TRABAJO DE GRADO

Estudio numérico y experimental de fenómenos hidrodinámicos que ocurren en bombas centrífugas como turbinas

Universidad EAFIT

Para la obtención del grado de Master en Ingeniería
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El experimentador que no sabe lo que está buscando no comprenderá lo que encuentra.
— Claude Bernard (1813-1878)

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Resumen

La tendencia mundial de administrar y operar a distancia las centrales hidroeléctricas está obligando a los expertos a replantear los estrategias de monitoreo y diagnóstico de sus máquinas.
Esto ha conducido también, a reducir el personal experto que reside *in-situ* y que se encarga de operar y mantener los sistemas técnicos, y además de atender cualquier eventualidad que pueda ocurrir. Por eso, desde hace ya varios años se han venido desarrollando sistemas expertos que puedan suplir las deficiencias del recurso humano.

Pero aunque tales sistemas han alcanzado niveles interesantes de independencia, aún requieren del acompañamiento de un experto que pueda interpretar las evidencias, emitir un diagnóstico y tomar una decisión. Un ejemplo de los aspectos que aún se deben perfeccionar, es el se las falsas alarmas que llegan a producir el efecto *"cry wolf"* y que terminan por inactivar el sistema.

Otra forma de enfrentar esta nueva dinámica de operación es la de subcontratar el servicio de diagnóstico técnico, que puede dar resultados aceptables, pero no siempre en el caso de centrales hidroeléctricas. Las centrales por lo general se encuentran en sitios remotos y en ocasiones blindadas por condiciones geográficas y climatológicas por lo que no es posible reaccionar rápidamente para atender una eventualidad cuando el experto y sus instrumentos no están cerca.

Una solución que resulta conveniente es de hecho, la centralización de la experticia para los servicios de monitoreo y diagnóstico técnico, soportados por una plataforma portátil e idealmente no-invasiva, que permanezca siempre junto a las máquinas y que pueda ser consultada *on-line*. De este modo una cantidad reducida de expertos tendrán acceso permanente a las variables o síntomas que definen el estado técnico de la maquinaria; ellos se encargarán de analizar las señales sintomáticas, evaluar los resultados, emitir juicios y elaborar reportes ejecutivos que finalmente llegarán a manos del administrador o persona encargada de la operación.

Esta alternativa aliviará molestias relacionadas con los procesos de monitoreo y diagnóstico: instrumentación/sensórica, cableado, acondicionamiento de señales, adquisición digital de datos, procesamiento de señales, administración y gestión de equipos, reporte de resultados, recomendaciones, etc.

Este proyecto propone en dos etapas, el diseño de una plataforma tecnológica que pueda soportar la alternativa mencionada. En detalle, el diseño de un sistema integrado de adquisición de datos que además de ser portátil, modular y escalable, adecuado para monitoreo de las principales variables de diagnóstico de una central hidroeléctrica; que aunque no incorpore un sistema experto, si ofrece las herramientas de análisis, diagnóstico y toma de decisiones del estado del arte.

Palabras clave:

- Fenómenos hidrodinámicos
- Generación hidroeléctrica
- Monitoreo no invasivo
- Monitoreo remoto
- Turbomáquinas hidráulicas

Abstract

The global trend to manage and operate remote hydroelectric plants is forcing experts to rethink the strategies for monitoring and diagnosis of their machines.

This has also led to reduce the expert staff living on-site and is responsible for operating and maintaining technical systems, and also to deal with any eventuality that may occur. So for several years and have been developing expert systems that can compensate for the shortcomings of human resources.

But although such systems have reached interesting levels of independence, still require the support of an expert who can interpret the evidence, make a diagnosis and decide. An example of the issues that still must be improved is the false alarms will fail to produce the effect "cry wolf" and that ultimately inactivate the system.

Another way to deal with this new dynamic operation is to outsource its technical diagnosis, which can give acceptable results, but not always in the case of hydroelectric plants. The plants are usually found in remote locations and sometimes shielded by geographical and climatic conditions so it is not possible to react quickly to meet an eventuality when the expert and its instruments are not around.

A solution that is appropriate is in fact the centralization of expertise for monitoring services and technical diagnosis, supported by a portable platform and ideally non-invasive, which always remain with the machines and can be found online. Thus a reduced number of experts have permanent access to variables or symptoms that define the technical condition of machinery; They are responsible for analyzing signals symptomatic, evaluate results, make judgments and develop executive reports that eventually reach the hands of the manager or person in charge of the operation.

This alternative will alleviate discomfort related to the processes of monitoring and diagnosis: instrumentation / sensors, cabling, signal conditioning, digital data acquisition, signal processing, administration and management of equipment, report findings, recommendations, etc.

This project proposes a two-stage design of a technology platform that can support alternative mentioned. In detail, the design of an integrated system of data acquisition in addition to being portable, modular and scalable, suitable for monitoring the main diagnostic variables of a hydroelectric plant; that although not incorporating an expert system if providing tools for analysis, diagnostic and decision making state of the art.

Key words:

- Hydrodynamic phenomena
- Hydroelectric generation
- Noninvasive monitoring
- Remote monitoring
- Hydraulic turbomachines

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Introducción

Las turbomáquinas son aquellas que absorben energía de un fluido y restituyen generalmente energía mecánica en el eje, como una turbina de vapor, una turbina hidráulica; o bien absorben energía mecánica en el eje y restituyen energía a un fluido como una bomba o un ventilador. El fluido puede ser un líquido o un gas y el órgano intercambiador de energía mecánica y de fluido, está dotado de movimiento rotativo; de allí la palabra Turbo o *Turbinis* de origen latín que significa que la máquina gira.

También se llaman máquinas de corriente o máquinas dinámicas y en ellas el intercambio de energía es debido a la variación del momento cinético del fluido en su paso por el órgano intercambiador de energía, dotado de movimiento rotativo, que se llama rodete. La ecuación de Euler o ecuación fundamental de las turbomáquinas, basada en el teorema del momento cinético, es básica para el estudio de estas máquinas [1].

Este tipo de máquinas presenta cierto tipo de problemas de funcionamiento, tales como la cavitación [2], estancamiento, caídas de presión entre otras muchas más, las cuales generan pérdidas y caídas tanto en el rendimiento mecánico como hidráulico, por lo cual es de vital importancia tanto para las industrias monitoreo sea el menos invasivo y remoto posible. Es aquí donde se formula desde la Universidad EAFIT el proyecto interno denominado GENERATRÓN, el cual pretendió avanzar en el estudio y desarrollo de tecnicas ingenieriles en el ámbito de las bombas-turbinas. De esta manera, los resultados de este proyecto de maestria son derivados del proyecto interno GENERATRÓN.

El objetivo principal tanto del proyecto interno GENERATRON como de este trabajo de grado es diseñar un sistema integrado de adquisición de datos que además de ser portátil (acceso remoto), modular y escalable, adecuado para monitoreo de las principales variables de diagnóstico de una central hidroeléctrica; que aunque no incorpore un sistema experto, si ofrece las herramientas de análisis, diagnóstico y toma de decisiones del estado del arte.

Para llevar a cabo el objetivo principal se propusieron varios objetivos específicos, los cuales son :

- Construir el estado de la técnica asociado al monitoreo y diagnóstico técnico de turbomáquinas hidráulicas.

- Seleccionar una turbomáquina hidráulica piloto, típica o representativa de centrales hidroeléctricas en Colombia y/o el mundo, el cual se desarrolló en el Capítulo 2.
- Identificar los fenómenos y fallos a ser monitoreados, que se puede ver en el Capítulo 5 y en el artículo presentado en el Capítulo 10.
- Definir las principales variables relacionadas con los fenómenos y fallos identificados, las cuales se ven referenciadas en el Capítulo 3 y en el Capítulo 7 .
- Proponer alternativas de instrumentación para la medición de las variables identificadas, que dichos instrumentos se presentan en el Capítulo 3 y posteriormente en el Capítulo 6.
- Establecer los parámetros de monitoreo adecuados para el monitoreo de las variables identificadas.
- Proponer alternativas de registradores/dataloggers que cumplan con las condiciones iniciales del diseño: portátil, modular, escalable, los cuales son presentados tanto en el Capítulo 4 como en el Capítulo 6.
- Generar simulaciones numéricas para encontrar relaciones entre las vibraciones de los alabes y las ondas de presión en la turbomaquina, desarrollado en el Capítulo 8.

Para desarrollar una metodología de monitoreo remoto y no invasivo de turbomáquinas primero se debe de conocer el comportamiento bajo diferentes regímenes de trabajo de una turbomáquina de estudio, el cual se presenta en el Capítulo 5, para así poder inducir los fenómenos en ellas y poder capturar y relacionar dicho fenómeno con las diferentes variables que se adquieren mediante sensores para así poder encontrar relacionen entre ellas.

En este trabajo se presenta una caracterización de una turbomáquina con el fin de conocer sus diferentes puntos de operación y relacionarlos con variables de fácil medición de forma no invasiva, para poder encontrar un fenómeno de estudio y de igual forma caracterizarlo, desde el punto de vista experimental y numérico.

Experimental Part I

1 Descripción del Laboratorio

En este capítulo se hace una presentación y descripción del Laboratorio de Hidráulica de la Universidad EAFIT, el banco de bombas y demás aspectos relevantes.

1.1 Información Técnica

1.1.1 Reseña

El Laboratorio de Hidráulica fue inaugurado en 1983, estuvo situado en el bloque 20 salón 101, hasta Noviembre de 2010. Actualmente situado en el bloque 19, primer piso; cuenta con un área de 300 m^2, con una distribución física conformada por espacios destinados para: Equipos de laboratorio, calibración de manómetros, salón de clases y oficina.

1.1.2 Servicios

El Laboratorio sirve de apoyo docente para las áreas de Mecánica de Fluidos, Hidráulica y Control Automático, también trabaja en Proyectos para los Departamentos de Ingeniería de

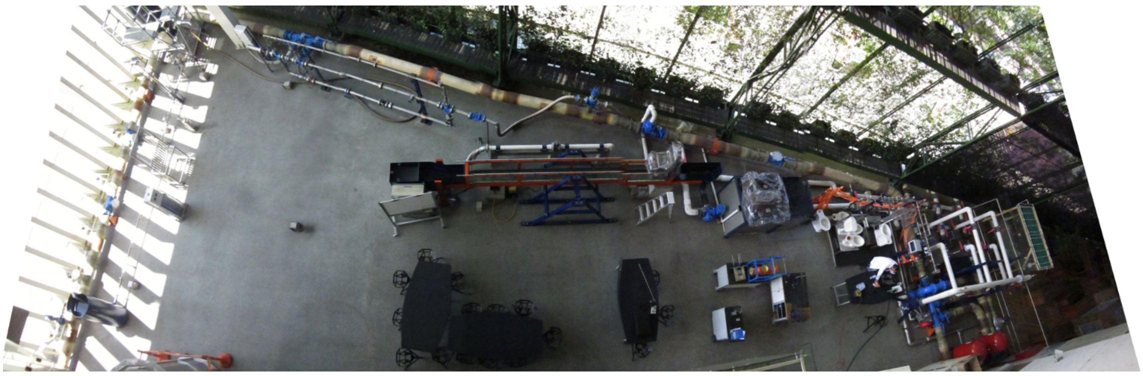


Figura 1.1: Vista superior del laboratorio.

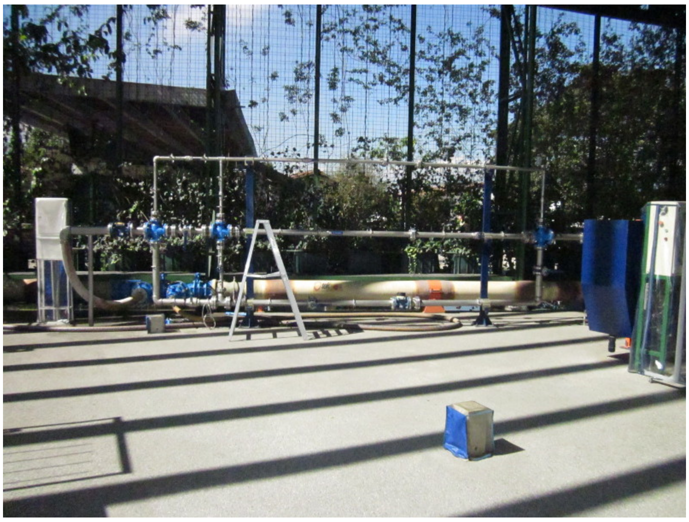


Figura 1.2: Red de Pérdidas en Accesorios y Tuberías.

Producción, Mecánica y Civil, y acompaña la realización de investigaciones, tesis de grado y actividades requeridas por los departamentos académicos.

Adicional a esto, desde 1998 el Laboratorio cuenta con un sistema de adquisición de datos en los equipos utilizados para las prácticas que posibilita el control y captura en formato digital de las variables relevantes para la realización de los laboratorios.

Desde el 2000 tiene a su cargo los equipos de la línea de Investigación en Ciencias del mar con los que se prestan asesorías a las empresas del sector Hidroeléctrico además de servir de soporte para las investigaciones que este grupo genera.

1.1.3 Recursos

Para satisfacer los requerimientos en los diferentes servicios que atiende, el Laboratorio cuenta con los siguientes equipos y materiales:

- Red de pérdidas en accesorios y tuberías.
- Tanque para calibración de vertederos.
- Canal de pendiente variable con posicionador 3D.
- Almenara para prácticas de golpe de ariete.
- Sistema de adquisición de datos.
- Micromolinete para medición de velocidad de flujo.
- Ecosonda Knudsen 320BP transducer de 12-200/28/200 Khz.

Figura 1.3: Canal abierto de pendiente variable.

- GPS diferencial TRIMBLE.
- Software para oceanografía.
- Sistema de bombeo serie paralelo.

Toda la información aquí presentada se encuentra en la página oficial del Laboratorio de Hidráulica [3].

1.2 Descripción

En la Figura 1.1 podemos observar una vista de la parte superior del Laboratorio, donde se encuentran la gran parte de los bancos experimentales con los que se cuenta, cada uno de ellos se describirá brevemente a continuación:

1.2.1 Red de Pérdidas en Accesorios y Tuberías

Como su nombre lo indica, este banco experimental sirve para realizar las ensayos de perdidas de presión en diferentes tipos de accesorios tales como codos, medidores de caudal, tees, uniones universales, uniones roscadas entre otros, este se puede observar en la Figura 1.2.

1.2.2 Canal de Pendiente Variable

En esta parte del laboratorio (Ver Figura 1.3) se pueden realizar pruebas y ensayos hidráulicos tales como:

(a) Entrada Cuarto Bombas.

(b) Sistema de Tuberías.

(c) Distribución de las Bombas.

Figura 1.4: Cuarto de Bombas.

- Fenómenos de Canal Abierto.
- Flujo de Modelos a Escala a Bajas Velocidades.
- Análisis de Cimientos Tipo Pila.
- Resalto y Choque Hidráulico.
- Contraflujos.

1.2.3 Almenara

En este banco experimental se realizan pruebas de golpes de ariete y pérdidas friccionales de flujo.

También se pueden llevar a cabo ensayos de flujos dinámicos.

1.2.4 Tanque Elevado

En esta parte del laboratorio se pueden realizar pruebas de carga y descarga de tanques, tiros parabólicos y monitoreo de niveles.

Figura 1.5: Almenara.

Figura 1.6: Tanque Elevado.

1.2.5 Vertedero

Este tanque permite realizar pruebas de vertimiento de fluidos y sirve como reservorio y sumidero para el banco de turbomáquinas.

1.2.6 Cuarto de Bombas

Este espacio se encuentra en el sótano del Bloque 19, y es desde aquí que se genera toda la potencia fluida necesaria para el laboratorio, cuenta con un total de 6 bombas, 4 de ellas de 10 HP y otras 2 de 9.5 HP.

Este sistema permite configurar todas las bombas de la manera que se desee, tanto en serie, paralelo y mixto, y posee un sistema de control y verificación del estado hidráulico entregado al laboratorio.

Figura 1.7: Vertedero.

Figura 1.8: Banco de Turbomáquinas.

1.2.7 Banco de Turbomáquinas

El Banco de Turbomáquinas esta compuesto por 3 bombas hidráulicas de 1.5, 3.0 y 9 *HP* respectivamente, y sirve como espacio propicio para la caraterización de bombas y turbinas hidráulicas a pequeña escala.

Adicional a todos estos bancos experimentales se cuenta con un anillo de tubería de escala industrial que permine conectar todos los bancos y realizar pruebas con caudales hasta de $200l/s$.

Dado que todo el proyecto de monitoréo se realiza en el Banco de Turbomáquinas se realizará una descripción mucho más detallada a continuación.

1.3 Banco de Turbomáquinas

Como se había descrito anteriormente, el Banco de Turbomáquinas esta compuesto por 3 bombas hidráulicas de 1.5, 3.0 y 9 *HP* respectivamente, las cuales se analizarán más detenidamente a continuación:

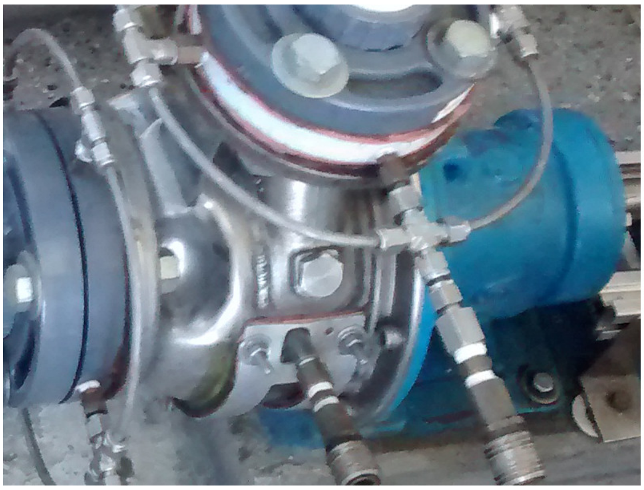


Figura 1.9: Bomba de Acero Inoxidable.

1.3.1 Bomba de 1.5 HP.

Esta bomba esta fabricada por la empresa *ITT - Goulds Pumps*[4],hace parte de la familia de bombas *G&L* de la serie *SSH*, está hecha de Acero Inoxidable 316, lo cual permite que se trabaje tanto con fluidos no corrosivos como con fluidos altamente corrosivos, su ficha técnica se encuentra en el Apendice A.1.

Su potencia es de $1.5HP.$. con una velocidad nominal de $1750rpm$. Tiene un diámetro de succión de 2 pulgadas y un diámetro de descarga de $2\frac{1}{2}$ pulgadas.

como se puede apreciar en la Figura 1.9, se han realizado ciertas adecuaciones a la bomba, entre las que se encuentra la instalación de ventanas de *Flexiglass*, con el fin de poder ver al interior de la misma e identificar que ocurre en el impeler; también se le han realizado perforaciones a lo largo de la voluta y la carcasa, todo esto con el fin de instalar diferentes transductores de presión para conocer el comportamiento del fluido a su interior.

El tubo de succión es de vidrio templado para poder observar que ocurre con el fluido especialmente cuando esta turbomáquina trabaja como turbina, pues en el se pueden observar fenómenos como la Torcha y contra-flujos.

1.3.2 Bomba de 3.0 HP.

Esta turbomáquina fue diseñada y fabricada por la empresa *SIHI*[5] con su filial *STERLING FLUID SYSTEMS GROUP*, realizada de fundición, lo cual permite que su costo sea más bajo, toda su infomración técnica se encuentra en el Apendice A.2.

Tiene una potencia nominal de $3.0HP.$ y trabaja a una velocidad de $1750rpm$. Sus dimensiones básicas son: diámetro de succión de $2\frac{1}{2}$ pulgadas y 2 pulgadas y un diámetro de descarga.

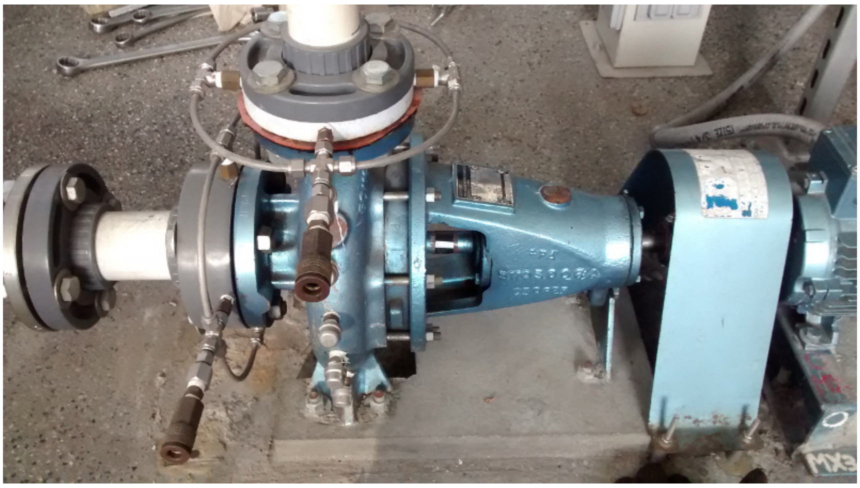


Figura 1.10: Bomba de 3 HP.

Como se puede apreciar en la Figura 1.10,esta turbomáquina cuenta con tomas de presión distribuidas en toda la voluta, ademas cuenta con dos ventanas en su parte frontal que permiten ver al interior de la misma.

1.3.3 Bomba de 9.0 HP.

Esta turbomáquina fue diseñada y fabricada por la empresa *KSB*[6] con su filial *Hidro MF Hidrolik*, realizada de fundición, lo cual permite que su costo sea más bajo.

Tiene una potencia nominal de $9.0 HP.$ y trabaja a una velocidad de $3600 rpm$. Sus dimensiones básicas son: diámetro de succión de $3\frac{1}{2}$ pulgadas y 3 pulgadas y un diámetro de descarga.

Igual que las bombas anteriores y como se puede apreciar en la Figura 1.11,esta turbomáquina cuenta con tomas de presión distribuidas en toda la voluta.

Debido a que la bomba de 1.5 HP. Presenta la mayor cantidad de beneficios al tener la tubería de succión y un torquimetro acoplado, se decide realizar las pruebas en esta turbomáquina.

En el siguiente capítulo se presentan las primeras mediciones en la turbomáquina seleccionada y el estado del laboratorio.

Figura 1.11: Bomba de 9 HP.

2 Estado del Laboratorio

2.1 Estado Turbomáquina

Las primeras pruebas para verificar el montaje y las variables a medir se realiza en la bomba de 1.5 HP.

Se utilizó un software desarrollado en el Laboratorio de Hidráulica para las practicas de laboratorio de curvas de bombas, este fue escrito en LabView, y se presentan los pantallazos de su interfaz gráfica.

La metodología seguida en estos primeros acercamientos fué la siguiente [1]:

- Conectar el motor de la bomba a un variador de velocidad.
- Ubicar los transductores de presión a la entrada y salida de la bomba.
- Energizar el sistema de adquisición de datos.
- Reiniciar el medidor de Torque.
- Prender el medidor de Caudal.
- Configurar las RPM del motor mediante el variador de velocidad y verificándolo con el tacómetro.
- Iniciar la toma de datos por 5 minutos.
- Cerrar la válvula estranguladora para obtener el nuevo caudal.
- Verificar y corregir las RPM del motor.
- Realizar una nueva adquisición de datos por 5 minutos.

[1] Los instrumentos se presentan en el Capítulo 3

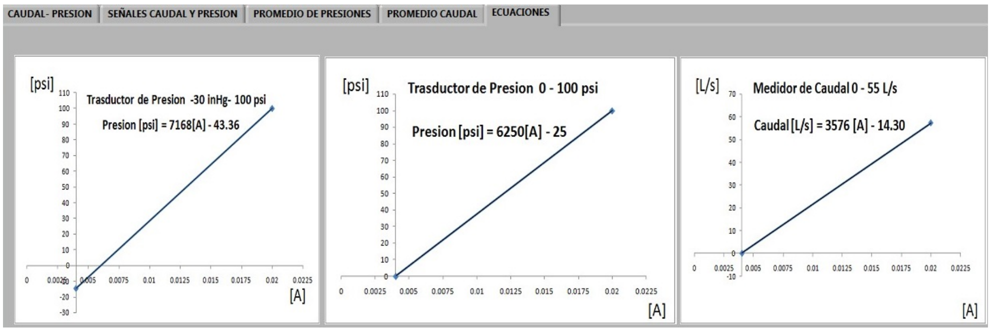


Figura 2.1: Ecuación Transductor de Presión mal seleccionado.

- Repetir los ultimos tres (3) pasos hasta que se obtenga la curva completa.
- Generar los datos en una rutina de MatLab.
- Analizar y Presentar los datos en gráficas.

Realizando estas primeras etapas se presentaron una gran cantidad de inconvenientes y problemas experimentales, los cuales se analizarán a continuación:

Los problemas presentados son de toda índole, pasando por los rangos de los instrumentos, estado de las tuberías, problemas de alineación entre otros muchos más, uno a uno de estos se analizarán y se explicará cuál fue el paso a seguir.

2.1.1 Transductor de Presión de Succión

Inicialmente se tenía un Transductor en la zona de succión de la bomba que tenia un rango de operación de 0 a 100 psi, esto genera un gran problema, pues para ciertos puntos de operación se pueden tener presiones de succión negativas, lo cual lleva a errores en la medición, aparte de que si se expone un transductor a presiones por fuera de su rango de operación por un tiempo prolongado este se puede llegar a averiar seriamente, en la Figura 2.1 se puede observar directamente en el software de adquisición de datos la ecuación de este sensor.

Debido a esto y aprovechando que en el laboratorio se tienen dos transductores de presión de rango -30 a 100 psi, se optó por cambiarlo y así tener tanto a la succión como a la descarga de la bomba estos dos transductores que cumplen los rangos de operación sin ningún inconveniente.

Una imagen física tanto del transductor mal seleccionado como del nuevo sensor se presenta en la Figura 2.2.

(a) Sensor mal seleccionado.

(b) Nuevo transductor de succión.

(c) Transductor de descarga.

Figura 2.2: Transductores de presión.

2.1.2 Desalineación del acople mecánico

El montaje mecánico inicial del sistema se puede observar en la Figura 2.3, aquí se puede encontrar cómo era la transmisión de potencia desde el motor hacia la bomba.

A la salida del motor se encontraba un acople mecánico tipo *Omega*, luego se tenía un eje hueco que conectaba el acople con la entrada al medidor de torque o Torquímetro, este se unía mediante chavetas y tornillos prensores.

Entre el eje de entrada de la bomba y el eje de salida del Torquímetro se disponía de otro eje hueco que de igual manera se conectaba mediante la utilización de chavetas y tornillos prensores.

Se puede evidenciar que el Torquímetro está descanzando sobre una estructura de perfiles de aluminio tipo *MICRO* y láminas en *"L"* que ayudan a sostener todo el sistema.

Cuando se colocaba en operación la bomba, el sistema generaba grandes vibraciones, a tal punto que se escuchaban ruidos de roce metálico, por lo que se decidió realizar una verificación de la alineación de dicho montaje, para esta verificación se contó con el apoyo del Jefe del Laboratorio de Metrología, John Alberto Betancurt, quien personalmente nos apoyo con la medición.

Para la medición se utilizaron dos Comparadores de Carátula de $0.01mm$ de apreciación. Estos se montaron sobre bloques macizos de acero y su punta de medición se coloco lo más perpendicular posible a los ejes, este montaje se puede apreciar en la Figura 2.4.

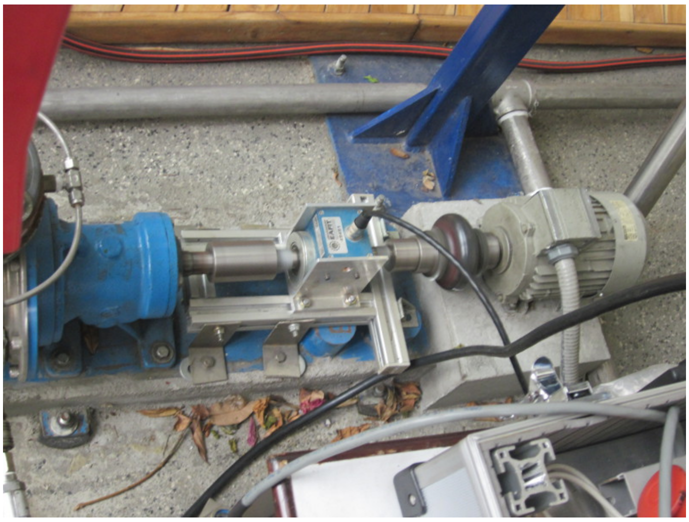


Figura 2.3: Montaje mecánico de la bomba.

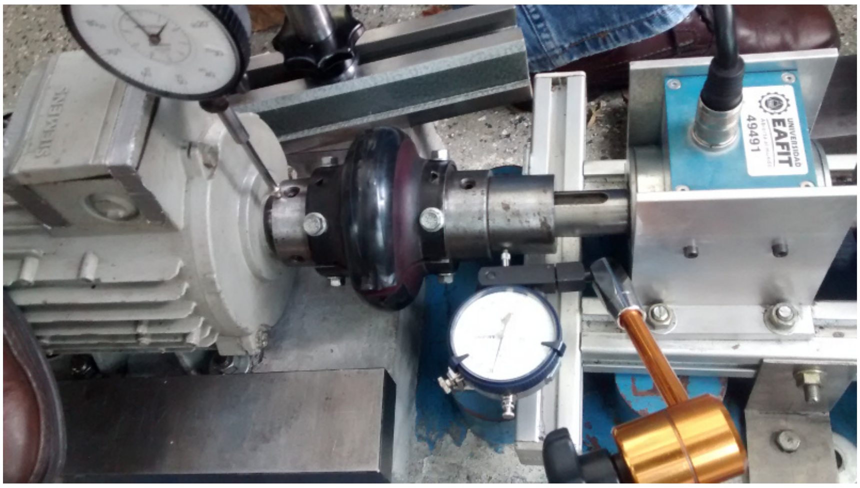


Figura 2.4: Análsis de alineación.

Gracias a esto se pudo cuantificar cuál era la desalinieación de todo el sistema, estas se presentan a continuación:

- Entre el motor y el acople *Omega* se tenían 0.26mm.
- A la salida del acople *Omega* se tenían 0.62mm.
- En la entrada del Torquímetro el valor fue de 0.17mm.
- En el eje de entrada de la bomba fue de 0.28mm.

Todos esos valores son excesivos para máquinas rotativas [7], por esta razón se decide cambiar los acoples de chavetas y el acople tipo *Omega* por acoples tipo *Estrella*, este nuevo montaje

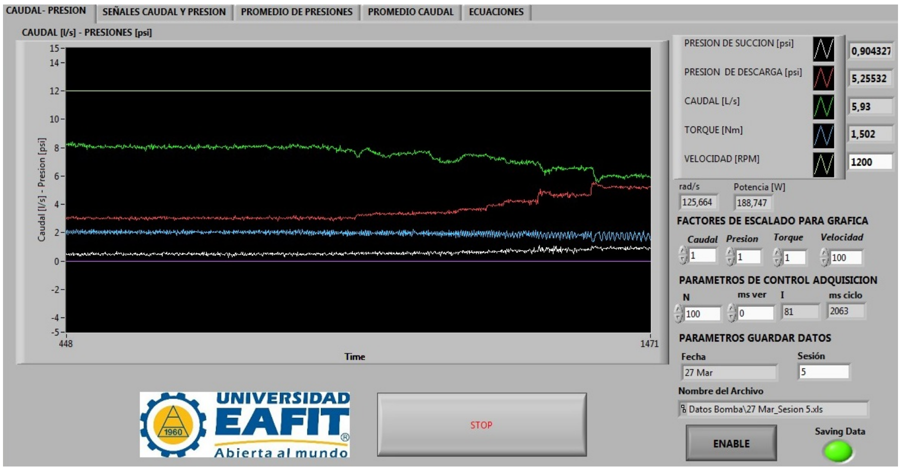


Figura 2.5: Señal atípica del Torquímetro.

se presenta en el Capítulo 6.

2.1.3 Torquímetro

Cuando se empezaron a presentar las vibraciones excesivas la señal que salia del torquímetro empezó a presentar un comportamiento atípico, como se puede apreciar en la Figura 2.5. Se generaban picos que afectaban completamente el cálculo de la potencia de la bomba, incurriendo en errores en la eficiencia supremamente graves

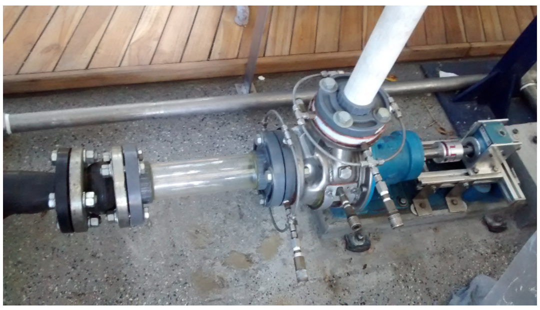


Figura 2.6: Nuevo montaje mecánico.

Se revisaron las conexiones eléctricas y la corriente de entrada al sensor y estas se encontraban en perfecto estado, así que se aprovechó que se debía de cambiar el montaje mecánico para revisar el estado del sensor al mismo tiempo.

Al desmontarlo se encontró que éste tenía graves daños, el principal de ellos era la ruptura de los tornillos prensores, haciendo así que la jaula de este quedara libre, lo que hacia que la señal no fuera pura, este daño se puede apreciar en la Figura 2.7.

Estos tornillos fallaron debido a esfuerzos cortantes excesivos como se puede ver en la Figura 2.7, esto se debe principalmente a la gran desalineación del sistema mecánico que, al aumentar las RPM en las pruebas a más de las RPM nominales, causaron un daño exponencial.

Se remplazaron dichos tornillos y se le colocaron nuevos rodamientos, ademas se realizaron

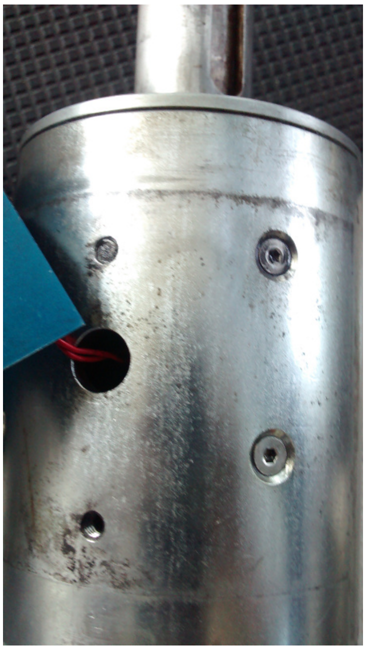


Figura 2.7: Falla del Torquímetro.

los cambios del montaje anteriormente descritos, como el cambio de acoples y se volvieron a realizar las pruebas para verificar el estado del sensor y de las vibraciones.

2.1.4 Motor

Al reiniciar las pruebas del estado de la bomba después de los cambios realizados se puso en operación la bomba a bajas revoluciones para ver su comportamiento, las vibraciones y los ruidos de contacto metálico desaparecieron por completo, pero a medida que se aumentaba la carga en el motor o se aceleraba, se sentía un olor penetrante y pérdida de potencia mecánica, así que se verificó el estado del motor.

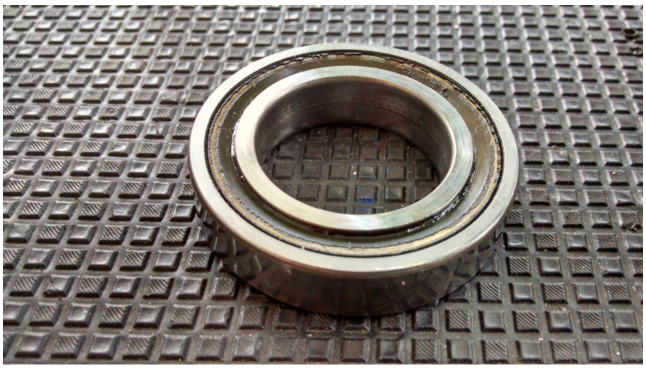


Figura 2.8: Estado de los rodamientos del motor.

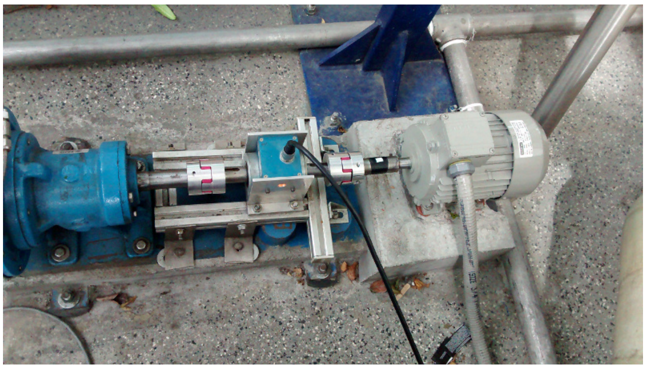


Figura 2.9: Motor nuevo y estado final del montaje.

Cuando este fue destapado se encontró que sus rodamientos estaban altamente desgastados, como se aprecia en la Figura 2.8, así que se reemplazaron y se reinició el sistema.

Pero al reiniciar las pruebas el motor continuó sobrecalentándose hasta el punto de quemarse por completo.

Debido a esto se tuvo que comprar un nuevo motor para reemplazarlo y volver a colocar todo en su lugar (ver Figura 2.9).

2.2 Estado Tubería

A la par que se realizaban las reparaciones tanto del torquímetro como el remplazo del motor se desmontó la tubería de succión de la bomba para verificar su estado.

Cuando se realizó el desmontaje se encontró que toda la tubería de hierro fundido estaba altamente corroída y cayéndose a pedazos, como se aprecia en la Figura 2.10. Debido a este estado tan lamentable, y con el fin de que el flujo del fluido fuera lo más ordenado posible, se pulió toda la reducción y se pintó con pintura en base de aceite para protegerla de la corrosión y disminuir las pérdidas por fricción en la energía del fluido.

Figura 2.10: Estado de la tubería de succión.

Después de lijar y pintar la reducción (ver resultado en la Figura 2.12) se desmontaron las otras dos reducciones del banco de turbo-máquinas, pues si se dejaban así se corría el riesgo de que se el arreglo no ayudara en mucho pues al ser un sistema conectado se podían ir partículas de oxido arrancadas por el flujo del fluido hacia cualquier parte.

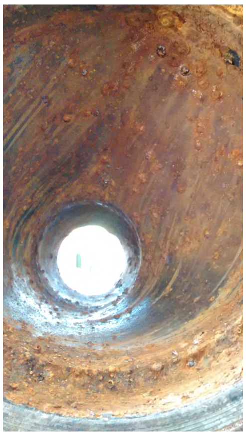


Figura 2.11: Estado de la tubería de succión desmontada.

Luego de este proceso las tres bombas del banco quedaron con sus tuberías de succión lizas y sin corrosión, lo cual ayudó a que el fluido viajara de una forma mucho más ordenada.

2.3 Estado del Agua

Uno de los insumos más importantes es el fluido de trabajo, que para nuestro caso es el agua, y esta debe de tener una excelente calidad, pero debido a la distribución del laboratorio (ver Figura 1.1) y a la pared verde que se tiene en el Edificio de Ingeniería se ve afectada constantemente debido a la caída de forma natural o debido a las condiciones climáticas de una gran cantidad de follaje, lo cual es contraproducente para las pruebas que se realizan, puesto que el paso de estos elementos en el circuito pueden realizar una gran cantidad de daños.

Estos daños pueden ser de variados tipos, los más co-

Figura 2.12: Tubería pintada.

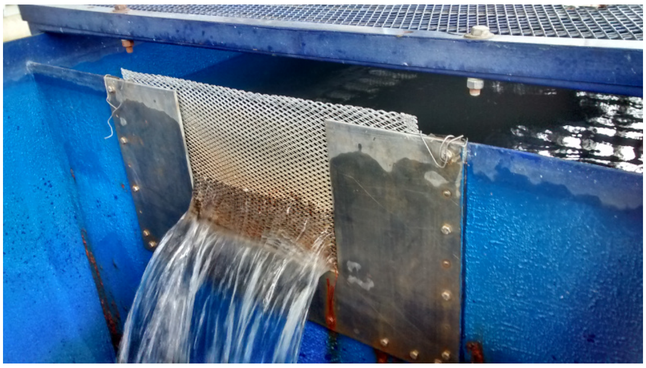


Figura 2.13: Rejilla.

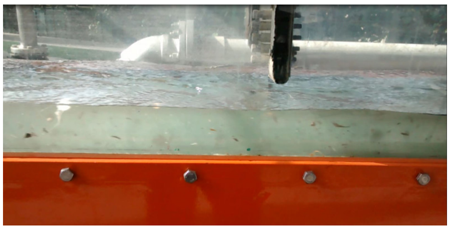
munes pueden ser errores en la medición del caudal, pues un cuerpo extraño afecta el valor de este; taponamiento en los anillos piezométricos de los transductores de presión y taponamientos en la tubería.

Pero el daño más grande que se puede generar con estos cuerpos extraños en el fluido se presenta cuando se está trabajando con las turbo-máquinas, pues los alabes se pueden ver afectados negativamente si se ingresara una rama gruesa, la cual puede rayar o averiar tanto el alabe como la carcaza o voluta,

Como se puede observar en la Figura 1.7, sobre el vertedero se colocó una tela protectora para proteger un poco el agua y así garantizar que al menos en la succión de las bombas no ingrese ningún elemento atípico.

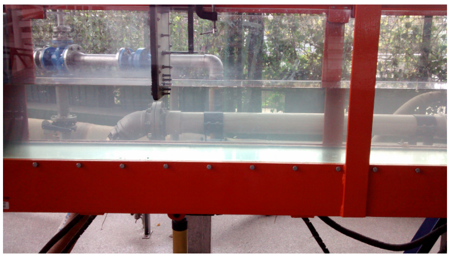
Complementando esta medida se instaló una malla metálica en el vertedero para atrapar todas las hojas y demás elementos que pudieran caer en el recorrido del anillo, esta rejilla se presenta en la Figura 2.13.

Otro aspecto que se puede considerar es el color del agua, este varía mucho dependiendo principalmente de las condiciones climáticas del día y del estado de aseo en el que se encuentre el espejo, estos casos se pueden apreciar en la Figura 2.14.



(a) Exceso de Hojas en el sistema.

(b) Agua sucia.



(c) Agua Limpia.

Figura 2.14: Estado del Agua en el Laboratorio.

Como se pudo apreciar al principio la bomba de 1.5 HP parecía ser la mas indicada a la hora de realizar la experimentación, pero debido a este gran numero de inconvenientes se opta por cambiar a la bomba de 3 HP.

3 Instrumentos

En este capítulo se presentarán todos y cada uno de los instrumentos utilizados tanto en las pruebas en la bomba de 1.5 HP como las pruebas en la bomba de 3.0 HP.

Se presentan las características principales de dichos instrumentos, pues sus fichas técnicas se encuentran en el Apéndice.

3.1 Tacómetros

Durante todas las mediciones se utilizaron dos tacómetros diferentes, debido a sus diferentes usos y señales de salida.

3.1.1 Tacómetro Convencional

Este tacómetro se utilizó inicialmente en las pruebas con la bomba de 1.5 HP y en la primera prueba en la bomba de 3.0 HP, su ficha técnica resumida se puede ver en la Tabla 3.1, la información completa se puede encontrar en el ApéndiceA.4.

La adquisición de las RPM en este tacómetro se realiza de forma visual (ver Figura 3.1), debido a esto no se puede tener un registro de las RPM medidas si no que se tiene es un promedio de ellas pero de forma manual y no automática, lo cual puede generar problemas a la hora de

Tabla 3.1: Ficha Técnica Tacómetro

Propiedad	**Valor**
Variable a Medir	Velocidad Angular
Unidades	RPM
Rango de Medición	0 a 99.999
Lectura Mínima	0,1 RPM
Trazabilidad	No

Figura 3.1: Tacómetro Convencional.

Tabla 3.2: Ficha Técnica Tacómetro con Señal

Propiedad	Valor
Variable a Medir	Velocidad Angular
Unidades	RPM
Rango de Medición	2,5 a 99.999
Lectura Mínima	1 @ 1000 RPM
Trazabilidad	No
Señal	Si

realizar un análisis más a fondo de las revoluciones.

Por este motivo se hizo necesario tener un nuevo tacómetro que pudiera generar una señal y adquirirla para tener un registro detallado de las RPM y poder analizarlas de una mejor manera, por tal motivo se adquirió un nuevo tacómetro, el cual se describe a continuación.

3.1.2 Tacómetro con Señal

Este nuevo tacómetro posee unas caracteristicas similares al tacómetro anterior, las cuales se pueden observar en la Tabla 3.2 y de forma más detallada en el Apendice A.5.

La gran diferencia que posee este equipo es que nos brinda la posibilidad de adquirir directamente desde el una señal de 0 a 5 voltios, lo cual permite saber con exactitud cuando en la turbomáquina se realizó un giro o revolución, esto va ha ser de vital importancia para análisis especializados como obtener una revolución característica de la turbomaquina en función de las vibraciones.

Este equipo se puede ver en la Figura 3.2, en la cual también se puede apreciar que le fue instalado un sistema de sujeción tipo Trípode, el cual permite no sostener el sensor manualmente, pues las vibraciones al sostenerlo de esta manera pueden afectar la medición, además,

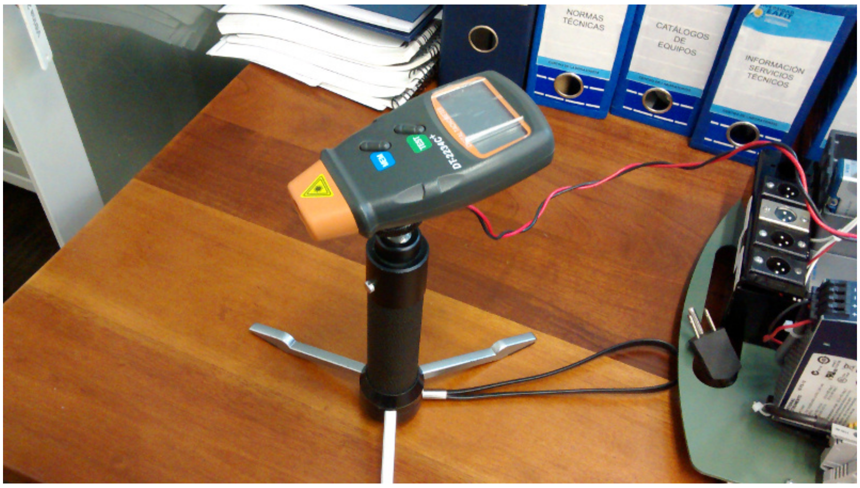


Figura 3.2: Tacómetro con señal.

Figura 3.3: Cableado de salida de la señal.

permite adquirir datos durante más tiempo.

3.2 Transductores de Presión

En el montaje se tienen dos transductores de presión, como se había indicando en el Capítulo 2.1.1, uno de ellos esta en la zona de baja presión (Zona de succión de la bomba) y el otro en la zona de alta presión (Zona de descarga de la bomba). Ambos son Transductores de Presión Piezoeléctricos poseen los mismos parámetros de operación, los cuales se presentan en la Tabla 3.3.

Estos transductores están calibrados y poseen trazabilidades verificables, las cuales se pueden encontrar en el Apéndice A.6, pero para estar mucho más seguros y cuantificar el error neto de

Tabla 3.3: Ficha Técnica Transductores de Presión

Propiedad	Valor
Variable a Medir	Presión Estática
Unidades	PSI
Rango de Medición	-30 inHg a 100 PSI
Lectura Mínima	0.1 PSI
Trazabilidad	Si
Señal	Si

medición del transductor se realizó una verificación directamente en el sistema de adquisición de datos, los resultados de esta verificación se pueden apreciar en la Figura 3.4 y el montaje experimental para dicha verificación se aprecia en la Figura 3.5.

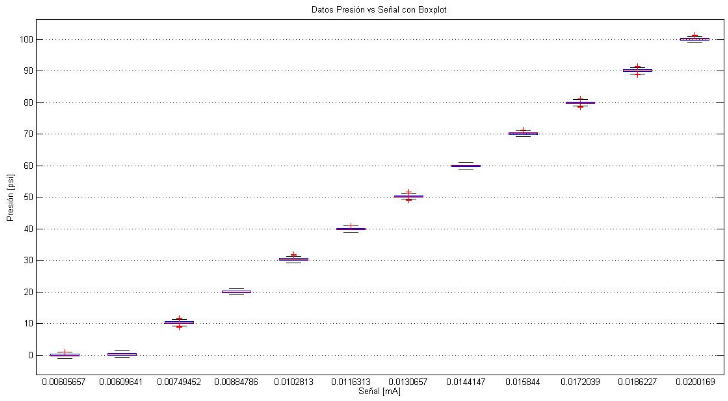
El proceso de verificación o de comparación se realizó en el banco de calibración de manómetros y transductores del Laboratorio de Hidráulica, en el cual se montaba en un toma el transductor de presión y en el otro se montaba el transductor de presión patrón, cuya lectura era adquirida por su propio sistema electrónico, mientras que los transductores de presión para las pruebas en la turbomáquina se adquiría la señal desde el sistema de adquisición de datos, el cual se expondrá en el Capítulo 4.

Se realizaron tomas de datos en cada punto durante 2 minutos, y se realizó la construcción de la curva de forma ascendente y luego de manera descendente en puntos intermedios con el fin de encontrar la histéresis del transductor, pero como se observa en la Figura 3.4(a) su comportamiento es altamente lineal.

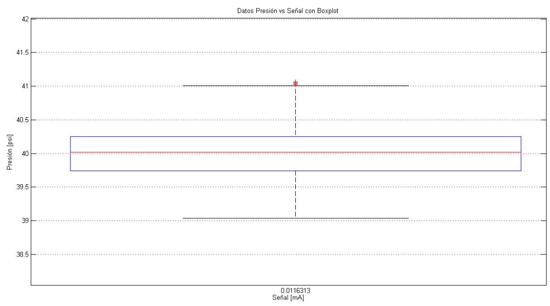
Pero a la hora de mirar cuál era la variación de la señal adquirida durante los 2 minutos y así calcular el error total, se obtuvo un resultado inesperado, pues se esperaba un error de 0.5 psi que es el valor reportado en el Informe de Calibracón (ver Apéndice A.6), pero el error encontrado fue de 1 psi en todas y cada una de las mediciones que se realizaron, esto se observa en la Figura 3.4(a), y un zoom de este efecto se presenta en la Figura 3.4(b), error que es admisible para las curvas que se realizan en este estudio pero queda abierta la posibilidad de reemplazar estos transductores dependiendo de los resultados que se obtengan en las diferentes pruebas.

3.3 Acelerómetros

Los acelerómetros son, junto al tacómetro con señal, uno de los instrumentos más importantes instalados en la turbomáquina de prueba, pues estos sensores permiten realizar análisis de vibraciones y así diagnosticar de una forma no invasiva el estado de la turbomáquina; en la Tabla 3.4 se puede encontrar una ficha técnica resumida, y en el Apéndice A.7 se encuentra toda la información técnica referente a los acelerómetros.



(a) Curva del Sensor.



(b) Zoom de la curva del Sensor.

Figura 3.4: Verificación Transductores de presión.

Los acelerómetros disponen una señal de salida de 0 a $5V$, además poseen un imán en su base que permite que sean fácilmente ajustables, como se aprecia en la Figura 3.6.

Este equipo debe de ser manipulado con bastante precaución, debido a su alta precisión y a su tecnología interna, por esta razón es el único equipo que cuenta con su propio protector, como se puede observar en la Figura 3.6.

A parte de las pruebas hidráulicas estos sensores se utilizaron en la prueba de análisis modal que se le realizó a la turbomáquina, el cual es descrito en el Capitulo 5.

3.4 Medidor de Caudal

El medidor de caudal es uno de los más importantes del laboratorio pues esta variable es de vital importancia para todas las prácticas se se realizan en el laboratorio.

El medidor de caudal que se tiene en el laboratorio es un medidor de tipo magnético de la marca Krohne [8], sus especificaciones técnicas se presentan en la Tabla 3.5 y sus prestaciones

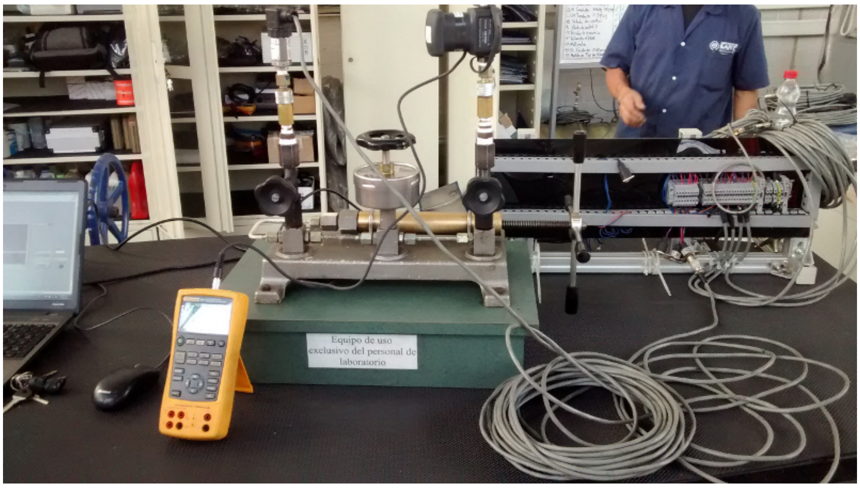


Figura 3.5: Montaje experimental para la verificación de los transductores de presión.

Tabla 3.4: Ficha Técnica Acelerómetros

Propiedad	**Valor**
Variable a Medir	Aceleración
Unidades	Gravedades (g)
Rango de Medición	0 a 50 g
Lectura Mínima	0.004 g
Trazabilidad	Si
Señal	Si

completas se pueden encontrar en el Apéndice A.8.

Este equipo genera una señal de corriente proporcional al flujo de agua que pase a través de el, esta señal es de 4 a $20mA$.

Debido a que se pueden tener diferentes sentidos de flujo es importante establecer cual es el sentido positivo para el medidor, este sentido esta establecido mediante una flecha en el sensor, esta se puede apreciar en la Figura 3.7.

Durante todas las pruebas o curvas que se realizaron no se presentaron problemas, pues el flujo del fluido era positivo con respecto al medidor, pero cuando se empezaron a realizar las Curvas Características o Curvas *"S"* de la turbomáquina (Ver Capítulo 7) se encontró que el medidor de caudal solamente puede dar señal cuando el flujo es positivo y no sale la señal cuando el flujo va en sentido contrario.

Se realizaron verificaciones de montaje y de programación para poder adquirir la señal completa, tanto positiva como negativa del flujo del fluido, pero no se pudo arreglar este inconveniente.

Figura 3.6: Acelerómetro.

Tabla 3.5: Ficha Técnica Medidor de Caudal

Propiedad	Valor
Variable a Medir	Caudal
Unidades	l/s
Rango de Medición	0 a 50 l/s
Lectura Mínima	0.1 l/s
Trazabilidad	No
Señal	Si

3.5 Martillo Modal

El martillo modal es un instrumento bastante valioso a la hora de realizar un análisis modal para encontrar las frecuencias naturales (Ver Capitulo 5), este cuenta con un sensor de carga en su parte superior para determinar la cantidad de fuerza con la que es golpeada la pieza analizada, tiene puntas intercambiables para excitar diferentes frecuencias naturales, este martillo se puede observar en la Figura 3.8 y sus características técnicas se encuentran en el Apéndice A.9.

Figura 3.7: Medidor de Caudal.

Figura 3.8: Martillo para análisis modal.

4 Sistema de Adquisición de Datos

Durante todas las pruebas es de vital importancia una correcta adquisición de datos, con el fin de tener un alto grado de confiabilidad y de repetitividad en todas las pruebas que se realizan, por esta razón se utiliza un sistema de alta tecnología, uno utilizado en el Laboratorio de Hidráulica en las primeras pruebas y otro del Laboratorio de Mecatrónica, cada uno de ellos se describen a continuación.

4.1 Sistema de Adquisición del Laboratorio de Hidráulica

Para todos los sistemas de datos que posee el laboratorio se tiene un sistema de adquisición desarrollado por la empresa *National Instruments*, este es un modelo *CompactRIO cRIO-9074*, las especificaciones técnicas se pueden ver en el Apéndice A.10,

Este sistema de Adquisición de Datos es bastante versátil, pues debido a su concepción modular, que puede adquirir diferentes tipos de señales, tanto de voltaje, corriente y otras especializadas como señales de galgas extenso-métricas, termocuplas; incluso existen módulos que en vez recibir las señales las generan, creando un gran abanico de posibilidades.

En el Laboratorio de Hidráulica se tienen una buena cantidad de módulos para la adquisición y generación de señales, pero debido al tipo de señales de los instrumentos que se utilizan para el monitoréo se utilizan dos (2) módulos en especial, el *NI 9203* y el *NI 9215*, que siven para señales en corriente y en voltaje respectivamente, para mas información de estos módulos diríjase a la página web http://www.ni.com/compactrio/esa/ [9].

Este sistema de adquisición de datos se puede observar en la Figura 4.1, donde podemos apreciar que este fue montado en una estructura de perfiles de aluminio para su fácil desplazamiento y para darle una mayor estabilidad estructural, ademas, en ese mismo montaje se coloco la unidad alimentadora para proteger los equipos de inconvenientes con las corrientes de alimentación. Adicional a todo esto se realizo el montaje de un Router de red inalambrica *WiFi*, con el fin de poder controlar el dispositivo o la adquisición de datos de forma remota.

Figura 4.1: Adquisición del Laboratorio de Hidráulica

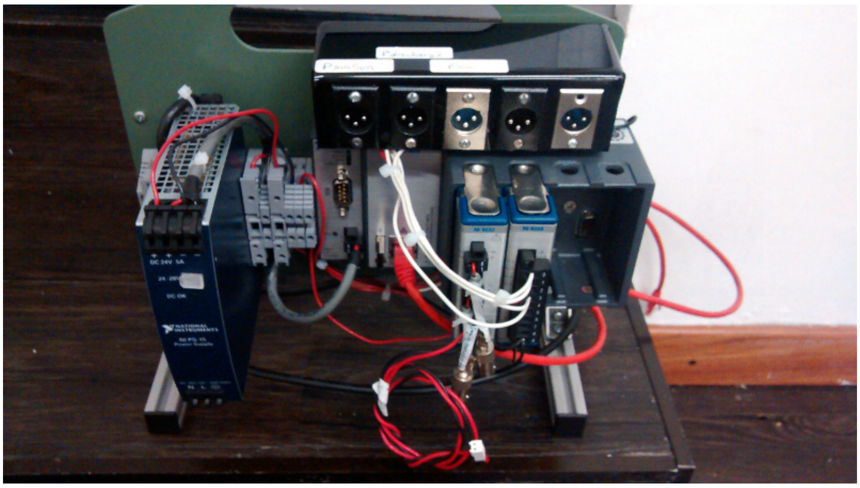


Figura 4.2: Adquisición del Laboratorio de Mecatrónica

Una de las grandes ventajas que posee este equipo es el hecho de que posee 7 *slots* o ranuras para la instalación de diferentes tarjetas de adquisición.

4.2 Sistema de Adquisición del Laboratorio de Mecatrónica

Al igual que el equipo anterior, este sistema de adquisición de datos fue desarrollado por la empresa *National Instruments*, este es un modelo *CompactRIO cRIO-9076*, las especificaciones técnicas de este se pueden ver en el Apéndice A.11.

A diferencia del equipo anterior, este sistema sólo posee 4 *slots* o ranuras, pero este equipo está únicamente a disposición de este proyecto, y no se necesita para las practicas de laboratorio, por lo cual se puede programar específicamente para las necesidades del proyecto.

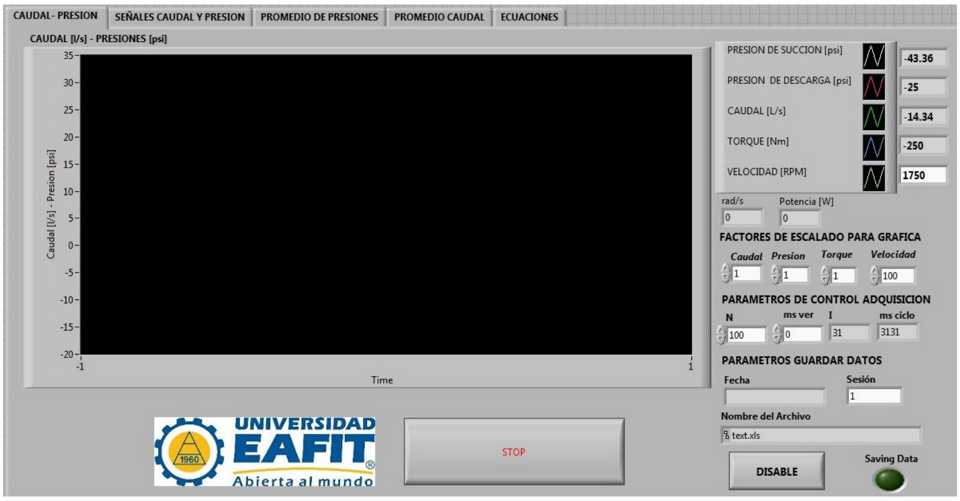


Figura 4.3: Interfaz código de Adquisición del Laboratorio de Hidráulica

En este sistema se tienen dos tarjetas de adquisición, una *NI 9203* de señales de corriente al igual que el sistema anterior, este es utilizado para adquirir las señales de los dos (2) transductores de presión y el medidor de caudal.

La otra tarjeta es una *NI 9232* especializada para señales de voltaje de entrada de ś$30V$, resolución de $24bits$, posee un rango dinámico de $99dB$, ademas de un acoplamiento de *AC/DC* seleccionable por software y lo más importante para las señales de los acelerómetros y tacómetro es que esta tarjeta posee un acondicionamiento de señales *IEPE* seleccionable por software (0 ó $4mA$).

Por estas razones se seleccionó trabajar con esta tarjeta y no con la *NI 9215*, ademas, se pudo realizar un montaje personalizado para nuestras necesidades, incorporándole un sistema de conexiones rápidas tipo micrófono, como se puede observar en la Figura 4.2.

4.3 Códigos de Adquisición

Para poder realizar las adquisiciones de datos de manera correcta y confiable se desarrollaron rutinas en $LabView$ ®, estos códigos se presentan a continuación.

4.3.1 Código inicial del Laboratorio de Hidráulica

El programa de adquisición de datos del Laboratorio de Hidráulica fue desarrollado por el Técnico Milton Marín, este consiste una interfaz gráfica donde se presentan las variables en tiempo real, esta interfaz fue presentada en la Figura 4.3, el programa tiene dos ciclos principales, uno de alta velocidad, que es en el cual se genera al adquisición de datos, y uno de baja donde se realiza el almacenamiento de las señales.

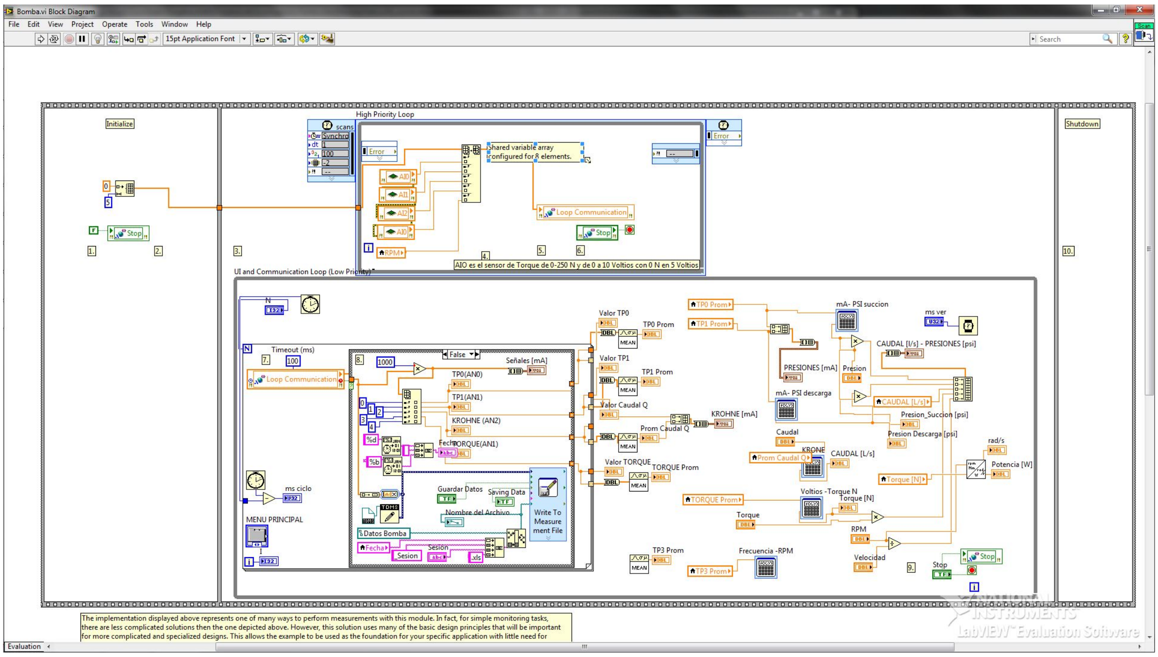


Figura 4.4: Código Laboratorio Hidráulica

Las gratificas que se presentan en el programa muestran las diferentes variables en unidades ingenieriles, es decir las presiones se presentan en psi, el torque se presentan en $N*m$ y el caudal en L/s, pero las señales se guardan en las unidades básicas adquiridas, es decir, en mili-amperios (mA) o en voltaje (V).

Un pequeño esquema del código se presenta en la Figura 4.4.

Uno de los inconvenientes que posee este código es el hecho de que cuando se lanza para guardar los datos no tiene una parada automática, es decir, el tiempo de adquisición se debe de configurar de forma externa con un cronometro de mano, lo cual produce varios problemas, entre ellos el más significativo consiste en que la longitud de los datos almacenados no es la misma para cada punto, lo que implica realizar un paso para homogeneizar de los datos antes de realizar el análisis de resultados.

Otro inconveniente que se encontró en este código se vio evidenciado cuando se empezaron a realizar las Curvas Características o Curvas *S*, pues para esta prueba se debe de mantener una altura constante (Ver Capitulo 7) y esto no se podía realizar de forma fácil en el código actual, por eso se decidió realizar una actualización a este código, esta se presenta a continuación.

4.3.2 Código Actualizado del Laboratorio de Hidráulica

Después de habar encontrado puntos a mejorar en el código de adquisición se procedió a fortalecerlo, y este mejoramiento se vio enfocado varios puntos principales, los cuales se expresan a continuación.

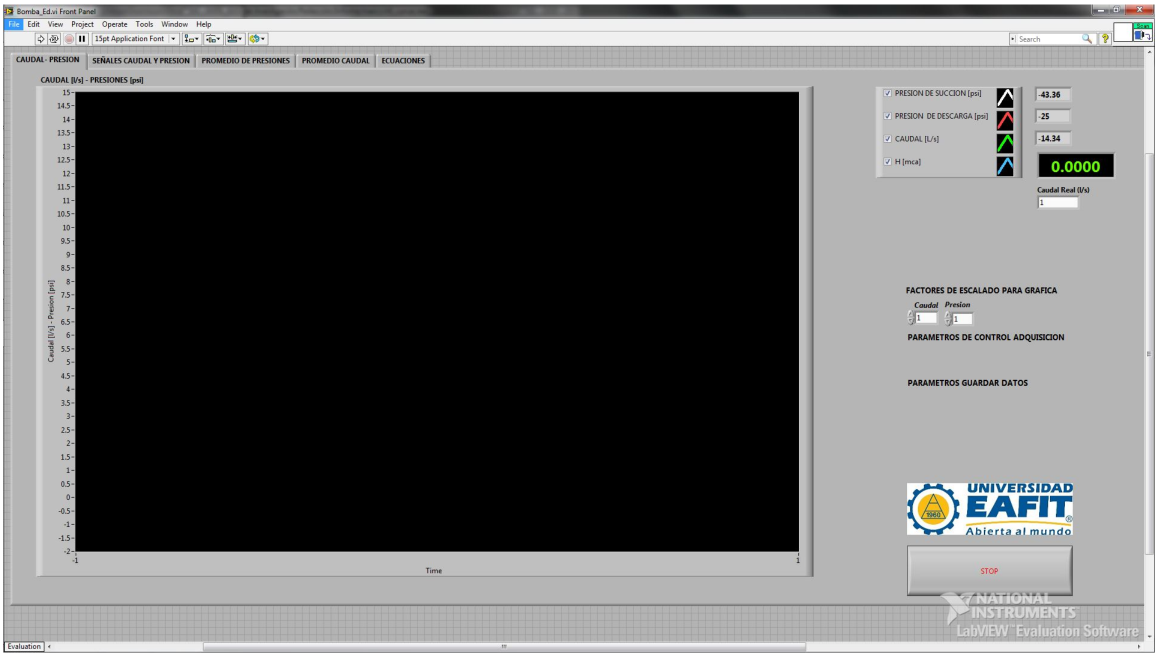


Figura 4.5: Interfaz del nuevo código de Adquisición del Laboratorio de Hidráulica

El primer item a mejorar era el ciclo de adquisición de datos, se mejoró el tiempo de adquisición colocando ciertas funciones que estaban en el ciclo de alta velocidad en el de baja, así se optimizó un poco este item, pero por la constitución propia del programa desarrollado no se pudo automatizar el tiempo de adquisición de datos.

El segundo item que se agregó al código inicial fue el cálculo de la altura hidráulica necesaria para la Curvas Características o Curvas S, pues en esta prueba se debe de mantener una altura constante (Ver Capitulo 7) y este dato se debía de calcular manualmente, ahora este cálculo se realiza directamente en el código y se muestra en tiempo real en una variable disponible en la interfaz gratifica.

Otro aspecto que se mejoró en este código fue la señal del caudal, pues como se había mostrado anteriormente (ver Capítulo 7) el medidor no permitía adquirir datos en la parte negativa del flujo, y para mejorar este aspecto se agregó una entrada manual del valor del caudal.

A parte de todo lo mencionado anteriormente, de este código se eliminó toda la parte de almacenamiento de datos, quedando solamente con el monitoréo en vivo de las variables adquiridas, puesto que para el almacenamiento se desarrolló un código que se mostrará más adelante en este capítulo.

Se puede apreciar en la Figura 4.5 la interfaz gráfica, y un diagrama del código se puede observar en la Figura 4.6.

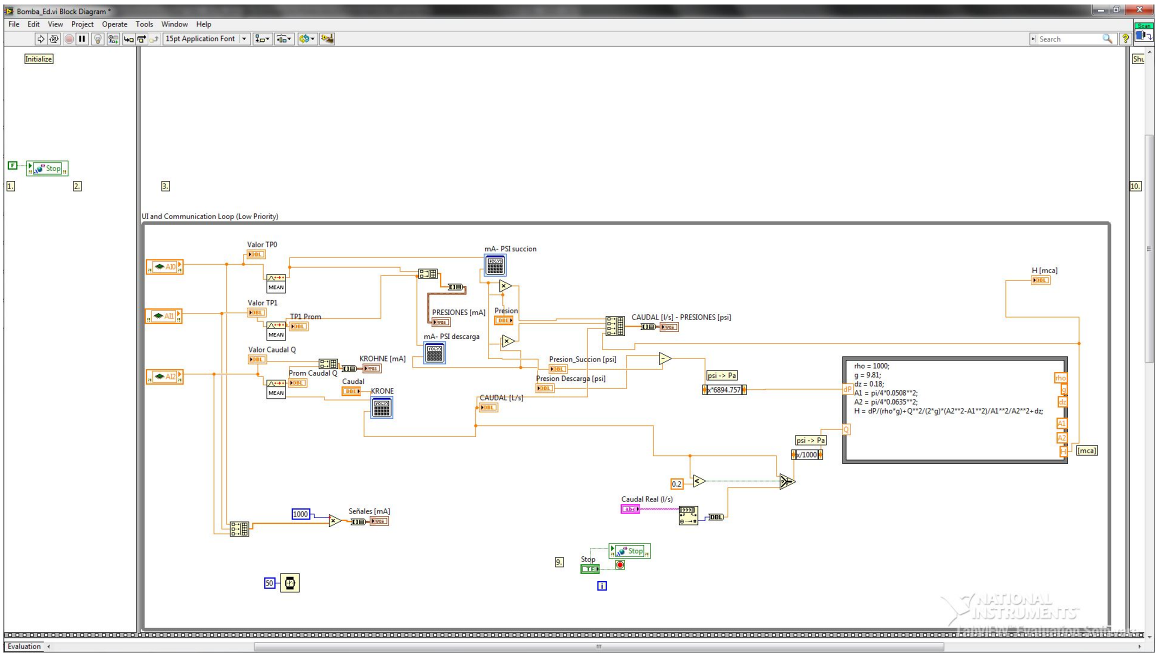


Figura 4.6: Código nuevo del Laboratorio Hidráulica

4.3.3 Código para el Análisis Modal

Para el análisis modal se utilizó un código tipo *Data Logger*, con el fín de adquirir las señales de las vibraciones debidas al impacto del martillo modal.

Este programa debe de adquirir 4 señales en simultaneo, tres (3) de acelerómetros ubicados en los tres ejes principales de la turbomáquina, y la cuarta señal es la del martillo modal; las tres primeras nos dan las aceleraciones inducidas por el golpe, mientras que la cuarta nos indica la intensidad o fuerza del impacto.

Dentro del programa se introdujo un código tipo *Trigger*, que detecta automáticamente el impacto del martillo y lanza la adquisición de datos, la interfaz gráfica se puede apreciar en la Figura 4.7 y un diagrama del código se presenta en la Figura 4.8.

En este análisis no se utilizo ninguno de los sistemas de adquisición de datos expuestos anteriormente, si no que se utilizo un *Rack USB* (Ver Figura 4.9), que permitía realizar un código más compacto y rápido, pues no se deben de realizar códigos complejos, además el ensamble es fácil y rápido comparado con los otros sistemas.

4.3.4 Código para la Construcción de las Curvas de la Turbomáquina

En el proceso de la generación de las curvas características de las Turbomáquinas (Ver Capítulo 7) se necesitaba poder adquirir la señal de todos los instrumentos antes mencionados, de forma que estas señales fueran sincronizadas y a una alta velocidad de adquisición para

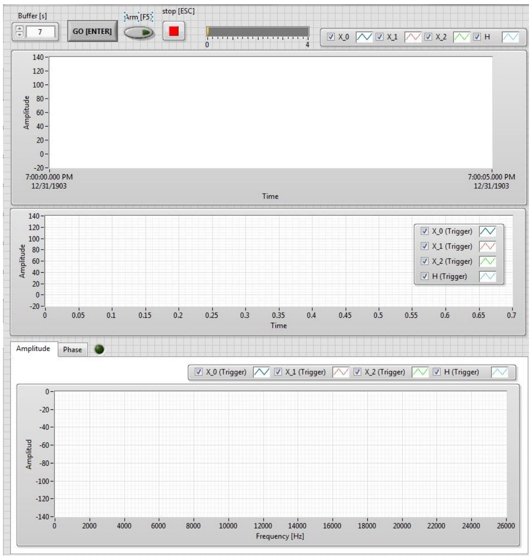


Figura 4.7: Interfaz Análisis Modal

poder estudiar fenómenos de frecuencias relativamente altas que pudieran aparecer en la turbomáquina, por esto se desarrollo un código que a diferencia de los otros códigos corre en el *PC*, este corría directamente en el *CompactRIO* mediante una programación llamada *FGPA*.

Este código tiene la capacidad de adquirir 8 canales, 3 de voltaje y 5 de corriente, lo cual permite conectar dos acelerómetros, un tacómetro, un medidor de caudal y 4 transductores de presión, todos estos canales sincronizados a una velocidad de lectura de 53.200Hz.

Otra gran diferencia que se puede encontrar en este código es que a diferencia de todos los anterior que corrían directamente desde la interfaz de $LabView$ ®, este código se desarrolló para que fuera completamente portable, su interfaz gráfica se puede apreciar en la Figura 4.10.

Sin embargo quedan varios aspectos a mejorar en este código que se esperan agregar en la siguiente fase del proyecto, tales como la hora del programa, que no esta bien actualizada, adicionar una función de análisis espectral en el mismo sistema de adquisición y aumentar la capacidad de almacenamiento.

Después de esta descripción de todos los instrumentos y códigos desarrollados en el siguiente capítulo se presentan los resultados obtenidos.

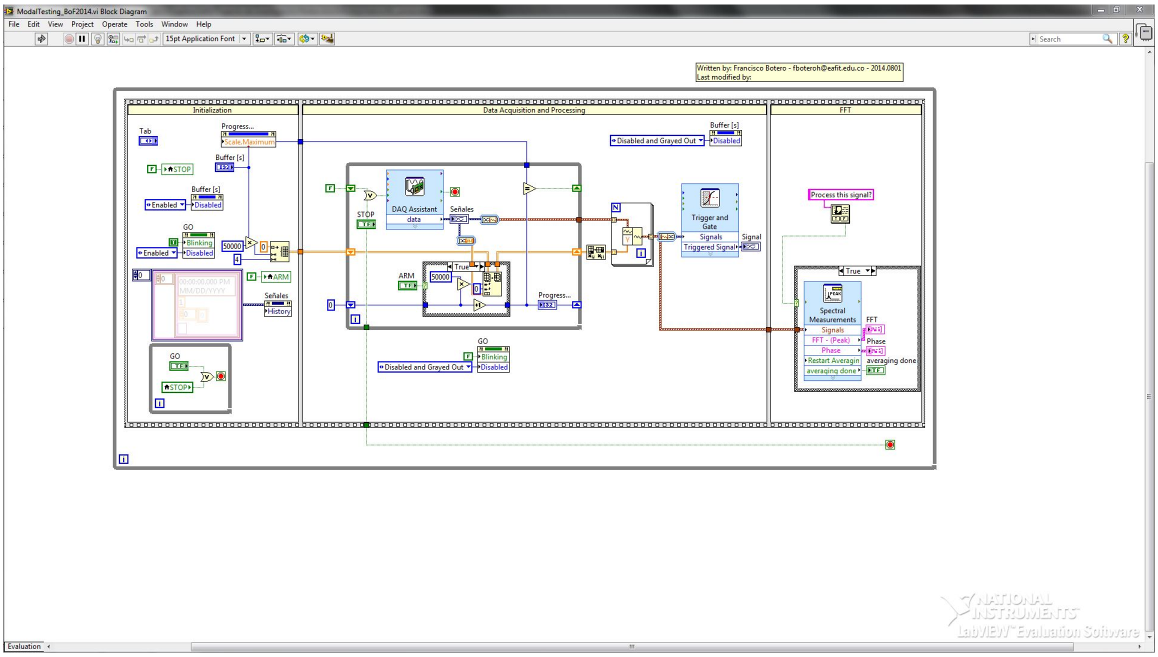


Figura 4.8: Código Análisis Modal

Figura 4.9: Rack USB

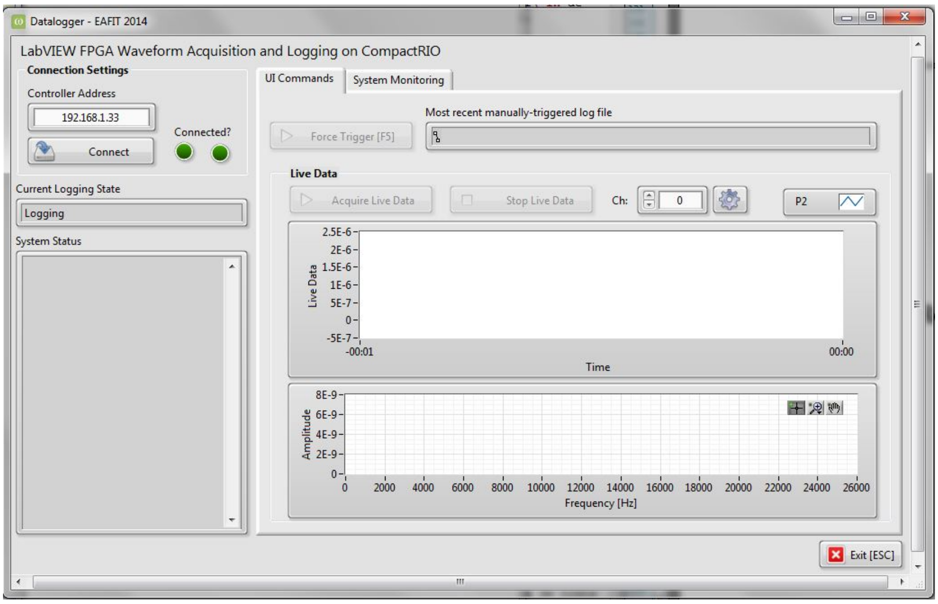


Figura 4.10: Interfaz Datalogger

5 Curvas y Resultados Obtenidos

A continuación se presentan los primeros resultados obtenidos:

5.1 Análisis Modal

El análisis modal consiste en poder encontrar las frecuencias naturales de un sistema, en este caso la bomba seleccionada para el desarrollo de este proyecto.

Para poder realizar este análisis se necesitaron de 3 acelerómetros y un martillo modal, los cuales fueron descritos en el Capítulo 3. Cada uno de los acelerómetros fué ubicado de manera alineada a los ejes principales de la turbomáquina, como se puede apreciar en la Figura 5.1.

Mediante el software desarrollado para este análisis y presentado en el Capítulo 4.3.3 se adquirieron los datos de los acelerómetros, quienes fueron exitados mediante el golpe realizado por el martillo modal, estos impactos controlados se repitieron 30 veces, 10 en por cada punto principal, un promedio de estos impactos en el dominio del tiempo se puede observar en la Figura 5.2.

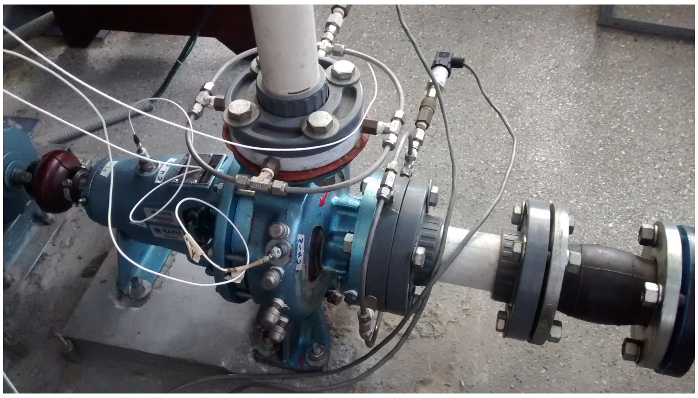


Figura 5.1: Montaje para el análisis modal

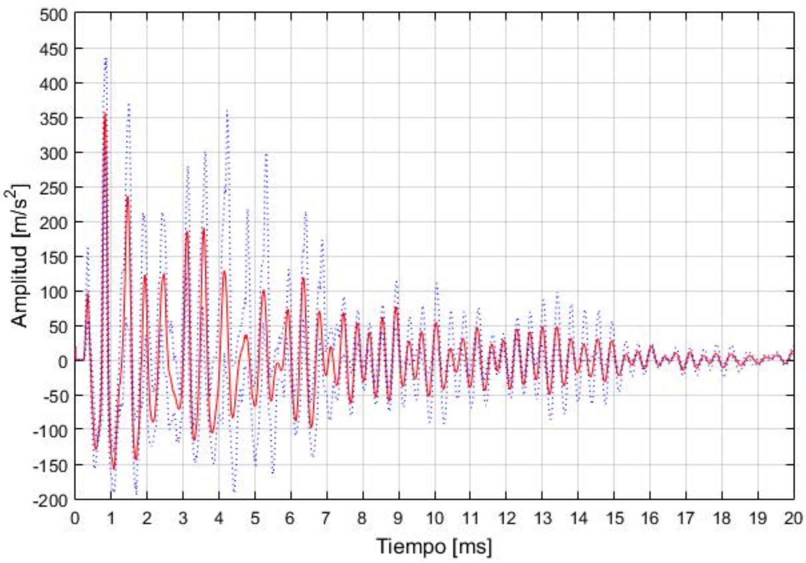


Figura 5.2: Amplitud Promedio vs Tiempo

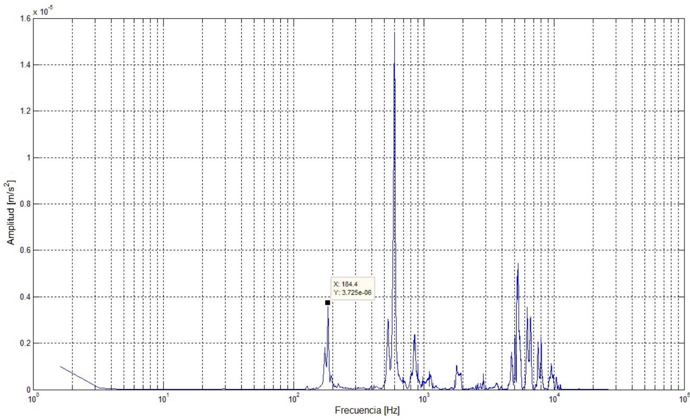


Figura 5.3: Espectro del análisis modal

Inmediatamente después de tener los resultados de los impactos y promediarlos, se procedió con el análisis en frecuencia, una gráfica de los resultados obtenidos se puede apreciar en la Figura 5.3.

De donde se puede observar que el primer modo de vibración del sistema se encuentra alrededor de los 184.4Hz, valor que dista de las frecuencias de rotación propias de la turbomáquina.

Cabe aclarar que este análisis se realizó con la turbomáquina completamente llena de agua, para que este análisis se realizara en las condiciones típicas de operación.

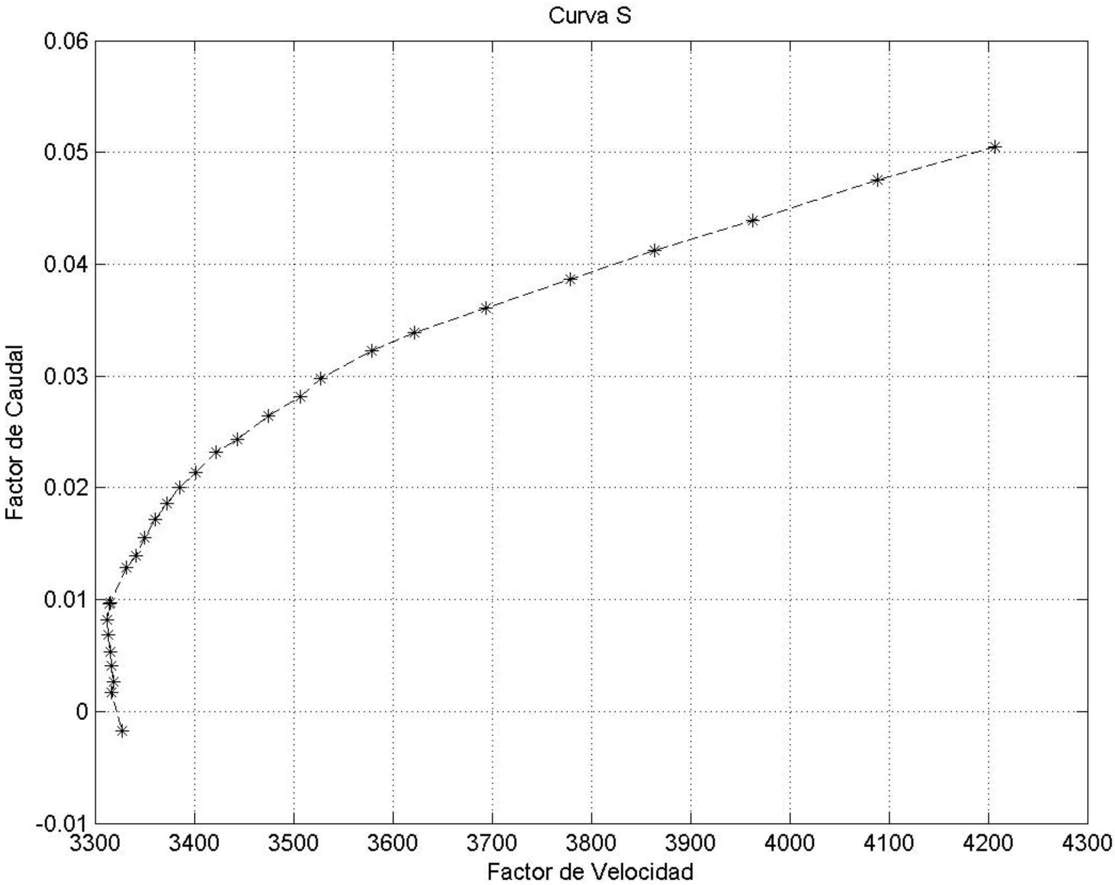


Figura 5.4: Curva S

5.2 Curva S o caracteristica de turbomáquinas

Una curva s o curva caracteristica de los cuadrantes de operación de una turbomáquina es una curva que permite comprender los modos o formas de operación. Para poder construir dicha curva, se necesita tener una altura constante, es decir, se debe simular en el laboratorio la cabeza de un embalse, lo que implica que la energia disponible sea constante. Lo que es equivalente a mantener la cabeza dinámica de bombeo en un valor fijo.

Gracias a la configuración del sistema de bombeo del laboratorio y al software desarrollado (ver capítulo 4) se pudo adquirir los datos necesarios.

La construcción de la curva se realizó siguiendo las indicaciones de la norma NCh2966 la cual es la traducción del la norma internacional IEC 60193:99 [10]. El resultado inicial se presenta en la Figura 5.4

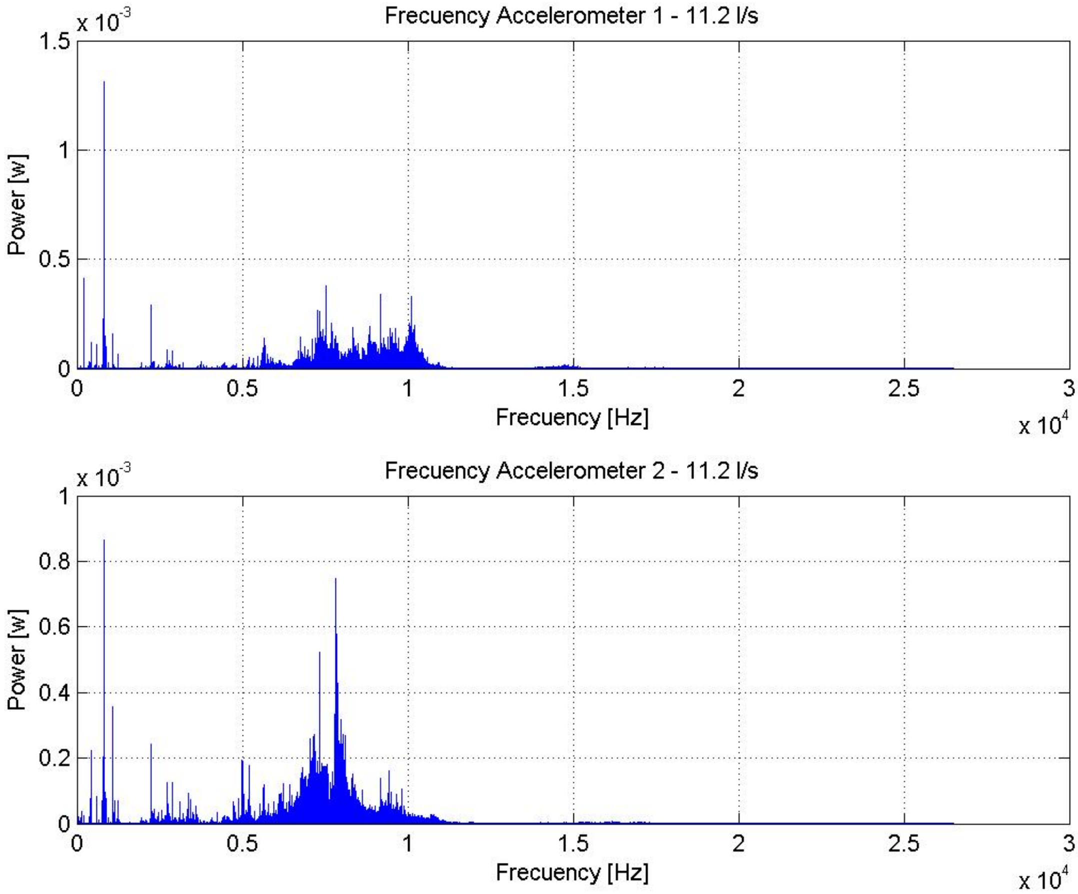


Figura 5.5: Espectro de los Acelerometros

5.3 Análisis de los Acelerómetros

A medida que se construia la curva s como las curvas de desempeño de la bomba, se iban registrando las vibraciones producidas por la operación misma de la turbomáquina y, al igual que en el análisis modal, se realizó un análisis en frecuencia para tener un espectro de operación, un espectro característico se presenta en la Figura 5.5. Cabe aclarar que las frecuencias naturales mensionadas anteriormente no se presentan en este espectro, lo cual da la tranquilidad de que en diferentes puntos de operación la turbomáquina no entra en resonancia.

5.4 RPM Característica

Al poder tener registrada a parte de los acelerómetros la señal del tacómetro se pudo realizar el análisis de RPM característica, el cual consiste en ver el comportamiento de la turbomáquina en una revolución. Este análisis permite ver fenómenos sincronizados con la rotación de la

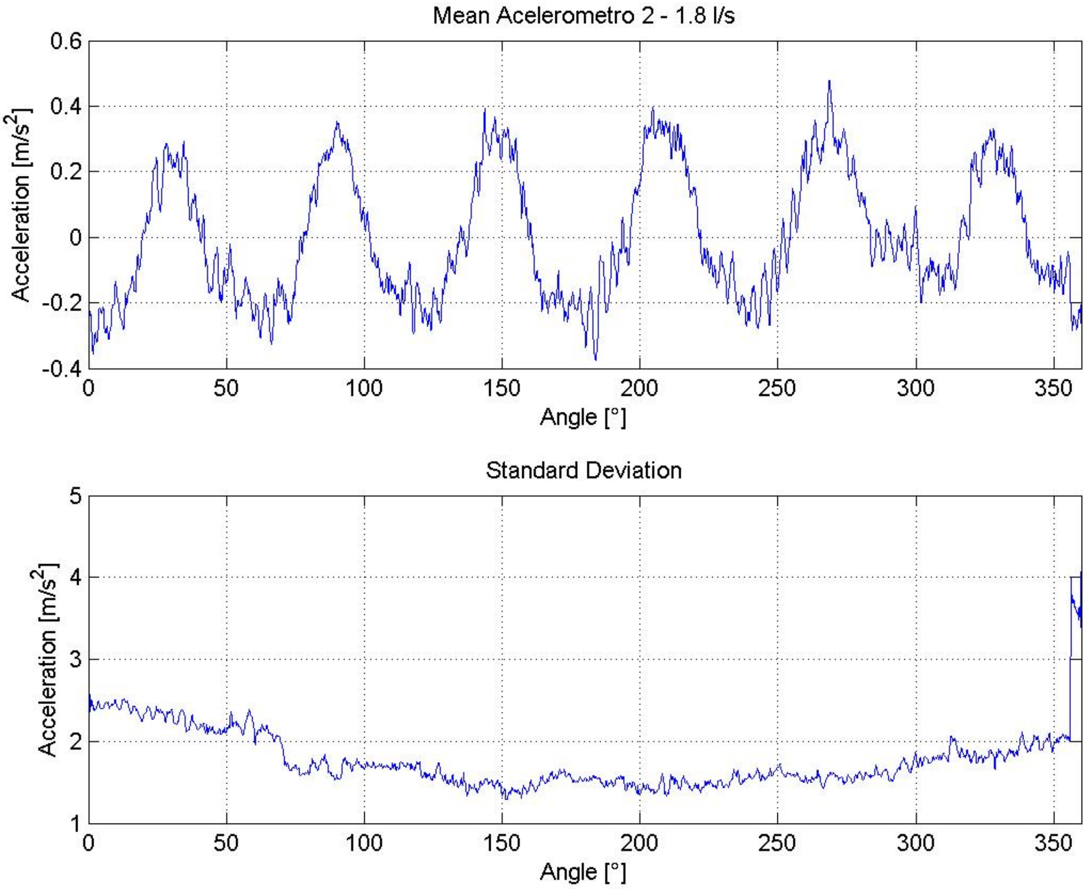


Figura 5.6: RPM Caracteristica

turbomáquina, pues elementos aleatorios quedan eliminados en el proceso de promediar las señales. El resultado del análisis de RPM caracteristica se puede observar en la Figura 5.6, de la cual se pueden ver 6 picos claramente detallados, los cuales corresponden al paso de álabes del rodete de la bomba seleccionada.

5.5 Curvas de la Turbomáquina

Para poder tener una idea de las capacidades de bombeo de la turbomáquina seleccionada se realizaron las curvas de la bomba, es decir, las curvas de catálogo de cabeza (H) contra caudal (Q) para diferentes revoluciones, el resultado se presenta en la Figura 5.7.

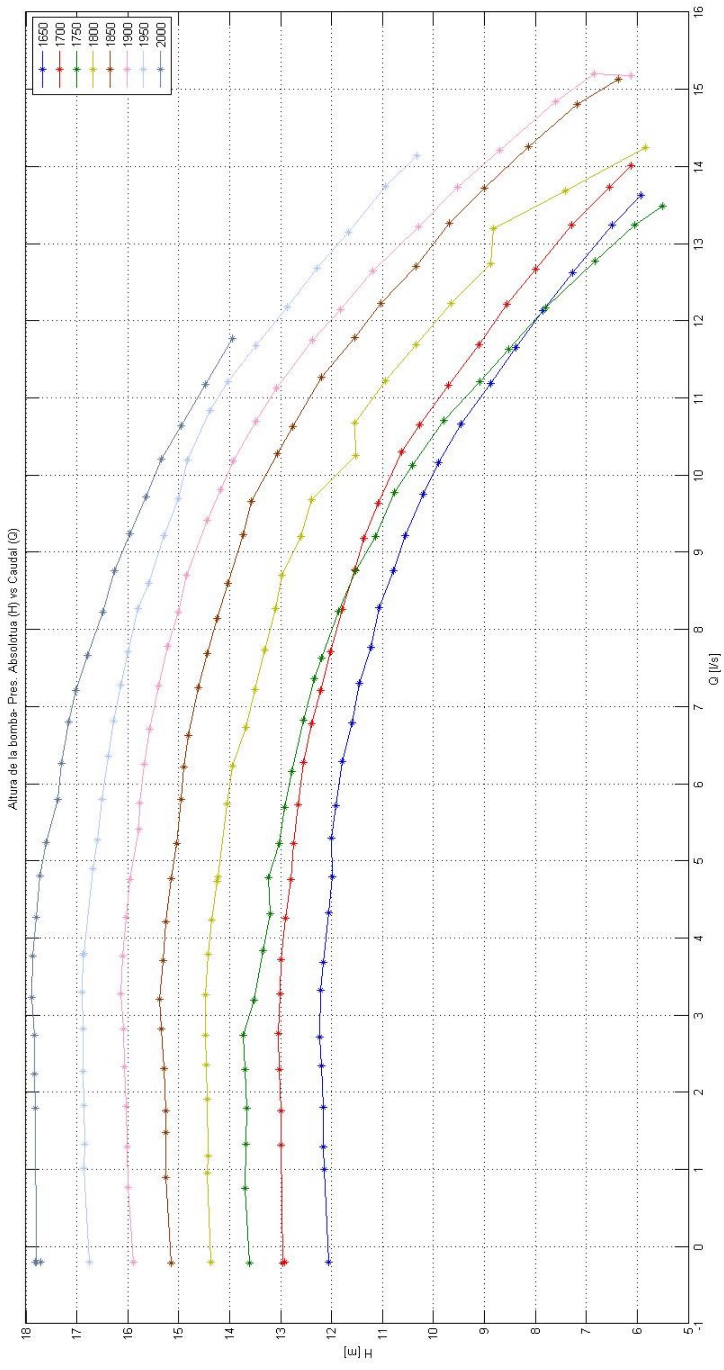


Figura 5.7: Curvas de la Turbomáquina

6 Cambios del Laboratorio, de la Turbomáquina y del Sistema de Adquisición de Datos

Como se pudo concluir en la Sección 2, cambiar de máquina de análisis o bomba de estudio era al mejor opción para unos mejores datos y mejores resultados, como los presentados en la Sección 5.

Pero en el transcurso de las mediciones se hizo necesario cambiar tres aspectos principales del sistema a analizar, los cuales fueron cambios como el software de adquisición de datos, nuevas tuberías en acrílico, y la pintura mejora geométrica de la turbina, estos cambios se explican a continuación:

6.1 Turbomáquina

Como se aprecia en la Sección 1.3.2, se tenía la turbomáquina instalada y lista para su utilización, pero debido a que esta sería nuestra máquina de interés se tomó la decisión de realizar un mantenimiento después de las tomas de datos presentadas anteriormente en la Sección 5.

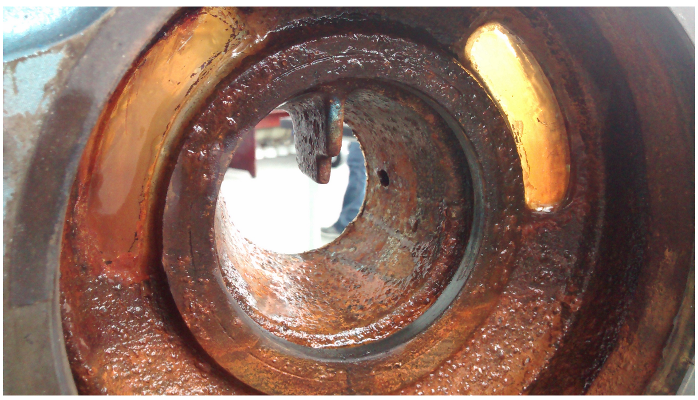


Figura 6.1: Obstáculo en la zona de succión.

Figura 6.2: Corrosión de la voluta.

Para esto se desmontó la bomba y se encontraron varios inconvenientes, los cuales fueron solucionados. Una descripción de lo encontrado se presenta a continuación:

6.1.1 Difusor de entrada

Al desmontar y desarmar por completo la bomba se revisó su zona de succión o zona de baja presión, en la cual se encontró un elemento que obstaculizaba el paso del fluido por esta área, como se puede observar en la Figura 6.1.

Este obstáculo puede cambiar por completo el comportamiento del fluido, por esta razón se tomó la decisión de cortar y pulir esta zona para que el flujo viajara de forma más ordena y sin alteraciones importantes. El resultado final se puede apreciar en la Figura 6.3.

6.1.2 Superficies de Flujo

Las superficies de flujo son aquellas que están en contacto directo con el fluido. Estas superficies se ven altamente afectadas por la corrosión, lo cual genera un cambio en su geometría; lo cual puede dar como resultado un cambio en las condiciones del flujo del fluido.

Estas alteraciones por corrosión se encontraron de forma muy marcada en la carcasa o voluta, como se aprecia en Figura 6.1 y en la Figura 6.2.

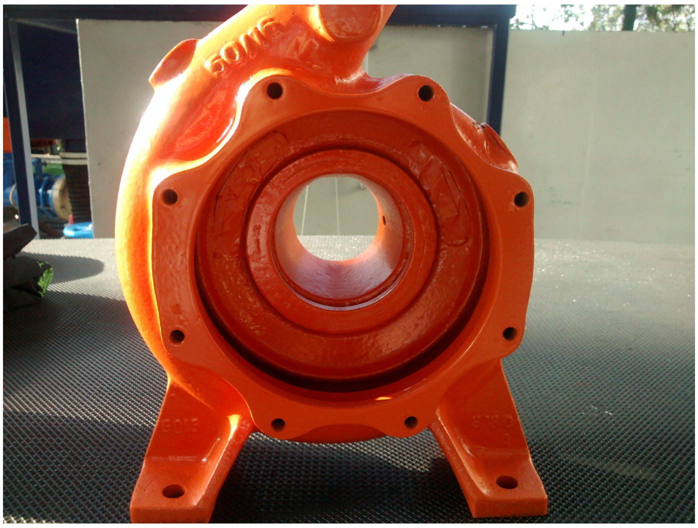


Figura 6.3: Pintura de la voluta.

Para solucionar este inconveniente se realizó un proceso de pulido a todas y cada una de las partes tanto de la voluta como del soporte posterior, con el fin de eliminar la corrosión encontrada.

Además para prevenir futuros inconvenientes se pintó de nuevo la bomba con pintura epóxica. Este proceso de pintura fue realizado en el Taller de Diseño, por parte del Técnico de Pintura, el resultado de este proceso se presentan tanto en la Figura 6.3 como en la Figura 6.4.

6.1.3 Impeler o Impulsor

Al igual que las superficies de flujo (ver Sección 6.1.2), el impeler o impulsor de la bomba se ha visto afectado por la corrosión (ver Figura 6.5), por lo que a este se le dio el mismo tratamiento de las superficies de flujo, realizando un pulido para luego pintar toda la superficie.

El proceso de pulido en el Impeler fue mucho más complejo y requirió más tiempo que el resto de superficies, pues se debía de respetar a cabalidad su geometría, pues realizar una modificación en sus ángulos de entrada o de salida, generan una alteración completa del comportamiento de la máquina, el impeler pulido se puede ver en la Figura 6.6.

En el proceso de pintura del Impeler entró en juego otro aspecto, pues además de pintarlo se aprovechó el hecho para marcar los álabes en diferentes zonas, con el fin, si en un futuro es posible, grabar en una cámara de alta velocidad los fenómenos ocurridos y mediante la demarcación realizada, poder identificar el comportamiento en cada álabe o en cada canal. El resultado final de pintura y demarcación se aprecia en la Figura 6.7.

Figura 6.4: Pintura de la voluta en la parte posterior.

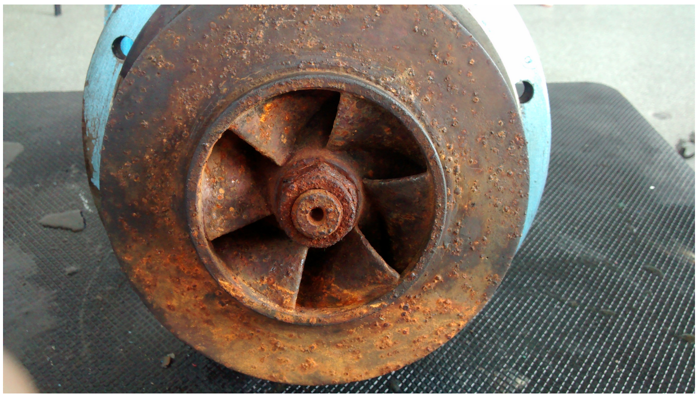


Figura 6.5: Impeler Corroido.

6.1.4 Sello Mecánico

Durante el mantenimiento de la bomba se presentó un inconveniente con el sello mecánico, pues este se fracturó totalmente durante su desmontaje, lo cual dejó inactiva la turbomáquina, en la Figura 6.8 se puede evidenciar este daño.

El sello se debió comprar nuevo para ser instalado, el proceso de compra del repuesto se realizó sin mayores contratiempos. Pero el inconveniente se debió a la situación de orden publico del país, dado que al momento del fallo se estaba llevando a cabo un paro camionero, lo cual hizo que los tiempos de entrega de el sello mecánico se triplicaran, pero al final se pudo solucionar y poner en marcha de nuevo la bomba.

Figura 6.6: Impeler Pulido.

6.2 Tuberías en Acrílico

Un aspecto que ayuda de manera positiva en la interpretación de un fenómeno es la visualización del mismo, si bien muchos fenómenos por su naturaleza son complejos de visualizar, el poder tener la facilidad de registrarlo gráficamente puede dar pie a una mejor comprensión del mismo y a la elaboración de mejores modelos o relaciones entre el fenómeno y sus variables.

Para nuestro caso la visualización de los fenómenos fluido-dinámicos de la turbomáquina, se tomó la decisión de cambiar las tuberías tanto de succión o zona de baja presión, como la de descarga o zona de alta presión; de *PVC* por acrílico transparente, dichas tuberías se presentan en la Figura 6.9.

Este cambio permite realizar la visualización de fases gaseosas dentro del flujo, tal como se puede apreciar en la Figura 6.10

6.3 Sistema de Adquisición de Datos

Como se presentó en la Sección 4.3, se implementaron varios códigos para la adquisición de los datos en las pruebas realizadas. Pero en el transcurso de dichas pruebas se encontraron nuevos problemas en los códigos, por lo que se realizó una nueva actualización a dichos códigos, principalmente al código del Laboratorio de Hidráulica y al código de adquisición de alta velocidad.

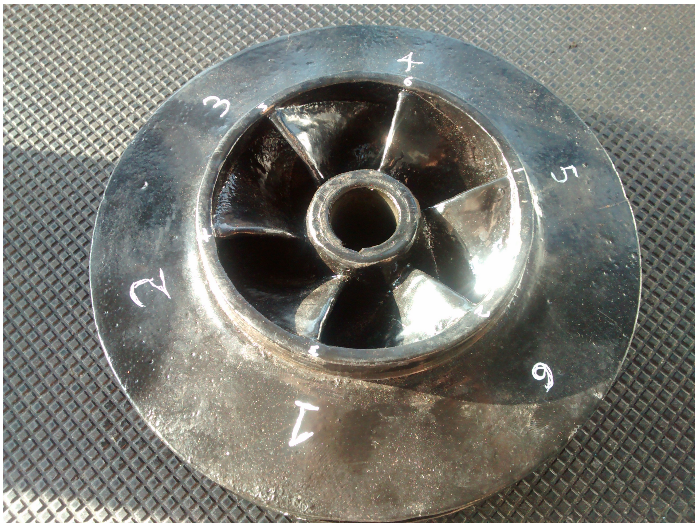


Figura 6.7: Impeler Pintado.

Figura 6.8: Fractura sello mecánico.

6.3.1 Nuevo código del Laboratorio de Hidráulica

Este código se debió actualizar por dos razones principales, la primera se debe a la centralización de sensores por parte del laboratorio, pues ya no se dispone de un sistema parcial móvil, si no de un sistema integral fijo donde se puede adquirir y controlar todas las variables del laboratorio, tales como sensores de presión, caudal y válvulas, como los variadores de velocidad de las bombas del sótano. Esto conllevo al cambio de las variables de entrada al código, pues los módulos cambiaron de posición en el *cRIO*, también se aprovechó para eliminar todos los ciclos de adquisición de datos, pues este se convirtió en un sistema de verificación de variables y control. La segunda razón del cambio radica precisamente en la condición de control, pues el sistema está diseñado para controlar las RPM de las bombas del sótano, lo cual hace que la construcción de curvas tipo "S" se realice de una manera mas

Figura 6.9: Tuberías en Acrílico.

rápida y eficiente. Así que este control de bombas se adicionó al software.

Estos dos cambios realizados hacen que el software se base exclusivamente en el control y monitoreo de las variables del laboratorio en tiempo real, pero en ningún momento se realiza adquisición de datos en este.

Su interfaz gráfica no se vio modificada.

6.3.2 Nuevo código de Adquisición de Datos

Los cambios en este código si bien fueron menores cambian significativamente su comportamiento, pues se le adicionaron 2 nuevos canales para adquirir señales en corriente, lo cual deja el sistema con 3 canales de señal en voltaje y 5 canales en corriente, todos sincronizados a la misma frecuencia de muestreo, lo cual permitirá realizar correlaciones entre más variables.

Estos fueron los cambios significativos del laboratorio y de la turbomáquina analizada, a continuación se presentan los nuevos resultados derivados de los cambios realizados.

Figura 6.10: Visualización de Fase Gaseosa.

Tabla 6.1: Ficha Técnica Sensor Dinámico de Presión

Propiedad	Valor
Variable a Medir	Presión Dinámica
Unidades	mV/PSI
Rango de Medición	0 a 100 mV/PSI
Lectura Mínima	0.007 PSI
Trazabilidad	No
Señal	Si

6.4 Cambios en los Sensores

A parte de los cambios en la máquina misma y en el sistema de adquisición de datos, se pudo invertir en un nuevo sensor dinámico de presión, el cual es descrito a continuación.

6.5 Sensor Dinámico de Presión

Los acelerómetros son, junto al tacómetro con señal, uno de los instrumentos más importantes instalados en la turbomáquina de prueba, pues estos sensores permiten realizar análisis de vibraciones y así diagnosticar de una forma no invasiva el estado de la turbomáquina; en la Tabla 6.1 se puede encontrar una ficha técnica resumida, y en el Apéndice A.12 se encuentra toda la información técnica referente a sensor de presión dinámica.

El sensor de presión dinámica tiene una señal de salida de 0 a $5V$, además poseen un acople roscado en su base que permite que sean fácilmente ajustables, como se aprecia en la Figura 6.11.

Este equipo debe de ser manipulado con bastante precaución, debido a su alta precisión y a su tecnología interna, por esta razón cuenta con su propio protector, como se puede observar en la Figura 6.11.

A parte de las nuevas pruebas hidráulicas, estos sensores se utilizaron en la prueba de análisis espectral que se le realizó a la turbomáquina, el cual es descrito en el Capitulo 7.

Figura 6.11: Sensor de presión dinámica.

Tabla 6.2: Ficha Técnica Medidor de Caudal por Ultra Sonido

Propiedad	Valor
Variable a Medir	Caudal
Unidades	l/s
Rango de Medición	-50 a 50 l/s
Lectura Mínima	0.01 l/s
Trazabilidad	Si
Señal	Si

6.6 Medidor de Flujo por Ultra Sonido

Como se presentó en la Parte 3.4, el medidor de flujo anterior no permite cuantificar los flujos en dos direcciones, lo cual lo volvía inviable para las pruebas que se llevan a cabo en el proyecto, por lo cual se tomó la decisión de cambiarlo.

El Coordinador del Laboratorio de Hidráulica, Jesus Alberto Pérez, realizó la adquisición de un medidor de flujo por ultra sonido no invasivo para diferentes diámetros y materiales de tuberías, el cual sí permite recolectar datos en ambos sentidos de flujo, este sensor se puede ver en la Figura 6.12, sus especificaciones técnicas se presentan en la Tabla 6.2 y su manual de operación se presenta en al Apéndice A.13.

Figura 6.12: Medidor de Flujo por Ultra Sonido.

7 Nuevas Curvas y Resultados Obtenidos

A continuación se presentan los resultados obtenidos después de los mejoramientos realizados al laboratorio:

7.1 Curva S

La curva S de las turbomáquinas permite conocer el comportamiento hidromecánico de la misma, pues esta curva se construye bajo ciertas condiciones especiales.

Para realizar esta curva se debe mantener la cabeza de la turbomáquina, o carga constante, con el fin de poder simular o hacer semejanza con un embalse en una central hidroeléctrica real.

En esta curva lo que varía son dos variables relacionadas entre sí, las cuales son el caudal y la velocidad de giro o rpm.

Además estas variables no se grafican directamente de esta manera, si no que se deben normalizar, mediante el cálculo de factores denominados factores de velocidad y de caudal, como se expresa en la norma NCh2966 la cual es la traducción del la norma internacional IEC 60193:99 [10].

Estas curvas se realizaron bajo dos cargas diferentes, a 4 y a 6 metros de altura, sus resultados se presentan en la Figura 7.1.

Además de las curvas comparativas entre diferentes cargas se realizó la curva S de los cuatro cuadrantes o cuatro formas de trabajo de una turbomáquina, la cual puede ser observada en la Figura 7.2. En esta figura se puede observar que se tiene un buen comportamiento de la turbomáquina, pero se ahondará más al respecto de los por menores de estos datos en la Sección 11 de resultados.

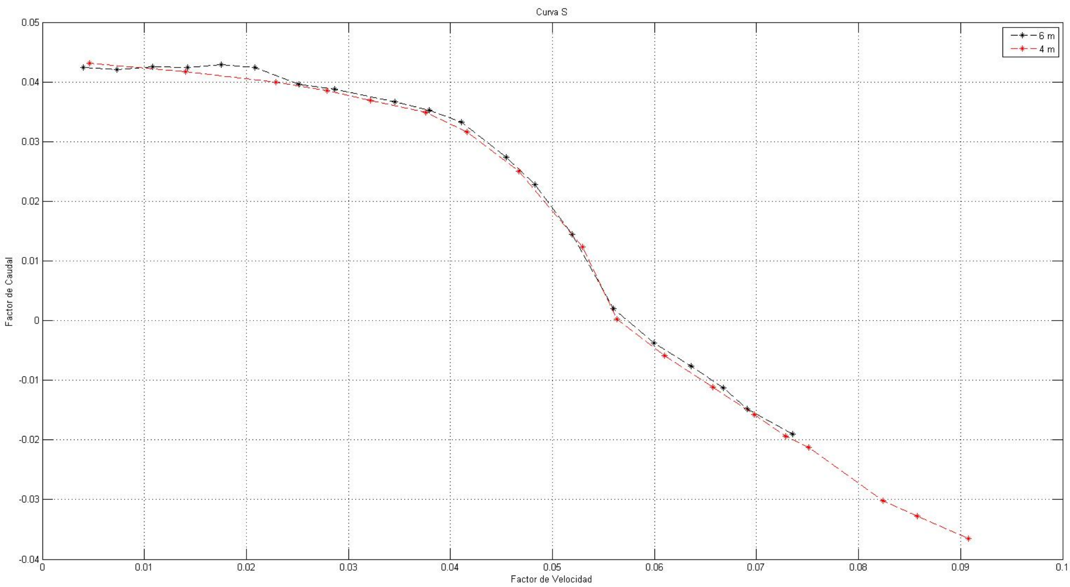


Figura 7.1: Curva S a 4 y 6 metros

7.2 Revolución Característica

Una ventaja que se tiene al poder analizar la señal completa de todos los sensores y estar estos sincronizados a su vez con la señal de velocidad o rpm, es que permite analizar que ocurre en cada revolución de la máquina, para poder comparar su comportamiento con respecto a otras variables, así pues, se puede ver como con un cambio en la velocidad como se ve afectada la variación de presión o de vibración.

Al tener estos datos y poder ubicarlos en un gráfico tipo *Waterfall*, donde se pueden ver estos elementos de manera más fácil y rápida, la cual se presenta en Figura 7.3

En esta figura (Figura 7.3) se puede ver que las lineas que son paralelas al eje de revolución no cambian con la variación de las rpm, lo cual indican que son constantes en la máquina; todas aquellas que lineas que no tienen este comportamiento si varían con la velocidad, lo cual puede indicar que dependen de la velocidad de rotación de la máquina.

Otro aspecto importante a resaltar son las amplitudes, a medida que mayor amplitudes aparezcan indican que mayores variaciones de presión o vibración se presenta, se espera que esto ocurra a mayores rpm, o aun mayor régimen de trabajo o carga.

Como se puede observar en la Figura 7.3, las mayores amplitudes en presión se presentan a 2000 rpm .

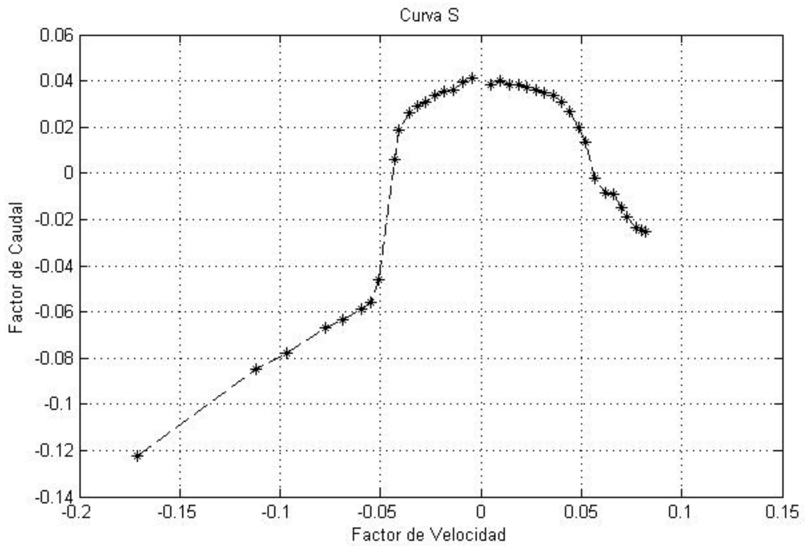


Figura 7.2: Curva S completa

7.3 Análisis Espectral

Después de los análisis realizados con los acelerómetros, y aprovechando el hecho del sensor dinámico de presión, se pudor realizar un estudio más detallado del comportamiento de la turbomáquina, realizando un análisis más detallado de las señales capturadas mediante los programas de adquisición de datos descritos previamente, con el objetivo ve revisar los modos o frecuencias que se pueden encontrar debidos a la operación misma de la máquina, el análisis espectral se realizó realizando una transformada de Fourier a la señal completa adquirida. El vector de frecuencias encontrado es dividido por la frecuencia de rotación de la máquina, con el fin de encontrar los órdenes de magnitud. Los órdenes de magnitud son las veces que pasa un fenómeno por revolución, es decir, si existen 6 álabes en la máquina, en una señal el paso de álabes es 6x, pues estos pasan 6 veces por cada revolución. Este tipo de análisis se pueden observar en la Figura 7.4.

Este análisis espectral permite encontrar componentes de vibración tanto sincrónicas como asincrónicas, además, por tener el sensor de presión dinámica se pueden encontrar componentes que solo dependen del fluido y no de la estructura misma de la máquina, lo cual ayuda en gran manera a entender el comportamiento mismo del fluido; mientras que los acelerómetros permiten ver tanto los efectos hidráulicos como estructurales.

7.4 Correlaciones

Una correlación cruzada entre señales permite conocer la injerencia de una señal sobre la otra, y para este caso, nos permite conocer si existe una relación directa entre las vibraciones medidas de la máquina y los fenómenos hidráulicos o debidos al fluido que se obtienen de las

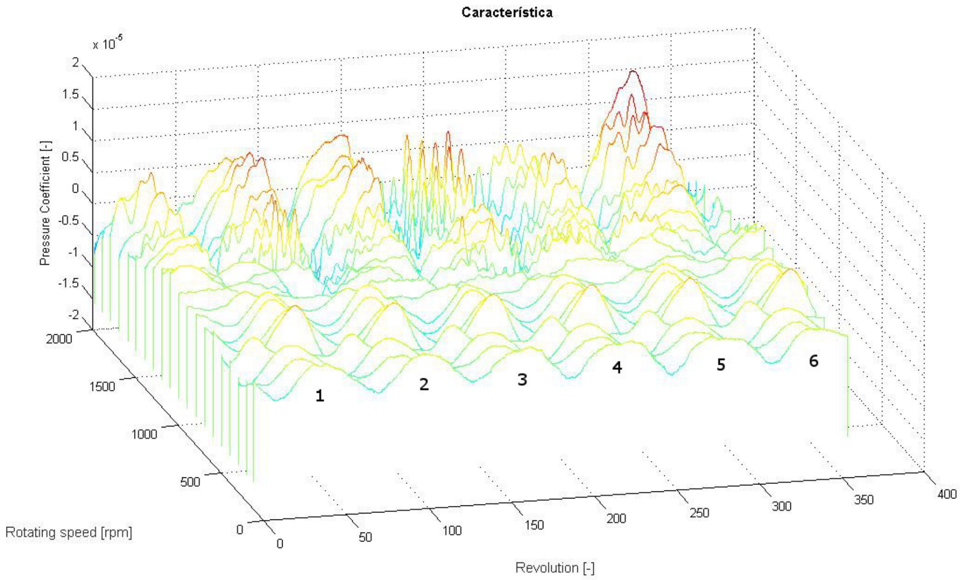


Figura 7.3: Revolución Característica

variaciones de presión adquiridas por el sensor dinámico.

Debido a que ambos sensores no están ubicados en la misma posición y existe un ángulo de desfase entre estos, se espera que la mayor correlación entre ambos sensores aparezca a un tiempo igual al que le toma un álabe pasar entre ambos sensores, pues si estos estuvieran en la misma posición la mayor correlación se presentaría en un tiempo igual a cero, que equivale a poner una señal encima de la otra, se puede ver la correlación entre señales en la Figura 7.5; además en esta Figura se puede ver que existe una diferencia entre las señales de $0.0001748 segundos$, que es el tiempo que se tarda el álabe en pasar por el sensor dinámico y el acelerómetro.

Después de realizar todos estos análisis y curvas se sintentizó el trabajo realizado en un artículo científico, el cual es presentado en el Capítulo 10.

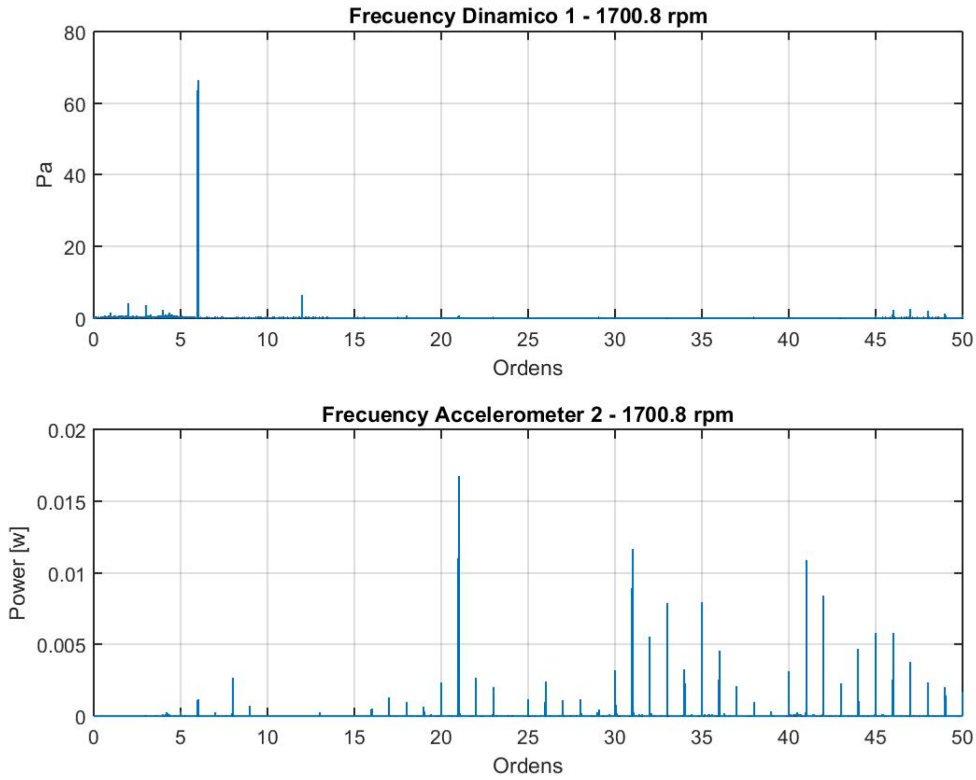


Figura 7.4: Espectro de las señales

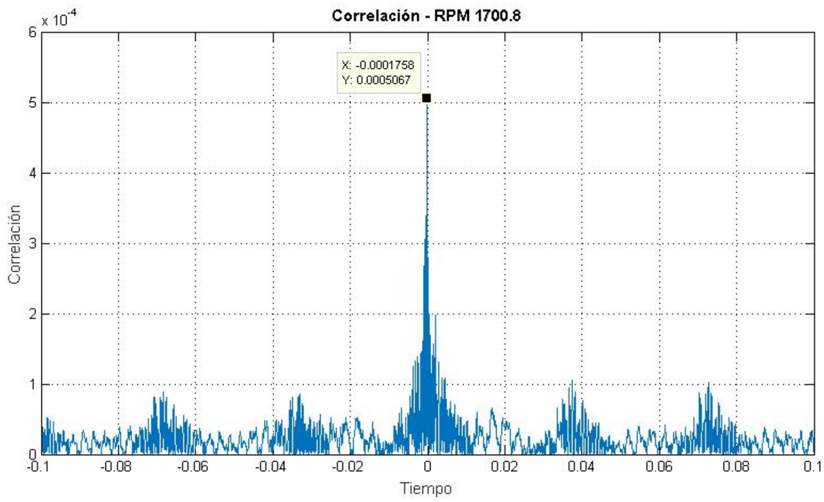


Figura 7.5: Correlación de Señales

Simulación Part II

8 Simulaciones

Otro gran aspecto del proyecto son las simulaciones numéricas, en especial las enfocadas al análisis de vibraciones de un álabe típico de turbo maquinaria, dichas vibraciones fueron analizadas de manéra experimental en la primera parte del proyecto, y al ver la importancia de estas se decidió ahondar en su causa raiz, puesto que los álabes de cualquier turbomáquina oscilan debido al paso del fluido, tal como fue encontrado por Ausoni [11]; además en este trabajo se pudo encontrar una relación entre la velocidad del fluido y la frecuencia de salida de los vórtices de *von Karman*, los cuales se pueden sincronizar a la velocidad de oscilación del álabe. Este último fenómeno llamado *Lock-In* es el interés de estudio en la parte de simulación de este trabajo.

8.1 Descripción del Experimento

Como se planteo anteriormente, el trabajo de Ausoni [11] será la guía para este análisis numérico, así pues lo primero que se realizó fue la digitalización del álabe analizado, para tener las mismas geometrías que en el experimento real, este modelo se puede observar

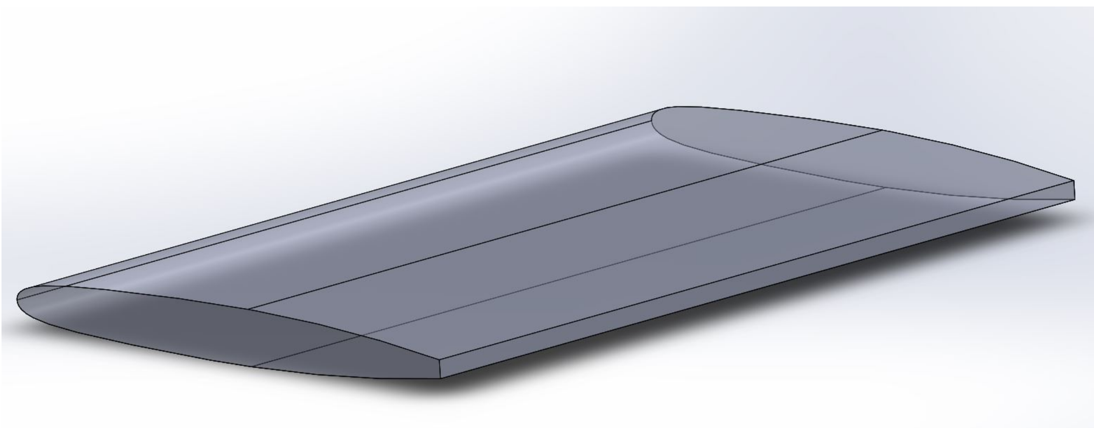


Figura 8.1: Alabe 3D.

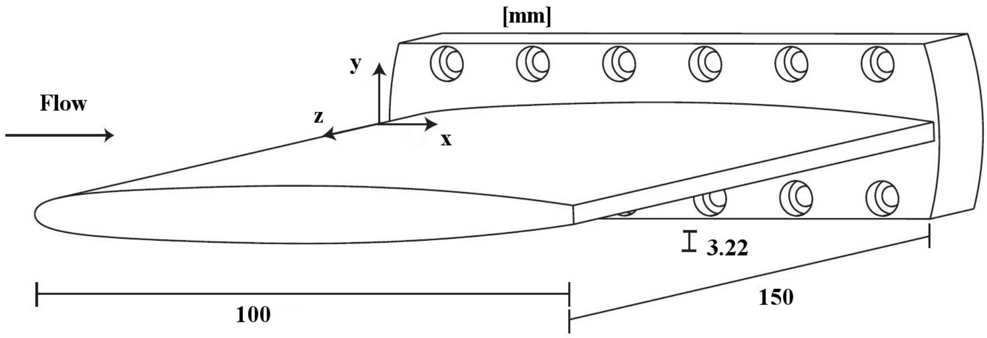


Figura 8.2: Alabe 3D con dimensiones.

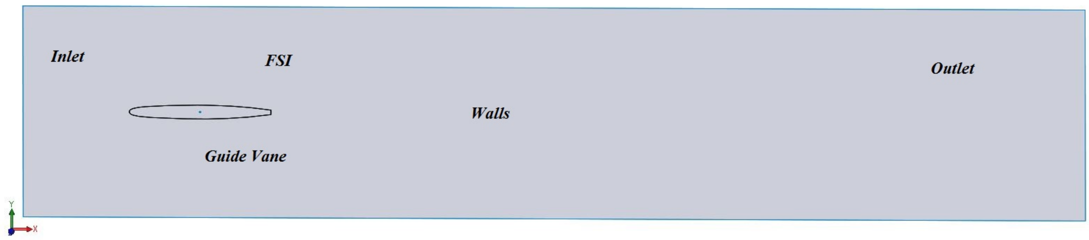


Figura 8.3: Alabe 2D.

en la Figura 8.1, este trabajo de digitalización fue realizado previamente por Ausoni [11] y Hasmatuchi [12], donde las dimensiones de este álabe se presentan en la Figura 8.2.

Esta geometría $3D$ se simplifica a una geometría 2D, en la que se mantienen las condiciones de geometría, tal como se puede observar en la Figura 8.3. Así pues los objetivo de la simulación es recrear los vórtices y el acople hidroacústico del álabe y el fluido; para conocer cual es la zona indicada para instalar un sensor dinámico que capte los vórtices; y para recrear numéricamente el fenómeno de *Lock-In* entre el fluido y el álabe.

8.1.1 Condiciones Iniciales

Las condiciones iniciales son cruciales para tener una convergencia de solución mucho mas rápida. Dos condiciones iniciales fueron impuestas:

- La primera fue iniciar la velocidad del fluido por todo el dominio, con un una función parabólica como se presenta en la Ecuación 8.1. Donde V_x es la componente de la velocidad en la coordenada x, V_i es la velocidad máxima inicial del perfil, y y es la coordenada y del punto.

- La segunda condición inicial se impuso al álabe, al cual se le dio una deformación o desplzasamiento inicial en base a la Ecuación 8.2. Donde δ_y es la deformación inicial en la coordenada y, y donde x es la coordenada x del punto.

$$V_x = V_i \times \frac{1 - y^2}{5626} \tag{8.1}$$

$$\delta_y = 1 - \frac{x}{50} \tag{8.2}$$

8.1.2 Condiciones de Borde

Las condiciones de borde son de vital importancia para poder tener una solución del sistema de ecuaciones planteado, pues estas son las que permiten tener una solución particular de nuestro problema, en este orden de ideas se impusieron las siguientes condiciones de borde:

- En la parte superior y en la parte inferior se tiene una condición tipo *Wall* o de pared.
- En la arista derecha la velocidad fue impuesta en el eje y con un valor de $V_y = 0.0$, puesto que esta arista es la salida del fluido.
- En la arista izquierda, la cual funciona como la entrada del fluido, se impone dicha velocidad de entrada en la componente x como se muestra en la Ecuación 8.1. Cabe aclasrar que el valor V_i es la velocidad deseada, en un rango que puede ir desde 1 hasta $20m/s$.
- Las últimas condiciones de borde y tal vez las más importantes se ubican sobre las aristas del álabe. La primera de ellas llamadas Interacción Fluido Estructura, conocida por sus siglas en ingles *FSI*, es la que permite realizar el acople Fluido-Estructura. La segunda condición es la actualización de malla, la cual permite que los desplazamientos de los nodos en el borde estructural sean los mismos que en el borde del fluido.

Todas estas condiciones se pueden ver en la Figura 8.4.

8.1.3 Materiales y sus Propiedades

En estos análisis numéricos se utilizaron dos materiales ,el Agua y el Acero, sus principales propiedades están expresadas en la Tabla 8.1.

8.1.4 Análisis Numérico

Para realizar el análisis numérico se utilizó el Método de los Elementos Finitos, *FEM* por sus siglas en inglés. Y para resolver este estudio se utilizó el Software Elmer [13], el cual permite

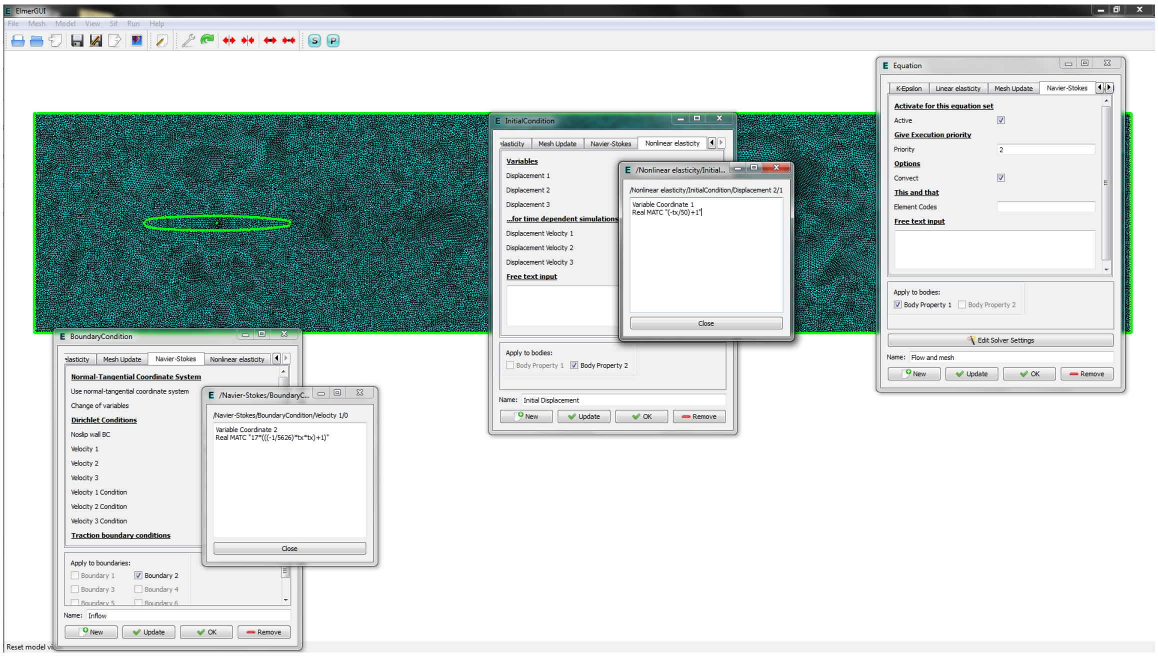


Figura 8.4: Condiciones de borde e iniciales en Elmer.

Tabla 8.1: Propiedades de los Materiales

Agua		Acero	
Densidad [kg/m^3]	998.3	Densidad [kg/m^3]	7850
Viscosidad [Pa*s]	1.002e-3	Velocidad del Sonido [m/s]	5100
Velocidad del Sonido [m/s]	1497	Módulo Elástico [Pa]	200e9
Módulo Elástico de Malla [Pa]	1.0e9	Módulo de Poisson	0.285
Módulo de Poisson de Malla	0.3		

analizar problemas multifísicos, además, de poder controlar los métodos y condiciones de solución.

Otro Software utilizado fué Gmsh [14], el cual permite realizar y generar todas las mallas utilizadas para todos y cada uno de los análisis evaluados.

Debido a la complejidad del problema estudiado se hace necesario utilizar un poder computacional elevado en comparación al desarrollado por un computador de escritorio. Este equipo de gran capacidad fue proporcionado por el Centro de Computación Científica de la Universidad Eafit APOLO [15], el cual tiene una capacidad instalada de 420 nodos.

8.1.5 Mallas

Como se mencionó en la sección anterior, las mallas fueron realizadas en el software Gmsh [14], en el cual se diferenciaron dos zonas importantes en la geometría a analizar, la primera

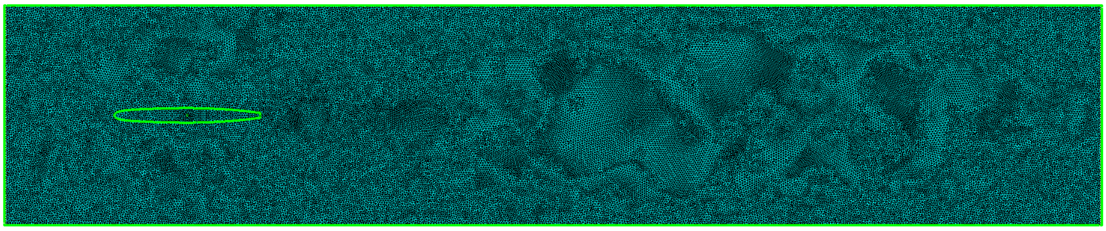


Figura 8.5: Malla Completa.

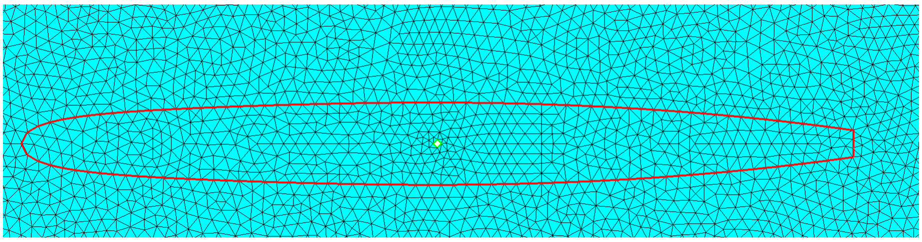


Figura 8.6: Malla Refinada.

zona para el análisis estructural del álabe, mientras que la segunda para el análisis de fluidos.

Una parte importante era la zona del *FSI* que realiza la unión entre la parte estructural y la parte de fluidos, en esta zona en particular se realizó un refinado de malla, para que la convergencia y exactitud fueran más altas y estables, la malla completa se puede apreciar en la Figura 8.5, donde también se puede observar que se realizó una malla no homogénea con el fin de que no se perdiera las fluctuaciones de presión y velocidad que son simétricas con respecto al eje central de la malla.

La malla refinada se puede observar en la Figura 8.6, donde en la zona roja se generan los fenómenos de capa límite, que son fundamentales para la generación de los vórtices de *von Karman*, principal interés de este análisis, por esto, esta zona tiene una malla con mejores propiedades que el resto.

8.1.6 Incremento en el Tiempo

El incremento en el tiempo o *Time Step* es el valor que determina cuantos segundos se avanza en la simulación por cada paso que esta da. Inicialmente este tiempo va directamente relacionado con la complejidad del problema y con los niveles de convergencia que se desean tener de la solución calculada por Elementos Finitos, así pues determinar este valor depende principalmente de este no genere problemas ya sea de aproximación (valores muy grandes) o de punto flotante (valores muy pequeños).

En este caso, a parte de que estas dos condiciones se cumplan, también se deben cumplir dos condiciones adicionales, la primera es que efectivamente se generen los vórtices, y la segunda

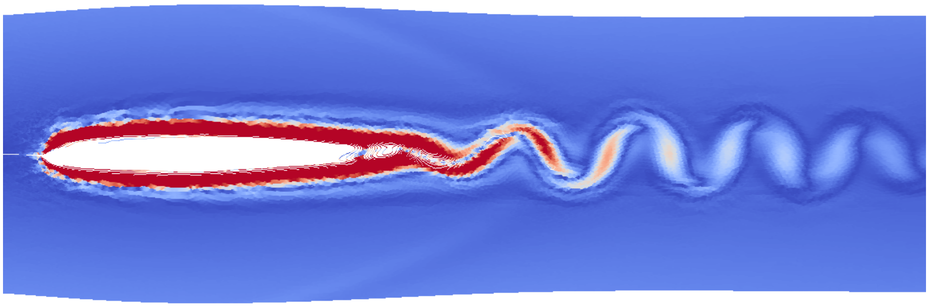


Figura 8.7: Vórtices de *von Karman* generados.

que la frecuencia del paso del tiempo cumpla la ley de Nyquist [16], para poder realizar análisis en frecuencia de los fenómenos encontrados.

Dado esto se impuso un incremento de 0.02 segundos.

8.2 Resultados de Simulación

Como se mencionó anteriormente, se desarrollaron dos experimentos numéricos, dichos resultados se presentan a continuación.

8.2.1 Resultados de la Ubicación de un Sensor Dinámico

El primer experimento analizado fue el de encontrar la ubicación de un sensor dinámico que fuera capaz de recibir las fluctuaciones debidas a los vórtices de *von Karman*.

Se realizaron simulaciones cambiando la velocidad de entrada, la cual varió entre 10 y 20m/s, en todos los casos se formaron los vórtices deseados, un ejemplo típico se presenta en la Figura 8.7, y un zoom de estos vórtices en la zona del desprendimiento se puede observar en la Figura 8.8.

Todos estos vórtices generan ondulaciones en la presión, si se grafícan estas variaciones en el borde de la simulación, que hace referencia a la pared de tubería que contiene el fluido, y además se cambian las velocidades se obtiene un comportamiento como se ve en la Figura 8.9.

Como se puede ver en la Figura 8.2, la longitud del álabe es de 100mm, además el álabe empieza en la coordenada 0 de la Figura 8.9, lo que hace que las fluctuaciones de presión tienen un máximo entre 200 y 300mm, lo que corresponde a una distancia de una y dos veces la longitud del álabe después de este, lo cual hace estas distancias ideales para la colocación de un sensor dinámico.

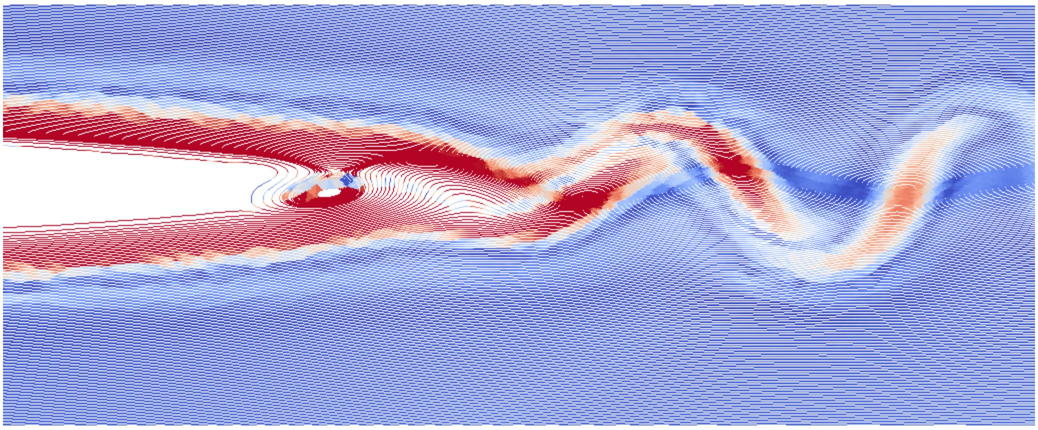


Figura 8.8: Vórtices de *von Karman* en el desprendimiento.

Si bien de la Figura 8.9, se puede observar que después de $300mm$ se siguen presentando las fluctuaciones de presión, pero estas van disminuyendo a medida que se alejan de el álabe, dependiendo de la sensibilidad del equipo dinámico podría seguir detectando estas fluctuaciones, pero lo mejor es adquirirlas en la zona donde estas son más fuertes, que es entre una y dos veces la longitud del álabe aguas abajo de este.

8.2.2 Resultados Acople Hidro-Acústico

El acople Hidro-Acústico o fluido-estructura relaciona la vibración del álabe con la salida de los vórtices de *von Karman*.

Para que este acople sea completo se deben de cumplir dos condiciones, la primera es que la vibración del álabe no se atenúe con el tiempo, si no que se mantenga, o bien estables, o bien se amplifiquen debido a las fuerzas del fluido. La segunda condición es que la frecuencia de generación de vórtices debe de coincidir, en gran medida, con la frecuencia de vibración del álabe.

Dadas estas dos condiciones primero analizaremos la de atenuación de la vibración con el tiempo.

Oscilaciones del álabe

Desde las primeras pruebas realizadas la generación de vórtices siempre estuvo presente, lo que se debió ajustar fue la oscilación del álabe mediante el tiempo de simulación y luego mediante el desplazamiento inicial para hacer que este fenómeno se generara más rapidamente.

En estos procesos iterativos se obtuvieron oscilaciones del álabe como la presentada en la Figura 8.10, donde se grafíca el desplazamiento vertical de la punta del álabe con respecto al tiempo de simulación.

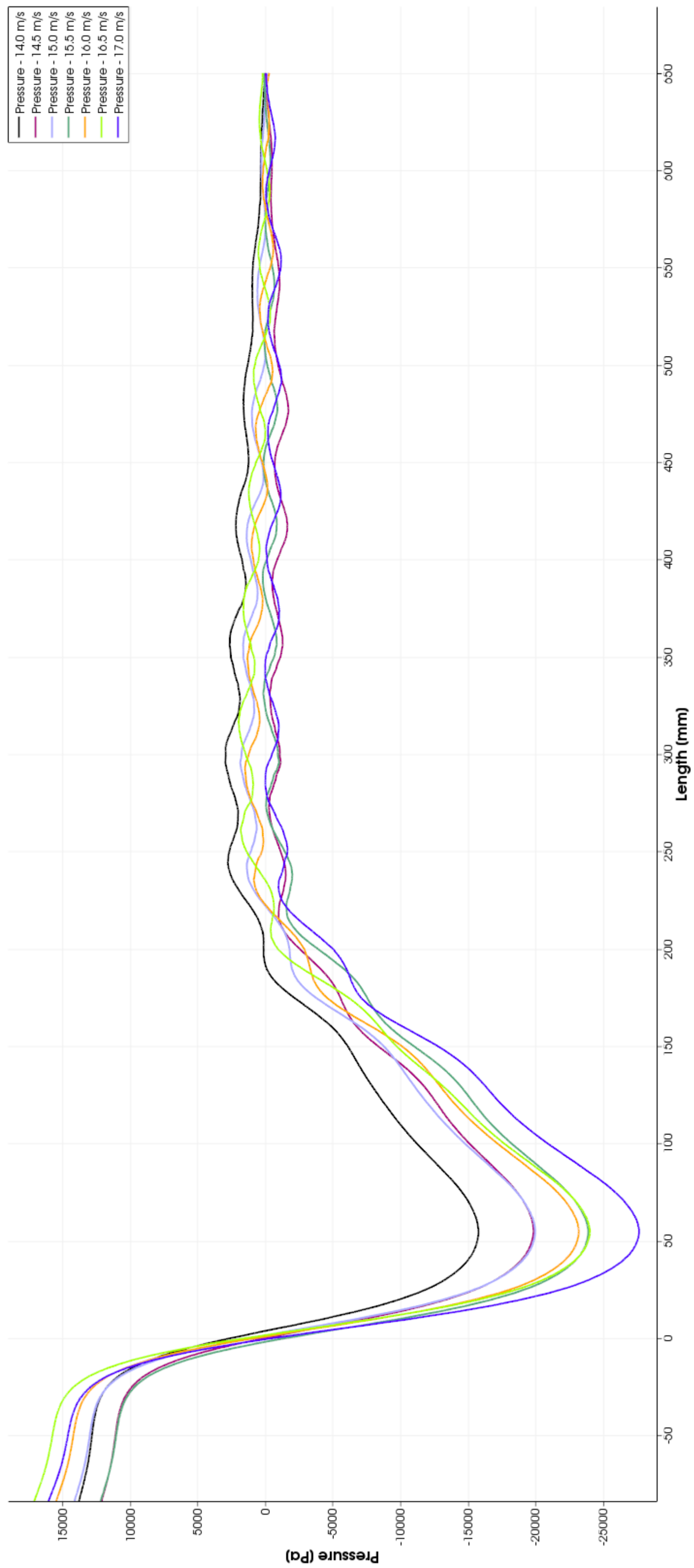


Figura 8.9: Presiones en la pared.

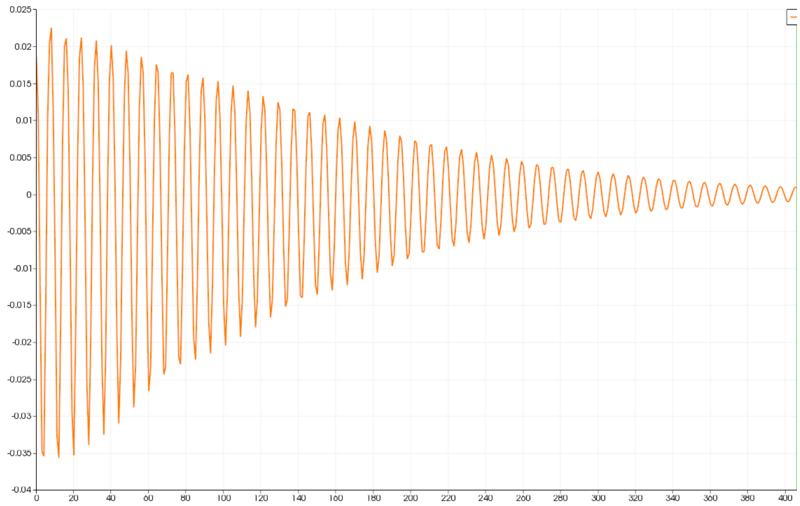


Figura 8.10: Desplazamiento no Acoplado del Álabe.

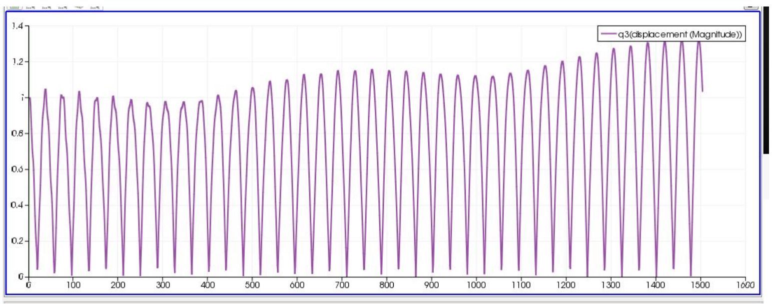


Figura 8.11: Desplazamiento Acoplado del Álabe.

De aquí podemos ver claramente cómo es atenuada esta oscilación, lo cual indica que no hay un acople entre las fuerzas debidas a las presiones del fluido sobre el álabe que hagan que este entre en resonancia con el fluido.

Otra interpretación que se le puede dar a la Figura 8.10, es que al final solamente sobrevive el módulo de oscilación natural del álabe correspondiente, así el tiempo de simulación se debe extender para ver que ocurre con este módulo. Al realizar esta comprobación se llegó a la conclusión que las oscilaciones si llegan a estabilizarse en una frecuencia dada por completo, aunque el tiempo de atenuación se incrementa considerablemente, por lo que se debe saltar esta etapa no estable y alcanzar el estado estable mediante el proceso descrito a continuación.

El siguiente proceso fue hacer posible el acople de oscilación del álabe, esto se realizó variando el valor de la deformación inicial planteada en la Ecuación 8.2, partiendo desde una deformación inicial de $2mm$ hasta no tener deformación inicial.

Modificar este item de deformación inicial lo que hace es, para una misma velocidad, reducir el tiempo de simulación, saltando toda la etapa fluctuante y llegar más rápido al estado de oscilación estable.

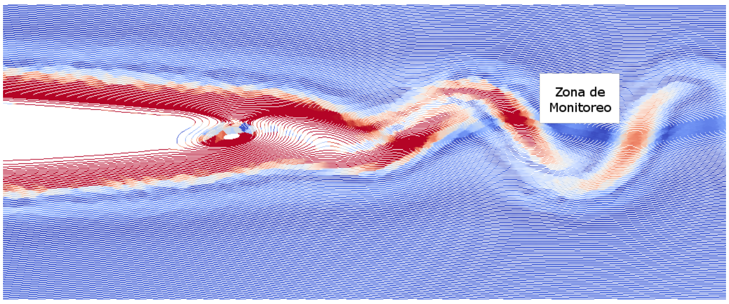


Figura 8.12: Posición de Monitoreo.

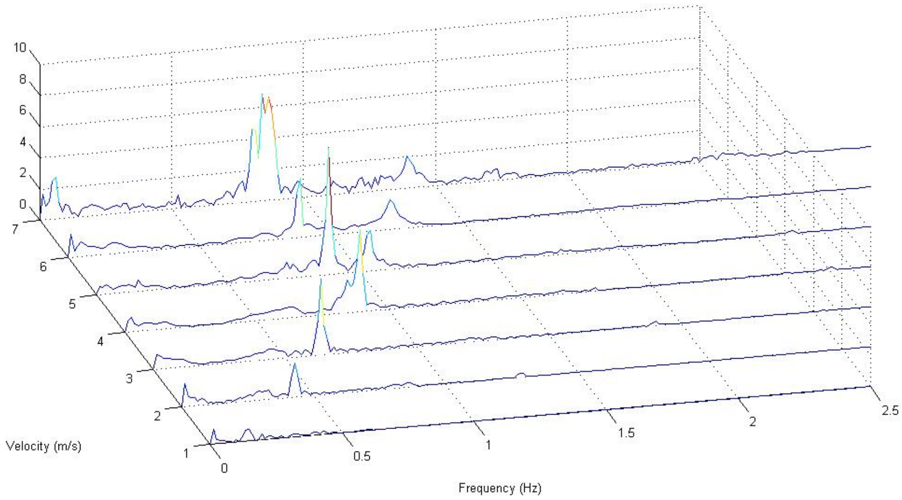


Figura 8.13: Frecuencia de Salida de Vórtices.

Después de un gran número de iteraciones se pudo llegar a resultados como los presentados en la Figura 8.11, donde esta oscilación se vuelve completamente estable, e incluso con el paso del tiempo se ve como se amplifica poco a poco debido a la resonancia con las cargas debidas a las fluctuaciones de presión generadas por los vórtices de *von Karman*.

Frecuencias de Oscilación

Luego de que las oscilaciones fueron generadas de manera estable, se empieza a revisar los vórtices generados, colocando un punto de monitoreo a una distancia de una vez el álabe, como se muestra en la Figura 8.12, además no se toma en la parte central para poder ver el paso de ambos vórtices.

Al realizar este monitoreo y variar la velocidad del fluido se varía la velocidad de entrada del fluido, desde 1 hasta $9m/s$, verificando la frecuencia de salida de álabes, en la Figura 8.13 se pueden observar los resultados obtenidos.

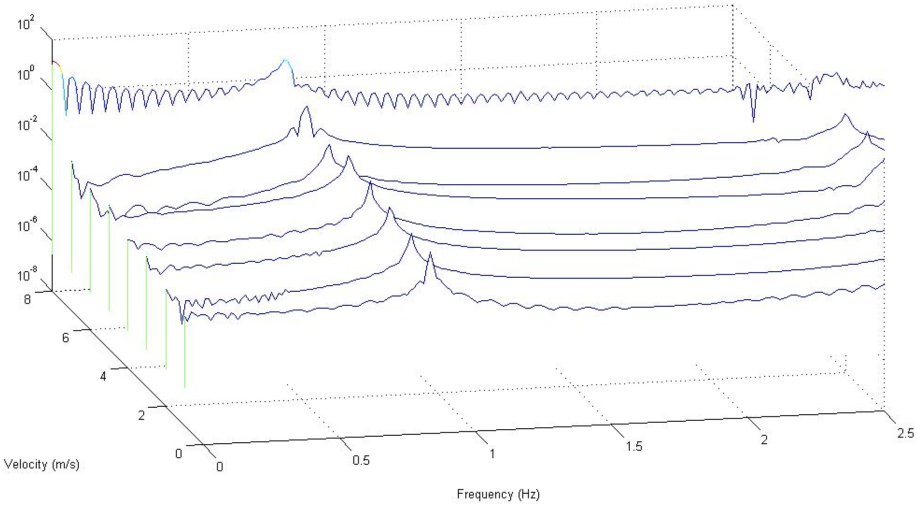


Figura 8.14: Oscilaciones del Álabe.

Además se revisó la frecuencia de oscilación del álabe, como se muestra en la Figura 8.14, la cual permite ver que la frecuencia de oscilación muestra que este está alrededor de 0.8 y 1.0Hz. Si se compara este valor con el presentado en la Figura 8.13 se puede ver que alrededor de los 0.85Hz se bloquea la salida de los vórtices, fenómeno conocido como *Lock-in*.

El artículo científico derivado de esta investigación se presenta en el Capítulo 10

Ponencias, Artículos y Conclusiones Part III

9 Estado del Proyecto y Ponencias

9.1 Objetivos Cumplidos

De los objetivos propuestos desde el principio del proyecto interno se presentan a continuación con su porcentaje de cumplimiento estimado.

- Selección de una turbomáquina hidráulica piloto, típica o representativa de centrales hidroeléctricas en Colombia y/o el mundo. 100%
- Construcción del estado del arte referente a PAT y de la técnica asociado al monitoreo y diagnóstico técnico de turbomáquinas hidráulicas. 100%
- Identificación de los fenómenos y fallos a ser monitoreados de acuerdo con el estado del arte, el estado de la técnica y la turbomáquina piloto, seleccionada para el estudio. 90%
- Definición de las principales variables relacionadas con los fenómenos y fallos identificados. 75%
- Desarrollo de las curvas experimentales para la PAT seleccionada. 100%
- Generación del Código para procesar los datos adquiridos en la parte experimental. 100%
- Simulación acoplada fluido-estructura. 100%
- Simulación (mallas y pruebas iniciales). 100%
- Simulaciones definitivas. 100%

9.2 Ponencias

De los resultados obtenidos del proyecto se presentó una ponencia para el *II Latin American Hydro Power and Systems Meeting* que se realizó los días 28 y 29 de Abril en la Universidad de La Plata en la cuidad de La Plata, Argentina.

El certificado de asistencia como ponente se presenta en el Anexo A.14.

Además se realizó la invitación al grupo latinoamericano de trabajo, en el Anexo A.15 se encuentra la carta de invitación.

En el Desarrollo del congreso se pudo realizar contactos internacionales principalmente con:

- Dr. Gerardo Lúcio Tiago Filho Secretario Ejecutivo del Centro Nacional de Referencia en Pequeñas Centrales Hidroeléctricas, Minas Gerais, Brasil.
- Ing. Sergio Liscia Director de la carrera Ingeniería Hidráulica, Universidad de la Plata, Argentina.
- Ing. Cecilia Verónica Lucino Investigadora, Universidad de la Plata, Argentina.
- Prof. Mohamed Farhat Investigador, École polytechnique fédérale de Lausanne, Lausanne, Suiza.
- Victor Hidalgo Investigador, State Key Laboratory of Hydroscience and Engineering, Tsinghua University, Beijing, China
- Ph.D Ing. Efraín Del Risco Investigador, Universidad del Valle, Cali, Colombia.
- G. Delgado Investigador, Universidad Michoacana de Sán Nicolás de Hidalgo, Morelia Michoacán, México.

10 Articulos derivados del proyecto

En este capítulo se presentan los dos artículos derivados del proyecto de investigación, ambos en proceso de publicación, por lo cual fueron redactados originalmente en el idioma Ingles, por esta razón son presentados en ese idioma.

10.1 Artículo derivado de la experimentación

Evidence of Rotating-Stall in Pump-as-Turbine System With Stable Characteristics

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Abstract

An experimental research turbine-pumps in a scale model was developed. The S-shaped characteristic curve of the turbo machine was analyzed in order to determine their behavior was constructed. Different point were analyzed, such as higher efficiency, runaway and points away from the optimum design point. It was evident that the machine has a sloping curve always negative; also a sub-synchronous system instability identified, evidenced both invasive sensors such as non-invasive.

Keywords: Turbo machinery, Rotary Instability, Pump-Turbines, Experimental, Rotating Stall

1. Introduction

Reversible hydraulic turbomachinery, for decades in anonymity, has begun to play an important role in the scenario of a world concerned about the production of clean and renewable energy [1, 2, 3]. They arise as suitable candidates to facilitate the inclusion of emerging clean and renewable technologies to the grid, while providing autonomous generation [4, 5, 6]. Energy captured from the sun, wind and tides, among others, is often irregular and intermittent. Therefore, connection to the grid is not straightforward. Instead, it can be firstly stored in the form of elevated water (gravitational potential energy) using a pump, and then, when it is the opportune time, such energy can be harnessed by a turbine providing the required power stability to make it available in the grid. Both functions can be performed by the same reversible hydraulic turbomachine, i.e. a pump-turbine. However, this advantage is in fact a compromise between the efficiency of the machine and the avoidance of harmful phenomena [7, 8, 9].

An undesired phenomenon affecting pump-turbines is the so-called rotating-stall (RS) . It could happen before synchronization, when stable runaway operation is needed in order to guide the machine up to the proper frequency and phase [10]. However, due to the violence of the flow and increased pressure fluctuations [11], this procedure can not be safely achieved. Sudden load rejection, and the intensification of structural vibrations are some of the symptoms with unwanted economic consequences. RS is associated with reversible turbomachines that exhibits unstable operation. fig. 1 shows a comprehensive representation of the characteristics in terms of dimensionless discharge (Q_{ED}) and rotational speed (n_{ED}) as described in the international standard IEC 60193 [12] and introduced in eq. (1) and eq. (2) as function of the impeller outler diameter D, the specific hydraulic energy of the machine E, Flow Q, and rotational speed n.

$$n_{ED} \; 84 \; \frac{N}{\sqrt{E}} \tag{1}$$

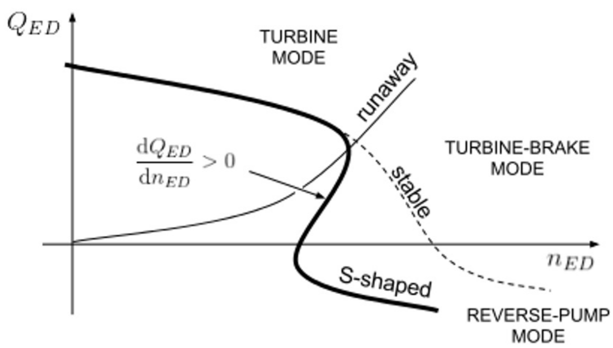

Figure 1: Q_{ED} vs n_{ED} characteristics.

$$Q_{ED} = \frac{Q}{D^2\sqrt{E}} \tag{2}$$

The machine is said unstable when it's characteristics own a S-shaped region; i.e. a positive slope in the turbine-brake mode. This operation mode is bounded by the runaway curve and the line of zero discharge. Theoretically, a S-shape is not a function because some elements of the domain are projected on more than one element of the image; in the practice, it corresponds to unstable operation with vortices and backflow dominating the flow patterns [13, 14, 11].

Centrifugal pumps, that work under the fundamental equation of turbomachines (Euler) [15], can be operated in reverse as well, in order to harvest energy from a flowing stream. In fact, such implementation is known as pump-as-turbine (PAT). They have numerous advantages over purpose-made pump-turbines for micro and pico-hydro power generation. Since they are mass-manufactured, they are low cost, they are available at standard sizes for a wide range of appliances, spare parts are easy available, etc [16]. Nonetheless, there are some drawbacks related to the design of impeller blades and the lack of wicket gate [17], operation is reduced to a narrower range of flow rates and unforeseen phenomena might appear reducing the lifespan of the installation; i.e. rotating-stall.

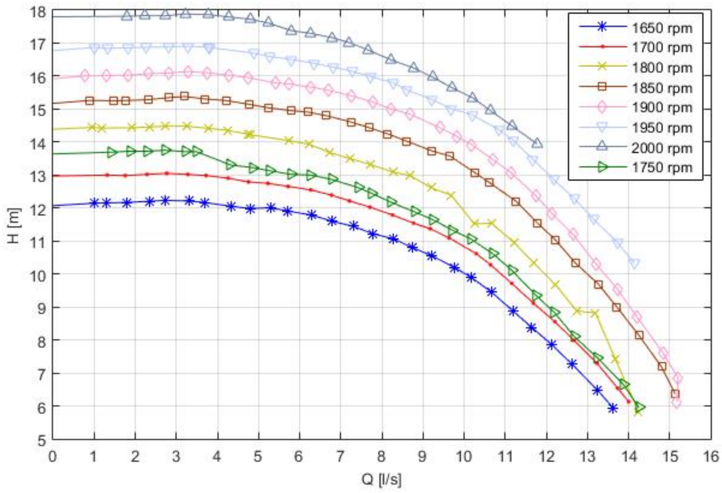

Figure 2: Characteristics curves of the pump-turbine.

Table 1: Properties of the impeller.

Property	**Value**
Impeler type	Closed Channel
Impeler diameter, D	$\sim 152.4mm$
Number of blades, b	6
Inner diameter, D_i	$\sim 63.5mm$
Outer diameter, D_o	$\sim 50.8mm$
Inlet angle, α	$\sim 67°$
Outlet angle, β	$\sim 23°$
Nominal rotating speed, n	$1750rpm(29.16Hz)$
Nominal power	$2.7kW$

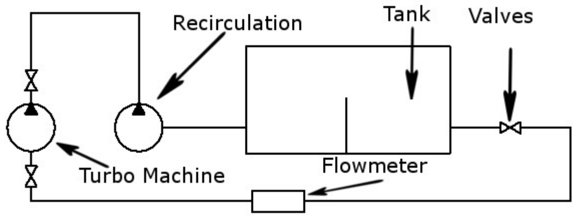

Figure 3: Diagram of the hydraulic circuit.

While hydropower is the largest source of clean and renewable energy worldwide, it is vital to continue guaranteeing the stability and security of the grid, specially when introducing irregular power sources. PAT can be an ideal candidate to allow small scale integration of emerging environment-friendly energies with the grid [18]. For instance, if they are implemented in pumped-storage plants, intermittent eco-power could drive the system in pumping mode to storage water at a higher level; later, it is released, operating in turbine mode, to feed the grid with the required power quality. However better understanding of hydrodynamic phenomena that might occur in PAT is mandatory to develop further maintenance procedures and diagnostic techniques. In that way, the appropriated exploitation of such machines is ensured, especially at off-design conditions.

Hence, this work is an experimental investigation of RS in a centrifugal pump with stable characteristics when running as turbine. Pressure fluctuations along with structural vibrations measurements were taken focused in the turbine-brake mode. The best efficiency point (BEP), runaway and zero discharge were considered as reference operating conditions. Some light is shed on a non-invasive technique that could be used to detect and characterize RS. Although investigations involving such phenomena are found in the literature from more than 30 years ago, they are related to pumps [19] and pump-turbines [20, 21], but not to PAT which is an interesting case study as follows.

2. Experimental Setup

A commercial 2.7 kW pump reference NOWA 5016 BN.CD2.0B.2 is fitted in the universal test rig for hydraulics systems of EAFIT University. This turbo machine can deliver a maximum discharge of $18l/s$ and a maximum head of 19 meters water column (mWC). The actual performance curves of the pump can be observed on fig. 2.

The pump features a closed channel impeller with 6 blades and outer diameter $D_o = 50.8mm$; further details are listed in table 1. Sense of rotation and speed were controlled through a frequency converter reference Mitsubishi FR-E700-203605 and elastomeric couplings are employed to isolate vibration and provide misalignment capacity.

The test rig is equipped with a recirculation system that can deliver up to $42.5kW$ and approximately $50mCW$ head. It was conceived to assess hydraulic performance of low to medium power turbo machines and components of hydraulic systems. The configured circuit is schematically illustrated in fig. 3. It is a closed-loop consisting of recirculation pumps, control valves, a reservoir and the device under test (PAT). Special attention was paid to the technical specifications stated in the IEC 60193 [12] for experimental purpose.

Specific instrumentation was adopted in order to collect evidence that helps describing the behavior of the hydrodynamic phenomena that may come to occur during the experiment. Dynamic pressure sensors were flush installed around the volute in a regular pattern; such configuration is intended for detecting the occurrence of RS, discerning the number of stalled cells and recover its kinematics.A pair of accelerometer, radially oriented, were also installed in the volute, close to the dynamic pressure monitoring locations, in order to correlate signals taken from mechanical and hydraulic signals in nature.

In addition to the sensors mentioned above, an optical keyphasor is installed to provide a once-per-revolution signal. This is particularly important to determine the required phase-timing information. Firstly, the position of the shaft and therefore the impeller can be known at any time; that is, passing blades can be correlated with the monitored signals during each rotation establishing reference framework to characterize the flow in the interior of the turbomachine. Secondly, rotational speed of the turbomachine for the respective operating point can be recovered; it is crucial because the experiment involves points at different rotating speeds.

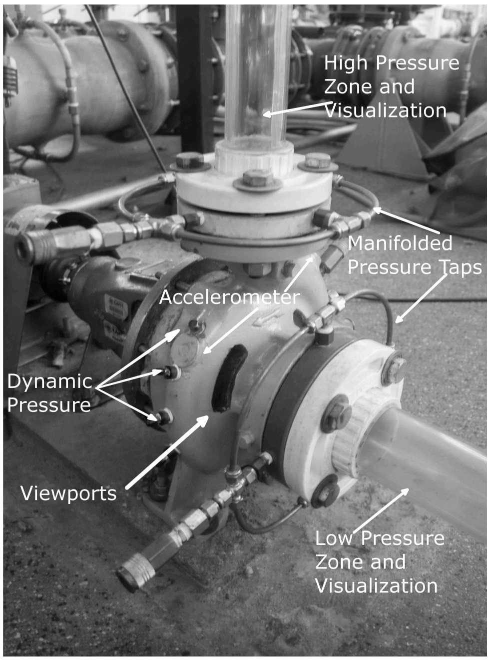

Figure 4: Installation of the pump-turbine.

The experimental setup can be seen in fig. 4. The monitoring points for dynamic pressure and vibration are marked on the spiral casing. Note that one of the accelermetes is between two consecutive pressure sensors: this helps to identify the source of the fluctuations in the signals: hydraulic or mechanical. Accelerometers are rigidly mounted. Dynamic pressure probes are mounted with their membranes flush with the hydraulic profile. Specific hydraulic energy and net positive suction specific energy are determined from the time-averaged value measured from the manifolded pressure taps (piezometric ring) at the high pressure and low pressure reference sections; each manifold comprises two pairs of opposed pressure taps, arranged on two diameters, at right angles, installed flush with the wall of the pipes. The measuring sections go together with a piece of transparent pipe for visualization issues. Furthermore, two plexiglass windows were adapted on the pump casing to observe phenomena like recirculation and cavitation inside the impeller channels and blade edges.

The synchronized signals were simultaneously recorded for each operating point using the data acquisition system cRIO National Instruments and the module NI-9232. Data were recorded at 34.13 samples per second per channel and AC coupling enabled to optimize the 24 bits resolution available. This module has anti-alias filters as well. For every measurement, 77 adjacent packages of 214 samples were collected for a total measurement time of 36.96 seconds; i.e. a maximum frequency resolution of 27.05 mHz.

In addition to the sensors mentioned above, a tachometer is installed for two main purposes. The first one is to calculate the rotational speed of the turbomachine for the respective operating point. And the second one is to identify when a complete revolution is performed; this is particularly important for the recognition of the passing blades during each rotation and then

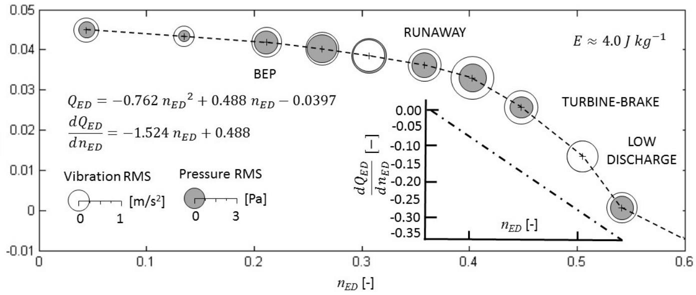

Figure 5: "S-shaped" characteristic curve of a pump-turbine in generating mode.

establish a reference framework to characterize the flow in the interior of the turbomachine.

The experimental setup can be seen in fig. 4. It is noted that high and low pressure pipes were replaced by transparent lines with the intention of visualization. Furthermore, two plexiglass windows were adapted on the pump casing to observe phenomena like recirculation, cavitation, chipping of the blades and many others.

3. Results

After tuning the system and validate the performance of the turbomachine in pumping mode (fig. 2), the sense of rotation is inverted and the machine is driven to the runaway condition for a fixed specific energy $4.00 Jkg^{-1}$. When the system was stabilized, the measurement was launched. Afterwards, the rotation speed was reduced systematically maintaining constant the specific and including the best efficiency point (*BEP*). Then, speed was increased step by step until flow was fully reversed. This journey is summarized in the Q_{ED} vs n_{ED} characteristic plotted in fig. 5. The RMS values of the centered pressure fluctuation and acceleration are overimposed on every operating point as the radius of a circle. To highlight the variations between them, distinctive scales were used for each magnitude.

As a matter of fact, the slope of the characteristic is always negative. Although that can be detected by inspection, it can be mathematically proven by interpolating the curve, particularly at the turbine-brake region, and compute its derivative. It is important to keep this in mind because it means that the curve is not S-shaped (fig. 5).

Judging by the behavior of the RMS values, it can be inferred that the vibration of the volute increases from BEP and peaks in runaway; then decreases with increasing speed and decreasing discharge in the turbine-brake region. Nevertheless, pressure fluctuations reach its peak at low discharge. A common pattern that suggest a direct relation between the data dispersion and the orderliness of the flow can be spotted: the narrower dispersion happens near the BEP whereas the widest arises in the turbine-brake region. This makes sense because, according to literature, conditions conducive to the increased dissipation of energy such as recirculation, vortices and even reverse flow are presented in such region. The dissipated energy appears as nonsynchronous and random pressure pulsations or as

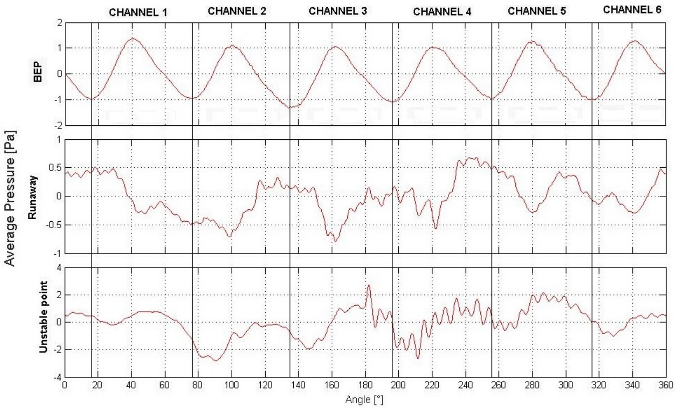

Figure 6: Phase average of the dynamic pressure measured on the spiral casing at BEP, runaway and low discharge condition.

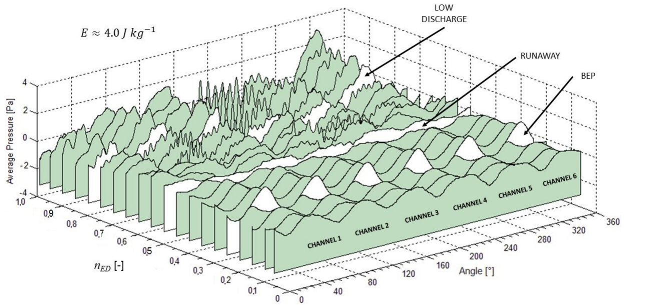

Figure 7: Phase average of the dynamic pressure for operating points on the Q_{ED} vs n_{ED} characteristic in generating mode.

structure-borne noise when propagates towards the body of the machine. At BEP, since flow is better organized, a more efficient conversion from hydraulic to mechanical power is given with reduced noise and vibration.

Consequently, the conditions labeled as BEP, runaway and low discharge were selected for phase average and frequency analysis.

The phase average is a powerful tool to comparatively analyze the operating points selected based on the raw pressure signals from several rotations. Phase information is recovered from the keyphasor as timestamps that indicates when a revolution ends and the next begins. This allows to split the records into consecutive segments containing pressure fluctuation for every revolution. The average of all segments is the "representative" revolution. Components of the signals whose frequencies are integer multiples of the rotating speed are preserved whilst nonsynchronous and stochastic events are attenuated. This means that phenomena such passing blades or rotating unbalance become evident but others such as cavitation and turbulence are suppressed. The advantage of this analysis can be noticed in fig. 6. At BEP only one significant fluctuation generated by the blades passage remains. Six peaks, similar to each other, are counted. Conversely, at runaway and low discharge conditions, where larger fluctuations are expected, it is no longer so clear. The decrease in the peak values, which appears to contradict the results reported in fig. 5, in fact, reveals that most of the energy content under such conditions is explained by stochastic and asynchronous phenomena.

Performing the phase average analysis for every point on the characteristic curve, it can be assembled the whole picture showing the evolution of the pressure fluctuation of the turbomachine running in the turbine quadrant. The result in fig. 7 exposes the behaviour of the pressure inside the volute at different rotating speeds. In other words, it shows the representative revolution for several operating points. The selected points for further analysis are tagged on the graph. Near the point of maximum efficiency one can clearly observe the passage of each of the blades of the impeller. The amplitude of this synchronic event decreases as the machine speed increases and becomes almost imperceptible at runaway. The authors call the reader's attention to note that up to runaway the machine can increase its rotational speed by consuming power from the fluid; at runaway there is (theoretically) zero energy transfer and that, from this point and for this particular case study, the machine needs to consume mechanical power in order to keep increasing the rotating speed, i.e. to transfer energy from the blades to the fluid. That's why synchronous fluctuations are rising and again important.

Table 2: Configuration parameters for spectral analysis.

Sampling frecuency (F_s)	$34,133$ Samples/s
Record length (L)	20^{20} Samples
Window type	Hanning
Window length (N_w)	2^{18} Samples
Overlap	$7/10$
Number of averages	142

For the reason that the main content of the dynamic pressure in the turbine-brake region can not be completely attributed to synchronous events, a frequency analysis of the dynamic pressure at low discharge is performed by means of the Welch's method [22]. This method is very convenient because it reduces noise stemming from imperfect and finite data. The spectrum is presented in fig. 8 and the respective setup parameters for its estimation are presented in table 2.

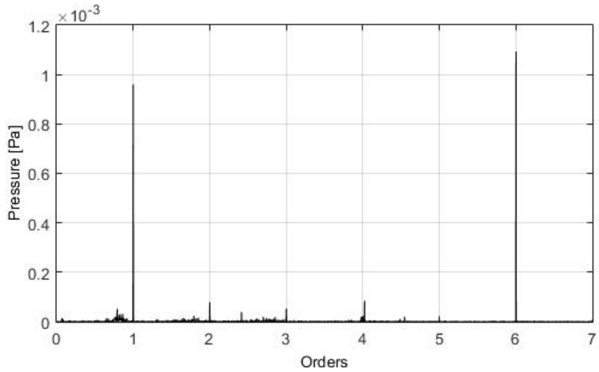

Figure 8: Spectral estimation for pressure fluctuations at low discharge conditions.

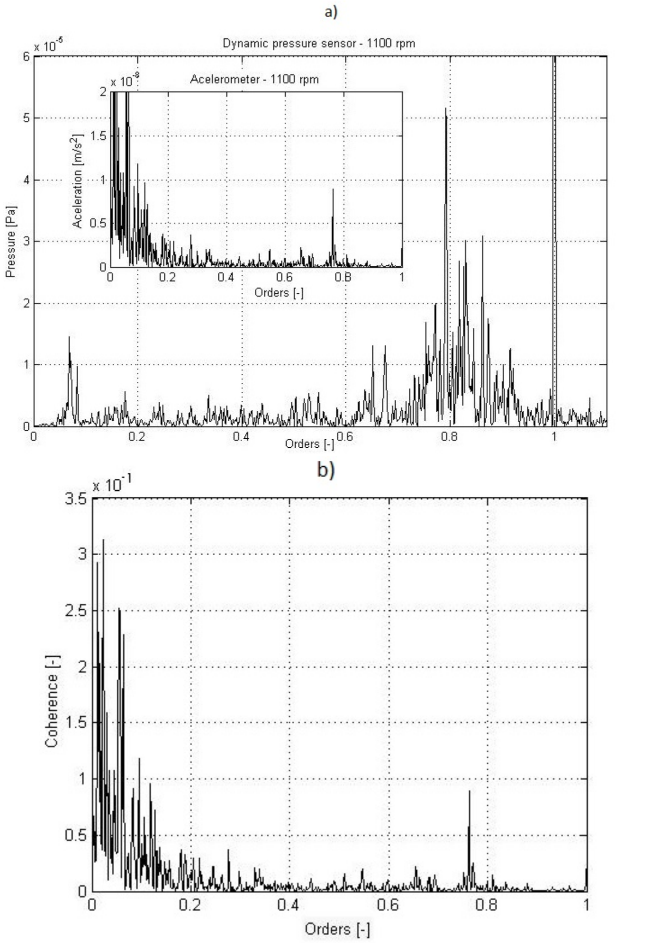

Figure 9: a) Subsynchronous spectrum for pressure and vibration sensors. b) Coherence function of pressure fluctuation and acceleration signals.

With the intention of identifying phenomena that produce pressure fluctuation components which have a fixed relationship to shaft rotative speed, frequency is expressed as a function of shaft rotative speed. For one thing, synchronous events dominate the spectrum; the rotating frequency appears at 1x and the passing blades component clearly arises at 6x. For another, the subsynchronous band (up to 1x) is dominated by a disturbance that can be seen emerging close to 0.8x, that is eighty percent of the speed of rotation.

A close up of to the subsynchronous band is detailed in fig. 9. Same analysis for acceleration signal is included as well. Moreover, taking advantage of the fact that both of the sensors were placed close together, coherence function was estimated and included in the same figure. Although the amplitudes for components into the subsynchronous band are generally not so significant, it is feasible to state that a comparatively important amount of energy arises near the 0.8x. In the one hand, low coherence is attributed to small space between pressure and vibration sensors which could lead to a lag in events in signals in the case of a rotating phenomena. As coherence takes into account amplitude, frequency and phase content from both signals, such phase shift impacts directly the grade of coherence. It is to be confirmed by a more detailed cross-correlation test. In

Table 3: Period of rotation.

Quantity	Value
$\Delta\phi$	$\frac{\pi}{10} rad$
Δt	$1.97 ms$
τ	$70.37 ms$
v_s	$88.59 rad/s$
k_s	1

the other hand, the components that were found to 0.8x suggest the detection of an interesting phenomenon, hydraulic in nature, that propagates to the structure requiring further analyses.

It is stated that the phenomenon happens in the fluid since sufficient evidence was found in the pressure fluctuation signals of the three sensors probes. It is also stated that its fluctuations transfers to the structure, because similar traces were found in signals from accelermeters installed close to the pressure sensors and sampled simultaneously which also revealed some degree of coherence in a specific frequency band. The phenomenon is therefore detectable by vibration analysis routines, avoiding complex assemblies and pressure taps installation.

So now the questions to address are: is it a rotating (or pulsating) phenomenon? and if so, does it rotate with the runner? is it stationary or transitory? Then, two analyses are performed. The first one is the cross-correlation between pressure fluctuations signals from consecutive sensors in the shaft wise sense. A digital bandpass filter is previously applied to the signals in order to keep the components related to the phenomenon. Therefore the cutting frequencies for an 8^{th} order Butterwoth topology were fixed at 0.6x and 1x. The highest correlation was pointed at $+1.97 \pm 0.43 ms$ indicating, first of all, that it is a phenomenon that rotates instead of pulsing inside the volute, and that it rotates in the direction of the impeller; in effect, this is the time it takes the phenomenon to sweep the angle of separation between consecutive sensors ($10° or \frac{\pi}{10} rad$) at 0.8x. Kinematics of the rotating phenomenon can also be recovered as stated by Botero et. al in [13]. For instance, eq. (3) and eq. (4) serve to estimate the number of stalled cells, k_s and its local propagating velocity, v_s.

$$k_s = \frac{\Delta\phi}{\Delta t} \quad (3)$$

$$v_s = \frac{2\pi\Delta t}{\tau\Delta\phi} \quad (4)$$

Where $\Delta\phi$ is a geometric parameter that represents the angle in radians between two consecutive pressure taps; Δt is the time taken by one cell to sweep $\Delta\phi$; τ is the time between two local maxims in the dynamic signal. The period of rotation can be estimated by finding the time for the first peak of the autocorrelation for one of the filtered pressure fluctuation signals. Magnitudes obtained for this case of study are contained in table 3. It is consistent with similar studies found in the literature performed on francis type pump-turbine scale models.

Likewise, evidence associated with the exchange of momentum between the impeller and the fluid was collected. In actual

Table 4: Configuration parameters to estimate the discrete STFT.

Method	STFT Specrogram
Frecuency bins	2048 Samples/s
Time steps	26 seconds
Window type	Hanning
Window length (N_w)	1024 Samples

fact, it was implemented the method proposed by [23], who found a dependence between the RS and geometric parameters of the machine. This relationship is presented in eq. (5).

$$\Omega_{RS} = \frac{\omega_{RS}}{\omega_{rot}} = \frac{\sin\alpha^2}{\sin\alpha^2 + \mu * \sin\beta^2} \quad (5)$$

Where μ is the ratio between the mass of fluid contained in the strator and the mass of fluid contained in the rotor or impeller. In adition α is the angle of the impeller inlet and β is the angle of the impeller outlet.

$$\mu = \frac{m_{stat}}{m_{rot}} = \frac{0.917kg}{0.288kg} = 3.184 \quad (6)$$

Thus, replacing on the Gyarmathy relationship whit $\alpha = 67°$ and $\beta = 23°$, which there are the angles of attack of the turbomachine analyzed is obtained a value of $\Omega_{RS} = 0.833$, which is quite close to the value observed.

The second analysis is conducted in the coupled time-frequency domain. Actually the discrete short-time Fourier transformation (STFT) [24, 25] was applied to the pressure fluctuation signal at the low discharge conditions. Result is shown in fig. 10. The parameters used for the estimation of such transformation are listed in table 4.

The axes are purposely adjusted to focus the reader's attention on the subsynchronous band. The frequency axis is expressed as a function of shaft rotative speed (orders) and extends up to 2x; 1x is an event with a frequency equal to impeller speed. The amplitude of the Fourier components are normalized with respect to the time average amplitude of the 1x in order to make clear the phenomenon observed within the subsynchronous band. Instead of being stable, it manifests itself as an intermittent event that comes and goes in uneven time intervals. Longest observed duration was around 5 seconds, corresponding to about 80 revolutions of the impeller. This behaviour explains the spectral leakage detected in fig. 9. These results are consolidated as strong evidence of the minifestacin of RS in the machine, at least under the specific LD operating conditions. Perhaps it is not wise to state that this is a fully developed RS, but one can start to talk about an intermittent and vanishing RS, its inception or simply about a transient RS taking place in a hydraulic turbomachine exhibiting stable Q_{ED} vs n_{ED} characteristics.

Rotating hydrodynamic phenomenon like this have been reported occurring in hydraulic turbomachines having negative sloped characteristics, as is the case Hasmatuchi [11], Botero [13], Braun [26], Widmer [27] among others, it was referred as Rotation Stall. So far, it was not found evidence of this phenomenon in turbomachinery sloping always negative.

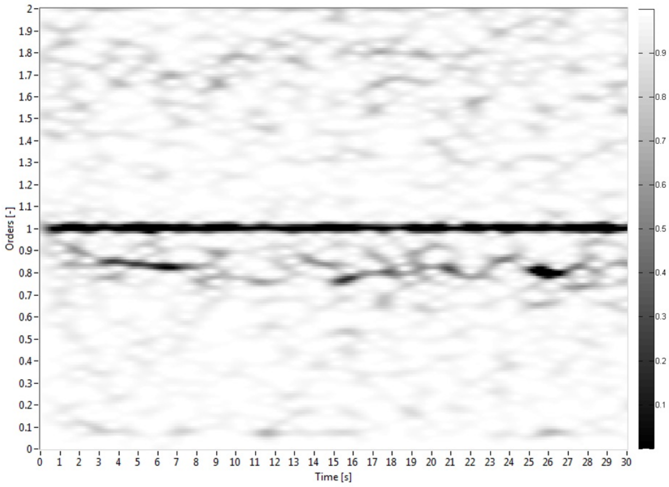

Figure 10: Coupled time-frequency analysis of the pressure fluctuation inside the spiral casing at low discharge condition.

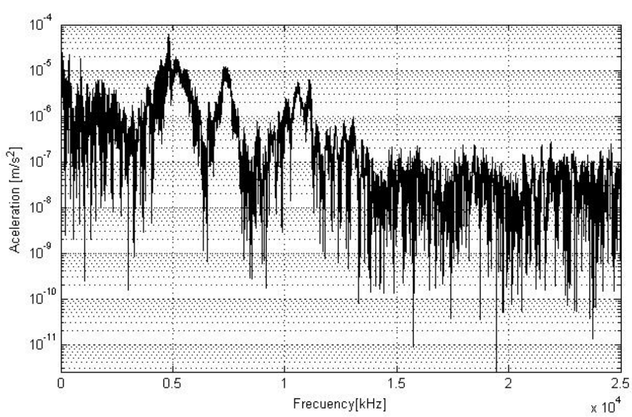

Figure 11: Frequency response function of the PAT obtained from the vibration measurement points.

The repeatability of the experiment was verified. System settings valves were adjusted to increase the inertia of the system, varying the pressure, as proposed by Dörfler [10]; the turbomachine was driven to the same operating points, ascending and descending along the characteristic, with similar results every time.

Along with the experimental curves, a supplementary modal analysis was carried out to determine if the capture RS frequency components are rather related to underlying natural frequencies of the system. It consisted in hitting the turbomachine with an instrumented hammer, while the turbo-machine was full of water. The response of the system was sensed by the accelerometers placed in the monitoring points mentioned above. This process was repeated 10 times and fig. 11 shows the average result of the transfer function. It can be observed that the natural frequencies of the turbomachine are far away from the subsynchronous band. Indeed, the significant vibration modes lies above $1000Hz$.

4. Conclusions

- Sub-synchronous instability was evidenced in the analyzed system, which corresponds to the Stall Rotation in machines with positive slope, but no comparable cases with negative slope study was found in the literature.

- The unstable phenomenon found could be reproduced, since the figures presented are the result of 10 sessions in the laboratory tests.

- Near the point of maximum efficiency it was evident that both pressure fluctuations and vibration are minimal throughout the course of the "S-shaped" curve.

- The instability occurs at a greater speed at runaway speed, and low discharge disappears very high degree of disorder in the fluid.

- It is important to emphasize the fact that a non-invasive sensors (accelerometer) and invasive sensor (Dynamic Pressure Sensor) exhibit the same behavior in the distribution of data, that is, both sensors see the same phenomenon.

- It is important to continue the experiment to check the kind of detachment found by the sensors.

- It is noted that the natural frequencies of the system are far from the operating frequencies and instability frequency presented.

- Comparing the theoretical value of the frequency of the Rotating Stall presented by Gyarmathy with the experimental value, there is a considerable overlap between these values.

Acknowledgment

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10.2 Artículo derivado de las simulaciones

Numerical Approach to Assess the Hydroelastic Coupling of Mechanical components for hydraulic Turbomachines

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Abstract
Since the modern engineering emerged, it has been needed a way to identify the phenomena occurring in hydraulic devices such as turbomachinery; and with the emergence of computational mechanics, It has been able to verify phenomena, even though they can be found by experimentation methods; they require not only highly complex devices, but also highly complex and expensive setups. The simulation is performed by means of an Open-Source software called *Elmer*. A fundamental case study, already analyzed by other author, is prepared and solved numerically. It is a particular guide vane subjected to a given flow conditions exhibiting hydroelastic coupling or "lock-in". This work aims to find a methodology to reproduce the behavior of the guide vane, especially it vibrations produced during "lock-in" conditions. Moreover, the way these vibrations propagate through the fluid, by multi-physics numerical simulation.
Keywords: Turbomachines, Simulation, Guide vane, Hydro-acoustic, Structural Vibrations, Elmer.

1. Introduction

Turbomachines are those that absorb energy from a fluid and generally restitute mechanical energy at the shaft. Alternatively, absorb mechanical energy at the shaft and restore the energy to a fluid. The fluid may be a liquid or a gas. The mechanical energy and fluid exchanger is endowed with rotatory motion; hence the word "turbo" or in latin *Turbinis*, means "the rotating machine". The fundamental Euler equation of turbo machines, based on the theorem of angular momentum, is basic for the study of these machines [1]. Hydraulic turbines play a major role in nowadays stage since the development of new technologies of sustainable energy such as solar, tidal or wind, but those technologies will be useful, perhaps, in the medium and long-term application. Meanwhile, hydropower is a great source of a clean worldwide energy in a short and a medium term application [2]. For this reason, it is important to continue developing maintenance procedures and related diagnostics techniques in order to keep it clean, safe and under-controlled.
These machines have a certain type of operating problems such as cavitation [3], stagnation, pressure fluctuations, among many more; which generate losses and declines in both mechanical and hydraulic performance. Therefore is significant for industries to keep all monitoring the least invasive and as remote as possible [4], [5].
Pressure fluctuations, as those derived from Von Karman Streets, could become a very dangerous phenomenon. If the frequency of the pressure pulsations developed during the vortex formation coincide with one of the natural frequencies of the machine, a hydroelastic coupling takes place increasing the fatigue failure risk. Severe damage in generating units have be reported by Egusquiza [6] and Finnegan [7]. Von Karman theories and their implications for the vibrations have been studied previously, particularly in

numerical analysis [8]–[10]. New theories have been developed for monitoring [11]–[14]; but it remains complicated to ensure convergence and numerical stability. Thus, a fundamental study case, which was already considered in the literature [15] is solved using numeric methods. It is a NACA profile, normally used as guide vanes of Francis type machines. In order to validate the proposed methodology, the hydroelastic behavior of the guide vane under different working regimes was considered.

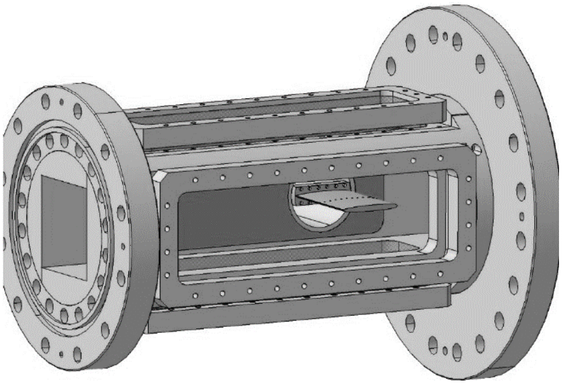

Figure 1, Experimentation Chamber [10].

2. Materials and methods

In order to perform the analysis drawn on a typical guide vane of turbomachinery, it was needed a flow cross-section area 150 mm wide, by 150 mm high, with a total length of 750 mm, as shown in Figure 1. Same configuration was previously studied by Ausoni [15] and details of the experimental setup can be found in the work of Zobeiri [10]. The guide vane was in all the cases oriented horizontally. In the experimental tests conducted by Zobeiri flow rates ranging from 14.0 to 17.0 m/s were used [10]. Same speeds are used for this numerical analysis. In addition, pressure was regulated in order to avoid cavitation in the cores of the vortex.
Numerical simulation of such situation is a challenging. Multi-physics setups may or may not develop the target phenomenon and, even, if it develops, convergence are not fully guaranted. To accelerate the numerical solution, an initial deformation was imposed on trailing edge. This deformation, equivalent to a Dirac, is described mathematically in Equation 2. The Dirac disturbance pretends to excite the natural frequencies of the guide vane and therefore induce the hydroelastic coupling if the flow conditions are conducive for it.

2.1. Guide Vane Geometry

The geometry of the guide vane can be observed in Figure 2.
It is based on the 0009 standard NACA - 7.8 45 / 1.93 Structural Steel [16], originality conceived to reduce drag in airfoils. However, in this case study (see Figure 2), the trailing edge was truncated, in order to be in-line with the experimental works reported by Aussoni [15]and Zobeiri [10]. It is well knwon than such modified profile generate a hydro-elastic coupling when tested in a high-speed cavitation tunnel. The reported range of speeds, where the phenomenon appears, is between 13 and 17 m/s [10]. For such reason, same ones are imposed as simulation speeds in this work.

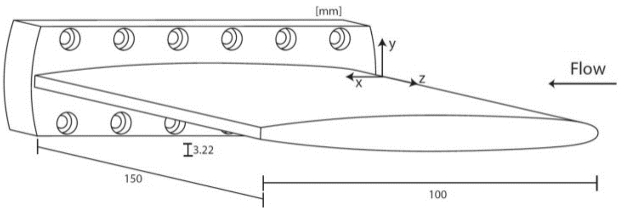

Figure 2, Guide Vane [10].

2.2. Numerical Analysis

For the numerical analysis it is used Finite Element Method (FEM), and the solver for this study is the Software Elmer [17], which allows a multi-physics problems; allowing great control of the solution methods.
Other Software used was Gmsh [18], which aids generating all meshes used in the analyses. Due to the complexity of the problem it is necessary to use a significant computing power, which was provided by *APOLO* Scientific Computing Center of EAFIT University [19]. It has an installed capacity of 420 nodes.

3. Calculation

For numerical analysis water and the steel were used. Steel was used for the guide vane and water is the fluid study. Their properties are found in Table 1.

Table 1, Material Properties [17].

Water		**Steel**	
Density [kg/m^3]	998.3	*Density [kg/m3]*	7850
*Viscosity [Pa*s]*	1.002e-3	*Speed of Sound [m/s]*	5100
Speed of Sound [m/s]	1497	*Young's Module[Pa]*	200.0e9
Meshing Elastic Module[Pa]	1.0e9	*Poisson*	0.285
Meshing Poisson	0.3		

As proved in previous studies [4],[10], vortices can be simplified to a 2D model if a hydro-elastic coupling appears. If this does not appear, the vortices are generated in a 3D distribution [15]. Since our interest is to analyze the hydro-elastic coupling, a 2D model was used as shown in Figure 2. This approach can be extended to a 3D analysis for further and more complex studies.

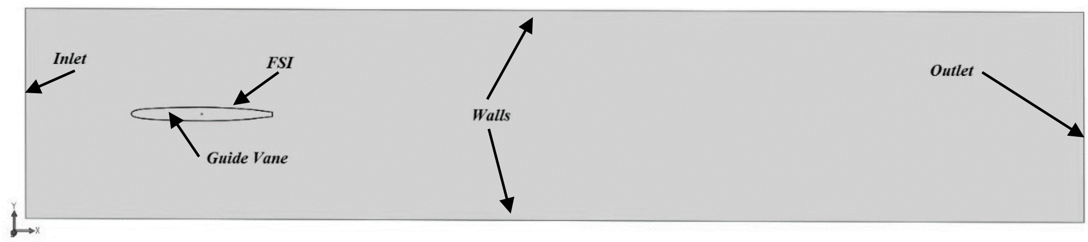

Figure 3, 2D Model.

The following boundary conditions, referenced in Figure 3, are keep for all simulations:

- On the upper and lower edges, "Wall" edge condition was applied.
- At the right edge speed was imposed on the y-axis with a value of *Vy* =0.0, because this is the outlet edge.
- On the left edge, which serves as inlet, the speed was imposed on the x-axis with a parabolic distribution, shown in Equation 1.

Equation 1, Speed distribution.

$$V_x = V_i \times \left(1 - \frac{y^2}{5626}\right)$$

Where the variable y is the vertical coordinate value of each point, and V_i is the desired velocity value in the range between 13 and 17 m/s.

- Over all the edges of the guide vane, the so-called Fluid Structure Interaction (FSI) condition is imposed. It allows for the coupled fluid-structural analysis. These edges have an "update mesh" setup as well, so that nodes of both of the bodies (structural and fluid) suffer the same displacements.

An important aspect is the step time. Because of the Nyquist's Law [21] the simulation step time should be maximum the half of the phenomenon period. For that reason, the simulation step time used was 0.001 s, which in the experimental arrangement would correspond to a sampling frequency of 1.0 kHz. Moreover, a total of 60 seconds were simulated.

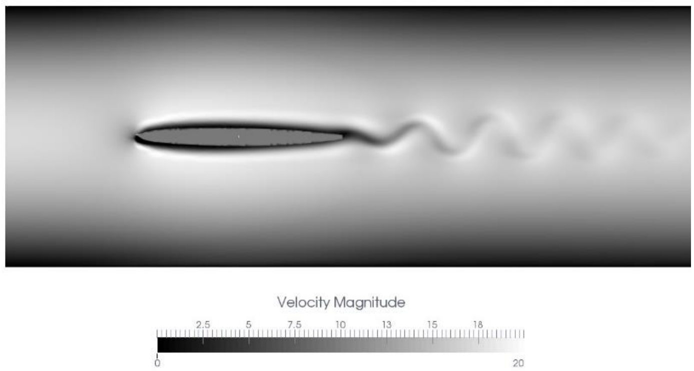

Figure 4, Velocity Distribution.

Initial conditions are crucial getting faster solution convergence rates. Two of them were imposed:

- The first one was that the initial speed of all the fluid has a parabolic distribution as shown in Equation 1.
- The second one refers to the guide van. It imposes an initial displacement along the axis as shown in Equation 2.

Equation 2, Guide Vane initial displacement.

$$\delta_y = 1 - \frac{x}{50}$$

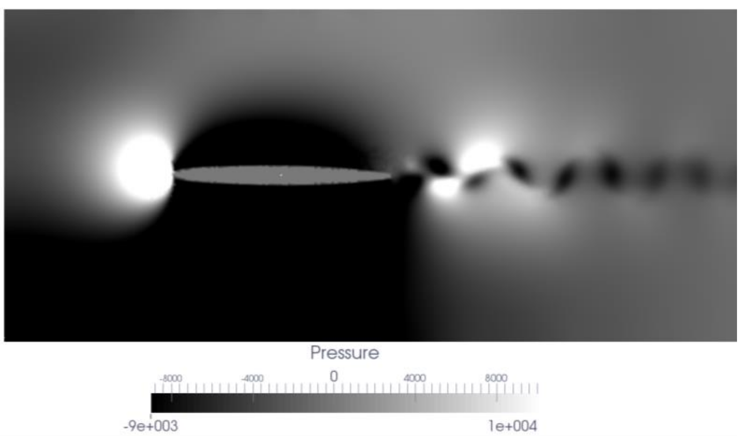

Figure 5. Pressure distribution.

Where the variable *x* is the value of the coordinate in the *x*-axis of each point, and δ_y is the value of the resulting initial displacement.

The mesh used for all simulations was the same. A first order triangular mesh was generated in Gmsh [18], which has 640,808 nodes, surface elements 1,277,684 and 1,918,492 boundary elements, it can be observed in Figure 6.

4. Results

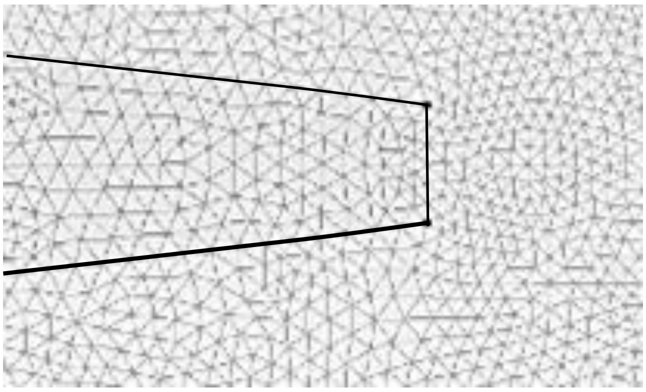

Figure 6, Guide vane mesh.

After several simulations, it reached a similitude between the real and the simulated phenomenon, which yielded reliable results, as it is shown in Figure 4. Vortex was generated, and the pressure distribution associated to these vortices was as expected. It is qualitatively close to the experimental works. As can be observed in Figure 5, after the generation of vortices, pressure waves travel and hit the pipe walls. Pressures on the wall were monitored in all simulated cases and presented in the Figure 7; actually, higher pressure fluctuations, which are important for diagnostics purposes in turbomachinery issues, are seen at a distance of once the span provided that the vortex is completely detached.

The pressure behavior can be gathered into well-defined groups. The first collecting speeds below 16 m/s, and the second one those over 16 m/s. The latter generates higher pressure differences due to the vortices appeared in the second group.

This difference in behavior is attributed to the structural-fluid coupling, as proposed by Zobeiri [10].

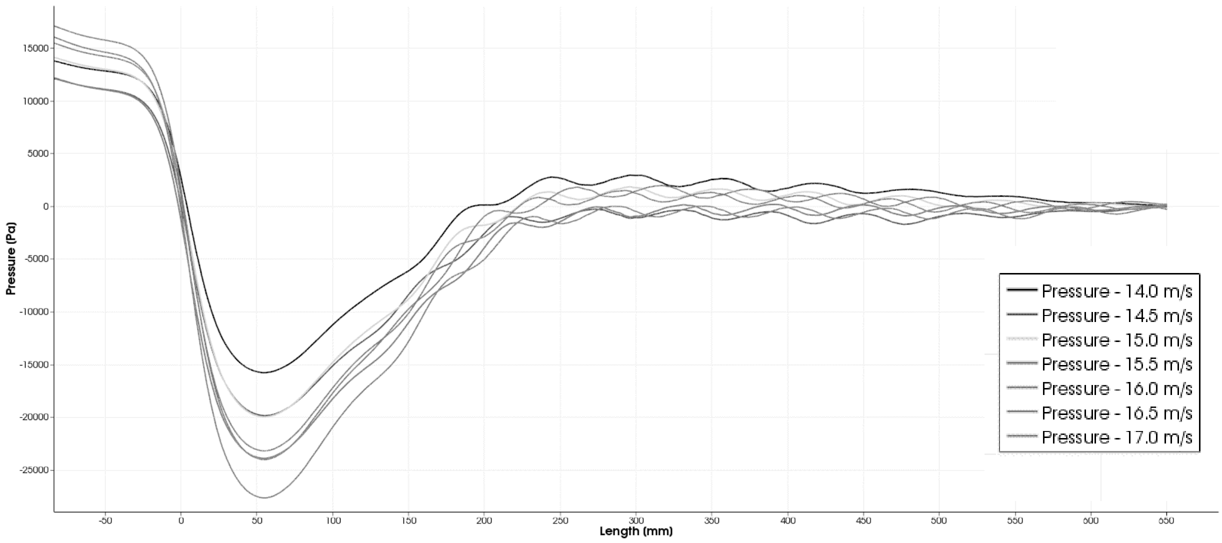

Figure 7, Walls pressure distribution.

5. Conclusions

- Using a numerical simulation it is possible to reproduce the generation of vortices on a turbomachine guide vane.
- The introduced approach leads to an accentuated convergence of the simulation and fast development of the structure-fluid interaction phenomenon.

- It was determined that a length equal to the length of the guide vane after it, is the highest-pressure fluctuations.
- It is recommended to perform simulations with smaller speed intervals to understand the behavior of the two groups of data found.
- The boundary layer is very important in the generation of vortices, therefore the mesh in this area must be as clean and small as possible.
- Numerical methods can support monitoring theories to find the optimal data collecting locations.
- Preliminary results revealed regions experimenting higher pressure fluctuations once the vortices appeared. It can be implemented in more complex simulations to help finding fatigue sensitive points on the turbomachine, during operation and even throughout the design process.

6. Acknowledgements

The authors thank in a very special way, the center of scientific computing Apolo [19], who supported the project and EAFIT University [22] who finances our research.

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11 Resultados y Concluciones

- Se definió la turbomáquina de estudio gracias a el conocimiento del laboratorio y su estado de operación.
- Curvas características del sistema fueron obtenidas de los procesos experimentales.
- La generación de las curvas caracteristicas de las bomba del Laboratorio de Hidráulica (ver Figura 5.7), permitirá realizar nuevas investigaciones en el tema, además, se tiene un contexto más claro de las capacidades hídricas del Laboratorio.
- Los códigos generados si bien pueden ser sujetos de mejoras, cumplen a cavalidad con sus funciones, además se han podido redefinir las variables importantes del laboratorio, centralizando el sistema de adquisición de datos en un solo punto.
- La Curva S fue desarrollada para los 4 cuadrantes(ver Figura 7.2), y esta será construida completamente en la segunda fase del proyecto.
- Para la construcción de todas las curvas se invirtió alrededor de 1120 horas en los Laboratorios y 340 horas aproximadamente en el proceso de análisis de datos y generación de los códigos.
- Los cambios realizados en el Laboratorio y en la Turbomáquina permitieron mejorar el nivel de confianza de las mediciones realizadas, además simplificó el montaje y procedimientos de las construcciones de las respectivas curvas.
- Como se pudo observar en la Figura 7.3, se pudo caracterizar el paso de álabes de la máquina, donde se pudo ver que el fluido se desorganiza a grandes revoluciones, donde en la curva "S" el fluido cambia su dirección. Otro aspecto importante es que cerca a las revoluciones de embalamiento de la máquina (entre 1000 y $1100 rpm$) presenta las menores fluctuaciones de presión.
- Un gran resultado que se obtuvo fue la correlación encontrada entre la señal de fluctuaciones de presión y la señal de salida de los acelerómetros (ver Figura 7.5), lo cual permite medir con acelerómetros los fenómenos hidráulicos que ocurren dentro de la

turbomáquina, lo cual permite diagnositicar y monitorear este típo de máquinas de la manera menos invasiva posible, que es el objetivo primario de este proyecto.

- La ubicación de un sensor dinámico a una distancia de una vez la longitud del álabe es uno de los resultados principales de la simulación realizada, como se puede ver en la Figura 8.9. Cabe aclarar que se hace necesario realizar simulaciones a diferentes velocidades. Estas simulaciones quedan propuestas para siguientes etapas del proyecto.

- Mediante una simulación numérica se pudo llegar a un resultado cercano al resultado experimental encontrado por Ausoni [11], donde el *Lock-in* es descubierto, este mismo efecto queda encontrado en la simulación como se puede ver en la Figura 8.14. Si bien es una muy buena aproximación el resultado obtenido al ser una simulación $2D$ queda pendiente realizar esta simulación con más puntos en $3D$ para una mejor aproximación a la parte experimental.

- La ponencia en la cuidad de La Plata, Argentina, fue un gran aprendizaje, pues se pudo conocer de primera mano que se está desarrollando en el ambiente latinoamericano, cuales son los temas de interés, que hace falta y hacia donde va la investigación en el ámbito de turbomáquinas, lo cual potencia esta investigación y la coloca en un contexto latinoamericano.

- Interactuar con pares internacionales y generar vínculos académicos es el mayor logro del congreso.

12 Trabajos Futuros

A lo largo del proyecto surgieron nuevos puntos de vista para atacar el tema de interes, pero debido tanto al tiempo como a los limitantes de otra índole no se pudieron llevar a cabo en este proyecto, pero que pueden ser punto de partida para futuros desarrollos, estos se presentan a continuación.

12.1 Digitalización del Impeler

Durante el proceso de pulido y pintura de la bomba que se describió en la Sección 6.1 y mientras se solucionaba el inconveniente del sello mecánico (ver Sección 6.1.4) se inició el proceso de digitalización del impulsor o impeler.

Esta digitalización fue posible gracias al Laboratorio de Metrología en cabeza de su Coordinador John Betancur, quien realizó los tramites necesarios para tener un equipo de digitalización láser en demostración, con el cual se pudo generar la malla de puntos, el proceso de digitalización se puede apreciar en la Figura 12.1.

Uno de los objetivos de realizar esta digitalización es poder tener una geometría virtual fiel a la real para poder utilizarla en simulaciones, tanto *CFD* como multifísicas.

Si bien el escaner entrega una nube de puntos superficial densa, el proceso de convertir esta nube en un sólido requiere un tiempo prolongado de trabajo, pues este es un proceso manual y un poco artesanal, dado que se deben de realizar abstracciones, simplificaciones y deducciones a partir de lo recopilado para poder obtener un sólido confiable.

El resultado final de la digitalización se puede ver en la Figura 12.2, la cual presenta una muy alta semejanza con la pieza real, respetando a cabalidad los diámetros de entrada y salida. Además esta pieza quedó hecha de forma tal que pude ser mallada en cualquier software que se disponga, lo cual la hace mucho más versátil.

12.2 Automatización del sistema de turbomáquinas

Gracias a las modificaciones realizadas en el laboratorio, y a la centralización del sistema de control y adquisición de señales es viable poder automatizar la construcción de curvas caracteristicas de turbomáquinas, de forma tal que se tenga un control estadístico de las variables analizadas, sin la necesidad de tener personal actuando sobre la máquina.

12.3 Visualización de Fenónmenos

Al poder contar con tuberia transparente tanto en la zona de alta presión como en la zona de baja presión, se pueden realizar inspecciones visuales de fenómenos como la torcha y la cavitación mediante estrategias gráficas.

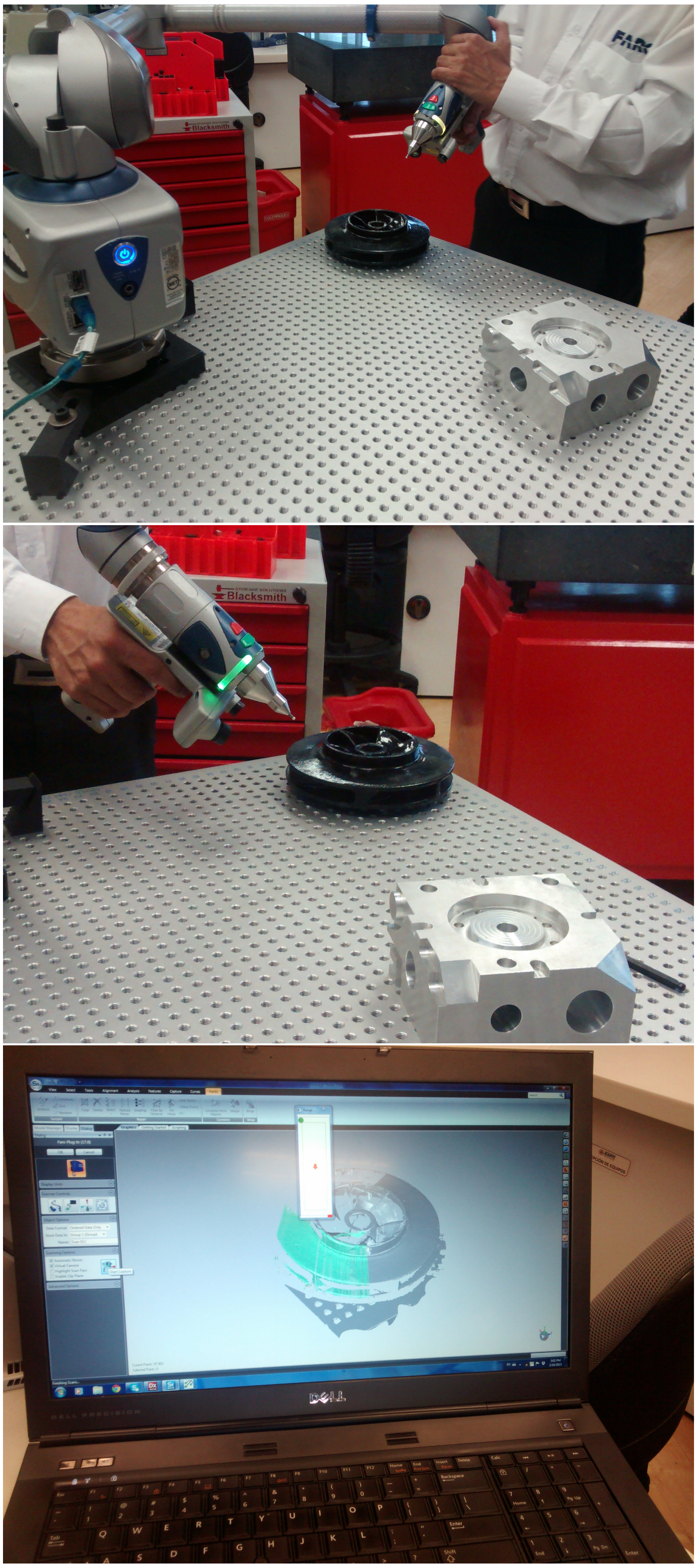

Figura 12.1: Digitalización Impeler.

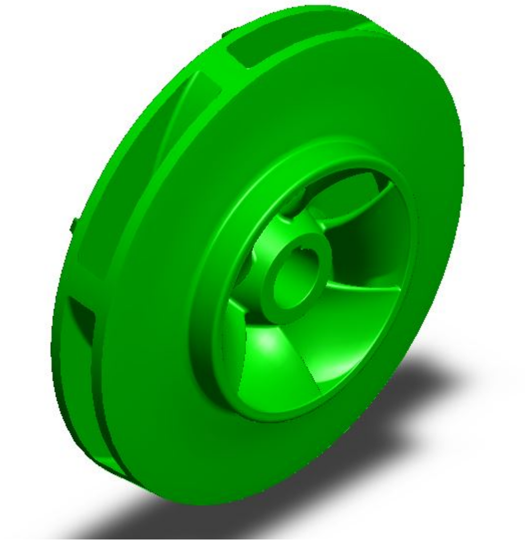

Figura 12.2: Pieza Virtualizada.

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Apéndice Part IV

A Apéndice

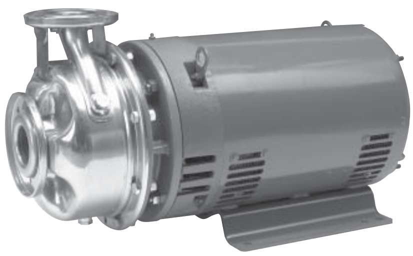
A.1 Bomba 1.5 HP

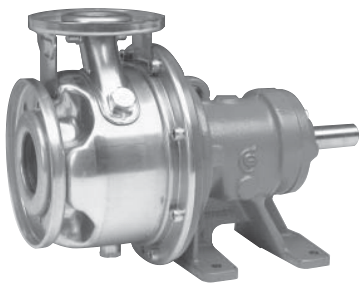
ITT

Commercial Water

Goulds Pumps

G&L SERIES SSH-C and SSH-F
Installation, Operation and
Maintenance Instructions





GOULDS PUMPS

Commercial Water.

www.goulds.com

 Engineered for life

Table of Contents

Owner's Information

Please fill in data from your pump nameplate.
Warranty information is on page 15.

Pump Model: ______________________

Serial Number: ______________________

Dealer: ______________________

Dealer's Phone Number: ______________________

Date of Purchase: ______________________

Installation Date: ______________________

SAFETY INSTRUCTIONS

TO AVOID SERIOUS OR FATAL PERSONAL INJURY OR MAJOR PROPERTY DAMAGE, READ AND FOLLOW ALL SAFETY INSTRUCTIONS IN MANUAL AND ON PUMP.

THIS MANUAL IS INTENDED TO ASSIST IN THE INSTALLATION AND OPERATION OF THIS UNIT AND MUST BE KEPT WITH THE PUMP.

This is a **SAFETY ALERT SYMBOL.** When you see this symbol on the pump or in the manual, look for one of the following signal words and be alert to the potential for personal injury or property damage.

DANGER Warns of hazards that **WILL** cause serious personal injury, death or major property damage.

WARNING Warns of hazards that **CAN** cause serious personal injury, death or major property damage.

CAUTION Warns of hazards that **CAN** cause personal injury or property damage.

NOTICE: INDICATES SPECIAL INSTRUCTIONS WHICH ARE VERY IMPORTANT AND MUST BE FOLLOWED.

THOROUGHLY REVIEW ALL INSTRUCTIONS AND WARNINGS PRIOR TO PERFORMING ANY WORK ON THIS PUMP.

MAINTAIN ALL SAFETY DECALS.

WARNING

Hazardous fluids can cause fire, burns or death.

UNIT NOT DESIGNED FOR USE WITH HAZARDOUS LIQUIDS OR FLAMMABLE GASES. THESE FLUIDS MAY BE PRESENT IN CONTAINMENT AREAS.

NOTICE: INSPECT UNIT FOR DAMAGE AND REPORT ALL DAMAGE TO THE CARRIER OR DEALER IMMEDIATELY.

1. Important Instructions

1. Inspect unit for damage. Report damage to carrier immediately.
2. Electrical supply must be a separate branch circuit with fuses or circuit breakers, wire sizes, etc., per National and Local electrical codes. Install an all-leg disconnect switch near pump.

WARNING

Hazardous voltage can shock, burn or cause death.

ALWAYS DISCONNECT ELECTRICAL POWER WHEN HANDLING PUMP OR CONTROLS.

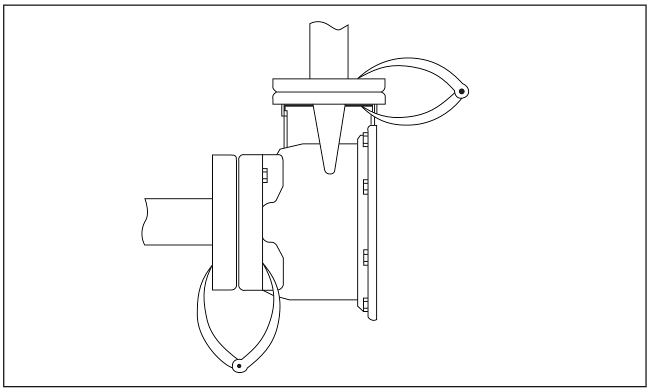
3. Motors must be wired for proper voltage (check nameplate). Wire size must limit maximum voltage drop to 10% of nameplate voltage at motor terminals, or motor life and pump performance will be lowered.
4. **Single-Phase:** Thermal protection for single-phase units is sometimes built-in (Check nameplate). If no built-in protection is provided, use a contactor with proper overload. Fusing is permissible if properly fused.
5. **Three-Phase:** Provide three-leg protection with proper size magnetic starter and thermal overloads.
6. Maximum Liquid Temperatures:
   212ºF (100ºC) with standard seal.
   250ºF (120ºC) with optional high-temperature seal.
7. Maximum allowable operating pressure: 230 PSI (15 bars).
8. Maximum number of starts per hour: 20, evenly distributed.
9. Regular Inspection and Maintenance will increase service life. Base schedule on operating time.

2. Installation

1. Close-coupled units may be installed inclined or vertical.

CAUTION **DO NOT INSTALL WITH MOTOR BELOW PUMP. CONDENSATION WILL BUILD UP IN MOTOR.**

2. Locate pump as near liquid source as possible (below level of liquid for automatic operation).
3. Protect from freezing or floods.
4. Allow adequate space for servicing and ventilation.
5. For close-coupled pumps, the foundation must be flat and substantial to eliminate strain when tightening bolts. Use rubber mounts to minimize noise and vibration. Tighten motor hold-down bolts before connecting piping to pump.
6. For frame-mounted pumps, permanent and solid foundation is required for smooth operation. Bedplate must be grouted to a foundation with solid footing.
7. Place unit in position on wedges located at four points (Two below approximate center of driver and two below approximate center of pump). Adjust wedges to level unit, bringing coupling halves into reasonable alignment. Level or plumb suction and discharge flanges.
8. Make sure bedplate is not distorted and final coupling alignment can be made within the limits of movement of motor and by shimming if necessary.
9. Tighten foundation bolts finger tight and build dam around foundation. Pour grout under bedplate making sure the areas under pump and motor feet are filled solid. Allow grout to harden 48 hours before further tightening foundation bolts.
10. All piping must be supported independently of the pump, and must "line-up" naturally. **Never draw piping into place by forcing the pump suction and discharge connections!**
11. Angular alignment of the flanges can best be accomplished using calipers at bolt locations (See illustration).



12. On frame-mounted units, tighten foundation, pump and driver hold-down bolts before connecting piping to pump.
13. Avoid unnecessary fittings. Select sizes to keep friction losses low.
14. After completing piping, rotate unit by hand to check for binding. **Note:** A screwdriver slot or flats are provided in end of motor shaft.

3. Alignment

1. No field alignment is necessary on close-coupled pumps.
2. Even though the pump-motor unit may have a factory alignment, in transit this alignment could be disturbed and must be checked prior to running.
3. Check the tightness of all hold-down bolts before checking the alignment.
4. If re-alignment is necessary, always move the motor. Shim as required.
5. Final alignment is achieved when parallel and angular requirements are achieved with both pump and motor hold down bolts tight.

⚠ CAUTION **ALWAYS RECHECK BOTH ALIGNMENTS AFTER MAKING ADJUSTMENTS.**

6. Parallel misalignment exists when the shafts are not concentric. Place dial indicator on one hub and rotate this hub 360° while taking readings on the outside diameter of the other hub. Parallel alignment occurs when Total Indicator Reading is .005" or less.
7. Angular misalignment exists when the shafts are not parallel. Place dial indicator on one hub and rotate this hub 360° while taking readings on the face of the other hub. Angular alignment is achieved when Total Indicator Reading is .005" or less.

4. Suction Piping

1. Low static lift and short, direct suction piping is desired. For suction lift over 15 feet, consult pump performance curve for ***Net Positive Suction Head Required***.
2. Suction pipe size must be at least equal to suction connection of pump.
3. If larger pipe is used, an eccentric pipe reducer (with straight side up) must be used at the pump.
4. Installation with pump below source of supply:
   4.1. Install isolation valve in piping for inspection and maintenance.
   4.2. Do not use suction isolation valve to throttle pump!
5. Installation with pump above source of supply:
   5.1. To avoid air pockets, no part of piping should be higher than pump suction connection. Slope piping upwards from liquid source.
   5.2. All joints must be airtight.
   5.3. Foot valve to be used only if necessary for priming, or to hold prime on intermittent service.
   5.4. Suction strainer open area must be at least triple the pipe area.
6. Size of inlet from liquid source, and minimum submergence over inlet, must be sufficient to prevent air entering pump.

5. Discharge Piping

1. Arrangement must include a check valve located between a gate valve and the pump. The gate valve is for regulation of capacity, or inspection of pump or check valve.
2. If reducer is required, place between check valve and pump.

6. Rotation

DO NOT PLACE HANDS IN PUMP WHILE CHECKING MOTOR ROTATION. TO DO SO WILL CAUSE SEVERE PERSONAL INJURY.

1. Pumps are right-hand rotation (Clockwise when viewed from the driver end). Switch power on and off. Observe shaft rotation. On frame-mounted units, check rotation before coupling pump to motor.
2. Single-Phase: Refer to wiring diagram on motor if rotation must be changed.
3. Three-Phase: Interchange any two power supply leads to change rotation.

7. Operation

1. Before starting, pump must be primed (free of air and suction pipe full of liquid) and discharge valve partially open.

⚠ CAUTION **PUMPED LIQUID PROVIDES LUBRICATION. IF PUMP IS RUN DRY, ROTATING PARTS WILL SEIZE AND MECHANICAL SEAL WILL BE DAMAGED.**

2. Make complete check after unit is run under operating conditions and temperature has stabilized. Check for expansion of piping. Check coupling alignment.
3. **Do not operate at or near zero flow**. Energy imparted to the liquid is converted into heat. Liquid may flash to vapor. Rotating parts require liquid to prevent scoring or seizing.

8. Maintenance

⚠WARNING Hazardous voltage

FAILURE TO DISCONNECT AND LOCKOUT ELECTRICAL POWER BEFORE ATTEMPTING ANY MAINTENANCE CAN CAUSE SHOCK, BURNS OR DEATH.

1. Bearings are located in and are part of the motor. For lubrication procedure, refer to manufacturer's instructions.

2. On frame-mounted units, regrease at 2,000 hours use or after 3 months. Use #2 Sodium or Lithium grease and fill until grease comes out of the relief fitting.

9. Disassembly

1. Always turn power off.

2. Drain system. Flush if necessary.

3. Remove motor hold-down bolts on close-coupled or disconnect coupling and remove spacer.

4. Remove casing bolts and pump hold-down bolts.

5. Remove motor and rotating element from casing.

6. Unscrew impeller bolt with a socket wrench. **Do not insert screwdriver between impeller vanes to prevent rotation.** It may be necessary to use a strap wrench around the impeller if impacting the socket wrench will not loosen the impeller bolt.

7. Remove impeller o-ring.

8. Insert two pry bars (180º apart) between impeller and seal housing. Pry off impeller.

9. Remove shaft sleeve, seal spring, cupwasher, seal rotary and impeller key.

10. Remove seal housing.

11. Place seal housing on flat surface. Press out stationary seal parts.

12. Remove deflector from shaft on frame-mounted units.

13. Remove bolts holding bearing cover to frame and remove bearing cover (frame-mount).

14. Remove lip seals from bearing frame and bearing cover (frame-mount).

15. Remove shaft and bearings from frame (frame-mount).

16. Remove bearing retaining ring (frame-mount).

17. Use bearing puller or arbor press to remove ball bearings (frame-mount).

18. Remove wear ring if excessively worn. Use pry bar and/or vicegrips.

10. Reassembly

1. All parts should be cleaned before assembly.

2. Refer to parts list to identify required replacement items.

3. Reassembly is the reverse of the disassembly procedure.

4. Replace lip seals if worn or damaged (frame-mount only).

5. Replace ball bearings if loose, rough or noisy when rotated (frame-mount only).

6. Check shaft for maximum runout of .005" TIR. Bearing seats and lip seal areas must be smooth and free of scratches or grooves. Replace if necessary (frame-mount only).

7. All mechanical seal components must be in good condition or leakage may result. Replacement of complete seal assembly, whenever seal has been removed, is good standard practice.

8. If wear ring is being replaced, do not use lubricants on the metal-to-metal fit when pressing in the replacement.

9. If the impeller is removed, as for example to effect a mechanical seal change, this procedure must be followed: Old impeller bolt and impeller o-ring cannot be reused.

10. Install the mechanical seal stationary seat in the seal housing, using soapy water as a lubricant to ease insertion.

11. S-Group – Install the mechanical seal spring retainer, spring and rotary assembly on the shaft sleeve using soapy water to lubricate. Slide the shaft sleeve over the pump shaft, be sure that a new shaft sleeve o-ring is used.

NOTE: THE SHAFT SLEEVE O-RING AND IMPELLER WASHER O-RING ARE ALMOST IDENTICAL IN DIAMETER. BE SURE TO USE THE SQUARE CROSS-SECTION O-RING IN THE IMPELLER WASHER. THE ROUND CROSS-SECTION O-RING IS USED IN THE SHAFT SLEEVE.

11. M-Group – Install the mechanical seal spring and rotary on the shaft sleeve using soapy water to lubricate. Slide the shaft sleeve over the pump shaft. Be sure that a new shaft sleeve o-ring is used. Place the mechanical seal spring retainer over the impeller hub.

12. Place the impeller key into the shaft keyway and slide the impeller in place. Install the impeller stud and impeller washer. Be sure that a new impeller o-ring is used. Tighten S-Group (3⁄8" thread) to 17 lb.ft. and M-Group (1⁄2" thread) to 38 lb.ft.

13. Replace casing bolts and tighten in a crossing sequence to the torque values indicated below.

S-Group – 25 lb.-ft. (35 N-m)

M-Group – 37 lb.-ft. (50 N-m)

14. Check reassembled unit for binding by rotating shaft with appropriate tool from motor end.

15. If rubbing exists, loosen casing bolts and proceed with tightening sequence again.

11. Troubleshooting

1. Motor does not start, and no noise or vibration occurs:
- **1.1.** Power supply not connected.
- **1.2.** Fuses or protection device tripped or defective.
- **1.3.** Loose or broken electrical connections.

2. Motor will not start, but generates noise and vibration:
- **2.1.** Motor not wired as directed on diagram.
- **2.2.** Shaft locked due to mechanical obstructions in motor or pump.
- **2.3.** Low voltage or phase loss on three phase supply.

3. Pump does not deliver rated capacity:
- **3.1.** Pump not filled and primed.
- **3.2.** Pump has lost prime due to leaks in suction line.
- **3.3.** Direction of rotation incorrect. See Rotation.
- **3.4.** Head required is higher than that originally specified. (Valve may be partially closed.)
- **3.5.** Foot valve clogged.
- **3.6.** Suction lift too high.
- **3.7.** Suction pipe diameter too small.

4. Protection trips as unit starts:
- **4.1.** Phase loss on three-phase supply.
- **4.2.** Protection device may be defective.
- **4.3.** Loose or broken electrical connections.
- **4.4.** Check motor resistance and insulation to ground.

5. Protection device trips too often:
- **5.1.** Protection may be set to a value lower than motor full load.
- **5.2.** Phase loss due to faulty contacts or supply cable.
- **5.3.** Liquid is viscous or its specific gravity is too high.
- **5.4.** Rubbing occurs between rotating and stationary parts.

6. Shaft spins with difficulty:
- **6.1.** Check for obstructions in the motor or the pump.
- **6.2.** Rubbing occurs between rotating and stationary parts.
- **6.3.** Check bearings for proper conditions.

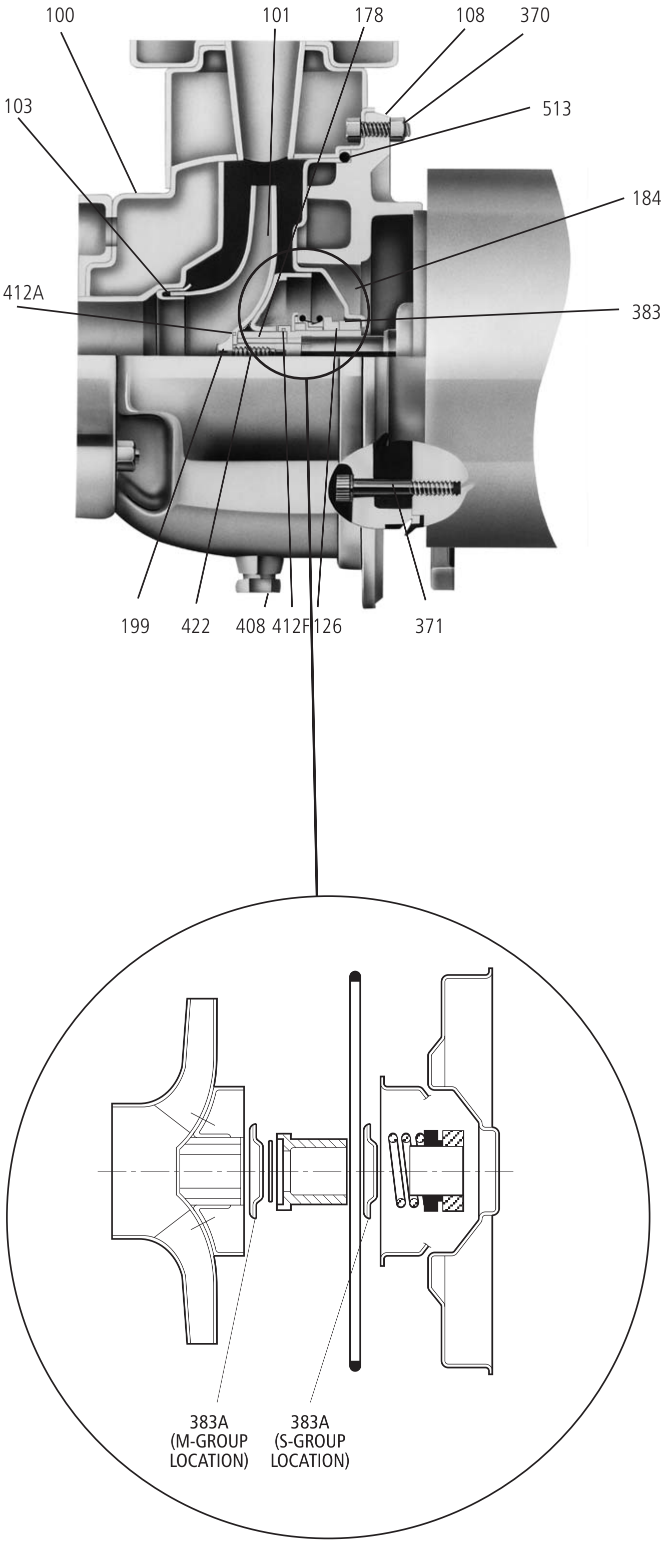
7. Pump vibrates, runs noisily, and flow rate is uneven:
- **7.1.** Pump runs beyond rated capacity.
- **7.2.** Pump or piping not properly secured.
- **7.3.** Suction lift too high.
- **7.4.** Suction pipe diameter too small.
- **7.5.** Cavitation caused by insufficient liquid supply or excessive suction losses.
- **7.6.** Impeller blockage.

8. When stopped, unit turns slowly in the reverse direction:
- **8.1.** Leaks on air locks in suction pipe.
- **8.2.** Partial blockage in check valve.

9. In pressure boosting applications, the unit starts and stops too often:
- **9.1.** Pressure switch settings are incorrect.
- **9.2.** Tank size may be incorrect.

10. In pressure boosting applications, the unit does not stop:
- **10.1.** Pressure switch maximum setting is higher than was specified.
- **10.2.** Direction of rotation incorrect. See **Rotation**.

SSH-C Components

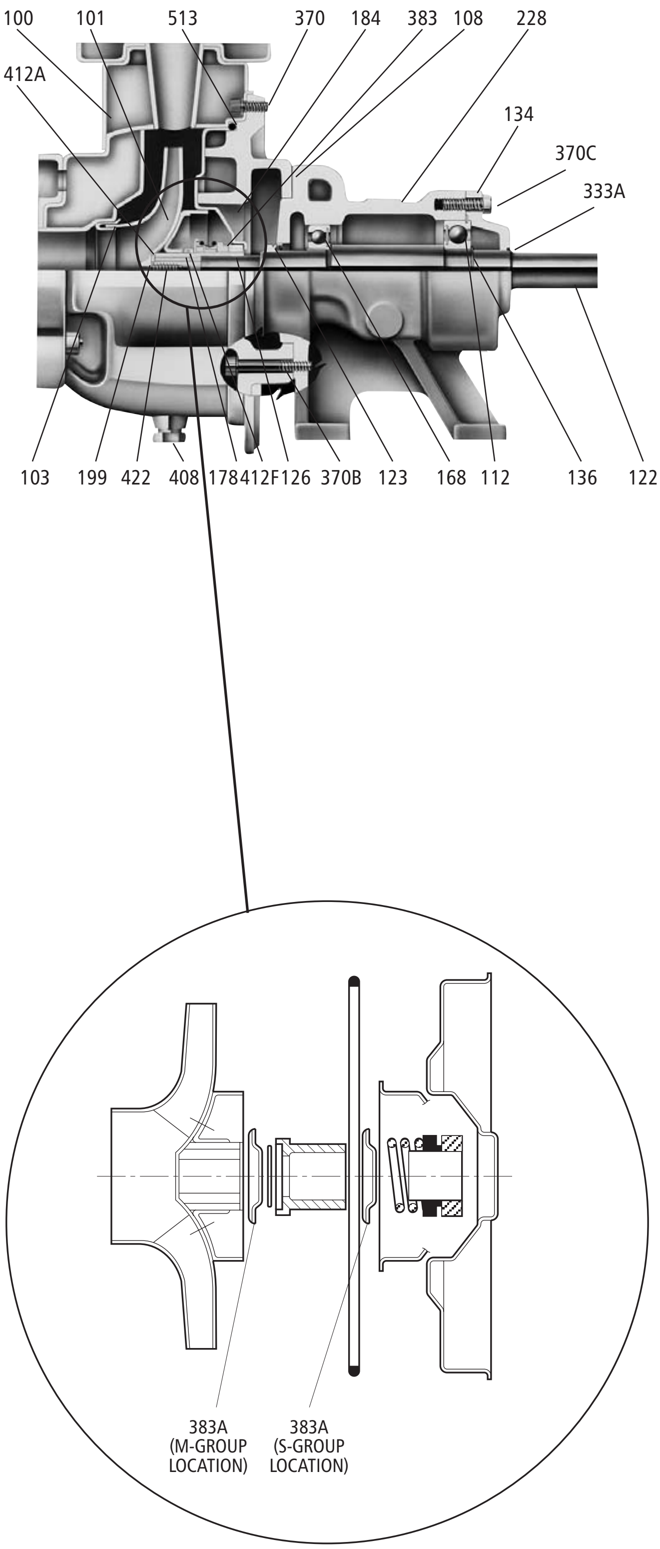


MATERIALS OF CONSTRUCTION

Item	Description	Material
100 101 103 184 370	Casing Impeller Wear Ring Seal Housing Socket Head Cap Screw (Casing to Adapter)	AISI TYPE 316L Stainless Steel
408	Drain Plug — ⅜ NPT	AISI TYPE 316 SS
126	Shaft Sleeve	316 SS
178	Impeller Key	Steel
422	Impeller Stud	Steel
199	Impeller Washer	316 SS
108	Adapter	Cast Iron ASTM A48CL20
371	Hex Head Cap Screw (Adapter to Motor)	Steel
412A	O-ring, impeller	BUNA-N
412F	O-ring, shaft sleeve	BUNA-N
513	O-Ring	BUNA-N
383	Mechanical Seal Part No. 10K13	Carbon/Ceramic Buna Elastomers 316 SS Metal Parts
383A	Spring Retainer	AISI Type 316 SS

OPTIONAL MECHANICAL SEALS

John Crane Type 21 Mechanical Seals						
Item	Part No.	Rotary	Stationary	Elastomers	Metal Parts	Intended Duty
383 Options	10K19	Carbon	Ni-Resist	EPR	316 SS	Hi-Temperature
	10K25		Ni-Resist	Viton		Chemical
	10K27		Tungsten Carbide	EPR		Hi-Temperature Mild Abrasive



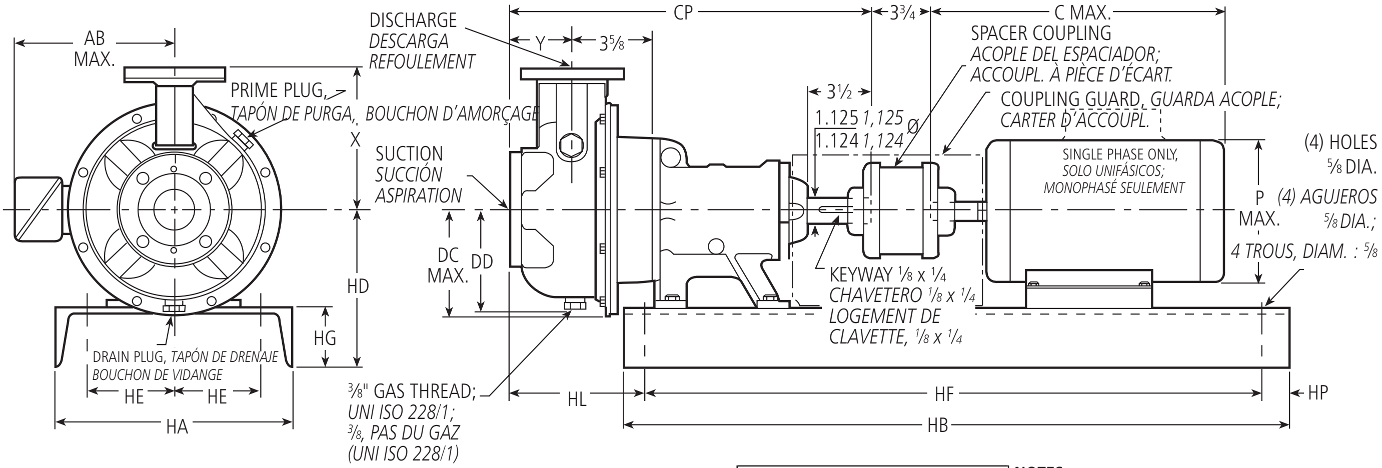
MATERIALS OF CONSTRUCTION

	Item	Description	Material
Pump End Components	100 101 103 184 370	Casing Impeller Wear Ring Seal Housing Socket Head Cap Screw	AISI TYPE 316L Stainless Steel
	408	Drain plug – ⅜ NPT	AISI TYPE 316 SS
	126	Shaft Sleeve	316 SS
	178	Impeller Key	Steel
	422	Impeller Stud	Steel
	199	Impeller Washer	316 SS
	412A	O-ring, impeller	BUNA-N
	412F	O-ring, shaft sleeve	BUNA-N
	513	O-Ring	BUNA-N
	383	Mechanical Seal Standard Part No. 10K13	Carbon/Ceramic BUNA-N Elastomers 316 SS Metal Parts
	383A	Spring Retainer	AISI Type 316SS
Power End Components	108 228 134	Adapter Bearing Frame Bearing Cover	Cast Iron ASTM A48 CL20
	122 168 112 136 370B 370C	Pump Shaft Ball Bearing (Inboard) Ball Bearing (Outboard) Retaining Ring Hex Head Cap Screw (Adapter to Bearing Frame) Hex Head Cap Screw (Bearing Frame to Cover)	Steel
	333A	Lip Seal	BUNA-N
	193	Grease Fitting	Steel
	123	V-Ring Deflector	BUNA-N

OPTIONAL MECHANICAL SEALS

John Crane Type 21 Mechanical Seals						
Item	Part No.	Rotary	Stationary	Elastomers	Metal Parts	Intended Duty
383 Options	10K19	Carbon	Ni-Resist	EPR	316 SS	Hi-Temperature
	10K25		Ni-Resist	Viton		Chemical
	10K27		Tungsten Carbide	EPR		Hi-Temperature Mild Abrasive

Channel Steel Bedplate, Clockwise Rotation Viewed from Drive End;
Fundación de Acero, Rotación en Dirección de las Agujas del Reloj Visto desde el Extremo del Motor;
Plaque de base profilée en U et rotation en sens horaire (vue de l'extrémité du moteur)



Dimensions and Weights – Determined by Pump,
Dimensiones y Pesos – Determinados por la Bomba;
Dimensions et poids – pompe

Pump, *Bomba, Pompe*		Suction *Succión* ① *Aspir.*	Discharge *Descarga* ① *Refoul.*	CP	DC Max., *DC Máx. DC max.*	DD	X	Y	Wt. (lbs.), *Peso (lib.) Poids*	HL: 143/145 – 183/184	HL: 213/215	HL: 254/256 – 284/286
9SH	1 X 2–6	2	1	16¾	5	4¾	6⅜	3⅛	56	9⅛	7⅝	3⅞
10SH	1 X 2–8				5⅝	5⅜	7⅛		64			
11SH	1 X 2–10			17 9/16	6⅞	6⅝	8⅞	4	86	10	8½	4¾
4SH	1½ X 2½–6	2½	1½	16 9/16	5	4¾	6⅜	3¼	57	9¼	7¾	4
7SH	1½ X 2½–8			17 5/16	5⅝	5⅜	7⅛	4	66	10	8½	4¾
5SH	2 X 2½–6		2		5	4¾			57			
8SH	2 X 2½–8				6	5¾	7 15/16		68			
6SH	2½ X 3–6	3	2½						59			

Dimension "HL" Determined by Pump and Bedplate, *Dimensión "HL" determinada la bomba y el motor, Dimensions HL – pompe et plaque de base*; Motor Frame Size, *Tamaño del bastidor del motor, Carcasse de moteur*

① For use with ANSI class 150 mating flanges.
Para usar con bridas que casan ANSI clase 150.
À utiliser avec des contre-brides ANSI, classe 150.

NOTES:
1. All pumps shipped in vertical discharge position. May be rotated in 90° increments. Tighten ⅜ – 16 casing bolts to 12 ft./lbs. torque.
2. Dimensions in inches.
3. Motor dimensions may vary with motor manufacturer.
4. Not to be used for construction purposes.

NOTAS:
1. *Todas las bombas transportadas en posición de descarga vertical. Pueden rotarse en aumentos de 90º. Apretar ⅜ – 16 tornillos de carcasa a 12 pies/libras potencia.*
2. *Las dimensiones en pulgadas.*
3. *Las dimensiones puede que varíen con los fabricantes..*
4. *No para propósitos de construcción.*

NOTA :
1. *L'orifice de refoulement est orienté vers le haut. On peut le tourner de 90° en 90°. Serrer les vis ⅜ - 16 du corps de pompe à 12 lbf·pi.*
2. *Les dimensions sont en pouces, et le poids, en livres.*
3. *Les dimensions et le poids du moteur peuvent varier selon le fabricant.*
4. *Ne pas utiliser les dimensions pour la construction si elles ne sont pas certifiées à cette effet.*

Available Motor and Bedplate Dimensions and Weights,
Pesos y Dimensiones Disponibles de la Fundación y del Motor
Dimensions et poids – moteur et plaque de base

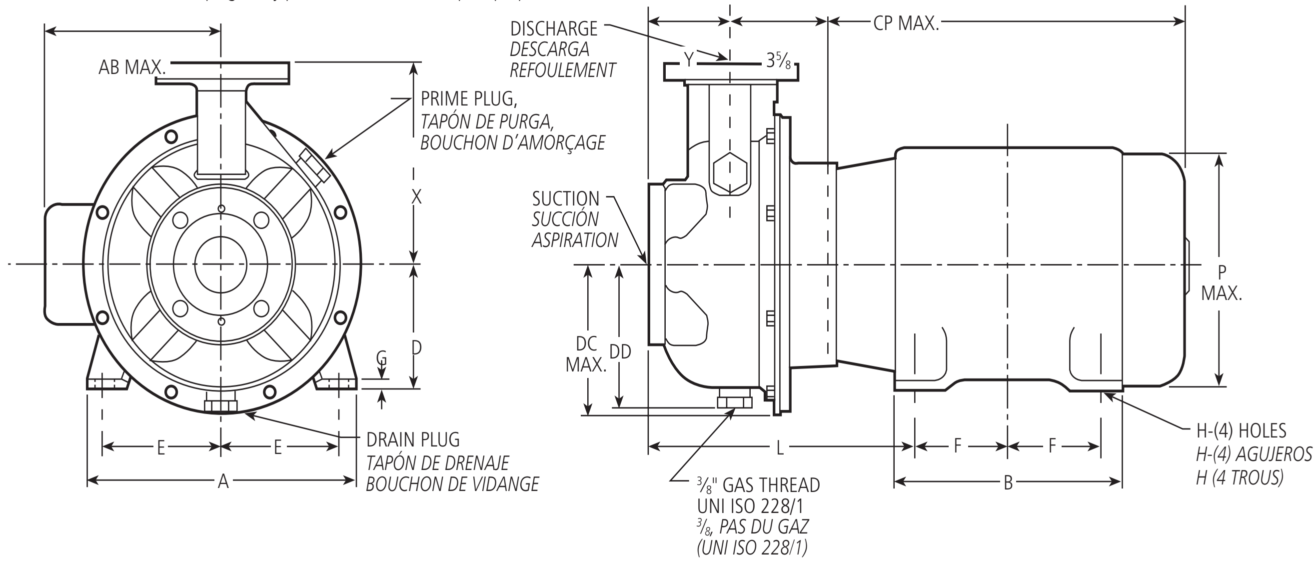
Motor Frame, *Armazón del Motor, Carcasse de moteur*	HP @ 3500 RPM, *HP a 3500 RPM, hp à 3 500 tr/min* – Single Phase, *Monofásicos, 1 Ø* – ODP	TEFC	Three Phase, *Trifásicos, 3 Ø* – ODP	TEFC	HP @ 1750 RPM, *HP a 1750 RPM, hp à 1 750 tr/min* – Single Phase, *Monofásicos, 1 Ø* – ODP	TEFC	Three Phase, *Trifásicos, 3 Ø* – ODP	TEFC	AB Max., *AB Máx., AB max.*	C Max., *C Máx., C max.*	P Max., *P Máx., P max.*	Wt. Max., *Peso Máx., Poids max.*	Bedplate Data, *Datos de la Fundación, Plaque de base* – HA	HB	HD*	HE	HF	HG	HP*	Wt. (lbs.), *Peso (libras), Poids*	Motor Shim, *Plancha de relleno del motor, Cale de moteur*	Bearing Frame Shim, *Plancha de relleno del bastidor del cojinete, Cale de palier*
143T					1	1	1	1	5¼	13⅜	6⅝	45	10	28	8	3¾	24	2¾	¾	48	1¾	–
145T	2	2	2 or *ou* 3	2	1½	1½	1½ or *ou* 2	1½ or *ou* 2		14¼		53										
182T	3	3	5	3	2	2	3	3	5⅞	16⅝	7⅞	74										
184T	5	5	7½	5	3 or *ou* 5	3	5	3		18⅛		95										
213T			10	7½					7⅜	18	9⅝	116	12	31	8¼	4¼	29	3	1	65	–	–
215T			15	10						19⅛		136										
254T			20	15					10⅛	21⅝	13	266	13	42	9¼	5¼	38½	4	1¾	110	–	1
256T			25	20						23⅜		264										
284TS			30	25					12⅝	24⅞	15	392	15	44	10½	5¾	40½	3½		124	–	1¾
286TS			40	30						26⅝		432										

Dimensions and weights vary with manufacturers. Dimensions in inches and weights in lbs.
"HP" Dimensions at motor end only.
* "HD" Dimension for 254T/256T motor frame on 1 x 2-10 only is 11"; A ¾" motor shim and a 1¾" bearing frame shim are required.

Dimensiones y pesos varían con los fabricantes. Dimensiones en pulgadas y pesos en libras.
Dimensiones "HP" sólo en el extremo del motor.
** La dimensión "HD" para el bastidor del motor 254T/256T de 1 x 2 - 10 es sólo 11"; se requieren una cuña del motor de ¾" y una cuña del bastidor de apoyo de 1¾".*
ODP = carcasse abritée (à ouvertures de ventilation protégées) ; TEFC = carcasse fermée autoventilée.
**Dimensions HP à l'extrémité du moteur seulement. La dimension HD pour la carcasse 254T ou 256T, version 1X2-10 seulement, est de 11 po ; une cale de moteur de ¾ po et une cale de palier de 1¾ po sont requises.*

SSH S-Group Close Coupled – Dimensions and Weights, *SSH Acople Cerrado – Dimensiones y Pesos, Dimensions et poids – SSH montée sur moteur, groupe S*

(All dimensions in inches and weights in lbs. Do not use for construction purposes.)
(Todas las dimensiones en pulgadas y pesos en libras. No usar para propósitos de construcción.)



Dimensions "L" Determined by Pump and Motor, *Dimensiones "L" Determinadas por la Bomba y el Motor, Dimensions L – pompe et moteur*													
Pump, *Bomba, Pompe*		150 lb. Flange, *Brida de 150 lib., Bride, 150 lb/po²*		CP Max., *CP Máx., CP max.*	DC Max., *DC Máx., DC max.*	DD	X	Y	Motor Frame Size, *Tamaño del Armazón del Motor, Carcasse de moteur*				Wt. (lbs.), *Pesos (libras), Poids*
		Suct. *Succ.* ① *Aspir.*	Disch. *Desc.* ① *Refoul.*						143/145	182/184	213/215	254/256	
9SH	1 x 2 – 6	2	1	25⅜	5	4¾	6⅜	3⅛	9⅝	10¼	11¼	—	24
10SH	1 x 2 – 8				5⅝	5⅜	7⅛						32
11SH	1 x 2 – 10			27⅞	6⅞	6⅝	8⅞	4	10½	11⅛	12⅛	12⅜	54
4SH	1½ x 2½ – 6	2½	1½	25½	5	4¾	6⅜	3¼	9¾	10⅜	11⅜	—	25
7SH	1½ x 2½ – 8			27⅞	5⅝	5⅜	7⅛	4	10½	11⅛	12⅛	12⅜	34
5SH	2 x 2½ – 6		2		5	4¾	6⅜						25
8SH	2 x 2½ – 8				6	4¾	7 15/16						36
6SH	2½ x 3 – 6	3	2½										27

① For use with ANSI class 150 mating flanges.
Para usar con bridas que casan ANSI clase 150.
À utiliser avec des contre-brides ANSI, classe 150.

NOTE:
1. Pumps shipped in vertical discharge as standard. For other orientations, remove casing bolts, rotate discharge to desired position, and tighten ⅜ – 16 bolts to 12 ft./lbs., 7/16 – 14 bolts to 20 ft./lbs.
2. ALL dimensions in inches.
3. Motor dimensions may vary with motor manufacturer.
4. Not for construction purposes.

NOTA:
1. *Las bombas se transportarán en descarga vertical como estándar. Para otras orientaciones, retirar los tornillos de la carcasa, rotar la descarga a la posición deseada, y apretar ⅜ – 16 tornillos a 12 pies/libras, 7/16 – 14 tornillos a 20 pies/libras.*
2. *TODAS las dimensiones en pulgadas.*
3. *Las dimensiones puede que varíen con los fabricantes.*
4. *No para propósitos de construcción.*

NOTA :
1. *L'orifice de refoulement est orienté vers le haut. Pour l'orienter autrement, enlever les vis de fixation du corps de pompe, placer l'orifice dans le sens voulu, puis reposer et serrer les vis ⅜ - 16 à 12 lbf·pi et 7/16 - 14 à 20 lbf·pi.*
2. *Les dimensions sont en pouces, et le poids, en livres.*
3. *Les dimensions et le poids du moteur peuvent varier selon le fabricant.*
4. *Ne pas utiliser les dimensions pour la construction si elles ne sont pas certifiées à cette effet.*

Dimensions Determined by JM Motor Frame, *Dimensiones Determinadas por el Armazón del Motor JM, Dimensions – carcasse de moteur JM*

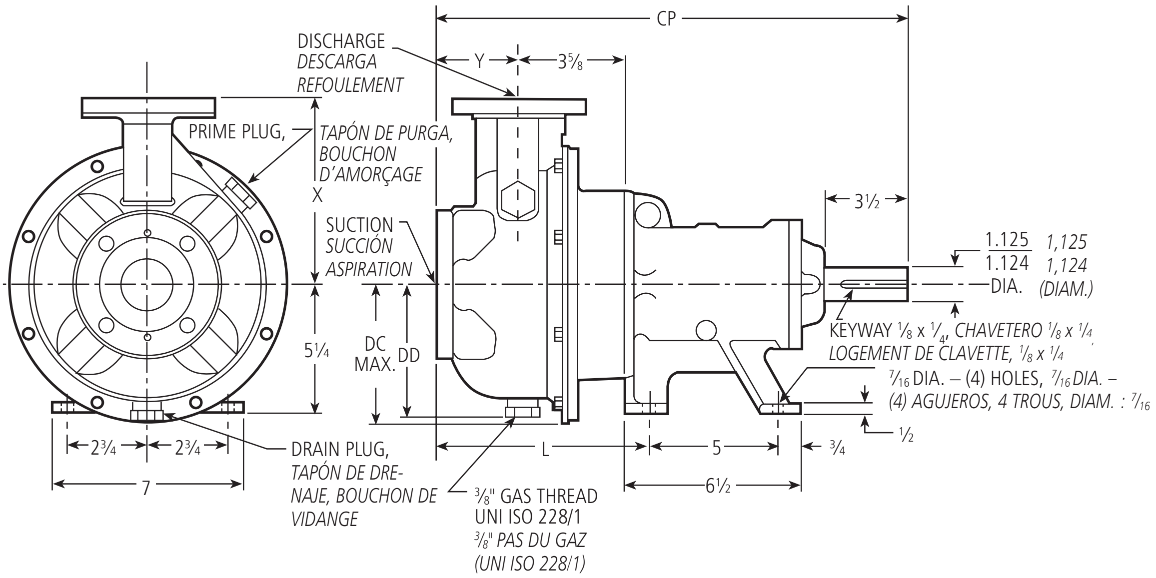
JM Frame, *JM Armazón, Carcasse*	A	AB	B	D	E	F	G	H Dia., *H Diám., H (diam.)*	P Max., *P Máx., P max.*	Motor Wt. (lbs.) *Peso Motor (lib.), Poids du moteur*
143JM	6½	5¼	6	3½	2¾	2	⅛	11/32	6⅝	41
145JM						2½				57
182JM	8½	5⅞	6½	4½	3¾	2¼	3/16	13/32	7⅞	77
184JM						2¾				97
213JM	9½	7⅜	8	5¼	4¼		7/32		9⅝	122
215JM						3½				155
254TCZ	11¼	9	9½	6¼	5	4⅛	¼	17/32	11½	265
256TCZ			11¾			5				320

Motor Frame Selections, *Selecciones del Armazón del Motor, Choix de carcasses de moteur*

Motor Frame, *Armazón del Motor, Carcasse*	Motor Horsepower, *Potencia del Motor, Puissance (hp)*							
	3500 RPM, *3500 RPM, 3 500 tr/min*				1750 RPM, *1750 RPM, 1750 tr/min*			
	1Ø, *Monofásicos 1 Ø*		3Ø, *Trifásicos 3 Ø*		1Ø, *Monofásicos 1 Ø*		3Ø, *Trifásicos 3 Ø*	
	ODP	TEFC	ODP	TEFC	ODP	TEFC	ODP	TEFC
143JM	–	–	–	–	–	–	1	1
145JM	2	2	2-3	2	1-1½	1-1½	1½-2	1½-2
182JM	3	3	5	3	2	2-3	3	3
184JM	5	5	7½	5	3	–	5	5
213JM	7½	–	10	7½	5	–	7½	7½
215JM	10	–	15	10-15	–	–	–	–
254TCZ	–	–	20	–	–	–	–	–
256TCZ	–	–	25	20-25	–	–	–	–

ODP = carcasse abritée (à ouvertures de ventilation protégées) ;
TEFC = carcasse fermée autoventilée.

SSH S-Group Frame-Mounted – Dimensions and Weights, *SSH Armazón Montado – Dimensiones y Pesos, Dimensions et poids – SSH montée sur palier, groupe S*



Dimensions and Weights – Bare Pump Only,
Dimensiones y Pesos – Solamente Bomba,
Dimensions et poids – pompe nue seulement

Pump, *Bomba, Pompe*		150 lb. Flange, *Brida de 150 lib., Bride, 150 lb/po²* Suction *Succión* ① *Aspir.*	Discharge *Descarga* ① *Refoul.*	DC Max., *DC Máx., DC max.*	DD	CP Max., *CP Máx., CP max.*	L	X	Y	Wt. (lbs.), *Peso (libras), Poids*
9SH	1 x 2 – 6	2	1	5	4¾	16¾	7⅝	6⅜	3⅛	56
10SH	1 x 2 – 8			5⅝	5⅜			7⅛		64
11SH	1 x 2 – 10			6⅞	6⅝	17 9/16	8½	8⅞	4	86
4SH	1½ x 2½ – 6	2½	1½	5	4¾	16 9/16	7¾	6⅜	3¼	56
7SH	1½ x 2½ – 8			5⅝	5⅜	17 5/16	8½	7⅛	4	64
5SH	2 x 2½ – 6		2	5	4¾					57
8SH	2 x 2½ – 8			6	5¾			6⅜		66
6SH	2½ x 3 – 6	3	2½							57

① For use with ANSI class 150 mating flanges.
Para usar con bridas que casan ANSI clase 150.
À utiliser avec des contre-brides ANSI, classe 150.

NOTE:

1. Pumps will be shipped with top vertical discharge as standard. For other orientations, remove casing bolts, rotate discharge to desired position, and tighten ⅜ –16 bolts to 12 ft./lbs., 7/16 – 14 bolts to 20 ft./lbs.
2. ALL dimensions in inches.
3. Not for construction purposes.

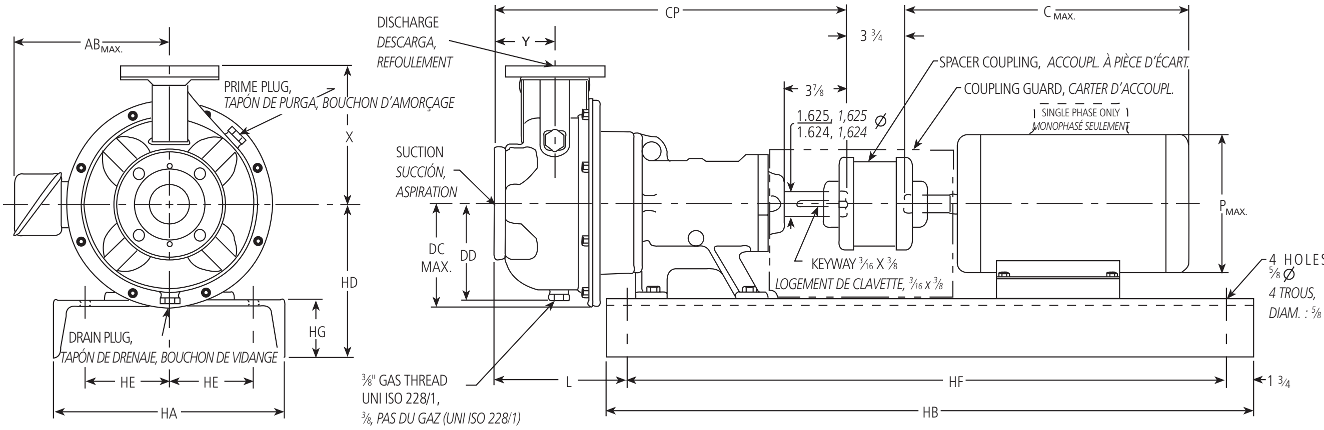
NOTA:

1. *Las bombas se transportarán con la descarga vertical superior como estándar. Para otras orientaciones, retirar los tornillos de la carcasa, rotar la descarga a la posición deseada, y apretar ⅜ – 16 tornillos a 12 pies/libras, 7/16 – 14 tornillos a 20 pies/libras.*
2. *TODAS las dimensiones en pulgadas.*
3. *No para propósitos de construcción.*

NOTA :

1. *L'orifice de refoulement est orienté vers le haut. Pour l'orienter autrement, enlever les vis de fixation du corps de pompe, placer l'orifice dans le sens voulu, puis reposer et serrer les vis ⅜ – 16 à 12 lbf·pi et 7/16 – 14 à 20 lbf·pi.*
2. *Les dimensions sont en pouces, et le poids, en livres.*
3. *Ne pas utiliser les dimensions pour la construction si elles ne sont pas certifiées à cette effet.*

Channel Steel Bedplate, Clockwise Rotation Viewed from Drive End;
Fundación de Acero, Rotación en Dirección de las Agujas del Reloj Visto desde el Extremo del Motor;
Plaque de base profilée en U et rotation en sens horaire (vue de l'extrémité du moteur)



Dimensions and Weights – Determined by Pump,
Dimensiones y Pesos – Determinados por la Bomba,
Dimensions et poids – pompe

Pump, *Bomba, Pompe*	Pump Size, *Tamaño de la Bomba, Dimensions*	① Suction *Succión Aspir.*	① Discharge *Descarga Refoul.*	CP	DC Max., *DC Máx., DC max.*	DD	L	X	Y	Wt. (lbs.), *Peso (libras), Poids*
24SH	1½ x 2½-10	2½	1½	23	6⅞	6⅝	10⅛	8 15/16	4	125
25SH	2 x 2½-10		2							125
22SH	2½ x 3-8	3	2½		6⅛	5⅞				125
27SH	2½ x 3-10				6⅞	6⅝		9 15/16		134
23SH	3 x 4-8	4	3	24			11⅛		5	136
28SH	3 x 4-10				7⅝	7⅜		11⅛		148

① For use with ANSI class 150 mating flanges.
Para usar con bridas que casan ANSI clase 150.
À utiliser avec des contre-brides ANSI, classe 150.

NOTE:
1. Pumps will be shipped with top vertical discharge as standard. For other orientations, remove casing bolts, rotate discharge to desired position and tighten ⅜ – 16 bolts to 12 ft./lbs.
2. ALL dimensions in inches.
3. Not for construction purposes.

NOTA:
1. *Las bombas se transportarán con la descarga vertical superior como estándar. Para otras orientaciones, retirar los tornillos de la carcasa, rotar la descarga a la posición deseada, y apretar ⅜ – 16 tornillos a 12 pies/libras.*
2. *TODAS las dimensiones en pulgadas.*
3. *No para propósitos de construcción.*

NOTA :
1. *L'orifice de refoulement est orienté vers le haut. Pour l'orienter autrement, enlever les vis de fixation du corps de pompe, placer l'orifice dans le sens voulu, puis reposer et serrer les vis ⅜ - 16 à 12 lbf·pi.*
2. *Les dimensions sont en pouces, et le poids, en livres.*
3. *Les dimensions et le poids du moteur peuvent varier selon le fabricant.*
4. *Ne pas utiliser les dimensions pour la construction si elles ne sont pas certifiées à cette effet.*

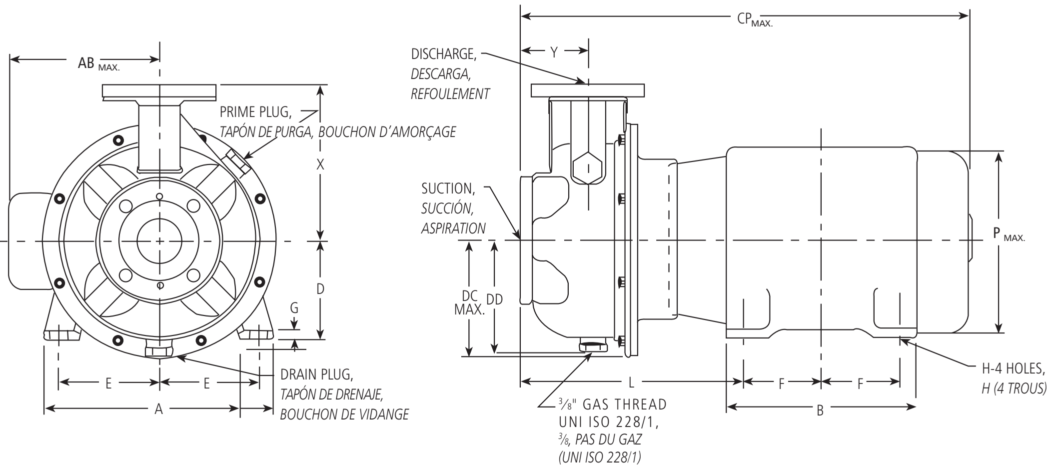
Available Motor and Bedplate Dimensions and Weights,
Pesos y Dimensiones Disponibles de la Fundación y del Motor,
Dimensions et poids – moteur et plaque de base

Motor Frame, *Armazón del Motor, Carcasse de moteur*	HP @ 3500 RPM, *hp à 3 500 tr/min*		HP @ 1750 RPM – T-Frame Only *hp à 1 750 tr/min – carc. T seulem.*				AB Max., *AB Máx., AB max.*	C Max., *C Máx., C max.*	P Max., *P Máx., P max.*	Wt. Max., *Peso Máx., Poids max.*	Bedplate Data, *Datos de la Fundación, Plaque de base*						
	Three Phase, *Trifásicos, 3 Ø*		Single Phase, *Monofásicos, 1 Ø*		Three Phase, *Trifásicos, 3 Ø*						HA	HB	HD	HE	HF	HG	Wt. (lbs.), *Peso (libras), Poids*
	ODP	TEFC	ODP	TEFC	ODP	TEFC											
184T			3 or *ou* 5	3	5	5	5⅞	18⅛	7⅞	95	13	42	10¼	5¼	38½	4	111
213T					7½	7½	7⅜	18	9⅝	116							
215T	15				10	10		19⅛		136							
254T	20	15			15	15	9½	21⅝	13	266							
256T	25	20			20	20		23⅜		264							
284TS/T	30	25			25	25	12⅝	24⅞	15	392	15	44	10½	5¾	40½	3½	124
286TS/T	40	30						26⅝		422							
324TS/T	50	40					14⅛	28¾	17⅜	592	18	48	12	7¼	44½	4	183
326TS/T	60	50						30¼		634							
364TS/T	75	60					15⅛	31⅝	18⅞	834			13				
365TS/T	100	75						32⅝		1000							
405TS/T		100					18	36⅞	20⅝	1060	22	56	14	7¼	52½	4	214

Dimensions and weights vary with manufacturers. Dimensions in inches and weights in lbs.
Dimensiones y pesos varían con los fabricantes. Dimensiones en pulgadas y pesos en libras.
ODP = carcasse abritée (à ouvertures de ventilation protégées) ; TEFC = carcasse fermée autoventilée.

SSH M-Group Close Coupled – Dimensions and Weights, *SSH Acople Cerrado – Dimensiones y Pesos, Dimensions et poids – SSH montée sur moteur, groupe M*

(All dimensions in inches and weights in lbs. Do not use for construction purposes.)
(Todas las dimensiones en pulgadas y pesos en libras. No usar para propósitos de construcción.)



Dimensions "L" Determined by Pump and Motor, *Dimensiones "L" Determinadas por la Bomba y el Motor, Dimensions L – pompe et moteur*

Pump, *Bomba, Pompe*	Pump Size, *Tamaño de la Bomba, Dimensions*	① Suction *Succión Aspir.*	① Discharge *Descarga Refoul.*	CP Max., *CP Máx., CP max.*	DC Max., *DC Máx., DC max.*	DD	X	Y	Wt. (lbs.), *Peso (libras), Poids*	Motor Frame Size, *Tamaño del Armazón del Motor, Carcasse de moteur*						
										140	180	210	250	280	320	360
24SH	1½ x 2 ½-10	2½	1½	34½	6⅞	6⅝	8 15/16	4	75	10½	11⅛	12⅛	13⅞		14⅜	-
25SH	2 x 2½-10		2	36					75							15
22SH	2½ x 3-8	3	2½		6⅛	5⅞			72	-						
27SH	2½ x 3-10				6⅞	6⅝	9 15/16		84	-	-					
23SH	3 x 4-8	4	3	37				5	86	11½	12⅛	13⅜	14⅞		15⅜	16
28SH	3 x 4-10				7⅝	7⅜	11⅛		98	-	-					

① For use with ANSI class 150 mating flanges.
Para usar con bridas que casan ANSI clase 150.
À utiliser avec des contre-brides ANSI, classe 150.

NOTES:
1. Pumps shipped in vertical discharge as standard. For other orientations, remove casing bolts, rotate discharge to desired position, and tighten ⅜ – 16 bolts to 12 ft./lbs., 7/16 – 14 bolts to 20 ft./lbs., ½ – 13 bolts to 35 ft./lbs.
2. Motor dimensions may vary with motor manufacturer.
3. Not for construction purposes.

NOTAS:
1. *Las bombas se transportarán en descarga vertical como estándar. Para otras orientaciones, retirar los tornillos de la carcasa, rotar la descarga a la posición deseada, y apretar ⅜ – 16 tornillos a 12 pies/libras, 7/16 – 14 tornillos a 20 pies/libras, ½ – 13 tornillos a 35 pies/libras.*
2. *TODAS las dimensiones en pulgadas.*
3. *No para propósitos de construcción.*

NOTA :
1. *L'orifice de refoulement est orienté vers le haut. Pour l'orienter autrement, enlever les vis de fixation du corps de pompe, placer l'orifice dans le sens voulu, puis reposer et serrer les vis ⅜ - 16 à 12 lbf·pi, 7/16 - 14 à 20 lbf·pi et ½ - 13 à 35 lbf·pi.*
2. *Les dimensions sont en pouces, et le poids, en livres.*
3. *Les dimensions et le poids du moteur peuvent varier selon le fabricant.*
4. *Ne pas utiliser les dimensions pour la construction si elles ne sont pas certifiées à cette effet.*

Dimensions Determined by JM Motor Frame, *Dimensiones Determinadas por el Armazón del Motor JM, Dimensions – carcasse de moteur JM*

Frame, *Armazón, Carcasse*	A	AB Max., *AB max.*	B	D	E	F	G	H	P Max., *P Máx., P max.*
145JM	6½	5¼	6	3½	2¾	2½	⅛	11/32	7 3/16
182JM	8½	5⅞	6½	4½	3¾	2¼	3/16	13/32	8½
184JM						2¾			
213JM	9½	7⅜	8	5¼	4¼		7/32		10 3/16
215JM						3½			
254JM	11¼	9	11¾	6¼	5	4⅛	¼	17/32	13¼
256JM						5			
284JM	12¼	12¼	12¼	7	5½	4¾			15
286JM						5½			
324JM	14	13¼	14	8	6¼	5¼	5/16	21/32	16 15/16
326JM						5½			
364TCZ	17¾	15⅛	15½	9	7	5⅝	1		19
365TCZ						6⅛			

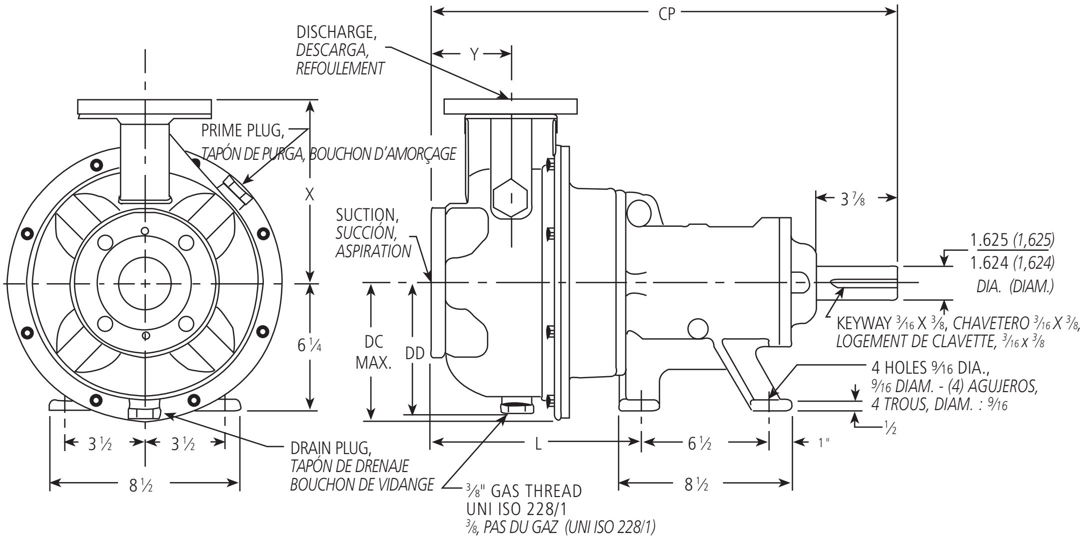
364TCZ and 365TCZ frames are built with 326JM shaft extensions.
Dimensions may vary with manufacturer.;
Los armazones 364TCZ y 365TCZ se construyen con extensiones del eje 326JM.
Las dimensiones puede que varíen con los fabricantes.;
Les carcasses 364TCZ et 365TCZ possèdent la rallonge d'arbre de la 326JM.

Motor Frame Selections, *Selecciones del Armazón del Motor, Choix de carcasses de moteur*

Frame, *Armazón, Carcasse*	Motor Horsepower, *Potencia del Motor, Puissance (hp)*						Wt. Max., *Peso Máx., Poids max.*
	3500 RPM, *3500 tr/min*		1750 RPM, *1750 tr/min*				
	3 PH, *Trifásicos, 3 Ø*		1 PH, *Monofásicos, 1 Ø*		3 PH, *Trifásicos, 3Ø*		
	ODP	TEFC	ODP	TEFC	ODP	TEFC	
145JM	–	–	–	–	2	2	57
182JM	–	–	2	2, 3	3	3	77
184JM	–	–	3	–	5	5	97
213JM	10	–	5	–	7½	7½	141
215JM	15	10	–	–	10	10	155
254JM	20	15	–	–	15	15	265
256JM	25	20	–	–	20	20	320
284JM	30	25	–	–	25	25	419
286JM	40	30	–	–	–	–	422
324JM	50	40	–	–	–	–	562
326JM	60	50	–	–	–	–	625
364TCZ	75	60	–	–	–	–	775
365TCZ	100	75, 100	–	–	–	–	905

364TCZ and 365TCZ frames are built with 326JM shaft extensions.
Los armazones 364TCZ y 365TCZ se construyen con extensiones del eje 326JM.
ODP = carcasse abritée (à ouvertures de ventilation protégées) ; TEFC = carcasse fermée autoventilée. Les carcasses 364TCZ et 365TCZ possèdent la rallonge d'arbre de la 326JM.

SSH M-Group Frame Mounted – Dimensions and Weights, *SSH Armazón Montado – Dimensiones y Pesos, Dimensions et poids – SSH montée sur palier, groupe M*



Dimensions and Weights – Bare Pump Only,
Dimensiones y Pesos – Solamente Bomba
Dimensions et poids – pompe nue seulement

<table>
<tr><th>Pump, Bomba, Pompe</th><th>Pump Size, Tamaño de la Bomba, Dimensions</th><th>① Suction Succión Aspir.</th><th>① Discharge Descarga Refoul.</th><th>CP</th><th>DC Max., DC Máx., DC max.</th><th>DD</th><th>L</th><th>X</th><th>Y</th><th>Wt. (lbs.), Peso (libras), Poids</th></tr>
<tr><td>24SH</td><td>1½ x 2½-10</td><td rowspan="2">2½</td><td>1½</td><td rowspan="4">23</td><td rowspan="2">6⅞</td><td rowspan="2">6⅝</td><td rowspan="4">10½</td><td rowspan="3">8 15/16</td><td rowspan="4">4</td><td>125</td></tr>
<tr><td>25SH</td><td>2 x 2½-10</td><td>2</td><td>125</td></tr>
<tr><td>22SH</td><td>2½ x 3-8</td><td rowspan="2">3</td><td rowspan="2">2½</td><td>6⅛</td><td>5⅞</td><td>125</td></tr>
<tr><td>27SH</td><td>2½ x 3-10</td><td rowspan="2">6⅞</td><td rowspan="2">6⅝</td><td rowspan="2">9 15/16</td><td>134</td></tr>
<tr><td>23SH</td><td>3 x 4-8</td><td rowspan="2">4</td><td rowspan="2">3</td><td rowspan="2">24</td><td rowspan="2">11½</td><td rowspan="2">5</td><td>136</td></tr>
<tr><td>28SH</td><td>3 x 4-10</td><td>7⅝</td><td>7⅜</td><td>11⅛</td><td>148</td></tr>
</table>

① For use with ANSI class 150 mating flanges.
Para usar con bridas que casan ANSI clase 150.
À utiliser avec des contre-brides ANSI, classe 150.

NOTES:
1. Pumps will be shipped with top vertical discharge as standard. For other orientations, remove casing bolts, rotate discharge to desired position, replace and tighten 3/8–16 bolts to 12 ft./lbs.
2. Motor dimensions may vary with motor manufacturer.
3. Not for construction purposes.

NOTAS:
1. *Las bombas se transportarán con la descarga vertical superior como estándar. Para otras orientaciones, retirar los tornillos de la carcasa, rotar la descarga a la posición deseada, y apretar 3/8 – 16 tornillos a 12 pies/libras.*
2. *TODAS las dimensiones en pulgadas.*
3. *No para propósitos de construcción.*

NOTA *:*
1. *L'orifice de refoulement est orienté vers le haut. Pour l'orienter autrement, enlever les vis de fixation du corps de pompe, placer l'orifice dans le sens voulu, puis reposer et serrer les vis 3/8 – 16 à 12 lbf·pi.*
2. *Les dimensions sont en pouces, et le poids, en livres.*
3. *Les dimensions et le poids du moteur peuvent varier selon le fabricant.*
4. *Ne pas utiliser les dimensions pour la construction si elles ne sont pas certifiées à cette effet.*

Declaration of Conformity

We at,
Goulds Pumps/ITT Industries
1 Goulds Drive
Auburn, NY 13021
Declare that the following products: SSH, NPE, MCS, MCC, 3656, 3656 SP, GB, SSV, SVI, NPO, Prime Line SP, HB, HMS, LC, NPV, LB, LBS Comply with Machine Directive 98/37/EC. This equipment is intended to be incorporated with machinery covered by this directive, but must not be put into service until the machinery into which it is to be incorporated has been declared in conformity with the actual provisions of the directive.

James M. Allocco
Product Manager

ITT

Commercial Water

GOULDS PUMPS LIMITED WARRANTY

This warranty applies to all water systems pumps manufactured by Goulds Pumps.

Any part or parts found to be defective within the warranty period shall be replaced at no charge to the dealer during the warranty period. The warranty period shall exist for a period of twelve (12) months from date of installation or eighteen (18) months from date of manufacture, whichever period is shorter.

A dealer who believes that a warranty claim exists must contact the authorized GouldsPumps distributor from whom the pump was purchased and furnish complete details regarding the claim. The distributor is authorized to adjust any warranty claims utilizing the Goulds Pumps Customer Service Department.

The warranty excludes:

(a) Labor, transportation and related costs incurred by the dealer;
(b) Reinstallation costs of repaired equipment;
(c) Reinstallation costs of replacement equipment;
(d) Consequential damages of any kind; and,
(e) Reimbursement for loss caused by interruption of service.

For purposes of this warranty, the following terms have these definitions:

(1) "Distributor" means any individual, partnership, corporation, association, or other legal relationship that stands between Goulds Pumps and the dealer in purchases, consignments or contracts for sale of the subject pumps.
(2) "Dealer" means any individual, partnership, corporation, association, or other legal relationship which engages in the business of selling or leasing pumps to customers.
(3) "Customer" means any entity who buys or leases the subject pumps from a dealer. The "customer" may mean an individual, partnership, corporation, limited liability company, association or other legal entity which may engage in any type of business.

THIS WARRANTY EXTENDS TO THE DEALER ONLY.

GOULDS PUMPS

IM184R04 December, 2006

Engineered for life

A.2 Bomba 3.0 HP

STERLING

HALBERG

CERTIFICADO DE GESTION DE LA CALIDAD

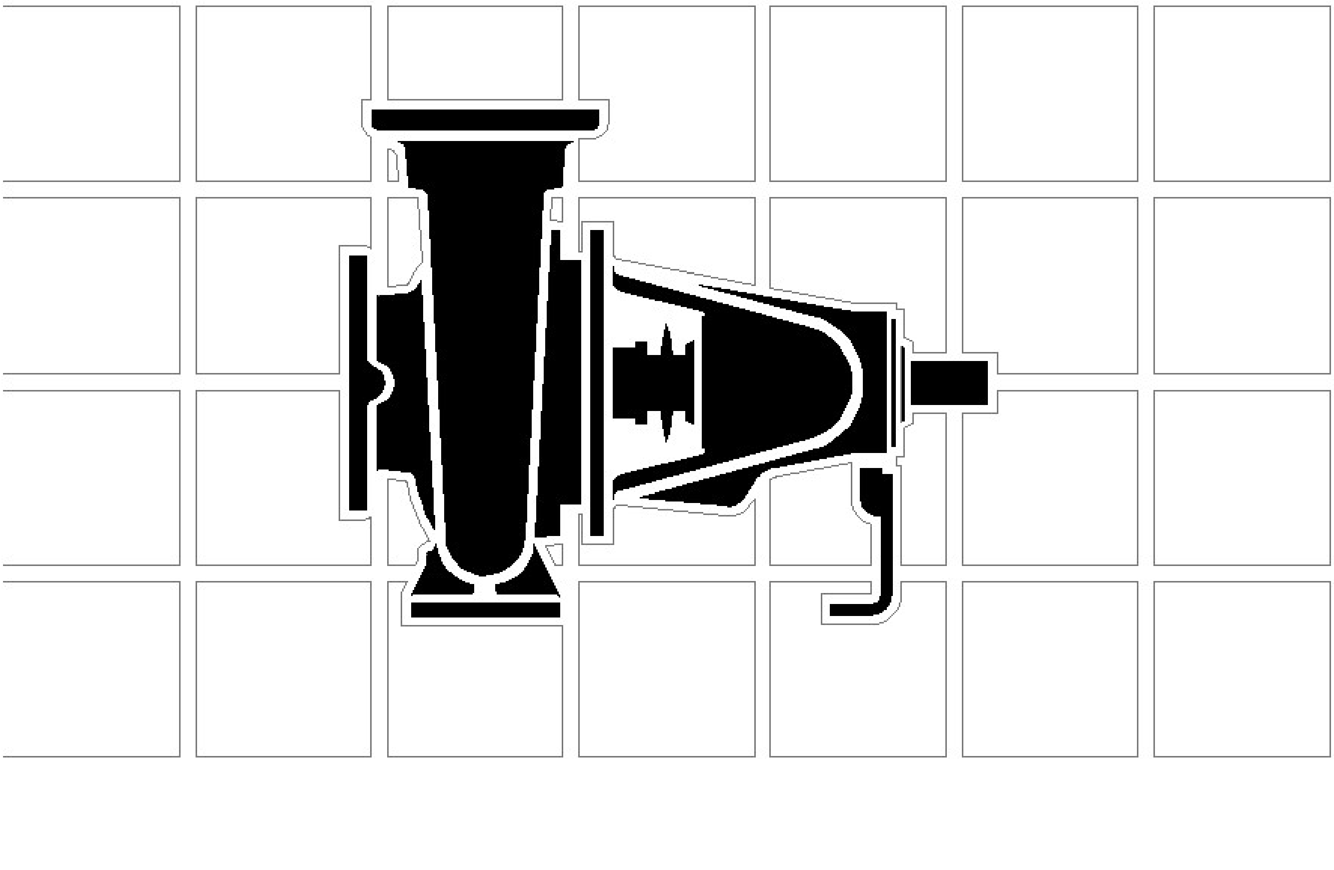
Código No. 1205-1

DISEÑO, DESARROLLO DE PROYECTOS, VENTA Y DISTRIBUCIÓN DE: BOMBAS, SISTEMAS DE BOMBEO Y EQUIPOS RELACIONADOS. FABRICACIÓN DE: BOMBAS CENTRÍFUGAS DE SUPERFICIE, BOMBAS SUMERGIBLES PARA AGUAS SERVIDAS Y BOMBAS DE VACÍO DE ANILLO LÍQUIDO.

NTC ISO 9001:2000

HALBERG NOWA

Bombas Centrífugas de Carcasa Espiral



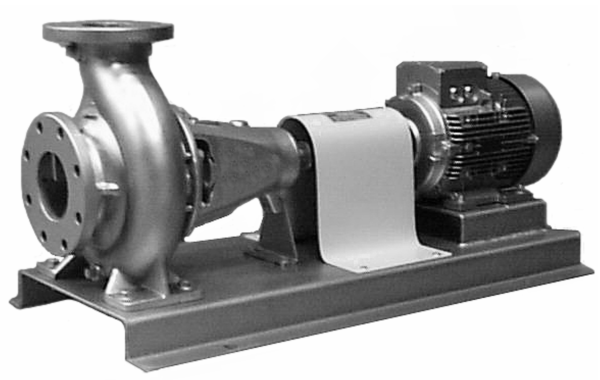
STERLING FLUID SYSTEMS GROUP

www.sterlingfluidsystems.com

CT0101.01.03 / Feb. 2003 / 1000

NOWA 3213...25032

según EN 733 / DIN 24255 y transnorma



DATOS TECNICOS

Caudal	: Máx.	1300	m^3/h
Altura	: Máx.	140	m
Velocidad	: Máx.	3600	r.p.m.
Temperatura	: Máx.	160	°C
Presión de la carcasa	: Máx.	16	bar
Cierre del eje	: Empaquetadura ó sello mecánico		

APLICACIONES

Las bombas centrífugas NOWA pueden emplearse en todas aquellas aplicaciones donde se tenga que trasegar líquidos limpios ó turbios no agresivos. Sus aplicaciones son principalmente:

- Abastecimiento de agua potable.
- Suministro de agua en general para agricultura e industria.
- Sistemas de rociadores (riego, contra incendio, etc.).
- Circulación de agua caliente hasta 160°C, agua de refrigeración y aceite en circuitos de refrigeración y calefacción.
- Bombeo de condensados gracias a un NPSH especialmente favorable
- En ejecución de bronce, fundición nodular, acero al carbono e inoxidable, pueden utilizarse en diferentes tipos de fluidos.

DESCRIPCION Y CONSTRUCCION

Bombas centrífugas con carcasa en espiral, horizontales de una sola etapa, con dimensiones y características de funcionamiento según EN 733 / DIN 24255 en construcción proceso, más tamaños transnorma.

El sistema proceso permite desmontar las partes giratorias hacia el lado del motor, sin necesidad de desacoplar las conducciones de aspiración y de impulsión. Si además se utiliza un acople de extensión, tampoco es necesario mover el motor.

El programa NOWA comprende 42 tamaños constructivos, pero mediante el empleo de unidades normalizadas, son utilizables solo seis (6) conjuntos de eje. Dentro de cada conjunto son intercambiables los siguientes elementos: el eje, el cierre del eje, la fijación del impulsor, los rodamientos y el soporte de los rodamientos (bastidor).

Apoyo del eje:

Un rodamiento rígido de una hilera de bolas según DIN 625 y un rodamiento de contacto angular de dos hileras de bolas según DIN 628, ambos con juego interno tipo C3 según DIN 620 y lubricados por grasa. Bajo pedido se pueden suministrar con lubricación por baño de aceite.

Presión máxima de trabajo (bar)**:**

Rango de Temperatura	Ejecución de materiales (ver pág. 4)	
	0B / 0C / 3B	1A / 2A / 4B
-10 hasta 110 °C	10(1)	16
110 hasta 160 °C	9	14

(1) En los tamaños 4026, 15050 y 20050: 14 bar hasta 30 °C

ATENCION: La presión máxima de trabajo es igual a la presión de aspiración más la presión de descarga para caudal cero

Bridas:

Bridas según ANSI B16.1 clases 125 ó 250, según el tipo de bomba. Posición de la brida de succión axial y de la brida de descarga radial orientada hacia arriba.

Sentido de giro:

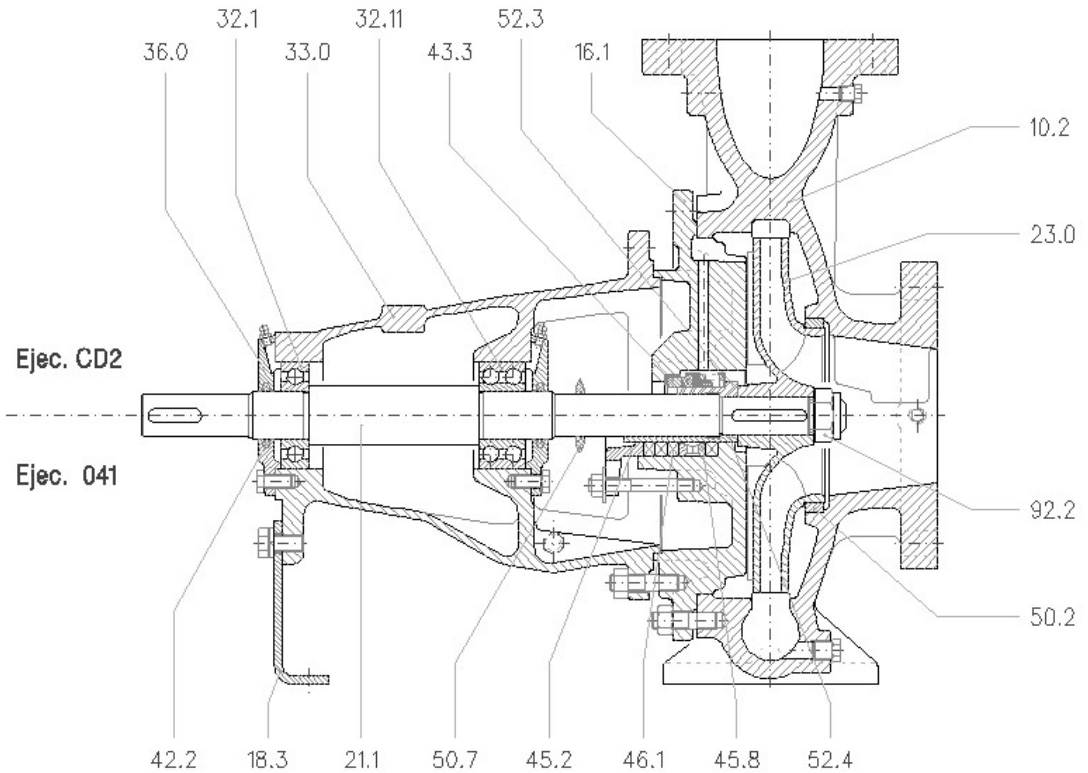
A la derecha (sentido horario), visto desde el extremo de accionamiento.

Cierre del eje:

El cierre del eje puede efectuarse mediante empaquetadura ó sello mecánico según sea requerido. En ambos casos, el eje está protegido por un casquillo de acero inoxidable.

- Ejecución 011: Prensaestopas prolongado sin anillo de cierre hidráulico. Temperatura: -10 hasta 110 ºC.
- Ejecución 041: Prensaestopas no refrigerado, con lubricación interna por el mismo líquido bombeado. Temperatura: -10 hasta 110 °C.
- Ejecución 051: Prensaestopas no refrigerado, con lubricación por líquido externo (conexión de entrada y salida). Temperatura: -10 hasta 110 °C.
- Ejecución 541: Prensaestopas con lubricación interna por el mismo líquido bombeado y chaqueta de refrigeración. Temperatura hasta 160 °C (No disponible para conjunto de eje C-55).
- Ejecución CD2: Sello mecánico monoresorte, no balanceado, lavado internamente por el mismo líquido bombeado. Temperatura: -10 hasta 110 °C.
- Ejecuciones con sellos mecánicos especiales ó de proceso son posibles; consultar con la fabrica.

PLANO DE CORTE Y LISTA DE PARTES

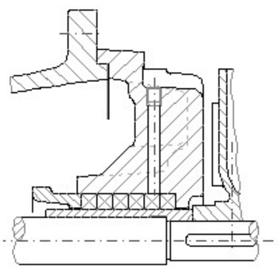


10.2	Carcasa	33.0	Soporte (Bastidor)	46.1	Empaquetadura
16.1	Tapa carcasa	36.0	Tapa rodamiento	50.2	Anillo de desgaste
18.3	Pata soporte	42.2	Anillo de fieltro	50.7	Anillo deflector
21.1	Eje	43.3	Sello mecánico	52.3	Casquillo del eje S.M.
23.0	Impulsor	45.2	Casquete prensaestopas	52.4	Casquillo del eje P.E.
32.1	Rodamiento exterior	45.8	Anillo de cierre hidráulico	92.2	Tuerca impulsor
32.11	Rodamiento interior				

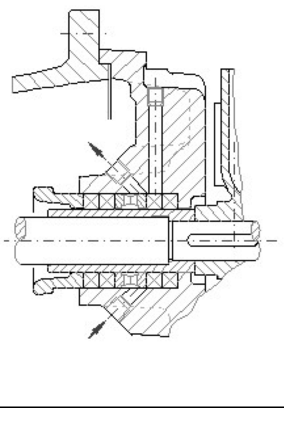
NOTA: Plano de corte de bomba con paletas dorsales. Los tamaños 15020, 15026, 20025 y todas las bombas con diámetro nominal del impulsor de 32, 40 y 50 cm, tienen anillo de desgaste en ambos lados del impulsor.

Otras ejecuciones de cierre del eje

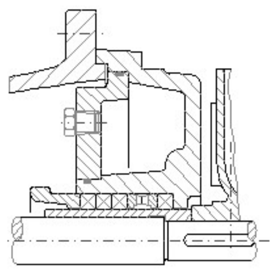
Ejecución 011
Prensaestopas prolongado
sin anillo de cierre hidráulico



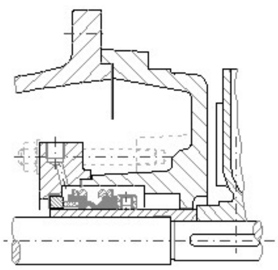
Ejecución 051
Prensaestopas con lubricación
por líquido externo



Ejecución 541
Prensaestopas con chaqueta
de refrigeración



Ejecución S.M. especiales
Sellos mecánicos especiales
o de proceso



EJECUCION DE MATERIALES

<table>
<tr><th rowspan="2">Pos.</th><th rowspan="2">Denominación</th><th colspan="6">Ejecución de materiales(1)</th></tr>
<tr><th>0B</th><th>0C</th><th>1A</th><th>2A</th><th>3B</th><th>4B</th></tr>
<tr><td>10.2</td><td>Carcasa</td><td rowspan="4">Fundición gris</td><td rowspan="3">Fundición gris</td><td rowspan="2">Fundición nodular</td><td rowspan="2">Ac. al Carbono (termorresist.)</td><td rowspan="4">Bronce</td><td rowspan="4">Acero inoxidable</td></tr>
<tr><td>16.1</td><td>Tapa carcasa</td></tr>
<tr><td>50.2</td><td>Anillo de desgaste</td><td rowspan="2">Fundición gris</td><td rowspan="2">Fundición gris</td></tr>
<tr><td>23.0</td><td>Impulsor</td><td>Bronce</td></tr>
<tr><td>21.1</td><td>Eje</td><td colspan="4">Acero al carbón AISI 1045(2)</td><td colspan="2">Acero inox. AISI 304 ó 316(3)</td></tr>
<tr><td>52.3/4</td><td>Casquillo del eje</td><td colspan="6">Acero inoxidable AISI 304 ó 316</td></tr>
<tr><td>46.1</td><td>Empaquetadura</td><td colspan="6">PTFE con grafito incorporado + Fibras de Aramid</td></tr>
<tr><td>43.3</td><td>Sello mecánico</td><td colspan="6">Carbón / Cerámica / Buna N / Acero inoxidable(4)</td></tr>
</table>

(1) Otras combinaciones de materiales son posibles bajo pedido.
(2) En bombas con conjunto de eje C-45 y potencias superiores a 120 HP – 1750 rpm y con conjunto de eje C-55 y potencias superiores a 240 HP – 1750 rpm, se emplea acero AISI 4340 ó 4140 bonificado.
(3) En bombas con conjunto de eje C-45 y potencias superiores a 90 HP –1750 rpm y con conjunto de eje C-55 y potencias superiores a 180 HP – 1750 rpm, se emplea acero AISI 420 modificado.
(4) De acuerdo al tipo de sello, se pueden suministrar otras combinaciones de material.

Especificación de los materiales fundidos

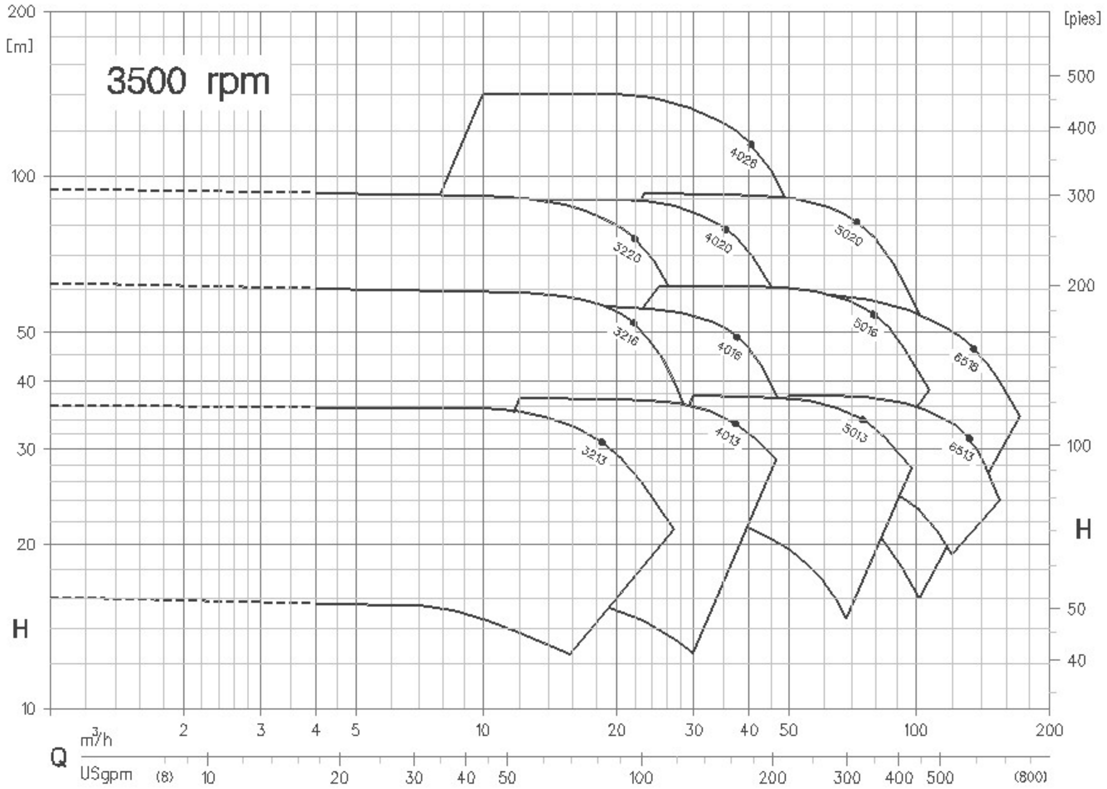
<table>
<tr><th>Descripción</th><th colspan="2">Norma colombiana NTC</th><th colspan="2">Norma alemana DIN</th><th>Norma americana ASTM</th></tr>
<tr><td>Fundición gris</td><td>(1370)</td><td>FG-200</td><td>(1691)</td><td>GG-20</td><td>A48 clase 30B</td></tr>
<tr><td>Fundición nodular</td><td>(1415)</td><td>Grado 400-15</td><td>(1693)</td><td>GGG-40</td><td>A536 clase 60-40-18</td></tr>
<tr><td>Ac. al Carbono (termorresist.)</td><td></td><td></td><td>(17200)</td><td>GS-C25</td><td>A216 clase WCB</td></tr>
<tr><td>Bronce</td><td></td><td></td><td>(1705)</td><td>G-CuSn 12 Ni</td><td>B427</td></tr>
<tr><td rowspan="2">Acero inoxidable</td><td></td><td></td><td>(17445)</td><td>G-X6CrNiMo18 10</td><td>A296 clase CF 8M</td></tr>
<tr><td></td><td></td><td>(17445)</td><td>G-X10CrNiMo18 9</td><td>A296 clase CF 12M</td></tr>
</table>

REGIMEN DE VELOCIDAD

Las velocidades máximas admisibles para los diferentes modelos de las bombas NOWA son:

<table>
<tr><th colspan="10">Tipo de bomba</th><th>Velocidad máxima [rpm]</th></tr>
<tr><td>3213</td><td>4013</td><td>5013</td><td>6513</td><td></td><td></td><td></td><td></td><td></td><td></td><td rowspan="4">3600</td></tr>
<tr><td>3216</td><td>4016</td><td>5016</td><td>6516</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3220</td><td>4020</td><td>5020</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>4026</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>8016</td><td></td><td></td><td></td><td></td><td></td><td rowspan="3">3000</td></tr>
<tr><td></td><td></td><td></td><td>6520</td><td>8020</td><td>10020</td><td>12520</td><td></td><td></td><td></td></tr>
<tr><td>3226</td><td></td><td>5026</td><td>6526</td><td>8026</td><td>10026</td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>15020</td><td></td><td></td><td rowspan="5">1800</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td>12526</td><td>15026</td><td>20025</td><td></td></tr>
<tr><td></td><td>4032</td><td>5032</td><td>6532</td><td>8032</td><td>10032</td><td>12532</td><td>15032</td><td>20032</td><td>25032</td></tr>
<tr><td></td><td></td><td></td><td></td><td>8040</td><td>10040</td><td>12540</td><td>15040</td><td>20040</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>15050</td><td>20050</td><td></td></tr>
</table>

CAMPOS DE APLICACION



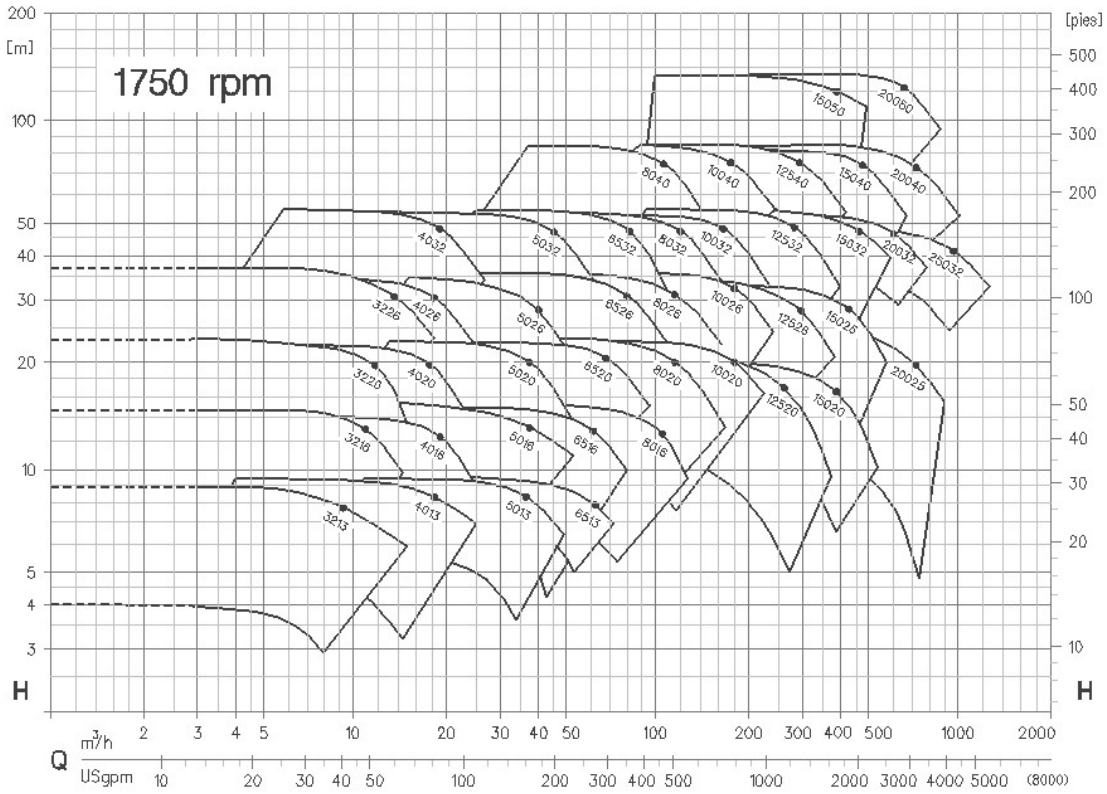
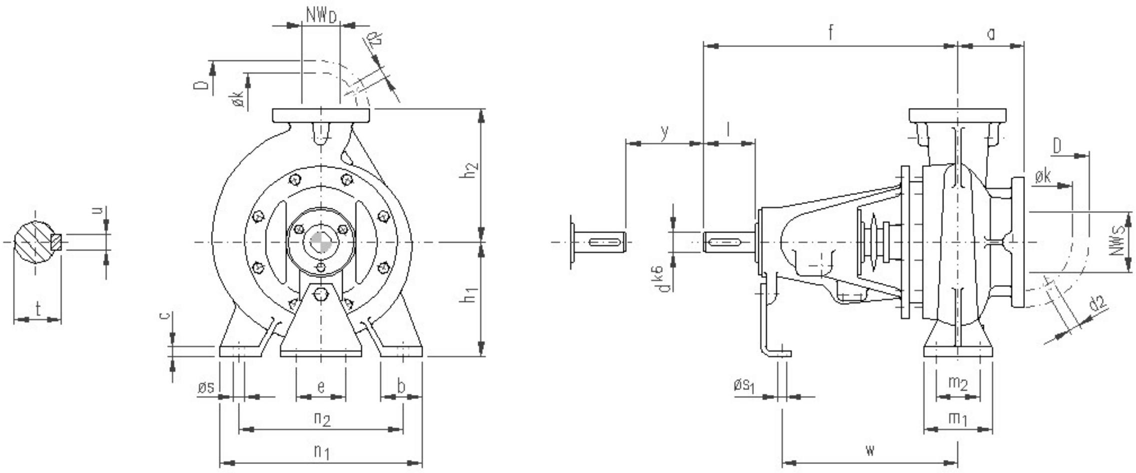


TABLA DE DIMENSIONES



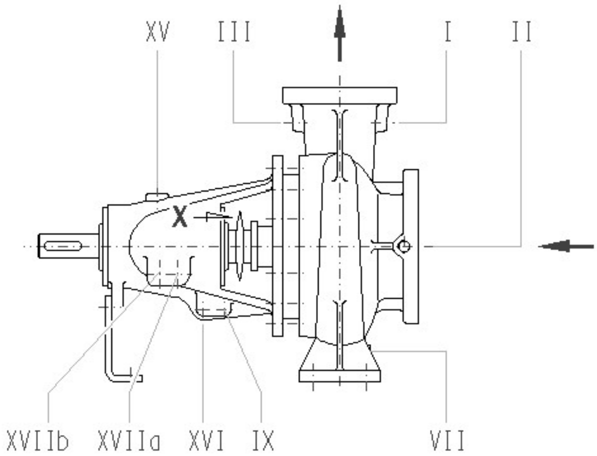
TIPO	EJE	MEDIDAS DE LA BOMBA						MEDIDAS DE LAS PATAS										EXTREMO DEL EJE				(1)
		NW_D	NW_S	a	f	h_1	h2	b	c	m_1	m_2	n_1	n_2	s	e	s_1	w	d	l	t	u	y
3213	25	1, 1/4"	2″	80	360	112	140	50	14	100	70	190	140	14	100	14	267	24	50	27	8	140
3216						132	160					240	190									
3220						160	180								110							
3226				100		180	225	65		125	95	320	250									
4013	25	1, 1/2"	2, 1/2"	80	360	112	140	50	14	100	70	210	160	14	100	14	267	24	50	27	8	140
4016						132	160					240	190									
4020				100		160	180					265	212		110							
*4026	35				470	180	225	65		125	95	320	250				342	32	80	35	10	
4032				125		200	250					345	280									
5013	25	2″	2, 1/2"	100	360	132	160	50	14	100	70	240	190	14	100	14	267	24	50	27	8	140
5016						160	180					265	212		110							
5020							200															
5026						180	225	65		125	95	320	250									
5032	35		3″	125	470	225	280					345	280				342	32	80	35	10	
6513	25	2, 1/2"	3″	100	360	160	180	65	14	125	95	280	212	14	110	14	267	24	50	27	8	140
6516							200															
6520						180	225					320	250									
6526	35				470	200	250	80	16	160	120	360	280	18			342	32	80	35	10	
6532				125		225	280					400	315									
8016	25	3″	4″	125	360	180	225	65	14	125	95	320	250	14	110	14	267	24	50	27	8	140
8020	35				470		250					345	280				342	32	80	35	10	
8026						200	280	80	16	160	120	400	315	18								
8032						250	315															
8040	45		5″		530	280	355					435	355				370	42	110	45	12	
10020	35	4″	5″	125	470	200	280	80	16	160	120	360	280	18	110	14	342	32	80	35	10	140
10026				140		225						400	315									
10032						250	315															
10040	45				530	280	355	100	18	200	150	500	400	23			370	42	110	45	12	
12520	35	5″	6″	140	470	250	315	80	18	160	120	400	315	18	110	14	342	32	80	35	10	180
12526							355		16													140
12532	45				530	280		100	18	200	150	500	400	23			370	42	110	45	12	
12540						315	400															
15020	35	6″	8″	160	470	280	400	100	18	150	150	550	450	23	110	14	342	32	80	35	10	180
15026	45				530		375					500	400				370	42	110	45	12	140
15032							400					550	450									
15040						315	450															
*15050	55			180	670	400	500		22			640	540		140	18	489	48	115	51,5	14	180
20025	45	8″	8″	160	595	280	400	100	22	150	150	500	400	23	110	14	435	42	110	45	12	200
20032	55		10″	200	670	355	450					550	450		140	18	489	48	115	51,5	14	180
20040				180			500															
*20050				200		425	620					700	600									
25032	55	10″	12″	250	670	375	560	120	28	240	190	620	520	23	140	18	489	48	115	51,5	14	180

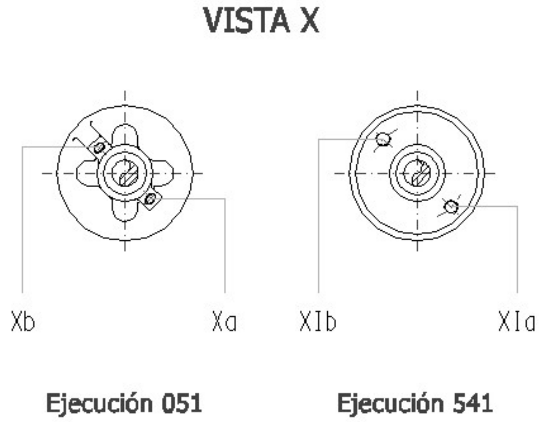
(1) Distancia necesaria entre los ejes del motor y la bomba, para desmontar el impulsor de la bomba hacia el lado del motor, sin mover el motor ni la carcasa de la bomba.

DIMENSIONES DE LAS BRIDAS															
	ANSI B16.1 clase 125											ANSI B16.1 clase 250				
NWD / NWS	1, 1/4"	1, 1/2"	2″	2, 1/2"	3″	4″	5″	6″	8″	10″	12″	1, 1/2"	2, 1/2"	6″	8″	10″
D	118	127	152	178	191	229	254	280	343	407	483	156	191	318	381	445
K	89	98	121	140	152	191	216	241	299	362	432	114	149	270	330	387
d2 x cantidad	16 x 4	16 x 4	19 x 4	19 x 4	19 x 4	19 x 8	22 x 8	22 x 8	22 x 8	25 x 12	25 x 12	22 x 4	22 x 8	22 x 12	25 x 12	30 x 16

* Las bombas tipo 4026, 15050 y 20050 tienen bridas según ANSI B16.1 clase 250 lbs

TABLA DE CONEXIONES





Pos.	Conexión	Tamaño bomba o conjunto eje	Dimensiones
I	Manómetro	32.., 40.., 50.., 65.., 8016/20/26, 10020 8032/40, 10026/32/40, 125.., 150.., 200.., 250..	R 1/4" – 18NPT R 1/2" – 14NPT
II	Manómetro	32.., 40.., 50.., 65.., 8016/20/26, 10020 8032/40, 10026/32/40, 125.., 150.., 200.., 250..	R 1/4" – 18NPT R 1/2" – 14NPT
III	Purga de aire(1)	Todos los tamaños	R 1/4" – 18NPT
VII	Drenaje	3213/16/20, 4013/16/20, 5013/16/20, 6513 3226, 4026/32, 5026/32, 6516/20/32, 80.., 100.., 125.., 150.., 200.., 250.. 15050, 20040	R 1/4" – 18NPT R 3/8" – 18 NPT R 1/2" – 14NPT
IX	Goteo ó fugas	Conjunto de eje 25 Conjunto de eje 35 Conjunto de eje 45 y 55	R 1/4" – 18NPT R 3/8" – 18NPT R 1/2" – 14NPT
Xa	Líq. cierre – entrada(1)	Conjunto de eje 25 Conjunto de eje 35, 45 y 55	R 1/8" – 27NPT R 1/4" – 18NPT
Xb	Líq. cierre – salida(1)	Conjunto de eje 25 Conjunto de eje 35, 45 y 55	R 1/8" – 27NPT R 1/4" – 18NPT
XIa	Líq. refrig. – entrada(2)	Conjunto de eje 25 y 35 (excepto 5032, 12520 y 15020)	R 1/4" – 18NPT
XIb	Líq. refrig. – salida(2)	Conjunto de eje 25 y 35 (excepto 5032, 12520 y 15020)	R 1/4" – 18NPT
XV	Llenado de aceite(1)	Todos los tamaños	∅ 20mm
XVI	Drenaje de aceite(1)	Todos los tamaños	R 1/4" – 18NPT
XVIIa	Mirilla de aceite(1)	Conjunto de eje 25 y 35 Conjunto de eje 45 y 55	R 1/2" – 14NPT R 3/4" – 14NPT
XVIIb	Regulador de nivel(1)	Todos los tamaños	R 1/4" – 18NPT

(1) Disponible según ejecución o bajo demanda

(2) Para ejecución 541 (Chaqueta de refrigeración)

DENOMINACION DE LA BOMBA

En la siguiente tabla se presenta la denominación de la bomba, en sus ejecuciones más comunes. Otras ejecuciones son posibles, consultar con la fábrica.

Tipo y tamaño	Apoyo de eje y Sentido de giro	Cierre de eje	Materiales de construcción	Junta carcasa
NOWA 3213 · · · 25032	BN Un rodamiento rigido de una hilera de bolas en el lado exterior (accionamiento) y un rodamiento de contacto angular de dos hileras en el lado interior; lubricados por grasa. Rotación a la derecha (sentido horario). CN Igual a BN pero con lubricación por aceite.	011 Prensaestopas prolongado no refrigerado, sin anillo de cierre hidráulico. 041 Prensaestopas no refrigerado con lubricación por el mismo líquido bombeado. 051 Prensaestopas no refrigerado con lubricación por líquido externo. 541 Como 041 pero con chaqueta de refrigeración. CD2 Sello mecánico monoresorte estándar.	0B Componentes principales de la bomba en fundición gris. 0C Componentes principales de la bomba en fundición gris, pero con impulsor en bronce. 1A Componentes principales de la bomba en fundición de hierro nodular ó acero termoresistente. 2A Componentes princiaples de la bomba en acero al carbono. 3B Componentes principales de la bomba en fundición de bronce. 4B Componentes principales de la bomba en fundición de acero inoxidable.	2 Junta plana

Ejemplo para el pedido:

Bomba NOWA tamaño 12526 en acero inoxidable, con rodamientos lubricados por grasa y cierre de eje mediante prensaestopas con lubricación interna: .... **NOWA 12526 BN.041.4B.2**

Sterling Fluid Systems (Colombia) S.A.
Cra. 34 A Nr. 4B-33 Bogotá D.C., Colombia
Tel: (57-1) 364 92 64 Fax: (57-1) 364 92 62 – 364 92 41 A.A. 151228
E-mail: info@sihi.com.co

A.3 Bomba 9.0 HP

Pump Data Sheet - GOULDS

Company: Bonneville Power Administration
Name:
Date: 2/9/2007
Selection: Gould Centrifugal Pump

Pump:

Size: 6BF

Type: CC_ENDSUCT_C
Synch speed: 3600 rpm

Speed: 3500 rpm
Dia: 6.375 in

Curve: GP 3656/3756

Impeller:

Specific Speeds:

Ns: ---
Nss: ---

Dimensions:

Suction: 4 in
Discharge: 3 in

Pump Limits:

Temperature: 212 °F
Pressure: 175 psi g
Sphere size: 0.5 in

Power: 15 hp
Eye area: --- in²

Search Criteria:

Flow: --- US gpm

Head: --- ft

Fluid:

Water
Density: 62.25 lb/ft³
Viscosity: 1.105 cP

Temperature: 60 °F
Vapor pressure: 0.2563 psi a
Atm pressure: 14.7 psi a

NPSHa: --- ft

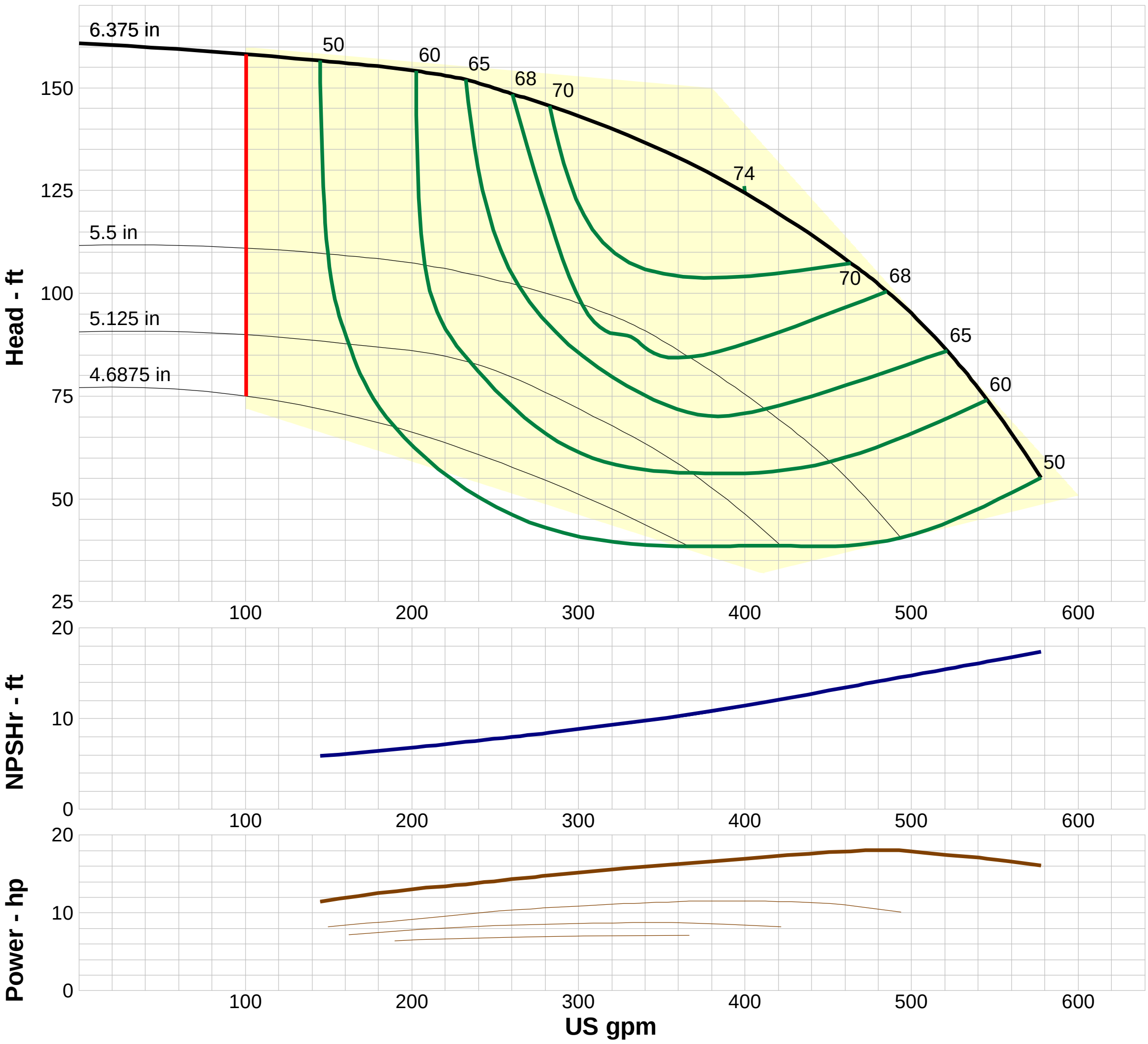
Motor:

Consult GOULDS to select a motor for this pump.

Pump Selection Warnings:

Design curve maximum power exceeds limit for the pump.

---- Data Point ----	
Flow:	400 US gpm
Head:	124 ft
Eff:	74%
Power:	17 hp
NPSHr:	11.5 ft
---- Design Curve ----	
Shutoff head:	161 ft
Shutoff dP:	69.5 psi
Min flow:	100 US gpm
BEP:	74% @ 400 US gpm
NOL power:	18.1 hp @ 485 US gpm
-- Max Curve --	
Max power:	18.1 hp @ 485 US gpm



Performance Evaluation:

Flow US gpm	Speed rpm	Head ft	Efficiency %	Power hp	NPSHr ft
554	3500	68.9	57	16.7	16.6
462	3500	108	70	17.9	13.5
370	3500	130	73	16.4	10.7
277	3500	146	70	14.7	8.36
185	3500	155	57	12.6	6.58

A.4 Tacómetro Inicial

Tacómetro, Modelo: MDT-2238A

Tacómetro Foto/Contacto Digital Modelo: MDT-2238A

Instrumento digital portátil, con LCD de 5 dígitos, precisión básica de 0.05%+1D, registro de máximo, mínimo y lectura actual y cambio de rango automático. Realiza medidas de RPM por medio foto-electrónico o por contacto y medidas de velocidad de superficie en m/min. Incluye como accesorios adaptadores y cintas reflectoras.

Descripción Técnica:

- Display: LCD 5 dígitos con lectura máxima de 99999.
- Tasa de Muestreo: 0.5 segundo (arriba de 120 RPM).
- Indicación de Batería Agotada.
- Memorización de los Valores Máximo, Mínimo y Última Lectura: "UP", "dn", y "LA" son mostrados, respectivamente, en el display.
- Selección de Rango: Automático.
- Distancia de Detección (Foto Tacómetro): 50mm ~ 500mm.
- Base de Tiempo: Cristal de Quartzo.
- Ambiente de Operación: 0°C ~ 50°C, RH < 80%.
- Ambiente de Almacenamiento: -20°C ~ -50°C, RH < 80%.
- Alimentación: 4 baterías AA de 1.5V.
- Consumo de Corriente: 50mA.
- Dimensiones: 160 (Al) x 72(An) x 37(P)mm.
- Peso: 300g (con baterías).

Eléctricas

- Rangos: 2.5 ~ 99999 RPM (Foto); 0.5 ~ 19999 RPM (Contacto); 0.05 ~ 1999.9 m / min (Superfície)
- Precisión: ± (0.05%+1D)
- Resolución: 0.1 RPM (2.5 ~ 999.9 RPM - Foto); 1 RPM (>= 1000 RPM - Foto); 0.1 RPM (0.5 ~ 999.9 RPM - Contacto); 1 RPM (>= 1000 RPM - Contacto); 0.01 m/min(0.05 ~ 99.99 m/min); 0.1 m/min (>= 100 m/min)

Accesorios

- Manual de Instrucciones
- Adaptador para Medir Velocidad de Superficie (Modelo TW-02)
- Adaptador para Medir RPM por Contacto
- Adaptador para Medida por Contacto
- Adaptador Tipo Cono (Modelo TC-02)
- Adaptador Tipo Embudo (Modelo TF-02)
- Cinta Reflectora para RPM (600mm) (Modelo FRT-60)
- Estuche para Transporte

Información Técnica:

Peso: 0,160 Kg

A.5 Tacómetro con señal

vectus importatum

Introduction for DT2234C+ DIGITAL TACHOMETER

DT2234C+ DIGITAL TACHOMETER

Descriptions for DT2234C+ DIGITAL TACHOMETER

Display: 5 digits, 18mm LCD
Test Range: 2.5 to 99,999 RPM (r/min)
Resolution: 0.1 RPM (2.5 to 999.9 RPM)
            1 RPM (over 1,000 RPM)
Accuracy: + (0.05%+1 digit)
Sampling Time: 0.8 sec. (over 60 RPM)
Test Range Select: Automatic
Detecting Distance: 50 to 500 mm/2 to 20inch (Laser)
Battery: 6F22 9V
Power Consumption: Approx.30mA (Laser)
Operation Temp.:0 to 50摅C (32 to 122摅F)
Size: 131*70*29mm
Weight: 160g (including battery)
Memory: Max. Value, Min. Value, Last Value.

Av da Invernada 12 - Vila Congonhas - CEP 04612-060 - São Paulo - SP
Fone / fax 011 5096 4654

Para honra e glória de ΙΧΘΥΣ

A.6 Informe Calibración Transductores de Presión

UNIVERSIDAD EAFIT
Abierta al mundo

Informe de Calibración
Calibration Report

Laboratorio: *Laboratory*	Hidráulica U. EAFIT	Número: 2014-03-06 (1 de 4) *Number*
Instrumento: *Instrument*	Transductor de Presión	
Fabricante: *Manufacturer*	WIKA	
Modelo: *Model*	N.A.	
Número de serie: *Serial number*	S# 2644313	
Rango de medición: *Measurement range*	-30 Inch Hg - 100 psi	
Solicitante: *Customer*	LABORATORIO DE HIDRAULICA.UNIVERSIDAD EAFIT	
Dirección: *Address*	CRA. 49 7 Sur 50. Medellin (ANT.)	
Fecha recepción de equipo: *Date of instrument reception*	2014-03-19	
Fecha de calibración: *Date of calibration*	2014-03-19	

Numero de paginas incluyendo anexos: 4
Number of pages and documents attached

====================

Calibrado por:
Tecnólogo
Milton César Marín Marín
Técnico II del laboratorio de hidráulica
Hydraulic Laboratory Technician II

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Revisado por:
Ingeniero
Jesús Alberto Pérez Mesa
Coordinador del laboratorio de hidráulica
Hydraulic Laboratory Coordinator

====================

Radicación:
File number
Fecha de emisión:2014/03/20
Date of issue

Este reporte expresa fielmente el resultado de las mediciones manométricas realizadas. No podrá ser reproducido total o parcialmente excepto cuando se haya obtenido previamente permiso por escrito del laboratorio que lo emite.
Los resultados contenidos en el presente reporte se refieren al momento y condiciones en que se realizaron las mediciones. El laboratorio no esta acreditado ante la súper intendencia de industria y comercio pero sus patrones tienen trazabilidad, el personal técnico cuenta con las pasantias en la SIC y se trabaja bajo normas reconocidas , además no se responsabiliza de los perjuicios que puedan derivarse del uso inadecuado de los instrumentos calibrados.
El usuario es responsable de la calibración de sus instrumentos a intervalos apropiados.

UNIVERSIDAD EAFIT
Abierta al mundo

Informe de calibración Número: 2014-03-06 (2 de 4)

Solicitante:	LABORATORIO DE HIDRAULICA. UNIVERSIDAD EAFIT.
Instrumento:	Transductor de presión
Fabricante:	WIKA
Serie:	S# 2644313
Identificación #:	N.A
Rango:	-30 In Hg a 100 psi
División de escala:	N.A.
Clase de exactitud:	0,25
Diámetro frente:	N.A.
Conexión:	1/2´ NPT Inferior .
Fecha de calibración:	Marzo 19 de 2014
Norma Empleada:	NTC 2263

El manómetro a calibrar fue comparado con un Modulo de Presión *(CL 0,004),* FLUKE 700P06 No. 91350601 utilizando como medio para transmitir las presiones Agua destilada.
Los patrones utilizados en la calibración de este instrumento están trazados a los patrones nacionales, loa cuales tienen trazabilidad a patrones internacionales reconocidos.
La temperatura ambiente del laboratorio durante las mediciones es de 26,0 °C ± 2 °C (Grados Celsius).

Al iniciar las medidas de regreso, a este manómetro se le mantuvo a la presión manométrica correspondiente al valor máximo que está indicado en su escala, durante el tiempo de 20 minutos.

RESULTADOS DE LA CALIBRACION

Presión Manométrica (No) Patrón (psi)	Lecturas (Pr) Ida (psi)	Lecturas (Pr) Regreso (psi)
0,0	0,016	0,045
10,0	9,984	10,041
20,0	19,994	20,037
30,0	30,012	30,055
40,0	40,023	40,037
50,0	50,055	50,033
60,0	60,029	60,029
70,0	70,047	70,033
80,0	80,036	80,043
90,0	90,047	90,040
100,0	100,000	100,000

La diferencia máxima en esta calibración entre el aparato sometido a prueba y el patrón es:

$$\Pr(prueba) - No(patron) = 0{,}06 \text{ psi}$$

Esta diferencia en porcentaje, respecto al valor máximo de la escala es:

$$\text{Porcentaje} = \frac{0{,}06}{114{,}73} \times 100 = 0{,}052\,\%$$

El porcentaje de error así obtenido es permitido en manómetros que correspondan a la clase de exactitud:

CL. 0,06	CL. 0,1	CL. 0,16	***CL. 0,25***	CL. 0,4
CL. 0,6	CL. 1,0	CL. 1,6	CL. 2,6	CL. 4,0

CL: Clase Metrologica

$$Tolerancia = \frac{0{,}25}{100} * 114{,}73 = \pm 0{,}2868 \text{ psi}$$

La incertidumbre de medición de cada una de las lecturas de presión que han sido dadas por el manómetro a prueba es:

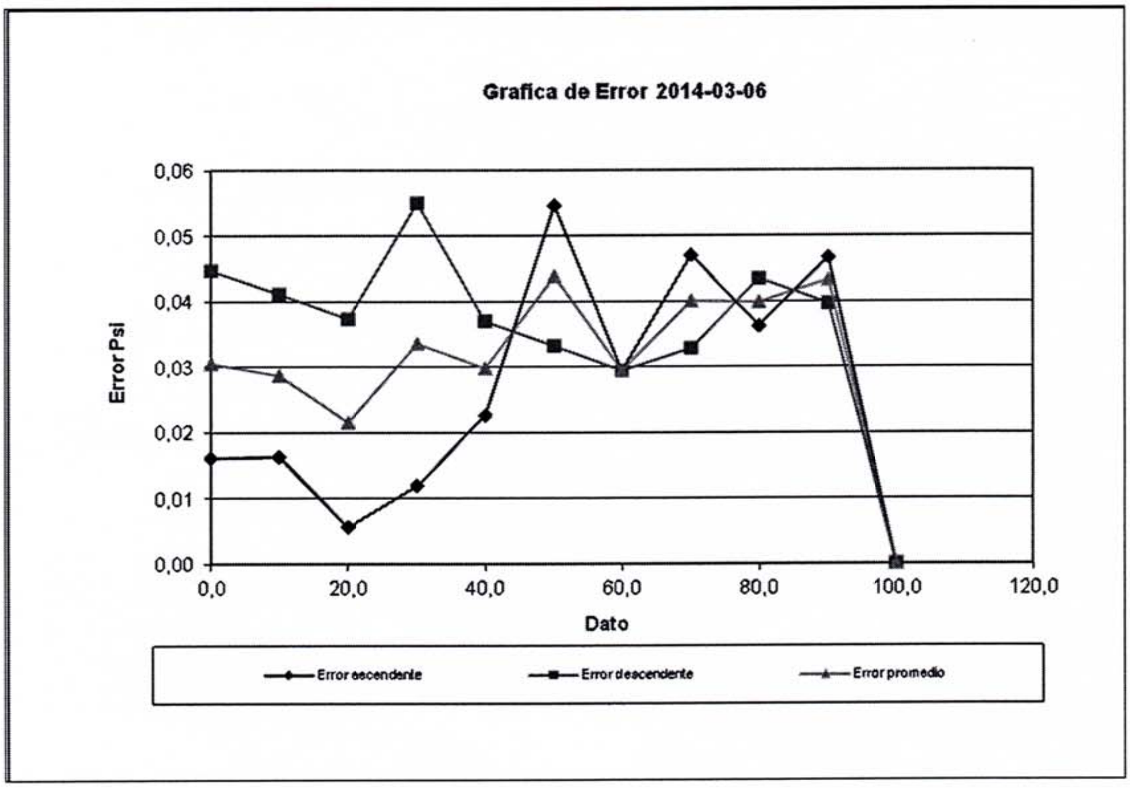
$$\pm\ 0{,}47 \text{ psi}$$

La incertidumbre reportada se ha determinado multiplicando la incertidumbre estándar combinada (patrón, método, resolución de manómetro a prueba) por el factor de cubrimiento k=2, con el cual se logra un nivel de confianza de aproximadamente un 95%.
El manómetro es provisto con una estampilla del laboratorio, que contiene fecha y número del Informe de Calibración.

Observaciones:

El manómetro es apto para seguir operando siempre y cuando el proceso admita el error con el cual quedo.

Anexo


Grafica de Error 2014-03-06
0,06
0,05
0,04
0,03
0,02
0,01
0,00
Error Psi
0,0
20,0
40,0
60,0
80,0
100,0
120,0
Dato
Error ascendente
Error descendente
Error promedio

A.7 Acelerómetros

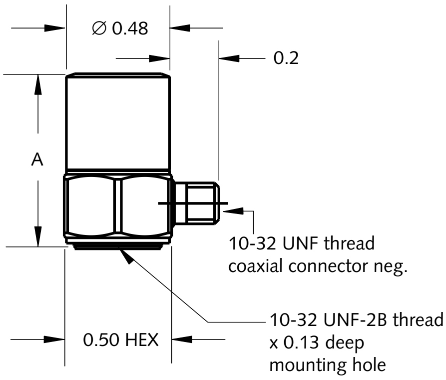
KISTLER
measure. analyze. innovate.

K-Shear® Accelerometers

Type 8702B…
8704B…

General Purpose, Voltage Mode Accelerometers

Small, relatively light weight general purpose accelerometers for vibration measurements in wide range of applications. Available in three measuring ranges 25g, 50g and 100g, all range types are available in a ground isolated option. These accelerometers feature a rugged, hermetically sealed construction.



- Low impedance, voltage mode
- Quartz-shear sensing elements
- Ultra-low base strain
- Minimal thermal transient response
- Lightweight, hermetically sealed titanium case
- Conforming to CE

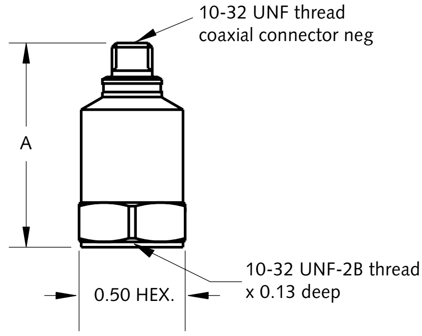
Dim	8702B…	8702B…M1
A	0.76	0.80

Description

The 8702B… side connector and 8704B… top connector accelerometer series use a unique shear mode sensing element made of stable quartz crystals. The quartz sensing elements afford excellent long-term stability that ensure repeatable, accurate measurements for many years. Additionally the shear element design provides low transverse sensitivity along with an insensitivity to base strain and thermal transients.

All units are hermetically sealed and are constructed entirely of titanium or a combination of titanium and stainless steel. An internal circuit Piezotron® impedance converter provides a high signal level at low impedance output.

Models identified with an M1 are ground isolated versions. All units are hermetically sealed and are constructed entirely of titanium or a combination of titanium and stainless steel.



Dim	8704B…	8704B…M1
A	0.96	0.98

Application

All types are designed for general purpose vibration measurement in a laboratory or industrial environment. They can be used for environmental testing (with or without temperature cycling), ESS , vehicle tests, automotive NVH testing, rotating machinery vibration analysis.

Accessing TEDS Data

Accelerometers with a "T" suffix are variants of the standard version incorporating the "Smart Sensor" design. Viewing an accelerometer's data sheet requires an Interface/Coupler such as Kistler's Model 5000M07 PDA based or 5000M04 PC (serial port) based TEDS Editor software. The Interface provides negative current excitation (reverse polarity) altering the operating mode of the PiezoSmart® sensor allowing the program editor software to read or add information contained in the memory chip.

8702B_000-239a-04.06

Tel 716-691-5100, Fax 716-691-5226, sales.us@kistler.com, www.kistler.com

KISTLER
measure. analyze. innovate.

Technical Data

Type		**Unit**	**8702/04B25**	**8702/04B50**	**8702/04B100**
Acceleration Range		g	±25	±50	±100
Acceleration Limit		gpk	±50	±100	±200
Transverse Acceleration Limit		gpk	±50	±100	±200
Threshold nom.		grms	0.002	0.004	0.006
Sensitivity (±5%)		mV/g	200	100	50
Resonant Frequency mounted, nom.		kHz	54	54	54
Frequency Response, ±5%		Hz	1 … 8000	0.5 … 10000	0.5 … 10000
Amplitude Non-linearity		%FSO	±1	±1	±1
Time Constant nom.		sec	1	2	1.5
Transverse Sensitivity nom., (max. 3)		%	1.5	1.5	1.5
Long Term Stability		%	±1	±1	±1
Environmental:					
Base Strain Sensitivity @ 250με		g/με	0.01	0.01	0.01
Shock Limit (1ms pulse)		gpk	2000	2000	2000
Temperature Coefficient of Sensitivity		%/°F	-0.030	-0.030	-0.030
Temperature Range Operating		°F	-65 … 212	-65 … 212	-65 … 212
Temperature Range Storage		°F	-95 … 250	-95 … 250	-95 … 250
Output:					
Bias nom.		VDC	11	11	11
Impedance		Ω	<100	<100	<100
Voltage full scale		V	±5	±5	±5
Current		mA	2	2	2
Source:					
Voltage		VDC	20 … 30	20 … 30	20 … 30
Constant Current		mA	4	4	4
Impedance min.		kΩ	100	100	100
Construction:					
Sensing Element		type	Quartz Shear	Quartz Shear	Quartz Shear
Housing/Base		material	Titanium	Titanium	Titanium
Sealing-housing/connector		type	Hermetic	Hermetic	Hermetic
Connector		type	10-32 UNF neg.	10-32 UNF neg.	10-32 UNF neg.
Weight	8702B… / 8704B…	grams	8.7 / 7.25	8.7 / 7.25	8.7 / 7.25
	8702B…M1 / 8704B…M1	grams	9.7 / 8	9.7 / 8	9.7 / 8
Mounting		type	10-32 UNF-2B thread	10-32 UNF-2B thread	10-32 UNF-2B thread
Mounting Torque		lbf-in	18	18	18

1 g = 9.80665 m/s², 1 inch = 25.4 mm, 1 gram = 0.03527 oz, 1 lbf-in = 0.1129 Nm

Mounting

A threaded 10-32 UNF stud provides positive attachment of the accelerometer to the test structure. Reliable and accurate measurements require that the mounting surface be clean and flat. The operating instruction manual for the 8702B… and 8704B… series accelerometers provides detailed information regarding mounting surface preparation.

Accessories Included

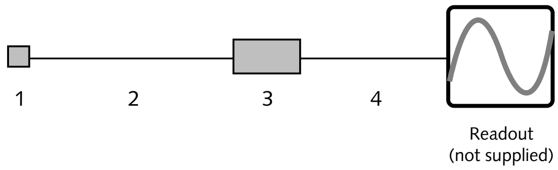
Accessories Included	Type
• 10-32 mounting stud	8402
• Mounting stud, 10-32 to M6; shipped only outside N. America	8411

Optional Accessories

Optional Accessories	Type
• Mounting magnet	8452A
• Triaxial mounting cube	8502

Measuring Chain

	Measuring Chain	Type
1	Low Impedance Sensor	87
2	Sensor cable, 10-32 pos. to BNC pos.	1761B…
3	Power Supply/Signal Conditioner	51…
4	Outout cable, BNC pos. to BNC pos.	1511



Ordering Key

8702B □ □ □

Measuring Range

±25g side connector	25
±50g side connector	50
±100g side connector	100

Variants

Ground isolated	M1

TEDS Templates (standard, M1 only)

Standard	-
Default, IEEE 1451.4 V0.9 Template 0 (UTID 1)	T
IEEE 1451.4 V0.9 Template 24 (UTID 116225)	T01
LMS Template 117, Free format Point ID	T02
LMS Template 118, Automotive Format (Field 14 Geometry = 0)	T03
LMS Template 118, Aerospace Format (Field 14 Geometry =1)	T04
P1451.4 v1.0 template 25 - Transfer Function Disabled	T05
P1451.4 v1.0 template 25 - Transfer Function Enabled	T06

Ordering Key

8704B □ □ □

Measuring Range

±25g top connector	25
±50g top connector	50
±100g top connector	100

Variants

Ground isolated	M1

TEDS Templates (standard, M1 only)

Standard	-
Default, IEEE 1451.4 V0.9 Template 0 (UTID 1)	T
IEEE 1451.4 V0.9 Template 24 (UTID 116225)	T01
LMS Template 117, Free format Point ID	T02
LMS Template 118, Automotive Format (Field 14 Geometry = 0)	T03
LMS Template 118, Aerospace Format (Field 14 Geometry =1)	T04
P1451.4 v1.0 template 25 - Transfer Function Disabled	T05
P1451.4 v1.0 template 25 - Transfer Function Enabled	T06

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A.8 Medidor de Caudal

IFC 100 Inicio rápido

Convertidor de señal para caudalímetros electromagnéticos

Revisión electrónica:
ER 2.1.xx
(SW.REV. 3.0x)

La documentación sólo está completa cuando se usa junto con la documentación relevante del sensor de caudal.

Avisos y símbolos empleados

¡PELIGRO!
Esta información se refiere al daño inmediato cuando trabaja con electricidad.

¡PELIGRO!
Estos avisos deben cumplirse a rajatabla. Hacer caso omiso a este aviso, incluso de forma parcial, puede provocar problemas de salud graves e incluso la muerte. También existe el riesgo de dañar el aparato o partes de la planta en funcionamiento.

¡AVISO!
Hacer caso omiso de este aviso de seguridad, aunque sea solo en parte, representa el riesgo de problemas de salud graves. También existe el riesgo de dañar el aparato o partes de la planta en funcionamiento.

¡PRECAUCIÓN!
Hacer caso omiso de estas instrucciones puede dar como resultado un daño en el aparato o partes de la planta en funcionamiento.

¡INFORMACIÓN!
Estas instrucciones contienen información importante para el manejo del aparato.

MANEJO

- Este símbolo indica todas las instrucciones para las acciones que se van a ser llevadas a cabo por el operador en la secuencia especificada.

➲ **Resultado**
Este símbolo se refiere a todas las consecuencias importantes de las acciones previas.

Instrucciones de seguridad para el operador

¡PRECAUCIÓN!
La instalación, ensamblaje, puesta en marcha y mantenimiento solo puede ser realizado por peronal entrenado. Siempre se deben seguir las directrices de seguridad y salud ocupacional.

AVISO LEGAL
La responsabilidad respecto a la idoneidad y al uso deseado de este aparato recae solamente en el usuario. El proveedor no asume ninguna responsabilidad en caso de uso indebido del cliente. Una instalación inadecuada y su funcionamiento pueden llevar a la pérdida de garantía. Además, se aplican "Las condiciones y términos de Venta". Estas aparecen en la parte trasera de la factura y forman la base de contrato de compra.

¡INFORMACIÓN!
- *Puede encontrar más información en el CD-ROM del manual que se suministra, en la hoja de datos, en manuales especiales, en los certificados y en la Website del fabricante.*
- *Si necesita devolver el aparato al fabricante o suministrador, por favor, rellene el impreso contenido en el CD-ROM y envíelo con el aparato. Desafortunadamente, el fabricante no puede reparar o inspeccionar el aparato sin el impreso completo.*

2.1 Propósito de uso

Los caudalímetros electromagnéticos están diseñados exclusivamente para medir el caudal y la conductividad de un medio líquido conductivo eléctricamente.

¡PELIGRO!
Para equipos que se empleen en zonas peligrosas, se aplican notas de seguridad adicionales; por favor consulte la documentación Ex.

¡AVISO!
Si el equipo no se utiliza según las condiciones de funcionamiento (consultar el capítulo "Datos técnicos"), la protección prevista podría verse perjudicada.

2.2 Alcance del suministro

¡INFORMACIÓN!
Revise las cajas cuidadosamente por si hubiera algún daño o signo de manejo brusco. Informe del daño al transportista y a la oficina local del fabricante.

¡INFORMACIÓN!
Compruebe la lista de repuestos para verificar que ha recibido todo lo que pidió.

¡INFORMACIÓN!
Mire la placa del fabricante del equipo para asegurarse de que el equipo se ha entregado según su pedido. Compruebe en la placa del fabricante la impresión correcta del voltaje para su alimentación.

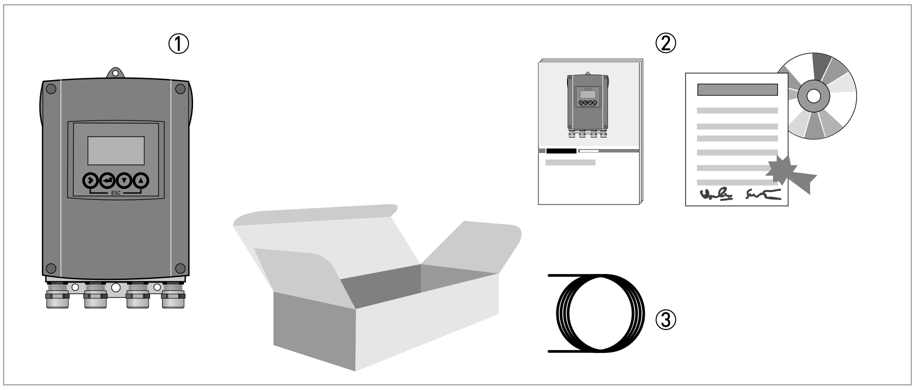


Figura 2-1: Alcance de suministro

① Equipo en la versión pedida
② Documentación (informe de calibración, Arranque Rápido, CD-Rom con documentación del producto para el sensor de medición y el convertidor de señal)
③ Cable de señal (solo para la versión remota)

2.3 Almacenamiento

- Almacene el aparato en un lugar seco y sin polvo.
- Evite la luz del sol directa de forma continua.
- Guarde el equipo en su caja original.
- Temperatura de almacenamiento: -40...+70°C / -40...+158°F

2.4 Transporte

Convertidor de señal

- Sin requisitos especiales.

Versión compacta

- No levante el equipo por el alojamiento del convertidor de señal.
- No use cadenas de elevación.
- Para transportar los equipos con bridas, use las correas de elevación. Envuelva éstas alrededor de las conexiones del proceso.

2.5 Especificaciones de la instalación

¡INFORMACIÓN!
Se deben tomar las siguientes precauciones para asegurar una instalación fiable.

- *Asegúrese de que hay espacio suficiente a los lados.*
- *Proteja el convertidor de señal de la luz del sol directa e instale una sombrilla si es necesario.*
- *Convertidores de señal instalados en los gabinetes de control requieren un enfriamiento adecuado, p.ej. con un ventilador o intercambiador de calor.*
- *No exponga el convertidor de señal a una vibración intensa. Los caudalímetros están probados para un nivel de vibración según el IEC 68-2-3.*

2.6 Montaje de la versión compacta

¡INFORMACIÓN!
El convertidor de señal se monta directamente en el sensor de medición. Para instalar el caudalímetro, por favor, siga las instrucciones de la documentación del producto suministrado para sensor de medida.

2.7 Montaje del housing de pared, versión remota

¡INFORMACIÓN!
Los materiales de ensamblaje y las herramientas no son parte de la entrega. Emplee los materiales de ensamblaje y las herramientas conforme a las directrices de seguridad y salud ocupacional pertinentes.

2.7.1 Montaje de pared

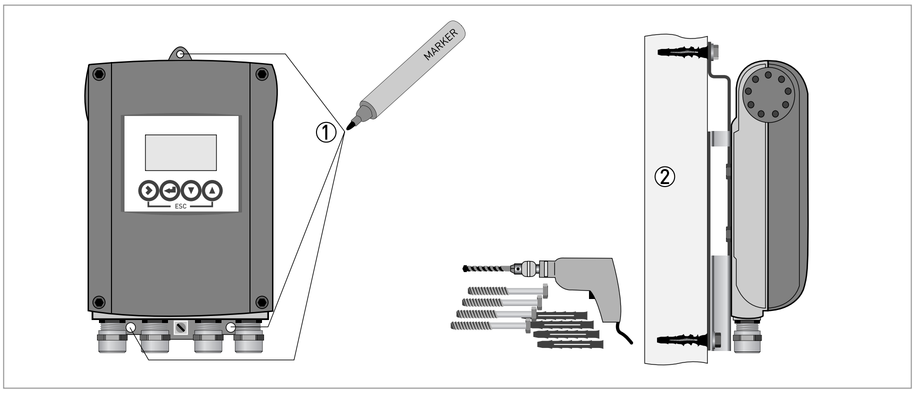
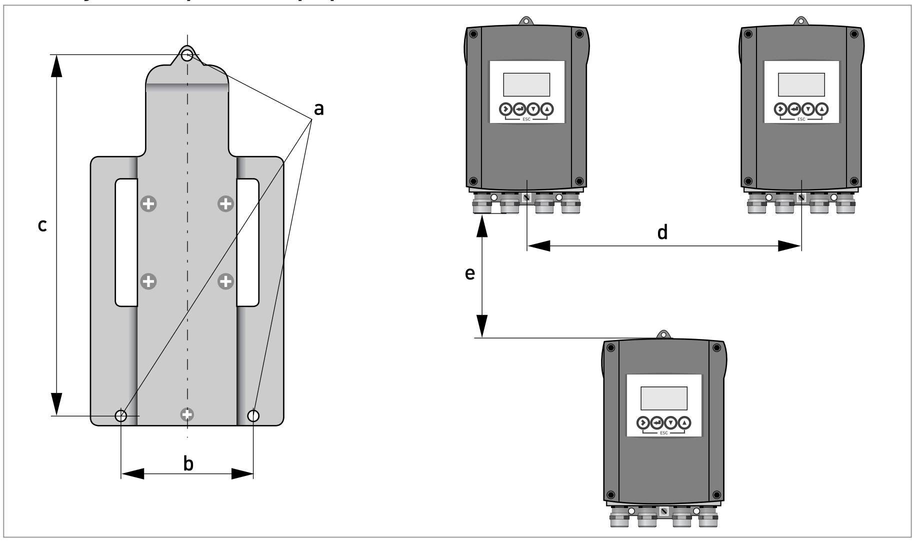


Figura 2-2: Montaje del housing de pared

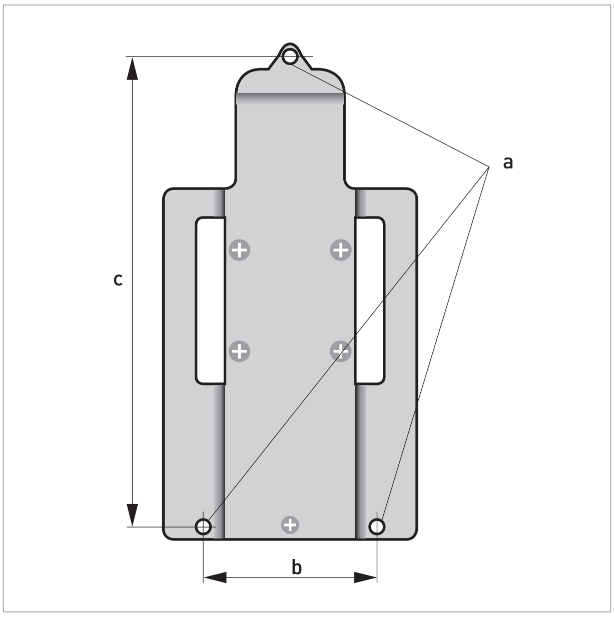
① Prepare los agujeros con ayuda de la placa de montaje. Para más información vaya a *Placa de montaje, versión de montaje en pared* en la página 8.
② Fije el equipo con seguridad a la pared con la placa de montaje.

Montaje múltiple de equipos unos al lado de otros



	[mm]	[pulgadas]
a	Ø6,5	Ø0,26
b	87,2	3,4
c	241	9,5
d	310	12,2
e	257	10,1

2.7.2 Placa de montaje, versión de montaje en pared



Dimensiones en mm y pulgadas

	[mm]	[pulgadas]
a	Ø6,5	Ø0,26
b	87,2	3,4
c	241	9,5

3.1 Instrucciones de seguridad

¡PELIGRO!
Todo el trabajo relacionado con las conexiones eléctricas solo se puede llevar a cabo con la alimentación desconectada. ¡Tome nota de los datos de voltaje en la placa de características!

¡PELIGRO!
¡Siga las regulaciones nacionales para las instalaciones eléctricas!

¡PELIGRO!
Para equipos que se empleen en zonas peligrosas, se aplican notas de seguridad adicionales; por favor consulte la documentación Ex.

¡AVISO!
Se deben seguir sin excepción alguna, las regulaciones de seguridad y salud ocupacional regionales. Cualquier trabajo hecho en los componentes eléctricos del aparato de medición debe ser llevado a cabo únicamente por especialistas entrenados adecuadamente.

¡INFORMACIÓN!
Mire la placa del fabricante del equipo para asegurarse de que el equipo se ha entregado según su pedido. Compruebe en la placa del fabricante la impresión correcta del voltaje para su alimentación.

3.2 Notas importantes sobre la conexión eléctrica

¡PELIGRO!
La conexión eléctrica debe realizarse en conformidad con la Directiva VDE 0100 "Reglas para las instalaciones eléctricas con tensiones de línea hasta 1000 V" o las reglas nacionales equivalentes.

¡PRECAUCIÓN!
- *Emplee entradas de cable adecuadas para todos los cables eléctricos.*
- *El sensor y convertidor se configuran juntos en fábrica. Por esta razón, por favor conecte los equipos en parejas. Asegúrese de que las constantes del sensor GK/GKL (ver los tipos de placas) están programados de forma idéntica.*
- *Si le fue entregado por separado o cuando instaló los equipos no estaban configurados juntos, programe el convertidor al tamaño DN y GK/GKL del sensor.*

3.3 Cables eléctricos para las versiones remotas, notas

3.3.1 Notas sobre el cable de señal A

¡INFORMACIÓN!
El cable de señal A (tipo DS 300) con doble protección asegura la transmisión correcta de los valores medidos.

Preste atención a las siguientes notas:

- Extender el cable de señal con elementos de sujeción.
- El cable de señal se puede extender tanto en el agua como en el suelo.
- El material aislante es resistente al fuego en conformidad con EN 50625-2-1, IEC 60322-1.
- El cable de señal no contiene halógenos ni plástico y no pierde su flexibilidad a baja temperatura.
- La conexión de la protección interna se realiza por medio del hilo trenzado (1).
- La conexión de la protección externa (60) se realiza por medio del hilo trenzado (6).

3.3.2 Nota sobre el cable de corriente de campo C

¡PELIGRO!
*Se utiliza un cable de cobre de dos hilos con protección como cable de corriente de campo. La protección **DEBE** estar conectada al alojamiento del sensor de medición y de convertidor de señal.*

¡INFORMACIÓN!
El cable de corriente de campo no forma parte del suministro.

3.3.3 Requisitos para los cables de señal proporcionados por el cliente

¡INFORMACIÓN!
Si el cable de señal no fue pedido, tendrá que proporcionarlo el propio cliente. Se deben cumplir los requisitos siguientes respecto a los valores eléctricos:

Seguridad eléctrica

- En conformidad con EN 60811 (Directiva baja tensión) o normas nacionales equivalentes.

Capacitancia de los conductores aislados

- Conductor aislado / conductor aislado < 50 pF/m
- Conductor aislado / protección < 150 pF/m

Resistencia de aislamiento

- R_{iso} > 100 GΩ x km
- U_{max} < 24 V
- I_{max} < 100 mA

Tensiones de prueba

- Conductor aislado / protección interna 500 V
- Conductor aislado / conductor aislado 1000 V
- Conductor aislado / protección externa 1000 V

Torsión de los conductores aislados

- Al menos 10 vueltas por metro, importante para proteger de los campos magnéticos.

3.4 Preparación de los cables de señal y de corriente de campo

¡INFORMACIÓN!
Los materiales de ensamblaje y las herramientas no son parte de la entrega. Emplee los materiales de ensamblaje y las herramientas conforme a las directrices de seguridad y salud ocupacional pertinentes.

3.4.1 Cable de señal A (tipo DS 300), construcción

- El cable de señal A es un cable con doble protección para la transmisión de las señales entre el sensor de medida y el convertidor de señal.
- Radio de curva: ≥ 50 mm / 2"

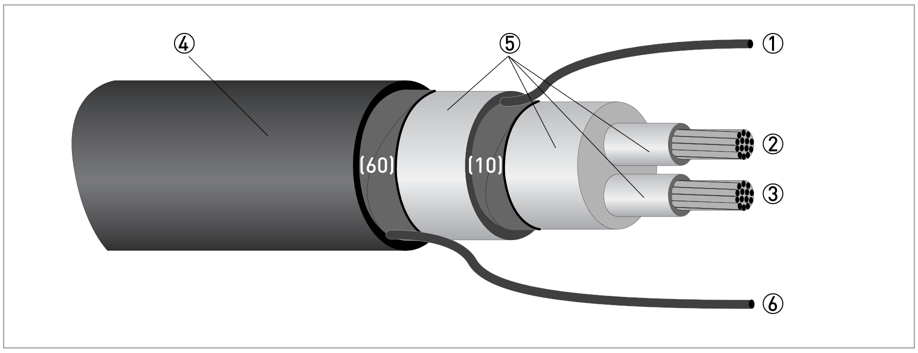


Figura 3-1: Cable de señal de construcción A

① Cable fijo (1) para la protección interna (10), 1,0 mm^2 Cu / AWG 17 (no aislado, desnudo)
② Cable de aislamiento (2), 0,5 mm^2 Cu / AWG 20
③ Cable de aislamiento (3), 0,5 mm^2 Cu / AWG 20
④ Funda exterior
⑤ Capas de aislamiento
⑥ Cable fijo (6) para la protección externa (60)

3.4.2 Longitud del cable de señal A

¡INFORMACIÓN!
Para temperaturas del medio superiores a los 150° C / 300° F, se necesita un cable de señal especial y una toma intermedia SD. Éstos están disponibles así como los esquemas de conexión eléctrica.

Sensor de medición	Tamaño nominal		Conductividad eléctrica mín. [µS/cm]	Curva del cable de señal A
	DN [mm]	[pulgadas]		
OPTIFLUX 1000 F	10...150	3/8...6	5	A1
OPTIFLUX 2000 F	25...150	1...6	20	A1
	200...1200	8...48	20	A2
OPTIFLUX 4000 F	2,5...150	1/10...6	1	A1
	200...1200	8...48	1	A2
OPTIFLUX 5000 F	2,5...100	1/10...4	1	A1
	150...250	6...10	1	A2
OPTIFLUX 6000 F	2,5...150	1/10...6	1	A1
WATERFLUX 3000 F	25...600	1...24	20	A1

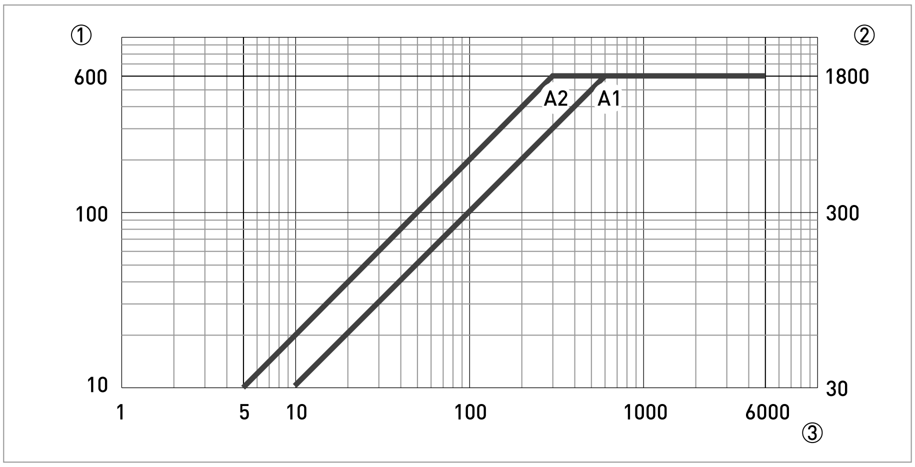


Figura 3-2: Longitud máxima del cable de señal A

① Longitud máxima del cable de señal A entre el sensor de medición y el convertidor de señal [m]
② Longitud máxima del cable de señal A entre el sensor de medición y el convertidor de señal [pies]
③ Conductividad eléctrica del medio a medir [µS/cm]

3.4.3 Preparación del cable de señal A, conexión al convertidor de señal

¡INFORMACIÓN!
Los materiales de ensamblaje y las herramientas no son parte de la entrega. Emplee los materiales de ensamblaje y las herramientas conforme a las directrices de seguridad y salud ocupacional pertinentes.

- La conexión de dos protecciones en el convertidor de señal se realiza mediante los hilos trenzados.
- Radio de curva: ≥ 50 mm / 2"

Materiales necesarios

- Tubo aislado de PVC, Ø2,5 mm / 0,1"
- Tubo termorrectráctil
- 2x férulas para cables según DIN 46 228: E 1,5-8 para los hilos trenzados (1, 6)
- 2x férulas para cables según DIN 46 228: E 0,5-8 para los conductores aislados (2, 3)

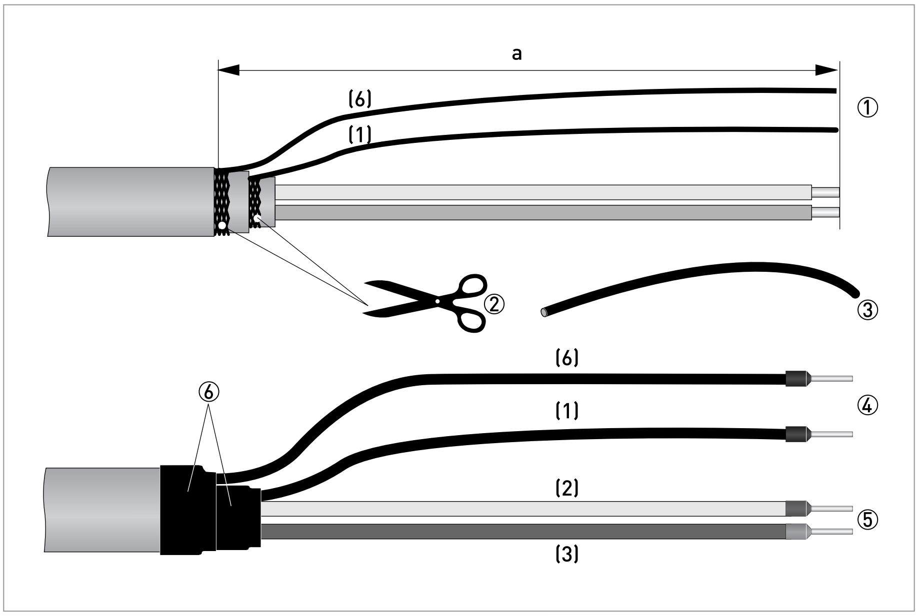


Figura 3-3: Preparación del cable de señal A

a = 80 mm / 3,15"

① Pelar el conductor hasta la dimensión a.
② Cortar la protección interna (10) y la protección externa (60). Asegurarse de no dañar los hilos trenzados (1, 6).
③ Deslizar el tubo de aislamiento sobre los hilos trenzados (1, 6).
④ Engarzar las férulas para cables en el hilo trenzado.
⑤ Engarzar las férulas para cables en los conductores (2, 3).
⑥ Tirar del tubo termorretráctil sobre el cable de señal preparado.

3.4.4 Preparación del cable de corriente de campo C, conexión al convertidor de señal

¡PELIGRO!
*Se utiliza un cable de cobre de dos hilos con protección como cable de corriente de campo. La protección **DEBE** estar conectada al alojamiento del sensor de medición y del convertidor de señal.*

¡INFORMACIÓN!
Los materiales de ensamblaje y las herramientas no son parte de la entrega. Emplee los materiales de ensamblaje y las herramientas conforme a las directrices de seguridad y salud ocupacional pertinentes.

- El cable de corriente de campo C no forma parte del suministro.
- Radio de curva: ≥ 50 mm / 2"

Materiales necesarios:

- Cable de cobre de al menos 2 hilos con protección con tubo termorretráctil
- Tubo de aislamiento de tamaño conforme al cable que se utiliza
- Férulas para cables DIN 46 228: tamaño conforme al cable que se utiliza

Longitud y sección transversal del cable de corriente de campo C

Longitud		Sección transversal A_F (Cu)	
[m]	[ft]	[mm^2]	[AWG]
0...150	0...500	2 x 0,75 Cu ①	2 x 18
150...300	500...1000	2 x 1,50 Cu ①	2 x 14
300...600	1000...2000	2 x 2,50 Cu ①	2 x 12

① Cu = sección transversal cobre

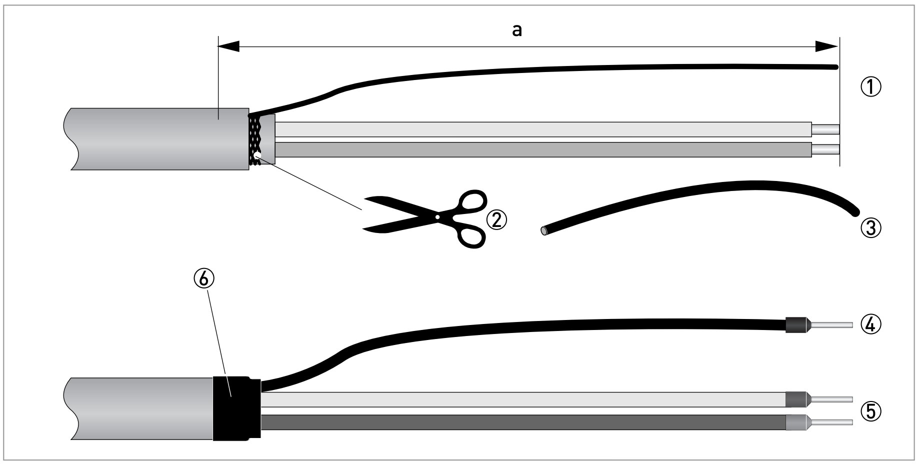


Figura 3-4: Cable de corriente de campo C, preparación para el convertidor de señal

a = 80 mm / 3,15"

① Pelar el conductor hasta la dimensión a.
② Si hay un hilo trenzado, retire la protección. Tener cuidado para no dañar el hilo trenzado.
③ Deslizar un tubo aislado sobre el hilo trenzado.
④ Engarzar una férula para cables en el hilo trenzado.
⑤ Engarzar las férulas para cables en los conductores.
⑥ Tirar del tubo termorretráctil sobre el cable preparado.

3.4.5 Preparación del cable de señal A, conexión al sensor de medida

¡INFORMACIÓN!
Los materiales de ensamblaje y las herramientas no son parte de la entrega. Emplee los materiales de ensamblaje y las herramientas conforme a las directrices de seguridad y salud ocupacional pertinentes.

- La protección externa (60) está conectada en el compartimiento de terminales del sensor de medición directamente mediante la protección y un clip.
- Radio de curva: ≥ 50 mm / 2"

Materiales necesarios

- Tubo de aislamiento de PVC, Ø2,0...2,5 mm / 0,08...0,1"
- Tubo termorrectráctil
- Férula para cables según DIN 46 228: E 1,5-8 para el hilo trenzado (1)
- 2x férulas para cables según DIN 46 228: E 0,5-8 para los conductores aislados (2, 3)

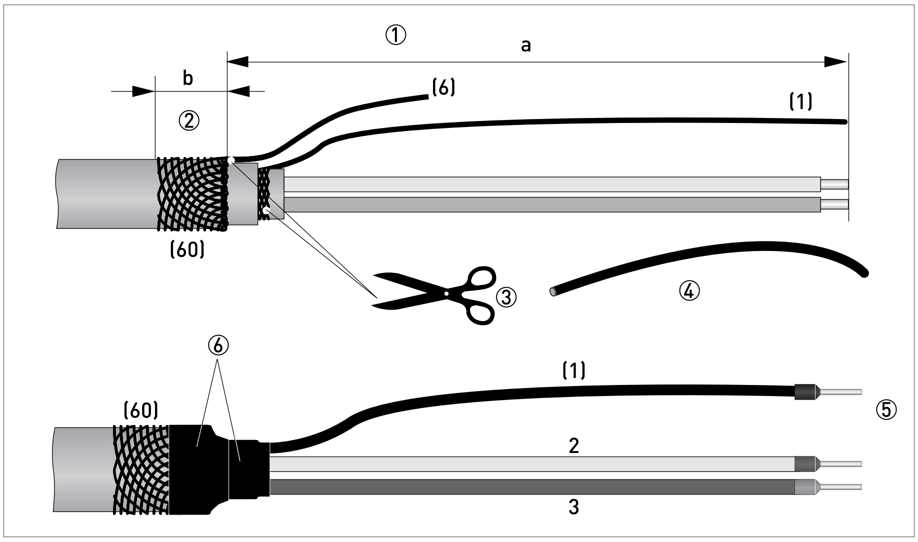


Figura 3-5: Preparación del cable de señal A, conexión al sensor de medida

a = 50 mm / 2"
b = 10 mm / 0,39"

① Pelar el conductor hasta la dimensión a.
② Cortar la protección externa (60) según la dimensión b y tirar de ella sobre la funda externa.
③ Retirar el hilo trenzado (6) de la protección externa y la protección interna (10). Tener cuidado para no dañar el hilo trenzado (1) de la protección interna.
④ Deslizar un tubo aislado sobre el hilo trenzado (1).
⑤ Engarzar las férulas para cables en los conductores 2 y 3 y el hilo trenzado (1).
⑥ Tirar del tubo termorretráctil sobre el cable de señal preparado.

3.4.6 Preparación del cable de corriente de campo C, conexión al sensor de medida

¡INFORMACIÓN!
Los materiales de ensamblaje y las herramientas no son parte de la entrega. Emplee los materiales de ensamblaje y las herramientas conforme a las directrices de seguridad y salud ocupacional pertinentes.

- El cable de corriente de campo no forma parte del suministro.
- La protección está conectada en el compartimiento de terminales del sensor de medición directamente mediante la protección y un clip.
- Radio de curva: ≥ 50 mm / 2"

Materiales necesarios

- Cable de cobre aislado de 2 hilos con protección
- Tubo de aislamiento de tamaño conforme al cable que se utiliza
- Tubo termorrectráctil
- Férulas para cables DIN 46 228: tamaño conforme al cable que se utiliza

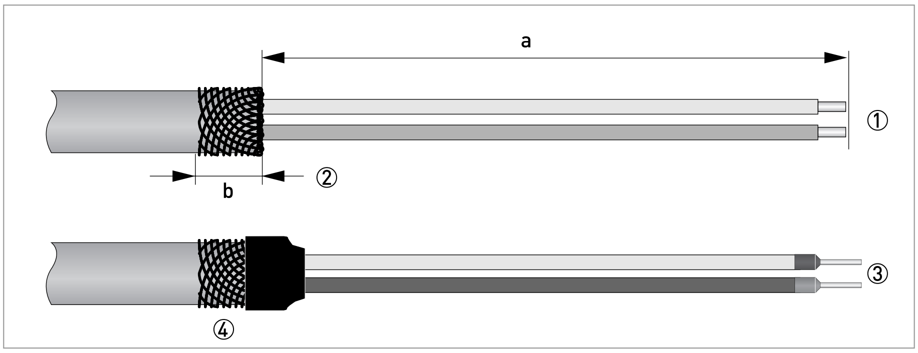


Figura 3-6: Preparación del cable de corriente de campo C

a = 50 mm / 2"
b = 10 mm / 0,4"

① Pelar el conductor hasta la dimensión a.
② Cortar la protección externa según la dimensión b y tirar de ella sobre la funda externa.
③ Engarzar las férulas para cables en ambos conductores.
④ Tirar del tubo termorretráctil sobre el cable preparado.

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3.5 Conexión de los cables de señal y de corriente de campo

¡PELIGRO!
Los cables solo se pueden conectar cuando la alimentación está apagada.

¡PELIGRO!
El aparato debe estar conectado a tierra según la regulación para proteger al personal de descargas eléctricas.

¡PELIGRO!
Para equipos que se empleen en zonas peligrosas, se aplican notas de seguridad adicionales; por favor consulte la documentación Ex.

¡AVISO!
Se deben seguir sin excepción alguna, las regulaciones de seguridad y salud ocupacional regionales. Cualquier trabajo hecho en los componentes eléctricos del aparato de medición debe ser llevado a cabo únicamente por especialistas entrenados adecuadamente.

3.5.1 Conexión de los cables de señal y de corriente de campo al convertidor de señal, versiones remotas

¡INFORMACIÓN!
La versión compacta se suministra pre-ensamblada desde fábrica.

Abrir el alojamiento

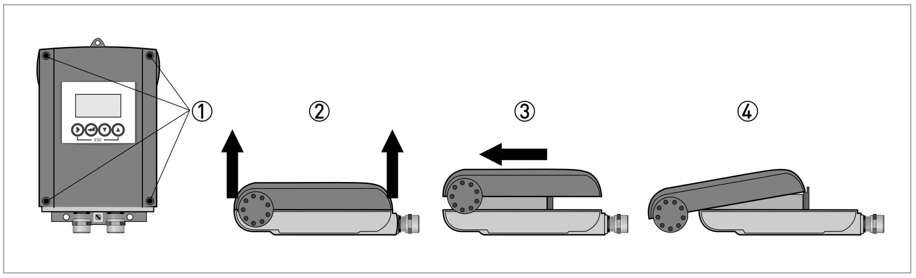

Figura 3-7: Abrir el alojamiento

① Aflojar los 4 tornillos con una herramienta adecuada.
② Levantar el alojamiento desde la parte superior e inferior al mismo tiempo.
③ Deslizar hacia arriba la tapa del alojamiento.
④ La tapa del alojamiento es guiada y sujetada por la bisagra interna.

Conexión de los cables de señal y de corriente de campo

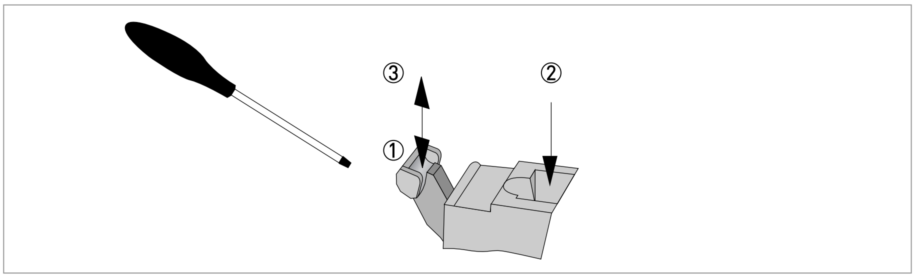

Figura 3-8: Función del terminal de conexión eléctrica

Conecte los conductores eléctricos como sigue:

① Apriete la palanca hacia abajo con un destornillador en buenas condiciones (filo de 3,5 mm ancho y 0,5 mm grueso).
② Inserte el conductor eléctrico dentro del tapón de entrada.
③ El conductor quedará sujeto tan pronto como la palanca se libere.

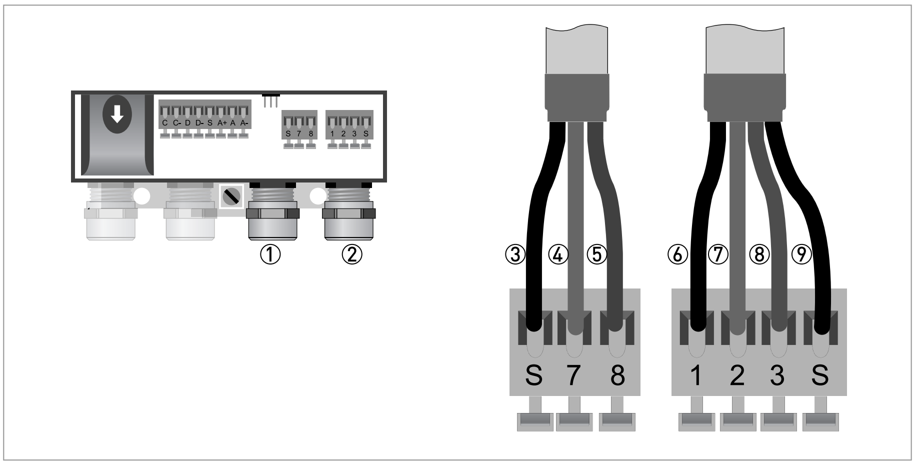

Figura 3-9: Conectar los cables de señal y corriente de campo

① Entrada de cable de corriente de campo
② Entrada de cable para cable de señal.
③ Conexión de la protección del cable de corriente de campo
④ Conductor eléctrico (7)
⑤ Conductor eléctrico (8)
⑥ Hilo trenzado (1) de la protección interna (10) del cable de señal
⑦ Conductor eléctrico (2)
⑧ Conductor eléctrico (3)
⑨ Hilo trenzado (S) de la protección externa (60)

3.5.2 Esquema de conexión para el cable de señal y de corriente de campo

¡PELIGRO!
El aparato debe estar conectado a tierra según la regulación para proteger al personal de descargas eléctricas.

- Un cable de cobre de dos hilos con protección se utiliza como cable de corriente de campo. La protección DEBE estar conectada al alojamiento del sensor de medición y del convertidor de señal.
- La protección externa (60) está conectada en el compartimiento de terminales del sensor de medición directamente mediante la protección y un clip.
- Radio de curva del cable de señal y de corriente de campo: ≥ 50 mm / 2"
- La siguiente figura es esquemática. Las posiciones de los terminales de conexión eléctrica pueden variar dependiendo de la versión del alojamiento.

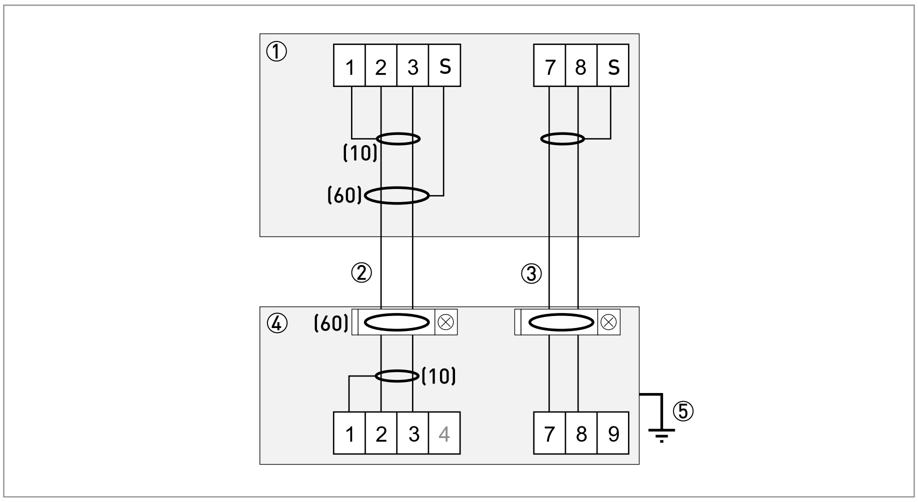

Figura 3-10: Esquema de conexión para el cable de señal y de corriente de campo

① Compartimiento de terminales eléctricos en el convertidor de señal
② Cable de señal A
③ Cable de corriente de campo C
④ Compartimiento de terminales eléctricos en el sensor de medición
⑤ Tierra funcional FE

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3.6 Puesta a tierra del sensor de medida

3.6.1 Método clásico

¡PELIGRO!
¡No debe haber diferencia de potencial entre el sensor de medición y el alojamiento o la tierra de protección del convertidor de señales!

- El sensor de medición debe estar puesto a tierra adecuadamente.
- El cable de tierra no debería transmitir ningún voltaje de interferencia.
- No emplee el cable de conexión a tierra más que para un equipo a tierra al mismo tiempo.
- Los sensores de medición están conectados a tierra por medio de un conductor de tierra funcional FE.
- Se suministran por separado instrucciones especiales para la puesta a tierra de varios de los sensores de medición disponibles.
- La documentación del sensor de medición contiene también indicaciones para el uso de los anillos de puesta a tierra y para la instalación del sensor de medición en tuberías metálicas o de plástico con recubrimiento interno.

3.7 Conexión de la alimentación

¡PELIGRO!
El aparato debe estar conectado a tierra según la regulación para proteger al personal de descargas eléctricas.

- Los alojamientos de los equipos, que están diseñados para proteger el equipo electrónico del polvo y la humedad, deberían guardarse siempre bien cerrados. Las distancias de fuga y los juegos están dimensionados según VDE 0110 e IEC 664 para categoría de contaminación 2. Los circuitos de alimentación están diseñados para categorías de sobretensión III y los circuitos de salida para categoría de sobretensión II.
- Se debe prever una protección del fusible ($I_N \leq 16$ A) para el circuito de alimentación de entrada, y también un dispositivo de desconexión (interruptor, disyuntor diferencial) para aislar el convertidor de señal.

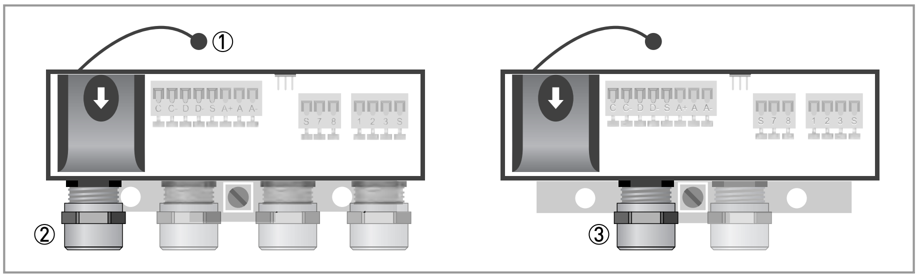

Figura 3-11: Compartimiento de terminales de alimentación

① Banda de retención de la tapa
② Entrada cable de alimentación, versión remota
③ Entrada cable de alimentación, versión compacta

Visión general

Versión	No-Ex	Ex
100...230 VAC	Estándar	Opcional
12...24 VDC	Estándar	-
24 VAC/DC	-	Estándar

- Abrir la tapa del compartimiento de terminales eléctricos presionándola y tirando de ella hacia adelante al mismo tiempo.

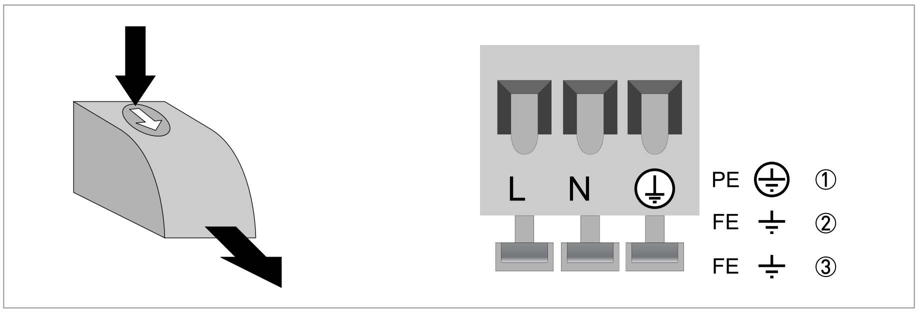

Figura 3-12: Conexión de la alimentación

① 100...230 VAC (-15% / +10%), 8 VA
② 24 VDC (-55% / +30%), 4 W
③ 24 VAC/DC (AC: -15% / +10%; DC: -25% / +30%), 7 VA y 4 W

- Cerrar la tapa una vez conectada la alimentación.

100...230 VAC (rango de tolerancia: -15% / +10%)

- Observe el voltaje y la frecuencia de alimentación (50...60 Hz) en la placa del fabricante.

¡INFORMACIÓN!
Se incluye 240 VAC + 5% en el rango de tolerancia.

12...24 VDC (rango de tolerancia: -55% / +30%)

- ¡Observe los datos en la placa del fabricante!
- Al conectar con tensiones funcionales muy bajas, hay que prever un dispositivo para la separación de protección (PELV) (VDE 0100 / VDE 0106 y IEC 364 / IEC 536 o según las normativas nacionales pertinentes).

¡INFORMACIÓN!
12 VDC - 10% se incluye en el rango de tolerancia.

24 VAC/DC (rango de tolerancia: AC: -15% / +10%; DC: -25% / +30%)

- AC: Observe el voltaje y la frecuencia de alimentación (50...60 Hz) en la placa del fabricante.
- DC: Al conectar con tensiones funcionales muy bajas, hay que prever un dispositivo para la separación de protección (PELV) (VDE 0100 / VDE 0106 y IEC 364 / IEC 536 o según las normativas nacionales pertinentes).

¡INFORMACIÓN!
*12 V **no** se incluye en el rango de tolerancia.*

3.8 Visión general de salidas

3.8.1 Descripción del número CG

CG 1_ _ _ _ _ 0 0
① ② ③ ④ ⑤

Figura 3-13: Marcar (número CG) del módulo electrónico y variantes de salida

① Número ID: 0
② Número ID: 0 = estándar; 9 = especial
③ Alimentación
④ Pantalla (versiones del lenguaje)
⑤ Versión de salida

3.8.2 Versiones de salidas fijas, no modificables

Este convertidor de señal está disponible con varias combinaciones de salidas.

- Las casillas grises en las tablas denotan terminales de conexión no usados o no asignados.
- En la tabla, solo se representan los dígitos finales del Nº CG.
- El terminal de conexión A+ solo será operativa en la versión básica de salidas.

<table>
<tr><th rowspan="2">Nº CG</th><th colspan="7">Terminales de conexión</th></tr>
<tr><th>A+</th><th>A</th><th>A-</th><th>C</th><th>C-</th><th>D</th><th>D-</th></tr>
<tr><td colspan="8">Salidas básicas (I/O) estándares</td></tr>
<tr><td rowspan="2">1 0 0</td><td></td><td colspan="2">I_p + HART® pasivo ①</td><td colspan="2" rowspan="2">S_p pasivo</td><td colspan="2" rowspan="2">P_p / S_p pasivo ②</td></tr>
<tr><td colspan="2">I_a + HART® activo ①</td><td></td></tr>
</table>

① función cambiada por reconexión
② cambiable

Descripción de abreviaciones empleadas

I_a	I_p	Salida de corriente activa o pasiva
P_p		Salida de pulso / frecuencia pasiva
S_p		Salida de estado / alarma pasiva

3.9 Conexión eléctrica de entradas

¡INFORMACIÓN!
Los materiales de ensamblaje y las herramientas no son parte de la entrega. Emplee los materiales de ensamblaje y las herramientas conforme a las directrices de seguridad y salud ocupacional pertinentes.

3.9.1 Conexión eléctrica de las salidas

¡PELIGRO!
Todo el trabajo relacionado con las conexiones eléctricas solo se puede llevar a cabo con la alimentación desconectada. ¡Tome nota de los datos de voltaje en la placa de características!

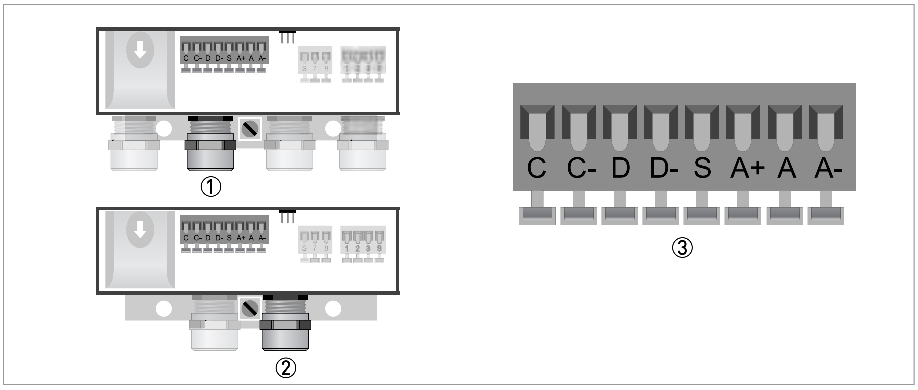

Figura 3-14: Conexión de las salidas

① Entrada del cable, versión remota
② Entrada del cable, versión compacta
③ Terminal S para protección

- Abra la tapa del alojamiento
- Empuje los cables preparados a través de la entrada de cables y conecte los conductores necesarios.
- Cierre la protección.
- Cierre la tapa del alojamiento.

¡INFORMACIÓN!
Asegúrese de que la junta del alojamiento está colocada adecuadamente, limpia y sin daños.

3.9.2 Colocación correcta de los cables eléctricos

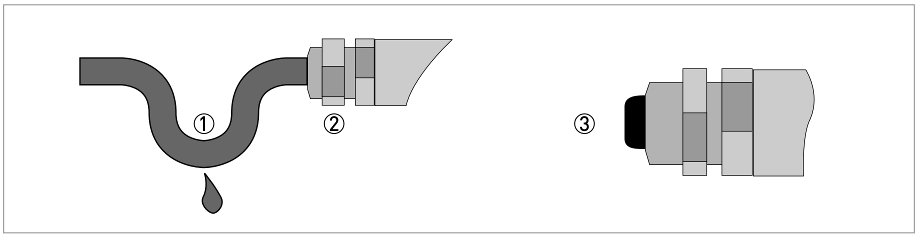

Figura 3-15: Proteja el alojamiento del polvo y del agua

① Para versiones compactas con entradas de cable casi horizontalmente orientadas, coloque los cables eléctricos necesarios con un bucle antigoteo como se muestra en la ilustración.
② Apriete la conexión del tornillo del cable de entrada con seguridad.
③ Selle las entradas del cable que no se necesiten con un tapón.

4.1 Conectando la alimentación

Antes de conectarse a la alimentación, compruebe por favor que el sistema haya sido instalado correctamente. Esto incluye:

- El equipo debe ser mecánicamente seguro y montarse conforme a las regulaciones.
- Las conexiones de alimentación deben haberse hecho conforme a las regulaciones.
- Los compartimentos del terminal eléctrico deben asegurarse y las cubiertas debe ser atornilladas.
- Compruebe que los datos de funcionamiento eléctrico de la fuente de alimentación sean correctos.

- Encendiendo la alimentación.

4.2 Poniendo en marcha el convertidor de señal

El equipo de medida es una combinación de uno a dos sensores de medición tipo abrazadera y un convertidor de señal. Todos los datos de funcionamiento se han programado en la fábrica de acuerdo con las especificaciones de su solicitud.

Cuando la alimentación está encendida, se lleva a cabo un auto-test. Después de que el equipo comience a medir, los valores serán mostrados en pantalla inmediatamente.

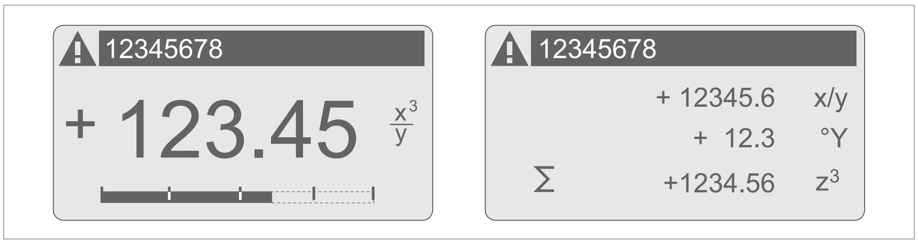

Figura 4-1: Muestras en pantalla en modo de medición (ejemplos para 2 o 3 valores medidos)
x, y y z denotan las unidades de valores medidos mostrados en pantalla

Es posible cambiar entre las dos ventanas de valores medidos, la pantalla de tendencia y la lista con mensajes de estado, presionando las teclas ↑ y ↓.

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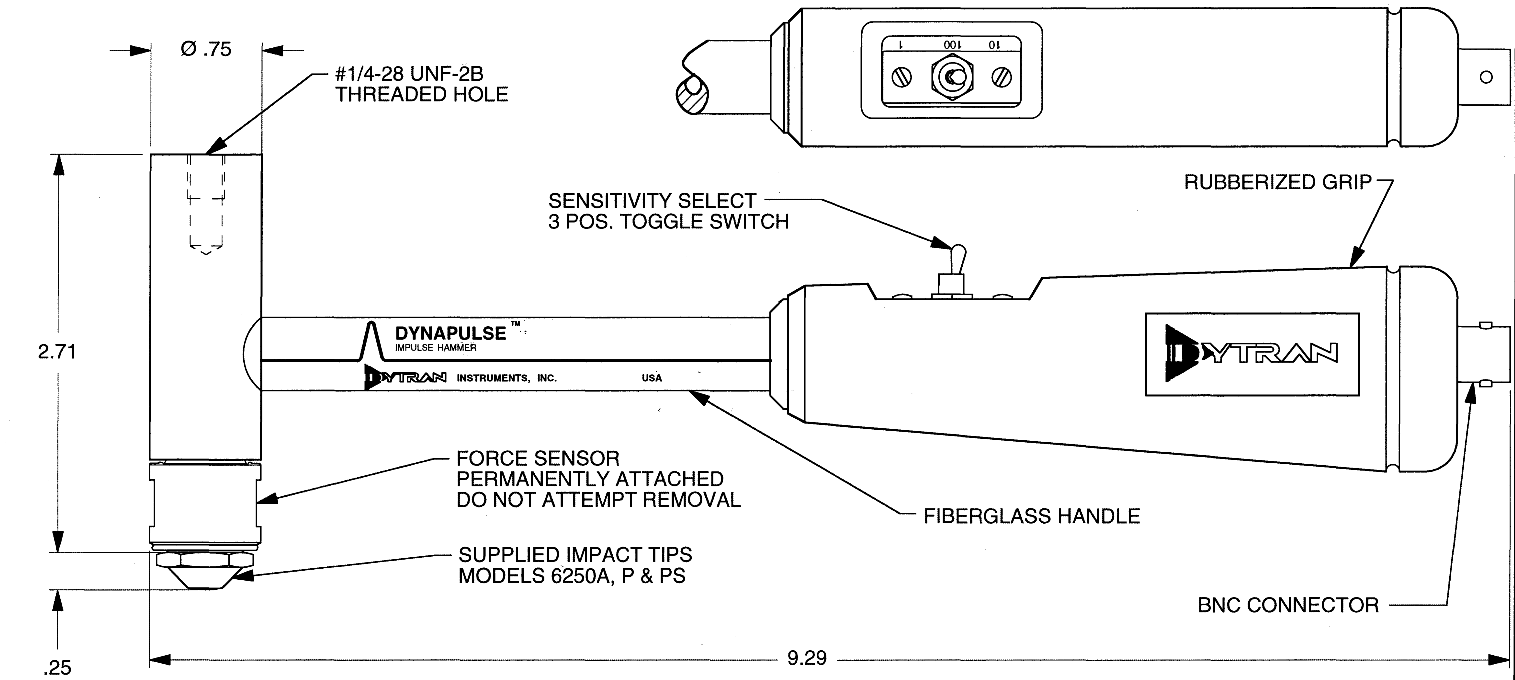
Visión global del producto KROHNE

- Caudalímetros electromagnéticos
- Caudalímetros de área variable
- Caudalímetros ultrasónicos
- Caudalímetros másicos
- Caudalímetros Vortex
- Controladores de caudal
- Medidores de nivel
- Medidores de temperatura
- Medidores de presión
- Productos de análisis
- Sistemas de medición para la industria del gas y petróleo.
- Sistemas de medida para tanques marítimos.

Oficina central KROHNE Messtechnik GmbH
Ludwig-Krohne-Str. 5
D-47058 Duisburg (Alemania)
Tel.:+49 (0)203 301 0
Fax:+49 (0)203 301 10389
info@krohne.de

La lista actual de los contactos y direcciones de KROHNE se encuentra en:
www.krohne.com

A.9 Martillo de Análisis Modal



MODEL NO.	SENSITIVITY
5850B	1, 10, 100 mV/LbF

MASTER
ONLY IF IN RED

DYTRAN INSTRUMENTS, INC.

CHATSWORTH, CA.

EXCEPT AS OTHERWISE NOTED

ALL DIMENSIONS IN INCHES
TOLERANCE: .XXX = ± .XX= ±

SURFACE FINISH
EXCEPT AS NOTED √

BREAK EDGES TO DEBURR
RADIUS OR CHAMFER

△ THESE DIAS ⊙ TO T.I.R.

FILLETS - MAX RAD.

SCALE 1X | REV | DATE | ECN

DATE 11/1/95 | PART NO.

DRAWN D.Z. | CHECKED N.C | MAT'L

APPROVED | NEXT ASSEMBLY | USED ON

TITLE **OUTLINE/INSTALLATION DRAWING, IMPULSE HAMMER 5850B**

DWG NO. **127-5850B**

SHEET 1 OF 1

1. WEIGHT - 256 GRAMS

SPECIFICATIONS, MODEL 5850B
THREE-RANGE IMPULSE HAMMER

SPECIFICATION	VALUE			UNITS
SWITCH POSITION	100	10	1	
RANGE (for +5V out)	50	500	5000	Lbs F
SENSITIVITY, ±10%	100	10	1	mV/Lb
MAXIMUM INPUT FORCE	1000	6000	8000	Lbs F
DISCHARGE TIME CONSTANT	15	150	1500	Sec

COMMON SPECIFICATIONS, ALL RANGES

STIFFNESS, SENSOR	11.4	Lbs F/µ in.
RESONANT FREQUENCY	>75	kHz
LINEARITY	±1	%FS
OUTPUT IMPEDANCE, MAX	100	Ohms
VOLTAGE BIAS	+7.5 to +12	VDC
SUPPLY (COMPLIANCE) VOLTAGE RANGE	+18 to +30	VDC
SUPPLY CURRENT RANGE	2 TO 20	mA
MATERIAL, HEAD/HANDLE	STAINLESS STEEL/FIBERGLAS	
WEIGHT, HEAD	150/5.3	Grams/Ounces
WEIGHT, TOTAL	275/9.7	Grams/Ounces
CONNECTOR, MODEL 5850B	BNC JACK, COAXIAL	

ACCESSORIES SUPPLIED WITH BASIC HAMMER:
1 EA. IMPACT TIP, MODEL 6250A (ALUMINUM), (1) MODEL 6250P (HARD PLASTIC) AND 6250PS, (SOFT PLASTIC)

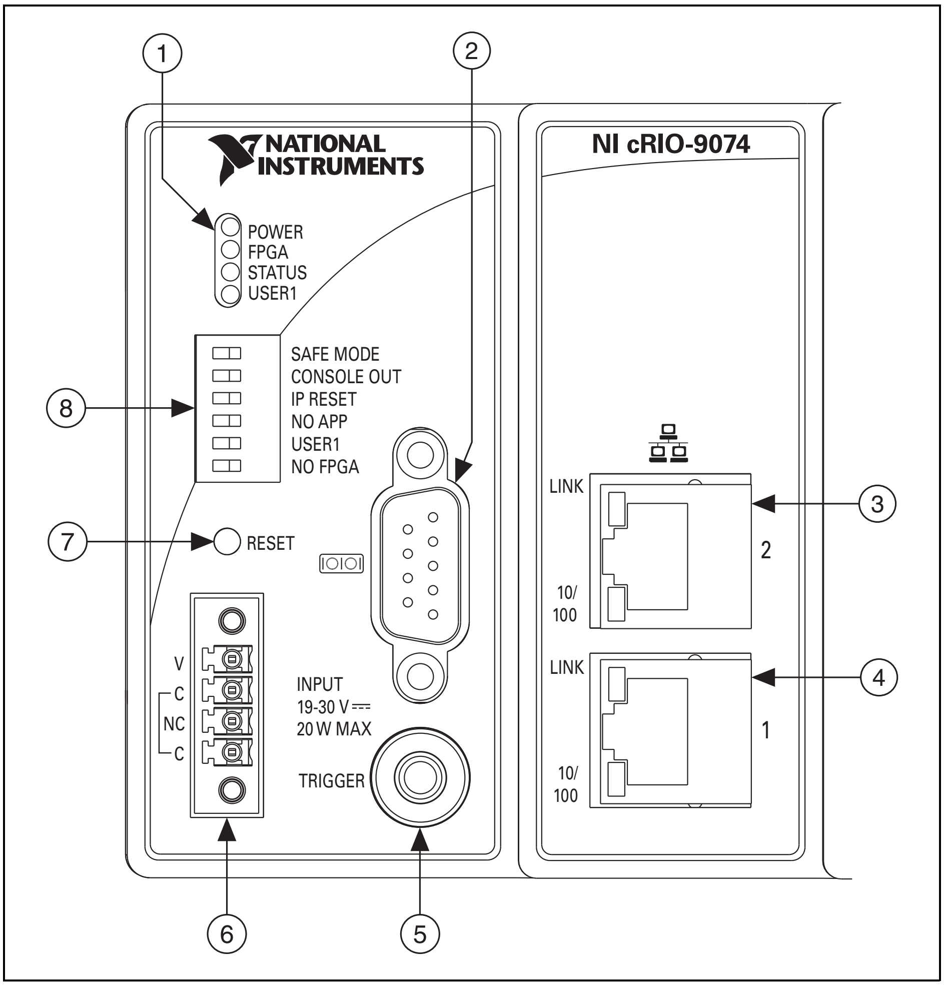
ACCESSORIES SUPPLIED WITH HAMMER KITS HB5850A & B AND HL5850A & B:
ABOVE 3 TIPS PLUS (2) HEAD EXTENDERS, 6270S1 AND 6270S2

A.10 Sistema de Adquisición del Laboratorio de Hidráulica

OPERATING INSTRUCTIONS AND SPECIFICATIONS

CompactRIO™ cRIO-9072/3/4

Reconfigurable Embedded Chassis with Integrated Intelligent Real-Time Controller for CompactRIO



1	LEDs	5	SMB Connector (cRIO-9074 Only)
2	RS-232 Serial Port	6	Power Connector
3	RJ-45 Ethernet Port 2 (cRIO-9074 Only)	7	Reset Button
4	RJ-45 Ethernet Port 1	8	DIP Switches

Figure 1. CompactRIO cRIO-9072/3/4

This document describes how to connect the cRIO-9072/3/4 to a network and how to use the features of the cRIO-9072/3/4. This document also contains specifications for the cRIO-9072/3/4.

Safety Guidelines

Operate the cRIO-9072/3/4 only as described in these operating instructions.

Safety Guidelines for Hazardous Locations

The cRIO-9072/3/4 is suitable for use in Class I, Division 2, Groups A, B, C, D, T4 hazardous locations; Class 1, Zone 2, AEx nL IIC T4 and Ex nL IIC T4 hazardous locations; and nonhazardous locations only. Follow these guidelines if you are installing the cRIO-9072/3/4 in a potentially explosive environment. Not following these guidelines may result in serious injury or death.

Caution Do *not* disconnect the power supply wires and connectors from the controller unless power has been switched off.

Caution Substitution of components may impair suitability for Class I, Division 2.

Caution For Zone 2 applications, install the CompactRIO system in an enclosure rated to at least IP 54 as defined by IEC 60529 and EN 60529.

Special Conditions for Hazardous Locations Use in Europe

Some chassis have been evaluated as Ex nL IIC T4 equipment under DEMKO Certificate No. 07 ATEX 0626664X. Each such chassis is marked Ex II 3G and is suitable for use in Zone 2 hazardous locations, in ambient temperatures of $-20 \leq Ta \leq 55$ °C.

Special Conditions for Marine Applications

Some chassis are Lloyd's Register (LR) Type Approved for marine applications. To verify Lloyd's Register certification, visit `ni.com/certification` and search for the LR certificate, or look for the Lloyd's Register mark on the chassis.

What You Need to Install CompactRIO Reconfigurable Embedded Hardware

- ❑ CompactRIO reconfigurable embedded chassis with integrated intelligent real-time controller
- ❑ C Series I/O modules
- ❑ DIN rail mount kit (for DIN rail mounting only)
- ❑ Two M4 or number 10 panhead screws (for panel mounting only)
- ❑ A number 2 Phillips screwdriver
- ❑ Power supply

Notes Visit `ni.com/info` and enter the Info Code `rdsoftwareversion` to determine which software you need to use the cRIO-9072/3/4.

The cRIO-9072/3/4 may be shipped with a clear protective film cover on the front panel. You can remove the film cover before installing the cRIO-9072/3/4.

Mounting the CompactRIO Reconfigurable Embedded Chassis

You can mount the chassis in any orientation on a 35 mm DIN rail or on a panel. Use the DIN rail mounting method if you already have a DIN rail configuration or if you need to be able to quickly remove the CompactRIO chassis. Use the panel mount method for high shock and vibration applications.

Caution Your installation must meet the following requirements for space and cabling clearance:

- Allow 25.4 mm (1 in.) on the top and the bottom of the chassis for air circulation.
- Allow 50.8 mm (2 in.) in front of modules for cabling clearance for common connectors, such as the 10-terminal, detachable screw terminal connector, as shown in Figure 2.

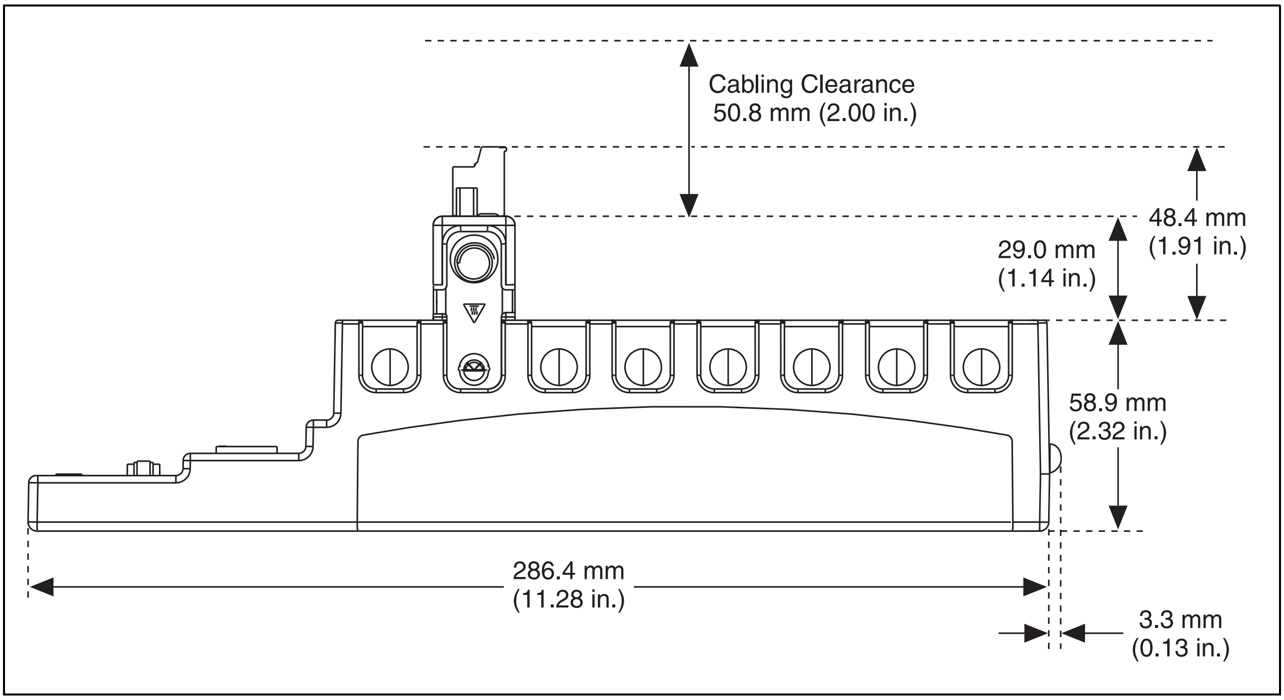


Figure 2. cRIO-9072/3/4, Bottom View with Dimensions

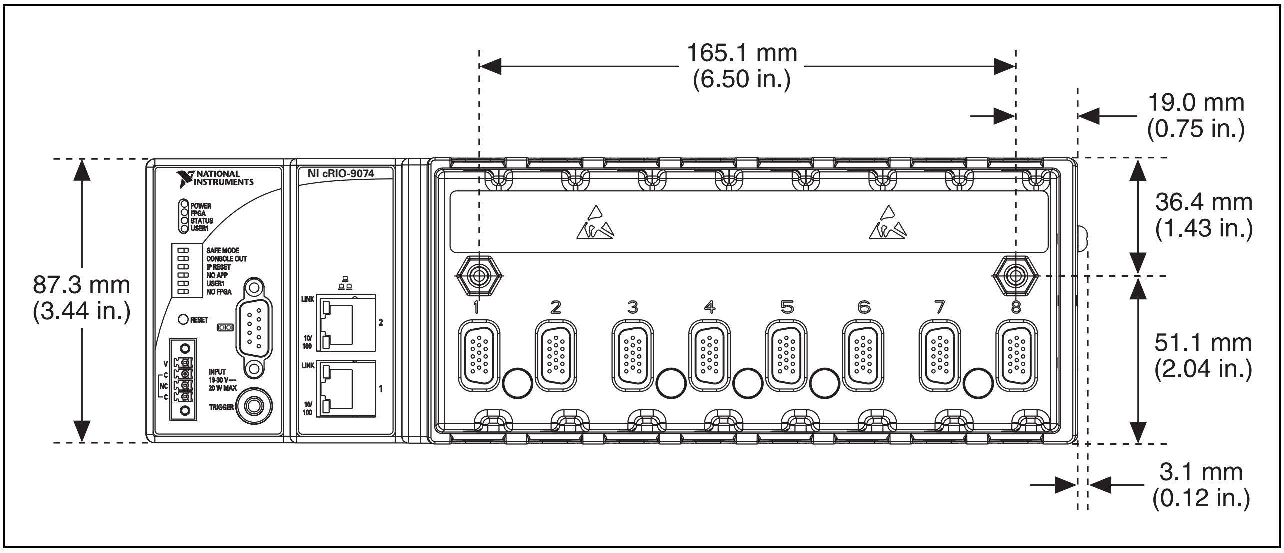


Figure 3. cRIO-9072/3/4, Front View with Dimensions

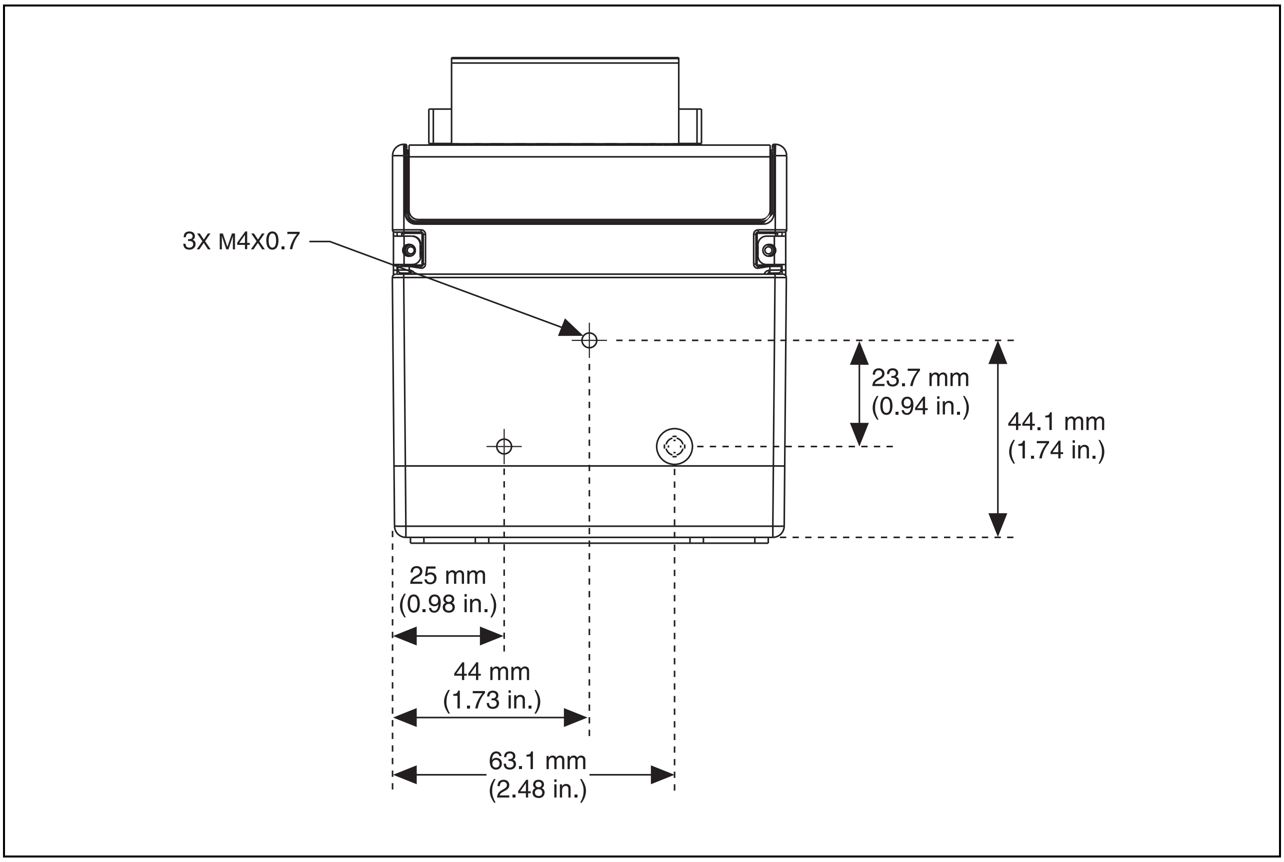


Figure 4. cRIO-9072/3/4, Side View with Dimensions

The following sections contain instructions for the mounting methods. Before using any of these mounting methods, record the serial number from the back of the chassis. You will be unable to read the serial number after you have mounted the chassis.

Caution Make sure that no I/O modules are in the chassis before mounting it.

Mounting the Chassis on a Panel

You can use the NI 9905 panel mount kit to mount the cRIO-9072/3/4 on a flat surface. Complete the following steps.

1. Fasten the chassis to the panel mount kit using a number 2 Phillips screwdriver and two M4 × 16 screws. National Instruments provides these screws with the panel mount kit. You *must* use these screws because they are the correct depth and thread for the panel.

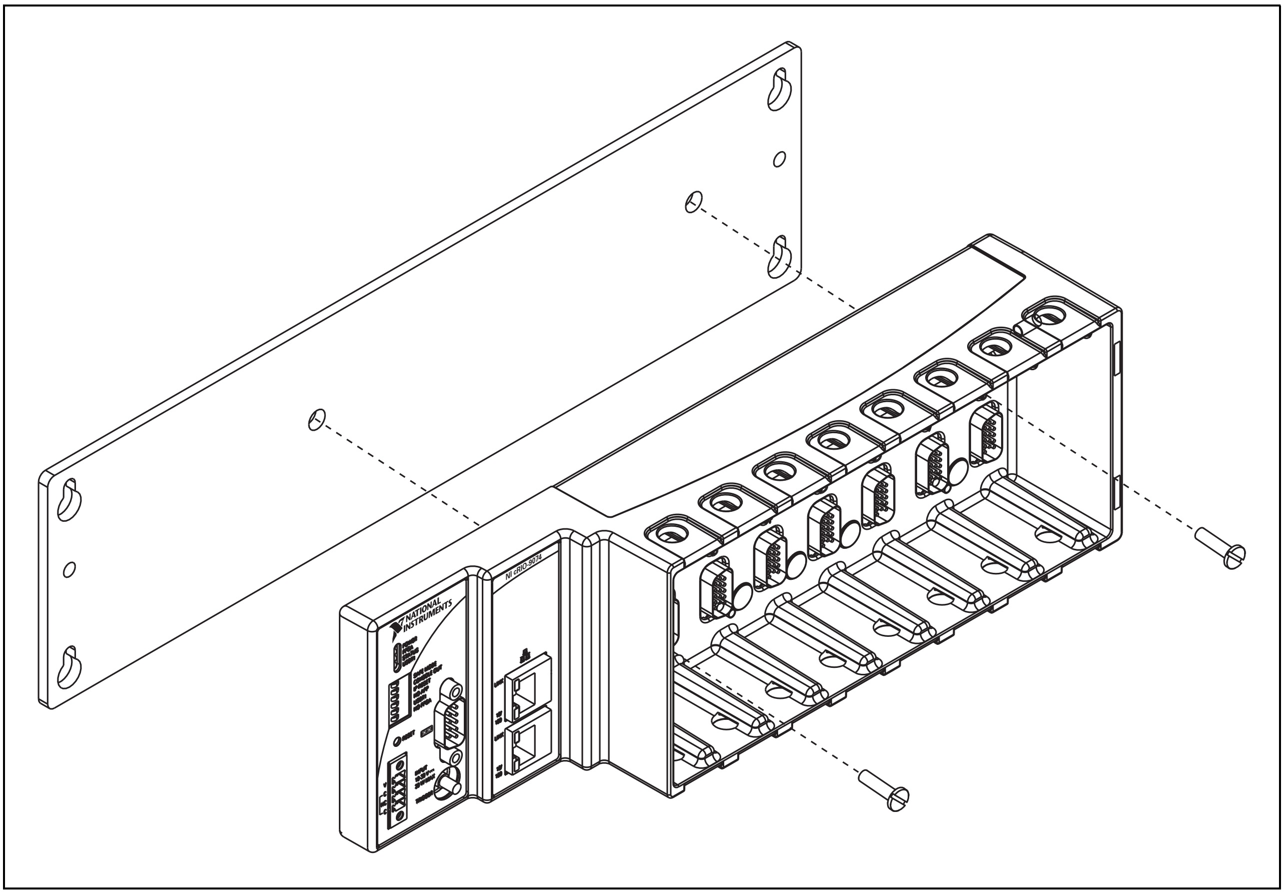


Figure 5. Installing the Panel Mount Accessory on the cRIO-9072/3/4

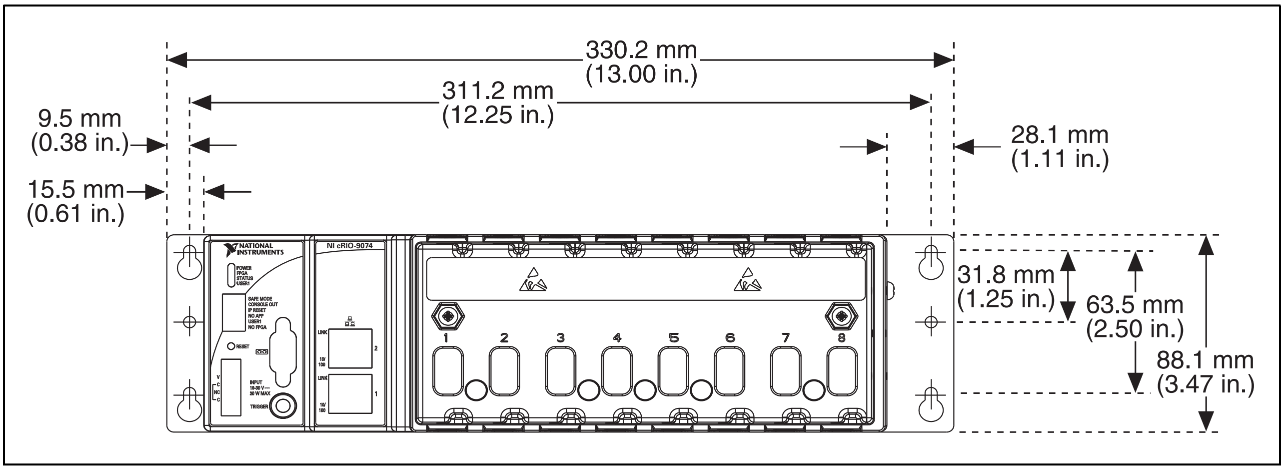


Figure 6. Dimensions of cRIO-9072/3/4 with Panel Mount Accessory Installed

2. Fasten the NI 9905 panel to the wall using the screwdriver and screws that are appropriate for the wall surface.

Caution Make sure that no I/O modules are in the chassis before removing it from the panel.

Mounting the Chassis on a DIN Rail

You can order the NI 9915 DIN rail mount kit if you want to mount the chassis on a DIN rail. You need one clip for mounting the chassis on a standard 35 mm DIN rail. Complete the following steps to mount the chassis on a DIN rail.

1. Fasten the DIN rail clip to the chassis using a number 2 Phillips screwdriver and two M4 × 16 screws. National Instruments provides these screws with the DIN rail mount kit.

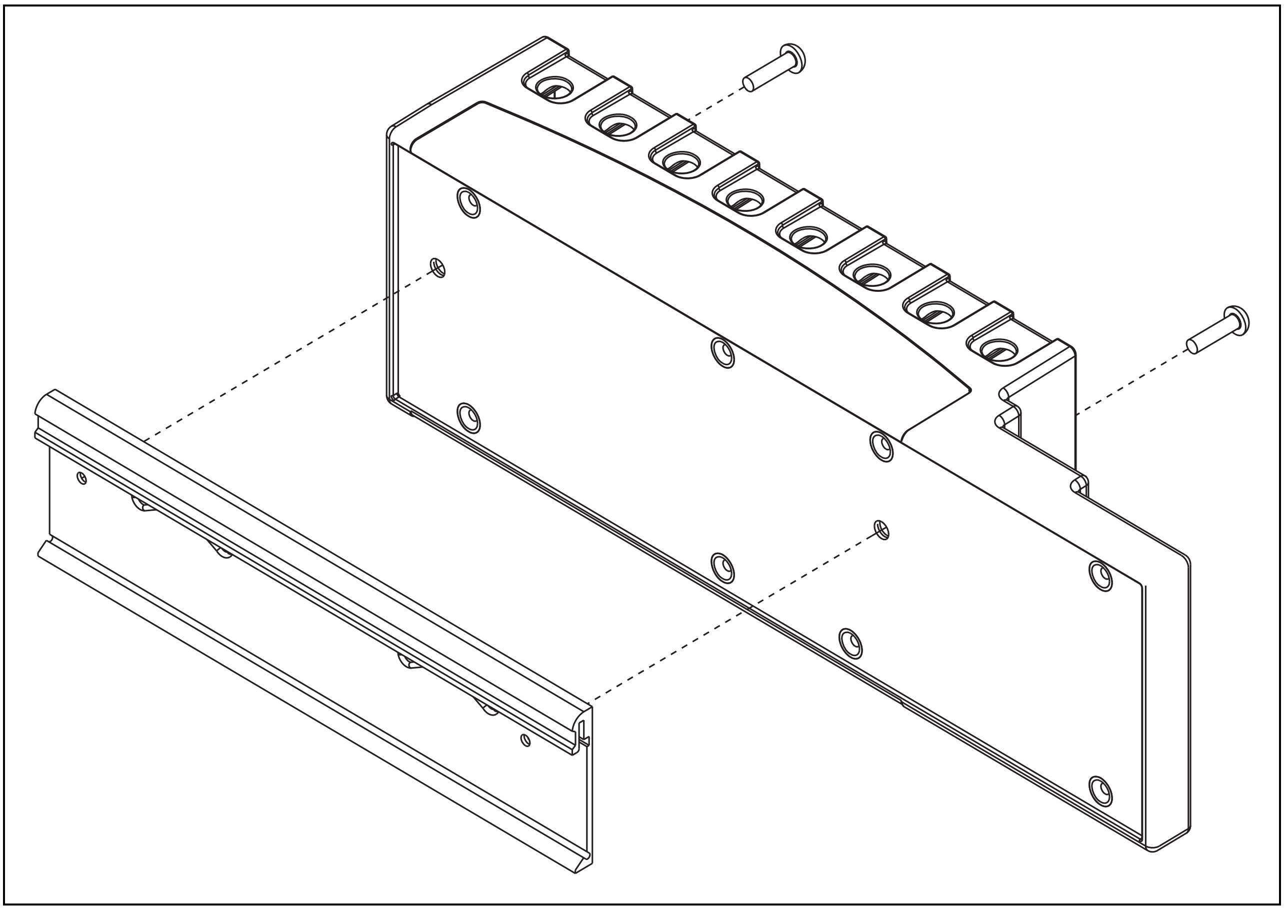
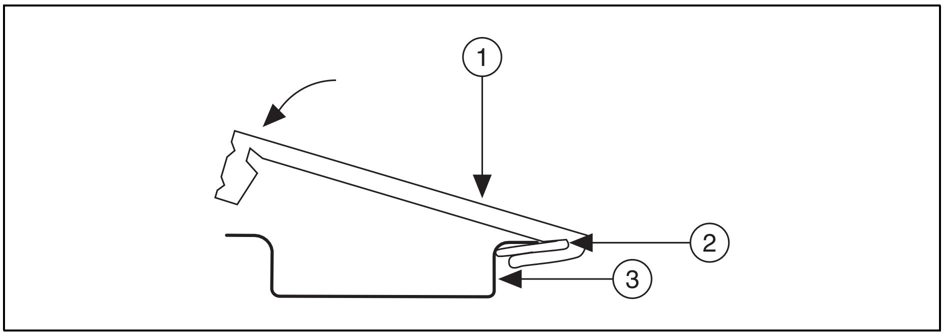


Figure 7. Installing the DIN Rail Clip on the cRIO-9072/3/4

2. Insert one edge of the DIN rail into the deeper opening of the DIN rail clip, as shown in Figure 8.



1	DIN Rail Clip	2	DIN Rail Spring	3	DIN Rail

Figure 8. One Edge of the DIN Rail Inserted in a Clip

3. Press down firmly on the chassis to compress the spring until the clip locks in place on the DIN rail.

Caution Make sure that no I/O modules are in the chassis before removing it from the DIN rail.

Installing C Series I/O Modules in the Chassis

Figure 9 shows the mechanical dimensions of C Series I/O modules.

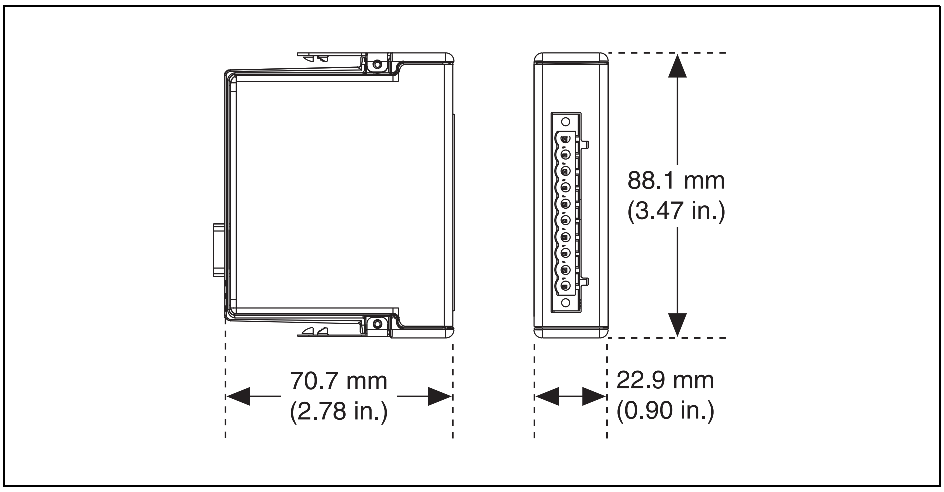
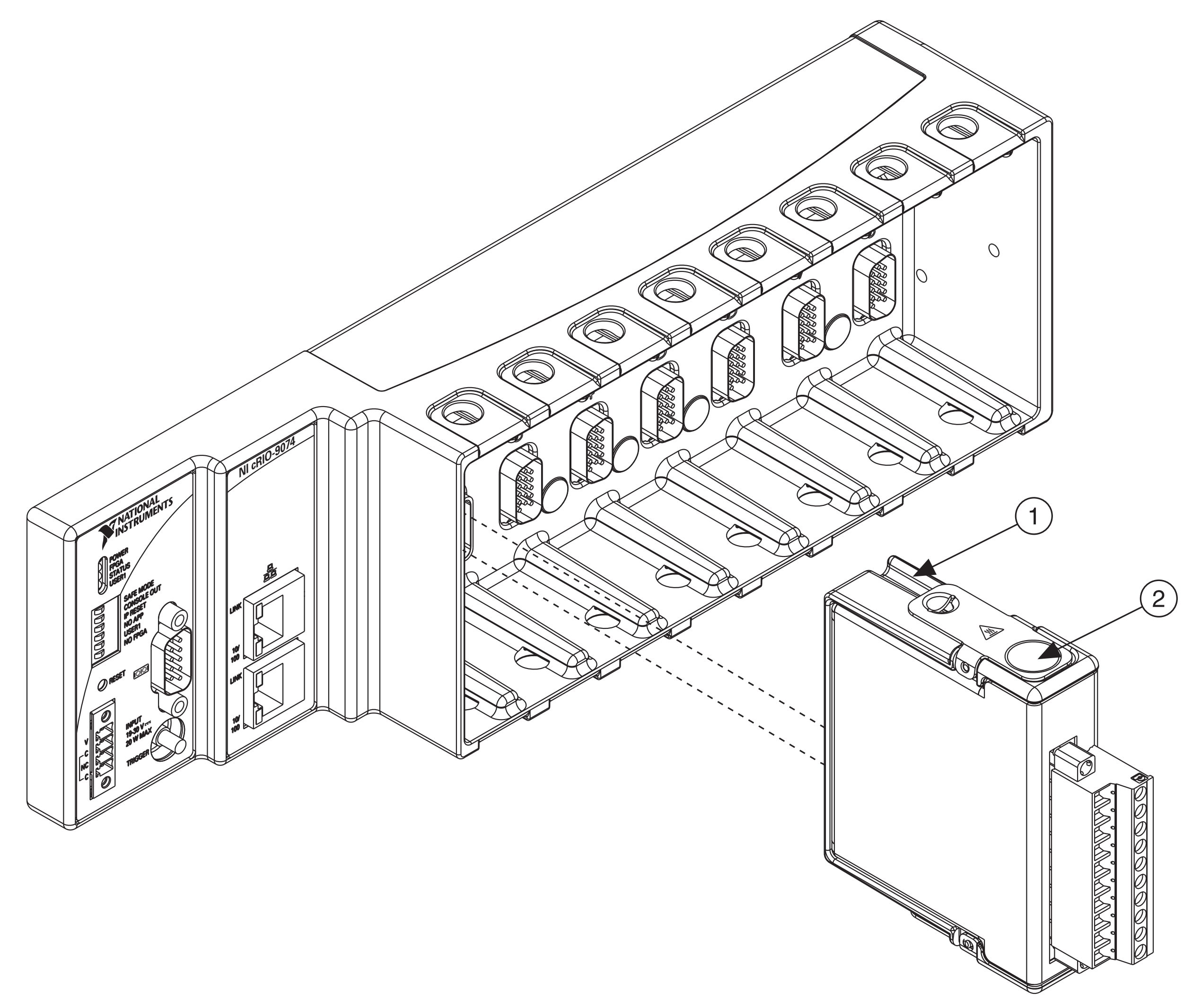


Figure 9. C Series I/O Module, Front and Side View with Dimensions

Complete the following steps to install a C Series I/O module in the chassis.

1. Make sure that no I/O-side power is connected to the I/O module. If the system is in a nonhazardous location, the chassis power can be on when you install I/O modules.
2. Align the I/O module with an I/O module slot in the chassis as shown in Figure 10. The module slots are labeled 1 to 8, left to right.



1 Insertion Groove	2 Latch

Figure 10. Installing an I/O Module in the Chassis

3. Squeeze the latches and insert the I/O module into the module slot.
4. Press firmly on the connector side of the I/O module until the latches lock the I/O module into place.
5. Repeat these steps to install additional I/O modules.

Removing I/O Modules from the Chassis

Complete the following steps to remove a C Series I/O module from the chassis.

1. Make sure that no I/O-side power is connected to the I/O module. If the system is in a nonhazardous location, the chassis power can be on when you remove I/O modules.
2. Squeeze the latches on both sides of the module and pull the module out of the chassis.

Connecting the Chassis to a Network

Connect the chassis to an Ethernet network using RJ-45 Ethernet port 1 on the controller front panel. Use a standard Category 5 (CAT-5) or better shielded, twisted-pair Ethernet cable to connect the chassis to an Ethernet hub, or use an Ethernet crossover cable to connect the chassis directly to a computer.

Caution To prevent data loss and to maintain the integrity of your Ethernet installation, do *not* use a cable longer than 100 m.

If you need to build your own cable, refer to the *Cabling* section for more information about Ethernet cable wiring connections.

The first time you power up the chassis, the BIOS network settings determine the initial IP settings and other network behavior. After powerup, you must install software on the chassis and configure the network settings in Measurement & Automation Explorer (MAX).

Note Installing software may change the network behavior of the chassis. For information about network behavior by installed software version, go to `ni.com/info` and enter the Info Code `ipconfigcrio`.

The BIOS network settings of the cRIO-9072/3/4 depend on the part number of the chassis. The part number is located on the bottom of the chassis.

BIOS Network Settings of cRIO-9072/3/4 with Part Number Beginning 192172

If the part number of the cRIO-9072/3/4 begins with 192172, the IP address, subnet mask, DNS address, gateway, and Time Server IP are all set to `0.0.0.0` at powerup.

The host computer communicates with the chassis over a standard Ethernet connection. If the host computer is on a network, you must configure the chassis on the same subnet as the host computer. If neither the host computer nor the chassis is connected to a network, you can connect the two directly using a crossover cable.

If you want to use the chassis on a subnet other than the one the host computer is on, first connect the chassis on the same subnet as the host computer. Use DHCP to assign an IP address or reassign a static IP address for the subnet where you want it to be and physically move it to the other subnet.

BIOS Network Settings of cRIO-9072/3/4 with Part Number Beginning 198944

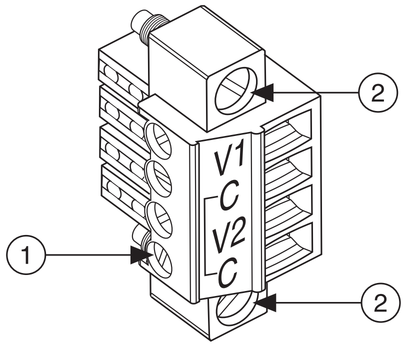
If the part number of the cRIO-9072/3/4 begins with 198944, the chassis attempts to initiate a DHCP network connection at powerup. If the chassis is unable to initiate a DHCP connection, it connects to the network with a link-local IP address with the form `169.254.x.x`.

The host computer communicates with the chassis over a standard Ethernet connection. If neither the host computer nor the chassis is connected to a network, you can connect the two directly using a crossover cable.

Wiring Power to the Chassis

The cRIO-9072/3/4 requires an external power supply that meets the specifications in the *Power Requirements* section. The cRIO-9072/3/4 filters and regulates the supplied power and provides power for all of the I/O modules. The cRIO-9072/3/4 has one layer of reverse-voltage protection. Complete the following steps to connect a power supply to the chassis.

1. Connect the positive lead of the power supply to the V terminal of the COMBICON power connector shipped with the cRIO-9072/3/4, and tighten the terminal screw. Figure 11 shows the terminal screws, which secure the wires in the screw terminals, and the connector screws, which secure the power connector on the front panel.



1 Terminal Screws	2 Connector Screws

Figure 11. COMBICON Power Connector

2. Connect the negative lead of the power supply to one of the C terminals of the power connector and tighten the terminal screw.
3. Optionally, you can connect the positive lead of another power supply to the other V terminal and the negative lead to one of the C terminals.
4. Install the power connector on the front panel of the cRIO-9072/3/4 and tighten the connector screws.

Caution The C terminals are internally connected to each other.

Powering On the cRIO-9072/3/4

When you apply power to the cRIO-9072/3/4, the controller runs a power-on self test (POST). During the POST, the Power and Status LEDs turn on. The Status LED turns off, indicating that the POST is complete. If the LEDs do not behave in this way when the system powers on, refer to the *Understanding LED Indications* section.

You can configure the cRIO-9072/3/4 to launch an embedded stand-alone LabVIEW RT application each time you boot the controller. Refer to the *Running a Stand-Alone Real-Time Application (RT Module)* topic of the *LabVIEW Help* for more information.

Chassis Reset Options

Table 1 lists the reset options available on CompactRIO systems such as the cRIO-9072/3/4. These options determine how the chassis behaves when the controller is reset in various conditions. Use the RIO Device Setup utility to select reset options. Access the RIO Device Setup utility by selecting **Start»All Programs»National Instruments»NI-RIO» RIO Device Setup**.

Table 1. CompactRIO Reset Options

Chassis Reset Option	Behavior
Do not autoload VI	Does not load the FPGA bit stream from flash memory.
Autoload VI on device powerup	Loads the FPGA bit stream from flash memory to the FPGA when the controller powers on.
Autoload VI on device reboot	Loads the FPGA bit stream from flash memory to the FPGA when you reboot the controller either with or without cycling power.

Connecting Serial Devices to the cRIO-9072/3/4

The cRIO-9072/3/4 has an RS-232 serial port to which you can connect devices such as displays or input devices. Use the Serial VIs to read from and write to the serial port from a LabVIEW RT application. For more information about the Serial VIs, refer to the *LabVIEW Help*.

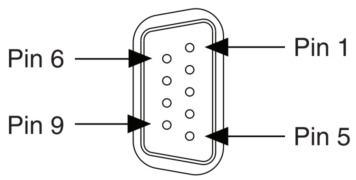


Figure 12. Controller Serial Port

Table 2. DB-9 Pin Descriptions

Pin	Signal
1	DCD
2	RXD
3	TXD
4	DTR
5	GND
6	DSR
7	RTS
8	CTS
9	RI

Using the Internal Real-Time Clock

The system clock of the cRIO-9012/9014 is synchronized with the internal high-precision real-time clock at startup. This synchronization provides timestamp data to the controller. You can also use the internal real-time clock to correct drift of the system clock. Refer to the *Internal Real-Time Clock* specification in the *Specifications* section for the accuracy specifications of the real-time clock.

Using the SMB Connector for Digital I/O (cRIO-9074 Only)

You can use the SMB connector of the cRIO-9074 to connect digital devices to the controller. For example, if you connect the pulse-per-second output of a GPS device to the SMB connector of the cRIO-9074, you can use the GPS device to correct for drift of the system clock.

For software that supports GPS drift-correction and other digital I/O through the SMB connector, go to `ni.com/info` and enter the Info Code `criosmb`.

Configuring DIP Switches

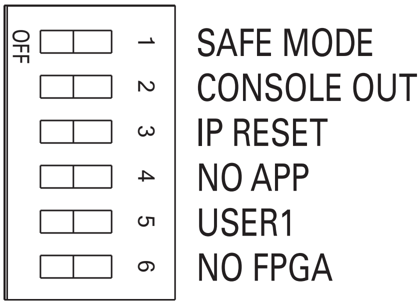


Figure 13. DIP Switches

All of the DIP switches are in the OFF position when the chassis is shipped from National Instruments.

SAFE MODE Switch

The position of the SAFE MODE switch determines whether the embedded LabVIEW Real-Time engine launches at startup. If the switch is in the OFF position, the LabVIEW Real-Time engine launches. Keep this switch in the OFF position during normal operation. If the switch is in the ON position at startup, the cRIO-9072/3/4 launches only the essential services required for updating its configuration and installing software. The LabVIEW Real-Time engine does not launch.

If the software on the controller is corrupted, you must put the controller into safe mode and reformat the controller drive. You can put the controller into safe mode by powering it up either with the SAFE MODE switch in the ON position or with no software installed on the drive. Refer to the *Measurement & Automation Explorer Help* for more information about installing software on a controller and reformatting the drive on the controller.

CONSOLE OUT Switch

With a serial-port terminal program, you can use the CONSOLE OUT switch to read the IP address and firmware version of the controller. Use a null-modem cable to connect the serial port on the chassis to a computer. Push the switch to the ON position. Make sure that the serial-port terminal program is configured to the following settings:

- 9,600 bits per second
- Eight data bits
- No parity

- One stop bit
- No flow control

The serial-port terminal program displays the IP address and firmware version of the chassis. Keep this switch in the OFF position during normal operation.

IP RESET Switch

Push the IP RESET switch to the ON position and reboot the controller to reset the IP address and other TCP/IP settings of the controller to the factory defaults. Refer to the *Troubleshooting Network Communication* section for more information about resetting the IP address. You also can push this switch to the ON position to unlock a chassis that was previously locked in MAX.

NO APP Switch

Push the NO APP switch to the ON position to prevent a LabVIEW RT startup application from running at startup. If you want to permanently disable a LabVIEW RT application from running at startup, you must disable it in LabVIEW. To run an application at startup, push the NO APP switch to the OFF position, create an application using the LabVIEW Application Builder, and configure the application in LabVIEW to launch at startup. If you already have an application configured to launch at startup and you push the NO APP switch from ON to OFF, the startup application is automatically enabled. For more information about automatically launching VIs at startup and disabling VIs from launching at startup, refer to the *Running a Stand-Alone Real-Time Application (RT Module)* topic of the *LabVIEW Help*.

USER1 Switch

You can define the USER1 switch for your application. To define the purpose of this switch in your embedded application, use the RT Read Switch VI in your LabVIEW RT embedded VI. For more information about the RT Read Switch VI, refer to the *LabVIEW Help*.

NO FPGA Switch

Push the NO FPGA switch to the ON position to prevent a LabVIEW FPGA application from loading at startup. The NO FPGA switch overrides the CompactRIO reset options described in the *Chassis Reset Options* section. After startup you can download to the FPGA from software regardless of switch position.

Using the RESET Button

Pressing the RESET button resets the processor in the same manner as cycling power.

Note The FPGA continues to run unless you select the **Autoload on Any Device Reset** boot option. Refer to the *Chassis Reset Options* section for more information.

Understanding LED Indications

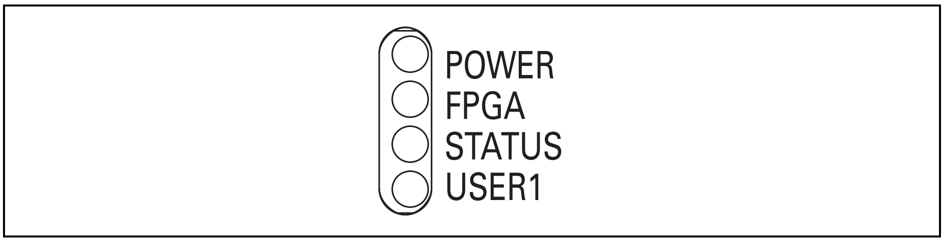


Figure 14. cRIO-9072/3/4 LEDs

POWER LED

The POWER LED is lit while the cRIO-9072/3/4 is powered on. This LED indicates that the power supply connected to the chassis is adequate.

FPGA LED

You can use the FPGA LED to help debug your application or easily retrieve application status. Use the LabVIEW FPGA Module and NI-RIO software to define the FPGA LED to meet the needs of your application. Refer to *LabVIEW Help* for information about programming this LED.

STATUS LED

The STATUS LED is off during normal operation. The cRIO-9072/3/4 indicates specific error conditions by flashing the STATUS LED a certain number of times every few seconds, as shown in Table 3.

Table 3. Status LED Indications

Number of Flashes Every Few Seconds	Indication
1	The chassis is unconfigured. Use MAX to configure the chassis. Refer to the *Measurement & Automation Explorer Help* for information about configuring the chassis.
2	The chassis has detected an error in its software. This usually occurs when an attempt to upgrade the software is interrupted. Reinstall software on the chassis. Refer to the *Measurement & Automation Explorer Help* for information about installing software on the chassis.
3	The chassis is in safe mode because the SAFE MODE DIP switch is in the ON position or there is no software installed on the chassis. Refer to the *Configuring DIP Switches* section for information about the Safe Mode DIP switch.
4	The software has crashed twice without rebooting or cycling power between crashes. This usually occurs when the chassis runs out of memory. Review your RT VI and check the memory usage. Modify the VI as necessary to solve the memory usage issue.
Continuously flashing	The chassis has detected an unrecoverable error. Contact National Instruments.
Continuously flashing or solid	The device may be configured for DHCP but unable to get an IP address because of a problem with the DHCP server. Check the network connection and try again. If the problem persists, contact National Instruments.

USER1 LED

You can define the USER1 LED to meet the needs of your application. To define the LED, use the RT LEDs VI in LabVIEW. For more information about the RT LEDs VI, refer to the *LabVIEW Help*.

Troubleshooting Network Communication

If the cRIO-9072/3/4 cannot communicate with the network, you can perform the following troubleshooting steps.

1. Move the IP RESET switch to the ON position.
2. Push the RESET button to cycle power to the chassis.
3. Configure the IP and other network settings in MAX.
4. Move the IP RESET switch to the OFF position.

Note The network behavior of the chassis after powering up with the IP RESET switch on depends on the version of LabVIEW RT installed. For information about the different network behaviors with different software versions, go to `ni.com/info` and enter the Info Code `ipconfigcrio`.

If you are unable to fix network communication with the LabVIEW RT network settings restored, you can restore the BIOS network settings of the chassis. Refer to the *Connecting the Chassis to a Network* section of this document for information about the BIOS network settings for different chassis revisions. Complete the following steps to restore the BIOS network settings of the chassis.

1. Move the IP RESET and SAFE MODE switches to the ON position.
2. Push the RESET button to cycle power to the chassis.
3. Configure the IP and other network settings in MAX.
4. Move the IP RESET and SAFE MODE switches to the OFF position.

Note If the chassis is restored to the BIOS network settings, the LabVIEW run-time engine does not load. You must reconfigure the network settings and restart the chassis for the LabVIEW run-time engine to load.

Specifications

The following specifications are typical for the –20 to 55 °C operating temperature range unless otherwise noted.

Network

Network interface ....10BaseT and 100BaseTX Ethernet

Compatibility ....IEEE 802.3

Communication rates ....10 Mbps, 100 Mbps, auto-negotiated

Maximum cabling distance.....................100 m/segment

RS-232 Serial Port

Maximum baud rate................................115,200 bps

Data bits 5, 6, 7, 8

Stop bits 1, 2

Parity...Odd, Even, Mark, Space

Flow control...RTS/CTS, XON/XOFF, DTR/DSR

SMB Connector (cRIO-9074 Only)

Output Characteristics

Minimum high-level output voltage

- With –100 µA output current ....2.9 V
- With –16 mA output current............2.4 V
- With –24 mA output current............2.3 V

Maximum low-level output voltage

- With 100 µA output current ....0.10 V
- With 16 mA output current..............0.40 V
- With 24 mA output current..............0.55 V

Driver type ....CMOS

Maximum sink/source current .... ±24 mA

Maximum 3-state output
leakage current .... ±5 µA

Input Characteristics

Minimum input voltage.......................... 0 V

Minimum low-level input voltage.......... 0.94 V

Maximum high-level input voltage........ 2.43 V

Maximum input voltage .... 5.5 V

Typical input capacitance....................... 2.5 pF

Typical resistive strapping .... 1 kΩ to 3.3 V

Memory

cRIO-9072, cRIO-9073

Nonvolatile..................................... 128 MB minimum

System memory .... 64 MB

cRIO-9074

Nonvolatile..................................... 256 MB minimum

System memory .... 128 MB

For information about the life span of the nonvolatile memory and about best practices for using nonvolatile memory, go to `ni.com/info` and enter the Info Code `SSDBP`.

Reconfigurable FPGA

cRIO-9072

Number of logic cells...................... 17,280

Available embedded RAM .... 432 kbits

cRIO-9073, cRIO-9074

Number of logic cells...................... 46,080

Available embedded RAM .... 720 kbits

For information about the life span of the nonvolatile memory and about best practices for using nonvolatile memory, go to `ni.com/info` and enter the Info Code `SSDBP`.

Internal Real-Time Clock

Accuracy ....200 ppm; 35 ppm at 25 °C

Power Requirements

Caution You must use a UL Listed ITE power supply marked *LPS* with the cRIO-9072/3/4.

Recommended power supply..................48 W, 24 VDC

Power consumption ....20 W maximum

Power supply input range ....19 to 30 V

Physical Characteristics

If you need to clean the controller, wipe it with a dry towel.

Screw-terminal wiring ....0.5 to 2.5 mm^2 (24 to 12 AWG) copper conductor wire with 10 mm (0.39 in.) of insulation stripped from the end

Torque for screw terminals.....................0.5 to 0.6 N · m (4.4 to 5.3 lb · in.)

Weight ....929 g (32.7 oz)

Safety Voltages

Connect only voltages that are within these limits.

V terminal to C terminal.........................35 V max, Measurement Category I

Measurement Category I is for measurements performed on circuits not directly connected to the electrical distribution system referred to as MAINS voltage. MAINS is a hazardous live electrical supply system that powers equipment. This category is for measurements of voltages from specially protected secondary circuits. Such voltage measurements include signal levels, special equipment, limited-energy parts of equipment, circuits powered by regulated low-voltage sources, and electronics.

Caution Do not connect the system to signals or use for measurements within Measurement Categories II, III, or IV.

Safety Standards

This product meets the requirements of the following standards of safety for electrical equipment for measurement, control, and laboratory use:

- IEC 61010-1, EN 61010-1
- UL 61010-1, CSA 61010-1

Note For UL and other safety certifications, refer to the product label or the *Online Product Certification* section.

Electromagnetic Compatibility

This product meets the requirements of the following EMC standards for electrical equipment for measurement, control, and laboratory use:

- EN 61326 (IEC 61326): Class A emissions; Industrial immunity
- EN 55011 (CISPR 11): Group 1, Class A emissions
- AS/NZS CISPR 11: Group 1, Class A emissions
- FCC 47 CFR Part 15B: Class A emissions
- ICES-001: Class A emissions

Note For the standards applied to assess the EMC of this product, refer to the *Online Product Certification* section.

Note For EMC compliance, operate this product according to the documentation.

CE Compliance CE

This product meets the essential requirements of applicable European Directives as follows:

- 2006/95/EC; Low-Voltage Directive (safety)
- 2004/108/EEC; Electromagnetic Compatibility Directive (EMC)

Online Product Certification

Refer to the Declaration of Conformity (DoC) for this product for additional regulatory compliance information. To obtain product certifications and the DoC for this product, visit `ni.com/certification`, search by model number or product line, and click the appropriate link in the Certification column.

Environmental Management

National Instruments is committed to designing and manufacturing products in an environmentally responsible manner. NI recognizes that eliminating certain hazardous substances from our products is beneficial to the environment and to NI customers.

For additional environmental information, refer to the *NI and the Environment* Web page at `ni.com/environment`. This page contains the environmental regulations and directives with which NI complies, as well as other environmental information not included in this document.

Waste Electrical and Electronic Equipment (WEEE)

EU Customers At the end of the product life cycle, all products *must* be sent to a WEEE recycling center. For more information about WEEE recycling centers, National Instruments WEEE initiatives, and compliance with WEEE Directive 2002/96/EC on Waste and Electronic Equipment, visit `ni.com/environment/weee`.

电子信息产品污染控制管理办法 （中国 RoHS）

中国客户 National Instruments 符合中国电子信息产品中限制使用某些有害物质指令 (RoHS)。关于 National Instruments 中国 RoHS 合规性信息，请登录 `ni.com/environment/rohs_china`。(For information about China RoHS compliance, go to `ni.com/environment/rohs_china`.)

Battery Replacement and Disposal

This device contains a long-life coin cell battery. If you need to replace it, use the Return Material Authorization (RMA) process or contact an authorized National Instruments sevice representative.

After replacement, recycle the old battery. For additional information, visit `ni.com/environment`.

Hazardous Locations

U.S. (UL)	Class I, Division 2, Groups A, B, C, D, T4; Class I, Zone 2, AEx nL IIC T4
Canada (C-UL)	Class I, Division 2, Groups A, B, C, D, T4; Class I, Zone 2, Ex nL IIC T4
Europe (DEMKO)	Ex nL IIC T4 (part numbers beginning with 192172F and 198944 only)

Environmental

The cRIO-9072/3/4 is intended for indoor use only, but it may be used outdoors if mounted in a suitably rated enclosure.

Operating temperature
(IEC 60068-2-1, IEC 60068-2-2) .... –20 to 55 °C

Note To meet this operating temperature range, follow the guidelines in the installation instructions for your CompactRIO system.

Storage temperature
(IEC 60068-2-1, IEC 60068-2-2) .... –40 to 85 °C

Ingress protection .... IP 40

Operating humidity
(IEC 60068-2-56) .... 10 to 90% RH, noncondensing

Storage humidity
(IEC 60068-2-56) .... 5 to 95% RH, noncondensing

Maximum altitude .... 2,000 m

Pollution Degree (IEC 60664) 2

Shock and Vibration

To meet these specifications, you must panel mount the CompactRIO system and affix ferrules to the ends of the power terminal wires.

Operating shock
(IEC 60068-2-27) .... 30 g, 11 ms half sine
50 g, 3 ms half sine,
18 shocks at 6 orientations

Operating vibration, random
(IEC 60068-2-64) .... 5 g_{rms}, 10 to 500 Hz

Operating vibration, sinusoidal
(IEC 60068-2-6) .... 5 g, 10 to 500 Hz

Cabling

Table 4 shows the standard Ethernet cable wiring connections for both normal and crossover cables.

Table 4. Ethernet Cable Wiring Connections

Pin	Connector 1	Connector 2 (Normal)	Connector 2 (Crossover)
1	white/orange	white/orange	white/green
2	orange	orange	green
3	white/green	white/green	white/orange
4	blue	blue	blue
5	white/blue	white/blue	white/blue
6	green	green	orange
7	white/brown	white/brown	white/brown
8	brown	brown	brown

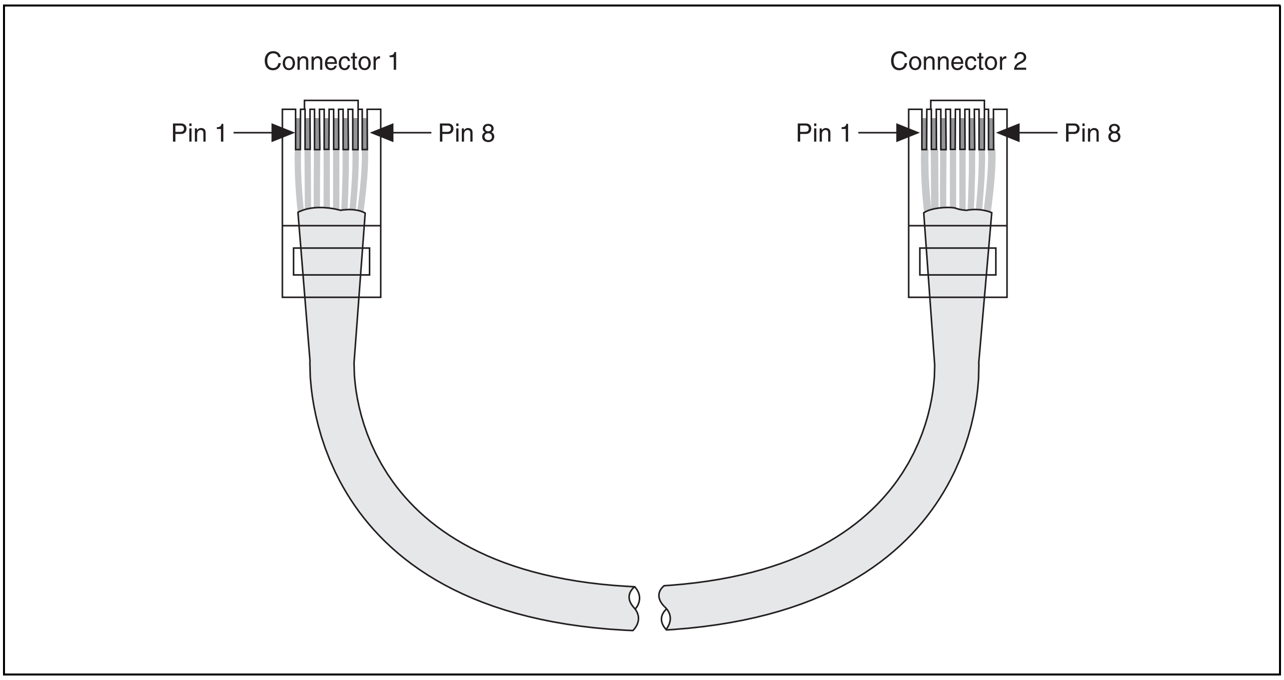


Figure 15. Ethernet Connector Pinout

Where to Go for Support

The National Instruments Web site is your complete resource for technical support. At `ni.com/support` you have access to everything from troubleshooting and application development self-help resources to email and phone assistance from NI Application Engineers.

National Instruments corporate headquarters is located at 11500 North Mopac Expressway, Austin, Texas, 78759-3504. National Instruments also has offices located around the world to help address your support needs. For telephone support in the United States, create your service request at `ni.com/support` and follow the calling instructions or dial 512 795 8248. For telephone support outside the United States, contact your local branch office:

Australia 1800 300 800, Austria 43 662 457990-0,
Belgium 32 (0) 2 757 0020, Brazil 55 11 3262 3599,
Canada 800 433 3488, China 86 21 5050 9800,
Czech Republic 420 224 235 774, Denmark 45 45 76 26 00,
Finland 358 (0) 9 725 72511, France 01 57 66 24 24,
Germany 49 89 7413130, India 91 80 41190000, Israel 972 3 6393737,
Italy 39 02 41309277, Japan 0120-527196, Korea 82 02 3451 3400,
Lebanon 961 (0) 1 33 28 28, Malaysia 1800 887710,
Mexico 01 800 010 0793, Netherlands 31 (0) 348 433 466,
New Zealand 0800 553 322, Norway 47 (0) 66 90 76 60,
Poland 48 22 328 90 10, Portugal 351 210 311 210,
Russia 7 495 783 6851, Singapore 1800 226 5886,
Slovenia 386 3 425 42 00, South Africa 27 0 11 805 8197,
Spain 34 91 640 0085, Sweden 46 (0) 8 587 895 00,
Switzerland 41 56 2005151, Taiwan 886 02 2377 2222,
Thailand 662 278 6777, Turkey 90 212 279 3031,
United Kingdom 44 (0) 1635 523545

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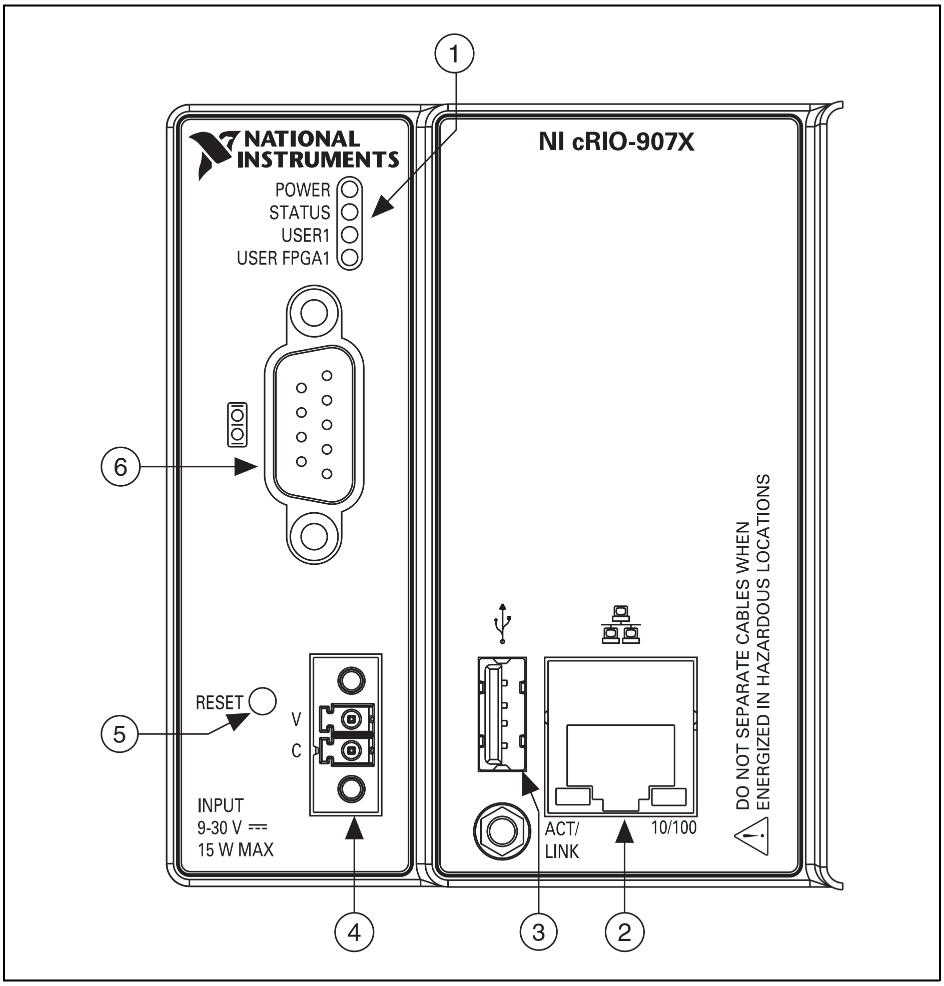
A.11 Sistema de Adquisición del Laboratorio de Mecatrónica

OPERATING INSTRUCTIONS AND SPECIFICATIONS

CompactRIO™ cRIO-9075/9076

Reconfigurable Embedded Chassis with Integrated Intelligent Real-Time Controller for CompactRIO



1	LEDs	4	Power Connector
2	RJ-45 Ethernet Port	5	Reset Button
3	USB Port (cRIO-9076 Only)	6	RS-232 Serial Port

Figure 1. cRIO-9075/9076 Front Panel

This document describes how to connect the cRIO-9075/9076 to a network and how to use the features of the cRIO-9075/9076. This document also contains specifications for the cRIO-9075/9076.

Safety Guidelines

Operate the cRIO-9075/9076 only as described in these operating instructions.

Safety Guidelines for Hazardous Locations

The cRIO-9075/9076 is suitable for use in Class I, Division 2, Groups A, B, C, D, T4 hazardous locations; Class 1, Zone 2, AEx nC IIC T4 and Ex nL IIC T4 hazardous locations; and nonhazardous locations only. Follow these guidelines if you are installing the cRIO-9075/9076 in a potentially explosive environment. Not following these guidelines may result in serious injury or death.

Caution Do *not* disconnect the power supply wires and connectors from the controller unless power has been switched off.

Caution Substitution of components may impair suitability for Class I, Division 2.

Caution For Zone 2 applications, install the CompactRIO system in an enclosure rated to at least IP 54 as defined by IEC 60529 and EN 60529.

Special Conditions for Hazardous Locations Use in Europe

Some chassis have been evaluated as Ex nA nL IIC T4 equipment under DEMKO Certificate No. 07 ATEX 0626664X. Each such chassis is marked Ex II 3G and is suitable for use in Zone 2 hazardous locations, in ambient temperatures of –20 °C ≤ Ta ≤ 55 °C.

Special Conditions for Marine Applications

Some chassis are Lloyd's Register (LR) Type Approved for marine applications. To verify Lloyd's Register certification, visit `ni.com/certification` and search for the LR certificate, or look for the Lloyd's Register mark on the chassis.

What You Need to Install the cRIO-9075/9076

- ❑ CompactRIO reconfigurable embedded chassis with integrated intelligent real-time controller
- ❑ C Series I/O modules
- ❑ DIN rail mount kit (for DIN rail mounting only)
- ❑ Panel mount kit (for panel mounting only)
- ❑ Two M4 or number 8 flathead screws (for mounting the chassis without one of the listed mounting kits)
- ❑ A number 2 Phillips screwdriver
- ❑ Power supply
- ❑ Ethernet cable

Notes Visit `ni.com/info` and enter the Info Code `rdsoftwareversion` to determine which software you need to use the cRIO-9075/9076.

Mounting the cRIO-9075/9076

You can mount the chassis horizontally on a flat, vertical, metallic surface such as a panel or wall. The maximum allowable ambient temperature for operation in this configuration is 55 °C. Figure 2 shows the chassis mounted horizontally.

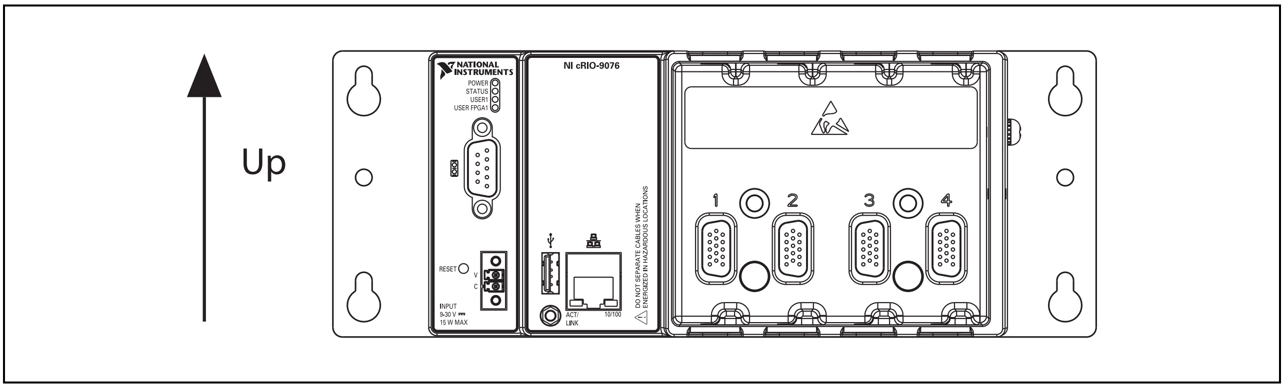


Figure 2. cRIO-9075/9076 Mounted Horizontally

You can also mount the chassis on a panel or wall in other orientations, on a non-metallic surface, on a 35 mm DIN rail, on a rack, in an enclosure, or on a desktop. Mounting the chassis in these or other configurations can reduce the maximum allowable ambient temperature and can affect the typical accuracy of modules in the chassis.

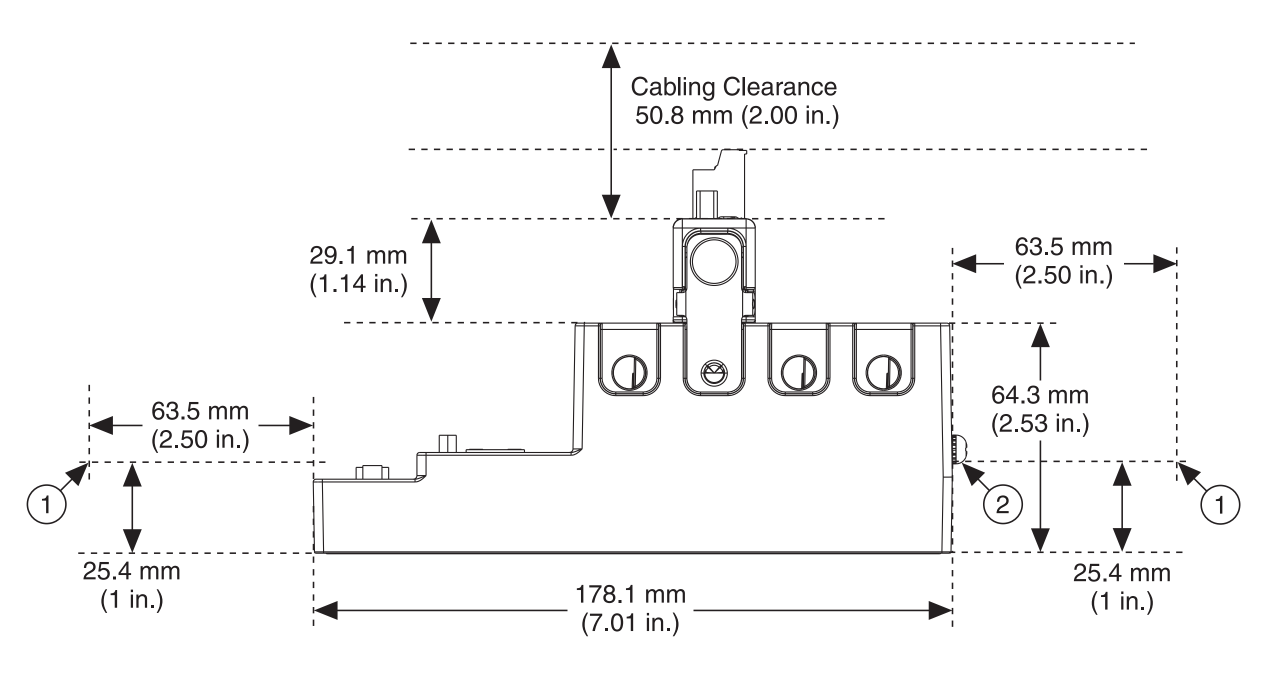
Note For information about how different mounting configurations can cause temperature derating, go to `ni.com/info` and enter the Info Code `criomounting`.

Note For information about typical accuracy specifications for modules, go to `ni.com/info` and enter the Info Code `criotypical`.

Note Measure the ambient temperature at each side of the chassis, 63.5 mm (2.5 in.) from the side and 25.4 mm (1 in.) forward from the rear of the chassis, as shown in Figure 3.

Caution Your installation must meet the following requirements for space and cabling clearance:

- Allow 25.4 mm (1 in.) on the top and the bottom of the chassis for air circulation.
- Allow 50.8 mm (2 in.) in front of modules for cabling clearance for common connectors, such as the 10-terminal, detachable screw terminal connector, as shown in Figure 3.



1 Measure ambient temperature here.	2 Chassis Grounding Screw

Figure 3. cRIO-9075/9076, Bottom View with Dimensions

Note Go to `ni.com/info` and enter the Info Code `rdcrioconn` to find the minimum cabling clearance for C Series modules with other connector types.

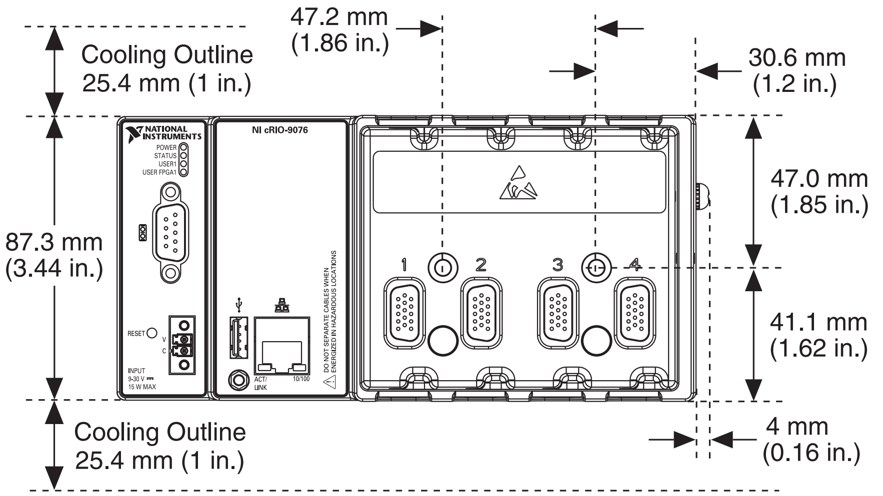


Figure 4. cRIO-9075/9076, Front View with Dimensions

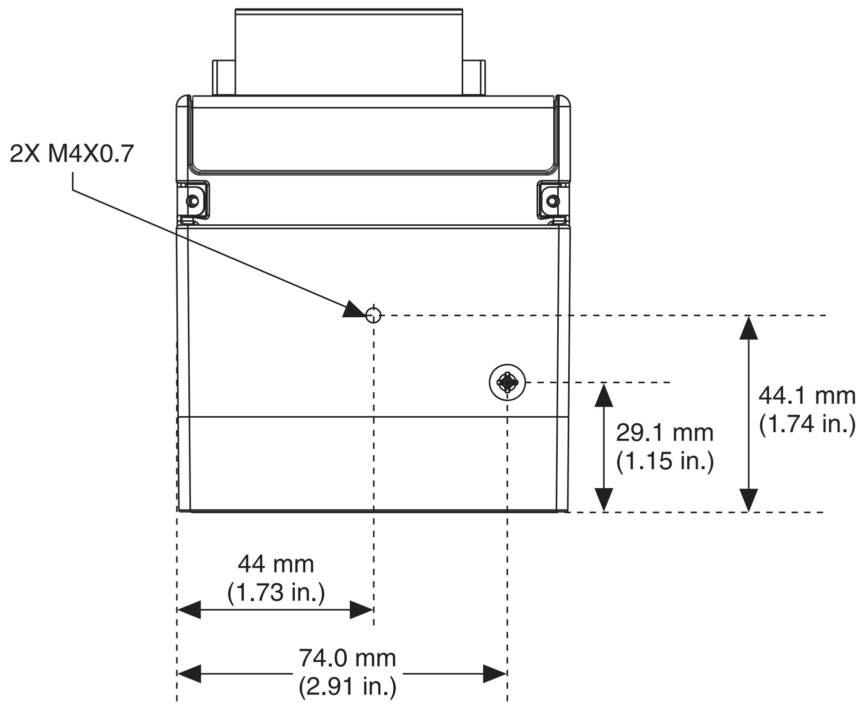


Figure 5. cRIO-9075/9076, Side View with Dimensions

Note For more information about the dimensions of the CompactRIO system, including detailed dimensional drawings, go to `ni.com/dimensions`.

The following sections contain instructions for the mounting methods. Before using any of these mounting methods, record the serial number from the back of the chassis. You will be unable to read the serial number after you have mounted the chassis.

Caution Make sure that no I/O modules are in the chassis before mounting it.

Mounting the Chassis on a Flat Surface Using the NI 9904 Panel Mount Kit

Panel or wall mounting is the best method for applications that are subject to high shock and vibration. You can use the NI 9904 panel mount kit to mount the cRIO-9075/9076 on a flat surface. Complete the following steps.

1. Fasten the chassis to the panel mount kit using a number 2 Phillips screwdriver and two M4 × 25 screws. National Instruments provides these screws with the panel mount kit. You *must* use these screws because they are the correct depth and thread for the panel. Tighten the screws to a maximum torque of 1.3 N · m (11.5 lb · in.).

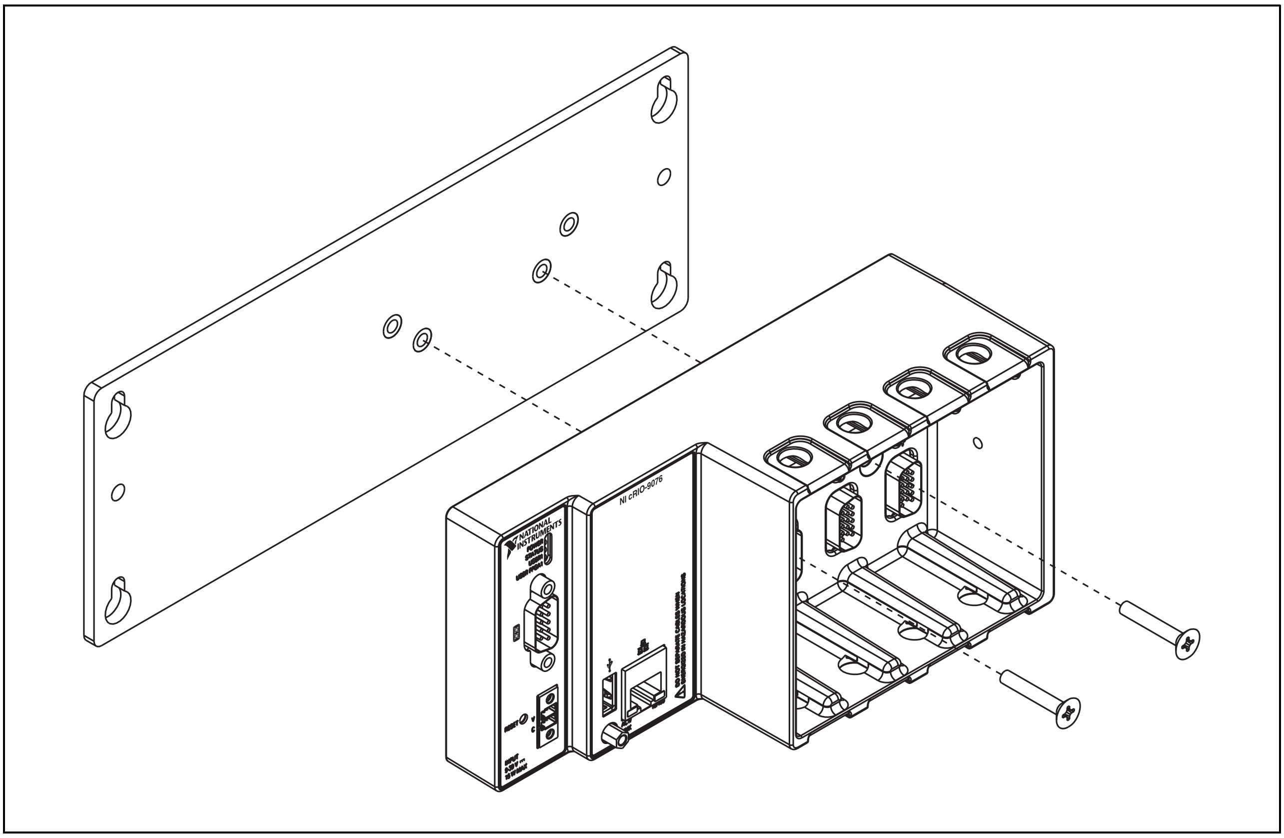


Figure 6. Installing the Panel Mounting Plate on the cRIO-9075/9076

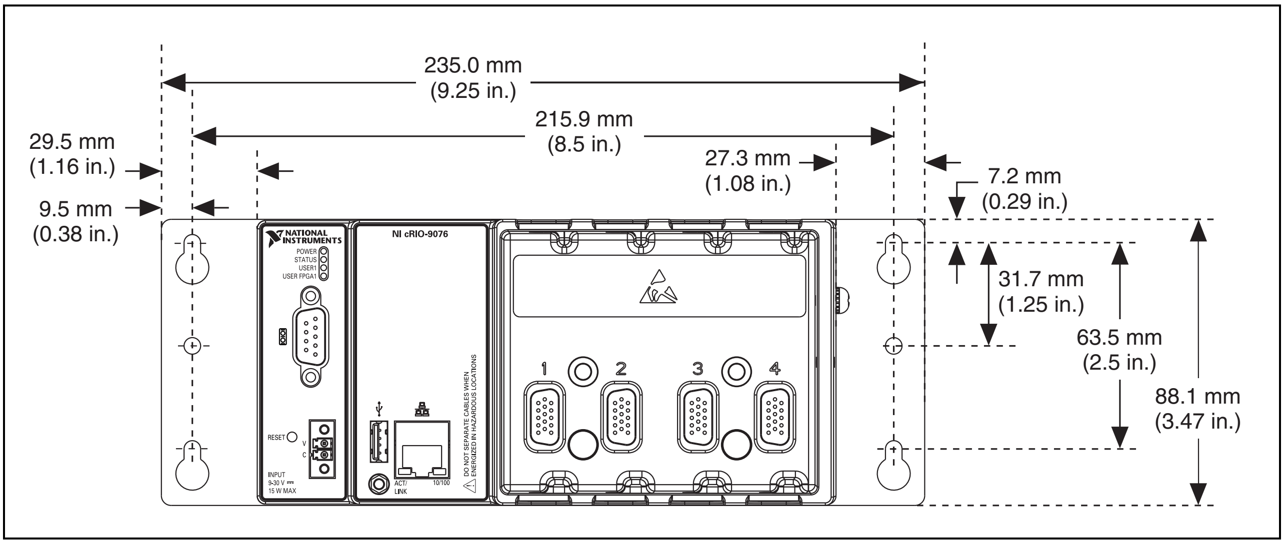


Figure 7. Dimensions of cRIO-9075/9076 with Panel Mounting Plate Installed

2. Fasten the NI 9904 panel to the wall using the screwdriver and screws that are appropriate for the wall surface. The maximum screw size is M4 or number 8.

Mounting the Chassis Directly on a Flat Surface Using the Mounting Holes

Panel or wall mounting is the best method for applications that are subject to high shock and vibration. If you do not have the NI 9904 panel mount kit and do not require the portability that the NI 9904 affords, you can mount the chassis directly on a flat surface using the mounting holes. Complete the following steps.

1. Align the chassis on the surface.
2. Fasten the chassis to the surface using M4 or number 8 flathead screws, as shown in Figure 8. National Instruments does not provide these screws with the chassis.

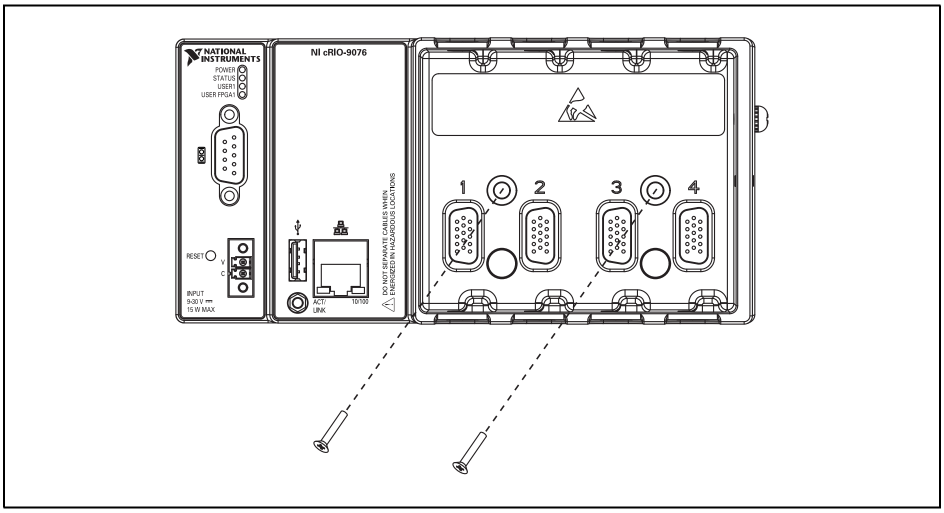


Figure 8. Mounting the Chassis Directly on a Flat Surface

Caution Make sure that no I/O modules are in the chassis before removing it from the surface.

Mounting the Chassis on a DIN Rail Using the NI 9912 DIN Rail Mount Kit

You can order the NI 9912 DIN rail mount kit if you want to mount the chassis on a DIN rail. You need one clip for mounting the chassis on a standard 35 mm DIN rail. Complete the following steps to mount the chassis on a DIN rail.

1. Fasten the DIN rail clip to the chassis using a number 2 Phillips screwdriver and two M4 × 25 screws. National Instruments provides these screws with the DIN rail mount kit. Tighten the screws to a maximum torque of 1.3 N · m (11.5 lb · in.).

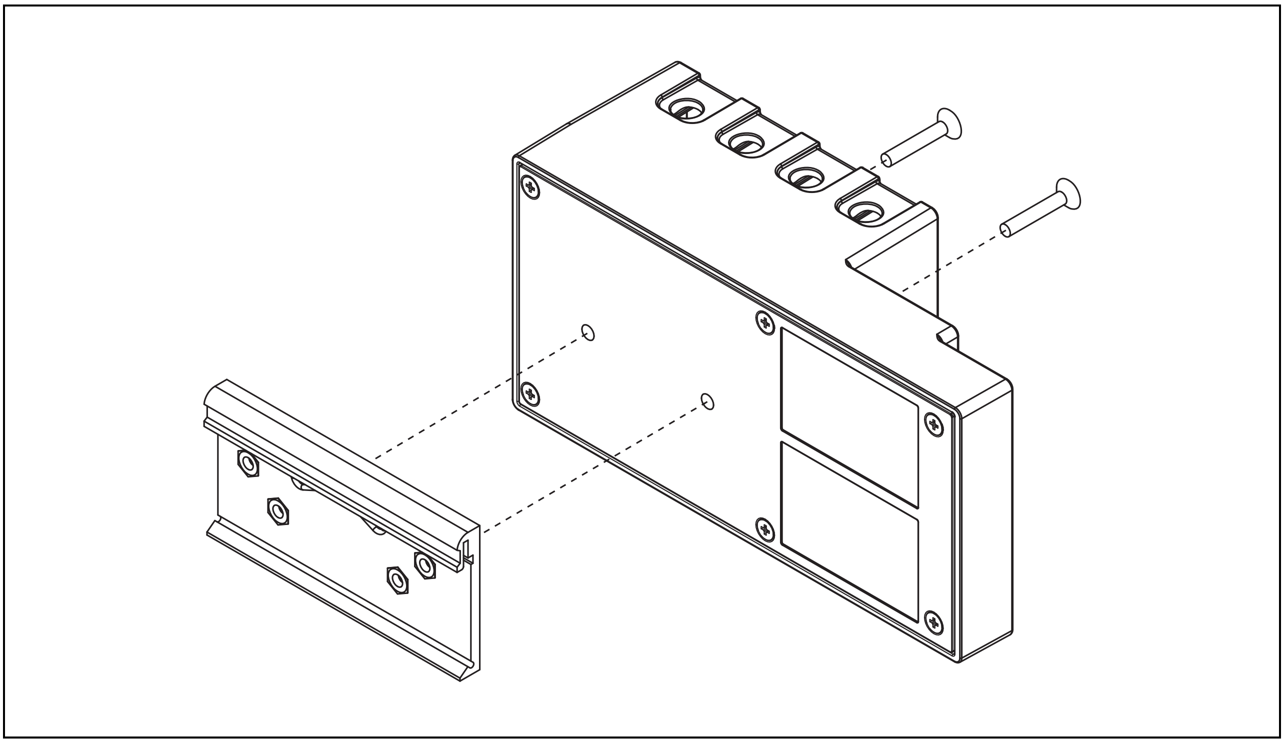
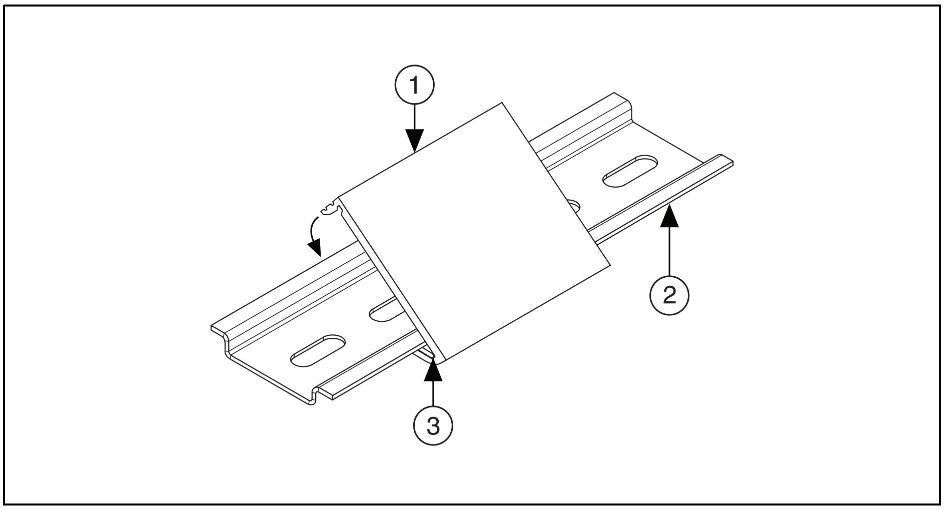


Figure 9. Installing the DIN Rail Clip on the cRIO-9075/9076

2. Insert one edge of the DIN rail into the deeper opening of the DIN rail clip, as shown in Figure 10.



1 DIN Rail Clip	2 DIN Rail	3 DIN Rail Spring

Figure 10. One Edge of the DIN Rail Inserted in a Clip

3. Press down firmly on the chassis to compress the spring until the clip locks in place on the DIN rail.

Mounting the Chassis on a Desktop Using the NI 9901 Desktop Mounting Kit

You can use the NI 9901 desktop mounting kit to mount the chassis on a desktop. You must install the adapter bracket using two M3 × 20 screws. The adapter bracket and the screws are included in the kit. Refer to the NI 9901 documentation for information about mounting the chassis on a desktop.

Installing C Series I/O Modules in the Chassis

Figure 11 shows the mechanical dimensions of C Series I/O modules.

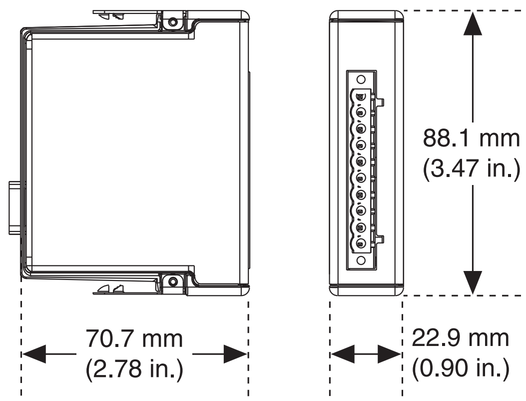
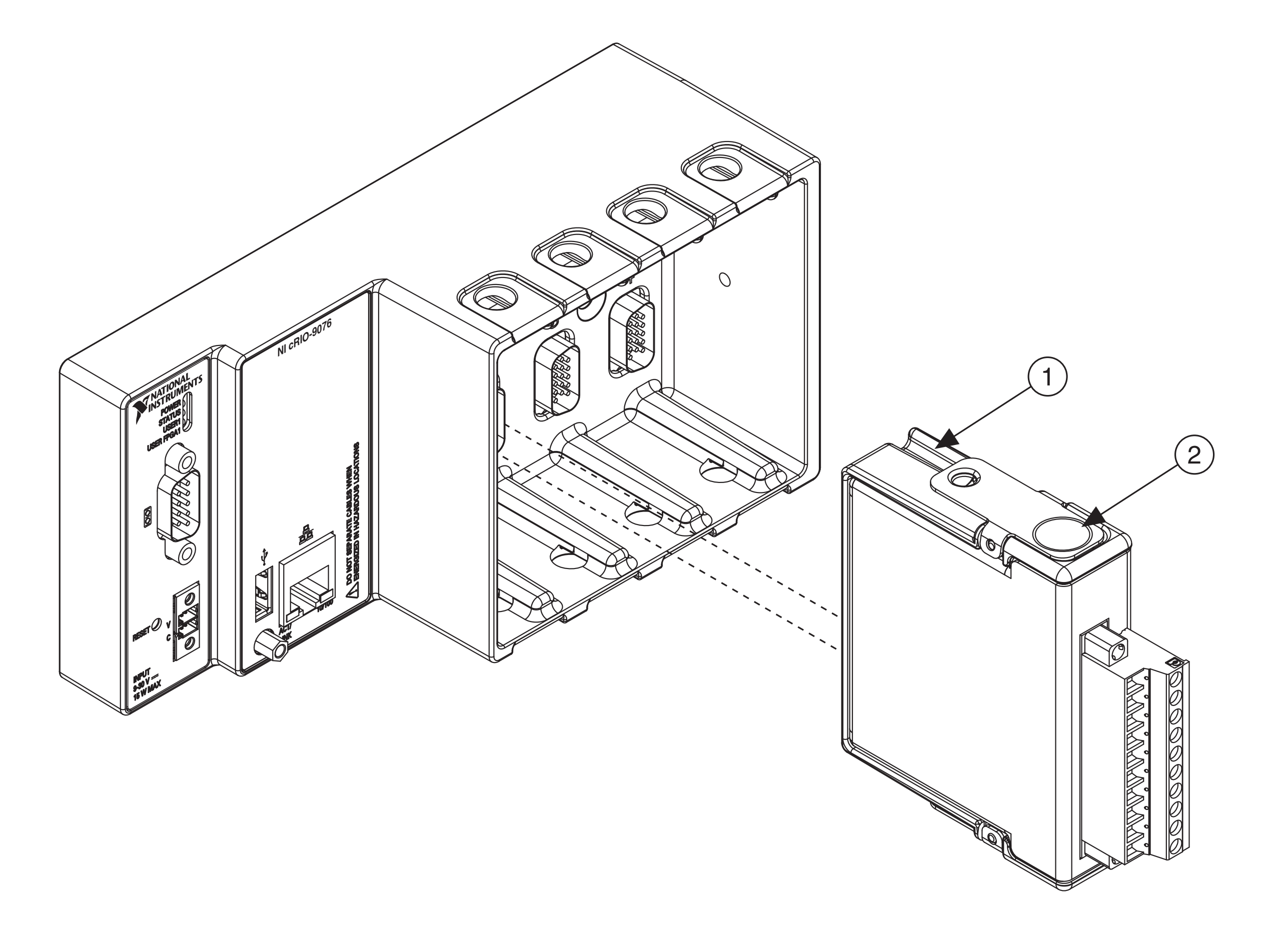


Figure 11. C Series I/O Module, Front and Side View with Dimensions

Complete the following steps to install a C Series I/O module in the chassis.

1. Make sure that no I/O-side power is connected to the I/O module. If the system is in a nonhazardous location, the chassis power can be on when you install I/O modules.
2. Align the I/O module with an I/O module slot in the chassis as shown in Figure 12. The module slots are numbered 1 to 4, left to right.



1 Insertion Groove	2 Latch

Figure 12. Installing an I/O Module in the Chassis

3. Squeeze the latches and insert the I/O module into the module slot.
4. Press firmly on the connector side of the I/O module until the latches lock the I/O module into place.
5. Repeat these steps to install additional I/O modules.

Removing I/O Modules from the Chassis

Complete the following steps to remove a C Series I/O module from the chassis.

1. Make sure that no I/O-side power is connected to the I/O module. If the system is in a nonhazardous location, the chassis power can be on when you remove I/O modules.
2. Squeeze the latches on both sides of the module and pull the module out of the chassis.

Connecting the Chassis to Earth Ground

You must connect the chassis grounding screw to earth ground. Refer to Figure 3 for the location of the grounding screw. Complete the following steps to connect to earth ground:

1. Attach a ring lug to a 1.6 mm^2 (14 AWG) or larger wire.
2. Remove the grounding screw from the grounding terminal on the right side of the chassis. Refer to Figure 3 for the location of the chassis grounding screw.
3. Attach the ring lug to the grounding terminal.
4. Tighten the grounding screw to 0.5 N · m (4.4 lb · in.) of torque.
5. Attach the other end of the wire to earth ground using a method appropriate for the application.

Note If you use shielded cabling to connect to a C Series I/O module with a plastic connector, you must attach the cable shield to the chassis grounding terminal using 1.3 mm^2 (16 AWG) or larger wire. Use shorter wire for better EMC performance.

For more information about earth ground connections, go to `ni.com/info` and enter the Info Code `earthground`.

Connecting the Chassis to a Network

Connect the chassis to an Ethernet network using the RJ-45 Ethernet port on the controller front panel. Use a standard Category 5 (CAT-5) or better shielded, twisted-pair Ethernet cable to connect the chassis to an Ethernet hub, or use an Ethernet crossover cable to connect the chassis directly to a computer.

Caution To prevent data loss and to maintain the integrity of your Ethernet installation, do *not* use a cable longer than 100 m.

The first time you power up the chassis, it attempts to initiate a DHCP network connection. If the chassis is unable to initiate a DHCP connection, it connects to the network with a link-local IP address with the form `169.254.x.x`. After powerup, you must install software on the chassis and configure the network settings in Measurement & Automation Explorer (MAX).

Note Installing software may change the network behavior of the chassis. For information about network behavior by installed software version, go to `ni.com/info` and enter the Info Code `ipconfigcrio`.

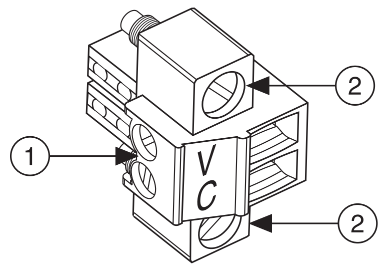
Wiring Power to the Chassis

The cRIO-9075/9076 requires an external power supply that meets the specifications in the *Power Requirements* section. The cRIO-9075/9076 filters and regulates the supplied power and provides power for all of the I/O modules. The cRIO-9075/9076 has one layer of reverse-voltage protection. Complete the following steps to connect a power supply to the chassis.

1. Ensure that the power supply is turned off.

Caution Do *not* install or remove the power connector from the front panel of the cRIO-9075/9076 while power is applied.

2. Connect the positive lead of the power supply to the V terminal of the COMBICON power connector shipped with the cRIO-9075/9076, and tighten the terminal screw. Figure 13 shows the terminal screws, which secure the wires in the screw terminals, and the connector screws, which secure the power connector on the front panel.



1 Terminal Screws	2 Connector Screws

Figure 13. COMBICON Power Connector

3. Connect the negative lead of the power supply to the C terminal of the power connector and tighten the terminal screw.
4. Install the power connector on the front panel of the cRIO-9075/9076 and tighten the connector screws.
5. Turn on the power supply.

Powering On the cRIO-9075/9076

When you apply power to the cRIO-9075/9076, the controller runs a power-on self test (POST). During the POST, the Power and Status LEDs turn on. The Status LED turns off, indicating that the POST is complete. If the LEDs do not behave in this way when the system powers on, refer to the *Understanding LED Indications* section.

You can configure the cRIO-9075/9076 to launch an embedded stand-alone LabVIEW RT application each time you boot the controller. Refer to the *Running a Stand-Alone Real-Time Application (RT Module)* topic of the *LabVIEW Help* for more information.

Restarting the cRIO-9075/9076 Using the Reset Button

Pressing the Reset button restarts the controller. The FPGA continues to run unless you have selected the **Autoload VI on device reboot** chassis reset option. Refer to the *Chassis Reset Options* section for more information.

To restart the cRIO-9075/9076 in safe mode, press and hold the Reset button for 5 s, then release it. The Status LED lights solid yellow, indicating that the cRIO-9075/9076 is in safe mode. Refer to the MAX help for information about safe mode.

Controller Startup Options

You can configure the following controller startup options in MAX:

- Safe Mode
- Console Out
- IP Reset
- No App
- No FPGA App

To turn these startup options on or off, select the controller under **Remote Systems** in the MAX configuration tree, then select the **Controller Settings** tab. Refer to the MAX help for information about the startup options and how to configure the controller.

Chassis Reset Options

Table 1 lists the reset options available on CompactRIO systems such as the cRIO-9075/9076. These options determine how the chassis behaves when the controller is reset in various conditions. Use the RIO Device Setup utility to select reset options. Access the RIO Device Setup utility by selecting **Start»All Programs»National Instruments»NI-RIO» RIO Device Setup**.

Table 1. CompactRIO Reset Options

Chassis Reset Option	Behavior
Do not autoload VI	Does not load the FPGA bit stream from flash memory.
Autoload VI on device powerup	Loads the FPGA bit stream from flash memory to the FPGA when the controller powers on.
Autoload VI on device reboot	Loads the FPGA bit stream from flash memory to the FPGA when you reboot the controller either with or without cycling power.

Connecting Serial Devices to the cRIO-9075/9076

The cRIO-9075/9076 has an RS-232 serial port to which you can connect devices such as displays or input devices. Use the Serial VIs to read from and write to the serial port from a LabVIEW RT application. For more information about the Serial VIs, refer to the *LabVIEW Help*.

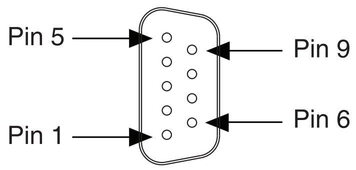


Figure 14. Controller Serial Port

Table 2. DB-9 Pin Descriptions

Pin	Signal
1	DCD
2	RXD
3	TXD
4	DTR
5	GND
6	DSR
7	RTS
8	CTS
9	RI

Understanding LED Indications

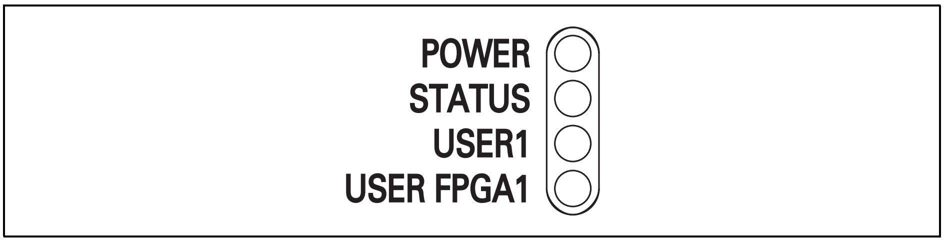


Figure 15. cRIO-9075/9076 LEDs

POWER LED

The POWER LED is lit while the cRIO-9075/9076 is powered on. This LED indicates that the power supply connected to the chassis is adequate.

STATUS LED

The STATUS LED is off during normal operation. The cRIO-9075/9076 indicates specific error conditions by flashing the STATUS LED a certain number of times every few seconds, as shown in Table 3.

Table 3. Status LED Indications

Number of Flashes Every Few Seconds	Indication
2	The chassis has detected an error in its software. This usually occurs when an attempt to upgrade the software is interrupted. Reinstall software on the chassis. Refer to the *Measurement & Automation Explorer Help* for information about installing software on the chassis.
3	The chassis is in safe mode. Refer to the *Measurement & Automation Explorer Help* for information about safe mode.
4	The software has crashed twice without rebooting or cycling power between crashes. This usually occurs when the chassis runs out of memory. Review your RT VI and check the memory usage. Modify the VI as necessary to solve the memory usage issue.
Continuously flashing or solid	The chassis has detected an unrecoverable error. Contact National Instruments.

USER1 LED

You can define the USER1 LED to meet the needs of your application. To define the LED, use the RT LEDs VI in LabVIEW. For more information about the RT LEDs VI, refer to the *LabVIEW Help*.

USER FPGA1 LED

You can use the USER FPGA1 LED to help debug your application or easily retrieve application status. Use the LabVIEW FPGA Module and NI-RIO software to define the USER FPGA1 LED to meet the needs of your application. Refer to *LabVIEW Help* for information about programming this LED.

Using the System Clock to Provide Data Timestamps

At startup, the system clock resets to January 1, 1970, 12:00 a.m. (midnight). For information about synchronizing the system clock with an SNTP time server on the network at startup, go to `ni.com/info` and enter the Info Code `criosntp`.

Troubleshooting Network Communication

If the cRIO-9075/9076 cannot communicate with the network, you can perform the following troubleshooting steps.

1. Hold the Reset button down for 5 s, then release it. The Status LED turns on, then starts blinking three times every few seconds. The chassis is now in safe mode with output from the serial port enabled. You can use a serial port terminal to read the IP address of the controller. If you want the controller to attempt a new DHCP connection, proceed to step 2.
2. Hold the Reset button down for 5 s, then release it. The Status LED repeats the same behavior. The cRIO-9075/9076 attempts to establish a new DHCP connection. If it fails, it assigns itself a link-local IP address. If the DHCP connection is successful and appropriate for your application, skip to step 4.
3. Configure the IP and other network settings in MAX.
4. Press and release the Reset button to reboot the chassis.

Where to Go from Here

Now that you have set up the cRIO-9075/9076 and configured it on your network, you can start using it in your applications. The following figure shows the main components of the CompactRIO documentation that you may find helpful as you program and use the cRIO-9075/9076.

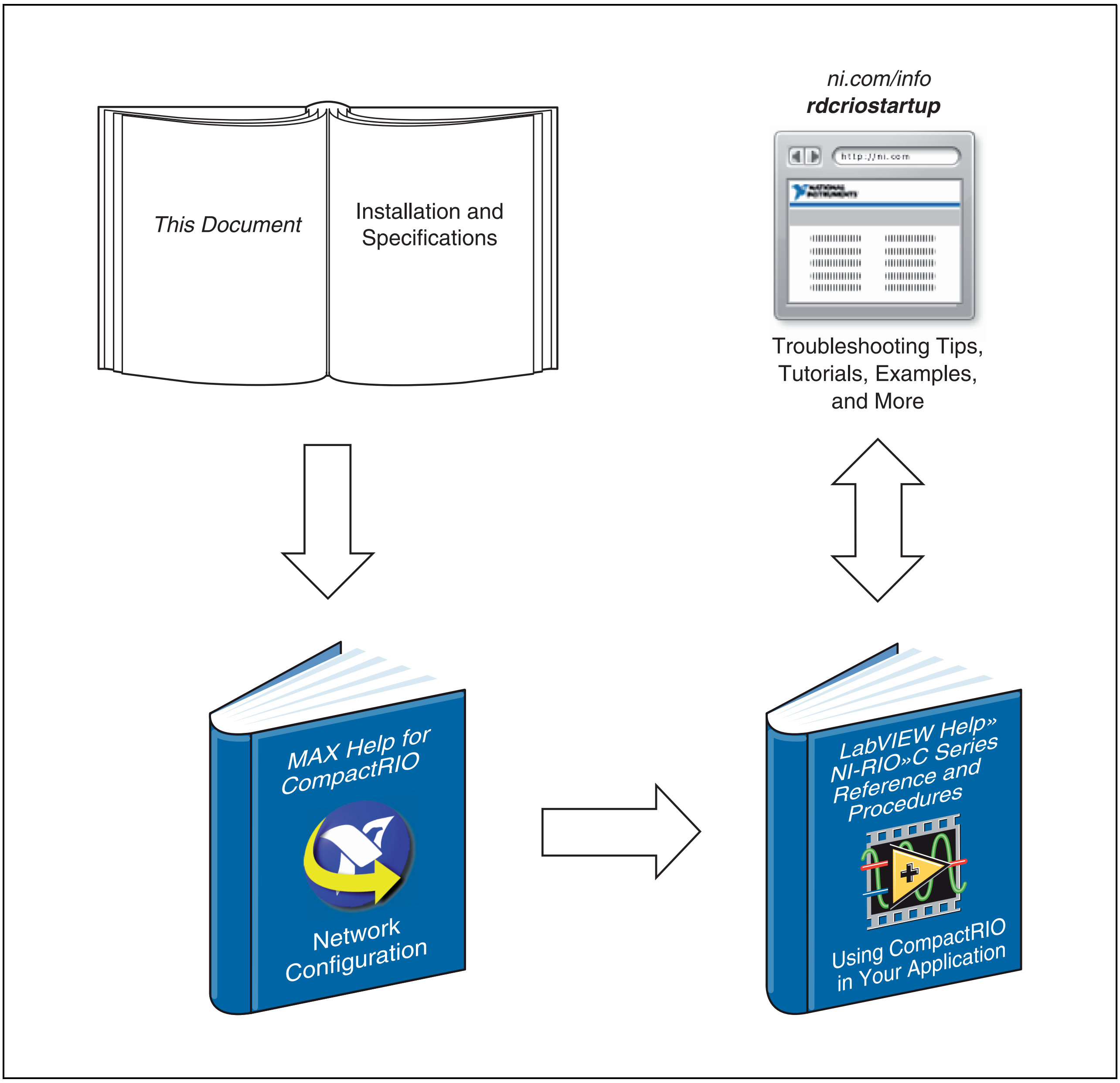


Figure 16. CompactRIO Documentation

Specifications

The following specifications are typical for the –20 to 55 °C operating temperature range unless otherwise noted.

Network

Network interface .... 10BaseT and 100BaseTX Ethernet

Compatibility .... IEEE 802.3

Communication rates .... 10 Mbps, 100 Mbps, auto-negotiated

Maximum cabling distance .... 100 m/segment

RS-232 Serial Port

Maximum baud rate .... 230,400 bps

Data bits 5, 6, 7, 8

Stop bits... 1, 2

Parity .... Odd, Even, Mark, Space

Flow control .... RTS/CTS, XON/XOFF, DTR/DSR

Memory

cRIO-9075

- Nonvolatile...................................... 256 MB minimum
- System memory .... 128 MB

cRIO-9076

- Nonvolatile...................................... 512 MB minimum
- System memory .... 256 MB

For information about the life span of the nonvolatile memory and about best practices for using nonvolatile memory, go to `ni.com/info` and enter the Info Code `SSDBP`.

Reconfigurable FPGA

cRIO-9075

FPGA type	Xilinx Spartan-6 LX 25
Number of flip-flops	30,064
Number of 6-input LUTs	15,032
Number of DSP48s	38
Available block RAM	936 kbits
Number of DMA channels	5

cRIO-9076

FPGA type	Xilinx Spartan-6 LX 45
Number of flip-flops	54,576
Number of 6-input LUTs	27,288
Number of DSP48s	58
Available block RAM	2,088 kbits
Number of DMA channels	5

Power Requirements

Caution You must use a UL Listed ITE power supply marked *LPS* with the cRIO-9075/9076.

Recommended power supply	24 W, 24 VDC
Power consumption	15 W maximum
Power supply input range	9 to 30 V

Physical Characteristics

If you need to clean the controller, wipe it with a dry towel.

Screw-terminal wiring	0.5 to 2.5 mm^2 (24 to 12 AWG) copper conductor wire with 10 mm (0.39 in.) of insulation stripped from the end
Torque for screw terminals	0.5 to 0.6 N · m (4.4 to 5.3 lb · in.)
Weight	643 g (22.7 oz)

Safety Voltages

Connect only voltages that are within these limits.

V terminal to C terminal .... 30 V max, Measurement Category I

Measurement Category I is for measurements performed on circuits not directly connected to the electrical distribution system referred to as MAINS voltage. MAINS is a hazardous live electrical supply system that powers equipment. This category is for measurements of voltages from specially protected secondary circuits. Such voltage measurements include signal levels, special equipment, limited-energy parts of equipment, circuits powered by regulated low-voltage sources, and electronics.

Caution Do not connect the system to signals or use for measurements within Measurement Categories II, III, or IV.

Safety Standards

This product meets the requirements of the following standards of safety for electrical equipment for measurement, control, and laboratory use:

- IEC 61010-1, EN 61010-1
- UL 61010-1, CSA 61010-1

Note For UL and other safety certifications, refer to the product label or the *Online Product Certification* section.

Electromagnetic Compatibility

This product meets the requirements of the following EMC standards for electrical equipment for measurement, control, and laboratory use:

- EN 61326 (IEC 61326): Class A emissions; Industrial immunity
- EN 55011 (CISPR 11): Group 1, Class A emissions
- AS/NZS CISPR 11: Group 1, Class A emissions
- FCC 47 CFR Part 15B: Class A emissions
- ICES-001: Class A emissions

Note For the standards applied to assess the EMC of this product, refer to the *Online Product Certification* section.

Note For EMC compliance, operate this product according to the documentation.

CE Compliance

This product meets the essential requirements of applicable European Directives as follows:

- 2006/95/EC; Low-Voltage Directive (safety)
- 2004/108/EEC; Electromagnetic Compatibility Directive (EMC)

Online Product Certification

Refer to the Declaration of Conformity (DoC) for this product for additional regulatory compliance information. To obtain product certifications and the DoC for this product, visit `ni.com/certification`, search by model number or product line, and click the appropriate link in the Certification column.

Environmental Management

National Instruments is committed to designing and manufacturing products in an environmentally responsible manner. NI recognizes that eliminating certain hazardous substances from our products is beneficial to the environment and to NI customers.

For additional environmental information, refer to the *NI and the Environment* Web page at `ni.com/environment`. This page contains the environmental regulations and directives with which NI complies, as well as other environmental information not included in this document.

Waste Electrical and Electronic Equipment (WEEE)

EU Customers At the end of the product life cycle, all products *must* be sent to a WEEE recycling center. For more information about WEEE recycling centers, National Instruments WEEE initiatives, and compliance with WEEE Directive 2002/96/EC on Waste and Electronic Equipment, visit `ni.com/environment/weee`.

电子信息产品污染控制管理办法 （中国 RoHS）

中国客户 National Instruments 符合中国电子信息产品中限制使用某些有害物质指令 (RoHS)。关于 National Instruments 中国 RoHS 合规性信息，请登录 `ni.com/environment/rohs_china`。(For information about China RoHS compliance, go to `ni.com/environment/rohs_china`.)

Hazardous Locations

U.S. (UL)... Class I, Division 2, Groups A, B, C, D, T4; Class I, Zone 2, AEx nC IIC T4

Canada (C-UL)...................................... Class I, Division 2, Groups A, B, C, D, T4; Class I, Zone 2, Ex nL IIC T4

Europe (DEMKO)................................. Ex nA nL IIC T4

Environmental

Operating temperature
(IEC 60068-2-1, IEC 60068-2-2).......... –20 to 55 °C

Note To meet this operating temperature range, follow the guidelines in the installation instructions for your CompactRIO system.

Storage temperature
(IEC 60068-2-1, IEC 60068-2-2).......... –40 to 85 °C

Ingress protection.................................. IP 40

Operating humidity
(IEC 60068-2-56).................................. 10 to 90% RH, noncondensing

Storage humidity
(IEC 60068-2-56).................................. 5 to 95% RH, noncondensing

Pollution Degree (IEC 60664) 2

Maximum altitude................................. 2,000 m

Indoor use only.

Shock and Vibration

To meet these specifications, you must panel mount the CompactRIO system and affix ferrules to the ends of the power terminal wires.

Operating shock
(IEC 60068-2-27) ....30 g, 11 ms half sine
50 g, 3 ms half sine,
18 shocks at 6 orientations

Operating vibration, random
(IEC 60068-2-64) ....5 g_{rms}, 10 to 500 Hz

Operating vibration, sinusoidal
(IEC 60068-2-6) ....5 g, 10 to 500 Hz

Where to Go for Support

The National Instruments Web site is your complete resource for technical support. At `ni.com/support` you have access to everything from troubleshooting and application development self-help resources to email and phone assistance from NI Application Engineers.

National Instruments corporate headquarters is located at 11500 North Mopac Expressway, Austin, Texas, 78759-3504. National Instruments also has offices located around the world to help address your support needs. For telephone support in the United States, create your service request at `ni.com/support` and follow the calling instructions or dial 512 795 8248. For telephone support outside the United States, visit the Worldwide Offices section of `ni.com/niglobal` to access the branch office Web sites, which provide up-to-date contact information, support phone numbers, email addresses, and current events.

375650B-01 Oct11

A.12 Sensor de Presión Dinámico

Dytran Instruments, Inc.
21592 Marilla St. Chatsworth, CA 91311 Ph: 818-700-7818 Fax 818-700-7880
www.dytran.com email: info@dytran.com

ilac-MRA | ACCREDITED Calibration Laboratory CERT#1672.01

CALIBRATION CERTIFICATE
LIVM DYNAMIC PRESSURE SENSOR

CUSTOMER:	SIELECOM SAS		TEST REPORT #:	2104	
PURCHASE ORDER #:	C15001	SALES ORDER #:	171816	PROCEDURE:	TP2006
MODEL:	2005V	SERIAL #:	2104	TEMP (°C): 23	HUMIDITY (%): 38
NEW UNIT	X	RE-CALIBRATION [1]		AS RECEIVED CODE	AS RETURNED CODE
BIAS VOLTAGE (VDC):	10.5		DISCHARGE T.C. (sec):	0.18	
CALIBRATION PERFORMED AT	10	Lb-in MOUNTING TORQUE			

PRESSURE (psi)	SENSITIVITY (mV/psi)	PRESSURE (psi)	SENSITIVITY (mV/psi)
0.29	104.32		

REMARKS: NONE

TEST EQUIPMENT LIST - CALIBRATION STATION # 4

DII #	MANUFACTURER	MODEL	SERIAL #	DESCRIPTION	CAL DATE	DUE DATE
1042	FLUKE	45	8850043	MULTIMETER	05/29/14	05/29/15
1718	DYTRAN INST.	2013D	2301	MICROPHONE	02/04/14	05/04/15
911	KENWOOD	CS-5230	8020007	OSCILLOSCOPE	09/24/14	09/24/15

[1] AS RECEIVED / AS RETURNED CODES:
- 1 = IN TOLERANCE, NO ADJUSTMENTS
- 2 = IN TOLERANCE, BUT ADJUSTED
- 3 = OUT OF TOLERANCE < 5%
- 4 = OUT OF TOLERANCE > 5%
- 5 = REPAIR REQUIRED
- 6 = REPAIRED AND CALIBRATED
- 7 = UNIT NON-REPAIRABLE, RECOMMEND REPLACEMENT
- 8 = UNIT SERVICEABLE WITH CURRENT CALIBRATION DATA

[2] THIS CALIBRATION WAS PERFORMED PER MIL-STD-45662A, ANSI/NCSL Z540-1-1994, ISO 10012-1 AND IS TRACEABLE TO THE NIST THROUGH TEST REPORT NUMBER: 2609100001 DUE 05-04-2015.
ESTIMATED UNCERTAINTY OF CALIBRATION: 2.5%.

CALIBRATION TECHNICIAN: VINH VU — 17 CAL

TEST DATE : 04/07/15
RECOMMENDED RECALL DATE : 04/07/16

DYTRAN INSTRUMENTS INC.
21592 MARILLA ST.
CHATSWORTH, CA 91311
818/700-7818

P A C K I N G S L I P

Shipper # 110322
Page # 2
SO # 171816
SO Date 03-27-15
Cancel Date

Sold To	Ship To
9809	9809
SIELECOM SAS	SIELECOM SAS
CARRERA 13 #35-10	CARRERA 13 #35-10
OFFICINA 904	OFFICINA 904
BUCARAMANGA, SANTANDER 04125	BUCARAMANGA, SANTANDER 04125
COLOMBIA	COLOMBIA

Ship Date	Customer PO	Rep	Ship Via	Freight Tag
04-07-15	C15001	9809	TBD BY CUSTOMER (SEE KM SALES)	COLLECT

Qty Ord	Qty Ship	Qty BO	Part #	Description

CERTIFICATION OF CONFORMANCE

We certify that the products or services listed above are in conformance with the requirements of your purchase order.

Objective evidence of manufacturing, inspection and testing is on file and available for review at our facility.

Where materials or services incorporated in any of the items listed above have been procured by us from vendors, we certify that test reports or suitable evidence of compliance with the requirements of the purchase order have been obtained by us and are available from our files.

Products are in compliance with all applicable regulatory guidelines. Certificates are enclosed as required.

Calibrations are in accordance with ISO/IEC 17025, ANSI/NCSL Z540-1-1994, ISO 10012-1 and are NIST (National Institute of Standards and Technology) traceable.

4-7-15

Quality Assurance Date

DYTRAN INSTRUMENTS, INC.
Dynamic Transducers and Systems
21592 Marilla St. • Chatsworth, CA 91311 • Phone 818-700-7818
www.dytran.com • e-mail: info@dytran.com

OG2005V.DOC
05-11-04

OPERATING INSTRUCTIONS

MODEL 2005V

HIGH SENSITIVITY, ACCELERATION COMPENSATED

LIVM DYNAMIC PRESSURE SENSOR

This manual includes:

1) Specifications, Model 2005V
2) Supplemental operating guide Model 2005V
3) Outline/Installation Drawing Model 2005V

NOTE: **LIVM** is Dytran's trademark for its line of **L**ow **I**mpedance **V**oltage **M**ode sensors with built-in amplifiers operating from constant current sources over two wires. **LIVM** instruments are compatible with most other manufacturers' comparable systems.

DYTRAN INSTRUMENTS, INC.

Dynamic Transducers and Systems
21592 Marilla St. • Chatsworth, CA 91311 • Phone 818-700-7818
www.dytran.com • e-mail: info@dytran.com

SPECIFICATIONS MODEL 2005V
DYNAMIC PRESSURE SENSOR

SPECIFICATION	VALUE	UNITS
PHYSICAL		
WEIGHT	43	grams
SIZE (HEX x HEIGHT)	.625 x 2.0	inches
	15.9 x 52	mm
MOUNTING PROVISION	1/8-27 NPT Male Thread	
CONNECTOR, AXIALLY MOUNTED AT TOP	TNC Jack	
DIAPHRAGM MATERIAL	Stainless Steel	
PERFORMANCE		
SENSITIVITY, ±10%	100	mV/psi
RANGE F.S. FOR +5 VOLTS OUT	+50	psi
MAXIMUM PRESSURE	1000	psi
MOUNTED RESONANT FREQUENCY, NOM.	90	kHz
MINIMUM RISE TIME OF INPUT PRESSURE PULSE	2	μsec
EQUIVALENT ELECTRICAL NOISE FLOOR (RESOLUTION)	.0007	psi
LINEARITY [1]	±1	% F.S.
ACCELERATION SENSITIVITY, AXIAL DIRECTION	.002	psi/g
DISCHARGE TIME CONSTANT	0.16	sec
LOWER -3db FREQUENCY	1.0	Hz
ENVIRONMENTAL		
MAXIMUM VIBRATION	3000	g rms
MAXIMUM SHOCK	10,000	g pk
TEMPERATURE RANGE	-100 to +275	°F
	-73 to +135	°C
MAXIMUM FLASH TEMPERATURE AT DIAPHRAGM	+3000	°F
	+1600	°C
THERMAL COEFFICIENT OF SENSITIVITY	0.01	%/°F
	0.02	%/°C
ENVIRONMENTAL SEAL	Hermetic	
	Welded / Glass to Metal	
POWER /SIG GND ISOLATION	10MΩ min @ 50VDC	
ELECTRICAL		
EXCITATION (COMPLIANCE) VOLTAGE RANGE	+18 to +30	Vdc
EXCITATION CURRENT RANGE [2]	+2 to +20	mA
OUTPUT IMPEDANCE, NOM.	100	Ω
OUTPUT BIAS VOLTAGE, NOM	+10	Vdc
OUTPUT SIGNAL POLARITY FOR INCREASING PRESSURE	Positive Going	

NOTES:

[1] PERCENT FULL SCALE, ZERO BASED BEST FIT STRAIGHT LINE METHOD.
[2] FROM CONSTANT CURRENT TYPE POWER UNIT ONLY. THIS SENSOR **MUST NOT BE CONNECTED** TO A DC POWER SOURCE WITHOUT CURRENT LIMITING, 20 mA MAXIMUM.
[3] A CALIBRATION CERTIFICATE TRACEABLE TO NIST IS SUPPLIED WITH EACH INSTRUMENT.

OPERATING INSTRUCTIONS MODELS 2005V PRESSURE SENSOR

INTRODUCTION

Model 2005V is a high sensitivity (100 mV/psi) probe style miniature pressure sensor designed to measure dynamic pressure phenomena such as pressure perturbations in hydraulic and pneumatic systems and for fast rise time measurements such as in shock tubes or field blast testing.

This miniature pressure sensor utilizes pure synthetic alpha quartz in compression mode to create an output signal exactly analogous to pressure impinging on the thin stainless steel diaphragm. The 2005V can measure pressure perturbations at frequencies from .08 Hz to 80 kHz and higher and pressure steps or pulses to 2μsec rise time.

Model 2005V features LIVM operation, i.e., a tiny amplifier built inside the housing accepts the very high impedance charge signal from the quartz element and lowers its output impedance by many orders of magnitude providing a low impedance voltage mode output signal.

Model 2005V is acceleration compensated in the axial direction to minimize the effects of acceleration on the body of the instrument during measurements where the instrument is subjected to motion such as when field blast testing. An internal accelerometer, integral with the quartz pressure element, cancels the unwanted acceleration effects of the masses of the diaphragm and end piece of the sensor, making the sensor sensitive to pressure only.

DESCRIPTION

Refer to outline/installation drawing 127-2005V for a physical description of Model 2005V.

Figure 1, following, is a cross sectional representation of Model 2005V.

Model 2005V is a slender probe with .310 diameter diaphragm and 1/8-27 NPT mounting threads which are integral to the body of the probe.

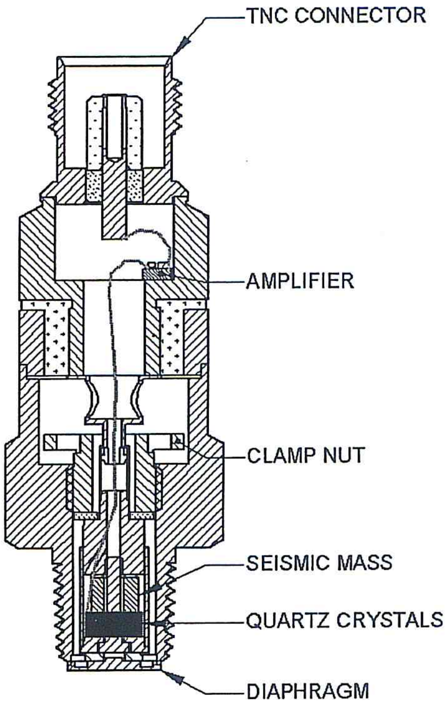


FIGURE 1 Cross sections Model 2005V

Self-generating quartz elements consist of heavily preloaded quartz discs for highest rigidity. Pressure acting on the diaphragm compresses the discs and produces electrical charge exactly analogous to this pressure. The charge (approximately 1 pC/psi) is converted to a voltage by virtue of the self capacitance of the crystals and the input capacitance of the IC amplifier. in accordance with the electrostatic equation, equation 1.0.

$$\Delta V = \frac{\Delta Q}{C} \qquad \text{Eq 1.0}$$

where:

ΔV = change in voltage across crystal element
ΔQ = change in charge generated by the change in input pressure
C = the total shunt capacitance of the quartz element (including the amplifier input capacitance).

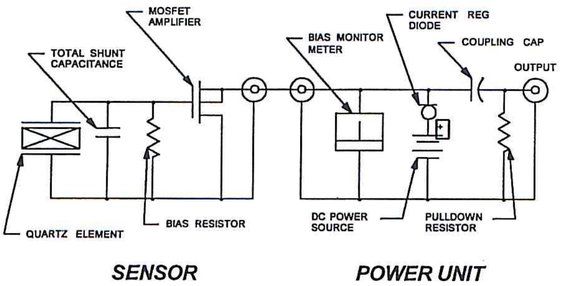


Figure 2 Simplified schematic of sensor and power unit

Figure 2 is a simplified schematic of the 2005V sensor with power unit. ΔV created by pressure acting upon the quartz element is amplified and superimposed upon the +10 volt DC bias of the amplifier.

The sensor is normally connected to the power unit with a single TNC coaxial cable but in many cases, a two wire cable of almost any type will do. Since the signal level at the output connector of the sensor is at a very low impedance level, it is not susceptible to interference or attenuation as would a high impedance signal.

The DC bias level of the sensor amplifier is blocked by the coupling capacitor in the power unit but the ΔV (the pressure information) is allowed to pass on to the readout instrument.

The current regulating diode (or constant current circuit) in the power unit applies a fixed current to the sensor amplifier and because of its high dynamic impedance, allows the sensor amplifier to operate at essentially unity gain.

INSTALLATION

Before attempting to install these sensors, refer to the outline/installation drawing provided with the sensor which pertains to your installation.

At the factory, the calibration of these instruments is performed at a precise installation torque level. Therefore, in order to minimize mounting errors due to varying mounting torques, it is advised that the recommended mounting torque be observed when installing the probe. These errors are admittedly very small but for most accurate and repeatable results it is good practice to do so.

Model 2005V is designed to mount directly into 1/8-27 pipe thread. After installation, if possible, check for leaks by slowly increasing the pressure and looking for evidence of a leak. If a leak is found, try re-mounting the instrument before looking for other causes. Inspect the seal seat if retorquing does not seal the unit.

ELECTRICAL INTERCONNECTIONS

Connect the power unit Sensor jack to the pressure sensor using a TNC connector (Model 6410AXX TNC to BNC as an example). XX represents the cable length in feet.

As shown in figure 3 below, the sensor is connected to the "sensor" jack and the "output" jack of the power unit is connected to the readout instrument, which could be a digital storage oscilloscope, a spectrum analyzer or other data collecting instrumentation.

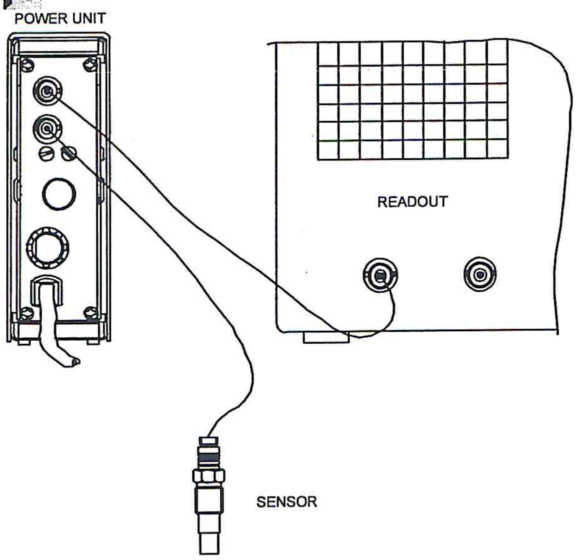


Figure 3 Equipment Interconnect

Secure cables securely (hand tight, no pliers) and secure cable at sensor end with shrink tubing over the connector and sealing tower provided on the top of the sensor to protect connections in damp or dirty environments.

After powering up the power unit, wait a few seconds for coupling capacitors to charge. The output voltage will cease to "drift" after several seconds and the system is ready to go.

CALIBRATION

These sensors are calibrated at the factory to determine the exact sensitivity, using dynamic calibration hydraulic methods. The actual calibrated sensitivities are given on individual calibration certificates supplied with each instrument.

Because of the relatively short discharge time constants of these units, field calibration methods by quasi static means (such as by a dead weight tester) are very difficult. Should recalibration become necessary, contact the factory for details on the low cost calibration services available.

FREQUENCY RESPONSE

Series 2200V sensors are truly DYNAMIC pressure sensors, i.e., they respond to changes in pressure and can do so very quickly and at rise times as fast as several microseconds and as slow as several seconds.

They cannot however, measure STATIC pressures, i.e., pressure changes lasting more than several seconds. This section of this manual is an attempt to the advantages as well as the limitations of this type of sensor.

LOW FREQUENCY RESPONSE

If a steady state (static) pressure is applied to the diaphragm of these sensors, the output voltage will respond instantly to this change in pressure with a corresponding change in output voltage. However, the output signal will immediately begin discharging toward the quiescent bias voltage level at a rate determined by the discharge time constant of the sensor. Consult the calibration certificate for the exact discharge time constant (TC) of each sensor.

Figure 4 below, is a representation of the response of the 2200V series sensors to a step function of input pressure.

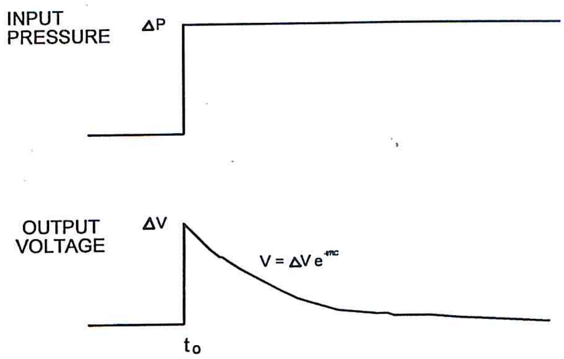


Figure 4 Response to a steady state input

The output voltage response follows the classical exponential decay formula:

$$v = \Delta V\, e^{-t/RC} \qquad \text{Eq. 3}$$

Where:

v = instantaneous output voltage at any time t (in Volts)
ΔV = initial voltage response to the input step pressure (in Volts)
RC = TC = the discharge time constant of the sensor (in seconds)
e = the base of natural logarithms
t = time (in seconds)

It is thus, the discharge time constant which determines the low frequency response of the sensor. The first 10% of the curve shown in Fig. 4 is relatively linear, therefore some estimates as to accuracy of measurements at various event times is possible. For example, in one percent of the TC, the sensor will discharge 1% of the voltage, therefore, for 1% accuracy of measurement, it is necessary to have a discharge TC of at least 100 times the longest event time.

If the sensor TC is 2 seconds, an event of 2/100 of a second (or 20 milliseconds) duration will be accurate to 1%. An event of twice the duration, i.e., 40 milliseconds, will have a 2% error inherent due to the TC of the sensor.

Use caution here when making this determination however, since the total TC of the system, including power unit and readout instrument, must be taken into account.

Jumping to the frequency base, to find the low frequency at which the sensor will be 3db down from the reference frequency (usually 1kHz) use equation 4 below.

$$f_{-3db} = \frac{0.16}{TC} \qquad \text{Eq 4}$$

where:

f_{-3db} = frequency at which the sensor response is 3db down from the reference frequency
TC = discharge time constant of the sensor

High frequency response

Figure 5 below, illustrates the typical frequency response of the 2005V series sensors.

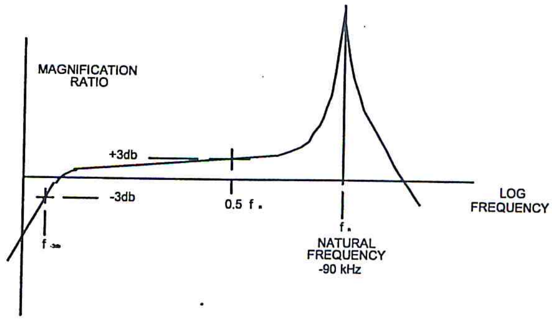


Figure 5 Typical frequency response characteristics, series 2005V

Since the piezo element is a typical second order system, mechanically, the high frequency response is that of an under damped spring-mass system., i.e., the response will exhibit a rising characteristic as frequency increases, then as resonance is approached, a sharply rising upswing as shown in figure 5.

The upper 3db frequency will be approx. 0.5 times f_n. The resonant frequency is approx. 90 kHz making the upper 3db frequency (the frequency at which the output has risen 3db) approx. 45 kHz.

These guidelines loosely define the useable frequency range of these sensors. Consult the factory for help with specific measurement problems not covered in this guide such as those situations where special longer TC's may be necessary.

Fault monitor meter

Most Dytran power units for LIVM sensors feature a voltmeter which monitors the bias voltage of the LIVM sensor amplifier. This feature is very useful when trouble shooting system problems. Consult the paper "Low Impedance Voltage Mode (LIVM) Theory and Operation" included with this operating guide for a complete treatment of this topic.

Some precautions

If the pressure sensor is to be used in a thermally active environment such as in blast or other explosive pressure measurements, it may be necessary to thermally shield the diaphragm with an insulating or ablative coating to preclude excessive thermally induced transient output voltage swings and to protect the diaphragm against damage from particle impingement that could damage or abrade the diaphragm.

Black vinyl electrician's tape, available at most hardware stores, has proven to be an excellent material for protection of the diaphragm and for the reduction of transient thermal effects in many cases.

More sophisticated ablative coatings such as many of the silicone rubber compounds available are very acceptable for this use. The application of these materials to the diaphragm will not alter the sensitivity of the sensor due to the high relative stiffness of the sensor element compared to the coatings. The coatings become transparent to pressure changes as far as the sensor is concerned.

Do's and don'ts

Here are some guidelines to help get maximum life and utility from your sensor investment:

1) Do not under any circumstances, connect power to the sensor using a DC voltage supply (battery or power supply) without current limiting to 20 mA maximum. To do so will instantly destroy the integral sensor amplifier. This type of misuse is not covered by the warranty.

2) Do not exceed the maximum rated temperature of your sensor. To do so may damage the IC amplifier and may lead to early failure or increased background noise.

3) Monitor the mounting torque of the sensor probe carefully during installation. Over-torquing can strip threads, overstress the sensor body, damage mounting port or sensor seal surfaces, damage seals and change the calibration factor of the sensor. On the other hand, too little torque can result in calibration errors, leaks and/or damaged seals when high pressures are encountered.

4) Checks seal surfaces carefully for burrs, chips, nicks and other imperfections which could damage the sensor seal surface and preclude a leak free installation.

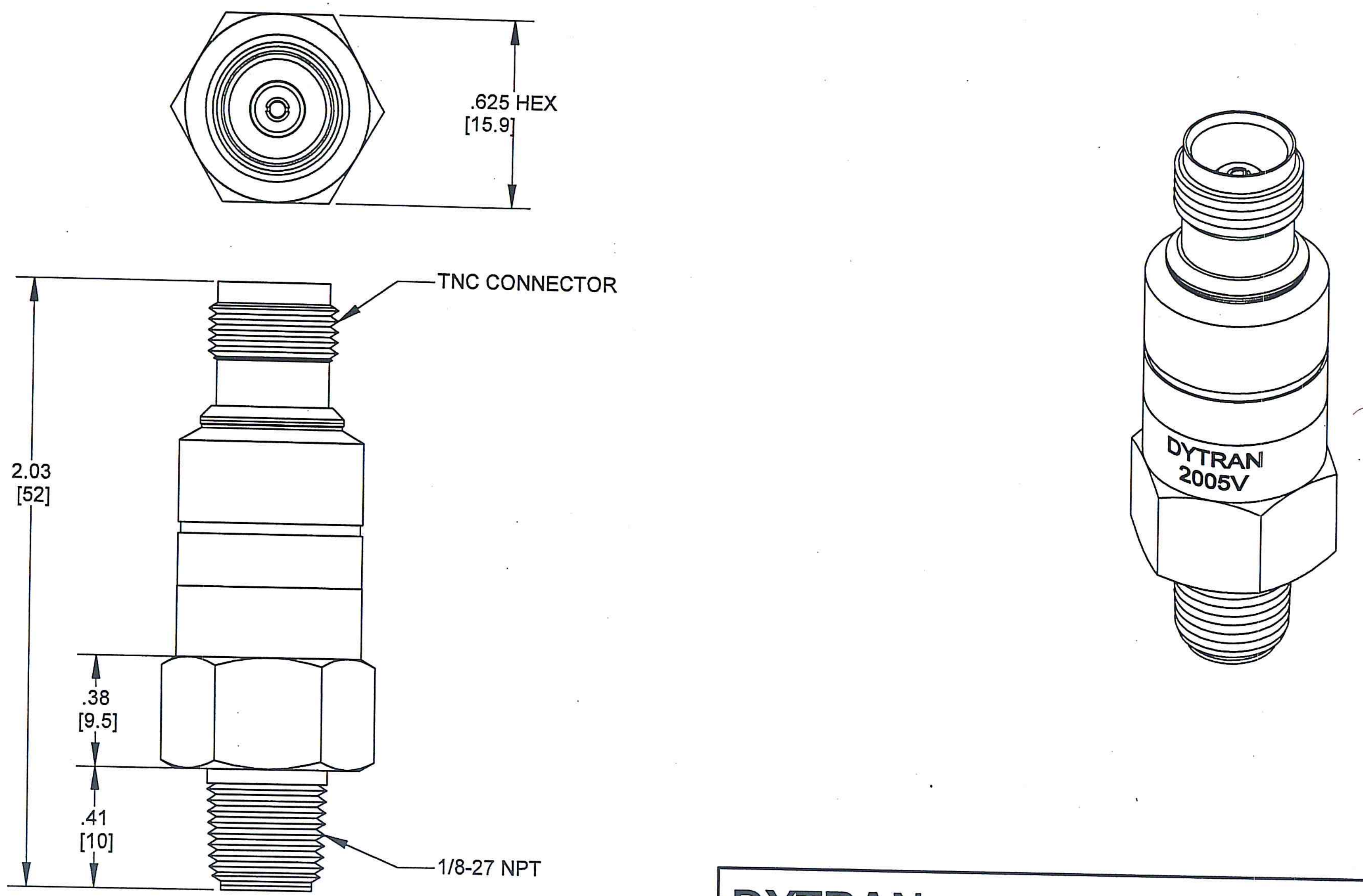
5) Bleed entrapped air out of hydraulic installations by first torquing the sensor in hand tight, then slowly increasing pressure until leaking oil has no included air bubbles. In most cases, entrapped air will give erroneous results when measuring fast transient events.

6) Don't forget to consider the frequency limiting effects of long passages ahead of the diaphragm due to "pipe organ" effects. Consult the factory for more information on this topic.

7) Protect cable connections with shrink tubing in wet and dirty environments. Use the shrink tower provided at the top of the sensor to anchor the tubing.

Maintenance and repair

The sealed construction of the model 2005V precludes field maintenance. Should a problem occur, contact the factory for help in troubleshooting or for instructions in returning the instrument for inspection, repair and/or recalibration. In no case will Dytran proceed with a repair or recalibration without first notifying you of the charges.



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1. Body Material: 304L CRES
2. Weight: 43 grams nominal

EXCEPT AS OTHERWISE NOTED	
ALL DIMENSIONS IN INCHES TOLERANCE: XXX = ±.005 .XX = ± .01	
SURFACE FINISH EXCEPT AS NOTED	63 √
BREAK EDGES TO DEBURR RADIUS OR CHAMFER	
FILLETS:	MAX R

DYTRAN INSTRUMENTS, INC. CHATSWORTH, CA

SCALE 2:1		REV -	DATE -	ECN -	
DATE 2/16/2004		PART NO. MODEL 2005V			
DRAWN PML	CHECKED	MATERIAL			
APPROVED		NEXT ASSEMBLY		USED ON 2005V	
TITLE OUTLINE DRAWING, MODEL 2005V				DWG NO. 127-2005V	
				SHEET 1 OF 1	

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LOW IMPEDANCE VOLTAGE MODE (LIVM) SYSTEMS, THEORY AND OPERATION

LIVM: WHAT IS IT?

LIVM is Dytran's trademark for our version of **L**ow **I**mpedance **V**oltage **M**ode piezoelectric instruments, i.e., piezo instruments with integral-impedance-converting amplifiers operating from constant current supplies over two wires. **LIVM** instruments are entirely compatible the new industry standard **IEPE** designated systems.

LIVM instruments produced at Dytran include force, pressure and acceleration sensors. Each class of sensors is produced in many varieties for a wide range of applications.

Also falling under the class of **LIVM** instruments are in-line charge amplifiers that utilize the same two-wire constant current operating mode as the **LIVM** sensors.

Operating principles for **LIVM** sensors and in-line amplifiers are similar in that they utilize the same two-wire constant current operating mode. The amplifiers built into the sensors are either MOSFET-input voltage or charge amplifiers or JFET-input charge amplifiers.

All types of **LIVM** amplifiers serve to convert the very high impedance of the piezoelectric crystals to much lower impedance voltage signals that have the capability of driving long cables with little or no signal degradation.

THEORY OF OPERATION

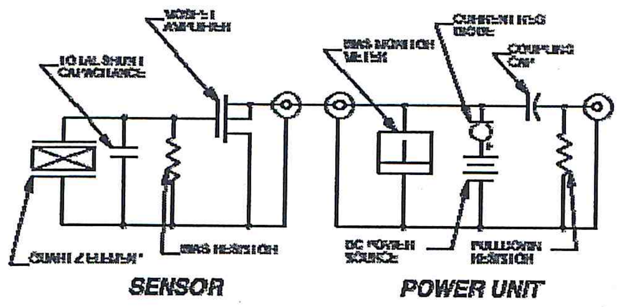

FIGURE 1: TYPICAL LIVM VOLTAGE MODE SYSTEM

Figure 1 is a simplified schematic of a basic LIVM system including the sensor with integral electronics, the cable and the power unit. The sensor amplifier in this case is the unity gain voltage follower. This is the type of amplifier used in most **LIVM** sensors and almost exclusively used with quartz element sensors.

The sensing element (force, pressure or acceleration), usually made with quartz or piezoceramic crystals, is connected directly to the gate of a FET input integrated circuit (IC) amplifier. This amplifier is operated as a source follower and, as such, has unity voltage gain.

The source terminal of the IC is supplied with constant current over the range of 2 to 20 mA at a compliance (supply) voltage of +18 to +30 volts DC. The power unit may take the form of many different configurations from simple battery powered 2 mA units with constant current diode, to line-powered adjustable current power units able to supply 2 to 20 mA of constant current from adjustable constant current circuits.

In either case, the constant current device (current diode or constant current circuit), acts as the source impedance for the unity gain IC built into the sensor or for the in-line charge amplifier.

Under quiescent conditions, the IC will bias itself at approximately +10 volts DC at the input (source) terminal of the sensor. (Some special variations will bias at different voltages depending upon the specific application). This sensor bias voltage is monitored and displayed, on most Dytran power units, and this feature serves as a handy trouble-shooting tool, serving as an indicator for normal or abnormal operation. (More on this topic in a following section, "The fault monitoring monitor as a trouble-shooting tool").

The sensor signal, produced by the measurand acting upon the piezo element, is superimposed upon the sensor bias voltage and appears at the "Sensor" jack of the power unit. At this point, the DC bias portion of the signal is blocked by a coupling capacitor and the AC (signal) portion is coupled directly to the "Output" jack of the power unit.

The Output jack may then be connected directly to the input of readout instruments (oscilloscopes, spectrum analyzers, AC meters, frequency counters, etc.). The very low output impedance of the **LIVM** sensor (about 150 Ohms) makes the effect of most readout instruments on the signal, negligible.

Be aware that the coupling capacitor in the power unit (usually 10 μF) and the impedance of the readout load constitute a high-pass filter that may set the low frequency response of the system below the LF response built into the sensor. In most accelerometer applications, the 10 μF capacitor provides ample time constant to allow vibration measurements down to fractions of a Hz.

Dytran also manufactures DC-coupled power unit for **LIVM** sensors that utilizes an active variable voltage level amplifier circuit to "buck out" the DC bias voltage of the sensor. One such unit, model 4115B, supplies constant current to the sensor and direct-couples the sensor to the output jack eliminating the coupling capacitor. This feature allows the user to take full advantage of the long time constant built into the sensor and precludes the effect of readout instrument load on the low frequency response of the system. Model 4115B is especially useful for very long-duration (quasi-static) measurements especially with force and pressure sensors.

OPERATION, GENERAL

Special note: LIVM sensors depend on the power unit to supply a fixed amount of current to the sensor IC. These IC circuits will absorb any amount of current supplied until they exceed their power rating and burn up. For this reason, never apply power to an **LIVM** sensor without this current limiting protection. This precludes the connection of **LIVM** sensors directly to batteries, DC power units and many types of resistance measuring devices. Never measure the continuity of an LIVM sensor with any type of Ohmmeter. This type of measurement is redundant and may lead to destruction of the sensor. To determine if the IC is intact, use the monitor meter on the front panel of your Dytran power unit. This topic is covered in the following section, "The fault monitoring meter as a trouble-shooting tool".

After installing the sensor in accordance with instructions in the operating guide (manual) supplied with each sensor, connect the sensor to the power unit's "Sensor" jack. This jack, in most cases, is a BNC coaxial connector. You should have been supplied with the proper cable to connect the sensor to the power unit you have selected. If you were not and/or do not have such a cable, contact the factory for help.

It is important to carefully support the sensor cable, especially in situations where there is movement between the sensor and its surroundings. This practice will prolong cable life and will diminish or preclude the effects of triboelectric (cable generated) noise on the signal.

THE FAULT-MONITOR METER: A TROUBLE -SHOOTING TOOL

Most Dytran power units incorporate a dc voltmeter on the front panel that measures the DC bias voltage at the sensor terminal. Measuring this voltage supplies information about the "health" of the measurement system. The three conditions it can identify are 1) normal operation, 2) shorted cable or sensor or faulty power unit and 3) open sensor or cable connection. We will examine each possibility here.

NOTE: The fault-monitor meter may be the LED style shown on the left, Fig. 2, or the D'Arsonval panel meter style shown on the right, Fig. 2.

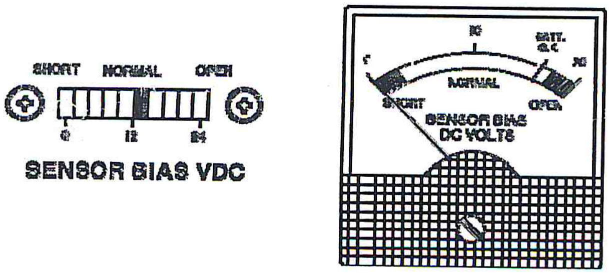

FIGURE 2: TYPICAL FAULT MONITOR METERS

NORMAL OPERATION

Under most normal operating conditions, the monitor meter will indicate approx. mid-scale (+10 to +13 volts DC) when the sensor is connected. Many of the meter faces have a "Normal" area delineated to indicate that the sensor is functioning and the cable from sensor to power unit is neither open nor shorted. It is possible that certain failure modes of the sensor can produce "Normal" indications but these modes are very rare. In most cases, if the meter reads in the "Normal" area, the system is viable.

As a further quick check on normal operation, with some sensors such as pressure and force sensors, pressing on the diaphragm or force sensitive surface with a finger can cause the monitor meter pointer to deflect showing that the sensor is "alive". With some higher sensitivity accelerometers, shaking them by hand can deflect the monitor meter enough to show the sensor is functioning.

OPEN SENSOR OR CABLE (FULL SCALE METER READING)

If the sensor amplifier is blown or the cable connecting sensor to power unit is open, the monitor meter will read in the "OPEN" area of the scale since the current source in the power unit has no load. To check if the problem is in the sensor, disconnect the sensor from its cable (leaving the other end connected to the power unit), and short across the open end of the cable with a metallic object while observing the meter. If the meter does not indicate zero ("short") while the sensor end of the cable is shorted, the cable is open. Replace the cable and try the sensor again, looking for the "Normal" indication.

If the meter reads zero when the short is applied, the cable is OK but the sensor is open. If another sensor is available, try it to verify the finding.

SHORTED SENSOR OR CABLE ("SHORT" METER READING)

If the fault-monitor meter reads in the "Short" area after connecting the sensor, this means that there is a short in the cable or sensor.

This condition cannot damage the power unit since the constant current circuit in the power unit limits the maximum current. Sometimes, shards of metal can scrape off of the cable connector of the 10-32 cables and these may short across the sensor connection. Check for this. Cleaning with a stiff-bristled brush will dislodge such metal shards.

If a short is still indicated, then the problem is with the cable or the power unit. Disconnect the cable from the power unit and observe the meter reading. If the meter reads full scale, the power unit is OK and the problem is a shorted cable or sensor. Replace the cable to verify.

MAINTENANCE AND REPAIR

Because of their small size and sealed construction, field maintenance of **LIVM** sensors is limited to cleaning of connectors and maintenance of mounting surfaces.

Clean connectors with a cloth or paper wipe dipped in solvents such as alcohol, Freon, etc. For hermetically sealed units, acetone may be used also. Acetone is not recommended for non-hermetic units.

Clean epoxy from the mounting surfaces of accelerometers, if necessary, with acetone or other solvents to dissolve and remove epoxies and other adhesives.

If the problem you are having is poor low frequency response and the sensor is not hermetically sealed, baking in a 250° oven for one hour will often get rid of moisture that may have condensed and shorted across the crystals which would shortened the discharge time constant.

If you cannot solve the problem, call the factory for assistance in trouble-shooting the system or for instructions for returning the instrument for evaluation and/or possible repair.

If the instrument is to be returned, you will be issued a Returned Material Authorization (RMA) number by the service department to help speed the instrument through the evaluation process. Do not return an instrument without first contacting the factory.

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WARRANTY

Dytran Instruments, Inc. warrants its products against defects in materials and workmanship for a period of one year after delivery. During the warranty period, Dytran, at its option, will either repair or replace products which prove to be defective.

WARRANTY LIMITS

1. Improper or inadequate maintenance by the buyer.
2. Unauthorized modification or misuse.
3. Improper installation by the buyer.

EXCLUSIVE REMEDIES

The remedies provided herein are the buyer's sole and exclusive remedies. Dytran shall not be liable for any direct, indirect, special, incidental or consequential tort or any other legal theory. Dytran warrants only the free recalibration of any sensor which deviates beyond its calibrated value within the warranty period.

Contact he factory for return instructions before sending any material for repair.

A.13 Sensor de Caudal por Ultra Sonido

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Measurement & Control

Flow

TransPort® PT878

Portable Liquid Flowmeter

User's Manual

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Portable Liquid Flowmeter

User's Manual

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Information Paragraphs

Note: *These paragraphs provide additional information about the topic which is helpful but is not essential to proper completion of the task.*

Important: *These paragraphs provide emphasis to instructions that are essential to proper setup of the equipment. Failure to follow these instructions carefully may cause unreliable performance.*

WARNING! Indicates a potentially hazardous situation which can result in serious personal injury or death, if it is not avoided.

CAUTION! Indicates a potentially hazardous situation which can result in minor or moderate injury to personnel or damage to the equipment, if it is not avoided.

Safety Issues

WARNING! It is the responsibility of the user to make sure all local, county, state and national codes, regulations, rules and laws related to safety and safe operating conditions are met for each installation.

Auxiliary Equipment

Local Safety Standards

The user must make sure that he operates all auxiliary equipment in accordance with local codes, standards, regulations, or laws applicable to safety.

Working Area

WARNING! Auxiliary equipment may have both manual and automatic modes of operation. As equipment can move suddenly and without warning, do not enter the work cell of this equipment during automatic operation, and do not enter the work envelope of this equipment during manual operation. If you do, serious injury can result.

WARNING! Make sure that power to the auxiliary equipment is turned OFF and locked out before you perform maintenance procedures on the equipment.

Qualification of Personnel

Make sure that all personnel have manufacturer-approved training applicable to the auxiliary equipment.

Personal Safety Equipment

Make sure that operators and maintenance personnel have all safety equipment applicable to the auxiliary equipment. Examples include safety glasses, protective headgear, safety shoes, etc.

Unauthorized Operation

Make sure that unauthorized personnel cannot gain access to the operation of the equipment.

Environmental Compliance

Waste Electrical and Electronic Equipment (WEEE) Directive

GE Measurement & Control is an active participant in Europe's *Waste Electrical and Electronic Equipment* (WEEE) take-back initiative, directive 2012/19/EU.

The equipment that you bought has required the extraction and use of natural resources for its production. It may contain hazardous substances that could impact health and the environment.

In order to avoid the dissemination of those substances in our environment and to diminish the pressure on the natural resources, we encourage you to use the appropriate take-back systems. Those systems will reuse or recycle most of the materials of your end life equipment in a sound way.

The crossed-out wheeled bin symbol invites you to use those systems.

If you need more information on the collection, reuse and recycling systems, please contact your local or regional waste administration.

Visit http://www.ge-mcs.com/en/about-us/environmental-health-and-safety/1741-weee-req.html for take-back instructions and more information about this initiative.

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Chapter 1. Features and Capabilities

Chapter 2. Initial Setup

Chapter 3. Programming Site Data

Chapter 4. Creating and Managing Sites

Chapter 5. Displaying and Configuring Data

Chapter 6. Programming Meter Settings

Chapter 7. Logging Data

Chapter 8. Servicing the PT878

Chapter 9. Diagnostics and Troubleshooting

Chapter 10. Specifications

Chapter 1. Features and Capabilities

The TransPort® Model PT878 is a transit-time flowmeter which combines all the features of a full-size flowmeter with the advantages of a portable instrument.

This section describes the TransPort features and general system, and explains the theory of operation.

1.1 Overview

The PT878 measures the flow rate of acoustically conductive single-phase fluids. This includes most clean liquids, sewage, some slurries, some oil/water mixtures, and liquids with a small percentage of entrained gas bubbles. The flowmeter provides one linear (0/4-20 mA) analog output of flow velocities or volumetric flow rate of these fluids, measuring velocities from ±0.03 to ±12 m/sec (±0.1 to ±40 ft/sec), along with one selectable frequency output or pulsed totalizer output.

The PT878 also provides two 4 to 20-mA analog inputs in order to connect temperature transmitters to measure energy flow rate of liquids. Energy flow rate may be calculated for water, glycol, and water/glycol mixtures.

The PT878 has the ability to store site data in files which can be accessed at a later time. Within the Main Menu, a set of forms (windows) asks you all the necessary setup information for a particular site. Once the necessary questions are answered, you simply save the information to a file.

The PT878 stores these files and other data in non-volatile memory, which retains the information even if power is off. The flowmeter itself runs on rechargeable or alkaline batteries for up to 10 hours.

This small lightweight flowmeter displays measurements in both numeric and graphical form on a EL-backlit, 240 x 200 pixel LCD graphic screen. The PT878 also has the capability of logging over 100,000 flow data points internally.

Using the USB communications port, the PT878 can transmit logged data, as well as real time data and other stored data. It is also computer-programmable via GE’s PanaView™ software.

1.1 Overview (cont.)

To assist you, the PT878 is fully equipped with context-sensitive on-line help which is accessible at any time by simply pressing the "?" (Help) key. Internal diagnostic and troubleshooting features help isolate and remedy common flowcell and transducer problems.

The PT878 operates with all standard GE transducers - wetted, clamp-on, hybrids (Pan-Adapta® plug), and buffered styles.

A built-in ultrasonic thickness gauge capability measures the pipe wall thickness when used with the optional thickness transducer.

1.2 System Description

The PT878 is one part of the flowmeter system. The flowmeter system consists of two essential subsystems: the flowcell and the electronics package (the PT878).

1.2.1 The Flowcell

The flowcell is that part of the system that uses ultrasonic pulses to interrogate the flow. It consists of the flowcell pipe and the transducers.

A. FLOWCELL PIPE - The flowcell can either be created in the existing piping (for example, by inserting wetted transducers into the pipe, or clamping non-wetted transducers onto the pipe), or inserted as a substitute pipe section (spoolpiece). The flowcell must provide mechanical support for the transducers and assure stable fluid conditions for accurate flow measurement.

B. TRANSDUCERS - The transducers convert electrical energy into ultrasonic pulses when in a transmit cycle, and convert the ultrasonic pulses back to electrical energy when in a receive cycle. In other words, they act like loudspeakers when transmitting the signal and microphones when receiving it. In the PT878 system, each transducer acts as both a receiver and transmitter, since a series of ultrasonic pulses are alternately sent upstream and then downstream through the flowcell.

1.2.2 Electronics Package

The PT878 consists of circuits that generate, receive, and measure the travel time of the ultrasonic pulses. It also contains a microcomputer that controls operation and calculates flow measurement parameters. Specific circuits function as follows:

- TRANSMIT SIGNAL GENERATOR - The transmit signal generator, under control of the microcomputer and timing circuit, synthesizes the signal that drives the transmitter.
- TRANSMITTER - The transmitter amplifies the signals from the transmit signal generator to a signal that drives the transmit transducer.
- RECEIVER - The receiver amplifies the received signals to a level suitable for the data acquisition circuitry.
- DATA ACQUISITION - The data acquisition circuitry digitizes the received signal and stores it in a buffer for processing by the microcomputer.
- TIMING CIRCUIT - The timing circuit generates the transmitter frequency, receive window, controls the data acquisition circuit and the direction of the transmission.
- MICROCOMPUTER - The microcomputer controls the PT878 flowmeter's operation and calculates flow measurements derived from the transmitted and digitized received signals. Also, the microcomputer continually checks for faults and allows the use of built-in diagnostics for troubleshooting.
- INPUT/OUTPUT - The input/output circuitry allows the flowmeter to indicate the measured flow with the 0/4-20 mA current loop, and to output to a remote device. The digital output supports frequency or pulse output, as well as use as a gate input; it can also act as a test point for triggering an oscilloscope from the transmit or receive window.

1.3 Theory of Operation

The PT878 is a transit-time ultrasonic flowmeter. When ultrasonic pulses are transmitted through a moving liquid, the pulses that travel in the same direction as the fluid flow (downstream) travel slightly faster than the pulses that travel against the flow (upstream). The PT878 uses various digital signal processing techniques, including cross-correlation, to determine transit times and then uses the transit times to calculate flow velocity.

During operation, two transducers serve as both ultrasonic signal generators and receivers. When mounted on a pipe, they are in acoustic communication with each other, so that each transducer can receive ultrasonic signals transmitted by the other transducer. Each transducer thus functions as a transmitter generating a certain number of acoustic pulses, and as a receiver for an identical number of pulses.

The flowmeter measures the time interval between transmission and reception of the ultrasonic signals in both directions. When the liquid in the pipe is not flowing, the transit-time downstream equals the transit-time upstream. When the liquid is flowing, the transit-time downstream is less than the transit-time upstream. The difference between the downstream and upstream transit-times is proportional to the velocity of the flowing liquid, and its sign indicates the direction of flow.

Chapter 2. Initial Setup

Before making measurements, you must prepare the PT878 for operation. This includes the following procedures:

- Making Electrical Connections
- Charging and/or Replacing Batteries
- Powering On and Off
- Using the Screen and Keypad
- Obtaining On-Line Help

Figure 1 below shows the PT878 in its standard soft case (a) and in the optional solid case (b). In the solid case, the interior is structured for optimal protection of the PT878 and its accessories.

Figure 1: The PT878 and Accessories

2.1 Making Electrical Connections

Before making measurements with the PT878, you must make all the necessary connections to the unit. This section describes how to connect the following:

- Power
- Transducers
- Input/Output
- USB Interface

Make all connections to the top of the PT878 unit as shown in Figure 2 below. Please note that you need to make the proper power and transducer connections only. The other connections are required for particular functions, but are not necessary for basic operation.

Note: *For a listing of Input/Output connections, see Table 1 on page 8.*

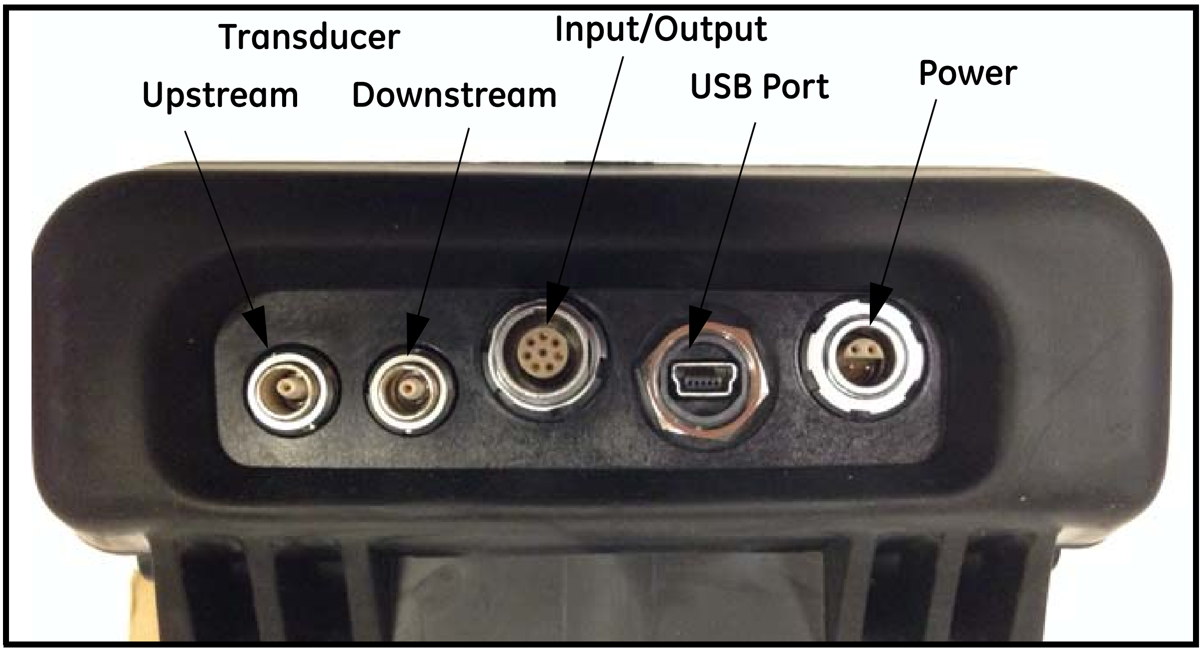

Figure 2: Connection Locations

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2.1.1 Power Connections

The PT878 is powered by either a 100-120/200-260 VAC wall mount plug-in module, or by 5 internal C_S-size NiCad high-energy rechargeable batteries or by a pack of 3.0 Ahr NiMH batteries. (An optional power supplement, part #703-1283, uses 6 AA alkaline batteries.) When you receive the PT878, the batteries are not charged; therefore, to make remote measurements using the batteries, follow the instructions on page 12 to charge the batteries. In either case, you must connect the power cord to the appropriate terminal as shown in Figure 2 on page 6.

WARNING! To ensure the safe operation of the PT878, you must install and operate it as described in this manual. In addition, be sure to follow all applicable safety codes and regulations for installing electrical equipment in your area. The PT878 and its transducers are designed for use only in general-purpose locations.

2.1.2 Transducer Connections

The transducer cables connect to the PT878 with LEMO® coaxial type connectors. Each color-coded cable should have a collar labeled UPSTREAM or DOWNSTREAM. Make transducer cable connections to the top of the flowmeter as shown in Figure 2 on page 6. Because there are various types of transducers and installations, transducer installation is discussed separately in the *Liquid Transducer Installation Guide* (916-055).

2.1.3 Input/Output Connections

The PT878 provides one 0/4-20 mA current output and two 4 to 20-mA analog inputs with switchable 16-V supply for loop- powered temperature transmitters. It also supports digital, frequency, and totalizer outputs.

Connect the inputs/outputs using a LEMO® multi-pin connector as in Figure 2 on page 6. The pin numbers for the connector and the color code for the standard input/output cable are shown in Table 1 on page 8.

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2.1.3 Input/Output Connections (cont.)

Table 1: Cable Assembly for Analog Inputs/Outputs

Pin Number	Wire Color	Description
1	Black	Analog Out 1
2	Red	16 V (switched)
3	White	Supply or Return Temperature (Input A)
4	Yellow	Supply or Return Temperature (Input B)
5	Green	Analog Ground
6	Orange	Digital Output (frequency output, pulse totalizer, diagnostic output or calibration gate)
7	Blue	Digital Ground
8	Violet	Receive Monitor

2.1.4 The USB Port

The TransPort™ PT878 portable ultrasonic flowmeter allows the user to update firmware, communicate with a PC running the GE PanaView™ graphical user interface software and transfer files via a built-in *USB Interface*. This manual provides instructions for performing these actions.

The PT878 USB design uses an RS232 to USB converter. which converts the USB data to standard serial port data. The RS232 communications protocol is used, which allows the meter to operate with both the GE PanaView graphical user interface software as well as commercially available terminal emulation programs such as HyperTerminal. The PT878 communications parameters, such as baud rate (300 to 38400 baud), can be set via the PT878 keypad.

Important: *All PC and PT878 communications parameters must match for successful data transfer.*

2.1.4 The USB Port (cont.)

The PT878 always ships with the latest firmware version installed. However, as new firmware versions become available, your PT878 firmware is easily updated via its USB interface.

The USB connector installed in the PT878 is IP67 rated and is leak-resistant, even if the instrument is exposed to water for a short period of time.

CAUTION! Be sure to use caution when connecting a USB cable to the PT878, if the meter's USB connector has been exposed to water.

2.1.4a USB Setup

The initial step for communicating with the PT878 through its USB interface is to make sure that the PC operating system recognizes the USB device in the PT878. This is done by connecting the PT878 to the PC with a USB cable and verifying that the PC operating system loads the correct drivers for the PT878 USB interface device.

USB Cable

The recommended USB cable for use between the PT878 and a PC is a USB A male to mini USB B male cable, such as GE p/n 238-407-LF or equivalent.

USB Drivers

To set up the USB drivers in Microsoft Windows®, complete the following steps:

1. Power on PT878.
2. Plug the mini B USB male connector into the PT878 USB port.
3. Plug the USB A male connector into any USB port on the PC.
4. Verify that Windows automatically loads the driver for the FTDI chip in the PT878.
5. Open the Control Panel>>Device Manager window and then select Ports (see Figure 3 below). Verify that the PT878 USB port is installed.

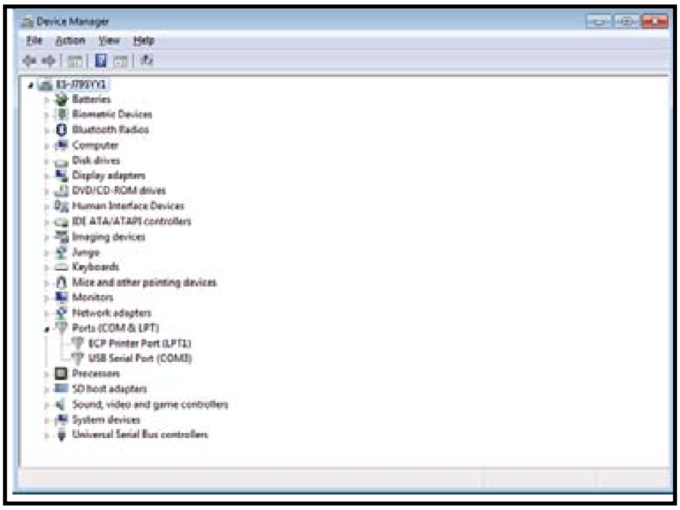

Figure 3: Device Manager Window

Note: *If the USB port is not automatically installed, the driver may be installed manually from the FTDI website.*

Install the drivers for the FT230XS UART from http://www.ftdichip.com.

Note: *For operation with the GE PanaView software, set the Com Port between COM1 and COM 9.*

Open the USB serial port settings window (see Figure 2 below) and match those listed in the PT878\Meter\Communications window at the PT878 UI. Note that the COM port settings may vary with theP C configuration.

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USB Drivers (cont.)

The USB driver setup is now complete.

Note: *The USB driver should recognize the flowmeter each time the PT878 is reconnected to the PC, but the COM port number may change depending on the PC configuration.*

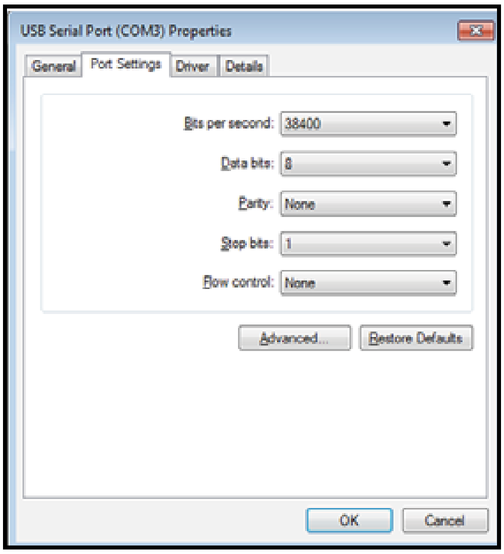


Figure 4: USB Serial Port Properties

2.2 Caring for the PT878 Batteries

The PT878 comes with self-contained, built-in rechargeable batteries to support portable operation. For optimum performance, these batteries require a minimum of maintenance.

CAUTION! Use only GE-approved batteries and desktop chargers. These chargers are designed to maximize battery life. Using other batteries or chargers voids the warranty and may cause damage.

Important: *For CE compliance, the PT878 is classified as a battery-powered device, not to be used with the AC adaptor.*

2.2.1 Charging and Storing the Batteries

When you receive the PT878, you will need to initially charge the batteries. Also, the battery may need recharging if it has not been used for a long period of time. The batteries must be charged up to 8 hours to receive the maximum charge. When fully charged, the batteries provide 8 to 10 hours of continuous operation. An internal battery gauge indicates the remaining power in the batteries.

To charge the batteries, simply plug the AC power module cord into the power jack (shown in Figure 2 on page 6) and be sure the battery pack is installed. When the PT878 is plugged into line voltage, the internal battery charger automatically charges the batteries, whether the PT878 is on or off. If the PT878 is on, the Battery icon in the upper right corner of the screen indicates battery status (as shown in Table 2 on page 13).

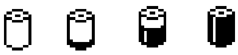
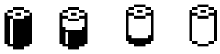
Note: *For version 1B of the PT878 software, you must also press the red power key in the upper right corner of the keypad. (See page 109 to determine your software version.)*

For optimal run time, charge the batteries only in temperatures from 50°F to 104°F (10°C to 40°C). Otherwise, the batteries will not be properly charged and will have a significantly reduced run time.

2.2.1 Charging and Storing the Batteries (cont.)

Store the batteries at temperatures from –4°F to 131°F (–20°C to 55°C) for periods of less than one month, or from 32°F to 104°F (0°C to 40°C) for longer periods. (If you are transporting them for two days or less, the batteries can withstand temperatures from –40°F to 158°F (–40°C to 70°C).

Table 2: Battery Status Icons

Icon	Battery Status
	Full battery
	Partially full battery
	Empty battery
	Fully charged battery, connected to AC power
	Charging battery
	Discharging battery
	Failure/missing battery
	Notification to check battery form (see page 114)

2.2.2 Replacing the Batteries

CAUTION! Replace batteries only with the specified rechargeable batteries. The battery charges when the unit is off. Do not attempt to recharge non-rechargeable batteries.

If you need to replace the rechargeable batteries, use the recommended 3.0 Ahr NiMH batteries (part number 200-081). While the batteries can be recharged up to 600 times, it is best to replace them when they no longer provide acceptable performance. To replace the batteries, remove the rubber boot, open the panel located on the back of the PT878 unit, disconnect the batteries, and replace with new ones (see Figure 5 on page 14).

2.2.2 Replacing the Batteries (cont.)

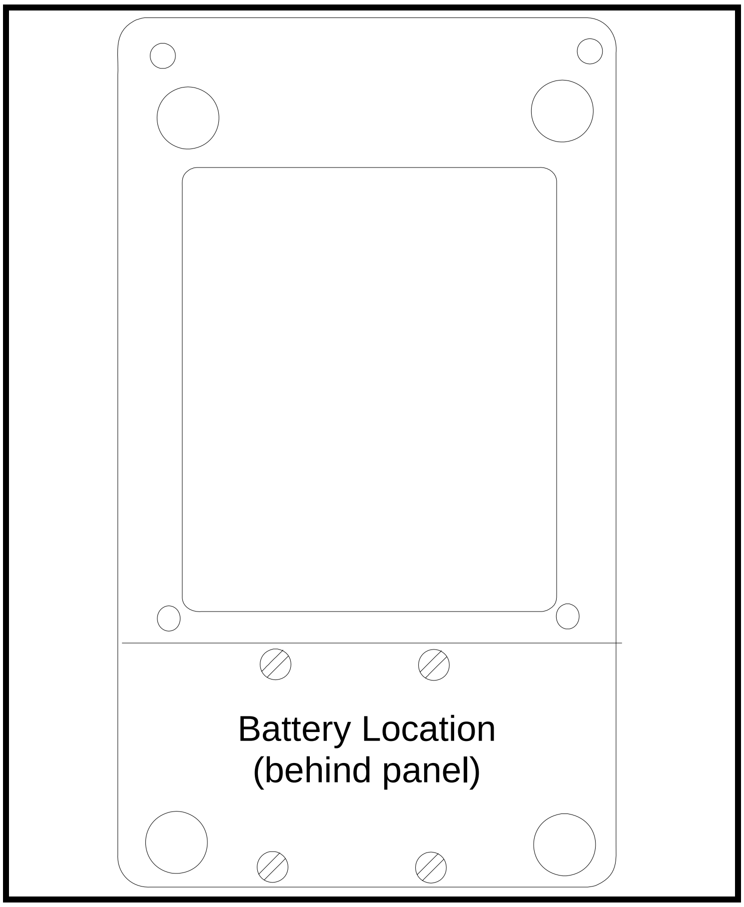


Figure 5: Battery Location

To further extend the battery power on the PT878, the GE Part #705-1283 option uses 6 AA alkaline batteries.

2.2.3 Disposing of Batteries

CAUTION! Never dispose of the batteries by incineration. Do not attempt to disassemble or short-circuit the batteries. For safety. do not handle a damaged or leaking battery.

Important: *Be sure to dispose of your battery properly. In some areas, battery disposal in business or household trash may be prohibited. For safe disposal options, contact your nearest GE-authorized service center.*

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2.3 Powering ON and OFF

To operate the PT878, the power cord must be plugged into line voltage or the battery must be charged as described previously.

Important: *For CE compliance, the PT878 is classified as a battery-powered device, not to be used with the AC adapter. To comply with CE certification, do not operate the meter with the charger plugged in.*

To turn the PT878 on, press the red button in the upper-right-hand corner of the keypad. Immediately upon power up the PT878 emits a short beep and displays a “PCI Loader” message. It then validates the instrument programming, and then displays the GE logo and the software version and emits a long beep. If the meter fails any of these tests, contact the factory.

WARNING! If the meter fails the backup battery test, you must send the unit back to the factory for a battery replacement. Make sure you keep the batteries charged until you are ready to ship the unit back to the factory. Before shipping, transfer all the log and site data to your PC.

2.3 Powering ON and OFF (cont.)

After the meter conducts all the self checks, the screen then appears similar to the one shown in Figure 6 below.

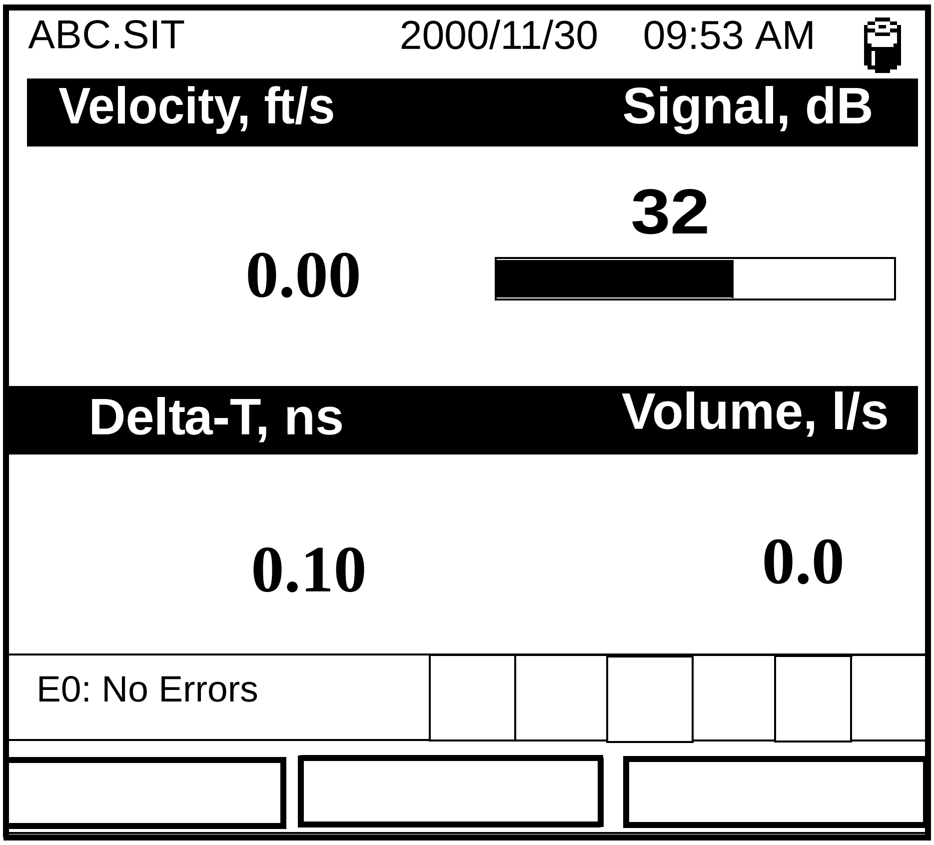

Figure 6: Screen After Powering ON

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2.3 Powering ON and OFF (cont.)

To turn the PT878 off, press the red key for 3 seconds. The screen now appears similar to Figure 7 below.

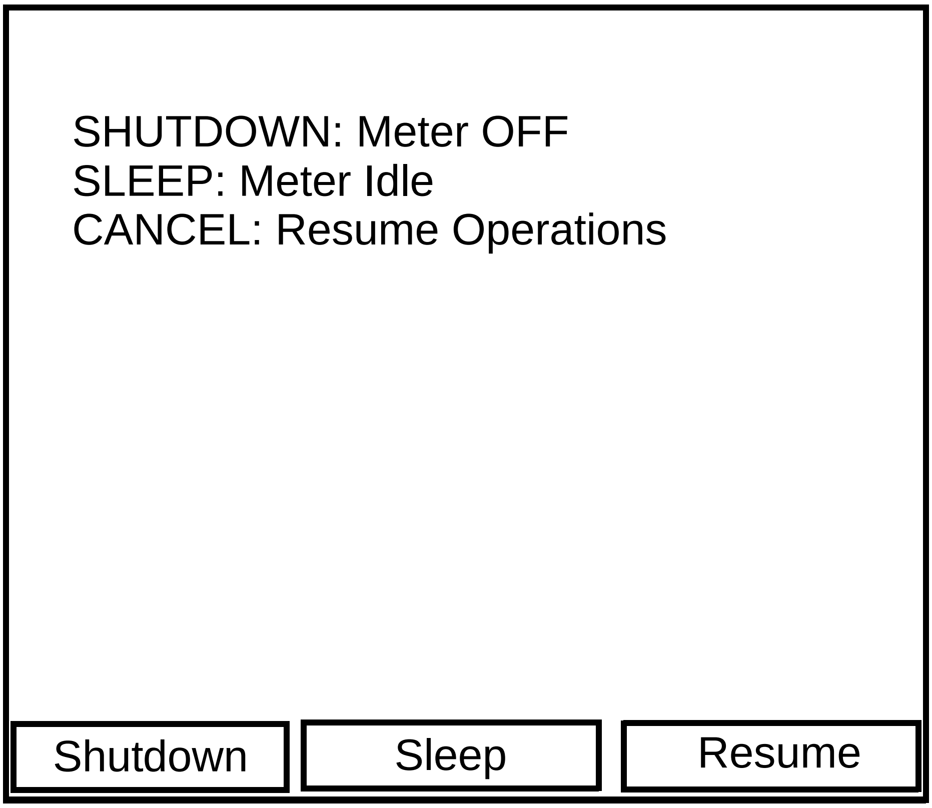

Figure 7: Shutdown Menu

Three options are available:

- Press [F1] to shut down the PT878, turning it completely off.
- Press [F2] to send the PT878 into sleep mode. In this mode, some of the power supplies shut down, but the PT878 remains in a standby mode. Users can resume taking measurements immediately by pressing the power button.
- Press [F3] to cancel the command and return the PT878 to normal operation.

If the PT878 locks up, you can reset it by holding the power key (the red key in the upper right corner) for 15 seconds.

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2.4 Using the Screen and Keypad

The essential features for operating the PT878 are the screen and keypad. Although these features are common on portable instruments, the PT878 design offers particular features to simplify and speed operation.

2.4.1 Screen

The primary function of the screen is to display information in order for you to accurately and easily take measurements. The PT878 screen consists of seven parts (see Figure 8 below).

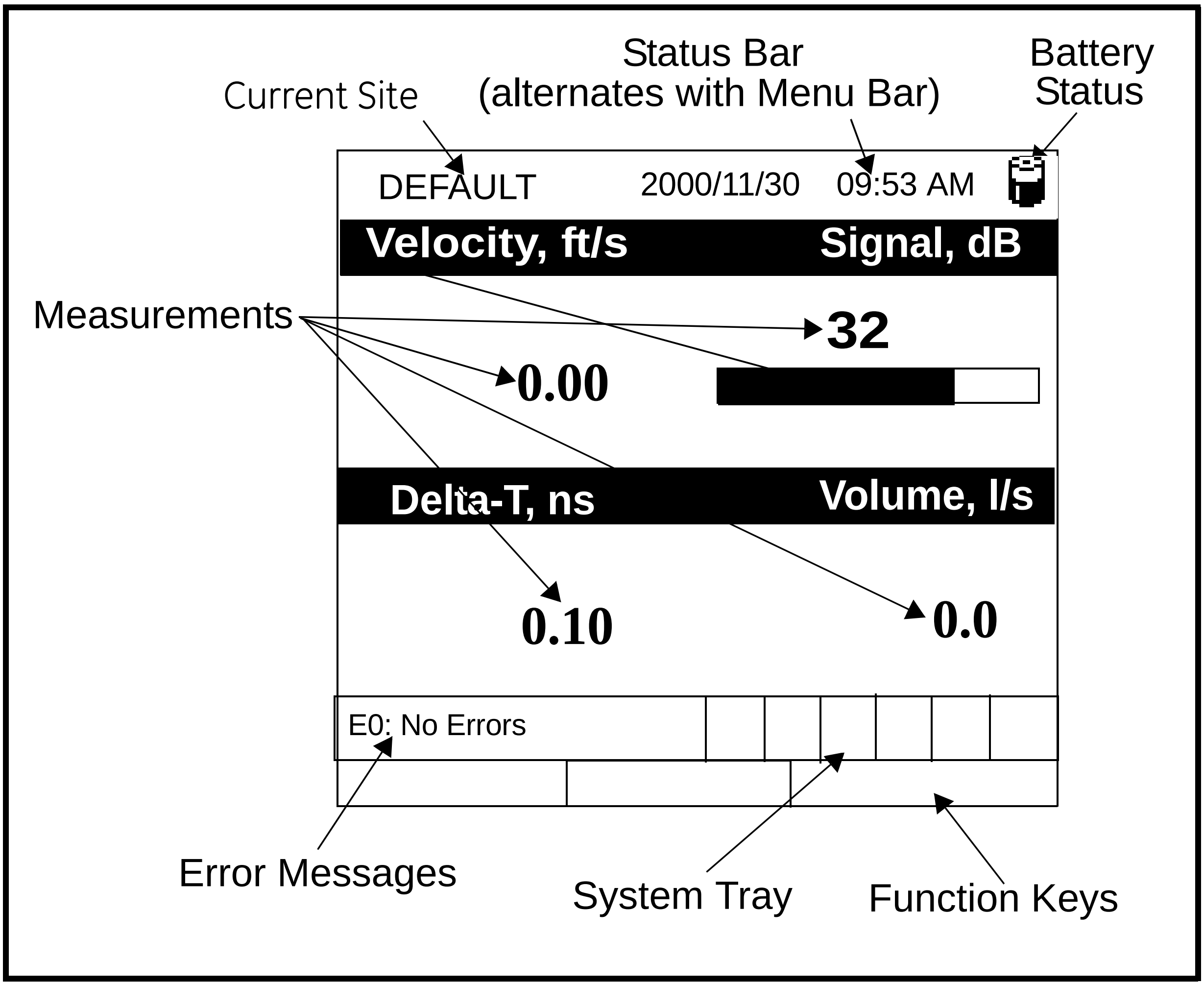


Figure 8: PT878 Screen in Operate Mode

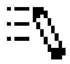
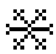
The top line of the screen is the **status bar,** which normally displays the time and date. However, when you press [MENU] (the menu key), the **Menu Bar** replaces the status line.

2.4.1 Screen (cont).

The middle of the screen shown in Figure 8 on page 18 is the **work area,** which displays the measured parameters, numeric measurements, and both bar and line graphs. (When you enter a selection on the Menu Bar discussed in Chapter 3, *Programming Site Data*, this area displays menu prompts.) A line at the bottom of the area also displays error code messages, which are described in more detail in Chapter 9, *Diagnostics and Troubleshooting*.

The **system tray** displays icons that indicate meter operations not otherwise shown. Table 3 below lists the icons and their meanings.

Table 3: Icons in the System Tray

Icon	Function	Meaning
	Alert	Indicates the meter encountered an error in operation.
	Log	Indicates a log is pending (no marks) or running (marks).
 	Heating/ cooling	Indicates heating or cooling energy mode.
	Stopwatch	Calibration Gate Operation: Watch is stopped when the gate is closed, or runs when it is open.
	Snapshot (To file)	Indicates that the Snapshot function has been activated, so users can take screen captures (see page 130).

The bottom of the screen displays the three **function key** options: F1, F2 and F3. These keys have different functions, depending on the task you are performing.

2.4.2 Keypad

The PT878 keypad has 25 keys. The functions for each key are as follows (see Figure 9 on page 21):

- 3 function keys ([F1], [F2], [F3]) — enable you to select the special functions which appear at the bottom of the screen.
- 12 numeric keys (including – and .) — enable you to enter numeric data.
- 4 arrow keys ([◀], [▶], [▲], [▼]) — enable you to move through the menu options.
- [?] Help key— enables you to access on-line help (discussed on page 22).
- [MENU] Menu key — enables you to access the Main Menu.
- [ENTER] — enables you to enter a particular menu, and enters selected values into the PT878 memory.
- [SEL] — enables you to move between data measurements on the screen.
- [ESC] — enables you to exit menus or menu options at any time; cancels a numeric entry.
- Red key [⏻] — turns the power on or off, and toggles the backlight on or off.

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2.4.2 Keypad (cont.)

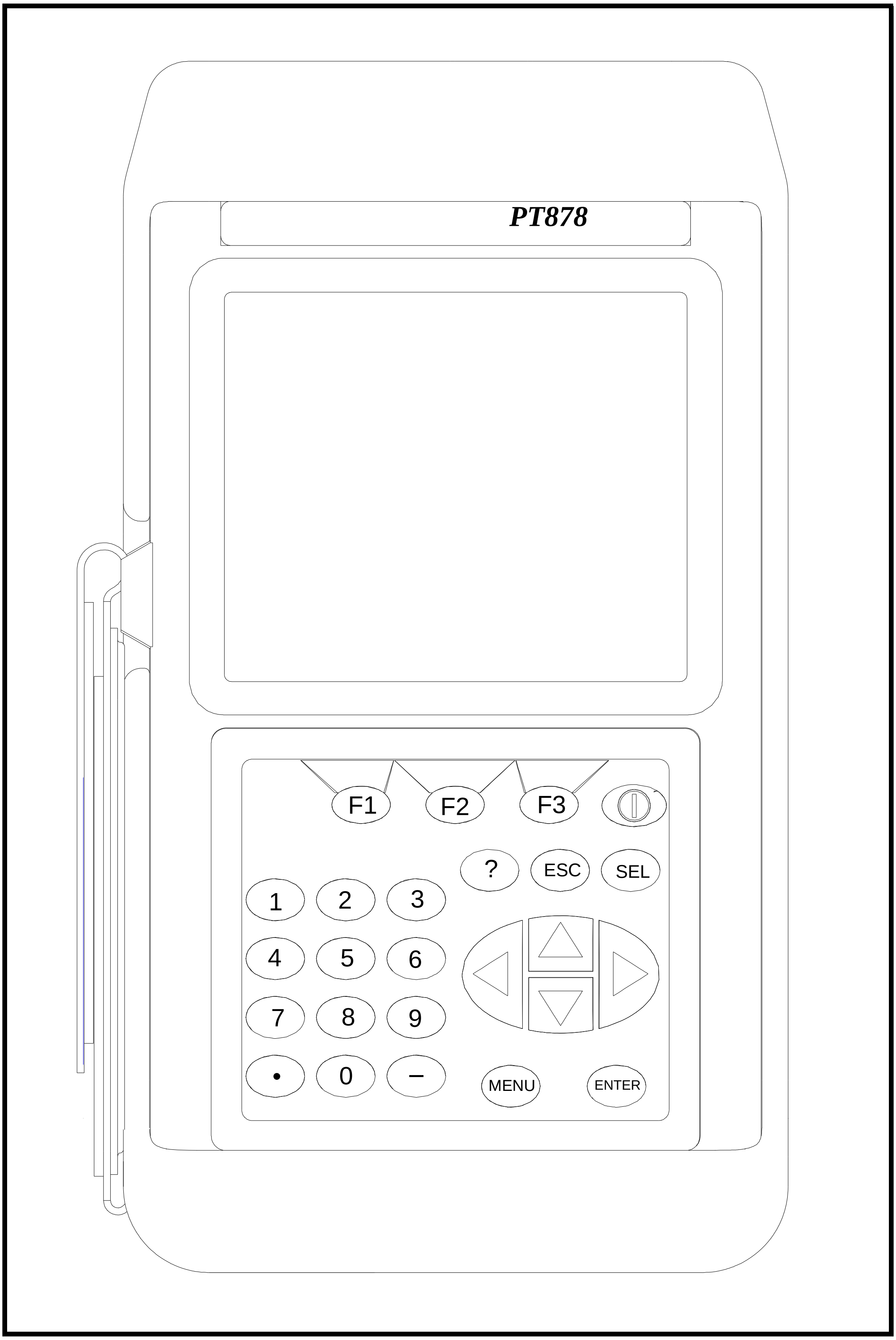

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Figure 9: PT878 Keypad

2.5 Obtaining On-Line Help

The PT878 offers context-sensitive on-line help screens that describe various features. You can access on-line help at any time by pressing the [?] key. The screen appears similar to Figure 10 below.

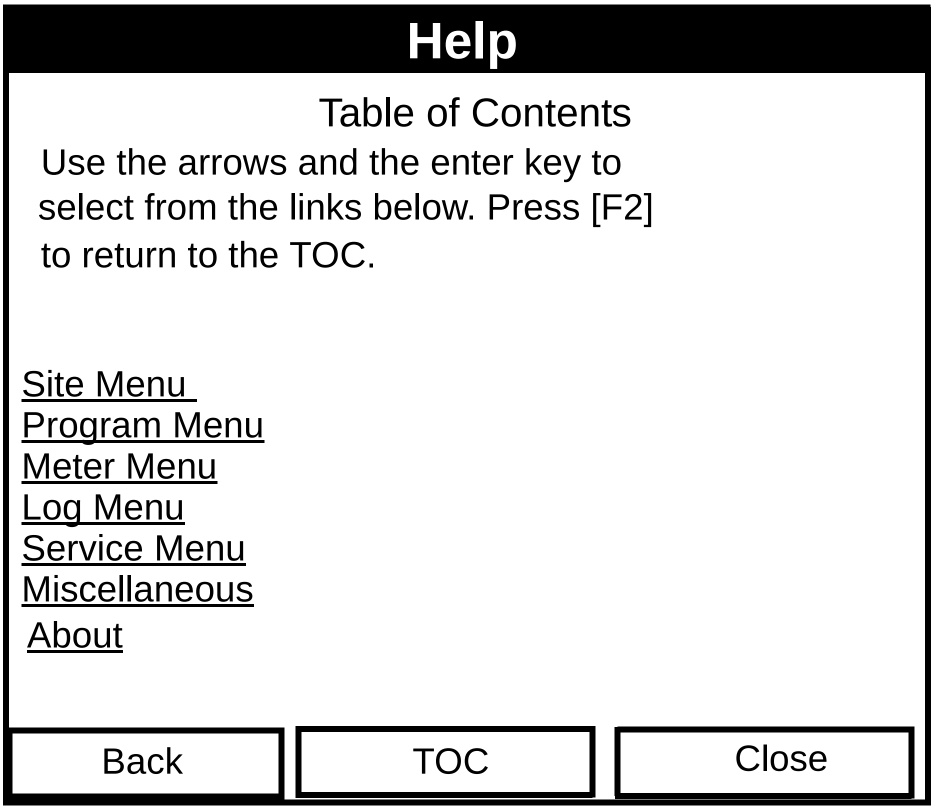

Figure 10: Main Help Menu

Use the three function keys and the [▲] and [▼] arrow keys to navigate to the desired menu, and press [ENTER]. Repeat this procedure to access the desired topic within the menu. When you have finished using the Help menu:

- Press [F1], Back, to move back one level.
- Press [F2], TOC, to return to the Table of Contents.
- Press [F3], Close, to return to the previous screen.

Chapter 3. Programming Site Data

On the PT878, a Program Menu (part of the Main Menu) enables you to enter information that is specific to each site:

- Transducer types and paths
- Pipe materials and linings
- Fluid types
- Heating or cooling energy flow rate
- Analog input and output parameters
- Digital output parameters
- User functions
- Correction factors

For immediate operation, the PT878 requires only transducer, pipe and fluid data. However, additional information allows you to tailor measurements as specifically as possible to your particular application. Once you have entered this data, you can save it in files and recall these files for later use. The PT878 can store up to 1 MB (or 32 site files) of data in the meter at any one time. But through the USB link, users can store an unlimited number of sites in a PC, and then upload the sites they will actually use.

This chapter covers entering:

- Transducer, pipe, and fluid parameters
- Input/output and other setup parameters
- User functions.

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3.1 Entering the Program Menu

To enter the Program Menu, press the [MENU] key at the lower right of the PT878 keypad. The Menu Bar replaces the Status Bar at the top of the screen. Press the [▶] arrow key once to scroll from the Site Menu to the Program Menu. At the Program Menu, press [ENTER]. The screen appears similar to Figure 9 below. While following the programming instructions, see Figure 139 on page 222 of Appendix A, *Menu Maps*.

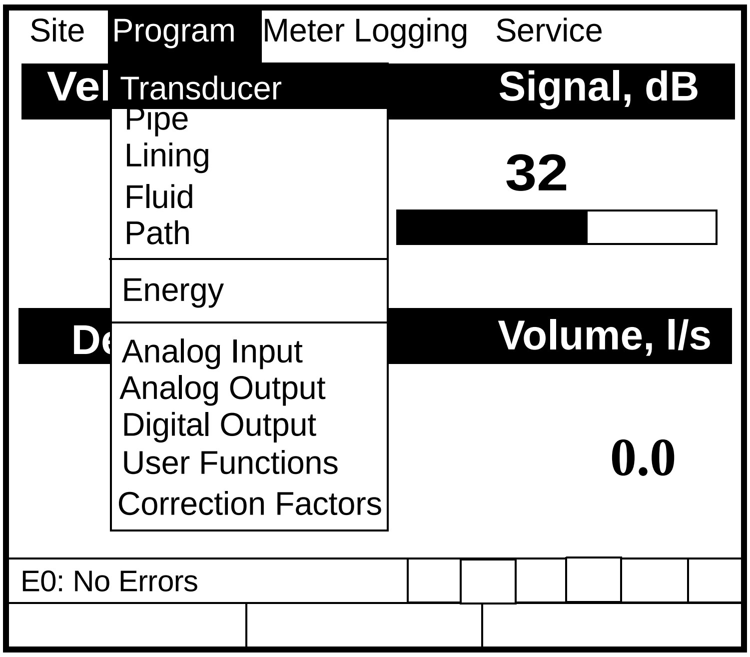

Figure 9: Program Menu

To scroll to a particular option, press the [▼]or [▲] arrow keys until you reach the option. Then press [ENTER] to open the option window.

When entering parameters in an option, press:

- The [▼] key to step through the available parameters
- The [▲] key to scroll back to a previously entered parameter
- The [F2] key (Cancel) or the [ESC] key to exit an option at any time and return to Operate Mode without changing the parameters.

Note: *If you enter an incorrect numeric value, press the* [◀] *key to erase the last digit entered.*

3.2 Entering Transducer Parameters

To enter the Transducer option, scroll to the Transducer entry on the Program Menu and press [ENTER]. The screen appears similar to Figure 10 below. To step through each parameter, press the [▼] key. Refer to Figure 143 on page 227 of Appendix A.

Note: *Refer to the* Liquid Transducer Installation Guide (916-055) *for additional information about transducers and configurations.*

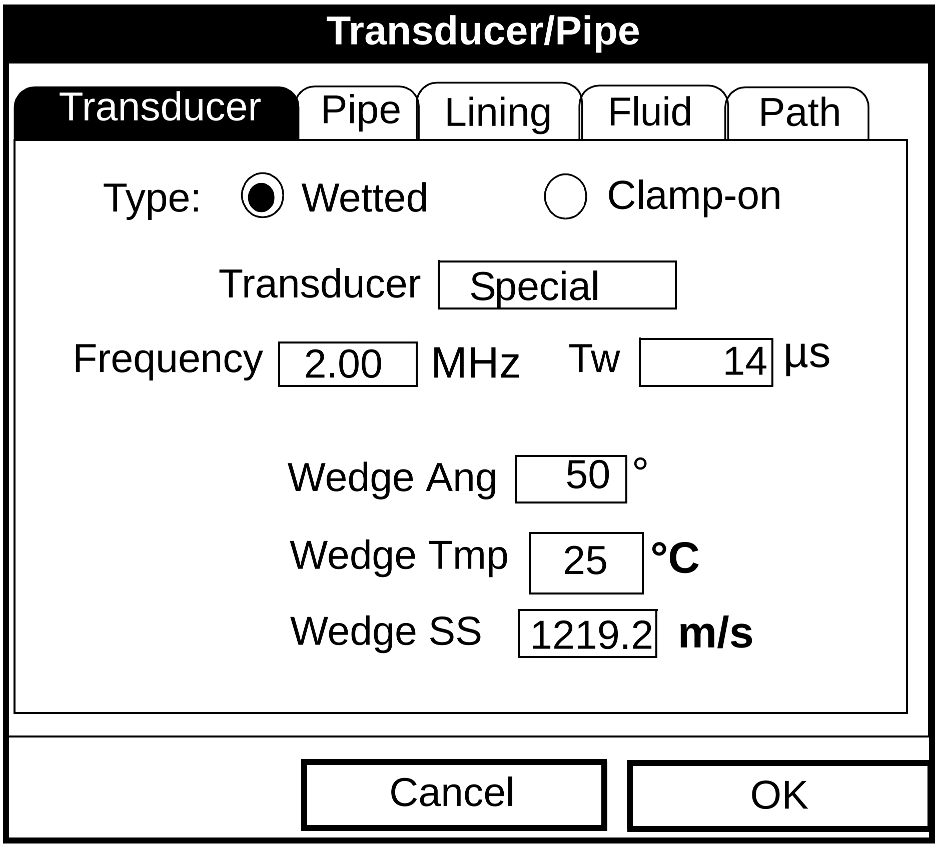

Figure 10: Transducer Option Window

1. The first prompt asks you to select whether you are using a wetted or a clamp-on transducer.

a. Use the [◀] and [▶] keys to scroll between the two types.

b. Press [ENTER] to confirm the choice.

3.2 Entering Transducer Parameters (cont.)

Note: *The choices made early in the Transducer and Pipe options determine the prompts available later. If the PT878 does not scroll to a particular parameter, it is not necessary for that transducer or pipe type. For example, the Lining window is not available if you select a wetted transducer.*

2. The next prompt asks you to enter the transducer number (printed on the transducer itself), or to specify that you are using a special application transducer.

a. From the Type prompt, press the [▼] key to reach the Transducer prompt, and press [ENTER].

b. A drop-down list of transducer numbers opens as in Figure 11 on page 25. (The list varies, depending on whether you have selected wetted or clamp-on in the previous prompt. See Table 4 on page 25.) Press the [▼] or [▲] keys to scroll to the appropriate number, or scroll to "Special" for a special application transducer. To speed scrolling, you can press the [▶] key to scroll down by a page, or the [◀] key to scroll up by a page.

c. Press [ENTER] to confirm your selection.

The program now varies, depending on whether you have selected standard or special transducers.

- If you have selected a standard wetted or clamp-on transducer, the PT878 comes programmed with the needed parameters. Proceed to *Confirming Entries* on page 30.
- However, if you have selected a special application transducer, go to page 26.

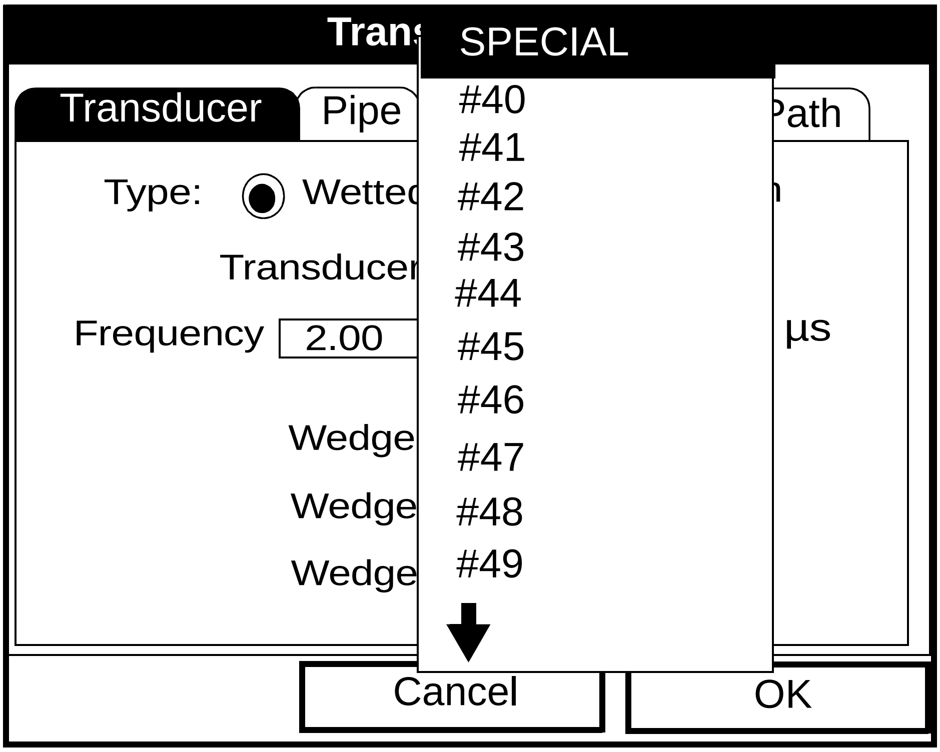

Figure 11: Transducer Numbers Drop-Down List

Table 4: Transducer Numbers Available

WETTED			CLAMP-ON			
SPECIAL		64	SPECIAL	23 (Shear)	113 (Shear)	307 (Shear)
40	52	65	1 (Rayleigh)	24 (Shear)	114 (Shear)	308 (Shear)
41	53	66	2 (Rayleigh)	25 (Shear)	115 (Shear)	309 (Shear)
42	54	67	3 (Rayleigh)	26 (Shear)	116 (Shear)	310 (Shear)
43	55	68	10 (Shear)	27 (Shear)	117 (Shear)	311 (Shear)
44	56	69	10 (Shear)	28 (Shear)	125 (Shear)	312 (Shear)
45	57	70	11 (Shear)	29 (Shear)	126 (Shear)	313 (Shear)
46	58	71	12 (Shear)	30 (Shear)	127 (Shear)	314 (Shear)
47	59	72	13 (Shear)	31 (Shear)	133 (Shear)	315 (Shear)
48	60	73	14 (Shear)	32 (Shear)	136 (Shear)	401 (Shear)
49	61	74	15 (Shear)	33 (Shear)	137 (Shear)	402 (Shear)
50	62	75	16 (Shear)	34 (Shear)	139 (Shear)	403 (Shear)
51	63	76	17 (Shear)	35 (Shear)	301 (Shear)	407 (Shear)
			18 (Shear)	36 (Shear)	302 (Shear)	408 (Shear)
			19 (Shear)	37 (Shear)	303 (Shear)	409 (Shear)
			20 (Shear)	38 (Shear)	304 (Shear)	410 (Shear)
			21 (Shear)	39 (Shear)	305 (Shear)	
			22 (Shear)	112 (Shear)	306 (Shear)	

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3.2.1 Parameters for Special Transducers

Note: *The factory will supply the information required below with the transducers.*

3. The prompt asks for the transducer frequency, to transmit a signal at a frequency to which the transducer can respond.

a. From the Transducer prompt, press the [▼] key to reach the Frequency prompt, and press [ENTER].

b. A drop-down list of five frequencies opens, ranging from 0.50 to 4.00 MHz. Scroll to the desired frequency, and press [ENTER].

4. The next prompt asks for Tw, the time delay. This parameter is actually the time the transducer signal spends travelling through the transducer and cable. The PT878 calculates the flow rate from the upstream and downstream transit times in the fluid, so the Tw (time delay) must be subtracted out for an accurate measurement. The factory supplies the time delay on a sheet of paper inside the transducer case.

a. From the Frequency prompt, press the [▶] key to reach the Tw prompt, and press [ENTER].

b. Use the numeric keys to enter the GE-supplied time delay and press [ENTER].

The program now varies, depending on whether you have selected a wetted or a clamp-on transducer.

- If you have selected a special wetted transducer, proceed to *Confirming Entries* on page 30.
- Special clamp-on transducers require three more inputs: wedge angle, wedge temperature, and wedge soundspeed.

5. When calculating the flow rate, the PT878 must take into account the wedge angle, the angle of the ultrasonic transmission.

a. From the Tw prompt, press the [▼] key to reach the Wedge Angle prompt, and press [ENTER].

b. Use the numeric keys to enter the factory-supplied wedge angle (in degrees) and press [ENTER].

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3.2.1 Parameters for Special Transducers (cont.)

Note: *If the error message in Figure 12 below, or one similar to Figure 13 on page 28 appears, the Pipe Soundspeed, Wedge Soundspeed, and/or the Wedge Angle may be in error. Review the pipe and wedge parameters currently entered and change one or more as necessary.*

Note: *To change pipe information, see* Entering Pipe Parameters *on page 30.*

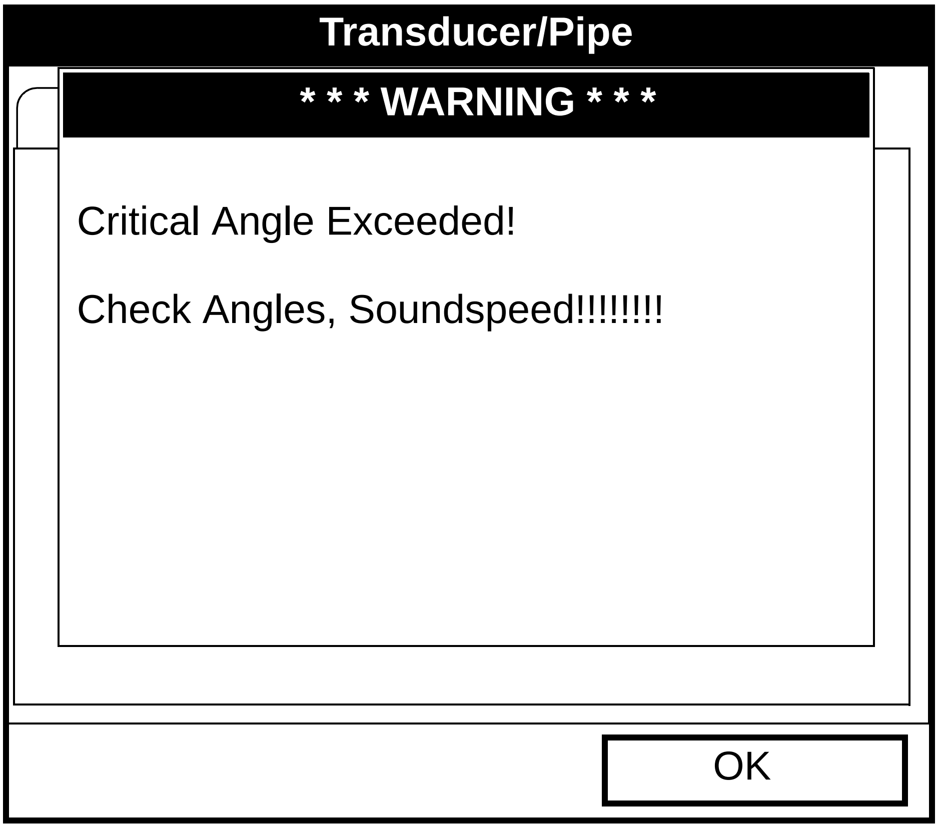

Figure 12: High Angle Error Message Window

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3.2.1 Parameters for Special Transducers (cont.)

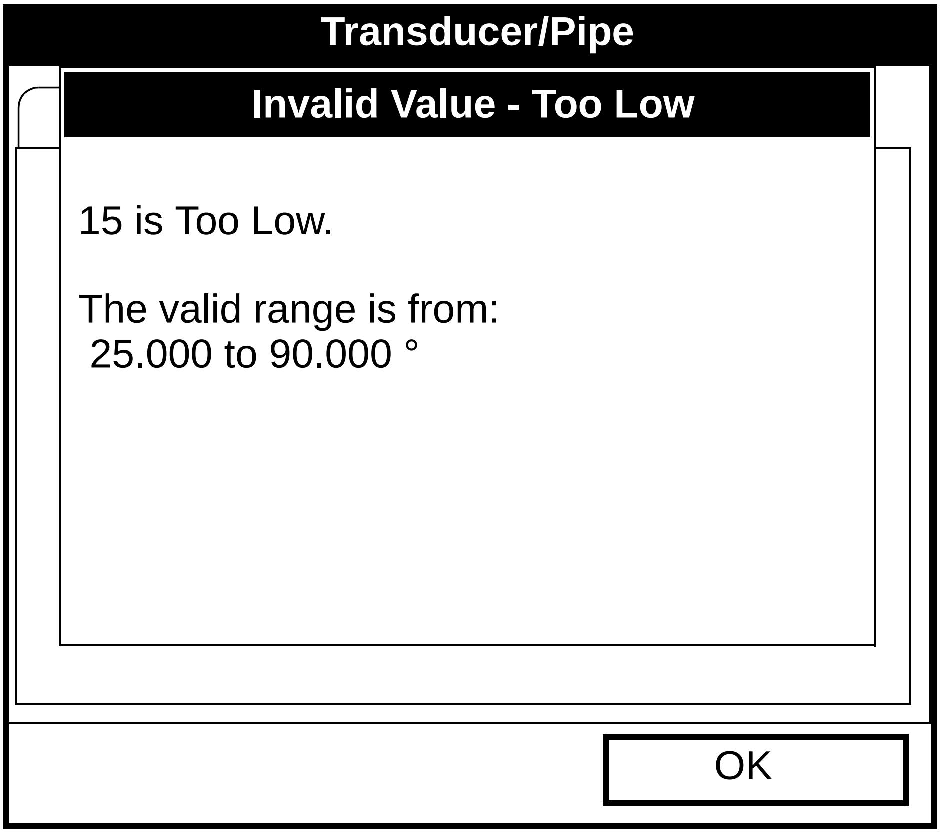

Figure 13: Low Angle Error Message Window

Note: *When the corrected information is entered, a message similar to Figure 14 appears. Press* [F3] (OK).

3.2.1 Parameters for Special Transducers (cont.)

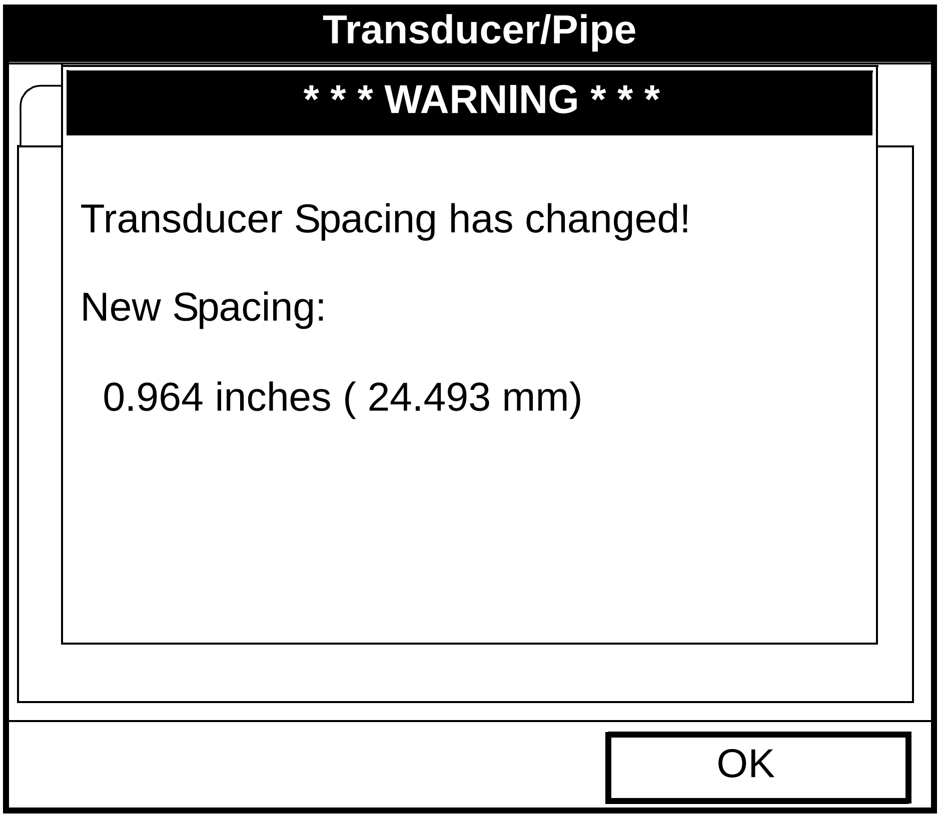

Figure 14: Transducer Spacing Change Window

6. The PT878 must also take into account the wedge temperature.

   a. From the Wedge Angle prompt, press the [▼] key to reach the Wedge Temperature prompt, and press [ENTER].

   b. Use the numeric keys to enter the wedge temperature (in degrees F or C) and press [ENTER].

7. Finally, the PT878 requires the wedge soundspeed.

   a. From the Wedge Temp prompt, press the [▼] key to reach the Wedge SS prompt, and press [ENTER].

   b. Use the numeric keys to enter the factory-supplied wedge soundspeed (in ft/sec or m/sec) and press [ENTER].

Pressing the [▼] key returns the meter to the Transducer tab at the top.

3.2.2 Confirming Entries

- To confirm the entries and return to Operate mode, press [F3] (OK).
- To leave the window without confirming the entries, press [F2] (Cancel) or the [ESC] key.

In either case, the PT878 returns to Operate Mode.

3.3 Entering Pipe Parameters

To enter the Pipe option, scroll to the Pipe entry on the Program Menu and press [ENTER]. (From the Transducer window, you can scroll back up to the Transducer tab and press the [▶] arrow key to reach the Pipe window, and press [ENTER].) The screen appears similar to Figure 15 below. To step through each parameter, press the [▼] key. Refer to Figure 139 on page 222 of Appendix A, *Menu Maps*.

Note: *Refer to the brochure* Soundspeeds and Pipe Size Data (914-004) *for additional information about pipe sizes and soundspeeds.*

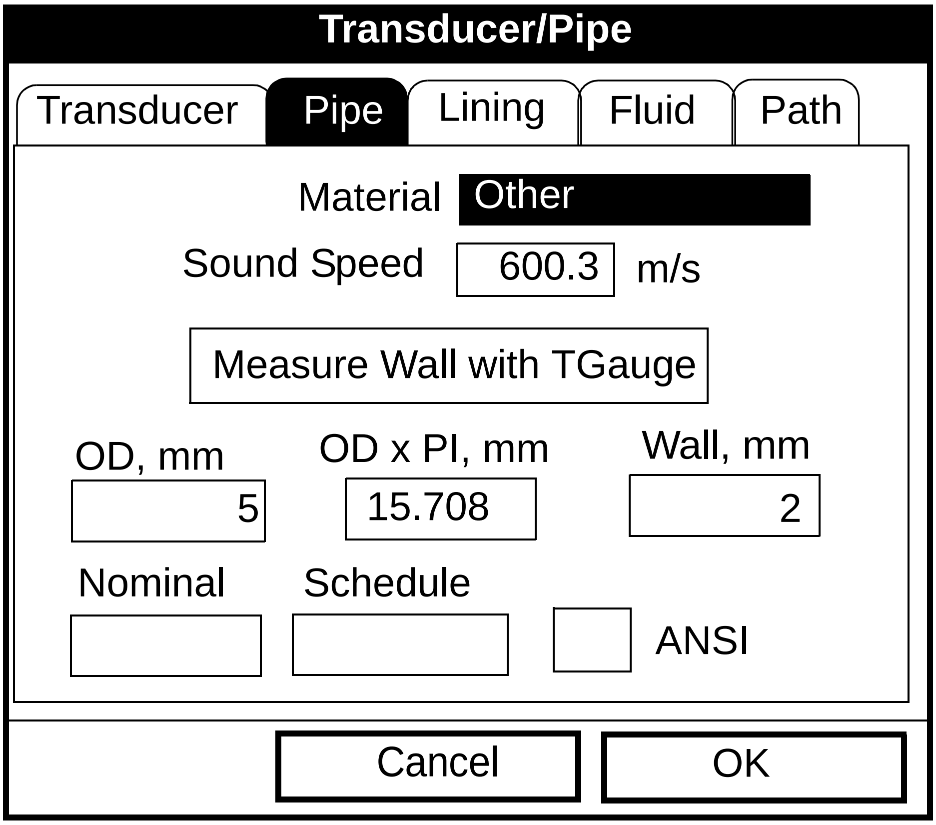

Figure 15: Pipe Option Window

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3.3 Entering Pipe Parameters (cont.)

1. The first prompt asks you to select the pipe material.

a. Press [ENTER] to enter the material prompt.

b. A drop-down list of materials opens. Table 5 below lists the available preprogrammed materials on the list. Press the [▼] or [▲] keys to scroll to the appropriate material, or scroll to “Other” for a material not on the list. You can press the [▶] key to scroll down by a page, or the [◀] key to scroll up by a page.

Table 5: Preprogrammed Pipe Materials

Pipe Material Category	Specific Material
Al - Aluminum	Rolled
Brass	None
Cu - Copper	Annealed or Rolled
CuNi - Copper/Nickel	70% Cu 30% Ni or 90% Cu 10% Ni
Glass	Pyrex, Flint, or Crown
Gold	Hard-drawn
Inconel	None
Iron	Armco, Ductile, Cast, Electrolytic
Monel	None
Nickel	None
Plastic	Nylon, Polyethylene, Polypropylene, PVC (CPVC), or Acrylic
Steel	Carbon Steel or Stainless Steel
Tin	Rolled
Titanium	None
Tungsten	Annealed, Carbide, Drawn
Zinc	Rolled
Other*	Any material

c. Press [ENTER] to confirm the choice.

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3.3 Entering Pipe Parameters (cont.)

d. If you have selected “Other,” the meter prompts you to enter the soundspeed. Use the numeric keys to type the desired soundspeed in the text box, and press [ENTER] to confirm the choice.

Note: *If the “Other” Pipe soundspeed entered is too large, given the previously entered Wedge soundspeed and angles, an error message similar to Figure 16 below will appear. Press* [F3] (OK) *(the error message disappears), and enter another soundspeed within the range specified.*

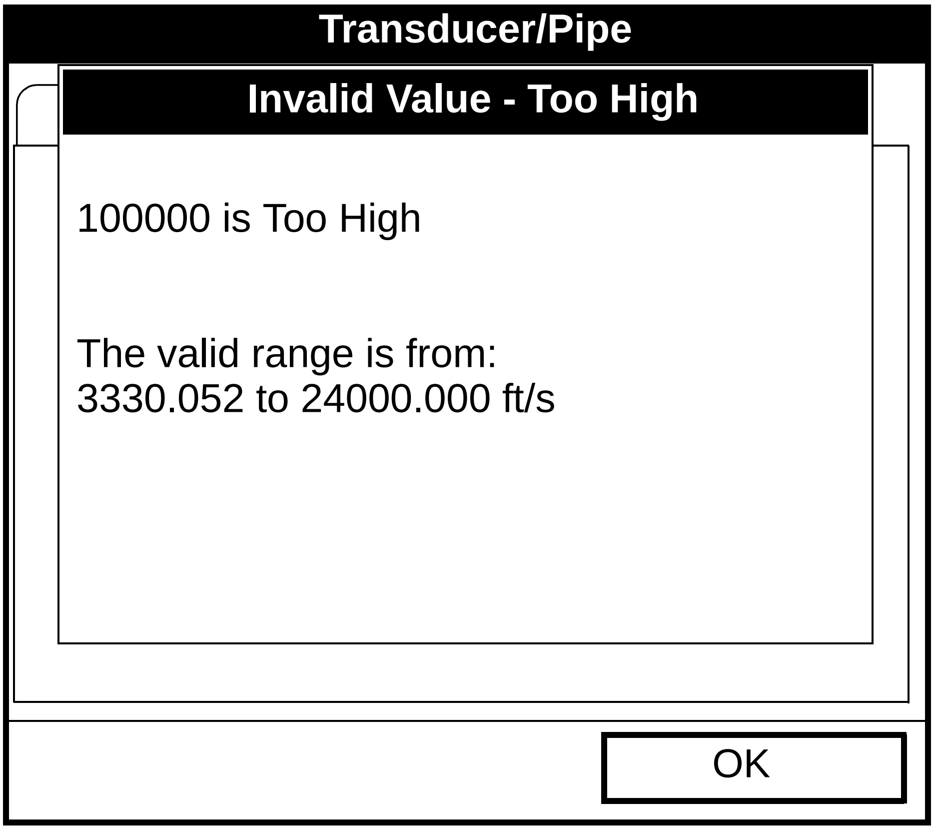

Figure 16: Soundspeed Error Message Window

Note: *When the corrected soundspeed is entered, a message similar to Figure 17 on page 33 appears. Press* [F3] (OK)*.to return to the Site Menu.*

3.3 Entering Pipe Parameters (cont.)

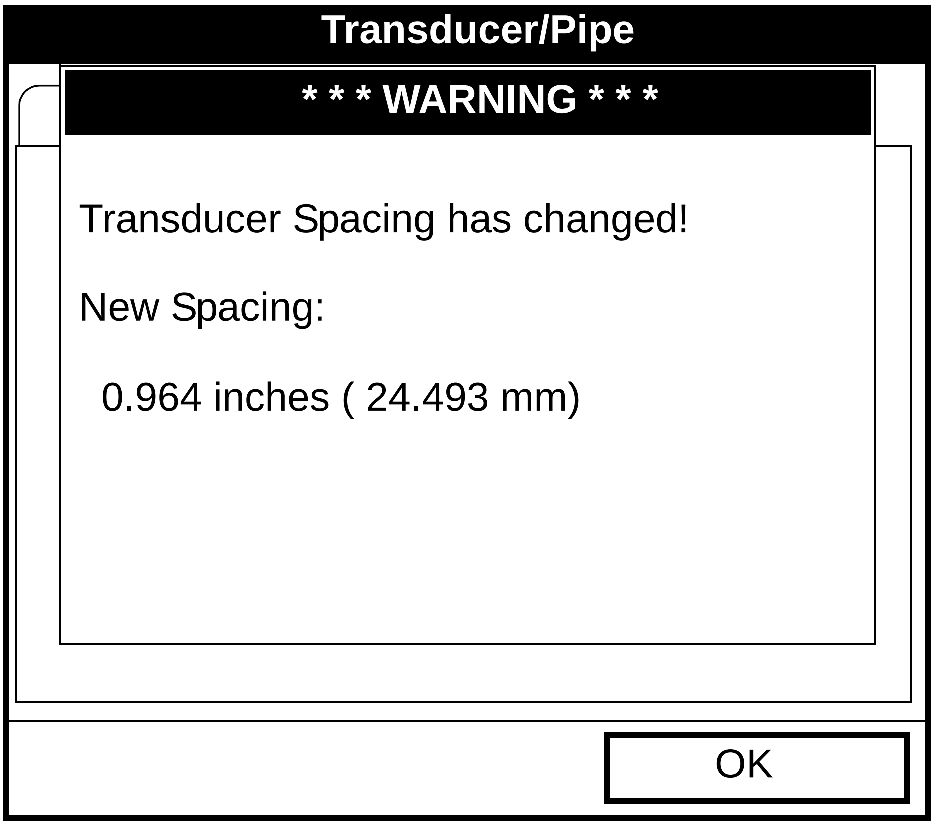

Figure 17: Transducer Spacing Change Window

2. The next prompt asks if you wish to measure the pipe wall with the internal thickness gauge. If you press [ENTER], the program moves to the T-Gauge Display option (as covered on page 162). When you have completed setting up and using the thickness gauge (as discussed in Chapter 8), press [F2] or [F3] to return to the Pipe tab.

3. For pipe diameter, two alternatives are available. At the Diameter prompt, the meter asks for the pipe outside diameter and thickness. But if you have selected certain pipe materials (carbon or stainless steel, cast iron, PVC and CPVC), you have the option of entering the pipe dimensions by a standardized schedule. Once you enter the nominal pipe size and identification, the PT878 determines the OD and wall thickness from an internal table.

3.3 Entering Pipe Parameters (cont.)

If you select a material that uses the Diameter alternative:

a. You must select from two choices, outside diameter or circumference.

- The prompt moves to the OD (outside diameter) text box. Type the thickness (in mm or in.) into the text box, and press [ENTER] to confirm the choice, or
- Move the prompt to the OD X PI (circumference) text box. Type the OD (in mm or in.) into the box, and press [ENTER] to confirm your choice.

b. In either case, the next prompt asks for the wall thickness. Type the value (in mm or in.) into the box, and press [ENTER] to confirm your choice.

Note: *The measurement units shown depend on the choices you have made in the English/Metric window or the Meter Settings menu.*

If you select a material that has the Schedule option:

a. The prompt asks if you wish to apply ANSI (the ANSI schedule). Press [ENTER] to select (or deselect) the ANSI box. (If you do not select the ANSI option, the prompt moves to the OD text box, and you enter the parameters for the Diameter alternative as discussed above.)

b. Press the [◀] key twice to move the prompt to the Nominal pipe size drop-down menu. Press [ENTER] to open the menu. Scroll to the desired pipe size, and press [ENTER] to confirm your choice.

c. Press the [▶] key to move the prompt to the Schedule drop-down menu. Press [ENTER] to open the menu. Scroll to the desired schedule, and press [ENTER] to confirm the choice.

After entering either diameter or schedule settings, pressing the [▲] key returns the meter to the Pipe Material prompt.

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3.3 Entering Pipe Parameters (cont.)

- To confirm the entries and return to Operate Mode, press [F3] (OK).
- To leave the window without confirming the entries, press [F2] (Cancel) or the [ESC] key.

In either case, the PT878 returns to Operate Mode.

- To return to the Pipe tab and scroll to other windows, press the [▲] key.

3.4 Entering Pipe Lining Parameters

To enter the Lining option, scroll to the Lining entry on the Program Menu and press [ENTER]. (From the Pipe window, you can scroll back up to the Pipe tab and press the [▶] arrow key to reach the Lining window, and press [ENTER].) The screen appears similar to Figure 18 below. To step through each parameter, press the [▼] key. While programming, refer to Figure 144 on page 228 of Appendix A, *Menu Maps*.

Note: *The Lining option is only available for clamp-on transducers.*

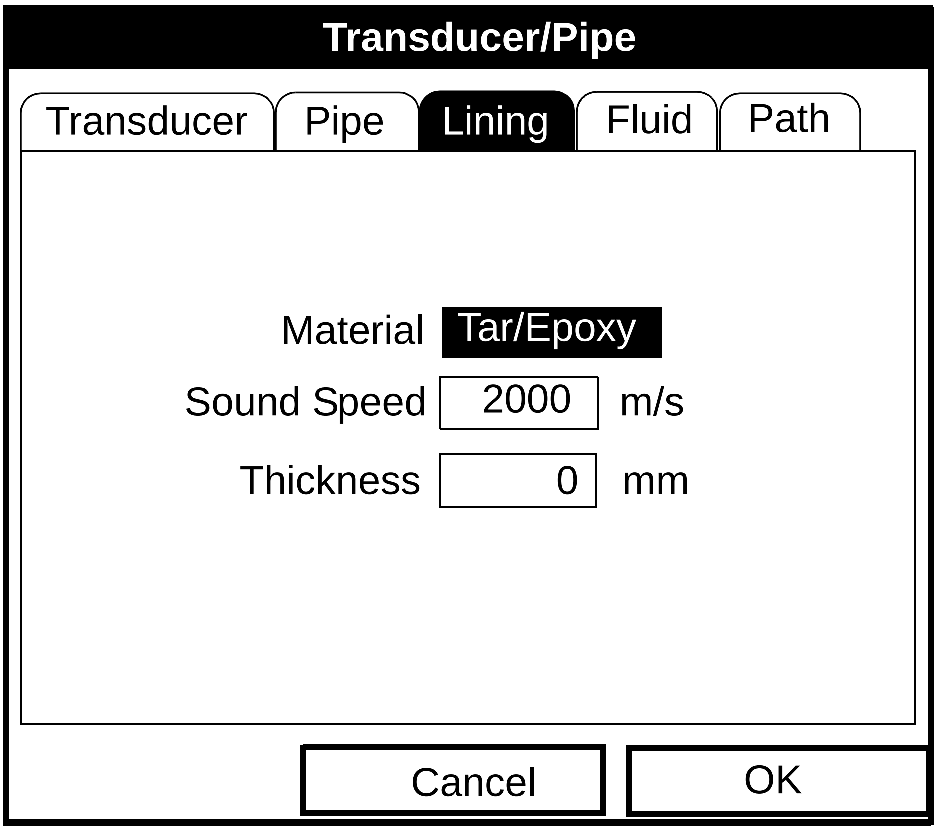

Figure 18: Pipe Lining Window

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3.4 Entering Pipe Lining Parameters (cont.)

1. The PT878 first prompts you to select the pipe lining material.

a. Press [ENTER] to open the drop-down list of lining materials.

b. Scroll to the appropriate material. If you do not see your lining material on the list, select "Other."

c. Press [ENTER] to confirm your choice.

Note: *If your pipe lining is not on the drop-down list, consult the factory for further information.*

2. The menu now follows one of two paths:

- If you have selected a preprogrammed material, the PT878 automatically supplies the correct soundspeed, and you can proceed to step 3.
- If you have selected "Other," the meter prompts you to enter the soundspeed. Use the numeric keys to type the desired soundspeed in the text box, and press [ENTER] to confirm the choice.

3. The meter now asks for the lining thickness. Use the numeric keys to enter the desired value in the text box, and press [ENTER] to confirm your entry.

Pressing the [▼] key returns the meter to the Lining tab.

- To confirm the entries and return to Operate Mode, press [F3] (OK). The PT878 returns to Operate Mode.
- To leave the window without confirming the entries, press [F2] (Cancel) or the [ESC] key. The PT878 returns to Operate Mode.
- To scroll to other windows, press the [◀] or [▶] key. Your changes will remain until you select OK or Cancel from one of the tabbed windows in the Transducer/Pipe form.

3.5 Entering Fluid Types and Speeds

To access the Fluid option, scroll to the Fluid entry on the Program Menu and press [ENTER]. (If you are already in the Transducer/Pipe form, press the [▶] arrow key to reach the Fluid window, and press [ENTER].)The screen appears similar to Figure 19 below. To step through each parameter, press the [▼] key. Refer to Figure 145 on page 229 of Appendix A, *Menu Maps*.

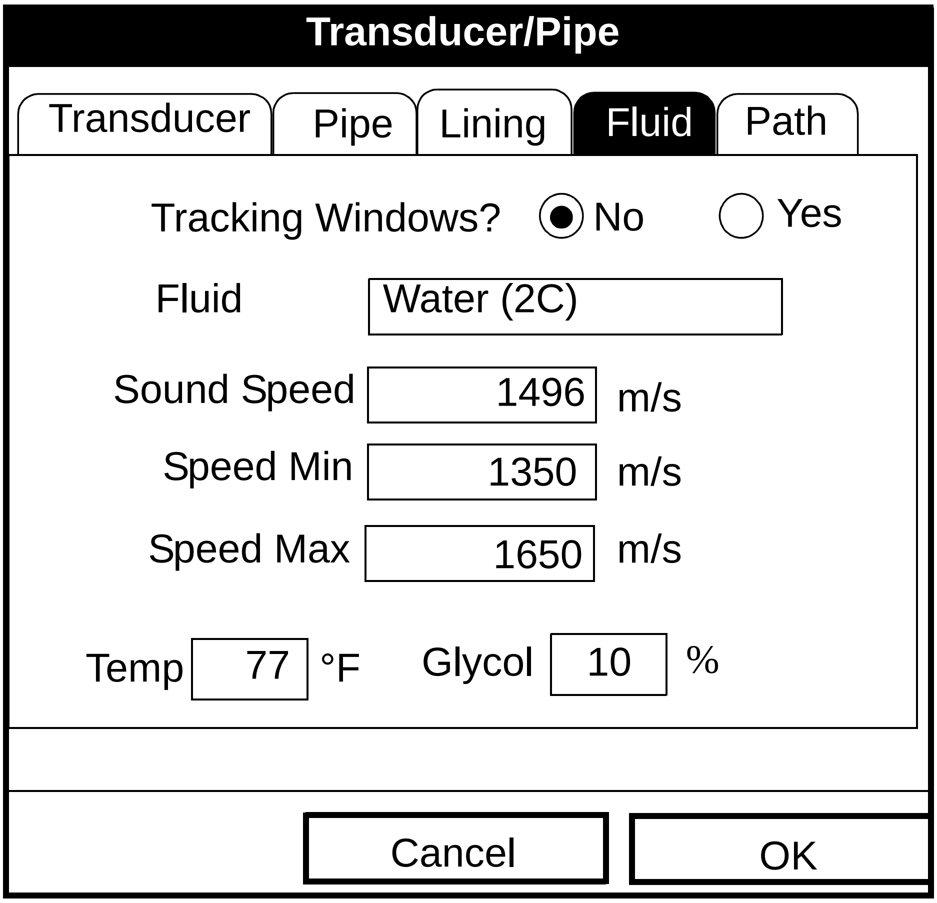

Figure 19: Fluid Type Window

1. The first prompt asks you to select whether or not you want Tracking Windows. These windows are used to detect the receive signal when you are unsure of the fluid soundspeed. (Default operation is “No.”)
   a. Use the [◀] and [▶] keys to scroll to the appropriate radio button.
   b. Press [ENTER] to confirm your selection.

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3.5 Entering Fluid Types and Speeds (cont.)

2. Next, you must select the fluid type.

a. Press [ENTER] to open the drop-down menu. Table 6 below lists the available choices, which vary with your selection of Tracking Windows or the Energy option.

Table 6: Fluid Type Selection

	Tracking Windows Off	Tracking Windows On
Energy Off	Other	Water (0-260°C)
	Water (0-260°C)	Oil
	Sea Water	Other
	Oil (22°C)	
	Crude Oil	
	Lube Oil (X200)	
	Methanol	
	Ethanol	
	LN2 (-199°C)	
	Freon (R-12)	
Energy On	Water/0-260°C	Water/0-260°C
	Water/Glycol (with glycol percentage)	Water/Glycol (with glycol percentage)
	Other (with single soundspeed)	Other (with minimum and maximum soundspeeds)

b. Scroll to the appropriate fluid. If you do not see your fluid on the list, select "Other."

Note: *Depending on your selection, additional prompts may appear, as specified in Table 6 above.*

c. Press [ENTER] to confirm your selection.

At the end of any sequence, pressing the [▼] key returns you to the Tracking Windows prompt.

- To confirm the entries and return to Operate Mode, press [F3] (OK).The PT878 returns to Operate Mode.
- To leave the window without confirming the entries, press [F2] (Cancel) or the [ESC] key. The PT878 returns to Operate Mode.
- To scroll to other windows, press the [◀] or [▶] key.

3.6 Entering the Signal Path Parameters

To enter the Path option, scroll to the Path entry on the Program Menu and press [ENTER]. (From the Lining window, you can scroll back up to the Lining tab and press the [▶] arrow key to reach the Path window, and press [ENTER].) The screen appears similar to Figure 20 below. To step through each parameter, press the [▼] key. Refer to Figure 146 on page 230 of Appendix A, *Menu Maps*.

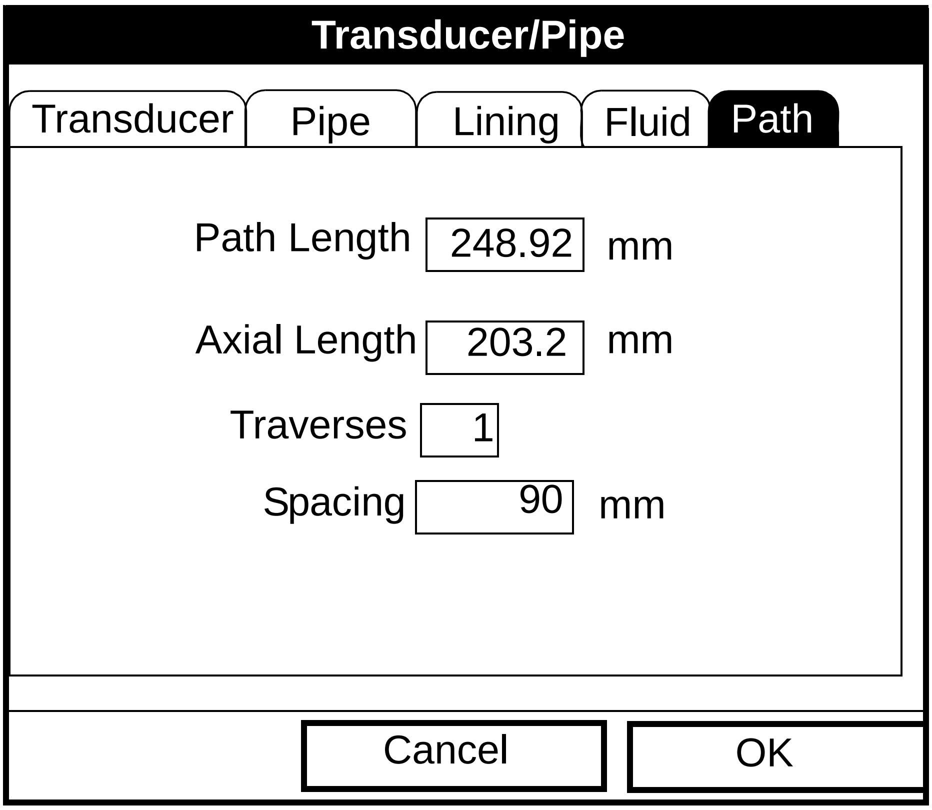

Figure 20: Signal Path Window

The prompts available for the Path option depend on whether you have selected clamp-on or wetted transducers in the Transducer menu. (If the PT878 does not scroll to a particular parameter, it is not necessary for that transducer type.)
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3.6.1 Path Parameters for Clamp-On Transducers

Note: *For wetted transducers, go to page 41.*

If you are using clamp-on transducers, the PT878 path menu includes two parameters:

- Traverses
- Spacing

1. The PT878 first prompts for traverses, the number of times the ultrasonic signal crosses the pipe (see the *Liquid Transducer Installation Guide* (916-055) for more details).

  a. Press [ENTER] to open the drop-down list of traverse numbers.

  b. Scroll to the appropriate number.

  c. Press [ENTER] to confirm the entry.

2. The next prompt displays the spacing of the transducers, as calculated from the information entered.

  a. Record this number and use it to space the transducers. (Use the *Liquid Transducer Installation Guide* (916-055) to assist in installing transducers on the pipe.) Press the [▼] key to scroll to the next parameter.

  b. If necessary, you can overwrite the spacing to match the actual physical spacing of the transducers. (Do not change the spacing by more than ±10% from that calculated by the meter.) Use the numeric keys to enter the desired value, and press [ENTER] to confirm the entry. If you have entered an invalid entry, the PT878 rejects the entry and displays an error message.

Note: *It is not recommended that you use a spacing other than the one calculated by the PT878.*

After you enter the spacing, pressing the [▲] key returns the prompt to the Traverses box, and then to the Path tab at the top of the screen.

3.6.2 Path Parameters for Wetted Transducers

If you are using wetted transducers, the PT878 path menu includes the following set of parameters:

- Path Length
- Axial Length

1. The meter first prompts for the path length (P) of the ultrasonic signal. GE has calculated the path length based on the transducer configuration for your particular application. Find the path length on the flowcell or on other supplied documentation.

a. Press [ENTER] to enter the text box.

b. Use the numeric keys to enter the appropriate number.

c. Press [ENTER] to confirm the entry.

Note: *If the documentation does not supply the path or axial lengths, refer to Appendix B,* Measuring P and L Dimensions, *to measure these lengths.*

2. The next prompt asks for the axial dimension (L) of the ultrasonic signal. Again, GE has calculated the axial dimension based on the transducer configuration for your particular application. Find the axial dimension on the flowcell or from other supplied documentation.

a. Press [ENTER] to enter the text box.

b. Use the numeric keys to enter the appropriate number.

c. Press [ENTER] to confirm the entry.

After you enter the axial length, press the [▲] key to return to the main Path tab at the top of the screen.

- To confirm the entries and return to Operate Mode, press [F3] (OK). The PT878 returns to Operate Mode.
- To leave the window without confirming the entries, press [F2] (Cancel) or the [ESC] key. The PT878 returns to Operate Mode.
- To scroll to other windows, press the [◀] or [▶] key.

3.7 Entering the Energy Option Parameters

The Energy Option enables you to calculate the energy of a system based on the temperature at a supply point, the temperature at a return point, and the flow of fluid through the system. To enter the Energy Option, scroll to the Energy entry on the Program Menu and press [ENTER]. The screen appears similar to Figure 21 below. To step through each parameter, press the [▼] key. While programming, refer to Figure 147 on page 231 of Appendix A, *Menu Maps*.

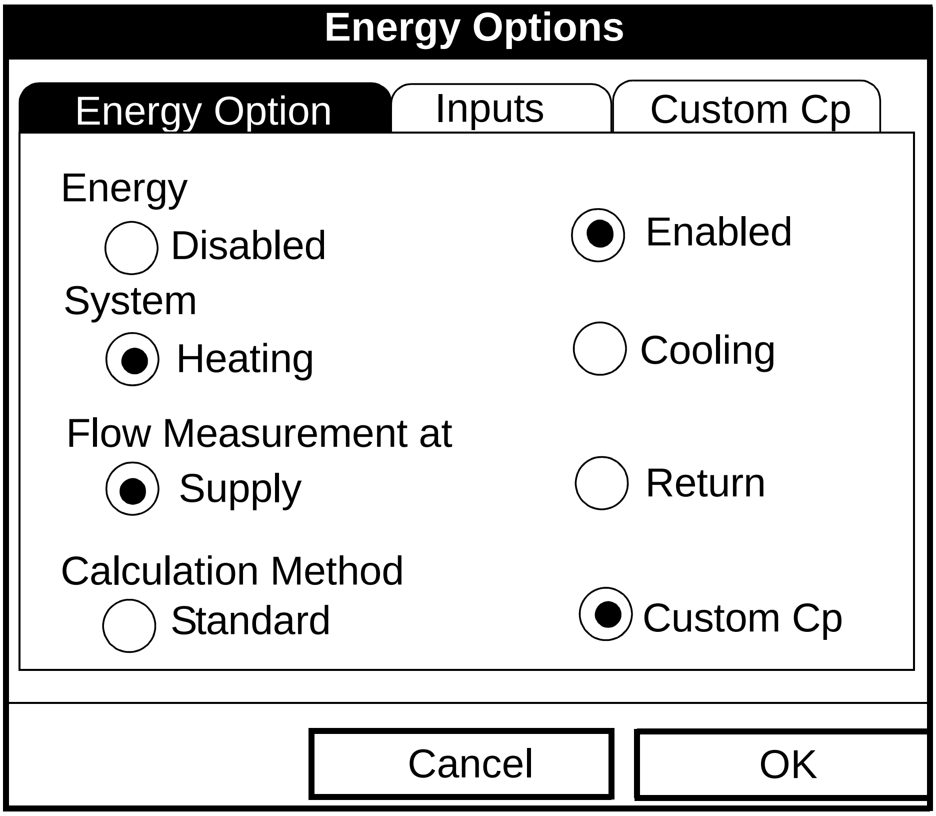

Figure 21: Energy Option Window

1. The first prompt asks if you want to disable or enable the Energy Option.
   a. Use the [◀] and [▶] keys to scroll to the appropriate radio button.
   b. Press [ENTER] to confirm your selection.

Note: *If you select “Disabled,” you cannot select any other prompt in this window.*

3.7 Entering the Energy Option Parameters (cont.)

2. The next prompt asks if you are using a heating or cooling system.
   a. Use the [◀] and [▶] keys to scroll to the appropriate radio button.
   b. Press [ENTER] to confirm your selection.
3. The program now asks if you are measuring flow at the point of supply or return.
   a. Use the [◀] and [▶] keys to scroll to the appropriate radio button.
   b. Press [ENTER] to confirm your selection.
4. The final prompt asks if you wish to use the standard or Custom Cp method for energy calculations. If you choose Custom Cp, you must enter tables for fluid enthalpy and density in the Custom Cp tab (see page 46).
   a. Use the [◀] and [▶] keys to scroll to the appropriate radio button.
   b. Press [ENTER] to confirm your selection.

Pressing the [▲] key returns the meter to the Energy prompt, and then to the Energy Option tab.

- To confirm the entries and return to Operate mode, press [F3] (OK). The PT878 returns to Operate Mode.
- To leave the window without confirming the entries, press [F2] (Cancel) or the [ESC] key. The PT878 returns to Operate Mode.

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3.7.1 Entering Inputs in the Energy Option

To enter input parameters in the Energy Option, return to the Energy Option tab at the top of the Energy Option window. Press the [▶] arrow key to reach the Inputs window, and press [ENTER]. The screen appears similar to Figure 22 below. To step through each parameter, press the [▼] key.

Important: *The supply and return must be on separate inputs.*

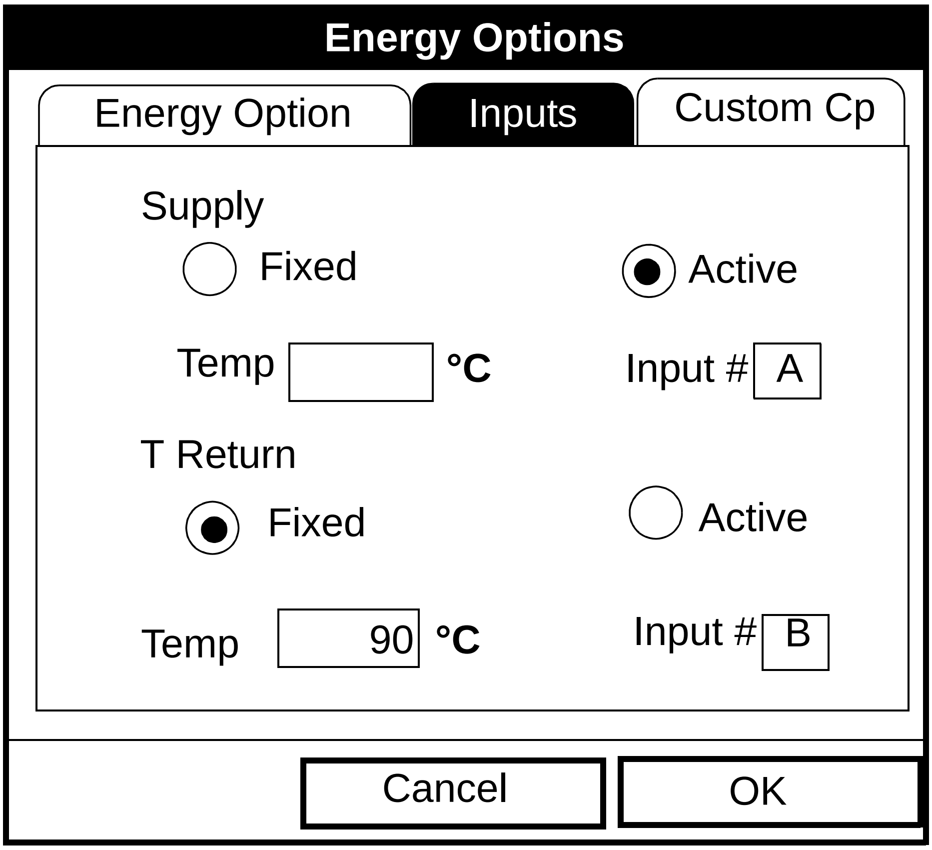

Figure 22: Inputs Tab in the Energy Option

1. The first prompt asks if the temperature supply is fixed or active.

a. Use the [◀] and [▶] keys to scroll to the appropriate radio button.

b. Press [ENTER] to confirm your selection.

3.7.1 Entering Inputs in the Energy Option (cont.)

2. The next prompt depends on whether you have selected a fixed or an active supply.

- If you have selected a fixed supply, the PT878 asks for the desired temperature. Use the numeric keys to enter the desired temperature (in degrees C), and press [ENTER] to confirm the entry.
- If you have selected an active supply, the PT878 asks for the desired input.

  a. Press [ENTER] to open the drop-down menu.

  b. Scroll to Input A or B.

  c. Press [ENTER] to confirm the entry.

3. The next prompt asks if the temperature return is fixed or active.

  a. Use the [◀] and [▶] keys to scroll to the appropriate radio button.

  b. Press [ENTER] to confirm your selection.

4. The next prompt depends on whether you have selected a fixed or an active return.

- If you have selected a fixed return, the PT878 asks for the desired temperature. Use the numeric keys to enter the desired temperature (in degrees C), and press [ENTER] to confirm the entry.
- If you have selected an active return, the PT878 asks for the desired input.

  a. Press [ENTER] to open the drop-down menu.

  b. Scroll to Input A or B.

  c. Press [ENTER] to confirm the entry.

Note: *If either input is fixed, the analog input(s) not used by the Energy Option can act as general-purpose inputs.*

Pressing the [▼] key returns the meter to the Inputs tab.

3.7.1 Entering Inputs in the Energy Option (cont.)

- To confirm the entries and return to Operate mode, press [F3] (OK). The PT878 returns to Operate Mode.
- To leave the window without confirming the entries, press [F2] (Cancel) or the [ESC] key. The PT878 returns to Operate Mode.

To enter data for Custom Cp calculations, proceed to the Custom Cp tab, discussed on page 46.

3.7.2 Entering Custom Cp Data in the Energy Option

To program Custom Cp tables in the Energy Option, return to the tabs at the top of the Energy Option window. Press the [▶] arrow key until you have highlighted the Custom Cp tab, and press [ENTER]. The screen appears similar to Figure 23 below. To step through each parameter, press the [▼] key.

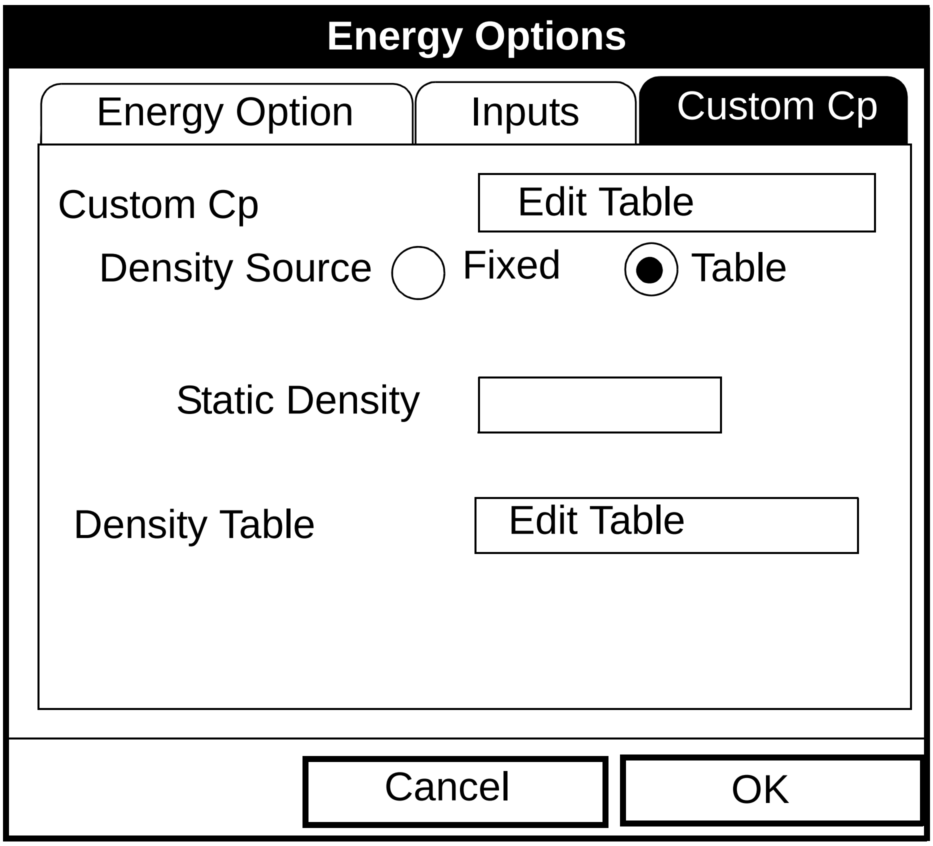

Figure 23: Custom Cp Tab in the Energy Option

3.7.2 Entering Custom Cp Data in the Energy Option (cont.)

1. The first prompt asks if you wish to enter or edit data in the Custom Cp (enthalpy) table.

a. Press [ENTER] to open the Custom Cp table, shown in Figure 24 on page 47.

b. Use the numeric keys to enter the desired temperature in degrees Kelvin, and press [ENTER] to confirm the entry.

c. Press the [▶] key to move to the kJ/kg/°K column (enthalpy in KiloJoules/Kilogram/°Kelvin). Use the numeric keys to enter the desired value, and press [ENTER].

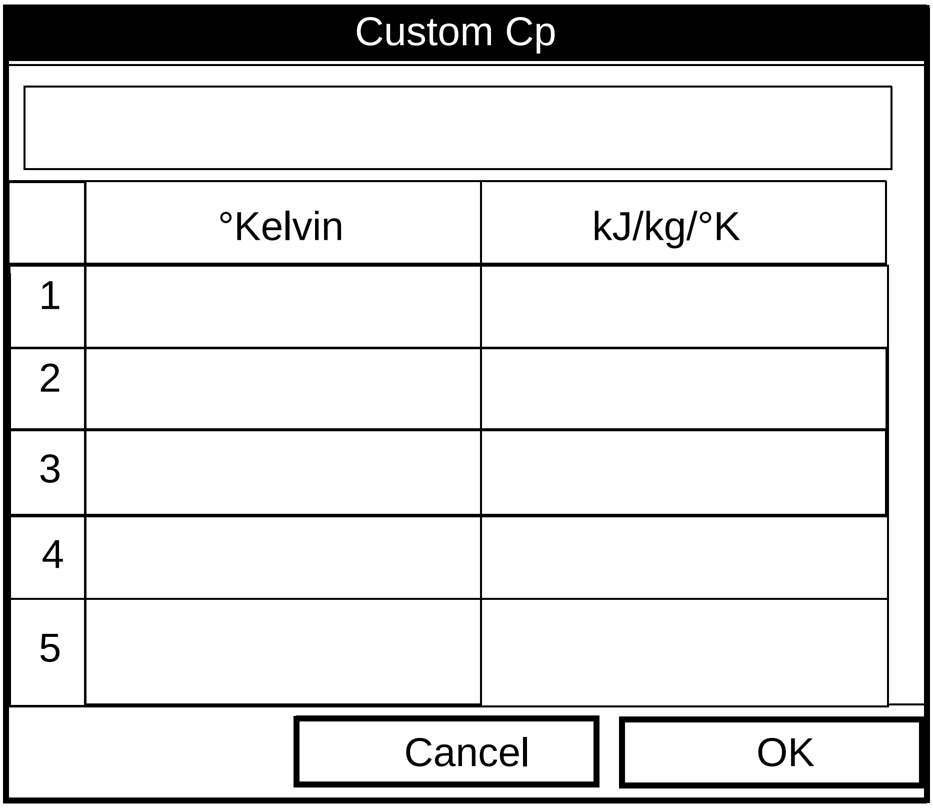

Figure 24: Custom Cp (temperature vs. enthalpy) Table

d. Repeat steps b and c for the remainder of the table.

e. When you have completed entering values, press [F3] (OK) to confirm the table and return to the Custom Cp window.

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3.7.2 Entering Custom Cp Data in the Energy Option (cont.)

2. The next prompt asks from which source — a fixed value or table — the PT878 will use for fluid density values. Use the [◀] and [▶] keys to scroll to the appropriate radio button, and press [ENTER].

3. The menu now varies, depending on your selection in step 2.

- If you selected “Fixed,” the PT878 asks for the fixed fluid density. Use the numeric keys to enter the desired value, and press [ENTER].
- If you selected “Table,” the meter highlights the “Edit Table” button.

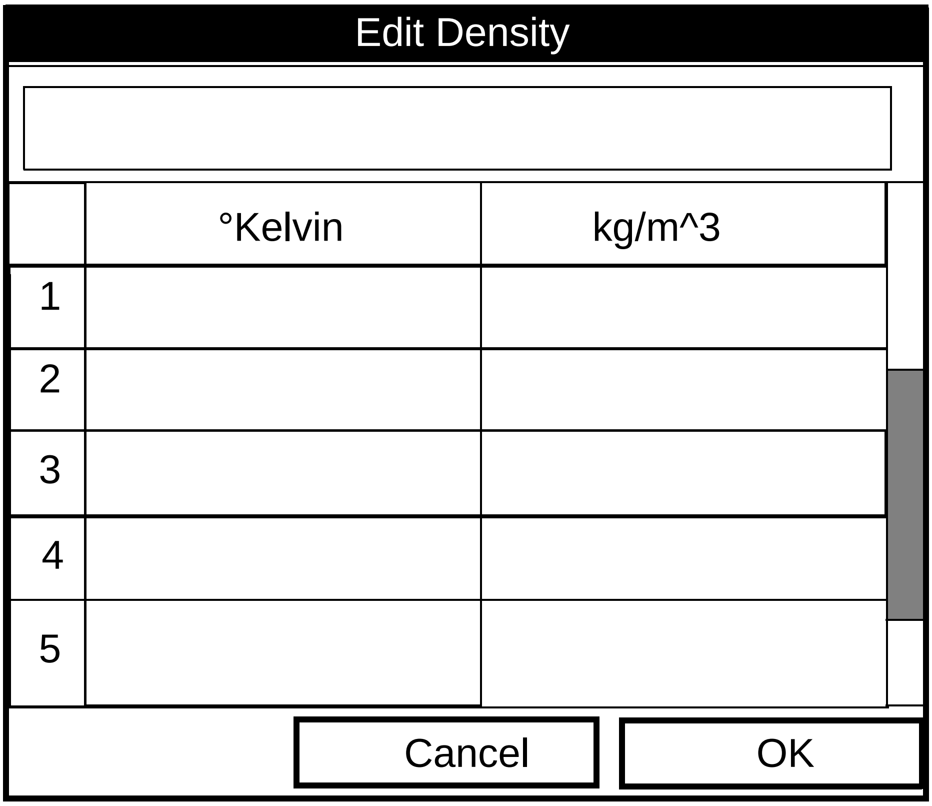

Figure 25: Fluid Density Table

a. Press [ENTER] to open the Edit Density table, shown in Figure 25 above.

b. Use the numeric keys to enter the desired temperature in degrees Kelvin, and press [ENTER].

c. Press the [▶] key to move to the kg/m^3 column (density in Kilogram/cubic meters). Use the numeric keys to enter the desired value, and press [ENTER].

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3.7.2 Entering Custom Cp Data in the Energy Option (cont.)

d. Repeat steps b and c for the remainder of the table.

e. When you have completed entering up to 20 values, press [F3] (OK) to confirm the table and return to the Custom Cp window.

- To confirm the entries and return to Operate mode, press [F3] (OK). The PT878 returns to Operate Mode.
- To leave the window without confirming the entries, press [F2] (Cancel) or the [ESC] key. The PT878 returns to Operate Mode.

3.8 Entering Analog Inputs

The Analog Input option enables you to specify parameters for general purpose or energy inputs. To enter the Inputs option, scroll to the Analog Input entry on the Program Menu and press [ENTER]. If you have not enabled the Energy Option (see page 42), the screen appears similar to Figure 26 below. To step through each parameter, press the [▼] key. Refer to Figure 148 on page 232 of Appendix A, *Menu Maps*.

3.8.1 Entering General-Purpose Analog Inputs

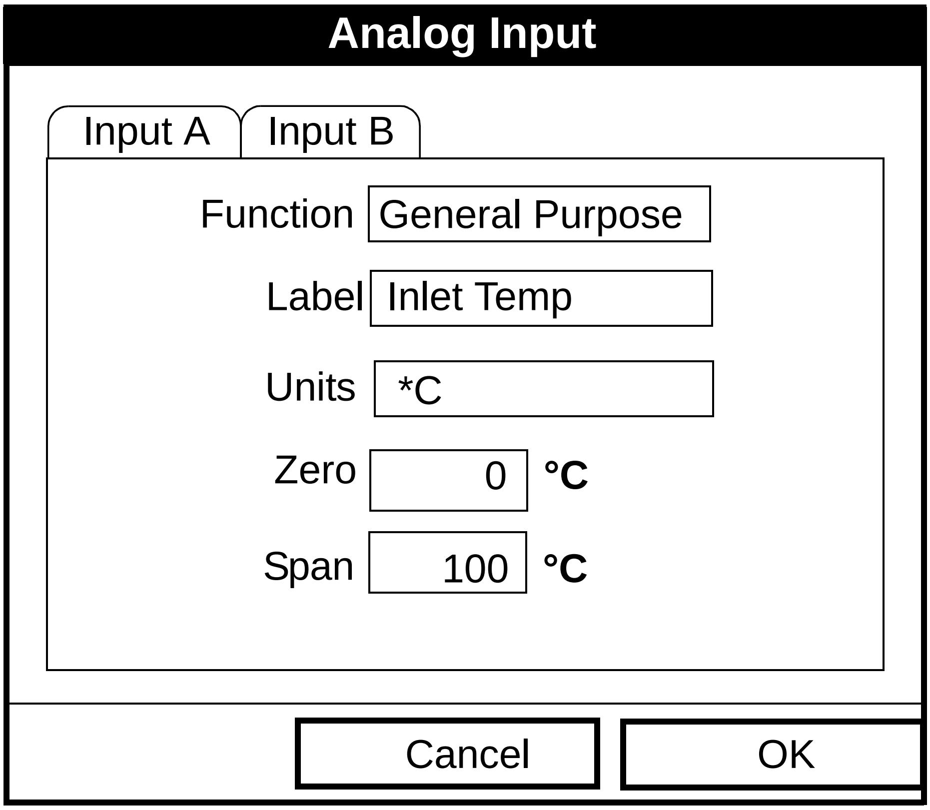

Figure 26: Analog Inputs Option Window

1. The first prompt asks you to select whether the desired function is off or general purpose.

a. Press [ENTER] to open the drop-down menu.

b. Scroll to the desired response.

c. Press [ENTER] to confirm your selection.

3.8.1 Entering General-Purpose Analog Inputs (cont.)

2. The next prompt asks if you want to label the input.

a. Press [ENTER] to enter the text box. The text creation window appears, as shown in Figure 27 below.

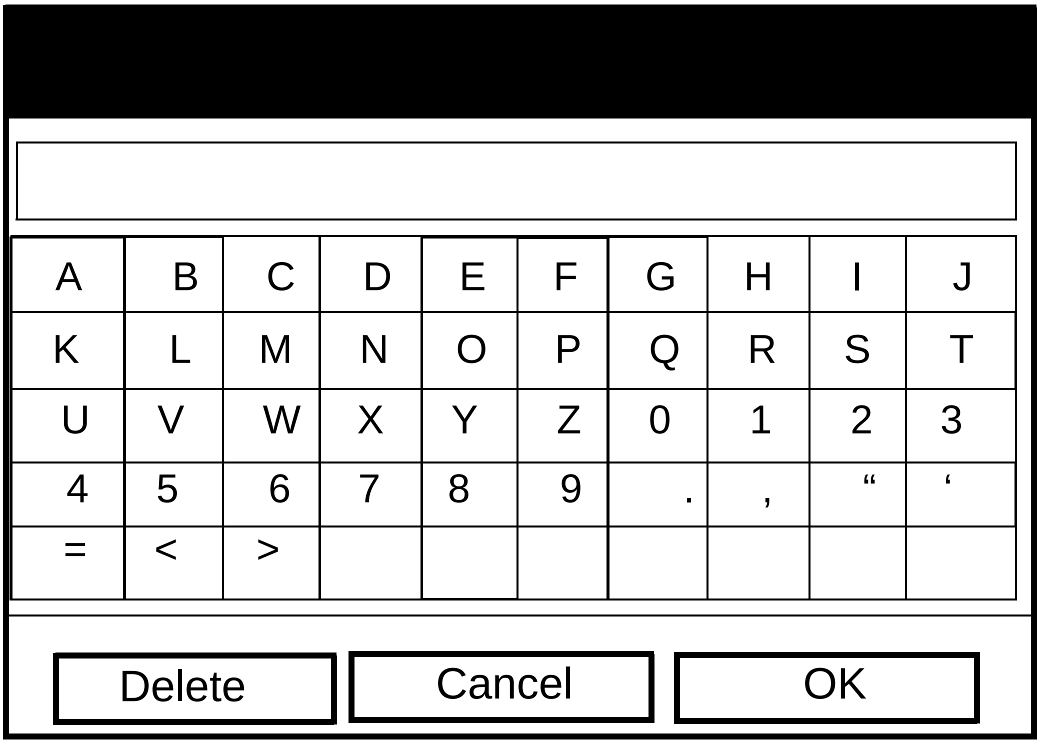

Figure 27: Text Creation Window

b. Use the four arrow keys to scroll to the desired letter or symbol, and press [ENTER] to add the letter to the name.

Note: *Pressing* [SEL] *causes the screen to show successively a set of upper-case (capital) letters, a set of lower-case letters, and a set of symbols. Use all three screens to create a desired label.*

c. Repeat this procedure for each letter or symbol you wish to add to the name. If you wish to delete a letter, press [F1] (Delete) to erase each letter or symbol, from right to left on the label.

d. When you have completed the label, press [F3] (OK) to confirm the label, or [F2] (Cancel) to leave the window without adding the label.

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3.8.1 Entering General-Purpose Analog Inputs (cont.)

3. The next prompt asks you to create a label for the units, if desired. (This label will appear to the right of the zero and span value boxes.) Press [ENTER] to reopen the text creation window, and follow the same steps covered in Step 2 on page 51.

4. The next prompt asks for the zero input value.

- **a.** Press [ENTER] to enter the text box.
- **b.** Use the numeric keys to enter the desired value.
- **c.** Press [ENTER] to confirm the entry.

5. The final prompt asks for the span input value.

- **a.** Press [ENTER] to enter the text box.
- **b.** Use the numeric keys to enter the desired value.
- **c.** Press [ENTER] to confirm the entry.

You have completed entering data for general-purpose inputs.

3.8.2 Entering Analog Inputs in the Energy Option

If you have enabled the Energy Option, the screen displays fewer options, as shown in Figure 28 below.

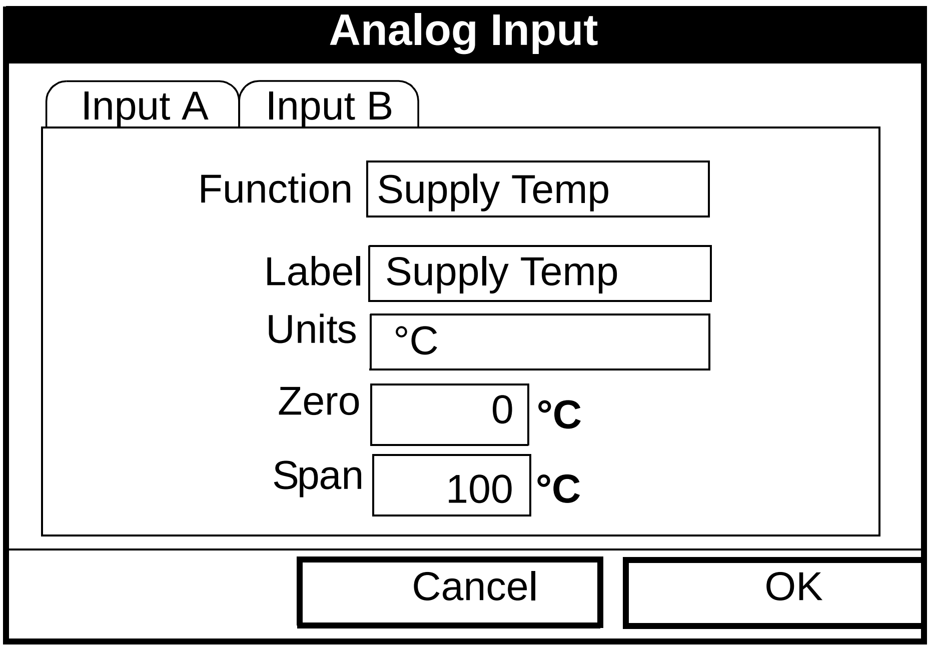

Figure 28: Analog Inputs Option Window - Energy Option Activated 327

3.8.2 Entering Analog Inputs in the Energy Option (cont.)

The screen displays the function (supply or return temperature), label (supply or return temperature) and units selected in the Inputs form of the Energy Option (see page 44). You cannot change these parameters in this form. Press the [▼] key to step through these parameters.

1. The first prompt asks for the zero input value.

- **a.** Press [ENTER] to enter the text box.
- **b.** Use the numeric keys to enter the desired value.
- **c.** Press [ENTER] to confirm the entry.

2. The final prompt asks for the span input value.

- **a.** Press [ENTER] to enter the text box.
- **b.** Use the numeric keys to enter the desired value.
- **c.** Press [ENTER] to confirm the entry.

You have completed entering parameters in the Analog Inputs option.

- To confirm the entries and return to Operate mode, press [F3] (OK). The PT878 returns to Operate Mode.
- To leave the window without confirming the entries, press [F2] (Cancel) or the [ESC] key. The PT878 returns to Operate Mode.

3.9 Entering the Analog Output

The Analog Output option enables you to enter information to set up output parameters. To enter the option, scroll to the Analog Output entry on the Program Menu and press [ENTER]. The screen appears similar to Figure 29 below. To step through each parameter, press the [▼] key. Refer to Figure 149 on page 233 of Appendix A, *Menu Maps*.

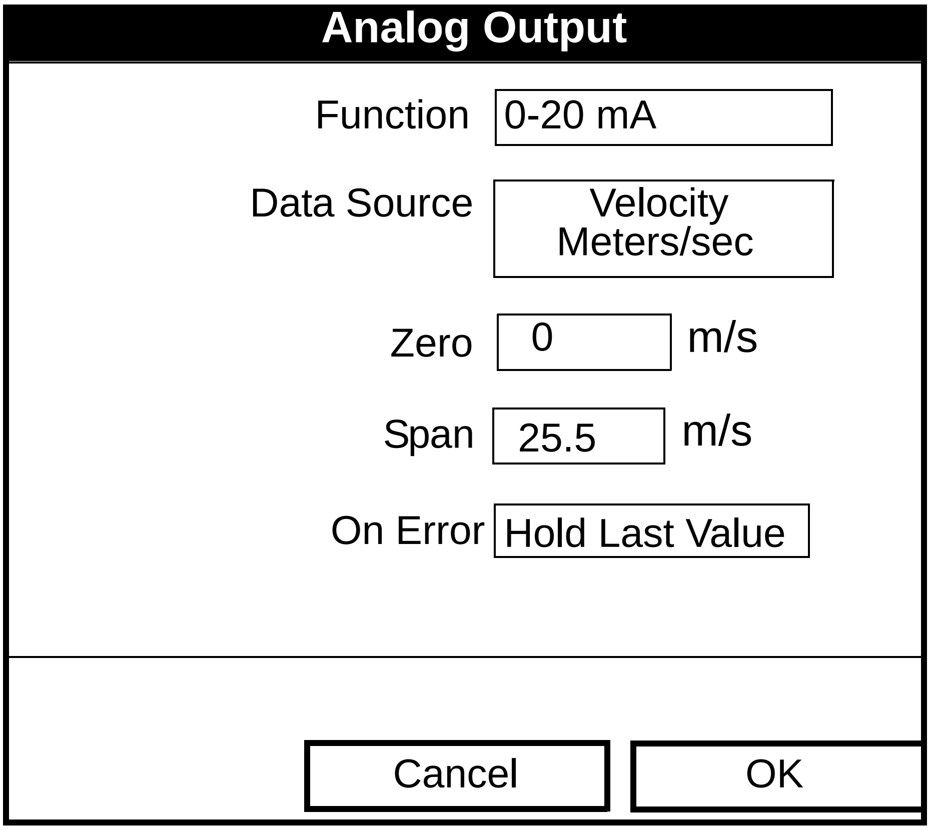

Figure 29: Analog Output Window

1. The first prompt enables you to select a range to send a current signal to a recording device.
   a. Press [ENTER] to open the drop-down menu.
   b. Scroll to the desired output from three choices: Off, 0-20 mA, and 4-20 mA.
   c. Press [ENTER] to confirm your selection.

Note: *If you select "Off," you will not be able to access any other parameters in this option.*

3.9 Entering the Analog Output (cont.)

2. The next prompt asks you to select the analog output type from a list of choices, as shown in Figure 30 below.

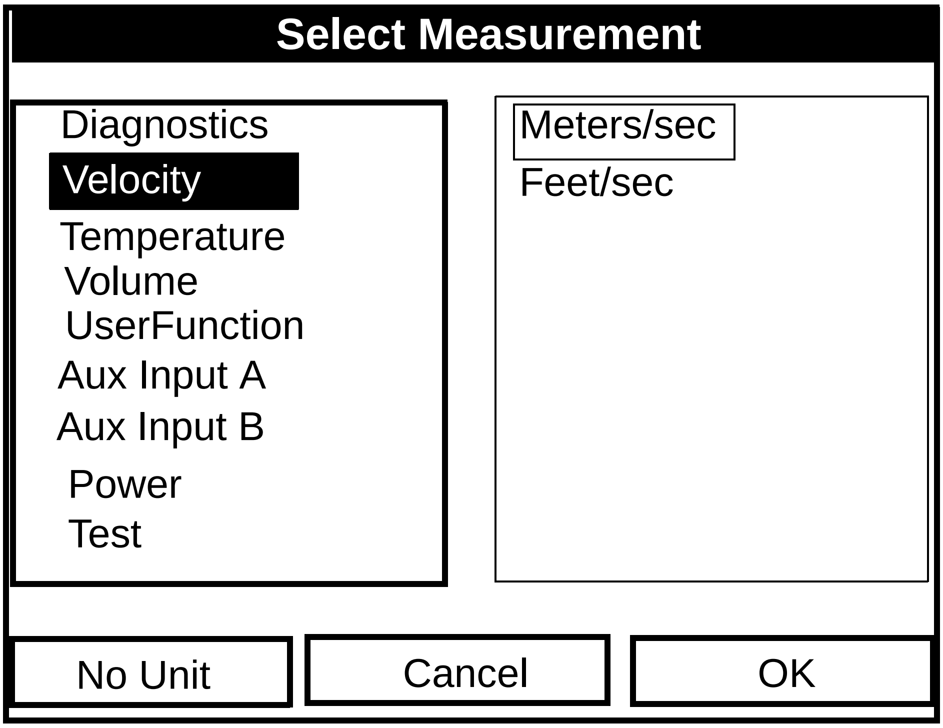

Figure 30: Data Source Selection Window

a. Press [ENTER] to open the window.

b. Scroll to the desired output type.

c. Press [SEL] to confirm your selection.

d. The prompt then moves to a list of unit types. (The available units depend on the selection made at the Data Source prompt.) Scroll to the desired output unit.

e. Press [F3] (OK) to confirm your selection.

3.9 Entering the Analog Output (cont.)

3. The next prompt asks you to enter the zero (base) value for the analog output. This value represents the 0/4 mA output (in flow units).

- **a.** Press [ENTER] to open the text box.
- **b.** Use the numeric keys to enter the desired value.
- **c.** Press [ENTER] to confirm your selection.

4. The next prompt asks you to enter the span (full scale) value for the analog output. This value represents the 20 mA output (in flow units).

- **a.** Press [ENTER] to open the text box.
- **b.** Use the numeric keys to enter the desired value.
- **c.** Press [ENTER] to confirm your selection.

5. The last prompt, On Error, asks you to select how the PT878 will handle the analog outputs in the event of a fault condition. The meter offers three alternatives:

- Hold Last Value (hold the last good reading)
- Force Low (force the reading to 0 or 4 mA)
- Force High (force the reading to 20 mA).

- **a.** Press [ENTER] to open the drop-down menu.
- **b.** Scroll to the desired selection.
- **c.** Press [ENTER] to confirm your selection.

You have completed entering data in the Analog Output option.

- To confirm the entries and return to Operate mode, press [F3] (OK). The PT878 returns to Operate Mode.
- To leave the window without confirming the entries, press [F2] (Cancel) or the [ESC] key. The PT878 returns to Operate Mode.

3.10 Entering the Digital Output

While resembling the Analog Output option, the Digital Output option enables you to set up parameters necessary for a digital output. To enter the option, scroll to the Digital Output entry on the Program Menu and press [ENTER]. The screen appears similar to Figure 31 below. To step through each parameter, press the [▼] key. While programming, refer to Figure 150 on page 234 of Appendix A, *Menu Maps*.

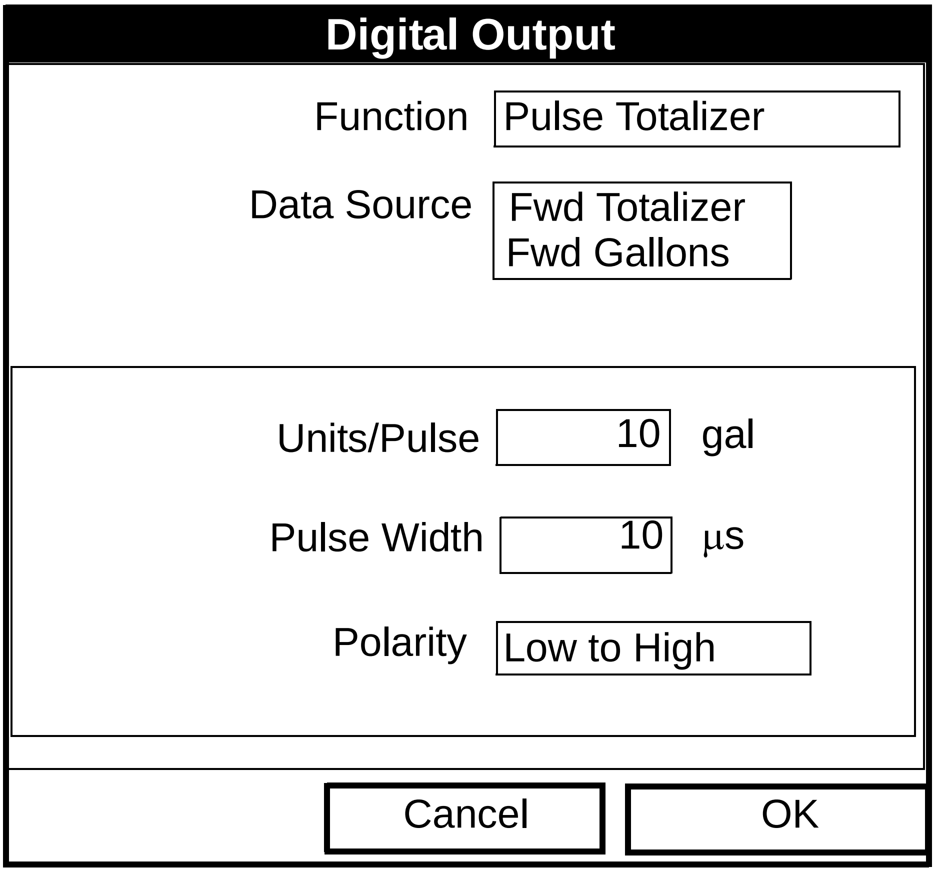

Figure 31: Digital Output Window

1. The first prompt enables you to select the output function from five choices:

- Off
- Pulse Totalizer
- Frequency
- Test Points
- Gate Input

3.10 Entering the Digital Output (cont.)

a. Press [ENTER] to open the drop-down menu.

b. Scroll to the desired function.

c. Press [ENTER] to confirm your selection.

Note: *If you select Off, you will not be able to access any other parameters in this option. If you select Test Points or Gate Input, the program goes at once to Step 4.*

2. The next prompt asks you to select the data source for the digital output. The choices vary with the function. For Pulse Totalizer (shown in Figure 31 on page 57, the available choices include:

- Forward Totalizer
- Reverse Totalizer
- Forward Energy
- Reverse Energy

a. Press [ENTER] to open the data source selection window, shown in Figure 30 on page 55.

b. Scroll to the desired source.

c. Press [SEL] to confirm your selection.

d. The prompt then moves to a list of unit types. (The available units depend on the selection made at the Data Source prompt.) Scroll to the desired output unit.

e. Press [F3] (OK) to confirm your selection.

3. The last set of parameters that appears depends on the selection you made at the Function prompt.

If you selected Pulse Totalizer:

The prompt asks for the units/pulse, the pulse width (in microseconds), and the polarity. (Figure 31 on page 57 illustrates a Digital Output window configured for the Pulse Totalizer function.) For the Units/Pulse and Pulse Width parameters: 333

3.10 Entering the Digital Output (cont.)

a. Press [ENTER] to open the text box.

b. Use the numeric keys to enter the desired value.

c. Press [ENTER] to confirm your selection.

For Polarity:

a. Press [ENTER] to open the drop-down menu.

b. Scroll to the desired polarity, either Low to High or High to Low.

c. Press [ENTER] to confirm your selection.

If you selected Frequency:

The prompt asks for the minimum and maximum frequencies and the duty cycle percentage. For each parameter:

a. Press [ENTER] to open the text box.

b. Use the numeric keys to enter the desired value.

c. Press [ENTER] to confirm your selection.

If you entered Test Points:

The prompt asks for the window (trigger) type from two choices, transmit and receive. These two windows can be used to trigger an oscilloscope to look at the receive signal output on another channel.

a. Press [ENTER] to open the drop-down menu.

b. Scroll to the desired signal.

c. Press [ENTER] to confirm your selection.

3.10 Entering the Digital Output (cont.)

If you entered Gate Input:

Note: *Gate Input is used to synchronize the totalizer with the meter calibration system (discussed on page 67). The gate stops and starts the meter totalizer, so that you can compare the totalizer figure with the measured volume of water in the weight tank.*

1. The prompt asks for the gate active.

a. Press [ENTER] to open the drop-down menu.

b. Scroll to the desired gate active, whether Contact Open or Contact Closed.

c. Press [ENTER] to confirm your selection.

2. The second prompt asks for the mode.

a. Press [ENTER] to open the drop-down menu.

b. Scroll to the desired mode, either Automatic or Manual.

c. Press [ENTER] to confirm your selection.

Stopwatch Totalizer

Through the Gate Input option, you can implement the Stopwatch Totalizer function to measure totals manually. To set up the Totalizer function:

1. At the Gate Active prompt, select Contact Open.

2. At the Mode prompt, select Manual, and press [ENTER]. (Selecting Automatic causes the totalizer to run continuously.)

The stopwatch icon (see page 19) appears in the system tray. To start or stop the function, press the minus (–) key on the keypad.

You have completed entering parameters in the Digital Output option.

- To confirm the entries and return to Operate mode, press [F3] (OK). The PT878 returns to Operate Mode.
- To leave the window without confirming the entries, press [F2] (Cancel) or the [ESC] key. The PT878 returns to Operate Mode.

3.11 Entering User Functions

User functions enable you to program mathematical equations on each measurement. You can also use any parameter in the meter to calculate a different parameter. To enter the User Functions option, scroll to the User Functions entry on the Program Menu and press [ENTER]. The screen appears similar to Figure 32 below. To step through each parameter, press the [▼] key. Refer to Figure 151 on page 235 of Appendix A, *Menu Maps*.

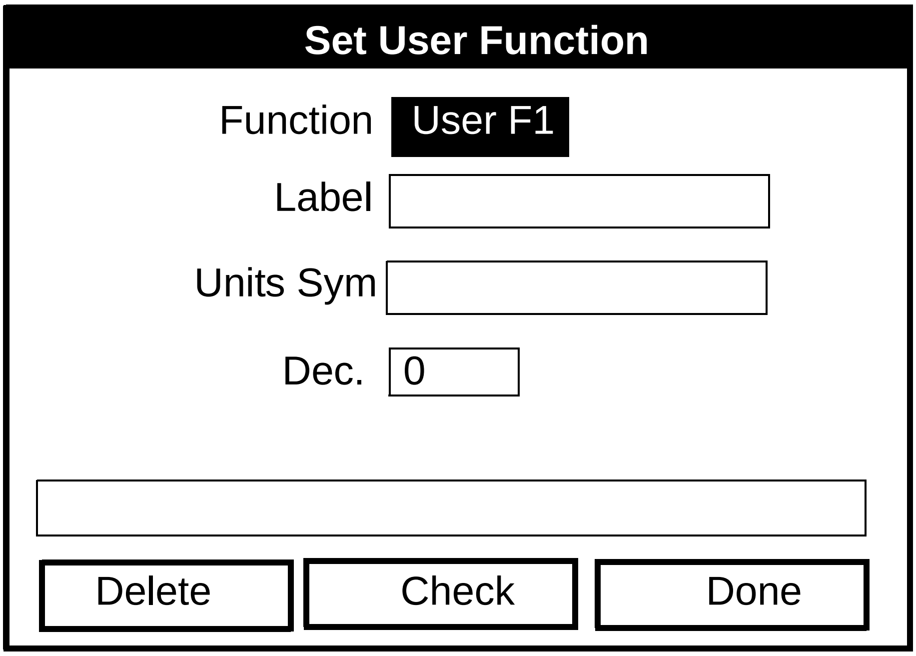

Figure 32: User Functions Window

1. The first prompt asks you to select the function number, 1 through 8.

a. Press [ENTER] to open the drop-down menu.

b. Scroll to the desired function number (User F1, User F2, etc.).

c. Press [ENTER] to confirm the entry.

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3.11 Entering User Functions (cont.)

2. The next prompt asks you to create a label for the function. The label corresponds to the measurement type (i.e., velocity or temperature), while the units symbol corresponds to the measurement units (i.e., feet/sec or degrees F).

a. Press [ENTER] to open the text creation window, which appears similar to Figure 33 below.

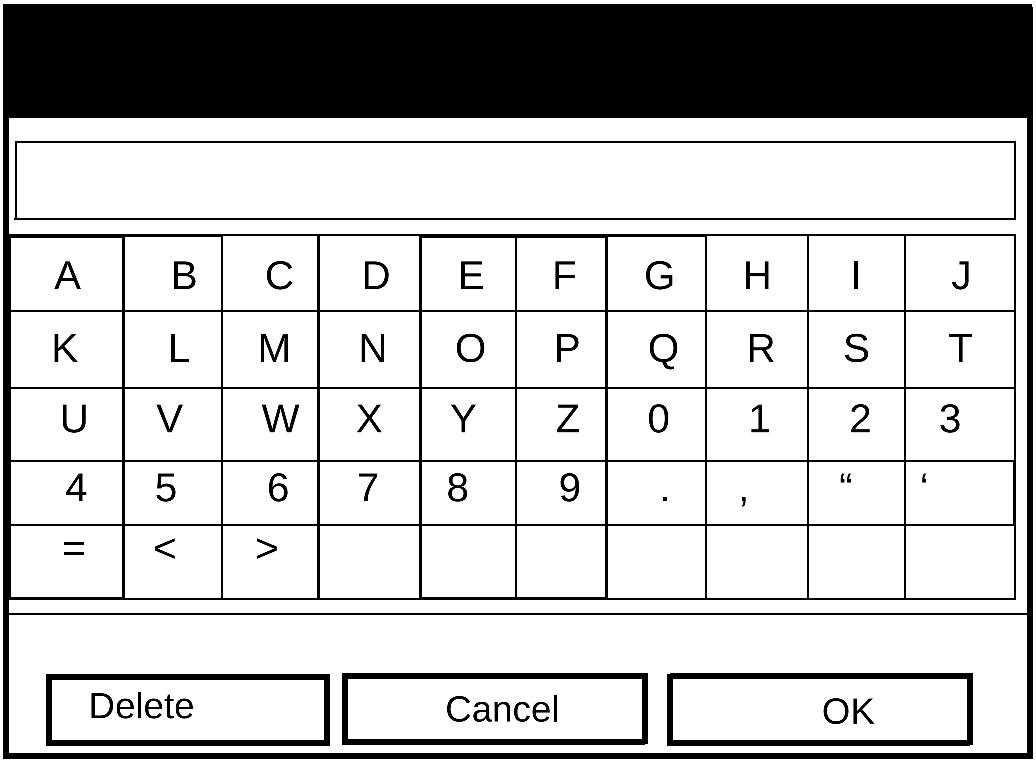

Figure 33: Text Creation Window

b. Use the four arrow keys to scroll to the desired letter or symbol, and press [ENTER] to add the letter to the label.

Note: *Pressing* [SEL] *causes the screen to alternate between a set of upper-case (capital) letters, a set of lower-case letters, and a set of symbols. Use all three screens to create a desired label.*

c. Repeat this procedure for each letter or symbol you wish to add to the label. If you wish to delete a letter, press [F1] (Delete) to erase each letter or symbol, from right to left on the label.

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3.11 Entering User Functions (cont.)

d. When you have completed the label, press [F3] (OK) to confirm the label, or [F2] (Cancel) to leave the window without adding the label.

3. The next prompt asks for the Units Symbol.

   a. Press [ENTER] to reopen the text creation window.

   b. Repeat the procedure used for the Label (on page 62) to create the Units Symbol.

   c. When you have completed the label, press [F3] (OK) to confirm the symbol, or [F2] (Cancel) to leave the window without adding the symbol.

4. The next prompt asks you to select the number of decimal places.

   a. Press [ENTER] to open the drop-down menu.

   b. Scroll to the desired number of decimal places, ranging from 0 to 4.

   c. Press [ENTER] to confirm the entry.

5. The final prompt asks for the function itself.

   a. Press [ENTER] to open the function creation window, which appears similar to Figure 34 on page 64.

   b. Use the four arrow keys to scroll to the desired function or table, and press [ENTER] to confirm each entry. Use the numeric keys to enter numeric values. Press [F1] (Delete) to remove any mistaken or unwanted symbols or numbers.

Note: *Pressing* [SEL] *causes the screen to alternate between a set of symbols and functions and a list of user functions. Use both screens to create the desired function.*

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3.11 Entering User Functions (cont.)

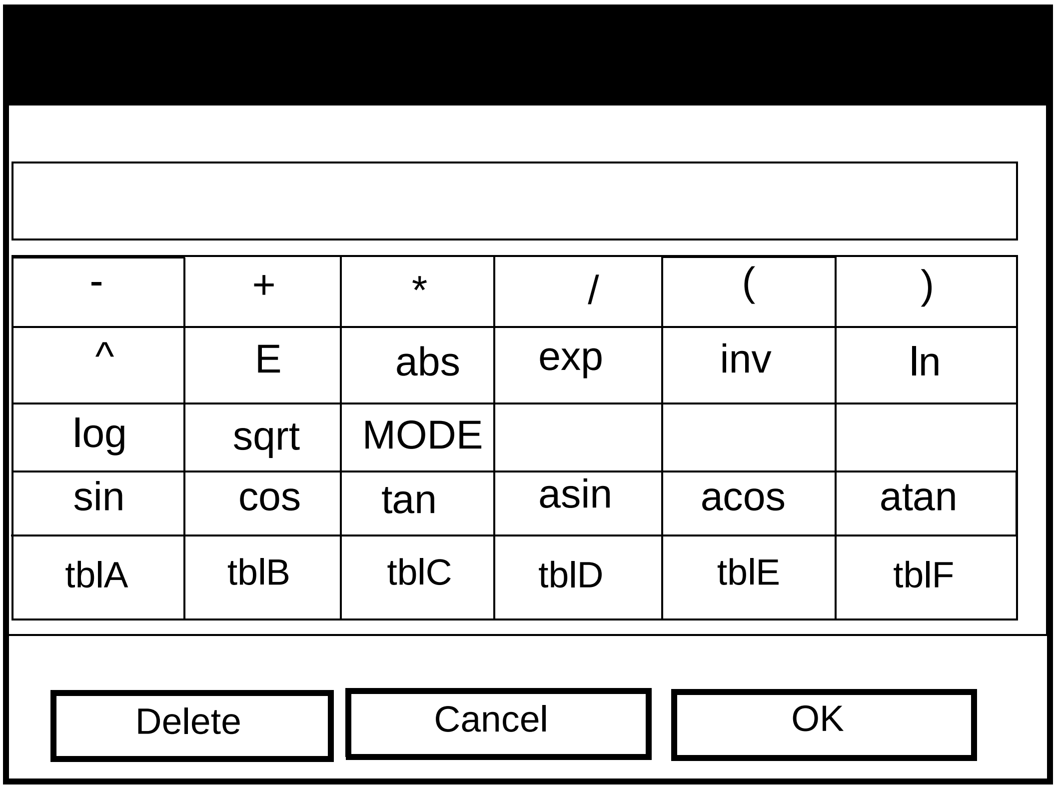

Figure 34: Function Creation Window

c. To enter a particular measured parameter into the equation, click on the MODE symbol in the middle of the third row. The Data Source Selection window (shown in Figure 30 on page 55) opens. Select the desired data source and unit as discussed on page 55, and press [F3] (OK) to confirm the entry.

d. When you have completed entering the function, press [F3] (OK) to confirm the entry and return to the User Function window.

6. GE recommends pressing [F2] (Check) to test the validity of the function. The PT878 displays either “OK” or a message such as “Syntax Error.”

- Press [F1] to delete the entire function, or
- Press [F3] (Done) to confirm the function and return to Operate Mode.

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3.11.1 Entering Correction Factors

The final option in the Program Menu, Correction Factors, allows you to enter and modify three correction factors: Reynolds Correction, Kinematic Viscosity and Calibration Factor. To enter the Correction Factors option, scroll to the Correction Factors entry on the Program Menu and press [ENTER]. The screen appears similar to Figure 35 below. To step through each parameter, press the [▼] key. Refer to Figure 152 on page 236 of Appendix A, *Menu Maps*.

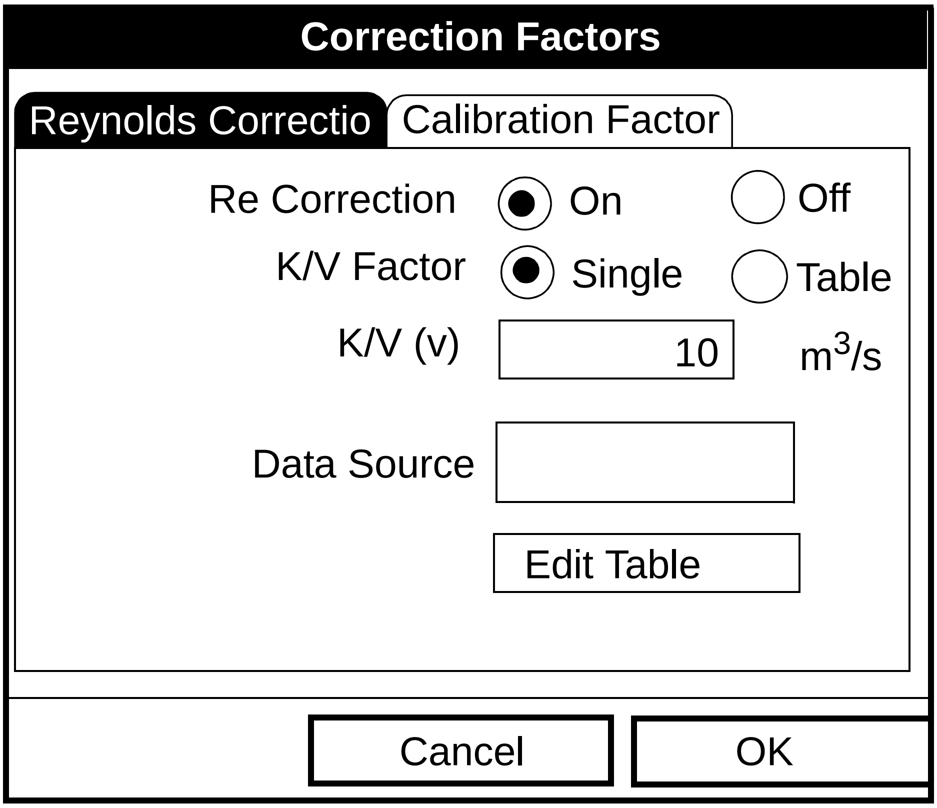

Figure 35: Reynolds Correction Window

3.11.2 Entering Reynolds Correction

The default for Reynolds Correction is "On." This correction factor should be on in most applications, including all those that utilize clamp-on transducers. It makes a small adjustment to the flow rate reported by the PT878, based on the Kinematic Viscosity. Reynolds Correction is necessary, as the velocity of the fluid measured along a diametrical path must be related to the total area average velocity over the entire pipe cross-section.

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3.11.2 Entering Reynolds Correction (cont.)

1. The first prompt asks if you want to enable the Reynolds Correction factor, a number based on the Kinematic Viscosity and flow rate of the fluid.

Note: *If you are using clamp-on transducers, you should enable Reynolds Correction.*

a. Use the [◀] and [▶] keys to scroll to the appropriate radio button.

b. Press [ENTER] to confirm your selection.

Note: *If you disable Reynolds Correction, you will not be able to enter any other values in this window.*

2. If you enable Reynolds Correction, you will also need to enter the Kinematic Viscosity of the fluid (available in the brochure *Soundspeeds and Pipe Size Data*, 914-004). The prompt asks for a kinematic viscosity value.

a. Press [ENTER] to open the text box.

b. Use the numeric keys to enter the desired value (from *Soundspeeds and Pipe Size Data*).

c. Press [ENTER] to confirm your selection.

You have completed entering data for a single Kinematic Viscosity factor. Proceed to *Entering a Calibration Factor* on page 67.

- To confirm the entries and return to Operate Mode, press [F3] (OK). The PT878 returns to Operate Mode.
- To leave the window without confirming the entries, press [F2] (Cancel) or the [ESC] key.

3.11.3 Entering a Calibration Factor

The Calibration Factor is used to calibrate or adjust the readings of the PT878 to another flow reference. To enter a Calibration Factor, return to the Reynolds Correction tab at the top of the Correction Factors option. Press the [▶] arrow key to reach the Calibration Factor window. The window appears similar to Figure 36 below. To step through each parameter, press the [▼] key.

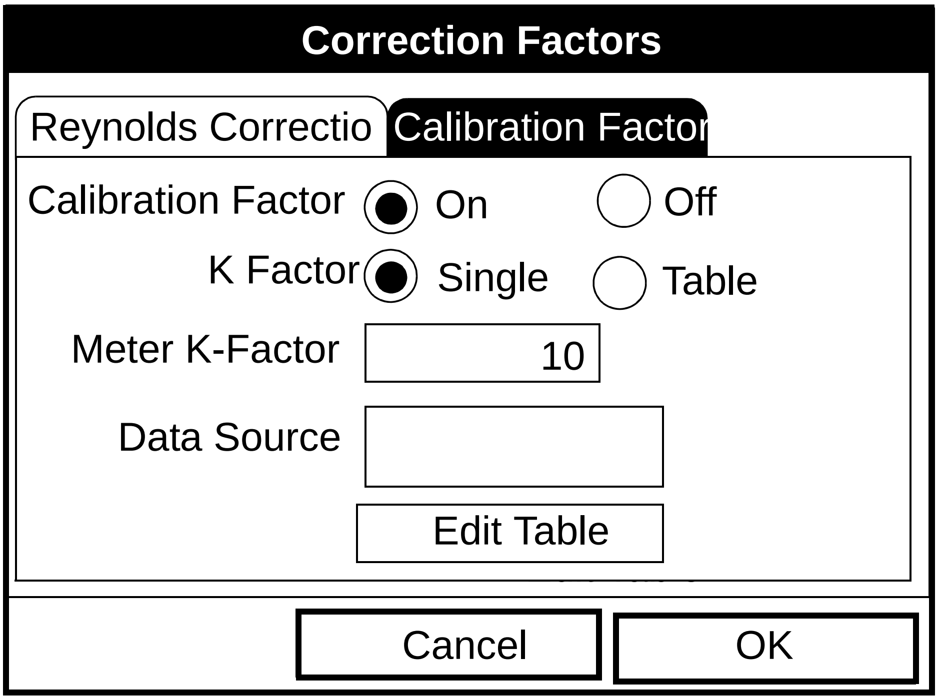

Figure 36: The Calibration Factor Window

1. The first prompt asks if you wish to enable the calibration factor.
   - **a.** Use the [◀] and [▶] keys to scroll to the appropriate radio button.
   - **b.** Press [ENTER] to confirm your selection.
2. The next prompt asks if you want a single K factor or a table of K factors.
   - **a.** Use the [◀] and [▶] keys to scroll to the appropriate radio button.
   - **b.** Press [ENTER] to confirm your selection.

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3.11.3 Entering a Calibration Factor (cont.)

3. The following steps depend on whether you select a single value or a table.

If you entered Single:

The prompt asks for a value. This feature enables a single multiplier to be applied to the flow rate reported by the PT878.

a. Press [ENTER] to open the text box.

b. Use the numeric keys to enter the desired value. Generally, if you have enabled the Reynolds Correction factor, the correction factor should be set to 1.00. Otherwise, the typical factor is between 0.5 and 2.00.

c. Press [ENTER] to confirm your selection.

You have completed entering data for a single Calibration Factor.

- To confirm the entries and return to Operate mode, press [F3] (OK). The PT878 returns to Operate Mode.
- To leave the window without confirming the entries, press [F2] (Cancel) or the [ESC] key. The PT878 returns to Operate Mode.

3.11.3 Entering a Calibration Factor (cont.)

If you entered Table:

The menu asks, first for the data source, and then for the entry of values into the Correction Factor table. This feature allows the user to “curve fit” velocity calibration multiple data points (from several different data sources or flow variables) to the flow rate reported by the PT878.

- **a.** Press [ENTER] to open the Data Source window.
- **b.** Press [F3] (OK) to confirm your selection. (Velocity is the only choice available.)

4. The prompt then asks if you wish to edit the K factor table.

- **a.** Press [ENTER] to open the table, which appears similar to Figure 37 below.

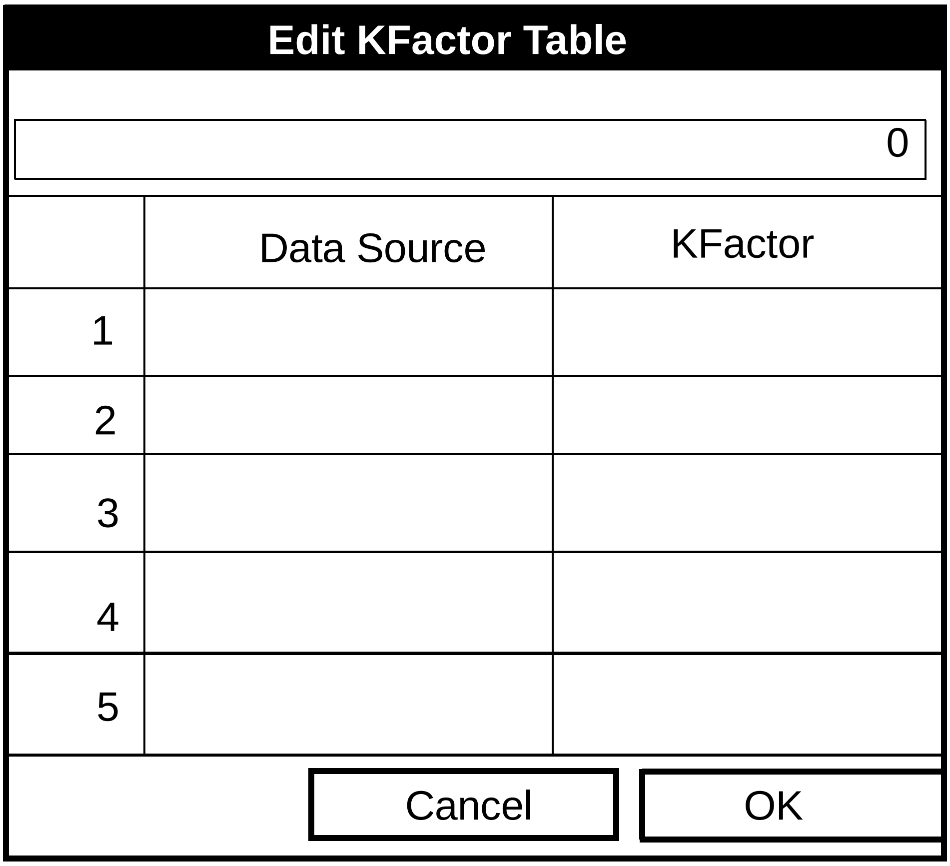

Figure 37: KFactor Table

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3.11.3 Entering a Calibration Factor (cont.)

b. Use the numeric keys to enter the desired value for the data source, and press [ENTER] to confirm the entry.

c. Press the [▶] key to move to the KFactor column. Use the numeric keys to enter the desired value, and press [ENTER] to confirm the entry.

d. Repeat steps b and c for the remainder of the table.

e. When you have completed entering values, press [F3] (OK) to confirm the table and return to the Correction Factors window.

You have completed entering data for correction factors.

- To confirm the entries and return to Operate mode, press [F3] (OK). The PT878 returns to Operate Mode.
- To leave the window without confirming the entries, press [F2] (Cancel) or the [ESC] key. The PT878 returns to Operate Mode.

Chapter 4. Creating and Managing Sites

As mentioned in Chapter 1, the PT878 can store site data in files for current and future access. (To learn how to program setup data, refer to Chapter 3, *Programming Site Data*.) After you answer the necessary questions, simply save the information to a site file. The Site Manager option then enables you to recall, rename, revert to, transfer or delete site files as needed.

To open the Site Menu, press the [MENU] key at the lower right of the PT878 keypad. The Menu Bar replaces the Status Bar at the top of the screen. Then press [ENTER]. The screen now appears similar to Figure 38 below. While following the programming instructions, refer to Figure 137 on page 219 and Figure 138 on page 221 of Appendix A, *Menu Maps*.

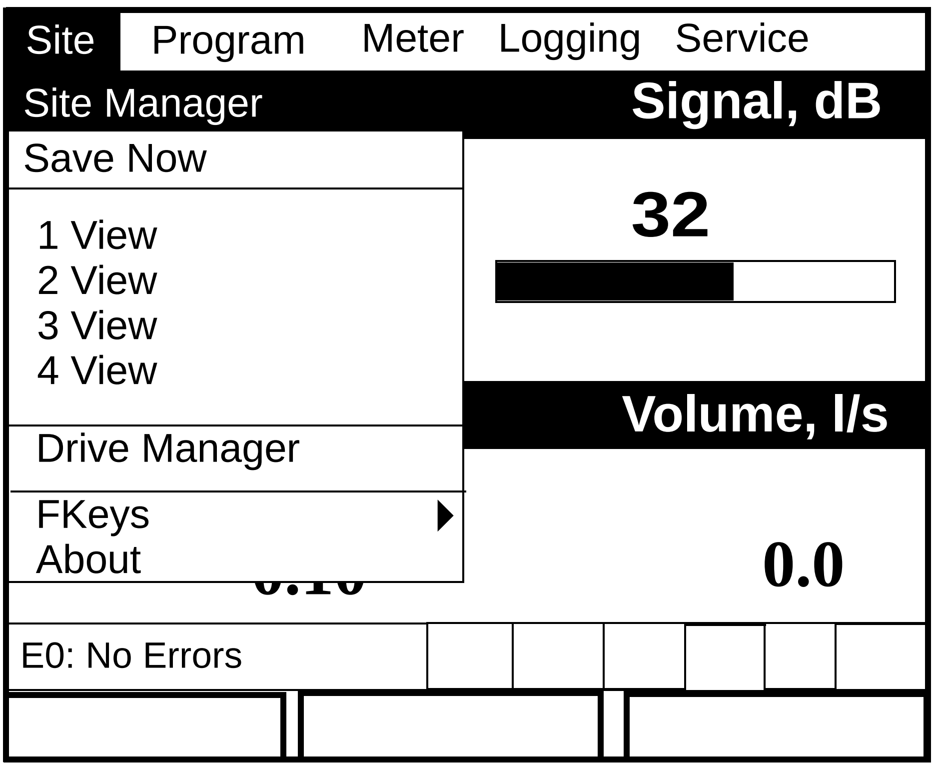

Figure 38: Site Menu

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4.1 The Site Manager

From the Site Menu, press [ENTER] to open the Site Manager. The screen appears similar to Figure 39 below.

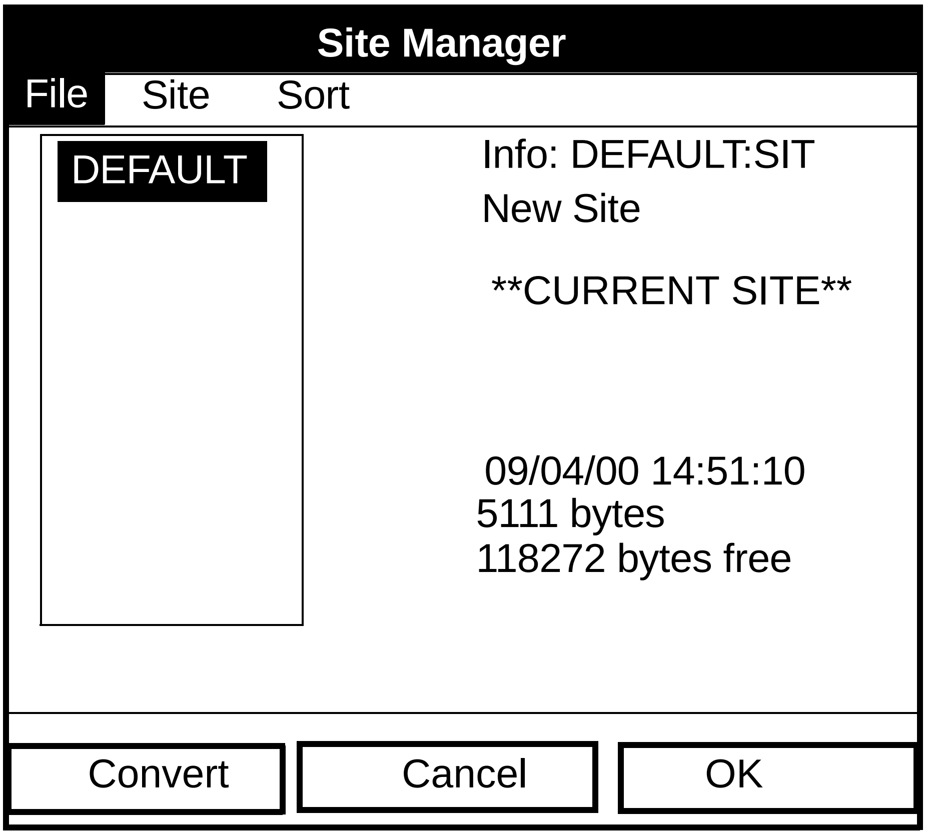

Figure 39: Site Manager Window

Note: *Each PT878 comes preprogrammed with a basic site,* Default, *which serves as a basis for saving data and creating other sites.*

The right section of the screen supplies information for the site highlighted in the list on the left: its date, time and size, as well as the remaining amount of free memory. You can use the [▼] and [▲] arrow keys to scroll to a particular site and display information pertaining to that site.

To open the Site Manager menu, press [MENU] and then [ENTER]. The screen now appears similar to Figure 40 on page 73.

4.1 The Site Manager (cont.)

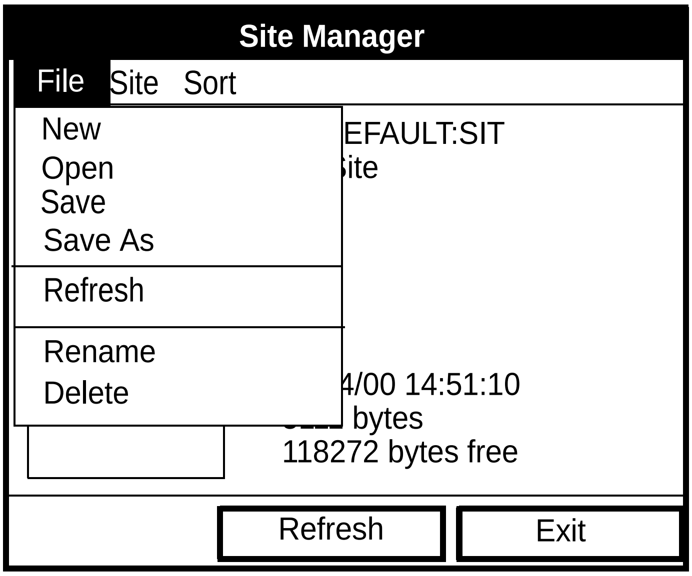

Figure 40: Site Manager Menu

Depending on the choice made above, proceed as follows:

- To create a new site, go to page 74.
- To open an existing site (thus replacing the current site), go to page 76.
- To save a current site, go to page 77.
- To refresh site information, go to page 79.
- To rename a site, go to page 78.
- To delete a site, go to page 80.

You can access five additional functions from the Site submenu (shown in Figure 48 on page 81).

- To add a site message, go to page 81.
- To transfer a site to a PC, go to page 83.
- To transfer a site in text format, go to page 83.
- To transfer a site from a PC to the PT878, go to page 85.

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4.1 The Site Manager (cont.)

You can arrange files from the Sort submenu (shown in Figure 53 on page 86)

- To sort files by name, go to page 86.
- To sort files by date, go to page 87.

4.1.1 Creating a New Site

Note: *Be sure you have entered the necessary setup data discussed in Chapter 3,* Programming Site Data*, before creating and saving a new site.*

To create a new site within the Site Manager, press [MENU] to open the File Menu. Be sure the option New is highlighted, and then press [ENTER]. The screen appears similar to Figure 41 below.

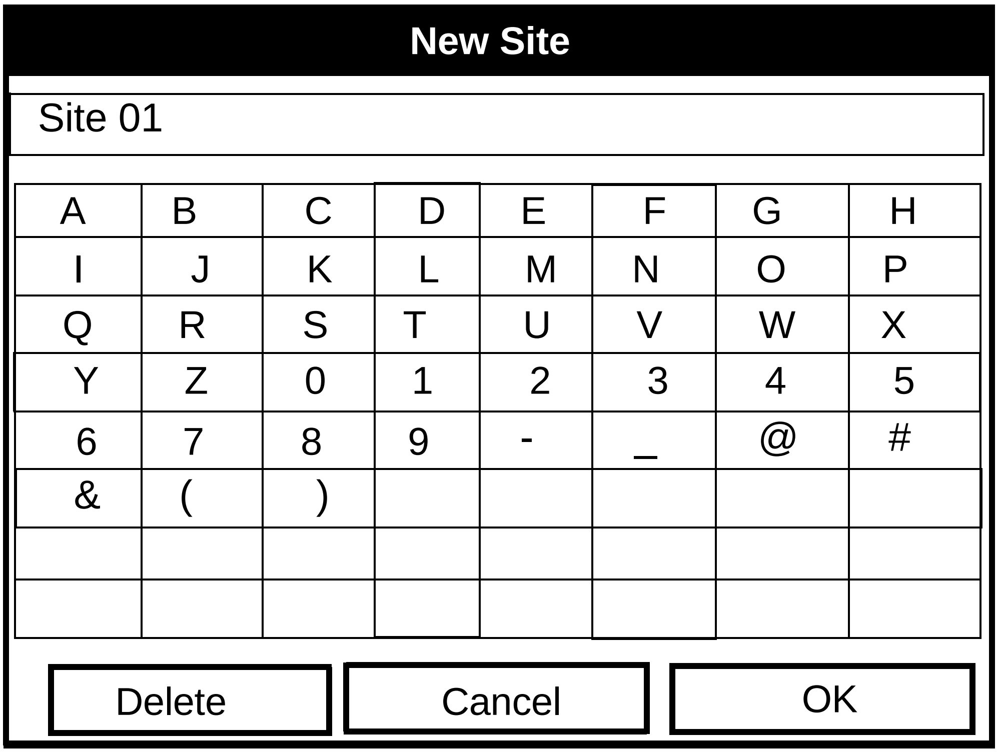

Figure 41: Name Entry Window for a New Site

1. Use the four arrow keys to scroll to the desired letter or number, and press [ENTER].

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4.1.1 Creating a New Site (cont.)

2. Repeat this procedure until you have created the desired site name of up to eight characters. (Press [F1], Delete, to remove any unwanted letters or numbers.)

3. When you have finished, press [F3] (OK) to confirm the entry, or [F2], Cancel, to leave the window without creating a site.

A second screen appears (as shown in Figure 42 below) asking if you want to use the currently highlighted site as a template, with the current display windows, measurements and programmed data. (To modify the display and measurements, refer to Chapter 5, *Displaying and Configuring Data*. To alter programming data, see Chapter 3, *Programming Site Data*.)

- Press [F2] (No) if you do not want to use it, or
- Press [F3] (Yes) if you do want to use it as a template.

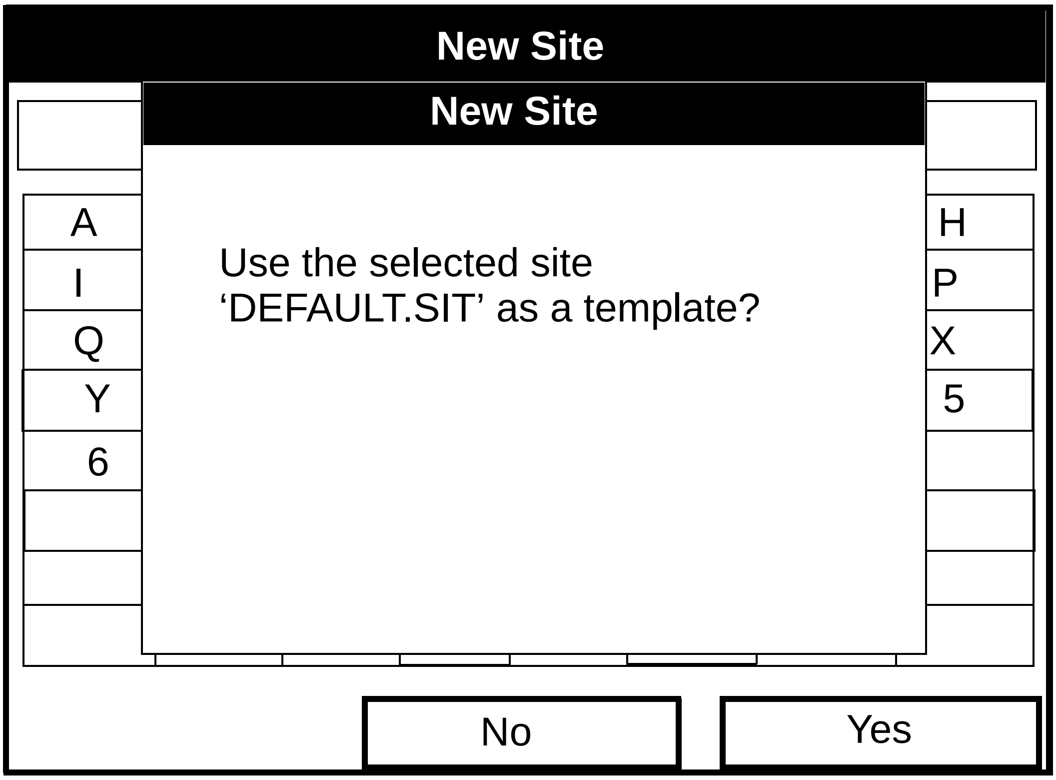

Figure 42: Template Confirmation Window

The meter returns to Operate Mode, with the new site name displayed in the upper left corner of the screen.

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4.1.2 Opening an Existing Site

If you want to return to a site you have previously saved, first highlight the replacement site in the left window of the Site Manager. Then press [MENU] to open the File Menu. Scroll to the Open option, and press [ENTER]. The screen appears similar to Figure 43 below.

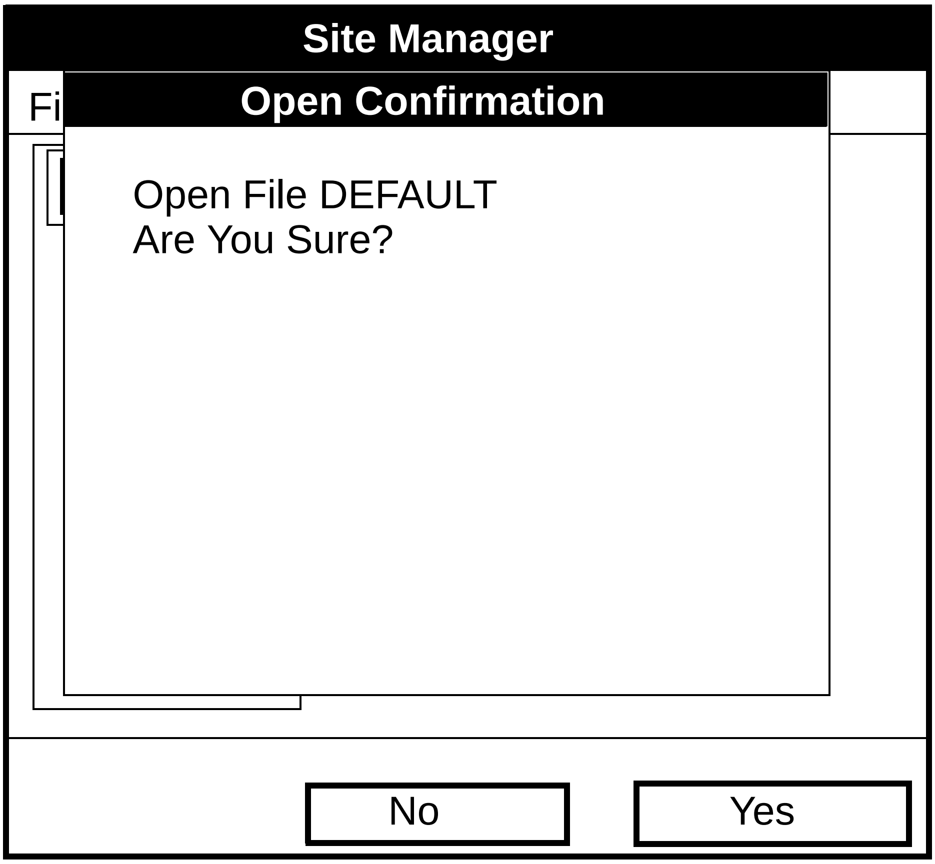

Figure 43: Open Site Confirmation Window

- Press [F2] (No) to cancel opening the site and return to the current site, or
- Press [F3] (Yes) to open the site.

If you have changed the current site, the PT878 asks if you want to save the changes to the previously opened site.

- Press [F2] (No) to cancel the changes, or
- Press [F3] (Yes) to confirm and save the changes.

The PT878 returns to Operate Mode, with the selected site displayed in the upper left corner of the screen. 351

4.1.3 Saving a Site

You can save the current site in one of two ways:

- From the Site Menu, you can scroll down to the Save Now option and press [ENTER], or
- From within the Site Manager, press [MENU] to open the File Menu, scroll to the Save option, and press [ENTER].

In either case, the screen appears similar to Figure 44 below.

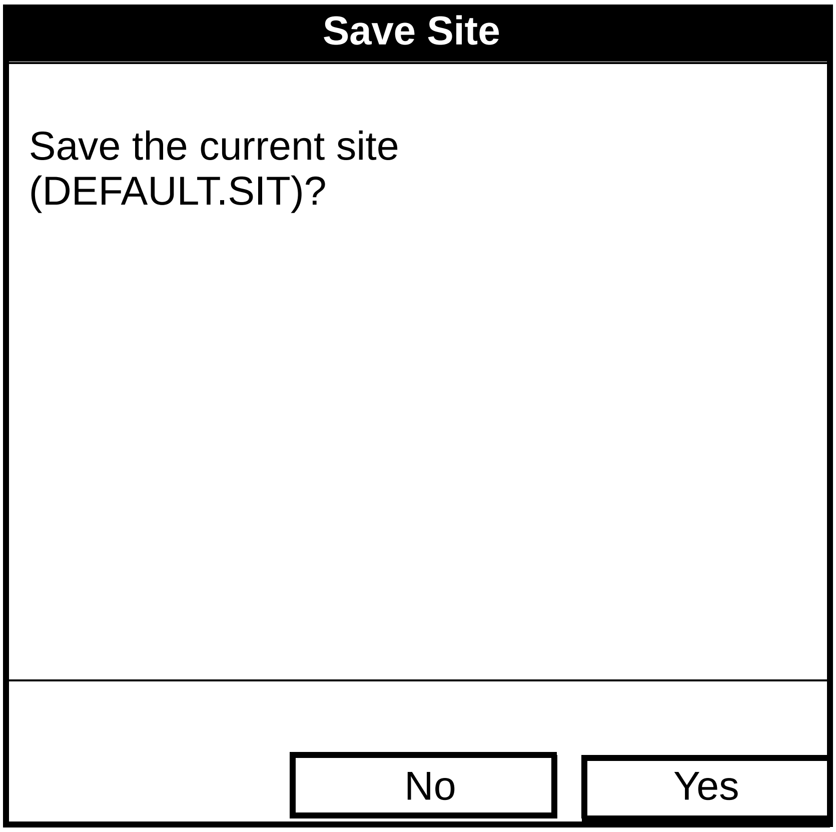

Figure 44: Save Current Site Window

- Press [F2] (No) to cancel saving the site, or
- Press [F3] (Yes) to save the site.

The PT878 remains in the current window (Operate Mode or Site Manager), with the current site saved.

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4.1.4 Saving a Site with a Different Name

If you want to save the current site with a different name, open the Site Manager, press [MENU] to open the File Menu, scroll to the Save As option, and press [ENTER]. The screen appears similar to Figure 45 below.

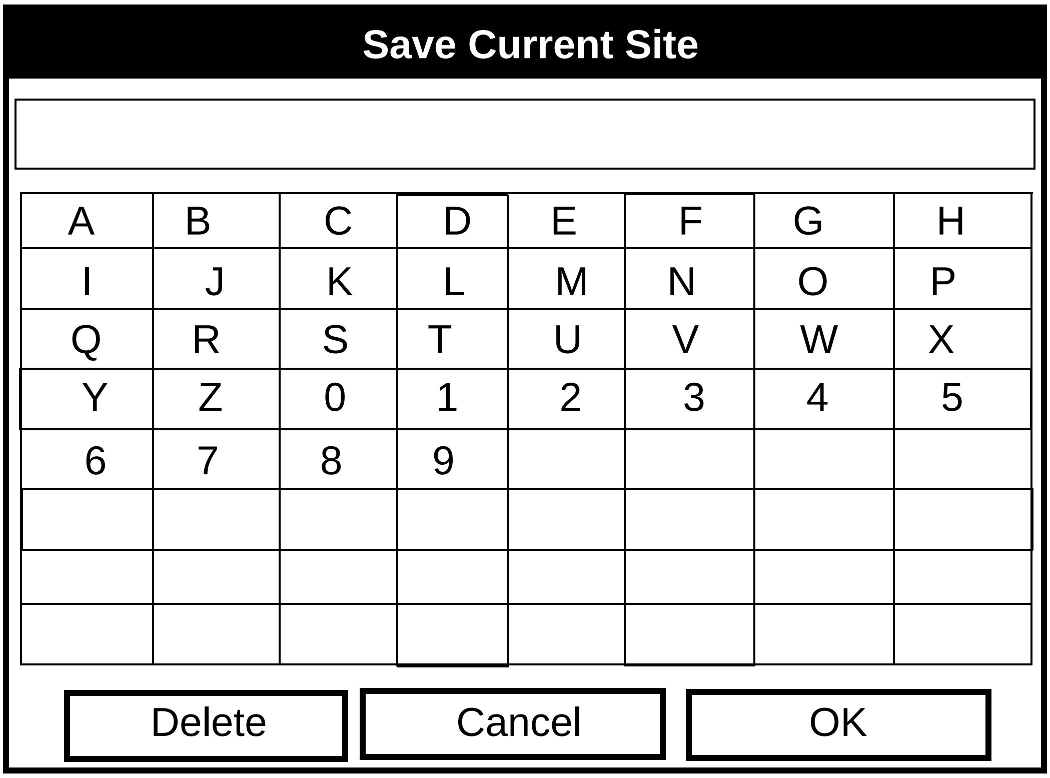

Figure 45: Save As (Another Name) Window

Use the four arrow keys to scroll to the desired letter or number, and press [ENTER]. Repeat this procedure until you have created the desired site name. (Press [F1], Delete, to remove any unwanted letters or numbers.) When you have finished,

- Press [F2] (Cancel) to erase the entry, or
- Press [F3] (OK) to confirm the entry.

The Save Site window then appears.

- Press [F2] (No) to cancel saving the site, or
- Press [F3] (Yes) to save the site.

The PT878 remains in Site Manager, with the current site saved under both the old and new names.

4.1.5 Refreshing a Site

You can refresh a site (updating the display with the most current information) in one of two ways:

- Press [F2], Refresh, to refresh the highlighted file.
- From the File Menu, scroll to the Refresh option and press [ENTER].

The updated information on the highlighted file appears in the window on the right. However, to save the file, you must use the Save option.

4.1.6 Renaming a Site

If you want to rename a site, first be sure the site has been highlighted in the left window of the Site Manager. Then press [MENU] to enter the File Menu, scroll to the Rename option, and press [ENTER]. The screen appears similar to Figure 46 below.

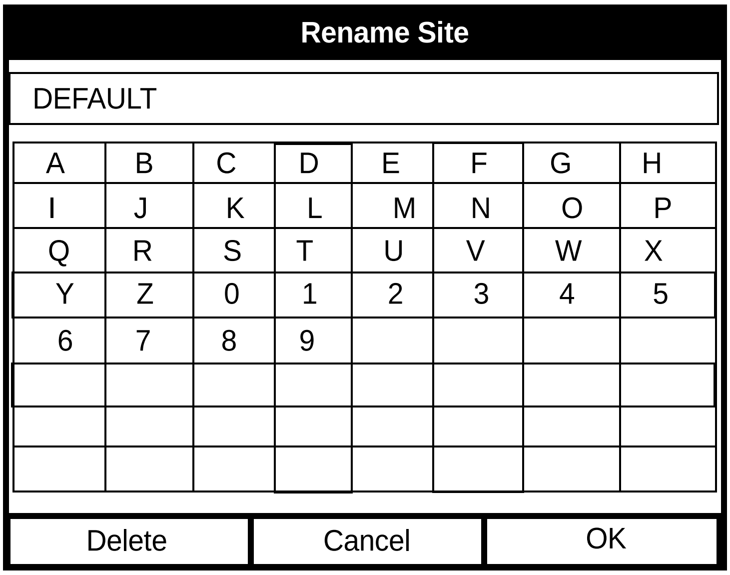

Figure 46: Rename Site Window

Use the four arrow keys to scroll to the desired letter or number, and press [ENTER]. Repeat this procedure until you have created the desired site name. (Press [F1], Delete, to remove any unwanted letters or numbers.) When you have finished,

- Press [F2] (Cancel) to erase the entry, or
- Press [F3] (OK) to confirm the entry.

PT878 remains in Site Manager, with the site listed under the new name.

4.1.7 Deleting a Site

To delete a site in the Site Manager, first be sure you have highlighted that site in the left window of the Site Manager. Then press [MENU] to open the File Menu, scroll to the Delete option, and press [ENTER]. The screen appears similar to Figure 47 below.

Figure 47: Delete Confirmation Window

- Press [F2], No, to cancel the deletion and return to the Site Manager, or
- Press [F3], Yes, to delete the site.

The Site Manager appears, with the highlighted site now deleted.

4.1.8 Creating a Site Message

The Site Message option allows you to add an explanatory message (with up to 30 characters or spaces) for any given site. To create a site message:

1. Press [MENU] to enter the File Menu. Then press the [▶] arrow key once to scroll from the File Menu to the Site Menu. Press [ENTER]. The screen appears similar to Figure 48 below.

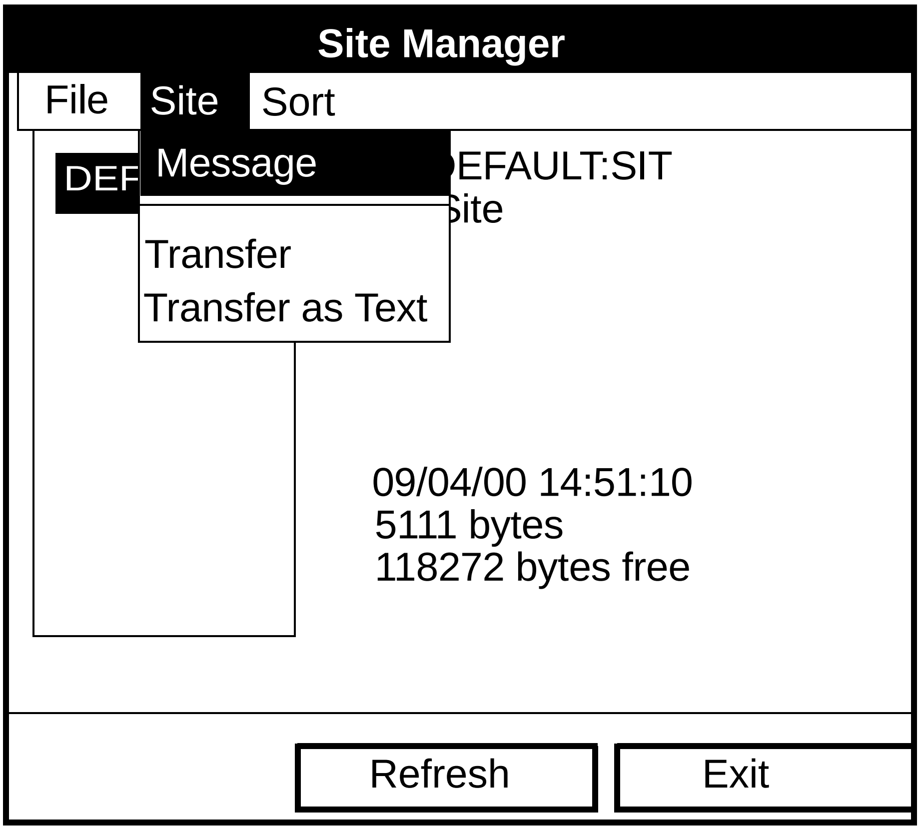

Figure 48: Site Menu in the Site Manager

2. Press [ENTER] to select "Message," which opens the text creation window, shown in Figure 49 on page 82.

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4.1.8 Creating a Site Message (cont.)

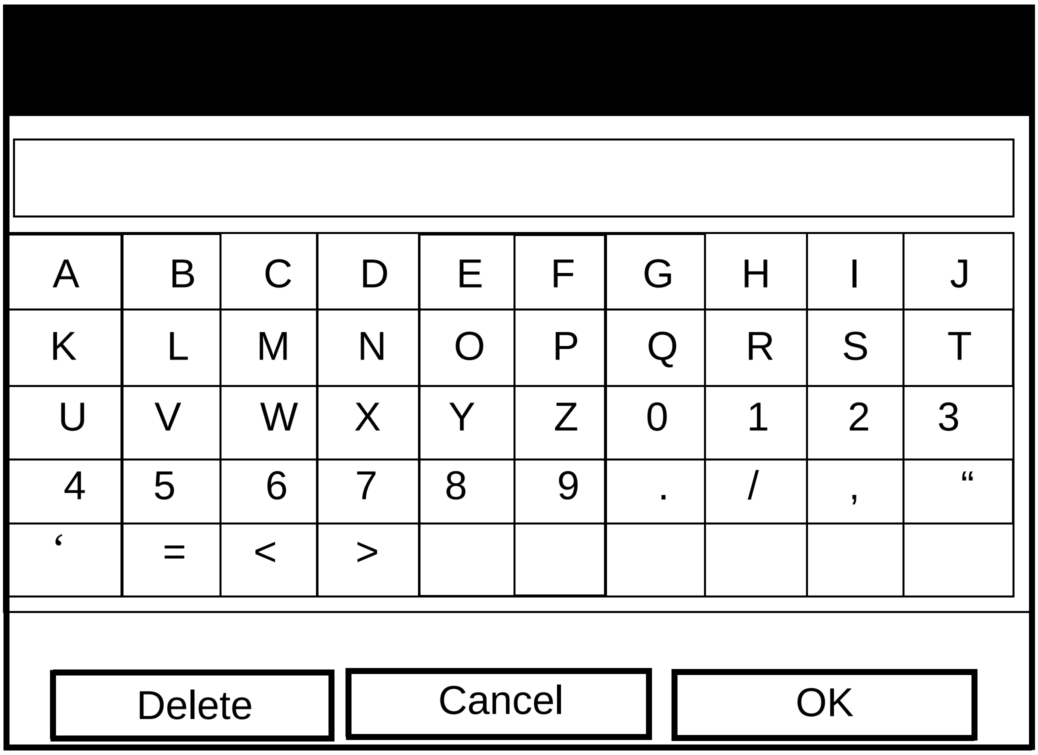

Figure 49: Text Creation Window

3. Use the four arrow keys to scroll to the desired letter or symbol, and press [ENTER] to add the letter to the message.

Note: *Pressing* [SEL] *causes the screen to alternate between a set of upper-case (capital) letters, a set of lower-case letters, and a set of symbols. Use all three screens to create a desired message.*

4. Repeat this procedure for each letter or symbol you wish to add to the message. If you wish to delete a letter, press [F1] (Delete) to erase each letter or symbol, from right to left on the label.

When you have completed the message, press [F3] (OK) to confirm the message, or [F2] (Cancel) to leave the window without adding the message.

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4.1.9 Transfer Files Between the PT878 and a PC

4.1.9a Site Files

Site files contain configuration parameters for the PT878. These parameters can be changed one at a time and saved in the meter's memory via either PanaView or the PT878 keypad. Site files can be transferred as text to the PC and transferred as files between the PC and the PT878 meter.

4.1.9b Transfer a Site File as Text using HyperTerminal

To transfer a PT878 site file to a PC as text using HyperTerminal, complete the following steps:

1. Connect the PT878 USB port to any USB port on the PC (page 9).
2. Start HyperTerminal and set up the communication link to match the PT878 Com port settings.
3. From the PT878 select Site\Site manager and select the site file you want to print to PC.
4. From Site manager select Site\Transfer as Text. This should print out the site file as text to HyperTerminal.

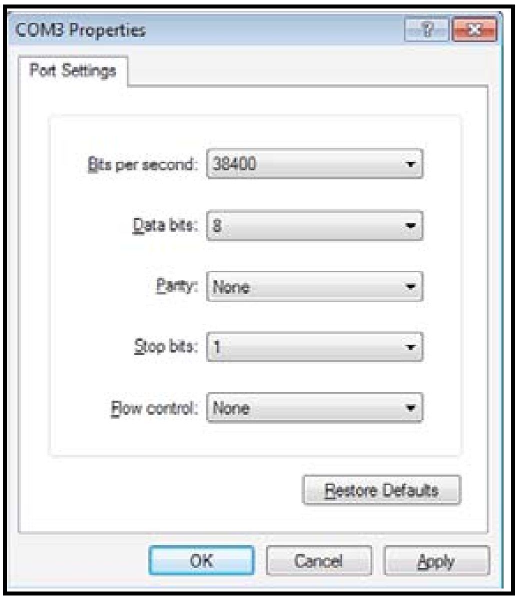

Figure 50: COM Properties

4.1.9b Transfer a Site File as Text using HyperTerminal

To save the site file as text in HyperTerminal, complete the following steps:

1. Select the *Transfer\Capture Text* option.

2. Select the location of the file and the filename. Then, click *Start*.

3. Transfer the site file as text from the PT878 and then select the *Transfer\Capture Text\End* option in HyperTerminal. The site file transfer is now complete.

4.1.9c Transfer a Site File as a File from the PT878 to a PC

To transfer a PT878 site file to a PC as a file, complete the following steps:

1. Connect the PT878 USB port to any USB port on the PC (page 9).
2. Start HyperTerminal and set up the communication link to match the PT878 Com port settings.
3. From the PT878 select *Site\Site Manager* and then select the site file you want to transfer to the PC.

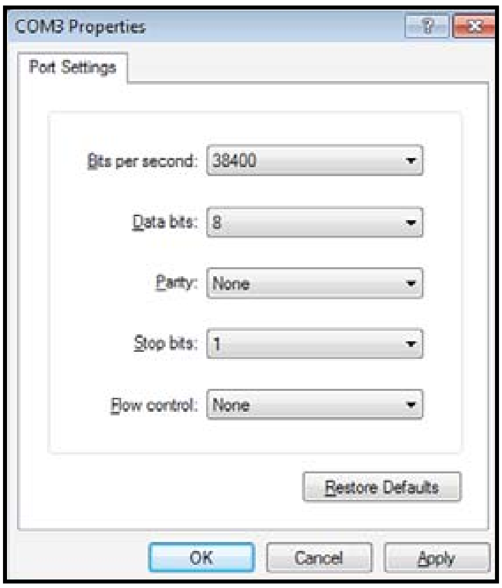

Figure 51: COM Properties

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4.1.9c Transfer a Site File as a File from the PT878 to a PC (cont.)

To save the site file as a file using HyperTerminal, complete the following steps:

1. Select the *Transfer\Receive File* option.
2. Select the location of the file and the XModem receiving protocol.
3. Click the *Receive* option and enter the Filename.
4. From PT878 *Site Manager*, select the *Site\Transfer* option. This will allow the PT878 to send the site file to a PC using the secure XModem protocol. File transfer is complete when the XModem Receive dialog box closes.

4.1.9d Transfer a Site File as a File from a PC to the PT878

To transfer a site file from a PC to the PT878 as a file, complete the following steps:

1. Connect the PT878 USB port to any USB port on the PC (page 9).
2. Start HyperTerminal and set up the communication link to match the PT878 Com port settings.
3. From the PT878 select Site\Site Manager and then select Site\Transfer from the PC. Type in the name of the site file and click OK.

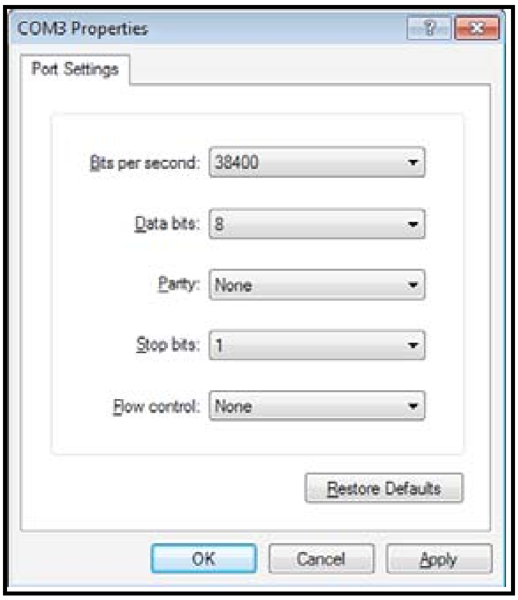

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Figure 52: COM Properties

4.1.9d Transfer a Site File as a File from a PC to the PT878 (cont.)

From HyperTerminal, complete the following steps:

1. Select the *Transfer\Send File* option.
2. Select the location of the file and the XModem protocol.
3. Click *Send*. File transfer is complete when the XModem Receive dialog box closes. The file should now appear in the PT878 Site Manager.

4.1.10 Listing Files by Name

If you want to list your files alphabetically by site name within the Site Manager, press [MENU] to open the File Menu. Then press the [▶] arrow key twice to scroll from the File Menu to the Sort Menu, shown in Figure 53 below. Press [ENTER]. The Site Manager screen refreshes, with the sites listed in alphabetical order.

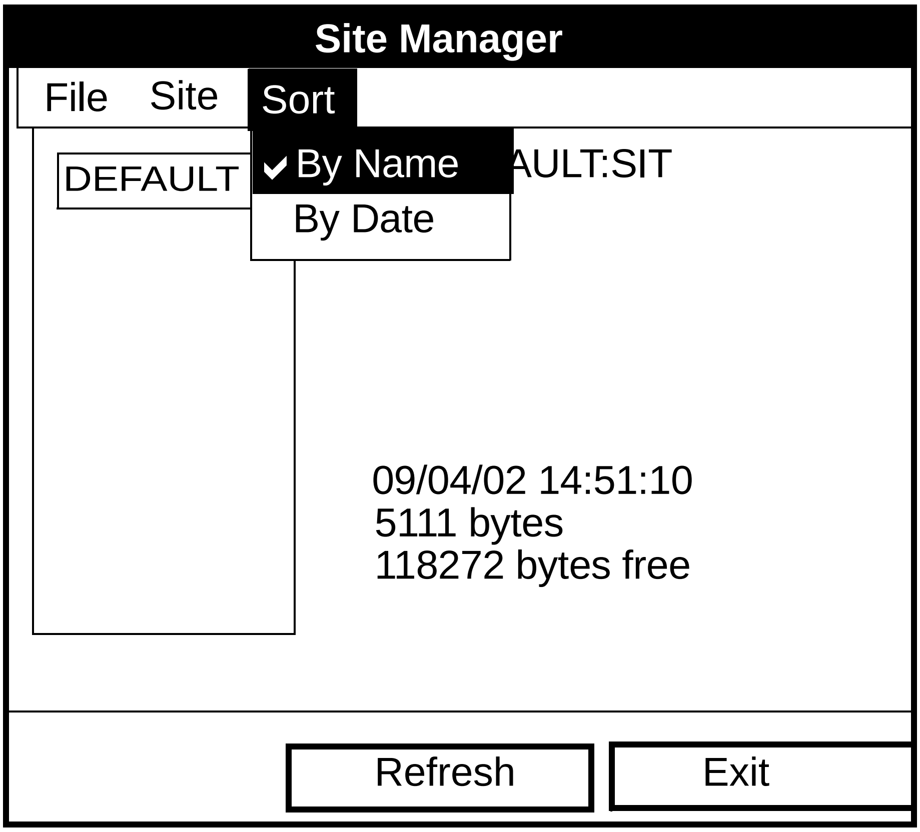

Figure 53: Sort Submenu

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4.1.11 Listing Files in Chronological Order

If you prefer to list your files chronologically by time of creation within the Site Manager, press [MENU] to open the File Menu. Then press the [▶] arrow key twice to scroll from the File Menu to the Sort Menu, and scroll to the By Date option. Press [ENTER]. The Site Manager screen refreshes, with the sites listed in chronological order, from the most recent to the earliest.

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[no content intended for this page - proceed to next page]

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Chapter 5. Displaying and Configuring Data

The PT878 allows you to view from one to four different measurement parameters simultaneously. The screen can show these parameters not only in numeric format, but as line or bar graphs as well.

You can configure any given measurement for your particular requirements. To configure an individual measurement, press [SEL] from the Operate Mode window shown in Figure 6 on page 16. A cursor appears next to the parameter closest to the upper left corner. Continuing to press [SEL] enables the cursor to scroll through the other displayed measurements. Once you have reached a particular window, pressing the [ENTER] button opens the menu for that window, as shown in Figure 54 below. To learn how to use the display window menu, see page 90 to page 94.

]

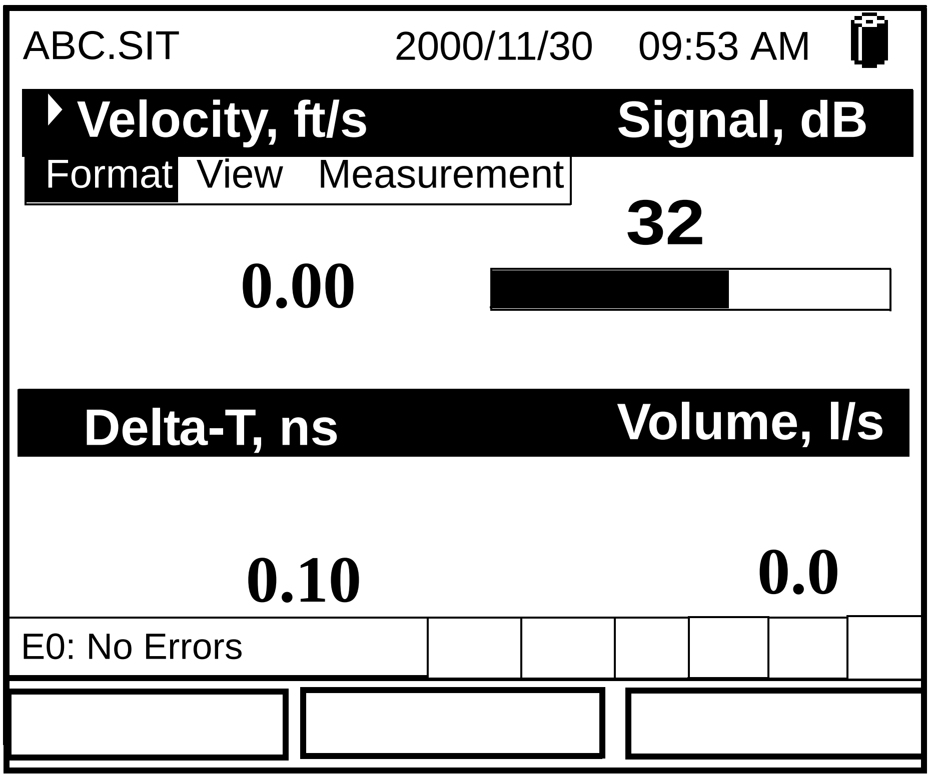

Figure 54: Display Screen After Pressing [SEL]

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5.1 The Format Option

The first option on the menu, Format, allows you to specify the type of notation and the number of decimal places for the measurement in that window. Press [ENTER] and the submenu shows two options, Decimal Place and Notation. Press the [▼] or [▲] arrow keys to select either entry, and press [ENTER]. The screen appears similar to Figure 55 below. To scroll to a particular parameter or menu entry, press the [▼] or [▲] key.

Note: *If the window displays a line or bar graph, the* Limits *option appears instead of* Format *in the menu.*

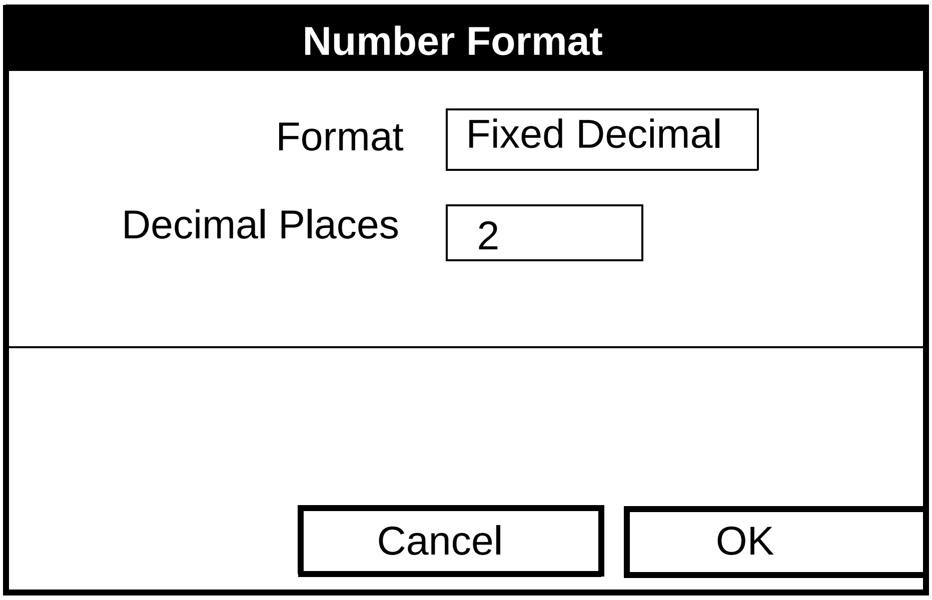

Figure 55: Number Format Window

1. The first entry, Format, asks you to select the numeric format from three choices: default, fixed decimal and scientific. Default provides the default resolution, while Fixed Decimal allows users to override the standard resolution. Scientific format displays the value in mantissa and exponent format.

a. Press [ENTER] to open the drop-down list of format choices.

b. Scroll to the appropriate selection.

c. Press [ENTER] to confirm your choice.

5.1 The Format Option (cont.)

2. The second step asks you to choose the number of decimal places to be displayed. Available choices range from 0 to 4 places.

   a. Press [ENTER] to open the drop-down list.

   b. Scroll to the appropriate number.

   c. Press [ENTER] to confirm your choice.

- To confirm the entries and return to Operate mode, press [F3] (OK).
- To leave the window without confirming the entries, press [F2] (Cancel) or the [ESC] key.

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5.2 The View Option

The second option, View, allows you to select the presentation of a parameter in one of three formats: numeric, line graph or bar graph.

1. From the Display Menu, press the [▶] key once to reach the View option, and then press [ENTER].
2. A drop-down menu shows the three formats. Scroll to the appropriate selection.
3. Press [ENTER] to confirm your selection.

The screen immediately displays any changes. For example, if you have changed the first parameter to a line graph, the screen appears similar to Figure 56 below.

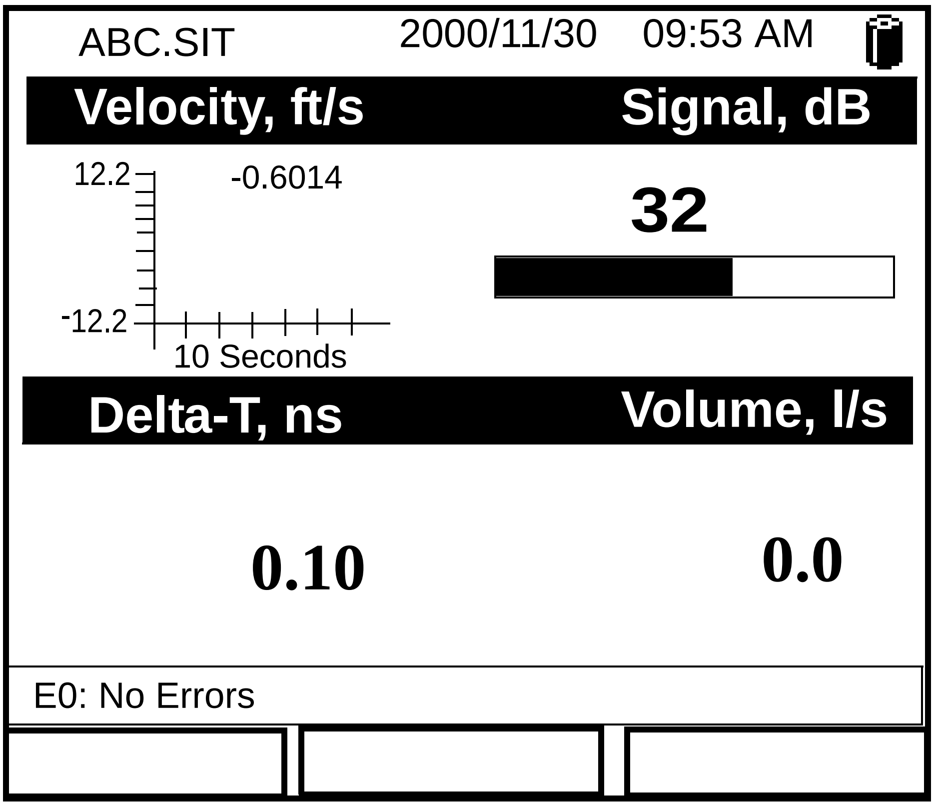

Figure 56: Screen After Format Change

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5.3 The Limits Option

Once you have configured a parameter as a line or bar graph, you might need to change its presentation or values. The Limits option (replacing the Format option for line and bar graphs) enables you to program the minimum or maximum values displayed, the time interval and the display of the average value.

To enter the Limits option:

1. Press [SEL] from the Operate Mode window until you have reached the desired measurement.
2. Press [ENTER] to open the Display Menu.
3. Be sure the Limits option is highlighted, and press [ENTER].
4. A drop-down menu entry, Change, appears. Press [ENTER] again.

The screen appears similar to Figure 57 below.

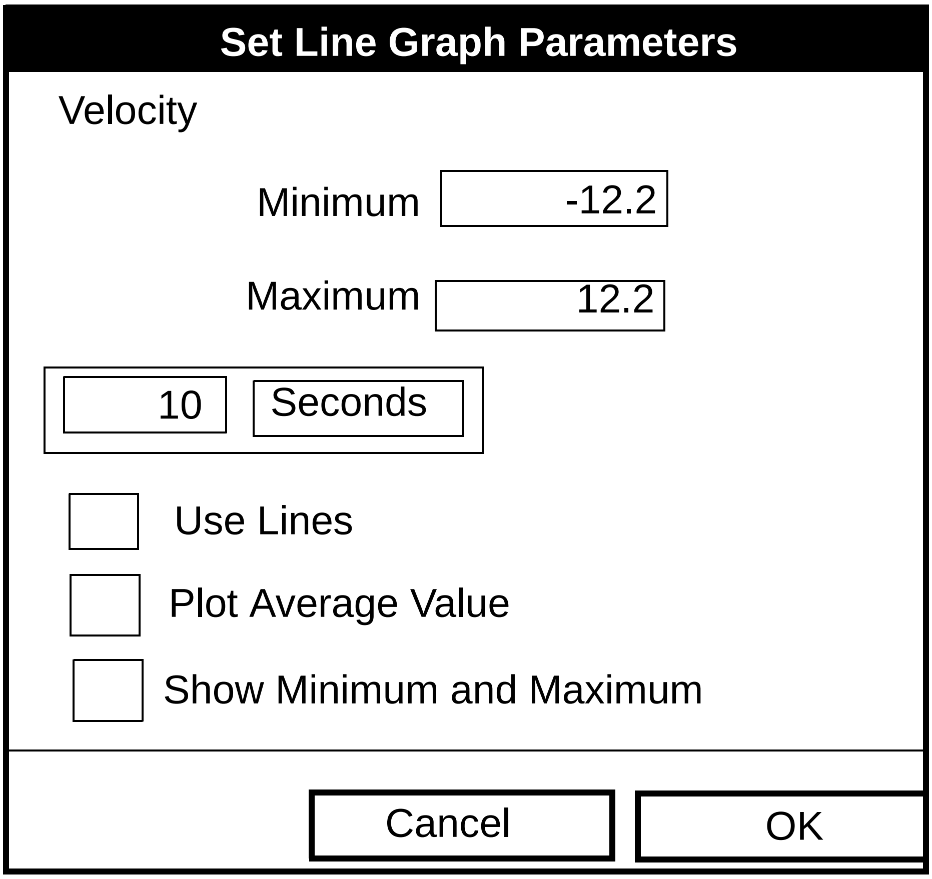

Figure 57: Line (or Bar) Graph Parameters Window

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5.3 The Limits Option (cont.)

5. The first prompt asks for the minimum value shown in the graph.

   a. Press [ENTER] to open the text box.

   b. Use the numeric keys to enter the desired value.

   c. Press [ENTER] to confirm the value.

6. Repeat the procedure in step 5 to enter the maximum value.

A line graph involves two more prompts.

7. The next prompt asks for the display interval.

   a. Press [ENTER] to open the text box. Use the numeric keys to enter the desired number. Press [ENTER] to confirm the value.

   b. The second box asks for the interval in terms of seconds, minutes, hours, or days. Press [ENTER] to open the drop-down menu, and then press the [▼] or [▲] keys to move to the desired parameter. Press [ENTER] to confirm the entry.

8. The final three prompts ask for details of the graph configuration: if you want to use lines, plot the average value, or show the minimum and maximum values. Press the [▼] key to step through each value, and press [ENTER] to add a given detail as part of the graph.

9. When you have configured the graph, press [F3] (OK) to confirm the graph settings.

The screen returns to Operate Mode, and displays any changes.

5.4 The Measurement Option

On occasion, you might need to change the actual parameter measured in a given window.The Measurement option enables you to reconfigure the window with one of five categories of data source (velocity, volume, forward or reverse totalizer, power, energy or diagnostics) and appropriate English or metric measurement units.

To enter the Measurement option:

1. Press [SEL] from the Operate Mode window until you have reached the desired measurement.
2. Press [ENTER] to open the Display Menu.
3. Be sure the Measurement option is highlighted, and press [ENTER].
4. A drop-down menu entry, Change, appears. Press [ENTER] again.

The screen appears similar to Figure 58 on page 96. The left column displays the five measurement data sources, while the right column displays English and metric measurement units (or, with the Diagnostics source shown, a list of diagnostics parameters).

5. Use the [▼] and [▲] arrow keys to reach the desired data source, and press [SEL].
6. Then use the [▼] or [▲] arrow keys to select the desired measurement unit (or diagnostic parameter). Press [F3] (OK) to confirm the entry.
7. The screen returns to Operate Mode, and displays any changes.

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5.4 The Measurement Option (cont.)

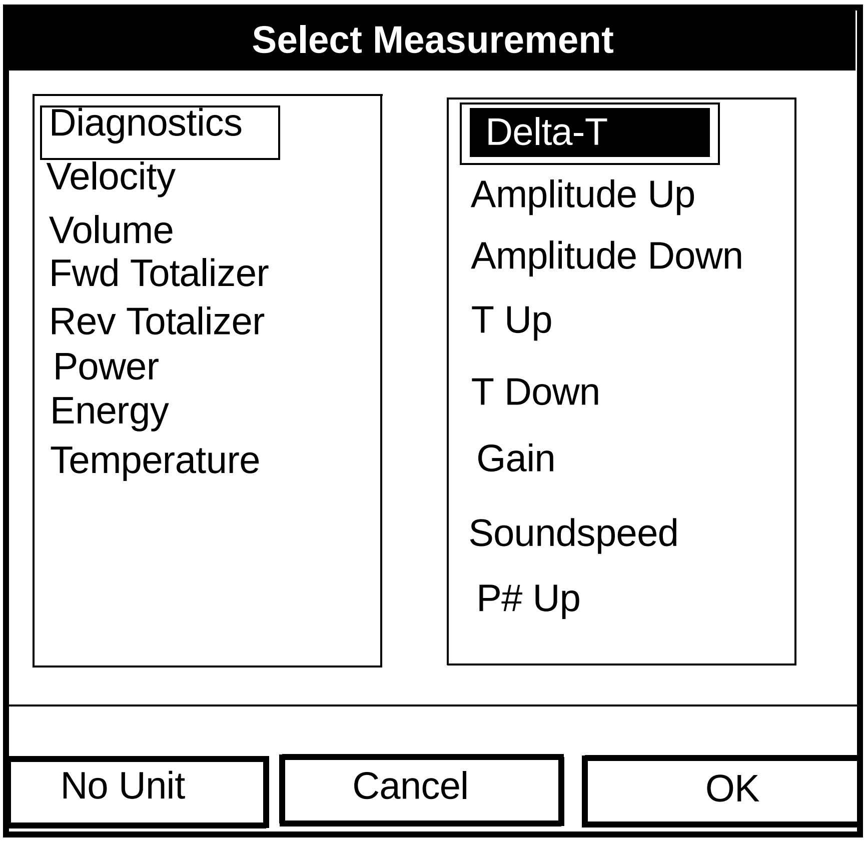

Figure 58: Measurement Menu Window

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5.5 Customizing the Display Screen

You might wish to display one or two parameters, or customize the soft keys to quickly access particular menus. The Site Menu enables you to make more comprehensive changes in your display screen.

To enter the Site Menu, press the [MENU] key at the lower right of the PT878 keypad. The Menu Bar replaces the Status Bar at the top of the screen. The Site Menu will be highlighted in the upper left corner. Press [ENTER] or the [▼] arrow key. The screen now appears similar to Figure 59 below. While following the programming instructions, refer to Figure 138 on page 221 of Appendix A, *Menu Maps*.

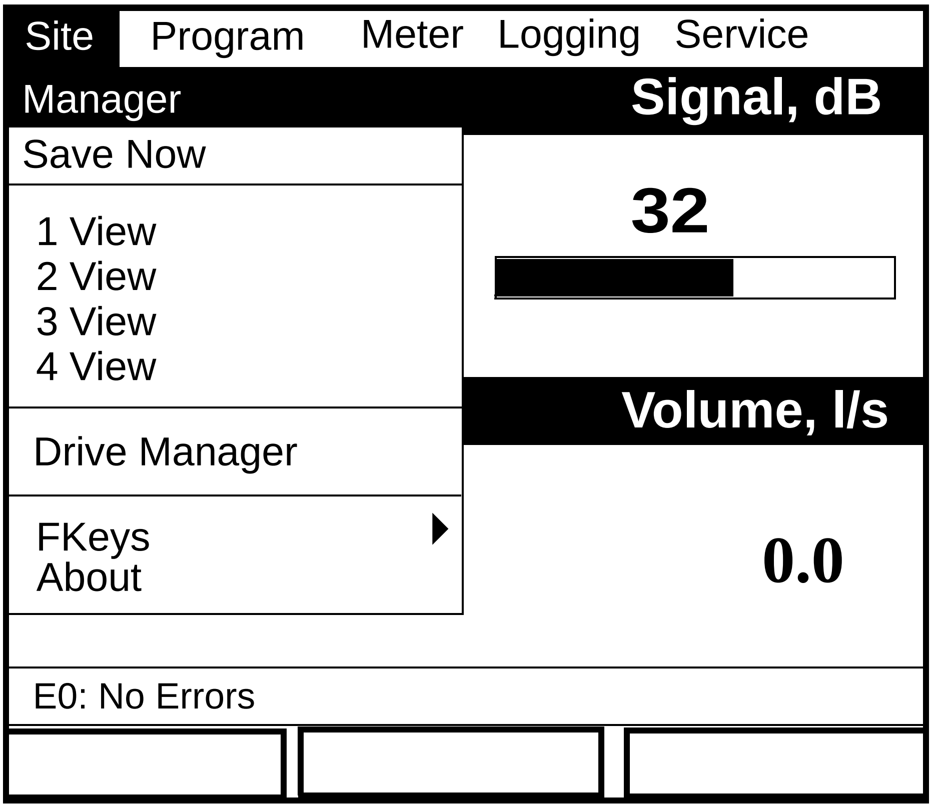

Figure 59: Site Menu

- To specify the number of parameters displayed, go to page 98.
- To customize or clear softkeys (FKeys), go to page 99.

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5.5.1 Specifying the Number of Displayed Parameters

As mentioned earlier, the PT878 can display one to four different measurement parameters simultaneously. However, sometimes you might wish to display only one or two parameters. To change the number of open display windows from within the Site Menu (shown in Figure 59 on page 97), use the [▼]or [▲] arrow keys to move to the desired number of views (1 View, 2 Views, etc.) Press [ENTER].

The screen displays the designated number of windows. For example, Figure 60 below shows the screen displayed in Figure 56 on page 92, reconfigured for a single view.

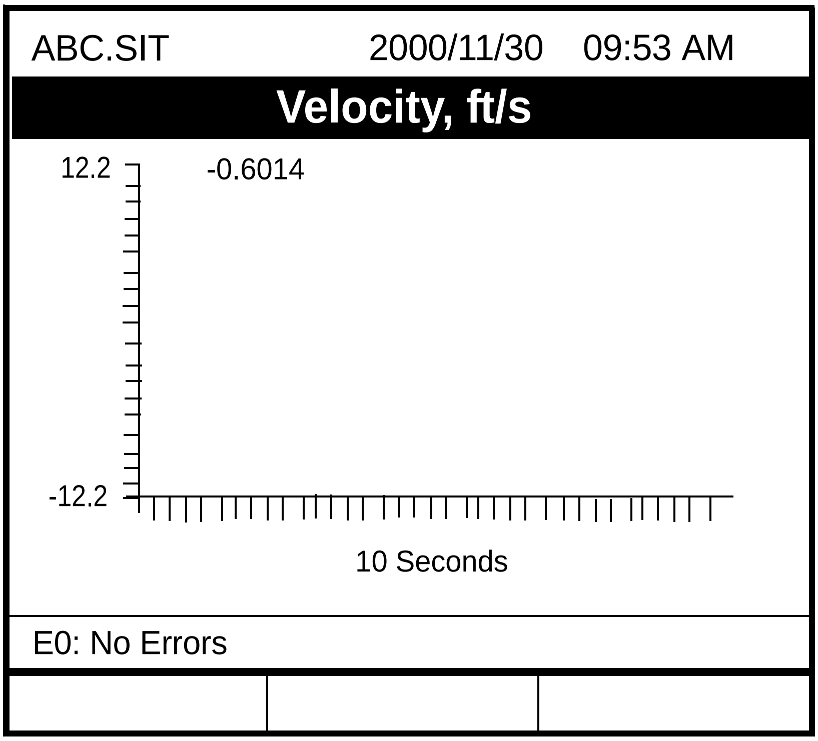

Figure 60: Display Screen Configured for Single View

Note: *The PT878 opens display windows clockwise from the upper left; that is, if you press "1 View," the parameter displayed in the upper left window appears. If you press "2 Views," the parameters shown in the two top windows appear. The view for "3 Views" adds the window in the lower left, and that for "4 Views" adds the window in the lower right.*

5.5.2 Customizing Softkeys

When the screen is in Operate Mode, you might wish to access a particular submenu frequently without the trouble of scrolling through menus. Customizing the softkeys ([F1], [F2] and [F3]) allows you to access up to three submenus by pressing the associated softkey. You can customize a softkey from the Site Menu or from within a particular menu.

- To customize a softkey from within the Site Menu:

1. From the Site Menu (shown in Figure 59 on page 97), use the [▼] or [▲] arrow keys to move to the FKeys entry on the menu. Press [ENTER]. The screen now appears similar to Figure 61 below.

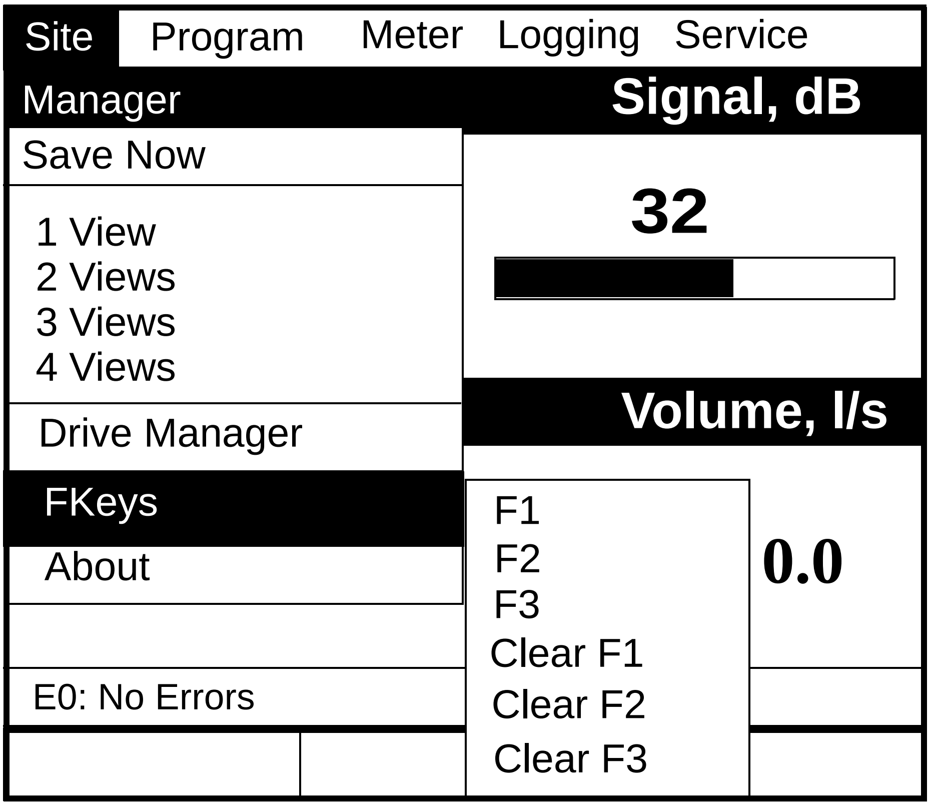

Figure 61: FKeys Menu

2. Use the [▼] or [▲] arrow keys to move to the desired FKey (1, 2 or 3) entry on the menu. Press [ENTER]. The Configure FKey window opens, as shown in Figure 62 on page 100.

5.5.2 Customizing Softkeys (cont.)

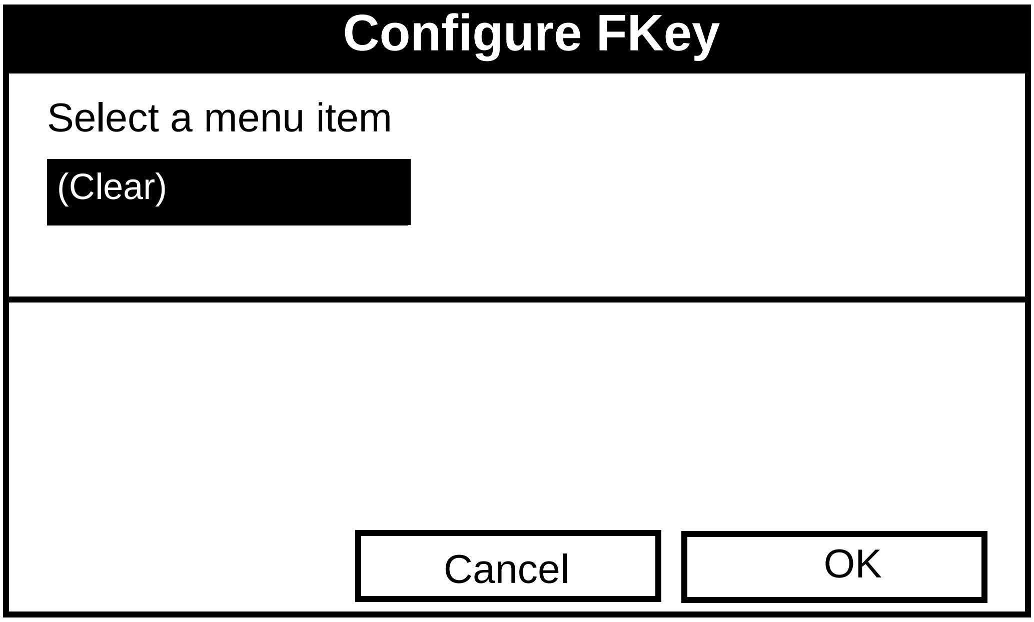

Figure 62: Configure FKey Window

3. Press [ENTER] to open the menu drop-down list. Then use the [▼] or [▲] arrow keys to scroll to the desired submenu (for example, Contrast).

4. Press [ENTER] to confirm the entry, and press [F3] (OK) to confirm the entry and close the window. (Press [F2] (Cancel) to close the window without changing the key.)

The screen now appears similar to Figure 63 on page 101, with the [F1] window displaying “Contrast.” Pressing [F1] opens the Contrast window.

- To customize a softkey from a particular menu:

1. Open the desired menu on the Menu Bar (see Chapters 3, 4, 6, 7 and 8 for details on particular menus) and scroll to the desired option.

2. Press the desired softkey. A window appears with the question, “Assign current menu command to FKeyX?”

3. Press [F3] (Yes) to confirm the assignment and close the window. (Press [F2] (No) to close the window without changing the key.)

5.5.2 Customizing Softkeys (cont.)

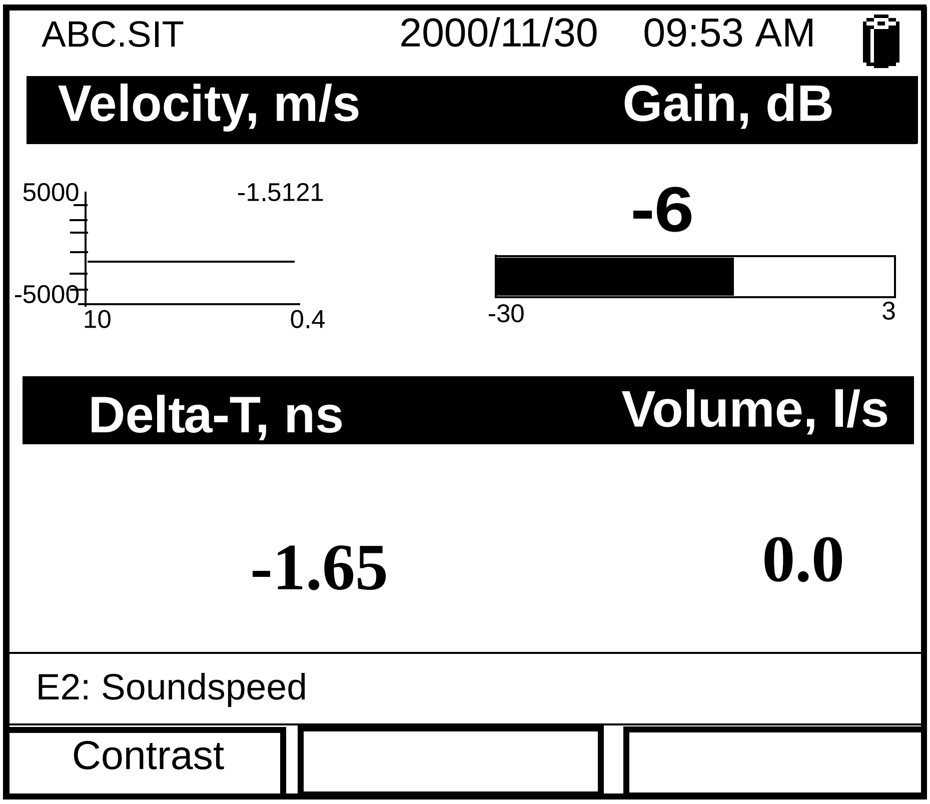

Figure 63: Display Screen with Modified Softkey

- To clear a softkey:

1. From the Site Menu (shown in Figure 59 on page 97), use the [▼] or [▲] arrow keys to move to the FKeys entry on the menu. Press [ENTER]. The screen now appears similar to Figure 61 on page 99.
2. Use the [▼] or [▲] arrow keys to move to the desired Clear FKey (1, 2 or 3) entry on the menu. Press [ENTER].

The softkey window clears. You can also clear the softkey through the Configure FKey window, by selecting (Clear) as an entry, pressing [ENTER] and then [F3] (OK).

Note: *Since the customized softkeys are saved globally, they will remain, even if you change site files.*

5.6 Managing Files — The Drive Manager

On occasion, you might want to review or transfer some or all of the files in the PT878. The Drive Manager allows you to view all the files stored in the meter. While following the programming instructions, refer to Figure 138 on page 221 of Appendix A, *Menu Maps*. To open the Drive Manager:

1. Press [MENU].
2. From the Site Menu (shown in Figure 59 on page 97), use the [▼] or [▲] arrow keys to move to the Drive Manager entry on the menu. Press [ENTER]. The screen now appears similar to Figure 64 below.

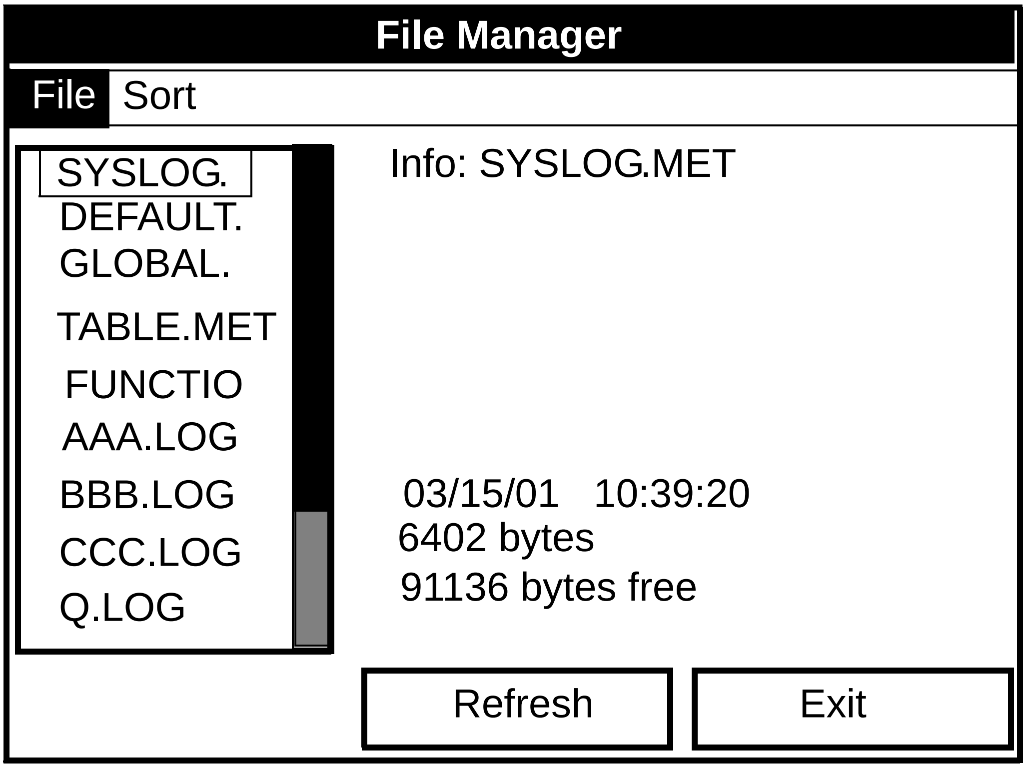

Figure 64: Drive Manager Window

The window on the left lists all the meter, site and log files in the PT878, while the window on the right displays information on the file highlighted in the left window.

5.6 Managing Files — The Drive Manager (cont.)

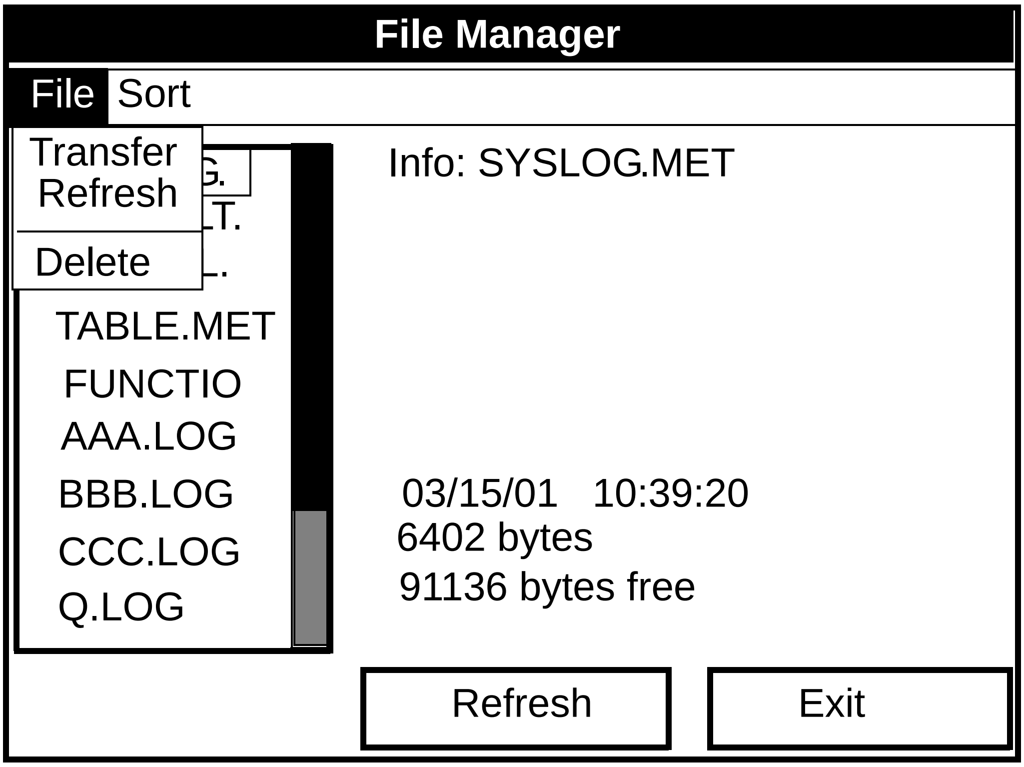

Figure 65: File Manager Menu

To transfer, refresh or delete a file, first be sure the file is highlighted in the window on the left. Then press [MENU] to open the File Menu, and scroll to the appropriate option, as shown in Figure 65 above. Press [ENTER]. The PT878 then performs the desired action with the file.

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5.6.1 Transferring a File to a PC

To upload a log, meter, bitmap or site file to a PC:

1. Connect the PT878 USB port to any USB port on the PC (page 9).
2. Start HyperTerminal and set up the communication link to match the PT878 Com port settings.
3. From the PT878 select *Site\Site Manager* and then select the file you want to transfer to the PC.
4. Select the *Transfer\Receive File* option.
5. Select the location of the file and the XModem receiving protocol.
6. Click the *Receive* option and enter the Filename.
7. From PT878 *Site Manager,* select the *Site\Transfer* option. This will allow the PT878 to send the site file to a PC using the secure XModem protocol. File transfer is complete when the XModem Receive dialog box closes.

5.6.2 Transferring a File from a PC to the PT878

Once you have stored site or meter files to a PC, you can then transfer them back to the PT878 over the USB interface. The PT878 only accepts files with a .sit (site) or .met (meter) extension. If you try renaming another type of file with a .sit or .met extension and transfer it, it will be transferred, but it will not function if you open it. Also, if you are transferring a file and the meter already has a file with the identical name, the meter will overwrite its current file with the transferred file. If the transferred file has a name longer than eight characters, the meter will shorten the name to eight characters, and replace any spaces in the name with underbars.

Note: *It is not possible to download log files back to the PT878.*

To download a site or meter file from a PC to a PT878:

1. Connect the PT878 USB port to any USB port on the PC(page 9).
2. Start HyperTerminal and set up the communication link to match the PT878 Com port settings.
3. From the PT878 select Site\Site Manager and then select Site\Transfer from the PC. Type in the name of the site file and click OK.

From HyperTerminal, complete the following steps:

1. Select the *Transfer\Send File* option.
2. Select the location of the file and the XModem protocol.
3. Click *Send*. File transfer is complete when the XModem Receive dialog box closes. The file should now appear in the PT878 Site Manager.

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5.6.3 Refreshing a File

To refresh a file so that the PT878 displays the most recent information, you have two options:

- Press [MENU], scroll to the Refresh option, and press [ENTER].
- Press [F2] (Refresh).

In either case, the window on the right of the File Manager displays the most recent file information.

5.6.4 Deleting a File

To delete a file in the File Manager, first be sure you have highlighted that file in the left window of the File Manager. Then press [MENU], scroll to the Delete option, and press [ENTER]. The screen appears similar to Figure 66 below.

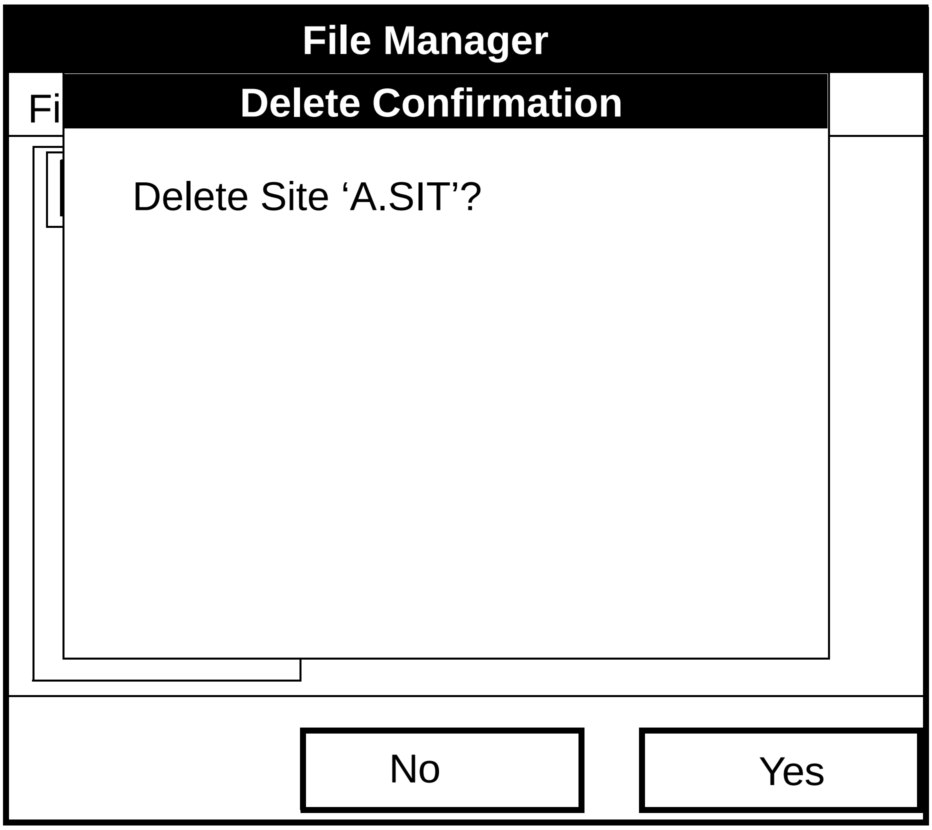

Figure 66: Delete Confirmation Window

- Press [F2], No, to cancel the deletion and return to the File Manager, or
- Press [F3], Yes, to delete the site.

The File Manager appears, with the highlighted site now deleted.

5.6.5 Listing Files by Name

If you want to list your files alphabetically by site name within the File Manager, press [MENU] to open the File Menu. Then press the [▶] arrow key to scroll from the File Menu to the Sort Menu, shown in Figure 67 below. Press [ENTER]. The File Manager screen refreshes, with the sites listed in alphabetical order.

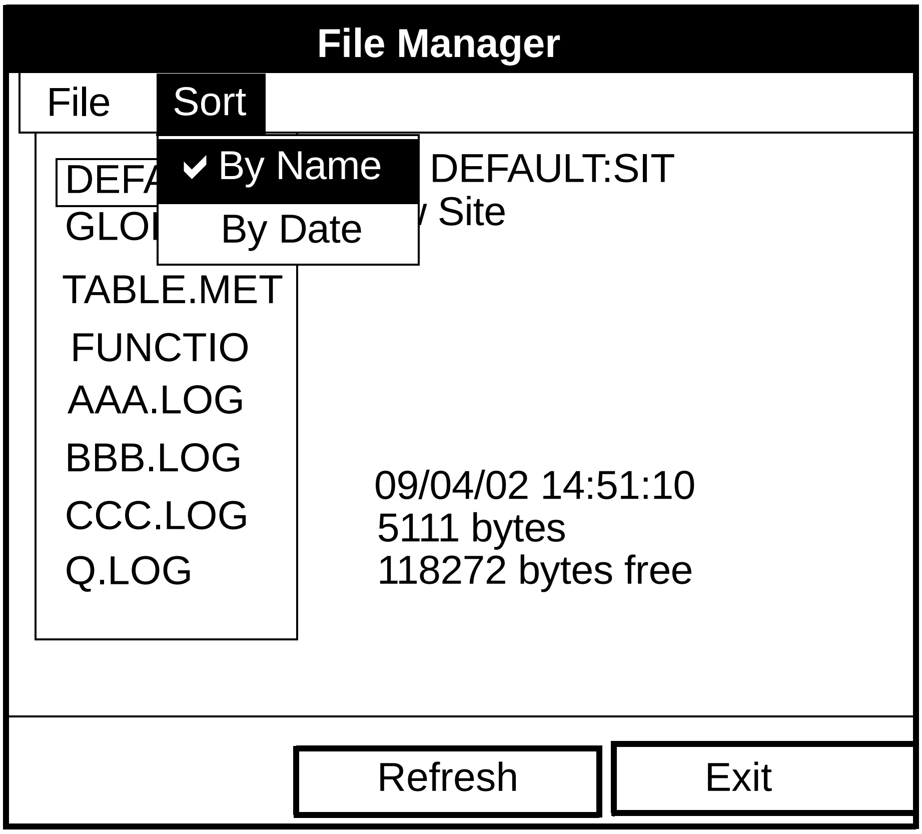

Figure 67: Sort Submenu

5.6.6 Listing Files in Chronological Order

If you prefer to list your files chronologically by time of creation within the File Manager, press [MENU] to open the File Menu. Then press the [▶] arrow key to scroll from the File Menu to the Sort Menu, and scroll to the By Date option. Press [ENTER]. The Site Manager screen refreshes, with the sites listed in chronological order, from the most recent to the earliest.

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5.7 Accessing Meter Data —The About Option

The About option displays useful information concerning the model number and software version of any given PT878. While the window normally appears briefly at startup, users might want to access the information for a longer period. To open the About window, scroll to the About option on the Site Menu and press [ENTER]. The screen appears similar to Figure 68 below. To access data on your specific PT878, press [F2] (Next).

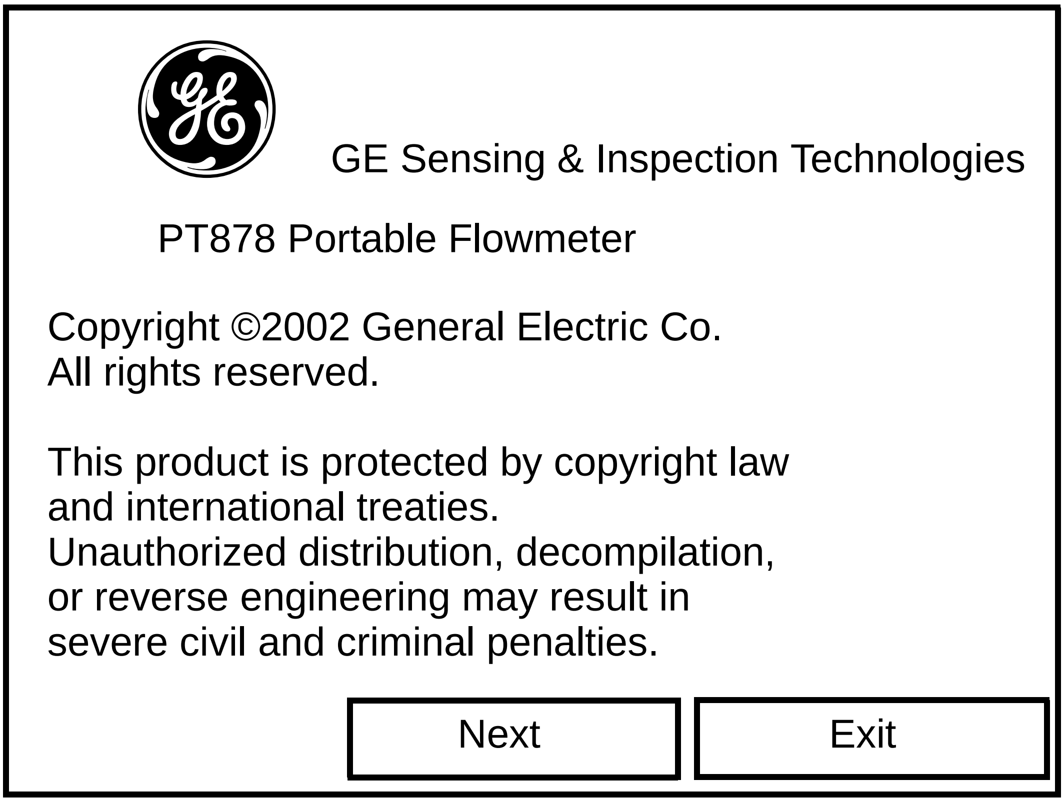

Figure 68: About Window

To return to Operate Mode, press [ESC] or [F3] (Exit).

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Chapter 6. Programming Meter Settings

Along with display formats and site data, PT878 users can program global settings for the meter that suit their individual preferences. The global settings include:

- English or Metric measurement units
- Battery power
- Date and time parameters and appearance (locale)
- Screen contrast
- Backlight timeout
- Language settings
- USB communications settings
- Resetting forward and reverse totals
- User tables
- Taking a bitmap capture of a screen

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6.1 Entering the Meter Menu

To enter the Meter Menu, press the [MENU] key at the lower right of the PT878 keypad. The Main Menu replaces the Status Bar at the top of the screen. Press the [▶] arrow key twice to scroll from the Site Menu to the Meter Menu. At the Meter Menu, press [ENTER]. The screen appears similar to Figure 76 below. While programming, refer to Figure 140 on page 223 of Appendix A, *Menu Maps*.

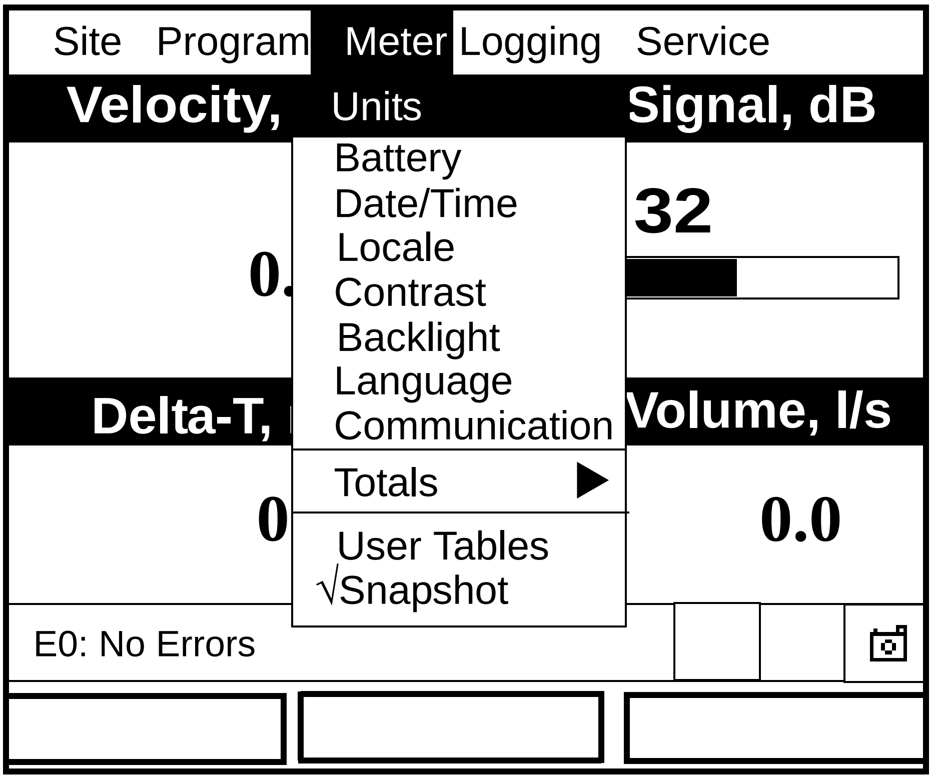

Figure 76: Meter Menu

To scroll to a particular option, press the [▼] or [▲] arrow keys until you reach the option. Then press [ENTER] to open the option window.

When entering parameters in an option, press:

- The [▼] key to step through the available parameters
- The [▲] key to scroll back to a previously entered parameter
- The [F2] key (Cancel) or the [ESC] key to exit an option at any time and return to Operate Mode without changing the parameters.

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6.2 Selecting Measurement Units

The first option, Units, enables you to select either English or Metric units as global measurement units for the PT878. The selected units then become the default settings for every measurement that has the option for metric/English units. To select the units, scroll to the Units entry on the Meter menu and press [ENTER]. The Meter Settings window opens, as shown in Figure 77 below.

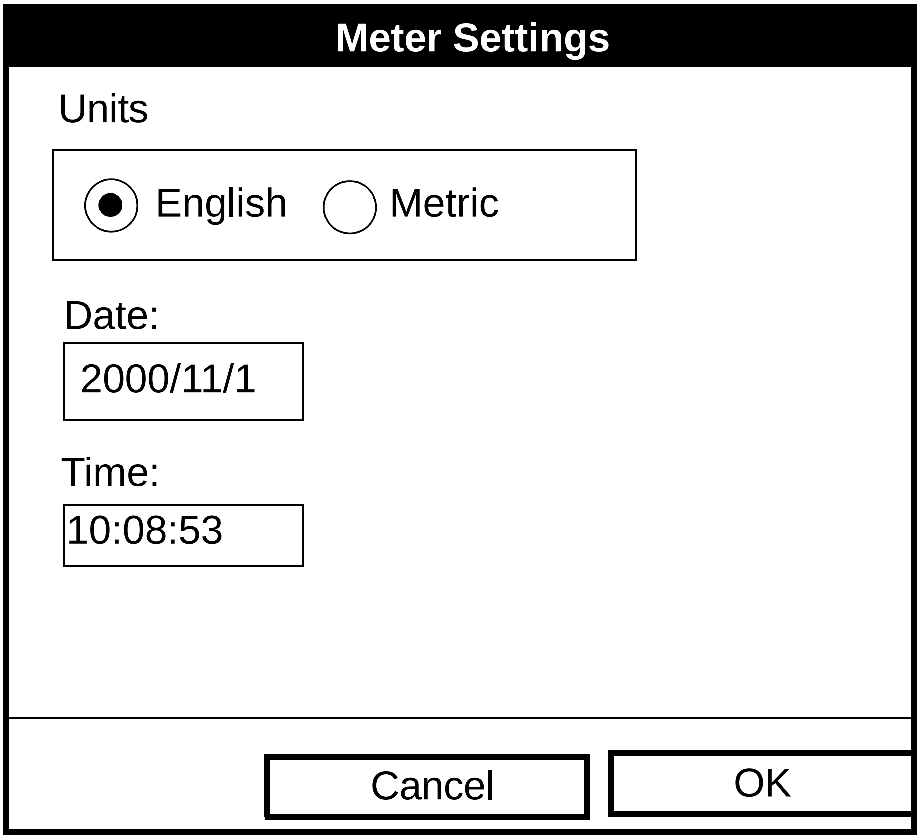

Figure 77: Meter Settings Window

1. Use the [◀] and [▶] keys to scroll between English and Metric units.
2. Press [ENTER] to confirm the choice.

6.3 The Battery Charger

The Battery option allows you to monitor the current run time and status of the internal rechargeable batteries, as well as to condition NiCad batteries to maintain the maximum life possible. Conditioning NiCad batteries (a process that can take up to 12 hours for a fully charged pack) discharges the pack completely and then performs a fast charge.

Note: *When conditioning the batteries, be sure you have plugged the AC adapter into the PT878 and pressed the power key. NiMH batteries normally do not require conditioning.*

To open the option window:

1. From the Meter menu, scroll to the Battery entry and press [ENTER]. The Battery Charger window opens, as shown in Figure 78 below.
2. If you wish to open the Part Number window, press [ENTER]. You can choose from a 1.8 Ahr NiCad battery (part number 200-058) or a 3.0 Ahr NiMH battery (part number 200-081). Scroll to the battery type you have installed and press [ENTER].

Note: *If you do not set the correct battery type in the Part Number window, the battery continues to function, but the battery status icons (see page 13) will not be accurate.*

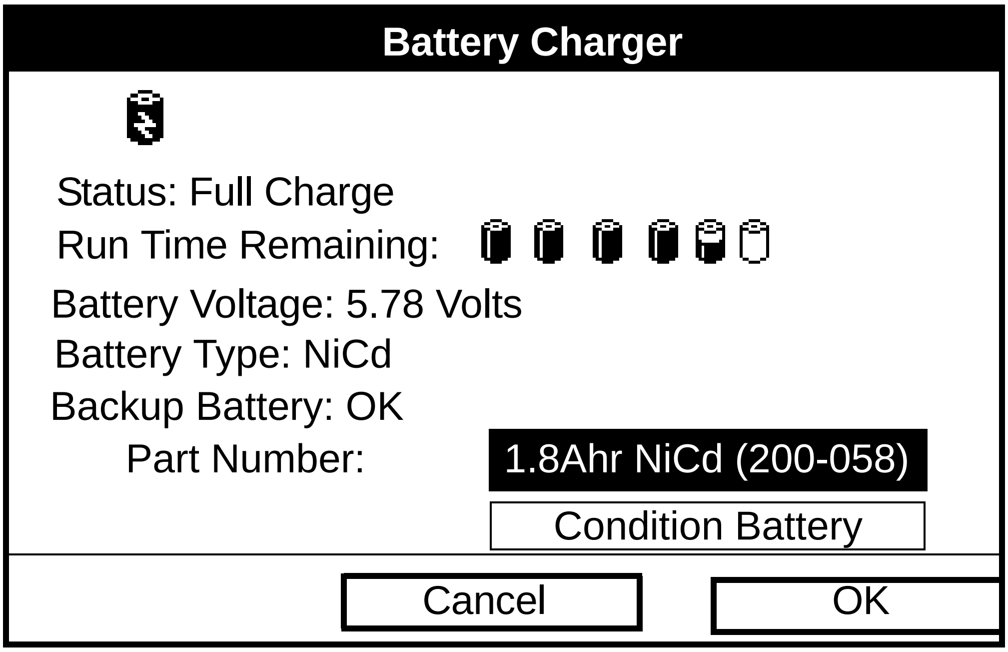

Figure 78: Battery Charger Window 389

6.3 The Battery Charger (cont.)

3. To condition the batteries, press the [ENTER] key. The “Condition Battery” window should now read “Stop.” The status line should change to “Discharging.” (Updating the status could take up to 30 seconds.)

Note: *It is advisable to condition NiCad batteries when their run time is reduced to 50% of their previous run time.*

4. To stop the discharge cycle, press the [ENTER] key and the “Condition Battery” window reappears. The status now changes to “On Charger.”

5. Press [F3] (OK) to return to Operate Mode.

6.4 Entering Date and Time

In Operate mode, the Status Bar displays the current date and time above the measurements in the upper right corner of the screen. The Date/Time option allows you to set the date or time, which are required for correct data logging operation.

To set the time:

1. From the Meter menu, scroll to the Date/Time entry and press [ENTER]. The Meter Settings window reopens, as shown in Figure 77 on page 113.

2. From the Units option, press the [▼] key once to reach the date text box. This box displays the current meter date.

3. Press [ENTER] to enter the text window. The meter highlights the center number. Use the [◀] and [▶] keys to scroll to any number you wish to change.

6.4 Entering Date and Time (cont.)

4. Two alternatives are available to change a highlighted number:

- Use the numeric keys to enter the desired number.
- Use the [▼] or [▲] arrow keys to scroll, in 1-digit increments, to the desired number. (For example, if the text box highlights 09, pressing the [▼] key twice changes the number to 07. You can scroll from 01 to 12 for the month and from 01 to 31 for the day (depending on the number you have selected for the month.)

In either case, press [ENTER] to confirm the entry.

To enter or change the time:

1. From the time text box, press the [▼] key once to scroll to the time text box. This box displays the current meter time.

2. Press [ENTER] to enter the text box. The meter highlights the first number. Use the [◀] and [▶] keys to scroll to any number you wish to change.

3. Two alternatives are available to change a highlighted number:

- Use the numeric keys to enter the desired number.
- Use the [▼] or [▲] arrow keys to scroll, in 1-digit increments, to the desired number. (For example, if the text box highlights 09, pressing the [▼] key twice changes the number to 07.) You can scroll from 01 to 12 for the hour and from 01 to 59 for the minute and second inputs.

4. In either case, press [ENTER] to confirm the entry.

Pressing the [▼] or [▲] arrow keys causes the meter to scroll within the Meter Settings options.

- To confirm the entries and return to Operate mode, press [F3] (OK). The PT878 returns to Operate Mode.
- To leave the window without confirming the entries, press [F2] (Cancel) or the [ESC] key. The PT878 returns to Operate Mode.

6.5 Changing Date and Time Appearance

In addition to setting the correct date and time, you can also change its presentation to suit local preferences. You can select a time display of AM/PM or 24-hour time.

To alter the time and date display:

1. From the Meter menu, scroll to the Locale entry and press [ENTER]. The Display Options window opens on the Format tab, as shown in Figure 79 below. To step through each parameter, press the [▼] key.

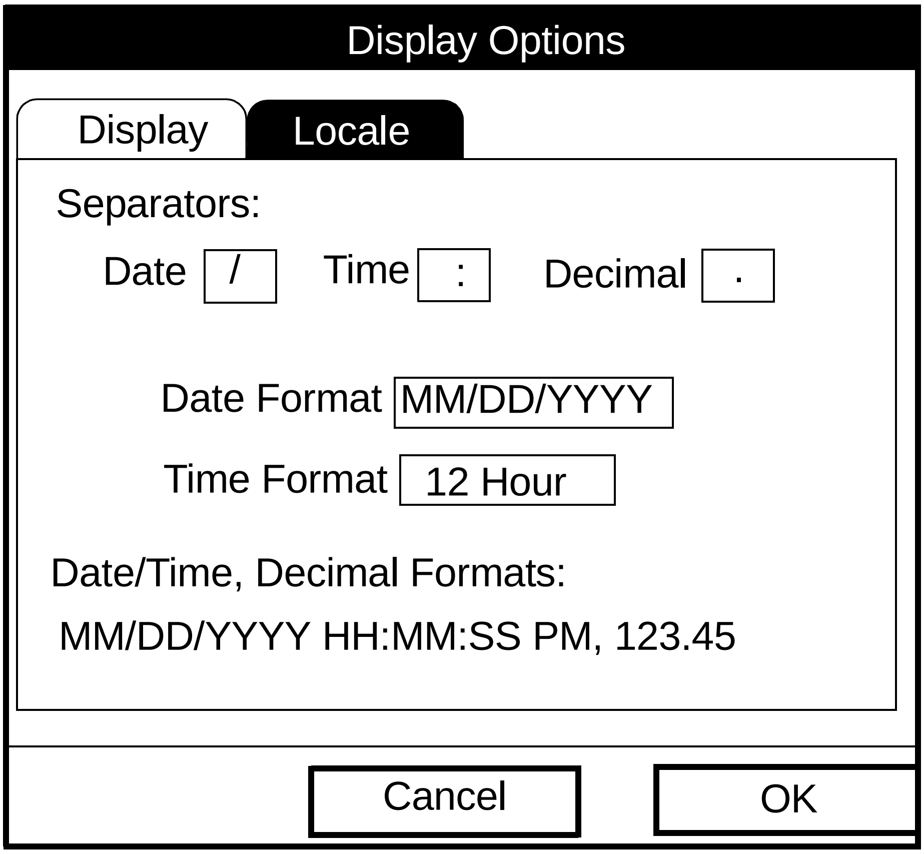

Figure 79: Format Tab in the Display Options Window

6.5 Changing Date and Time Appearance (cont.)

2. The first series of prompts asks you to select separator symbols for the date, time and decimal. You can choose from a dash, comma and slash (/) for the date; from a period and colon for the time: and from a period or comma for the decimal place. For each symbol type:

a. Press [ENTER] to open the drop-down menu.

b. Use the [▼] or [▲] arrow keys to scroll to the desired format.

c. Press [ENTER] to confirm your entry.

3. The next prompt asks you to select the date format.

a. Press [ENTER] to open the drop-down menu. Three options are available:

- YYYY/MM/DD (year/month/day)
- MM/DD/YYYY (month/day/year)
- DD/MM/YYYY (day/month/year)

b. Use the [▼] or [▲] arrow keys to scroll to the desired format.

c. Press [ENTER] to confirm your entry.

4. The PT878 now asks you to select whether you want the time presented in a 12-hour format (for example, 11:53:23 PM) or in a 24-hour format (23:53:23).

a. Press [ENTER] to open the drop-down menu.

b. Use the [▼] or [▲] arrow keys to scroll to the 12-hour or 24-hour entry.

c. Press [ENTER] to confirm your entry.

6.5 Changing Date and Time Appearance (cont.)

A line at the bottom, the Date/Time, Decimal Formats, displays how the format and separator selections will appear on the screen.

Pressing the [▼] arrow key returns the PT878 to the Locale tab.

- To confirm the entries and return to Operate mode, press [F3] (OK). The PT878 returns to Operate Mode.
- To leave the window without confirming the entries, press [F2] (Cancel) or the [ESC] key. The PT878 returns to Operate Mode.

6.6 Adjusting the Contrast

For more comfortable viewing in a particular environment, the PT878 enables you to adjust the screen contrast. To adjust the screen contrast:

1. From the Meter menu, scroll to the Contrast entry and press [ENTER]. The Display Options window opens on the Display tab, as shown in Figure 80 below. (From the Format tab, press the [◀] key to move to the Display tab.) To step through each parameter, press the [▼] key.

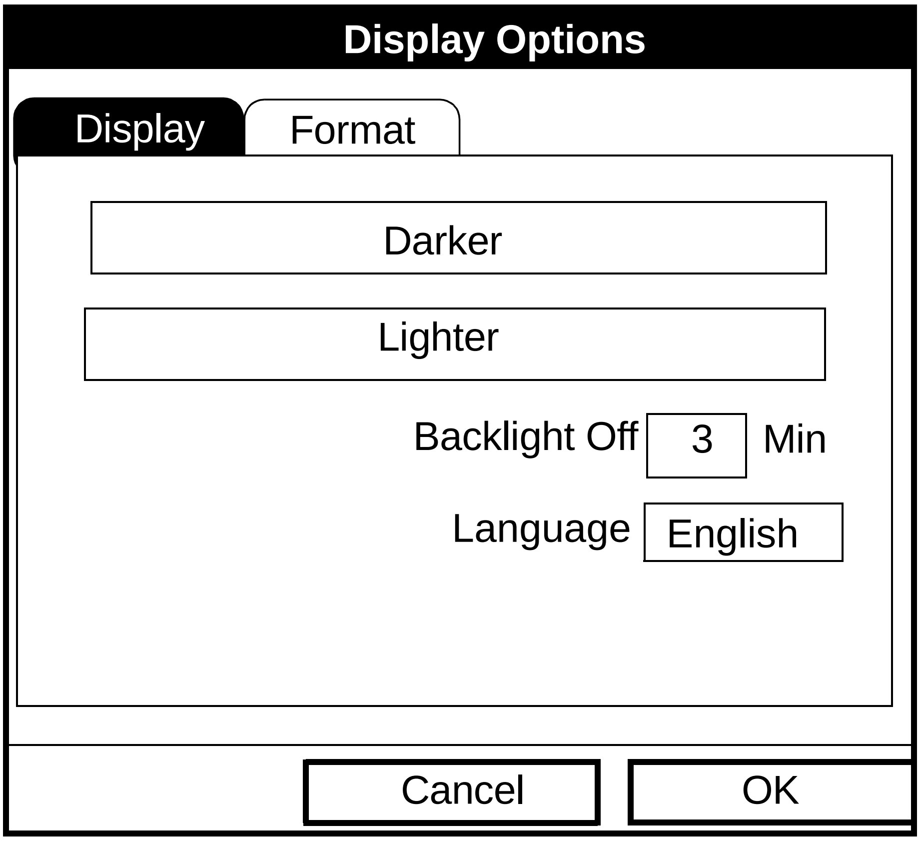

Figure 80: Display Tab in the Display Options Window

2. Scroll to the Darker or Lighter box as desired.
3. Press the [ENTER] button repeatedly until the screen has the desired contrast.

Note: *If you find the screen has become too light or too dark, scroll to the other box and press* [ENTER] *until you have adjusted the screen to your satisfaction.*

6.6 Adjusting the Contrast (cont.)

- To confirm the entries and return to Operate Mode, press [F3] (OK). The PT878 returns to Operate Mode.
- To leave the window without confirming the entries, press [F2] (Cancel) or the [ESC] key. The PT878 returns to Operate Mode.

6.7 Setting Backlight Timeout

By using the Backlight Timeout option, you can set a specified time that the PT878 backlight will remain on before turning itself off. Automatic turnoff enables the PT878 to conserve battery power.

To set the backlight timeout:

1. From the Meter menu, scroll to the Backlight entry and press [ENTER]. The Display Options window opens on the Display tab, as shown in Figure 80 on page 120.
2. Press the [▼] key three times to reach the Backlight Off text box.
3. Then press [ENTER] to enter the box.
4. Use the numeric keys to enter the number of minutes that the backlight remains on (from 0 to 99).
5. Press [ENTER] to confirm the entry.

- To confirm the entries and return to Operate mode, press [F3] (OK). The PT878 returns to Operate Mode.
- To leave the window without confirming the entries, press [F2] (Cancel) or the [ESC] key. The PT878 returns to Operate Mode.

Note: *You can turn the backlight on or off at any time by pressing the power switch for 1 second.*

6.8 Changing the Display Language

Important: *To use this option, you must have previously loaded a language translation file into the PT878.*

The PT878 offers the selection of several languages for its display. To change the display language:

1. From the Meter menu, scroll to the Language entry and press [ENTER]. The Display Options window opens on the Display tab, as shown in Figure 80 on page 120.
2. Press the [▼] key four times to reach the Language prompt.
3. Then press [ENTER] to enter the drop-down menu.
4. Scroll to the desired language on the menu, here shown as either English or Francais (French).
5. Press [ENTER] to confirm the entry, and [F3] (OK) to close the option.
6. Since changing the language requires restarting the PT878, a window (shown in Figure 81 below) opens, asking that you confirm the change. Press [F2] to cancel the change or [F3] to confirm the change.

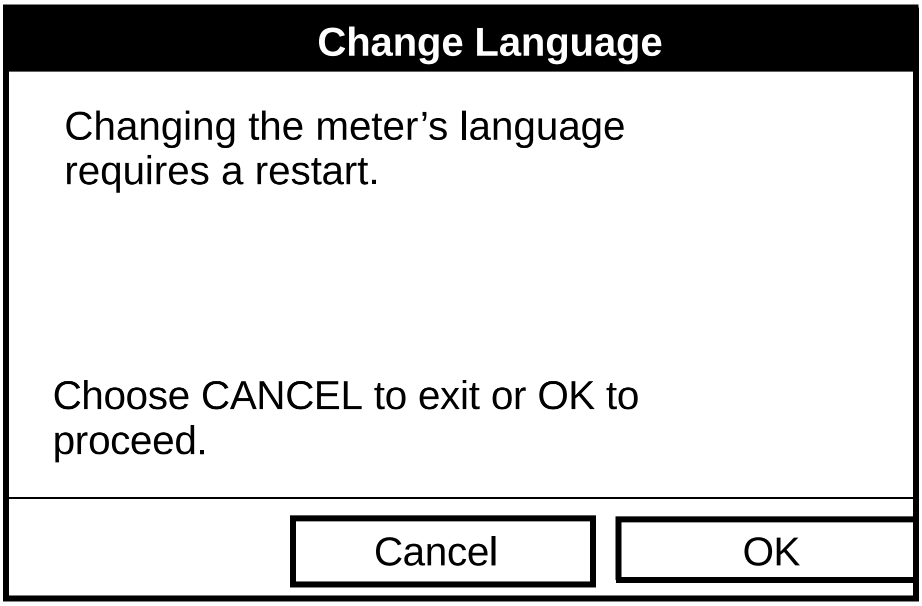

Figure 81: Confirmation Window for Language Change

6.8 Changing the Display Language (cont.)

The meter restarts in Operate Mode in the desired language. Figure 82 below illustrates a French version of the display shown in Figure 56 on page 92.

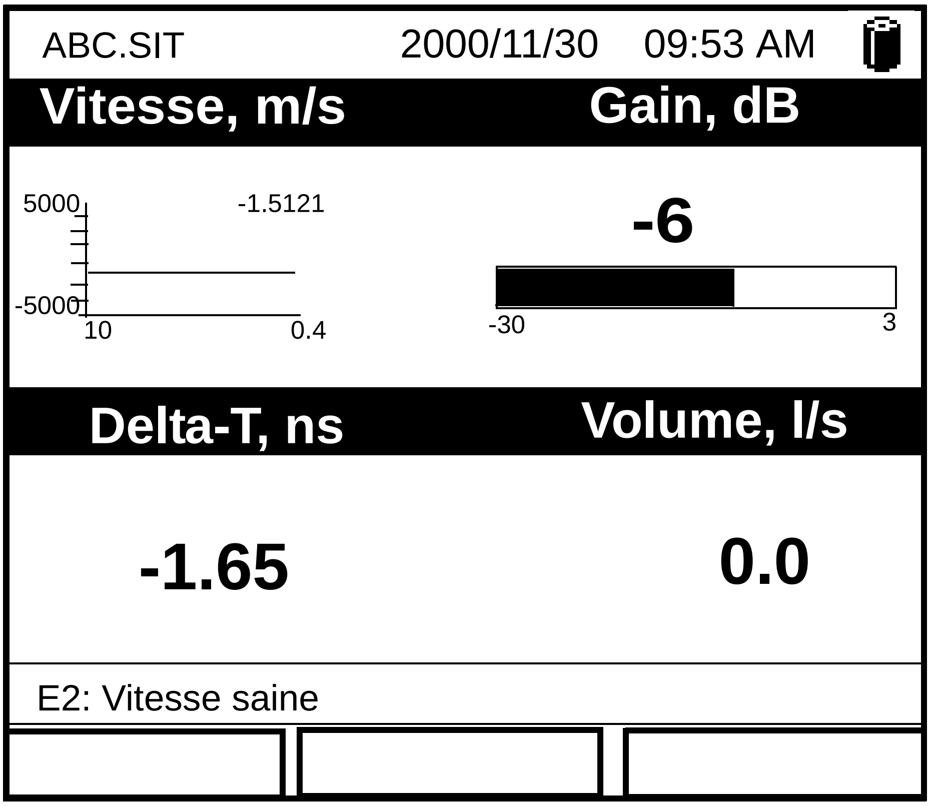

Figure 82: French Version of Typical Display

Note: *The PT878 defaults to US English. However, one or more alternate languages can be installed at any time. Consult your GE representative or www.ge-mcs.com for available languages.*

6.9 Changing Communications Settings

On occasion, you might need to change the parameters by which the PT878 communicates with a PC over the USB interface. While programming, see Figure 153 on page 237 of Appendix A, *Menu Maps*. To check or change these parameters:

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6.9 Changing Communications Settings (cont.)

1. From the Meter menu, scroll to the Communications entry and press [ENTER]. The Communications window appears similar to Figure 83 below.

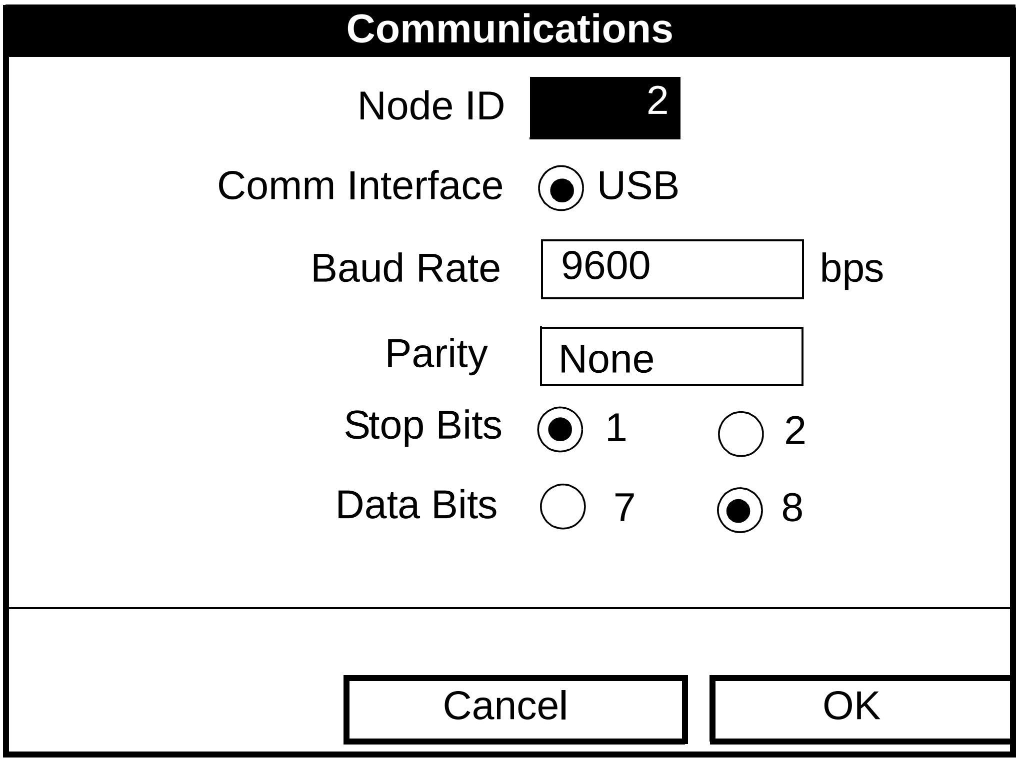

Figure 83: Communications Window

2. The first prompt asks for the node identification number, which can be any number from 1 to 240. *Do NOT change the node ID unless instructed by GE.*

a. Press [ENTER] to open the text box.

b. Use the numeric keys to enter the node ID.

c. Press [ENTER] to confirm the entry.

3. The next prompt confirms the USB communications interface.

6.9 Changing Communications Settings (cont.)

4. The program now asks for the baud rate. The default rate is 9600 bps.

a. Press [ENTER] to open the drop-down menu.

b. Use the [▼] or [▲] arrow keys to scroll to the desired rate, from 300 to 115.2K bps.

c. Press [ENTER] to confirm the entry.

5. The next prompt asks for the parity from five options: None, Mark, Space, Even or Odd. The default parity is None.

a. Press [ENTER] to open the drop-down menu.

b. Use the [▼] or [▲] arrow keys to scroll to the desired parity.

c. Press [ENTER] to confirm the entry.

6. The next prompt asks you to select either one or two stop bits.The default number is one. Use the [◀] and [▶] keys to scroll to the desired number, and press [ENTER].

7. The final prompt asks you to select either seven or eight data bits. The default number is 8. Use the [◀] and [▶] keys to scroll to the desired number, and press [ENTER].

- To confirm the entries and return to Operate Mode, press [F3] (OK). The PT878 returns to Operate Mode.
- To leave the window without confirming the entries, press [F2] (Cancel) or the [ESC] key. The PT878 returns to Operate Mode.

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6.10 Resetting Forward and Reverse Totals

On occasion, it might be necessary to clear and reset the forward and reverse totals computed by the Forward and Reverse Totalizers. To reset the totals:

1. From the Meter menu, scroll to the Totals entry and press [ENTER]. The window now appears similar to Figure 84 below.

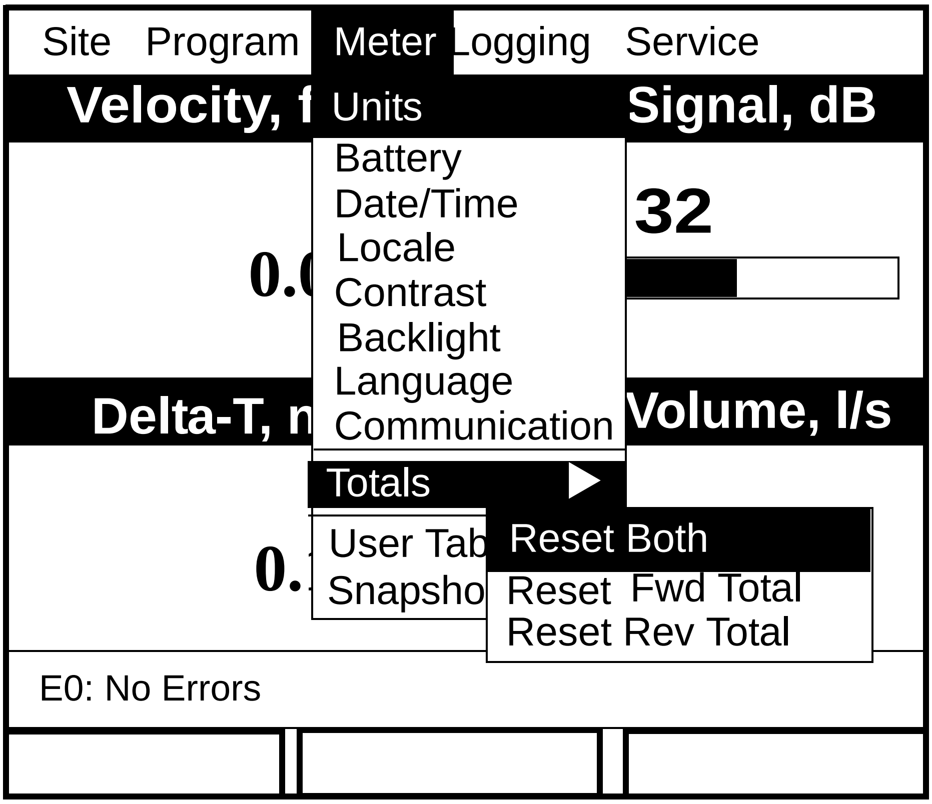

Figure 84: Resetting Totals Menu

2. Use the [▼] or [▲] arrow keys to choose the total to be reset.
3. Press [ENTER] to reset the total(s).

The meter resets the selected total(s) to 0.0 and returns to Operate Mode.

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6.11 Setting Up User Tables

When you program user functions (see page 61), you can also support them with up to six user tables of non-linear or empirical data. To program one or more user tables:

1. From the Meter menu, scroll to the User Tables entry and press [ENTER]. The window now appears similar to Figure 85 below.

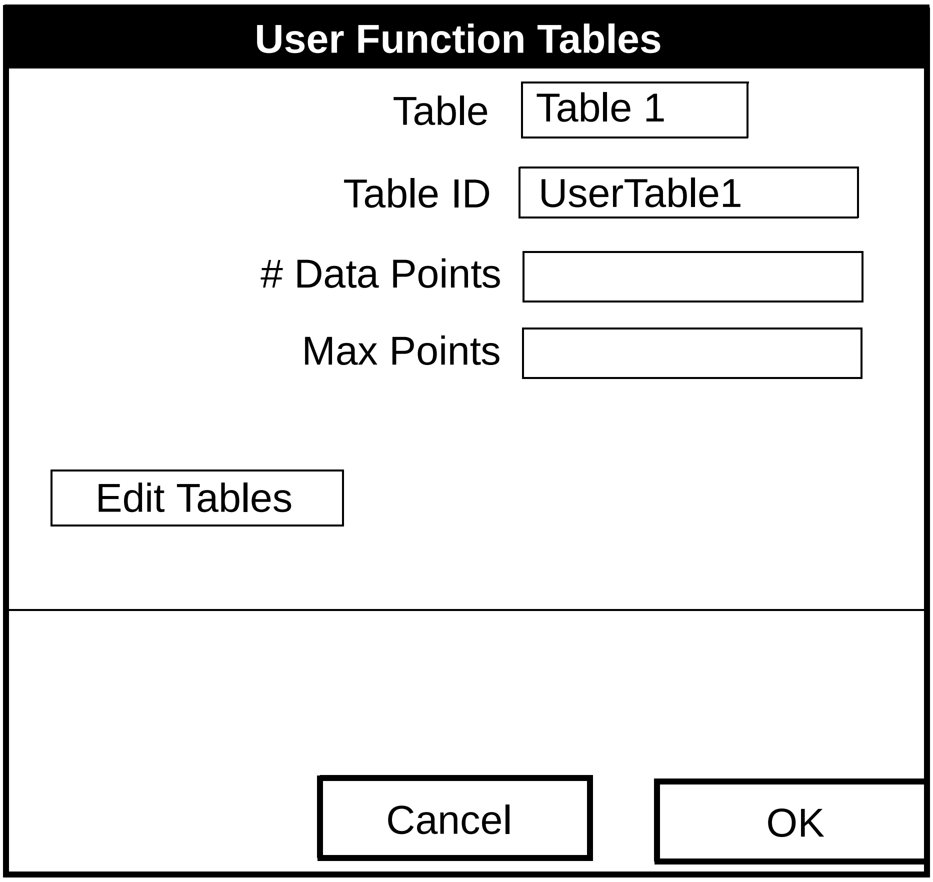

Figure 85: User Tables Window

2. The first prompt asks you to select the table to be programmed.

a. Press [ENTER] to open the drop-down menu.

b. Use the [▼] or [▲] arrow keys to scroll to the table you wish to program.

c. Press [ENTER] to confirm the entry.

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6.11 Setting up User Tables (cont.)

3. The next step is to create a Table ID.

a. Press [ENTER] to open the window. The screen now appears similar to Figure 86 below.

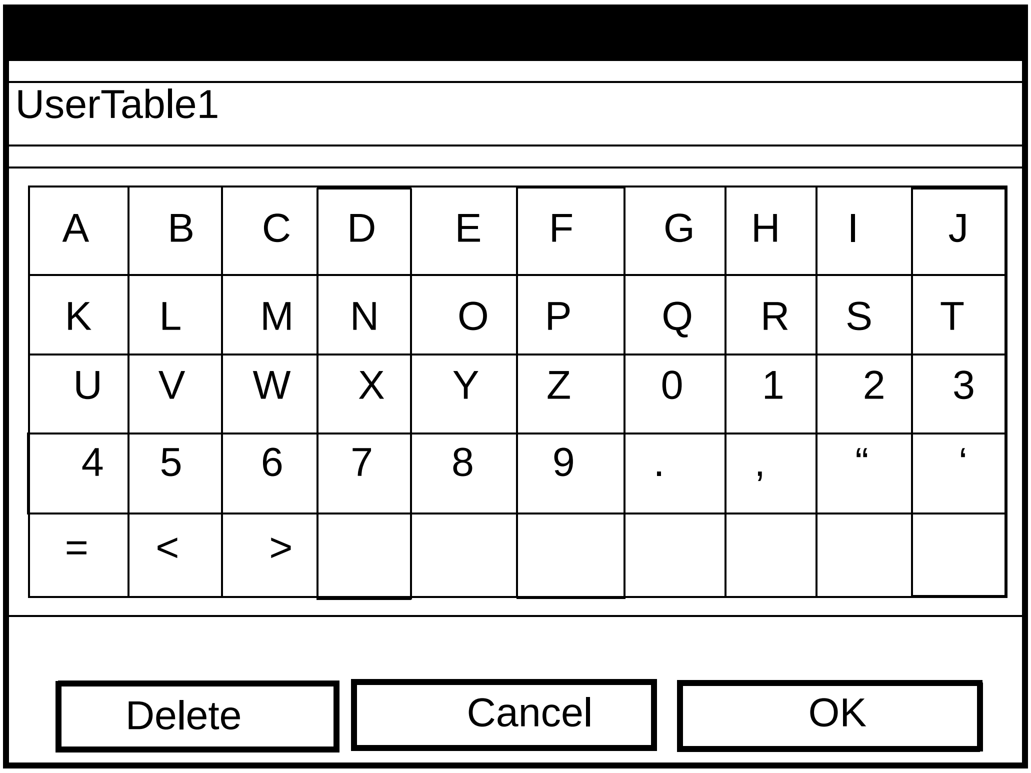

Figure 86: Text Creation Window

b. Use the four arrow keys to scroll to the desired letter or symbol, and press [ENTER] to add the letter to the label.

Note: *Pressing* [SEL] *causes the screen to alternate between a set of upper-case (capital) letters and a set of symbols. Use both screens to create the desired label.*

c. Repeat this procedure for each letter or symbol you wish to add to the label. If you wish to delete a letter, press [F1] (Delete) to erase each letter or symbol, from right to left on the label.

d. When you have completed the label, press [F3] (OK) to confirm the label, or [F2] (Cancel) to leave the window without adding the label.

Note: *It is not necessary to enter the “#Data Points” or “Max Points” text boxes.*

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6.11 Setting up User Tables (cont.)

4. The final prompt asks you to enter or change data in the user table.

a. Press [ENTER] to open the window. The screen appears similar to Figure 87 below.

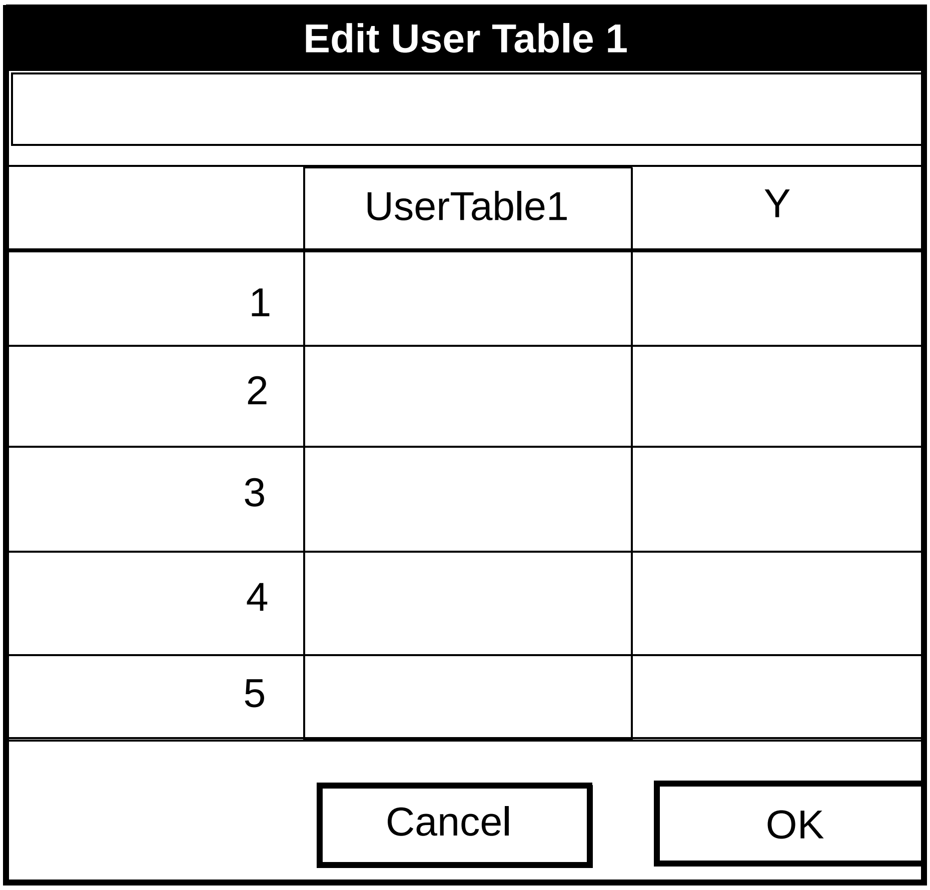

Figure 87: Edit User Table Window

b. Use the four arrow keys to move to the desired entry in the table.

c. Press [ENTER]. Then use the numeric keys to enter the desired data, which appears in the right corner of the window above the table.

d. Press [ENTER] to confirm the data, which then appears in the appropriate slot in the table.

e. Repeat steps b, c and d on the previous page 129 until you have completed entering data for the table.

f. When you have finished, press [F3] (OK) to confirm the entries or [F2] (Cancel) to leave the window without confirming the table.

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6.11 Setting up User Tables (cont.)

The program returns to the Edit Tables window.

- To confirm the entries and return to Operate Mode, press [F3] (OK). The PT878 returns to Operate Mode.
- To leave the window without confirming the entries, press [F2] (Cancel) or the [ESC] key. The PT878 returns to Operate Mode.

6.12 Taking a Bitmap Capture of a Current Screen

The Snapshot option enables you to take a screen capture of the current screen in bitmap format (.bmp) for display or storage in a Windows-based PC. To take a “snapshot” of the screen:

1. From the Meter menu, scroll to the Snapshot entry and press [ENTER].

2. Another menu opens with two entries: Off and To File. Scroll to the desired entry and press [ENTER].

Note: *An icon of a camera (for file capture — see page 19) appears at the far right of the status tray, indicating that you have activated the Snapshot option. Figure 76 on page 112 shows a screen with the Snapshot option activated.*

3. To capture a screen, press the [.] (decimal) button in the lower left corner of the keypad twice. The meter beeps, indicating that it has made a screen capture.

The captured file appears as “Screen 0X.bmp” in the Drive Manager (see page 102). To transfer the file to a PC, follow the instructions in *Transferring a File to a PC* on page 104.

Chapter 7. Logging Data

A powerful and flexible feature of the PT878 is data logging. The meter enables you to choose up to 12 parameters to log. Log files contain diagnostic and measurement data as programmed by the user. The log file is typically programmed in the PT878 Log Manager, but it can also be programmed using PanaView.You can also select the start time and date, end time and date, and time interval. Logs can run one at a time or simultaneously. Error and circular logs are also available. The logged data is internally stored in battery-backed-up memory. A fixed amount of memory is assigned to data logging. The frequency of the time interval, the length of the log run, and the number of logs affect the amount of memory required for a particular log. For example, a log that records every 5 seconds will use up more memory than a log that records every 5 minutes for a given amount of time. Once you make your data logging selections, the PT878 enables you to view the amount of memory left. You may also stop logging or view logged data while or after data is logged.

This section describes:

- How to enter the Logging Menu.
- How to set up a new log.
- How to view the data logger memory.
- How to start, stop or pause logging

7.1 Entering the Logging Menu

To enter the Logging Menu, press the [MENU] key at the lower right of the PT878 keypad. The Main Menu replaces the Status Bar at the top of the screen. Press the [▶] arrow key three times to scroll from the Site Menu to the Logging Menu. At the Logging Menu, press [ENTER]. The screen appears similar to Figure 88 below. Refer to Figure 141 on page 224 of Appendix A, *Menu Maps.*

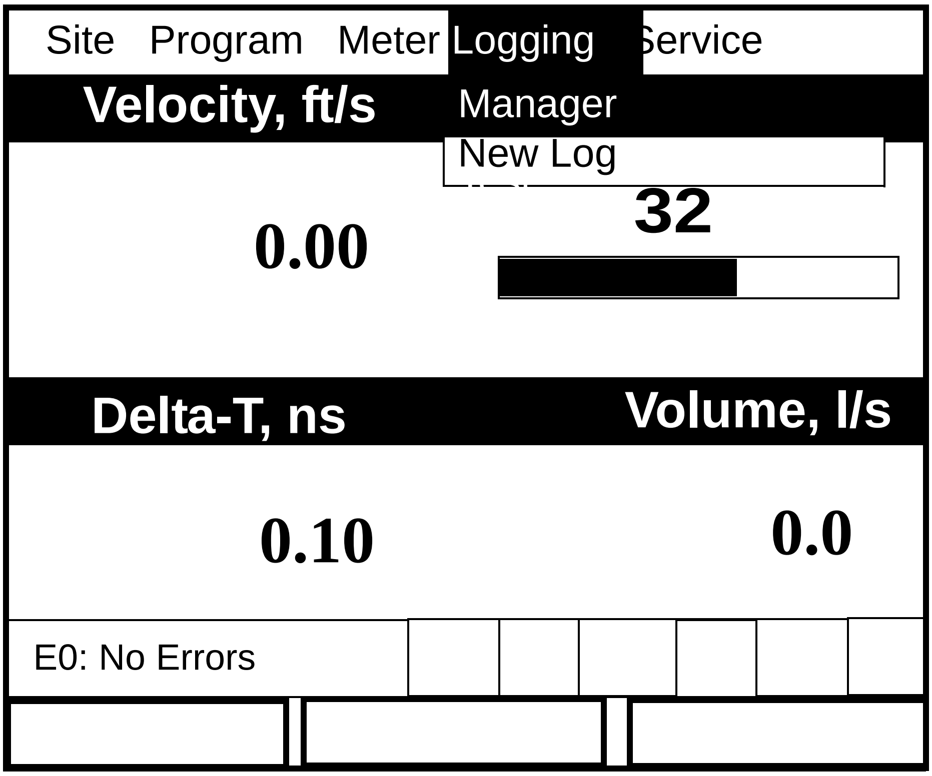

Figure 88: Logging Menu

To scroll to a particular option, press the [▼] or [▲] arrow keys until you reach the option. Then press [ENTER] to open the option window.

When entering parameters in an option, press:

- The [▼] key to step through the available parameters
- The [▲] key to scroll back to a previously entered parameter
- The [F2] key (Cancel) or the [ESC] key to exit an option at any time and return to Operate Mode without changing the parameters.

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7.2 The Log Manager

The Log Manager offers users a way to check the status and memory size of all the logs currently pending, running or finished. To select Log Manager, scroll to the Manager entry on the Logging Menu and press [ENTER]. The screen appears similar to Figure 89 below. The right section of the screen supplies information for the log highlighted in the list on the left. You can use the [▼] and [▲] arrow keys to scroll to a particular log and display information pertaining to that log.

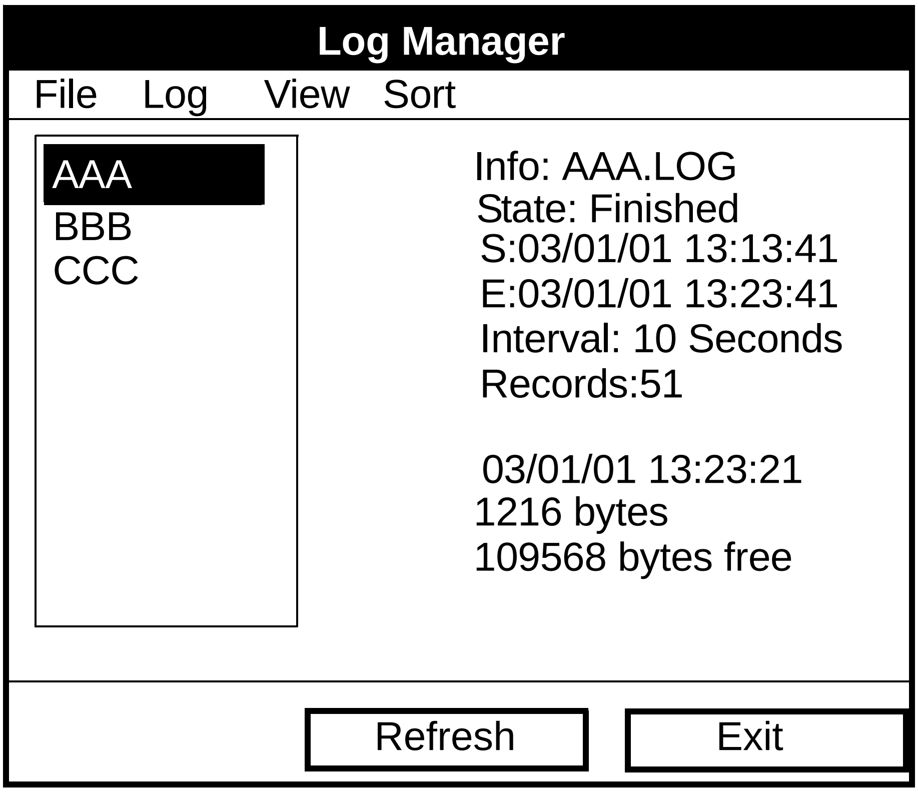

Figure 89: Log Manager Window

To access the menu for the Log Manager, press the [MENU] key. The cursor highlights the File Menu in the upper left corner. Use the [◀] and [▶] keys to scroll to the desired menu, and press [ENTER] to open the menu.

7.3 The File Menu

The File menu allows you, not only to create new logs, but also to copy, rename or delete logs, as well as to print them or transfer them to a PC. To open the File Menu from the Log Manager, press the [MENU] key and then [ENTER]. The screen appears similar to Figure 90 below.

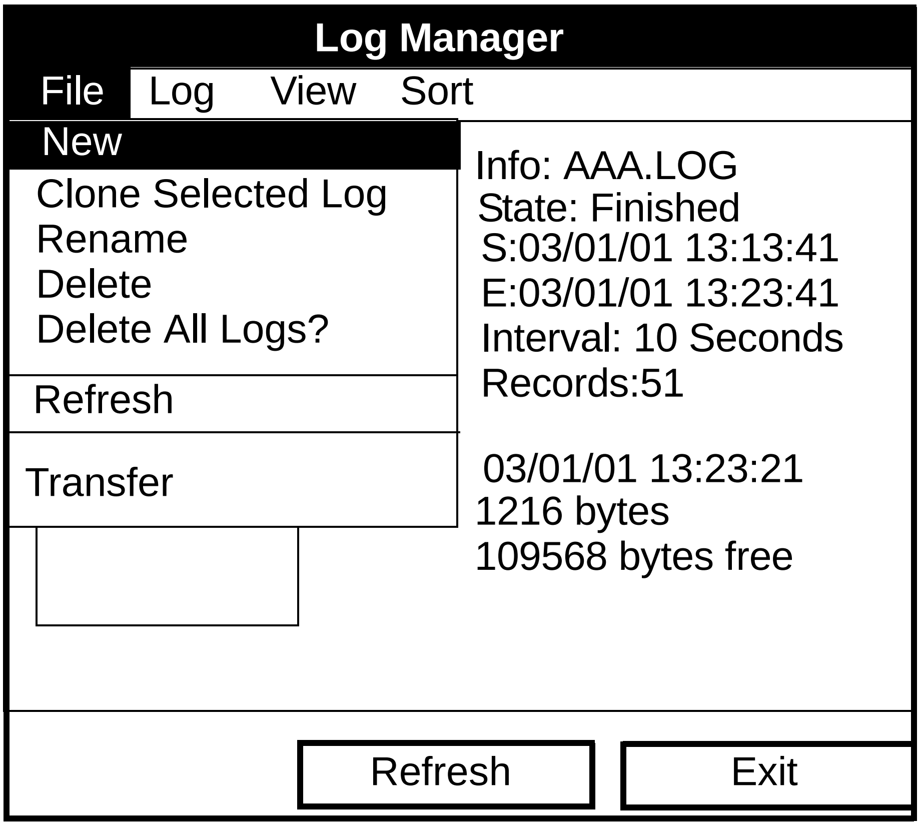

Figure 90: File Menu in the Log Manager

7.3.1 Setting up a New Log

The New Log option enables you to create and set up parameters for a new log. You can access this option in two ways:

- by scrolling to the New Log option in the Logging Menu (as shown in Figure 88 on page 132) and pressing [ENTER], or
- by scrolling to the New option in the File Menu of the Log Manager (as shown in Figure 90 on page 134) and pressing [ENTER].

In either case, the Create New Log screen appears similar to Figure 91 below. Use the four arrow keys to scroll to the desired letter or number, and press [ENTER]. Repeat this procedure until you have created the desired log name. (Press [F1], Delete, to remove any unwanted letters or numbers.) When you have finished, press [F3] (OK) to confirm the entry.

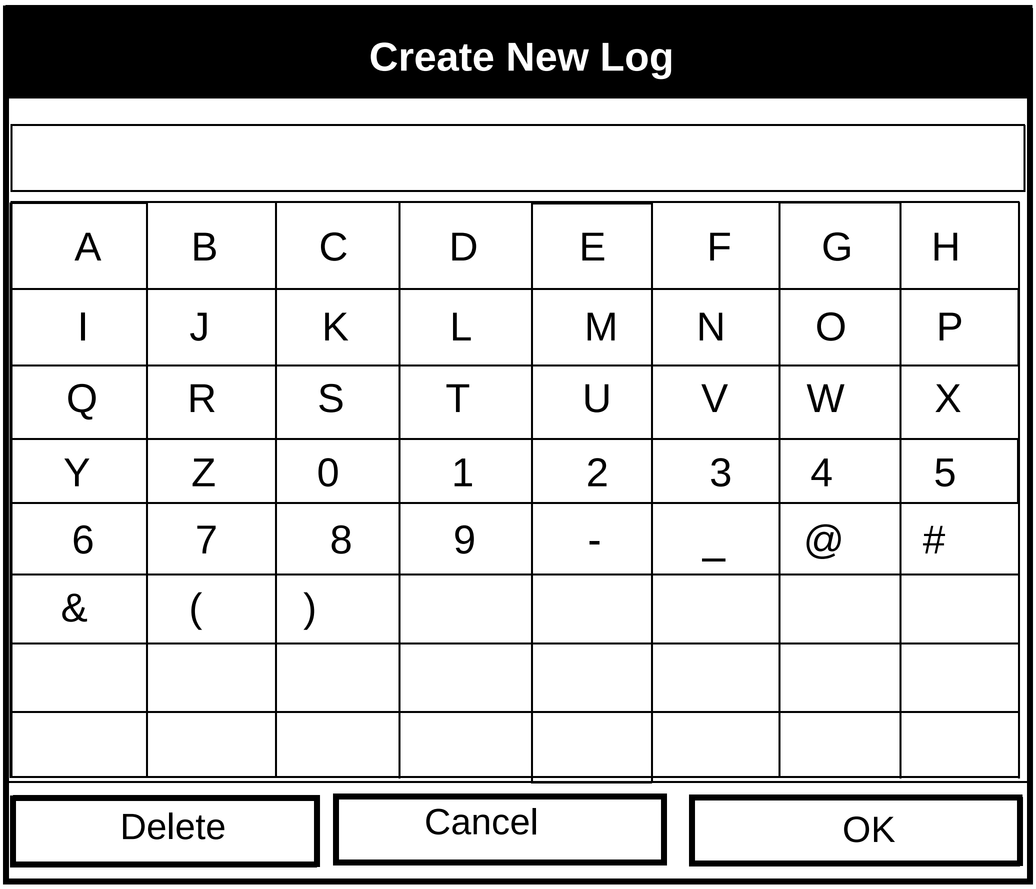

Figure 91: New Log Window

The PT878 now asks for log formatting and measurements. The screen appears similar to Figure 92 on page 136.

7.3.1 Setting up a New Log (cont.)

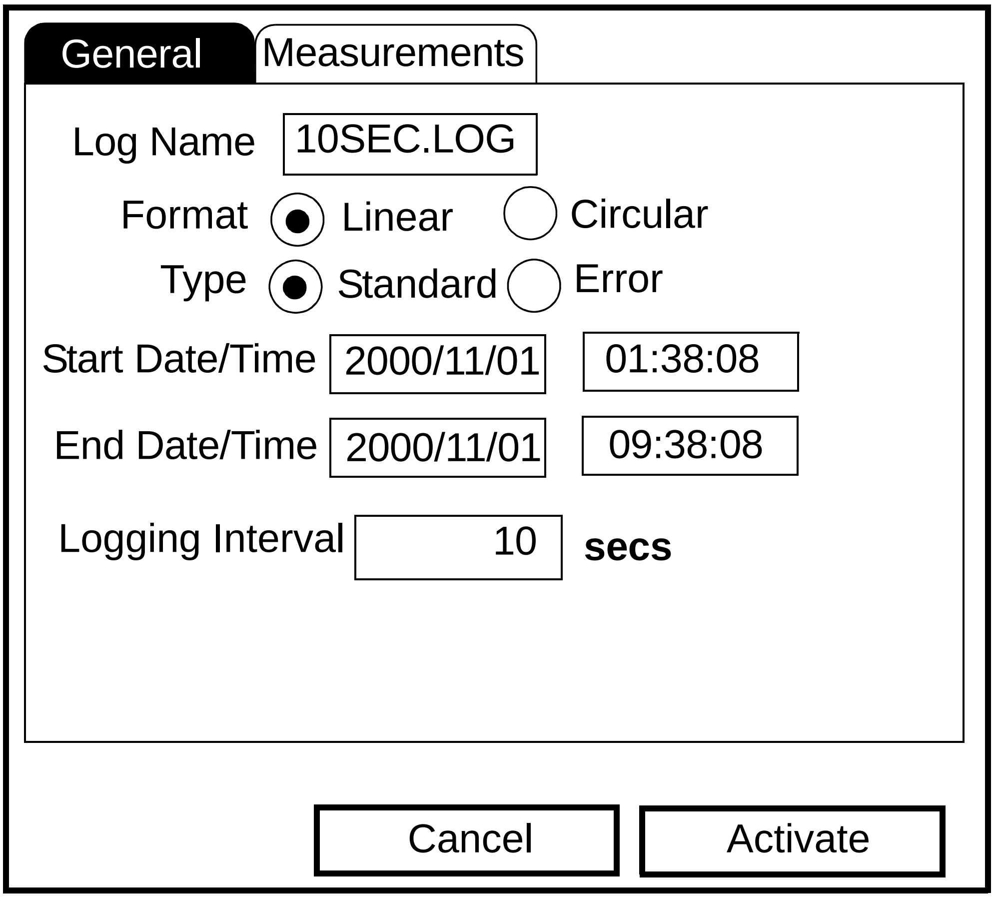

Figure 92: General Log Format Window

To step through each parameter, press the [▼] key.

1. The first prompt asks you to choose between a linear or circular format for the log.

a. Use the [◀] and [▶] keys to scroll to the appropriate radio button.

b. Press [ENTER] to confirm your selection.

2. The next prompt asks you to choose whether the log is to be a standard or error log.

a. Use the [◀] and [▶] keys to scroll to the appropriate radio button.

b. Press [ENTER] to confirm your selection.

7.3.1 Setting up a New Log (cont.)

3. The next prompt asks for the starting date and time.

a. Press [ENTER] to enter the text box. The meter highlights the first number. Use the [◀] and [▶] keys to scroll to any number you wish to change, or the [▶] key to scroll to the time box.

b. Two alternatives are available to change a highlighted number:

- Use the numeric keys to enter the desired number.
- Use the [▼] or [▲] arrow keys to scroll, in 1-digit increments, to the desired number. (For example, if the text box displays 09, pressing the [▼] key twice changes the number to 07.) You can scroll from 01 to 12 for the month and from 01 to 31 for the day (depending on the number you have selected for the month).

c. In either case, press [ENTER] to confirm the entry.

4. Follow the same procedure to enter the end date and time.

5. The final prompt in this window asks for the logging interval.

a. Press [ENTER] to open the text box.

b. Use the numeric keys to enter the desired interval in seconds.

c. Press [ENTER] to confirm the entry.

6. You have completed entering parameters in this window. To select the measurements,

a. Press the [▼] key to return to the Format prompt.

b. Then press the [▲] key to return to the General tab.

c. Finally, press the [▶] key to move to the Measurements tab, and press [ENTER]. The Measurements window appears similar to Figure 93 on page 138.

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7.3.1 Setting up a New Log (cont.)

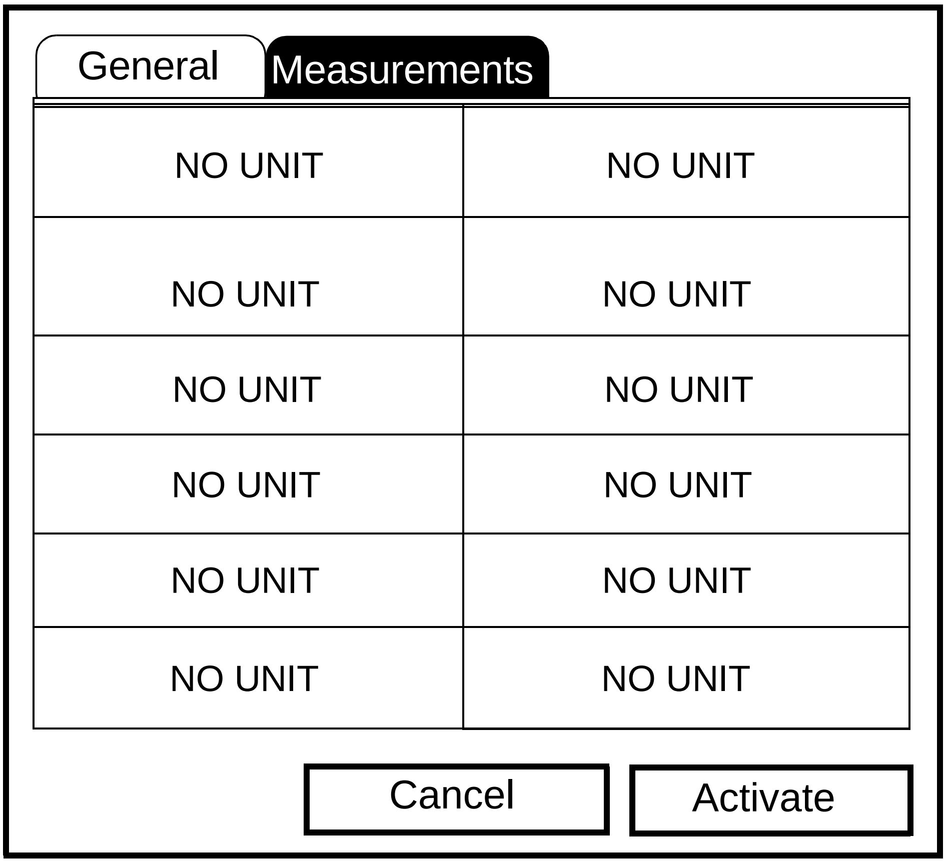

Figure 93: Log Measurements Window

To step through each entry, press the [▼] key.

1. Press [ENTER] to open the first entry. The Select Measurement window opens, as shown in Figure 94 on page 139.

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7.3.1 Setting up a New Log (cont.)

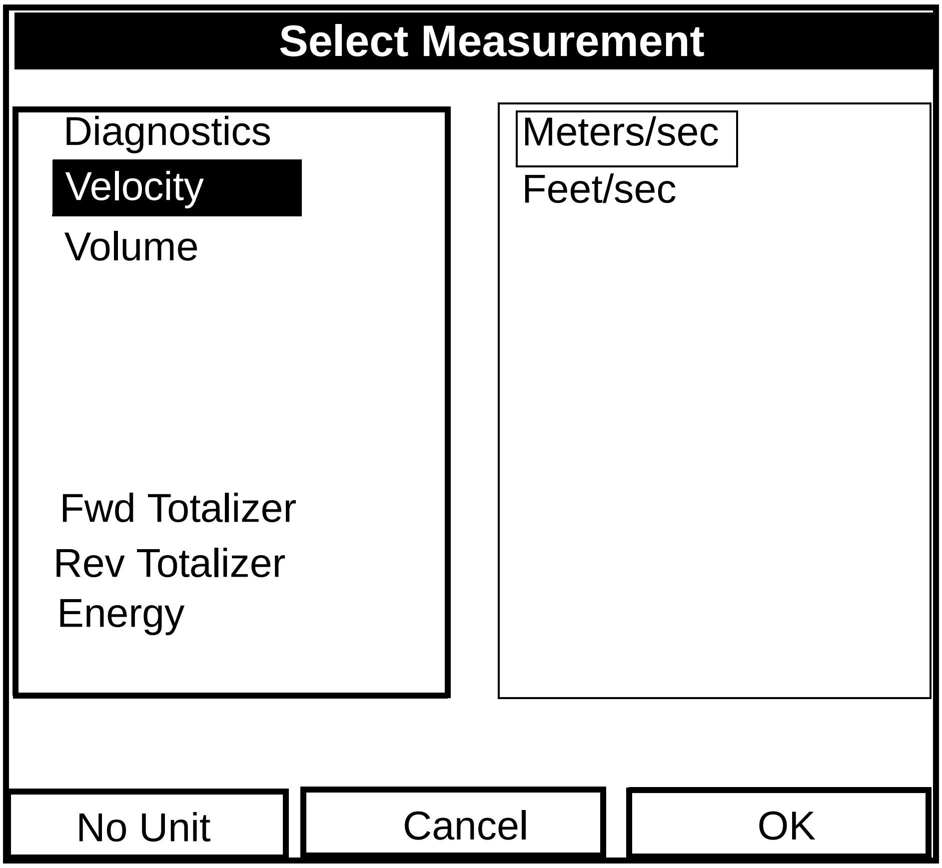

Figure 94: Select Measurement Window

2. Scroll to the desired output type.
3. Press [SEL] to confirm your selection.
4. The prompt then moves to a list of unit types. (The available units depend on the selection made at the Data Source prompt.) Scroll to the desired output unit.
5. Press [F3] (OK) to confirm your selection.
6. You can repeat this procedure for up to 12 different parameters.
7. When you have finished, press [F2] (Cancel) to cancel the entries, or [F3] (Activate) to confirm the entries and start the log.

If you started the log from the New Log option, the PT878 returns to Operate Mode, with a Pencil icon in the System Tray; if you started it from within the Log Manager, the meter returns to the Log Manager.

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7.3.2 Copying (Cloning) a Selected Log

In the Clone Selected Log option, you can copy the parameters of a particular log, modify the parameters, and start the copy. To copy a log,

1. First, select the log you wish to copy in the Log Manager (shown in Figure 89 on page 133).
2. Then open the File Menu, scroll to the Clone Selected Log option, and press [ENTER].
3. The Create New Log window (see Figure 91 on page 135) opens. Follow the procedure discussed on page 135 to create a log name, and press [F3] (OK) to confirm the name.
4. The General Log Format window (shown in Figure 92 on page 136) opens. Follow the procedure discussed on page 136 and page 137 to change any settings.

Note: *Unless otherwise specified, the cloned log always begins at the current date and time, and ends after the period of time used by the original log.*

5. If you wish, scroll to the Measurements window (shown in Figure 93 on page 138) and follow the procedure discussed on page 138 and page 139 to modify any parameters.
6. When you have completed modifying the log parameters, press [F2] (Cancel) to cancel the log or [F3] (Activate) to confirm and start the new log.

The PT878 returns to the Log Manager, which now displays the status of the cloned log.

7.3.3 Renaming a Log

To rename a log:

1. First, select the log you wish to rename in the Log Manager (shown in Figure 89 on page 133)).
2. Then open the File Menu, scroll to the Rename option, and press [ENTER].
3. The Rename Log window opens. (Except for the heading, the window is identical to the Create New Log window shown in Figure 91 on page 135.) Follow the procedure discussed on page 135 to create a log name, and press [F3] (OK) to confirm the name.

The PT878 returns to the Log Manager, which highlights the renamed log.

7.3.4 Deleting a Log

To delete a log:

1. First, select the log you wish to delete in the Log Manager (shown in Figure 89 on page 133)).
2. Then open the File Menu, scroll to the Delete option, and press [ENTER].
3. A delete confirmation window opens, as shown in Figure 95 on page 142. Press [F2] (No) to stop the deletion, or [F3] (Yes) to delete the log.

The Log Manager reappears, with the specified log deleted.

7.3.4 Deleting a Log (cont.)

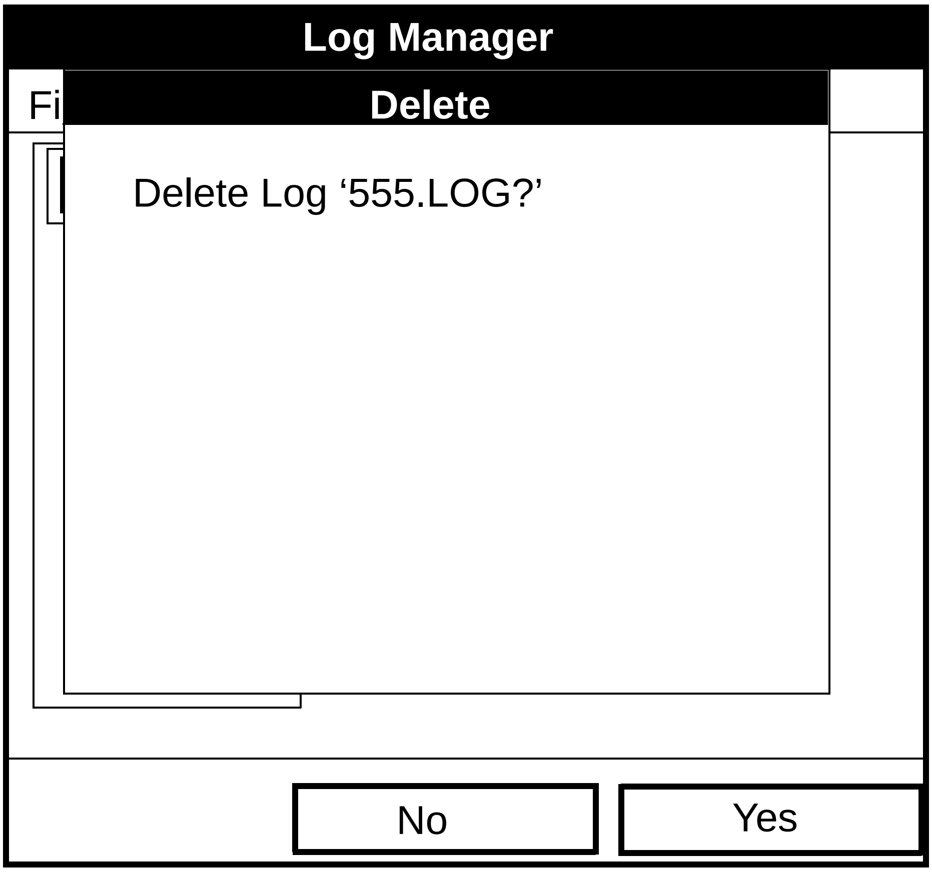

Figure 95: Delete Confirmation Window

7.3.5 Deleting All Logs

To clear the Log Manager and memory of all logs, open the File menu, scroll to the Delete All Logs option, and press [ENTER]. A window opens, asking, “Delete All Logs?” Press [F2] (No) to stop the deletion, or [F3] (Yes) to delete the logs.

A blank Log Manager appears. All logs have been deleted.

7.3.6 Refreshing the Log Manager Screen

To refresh the Log Manager screen and view the most recent information on a given log, select the log you wish to view in the Log Manager. Then open the File Menu, scroll to the Refresh option, and press [ENTER]. The screen momentarily blanks, and then reappears with the most current information on the highlighted log.

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7.3.7 Transferring a Log to a PC

Log files are only required to be transferred from the PT878 to a PC. This can be accomplished via either PanaView or HyperTerminal, as text or as binary data.

7.3.7a Transfer Log Files Using PanaView

To transfer a log file from the PT878 to a PC using PanaView, complete the following steps:

1. Connect the PT878 to the PC (page 9).
2. View the available logs from the PT878 in the Meter Logs section of the PanaView Explorer window. For example, see LOG01.log in page 143 below.
3. Double click the log file and the data will be pulled into PanaView. The data can then be displayed as a Graph and saved as a PC log file. If desired, the PC log file can now be exported as a CSV file so it can be opened with Microsoft Excel®.

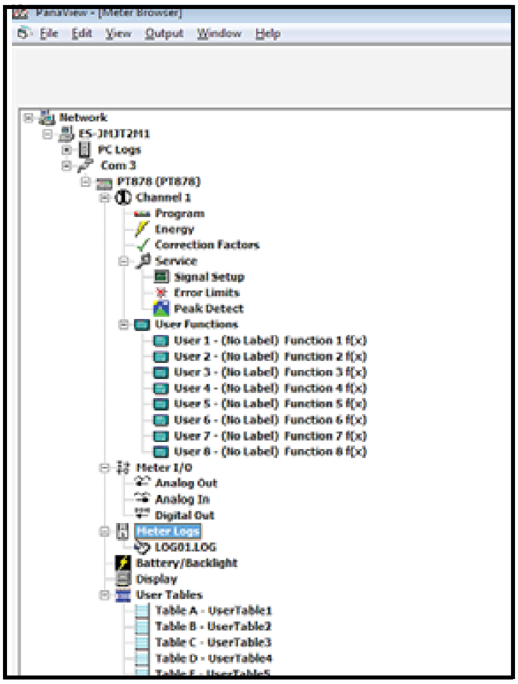

Figure 96: PanaView (Meter Browser)

7.3.7b Transfer Log Files as Text using HyperTerminal

To transfer a log file as text from the PT878 to a PC using HyperTerminal, complete the following steps:

1. Connect the PT878 to the PC(page 9).
2. Start HyperTerminal and set up the communication link to match the Com port and RS232 settings of the PT878 (see Figure 97 below).
3. From the PT878 select Logging\Log Manager and select the Log file you want to send to the PC.
4. From Log manager select File\Transfer as Text. This should print out the Log file as text to HyperTerminal.
5. To save the log file as text, from HyperTerminal proceed as follows:
   a. Select the Transfer\Capture Text option.
   b. Select the location and filename of the log file. Then, click Start.
   c. Transfer the log file as text from the PT878 and then select the Transfer\Capture Text\End option from HyperTerminal.

The log file transfer as text is now complete.

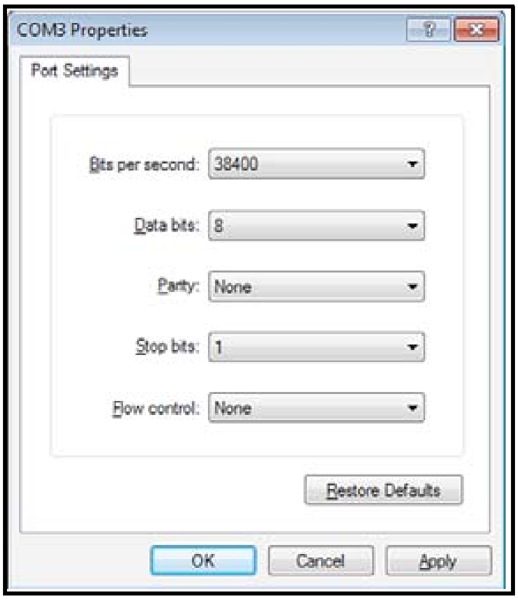

Figure 97: COM Properties

7.3.7c Transfer Log Files as Binary Data Using HyperTerminal

To transfer a log file as *binary data* from the PT878 to a PC using HyperTerminal, complete the following steps:

1. Connect the PT878 to the PC(page 9).
2. Start HyperTerminal and set up the communication link to match the Com port and RS232 settings of the PT878 (see Figure 9 below).
3. From the PT878 select Logging\Log Manager and select the Log file you want to send to the PC.
4. From Log Manager select File\Transfer as Text. This should print out the Log file as text to HyperTerminal.
5. To save the log file as binary data, from HyperTerminal proceed as follows:
    a. Select the Transfer\Receive File option.
    b. Select the location of the log file and select XModem as the receiving protocol.
    c. Click Receive and enter the desired filename, using a .log extension.
6. From the PT878 Site Manager, select the File\Transfer option. This will allow the PT878 to send the log file to the PC using the secure XModem protocol. File transfer is complete when the XModem Receive dialog box closes.

Note: *The file is transferred in GE Panametrics format and it must be opened using the GE PanalogViewer software.*

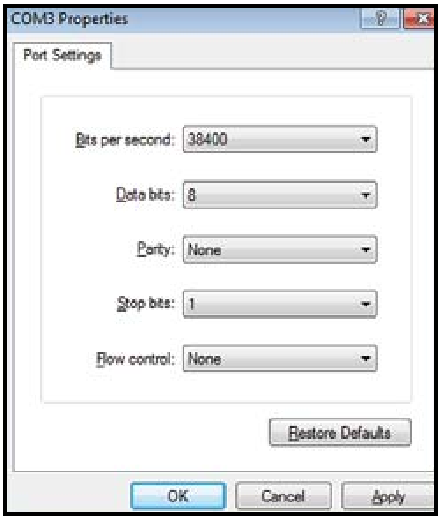

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Figure 98: COM Properties

7.4 The Log Menu

The Log Menu allows you to pause, restart or end any or all logs that are currently pending or running. (However, you cannot restart any finished logs, even if they were finished before the programmed end time.) To open the Log Menu in the Log Manager, press [MENU]. Scroll to the Log option, and press [ENTER]. The window appears similar to Figure 99 below.

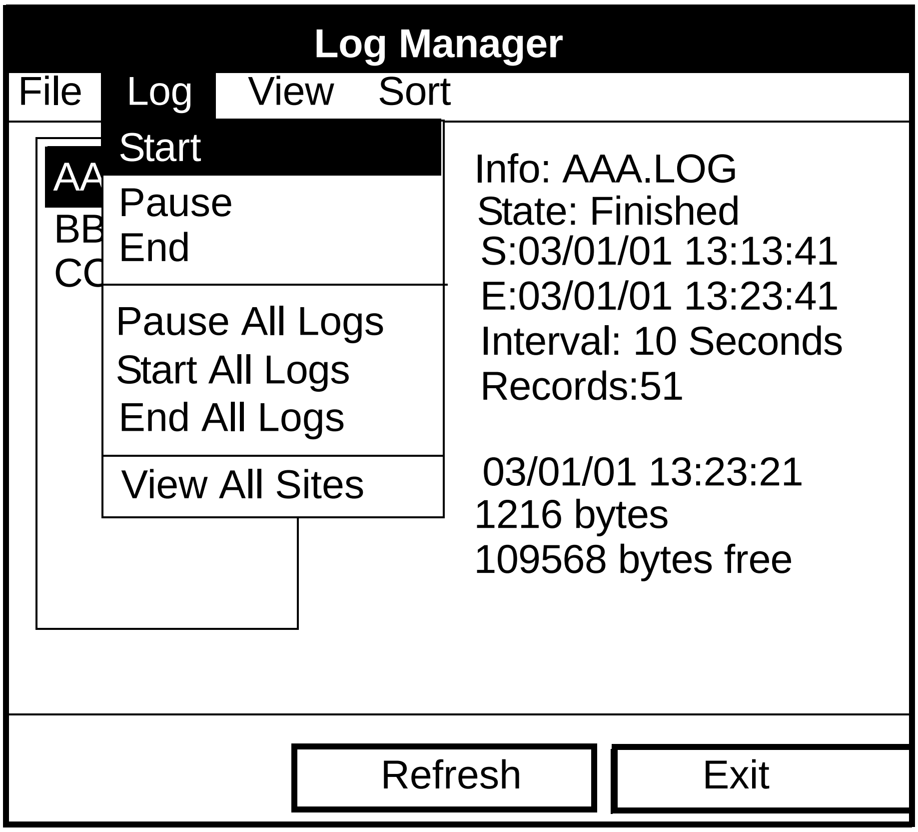

Figure 99: Log Menu in the Log Manager

7.4.1 Stopping (Pausing) a Log

To stop a log that is currently pending or running,

1. First, select the log you wish to pause in the Log Manager (shown in Figure 89 on page 133).
2. Then open the Log Menu, scroll to the Pause option, and press [ENTER].

The PT878 returns to the Log Manager, which displays the highlighted log with "Paused" in the State line.

7.4.2 Restarting a Log

To restart a paused log:

1. First, select the log you wish to restart in the Log Manager (shown in Figure 89 on page 133).
2. Then open the Log Menu, scroll to the Start option, and press [ENTER].

The PT878 returns to the Log Manager, which displays the highlighted log with a status of "Pending" or "Running."

7.4.3 Ending a Log

To end a log:

1. First, select the log you wish to end in the Log Manager (shown in Figure 89 on page 133).
2. Then open the Log Menu, scroll to the End option, and press [ENTER].

The PT878 returns to the Log Manager, which displays the highlighted log with a status of "Finished." The space not used by the finished log is freed for reuse.

Note: *You cannot restart a finished log. You must create a new log with the same parameters.*

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7.4.4 Stopping All Logs

To stop all log that are currently pending or running, open the Log Menu, scroll to the Pause All Logs option, and press [ENTER]. The PT878 returns to the Log Manager, which displays all log programmed to run now or in the future with a status of “Paused.”

7.4.5 Restarting All Logs

To restart all paused logs, open the Log Menu, scroll to the Start All Logs option, and press [ENTER]. The PT878 returns to the Log Manager, which displays the logs with a status of “Pending” or “Running.”

7.4.6 Ending All Logs

To end all currently pending or running logs, open the Log Menu, scroll to the End All Logs option, and press [ENTER].The PT878 returns to the Log Manager, which displays the running logs with a status of “Finished.”

7.4.7 View All Sites

To check on all logs, open the Log Menu, scroll to the View All Sites option, and press [ENTER]. Logs are associated with the site in use at the time the log is created. Thus, when another site is in use, the PT878 automatically starts different logs. By default, the Log Manager only displays the logs created with the current site. View All Sites allows the Manager to list logs for all sites.

7.5 The View Menu

Through the View menu, you can view the data of individual logs in graphical or spreadsheet formats. To open the View menu from the Log Manager, press [MENU]. Scroll to the View menu, and press [ENTER]. The screen appears similar to Figure 100 below.

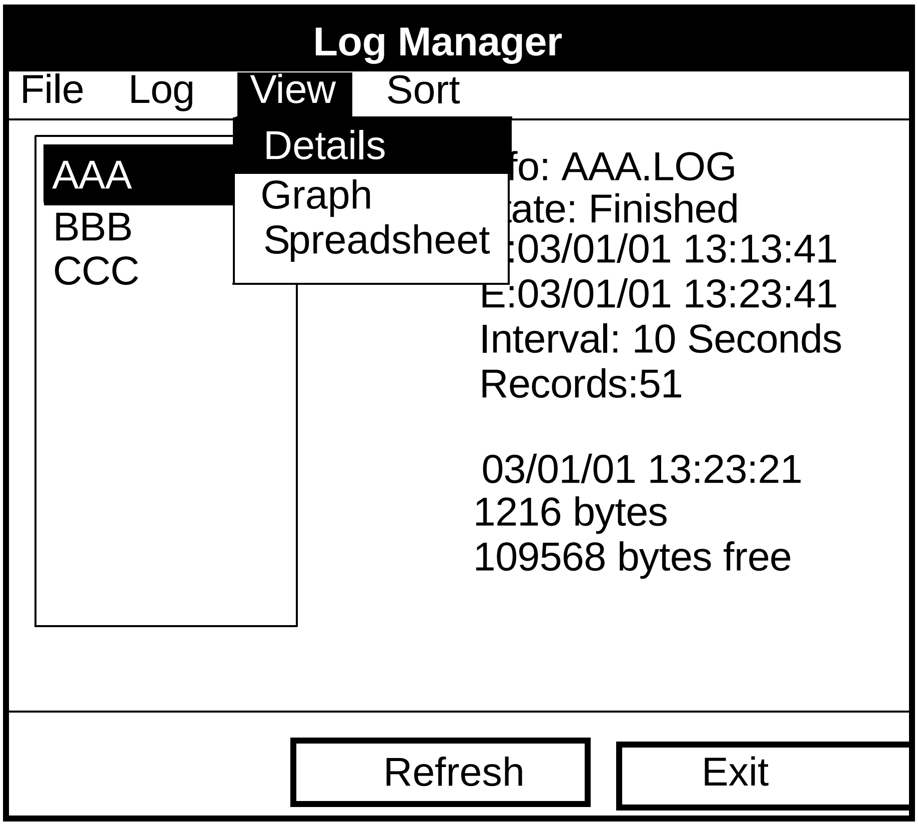

Figure 100: View Menu

7.5.1 Displaying Log Details

To view details of a given log, be sure the log is highlighted in the left window of the Log Manager. Then scroll to the View menu and press [ENTER]. Scroll to the Details option and press [ENTER]. The screen now appears similar to Figure 101 below.

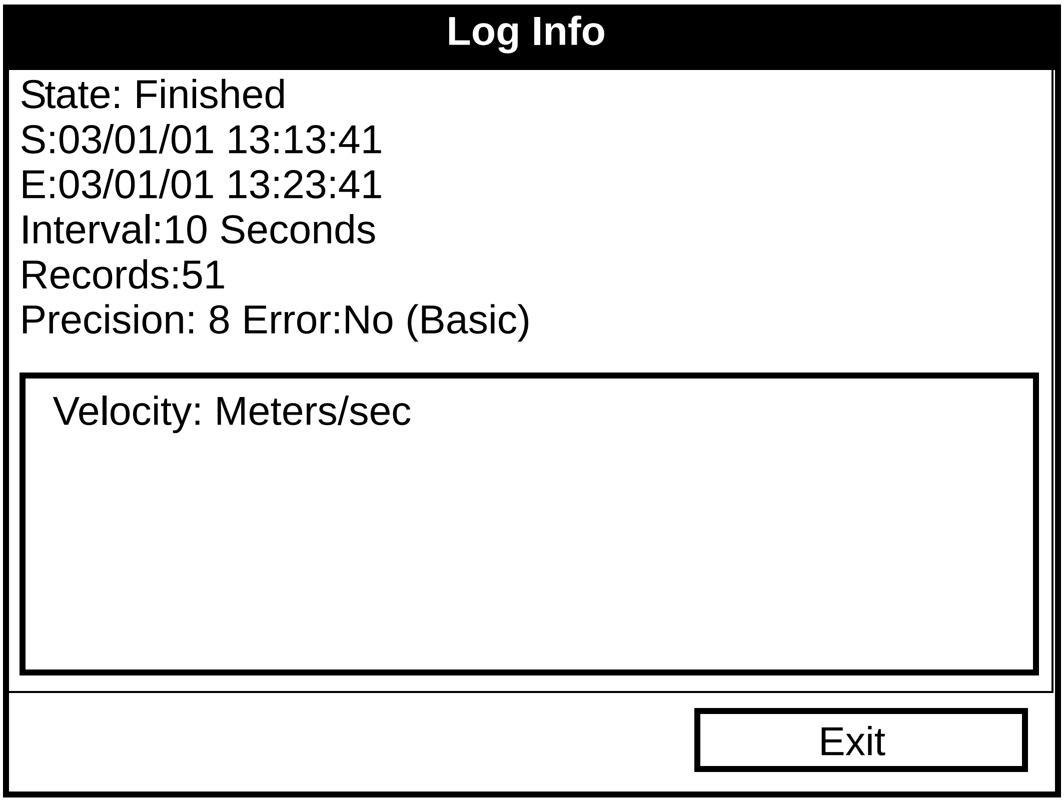

Figure 101: Log Details Display Window - List of Measurements in Log

Press [F2] (Cancel) or [F3] (OK) to return to the Log Manager.

7.5.2 Displaying Log Data in Graphical Form

To view a log in graphical form, be sure the log is highlighted in the left window of the Log Manager. Then scroll to the View menu and press [ENTER]. Scroll to the Graph option and press [ENTER].

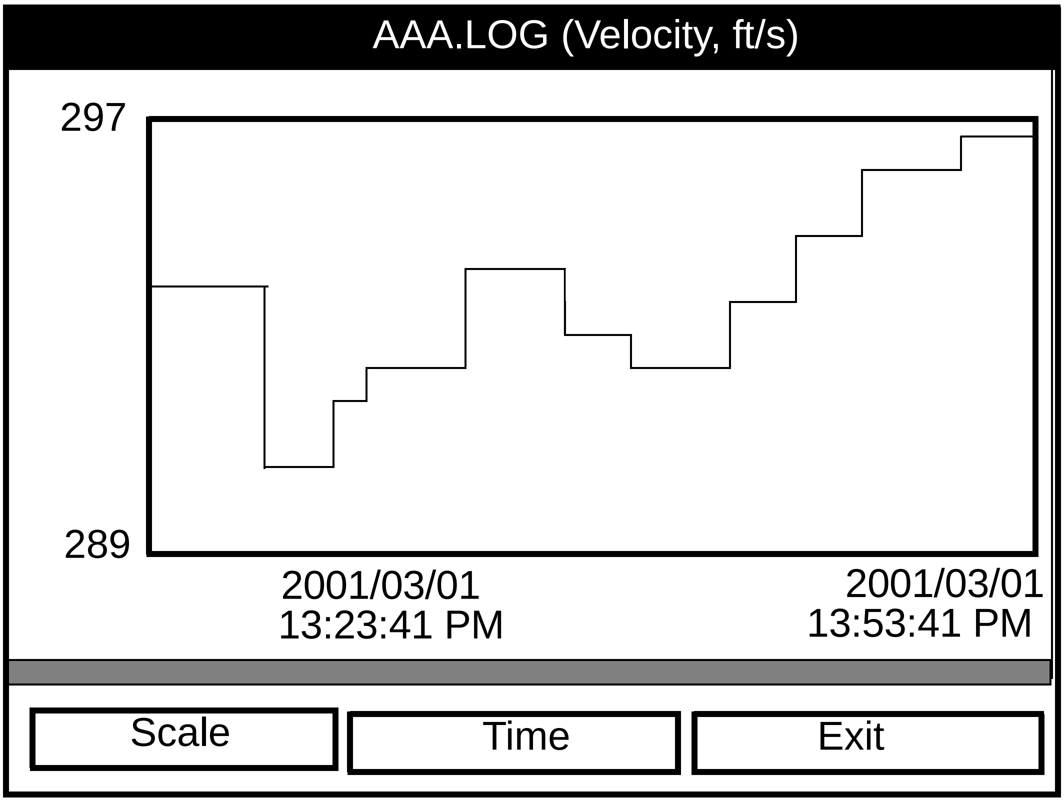

Figure 102: Log Graph Display Window

The Select Measurement window opens and lists the log measurement parameters. If a log contains more than one measurement, you must select which measurement to plot from the list displayed. Once you have chosen the measurement parameter, press [F3] (View). The screen now appears similar to Figure 102 above. (Press [F2], Cancel, to leave the window without viewing the graph.)

- If you wish to alter the graph scale, press [F1] (Scale) and go to page 152.
- If you wish to alter the time scale, press [F2] (Time) and go to page 153.
- To leave the window, press [F3] (Exit).

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7.5.2 Displaying Log Data in Graphical Form (cont.)

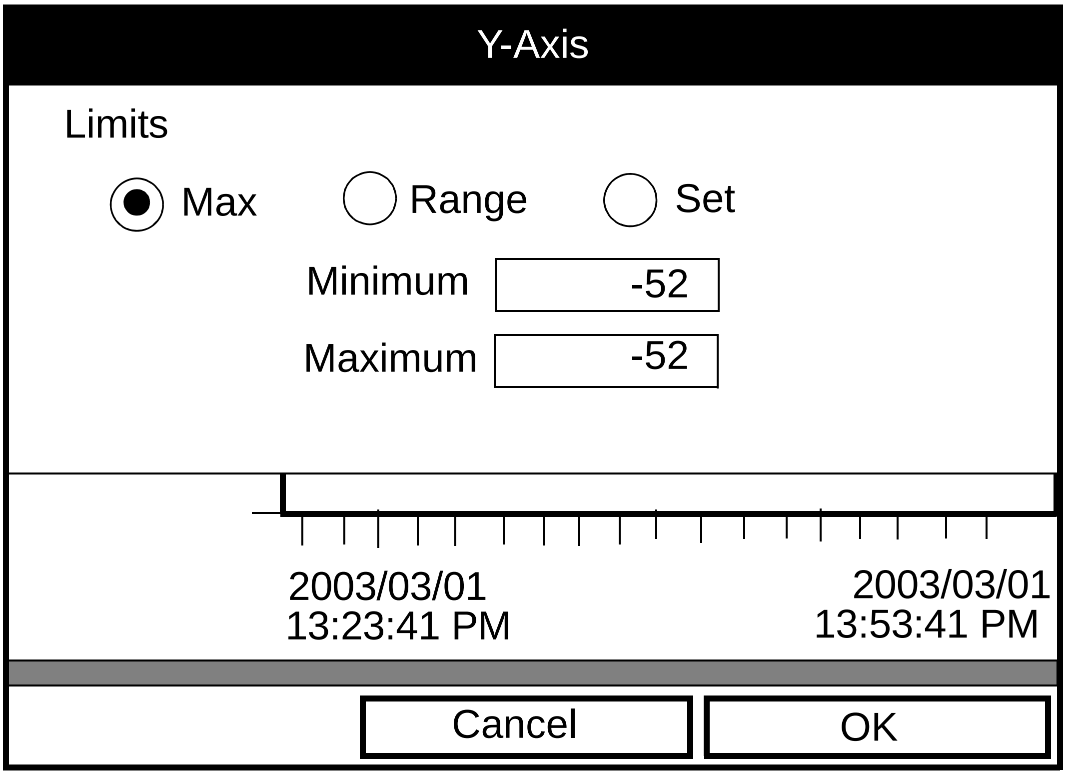

Figure 103: Y-Axis Window

The Y-Axis window (shown in Figure 103 above) allows you to specify whether the Y axis on the graph extends to the maximum value (Max), over the entire range (Range) or between certain specified values (Set).

1. Use the [◀] and [▶] keys to scroll to the desired limit type. Press [ENTER] to confirm the entry.

If you select Max or Range for limits, you have finished entering data in this form. If you select Set, the PT878 asks for minimum and maximum limits.

2. Press the [▼] key to reach the Minimum text box.

   a. Press [ENTER] to open the text box.

   b. Use the numeric keys to enter the desired value.

   c. Press [ENTER] to confirm the entry.

3. Repeat step 2 to enter the Maximum value.

4. When you have finished, press [F2] (Cancel) to cancel the entries, or [F3] (OK) to confirm the entries and change the graph.

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7.5.2 Displaying Log Data in Graphical Form (cont.)

If you wish to alter the time scale, press [F2] (Time). The Enter Time window appears similar to Figure 104 below.

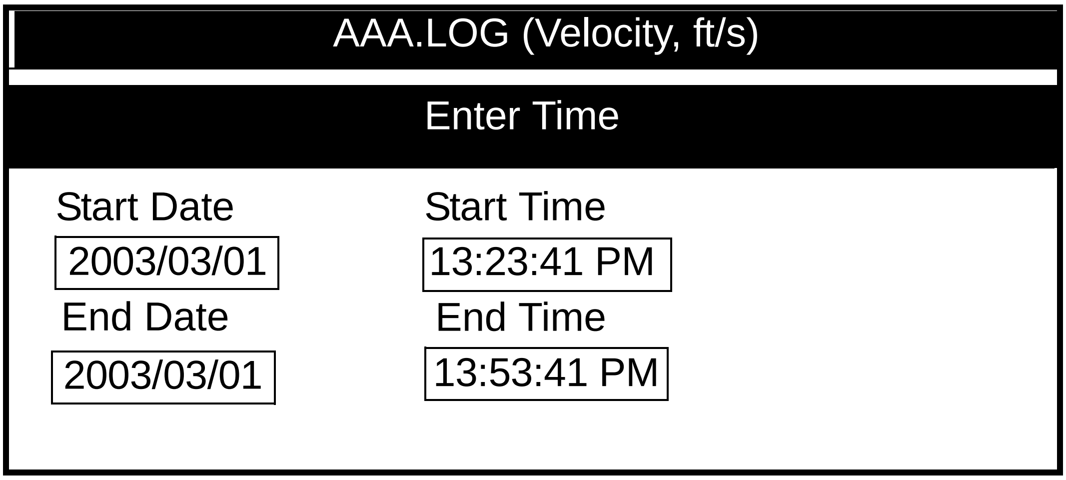

Figure 104: Enter Time Window

1. Use the arrow keys to scroll to the desired text box. Press [ENTER] to open the box.
2. Two alternatives are available to change a highlighted date or time:
   - Use the numeric keys to enter the desired number.
   - Use the [▼] or [▲] arrow keys to scroll, in 1-digit increments, to the desired number. (For example, if the text box displays 09, pressing the [▼] key twice changes the number to 07.) You can scroll from 01 to 12 for the month, from 01 to 31 for the day (depending on the number you have selected for the month), and from 0 to 59 for minutes and seconds.

In either case, press [ENTER] to confirm the entry.

3. Repeat step 2 for any other entries you wish to change.

When you have finished, press [F3] (OK) to confirm the entries and close the window, or press [F2] (Cancel) to leave the window without changing the entries.

7.5.3 Displaying Log Data in Spreadsheet Form

To view a log in spreadsheet form, be sure the log is highlighted in the left window of the Log Manager. Then scroll to the View menu and press [ENTER]. Scroll to the Spreadsheet option and press [ENTER]. The screen now appears similar to Figure 105 below.

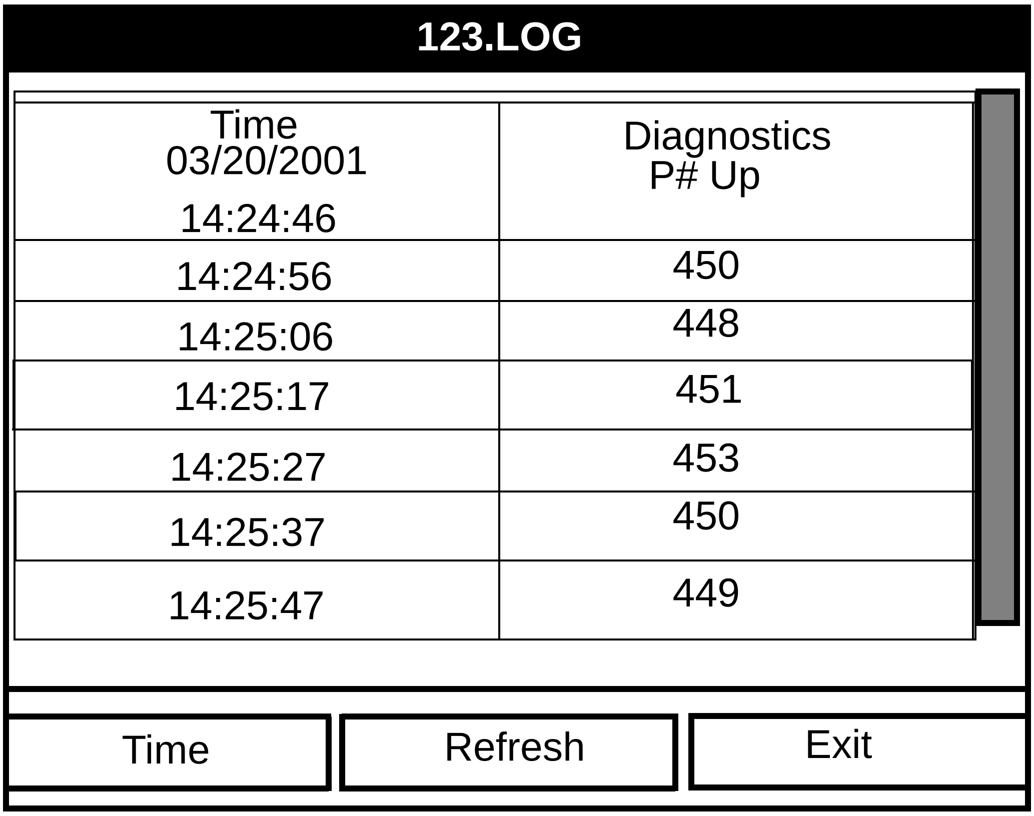

Figure 105: Log Spreadsheet Window

Use the [◀] and [▶] keys to scroll to other columns, or the [▼] or [▲] keys to scroll backward or forward in time.

- To alter the times displayed, press [F1] (Time). The Enter Time window (shown on page 153) opens. Follow the instructions on page 153 to change the date or time.
- To refresh the display, press [F2] (Refresh). The display shows the most current data.
- Press [F3] (Exit) to return to the Log Manager.

7.6 The Sort Menu

The Sort Menu within the Log Manager allows you to arrange your log list either alphabetically (By Name) or chronologically (By Date).

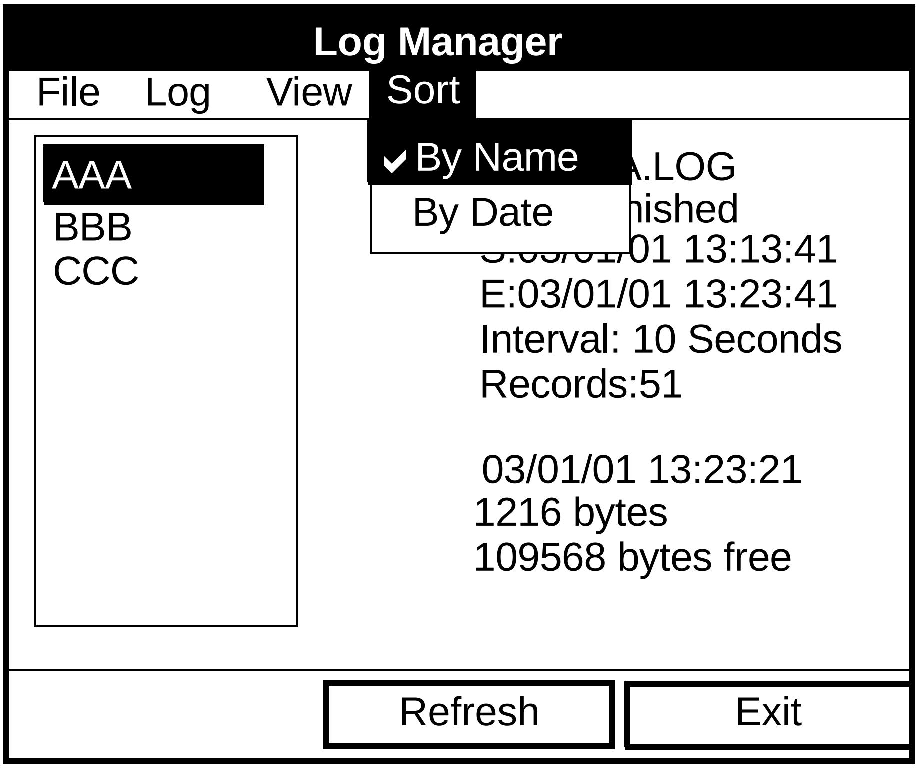

Figure 106: Sort Menu in the Log Manager

7.6.1 Listing Logs by Name

If you want to list your logs alphabetically by log name within the Log Manager, press [MENU] to open the File Menu. Then scroll from the File Menu to the Sort Menu, shown in Figure 106 above. Press [ENTER]. The Log Manager screen refreshes, with the sites listed in alphabetical order.

7.6.2 Listing Logs in Chronological Order

If you prefer to list your logs chronologically by time of creation within the Log Manager, press [MENU] to open the File Menu. Then scroll from the File Menu to the Sort Menu, and scroll to the By Date option. Press [ENTER]. The Log Manager screen refreshes, with the sites listed in chronological order, from the most recent to the earliest.

[no content intended for this page - proceed to next page]

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Chapter 8. Servicing the PT878

For user convenience, the PT878 offers a Service Menu. This menu enables users to perform a variety of functions that they might occasionally require:

- output reports
- set up and view the thickness gauge measurements
- calibrate the PT878
- run diagnostics
- set up signal parameters and peak detection
- define error limits
- test the PT878 screen and keys
- diagnose setup problems with the impulse response
- check test points
- return to factory default parameters
- load updated versions of the meter program into the PT878.

8.1 Entering the Service Menu

To enter the Service Menu, press the [MENU] key at the lower right of the PT878 keypad. The Menu Bar replaces the Status Bar at the top of the screen. Press the [▶] arrow key four times to scroll from the Site Menu to the Service Menu. At the Service Menu, press [ENTER]. The screen appears similar to Figure 105 below. When programming, refer to Figure 142 on page 225 of Appendix A, *Menu Maps*.

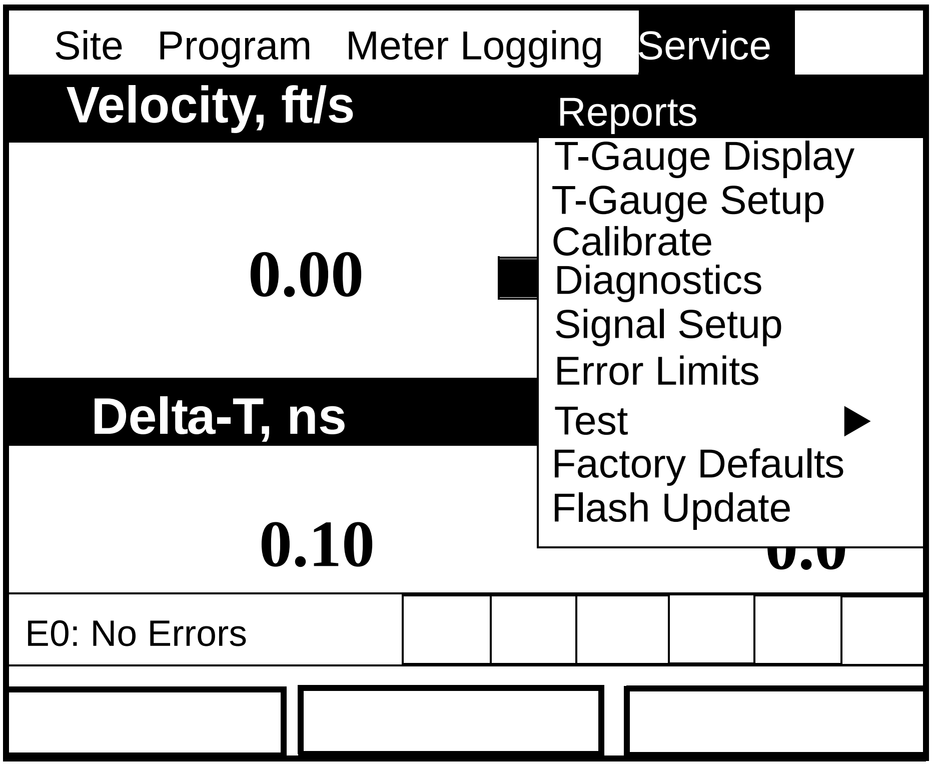

Figure 105: Service Menu

To scroll to a particular option, press the [▼] or [▲] arrow keys until you reach the option. Then press [ENTER] to open the option window.

When entering parameters in an option, press:

- The [▼] key to step through the available parameters.
- The [▲] key to scroll back to a previously entered parameter.
- The [F2] key (Cancel) or the [ESC] key to exit an option at any time and return to Operate Mode without changing the parameters.

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8.2 Transferring Reports

Reports are found in the PT878 Service\Reports menu. The reports are used in troubleshooting as well as for data backup, and they may be transferred from the PT878 to a PC using HyperTerminal. Reports include:

- Drive contents
- Current site data
- Global settings
- User functions
- User tables
- Menu commands

To transfer a report as text from the PT878 to a PC using HyperTerminal, complete the following steps:

1. Connect the PT878 to the PC, as discussed on page 9.

2. Start HyperTerminal and set up the communication link to match the Com port and RS232 settings of the PT878 (see Figure 106 below).

3. From the PT878 select the Service\Reports option. Then, select the Report file you want to send to the PC and select Transfer.

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8.2 Transferring Reports (cont.)

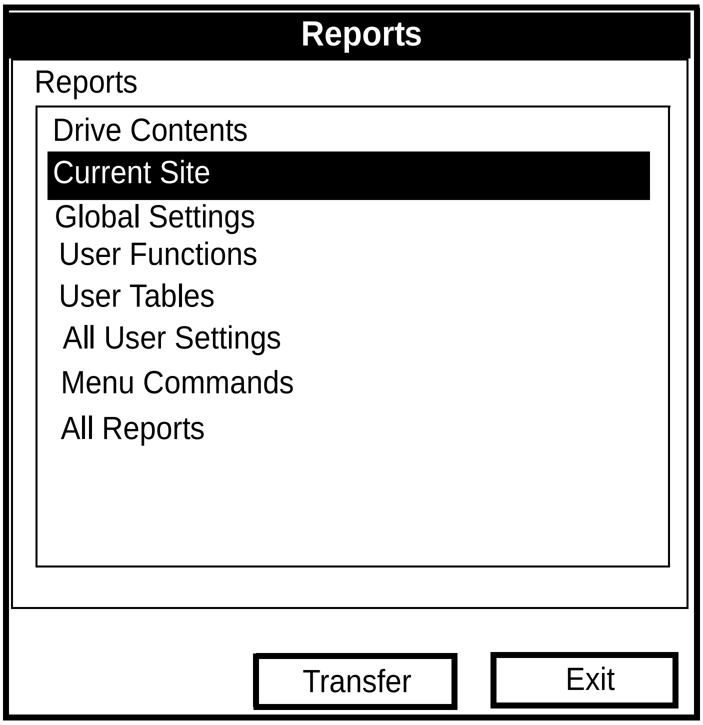


Figure 106: Reports Window

4. To save the Report as text, from HyperTerminal proceed as follows:

   a. Select the Transfer\Capture Text option.

   b. Select the location and filename of the Report file. Then, click **Start**.

   c. Select Transfer Report from the PT878 and then select Transfer\Capture Text\End from HyperTerminal. The Report transfer is now complete.

8.2 Transferring Reports (cont.)

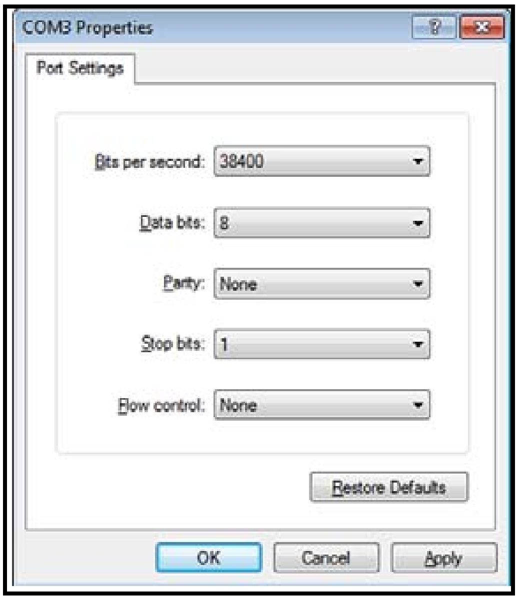
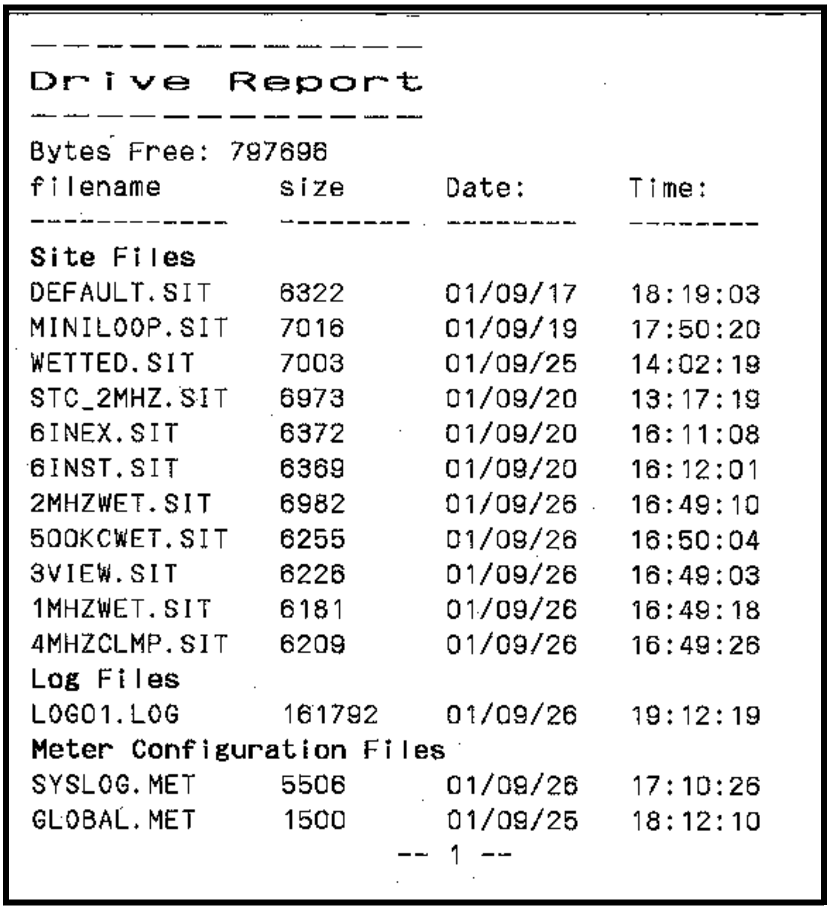


Figure 107: COM Properties



Drive Report

Bytes Free: 797696

filename	size	Date:	Time:
Site Files			
DEFAULT.SIT	6322	01/09/17	18:19:03
MINILOOP.SIT	7016	01/09/19	17:50:20
WETTED.SIT	7003	01/09/25	14:02:19
STC_2MHZ.SIT	6973	01/09/20	13:17:19
6INEX.SIT	6372	01/09/20	16:11:08
6INST.SIT	6369	01/09/20	16:12:01
2MHZWET.SIT	6982	01/09/26	16:49:10
500KCWET.SIT	6255	01/09/26	16:50:04
3VIEW.SIT	6226	01/09/26	16:49:03
1MHZWET.SIT	6181	01/09/26	16:49:18
4MHZCLMP.SIT	6209	01/09/26	16:49:26
Log Files			
LOG01.LOG	161792	01/09/26	19:12:19
Meter Configuration Files			
SYSLOG.MET	5506	01/09/26	17:10:26
GLOBAL.MET	1500	01/09/25	18:12:10

-- 1 --

Figure 108: Printout of a Typical Drive Report

8.3 Setting up the Thickness Gauge

For greatest accuracy in flow applications, the PT878 can measure pipe wall thickness using an optional thickness gauge transducer, instead of relying on the nominal pipe wall thickness. In Thickness Gauge mode, the PT878 does not measure flow, but it can determine the thickness of most standard metal and plastic pipe materials over a range from 0.05 to 3 in. (1.3 to 76.2 mm).

The PT878 offers two basic thickness gauge functions: using the gauge to measure thickness after entering the pipe material, and calibrating the gauge. For the highest possible accuracy, you can also calibrate the velocity of the pipe material.

Using the thickness gauge involves three steps:

1. Enter the material and soundspeed (refer to Figure 109 on page 163).

2. Measure the pipe wall thickness (in the Display window on page 165).

3. If the measurement seems unreasonable, examine the acoustic signal to diagnose the problem (in the Graph window on page 166).

Calibrating the thickness gauge involves up to two additional steps:

4. Calibrate the thickness gauge itself (in the Zero window on page 168).

5. Calibrate the velocity of the pipe material (in the Velocity window on page 171), if possible and if the pipe material is not the material entered in the Zero window. This step requires a trustworthy reference, either a section of pipe (such as a flange or open pipe section) that can be measured with calipers or another measurement device, or a thickness calibration block from the same pipe material.

8.4 Measuring Pipe Wall Thickness

8.4.1 Entering the Material and Soundspeed

Important: *The factory recommends calibrating the thickness gauge periodically (as discussed on page 168) before measuring thickness.*

To enter the Thickness Gauge Display option, scroll to the T-Gauge Display entry on the Service Menu and press [ENTER]. The screen appears similar to Figure 109 below.

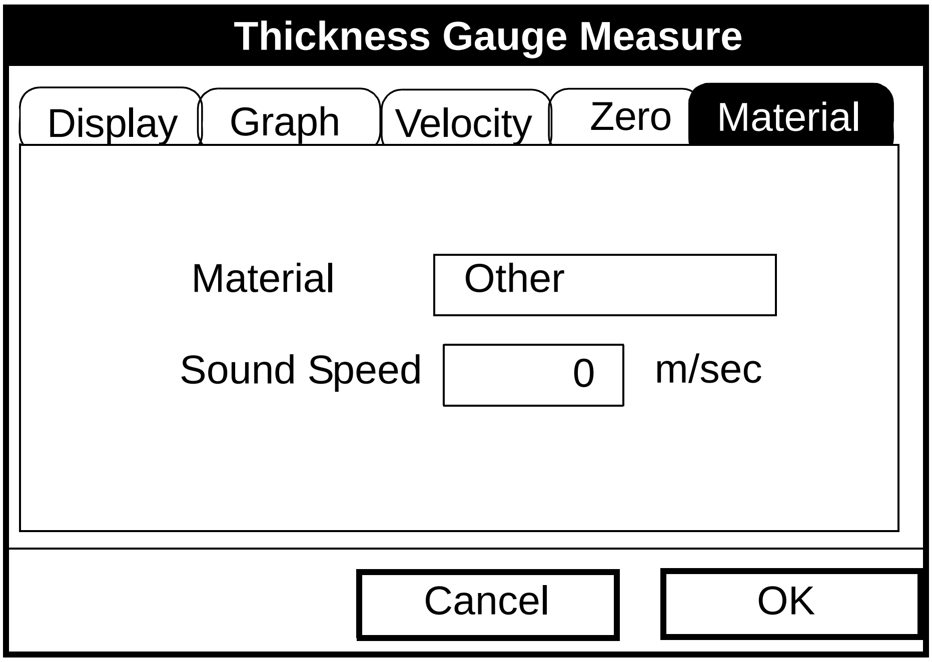


Figure 109: Material Window

1. From the Thickness Gauge Display option, press the [▶] arrow key four times to enter the Material window.
2. The first prompt asks you to select the material for the pipe wall you wish to measure from a drop-down list.
   a. Press [ENTER] to open the list.
   b. Use the [▼] or [▲] arrow keys to scroll to the desired material.
   c. Press [ENTER] to confirm your selection.

8.4.1 Entering the Material and Soundspeed (cont.)

If you have selected a preprogrammed material, you have completed entering data in this window. Pressing the [▼] key returns the program to the Material tab. But if you selected “Other,” you can also enter a specific soundspeed.

3. To enter the soundspeed:

a. Press [ENTER] to open the text box.

b. Use the numeric keys to enter the desired soundspeed (from the brochure *Soundspeeds and Pipe Size Data*, 914-004).

c. Press [ENTER] to confirm your entry.

To leave the Material window:

- Press the [◀] or [▶] arrow key to move to another tab to take readings or perform a velocity calibration.
- Press [F2] (Cancel) to return to Operate Mode without confirming the soundspeed value.
- Press [F3] (OK) to confirm the new value. The PT878 returns to Operate Mode.

8.4.2 Measuring Thickness in Numeric Format

To measure the actual thickness of a pipe, hold the calibrated transducer steady, press the [◀] or [▶] arrow key until you reach the Display tab and press [ENTER]. The T-Gauge Display option shows the thickness measurement in numeric format (displayed in Figure 110 below).

Note: *Refer to Appendix D,* Ultrasonic Thickness Gauge Theory of Operation, *page 251, to learn how to position and align the transducer.*

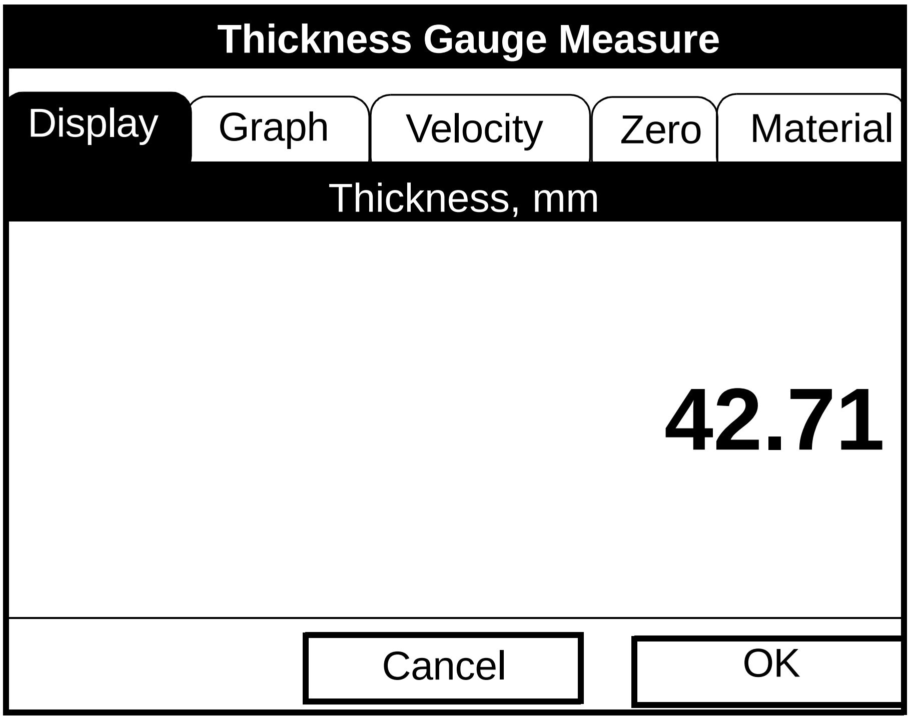


Figure 110: Thickness Gauge Display Window

Be sure the “Noise” or “Los” (loss of signal) boxes do not appear. Press [F2] (Cancel) or [F3] (OK) to return to Operate Mode, or press the [▶] arrow key to move to another window in the option.

8.4.3 Displaying the Receive Signal in Graphical Format

Used chiefly for diagnostic purposes, the Graph option helps to determine why the thickness gauge is not working if you suspect a problem. The graph shows an image of the acoustic signal. If the display does not show a signal image similar to Figure 111 below, you may have a problem with the transducer, couplant, or the programmed values. Also, some materials (such as PTFE or fiberglass) do not support acoustic signals.

To open the Graph window and display the receive signal graphically, press the [◀] or [▶] arrow key until you reach the Graph tab and press [ENTER]. The screen appears similar to Figure 111 below.

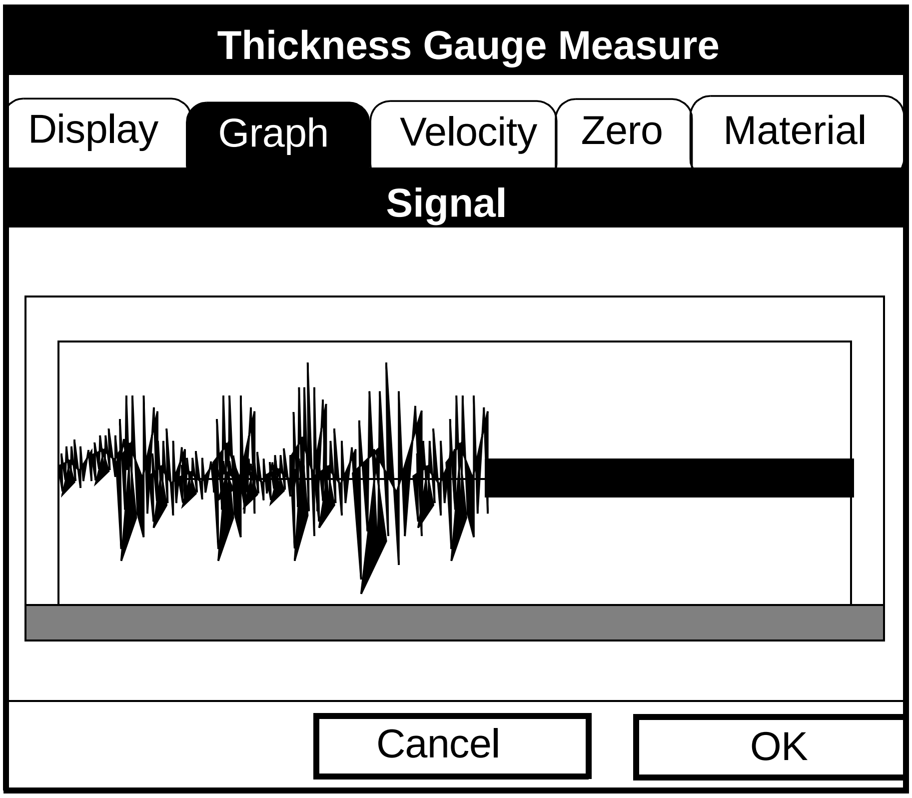


Figure 111: Thickness Gauge Graph Window

Press [F2] (Cancel) or [F3] (OK) to return to Operate Mode, or press the [▶] arrow key to move to another window in the option. However, if you wish to adjust the graph, press the [▼] key. The screen now appears similar to Figure 112 on page 167.

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8.4.3 Displaying the Receive Signal in Graphical Format (cont.)

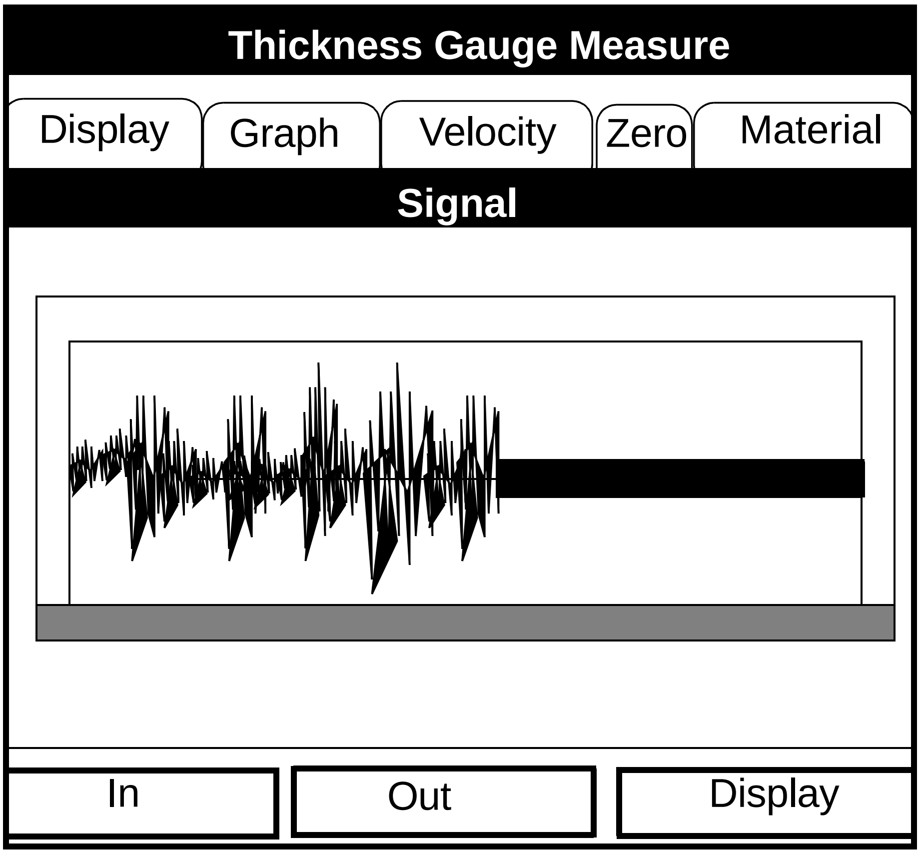

Figure 112: Graph Window in Zoom Format

- Press [F1] (In) to zoom in to magnify screen details.
- Press [F2] (Out) to zoom out fully.
- Press [F3] to toggle between the left and right cursors.
- Press [◀] and [▶] to move the selected cursor left and right.
- Press [▼] to select the graph.
- Press [▲] to return to tab navigation.
- Press [ESC] to return to Operate Mode without saving the calibration changes.

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8.4.4 Calibrating the Thickness Gauge Transducer

To zero the transducer offsets, go to the Zero tab. Press the [◀] or [▶] arrow key until you reach the Zero tab and press [ENTER]. The screen appears similar to Figure 113 below.

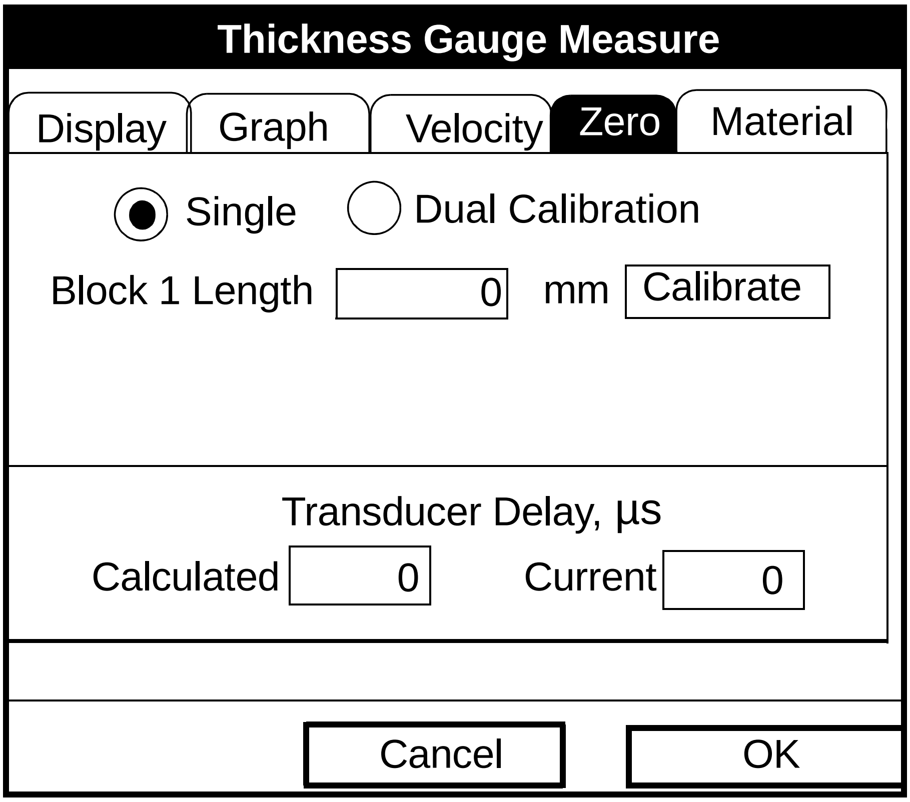

Figure 113: Zero Window

Dual-Point Calibration

Note: *The factory recommends dual calibration. Dual-point calibration is more reliable, but it requires two known thickness levels of the calibration material. Use single-point calibration only if you know the velocity of the calibration block material to a high degree of accuracy. For single-point calibration, complete the following procedure, but skip steps 6, 7 and 8. See Appendix D for more information.*

Dual-Point Calibration (cont.)

1. Press the [▼] arrow key to enter the window.
2. The first prompt asks you to choose between single and dual-point calibration. Use the [◀] and [▶] arrow keys to move to the Dual radio button and press [ENTER].
3. The next prompt asks you to enter the length of Block 1. (If you are using a GE-supplied test block, the length is printed on the block.)
   a. Press [ENTER] to open the text box.
   b. Use the numeric keys to enter the length.
   c. Press [ENTER] to confirm the entry.
4. Press [▶] to move to the Calibrate button, and press [ENTER] to prepare for calibration. Then apply couplant B to the Block 1 surface, and hold the transducer against the block.
5. When you have the transducer firmly pressed against the block and the Ready button appears, press [ENTER] again to perform the calibration.

Note: *For single-point calibration, skip to step 9.*

6. The next prompt asks you to enter the length of Block 2.
   a. Use the arrow keys to move to the Block 2 text box.
   b. Press [ENTER] to open the text box.
   c. Use the numeric keys to enter the length.
   d. Press [ENTER] to confirm the entry.
7. Press [▶] to move to the Calibrate button, and press [ENTER] to prepare for calibration. Then apply couplant B to the block surface, and hold the transducer against the block.
8. When you have the transducer firmly pressed against the block, press [ENTER] (Ready button) again to perform the calibration.
9. Hold the transducer steady until the Set button appears. Press [ENTER] to store the calibration.

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Dual-Point Calibration (cont.)

Important: *Be sure to hold the transducer steady until the GE wait cursor disappears.*

10. Use the [▲] key to return to the Zero tab, and then scroll to the Display tab (page 165) to confirm the block length within ±0.002. If the measurement is not within this limit, recalibrate the transducer offsets.

Once you have completed calibration, the transducer should remain calibrated until the meter memory is cleared or a dramatic shift in ambient conditions occurs.

To leave the Zero window:

- Press the [◀] or [▶] arrow key to move to another tab to take readings or perform a velocity calibration.
- Press [F2] (Cancel) to return to Operate Mode without confirming the soundspeed value.
- Press [F3] (OK) to confirm the new value. The PT878 returns to Operate Mode.

8.4.5 Calculating Velocity (Pipe Material Soundspeed)

The nominal soundspeed for your pipe material will give thickness measurements of reasonable accuracy. However, for greater accuracy, calibrate pipe material sound velocity.

Important: *This step is necessary only if the actual pipe material soundspeed differs from the soundspeed of the material used in the calibration block. It is possible only if you have a sample of pipe material with thickness known to a high level of precision.*

To open the Velocity window, press the [◀] or [▶] arrow key until you reach the Velocity tab and press [ENTER]. The screen appears similar to Figure 114 below.

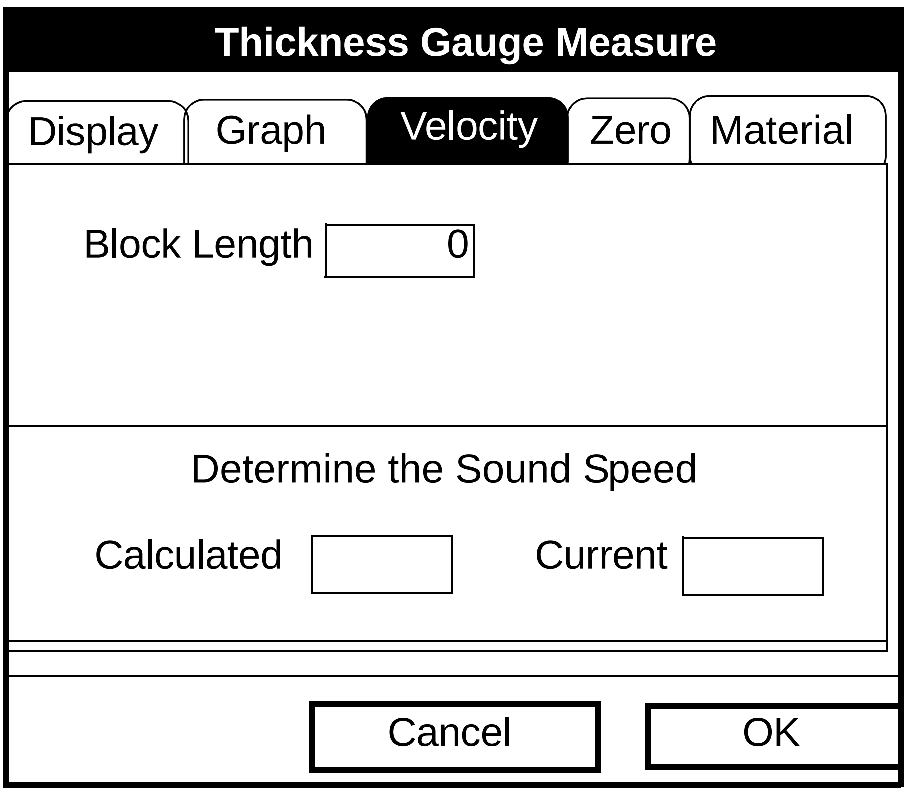

Figure 114: Soundspeed Window

1. Scroll to the Velocity tab as shown in Figure 114 above. Press [ENTER].

8.4.5 Calculating Velocity (Pipe Material Soundspeed) (cont.)

2. To enter the block length (here, the thickness of the sample as measured with a caliper or calibrated sample), press the [▼] arrow key and then press [ENTER] to open the Block Length text box. Use the numeric keys to enter the desired block length. Press [ENTER] to confirm the entry.

3. Prepare the sample for calibration by applying couplant B to its surface, and press [ENTER]. The screen now appears similar to Figure 115 below.

4. Hold the transducer steady against the sample, and wait for the Set button to appear.

5. To calibrate the gauge, press the [▼] arrow key to move to the Set button.

6. Press [ENTER] (Set button) to start the calibration sequence.

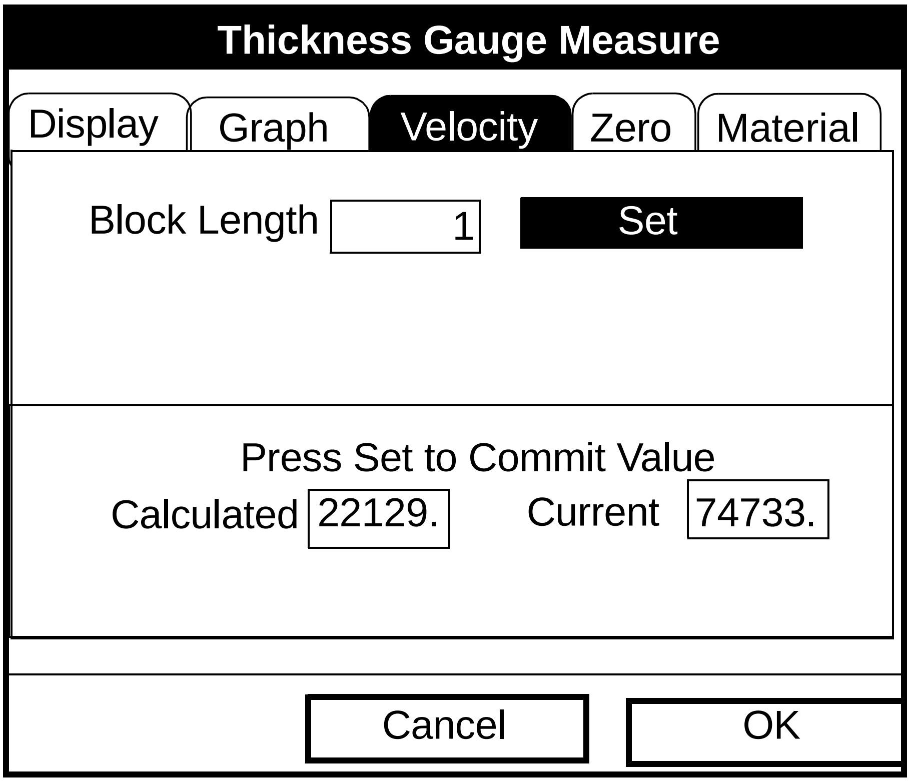

Figure 115: Velocity Window - Calculated and Current Values

8.4.5 Calculating Velocity (Pipe Material Soundspeed) (cont.)

7. The “Calculated” box shows the thickness value measured. The PT878 asks for confirmation of the calculated and current values. Press [ENTER] to commit the calculated value, or to recalculate the value.

Note: *If you commit the calculated value, the settings in the Material window also change from the previous material to “Other” with the new soundspeed.*

To leave the Velocity window:

- Press the [◀] or [▶] arrow key to move to another tab.
- Press [F2] (Cancel) to return to Operate Mode without confirming the soundspeed value.
- Press [F3] (OK) to confirm the new value and return to Operate Mode.

8.5 Programming the Thickness Gauge

While the T-Gauge Display option allows you to program the appropriate material and soundspeed, the Thickness Gauge Setup option enables you to view or change five parameters:

- Low Signal Threshold
- Transducer Delay
- Signal Inversion
- Noise Threshold
- Detection Threshold

Note: *The thickness gauge programming settings are entered at the factory. You should not change them unless instructed by the factory.*

The Programming window appears similar to Figure 116 on page 174.

8.5 Programming the Thickness Gauge (cont.)

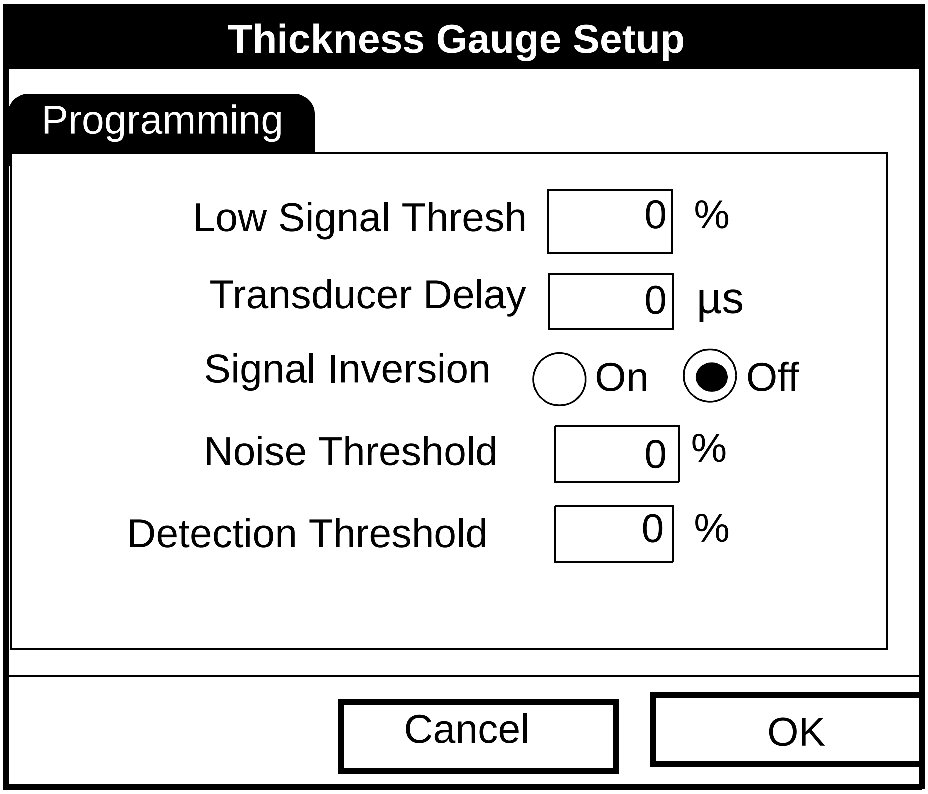

Figure 116: Thickness Gauge Programming Window

1. Press the [▼] arrow key to enter the window.
2. The first prompt asks for the low signal threshold. If the signal strength falls below this value, a “Low Signal” message appears on the screen. To change this value:
   a. Press [ENTER] to open the text box.
   b. Use the numeric keys to enter the desired value.
   c. Press [ENTER] to confirm your entry.
3. The next value, transducer delay, represents the time the ultrasonic signal takes to travel from the meter to the pipe material surface. To change this value:
   a. Press [ENTER] to open the text box.
   b. Use the numeric keys to enter the desired value.
   c. Press [ENTER] to confirm your entry.

8.5 Programming the Thickness Gauge (cont.)

4. The signal inversion prompt enables you to invert the thickness transducer signal. Signal inversion may be necessary if your thickness readings show unusual jitter, or for certain unusual combinations of pipe and fluid or pipe and lining. Consult the factory before measuring the thickness of lined pipes.

Note: *When measuring the thickness of certain pipe materials, you might need to drain the pipe before measuring the pipe wall, because certain pipe/liquid combinations muffle the ultrasonic echo.*

Signal inversion should be on, unless you have received other instructions. To change its status, use the [◀] and [▶] arrow keys to move to the appropriate radio button and press [ENTER].

5. To enter the noise threshold:

a. Press [ENTER] to open the text box.

b. Use the numeric keys to enter the desired value.

c. Press [ENTER] to confirm your entry.

6. The final value, the detection threshold, represents the percent of peak the PT878 uses to make measurements. It will consider anything above the entered percentage as part of the signal. To change this value:

a. Press [ENTER] to open the text box.

b. Use the numeric keys to enter the desired value.

c. Press [ENTER] to confirm your entry.

You have finished entering values for the Programming window. To leave this window:

- Press the [◀] arrow key to move to the Materials tab.
- Press [F2] (Cancel) to return to Operate Mode without confirming the changes. The PT878 returns to Operate Mode.
- Press [F3] (OK) to confirm the new data and return to Operate Mode. The PT878 returns to Operate Mode.

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8.6 Displaying Diagnostic Parameters

The Diagnostics option enables you to view current diagnostic parameters without having to open a display window in Operate Mode. To enter the option, scroll to the Diagnostics entry on the Service Menu and press [ENTER]. The screen appears similar to Figure 117 below.

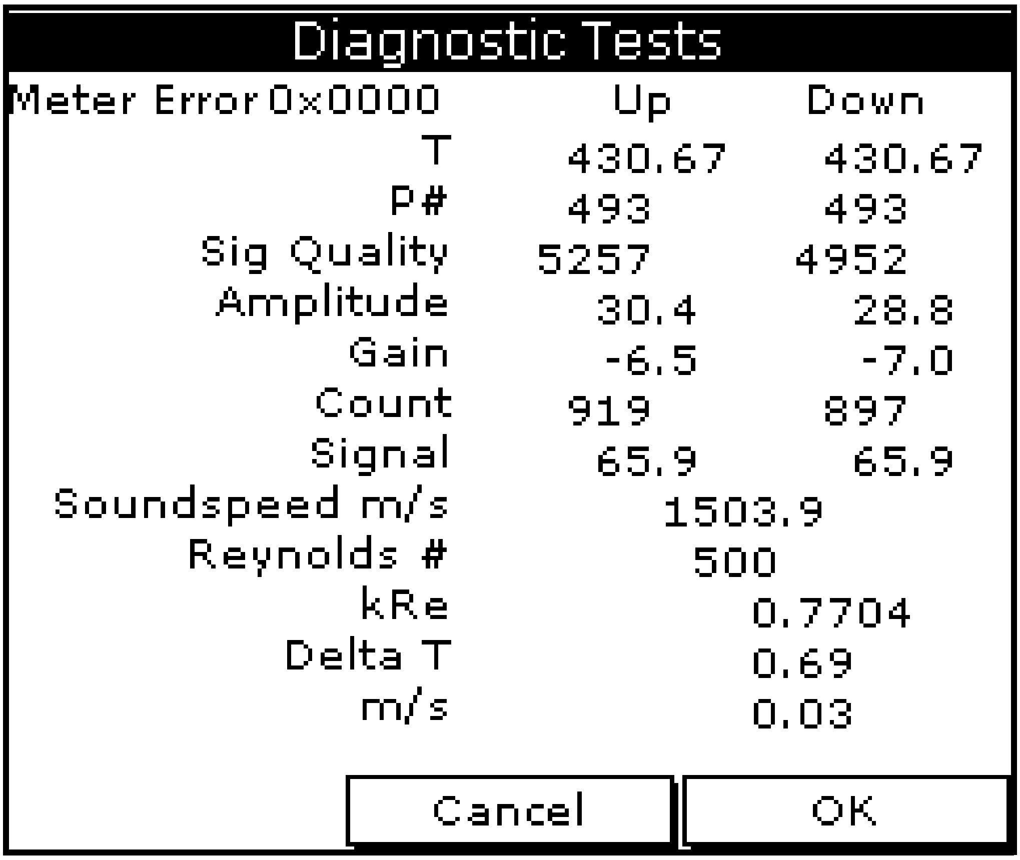

Figure 117: Diagnostics Window

Press [F2] (Cancel) or [F3] (OK) to close the window and return to Operate Mode.

Note: *For an explanation of diagnostic parameters, refer to Chapter 9,* Diagnostics and Troubleshooting.

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8.7 Calibrating the Analog Output and Inputs

The Calibration option allows you to calibrate the analog output and inputs. To enter the option, scroll to the Calibrate entry on the Service Menu and press [ENTER]. The screen appears similar to Figure 118 below.

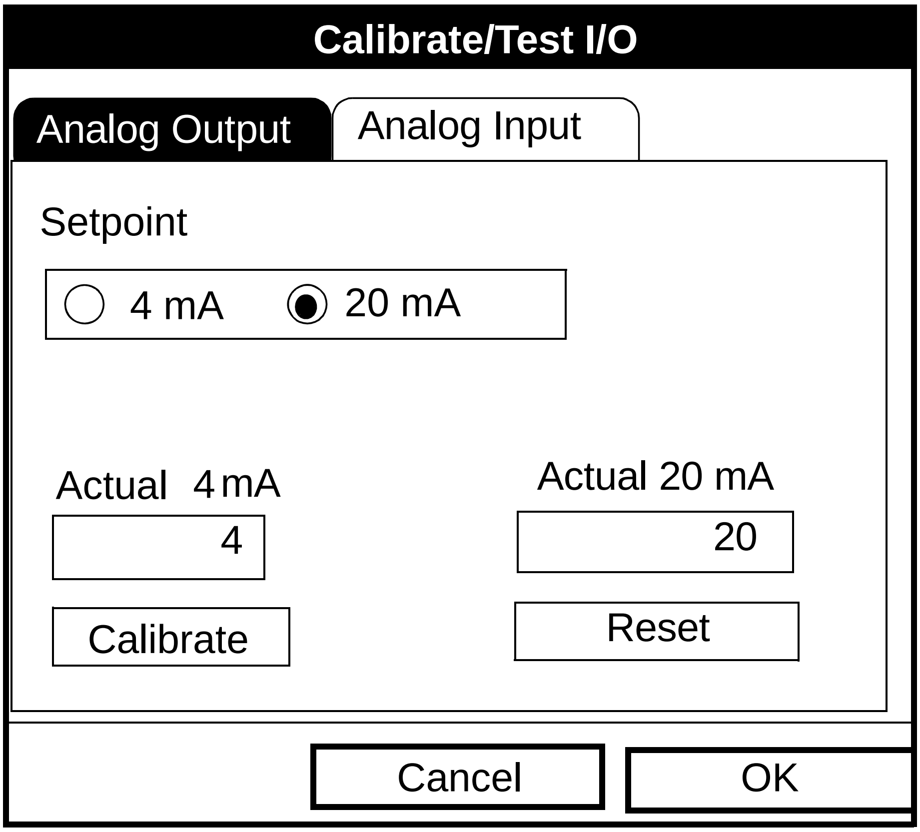

Figure 118: Outputs Window in the Calibration Option

8.7.1 Calibrating the Analog Output

The calibration procedure consists of calibrating the analog output zero point (0 or 4 mA) and then calibrating the full scale point (20 mA). You enter, first the setpoint, and then the actual value derived from an ammeter or digital voltmeter. The analog outputs have a resolution of ±5.0 µA. Press the [▼] arrow key to enter the Analog Output window.

8.7.1 Calibrating the Analog Output (cont.)

1. Connect the digital multimeter to the analog output.
2. The next prompt asks for the setpoint (4 or 20 mA). Use the [◀] and [▶] arrow keys to move to the appropriate radio button and press [ENTER].
3. The next prompt asks you to enter the actual value shown on the multimeter or ammeter.
   a. Press [ENTER] to open the text box.
   b. Use the numeric keys to enter the desired value.
   c. Press [ENTER] to confirm your entry.
4. Repeat steps 2 and 3 for the other setpoint.
5. Press the [▼] arrow key to move to the Calibrate box, and then press [ENTER] to calibrate the output.

If you are unsatisfied with the calibration, you can reset the inputs to factory defaults. Press the [▶] arrow key to move to the Reset box, and then press [ENTER] to undo the calibration.

You have completed calibrating the outputs. To leave the Output window,

- Press the [▲] key to return to the Output tab, and the [▶] arrow key to move to the Input tab.
- Press [F2] (Cancel) to return to Operate Mode without confirming the changes.
- Press [F3] (OK) to confirm the new data. The PT878 returns to Operate Mode.

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8.7.2 Calibrating Inputs

To open the Inputs window, press the [▶] arrow key and press [ENTER]. The screen appears similar to Figure 119 below.

Note: *Calibrating the analog inputs requires use of a current source.*

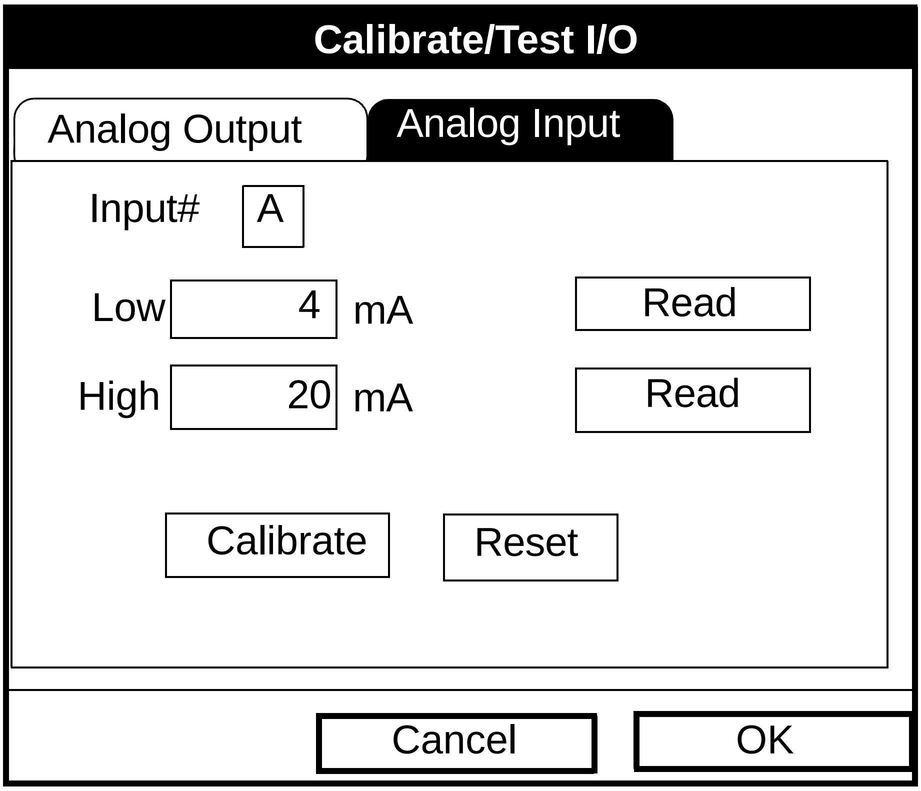

Figure 119: Inputs Window in the Calibrate Option

1. Press the [▼] arrow key to enter the window.
2. The first prompt asks you to select the input.
   a. Press [ENTER] to open the drop-down list.
   b. Use [▼]or [▲] arrow key to scroll to the desired output (A or B).
   c. Press [ENTER] to confirm your selection.
3. The next prompt asks for the value to which you want to set the low input (0 or 4 mA).
   a. Press [ENTER] to open the text box.
   b. Use the numeric keys to enter the desired value.
   c. Press [ENTER] to confirm your entry.

8.7.2 Calibrating Inputs (cont.)

4. Press the [▶] arrow key to move to the Read box, and then press [ENTER] to read the low input.

5. The next prompt asks for the value to which you want to set the high input (20 mA).

  a. Press [ENTER] to open the text box.

  b. Use the numeric keys to enter the desired value.

  c. Press [ENTER] to confirm your entry.

6. Press the [▶] arrow key to move to the Read box, and then press [ENTER] to read the high input.

7. Press the [▼] key to move to the Calibrate box, and press [ENTER] to calibrate the inputs.

8. At this point, you have two options:

  a. If you are unsatisfied with the calibration, you can reset the inputs to factory defaults. Press the [▶] arrow key to move to the Reset box, and then press [ENTER] to undo the calibration.

  b. If you are satisfied with the calibration, press the [▼] key to return to the Input# prompt, and repeat steps 2 through 8 for the other input.

You have completed calibrating the inputs. To leave the Inputs window,

- Press the [▲] key to return to the Inputs tab, and the [◀] arrow key to move to the Outputs tab.
- Press [F2] (Cancel) to return to Operate Mode without confirming the changes.
- Press [F3] (OK) to confirm the new data. The PT878 returns to Operate Mode.

8.8 Setting up Signal Parameters

The Signal Setup option enables you to set parameters that affect the transducer signal:

- Delta-T Offset
- Transmit Sample Size
- Zero Cutoff
- Velocity Averaging
- Errors Allowed
- Peak Detection Method
- Peak Thresholds
- Transmit Code

To enter the option, scroll to the Signal Setup entry on the Service Menu and press [ENTER]. The screen appears similar to Figure 120 below.

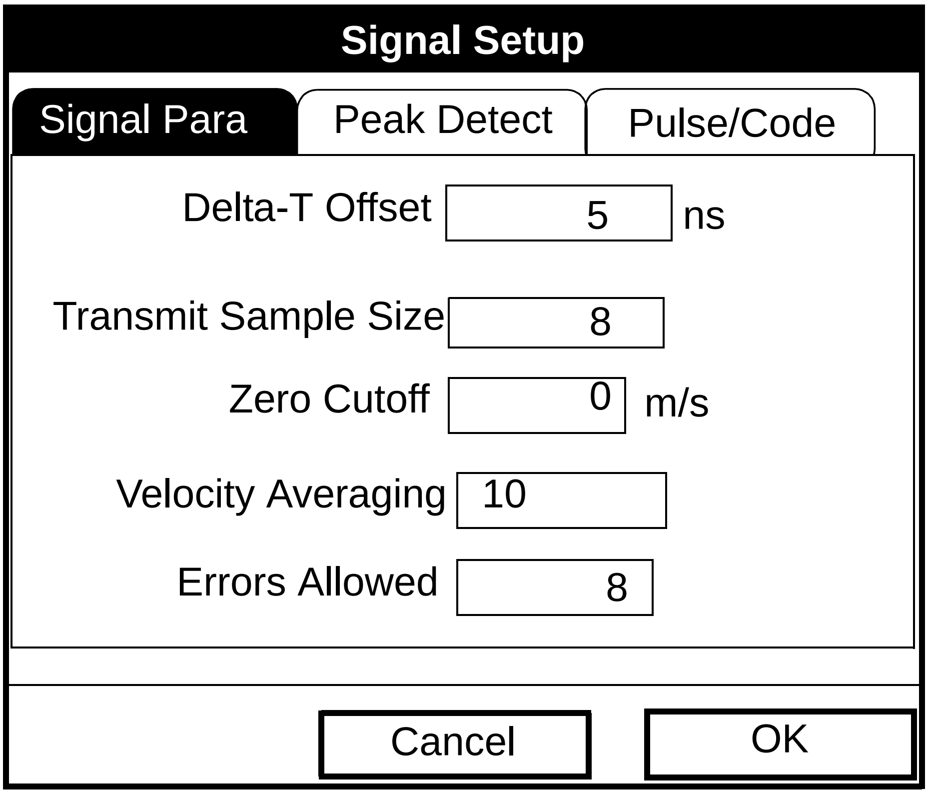

Figure 120: Signal Parameter Window

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8.8.1 Setting up Signal Parameters

1. Press the [▼] arrow key to enter the window.

2. The first prompt asks for the Delta-T offset. Delta-T is the difference between the upstream and downstream transit time of the transducers. The Delta-T offset should normally be set to zero.

Note: *Consult the factory before performing this step.*

- **a.** Press [ENTER] to open the text box.
- **b.** Use the numeric keys to enter the desired value.
- **c.** Press [ENTER] to confirm your entry.

3. The next prompt, the transmitter sample size, is the number of pulses each transmitter (upstream and downstream) emits. It is set to 8 by default.

Note: *Consult the factory before performing this step.*

- **a.** Press [ENTER] to open the drop-down list.
- **b.** Use the [▼] or [▲] arrow keys to scroll to the desired number.
- **c.** Press [ENTER] to confirm your selection.

4. The next prompt asks for the zero cutoff. Near “zero” flow, the PT878 may have fluctuating readings due to small offsets (caused by factors such as thermal drift in the fluid). The zero cutoff causes velocity measurements less than the cutoff to be reported as zero. To set the cutoff:

- **a.** Press [ENTER] to open the text box.
- **b.** Use the numeric keys to enter the desired value.
- **c.** Press [ENTER] to confirm your entry.

8.8.1 Setting up Signal Parameters (cont.)

5. The next prompt asks for velocity averaging.

a. Press [ENTER] to open the drop-down list.

b. Use the [▼] or [▲] arrow keys to scroll to the desired number of velocity measurements to average together to smooth out noise in the system.

c. Press [ENTER] to confirm your selection.

6. The final prompt, errors allowed, specifies the number of errors the meter can record before displaying an error message.

a. Press [ENTER] to open the text box.

b. Use the numeric keys to enter the desired value.

c. Press [ENTER] to confirm your entry.

You have finished entering data in the Signal Parameter window. To leave this window,

- Press the [▼] key to return to the Signal Parameter tab, and the [▶] arrow key to move to the Peak Detection tab.
- Press [F2] (Cancel) to return to Operate Mode without confirming the changes.
- Press [F3] (OK) to confirm the new data. The PT878 returns to Operate Mode.

8.8.2 Setting up Peak Detection

The PT878 can use two different methods to identify the peak of the received signal. In the "Peak" method, the peak is identified by testing a derivative of the signal. In the "Threshold" method, the peak is identified as the point where the signal crosses a threshold that is a percentage of the maximum signal detected. The peak method is more reliable in identifying the signal in dynamic conditions, while the threshold method is more reliable in marginal signal conditions.

Note: *Do not change the peak detection method or values unless recommended by the factory.*

From the Signal Parameter tab, press the [▶] arrow key to move to the Peak Detection tab. The window appears similar to Figure 121 below.

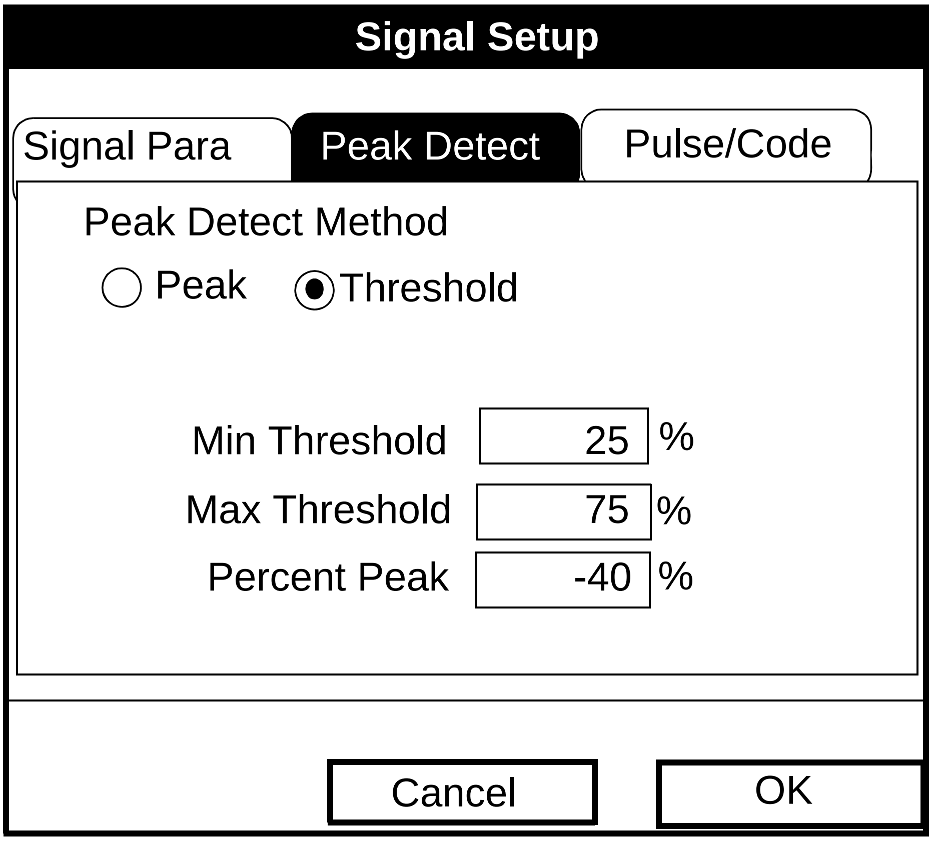

Figure 121: Peak Detection Window - Signal Setup Option

8.8.2 Setting up Peak Detection (cont.)

1. The first prompt asks for the peak detection method. Use the [◀] and [▶] arrow keys to move to the appropriate radio button and press [ENTER].

If you have selected the peak detection method, you have completed entering data in this window. But if you have selected the threshold method, you must also enter the minimum and maximum threshold percentage (available from 0 to 100) used to measure transit time.

2. To enter the minimum threshold:

a. Press [ENTER] to open the text box.

b. Use the numeric keys to enter the desired percentage.

c. Press [ENTER] to confirm your entry.

3. Repeat step 2 to enter the maximum threshold.

4. The final prompt asks for the percent of peak.

a. Press [ENTER] to open the text box.

b. Use the numeric keys (and the - key for negative numbers) to enter the desired percentage.

c. Press [ENTER] to confirm your entry.

You have completed entering data for Peak Detection. To leave this window,

- Press the [▲] key to return to the Peak Detection tab, and the [◀] arrow key to move to the Signal Parameter tab.
- Press [F2] (Cancel) to return to Operate Mode without confirming the changes.
- Press [F3] (OK) to confirm the new data and return to Operate Mode.

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8.8.3 Selecting the Transmit Code

The Pulse/Code tab allows users to select the transmit code used by the PT878 to make measurements. The default option, “Auto,” directs the meter to select the optimal code, based on the pipe size. From the Signal Parameter tab, press the [▶] arrow key twice to move to the Pulse/Code tab, as shown in Figure 122 below.

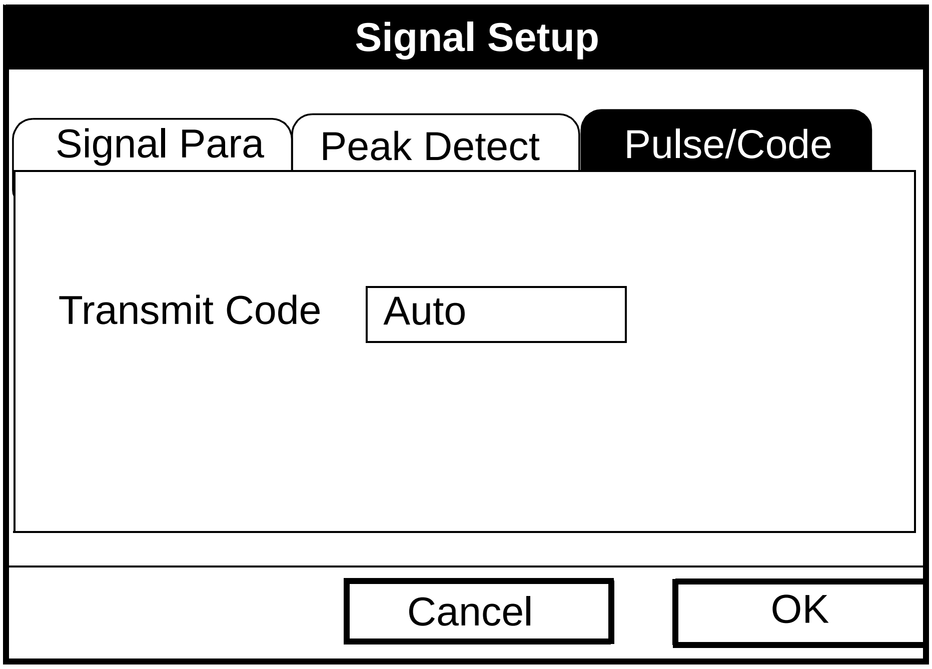

Figure 122: Pulse/Code Window - Signal Setup Option

1. Press the [▼] arrow key to reach the Transmit Code prompt, and press [ENTER] to open the drop-down menu.
2. Use the [▼] or [▲] arrow keys to scroll to the desired number of pulses (1, 2, 4, 11) or to Auto for automatic code selection.

You have completed entering the Transmit Code. To leave this window,

- Press the [▲] key to return to the Pulse/Code tab, and the [◀] arrow key to move to the Signal Parameter tab.
- Press [F2] (Cancel) to return to Operate Mode without confirming the changes.
- Press [F3] (OK) to confirm the new data and return to Operate Mode.

8.9 Setting Error Limits

The Error Limits option enables you to set limits for an incoming signal. When the signal falls outside the programmed limits, an error indication appears. To enter this option, scroll to the Error Limits entry on the Service Menu and press [ENTER]. The screen appears similar to Figure 123 below.

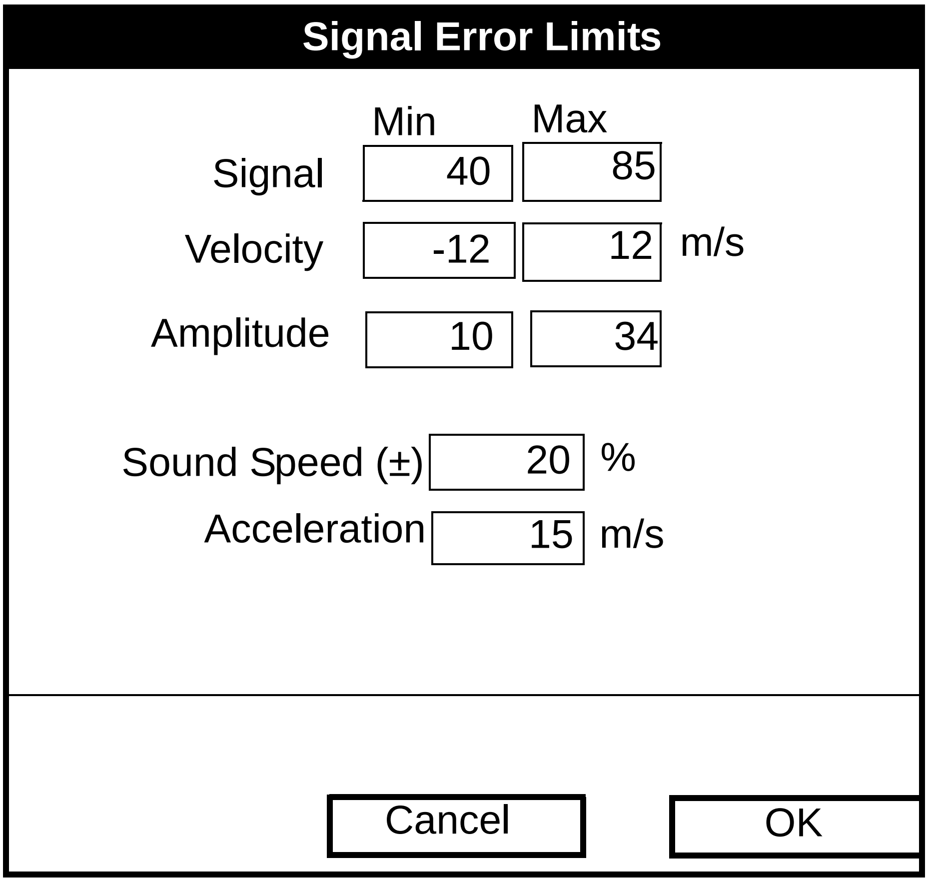

Figure 123: Signal Error Limits Option

1. The first prompt asks for the minimum and maximum limits for the transducer signal received by the PT878. The default values are 40 for minimum and 85 for maximum. The E1: LOW SIGNAL error message appears if the signal strength falls below the limit programmed here.

To enter the minimum signal

a. Press [ENTER] to open the text box.

b. Use the numeric keys to enter the desired value.

c. Press [ENTER] to confirm your entry.

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8.9 Setting Error Limits (cont.)

d. Press the [▶] arrow key to move to the maximum signal box, and repeat steps a, b and c.

e. Press the [◀] arrow key to return to the minimum signal box, and the [▼] key to move to the next limit.

2. The next prompt calls for the low and high velocity limits. The E3: VELOCITY RANGE error message appears if the velocity falls outside these limits. Repeat Step 1 on page 187 to enter the desired limits.

3. The third prompt calls for the low and high limits for the amplitude discriminator. The discriminator measures the size of the transducer signal sent from the PT878. If the signal falls outside these limits, the E5: AMPLITUDE ERROR message appears. Repeat Step 1 on page 187 to enter the desired limits.

4. The fourth prompt asks for the acceptable limits for the soundspeed, based on conditions in your particular system. The E2: SOUNDSPEED ERROR message appears if the fluid soundspeed exceeds that entered in the Pipe option of the Program menu by more than this percentage. The default value is 20% of the nominal soundspeed.

a. Press [ENTER] to open the text box.

b. Use the numeric keys to enter the desired percentage.

c. Press [ENTER] to confirm your entry.

5. The final prompt asks for the acceleration limit for detecting cycle skipping. The E6: ACCELERATION ERROR message appears if the velocity changes by more than this limit from one reading to the next.

a. Press [ENTER] to open the text box.

b. Use the numeric keys to enter the desired speed.

c. Press [ENTER] to confirm your entry.

8.9 Setting Error Limits (cont.)

Note: *In the velocity and acceleration boxes, if the PT878 currently displays metric measurements, the F1 softkey displays the word "English." If it displays English measurements, the F1 softkey displays "Metric." Press* [F1] *to display the measurement in the alternate format.*

You have completed entering signal error limits.

- Press [F2] (Cancel) to return to Operate Mode without confirming the error limits, or
- Press [F3] (OK) to confirm the new limits and return to Operate Mode.

8.10 The Test Option

Within the Service Menu, the Test option includes seven tests to ensure that the PT878 is performing properly: Test Screen, Test Keys, Watchdog Test, Impulse Response, Wave Snapshot, Simulate and Battery Test.To enter this option, scroll to the Test entry on the Service Menu and press [ENTER]. The screen appears similar to Figure 124 below.

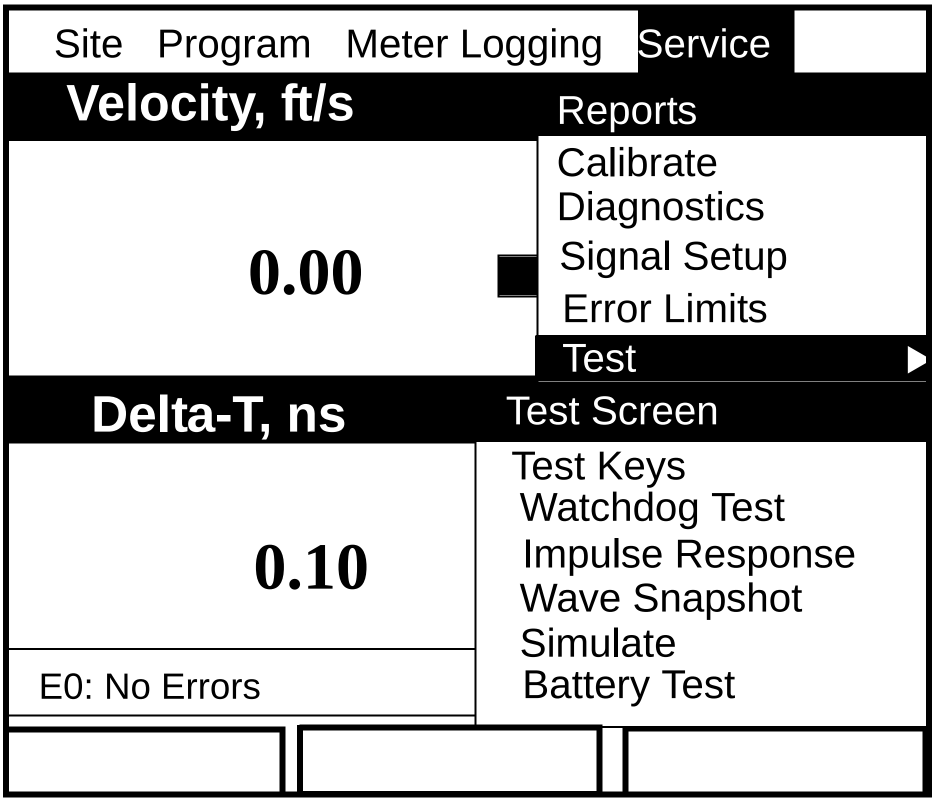

Figure 124: Test Option in the Service Menu

Scroll to the desired entry in the option menu and press [ENTER].

8.10.1 Testing the Screen

To test the proper functioning of the PT878 screen, scroll to the Test Screen option in the Test Menu and press [ENTER]. The screen then shows the message, "Press Any Key To Continue." Once you press a key, a screen with a checkerboard pattern appears, as shown in Figure 125 below.

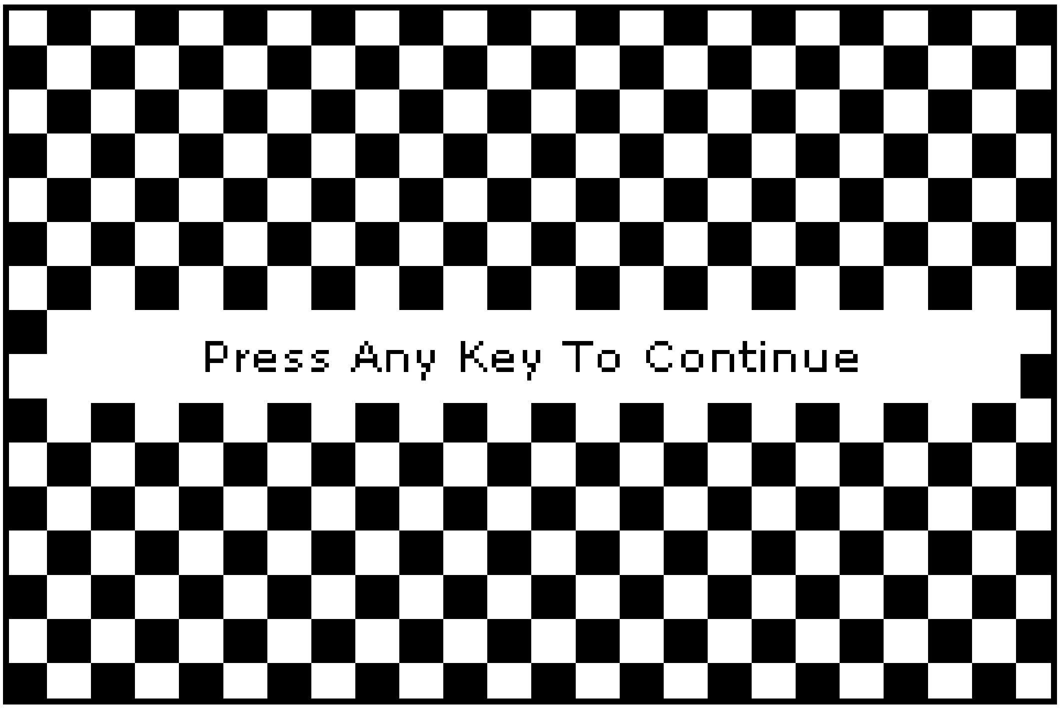

Figure 125: Functioning Test Screen

Pressing a key two more times should result in two more checkerboard patterns, followed by a series of dark and light screens. Pressing the key through this sequence should return the PT878 to Operate Mode. If the test does not proceed according to this sequence, please consult the factory.

8.10.2 Testing the Keys

The Test Keys option checks the functioning of the various keys on the keypad. To start the test, scroll to the Test Keys option on the Test Menu and press [ENTER]. The screen appears similar to Figure 126 below. Press any key on the keypad, and a window representing that key should darken.

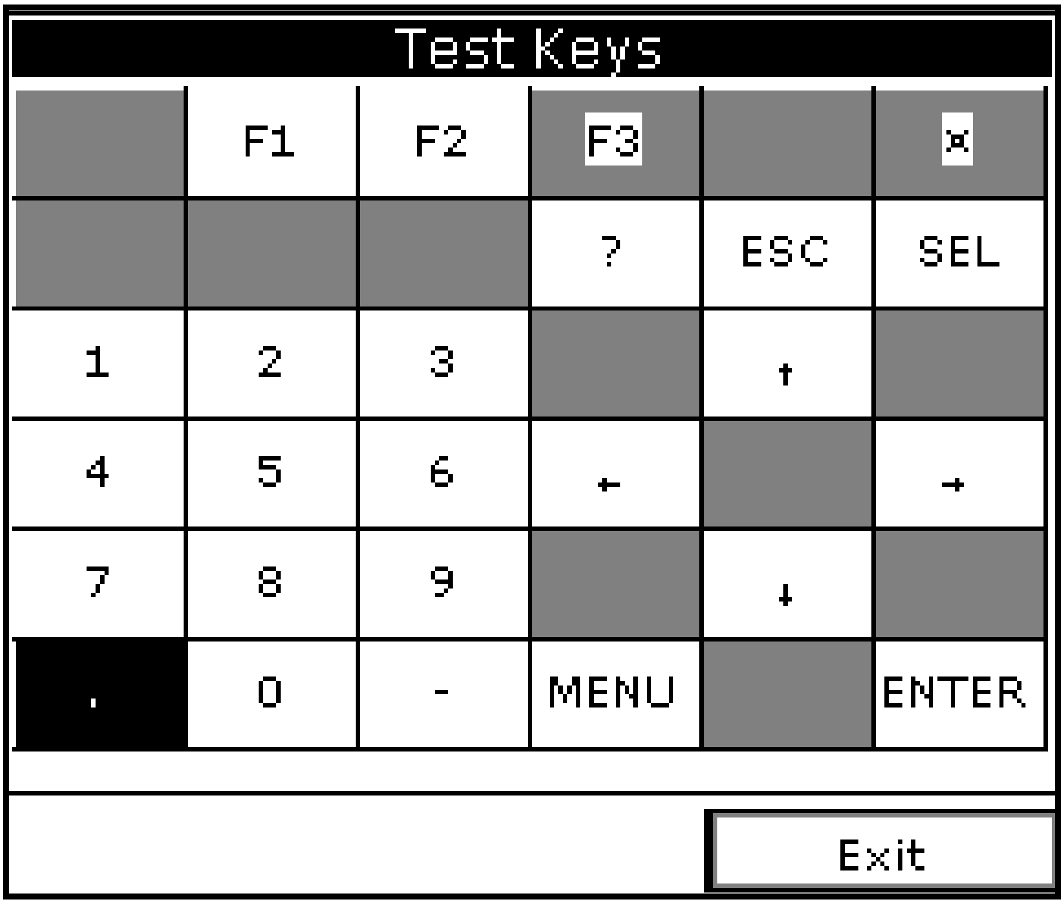

Figure 126: Test Keys Window

Pressing the [F3] key returns the meter to the Operate Mode. If any key does not appear on the screen, contact the factory.

Note: *The power key does not appear.*

8.10.3 Testing the Watchdog Timer Circuit

The PT878 includes a watchdog timer circuit. If a software error causes the meter to stop responding, this circuit automatically resets the meter. A properly functioning PT878 restarts if you run the Watchdog Test.

To start the Watchdog Test, scroll to the Watchdog Test option in the Test Menu and press [ENTER]. The screen appears similar to Figure 127 below.

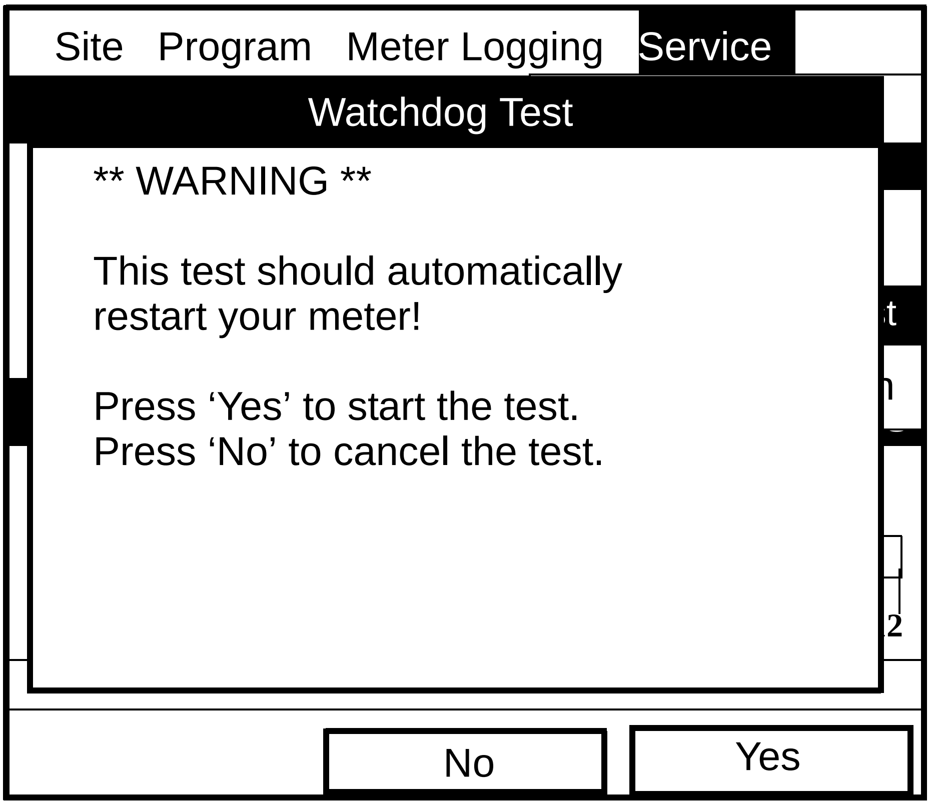

Figure 127: Watchdog Test Screen

Press [F2] (No) to cancel the test and return to the Menu screen, or press [F3] (Yes) to start the test. The PT878 should go blank for a few seconds, and then restart. If it does not follow this sequence, consult the factory.

8.10.4 Setting Impulse Response

The Impulse Response option enables you to force the meter to transmit in one direction only, without changing the AGC setting. You can then diagnose problems with transducer, pipe, or fluid configurations. To enter the option, scroll down to the Impulse Response entry in the Service Menu and press [ENTER]. The screen appears similar to Figure 128 below.

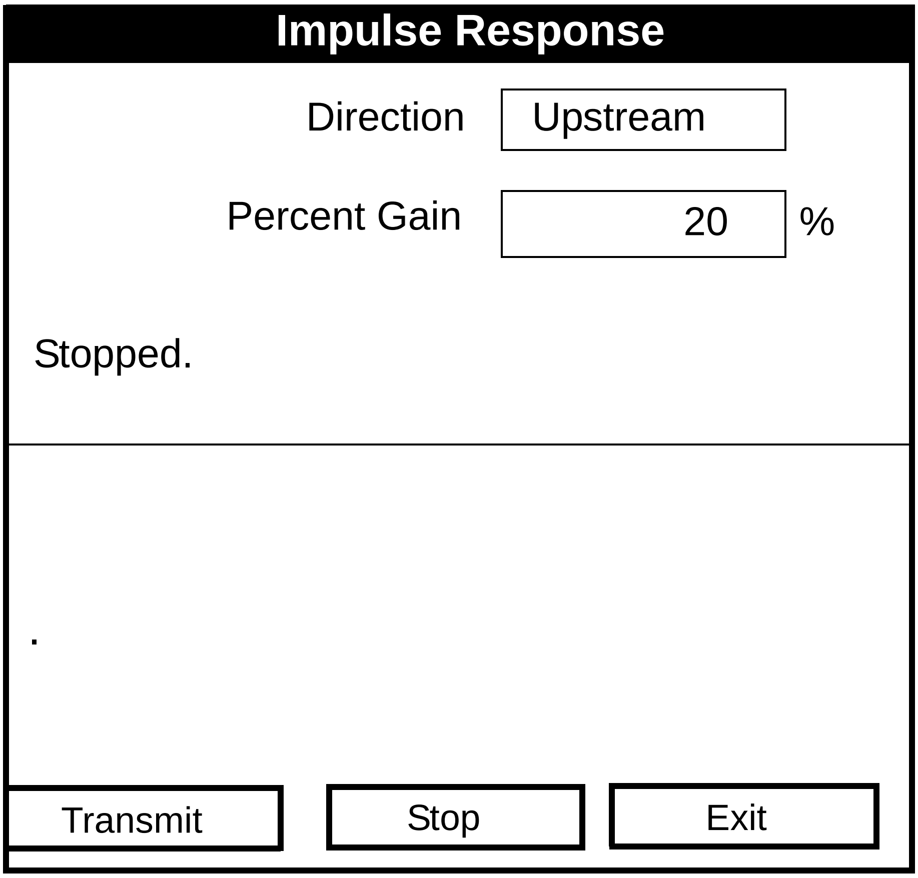

Figure 128: Impulse Response Option

1. The first prompt asks in which direction you wish the meter to transmit, upstream or downstream.
   a. Press [ENTER] to open the drop-down list.
   b. Use the [▼] or [▲] arrow keys to scroll to the desired number.
   c. Press [ENTER] to confirm your selection.

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8.10.4 Setting Impulse Response (cont.)

2. The second prompt asks for the percent of gain.

   a. Press [ENTER] to open the text box.

   b. Use the numeric keys to enter the desired percentage.

   c. Press [ENTER] to confirm your entry.

You have completed entering data for the Impulse Response option.

- Press [F1] to start transmitting in the chosen direction.
- Press [F2] to stop transmitting.
- Press [F3] to leave the option and return to Operate Mode.

8.10.5 Taking Wave Samples for Diagnosis

The Wave Snapshot option allows you to capture receive signals to a file that you can send to a PC for diagnostic purposes. To use this option, scroll down to the Wave Snapshot entry in the Service Menu and press [ENTER]. The PT878 then captures three pairs of upstream and downstream raw signals to a file named Wave01.met. (If you repeat the captures, the successive files will be named Wave02.met, Wave03.met, etc.) You can then transfer the files over the IR port to a PC for analysis by a service engineer.

Note: *Refer to page 104 for information on transferring a file to a PC.*

8.10.6 Transferring a Wave Snapshot

The Wave Snapshot function creates data files in the PT878 that correspond to raw and correlated data. This data is useful to review meter performance in certain applications. Wavesnapshot is generated at the PT878 UI by pressing the Service\Test\Wavesnapshot option. The file name is typically WAVExx.met, where xx is a sequential number.

To transfer a Wave Snapshot file from the PT878 to a PC using HyperTerminal, complete the following steps:

1. Connect the PT878 to the PC.
2. Start HyperTerminal and set up the communication link to match the Com port and RS232 settings of the PT878 (see Figure 129 on the next page).
3. From the PT878 select the Site\Drive Manager option and then select the WAVExx.met file you want to send to the PC.
4. To send the Wave Snapshot file, from HyperTerminal proceed as follows:
   a. Select the Transfer\Receive File option.
   b. Select the location of the file and select the XModem receiving protocol.
   c. Click Receive and enter the desired filename, using the .met extension.
5. From the PT878 Site Manager select the File\Transfer option. This will allow the PT878 to send the file to the PC using the secure XModem protocol. File transfer is complete when the XModem Receive dialog box closes.

Note: *The file is transferred in GE Panametrics format and it must be opened using the DOS ConvertWave.exe program provided by GE.*

8.10.6 Transferring a Wave Snapshot (cont.)

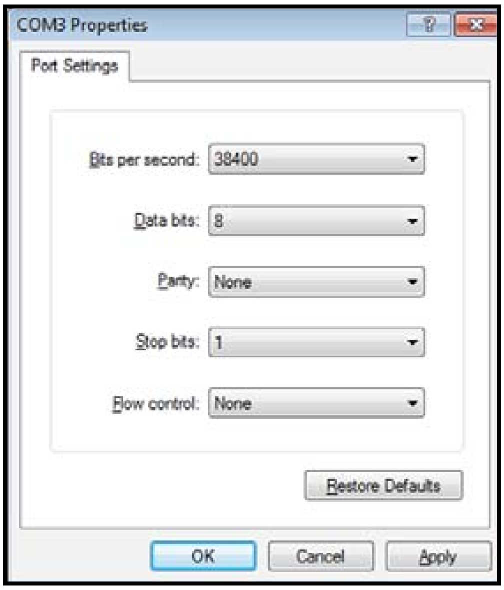

Figure 129: COM Properties

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8.10.7 Testing the Battery

The Battery Test option provides additional battery information for service troubleshooting. To enter the option, scroll down to the Battery Test entry in the Service Menu and press [ENTER]. The screen appears similar to Figure 130 below.

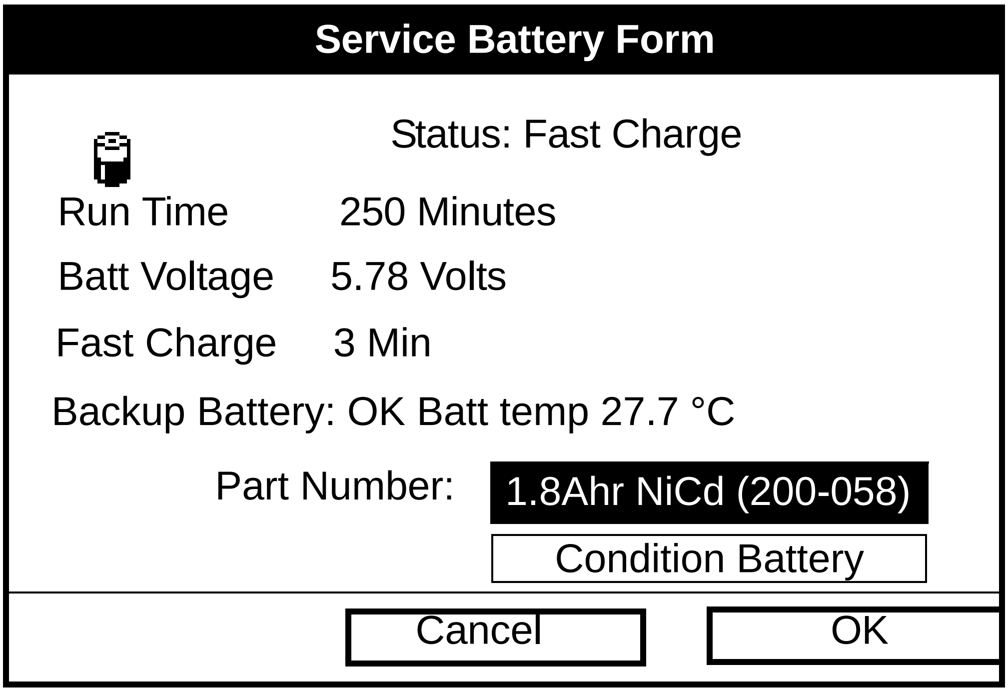

Figure 130: Battery Test Option

The screen displays current status (Fast Charge, On Charge, Discharging, or On Battery), the time remaining for the PT878 to run on the battery, the time for the Fast Charge, and the current condition of the backup battery.

1. If you wish to open the Part Number window, press [ENTER]. You can choose from a 1.8 Ahr NiCd battery (part number 200-058) or a 3.0 Ahr NiMH battery (part number 200-081). Scroll to the battery type you have installed and press [ENTER].
2. To condition the batteries, press the [ENTER] key. The “Condition Battery” window should now read “Stop.” The status line should change to “Discharging.” (Updating the status could take up to 30 sec.)
3. To stop the discharge cycle, press the [ENTER] key and the “Condition Battery” window reappears. The status now changes to “On Charger.”
4. Press [F3] (OK) to return to Operate Mode.

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8.11 Resetting to Factory Default Parameters

For various reasons, you might wish to return the PT878 to its original settings. The Factory Defaults option enables you to return the meter to its preprogrammed default settings. To enter the option, scroll down to the Factory Defaults entry in the Service Menu and press [ENTER]. The screen will appear similar to Figure 131 below.

Note: *All sites and logs will be lost if you use the Factory Defaults option. Be sure to transfer all sites and logs before resetting!*

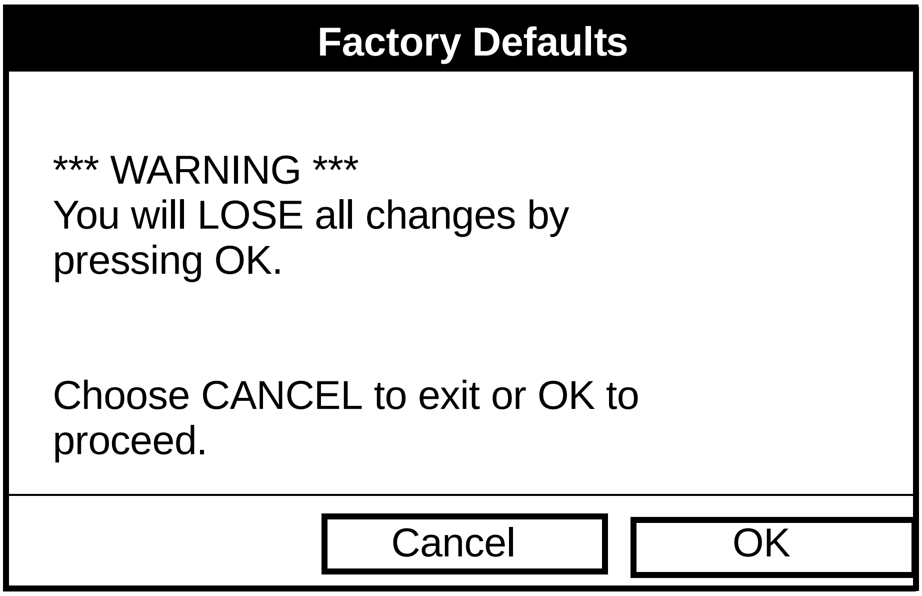

Figure 131: Factory Defaults Option

1. To restore Factory Default settings:

- Press [F2] (Cancel) to return to Operate Mode without changing the current settings.
- Press [F3] (OK) to confirm that you wish to restore the factory default settings.

2. The program asks for confirmation: “Are you SURE?” Repeat the procedure shown in Step 1 above.

The PT878 replaces the default site file and the global meter settings with the factory default settings, and returns to Operate Mode.

8.12 Updating PT878 Firmware

The PT878 firmware update process uses a terminal emulation program. To update the PT878 firmware using its USB interface, complete the following steps:

1. Connect the PT878 to the PC (page 9).
2. Start HyperTerminal and set up the communication link to match the Com port and RS232 settings of the PT878 (see Figure 132 below).

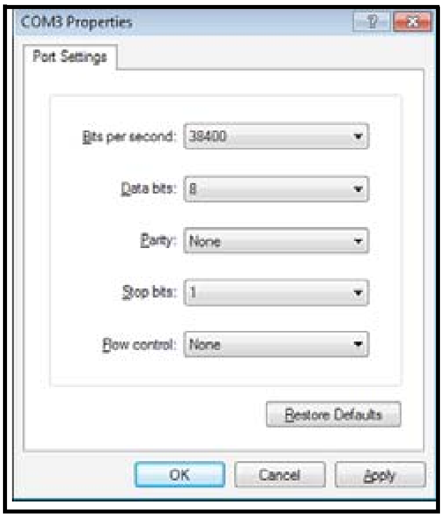

Figure 132: COM Properties

3. Power up the PT878 and press “0”. Then, press Yes to “reload Flash”.
4. In HyperTerminal, select the Transfer\Send File option and select the XModem protocol. Browse for the firmware file and select Send (see Figure 133 below).
5. After the firmware upload is complete, the PT878 will automatically reboot and perform a CRC check.

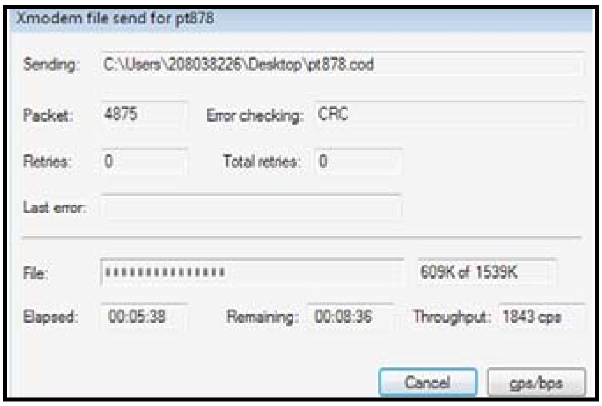

Figure 133: PT878 XModem File Send

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Chapter 9. Diagnostics and Troubleshooting

The TransPort is a reliable instrument that is easy to maintain. It will provide accurate flow measurement readings as long as it is operated as described in this manual. If problems do arise with the electronics, transducers or the flowcell, the TransPort displays an error message specifying the possible problem. The TransPort also has a set of diagnostic parameters to help you find and remedy the problem.

In general, troubleshooting may be necessary if the TransPort displays an error message, the flow readings are erratic, or you have other reasons to doubt the accuracy of readings (for example, readings do not agree with other flow measuring devices connected to the same process).

This section describes error messages, diagnostic parameters, and shows you how to isolate problems to one of the following areas:

- Electronics, including programmed values
- Flowcell, which includes the pipe and fluid
- Transducers and cables.

9.1 Error Code Messages

Error Code messages appear on the screen while you are displaying measurements. When logs appear in graph form, errors are indicated by a vertical gray bar at the point of error. When they appear in a spreadsheet format, errors are indicated by their number, in place of the measurement. The Error Code messages are only general descriptions of the possible problems. Use Table 7 below to isolate and remedy the problem. If you are unable to remedy the problem, contact the factory.

Note: *We suggest that, in order to isolate the indicated problem more easily, you obtain a test flowcell. Contact the factory for details.*

Table 7: Error Messages

Error	Problem	Possible Cause	Action
E0	No error.	Displays briefly after display of another error message	None required. Measurement is valid.
E1	Low Signal - Poor ultrasonic signal strength.	Broken cable. Flowcell problem. Transducer problem. Electronic failure.	Check transducer cable. See Flowcell Problems on page 206 and Transducer Problems on page 208. Check programming and transducer spacing. Contact the factory if problem persists.
E2	Soundspeed Error (Soundspeed is programmed using the Program Menu Pipe option, as described in Chapter 5.)	Poor flow conditions. Incorrect programming. Bad transducer spacing. Measurement is very different from the programmed soundspeed.	Check soundspeed against nominal soundspeed. See Flowcell Problems on page 206 and Transducer Problems on page 208. Check programming and transducer spacing.

Table 7: Error Messages (cont.)

Error	Problem	Possible Cause	Action
E3	Velocity Range - Velocity exceeds programmed limits (Velocity limit is programmed using the Service Menu Error Limits option as described in Chapter 8.)	Programming error, poor flow conditions, or bad transducer spacing.	Make sure flow rate is within ±12m/s (±40 ft/s). Check programming and transducer spacing. If programmed value is outside of limit, change the limits as described in Chapter 8 on page 187. See Flowcell Problems on page 206 and Transducer Problems on page 208.
E4	Signal Quality	If too high - electronic failure. If too low - flowcell, electrical problem.	Check for source of electrical interference. Check electronics with a test flowcell. If unit still fails to operate, contact the factory
E5	Amplitude Error	Excessive particles or bubbles present in fluid. A lot of second phase present	See Flowcell Problems on page 206.
E6	Cycle skip, Acceleration	Poor flow conditions or bad transducer spacing.	Check transducer spacing as programmed and as set on pipe. See Flowcell Problems on page 206 and Transducer Problems on page 208.
E7	Analog Out Error	Under current output.	Check that output load is within specification <550 ohm.
E8	Temperature Input Supply	Supply temperature input out of range.	Check cable and transmitter.
E9	Temperature Input Return	Return temperature input out of range.	Check cable and transmitter.

9.2 Displaying Diagnostic Parameters

As part of its measurement menu, the PT878 offers a list of diagnostic parameters to aid in troubleshooting in the event of flowcell, transducer, or electrical problems. You can select any diagnostic parameter for display as a measurement as discussed in Chapter *5, Displaying and Configuring Data*, on page 95. Table 8 below shows all the available diagnostic parameters and ranges.

Table 8: Diagnostic Parameters

Diagnostic Parameter	Displays	Good	Bad
DT	Displays Delta T, or the difference between the upstream and downstream transit times.	N/A	Continuous large fluctuations of 1 ms or more.
Amplitude Up	Displays the value for the amplitude discriminator of the upstream transducer.	20-28	<20 or >28
Amplitude Down	Displays the value for the amplitude discriminator of the downstream transducer.	20-28 fluctuations	< 20 or > 28 fluctuations
T Up	Displays the upstream transit time of the ultrasonic signal in micro seconds.	N/A	N/A
T Down	Displays the downstream transit time of the ultrasonic signal in micro seconds.	N/A	N/A
Gain/Up	Displays upstream gain in dB.	N/A	N/A
Gain/Dn	Displays downstream gain in dB.	N/A	N/A
Soundspeed (m/s or f/s)	Displays the measured soundspeed of the fluid.	Check the soundspeed of fluid in *Soundspeeds and Pipe Size Data.*	
P#up	Displays signal peaks for the upstream transducer.	100-900	<100, >900
P#dn	Displays signal peaks for the downstream transducer.	100-900	<100, >900
Reynolds #	Displays the Reynolds Number.	N/A	N/A
K(RE)	Displays the K Factor, based on the Reynolds Number.	N/A	N/A
Raw Up	Displays raw upstream signal.	N/A	N/A
Raw Down	Displays raw downstream signal.	N/A	N/A

Table 8: Diagnostic Parameters (cont.)

Diagnostic Parameter	Displays	Good	Bad
Xmit Corr Up	Displays raw upstream signal correlated with transmit signal.	N/A	N/A
Xmit Corr Dn	Displays raw downstream signal correlated with transmit signal.	N/A	N/A
Cross Corr	Displays transmit upstream signal correlated with transmit downstream signal.	N/A	N/A
SS up	Displays the signal strength for the upstream transducer.	50-80	<50
SS do	Displays the signal strength for the downstream transducer.	50-80	<50
PEAK%	Displays the Percent of Peak. Set to -40 by default. To change see page 185.	N/A	N/A
Qup	Displays the signal quality for the upstream transducer.	±300 or higher	between ±100
Qdown	Displays the signal quality for the downstream transducer.	±300 or higher	between ±100
NFup	Displays the normalization factor for the upstream transducer.	0.85 - 1.0	<0.85
NFdn	Displays the normalization factor for the downstream transducer.	0.85 - 1.0	<0.85
TEMPs	Displays the temperature for the supply input (energy measurement).	N/A	N/A
TEMPr	Displays the temperature for the return input (energy measurement).	N/A	N/A
Ts - Tr	Displays the difference between the temperature for supply input and the temperature for return input (energy measurement).	N/A	N/A
DENSs	Displays the density for the supply input. (Energy measurement.)	N/A	N/A
DENSr	Displays the density for the return input. (Energy measurement.)	N/A	N/A
DELTh	Displays the delta enthalpy, or difference between the supply and return enthalpy (enthalpy is a measure of energy contained in the fluid.) (Energy measurement.)	N/A	N/A

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9.3 Flowcell Problems

Flowcell problems fall into two categories: fluid problems and pipe problems. Read the following sections carefully to determine if such problems exist.

9.3.1 Fluid Problems

Most fluid-related problems can be solved by proper design of the flowmeter installation and the proper choice of transducer frequency. Contact the factory if you cannot solve a fluid-related problem.

Certain fluid properties may prevent proper flow measurement. Some fluid properties that cause problems are listed below.

1. THE FLUID MUST BE HOMOGENOUS, SINGLE PHASE, RELATIVELY CLEAN, and FLOWING STEADILY. Solid particles and gas bubbles absorb and disperse ultrasound. Although, in some cases, solids and gases have little effect on the operation of the TransPort, excessive amounts will prevent ultrasound transmission through the fluid and interfere with proper flow measurement. Temperature gradients may also cause a problem.
2. THE FLUID MUST NOT CAVITATE NEAR THE FLOWCELL. Fluids with a high vapor pressure may cavitate near or in the flowcell. This causes problems resulting from gas bubbles in the fluid. Cavitation can usually be controlled through proper installation design.
3. THE FLUID MUST NOT ATTENUATE ULTRASOUND EXCESSIVELY. Some fluids, particularly those that are very viscous, absorb ultrasound energy. In these cases an “E1” will display on the screen to indicate that the ultrasonic signal is not of sufficient strength for reliable measurements.
4. THE FLUID SOUNDSPEED MUST NOT VARY EXCESSIVELY. The TransPort will tolerate relatively wide, but slow, changes in fluid soundspeed due to changes in fluid composition and temperature. However, if you are measuring a fluid that is considerably different from the fluid programmed into the TransPort, you may have to adjust the meter for the new fluid. Refer to Chapter 3, *Programming Site Data*, on page 37.

9.3.2 Pipe Problems

Improper pipe conditions and/or flowcell installation can cause problems with fluid flow measurement. Check the items below if you suspect this class of problem. Contact the factory for unsolved pipe-related problems.

1. THE INSIDE OF THE PIPE OR FLOWCELL MUST BE RELATIVELY CLEAN. Excessive build up of scale, rust, or debris will interfere with flow measurement. Generally, a thin coating or a solid well-adhered buildup on the pipe wall will not cause problems. Loose scale and thick coatings (such as tar or oil) will interfere with ultrasound transmission and may result in incorrect or unreliable measurements.
2. THE FLOWCELL ORIENTATION MUST NOT ALLOW SEDIMENT OR GAS ENTRAPMENT AT THE TRANSDUCER LOCATIONS. Sediment or gas trapped in the transducer ports for wetted transducers, or at the transducer locations for clamp-on transducers, will interfere with flow measurement. Realignment of the flowcell or transducers often cures these problems. In some cases different transducers may be used that protrude into the flow stream.
3. THE PIPE OR FLOWCELL DIMENSIONS MUST BE ACCURATE. The accuracy of your flow measurements will be no better than the accuracy of your programmed pipe or flowcell dimensions. If GE did not supply your flow cell, the dimensions you program must be consistent with the required flow accuracy. Check your pipe for wall thickness, diameter, dents, eccentricity, weld deformity, and straightness.
4. THE PIPE SURFACES SHOULD BE SMOOTH (FOR CLAMP-ON). When using clamp-on transducers, both the inside and the outside of the pipe at the transducer locations must be smooth. If the pipe is extremely rough, the ultrasonic signal will be scattered by the rough surface, and will not be received by the flowmeter, preventing flow measurement.
5. THE PIPE MUST ALLOW ULTRASOUND TO PASS THROUGH (FOR CLAMP-ON). Some pipe materials or linings such as Fiberglass (or generic fiber reinforced pipe), Teflon, and polyethylene, absorb ultrasound and may cause problems in clamp-on applications. Pipes with extremely thick walls or high OD to ID ratios may also present
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9.4 Transducer Problems

Ultrasonic transducers are rugged. However, they are subject to physical damage due to mishandling and chemical attack. Clamp-on transducers are also subject to installation variables such as physical misalignment and faulty coupling to the pipe on which they are mounted.

Because transducer problems are largely dependent on the type of transducer used, wetted or clamp-on, the following list of potential problems is grouped according to transducer type. Contact the factory if you cannot solve a transducer-related problem.

9.4.1 Wetted Transducer Problems

1. LEAKS

Leaks may occur around the transducer and in the fittings of the flow cell. Repair as you would any other leak. Check the transducer and cables for damage if the leaking fluid is corrosive.

2. CORROSION DAMAGE

Wetted transducers may be damaged by corrosive fluids if the transducer material does not match the application. Most often, corrosion damage occurs at the electrical connector. To check for damage, remove the transducer from the flow cell. If the wetted end of the transducer is rough and pitted, the transducer may have to be replaced. GE can supply suitable transducer materials for most fluids. Contact the factory for information on special transducers.

3. INTERNAL DAMAGE

An ultrasonic transducer consists of a ceramic “crystal” bonded to the transducer case. The bond between the crystal and the case may be damaged by extreme mechanical shock and by temperature extremes. The crystal itself can also be damaged by the same conditions. The internal wiring can be corroded or shorted if contaminants enter the transducer housing.

9.4.1 Wetted Transducer Problems (cont.)

4. PHYSICAL DAMAGE

Transducers may be physically damaged by dropping them onto a hard surface or striking them against another object. Usually the connector on the transducer is the part that is damaged, as it is the most fragile. Minor damage may be repaired by carefully bending the connector back into shape. If the connector cannot be repaired, replace the transducers. Note that transducers must be replaced in pairs. Before replacement, make sure that the transducer number in the programmed parameters is the one engraved on the new transducers (see Chapter 3, *Programming Site Data*).

9.4.2 Clamp-on Transducer Problems

1. POOR COUPLING TO PIPE

Clamp-on transducers must be in intimate contact with the pipe. The pipe wall must be smooth and generally free of paint. The couplant material must fill voids between the transducer and the pipe, and must be firmly coupled or bonded to both the pipe and the transducer. The pipe and transducer must be clean and dry for permanent couplant, such as grease or epoxy, to adhere properly. Enough pressure must be applied to the transducer by its clamp to hold it firmly against the pipe.

2. MISALIGNMENT

The transducer transmits relatively narrow beams of ultrasound, and therefore transducer alignment is critical to assure that the beam can travel from one transducer to the other without undue attenuation. Be sure to exactly follow the instructions that came with your transducers and clamping fixtures. Also, be sure that the transducer spacing agrees with the calculated spacing (S).

3. INTERNAL DAMAGE

Ultrasonic transducers consist of a ceramic “crystal” bonded to the transducer case. The bond between the crystal and the case may be damaged by extreme shock and by temperature extremes. The crystal itself can also be damaged by the same conditions. The internal wiring can be corroded or shorted if contaminants enter the transducer housing.

9.4.2 Clamp-on Transducer Problems (cont.)

4. PHYSICAL DAMAGE

Transducers may be physically damaged by being dropped onto a hard surface or being struck against another object. Usually the transducer connector is the part that is damaged, as it is the most fragile. Minor damage may be repaired by carefully bending the connector back into shape. If the connector cannot be repaired, replace the transducers. Note that transducers must be replaced in pairs, and that after replacement the flowmeter parameters should be checked (see Chapter 3, *Programming Site Data*).

5. CYCLE SKIP CONDITION

A cycle skip is usually caused by a distorted or altered signal due to poor couplant, bad wall, or unusual fluid disturbances. To resolve a cycle skip, recouple both transducers with proper couplant. Try standard CPL-1 couplant that is good to 212°F (100°C) or CPL-2 for up to 500°F (260°C). In addition, make sure the pipe wall is free of paint and rust.

Contact the factory if you cannot solve a transducer-related problem.

9.4.3 Relocating Transducers

If the coupling or pipe wall are not the problem, try relocating the transducers using the following method. However, before beginning, make sure the transducers are not located on or near pipe welds or seams:

Move one transducer about 1/2 inch (12.7 mm) closer to the other transducer. If this resolves the problem, you must modify the “S” dimension programmed into the PT878 by using the following steps:

1. Press [MENU].
2. Scroll to the Program menu and press [ENTER].
3. Scroll to the Path option and press [ENTER].Then scroll down to the Spacing box and press [ENTER].
4. Use the numeric keys to enter the transducer spacing. Subtract 0.5 in. (12.7 mm) from the original “S” and enter the new “S” dimension.
5. Press [F3] (OK).

If this method does not resolve the problem, contact the factory.

Chapter 10.Specifications

This section contains specifications for the following:

- Overall
- Electrical
- Transducer
- Fluid Types
- Pipe Size and Materials
- Available Options

10.1 Overall

10.1.1 Hardware Configuration

Channel Options: Single channel
Mode Options: Transit-time

10.1.2 Size/Weight

Size without boot: 238 × 138 × 38 mm
(9.4 × 5.5 × 1.5 inches)

Weight with boot: 1.36 kg (3 lb)

10.1.3 Enclosure

Submersible, IP67

10.1.4 Flow Accuracy (Velocity, % of reading):

Clamp-on Transducers: **Pipe Diameter > 150 mm (6 in.)**

±1% to 2% of reading typical

Pipe Diameter ≤ 150 mm (6 in.)
±2 to 5% of reading typical

Note: *Accuracy depends on pipe size and whether measurement is one-path or two-path. Accuracy to ±0.5% of reading may be achievable with process calibration.*

Range: –12.2 to 12.2 m/s (–40 to 40 ft/s)

Rangeability: 400:1

Repeatability: ±0.1% to 0.3% of reading

Note: *Specifications assume a fully developed flow profile (typically 10 diameters upstream and 5 diameters downstream of straight pipe run) and flow velocity greater than 1 ft/s (0.3 m/s).*

Energy Accuracy (% of reading): The accuracy of the energy measurement is a combination of the accuracy of the flow and temperature measurement. Accuracy of 1% is typical for calibrated systems.

Low Voltage Directive Compliance: This unit complies with European Standard EN61010-1 Installation Category II, Pollution Degree 2.

EMC Directive Compliance This unit complies with EN61326:1998 CL.A Annex C. For continuous unmonitored operation, follow provisions of the 89/336/EMC Compliance.

10.2 Electrical

Internal Batteries

Type: Rechargeable batteries. (Optional NiCad 6_R nonrechargeable alkaline available.)

Battery Life: 9-11 hours of continuous operation is typical

Battery Charger:

Input: 100-250 VAC, 50/60 Hz, 0.38 A

Memory: 1 MB datalog/site battery-backed RAM
1 MB program FLASH memory

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Environmental

Operating
Temperature: –20 to 55°C (–4 to 131° F)

Storage
Temperature: –40 to 70°C (–40 to 158° F)

Note: *To ensure maximum battery life storage, do not exceed 35 °C (95° F) for long periods.*

Operating Modes

Flow Measurement: Transit-Time™ mode with clamp-on or wetted transducers

Energy: To calculate energy flow rate, use the external loop-powered RTD transmitter (Part # 2CHRT)

Input/Output

Keypad: 25-key rubberized tactile membrane keypad

Display: 240 × 200 pixel LCD graphic display with EL backlight

Communications: USB port

Analog Output: One 4-20 mA or 0-20 mA current output

Digital Output: One user-selectable pulse (solid-state, 5-V max.) or frequency (5-V square wave, 100 to 10,000 Hz)

Analog Input: Two 4-20 mA analog inputs with switchable 16 V supply for loop-powered temperature transmitters

Acoustic: One pair of LEMO® coaxial transducer connectors

Cable and length: Cable length 8 m (25 ft) standard. Up to 305 m (1000 ft) optional with extension cables.

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10.3 Operational Specifications

Site Parameter Programming:	Menu-driven operator interface using a keypad and "soft" function keys. On-line help functions including pipe tables. Storage for saving parameters for up to 64 sites.
Data Logging:	Memory capacity to log over 100,000 flow data points. Keypad programmable for log units, update times and start and stop times.
Display Functions:	Graphic displays shows flow in numeric or graphical format. Also displays logged data. Supports multiple languages: English, French, German, Japanese, Spanish, (Castilian and South American), Italian, Portuguese, Dutch, Russian and Swedish.
Totalizers:	Pulse or frequency totalizer output.

10.4 Transducer

10.4.1 Clamp-On Ultrasonic Flow Transducers

Temperature Range:

Standard: –40° to 150°C (–40° to 300°F)

Optional (overall):–190° to 300°C (–310° to 572°F)

Housing:

Standard: None

Optional: List models or consult factory:

Mounting: SS Chain or strap, welded or magnetic clamping fixtures

10.4.2 Temperature Transducers

Types: Loop-powered 3-wire platinum RTDs;clamp-on and wetted (thermowell) types are available.

Accuracy: 0.15°C wetted RTDs (matched pairs)

Range: –20 to 260°C (-4 to 500°F)

10.5 Pipe Size and Material

10.5.1 Clamp-On Transducers:

Materials: All metals, most plastics; consult GE Sensing for concrete, composite materials and highly corroded or lined pipes

Pipe Sizes: 12.7 mm to 7.6 m outside (OD) (0.5 to 300 in.)

Pipe Wall Thickness: Up to 75 mm (3 in.)
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10.6 Available Options

Thickness Measuring Mode

Standard Transducer: GE Measurement & Control dual element transducer

Pipe Thickness Range: 1.3 to 76.2 mm (0.05 to 3.0 in.)

Pipe Materials: Most standard metal and plastic pipe materials

Accuracy: ±1% typical or ±0.05 mm (±0.002 in.)

Display Resolution: 0.01 mm (0.001 in.)

Thermal Exposure: Continuous operation to 37°C (100°F)
Intermittent operation to 260° C (500° F)
for 10 seconds followed by air cooling for 2 minutes.

Energy Equipment

Dual RTD transmitter; two 4 to 20-mA transmitters with input for 3-wire RTD (100 Ω Pt) and terminals for 4 to 20-mA output; and 6-ft. cable

PC Option

USB Port enables connection to desktop or laptop PCs

PC Interface Software

PanaView™ Instrument Interface Software

Appendix A.Menu Maps

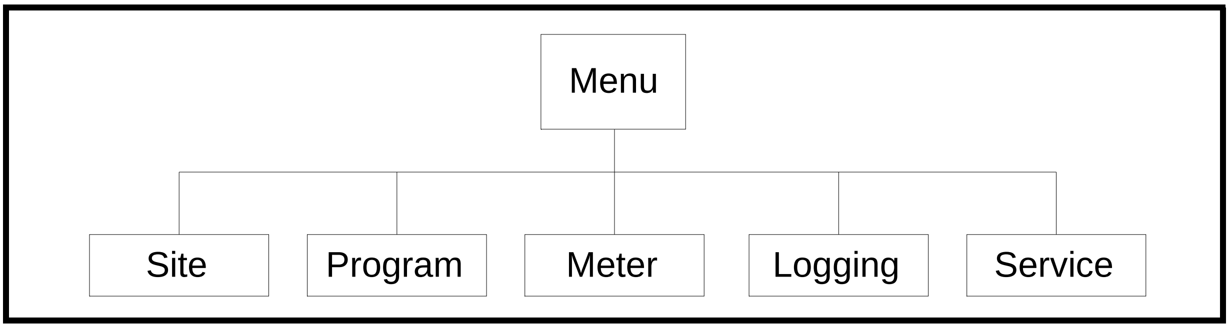


Figure 137: Main Menu

- **Site Menu** - Figure 138 on page 221.
- **Program Menu** -
  - Pipe Option - Figure 139 on page 222
  - Transducer Option - Figure 143 on page 227
  - Lining Option - Figure 144 on page 228
  - Fluid Option - Figure 145 on page 229
  - Path Option - Figure 146 on page 230
  - Energy Option - Figure 147 on page 231
  - Analog Input Option - Figure 148 on page 232
  - Analog Output Option - Figure 149 on page 233
  - Digital Output Option - Figure 150 on page 234
  - User Functions Option - Figure 151 on page 235
  - Correction Factors Option - Figure 152 on page 236
- **Meter Menu** -
  - Meter Menu - Figure 140 on page 223
  - Communications Option - Figure 153 on page 237.
- **Logging Menu** - Figure 141 on page 224.
- **Service Menu** - Figure 142 on page 225

[no content intended for this page - proceed to next page]

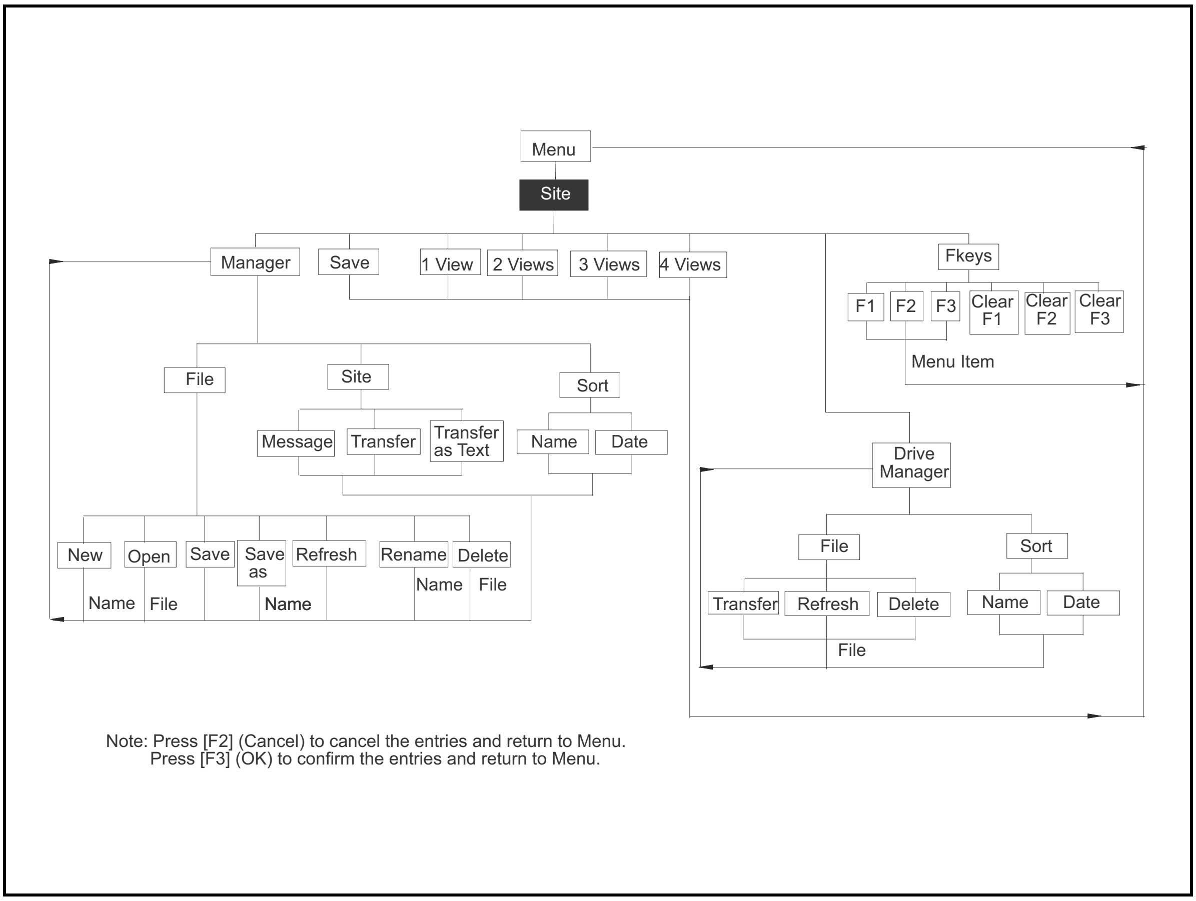


Figure 138: Site Menu

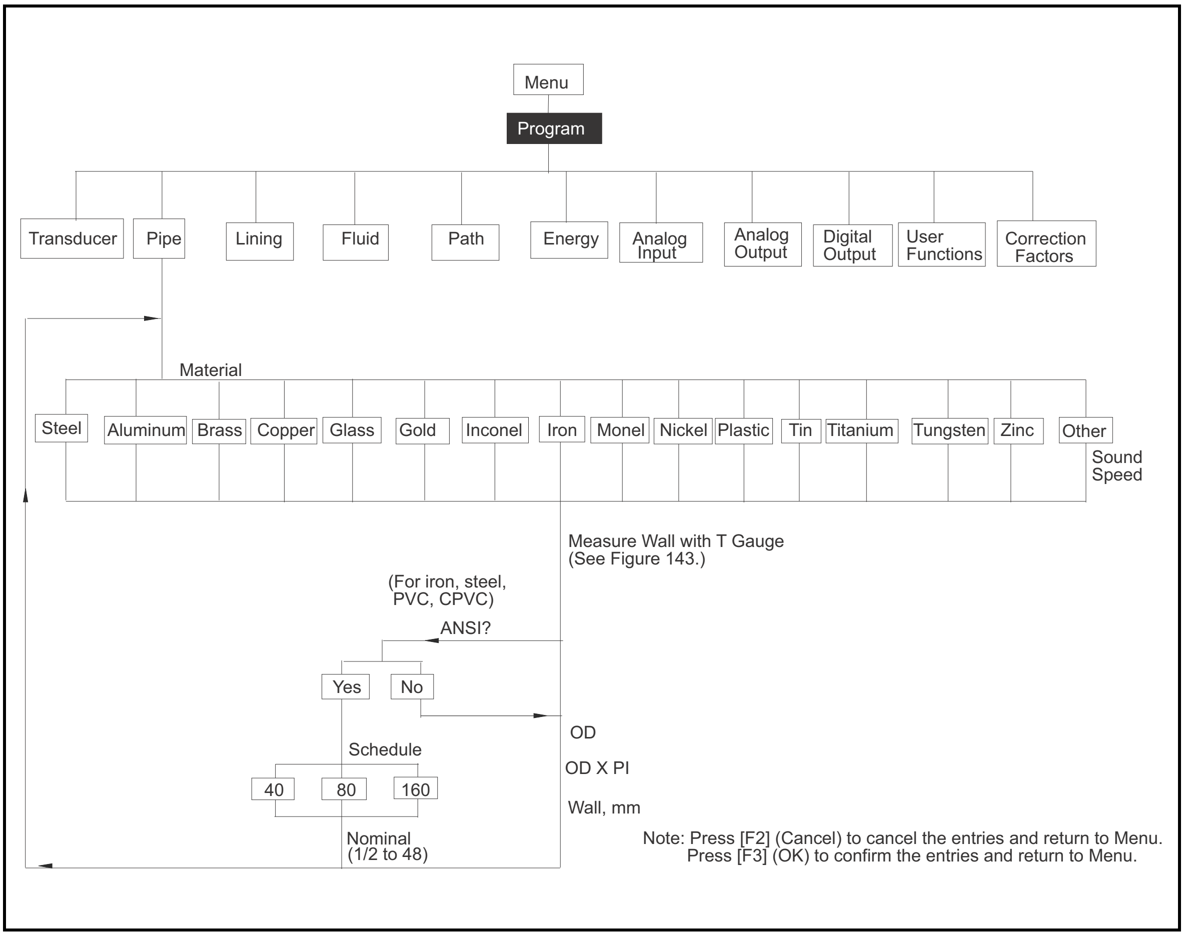


Figure 139: Program Menu with Pipe Option

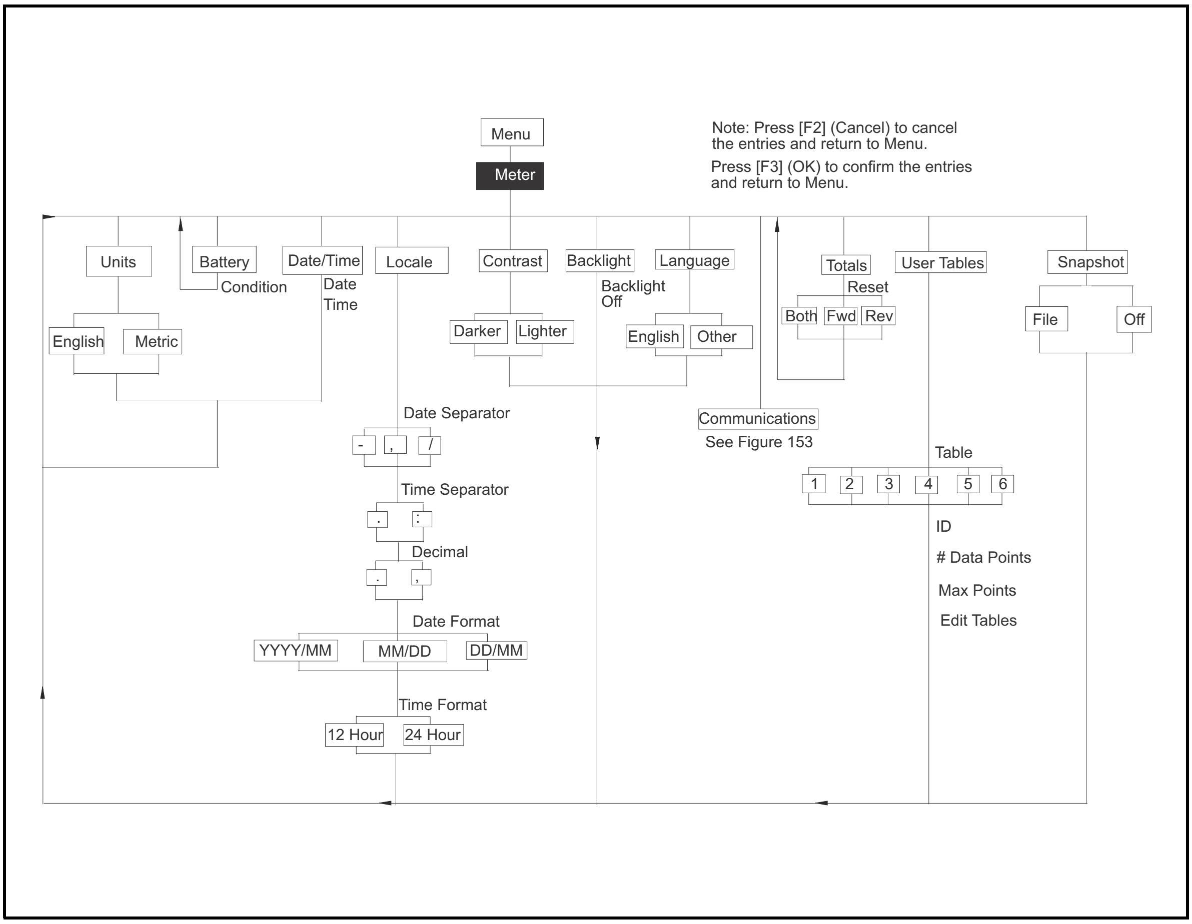


Figure 140: Meter Menu

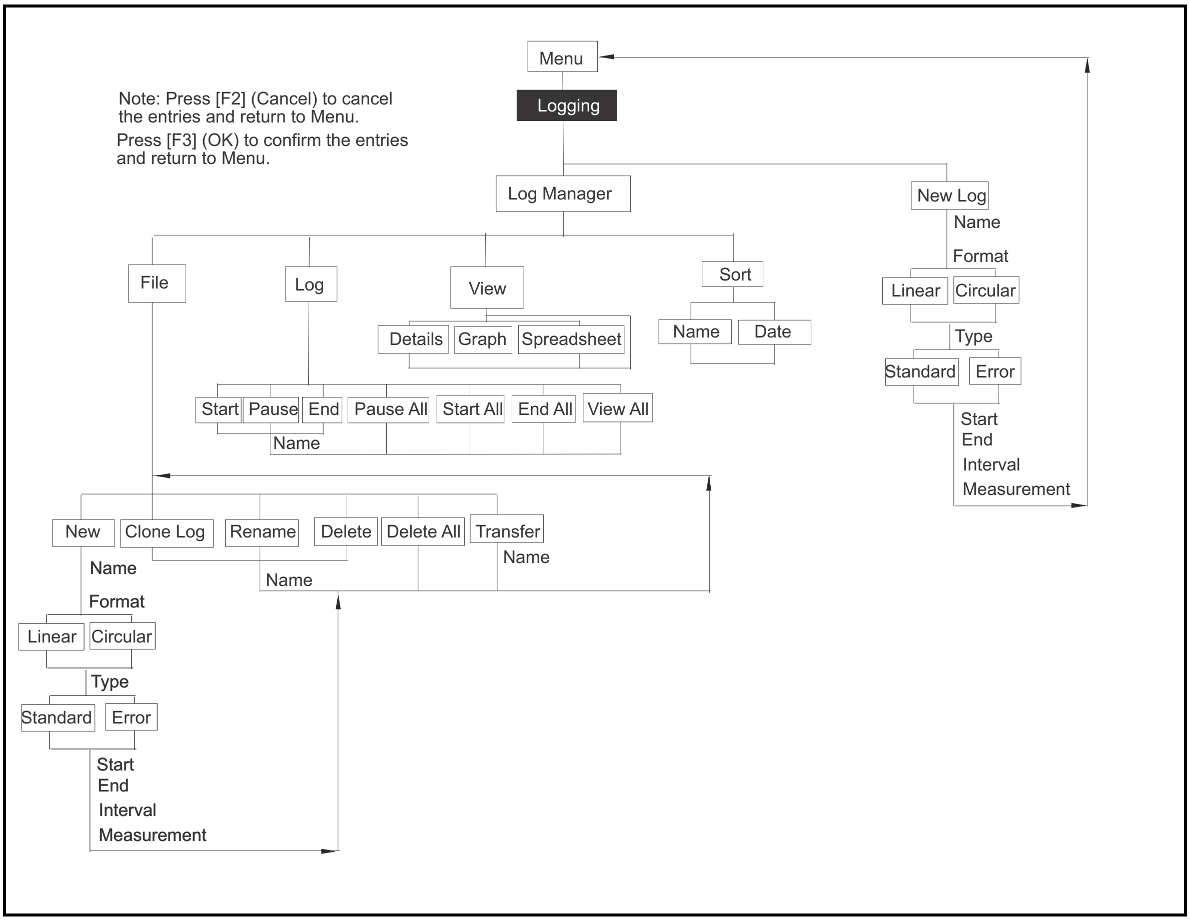


Figure 141: Logging Menu

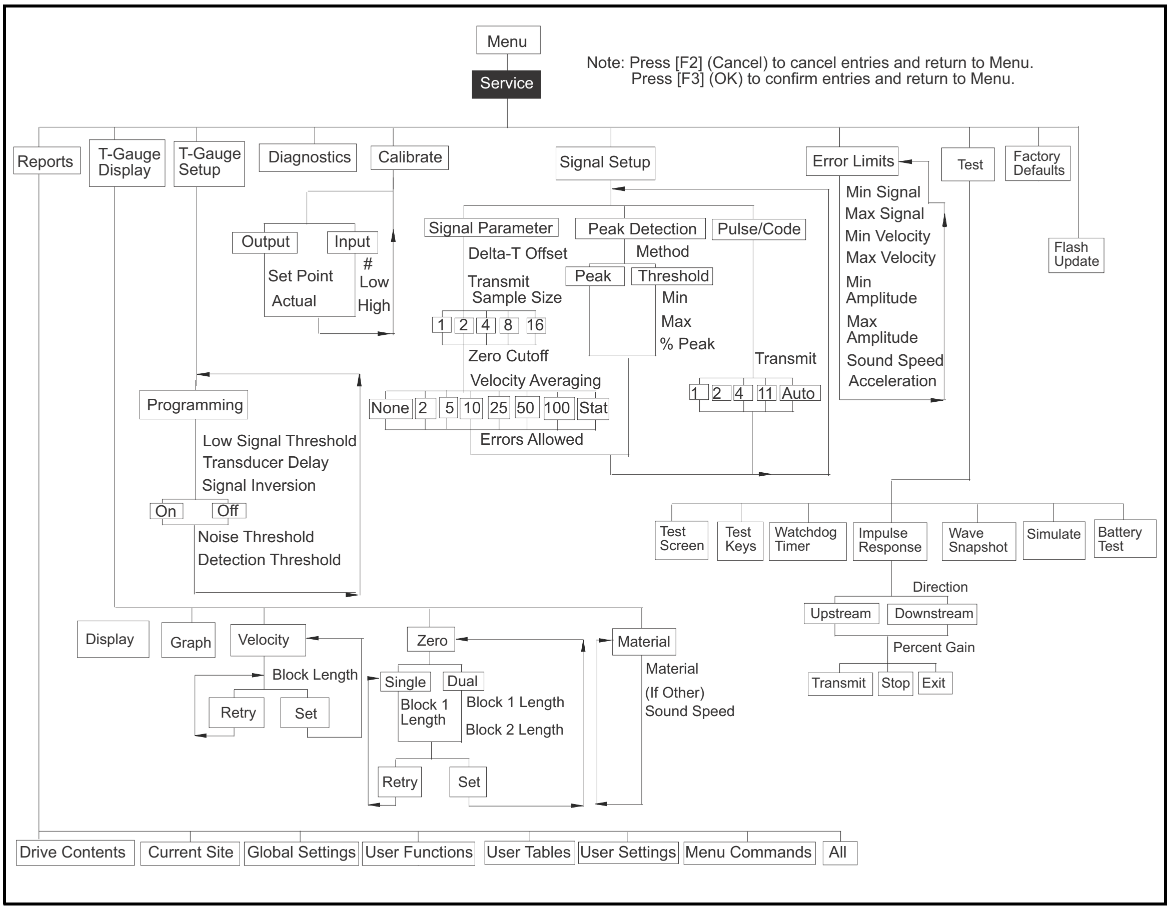


Figure 142: Service Menu

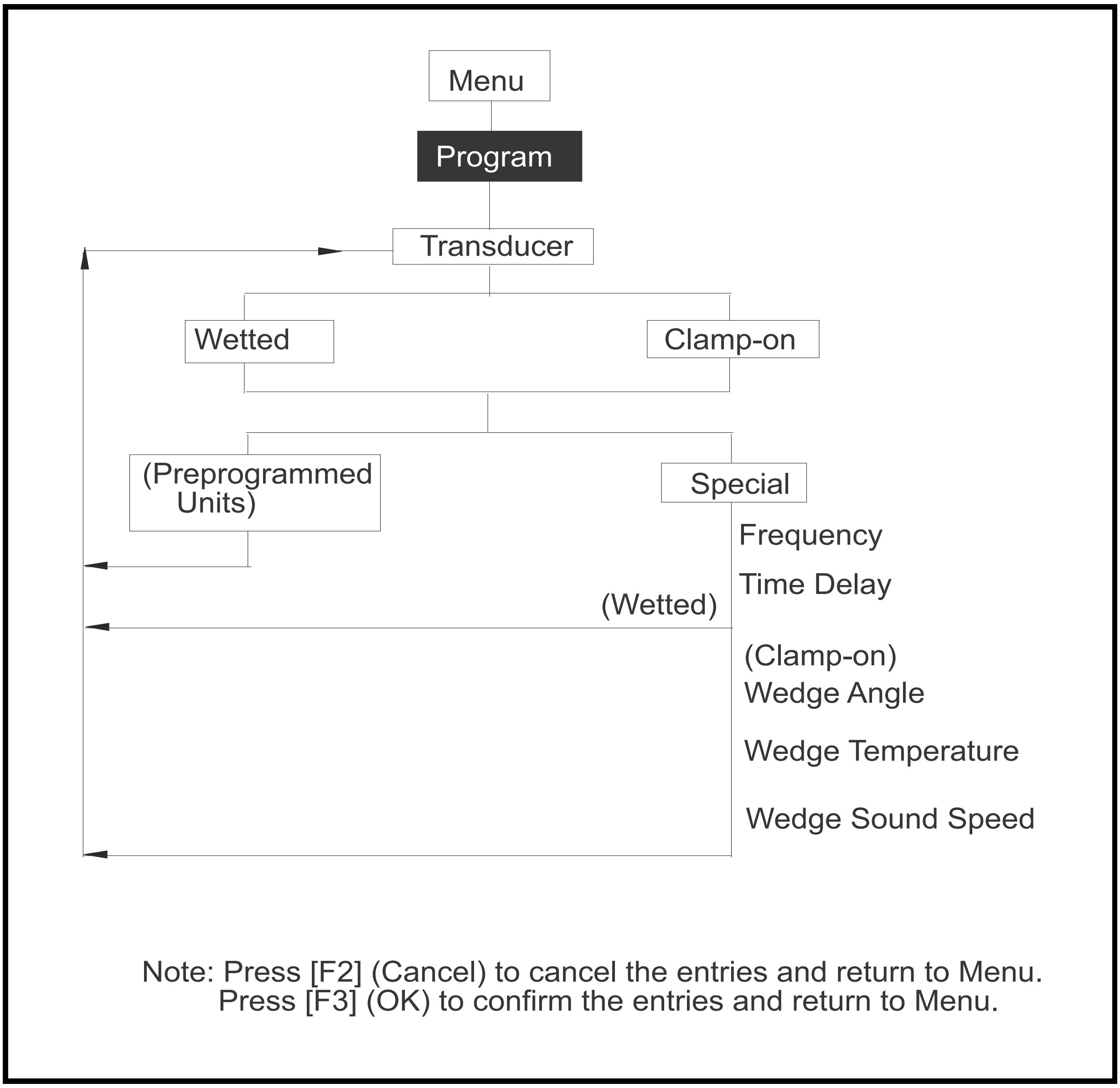


Figure 143: Transducer Option

500

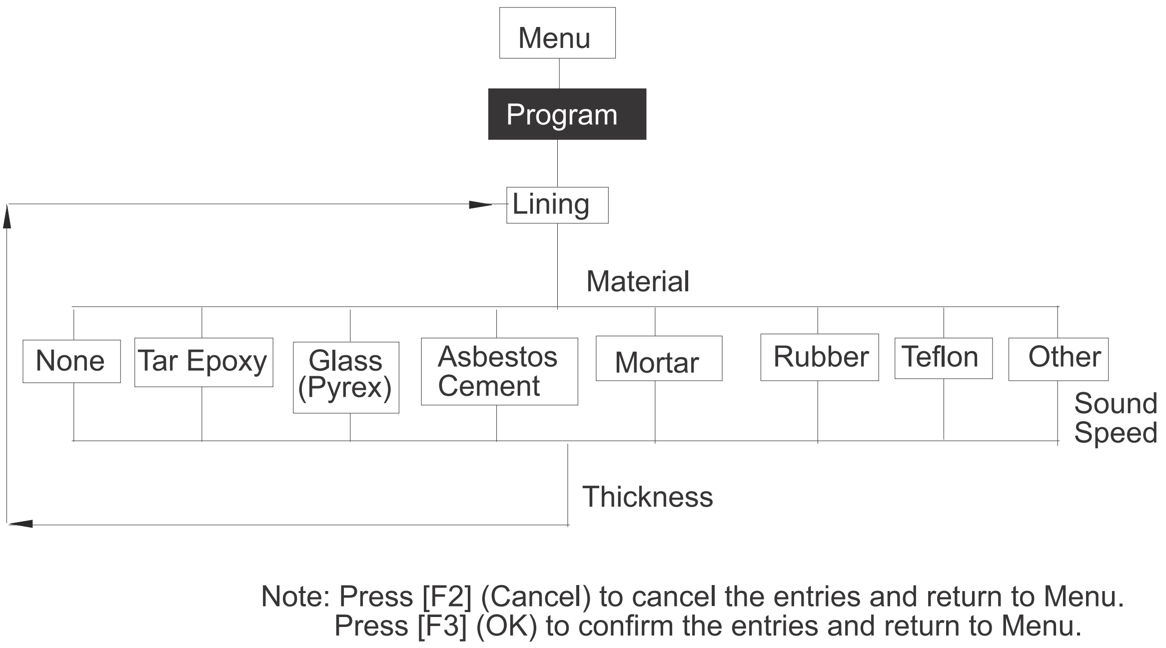


Figure 144: Lining Option

501

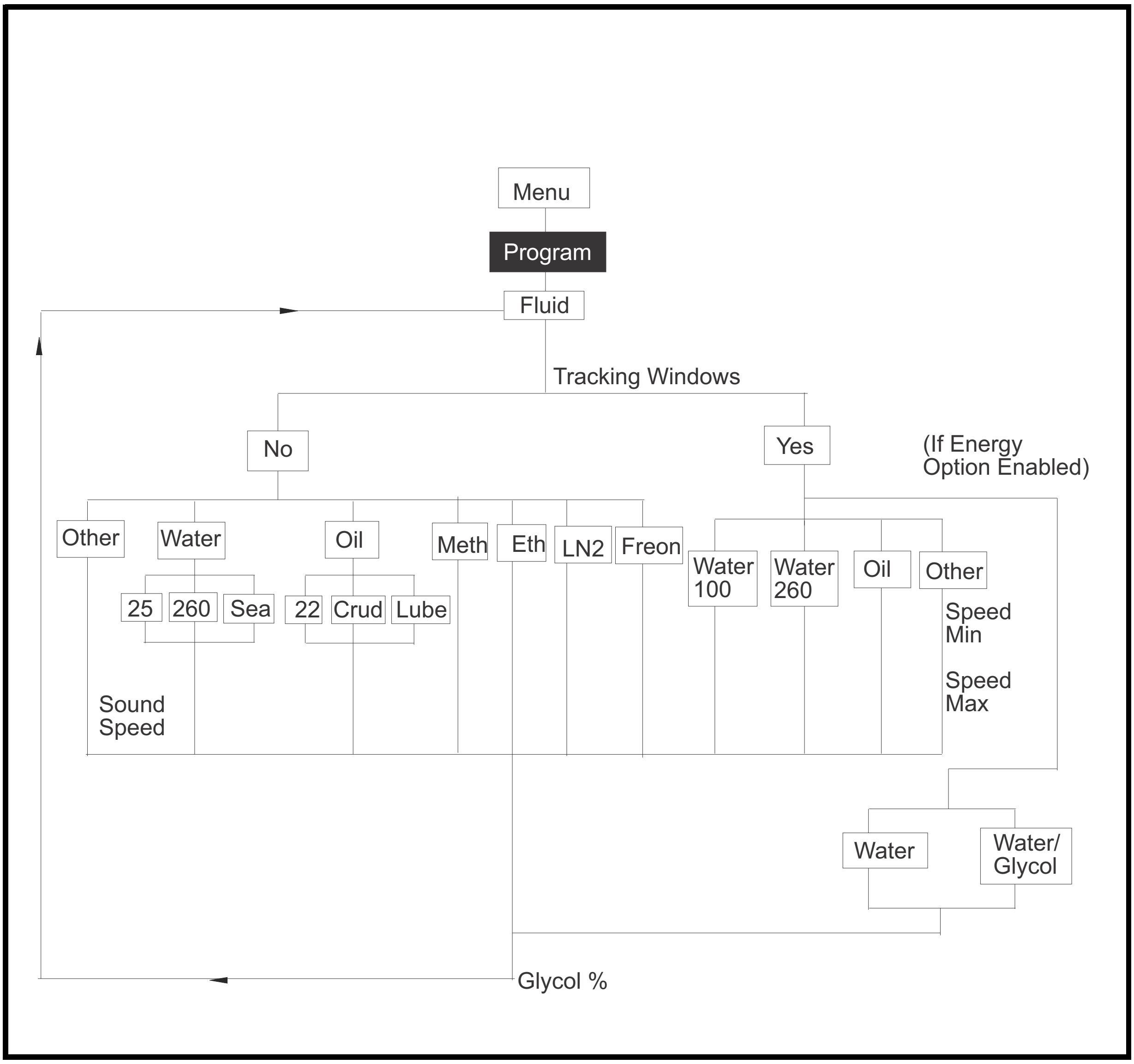
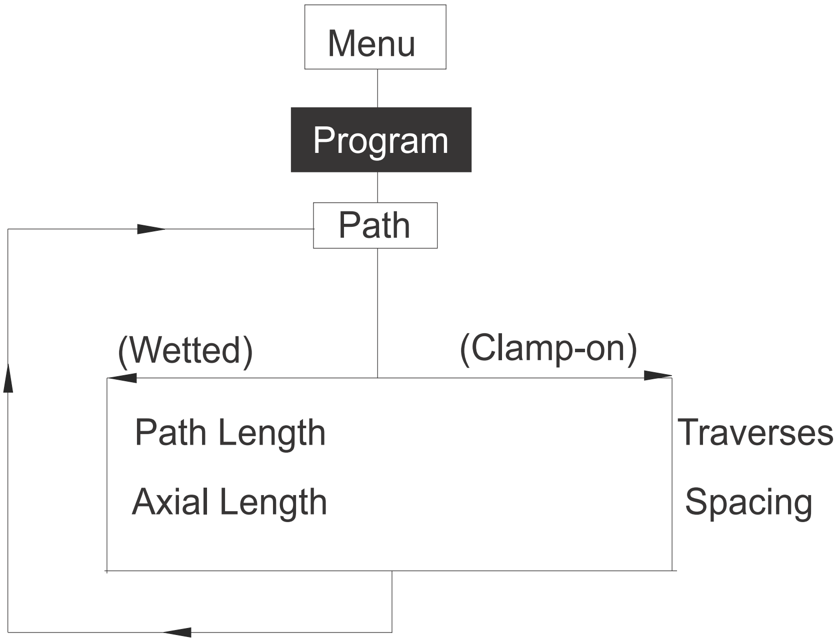


Figure 145: Fluid Option

502



Note: Press [F2] (Cancel) to cancel the entries and return to Menu.
Press [F3] (OK) to confirm the entries and return to Menu.

Figure 146: Path Option

503

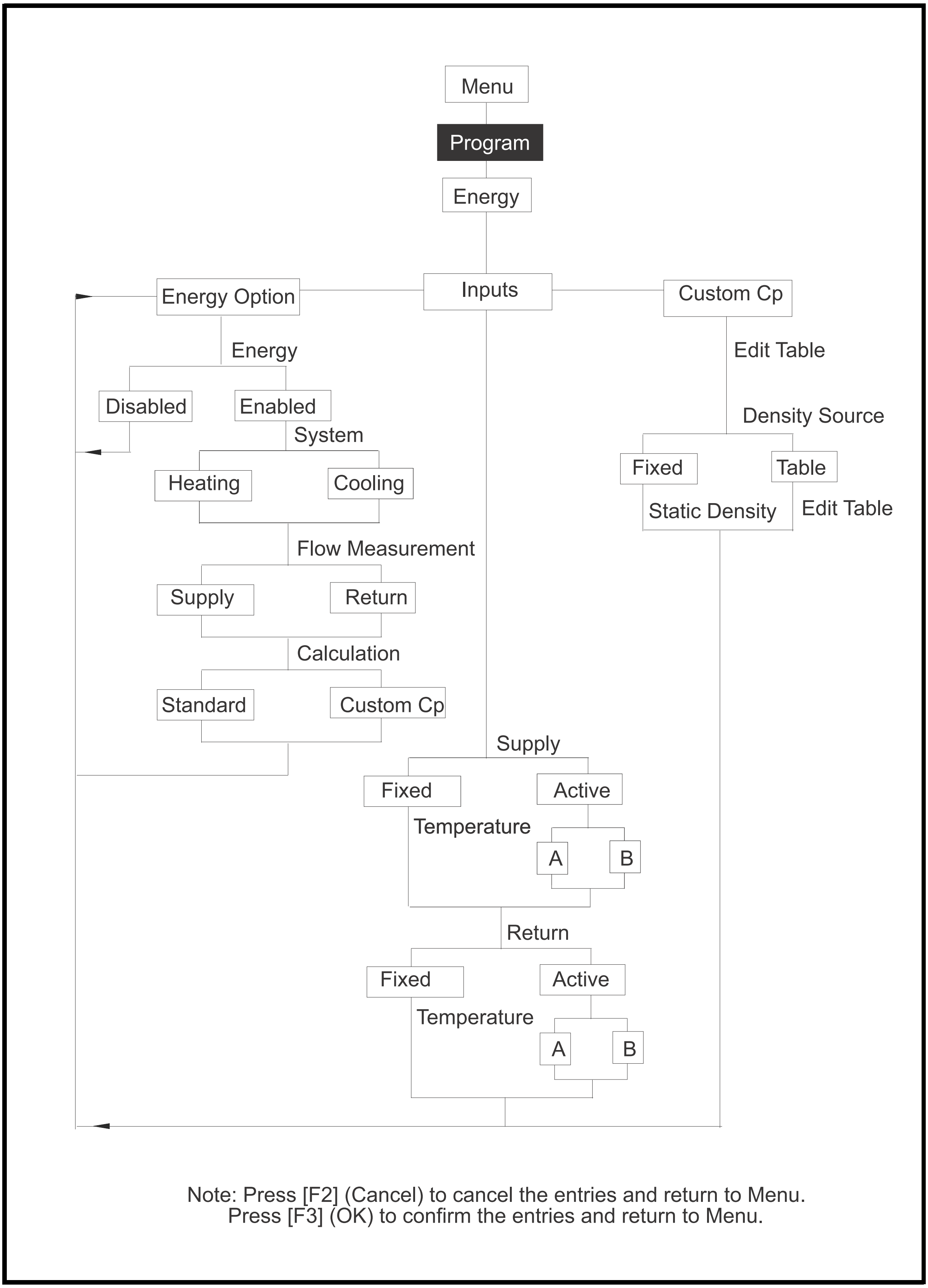
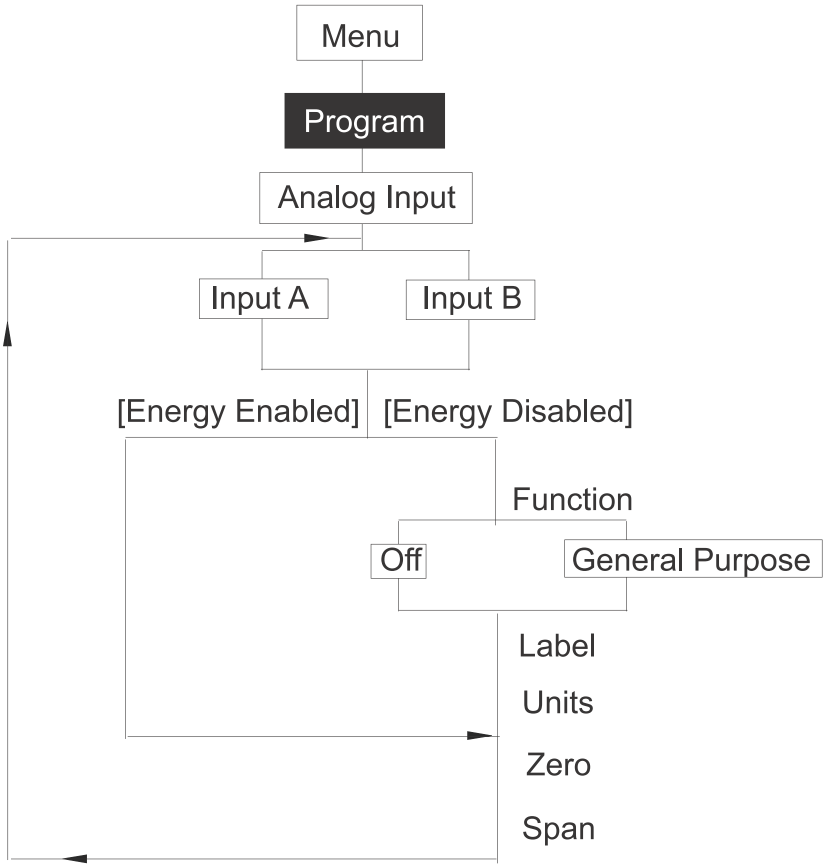


Figure 147: Energy Option

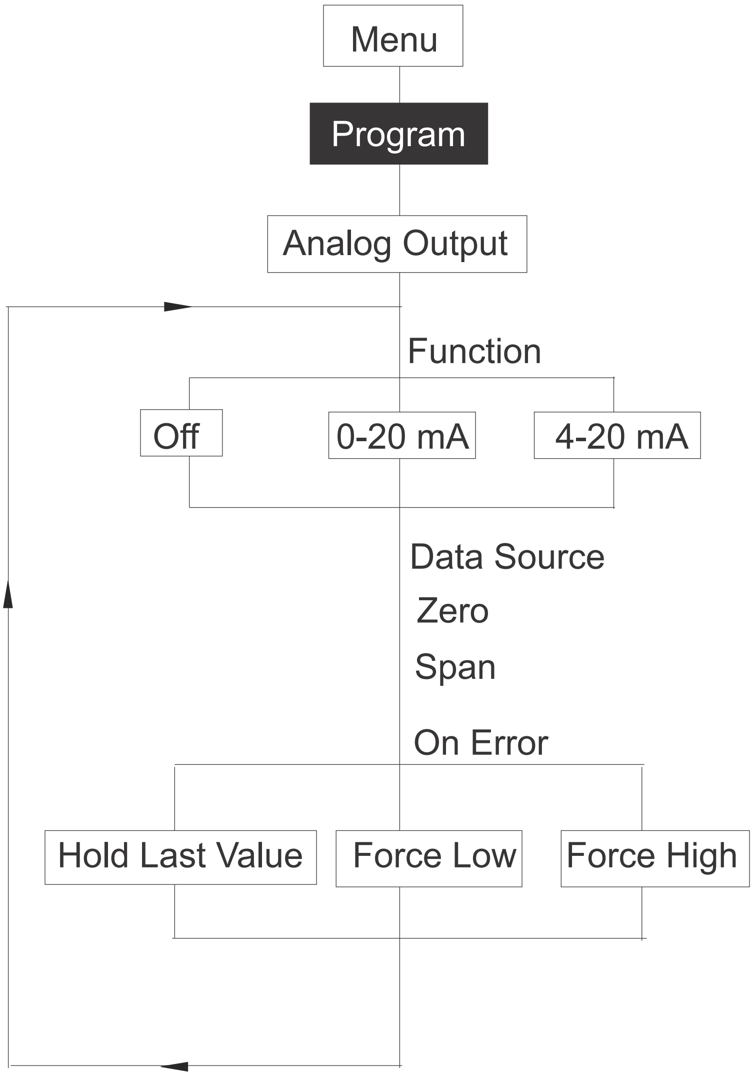
504



Note: Press [F2] (Cancel) to cancel the entries and return to Menu.
Press [F3] (OK) to confirm the entries and return to Menu.

Figure 148: Analog Input Option

505



Note: Press [F2] (Cancel) to cancel the entries and return to Menu.
Press [F3] (OK) to confirm the entries and return to Menu.

Figure 149: Analog Output Option

506

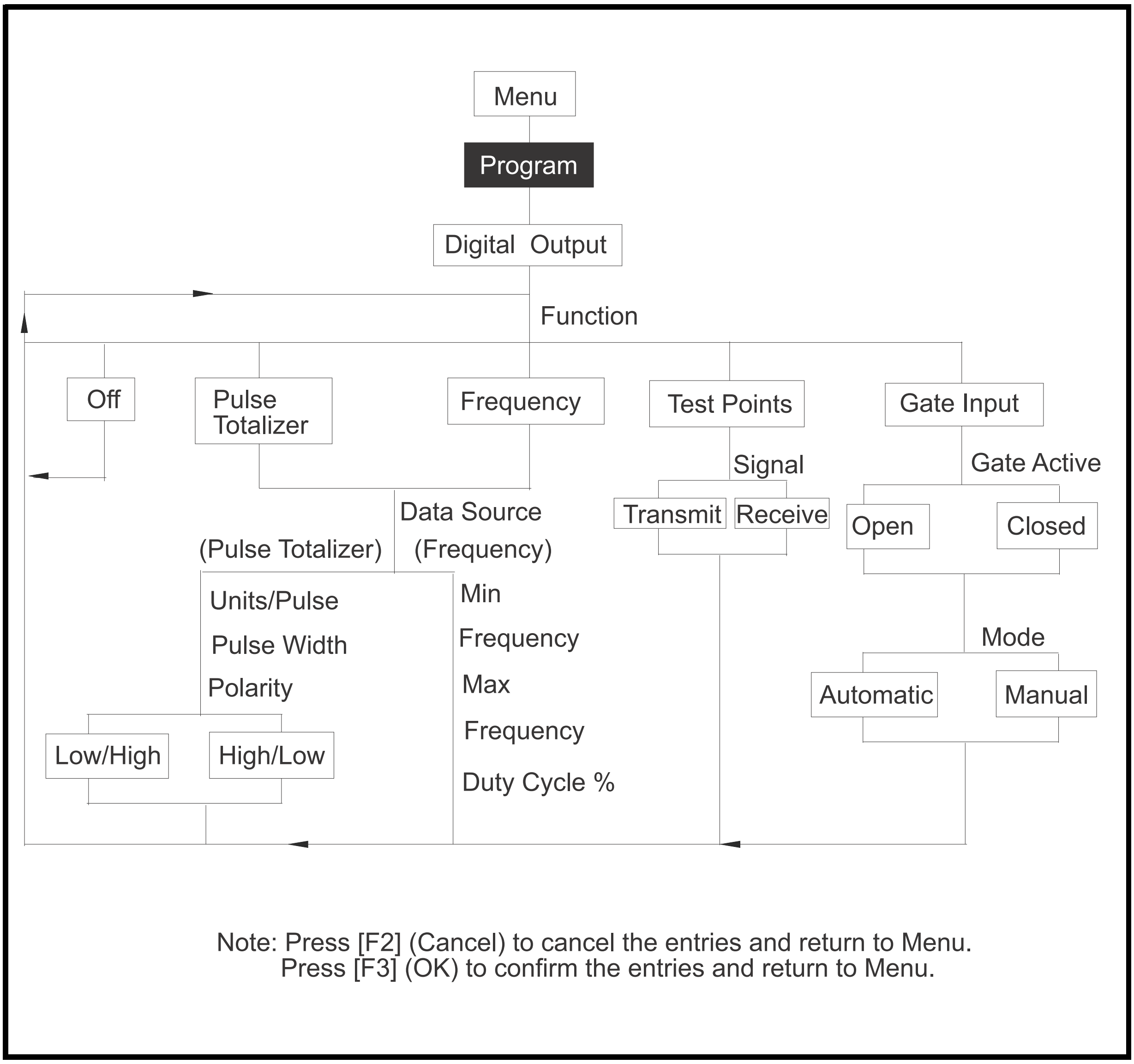


Figure 150: Digital Output Option

507

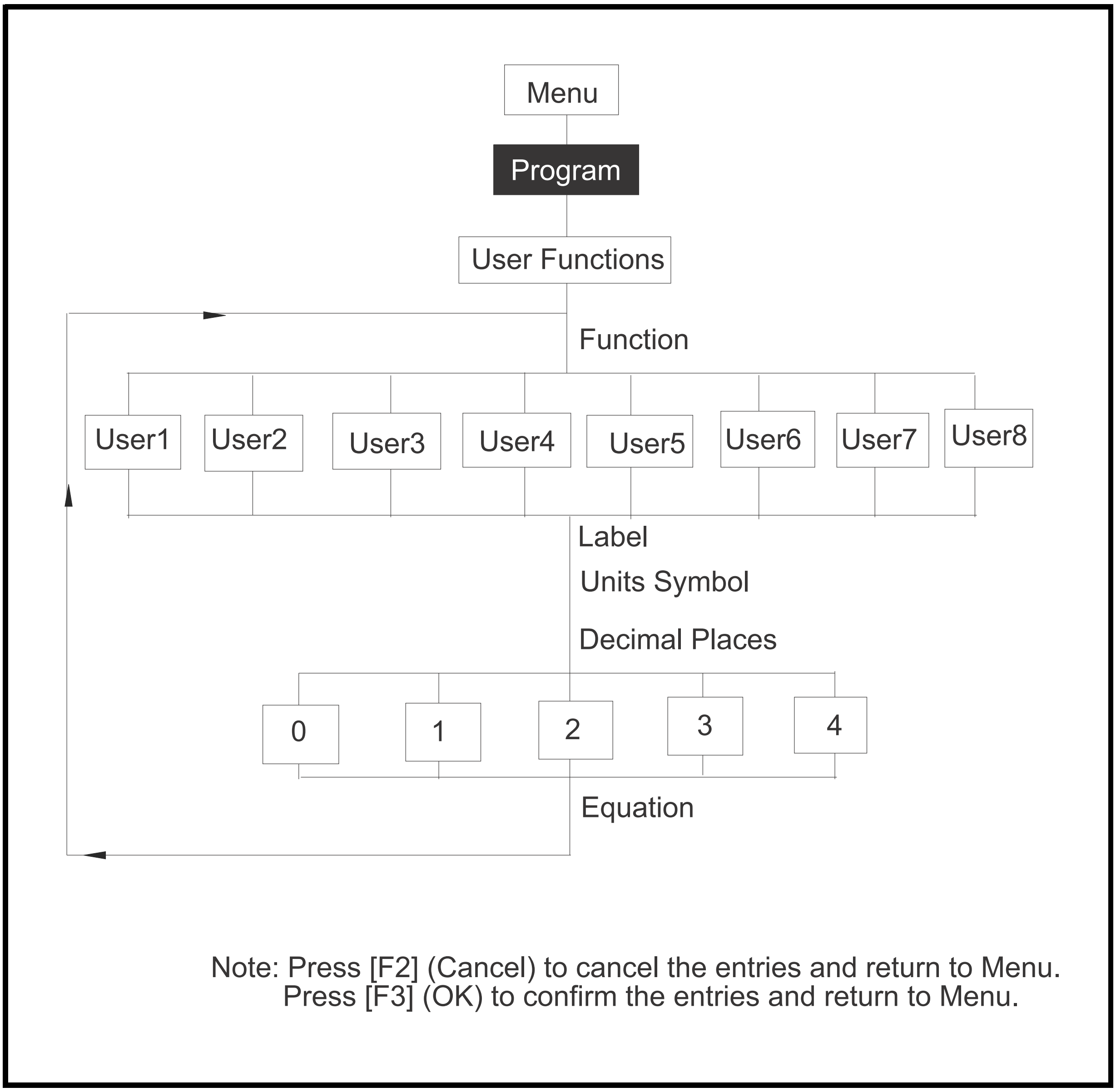


Figure 151: User Functions Option

508

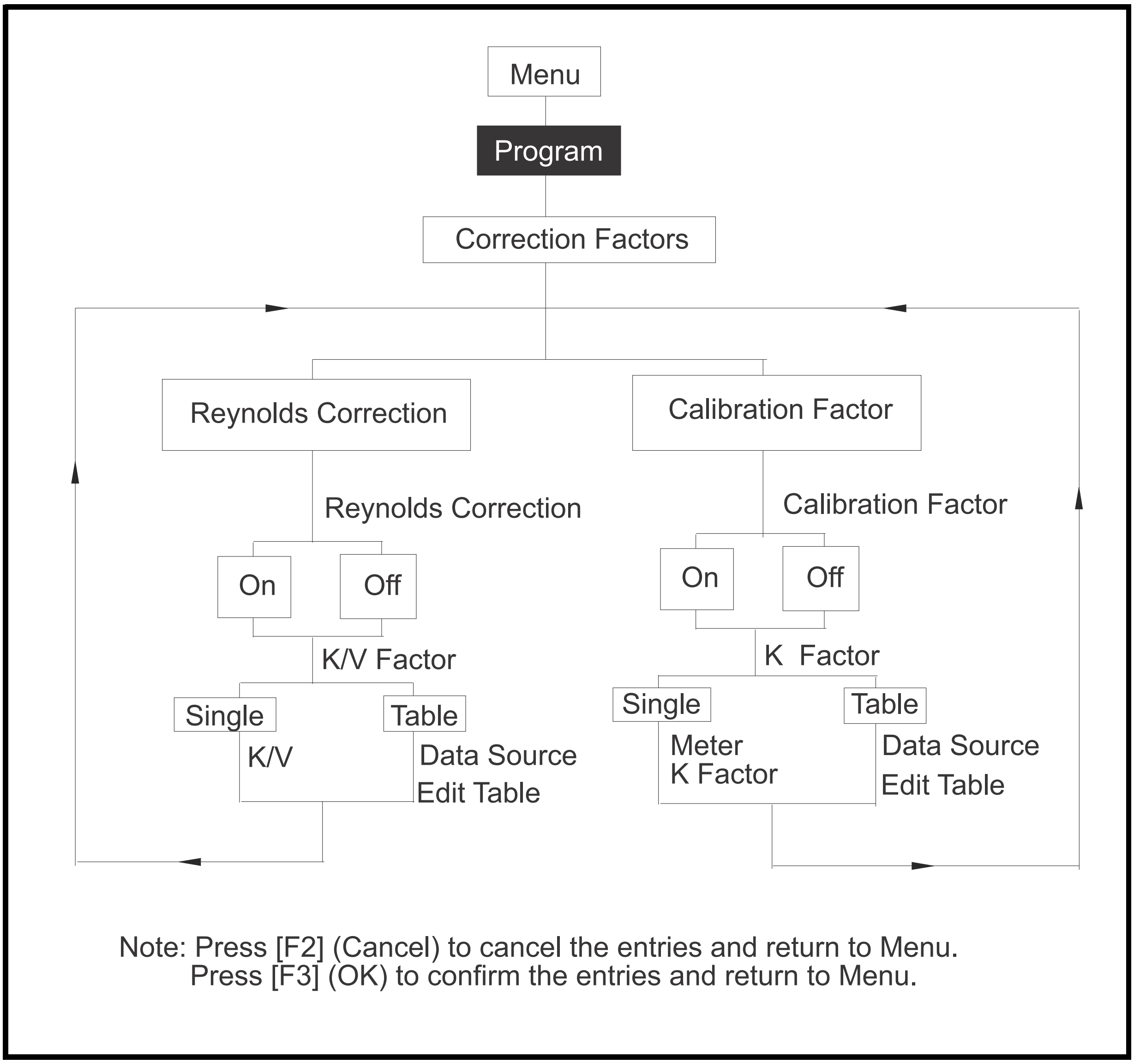


Figure 152: Correction Factors Option

509

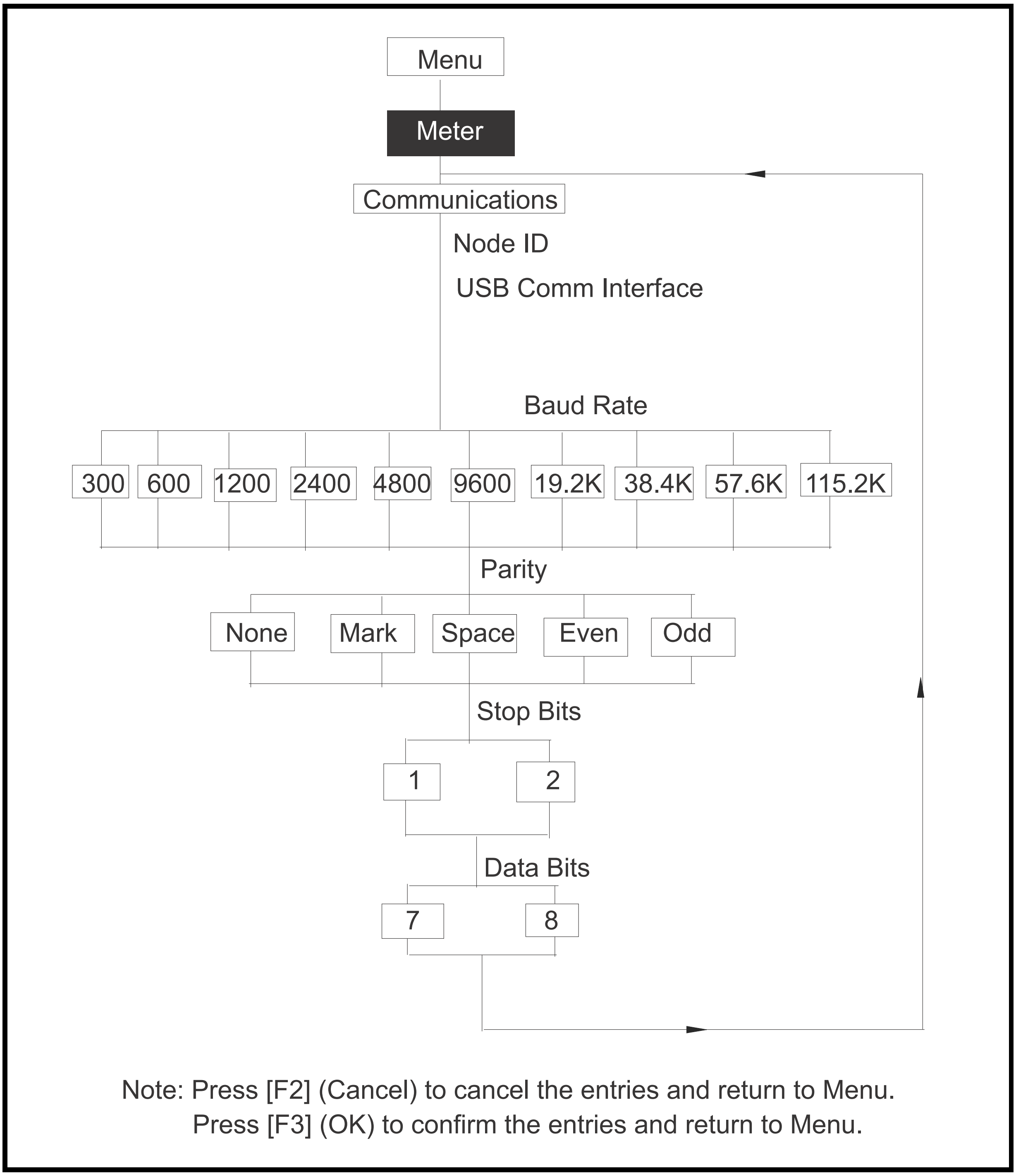


Figure 153: Communications Option

510

[no content intended for this page - proceed to next page]

Appendix B.Measuring P and L Dimensions

If you are using wetted transducers, the PT878 requires you to enter the path length (P) and the axial dimension (L). P is the transducer face-to-face distance, and L is the axial projection of P in the flow stream.

To determine L, physically measure the distance between the center of the transducer ports at the inside wall as shown in Figure 154 below, if possible. If not, consult the factory.

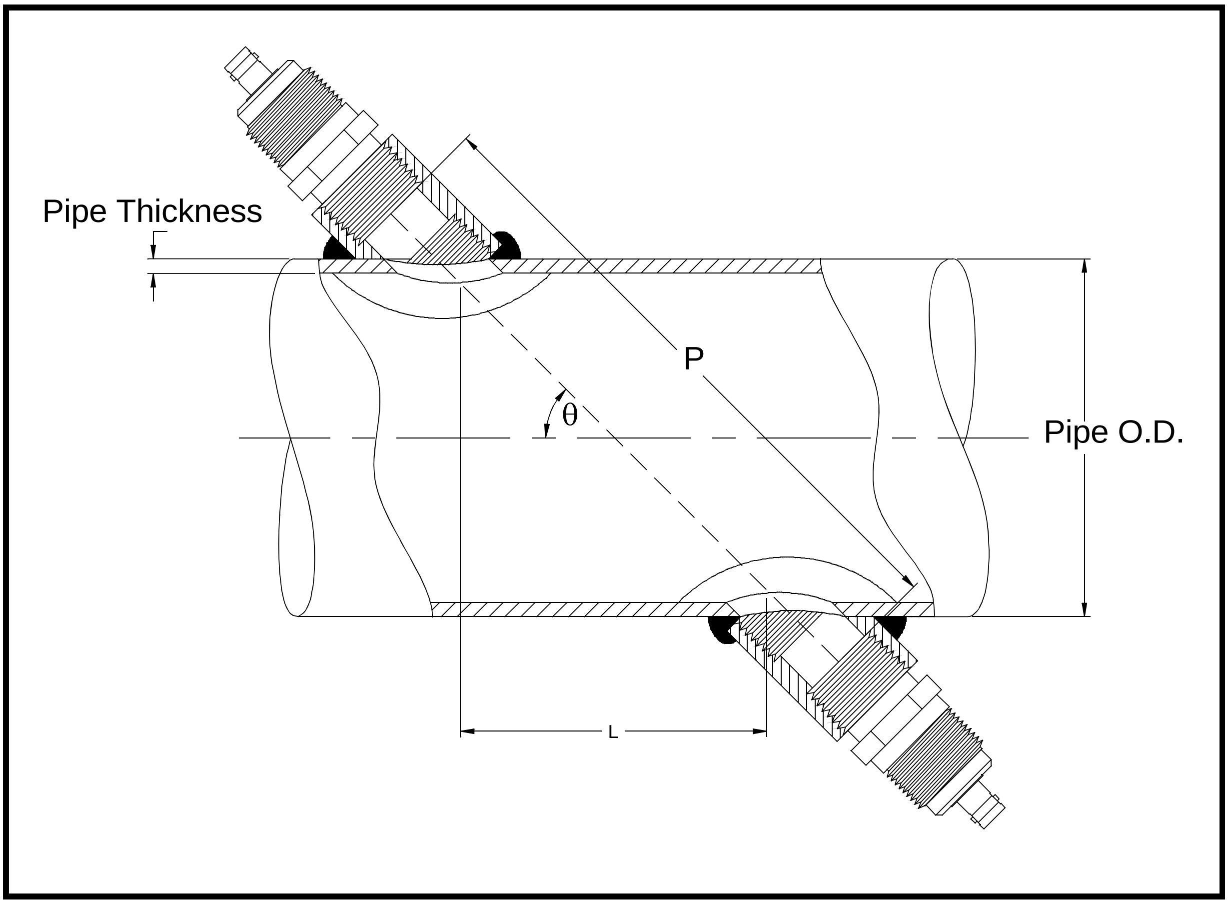


Figure 154: Top View of 180° Transducer Installation

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To determine P, you need the following:

- the pipe inside diameter (ID)
- the wall thickness (WT)
- the installed pipe coupling length (CL)
- the transducers face depth (FD)
- the mounting angle (MA)

Use Figure 155 below to properly measure the coupling length. Typically, the transducer face is positioned just outside the inside diameter (ID) of the pipe, or slightly retracted inside the coupling.

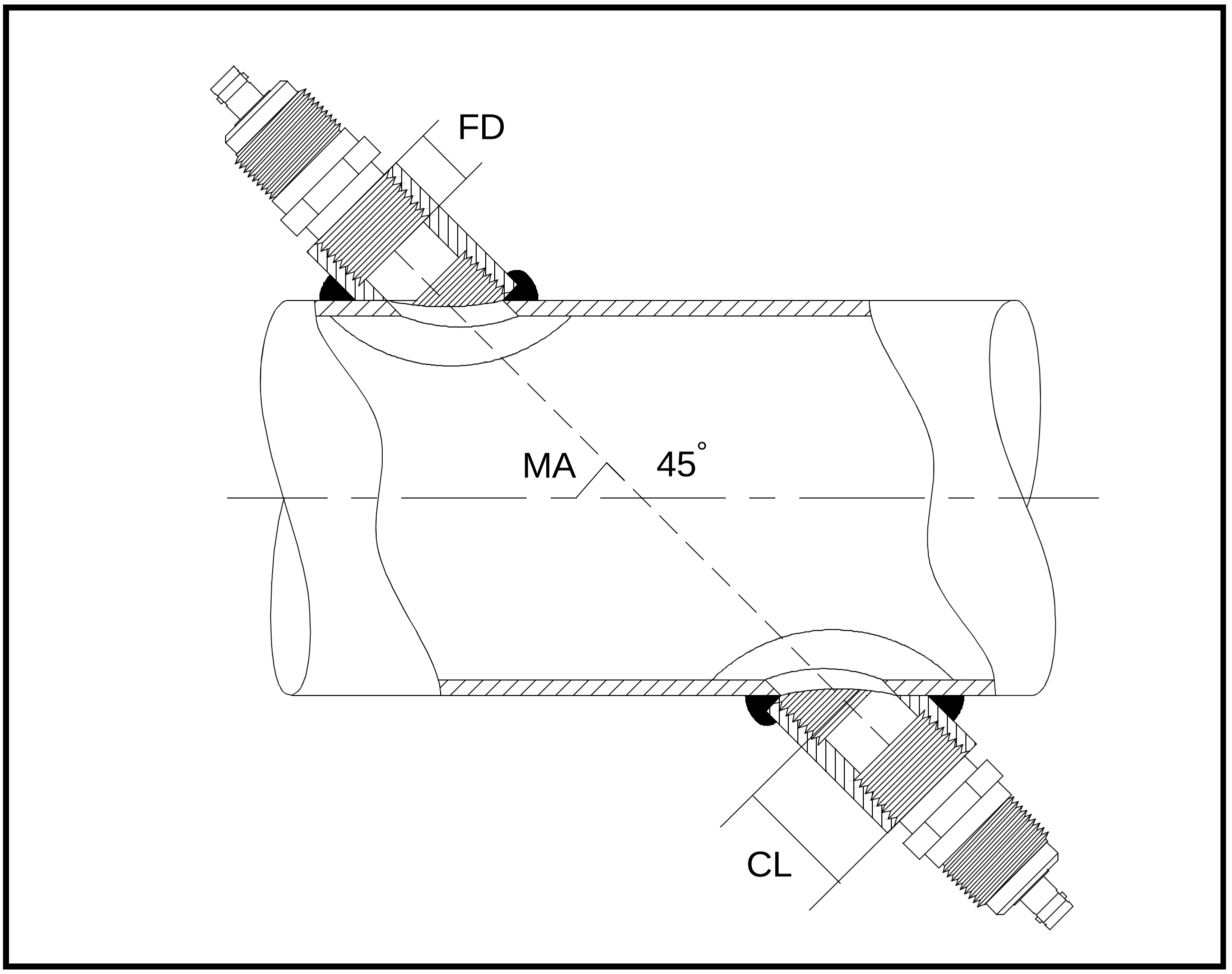

Figure 155: Determining the Pipe Coupling Length 513

Use the following formula to determine the P dimension:

[ID + 2(WT)]/(cos MA) = 2 (CL- FD) = P dimension

For example, given the following:

- inside diameter (ID) = 48”
- wall thickness (WT) = 3/8”
- installed coupling length (CL) = 2.0”
- a transducer face depth (FD) = 1.75”
- mounting angle (MA) = 45°

The P dimension would be:

[48 + 2(3/8)]/(0.7071) + 2(2.0-1.75) = 69.4”

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[no content intended for this page - proceed to next page]

Appendix C.Temperature Transmitter Installation

The PT878 requires a supply and return temperature input to measure energy rate and consumption. You must connect the temperature sensors to a 4 to 20 mA transmitter (powered by the PT878 or externally) and then from the transmitter to the PT878 (a special GE cable is required to make transmitter-to-PT878 connections).

The factory can supply the Resistive Temperature Device (RTD) and a Dual Transmitter (DTR) or you may supply your own. If you supply your own equipment, you will need to order a special GE cable with a LEMO connector to make connections from the transmitter to the PT878.

To install the RTDs, you need to do the following:

- find a suitable installation site
- mount RTDs on the pipe
- make electrical connections

Use the instructions that follow to install the RTDs.

C.1 Guidelines for RTD Installation

You should have discussed possible installation sites with an applications engineer or field sales person by the time you receive the RTDs. However, you should follow these guidelines to ensure accurate temperature measurement:

- Do not install the RTD on a pipe seam.
- Clean the pipe at the installation location.
- Do not install the RTD on the top or the bottom of the pipe.
- Apply thermal couplant to the RTD before mounting it to the pipe.
- Insulate the pipe and RTD after installation.

If you have a GE RTD, use the instructions in the next section to properly mount the RTD on the pipe.

C.2 Mounting RTDs on the Pipe

The factory supplies a clamping fixture to mount the RTDs to the pipe; however, you must assemble the clamping fixture before you can mount the RTDs to the pipe. Use the following instructions below to mount the RTDs.

C.2.1 Assembling the Clamping Fixture

The clamping fixture consists of the following parts:

- one strap (length depends on the pipe size)
- a screw buckle
- a feeder buckle

To assemble the clamping fixture:

1. Cut the strap equal to the circumference of the pipe.
2. Fold 1/2 inch of one end of the strap into a hook shape.
3. Secure the screw buckle to one end of the strap by placing the strap through the buckle and folding the strap.
4. Crimp the strap closed to secure the screw buckle in place.
5. Each RTD has a securing post (located on the rounded portion of the RTD) that secures the RTD in place when it is mounted on the pipe. Place the RTD on the strap by sliding the strap under the securing post.

Important: *Make sure you place the RTD on the strap so when the strap is wrapped around the pipe, the flat surface of the RTD sits against the pipe.*

6. Secure the feeder buckle to the other end of the strap by placing the strap through the buckle and folding the strap (the folded section should be approximately 1/2 inch).
7. Crimp the strap closed to secure the feeder buckle in place.

Repeat steps 1 through 7 for the remaining RTD and clamping fixture. When you have completed assembly, proceed to the next section to fasten the RTD to the pipe.

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C.2.2 Mounting the RTD to the Pipe

Use the steps below to fasten the RTD to the pipe:

1. Prepare the pipe where you intend to place the RTD. The area should be clean and free of loose material.
2. Apply couplant (GE part number 401-001) to the copper face of the RTD. Use enough couplant to cover the face of the RTD, but not so much that the couplant oozes out from underneath.
3. Position the RTD on the pipe and wrap the clamping fixture around the pipe.
4. To secure the RTD, you place the feeder buckle into the screw buckle and use a screwdriver to tighten. Turn the screw clockwise until the strap is set securely against the RTD.

Proceed to the following section to make electrical connections.

C.3 Making Electrical Connections

The PT878 will not accept a signal directly from the RTD; therefore, you must have some type of 4 to 20-mA transmitter. The factory supplies a dual transmitter (DTR) with a special LEMO connector that attaches to the PT878. The PT878 supplies power to the DTR using an internal 16 V supply. If you decide to supply your own transmitter, you can use the 16 V supply to power your transmitter; however, you will need to order the special LEMO connector cable to connect your transmitter to the PT878.

To make electrical connections, you must connect the RTD sensor to the 4 to 20-mA transmitter, and then connect the DTR to the PT878. Use the following sections to make electrical connections.

C.3.1 Connecting the RTD to the 4 to 20-mA Transmitter

RTDs should have two common leads and one signal lead. If you are using a GE RTD, the wire colors may vary; however, two of the RTD wires will be the same color. The wires that are the same color are the common leads and the remaining wire is the signal lead.

If you are using your own transmitter, make the necessary connections. If you are using the GE DTR, connect the RTD wires to the terminal block labeled RTD Inputs. Connect the common and signal wires to the appropriate pins as designated on the terminal block label.

Important: *The supply and return RTD cables must be the same length in order to make accurate temperature measurements.*

When you have completed supply and return connections, proceed to the next section.

C.3.2 Connecting the Transmitter to the PT878

If you are using the GE DTR, simply plug the LEMO connector into the I/O connector as shown in Figure 156 below.

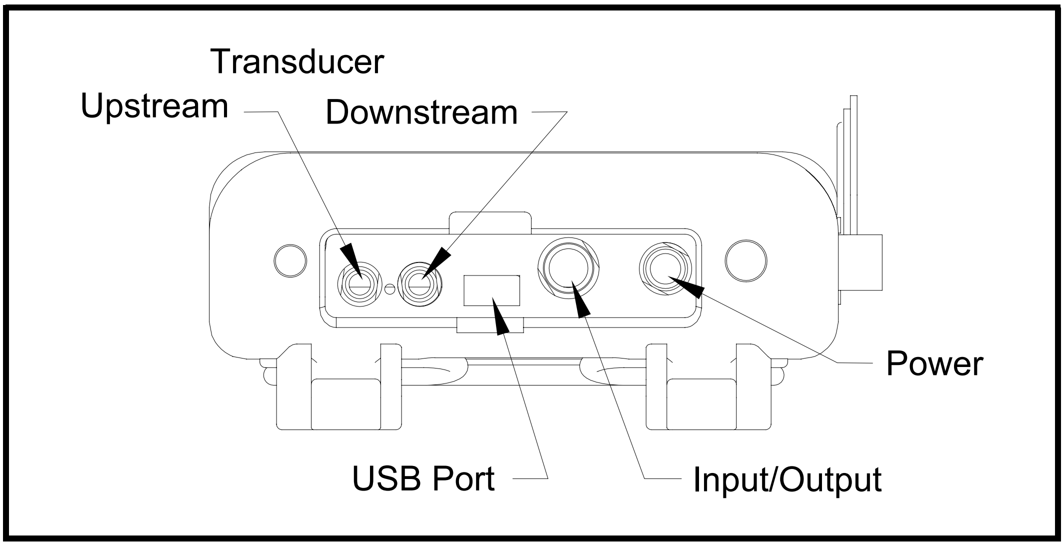

Figure 156: Connection Locations

Note: *For input/output cable connections see Table 1 on page 8.*

If you are using your own transmitter, you must connect the special GE cable to your transmitter as shown in Table 9 below.

Table 9: Cable Connections from GE Cable to Customer-Supplied Transmitter

Pin Number GE Cable	Wire Color GE Cable	Description
2	Red	16 V (unpowered transmitters only)
3	White	Supply Temperature
4	Yellow	Return Temperature
5	Green	Ground (for both supply and return)

Once you complete making the above connection, plug the LEMO connector into the I/O connector as shown in Figure 156 above. You have completed RTD installation.

[no content intended for this page - proceed to next page]

Appendix D.Ultrasonic Thickness Gauge Theory of Operation

All ultrasonic thickness gauging involves timing the round trip of a sound pulse in a test material. Because solid metal has an acoustic impedance that differs from that of gasses, liquids, or corrosion products such as scale or rust, the sound pulse will reflect from the far surface of the remaining metal. The test instrument is programmed with the velocity of sound in the test material, and computes the wall thickness from the simple formula

$$\text{Distance} = \text{Velocity} \times \text{Time}$$

Single element transducers use one element as both transmitter and receiver. Dual element transducers incorporate separate transmitting and receiving elements. These elements are mounted on delay lines that are usually cut at an angle to the horizontal plane (the roof angle), so that the transmitting and receiving beam paths cross beneath the surface of the test piece. This crossed-beam design of duals provides a pseudo-focussing effect that optimizes measurement of minimum wall thickness in corrosion applications. Duals will be more sensitive than single element transducers to echoes from the base of pits that represent minimum remaining wall thickness. Also, duals may often be used more effectively on rough outside surfaces. Couplant trapped in pockets on rough sound entry surfaces can produce long, ringing interface echoes that interfere with the near surface resolution of single element transducers. With a dual, the receiver element is unlikely to pick up this false echo. Finally, duals may be designed for high temperature measurements that would damage single element contact transducers.

D.1 Factors Affecting Performance and Accuracy

A. Surface Condition - Loose or flaking scale, rust, corrosion or dirt on the outside surface of a test piece will interfere with the coupling of sound energy from the transducer into the test material. Thus, any loose debris of this sort should be cleaned from the specimen with a wire brush or file before measurements are attempted. Generally it is possible to make corrosion measurements through thin layers of rust, as long as the rust is smooth and well bonded to the metal below. Some very rough cast or corroded surfaces may have to be filed or sanded smooth in order to insure proper sound coupling. It may also be necessary to remove paint if it has been applied in thick coats, or if it is flaking off the metal. While it is often possible to make corrosion measurements through thin coats of paint (on the order of a few thousandths of an inch or 0.1 - 0.2 mm), thick paint will attenuate signals or possibly create false echoes, causing inaccurate measurements.

Severe pitting on the outside surface of a pipe or tank can be a problem. On some rough surfaces, the use of a gel or grease rather than a liquid couplant will help transmit sound energy into the test piece. In extreme cases it will be necessary to file or grind the surface sufficiently flat to permit contact with the face of the transducer. In applications where deep pitting occurs on the outside of a pipe or tank it is usually necessary to measure remaining metal thickness from the base of the pits to the inside wall. There are sophisticated ultrasonic techniques utilizing focussed immersion transducers that can measure directly from the base of the pit to the inside wall, but this is generally not practical for field work. The conventional technique is to measure unpitted metal thickness ultrasonically, measure pit depth mechanically, and subtract the pit depth from the measured wall thickness. Alternately, one can file or grind the surface down to the base of the pits and measure normally.

As with any difficult application, experimentation with actual product samples is the best way to determine the limits of a particular gauge/transducer combination on a given surface.

D.1.1 Transducer Positioning/Alignment

For proper sound coupling the transducer must be pressed firmly against the test surface. On small diameter cylindrical surfaces such as pipes, hold the transducer so that the sound barrier material visible on the probe face is aligned perpendicular to the center axis of the pipe. See Figure 157 below.

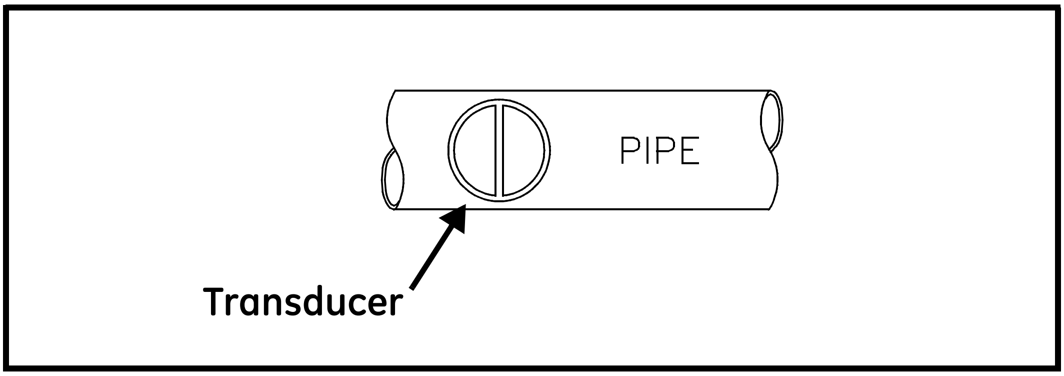

Figure 157: Proper Alignment of Transducers for Cylindrical Surfaces

While firm hand pressure on the transducer is necessary for good readings, the probe should never be scraped along or twisted against a rough metal surface. This will scratch the face of the transducer and eventually degrade performance. The safest technique for moving a transducer along a rough surface is to pick it up (not slide it) and reposition it for each measurement.

Remember that an ultrasonic test measures thickness at only one point within the beam of the transducer. In corrosion situations, wall thicknesses often vary considerably. Test procedures usually call for making a number of measurements within a defined area and establishing a minimum and/or average thickness. Ideally, data should be taken at increments no greater than half the diameter of the transducer, to insure that no pits or other local variations in wall thickness are missed. It is up to the user to define a pattern of data collection appropriate to the needs of a given application.

It is possible that on some severely corroded or pitted materials there will be spots where readings cannot be obtained. This can happen when the inside surface of the material is so irregular that the sound energy is scattered rather than being reflected back to the transducer. The lack of a reading may also indicate a thickness outside the range of the transducer and instrument being used. Generally, an inability to obtain a valid thickness reading at a particular point on a test specimen could be a sign of a seriously degraded wall which may warrant investigation by other means.

D.1.2 Calibration

The accuracy of measurements are only as good as the accuracy and care with which the gauge has been calibrated. It is essential that the thickness gauge be calibrated (as shown on page 162) whenever the transducer is changed or you have a reason to doubt the accuracy of the readings. Periodic checks with samples of known thicknesses are recommended to verify that the gauge is operating properly.

D.1.3 Taper or Eccentricity

If the contact surface and the back surface are tapered or eccentric with respect to each other, the return echo again becomes distorted and the accuracy of measurement is diminished.

D.1.4 Acoustic Properties of the Material

There are several conditions found in engineering materials that can severely limit the accuracy and thickness range that can be measured.

D.1.4a Sound Scattering

In some materials, notably certain types of cast stainless steel, cast irons, and composites, the sound energy is scattered from individual crystallites in the casting or from dissimilar materials within the composite. This effect reduces the ability to discriminate a valid return echo from the back side of the material and limits the ability to gauge the material ultrasonically.

D.1.4b Velocity Variations

A number of materials exhibit significant variations in sound velocity from point-to-point within the material. Certain types of cast stainless steels and brass exhibit this effect due to a relatively large grain size and the anisotropy of sound velocity with respect to grain orientation. Other materials show a rapid change in sound velocity with temperature. This is characteristic of plastic materials where temperature must be controlled in order to obtain maximum precision in the measurement.

D.1.4c Sound Attenuation or Absorption

In many organic materials, such as low density plastics and rubber, sound is attenuated very rapidly at the frequencies used in normal ultrasonic thickness gaging. Therefore, the maximum thickness that can be measured in these materials is often limited by sound attenuation.

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Appendix E. Material Safety Data Sheet for Couplant

(To comply with 29 CFR 1910.1200) Effective Date 4/1/98

Note: *N/A = not applicable or not available*

E.1 Product Identification

Product Name: **SOUNDSAFE®**
Generic Name: Ultrasonic Couplant
Manufacturer: Sonotech, Inc.
774 Marine Dr., Bellingham, WA 98225
360-671-9121
FAX: 360-671-9024
E-mail: sonotech@nas.com
http://www.sonotech-inc.com

NFPA Hazardous Materials Identification System (est)

Health 0
Flammability....................0
Reactivity...........................0

E.2 Hazardous Ingredients

This material does not contain any ingredients having known health hazards in concentrations greater than 1%.

This material does not contain any known or suspected carcinogens.

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E.3 Physical Data (nominal)

Boiling Point: >220°F
Freezing Point: <20°F
Vapor Pressure: N/A
Evaporation Rate: N/A
Solubility in Water: complete
Appearance and Odor: water white, opaque gel; bland odor
pH: 7.35 - 7.9
Acoustic Imp.: 1.726 X 10^6
Vapor Density: N/A
Specific Gravity: 1.05

E.4 Fire and Explosion Hazard Data

Flash Point: none
Upper Exposure Limit: none
Lower Exposure Limit: none
Special Fire Fighting Procedures: N/A
Extinguishing media: N/A
Unusual Fire and Explosion Hazards: none

E.5 Reactivity Data

Stability: stable
Conditions to Avoid: none
Incompatibility *(Materials to Avoid)*: none known
Hazardous Polymerization: will not occur
Hazardous decomposition or Byproducts: none known

E.6 Health Hazard and First Aid Data

Routes of Entry: [1]
Skin: not likely
Eyes: not normally
Ingestion: not normally
Inhalation: no

[1]**SOUNDSAFE**® contains only food grade and cosmetic grade ingredients.

Effects of Overexposure:
Acute: May cause temporary eye irritation.
Chronic: None expected.

First Aid Procedures:
Skin: Remove with water if desired.
Eyes: Flush with water for 15 minutes.
Ingestion: For large quantities, induce vomiting and call a physician.
Inhalation: N/A

E.7 Storage and Handling Information

Precaution to be taken in handling and storage:
Store between 20°F and 120°F. Spills are slippery and should be cleaned up immediately.

Steps to be taken in case material is released or spilled: Pick up excess for disposal. Clean with water.

Waste disposal method: Dispose of in accordance with federal, state, and local regulations.

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E.8 Control Measures

Respiratory Protection: not required
Ventilation: not required
Protective Gloves: on individuals demonstrating sensitivity to SOUNDSAFE®
Eye Protection: as required by working conditions
Other Protective Equipment: not required

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Appendix F. Glossary

AGC — Automatic gain control, which sets the receive amplifier based on measured signal strength. This electronic circuit automatically adjusts the gain of the receive amplifier to maintain the correct receive signal amplitude.

Calibration Factor — Correction factor used as a reference for the flowmeter electronics to ensure accurate readings, and available either as a single number or as a table.

Delta-T Offset — A programmed value of which half is added to the upstream transit time and half is subtracted from the downstream transit time. It can be used to offset the flow velocity reading, and is normally set to zero.

Detection Threshold — Percent of peak the PT878 thickness gauge uses to make measurements

Energy Option — Option that enables flow measurement in a heating or cooling system. The option calculates the energy of a system based on the temperature at a supply point, the temperature at a return point, and the flow of fluid through the system.

Errors Allowed — Parameter that specifies the number of errors the meter can record before displaying an error message. The number of errors is N out of 16 where N equals the number of errors allowed.

Flowcell — The part of the flowmeter system, consisting of the flowcell pipe and the transducers, that uses ultrasonic pulses to interrogate the flow.

Flowcell Pipe — A section of piping that acts as part of the flowcell; it is either a section of existing piping with the transducers or inserted as a substitute pipe section (spoolpiece).

Form — Software window that opens when a user enters a given menu.

Impulse Response — Option in the Service Menu that enables you to force the meter to transmit in one direction only, without changing the amplifier gain setting.

Locale — Format for displaying the time and date.

Peak Detection — A method for identifying the ultrasonic signature in the received signal. In the “Peak” method, the peak is identified by testing a derivative of the signal. In the “Threshold” method, the peak is identified as the point where the signal crosses a threshold that is a percentage of the maximum signal detected.

Receive Window — A window of time during which the PT878 tries to detect the ultrasonic signal. It is determined by using the fluid soundspeed and the signal path length to estimate when the signal will arrive at the receiving transducer.

Reynolds Correction — Correction factor based on the Kinematic Viscosity and flow rate of the fluid.

Signal Inversion — Option that enables a thickness gauge user to invert the transducer signal.

Signal Path — Path the ultrasonic signal travels from one transducer to the other.

Simulate — Option in the Service Menu that allows users to simulate measurements based on a waveform stored in the PT878.

Site — A location on a pipe where measurements are made. The site includes the transducers, pipe, fluid type, pipe material and other parameters.

Site File — Instrument program that combines all the necessary parameters (transducer, pipe, fluid, etc.) for a particular measurement location.

Snapshot — Option in the Meter Menu to take screen captures in bitmap format of a given screen display.

Soundspeed — Speed at which a sound wave travels through a given material.

Thickness Gauge — Option that allows the PT878, with an optional thickness gauge transducer, to determine the thickness of most standard metal and plastic pipe materials over a range from 0.05 to 3 in. (1.3 to 76.2 mm).

Tw (**time in wedge**) **—** Time the transducer signal spends travelling through the transducer and cable. This time has to be subtracted from the transit time to determine how much time the signal spent in the fluid.

Tracking Windows — A feature which allows the receive window to move automatically if the ultrasonic signal is lost. The PT878 will set up the window in various positions based on a minimum and maximum soundspeed range. In seek mode, the meter will test every position until it detects a receive signal that passes the error tests. The first window (highest soundspeed setting) that passes the tests is the detected window. The meter will then track the receive signal.

Transducer Delay — Time the ultrasonic signal takes to travel from the meter to the pipe material surface. It is a similar measurement to Tw, except that the delay is subtracted from the transit time to find out how much time is spent in the wall.

Transducers — Devices that convert electrical energy into ultrasonic pulses when in a transmit cycle, and convert the ultrasonic pulses back to electrical energy when in a receive cycle. They can be fixed to the outside of the flowcell pipe (clamp-on) or inserted into the pipe to directly measure the fluid (wetted).

Transmitter Sample Size —Number of pulses the transmitter emits in one direction (upstream or downstream) before transmitting in the other direction. It is set to 8 by default.

Transit-Time — Flow measurement technique based on the principle that when ultrasonic pulses are transmitted through a moving liquid, the pulses that travel in the same direction as the fluid flow (downstream) travel slightly faster than the pulses that travel against the flow (upstream). When the liquid in the pipe is not flowing, the transit-time downstream equals the transit-time upstream. When the liquid is flowing, the transit-time downstream is less than the transit-time upstream. The difference between the downstream and upstream transit-times is proportional to the velocity of the flowing liquid, and its sign indicates the direction of flow.

Traverses — Number of times the ultrasonic signal crosses the pipe.

User Functions — User-defined mathematical equations for use with any measurement.

User Tables — User-defined tables of data for use with user functions.

Velocity Averaging — Parameter that averages a desired number of velocity measurements to smooth out or dampen noise in the system.

Watchdog Test — Option in the Service Menu that tests the watchdog timer circuit. If a software error causes the meter to stop responding, this circuit automatically resets the meter

Wave Snapshot — Option in the Service Menu that enables users to capture waveforms for downloading to a PC for analysis, or for simulating a flow measurement.

Wedge Angle — Angle of the transducer's ultrasonic transmission in the transducer wedge.

Zero Cutoff — Parameter that causes velocity measurements less than the absolute value of the cutoff (either positive or negative values) to be reported as zero.

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Warranty

Each instrument manufactured by GE Sensing is warranted to be free from defects in material and workmanship. Liability under this warranty is limited to restoring the instrument to normal operation or replacing the instrument, at the sole discretion of GE Sensing. Fuses and batteries are specifically excluded from any liability. This warranty is effective from the date of delivery to the original purchaser. If GE Sensing determines that the equipment was defective, the warranty period is:

- one year from delivery for electronic or mechanical failures
- one year from delivery for sensor shelf life

If GE Sensing determines that the equipment was damaged by misuse, improper installation, the use of unauthorized replacement parts, or operating conditions outside the guidelines specified by GE Sensing, the repairs are not covered under this warranty.

The warranties set forth herein are exclusive and are in lieu of all other warranties whether statutory, express or implied (including warranties or merchantability and fitness for a particular purpose, and warranties arising from course of dealing or usage or trade).

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Return Policy

If a GE Sensing instrument malfunctions within the warranty period, the following procedure must be completed:

1. Notify GE Sensing, giving full details of the problem, and provide the model number and serial number of the instrument. If the nature of the problem indicates the need for factory service, GE Sensing will issue a RETURN AUTHORIZATION NUMBER (RAN), and shipping instructions for the return of the instrument to a service center will be provided.
2. If GE Sensing instructs you to send your instrument to a service center, it must be shipped prepaid to the authorized repair station indicated in the shipping instructions.
3. Upon receipt, GE Sensing will evaluate the instrument to determine the cause of the malfunction.

Then, one of the following courses of action will then be taken:

- If the damage is covered under the terms of the warranty, the instrument will be repaired at no cost to the owner and returned.
- If GE Sensing determines that the damage is not covered under the terms of the warranty, or if the warranty has expired, an estimate for the cost of the repairs at standard rates will be provided. Upon receipt of the owner's approval to proceed, the instrument will be repaired and returned.

GE
Sensing

EC DECLARATION OF CONFORMITY

DOC-0011, Rev. A

We,

GE Sensing
1100 Technology Park Drive
Billerica, MA 01821
USA

declare under our sole responsibility that the

TransPort® PT878 Portable Ultrasonic Flowmeter
TransPort® PT878GC Clamp-On Portable Ultrasonic Flowmeter

to which this declaration relates, arein conformity with the following standard:

- EN 61326-1: 2006, Class A, Table A.1, Portable Equipment

following the provisions of the 2004/108/EC EMC Directive.

The units listed above and any ancillary equipment supplied with them do not bear CE marking for the Pressure Equipment Directive, as they are supplied in accordance with Article 3, Section 3 (sound engineering practices and codes of good workmanship) of the Pressure Equipment Directive 97/23/EC for DN<25.

Billerica - August 23, 2010
Issued

Gary Kozinski

Mr. Gary Kozinski
Certification & Standards, Lead Engineer

CE

Customer Support Centers

U.S.A.

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An ISO 9001:2008 Certified Company

www.ge-mcs.com/en/about-us/quality.html

www.ge-mcs.com

A.14 Certificado Asistencia Congreso

II latinamerican HYDRO POWER AND SYSTEMS MEETING

IAHR AIRH

Certificate

This is to certificate that Mr(s) **Daniel Felipe Tobon Espinosa** attended the **II LATIN AMERICAN HYDRO POWER & SYSTEMS MEETING**, held on April 28 -29, 2015 in La Plata, Argentina.

La Plata, April 29th, 2015

Prof. Sergio Oscar Liscia
Chairman of II Latin American Hydro Power and Systems Meeting

ORGANIZED BY: IAHR AIRH; latinamerican Working Group; Universidad Nacional de La Plata; Facultad de Ingeniería; UNIFEI; CERPCH; HIDROMECANICA Facultad de Ingeniería U.N.L.P.

SPONSORS: SPU Secretaría de Políticas Universitarias; Entidad Binacional Yacyreta; Subsecretaría de Recursos Hídricos; VOITH Engineered Reliability; UNaM Universidad Nacional de Misiones

SUPPORTING MEMBERS: ALSTOM; ANDRITZ Hydro; BARDELLA; IMPSA; KSB; VOITH Engineered Reliability

A.15 Carta de Invitación

Itajubá-MG, Brasil 12 de Mayo del 2015

UNIVERSIDAD EAFIT
Escuela de Ingeniería
Carrera 49, nº 7 Sur
Medellín
COLOMBIA

Estimados Señores,

Después de participar del evento mundial de la “International Association for Hydro-Environment Enginneering and Research-IAHR” un grupo de investigadores y empresas latino-americanas decidieron unir esfuerzos para aumentar la interacción en el area de máquinas hidráulicas y sistemas en América Latina para el desarrollo regional de la investigación y ampliar la difusión de esas investigaciones a nivel internacional.

De esta forma, en 2010, después de la conferencia de la IAHR realizada en Rumania, fue lanzado el **“Latin American Working Group – IAHR Hydraulic Machines & Systems Committee”**, que inició sus actividades en 2012 bajo la coordinación del Prof. François Avellan (EPFL-Suíça) y desde 2013, está bajo la coordinación del Prof. Eduard Egusquiza (UPC-Espanha).

El objetivo del Grupo de Trabalho Latino Americano es reforzar la presencia de América Latina em la producción científica internacional, actualmente a través de dos iniciativas: un evento bianual y una publicación técnico-científica.

Así, nos gustaría invitarlo a participar de este grupo, todas las atividades del LAWG-IAHR pueden ser acompanhadas en el sitio web www.latiniahr.org . Será un honor recibir trabajos de su institución para la publicación “American Journal of Hydropower, Environment and Systems”.

A la espera de su respuesta, enviamos nuestros cordiales saludos.

Atentamente,

Prof. Dr. Geraldo Lúcio Tiago Filho

Presidente