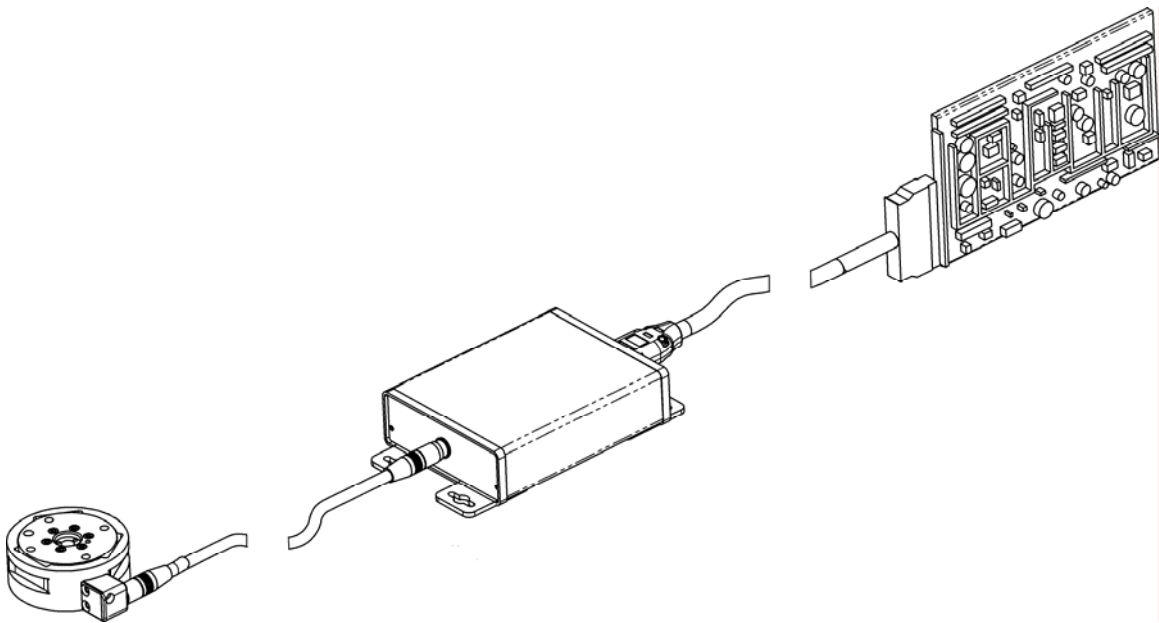




DAQ F/T

*Multi-Axis Force/Torque
Sensor System*

Installation and Operation Manual



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Engineered Products for Robotic Productivity

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Forward

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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.

Any modifications to the device could impact compliance. It is the user's responsibility to certify the device remains compliant after modifications

CE Conformity



This device complies with EMC Directive 89/336/EEC and conforms to the following standards: ENS5011:1998, ANSI C63.4:1992, ENG1000-4-2:1995, ENG1000-4-3:1995, ENG1000-4-6:1995.

Aside

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

1. Serial number (e.g.; FT01234)
2. Transducer model (e.g.; Nano17, Gamma, Theta, etc.)
3. Calibration (e.g.; US-15-50:5V, SI-65-5:10V, 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.

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Quick Start

Perform the following steps to get your system installed and running on your Windows® computer system.

Installing Data Acquisition Card

1. Install the National Instruments data acquisition hardware and software following the instructions included with the National Instruments product. When finished you should have installed the data acquisition hardware and the program *Measurement & Automation (MAX)*.

Installing ATI Software

2. Place the ATI Industrial Automation CD in your computer. The installation program should start automatically. If it does not start automatically you will need to run *SETUP.EXE* found in the root directory of the CD. Follow the installation instructions given by the program. This software is for Windows® 95 and later Windows® operating systems.
3. View the *README.TXT* file found in the root directory of the CD.
4. Copy your transducer's calibration file from the CD directory *Calibration* to the *ATI DAQ FT* directory on your computer (this directory was created when you installed the software). The calibration file name is based on the transducer's serial number and is in the format *FTxxxx.CAL*.

Connecting Transducer Hardware

5. Connect the transducer to the Power Supply Box or Interface Box/Power Supply with the appropriate cable.
6. Connect the Power Supply Box or Power Supply/Interface Box to the data acquisition hardware using the supplied cable.
7. Run the demo program found in the Start menu under *Programs/ATI DAQ FT/ATI DAQ FT Demo*.
8. Click on the menu *File*, then *Open Calibration*. Find the calibration data file you saved earlier and click the *Open* button.. Select the file with the name similar to *FTxxxx.CAL* and click on the *Open* button.
9. You can find program samples in the CD directory *SAMPLES*.

Please contact ATI for any information you may need for installation and configuration of your new system.



CAUTION: Each transducer has a maximum measurement range and a maximum overload capacity. **Exceeding the transducer's overload capacity can cause permanent damage.** Smaller transducers have lower overload capacities. Torque in X and Y are usually the easiest axes to accidentally overload.

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Glossary of Terms

Terms	Conditions
Accuracy	See Measurement Uncertainty.
ActiveX Component	A reusable software component for the Windows® applications.
Compound Loading	Any load that is not purely in one axis.
DAQ	Data Ac quisition device.
FS	Full-S cale.
F/T	Force and Torque.
Fxy	The resultant force vector comprised of components Fx and Fy.
Hysteresis	A source of measurement caused by the residual effects of previously applied loads.
IFPS	InterFace/Power S upply box.
LabVIEW	A graphical programming environment created for data acquisition tasks by National Instruments.
Maximum Single-Axis Overload	The largest amount of pure load (not compound loading) that the transducer can withstand without damage.
MAP	M ounting Ad aptor P late. The MAP part of the transducer is attached to the fixed surface or robot arm.
Measurement Uncertainty	The maximum expected error in measurements, as specified on the calibration certificate.
NI	N ational I nstruments Corporation, the owner of the “National Instruments” and “LabVIEW” trademarks. (www.ni.com)
Overload	The condition where more load is applied to the transducer than it can measure. This will result in saturation.
PCMCIA	A small computer card for use in most laptop computers.
Point of Origin	The point on the transducer from which all forces and torques are measured.
PS	P ower S upply box.
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.
Resolution	The smallest change in load that can be measured. This is usually much smaller than accuracy.
Saturation	The condition where the transducer or data acquisition hardware has a load or signal outside of its sensing range.
Sensor System	The entire assembly consisting of parts from transducer to data acquisition card.
TAP	T ool Ad aptor P late. 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.
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.

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1. Getting Started

1.1 Introduction

This section gives instructions for setting up the F/T system. Final installation is covered in *Section 2*. After setting up the system, a test is performed to check for problems. It is possible to start learning the commands described in *Section 4* before starting the final installation.



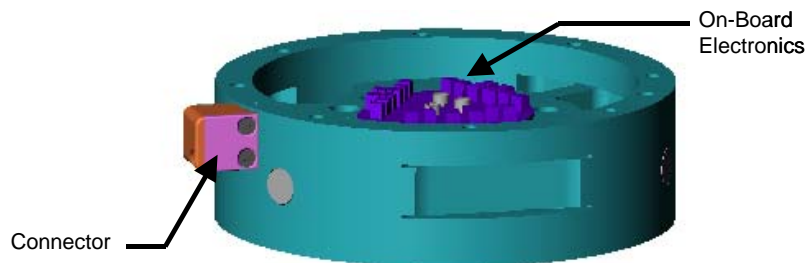
CAUTION: The Force/Torque transducer, the calibration data loaded on the CD and the IFPS box, if applicable, have been assigned matching serial numbers when the system was calibrated. If these serial numbers assigned to your F/T system do not match, the force / torque outputs will be incorrect. Please do not mix system components from different systems.

1.2 Unpacking

- Check the shipping container and components for damage due to shipping. Any damage should be reported to ATI Industrial Automation.
- Check the packing list for omissions.
- The following are standard components for an F/T system (If you will be using your own data acquisition system, you may not receive all the items.):
 - Transducer
 - Transducer cable (for 9105-TIF transducers)
 - Power Supply or Interface Power Supply Box
 - Power Supply cable
 - Data Acquisition Card and its CD – if ordered
 - ATI software CD
 - This manual.
- The following are optional components:
 - Mounting ring-plug adaptor; replaces mounting adaptor on some models
 - Tool ring-plug adaptor; replaces tool adaptor on some models.



CAUTION: The transducer, Power Supply box, Interface Power Supply box, and DAQ card are susceptible to damage from electrostatic discharge whenever they are not connected to a plugged-in computer. Do not touch the electronics or the connector pins when handling the transducer.



1.3 System Components Description

1.3.1 Transducer

The transducer is a compact, rugged, monolithic structure that converts force and torque into analog strain gauge signals. The transducer is commonly used as a wrist sensor mounted between a robot and a robot end-effector. Factory-installed overload pins give Delta and Theta transducers extra protection from damage due to inadvertent overloads. *Figure 1.1* shows the transducer with a standard tool adaptor.

For further information not in this section see:

- *Appendix A* for specifications (i.e. resolution, weight).
- *Appendix B* for mechanical drawings.
- *Section 2, Final Installation*, for mounting and cable routing.

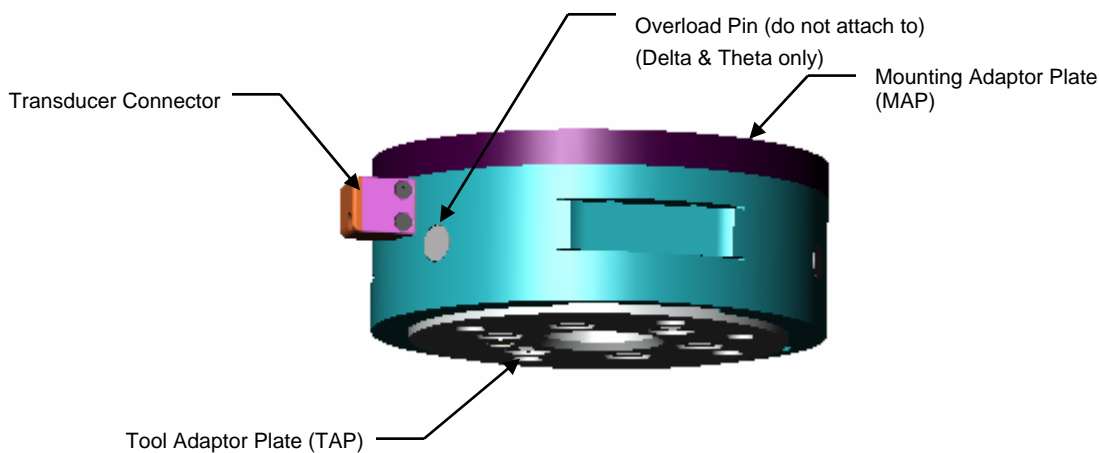


Figure 1.1—Transducer

Aside:

The transducer is designed to withstand extremely high overloading through its use of strong materials and quality silicon strain gauges. Some models use a hardened stainless steel with twice the strength of titanium for overload protection while other transducers use mechanical overload pins to prevent damage.

1.3.2 Transducer Cable

The high-flex life transducer cable is electrically shielded to protect transmission from the transducer Power Supply or Interface Power Supply boxes, small transducers have the cable integrally attached. Larger transducers have a separate cable [See *Figure 1.2*].

For further information not in this section see:

- *Section 2, Final Installation*, for cable routing.



Figure 1.2a—Transducer Cable for 9105-TIF Transducers



Figure 1.2b—Integral Transducer Cable on Small Transducers

1.3.3 Power Supply and Interface/Power Supply Boxes

The Interface Power Supply box is typically used with the small Nano and Mini transducers. It supplies power to the transducer and electronics as well as conditioning the transducer signals to be used with a data acquisition system. The transducer's 12-pin cable plugs into this box. The Power Supply box is used with larger transducers that have on board interface electronics. The 20-pin transducer cable plugs into this box.

1.3.4 Power Supply Cable

The robust power supply cable connects the Power Supply box or Interface Power Supply box to the data acquisition system. This cable usually has a connector on the data acquisition end, but is also available unterminated.

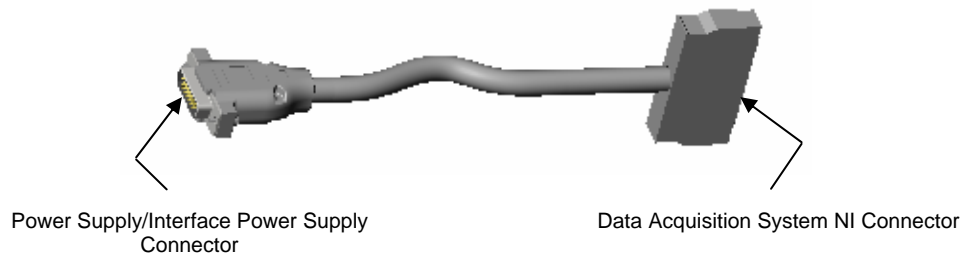


Figure 1.3—Power Supply Cable

1.3.5 Data Acquisition System

The data acquisition system converts the transducer signals from analog voltages into data your computer can use. This data is not the final force and torque values. The data acquisition system also supplies raw power to the transducer system.

1.3.6 F/T Software CD

The F/T software CD contains the software and calibration data that your computer uses to convert the transducer readings into usable force and torque output. It also has Microsoft

Windows® drivers, sample programs, C source code, and detailed help files. The most recent release of the DAQ software can be found on the web at <http://www.ati-ia.com/download/software.htm>.

1.3.7 Interface Plates

The larger transducers come with a standard mounting adaptor to mechanically attach the transducer to your robot arm or apparatus that will be applying the force. The transducer also has a standard tool adaptor with an ISO 9409-1 interface for Gamma, Delta, and Theta models for attaching your tool.

The mounting adaptor consists of:

- Mounting adaptor plate
- Mounting screws

For further information not in this section see:

- *Section 2, Installation*
- *Appendix B, Mechanical Layout*

1.4 Connecting the System Components

1.4.1 Connecting the Transducer Cable

Large DAQ F/T transducers connect to the system through a high-density 20-pin connector. (see *Figure 1.3*). The Nano and Mini F/Ts have integral cables.

Connect the transducer cable connector to the transducer as follows:

- Lightly place the connector into port on the transducer. Do not push.
- Line up the groove on the connector to the key in the port by rotating the connector while lightly forcing the connector into the port. When the groove lines up the connector will go noticeably deeper into the port.
- Screw the connector shell into the transducer until it seats firmly.

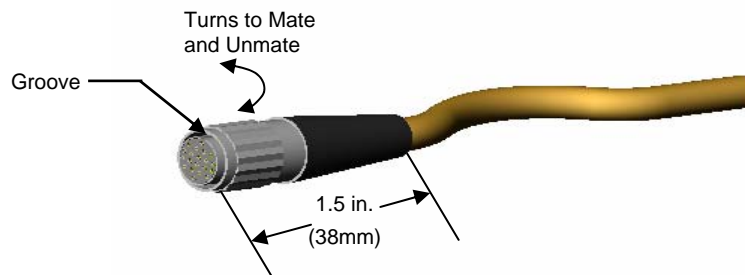


Figure 1.4—Transducer Connector

Disconnect the transducer connector from the transducer port by unscrewing the connector shell.



CAUTION:

Cables on the Nano and Mini transducers are permanently attached to the transducer and can not be disconnected. Do not attempt to disassemble these transducers as **damage will occur**.

1.4.2 Installing the Data Acquisition Hardware

Install the data acquisition hardware and its accompanying software following the instructions included with the hardware.

1.4.3 Connecting to the Data Acquisition Hardware

If you are using a NI PCMCIA (a small PC card for laptop computers), you will need to attach the short adaptor cable to the card. The other end of the adaptor cable connects to the F/T Power Supply cable.

Connect the 26-pin D-subminiature connector side of the Power Supply cable to the Power Supply or Interface Power Supply box. Tighten the jackscrews on the connector to insure a good electrical connection.

Connect the 68-pin connector side of the Power Supply cable to the NI data acquisition hardware. Tighten the jackscrews on the connector to insure a good electrical connection. Please note that the PCMCIA adaptor does not use the jackscrews. In this case you must insure the connectors do not get pulled apart.

Aside:

If you are not using a National Instruments E-Series DAQ board, you will have to provide your own connector at that end of the cable.

1.4.4 Testing with the ATI DAQ Demo on a Windows® Computer

Install the F/T software by inserting the CD in your computer. The installation program should start automatically. If it does not start automatically, you will need to run *SETUP.EXE* found in the root directory of the CD. Follow the installation instructions given by the program.

View the *README.TXT* file found in the root directory of the CD.

Copy your transducer's calibration file(s) from the CD directory *\Calibration* to the program directory *ATI DAQ FT*. Calibration file names are based on the transducer's serial number and is in the format of *FTxxx.CAL*. There will be multiple calibration files if the system was ordered with more than one calibration.

Run the demo program found in the Start Menu under *Programs\ATI DAQ FT\ATI DAQ FT Demo*. In the program you must load the calibration data. Do this by clicking on the menu *File*, then *Open Calibration*. Find the calibration data file you saved earlier and click the *Open* button. At this point the program should be displaying two sets of bar graphs; one labeled *Force* and the other labeled *Torque*. The center bottom of the demo window will show the transducer model and calibration for the loaded calibration file.

Gently apply load to the transducer without over-ranging the transducer. You should see the bar graphs respond.

Aside:

The ATI DAQ demo only works in conjunction with National Instruments DAQ boards.

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2. Installation

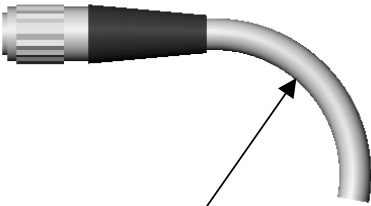
2.1 Introduction

This section will assist the user in mounting the transducer, tooling, and the transducer cable.

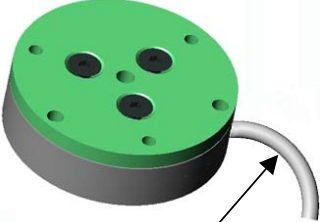
2.2 Routing the Transducer Cable

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 *Section 1.4* for the transducer cable interfacing. If the desired application results in the cable rubbing then use a plastic spiral wrap for protection.

 **CAUTION:** When a cable is cycling below the minimum bending radius, the cable may fail due to fatigue. A smaller radius may be used if it is not being cycled.





Minimum cycled
bending radius 60mm
(at room temperature)



Minimum cycled
bending radius 40mm
(at room temperature)

The minimum cycled bending radius is different with significant temperature changes, increasing with lower temperature and decreasing for higher temperature.

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

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

2.3 Mounting the Transducer

There are two different Methods, I and II, for mounting most F/T transducers. Mount the transducer to a structure with sufficient mechanical strength. Not doing so can lead to sub-optimum performance. **The Nano, Mini and Omega transducers have mounting and tool adaptors which cannot be removed, so only Method II can be used.**

2.3.1 Transducer Mounting Method I:

Uses the standard mounting adaptor to attach the transducer. You must machine the bolt pattern of your device (i.e. robot) into the mounting adaptor. You will not be able to use the mounting adaptor alone if your device covers the mounting screws used to connect the transducer. If this is the case, use Method II.

Use the mounting adaptor to attach the transducer as follows

- Ensure that you provide sufficient clearance between the mounted transducer and other fixtures, and that total stack height is acceptable. Also ensure that after the mounting adaptor is attached to the robot (or other device) you will have access to the mounting screws for attaching the transducer.
- Machine the mounting adaptor plate for attaching to your robot (or other device). Mounting adaptor plate dimensions are shown in Appendix B, Mechanical Layout [see *Figure 2.1*]. **All user-supplied screws must be flush with the inside of the mounting adaptor to ensure proper clearance for the electronics inside the transducer.**
- Attach the mounting adaptor to the robot (or other device). Attach the transducer to the mounting adaptor with the screws and dowel pin provided. Thread locker is recommended to prevent the screws from backing out due to vibration (e.g. Loctite thread locker No. 222).

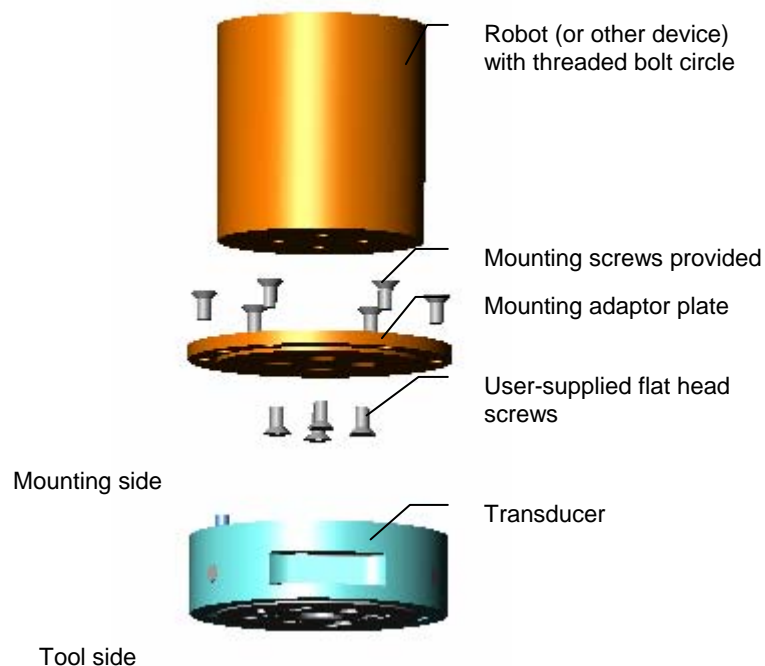


Figure 2.1—Attaching the transducer with the mounting adaptor plate

2.3.2 Transducer Mounting Method II:

Use your own interface plate to bolt directly to the transducer or (for the Nano, Mini or

Omega models) the mounting adaptor.

Use *Appendix B, Mechanical Layout*, for detailed mechanical drawings of the transducer and all interface plates. Detailed descriptions of each method are shown on the next two pages.



CAUTION: Do not attempt to drill, tap, machine, or otherwise modify the transducer. This could damage the transducer and will void the warranty. Do not attempt to remove any part of Nano, Mini, or Omega model transducers as damage will occur.

Aside:

Examine the cable routing (*Section 2.2*) before modifying the mounting adaptor plates. The F/T system's default point of origin is at the center of the mounting adaptor surface. See *Appendix B, Mechanical Layout*, for drawings showing the default point of origin.

2.4 Mounting Your Tool

The tool adaptor is factory installed and the bolt circle is shown in *Appendix B, Mechanical Layout*. Most F/T tool adaptors follow the ISO 9409-1 mounting pattern. Machine your tool interface plate to attach to this bolt circle.



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

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3. How It Works

3.1 Introduction

This section provides a functional outline of the F/T system. The F/T system is broken into three areas: electrical, controlling software, and mechanical. A mechanical description is shown in *Section 3.2*. A graphical representation of the electronics and software is presented in *Section 3.3*.

3.2 Mechanical Description

The property of forces was first stated by Newton in his third law of motion: *To every action there is always opposed an equal reaction; or, the mutual action of two bodies upon each other are always equal, and directed to contrary parts.* The transducer reacts to applied forces and torques using Newton's third law.

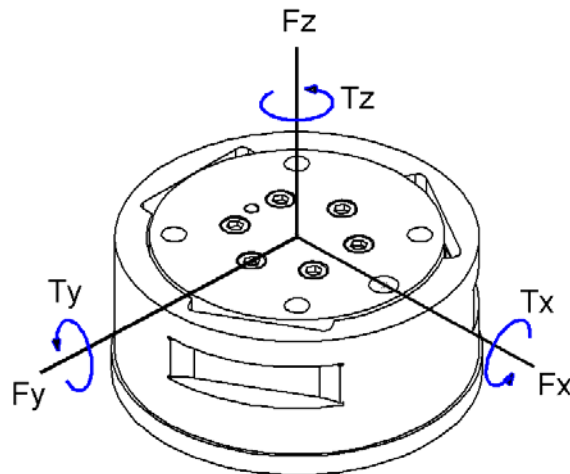


Figure 3.1—Applied force and torque vector on transducer

The force applied to the transducer flexes three symmetrically placed beams using Hooke's law:

$$\sigma = E \cdot \epsilon$$

σ = Stress applied to the beam (σ is proportional to force)

E = Elasticity modulus of the beam

ϵ = Strain applied to the beam

Aside:

The transducer is monolithic structure. The beams are machined from a solid piece of metal. This decreases hysteresis and increases the strength and repeatability of the structure.

Semiconductor strain gauges are attached to the beams and are considered strain-sensitive resistors. The resistance of the strain gauge changes as a function of the applied strain as follows:

$$\Delta R = S_a \cdot R_0 \cdot \varepsilon$$

ΔR = Change in resistance of strain gauge
 S_a = Gauge factor of strain gauge
 R_0 = Resistance of strain gauge unstrained
 ε = Strain applied to strain gauge

The electronic hardware, described in *Section 3.3*, measures the change in resistance and the software, described in *Section 4*, converts this change to force and torque components.

3.3 Electronic Hardware

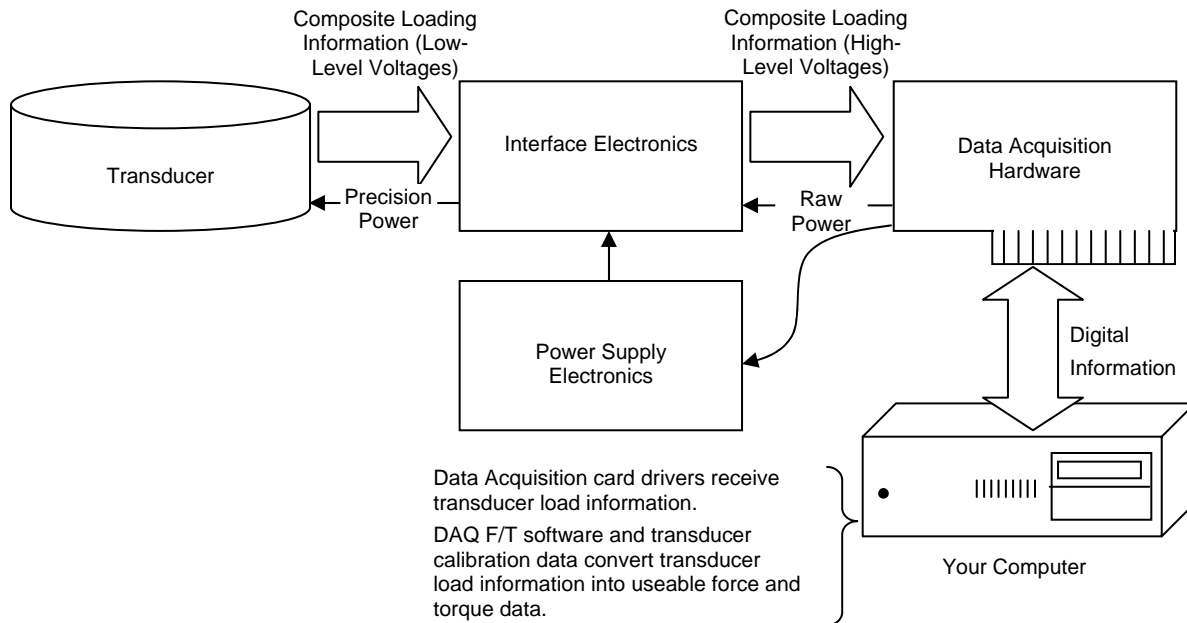


Figure 3.2—Electronic Hardware Outline

4. ATI DAQ Software

The computer that you connect your F/T system's data acquisition card to performs the important functions of converting the data acquisition card data into useful force and torque values and making these values available for use to you.

The ATI DAQ F/T Software CD contains reusable software components that you can use to build your application, as well as sample applications to get you started. (Unless otherwise noted, all Windows® components and applications support Windows® 95, 98, Me, NT, 2000, and XP.)

Aside:

The ATI DAQ F/T software CD contains extensive documentation on its software. Check this documentation for detailed help. CD updates can be found at http://www.ati-ia.com/download/DAQ_FT/DAQ%20FT%20Software.htm.

4.1 Reusable Software Components

4.1.1 ATI DAQFT Automation Server

This Windows® ActiveX component reads calibration files, configures the transducer system, and converts raw voltages from any data acquisition system into forces and torques. ATIDAQFT can be used in development platforms that support ActiveX or Automation containment, including Microsoft Visual Basic 6.0, Microsoft Visual C++, Microsoft.NET Platform, National Instruments LabVIEW, and many others. Its programming API is documented in the ATIDAQFT help files.

4.1.2 C Library

This code library uses standard ANSI C to read calibration files, configure the transducer system, and convert voltage data from any data acquisition system into forces and torques.

4.2 Sample Applications

4.2.1 Windows® Demo (Visual Basic 6.0)

This executable program is a good place to try out your new transducer system in Windows®. It uses National Instruments-DAQ and ATIDAQFT to give a real-time display of F/T data from National Instruments E-Series Multifunction I/O devices. It provides complete options for configuration of the F/T system. Microsoft Visual Basic 6.0 source is included.

4.2.2 LabVIEW Sample

This is a demo application in LabVIEW using the ATIDAQFT Automation server and the Analog Input VIs provided by NI-DAQ. This sample application provides a real-time display of F/T data.

4.3 Designing Your DAQ F/T Application

Your DAQ F/T application must include at least two components:

4.3.1 Device Drivers for Your DAQ Device and Target Operating System

National Instruments includes several sets of Windows[®] device drivers with E-Series devices, including 32-bit DLLs, LabVIEW VIs, and ActiveX controls. Non-Windows[®] device drivers for National Instruments systems may be available from third-party sources. For other brands of data acquisition devices, device drivers must be obtained from the device manufacturer or a third-party source.

4.3.2 ATI DAQ F/T Components or C Library

This part of your application is used to load a calibration file, apply settings such as tool transformations, and convert raw voltages into forces and torques. For Windows[®] applications, the ATIDAQFT Automation server is recommended. The conversion to forces and torques can occur in real-time, or can be applied as a batch operation at the end of the acquisition operation.

5. Electrical Connection Information

This section contains detailed information about the electrical connections of the various F/T system components.

Aside:

Information in this section is intended for advanced users. Users whose systems include an ATI-supplied DAQ card may skip this section.

The ATI DAQ F/T software features a modular design to allow you to use our system with any data acquisition system capable of electrically interfacing to the transducer.

Once you have obtained the digitized transducer data per your data acquisition card instructions, the data needs to be transformed into force and torque data using the drivers and instructions on the ATI DAQ F/T software CD.

5.1 Signals and Power



CAUTION: The analog signals output by the transducer do not map directly into force and torque vectors. ATI DAQ F/T software must be used to convert these values into force and torque data.

Signal Name	Description
SGx Output	The non-inverting (positive) half of output of SGx
SGx Reference	The inverting (negative) half of output of SGx
+V _{ANA}	Positive power supply used by transducer
AGnd	Power supply return used by transducer
-V _{ANA}	Negative power supply used by transducer
+5V	Positive power used by PS or IFPS box
0V	Power supply return used by PS or IFPS box
AIgnd	Analog Input Ground used for input current return from data acquisition card
Reserved	This connection has an internal or future use. Do not use.

Table 5.1—Signal Descriptions

Systems with an ATI supplied DAQ card have their power derived from the DAQ card. If you are using your own DAQ card, you will need to provide a +5V power and 0V power to the PS or IFPS box. Without a PS box you will need to supply +V_{ANA}, AGnd, and -V_{ANA} power to the transducer. (This applies to 9105-TIF transducers only; 9105-TW transducers require their IFPS box.)

5.2 Electrical Specifications

5.2.1 PS and IFPS box with transducer attached.

Signal	Minimum	Typical	Maximum	Units
+5V Power Input Voltage	4.75	5.00	9.00	V DC
+5V Power Input Current		260		mA
+5V Power Input Noise			75	mV p-p
+5V Power Input Regulation			0.5%	

Table 5.2—PS and IFPS box with transducer attached

5.2.2 Transducer with Onboard Interface Board

Signal	Minimum	Typical	Maximum	Units
+V _{ANA} Power Input Voltage	13.00	15.00	17.00	V DC
-V _{ANA} Power Input Voltage	-17.00	-15.00	-13.00	V DC
+V _{ANA} Power Input Current		16		mA
AGnd Power Input Current		25		mA
-V _{ANA} Power Input Current		-41		mA
V _{ANA} Power Input Noise			75	mV p-p
V _{ANA} Power Input Regulation			0.5%	

Table 5.3—Transducer with Onboard Interface Board

5.2.3 Transducer Output Signals

These are output by the transducer and passed through the PS box or are output by the IFPS box.

Signal	Minimum	Maximum	Units
SGx output*	-V _{ANA} +0.6	+V _{ANA} -0.8	V
SGx reference	AGnd	AGnd	V
SGx output, over 10V calibrated range	-10	+10	V
SGx output, over 5V calibrated range	-5	+5	V

* These output levels only occur if the transducer is loaded significantly past its calibration range.

Table 5.4—Transducer Output Signals

The transducer outputs are designed to work with a differential input to the DAQ system for best performance.

The calibrated output voltage range is indicated as a suffix to the calibration. For example, a GAMMA transducer with SI-65-5 calibration and a +10V output voltage range would be expressed as a GAMMA/SI-65-5:10V. The output voltage range can also be read using the OutputRange property of the ATIDAQFT software component.

5.3 Transducer Signals

This section covers the connections for transducers with on-board electronics (9105-TIF part numbers). These transducers have a 20-pin connector. User connections to transducers without on-board electronics (9105-TW part numbers) are not supported and therefore not covered in this document.

The transducer connector mates to a Hirose HR25-9TP-20S connector. Wire colors are shown for use with 9105-C-H-U cable assemblies.

Note: Multi-colored wires are identified as follows: The first color listed is the predominant color of the wire and the second color is the stripe on the wire.

Pin	Description	Wire Colors	Pin	Description	Wire Colors
1	SG0 output	Brown	11	-V _{ANA} power input	Red/White
2	Reserved	Orange	12	SG1 reference	Yellow/White
3	SG0 reference	Brown/White	13	SG4 output	Violet
4	SG3 reference	Blue/White	14	Reserved	White
5	SG5 reference	Grey/White	15	Reserved	Black/White
6	+V _{ANA} power input	Red	16	Reserved	Orange/White
7	SG1 output	Yellow	17	SG2 output	Green
8	SG3 output	Blue	18	SG4 reference	Violet/White
9	SG5 output	Grey	19	Reserved	White/Black
10	AGnd power input	Black	20	SG2 reference	Green/White
			Shell	Shielding	Shield

Table 5.5—Transducer connector connections and 9105-C-H-U cable wire colors

5.4 PS and IFPS Signals

5.4.1 PS 20-pin Circular Connector

These signals and pin numbering are the same as the transducer signals listed in Section 5.3. See Table 5.5.

5.4.2 PS and IFPS 26-pin High Density D-Subminiature Connector

This connector mates to an industry standard female 26-pin high-density D-subminiature connector with screw locks. Wire colors are shown for use with 9105-C-PS-U cable assemblies.

Pin	Description	Wire Colors	Pin	Description	Wire Colors
1	Reserved	Orange	11	0V power input	Red/White
2	+5V power input	Red	12	Reserved	White/Black
3	Reserved	White	13	SG5 reference	Grey/White
4	SG5 output	Grey	14	SG4 reference	Violet/White
5	SG4 output	Violet	15	SG3 reference	Blue/White
6	SG3 output	Blue	16	SG2 reference	Green/White
7	SG2 output	Green	17	SG1 reference	Yellow/White
8	SG1 output	Yellow	18	SG0 reference	Brown/White
9	SG0 output	Brown	19	Reserved	Black/White
10	Reserved	Orange/White	22	AIgnd	Black
			Shell	Shielding	Shield

Table 5.6—PS box and IFPS box connector connections and 9105-C-PS-U cable wire colors

5.4.3 DAQ Card Connections

Our standard DAQ card configuration is based on the National Instruments E-Series 68-pin connector. Advanced users can use the following table to better understand the system connections. Unlisted connector pins are not used.

H	PS	NI	Signal	H	PS	NI	Signal
	2	8	+5V power	8	6	30	SG3 output
	11	13	0V power	4	15	63	SG3 reference
6			+V _{ANA} power	13	5	28	SG4 output
10	22	56	AGnd/AIGnd	18	14	61	SG4 reference
11			-V _{ANA} power	9	4	60	SG5 output
1	9	68	SG0 output	5	13	26	SG5 reference
3	18	34	SG0 reference	14	3	25	reserved
7	8	33	SG1 output	19	12	58	reserved
12	17	66	SG1 reference	2	1	57	reserved
17	7	65	SG2 output	16	10	23	reserved
20	16	31	SG2 reference	15	19	52	reserved

H = connectors between 9105-TIF transducer and PS box

PS = DAQ-side connector on PS and IFPS box

NI – DAQ connector or National Instruments E-Series boards

Table 5.7—System Connections

5.5 Using Unused DAQ Card Resources

There are additional functions available on the ATI-supplied DAQ card that are not used in the standard configuration. Information about using these resources is outside the scope of this manual. Users who wish to use these need to consult the DAQ card documentation for connections and functionality. Table 5.7 shows which signals are used by the F/T system and cannot be used for other purposes. Additional connections to the DAQ card can introduce ground loops and noise if not designed properly.

6. Advanced Topics

6.1 Data Collection Rates

Our DAQ F/T sensor systems are designed to be electrically compatible with most commercially available general-purpose and high-accuracy data acquisition hardware. For best performance in all applications, the transducer electronics do not filter the outputs. This allows collection of all transducer frequency content. Please note that to satisfy the Nyquist Theorem[†], the data needs to be coupled at a rate that is greater than twice the highest frequency present, even if you are not interested in data at that frequency.

Please note that significant error can be introduced in the transducer data if a National Instruments E-Series card is sampling each data set at over 40 kHz (240 kHz per channel). Users with fast NI-DAQ devices should not use the single-scan functions of NI-DAQ, such as `AI_Read_Scan` and `AI-VRead_Scan`. A buffered operation (such as `Scan_Op`) should be used instead. In the demo, *ATI DAQ FT Demo*, the *Buffer Mode* option should be enabled.

[†] The Nyquist Theorem applies to data collection and states that data acquired must be collected at a data rate greater than twice the highest frequency present in the data, otherwise the data will be erroneous. The theorem was developed by Henry Nyquist as he sought to improve communications systems in the first part of the twentieth century.

6.2 Detecting Failures (Diagnostics)

The F/T system is designed to output voltages that are within the specified output voltage range ($\pm 5V$ or $\pm 10V$) as long as the transducer is not being overloaded and the transducer is connected to the PS or IFPS box. If the transducer cable is disconnected or has been damaged, the output of the system will be outside the specified output voltage range. By performing periodic checks of the voltages, a failure can be detected. If any of the voltages are at or outside this range, there may be a problem with the transducer or its cabling.

Sensitivity checking of the transducer can also be used to measure the transducer system's health. This can be 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).

6.3 Scheduled Maintenance

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 6.2—Detecting Failures (Diagnostics)* to detect any failures.

The transducer must be kept free of excessive dust, debris, or moisture. Applications with metallic debris (i.e., electrically-conductive) must protect the transducer from this debris. Transducers without specific factory-installed protection are to be considered unprotected.

The internal structure of the transducers can become clogged with particles and will become uncalibrated or even damaged.

Periodic calibration of the transducer and DAQ card 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 A Word about Resolution

ATI's transducers have a three sensing beam configuration, where the three beams are equally spaced around a central hub and attached to the outside wall of the transducer. This design transfers applied loads to multiple sensing beams and allows the transducer to increase its sensing range in a given axis if a counterpart axis has reduced loading (see Section 7.2's compound loading information).

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 gauges is evenly distributed as load is applied. In the worst case scenario, the discrete value of all involved gauges increases at the same time. The typical scenario will be somewhere in 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-gauge effects can be modeled as a normal distribution, this value represents the most commonly perceived, average resolution. The DAQ F/T resolutions are based on real-number calculations and do not result in clean fractions. To express the values as clean fractions, we simply use the values that a 16-bit DAQ card could achieve. Although this misrepresents the actual performance of the transducers, it results in a close (and always conservative) estimate.

6.5 Environmental

The standard F/T system is designed to be used in standard laboratory or light-manufacturing conditions. Transducers with an IP65 designation are able to withstand dusty environments, as well as wash down.

	Storage	Operation	Units
9105-TIF Transducer	-5 to 75	0 to 60	°C
9105-TW Transducer	-5 to 120	-5 to 120	°C
PS box	-30 to 75	0 to 60	°C
IFPS box	-30 to 75	0 to 60	°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 6.1—Transducer Temperature Ranges

6.6 Accuracy Over Temperature

Typical errors introduced over temperature for F/T transducers with hardware temperature compensation are listed below. These changes in sensitivity are independent of the transducer's rated accuracy at room temperature; the two accuracy ratings must be added to find an overall estimated accuracy at a certain temperature. This overall accuracy assumes that the unloaded and loaded measurements were taken at the same temperature.

Deviation from 22°C	Typical Gain Error
---------------------	--------------------

$\pm 5^{\circ}\text{C}$	0.1%
$\pm 15^{\circ}\text{C}$	0.5%
$\pm 25^{\circ}\text{C}$	1%
$\pm 50^{\circ}\text{C}$	5%

Table 6.2—Error Introduced Over Temperature for Non-Gamma Transducers

Deviation from 22°C	Typical Gain Error
$\pm 5^{\circ}\text{C}$	0.1%
$\pm 15^{\circ}\text{C}$	0.5%
$\pm 25^{\circ}\text{C}$	1.5%
$\pm 50^{\circ}\text{C}$	7%

Table 6.3—Error Introduced Over Temperature for Gamma Transducers

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7. Appendix A—Transducer Specifications

7.1 How to Select an F/T Transducer

7.1.1 Calculate Expected Moment and Forces

Moment capacity is usually the determining factor in choosing the best transducer model for your application. The end-effector attached to the transducer as well as the tasks being performed will generate forces on the transducer, which will result in a moment. The moment is the applied force (dynamic and static together) multiplied by the distance from the transducer origin to the point at which the force is applied. It is important to also consider overload conditions beyond the normal operating forces and moments the transducer will experience.

7.1.2 Identify transducer strength

Use the Quick-Selection Guide below to compare the measuring ranges of the transducer models available.

Specification Description	Nano17	Nano25	Nano43	Mini40	Mini45	Gamma	Delta	Theta	Omega160	Omega190
Max Fxy ±lb (±N)	12 (50)	50 (250)	8 (36)	20 (80)	120 (580)	30 (130)	150 (660)	600 (2500)	600 (2500)	1600 (7200)
Max Txy ±in-lb (±N-m)	4 (0.5)	50 (6)	4 (0.5)	40 (4)	160 (20)	100 (10)	600 (60)	3600 (400)	3600 (400)	12000 (1400)
Weight[†] lb (kg)	0.02 (0.01)	0.14 (0.07)	.09 (.04)	0.11 (0.05)	0.20 (.09)	0.56 (0.25)	2.0 (0.91)	11.0 (4.99)	6.0 (2.72)	14.0 (6.35)
Diameter[†] in (mm)	0.67 (17)	0.99 (25)	1.69 (43)	1.57 (40)	1.77 (45)	2.97 (75.4)	3.72 (94.5)	6.10 (155)	6.14 (156)	7.48 (190)
Height[†] in (mm)	0.57 (14.5)	0.85 (21.6)	0.45 (11.5)	0.48 (12.3)	0.62 (15.7)	1.31 (33.3)	1.31 (33.3)	2.41 (61.1)	2.20 (55.9)	2.20 (55.88)

[†] Specifications include standard interface plates.

7.1.3 Verify resolution

Next, the required resolution should be considered. A fine resolution requirement can conflict with a transducer chosen based on moment capacity. Transducers with larger ranges have coarser resolutions.

7.1.4 Inspect other transducer specifications

Compare the detailed specifications of the chosen transducer to those of your application requirements to be certain the chosen transducer is appropriate for your application.

Example

The expected maximum measured load is 98N (10Kg) of force and the end-effector is 25cm long. The moment generated would be 24.5N-m.

The best F/T would be a Delta/SI-330-30 (330N, 30N-m) which can handle the 24.5N-m moment. The maximum single-axis moment rating (Txy) of this model is 230 N-m, which should be sufficient for overload situations.

Aside:

The published payloads of robots are typically the maximum load the robot can handle at published positional resolution. The robot can actually handle much larger loads, but with some loss of positional repeatability. During a crash both inertia and the sudden deceleration can generate large loads. Robots are typically overpowered for an application, and the robot is capable of exerting loads many times its rated loads.

You may decide to select a transducer with a lower payload with the understanding that this will increase the chances of damaging the transducers during a crash.

Aside:

We highly recommend the use of a robotic crash protection or breakaway device such as ATI's Protector as an added measure of F/T transducer protection in all robotic applications.

7.2 Transducer and Calibration Specifications

7.2.1 Nano17

Calibration	English (US)			Metric (SI)		
	US-3-1	US-6-2	US-12-4	SI-12-0.12	SI-25-0.25	SI-50-0.5
Rated Sensing Ranges						
Fx, Fy	±3 lb	±6 lb	±12 lb	±12.0 N	±25 N	±50 N
Fz	±4.25 lb	±8.5 lb	±17 lb	±17 N	±35 N	±70 N
Tx, Ty, Tz	±1 in-lb	±2 in-lb	±4 in-lb	±120 Nmm	±250 Nmm	±500 Nmm
Resolution*						
Fx, Fy	1/5120 lb	1/2560 lb	1/1280 lb	1/1280 N	1/320 N	1/160 N
Fz	1/5120 lb	1/2560 lb	1/1280 lb	1/1280 N	1/640 N	1/320 N
Tx, Ty	1/32000 in-lb	1/16000 in-lb	1/8000 in-lb	1/256 Nmm	1/128 Nmm	1/64 Nmm
Tz	1/32000 in-lb	1/16000 in-lb	1/8000 in-lb	1/256 Nmm	1/128 Nmm	1/64 Nmm

Physical Properties	US	Metric
Stiffness (Calculated)		
X-axis and Y-axis force (Kx, Ky)	53×10 ³ lb/in	9.3×10 ⁶ N/m
Z-axis force (Kz)	69×10 ³ lb/in	12×10 ⁶ N/m
X-axis and Y-axis torque (Ktx, Kty)	2.2×10 ³ in-lb/rad	250 Nm/rad
Z-axis torque (Ktz)	3.5×10 ³ in-lb/rad	390 Nm/rad
Resonant Frequency (Measured)		
Fx, Fy, Tz	7.2 kHz	
Fz, Tx, Ty	7.2 kHz	
Maximum Single-axis Load		
Fx, Fy	±79 lb	±350 N
Fz	±170 lb	±750 N
Tx, Ty	±21 in-lb	±2.4 Nm
Tz	±28 in-lb	±3.1 Nm
Weight		
Transducer with standard aluminum plates	0.021 lb	9.4 g
Transducer with stainless steel plates	0.073 lb.	33 g
Material		
Transducer	Hardened Stainless Steel	
Mounting and tool adaptors	Aircraft Aluminum	

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

7.2.2 Nano25

Calibration	English (US)		Metric (SI)	
	US-25-25	US-50-50	SI-125-3	SI-250-6
Rated Sensing Ranges				
Fx, Fy	±25 lb	±50 lb	±125 N	±250 N
Fz	±100 lb	±200 lb	±500 N	±1000 N
Tx, Ty	±25 in-lb	±50 in-lb	±3 Nm	±6 Nm
Tz	±25 in-lb	±30 in-lb	±3 Nm	±3.4 Nm
Resolution*				
Fx, Fy	1/896 lb	1/448 lb	1/192 N	1/96 N
Fz	3/896 lb	3/448 lb	1/64 N	1/32 N
Tx, Ty,	1/640 in-lb	1/320 in-lb	1/5280 Nm	1/2640 Nm
Tz	1/1280 in-lb	1/640 in-lb	1/10560 Nm	1/5280 Nm

Physical Properties	US	Metric
Stiffness (Calculated)		
X-axis and Y-axis force (Kx, Ky)	300×10 ³ lb/in	53×10 ⁶ N/m
Z-axis force (Kz)	630×10 ³ lb/in	110×10 ⁶ N/m
X-axis and Y-axis torque (Ktx, Kty)	57×10 ³ in-lb/rad	6440 Nm/rad
Z-axis torque (Ktz)	82×10 ³ in-lb/rad	9260 Nm/rad
Resonant Frequency (Measured)		
Fx, Fy, Tz	3.6 kHz	
Fz, Tx, Ty	3.8 kHz	
Maximum Single-axis Load		
Fx, Fy	±520 lb	±2300 N
Fz	±1400 lb	±6300 N
Tx, Ty	±310 in-lb	±35 Nm
Tz	±560 in-lb	±63 Nm
Weight		
Transducer with stainless steel plates	0.14 lb	65 g
Material		
Transducer	Hardened Stainless Steel	
Mounting and tool adaptors	Hardened Stainless Steel	

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

Note: Applying moments beyond ±30 in-lb (±3.4Nm) in Tz can cause hysteresis and permanent zero-point change in this transducer

7.2.3 Nano43

Calibration	English (US)		Metric (SI)	
	US-4-2	US-8-4	SI-18-0.25	SI-36-0.5
Rated Sensing Ranges				
Fx, Fy	±4 lb	±8 lb	±18 N	±36 N
Fz	±4 lb	±8 lb	±18 N	±36 N
Tx, Ty	±2 in-lb	±4 in-lb	±250 Nmm	±500 Nmm
Tz	±2 in-lb	±4 in-lb	±250 Nmm	±500 Nmm
Resolution*				
Fx, Fy	1/4640 lb	1/2320 lb	1/1024 N	1/512 N
Fz	1/4640 lb	1/2320 lb	1/1024 N	1/512 N
Tx, Ty,	1/9280 in-lb	1/4640 in-lb	1/80 Nmm	1/40 Nmm
Tz	1/9280 in-lb	1/4640 in-lb	1/80 Nmm	1/40 Nmm

Physical Properties	US	Metric
Stiffness (Calculated)		
X-axis and Y-axis force (Kx, Ky)	30×10 ³ lb/in	5.2×10 ⁶ N/m
Z-axis force (Kz)	30×10 ³ lb/in	5.2×10 ⁶ N/m
X-axis and Y-axis torque (Ktx, Kty)	6.8×10 ³ in-lb/rad	770 Nm/rad
Z-axis torque (Ktz)	10×10 ³ in-lb/rad	1.1×10 ³ Nm/rad
Maximum Single-axis Load		
Fx, Fy	±68 lb	±300 N
Fz	±89 lb	±400 N
Tx, Ty	±30 in-lb	±3.4 Nm
Tz	±48 in-lb	±5.4 Nm
Weight		
Transducer with standard aluminum plates	0.085 lb	38 g
Transducer with stainless steel plates	0.21 lb	95 g
Material		
Transducer	Hardened Stainless Steel	
Mounting and tool adaptors	Aircraft Aluminum	

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

7.2.4 Mini40

Calibration	English (US)			Metric (SI)		
	US-5-10	US-10-20	US-20-40	SI-20-1	SI-40-2	SI-80-4
Rated Sensing Ranges						
Fx, Fy	±5 lb	±10 lb	±20 lb	±20 N	±40 N	±80 N
Fz	±15 lb	±30 lb	±60 lb	±60 N	±120 N	±240 N
Tx, Ty, Tz	±10 in-lb	±20 in-lb	±40 in-lb	±1 Nm	±2 Nm	±4 Nm
Resolution*						
Fx, Fy	1/3200 lb	1/1600 lb	1/800 lb	1/800 N	1/400 N	1/200 N
Fz	1/1600 lb	1/800 lb	1/400 lb	1/400 N	1/200 N	1/100 N
Tx, Ty	1/3200 in-lb	1/1600 in-lb	1/800 in-lb	1/32 Nmm	1/16 Nmm	1/8 Nmm
Tz	1/3200 in-lb	1/1600 in-lb	1/800 in-lb	1/32 Nmm	1/16 Nmm	1/8 Nmm

Physical Properties	US	Metric
Stiffness (Calculated)		
X-axis and Y-axis force (Kx, Ky)	65×10 ³ lb/in	11×10 ⁶ Nm
Z-axis force (Kz)	134×10 ³ lb/in	23×10 ⁶ Nm
X-axis and Y-axis torque (Ktx, Kty)	29×10 ³ in-lb/rad	3300 Nm/rad
Z-axis torque (Ktz)	38×10 ³ in-lb/rad	4300 Nm/rad
Resonant Frequency (Measured)		
Fx, Fy, Tz	3.2 kHz	
Fz, Tx, Ty	4.9 kHz	
Maximum Single-axis Load		
Fx, Fy	±200 lb	±890 N
Fz	±610 lb	±2700 N
Tx, Ty	±190 in-lb	±22 Nm
Tz	±190 in-lb	±21 Nm
Weight		
Transducer with standard aluminum plates	0.11 lb	50 g
Transducer with stainless steel plates	0.23 lb	104 g
Material		
Transducer	Hardened Stainless Steel	
Mounting and tool adaptors	Aircraft Aluminum	

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

7.2.5 Mini45

Calibration	English (US)			Metric (SI)		
	US-30-40	US-60-80	US-120-160	SI-145-5	SI-290-10	SI-580-20
Rated Sensing Ranges						
Fx, Fy	±30 lb	±60 lb	±120 lb	±145 N	±290 N	±580 N
Fz	±60 lb	±120 lb	±240 lb	±290 N	±580 N	±1160 N
Tx, Ty, Tz	±40 in-lb	±80 in-lb	±160 in-lb	±5 Nm	±10 Nm	±20 Nm
Resolution*						
Fx, Fy	1/640 lb	1/320 lb	1/80 lb	1/128 N	1/64 N	1/32 N
Fz	1/320 lb	1/160 lb	1/80 lb	1/64 N	1/32 N	1/16 N
Tx, Ty	1/704 in-lb	1/176 in-lb	1/176 in-lb	1/6016 Nm	1/3008 Nm	1/1504 Nm
Tz	1/704 in-lb	1/352 in-lb	1/176 in-lb	1/6016 Nm	1/3008 Nm	1/1504 Nm

Physical Properties	US	Metric
Stiffness (Calculated)		
X-axis and Y-axis force (Kx, Ky)	430×10 ³ lb/in	75×10 ⁶ Nm
Z-axis force (Kz)	560×10 ³ lb/in	98×10 ⁶ Nm
X-axis and Y-axis torque (Ktx, Kty)	150×10 ³ in-lb/rad	17 Nm/rad
Z-axis torque (Ktz)	310×10 ³ in-lb/rad	35 Nm/rad
Resonant Frequency (Measured)		
Fx, Fy, Tz	3.2 kHz	
Fz, Tx, Ty	4.9 kHz	
Maximum Single-axis Load		
Fx, Fy	±1200 lb	±5100 N
Fz	±2300 lb	±10000 N
Tx, Ty, Tz	±950 in-lb	±110 Nm
Tx, Ty, Tz	±1200 in-lb	±140 Nm
Weight		
Transducer with standard aluminum plates	0.21 lb	95 g
Transducer with stainless steel plates	0.36 lb	163 g
Material		
Transducer	Hardened Stainless Steel	
Mounting and tool adaptors	Aircraft Aluminum	

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

7.2.6 Gamma

Calibration	English (US)			Metric (SI)		
	US-7.5-25	US-15-50	US-30-100	SI-32-2.5	SI-65-5	SI-130-10
Rated Sensing Ranges						
Fx, Fy	±7.5 lb	±15 lb	±30 lb	±32 N	±65 N	±130 N
Fz	±25 lb	±50 lb	±100 lb	±100 N	±200 N	±400 N
Tx, Ty, Tz	±25 in-lb	±50 in-lb	±100 in-lb	±2.5 Nm	±5 Nm	±10 Nm
Resolution*						
Fx, Fy	1/2560 lb	1/1280 lb	1/640 lb	1/640 N	1/320 N	1/160 N
Fz	1/1280 lb	1/640 lb	1/320 lb	1/320 N	1/160 N	1/80 N
Tx, Ty	1/1280 in-lb	1/640 in-lb	1/320 in-lb	1/8000 Nm	3/16000 Nm	1/3200 Nm
Tz	1/1280 in-lb	1/640 in-lb	1/320 in-lb	1/8000 Nm	3/16000 Nm	1/3200 Nm

Physical Properties	US	Metric
Stiffness (Calculated)		
X-axis and Y-axis force (Kx, Ky)	52×10 ³ lb/in	9.1×10 ⁶ N/m
Z-axis force (Kz)	100×10 ³ lb/in	18×10 ⁶ N/m
X-axis and Y-axis torque (Ktx, Kty)	93×10 ³ in-lb/rad	11×10 ³ Nm/rad
Z-axis torque (Ktz)	140×10 ³ in-lb/rad	16×10 ³ Nm/rad
Resonant Frequency (Measured)		
Fx, Fy, Tz	1.4 kHz	
Fz, Tx, Ty	2.0 kHz	
Maximum Single-axis Load		
Fx, Fy	±270 lb	±1200 N
Fz	±910 lb	±4100 N
Tx, Ty	±690 in-lb	±79 Nm
Tz	±730 in-lb	±82 Nm
Weight		
Transducer with standard aluminum MAP plates	0.56 lb	250 g
Transducer with ring/plug TAP	0.75 lb	325 g
Transducer with ring/plug MAP	0.8 lb	375 g
Material		
Transducer	Aircraft Aluminum	
Standard mounting adaptor	Aircraft Aluminum	
Ring/Plug adaptors	Aircraft Aluminum	

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

7.2.7 Delta

Calibration	English (US)			Metric (SI)		
	US-50-150	US-75-300	US-150-600	SI-165-15	SI-330-30	SI-660-60
Rated Sensing Ranges						
Fx, Fy	±50 lb	±75 lb	±150 lb	±165 N	±330 N	±660 N
Fz	±150 lb	±225 lb	±450 lb	±495 N	±990 N	±1980 N
Tx, Ty, Tz	±150 in-lb	±300 in-lb	±600 in-lb	±15 Nm	±30 Nm	±60 Nm
Resolution*						
Fx, Fy	1/512 lb	1/256 lb	1/128 lb	1/128 N	1/64 N	1/32 N
Fz	1/256 lb	1/128 lb	1/64 lb	1/64 N	1/32 N	1/16 N
Tx, Ty	3/512 in-lb	3/256 in-lb	3/128 in-lb	1/2112 Nm	3/3200 Nm	3/1600 Nm
Tz	1/256 in-lb	1/128 in-lb	1/64 in-lb	1/2112 Nm	3/3200 Nm	3/1600 Nm

Physical Properties	US	Metric
Stiffness (Calculated)		
X-axis and Y-axis force (Kx, Ky)	210×10 ³ lb/in	37×10 ⁶ N/m
Z-axis force (Kz)	350×10 ³ lb/in	61×10 ⁶ N/m
X-axis and Y-axis torque (Ktx, Kty)	460×10 ³ in-lb/rad	52×10 ³ Nm/rad
Z-axis torque (Ktz)	830×10 ³ in-lb/rad	94×10 ³ Nm/rad
Resonant Frequency (Measured)		
Fx, Fy, Tz	1.5 kHz	
Fz, Tx, Ty	1.7 kHz	
Maximum Single-axis Load		
Fx, Fy	±770 lb	±3400 N
Fz	±2600 lb	±12,000 N
Tx, Ty,	±2000 in-lb	±220 Nm
Tz	±3700 in-lb	±420 Nm
Weight		
Transducer with standard aluminum MAP plates	2.0 lb	910 g
Transducer with ring/plug TAP	2.6 lb	1152 g
Transducer with ring/plug MAP	2.7 lb	1236 g
Material		
Transducer	R _c 32 Stainless Steel	
Standard mounting adaptor	Aircraft Aluminum	

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

7.2.8 Delta IP65

Calibration	English (US)			Metric (SI)		
	US-50-150	US-75-300	US-150-600	SI-165-15	SI-330-30	SI-660-60
Rated Sensing Ranges						
Fx, Fy	±50 lb	±75 lb	±150 lb	±165 N	±330 N	±660 N
Fz	±150 lb	±225 lb	±450 lb	±495 N	±990 N	±1980 N
Tx, Ty, Tz	±150 in-lb	±300 in-lb	±600 in-lb	±15 Nm	±30 Nm	±60 Nm
Resolution (minimum)						
Fx, Fy	1/32 lb	1/16 lb	1/8 lb	1/8 N	1/4 N	1/2 N
Fz	1/16 lb	1/8 lb	1/4 lb	1/4 N	1/2 N	1 N
Tx, Ty	3/32 in-lb	3/16 in-lb	3/8 in-lb	1/132 Nm	3/200 Nm	3/100 Nm
Tz	1/16 in-lb	1/8 in-lb	1/4 in-lb	1/132 Nm	3/200 Nm	3/100 Nm
Counts Value						
Fx, Fy, Fz	32 / lb	16 / lb	8 / lb	8 / N	4 / N	2 / N
Tx, Ty, Tz	32 / in-lb	16 / in-lb	8 / in-lb	133.3 / Nm	66.7/Nm	33.33/Nm
Analog Output						
<i>Analog Range</i>						
Fx, Fy	±37.5 lb	±75 lb	±150 lb	±165 N	±330 N	±660 N
Fz	±37.5 lb	±75 lb	±150 lb	±165 N	±330 N	±660 N
Tx, Ty, Tz	±150 in-lb	±300 in-lb	±600 in-lb	±15 Nm	±30 Nm	±60 Nm
<i>± 5 V Sensitivity</i>						
Fx, Fy	7.5 lb/V	15 lb/V	30 lb/V	33 N/V	66 N/V	132 N/V
Fz	7.5 lb/V	15 lb/V	30 lb/V	33 N/V	66 N/V	132 N/V
Tx, Ty, Tz	30 in-lb/V	60 in-lb/V	120 in-lb/V	3 Nm	6 Nm/V	12 Nm/V
<i>± 10 V Sensitivity</i>						
Fx, Fy, Fz	3.75 lb/V	7.5 lb/V	15 lb/V	16.5 N/V	33 N/V	66 N/V
Fz	3.75 lb/V	7.5 lb/V	15 lb/V	16.5 N/V	33 N/V	66 N/V
Tx, Ty, Tz	15 lb/V	30 in-lb/V	60 in-lb/V	1.5 Nm/V	3 Nm/V	6 Nm/V
Tool Transform Factor	0.01 in/unit	0.01 in/unit	0.01 in/unit	0.6 mm/unit	0.6 mm/unit	0.6 mm/unit

Physical Properties	US	Metric
Stiffness (Calculated)		
X-axis and Y-axis force (Kx, Ky)	210×10 ³ lb/in	37×10 ⁶ N/m
Z-axis force (Kz)	350×10 ³ lb/in	61×10 ⁶ N/m
X-axis and Y-axis torque (Ktx, Kty)	460×10 ³ in-lb/rad	52×10 ³ Nm/rad
Z-axis torque (Ktz)	830×10 ³ in-lb/rad	94×10 ³ Nm/rad
Maximum Single-axis Load		
Fx, Fy	±770 lb	±3400 N
Fz	±2600 lb	±12,000 N
Tx, Ty,	±2000 in-lb	±220 Nm
Tz	±3700 in-lb	±420 Nm
Weight		
Transducer with standard aluminum MAP plates	4.4 lb	1.995 g
Material		
Transducer	R _c 32 Stainless Steel	
Standard mounting adapter	Stainless Steel	

7.2.9 Theta

Calibration	English (US)			Metric (SI)		
	US-200-1000	US-300-1800	US-600-3600	SI-1000-120	SI-1500-240	SI-2500-400
Rated Sensing Ranges						
Fx, Fy	±200 lb	±300 lb	±600 lb	±1000 N	±1500 N	±2500 N
Fz	±500 lb	±875 lb	±1500 lb	±2500 N	±3750 N	±6250 N
Tx, Ty, Tz	±1000 in-lb	±1800 in-lb	±3600 in-lb	±120 Nm	±240 Nm	±400 Nm
Resolution*						
Fx, Fy	1/128 lb	5/272 lb	1/32 lb	1/16 N	1/8 N	1/8 N
Fz	1/64 lb	5/136 lb	1/16 lb	1/16 N	1/8 N	1/4 N
Tx, Ty	1/32 in-lb	5/64 in-lb	1/8 in-lb	1/160 Nm	1/80 Nm	1/80 Nm
Tz	1/32 in-lb	5/64 in-lb	1/8 in-lb	1/320 Nm	1/160 Nm	1/80 Nm

Physical Properties	US	Metric
Stiffness (Calculated)		
X-axis and Y-axis force (Kx, Ky)	420×10 ³ lb/in	73.0×10 ⁶ N/m
Z-axis force (Kz)	710×10 ³ lb/in	125×10 ⁶ N/m
X-axis and Y-axis torque (Ktx, Kty)	3.0×10 ⁶ in-lb/rad	3.4×10 ⁵ Nm/rad
Z-axis torque (Ktz)	4.8×10 ⁶ in-lb/rad	5.4×10 ⁵ Nm/rad
Resonant Frequency (Measured)		
Fx, Fy, Tz	680 Hz	
Fz, Tx, Ty	820 Hz	
Maximum Single-axis Load		
Fx, Fy	±5700 lb	±25,000 N
Fz	±14,000 lb	±61,000 N
Tx, Ty	±22,000 in-lb	±2500 Nm
Tz	±24,000 in-lb	±2700 Nm
Weight		
Transducer with standard aluminum MAP plates	9.6 lb	4354 g
Transducer with stainless steel plates	14 lb	6234 g
Material		
Transducer	R _c 32 Stainless Steel	
Standard mounting adaptor	R _c 32 Stainless Steel	

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

7.2.10 Theta IP65

Calibration	English (US)			Metric (SI)		
	US-200-1000	US-300-1800	US-600-3600	SI-1000-120	SI-1500-240	SI-2500-400
Rated Sensing Ranges						
Fx, Fy	±200 lb	±300 lb	±600 lb	±1000 N	±1500 N	±2500 N
Fz	±500 lb	±875 lb	±1500 lb	±2500 N	±3750 N	±6250N
Tx, Ty, Tz	±1000 in-lb	±1800 in-lb	±3600 in-lb	±120 Nm	±240 Nm	±400 Nm
Resolution (minimum)						
Fx, Fy	1/8 lb	5/17 lb	1/2 lb	1 N	1 N	2 N
Fz	1/4 lb	10/17 lb	1 lb	1 N	2 N	3 N
Tx, Ty, Tz	1/2 in-lb	5/4 in-lb	2 in-lb	1/20 Nm	1/10 Nm	1/20 Nm
Counts Value						
Fx, Fy, Fz	8 / lb	3.4 / lb	2 / lb	2 / N	1 / N	1 / N
Tx, Ty, Tz	4 / in-lb	0.8 / in-lb	1 / in-lb	20 / Nm	10 / Nm	5 / Nm
Analog Output						
<i>Analog Range</i>						
Fx, Fy	±200 lb	±300 lb	±600 lb	±1000 N	±1500 N	±2500 N
Fz	±200 lb	±300 lb	±600 lb	±1000 N	±1500 N	±2500 N
Tx, Ty, Tz	±1000 in-lb	±1800 in-lb	±3600 in-lb	±120 Nm	±240 Nm	±400 Nm
<i>± 5 V Sensitivity</i>						
Fx, Fy	40 lb/V	60 lb/V	120 lb/V	200 N/V	300 N/V	500 N/V
Fz	40 lb/V	60 lb/V	120 lb/V	200 N/V	300 N/V	500 N/V
Tx, Ty, Tz	200 in-lb/V	360 in-lb/V	720 in-lb/V	24 Nm	48 Nm	80 Nm
<i>± 10 V Sensitivity</i>						
Fx, Fy, Fz	20 lb/V	30 lb/V	60 lb/V	100 N/V	150 N/V	250 N/V
Fz	20 lb/V	30 lb/V	60 lb/V	100 N/V	150 N/V	250 N/V
Tx, Ty, Tz	100 lb/V	180 in-lb/V	360 in-lb/V	12 Nm/V	24 Nm/V	40 Nm/V
Tool Transform Factor	0.02 in/unit	0.0425 in/unit	0.02 in/unit	1 mm/unit	1 mm/unit	2 mm/unit

Physical Properties	US	Metric
Stiffness (Calculated)		
X-axis and Y-axis force (Kx, Ky)	420×10 ³ lb/in	73.0×10 ⁶ N/m
Z-axis force (Kz)	710×10 ³ lb/in	125×10 ⁶ N/m
X-axis and Y-axis torque (Ktx, Kty)	3.0×10 ⁶ in-lb/rad	3.4×10 ⁵ Nm/rad
Z-axis torque (Ktz)	4.8×10 ⁶ in-lb/rad	5.4×10 ⁵ Nm/rad
Maximum Single-axis Load		
Fx, Fy	±5700 lb	±25,000N
Fz	±14,000 lb	±61,000 N
Tx, Ty	±22,000 in-lb	±2500 Nm
Tz	±24,000 in-lb	±2700 Nm
Weight		
Transducer with standard aluminum MAP plates	19.85 lb	9.003 g
Material		
Transducer	R _c 32 Stainless Steel	
Standard mounting adapter	R _c 32 Stainless Steel	

7.2.11 Omega160

Calibration	English (US)			Metric (SI)		
	US-200-1000	US-300-1800	US-600-3600	SI-1000-120	SI-1500-240	SI-2500-400
Rated Sensing Ranges						
Fx, Fy	±200 lb	±300 lb	±600 lb	±1000 N	±1500 N	±2500 N
Fz	±500 lb	±875 lb	±1500 lb	±2500 N	±3750 N	±6250 N
Tx, Ty, Tz	±1000 in-lb	±1800 in-lb	±3600 in-lb	±120 Nm	±240 Nm	±400 Nm
Resolution*						
Fx, Fy	1/128 lb	5/272 lb	1/32 lb	1/16 N	1/8 N	1/8 N
Fz	1/64 lb	5/136 lb	1/16 lb	1/16 N	1/8 N	3/16 N
Tx, Ty	1/32 in-lb	5/64 in-lb	1/8 in-lb	1/160 Nm	1/80 Nm	1/80 Nm
Tz	1/32 in-lb	5/64 in-lb	1/8 in-lb	1/320 Nm	1/160 Nm	1/80 Nm

Physical Properties	US	Metric
Stiffness (Calculated)		
X-axis and Y-axis force (Kx, Ky)	400×10 ³ lb/in	70.0×10 ⁶ N/m
Z-axis force (Kz)	680×10 ³ lb/in	120×10 ⁶ N/m
X-axis and Y-axis torque (Ktx, Kty)	2.9×10 ⁶ in-lb/rad	3.3×10 ⁵ Nm/rad
Z-axis torque (Ktz)	4.7×10 ⁶ in-lb/rad	5.3×10 ⁵ Nm/rad
Resonant Frequency (Measured)		
Fx, Fy, Tz	1.3 kHz	
Fz, Tx, Ty	1.0 kHz	
Maximum Single-axis Load		
Fx, Fy	±4000 lb	±18,000 N
Fz	±11,000 lb	±48,000 N
Tx, Ty, Tz	±15,000 lb	±1700 Nm
Tx, Ty, Tz	±17,000 lb	±1900 Nm
Weight		
Transducer with standard aluminum MAP plates	6.3 lb	2850 g
Transducer with stainless steel plates	12 lb	5365 g
Material		
Transducer	Hardened Stainless Steel	
Mounting and tool adaptors	Aircraft Aluminum	

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

7.2.12 Omega160 IP65

Calibration	English (US)			Metric (SI)		
	US-200-1000	US-300-1800	US-600-3600	SI-1000-120	SI-1500-240	SI-2500-400
Rated Sensing Ranges						
Fx, Fy	±200 lb	±300 lb	±600 lb	±1000 N	±1500 N	±2500 N
Fz	±500 lb	±875 lb	±1500 lb	±2500 N	±3750 N	±6250N
Tx, Ty, Tz	±1000 in-lb	±1800 in-lb	±3600 in-lb	±120 Nm	±240 Nm	±400 Nm
Resolution (minimum)						
Fx, Fy	1/8 lb	5/17 lb	1/2 lb	1 N	1 N	2 N
Fz	1/4 lb	10/17 lb	1 lb	1 N	2 N	3 N
Tx, Ty, Tz	1/2 in-lb	5/4 in-lb	2 in-lb	1/20 Nm	1/10 Nm	1/20 Nm
Counts Value						
Fx, Fy, Fz	8 / lb	3.4 / lb	2 / lb	2 / N	1 / N	1 / N
Tx, Ty, Tz	4 / in-lb	0.8 / in-lb	1 / in-lb	20 / Nm	10 / Nm	5 / Nm
Analog Output						
<i>Analog Range</i>						
Fx, Fy	±200 lb	±300 lb	±600 lb	±1000 N	±1500 N	±2500 N
Fz	±200 lb	±300 lb	±600 lb	±1000 N	±1500 N	±2500 N
Tx, Ty, Tz	±1000 in-lb	±1800 in-lb	±3600 in-lb	±120 Nm	±240 Nm	±400 Nm
<i>± 5 V Sensitivity</i>						
Fx, Fy	40 lb/V	60 lb/V	120 lb/V	200 N/V	300 N/V	500 N/V
Fz	40 lb/V	60 lb/V	120 lb/V	200 N/V	300 N/V	500 N/V
Tx, Ty, Tz	200 in-lb/V	360 in-lb/V	720 in-lb/V	24 Nm	48 Nm	80 Nm
<i>± 10 V Sensitivity</i>						
Fx, Fy, Fz	20 lb/V	30 lb/V	60 lb/V	100 N/V	150 N/V	250 N/V
Fz	20 lb/V	30 lb/V	60 lb/V	100 N/V	150 N/V	250 N/V
Tx, Ty, Tz	100 lb/V	180 in-lb/V	360 in-lb/V	12 Nm/V	24 Nm/V	40 Nm/V
Tool Transform Factor	0.02 in/unit	0.0425 in/unit	0.02 in/unit	1 mm/unit	1 mm/unit	2 mm/unit

Physical Properties	US	Metric
Stiffness (Calculated)		
X-axis and Y-axis force (Kx, Ky)	400×10 ³ lb/in	70.0×10 ⁶ N/m
Z-axis force (Kz)	680×10 ³ lb/in	120×10 ⁶ N/m
X-axis and Y-axis torque (Ktx, Kty)	2.9×10 ⁶ in-lb/rad	3.3×10 ⁵ Nm/rad
Z-axis torque (Ktz)	4.7×10 ⁶ in-lb/rad	5.3×10 ⁵ Nm/rad
Maximum Single-axis Load		
Fx, Fy	±4000 lb	±18,000N
Fz	±11,000 lb	±48,000 N
Tx, Ty, Tz	±15,000 lb	±1700 Nm
Tx, Ty, Tz	±17,000 lb	±1900 Nm
Weight		
Transducer with standard aluminum MAP plates	13.54 lb	6.141 g
Material		
Transducer	Hardened Stainless Steel	
Mounting and tool adapters	Stainless Steel	

7.2.13 Omega190

Calibration	English (US)			Metric (SI)		
	US-400-3000	US-800-6000	US-1600-12000	SI-1800-350	SI-3600-700	SI-7200-1400
Rated Sensing Ranges						
Fx, Fy	±400 lb	±800 lb	±1600 lb	±1800 N	±3600 N	±7200 N
Fz	±1000 lb	±2000 lb	±4000 lb	±4500 N	±9000 N	±18000 N
Tx, Ty, Tz	±3000 in-lb	±6000 in-lb	±12000 in-lb	±350 Nm	±700 Nm	±1400 Nm
Resolution*						
Fx, Fy	5/256 lb	5/128 lb	5/64 lb	3/32 N	3/16 N	3/8 N
Fz	5/128 lb	5/64 lb	5/32 lb	5/32 N	5/16 N	5/8 N
Tx, Ty	5/512 in-lb	5/256 in-lb	5/128 in-lb	5/384 Nm	5/192 Nm	5/96 Nm
Tz	5/768 in-lb	5/384 in-lb	5/192 in-lb	5/576 Nm	5/288 Nm	5/144 Nm

Physical Properties	US	Metric
Stiffness (Calculated)		
X-axis and Y-axis force (Kx, Ky)	1.4×10 ⁶ lb/in	250×10 ⁶ N/m
Z-axis force (Kz)	2.1×10 ⁶ lb/in	370×10 ⁶ N/m
X-axis and Y-axis torque (Ktx, Kty)	14×10 ⁶ in-lb/rad	1.6×10 ⁶ Nm/rad
Z-axis torque (Ktz)	14×10 ⁶ in-lb/rad	3.3×10 ⁶ Nm/rad
Maximum Single-axis Load		
Fx, Fy	±8000 lb	±36,000 N
Fz	±25,000 lb	±110,000 N
Tx, Ty, Tz	±49,000 lb	±5500 Nm
Tx, Ty, Tz	±72,000 lb	±8100 Nm
Weight		
Transducer with standard aluminum MAP plates	13 lb	5824 g
Transducer with stainless steel plates	19 lb	8768 g
Material		
Transducer	Hardened Stainless Steel	
Mounting and tool adaptors	Aircraft Aluminum	

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

7.2.14 Omega190 IP65

Calibration	English (US)			Metric (SI)		
	US-400-3000	US-800-6000	US-1600-12000	SI-1800-350	SI-3600-700	SI-7200-1400
Rated Sensing Ranges						
Fx, Fy	±400 lb	±800 lb	±1600 lb	±1800 N	±3600 N	±7200 N
Fz	±1000 lb	±2000 lb	±4000 lb	±4500 N	±9000 N	±18000 N
Tx, Ty, Tz	±3000 in-lb	±6000 in-lb	±12000 in-lb	±350 Nm	±700 Nm	±1400 Nm
Resolution (minimum)						
Fx, Fy	5/16 lb	5/8 lb	5/4 lb	3/2 N	3 N	6 N
Fz	5/8 lb	5/4 lb	5/2 lb	5/2 N	5 N	10 N
Tx, Ty	5/32 in-lb	5/16 in-lb	5/8 in-lb	5/24 Nm	5/12 Nm	5/6 Nm
Tz	5/48 in-lb	5/24 in-lb	5/12 in-lb	5/36 Nm	5/18 Nm	5/9 Nm
Counts Value						
Fx, Fy, Fz	9.6 / lb	4.8 / lb	2 / lb	2 / N	1 / N	0.5 / N
Tx, Ty, Tz	1.6 / in-lb	0.8 / in-lb	0.4 / in-lb	14.4 / Nm	7.2 / Nm	3.6 Nm
Analog Output						
<i>Analog Range</i>						
Fx, Fy	±400 lb	±800 lb	±1600 lb	±1800 N	±3600 N	±7200 N
Fz	±400 lb	±800 lb	±1600 lb	±1800 N	±3600 N	±7200 N
Tx, Ty, Tz	±3000 in-lb	±6000 in-lb	±12000 in-lb	±350 Nm	±700 Nm	±1400 Nm
<i>± 5 V Sensitivity</i>						
Fx, Fy	80 lb/V	160 lb/V	320 lb/V	360 N/V	720 N/V	1440 N/V
Fz	80 lb/V	160 lb/V	320 lb/V	360 N/V	720 N/V	1440 N/V
Tx, Ty, Tz	600 in-lb/V	1200 in-lb/V	2400 in-lb/V	70 Nm	140 Nm	280 Nm
<i>± 10 V Sensitivity</i>						
Fx, Fy, Fz	40 lb/V	80 lb/V	160 lb/V	180 N/V	360 N/V	720 N/V
Fz	40 lb/V	80 lb/V	160 lb/V	180 N/V	360 N/V	720 N/V
Tx, Ty, Tz	300 lb/V	600 in-lb/V	1200 in-lb/V	35 Nm/V	70 Nm/V	140 Nm/V
Tool Transform Factor	0.06 in/unit	0.06 in/unit	0.06 in/unit	1.389×10 ⁻³ mm/unit	1.389×10 ⁻³ mm/unit	1.389×10 ⁻³ mm/unit

Physical Properties	US	Metric
Stiffness (Calculated)		
X-axis and Y-axis force (Kx, Ky)	1.4×10 ⁶ lb/in	250×10 ⁶ N/m
Z-axis force (Kz)	2.1×10 ⁶ lb/in	370×10 ⁶ N/m
X-axis and Y-axis torque (Ktx, Kty)	14×10 ⁶ in-lb/rad	1.6×10 ⁶ Nm/rad
Z-axis torque (Ktz)	14×10 ⁶ in-lb/rad	3.3×10 ⁶ Nm/rad
Maximum Single-axis Load		
Fx, Fy	±8000 lb	±36,000 N
Fz	±25,000 lb	±110,000 N
Tx, Ty, Tz	±49,000 lb	±5500 Nm
Tx, Ty, Tz	±72,000 lb	±8100 Nm
Weight		
Transducer with standard aluminum MAP plates	29.44 lb	13.335 g
Material	Hardened Stainless Steel	
Transducer	Stainless Steel	
Mounting and tool adapters	Stainless Steel	

7.3 Compound Loading Ranges of F/T Sensors

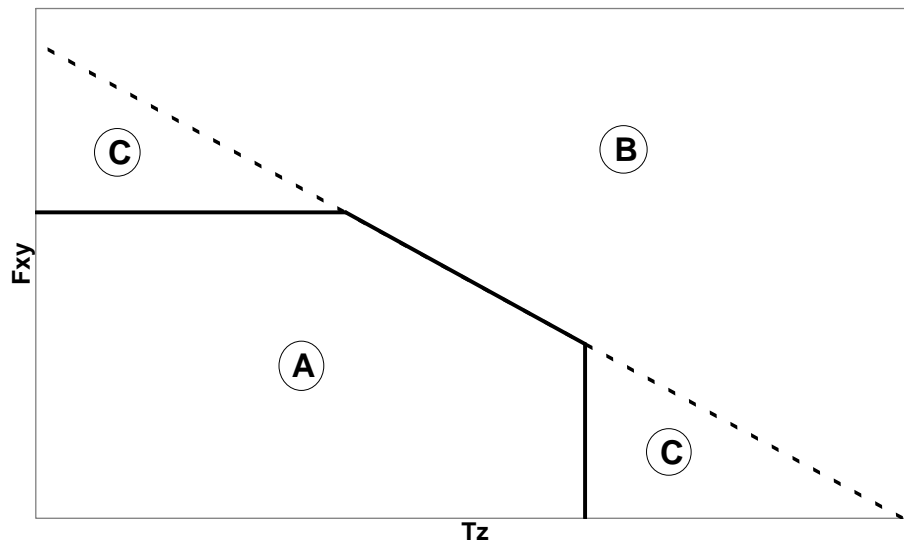
The F/T sensor's strain gauges are optimally placed to share information between the forces and torques applied to the sensor. Because of this sharing, it is possible to saturate the transducer with a complex load that has components below the rated load of the sensor. However, this arrangement allows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

These graphs 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.

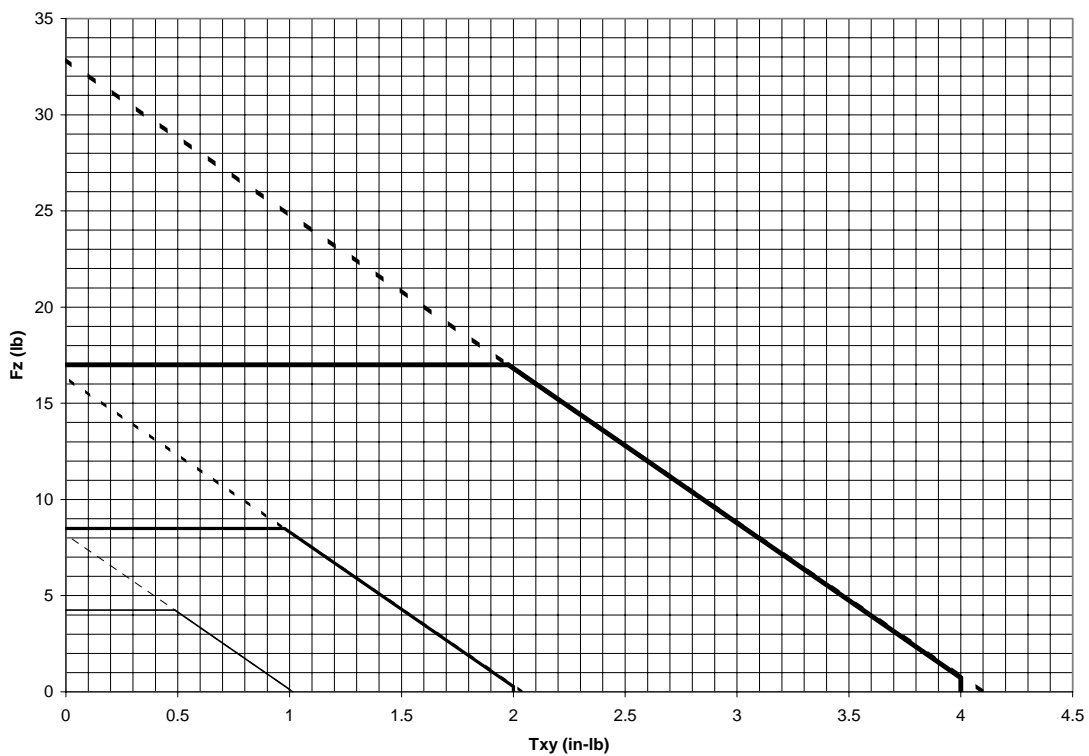
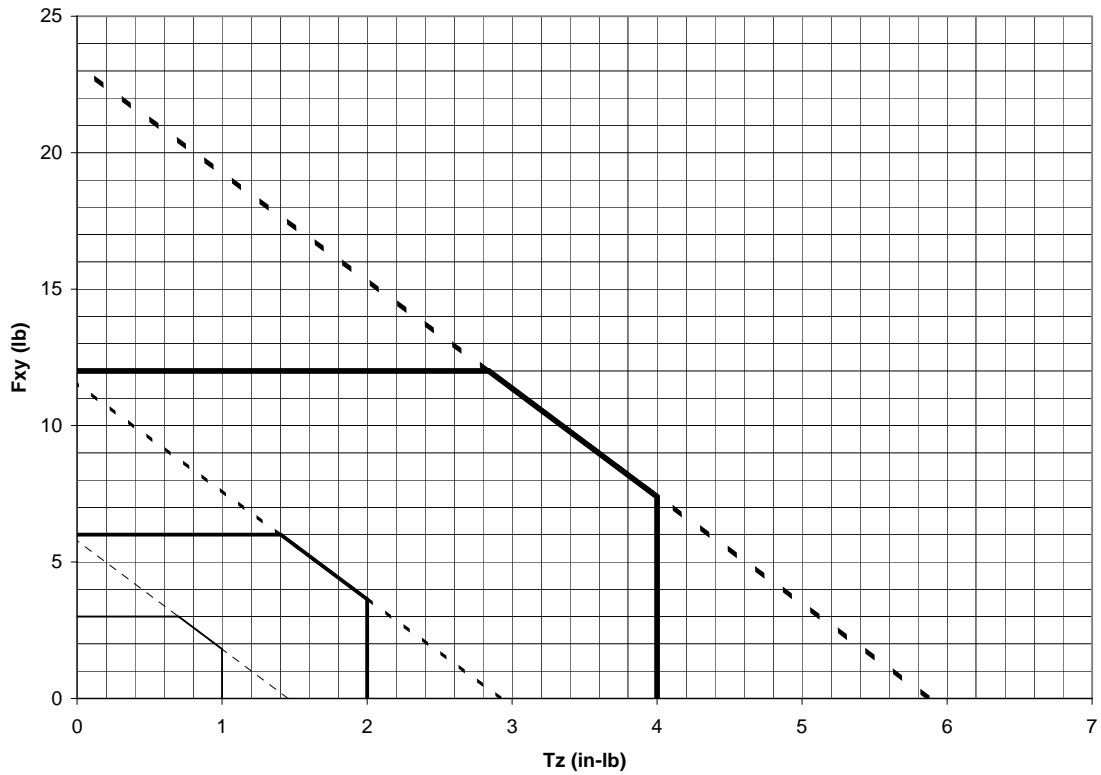
The following sample graph shows how operating ranges can change with complex loading. The labels indicate the following regions:

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

Sample Graph

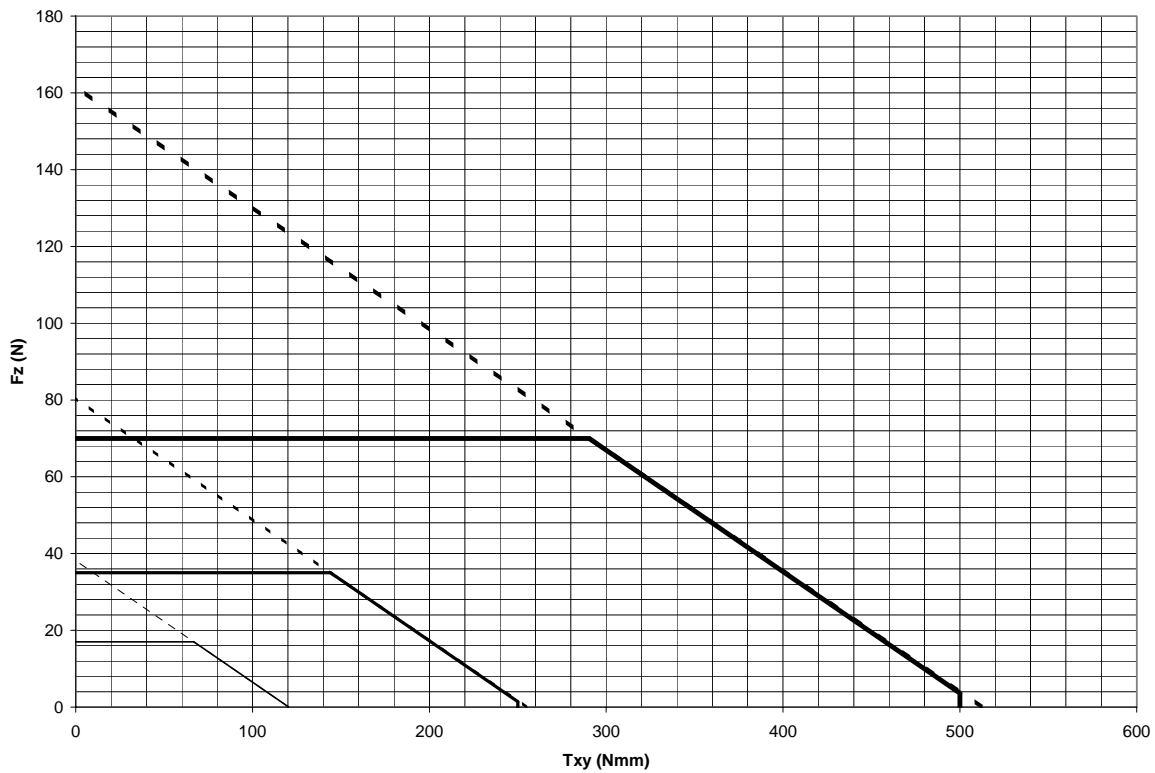
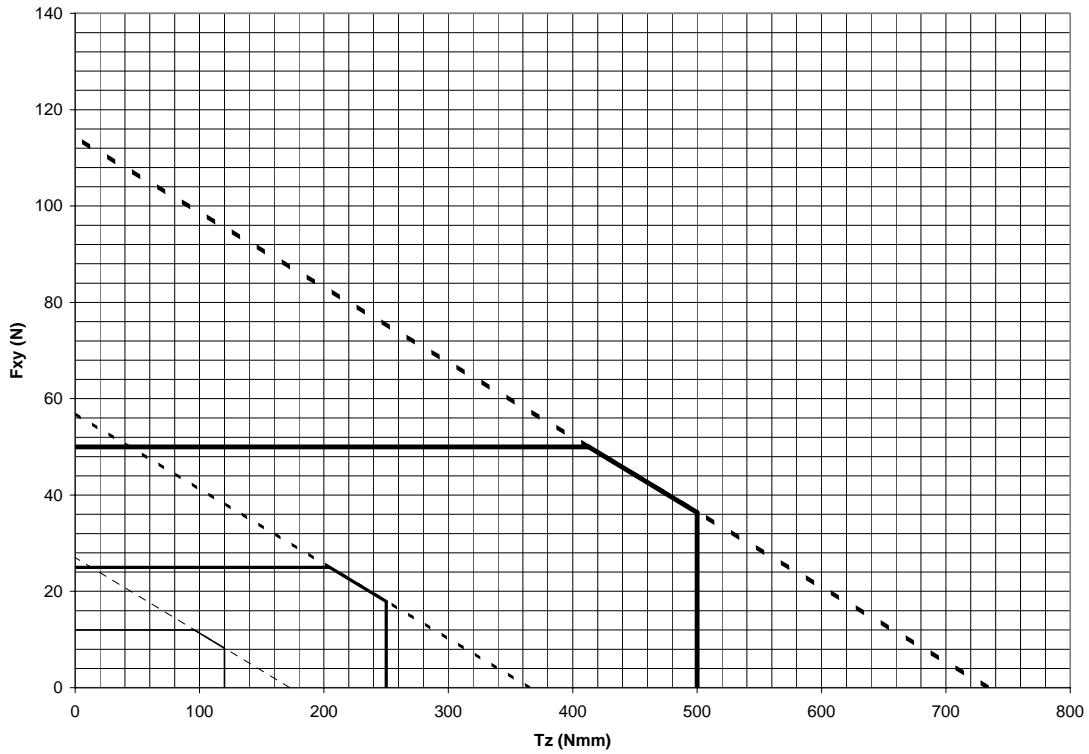


7.3.1 Nano17 (US Calibration)



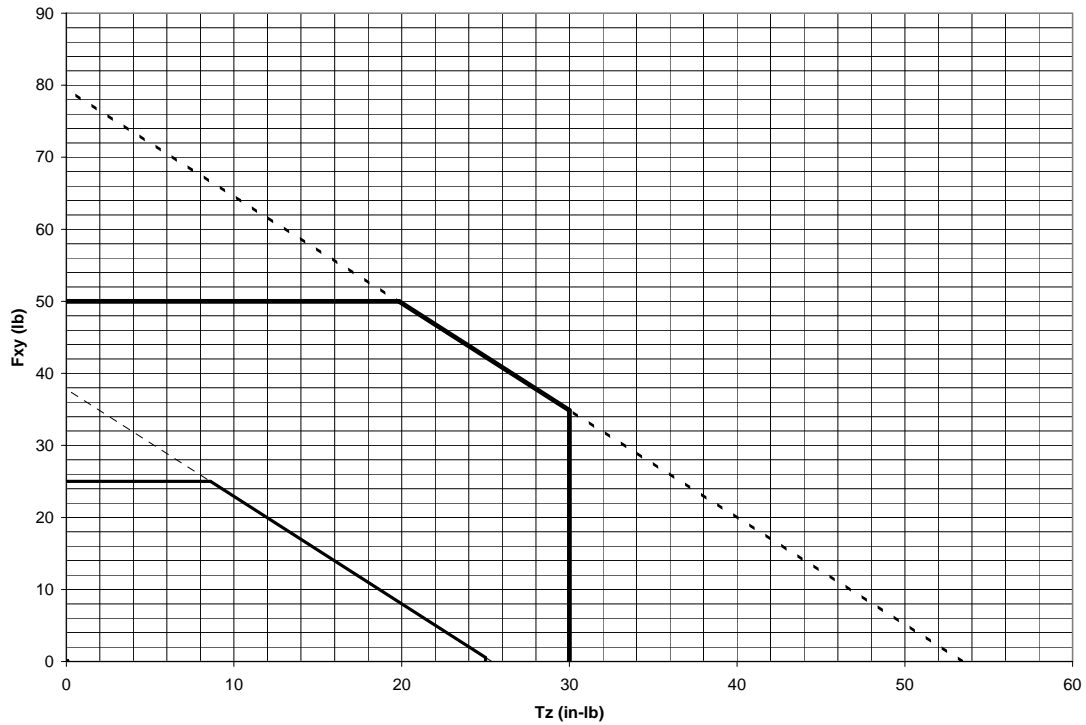
Nano17 US-12-4
 Nano17 US-6-2
 Nano17 US-3-1

7.3.2 Nano17 (SI Calibration)

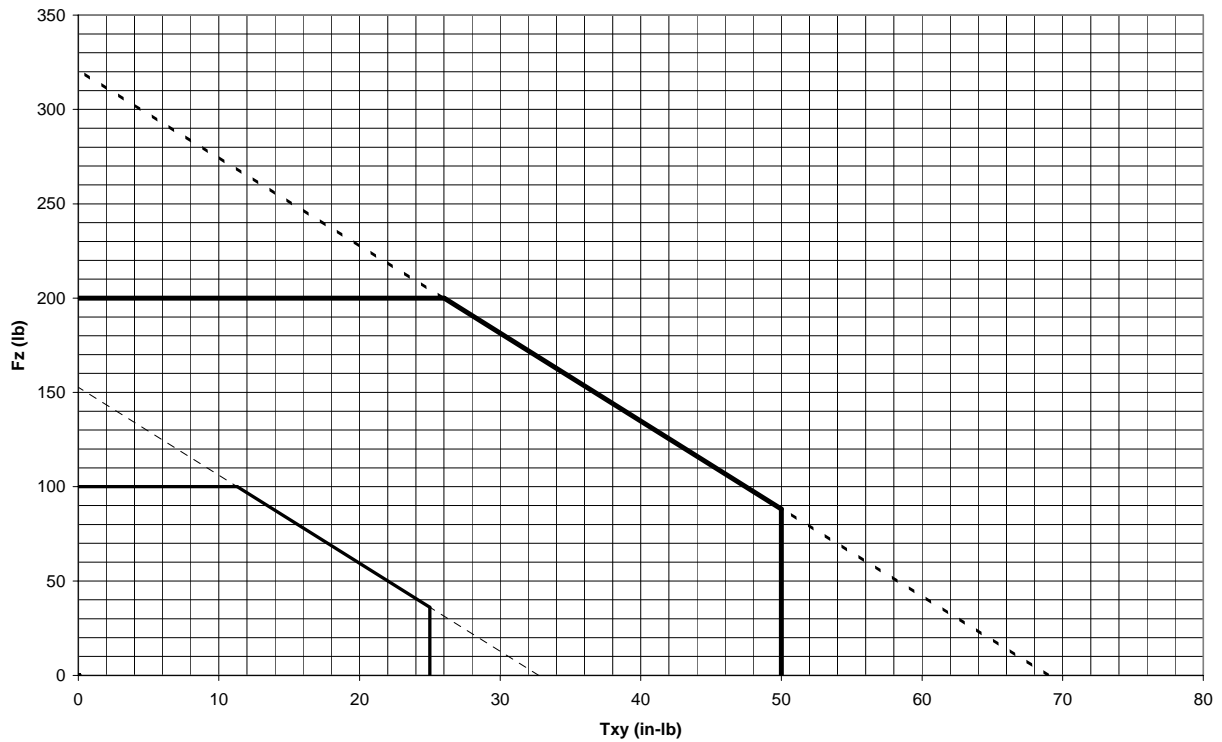


Nano17 SI-50-0.5
 Nano17 SI-25-0.25
 Nano17 SI-12-0.12

7.3.3 Nano25 (US Calibration)



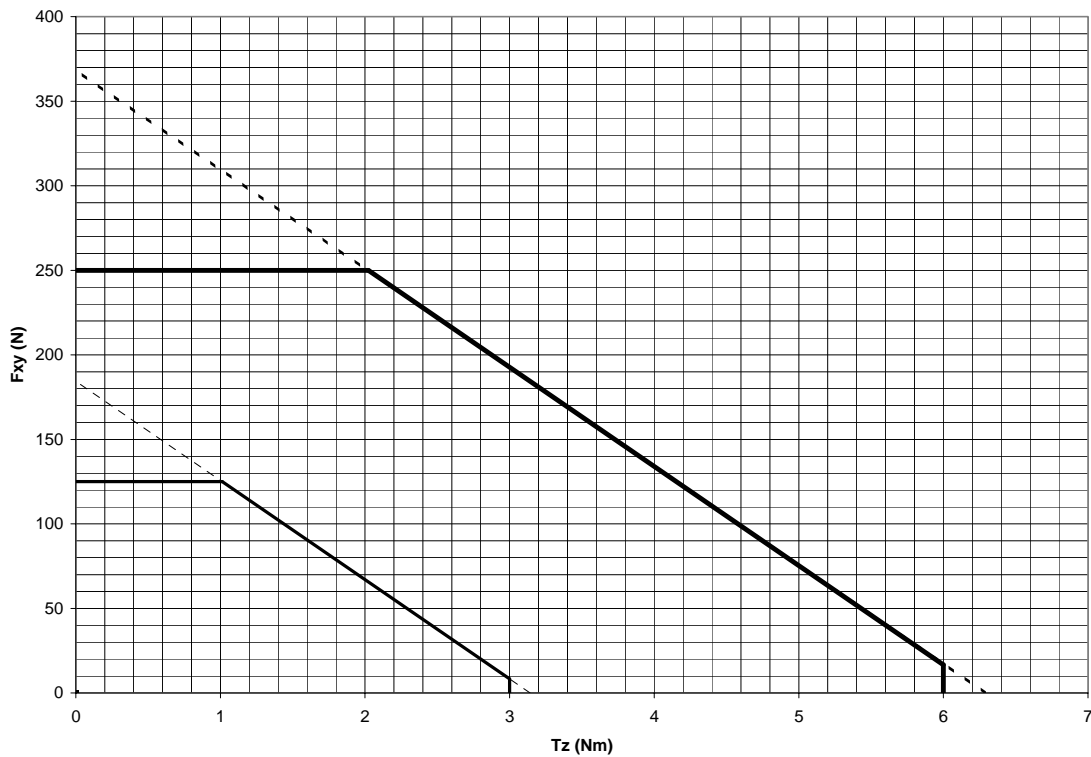
Note: Applying moments beyond ± 30 in-lb (± 3.4 Nm) in Tz can cause hysteresis and permanent zero-point change in this transducer



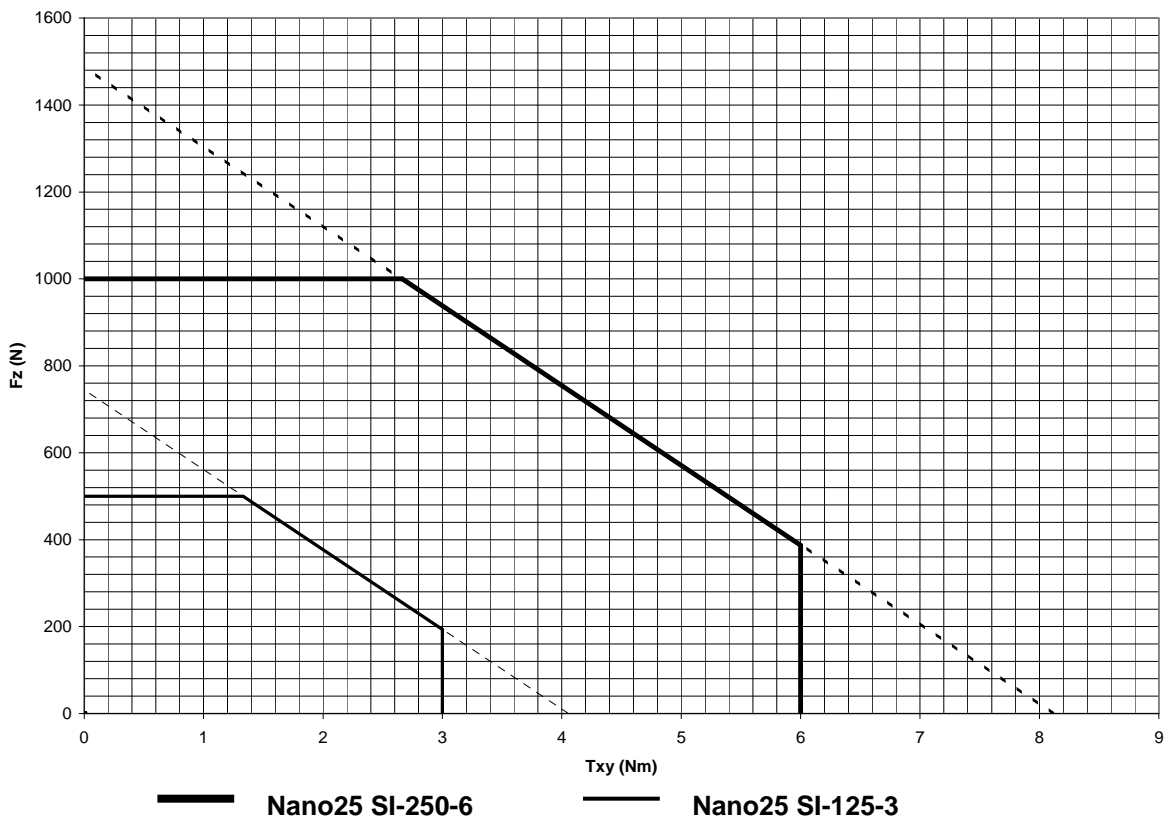
— Nano25 US-50-50

— Nano25 US-25-25

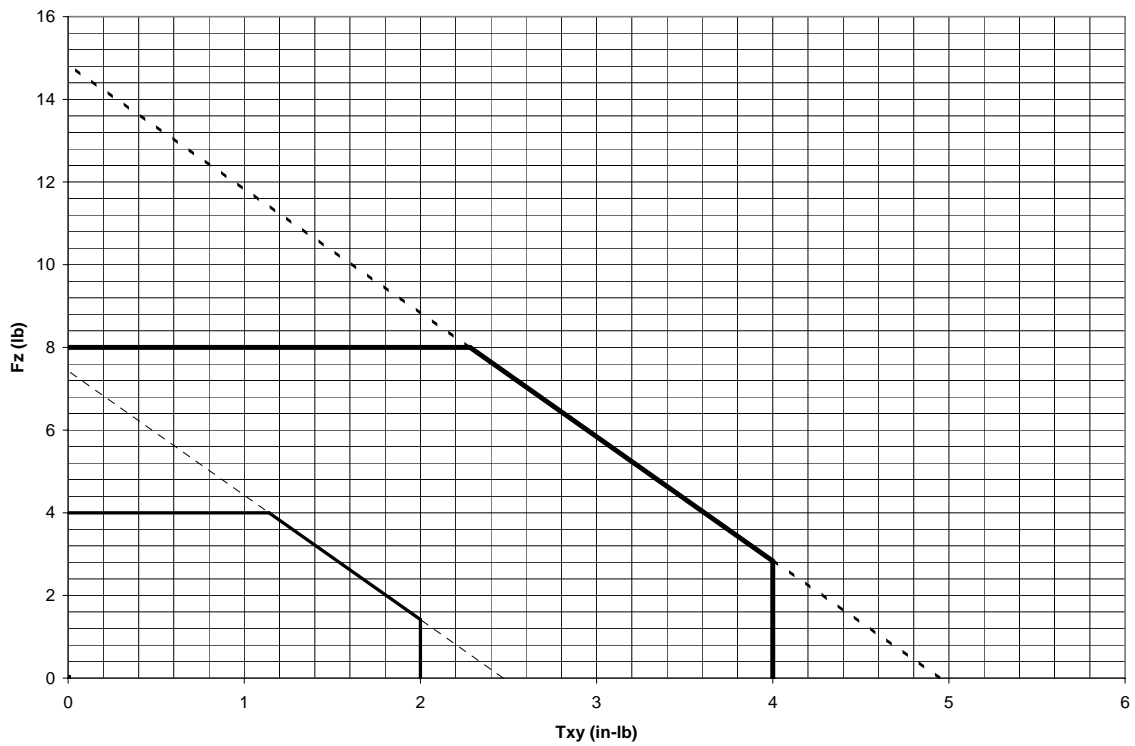
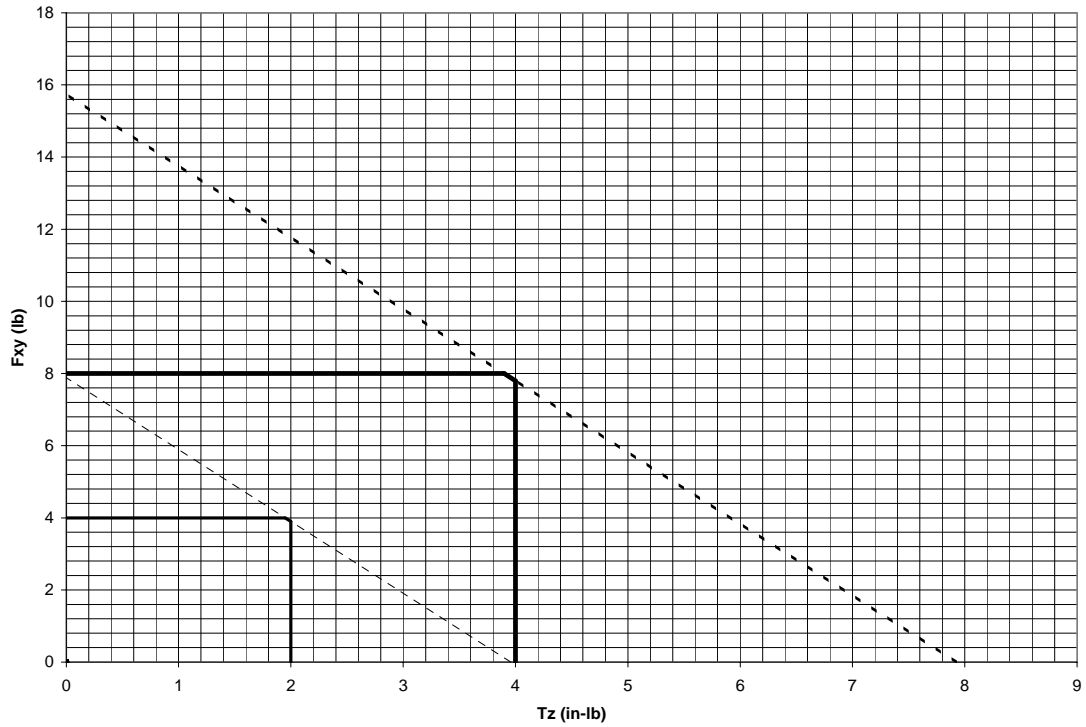
7.3.4 Nano25 (SI Calibration)



Note: Applying moments beyond ± 30 in-lb (± 3.4 Nm) in Tz can cause hysteresis and permanent zero-point change in this transducer

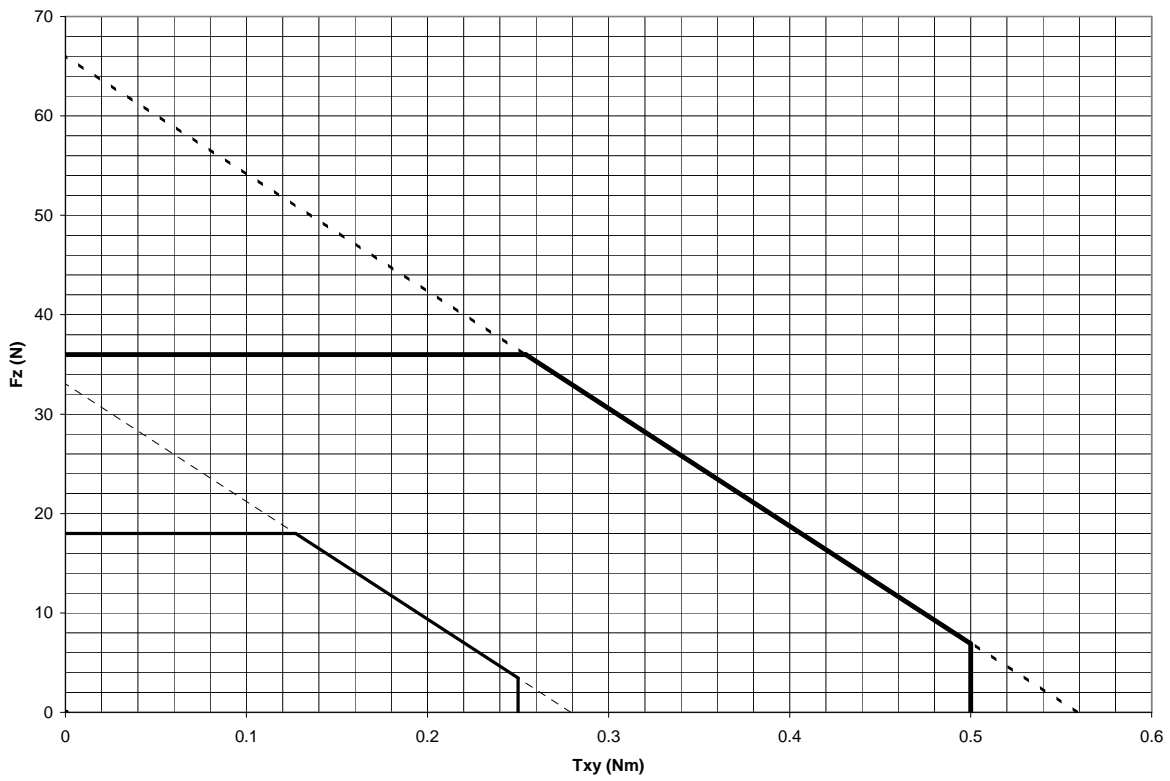
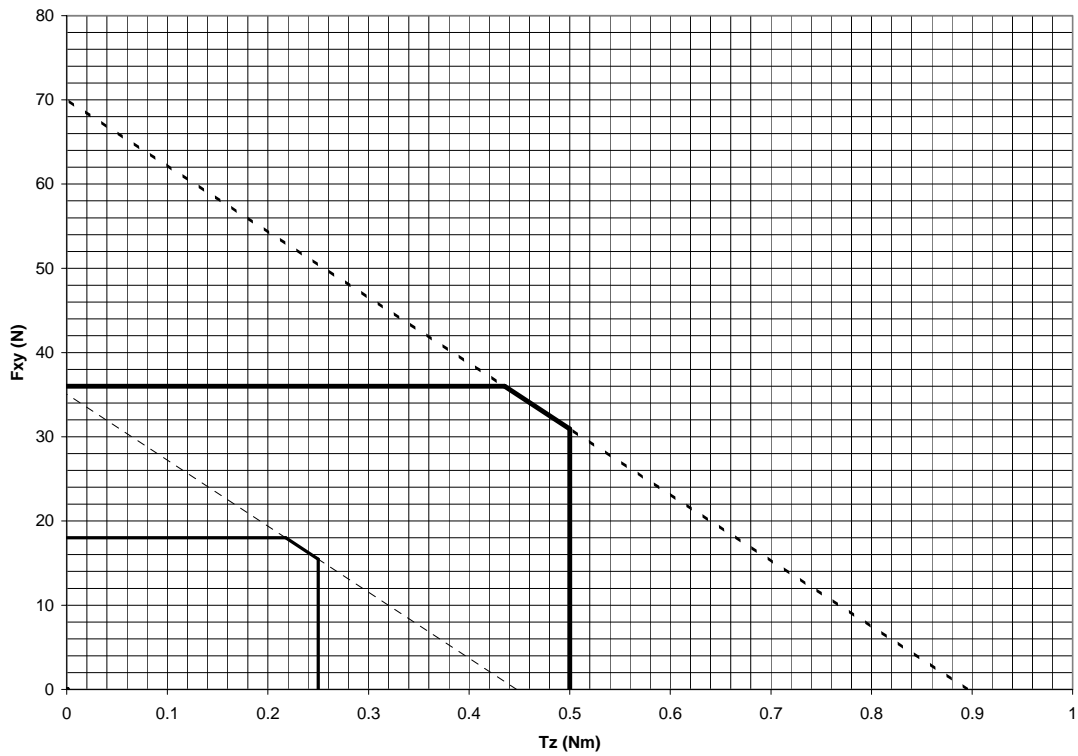


7.3.5 Nano43 (US Calibration)



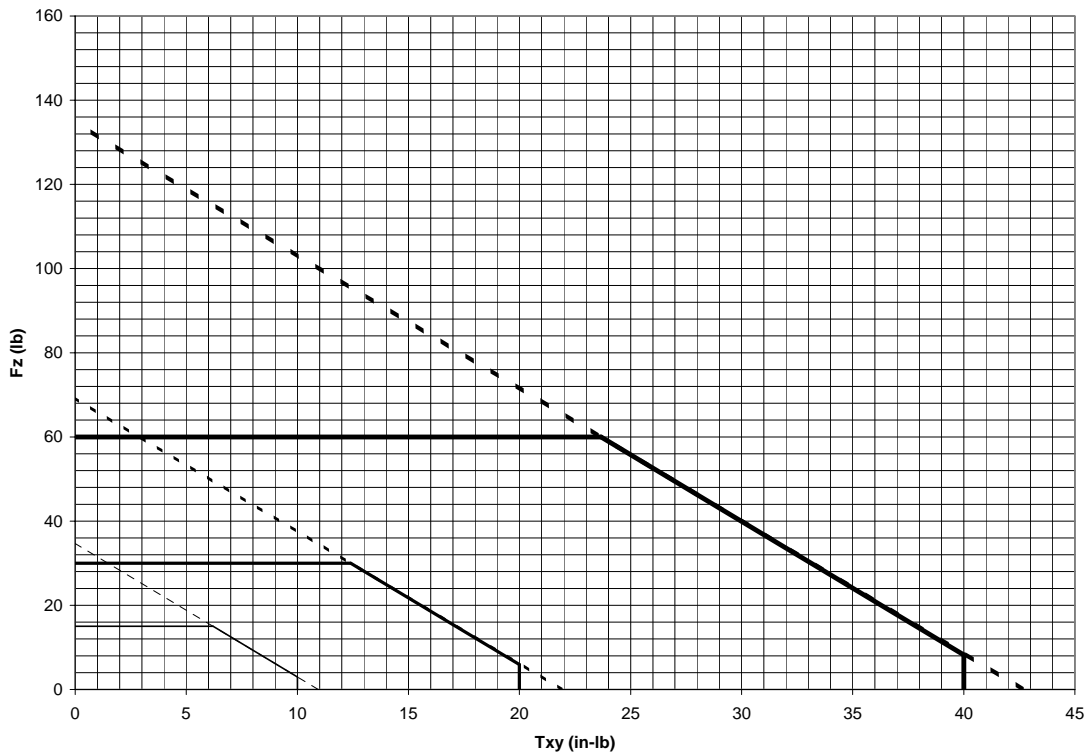
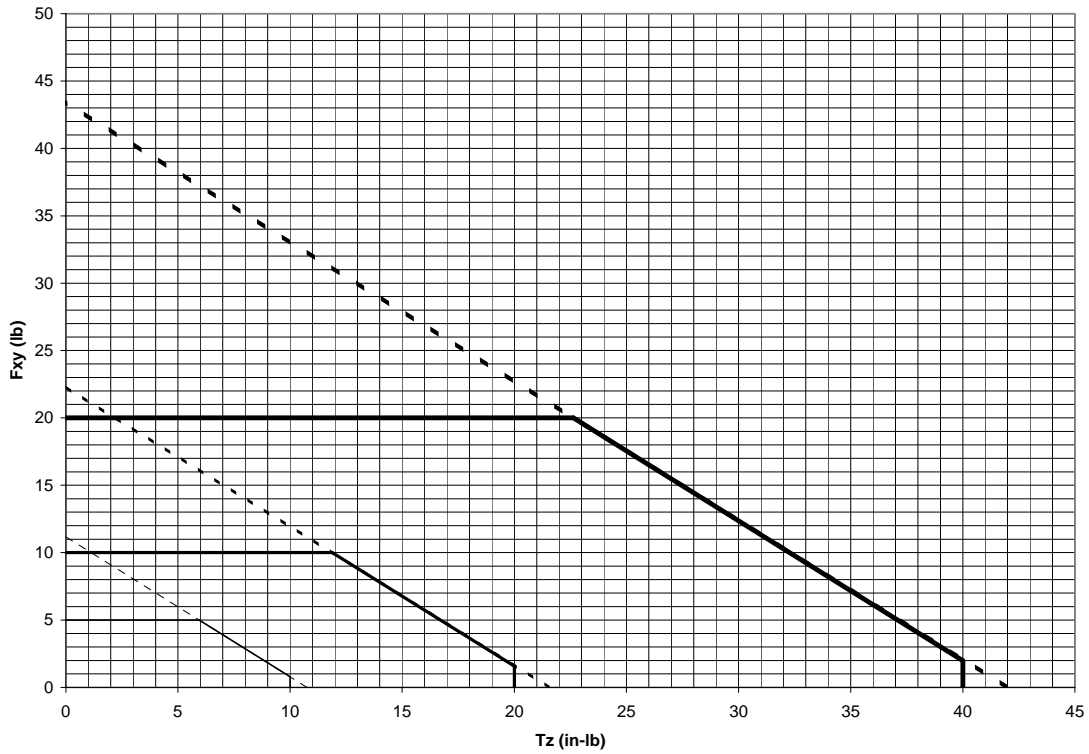
Nano43 US-8-4
 Nano43 US-4-2

7.3.6 Nano43 (SI Calibration)



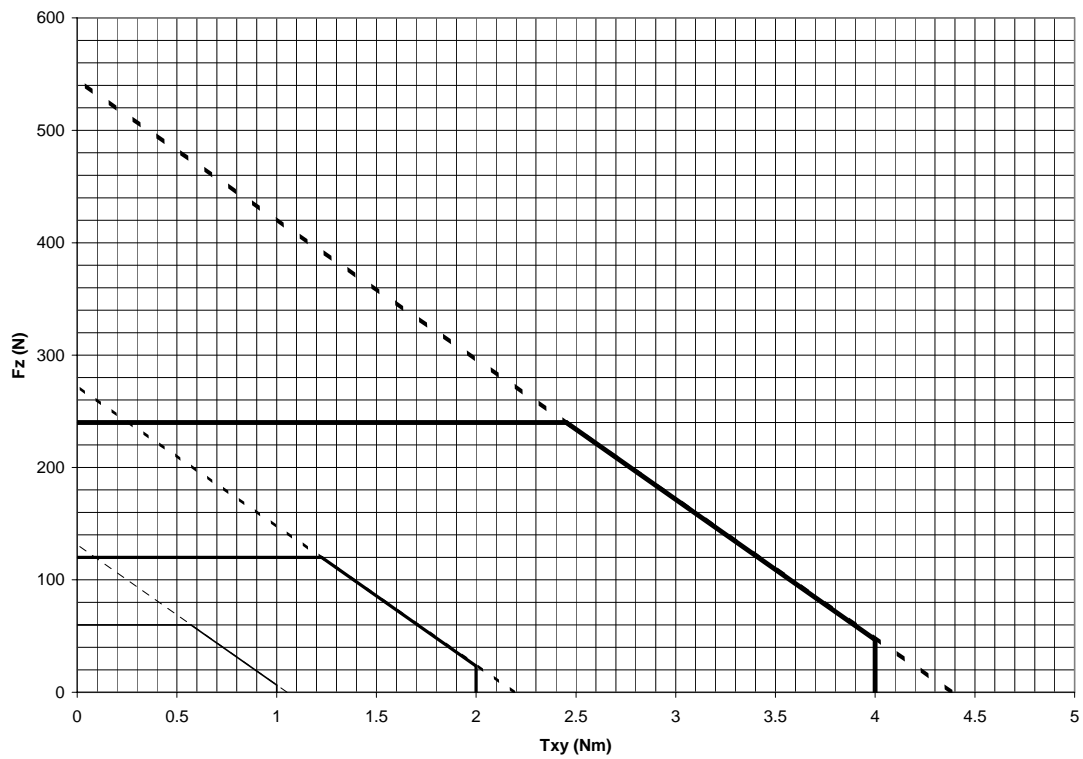
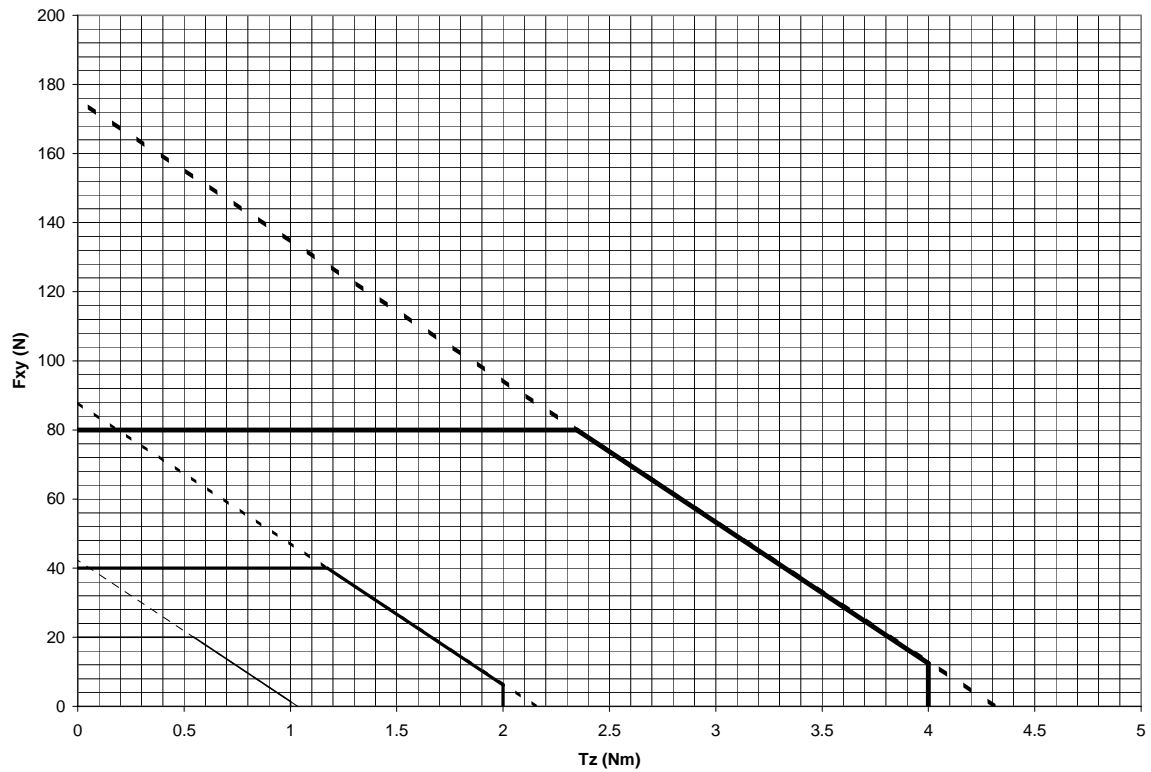
Nano43 SI-36-0.5
 Nano43 SI-18-0.25

7.3.7 Mini40 (US Calibration)



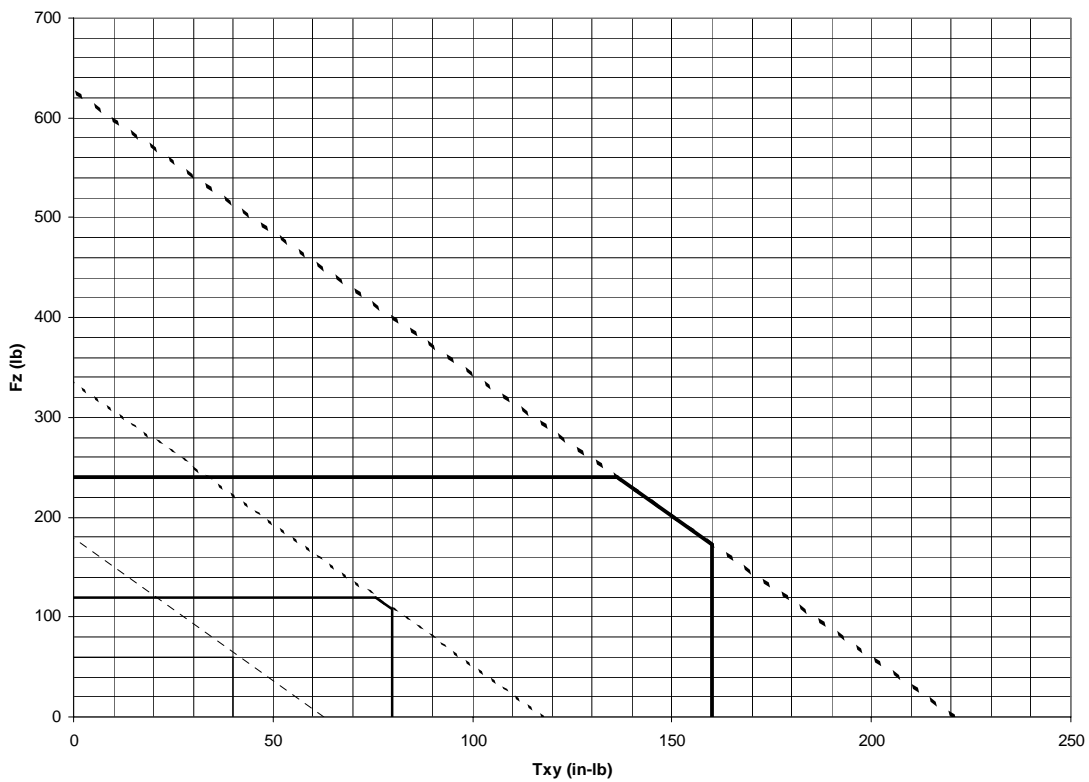
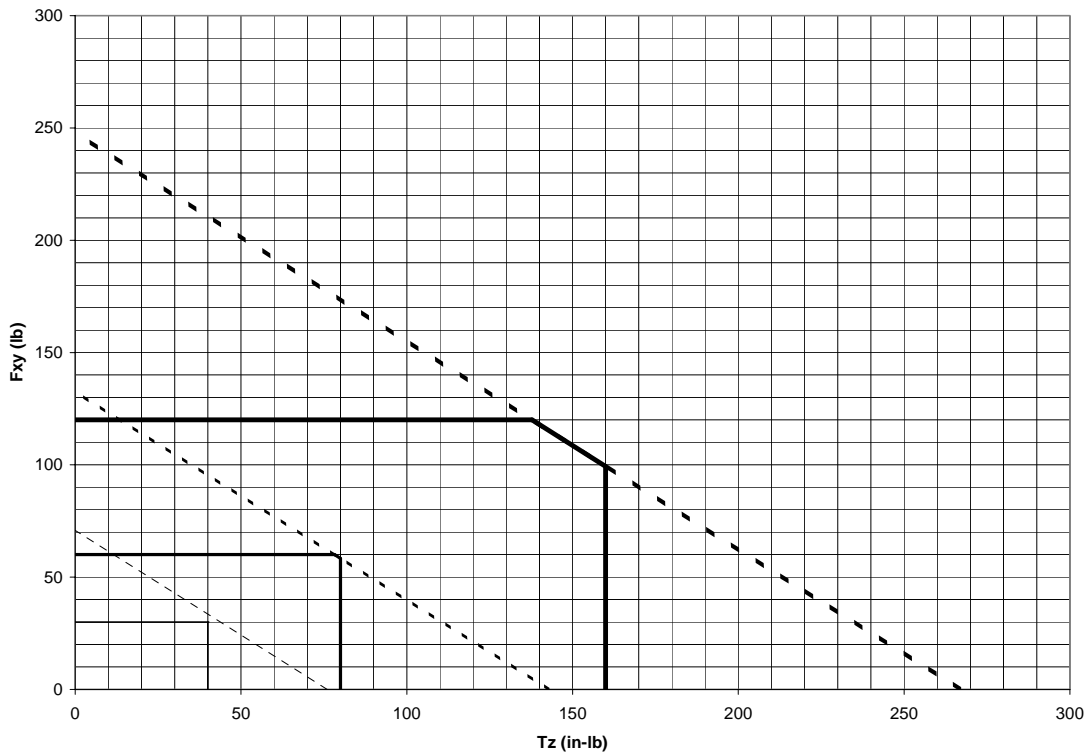
Mini40 US-20-40
 Mini40 US-10-20
 Mini40 US-5-10

7.3.8 Mini40 (SI Calibration)



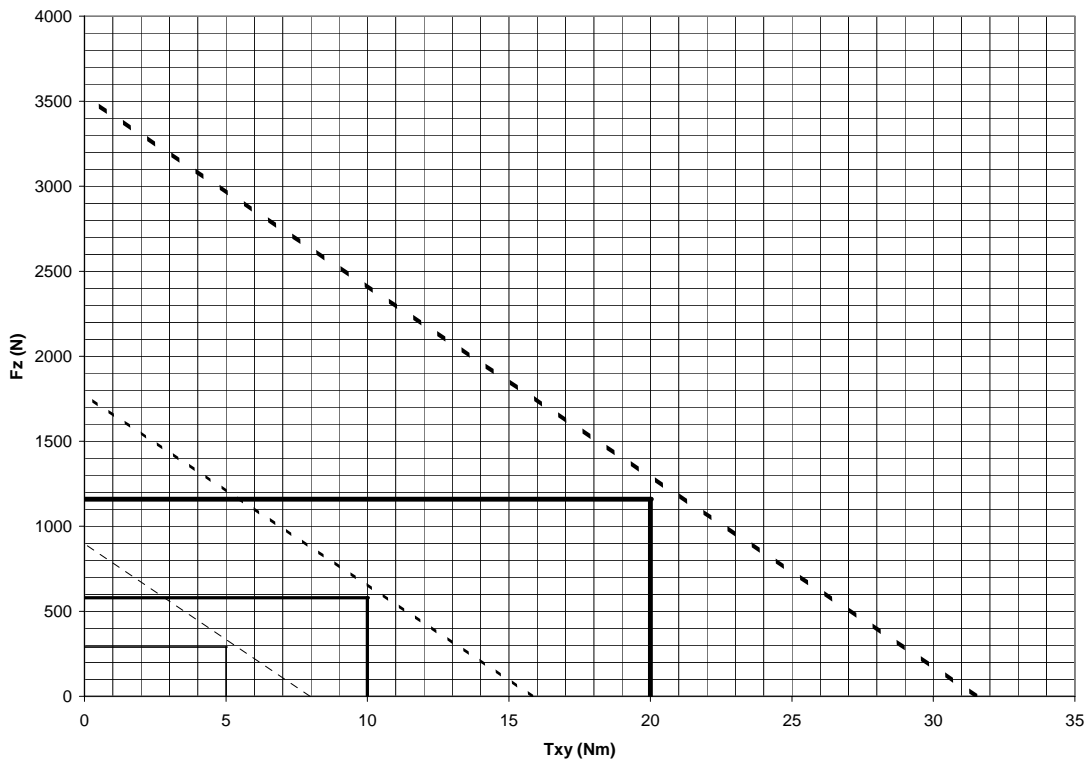
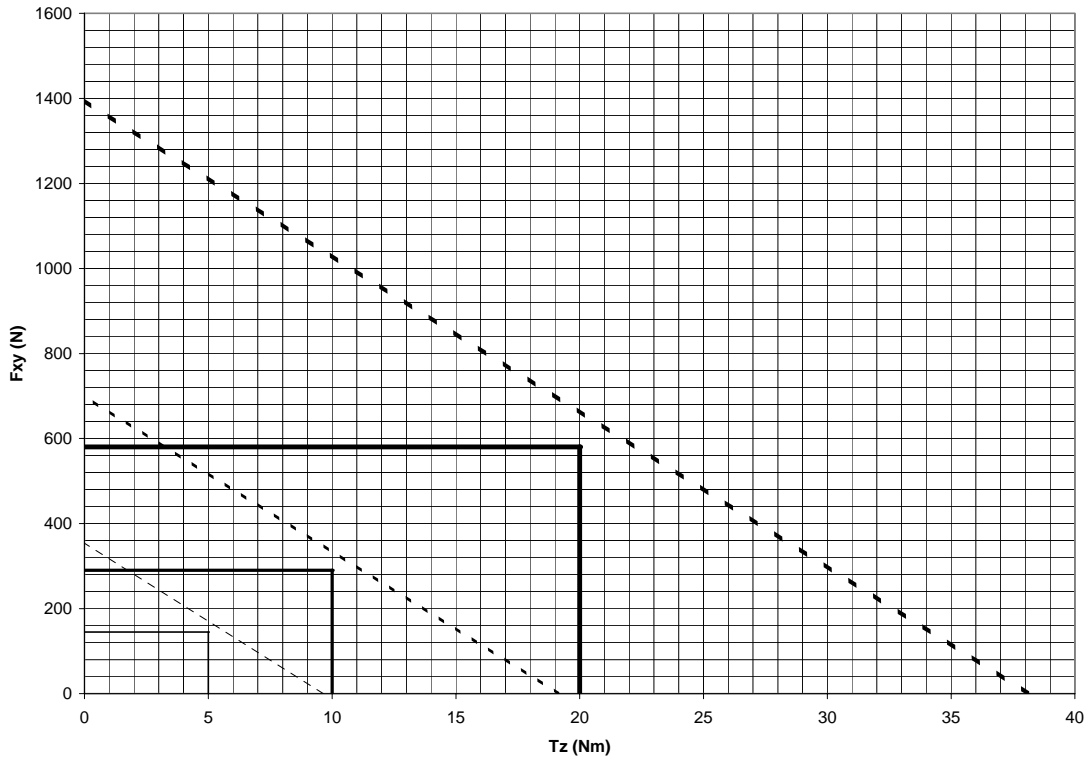
Mini40 SI-80-4
 Mini40 SI-40-2
 Mini40 SI-20-1

7.3.9 Mini45 (US Calibration)



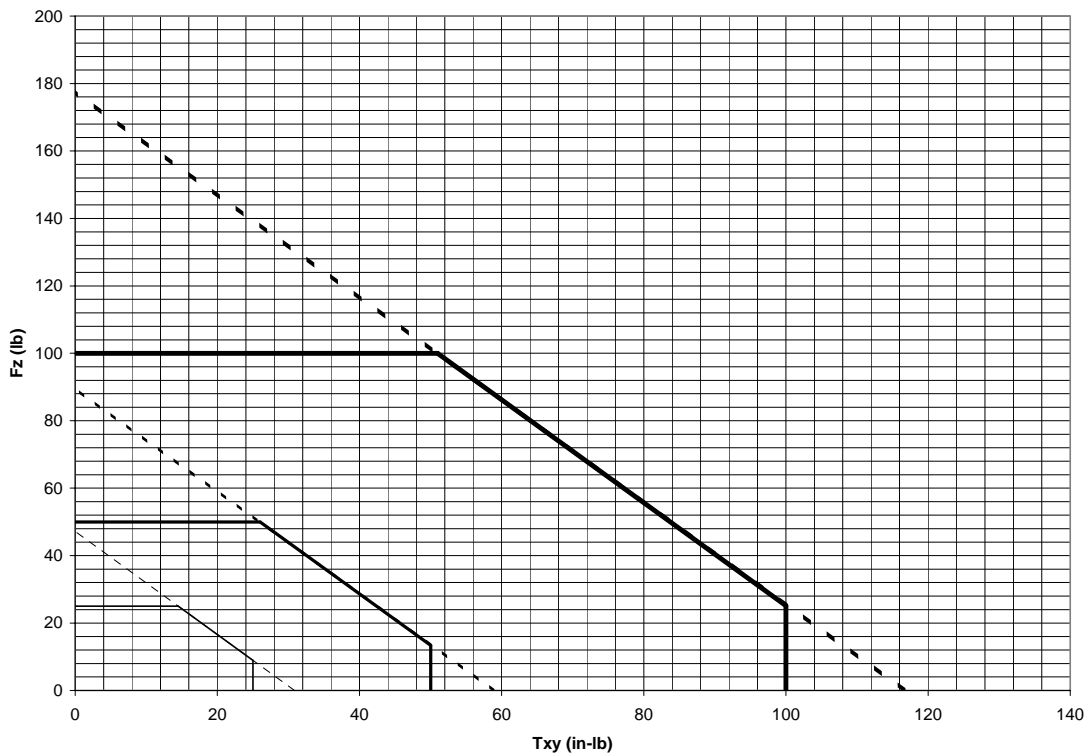
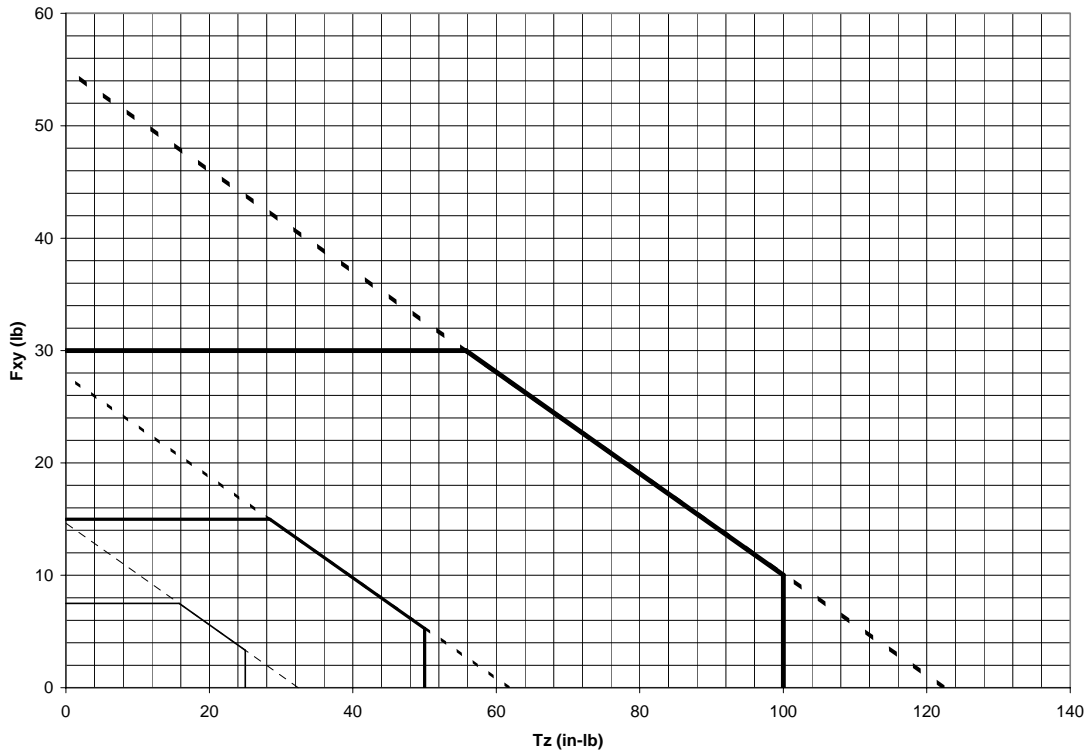
Mini45 US-120-160
 Mini45 US-60-80
 Mini45 US-30-40

7.3.10 Mini45 (SI Calibration)



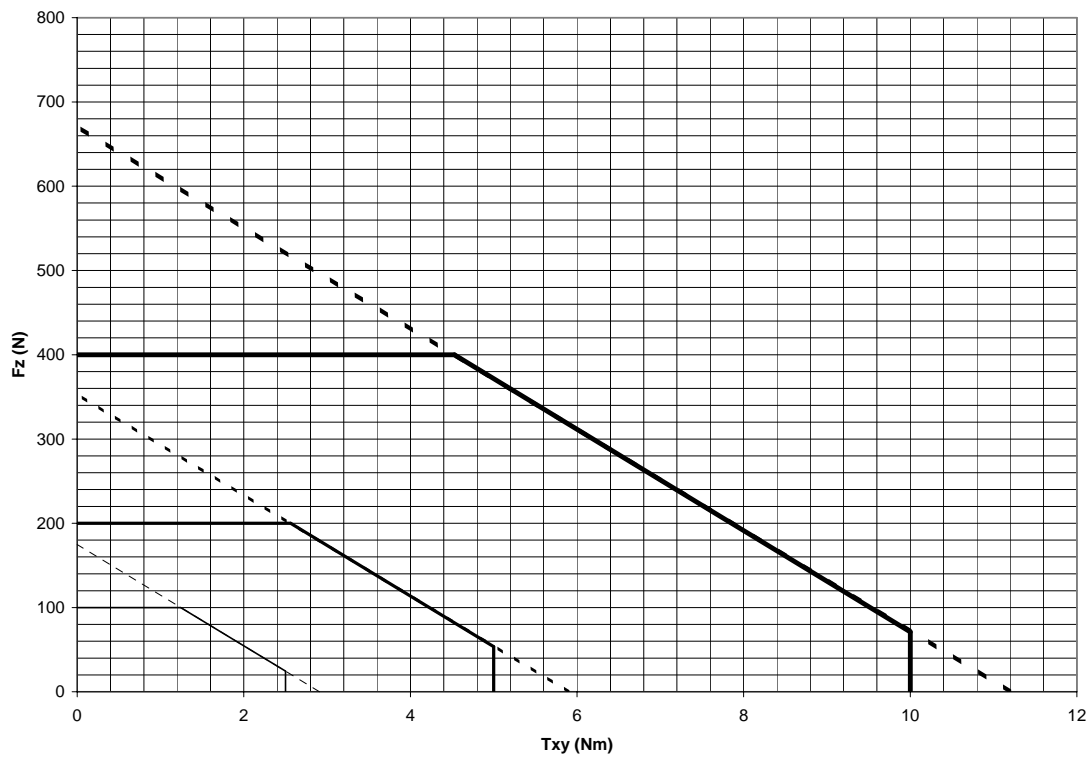
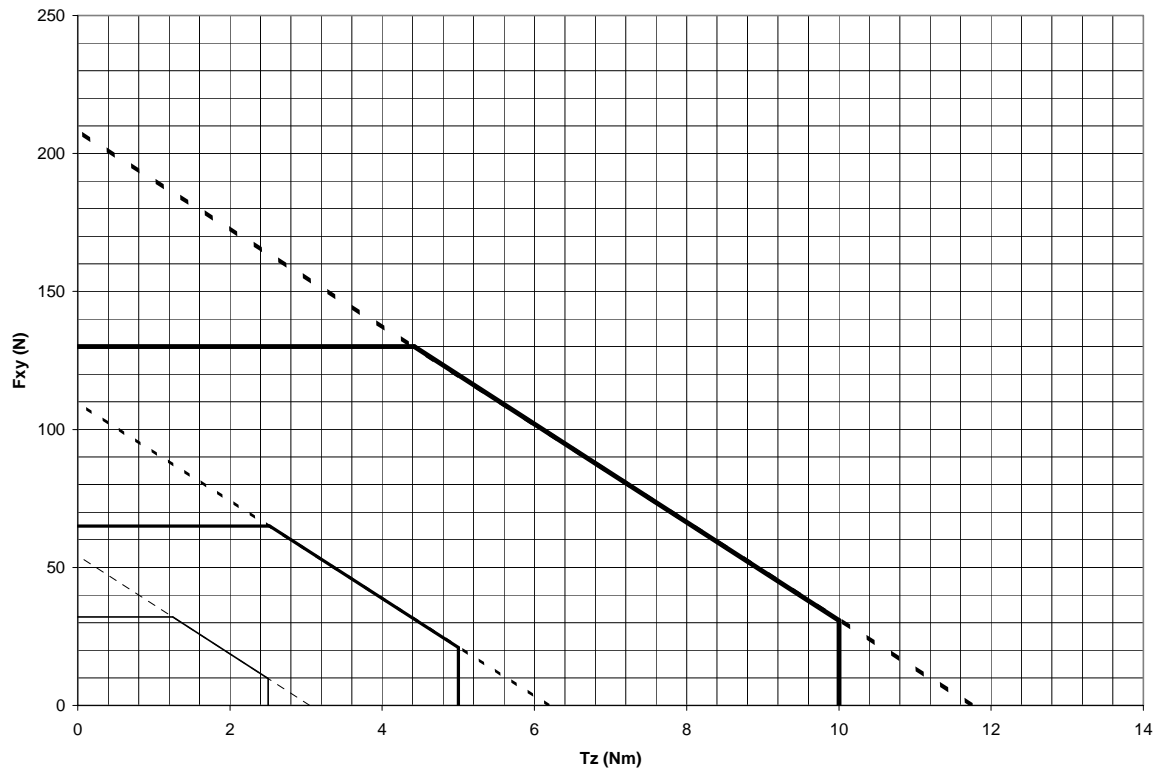
Mini45 SI-580-20
 Mini45 SI-290-10
 Mini45-SI-145-5

7.3.11 Gamma (US Calibration)



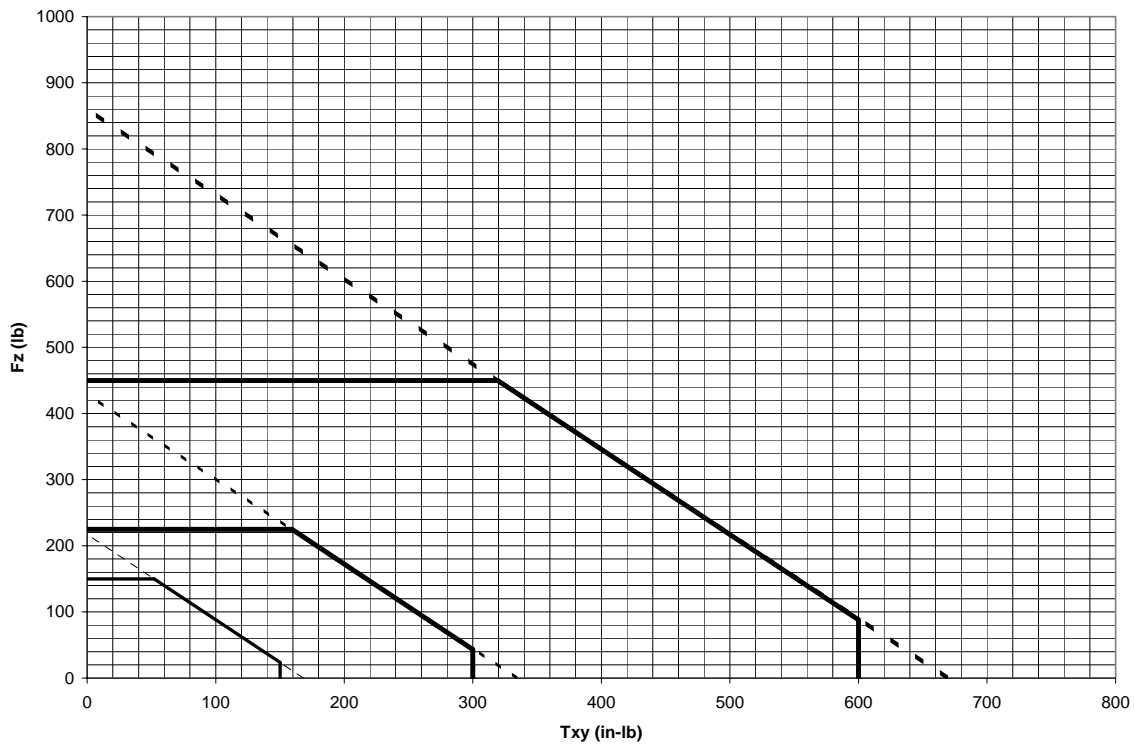
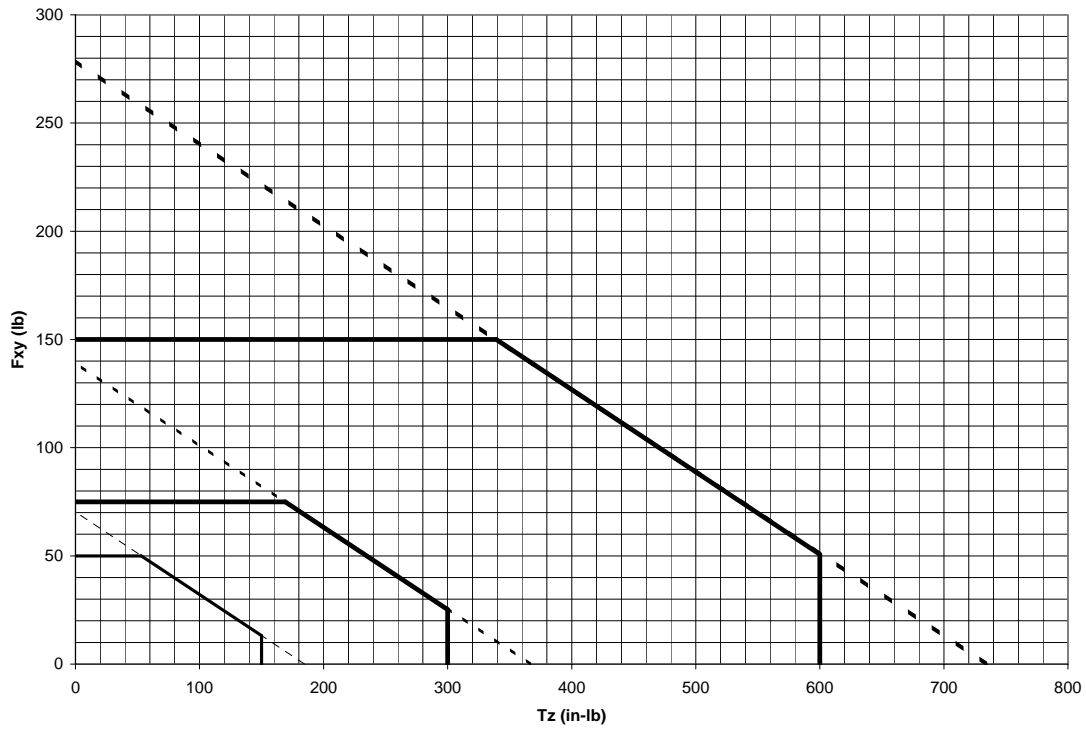
Gamma US-30-100
 Gamma US-15-50
 Gamma US-7.5-25

7.3.12 Gamma (SI Calibration)



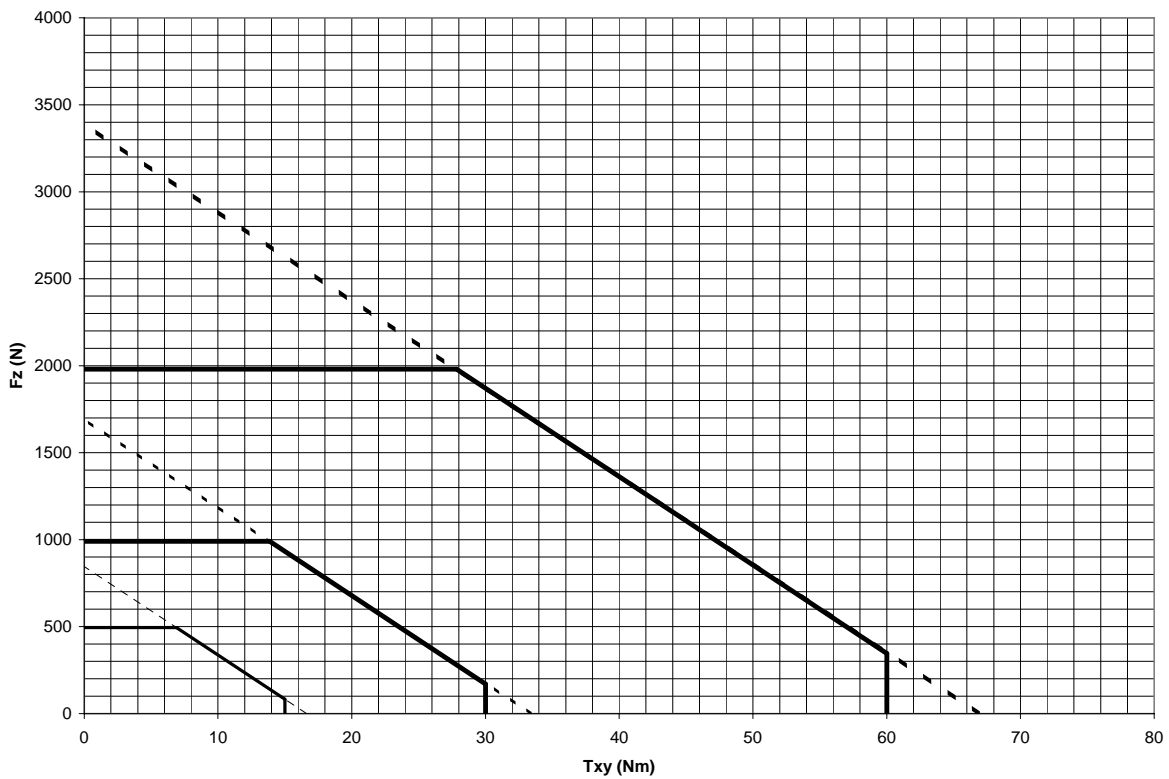
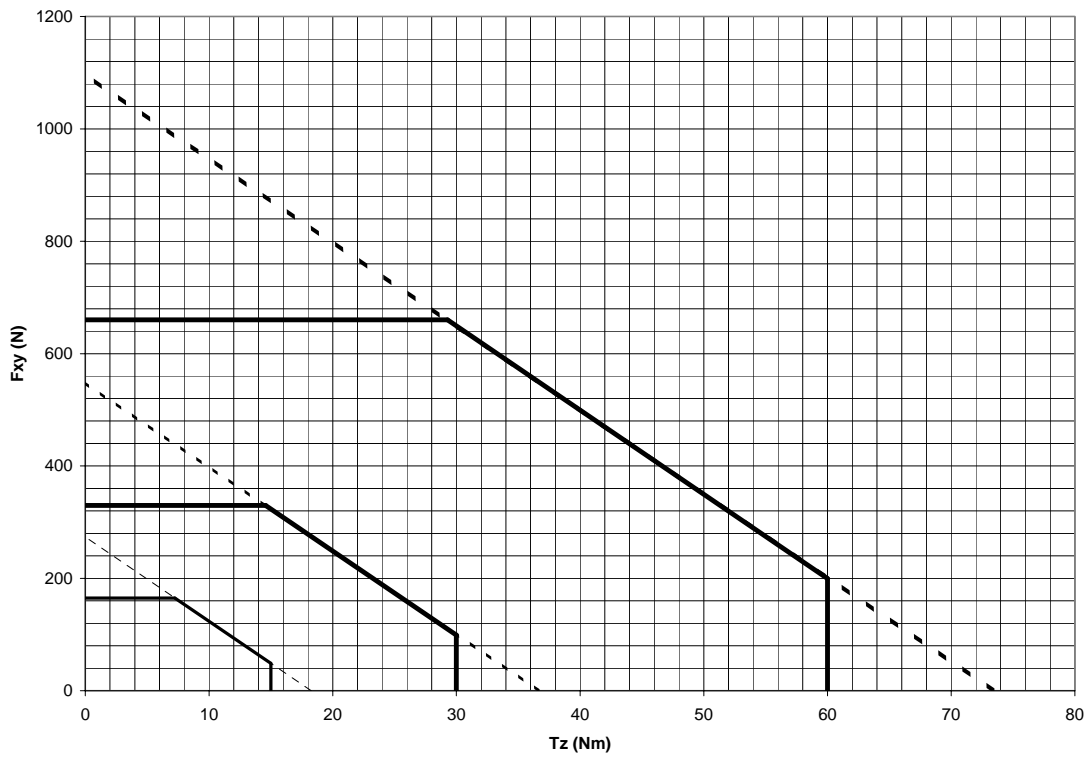
Gamma SI-130-10
 Gamma SI-65-5
 Gamma SI-32-2.5

7.3.13 Delta and Delta IP65 (US Calibration)



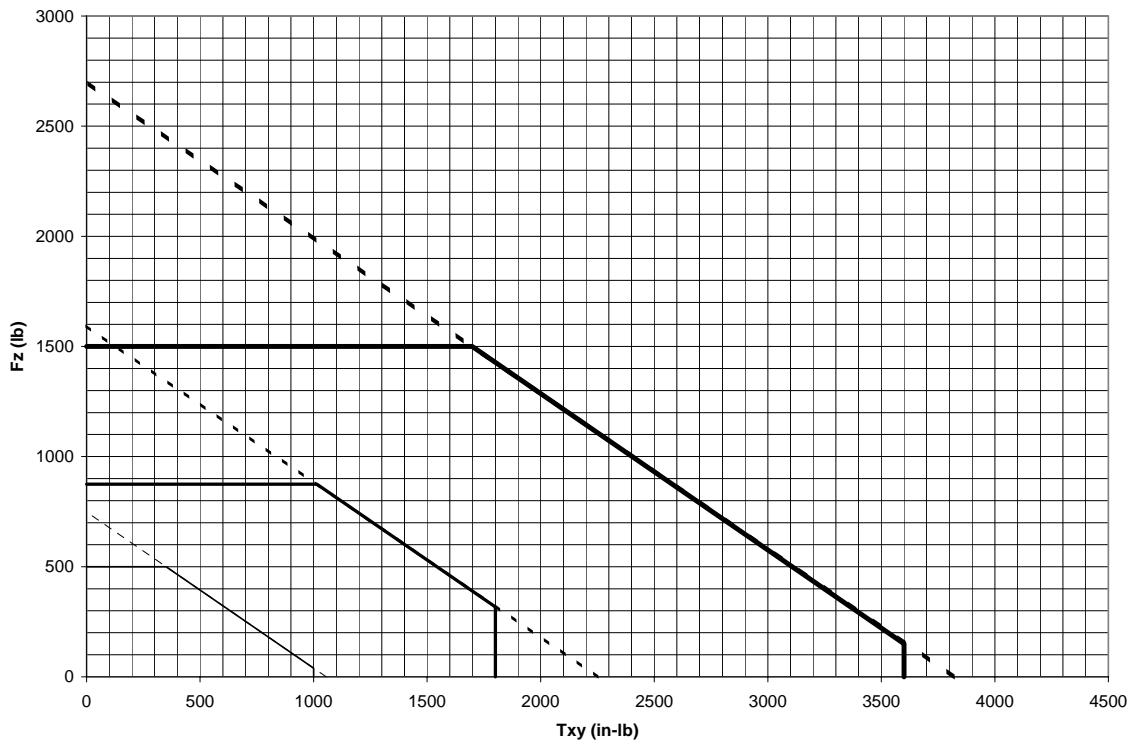
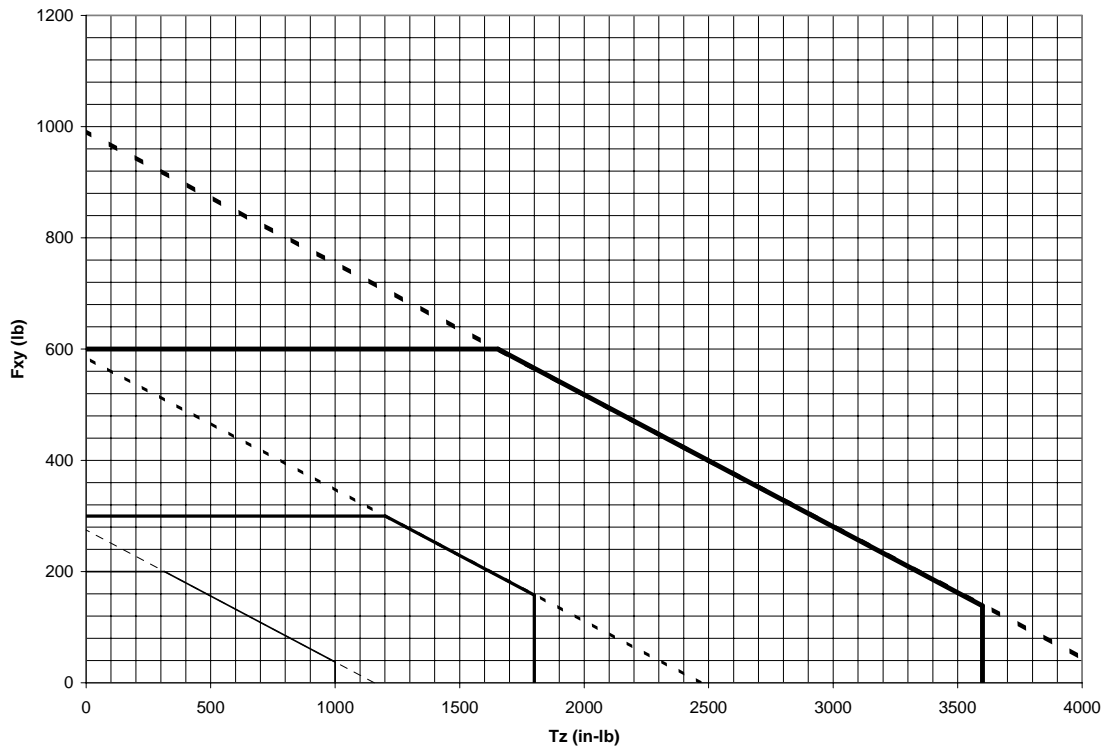
Delta US-150-600
 Delta US-75-300
 Delta US-50-150

7.3.14 Delta and Delta IP65 (SI Calibration)



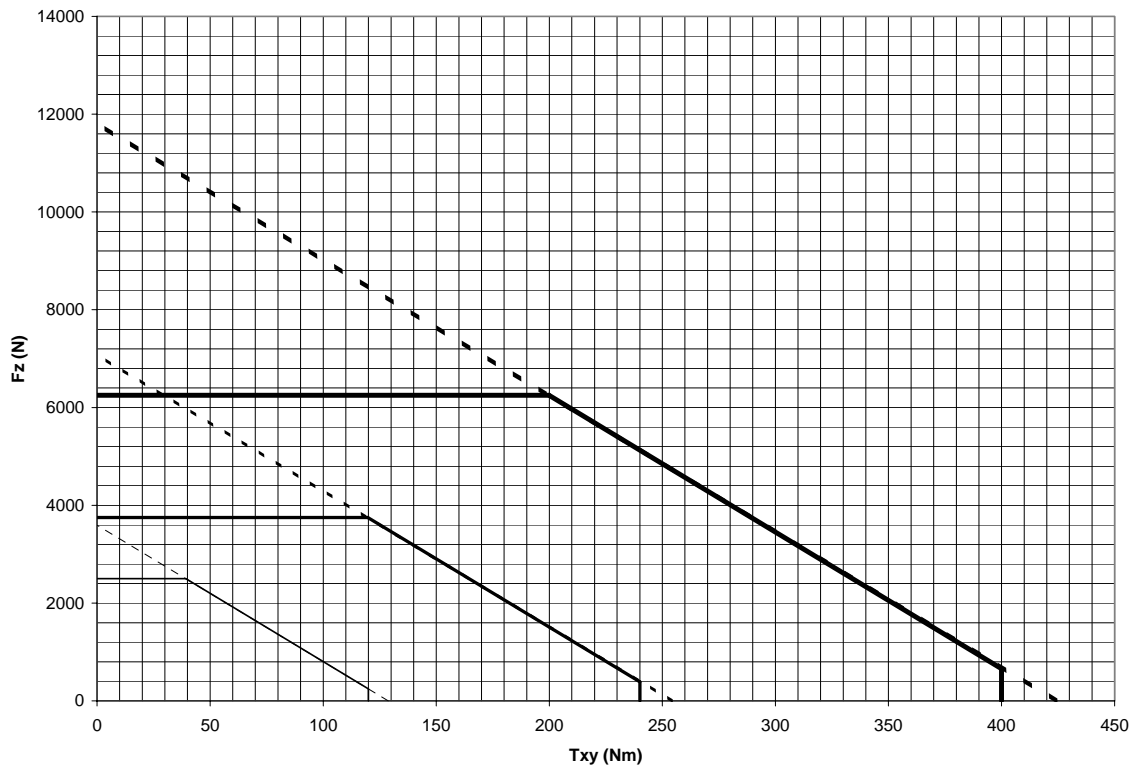
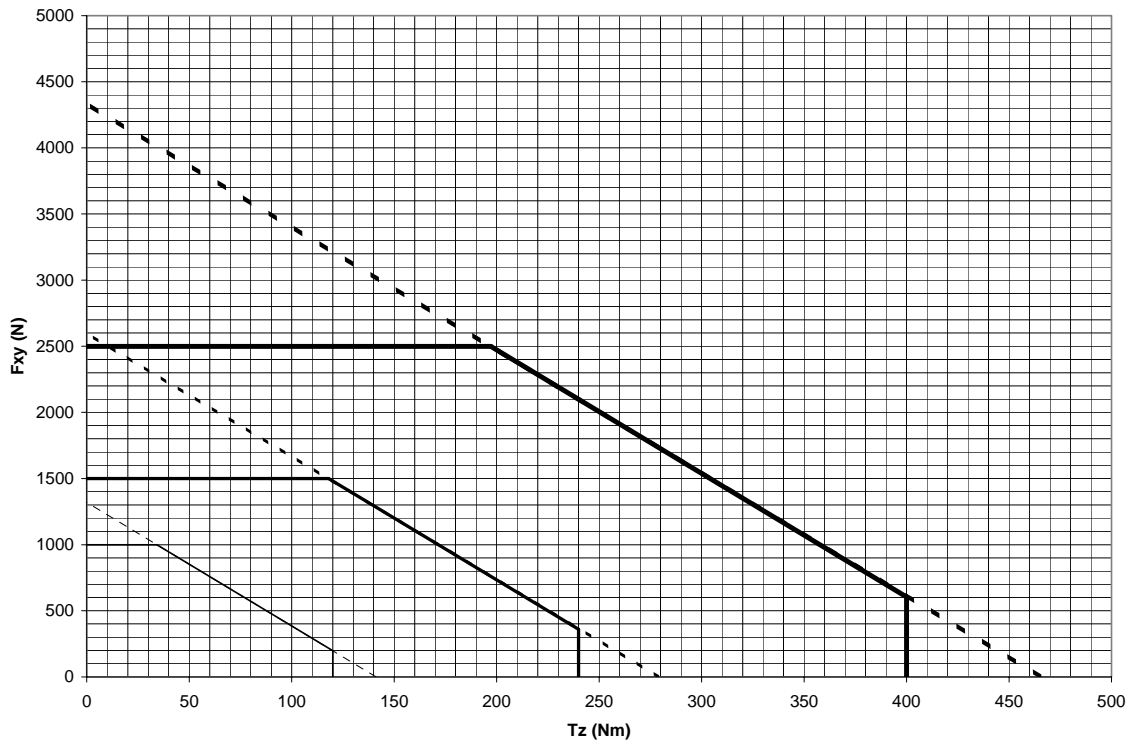
Delta SI-660-60
 Delta SI-330-30
 Delta SI-165-15

7.3.15 Theta and Theta IP65 (US Calibration)



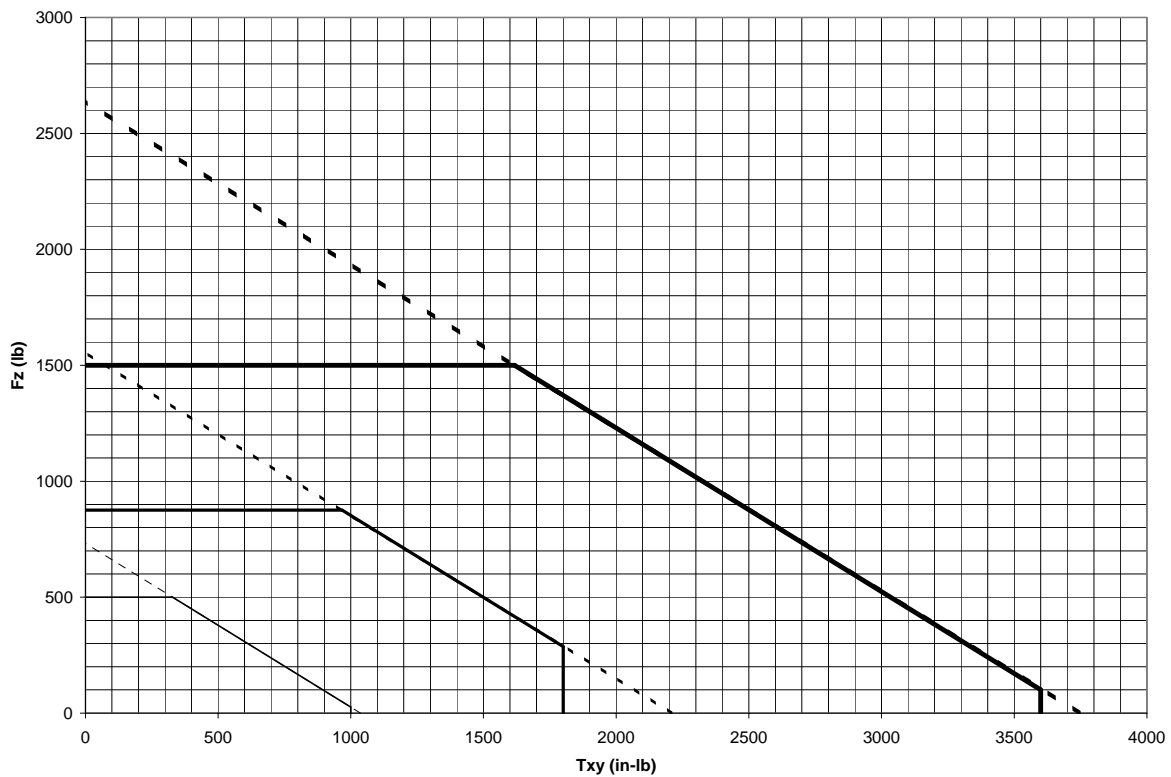
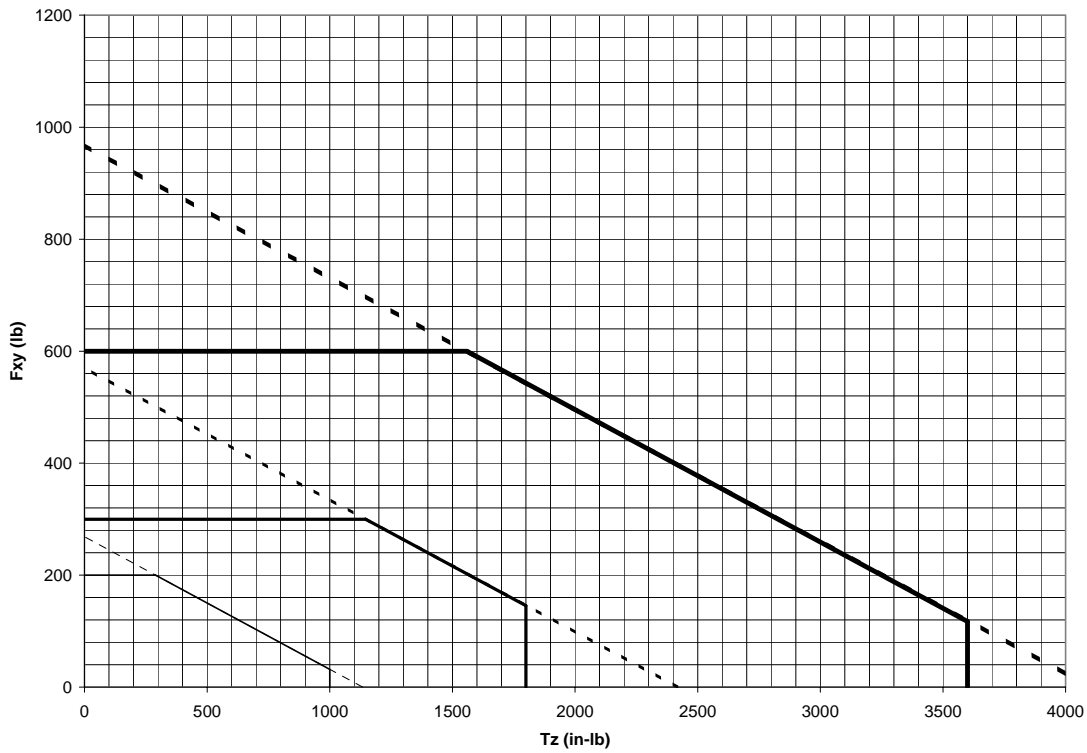
Theta US-600-3600
 Theta US-300-1800
 Theta US-200-1000

7.3.16 Theta and Theta IP65 (SI Calibration)



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

7.3.17 Omega160 and Omega160 IP65 (US Calibration)

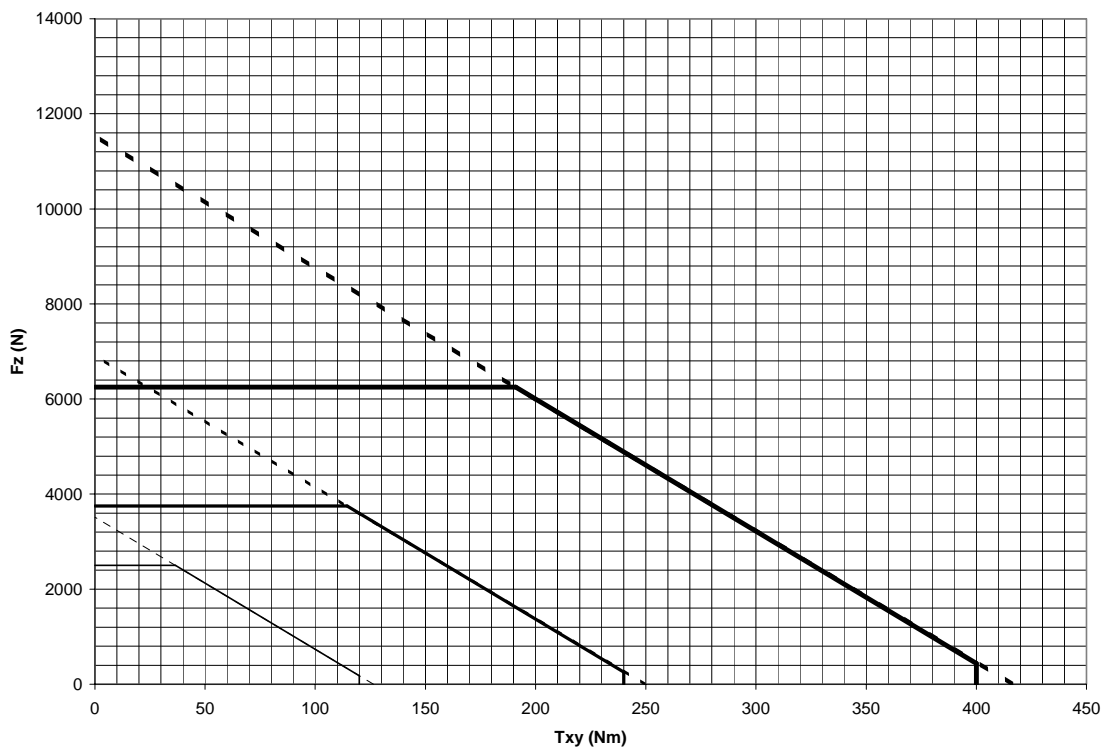
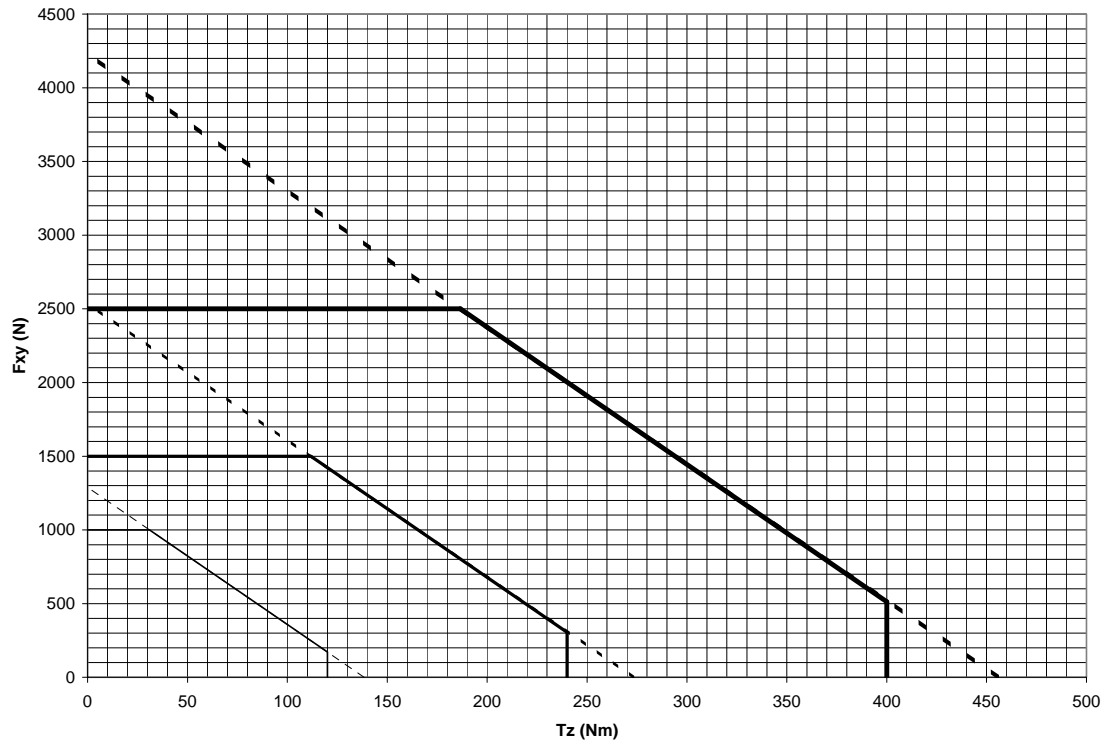


Omega160 US-600-3600

Omega160 US-300-1800

Omega160 US-200-1000

7.3.18 Omega160 and Omega160 IP65 (SI Calibration)

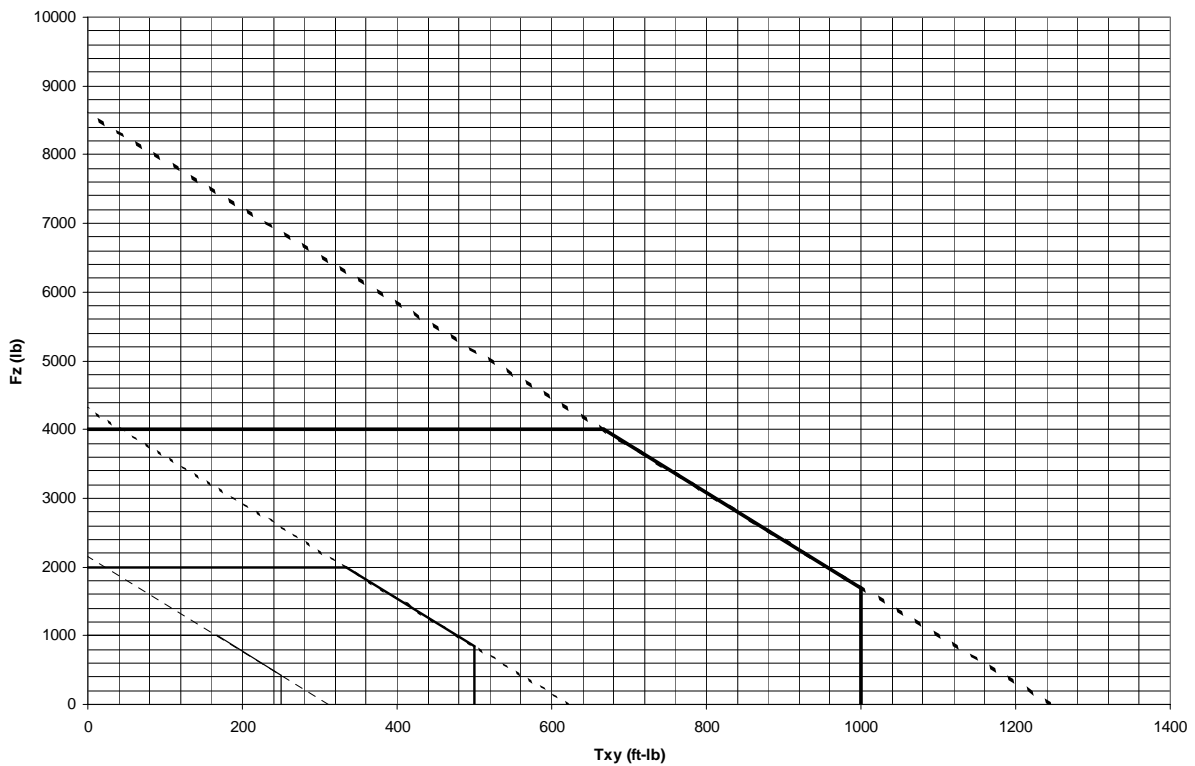
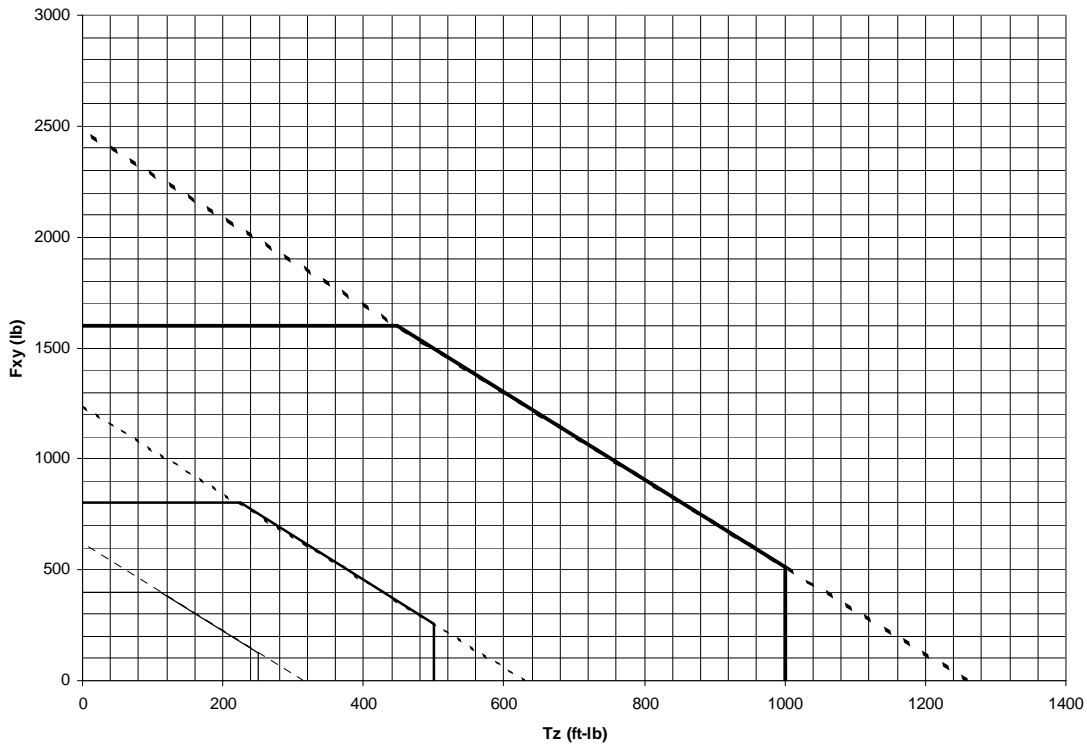


Omega160 SI-2500-400

Omega160 SI-1500-240

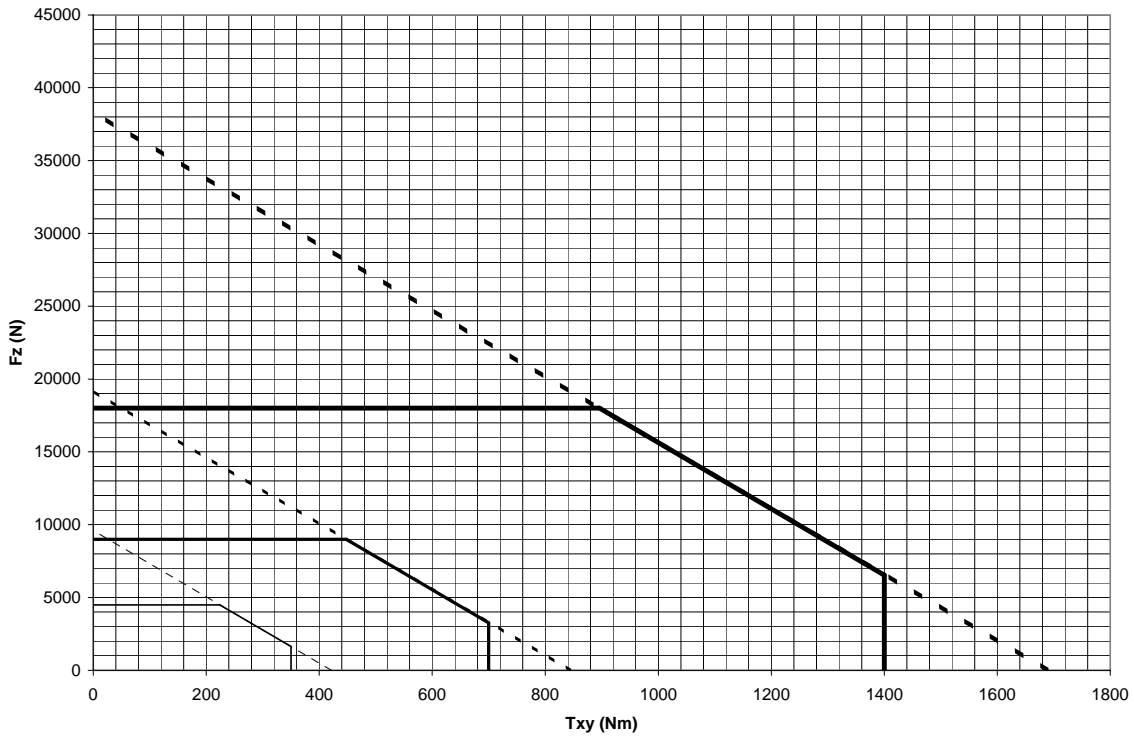
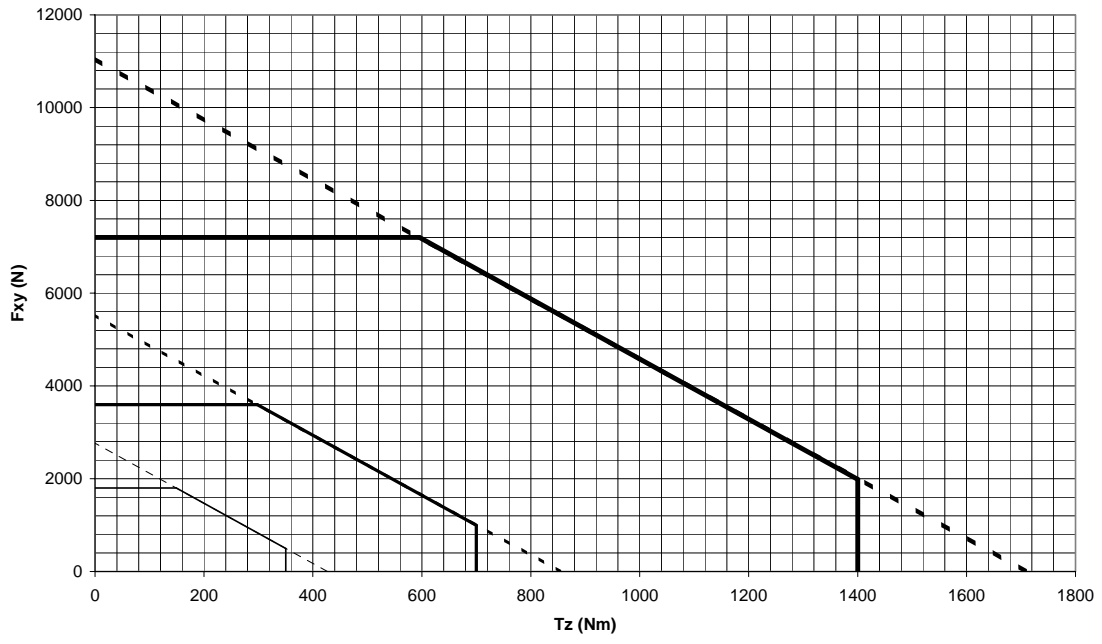
Omega160 SI-1000-120

7.3.19 Omega190 and Omega190 IP65 (US Calibration)



Omega190 US-1600-12000
 Omega190 US-800-6000
 Omega190 US-400-3000

7.3.20 Omega190 and Omega190 IP65 (SI Calibration)



Omega190 SI-7200-1400

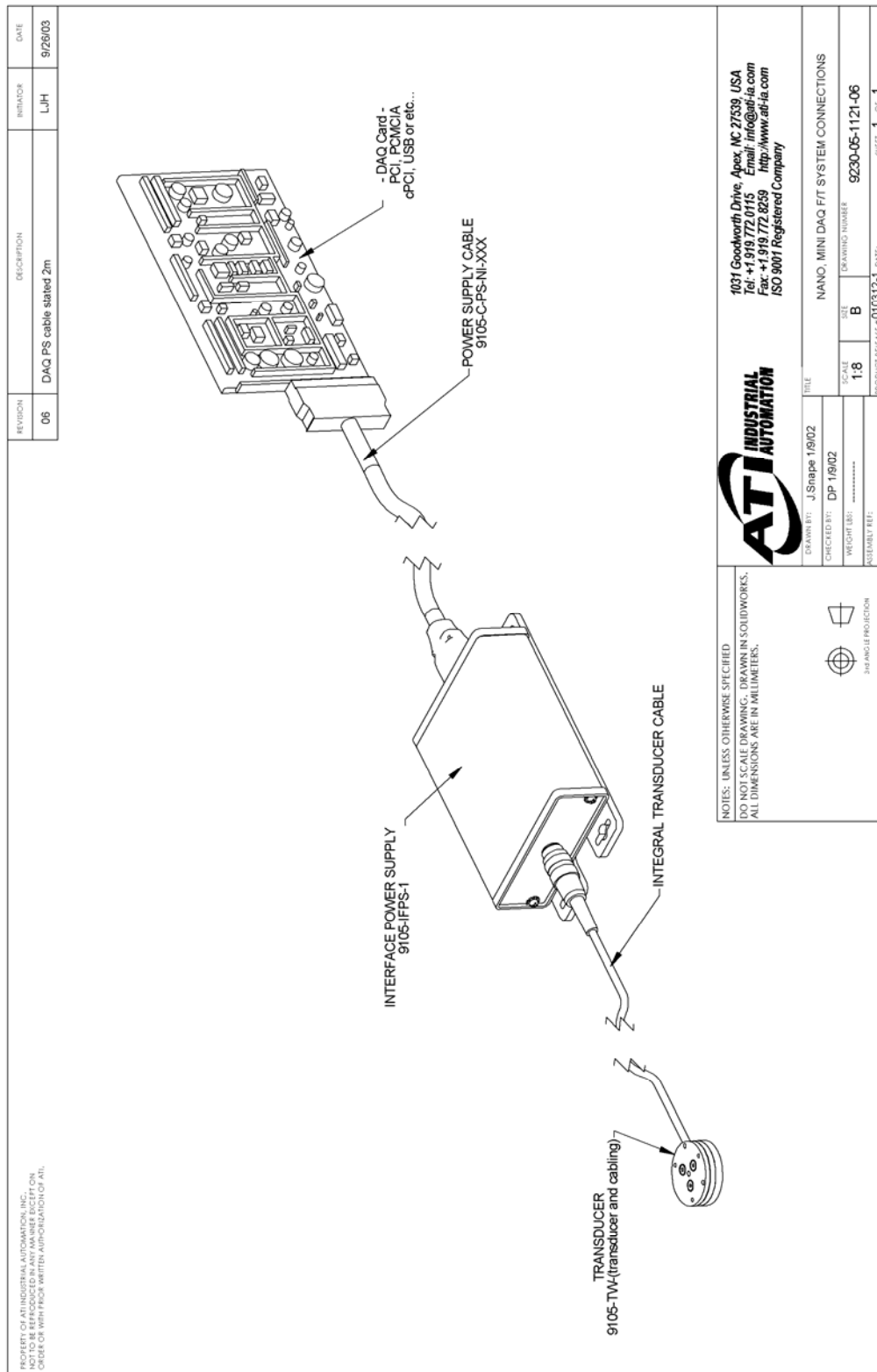
Omega190 SI-3600-700

Omega190 SI-1800-350

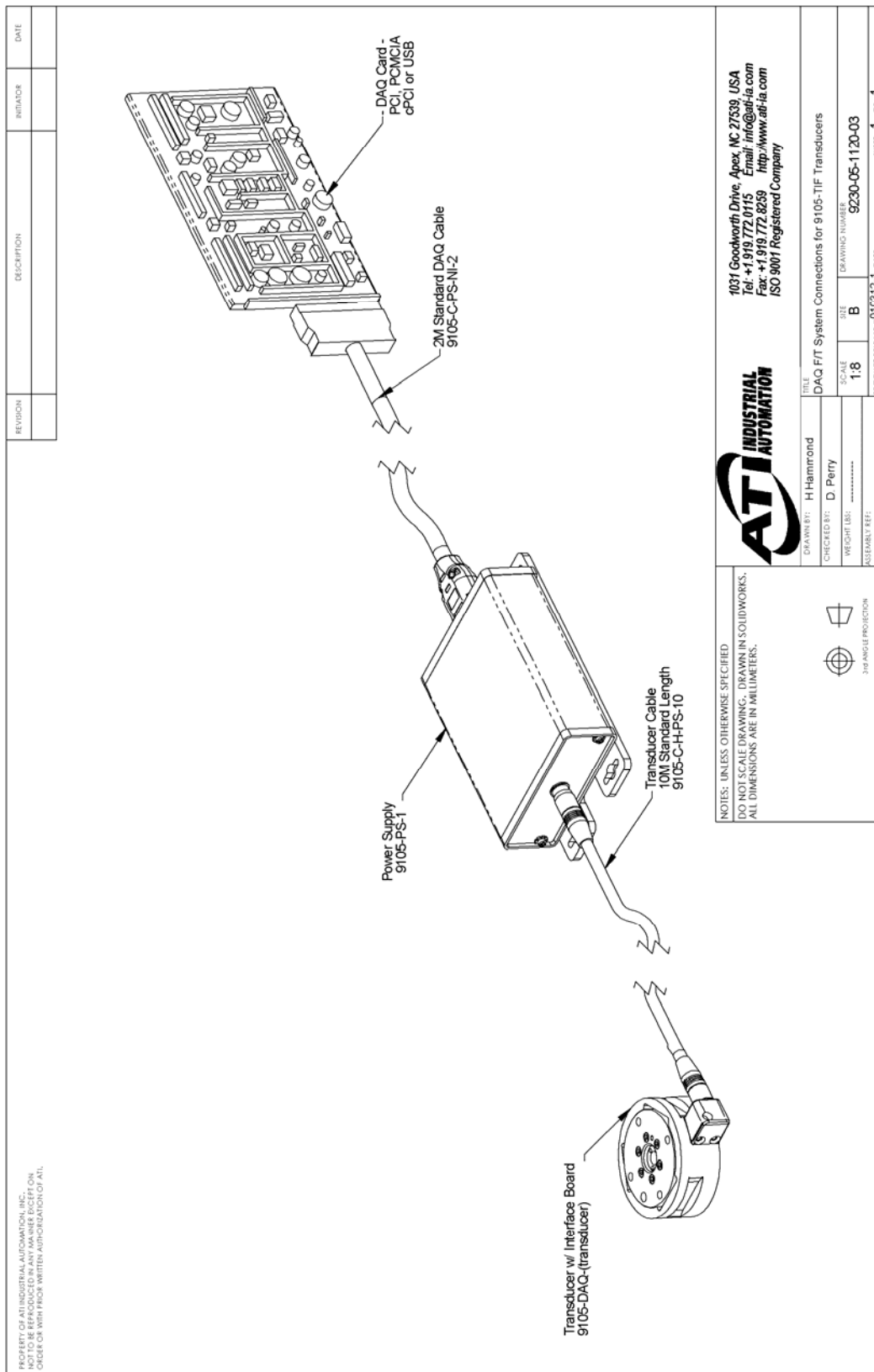
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8. Appendix B—Mechanical Layout

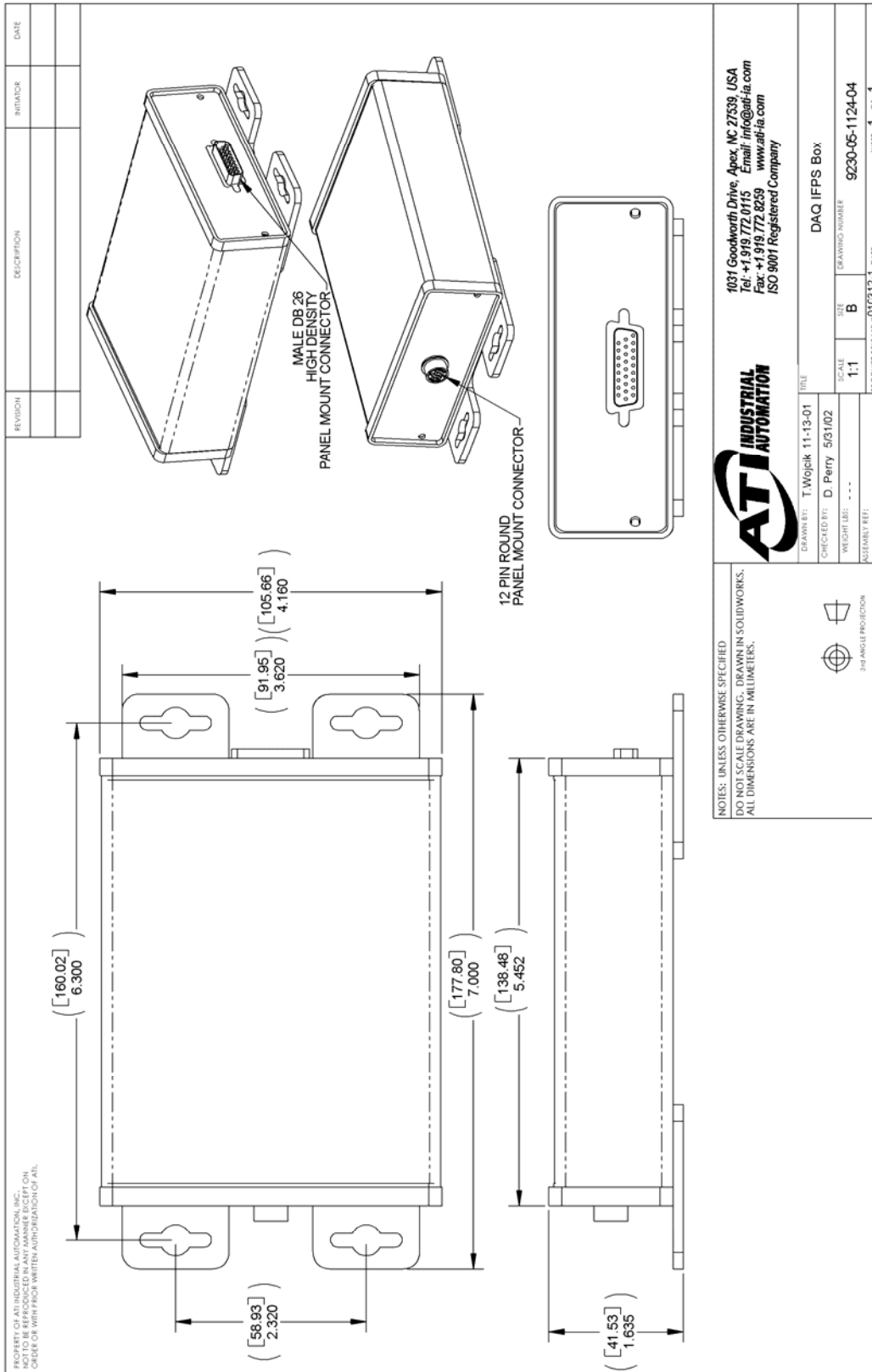
8.1 Nano, Mini DAQ F/T System Connections



8.2 DAQ F/T System Connections for 9105-TIF Transducers



8.3 DAQ IFPS Box

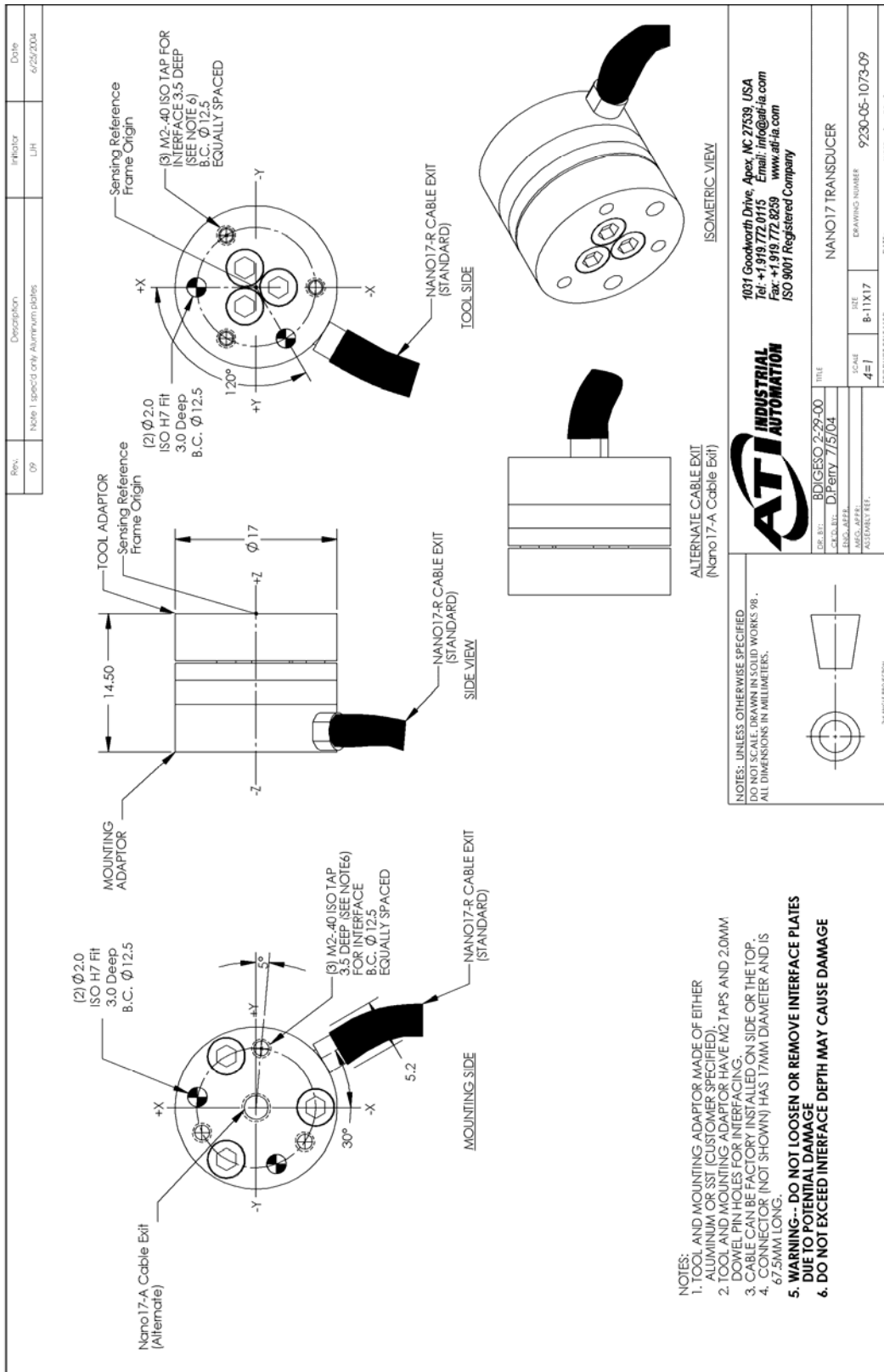


1031 Goodworth Drive, Apex, NC 27539, USA
 Tel: +1 919.772.0115 Email: info@ati-ia.com
 Fax: +1 919.772.8259 www.ati-ia.com
 ISO 9001 Registered Company

REVISION	DESCRIPTION	INITIATOR	DATE

DRAWN BY: T. Wojcik 11-13-01	TITLE: DAQ IFPS Box
CHECKED BY: D. Perry 5/31/02	DRAWING NUMBER: 9230-05-1124-04
WEIGHT LBS: ...	SCALE: 1:1
ASSEMBLY TREE:	SIZE: B
	PRODUCT RELEASE #01C312-1 DATE: SHEET 1 OF 1

8.4 Nano17 Transducer



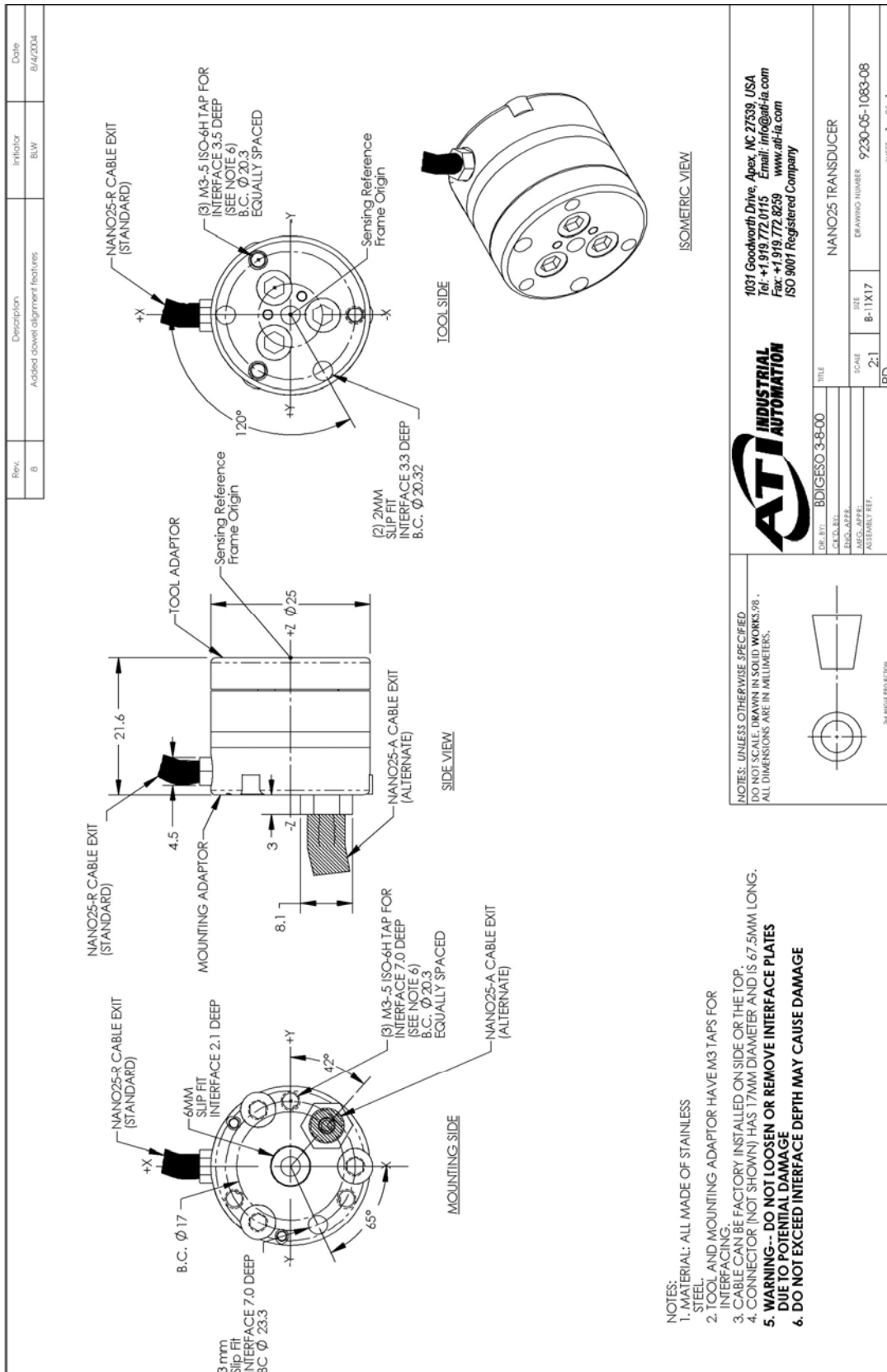
Rev:	Description:	Author:	Date:
09	Note 1, special only Aluminum plates	LH	6/25/2004

		1031 Goodworth Drive, Apex, NC 27539, USA Tel: +1 919 772 0115 Fax: +1 919 772 8259 Email: info@ati-ia.com www.ati-ia.com ISO 9001 Registered Company	
		DR. BY: BDI/GESO 2-29-00 DATE: 7/15/04 TITLE: NANO17 TRANSDUCER	DRAWING NUMBER: 9230-05-1073-09 SIZE: 8-11X17 SCALE: 4=1
PRODUCT RELEASE# _____ DATE: _____ SHEET 1 OF 1			

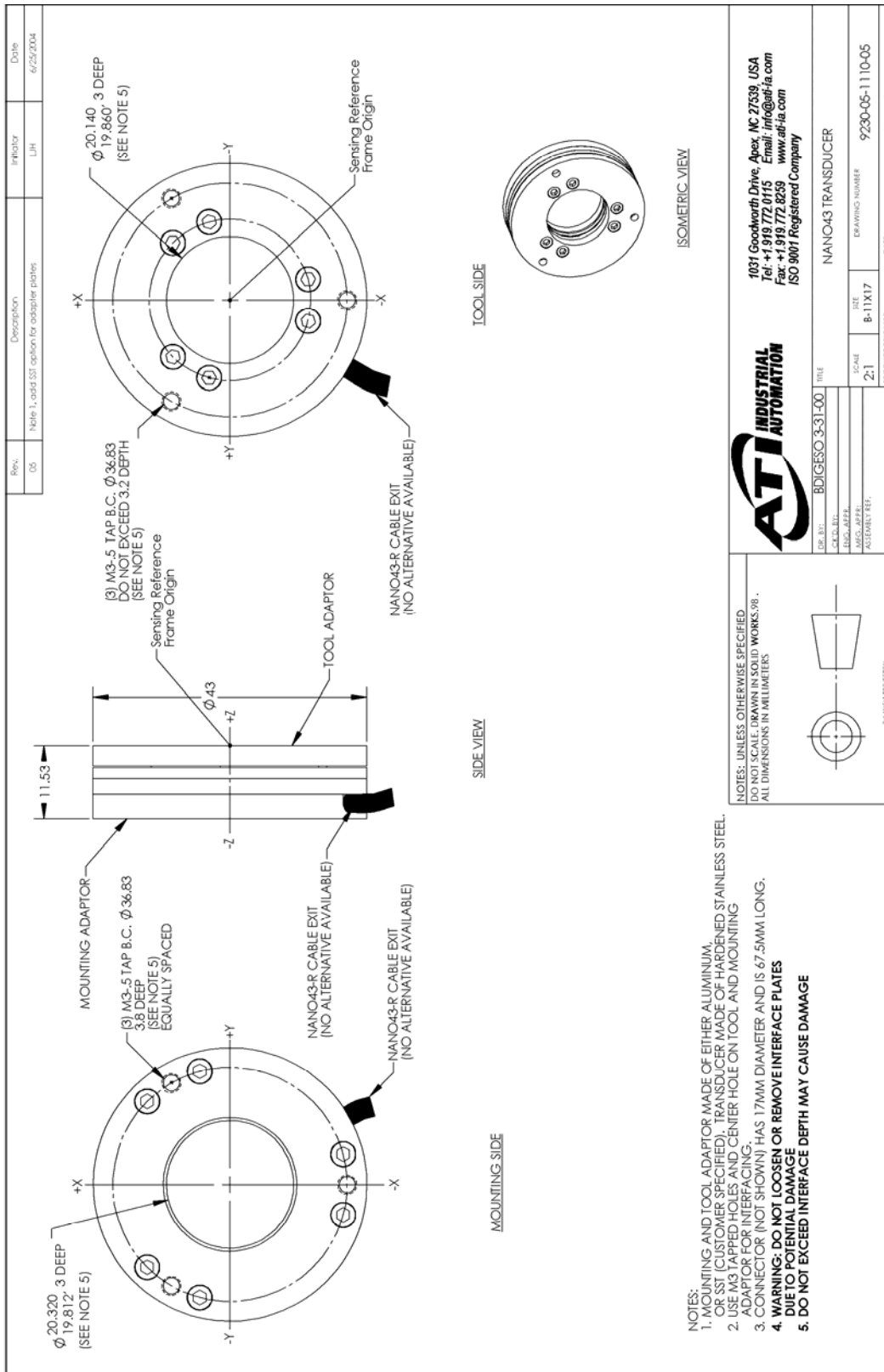
NOTES: UNLESS OTHERWISE SPECIFIED DO NOT SCALE. DRAWN IN SOLID WORKS 98. ALL DIMENSIONS IN MILLIMETERS.

3d MODEL PROJECTION

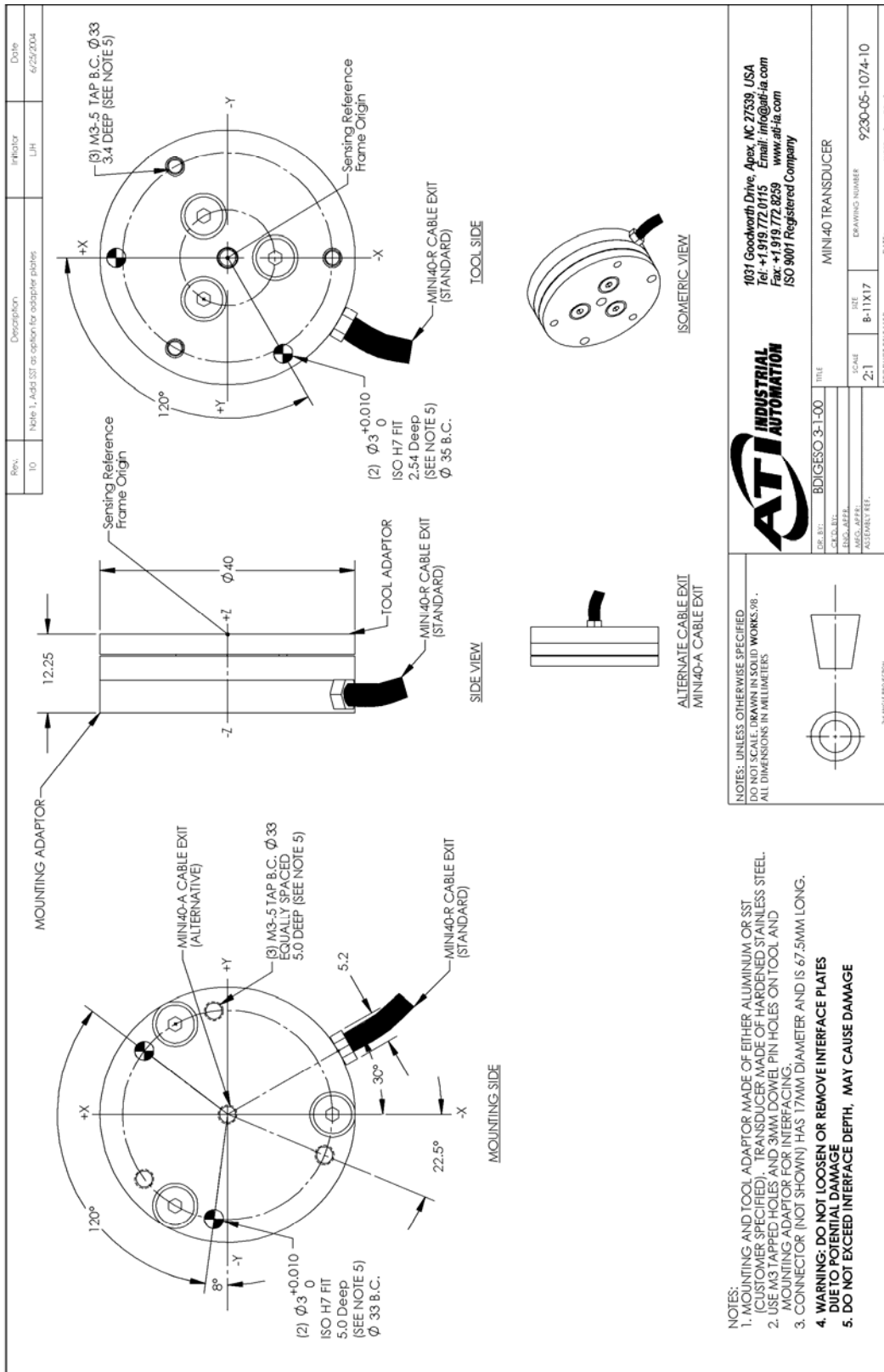
8.5 Nano25 Transducer



8.6 Nano43 Transducer



8.7 Mini40 Transducer

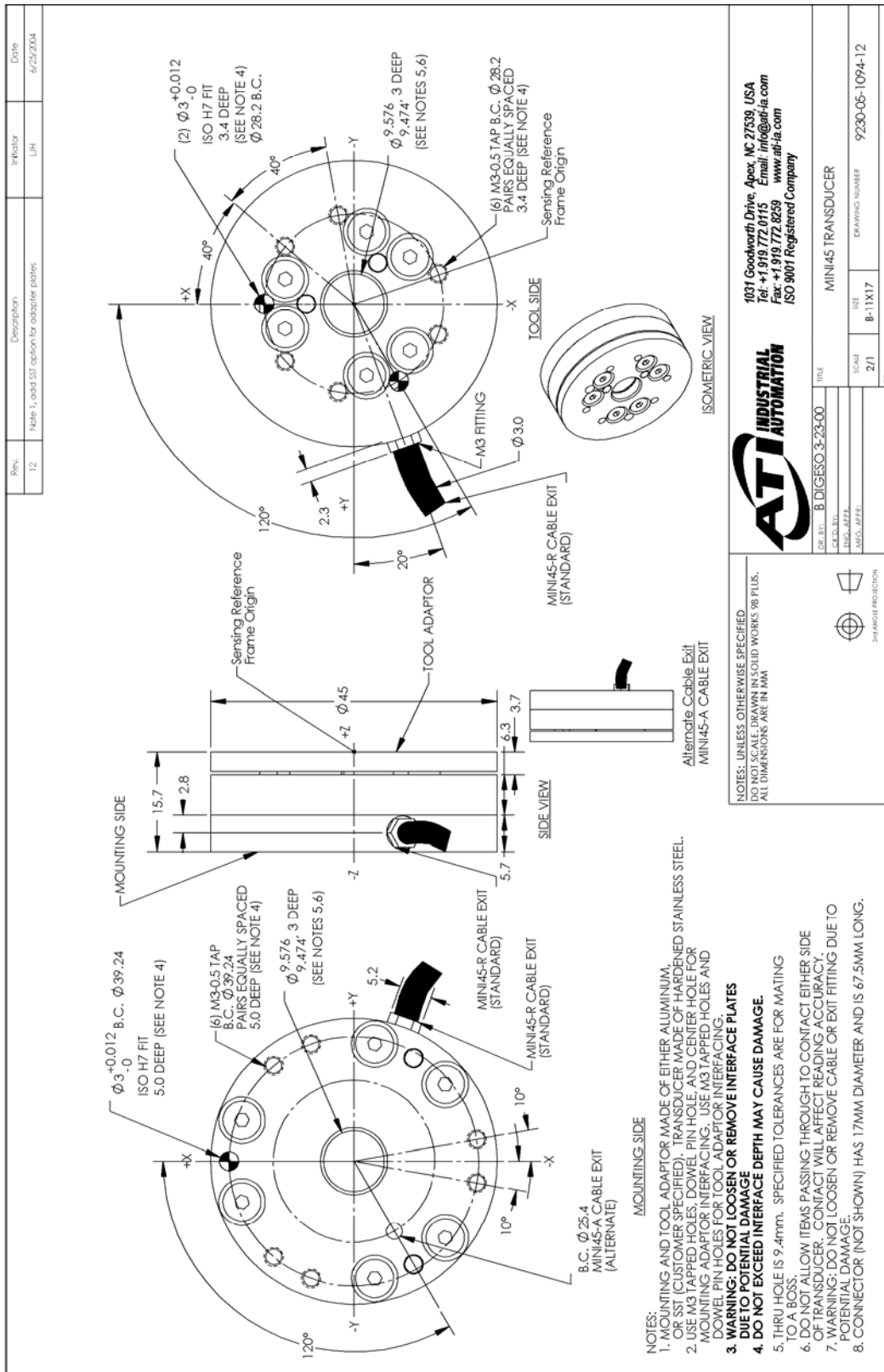


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 Fax: +1 919 772 8259 www.ati-ia.com
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DATE: 6/25/2004	DATE: 6/25/2004
REV: 10	REV: 10
DESCRIPTION: Hole 1, Add SST as option for adaptor plates	DESCRIPTION: Hole 1, Add SST as option for adaptor plates
INSTRUCTOR: LH	INSTRUCTOR: LH
TITLE: MINI40 TRANSDUCER	TITLE: MINI40 TRANSDUCER
SCALE: 2:1	SCALE: 2:1
SIZE: 8-11X17	SIZE: 8-11X17
DRAWING NUMBER: 9230-05-1074-10	DRAWING NUMBER: 9230-05-1074-10
PRODUCT RELEASE #	PRODUCT RELEASE #
SHEET 1 OF 1	SHEET 1 OF 1

8.8 Mini45 Transducer



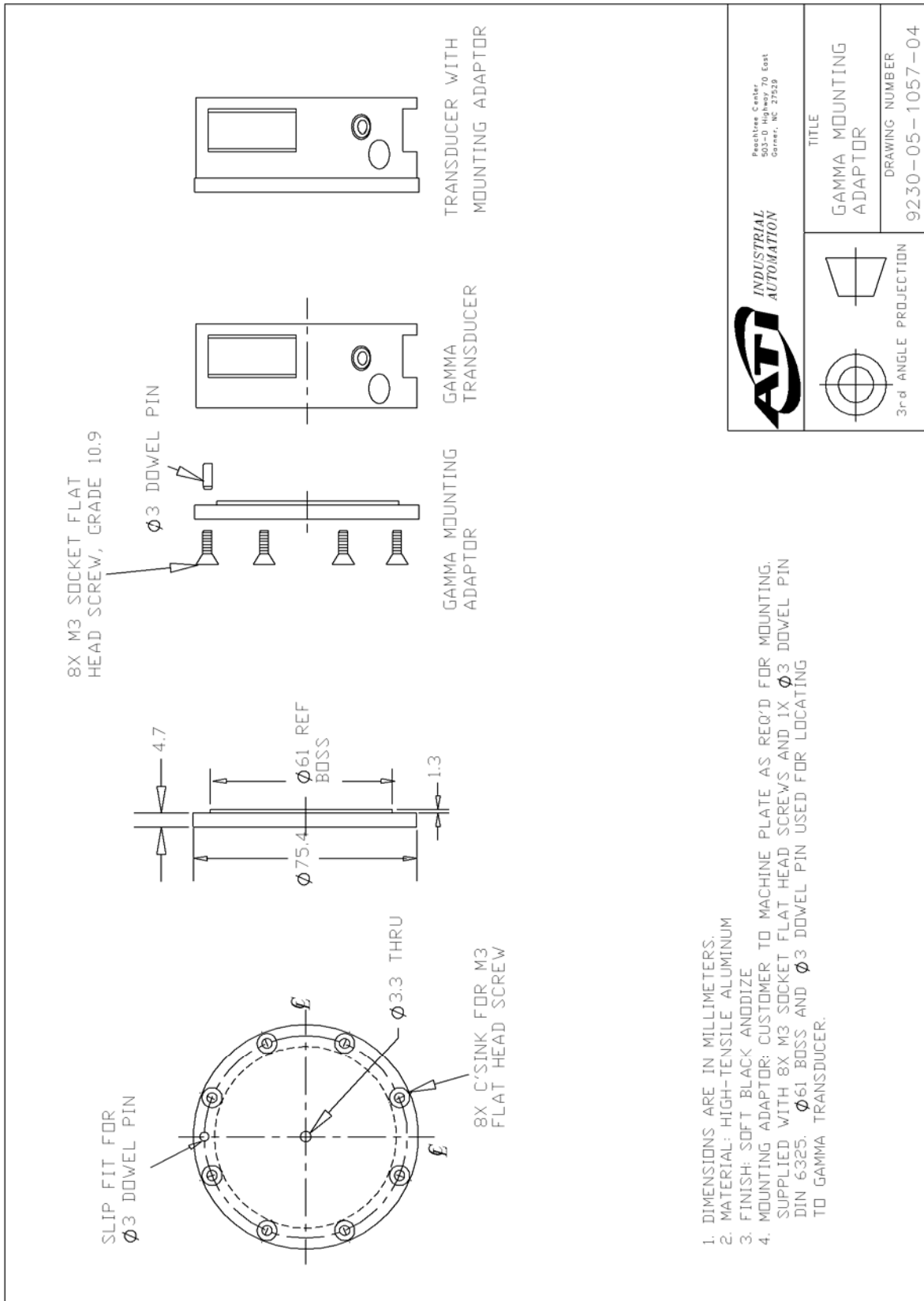
Rev:	12	Description:	Hole 1, add SST option for adapter plates	Author:	LH	Date:	6/25/2004
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		1031 Goodworth Drive, Apex, NC 27539 USA Tel: +1 919 772 0115 Fax: +1 919 772 8259 Email: info@ati-ia.com www.ati-ia.com ISO 9001 Registered Company	
DF. BY:	B DIGESIO 3-23-00	TITLE:	MINI45 TRANSDUCER
SCALE:	2/1	DRAWING NUMBER:	9230-05-1094-12
SIZE:	B-11X17	SHEET:	OF 1

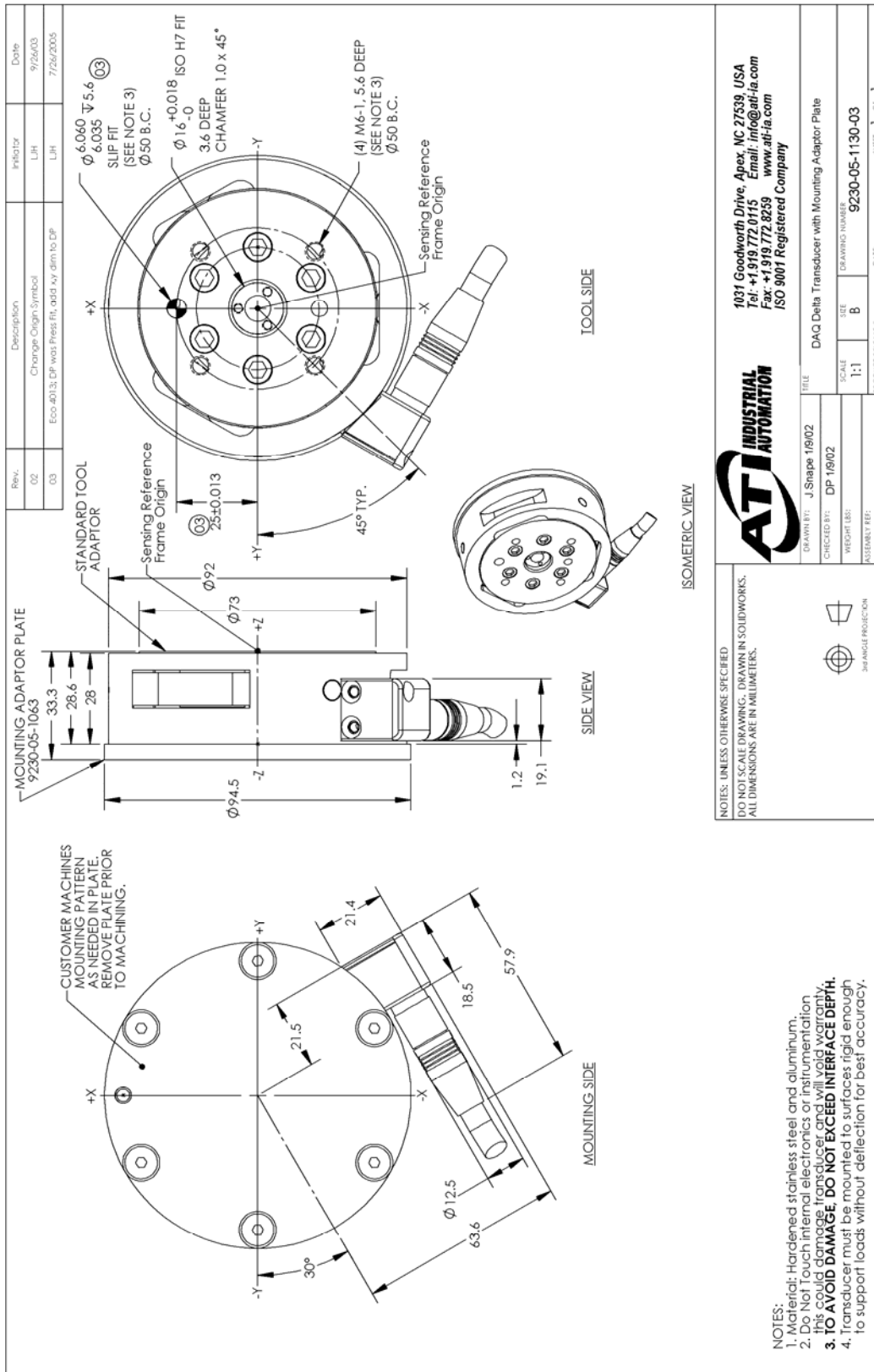
NOTES: UNLESS OTHERWISE SPECIFIED
 DO NOT SCALE. DRAWN IN SOLID WORKS 98 PLUS.
 ALL DIMENSIONS ARE IN MM

THIRD ANGLE PROJECTION

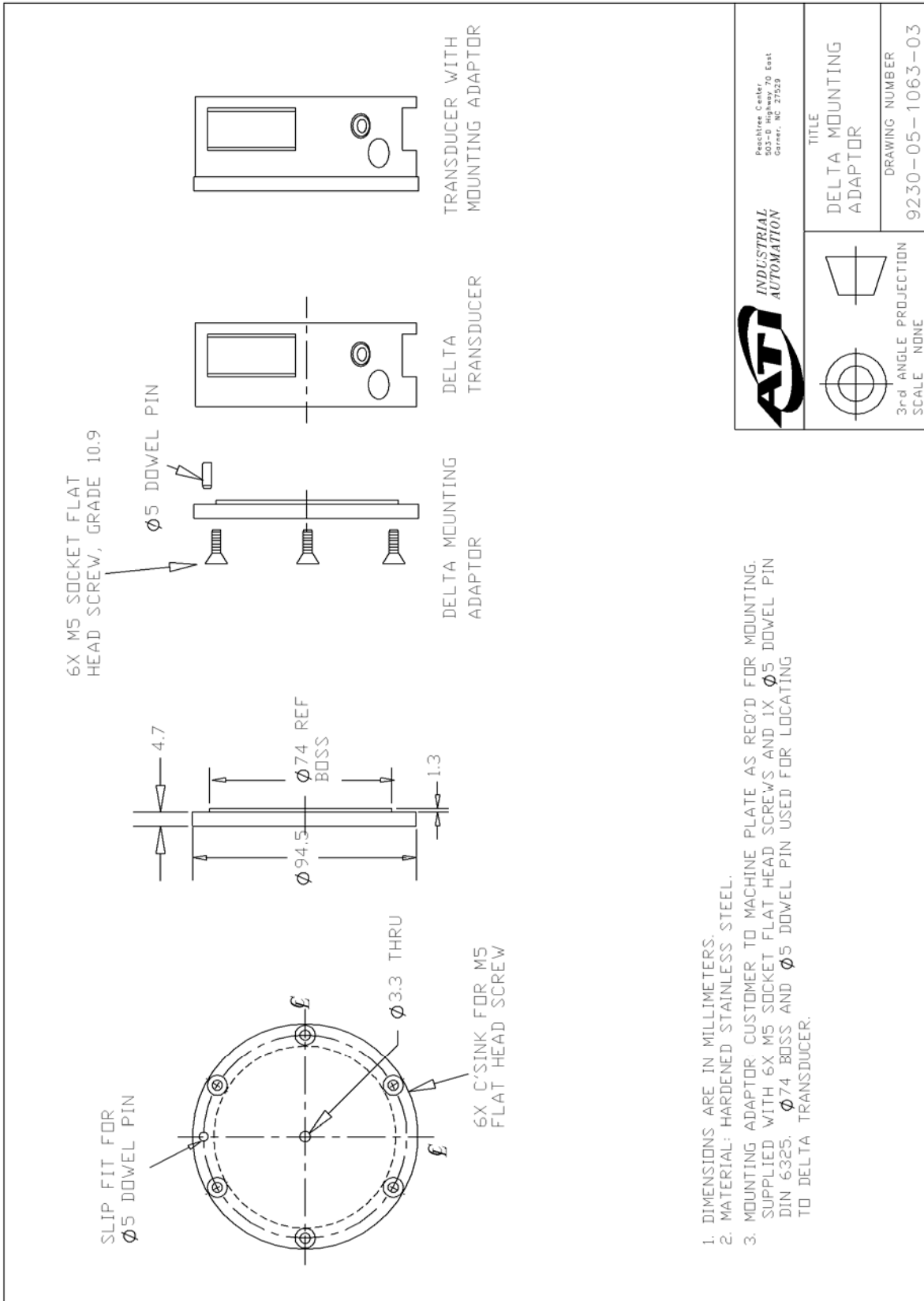
8.10 Gamma Mounting Adaptor



8.11 DAQ Delta Transducer with Mounting Adaptor Plate

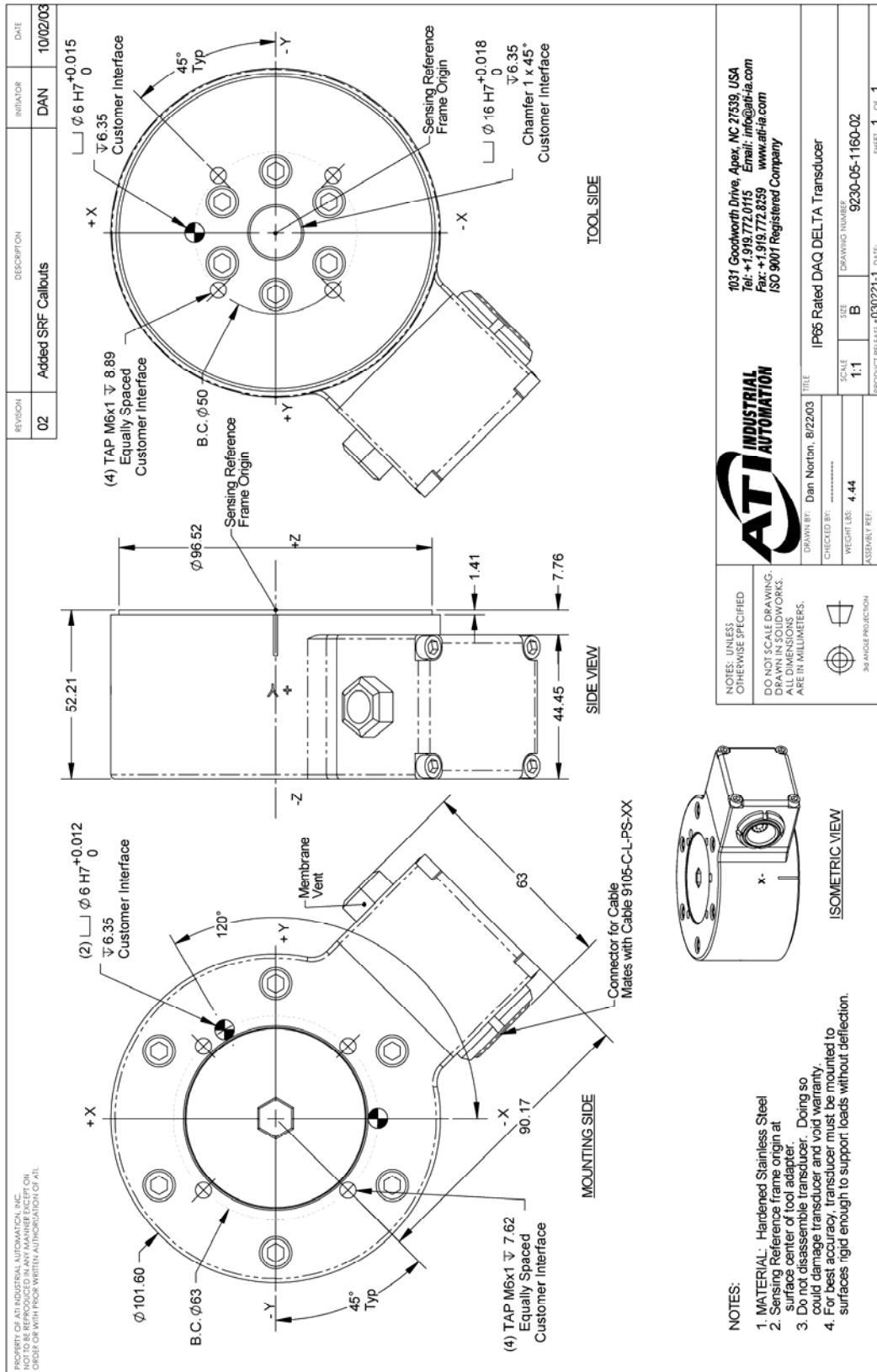


8.12 Delta Mounting Adaptor

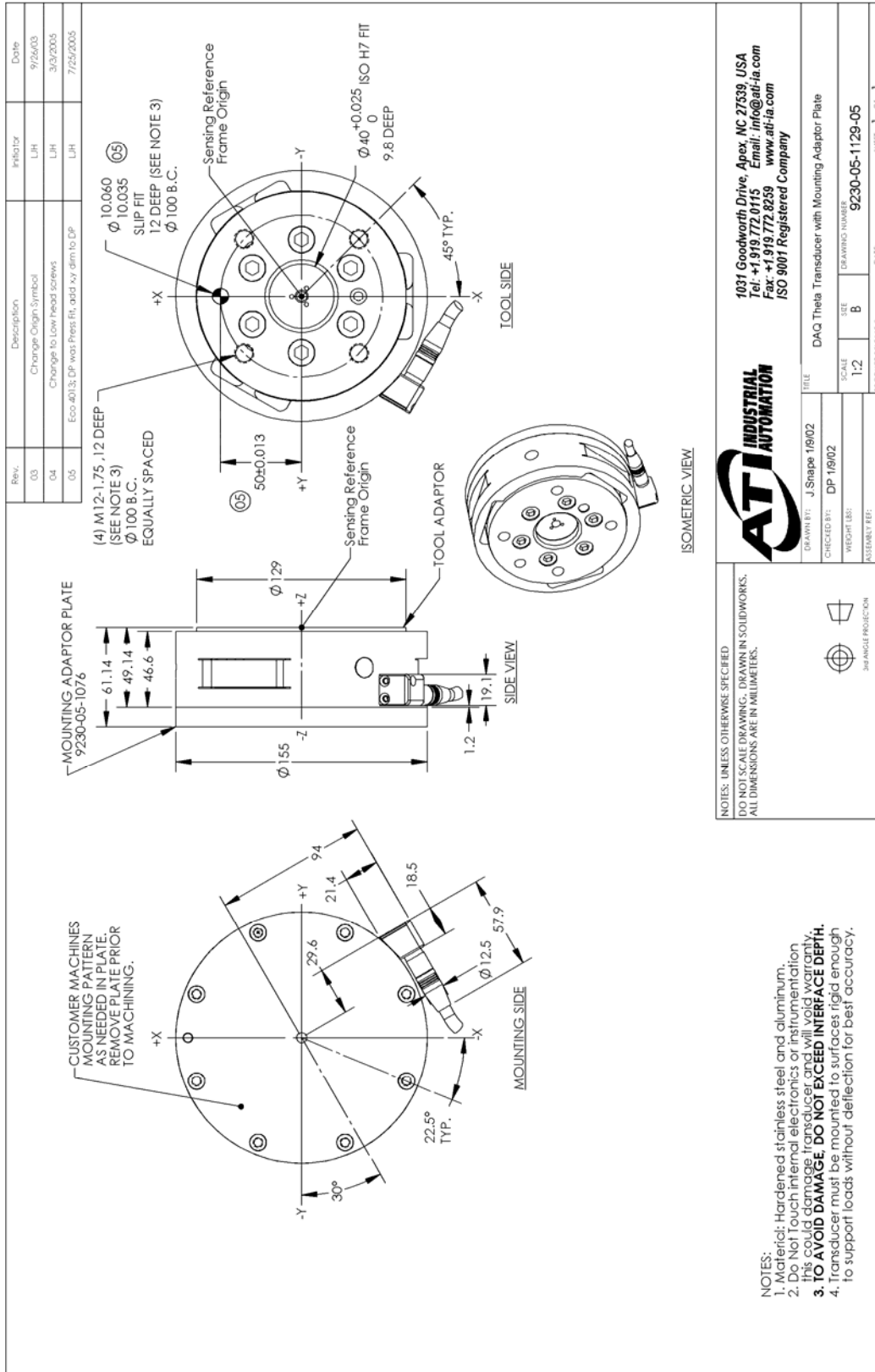


1. DIMENSIONS ARE IN MILLIMETERS.
2. MATERIAL: HARDENED STAINLESS STEEL.
3. MOUNTING ADAPTOR CUSTOMER TO MACHINE PLATE AS REQ'D FOR MOUNTING. SUPPLIED WITH 6X M5 SOCKET FLAT HEAD SCREWS AND 1X Ø5 DOWEL PIN DIN 6325. Ø74 BOSS AND Ø5 DOWEL PIN USED FOR LOCATING TO DELTA TRANSDUCER.

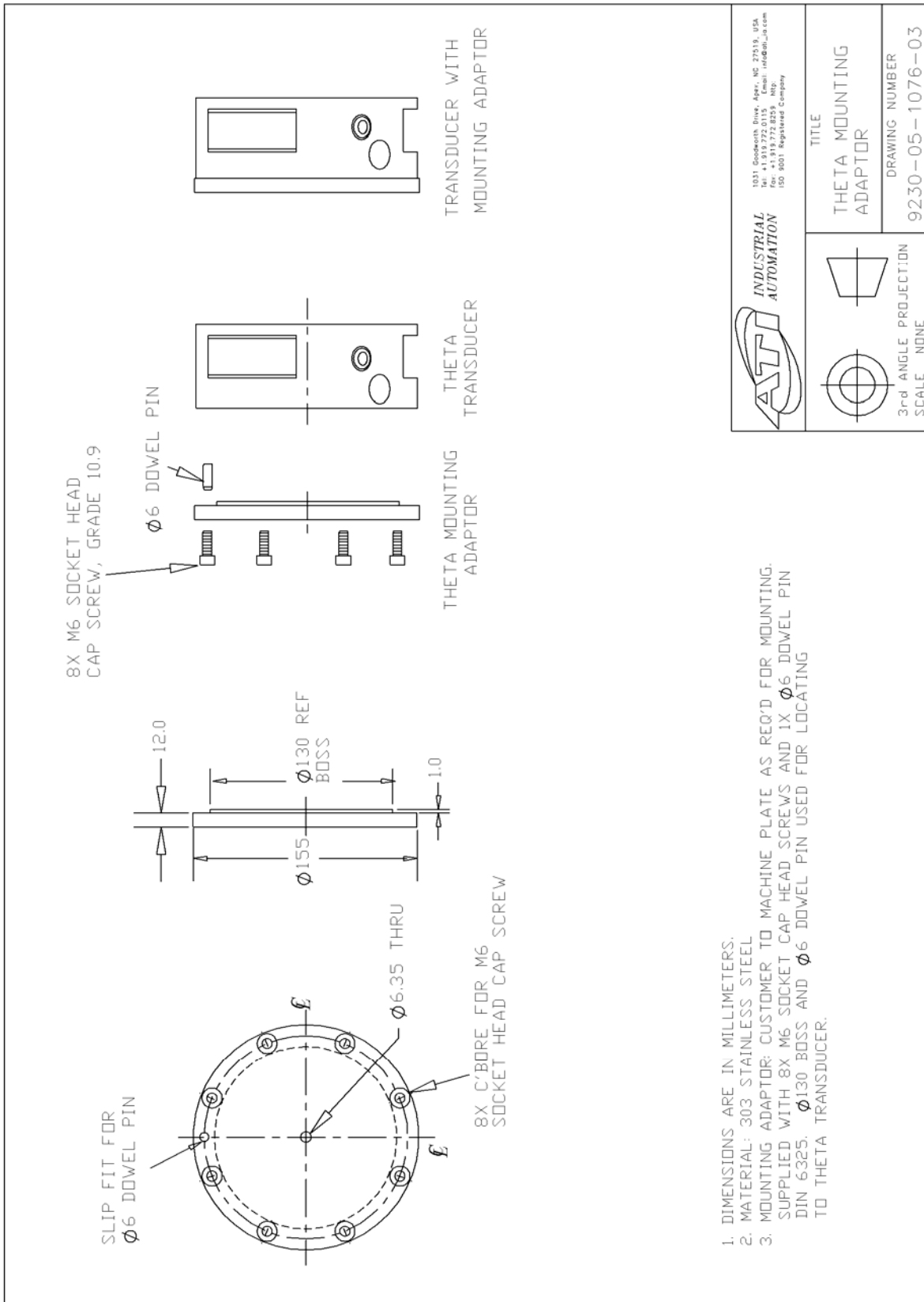
8.13 IP65 Rated DAQ Delta Transducer



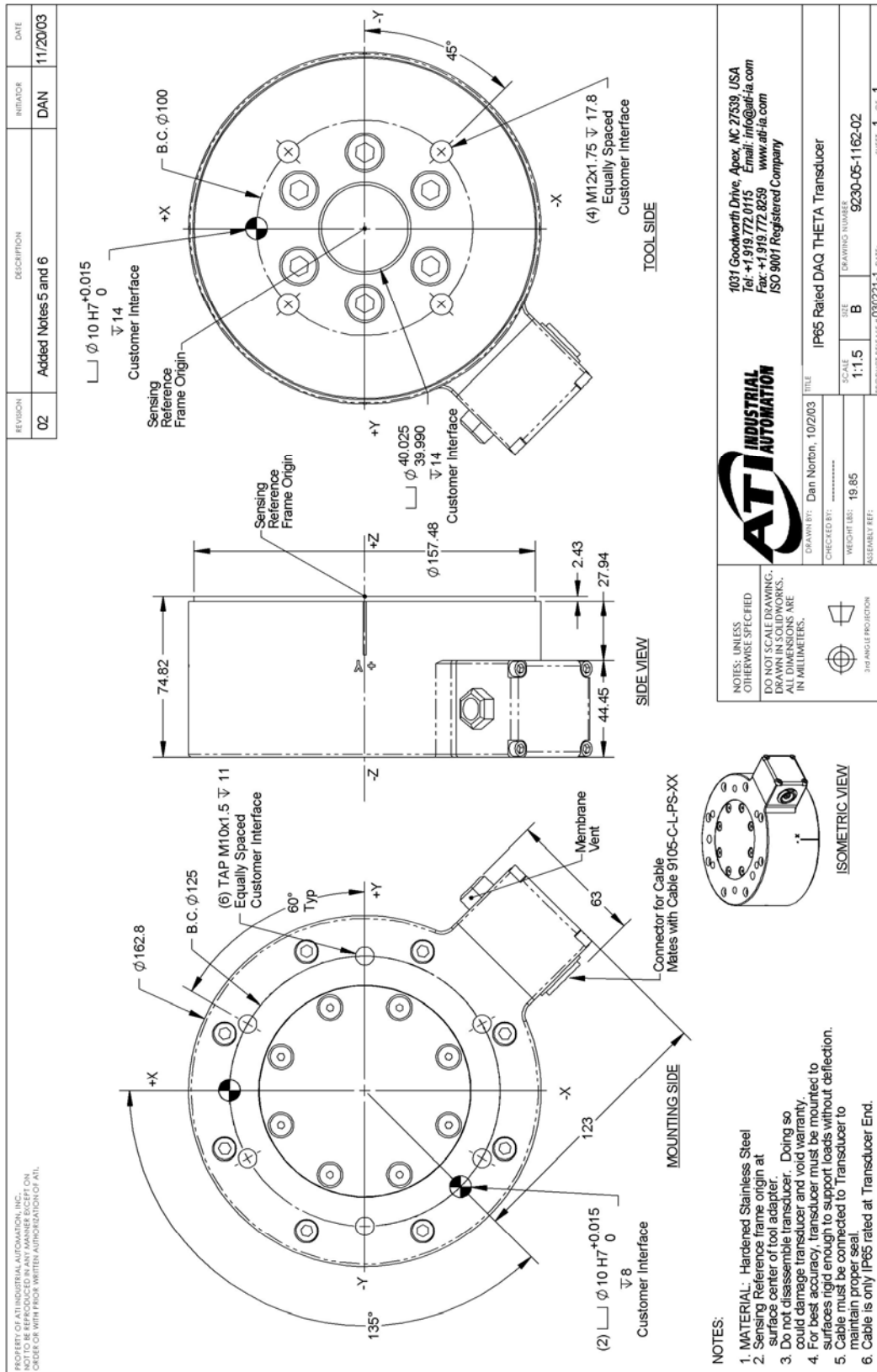
8.14 DAQ Theta Transducer with Mounting Adaptor Plate



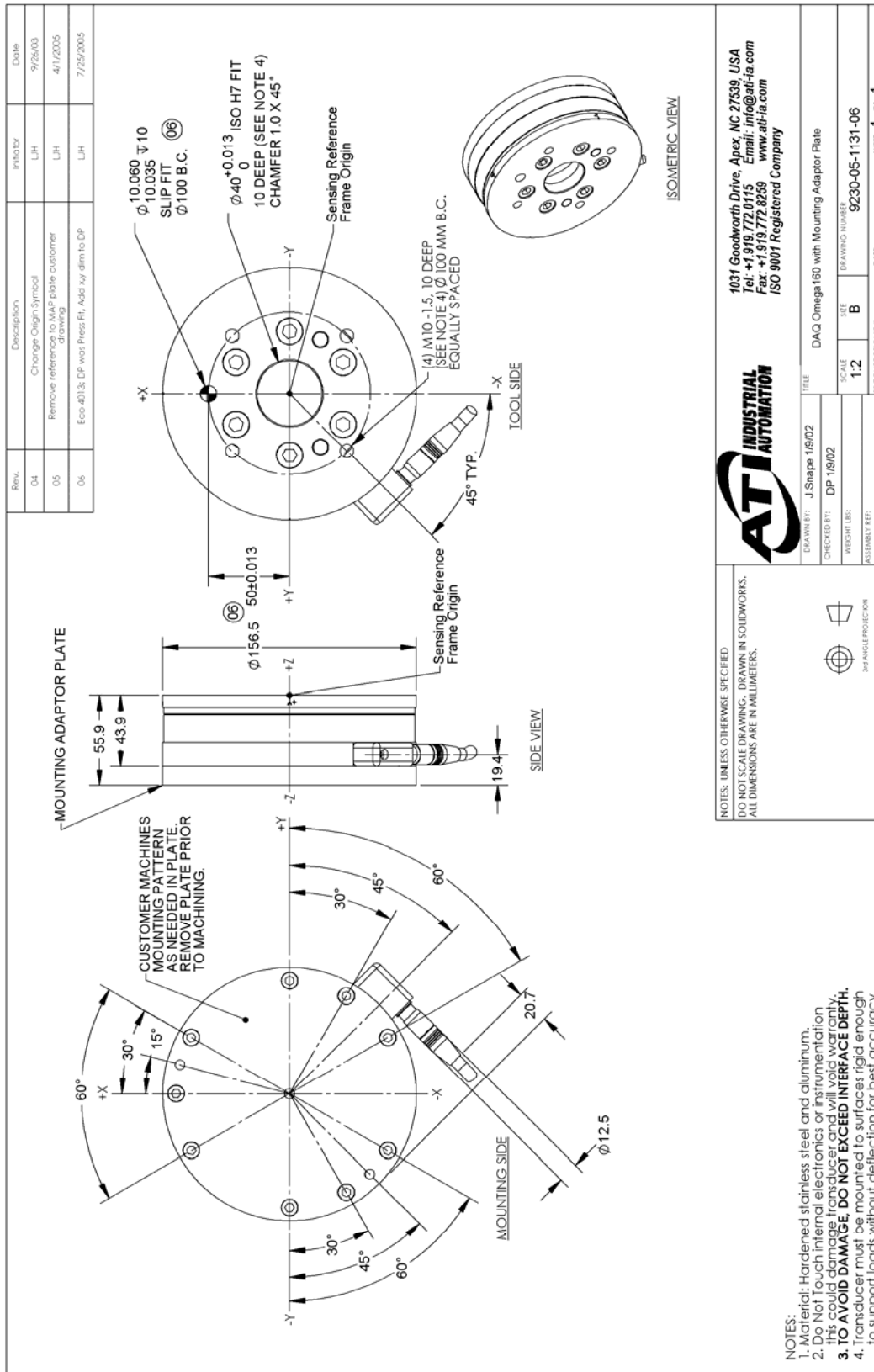
8.15 Theta Mounting Adaptor



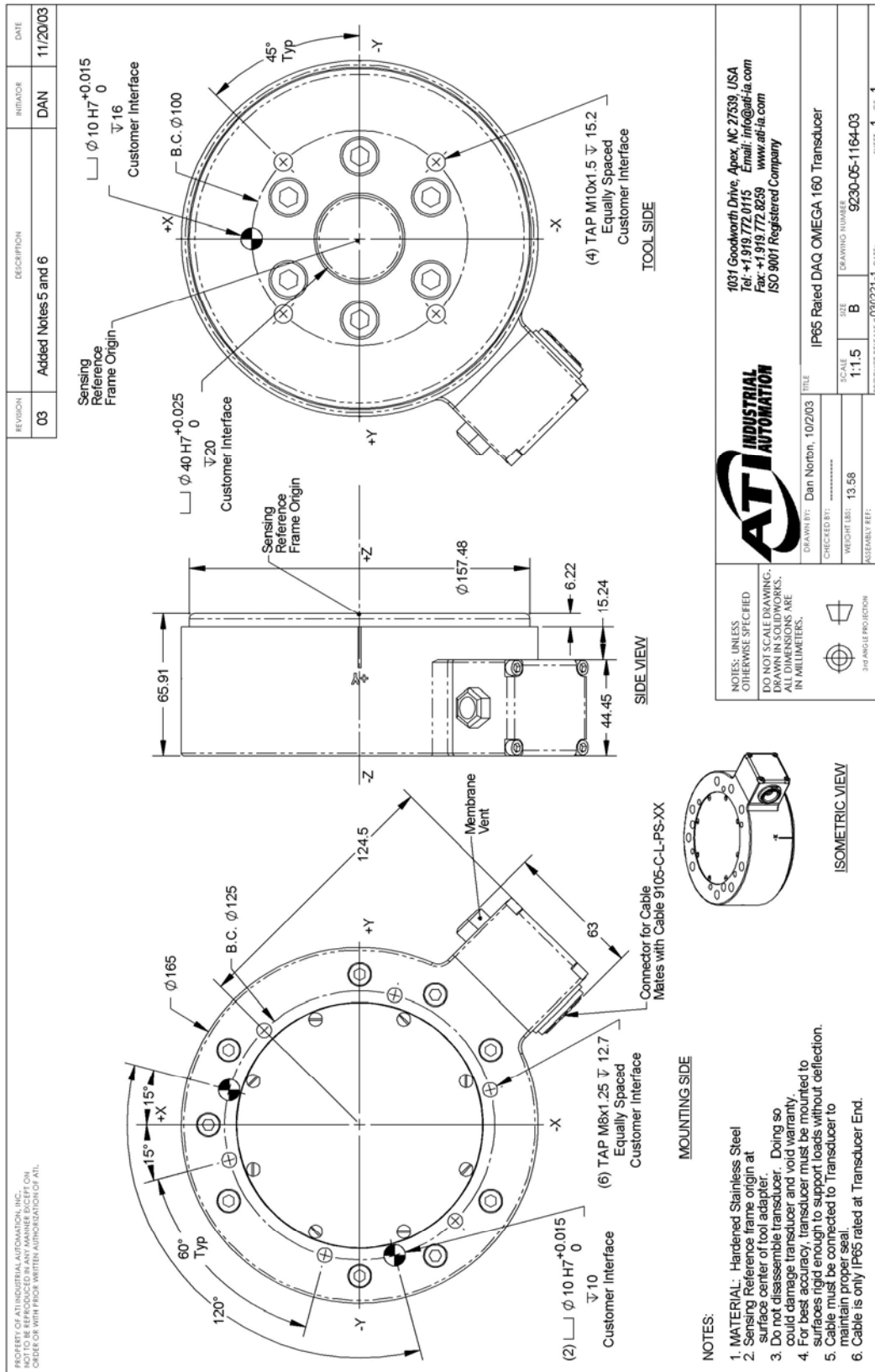
8.16 IP65 Rated DAQ Theta Transducer



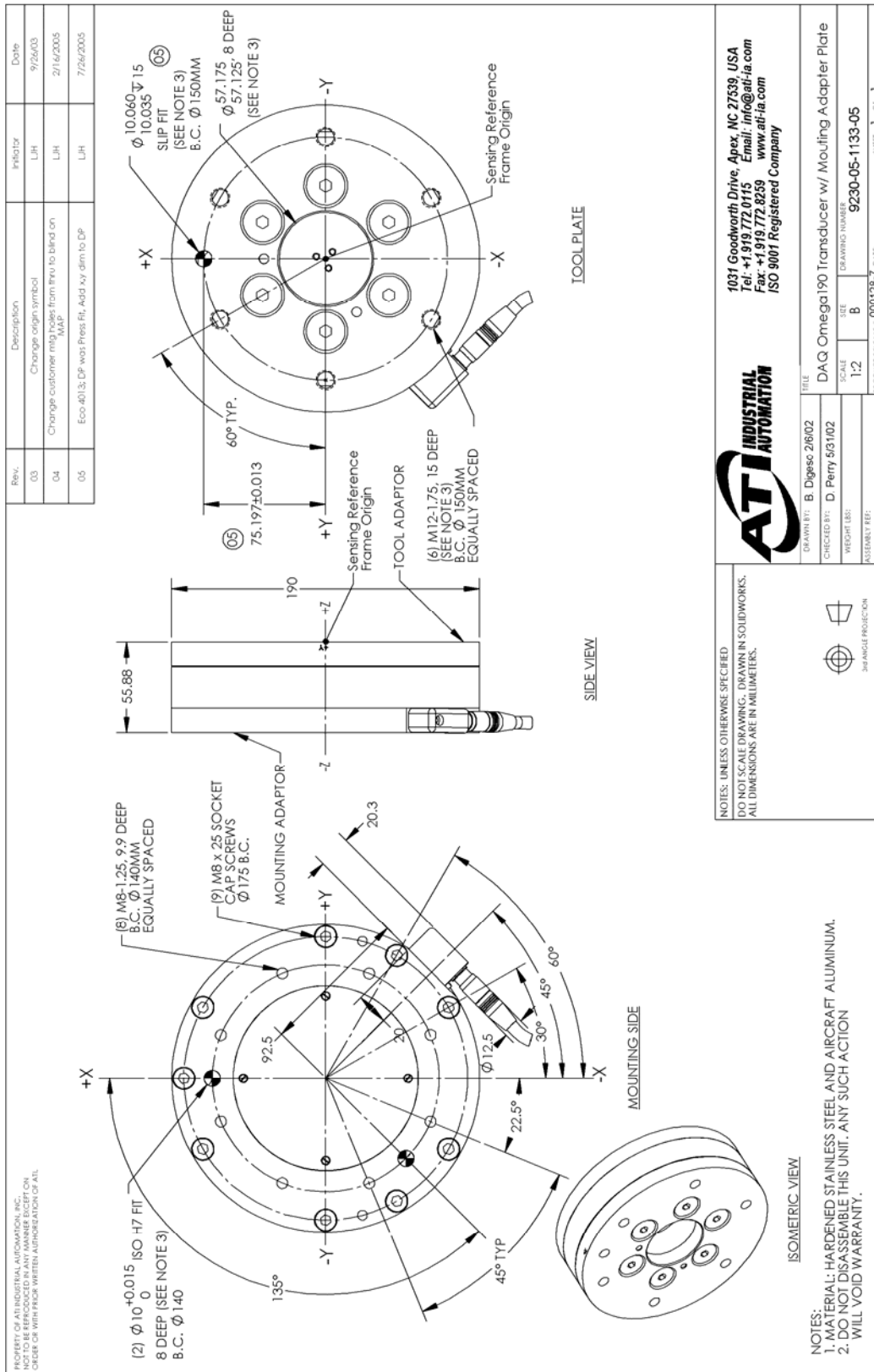
8.17 DAQ Omega160 with Mounting Adaptor Plate



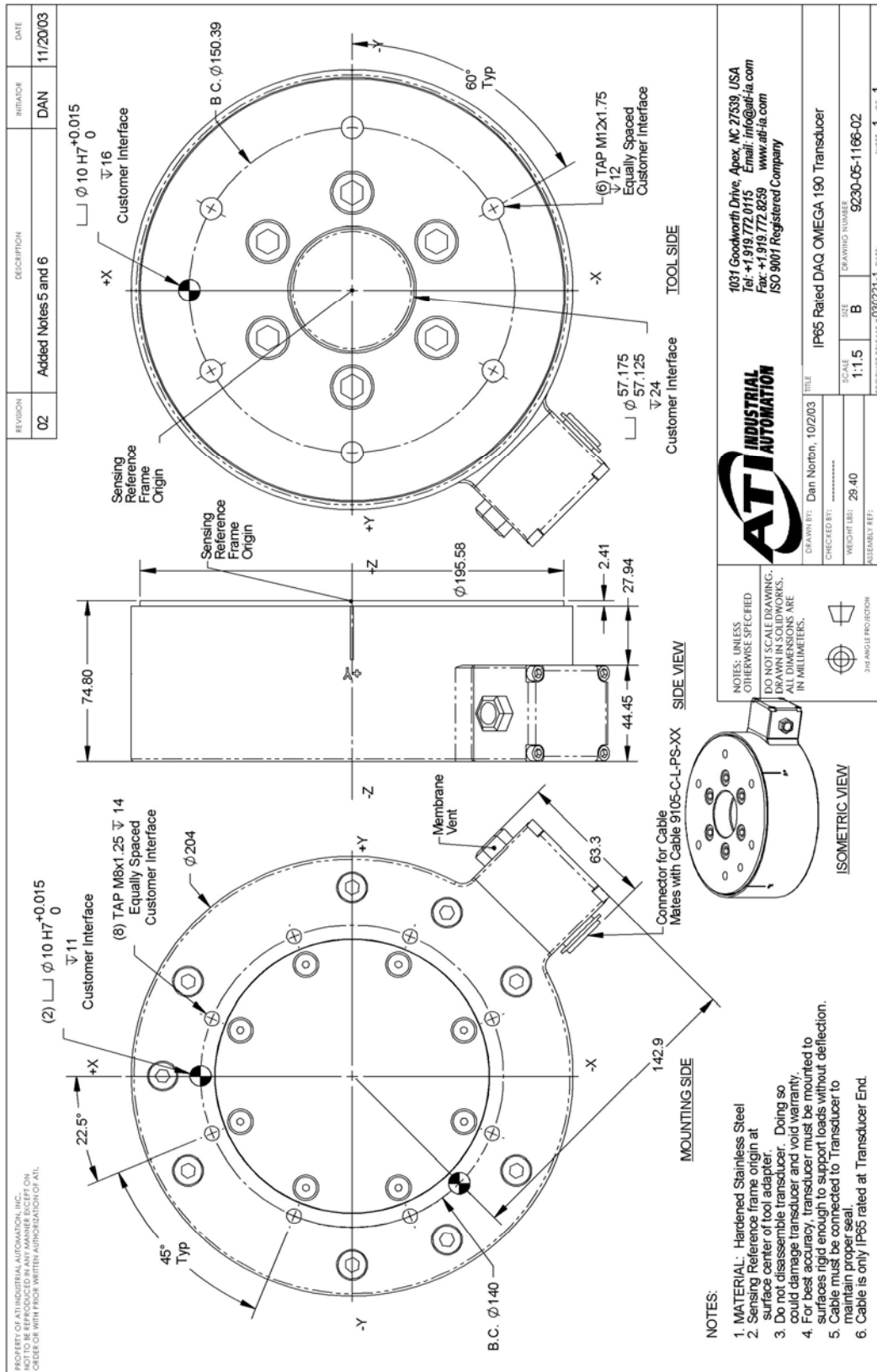
8.18 IP65 Rated Mux Omega 160 Transducer



8.19 DAQ Omega190 Transducer w/Mounting Adaptor Plate



8.20 IP65 Rated DAQ Omega 190 Transducer



9. Terms and Conditions of Sale

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

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

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

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

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

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

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

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

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