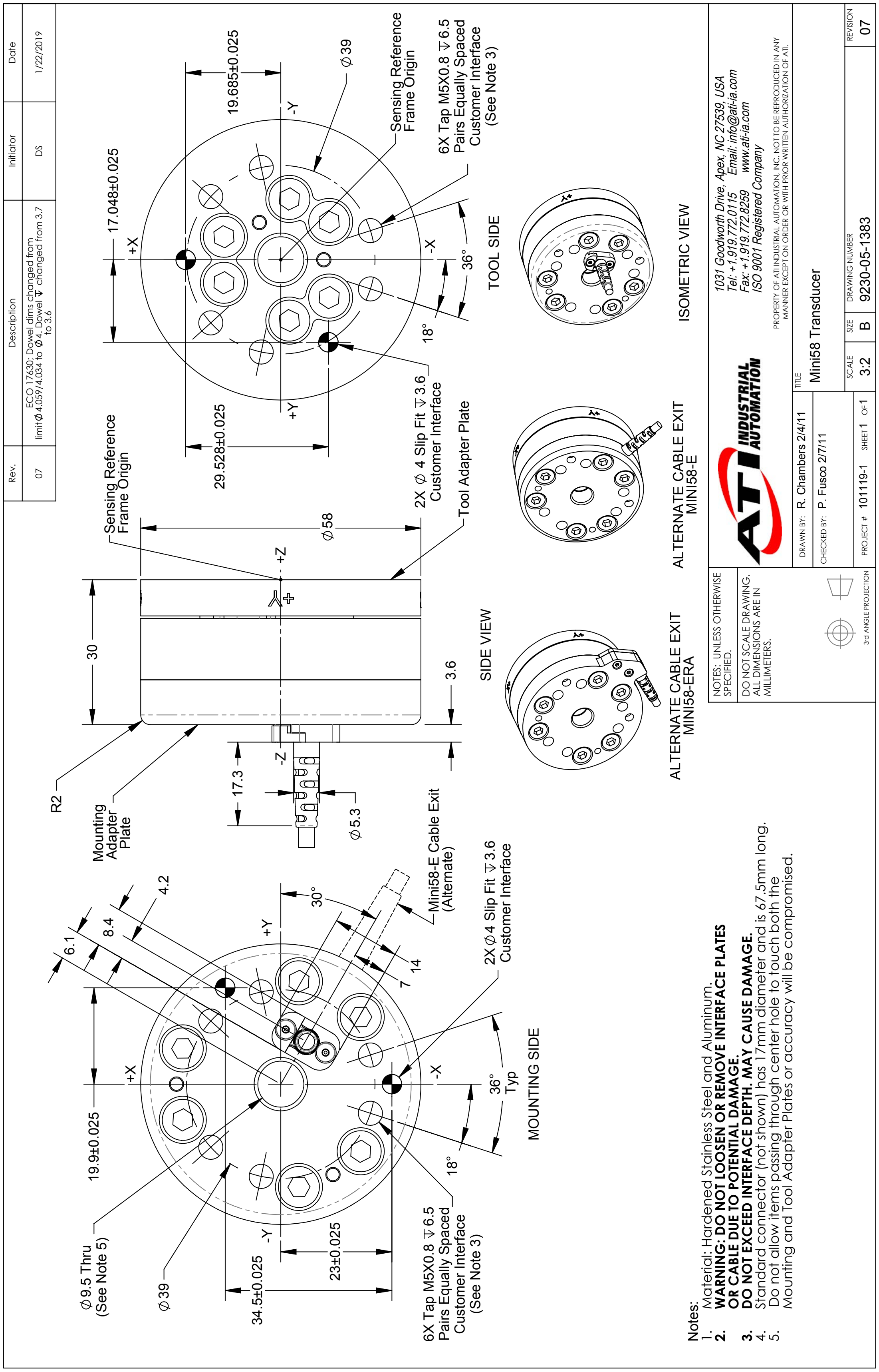
5.10.10 Mini58 (SI Calibration Complex Loading)(Includes IP60/IP65/IP68)[1]



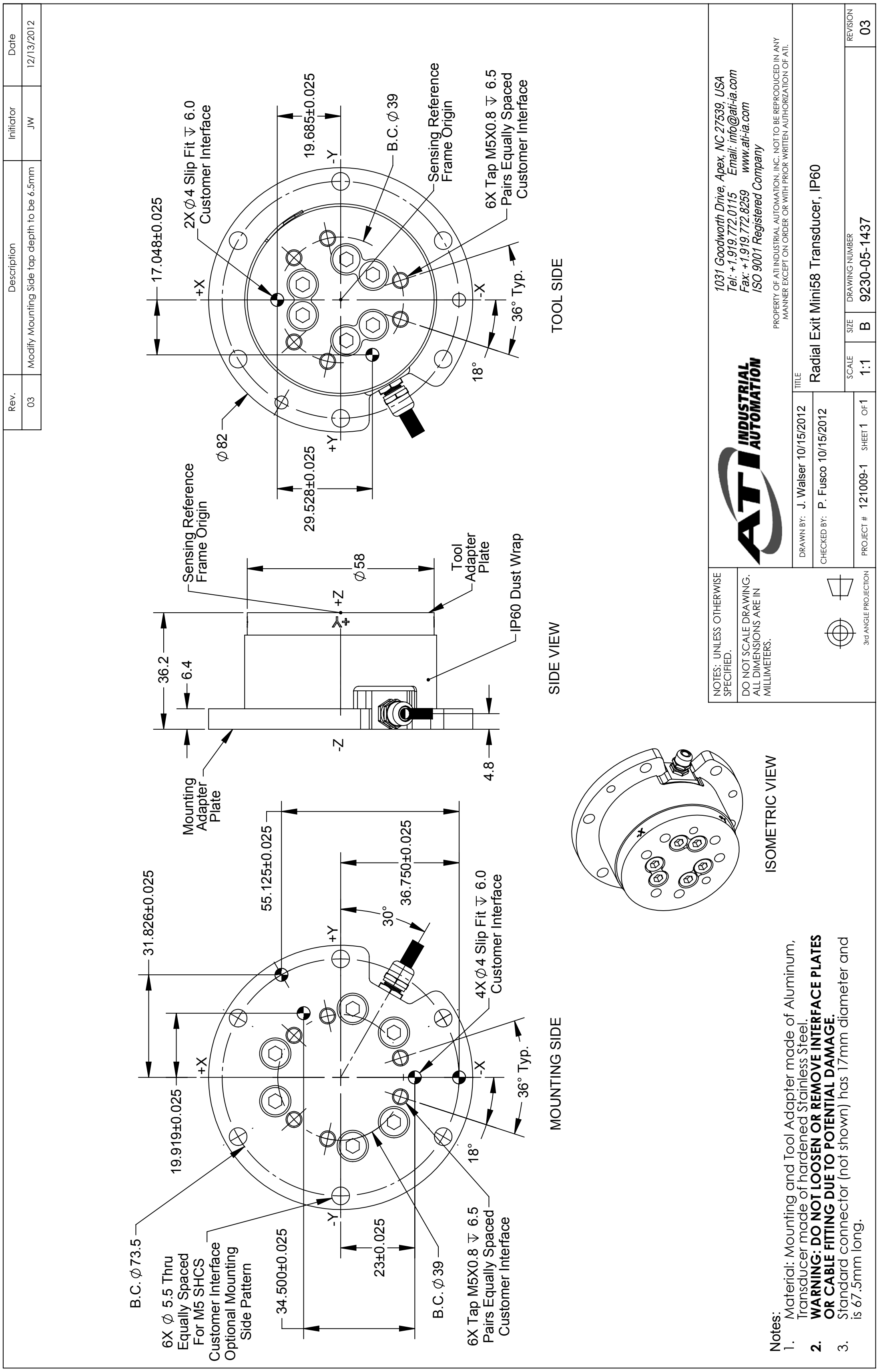


Note: 1. For IP68 version see caution on physical properties page.

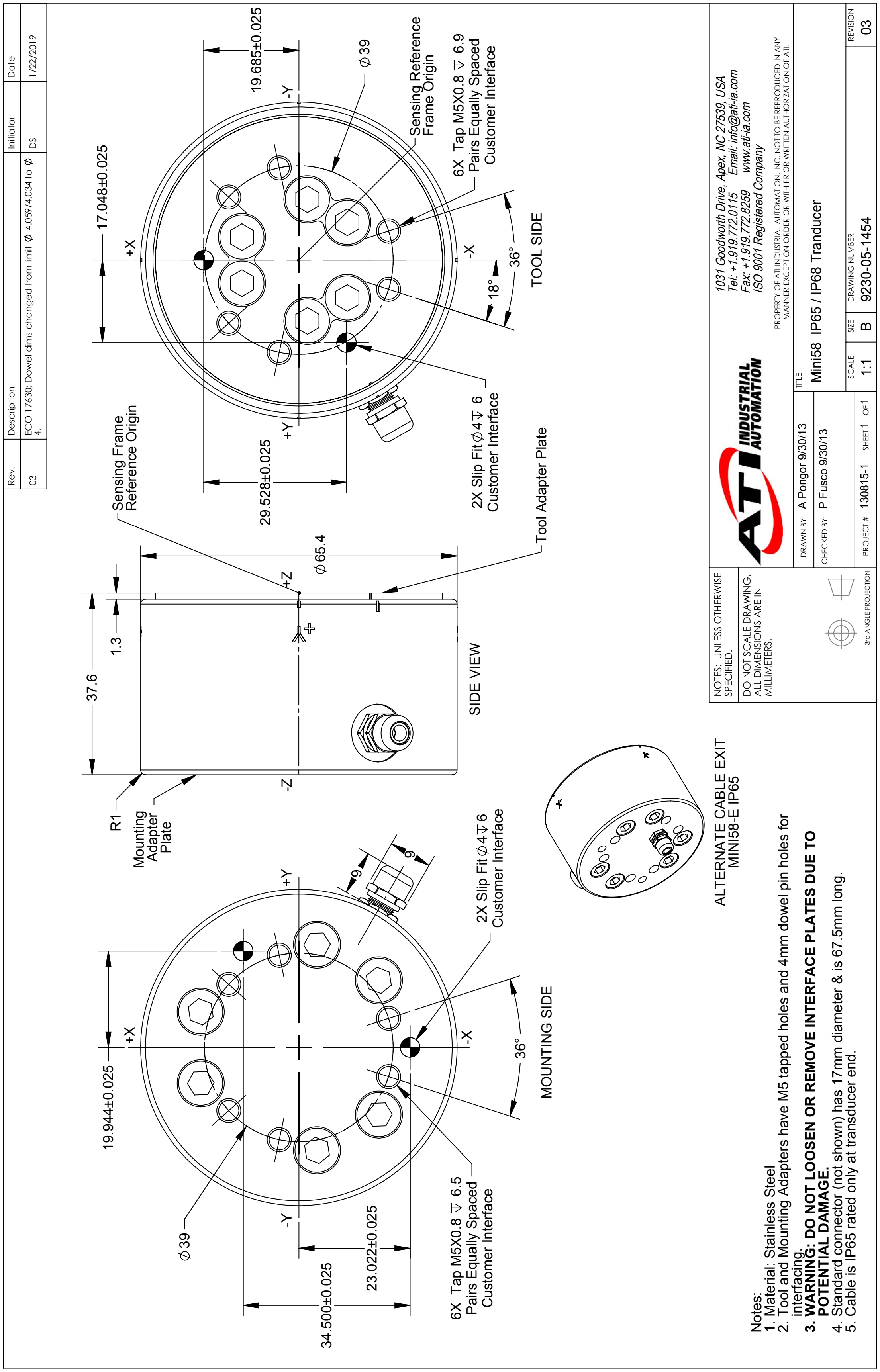
5.10.11 Mini58 Transducer Drawing



5.10.12 Mini58 IP60 Transducer Drawing



5.10.13 Mini58 IP65/IP68 Transducer Drawing



5.11 Mini85 Specifications (Includes IP60 Versions)

5.11.1 Mini85 Physical Properties

Table 4.53—Mini85 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±2800 lbf	±13000 N
Fz	±6100 lbf	±27000 N
Txy	±4400 inf-lb	±500 Nm
Tz	±5400 inf-lb	±610 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	4.4×10^5 lb/in	7.7×10^7 N/m
Z-axis force (Kz)	6.8×10^5 lb/in	1.2×10^8 N/m
X-axis & Y-axis torque (Ktx, Kty)	7.2×10^5 lbf-in/rad	8.1×10^4 Nm/rad
Z-axis torque (Ktz)	1.2×10^6 lbf-in/rad	1.3×10^5 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	2400 Hz	2400 Hz
Fz, Tx, Ty	3100 Hz	3100 Hz
Physical Specifications		
Weight[1]	1.4 lb	0.635 kg
Diameter[1]	3.35 in	85.1 mm
Height[1]	1.17 in	29.8 mm

Note:
1. Specifications include standard interface plates.

5.11.2 Calibration Specifications (excludes CTL calibrations)

Table 4.54— Mini85 Calibrations (excludes CTL calibrations)[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Mini85	US-105-185	105	210	185	185	1/52	7/260	5/168	1/48
Mini85	US-210-370	210	420	370	370	5/128	3/64	5/84	1/24
Mini85	US-420-740	420	840	740	740	5/64	3/32	5/42	1/12
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Mini85	SI-475-20	475	950	20	20	9/112	3/28	5/1496	7/2992
Mini85	SI-950-40	950	1900	40	40	9/56	3/14	5/748	7/1496
Mini85	SI-1900-80	1900	3800	80	80	9/28	3/7	5/374	7/748
		Sensing Ranges				**Resolution (DAQ, Net F/T)[3]**			

Notes:
1. These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. DAQ resolutions are typical for a 16-bit data acquisition system.

5.11.3 CTL Calibration Specifications

Table 4.55— Mini85 CTL Calibrations[1, 2]

Sensor	(US) Standard Calibration	Fx,Fy (lbf)	Fz (lbf)	Tx,Ty (lbf-in)	Tz (lbf-in)	Fx,Fy (lbf)	Fz (lbf)	Tx,Ty (lbf-in)	Tz (lbf-in)
Mini85	US-105-185	105	210	185	185	1/26	7/130	5/84	1/24
Mini85	US-210-370	210	420	370	370	5/64	3/32	5/42	1/12
Mini85	US-420-740	420	840	740	740	5/32	3/16	5/21	1/6
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Mini85	SI-475-20	475	950	20	20	9/56	3/14	5/748	7/1496
Mini85	SI-950-40	950	1900	40	40	9/28	3/7	5/374	7/748
Mini85	SI-1900-80	1900	3800	80	80	9/14	6/7	5/187	7/374
		Sensing Ranges				**Resolution (Controller)**			

Notes:

1. 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.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.

5.11.4 CTL Analog Output

Table 4.56— Mini85 Analog Output

Sensor	(US) Standard Calibration	Fx,Fy (lbf)	Fz (lbf)	Tx,Ty,Tz (lbf-in)	Fx,Fy (lbf/V)	Fz (lbf/V)	Tx,Ty,Tz (lbf-in/V)
Mini85	US-105-185	±105	±210	±185	10.5	21	18.5
Mini85	US-210-370	±210	±420	±370	21	42	37
Mini85	US-420-740	±420	±840	±740	42	84	74
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty,Tz (Nm)**	**Fx,Fy (N/V)**	**Fz (N/V)**	**Tx,Ty,Tz (Nm/V)**
Mini85	SI-475-20	±475	±950	±20	47.5	95	2
Mini85	SI-950-40	±950	±1900	±40	95	190	4
Mini85	SI-1900-80	±1900	±3800	±80	190	380	8
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

Note:

1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.

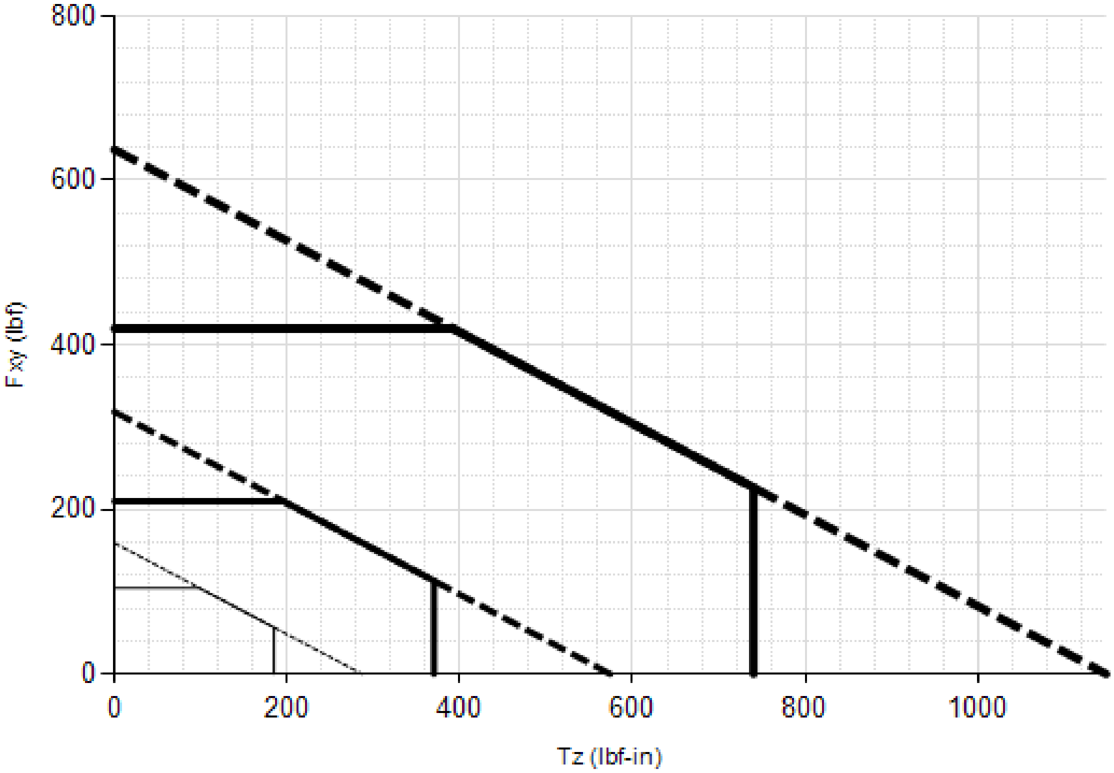
5.11.5 CTL Counts Value

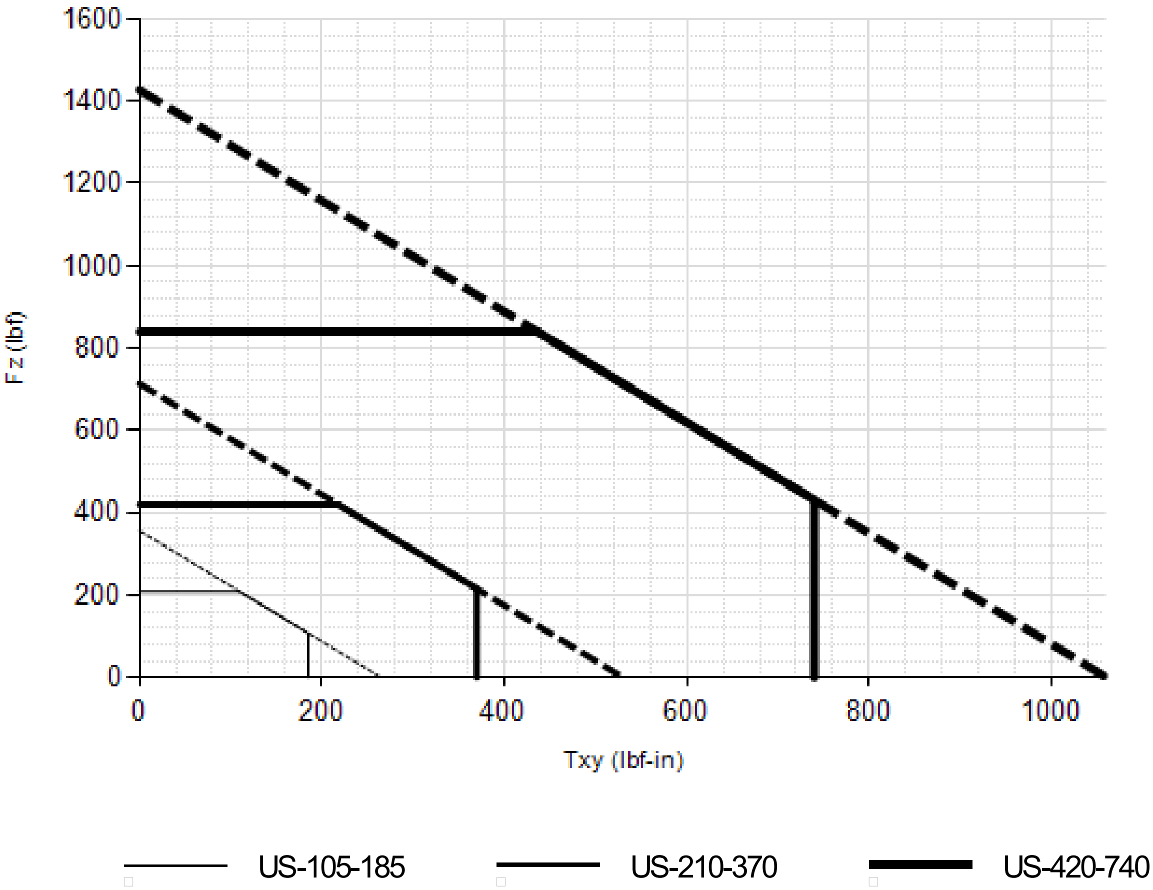
Table 4.57—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ N)**	**Tx, Ty, Tz (/ Nm)**
Mini85	US-105-185 / SI-475-20	1040	1344	448	11968
Mini85	US-210-370 / SI-950-40	512	672	224	5984
Mini85	US-420-740 / SI-1900-80	256	336	112	2992
Mini85	Tool Transform Factor	See Tool Transform Factor table			
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

5.11.6 Tool Transform Factor

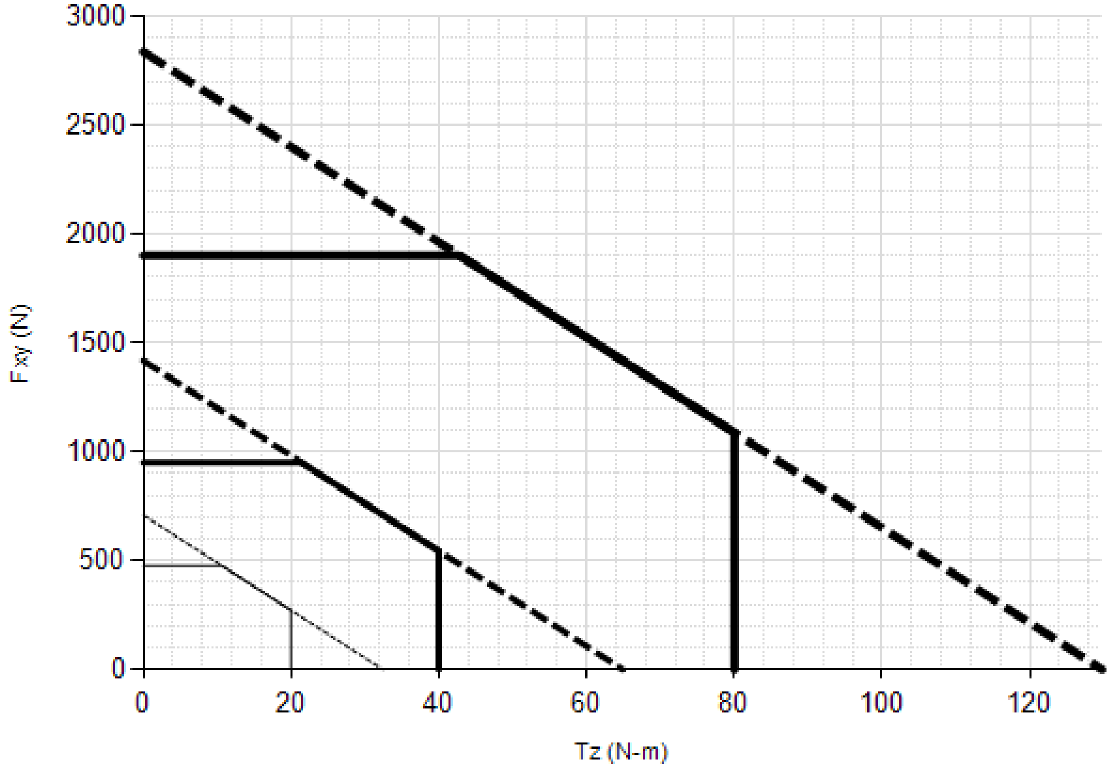
Table 4.58—Tool Transform Factor			
Sensor	**Calibration**	**US (English)**	SI (Metric)
Mini85	US-105-185 / SI-475-20	0.00774 in/lbf	0.374 mm/N
Mini85	US-210-370 / SI-950-40	0.00762 in/lbf	0.374 mm/N
Mini85	US-420-740 / SI-1900-80	0.00762 in/lbf	0.374 mm/N

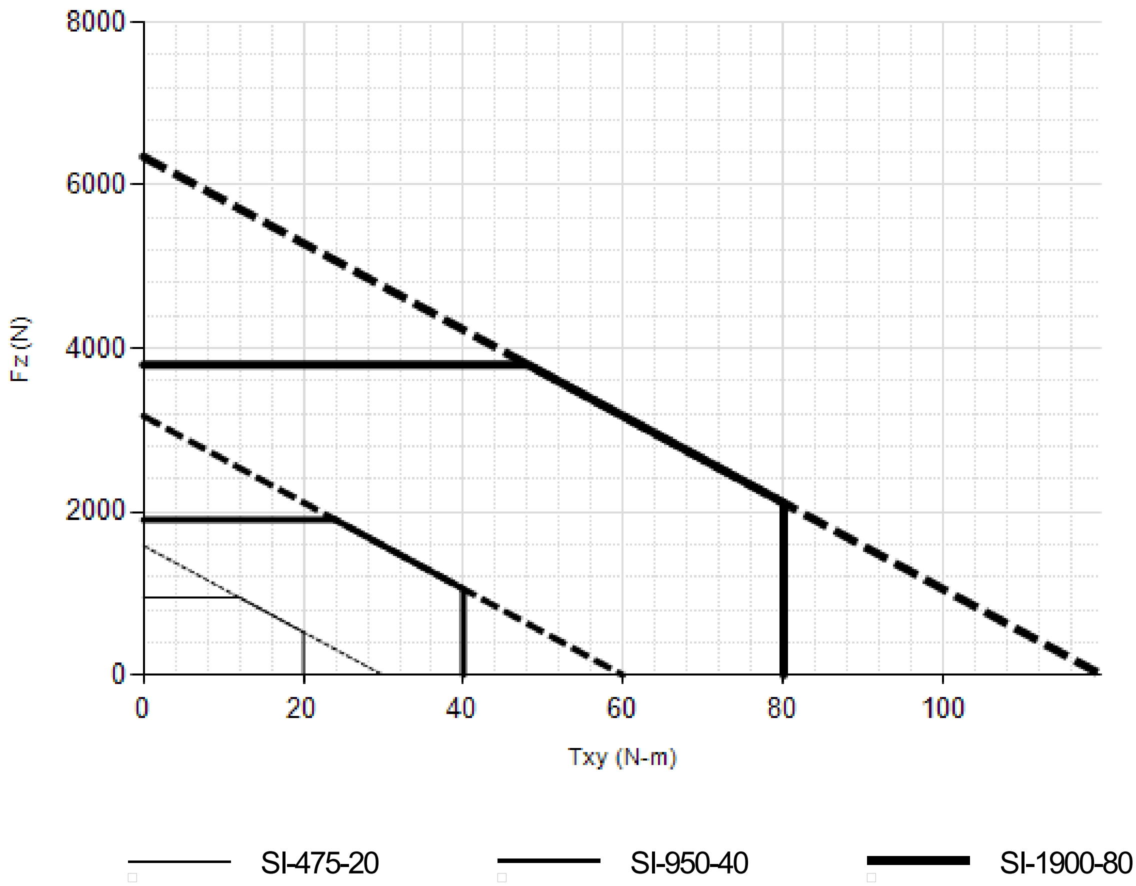
5.11.7 Mini85 (US Calibration Complex Loading)(Includes IP60)



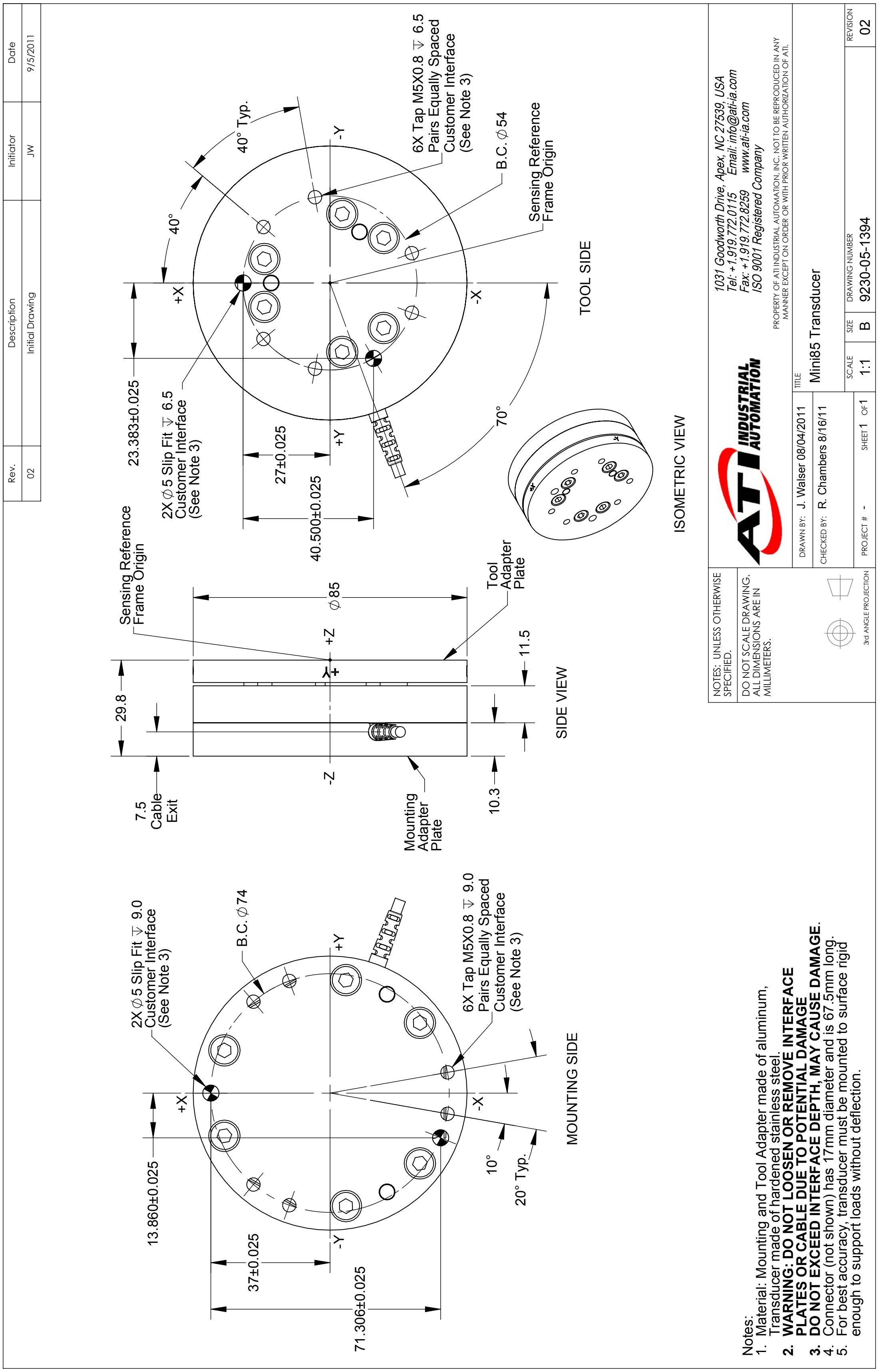


5.11.8 Mini85 (SI Calibration Complex Loading)(Includes IP60)

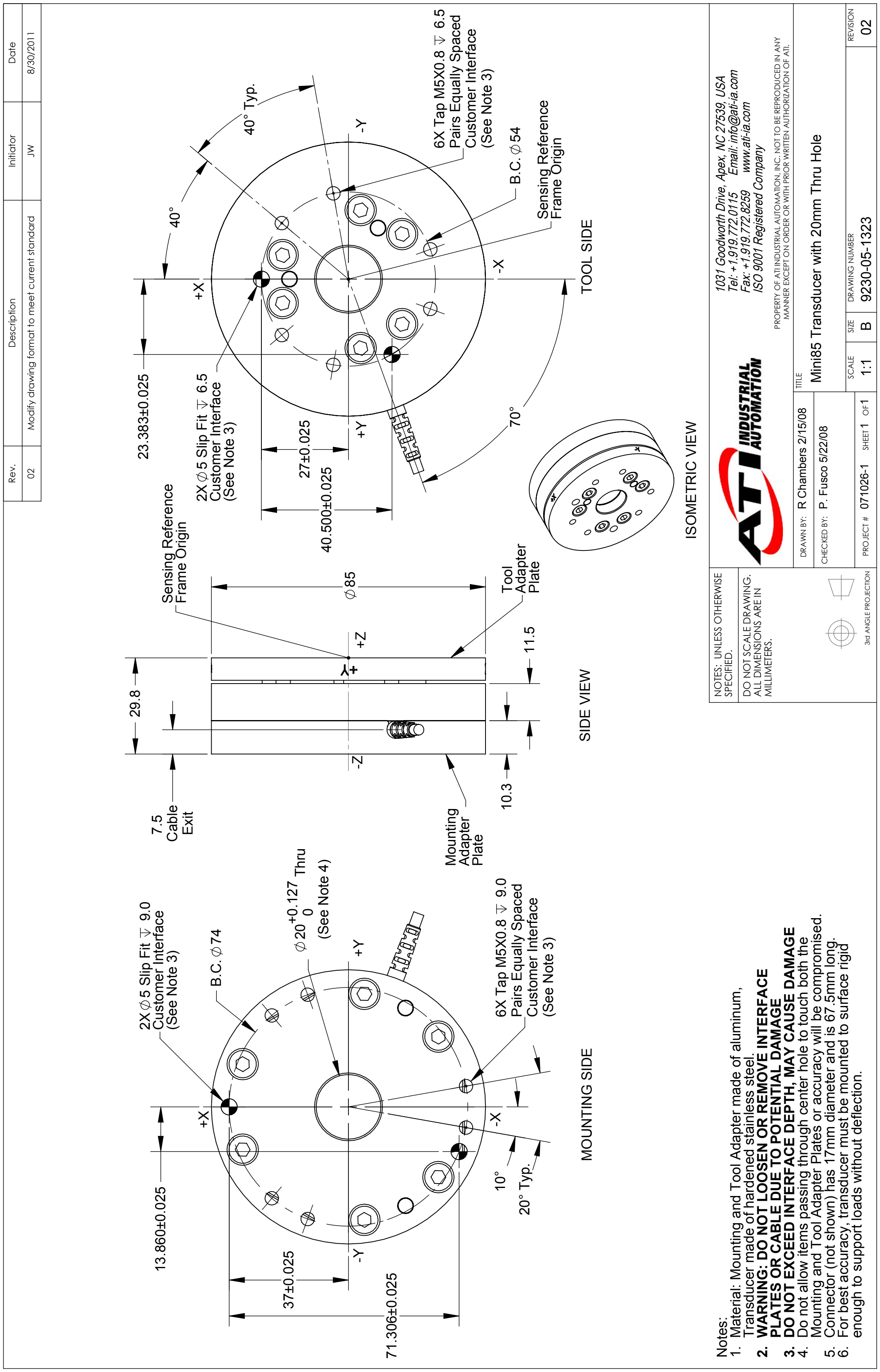




5.11.9 Mini85-E Transducer Drawing



5.11.10 Mini85 IP60 Transducer with 20mm Through-Hole Drawing



5.12 Gamma Specifications (Includes IP60/IP65/IP68 Versions)

5.12.1 Gamma Physical Properties

Table 4.59—Gamma Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±280 lbf	±1200 N
Fz	±930 lbf	±4100 N
Txy	±700 inf-lb	±79 Nm
Tz	±730 inf-lb	±82 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	5.2×10^4 lb/in	9.1×10^6 N/m
Z-axis force (Kz)	1.0×10^5 lb/in	1.8×10^7 N/m
X-axis & Y-axis torque (Ktx, Kty)	9.3×10^4 lbf-in/rad	1.1×10^4 Nm/rad
Z-axis torque (Ktz)	1.4×10^5 lbf-in/rad	1.6×10^4 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	1400 Hz	1400 Hz
Fz, Tx, Ty	2000 Hz	2000 Hz
Physical Specifications		
Weight[1]	0.562 lb	0.255 kg
Diameter[1]	2.97 in	75.4 mm
Height[1]	1.31 in	33.3 mm

Note:
1. Specifications include standard interface plates.

5.12.2 Gamma IP60 Physical Properties

Table 4.60—Gamma IP60 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±280 lbf	±1200 N
Fz	±930 lbf	±4100 N
Txy	±700 inf-lb	±79 Nm
Tz	±730 inf-lb	±82 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	5.2×10^4 lb/in	9.1×10^6 N/m
Z-axis force (Kz)	1.0×10^5 lb/in	1.8×10^7 N/m
X-axis & Y-axis torque (Ktx, Kty)	9.3×10^4 lbf-in/rad	1.1×10^4 Nm/rad
Z-axis torque (Ktz)	1.4×10^5 lbf-in/rad	1.6×10^4 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	1200 Hz	1200 Hz
Fz, Tx, Ty	1200 Hz	1200 Hz
Physical Specifications		
Weight[1]	1.03 lb	0.467 kg
Diameter[1]	3.9 in	99.1 mm
Height[1]	1.56 in	39.6 mm

Note:
1. Specifications include standard interface plates.

5.12.3 Gamma IP65 Physical Properties

Table 4.61—Gamma IP65 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±280 lbf	±1200 N
Fz	±930 lbf	±4100 N
Txy	±700 inf-lb	±79 Nm
Tz	±730 inf-lb	±82 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	$5.2x10^4$ lb/in	$9.1x10^6$ N/m
Z-axis force (Kz)	$1.0x10^5$ lb/in	$1.8x10^7$ N/m
X-axis & Y-axis torque (Ktx, Kty)	$9.3x10^4$ lbf-in/rad	$1.1x10^4$ Nm/rad
Z-axis torque (Ktz)	$1.4x10^5$ lbf-in/rad	$1.6x10^4$ Nm/rad
Resonant Frequency		
Fx, Fy, Tz	1000 Hz	1000 Hz
Fz, Tx, Ty	970 Hz	970 Hz
Physical Specifications		
Weight[1]	2.4 lb	1.09 kg
Diameter[1]	4.37 in	111 mm
Height[1]	2.06 in	52.3 mm
Note: 1. Specifications include standard interface plates.		

5.12.4 Gamma IP68 Physical Properties

Table 4.62—Gamma IP68 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±280 lbf	±1200 N
Fz	±930 lbf	±4100 N
Txy	±700 inf-lb	±79 Nm
Tz	±730 inf-lb	±82 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	$5.2x10^4$ lb/in	$9.1x10^6$ N/m
Z-axis force (Kz)	$1.0x10^5$ lb/in	$1.8x10^7$ N/m
X-axis & Y-axis torque (Ktx, Kty)	$9.3x10^4$ lbf-in/rad	$1.1x10^4$ Nm/rad
Z-axis torque (Ktz)	$1.4x10^5$ lbf-in/rad	$1.6x10^4$ Nm/rad
Resonant Frequency		
Fx, Fy, Tz	1250 Hz	1250 Hz
Fz, Tx, Ty	940 Hz	940 Hz
Physical Specifications		
Weight[1]	4.37 lb	1.98 kg
Diameter[1]	4.37 in	111 mm
Height[1]	2.06 in	52.3 mm
Note: 1. Specifications include standard interface plates.		

CAUTION: 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.

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

5.12.5 Calibration Specifications (excludes CTL calibrations)

Table 4.63— Gamma Calibrations (excludes CTL calibrations)[1, 2]

Sensor	(US) Standard Calibration	Fx,Fy (lbf)	Fz[3] (lbf)	Tx,Ty (lbf-in)	Tz (lbf-in)	Fx,Fy (lbf)	Fz[3] (lbf)	Tx,Ty (lbf-in)	Tz (lbf-in)
Gamma	US-7.5-25	7.5	25	25	25	1/640	1/320	1/320	1/320
Gamma	US-15-50	15	50	50	50	1/320	1/160	1/160	1/160
Gamma	US-30-100	30	100	100	100	1/160	1/80	1/80	1/80
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Gamma	SI-32-2.5	32	100	2.5	2.5	1/160	1/80	1/2000	1/2000
Gamma	SI-65-5	65	200	5	5	1/80	1/40	10/13333	10/13333
Gamma	SI-130-10	130	400	10	10	1/40	1/20	1/800	1/800
		Sensing Ranges				**Resolution (DAQ, Net F/T)[4]**			

Notes:

1. These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.
4. DAQ resolutions are typical for a 16-bit data acquisition system.

5.12.6 CTL Calibration Specifications

Table 4.64— Gamma CTL Calibrations[1, 2]

Sensor	(US) Standard Calibration	Fx,Fy (lbf)	Fz[3] (lbf)	Tx,Ty (lbf-in)	Tz (lbf-in)	Fx,Fy (lbf)	Fz[3] (lbf)	Tx,Ty (lbf-in)	Tz (lbf-in)
Gamma	US-7.5-25	7.5	25	25	25	1/320	1/160	1/160	1/160
Gamma	US-15-50	15	50	50	50	1/160	1/80	1/80	1/80
Gamma	US-30-100	30	100	100	100	1/80	1/40	1/40	1/40
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Gamma	SI-32-2.5	32	100	2.5	2.5	1/80	1/40	1/1000	1/1000
Gamma	SI-65-5	65	200	5	5	1/40	1/20	5/3333	5/3333
Gamma	SI-130-10	130	400	10	10	1/20	1/10	1/400	1/400
		Sensing Ranges				**Resolution (Controller)**			

Notes:

1. 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.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.

5.12.7 CTL Analog Output

Table 4.65— Gamma Analog Output

Sensor	(US) Standard Calibration	Fx,Fy (lbf)	Fz[2] (lbf)	Tx,Ty,Tz (lbf-in)	Fx,Fy (lbf/V)	Fz[2] (lbf/V)	Tx,Ty,Tz (lbf-in/V)
Gamma	US-7.5-25	±7.5	±25	±25	0.75	2.5	2.5
Gamma	US-15-50	±15	±50	±50	1.5	5	5
Gamma	US-30-100	±30	±100	±100	3	10	10
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[2] (N)**	**Tx,Ty,Tz (Nm)**	**Fx,Fy (N/V)**	**Fz[2] (N/V)**	**Tx,Ty,Tz (Nm/V)**
Gamma	SI-32-2.5	±32	±100	±2.5	3.2	10	0.25
Gamma	SI-65-5	±65	±200	±5	6.5	20	0.5
Gamma	SI-130-10	±130	±400	±10	13	40	1
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

Notes:

1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.
2. For IP68 version see caution on physical properties page.

5.12.8 CTL Counts Value

Table 4.66—Counts Value

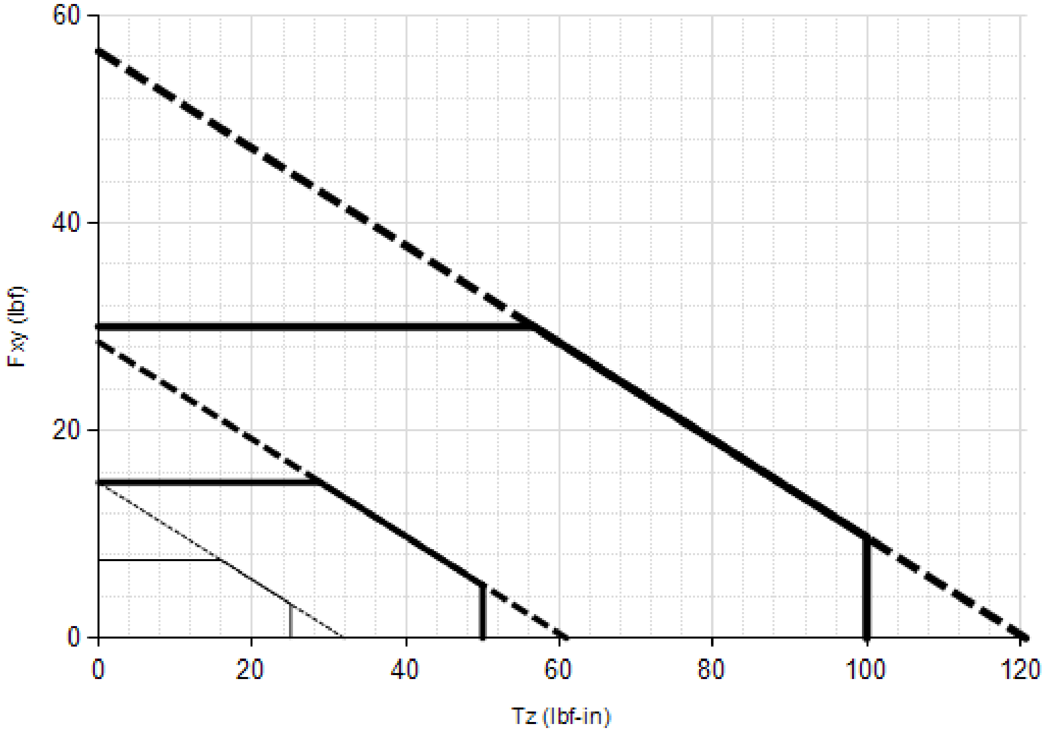
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ N)**	**Tx, Ty, Tz (/ Nm)**
Gamma	US-7.5–25 / SI-32–2.5	2560	2560	640	8000
Gamma	US-15–50 / SI-65–5	1280	1280	320	5333.33
Gamma	US-30–100 / SI-130–10	640	640	160	3200
Gamma	Tool Transform Factor	See Tool Transform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

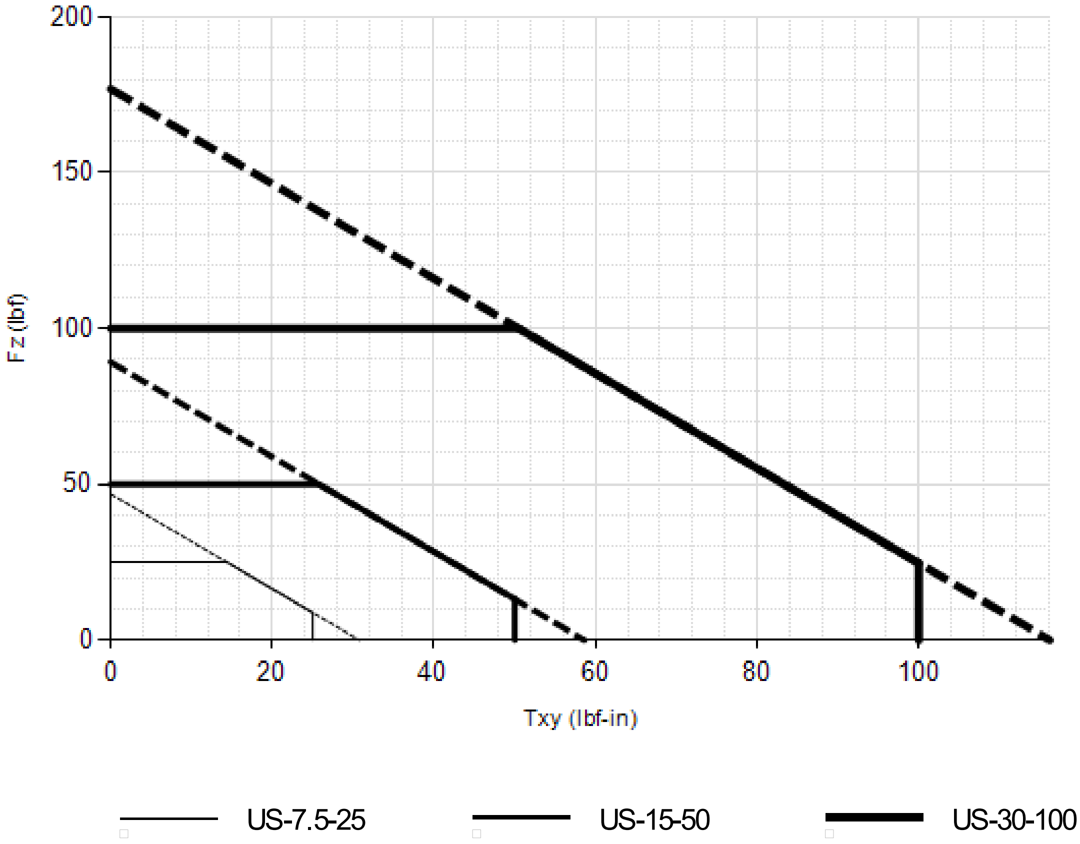
5.12.9 Tool Transform Factor

Table 4.67—Tool Transform Factor

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

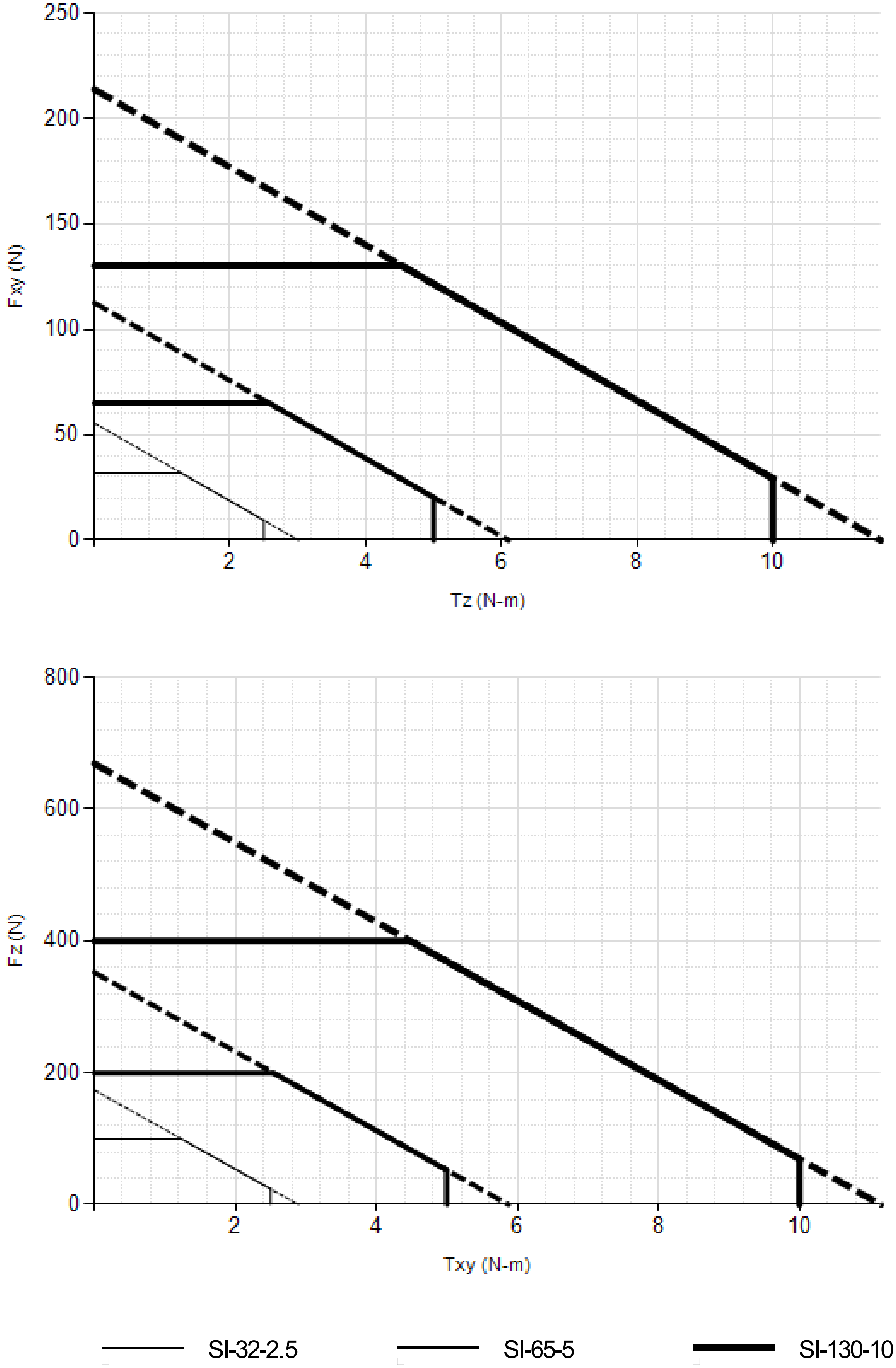
5.12.10 Gamma (US Calibration Complex Loading) (Includes IP60/IP65/IP68)[1]





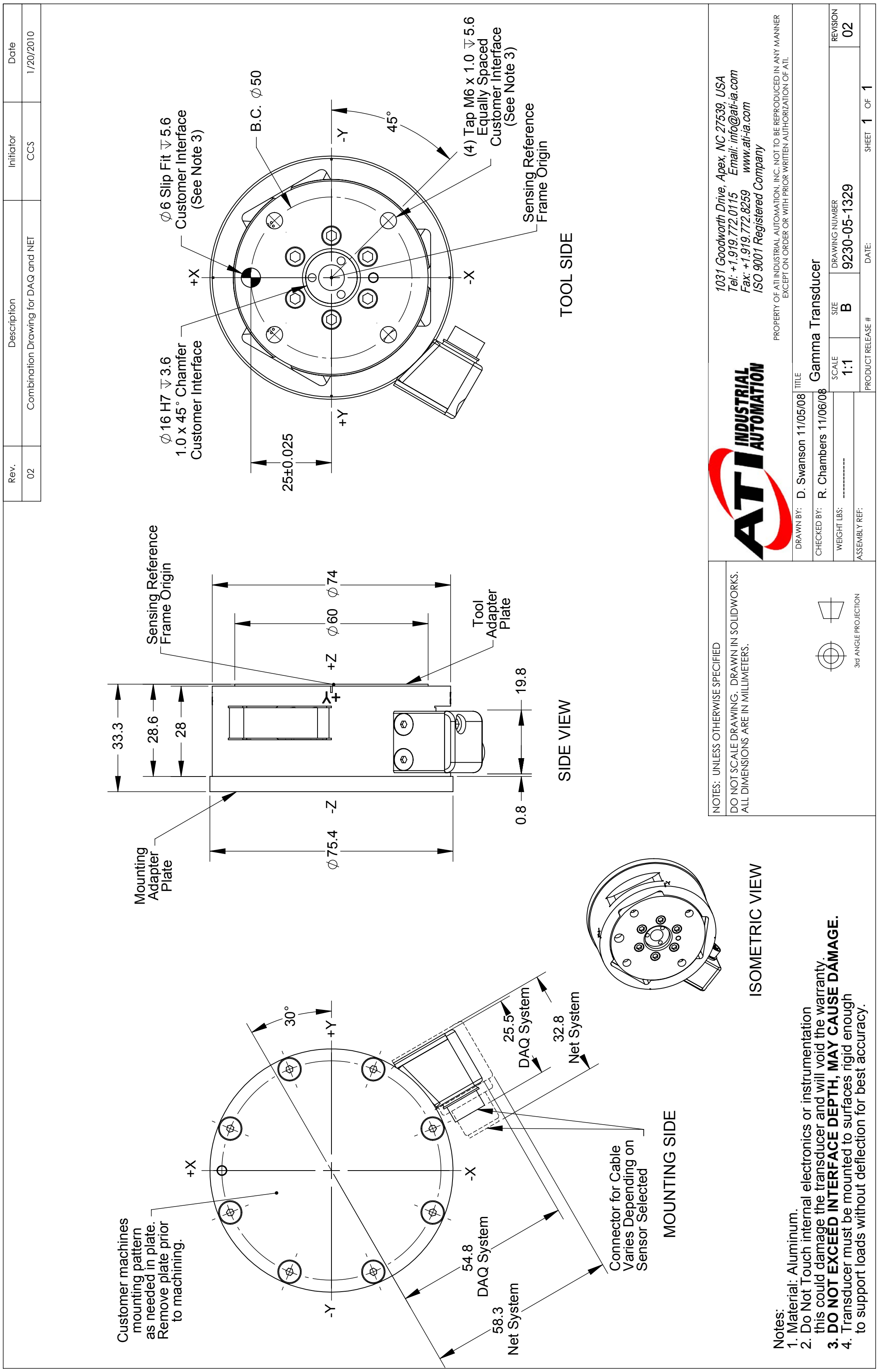
Note: 1. For IP68 version see caution on physical properties page.

5.12.11 Gamma (SI Calibration Complex Loading) (Includes IP60/IP65/IP68)[1]

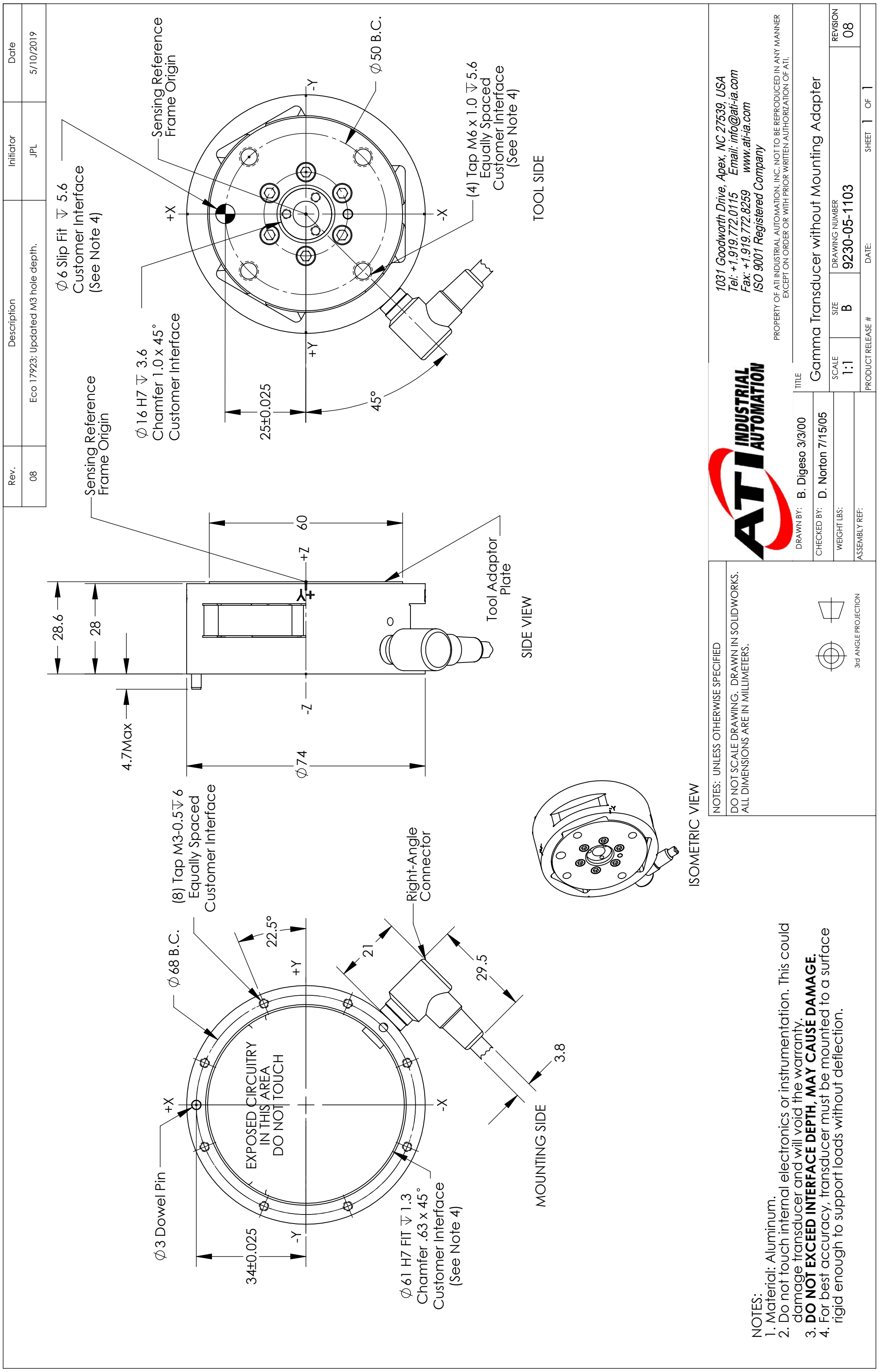


Note: 1. For IP68 version see caution on physical properties page.

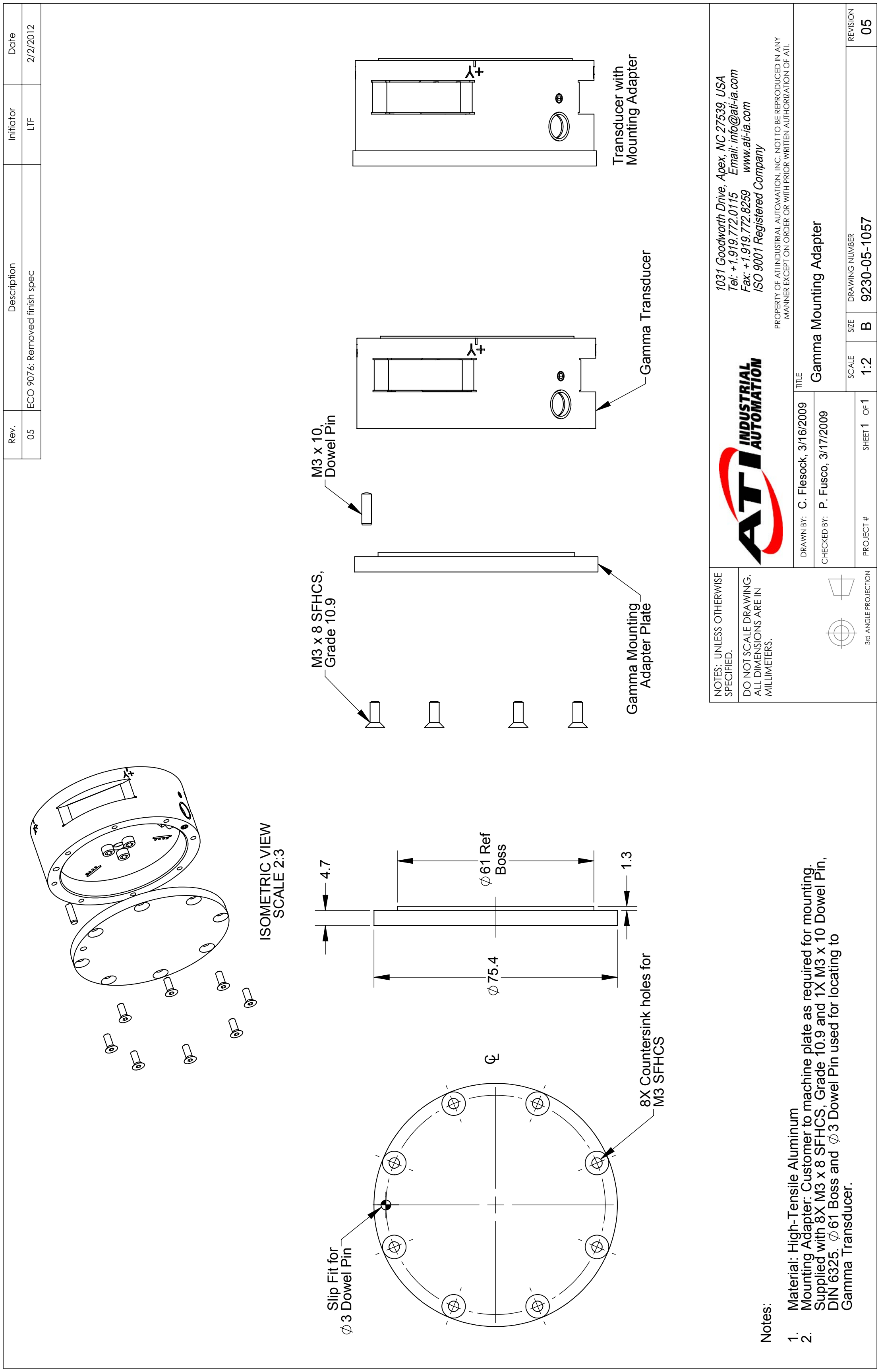
5.12.12 Gamma DAQ/Net Transducer Drawing



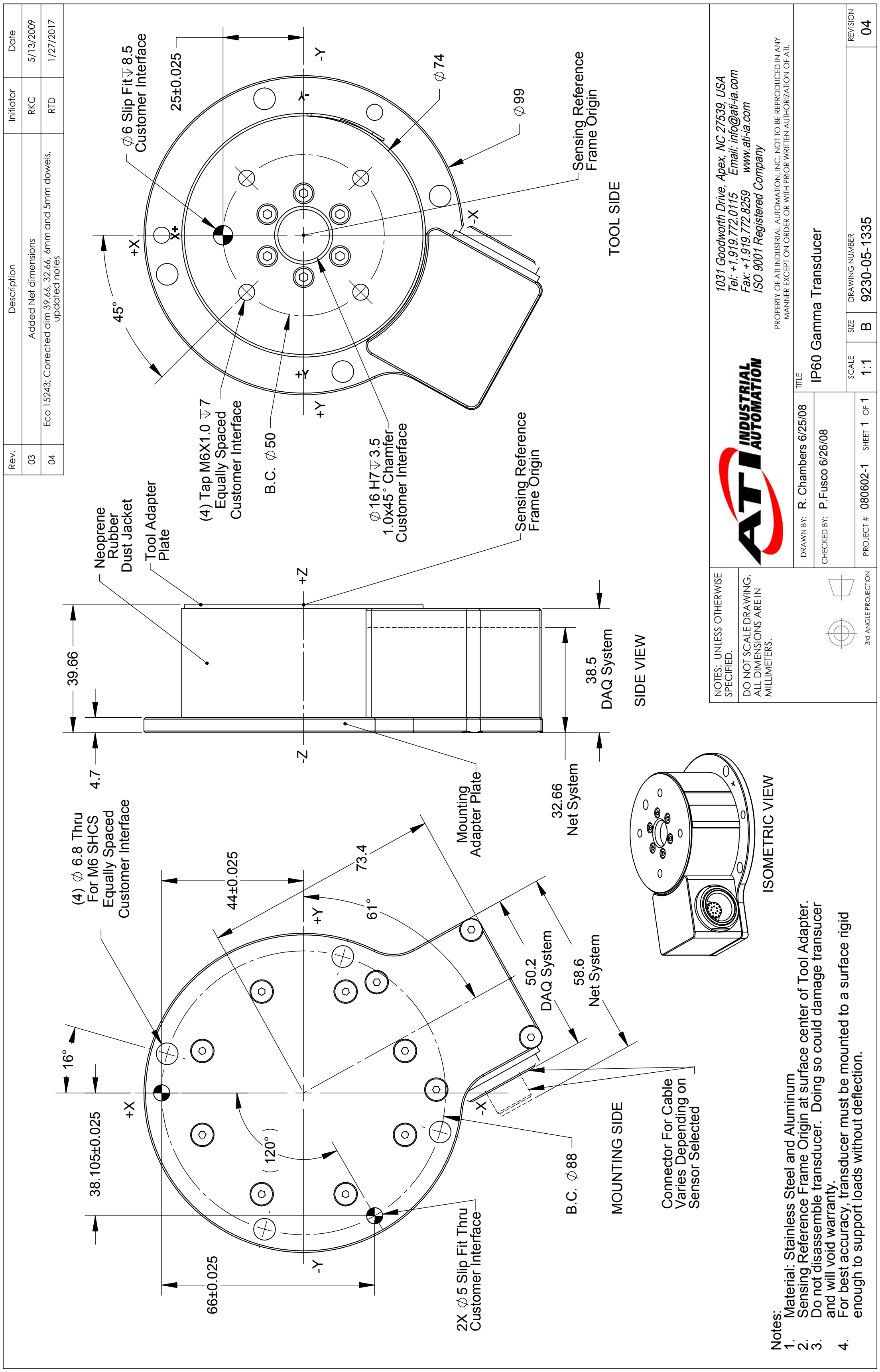
5.12.13 9105-T-Gamma Transducer without Mounting Adapter Drawing



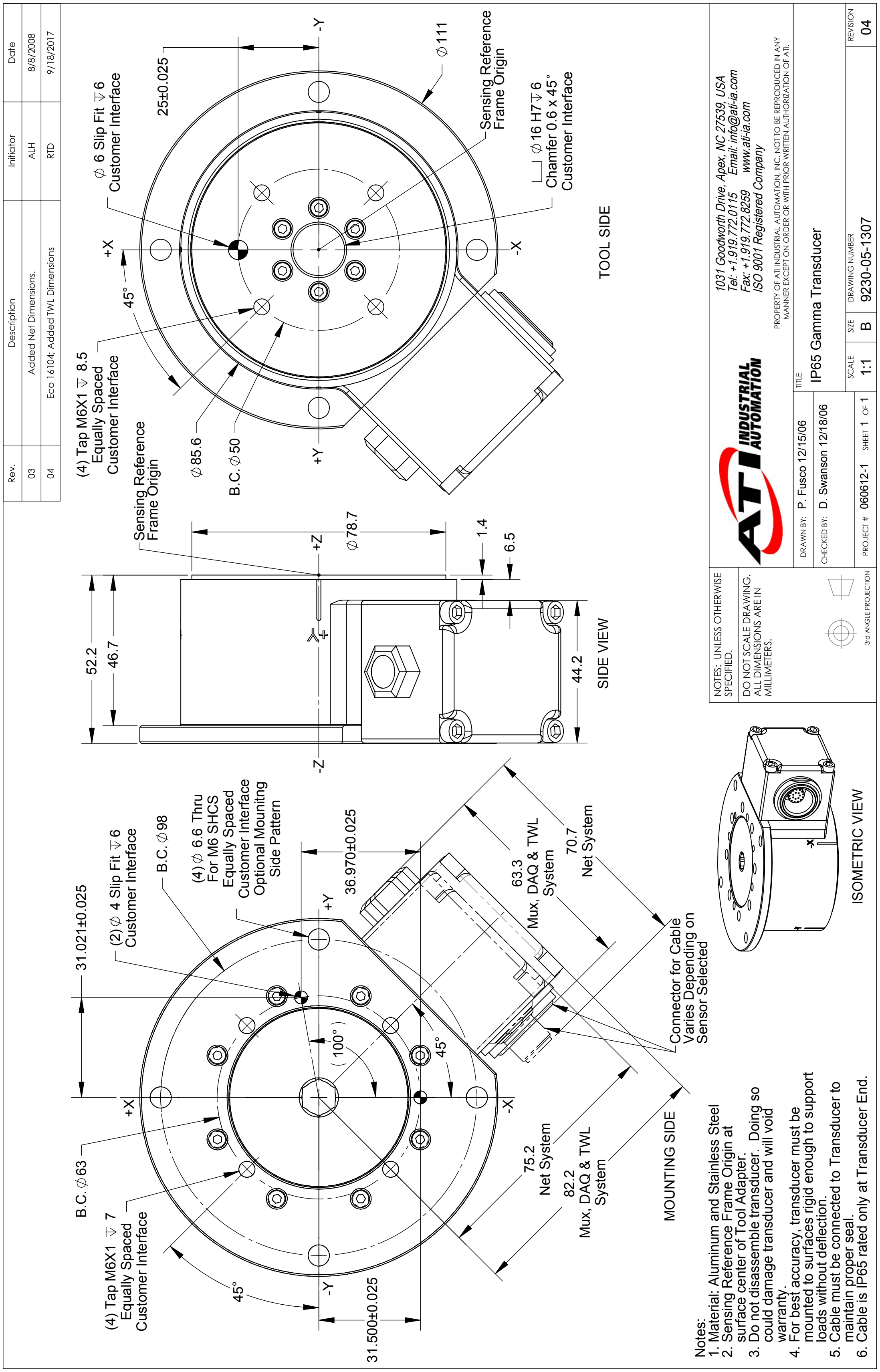
5.12.14 Gamma Mounting Adapter Plate Drawing



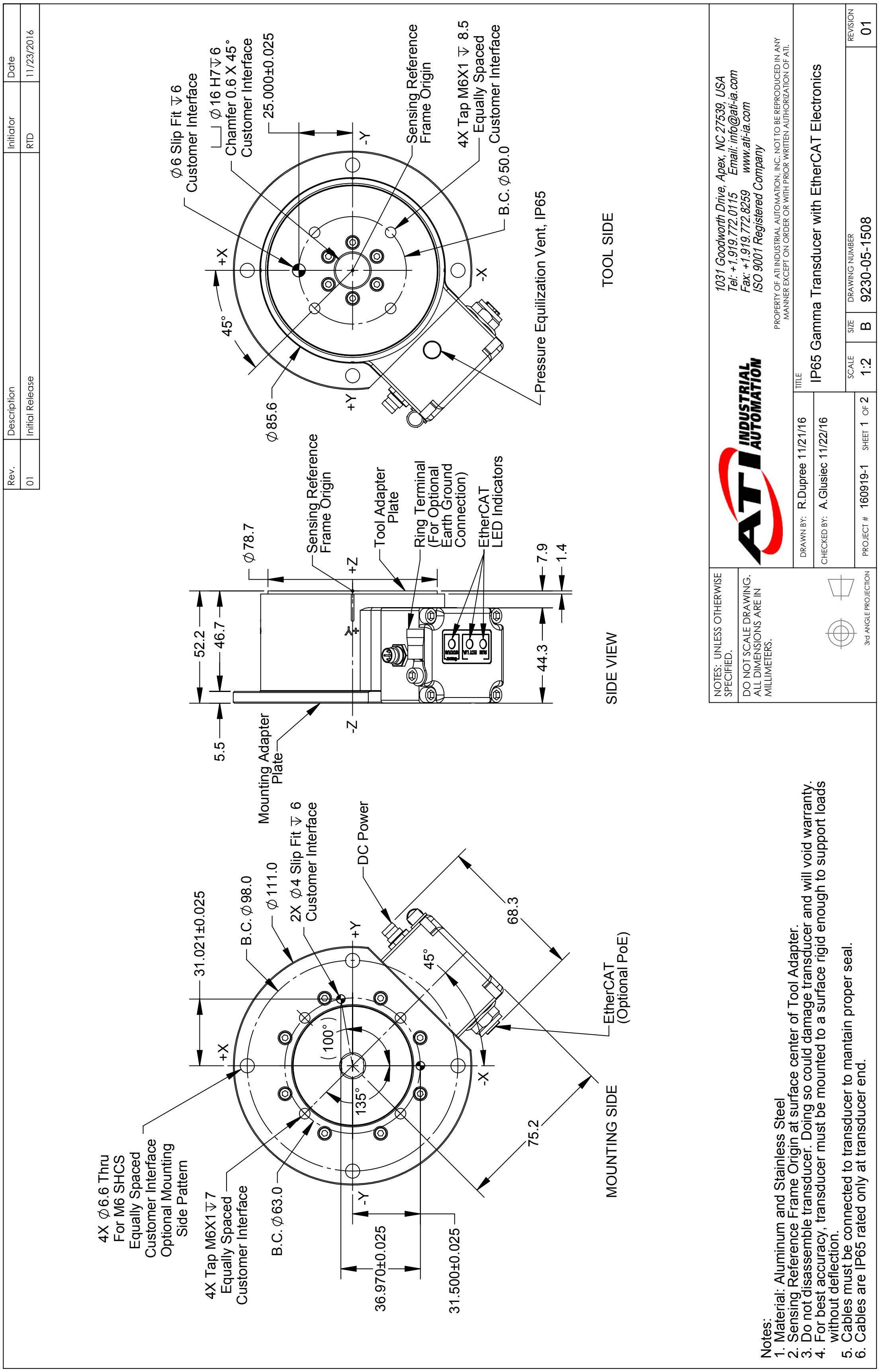
5.12.15 Gamma IP60 Transducer Drawing



5.12.16 Gamma IP65 Transducer Drawing

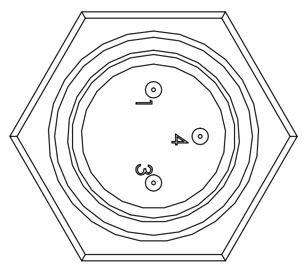


5.12.17 ECAT Gamma IP65 Transducer Drawing



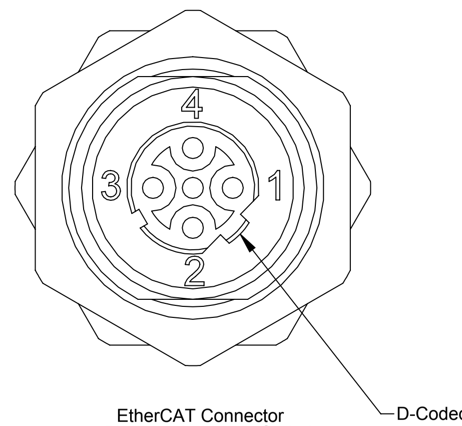
Rev.	Description	Initiator	Date
-	See Sheet1	-	-

Pin No.	Signal
1	V+
3	GND
4	N/C

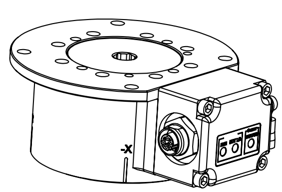


DC Power Connector
3-Pin Male M8

Pin No.	Signal
1	TX+
2	RX+
3	TX-
4	RX-
Shell	Connector Block Housing



EtherCAT Connector
4-Pin Female M12 D-Coded



ISOMETRIC VIEW

NOTES: UNLESS OTHERWISE SPECIFIED.

DO NOT SCALE DRAWING. ALL DIMENSIONS ARE IN MILLIMETERS.

3rd ANGLE PROJECTION

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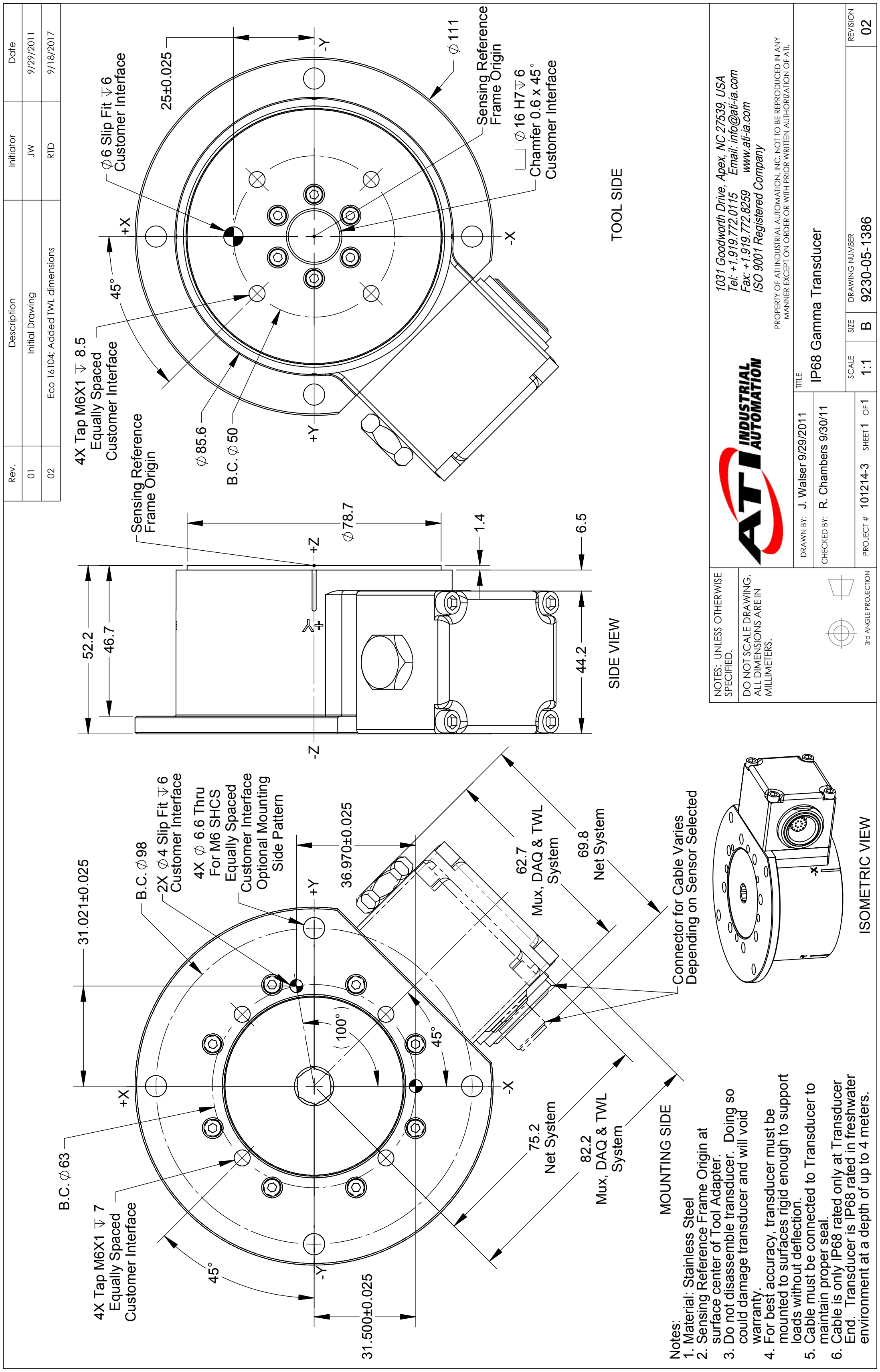
DRAWN BY: R.Dupree 11/21/16
CHECKED BY: A.Glusiec 11/22/16
PROJECT # 160919-1 SHEET 2 OF 2

TITLE: IP65 Gamma Transducer with EtherCAT Electronics

SCALE	SIZE	DRAWING NUMBER	REVISION
1:2	B	9230-05-1508	01

5.12.18 Gamma IP68 Transducer Drawing



5.13 Delta Specifications (Includes IP60/IP65/IP68 Versions)

5.13.1 Delta Physical Properties

Table 4.68—Delta Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±840 lbf	±3700 N
Fz	±2300 lbf	±10000 N
Txy	±2500 inf-lb	±280 Nm
Tz	±3600 inf-lb	±400 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	$2.0x10^5$ lb/in	$3.6x10^7$ N/m
Z-axis force (Kz)	$3.4x10^5$ lb/in	$5.9x10^7$ N/m
X-axis & Y-axis torque (Ktx, Kty)	$4.6x10^5$ lbf-in/rad	$5.2x10^4$ Nm/rad
Z-axis torque (Ktz)	$8.1x10^5$ lbf-in/rad	$9.1x10^4$ Nm/rad
Resonant Frequency		
Fx, Fy, Tz	1500 Hz	1500 Hz
Fz, Tx, Ty	1700 Hz	1700 Hz
Physical Specifications		
Weight[1]	2.01 lb	0.913 kg
Diameter[1]	3.72 in	94.5 mm
Height[1]	1.31 in	33.3 mm

Note:
1. Specifications include standard interface plates.

5.13.2 Delta IP60 Physical Properties

Table 4.69—Delta IP60 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±840 lbf	±3700 N
Fz	±2300 lbf	±10000 N
Txy	±2500 inf-lb	±280 Nm
Tz	±3600 inf-lb	±400 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	$2.0x10^5$ lb/in	$3.6x10^7$ N/m
Z-axis force (Kz)	$3.4x10^5$ lb/in	$5.9x10^7$ N/m
X-axis & Y-axis torque (Ktx, Kty)	$4.6x10^5$ lbf-in/rad	$5.2x10^4$ Nm/rad
Z-axis torque (Ktz)	$8.1x10^5$ lbf-in/rad	$9.1x10^4$ Nm/rad
Resonant Frequency		
Fx, Fy, Tz	1100 Hz	1100 Hz
Fz, Tx, Ty	1100 Hz	1100 Hz
Physical Specifications		
Weight[1]	4 lb	1.81 kg
Diameter[1]	4.6 in	117 mm
Height[1]	1.85 in	47.1 mm

Note:
1. Specifications include standard interface plates.

5.13.3 Delta IP65 Physical Properties

Table 4.70—Delta IP65 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±840 lbf	±3700 N
Fz	±2300 lbf	±10000 N
Txy	±2500 inf-lb	±280 Nm
Tz	±3600 inf-lb	±400 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	2.0×10^5 lb/in	3.6×10^7 N/m
Z-axis force (Kz)	3.4×10^5 lb/in	5.9×10^7 N/m
X-axis & Y-axis torque (Ktx, Kty)	4.6×10^5 lbf-in/rad	5.2×10^4 Nm/rad
Z-axis torque (Ktz)	8.1×10^5 lbf-in/rad	9.1×10^4 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	880 Hz	880 Hz
Fz, Tx, Ty	920 Hz	920 Hz
Physical Specifications		
Weight[1]	3.91 lb	1.77 kg
Diameter[1]	4.96 in	126 mm
Height[1]	2.06 in	52.2 mm
Note: 1. Specifications include standard interface plates.		

5.13.4 Delta IP68 Physical Properties

Table 4.71—Delta IP68 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±840 lbf	±3700 N
Fz	±2300 lbf	±10000 N
Txy	±2500 inf-lb	±280 Nm
Tz	±3600 inf-lb	±400 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	2.0×10^5 lb/in	3.6×10^7 N/m
Z-axis force (Kz)	3.4×10^5 lb/in	5.9×10^7 N/m
X-axis & Y-axis torque (Ktx, Kty)	4.6×10^5 lbf-in/rad	5.2×10^4 Nm/rad
Z-axis torque (Ktz)	8.1×10^5 lbf-in/rad	9.1×10^4 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	950 Hz	950 Hz
Fz, Tx, Ty	960 Hz	960 Hz
Physical Specifications		
Weight[1]	5.8 lb	2.63 kg
Diameter[1]	4 in	102 mm
Height[1]	2.06 in	52.2 mm
Note: 1. Specifications include standard interface plates.		

CAUTION: 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.

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

5.13.5 Calibration Specifications (excludes CTL calibrations)

Table 4.72— Delta Calibrations (excludes CTL calibrations)[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Delta	US-50-150	50	150	150	150	1/128	1/64	3/128	1/64
Delta	US-75-300	75	225	300	300	1/64	1/32	3/64	1/32
Delta	US-150-600	150	450	600	600	1/32	1/16	3/32	1/16
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Delta	SI-165-15	165	495	15	15	1/32	1/16	1/528	1/528
Delta	SI-330-30	330	990	30	30	1/16	1/8	5/1333	5/1333
Delta	SI-660-60	660	1980	60	60	1/8	1/4	10/1333	10/1333
		Sensing Ranges				**Resolution (DAQ, Net F/T)[4]**			

Notes:

1. These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.
4. DAQ resolutions are typical for a 16-bit data acquisition system.

5.13.6 CTL Calibration Specifications

Table 4.73— Delta CTL Calibrations[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Delta	US-50-150	50	150	150	150	1/64	1/32	3/64	1/32
Delta	US-75-300	75	225	300	300	1/32	1/16	3/32	1/16
Delta	US-150-600	150	450	600	600	1/16	1/8	3/16	1/8
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Delta	SI-165-15	165	495	15	15	1/16	1/8	1/264	1/264
Delta	SI-330-30	330	990	30	30	1/8	1/4	10/1333	10/1333
Delta	SI-660-60	660	1980	60	60	1/4	1/2	5/333	5/333
		Sensing Ranges				**Resolution (Controller)**			

Notes:

1. 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.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.

5.13.7 CTL Analog Output

Table 4.74— Delta Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[2] (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz[2] (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Delta	US-50-150	±50	±150	±150	5	15	15
Delta	US-75-300	±75	±225	±300	7.5	22.5	30
Delta	US-150-600	±150	±450	±600	15	45	60
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[2] (N)**	**Tx,Ty,Tz (Nm)**	**Fx,Fy (N/V)**	**Fz[2] (N/V)**	**Tx,Ty,Tz (Nm/V)**
Delta	SI-165-15	±165	±495	±15	16.5	49.5	1.5
Delta	SI-330-30	±330	±990	±30	33	99	3
Delta	SI-660-60	±660	±1980	±60	66	198	6
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

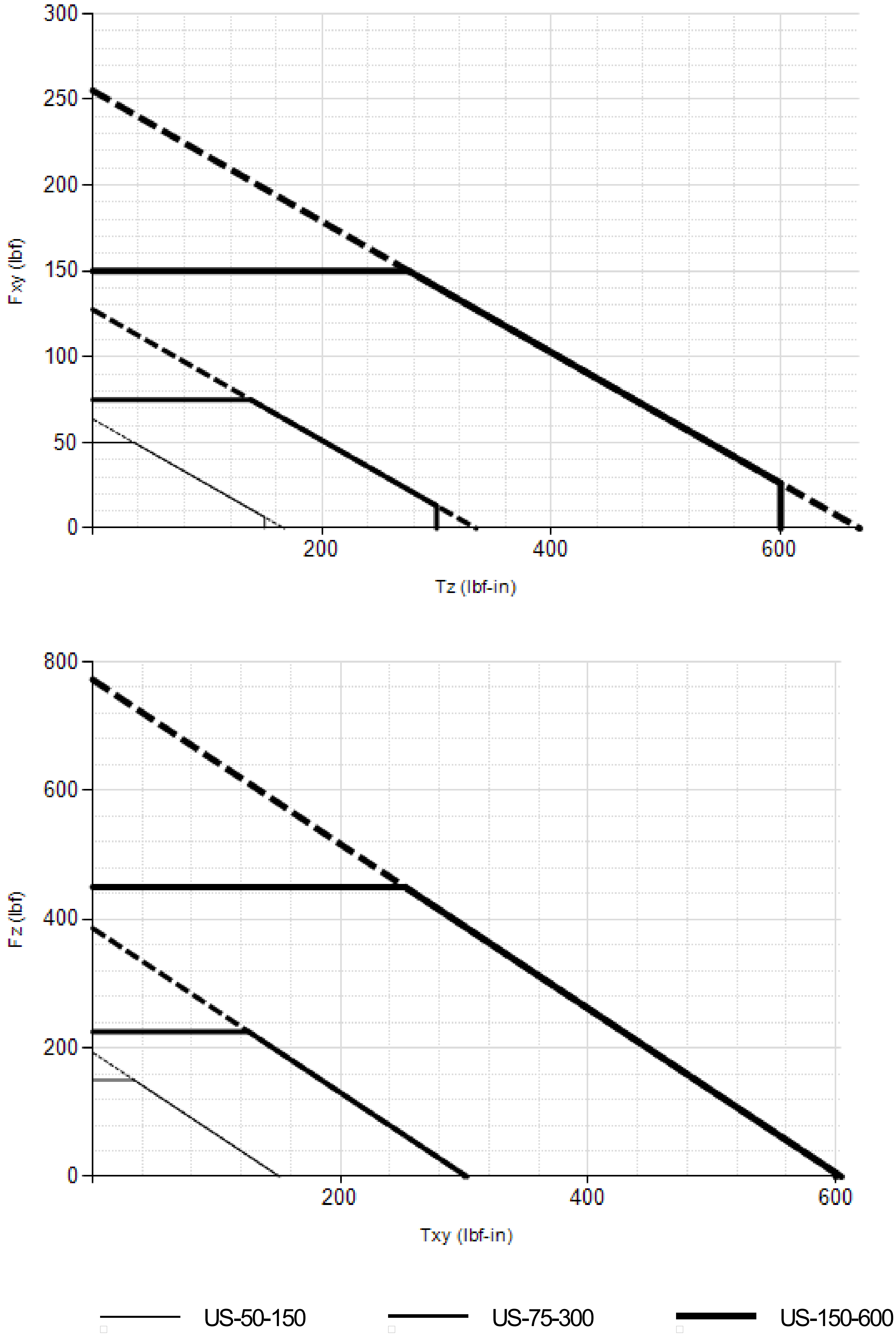
Notes:

1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.
2. For IP68 version see caution on physical properties page.

5.13.8 CTL Counts Value

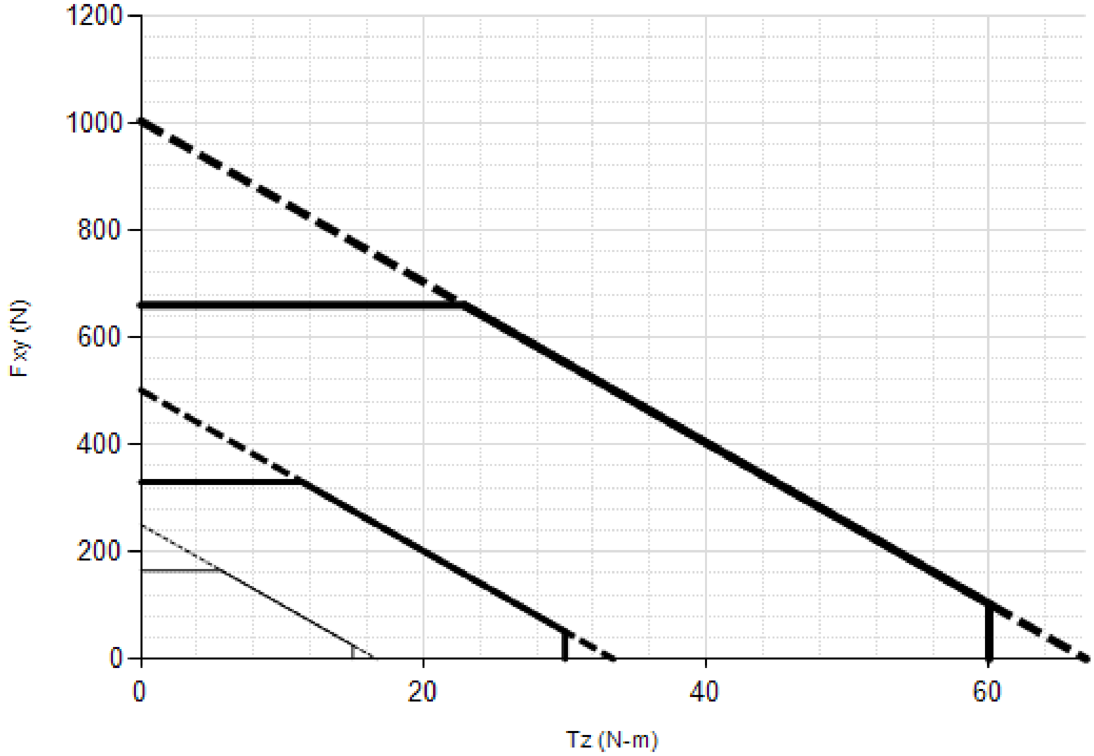
Table 4.75—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ N)**	**Tx, Ty, Tz (/ Nm)**
Delta	US-7.5–25 / SI-32–2.5	512	512	128	2112
Delta	US-15–50 / SI-65–5	256	256	64	1066.67
Delta	US-30–100 / SI-130–10	128	128	32	533.333
Delta	Tool Transform Factor	0.01 in/lbf		0.6 mm/N	
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

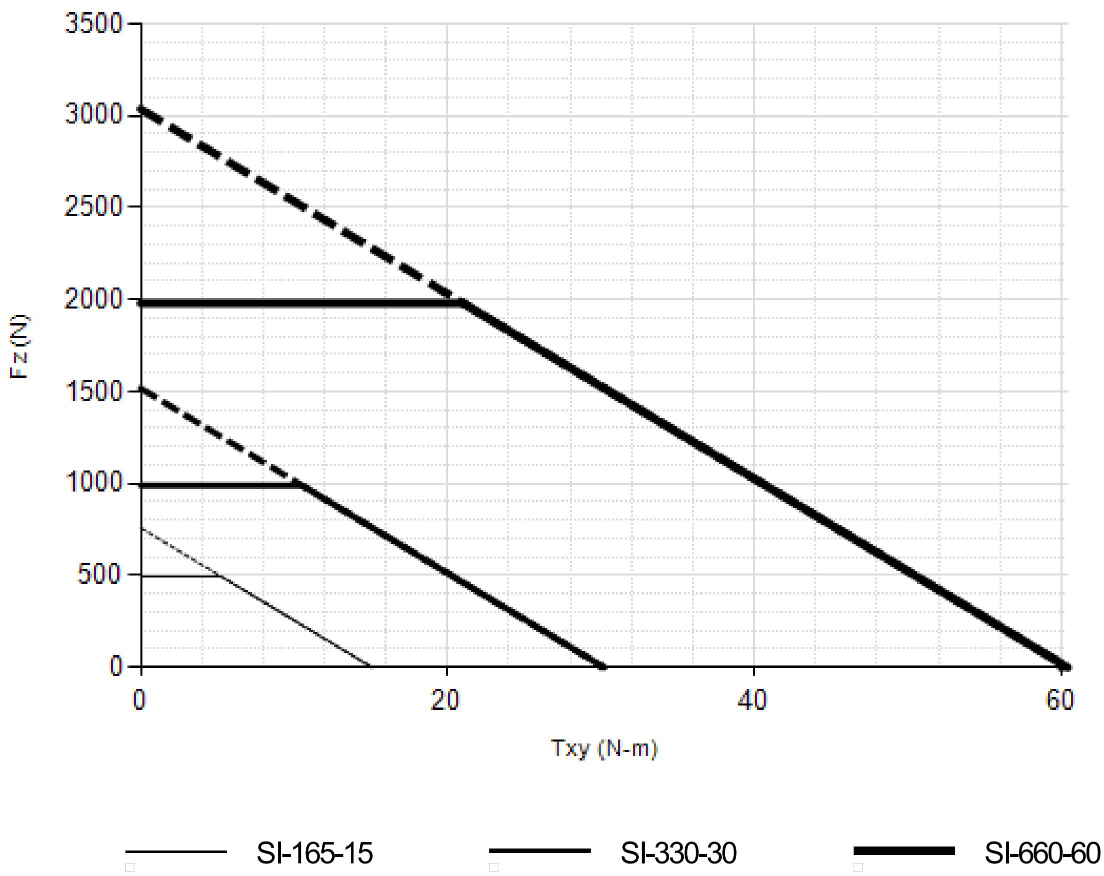
5.13.9 Delta (US Calibration Complex Loading)(Includes IP60/IP65/IP68)[1]



Note: 1. For IP68 version see caution on physical properties page.

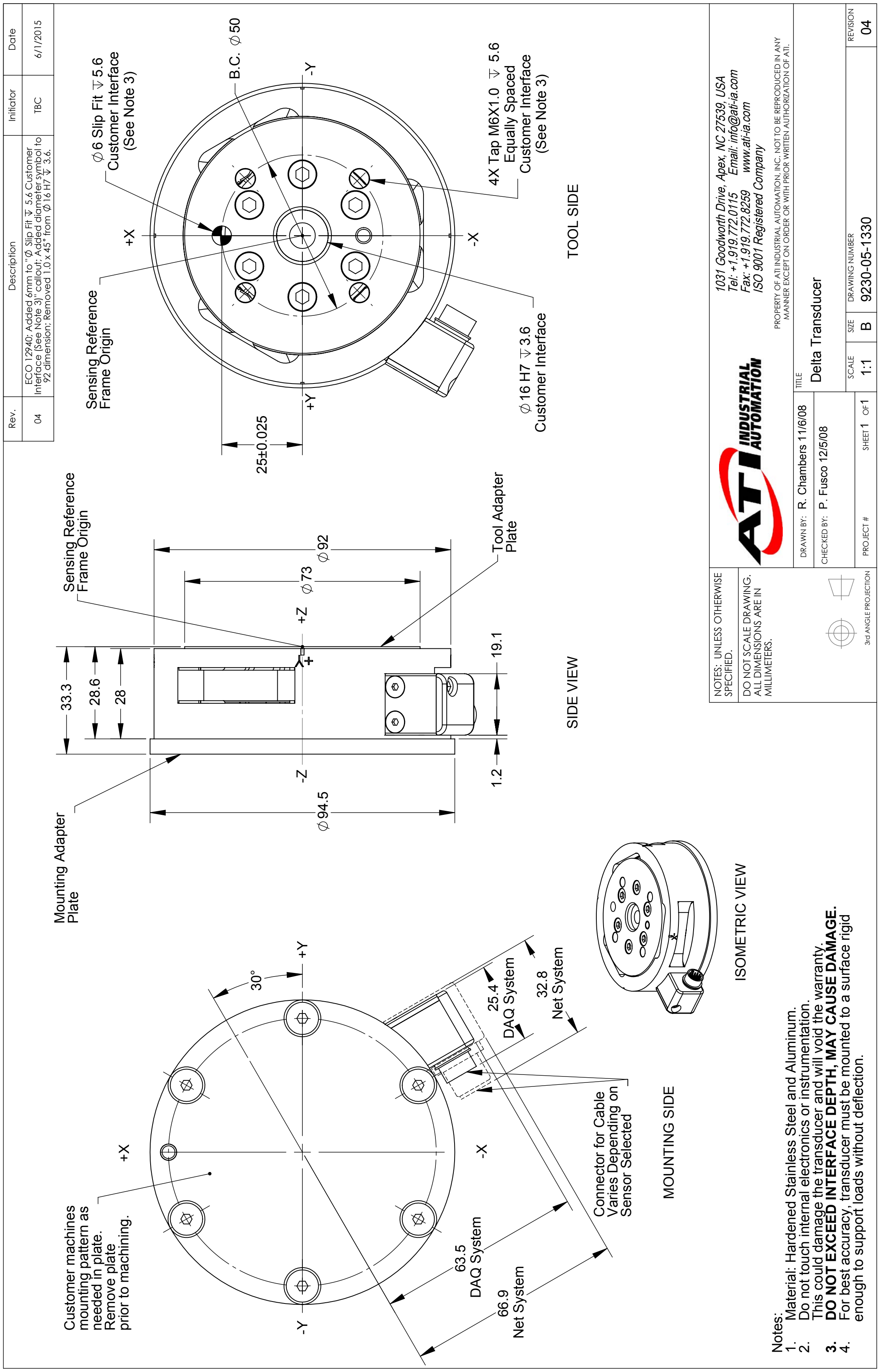
5.13.10 Delta (SI Calibration Complex Loading)(Includes IP60/IP65/IP68)[1]



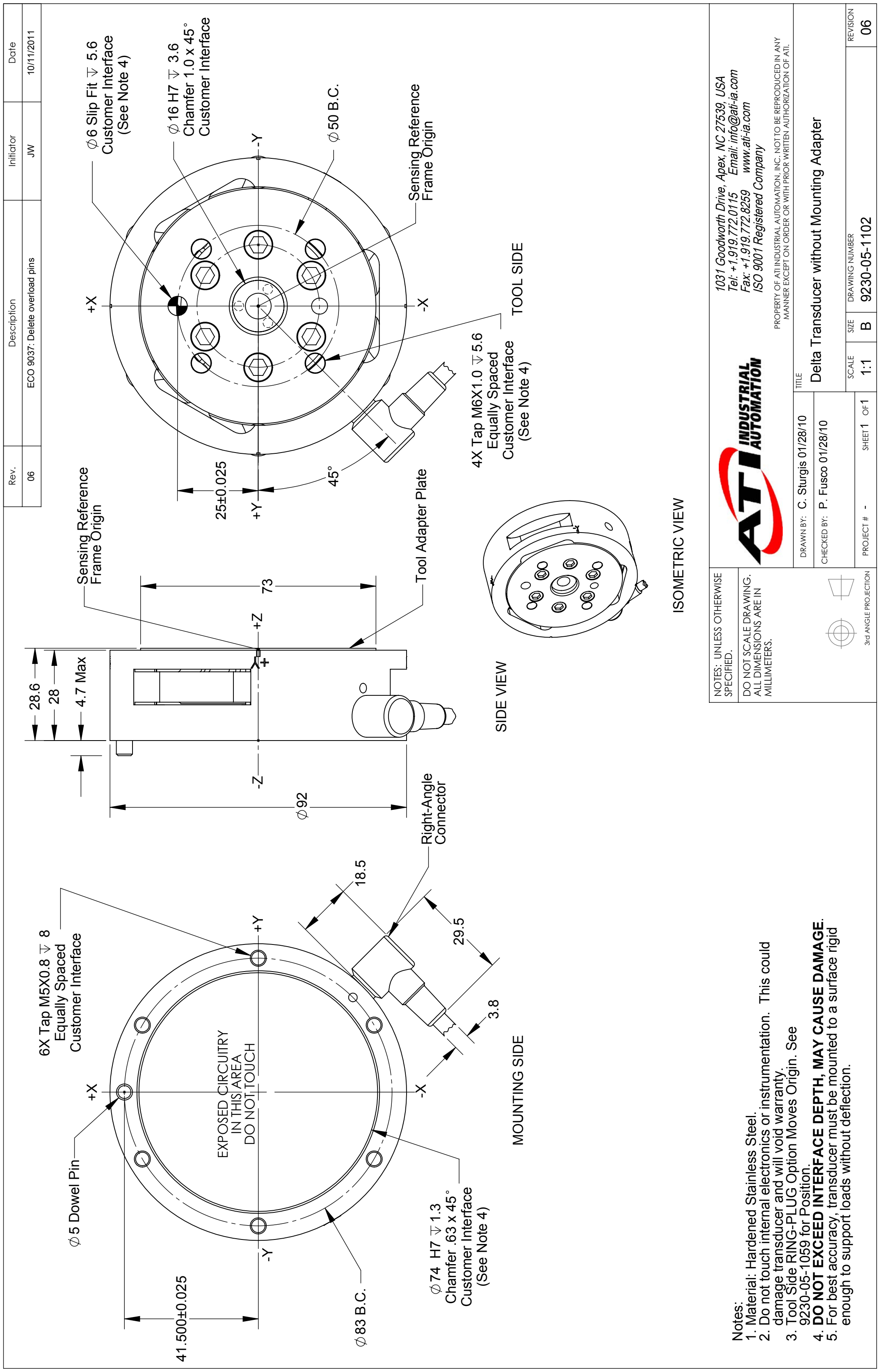


Note: 1. For IP68 version see caution on physical properties page.

5.13.11 Delta DAQ/Net Transducer Drawing

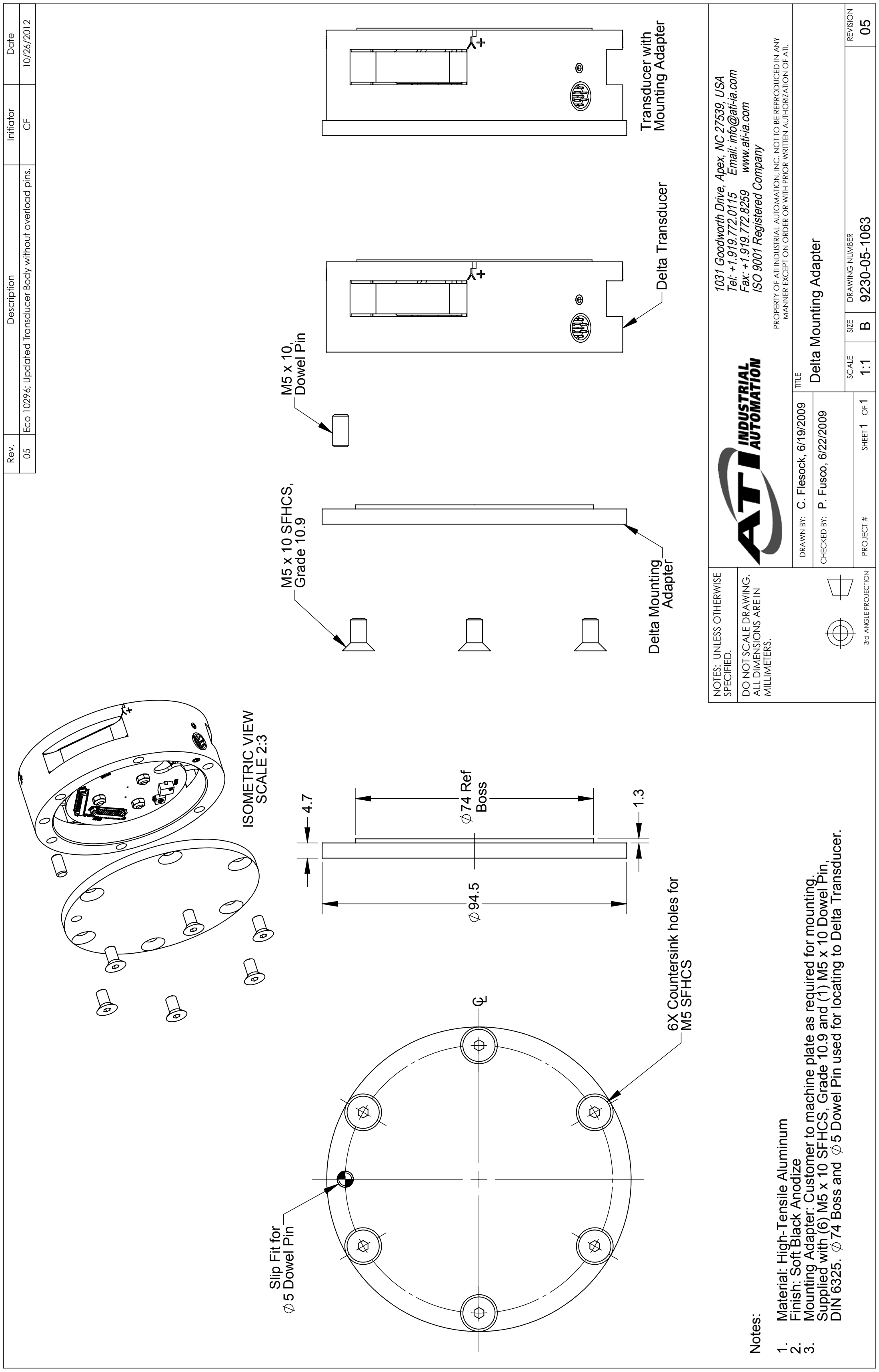


5.13.12 9105-T-Delta Transducer without Mounting Adapter Drawing

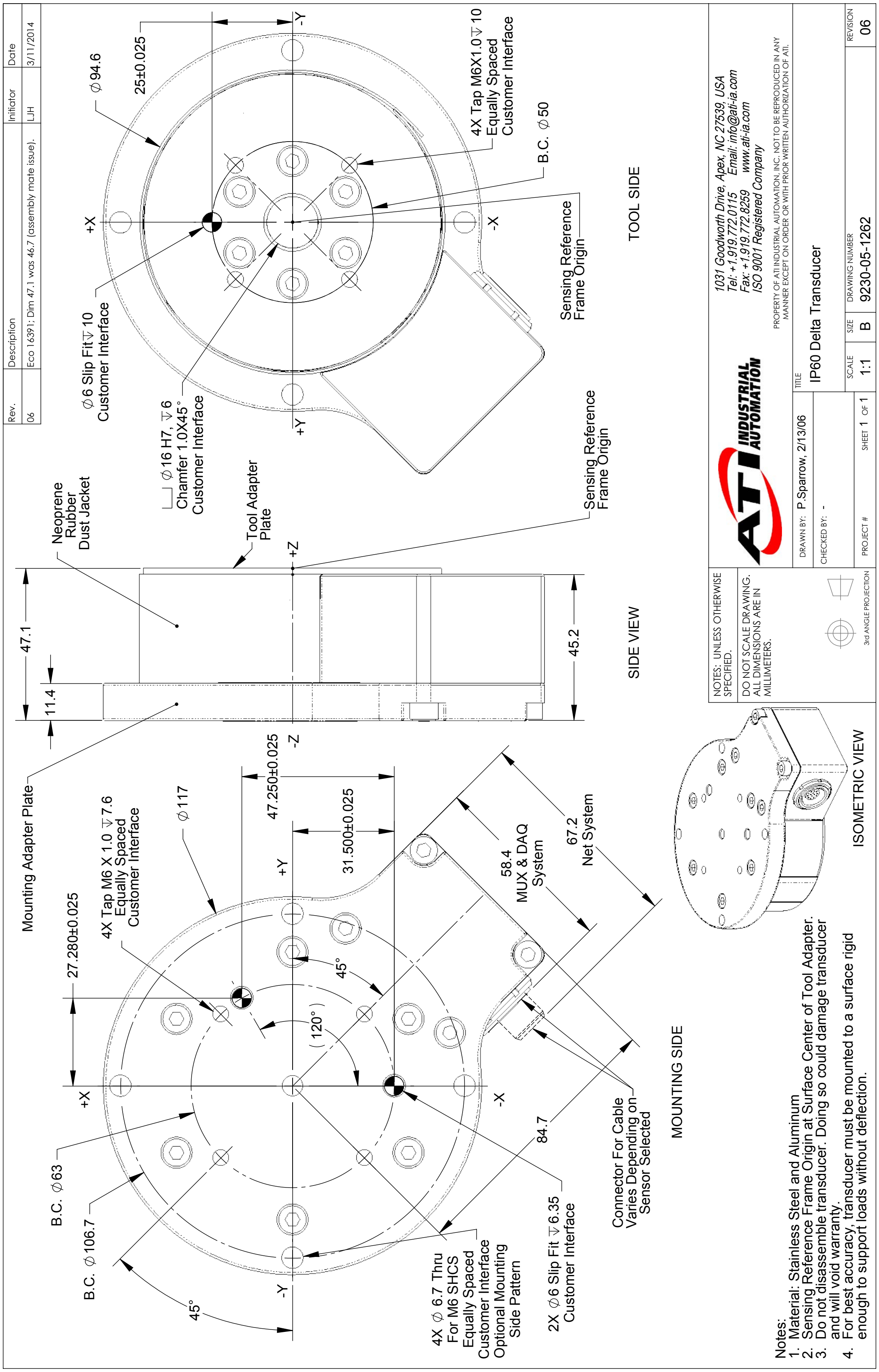


Note: Mux transducers are used in F/T Controller systems.

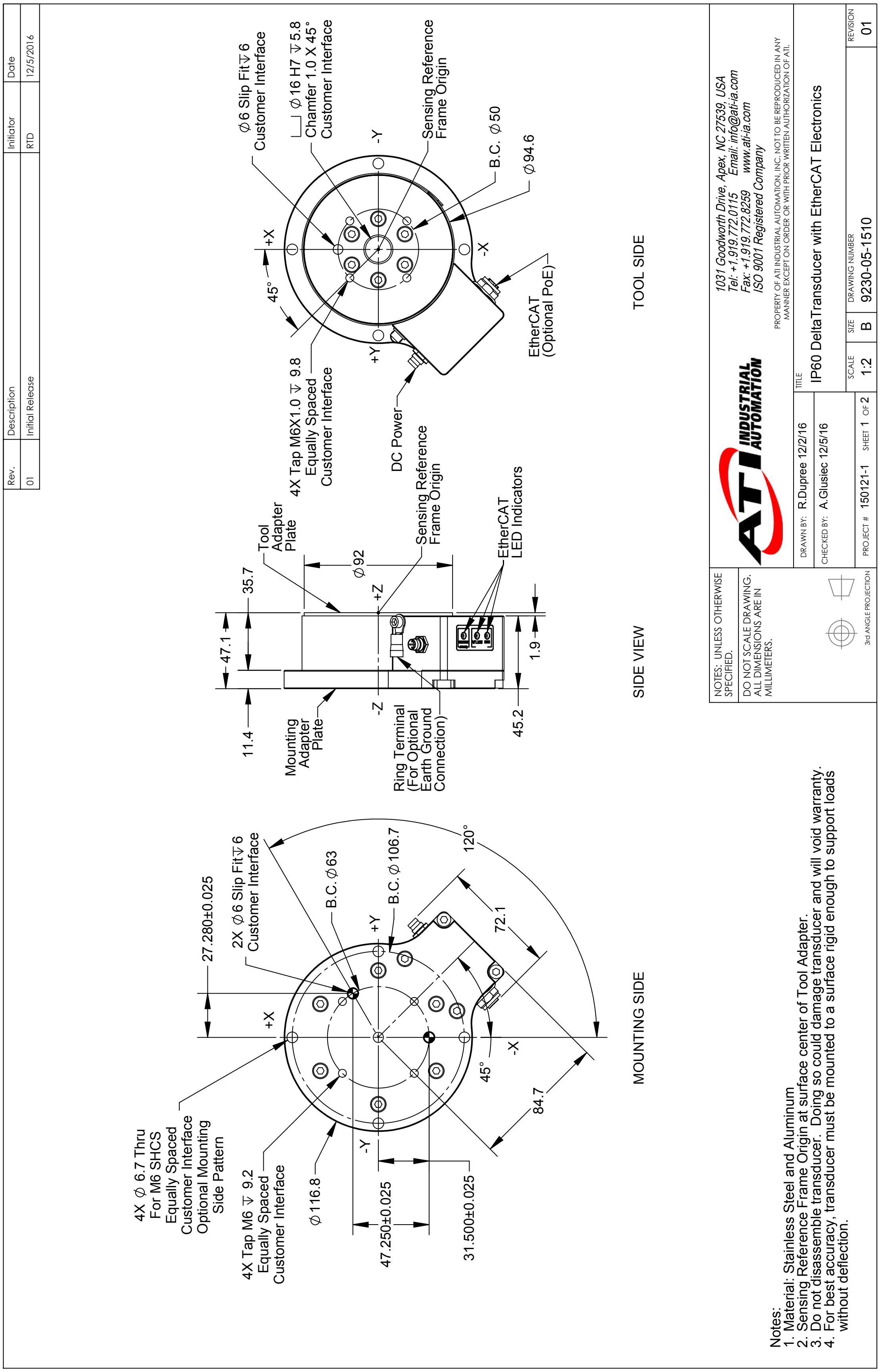
5.13.13 Delta Mounting Adapter Drawing

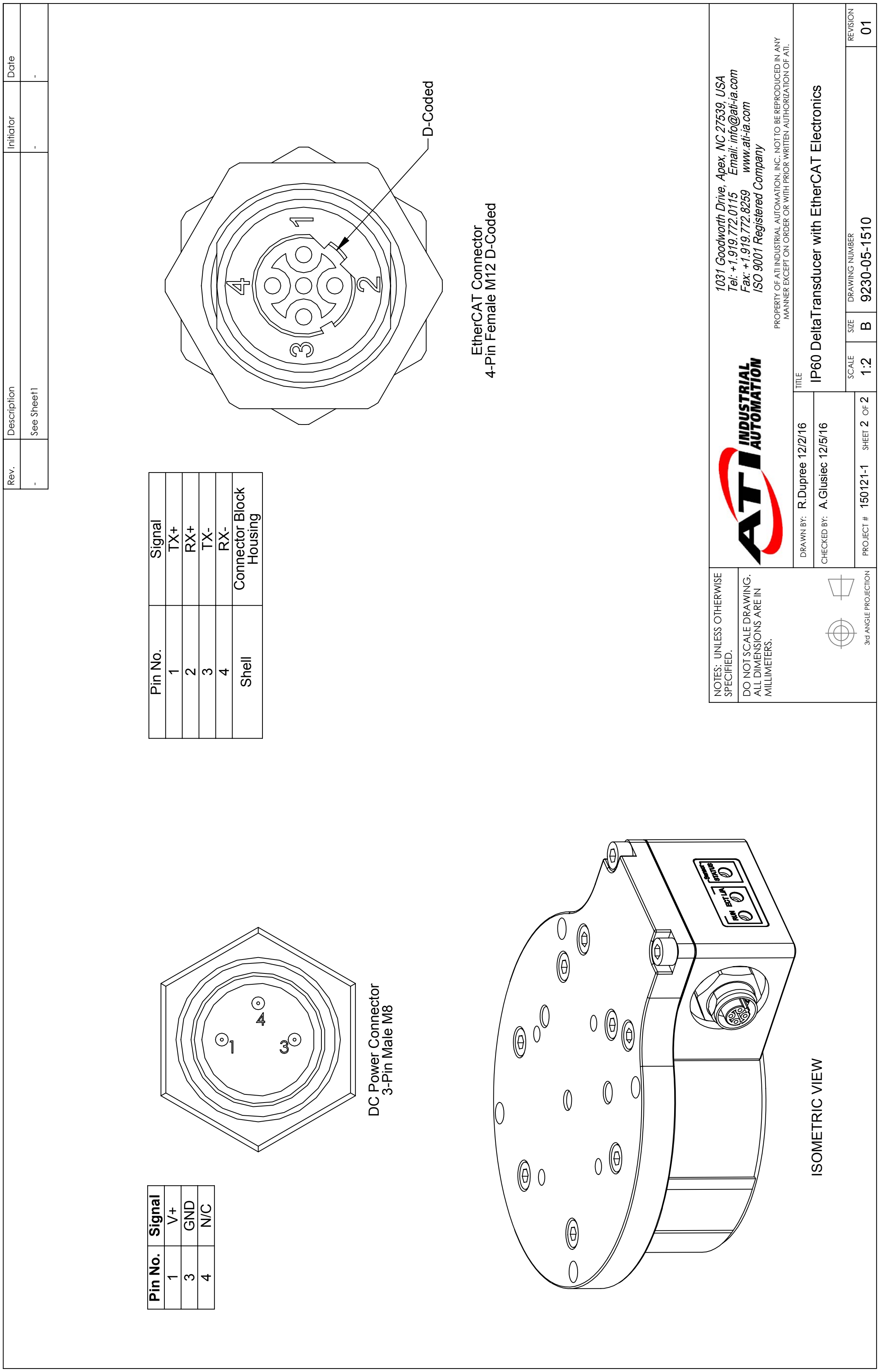


5.13.14 Delta IP60 Transducer Drawing



5.13.15 ECAT Delta IP60 Transducer Drawing




Rev. | Description | Initiator | Date
- | See Sheet1 | - | -
Pin No. | Signal
1 | V+
3 | GND
4 | N/C
DC Power Connector
3-Pin Male M8
Pin No. | Signal
1 | TX+
2 | RX+
3 | TX-
4 | RX-
Shell | Connector Block Housing
D-Coded
EtherCAT Connector
4-Pin Female M12 D-Coded
ISOMETRIC VIEW
NOTES: UNLESS OTHERWISE SPECIFIED.
DO NOT SCALE DRAWING.
ALL DIMENSIONS ARE IN MILLIMETERS.
3rd ANGLE PROJECTION
ATI INDUSTRIAL AUTOMATION
1031 Goodworth Drive, Apex, NC 27539, USA
Tel: +1.919.772.0115 Email: info@ati-ia.com
Fax: +1.919.772.8259 www.ati-ia.com
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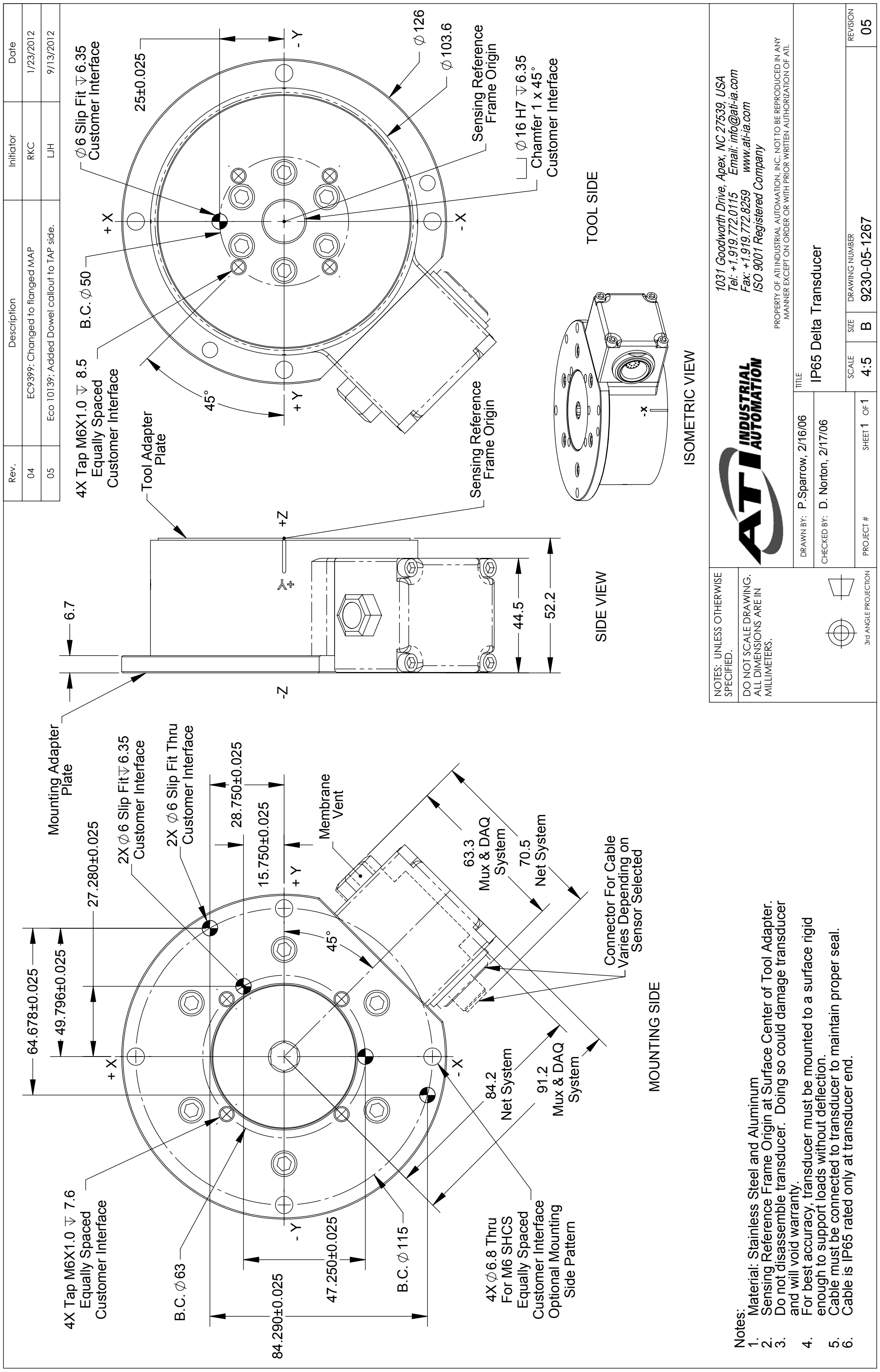
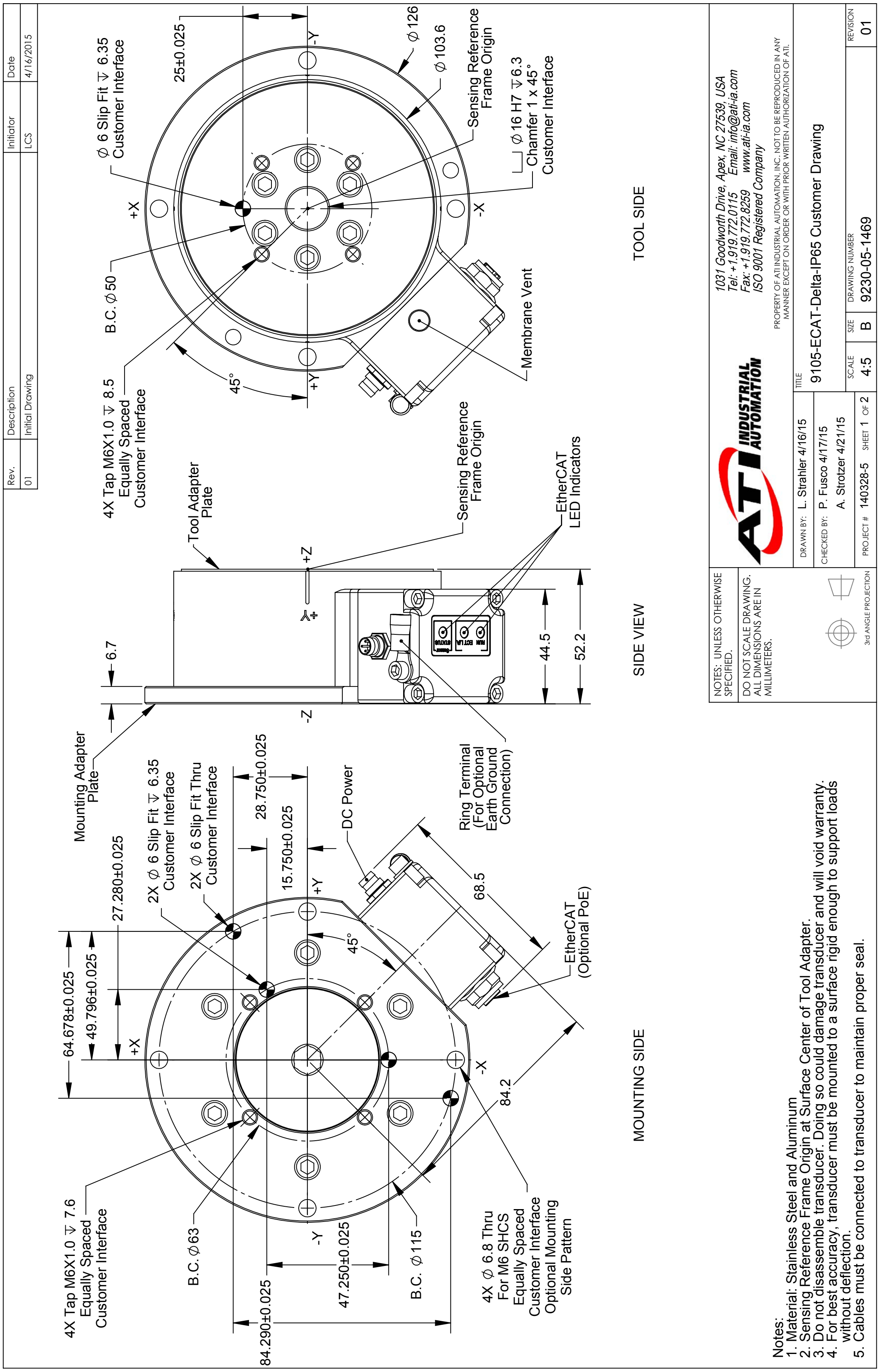
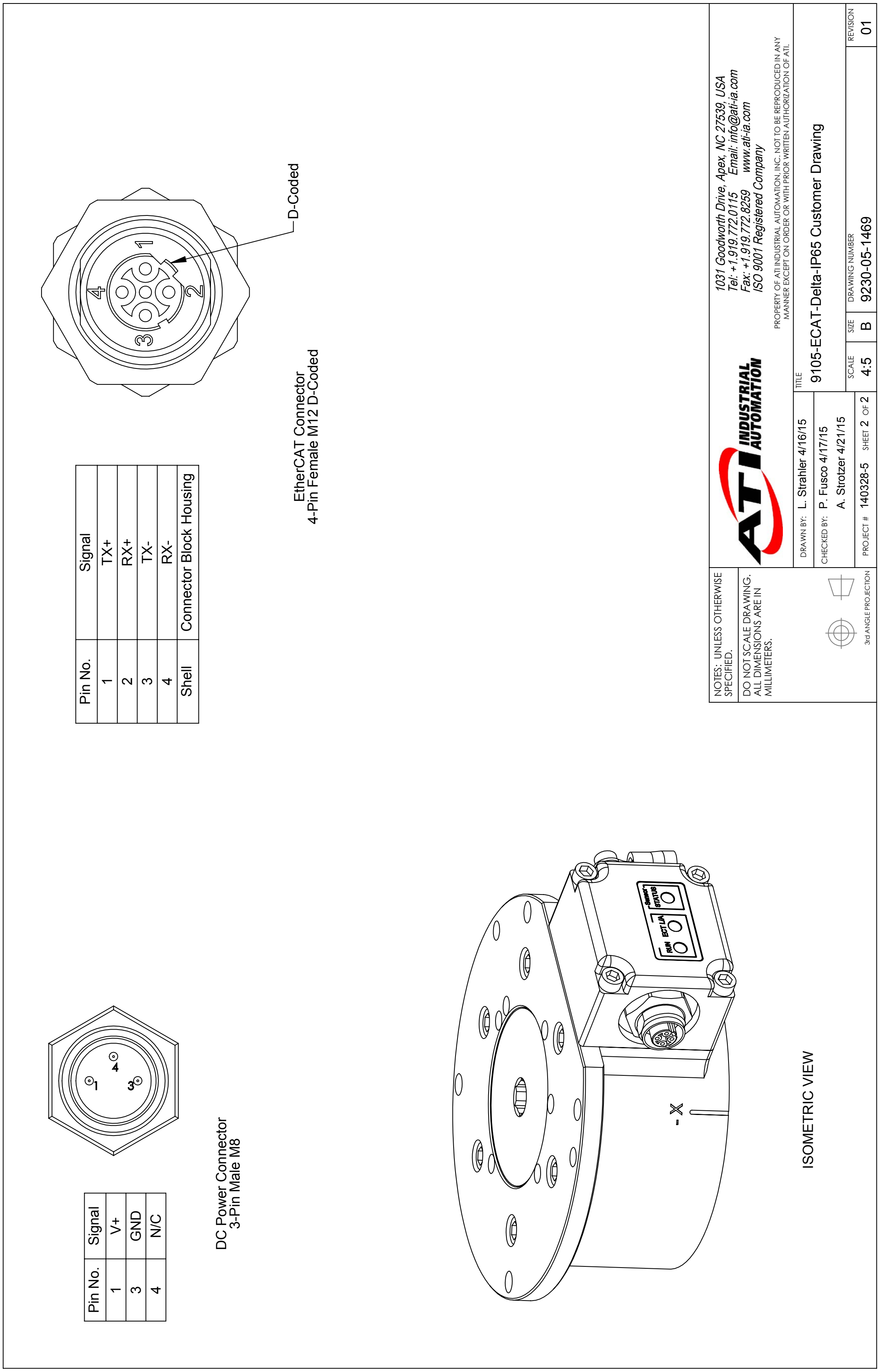
DRAWN BY: R.Dupree 12/2/16
CHECKED BY: A.Glusiec 12/5/16
PROJECT # 150121-1
SHEET 2 OF 2
TITLE
IP60 DeltaTransducer with EtherCAT Electronics
SCALE 1:2
SIZE B
DRAWING NUMBER 9230-05-1510
REVISION 01

5.13.16 Delta IP65 Transducer Drawing



5.13.17 ECAT Delta IP65 Transducer Drawing




D-Coded
EtherCAT Connector
4-Pin Female M12 D-Coded
Pin No. | Signal
1 | TX+
2 | RX+
3 | TX-
4 | RX-
Shell | Connector Block Housing
DC Power Connector
3-Pin Male M8
Pin No. | Signal
1 | V+
3 | GND
4 | N/C
- X
ISOMETRIC VIEW
NOTES: UNLESS OTHERWISE SPECIFIED.
DO NOT SCALE DRAWING.
ALL DIMENSIONS ARE IN MILLIMETERS.
3rd ANGLE PROJECTION
INDUSTRIAL AUTOMATION
1031 Goodworth Drive, Apex, NC 27539, USA
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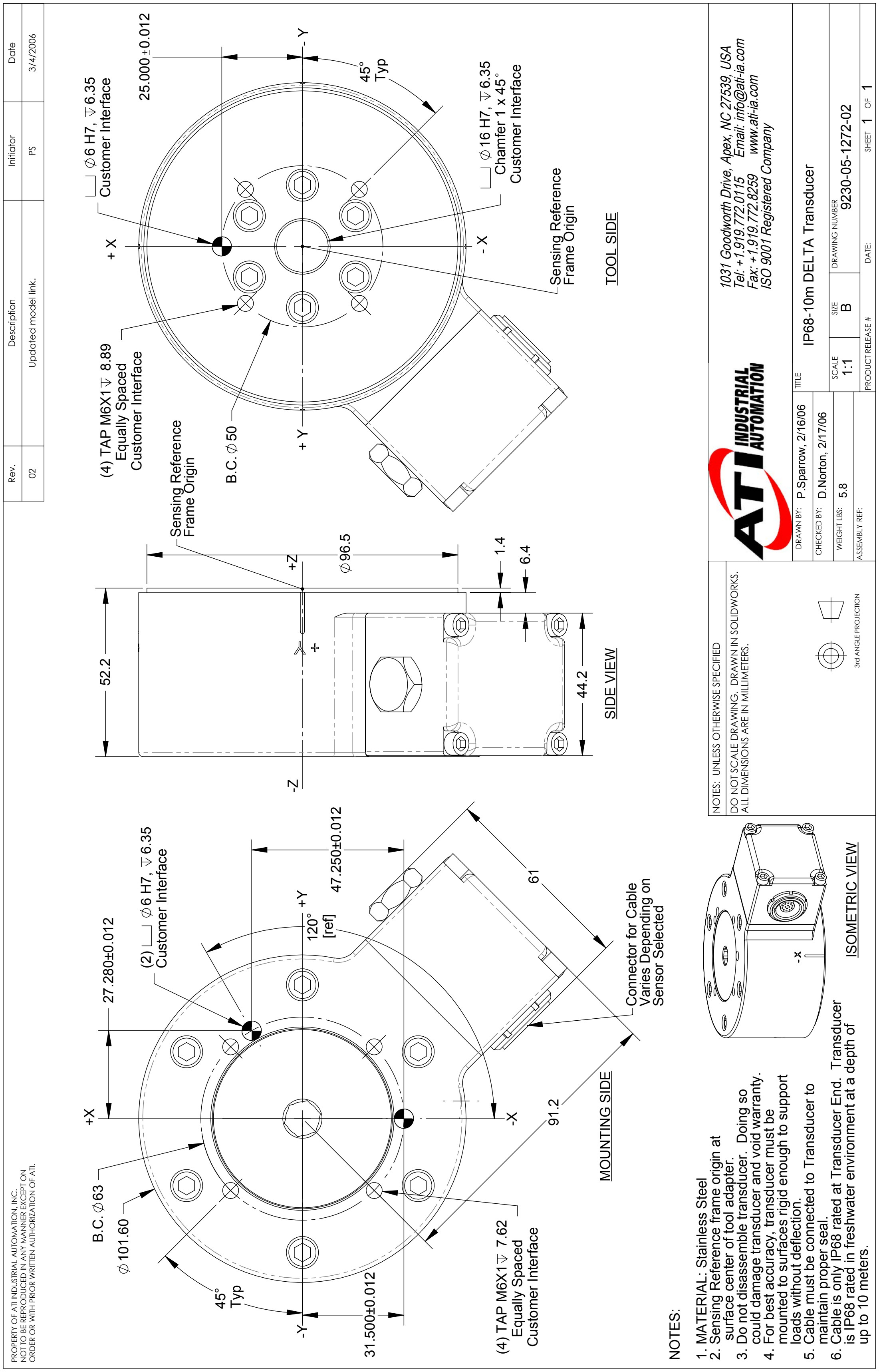
DRAWN BY: L. Strahler 4/16/15
CHECKED BY: P. Fusco 4/17/15
A. Strotzer 4/21/15
TITLE
9105-ECAT-Delta-IP65 Customer Drawing
PROJECT # 140328-5
SHEET 2 OF 2
SCALE 4:5
SIZE B
DRAWING NUMBER 9230-05-1469
REVISION 01

5.13.18 Delta IP68 Transducer Drawing



5.14 Theta Specifications (Includes IP60/IP65/IP68 Versions)

5.14.1 Theta Physical Properties

Table 4.76—Theta Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±4500 lbf	±20000 N
Fz	±11000 lbf	±51000 N
Txy	±18000 inf-lb	±2000 Nm
Tz	±18000 inf-lb	±2000 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	4.0×10^{5} lb/in	7.1×10^{7} N/m
Z-axis force (Kz)	6.9×10^{5} lb/in	1.2×10^{8} N/m
X-axis & Y-axis torque (Ktx, Kty)	3.0×10^{6} lbf-in/rad	3.4×10^{5} Nm/rad
Z-axis torque (Ktz)	4.7×10^{6} lbf-in/rad	5.3×10^{5} Nm/rad
Resonant Frequency		
Fx, Fy, Tz	680 Hz	680 Hz
Fz, Tx, Ty	820 Hz	820 Hz
Physical Specifications		
Weight[1]	11 lb	4.99 kg
Diameter[1]	6.1 in	155 mm
Height[1]	2.41 in	61.1 mm
Note: 1. Specifications include standard interface plates.		

5.14.2 Theta IP60 Physical Properties

Table 4.77—Theta IP60 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±4500 lbf	±20000 N
Fz	±11000 lbf	±51000 N
Txy	±18000 inf-lb	±2000 Nm
Tz	±18000 inf-lb	±2000 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	4.0×10^{5} lb/in	7.1×10^{7} N/m
Z-axis force (Kz)	6.9×10^{5} lb/in	1.2×10^{8} N/m
X-axis & Y-axis torque (Ktx, Kty)	3.0×10^{6} lbf-in/rad	3.4×10^{5} Nm/rad
Z-axis torque (Ktz)	4.7×10^{6} lbf-in/rad	5.3×10^{5} Nm/rad
Resonant Frequency		
Fx, Fy, Tz	N/A	N/A
Fz, Tx, Ty	N/A	N/A
Physical Specifications		
Weight[1]	19 lb	8.62 kg
Diameter[1]	7.63 in	194 mm
Height[1]	2.91 in	74 mm
Note: 1. Specifications include standard interface plates.		

5.14.3 Theta IP65/IP68 Physical Properties

Table 4.78—Theta IP65/IP68 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±4500 lbf	±20000 N
Fz	±11000 lbf	±51000 N
Txy	±18000 inf-lb	±2000 Nm
Tz	±18000 inf-lb	±2000 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	4.0×10^{5} lb/in	7.1×10^{7} N/m
Z-axis force (Kz)	6.9×10^{5} lb/in	1.2×10^{8} N/m
X-axis & Y-axis torque (Ktx, Kty)	3.0×10^{6} lbf-in/rad	3.4×10^{5} Nm/rad
Z-axis torque (Ktz)	4.7×10^{6} lbf-in/rad	5.3×10^{5} Nm/rad
Resonant Frequency		
Fx, Fy, Tz	N/A	N/A
Fz, Tx, Ty	N/A	N/A
Physical Specifications		
Weight[1]	19.8 lb	9 kg
Diameter[1]	6.41 in	163 mm
Height[1]	2.95 in	74.8 mm
Note: 1. Specifications include standard interface plates.		

CAUTION: 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.

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

5.14.4 Calibration Specifications (excludes CTL calibrations)

Table 4.79— Theta Calibrations (excludes CTL calibrations)[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Theta	US-200-1000	200	500	1000	1000	1/32	1/16	1/8	1/8
Theta	US-300-1800	300	875	1800	1800	5/68	5/34	5/16	5/16
Theta	US-600-3600	600	1500	3600	3600	1/8	1/4	1/2	1/2
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Theta	SI-1000-120	1000	2500	120	120	1/4	1/4	1/40	1/80
Theta	SI-1500-240	1500	3750	240	240	1/2	1/2	1/20	1/40
Theta	SI-2500-400	2500	6250	400	400	1/2	1	1/20	1/20
		Sensing Ranges				**Resolution (DAQ, Net F/T)[4]**			

Notes:

1. These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.
4. DAQ resolutions are typical for a 16-bit data acquisition system.

5.14.5 CTL Calibration Specifications

Table 4.80— Theta CTL Calibrations[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Theta	US-200-1000	200	500	1000	1000	1/16	1/8	1/4	1/4
Theta	US-300-1800	300	875	1800	1800	5/34	5/17	5/8	5/8
Theta	US-600-3600	600	1500	3600	3600	1/4	1/2	1	1
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Theta	SI-1000-120	1000	2500	120	120	1/2	1/2	1/20	1/40
Theta	SI-1500-240	1500	3750	240	240	1	1	1/10	1/20
Theta	SI-2500-400	2500	6250	400	400	1	2	1/10	1/10
		Sensing Ranges				**Resolution (Controller)**			

Notes:

1. 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.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.

5.14.6 CTL Analog Output

Table 4.81— Theta Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[2] (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz[2] (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Theta	US-200-1000	±200	±500	±1000	20	50	100
Theta	US-300-1800	±300	±875	±1800	30	87.5	180
Theta	US-600-3600	±600	±1500	±3600	60	150	360
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[2] (N)**	**Tx,Ty,Tz (Nm)**	**Fx,Fy (N/V)**	**Fz[2] (N/V)**	**Tx,Ty,Tz (Nm/V)**
Theta	SI-1000-120	±1000	±2500	±120	100	250	12
Theta	SI-1500-240	±1500	±3750	±240	150	375	24
Theta	SI-2500-400	±2500	±6250	±400	250	625	40
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

Notes:
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.
2. For IP68 version see caution on physical properties page.

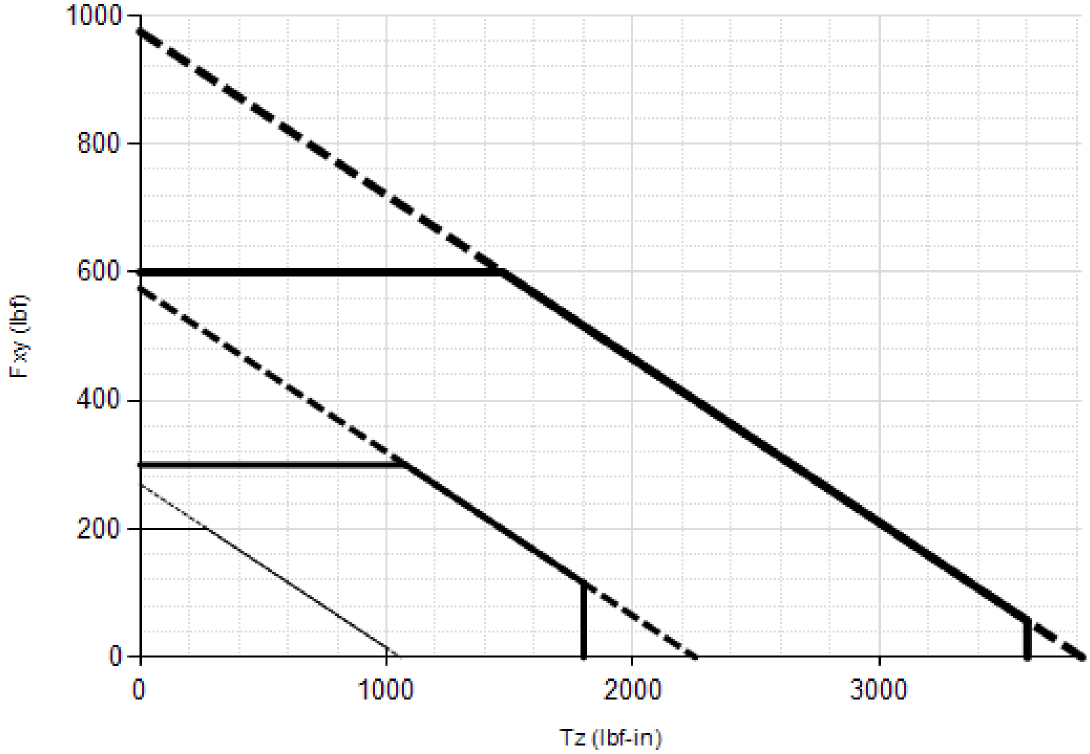
5.14.7 CTL Counts Value

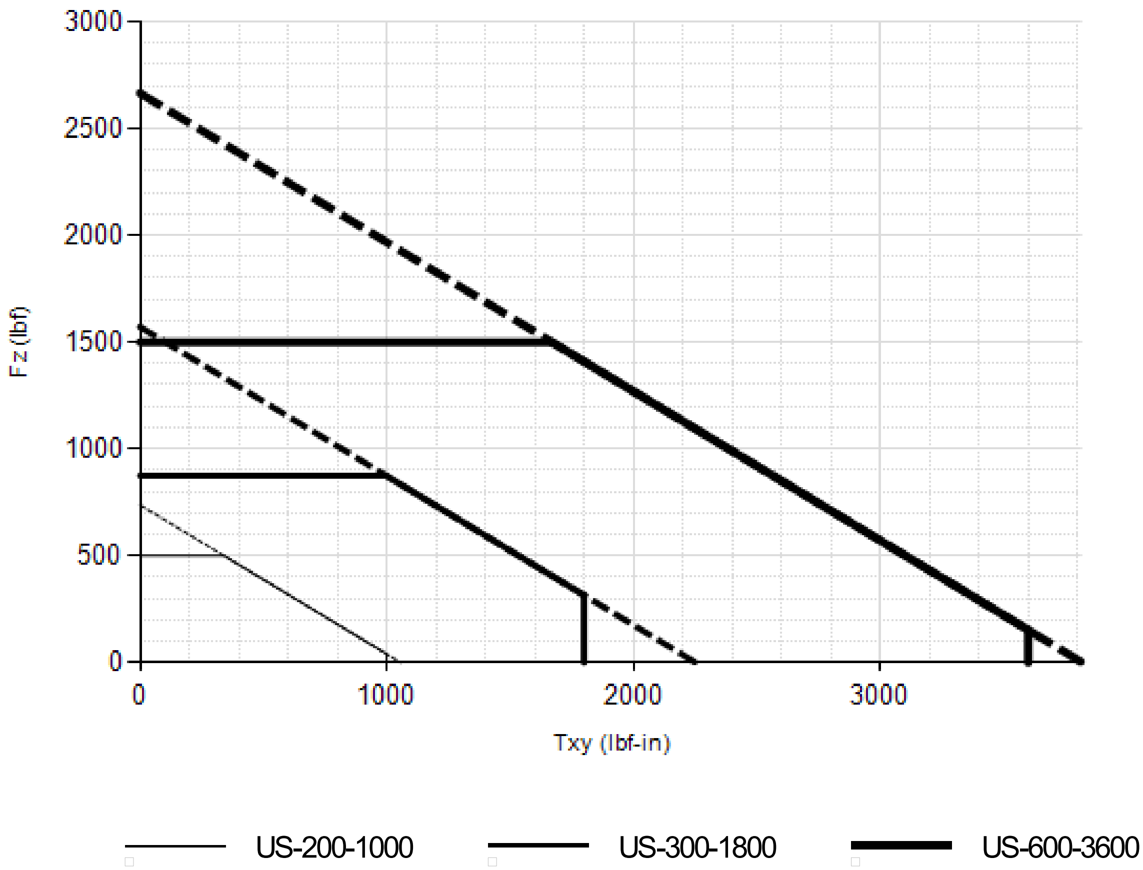
Table 4.82—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ N)**	**Tx, Ty, Tz (/ Nm)**
Theta	US-200–1000 / SI-1000–120	128	64	32	320
Theta	US-300–1800 / SI-1500–240	54.4	12.8	16	160
Theta	US-600–3600 / SI-2500–400	32	16	16	80
Theta	Tool Transform Factor	See Tool Transform Factor table			
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

5.14.8 Tool Transform Factor

Table 4.83—Tool Transform Factor			
Sensor	**Calibration**	**US (English)**	SI (Metric)
Theta	US-200–1000 / SI-1000–120	0.02 in/lbf	1 mm/N
Theta	US-300–1800 / SI-1500–240	0.0425 in/lbf	1 mm/N
Theta	US-600–3600 / SI-2500–400	0.02 in/lbf	2 mm/N

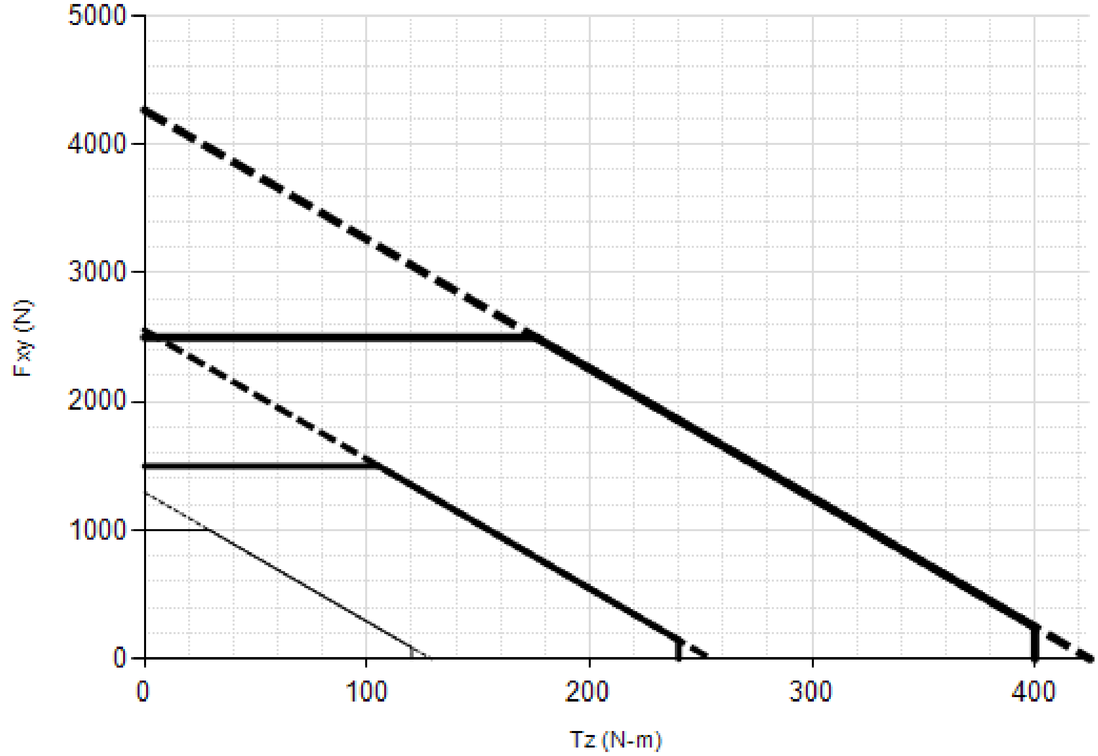
5.14.9 Theta (US Calibration Complex Loading)(Includes IP60/IP65/IP68)[1]

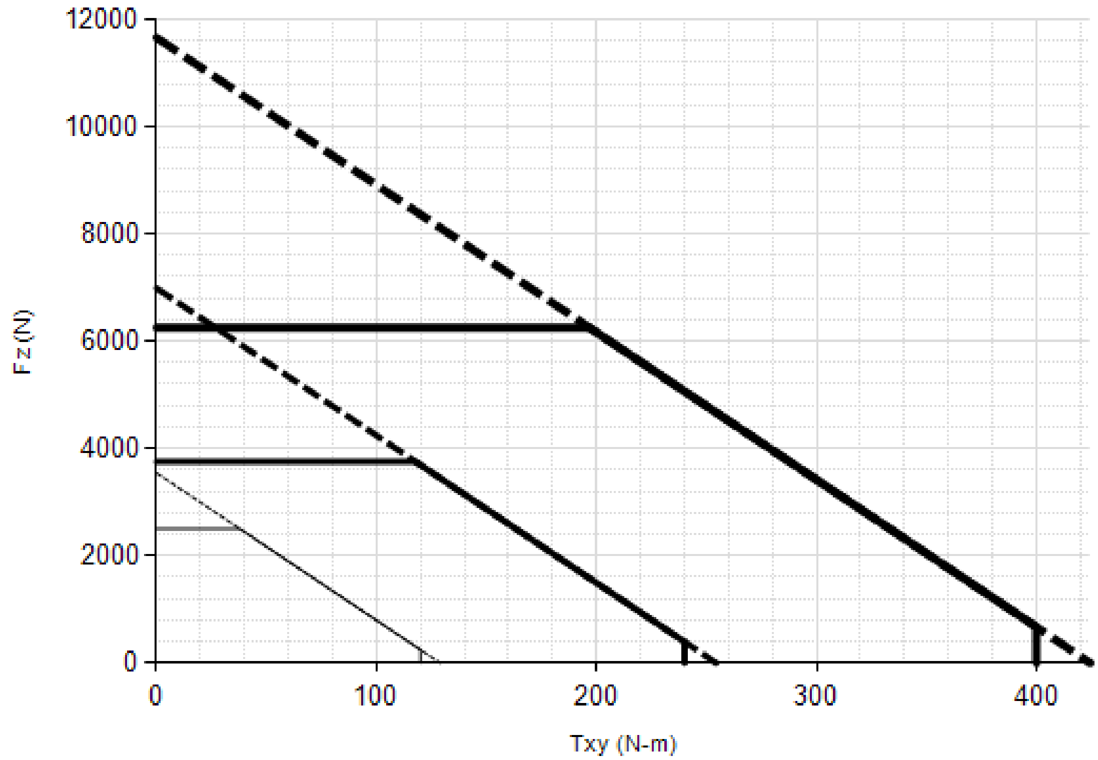




Note: 1. For IP68 version see caution on physical properties page.

5.14.10 Theta (SI Calibration Complex Loading)(Includes IP60/IP65/IP68)[1]

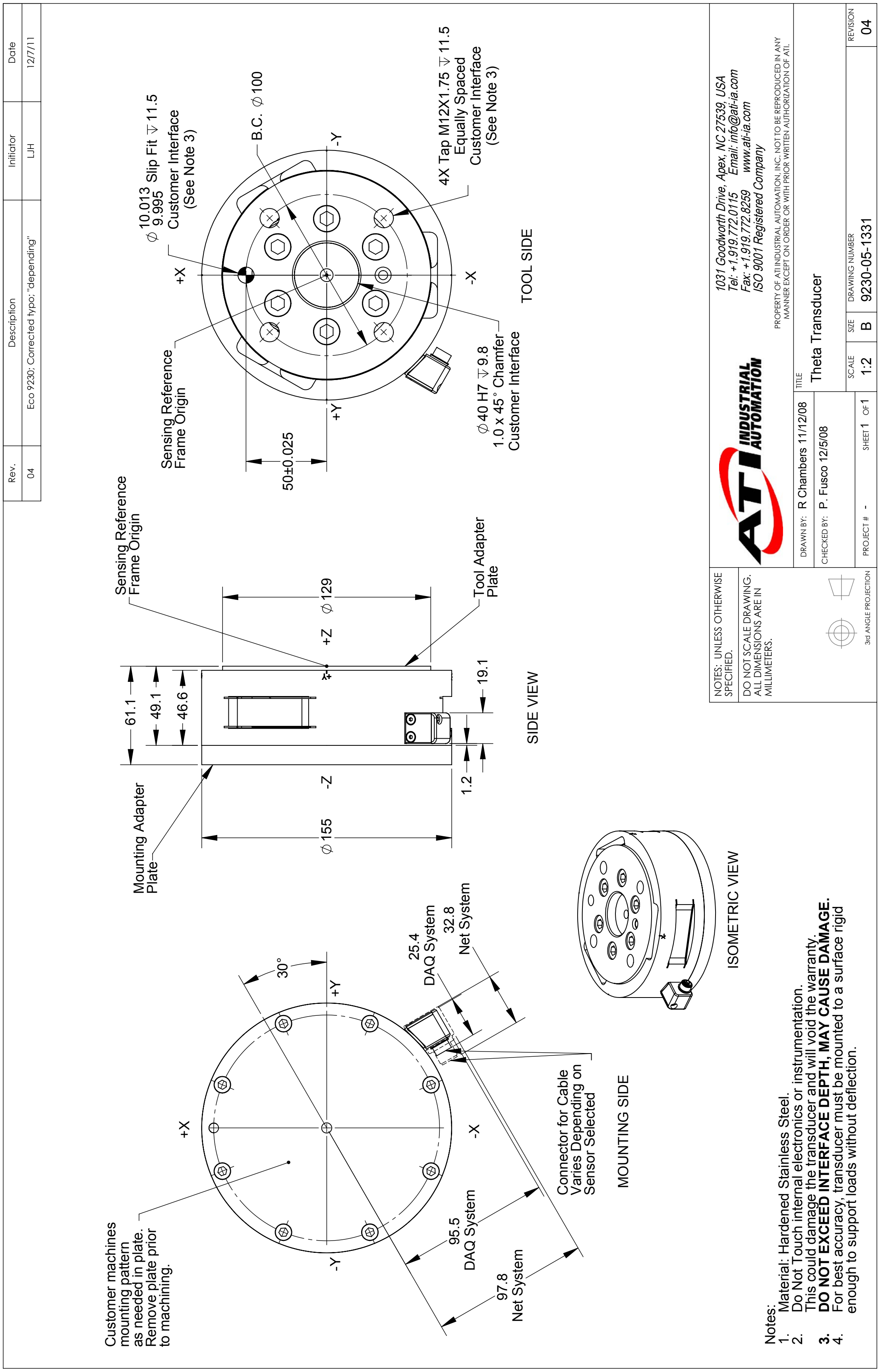




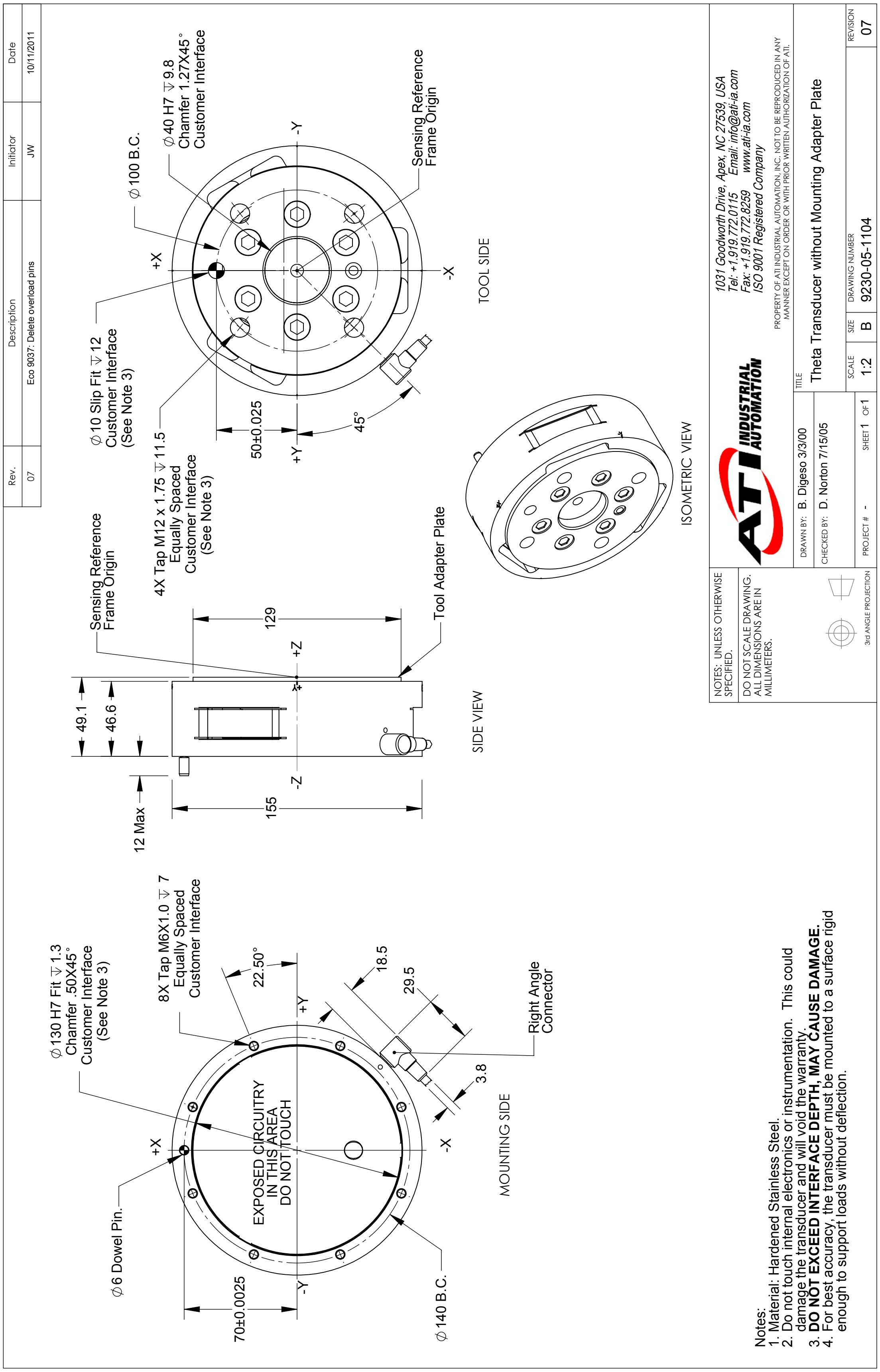
SI-1000-120 SI-1500-240 SI-2500-400

Note: 1. For IP68 version see caution on physical properties page.

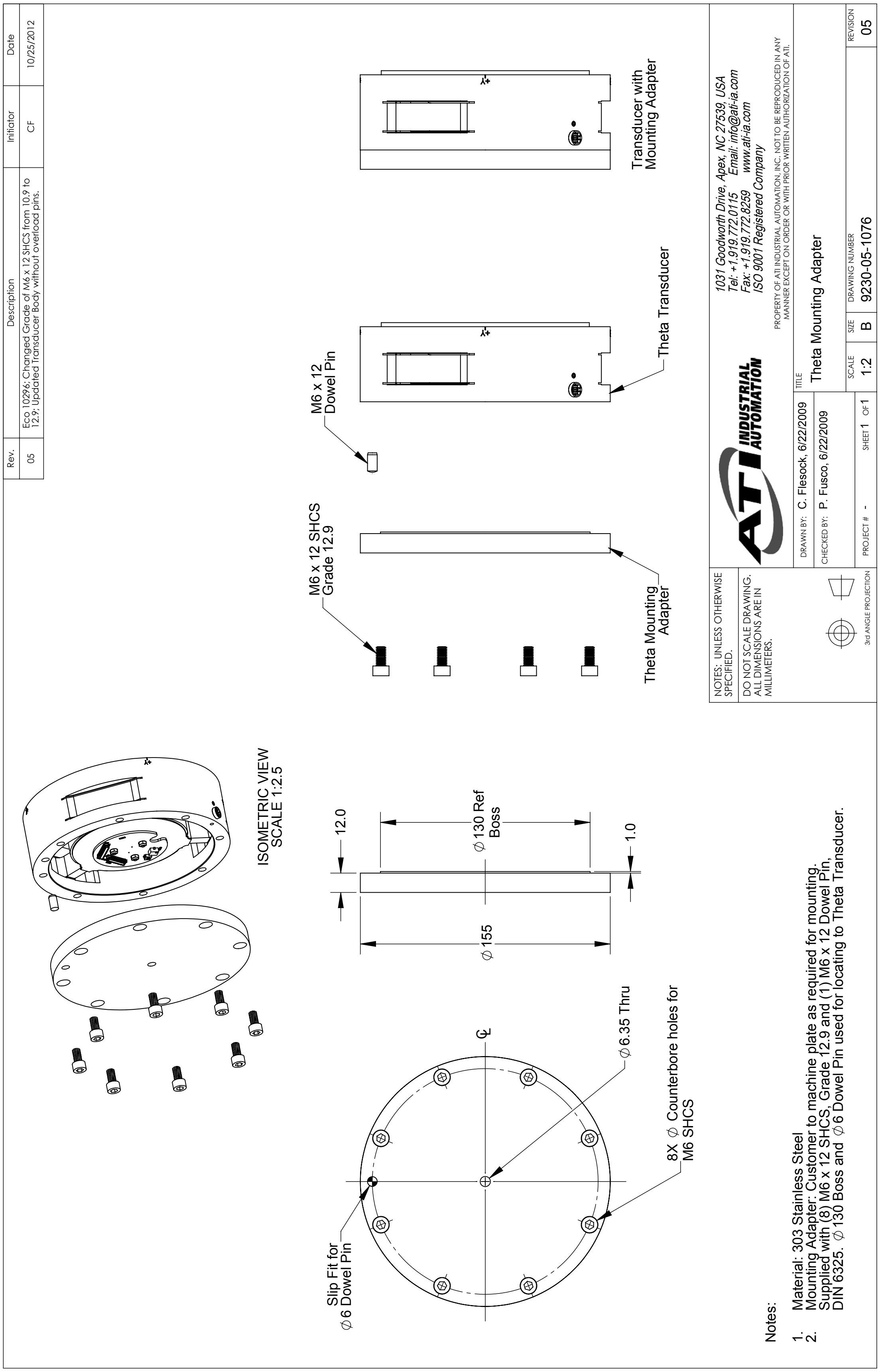
5.14.11 Theta DAQ/Net Transducer Drawing



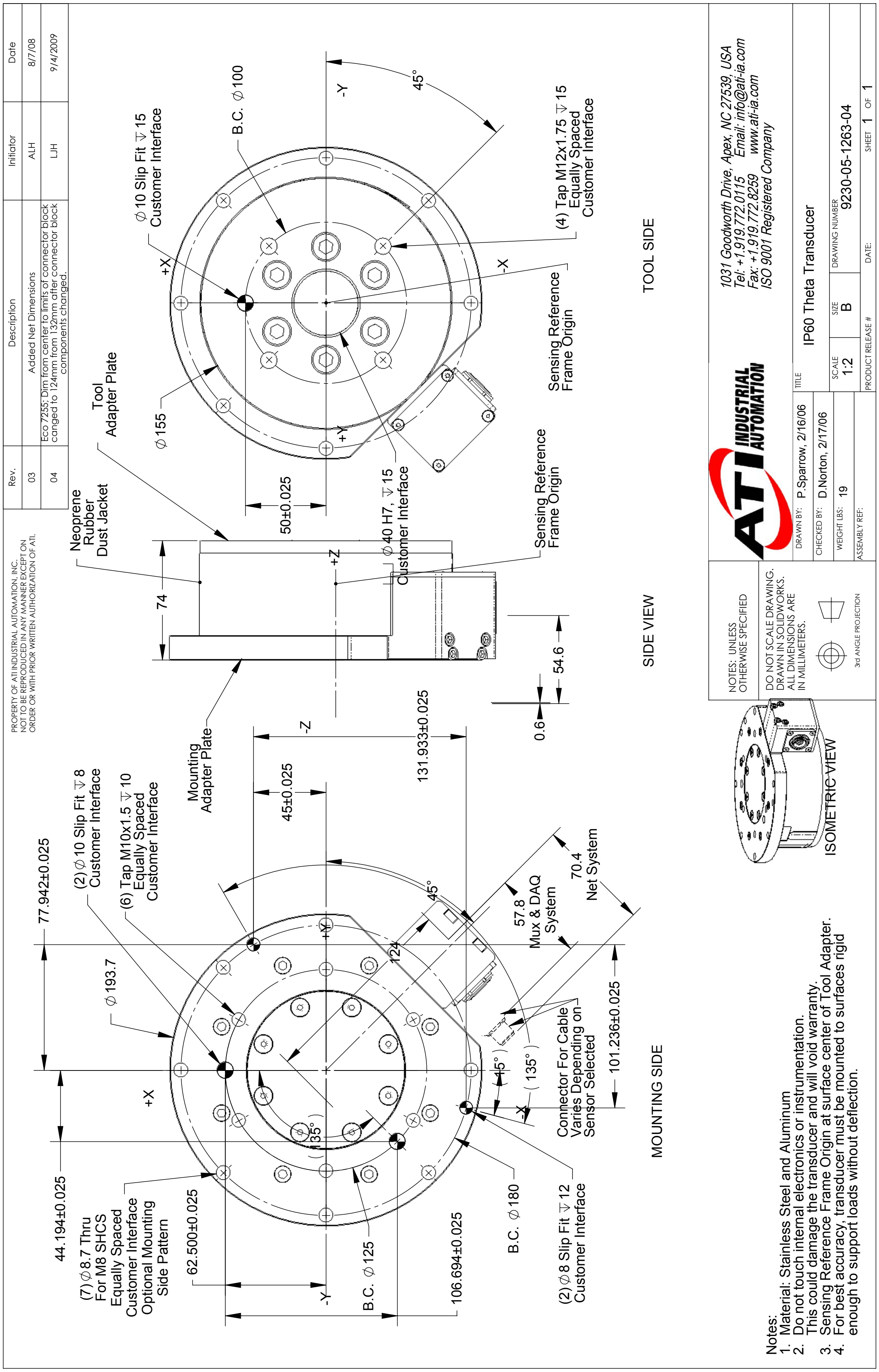
5.14.12 9105-T-Theta Transducer without Mounting Adapter Drawing



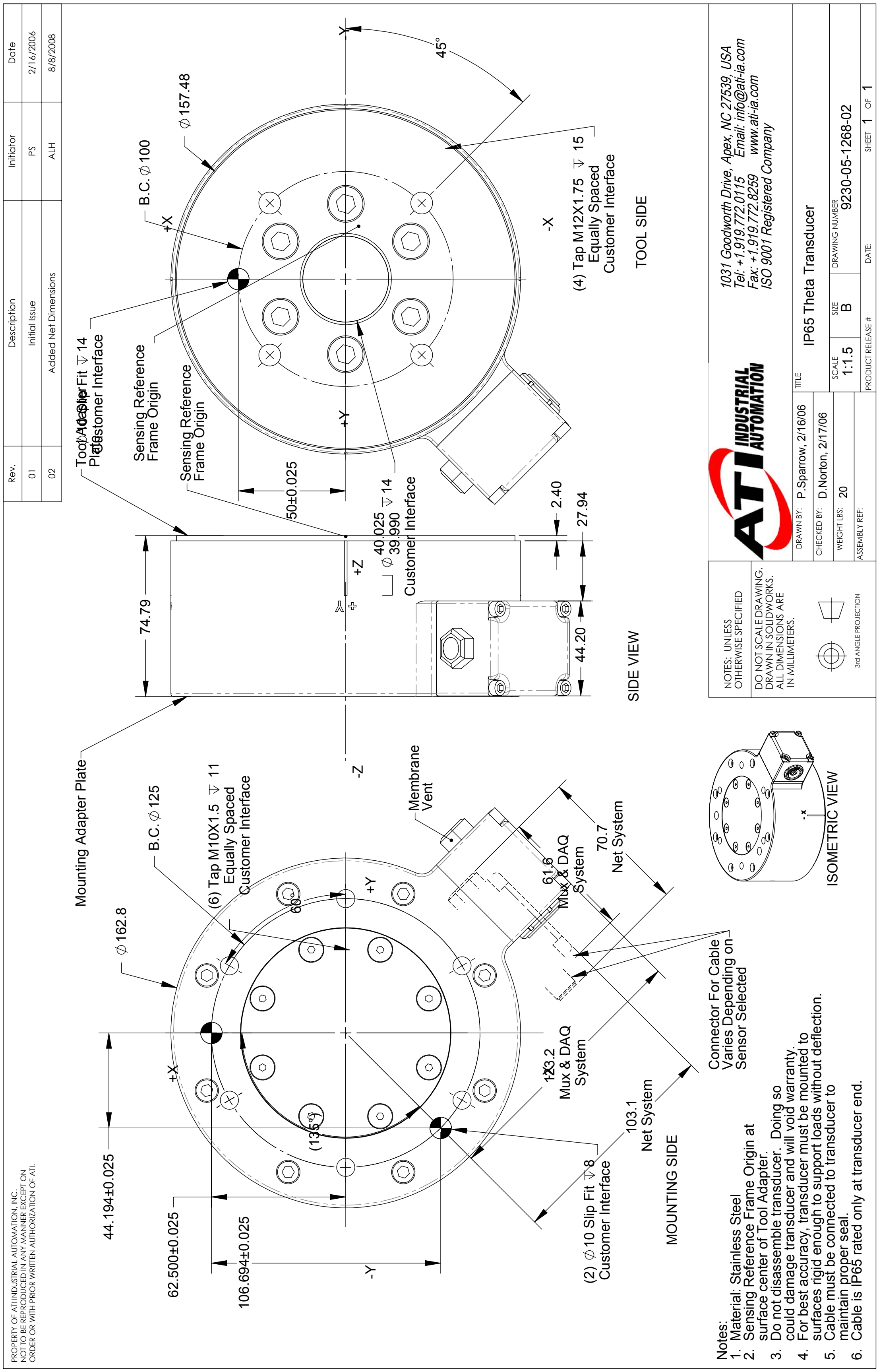
5.14.13 Theta Mounting Adapter Plate Drawing



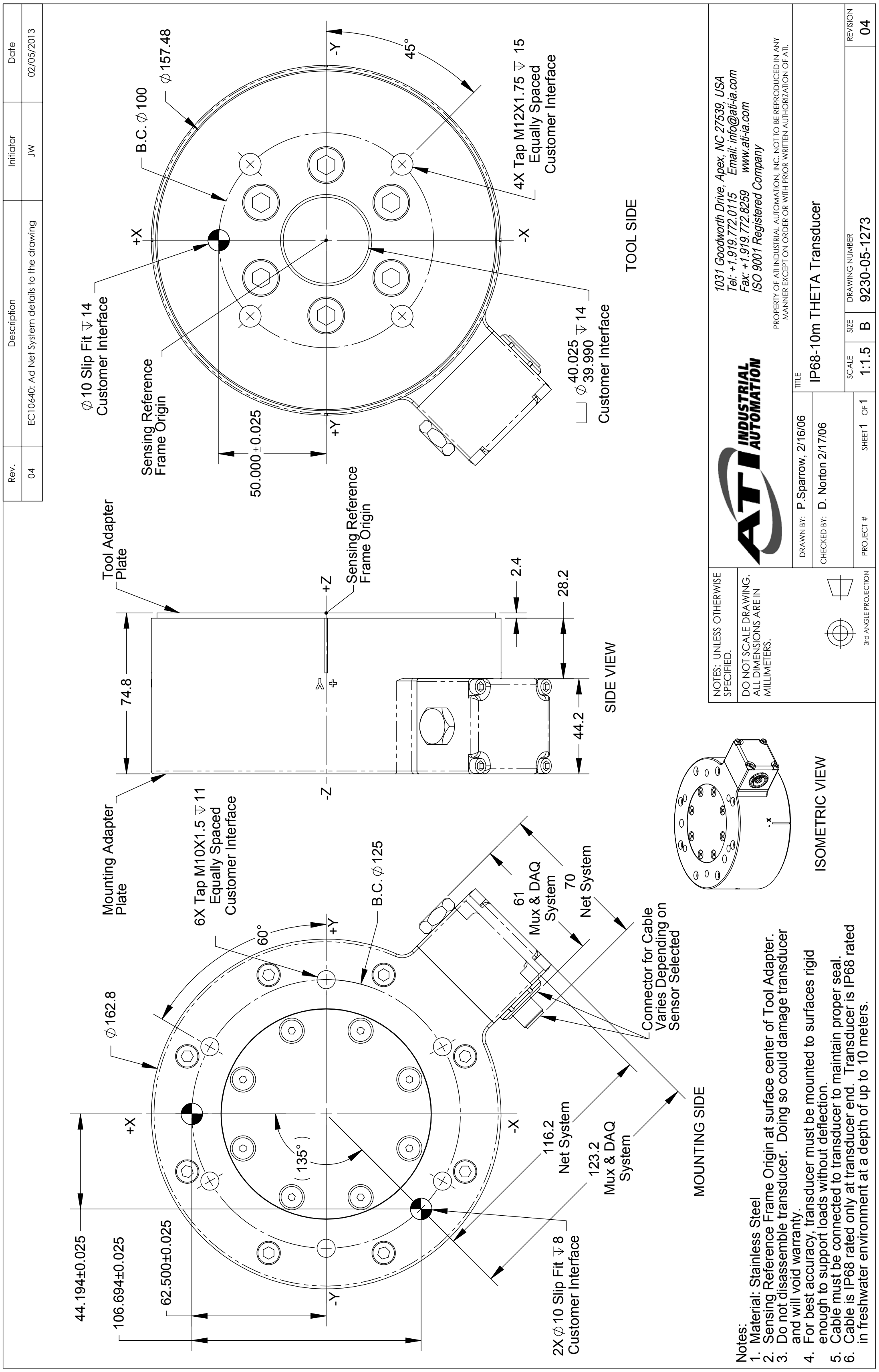
5.14.14 Theta IP60 Transducer Drawing



5.14.15 Theta IP65 Transducer Drawing



5.14.16 Theta IP68 Transducer Drawing



5.15 Omega85 Specifications (Includes IP60/IP65/IP68 Versions)

5.15.1 Omega85 Physical Properties

Table 4.84—Omega85 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±2800 lbf	±13000 N
Fz	±6100 lbf	±27000 N
Txy	±4400 inf-lb	±500 Nm
Tz	±5400 inf-lb	±610 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	4.4×10^5 lb/in	7.7×10^7 N/m
Z-axis force (Kz)	6.8×10^5 lb/in	1.2×10^8 N/m
X-axis & Y-axis torque (Ktx, Kty)	7.2×10^5 lbf-in/rad	8.1×10^4 Nm/rad
Z-axis torque (Ktz)	1.2×10^6 lbf-in/rad	1.3×10^5 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	2100 Hz	2100 Hz
Fz, Tx, Ty	3000 Hz	3000 Hz
Physical Specifications		
Weight[1]	1.45 lb	0.658 kg
Diameter[1]	3.35 in	85.1 mm
Height[1]	1.32 in	33.4 mm
Note: 1. Specifications include standard interface plates.		

5.15.2 Omega85 IP65/IP68 Physical Properties

Table 4.85—Omega85 IP65/IP68 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±2800 lbf	±13000 N
Fz	±6100 lbf	±27000 N
Txy	±4400 inf-lb	±500 Nm
Tz	±5400 inf-lb	±610 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	4.4×10^5 lb/in	7.7×10^7 N/m
Z-axis force (Kz)	6.8×10^5 lb/in	1.2×10^8 N/m
X-axis & Y-axis torque (Ktx, Kty)	7.2×10^5 lbf-in/rad	8.1×10^4 Nm/rad
Z-axis torque (Ktz)	1.2×10^6 lbf-in/rad	1.3×10^5 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	N/A	N/A
Fz, Tx, Ty	N/A	N/A
Physical Specifications		
Weight[1]	4.2 lb	1.91 kg
Diameter[1]	3.65 in	92.7 mm
Height[1]	1.52 in	38.7 mm
Note: 1. Specifications include standard interface plates.		

CAUTION: 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.

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

5.15.3 Calibration Specifications (excludes CTL calibrations)

Table 4.86— Omega85 Calibrations (excludes CTL calibrations)[1, 2]

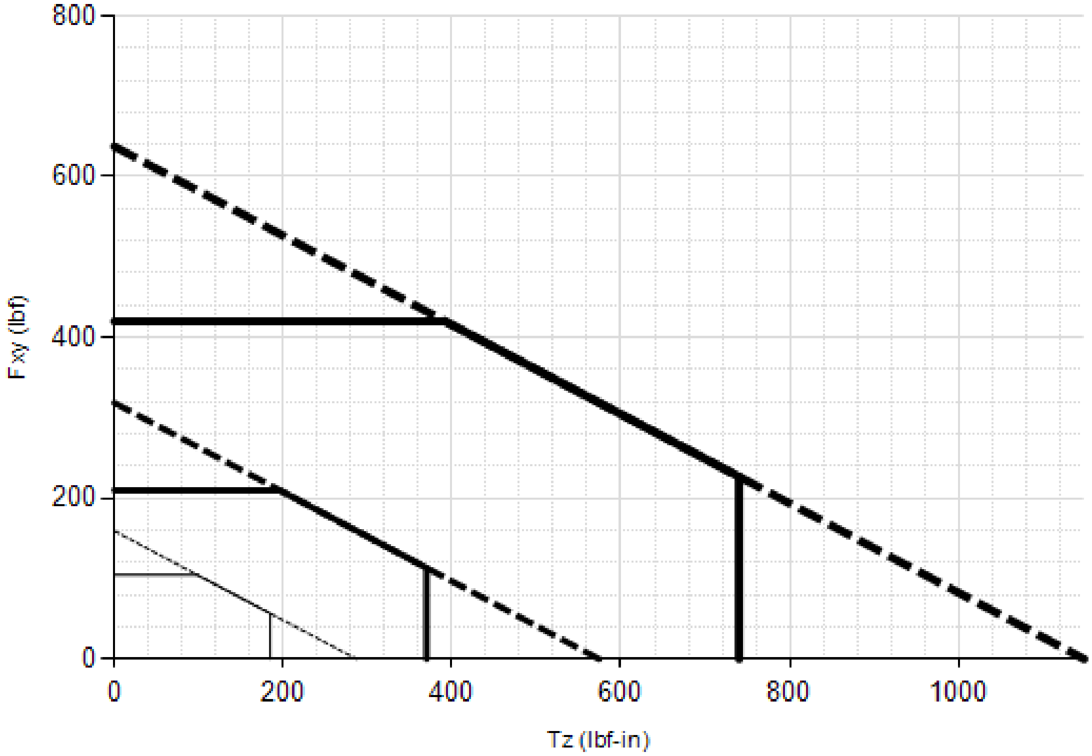
Sensor	(US) Standard Calibration	Fx,Fy (lbf)	Fz[3] (lbf)	Tx,Ty (lbf-in)	Tz (lbf-in)	Fx,Fy (lbf)	Fz[3] (lbf)	Tx,Ty (lbf-in)	Tz (lbf-in)
Omega85	US-105-185	105	210	185	185	1/52	3/130	3/112	1/48
Omega85	US-210-370	210	420	370	370	5/128	3/64	3/56	1/24
Omega85	US-420-740	420	840	740	740	5/64	3/32	3/28	1/12
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Omega85	SI-475-20	475	950	20	20	1/14	3/28	5/1496	7/2992
Omega85	SI-950-40	950	1900	40	40	1/7	3/14	5/748	7/1496
Omega85	SI-1900-80	1900	3800	80	80	2/7	3/7	5/374	7/748
		Sensing Ranges				**Resolution (DAQ, Net F/T)[4]**			

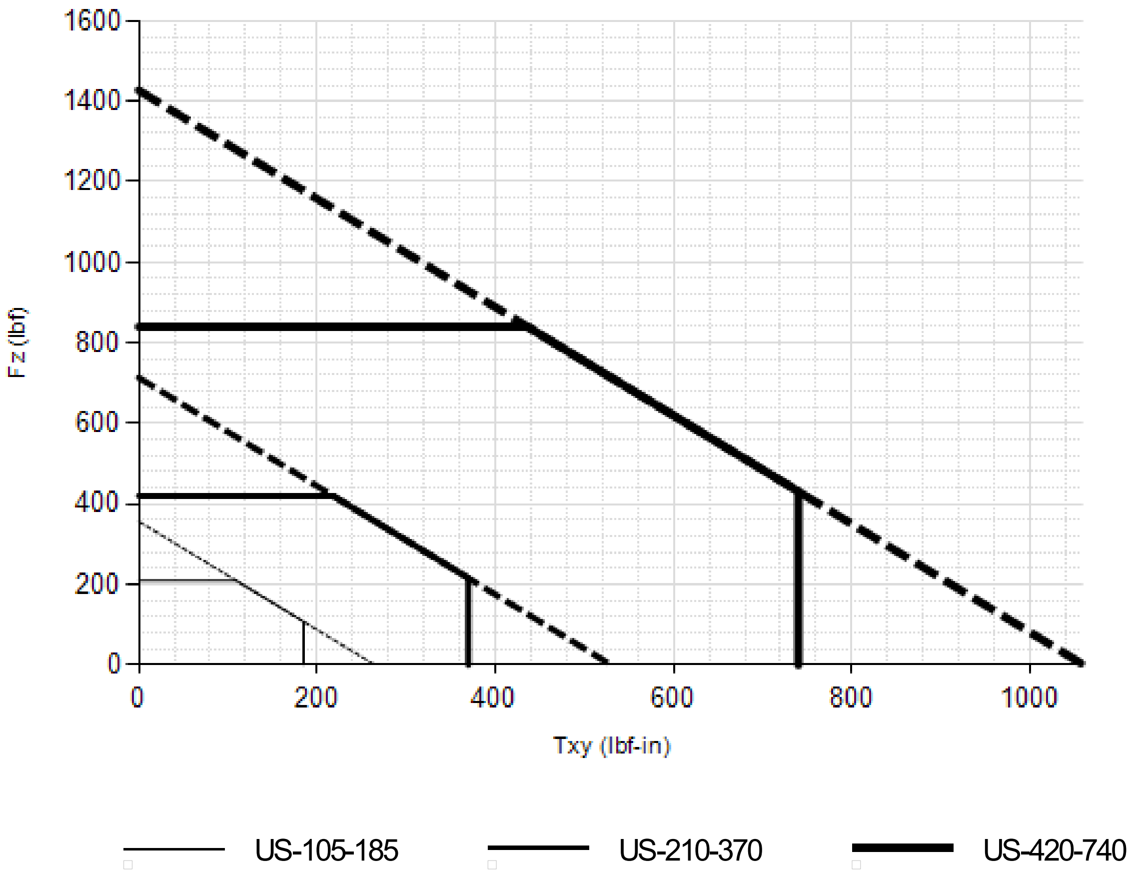
Notes:

1. These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.
4. DAQ resolutions are typical for a 16-bit data acquisition system.

NOTICE: 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.

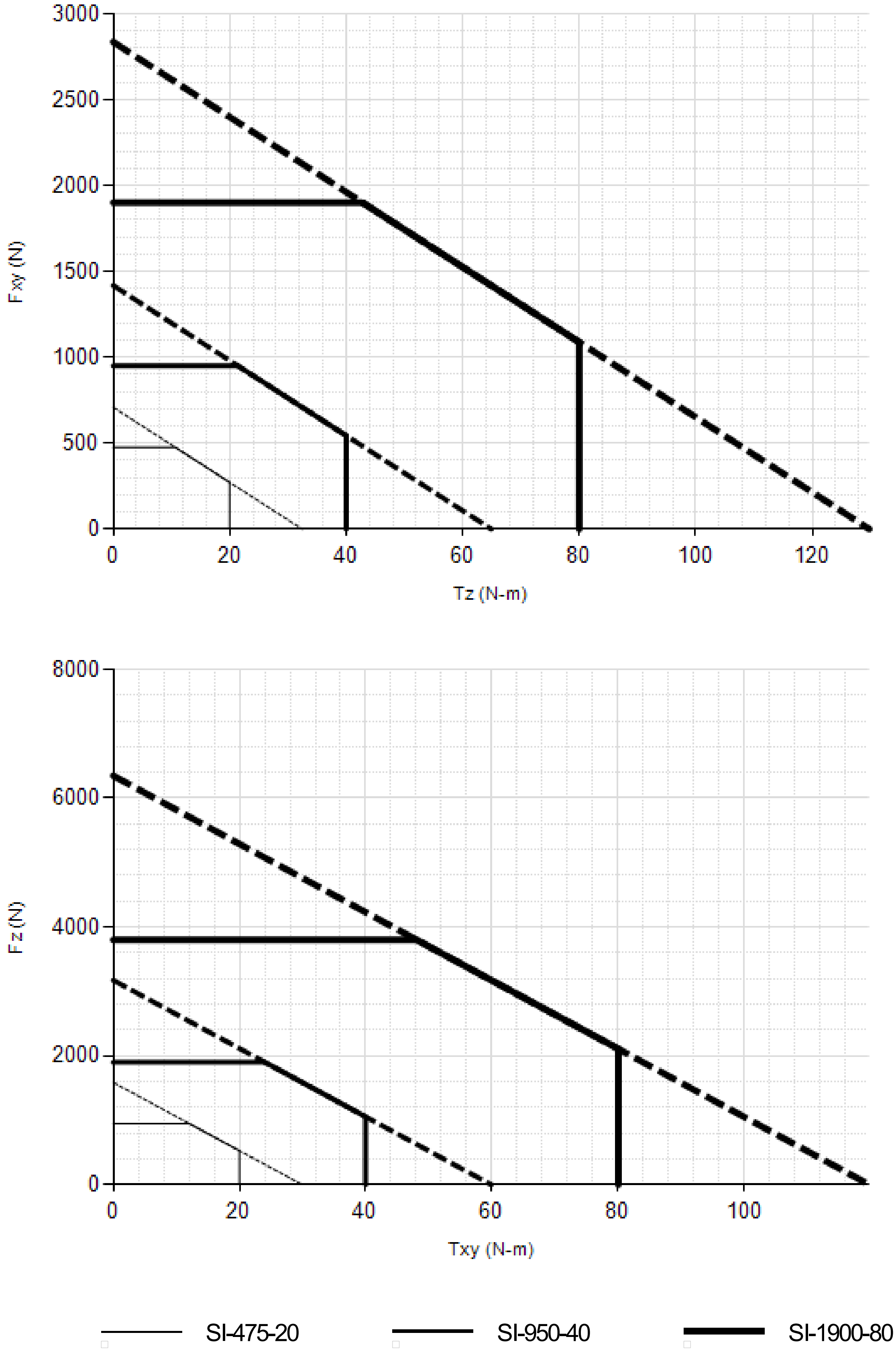
5.15.4 Omega85 (US Calibration Complex Loading)(Includes IP65/IP68)[1]





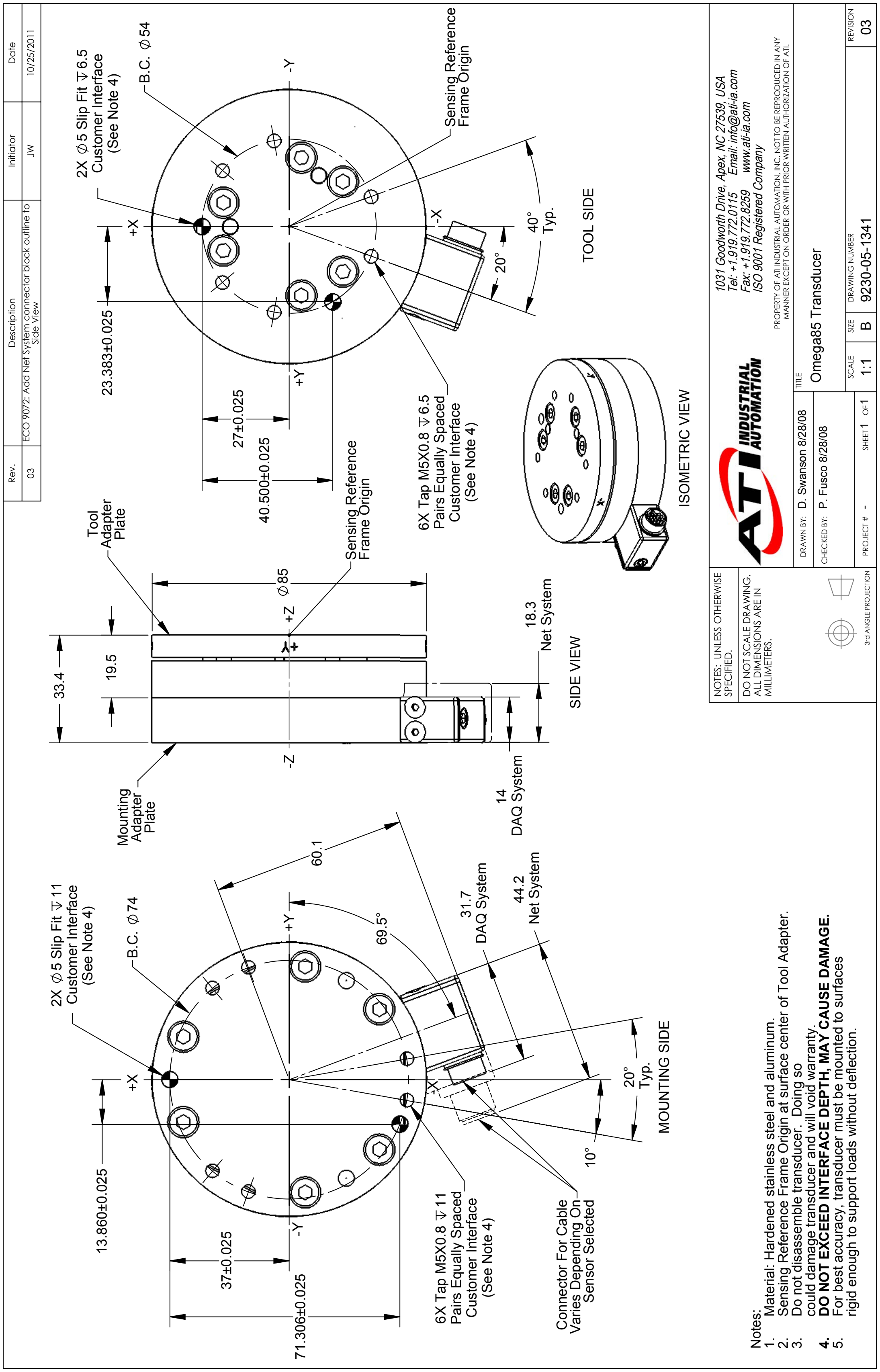
Note: 1. For IP68 version see caution on physical properties page.

5.15.5 Omega85 (SI Calibration Complex Loading)(Includes IP65/IP68)[1]

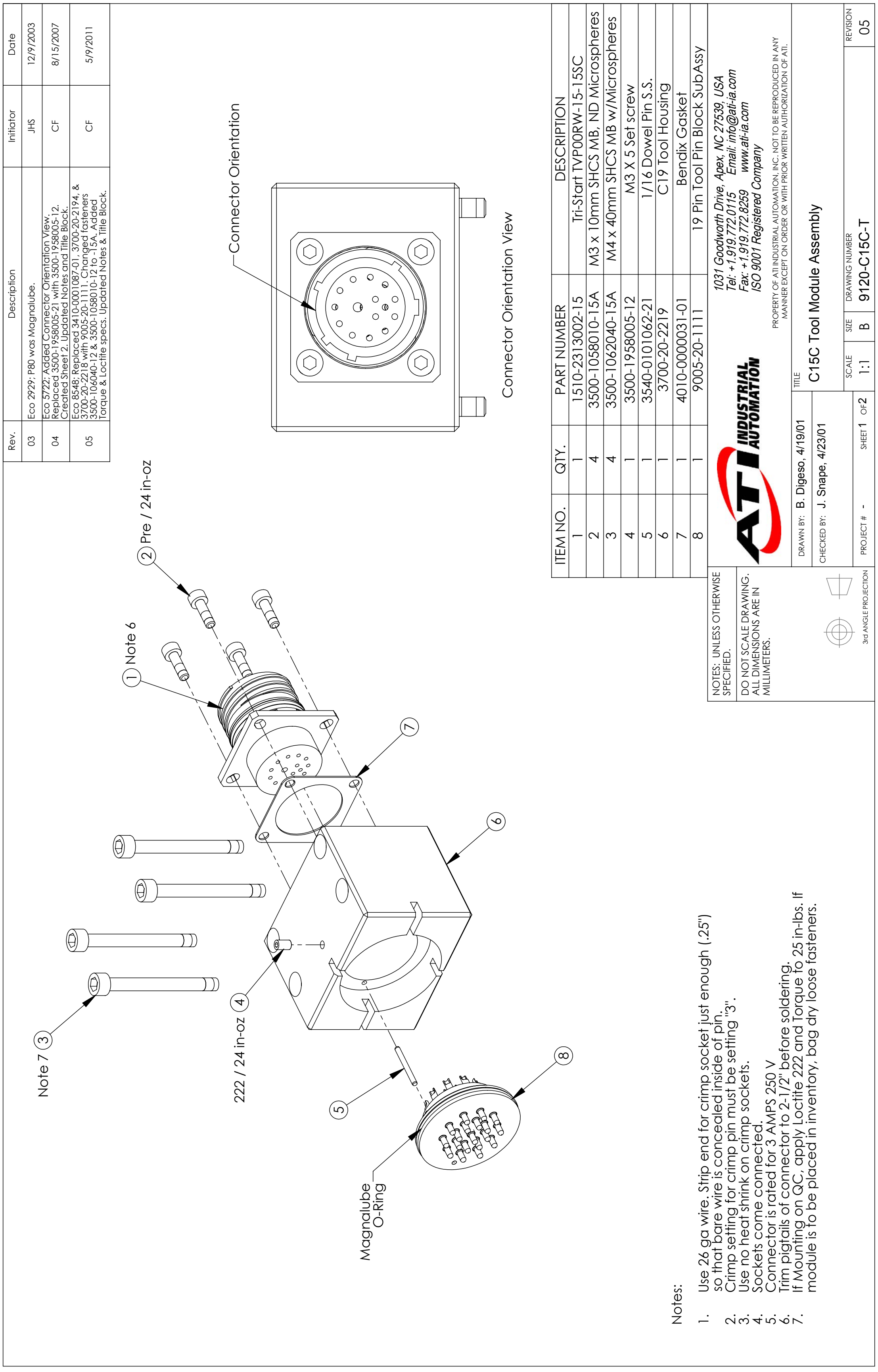


Note: 1. For IP68 version see caution on physical properties page.

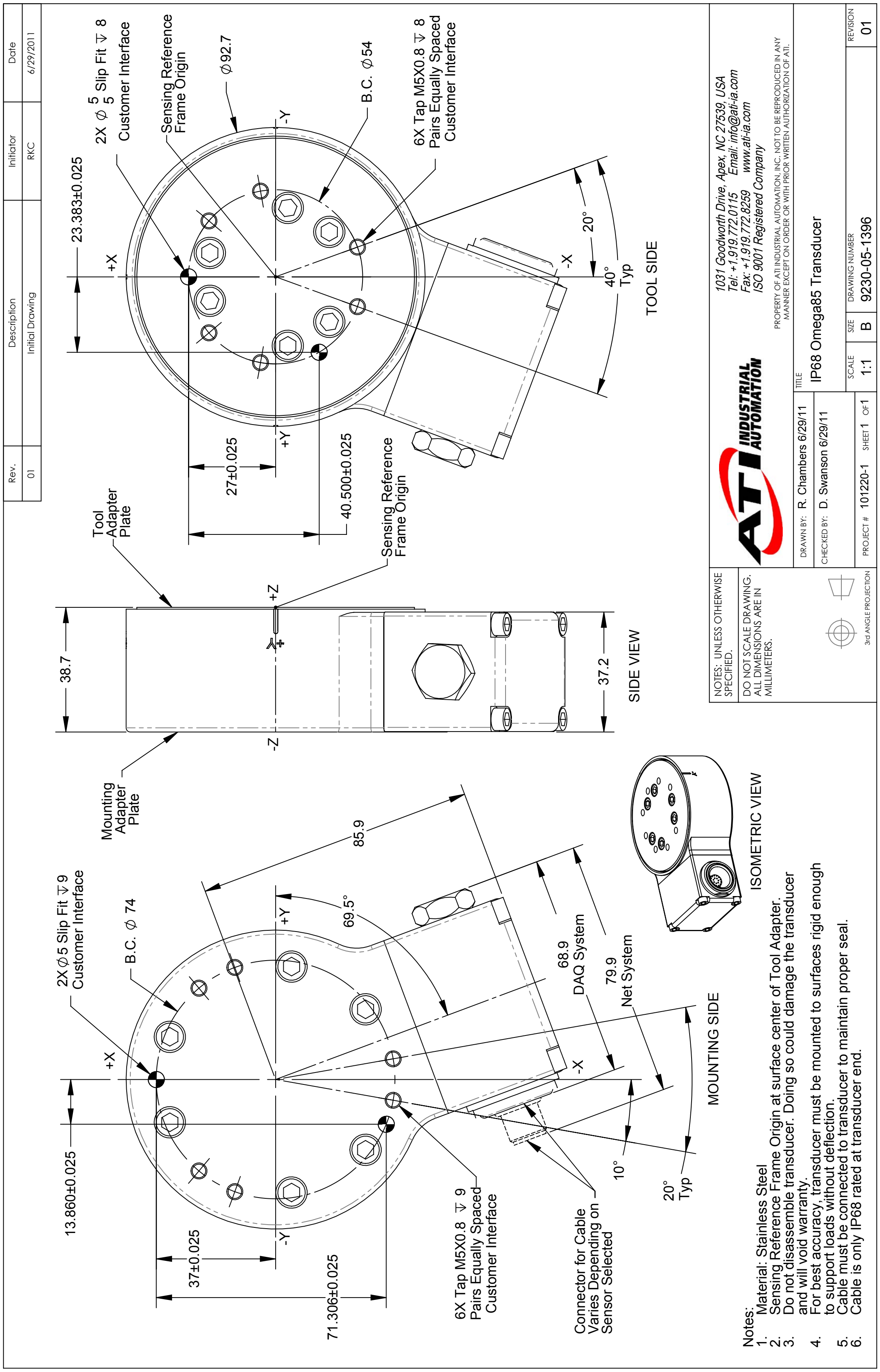
5.15.6 Omega85 Transducer Drawing



5.15.7 Omega85 IP65 Transducer Drawing



5.15.8 Omega85 IP68 Transducer Drawing



5.16 Omega160 Specifications (Includes IP60/IP65/IP68 Versions)

5.16.1 Omega160 Physical Properties

Table 4.87—Omega160 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±3900 lbf	±18000 N
Fz	±11000 lbf	±48000 N
Txy	±15000 inf-lb	±1700 Nm
Tz	±17000 inf-lb	±1900 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	$4.0x10^5$ lb/in	$7.0x10^7$ N/m
Z-axis force (Kz)	$6.8x10^5$ lb/in	$1.2x10^8$ N/m
X-axis & Y-axis torque (Ktx, Kty)	$2.9x10^6$ lbf-in/rad	$3.3x10^5$ Nm/rad
Z-axis torque (Ktz)	$4.6x10^6$ lbf-in/rad	$5.2x10^5$ Nm/rad
Resonant Frequency		
Fx, Fy, Tz	1300 Hz	1300 Hz
Fz, Tx, Ty	1000 Hz	1000 Hz
Physical Specifications		
Weight[1]	6 lb	2.72 kg
Diameter[1]	6.16 in	157 mm
Height[1]	2.2 in	55.9 mm
Note: 1. Specifications include standard interface plates.		

5.16.2 Omega160 IP160 Physical Properties (Includes ECAT)

Table 4.88—Omega160 IP160 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±3900 lbf	±18000 N
Fz	±11000 lbf	±48000 N
Txy	±15000 inf-lb	±1700 Nm
Tz	±17000 inf-lb	±1900 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	$4.0x10^5$ lb/in	$7.0x10^7$ N/m
Z-axis force (Kz)	$6.8x10^5$ lb/in	$1.2x10^8$ N/m
X-axis & Y-axis torque (Ktx, Kty)	$2.9x10^6$ lbf-in/rad	$3.3x10^5$ Nm/rad
Z-axis torque (Ktz)	$4.6x10^6$ lbf-in/rad	$5.2x10^5$ Nm/rad
Resonant Frequency		
Fx, Fy, Tz	1100 Hz	1100 Hz
Fz, Tx, Ty	1000 Hz	1000 Hz
Physical Specifications		
Weight[1]	16.9 lb	7.67 kg
Diameter[1]	7.63 in	194 mm
Height[1]	2.27 in	57.7 mm
Note: 1. Specifications include standard interface plates.		

5.16.3 Omega160 IP65/IP68 Physical Properties

Table 4.89—Omega160 IP65/IP68 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±3900 lbf	±18000 N
Fz	±11000 lbf	±48000 N
Txy	±15000 inf-lb	±1700 Nm
Tz	±17000 inf-lb	±1900 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	4.0×10^{5} lb/in	7.0×10^{7} N/m
Z-axis force (Kz)	6.8×10^{5} lb/in	1.2×10^{8} N/m
X-axis & Y-axis torque (Ktx, Kty)	2.9×10^{6} lbf-in/rad	3.3×10^{5} Nm/rad
Z-axis torque (Ktz)	4.6×10^{6} lbf-in/rad	5.2×10^{5} Nm/rad
Resonant Frequency		
Fx, Fy, Tz	1200 Hz	1200 Hz
Fz, Tx, Ty	900 Hz	900 Hz
Physical Specifications		
Weight[1]	16 lb	7.26 kg
Diameter[1]	6.5 in	165 mm
Height[1]	2.59 in	65.9 mm

Note:
1. Specifications include standard interface plates.

CAUTION: 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.

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

5.16.4 Calibration Specifications (excludes CTL calibrations)

Table 4.90— Omega160 Calibrations (excludes CTL calibrations)[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Omega160	US-200-1000	200	500	1000	1000	1/32	1/16	1/8	1/8
Omega160	US-300-1800	300	875	1800	1800	5/68	5/34	5/16	5/16
Omega160	US-600-3600	600	1500	3600	3600	1/8	1/4	1/2	1/4
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Omega160	SI-1000-120	1000	2500	120	120	1/4	1/4	1/40	1/80
Omega160	SI-1500-240	1500	3750	240	240	1/4	1/2	1/20	1/40
Omega160	SI-2500-400	2500	6250	400	400	1/2	3/4	1/20	1/20
		Sensing Ranges				**Resolution (DAQ, Net F/T)[4]**			

Notes:

1. These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.
4. DAQ resolutions are typical for a 16-bit data acquisition system.

5.16.5 CTL Calibration Specifications

Table 4.91— Omega160 CTL Calibrations[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Omega160	US-200-1000	200	500	1000	1000	1/16	1/8	1/4	1/4
Omega160	US-300-1800	300	875	1800	1800	5/34	5/17	5/8	5/8
Omega160	US-600-3600	600	1500	3600	3600	1/4	1/2	1	1/2
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Omega160	SI-1000-120	1000	2500	120	120	1/2	1/2	1/20	1/40
Omega160	SI-1500-240	1500	3750	240	240	1/2	1	1/10	1/20
Omega160	SI-2500-400	2500	6250	400	400	1	1 1/2	1/10	1/10
		Sensing Ranges				**Resolution (Controller)**			

Notes:

1. 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.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.

5.16.6 CTL Analog Output

Table 4.92— Omega160 Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[2] (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz[2] (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Omega160	US-200-1000	±200	±500	±1000	20	50	100
Omega160	US-300-1800	±300	±875	±1800	30	87.5	180
Omega160	US-600-3600	±600	±1500	±3600	60	150	360
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz (N)**	**Tx,Ty,Tz (Nm)**	**Fx,Fy (N/V)**	**Fz[2] (N/V)**	**Tx,Ty,Tz (Nm/V)**
Omega160	SI-1000-120	±1000	±2500	±120	100	250	12
Omega160	SI-1500-240	±1500	±3750	±240	150	375	24
Omega160	SI-2500-400	±2500	±6250	±400	250	625	40
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

Notes:
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.
2. For IP68 version see caution on physical properties page.

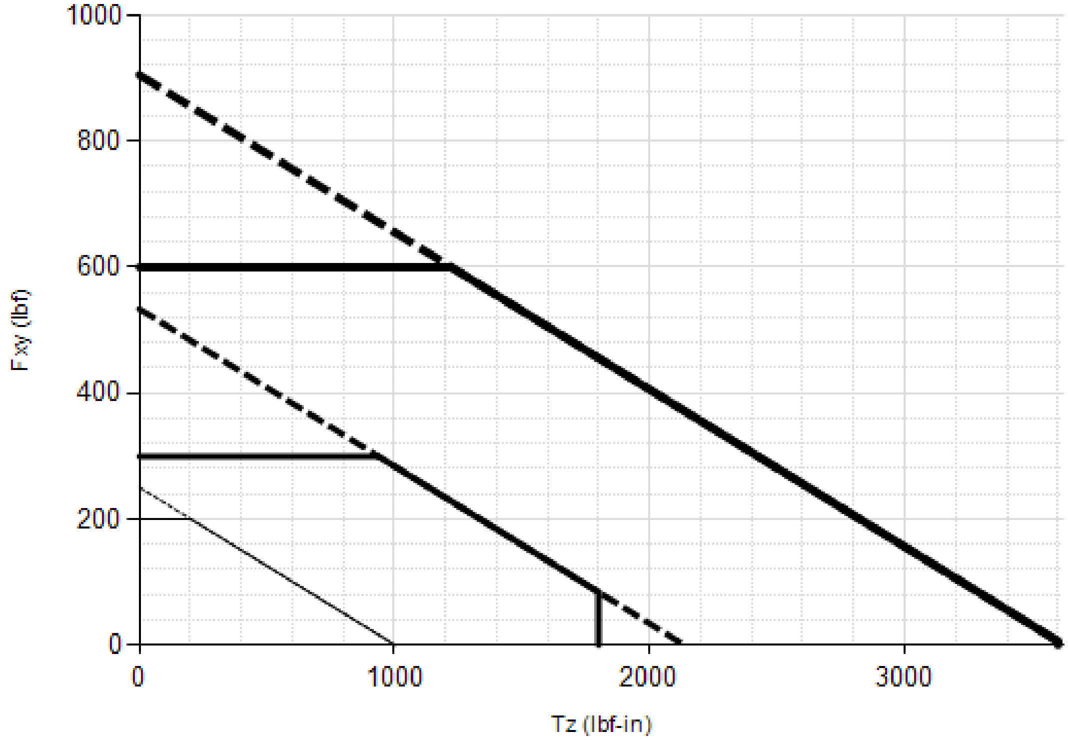
5.16.7 CTL Counts Value

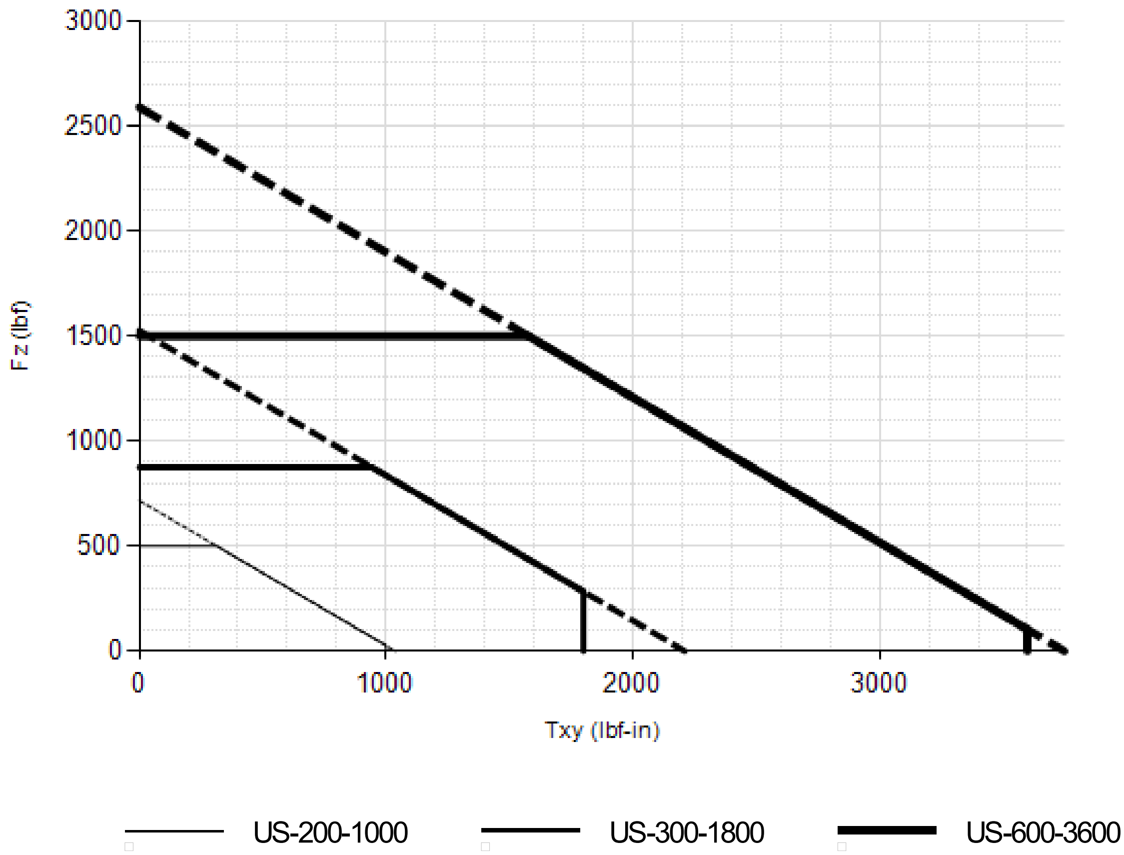
Table 4.93—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ N)**	**Tx, Ty, Tz (/ Nm)**
Omega160	US-200–1000 / SI-1000–120	128	64	32	320
Omega160	US-300–1800 / SI-1500–240	54.4	12.8	16	160
Omega160	US-600–3600 / SI-2500–400	32	16	16	80
Omega160	Tool Transform Factor	See Tool Transform Factor table			
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

5.16.8 Tool Transform Factor

Table 4.94—Tool Transform Factor			
Sensor	**Calibration**	**US (English)**	SI (Metric)
Omega160	US-200–1000 / SI-1000–120	0.02 in/lbf	1 mm/N
Omega160	US-300–1800 / SI-1500–240	0.0425 in/lbf	1 mm/N
Omega160	US-600–3600 / SI-2500–400	0.02 in/lbf	2 mm/N

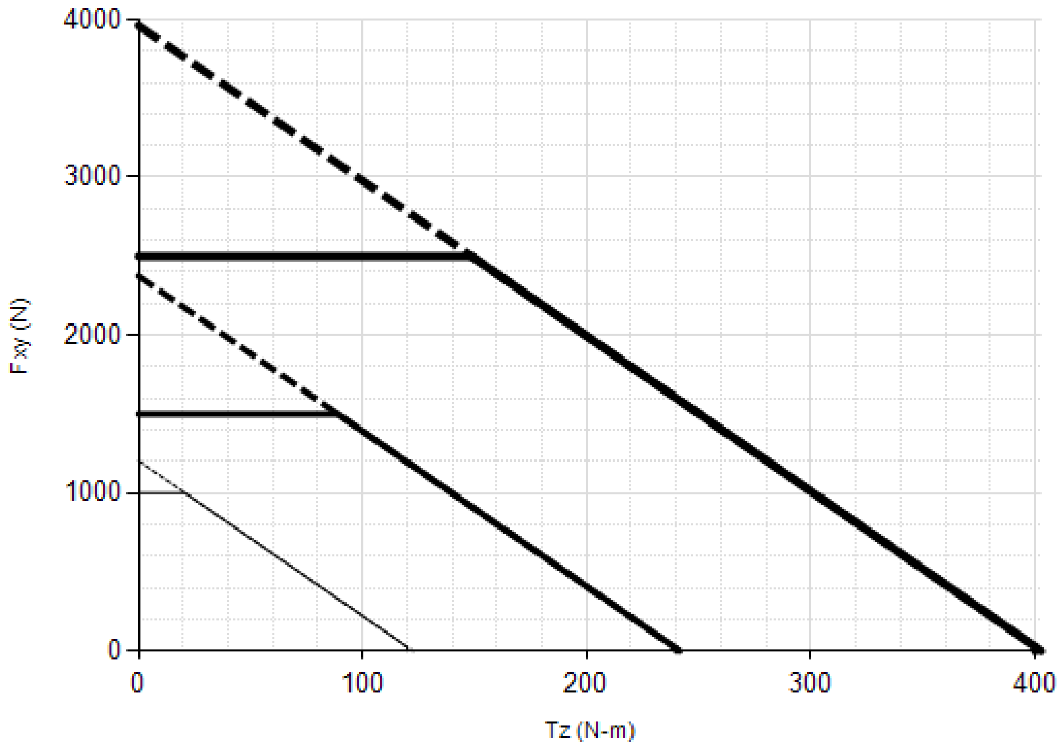
5.16.9 Omega160 (US Calibration Complex Loading) (Includes IP60/IP65/IP68)[1]

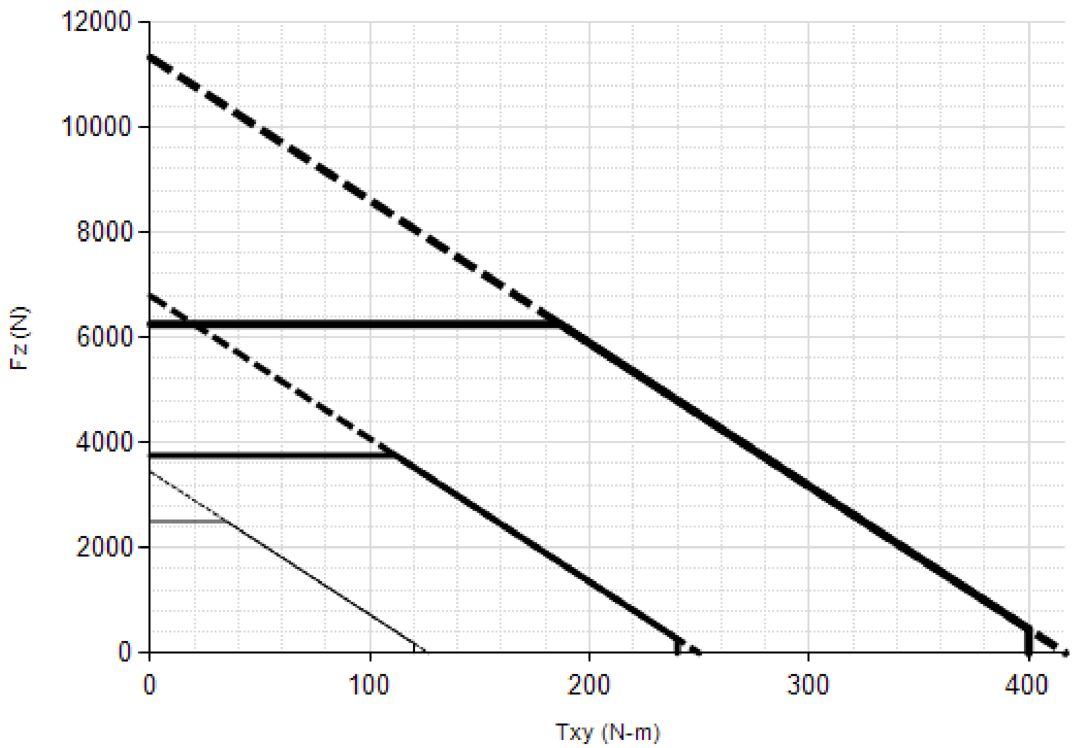




Note: 1. For IP68 version see caution on physical properties page.

5.16.10 Omega160 (SI Calibration Complex Loading) (Includes IP60/IP65/IP68)[1]

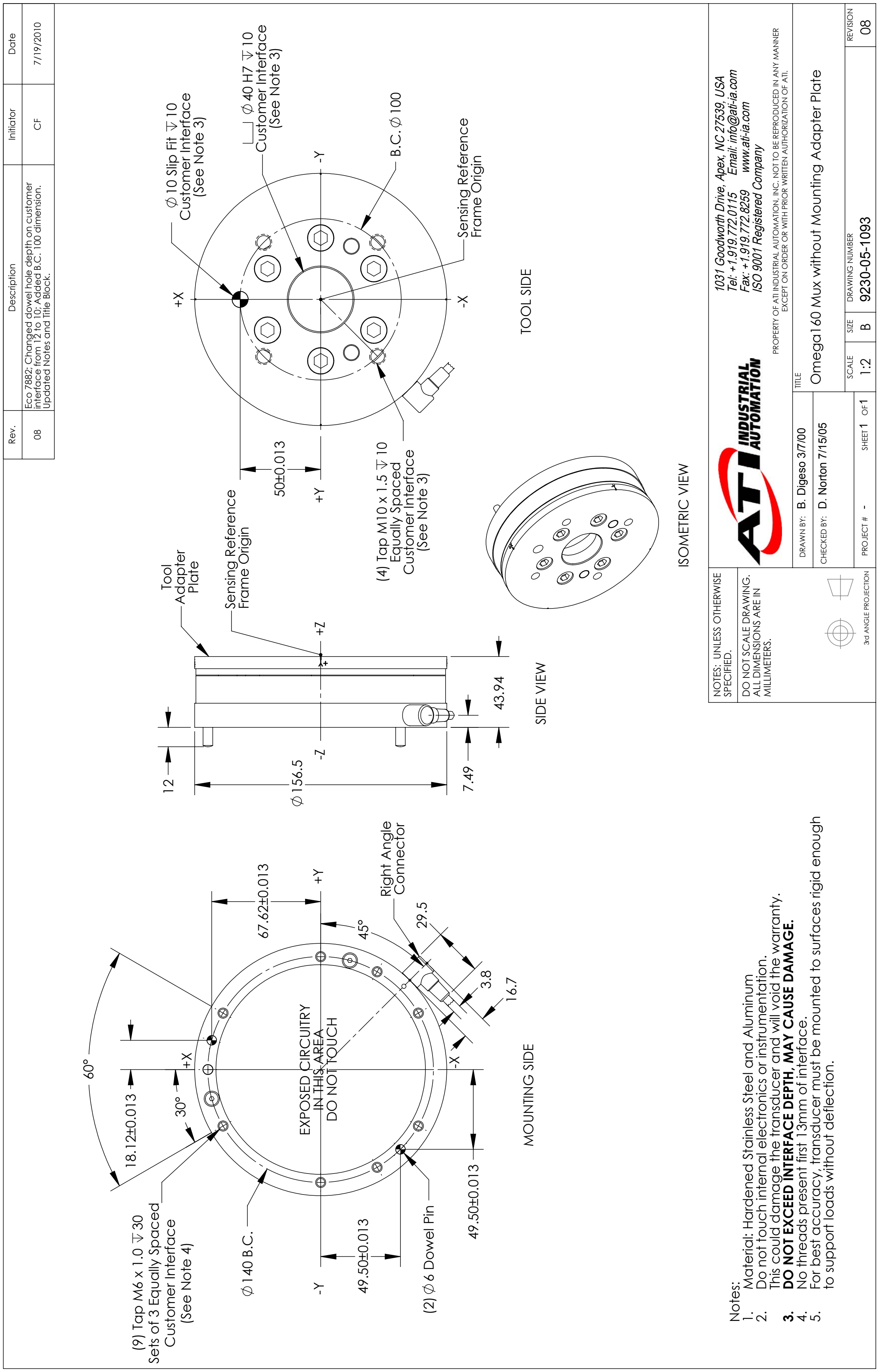




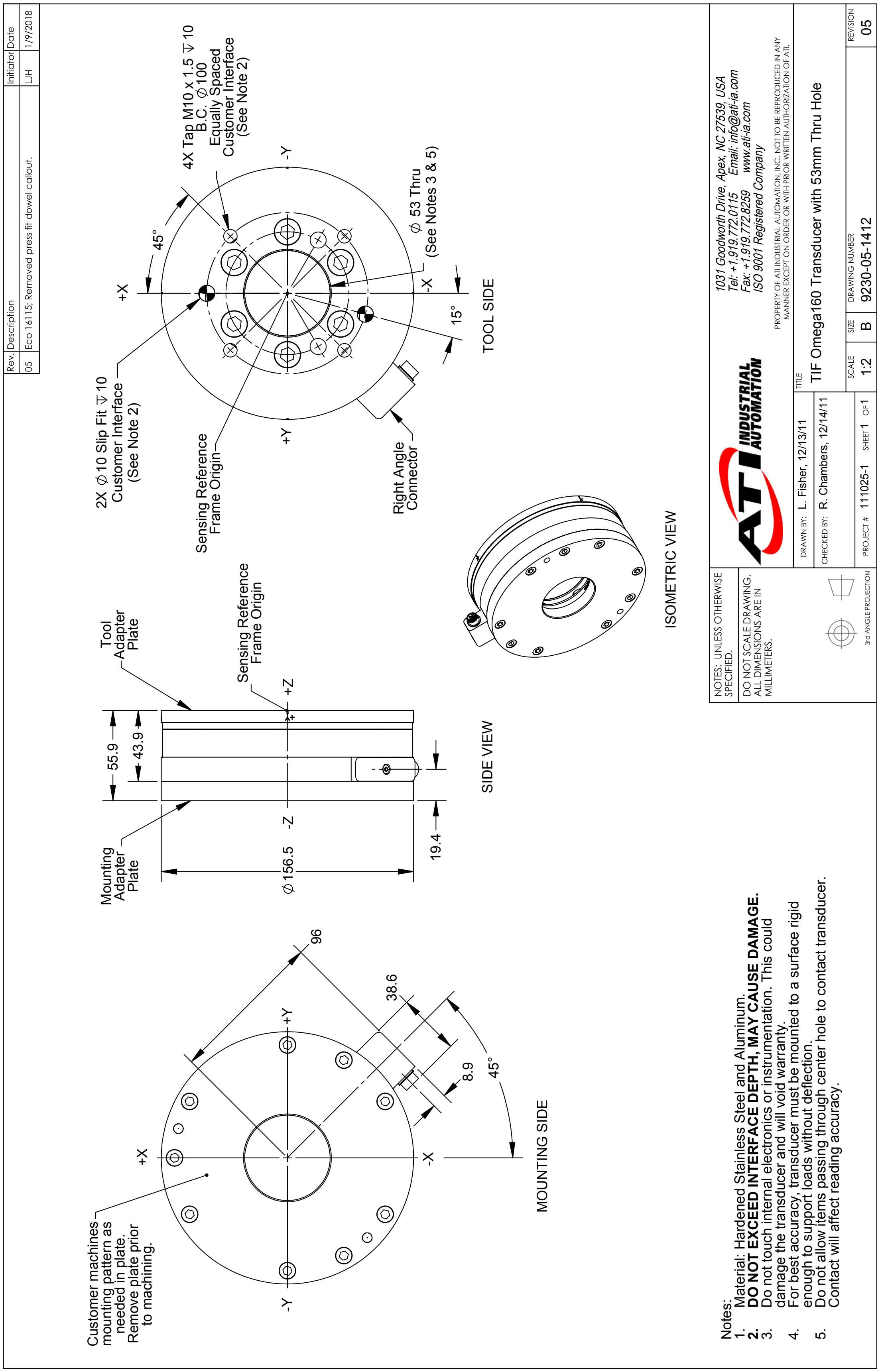
SI-1000-120 SI-1500-240 SI-2500-400

Note: 1. For IP68 version see caution on physical properties page.

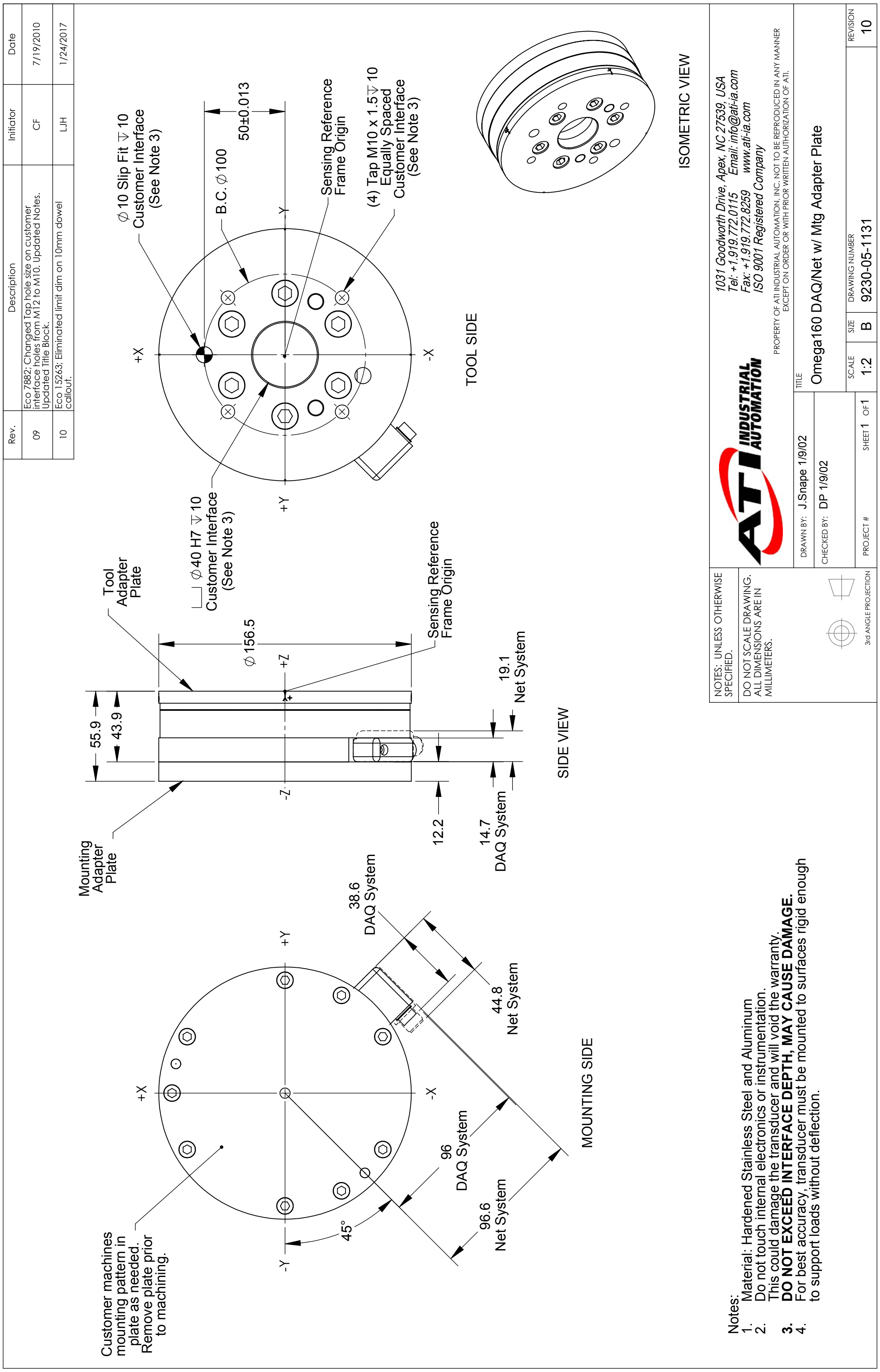
5.16.11 Omega160 Transducer without Mounting Adapter Drawing



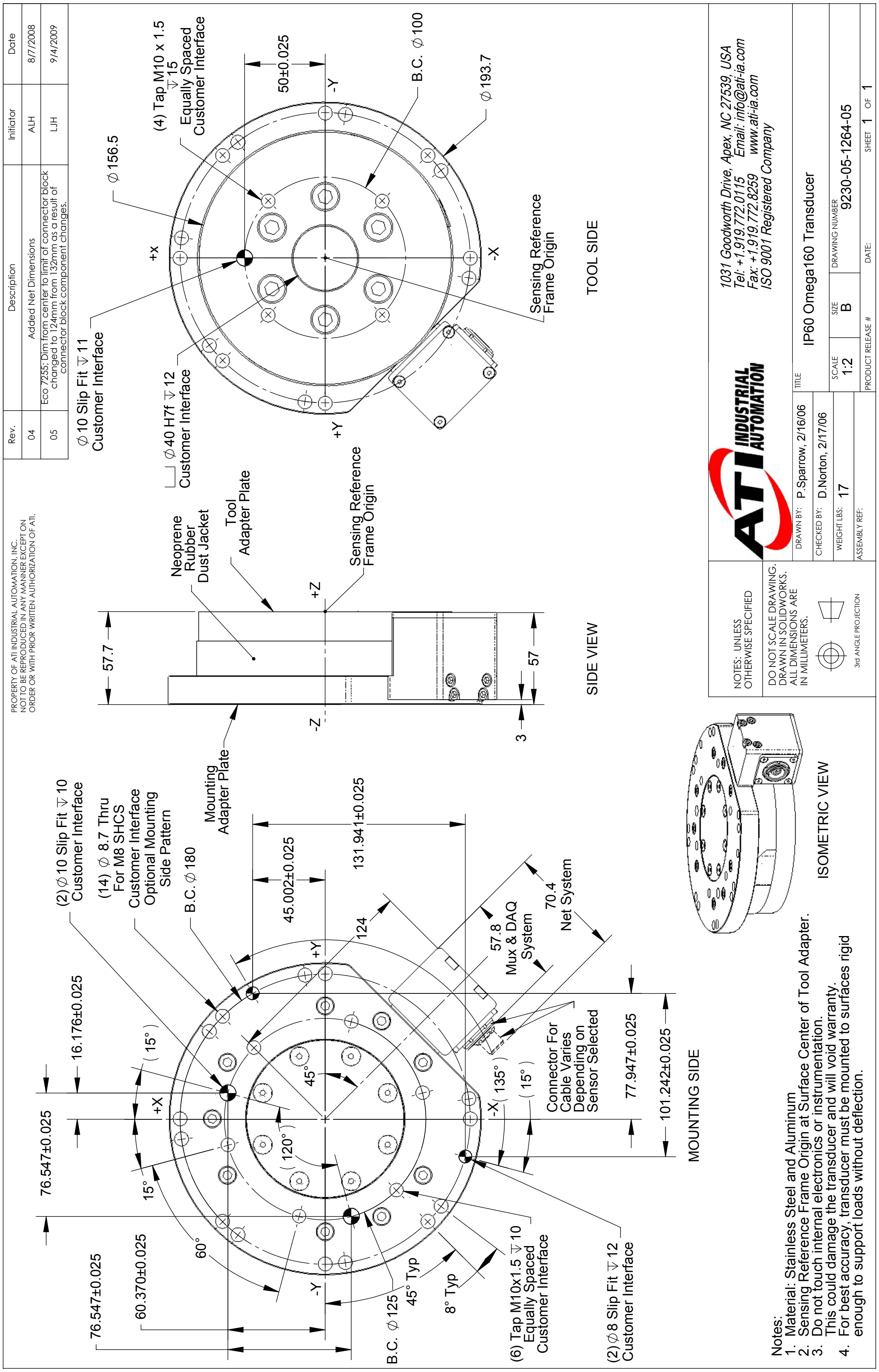
5.16.12 Omega160 Transducer with 53mm Through Hole



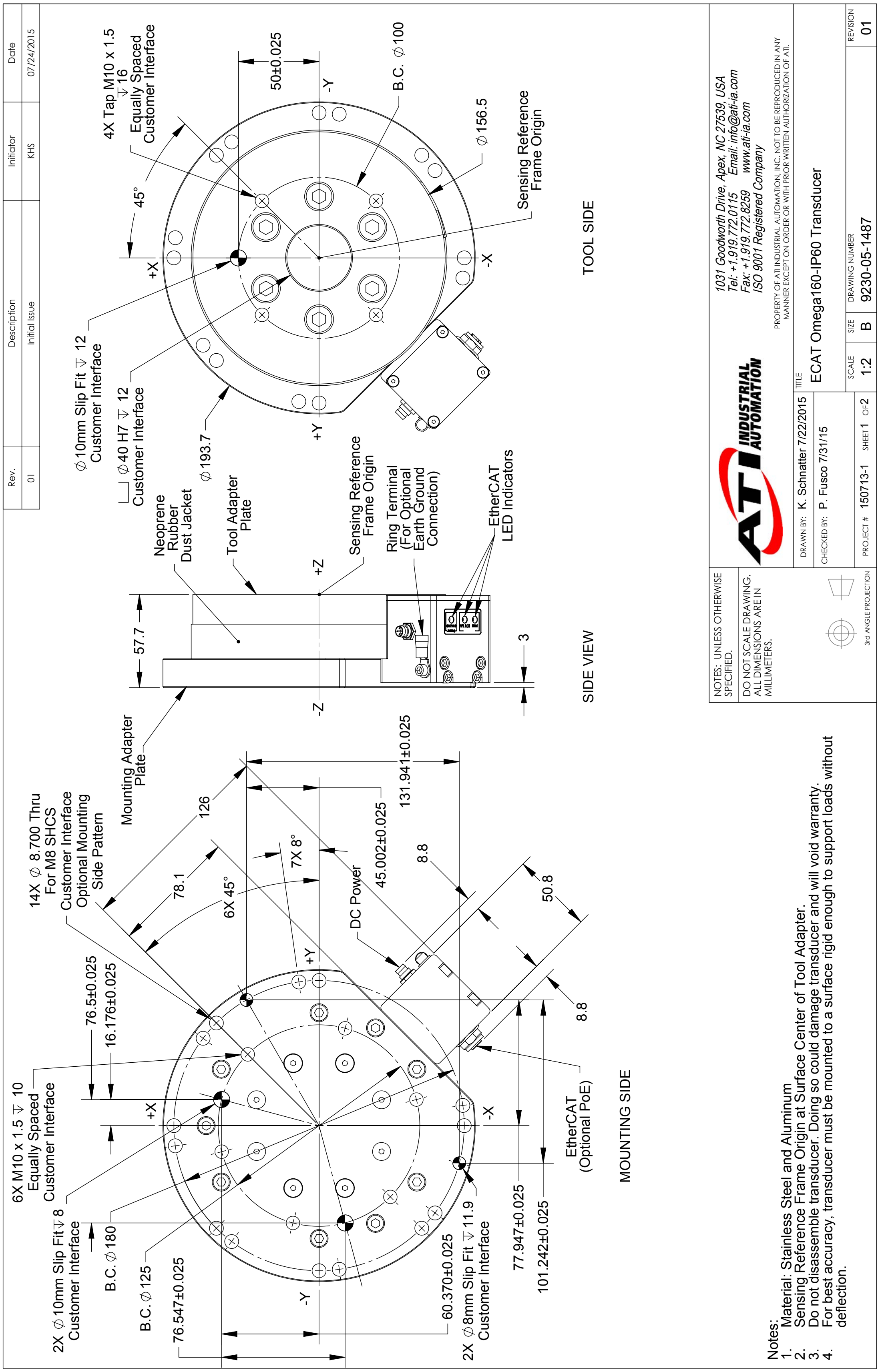
5.16.13 Omega160 Transducer with Mounting Adapter Drawing

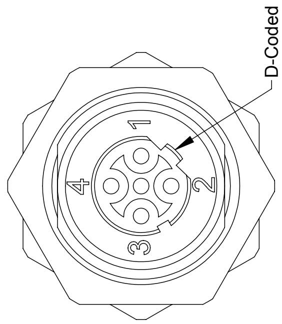


5.16.14 Omega160 IP60 Transducer Drawing



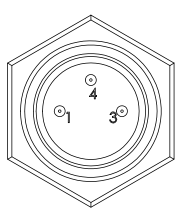
5.16.15 ECAT Omega160 IP60 Transducer Drawing





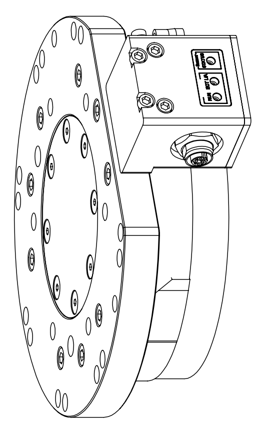
Pin No.	Signal
1	TX+
2	RX+
3	TX-
4	RX-
Shell	Connector Block Housing

EtherCAT Connector
4 pin Female M12 D-Coded



Pin No.	Signal
1	V+
3	GND
4	N/C

DC Power Connector
3 pin Male M8



ISOMETRIC VIEW

NOTES: UNLESS OTHERWISE SPECIFIED.
DO NOT SCALE DRAWING.
ALL DIMENSIONS ARE IN MILLIMETERS.

3rd ANGLE PROJECTION

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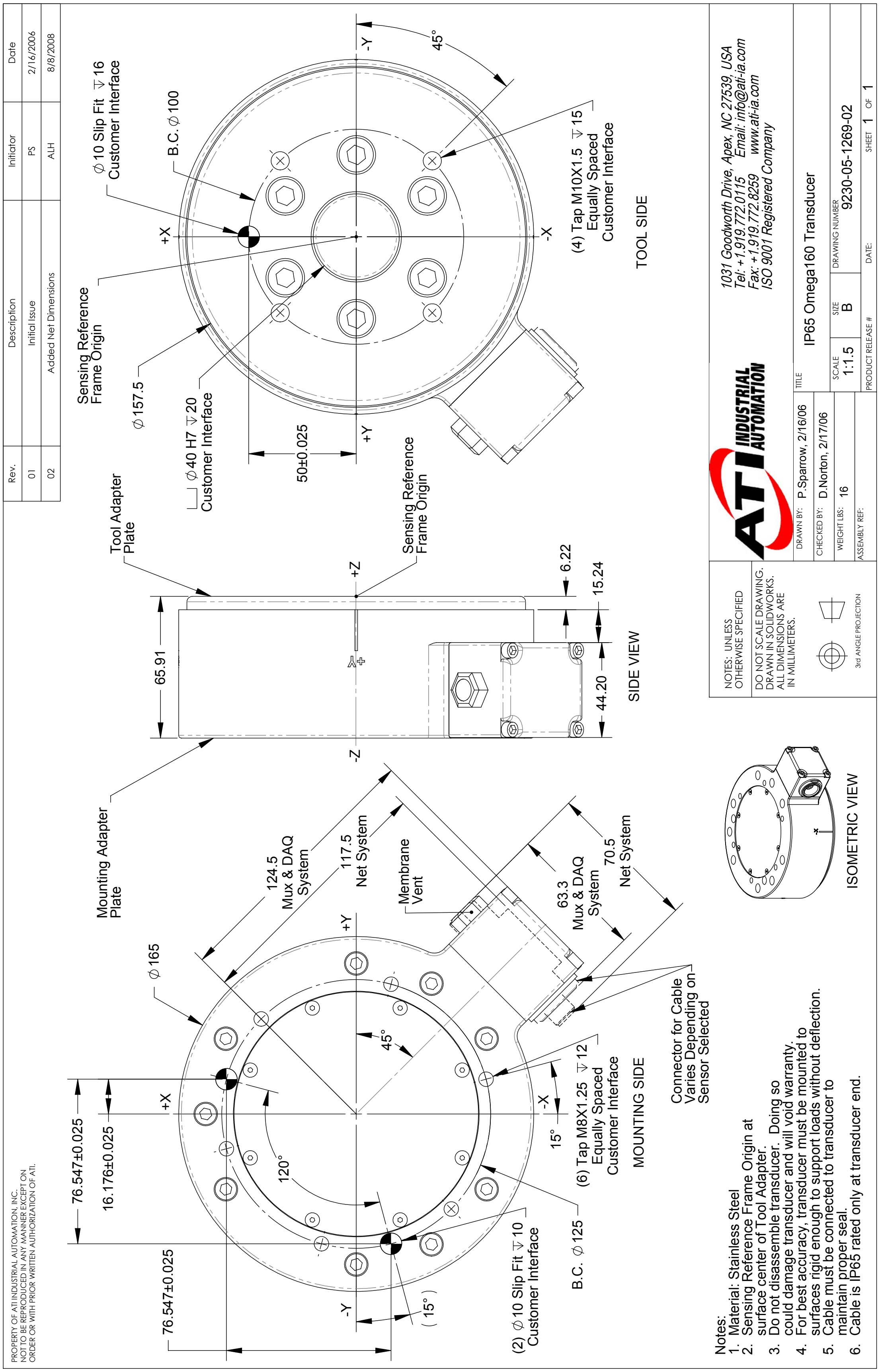
DRAWN BY: K. Schnatter 7/22/2015
CHECKED BY: P. Fusco 7/31/15
PROJECT # 150713-1 SHEET 2 OF 2

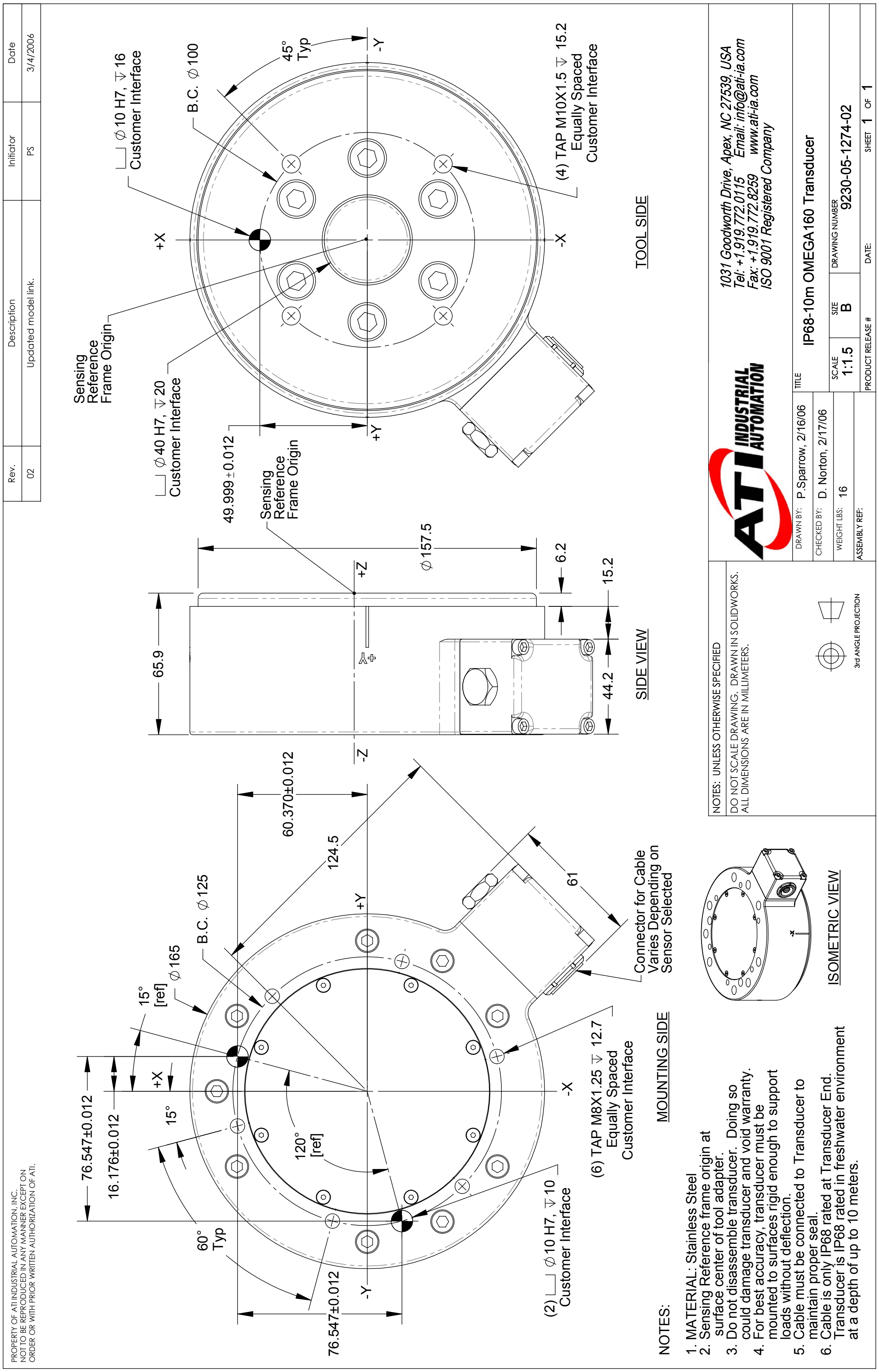
TITLE: ECAT Omega160-IP60 Transducer

SCALE 5:1 | SIZE B | DRAWING NUMBER 9230-05-1487 | REVISION 01

5.16.16 Omega160 IP65 Transducer Drawing



5.16.17 Omega160 IP68 Transducer Drawing



5.17 Omega190 Specifications (Includes IP60/IP65/IP68 Versions)

5.17.1 Omega190 Physical Properties

Table 4.95—Omega190 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±8000 lbf	±36000 N
Fz	±25000 lbf	±110000 N
Txy	±60000 lbf-in	±6800 Nm
Tz	±60000 lbf-in	±6800 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	1.4×10^{6} lb/in	2.4×10^{8} N/m
Z-axis force (Kz)	2.1×10^{6} lb/in	3.6×10^{8} N/m
X-axis & Y-axis torque (Ktx, Kty)	1.4×10^{7} lbf-in/rad	1.5×10^{6} Nm/rad
Z-axis torque (Ktz)	2.8×10^{7} lbf-in/rad	3.2×10^{6} Nm/rad
Resonant Frequency		
Fx, Fy, Tz	N/A	N/A
Fz, Tx, Ty	N/A	N/A
Physical Specifications		
Weight[1]	14 lb	6.35 kg
Diameter[1]	7.48 in	190 mm
Height[1]	2.2 in	55.9 mm
Note: 1. Specifications include standard interface plates.		

5.17.2 Omega190 IP60 Physical Properties

Table 4.96—Omega190 IP60 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±8000 lbf	±36000 N
Fz	±25000 lbf	±110000 N
Txy	±60000 lbf-in	±6800 Nm
Tz	±60000 lbf-in	±6800 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	1.4×10^{6} lb/in	2.4×10^{8} N/m
Z-axis force (Kz)	2.1×10^{6} lb/in	3.6×10^{8} N/m
X-axis & Y-axis torque (Ktx, Kty)	1.4×10^{7} lbf-in/rad	1.5×10^{6} Nm/rad
Z-axis torque (Ktz)	2.8×10^{7} lbf-in/rad	3.2×10^{6} Nm/rad
Resonant Frequency		
Fx, Fy, Tz	1200 Hz	1200 Hz
Fz, Tx, Ty	1200 Hz	1200 Hz
Physical Specifications		
Weight[1]	31 lb	14.1 kg
Diameter[1]	9.37 in	238 mm
Height[1]	2.9 in	73.7 mm
Note: 1. Specifications include standard interface plates.		

5.17.3 Omega190 IP65/IP68 Physical Properties

Table 4.97—Omega190 IP65/IP68 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±8000 lbf	±36000 N
Fz	±25000 lbf	±110000 N
Txy	±60000 lbf-in	±6800 Nm
Tz	±60000 lbf-in	±6800 Nm)
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	1.4×10^{6} lb/in	2.4×10^{8} N/m)
Z-axis force (Kz)	2.1×10^{6} lb/in	3.6×10^{8} N/m
X-axis & Y-axis torque (Ktx, Kty)	1.4×10^{7} lbf-in/rad	1.5×10^{6} Nm/rad
Z-axis torque (Ktz)	2.8×10^{7} lbf-in/rad	3.2×10^{6} Nm/rad
Resonant Frequency		
Fx, Fy, Tz	1400 Hz	1400 Hz
Fz, Tx, Ty	980 Hz	980 Hz
Physical Specifications		
Weight[1]	29 lb	13.2 kg
Diameter[1]	8.03 in	204 mm
Height[1]	2.94 in	74.8 mm
Note: 1. Specifications include standard interface plates.		

CAUTION: 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.

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

5.17.4 Calibration Specifications (excludes CTL calibrations)

Table 4.98— Omega190 Calibrations (excludes CTL calibrations)[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Omega190	US-400-3000	400	1000	3000	3000	5/64	5/32	15/32	5/16
Omega190	US-800-6000	800	2000	6000	6000	5/32	5/16	15/16	5/8
Omega190	US-1600-12000	1600	4000	12000	12000	5/16	5/8	1 7/8	1 1/4
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Omega190	SI-1800-350	1800	4500	350	350	3/8	3/4	5/96	5/144
Omega190	SI-3600-700	3600	9000	700	700	3/4	1 1/2	5/48	5/72
Omega190	SI-7200-1400	7200	18000	1400	1400	1 1/2	3	5/24	5/36
		Sensing Ranges				**Resolution (DAQ, Net F/T)[4]**			

Notes:

1. These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.
4. DAQ resolutions are typical for a 16-bit data acquisition system.

5.17.5 CTL Calibration Specifications

Table 4.99— Omega190 CTL Calibrations[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Omega190	US-400-3000	400	1000	3000	3000	5/32	5/16	15/16	5/8
Omega190	US-800-6000	800	2000	6000	6000	5/16	5/8	1 7/8	1 1/4
Omega190	US-1600-12000	1600	4000	12000	12000	5/8	1 1/4	3 3/4	2 1/2
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Omega190	SI-1800-350	1800	4500	350	350	3/4	1 1/2	5/48	5/72
Omega190	SI-3600-700	3600	9000	700	700	1 1/2	3	5/24	5/36
Omega190	SI-7200-1400	7200	18000	1400	1400	3	6	5/12	5/18
		Sensing Ranges				**Resolution (Controller)**			

Notes:

1. 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.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.

5.17.6 CTL Analog Output

Table 4.100— Omega190 Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[2] (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz[2] (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Omega190	US-400-3000	±400	±1000	±3000	40	100	300
Omega190	US-800-6000	±800	±2000	±6000	80	200	600
Omega190	US-1600-12000	±1600	±4000	±12000	160	400	1200
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[2] (N)**	**Tx,Ty,Tz (Nm)**	**Fx,Fy (N/V)**	**Fz[2] (N/V)**	**Tx,Ty,Tz (Nm/V)**
Omega190	SI-1800-350	±1800	±4500	±350	180	450	35
Omega190	SI-3600-700	±3600	±9000	±700	360	900	70
Omega190	SI-7200-1400	±7200	±18000	±1400	720	1800	140
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

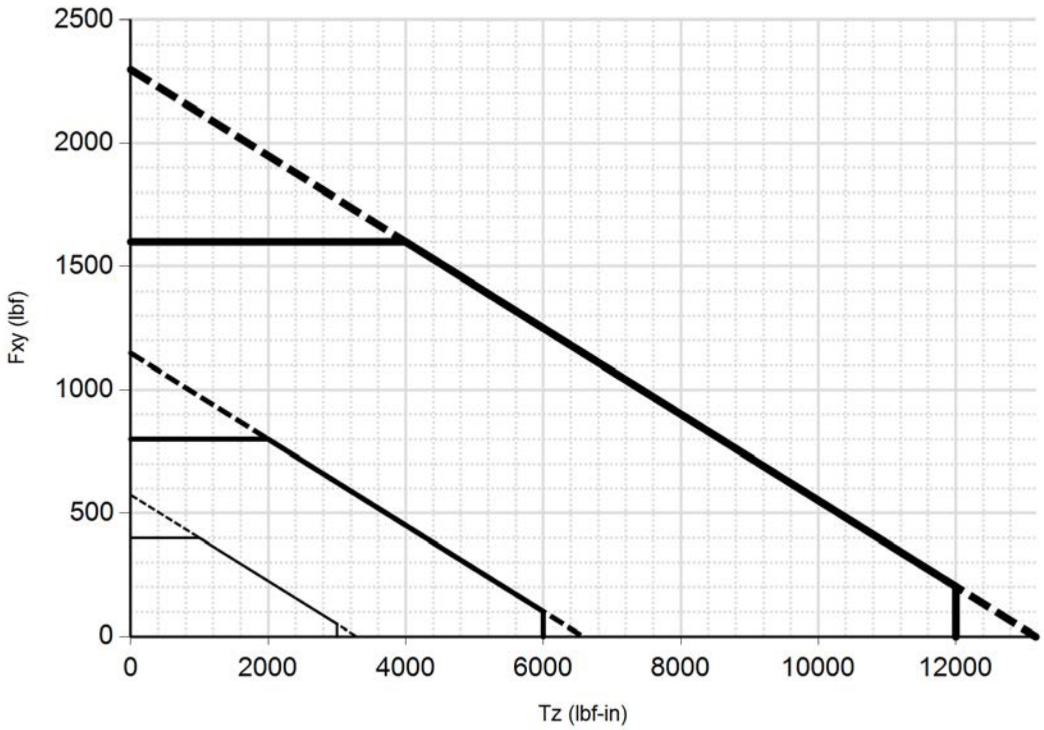
Notes:

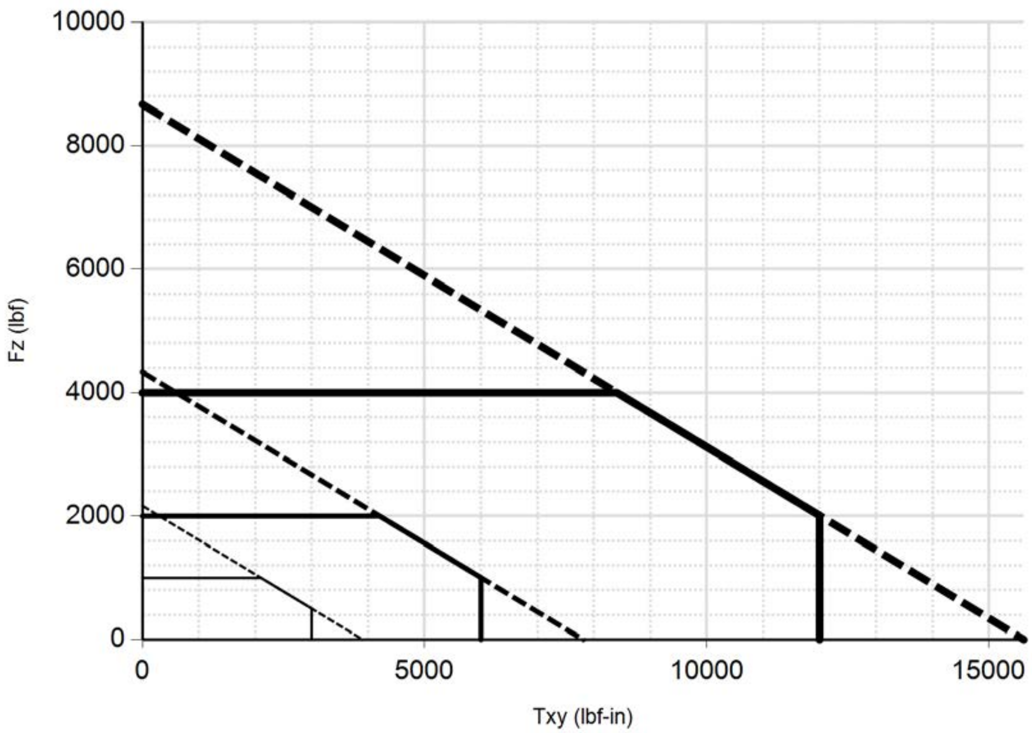
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.
2. For IP68 version see caution on physical properties page.

5.17.7 CTL Counts Value

Table 4.101—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ N)**	**Tx, Ty, Tz (/ Nm)**
Omega190	US-400-3000 / SI-1800-350	153.6	307.2	32	230.4
Omega190	US-800-6000 / SI-3600-700	76.8	153.6	16	115.2
Omega190	US-1600-12000 / SI-7200-1400	38.4	76.8	8	57.6
Omega190	Tool Transform Factor	0.005 in/lbf		1.3889 mm/N	
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

5.17.8 Omega190 (US Calibration Complex Loading) (Includes IP60/IP65/IP68)[1]

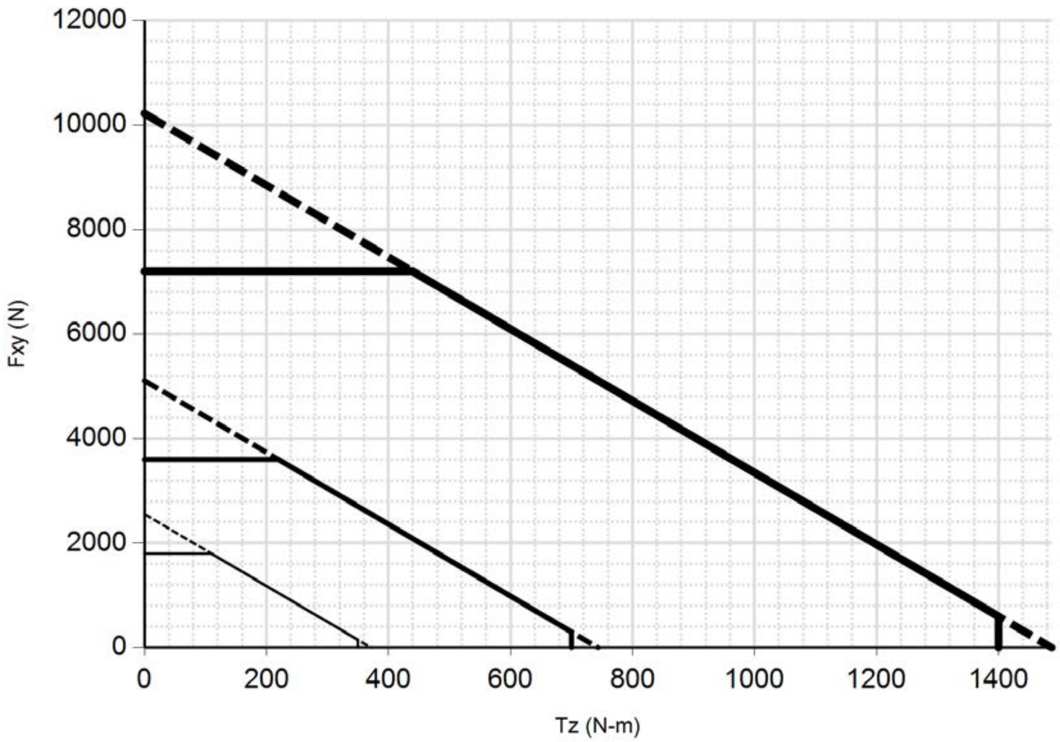


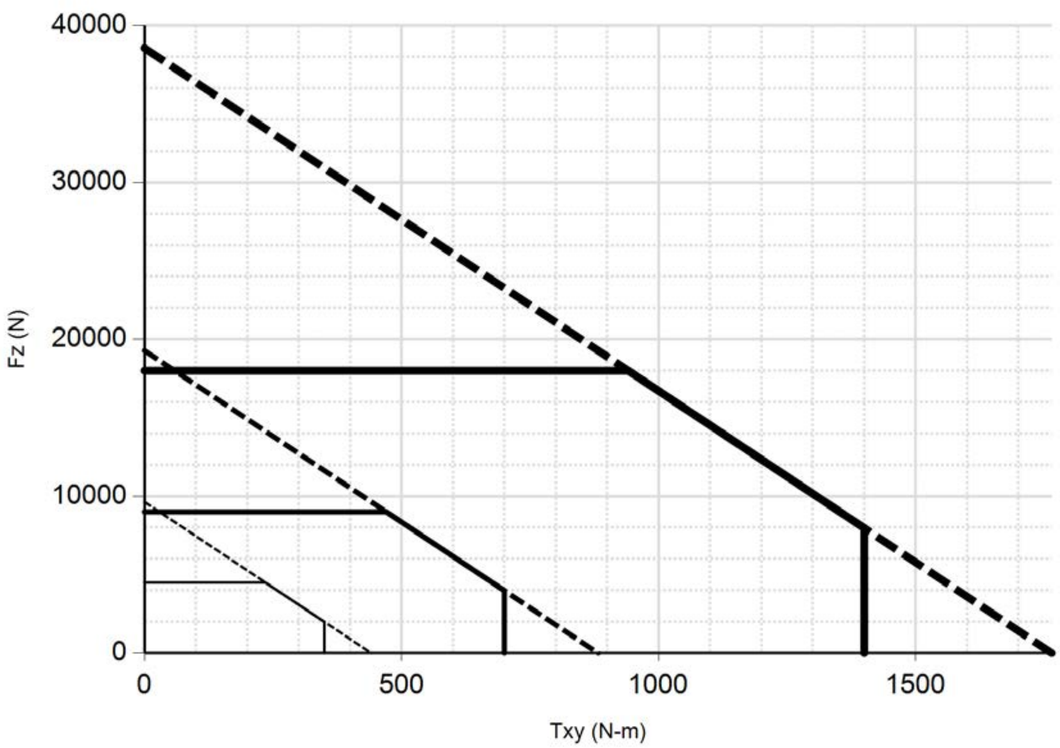


US-400-3000   US-800-6000   US-1600-12000

Note: 1. For IP68 version see caution on physical properties page.

5.17.9 Omega190 (SI Calibration Complex Loading) (Includes IP60/IP65/IP68)[1]

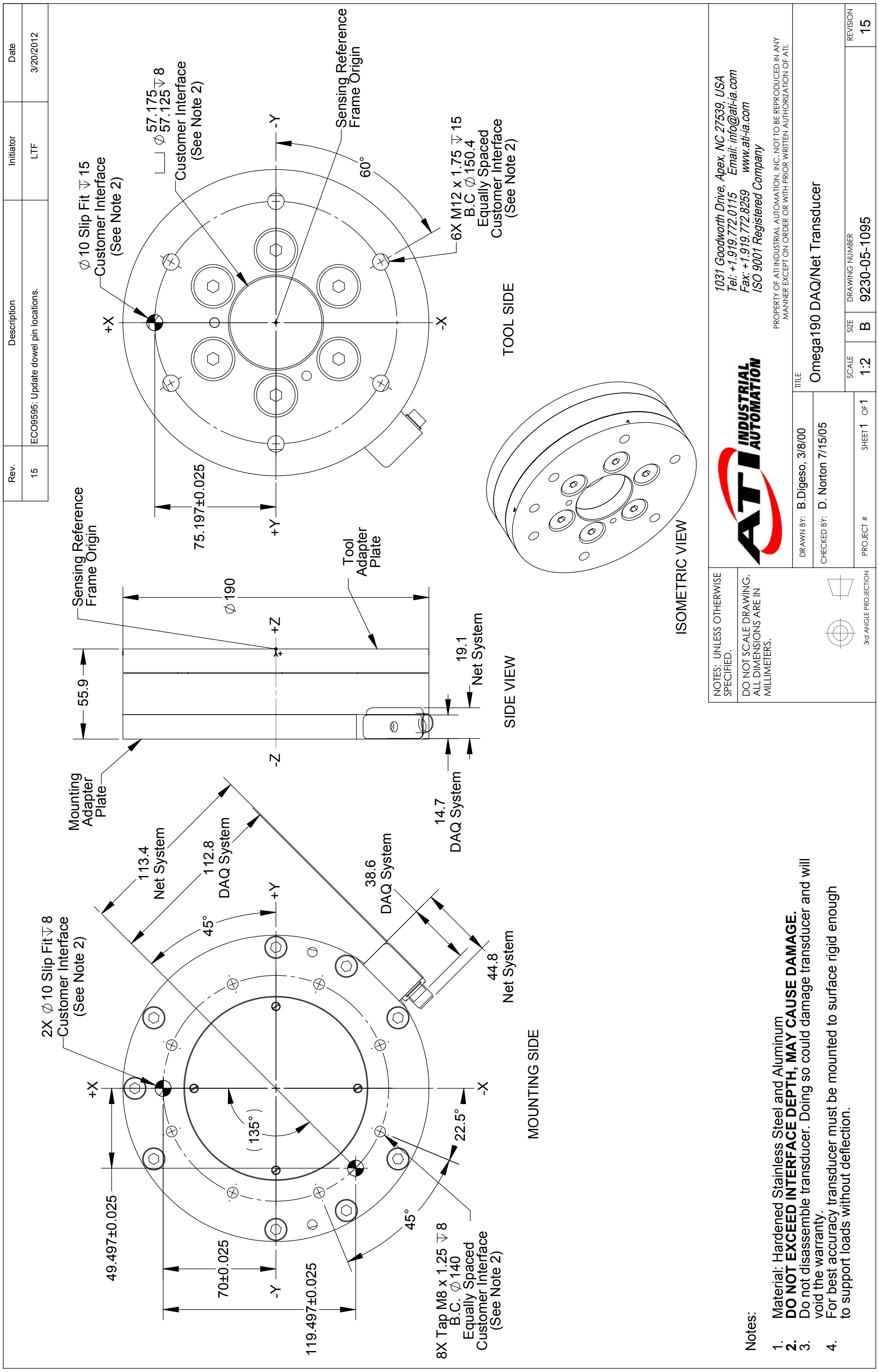




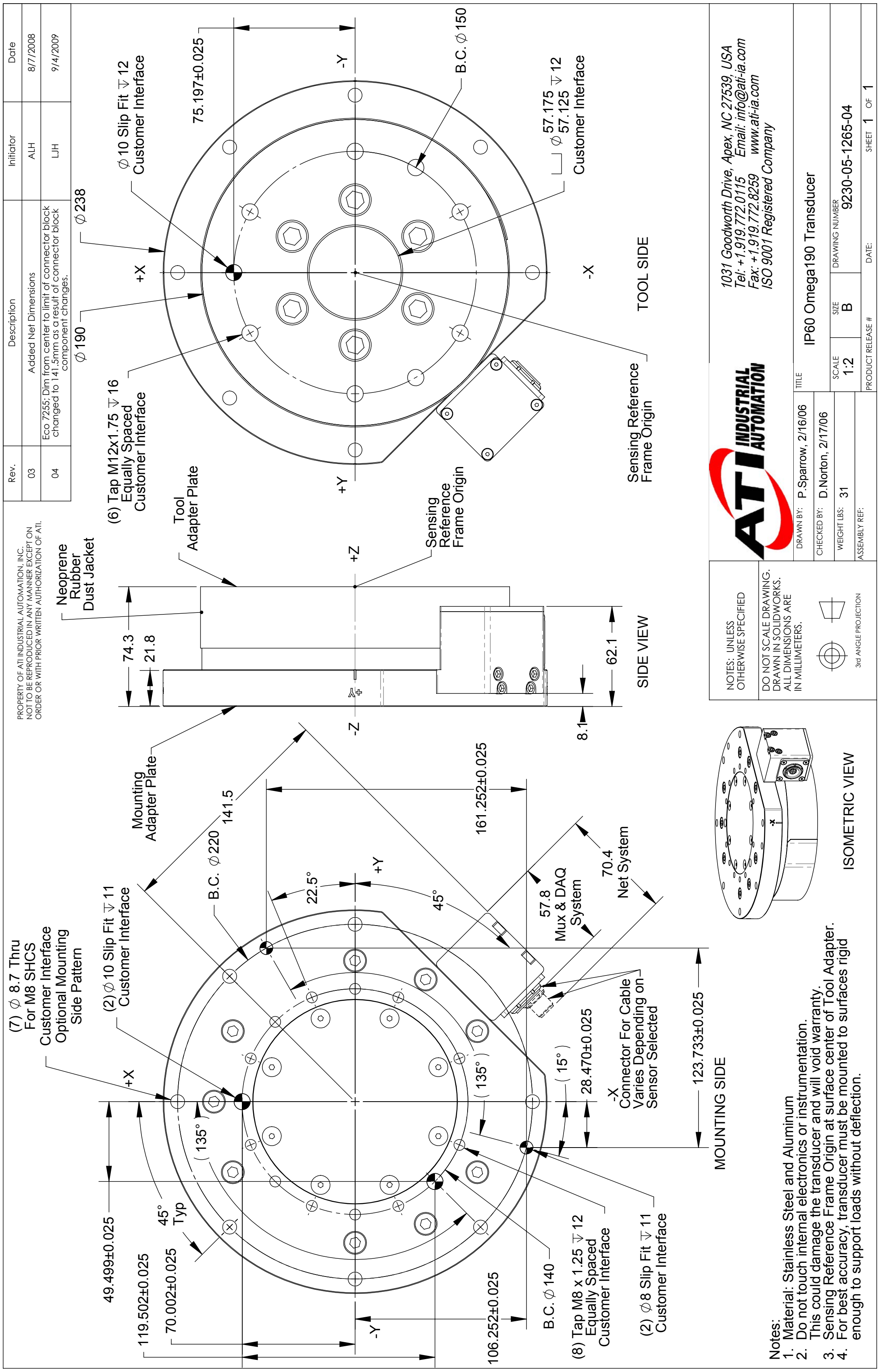
SI-1800-350 SI-3600-700 SI-7200-1400

Note: 1. For IP68 version see caution on physical properties page.

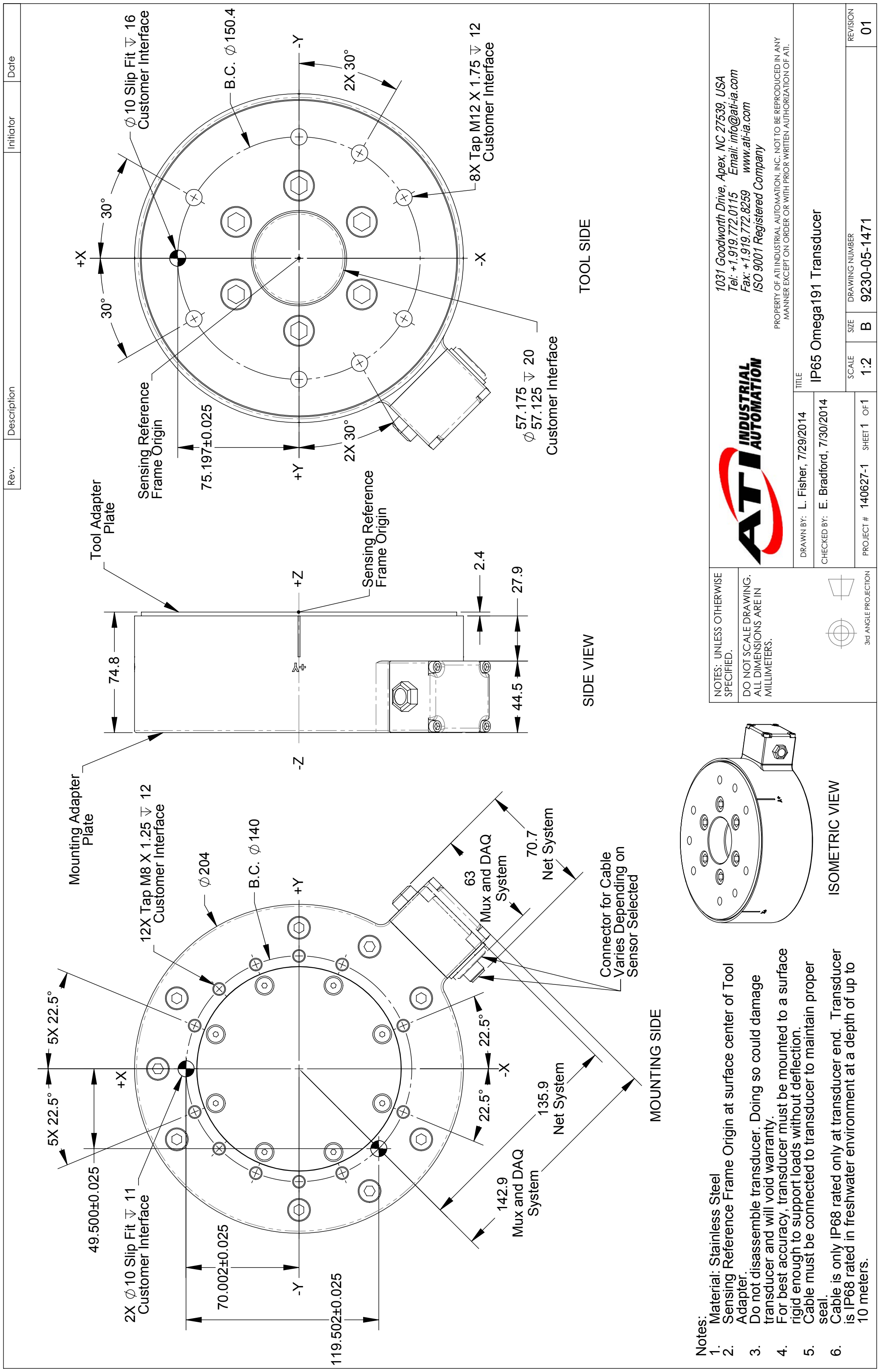
5.17.10 Omega190 DAQ/Net Transducer Drawing



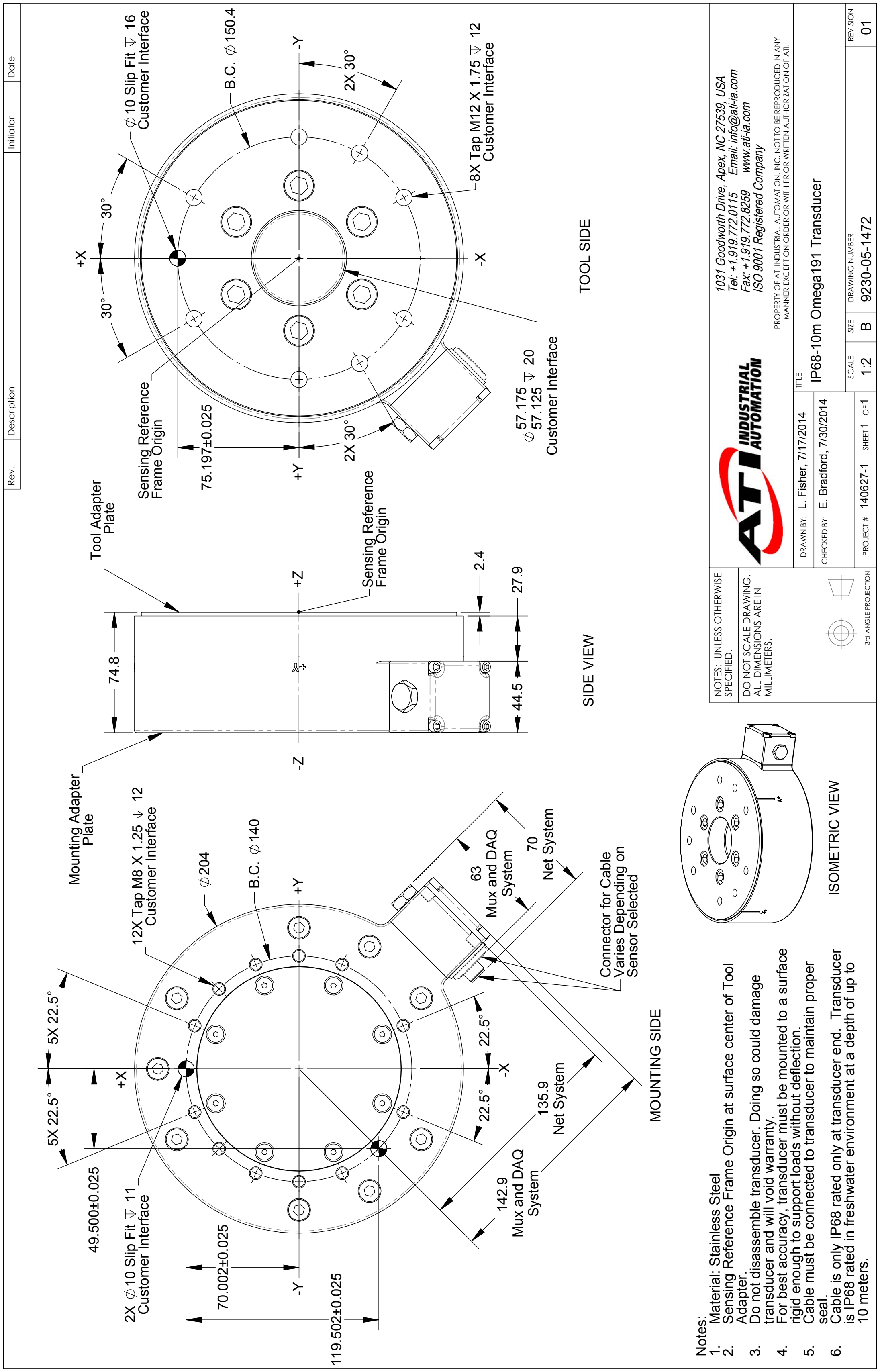
5.17.11 Omega190 IP60 Transducer Drawing



5.17.12 Omega190 IP65 Transducer Drawing



5.17.13 Omega190 IP68 Transducer Drawing



5.18 Omega191 Specifications (Includes IP60/IP65/IP68 Versions)

5.18.1 Omega191 Physical Properties

Table 4.102—Omega191 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±8000 lbf	±36000 N
Fz	±25000 lbf	±110000 N
Txy	±60000 inf-lb	±6800 Nm
Tz	±60000 inf-lb	±6800 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	1.4×10^{6} lb/in	2.4×10^{8} N/m
Z-axis force (Kz)	2.1×10^{6} lb/in	3.6×10^{8} N/m
X-axis & Y-axis torque (Ktx, Kty)	1.4×10^{7} lbf-in/rad	1.5×10^{6} Nm/rad
Z-axis torque (Ktz)	2.8×10^{7} lbf-in/rad	3.2×10^{6} Nm/rad
Resonant Frequency		
Fx, Fy, Tz	N/A	N/A
Fz, Tx, Ty	N/A	N/A
Physical Specifications		
Weight[1]	20.8 lb	9.41 kg
Diameter[1]	7.48 in	190 mm
Height[1]	2.52 in	64 mm
Note: 1. Specifications include standard interface plates.		

5.18.2 Omega191 IP60 Physical Properties

Table 4.103—Omega191 IP60 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±8000 lbf	±36000 N
Fz	±25000 lbf	±110000 N
Txy	±60000 inf-lb	±6800 Nm
Tz	±60000 inf-lb	±6800 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	1.4×10^{6} lb/in	2.4×10^{8} N/m
Z-axis force (Kz)	2.1×10^{6} lb/in	3.6×10^{8} N/m
X-axis & Y-axis torque (Ktx, Kty)	1.4×10^{7} lbf-in/rad	1.5×10^{6} Nm/rad
Z-axis torque (Ktz)	2.8×10^{7} lbf-in/rad	3.2×10^{6} Nm/rad
Resonant Frequency		
Fx, Fy, Tz	1200 Hz	1200 Hz
Fz, Tx, Ty	1200 Hz	1200 Hz
Physical Specifications		
Weight[1]	31 lb	14.1 kg
Diameter[1]	9.37 in	238 mm
Height[1]	2.9 in	73.7 mm
Note: 1. Specifications include standard interface plates.		

5.18.3 Omega191 IP65/IP68 Physical Properties

Table 4.104—Omega191 IP65/IP68 Physical Properties		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±8000 lbf	±36000 N
Fz	±25000 lbf	±110000 N
Txy	±60000 inf-lb	±6800 Nm
Tz	±60000 inf-lb	±6800 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	$1.4x10^{6}$ lb/in	$2.4x10^{8}$ N/m
Z-axis force (Kz)	$2.1x10^{6}$ lb/in	$3.6x10^{8}$ N/m
X-axis & Y-axis torque (Ktx, Kty)	$1.4x10^{7}$ lbf-in/rad	$1.5x10^{6}$ Nm/rad
Z-axis torque (Ktz)	$2.8x10^{7}$ lbf-in/rad	$3.2x10^{6}$ Nm/rad
Resonant Frequency		
Fx, Fy, Tz	1400 Hz	1400 Hz
Fz, Tx, Ty	980 Hz	980 Hz
Physical Specifications		
Weight[1]	29 lb	13.2 kg
Diameter[1]	8.03 in	204 mm
Height[1]	2.94 in	74.8 mm

Note:
1. Specifications include standard interface plates.

CAUTION: 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.

Submersion Depth		
IP68 Omega191	**US**	**Metric**
Fz preload at 10 m depth	661 lb	2941 N
Fz preload at other depths	-20 lb/ft × depthInFeet	-294 N/m × depthInMeters

5.18.4 Calibration Specifications (excludes CTL calibrations)

Table 4.105— Omega191 Calibrations (excludes CTL calibrations)[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Omega191	US-400-3000	400	1000	3000	3000	5/64	5/32	15/32	5/16
Omega191	US-800-6000	800	2000	6000	6000	5/32	5/16	15/16	5/8
Omega191	US-1600-12000	1600	4000	12000	12000	5/16	5/8	1 7/8	1 1/4
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Omega191	SI-1800-350	1800	4500	350	350	3/8	3/4	5/96	5/144
Omega191	SI-3600-700	3600	9000	700	700	3/4	1 1/2	5/48	5/72
Omega191	SI-7200-1400	7200	18000	1400	1400	1 1/2	3	5/24	5/36
		Sensing Ranges				**Resolution (DAQ, Net F/T)[4]**			

Notes:

1. These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.
4. DAQ resolutions are typical for a 16-bit data acquisition system.

5.18.5 CTL Calibration Specifications

Table 4.106— Omega191 CTL Calibrations[1, 2]									
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**	**Fx,Fy (lbf)**	**Fz[3] (lbf)**	**Tx,Ty (lbf-in)**	**Tz (lbf-in)**
Omega191	US-400-3000	400	1000	3000	3000	5/32	5/16	15/16	5/8
Omega191	US-800-6000	800	2000	6000	6000	5/16	5/8	1 7/8	1 1/4
Omega191	US-1600-12000	1600	4000	12000	12000	5/8	1 1/4	3 3/4	2 1/2
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Omega191	SI-1800-350	1800	4500	350	350	3/4	1 1/2	5/48	5/72
Omega191	SI-3600-700	3600	9000	700	700	1 1/2	3	5/24	5/36
Omega191	SI-7200-1400	7200	18000	1400	1400	3	6	5/12	5/18
		Sensing Ranges				**Resolution (Controller)**			

Notes:

1. 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.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.

5.18.6 CTL Analog Output

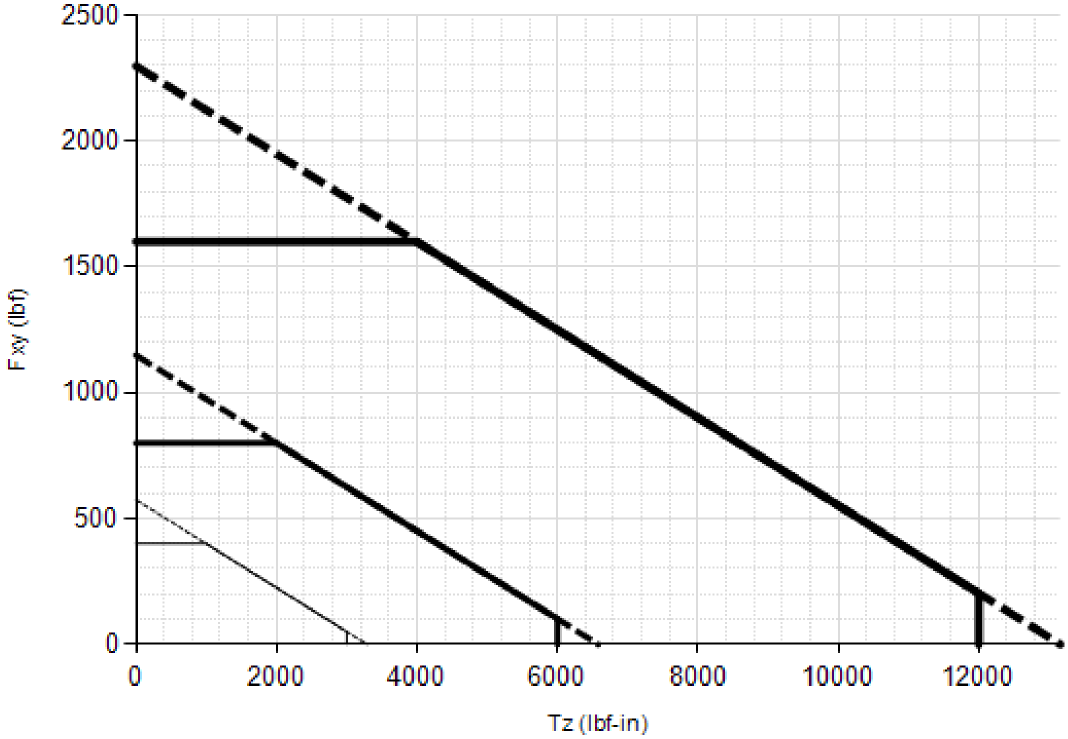
Table 4.107— Omega191 Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[2] (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz[2] (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Omega191	US-400-3000	±400	±1000	±3000	40	100	300
Omega191	US-800-6000	±800	±2000	±6000	80	200	600
Omega191	US-1600-12000	±1600	±4000	±12000	160	400	1200
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[2] (N)**	**Tx,Ty,Tz (Nm)**	**Fx,Fy (N/V)**	**Fz[2] (N/V)**	**Tx,Ty,Tz (Nm/V)**
Omega191	SI-1800-350	±1800	±4500	±350	180	450	35
Omega191	SI-3600-700	±3600	±9000	±700	360	900	70
Omega191	SI-7200-1400	±7200	±18000	±1400	720	1800	140
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

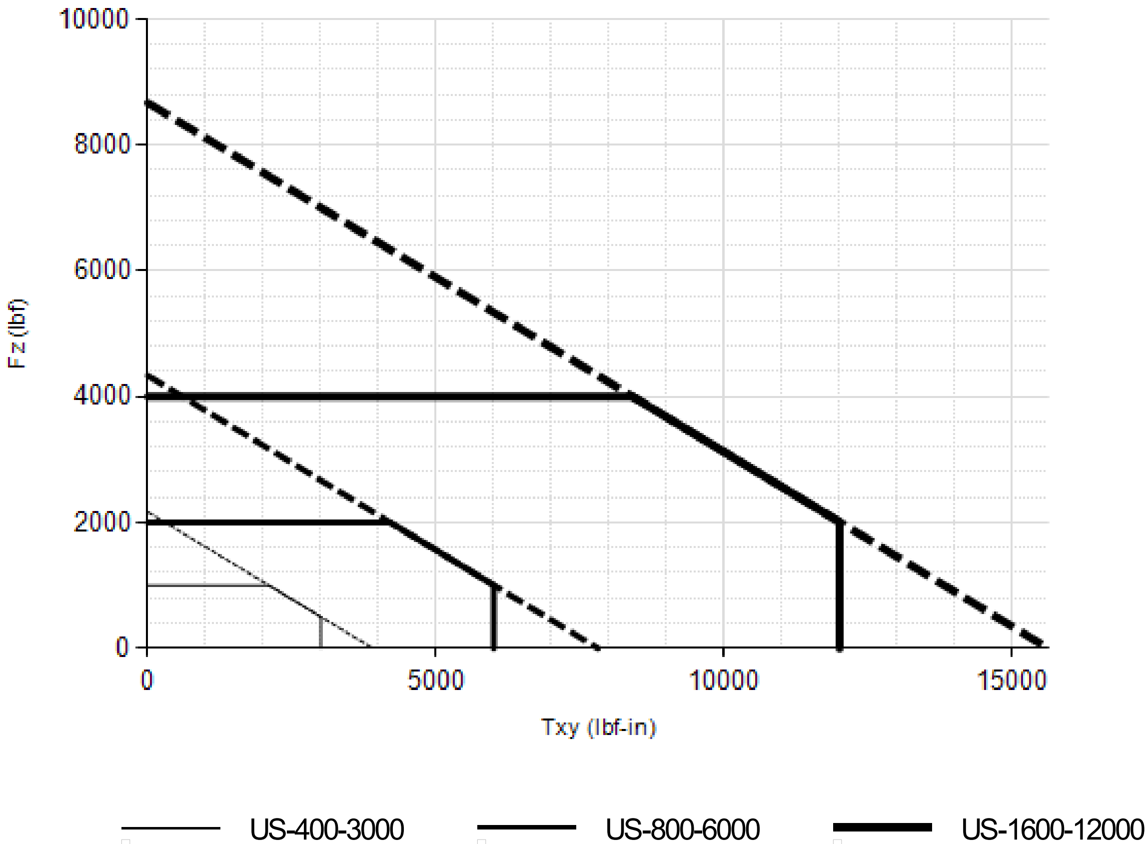
Notes:
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.
2. For IP68 version see caution on physical properties page.

5.18.7 CTL Counts Value

Table 4.108—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ N)**	**Tx, Ty, Tz (/ Nm)**
Omega191	US-400-3000 / SI-1800-350	153.6	307.2	32	230.4
Omega191	US-800-6000 / SI-3600-700	76.8	153.6	16	115.2
Omega191	US-1600-12000 / SI-7200-1400	38.4	76.8	8	57.6
Omega191	Tool Transform Factor	0.005 in/lbf		1.3889 mm/N	
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

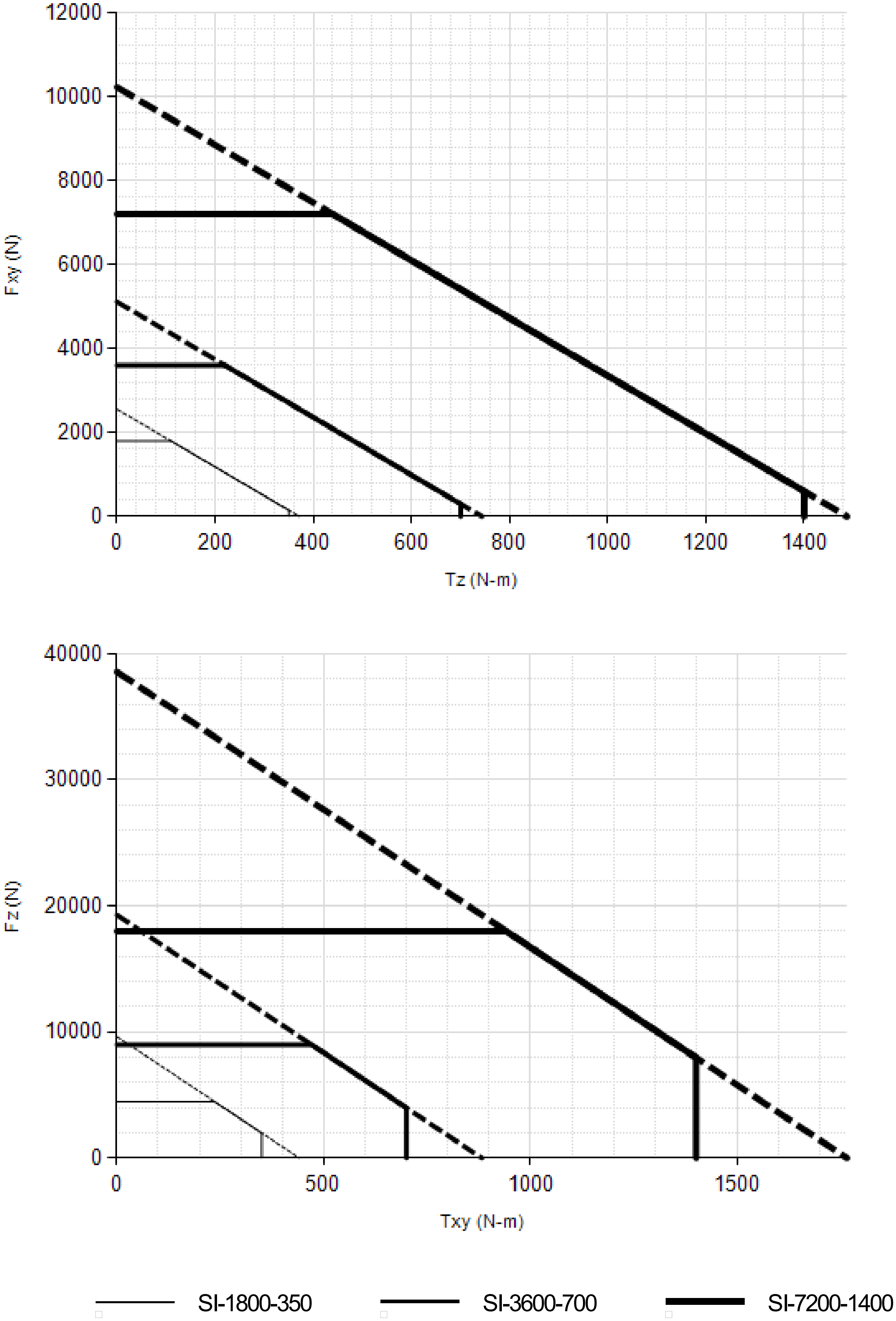
5.18.8 Omega191 (US Calibration Complex Loading) (Includes IP60/IP65/IP68)[1]





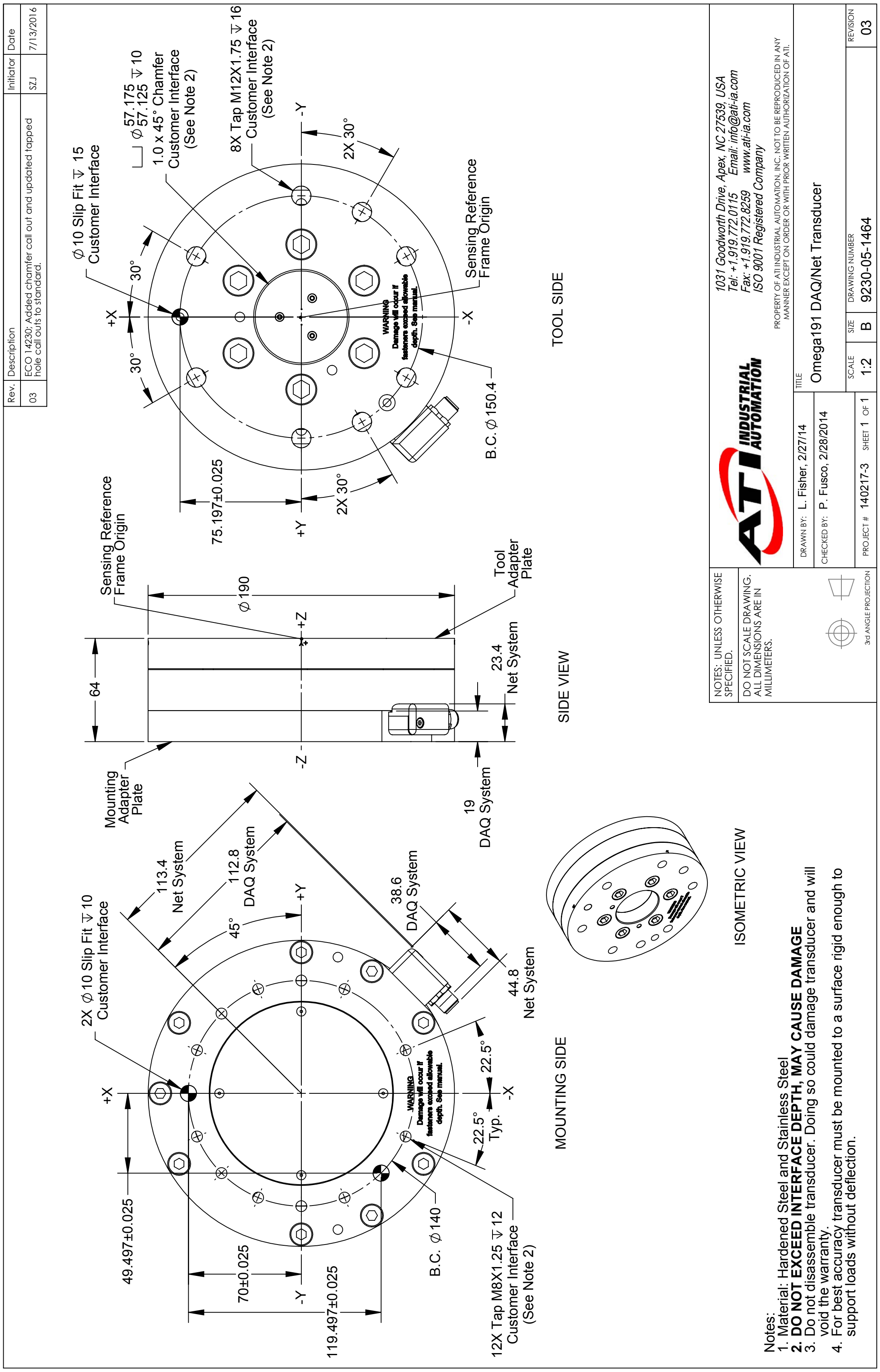
Note: 1. For IP68 version see caution on physical properties page.

5.18.9 Omega191 (SI Calibration Complex Loading) (Includes IP60/IP65/IP68)[1]

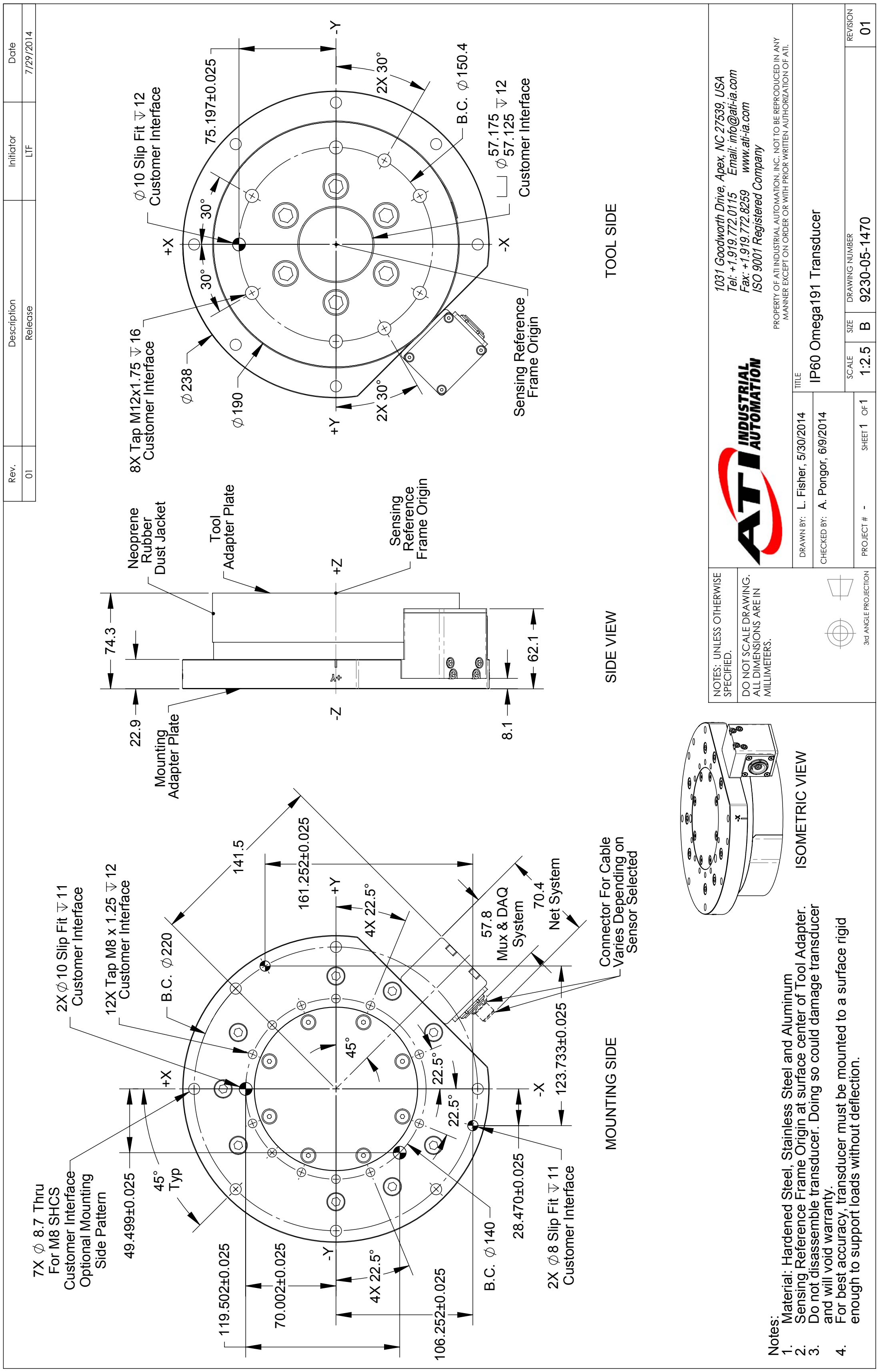


Note: 1. For IP68 version see caution on physical properties page.

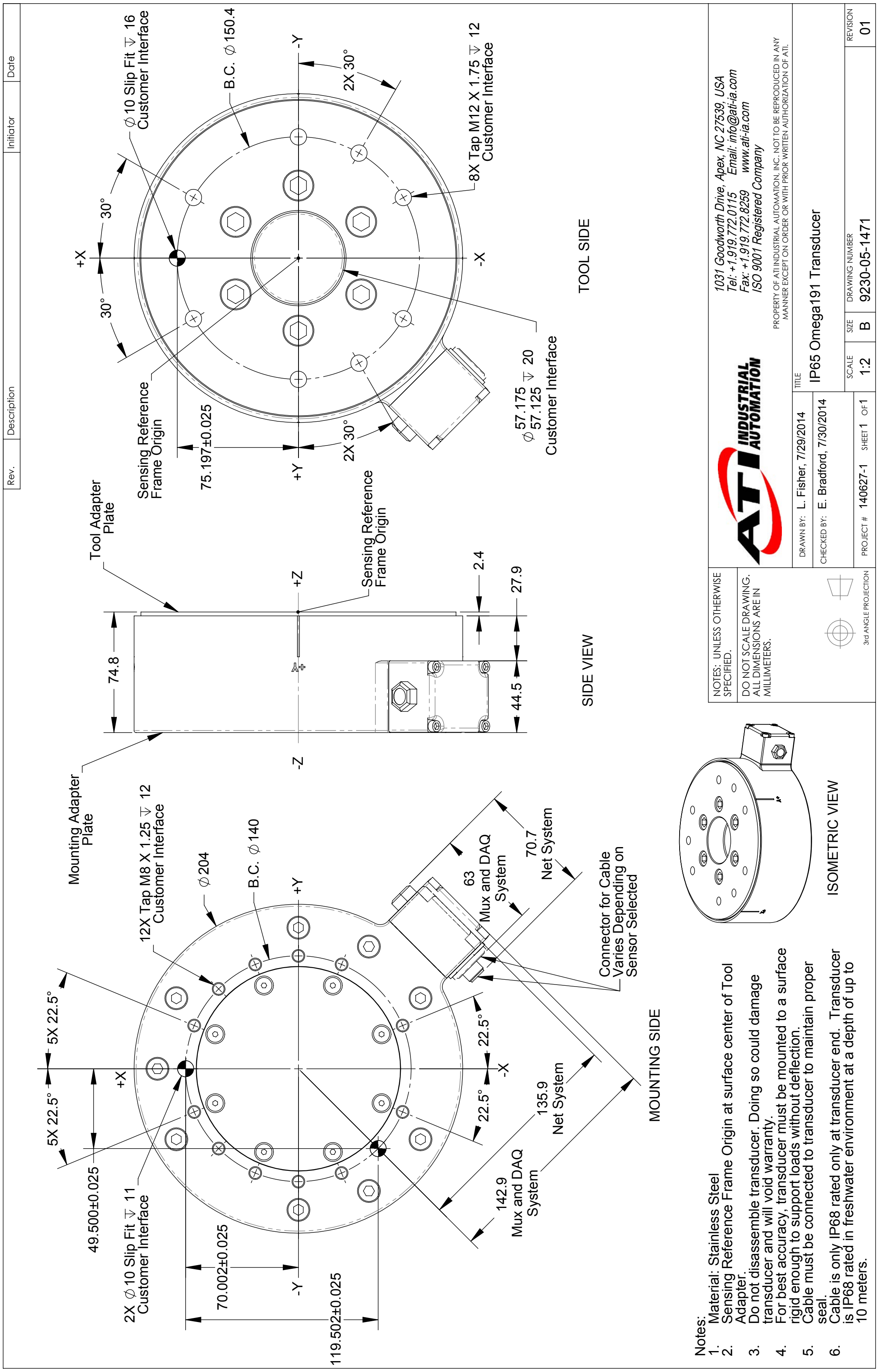
5.18.10 Omega191 DAQ/Net Transducer Drawing



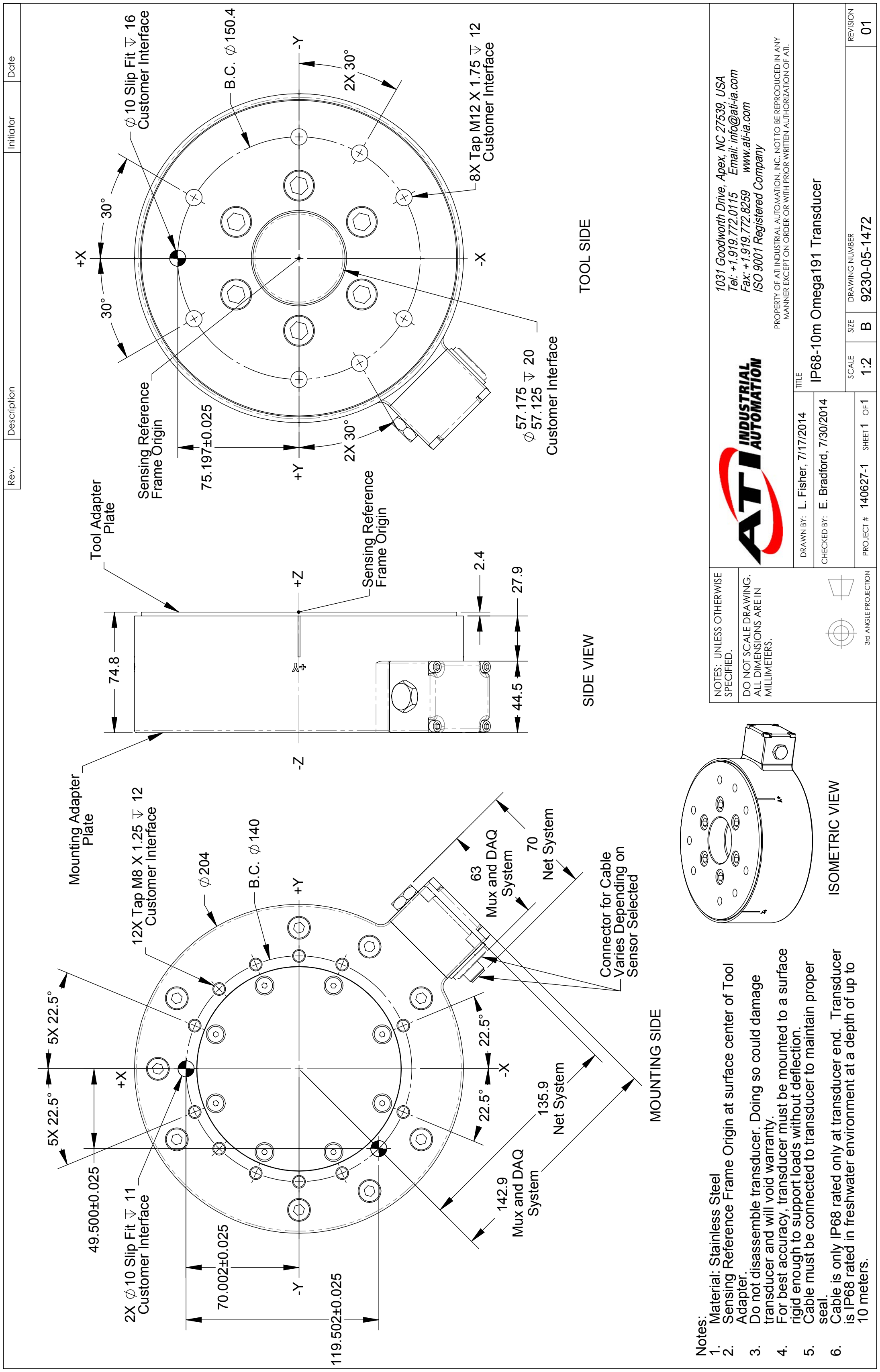
5.18.11 Omega191 IP60 Transducer Drawing



5.18.12 Omega191 IP65 Transducer Drawing



5.18.13 Omega191 IP68 Transducer Drawing



5.19 Omega250 Specifications (Includes IP60/IP65/IP68)

5.19.1 Omega250 Physical Properties (Includes IP60/IP65/IP68)

Table 4.109—Omega250 Physical Properties (Includes IP60/IP65/IP68)

Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±37000 lbf	±160000 N
Fz	±74000 lbf	±330000 N
Txy	±180000 inf-lb	±21000 Nm
Tz	±220000 inf-lb	±25000 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	2.4x10^6 lb/in	4.2x10^8 N/m
Z-axis force (Kz)	3.2x10^6 lb/in	5.6x10^8 N/m
X-axis & Y-axis torque (Ktx, Kty)	2.7x10^7 lbf-in/rad	3.0x10^6 Nm/rad
Z-axis torque (Ktz)	5.5x10^7 lbf-in/rad	6.2x10^6 Nm/rad
Resonant Frequency		
Fx, Fy, Tz	780 Hz	780 Hz
Fz, Tx, Ty	770 Hz	770 Hz
Physical Specifications		
Weight[1]	70 lb	31.8 kg
Diameter[1]	11.6 in	295 mm
Height[1]	3.74 in	94.9 mm

Note:
1. Specifications include standard interface plates.

CAUTION: 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.

Submersion Depth

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

5.19.2 Calibration Specifications (excludes CTL calibrations)

Table 4.110— Omega250 Calibrations (excludes CTL calibrations)[1, 2]

Sensor	(US) Standard Calibration	Fx,Fy (lbf)	Fz[3] (lbf)	Tx,Ty (lbf-in)	Tz (lbf-in)	Fx,Fy (lbf)	Fz[3] (lbf)	Tx,Ty (lbf-in)	Tz (lbf-in)
Omega250	US-900-4500	900	1800	4500	4500	1/2	1/2	1	1
Omega250	US-1800-9000	1800	3600	9000	9000	1	1	2	2
Omega250	US-3600-18000	3600	7200	18000	18000	2	2	5	5
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Omega250	SI-4000-500	4000	8000	500	500	1	2	1/8	1/8
Omega250	SI-8000-1000	8000	16000	1000	1000	2	4	1/4	1/4
Omega250	SI-16000-2000	16000	32000	2000	2000	4	8	1/2	1/2
		Sensing Ranges				**Resolution (DAQ, Net F/T)[4]**			

Notes:
1. These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.
4. DAQ resolutions are typical for a 16-bit data acquisition system.

5.19.3 CTL Calibration Specifications

Table 4.111— Omega250 CTL Calibrations[1, 2]

Sensor	(US) Standard Calibration	Fx,Fy (lbf)	Fz[3] (lbf)	Tx,Ty (lbf-in)	Tz (lbf-in)	Fx,Fy (lbf)	Fz[3] (lbf)	Tx,Ty (lbf-in)	Tz (lbf-in)
Omega250	US-900-4500	900	1800	4500	4500	1	1	2	2
Omega250	US-1800-9000	1800	3600	9000	9000	2	2	5	5
Omega250	US-3600-18000	3600	7200	18000	18000	5	5	10	10
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**	**Fx,Fy (N)**	**Fz[3] (N)**	**Tx,Ty (Nm)**	**Tz (Nm)**
Omega250	SI-4000-500	4000	8000	500	500	2	4	1/4	1/4
Omega250	SI-8000-1000	8000	16000	1000	1000	4	8	1/2	1/2
Omega250	SI-16000-2000	16000	32000	2000	2000	8	16	1	1
		Sensing Ranges				**Resolution (Controller)**			

Notes:
1. 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.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. For IP68 version see caution on physical properties page.

5.19.4 CTL Analog Output

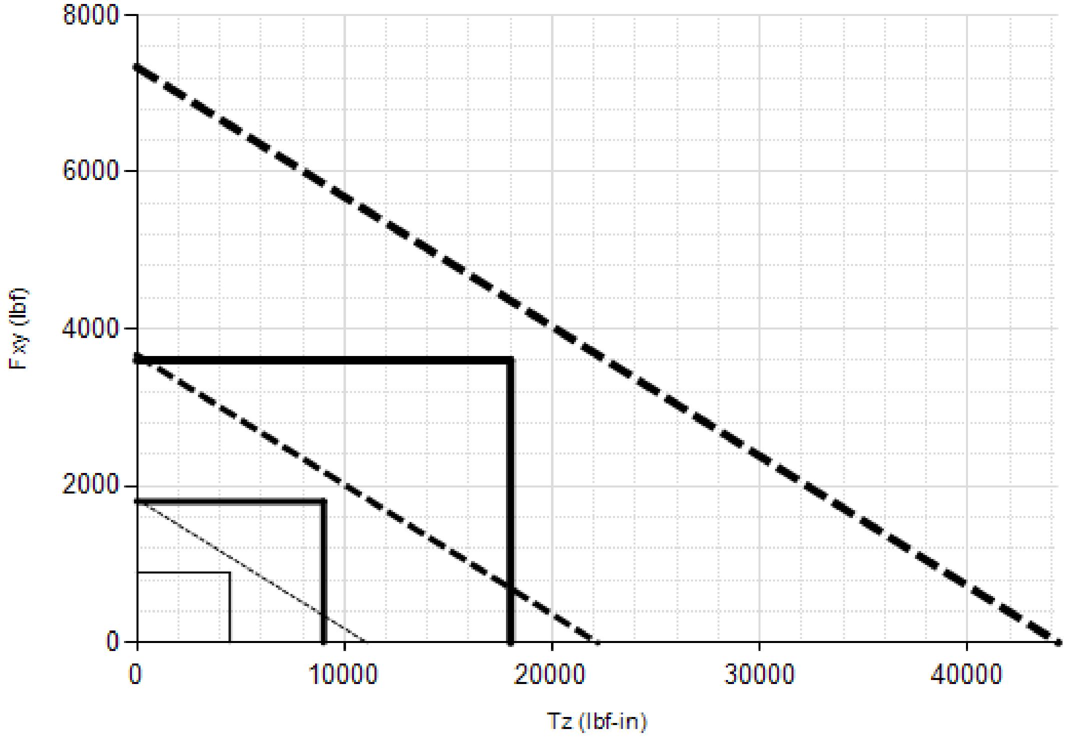
Table 4.112— Omega250 Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz[2] (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz[2] (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Omega250	US-900-4500	±900	±1800	±4500	90	180	450
Omega250	US-1800-9000	±1800	±3600	±9000	180	360	900
Omega250	US-3600-18000	±3600	±7200	±18000	360	720	1800
Sensor	**(SI) Metric Calibration**	**Fx,Fy (N)**	**Fz[2] (N)**	**Tx,Ty,Tz (Nm)**	**Fx,Fy (N/V)**	**Fz[2] (N/V)**	**Tx,Ty,Tz (Nm/V)**
Omega250	SI-4000-500	±4000	±8000	±500	400	800	50
Omega250	SI-8000-1000	±8000	±16000	±1000	800	1600	100
Omega250	SI-16000-2000	±16000	±32000	±2000	1600	3200	200
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

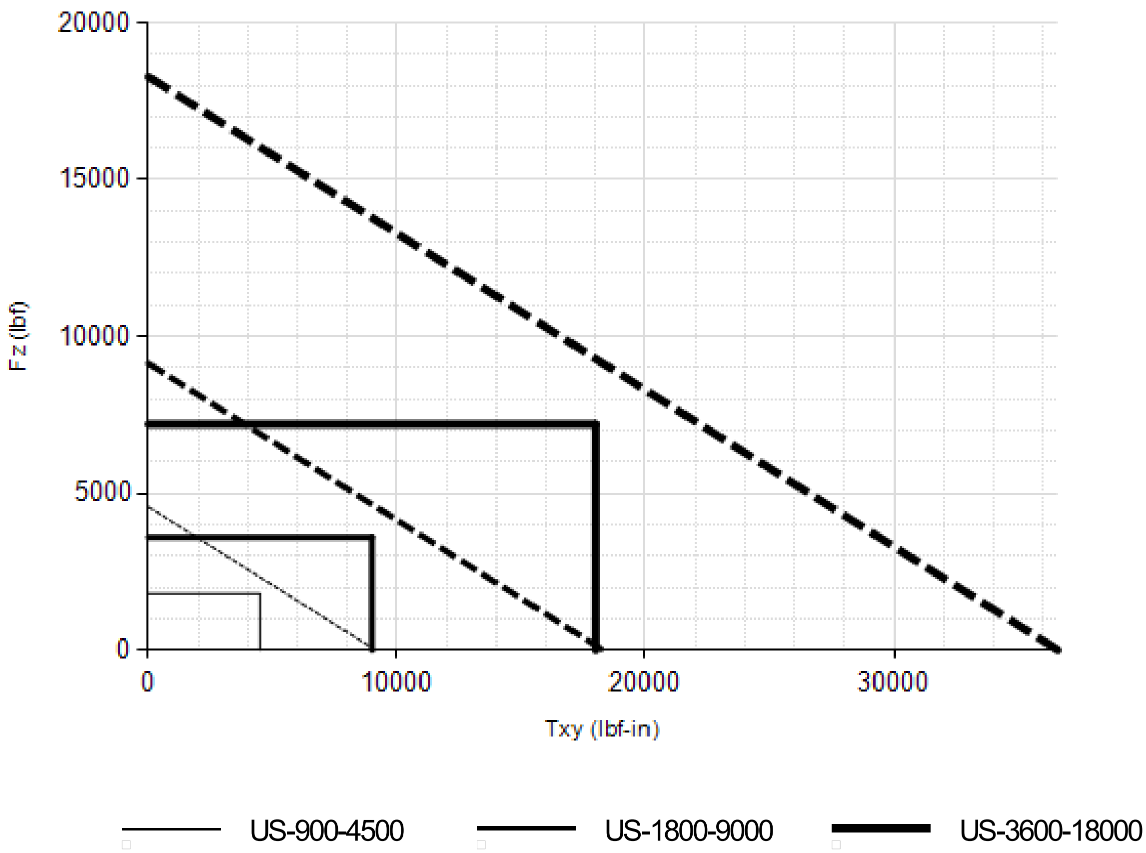
Notes:
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.
2. For IP68 version see caution on physical properties page.

5.19.5 CTL Counts Value

Table 4.113—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ N)**	**Tx, Ty, Tz (/ Nm)**
Omega250	US-900–4500 / SI-4000–500	8	4	4000	32000
Omega250	US-1800–9000 / SI-8000–1000	4	2	2000	16000
Omega250	US-3600–18000 / SI-16000-2000	2	1	1000	8000
Omega250	Tool Transform Factor	0.02 in/lbf		1.25 mm/N	
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

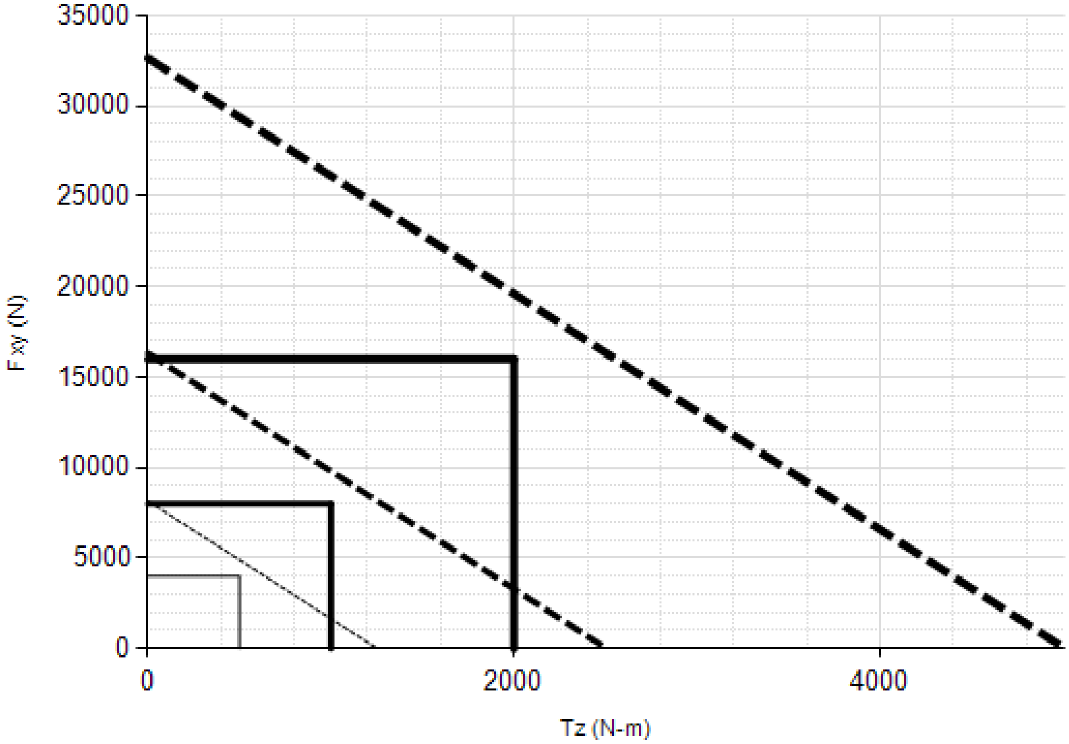
5.19.6 Omega250 (US Calibration Complex Loading) (Includes IP60/IP65/IP68)[1]

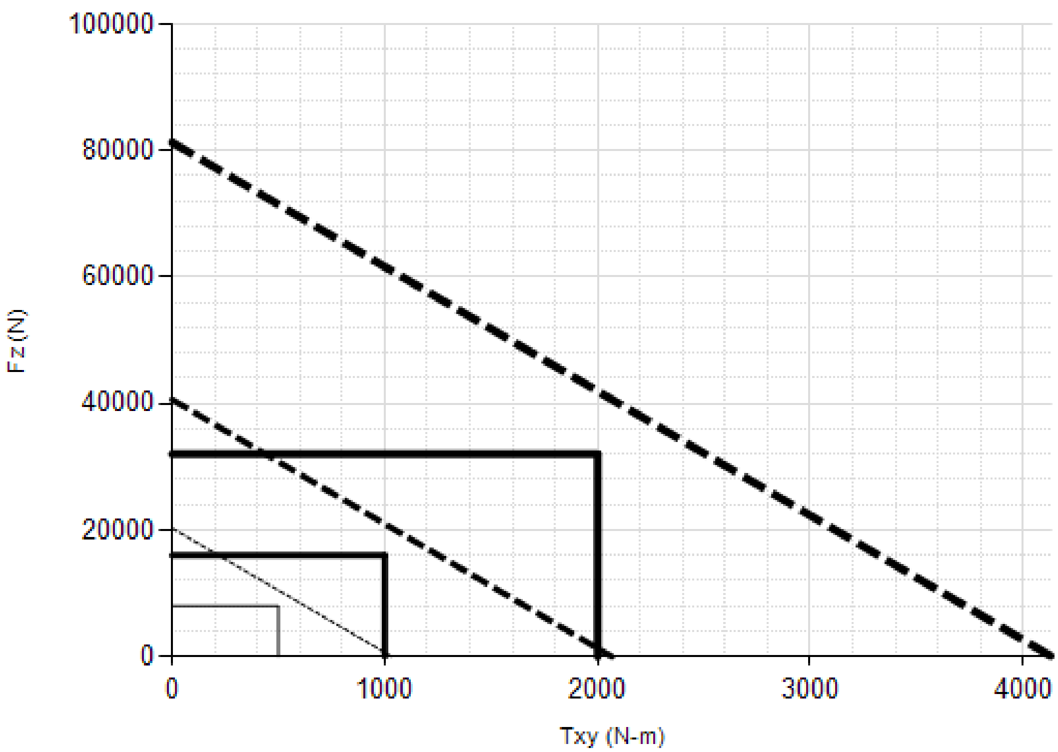




Note: 1. For IP68 version see caution on physical properties page.

5.19.7 Omega250 (SI Calibration Complex Loading) (Includes IP60/IP65/IP68)[1]

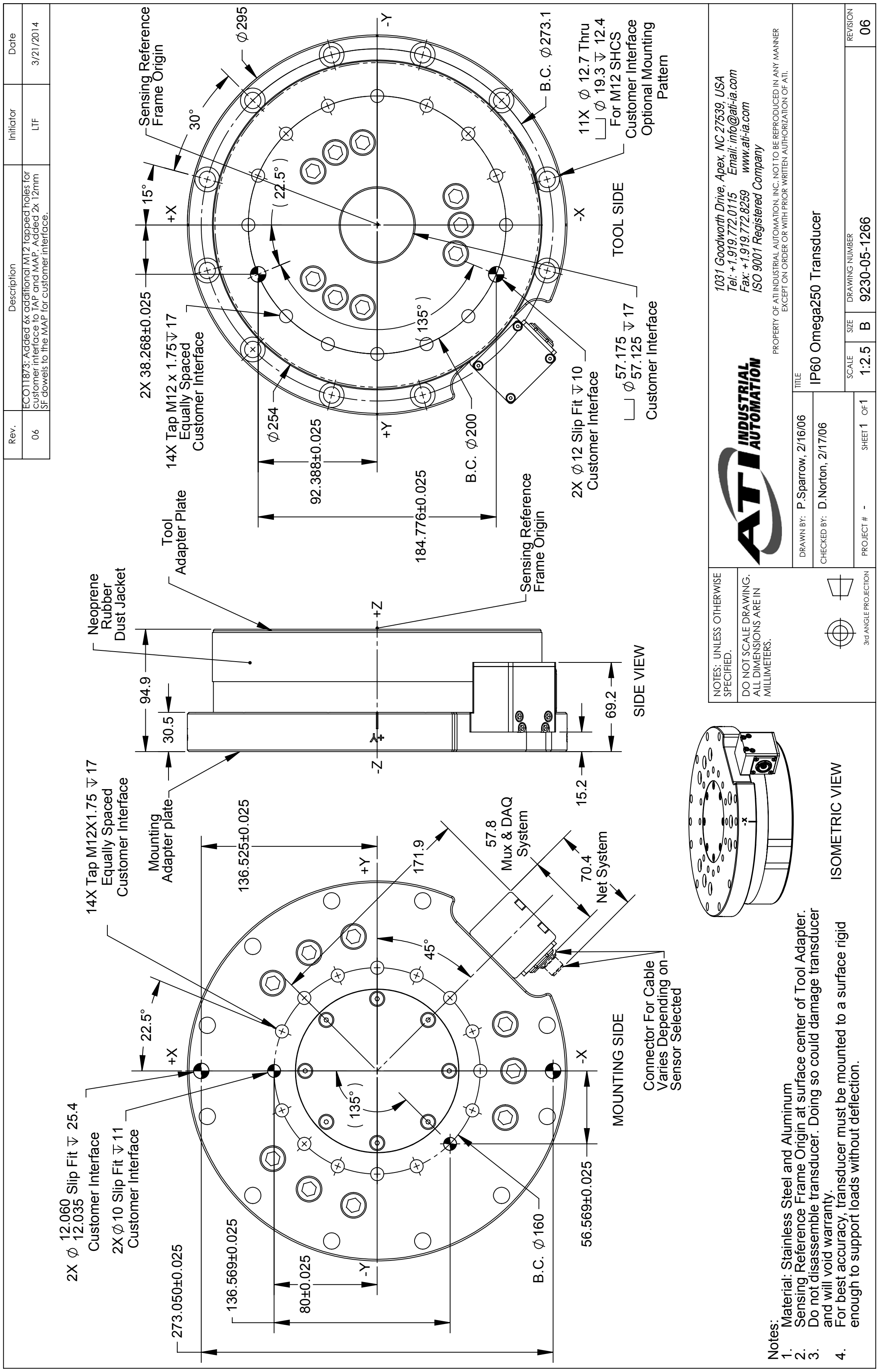




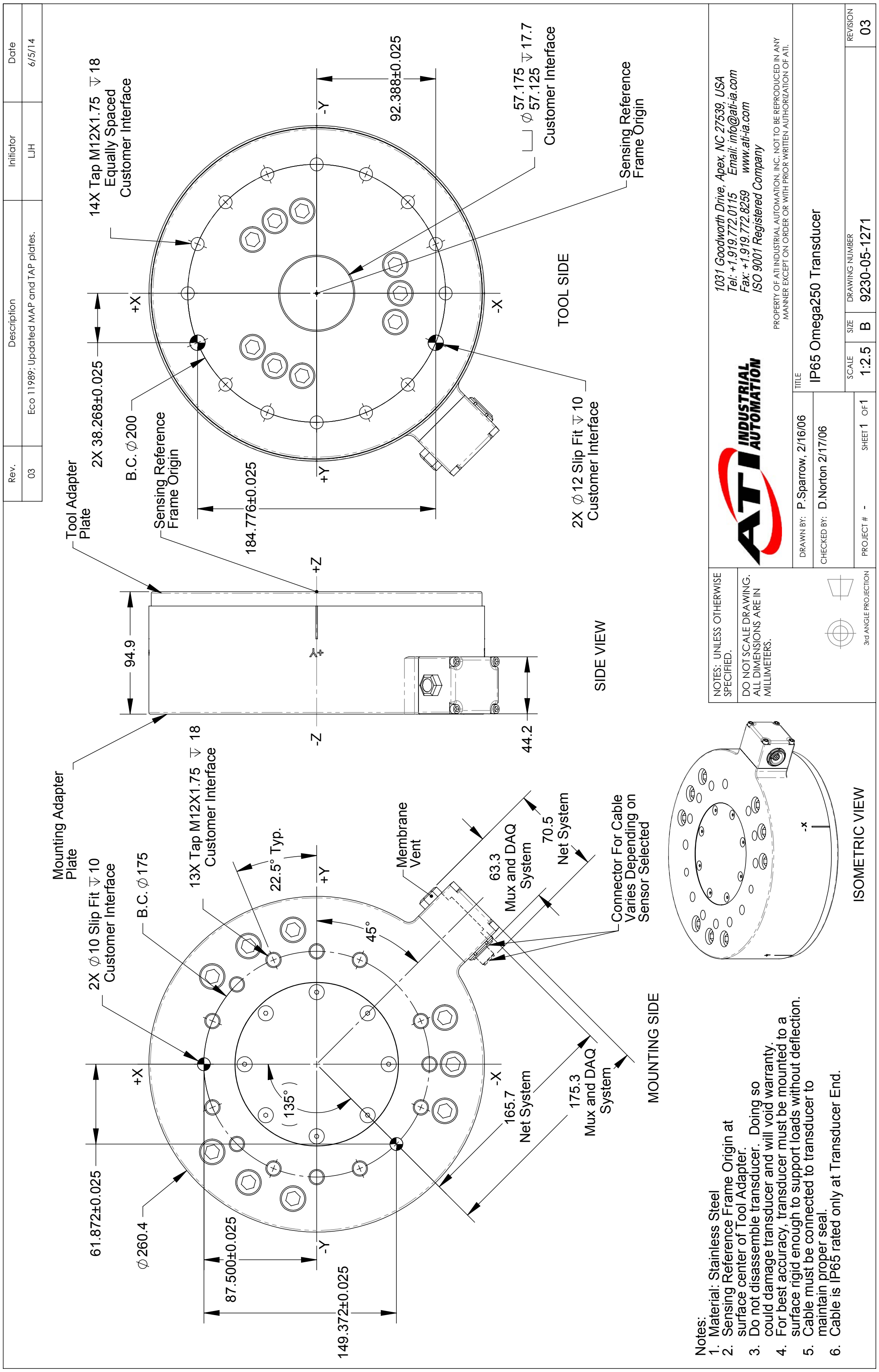
SI-4000-500 SI-8000-1000 SI-16000-2000

Note: 1. For IP68 version see caution on physical properties page.

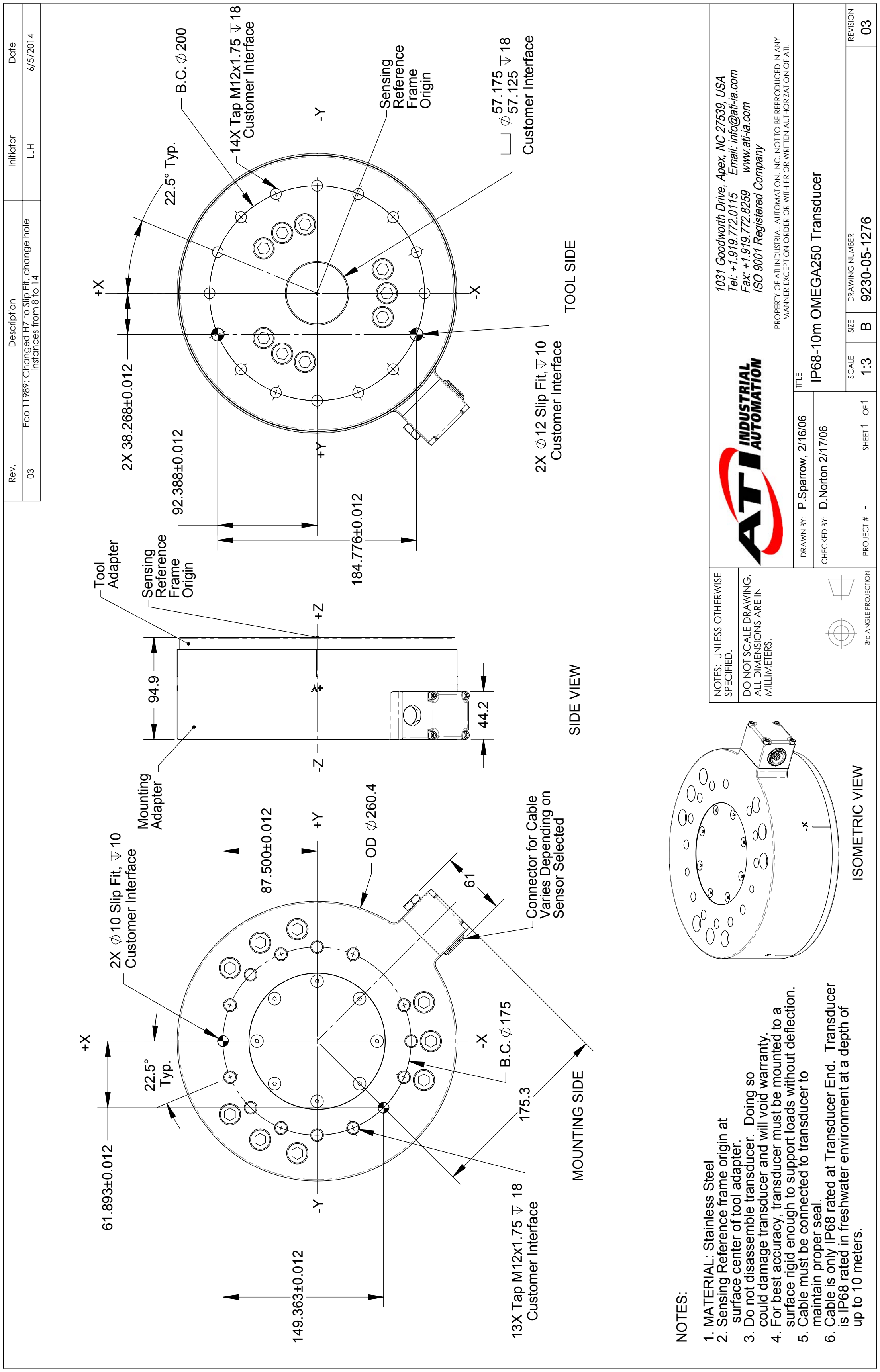
5.19.8 Omega250 IP60 Transducer Drawing



5.19.9 Omega250 IP65 Transducer Drawing



5.19.10 Omega250 IP68 Transducer Drawing



5.20 Omega331 Specifications (Includes IP65)

5.20.1 Omega331 Physical Properties (Includes IP65)

Table 4.114—Omega331 Physical Properties (Includes IP60/IP65)		
Single-Axis Overload	**(US) Standard Units**	**(SI) Metric Units**
Fxy	±53000 lbf	±240000 N
Fz	±120000 lbf	±520000 N
Txy	±280000 inf-lb	±32000 Nm
Tz	±320000 inf-lb	±36000 Nm
Stiffness (Calculated)		
X-axis & Y-axis forces (Kx, Ky)	$6.9x10^6$ lb/in	$1.2x10^9$ N/m
Z-axis force (Kz)	$7.3x10^6$ lb/in	$1.3x10^9$ N/m
X-axis & Y-axis torque (Ktx, Kty)	$8.1x10^7$ lbf-in/rad	$9.2x10^6$ Nm/rad
Z-axis torque (Ktz)	$2.1x10^8$ lbf-in/rad	$2.4x10^7$ Nm/rad
Resonant Frequency		
Fx, Fy, Tz	N/A	N/A
Fz, Tx, Ty	N/A	N/A
Physical Specifications		
Weight[1]	104 lb	47 kg
Diameter[1]	13 in	330 mm
Height[1]	4.22 in	107 mm
Note: 1. Specifications include standard interface plates.		

5.20.2 Calibration Specifications (excludes CTL calibrations)

Table 4.115— Omega331 Calibrations (excludes CTL calibrations)[1, 2]

Sensor	(US) Standard Calibration	Fx,Fy (lbf)	Fz (lbf)	Tx,Ty (lbf-in)	Tz (lbf-in)	Fx,Fy (lbf)	Fz (lbf)	Tx,Ty (lbf-in)	Tz (lbf-in)
Omega331	US-2250-13000	2250	5250	13000	13000	3/8	1	3 3/4	1 7/8
Omega331	US-4500-26000	4500	10500	26000	26000	3/4	2	7 1/2	3 3/4
Omega331	US-9000-52000	9000	21000	52000	52000	1 1/2	4	15	7 1/2
Sensor	**(SI) Metric Calibration**	**Fx,Fy (kN)**	**Fz (kN)**	**Tx,Ty (kNm)**	**Tz (kNm)**	**Fx,Fy (kN)**	**Fz (kN)**	**Tx,Ty (kNm)**	**Tz (kNm)**
Omega331	SI-10000-1500	10	22	1.5	1.5	1/640	1/240	3/8000	3/16000
Omega331	SI-20000-3000	20	44	3	3	1/320	1/120	3/4000	3/8000
Omega331	SI-40000-6000	40	88	6	6	1/160	1/60	3/2000	3/4000
		Sensing Ranges				**Resolution (DAQ, Net F/T)[3]**			

Notes:

1. These system resolutions quoted are the effective resolution after dropping four counts of noise. The effective resolution can be improved with filtering.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.
3. DAQ resolutions are typical for a 16-bit data acquisition system.

5.20.3 CTL Calibration Specifications

Table 4.116— Omega331 CTL Calibrations[1, 2]

Sensor	(US) Standard Calibration	Fx,Fy (lbf)	Fz (lbf)	Tx,Ty (lbf-in)	Tz (lbf-in)	Fx,Fy (lbf)	Fz (lbf)	Tx,Ty (lbf-in)	Tz (lbf-in)
Omega331	US-2250-13000	2250	5250	13000	13000	3/4	2	7 1/2	3 3/4
Omega331	US-4500-26000	4500	10500	26000	26000	1 1/2	4	15	7 1/2
Omega331	US-9000-52000	9000	21000	52000	52000	3	8	30	15
Sensor	**(SI) Metric Calibration**	**Fx,Fy (kN)**	**Fz (kN)**	**Tx,Ty (kNm)**	**Tz (kNm)**	**Fx,Fy (kN)**	**Fz (kN)**	**Tx,Ty (kNm)**	**Tz (kNm)**
Omega331	SI-10000-1500	10	22	1.5	1.5	1/320	1/120	3/4000	3/8000
Omega331	SI-20000-3000	20	44	3	3	1/160	1/60	3/2000	3/4000
Omega331	SI-40000-6000	40	88	6	6	1/80	1/30	3/1000	3/2000
		Sensing Ranges				**Resolution (Controller)**			

Notes:

1. 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.
2. Applied loads must be within range in each of the six axes for the F/T sensor to measure correctly.

5.20.4 CTL Analog Output

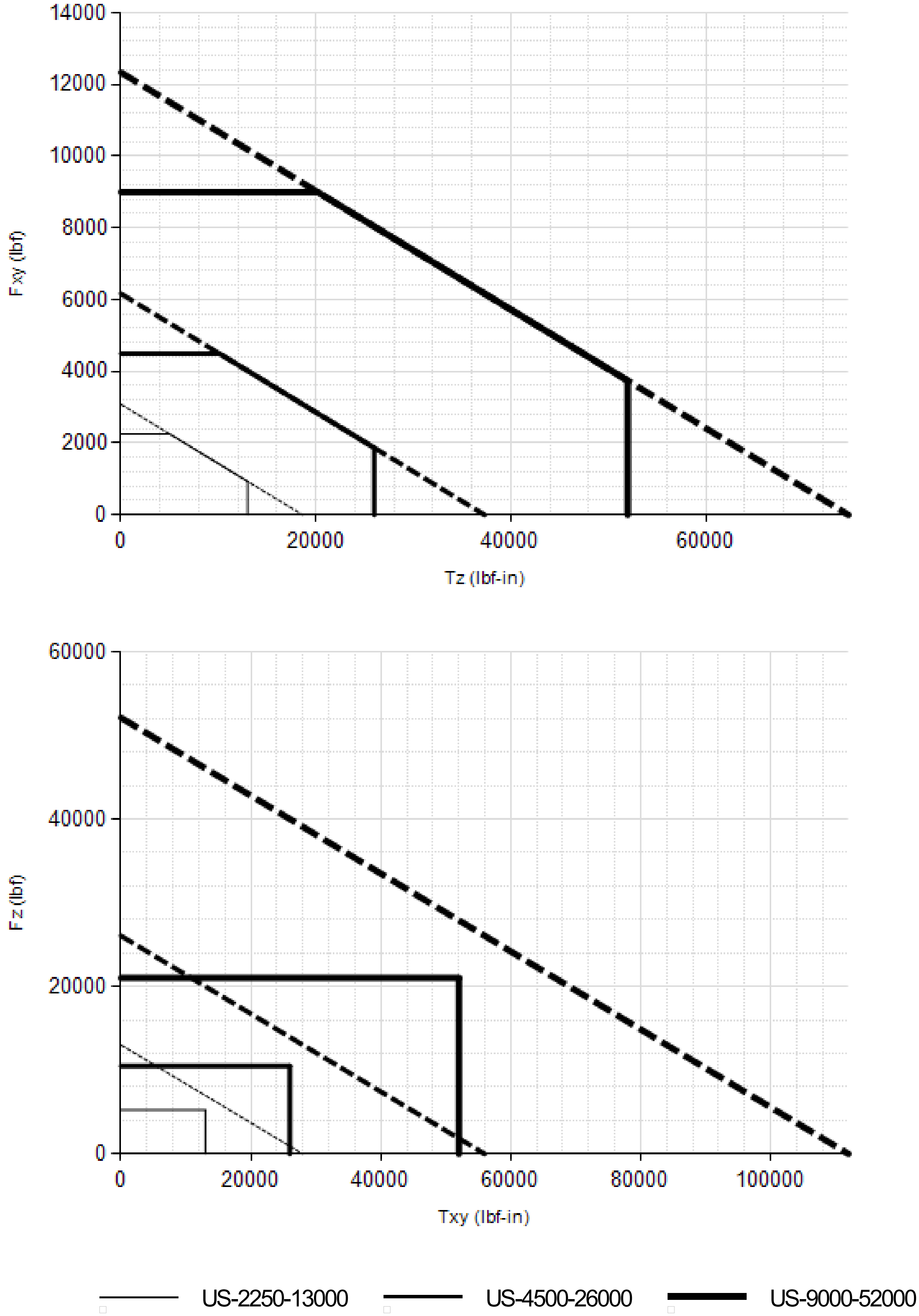
Table 4.117— Omega331 Analog Output							
Sensor	**(US) Standard Calibration**	**Fx,Fy (lbf)**	**Fz (lbf)**	**Tx,Ty,Tz (lbf-in)**	**Fx,Fy (lbf/V)**	**Fz (lbf/V)**	**Tx,Ty,Tz (lbf-in/V)**
Omega331	US-2250-13000	±2250	±5250	±13000	225	525	1300
Omega331	US-4500-26000	±4500	±10500	±26000	450	1050	2600
Omega331	US-9000-52000	±9000	±21000	±52000	900	2100	5200
Sensor	**(SI) Metric Calibration**	**Fx,Fy (kN)**	**Fz (kN)**	**Tx,Ty,Tz (kNm)**	**Fx,Fy (kN/V)**	**Fz (kN/V)**	**Tx,Ty,Tz (kNm/V)**
Omega331	SI-10000-1500	±10	±22	±1.5	1	2.2	0.15
Omega331	SI-20000-3000	±20	±44	±3	2	4.4	0.3
Omega331	SI-40000-6000	±40	±88	±6	4	8.8	0.6
		Analog Output Range			**Analog ±10V Sensitivity[1]**		

Note:
1. ±5V Sensitivity values are double the listed ±10V Sensitivity values.

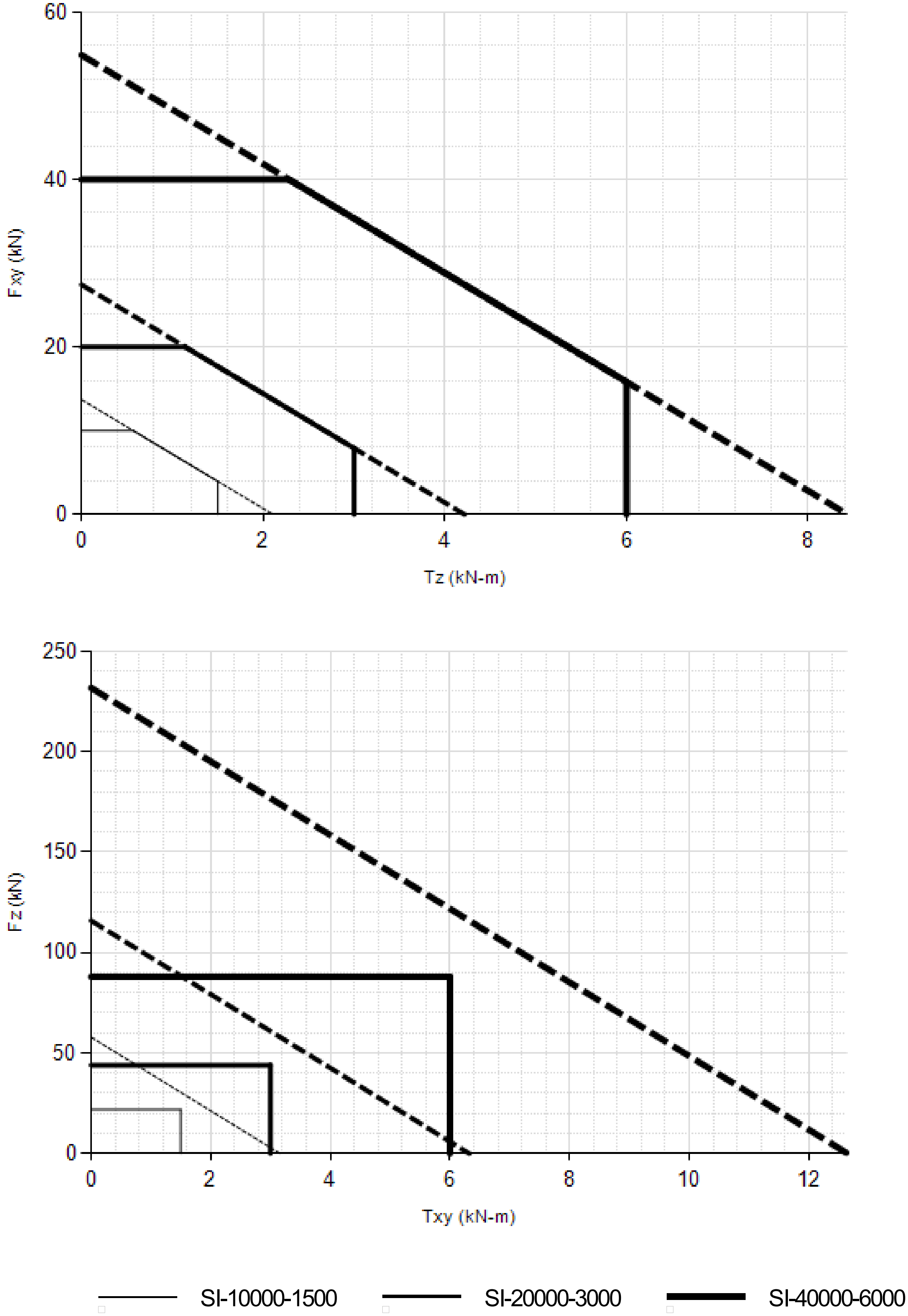
5.20.5 CTL Counts Value

Table 4.118—Counts Value					
Sensor	**Calibration**	**Fx, Fy, Fz (/ lbf)**	**Tx, Ty, Tz (/ lbf-in)**	**Fx, Fy, Fz (/ kN)**	**Tx, Ty, Tz (/ kNm)**
Omega331	US-2250–13000 / SI-10000–1500	32	6.4	7680	64000
Omega331	US-4500–26000 / SI-20000–3000	16	3.2	3840	32000
Omega331	US-9000–52000 / SI-40000–6000	8	1.6	1920	16000
Omega331	Tool Transform Factor	0.05 in/lbf		1.2 mm/N	
		Counts Value – Standard (US)		**Counts Value – Metric (SI)**	

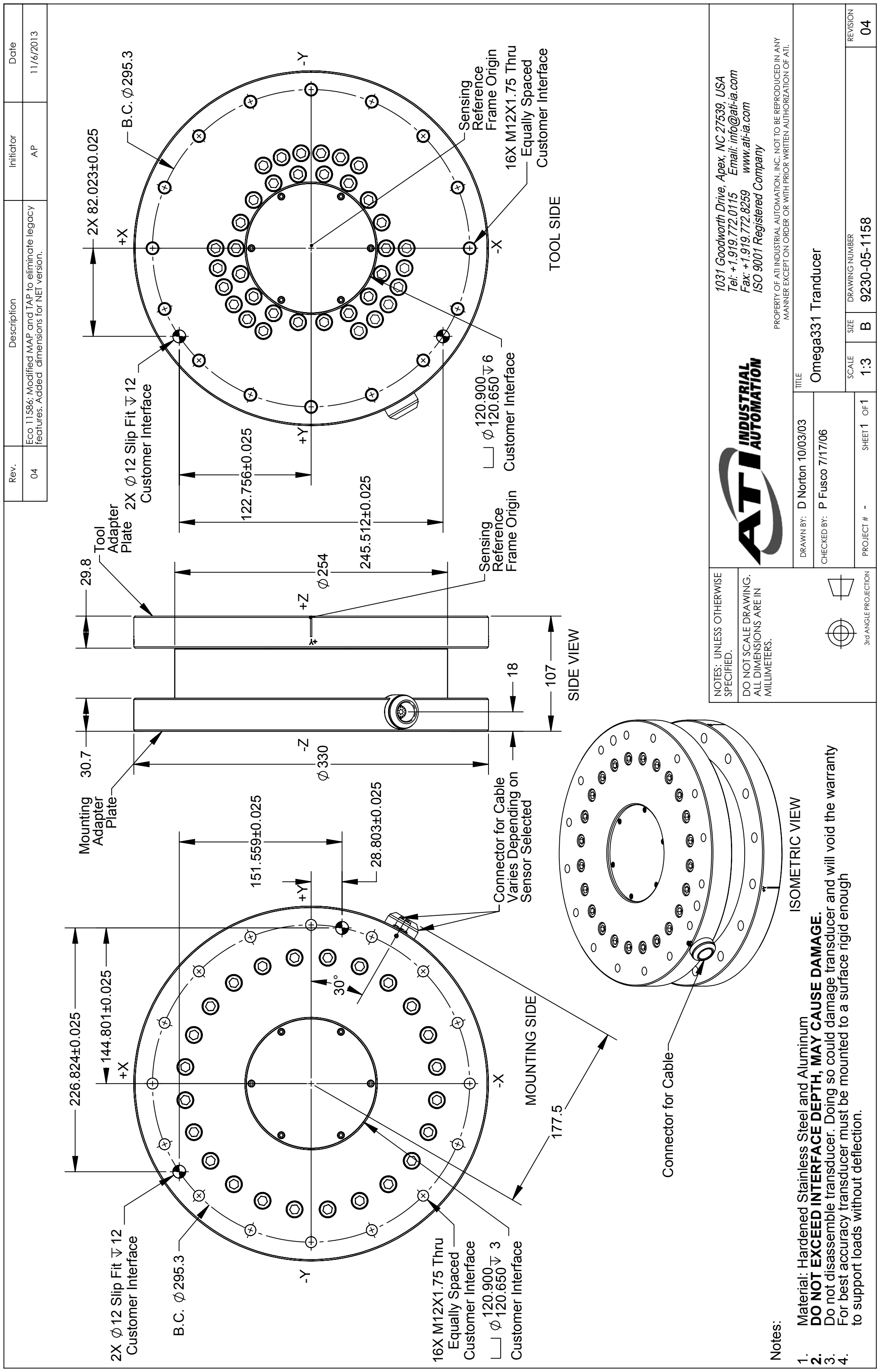
5.20.6 Omega331 (US Calibration Complex Loading) (Includes IP65)



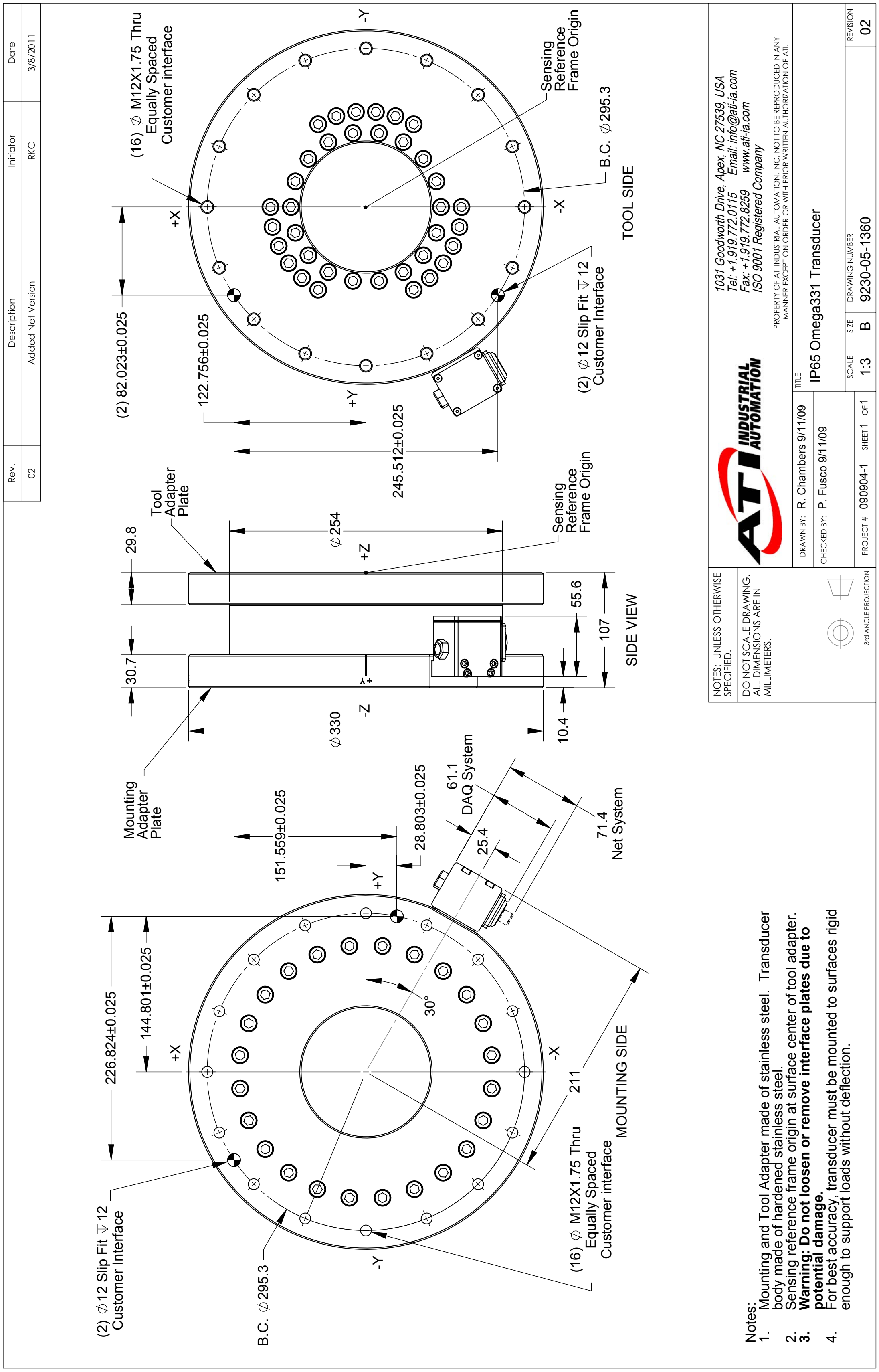
5.20.7 Omega331 (SI Calibration Complex Loading) (Includes IP65)



5.20.8 Omega331 Transducer Drawing



5.20.9 Omega331 IP65 Transducer Drawing



6. Advanced Topics

6.1 Reducing Noise

6.1.1 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.

6.1.2 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.

6.2 Detecting Failures (Diagnostics)

6.2.1 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 is saturated or otherwise inoperable, **all transducer F/T readings are invalid**. It is vitally important to monitor for these conditions.

6.3 Scheduled Maintenance

6.3.1 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.

6.3.2 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.

6.4 Transducer Cabling

6.4.1 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.

6.4.2 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.

6.5 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.

7. 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.

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