WARRANTY

Ruska Instrument Corporation warrants its products to conform to or exceed the specifications as set forth in its catalogs in use at the time of sale and reserves the right, at its own discretion, without notice and without making similar changes in articles previously manufactured, to make changes in materials, designs, finish, or specifications. Ruska Instrument Corporation warrants products of its own factory against defects of material or workmanship for a period of one year from date of shipment.

Liability of Ruska Instrument Corporation, under this warranty, shall be limited to replacing, free of charge (FOB Houston, Texas), any such parts proving defective within the period of this warranty, but Ruska Instrument Corporation will not be responsible for transportation charges nor consequential damages.

The warranty of Ruska Instrument Corporation is not made for products manufactured by others which are illustrated and described in Ruska catalogs nor incorporated in Ruska products in essentially the same form as supplied by the original manufacturer. With respect to the warranties, the original manufacturers supplant the warranty of Ruska Instrument Corporation, but, in applicable instances, the latter agrees to use its best efforts to have original suppliers make good their warranties.

COPYRIGHT NOTICE

DISCLAIMER

No representations or warranties are made with respect to the contents of this user's manual. Further, Ruska Instrument Corporation reserves the right to revise this manual and to make changes from time to time in the content hereof without obligation to any person of such revision.

TRADEMARK NOTICE

RUSKA ® is a trademark of Ruska Instrument Corporation.

Trademarks or tradenames are subject to state and federal laws concerning their unauthorized use or other infringements. The fact that the product marks or names in this manual do not bear a trademark symbol DOES NOT mean that the product name or mark is not registered as a trademark or tradename. Any queries concerning the ownership or existence of any trademarks or tradenames mentioned in this manual should be independently confirmed with the manufacturer or distributor of the product.

REVISION NOTICE

RELEASE NUMBER	REV.	DATE OF RELEASE	DESCRIPTION
2455-1D01	A	1/14/93	Original Release - DR No. 7748
2455-1D01	B	1/20/95	Second Release - DR No. 7748

REVISION HISTORY

RELEASE 2455-1D01 Revision A (1/14/93)
Original Release - DR No. 7748

RELEASE 2455-1D01 Revision B (1/20/95)
Second Release - DR No. 7748

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES (CONTINUED)

DISCLAIMER

Throughout this manual the terms Piston Pressure Gage and Dead Weight Gage are used interchangeably. The abbreviation DWG is used instead of PPG to avoid any possible confusion which could arise due to the fact that Ruska produces a Portable Pressure Gage (PPG - model number 62xx).

This manual needs to be read in its entirety before proceeding with the use of the Dual Float Position Indicator (DFPI) as an accurate measurement tool.

THIS PAGE INTENTIONALLY LEFT BLANK

SECTION 1
GENERAL INFORMATION

1.1 INTRODUCTION

This manual contains the operating instructions for the Model 2455 Dual Float Position Indicator (DFPI) manufactured by Ruska Instrument Corporation, Houston, Texas.

1.2 GENERAL INFORMATION

The primary function of the Ruska Model 2455 Dual Float Position Indicator is to provide accurate measurements and indications of float positions and sink rates for the mass platters used on Piston Pressure Gages manufactured by Ruska and other suppliers. When the appropriate options are installed, the instrument is capable of simultaneously measuring float position from two separate locations on each of two different piston pressure gages. Utilizing two float position sensors mounted 180 degrees apart on one piston pressure gage allows the outputs of the two sensors to be averaged. This cancels any varying component of the float position signal which might result from minor run-out in the rotation of the masses. Mounting float position sensors on two piston pressure gages aids in the cross-float process by allowing direct, real-time comparisons of the relative sink rates of the two gages.

The 2455 has many additional standard and optional features which further assist the metrologist in obtaining the highest possible accuracy from piston pressure gages, while simplifying the process of taking data. These features are discussed below.

1.3 FEATURES

The following features are standard in every DFPI:

- **Position Calibration in Software:** There are no potentiometers and no interacting manual adjustments to be made in order to calibrate the position sensors. The user simply places precision calibration disks between the sensor and the mass platter and enters the resulting position via a front panel keypad. The internal microprocessor computes linearization coefficients, during calibration, and stores them in memory for use in accurately calculating and displaying float position and sink rate.
- **User selectable Position Functions:** The user can select the number of position sensors to be activated. When two position sensors are installed 180 degrees apart, on a single piston pressure gage, the user may select whether to read position information from only one sensor or to read both sensors and average the readings. The averaging procedure can virtually eliminate any variation in indicated position resulting from run-out in the rotating mass platters.

- **User controlled alarm:** The internal audible alarm can be turned on or off. When turned on, it can be set to provide an audible indication when the float position sinks below a user specified position.
- **User adjustable smoothing:** The user is given the option of applying a smoothing function to the sink rate information.
- **Support for two RTD temperature sensors:** Input circuitry and temperature readouts are available for use with two platinum resistance temperature sensors. Generally, a temperature probe is installed in the piston pressure gage near the cylinder to provide a measurement of the piston/cylinder temperature. This information can be used to calculate a correction factor for the piston's effective area, when the highest available accuracy is required.
- **Choice of Measurement Units:** The user can select Metric or English units for each of the displayed measurements. This includes position and temperature.
- **Choice of operating voltage and power cord:** The 2455 utilizes a power supply which will accept AC voltages ranging from 100 to 250 VAC and either 50 or 60 Hz. The power receptacle accepts the standard IEC-320 power connector, allowing the use of any nation's standard power cord. This power supply setup is very versatile and eliminates the need to select the required operating voltage.
- **Serial Interface:** An RS-232 serial interface allows the DFPI to be interfaced with a host computer for easy data acquisition. Communication parameters (baud rate, parity, etc.) may be varied to match most host computer requirements.
- **Self-Test:** When power is first applied, the instrument executes a built in test of all vital internal functions, and reports any error conditions. The operator may command that the instrument execute this test at any time during operation.
- **Ease of Operation:** All local operations may be accessed through a menu driven user interface which provides full prompting.
- **Non-volatile settings:** All of the user's menu and function settings are stored in a non-volatile semiconductor memory, and are restored when the system is powered on.
- **Sturdy Case:** The 2455 is supplied in a sturdy aluminum case with a retractable tilt-up stand. The carrying handle is reinforced with steel to ensure long life and dependability.

1.4 ACCESSORIES AND OPTIONS

The standard 2455 DFPI is supplied with the number of position sensors specified by the user, a power cord specified by the user, and a user's manual. Before the DFPI can be used, the correct number and appropriate position and temperature sensors must be installed on the piston pressure gages and connected to the DFPI. These items are normally ordered for a specific piston pressure gage, since the mountings generally differ according to the type of gage used.

The following items may be added to the DFPI to enhance its operation or provide extended features.

- **IEEE-488 Interface:** The DFPI accommodates an IEEE-488 plug-in module, which can be quickly installed in a receptacle in the instrument's rear panel.
- **Carrying Case:** This soft-sided case holds the DFPI, User's Manual, and other accessories. It is padded to protect the instrument, and has provisions for storing tools, nylon gloves, and the position calibration disks.
- **Rack Mount Kit:** If rack mounting of the DFPI is desired, this 5.219" high rack mount kit can be used to mount the instrument in a standard 19" rack.

THIS PAGE INTENTIONALLY LEFT BLANK

SECTION 2

THEORY OF OPERATION

2.1 INTRODUCTION

The Ruska Model 2455 uses state of the art sensors, microcomputer, and display technology to provide a highly accurate, flexible, and user friendly instrument. This portion of the manual reduces the DFPI to its individual function blocks and explains the relationship of each subsystem to the system as a whole.

2.2 THE DFPI: A FUNCTIONAL DIAGRAM

Figure 2-1 shows a simplified block diagram of the 2455 DFPI. Each subsystem will be discussed in the following sections.

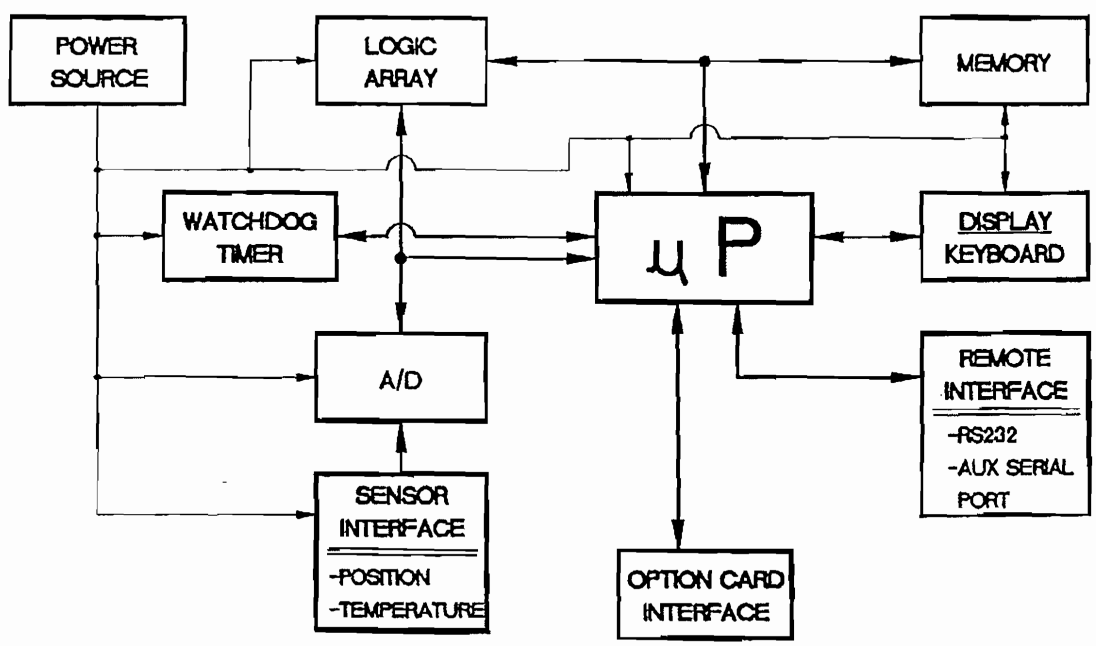

FIGURE 2-1

FUNCTIONAL DIAGRAM OF DFPI

2.2.1 POWER SUPPLY

The DFPI is designed to accept all universal standard AC line voltages. No user power selection switches are required because the DFPI has an universal input power supply. The power receptacle accepts the standard IEC-320 power connector. For specific information on acceptable power input ratings refer to Section 3.5.

2.2.2 POSITION SENSOR INTERFACE

This interface allows for the integration of one to four position sensors which gives many possible operating combinations. This interface consists of four BNC connectors located on the back panel.

2.2.3 TEMPERATURE SENSOR INTERFACE

Compensation for the effects of temperature fluctuations on a system is often a requirement for obtaining high accuracy data. Thus, Ruska has included two standard interface ports which allows for the use of two temperature sensors. The use and calibration of these two ports and the associated Platinum Resistance Temperature sensors is described in Section 4.6.

2.2.4 MICROPROCESSOR

The microprocessor controls all of the system's operations, which include the controlling of the user interface, communications interface, and data manipulations.

The elimination of all potentiometers is a result of the microprocessor's ability to use calibration coefficients to generate the necessary corrections required to produce accurate data. This simplification of the system allows for long term stability which is not possible with the use of potentiometers.

The multitude of communication options is a result of the microprocessor's power and efficiency. Using these communication links, the microcomputer can receive commands, configure the system, and supply information in response to requests, whether the requests are from the local or a remote station.

The microprocessor also performs diagnostic tests within the system. It always performs a self diagnostic routine when power is first applied and can perform this test during operation if desired.

2.2.5 LOGIC ARRAY

The logic array allows for an efficient addressing scheme to be implemented by decoding the address signals produced by the microprocessor. Also, the system requires various periodic signals to be generated and this is accomplished by the logic array.

The logic array greatly reduces the number of parts which would be required to accomplish the address decoding and periodic signal generation. This simplification of the circuit increases the reliability and versatility of the entire system.

2.2.6 MEMORY

The main board has EPROM for program storage, RAM for work area, and EEPROM for sensor coefficients and system configuration storage.

Sensor coefficients are stored in the EEPROM after a calibration routine is completed and are used in the linearization of data generated with the particular sensor. The system configuration, which consists of all user selectable menu settings, is stored in the EEPROM. Examples of such information include the active units of measure and the RS-232 configuration. Thus, the user is not required to select the menu settings each time the system is powered on.

2.2.7 WATCHDOG TIMER

A watchdog timer is utilized to reset the microprocessor if the system should suffer certain temporary operational problems. The programming instructs the microprocessor to periodically reset the watchdog timer. Should the processor cease operation of its main program, it would cease resetting the watchdog timer. The watchdog timer would then time out, and reset the processor. In this event, the processor would start operation of its program from the beginning, starting with the self diagnostics tests. Detectable errors would be reported to the user.

2.2.8 DISPLAY AND KEYBOARD

The DFPI incorporates a vacuum fluorescent display and touch keypad which allows this system to operate independent of external support. Since the system is menu driven the consequence of pressing a key is dependent upon which menu is currently displayed on the screen. The function of the keypad and the use of the menu system is described throughout Section 4.

2.2.9 RS-232 INTERFACE

The DFPI is equipped with two RS-232 ports. The Main Serial Port is designated for standard serial interfacing to a host computer. This interface creates many possible data gathering uses available to the DFPI customer. An explanation of how to use the available Host Computer functions is presented in Section 5. The Auxiliary Serial Port is available for future expansion depending upon customer's needs.

2.2.10 PLUG-IN MODULE INTERFACE

A variety of plug-in modules is available for use with the DFPI to enhance its capabilities. For example, an IEEE-488 interface card is available for the DFPI to allow the user to remotely gather applicable data. These modules are easy for the user to install into the recessed slot provided in the rear panel.

THIS PAGE INTENTIONALLY LEFT BLANK

SECTION 3

PREPARATION FOR USE

3.1 INTRODUCTION

This section of the manual covers the information necessary for the initial installation of a DFPI.

3.2 THE FRONT PANEL

All of the control keys necessary for Local operation are found on the front panel, as shown in Figure 3-1. The function of the control keys is discussed in Section 4.2.

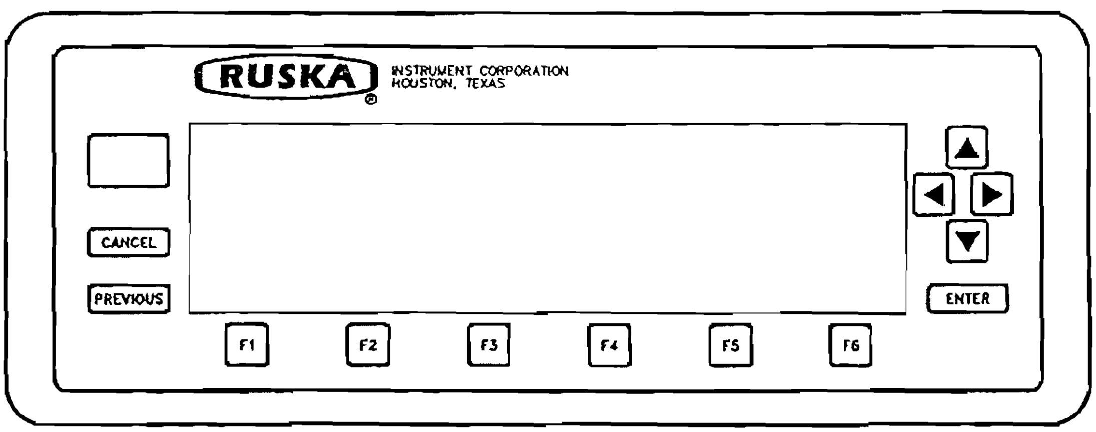

FIGURE 3-1

THE FRONT PANEL

3.3 THE REAR PANEL

All of the interface connections and power supply assembly are found on the rear panel of the instrument, as shown in Figure 3-2.

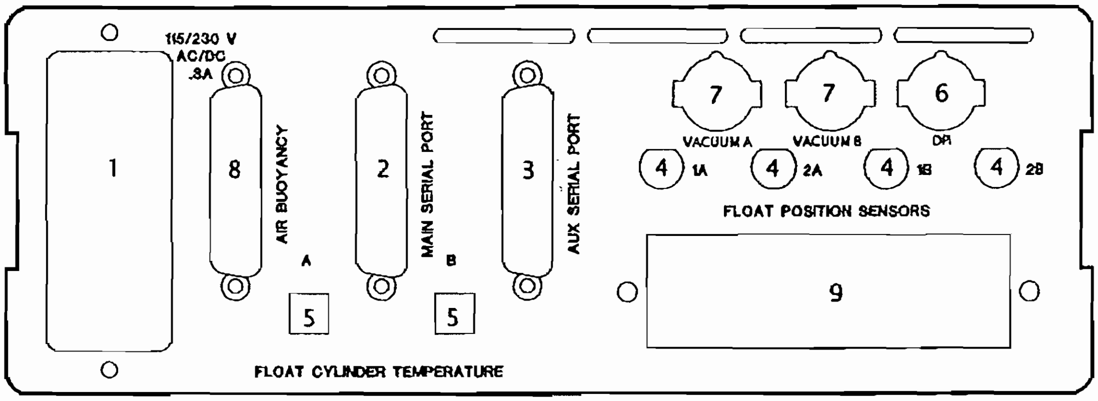

FIGURE 3-2

THE REAR PANEL

3.3.1 INTERFACE CONNECTORS

All of the interface connectors of the DFPI are listed below in Table 3-1 and are referenced to Figure 3-2.

REFERENCE	PURPOSE	TYPE
1	POWER	IEC-320
2	MAIN SERIAL	25 PIN DB FEMALE
3	AUX SERIAL	25 PIN DB FEMALE
4	POSITION SENSOR	BNC
5	TEMPERATURE SENSOR	4 PIN RJ
6	DPI	8 PIN DIN
7	VACUUM SENSOR	7 PIN DIN
8	AIR BUOYANCY MODULE	25 PIN DB FEMALE
9	OPTION CARD	IEEE-488 PLUG-IN

TABLE 3-1

BACK PANEL INTERFACE TERMINALS

NOTE: Do not attach anything to the DFPI until instructions explaining the operation of the device have been read.

3.3.2 UNDERSTANDING REAR PANEL LABELS

The back panel has enough terminals to connect the required sensors for two separate piston pressure gage systems. Thus there are terminals for two temperature probes and four position sensors. The four position sensor terminals are labeled as 1A, 2A, 1B, and 2B. The temperature ports are labeled as A and B.

The capital letters A and B distinguish the two separate systems. One piston pressure gage system is labeled A and the other is labeled B. This notation applies to the back panel and all documentation associated with DFPI. The labeling scheme of 1A and 2A refers to position sensor 1 and position sensor 2 of DWG A while 1B and 2B refers to sensor one and two of DWG B.

Sensor number one of both DWG A and DWG B is the primary sensor. When only one sensor is used to measure position (Refer Section 4.5.4) then the sensor should be connected to terminal number one. If two sensors are used on one DWG (Refer Section 4.5.4) then a sensor must be connected to terminal one and two. If only one DWG is being used then the preferred piston pressure gage is DWG A (Refer Section 4.7.5.2)

3.4 GETTING STARTED

Unpack the DFPI. The items which should be included with the DFPI are a power cord and four calibration disks. Any other devices and interface connectors ordered should be identified. After the DFPI has been unpacked, inspect the unit for any external signs of damage. Also inspect the power cord, the position sensor(s) and any other items received for exterior damage.

NOTE: Do not use any item which has sustained damage.

3.5 POWER SUPPLY

The power supply in the DFPI is capable of accepting most standard AC voltage sources. These ratings include all values between 100 and 250 VAC at 50 or 60 Hz. There are no settings required of the user to specify the input voltages. The DFPI can be moved freely from an outlet rated for one of the acceptable AC voltages to another outlet which is rated differently. The DFPI should not be operated at voltages outside the range of 100 to 250 VAC.

3.5.1 POWER CONNECTOR

The back panel provides a standard IEC-320 fused connector which accepts most nation's standard power cord. The two fuses are 250 VAC nominal, 1 Amp, slow blow fuse.

3.6 POWER UP

Verify that the power switch on the back panel is in the OFF position, which is designated by the numeral zero.

With the power cord disconnected at both ends, plug the power cord into the back panel connector and then into an acceptable power outlet.

Turn on the DFPI by flipping the rocker switch to the ON position.

Once the DFPI receives power the system will run an initial self diagnostic test. The first time power is applied, it is likely that the system will show an ERROR 3 has occurred. This error signifies that the system has never been calibrated. This should not be considered a problem but should serve as a reminder to the user that calibration is required (Refer to Section 4 for calibration procedures). Pressing the ENTER key will allow the system to continue. When this test is passed the Main Screen, similar to Figure 4-1 (front panel display), will be displayed. If any other error code should appear then refer to Section 4.7.3.1 "ERROR CODES."

SECTION 4

LOCAL OPERATION

4.1 INTRODUCTION

At this point, the unit should have been prepared as explained in Section 3. This section of the manual contains local operating instructions which includes an explanation of the various menu paths and associated functions.

4.2 FRONT PANEL KEY PAD

The front panel consists of four arrow keys, six function keys, and a CANCEL, PREVIOUS, and an ENTER key. Each key performs a standard function regardless of which screen or menu is currently being displayed. If no purpose is associated with a function or an arrow key then pressing the key will produce no result.

ARROW KEYS — The arrow keys are used to control the cursor when a value must be entered. The left and right keys are used to select position and the up and down keys are used to change the value of the position.

FUNCTION KEYS — The function keys are used to step through the menus from the higher level menus to the lower level menus. The significance of these keys is dependent upon what menu or function choices appear on the display. Throughout this manual the function keys will be abbreviated with a capital letter F, followed by the appropriate numeral (example:F1 = function key number one).

ENTER — The ENTER key moves the system from the current menu to the next higher level menu. When any values are changed the ENTER key stores these changes in the non-volatile memory, thus these changes will remain configured even if the system is powered off and on.

CANCEL/PREVIOUS — These keys are used to return to a previous menu or function without executing any calibration routines or saving any system configuration to EEPROM.

4.3 MAIN SCREEN

If the instructions in Section 3 were followed then the Main Display should be displayed as shown, in Figure 4-1. If the Main Display is not shown then the PREV key should be pressed as many times as is necessary to return the system to the Main Display.

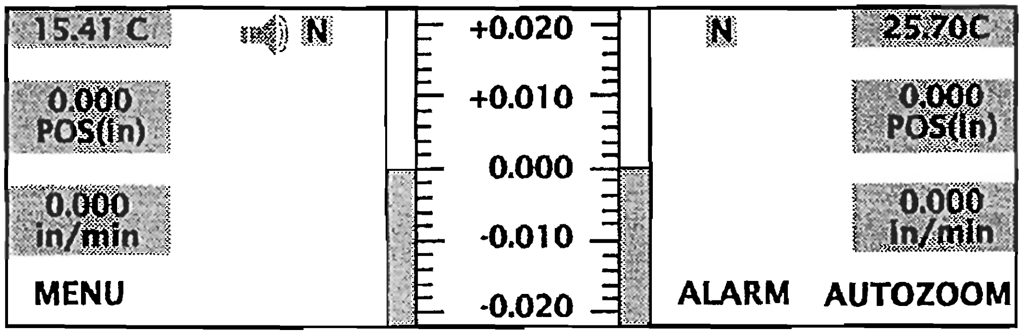

FIGURE 4-1

MAIN DISPLAY

The left side of the screen represents the information for DWG A and the right side of the screen displays DWG B. Along the left and right sides of the screen are displayed the temperature, position, and rate for DWG A and DWG B. The center of the screen displays bar graphs which represent the position levels with respect to midfloat as indicated in the position windows. Along the upper portion of the screen are three symbols. From left to right, these symbols are the alarm activate, and Average/Non-Average indicators.

NOTE: There is no reason for concern if only one half of the Main Display is shown. This will be discussed in Section 4.7.5.2 'Dual / Single'.

If the displayed values for temperature, position or rate are blank, this is an indication that a sensor is not calibrated or connected

4.3.1 MAIN SCREEN FUNCTION KEYS

When the main screen is displayed there are three active keys — F1 (MENU), F5 (ALARM), and F6 (ZOOM).

Pressing the F1 key will open the Main Menu which is described in Section 4.4.

F5 is the activate/deactivate switch for the alarm. The alarm symbol is displayed on the Main Screen when the alarm is activated. The purpose of this alarm is described in Section 4.5.6 - SETPOINT.

Pressing F6 will change the scale of the bar graph to one of three ranges or the Autozoom mode. The available scales are shown below in Table 4-1. The Autozoom mode automatically selects the most appropriate scale.

INCHES	CENTIMETERS
-0.200 TO 0.200	-0.500 TO 0.500
-0.050 TO 0.050	-0.150 TO 0.150
-0.020 TO 0.020	-0.050 TO 0.050

TABLE 4-1

BAR GRAPH SCALES

NOTE: Throughout this manual, the position of zero inches or centimeters is referenced to the midfloat position.

MAIN MENU

ADJUSTMENTS

FPI RTD MORE

FIGURE 4-2

MAIN MENU

4.4 HIGH LEVEL MENU ORGANIZATION

When the Main Display is shown on the screen the Main Menu can be selected by pressing F1. The Main Menu is shown below in Figure 4-2.

The major functions necessary for the operation of the DFPI are accessible through the Main Menu. The menu paths and system operation for each of the topics shown in Figure 4-2 are discussed in the following sections. The FPI CALIBRATION is discussed in Section 4.5, RTD ADJUSTMENTS are discussed in Section 4.6, and the SUB MENU (selection F6 '- MORE' in Figure 4-2) is discussed in Section 4.7.

4.5 FLOAT POSITION CALIBRATION

NOTE: This section needs to be read in its entirety before proceeding with the use of the DFPI as an accurate position measurement tool.

When the Main Menu is displayed the FPI CALIBRATION menu can be selected by pressing F3. This will display Figure 4-3 on the screen.

FLOAT POSITION

CALIBRATE		ZERO		CALIBRATE	
DWGA	DWGB	DWGA	DWGB	DWGA	DWGB

FIGURE 4-3

FLOAT POSITION MENU

Each position sensor and each channel have unique characteristics requiring calibration which allows for the incoming signals to be properly interpreted. Because of this, it is necessary that a sensor be dedicated to the channel it was calibrated on. If a sensor is used with a channel which it was not calibrated on then the calibration routine will need to be redone for the new sensor and channel combination. Recalibrating a channel will erase any previous calibrations done on that channel.

Since each of the four channels is calibrated using the same routine, the following explanation will focus on the calibration of DWG A and sensor 1. If the calibration of DWG B and sensor 2 is desired then simply substitute B for A and 2 for 1 throughout this section.

NOTE: Information generated on the input ports 1A and 1B is displayed on the main screen, DWG A shows up on the left and DWG B shows up on the right. After calibrating 2A or 2B (if applicable) the values generated by these position sensors can only be seen in the form of an average. Sensors 1 and 2 of DWG A are averaged together and sensors 1 and 2 of DWG B are averaged together.

When the FLOAT POSITION menu Figure 4-3 is displayed and F1 is chosen the screen shown in Figure 4-4 will be displayed.

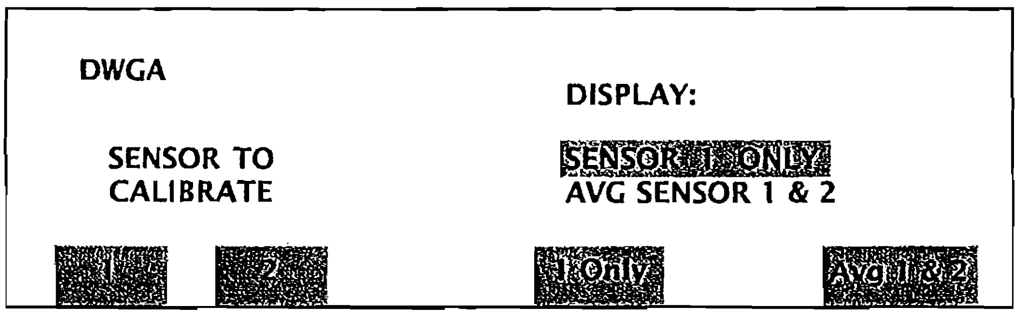

FIGURE 4-4

SENSOR SELECTION MENU - DWG A POSITION CALIBRATION

Since this is an explanation of how to calibrate sensor 1 of DWGA then F1 should be chosen in Figure 4-4. This choice will cause the following screen to be displayed.

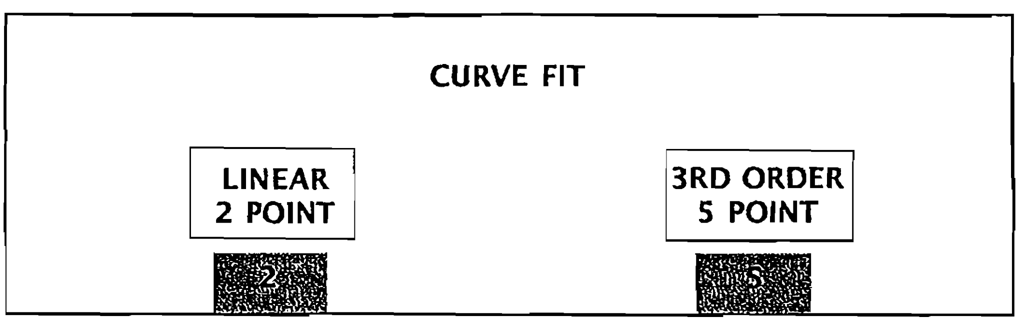

FIGURE 4-5

SELECTION OF CALIBRATION MODEL

A discussion of the benefits of each calibration method, the two and five point methods, is given in Section 4.5.3. For this portion of the discussion the two point calibration will be used. Thus the F2 key should be pressed and this will cause the following screen, Figure 4-6, to be displayed.

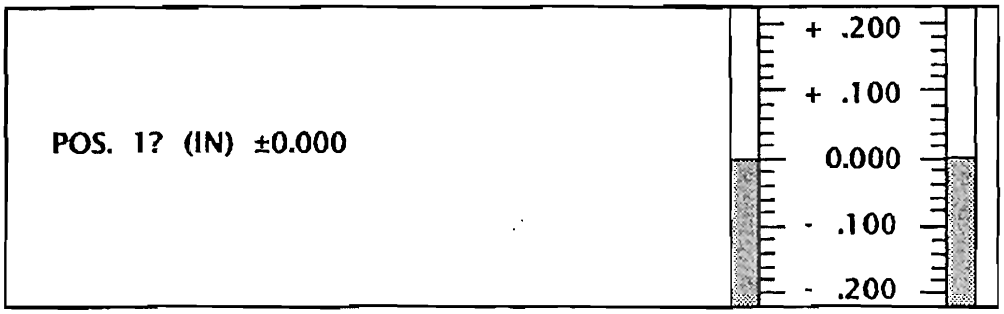

FIGURE 4-6

FLOAT POSITION CALIBRATION SCREEN

The sensor which is being calibrated needs to be attached to the appropriate output of the DFPI.

4.5.1 CALIBRATION ROUTINE

This routine will be repeated two or five times in order to provide the required number of calibration points.

1. Place a calibration spacer on the sensor being calibrated.

   The order in which the chosen spacers are used is not important to this calibration routine. The selection of appropriate spacers is discussed in Section 4.5.3.

2. Displace the mass platter of the DWG or the supplied mass platter simulator against the calibration spacer.

3. Make sure that the spacer is sitting flush against the sensor and the weight is flush against the disk.

4. Using the arrow keys, input the spacer height in the appropriate units. Refer to Section 4.7.1, "Units," if the desired units are not displayed.

   The spacer height can be entered with respect to the position sensor or the desired mid float level. In either case all values must be entered with respected to the same reference.

5. Verify that the entered value and units are correct. Again verify that the calibration spacer and weight are sitting flush and then press ENTER.

6. This calibration point is now saved in memory and will be used to create a model of this system. Repeat steps one through five as many times as is required to complete the chosen calibration routine.

NOTE: When using the mass platters of the DWG extreme caution must be taken not to apply too much force to the float position sensor and stand.

4.5.2 CALIBRATION ENVIRONMENT

When calibrating the DFPI it is usually desirable to do the calibration in the environment in which the sensor will be used. This is a result of the fact that position sensors are sensitive to the shape, size and material of surrounding objects. Thus, the calibration procedure described in section 4.5.1 should be done with the sensor mounted in position on the DWG and a typical mass platter or the supplied mass platter simulator.

4.5.3 CHOOSING A CALIBRATION MODEL

The following information describes the necessary considerations in order to choose the correct calibration procedure.

4.5.3.1 Five Point Calibration

When the five point calibration routine is executed a third order model of the sensor and DFPI system characteristics is generated. This order of model is provided as an option because this system consistently shows characteristics which are clearly a third order function over the specified operating range. In order to eliminate the need for having a sensor dedicated to a specific input port, the five point calibration is capable of accurately modeling any combination of sensor and input circuitry. An example of a typical sensor characteristic and the associated third order model is shown in Figure 4-7.

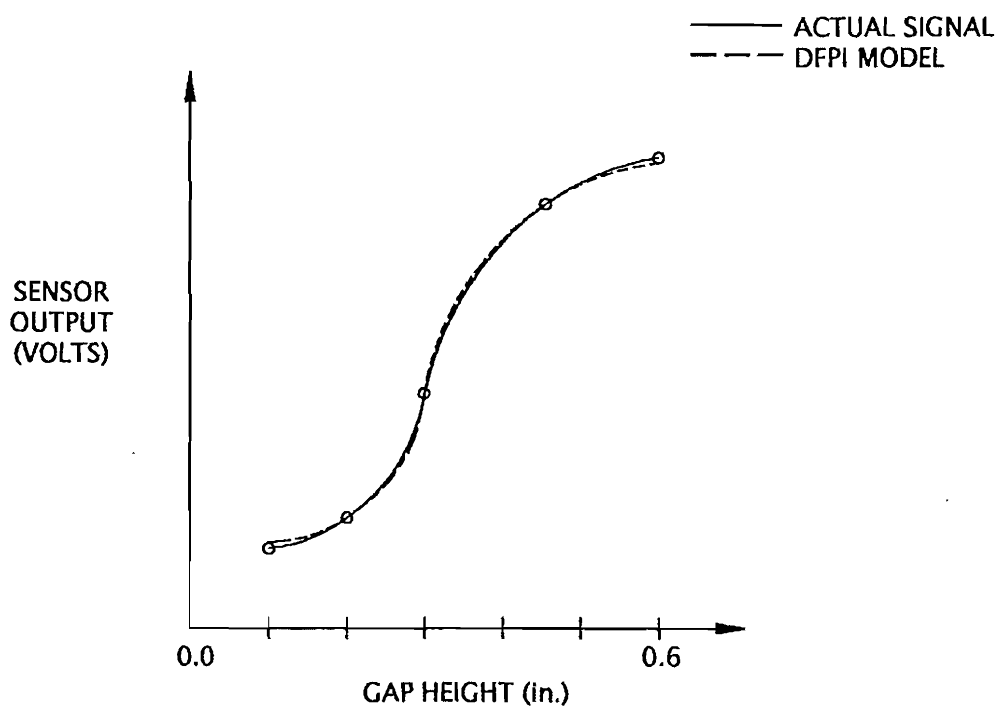

FIGURE 4-7

SENSOR AND 3RD ORDER MODEL CHARACTERISTICS

NOTE: Figure 4-7 does not represent any specific DFPI nor sensor. This graph is for visual effect only and no numerical value should be derived from this graph because nonlinearities have been exaggerated for emphasis.

The five point calibration allows for accurate data (refer to specifications) over large gap ranges such as 0.1 to 0.5 inches.

When choosing the five spacer heights it is best to choose five, evenly spaced, values. The spacers included with the DFPI allow for five evenly spaced heights. A typical selection of spacer heights might be 1/8, 1/4, 3/8, 1/2, and 5/8 inches.

The accuracy of the position display outside the calibrated range can not be guaranteed and should not be considered valid data.

4.5.3.2 Two Point Calibration

When the two point calibration routine is executed a linear model of the sensor and DFPI system characteristics is generated. This order of model is provided as an option because very often the important operating range is small enough that a linear model is more than sufficient and the two point calibration is easier to handle. An example of a typical sensor characteristic and two examples of linear models are shown in Figure 4-8.

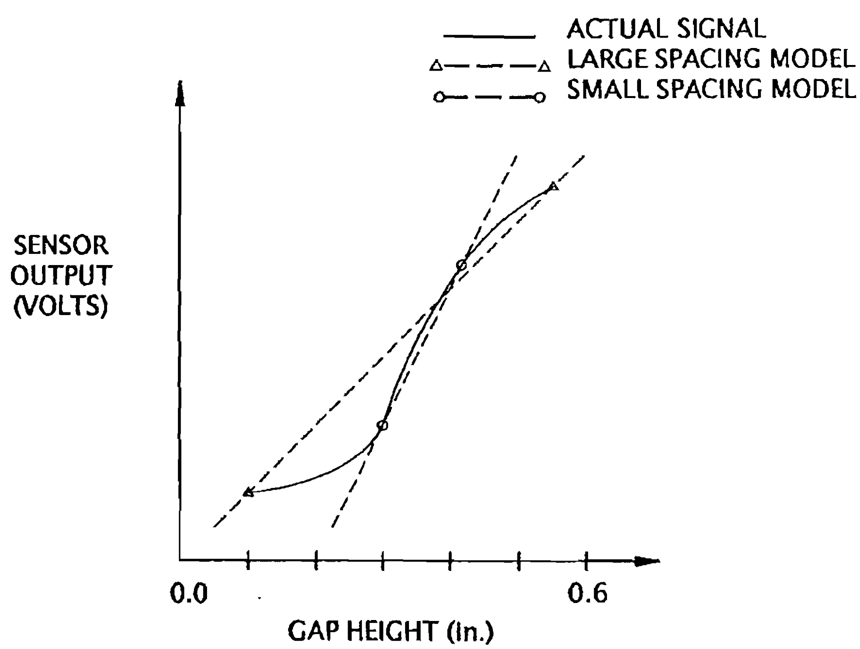

FIGURE 4-8

SENSOR AND LINEAR MODEL CHARACTERISTICS

NOTE: Figure 4-8 does not represent any specific DFPI nor sensor. This graph is for visual effect only and no numerical value should be derived from this graph because nonlinearities have been exaggerated for emphasis.

The two point calibration allows for quality data over small gap ranges which are 0.2 or 0.1 inches high.

When choosing the two spacer heights it is necessary to choose the values so that they contain only the heights of interest. The included spacers allow for many combinations of two heights.

The accuracy outside the calibrated range can not be guaranteed and should not be considered valid data. The two point calibration method is not capable of following the unique characteristics of a sensor and thus the related errors are dependent on the sensor and calibration points used.

4.5.4 AVERAGE / NON-AVERAGE

This selection allows the Main Screen to display either the single sensor or two sensor average position values. The average selection is chosen when the position sensors are set up 180 degrees apart to account for runout in rotating mass platters. This selection is done seperately for system A and system B by pressing either F1 or F2 from the Float Position Menu (Figure 4-3). The choice of using a single sensor or averaged sensors is made by pressing either F4 or F6. The Non-Average mode displays the position readings of sensor one for DWG A (1A) and DWG B (1B) on the Main Display. The Average mode displays the average of the position readings of sensor 1 and sensor 2 for both DWG A and DWG B (example: position (DWG A) = [(1A + 2A) / 2]).

4.5.5 ZEROING

The output readings displayed on the Main Display can be zeroed around any obtainable height within the calibrated range. It is most common for the zero position to be set using the mid-float index mark associated with the DWG. If during calibration the spacings were expressed relative to midfloat then zeroing after calibration is not required.

NOTE: Zeroing a channel is only valid if done after the system has been calibrated. Performing a calibration on the system will erase any previous zero point on the same channel.

If F3 or F4 is pressed when the FLOAT POSITION menu is shown then the following display, shown in Figure 4-9, will be displayed.

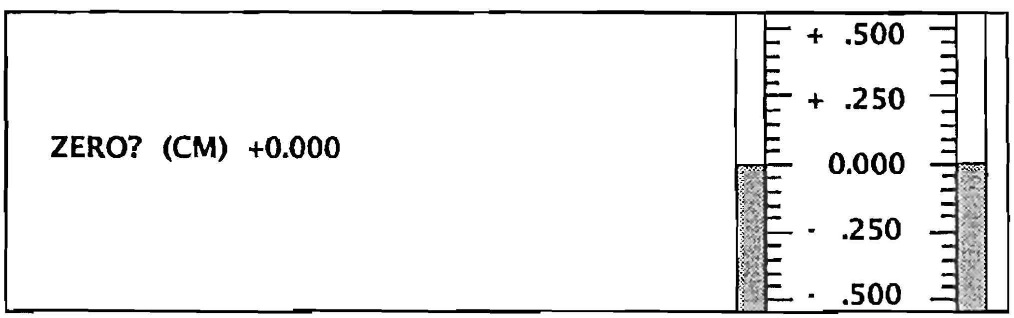

FIGURE 4-9

ZERO FLOAT POSITION SCREEN

After Figure 4-9 is displayed, the zeroing of the system can be executed by the following instructions.

(1) The mass platter should be lowered to the desired mid-float level using the mid-float index mark or a calibration spacer.

(2) Once the mid-float level is established then the value of 0.000in (cm) should be entered.

The zeroing function is performed once for each DWG. If the DWG is in the two sensor averaging mode then both sensors should be installed and the mass platter lowered over both sensors simultaneously before the zero value is entered.

The above instructions are the only steps required in setting the zero position unless the desired mid-float height can not be obtained from the available calibration spacers nor mid float index mark. If this situation does occur then the following procedure should be used to set mid float.

(1a) Using a calibration spacer, the mass platter should be set to a known height from the position sensor. Check to make sure the spacer and mass platter are sitting flush against each other.

(2a) Enter the value which would be displayed on the Main Display, as a result of the current position, if the system had already been zeroed as desired.

Example: Suppose that a mid-float height of 0.30 inches above the sensor is desired but the closest available calibrated height is 0.40 inches. The value which should be entered into the zero window is 0.10 inches because 0.10 inches is the value which would be shown on the Main Display when the platter weight is 0.40 inches away from the sensor. If the closest known calibrated height is 0.20 inches then the value that would be enter is -0.10 inches.

4.5.6 ALARM SETPOINT

If F5 or F6 is selected from the FLOAT POSITION MENU, in order to enter the alarm setpoint of either DWG A or DWG B, then the screen shown in Figure 4-10 will be displayed.

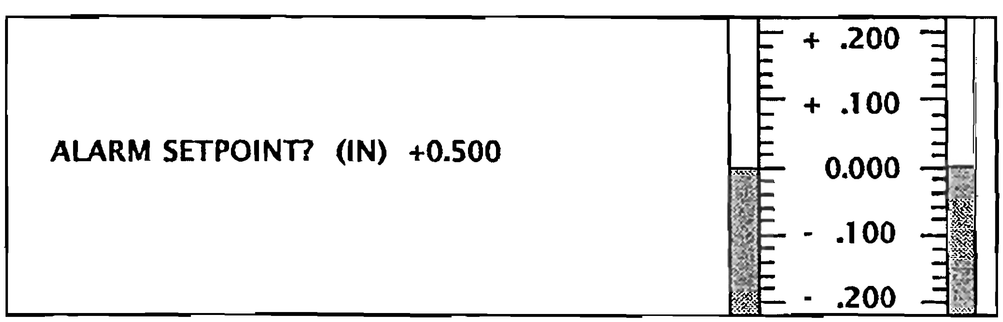

FIGURE 4-10

SETPOINT SELECTION DISPLAY

The current alarm setpoint will be displayed in the setpoint window. Use the arrow keys to change the setpoint and press ENTER to save the new setpoint.

If the position displayed on the Main Display falls below the related setpoint then the ALARM, if activated (refer Section 4.3.1), will sound. The alarm will continue to sound until either the position level is raised above the setpoint or the alarm is deactivated.

4.6 RTD ADJUSTMENTS

Overview

This temperature measurement system is designed to implement the Intenational Temperature Scale of 1990 (ITS-90) as defined in NIST Technical Note 1265. In order to implement this system the Platinum Resistance Temperature Device must be calibrated per the ITS-90 definition in which a value for resistance at the triple point of water (Rtp) and a slope correction factor (a10) are given to characterize a PRT (refer to section 4.6.2). In order to complete the system the 2455 DFPI must be calibrated to accurately provide a relationship between the measured voltage signal and ohms (refer to ohms calibration 4.6.3). The ITS-90 equations for PRTs are used to convert the ohms measurement into a corresponding temperature.

4.6.1 RTD ADJUSTMENT MENU

When the main menu is displayed the RTD Adjustments menu can be selected by pressing F4. This will display Figure 4-11.

```
                  |  F3   RTD COEFFICIENTS
SELECT            |  F4   ELECTRONIC ALIGNMENT
RTD #             |  F5   OHMS CALIBRATION
                  |
DWGA    DWGB      |  F3      F4      F5
```

FIGURE 4-11

RTD ADJUSTMENT MENU

4.6.2 RTD COEFFICIENTS

The DFPI will store the coefficients for up to ten RTDs with each set of coefficients being represented by a number from one to ten. In order to enter or change these coefficients press F3 from the RTD adjustment menu (Figure 4-11). Pressing F3 will display the RTD COEFFICIENTS menu (Figure 4-12).

```
RTD COEFFICIENTS                          DWGA=1,   DWGB=2

                              Rtp   100.0000
   RTD #1                     a10   -0.0200000

  PREV     NEXT     a10/Rtp
```

FIGURE 4-12

RTD COEFFICIENTS MENU

Pressing the PREV key (F1) or the NEXT key (F2) the coefficients for RTDs one through ten can be viewed.

In order to edit these coefficients select the RTD number desired then use the a10/Rtp key (F3) to select the proper coefficient. Use the arrow keys to manipulate the value. The RTD probe should be labeled with the assigned number from one to ten so it can be easily associated with its appropriate coefficients.

For a standard Platinum 100 Ohm RTD with TCR of 0.00385 C^{-1} a nominal Rtp value is 100.0000 and a nominal a10 value is -0.020. These numbers should be taken from the individual RTDs calibration report.

The top right hand corner of the RTD coefficients menu displays which RTD numbers are currently selected for each of the two temperature ports (Refer section 4.6.2.1).

4.6.2.1 SELECTING CURRENT RTD COEFFICIENTS

In order to select which RTD coefficients are being used in the temperature conversion equations for DWGA and DWGB either F1 (DWGA) or F2 (DWGB) should be pressed while in the RTD ADJUSTMENTS MENU (Figure 4-11).

Upon selecting F1 or F2 the following display will appear.

```
   ENTER RTD # FOR DWG A  1
```

FIGURE 4-13

RTD SELECTION MENU

The RTD number desired for use with the specified DWG should be entered using the arrow keys. The coefficients associated with each RTD number can be viewed or modified (refer to section 4.6.2).

4.6.3 OHMS CALIBRATION

This procedure is a calibration of the electronics for voltage to ohms measurement and a calibration of the internal alignment resistors used in the Electronic Alignment procedure. The Ohms Calibration procedure requires two calibrated resistors connected with the same four wire configuration as the RTDs. It is suggested that the resistors range between 99 and 125 ohms. For a standard 100 ohm platinum RTD the range of 10°C to 40°C is nominally equivalent to 104 ohms to 115 ohms and the range of 18°C to 28°C is nominally equivalent to 107 ohms to 111 ohms.

To begin the OHMS CALIBRATION procedure press F5 from the RTD ADJUSTMENTS menu. The display in Figure 4-14 will be shown.

```
OHMS CALIBRATION            CHANNEL  A  093.4882 OHMS

CONNECT LOW CAL RESISTOR TO CHANNEL A
ENTER RESISTANCE: 106.5000 OHMS
```

FIGURE 4-14

OHMS CALIBRATION

From this point the following steps will be executed

1. Connect the low calibration resistor to channel A and enter the ohms value.

   Press Enter.

2. Connect the high calibration resistor to channel A and enter the ohms value.

   Press Enter.

3. Connect the low calibration resistor to channel B and enter the ohms value.

   Press Enter.

4. Connect the high calibration resistor to channel B and enter the ohms value.

   Press Enter.

5. Disconnect all probes from the temperature ports.

   Press Enter

4.6.4 ELECTRONIC ALIGNMENT

The electronic alignment procedure is user invoked and realigns the 2455 electronics with several known internal resistance values (refer to section 4.6.3) to insure long term stability. When F4 is selected from the RTD ADJUSTMENT menu (Figure 4-11) then Figure 4-15 will be displayed.

ELECTRONIC ALIGNMENT

Disconnect all probes from Channel A & B
Press any key to continue

FIGURE 4-15

ELECTRONIC ALIGNMENT

To discontinue press the Cancel or Previous keys otherwise press any other key.

At this point the software will switch in the internal resistors and regenerate the voltage to ohms slope and thus realign the hardware of the 2455. This alignment is designed to realign the 2455 for temperature measurement between the range of 18°C and 28°C.

4.7 SUB MENU

The SUB MENU is reached by pressing F6 while in the MAIN MENU. The SUB MENU contains the information necessary for specifying the system configuration, and is shown in the Figure 4-16.

SUB MENU

UNITS | RS232 | SELF TEST | VIEW SYSTEM CONFIG | DISP SETUP

FIGURE 4-16

SUB MENU

4.7.1 UNITS

By pressing F2, while in the SUB MENU, the UNITS selection menu will be displayed as shown in Figure 4-17. The measurement units shown on the display are the units which are currently being used by the DFPI.

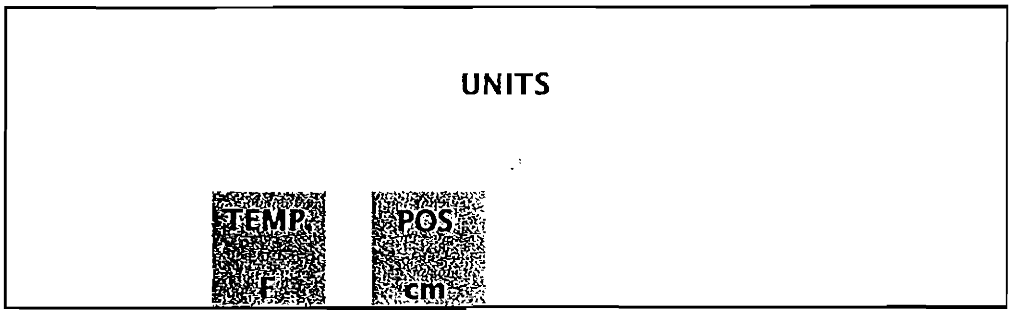

FIGURE 4-17

UNITS SELECTION DISPLAY

Pressing F2 will toggle between Celsius and Fahrenheit.

Pressing F3 will toggle between centimeter and inch.

After selecting the desired units;

Pressing ENTER will save the selection as the new default values at power on.

Pressing CANCEL or PREVIOUS will save the selections for only the current session and will be lost at power off.

4.7.1.1 Conversion Factors

inch	=	centimeter x 2.54
Celsius	=	((Fahrenheit - 32) x 5) / 9

TABLE 4-2

CONVERSION FACTORS

4.7.2 RS-232 CONFIGURATION

The RS-232 port can be configured by pressing F3 while in the SUB MENU. The following screen will be displayed.

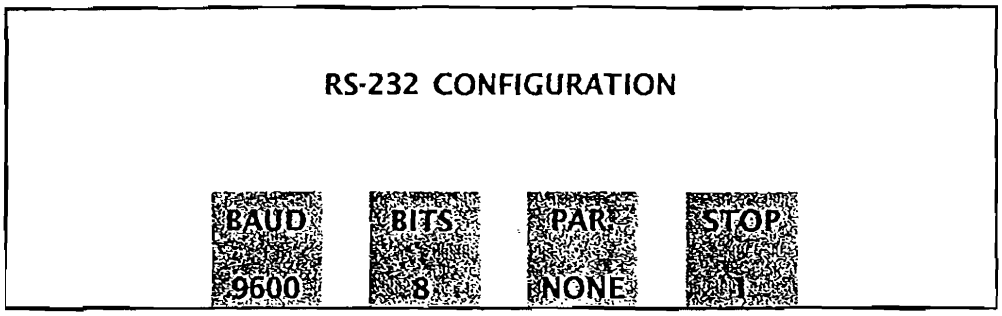

FIGURE 4-18

RS-232 CONFIGURATION DISPLAY

Pressing the appropriate function key will change the configuration. By pressing a particular function key several times the possible choices can be shown.

Selections :

Baud Rate	1200,2400,9600 or 19200
No. Bits	7 or 8
Parity	None, Even or Odd
Stop Bits	1 or 2

The ENTER key will save any changes and modify the default values.

The CANCEL and PREVIOUS keys only save the changes for use during the current session.

4.7.3 SELF TEST

A self test can be commanded of the system by pressing F4 while in the SUB MENU. The system will undergo the same test that is performed at power on. If any errors are found then the system will inform the user.

4.7.3.1 Errors - Local

The errors which the self test is capable of detecting are described with the following error codes.

ERROR 1	—	BAD ROM CHECKSUM
ERROR 2	—	RAM FAILURE
ERROR 3	—	BAD EEPROM CHECKSUM
ERROR 4	—	TEXT FAILURE
ERROR 5	—	GRAPHICS FAILURE

TABLE 4-3

ERROR CODES FOR SELF TEST

4.7.4 SYSTEM CONFIGURATION

An overview of the system can be viewed by pressing F5 while in the SUB MENU. The system configuration screen is shown in Figure 4-19.

GPIB dev: 5 UNITS: cm, deg C

RS232:
9600, 8, NONE, 1

RTD:
A=1, B=2 VER. 2455-1.00 RevB

FIGURE 4-19

SYSTEM CONFIGURATION DISPLAY

The information which is unique to this screen is the GPIB and Software Version number information.

If installed, the address of the IEEE-488 card is displayed in the upper left hand corner.

The version number of the software included in the DFPI is displayed in the lower right hand corner.

4.7.5 DISPLAY SETUP

The Display Setup screen, as shown in Figure 4-20, allows the user to control the format of the Main Display. The selections offered in this menu can be changed during operation without disturbing an ongoing process.

Pressing F6 while in the Sub Menu will cause the Display Setup screen to be displayed.

DISPLAY SETUP

DWG DUAL RATE FLTR 10

FIGURE 4-20

DISPLAY SETUP

4.7.5.1 FILTER

The sink rate can be filtered in order to steady the output readings. By selecting F4, while in the Display Setup screen, a cursor will appear in the window below the word Filter. By using the arrow keys the sink rate filtering value can be changed. A filtering value of 1 is equivalent to no filtering and a value of 255 is equivalent to the maximum level of filtering.

NOTE: It is possible to filter the rate values displayed on the Main Screen to such an extent that the displayed readings may lag too far behind the actual values to provide a meaningful reading.

4.7.5.2 DUAL / SINGLE

On the Main Screen, two sets of information can be displayed for independent Piston Pressure Gages. If the information for only one DWG is desired then the values for the second DWG can be removed from the main screen. The F3 key functions as a toggle switch. By pressing the F3 key the operating window will either show a DUAL for dual mode or a SNGL for single mode. In single mode, only DWG A will be displayed.

THIS PAGE INTENTIONALLY LEFT BLANK

SECTION 5

REMOTE OPERATION

5.1 INTRODUCTION

The DFPI may be operated remotely by connecting a computer, or Host, to either the RS-232 interface or the optional IEEE-488 interface on the back panel of the DFPI (see Figure 3-2). The purpose of these interface connections is to enable the user to gather precise data and perform independent analysis of the information. This portion of this manual contains the remote operating instructions for the DFPI.

5.2 MESSAGE SYNTAX

This section describes the message syntax, meaning and response that are common for both the RS-232 and the IEEE interface.

The DFPI produces a message only in response to a request received from the host.

All messages sent to the DFPI must be terminated by a line feed (0A hex), carriage return (0D hex) or both. All messages sent to the host from the DFPI are terminated with a line feed.

The message syntax is case insensitive. Thus the message may be sent in either upper or lower case.

5.2.1 MESSAGES

Table 5-1 alphabetically lists all the commands that the DFPI is capable of recognizing. The 'Message' column describes the syntax of the command. The 'Response' column describes the action of the command and the reaction of the DFPI.

TABLE 5-1

REMOTE COMMANDS

MESSAGE FROM HOST	RESPONSE
AD*n*	Returns 'AD*n*,a,b,c,d,t' where a,b,c,d are the 16 bit hex values of channels one through four of the specified convertor. The convertor is specified by *n*; *n* being 1,2,3,, or 4. 't' is the time as defined by the function 'ET'. A/D Mapping *n* = Convertor number

Channel	1	2	3	4
a	Pos. 1A	Pos. 2A	Temp DWGA	—
b	Pos. 1B	Pos. 2B	Temp DWGB	—
c	—	—	Vac. Sensor	—
d	—	—	DPI Null Ind.	—

MESSAGE FROM HOST	RESPONSE
ER	Returns 'ER,*n*' where *n* is the first error message on the stack as defined in Sections 4.8.3.1 and 5.2.2.
ET	Returns 'ET,*n*' where n is the 32 bit value of the elapsed time in tenths of seconds. When ET = 864000 (24 hours), ET is reset to zero.
ET,*n*	Sets the elapsed time to *n* in tenths of seconds. *n* is a number between 0 and 864000.
FCA1, *n*	Returns 'FCA1,*n*,*x*' where *n* is the selected coefficient of the FLOAT POSITION conversion equation for DWG A sensor 1 and *x* is the value of the coefficient. *n* = 0 selects c0 *n* = 1 selects c1 *n* = 2 selects c2 *n* = 3 selects c3 Float Position = c0 + c1*(A/D) + c2*(A/D)^2 + c3*(A/D)^3
FCA1,*n*,x	Sets the n value of the Float Position equation for DWGA sensor 1 to x.
FCA2,n	Same as FCA1,n but operation is for DWG A sensor 2.
FCA2,n,x	Sets the n value of the Float Position equation for DWGA sensor 2 to x.
FCB1,n	Same as FCA1,n but operation is for DWG B sensor 1.
FCB1,n,x	Sets the n value of the Float Position equation for DWGB sensor 1 to x.
FCB2,n	Same as FCA1,n but operation is for DWG B sensor 2.
FCB2,n,x	Sets the n value of the Float Position equation for DWGB sensor 2 to x.
FPA	Returns FPA,x where x is the calculated float position of DWG A in centimeters.
FPB	Returns 'FPB,x' where x is the calculated float position of DWG B in centimeters.
FTA	Returns 'FTA,*x*,*y*,*t*' where *x* and *y* are 16 bit A/D hex values of float position sensors 1 and 2 of DWG A. *t* is the 32 bit decimal value for the elapsed timed.
FTB	Returns 'FTB,*x*,*y*,*t*' - Refer to FTA.
PL	Panel lock, disables local keyboard entries.
PL0	Unlocks panel.
RTA	Returns 'RTA,x,u' where x is the calculated temperature of DWG A in Centigrade and u is the units currently displayed on the 2455.
RTB	Returns 'RTb,x,u' where x is the calculated temperature of DWG B in Centigrade and u is the units currently displayed on the 2455.
SRA	Returns 'SRA,*x*' where *x* is the calculated sink rate of DWG A in centimeters/min.
SRB	Returns 'SRB,*x*' where *x* is the calculated sink rate of DWG B in centimeters/min.
ST	Executes the self test and returns 'ST,*n*' where n is the first error,, if any. Additional errors may be read with the ER command.
SV	Returns software version number.
	Note: All references to A/D values describe the actual output of the analog to digital convertors. This output data is equivalent to the output voltages of the position sensor and the associated frequency to DC convertor. A Hex value on one A/D in no way corresponds to the same value on another A/D output in terms of distance nor temperature.

5.2.2 ERROR CODES - REMOTE

These errors are unique to the remote operation. The error codes associated with system function are found in Section 4.7.3.1.

ERROR 8	SYNTAX ERROR
ERROR 9	BAD PARAMETER

TABLE 5-2

ERROR CODES FOR HOST INTERFACE

5.3 SERIAL INTERFACE DETAILS

The serial interface does not have a remote state. The front panel remains fully functional during serial communications.

5.3.1 CONFIGURATION

The serial interface is configured through the front panel. See Section 4.8.2 for instructions. The configuration includes the baud rate, the parity selection, the number of data bits, and the number of stop bits. The possibilities for each parameter are shown below.

Baud	1200, 2400, 9600, 19200
Parity	None, Even, Odd
Bits	7 or 8
Stop bits	1 or 2

5.3.2 INTERFACE CONNECTOR

The pin-out for the RS-232-C connector located on the rear panel is shown in Figure 5-1.

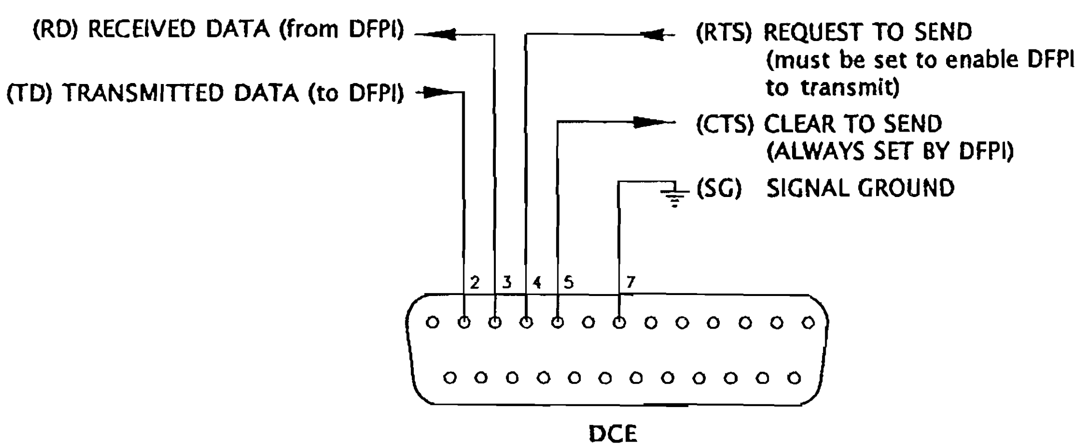

FIGURE 5-1

INTERFACE CONNECTOR PIN LOCATIONS

5.3.3 SERIAL COMMUNICATIONS CONNECTIONS

When using any software that communicates with the serial communications port through the PC BIOS, connect the communication cable according to the table below. (An adaptor is available from Ruska: Part number 6220-ADP-001.)

Host Computer Serial Connector (9 pin)	Host Computer Serial Connector (25 pin)	Signal	DFPI RS-232 Serial Connector (25 pin)
3	2	TD	2
2	3	RD	3
7	4	RTS	4
8	5	CTS	5
6	6	DSR	
1	8	CD	
4	20	DTR	
5	7	SG	7

TABLE 5-3

COMMUNICATION CABLE CONNECTION

5.3.4 ERROR/STATUS

The serial interface will not respond to values being placed into the error/status buffer regardless of the cause, including syntax errors on received messages. The host computer must read the values from the status buffer with the 'ER' message.

5.4 IEEE INTERFACE DETAILS

This interface standard is described by the publication ANSI/IEEE Std 488-1987.1, IEEE Standard Digital Interface for Programmable Instrumentation, (hereafter referred to as IEEE-488 standard). This publication may be purchased from:

Institute of Electrical and Electronics Engineers, Inc

345 East 47th Street

New York, NY 10017

USA

It is assumed that the reader has some familiarity with the IEEE-488 interface. This section will describe the interface capabilities, remote/local operation, configuration and device dependent messages.

5.4.1 CAPABILITIES

The following identification codes define the interface capabilities of the DFPI. Their meaning is described in the IEEE-488 standard.

Code	Description
SH1	Source Handshake, Complete Capability
AH1	Acceptor Handshake, Complete Capability
T2	Basic Talker, Serial Poll
L2	Basic Listener
SR1	Service Request, Complete Capability
RL1	Remote-Local, Complete Capability
PP0	Parallel Poll, No Capability
DC1	Device Clear, Complete Capability
DT0	Device Trigger, No Capability
C0	Controller, No Capability

5.4.2 REMOTE/LOCAL OPERATION

In local mode, the DFPI is operated manually through the front panel. Section 4, "Local Operation," covers local operation. The DFPI always powers up in local mode.

In remote mode, the DFPI is operated by a computer connected to the RS-232 or IEEE-488 interfaces. Most functions that can be performed in local mode can also be performed remotely. The remote mode is entered automatically when the host computer addresses the DFPI. When in the remote mode, the front panel continues to display and function as discussed in Section 4, Local Operation. In order to prevent the use of the local keypad panel lock command (PL Table 5-1) which will deactivate the local keypad. When the local keypad is deactivated a padlock symbol will be displayed on the front panel display. The front panel can be unlocked with the PL0 command (Table 5-1). When the remote mode is first entered, all variables maintain their present values.

5.4.3 CONFIGURATION

The only configuration required for the IEEE-488 interface is the setting of the DFPI device address. The DFPI uses a single address for both receiving (LISTEN) and sending (TALK) messages. The address may be set to any value between 0 and 30 inclusive. The address may be observed on the front panel by using the System Configuration Screen (see Section 4.7.4); however, the address must be physically set on the DIP switch on the IEEE-488 plug-in board.

To set the IEEE-488 address:

1. Turn the DFPI off.
2. Remove the IEEE-488 plug-in board. This is the board that has the IEEE connector.

3. Locate SW1 and set positions 4 thru 8 to the desired address. Figure 5-2 shows the switch positions, weighting and polarity.

   SW1 positions 1 thru 3 are presently not used but should be set false (0) in the event that future software revisions assign meaning to them.

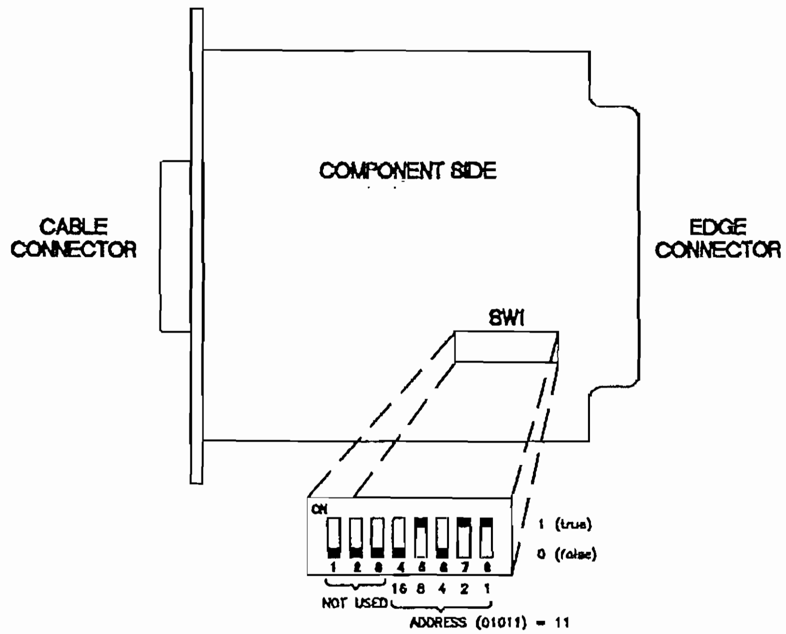

FIGURE 5-2

IEEE-488 PLUG-IN BOARD

5.4.4 DEVICE DEPENDENT MESSAGES

Device dependent messages include all transfers of data between the host computer and the DFPI. Device dependent message syntax for the IEEE-488 interface is the same as for the serial interface and is covered in Section 5.2.

5.4.4.1 Sending Messages to the DFPI

Messages are sent to the DFPI by addressing it to Listen and sending it one of the messages described in Section 5.2.1. For example, to perform a self test on the system, address the DFPI to listen and then send the message 'ST' followed by a carriage return or line feed.

5.4.4.2 Reading Values From the DFPI

The DFPI sends, or outputs, messages when it is addressed to talk. The host computer should first specify the output by addressing the DFPI to Listen and sending it the message desired and then addressing the DFPI to Talk.

5.4.5 ERROR/STATUS

When a status or error code is placed in the status buffer, a service request will be generated on the IEEE-488 interface.

5.4.6 SERIAL POLL/SERVICE REQUEST

The status byte returned by the DFPI during a serial poll has the following meaning. The DFPI will buffer a maximum of 4 service requests. They are returned in the order of occurrence. If 4 service requests are stored and another occurs, it will be lost.

Status			Condition
ASCII	DEC	HEX	
0	48	30	No special conditions,, did not request service.
A	65	41	Error/status condition occurred. The condition can be read using the 'ER' message.
B	66	42	Next pressure value available in continuous pressure transmission mode. Pressure value can be read using the 'PB' message.
C	67	43	Next rate value available in continuous rate transmission mode. Rate value can be read using the 'RS' command.

THIS PAGE INTENTIONALLY LEFT BLANK

SECTION 6

PREVENTIVE MAINTENANCE

6.1 INTRODUCTION

The DFPI contains no user serviceable parts and is virtually maintenance free. The float position and temperature calibrations are the only routines necessary to keep the system operating within specifications.

If instrument failure is suspect then the user is advised to run the self test described in Section 4.7.3. Do not attempt to correct an internal problem. Instead, contact Ruska and report the problem.

When contacting Ruska, be prepared to furnish the serial number and software version. The software version number is found on the system configuration screen (section 4.7.4).

THIS PAGE INTENTIONALLY LEFT BLANK

SECTION 7

SPECIFICATIONS

7.1 INTRODUCTION

This portion of the manual discusses the parameters which can affect the unit's measurement precision.

7.2 WARM UP TIME

The DFPI should be allowed approximately 15 minutes to warm up. If the DFPI was stored at a temperature different from ambient by more than 5°C then the warm up time should be extended by 15 minutes for each additional 5°C.

If the DFPI drives a sensor (i.e. position sensors) then it is necessary for the sensor to warm up while connected to the DFPI.

7.3 TEMPERATURE EFFECTS

7.3.1 POSITION

The DPFI unit has been shown to provide stable position readings as temperature varies. Larger gap spacings, with respect to the sensor, are more susceptible to variations of temperature. For a 0.400 inch gap, a room temperature increase from 18°C to 28°C can result in as much as 0.006 inch change in position reading, while a 0.200 inch gap will demonstrate a change of 0.002 inches.

7.4 CALIBRATION PERIOD

The position sensors should be recalibrated when the environment in which they were originally calibrated is changed. This could involve a change in the type of DWG, mass platter, sensor location, or atmospheric changes. At the user's discretion, the system should be periodically recalibrated.

7.5 SENSOR SPECIFICATION

7.5.1 POSITION SENSOR

The position sensors are sensitive to temperature changes and should be used at the temperature at which the sensor was calibrated. Refer to Section 7.3 for magnitude of the temperature effect.

7.6 STORAGE

The DFPI should be stored in a cool and dry environment. Refer to Section 8 for instructions.

SECTION 8

PREPARATION FOR STORAGE/SHIPMENT

8.1 DISCONNECT INSTRUCTIONS

NOTE: It is essential that the procedures mentioned in Sections 8.1 through 8.3 be strictly adhered to in order to prevent damage to the instrument. Failure to follow these procedures may result in damage during shipment that will not be covered by the carrier's insurance.

---

1. Turn the power switch off.
2. Disconnect all devices connected to the Rear Panel of the DFPI.
3. Remove the power cable from the power receptacle.

8.2 PACKING INSTRUCTIONS

The instructions below must be strictly followed in order to prevent damage to the instrument.

Preventing damage to the DFPI is accomplished by cradling the device within a box such that the DFPI is restrained but still has resilience. The two most successful materials for this purpose are rubber foam and flexible polyurethane foams. Styrofoam, poured "foam in place" mixtures, and other rigid foams are not suitable. Even polyfoam or rubber foam should be cut into strips so that it will not present a large rigid surface to the DFPI.

Ruska has found that corrugated cardboard boxes provide the best packing. The boxes sometimes arrive damaged, but the contents are usually intact. A minimum of 1 inch of foam should separate the inner surface of the box and any portion of the DFPI. Wood or metal boxes do not absorb shock when dropped and therefore are not recommended.

If the original packing and shipping materials were retained, use them for packing the DFPI. If the DFPI is being packed for long-term storage (more than 30 days), place a desiccant bag with the unit inside a plastic bag. The DFPI should be stored in a cool and dry place.

8.3 PREPARATION FOR SHIPMENT

In general, prepare the DFPI for shipment as follows.

1. In order to minimize turn-around time, Ruska should be notified of the return of equipment prior to shipment (contact customer service). When notifying Ruska please include the part number, serial number, purchase order number, billing and ship to address, and the buyer's name and phone number. This information should be duplicated and included with the shipment when the goods are returned. There will be a minimal charge for inspection and/or evaluation of returned goods.

2. Enclose the DFPI in plastic or any good water barrier material. Anti-static material is advisable.
3. Carton (size 12 x 12 x 6 inches): Cover top, bottom and sides with polyfoam.
4. Inside the carton, include the following:
   a. Statement of the problem or service needed. Be specific. Include any local or remote error codes that occurred during operation, and if possible, mention the component suspected of failure. Also include the name and telephone number of a knowledgeable technician for consultation.
   b. The part number, serial number, return address, and purchase order number.
5. Seal the carton, using gummed tape.
6. Address the carton to:

RUSKA INSTRUMENT CORPORATION

3601 Dunvale

Houston, TX 77063

7. Labels recommended are THIS SIDE UP, HANDLE WITH CARE, DO NOT DROP, and FRAGILE.

8.4 SHIPPING INSTRUCTIONS

Ruska recommends the use of air freight for transportation. Surface transportation subjects the shipment to more frequent handling and much more intense shock.

Again, it is essential that the procedures mentioned in Sections 8.1 through 8.4 be strictly adhered to in order to prevent damage to the instrument.

APPENDIX A

OPENING THE ENCLOSURE

Normally, the user should not need to open the DFPI enclosure. However, if it becomes appropriate to open the unit (for example, to change the software), the following procedure is recommended.

A. Place the unit on a soft surface to protect its finish. Stand it on its back panel, with the bottom sheet metal panel facing you.

B. Remove the four screws securing the tilt-up stand to the unit. Set the stand components aside.

C. Loosen (but do not remove) the two screws securing the soft rubber feet to the bottom of the unit. Remove the two flat head screws near the soft rubber feet.

D. Grasp the unit on both sides at the top. Use your thumbs to press the upper portion of the sheet metal bottom toward the interior of the unit, so that it deflects inward about 1/4 inch.

E. While continuing to press the bottom inward, slide your thumbs upward to push the nearer edge of the bezel up and away from its locking pins. Rotate the bezel upward and separate it from the unit. Set it aside.

F. Disconnect the display board connector from the main board, and set the display board aside.

G. Remove the two soft rubber feet and set them aside for later use.

H. While holding the rear bezel flat on the work surface, push the upper portion of the sheet metal top away from you, separating it from the assembly. Set the top aside.

I. Lay the bottom and bezel flat on the work surface, and set them aside for later use.

To reassemble, reverse this procedure.

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX B

CALIBRATION

B.1 CALIBRATION BY CROSSFLOAT

Two procedures may be followed when calibrating a dead-weight gage against the standard. The procedure for manipulation of the apparatus in each instance is approximately the same, but the results differ somewhat in accuracy.

In one procedure, all known variables influencing the results of the test are controlled or are corrected to the best of the operator's ability. Observations are made using currently established techniques with estimated corrections for transient or recurring disturbances. The accumulated data are recorded in a way which will permit an error analysis of the completed experiment. Constants obtained for the test gage are reported in a manner that will allow the necessary corrections to be applied for the proper use of the gage. At the conclusion, it may be considered that the results of the test are the best obtainable from the equipment and techniques administered. It is this procedure that is used when it is desired to transmit the accuracy of the standard to another instrument with the least loss.

The second procedure is one in which an instrument is crossfloated against the standard in the manner of an acceptance test. Such occasions occur where a transfer standard must be periodically recalibrated against a primary one. It is not necessary to determine the total error of the experiment. It is required only that the error of the test instrument will not exceed a certain value. In this test, the corrections of certain variables of the test gage are intentionally disregarded because they are not applied during normal use of the instrument. This type of test usually falls in the category of the one-in-ten rule for calibration of production equipment. The standard must have an uncertainty of one tenth that allowed for the test instrument.

It is significant to note that the calibration of an instrument under the one-in-ten system does not permit the operator to disregard any of the corrections that should be applied to the standard gage. The standard is capable of measuring a pressure to the manufacturer's claimed accuracy only when it is operated in the manner prescribed by the manufacturer. Since the accuracy of a piston pressure gage is largely dependent on the operating technique, there is a tendency for some operators to avoid applying the displeasing corrections with the false justification that they are not apparent in the test.

It is frequently the practice to use one of the less accurate dead-weight testers on a production line for the calibration of dial-type pressure gages or transducers. In some instances, it is claimed that, without corrections, the gage is capable of making pressure measurements with an error that will not exceed 0.1% of the observed pressure. This claim may be considered somewhat liberal when it can be shown that variations in the force of gravity (which is a multiplier in the determination of the total force exerted by the weights) may exceed the claim by almost 100% within continental United States. The most elementary error analysis indicates that the uncertainty in the observed pressure is the sum of the uncertainties of the area of the piston, of the force acting on the piston and of the failure of the piston to reproduce the pressure faithfully. If all the error is assigned to the force acting upon the piston, there is nothing left for the uncertainty of the remaining contributors. It is possible and highly probable that these gages will perform according to the claims if only the one correction is made for the effects of gravity upon the weights.

Some caution should be exercised in the use of these gages after an acceptance test or periodic recalibration. It frequently happens that errors in the adjustment of the weights and in the area of the piston will compensate for the local value of gravity. Under these conditions, a gage will measure a pressure within the claimed limits. The weights, however, may not be pooled with other sets of weights of the same make because, when used on another piston, the observed pressure may be out of tolerance. If a number of such pistons and weights are to be used interchangeably in a production process, an arrangement must be devised that will assure all the measurements to fall within the specified limits. Such an arrangement could involve the actual readjustment of all weights to produce the proper force at the local value of gravity and on the piston of mean area of all those in use. The tolerances for adjustment of the weights would, of course, make allowance for the total variation in piston areas, temperature effects, resolution of the gages and effect of air buoyancy.

B.2 INSPECTION OF WEIGHTS

The weights for a piston pressure gage must be thoroughly clean and in good condition before the gage can be properly calibrated.

If the weights are constructed so that axial alignment is obtained by nesting, it is possible that, by careless handling or such, the pilots and recesses may have become upset and no longer mesh in the proper way. In reconditioning the weights, the upset portions should not be cut away to restore the mesh, because the loss of metal would certainly be undesirable. Instead, the metal should be forged back into place as well as possible to conserve the metal of the weight. The history of the mass would then be more reliable.

Any severe nicks or edge crushes should be remedied in the same way. Craters or knots of metal formed by nicks or crushes are subject to rapid wear and subsequent loss of metal; also, the projecting metal causes the weight to be misaligned in the stack.

B.3 CALIBRATION OF WEIGHTS

The weights, thoroughly clean and in good condition, must now be calibrated. A distinction is made between the terms "Calibration" and "Adjustment".

Adjustment of a weight implies removal or addition of metal in controlled manner such that the mass of the weight is changed to a specified value. An adjusting tolerance allows the mechanic to accomplish this assignment economically.

In a controlled environment, and with more expensive equipment, the actual mass may be determined with an accuracy which is only a fraction of the adjusting tolerance. It is this determination and subsequent reporting of the results that is defined as calibration of the weight.

No adjustment is normally made on the weights of a set unless some of the smaller weights, being of two-piece construction, have obviously been tampered with. Adjustment must then be made by adding brass slugs to the adjusting cavity and the adjustment must be of a precision comparable to that of the remaining weights of the set.

The method of weight calibration is that of direct substitution of a known mass for the gage weights, i.e., after a gage weight has been balanced by some mass on a suitable instrument, the weight is replaced and the original balance restored by mass of known quantity. With this method, some of the instrument errors are canceled. The precision to which these measurements must be made depends, of course, upon the class of equipment being calibrated.

Values of mass are reported in units of APPARENT MASS VERSUS BRASS STANDARDS. In the table of reported masses, values under the heading APPARENT MASS VERSUS BRASS are those which the weights appear to have when compared in air under *NORMAL CONDITIONS* against *NORMAL BRASS STANDARDS*—no correction being made for the buoyant effect of air. *NORMAL CONDITIONS* are 25°C and air density of 1.2 mg/cm^3. NORMAL BRASS has a density of 8.4 gms/cm^3 at 0°C and a coefficient of cubical expansion of 0.000054°C. True mass values are those which might be observed in air of zero density, i.e., in a vacuum.

B.4 PISTON PRESSURE GAGE INSPECTION AND PREPARATION FOR CALIBRATION

The piston pressure gage must be in good mechanical condition before a calibration is started. Any damage that has resulted from normal wear, misuse, or shipping must be repaired to the extent that is possible by the calibrating facility. When the gage is in good mechanical condition, it must be cleaned before installation on the crossfloat bench.

Cleaning procedures must be adequate for elimination of all substances that may affect the performance of the gage. These substances vary from particulate contamination of the liquid to deposits of oil varnish on the essential parts of the mechanism. It is left to the operator to decide what cleaning procedures will satisfy his particular requirements.

There are certain physical measurements that must be made on the piston assembly. These measurements may be made before the assembly is reinstalled in the gage. They are described in the next section.

B.5 CALIBRATION OF THE PISTON GAGE

B.5.1 PRELIMINARY OPERATIONS

In order to simplify the instructions, procedures are given in command form. The instrument being calibrated will be referred to as the test gage.

1. Set the test gage on the test bench and connect it to the standard gage, making certain that the connecting tube is in good alignment and free of stresses. Remove the piston assembly and rinse it with a solvent in preparation for the measurements that follow.

2. It is necessary to determine the position of the reference plane of measurement of the piston with respect to some external reference mark on the gage. The dimensions of the piston determine the position of the reference plane. If the measurements are made carefully, the computed position of the reference plane will probably be within 0.01 inch of the true position. All measurements should be recorded in a manner that will cause the least ambiguity. If a data form is not available, one should be designed. The geometry or profile of the piston assembly and loading table should be sketched with dimension lines. A form used by Ruska is included in the appendix.

a. Measure and record the dimensions shown for the piston assembly, weight-loading table, and sleeve weight.

b. Remove the piston from the cylinder, clean it with a mild solvent, and determine the mass of the complete piston assembly, including the enlarged portion at the bottom. Thrust bearings and their retainers usually are not a part of the tare mass. When the piston is restrained from overpressure by an enlargement which acts against a bearing, the retainer is captured by the pressure housing and is not permitted to ride on the enlargement during a measurement.

c. Clean the piston-cylinder assembly thoroughly and reassemble it to the gage. Remove any trapped air from beneath the cylinder.

d. Clean the weight-loading table, measure its overall length, and determine its mass. Record the dimensions.

e. Measure the distance from the index line on the sleeve, or hanger weight, to the seat where the weight rests on the weight-loading table. Record.

f. Compute the volume of the enlarged (submerged) portion of the piston and divide by the area of the piston. The quotient is the length that the enlargement would have if all the material were contained in a cylinder of the diameter of the piston. The increase in length of the enlarged portion is added to the overall length of the piston with its enlargement.

g. The various dimensions are summed as follows:

   (1) Add the new length of the piston to the length of the weight-loading table.

   (2) Subtract the combined lengths from the depth of the sleeve of the sleeve weight as measured with respect to the index line. The difference obtained is the relative position of the reference pressure plane to the index line of the sleeve weight. In order to associate the reference plane of the dead weight gage to the remainder of the system, readings are made when the weights are floating at a particular height with respect to some common plane of the system. This plane is usually chosen at the position of the index line of the post which is attached to the base of the gage.

   (3) Measure the difference between the chosen plane (which is the index line on the index post) of the test gage and that of the standard gage. This measurement may be made with a cathetometer, a water-tube level, or a bar on which a sensitive level vial is mounted.

   (4) Add this value with its appropriate sign to the difference obtained in (2).

   (5) Add the difference in the reference plane of the standard gage and its index plane to the value obtained in (4). The result is the difference between the two reference planes of both gages when each is floating with the line of the sleeve weight coincident with the mark of the index post. The total difference between these two planes is referred to as the hydraulic head, oil head or h. The equivalent pressure is h x liquid density = p.

h. The approximate value of the hydraulic head of the oil used is .031 psi per inch of height. Therefore, if the difference in height (in inches) of the reference planes of the two gages is multiplied by .031, the product will be the correction in PSI that one gage will have with respect to the other.

If the reference plane of the test gage is below that of the standard, the pressure seen by the test gage is the pressure of the standard plus the oil (P) (refer to Figure B-1 below).

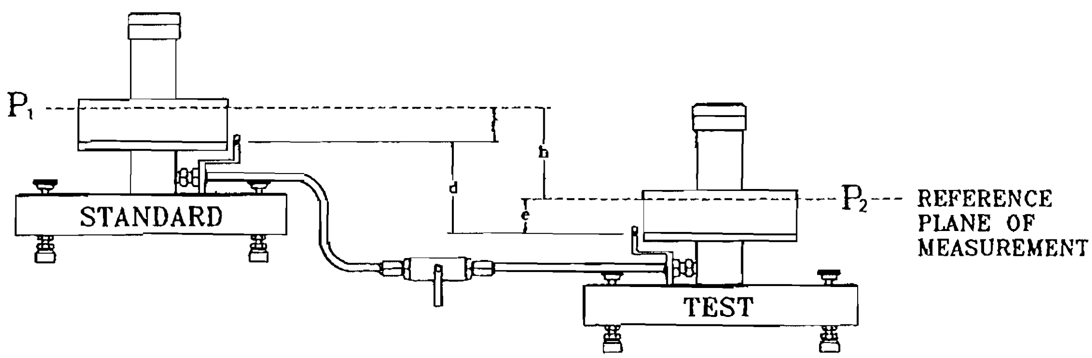

FIGURE B-1

FLUID DESIGNATIONS IN PISTON GAGE CROSSFLOAT PROCESS

B.6 CALIBRATION OF PISTON GAGES - THE MEASUREMENT PROCESS

In some instances, a piston gage may be calibrated by direct measurement of the piston and cylinder. The measurement can be made to a high degree of accuracy and will satisfy the requirement for determination of the effective area of the piston except for those occasions on which a pressure coefficient must also be determined. A piston gage may be directly compared with a standard instrument, the pressure coefficient and piston area of which are known. The comparison—or crossfloat, as it is called by pressure technicians—can be accomplished with an uncertainty of only a few parts in a million. The discussion which follows is intended to describe the cross-float procedure.

It is assumed that the instrument to be calibrated is one that has been in service and that certain inspection and preparation procedures must be followed before the calibration may be started. It is further assumed that the instrument normally operates with a liquid or gas as the pressurizing medium and that it will operate properly with the same liquid or gas as that used in the standard. Allowances must be made in the interpretation of the suggested procedure for instruments employing gases or liquids other than those of the standard.

The objective of a crossfloat operation is to determine the constants of the piston being calibrated in terms of those which are known for the standard. The area of the piston and the pressure coefficient of the area are the quantities of primary interest. If a given pressure is established with the standard and the test gage brought to balance, a value of pressure may be assigned to the test instrument after suitable corrections have been made. The masses on the test gage are known; they may be summed and converted to force units. When the force on the test piston is divided by its pressure, the quotient represents the piston area. These observations are conducted at various pressures throughout the range of the instrument. The reduced data result in three values of interest:

a. The area of the piston at no-load pressure.

b. The coefficient of elastic distortion of the cylinder.

c. A coefficient of precision for the test.

A sufficient number of observations must be conducted in order to provide the redundancy needed for determination of the precision coefficient.

The quantities of a and b, are related as follows:

$$A_e = A_o(1+bp)$$

where

A_e is the mean area of the piston and of the cylinder at any pressure greater than no-load conditions.

A_o is the value of Ae at no-load.

b is the fractional change in area per unit of pressure with dimensions A/ A/pressure unit.

p is the pressure beneath the piston.

Data for a number of observations at different pressures are reduced such that values of A_e are comparable. These areas are plotted on coordinates having scales that show the scatter in the observed vales. A best-fit (regression) line is fitted to the plot. The intercept of the line with the zero pressure coordinate represents the value of A_o for the test piston; the loci of all other point of the line are values of A_e as a function of pressure. A particular A_e and its corresponding pressure, p, are selected near the maximum pressure and are substituted in the relation:

$$b = \frac{A_e - A_o}{pA_o}$$

After evaluation of b, the computed A_e is determined for each of the pressures in the observation above. The differences in the computed A_e and observed A_e are the deviations, or residuals, from which the standard deviation of the variability of the test is calculated.

Forms and worksheets are designed for convenient tabulation, and reduction of the observed data. The completed forms and worksheets serve as the basis for documentation of the measurement process. They must be retained as evidence of the procedures followed in the experiment and of the continuous history of the test instrument. Samples of an acceptable form is included in the appendix.

B.7 CROSSFLOAT BALANCING WITH THE PROXIMITY INDICATOR

In making a comparison of one piston pressure gage to another, the two gages are connected together and brought to balance at various pressures. The balancing operation is identical with that employed on an equal-arm weight balance where the mass of one weight is compared to another. In each instance the operator must decide when the balance is complete. The two gages are considered to be in balance when the sink rate of each is normal for that particular pressure. At this condition there is no pressure drop in the connecting line and consequently no movement of the oil or gas. The condition can be difficult to recognize, particularly if there is no means of amplification in the method of observing. The precision of the comparison will depend directly upon the ability of the operator to judge the condition in which the two gages are balanced.

Of the different methods used in amplifying the signals that are generated by the crossfloat process, one is presently in use that is rapid and convenient. An electronic sensor, which indicates the floating position of the piston, is placed above or beneath the weights of each gage. The output signal from the sensor is processed and fed to an analog meter having a vertical scale. The scale is calibrated in units of displacement of the piston. Two meters— one for each instrument—are placed side-by-side for simultaneous viewing. A constant-volume valve, inserted between the gages, is also required. A description of the crossfloat process follows.

At a given pressure, and with the valve open, the two gages are brought to an approximate balance, either by observing the weights directly or by use of the two proximity indicators. The degree of balance must be reasonably complete in order that the floating positions will remain constant for a few seconds after being manually adjusted. It is necessary to determine the relative sink rates of the two gages before the balance can be completed. The criterion for a complete balance is the condition in which each gage sinks at its normal rate when they are connected together.

From the arrangement of the components illustrated in Figure B-2, it may be seen that, with the isolation valve open, the entire system may be pressurized with the manually-operated pump. A procedure for completing the balance — given in command form — will be described in the following pages.

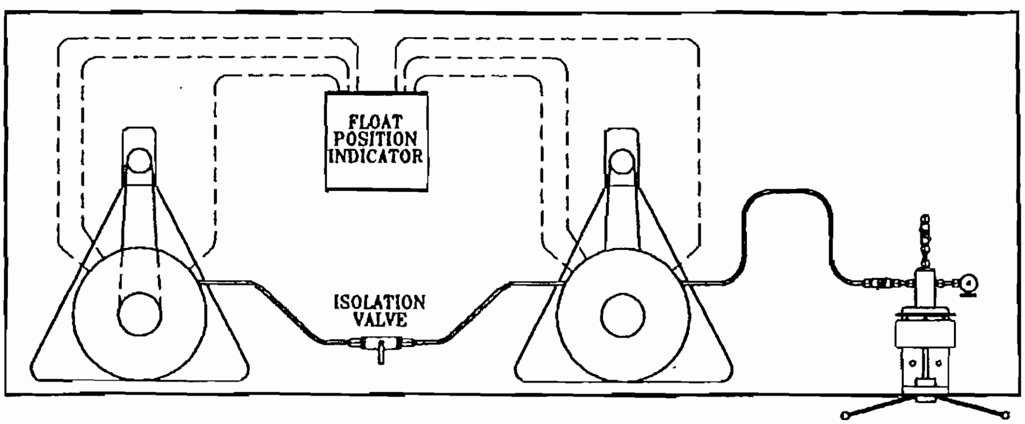

FIGURE B-2
COMPONENT ARRANGEMENT FOR CROSSFLOATING WITH FLOAT POSITION INDICATOR

When possible, it is preferred to conduct the calibration without the use of electric drive motors. The motors add heat to the instrument and increase the uncertainty in the measurement of the piston temperature. The drive belt and piston-driving sleeve should be removed from the gage so that the weights will spin freely with only the friction of the weight-loading table spindle and piston acting to decelerate the motion. When the stack of weights becomes small enough that there is insufficient momentum to carry the rotation through an observation, the driving mechanism should be reinstalled.

It is probably only a matter of preference whether the test gage is calibrated with increasing pressures or with decreasing pressures. Since the test gage has been disassembled for the cleaning operations and for the preliminary measurements, the newly-assembled gage should be subjected to its maximum pressure before the test is started. This pressure seats the components together with the maximum force and should eliminate the possibility of a change occurring during calibration as a result of improperly seated components. The pressure serves further to assist in exclusion of residual air by forcing it out around the piston and by driving it into solution. It is of some advantage, therefore, in starting the calibration at the greatest pressure.

The following procedures are based on the practice of beginning the calibration at the maximum pressure.

1. Load both gages with weights equivalent to the approximate highest test pressure. The weights should be applied in numerical order for reasons that be explained later. It is not important for either of the gages to have weights equivalent to an exact value of pressure because disturbances in the conditions that occur during the observations will result in variations in the pressure. The true pressure will be computed from observations at the time each balance is completed. Check the level vials for a change in the instrument that may have resulted from the applied load.

2. Open the isolation valve and pressurize the system until one of the gages rises to a floating position. It is convenient to have a particular group of weights on the standard instrument. If the group is used repeatedly for calibrations, the calculations for this group will be reusable and time will be saved in the measurement process. This practice requires the balancing or trimming to be performed on the stack of weights on the test gage.

   In the beginning, it will be found that the sink rates of the gages are unusually large. The unusual rate is a result of the shrinkage of the liquid having lost its heat. The heat is produced by the work of pressurization. A period of at least 10 minutes should be allowed for the heat to become distributed and for the system to become quiet. During this time, some preliminary balancing operations may be started.

   With the pump, raise the floating piston to a position near the top of its stroke and set the weights in motion. Test the state of the initial balance by pressing down on the floating weights. Adjust the weights of the test gage so that the balance is improved. Continue the adjustment until it is apparent that the systematic procedure should be started.

3. While the valve is open, adjust the floating position of the left gage piston with the pump (it may be the test gage or the standard) to a value between 24 and 28 on the

position meter. The starting figure for the sink rate measurement is 20; it is purely arbitrary. As the left piston sinks to the 20 mark, there will be time to adjust the right piston to match it.

4. Close the isolation valve.

5. The float position of the right piston must be adjusted for arrival at the 20 mark at the same time as the left one. If it happens that the right piston sinks more slowly than the left, it is likely that the final adjustment of the hand pump will be made by withdrawing the plunger. This situation is to be avoided because the slack in the pump spindle nut will be in the direction as to allow the plunger to creep out of the cylinder by the action of the pressure. A false sink rate will be observed. The final adjustment with the pump *must* be made with an advancing motion of the plunger.

   It is not necessary for each piston to be exactly at the 20 mark at the beginning of the measurement. A mental correction may be applied for one that is high or low.

6. Allow the two pistons to sink undisturbed. When the faster-sinking piston arrives at the zero mark, make a note of the position of the other.

7. Open the valve and adjust the position of the left piston to 4-to-8 units above its intended starting point. If the left piston was the faster-sinking one, the starting point will be 20. If it was the slower one, the starting position will be 20-x where x is the number of units noted in 6 above. Close the valve.

8. Adjust the right piston to a position that will allow both pistons to arrive at their starting points at the same time. Again, the final pump plunger motion must be in an advancing direction.

9. Open the valve when each piston is at its intended starting position.

10. Allow the two pistons to sink undisturbed. If they do not arrive at zero at the same time, make a correction in the trim weights on the test gage and repeat the operations 7 through 10.

    Wind currents, temperature ripple and body convection currents may disturb the process. Indeed, expansion of the oil in the connecting tube from an air current of different temperature can seriously affect the apparent sink rate of the piston. The operator should stand away from the table as the final test of observed.

    An advantage of the float-position balancing indicator results from the type of information displayed. The operator can complete the balancing operation without removing his eyes from the meters except when changing weights and adjusting positions for the next observation. When a satisfactory balance is obtained, the decision is made at the moment the two pistons are floating at their correct measuring positions. This condition is essential for good precision.

    The value for relative sink rates at one pressure may not necessarily be valid at other pressures. Cylinders of different designs and of different materials will have characteristic sink rates. The best work requires a determination of relative sink rates at each pressure level.

    The quality of a piston gage is judged by its sink rate and by its ability to detect small changes in pressure. The latter characteristic is called its resolution and is measured and recorded at each pressure point. Small weights, in decreasing size, are added to or subtracted from the group of weights until a weight added or removed no longer causes a perceptible change in the balance. The smallest increment that will produce a detectable change in the state of equilibrium represents the resolution of the entire system.

With the completion of the test for sensitiveness, the work of obtaining the first test point is finished except for releasing the pressure. Operation of the equipment should be carried out in a way as to insure maximum safety at all times. When raising or lowering the pressure of the gage, the hand pump should be turned slowly to prevent damage to the piston or its stops. If the pressure is changed too quickly, the piston is likely to be damaged by the sudden shock as the piston is stopped at the end of its travel. The isolation valve should be opened after each observation.

The pressure is reduced to a value somewhat less than the next test point and the rotation stopped that the weights may be counted and recorded.

11. The total weight load contributing to the pressure measured must be recorded with care. Each weight is identified by a number or a symbol and its individual mass is tabulated in the mass-section report. The symbols representing the weights are recorded on the data recording sheet and the number of individual weights in the stack is determined by count; the number of entries on the data sheet must agree with the counted number of weights. The tare mass must also be included in the count and tabulation. The process of tabulating, counting and verifying must be repeated to make certain that no mistake has been made.

    For convenience of reporting, the large platters should always be kept in numerical order and placed on the stack in that order. The values of the masses are listed as cumulative sums, and it is necessary to list only the first and last platters of the stack when tabulating on the work sheet. It is agreed that the first (1) and last (5) weights will be listed as "1-5", which means that the first and last weights are included in the group.

12. The gages may now be prepared for the next lower pressure. Certain precautions must be taken to assure the change to be made with safety. A rule that must be followed during the operation of any dead weight gage concerns the act of releasing the pressure after a measurement. The pressure must never be released by opening a valve or bleed screw, because if the piston is in a floating position, it will fall on the limiting stop and may be damaged. The pressure must be reduced by withdrawing the hand pump plunger until the piston is resting on the thrust plate or whatever stop is provided. Then, if it is desired to remove the pressure entirely, a valve may be opened.

    In changing the weights, care must be taken to prevent damage to the piston or thrust bearing as the weight is added or removed. If the weights are floating and one is removed quickly, the whole mass will be forced upward against the limiting stop, and the resulting shock may cause damage. A safe procedure is to reduce the pressure comfortably below the next lower test point before removing any weights.

    When the weights are added to the stack, they must be set down accurately and deliberately so that the pilot of the lower weight enters the recess of the weight being applied. If the weights are carelessly stacked, after years of service the edges of the nesting surfaces will become upset and the weights will no longer fit together. The resulting misalignment may cause the weights to hang with uneven axial load on the weight table.

B.8 THE TEST REPORT

Upon completion of the calculations and determination of the effective area at zero PSIG, a report must be compiled. The individuals for whom the gage was calibrated must be supplied with all the data that was obtained in the calibration. The accompanying format is an example of a report that satisfies these conditions for a particular gage.

Identification of the gage and/or piston calibrated and of the master to which it was compared are shown on the report. The identifying number and calibrating facility of the master gage are shown, in order that complete traceability to the National Bureau of Standards can be made at any time.

Values of mass for all the weights must be listed and the values qualified as to their unit of measure; i.e., grams, apparent mass versus brass standards.

The effective area of the piston for zero PSIG must be given with its corrections for change with pressure and temperature. The reference plane of the piston, to which all measurements must be reduced, is noted.

Finally, a statement concerning the accuracy and precision of the determination must be made in order that the technician using the gage may evaluate subsequent measurements.

The usual manner of denoting the accuracy of a piston pressure gage is expression of the expected error of a single measurement as a percentage of the quantity being measured or as some minimum value of pressure—whichever is greater. Some level of confidence must be chosen that will give the accuracy figure a realistic meaning. If it is reported that the figure is based on the sum of the estimated systematic errors and two standard deviations of the variability of the calibrating process, the user may infer that, for 95 measurements out of 100, his error may not exceed the stated value. All of the uncertainties preceding the test are accumulated and shown as the systematic error for the area of the reference piston and for the mass of the weights used in the test. In estimating the uncertainty of the area of the test piston, the uncertainties of each of the following quantities contribute:

Area of the Reference Piston

Mass of Weights on Reference Piston

Mass of Weights on the Test Piston

Precision of the Comparison

Piston Temperatures and Relative Axial Tilt

Although the last two listings are likely to be of random character, their contribution to the uncertainty of the test piston area is small. The errors arising from these effects are added numerically to those of the remaining quantities rather than being added vectorially.

THIS PAGE INTENTIONALLY LEFT BLANK

RUSKA INSTRUMENT CORPORATION
DEAD WEIGHT GAGE CROSSFLOAT DATA TABULATION

DATE ____________

PURCHASED BY ____________ MFR. ____________ MODEL ____________

RANGE ____________ JOB ____________ OBSERVER ____________

STANDARD GAGE S/N ____________ TEST GAGE S/N ____________

PISTON S/N ____ WT. SET S/N ____ "A" WT.S/N ____	PISTON S/N ____ WT. SET S/N ____ "A" WT.S/N ____
PISTON TARE SURFACE TENSION* ____ (a) TOTAL TARE	PISTON TARE SURFACE TENSION* ____ (a) TOTAL TARE
THERMOMETER S/N ____ CORRECTION ____	THERMOMETER S/N ____ CORRECTION ____

TEST	NOM. PSI	MASS LOAD	TARE	OBS. CORR	ROTATION	MASS LOAD	TARE	OBS. CORR	RES. PSI	AIR TEMP
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										

ROTATION OF STANDARD PISTON CLOCKWISE
ALL TEST POINTS

* If the piston mass is to be corrected for gravity and buoyancy, the surface tension forces may be included in the correction without introducing significant error.

FORM ENG-361-C 8/86

STATEMENT OF ACCURACY—PISTON PRESSURE GAGE

MODEL: SERIAL NO.: PISTON: DATE: ____________

This calibration was made by intercomparing the above Dead Weight Gage with Ruska Instrument Corporation Laboratory Gage Piston No. ________. This piston is referenced to National Bureau of Standards Test Number ____________________, which was issued for the standard piston at Ruska Instrument Corporation.

The systematic error in the reported value of Ao is estimated to be _____ parts per million. The standard deviation of the measurement process variability for ______ independent observations is _____ PPM. The uncertainty in the reported value of b is estimated to be ________________. The reported value of mass for the sum of the tare components is estimated to be correct within _____ PPM and is referenced to NBS Test Number

All tests were conducted in a controlled environment and with instrumentation adequate for assurance that the reported values are reliable.

JOB No. ________________________________

APPENDIX C

TEMPERATURE EFFECT ON PISTON PRESSURE GAGE SYSTEMS

Piston Pressure Gages are temperature sensitive and therefore must be corrected to a common temperature datum.

Variations in the indicated pressure resulting from changes in temperature arise from the expected change in effective area of the piston. Treatment, therefore, is a straightforward application of the thermal coefficients of the materials of the piston and cylinder. By substituting the difference in the working temperature from the reference temperature and the thermal coefficient of area expansion in the relation

$$A_{o(t)} = A_{o(Ref.t)}(1 + C\,\Delta t)$$

the area corresponding to the new temperature may be found.

In the equation above,

$A_{o(t)}$ = Area corrected to the working temperature.

$A_{o(Ref.t)}$ = Area of the piston at zero PSIG and at the selected reference temperature.

C = Coefficient of superficial expansion as indicated in the test report.

Δt = Difference between working temperature and reference temperature.

The magnitude of error resulting from a temperature change of 5°C for a tungsten carbide piston in an alloy-steel cylinder is approximately .008% (Refer to Table C-1).

PISTON METAL	CYLINDER METAL	CHANGE OF A [illegible] °C CELSIUS
Tungsten Carbide	Tungsten Carbide	9.1×10^{-6}
Tungsten Carbide	440C Steel	1.5×10^{-5}
440C Steel	440C Steel	2.0×10^{-5}
440C Steel	Bronze	3.0×10^{-5}

TABLE C-1

TEMPERATURE EFFECTS ON VARIOUS SYSTEMS

C = (Coefficient of Expansion of Piston Metal + Coefficient of Expansion of Cylinder Metal).

For work of high precision, gage temperatures are read to the nearest 0.1°C.

THIS PAGE INTENTIONALLY LEFT BLANK

ADDENDUM A
VACUUM OPTION

1.0 GENERAL

The function of the Ruska 2455 Vacuum Option is to provide accurate measurements of the vacuum levels when Piston Pressure Gages are operated in the absolute mode. The option contains three pieces, a solid state vacuum sensor, an electronics module, and a connecting cable. The 2455 will support up to two of these vacuum options.

2.0 THEORY OF OPERATION

The vacuum sensor is a solid state thermal conducting balanced Wheatstone bridge which maintains the sensor at 20°C above ambient temperature at all times. As gas pressure is reduced less power is required to maintain the 20°C temperature differential. The electronics module generates the required power level. It monitors this power level and linearizes it. The output is fed to the 2455 as a voltage level. This level is measured by an A/D converter in the 2455.

3.0 PREPARATION FOR USE

The option contains three pieces, a solid state vacuum sensor, an electronics module, and a connecting cable. The vacuum sensor comes with a 1/8" NPT fitting. Apply Teflon tape and screw the fitting into the Piston Pressure Gage housing using whatever adapters are required for the particular application. The electronics module mates directly to the sensor. The 15 pin D connector of the cable plugs on to the electronics module. The 5 pin DIN connector on the cable is plugged into either VACUUM A or VACUUM B on the rear of the 2455 depending on which channel you wish to monitor.

WARNING: DO NOT MAKE ANY OF THESE CONNECTIONS WITH POWER APPLIED TO THE 2455. THE SENSOR CAN BE DESTROYED.

4.0 LOCAL OPERATION

Vacuum for each enabled channel is displayed on the top level screen of the 2455. The units screen can be used to change the units of vacuum, pressure, and density. The F3 key, labeled 'VAC' toggles between µHg and mTorr.

5.0 REMOTE OPERATION

Three remote query commands are available to support the vacuum option. These are shown in table AA-1

TABLE AA-1
REMOTE COMMANDS

MESSAGE FROM HOST	RESPONSE
VR	VR,<chan A vac>,<chan B vac>
VRA	VRA,<chan A vac>
VRB	VRB,<chan B vac>

6.0 SPECIFICATIONS

Specifications for the vacuum option are shown in table AA-2

TABLE AA-2
VACUUM SPECIFICATIONS

PARAMETER	SPECIFICATION
Warm up time	15 minutes
Range	1µHg to 10,000µHg
Operating temperature	0°C to 50°C
Repeatability	10µHg @100µHg
Sensor volume	<0.7 cc
Sensor position	Any

7.0 CALIBRATION

Calibration of the vacuum option is a two point calibration. The electronics module has two potentiometers labeled 'ATMOSPHERE' and 'VACUUM'. Lower the pressure as low as possible, preferably below 25µHg. Adjust the vacuum pot for a 25µHg reading on the 2455. Set the pressure to about 9000µHg and adjust the atmosphere pot for a similar reading on the 2455. Repeat this process until the correct readings are observed with no adjustment.

ADDENDUM B
AIR DENSITY OPTION

1.0 GENERAL

The air density module measures barometric pressure, relative humidity, and air temperature. These measurements can be used to correct for variations in air density when using Piston Pressure Gages.

2.0 THEORY OF OPERATION

The barometric pressure transducer is a piezoresistive monolithic silicon shear stress strain gage. It is internally temperature compensated. Its voltage output is measured by a 16 bit A/D converter. The relative humidity sensor is a monolithic IC using a capacitive polymer to sense humidity. It is temperature compensated in software. Its voltage output is measured by a 16 bit A/D converter. The temperature sensor is a thin film platinum 1000 ohm RTD. It is driven by a 0.8 ma constant current source. The voltage across the RTD is measured by a 16 bit A/D converter.

3.0 PREPARATION FOR USE

The air density module is a self contained package which is designed to be plugged directly in the 2455. It has a single 25 pin D-Sub connector with thumb screws. To install the unit turn power off on the 2455. Connect the module to the connector on the 2455 labeled external module. Tighten the thumb screws. Turn power on. Never connect or disconnect this module with power applied.

4.0 LOCAL OPERATION

The top level screen of the 2455 has the F2 key marked 'AIR DEN'. Pressing the F2 key brings up the air density display. If no air density module is detected that fact is displayed. The air density screen displays density, temperature, barometric pressure, and relative humidity. The units screen can be used to change the units of temperature, pressure, and density. The F1 key toggles between degrees C and degrees F. The F4 key, labeled 'PRES' toggles between mbar, psi, kPa, kg/cm^2, mmHg, cmHg, and inHg. The F5 key, labeled 'DENSITY', toggles between kg/m^3, lb/in^3, and g/cm^3.

5.0 REMOTE OPERATION

Five remote query commands are available to support the air density option. These are shown in table AB-1.

TABLE AB-1
REMOTE COMMANDS

MESSAGE FROM HOST	RESPONSE
ABP	ABP,<baro pressure>
ABT	ABT,<ambient temp>
ABH	ABH,<%RH>
ABD	ABD,<air density>
AB	AB,<baro pressure>,<ambient temp>,<%RH>

Note that ABP returns pressure in kPa while AB returns pressure in psi. Temperature is always returned in degrees C. Relative humidity is returned in %RH. Density is returned in g/cm^3.

6.0 SPECIFICATIONS

Specifications for the air density option are shown in table AB-2

TABLE AB-2
AIR DENSITY SPECIFICATIONS

PARAMETER	SPECIFICATION
Warm up time	15 minutes
Operating temperature	10°C to 40°C
Pressure Range	11.5 to 16.5 psi
Temperature Range	18 to 28 °C
Relative Humidity Range	10 to 90 %
Pressure Accuracy	5 mmHg
Temperature Accuracy	2°C
RH Accuracy	15%

7.0 CALIBRATION

Place the ADM module in the proper chamber and connect it to the 2455 using the extension cable. Allow the unit to warm up for at least 30 minutes. Press the MENU function key F1. If the ADM is detected F5 will say 'AIR DEN'. If not check the connections or replace the faulty link. Press the F5 key F1 is now 'BARO', F2 is 'RH', and F3 is 'TEMP'. The procedure for each is very similar so only the first will be detailed. Press the F1 key to calibrate barometric pressure. The 2455 will prompt for the calibration password. Enter '0547' by using the arrow keys. Left and right arrows move between digits and up and down arrow keys increment and decrement the digit. Press 'ENTER' when done. The screen now displays the current slope and offset coefficients. F1 allows the 'SLOPE' to be entered. F2 allows the 'OFFSET' to be entered. F5 performs a one point calibration and F6 performs a two point calibration. Select a two point calibration by pressing F6. Set the chamber pressure to 11.5 psia ±0.5. Then enter the exact pressure. Now set the chamber pressure to 16.5 psia ±0.5. Then enter the exact pressure. Record the pressures and the slope and offset coefficients on the report form. The previous key allows moving up to the top level calibration menu. Repeat the above procedure for temperature and relative humidity. Temperature must be calibrated before relative humidity. For temperature use 18±0.5 degrees C and 28±0.5 degrees C. For relative humidity use a vacuum to achieve 0% humidity and ambient room humidity for the second point.

NOTES