DELTA-*C*
TECHNOLOGIES INC.

WATER-IN-OIL ANALYZER
MODEL DC-1500 & DC-3500F

Multi Curve

Instruction Manual

Created - June 27, 2001
Rev 0.1 - April 1, 2002

Delta-C Technologies Inc.
Enderby, BC, Canada
V0E 1V0

Telephone	(250) 838-6590
Fax	(250) 838-6072
e-mail	doublet@delta-c.com
Web site	http://www.delta-c.com

TABLE OF CONTENTS

1.0 INTRODUCTION

The Type DC-1500/DC-3500F analyzer consists of a microprocessor-based electronics unit mounted on a caged probe. A 1000 Ohm RTD assembly is mounted in the probe and provides a temperature input to the analyzer.

The analyzer uses the capacitance principle. A cylindrical sensor and outer barrel are fixed in size and distance from each other and form the electrodes of a coaxial capacitor. The oil sample flows between the "plates" as a dielectric fluid, changing the capacitance of the assembly proportionally with the change in dielectric constant of the fluid. The measured capacitance is converted to a water content output signal by the microprocessor and associated components.

Although the capacitance approach to the measurement of water in oil is sound in principle, previous methods have had limited success. This is caused by the difficulty of measuring the small capacitance change of a large standing value and implementing accurate compensation for the effect of temperature changes on the dielectric constant. Indeed, some instruments do not even make the effort. In any measurement system, accuracy depends on the number and stability of the components involved in the signal chain. Analog circuits used in other instruments (even those that incorporate digital displays) have, of necessity, many components that add errors at each stage of the signal processing with the consequent inferior performance.

In contrast, the DC-1500/DC-3500F analyzer's design reduces the primary dependency to a single component whose characteristics are known and well controlled. This, and the application of sophisticated algorithms, using a microprocessor, allows the DC-1500/DC-3500F to deliver stability and accuracy unmatched by others. A further benefit of this instrument is that it can be used to accurately determine variables necessary for its own calibration.

Temperature compensation is provided by an RTD input to the microprocessor. The RTD input shifts the calibration curve in the microprocessor, proportionally with a change in temperature. This shift is assumed to be linear with small temperature changes and small water percentages.

1.1 Multi curve operation

To accommodate various density oils, three separate calibrations and alarm settings are available.

Each curve is fully independent of the others as are the alarm settings. All other functions such as analog output are common, that is, there is only a single 4 – 20 mA output calibration.

Current active curve is indicated by a bracketed number at the beginning of the command line like this:

[1] Command (? for help) >

Also, when commands like **DB** are executed, the curve number is displayed at the end of the line as follows:

Display BS&W - Curve #[1]

Selection of the curves is available only through the serial port using the command **SC .**

1.2 Updating the program

The program in this instrument is stored in flash memory, which means that the user is able to upgrade to newer versions as they may become available. This requires a computer that has a terminal program that can download text files. For Windows operating systems this can be Terminal or HyperTerm as provided for Windows 3.1 and Windows 95 respectively. The user is directed to the terminal program's Help facilities for a detailed explanation of how it operates.

NOTE: When changing settings, such as baud rate, in HyperTerm, it must be in the disconnected mode!

The DC-1500 analyzer's program is in fact two programs, one is a loader program that is always present and the other is the actual application that performs the measurement function.

The special commands are not explicitly shown on the help screen because the inadvertent execution can remove the measurement function, so, one should be very sure that it is indeed intended.

To upgrade a unit that is already running the BS&W application,
do the following -

1. Type the command **Z** (upper case).

The unit should respond with **Run Boot Loader (Y)?**

2. Type **Y** (upper case).

The unit should respond with

Booting down ...
*****
Boot Address = 0x1010
Flash ID = 0x22DF
LDR Loader
Jun 21 2000 @ 23:28:48
LDR >

3. Type the command **L** to erase the application and load the new application.

The unit should respond with

Erase existing program and load new program
Are you sure (Y)?

4. Type **Y** (upper case)

This will erase the application area to prepare it for a download.

The unit should respond with

Erasing device . . .

and after a few seconds, the unit should respond with

Erased
Load Program

The erasure operation takes less than 10 seconds.

5. Send the new BSW program using the **Send Text File** transfer function of the terminal emulator.

Do not use the binary transfer option.

The unit will respond with strings of dots

,.................

while the application is downloading.

It may take three to five minutes for the download to be completed and the string of progress dots may not be displayed at a steady rate with some terminal programs; please be patient.

At the end of the download, the unit will respond with

Start @ 0x88000
FLASH : 29,616
Total : 41,219 bytes
Check = 0x012F1728
LDR >

Note - the Start value will always be 0x88000 (for the BS&W).

The other values will be different with future versions of the application.

6. Type the command **G** to start normal operation of the analyzer.

Of course, the unit can also be restarted doing a power down and up.

If the concluding information (Start @ 0x88000 …..) does not appear in five minutes, something has occurred to stop the transfer and the unit should be powered down and up again and Program cycle should be re-started again.

2.0 ASSEMBLY AND INSTALLATION

2.1 Sensor Assembly

Assembly Instructions:

If the analyzer needs internal cleaning and this can not be done by back flushing with a solvent, do not try to disassemble the unit at the installation site. Disconnect all piping and electrical connections and take the unit to the shop to allow for proper re-assembly.

When re-assembling make sure that all the O-rings are clean and covered with heavy grease before tightening the threaded connections.

Some threaded connections should not be undone after initial factory installation. These connections are on both ends of the 1.25” conduit nipple (Part #18) and on both ends of the sensor barrel (Part #05) to the 2” collars (Part #06). All mentioned threads are secured with "Threadlock" compound.

When disassembling the sensor, remove the electronic module first to prevent damage to the RTD temperature probe.

When ready to reassemble, after cleaning the parts, start at the bottom end by clamping in the lower end cap in a bench vise. Do not forget to install the compression spring before the insulator is inserted in the end cap.

Take the sensor barrel with the two collars and screw one end onto the end cap; it does not matter which end. Gently tighten the 2” threaded connection while making sure that the shoulder of the collar seats firmly on the end cap.

Now, install the sensor plug by inserting it from the top end of the barrel, making sure that the end of the plug fits into the hole of the lower insulator.

Test the spring action by pushing down on the guide tube and be sure that the 1/4" O-ring is in place on the guide tube.

The upper end cap is still attached to the 1.25” conduit nipple and the electrical housing.

Inspect the 1.5” O-ring between the upper insulator and inside the upper end cap and apply ample amounts of grease to the O-ring. There should be good lubrication at this point. Make sure no grease
is allowed to spill on top of the insulator as this will attract moisture between the guide rod and the surrounding metal causing measurement drift later.

Before inserting the top insulator in the seal housing prepare the installation of the RTD sensor in the insulator by applying a drop of heat conducting grease in the thermowell hole in the insulator. The RTD must be properly anchored in the thermowell by inserting a small piece of solid plastic wire insulation or equal on top of the RTD.

The plastic wire should have an OD= to 0.1 inch to get a proper friction fit. The length of this plastic insulation should be about 0.75 inch long.

After inserting the insulator, line up the RTD wire with the electrical enclosure, as shown in figure 1, and make sure it stays this way when tightening the threaded joint.

Now lift the electrical enclosure and upper end cap with insulator, and slip the subassembly over the guide tube.

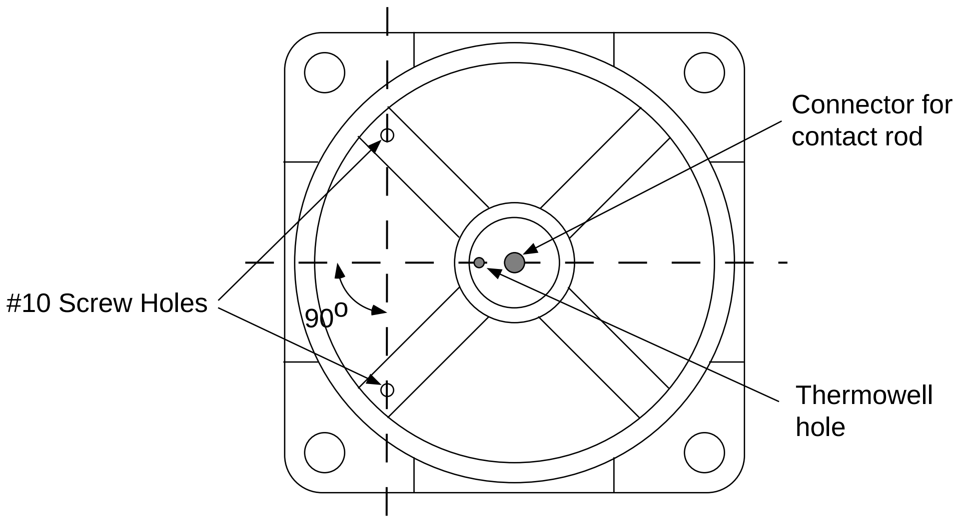


Figure 1 Thermowell hole alignment to case

Note: Thermowell hole in the insulator must be on a line that is at 90° to the line through the #10 mounting screw holes.

Now lower the module to the bottom of the enclosure while making sure that the bronze contact rod has a slight friction fit when inserted into the guide tube and that the RTD element stays inserted in the insulator. The RTD wire is pulled through the slot in the mounting bracket. Gently pull on the wire to test if the RTD stays in the thermowell hole.

Do a hydraulic pressure test up to 3240 psig and check for leaks. Hold for 5 minutes.

2.2 Analyzer Installation

Mechanical Installation

The analyzer is normally installed in a vertical position with flow from bottom to top. This helps prevent the accumulation of gas bubbles in the probe assembly.

An adequate circulation rate is required to prevent water separation in the probe assembly.

For oil service, a minimum rate of 4 USGPM is recommended. If the oil has a high wax content a flow rate of 20 GPM may be required to prevent wax built up on the sensor elements. The cross sectional flow area of the sensor is about 0.75 sq. inch.

For condensate service, a minimum rate of 9 USGPM is required. This liquid has a tendency to separate from any free water quite easily and high flow rates through the sensor will help to prevent this from happening.

The maximum rate is limited by the amount of driving force available. However, care must be taken to prevent any gas breakout of volatile liquids with a low bubble point in the probe assembly caused by very high flow rates.

A sample stream of liquid is normally passed through the probe assembly. The driving force can be supplied by a small pump, by a restriction in the main line, or by a pump discharge to suction by-pass loop (see figure 8.) The user must be sure that this sample represents a true composition of the main line flow.

The unused top connection of the sensor is a convenient location to install a sample draw-off/vent valve.

Electrical Installation

The Type DC-1500/DC-3500F analyzer has been designed for installation in a Class I, Div. 1, Gr. C&D area. The electrical installation must conform to the requirements of applicable local electrical codes.

Refer to Figure 4 for details in the terminal connections.

Power Supply

Terminals #1 and #2 are provided for the power input with #1 as negative and #2 as positive. The power supply voltage required is between 18 and 28 V DC and can be grounded or ungrounded. The power supply input is fully isolated from ground to allow use of standard ground fault detectors in D.C. power systems. An internal self-resetting fuse protects against catastrophic failure, no spare fuse is required.

Densitometer input

This instrument is designed to accept a frequency input from the Solartron family of densitometers. For hazardous area application, an intrinsically safe barrier must be used. This is described in the densitometer user's manual. Note that only the exact type of specified barrier may be used.

Analog Output

Terminals #5 (negative) and #6 (positive) are used for 0/4 to 20 mA output. The DC-1500/DC-3500F powers the loop. To prevent ground loop problems, the analog output is fully isolated from instrument ground. Maximum loop load is 600 Ohms.

RS-232C I/O

Terminals #7, #8 and # 9are provided for RS-232C communications. Terminal #7 is common, terminal #8 is RD and terminal #9 is TD. The analyzer is the computer and the configuring device is a "Dumb Terminal". The "Dumb Terminal" should have a screen with a minimum of 8 lines and 65 characters per line. If the configuring device is a computer, a program such as "Kermit" or "Procomm" or "Terminal" or "HyperTerm" may be used to emulate a terminal. When computers are used as terminals RD and TD must be reversed when wiring the RS-232C port. It is recommended that shielded cable be used between the terminal and the analyzer with no less than 20 AWG conductors and not exceeding 300 feet in length.

RS-485 I/O

Terminals 10 and 11 are used. Terminal 11 is the A line terminal 10 is the B line according to RS-485 convention.

Temperature Input

Terminals #12 and #13 are used for the temperature sensor input connections. To test the RTD, disconnect it and measure the resistance and temperature. Then consult the RTD tables.

Relay Contacts

Terminals #14 and #15 provide a normally open contact. This contact is isolated and rated for 2 Amps @ 24V DC non-inductive load.

An inductive load snubber is required to prolong the life of the relay contacts. An inductive load is a load like an external relay or an electric solenoid valve that has a coil. A suitable snubber for a DC coil would be a diode whose cathode is connected to the more positive terminal of the coil.

The Electrical Code allows only AC and DC voltages of less than 30 volts for this instrument.

Do NOT attempt to use any higher voltage.

A suitable 2.5 amp fuse in the "hot" supply circuit should be used to protect the relay and circuit board traces against accidental burn-out.

To provide fail-safe operation, a normally open contact is provided. When the unit is powered up and the water content is below the alarm point, the contacts will be closed. On power failure or measurement above the alarm setpoint, the contacts will open and trip the user's annunciator.

3.0 CALIBRATION THEORY

For low water content, in the range of 0 to 10%, the variation of dielectric constant with water concentration may be considered to be linear and is of the form:

$R = ax+b$

where

R = ratio value proportional to dielectric constant

x = concentration of water in oil

a = slope

b = intercept

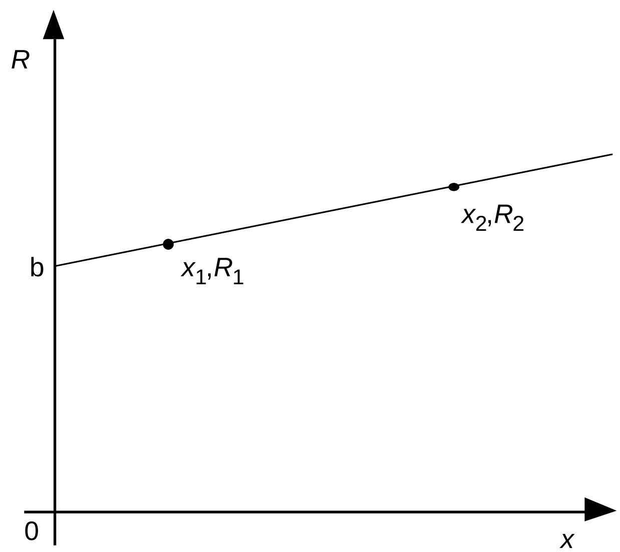


Figure 2 Ratio vs. water content

To completely characterize the curve, two known points are necessary. These are shown in Fig. 2 as x_1, R_1 and x_2, R_2. During the calibration process, the DC-1500/DC-3500F analyzer measures R_1 and R_2 and the corresponding x_1 and x_2 values are supplied by the operator.

This equation, by itself, is not adequate for measurement because the dielectric constant is also significantly affected by the oil temperature. The dependency, for most oils, is negative, such that the dielectric constant decreases with increasing temperature.

The combination of the two effects describes a plane as shown in Fig. 3 below:

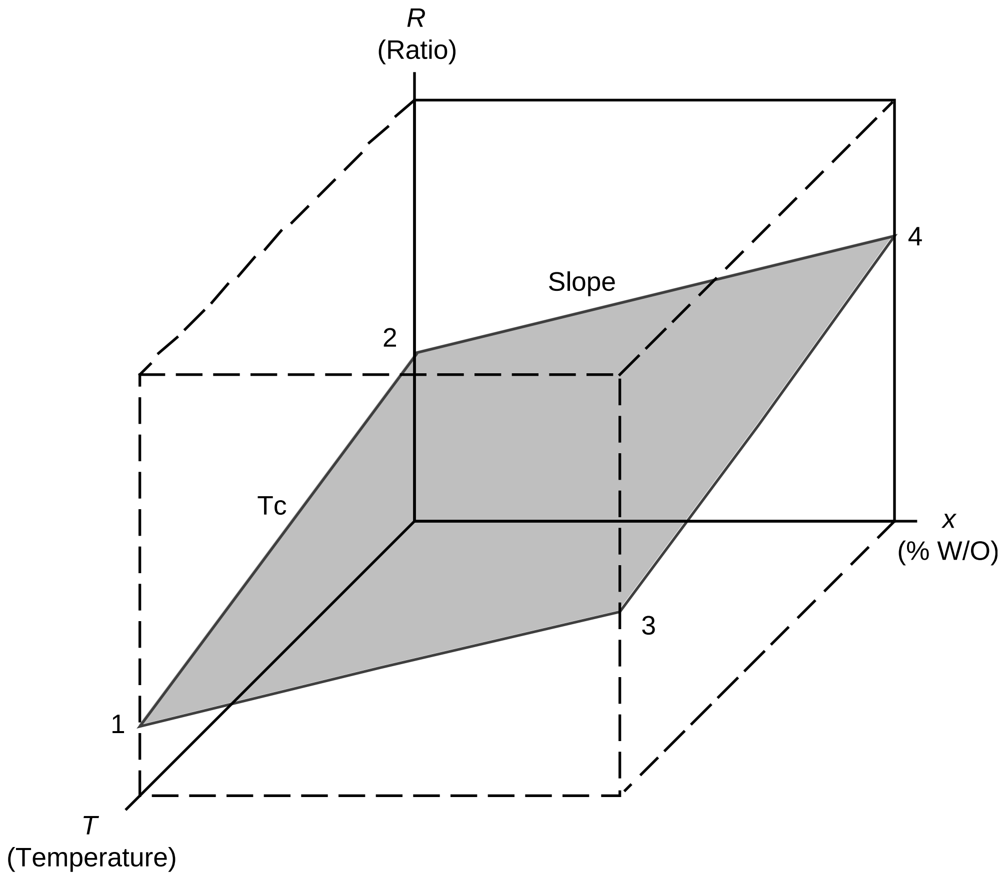


Figure 3 Ratio vs. water content and temperature

The correspondence to Figure 2 is that the temperature variation simply shifts the curve up and down in the *R-x* plane. The additional information required is the temperature compensation, which, along with the temperature measurements, characterizes the plane. The section on Temperature Compensation describes how to use the Analyzer to measure this factor accurately.

4.0 CALIBRATION

4.1 Operator Interface

The analyzer software is a menu driven system where all tasks related to calibration or viewing guide the operator through the process by lists of questions. Whenever a value is required the unit of measurement is shown. For example, when the alarm delay is to be set, the menu question will show that the number is in units of seconds (the operator does not have to type the units, in this case "sec").

Some special keys are used by the analyzer:

(esc) The key marked ESC
(cr) The key marked ENTER or RETURN
(bs) The key marked BS., BACKSPACE or the left arrow
(del) The key marked DEL or DELETE

The following general rules apply to the operation of the analyzer:

1. Typing (esc) aborts the current command and **leaves previous values intact**.

2. Whenever a number is required, the following keys are allowed: 0 through 9

(.) decimal point
(bs) erases last entered character
(del) erases last entered character
(esc) abort numeric entry return to command level
(cr) accept current number

If no new numbers have been typed on the current line, then it will retain the old value. This is a way to examine previous calibration values without disturbing anything.

3. Whenever Y/N is required, the following keys are valid:

(Y) accepts the current values
(N) leaves the old information intact and moves to the next question
(cr) leaves the old information intact and moves to the next question
(esc) aborts the current command without changing previous values.

When the monitor is waiting for a command, the following is displayed:

Command (? for help) >

4.2 Calibration

The analyzer is calibrated with a computer terminal, using an RS-232C interface. Calibration should be carried out in the following sequence:

1) Determine Temperature Compensation of the fluid.

2) Perform Water Content Calibration using either "Calibrate Full" or "Calibrate Simple".

3) Perform analog output calibration and alarm relay calibration if desired.

A menu is available on the computer terminal that displays the available commands. This menu is accessed by typing the key **?** and displays :

CS - calibrate simple
CF - calibrate full
CO - calibrate output
CT - calibrate temperature
CD - calibrate density
SA - set alarm
SB - set BS&W averaging
SO - set output averaging
ST - set temperature averaging
SD - set density averaging
SU - Set units
SC - Select curve
DB - display BS & W
DC -display/modify Calibration
DI - display information
<ESC> - exit/abort

The calibration steps and these commands are explained in greater detail on the following pages.

Temperature Compensation

An emulsion of water in oil exhibits a temperature dependency such that an increase in temperature causes a decrease in the mixture's dielectric constant. This decrease is a zero shift and shows as an apparent decrease in water content of approximately 0.03% water per °C.

In order to compensate, the DC-1500/DC-3500F Analyzer is able to measure the oil temperature in the measurement cell. It measures the temperatures during calibration, calculates normalization factors and applies a supplied correction factor so that the correct water content is measured.

The instrument may be used to determine, very accurately, the correct temperature compensation factor.

Although the temperature factor above is shown in terms of % water per °C, for purposes of transferability, the DC-1500/DC-3500F uses the units of % per °C. This is in fact the percent change in dielectric constant (dimensionless) per degree Celsius.

To determine the temperature compensation factor proceed as follows:

Provide the means to circulate dry oil, the identical type that is used in the field measurement, through the measuring cell and a means to heat the oil.

Start circulating cool oil at normal ambient conditions.

Use the command **DB** to display water content, temperature and R (R is a raw measurement value directly proportional to the dielectric constant). These are displayed in the order as above from left to right.

Ignore the water content value (the instrument need not be calibrated for this procedure) and note the temperature and R value until they stabilize.

When stable, record the temperature as T_1 and R as R_1.

Apply heat to raise the oil temperature by 10 or more degrees Celsius and wait until the temperature has stabilized. Usually a fast and steady oil circulation in a closed loop will increase the temperature, provided that the sensor is well insulated.

Record the new temperature as T_2 and R as R_2.

Solve the equation $R = aT + R_O$ as follows:

$$a = \frac{(R_2 - R_1)}{(T_2 - T_1)}$$

$$R_o = R_2 - aT_2$$

Then, the temperature compensation factor (T_c) is determined:

$$T_c = 100a/R_0 \quad \text{in percent}$$

Record the temperature compensation factor. It will be entered into the Analyzer during the water content calibration step.

Typical values for T_c are:

				T_c
Gravity	0.95	to	1.00 gm/cc	-0.01
Gravity	0.80	to	0.95 gm/cc	-0.03
Gravity	0.50	to	0.80 gm/cc	-0.05

Because of the wide variation in T_c, it is desirable to test the oil rather than rely on the above estimates.

The dimensionless units of T_c are in terms of %R/°C.

Please note that the T_c combines the temperature coefficient of the sensor and the oil. The sensor Tc has a positive slope and the oil has a larger and negative slope. For some of the heavier crude oils it will appear as if the T_c is zero, but actually the two T_cs cancel each other.

CS - Calibrate Simple

There are instances when the instrument is installed and it is not possible to perform a proper two point calibration but one still wishes to operate the monitor.

The **CS** calibration function provides for just such cases, however, performance is less accurate for this mode than the specifications. Even so, the intelligence built into the DC-1500/DC-3500F allows the addition of accurate data to bring calibration to full accuracy at a later date.

This mode is a single point calibration using one measurement and an intelligently estimated slope value supplied by the operator.

To calibrate the instrument using the single point method and proceed as follows:

At the top command level type **CS.**

Machine responds with:

Calibrate Simple - Curve #[1] (Number will reflect curve in use)
Measure point now (Y/N)?

At this point, a sample of the oil should be drawn and Type **Y**.

The response is to display the raw value R and the temperature followed by the next prompt.

Water Content (%)?

Type in the known water content (the % character does not have to be typed) and **(cr)** which advances the menu to:

Slope (dR/d%)? **(Water slope Figure 3)**

An intelligent estimate of the slope must now be supplied. If it is not known, then use an estimate of 0.030 for common crudes.

The next menu item is:

Temperature Compensation (%/C, SIGN REQUIRED!)?

(Temp slope Figure 3)

Type in the compensation value, if not known use -0.030 for light crudes.

NOTE! The temperature compensation value entry requires the negative sign if the coefficient is negative.

Next prompt is:

Done (Y/N/esc)

Type **Y** if satisfied with calibration, **N** if any changes necessary or (esc) to abandon updating the operating memory values.

If the user simply wishes to review the calibration values, enter **CS** and type a **(cr)** for every prompt to display the values. At the last prompt, type **(esc)** to return to the top command level.

CF - Calibrate Full

This is the normal, full-accuracy calibration method for the DC-1500/DC-3500F Analyzer. It allows partial calibration to be done as circumstances permit, then, when all required values are known, the working coefficient memory may be updated.

With this advanced method, laboratory standard calibration can be achieved for the actual oil in use, by drawing samples during this process, analyzing them in the lab and entering the results into the monitor at a later date. All data is stored in non-volatile memory so that partial calibration data is not affected by power failures.

Before calibration, make sure that samples can be drawn for analysis and that the oil contains some water for at least one of the two calibration points.

For full calibration, proceed by typing **CF**; the response is:

Calibrate Full - Curve #[1]
Measure Point #1 now (Y/N)?

Now, draw a sample of oil for analysis, and while drawing, type **Y**.

Record the displayed R value as R_1 and temperature as T_1.

The next prompt is:

Water content #1 (%)

If the value is known exactly (as may be the case for lab test stands) type it in, followed by **(cr)** to store it in memory. Otherwise type **N** for entry at some later date.

Similarly, follow the above procedure for point #2.

The last prompt for data is:

Temperature Compensation (%/C, SIGN REQUIRED!)?

NOTE! The temperature compensation value entry requires the negative sign if the coefficient is negative.

Type in the correct value, then **(cr)** to advance to:

Done (Y/N/esc) ?

If all values have been entered, type **Y**. This places the data in working memory. If calibration is incomplete, type **(esc)**. The missing data will be entered later.

If any item needs to be modified, type **N**. This will begin the CF procedure again.

It is also advisable to keep a permanent written record of the calibration values in case of accidental modification or instrument repair (but not replacement). Using the DC (Display/Modify Calibration) command, all calibration data can be restored by typing in previously recorded values.

If a mistake has been made, but records were kept, use (esc) to abort and restore the data using the DC command. This avoids the need to repeat the full calibration procedure.

CO - Calibrate Analog Output

The analog output of the DC-1500/DC-3500F Analyzer requires a stable current meter to measure the current during calibration. The meter's accuracy should be in the 4 1/2 digit class because the monitor output is very stable and has a resolution of 1 part in 65,536 or 0.0015% of full SPAN.

Typing **CO** will show:

Calibrate - Output
Zero Scale Output (%)?

The question being asked is what water content should represent zero scale value.

This could be 0.00% or some elevated span zero such as 2.00%.

The desired value should now be typed followed by a **(cr)**. If the existing value is only to be examined, press the **(cr)** only. Next prompt is:

Full Scale Output (%)?

Similarly, type in the water content for full scale output or just a **(cr)** to examine current value.

Next prompt is:

Calibrate Zero (Y/N)?

At this point the monitor is asking if you wish to proceed with trimming the output at 4 mA. or any other value to match the display scale. If **N** is typed, it will proceed to the full scale trim, **(esc)** aborts, leaving previous calibration intact.

Typing **Y** shows the following HELP instructions:

Use one of the following:

U **increase output (coarse)**
u **increase output (fine)**
+ **increase output (nudge)**
D **decrease output (coarse)**
d **decrease output (fine)**
- **decrease output (nudge)**
<cr> **to accept calibration**
<esc> **to abort calibration**

Each press of the upper case **U** increases the current output; for fast change use the auto key repeat (available on most terminals) by holding the shift and the U key down. Once the output is close to the desired 4 mA. value, use the lower case u to reach it at a slower rate. For very slow, exact adjustment, use the + and - keys

When satisfied with the zero value, press the **(cr**) to bring up the next prompt:

Calibrate Full (Y/N)?

As for the zero trim, use the **U, u, D, d, + and -** keys to reach the desired value followed by a **(cr)**.

Now the prompt is:

Done (Y/N/esc)?

Typing **Y** completes the calibration and places the values into permanent memory.

It may be noted that 4 mA. is not the lower limit of the current output, but is in fact 0 mA. If so desired, the low end could be set to any value.

For units with serial numbers 0014001 to 0014100, built in limiting holds the current output between 4 and 20mA.

Similarly, the full scale output may be set at any value with an upper limit of about 22 mA., but it must be higher than the "elevated zero".

Because there is no interaction between the zero scale and full scale value, the scaling procedure need only be done once.

CT - Calibrate Temperature

Temperature calibration is performed at the factory and it should not be necessary to recalibrate in the field unless by some accident the calibration values were destroyed. Should this happen, the unit may be returned to the factory or an attempt may be made to recalibrate. Two resistors are required and should have values about 90 to 100^{o}C apart in the range of 0 to +120^{o}C.

A table of resistance values is provided at the end of this section.

If recalibration is necessary, proceed as follows:

Connect an appropriate accurately known resistor corresponding to a temperature in the 0 to 20 ^{o}C range.

Set the temperature averaging value to 100, see command ST

Type **CT**, response will be

Calibrate - Temperature

Temperature #1 (C)?

Type the corresponding temperature and carriage return. The next prompt will be:

Temperature #2 (C)?

Switch to a resistor corresponding to temperature in the 100 to 120 ^{o}C range and wait 15 seconds for the averaging to settle out then type in the corresponding temperature.

Wait 15 seconds again then press carriage return.

Next prompt is:

Done (Y/N/esc)?

Type **Y** and the calibration is complete.

CD - Calibrate Density

In order to use the density signal, the densitometer calibration factors must be entered. These factors are unique to each densitometer and are listed on the Calibration Certificate that was supplied with the densitometer.

The following example is just that, an example, and the factors shown will not be correct for the actual densitometer in service.

To calibrate the densitometer type the new command **CD**, program responds with:

Calibrate Density

K0 = -1.315507e+03

K1 = -3.013561e-01

K2 = 1.357348e-03

K18 = -4.836800e-04

K19 = -6.103510e-01

Coefficient #0 (K0)?

The coefficients listed the first time will be garbage, don't be concerned about this.

Type in each coefficient exactly as shown on the Calibration Certificate.

The steps should look as follows:

Calibrate Density

K0 = 1.000000e+??

K1 = 1.000000e+??

K2 = -0.000000e+00

K18 = -0.000000e+00

K19 = -0.000000e+00

Coefficient #0 (K0)? -1.315507e+03

Coefficient #1 (K1)? -3.013561e-01

Coefficient #2 (K2)? 1.357348e-03

Coefficient #18 (K18)? -4.836800e-04

Coefficient #19 (K19)? -6.103510e-01

Done (Y/N/esc)?

Type **Y** at this point.

Calibration values can be reviewed at this point by typing **CD**, if correct, press the **<esc>** key to get out.

After this, typing **DB** will show:

Display BS&W - Curve #[1]

(type <esc> to exit)

[1] 100222. ppm 53.67 C 1.357986 869.53 kg/m^3
[1] 100226. ppm 53.71 C 1.357999 869.50 kg/m^3
[1] 100225. ppm 53.75 C 1.357996 869.47 kg/m^3

etc.

SA - Set Alarm

Alarm conditions are continually monitored and signaled according to operator defined values. The pick-up and drop-out values may be defined, as well as a time delay to avoid tripping on transient conditions. The different pick-up and drop-out levels provide hysteresis to avoid "rattling" the alarm relay.

It should be noted that alarm pick-up means that the alarm relay will in fact be de-energized if the water content exceeds the pick-up value. This is a normal fail-safe type of arrangement for cases of power failure or program failure (The Model DC-1500/DC-3500F also has a watchdog timer, resetting the processor and dropping the alarm relay if the program runs amok).

Typing SA gives:

[1] Alarm Pick-up (%)?

Number [1] indicates curve in use, each curve has its own alarm settings

If only the dropout value is to be changed or just examined, then a (cr) will show the value and advance to the next step. Otherwise, type in the desired value and a (cr) to advance:

[1] Alarm Drop-out (%)?

Again, the value may be changed or observed and then move to the next step:

[1] Alarm Delay (sec)

Type in a new delay followed by a **(cr)** or **(cr)** only to keep the old value.

The maximum delay is approximately 43 million seconds.

Next on the display:

Done (Y/N/esc)?

If done, type **Y**, otherwise type **N** or a **(cr)** and it will go back to the beginning of the alarm set menu.

Note that pressing **(esc)** anytime during the SA sequence will abort back to the command level and the values before the menu was called are retained, but the just typed values are all discarded.

Although the delay may be set in increments of one second, the actual delay has about a three second uncertainty. The alarm relay is only changed during the few milliseconds between measurement cycles. This is done to prevent any errors in measurement due to noise from load switching.

SB - Set BS&W Averaging

If the user wishes to decrease the effect of random noise that affects all measurements, averaging may be applied. The method used is 'window averaging', that is a running average of the last number of measurements is displayed. This number can be a maximum of 64.

Keep in mind that each measurement takes approximately 3 seconds so that a large number will result in sluggish response.

SO - Set Output Averaging

As for the input measurement, averaging can be applied to the
4 - 20 mA output. The maximum value is 64.

ST - Set Temperature Averaging

Similar to the previous averaging commands, the temperature values can be averaged. The maximum value is 256

SD - Set Density Averaging

Density averaging values can be set to a maximum value of 256.

SU - Set Units

The analyzer can display water content in units of % or parts per million. The selection is made as follows:

Typing **SU** brings the following response:

Set Units
1) ppm
*** 2) %**
Select (1 or 2)?

The asterisk before 1) or 2) shows the current units.

Typing the appropriate number results in:

Done (Y/N/esc)?

Typing **Y** yields the response:

Set Units Done

Command (? for help) >

SC – Select curve

One of three curves may be selected for current operation, typing the command results in the response:

Select Calibration Curve
Current Curve #1
Select (1 or 2 or 3)?

Type the desired number

Done (Y/N/esc)?

Typing **Y** yields the response:

Set Curve Done

[1] Command (? for help) >

DB - Display Water Content

This command will continuously display the current water content, the temperature, the Ratio and density in that order. If there is no densitometer present or it has failed, **NO DENS** will be displayed in the density value position.

Display BS&W - Curve #[1]

(type <esc> to exit)

[1] 0.0224 % 52.71 C 1.069492 997.94 kg/m^3
[1] 0.0224 % 52.71 C 1.069492 997.94 kg/m^3

To exit, press **(esc).**

DC - Display/Modify Calibration

This command allows a review of the complete set of calibration data in the working area. In addition, the data can be modified to allow recovery in case of accidental changes. (The numbers shown are only examples, actual numbers depend on each unit's calibration).

Typing DC will show:

Display/Modify Calibration - Curve # [1]
Ratio #1 = 1.069492
Water Content #1 = 0.1100 %
Temperature #1 = 25.44 C
Ratio #2 = 1.164575
Water Content #2 = 10.1100 %
Temperature #2 = 26.05 C
Temperature Compensation = -0.0250 %/C
Ratio #1 ?

For each item presented on the last line, the operator may type in a new value or just press **(cr)** to keep the current value that is then displayed and the next item prompted. At the end of the list, the question **Done (Y/N/esc)?** is presented.

As for the calibration routines, typing **Y** will replace the working data with the data just modified. The temporary memory area used by the calibration routines is also updated by the **Y** response. Typing **N** erases the current value before typing in an updated value.

If no changes are required, then **(esc)** may be pressed at any point to return to the top command level.

DI - Display Information

This command will list various hardware and software version information and serial number that can be useful for troubleshooting purposes. The information will be similar to:

Flash ID = 0x22DF [AM29F100B]

RAM Size = 0x10000

S/N:0014071

H/W Level = Ver 0.1

BS&W V110

The following table lists resistance values in the range of interest. Available resistors will probably not be exact for whole degrees so that linear interpolation will need to be used to calculate exact temperature values for calibration

1000 Ohm RTD resistance table

Best linear fit table of values for +20 to 100 ºC

Temp C	R Ohms	Temp C	R Ohms	Temp C	R Ohms	Temp C	R Ohms
0	1001.84	**30**	1113.97	**60**	1226.10	**90**	1338.24
1	1005.58	31	1117.71	61	1229.84	91	1341.97
2	1009.31	32	1121.45	62	1233.58	92	1345.71
3	1013.05	33	1125.18	63	1237.32	93	1349.45
4	1016.79	34	1128.92	64	1241.05	94	1353.19
5	1020.53	35	1132.66	65	1244.79	95	1356.93
6	1024.26	36	1136.40	66	1248.53	96	1360.66
7	1028.00	37	1140.14	67	1252.27	97	1364.40
8	1031.74	38	1143.87	68	1256.01	98	1368.14
9	1035.48	39	1147.61	69	1259.74	99	1371.88
10	1039.22	**40**	1151.35	**70**	1263.48	**100**	1375.61
11	1042.95	41	1155.09	71	1267.22	101	1379.35
12	1046.69	42	1158.82	72	1270.96	102	1383.09
13	1050.43	43	1162.56	73	1274.69	103	1386.83
14	1054.17	44	1166.30	74	1278.43	104	1390.57
15	1057.90	45	1170.04	75	1282.17	105	1394.30
16	1061.64	46	1173.78	76	1285.91	106	1398.04
17	1065.38	47	1177.51	77	1289.65	107	1401.78
18	1069.12	48	1181.25	78	1293.38	108	1405.52
19	1072.86	49	1184.99	79	1297.12	109	1409.25
20	1076.59	**50**	1188.73	**80**	1300.86	**110**	1412.99
21	1080.33	51	1192.46	81	1304.60	111	1416.73
22	1084.07	52	1196.20	82	1308.33	112	1420.47
23	1087.81	53	1199.94	83	1312.07	113	1424.20
24	1091.54	54	1203.68	84	1315.81	114	1427.94
25	1095.28	55	1207.41	85	1319.55	115	1431.68
26	1099.02	56	1211.15	86	1323.29	116	1435.42
27	1102.76	57	1214.89	87	1327.02	117	1439.16
28	1106.50	58	1218.63	88	1330.76	118	1442.89
29	1110.23	59	1222.37	89	1334.50	119	1446.63

5.0 APPENDICES

5.1 Specifications

General

Water in Oil range	0.00 to 10.00%
Minimum sample flow rate	4 USGPM for oil (no wax) 9 USGPM for condensate
Resolution	0.001% water
Temperature stability	0.0015% water/°C
Temperature sensor	1000 Ohm platinum RTD
Temperature compensation range	32°F to +300°F (0°C-150°C), linear
Shipping weight	42 lbs (19.1 kg)

Mechanical

Construction material	Type 316 SS or Duplex SS
Maximum working pressure	2160 psig @ 100°F (15 MPa @ 38°C)
Maximum fluid temperature	275°F (135°C)
Maximum ambient temperature	185°F (85°C)
Operating temp for electronics	-40°F to +185°F (-40°C to +85°C)
Storage temp for electronics	-40°F to +185°F (-40°C to +85°C)
Sample line connection size	1" NPT or 1" flanged
Specific volume	0.070 U.S. gallon (235 ml)
Sensor cross section flow area	Approx. 0.75 $inch^2$ ($4.84cm^2$)

Electrical

Power Required	18 - 28 VDC @ 150 mA. (Grounded or ungrounded)
Enclosure	Hazardous area Class I, Div. 1, Gr. C&D EEx d IIB T4, zone 1, IP65

Output

Analog current	4 - 20 mA. DC, isolated, self-powered
Maximum load	600 Ohms
Isolation voltage	500 Volts peak
Relay contacts	SPST-NO 2 Amp @ 24V DC, Non-inductive
Adjustable delay	0-43 million seconds
Adjustable hysteresis	0-10.00% water

Terminal/Computer Interface.

Asynchronous	
RS-232C	Full duplex
RS-485	Half duplex (application specific)
Speed	9600 Baud
Word size	8 Bits
Parity	None
Stop bits	One

5.2 Parts List

Probe (See Figure 7)

Part No.	**Item**	**Type**
03	Upper guide tube	Stainless steel
04	Sensor plug	Fluorocarbon Coated steel
05	Sensor barrel	Stainless steel
06	Upper & lower collar	Stainless steel
08	Upper end cap	Stainless steel
09	Upper insulator	Ceramic
10	Lower end cap	Stainless steel
11	Lower insulator	Ceramic
12	0.375" x 0.250" x 0.0625" O-ring	Viton
13	1.500" x 1.250" x 0.125" O-ring	Viton
14	2.000" x 1.750" x 0.125" O-ring (2)	Viton
21	2.250" x 2.000" x 0.125" O-ring (2)	Viton
15	Spring	Inconel
16	RTD temperature sensor (1000 Ohm Pt)	Alumina-epoxy case
17	Contact rod	Bronze
18	Conduit nipple, 1 1/4" x 3"	Stainless steel
19	Explosion proof enclosure	Copper free aluminum

Electronics

Type DC-1500/DC-3500F Electronic assembly

Recommended Spare Parts

Mechanical for DC-1500

2 only	O-Rings	2.0" x 1.750" x 0.125"	Viton
1 only	O-Rings	1.5" x 1.250" x 0.125"	Viton
1 only	O-Ring	0.375” x 0.250” x 0.0626”	Viton

Mechanical for DC-3500F

1 only O-Ring **To be specified on application** (indicate serial number)

Electrical for DC-1500 or DC-3500F

1 only	RTD Temp. Sensor 1000 Ohm	P/N HEL-716-U-0-12-00
1 only	Electronic Module	DC-1500/DC-3500F

5.3 Diagrams

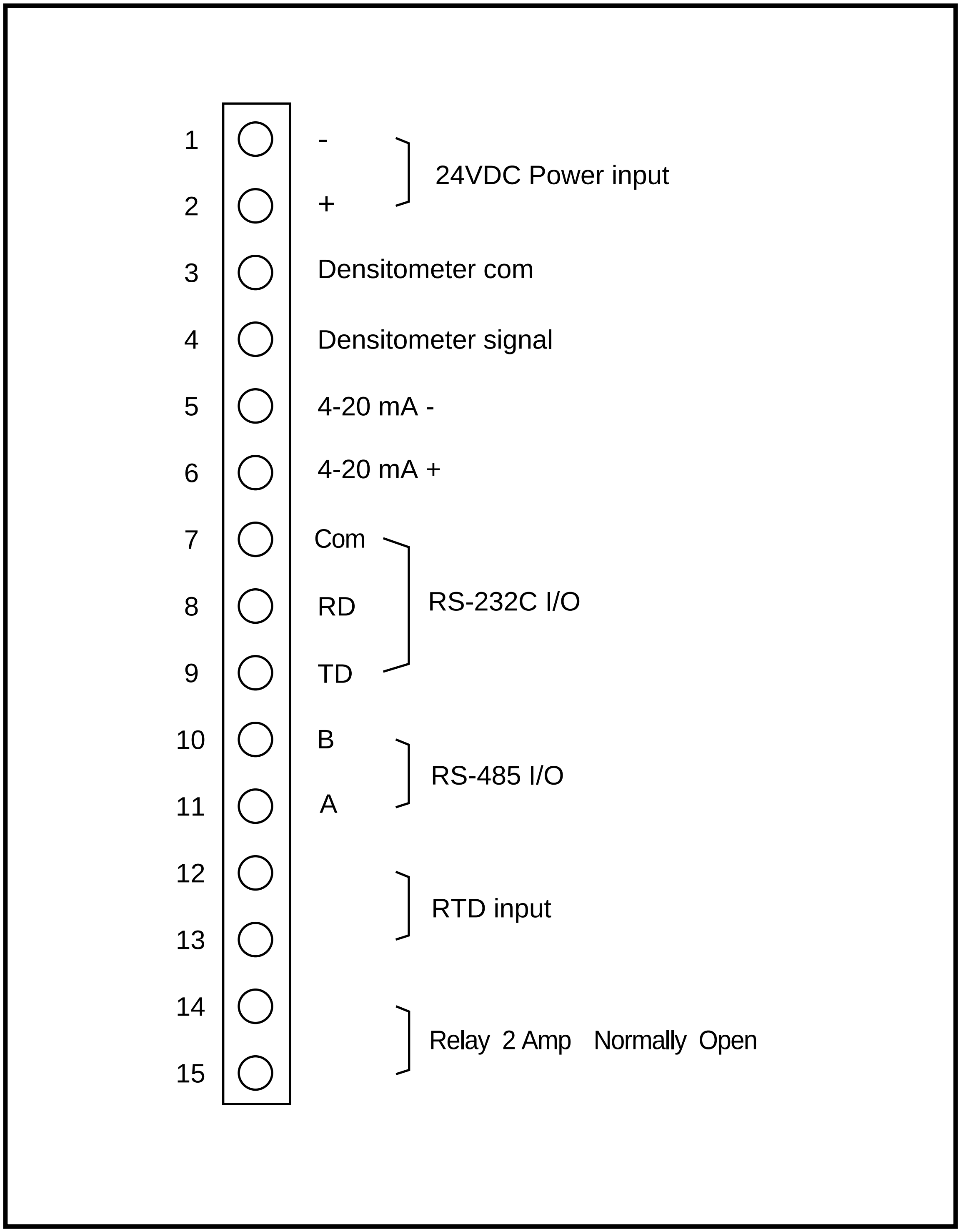


Figure 4 Terminal Wiring

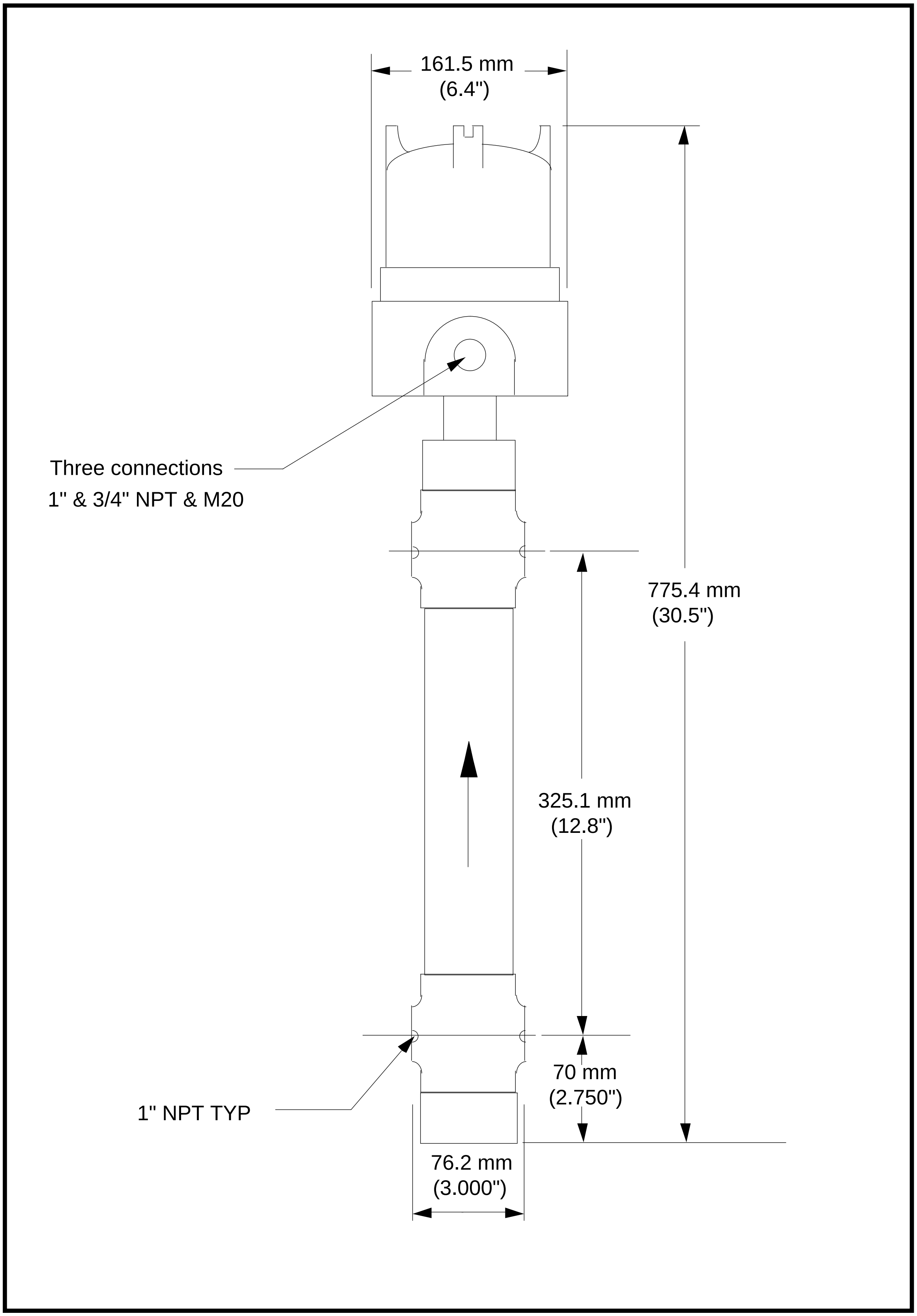


Figure 5 DC-1500 Dimensions

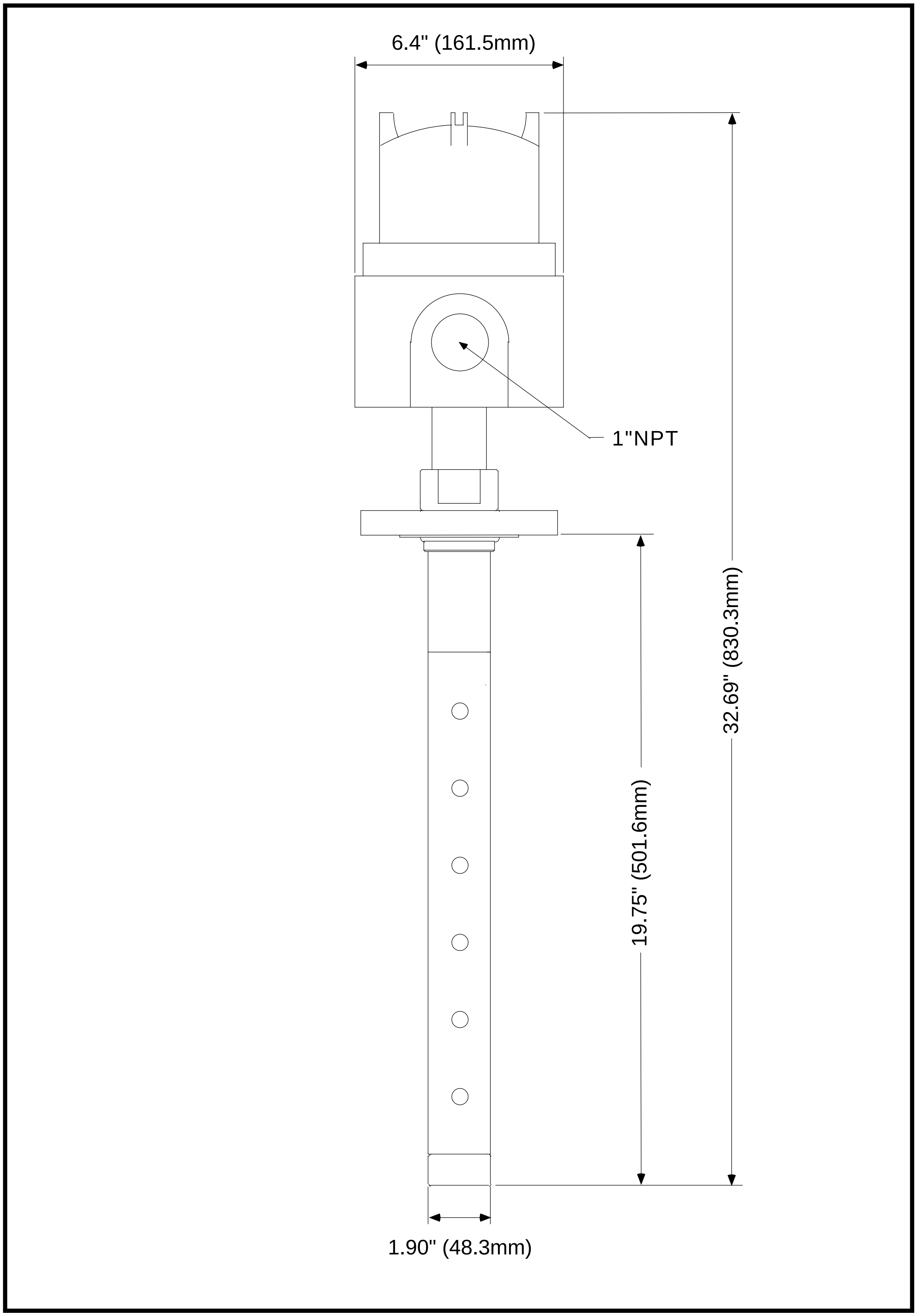


Figure 6 DC-3500F Dimensions

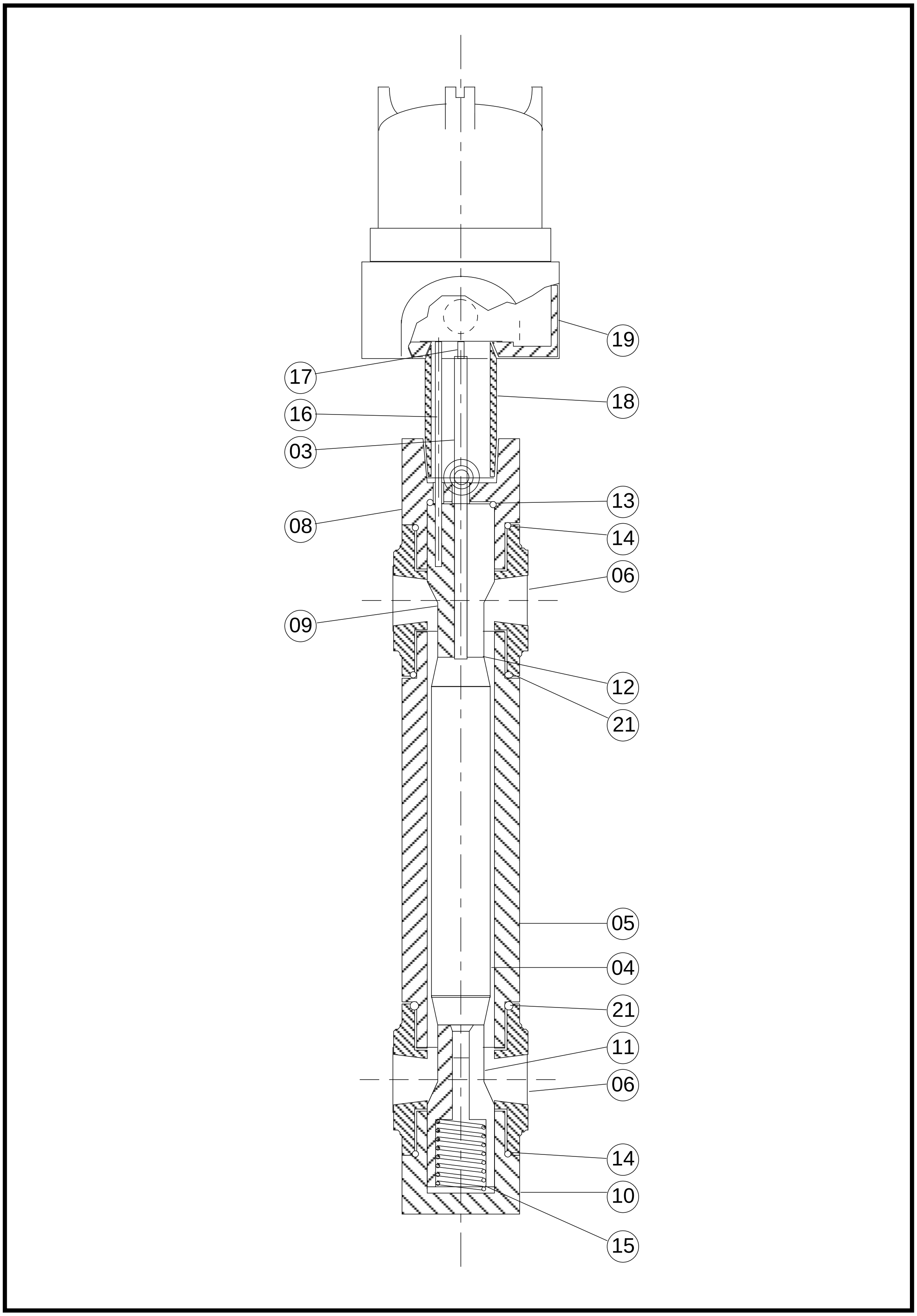
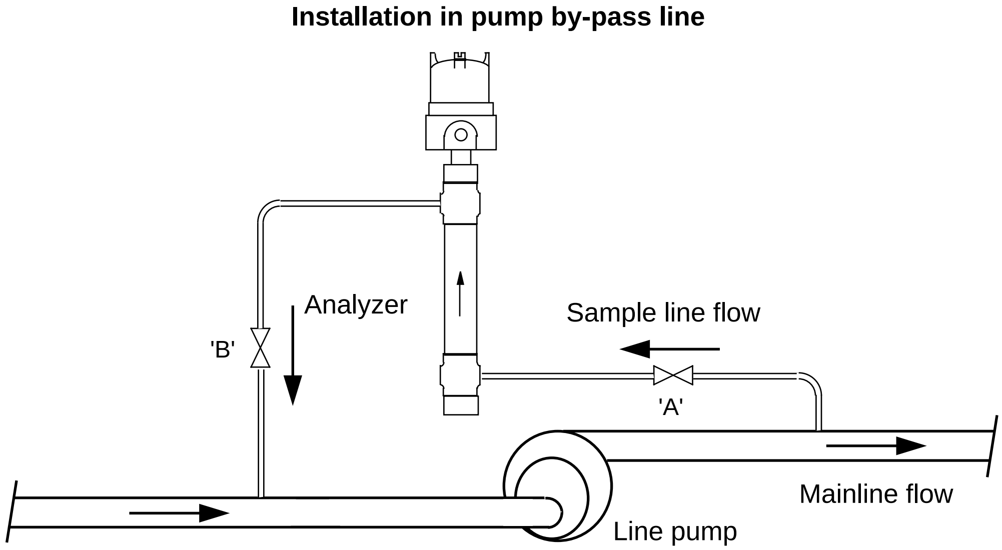
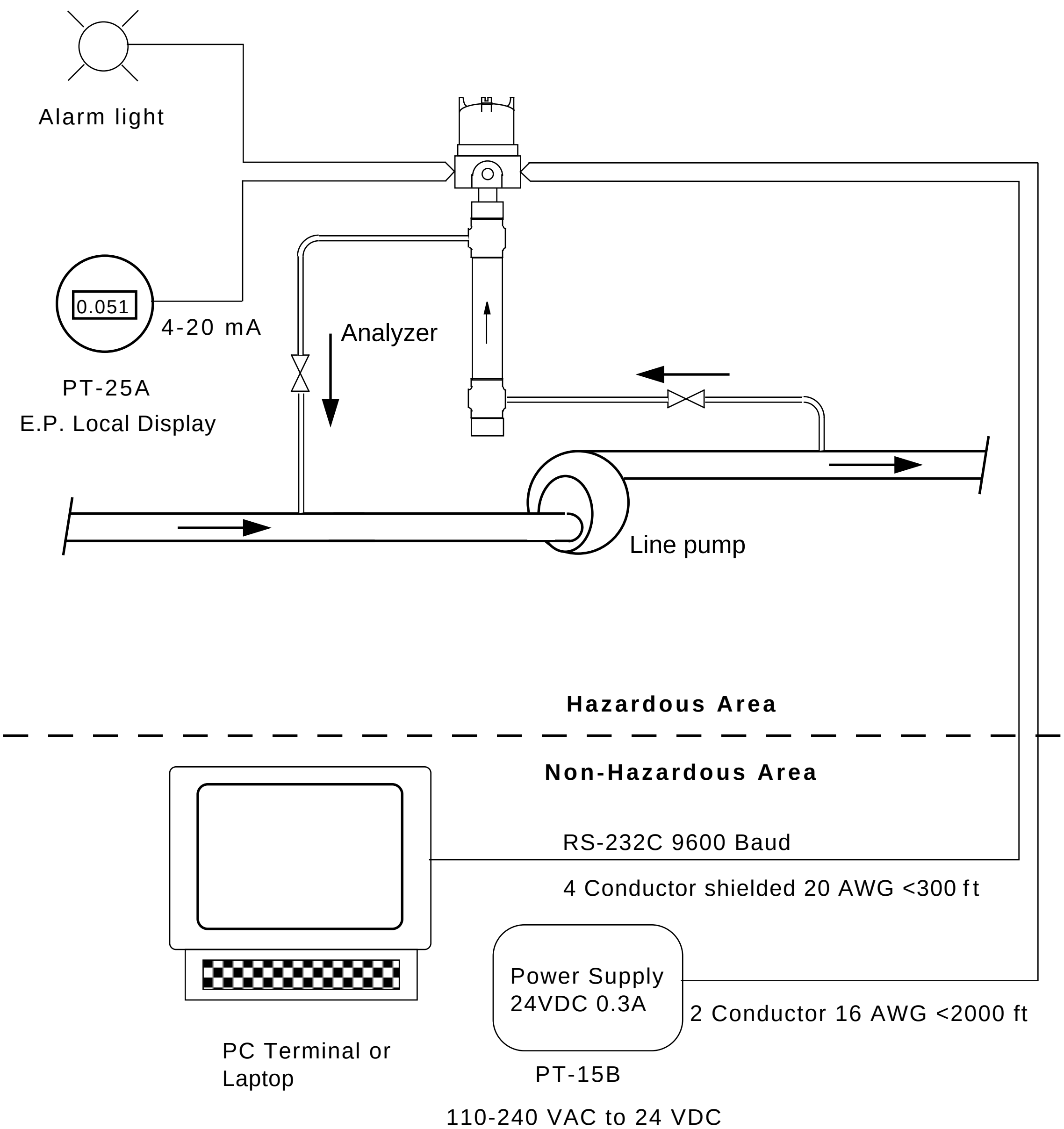


Figure 7 DC-1500 Assembly Diagram



Upstream shut-off valve 'A' on sample line must be wide open.
Use only the downstream shut-off valve 'B' to throttle the sample flow.
Use 1" or 3/4" steel pipe or 1/2" steel tubing for sample line.
Sample line flow velocity must not be less than 4 feet per second.

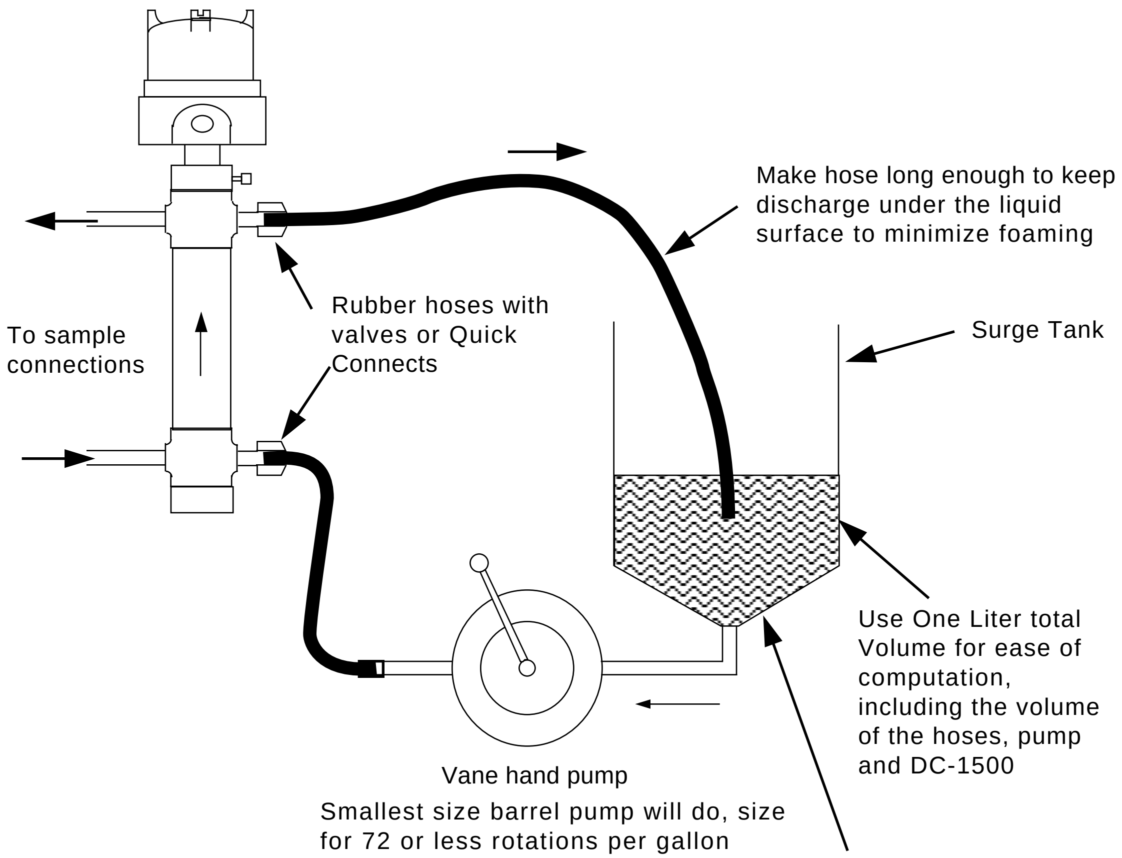
Figure 8 DC-1500 Installation Diagram



Note :
Sample take-off point should be as close to the pump discharge as possible (< 5 Pipe dia.). Maintain a high flow velocity in the sample line by not over sizing the line size(<3/4"). Keep the sample lines short and prevent flashing in the sample lines.

Install 3/4" Quick Connect fittings on second set of inlet and outlet ports for hose connection to flushing fluid pump (Diesel, Varsol or equal)

Figure 9 DC-1500 Application



Calibration Procedure :

1) Shut off both valves to the sample line
2) Drain the sensor probe through the bottom valve
3) Connect the hand pump hose to the bottom connection
4) Pour one litre* of currently used dry oil into the surge tank
5) Operate the pump and watch for the oil to circulate through the upper hose back into the surge tank
6) Circulate the oil slowly enough to prevent foaming.
7) To get the second calibration point as per the Instruction Manual, dump a 53* cubic centimeter volume of water into the surge tank and wait until the reading (code DB) on the terminal is stabilized while pumping the oil around.
8) The oil sample now has a 5 % water content of suitable accuracy for calibration purposes.
9) Enter calibration data as per the Instruction Manual.

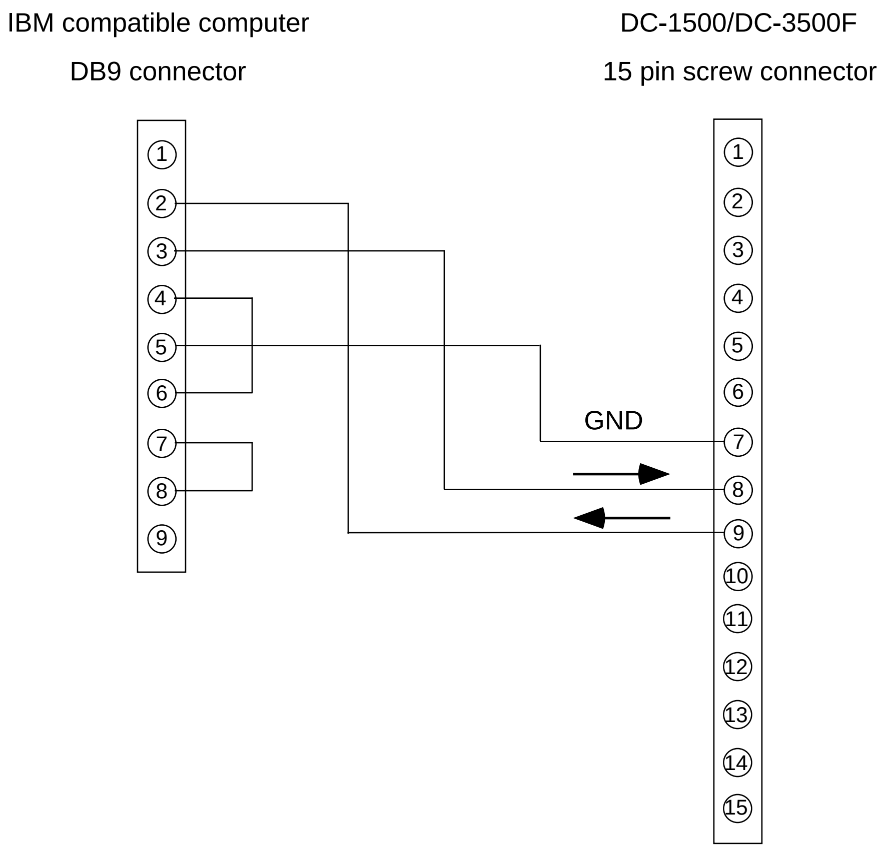
Note : To establish the temperature coefficient of the particular oil used, the oil needs to be heated about 15 to 25 °F. Use a dipstick heater or electric coil heater (coffee cup warmer) and insert this in the surge tank while watching the temperature measurement on the screen of the terminal

Circulating the oil over an extended time will heat up the oil about 5 to 10 degrees also.

* Using one quart of dry oil with two ounces of water results in 5.88 % water content increase.

Drawing # 941215

Figure 10 DC-1500 calibrator for non-volatile liquids only



Use a terminal program to communicate with the DC-1500/DC-3500F.

For MS-DOS, PROCOMM or Kermit are suitable.

For Windows, use the Terminal or HyperTerm program that is included with it.

Figure 11 Computer connection wiring diagram