PHASE DYNAMICS

Technology That Produces
Precision Measurements

INSTALLATION
AND
INSTRUCTION
MANUAL

PHASE DYNAMICS, INC.
Standalone Water in Hydrocarbon Analyzer

July 28, 2006
Document Number 0062-00000-000C

WARRANTY

This Phase Dynamics product is warranted against defects in material and workmanship for a period of one year from date of shipment. During the warranty period, Phase Dynamics will, at it's option, either repair or replace products which are defective.

For warranty service or repair, this product must be returned to Phase Dynamics. Buyer shall prepay shipping charges to Phase Dynamics and Phase Dynamics shall pay shipping charges to return the product to the Buyer. However, Buyer shall pay ALL shipping charges, duties, and taxes for products returned to (or from) Phase Dynamics from (or to) a country other than the contiguous states of the United States of America.

Phase Dynamics warrants that its software and firmware designated by Phase Dynamics for use with an instrument will execute its programming instructions when properly installed on that instrument. Phase Dynamics does not warrant that the operation of the instrument, or software, or firmware will be uninterrupted or error free.

ATTENTION
The Analyzer Module is a sealed unit. Opening the unit will void the warranty. Any information contained within this document that refers to the internal configuration of the analyzer module is for authorized factory technician use only.

LIMITATION OF WARRANTY

The foregoing warranty shall not apply to defects resulting from improper or inadequate maintenance by Buyer, Buyer-supplied software or interfacing, unauthorized modification or misuse, operation outside of the environmental specifications for the product, or improper site preparation or maintenance.

EXCLUSIVE REMEDIES

The remedies provided herein are Buyer's sole and exclusive remedies. Phase Dynamics shall not be liable for any direct, indirect, special, incidental, or consequential damages, whether based on contract, tort, or any other legal theory.

PREFACE

SAFETY INFORMATION

THIS PRODUCT AND RELATED DOCUMENTATION MUST BE REVIEWED FOR FAMILIARIZATION WITH SAFETY MARKINGS AND INSTRUCTIONS BEFORE OPERATION.

SAFETY LABELS

WARNING
Denotes a hazard. It calls attention to a procedure, practice, or the like, which, if not correctly performed or adhered to, could result in personal injury. Do not proceed beyond a WARNING sign until the indicated conditions are fully understood and met.

CAUTION
Denotes a hazard. It calls attention to an operating procedure, practice, or the like, which, if not correctly performed or adhered to, could result in damage to or destruction of part or all of the product. Do not proceed beyond a CAUTION sign until the indicated conditions are fully understood and met.

BEFORE APPLYING POWER

Verify that the line voltage is appropriate for the analyzer. Refer to the installation section.

ELECTROSTATIC DISCHARGE

CAUTION
Protect circuit boards and terminals from ESD at all times.

All of the printed circuit board assemblies of this system are susceptible to damage from electrostatic discharge (ESD). Use appropriate grounding through the use of grounded wrist straps or other acceptable form of ESD protection when handling ESD sensitive components.

SAFETY EARTH GROUND

WARNING
An uninterruptible safety Earth ground must be provided from the main power source to the product input wiring terminals. Using Neutral as Earth Ground may cause a potential shock hazard that could result in personal injury.

This product is provided with a protective Earth terminal, located on the bottom of the oscillator housing.
Any interruption of the protective grounding conductor (inside or outside the instrument) or disconnecting the protective Earth terminal will cause a potential shock hazard that could result in personal injury.
Whenever it is likely that the protection has been impaired, the instrument must be made inoperative and be secured against any unintended operation.
If this instrument is to be energized via an autotransformer (for voltage reduction), make sure the common terminal is connected to the Earth pole terminal (neutral) of the power source.
Instructions for adjustments while covers are removed and for servicing are for use by service-trained personnel only. To avoid dangerous electrical shock, do not perform such adjustments or servicing unless qualified to do so.

ATTENTION LABELS

ATTENTION
Denotes an important step or technical note. It calls attention to an important procedure or note.

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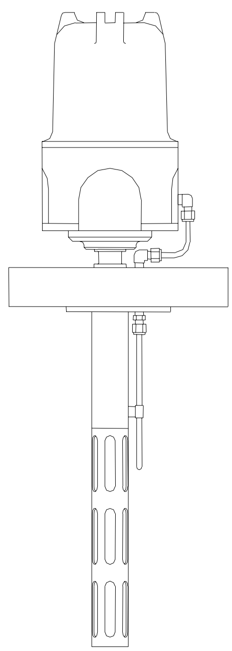
PHASE DYNAMICS, INC.

Standalone Water in Hydrocarbon Analyzer



1. ANALYZER SPECIFICATIONS

1.1 SYSTEM

Range of Measurement	0-4%, 0-10%, 0-20%, 0-Inversion, 80-100%, or 0-100% water content
Accuracy	±1.0% of scale
Repeatability	±0.05% of scale
Flowing Fluid Temperature	Low water content: 4° to 82°C, optional 93°C - high temperature unit Full water content: up to 315°C

1.2 ANALYZER MODULE + MEASUREMENT SECTION

Power Requirements	24VDC±10%, 1.5A
Ambient Operating Temperature	-20° to 50°C
Storage Temperature	-40° to 85°C
Pressure rating	Up to 1,500psig, depending on process connection
Installation weight and size:	See installation drawings in Appendix F

1.4 SYSTEM CABLE (OPTIONAL)

Composite cable, 9 Conductor, 3 Drain wires

COMP A:	(2)	Twisted, Shielded Pair (BRN|YEL) (BLU|WHT) Characteristic Impedance: Z_0 = 55.3Ω Velocity = $179x10^6$m/sec = 0.597C Resistance = 80.3Ω / 1000m Inductance = 309μH / 1000m Capacitance = 1000nF / 1000m Conductor type: #24AWG 19/36 TIN COPPER Insulation type: SR-PVC 0.254mm Shield: 0.0381mm A/M FOIL Drain wire: #24AWG 19/36 TIN COPPER
COMP B:	(1)	Twisted, Shielded Pair (ORG|GRY) Characteristic Impedance: Z_0 = 50.0Ω Velocity = $173x10^6$m/sec = 0.291C Resistance = 31.5Ω / 1000m Inductance = 289μH / 1000m Capacitance = 116nF / 1000m Conductor type: #20AWG 19/32 TIN COPPER Insulation type: PVC 0.406mm Shield: 0.0381mm A/M FOIL Drain wire: #20AWG 19/32 TIN COPPER
COMP C:	(3)	Conductor (RED) (BLK) (GRN) R/d = 19.5Ω / 1000m Conductor type: #18AWG 19/30 TIN COPPER Insulation type: PVC 0.406mm

Jacket Type	PVC 1.1mm
Jacket Color	Chrome Grey
Nominal Diameter (O.D.)	9.68mm
Temperature	105°C
Voltage	300V
Approvals	UL AWM 2517, CSA AWM FT1

1.5 STANDARD FEATURES

- Wetted metal 316L stainless steel
- No moving parts
- Real-time measurement of water content
- Temperature-compensated measurement for high accuracy
- Surge suppression at line voltage input
- Built-in self-tests for diagnostics
- Data logging to internal FLASH memory
- One MODBUS® RTU RS-485 communication channel
- Auxiliary communication channel of either RS-485 MODBUS® RTU or an isolated 4-20mA analog output with HART®. An open-collector driver-enable signal is provided.

1.6 OPTIONS

- Materials of construction (Duplex, Carpenter 20, etc.)
- Process connections: ANSI 150, 300, or 600 flanges; others upon request
- Extended analyzer ranges (i.e. 0-4%, 0-10%, 0-20%, 0-Inversion, 80-100%, or 0-100% available)
- Net Oil and Net Water Computer*: The module reads a user-supplied flow meter to calculate net oil, net water, and/or total fluid values; or the module accepts a user input for density.
- Density Correction*: The module reads a user-supplied densimeter to correct the water content calculation; or the module accepts a user input for density.
- Network Relay Option*: MODBUS® slaves can be "transparently" accessed indirectly through the main communication channel via the auxiliary channel.

*May require Auxiliary MODBUS® RTU RS-485 option

1.7 PC SOFTWARE & TOOLS

- *Data Log Fetch Tool**: retrieves logged data from the Module's internal memory through the main communication port and formats to CSV output.
- *Analyzer Configuration Utility**: loads program, reads memory and log data, displays current readings, configures with GUI, logs data, reads, and writes the module's configuration through the main communication port.
- *Mini Analyzer Configuration Utility**: loads program, reads memory and log data, reads, and writes the module's configuration through the main communication port.
- Research Analyzer*

* Requires a Windows-based computer with an RS-485 connection.

2. SYSTEM OVERVIEW

2.1 DESCRIPTION

This Phase Dynamics analyzer measures the percentage of water in a flowing hydrocarbon liquid stream. The measurement technique is based on a principle known as oscillator load-pull. The system is designed with no moving parts and is calibrated for the highest accuracy over a broad range of pressure, flow rate and temperature.

2.1.1 MEASUREMENT SECTION

The measurement sections, shown in Figures 2.1 and 2.2, are an assembly of

1. a measurement section,
2. a temperature sensor, and
3. a microwave oscillator/analyzer module mounted within a protective enclosure.

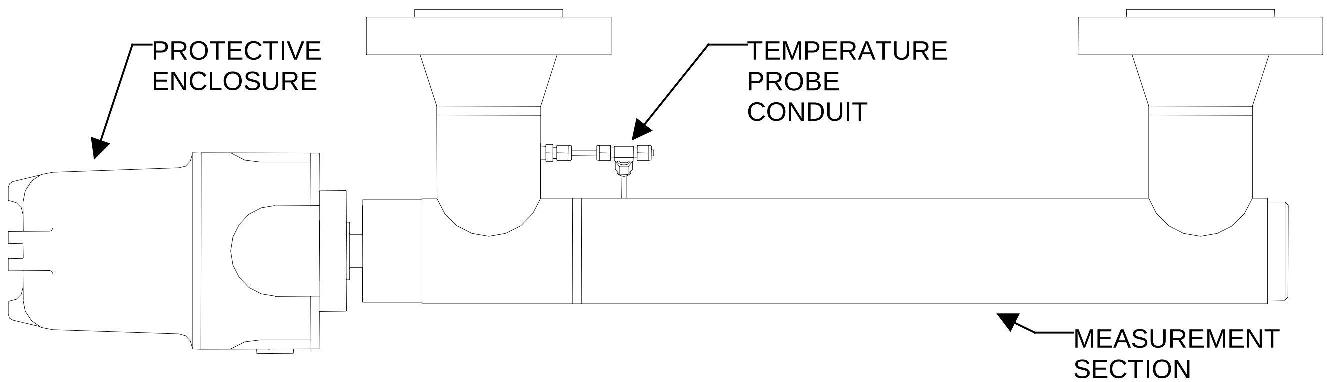


Figure 2.1 - Typical Flow-Through Measurement Section

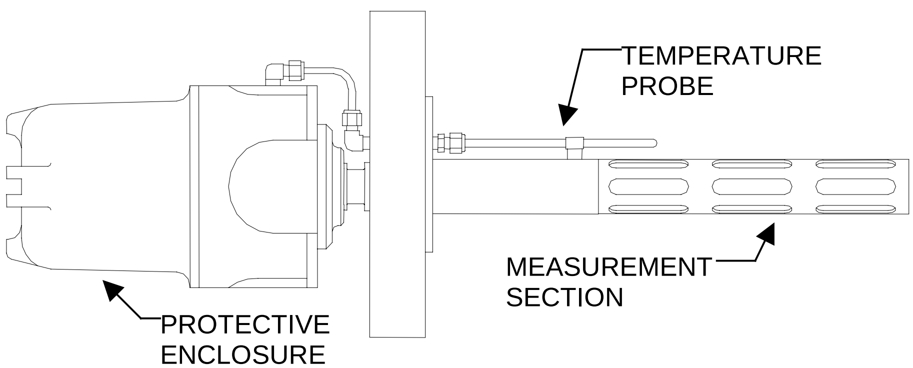


Figure 2.2 - Typical Insertion Measurement Section

2.2 TYPICAL OPERATION

During typical operation, the analyzer's operating sequence can be described as follows:

On power-up, the analyzer module performs a set of self-tests to assure functionality.

A heater maintains the oscillator at 70°C. This eliminates any frequency drift due to circuit temperature changes, which may result in errors in the water content calculation.

Fluids flowing through the measurement section act on the unbuffered microwave oscillator to force a change in its natural frequency of oscillation. The resultant frequency is measured and applied to the water content calculation.

The 4-wire RTD temperature sensor, protruding directly into the liquid stream through the measurement section wall of the saddle nearest the microwave oscillator, transmits the temperature signal to the analyzer module.

The analyzer measures the oscillator's reflected power and frequency. The reflected power and the frequency information is used to determine an out-of-range condition or the emulsion phase condition whereby the water content is calculated using the frequency and fluid temperature with factory-derived coefficients.

The frequency measurement cycle is repeated approximately once per second to provide a real-time measurement of water content.

While measuring the water content, the analyzer periodically executes self-test diagnostic functions to determine if any functional aspect of the system is in error. These self-tests are completed "in the background" and in no way affect the fundamental measurement or calculation of water content.

2.3 PRINCIPLE OF OPERATION (OSCILLATOR LOAD-PULL)

Phase Dynamics analyzers achieve superior performance by utilizing microwave oscillator load-pull. Load-pull is the term given to describe the frequency change of an unbuffered oscillator as its output load varies. Circuit components and the external load impedance determine an unbuffered oscillator's frequency. The permittivities of the materials in the measurement section through which the microwaves propagate determine the output load. For low-loss materials such as low water content crude oil, the dielectric constant approximates the permittivity of the emulsions.

A typical flow-through measurement section has a small solid rod mounted inside a larger diameter pipe, as shown in Figure 2.3. One end of the rod is connected to an unbuffered oscillator and the other end connects to the center of a welded "shorting" plug, or left open depending on the design. The rod may be bare or covered with ceramic. Electrically this pipe and rod combination is a coaxial transmission line terminating into a short-circuit or an open-circuit, depending on the type of analyzer. The fluids flow through the measurement section. The microwave signal travels the length of the center rod twice; down the pipe from the oscillator, then reflects at the end and traverses back to the oscillator module.

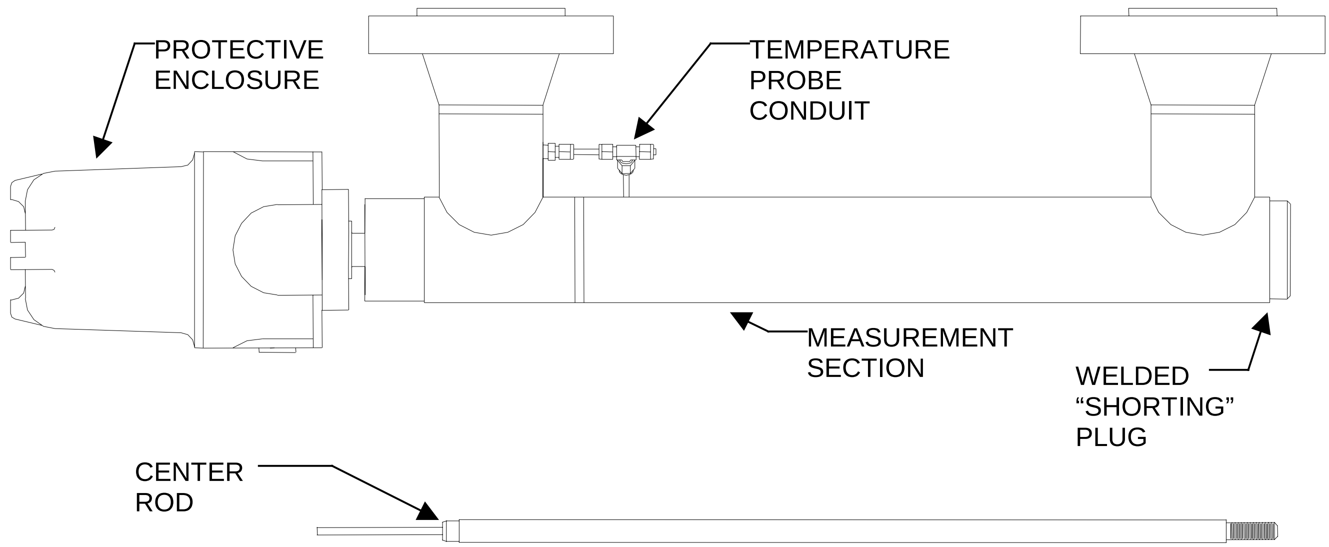


Figure 2.3 - Typical Flow-Through Measurement Section and Center Rod

Primarily, the dielectric constant of the emulsion in the measurement section determines the unbuffered oscillator’s frequency. There is a large difference in the relative dielectric constant of oil (2.2) and water (68). This large dielectric difference results in the design of an instrument of a manageable size and a reasonable oscillator frequency. The dielectric constant of the fluid is proportional to the water-to-oil ratio in the measurement section. As the complex load impedance changes, due to a change in the percentage of water in the oil, the frequency of the oscillator changes. The frequency and the fluid temperature are continuously measured. These values are used to calculate the water content.

In summary, the permittivity of the oil-water emulsion in the measurement section provides a complex impedance, or load. The load acts directly upon the unbuffered oscillator to force a predictable, repeatable and precise change in frequency. This frequency is proportional to the water content of the emulsion. The analyzer uses the measured frequency to calculate and update the water content every second.

2.4 OIL AND WATER CONTINUOUS EMULSIONS (FULL RANGE ANALYZERS)

Oil-water emulsions may exist in two phase-states. The emulsion may be described as water drops suspended in a continuous medium of oil (oil continuous or oil external) or oil drops suspended in a continuous medium of water (water continuous or water external). The phase of the emulsion is determined by a number of factors including water content, temperature, pressure, salinity, crude API, presence of emulsifiers, etc.

Furthermore, there is a wide range of water contents (about 40-90%) which may exist in either phase. The system must first determine the correct phase before any accurate water content data may be calculated.

The oscillator of each system contains two separate circuits, each operating at different frequencies. Each circuit is optimized for the best pulling for a particular phase - one oscillator for oil continuous emulsions and the other for water continuous emulsions. These circuits are often referred to as the Oil Oscillator and the Water Oscillator.

At times, two emulsions, one oil continuous and one water continuous, with significantly different water contents, may give the same measured frequency of the load-pull system. A second parameter is measured to distinguish the phase.

The emulsion phase-state is determined by the oscillator’s reflected power. Water continuous emulsions yield much lower reflected power levels than oil continuous emulsions because the energy is dissipated through the conductive water, as shown in Figure 2.4.

Oil continuous emulsions are much less lossy than water continuous emulsions. For this case, the microwave energy travels down the measurement section and back with very little loss in the emulsion itself; the reflected power level is higher than that for water continuous emulsions, as shown in Figure 2.4.
In summary, the system monitors the reflected power level to determine the phase. Oil continuous emulsions exhibit much higher power levels than water continuous emulsions. Once the phase is determined, the analyzer calculates the water content using the oscillator frequency correlating to the current emulsion phase.

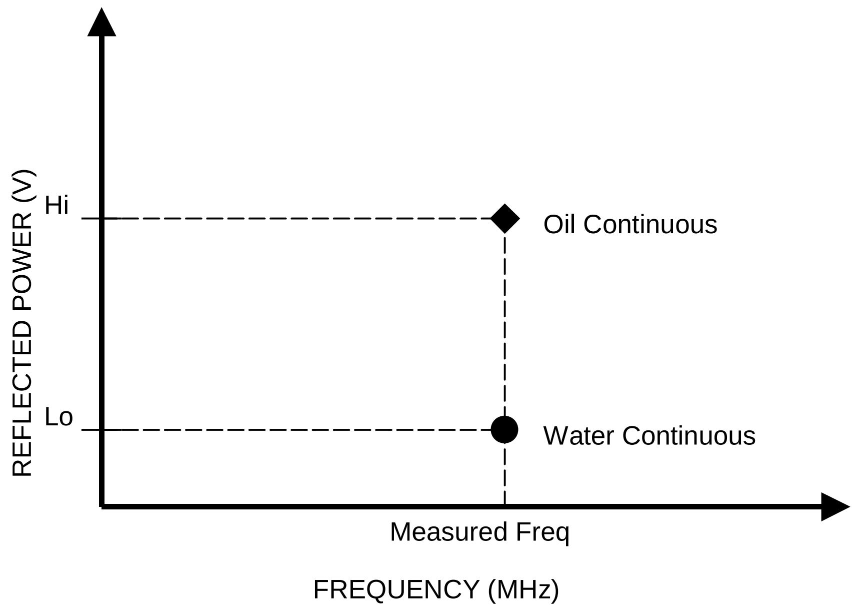


Figure 2.4 - Reflected Power Levels for Oil-Water Emulsions

2.5 EFFECT OF DISSOLVED SALTS (FULL & HIGH RANGE ANALYZERS)

For water continuous emulsions, dissolved salts significantly affect the load (measurement section plus liquids) as seen by the microwave oscillator. For oil continuous emulsions, dissolved salts have little or no effect. One measured frequency corresponds to a range of water contents in the water continuous phase, depending on the concentration of dissolved salts, as shown in Figure 2.5.

Each Phase Dynamics system includes compensation for effects due to dissolved salts. Accurate measurement and manual entry of the salinity is required for accurate water content measurements.

IMPORTANT
For optimum performance, it is IMPERATIVE that the salinity calibration routine be executed properly.

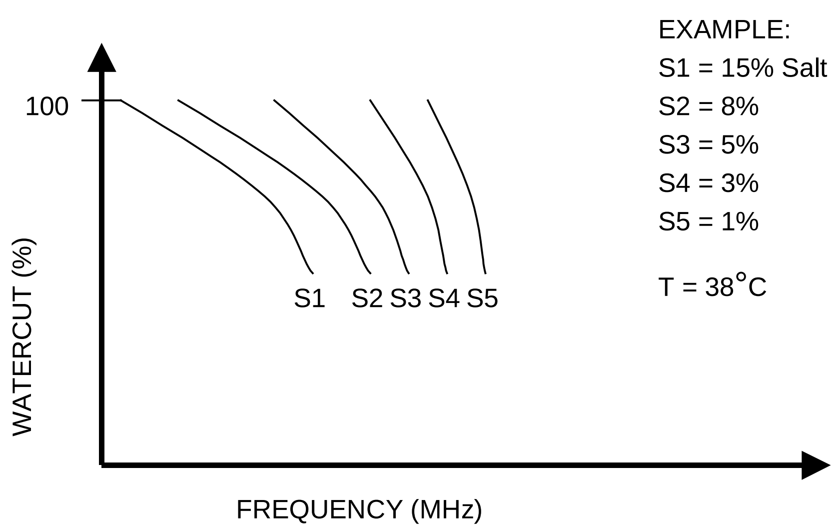


Figure 2.5 - Effect of Dissolved Salts

3. INSTALLATION

3.1 PRE-INSTALLATION NOTES

The materials of construction for Phase Dynamics analyzers are capable of withstanding a wide variety of harsh environments. The measurement section itself is made of standard pipe and flanges that are used on a routine basis for the industry serviced. The microwave oscillator is assembled in a protective housing which is then completely enclosed in an explosion-proof junction box, provided with a screw-on cap for access.

The oscillator inside the analyzer contains a miniature heater to maintain the critical circuit at 70°C. The junction box protecting the analyzer module is provided with an O-ring for the screw-on cap and forms a watertight seal.

3.2 MOUNTING CONSIDERATIONS

The preferred orientation of the measurement section is vertical with the analyzer end up. Fluid flow comes into the connection closest to the analyzer and exits the other port. For best results, liquid flow in the measurement section should be turbulent to keep the oil and water mixed and to “flush” any gas or water accumulation within the measurement section. (A static mixer may be necessary for very low flow rates.)

If free gas is present in the liquid stream, the output should be mounted higher than the input to allow the gas to escape the measurement section. Gas tends to decrease the calculated water content.

For slipstream applications, verify that the fluids flowing through the measurement section precisely represent the fluids of the main stream. For best results in slipstream plumbing, the input line-pipe should be the same diameter, or smaller, as that of the measurement section.

While the above guidelines are the preferred orientation, field experience has verified the accurate measurement of water content for a variety of mounting schemes, including vertical, either end up, horizontal, flanges up or down, and the measurement section “on its side”.

The most important points to keep in mind are:

1. well-mixed water and oil in the measurement section,
2. turbulent flow,
3. zero gas content (or, at least, long term constant gas content), and
4. representative emulsions in slip-streams.

3.3 INSTALLATION DRAWINGS

Detailed installation drawings are included with each system to assist in preparation of mounting and installation. Refer to the appropriate drawings for installation of your particular system.

3.4 BASIC ELECTRICAL WIRING

Mount the measurement section according to the appropriate installation drawing.

Failure to provide EARTH GROUND may cause a shock hazard that could result in personal injury. Also, the instrument may be damaged and will not operate properly - the warranty is voided.

WARNING
An uninterruptible safety Earth ground MUST BE provided from the main power source to the Power input board terminal marked EARTH GROUND.

Connecting NEUTRAL to EARTH GROUND is NOT sufficient for safety Earth ground.

Please refer to the installation drawings for more wiring options.

Each Phase Dynamics analyzer is equipped to measure the process stream temperature with a 4-wire RTD. Verify that the wires of the temperature probe are connected properly to the plug on the end of the analyzer module.

Once connected, the Phase Dynamics analyzer is ready for the startup procedure.

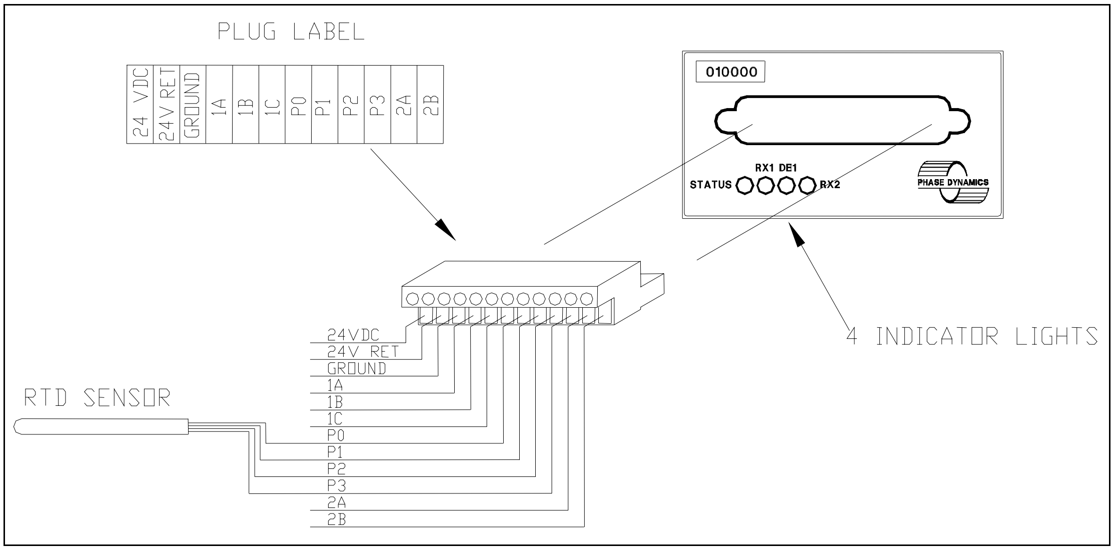


Figure 3.1 - Analyzer Plug Wiring Diagram

Table 3.1 - Typical Analyzer Wiring (RS-485 Network Port)

Terminal	Wire Color	Function
24 VDC	RED	24VDC
24V RET	BLACK	24VDC RETURN
GROUND	GREEN	EARTH GROUND
1A	WHITE	NETWORK PORT: A – RS-485
1B	BLUE	NETWORK PORT: B – RS-485
1C	GRAY	NETWORK PORT: C – Driver Enable (Open-Collector output)
P0	RED	RTD DRIVE HIGH
P1	RED	RTD SENSE HIGH
P2	BLACK	RTD SENSE LOW
P3	BLACK	RTD DRIVE LOW
2A	BROWN	MODBUS PORT: A – RS-485
2B	YELLOW	MODBUS PORT: B – RS-485
GND LUG	USER (GREEN)	EARTH GROUND
-	DRAIN (BLU|WHT)	MODBUS PORT DRAIN
-	DRAIN (BRN|YEL)	NETWORK PORT DRAIN
-	DRAIN (ORG|GRY)	NOT USED
-	ORANGE	NOT USED

Table 3.2 - Typical Analyzer Wiring (HART Network Port)

Terminal	Wire Color	Function
24 VDC	RED	24VDC
24V RET	BLACK	24VDC RETURN
GROUND	GREEN	EARTH GROUND
1A	WHITE	NETWORK PORT: A – isolated current return
1B	BLUE	NETWORK PORT: B – isolated current output
1C	GRAY	NETWORK PORT: C – Driver Enable (Open-Collector output)
P0	RED	RTD DRIVE HIGH
P1	RED	RTD SENSE HIGH
P2	BLACK	RTD SENSE LOW
P3	BLACK	RTD DRIVE LOW
2A	BROWN	MODBUS PORT: A – RS-485
2B	YELLOW	MODBUS PORT: B – RS-485
GND LUG	USER (GREEN)	EARTH GROUND
-	DRAIN (BLU|WHT)	MODBUS PORT DRAIN
-	DRAIN (BRN|YEL)	NETWORK PORT DRAIN
-	DRAIN (ORG|GRY)	NOT USED
-	ORANGE	NOT USED

3.5 COMMUNICATION CONNECTIONS

3.5.1 MAIN MODBUS® RTU CONFIGURATION PORT #2

The main MODBUS® RTU RS-485 port, labeled 2A(+) & 2B(-), can be used for various functions.
1. Phase Dynamics utilities, configuration tools, etc
2. Operator interface terminal
3. SCADA application designed by the user

The receiver's input resistance is 12kΩ.
The slew rate limited port has fuse protection, ESD protection, and transient voltage suppression.
Indicator RX2 indicates incoming data.
Please refer to Appendix A for more information about MODBUS®.

TECH NOTE
Internal dip switch 54.S2C forces default port settings for port 2 on restart.

3.5.2 AUXILIARY NETWORK COMMUNICATION PORT #1

There are two options on the basic auxiliary communication card.
1. MODBUS® RTU
2. HART® / ISOLATED ANALOG OUTPUT (4-20mA)

A transmit indicator signal is available on 1C. When transmitting on port 1, 1C goes low and the driver-enable indicator DE1 illuminates.
1C is an optically isolated open-collector output and must be pulled up for operation and is ground referenced at 24V RET. Terminal 1C has reverse-voltage protection, ESD protection, and transient voltage suppression. The maximum pull-up voltage is 24VDC and the maximum current draw is 40mA. A 10kΩ 1/8W pull-up resistor is recommended.

TECH NOTES
1. **The internal dip switch 56.S1D enables the 10kΩ pull-up resistor to the internally protected 24VDC, for terminal 1C.**
2. **Dip switch 54.S2B forces default port settings for port 1 on restart.**

MODBUS® RTU

The network MODBUS® RTU RS-485 port, labeled 1A(+) & 1B(-), can be used for any SCADA application.
The receiver's input resistance is 12kΩ.
The slew rate limited port has fuse protection, ESD protection, and transient voltage suppression.
Indicator RX1 shows incoming data.
Please refer to Appendix A for more information about MODBUS®.

TECH NOTES
1. The maximum allowable common-mode voltage range is –7V to +12V.

HART® / ISOLATED ANALOG OUTPUT (4-20mA)

The network HART® BELL202 / ISOLATED ANALOG OUTPUT (4-20mA) port, labeled 1A(-) & 1B(+), can be used for any HART® application.
The $1kV_{RMS}$ isolated 4-20mA output is self-powered. The maximum allowable loop resistance is 600Ω.
The port has fuse protection, ESD protection, and transient voltage suppression
Please refer to Appendix B for more information about HART®.

TECH NOTE
Dip switch 56.S1B enables the current output to terminal 1B. Dip switch 56.S2A enables the current loop return through terminal 1A. Dip switch 56.S2B enables the BELL202 output to terminal 1B. For BELL202 and/or loop operation, 56.S2A must be enabled. These dip switches control the MODBUS® port options on this card and shall remain OFF: 56.S2C, 56.S2D, 56.S3A, 56.S3B, 56.S3C, and 56.S3D.

4. DETAILED FUNCTIONAL DESCRIPTIONS

Following is a description of various operating routines for the Phase Dynamics analyzer and functional descriptions of each printed circuit board. The analyzer module is sealed and user access is not recommended. If the analyzer is opened, the warranty may be voided.

4.1 POWER-UP SYSTEM TESTS

Upon powering up, the system executes a series of self-tests. The user configuration CRC is verified for device integrity. If it fails, the factory backup configuration is checked and copied over the user configuration. If the factory CRC fails, the analyzer sets up basic default values in order to function. The SRAM is tested for bit failure.

After passing self-test the microprocessor initializes the data and peripherals. The software is interrupt driven and the main loop updates the LCD with the latest values and checks for any switches which have been pressed.

4.2 PERIODIC SELF TESTS

The major functional areas checked by the built-in tests are:

- program memory integrity (FLASH)
- configuration memory integrity (FLASH)
- internal microprocessor memory (INTRAM)
- data memory (EXTRAM)
- time base check

4.3 TYPICAL OPERATION

The microprocessor reads the counters and computes a raw frequency from the microwave oscillator. The fluid temperature is measured. The temperature-compensated water content value is then calculated by using the coefficients, which were determined during calibration and stored in FLASH memory.

4.4 POWER AND SIGNAL CONDITIONING BOARD

All boards connect to this board. All signals, either internal or external (on terminal plug), pass through this board. This board does many functions:

- fuses and surge protection for all external connections
- Power conditioning and distribution
- signal conditioning
- analog conversion for the measurement and tuning
- RS-485 transceiver for port 2

4.5 PROCESSOR BOARD

A Digital Signal Processor (DSP) performs calculations and controls the hardware. A Complex Programmable Logic Device (CPLD) is programmed to measure frequency and control various logic functions related to the hardware.

The processor board functions include:

- status and communication indicator lights
- oscillator control
- oscillator heater enable

- communication through ports 1 and 2 with UART and various protocols
- frequency measurement
- read ADC conversions for input voltages
- set DAC for output control voltages such as the tuning voltage
- process and RTU calculations
- RTU functions
- diagnostic functions

PB1 causes a system reset.
The dip switches play an important role in the initial factory programming of the processor board using the JTAG header J2. Initially, the CPLD is programmed and the boot loader program is stored into FLASH memory.
Normally, it is best to chain the JTAG ports of each device. This is done by turning ON: S1A, S1D, S2D and turning OFF: S1B, S1C.
For independent JTAG operation, turn OFF: S2D and

- for CPLD: turn ON: S1A, S1C and turn OFF: S1B. S1D
- for DSP: turn ON: S1B, S1D and turn OFF: S1A. S1C

S2B and S2C will force the port defaults upon reset. The defaults are listed in Table 6.1.

Table 4.1 - DIP SWITCH 54.S1

A	B	C	D
JTAG CPLD TDI	JTAG DSP TDI	JTAG CPLD TDO	JTAG DSP TDO

Table 4.2 - DIP SWITCH 54.S2

A	B	C	D
ENABLE WATCHDOG TIMER	FORCE PORT 1 DEFAULTS	FORCE PORT 2 DEFAULTS	JTAG CPLD TDO → DSP TDI

Table 4.3 - Port Default Settings

Parameter	Port 1 MODBUS®	Port 1 HART®	Port 2 MODBUS®	MODBUS® (strict rules)
Slave Address	1	0	1	-
Baud Rate	9600	1200	9600	-
Number of Bits	8	8	8	8
Parity	None	Odd	None	-
Number of Stop Bits	1	1	1	1
End of Transmission Delay	10.0	1.0	10.0	3.5
Transmit Prefix	1.5	1.5	1.5	0.0
Transmit Suffix	0.0	1.0	0.0	0.0
Network Watchdog	50.0	2.0	50.0	1.5

Table 4.4 - Definitions of timing parameters (in byte-times):

End of Transmission Delay	The time from the end of transmission that the receiving device must wait until it can begin its response. (Response Delay)
Transmit Prefix	The time that the transmitter holds the network at a STOP (1) condition prior to sending the data.
Transmit Suffix	The time that the transmitter holds the network at a STOP (1) condition after sending the data.
Network Watchdog	The time to reset the incoming packet state if no data has been received. Incoming data will continually reset this timer.

There are four status indicator lights that are located on the front panel of the analyzer module.
The main status indicator blinks 1 time per second when there are no diagnostic errors, otherwise it blinks at twice that rate. When the boot loader is executing, the status indicator blinks very fast.

Table 4.5 – Indicator Lights

INDICATOR	DESCRIPTION
STATUS	1. This indicator flashes 1 once per second if DIAGNOSTICS = 0. Otherwise it flashes twice per second. 2. On boot, the STATUS light will flash fast while the boot loader is operating. 3. When storing data to FLASH memory, the light will remain ON.
RX1	ON while data (0) is being received on port 1
DE1	ON while port 1 is transmitting
RX2	ON while data (0) is being received on port 2

The boot loader is a small program that looks for commands during the first 5 seconds after power-up. It. can read, write, and configure the analyzer module with commands and data sent through port 2. The boot loader can read and write to anywhere within the FLASH memory; using the Intel hex file format. The typical functions of the boot loader are:

- store the main program into FLASH memory
- clear the configuration
- restore the factory configuration
- set the Analyzer Module ID number
- set the Phase Dynamics, Inc. ESN (one time only)

An external watchdog should cause a reset in the event that the processor “hangs”. The watchdog is enabled by turning ON: S2A. The CPLD may disable the watchdog for time-extensive events such as programming the FLASH memory.

4.6 MICROWAVE OSCILLATOR BOARD

The measurement section and the analyzer module are considered a MATCHED SET. Information derived about the measurement section and oscillator during calibration is stored in FLASH memory on the processor board.

IMPORTANT
THE ANALYZER MODULE SHOULD NEVER BE REMOVED FROM THE MEASUREMENT SECTION!

The microwave oscillator is heated to maintain an internal temperature of approximately 70°C, for stable operation. It has no output buffer amplifier or isolation circuit, which are typically used in oscillator applications.

4.7 AUXILIARY BOARD

The auxiliary board controls terminals 1A, 1B, and 1C. They are surge and fuse protected.

4.7.1 RS-485 + BELL202 + 4-20mA CURRENT LOOP MODULE

This is a factory configurable, universal option that may be setup for

1. RS-485 (MODBUS®),
2. BELL-202 (HART®),
3. 4-20mA current loop output, or
4. BELL-202 (HART®) + 4-20mA current loop output.

The current loop is DC isolated and self-powered. Limited versions of this board are available. (ie: RS-485 only)

DIP SWITCH 56.S1

A	B	C	D
PORT1 TYPE Indicator ON: MODBUS® RS-485 OFF: HART® BELL-202	CURRENT LOOP Enable 4-20mA source	N/A	Enable 10kΩ PULLUP resistor to 24VDC on terminal C1

DIP SWITCH 56.S2

A	B	C	D
CURRENT LOOP Enable 4-20mA return and BELL-202 common	BELL-202	RS-485 terminal A	RS-485 terminal B

DIP SWITCH 56.S3

A	B	C	D
Enable 620Ω PULLUP to 3.3VDC on terminal A	Enable 620Ω PULL-DOWN on terminal B	Enable RC termination across A & B	Shunt capacitor on termination

5. CALIBRATION PROCEDURE

5.1 FACTORY CALIBRATION - LOW & MID RANGE ANALYZERS

Each Phase Dynamics Analyzer is carefully calibrated at the factory prior to delivery. A precisely controlled flow loop is used to determine the unit's frequency response as a function of water content. This response determines the coefficients used to compute water content from the measured frequency. The calibration flow loop is also used to measure the effects of temperature on the system. This provides for a temperature compensated water content calculation. Appendix D includes a comparison of various laboratory methods for the determination of water in crude oil.

5.2 FIELD CALIBRATION - LOW & MID RANGE ANALYZERS

Field conditions may differ from those simulated in the factory. The analyzer may require field adjustment to compensate for these differences. A worksheet is included to assist in field calibration of the analyzer. The recommended procedure for field calibration of the analyzer is as follows:

5.2.1 MANUAL CALIBRATION

1. Collect an appropriate sample of crude oil and water for analysis. The sample must represent the crude oil and water flowing through the measurement section.
2. While collecting the sample, note and record the analyzer's displayed Water Cut value.
3. Record the fluid temperature displayed by the analyzer, Oil Adjust , and Oil Index values.
4. Measure the water content of the sample via some laboratory method (distillation or titration recommended).
5. Compare this result to the analyzer's displayed value.
6. Repeat the above steps of collection and analysis for a few samples and a range of water contents.

Calculate the difference for each pair of displayed and measured water contents. Typically, the difference will be constant for all the samples.
Enter the Oil Adjust value needed so that the displayed water content is equal to the laboratory-measured water content. When done, save the configuration.
If the difference between the displayed and laboratory-measured values vary appreciably for several samples, collect and analyze enough samples to be confident that the difference is not constant. If necessary, call Technical Support for assistance.

5.2.2 AUTOMATIC CALIBRATION

1. Command the analyzer to CAPTURE data for the current phase and stream.
2. Meanwhile, collect an appropriate sample of crude oil and water for analysis. The sample must represent the crude oil and water flowing through the measurement section.
3. When the analyzer has completed its sampling, command the analyzer to SAVE the data.
4. Measure the water content of the sample via some laboratory method (distillation or titration recommended).
5. Enter the measured value into the Water Cut field and the analyzer will automatically calculate the Oil Adjust based on the data when the sample was taken.
6. Save the configuration.

5.3 FACTORY CALIBRATION - FULL & HIGH RANGE ANALYZERS

Each Phase Dynamics Analyzer is carefully calibrated at the factory prior to delivery. A precisely controlled flow loop is used to determine the unit's frequency response as a function of water content. This response determines the coefficients used to compute water content from the measured frequency. For water external emulsions, dissolved salts affect the analyzer's response. The instrument is factory calibrated over a wide range of dissolved salts using Sodium Chloride (NaCl). In the field, dissolved salts are determined by several dissolved solids including barium, bicarbonate, calcium, carbonate, chloride, iron, magnesium, potassium, sodium, sulfate, etc. The calibration flow loop is also used to measure the effects of temperature on the system. This provides for a temperature compensated water content calculation. Appendix D includes a comparison of various laboratory methods for the determination of water in crude oil.

5.4 FIELD SALINITY CALIBRATION - FULL & HIGH RANGE ANALYZERS

Since the load-pull system is sensitive to dissolved salts for water continuous emulsions, it is very important to field calibrate for water salinity at any appropriate time. These times may include new well, new product, new formation, change in season, change in background of water, process change resulting in a different water salinity, etc.

IMPORTANT
For optimum performance, it is IMPERATIVE that the salinity calibration routine be executed properly.

5.4.1 AUTOMATIC CALIBRATION

To calibrate for the current water salinity, pump through (or pour into) the measurement section a water sample representative of the produced water under test. It is recommended to complete the salinity calibration for the highest water content attainable. At a minimum, salinity calibration must be executed for water continuous emulsions.

1. Command the analyzer to CAPTURE data.
2. Meanwhile, collect an appropriate sample of crude oil and water for analysis. The sample must represent the crude oil and water flowing through the measurement section.
3. When the analyzer has completed its sampling, command the analyzer to SAVE the data.
4. Measure the water content of the sample via some laboratory method (distillation or titration recommended).
5. Enter the measured value into the Water Cut field and the analyzer will automatically calculate the Salinity based on the data when the sample was taken.
6. Save the configuration

The Salinity Calibration routine is used to compensate for the difference between the salinity compositions of the field water and the factory calibration water. The salinity of the water used during the factory calibration is determined by the amount of pure sodium chloride (NaCl) in water. In the field, the apparent salinity of the water is determined by several dissolved solid species including barium, bicarbonate, calcium, carbonate, chloride, iron, magnesium, potassium, sodium, sulfate, etc. The Salinity Calibration should be completed the first time a new stream ID is defined or when the composition of the field salinity has changed.
This routine calculates the Salinity based on the sodium chloride concentrations used in the factory calibration.
Each and every stream should be initially calibrated using the Salinity Calibration routine. Each stream ID will include a corresponding Salinity value.

Date: ________________ Location:___________________

Serial Number of Unit: ___________________________________
Method of Calibration: ___________________________________
Calibration Worksheet

Sample ID	Time	Displayed Temp	Displayed Water Content	Measured Water Content	Oil Adjust	Oil Index	Water Index	Salinity

6. THEORY OF OPERATION - LOW RANGE ANALYZERS

The following sections describe, in detail, the specific operation of the Phase Dynamics load-pull system and how it is used to measure water content. The sections are separated into two main parts - one describing the fundamental behavior of the instrument to changing water content and one describing temperature effects.

6.1 DETAILED DESCRIPTION OF FREQUENCY RESPONSE

The load-pull system relates a measured oscillator frequency to water content. During factory calibration, coefficients are derived to relate the measured frequency to water content for a given temperature. The water content is calculated as follows;

$$\begin{aligned}\text{Water content} = \; & O3 \times (\text{Frequency} + \text{Oil Index})^3 \\ + \; & O2 \times (\text{Frequency} + \text{Oil Index})^2 \\ + \; & O1 \times (\text{Frequency} + \text{Oil Index}) \\ + \; & O0 \\ + \; & \text{Oil Adjust}\end{aligned}$$

where Frequency is the measured oscillator frequency,

O3, O2, O1 and O0 are the oil constants (O-constants),

Oil Index is a frequency index value, and

Oil Adjust is a linear offset value.

The factory default values for Oil Index and Oil Adjust are zero (0). In this case the above equation simplifies to;

$$\text{Water content} = O3 * \text{Freq}^3 + O2 * \text{Freq}^2 + O1 * \text{Freq} + O0.$$

Figure 6.1 shows a typical factory calibration curve for constant temperature.

To compensate for differences between the factory calibration and actual process conditions, a linear offset factor, Oil Adjust, may be added to or subtracted from the computed water content. The effect of Oil Adjust is as shown in Figure 6.2.

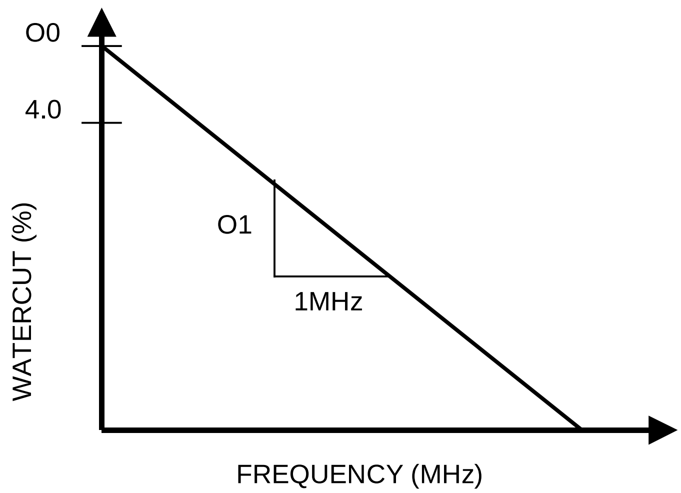


Figure 6.1 - Linear Factory Calibration, Frequency versus Water Content

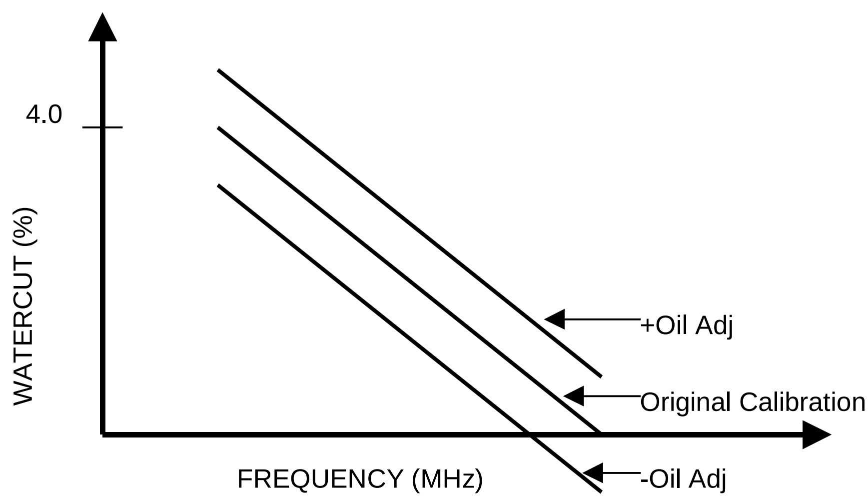


Figure 6.2 - Effect of Changing Oil Adjust

On rare occasions, it may be necessary to include a frequency index, Index, for improved accuracy. The effect of Index is as shown in Figure 6.3. Note: The preferred method for field calibration includes the use of Oil Adjust, as opposed to Index. However, Index is included to provide greater flexibility to the user, if needed.

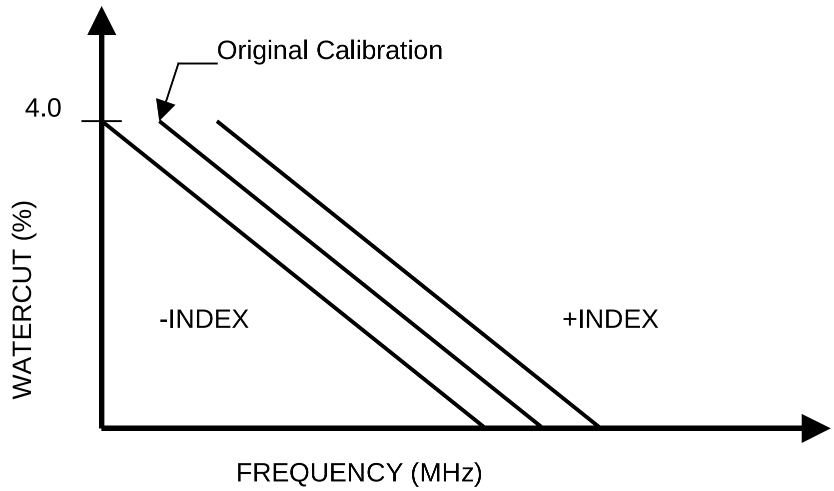


Figure 6.3 - Effect of Changing Index

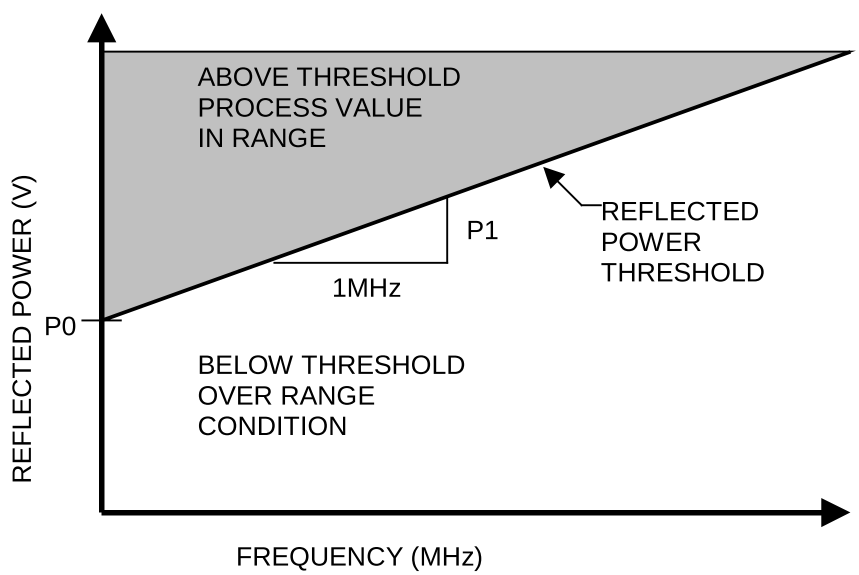


Figure 6.4 - Reflected Power Threshold Curve

The Phase Dynamics Water in Hydrocarbon Analyzer includes an operational feature which allows the instrument to determine an over range condition for the measured water content. The reflected power (Ref Pwr) signal from the oscillator module is measured and compared to a threshold value; it is a DC voltage indicative of the signal level reflected from the measurement section. Typically, the measured level will be above the threshold value when the measured water content is in range. For the over range condition, the reflected power level will be below the threshold value.

The reflected power threshold level (RP Threshold) may be frequency dependent and is given by;

RP Threshold = P1 x (Frequency + Index) + P0

where Frequency is the measured oscillator frequency, Index is the frequency index,

P1 is the slope of the threshold curve, and

P0 is the intercept of the threshold curve.

Figure 6.4 shows a typical reflected power threshold curve for the Phase Dynamics Analyzer.

6.2 TEMPERATURE COMPENSATION

Compensation for temperature effects must be included for best performance of the analyzer. Temperature changes the permittivity of most materials; this change in permittivity presents a changing load to the oscillator, which changes its frequency. Thus, without temperature compensation, a changing process temperature would cause changes in frequency, which would lead to errors in the calculated water content.
Temperature is measured by a probe located in one of the pipe saddles on a flow through, or in parallel to the measurement section on an insertion, and protrudes into the liquid stream.
Figure 16 shows the effect of temperature for a typical application. Temperature compensation is included by factory calibrating the analyzer over a range of temperatures. Coefficients relating frequency to water content are derived for each calibration temperature. For example, a unit calibrated at 15, 40, and 70 degrees Celsius will have three sets of O-constants, one set at each temperature.

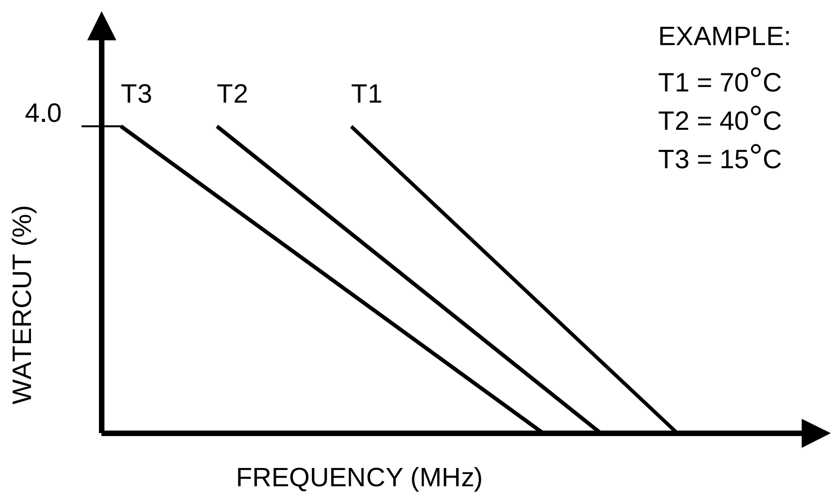


Figure 6.5 - Effect of Temperature on Frequency

The calculated water content includes compensation for fluid temperature; no manual compensation by the user is necessary. The Temp Adjust feature is used to adjust the temperature probe's measured value to match the actual liquid temperature, if necessary.
For measured temperatures that are between factory calibration temperatures, a linear interpolation is used to compensate for temperature effects.

6.3 VIEWING THE O-CONSTANTS

For oil continuous emulsions, there is one set of O-constants for each factory calibration temperature. The values of the O-constants may not be changed but it may be useful to view them. Please refer to the MODBUS® Coefficient Table A.4.

7. THEORY OF OPERATION - FULL RANGE ANALYZERS

The following sections describe, in detail, the specific operation of the Phase Dynamics load-pull system and how it is used to measure water content. The sections are separated into two main parts - one describing the behavior of the instrument for oil continuous emulsions and one for water continuous emulsions.

7.1 DETAILED DESCRIPTION FOR OIL CONTINUOUS EMULSIONS

The load-pull system relates a measured oscillator frequency to a water content. For oil emulsions, the system is factory calibrated by injecting saltwater into a flowing volume of oil. Coefficients are derived to relate the measured frequency to the water content for a given temperature. The water content for oil continuous emulsions at a constant temperature is calculated as follows;

$$
\begin{aligned}
\text{Water content} = \; & \text{O3} \times (\text{Frequency} + \text{Oil Index})^3 \\
+ \; & \text{O2} \times (\text{Frequency} + \text{Oil Index})^2 \\
+ \; & \text{O1} \times (\text{Frequency} + \text{Oil Index}) \\
+ \; & \text{O0} \\
+ \; & \text{Oil Adjust}
\end{aligned}
$$

where Frequency is the measured oscillator frequency,

O3, O2, O1, and O0 are the oil constants (O-constants) ,

Oil Index is a frequency index value for oil continuous emulsions, and

Oil Adjust is a linear offset value for oil continuous emulsions.

The factory default values for Oil Index and Oil Adjust are zero (0). In this case the above equation simplifies to;

$$\text{Water content (Oil Phase)} = \text{O3} * \text{Freq}^3 + \text{O2} * \text{Freq}^2 + \text{O1} * \text{Freq} + \text{O0}.$$

Figure 7.1 shows a typical oil continuous calibration curve for constant temperature.

For improved accuracy, a linear offset factor, Oil Adjust, may be added to or subtracted from the computed water content. The effect of Oil Adjust is as shown in Figure 7.2. The value of Oil Adjust is most likely stream specific; each liquid stream may require its own Oil Adjust.

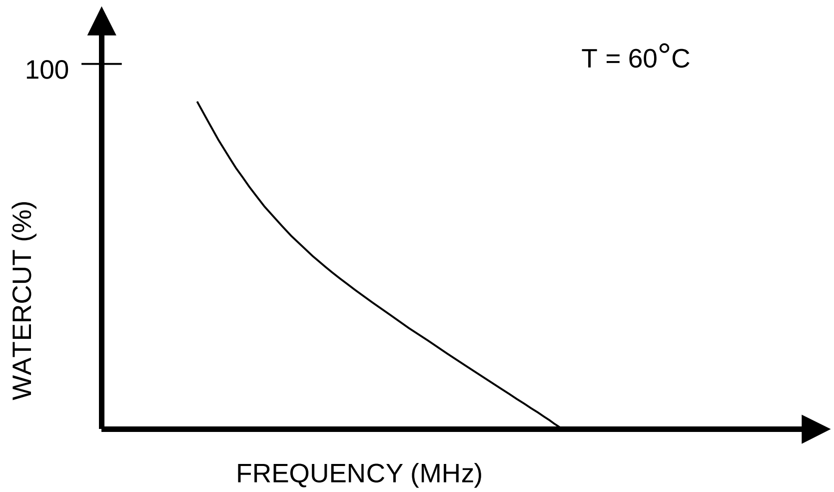


Figure 7.1 - Factory Calibration, Frequency vs. Water Content, Oil Continuous

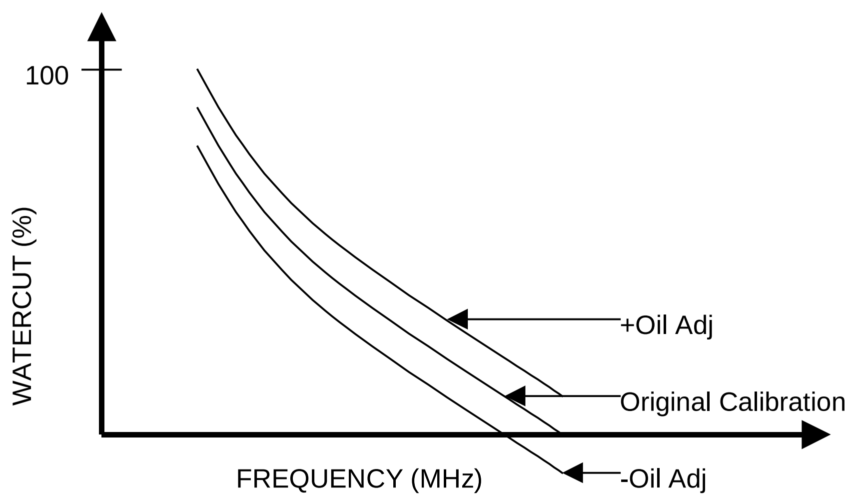


Figure 7.2 - Effect of Changing Oil Adjust

At times, it may be necessary to include a frequency index, Oil Index, for improved accuracy. The effect of Oil Index is as shown in Figure 7.3. This parameter is NOT stream specific; this value is used in calculation of oil continuous water content for ALL streams.

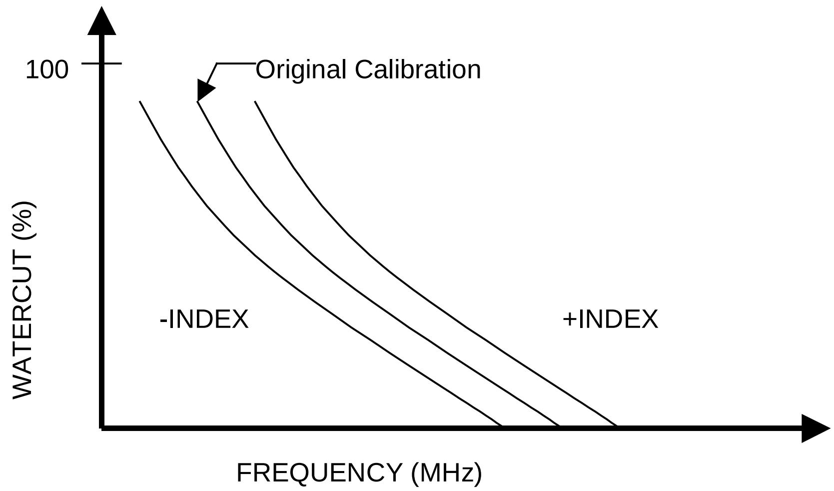


Figure 7.3 - Effect of Changing Oil Index

For oil continuous emulsions, the measured reflected power level is greater than the threshold power level (RP Threshold), which is related to the oscillator frequency (Frequency) and given by;

RP Threshold (Oil Phase) = O P1 * (Frequency + Oil Index) + O P0,

where Frequency is the measured oscillator frequency,

Oil Index is the frequency index,

O P1 is the slope of the threshold curve, and

O P0 is the intercept of the threshold curve.

This is true for measured frequencies greater than OilLo and less than OilHi. For all other frequencies, the emulsion is oil continuous.
Figure 7.4 shows the reflected power threshold curve for oil continuous emulsions.
For measured power levels above the threshold, the emulsion is oil continuous and the oil oscillator's frequency is measured and water content calculated. For measured power levels below the threshold, the system switches to the water emulsion oscillator and rechecks the power level to confirm the water continuous phase state.

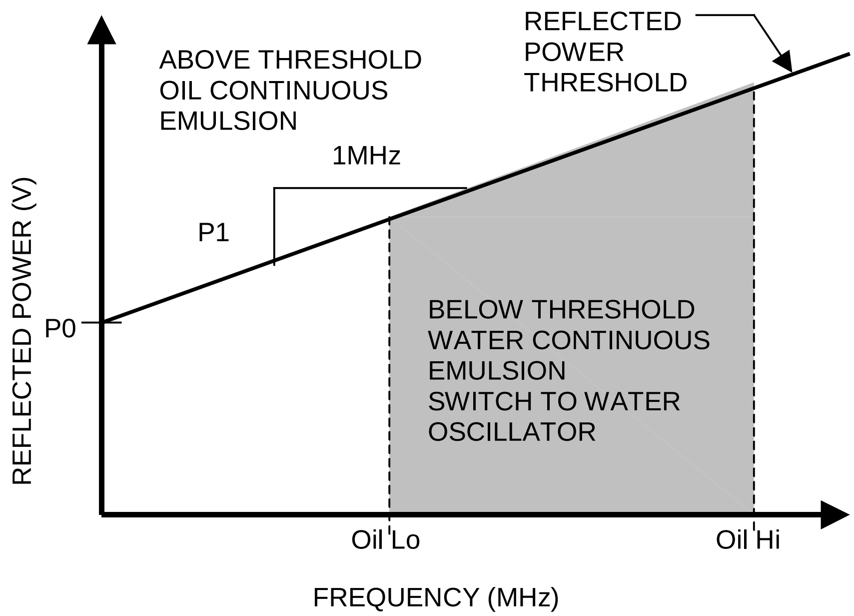


Figure 7.4 - Reflected Power Threshold Curve, Oil Continuous

7.2 DETAILED DESCRIPTION FOR WATER CONTINUOUS EMULSIONS

For water continuous emulsions, the system is factory calibrated over a wide range of temperature and salinity. Coefficients are derived to relate the measured oscillator frequency to water content for a given temperature and salinity. The water content (for a given temperature and salinity) is calculated as follows;

$$\begin{aligned}\text{Water content} = \; & \text{W3 x (Frequency + Water Index)}^3 \\ + \; & \text{W2 x (Frequency + Water Index)}^2 \\ + \; & \text{W1 x (Frequency + Water Index)} \\ + \; & \text{W0} \\ + \; & \text{Water Adjust}\end{aligned}$$

where Frequency is the measured oscillator frequency,

W3, W2, W1, and W0 are the water constants (W-constants) ,

Water Index is a frequency value for water continuous emulsions, and

Water Adjust is a linear offset value for water continuous emulsions.

The factory default values for Water Index and Water Adjust are zero (0). In this case the above equation simplifies to;

$$\text{Water content (Water Phase)} = \text{W3} * \text{Freq}^3 + \text{W2} * \text{Freq}^2 + \text{W1} * \text{Freq} + \text{W0}.$$

Figure 7.5 shows a typical set of water continuous calibration curves for a family of salinity values and one temperature. Each salinity curve is described by its own sets of W-constants; that is, the W-constants for one salinity are different than the W-constants for another salinity.

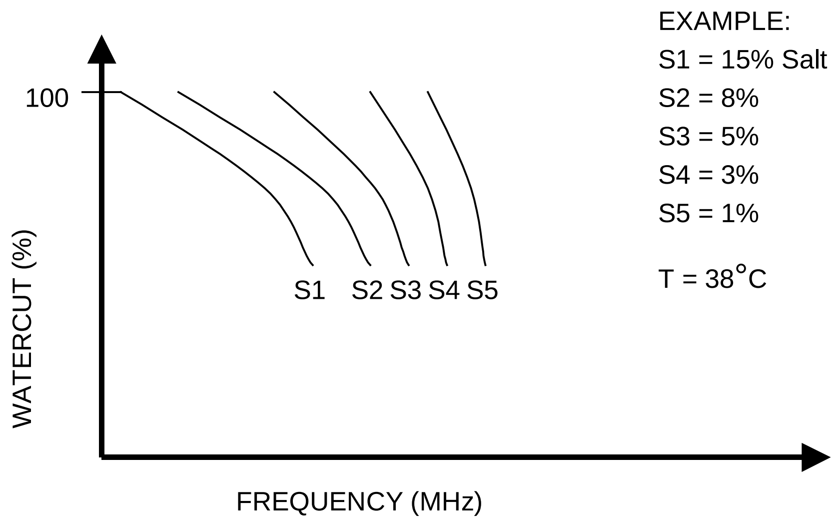


Figure 7.5 - Factory Calibration, Frequency vs. Water Content, Water Continuous

IMPORTANT
For optimum performance, it is IMPERATIVE that the salinity calibration routine be executed properly.

For field salinity values that are between the factory calibration values, linear interpolation is used to compensate for salinity effects.
For improved accuracy, a linear offset factor, Water Adjust, may be added to or subtracted from the computed water content. The effect of Water Adjust is as shown in Figure 7.6. The value of Water Adjust is most likely stream specific; each liquid stream may require its own Water Adjust.

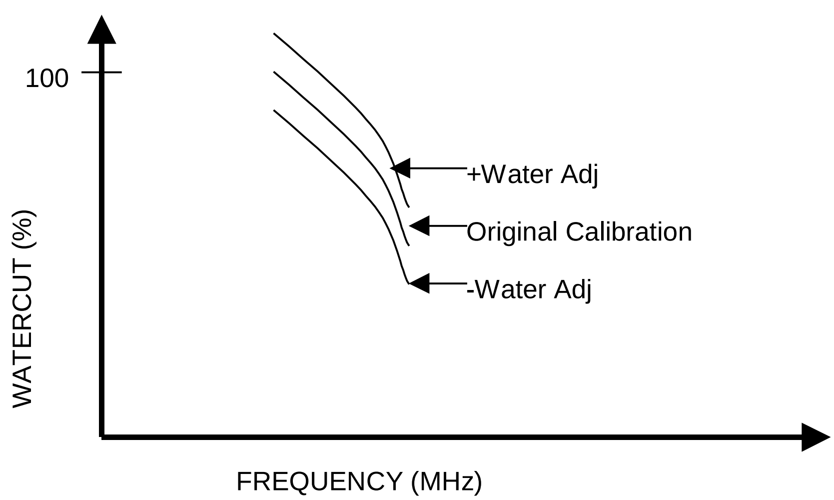


Figure 7.6 - Effect of Changing Water Adjust

The water continuous frequency index value, Water Index, is used to help compensate for the difference between the salinity compositions of the field water and the sodium chloride used during factory calibration. The Water Index value is calculated by the system during the Salinity Calibration and is stream specific. Each liquid stream will include its own Water Index value. The value of Water Index may be manually changed.

7.3 TEMPERATURE COMPENSATION

Temperature effects are compensated for within oil and water continuous emulsions. Compensation for temperature must be included for best performance of the analyzer. Temperature changes the permittivity of water significantly; this change in permittivity presents a changing load to the oscillator; which would change its frequency. Thus, without temperature compensation, a changing liquid temperature would cause a change in frequency; which would lead to errors in the calculated water content.

Temperature is measured by a probe located in one of the pipe saddles on a flow through, or in parallel to the measurement section on an insertion, and protrudes into the liquid stream.

Figure 7.8 shows the effect of temperature for oil continuous emulsions. Temperature compensation is accomplished by calibrating the load-pull system over a range of temperatures. Coefficients relating frequency to water content are derived for each calibration temperature. For example, a unit calibrated at 15, 38 and 60 degrees Celsius will have three sets of O-constants, one set at each temperature.

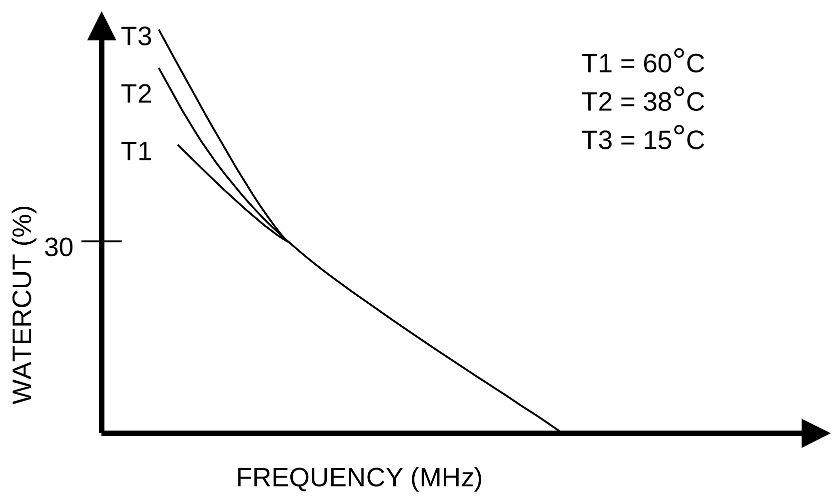


Figure 7.8 - Effect of Temperature on Frequency, Oil Continuous

Figure 7.9 shows the effect of temperature for water continuous emulsions for a given salinity. Temperature compensation is included by factory calibrating the load-pull system over a range of temperatures for several different salts. For example, a unit calibrated at 15, 38, and 60 degrees Celsius at 2% salinity will have three sets of W-constants, one set at each temperature. For 3% salinity, the same unit calibrated at 15, 38, and 60 degrees Celsius will have three more sets of W-constants, again, one set for each temperature.

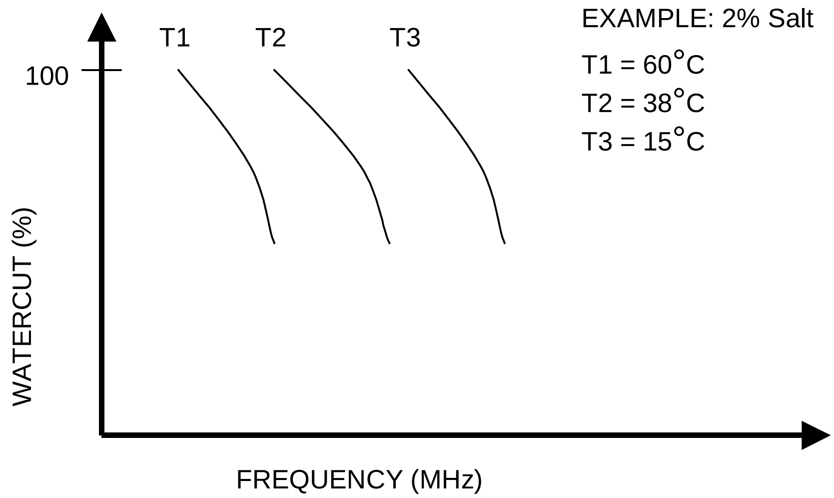


Figure 7.9 - Effect of Temperature on Frequency, Water Continuous, One Salinity

The water content includes compensation for fluid temperature; no manual compensation by the user is necessary. The Temp Adj. feature is used to adjust the temperature probe's reading, but does not affect the temperature compensation.
Linear interpolation is used to compensate for temperature effects for measured temperatures that are between factory calibration temperatures.

7.4 VIEWING THE O-CONSTANTS

For oil continuous emulsions, there is one set of O-constants for each factory calibration temperature. The values of the O-constants may not be changed but it may be useful to view them. Please refer to the MODBUS® Coefficient Table A.4.

7.5 VIEWING THE W-CONSTANTS

For water continuous emulsions, there is one set of W-constants for each combination of salinity and temperature tested during factory calibration. The values of the W-constants may not be changed but it may be useful to view them. Please refer to the MODBUS® Coefficient Table A.4.

8. THEORY OF OPERATION - MID RANGE ANALYZERS

Mid range analyzers act just like low range analyzers, except that they are designed for a wider range; from 0% water content to phase inversion. Phase inversion is when the fluid changes its emulsion phase and becomes water continuous. This typically occurs between 70% and 80% water content.

9. THEORY OF OPERATION - HIGH RANGE ANALYZERS

High range analyzers are designed to measure within the water continuous phase only. They act just like full range analyzers, except they do not make measurements when the fluid is oil continuous.

10. ANALYZERS

Analyzers are generic devices that can be developed into an actual product. Phase Dynamics, Inc. offers research analyzer tools for the user to develop his unique process. Upon completion of the research, the user may request Phase Dynamics, Inc. to generate a new module profile that contains the multi-variable coefficients for calculating the process values based on readings from the analyzer module.

11. INSTRUMENT REPAIR AND SERVICE

11.1 ASSISTANCE AND FACTORY ADDRESS

Product maintenance agreements and other customer assistance agreements are available for this Phase Dynamics analyzer.

Phase Dynamics, Inc.
1251 Columbia Drive
Richardson, TX 75081
Voice: 972-680-1550
Fax: 972-680-3262

11.2 ELECTROSTATIC DISCHARGE (ESD)

CAUTION
Protect circuit boards and terminals from ESD at all times.

All of the printed wiring board assemblies contain electronic components, which are sensitive to electrostatic discharge. Components damaged by ESD greatly increase the likelihood of a system error or failure.
Care should be taken to prevent damage from electrostatic discharge when working with the system. The technician should be wearing a ground strap. Boards removed from the system should be kept in anti-static bags.

11.3 MEASUREMENT SECTION AND ANALYZER

No field repair of the measurement section, analyzer module, or temperature probe should be necessary. If repair of these parts is needed, please consult Phase Dynamics.

11.4 RETURNING ITEMS TO THE FACTORY

Please telephone Phase Dynamics prior to returning any equipment for service or repair. A return merchandise authorization (RMA) number may be required prior to shipment. Please include the following information with returned items:

1. Company Name and Address
2. Key Contact Name and Address
3. Serial number of item(s) being returned
4. A completed copy of the Troubleshooting Worksheet
5. Return merchandise authorization (RMA) number (if required)

11.5 RETURNING THE ANALYZER AND MEASUREMENT SECTION

Please drain and clean the measurement section of any and all dangerous or hazardous materials before returning to the factory.
Pack the analyzer and measurement section in the original shipping carton.
If the original carton is missing, contact Phase Dynamics.
Place a packing slip on the outside of the carton containing both the return authorization and the serial number.

11.6 TROUBLESHOOTING WORKSHEET

The next few pages contain the Troubleshooting Worksheets. Please complete the form prior to contacting Technical Support.

PHASE DYNAMICS

Phase Dynamics, Inc.

1251 Columbia Dr.
Richardson, TX 75081
Voice: 972-680-1550
Fax: 972-680-3262
techsupport@phasedynamics.com
www.phasedynamics.com

RMA Number	
Module ID	
Measurement Section Serial Number	
PDI CONTACT	

TROUBLESHOOTING WORKSHEET

DATE ______________

COMPANY ________________________________ PHONE __________________________

CONTACT ________________________________ FAX __________________________

LOCATION ________________________________ EMAIL __________________________

PROCESS-RELATED DATA

(For Low, Mid, & Full Range Analyzers)	
Actual Process Value (Water Cut)	%
Process Value (Water Cut)	%
Oil Frequency	MHz
Oil Reflected Power	V
Oil Adjust	%
Oil Index	MHz
Process Temperature	□ °C □ °F
Oil P0	V
Oil P1	V/MHz
Oil Frequency Low	MHz
Oil Frequency High	MHz
Density	
Typical Flow Rate	

(For Full & High Range Analyzers)	
Actual Salinity	%
Salinity	%
Water Frequency	MHz
Water Reflected Power	V
Water Adjust	%
Water Index	MHz
Emulsion Phase	□ Oil-Cont □ Water-Cont □ Other
Water - Oil Frequency Low	MHz
Water - Oil Frequency High	MHz
Water Frequency Low	MHz
Water Frequency High	MHz

ANALYZER VOLTAGES - Measure the following voltages while the analyzer is powered.

Terminal 1	Terminal 2	Measurement
24VDC	24V RET	V
24VDC	GROUND (Earth)	V
24VDC	Chassis	V

INTERNAL DIAGNOSTICS

DAC 1	V	DAC 2	V
ADC 1	V	ADC 2	V
ADC 3	V	ADC 4	V
DIAGNOSTICS		Internal Temperature	°C
ERROR CODE/MSG			

RTD

Disconnect the plug from the analyzer and measure the RTD resistance with an ohmmeter.

1. Measure P0 to P1. Is it 0Ω? ☐ YES ☐ NO _______ Ω
2. Measure P2 to P3. Is it 0Ω? ☐ YES ☐ NO _______ Ω
3. Measure P0 to P3. Does it measure 100-200Ω? ☐ YES ☐ NO _______ Ω

Disconnect wire P0 from the plug and connect an ammeter in series with it.
Connect the plug to the analyzer and make sure the analyzer is powered ON.

Measure the RTD current. Is it 0.200mA? ☐ YES ☐ NO _______ mA

If your meter cannot read less than 1mA, disconnect the RTD and place a precision 1000Ω resistor across P0 and P3 and measure the voltage across the resistor.

Is it 200mV? ☐ YES ☐ NO _______ mV

Disconnect the plug from the analyzer and reconnect the RTD.

STATUS INDICATOR

Indicate the behavior of the Status Indicator light.

☐ Blinks 1 time per second ☐ Blinks 2 times per second ☐ OTHER _______________

☐ Amber (Red & Green) ☐ Red ☐ Green

DESCRIPTION OF THE PROBLEM:

____

____

____

NOTES:

____

____

____

12. TROUBLESHOOTING GUIDE

ERROR	DESCRIPTION	ACTION
Reset Basics	The analyzer has detected an error in the User Configuration and the Factory Configuration. Basic defaults have been loaded for operability. ALL data shall be considered invalid.	Contact Technical Support.
Reset	The unit has been reset, probably due to a power cycle.	If the condition persists, contact Technical Support.
Process out of range	The process value has exceeded its bounds.	1. Complete the Troubleshooting Worksheet. 2. Check Oil Adjust, Water Adjust, and Salinity parameters. 3. Check reflected power (OIL) and compare to the power threshold line OIL P1, P0 to determine if the analyzer has detected the correct emulsion phase. 4. Check frequencies and compare to their boundaries. 5. Contact Technical Support.
Temperature error	The temperature has exceeded its bounds.	Check RTD and RTD assembly.
Frequency error	The frequency has exceeded its bounds.	1. Complete the Troubleshooting Worksheet. 2. Check frequencies and compare to their boundaries. 3. Contact Technical Support.
Variable Unit	An invalid unit code is detected. Data may be invalid.	Contact Technical Support.
Variable Bounds	A variable has exceeded its bounds. Data may be clipped or invalid.	Contact Technical Support.
Timer Failed	A timer has failed to initialize, or its queue is full.	Contact Technical Support.
Execute Failed	An execution event has failed, or its queue is full.	Contact Technical Support.
FLASH Memory	FLASH memory has failed.	Contact Technical Support.
Internal Memory	Internal memory has failed.	Contact Technical Support.
External Memory	External memory has failed.	Contact Technical Support.

ERROR	DESCRIPTION	ACTION
Scaling error	Unable to scale primary variable for current output loop.	Check endpoint values.
Current Loop error	The loop current output does not correspond to the primary variable.	1. Check HART address and if current loop is in fixed mode. 2. Check for error conditions that may signal with current loop.
Salinity Calibration Over Range	The calculated salinity is greater than maximum.	Repeat Salinity Calibration.
Salinity Calibration Under Range	The calculated Salinity is less than minimum.	Repeat Salinity Calibration.
Salinity Calibration not Water Continuous	Fluid stream is oil continuous.	Repeat Salinity Calibration when water continuous.
Salinity Time	Not enough time for adequate salinity sample.	Allow more time for data capture.

13. GLOSSARY

TERM	DEFINITION
ADC	Analog to Digital Converter
bypass	a section of pipe that circumvents a restricted flow; by slipstreaming, in order to pass a representative sample for measurement
center rod	the main part of the measurement section that is connected directly to the microwave oscillator
CPLD	Complex Programmable Logic Device – a non-volatile device that can be reprogrammed to perform a variety of functions
CRC	Cyclical Redundancy Check - an error correction code
DAC	Digital to Analog converter
densimeter	a device that measures density or specific gravity
dielectric constant	See *relative permittivity*.
dip switch	a set of small switches that are used for setting options on a circuit board
discrete-time signal	1. a signal that has finite elements, each of which is separated by a time interval 2. a representative signal that may be derived from a continuous-time signal by periodically sampling it with an ADC
DSP	Digital Signal Processor – a microprocessor designed especially for handling the processing of discrete-time signals
emulsifier	a surfactant that promotes the formation of an emulsion
emulsion	a suspension of small globules of one liquid in a second liquid with which the first will not mix
emulsion phase	a term for expressing which liquid surrounds the other within an emulsion
ESD	Electrostatic Discharge
EXTRAM	External RAM – memory that is located outside the microprocessor
extrapolate	to estimate values outside of a range, from known values within the range
FLASH	a type of memory that can be reprogrammed electronically
FS30K	scaled data where 30000 is the maximum bound and 0 is the minimum bound

TERM	**DEFINITION**
ground strap	a temporary connection to ground, worn by a technician for handling ESD sensitive components
HART	Highway Addressable Remote Transducer – a simple communications protocol for supervisory control and data acquisition
Impedance	a measurement of the opposition to the flow of electric current – usually consists of resistance and reactance
Incident power	a measure of power that is transmitted from the source
Interpolate	to estimate a value between two known values
INTRAM	Internal RAM – memory contained inside the microprocessor
JTAG	Joint Test Action Group
LCD	Liquid Crystal Display
Load	the burden on the oscillator, often expressed in terms of impedance
Microwave	an electromagnetic wave, one millimeter to one meter in wavelength
MODBUS	a widely supported standardized communications protocol for supervisory control and data acquisition
MSVE	an abbreviation for MENU, SELECT, VALUE, and ENTER
oil adjust	offset value for the computation of the water content, in the oil continuous phase
oil continuous	an emulsion whereby the oil surrounds the water
oil external	See *oil continuous*.
oil index	frequency offset value for the oil oscillator
oil P0, P1	the parameters that represent a threshold line for the reflected power of the oil oscillator to determine the emulsion phase; P1 = the slope of the line, and P0 = the offset of the line
OIT	Operator Interface Terminal – an interface, usually local, that is used for supervisory control and data acquisition
Oscillator load-pull	the property where the oscillator will change frequency based on changes in the load
Permittivity	a measure of the ability of a substance to resist an electric field
Phase	See *emulsion phase*.

TERM	**DEFINITION**
Reflected power	a measure of power that is reflected back from the load to the source
Relative permittivity	a ratio of permittivity with respect to the permittivity of a vacuum
RTD	Resistance Temperature Detector – operates on the principle of the change in electrical resistance in wire as a function of temperature
RTU	Remote Terminal Unit
salinity	the ratio of the mass of salt to the mass of water that it is dissolved into
SCADA	Supervisory Control and Data Acquisition
seal plug	the plug on the end of the center rod that seals it to the measurement section
shorting plug	a termination plug at the end of the measurement section that connects to the center rod
slipstream	1. the area of reduced pressure behind an obstruction in a moving fluid 2. See *bypass*.
SRAM	Static RAM – memory used by the microprocessor
stream	the liquid flow that is being measured
surfactant	a surface-active substance
UART	Universal Asynchronous Receiver/Transmitter
watchdog	a timer that restarts a process when it times out, a dead-man's switch
water adjust	offset value for the computation of the water content, in the water continuous phase
water continuous	an emulsion whereby the water surrounds the oil
Water Cut	water content, often represented in percent
water external	See *water continuous*.
water index	frequency offset value for the water oscillator

APPENDIX A

A.1 MODBUS® RTU

The Phase Dynamics Analyzer can communicate with MODBUS®-compatible hosts in a multi-drop RS-485 2-wire network. This appendix specifies the mapped addresses for the available data types, the implemented function codes, diagnostics, and other operational characteristics within the Phase Dynamics Analyzer.

Valid Function Codes	Address (Data) Type	Access	Description
01, 05, 15	Coil	Read/Write	Single ON/OFF Bit (Boolean)
02	Discrete Input	Read-Only	Single ON/OFF Bit (Boolean)
03, 04, 16	Floating-Point & Long Integer Register	Read-Only & Read/Write	Single Precision IEEE 754 Floating-Point Format or Long Integer Format using two consecutive 16-bit Registers
04	Input Register	Read-Only	Integer Format using a single 16-bit Register
03, 06, 16	Holding Register	Read/Write	Integer Format using a single 16-bit Register
03, 04, 06, 16	ASCII Characters	Read-Only & Read/Write	Two ASCII Characters Packed in a single 16-bit Register

Coils, Discrete Inputs, and Registers may use the same address. The Function Code will determine which type of data is to be accessed.

A.2 FLOATING-POINT / LONG INTEGER FORMAT

All floating-point register pairs are in the IEEE 754 Floating-Point Format. The standard byte transmission order is high to low per the following table:

A	B	C	D
SEEE EEEE	EMMM MMMM	MMMM MMMM	MMMM MMMM

A different byte transmission order can be requested by adding an offset to the floating-point and long integer register pairs that are to be accessed. The following table describes the offsets and the associated byte transmission orders:

REGISTER OFFSET	BYTE TRANSMISSION ORDER	DESCRIPTION
0	A B C D	IEEE 754 Floating-Point Format Standard
2000	C D A B	IEEE 754 Floating-Point Format Word-swapped
4000	D C B A	IEEE 754 Floating-Point Format Reverse
6000	B A D C	IEEE 754 Floating-Point Format Byte-swapped
8000	A B C D	Scaled Long integer Standard

A.3 INTEGER / ASCII BYTE-PAIR FORMAT

All word and ASCII byte-pair registers are transmitted high byte then low byte (AB). Integers are scaled, when appropriate. The scale factor is listed in the table.

A.4 ANALYZER MODES

The analyzer mode instructs the analyzer how to operate.

TYPE	Code
Low Range	0
Full Range	1
Analyzer	2
Mid Range	3
High Range	4
Gas Analyzer	5
CCM	6

A.5 DIAGNOSTICS REGISTER BIT DEFINITIONS

Table A.1 - DIAGNOSTICS

15	14	13	12	11	10	9	8
Reset Basics	Reset	Process Hi	Process Lo	Temp Hi	Temp Lo	Frequency Hi	Frequency Lo

7	6	5	4	3	2	1	0
Internal Memory	VAR Unit	VAR Bounds	FLASH Write-Protected	FLASH Memory	Timer Failed	Execute Failed	External Memory

DIAGNOSTICS FLAG	DESCRIPTION
Reset Basics	The analyzer has detected an error in the User Configuration and the Factory Configuration. Basic defaults have been loaded for operability. ALL data shall be considered invalid.
Reset	The unit has been reset, probably due to a power cycle.
Process High	The process value has exceeded its upper bound.
Process Low	The process value has exceeded its lower bound.
Temperature High	The temperature has exceeded its upper bound.
Temperature Low	The temperature has exceeded its lower bound.
Frequency High	The frequency has exceeded its upper bound.
Frequency Low	The frequency has exceeded its lower bound.
Internal Memory	Internal memory has failed its check routine.
Variable Unit	An invalid unit code is detected. Data may be invalid.
Variable Bounds	A variable has exceeded its bounds. Data may be clipped or invalid.
FLASH Write-Protected	A write-protect error occurred while attempting to write to FLASH memory.
FLASH Memory	FLASH memory has failed its check routine.
Timer Failed	A timer has failed to initialize, or its queue is full.
Execute Failed	An execution event has failed, or its queue is full.
External Memory	External memory has failed its check routine.

A.6 DIAGNOSTICS ERROR CODE

The most recent DIAGNOSTICS ERROR CODE remains until it is manually cleared.

ERROR	DESCRIPTION
0	No error
1	Frequency error
4	User Temperature is out of range
5	Scaling error – cannot scale current output
6	Water Cut over range
8	FLASH failure
9	INTERNAL RAM failure
10	EXTERNAL RAM failure
11	Water Cut under range
15	Current Loop error
16	Reset Basics
21	Salinity Time
22	Salinity Calibration over range
23	Salinity Calibration under range
24	Salinity Calibration not water continuous
25	Temperature under range
26	Temperature over range
34	Oil Calibration not oil continuous

A.7 SAVING THE USER-CONFIGURATION

Notes:
1. Saving the configuration degrades the FLASH memory.
2. Saving ANY data will cause the ENTIRE (Coefficient Table (>60000) and Configuration Table) configuration to be stored.
3. All auto-saves will save the ENTIRE configuration. There is, however, no Auto-save mode for the Coefficient Table. To save it, either write to an auto-save register, or write to the "*Save User Configuration*" coil.
4. Locking and unlocking the device is considered to be an auto-save operation.

Upon completion of the setup, the user MUST save the configuration. There are three methods available to accomplish this:
1. Since all configuration data is updated in RAM, the unit will perform with the parameters as they are changed (except for the communications setup). However, upon reset, these parameters revert to their saved setting. To save the changes, write to the *"Save User Configuration"* coil.
2. Sometimes a user will only need to update a few items. In most cases, the AUTOSAVE mode can be used. Simply add the appropriate offset to the address and your entire configuration will be automatically saved upon writing to that register. Care must be taken as to not use this too frequently because it will degrade the FLASH memory. Reading the offset registers will not cause an automatic save of the configuration.
3. An alternate AUTOSAVE mode is available for use with long integer or floating-point register pairs. The *"Automatic Save on Pair Boundary"* mode causes data to be saved upon write to the upper register boundary. For example, 00011..00012 is the register pair for Salinity. To automatically save this register, simply add 1 to the register address to read/write 00012..00013. This will only cause a boundary shift, and will not affect neighboring registers. If the *"Automatic Save on Pair Boundary"* mode is not set for the port, an address error will occur. Reading the offset registers will not cause an automatic save of the configuration.

TYPE	OFFSET
Integer	10000
Floating-Point / Long Integer	10000, 1*
Discrete IO / Coils	10000

*This mode requires setting the *"Automatic Save on Pair Boundary"* coil for the corresponding port.

A.8 WRITE-PROTECTION

Notes:
1. Upon lock or unlock, the configuration will be automatically saved!

The factory default codes is 1234.
To unlock the PORT, simply enter the password into register 49990.
The Lock status bit 00050 reflects the current lock status of the port.
To lock the port, simply write a 1 to the Lock status bit.
To change the password for a port, the unit must be unlocked.
The password register is 49980
The passwords cannot be read and will show 0x0000.
There is a 10-second lockout if a wrong password is detected.

The FACTORY MODE unlock is limited to factory use and is not available to the user.

A.9 CALIBRATION WITH MODBUS

The Phase Dynamics Analyzer has two automatic-calibration modes. These modes allow the user to enter the measured water content to automatically adjust the parameters.

Prior to automatic-calibration, the user must take a sample and set the appropriate data-capture coil (Oil/Water). This captured data will be used later when the current water content value is entered directly into the Calibrate Oil/Water registers. If this is not done first, the current measurements will be used instead. The oil calibration affects the oil adjust and the water calibration affects the salinity. These values can also be adjusted manually, if desired. It is recommended that the configuration be saved upon completion of a capture.

Table A.2 - MODBUS® INTEGER TABLE

ADDRESS (ABSOLUTE)	SCALE	U	F	DESCRIPTION
40001	1			Serial Number – Measurement Section
40002	1	✓	✓	Diagnostics
40003	1	✓	✓	Extended Diagnostics
40004	1	✓	✓	Diagnostics Error Code
40005	1	✓	✓	Diagnostics Message Code
40006	100			Process Value (Water Content)
40007	10			Process Temperature
40008	10			User Temperature
40009	1			Emulsion Phase
40010	1	✓	✓	Stream Select
40011	100	✓	✓	Salinity
40012	100	✓	✓	Oil Adjust
40013	100	✓	✓	Water Adjust
40014	1	✓	✓	Unit Code – Temperature
40015	1	✓	✓	Mode - Oil Calculation
40016	1	✓	✓	Mode - Density Correction
40017	1	✓	✓	Density Correction Mode Modbus Master Port Select
40018	1			Timer Counter
40019	1	*	*	Mode – Demo Analyzer
40020	1		✓	Mode – Analyzer
40021	1			Manufacturer ID
40022	1			HART Command Revision
40023	1			HART Transmitter Revision
40024	1			Firmware Version
40025	1			Hardware Version
40026	1	✓	✓	Number of Samples to Average
40027	1		✓	Oil Phase Calculation Oscillator Select
40028	1		✓	Water Phase Calculation Oscillator Select
40029	1	✓	✓	NaN Value for Integer
40030	1			Power Cycle Counter
40031	1	✓	✓	Mask - Diagnostics
40032	1	✓	✓	Mask - Extended Diagnostics
40091	FS30K			Frequency – Oil Oscillator
40092	FS30K			Incident Power – Oil Oscillator
40093	FS30K			Reflected Power – Oil Oscillator
40094	FS30K			Frequency – Water Oscillator
40095	FS30K			Incident Power – Water Oscillator
40096	FS30K			Reflected Power – Water Oscillator
40097	FS30K			Temperature
40098	FS30K			Water Content
42101	1	✓	✓	[1] Port – Slave Address
42102	0.01	✓	✓	[1] Port – Baud Rate
42103	1	✓	✓	[1] Port – Parity
42104	100	✓	✓	[1] Port – EOT Delay
42105	100	✓	✓	[1] Port – Prefix
42106	100	✓	✓	[1] Port – Suffix

ADDRESS (ABSOLUTE)	SCALE	U	F	DESCRIPTION
42107	100	✓	✓	[1] Port – Watchdog
42108	1	✓	✓	[1] Port – Number of Bits
42109	1	✓	✓	[1] Port – Stop Bits
42110	1	✓	✓	[1] Port – Number of Retries
42111	1	✓	✓	[1] Port – Poll Time
42112	1	✓	✓	[1] Port – Timeout
42113..42124		✓	✓	[2] Port
42125..42136		✓	✓	[3] Port
42137..42148		✓	✓	[4] Port
42149		✓	✓	HART – Address (EEA)
42150	1	✓	✓	HART – Number of Preambles
44001	1	✓	✓	Capture Oil – Number of Oil Oscillator Samples
44002	1			Capture Oil – Current Sample
44003..44008	1			Capture Oil – Time & Date Stamp
44011	1	✓	✓	Capture Water – Number of Oil Oscillator Samples
44012	1			Capture Water – Current Sample
44013..44018	1			Capture Water – Time & Date Stamp
48001	1	✓	✓	[1] Flow Computer – process unit code
48002	1	✓	✓	[1] Flow Computer – temperature unit code
48003	1	✓	✓	[1] Flow Computer – pressure unit code
48004	1	✓	✓	[1] Flow Computer – density unit code
48005	1	✓	✓	[1] Flow Computer – flow class code
48006	1	✓	✓	[1] Flow Computer – flow unit code
48007	1	✓	✓	[1] Flow Computer – accumulator unit code
48008	1	✓	✓	[1] Flow Computer – oil density unit code
48009	1	✓	✓	[1] Flow Computer – oil density @STP unit code
48010	1	✓	✓	[1] Flow Computer – water density unit code
48011	1	✓	✓	[1] Flow Computer – water density @STP unit code
48012	1	✓	✓	[1] Flow Computer – number of pulses per accumulation unit
48013	1	✓	✓	[1] Flow Computer – API Correction Table
48021..48033	1	✓	✓	[2] Flow Computer unit codes
48041..48053	1	✓	✓	[3] Flow Computer unit codes
48201..48202	1	✓	✓	[1] Analog Input variable class, unit code
48203..48204	1	✓	✓	[2] Analog Input variable class, unit code
48205..48206	1	✓	✓	[3] Analog Input variable class, unit code
48207..48208	1	✓	✓	[4] Analog Input variable class, unit code
48209..48210	1	✓	✓	[5] Analog Input variable class, unit code
48211..48212	1	✓	✓	[1] Analog Output variable class, unit code
48213..48214	1	✓	✓	[2] Analog Output variable class, unit code
48215..48216	1	✓	✓	[3] Analog Output variable class, unit code
48217..48218	1	✓	✓	[4] Analog Output variable class, unit code
48219..48220	1	✓	✓	[5] Analog Output variable class, unit code
48221..48222	1	✓	✓	[6] Analog Output variable class, unit code
48223..48224	1	✓	✓	[7] Analog Output variable class, unit code
48225..48226	1	✓	✓	[8] Analog Output variable class, unit code

ADDRESS (ABSOLUTE)	SCALE	U	F	DESCRIPTION
48227..48228	1	✓	✓	[1] Relay variable class, unit code
48229..48230	1	✓	✓	[2] Relay variable class, unit code
45001..45002	1	✓	✓	HART – Date
45003..45019	1	✓	✓	HART – Long Tag
45020..45024	1	✓	✓	HART – Short Tag
45025..45033	1	✓	✓	HART – Description
45034..45050	1	✓	✓	HART – Message
45053..45054	1		✓	Calibration Version
45055..45057	1		✓	Calibration Technician
45058..42078	1		✓	Copyright
45079..45089	1		✓	Analyzer Information
45090..45095	1		✓	Assembly Date
49000	1	✓	✓	Scratchpad Mirror of 49001
49001..49050	1	✓	✓	Scratchpad
49101..49120	1	✓	✓	User-Select Register Configuration
49980	1	✓	✓	Password Change
49990	1	*	*	Unlock (enter password here)

Table A.3 - MODBUS® FLOATING-POINT / LONG INTEGER TABLE

ADDRESS (ABSOLUTE)	SCALE (LONG INT)	U	F	DESCRIPTION
00001	1			Serial Number – Measurement Section
00003	1	✓	✓	Diagnostics
00005	1	✓	✓	Extended Diagnostics
00007	1	✓	✓	Diagnostics Error Code
00009	1	✓	✓	Diagnostics Message Code
00011	1000			Process Value (Water Content)
00013	10			Process Temperature
00015	10			User Temperature
00017	1			Emulsion Phase
00019	1	✓	✓	Stream Select
00021	100	✓	✓	Salinity
00023	100	✓	✓	Oil Adjust
00025	100	✓	✓	Water Adjust
00027	1	✓	✓	Unit Code – Temperature
00029	1000			Unadjusted, Unclipped Water Content Value
00031	1000	✓	✓	Oil Index
00033	1000	✓	✓	Water Index
00035	10000	✓	✓	Oil P0
00037	10000	✓	✓	Oil P1
00039	100	✓	✓	Calibrate Oil Phase
00041	100	✓	✓	Calibrate Water Phase
00101	1000			Frequency – Oil Oscillator
00103	1000			Incident Power – Oil Oscillator
00105	1000			Reflected Power – Oil Oscillator
00107	1000			IP/RP – Oil Oscillator
00109	1000			IP/RP (dB) – Oil Oscillator
00111	1000			Frequency – Water Oscillator
00113	1000			Incident Power – Water Oscillator
00115	1000			Reflected Power – Water Oscillator
00117	1000			IP/RP – Water Oscillator
00119	1000			IP/RP (dB) – Water Oscillator
00201	1000	✓	✓	Oil Calculation Cutoff Value
00203	1000	✓	✓	Oil Calculation Curve 1 Maximum Value
00205	1000	✓	✓	Oil Calculation Curve 2 Maximum Value
00701	1000	✓	✓	Dampening Value – Water Content
00703	1000		✓	Minimum – Water Content
00705	1000		✓	Maximum – Water Content
00707	1000	✓	✓	Alarm Low – Water Content
00709	1000	✓	✓	Alarm High – Water Content
00711	1000	✓	✓	Dampening Value – Process Temperature
00713	10		✓	Minimum – Process Temperature
00715	10		✓	Maximum – Process Temperature

ADDRESS (ABSOLUTE)	**SCALE (LONG INT)**	**U**	**F**	**DESCRIPTION**
00717	10	✓	✓	Alarm Low – Process Temperature
00719	10	✓	✓	Alarm High – Process Temperature
00721	10	✓	✓	User Temperature Adjust
00723	100		✓	Minimum – Salinity
00725	100		✓	Maximum – Salinity
00727	1000	✓	✓	Minimum – Oil Frequency
00729	1000	✓	✓	Maximum – Oil Frequency
00731	1000	✓	✓	Low Oil Frequency
00733	1000	✓	✓	High Oil Frequency
00735	1000	✓	✓	Minimum – Water Frequency
00737	1000	✓	✓	Maximum – Water Frequency
00739	1000	✓	✓	Low Water Frequency
00741	1000	✓	✓	High Water Frequency
00801	10000			Oscillator Select Voltage
00803	10000			VTUNE Output Voltage
00805	10000			TUNE Select Voltage
00807	10000			Reflected Power
00809	10000			Incident Power
00811	10000			Process Temperature
00813	10000			Electronics Temperature
00815	10000			Ground Sense Voltage
00817	10000			VTUNE Input Voltage
00819	10000	✓	✓	[1] DAC output voltage for Analog Output
00821	10000	✓	✓	[2] DAC output voltage for Analog Output
00823	10000	✓	✓	[3] DAC output voltage for Analog Output
00825	10000	✓	✓	[4] DAC output voltage for Analog Output
00827	10000	✓	✓	[5] DAC output voltage for Analog Output
00829	10000	✓	✓	[6] DAC output voltage for Analog Output
00831	10000	✓	✓	[7] DAC output voltage for Analog Output
00833	10000	✓	✓	[8] DAC output voltage for Analog Output
00835	10000	✓	✓	[1] ADC input voltage for Analog Input
00837	10000	✓	✓	[2] ADC input voltage for Analog Input
00839	10000	✓	✓	[3] ADC input voltage for Analog Input
00841	10000	✓	✓	[4] ADC input voltage for Analog Input
00843	10000	✓	✓	[5] ADC input voltage for Analog Input
00871	1	✓	✓	[1] Relay – Mode
00873	1	✓	✓	[1] Relay – Status Mask
00875	1	✓	✓	[1] Relay – Variable Select
00877	1	✓	✓	[1] Relay – Setpoint Value
00881	1	✓	✓	[2] Relay – Mode
00883	1	✓	✓	[2] Relay – Status Mask
00885	1	✓	✓	[2] Relay – Variable Select

ADDRESS (ABSOLUTE)	SCALE (LONG INT)	U	F	DESCRIPTION
00887	1	✓	✓	[2] Relay – Setpoint Value
00889	1000	✓	✓	Density – Correction Factor for Temperature
00891	1000	✓	✓	Density – Correction Factor for Density
00893	1000	✓	✓	Density – Correction Factor Offset
00895	100	✓	✓	Density – Water Content Correction Factor
00897	100	✓	✓	Density – Water Content Correction Offset
00899	100	✓	✓	Density – Factory Calibration Density in API60F
01001	100	✓	✓	[1] Analog Input – Current
01003	100			[1] Analog Input – Current Percent of Range
01005	1	✓	✓	[1] Analog Input – Value
01007	1	✓	✓	[1] Analog Input – Variable Select
01009	1000	✓	✓	[1] Analog Input – Current Dampening Value
01011	1	✓	✓	[1] Analog Input – Minimum Trim Value
01013	1	✓	✓	[1] Analog Input – Maximum Trim Value
01015	1000	✓	✓	[1] Analog Input – Minimum Trim Value Current
01017	1000	✓	✓	[1] Analog Input – Maximum Trim Value Current
01019	100	✓	✓	[1] Analog Input – Lower Range Value
01021	100	✓	✓	[1] Analog Input – Upper Range Value
01031..01052				[2] Analog Input
01061..01082				[3] Analog Input
01091..01112				[4] Analog Input
01121..01142				[5] Analog Input
01201	100	✓	✓	[1] Analog Output – Current
01203	100			[1] Analog Output – Current Percent of Range
01205	1	✓	✓	[1] Analog Output – Variable Select
01207	1000	✓	✓	[1] Analog Output – Current Dampening Value
01209	1000	✓	✓	[1] Analog Output – Proportional Constant
01211	1000	✓	✓	[1] Analog Output – Integral Constant
01213	1000	✓	✓	[1] Analog Output – Derivative Constant
01215	1000	✓	✓	[1] Analog Output – Manual Percent Input
01217	1000	✓	✓	[1] Analog Output – PID Setpoint
01219	1	✓	✓	[1] Analog Output – Minimum Trim Value
01221	1	✓	✓	[1] Analog Output – Maximum Trim Value
01223	1000	✓	✓	[1] Analog Output – Minimum Trim Value Current
01225	1000	✓	✓	[1] Analog Output – Maximum Trim Value Current
01227	100	✓	✓	[1] Analog Output – Lower Range Value
01229	100	✓	✓	[1] Analog Output – Upper Range Value
01231..01260				[2] Analog Output
01261..01290				[3] Analog Output
01291..01320				[4] Analog Output
01321..01350				[5] Analog Output
01351..01380				[6] Analog Output
01381..01410				[7] Analog Output
01411..01440				[8] Analog Output
01701	1			[1] Port – Watchdog Counter

ADDRESS (ABSOLUTE)	**SCALE (LONG INT)**	**U**	**F**	**DESCRIPTION**
01703	1			[1] Port – Error Counter
01705	1			[1] Port – Invalid Command Counter
01707	1			[1] Port – Invalid Packet Counter
01709	1			[1] Port – Success Counter
01711	1			[1] Port – Number of Retries Counter
01713..01724				[2] Port Counters
01725..01736				[3] Port Counters
01737..01748				[4] Port Counters
01749..01758				[5] Port Counters
01759..01768				[7] Port Counters
01769..01778				[8] Port Counters
01851	1			LOG – n
01853	1			LOG – maximum records per sector
01855	1			LOG – current sector
01857	1			LOG – number of possible sectors
01859	1	✓	✓	LOG – Sampling Period
01861	1			LOG – Index
01901..01940	1000	✓	✓	Scratchpad
01951..01965	1			ESN
01967	1		✓	Serial Number – Measurement Section
01969	1		✓	Serial Number – Power Board
01971	1		✓	Serial Number – Processor Board
01973	1		✓	Serial Number – Communications Board
01975	1		✓	Serial Number – Analyzer Board
01977	1		✓	Serial Number – Analog I/O Board
01979	1		✓	Serial Number – Motherboard
01981	1		✓	Serial Number – DC Board
01983	1		✓	Serial Number – Oscillator
01985	1	✓	✓	Final Assembly Number
20001	1000	✓	✓	[1] Flow Computer – Process Value (Water Content)
20003	10	✓	✓	[1] Flow Computer – Process Temperature
20005	1000	✓	✓	[1] Flow Computer – Pressure
20007	1000	✓	✓	[1] Flow Computer – Density
20009	1000			[1] Flow Computer – PDI Corrected Density
20011	100	✓	✓	[1] Flow Computer – Salinity
20013	1000	✓	✓	[1] Flow Computer – Meter Factor
20015	1000	✓	✓	[1] Flow Computer – Shrinkage
20017	1000	✓	✓	[1] Flow Computer – Oil Density
20019	1000	✓	✓	[1] Flow Computer – Oil Density @STP
20021	1000	✓	✓	[1] Flow Computer – Water Density
20023	1000	✓	✓	[1] Flow Computer – Water Density @STP
20025	1000			[1] Flow Computer – VCF Oil
20027	1000			[1] Flow Computer – VCF Water
20029	1000			[1] Flow Computer – Net Water Content
20031	1000	✓	✓	[1] Flow Computer – Total Flow Rate
20033	1000			[1] Flow Computer – Oil Flow Rate

ADDRESS (ABSOLUTE)	SCALE (LONG INT)	U	F	DESCRIPTION
20035	1000			[1] Flow Computer – Water Flow Rate
20037	1000			[1] Flow Computer – Gross Total
20039	1000			[1] Flow Computer – Gross Oil
20041	1000			[1] Flow Computer – Gross Water
20043	1000			[1] Flow Computer – Pulse Counter
20045	1000			[1] Flow Computer – Pulse Flow
20047	1000			[1] Flow Computer – Pulse Total
20049	1000			[1] Flow Computer – Net Flow Total
20051	1000			[1] Flow Computer – Net Flow Oil
20053	1000			[1] Flow Computer – Net Flow Water
20055	1000			[1] Flow Computer – Net Total
20057	1000			[1] Flow Computer – Net Oil
20059	1000			[1] Flow Computer – Net Water
20061	1000	✓	✓	[1] Flow Computer – α
20201..20262				[2] Flow Computer
20401..20462				[3] Flow Computer

Table A.4 - MODBUS® DISCRETE IO / COIL TABLE

ADDRESS (ABSOLUTE)	**U**	**F**	**DESCRIPTION**
00001..00016	✓	✓	Diagnostics
00017..00032	✓	✓	Extended Diagnostics
00033	✓	✓	Alarm
00034	✓	✓	Error
00035		✓	Demo Mode
00036	✓	✓	Data Change Indicator (automatically clears when data is saved)
00037			Real Time Clock is Present
00039			Alarm High – Water Content
00040			Alarm Low – Water Content
00041			Alarm High – Temperature
00042			Alarm Low – Temperature
00043			Alarm High – Electronics Temperature
00044			Alarm Low – Electronics Temperature
00050	✓	✓	Lock & Lock Status
00101	✓	✓	Select Temperature Units Degree C
00102	✓	✓	Capture Oil Phase Data Record
00103	✓	✓	Capture Water Phase Data Record
00104	✓	✓	Ignore Modbus Data Exceptions
00105	✓	✓	Autosave on Pair Boundary in Modbus
00106	✓	✓	Force Hart Command Revision 5
00107	✓	✓	Enable Current Loop Output
00111		✓	Force Into Research Analyzer Mode
00113		✓	Disable the Oscillator’s Heater
00115	✓	✓	Enable Periodic Built-in Tests
00116	*	*	Perform Full Self-test
00117	*	*	System Reset
00118	✓	✓	Save the User Configuration
00119	✓	✓	Restore the User Configuration
00120	*	*	Restore Factory Defaults
00123	✓	✓	LOG – Enable Periodic Logging
00124	✓	✓	LOG – Enable Erase on Next Cycle
00125	✓	✓	LOG – Enable Configuration Logging
00126	✓	✓	LOG – Enable Error Logging
00127	*	*	System Restart

Table A.5 - MODBUS® COEFFICIENT TABLE (IEEE ABCD)

ADDRESS (ABSOLUTE)	**U**	**F**	**DESCRIPTION**
60001..60002		✓	TEMP OIL MAX
60003..60022		✓	TEMPS OIL
60023..60102		✓	COEFF TEMP OIL
60103..60104		✓	SALT MAX
60105..60144		✓	SALTS
60145..60146		✓	TEMP WATER MAX
60147..60176		✓	TEMPS WATER
60177..62576		✓	COEFF SALT TEMP WATER
62577..62696	✓	✓	Salinity (Stream)
62697..62816	✓	✓	Oil Adjust (Stream)
62817..62936	✓	✓	Water Adjust (Stream)
62937..63056	✓	✓	Water Alarm Low (Stream)
63057..63176	✓	✓	Water Alarm High (Stream)

APPENDIX B

B.1 HART®

The Phase Dynamics Analyzer can communicate with HART® compatible hosts in a multi-drop or point-to-point network. This appendix specifies the protocol, setup and configuration settings.
HART® instruments communicate over a half-duplex network at 1200 baud, 8 bits, odd parity, and 1 stop bit. HART® 202 supports older current loops in either a point-to-point or multi-drop network. Phase Dynamics' implementation of HART® is user-selectable to communicate HART®5 or HART®6 according to the *Universal Command Specification Revision 5.2 or Revision 6.0 and the Data Link Layer Specification Revision 8.1.* The transmitter revision is 2.

The three HART® Dynamic Variables are:

VARIABLE	DESCRIPTION	UNIT
PRIMARY	Process (Water Cut)	%
SECONDARY	Temperature	°C
TERTIARY	Emulsion Phase	(None)

A handheld device such as a Rosemount 275 or 375 communicator may be connected directly to the terminals labeled 1A and 1B on the analyzer module's network port. The output current represents the primary variable.

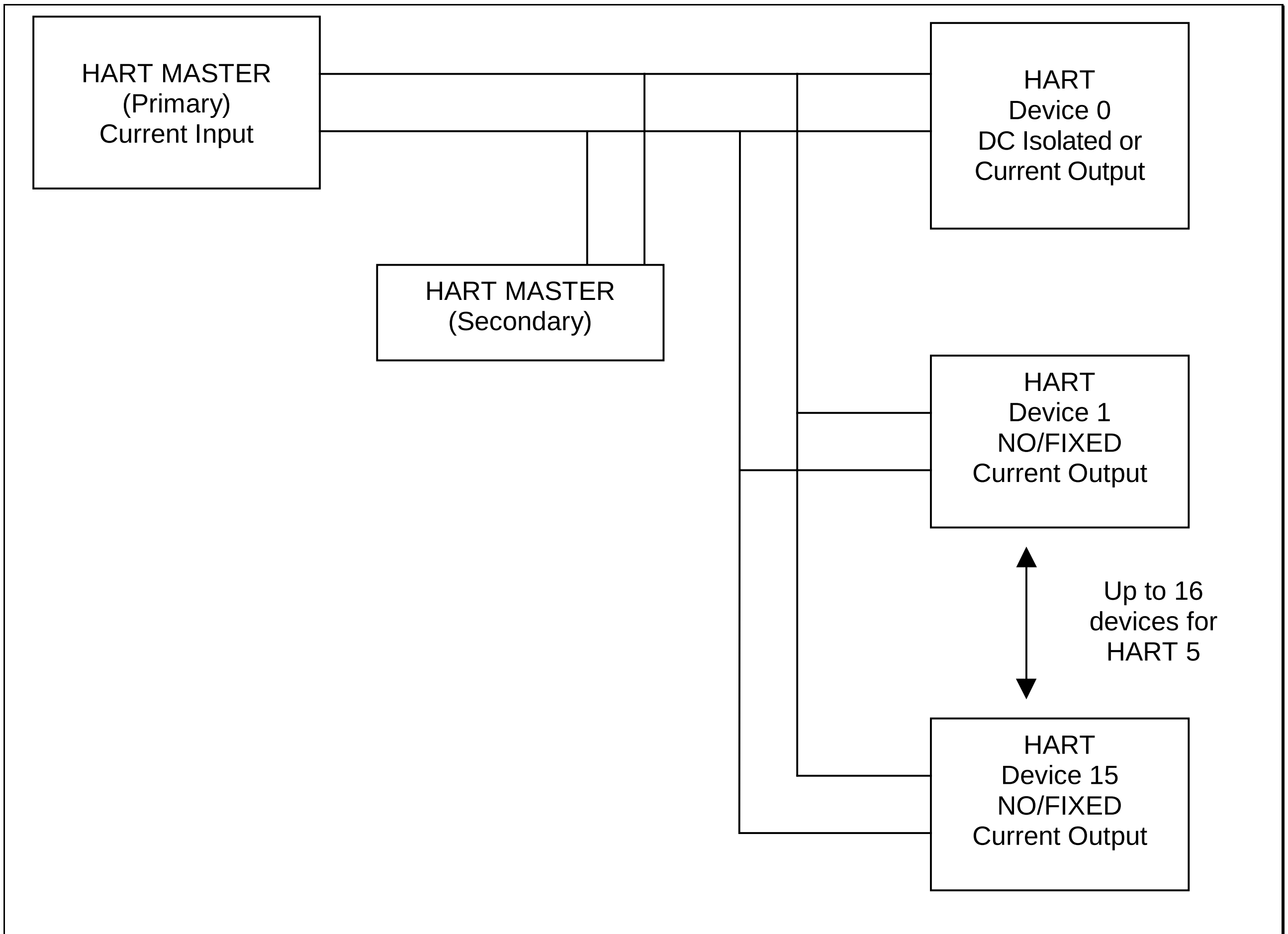


Figure B.1 - Typical HART® Connection Diagram

B.2 COMMAND 128: READ FLOATING-POINT DEVICE PARAMETERS

This command allows a Master to request the value of up to four Floating-Point Device Parameters. In other words, a Master may request only 1, 2, 3, or 4 Floating-Point Device Parameters. The Field Device must answer these Master requests without returning Response Code 5, *Too Few Data Bytes Received*. If the Field Device receives 1, 2, or 3 Request Data Bytes, it must return only the corresponding number of Floating-Point Device Parameters (see table below).

For a list of Floating-Point Device Parameters, please refer to the *Floating-Point Device Parameter Table*.

Command 128 Response Based on Number of Floating-Point Device Parameters Requested

Number of Device Parameters Requested	Number of Requested Data Bytes	Number of Response Data Bytes
1	1	7
2	2	14
3	3	21
4	4	28

Request Data Bytes

Byte	Format	Description
0	Unsigned-8	Slot 0: Floating-Point Device Parameter Code
1	Unsigned-8	Slot 1: Floating-Point Device Parameter Code
2	Unsigned-8	Slot 2: Floating-Point Device Parameter Code
3	Unsigned-8	Slot 3: Floating-Point Device Parameter Code

Response Data Bytes

Byte	Format	Description
0	Unsigned-8	Slot 0: Floating-Point Device Parameter Code
1	Enum	Slot 0: Floating-Point Device Parameter Variable Classification
2	Enum	Slot 0: Floating-Point Device Parameter Unit Code
3 - 6	Float	Slot 0: Floating-Point Device Parameter Value
7	Unsigned-8	Slot 1: Floating-Point Device Parameter Code
8	Enum	Slot 1: Floating-Point Device Parameter Variable Classification
9	Enum	Slot 1: Floating-Point Device Parameter Unit Code
10 - 13	Float	Slot 1: Floating-Point Device Parameter Value
14	Unsigned-8	Slot 2: Floating-Point Device Parameter Code
15	Enum	Slot 2: Floating-Point Device Parameter Variable Classification
16	Enum	Slot 2: Floating-Point Device Parameter Unit Code
17 -20	Float	Slot 2: Floating-Point Device Parameter Value
21	Unsigned-8	Slot 3: Floating-Point Device Parameter Code
22	Enum	Slot 3: Floating-Point Device Parameter Variable Classification
23	Enum	Slot 3: Floating-Point Device Parameter Unit Code
24 - 27	Float	Slot 3: Floating-Point Device Parameter Value

Command-Specific Response Codes

Code	Class	Description
0	Success	No Command-Specific Errors
2	Error	Invalid Selection
5	Error	Too Few Data Bytes Received
32	Error	Device Busy

B.3 COMMAND 129: WRITE FLOATING-POINT DEVICE PARAMETER

This command allows a Master to set the value of one Floating-Point Device Parameter. The Floating-Point Device Parameter Unit Code received with this command does not affect the Floating-Point Device Parameter Units of the Field Device. The Floating-Point Device Parameter value will be returned in the same units as received.

For a list of Floating-Point Device Parameters, please refer to the *Floating-Point Device Parameter Table*.

Request Data Bytes

Byte	Format	Description
0	Unsigned-8	Floating-Point Device Parameter Code
1	Enum	Floating-Point Device Parameter Variable Classification
2	Enum	Floating-Point Device Parameter Unit Code
3 - 6	Float	Floating-Point Device Parameter Value

Response Data Bytes

Byte	Format	Description
0	Unsigned-8	Floating-Point Device Parameter Code
1	Enum	Floating-Point Device Parameter Variable Classification
2	Enum	Floating-Point Device Parameter Unit Code
3 - 6	Float	Floating-Point Device Parameter Value

Command-Specific Response Codes

Code	Class	Description
0	Success	No Command-Specific Errors
2	Error	Invalid Selection
3	Error	Value too high
4	Error	Value too low
5	Error	Too Few Data Bytes Received
7	Error	In Write-Protect Mode
12	Error	Invalid Variable Classification
18	Error	Invalid Unit Code
32	Error	Device Busy

B.4 COMMAND 130: READ DISCRETE

This command allows a Master to read one Device Discrete value.
For a list of Device Discretes, please refer to the *Device Discrete Table*.

Request Data Bytes

Byte	Format	Description
0	Unsigned-8	Device Discrete Code

Response Data Bytes

Byte	Format	Description
0	Unsigned-8	Device Discrete Code
1	Bit – 0	Device Discrete Value

Command-Specific Response Codes

Code	Class	Description
0	Success	No Command-Specific Errors
2	Error	Invalid Selection
5	Error	Too Few Data Bytes Received
32	Error	Device Busy

B.5 COMMAND 131: WRITE DISCRETE

This command allows a Master to write one Device Discrete value.
For a list of Device Discretes, please refer to the *Device Discrete Table*.

Request Data Bytes

Byte	Format	Description
0	Unsigned-8	Device Discrete Code
1	Bit – 0	Device Discrete Value

Response Data Bytes

Byte	Format	Description
0	Unsigned-8	Device Discrete Code
1	Bit – 0	Device Discrete Value

Command-Specific Response Codes

Code	Class	Description
0	Success	No Command-Specific Errors
2	Error	Invalid Selection
5	Error	Too Few Data Bytes Received
7	Error	In Write-Protect Mode
12	Error	Invalid Value
32	Error	Device Busy

B.6 COMMAND 132: READ INTEGER DEVICE PARAMETER

This command allows a Master to request the value of up to four Integer Device Parameters. In other words, a Master may request only 1, 2, 3, or 4 Integer Device Parameters. The Field Device must answer these Master requests without returning Response Code 5, *Too Few Data Bytes Received*. If the Field Device receives 1, 2, or 3 Request Data Bytes, it must return only the corresponding number of Integer Device Parameters (see table below).

For a list of Integer Device Parameters, please refer to the *Integer Device Parameter Table*.

Command 132 Response Based on Number of Integer Device Parameters Requested

Number of Device Parameters Requested	Number of Requested Data Bytes	Number of Response Data Bytes
1	1	5
2	2	10
3	3	15
4	4	20

Request Data Bytes

Byte	Format	Description
0	Unsigned-8	Slot 0: Integer Device Parameter Code
1	Unsigned-8	Slot 1: Integer Device Parameter Code
2	Unsigned-8	Slot 2: Integer Device Parameter Code
3	Unsigned-8	Slot 3: Integer Device Parameter Code

Response Data Bytes

Byte	Format	Description
0	Unsigned-8	Slot 0: Integer Device Parameter Code
1	Enum	Slot 0: Integer Device Parameter Variable Classification
2	Enum	Slot 0: Integer Device Parameter Unit Code
3 – 4	Unsigned-16	Slot 0: Integer Device Parameter Value
5	Unsigned-8	Slot 1: Integer Device Parameter Code
6	Enum	Slot 1: Integer Device Parameter Variable Classification
7	Enum	Slot 1: Integer Device Parameter Unit Code
8 – 9	Unsigned-16	Slot 1: Integer Device Parameter Value
10	Unsigned-8	Slot 2: Integer Device Parameter Code
11	Enum	Slot 2: Integer Device Parameter Variable Classification
12	Enum	Slot 2: Integer Device Parameter Unit Code
13 – 14	Unsigned-16	Slot 2: Integer Device Parameter Value
15	Unsigned-8	Slot 3: Integer Device Parameter Code
16	Enum	Slot 3: Integer Device Parameter Variable Classification
17	Enum	Slot 3: Integer Device Parameter Unit Code
18 – 19	Unsigned-16	Slot 3: Integer Device Parameter Value

Command-Specific Response Codes

Code	Class	Description
0	Success	No Command-Specific Errors
2	Error	Invalid Selection
5	Error	Too Few Data Bytes Received
32	Error	Device Busy

B.7 COMMAND 133: WRITE INTEGER DEVICE PARAMETER

This command allows a Master to set the value of one Integer Device Parameter. The Integer Device Parameter Unit Code received with this command does not affect the Integer Device Parameter Units of the Field Device. The Integer Device Parameter value will be returned in the same units as received.
For a list of Integer Device Parameters, please refer to the *Integer Device Parameter Table*.

Request Data Bytes

Byte	Format	Description
0	Unsigned-8	Integer Device Parameter Code
1	Enum	Integer Device Parameter Variable Classification
2	Enum	Integer Device Parameter Unit Code
3 - 4	Integer-16	Integer Device Parameter Value

Response Data Bytes

Byte	Format	Description
0	Unsigned-8	Integer Device Parameter Code
1	Enum	Integer Device Parameter Variable Classification
2	Enum	Integer Device Parameter Unit Code
3 – 4	Integer-16	Integer Device Parameter Value

Command-Specific Response Codes

Code	Class	Description
0	Success	No Command-Specific Errors
2	Error	Invalid Selection
3	Error	Value too high
4	Error	Value too low
5	Error	Too Few Data Bytes Received
7	Error	In Write-Protect Mode
12	Error	Invalid Variable Classification
18	Error	Invalid Unit Code
32	Error	Device Busy

B.8 COMMAND 134: READ DEVICE VARIABLES

This command allows a Master to request the value of up to four Device Variables. In other words, a Master may request only 1, 2, 3, or 4 Device Variables. The Field Device must answer these Master requests without returning Response Code 5, *Too Few Data Bytes Received*. If the Field Device receives 1, 2, or 3 Request Data Bytes, it must return only the corresponding number of Device Variables (see table below).
For a list of Device Variables, please refer to the *Device Variable Table*.

Command 134 Response Based on Number of Device Variables Requested

Number of Device Variables Requested	Number of Requested Data Bytes	Number of Response Data Bytes
1	1	9
2	2	17
3	3	25
4	4	33

Request Data Bytes

Byte	Format	Description
0	Unsigned-8	Slot 0: Device Variable Code
1	Unsigned-8	Slot 1: Device Variable Code
2	Unsigned-8	Slot 2: Device Variable Code
3	Unsigned-8	Slot 3: Device Variable Code

Response Data Bytes

Byte	Format	Description
0	Bits	Extended Field Device Status
1	Unsigned-8	Slot 0: Device Variable Code
2	Enum	Slot 0: Device Variable Classification
3	Enum	Slot 0: Device Variable Unit Code
4 – 7	Float	Slot 0: Device Variable Value
8	Bits	Slot 0: Device Variable Status
9	Unsigned-8	Slot 1: Device Variable Code
10	Enum	Slot 1: Device Variable Classification
11	Enum	Slot 1: Device Variable Unit Code
12 – 15	Float	Slot 1: Device Variable Value
16	Bits	Slot 1: Device Variable Status
17	Unsigned-8	Slot 2: Device Variable Code
18	Enum	Slot 2: Device Variable Variable Classification
19	Enum	Slot 2: Device Variable Unit Code
20 – 23	Float	Slot 2: Device Variable Value
24	Bits	Slot 2: Device Variable Status
25	Unsigned-8	Slot 3: Device Variable Code
26	Enum	Slot 3: Device Variable Variable Classification
27	Enum	Slot 3: Device Variable Unit Code
28 – 31	Float	Slot 3: Device Variable Value
32	Bits	Slot 3: Device Variable Status

Command-Specific Response Codes

Code	Class	Description
0	Success	No Command-Specific Errors
2	Error	Invalid Selection
5	Error	Too Few Data Bytes Received
32	Error	Device Busy

B.9 COMMAND 135: READ INTEGER DEVICE VARIABLES

This command allows a Master to request the value of up to four Integer Device Parameters. In other words, a Master may request only 1, 2, 3, or 4 Integer Device Parameters. The Field Device must answer these Master requests without returning Response Code 5, *Too Few Data Bytes Received*. If the Field Device receives 1, 2, or 3 Request Data Bytes, it must return only the corresponding number of Integer Device Variables (see table below).

For a list of Integer Device Variables, please refer to the *Integer Device Variable Table*.

Command 135 Response Based on Number of Integer Device Variables Requested

Number of Device Parameters Requested	Number of Requested Data Bytes	Number of Response Data Bytes
1	1	5
2	2	10
3	3	15
4	4	20

Request Data Bytes

Byte	Format	Description
0	Unsigned-8	Slot 0: Integer Device Variable Code
1	Unsigned-8	Slot 1: Integer Device Variable Code
2	Unsigned-8	Slot 2: Integer Device Variable Code
3	Unsigned-8	Slot 3: Integer Device Variable Code

Response Data Bytes

Byte	Format	Description
0	Unsigned-8	Slot 0: Integer Device Variable Code
1	Enum	Slot 0: Integer Device Variable Classification
2	Enum	Slot 0: Integer Device Variable Unit Code
3 – 4	Unsigned-16	Slot 0: Integer Device Variable Value
5	Unsigned-8	Slot 1: Integer Device Variable Code
6	Enum	Slot 1: Integer Device Variable Classification
7	Enum	Slot 1: Integer Device Variable Unit Code
8 – 9	Unsigned-16	Slot 1: Integer Device Variable Value
10	Unsigned-8	Slot 2: Integer Device Variable Code
11	Enum	Slot 2: Integer Device Variable Classification
12	Enum	Slot 2: Integer Device Variable Unit Code
13 – 14	Unsigned-16	Slot 2: Integer Device Variable Value
15	Unsigned-8	Slot 3: Integer Device Variable Code
16	Enum	Slot 3: Integer Device Variable Classification
17	Enum	Slot 3: Integer Device Variable Unit Code
18 – 19	Unsigned-16	Slot 3: Integer Device Variable Value

Command-Specific Response Codes

Code	Class	Description
0	Success	No Command-Specific Errors
2	Error	Invalid Selection
5	Error	Too Few Data Bytes Received
32	Error	Device Busy

B.10 HART® TABLES

B.10.1 HART® DYNAMIC VARIABLES

The following table lists the Dynamic Variables that are available using the HART® protocol.

Table B.1 - HART® Dynamic Variable Table

Dynamic Variable Number	Description
0 PRIMARY	Process (Water Cut)
1 SECONDARY	Temperature
2 TERTIARY	Emulsion Phase – 0.0 = Oil continuous, 1.0 = Water continuous, 2.0 = Undetermined

B.10.2 HART® DEVICE PARAMETERS – FLOATING-POINT

The following table lists the Floating-Point Device Parameters that are available to be read and written using the HART® protocol. Command 128 reads one through four Floating-Point Device Parameters and Command 129 writes one Floating-Point Device Parameter.

Table B.2 - HART® Floating-Point Device Parameter Table

Parameter Number	Description
0	Salinity – based on Stream Number
1	Oil Adjust (Cal. Factor) – based on Stream Number
2	Oil Frequency Index
3	Water Adjust – based on Stream Number
4	Water Frequency Index
5	Alarm Relay Set Point – based on Stream Number (Standard Electronics Only)
6	Output Loop 4 mA Point
7	Output Loop 20 mA Point
8	Temperature Adjust
9	Oil P0
10	Oil P1
11	Oil Low Frequency
12	Oil High Frequency
13	Water Low Frequency
14	Water High Frequency
15	Auto-Cal Oil Value
16	Auto-Cal Water Value
17	Calibration API
18	Density Correction A1 Coefficient
19	Density Correction A0 Coefficient
20	4 mA API Density
21	20 mA API Density
22	4 mA kg/m3 Density
23	20 mA kg/m3 Density

B.10.3 HART® DEVICE DISCRETES

The following table lists the Device Discrete items that are available to be read and written using the HART® protocol. Command 130 reads one Device Discrete and Command 131 writes one Device Discrete. A value of 0 = OFF and 1 = ON.

Table B.3 - HART® Device Discrete Table

Discrete Number	Description
0	Alarm Relay (Standard Electronics - Read Only)
1	Error Relay (Standard Electronics - Read Only)
2	Write Protect
3	Clear Gross Fluid Accumulators
4	Restore Factory Defaults
5	Restore Stream (Well) Defaults
6	Master Reset
7	Clear Analyzer Diagnostics
8	Clear Analyzer Error Code
9	Built-In Test Enable
10	Alarm Relay Greater Than or Equal to Set Point
11	Stream Select Mode (Standard Electronics)
12	Error Relay Normally Closed
13	Temperature in degrees C
14	Use HART® Universal Command Revision 5
15	Active Current Loop Mode
16	Capture Oil Auto-Cal Data
17	Capture Water Auto-Cal Data
18	Modbus Enable
19	Dual Pulsed Relays
20	Emulsion Phase Relay
21	Temperature Averaging
22	Data Change Indicator
23	Save Configuration

B.10.4 HART® DEVICE PARAMETERS – INTEGER

The following table lists the Integer Device Parameters that are available to be read and written using the HART® protocol. Command 132 reads one through four Integer Device Parameters and Command 133 writes one Integer Device Parameter.

Table B.4 - HART® Integer Device Parameter Table

Parameter Number	Description
0	Stream Number
1	Samples to Average
2	Phase Holdover Cycles
3	Alarm Relay Delay
4	Flow Meter Type
5	Flow Volume Units
6	Flow Rate Time Units
7	Counts Per Flow Unit
8	20 mA Maximum Flow Rate Input
9	Accumulator Display Format
10	4 mA D/A Counts
11	20 mA D/A Counts
12	HART Response Delay
13	Number of Response Preambles
14	Reference Current Mode
15	Oil Auto-Cal Samples
16	Water Auto-Cal Samples
17	Density Correction Mode
18	Modbus Slave Address
19	Modbus Baud Rate
20	Modbus Parity
21	Modbus Stop Bits
22	Modbus Response Delay

B.10.5 HART® DEVICE VARIABLES

The following table lists the Device Variables that are available to be read using the HART® protocol. Command 134 reads one through four Device Variables.

Table B.5 - HART® Device Variable Table

Variable Number	Description
0	Water Cut
1	Temperature
2	Emulsion Phase – 0.0 = Oil-continuous, 1.0 = Water-continuous, 2.0 = Undetermined
3	Analyzer Diagnostics
4	Analyzer Error Code
5	Oil Oscillator Frequency
6	Oil Oscillator Incident Power
7	Oil Oscillator Reflected Power
8	Water Oscillator Frequency
9	Water Oscillator Incident Power
10	Water Oscillator Reflected Power
11	Gross Oil Accumulator (Flow Meter Required)
12	Gross Water Accumulator (Flow Meter Required)
13	Gross Total Fluids Accumulator (Flow Meter Required)
14	Oil Flow Rate (Flow Meter Required)
15	Water Flow Rate (Flow Meter Required)
16	Total Fluid Flow Rate (Flow Meter Required)
17	Internal Temperature (Stand-alone Electronics Only)
18	Analog Input 1
19	Analog Input 1 Percent of Range
20	Analog Input 2
21	Analog Input 2 Percent of Range
22	Analog Input 3
23	Analog Input 3 Percent of Range
24	Analog Input 4
25	Analog Input 4 Percent of Range
26	Analog Input 5
27	Analog Input 5 Percent of Range
28	Analog Output 1
29	Analog Output 1 Percent of Range
30	Analog Output 2
31	Analog Output 2 Percent of Range
32	Analog Output 3
33	Analog Output 3 Percent of Range
34	Analog Output 4
35	Analog Output 4 Percent of Range
36	Analog Output 5
37	Analog Output 5 Percent of Range
38	Analog Output 6
39	Analog Output 6 Percent of Range
40	Analog Output 7

41	Analog Output 7 Percent of Range
42	Analog Output 8
43	Analog Output 8 Percent of Range
44	Flow Computer 1 – Pulse Frequency
45	Flow Computer 1 – Water Content
46	Flow Computer 1 – Temperature
47	Flow Computer 1 – Pressure
48	Flow Computer 1 – Salinity
49	Flow Computer 1 – Density
50	Flow Computer 1 – Oil Density
51	Flow Computer 1 – Water Density
52	Flow Computer 1 – Oil Flow Rate
53	Flow Computer 1 – Water Flow Rate
54	Flow Computer 1 – Total Flow Rate
55	Flow Computer 1 – Gross Oil
56	Flow Computer 1 – Gross Water
57	Flow Computer 1 – Gross Total
58	Flow Computer 1 – Net Oil
59	Flow Computer 1 – Net Water
60	Flow Computer 1 – Net Total
61	Flow Computer 1 – Net Flow Rate Oil
62	Flow Computer 1 – Net Flow Rate Water
63	Flow Computer 1 – Net Flow Rate Total
64	Flow Computer 2 – Pulse Frequency
65	Flow Computer 2 – Water Content
66	Flow Computer 2 – Temperature
67	Flow Computer 2 – Pressure
68	Flow Computer 2 – Salinity
69	Flow Computer 2 – Density
70	Flow Computer 2 – Oil Density
71	Flow Computer 2 – Water Density
72	Flow Computer 2 – Oil Flow Rate
73	Flow Computer 2 – Water Flow Rate
74	Flow Computer 2 – Total Flow Rate
75	Flow Computer 2 – Gross Oil
76	Flow Computer 2 – Gross Water
77	Flow Computer 2 – Gross Total
78	Flow Computer 2 – Net Oil
79	Flow Computer 2 – Net Water
80	Flow Computer 2 – Net Total
81	Flow Computer 2 – Net Flow Rate Oil
82	Flow Computer 2 – Net Flow Rate Water
83	Flow Computer 2 – Net Flow Rate Total
84	Flow Computer 3 – Pulse Frequency
85	Flow Computer 3 – Water Content
86	Flow Computer 3 – Temperature
87	Flow Computer 3 – Pressure
88	Flow Computer 3 – Salinity
89	Flow Computer 3 – Density
90	Flow Computer 3 – Oil Density

91	Flow Computer 3 – Water Density
92	Flow Computer 3 – Oil Flow Rate
93	Flow Computer 3 – Water Flow Rate
94	Flow Computer 3 – Total Flow Rate
95	Flow Computer 3 – Gross Oil
96	Flow Computer 3 – Gross Water
97	Flow Computer 3 – Gross Total
98	Flow Computer 3 – Net Oil
99	Flow Computer 3 – Net Water
100	Flow Computer 3 – Net Total
101	Flow Computer 3 – Net Flow Rate Oil
102	Flow Computer 3 – Net Flow Rate Water
103	Flow Computer 3 – Net Flow Rate Total
104	CCM Gas Flow Rate
105	CCM Gas Total
106	CCM Gas Density
107	Stream Select
108	Salinity
109	CCM Vessel Level 1
110	CCM Vessel Level 2
111	CCM Setpoint Level 1
112	CCM Setpoint Level 2
113	CCM Vessel Pressure 1
114	CCM Vessel Pressure 2
115	CCM Vessel Pressure Setpoint 1
116	CCM Vessel Pressure Setpoint 2

B.10.6 HART® INTEGER DEVICE VARIABLES

The following table lists the Integer Device Variables that are available to be read using the HART® protocol. Command 134 reads one through four Integer Device Variables.

Table B.6 - HART® Integer Device Variable Table

Variable Number	Description
0	HART® Diagnostics
1	Analyzer Diagnostics
2	Analyzer Error Code
3	Emulsion Phase 0 = Oil-continuous, 1 = Water-continuous, 2 = Undetermined
4	Analyzer Diagnostics Enumerated

APPENDIX C

C.1 Logging to the Internal FLASH Memory

The Analyzer has the capability to log data, changes to configuration, and events within its internal FLASH memory. This data can be used for diagnostic and trend analysis. When the end of the log has been reached, it will automatically purge the oldest records. The data can be retrieved with the optional *Data Log Fetch Too*l.

C.2 Log Record Types

There are three types of records stored within the log. The user may enable each record type.

C.2.1 Periodic Data Record

The periodic data record is entered into the log on a preset interval. This data includes:

- Diagnostics
- Time Code
- Time & Date (if available)
- Process / Raw Water Content
- Process Temperature
- Water Oscillator's Frequency
- Oil Oscillator's Frequency
- Oil Oscillator's Reflected Power

C.2.2 Configuration Data Change Record

Upon ANY configuration write event, via MODBUS®, the changes are recorded for each data item that is affected. The record includes the port number, address, time code, and data value.

C.2.3 Event Record

Errors and Alarms are recorded in the same format as a periodic event, but at the time that they occur.

APPENDIX D

D.1 COMPARISON OF METHODS FOR THE DETERMINATION OF WATER IN OIL

Three methods for determination of water content are distillation, titration and centrifugal separation (shake-out). The ASTM designations for these are D4006, D4377, and D4007, respectively.
Table E.1 summarizes the comparison between these methods.

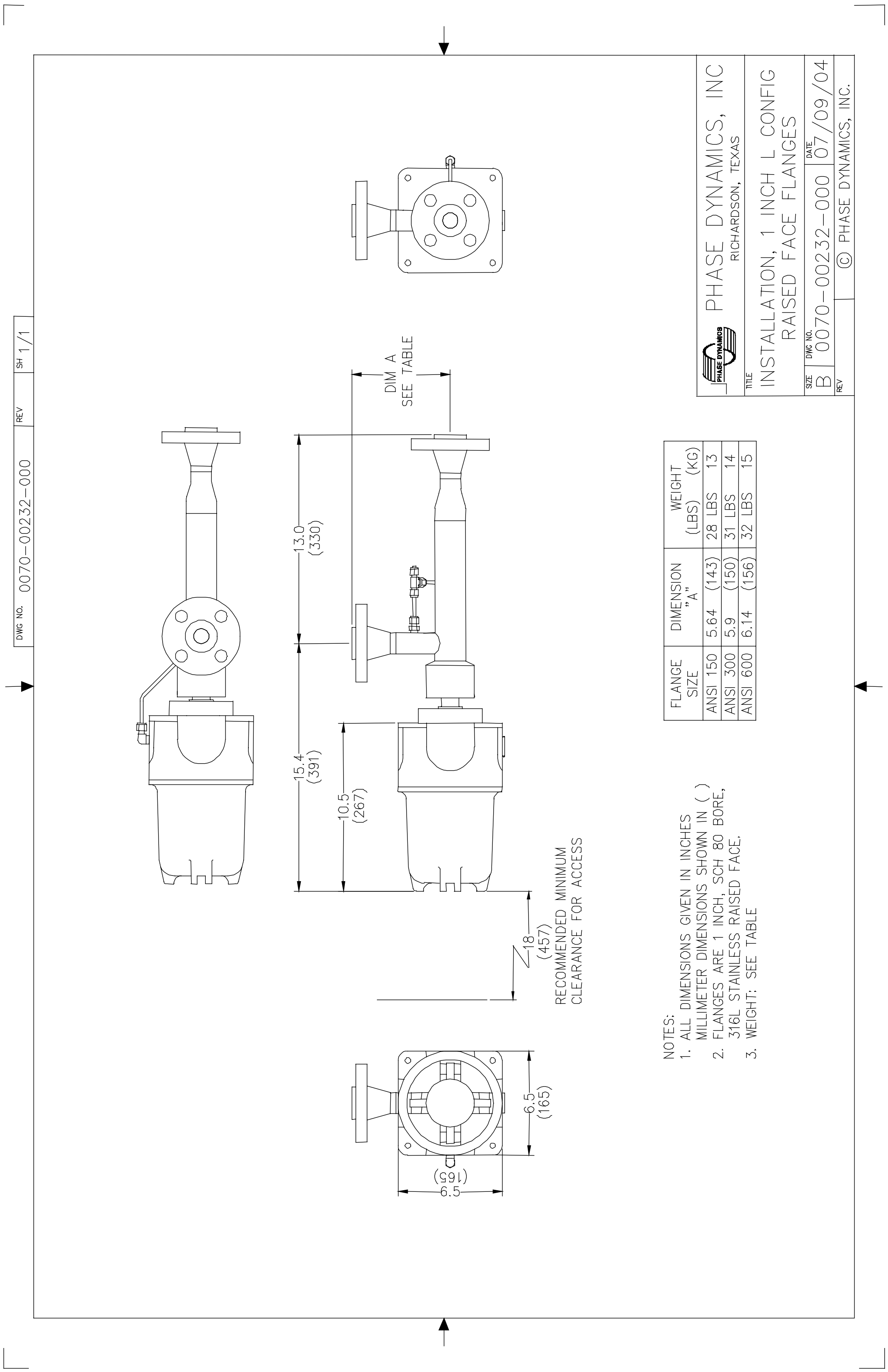
Table E.1 - Comparison of Water in Crude Methods of Water Contents Less than 1%

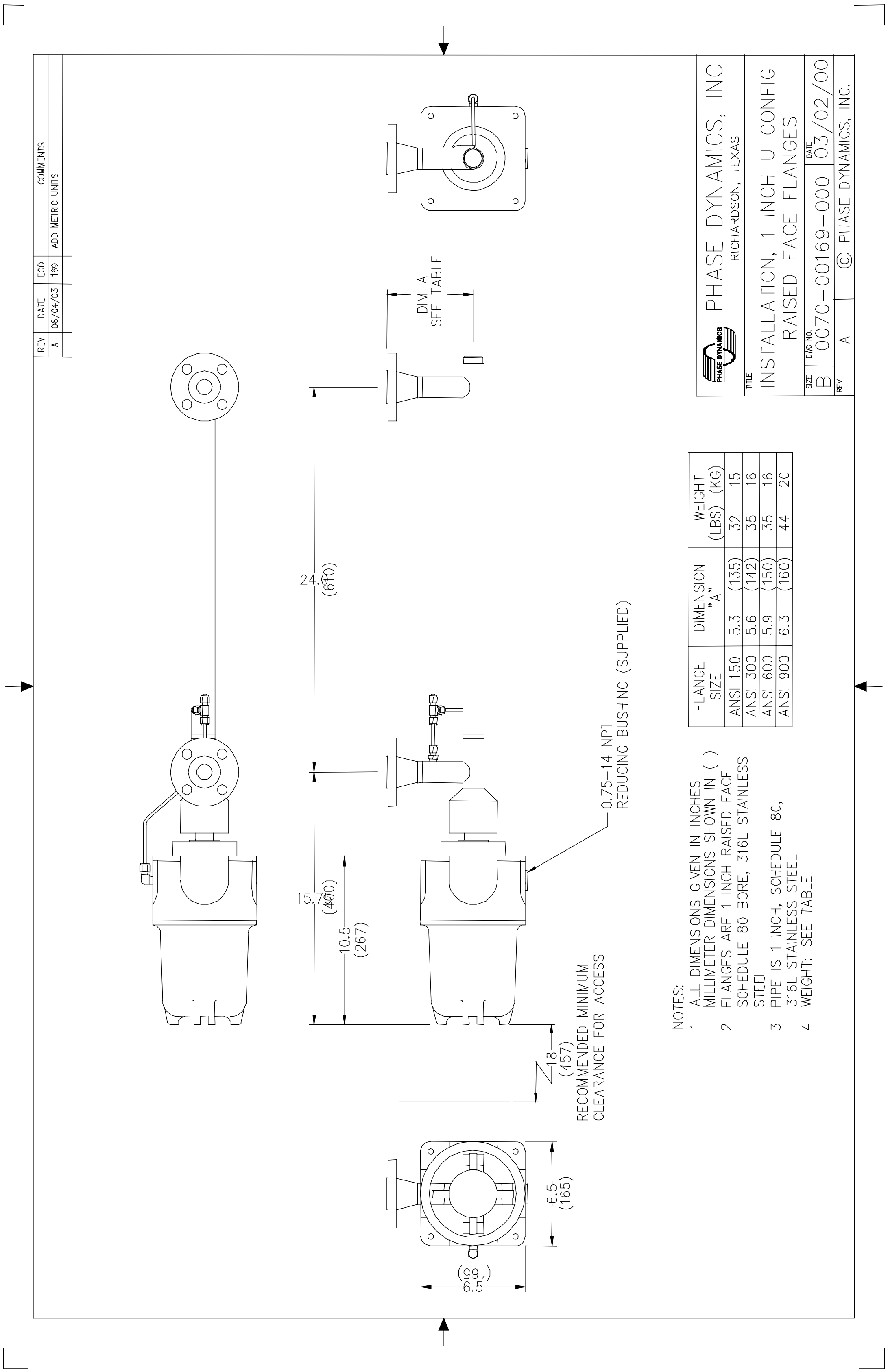
Method	ASTM	Sample Size	Reproducibility	Repeatability
Distillation	D4006	200mL minimum	0.08%	0.11%
Titration	D4377	2-5g	0.04%	0.15%
Centrifuge	D4007	100mL	0.12%	0.28%

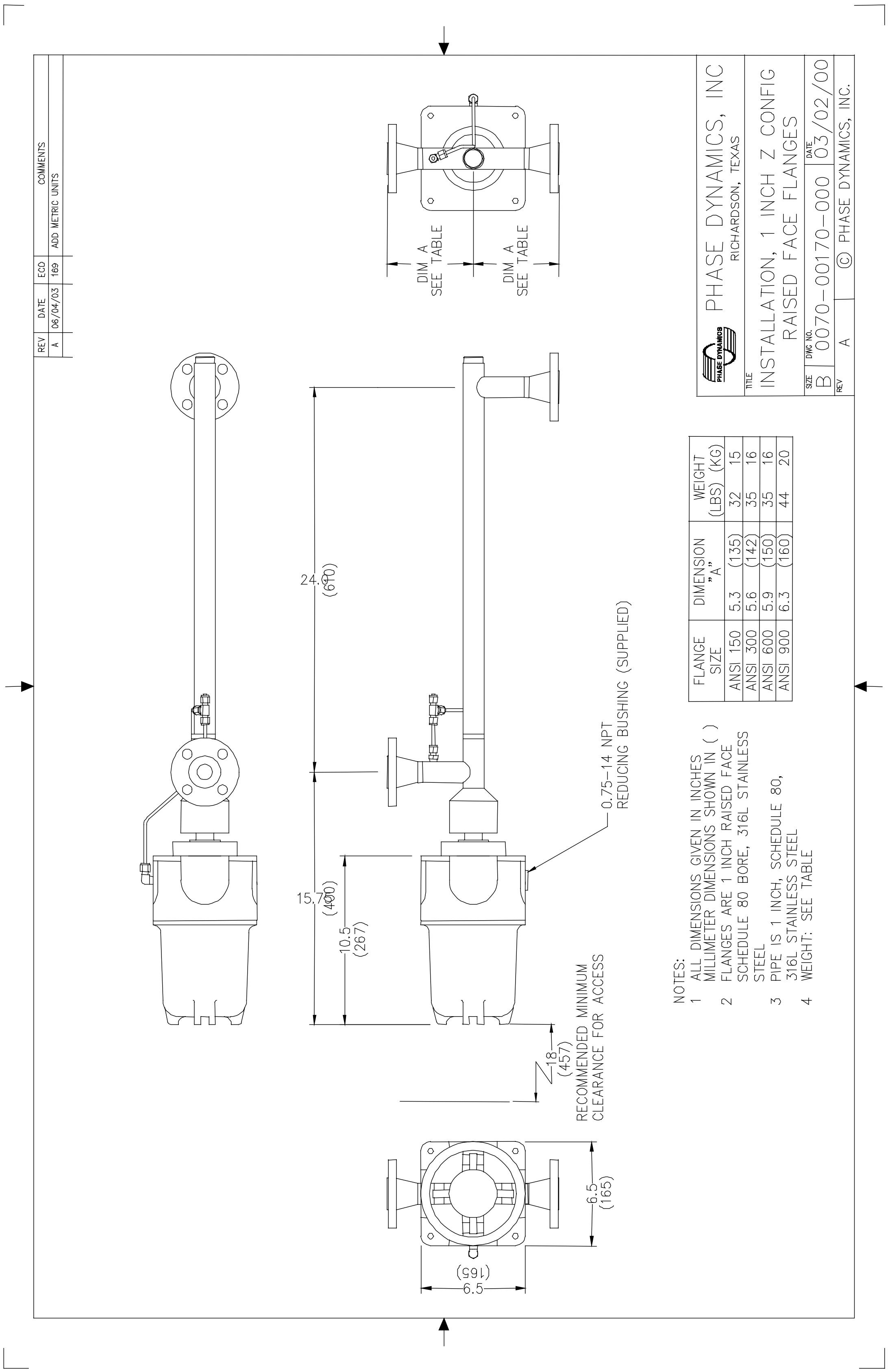
Repeatability is the difference between successive test results, obtained by the same operator with the same apparatus under constant operating conditions on identical test material. Reproducibility is the difference between the two single and independent test results obtained by different operators working in different laboratories on identical test material. Both distillation and titration are excellent tests to verify the water content of an oil/water emulsion. Centrifuge is not recommended for precise water contents less than 1.0%.

APPENDIX E

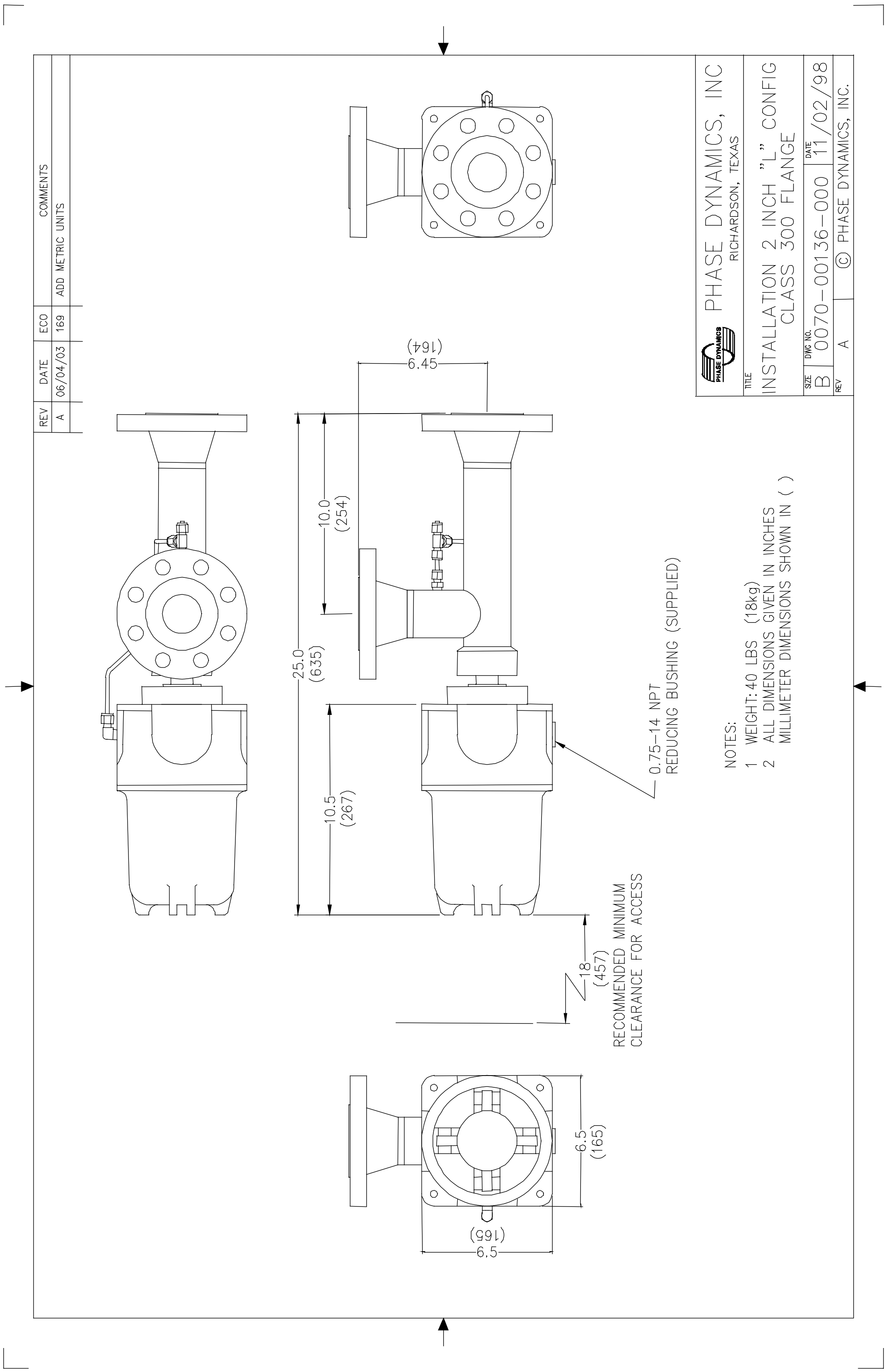
E.1 INSTALLATION DRAWINGS

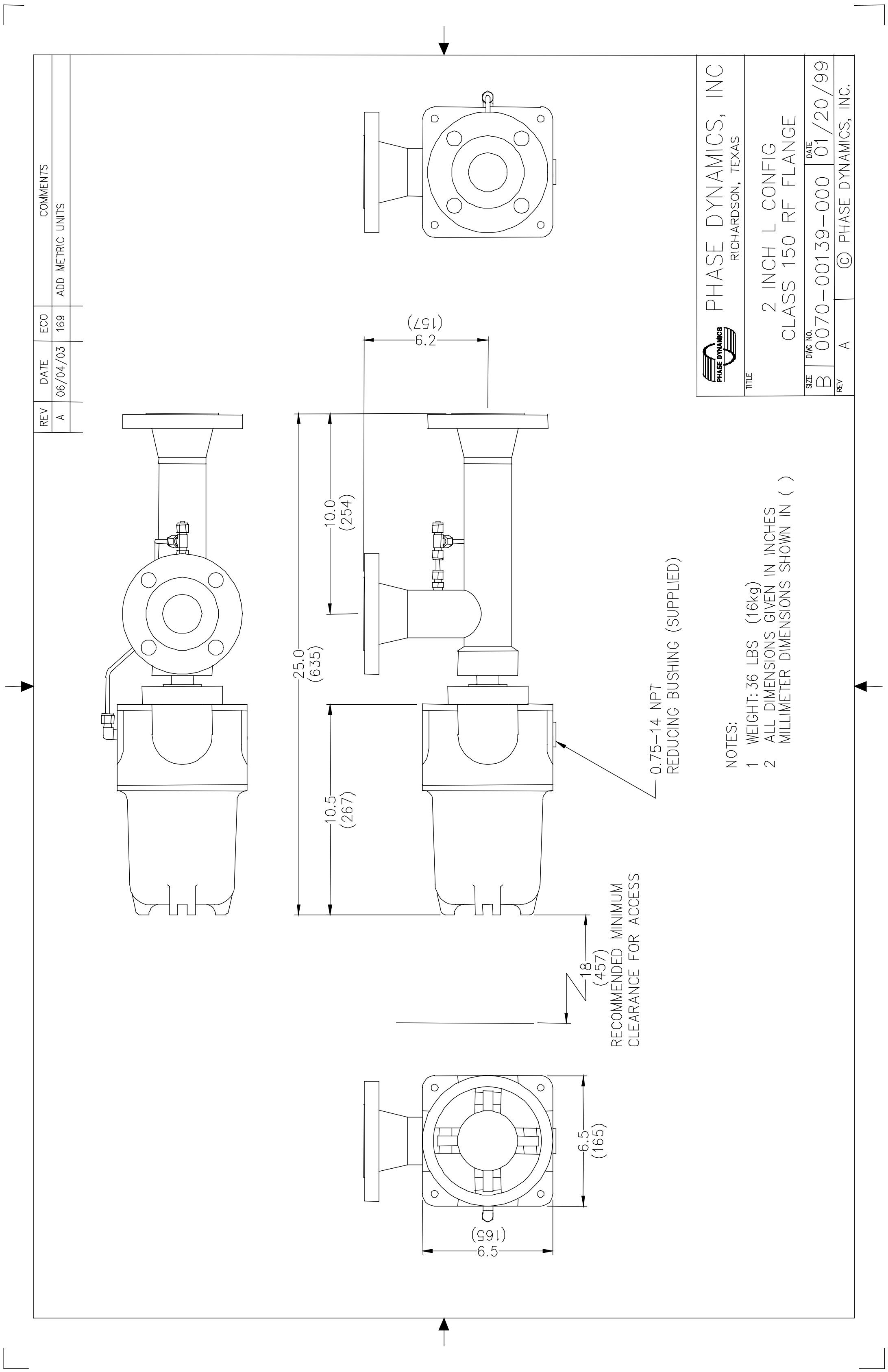

PHASE DYNAMICS, INC
RICHARDSON, TEXAS
TITLE
INSTALLATION, 1 INCH L CONFIG
RAISED FACE FLANGES
SIZE B
DWG NO. 0070-00232-000
DATE 07/09/04
REV
© PHASE DYNAMICS, INC.
DWG NO. 0070-00232-000
REV
SH 1/1
DIM A
SEE TABLE
13.0
(330)
15.4
(391)
10.5
(267)
18
(457)
RECOMMENDED MINIMUM
CLEARANCE FOR ACCESS
6.5
(165)
6.5
(165)
FLANGE SIZE | DIMENSION "A" | WEIGHT (LBS) (KG)
ANSI 150 | 5.64 (143) | 28 LBS 13
ANSI 300 | 5.9 (150) | 31 LBS 14
ANSI 600 | 6.14 (156) | 32 LBS 15
NOTES:
1. ALL DIMENSIONS GIVEN IN INCHES
MILLIMETER DIMENSIONS SHOWN IN ( )
2. FLANGES ARE 1 INCH, SCH 80 BORE,
316L STAINLESS RAISED FACE.
3. WEIGHT: SEE TABLE

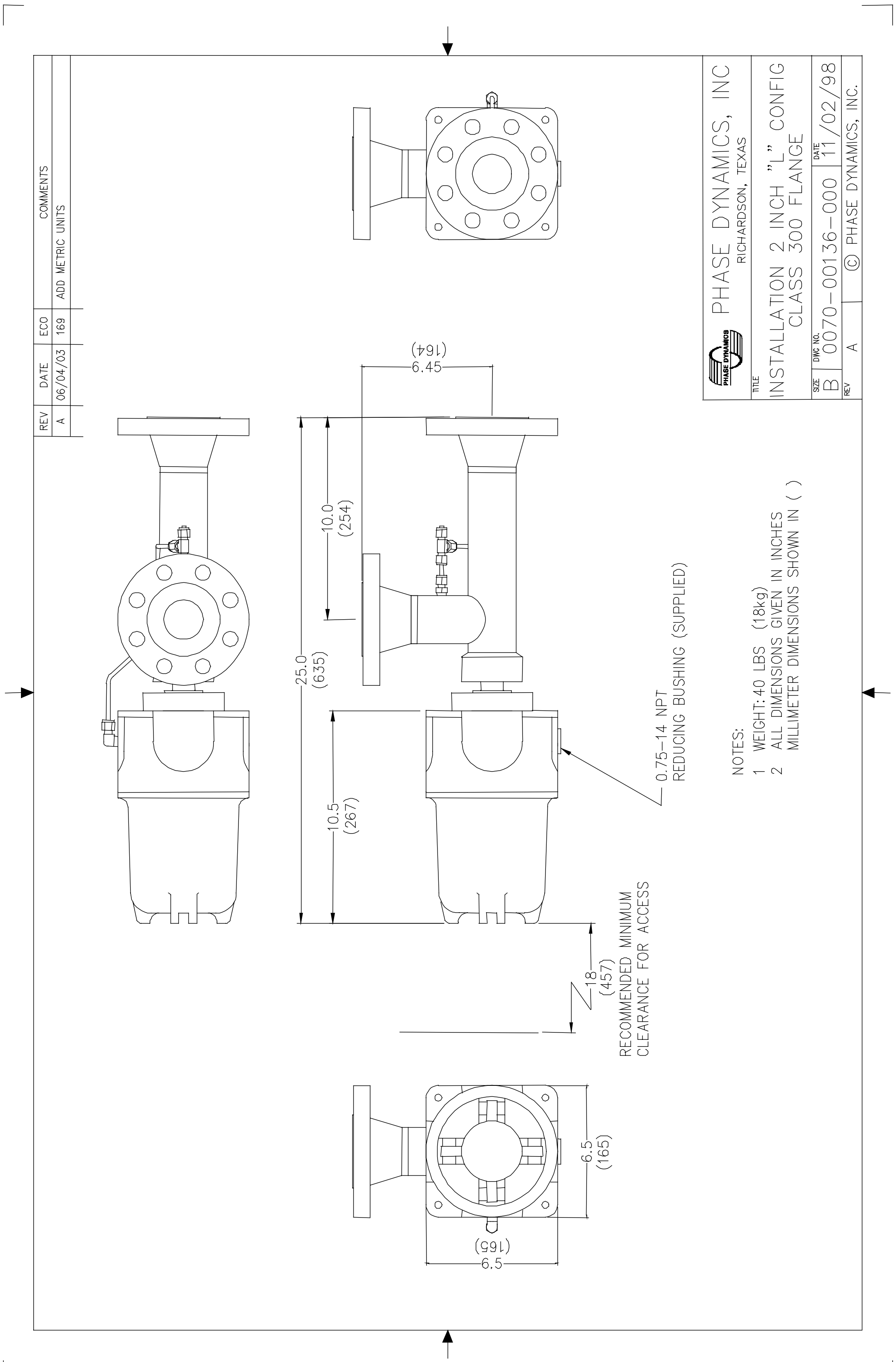

REV | DATE | ECO | COMMENTS
A | 06/04/03 | 169 | ADD METRIC UNITS
DIM A
SEE TABLE
24.0
(610)
15.7
(400)
10.5
(267)
18
(457)
RECOMMENDED MINIMUM
CLEARANCE FOR ACCESS
0.75-14 NPT
REDUCING BUSHING (SUPPLIED)
6.5
(165)
6.5
(165)
NOTES:
1 ALL DIMENSIONS GIVEN IN INCHES
MILLIMETER DIMENSIONS SHOWN IN ( )
2 FLANGES ARE 1 INCH RAISED FACE
SCHEDULE 80 BORE, 316L STAINLESS
STEEL
3 PIPE IS 1 INCH, SCHEDULE 80,
316L STAINLESS STEEL
4 WEIGHT: SEE TABLE
FLANGE SIZE | DIMENSION "A" | WEIGHT (LBS) (KG)
ANSI 150 | 5.3 (135) | 32 15
ANSI 300 | 5.6 (142) | 35 16
ANSI 600 | 5.9 (150) | 35 16
ANSI 900 | 6.3 (160) | 44 20
PHASE DYNAMICS
PHASE DYNAMICS, INC
RICHARDSON, TEXAS
TITLE
INSTALLATION, 1 INCH U CONFIG
RAISED FACE FLANGES
SIZE B
DWG NO. 0070-00169-000
DATE 03/02/00
REV A
© PHASE DYNAMICS, INC.

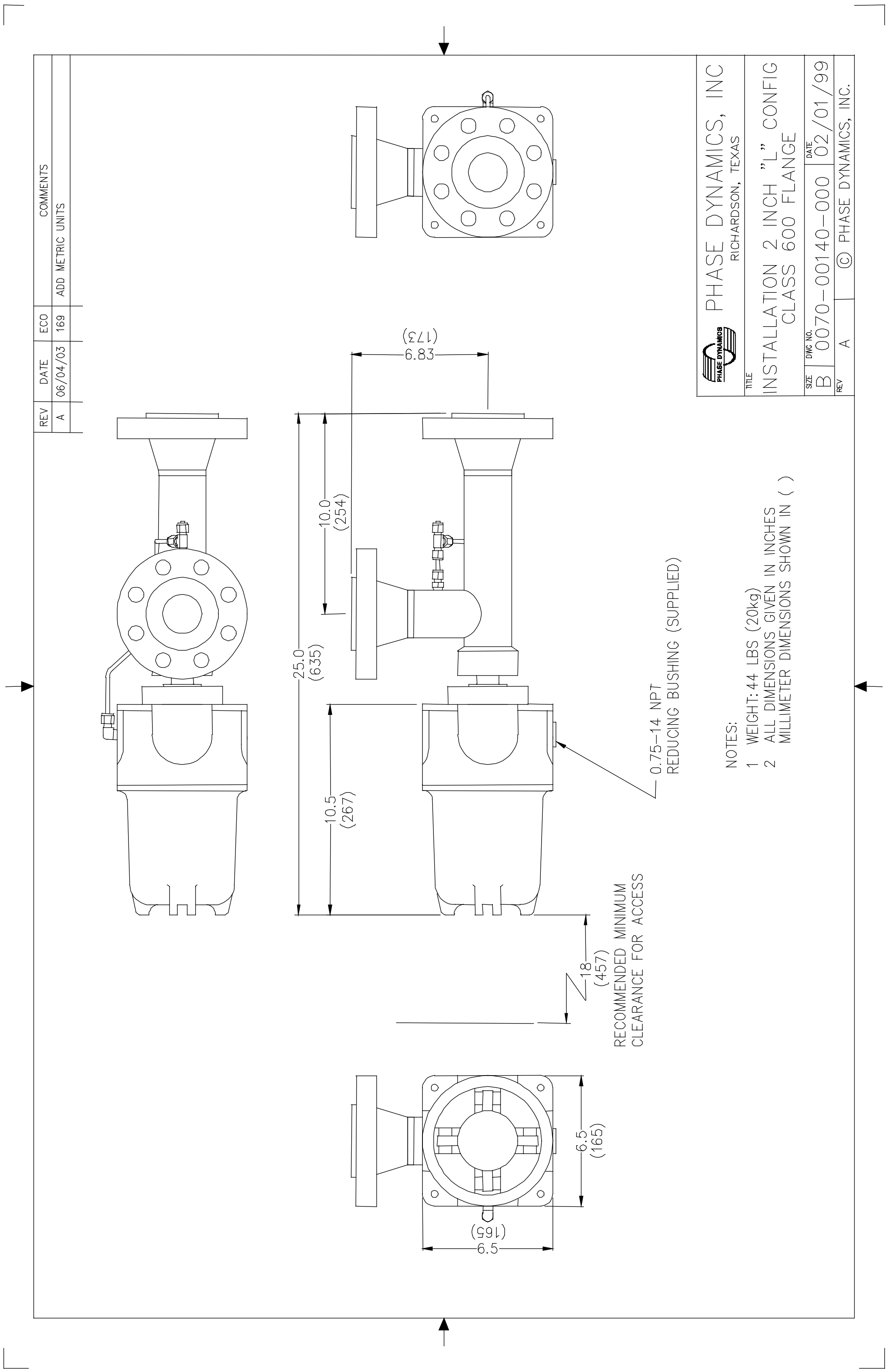


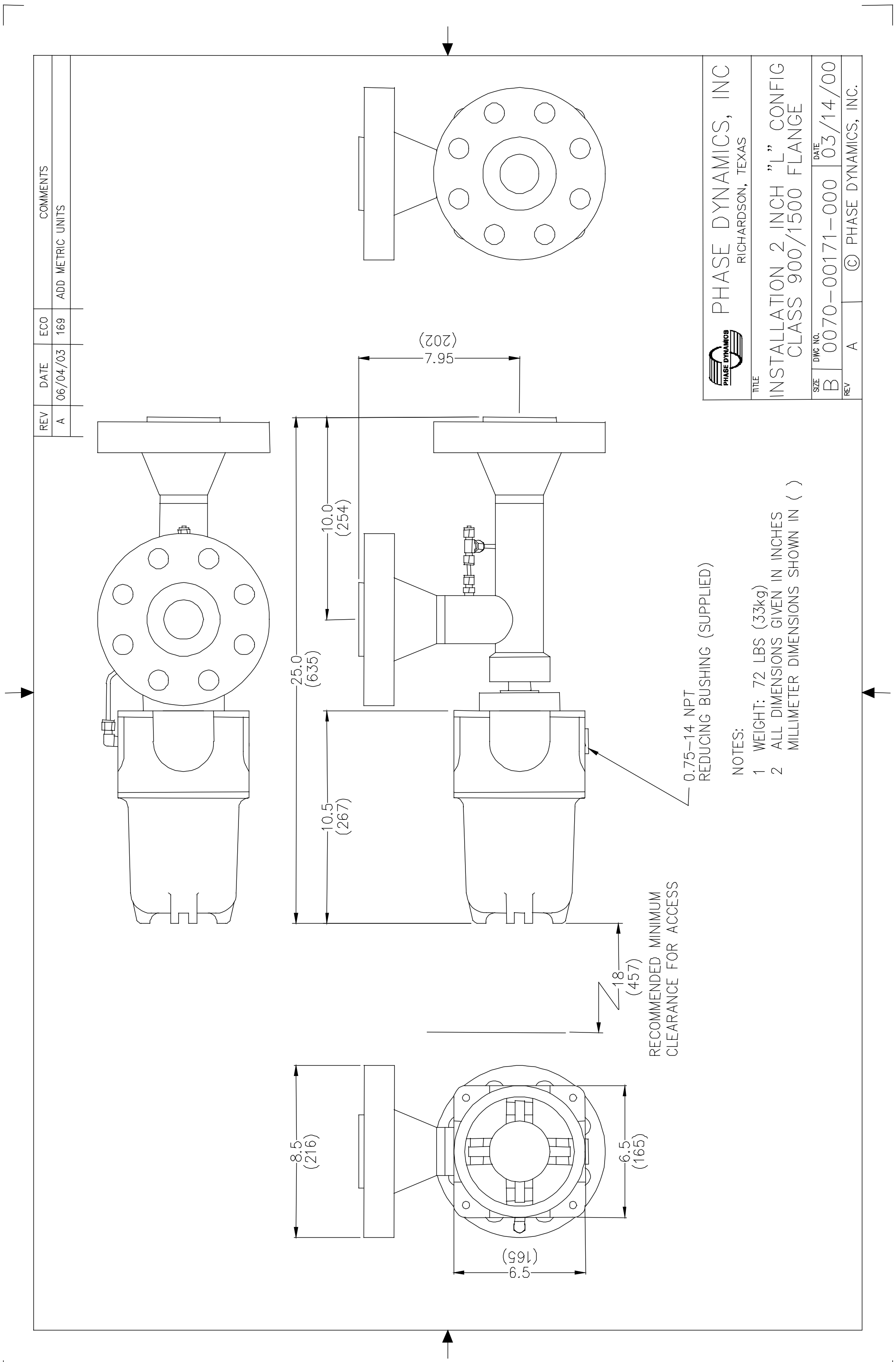
REV | DATE | ECO | COMMENTS
A | 06/04/03 | 169 | ADD METRIC UNITS
DIM A SEE TABLE
DIM A SEE TABLE
24.0 (610)
15.75 (400)
10.5 (267)
0.75-14 NPT REDUCING BUSHING (SUPPLIED)
18 (457) RECOMMENDED MINIMUM CLEARANCE FOR ACCESS
6.5 (165)
6.5 (165)
FLANGE SIZE | DIMENSION "A" | WEIGHT (LBS) (KG)
ANSI 150 | 5.3 (135) | 32 15
ANSI 300 | 5.6 (142) | 35 16
ANSI 600 | 5.9 (150) | 35 16
ANSI 900 | 6.3 (160) | 44 20
NOTES:
1 ALL DIMENSIONS GIVEN IN INCHES MILLIMETER DIMENSIONS SHOWN IN ( )
2 FLANGES ARE 1 INCH RAISED FACE SCHEDULE 80 BORE, 316L STAINLESS STEEL
3 PIPE IS 1 INCH, SCHEDULE 80, 316L STAINLESS STEEL
4 WEIGHT: SEE TABLE
PHASE DYNAMICS
PHASE DYNAMICS, INC
RICHARDSON, TEXAS
TITLE
INSTALLATION, 1 INCH Z CONFIG RAISED FACE FLANGES
SIZE B
DWG NO. 0070-00170-000
DATE 03/02/00
REV A
© PHASE DYNAMICS, INC.


PHASE DYNAMICS, INC
RICHARDSON, TEXAS
TITLE
INSTALLATION 2 INCH "L" CONFIG
CLASS 300 FLANGE
SIZE
B
DWG NO.
0070-00136-000
DATE
11/02/98
REV
A
© PHASE DYNAMICS, INC.
REV
DATE
ECO
COMMENTS
A
06/04/03
169
ADD METRIC UNITS
6.45
(164)
10.0
(254)
25.0
(635)
10.5
(267)
18
(457)
RECOMMENDED MINIMUM
CLEARANCE FOR ACCESS
0.75-14 NPT
REDUCING BUSHING (SUPPLIED)
NOTES:
1 WEIGHT: 40 LBS (18kg)
2 ALL DIMENSIONS GIVEN IN INCHES
MILLIMETER DIMENSIONS SHOWN IN ( )
6.5
(165)
6.5
(165)

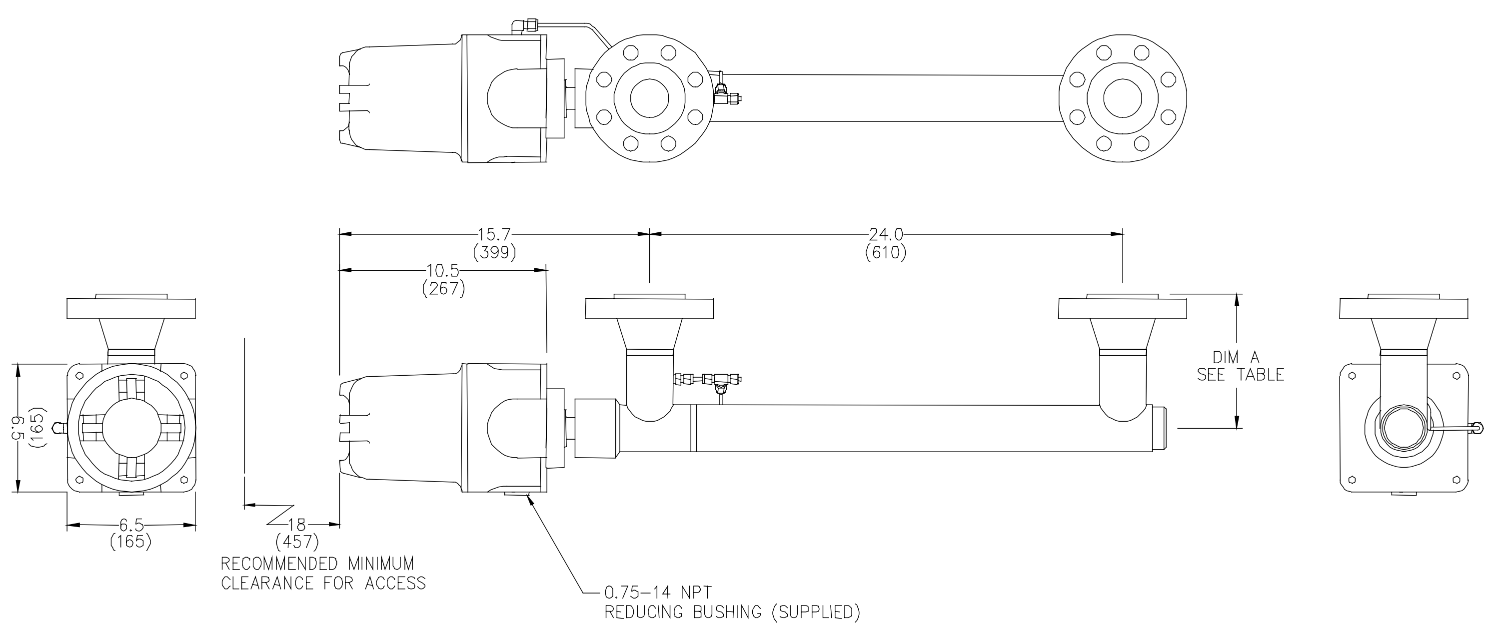

REV | DATE | ECO | COMMENTS
A | 06/04/03 | 169 | ADD METRIC UNITS
PHASE DYNAMICS, INC
RICHARDSON, TEXAS
TITLE
2 INCH L CONFIG
CLASS 150 RF FLANGE
SIZE B
DWG NO. 0070-00139-000
DATE 01/20/99
REV A
© PHASE DYNAMICS, INC.
6.2
(157)
10.0
(254)
25.0
(635)
10.5
(267)
0.75-14 NPT
REDUCING BUSHING (SUPPLIED)
NOTES:
1 WEIGHT:36 LBS (16kg)
2 ALL DIMENSIONS GIVEN IN INCHES
MILLIMETER DIMENSIONS SHOWN IN ( )
18
(457)
RECOMMENDED MINIMUM
CLEARANCE FOR ACCESS
6.5
(165)
6.5
(165)


REV | DATE | ECO | COMMENTS
A | 06/04/03 | 169 | ADD METRIC UNITS
PHASE DYNAMICS, INC
RICHARDSON, TEXAS
TITLE
INSTALLATION 2 INCH "L" CONFIG
CLASS 300 FLANGE
SIZE B
DWG NO. 0070-00136-000
DATE 11/02/98
REV A
© PHASE DYNAMICS, INC.
6.45
(164)
10.0
(254)
25.0
(635)
10.5
(267)
0.75-14 NPT
REDUCING BUSHING (SUPPLIED)
NOTES:
1 WEIGHT: 40 LBS (18kg)
2 ALL DIMENSIONS GIVEN IN INCHES
MILLIMETER DIMENSIONS SHOWN IN ( )
18
(457)
RECOMMENDED MINIMUM
CLEARANCE FOR ACCESS
6.5
(165)
6.5
(165)


REV | DATE | ECO | COMMENTS
A | 06/04/03 | 169 | ADD METRIC UNITS
PHASE DYNAMICS, INC
RICHARDSON, TEXAS
TITLE
INSTALLATION 2 INCH "L" CONFIG
CLASS 600 FLANGE
SIZE B
DWG NO. 0070-00140-000
DATE 02/01/99
REV A
© PHASE DYNAMICS, INC.
6.83
(173)
10.0
(254)
25.0
(635)
10.5
(267)
0.75-14 NPT
REDUCING BUSHING (SUPPLIED)
NOTES:
1 WEIGHT:44 LBS (20kg)
2 ALL DIMENSIONS GIVEN IN INCHES
MILLIMETER DIMENSIONS SHOWN IN ( )
18
(457)
RECOMMENDED MINIMUM
CLEARANCE FOR ACCESS
6.5
(165)
6.5
(165)


REV | DATE | ECO | COMMENTS
A | 06/04/03 | 169 | ADD METRIC UNITS
PHASE DYNAMICS
PHASE DYNAMICS, INC
RICHARDSON, TEXAS
TITLE
INSTALLATION 2 INCH "L" CONFIG
CLASS 900/1500 FLANGE
SIZE
B
DWG NO.
0070-00171-000
DATE
03/14/00
REV
A
© PHASE DYNAMICS, INC.
7.95
(202)
10.0
(254)
25.0
(635)
10.5
(267)
0.75-14 NPT
REDUCING BUSHING (SUPPLIED)
NOTES:
1 WEIGHT: 72 LBS (33kg)
2 ALL DIMENSIONS GIVEN IN INCHES
MILLIMETER DIMENSIONS SHOWN IN ( )
18
(457)
RECOMMENDED MINIMUM
CLEARANCE FOR ACCESS
8.5
(216)
6.5
(165)
6.5
(165)

REV	DATE	ECO	COMMENTS
A	11/09/99	137	ADD NOTES 2 ,3, 4
B	06/04/03	169	ADD METRIC UNITS



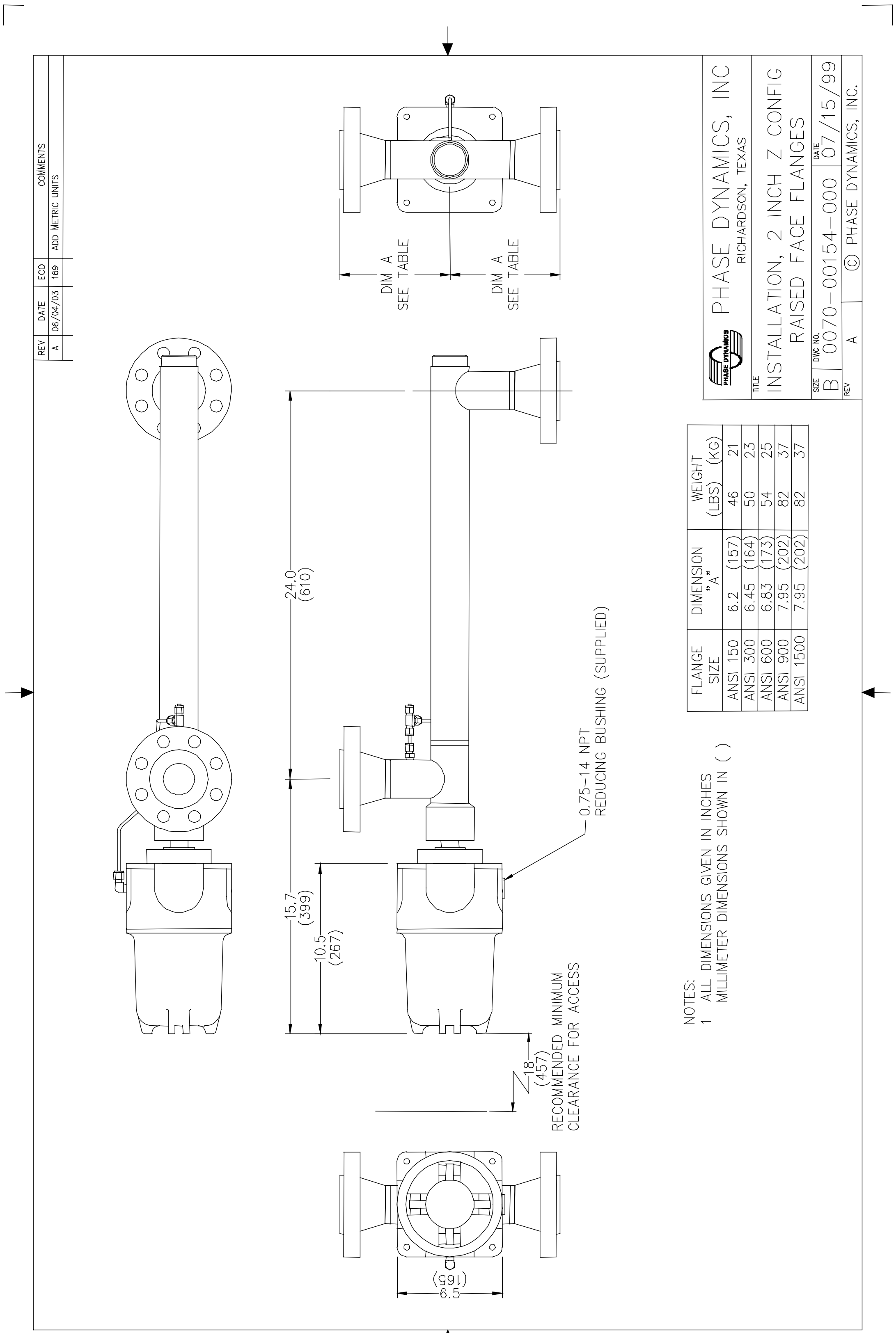
NOTES:
1 ALL DIMENSIONS GIVEN IN INCHES MILLIMETER DIMENSIONS SHOWN IN ( )
2 FLANGES ARE 2 INCH RAISED FACE SCHEDULE 80 BORE, 316L STAINLESS STEEL
3 PIPE IS 2 INCH, SCHEDULE 80, 316L STAINLESS STEEL
4 WEIGHT: SEE TABLE

FLANGE SIZE	DIMENSION "A"		WEIGHT (LBS)	WEIGHT (KG)
ANSI 150	6.2	(157)	46	21
ANSI 300	6.45	(164)	50	23
ANSI 600	6.83	(173)	54	25
ANSI 900	7.95	(202)	82	37
ANSI 1500	7.95	(202)	82	37

PHASE DYNAMICS, INC
RICHARDSON, TEXAS

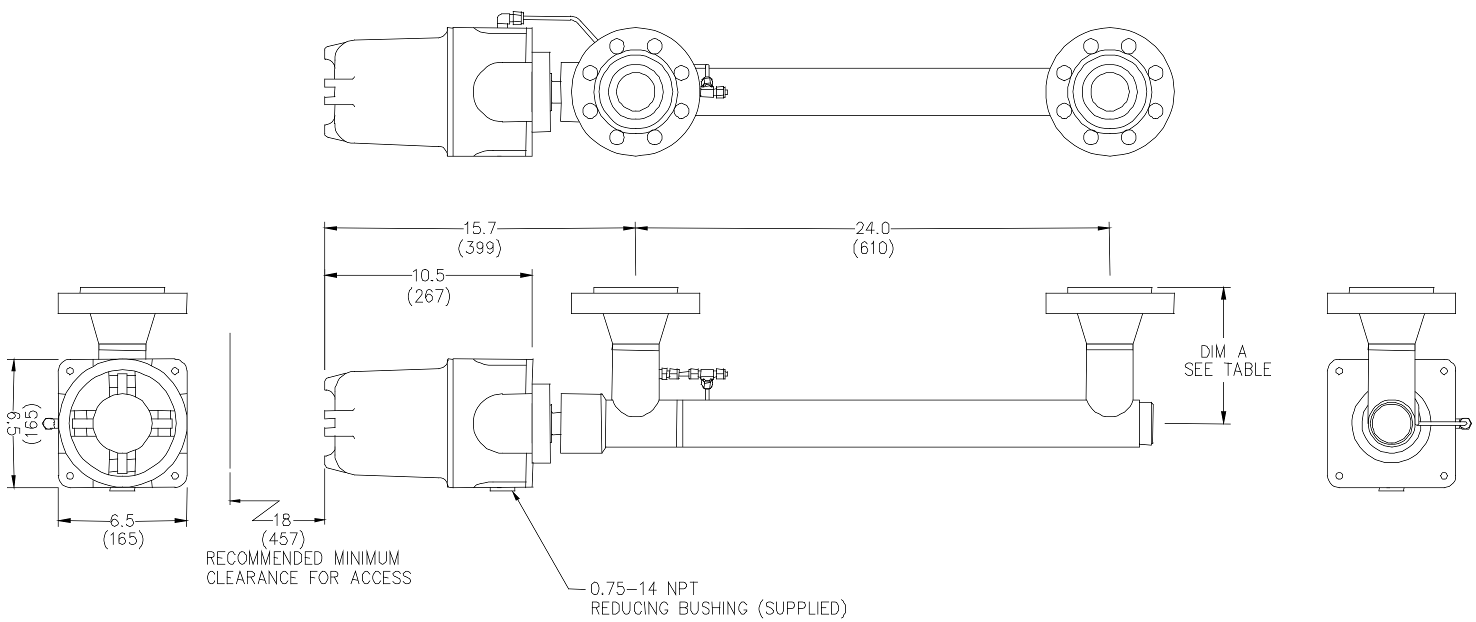
TITLE
INSTALLATION, 2 INCH U CONFIG
RAISED FACE FLANGES

SIZE B | DWG NO. 0070–00153–000 | DATE 06/17/99
REV B | © PHASE DYNAMICS, INC.



FLANGE SIZE	DIMENSION "A"		WEIGHT (LBS)	(KG)
ANSI 150	6.2	(157)	46	21
ANSI 300	6.45	(164)	50	23
ANSI 600	6.83	(173)	54	25
ANSI 900	7.95	(202)	82	37
ANSI 1500	7.95	(202)	82	37

REV	DATE	ECO	COMMENTS
A	06/04/03	169	ADD METRIC UNITS



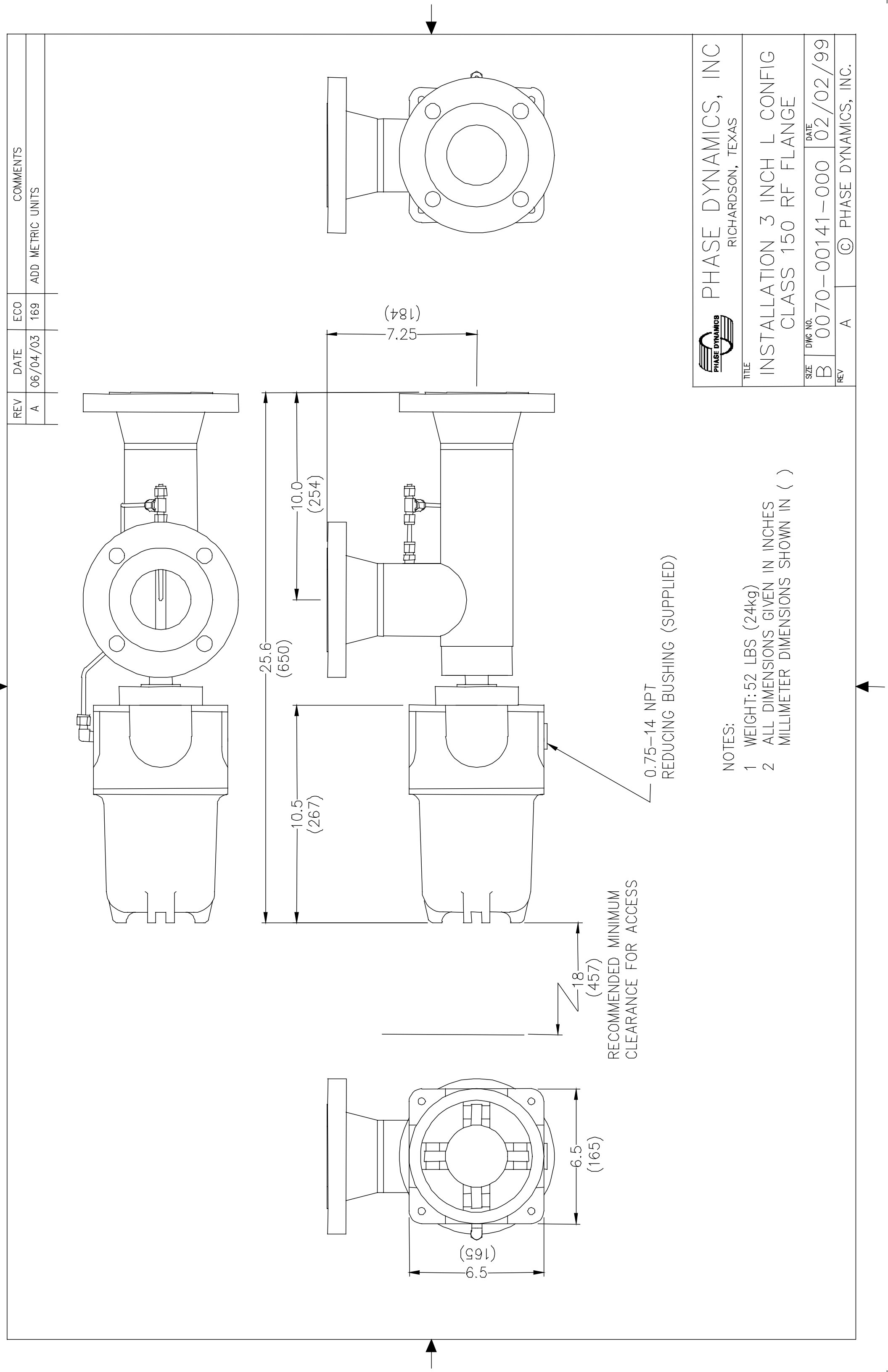
NOTES:
1 ALL DIMENSIONS GIVEN IN INCHES
  MILLIMETER DIMENSIONS SHOWN IN ( )
2 FLANGES ARE 2 INCH RTJ TYPE
  SCHEDULE 80 BORE, 316L STAINLESS STEEL
3 PIPE IS 2 INCH, SCHEDULE 80, 316L
  STAINLESS STEEL
4 WEIGHT: SEE TABLE

FLANGE SIZE	DIMENSION "A"		WEIGHT (LBS)	(KG)
ANSI 300 RTJ	6.5	(165)	50	23
ANSI 600 RTJ	6.9	(175)	54	25
ANSI 900 RTJ	8.0	(203)	82	37
ANSI 1500 RTJ	8.0	(203)	82	37

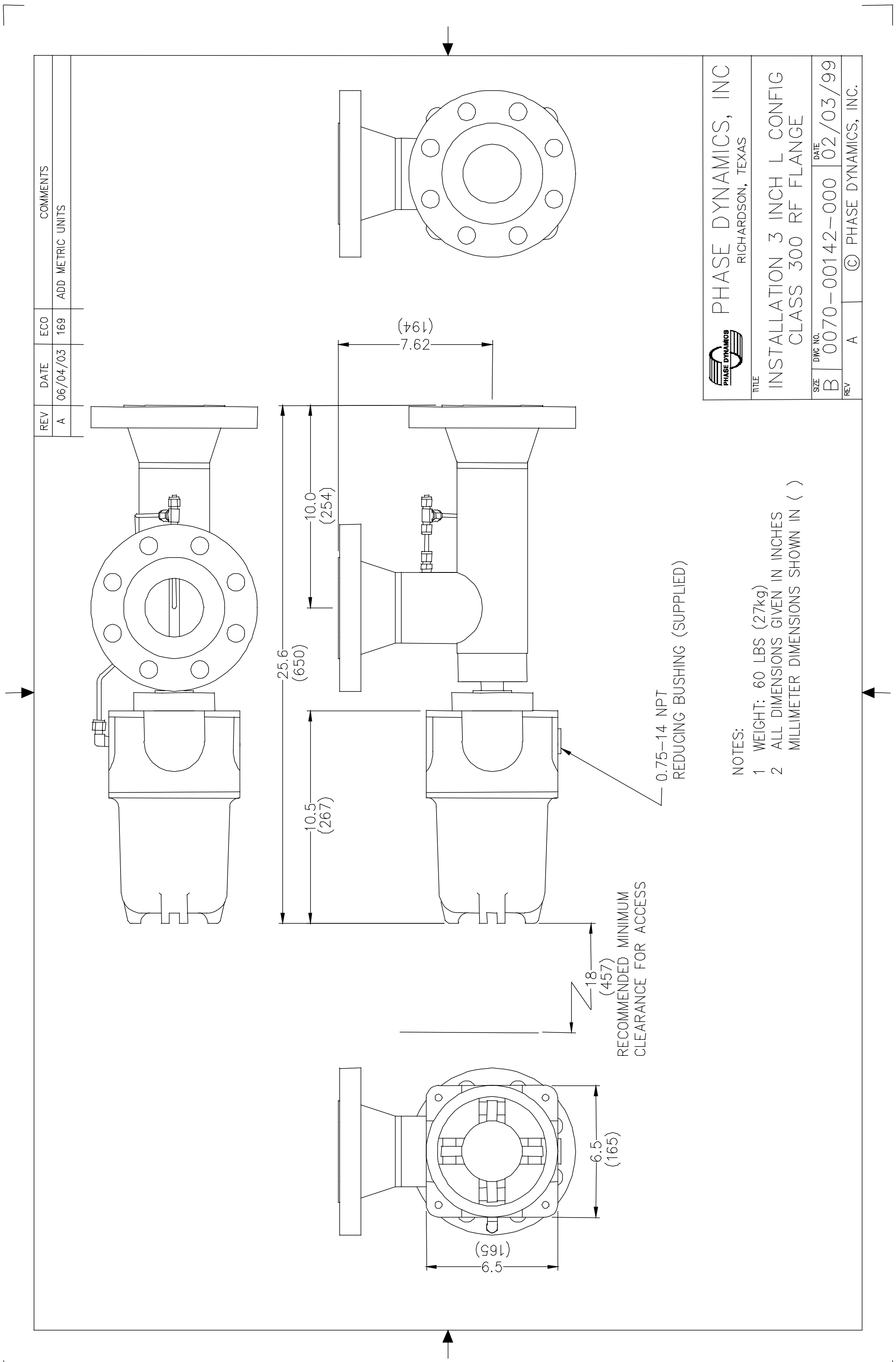
PHASE DYNAMICS, INC
RICHARDSON, TEXAS

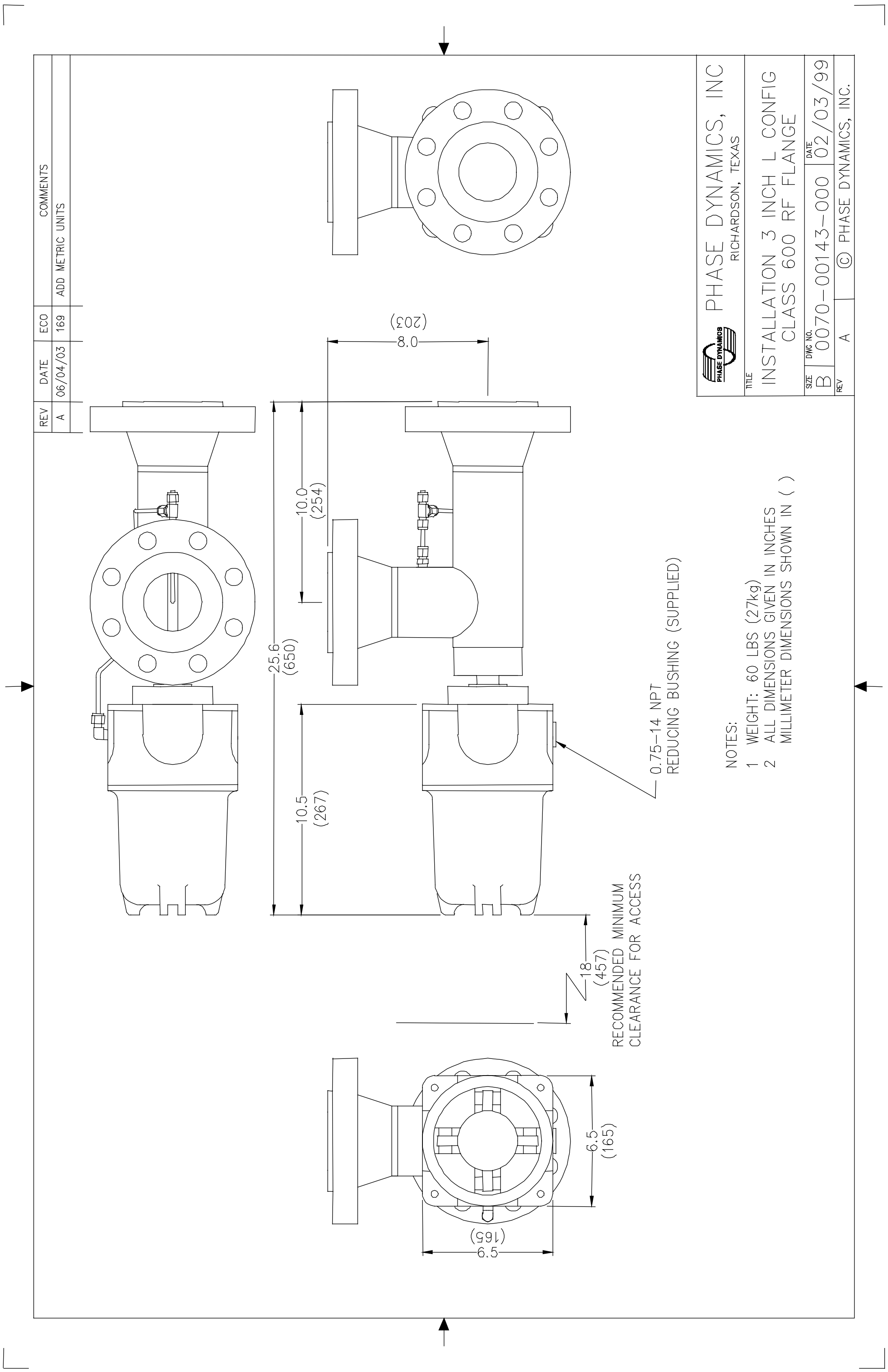
TITLE
INSTALLATION, 2 INCH U CONFIG
RTJ FLANGES

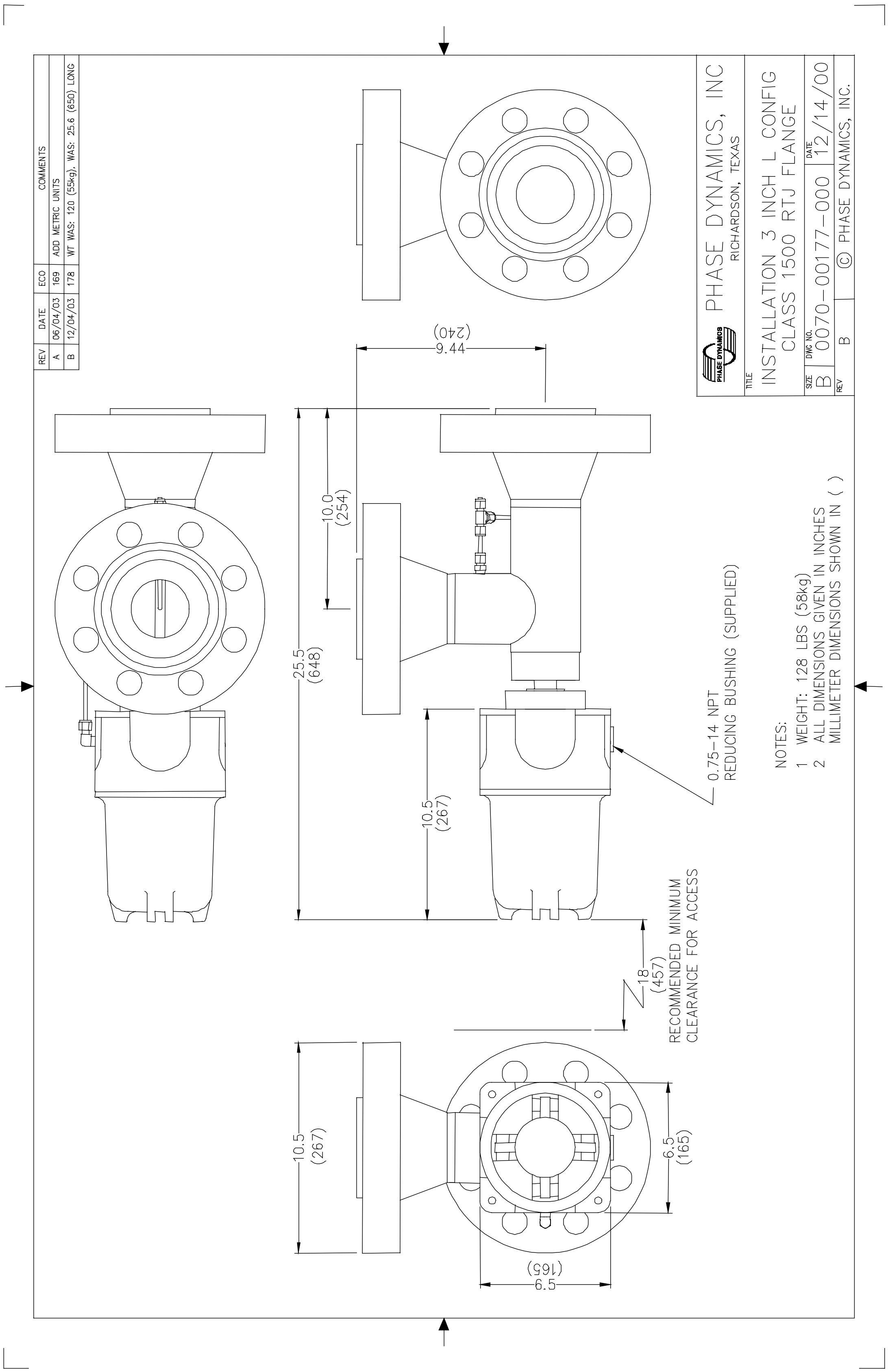
SIZE	DWG NO.	DATE
B	0070-00201-000	12/20/01
REV A		© PHASE DYNAMICS, INC.

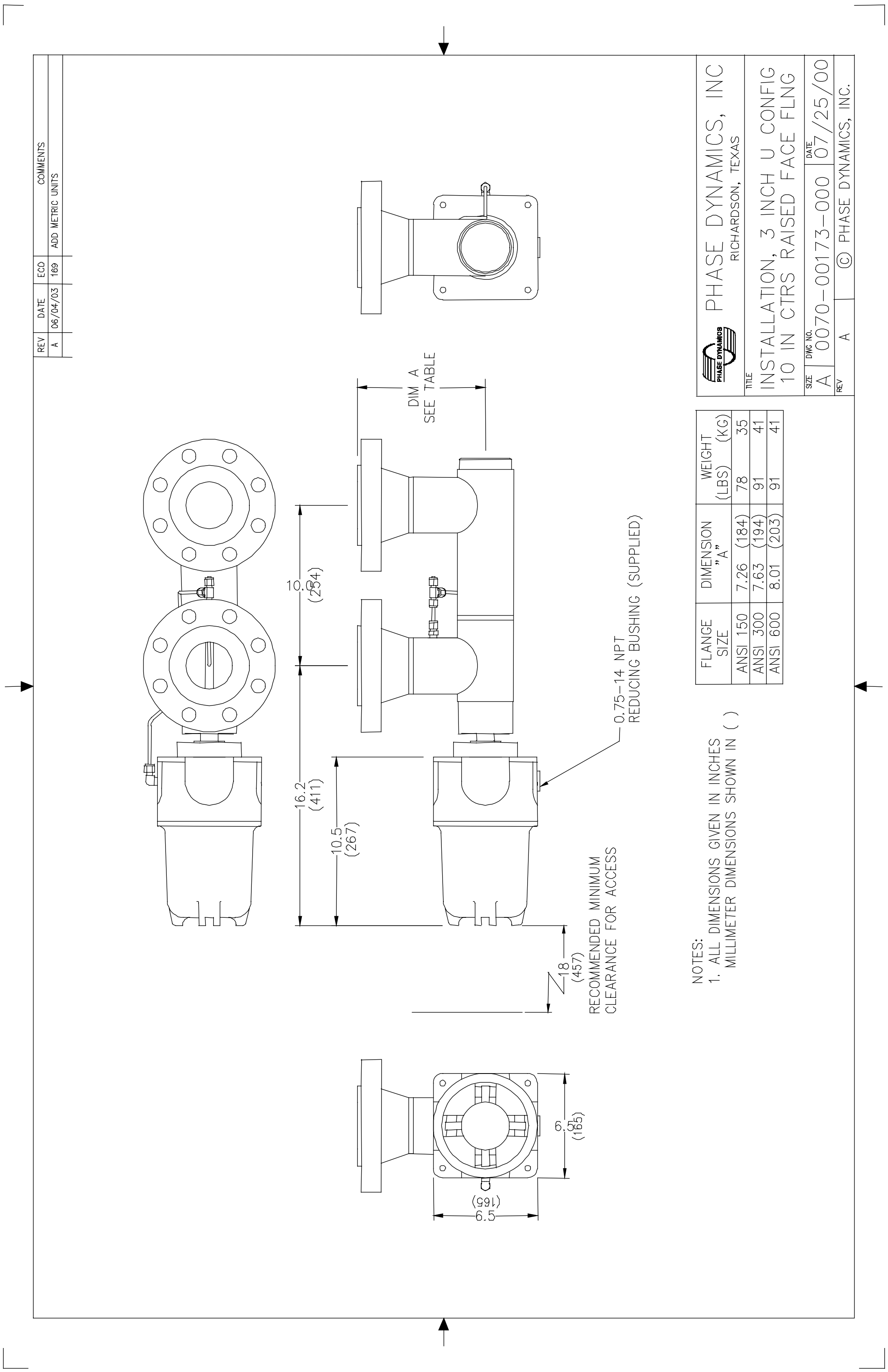


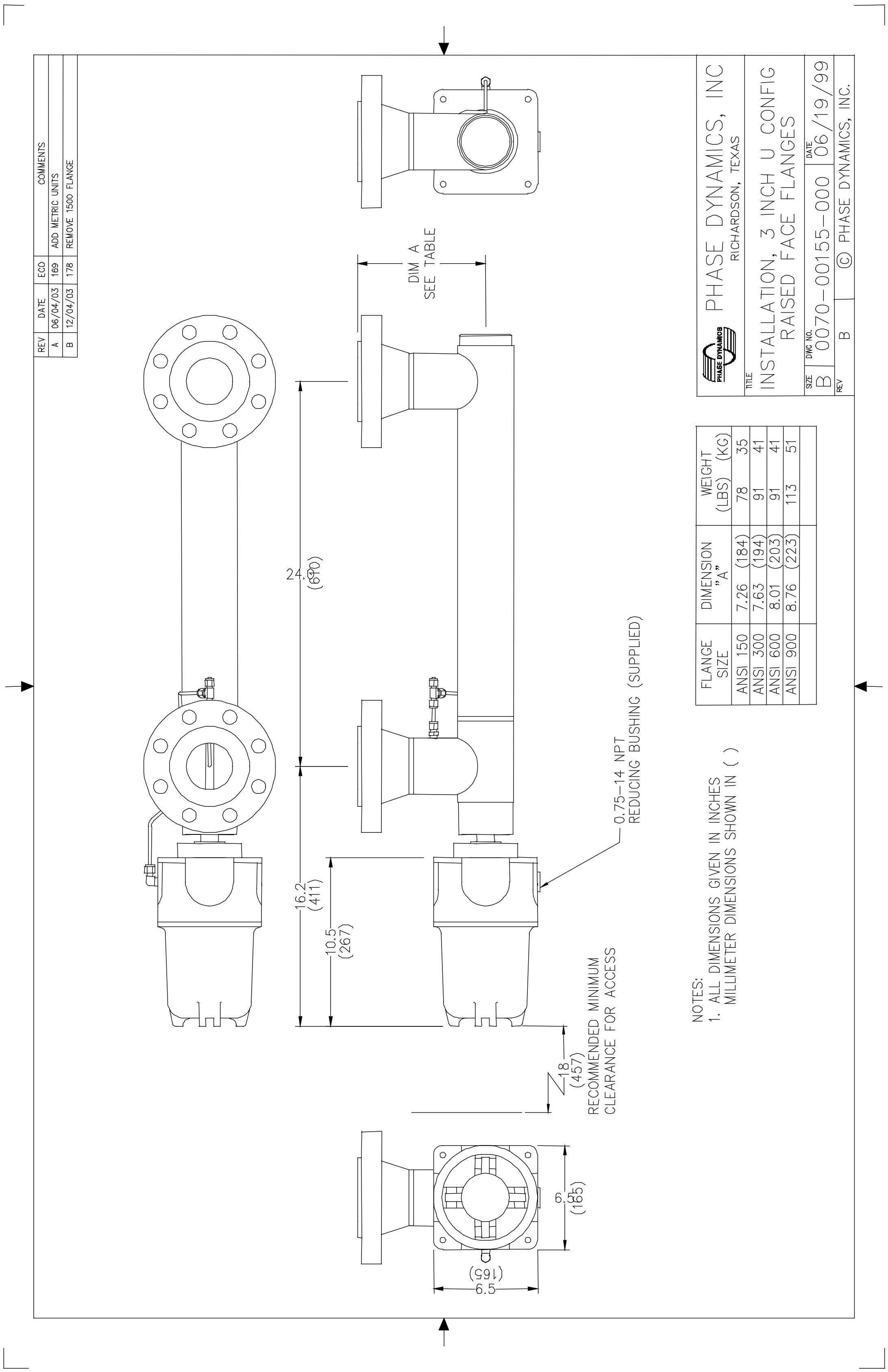
REV | DATE | ECO | COMMENTS
A | 06/04/03 | 169 | ADD METRIC UNITS
7.25
(184)
10.0
(254)
25.6
(650)
10.5
(267)
18
(457)
RECOMMENDED MINIMUM
CLEARANCE FOR ACCESS
0.75-14 NPT
REDUCING BUSHING (SUPPLIED)
6.5
(165)
6.5
(165)
NOTES:
1 WEIGHT: 52 LBS (24kg)
2 ALL DIMENSIONS GIVEN IN INCHES
MILLIMETER DIMENSIONS SHOWN IN ( )
PHASE DYNAMICS, INC
RICHARDSON, TEXAS
TITLE
INSTALLATION 3 INCH L CONFIG
CLASS 150 RF FLANGE
SIZE B
DWG NO. 0070-00141-000
DATE 02/02/99
REV A
© PHASE DYNAMICS, INC.


REV
DATE
ECO
COMMENTS
A
06/04/03
169
ADD METRIC UNITS
PHASE DYNAMICS, INC
RICHARDSON, TEXAS
TITLE
INSTALLATION 3 INCH L CONFIG
CLASS 300 RF FLANGE
SIZE
B
DWG NO.
0070-00142-000
DATE
02/03/99
REV
A
© PHASE DYNAMICS, INC.
7.62
(194)
10.0
(254)
25.6
(650)
10.5
(267)
0.75-14 NPT
REDUCING BUSHING (SUPPLIED)
NOTES:
1 WEIGHT: 60 LBS (27kg)
2 ALL DIMENSIONS GIVEN IN INCHES
MILLIMETER DIMENSIONS SHOWN IN ( )
18
(457)
RECOMMENDED MINIMUM
CLEARANCE FOR ACCESS
6.5
(165)
6.5
(165)


REV
DATE
ECO
COMMENTS
A
06/04/03
169
ADD METRIC UNITS
PHASE DYNAMICS, INC
RICHARDSON, TEXAS
TITLE
INSTALLATION 3 INCH L CONFIG
CLASS 600 RF FLANGE
SIZE
B
DWG NO.
0070-00143-000
DATE
02/03/99
REV
A
© PHASE DYNAMICS, INC.
8.0
(203)
10.0
(254)
25.6
(650)
10.5
(267)
18
(457)
RECOMMENDED MINIMUM
CLEARANCE FOR ACCESS
0.75-14 NPT
REDUCING BUSHING (SUPPLIED)
NOTES:
1 WEIGHT: 60 LBS (27kg)
2 ALL DIMENSIONS GIVEN IN INCHES
MILLIMETER DIMENSIONS SHOWN IN ( )
6.5
(165)
6.5
(165)

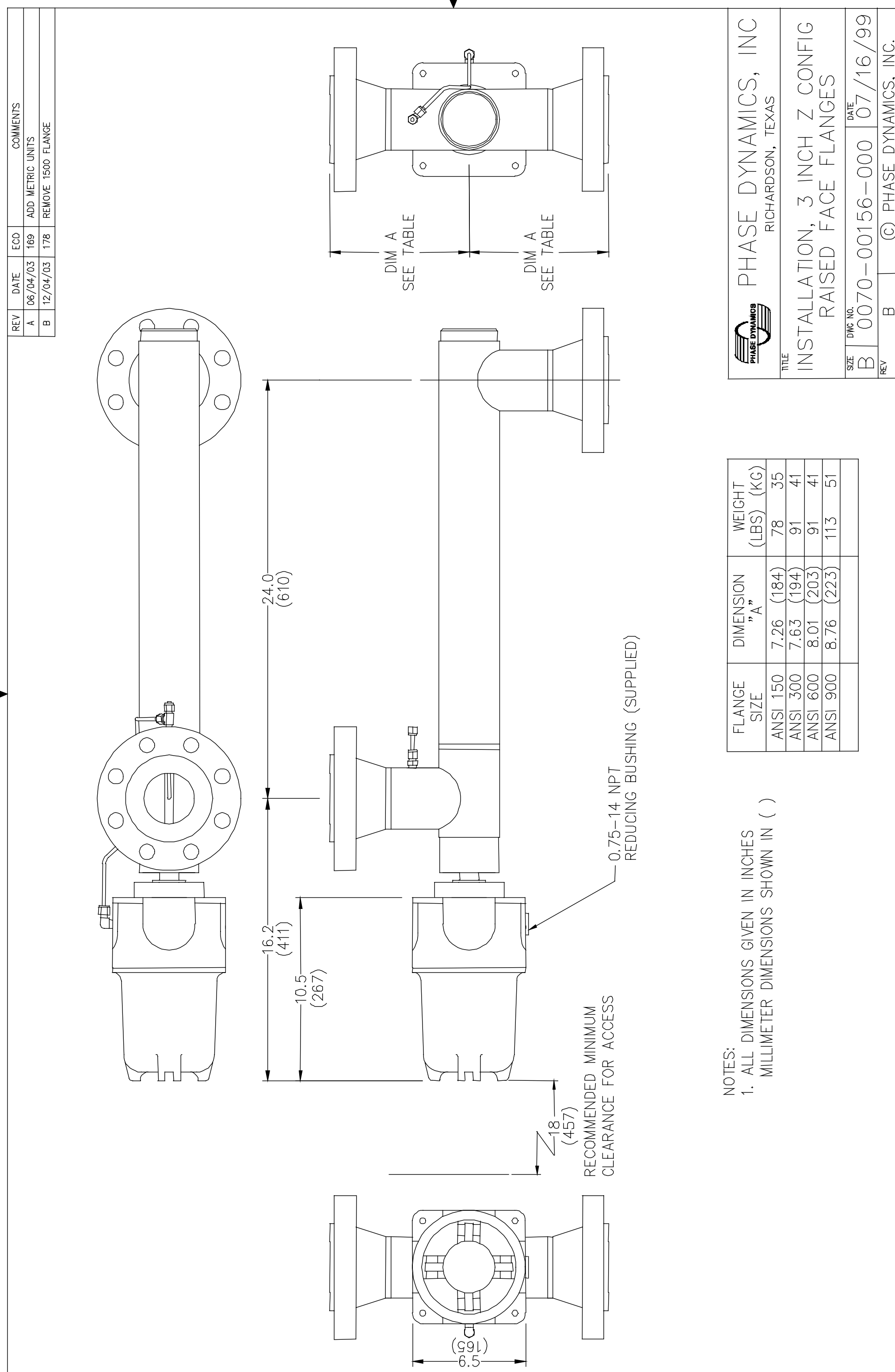

REV DATE ECO COMMENTS
A 06/04/03 169 ADD METRIC UNITS
B 12/04/03 178 WT WAS: 120 (55kg), WAS: 25.6 (650) LONG
PHASE DYNAMICS, INC
RICHARDSON, TEXAS
TITLE
INSTALLATION 3 INCH L CONFIG
CLASS 1500 RTJ FLANGE
SIZE B
DWG NO. 0070-00177-000
DATE 12/14/00
REV B
© PHASE DYNAMICS, INC.
9.44
(240)
10.0
(254)
25.5
(648)
10.5
(267)
0.75-14 NPT
REDUCING BUSHING (SUPPLIED)
NOTES:
1 WEIGHT: 128 LBS (58kg)
2 ALL DIMENSIONS GIVEN IN INCHES
MILLIMETER DIMENSIONS SHOWN IN ( )
18
(457)
RECOMMENDED MINIMUM
CLEARANCE FOR ACCESS
10.5
(267)
6.5
(165)
6.5
(165)


REV | DATE | ECO | COMMENTS
A | 06/04/03 | 169 | ADD METRIC UNITS
PHASE DYNAMICS, INC
RICHARDSON, TEXAS
TITLE
INSTALLATION, 3 INCH U CONFIG
10 IN CTRS RAISED FACE FLNG
SIZE A
DWG NO. 0070-00173-000
DATE 07/25/00
REV A
© PHASE DYNAMICS, INC.
DIM A
SEE TABLE
FLANGE SIZE | DIMENSION "A" | WEIGHT (LBS) (KG)
ANSI 150 | 7.26 (184) | 78 35
ANSI 300 | 7.63 (194) | 91 41
ANSI 600 | 8.01 (203) | 91 41
10.0 (254)
0.75-14 NPT
REDUCING BUSHING (SUPPLIED)
16.2 (411)
10.5 (267)
18 (457)
RECOMMENDED MINIMUM
CLEARANCE FOR ACCESS
NOTES:
1. ALL DIMENSIONS GIVEN IN INCHES
MILLIMETER DIMENSIONS SHOWN IN ( )
6.5 (165)
6.5 (165)

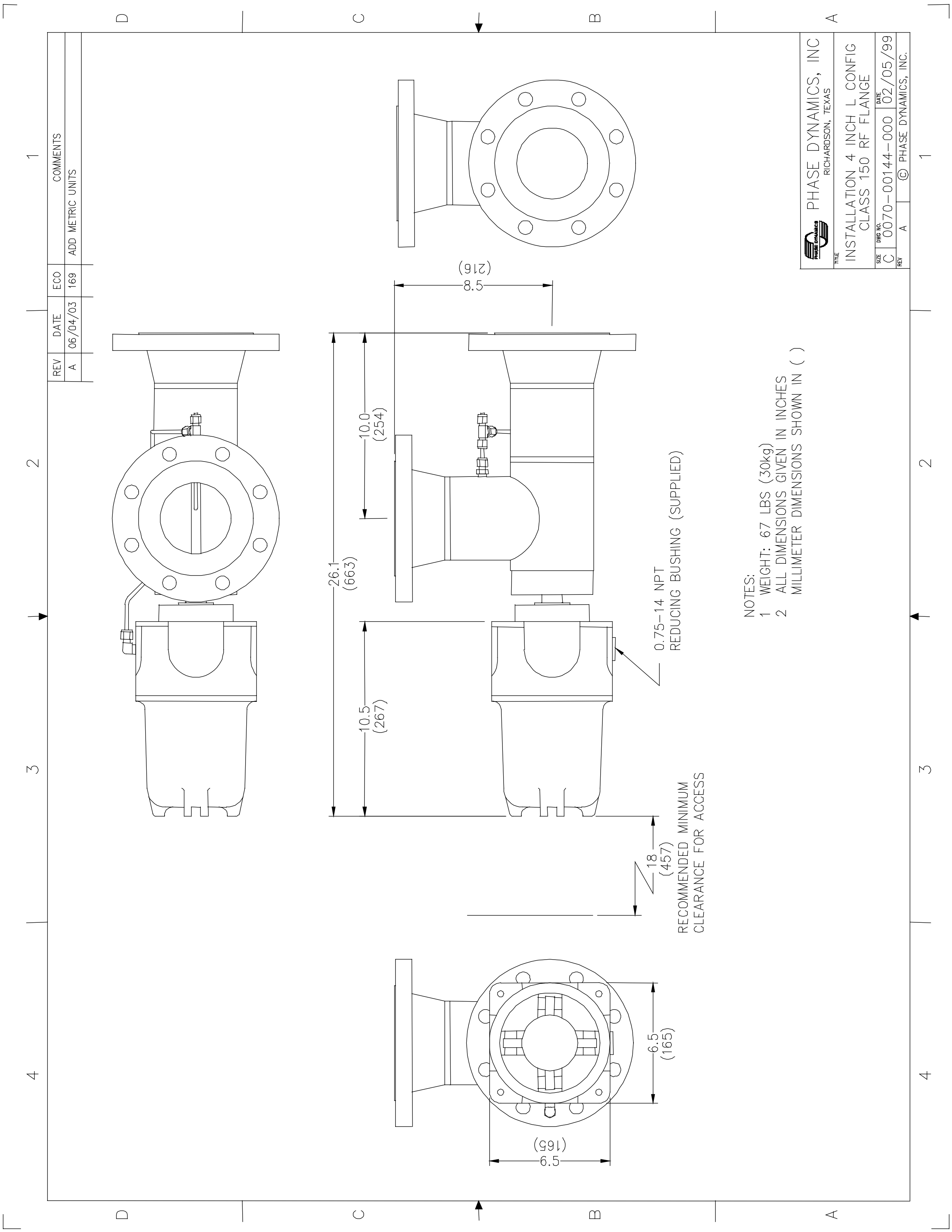


REV	DATE	ECO	COMMENTS
A	06/04/03	169	ADD METRIC UNITS
B	12/04/03	178	REMOVE 1500 FLANGE

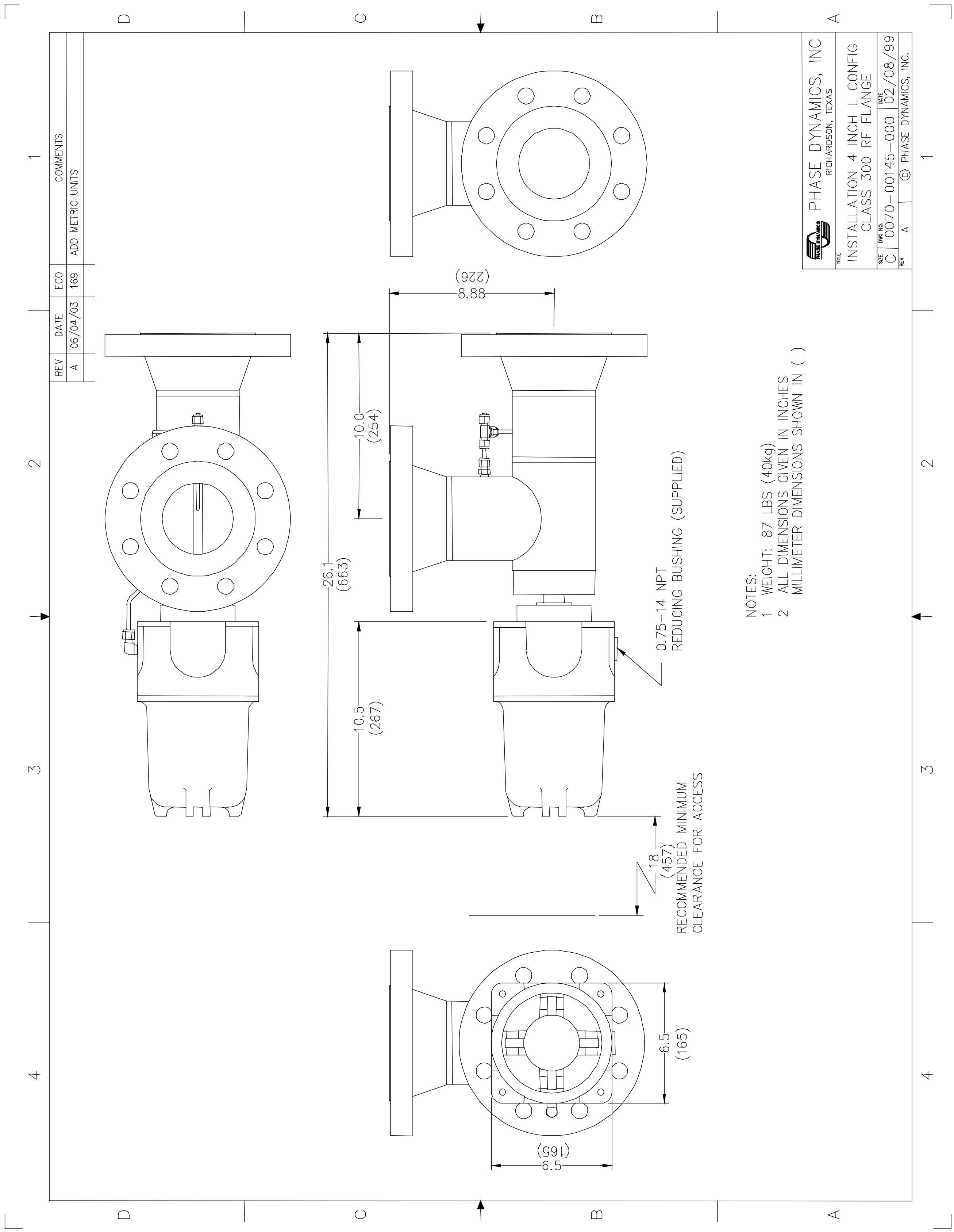
FLANGE SIZE	DIMENSION "A"	WEIGHT (LBS) (KG)
ANSI 150	7.26 (184)	78 35
ANSI 300	7.63 (194)	91 41
ANSI 600	8.01 (203)	91 41
ANSI 900	8.76 (223)	113 51



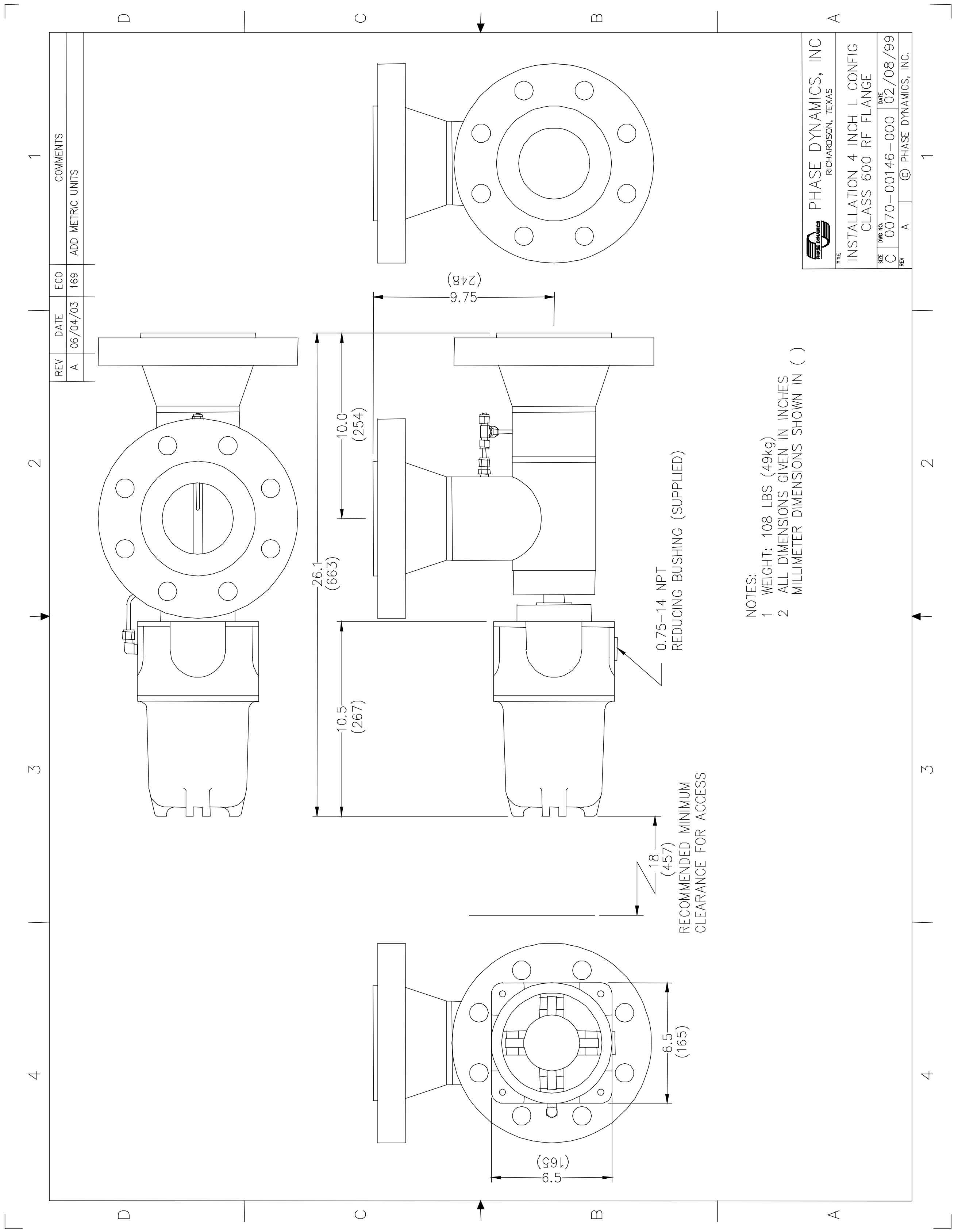
FLANGE SIZE	DIMENSION "A"	WEIGHT (LBS)	(KG)
ANSI 150	7.26 (184)	78	35
ANSI 300	7.63 (194)	91	41
ANSI 600	8.01 (203)	91	41
ANSI 900	8.76 (223)	113	51

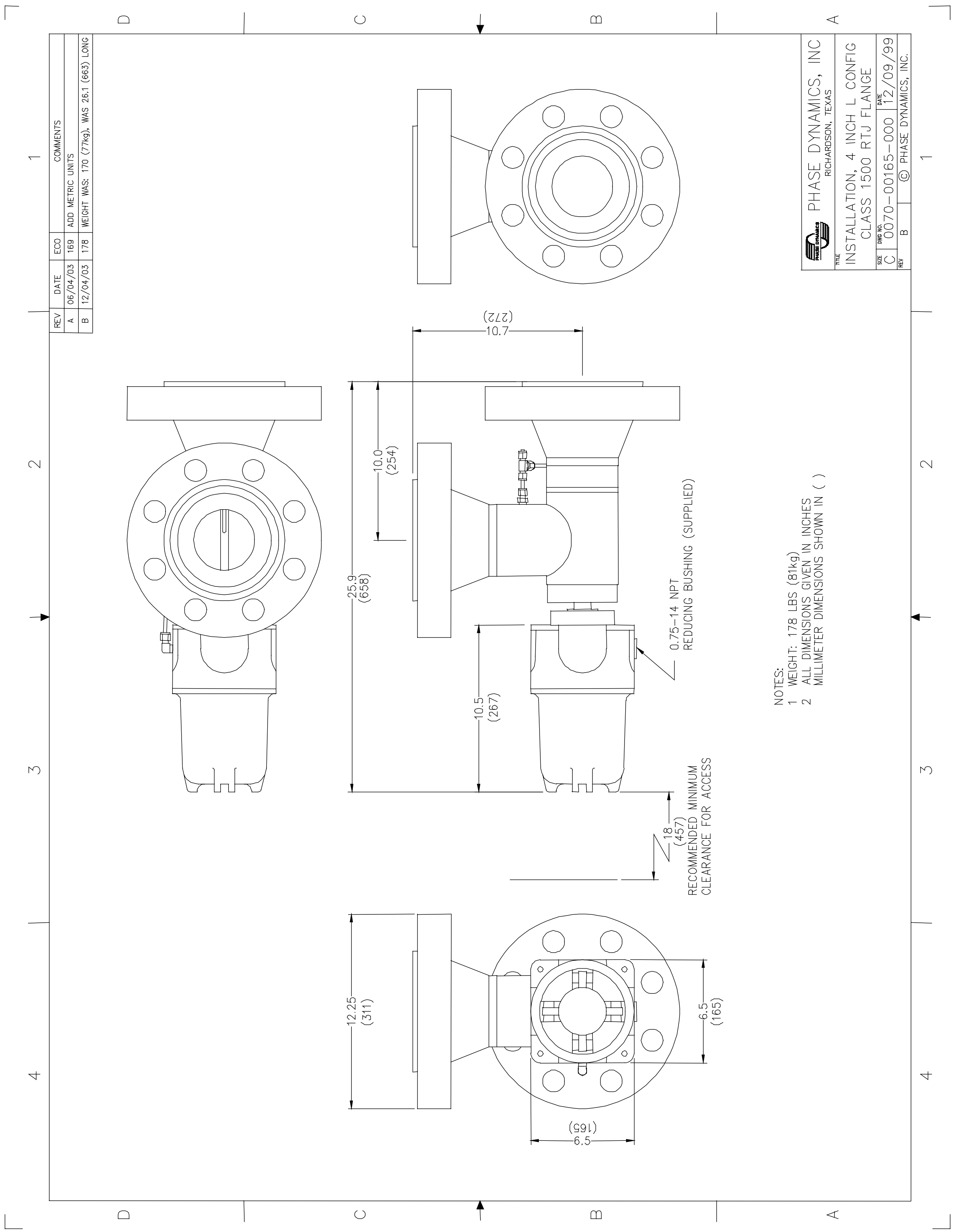


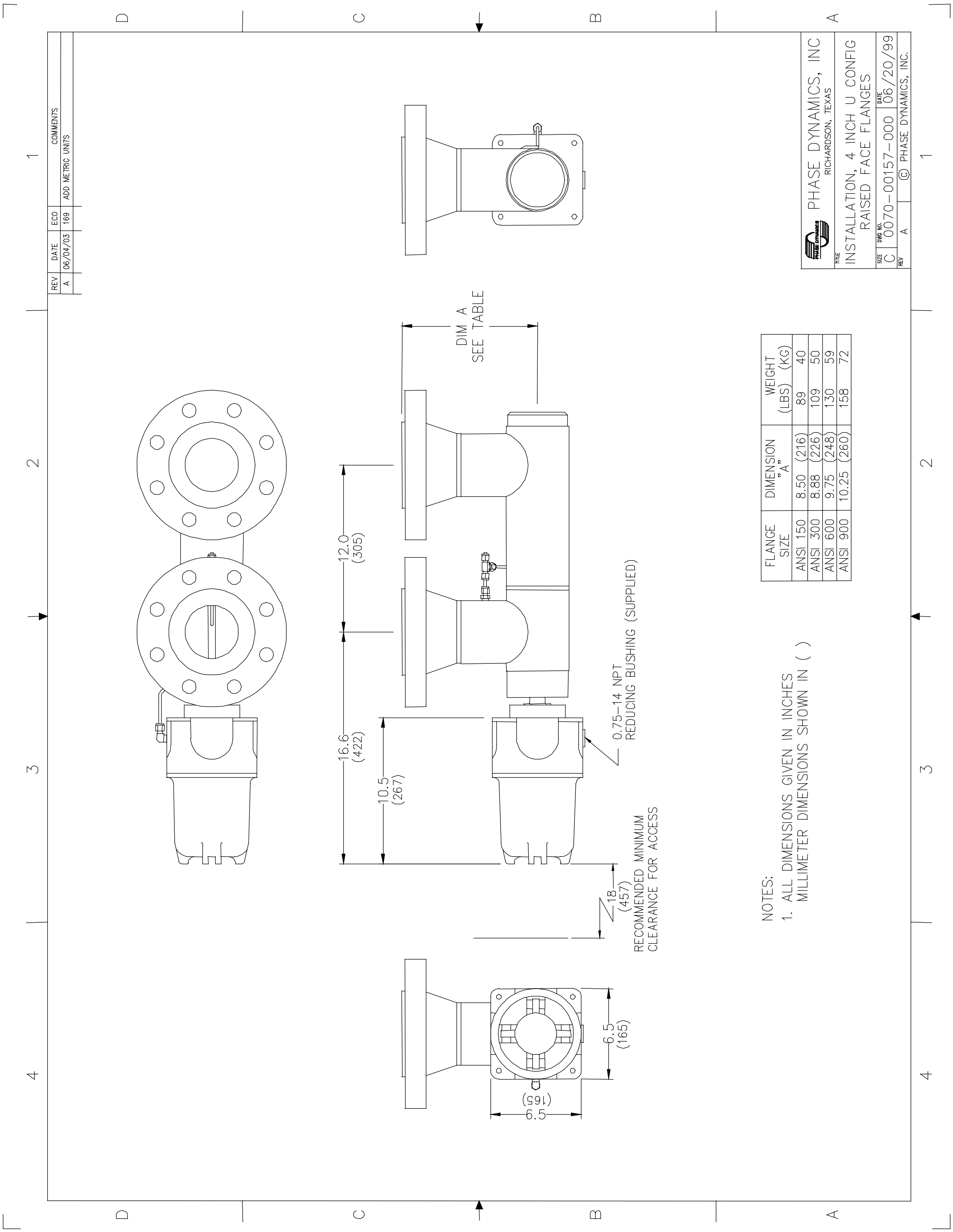
REV
A
DATE
06/04/03
ECO
169
COMMENTS
ADD METRIC UNITS
8.5
(216)
10.0
(254)
26.1
(663)
10.5
(267)
0.75-14 NPT
REDUCING BUSHING (SUPPLIED)
18
(457)
RECOMMENDED MINIMUM
CLEARANCE FOR ACCESS
6.5
(165)
6.5
(165)
NOTES:
1 WEIGHT: 67 LBS (30kg)
2 ALL DIMENSIONS GIVEN IN INCHES
MILLIMETER DIMENSIONS SHOWN IN ( )
PHASE DYNAMICS, INC
RICHARDSON, TEXAS
TITLE
INSTALLATION 4 INCH L CONFIG
CLASS 150 RF FLANGE
SIZE
C
DWG NO.
0070-00144-000
DATE
02/05/99
REV
A
© PHASE DYNAMICS, INC.

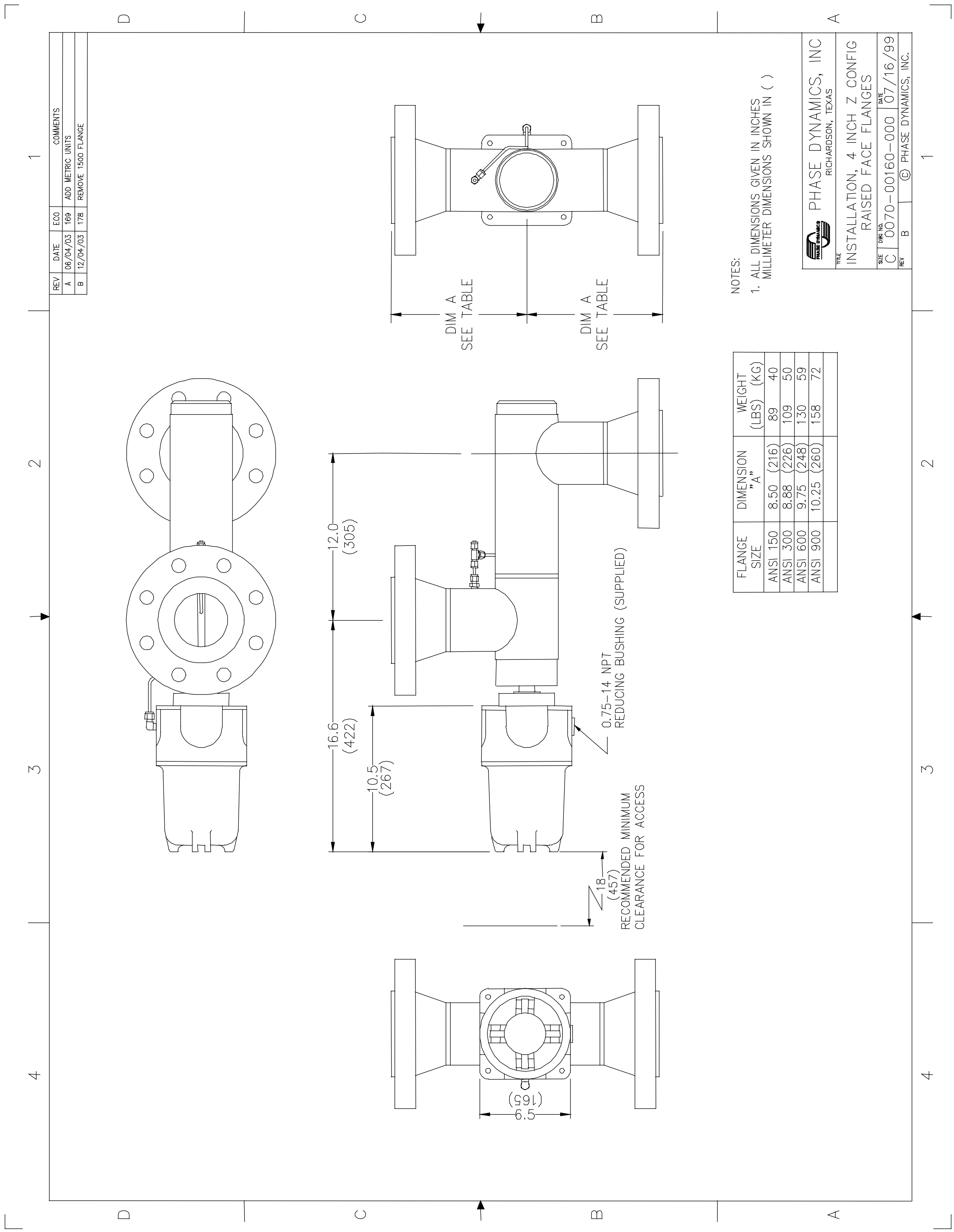


PHASE DYNAMICS, INC
RICHARDSON, TEXAS
TITLE
INSTALLATION 4 INCH L CONFIG
CLASS 300 RF FLANGE
SIZE C
DWG NO. 0070-00145-000
DATE 02/08/99
REV A
© PHASE DYNAMICS, INC.
REV | DATE | ECO | COMMENTS
A | 06/04/03 | 169 | ADD METRIC UNITS
NOTES:
1 WEIGHT: 87 LBS (40kg)
2 ALL DIMENSIONS GIVEN IN INCHES
MILLIMETER DIMENSIONS SHOWN IN ( )
8.88
(226)
10.0
(254)
26.1
(663)
10.5
(267)
0.75-14 NPT
REDUCING BUSHING (SUPPLIED)
18
(457)
RECOMMENDED MINIMUM
CLEARANCE FOR ACCESS
6.5
(165)
6.5
(165)
A
B
C
D
1
2
3
4

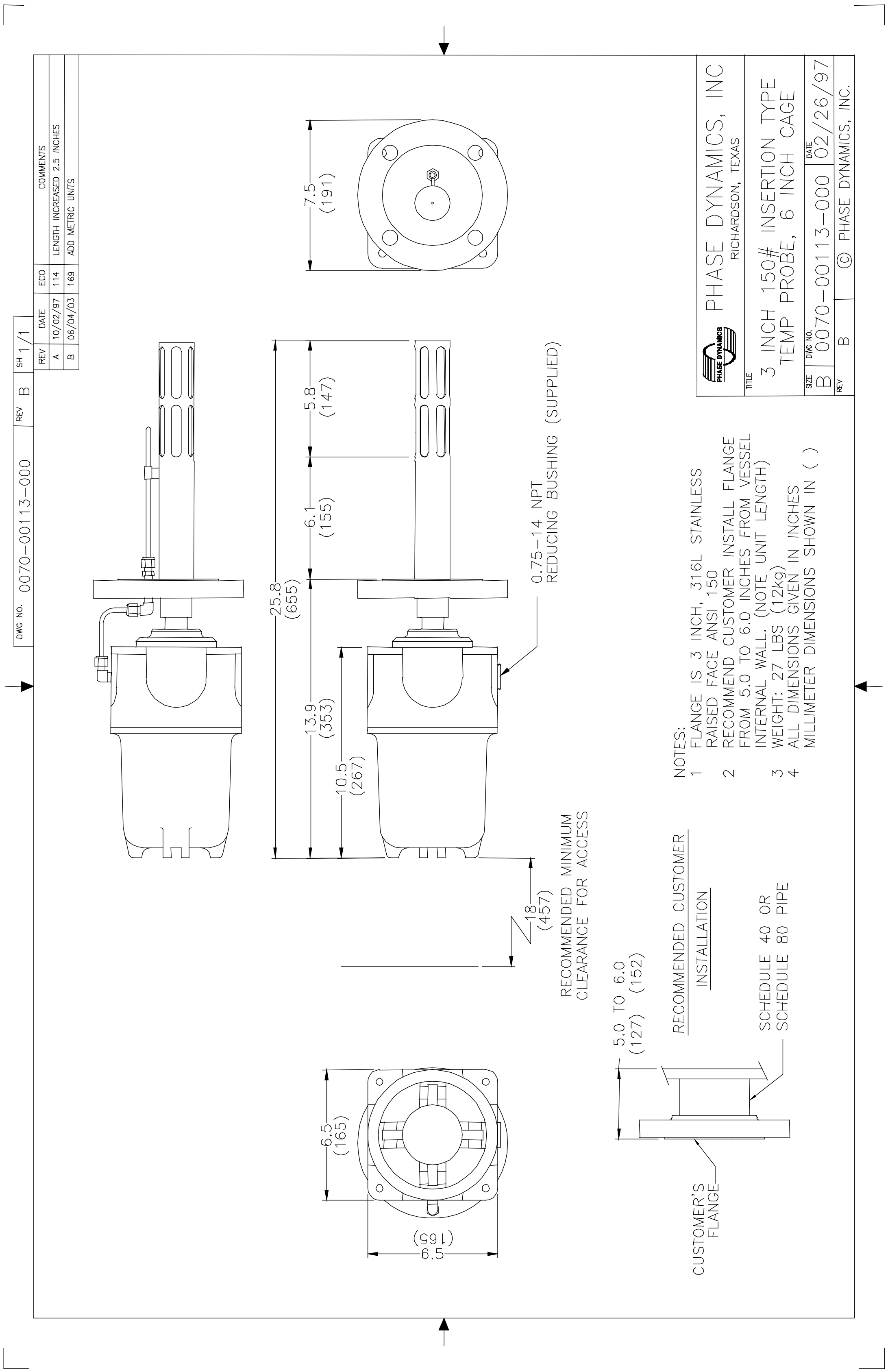

REV | DATE | ECO | COMMENTS
A | 06/04/03 | 169 | ADD METRIC UNITS
PHASE DYNAMICS, INC
RICHARDSON, TEXAS
INSTALLATION 4 INCH L CONFIG
CLASS 600 RF FLANGE
C 0070-00146-000 02/08/99
A © PHASE DYNAMICS, INC.
9.75
(248)
10.0
(254)
26.1
(663)
10.5
(267)
0.75-14 NPT
REDUCING BUSHING (SUPPLIED)
18
(457)
RECOMMENDED MINIMUM
CLEARANCE FOR ACCESS
6.5
(165)
NOTES:
1 WEIGHT: 108 LBS (49kg)
2 ALL DIMENSIONS GIVEN IN INCHES
MILLIMETER DIMENSIONS SHOWN IN ( )

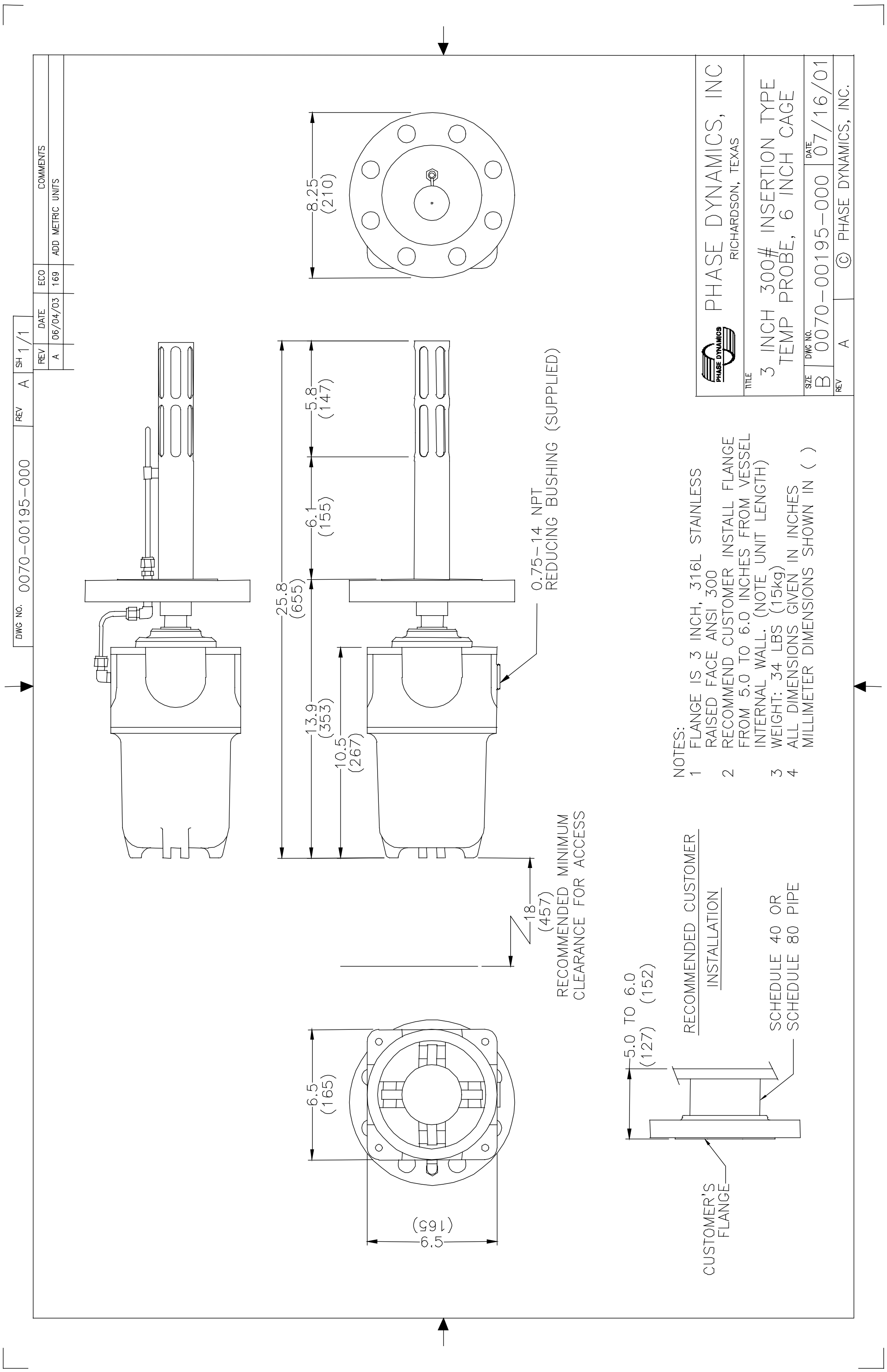

REV DATE ECO COMMENTS
A 06/04/03 169 ADD METRIC UNITS
B 12/04/03 178 WEIGHT WAS: 170 (77kg), WAS 26.1 (663) LONG
PHASE DYNAMICS, INC
RICHARDSON, TEXAS
TITLE INSTALLATION, 4 INCH L CONFIG CLASS 1500 RTJ FLANGE
SIZE C
DWG NO. 0070-00165-000
DATE 12/09/99
REV B
© PHASE DYNAMICS, INC.
10.7 (272)
10.0 (254)
25.9 (658)
10.5 (267)
0.75-14 NPT REDUCING BUSHING (SUPPLIED)
18 (457) RECOMMENDED MINIMUM CLEARANCE FOR ACCESS
NOTES:
1 WEIGHT: 178 LBS (81kg)
2 ALL DIMENSIONS GIVEN IN INCHES MILLIMETER DIMENSIONS SHOWN IN ( )
12.25 (311)
6.5 (165)
6.5 (165)

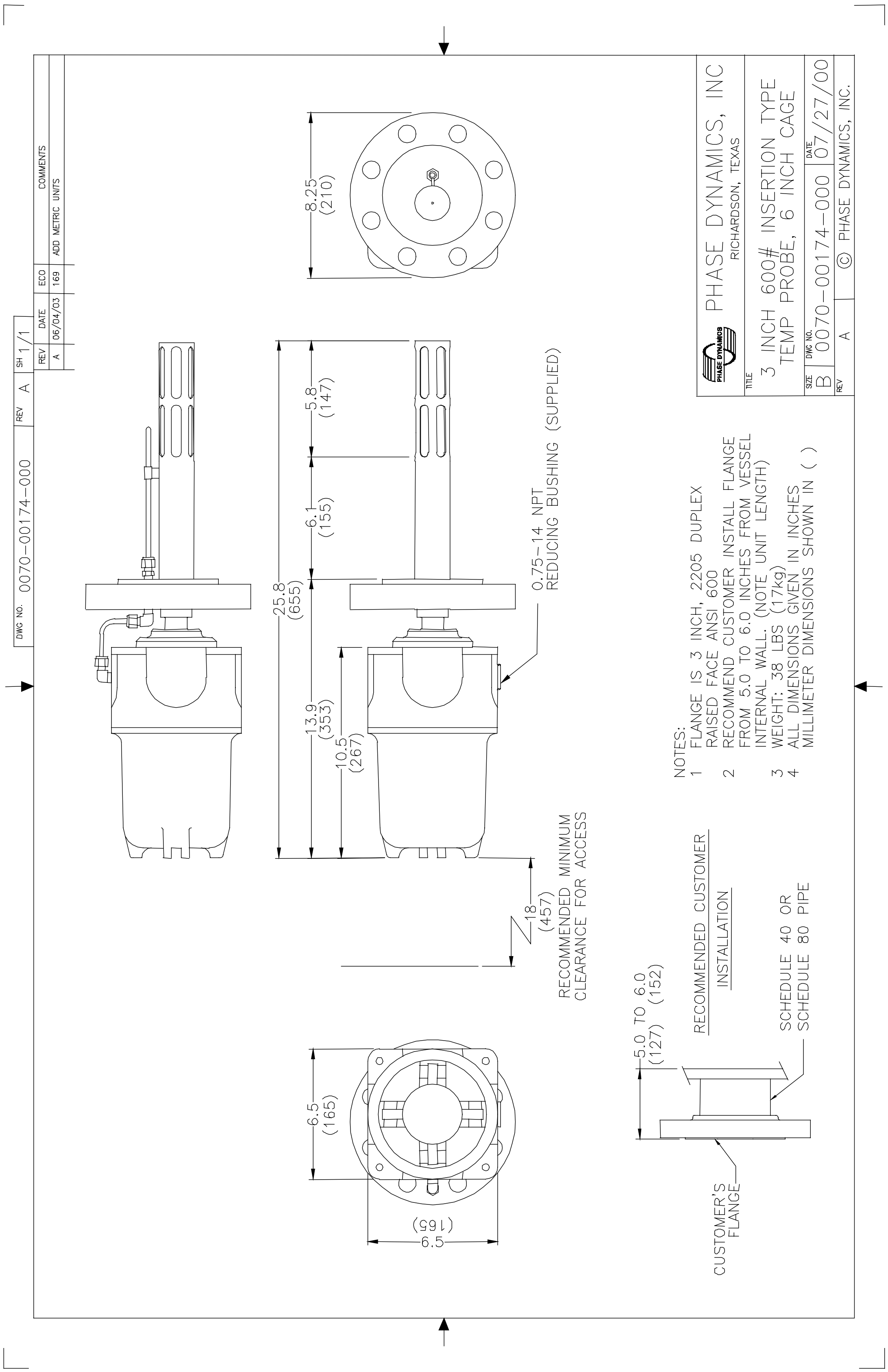

REV | DATE | ECO | COMMENTS
A | 06/04/03 | 169 | ADD METRIC UNITS
DIM A
SEE TABLE
FLANGE SIZE | DIMENSION "A" | WEIGHT (LBS) (KG)
ANSI 150 | 8.50 (216) | 89 40
ANSI 300 | 8.88 (226) | 109 50
ANSI 600 | 9.75 (248) | 130 59
ANSI 900 | 10.25 (260) | 158 72
12.0
(305)
16.6
(422)
10.5
(267)
0.75-14 NPT
REDUCING BUSHING (SUPPLIED)
18
(457)
RECOMMENDED MINIMUM
CLEARANCE FOR ACCESS
6.5
(165)
NOTES:
1. ALL DIMENSIONS GIVEN IN INCHES
MILLIMETER DIMENSIONS SHOWN IN ( )
PHASE DYNAMICS, INC
RICHARDSON, TEXAS
TITLE
INSTALLATION, 4 INCH U CONFIG
RAISED FACE FLANGES
SIZE C
DWG NO. 0070-00157-000
DATE 06/20/99
REV A
© PHASE DYNAMICS, INC.

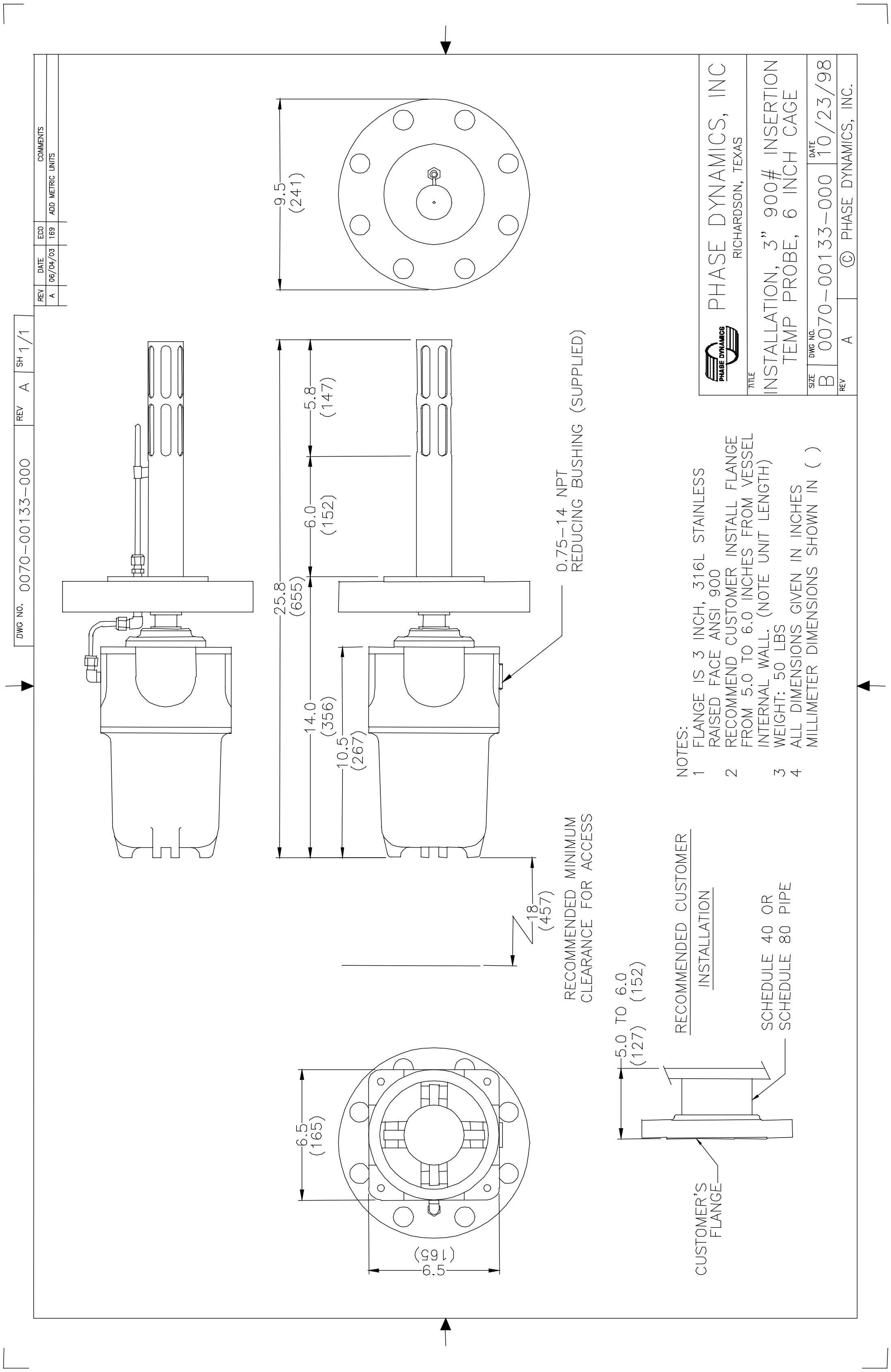


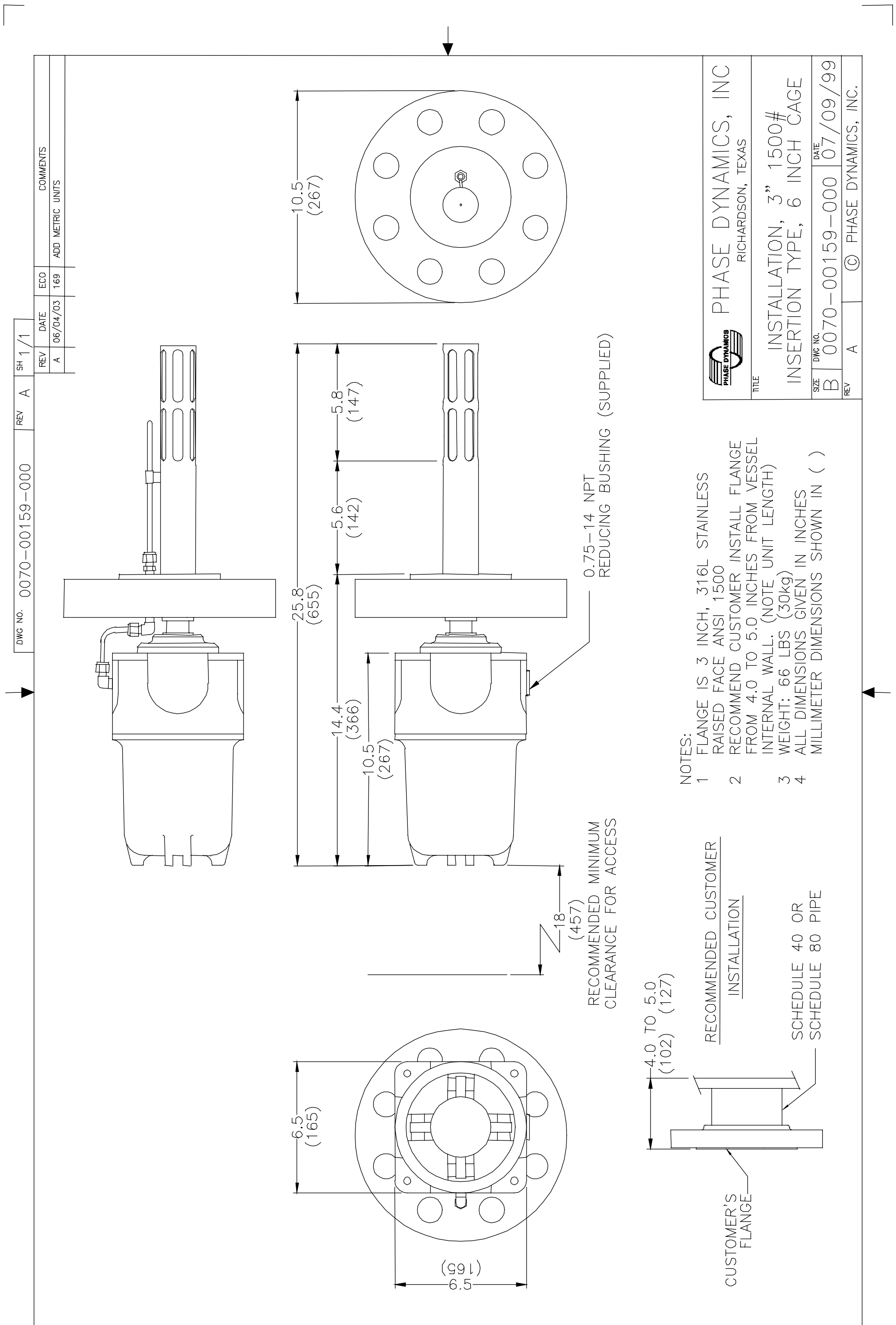
FLANGE SIZE	DIMENSION "A"	WEIGHT (LBS)	(KG)
ANSI 150	8.50 (216)	89	40
ANSI 300	8.88 (226)	109	50
ANSI 600	9.75 (248)	130	59
ANSI 900	10.25 (260)	158	72

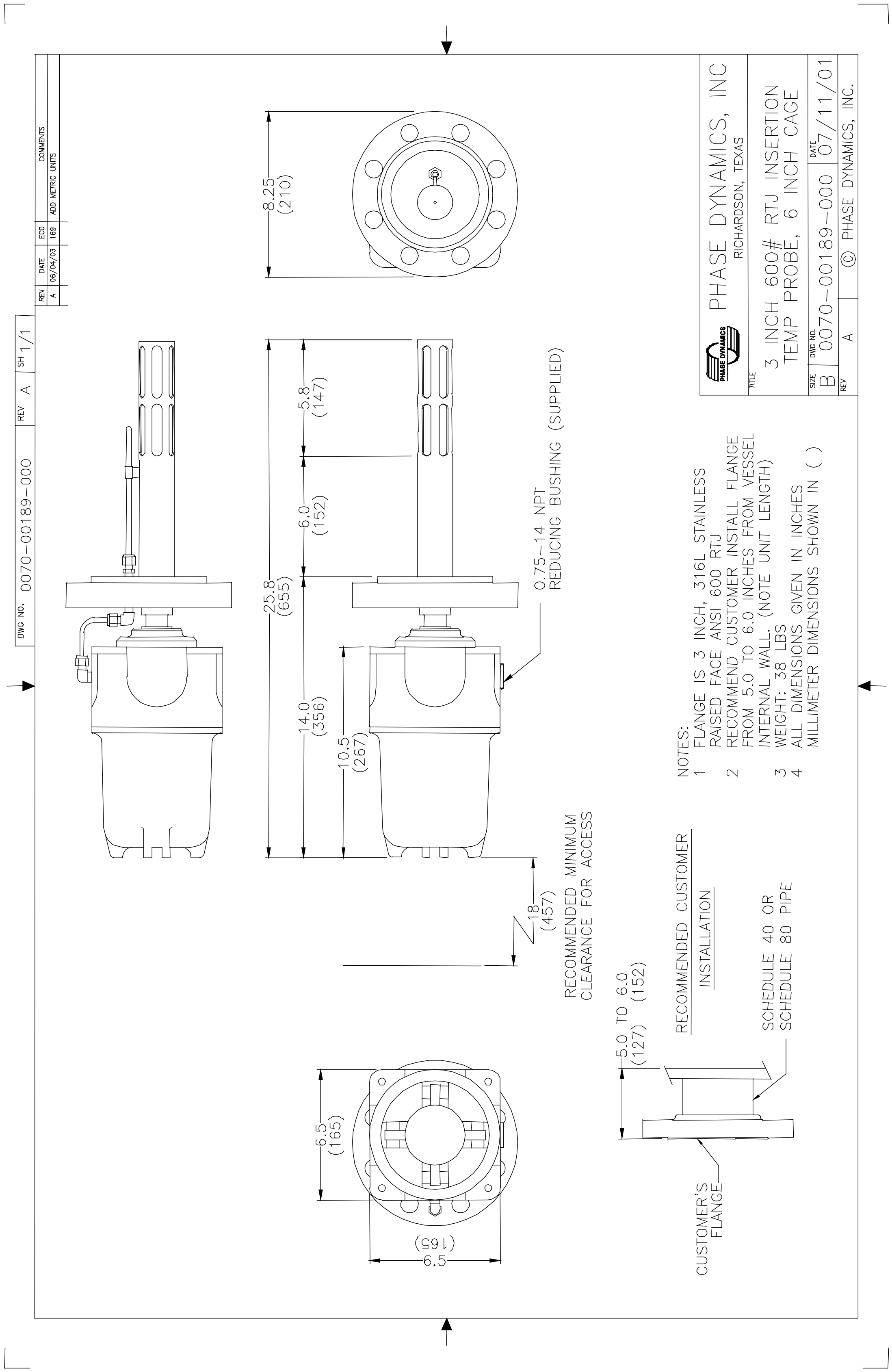

DWG NO. 0070-00113-000
REV B
SH 1/1
REV | DATE | ECO | COMMENTS
A | 10/02/97 | 114 | LENGTH INCREASED 2.5 INCHES
B | 06/04/03 | 169 | ADD METRIC UNITS
7.5 (191)
5.8 (147)
6.1 (155)
25.8 (655)
13.9 (353)
10.5 (267)
0.75-14 NPT REDUCING BUSHING (SUPPLIED)
18 (457) RECOMMENDED MINIMUM CLEARANCE FOR ACCESS
NOTES:
1 FLANGE IS 3 INCH, 316L STAINLESS RAISED FACE ANSI 150
2 RECOMMEND CUSTOMER INSTALL FLANGE FROM 5.0 TO 6.0 INCHES FROM VESSEL INTERNAL WALL. (NOTE UNIT LENGTH)
3 WEIGHT: 27 LBS (12kg)
4 ALL DIMENSIONS GIVEN IN INCHES MILLIMETER DIMENSIONS SHOWN IN ( )
RECOMMENDED CUSTOMER INSTALLATION
5.0 TO 6.0 (127) (152)
SCHEDULE 40 OR SCHEDULE 80 PIPE
CUSTOMER'S FLANGE
6.5 (165)
6.5 (165)
PHASE DYNAMICS, INC
RICHARDSON, TEXAS
TITLE 3 INCH 150# INSERTION TYPE TEMP PROBE, 6 INCH CAGE
SIZE B
DWG NO. 0070-00113-000
DATE 02/26/97
REV B
© PHASE DYNAMICS, INC.

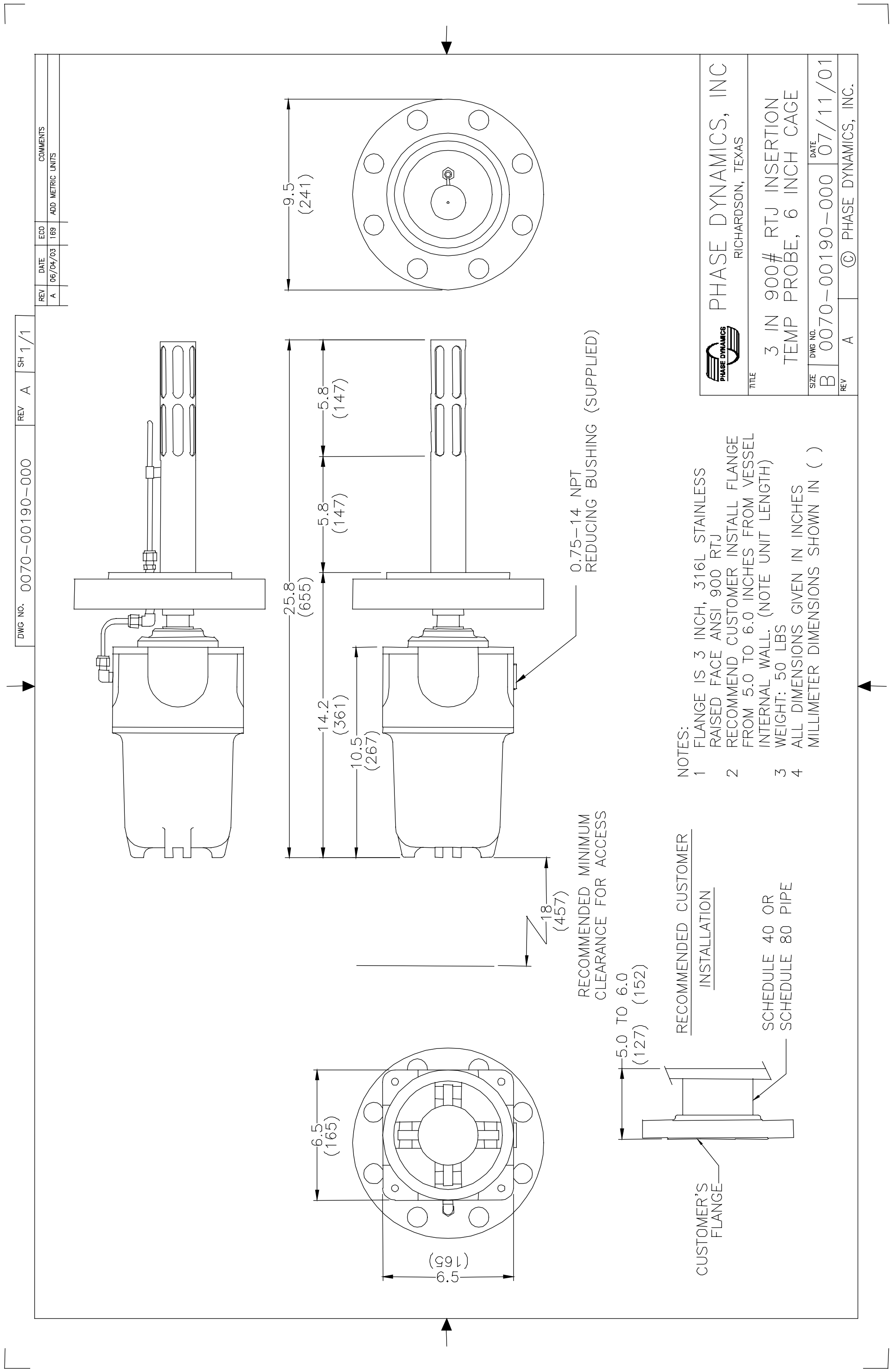

DWG NO. 0070-00195-000
REV A
SH 1/1
REV | DATE | ECO | COMMENTS
A | 06/04/03 | 169 | ADD METRIC UNITS
8.25 (210)
5.8 (147)
6.1 (155)
25.8 (655)
13.9 (353)
10.5 (267)
0.75-14 NPT REDUCING BUSHING (SUPPLIED)
18 (457) RECOMMENDED MINIMUM CLEARANCE FOR ACCESS
6.5 (165)
6.5 (165)
5.0 TO 6.0 (127) (152)
RECOMMENDED CUSTOMER INSTALLATION
SCHEDULE 40 OR SCHEDULE 80 PIPE
CUSTOMER'S FLANGE
NOTES:
1 FLANGE IS 3 INCH, 316L STAINLESS RAISED FACE ANSI 300
2 RECOMMEND CUSTOMER INSTALL FLANGE FROM 5.0 TO 6.0 INCHES FROM VESSEL INTERNAL WALL. (NOTE UNIT LENGTH)
3 WEIGHT: 34 LBS (15kg)
4 ALL DIMENSIONS GIVEN IN INCHES MILLIMETER DIMENSIONS SHOWN IN ( )
PHASE DYNAMICS, INC
RICHARDSON, TEXAS
TITLE 3 INCH 300# INSERTION TYPE TEMP PROBE, 6 INCH CAGE
SIZE B
DWG NO. 0070-00195-000
DATE 07/16/01
REV A
© PHASE DYNAMICS, INC.


DWG NO. 0070-00174-000
REV A
SH 1/1
REV DATE ECO COMMENTS
A 06/04/03 169 ADD METRIC UNITS
8.25
(210)
5.8
(147)
6.1
(155)
25.8
(655)
13.9
(353)
10.5
(267)
0.75-14 NPT
REDUCING BUSHING (SUPPLIED)
18
(457)
RECOMMENDED MINIMUM
CLEARANCE FOR ACCESS
6.5
(165)
6.5
(165)
5.0 TO 6.0
(127) (152)
RECOMMENDED CUSTOMER
INSTALLATION
SCHEDULE 40 OR
SCHEDULE 80 PIPE
CUSTOMER'S
FLANGE
NOTES:
1 FLANGE IS 3 INCH, 2205 DUPLEX
RAISED FACE ANSI 600
2 RECOMMEND CUSTOMER INSTALL FLANGE
FROM 5.0 TO 6.0 INCHES FROM VESSEL
INTERNAL WALL. (NOTE UNIT LENGTH)
3 WEIGHT: 38 LBS (17kg)
4 ALL DIMENSIONS GIVEN IN INCHES
MILLIMETER DIMENSIONS SHOWN IN ( )
PHASE DYNAMICS, INC
RICHARDSON, TEXAS
TITLE
3 INCH 600# INSERTION TYPE
TEMP PROBE, 6 INCH CAGE
SIZE B
DWG NO. 0070-00174-000
DATE 07/27/00
REV A
© PHASE DYNAMICS, INC.


PHASE DYNAMICS, INC
RICHARDSON, TEXAS
TITLE
INSTALLATION, 3" 900# INSERTION
TEMP PROBE, 6 INCH CAGE
SIZE B
DWG NO. 0070-00133-000
DATE 10/23/98
REV A
© PHASE DYNAMICS, INC.
DWG NO. 0070-00133-000
REV A
SH 1/1
REV DATE ECO COMMENTS
A 06/04/03 169 ADD METRIC UNITS
9.5 (241)
5.8 (147)
6.0 (152)
25.8 (655)
14.0 (356)
10.5 (267)
0.75-14 NPT
REDUCING BUSHING (SUPPLIED)
18 (457)
RECOMMENDED MINIMUM
CLEARANCE FOR ACCESS
NOTES:
1 FLANGE IS 3 INCH, 316L STAINLESS
RAISED FACE ANSI 900
2 RECOMMEND CUSTOMER INSTALL FLANGE
FROM 5.0 TO 6.0 INCHES FROM VESSEL
INTERNAL WALL. (NOTE UNIT LENGTH)
3 WEIGHT: 50 LBS
4 ALL DIMENSIONS GIVEN IN INCHES
MILLIMETER DIMENSIONS SHOWN IN ( )
RECOMMENDED CUSTOMER
INSTALLATION
5.0 TO 6.0
(127) (152)
SCHEDULE 40 OR
SCHEDULE 80 PIPE
CUSTOMER'S
FLANGE
6.5 (165)
6.5 (165)


DWG NO. 0070-00159-000
REV A
SH 1/1
REV A
DATE 06/04/03
ECO 169
COMMENTS ADD METRIC UNITS
10.5 (267)
25.8 (655)
5.8 (147)
5.6 (142)
14.4 (366)
10.5 (267)
0.75-14 NPT REDUCING BUSHING (SUPPLIED)
18 (457) RECOMMENDED MINIMUM CLEARANCE FOR ACCESS
6.5 (165)
6.5 (165)
4.0 TO 5.0 (102) (127)
RECOMMENDED CUSTOMER INSTALLATION
SCHEDULE 40 OR SCHEDULE 80 PIPE
CUSTOMER'S FLANGE
NOTES:
1 FLANGE IS 3 INCH, 316L STAINLESS RAISED FACE ANSI 1500
2 RECOMMEND CUSTOMER INSTALL FLANGE FROM 4.0 TO 5.0 INCHES FROM VESSEL INTERNAL WALL. (NOTE UNIT LENGTH)
3 WEIGHT: 66 LBS (30kg)
4 ALL DIMENSIONS GIVEN IN INCHES MILLIMETER DIMENSIONS SHOWN IN ( )
PHASE DYNAMICS, INC
RICHARDSON, TEXAS
TITLE
INSTALLATION, 3" 1500# INSERTION TYPE, 6 INCH CAGE
SIZE B
DWG NO. 0070-00159-000
DATE 07/09/99
REV A
© PHASE DYNAMICS, INC.


PHASE DYNAMICS, INC
RICHARDSON, TEXAS
TITLE
3 INCH 600# RTJ INSERTION
TEMP PROBE, 6 INCH CAGE
SIZE B
DWG NO. 0070-00189-000
DATE 07/11/01
REV A
© PHASE DYNAMICS, INC.
DWG NO. 0070-00189-000
REV A
SH 1/1
REV A DATE 06/04/03 ECO 169 COMMENTS ADD METRIC UNITS
8.25 (210)
25.8 (655)
5.8 (147)
6.0 (152)
14.0 (356)
10.5 (267)
0.75-14 NPT
REDUCING BUSHING (SUPPLIED)
18 (457)
RECOMMENDED MINIMUM
CLEARANCE FOR ACCESS
NOTES:
1 FLANGE IS 3 INCH, 316L STAINLESS
RAISED FACE ANSI 600 RTJ
2 RECOMMEND CUSTOMER INSTALL FLANGE
FROM 5.0 TO 6.0 INCHES FROM VESSEL
INTERNAL WALL. (NOTE UNIT LENGTH)
3 WEIGHT: 38 LBS
4 ALL DIMENSIONS GIVEN IN INCHES
MILLIMETER DIMENSIONS SHOWN IN ( )
RECOMMENDED CUSTOMER
INSTALLATION
5.0 TO 6.0
(127) (152)
SCHEDULE 40 OR
SCHEDULE 80 PIPE
CUSTOMER'S
FLANGE
6.5 (165)
6.5
(165)



PHASE DYNAMICS, INC
RICHARDSON, TEXAS
TITLE
3 IN 900# RTJ INSERTION
TEMP PROBE, 6 INCH CAGE
SIZE B
DWG NO. 0070-00190-000
DATE 07/11/01
REV A
© PHASE DYNAMICS, INC.
DWG NO. 0070-00190-000
REV A
SH 1/1
REV | DATE | ECO | COMMENTS
A | 06/04/03 | 169 | ADD METRIC UNITS
NOTES:
1 FLANGE IS 3 INCH, 316L STAINLESS RAISED FACE ANSI 900 RTJ
2 RECOMMEND CUSTOMER INSTALL FLANGE FROM 5.0 TO 6.0 INCHES FROM VESSEL INTERNAL WALL. (NOTE UNIT LENGTH)
3 WEIGHT: 50 LBS
4 ALL DIMENSIONS GIVEN IN INCHES MILLIMETER DIMENSIONS SHOWN IN ( )
0.75-14 NPT
REDUCING BUSHING (SUPPLIED)
9.5 (241)
5.8 (147)
5.8 (147)
25.8 (655)
14.2 (361)
10.5 (267)
18 (457)
RECOMMENDED MINIMUM
CLEARANCE FOR ACCESS
RECOMMENDED CUSTOMER
INSTALLATION
SCHEDULE 40 OR
SCHEDULE 80 PIPE
5.0 TO 6.0
(127) (152)
6.5 (165)
6.5 (165)
CUSTOMER'S
FLANGE

INDEX