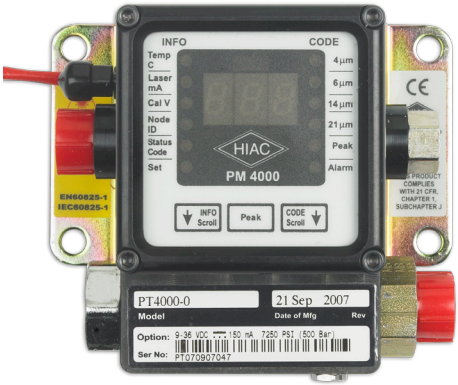
# *Operator Manual*

## HIAC PM4000
## ON-LINE LASER PARTICLE MONITOR

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*EXCELLENCE IN PROCESS ANALYTICS*

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# Manual Overview

## About This Manual

The information in this manual has been carefully checked and is believed to be accurate. However, Hach Ultra assumes no responsibility for any inaccuracies that may be contained in this manual. In no event will Hach Ultra be liable for direct, indirect, special, incidental, or consequential damages resulting from any defect or omission in this manual, even if advised of the possibility of such damages. In the interest of continued product development, Hach Ultra reserves the right to make improvements in this manual and the products it describes at any time, without notice or obligation.

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## Safety Conventions

**WARNING**

*A warning is used to indicate a condition which, if not met, could cause serious personal injury and/or death. Do not move beyond a warning until all conditions have been met.*

**CAUTION:**

*A caution is used to indicate a condition which, if not met, could cause damage to the equipment. Do not move beyond a caution until all conditions have been met.*

**Note:**
*A note is used to indicate important information or instructions that should be considered before operating the equipment.*

## General Safety Considerations

These safety guidelines should be read carefully and understoof before operating the PM4000.

- All service procedures should be conducted by properly trained service personnel.
- Follow all procedures in “Performance Verification Recommendations” on page 73 before shipping a unit to a service center for repair or performance re-verification.

**WARNING**
*Only factory certified personnel should perform service of the PM4000. Attempts by untrained personnel to disassemble, alter, modify or adjust the electronics and/or hydraulics may result in personal injury and damage to the PM4000.*

## Safety Information

**WARNING**
*At no time should covers be removed. This is a laser-based instrument and the user risks injury if exposed to the laser.*

The PM4000 monitor contains a laser-based sensor that is a Class 1 product (as defined by 21 CFR, Subchapter J, of the Health and Safety Act of 1968) when used in normal operation. This manual contains no procedures for service of internal parts. Service should be performed only by factory-authorized personnel.

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The PM4000 has been evaluated and tested in accordance with EN 61010-1:1993, "Safety Requirements For Electrical Equipment For Measurement, Control, and Laboratory Use," IEC 825-1:1993, "Safety of Laser Products," and other applicable industrial standards (e.g., ISO 4406, ISO 6149-2).

## Warranty

Hach Ultra warrants that this instrument will be free of defects in materials and workmanship for a period of one (1) year from the shipping date. If any instrument covered under this warranty proves defective during this period, Hach Ultra will, at its option, either repair the defective product without charge for parts and labor, or provide an equivalent replacement in exchange for the defective product.

To obtain service under this warranty, the customer must notify the nearest Hach Ultra service support center on or before the expiration of the warranty period and follow their instructions for return of the defective instrument. The customer is responsible for all costs associated with packaging and transporting the defective unit to the service support center, and must prepay all shipping charges. Hach Ultra will pay for return shipping if the shipment is to a location within the same country as the service support center.

This warranty shall not apply to any defect failure or damage caused by improper use or maintenance or by inadequate maintenance or care. This warranty shall not apply to damage resulting from attempts by personnel other than Hach Ultra representatives, or factory-authorized and trained personnel, to install, repair or service the instrument; to damage resulting from improper use or connection to incompatible equipment; or to instruments that have been modified or integrated with other products when the effect of such modification or

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integration materially increases the time or difficulty of servicing the instrument.

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## Revision History

- Edition D, May 2002, Pacific Scientific Instruments.
- Edition C, Version B, Initial release, October 2000.

## Acknowledgements


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# 1 Introduction

The Model PM4000 On-line Laser Particle Monitor is designed to monitor the contamination levels in fluid power and lubricating systems. The PM4000 provides cumulative particle concentration information at > 4 µm, > 6 µm, > 14 µm sizes applicable to the ISO 4406, ISO 11943, and ISO 11171 requirements for optical particle counters. A > 21 µm channel is also provided for large particle concentration information.

Machine operators are alerted to changes in particle contamination levels in a machine's fluid by the indications provided from the PM4000. These indications can provide an early warning of component wear, filter or seal failures, water ingress, cavitation, oil oxidation, poor oil lubrication properties due to viscosity issues, changes in both additive and base oil stock, or other anomalies.

## 1.1 Identifying the Product

A PM4000 system consists of two basic parts:

- PT4000 Particle Transducer
- IM4000 Interface Module

The PT4000 Particle Transducer contains the sensing device and electronics for detecting the level of contamination. The laser-based sensor uses light blocking (extinction) technology for particle detection; particles, passing through an optical flow cell, block an amount of laser light proportional to the size of the particle. The particle concentration data from the PT4000 are sent to the IM4000 via a fiber optic cable. The data may also be directly collected through the IrDA port by any PDA device with IR capabilities (e.g., a Palm® PDA) or a PC with IR capabilities.

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The IM4000 converts the raw particle count data from the PT4000 for display or use in acquisition, logging, or control systems. A terminal emulation program can be used to read the ASCII data string.

## 1.2 PM4000 System Options

The following options are available at the time of the initial order or any time thereafter by returning either the PT4000 or IM4000 to the factory. Conversion of the PM4000 to another configuration may require the return of both units to the factory, depending upon the desired configuration. When ordering a PM4000 monitor, the model number will be followed by a two digit suffix (example: PM4000-**23**) signifying the type of transducer (first digit) and interface module (second digit). These digits are defined below.

*Table 1-1 :* PT4000 Transducer Suffix Definitions

| Suffix | Option |
|---|---|
| -1x | Equipped with an internal flow regulator |
| -2x | Equipped with a check valve to control flow |
| -3x | No flow control, external flow regulation required |
| -4x | Same as -1x with integrated LED display |
| -5x | Same as -2x with integrated LED display |
| -6x | Same as -3x with integrated LED display |
| -7x | Same as -1x with moderate pressure internal flow regulator |
| -8x | Same as -7x with an LED display |
| -9x | Same as -1x with low pressure internal flow regulator |
| -0x | Same as -9x with an LED display |

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*Table 1-2 :* IM4000 Interface Module Suffix Definitions

| Suffix | Option |
|---|---|
| -x1 | Optical Fiber to DB-9 for RS-232 output (DCE/computer usage) |
| -x3 | Optical Fiber to DB-15 for 0 to 5 VDC analog output and Modbus protocol on RS-232/RS-485 |
| -x4 | Optical Fiber to remote LED display with dry alarm contact closure |
| -x5 | Optical Fiber to remote LED display with dry alarm contact closure |

### Performance Validation

Individual PM4000 Particle Monitors cannot be calibrated. However, there is an option to verify the PM4000 performance using ISO Medium Test Dust (MTD) at 2.8 mg/l.

## 1.3 Unpacking and Initial Inspection

The PM4000 monitor is thoroughly inspected at the factory and is ready for use upon receipt. Inspect the shipping carton for damage. If the carton is damaged, notify the carrier and save the carton for carrier inspection. Inspect the monitor for broken parts, scratches, dents, or other damage. If the carton is not damaged, keep for reshipment in the event repair is necessary. The shipping carton should contain the following:

- One PT4000 and one IM4000 as ordered
- PM4000 CD-ROM
- Fiber optic cable
- Operator Manual

Contact Hach Ultra at 1-800-866-7889 or 1-541-472-6500 if any items are missing.

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# 2 PM4000 Configuration

A PM4000-13 is shown in this section as an example. The unit's components are shown in Figure 2-1.

The **-13** suffix describes the combination of a PT4000**-1** and an IM4000**-3**. Referring to the description of these components on the preceding pages, this system will operate on a fluid line that is pressurized and internally reduce the pressure to a near atmospheric level for return to a reservoir.

The output signal from the PT4000-1 will be connected to the IM4000-3 by a fiber optic cable up to 150 ft. (45.7 meters) in length. This length allows the interface module to be installed in a remote location isolated from the machinery. A more suitable location for data collection and analysis may be a control cabinet, an adjacent room, or office. The IM4000-3 output provides the data to a computer in several formats as described earlier.

Data collection directly at the transducer may be achieved using the IrDA port on the transducer and a device with IR capabilities, such as a personal digital assistant (PDA) or a laptop computer. The PT4000 must be configured in text mode for this type of data collection (see "Setting PT4000 Parameters" on page 25). The data collected may later be downloaded to a PC for analysis.

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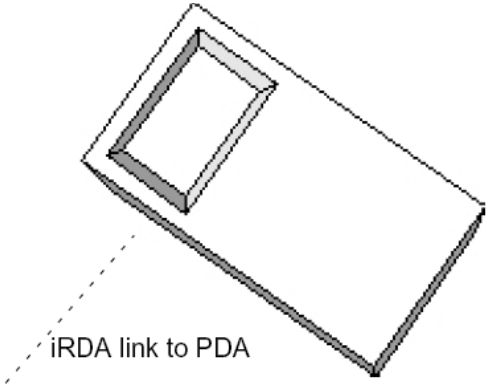



*Fig 2-1 :* Sample Configuration (PT4000-1 and IM4000-3)

## 2.1 PT4000 Overview

The PT4000 transducer is available in four basic configurations (Figure 2-2) for different applications. Each version can be integrated with an LED display for a total of eight variants.

For any PT4000, different fluid viscosities will affect the performance of the instrument. Further details concerning viscosity are provided in “Installation” on page 29.

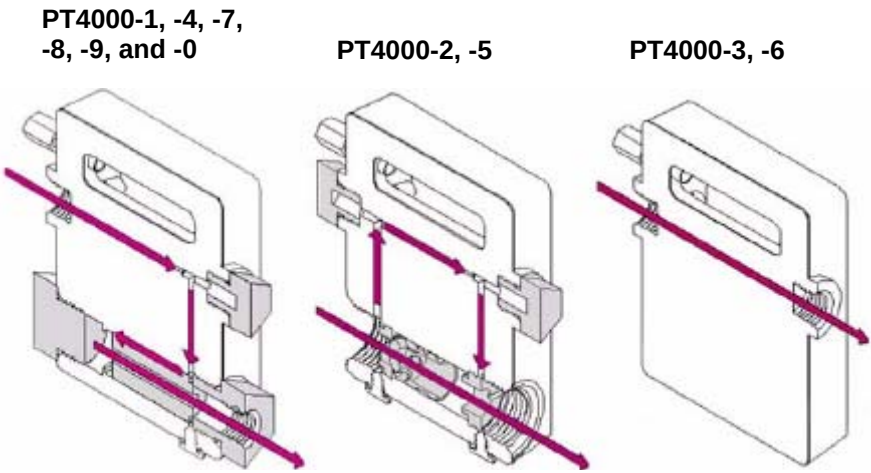


*Fig 2-2 :* Basic PT4000 Options (cross-section view)

### a) PT4000-1, -4, -7, -8, -9, and -0

The PT4000-1, -4, -7, -8, -9, and -0 have a flow inhibitor downstream of the sensor that restricts and controls fluid flow from variable high-pressure sources. The pressure is reduced to near atmospheric for return to a hydraulic fluid reservoir. The inlet pressure range is 400 to 7000 psi (27.6 to 482.5 bar) for the PT4000-1 and -4; 100 to 1200 psi (3.4 to 82.7 bar) for the PT4000-7 and -8; and 20 to 200 psi (1.4 to 6.9 bar) for the PT4000-9 and -0.

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## b) PT4000-2 and -5

The PT4000-2 and -5 are for inline flow applications and use a built-in check valve to divert flow from a varying pressure/flow system. The fluid flow rate for the PT4000-2 and -5 is 1 to 10 gal/min (3.8 to 37.9 L/min) for the entire pressure range of the instrument.

**Note:**
*A Minimess sampling port accessory is available with all PT4000 configurations for easily extracting a sample for external analysis without disconnecting the unit. When drawing a sample in this fashion, disregard the data from the PT4000 because excessive flow rates are created.*

## c) PT4000-3 and -6

The PT4000-3 and -6 use straight-through flow for operation in constant flow and pressure fluid systems. The flow rate must be externally controlled and must be at least 20 psi (1.4 bar) and between 0.01 to 0.1 gal/min (50 to 500 ml/min).

## d) PT4000-4, -6, -8, and -0

The PT4000-4, -5, -6, -8, and -0 transducers include an on-board 3-digit LED display that displays the selected ISO code value (in the selected size range). The code may be converted to particle counts/ml (“HIAC 4406 Codes” on page 53). The LED display can also display other functions and parameters as described in “Indicators and Controls” on page 64.

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*Table 2-1 :* PT4000 Versions

| Suffix | Flow Control Method | Local Display |
|---|---|---|
| PT4000-1 | Internal flow control inhibitor (high pressure: 400 to 7,000 psi (27.6 to 482.5 bar) | No |
| PT4000-2 | Internal check valve | No |
| PT4000-3 | None, external flow control required | No |
| PT4000-4 | Internal flow control inhibitor (high pressure: 400 to 7,000 psi (27.6 to 482.5 bar) | Yes |
| PT4000-5 | Internal check valve | Yes |
| PT4000-6 | None, external flow control required | Yes |
| PT4000-7 | Internal flow control inhibitor (moderate pressure: 100 to 1200 psi (3.4 to 82.7 bar) | No |
| PT4000-8 | Internal flow regulator (moderate pressure: 100 to 1200 psi (3.4 to 82.7 bar) | Yes |
| PT4000-9 | Internal flow control inhibitor (low pressure: 20 to 200 psi (1.4 to 6.9 bar) | No |
| PT4000-0 | Internal flow control inhibitor (low pressure: 20 to 200 psi (1.4 to 6.9 bar) | Yes |

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## 2.2 IM4000 Description

The IM4000 interface module is available in four variants to meet a wide variety of applications. Refer to Figure 2-3 through Figure 2-6 for illustration.

### a) IM4000-1

The IM4000-1 has a DCE configuration (9-pin female) for attachment directly to a computer's RS-232 serial port. Power is supplied by the computer (or PDA) serial port through the DB-9 connector. The IM4000-1 receives raw serial data from the PT4000 transducer via a fiber optic cable and transmits the data to the computer or PDA.

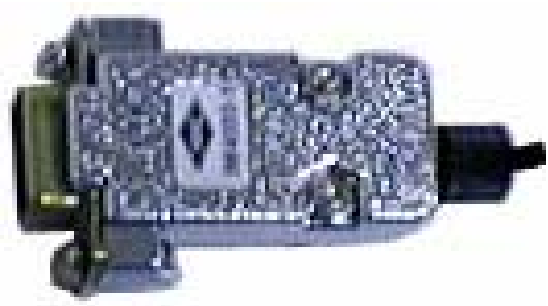

*Fig 2-3 :* IM4000-1

### b) IM4000-3

The IM4000-3 receives raw serial data input from the PT4000 transducer through a fiber optic cable. This data string is analyzed and converted into 0 to 5 VDC analog output voltages proportional to ISO codes and also into ModBus ASCII device protocol for interface to a PLC or computer via RS-485 and RS-232 serial. All signal outputs, and the input supply voltage (+9 to +36 VDC), are connected to the IM4000-3 through the DB-15 connector.

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*Fig 2-4 :* IM4000-3

## c) IM4000-4

The IM4000-4 receives raw serial data input from the PT4000 transducer through 0.04 in. (1 mm) fiber optic cable. The serial data string is decoded within the IM4000-1. Results are displayed on the front panel 3-digit LED display. The code number displayed is categorized in four size channels:

- > 4 µm
- > 6 µm
- > 14 µm
- > 21 µm

The code number represents a range of cumulative particle counts/ml as defined in “HIAC 4406 Codes” on page 53. The user can also select internal information about the transducer (Temp C, laser mA, Cal V, Node ID, status code).

Alarm levels can be programmed for any of the four particle size channels. When set, an alarm indicator will flash if the maximum acceptable ISO alarm level is reached. The alarm indicator is also activated if the associated PT4000 generates an error code. In this instance, both the **Alarm** and **Status** LEDs will flash and the display shows the status code as a hexadecimal number. Refer to “Common Error Codes” on page 57 to decode this number and determine the cause of the alarm. The alarm also drives a dry contact closure, which can be used to energize an external alarm indicator (visual or auditory). The external alarm power must not exceed 35 VDC at 100 mA.

**Note:**
*Deactivate alarms on the IM4000-4 and -5 by pressing any button. Supply voltage is external and can be from a +9 to +36 VDC source or from an optional +9 VDC battery.*

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*Fig 2-5 :* IM4000-4

## d) **IM4000-5**

The IM4000-5 receives the raw signal from the PT4000 through the 0.04 in. (1 mm) fiber optic cabling. The serial data string is decoded within the remote display of this module.

Results are displayed on the front panel 3-digit LED display. The code number displayed is categorized in four size channels:

- > 4 µm
- > 6 µm
- > 14 µm
- > 21 µm

The code number represents a range of cumulative particle counts/ml as defined in “HIAC 4406 Codes” on page 53. The user can also select internal information about the transducer (Temp C, laser mA, Cal V, Node ID, status code).

Alarm levels can be programmed for any of the four particle size channels. When set, an alarm indicator will flash if the minimum acceptable ISO alarm level is exceeded. The alarm indicator is also activated if the associated PT4000 generates an error code. In this instance, both the **Alarm** and **Status** LEDs will flash and the display shows the status code as a hexadecimal number. Refer to “Common Error Codes” on page 57 to decode this number and determine the cause of the alarm. The alarm also drives a dry contact closure, which can be used to energize an external alarm indicator (visual or auditory). The external alarm power must not exceed 35 VDC at 100 mA.

**Note:**
*Deactivate alarms on the IM4000-4 and -5 by pressing any button. Supply voltage is external and can be from a +9 to +36 VDC source or from an optional +6 VDC battery.*

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*Fig 2-6 :* IM4000-5

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# 3 Pre-Programming the PT4000

**Note:**
*The PT4000 may be programmed before installation.*

Install the software from the PM4000 CD-ROM on a desktop PC. Then, use the software supplied with the PDA to copy it to the PDA .

## 3.1 Configuring the On-line Software

1) To change configuration settings in the On-line communications program, launch the program, and then tap the **Menu** button (lower left corner of the graffiti area).
2) Tap the **Communications** tab and verify the settings listed in Table 3-1.

*Table 3-1 :* Communications Setting

| Setting | Value |
|---|---|
| Port setting | IrCOMM |
| Baud | 9600 |
| Data bits | 8 |
| Parity bits | N(none) |
| Stop bits | 1 |
| RTS/CTS | Checked |
| XON/XOFF | Unchecked |

3) Tap **OK**, and then tap the **Menu** button again.
4) Select **Terminal**, and verify all check boxes are unchecked except where indicated in Terminal Settings. Verify the settings are the same as those listed in Table 3-2.

*Table 3-2 :* Terminal Settings

| Setting | Value |
|---|---|
| Emulation Mode | VT100 |
| Font | Small |
| Return | CR |
| Backspace | BS |
| Display Follows Cursor | Checked |
| Pacing Option | OFF |

5) Tap **OK** to return to the **Terminal Screen**. The program is now configured for use.

**Note:**
*The box marked* **ON** *at the bottom of On-line's Terminal Screen must be enabled (black after tapped) before the PDA can communicate with the PT4000.*

## 3.2 Configuring the PDA

This assumes the PDA device being configured is running Palm OS Version 3.x. Configuration of other PDA operating systems may vary slightly.

1) Open the PDA's **Preferences** section (usually in the system folder) and select the **Connection** pull-down tab.
2) Tap **IR to PC/Handheld**.
3) Tap **Edit** and verify **Connection Method** is **IrCOMM to PC**.
4) Tap **Details** tab and verify **speed = 9600 bps** and flow control is **Automatic**.
5) Tap **OK** and then the **House** symbol to leave the **Preferences** section.

## 3.3 Setting PT4000 Parameters

The PM4000 firmware allows for operating parameters to be changed via the IrDA port on the PT4000 transducer using a PDA device with IrDA capability running the appropriate terminal software.

The IM4000 interface module need not be connected. Upon power up, the PT4000 scans the IrDA port, allowing the test parameters to be reprogrammed. If the setup dialog is not opened in the first 30 seconds, the previously saved setup will be used.

**CAUTION:**
*The IRDA port in the LED Display can be inadvertently activated during the first 30 seconds of operation (during the IrDA search cycle) when placed in close proximity to high power fluorescent lighting such as bench top lights placed at a right angle within 24 inches of the PT/ IM4000 display. Although the PT/ IM4000 will continue to process and transmit data via its fiber optic cable, the LED Display may be temporarily locked by its assumption that a transmission or reprogramming is in process. The interface may be reset by communicating momentarily with a PDA, or by a power off/on cycle. If it remains necessary to operate the unit in the presence of intense lighting, a piece of opaque material/tape may be placed over the PT/ IM4000 display to temporarily shield the IRDA port.*

The internal setup program of a PT4000 may be changed as follows:

1) Make sure all settings described in “Configuring the PDA” on page 24 have been verified.
1) Attach the DC power input cable of the transducer to an *unenergized* 9 to 36 VDC power source, white wire to +V, black wire to ground.

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2) Point the PDA at the transducer's IrDA port, then energize the power source connected in step 1.
3) When prompted to enter the configuration mode, enter **Yes**. The factory default menu displays as shown in Figure 3-1.

```
**** PT4000 CONFIGURATION MENU ****

1   SYSTEM ID #1 (0-9999)..... 5281
2   SYSTEM ID #2 (0-9999)..... 1247
N   NODE ID (1-247) ..... 138
M   SAMPLE MODE (TIME/EVENT) ..... T
O   SAMPLE OUTPUT (SINGLE/AVERAGE) ..... S
S   Sample Standard (ISO) ..... I
P   SAMPLE PERIOD (MM:SS) ..... 01:00
H   SAMPLE HOLD (MM:SS)..... 04:00
E   EVENT LEVEL (0-10000)..... 5000
F   OUTPUT FORMAT (RAW/TERMINAL) .....R
Q   QUIT
```

*Fig 3-1 :* PT4000 Configuration Menu

4) To change a specific parameter, enter the letter or number of the parameter to be changed and wait for the PT4000 to respond. Then enter the updated configuration when prompted.
5) End the sequence by typing **Q**. All the configuration information will be saved in nonvolatile memory.

**Note:**
*The PT4000 and PDA may take several seconds to respond via an IrDA port.*

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- **System ID** and **Node** parameters provide a unique identification of each unit (required for networking of units).
- **Sample Mode** is either based on accumulated time (defined by parameter P) or accumulated counts (channel 1 only). The event level is defined by parameter E.
- **Sample Output** is either based on discrete sample events or a sliding window-weighted average of the last five samples.
- **Sample Period** should be set to achieve a statistically significant number of particles in the sample. For expected code ranges of 12 and greater, a one-minute sample time should be sufficient. Below that, the sample period should be doubled for each additional code level. For example, use a two-minute sample at ISO code 11.
- **Sample Standard** is ISO.
- **Sample Hold** times may be automatically extended at higher operating temperatures to protect laser life, see “Duty Cycle” on page 79.
- **Event Level** refers to the number of channel 1 events required if the sample mode is event driven.

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# 4 Installation

## 4.1 Installation Considerations

Figure 4-1 represents a simplified diagram of a possible fluid system, containing the common elements found in actual systems. Potential sampling points are labeled S1 through S14, other components are labeled as listed in Table 4-1:

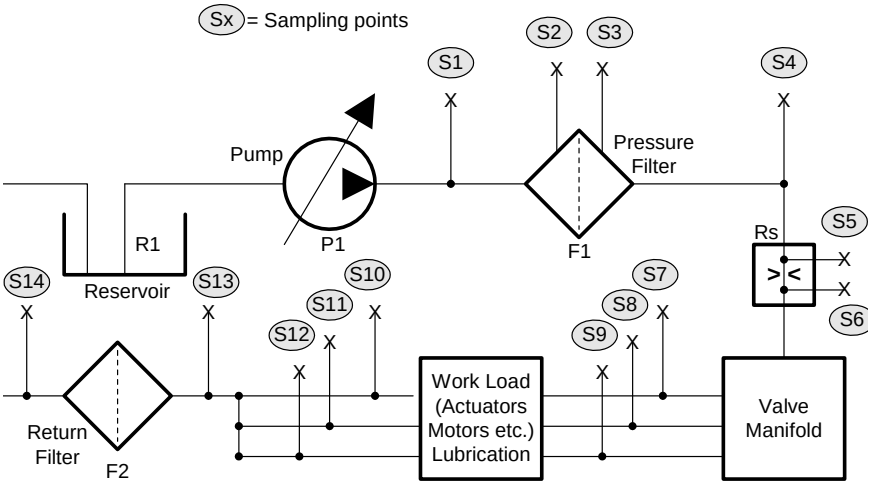


*Fig 4-1 :* Simplified Fluid System Diagram

*Table 4-1 :* Fluid System Components

| | |
|---|---|
| R1 | Reservoir |
| P1 | Pressure pump |
| F1 | Pressure filter |
| F2 | Return Line Filter |
| R | Restriction |

These sample points potentially exist on systems as standard oil sampling ports. If a sample port is not in place, then one can be added using a **T** in the piping or by tapping a 1/4 inch (6.35 mm) sampling port into the pressure line. Sampling ports should be placed in active lines, ideally at points where there is some turbulent flow; such as at elbows and bends.

Connection to the PT4000 can be made using hose, microbore tube, or rigid pipe work. Consider using a minimess or similar quick disconnect sampling port on the system. This will allow the PT4000 to be disconnected for service or to relocate onto another sampling point, without shutting down the machine. If the unit will be hard plumbed, then a valve incorporated in the system would serve the same isolation function.

The fittings on the PT4000 are female SAE JI926 O-ring, which are easily adapted to 37 JIC flares using an adapter (4 required). Use of a minimess to SAE “O” type fitting with microbore hose is recommended if the unit is connected and disconnected frequently. The microbore tubing provides faster clean up time and better particle transportation due to the lower internal volume.

## a) PT4000-1, -4, -7, -8, -9, and -0 Installation Examples

A PT4000-1 connection could be made to on-line sample points S1-S9 with return to reservoir R1. S10-13 are also options provided there is enough pressure in the return lines.[1] The PT4000-9 or -0 sensors may be placed in positions S10 - S13 per Figure 4-1 when the line pressure matches the specified pressure rating for the sensor. Figure 4-2 shows an installaton at S2 at the filter inlet with

1. For lower pressure sample points, PT4000-7 or PT4000-9 transducers may be used. Refer to “Specifications” on page 75 for details.

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the return line to the reservoir. Refer to Figure 4-3, Figure 4-4, and Figure 4-5 for viscosity considerations.

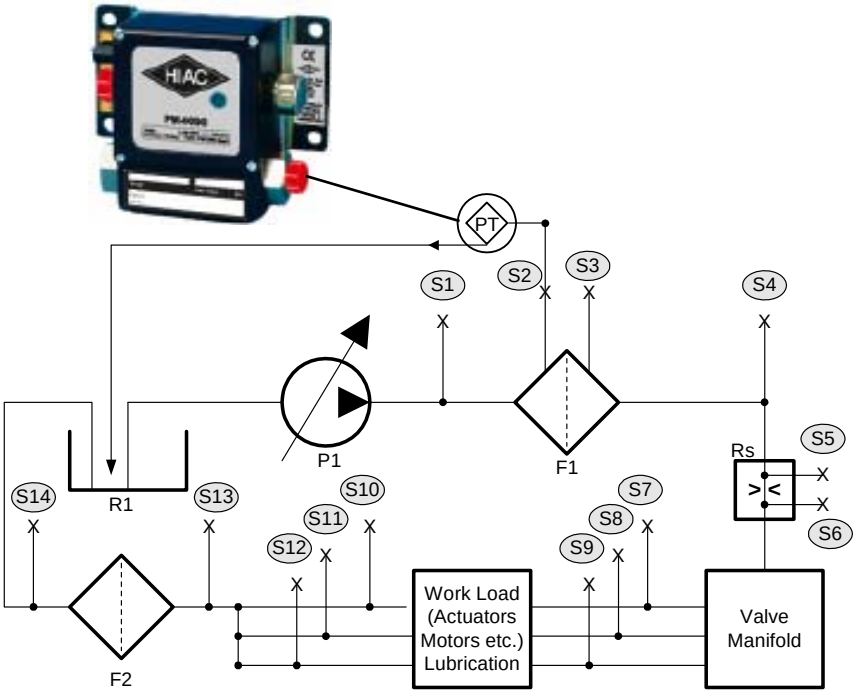


*Fig 4-2 :* Sample PT4000-1, -7, or -9 Installation

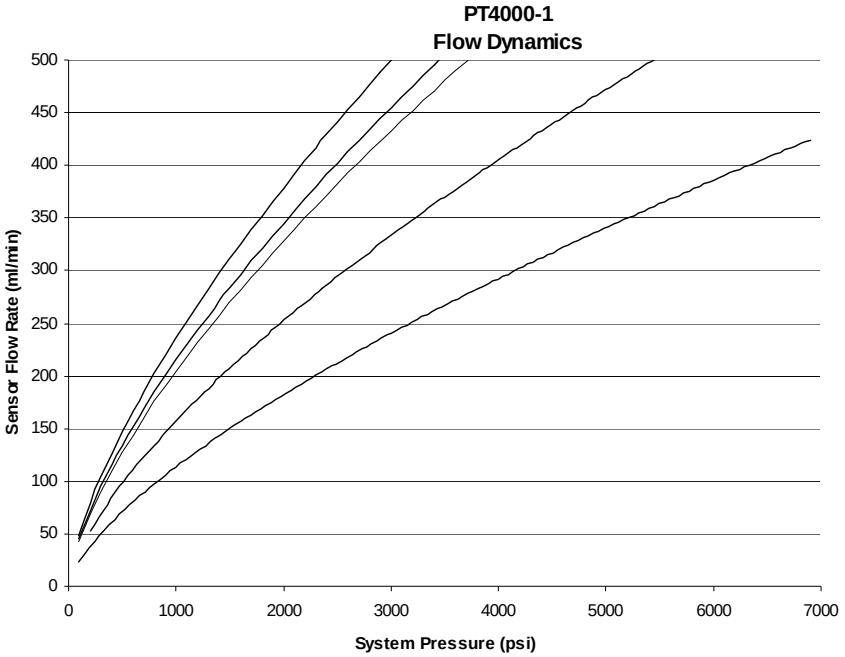


*Fig 4-3 :* PT4000-1, -4 Flow Dynamics

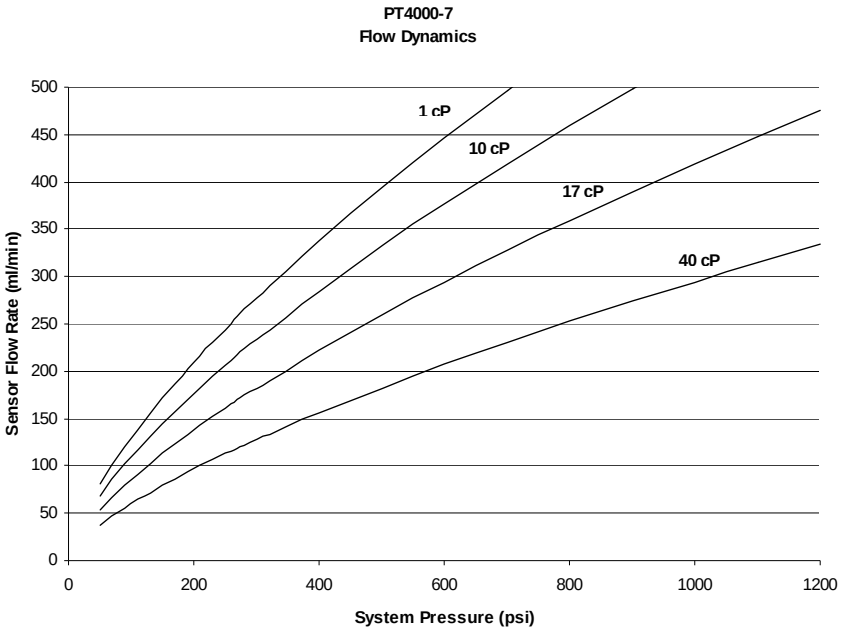


*Fig 4-4 :* PT4000-7, -8 Flow Dynamics

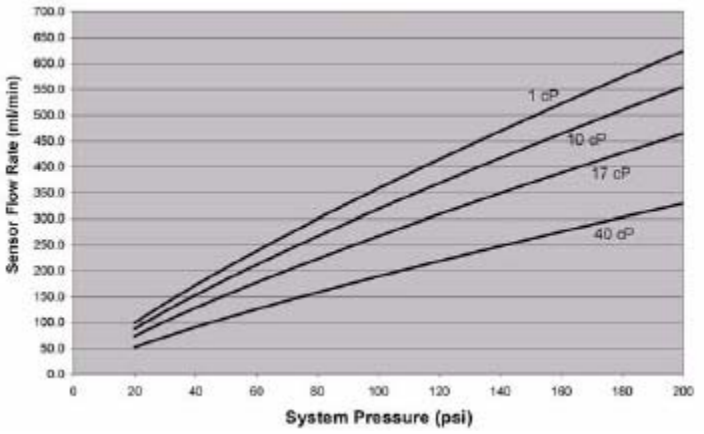


*Fig 4-5 :* PT4000-9, -0 Flow Dynamics

## b) PT4000-2 Installation Examples

Connect the PT4000-2 in any inline installation having flow rates between 1-12 GPM (45 LPM) and pressure within specifications. Install between two points of varying pressure in a bypass mode (differential pressure >20 psi (1.3 bar), where fluid is not diverted from work; that is, between S3-S5 where the pipe and elbow create a pressure loss). Figure 4-6 shows a PT4000-2 installed between the valve manifold and the work load. See Figure 4-7 for system flow rate considerations.

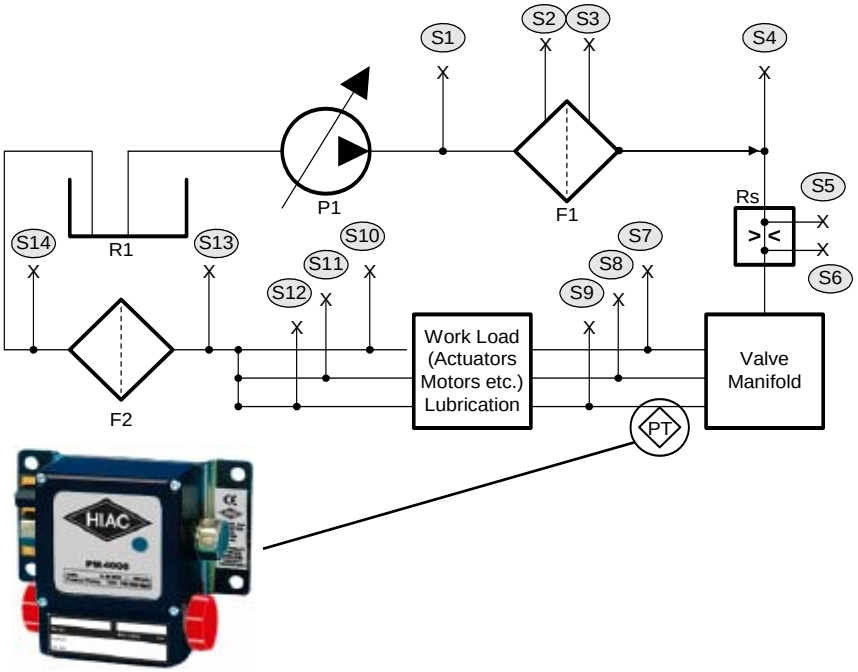


*Fig 4-6 :* Sample PT4000-2 Installation

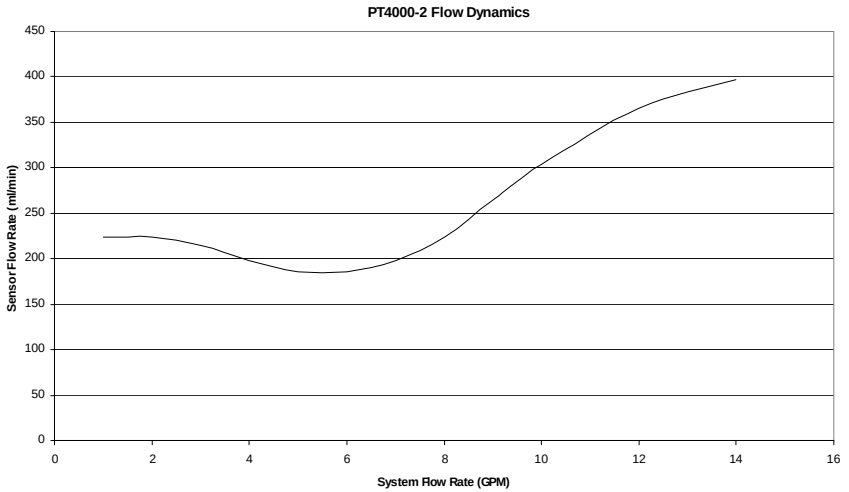


*Fig 4-7 :* PT4000-2 Flow Dynamics

## c) PT4000-3 Installation Examples

A PT4000-3 may be connected inline around any constant pressure drop in the system of ~5 to >30 psi (2.1 bar). This is represented as S5-S6 in Figure 4-8. Note: Fluid can return via the sensor. Do not install near an existing check valve. Acceptable return flow will not be possible in this location. This unit may also be installed between S13 and S14 using the differential pressure drop across the return line filter F2 to provide the required flow. Refer to Figure 4-9.

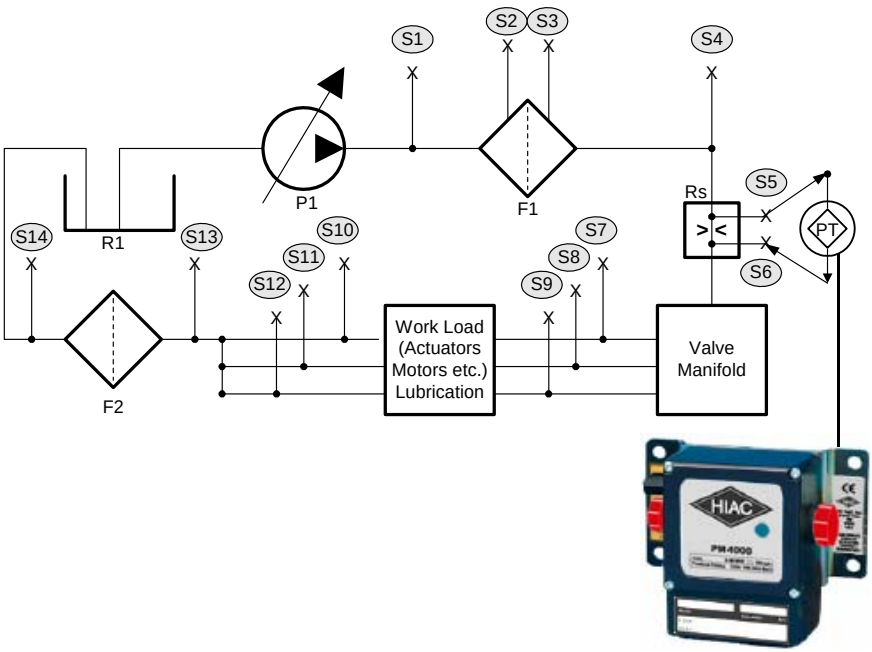


*Fig 4-8 :* Sample PT4000-3 Installation

Flow through the sensor of a PT4000-3 is laminar at the maximum flow of 0.13 gal/min (500 ml/min) down to 4 cP. Laminar flow is directly proportional to differential pressure and inversely proportional to viscosity by the following equation:

$$Q \alpha \frac{\mu}{\Delta P}$$

Where Q is in ml/min, $\mu$ is viscosity, and $\Delta P$ is the differential pressure across the sensor.

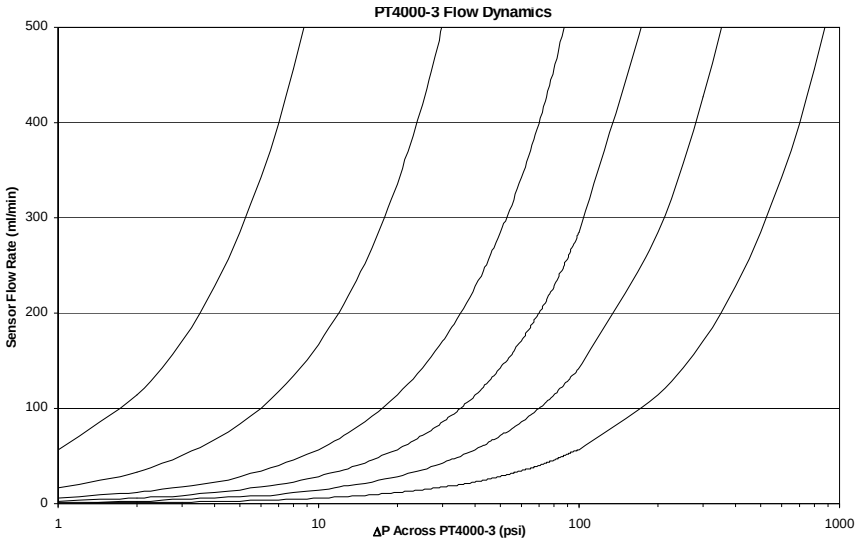


*Fig 4-9 :* PT4000-3 Flow Dynamics

## 4.2 Installation Procedure

**WARNING**

*Ensure power lines are de-energized before beginning procedure.*

The steps below and accompanying figures show a typical installation of the PM4000 system. There are four basic tasks:

1) Mount the transducer and interface module. The same mounting plate is used for IM4000-3, -4, or -5, as shown in Figure 4-10.
2) Plumb the fluid sample inlet and outlet lines to PT4000.
3) Connect DC power to both modules and connect the data cable between IM4000 and data collection system.
4) Connect the fiber optic cable between the PT4000 and the IM4000.

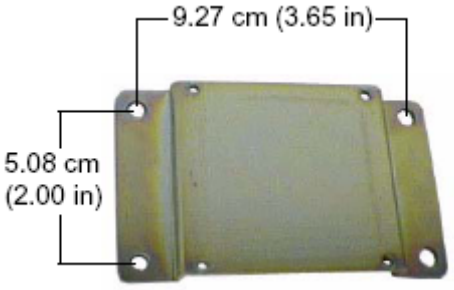


*Fig 4-10 :* Mounting Plate Dimensions

## a) Mounting

1) Fasten the mounting plate (with attached PT4000) to a wall or other permanent fixture using standard installation practices. Refer to the dimensions in Figure 4-10.
2) If using the -3, -4, or -5 option for the IM4000, fasten it at the desired location (typically within 20 ft. (6.1 m) of the transducer) by repeating step 1. The maximum distance between the two units is 150 ft. (45.7 m). Note: 20 ft. (6.1 m) of fiber optic cable is supplied.

## b) Hydraulic Installation

**WARNING**

*Verify that all hoses, microbore tube, rigid pipe, and fittings are rated at the maximum operating pressure of the fluid source before applying pressure.*

1) Connect the sample inlet hose to the proper fitting on the PT4000 in the system.
2) Connect the other end of the hose to desired sample point.
3) Tighten the hose fitting to standard specifications.
4) Connect the return hose between outlet port on the transducer in the system and the return reservoir or a downstream sample port.
5) Tighten the hose fitting to standard specifications.
6) Apply a fluid source to the transducer; allow fluid to flow through the transducer to purge the system of all air bubbles.

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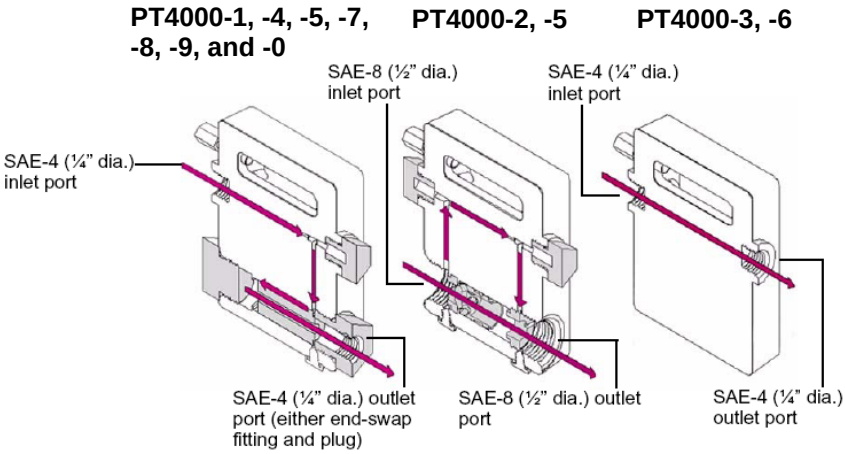


*Fig 4-11 :* Transducer Inlet and Outlet Port Identification

## c) Electrical Connections

1) Using standard electrical wiring practices, connect the red-jacketed DC input cable from the PT4000 to an *de-energized* +9 to +36 volt source with the white wire to positive (+) terminal of source, black wire to ground (-).
2) The green wire on the cable should be attached to earth ground.
3) Wire the power so that the PM4000 can be turned off when the sample point or machine is inactive. A local power switch will allow the unit to be reset as often as required.
4) Make remaining electrical connections using one of the procedures below, depending on the version of IM4000 used.

**Note:**

*The computer must be an Intel® Pentium® (or equivilent) or faster class of processor and have the communications port enabled in order to power the IM4000 correctly.*

## IM4000-1

Power for the IM4000-1 comes from the monitoring device (computer or PDA device).

1) Make connections as shown in Figure 4-12.
2) Start a count cycle by energizing the power source to the PT4000.

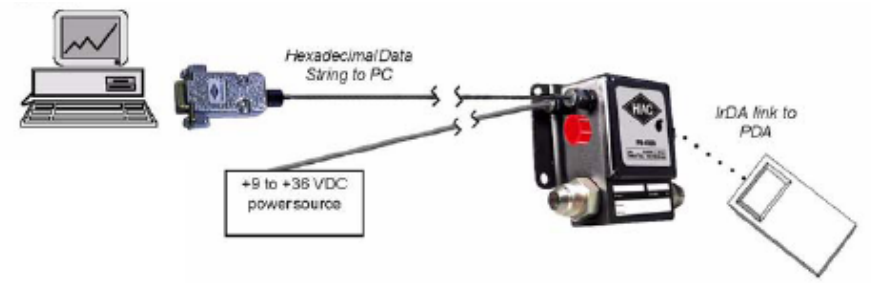


*Fig 4-12 :* IM4000-1 Signal Connections

*Table 4-2 :* IM4000-1 Pinout for DB-9 Connector

| Pin | Signal Name | IM4000-1 |
|---|---|---|
| 1 | CD | Output |
| 2 | RxD | Output |
| 3 | TxD | Input |
| 4 | DTR | Input |
| 5 | GND | NA |

| Pin | Signal Name | IM4000-1 |
|---|---|---|
| 6 | DSR | Output |
| 7 | RTS | Input |
| 8 | CTS | Output |
| 9 | RI | Output |

## IM4000-3

The IM4000-3 and the PT4000 in this configuration are each powered by their own external +9 to +36 V power source. Make connections as shown in Figure 4-13.

1) Plug the break-out cable into the DB-15 connector of the IM4000-3 interface module.
2) Set up the PT4000 for Raw Data output as described “Raw Data Record Format” on page 53.
3) For Modbus communications, connect the IM4000-3 to a data acquisition system such as a PLC. Refer to “Standard Modbus Protocol Information” on page 59 for protocol details.

   For greater distances to the readout device or for multiple PM4000 uses (-x3 only), connect RS485A, RS485B, and ground leads to an RS232-to-RS485 converter which, in turn, connects to the RS-232 port of the computer.
4) A total of eight analog voltage channels are available for direct monitoring and logging of the PT4000's data output. The analog channels 1-4 output a 0-5 V signal that is proportional to the ISO 4406 codes reported by the PT4000. The remaining four channels are assigned to specific instrument conditions.

   Channel 5 Temperature
   Channel 6 Laser Current
   Channel 7 Received Power
   Channel 8 Alarm Bits

5) To start a count cycle, energize the power source to the transducer and the interface module.

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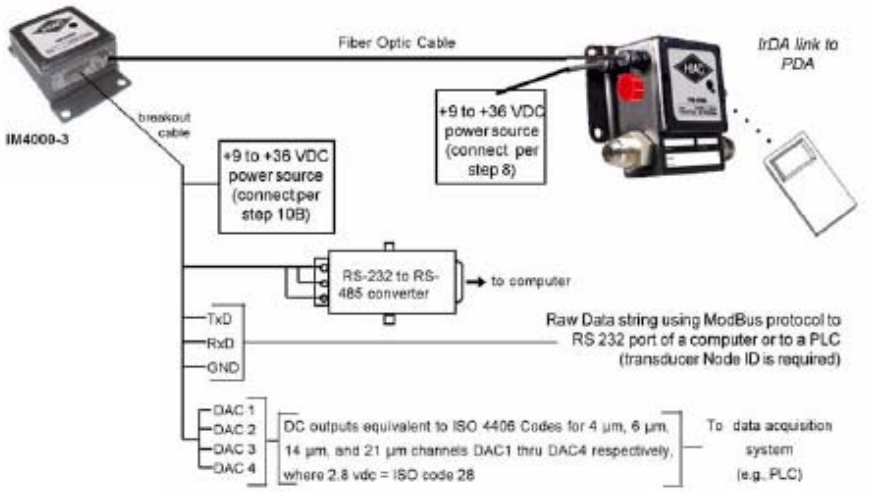


*Fig 4-13 :* PM4000-3 Signal Connections (breakout cable shown)

*Table 4-3 :* IM4000-3 Pinout, DB-15 Connector

| Pin | Signal Name |
|---|---|
| 1 | Pwr GND |
| 2 | DAC out 8 |
| 3 | DAC out 6 |
| 4 | DAC out 4 |
| 5 | DAC out 2 |
| 6 | RS-485 B |
| 7 | Shield GND |
| 8 | TxD |

| Pin | Signal Name |
|---|---|
| 9 | 9-to-36 VDC in |
| 10 | DAC out 7 |
| 11 | DAC out 5 |
| 12 | DAC out 3 |
| 13 | DAC out 1 |
| 14 | RS-485 A |
| 15 | RxD |

## IM4000-4, IM4000-5

The PT4000 in this configuration is powered using an external +9 to +36 VDC source and the IM4000-4 or -5 can be powered with an external +9 to +36 VDC source or by an optional +6 V battery. Make connections as shown in Figure 4-14.

1) Referring to IM4000-4 pinout of Table 4-4, connect leads from the voltage source selected to the appropriate pins of the cable connectors using safety-related wiring practices.
2) If using the dry alarm contact closure feature to energize an external alarm indicator (light, siren, etc.), connect alarm leads to the appropriate pins of the connector.
3) Verify the PT4000 output format is set to R (raw data) as established under “Raw Data Record Format” on page 53.
4) To start a count cycle, energize the power source to the transducer (the 3-digit display will illuminate for 10 seconds when any key is pressed).

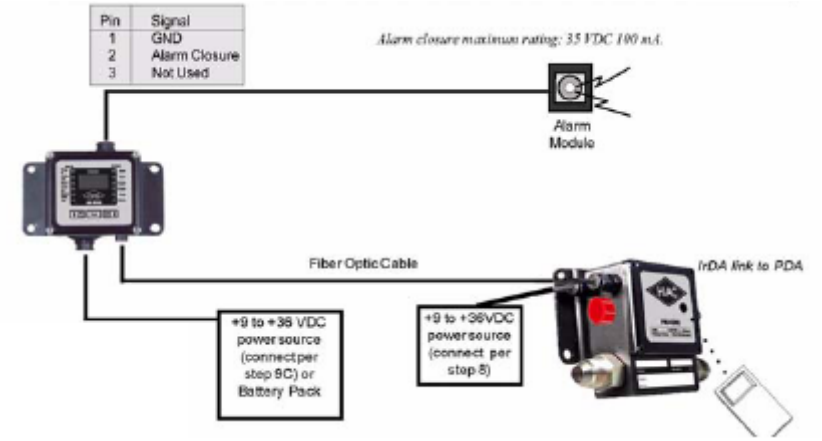


*Fig 4-14 :* IM4000-4 and -5 Signal Connections

*Table 4-4 :* IM4000-4 and -5 Pinouts

| Pin | Signal |
|---|---|
| 1 | Battery (+) |
| 2 | Battery (-) |
| 3 | DC supply (+) |
| 4 | DC supply (-) |

## d) Fiber Optic Connections

When connecting the supplied fiber optic cable between the transducer and the interface module, cable ends must be precisely trimmed to a flat face for optimum light transmission. The maximum fiber optic length is 150 ft. (45.7 m) before signal degradation begins. Connect the fiber optic to the PT4000 using this procedure.

1) Remove nut and ferrule from PT or interface module.
2) Slide the nut, then ferrule onto one end of the fiber optic cable.
3) Insert the fiber optic cable end into hole in the module where the nut and ferrule were removed until cable stops.
4) Tighten nut with torque to15 lb-in. (17 kg-cm).
5) Repeat for each PT and IM in system.
6) After power is applied, check the IM4000 end of the fiber optic for a red glow to verify the installation was successful.

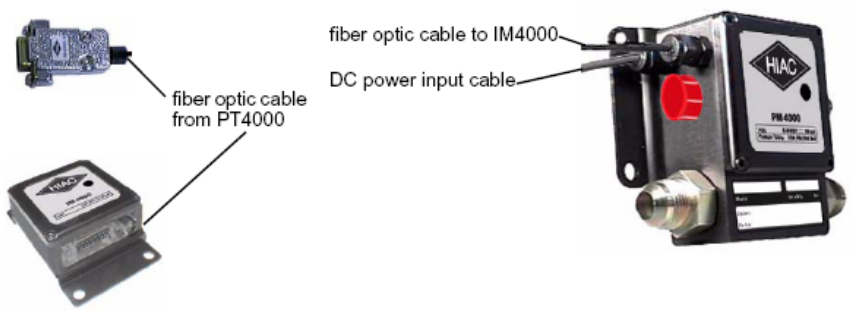


*Fig 4-15 :* Connection of Fiber Optic Cables

# 5 Data Acquisition

In any data acquisition setup, it takes approximately two seconds to complete the data transmission. This time is added into the operating cycle of the system.

## 5.1 Using the PM4000 DDE Driver with the IM4000-1

The PM4000 DDE Server interfaces between the PM4000 and DDE enabled software. It provides the links between the monitoring or analytical software and the counter's system data, sample data, and diagnostic data.

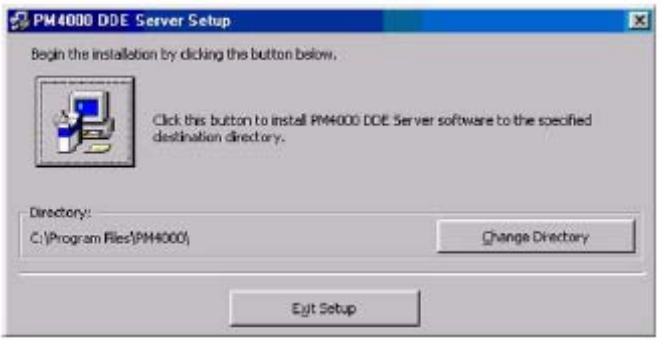


*Fig 5-1:* DDE Server Setup

The PM4000 software will run on Microsoft® Windows 98®, Windows ME®, Windows 2000®, Windows NT®, and Windows XP®. The system should be an Intel Pentium or higher processor with at least 64MB of RAM. To install the software:

1) Place the PM4000 DDE Server CD in the CD-ROM drive.

2) Click **Start > Run**, and type the path to the **setup.exe** file on the CD-ROM drive.
3) Choose the destination directory and click the **OK** or **Open** button to continue.
4) Choose the folder group where the program shortcut should be installed. This group will appear in the **Start** menu.

**Note:**
***For Windows 2000, Windows NT, and Windows XP users:*** *The program installation is user-specific. The system administrator should be able to add a shortcut for all users who will be using the software.*

5) Follow the rest of the prompts to complete the rest of the installation.

## 5.2 Setting Up a Counter for the First Time

1) Log on to the software and choose the **Options** menu.
2) Click the **Set-up Com Ports** button.
3) Check the box to enable the unit.
4) Select the COM port from the drop down list to which the PM4000 is connected. A name can also be defined in this screen.
5) To set up multiple counters, increase the number of supported counters in the **Options** screen (up to four) and click on the **Set-up Com Ports** button.
6) Associate each counter with its appropriate COM port.

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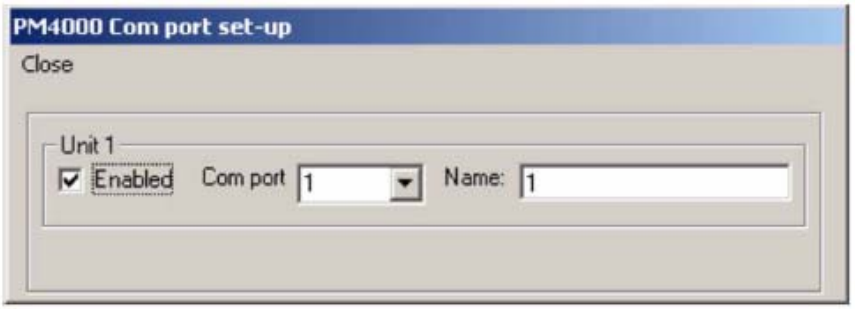


*Fig 5-2:* Com Port Setup Dialog

## 5.3 DDE Configuration

Once a counter has been configured, the DDE server waits for the updates from the counter and then makes that data available through DDE. The **Raw Data** screen, shown in Figure 5-3, displays the data from the counter and has the DDE connection instructions.

The **Raw Data** screen can be accessed by selecting **View > Raw Data**. Each box's data are available via DDE except the two boxes with the yellow background. To connect to the DDE Server, use the following information for server, topic, and item names:

| | |
|---|---|
| Server*:* | *PM4000* |
| Topic*:* | *UNIT1-4* |
| Item*:* | *Label of box* |

For example, Microsoft Excel® would use the following to connect to the 4 µm counts:

=PM|!unit1ISOcode4um

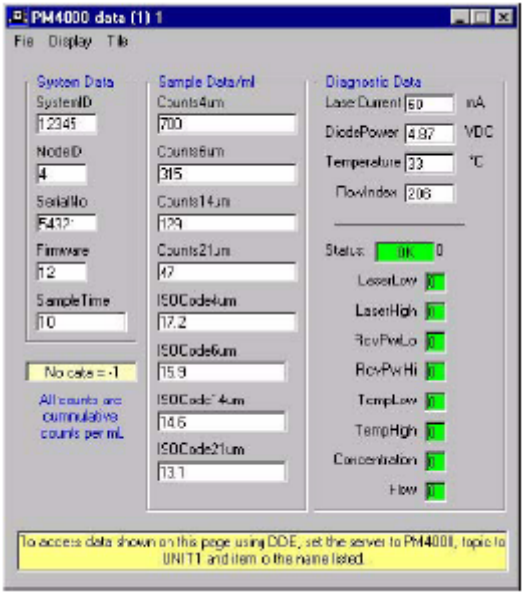


*Fig 5-3:* Raw Data Screen

Refer to “Serial Protocol Definitions” on page 55 for a complete description of the data record.

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## 5.4 Multiple Installation Considerations Using Modbus Protocol

The IM4000-3 has the capability for serial RS-485 data communication for networking with a controlling computer. The host computer controls activity on the serial link using a protocol which is compatible with systems supplied by Hach Ultra Analytics.

Only one station can transmit at a time, because a single twisted-pair wiring is used. The system requires that each PT4000 have a unique node identification number. These ID numbers must be set prior to usage (see “Setting PT4000 Parameters” on page 25). Data and commands are in the ASCII range while select numbers are not. Valid select numbers are in the range 1 (1 Hex) to 247 (FF Hex) and are sent as a single character.

These items may be needed to accommodate multiple monitor (RS-485) networking:

- RS-232/RS-485 converter: Changes typical RS-232 serial output of computers to RS485 (Figure 5-4).
- Wire, shielded, twisted pair (such as Belden PN 9841): Connects multiple PM4000 monitors.

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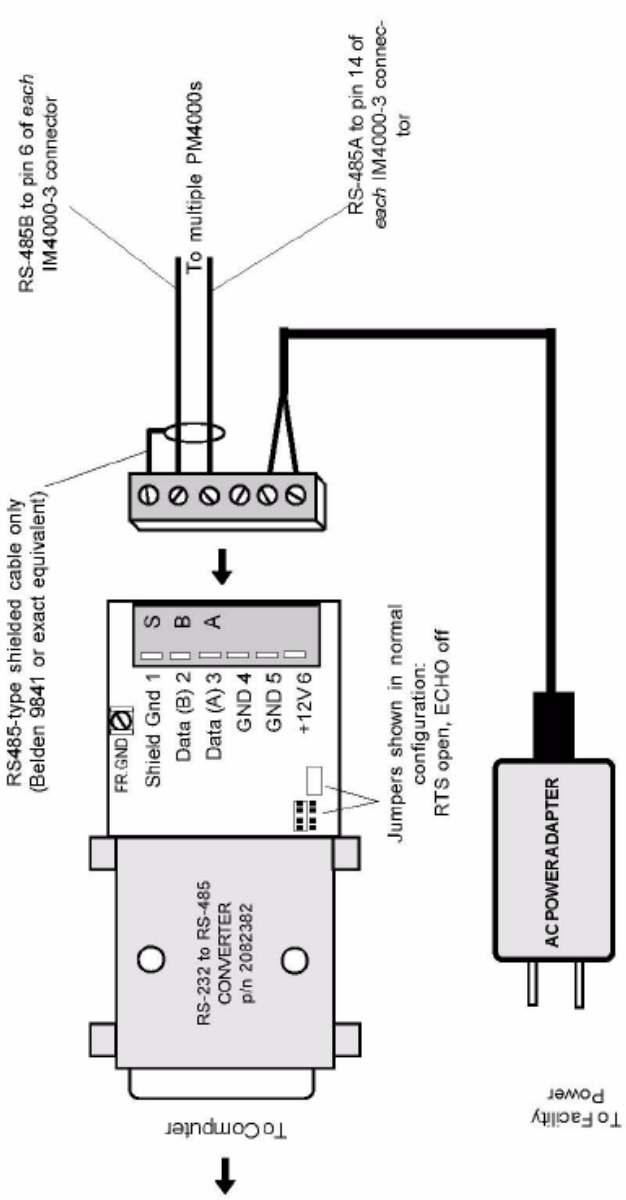


*Fig 5-4:* Using the RS232-to-RS-485 Converter in Multiple Applications

## 5.5 Raw Data Record Format

Each PT4000 transducer, regardless of model version, sends a record of its data. The raw data records are a serial bit stream of ASCII characters, where the position in the string identifies a character's meaning.

A sample string appears as follows:

;A10034A234A304dfA41AB102027a4B201e0140B300f003
cB401cae2fB50003d8B60003d8B7001C11824C21824C311
4fC409c4C50caC60caC70c5C8122D13bD21e0D321D480f4

Refer to “Serial Protocol Definitions” on page 55 for complete description of the data record.

The system tracks minimum and maximum levels of several parameters and reports the overall status as part of the post-sample data output transmission. In the example above, a flow index alarm (hex = 80; see Table 5-1 on page 61) was reported as active. The 4 µm Cumulative Counts/ml value (1186442) identifies this size channel as having a high level.

A system alarm appears on this line if system parameters are not operating within the following limits:

- Particle concentration = up to ISO 28 (2.5 million counts/ml, based on 4 m channel)
- Sensor received power (Cal V) = 4.70 to 4.90 VDC
- Laser drive current (Laser mA) = 30 to 62 mA
- System temperature (Temp C) = -10 to 60 °C (-14 to 140 °F)

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## 5.6 Terminal Output Format

Terminal output format is used to provide a user-friendly display on the IrDa device or other terminal emulation programs on the PC.

Figure 5-5 is a typical example of a Terminal Output display.

SAMPLE RECORD #1537

Sample Duration = 13 Secs

| | | |
|---|---|---|
| 4μm Cumulative Counts/ml | = | 1186442 |
| 6μm Cumulative Counts/ml | = | 1568 |
| 14μm Cumulative Counts/ml | = | 390 |
| 21μm Cumulative Counts/ml | = | 0.133 |

| | | |
|---|---|---|
| 4μm ISO Code | = | 27.8 |
| 6μm ISO Code | = | 18.2 |
| 14μm ISO Code | = | 16.2 |
| 21μm ISO Code | = | 4.6 |
| Flow Index = | 130 | |

| | | |
|---|---|---|
| RECEIVED POWER | = | 4.83 VDC |
| LASER DRIVE CURRENT | = | 0.048 A |
| SYSTEM POWER | = | 5.03 VDC |
| SYSTEM TEMPERATURE | = | 31.5 C |
| SYSTEM ALARMS | = | 82 |

*Fig 5-5:* Terminal Output Display

## 5.7 Changing Interface Module DAC Assignments (DAC 4-8)

DAC outputs are assignable between the following two sets of parameters:

- Laser Current, Received Power, System Power, System Alarms (default parameters)
- Peak ISO codes for Channel 1 since power up, (same for Channels 2, 3, and 4)

## 5.8 Serial Protocol Definitions

### a) Physical Layer

Serial bit stream - Optical fiber (plastic)

### b) Data Link Control

- Unidirectional, point-to-point link only

### c) Message Format

At the end of each sample period the PT outputs a complete data message consisting of system data, sample data, diagnostics data and message checksum groups. Messages consist of a unique start character followed by specific groups of data. Each data field in the message group consists of a message identifier (2 alpha/numeric bytes) followed by 1 or more bytes of data. Data (sent in ASCII encoded hexadecimal 0-9/A-F) may represent whole integer or fixed decimal values as specified in the message field definitions that follow. Messages conclude with an 8-bit checksum followed by a carriage return - line feed. This checksum value is the sum (no carry) of all bytes in the message.

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- Start of new message discriminator = ;
- PT system data
  - System Identifier = A1, 4 bytes (0xFFFF)
  - Node Identifier = A2, 2 bytes (0 to 0xFF)
  - Serial Number = A3, 4 bytes (0 to 0xFFFF)
  - Firmware Version = A4, 2 bytes (0 0xFF)
- Bytes reserved
  - B1, 7 bytes, reserved
  - B2, 7 bytes, reserved
  - B3, 7 bytes, reserved
  - B4, 7 bytes, reserved
  - B5, 6 bytes, reserved
  - B6, 6 bytes, reserved
  - B7 = Total sample time, 3 bytes (0 to 0xE0F represents 00:00 to 59:59 mm:ss)
- Sample data = see Note 1
  - Channel 1 cumulative counts/ml = C1, 4 bytes (0 to 0xFFFF)
  - Channel 2 cumulative counts/ml = C2, 4 bytes (0 to 0xFFFF)
  - Channel 3 cumulative counts/ml = C3, 4 bytes (0 to 0xFFFF)
  - Channel 4 cumulative counts/ml = C4, 4 bytes (0 to 0xFFFF)
  - Channel 1 ISO code = C5, 3 bytes (0x0A to 0x121 represents 01.0 to 28.9)
  - Channel 2 ISO code = C6, 3 bytes (0x0A to 0x121 represents 01.0 to 28.9)
  - Channel 3 ISO code = C7, 3 bytes (0x0A to 0x121 represents 01.0 to 28.9)
  - Channel 4 ISO code = C8, 3 bytes (0x0A to 0x121 represents 01.0 to 28.9)

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- Diagnostics data
  - Laser Drive Current = D1, 2 bytes (0 to 0x46 represents .000 to .070 A)
  - Photodiode Received Power = D2, 3 bytes (0 to 0x1F4 represents 0.00 to 5.00 vdc)
  - Ambient Temperature = D3, 2 bytes (0 to 0x7F = positive C/0x80 to 0xFF = negative C).
  - System alarm status = D4, 2 bytes (0 to 0xFF) - bit map, decode as follows:
    - Bit 0 = laser drive current low alarm
    - Bit 1 = laser drive current high alarm
    - Bit 2 = photo diode received power low alarm
    - Bit 3 = photo diode received power high alarm
    - Bit 4 = system temperature low alarm
    - Bit 5 = system temperature high alarm
    - Bit 6 = concentration alarm
    - Bit 7 = flow index alarm

## d) Common Error Codes

| LED display | Alarm Condition (s) | Set Bits |
|---|---|---|
| 001 | Laser Current Low | Bit 0 |
| 002 | Laser Current High | Bit 1 |
| 004 | Photodiode Low Power | Bit 2 |
| 005 | Laser Current Low and Photodiode Low | Bits 0, 2 |
| 006 | Laser Current High, Photodiode Low Power | Bits 1, 2 |
| 008 | Photodiode High Power | Bit 3 |
| 009 | Laser Current Low, Photodiode High Power | Bits 0, 3 |
| 010 | Temperature Low | Bit 4 |

| LED display | Alarm Condition (s) | Set Bits |
|---|---|---|
| 014 | Temperature Low, Photodiode Low Power | Bits 4, 2 |
| 018 | Temperature Low, Photodiode High Power | Bits 4, 3 |
| 020 | Temperature High | Bit 5 |
| 021 | Laser Current Low, Temperature High | Bits 0, 5 |
| 022 | Temperature High, Laser Current High | Bits1, 5 |
| 024 | Temperature High, Photodiode Low Power | Bits 5, 2 |
| 028 | Temperature High, Photodiode High Power | Bits 5, 3 |
| 040 | Concentration High | Bit 6 |
| 042 | Concentration High, Laser Current High | Bits 6, 1 |
| 044 | Concentration High and Photodiode Low | Bits 6, 2 |
| 048 | Concentration High, Photodiode High Power | Bits 6, 3 |
| 050 | Temperature Low, Concentration High | Bits 4, 6 |
| 060 | Temperature High, Concentration High | Bits 5, 6 |
| 080 | Flow Index | Bit 7 |
| 081 | Flow Index, Laser Current High | Bits 1, 7 |
| 082 | Flow Index, Laser Current Low | Bits 0, 7 |
| 084 | Flow Index, Photodiode Low Power | Bits 2, 7 |
| 088 | Flow Index, Photodiode High Power | Bits 3, 7 |
| 090 | Flow Index, Temperature Low | Bits 4, 7 |
| 0A0 | Flow Index and Temperature High | Bits 5, 7 |
| 00A | Laser Current High, Photodiode High Power | Bits 1, 3 |
| 00C | Temperature Low, Laser Current High | Bits 4, 1 |
| 0C0 | Flow Index, Concentration High | Bits 6, 7 |

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Example output message format:

;A12107A28aA304dfA41CB10000000B20000000B30000000
B40000000B5000000B6000000B7005C10000C20000C30000C4
0000C500C600C700C800D141D2009D319D44698<cr><lf>

**Note:**
*Cumulative counts are scaled to fit 4 bytes as follows:*

*For ISO codes < 11.0, output = raw count data / 1000*

*For ISO codes >20.2, output = raw count data *1000.*

*For ISO codes 11.0 thru 20.2, output represents true counts.*

## 5.9 Standard Modbus Protocol Information

This is a listing of the register map for the IM4000 Interface Module in accordance with Modbus standard protocol.

The Decoder recognizes:

- Modbus standard Command 03: Read Holding Registers
- Modbus standard Command 06: Preset Single Register (for example, Load Single Register).

The Modbus Protocol stipulates that data is exchanged in the form of a register, which consists of 2 bytes.

- A Read inquiry (Command 03) comes in thus:
- Start Character (Colon)
- Device Address (one byte HEX)
- Function Type (one byte HEX)
- Start Address Hi Byte (HEX always zero for us)
- Start Address Low Byte (HEX-address of the Register the requestor wants output)
- Number of Registers Hi Byte (HEX always zero for us)

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- Number of Registers Lo Byte (HEX)
- LRC Checksum of message (HEX 1 Byte)
- ASCII Carriage Return-Line Feed

The message returned is in the same standard Modbus format:

- Start Character (Colon)
- Device Address (one byte HEX)
- Function Type (one byte HEX)
- Byte Count (HEX) two bytes per requested register
- The data bytes, two bytes per requested number of registers, higher address first
- LRC Checksum of message (HEX 1 Byte)
- ASCII Carriage Return-Line Feed

One special message is sent out using Code 03 to request the unit's assigned Node Identifier. The Node Identifier is the ID that Modbus uses to communicate with a particular unit. The request goes out in the form of a Broadcast with the Node Identifier set to 00. Technically, this violates the Modbus standard, since if a group of Enumerators were all attached to one RS485 control line, ALL would respond to this broadcast. However, we need a way to determine what a given unit's node ID is set to before we can talk to it. Therefore, this command must be used with ONLY ONE Interface Module hooked up to the controller's Comm port.

An example of a Broadcast Message would be:
:000300220001DA

This says, in effect, Send Command 3 to Node ID 0 and request one Register's worth of data located at Address 0022 (the address of the Node ID) as returned information.î

A response from the Interface Module, assuming its Node ID is set to 0xA0, would be: A0030200A0BB, translated as Node A0 is sending back one register (2 Bytes) of data. The data are 00 A0î.

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The list of registers available for output via Modbus protocol using Command 03 is shown in Table 5-1.

*Table 5-1 :* Registers available for Modbus Output

| Address | | Function |
|---|---|---|
| **HEX** | **DEC** | |
| 0x2 | 33 | A1=Unit ID #1: 1 Register HEX (0 to 0xFFFF) |
| 0x23 | 35 | A2=Node ID: 1 Register HEX (0 to 0x00FF) |
| 0x25 | 37 | A3=Unit ID #2: 1 Register HEX (0 to 0xFFFF) |
| 0x27 | 39 | A4=Firmware Version: 1 Register HEX (0 to 0x00FF) |
| 0x29 | 41 | B1=Reserved |
| 0x2D | 45 | B2=Reserved |
| 0x31 | 49 | B3=Reserved |
| 0x35 | 53 | B4=Reserved |
| 0x39 | 57 | B5=Reserved |
| 0x3D | 61 | B6=Chan 4 event count: 2 Registers HEX (0 to 0x00FFFFFF) |
| 0x41 | 65 | B7=total sample time: 1 Register HEX (0 to 0x0E0F=0 to 59:59 minutes/seconds) |
| 0x43 | 67 | C1=Channel 1 cumulative counts/ml: 1 Register HEX (0 to 0xFFFF) |
| 0x45 | 69 | C2=Channel 2 cumulative counts/ml: 1 Register HEX (0 to 0xFFFF) |
| 0x47 | 71 | C3=Channel 3 cumulative counts/ml: 1 Register HEX (0 to 0xFFFF) |
| 0x49 | 73 | C4=Channel 4 cumulative counts/ml: 1 Register HEX (0 to 0xFFFF) |
| 0x4B | 75 | C5=Channel 1 ISO Code: 1 Register HEX (0x0A to 0x0121=1.0 to 28.9) |

*Table 5-1 :* Registers available for Modbus Output (Continued)

| Address | | Function |
|---|---|---|
| **HEX** | **DEC** | |
| 0x4D | 77 | C6=Channel 2 ISO Code: 1 Register HEX (0x0A to 0x0121) |
| 0x4F | 79 | C7=Channel 3 ISO Code: 1 Register HEX (0x0A to 0x0121) |
| 0x51 | 81 | C8=Channel 4 ISO Code: 1 Register HEX (0x0A to 0x0121) |
| 0x53 | 83 | D1=Laser Drive Current: 1 Register HEX (0 to 0x0046=0 to 70 ma) |
| 0x55 | 85 | D2=Photodiode Rcv Power: 1 Register HEX ( 0 to 0x01F4=0 to 5.00 VDC) |
| 0x57 | 87 | D3=Ambient Temperature: 1 Register HEX (0 to 0x007F=positive deg C 0x0080 to 0x00FF=negative deg C) |
| 0x59 | 89 | D4=System Alarm Status: 1 Register HEX (each bit decodes as an alarm status bit) |
| 0x5B | 91 | Holds register# to put out to DAC port 5 (1 Register) |
| 0x5D | 93 | Holds register# to put out to DAC port 6 (1 Register) |
| 0x5F | 95 | Holds register# to put out to DAC port 7 (1 Register) |
| 0x61 | 97 | Holds register# to put out to DAC port 8 (1 Register) |
| 0x63 | 99 | holds peak ISO codes for C1 since power-up. (Power-up clears)( 1 Register) |
| 0x65 | 101 | holds peak ISO codes for C2 since power-up. (Power-up clears)( 1 Register) |
| 0x67 | 103 | holds peak ISO codes for C3 since power-up. (Power-up clears)( 1 Register) |
| 0x69 | 105 | holds peak ISO codes for C4 since power-up. (Power-up clears)( 1 Register) |

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A **Write to Single Register** Command 06 is used ONLY to assign a register's value to one of the assignable DAC voltage outputs 5, 6, 7, or 8. This is done by writing a register number corresponding to the storage address for the desired information into a pointer, or holding register, assigned to a given DAC channel.

*Table 5-2 :* Pointer Registers

| HEX | |
|---|---|
| 0x5B | Holds register# to put out to DAC port 5 (1 Register) |
| 0x5D | Holds register# to put out to DAC port 6 (1 Register) |
| 0x5F | Holds register# to put out to DAC port 7 (1 Register) |
| 0x61 | Holds register# to put out to DAC port 8 (1 Register) |

*Table 5-3 :* Valid entries for Pointer Registers

| Address | Function |
|---|---|
| 0x0053 | Laser Current |
| 0x0055 | Received Power |
| 0x0057 | Ambient Temp |
| 0x0063 | Peak ISO Ch 1 |
| 0x0065 | Peak ISO Ch 2 |
| 0x0067 | Peak ISO Ch 3 |
| 0x0069 | Peak ISO Ch 4 |

For example, if the user wishes to have DAC channel 5 latch a DC voltage, which corresponds to the Ambient Temperature in degrees C and DAC channel 6 latch Received Power, then the Register at 0x5B will be loaded with 0x0057 and the Register at 0x5D will be loaded with 0x0055.

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Subsequent data from the Interface Module Enumerator, will cause a DC voltage corresponding to the Ambient Temperature to appear at DAC Output 5, and DAC output 6 will show photodiode Received Power.

A Write Inquiry (Command 06) appears as shown in Figure 5-6:

| |
|---|
| Start Character (Colon) |
| Device Address (one byte HEX)\ |
| Function Type (one byte HEX)\ |
| Start Address Hi Byte (HEXóalways zero for us) |
| Start Address Low Byte (HEX-address of the Register the requestor wants output) |
| Data first Byte (goes into FIRST address; e.g., 0x30) |
| Data second Byte (goes into SECOND address; such as 0x31) |
| LRC Checksum of message (HEX 1 Byte) |
| ASCII Carriage Return-Line Feed |

*Fig 5-6:* Write Inquiry

If received and correct, this message will be echoed back verbatim.

## 5.10 Indicators and Controls

The only PM4000 system components with user controls or indicators are the IM4000-3 and -4, -5; along with the PT4000-0, -4, -5, -6, and -8 which are similar to the IM4000-4. It is important to remember the distinction between the IrDA window on the PT4000 and the status LED on the IM4000-3.


*Fig 5-7:* IM4000-3 Indicator Location

In the IM4000-4 and -5 interface module and PT4000-0, -4, -5, -6 and -8 transducers, each key has a specific function and each indicator has a specific meaning when illuminated. Figure 5-7 shows the location of each key and indicator.

1) **ISO** LEDs: 4 µm, 6 µm, 14 µm, 21 µm when on steady indicates selected size range for display, when flashing indicates alarm limits have been exceeded for that size.
2) **Peak** LED: indicates the peak value recorded since the last time power was turned off.
3) **Alarm** LED: flashes 4 times during power up, and flashes along with the selected size range LED when a set alarm limit has been exceeded.
4) **ISO Scroll Down** key: for selecting one of four ISO codes. When pressed with INFO Scroll Down key, allows for setting the right hand digit of an ISO code alarm value. Press both keys when finished setting alarm.

5) **Peak** key: activates the peak value recorded since the last reset; also when setting an ISO code alarm value sets the center digit.
6) **INFO Scroll Down** key: for scrolling through INFO selections and viewing the status code. Also, when pressed with ISO Scroll Down key, allows for setting the left hand digit of an ISO code alarm value. Press both keys when finished setting alarm.
7) **SET** LED: illuminates during an alarm and while setting an alarm level. Alarm levels are non-volatile and will remain set until set again
8) **Status Code** LED: flashes during a system alarm. The LED display shows the status code message if a system alarm occurs (code is in hexadecimal format--see "Serial Protocol Definitonsî for more information).
9) **INFO** LEDs:
   - **Temp C** processor's internal temperature is being displayed -40 to 185 °F (-40 °C to 85 °C).
   - **Laser mA** current of the sensor laser is being displayed (30 to 65 mA).
   - **CAL V** photo detector voltage is being displayed (4.7 to 4.9 VDC).
   - **Node ID** the identification assigned this unit is being displayed (1 to 247).
10) **3-digit LED**: displays the value of selected function/parameter or a status code message if a system alarm occurs. Codes are in hexadecimal format; see “Serial Protocol Definitions” on page 55 for more information. If the PT4000 is not configured for Raw Data Mode, the LED Display is disabled and will display **000**.

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11) **IrDA port**: for accessing the transducer's raw data record or for changing transducer test / operating parameters.


*Fig 5-8:* IM4000-4, -5 and PT4000-0, -4, -5, -6, -8 Indicators and Controls (IM4000 shown)

**Note:**
*When operating on battery power, the IM4000-4 will turn off after 10 seconds of inactivity to conserve battery life. Press any key to restore operation.*

**Note:**
*If it becomes necessary to clean the PM4000 during operation, be careful not to inadvertantly press keys on the front panel, as undesirable operations may be accidentally initiated.*

## 5.11 Setting Alarm Limits on the LED Display

The LED Display can be programmed to alarm at a specified contamination level. Alarm limits are based on ISO codes and the channels may be set independently of one another (such as, four different alarm levels for each of the four size channels may be set). The alarm limits are typically set to indicate when a fluid reaches a high contamination level (unacceptably dirty). However, the alarms can also be used to indicate when a fluid becomes sufficiently clean by watching to see when an alarm condition ends.

Programming is done at the LED Display's panel, using the buttons specified in Figure 5-5 on page 54. These buttons will be referred to as #4, #5, and #6, in keeping with the nomenclature in Figure 5-5.

1) Scroll through the size channels by pressing #4 until the ISO LED is beside the desired channel.
2) Press #4 and #6 simultaneously to begin programming.
3) The alarm level displays. **00.0** indicates there is no alarm limit for this channel (default).
4) Use #4, #5, and #6 to enter the ISO code alarm limit (maximum of 29):
   - Use #4 to change the “tenths” position digit to the desired number (0-9).
   - Use #5 to change the digit in the “ones” position to the desired number (0-9) .
   - Use #6 to change the digit in the “tens” position to the desired number (0, 1 or 2).
5) Press #4 and #6 simultaneously to end programming.

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At this point, the PT4000 will resume sampling and will monitor for the set alarms. If the programmed ISO code is exceeded, then a visual alarm is seen on the display, as described in “Indicators and Controls” on page 64.

The programmed alarm condition is also available on the IM4000-4 data/signal-out line. These are the dry contact closures to drive external alarms such as strobe lights and sirens.

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# 6 Troubleshooting Tips

The mechanical and electrical parts of the PT4000 are rugged enough to sustain routine operation for extended periods. The following tips may help solve problems that can occur during normal daily use. If additional assistance is required, contact Technical Support at +1 800-866-7889 or +1 541-472-6500..

*Table 6-1 :* Troubleshooting Actions

| Symptom | Cause | Solution |
|---|---|---|
| High laser current/low received power values | Air bubbles or a blockage in the sensor. | • Check the flow rate through the sensor by taking a sample off the PM4000 output (such as via a minimess sampling port).<br>• While taking the sample, check the effluent for visible air bubbles.<br>• If the flow is unblocked and no air bubbles are present, contact Technical Support. |
| Counts/ml indication dropped to near zero | A plugged flow control valve, if using a PT4000-1. | The flow control valve should only be removed with a flow control removal tool (PN #3050765); removal of the flow control by other means will void the warranty and could damage the PT4000 and/or flow control valve. |
| Erratic count levels and oil deposits on the IrDA window on the PT4000 | An internal leak. | • Check to ensure that the system flow rate and pressure are within the PM4000's operating specifications.<br>• If the system is within specifications and the PM4000 is still displaying erratic counts, check the flow for bubbles, as described above.<br>• If the erratic counts persist, contact Technical Support. |

*Table 6-1 :* Troubleshooting Actions (Continued)

| Symptom | Cause | Solution |
|---|---|---|
| LED display shows all zeroes and disabled DDE | Mode is set to **Terminal** rather than **Raw**. | Set the mode to **Raw** as described in "Setting PT4000 Parameters" on page 25. |
| Uneven lighting in the LED display | Normal and a function of the compact design of the PM4000. | No action required. |
| No particle counting output | Incorrect flow | Verify flow rate is correct for instrument model number |
| No particle counting output | Palm Pilot | • Verify that sample and hold time are correct<br>• Verify that instrument is in Raw Output Mode<br>• Cycle power |

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# Appendix A: Service Procedures

## A.1 Performance Verification Recommendations

The PM4000 can be returned annually for performance verification. To return the Model PT4000 On-line Laser Particle Monitor for service, first obtain a returned material authorization number (RA#). The RA# number is necessary for any instrument that requires repair or performance verification by an authorized service center. Include the RA# number on the shipping label when the instrument is returned.

## A.2 Return Authorization Process

While the RA# process is described in this section, for the most up-to-date RA# process information, including copies of all required forms, call Hach Ultra Analytics at +1 800-866-7889 or +1 541-472-6500.

To return an instrument for credit, please contact the local sales representative.

**WARNING**

*The following actions must be performed when returning any unit for any reason to prevent personal injury and/or damage to the unit.*

## A.3 Technical Support Information

Technical Support Engineers are available to provide high quality advice and recommendations for applications, product operation, measurement specifications, hardware and software, factory and customer site training.

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Please provide name, company, phone, fax, model number, serial number and comment or question.

Call +1 (541) 472-6500
Toll Free (800) 866-7889 (US/CA)
Fax +1 (541) 474-7414
6:00 AM to 5:00 PM Pacific Time
Monday through Friday
Email: TechSupportGP@hachultra.com

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# Appendix B: Specifications

| | |
|---|---|
| **Sizes** | 4, 6, 14, and 21 µm (ISO MTD) |
| **Light Source** | Laser diode |
| **Performance Verification** | Optional validation certificate available (ISO MTD at 2.8 mg/L concentration) |
| **Reproducibility** | 0.5 ISO code (minimum concentration ISO MTD 2.8 mg/L, maximum ISO code = 24) |
| **Display** | Optional local display presents ISO codes, HIAC codes and alarms |
| **Power** | 9 to 36 VDC, 150 mA (power must be supplied to instrument for operation) |
| **Output** | RS-232, RS-485, 0 to 5 volts, Modbus, alarms, local and remote displays |
| **Reports** | ISO 4406 and codes for 4, 6, 14, 21 µm (ISO MTD), particles/mL |
| **Fitting Connections** | SAE -4 and -8 |
| **Sensor Flow Rate** | 50 to 500 mL/min (0.01 to 0.1 gal/min) through view area<br>All units except the PT4000-3 offer integrated flow rate controllers |
| **Fluid Compatibility** | Hydraulic and lubrication oils (mineral and synthetic) and phosphate ester |
| **Wetted materials** | Brass, aluminum (anodized), steel, stainless steel, sapphire, Aflas® |
| **Viscosity** | 2 cSt (32 SUS) to 424 cSt<br>(viscosities tested at ambient temperature: 25°C +/- 2 degrees) |

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| | |
|---|---|
| **Environment** | Operating Temperature: -10 to 60°C (-14 to 140°F) |
| | Storage Temperature: -40 to 85°C (-40 to 185°F) |
| | 97% relative humidity, non-condensing |
| **IP Rating** | 67 |
| **Accessories Included** | DDE Software, 6.1 m (20 ft) Fiber Optic Cable, Operator's Manual (with PM4000-xx only, not included with PT4000-x) |

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| | |
|---|---|
| **Model PT4000-x**<br>Particle Transducer | **Internal Flow Control Inhibitor**<br>-1 High pressure 27.6 to 482.5 bar (400 to 7,000 psi)<br>-4 High pressure 27.6 to 482.5 bar (400 to 7,000 psi) with local display<br>-7 Moderate pressure 3.4 to 82.7 bar (100 to 1200 psi)<br>-8 Moderate pressure 3.4 to 82.7 bar (100 to 1200 psi) with local display<br>-9 Low pressure 1.4 to 6.9 bar (20 to 200 psi)<br>-0 Low pressure 1.4 to 6.9 bar (20 to 200 psi) with local display<br>**Internal Check Flow Control**<br>-2 3.8 to 37.9 L/min (1 to 10 gal/min), 1.4 to 482.5 bar (20 to 7000 psi)<br>-5 3.8 to 37.9 L/min (1 to 10 gal/min), 1.4 to 482.5 bar (20 to 7000 psi) with local display<br>**No Integrated Flow Control**<br>-3 50 to 500 mL/min (0.01 to 0.1 gal/min), 1.4 to 482.5 bar (20 to 7,000 psi)<br>-6 50 to 500 mL/min (0.01 to 0.1 gal/min), 1.4 to 482.5 bar (20 to 7,000 psi) with local display<br>**Weight (includes mounting bracket)**<br>PT4000-1, -2, -3, -7, -9: 2 lbs., 1 lb., 12 oz. (0.77kg.)<br>PT4000-4, -5, -6, -8, -0: 2 lbs., 1 lb., 13 oz. (0.78kg.)<br>**Dimensions (WxHxD, includes projections, excludes bracket)**<br>PT4000-1, -2, -3, -7, -9: 9.4 x 8.7 x 3.6 cm (3.7" x 3.4" x 1.4")<br>PT4000-4, -5, -6, -8, -0: 9.4 x 8.7 x 4.6 cm (3.7" x 3.4" x 1.8") |

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| | |
|---|---|
| **Model IM4000-x**<br>Computer/ PLC Interface | -1 RS-232 dongle<br>-3 Modbus, RS-232/RS-485, 0 to 5 volt<br>-4 Remote LED display with programmable contamination alarm levels, dry contact closure (triggers on alarm)<br>-5 Remote LED display with programmable cleanliness alarm levels, dry contact closure (triggers on alarm)<br>**Weight (includes mounting bracket)**<br>IM4000-1: 0.7 oz. (20 g.)<br>IM4000-3: 9.4 oz. (266 g.)<br>IM4000-4: 10.6 oz. (301 g.)<br>IM4000-5: 10.6 oz. (301 g.)<br>**Dimensions (WxHxD, includes projections, excludes bracket)**<br>IM4000-1: 3.1 cm x 5.1 cm x 1.5 cm (1.2" x 2.0" x 0.6")<br>IM4000-3: 6.1 cm x 6.6 cm x 2.5 cm (2.4" x 2.6" x 1.0")<br>IM4000-4: 6.1 cm x 6.6 cm x 3.6 cm (2.4" x 2.6" x 1.4")<br>IM4000-5: 6.1 cm x 6.6 cm x 3.6 cm (2.4" x 2.6" x 1.4") |
| **Optional Accessories** | Minimess Sampling Port SAE -4<br>Minimess Microbore Sampling Hose |

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## B.1 Duty Cycle

In order to protect the laser diode, The PM4000 will automatically adjust the Duty Cycle as temperature increases. The Duty Cycle is the ratio of the Sample Period to the total time between data output (which is the sum of the Sample Period and the Sample Hold, or hold time). The factory setting is for a Sample Period of one minute and a Sample Hold of four minutes.

When the operating temperature exceeds 140 °F (60 °C), the Duty Cycle will decrease to 50%; above 158 °F (70 °C), the Duty Cycle drops to 25%; above 75% the Duty Cycle drops to 10%; and at 176 °F (80 °C), the Duty Cycle drops to 1.0%.

The PM4000 adjusts the Duty Cycle by changing the Sample Hold time only. The Sample Period will not change.

It is important to note that if the sensor detects a temperature above 176 °F (80 °C), it will go into a 1.0% Duty Cycle and will be dormant for an extended period of time, approximately 17 hours, using factory settings. The PM4000 will NOT check the operating temperature again until the end of the cycle.

For example, if a PM4000 with factory settings detects an operating temperature of 108 °F (42 °C), it will output data every five minutes: 1 minute of sampling and 4 minutes of hold time.

If the operating temperature rises to 162 °F (72 °C), the unit makes no changes. Above 158 °F (70 °C), the PM4000 is forced into a 25% Duty Cycle. However, the factory setting is already at 20%, so there is no change to the operation of the PM4000 so, the PM4000 would continue outputting data every five minutes.

If, at the end of one of these cycles, the operating temperature were found to be 181 °F (83 °C), the PM4000

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would force a duty cycle of 1.0% by adjusting the Sample Hold to 999 minutes. At this point, the PM4000 will not take another reading for 16 hours 40 minutes. Even if the operating temperature returned to 162 °F (72 °C) after only three minutes, the PM4000 will NOT resume normal sampling for 16 hours 40 minutes.

This can, of course, be circumvented by cycling power to the PM4000; turning the unit off and then on again will reset the PM4000.

There is a minimum hold time in Raw Data mode of 2 sec. and in Terminal mode of 15 sec.

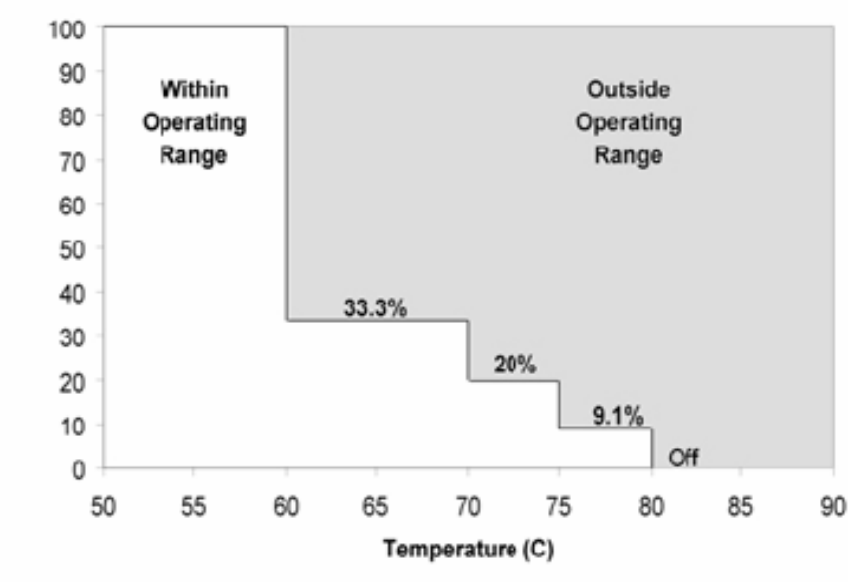


*Fig B-1 :* Operation Range Related to Temperature

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# Appendix C: HIAC 4406 Codes

Based on ISO 4406.

To convert HIAC codes to ISO codes, simply delete all digits to the right of the decimal point, without rounding. For example, a HIAC code readout of 7.2 would correspond to an ISO code of 7, and a HIAC code of 7.8 would also correspond to an ISO code of 7.

The sample period should be set to achieve a statistically significant number of particles in the sample. For expected ISO code ranges of 12 A and greater, a one minute sample time should be sufficient. Below that, the sample period should be doubled for each one ISO code level. For example, use a two-minute sample at ISO code 11.

| HIAC CODE # | Particle Count/ml > |
|---|---|
| 5.0 | 0.160 |
| 5.1 | 0.176 |
| 5.2 | 0.192 |
| 5.3 | 0.208 |
| 5.4 | 0.224 |
| 5.5 | 0.240 |
| 5.6 | 0.256 |
| 5.7 | 0.272 |
| 5.8 | 0.288 |
| 5.9 | 0.304 |
| 6.0 | 0.320 |
| 6.1 | 0.352 |
| 6.2 | 0.384 |
| 6.3 | 0.416 |
| 6.4 | 0.448 |
| 6.5 | 0.480 |

| HIAC CODE # | Particle Count/ml > |
|---|---|
| 6.6 | 0.512 |
| 6.7 | 0.544 |
| 6.8 | 0.576 |
| 6.9 | 0.608 |
| 7.0 | 0.640 |
| 7.1 | 0.706 |
| 7.2 | 0.772 |
| 7.3 | 0.838 |
| 7.4 | 0.904 |
| 7.5 | 0.970 |
| 7.6 | 1.036 |
| 7.7 | 1.102 |
| 7.8 | 1.168 |
| 7.9 | 1.234 |
| 8.0 | 1.300 |
| 8.1 | 1.42 |

| HIAC CODE # | Particle Count/ml > |
|---|---|
| 8.2 | 1.54 |
| 8.3 | 1.66 |
| 8.4 | 1.78 |
| 8.5 | 1.90 |
| 8.6 | 2.02 |
| 8.7 | 2.14 |
| 8.8 | 2.26 |
| 8.9 | 2.38 |
| 9.0 | 2.50 |
| 9.1 | 2.75 |
| 9.2 | 3.00 |
| 9.3 | 3.25 |
| 9.4 | 3.50 |
| 9.5 | 3.75 |
| 9.6 | 4.00 |
| 9.7 | 4.25 |

| HIAC CODE # | Particle Count/ml > |
|---|---|
| 9.8 | 4.50 |
| 9.9 | 4.75 |
| 10.0 | 5.0 |
| 10.1 | 5.5 |
| 10.2 | 6.0 |
| 10.3 | 6.5 |
| 10.4 | 7.0 |
| 10.5 | 7.5 |
| 10.6 | 8.0 |
| 10.7 | 8.5 |
| 10.8 | 9.0 |
| 10.9 | 9.5 |
| 11.0 | 10 |
| 11.1 | 11 |
| 11.2 | 12 |
| 11.3 | 13 |

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| HIAC CODE # | Particle Count/ml > |
|---|---|
| 11.4 | 14 |
| 11.5 | 15 |
| 11.6 | 16 |
| 11.7 | 17 |
| 11.8 | 18 |
| 11.9 | 19 |
| 12.0 | 20 |
| 12.1 | 22 |
| 12.2 | 24 |
| 12.3 | 26 |
| 12.4 | 28 |
| 12.5 | 30 |
| 12.6 | 32 |
| 12.7 | 34 |
| 12.8 | 36 |
| 12.9 | 38 |
| 13.0 | 40 |
| 13.1 | 44 |
| 13.2 | 48 |
| 13.3 | 52 |
| 13.4 | 56 |
| 13.5 | 60 |
| 13.6 | 64 |
| 13.7 | 68 |
| 13.8 | 72 |
| 13.9 | 76 |
| 14.0 | 80 |
| 14.1 | 88 |
| 14.2 | 96 |
| 14.3 | 104 |

| HIAC CODE # | Particle Count/ml > |
|---|---|
| 14.4 | 112 |
| 14.5 | 120 |
| 14.6 | 128 |
| 14.7 | 136 |
| 14.8 | 144 |
| 14.9 | 152 |
| 15.0 | 160 |
| 15.1 | 176 |
| 15.2 | 192 |
| 15.3 | 208 |
| 15.4 | 224 |
| 15.5 | 240 |
| 15.6 | 256 |
| 15.7 | 272 |
| 15.8 | 288 |
| 15.9 | 304 |
| 16.0 | 320 |
| 16.1 | 352 |
| 16.2 | 384 |
| 16.3 | 416 |
| 16.4 | 448 |
| 16.5 | 480 |
| 16.6 | 512 |
| 16.7 | 544 |
| 16.8 | 576 |
| 16.9 | 608 |
| 17.0 | 640 |
| 17.1 | 706 |
| 17.2 | 772 |
| 17.3 | 838 |

| HIAC CODE # | Particle Count/ml > |
|---|---|
| 17.4 | 904 |
| 17.5 | 970 |
| 17.6 | 1036 |
| 17.7 | 1102 |
| 17.8 | 1168 |
| 17.9 | 1234 |
| 18.0 | 1300 |
| 18.1 | 1420 |
| 18.2 | 1540 |
| 18.3 | 1660 |
| 18.4 | 1780 |
| 18.5 | 1900 |
| 18.6 | 2020 |
| 18.7 | 2140 |
| 18.8 | 2260 |
| 18.9 | 2380 |
| 19.0 | 2500 |
| 19.1 | 2750 |
| 19.2 | 3000 |
| 19.3 | 3250 |
| 19.4 | 3500 |
| 19.5 | 3750 |
| 19.6 | 4000 |
| 19.7 | 4250 |
| 19.8 | 4500 |
| 19.9 | 4750 |
| 20.0 | 5000 |
| 20.1 | 5500 |
| 20.2 | 6000 |
| 20.3 | 6500 |

| HIAC CODE # | Particle Count/ml > |
|---|---|
| 20.4 | 7000 |
| 20.5 | 7500 |
| 20.6 | 8000 |
| 20.7 | 8500 |
| 20.8 | 9000 |
| 20.9 | 9500 |
| 21.0 | 10000 |
| 21.1 | 11000 |
| 21.2 | 12000 |
| 21.3 | 13000 |
| 21.4 | 14000 |
| 21.5 | 15000 |
| 21.6 | 16000 |
| 21.7 | 17000 |
| 21.8 | 18000 |
| 21.9 | 19000 |
| 22.0 | 20000 |
| 22.1 | 22000 |
| 22.2 | 24000 |
| 22.3 | 26000 |
| 22.4 | 28000 |
| 22.5 | 30000 |
| 22.6 | 32000 |
| 22.7 | 34000 |
| 22.8 | 36000 |
| 22.9 | 38000 |
| 23.0 | 40000 |
| 23.1 | 44000 |
| 23.2 | 48000 |
| 23.3 | 52000 |

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| HIAC CODE # | Particle Count/ml > |
|---|---|
| 23.4 | 56000 |
| 23.5 | 60000 |
| 23.6 | 64000 |
| 23.7 | 68000 |
| 23.8 | 72000 |
| 23.9 | 76000 |
| 24.0 | 80000 |
| 24.1 | 88000 |
| 24.2 | 96000 |
| 24.3 | 104000 |
| 24.4 | 112000 |
| 24.5 | 120000 |
| 24.6 | 128000 |
| 24.7 | 136000 |
| 24.8 | 144000 |

| HIAC CODE # | Particle Count/ml > |
|---|---|
| 24.9 | 152000 |
| 25.0 | 160000 |
| 25.1 | 176000 |
| 25.2 | 192000 |
| 25.3 | 208000 |
| 25.4 | 224000 |
| 25.5 | 240000 |
| 25.6 | 256000 |
| 25.7 | 272000 |
| 25.8 | 288000 |
| 25.9 | 304000 |
| 26.0 | 320000 |
| 26.1 | 352000 |
| 26.2 | 384000 |
| 26.3 | 416000 |

| HIAC CODE # | Particle Count/ml > |
|---|---|
| 26.4 | 448000 |
| 26.5 | 480000 |
| 26.6 | 512000 |
| 26.7 | 544000 |
| 26.8 | 576000 |
| 26.9 | 608000 |
| 27.0 | 640000 |
| 27.1 | 706000 |
| 27.2 | 772000 |
| 27.3 | 838000 |
| 27.4 | 904000 |
| 27.5 | 970000 |
| 27.6 | 1036000 |
| 27.7 | 1102000 |
| 27.8 | 1168000 |

| HIAC CODE # | Particle Count/ml > |
|---|---|
| 27.9 | 1234000 |
| 28.0 | 1300000 |
| 28.1 | 1420000 |
| 28.2 | 1540000 |
| 28.3 | 1660000 |
| 28.4 | 1780000 |
| 28.5 | 1900000 |
| 28.6 | 2020000 |
| 28.7 | 2140000 |
| 28.8 | 2260000 |
| 28.9 | 2380000 |
| > 29.0 | 2500000 |

To convert HIAC codes to ISO codes, simply delete all digits to the right of the decimal point, **without** rounding. For example. A HIAC code readout of 7.2 would correspond to an ISO code of 7, and a HIAC code of 7.8 would also correspond to an ISO code of 7.

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# Annex

## Tables and illustrations



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# User Notes

**Global Headquarters**
6, route de Compois C.P. 212
CH-1222 Vesenaz, Geneva, Switzerland
Tel +41 (0)22 594 64 00
Fax +41 (0)22 594 64 99

**Americas Headquarters**
481 California Avenue
Grants Pass, Oregon 97526 USA
Tel 1 800 866 7889 / +1 541 472 6500
Fax +1 541 472 6170

**www.hachultra.com**