USER MANUAL

MODEL 455-63

ULTRA-PURE WATER CONDUCTIVITY ANALYZER

IC CONTROLS

um-455-211-63-apdx

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455-63 Menu

The conductivity input menu has a number of additional settings that control the conductivity, temperature compensation, and conductivity display options.

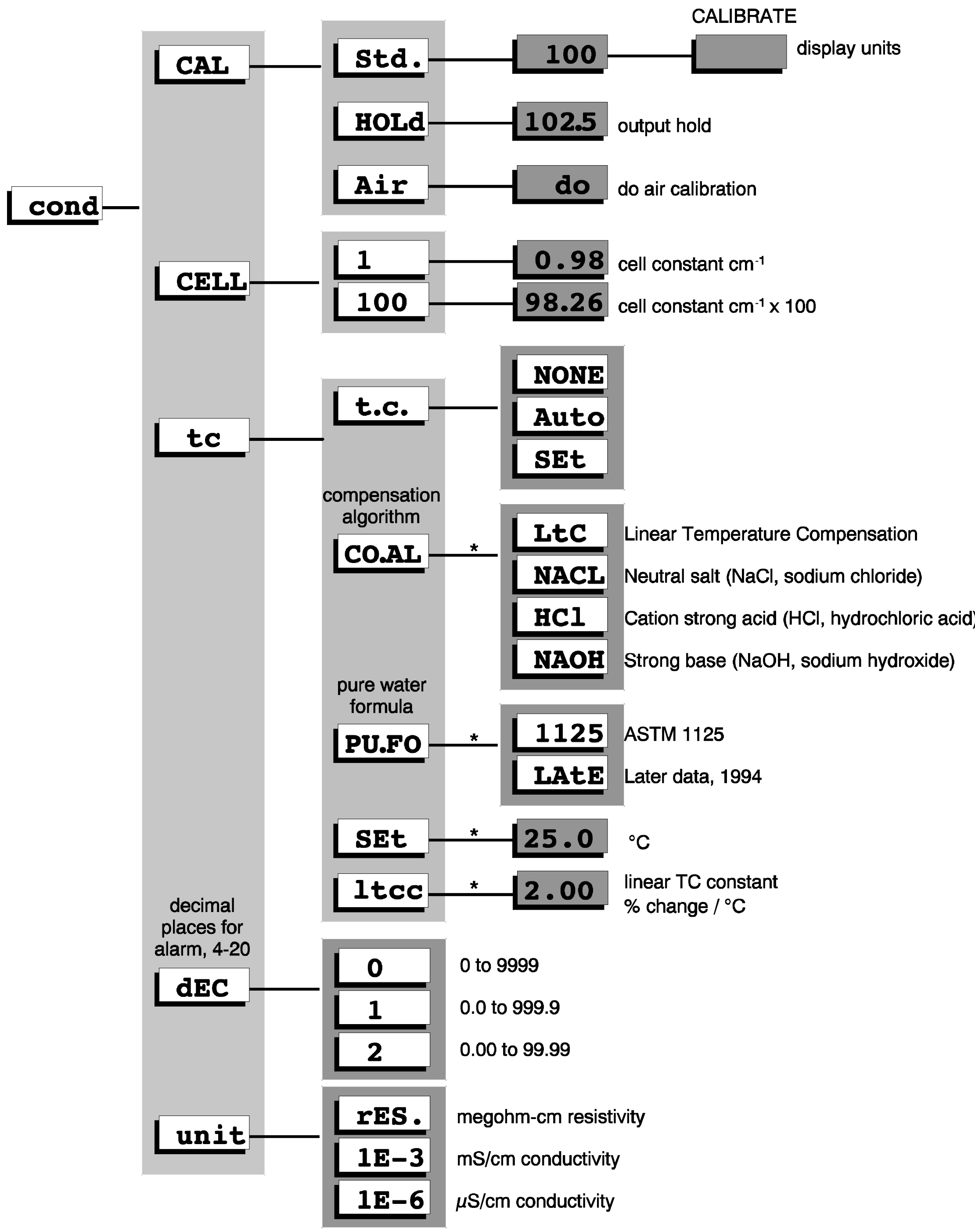

Illustration 1 Conductivity menu

High Purity Water Measurement

Overview

The 455-63 configuration is intended for use with a 402 or 403 with a 0.01/cm cell constant. It will measure the conductivity or resistivity of pure water samples below 10 µS/cm in continuous flowing samples. In order to know the conductivity of ultra-pure water it is required to do accurate temperature compensation at very low conductivities, e.g. conductivities below 10 microsiemens/cm. Water without any chemical impurities will still have a conductivity because of the presence of H^+ and OH^- ions due to the self-ionization of water. Ultra-pure water has a conductivity of 0.55 microsiemens/cm or 18.18 megohm·cm at 25 °C.

The self-ionization of water is strongly temperature-dependent. For accurate temperature compensation the conductivity of the pure solvent must be subtracted from that of the solution to determine the conductivity of the electrolyte. Simply applying a linear per-degree-Celsius temperature adjustment will not give accurate temperature compensation in high purity waters.

Illustration 2 shows the conductivity of ultra-pure water in microsiemen/cm over the range 0 °C to 100 °C.

Since pure water conductivity measurement is detecting trace amounts of ionic contaminants in the already temperature dependent self-ionizing water, the installation and calibration setup must make special provisions to eliminate or reduce any trace contaminants. Further, the trace contaminants themselves exhibit variable temperature coefficients in pure water that can rise as high as 7 % per °C. The 455-63 analyzer has different temperature coefficient algorithms to allow the user to select for neutral salts, acidic, or basic samples (as well as the traditional linear % per °C).

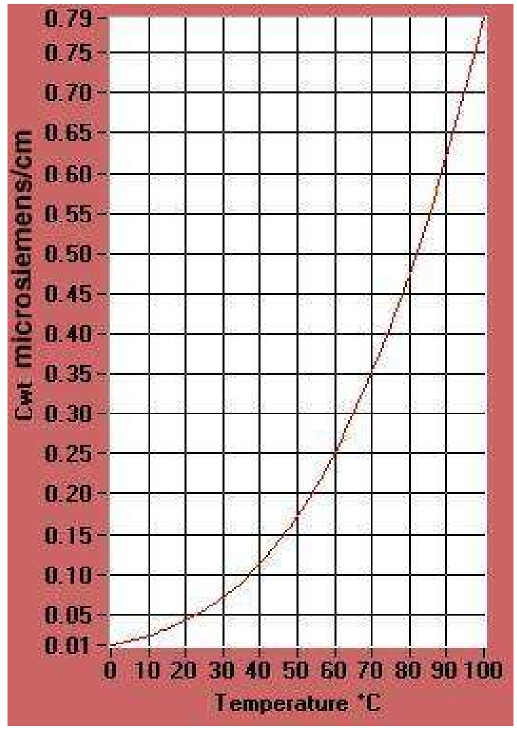

Illustration 2 conductivity of pure water

Since high-purity water contains little dissolved material it is like a dry sponge ready to soak up any contaminant it meets. Absorption of carbon dioxide on exposure to air will result in carbonic acid formation and cause a real change in conductivity of up to 2 to 3 microsiemens/cm. This fact can be readily demonstrated by taking a beaker of fresh demin water from a laboratory column, with conductivity electrode inserted and showing less than 0.5 microsiemens/cm, then bubbling compressed air through it and observing the conductivity reading quickly rise to between 2 and 3 microsiemens/cm. Alternately if dissolved gases are in the sample, on exposure to air they may escape (similar to opening a bottle of pop). Clearly calibrations using open containers of high purity water will have problems that the same samples in continuously flowing enclosed tubing should not encounter.

455-63 and ASTM D5391-99

The IC Controls 455-63 analyzer together with a model 402 or 403 sensor with cell constant 0.01/cm and -73 flow cell is designed to meet the requirements of ASTM D5391-99 for Flowing High Purity Water Samples (less than 10 µS/cm), when calibrated with A1100161 NIST-traceable 100 microsiemens/cm standard or A1100232 conductivity standard “D”

146.93 microsiemens/cm). To obtain the full benefits, the user should acquire a copy of the standard and ensure sampling and calibration techniques used on site meet the requirements of the standard.

The IC Controls 402-0.01 conductivity sensor (or the 403) can be provided with factory- certified cell constant, traceable directly to NIST Standard Reference Material 3191 of 100 µS/cm. Alternatively IC Controls can factory-certify the sensor cell constant with Standard "D" of ASTM method D1125, 146.93 µS/cm.

-63 Sensor Mounting

It is recommended that the sensor be located as near as possible to the conductivity transmitter, to minimize any effects of ambient electrical noise interference. Use option -73 flowcell to exclude air contact with the sample, followed by a sample take-off point where an additional sensor can be installed for calibrations. When in a shared sample line with pH sensors, the conductivity sensor should be first, pH reference electrodes leak KCl into the sample, thereby raising its conductivity. Flow sensors can be in any orientation but should be mounted tip down at an angle anywhere from 15° above horizontal to vertical, 15° above horizontal is best because entrained bubbles will rise to the top and grit will sink.

Stainless steel sample lines are recommended for pure water samples to maintain their integrity. The sensors can handle pressures up to 100 psi. Any sample flow rate will work, however 2 meters per second (6 feet per second) has been found to minimize iron oxide grit buildups.

Sensor Wiring

The basic wiring for IC Controls conductivity sensors is shown in drawing D5920095, as well as a description of the model 400 interface to the analyzer. This wiring scheme is intended for cable runs less than 20 meters (65 feet) where electrical interference is low. This cable is available from IC Controls as A9200000.

Notes:

1. The IC Controls conductivity wiring configuration uses an analyzer-driven shield to minimize wire capacitance effects. **The driven shield should not be connected to ground. Connecting the shield to ground will give false high conductivity readings.**
2. The IC Controls conductivity system uses a 1000 ohm RTD. This achieves 10 times better temperature accuracy by reducing the relative impact of lead and contact resistance on error.
3. Leads longer than 20 meters (65 feet) require an air "zero" calibration, to compensate for wire capacitance and resistance effects.

All low-level sensor signals should be run through a dedicated conduit. Take care to route all signal wiring away from AC power lines, to minimize unwanted electrical interference. When installing sensor cable in conduit, use caution to avoid scraping or cutting the cable insulation, the resulting short of the cable's internal driven shield will cause conductivity errors. Avoid twisting the sensor lead, to minimize possibilities for broken wire. Make sure the sensor connections are clean and tight.

Instrument Shop Test Startup

Check calibration as described below is based on using IC Controls A1400051 low-conductivity calibration kit.

1. Apply 115/240 VAC power to the analyzer.
2. Set display units [cond] [unit] to [1E-6] (µS/cm).
3. Hook up your sensor via TB200, and remove the orange protective cap, (for this test we need a 0.01/cm cell constant).
4. With the sensor in air, the 455-63 analyzer should come up reading between 0.0 µS/cm and 0.5 µS/cm.
5. Run an "Air" zero calibration, use wires to be field installed and allow 30 minutes warm-up time for the electronics to stabilize.
6. Run the "Std." (span) calibration, place the sensor in 100 µS/cm standard. The display should read 100 µS/cm ±1 µS/cm.
7. To check for general performance place the sensor in 10 µS/cm standard. The display should read approximately 10 to 13 µS/cm.
8. Before putting analyzer into operation verify your settings to ensure that they agree with

intended setup. For the 4-20 mA output, set high limit and low limit.

9. Set preference for temperature °C/°F units in [CONF][unit].
10. Set desired input signal damping if known, (normally 5 second).
11. Unit is now ready for field installation.

Alternatively the above calibration can be done using a resistor. Note that this method does not take into account the impact of resistance and capacitance of the sensor wire.

1. Substitute a 100 ohm 1% resistor for the TC and cell in step 3.
2. Set the cell constant to 0.01/cm.
3. The analyzer should read approximately 0 °C and 10 µS/cm.
4. Skip steps 5 and 6.
5. In step 7 substitute the sensor with a 10 kilohm 1% resistor. The analyzer should read approximately 1.0 µS/cm.

Conductivity Display Units

The 455-63 analyzer displays conductivity as microsiemens/cm units by default, but also allows display in millisiemens/cm or as resistivity in megohms·cm. Resistivity units are millions of ohms per centimeter of water.

The conversion between microsiemens/cm and megohm·cm is simple since the two units are reciprocals:

$$megohm \cdot cm = \frac{1}{microsiemens / cm}$$

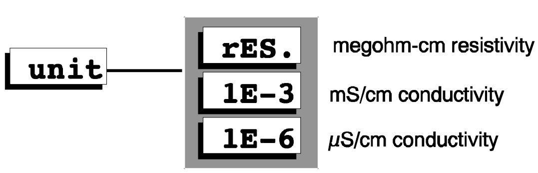

Illustration 3 Unit selection

TC Auto/Manual

The basic temperature compensation method is accessed as [cond][tc] [t.c.]. The options are [NONE] no temperature compensation, [AUTO] automatic temperature compensation, and [SEt] manual setpoint. For HIGH PURITY WATER when the basic TC selection is set to Auto there are additional Auto compensation algorithms selectable under CO.AL (below) to handle the high and nonliear characteristics of Neutral, Acidic, and Basic background samples.

Automatic temperature compensation uses the temperature RTD in the conductivity sensor to measure temperature.

Manual temperature compensation uses the temperature set by the user in [cond][tc] [SEt.].

Note:The [SEt] frame is not accessible until manual TC has been selected.

NONE, or "no temperature compensation" lets the analyzer measure uncompensated conductivity or resistivity. This is a requirement in the pharmaceutical industry following USP 23 <645> requirements. Selecting [NONE] is the same as using manual TC with the setpoint set to 25°C.

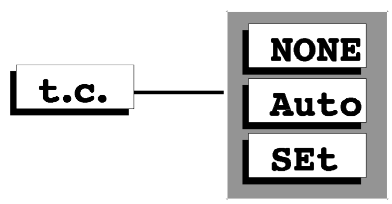

Illustration 4 Compensation method

Pure Water Formula Selection

Much work has been done over the years to establish the temperature dependence of pure water. Early analog implementations used thermistors to achieve temperature compensation, but may not have been very accurate. Current microprocessor technology, such as in the 455, allows for accurate, continuous compensation over the entire temperature range 0-100°C.

The earliest widely-used pure water equation was developed at the General Electric Vallecitos Nuclear Training Center. This formula still agrees to within 1% with today's formulas over the range of 15 to 67°C.

Illustration 2 shows the temperature dependence of pure water. The conductivity or resistivity of pure water without any impurities is very dependent on temperature. At low temperatures close to 0°C the change in conductivity is about 7% per degree Celsius. Clearly the implementation of pure water temperature correction is important. Since work in this area is still ongoing, the 455 analyzer allows the selection of two pure water temperature compensation formulas.

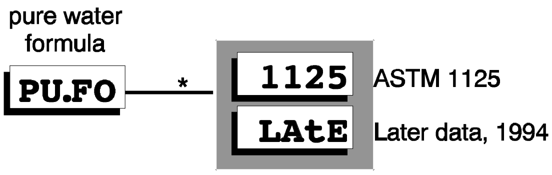

Illustration 5 Pure water formula

ASTM 1125 TC Formula

This curve is the default curve implemented in the 455-63 analyzer. It is selected under PU.FO, 1125. Refer to table 1. Work done in the 1980's led to the development of these generally-accepted Pure Water Temperature compensation values, that were included into ASTM standard D 1125-95 (1999).

°C	µS/cm	MΩ·cm
0	0.01165	85.841
5	0.01661	60.217
10	0.02310	43.297
15	0.03143	31.820
20	0.04194	23.844
25	0.05501	18.180
30	0.07101	14.082
35	0.09037	11.065
40	0.11351	8.810
45	0.14082	7.101
50	0.17269	5.791
55	0.20945	4.774
60	0.25140	3.978
65	0.29875	3.347
70	0.35164	2.844
75	0.41017	2.438
80	0.47438	2.108
85	0.54440	1.837
90	0.62046	1.612
95	0.70303	1.422
100	0.79303	1.261

Table 1 ASTM 1125 data

Later TC Formula

Ongoing work produced later data published in *ULTRA PURE WATER* in December 1994. This data presents slightly refined data based on new research, which looks good but has not yet undergone scientific method peer testing, been accepted and included in standards. To give you the greatest flexibility possible the 455-63 includes this data as an option, selected under PU.FO, LAtE.

°C	µS/cm	MΩ·cm
0	0.01162	86.072
5	0.01659	60.266
10	0.02312	43.256
15	0.03150	31.751
20	0.04205	23.782
25	0.05512	18.143
30	0.07105	14.074
35	0.09022	11.084
40	0.11298	8.851
45	0.13970	7.158
50	0.17071	5.858
55	0.20637	4.846
60	0.24697	4.049
65	0.29280	3.415
70	0.34410	2.906
75	0.40110	2.493
80	0.46392	2.156
85	0.53276	1.877
90	0.60775	1.645
95	0.68908	1.451
100	0.77697	1.287

Table 2 Later data, 1994

Solute Algorithm Selection

The temperature compensation of high-purity water changes depending on the chemistry of the traces of salts or impurities present in it. To properly correct for this you should select the solute compensation algorithm that best matches the chemistry of the water you are measuring. Examples; a) Cation Demineralizer effluent application would use the Acidic algorithm, b) Boiler water with treatment byproduct ammonia would use the Basic algorithm, c) Mixed bed polisher product water with only traces of salts left would use the Neutral salt algorithm.

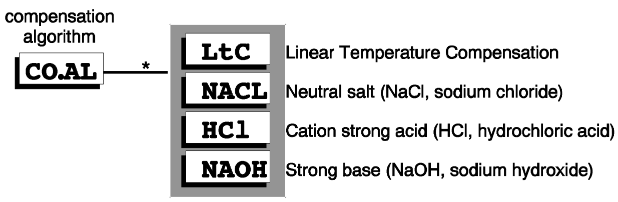

Illustration 6 Compensation algorithm

Illustration 7 shows the non-linear dependence on temperature for the different solute compensation algorithms, that are additive to the Pure Water Formula selected above.

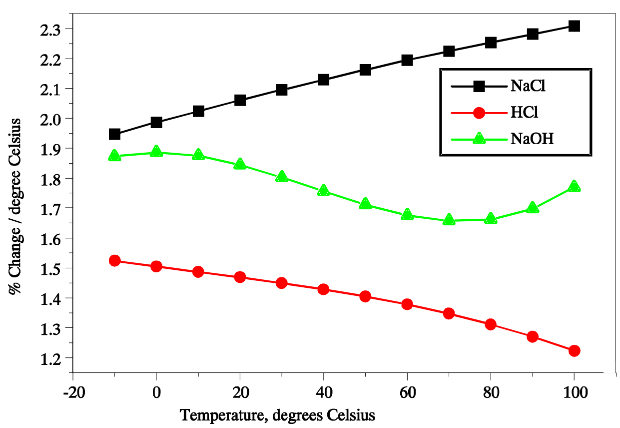

Illustration 7 Additive sample chemistry compensation

Linear [LtC]

The historical temperature compensation is linear at 2.00%/°C compensation, or can be edited to a different value. The LTCC Linear Temperature Compensation Constant is adjusted by (editing) selecting [cond][tc] [ltcc] from the menu and adjusting the value.

Refer also to the section *Conductivity Calibration, Temperature Compensation* in the 455 user manual.

Neutral Salt [NACl]

The 455-63 default temperature compensation is for Neutral Salt (in theory pure water is neutral). Samples with a neutral pH close to 7 can select the sodium chloride compensation algorithm. In a neutral salt solution the number of hydrogen and hydroxyl ions are approximately equal.

This algorithm is usually satisfactory for monitoring the effluent of mixed bed ion exchange. Neutral compensation is also applicable to boiling water reactor water samples because they are normally close to neutral pH. Makeup water and nuclear boiling water reactor plant water are untreated and neutral mineral traces are the most common contaminants.

Acidic / Cation [HCl]

Samples with strong acid such as hydrochloric acid which completely dissociates in water should use the acidic algorithm.

Cation exchangers used by the power industry remove chemicals not of interest, and substitute the far more conductive hydrogen. It also results in an acidic sample, which requires use of acid compensation to achieve accuracy.

Cation conductivity analyzers should also use this solute selection.

Basic [NAOH]

Samples with strong base such as sodium hydroxide which completely dissociates in water should use the basic algorithm. Boiler water with treatment byproduct ammonia would use the basic algorithm.

Start-up Settings

The 455-63 conductivity analyzer's default assumes a sensor with a cell constant of 0.01/cm which is stored in its memory. By default, the analyzer comes up reading conductivity in microsiemens per centimeter. The cell constant of the sensor must match the cell constant stored in the analyzer memory. If other than a 0.01/cm cell constant is used, change the constant stored by the analyzer so that the analyzer will read properly.

Temperature has a big impact on conductivity readings. At the historical rate, 2% change per °C, a 25°C temperature shift can produce a 50% error if the reading is not compensated. Since the conductivity of high-purity water has larger and non-linear temperature dependence the errors could be huge. The 455-63 HPW default TC correction is Auto, Pure Water Formula for ASTM 1125, Chemical Solute Algorithm for NACL (in theory pure water is neutral). Both for high accuracy work and high purity water applications IC Controls recommends the user check the actual chemicals involved and change the solute selection setting if necessary.

Conductivity sensor effective surface areas can be changed by contact with the process. At high-purity water measurement conditions cabling capacitance and resistance sometimes influence the readings. IC Controls recommends both an air zero calibration and a standard calibration of the conductivity sensor to determine the effective cell constant. This procedure requires a conductivity or resistivity standard from which the effective sensor cell constant can be determined, or a second calibrated sensor and analyzer.

PURE WATER CALIBRATION

The 455-63 HPW conductivity sensor analyzer system is most easily calibrated using 100 µS/cm standard conductivity solution. Alternatively grab-sample analysis verses a previously calibrated reference conductivity meter using an in line flow conductivity sensor can be used.

Ionic movement, and therefore conductivity, is proportional to temperature. The effect is predictable and repeatable for most chemicals, although unique to each. In High Purity Water it is of major importance, and IC Controls recommends the user check the application and ensure the appropriate TC Algorithm is in use. Calibration using the wrong HPW algorithm will incorporate large errors into the results.

Overall system accuracy is maintained by calibrating the sensor and analyzer together in a standard close to the expected sample concentration. Calibration determines the effective cell constant of the conductivity sensor. The cell constant is affected by the shape of the sensing surface and electrode surface characteristics. The effective cell constant will change over time as deposits form, and anything else affects either the controlled volume or the effective electrode surface area.

The 455-63 features an output hold. Output hold goes into effect as soon as a calibration is started. The output hold will stay in effect until a) you select sample, b) no key is pressed for 15 minutes, c) the power is interrupted so the analyzer reboots.

The output hold feature avoids false alarms and erratic signal output caused by a routine calibration.

Selecting a standard

Conductivity standards provide the simplest method of calibrating the 455-63 analyzer. The three standards most commonly used for calibration are: 100, 1000, and 10,000 µS/cm at 25°C (77°F).

Calibration using 100 µS/cm Standard

These instructions use an IC Controls A1400051 Low Range Conductivity Calibration Kit.

The A1400051 is a calibration kit containing solutions and items necessary for calibrating. The kit consists of the following items:

Content Description	*Qty & Size*	*Part No.*
Conductivity standard 100 µS/cm	2 x 500 mL	A1100161
Demin water	4 x 500 mL	A1100192
Syringe	1 x 10 mL	A7400031
Polyethylene graduated cylinders, set of 2.	2 x 100 mL	A1100007
Sensor cleaning brush, ¼ inch	1	A1100016
Instruction sheet		

Instructions for A1400051 Low-Range Cond. Calibration Kit

1. Set up the calibration supplies where you plan to do the calibration. Lay out the two graduated cylinders, one for span or high-end standard, one for low-end standard. Set out the sensor cleaning brush, syringe, standards and rinse solutions.
2. Remove the conductivity sensor from the process and examine it for deposits. Use demin water to flush away any deposits within the cell measurement area. Tenacious deposits may require chemical cleaning, see A1400054 Kit.
3. Pour approximately 75 mL of 100 µS/cm high-end conductivity standard into a graduate so it is about three quarters full. Lower the conductivity cell into the graduate.

   Tip: Ensure there are no air bubbles inside the cell, they will cause low conductivity readings. Remove by tapping or alternately raise / lower the sensor to flush them out.
4. With the conductivity cell centered and no air bubbles in the cell, monitor the reading for stability, then calibrate.

   Note: The reading may gradually change while the sensor equilibrates to the standard temperature. With micro analyzers, the program acts as an expert thermal equilibrium detector and flashes its reading until the temperature stabilizes.

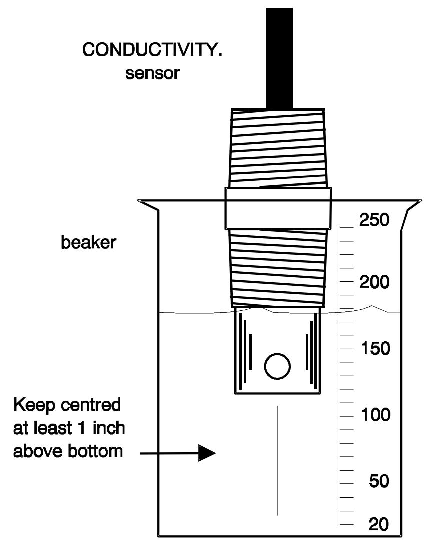

Illustration 8 sensor positioning

5. Select [cond][CAL][std] from the menu, then change the displayed standard value to that of the standard you are using., (megohm-cm, µS/cm or mS/cm, depending on the setting of [cond] [unit]).
6. Press *Right* to start the calibration. The analyzer will display a flashing concentration reading. From here on the calibration process is automatic.
7. Acting like an analyzer expert, the analyzer will wait until the reading has stabilized, then calculate the cell constant using the temperature-compensated value of the conductivity standard.
   The display stops blinking and shows the conductivity of the standard.

   Note
   a) It is possible to repeat or restart the calibration at any time. Simply press *Cancel*, then Select to restart or to repeat the calibration.
   b)If a problem is detected during calibration, a caution or error message will be displayed. Refer to "Caution or error message" tables.
8. Verify your calibration by:
   a) Note the cell constant in menu under CELL, and repeat steps 3)& 4) three times, or until three CELL constant readings are consistent.
   b) Rinse the sensor in demin water.
   c) Check with 10 µS/cm low-end standard at about 10% of scale using the procedure from 3) and 4) above.

Calibration Notes

- Used conductivity standard should be discarded because exposure to air and contamination causes the conductivity of standards to change.
- Make low-end standard by dilution
  Example: to 100 mL graduated cylinder add 7.5 mL 100 µS/cm standard, then top up to 75 mL to get 10 µS/cm standard.
- **CAUTION**: low-conductivity water will dissolve CO_2 from the air, raising conductivity 1 to 2 µS/cm, plus leach contaminants in storage from containers,and carry over on the sensor, so 10 µS/cm will likely read 11, 12, or 13 µS/cm (possibly even more).
- If the sensor reads correctly the calibration and sensor condition are good. If the sensor reads wrong it may have had trapped bubbles inside, or traces of 100 µS/cm standard. Re-test three times, or until three readings are consistent; if problem persists, try chemical cleaning.
- A clean, rinsed and dried conductivity sensor should read near zero in air. If it does not, troubleshoot the sensor, wiring, and analyzer.
- Low-conductivity grab samples taken to the laboratory for calibration checks are not reliable due to CO_2 absorption from air.
- **CAUTION:** Standards less than 10 µS/cm made in air will dissolve CO_2, raising conductivity 1 to 3 µS/cm, so are unreliable. Stored demin will also have conductivity readings of 2 or 3 µS/cm due to chemicals dissolved from containers and should not be used. For 1 µS/cm standards, try first triple rinsing all vessels with sample of less than 1 µS/cm conductivity, then diluting the standard using sample of less than 1 µS/cm. Alternately contact IC Controls Customer Service.

Calibration Using ASTM "D"

ASTM "D" standard with conductivity 146.93 µS/cm at 25 °C can be substituted for 100 µS/cm standard in the above calibration procedure. When using ASTM "D" Standard (P/N A1100232) users may wish to follow the procedures outlined in ASTM D1125.

Calibration by Grab-Sample

This modified grab-sample technique is quicker and easier if the sensor is not easily accessible, and with the high probability that pure water samples of less than 10 µS/cm will be changed on exposure to air, it is recommended. This procedure describes how to calibrate the analyzer without taking the sensor out of the process. To calibrate measure the sample with a second calibrated analyzer and flow sensor, similar to ASTM D 5391-99 for conductivity/resistivity of a flowing high-purity water sample. Since most portable and laboratory conductivity instruments do not have flow sensors and use limited 2% per °C temperature compensation (not acceptable under ASTM D 5391-99 for High Purity Water), IC Controls recommends use of a second high-purity analyzer and 401-0.01-73 sensor to determine the actual conductivity of the sample.

1. Obtain the following materials: a second calibrated 455-63 conductivity analyzer and 401-0.01-73 sensor of known constant.
2. Record the cell constant of the sensor. The cell constant is displayed by pressing *Sample*, and then selecting [cond][CELL] [1] from the menu.
3. Tube up the calibration cell to the outlet of your process sensor to get a representative flowing sample from the process without exposure to air. In order for the procedure to work the sample you are drawing must be representative of the sample being measured by the on-line analyzer.
4. Record the conductivity/resistivity and temperature of the sample as displayed by the on-line conductivity analyzer.
5. Measure the conductivity of the sample using the second 455-63 conductivity analyzer and record the conductivity reading and temperature.

   Note: For accurate results the sample must be at the same temperature and the analyzers must use the same temperature compensation method. Allow considerable time for the calibration sensor to rinse down and equilibrate to the sample level. A stable reading close to the on-line sensor reading acts as a good indicator.

6. Calculate the new cell constant to be entered into the 455 analyzer using the following formula:

$$new\ cell\ const = \frac{lab\ reading}{field\ reading} \times old\ cell\ const$$

For example, if the 455 analyzer is reading 8.2 µS/cm, the cell constant (from step 2) is 0.01/cm, and the reading from the second method is 8.9 µS/cm, then the new cell constant becomes

$$new\ cell\ const = \frac{8.9}{8.2} \times 0.01/cm = 0.0109/cm$$

7. Adjust the cell constant to the new value, e.g. 0.0109/cm as in the example. The cell constant is adjusted by selecting [cond] [CELL] [100] [01.00]from the menu. Press *Enter* to go into edit mode, then adjust the displayed value to [01.09]. Press *Enter* again to exit edit mode

Air Zero Calibration

It is not necessary to repeat "Air" cal every time a regular calibration is performed.

An air calibration should be performed anytime a new sensor is installed. When a sensor is in air, the conductivity measured by the sensor is expected to be zero. It is not uncommon to find some small conductivity signal with the dry sensor in air or even with no sensor connected at all. This measurement can be due to background noise, lead wire pickup (antenna effect), grounding problems, etc. The air calibration is designed to subtract the small errors of this interference signal from the real measurement in order to give a true zero reading.

1. Do the zero cal any time a new sensor is installed.
2. Make sure that the sensor is dry before zeroing. The analyzer should be reading a low conductivity value.
3. From the menu select [cond] [CAL] [Air] and push select. The analyzer will show a flashing [do].
4. When the sensor is ready to be calibrated, press *Enter*.
5. Press *Sample*. With the sensor still dry and in air, the conductivity should read 0.00 µS/cm.

Possible problem:
When you press *Enter* with the flashing [do] displayed, the analyzer will not do the zero cal, but instead will show the current range number, e.g. [rnG.2]. For a zero cal the analyzer needs to be on range 4, the range with the highest gain. If the analyzer isn't on range 4 then the sensor probably is not in air, or is wet. Correct the sensor situation and try again.

USER MANUAL

MODEL 455

CONDUCTIVITY ANALYZER

um-455-212

IC CONTROLS

CONTENTS

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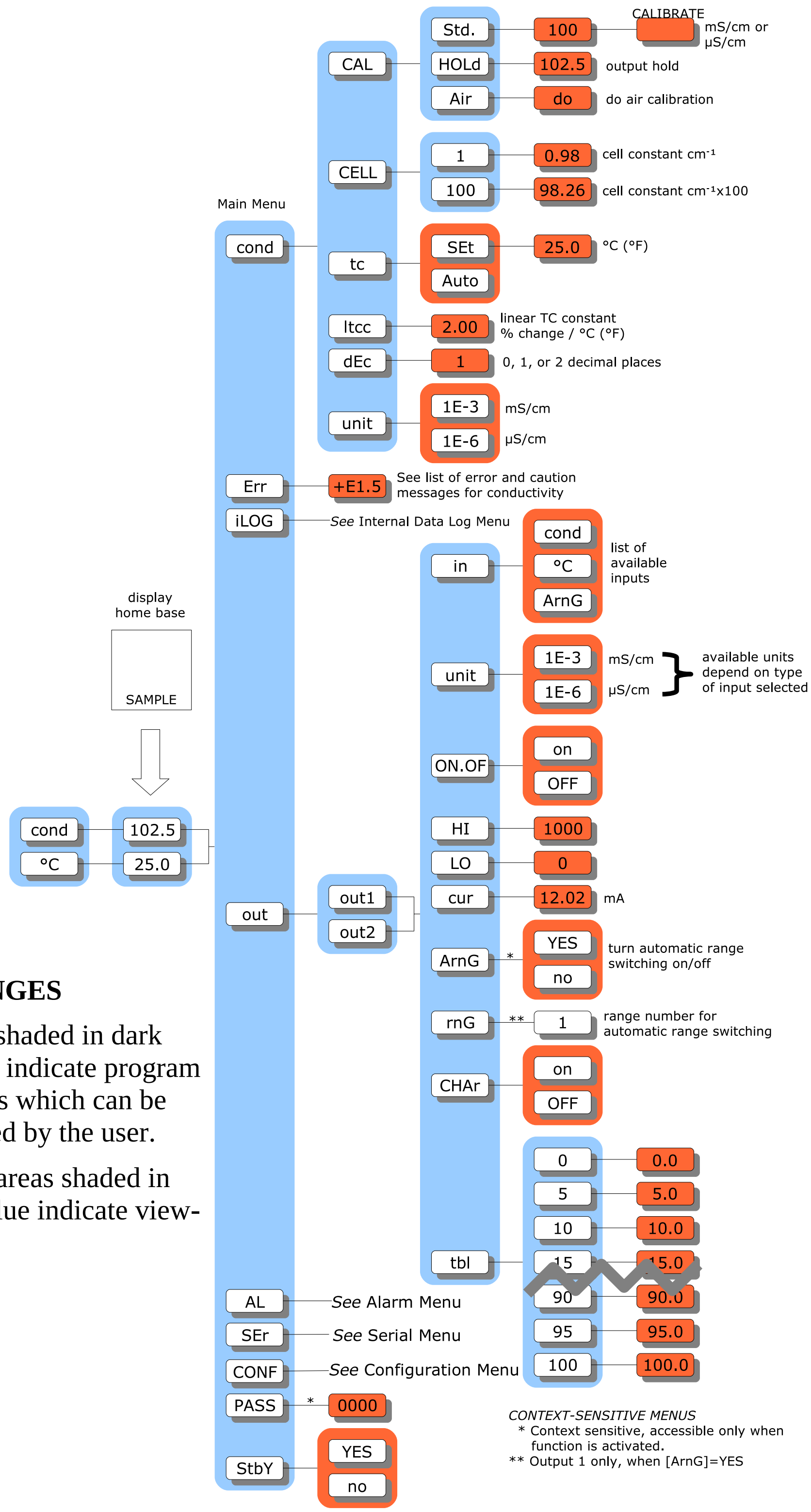
455 MENUS



CHANGES

Areas shaded in dark orange indicate program settings which can be changed by the user.

Menu areas shaded in light blue indicate view-only.

Illustration 1: Menu overview

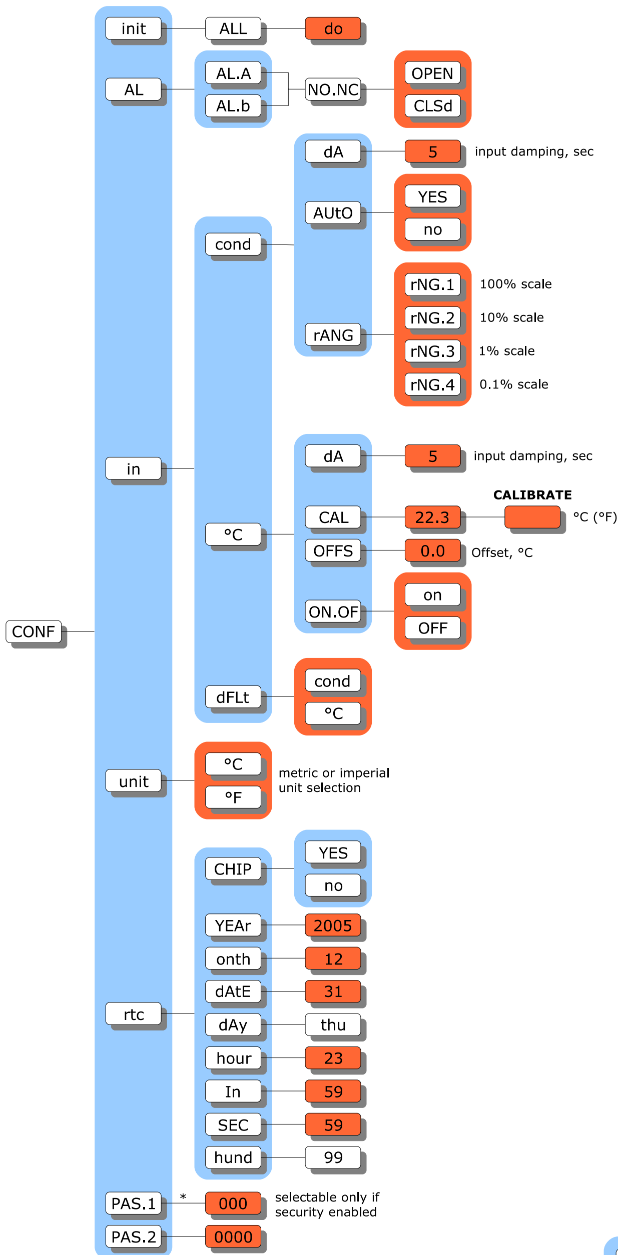


Illustration 2: Configuration menu

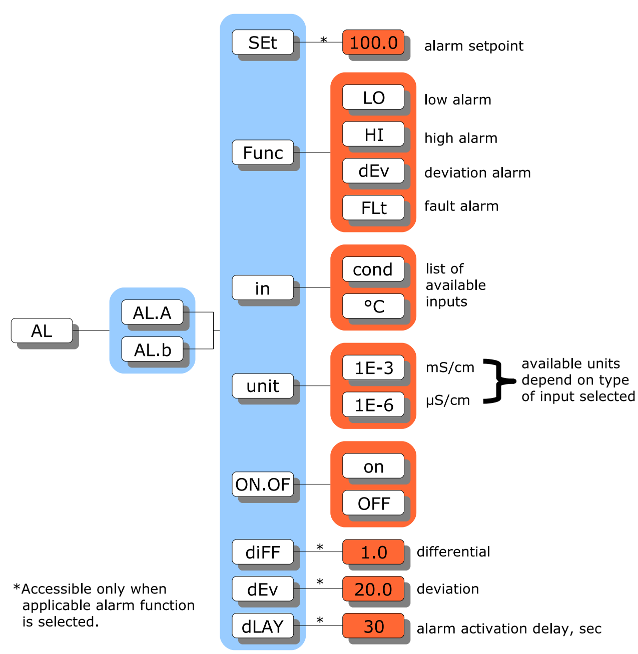


Illustration 3: Alarm menu

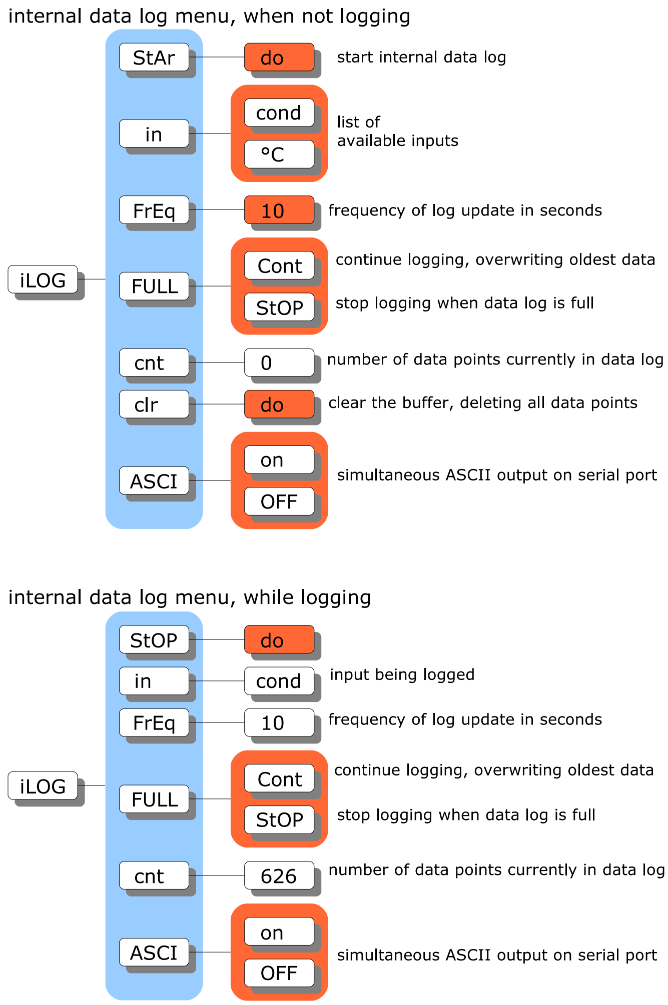


Illustration 4: Internal data log menu

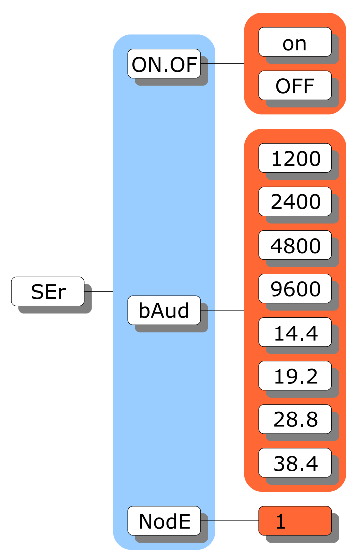


Illustration 5: Serial menu

INTRODUCTION

The model 455 is IC Controls' industrial-quality remote operational CONDUCTIVITY analyzer, designed to give maximum flexibility, reliability, and ease-of-use. The model 455 is shipped from the factory calibrated at 0 µS/cm to 1 000 µS/cm and 4 mA to 20 mA and should not require recalibration other than sensor cell constant installation (if different from 1.0/cm). It has four auto-ranging input ranges, two isolated 4 mA to 20 mA outputs, two 10 A SPDT relays, plus a serial communication port. Its microprocessor intelligence recognizes specific conductivity standards to auto-calibrate, holds output during calibration, notifies user of diagnosed sensor or analyzer faults, plus stores in memory the last 12 calibration records, 1 000 minute measurement trend, alarms, power outages, and diagnostic messages, all date and time stamped.

The 455 is one of a series of 115/230 VAC process analyzers supplied in a corrosion resistant IP65 (NEMA 4X) water and dust-tight case. These analyzers are also available for pH, ORP, dissolved oxygen and chlorine, plus as two-wire versions with an optional explosion proof rating. In the case of conductivity, the analyzer powers a sensor and measures the resulting signal corresponding to the actual conductivity and temperature. The analyzer conditions and digitizes the signal for maximum accuracy, and then sends it out as a digital output and/or on 4 mA to 20 mA outputs.

Features

The 455 CONDUCTIVITY analyzer features:

1. Intuitive user friendly program; easy-to-use.
2. Auto-calibration; recognizes specific conductivity standards.
3. Auto-ranging over 4 input ranges.
4. Self and sensor diagnostics.
5. Output hold during calibration.
6. Stores 12 calibration records.
7. Stores alarms, caution and error messages.
8. Stores running 1 000 minute conductivity trend.
9. Two programmable 4 mA to 20 mA outputs.
10. Two programmable alarms.
11. Serial digital output and for remote operation.
12. Optional PID control.
13. Optional concentration measurement in % NaOH, % H_2SO_4, % HCl and % NaCl.
14. Optional measurement of TDS, resistivity and salinity.
15. Three level security to protect settings.
16. Hidden alignment; accessible when needed.
17. Durable housing; IP65, NEMA 4X.

Specifications

Physical Data	
PROPERTY	***CHARACTERISTIC***
Display	Four and one half LCD digits, 1.5 cm (0.6 in) displays for conductivity, temperature, error codes, prompts and diagnostic information (*back-lit display optional*)
Display Ranges	Conductivity: 0 µS/cm to 1 µS/cm, 0 µS/cm to 1,000 µS/cm, and 0 mS/cm to 1,000 mS/cm Temperature: -10.0 °C to 210 °C (14.0 °F to 410 °F)
Keypad	8 pushbutton entry keys
LED's	2 alarms (A and B), 1 auto, 1 error
Case Dimensions	12.0 cm (H) × 20.0 cm (W) × 7.5 cm (D) (4.7 in (H) × 7.9 in (W) × 3.0 in (D))
Weight	1.1 kg (2.5 lb)
Shipping Weight	2.3 kg (5.0 lb)
Shipping Dimensions	30 cm × 23 cm × 23 cm (12 in × 9 in × 9 in)
Environmental Data	
PROPERTY	***CHARACTERISTIC***
Temperature	Operational: 5.0 °C to 45 °C (41.0 °F to 113 °F) Storage: -10.0 °C to 55 °C (14.0 °F to 131 °F) Relative Humidity: 95 % maximum; non-condensing
Environment Ratings	Housing: IP65 (Nema 4X) Pollution Degree: 2 Installation Category: II
Electrical Ratings	115/230 VAC, 0.25 A, 50/60 Hz
Electrical Requirements	115/230 VAC ± 10 %, 50 W

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Specifications

<table>
<tr><th colspan="2">Operational Data</th></tr>
<tr><th>PROPERTY</th><th>CHARACTERISTIC</th></tr>
<tr><td>Accuracy</td><td>Conductivity: ± 0.2 % of measured range
Temperature: ± 0.1 °C</td></tr>
<tr><td>Precision</td><td>Conductivity: ± 0.1 % or 2 digits, whichever is greater.
Temperature: ± 1 digit (0.1 °C)</td></tr>
<tr><td>Response Time</td><td>90% within 5 s (default), function of flow and temperature.
Damping adjustment: 3 s to 99 s</td></tr>
<tr><td>Temperature Compensation</td><td>
<table>
<tr><th>Compensation Type</th><th>Function</th><th>Characteristic</th></tr>
<tr><td rowspan="2">Linear</td><td>Default</td><td>2 % per °C</td></tr>
<tr><td>Adjustable</td><td>0.1% to 5.0% per °C</td></tr>
<tr><td>None</td><td>USP 23</td><td><645></td></tr>
<tr><td>High Purity</td><td>Selectable</td><td>Neutral, acidic, basic, ASTM D1125 or latest.</td></tr>
<tr><td>% Concentration</td><td>Selectable</td><td>NaOH, H_2SO_4, HCl or NaCl.</td></tr>
</table>
Automatic 1000 Ω RTD
Auto: -10.0 °C to 210 °C (14.0 °F to 410 °F)
Manual: -10.0 °C to 210 °C (14.0 °F to 410 °F)</td></tr>
<tr><td>Cell Constant Range</td><td>0.001/cm to 100.0/cm</td></tr>
<tr><td>Auto-Range Multipliers</td><td>Cell constant ×100, ×1000, ×10,000, or ×100,000</td></tr>
<tr><td>Security</td><td>3 access-level security; partial and/or all settings may be protected via 3- and/or 4 digit security code.</td></tr>
<tr><td>Alarms</td><td>Two independent, assignable, programmable, configurable, failsafe NO/NC or auto-range BCD alarm relays; SPDT, Form C, rated 10 A 115 V/5 A 230 V; 5 position BCD contact closure.</td></tr>
<tr><td>Controls</td><td>Single PID (optional); standard, pump pulser or time proportional.</td></tr>
<tr><td>Outputs</td><td>Two continuous, assignable, programmable 4 mA to 20 mA, or 0 mA to 20 mA outputs; isolated, max. load 600; Convertible from 1 VDC to 5 VDC or 0 VDC to 5 VDC.</td></tr>
<tr><td>Communication</td><td>Via RS485 bidirectional serial data port; require IC Net™ 2000 software.</td></tr>
</table>

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INSTALLATION

Analyzer Mounting

The conductivity sensor is typically supplied with at least a 1.5 m (5 ft) lead as standard. The 455 analyzer should be kept within the sensor lead length and mounted on a wall, ideally at eye level. Position the analyzer to allow the sensor, still connected to the analyzer, to be removed and the electrode tip placed in a beaker on the floor for cleaning or calibration. Assume the safest place for the beaker is on the floor the service person stands on. Horizontal separation between rows of analyzers should allow for electrode leads which need periodic replacement, and the electrical conduit. IC Controls recommends a minimum separation of 10 cm (4 in) between rows/columns.

As standard, the 455 comes with four internal 0.43 cm (0.17 in) holes for surface mounting screws spaced 18.8 cm (7.41 in) wide and 8.8 cm (3.47 in) high. Case dimensions are 20 cm x 12 cm x 7.5 cm (w, h, d) or 7.87 in x 4.72 in x 2.75 in (w, h, d) as shown on drawing D4830022.

Pipe mounting kit, option -8 for 5 cm (2 in) pipe, P/N A2500255, is shown on drawing D4950053. It may also be used to surface mount the analyzer by removing the 2 inch U bolts and using the holes in the mounting plate for wall studs (*using customer-supplied studs*). The mounting plate dimensions are 20.3 cm x 21.6 cm (8 in x 8.5 in) with elongated U bolt holes.

Panel mounting kit, option -9, P/N A2500201, is shown on drawing D4950054. It requires a customer supplied panel cut-out, 20.6 cm (8.1 in) wide x 12.2 cm (4.8 in) high, with two 0.4 cm (0.15 in) screw holes centered 22.6 cm (8.9 in) apart and 6.1 cm (2.4 in) below top of cutout. The panel bezel dimensions are 24.1 cm x 15.9 cm (9.5 in x 6.25 in).

Wiring

Power for the 455 analyzer is 115/230 VAC ± 10%, single phase 50/60 Hz, and 0.25 A. Connections are made at TB400 inside the instrument enclosure; refer to drawing D5920093. The microprocessor requires a suitable ground to ensure stable operation. A power line with the third wire connected to earth ground should be adequate, however, a local earth rod may prove more fitting.

There are three 2.0 cm (0.875 in) holes for 0.5 inch conduit in the bottom of the enclosure. IC Controls recommends that AC be brought in through the right-hand entrance for power and alarms; 4 mA to 20 mA and digital low voltage wiring be brought in through the center entrance, and sensor leads be passed through the left-hand entrance. Conduit should be flexible, watertight, and sealed using a gasket to maintain environmental integrity within the enclosure.

Connect the two relay/alarm contacts;

Alarm A: contact TB300
Alarm B: contact TB301

Connect the two isolated 4 mA to 20 mA outputs;

Output 1: contact TB303
Output 2: contact TB304

Sensor Mounting

It is recommended that the sensor be located as near as possible to the conductivity analyzer to minimize any effects of ambient electrical noise interference. Flow sensors can be in any orientation but should be mounted tip down at an angle anywhere from 15 degrees above horizontal to vertical. 15 degrees above horizontal is best because air bubbles will rise to the top and debris will sink, both bypassing the sensor.

Submersion sensors should not be mounted where a lot of air bubbles rise in the tank, they will cause spikes in the conductivity readout. If an air bubble is allowed to lodge in the sensing tip, electrical continuity between the electrodes may be disrupted.

Sensor Wiring

The basic wiring scheme for all IC Controls' conductivity sensors is shown in drawing D5920095, including a description of the 400 interface to the analyzer. This wiring scheme is intended for cable runs less than 20 m (65 ft) where electrical interference is low. This cable is available from IC Controls as P/N A9200000.

All low-level sensor signals should be run through a dedicated conduit. Take care to route all signal wiring away from AC power lines in order to minimize unwanted electrical interference. When installing sensor cable in conduit, use caution to avoid scraping or cutting the cable insulation - the resulting short of the cable's internal drive shield will cause conductivity errors. Avoid twisting the sensor lead to minimize potential for broken wires. Ensure the sensor connections are clean and tight.

Instrument Shop Test Startup

Note: For this test example, assume the conductivity sensor has a 1.0/cm cell constant.

1. Apply 115/230 VAC power to the analyzer.
2. Hook up the sensor via TB201 and remove orange protective cap. Keep for future use.
3. With the sensor dry and in air, the 455 conductivity analyzer should display a reading of 0.0 µS/cm ± 0.5 µS/cm.
4. Perform an "air" zero calibration; use wires to be field installed and allow 30 minutes warm-up time for the electronics to stabilize.
5. Run the "Std." (span) calibration; place the sensor in 1000 µS/cm standard. The display should read approximately 1000 µS/cm ± 10 µS/cm.
6. To check for general performance, place the sensor in 100 µS/cm standard. The display should read approximately 100 µS/cm ± 5 µS/cm.
7. Before placing analyzer into operation, verify settings to ensure that they coincide with the intended setup. Refer to *Appendix D: Default Settings* section. For the 4 mA to 20 mA output, set high limit and low limit.
8. Set preference for temperature units as °C or °F in [CONF] [unit].
9. Set desired input signal damping if known; default is 5 seconds.
10. Install password security, if desired.
11. The unit is now ready for field installation.

NOTICE OF COMPLIANCE

US

This meter may generate radio frequency energy and if not installed and used properly, that is, in strict accordance with the manufacturer's instructions, may cause interference to radio and television reception. It has been type-tested and found to comply with the limits for a Class A computing device in accordance with specifications in Part 15 of FCC Rules, which are designed to provide reasonable protection against such interference in an industrial installation. However, there is no guarantee that interference will not occur in a particular installation. If the meter does cause interference to radio or television reception, which can be determined by turning the unit off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

* Reorient the receiving antenna
* Relocate the meter with respect to the receiver
* Move the meter away from the receiver
* Plug the meter into a different outlet so that the meter and receiver are on different branch circuits

If necessary, the user should consult the dealer or an experienced radio/television technician for additional suggestions. The user may find the following booklet prepared by the Federal Communications Commission helpful: *How to Identify and Resolve Radio-TV Interference Problems*. This booklet is available from the U.S. Government Printing Office, Washington, D.C., 20402. Stock No. 004-000-00345-4.

CANADA

This digital apparatus does not exceed the Class A limits for radio noise emissions from digital apparatus set out in the Radio Interference Regulations of the Canadian Department of Communications.

Le present appareil numérique n' émet pas de bruits radioélectriques depassant les limites applicables aux appareils numériques (de la class A) prescrites dans le Règlement sur le brouillage radioélectrique édicté par le ministère des Communications du Canada.

STARTUP

Analyzer Start-up Tests

1. Install the model 455 analyzer according to the instructions in the *Installation* section.
   Verify power supply has been wired for proper voltage and instrument is suitably grounded.
2. Turn on flow at sample inlet or insert sensor in sample.
3. Power up the 455 analyzer.
4. The startup procedure will begin by alternately flashing [tESt] and [——] while performing the memory tests.
5. The analyzer will display in sequence the analyzer model number, in this case [455], and the program version number, eg. [2.10].
6. The display test lights each of the implemented display segments in turn. At the same time, each of the LEDs will be lighted in turn.
7. If the analyzer passes all the tests, then the hardware is functioning properly, and the analyzer will proceed to display the conductivity reading.
8. If the analyzer displays [+Err], this indicates that the conductivity input is off-scale. The error LED will be lit as long as an input is off-scale. An off-scale error can indicate that the sensor is not in solution, is off-scale, or is not connected properly. If the error LED remains lit, press the *ERROR* key to see what errors have been detected by the analyzer.
9. After completing the above steps, the analyzer is now in normal operational mode. Analyzer settings and parameters can be viewed and/or changed at any time using the keypad. Refer to *455 Menus* on page 3 to 5.

Start-up Settings

The 455 analyzer default assumes a sensor with a cell constant of 1.0/cm which is stored in its memory. By default, the analyzer displays conductivity.

The cell constant of the sensor must match the cell constant stored in the analyzer memory. If a cell constant other than 1.0/cm is used, change the constant stored by the analyzer so that the analyzer will read properly.

Temperature has a big impact on conductivity readings, typically 2% change per °C. A 25 °C temperature shift can produce a 50% error if the reading is not compensated. The 455 default correction is 2% per °C (1.11% per °F). For high accuracy work and high purity water applications, IC Controls recommends that the user check the actual chemical rate and change the setting if necessary.

A conductivity sensor's effective surface area can be changed by contact with the process. IC Controls recommends a calibration of the conductivity sensor to determine the effective cell constant. This procedure requires a conductivity standard from which the effective cell constant can be determined.

EASY MENU

The layout of the program is shown in the *455 Menus* starting on page 3.

Remembers Where You Were

The analyzer remembers where *SAMPLE* is. The sample display is home base for the program. The program also remembers which menu selections were used last and loops around the columns. The menu can be accessed using the arrow keys to find any parameter then press *SAMPLE* to return to the displayed reading. Then using the *Right* arrow key return to exactly where you were.

Home Base: Press Sample

From anywhere in the menu, the *SAMPLE* key can be used to return to displaying conductivity. The program will safely abort whatever it was doing at the time and return to displaying the conductivity reading.

The conductivity display is the default sample display for the analyzer. The analyzer's inputs, conductivity and temperature, are arranged underneath each other at the left-hand side of the menu. Use the *Up* or *Down* arrow key to display each of the readings in turn.

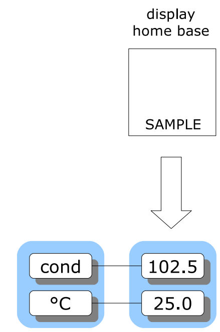


Illustration 6: Home base

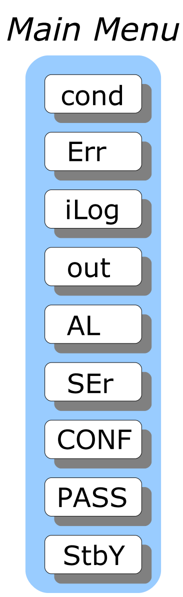


Illustration 7: Main menu

Display Features

1. The analyzer has a built-in timer which returns the program to displaying conductivity if no key is pressed for 15 minutes. This time-out has the same effect as pressing the *SAMPLE* key. If security has been enabled, then the time-out will change the access level back to 0 or 1 automatically which gives the user read-only access. The user will have to enter an appropriate password to go to a higher access level.
2. When the sample value is displayed, pressing the *Left* arrow key will show which of conductivity or temperature is displayed. Pressing *Right* arrow key displays the sample reading again.
3. Each input can be turned off and thereby effectively disappear from the menu if it is turned off in the configuration menu. To change the configuration, refer to the *Configuration of Program* section.
4. The main sample, ie. the input that is displayed first when the *SAMPLE* key is pressed, can be changed. By default the main input is [cond]. Change the default in [CONF] [in] [dFLt]. Refer to the *Configuration of Program* section for further details.

Arrow Keys

The four arrow keys on the keypad are used to move around in the menu.

Example:
Press *SAMPLE* to make sure that display is at home base. Press the *Right* arrow key. One of the prompts in the column starting with [out] will be displayed. Use the *Up* or *Down* arrow keys to display the prompt above or below. If the prompt at the top or the bottom is displayed, the program will loop around. Press the *Up* or *Down* key until [AL] is displayed. Press the *Left* key to return to the sample display. Press the *Right* key again and [AL] will be displayed.

AUTO and MANUAL Keys

The AUTO and MANUAL keys are used to implement the alarm override feature on analyzers that do not use the PID option. Refer to the *Alarm Override* heading in the *Alarm Functions* section for a description of these key functions.

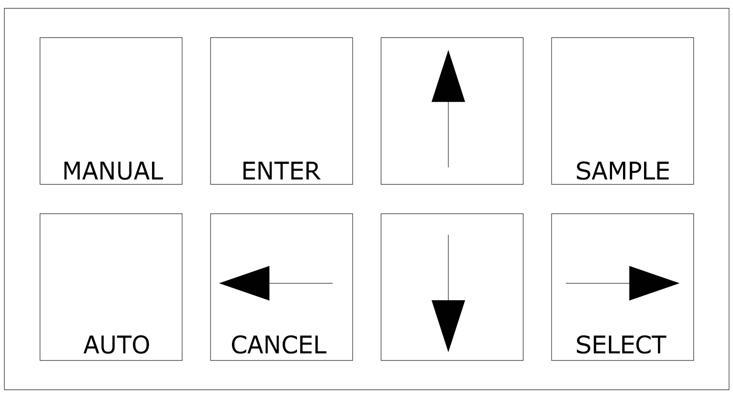


Illustration 8: Analyzer keypad

Standby Mode

In standby, the alarms will not function and the 4 mA to 20 mA outputs will go to 4.00 mA. When *SAMPLE* is pressed, the inputs will show [StbY].

The analyzer will not resume normal operations until the analyzer is taken out of standby. While in standby, the entire menu and all of the settings are accessible to the operator as before. None of the settings will take effect until the analyzer is returned to normal operation.

The standby feature is protected by security level 2.

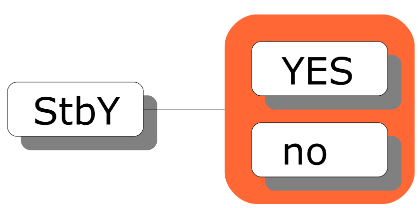


Illustration 9: Standby menu

EDIT MODE

Edit mode is used to change a numeric value or to select between different options. Values and settings which can be edited are identified by the darker shading in the menu. Any frame which has a white background cannot be modified.

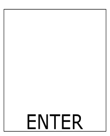
Editing by Selecting a Setting

Editing a value is like picking an option from a list - only one item on the list can be seen at a time. To change the setting, press *ENTER* to go into edit mode. The display will start blinking. Use the *Up* or *Down* arrow key to switch between the possible options and then press *ENTER* again to accept the new setting and leave edit mode.

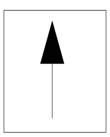
Example*:* Turn alarm A off.

From the menu, select [Al] [Al.A] [ON.OF]. The analyzer will now display either [ON] or [OFF], which are the two choices. To change the setting, press *ENTER* to go into edit mode. The display will start blinking. Use the *Up* or *Down* arrow key to switch between the possible options. When [ON] is displayed, press *ENTER* again to accept the new setting and leave edit mode.

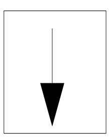
Summary of Key Functions in Edit Mode



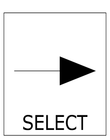
Enters edit mode. The entire display or a single digit will blink to indicate that the analyzer is in edit mode. Press the *ENTER* key again to leave edit mode and accept the new value.



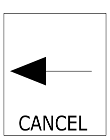
Adjusts blinking digit upward or selects the previous item from the list. If a 9 is displayed then the digit will loop around to show 0.



Adjusts blinking digit downward or selects the next item from the list. If a 0 is displayed then the digit will loop around to show 9.



Numeric values only: move to the right one digit. If blinking is already at last digit, the display will loop to the ± sign on the left.



Numeric values: move left one digit. If blinking is at the ± sign then blinking goes to last character.
Settings: restore the initial value if it was changed. Otherwise leaves edit mode without doing anything.

Illustration 10: Edit keys

Temperature °C or °F

By default, the analyzer will use metric units. This means that temperature will be displayed using degrees Celsius and that the prompt for the temperature input will be [°C]. The analyzer can also use imperial units. For imperial units, temperature will be displayed using degrees Fahrenheit and the prompt for the first temperature input will be [°F] instead of [°C].

In this instruction manual, the temperature input is always identified as [°C] throughout the menus.

To select imperial units for the analyzer, select [unit] from the configuration menu, then go into edit mode and change the [°C] setting to [°F].

Input Damping

The conductivity and temperature measurements can be damped to provide the user with a means to alleviate rapidly-varying or noisy signals. The available damping range is 3 s to 99 s; with 0, there would be no damping and each reading the analyzer made would be used to directly update the display and 4 mA to 20 mA output. The factory default of 5 s adds the next four seconds worth of readings to the first and divides by five; this provides a fast response. Selecting 99 s adds the readings for 99 s and divides by 99, providing smooth damping out of turbulent readings. Any selection between 3 s and 99 s can be made.

Select [CONF] [in] from the menu. Use the up or down arrow key to select the input to be adjusted, then select the [dA] frame. Press *ENTER* to edit the input damping to the selected seconds. Press *ENTER* to leave edit mode.

Real-Time Clock

The analyzer clock is used for internal date/time stamping of system events and the internal data log. Both the system events and the internal data log are accessed using the IC Net Intelligent Access Program, which is available as option -35. Analyzers purchased with option -34 have a real-time clock which will maintain the correct time and date even when the analyzer power is turned off.

CONDUCTIVITY MEASUREMENT

What is conductivity?

Electrical conductivity is a measure of the ability of a solution to carry a current. Current flow in liquids differs from that in metal conductors in that electrons cannot flow freely, but must be carried by ions. Ions are formed when a solid such as salt is dissolved in a liquid to form electrical components having opposite electrical charges. For example, sodium chloride separates to form Na^+ and Cl^- ions. All ions present in the solutions contribute to the current flowing through the sensor and therefore, contribute to the conductivity measurement. Electrical conductivity can therefore be used as a measure of the concentration of ionizable solutes present in the sample.

Conductivity Units

Electrical resistivity uses the unit of ohm meter or Ω·m. Electrical conductivity is the reciprocal of electrical resistivity. Rather than use the units $\Omega^{-1}\cdot m^{-1}$, in 1971 the unit “siemens” (symbolized by the capital letter S) was adopted by the General Conference on Weights and Measures as an SI derived unit. The unit for electrical conductivity becomes siemens per meter. The siemens unit is named after Werner von Siemens, the 19th century German inventor and entrepreneur in the area of electrical engineering.

MEASUREMENT	***UNITS***
resistance	ohm
conductance	siemens, mho
resistivity	ohm
conductivity	siemens/cm

Table 1 Electrical conductivity measuring units

North American practice continues to see the use of unit mho/cm to measure conductivity, where the unit “mho” is a reciprocal ohm. The word “mho” is the word “ohm” spelled backwards. Because of the history of conductivity measurements in micromho/cm and millimho/cm, it is common to see these measurements translated to microsiemens/cm and millisiemens/cm because there is a one-to-one correspondence between these units.

What is a Cell Constant?

The volume of the liquid between the electrodes must be exact so that the analyzer can determine how much current will flow through a known amount of liquid. The controlled volume of a conductivity sensor is referred to as its *cell constant*.

A cell constant of 1.0/cm describes a cell with an enclosed volume equal to 1.0 cm^3. A cell constant of 1.0/cm is the easiest constant to work with as conductivity describes the amount of current flow per centimeter.

A cell constant is usually chosen to produce a steady flow of current between the two electrodes. Moderate current and voltage levels can usually be achieved by selecting the proper cell constant. A high cell constant is used for solutions with high conductivity, and a low cell constant is used for solutions with low conductivities.

Measurement Range

The 455 conductivity analyzer is an auto-ranging analyzer. The input circuit has four ranges and will switch automatically to avoid going off-scale.

The range, e.g. 0 µS/cm to 10,000 µS/cm, is determined by the gain used by the analyzer plus the cell constant of the sensor. Ranges in this manual are based on a cell constant of 1.0/cm.

The analyzer gains are 100, 1,000, 10,000, and 100,000. Table 2, Guide to Cell Constants and their Usable Ranges, indicates maximums for the ranges using available cell constants.

Manual Range Switching

By default, the analyzer is in auto-range mode. To change to manual mode, go to configuration menu; [CONF] [in] [cond] [AUtO], edit from [YES] to [no]. The range can now be manually adjusted by changing the setting in [CONF] [in] [cond] [rANG].

Cell Constant and Range

Changing the cell constant to 0.01/cm, achieves ranges of 1 µS/cm, 10 µS/cm, 100 µS/cm, and 1,000 µS/cm while 20/cm achieves 2,000 µS/cm, 20,000 µS/cm, 200,000 µS/cm, and 2,000,000 µS/cm.

If the sensor is replaced with a sensor having a different cell constant, the cell constant needs to be changed in memory. Select [CONF] [cond] [CELL] [1] from the menu, then edit the cell constant. The program will allow cell constants between 0.001/cm and 99.99/cm to be entered.

Guide to Cell Constant Usable Ranges

CELL CONSTANT cm^{-1}	***DESIGN RANGE*** *µS/cm*	***LOWEST RANGE*** *µS/cm*	***HIGH RANGE*** *µS/cm*	***OVER-RANGE **** *µS/cm*
0.01	0 to 10	0 to 1	0 to 100	0 to 1 000*
0.02	0 to 20	0 to 2	0 to 200	0 to 2 000*
0.1	0 to 100	0 to 10	0 to 1 000	0 to 10 000*
0.2	0 to 200	0 to 20	0 to 2 000	0 to 20 000*
0.5	0 to 500	0 to 50	0 to 5 000	0 to 50 000*
1.0	0 to 1 000	0 to 100	0 to 10 000	0 to 100 000*
2.0	0 to 2 000	0 to 200	0 to 20 000	0 to 200 000*
5.0	0 to 5 000	0 to 500	0 to 50 000	0 to 500 000*
10.0	0 to 10 000	0 to 1 000	0 to 100 000	0 to 1 000 000*
20.0	0 to 20 000	0 to 2 000	0 to 200 000	0 to 1 000 000*
50.0	0 to 50 000	0 to 5 000	0 to 500 000	0 to 1 000 000*

* *Note:* use over-range with caution. Some sensor designs may limit when used on over-range and may not reach the maximum shown.

Table 2 Cell constant usable ranges

Displayed Conductivity Units

When the analyzer is reading conductivity as microsiemens and the conductivity goes above 9,999 µS/cm, the analyzer shows [+Err] instead of a reading. Internally, the analyzer is still calculating the conductivity reading correctly, but it cannot be displayed properly. When this condition occurs, CA1.9 will appear in the error menu.

Conductivity can be displayed using either µS/cm or mS/cm units where;

$$1\, mS/cm = 1\,000\, \mu S/cm$$

Normally it is best to display the conductivity using µS/cm units for maximum resolution and to switch to millisiemens per centimeter, mS/cm, only if the sample exceeds 9,999 µS/cm. By changing the display units a reading of 9 000 µS/cm would change to 9.00 mS/cm.

By default, the analyzer reads in µS/cm. To change the displayed conductivity units, edit the setting in [cond] [unit]. The options are [1E-3] for mS/cm (1E-3 is scientific notation for milli or thousandth) and [1E-6] for µS/cm (1E-6 is scientific notation for micro or millionth).

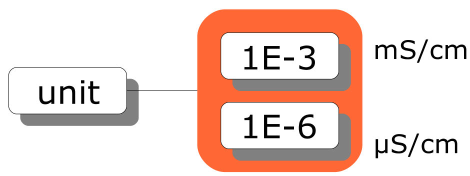


Illustration 11: Units for conductivity input

CONDUCTIVITY CALIBRATION

The conductivity loop is usually calibrated using standard conductivity solutions. Alternatively, grab-sample analysis on a previously calibrated laboratory reference conductivity meter can be used.

Overall system accuracy is maintained by calibrating the sensor and analyzer together in a standard close to the expected sample concentration. Calibration determines the effective cell constant of the conductivity sensor. The cell constant is affected by the shape of the sensing surface and electrode surface characteristics. The effective cell constant will change over time as deposits form, and anything else that affects either the controlled volume or the effective electrode surface area.

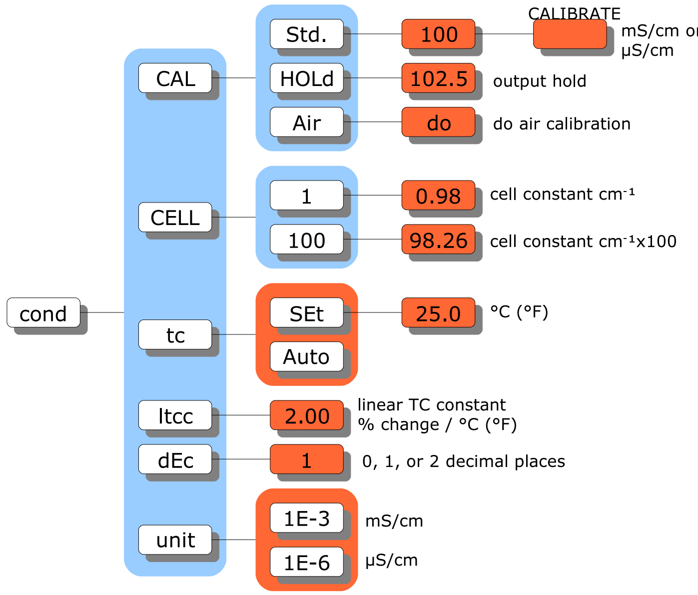


Illustration 12: Conductivity menu

The 455 features an **output hold**. Output hold goes into effect as soon as a calibration is started. The output hold will stay in effect until;

a) *SAMPLE* key is pressed

b) no key is pressed for 15 minutes

c) the power is interrupted and analyzer reboots

The output hold feature avoids false alarms and erratic signal output caused by a routine calibration.

Selecting a Standard

Conductivity standards provide the simplest and most accurate method for calibrating the 455 analyzer. The analyzer has been programmed to recognize the three standards most commonly used for calibration; 100 µS/cm, 1 000 µS/cm, and 10 000 µS/cm at 25 °C (77 °F). Simply place the sensor in the standard and the analyzer will use the correct temperature adjusted value for the standard.

Temperature dependence of standards

To achieve greater accuracy, the temperature compensated values for the 100 µS/cm, 1 000 µS/cm, and 10 000 µS/cm conductivity standards are calculated by the analyzer. If manual temperature compensation has been selected, then the manual temperature compensation set-point is used as the standard temperature.

Other standards or custom standards

If a “custom value” conductivity standard is to be used, press *SELECT* [Cal] *SELECT* [100], then *ENTER* to edit to the known value. Values entered this way should be the known value at the current temperature as they are not temperature-compensated by the analyzer.

Calibration Using Standards

Select a conductivity standard with a concentration that is close to the expected sample concentration. A second conductivity standard can be used to verify that the conductivity sensor is responding properly. This second standard can be any value but typically 10% of the first standard works well giving checks at 100% and 10% of range.

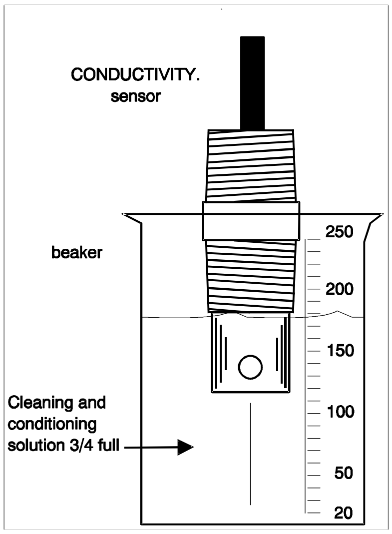


Illustration 13: Conductivity calibration

1. Obtain calibration supplies such as a graduated cylinder or beaker which is large enough to submerse the conductivity sensor, plus distilled or deionized water in a squeeze bottle for rinsing, or an IC Controls calibration kit.
2. Remove the conductivity sensor from the process and inspect the sensor for any deposits. If the sensing surface is coated, clean the sensor before proceeding. Refer to the *Sensor Maintenance* section. Rinse the sensor cell area with distilled water.
3. Rinse the graduated cylinder or beaker with some of the standard, then pour the selected higher conductivity standard into the graduated cylinder or beaker.
4. Immerse the sensor and ensure the sensor electrode area is completely submerged. If the sensor has vent holes, then the sensor must be submerged below the vent holes and there must be no air bubbles inside.

Important:

a) Air bubbles inside the controlled volume area of the conductivity sensor cause major upsets to ion flow and result in large errors in the reading.

b) If the analyzer is not reading on-scale, it may be because the automatic ranging is “OFF” and the wrong range has been manually selected. Refer to *Configuration of Program* section.

5. Select [cond] [CAL] [std] from the menu, and press *SELECT.* Edit the displayed standard value to that of the standard you are using in mS/cm or μS/cm depending on the setting of [cond] [unit].
6. Press *SELECT* to start the calibration. The analyzer will display a flashing concentration reading. From here on the calibration process is automatic - the analyzer will wait until the reading has stabilized, then calculate the cell constant using the temperature-compensated value of the conductivity standard. The display stops blinking and shows the conductivity of the standard upon completion of calibration.

NOTE:

a) *It is possible to repeat or restart the calibration at any time. Simply press* CANCEL, *then* SELECT *to restart or to repeat the calibration.*

b) *If a problem is detected during calibration, a caution or error message will be displayed. Refer to* Error Messages *section.*

7. The conductivity sensor and analyzer pair are now calibrated. Used conductivity standard should be discarded because exposure to air and contamination causes the conductivity value of standards to change.

NOTE:

a) *You can inspect and/or manually adjust the cell constant by selecting* [cond] [CELL] [1] *from the menu.*

b) *The sensor condition can be verified by measuring the concentration of a second standard. Rinse the sensor surface with deionized water and then measure the concentration of the second standard (refer to step 4). If the analyzer reads correctly, the sensor condition is good. If the analyzer does not read correctly, the sensor may not be responding properly and may need to be cleaned.*

c) *It is possible that electrical pickup may cause an erroneous reading, such as an elevated zero with the sensor in air.*
Normally an "air calibration" for zero is only needed if the sensor has been replaced.
CAUTION*: To get an accurate air calibration, the sensor must be completely dry for zero air calibration.*

Calibration by Grab-Sample

The grab-sample technique is quicker and easier if the sensor is not easily accessible. This procedure describes how to calibrate the analyzer without removing the sensor out of the process. The procedure requires that the sample be measured using a second analyzer. Typically a laboratory analyzer is used to determine the actual conductivity of the sample.

1. Obtain the following materials:
    a) a second conductivity analyzer
    b) sensor of known constant
    c) calibration standards
    d) a clean beaker for taking a sample
    e) a calculator
2. Calibrate the second conductivity unit.
3. Record the cell constant of the sensor being used with the model 455. The cell constant is displayed by pressing *SAMPLE*, and then selecting [cond] [CELL] [1] from the menu.
4. Draw a sample from the process. In order for the procedure to work properly, the sample taken must be representative of the sample being measured by the 455 conductivity analyzer.
5. Record the conductivity and temperature of the sample as displayed by the 455 conductivity analyzer.
6. Measure the conductivity of the sample using the second conductivity analyzer and record the conductivity reading. For accurate results, the sample must be at the same temperature and the analyzers must use the same temperature compensation method.

7. Calculate the new cell constant to be entered into the 455 analyzer using the following formula:

$$new\ cell\ constant = \frac{lab\ reading}{field\ reading} \times old\ cell\ constant$$

For example, if the 455 analyzer is reading 820 µS/cm, the cell constant (from step 2) is 1.0/cm, and the reading from the second method is 890 µS/cm, then the new cell constant becomes:

$$new\ cell\ constant = \frac{890\,\mu S/cm}{820\,\mu S/cm} \times 1.0/cm = 1.09/cm$$

8. Adjust the cell constant to the new value, e.g. 1.09/cm, as in the example. The cell constant is adjusted by selecting [cond] [CELL] [1] from the menu. Press *ENTER* to get into edit mode, then adjust the displayed value.
9. The analyzer should now read accurately.

Air Zero Calibration

It is not necessary to repeat an “Air” calibration every time a regular calibration is performed.

An air calibration should be performed anytime a new sensor is installed. When a sensor is in air, the conductivity measured by the sensor is expected to be zero. It is not uncommon to find some small conductivity signal with the dry sensor in air or even with no sensor connected at all. This measurement may be attributed to background noise, lead wire pickup (antenna effect) or grounding problems. The air calibration is designed to subtract the small errors of this interference signal from the real measurement in order to give a true zero reading.

1. Perform a zero calibration any time a new sensor is installed.
2. Ensure that the sensor is dry before zeroing. The analyzer should be reading a low conductivity value.
3. From the menu select [cond] [Air] and press *SELECT*. The analyzer will show a flashing [do].
4. When the sensor is ready to be calibrated, press *ENTER*.
5. Press *SAMPLE*. With the sensor still dry and in air, the conductivity should read 0.00 µS/cm.

Potential problem:
When you press *ENTER* with the flashing [do] displayed, the analyzer will not perform the zero calibration but will show the current range number, eg. [rnG.2]. For a zero calibration to be successful, the analyzer needs to be on range 4, the range with the highest gain. If the analyzer is not on range 4, the sensor is likely not in air, or is wet. Correct the sensor situation and try again.

Temperature Compensation (TC)

Ionic movement, and therefore conductivity measurement, is directly proportional to temperature. The effect is predictable and repeatable for most chemicals, although unique to each chemical. The effect is instantaneous and quite large, typically between a 1% to 3% change per degree Celsius, with reference to the value at 25 °C. Many industrial applications encounter fluctuating temperature and thus require automatic compensation. IC Controls' conductivity sensors include a temperature compensator built into the sensor.

The 455 analyzer uses a linear temperature compensation method with a default setting of 2%/°C. 2%/°C is an average value commonly found in many water samples containing some dissolved solids. Over wide temperature spans, e.g. 0 °C to 100 °C, the temperature compensation factor often does not remain constant making it difficult to obtain a good value. If the temperature curve of the sample is known, set the linear TC constant to match the curve in the temperature range the analyzer will be measuring in.

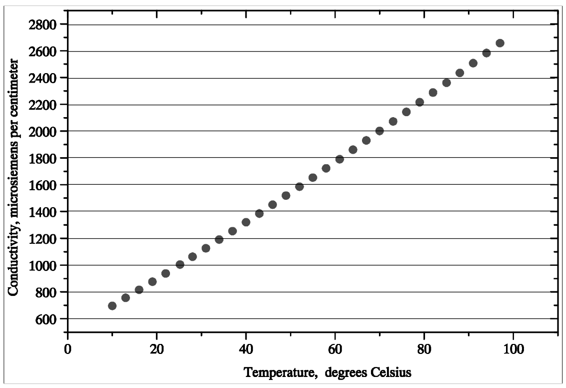


Illustration 14: Typical temperature response

Manual Compensation

If automatic temperature compensation is not available, manual temperature compensation may be used. If the temperature of the sample is constant, set the manual TC temperature to reflect the process temperature. If the process temperature varies or is unknown, the default temperature of 25 °C or 77 °F is normally used.

TC for High Purity Water

Very low conductivity water or “high purity” water is highly temperature-dependent. The presence of trace impurities such as acids, salts, and bases each dramatically and uniquely affect the TC curve required.

Setting the Linear TC Constant

Depending on the chemical involved, the value for temperature compensation will vary. The values change from approximately 1% to 3%. Table 3 is a general guide for typical applications.

The formula for the temperature-corrected conductivity value is:

$$conductivity = \frac{K_{cell}}{R} \frac{1}{1+(\alpha/100)*(T-25)}$$

where

conductivity is the temperature-compensated reading in siemens/cm;

K_{cell} = cell constant in cm^{-1} , typically in the range 0.01/cm to 50/cm;

R = measured resistance in ohms;

α = temperature compensation factor as % change per °C, typically close to 2.0;

T = current temperature in degrees Celsius.

The linear TC constant is normally displayed as percent change per degree Celsius. If the units for temperature are changed from °C to °F, then the linear TC constant automatically changes to percent change per degree Fahrenheit.

Some chemicals that are frequently diluted for use have non-linear temperature compensation requirements. As a result, IC Controls has provided special program versions with TC curves in the memory for some common chemicals used in industry such as NaOH (455-21), H_2SO_4 (455-22), HCl (455-23), and NaCl (455-24), that read out in % concentration; plus TDS, Total Dissolved Solids (455-25), resistivity (455-26), and very low conductivity or high purity water (455-63).

Substance	*% change per °C*
acids	1.0% to 1.6% per °C
bases	1.8% to 2.2% per °C
salts	2.2% to 3.0% per °C
neutral water	2.0% per °C

Table 3Typical temperature response

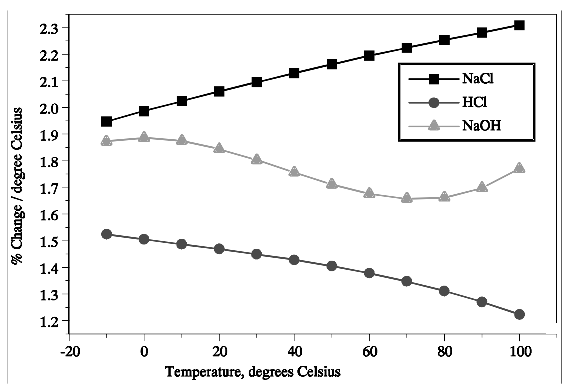


Illustration 15: Non-linear temperature

Conductance Data for Commonly-Used Chemicals

Examples of conductance of various materials with changing concentration are shown below. Sodium Hydroxide (NaOH) also exhibits quite variable temperature related rates of concentration change. It is clear from the graph that both Sulfuric Acid, H_2SO_4, and Nitric Acid, HNO_3, have unusual 'conductivity' vs. '% by weight' relationships as well. It clearly shows that there is no "conductivity constant" between chemical combinations.

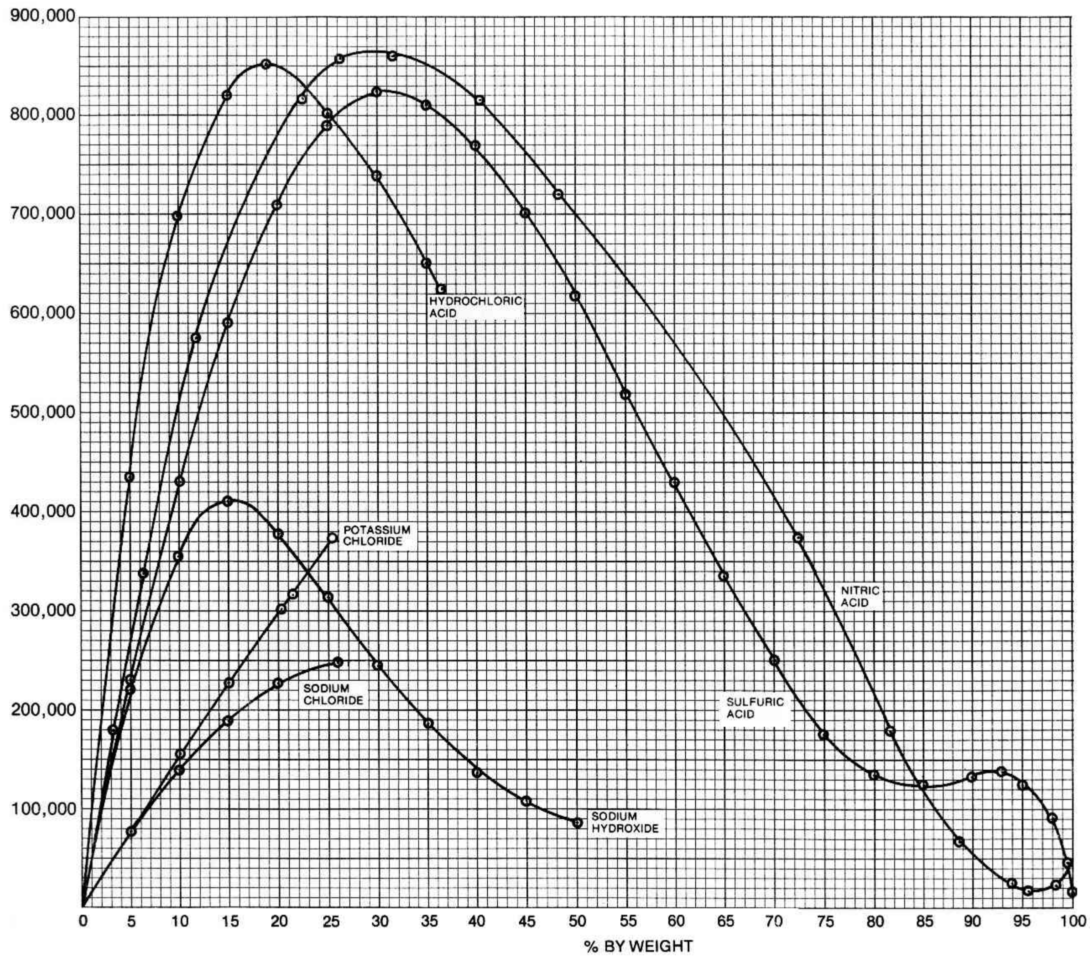


Illustration 16: Conductivity (µS/cm) vs. Chemical concentration

ERROR MESSAGES

Detected errors and/or cautions can be displayed by the analyzer. From the main menu select [Err]. If there are no error or caution messages, [NONE] will be displayed, otherwise scroll through the error list using the *Up* and *Down* arrow keys. Errors and cautions cannot be removed from this list directly; each error or caution will be removed automatically when appropriate, eg. errors associated with improper calibration will be cleared after a successful calibration.

input / source	*input number for error and caution messages*
Conductivity	1
Temperature	2
Alarm A	7
Alarm B	8

Table 4: Input numbers

Error messages are numbered. Errors 1 through 5 are identified as [En.e] where *n* is the input number and e is the error number. Messages 6 through 9 are less serious and are identified as cautions instead, eg. [CAn.e].

Off-scale errors for conductivity are not numbered and are identified as [+Err] and [-Err], depending on whether the input is at the top or the bottom of the scale. The off-scale error is displayed instead of the sample reading and does not show up in the error menu with the numbered error messages, if any.

Error message indicators can be annoying when one has already been made aware of them. A method has been provided to turn off the error LED and the fault alarm for a particular error message. Refer to the heading *Acknowledging an Error Message* below for the exact procedure.

The error LED will remain on as long as there is an unacknowledged error or caution message or as long as any input is off-scale. Each source of error must be removed or acknowledged before the error LED will go off.

Acknowledging an Error Message

Select [Err] from the main menu. Use the *Up* or *Down* arrow key until the error message to be acknowledged is displayed.

Errors are displayed with either a positive (+) sign or a negative sign (-) in front. The + sign is used to indicate an active or unacknowledged error, the - sign indicates an inactive or acknowledged error. Acknowledging the error will change the sign from + to -.

Press *ENTER* to go into edit mode. The + or - sign will be flashing. Use the *Up* or *Down* arrow key to change the sign, then press *ENTER* again.

An acknowledged error message is cleared for one occurrence of the error only. If the error reappears, the sign changes from - to + and the error message must be acknowledged again.

Error Messages for Conductivity

Error	***Description***	***Causes***	***Solutions***
E1.1	Electrode has not stabilized after 5 minutes of calibration.	Poor electrode performance; sample is not stable; interference.	Check electrode and setup until stable reading is achieved; redo calibration.
E1.2	Effective cell constant would be less than 0.001. Previous cell constant retained.	Incorrect or contaminated standard used for calibration.	Redo calibration using correct or fresh standard. Refer to *Troubleshooting* section.
E1.3	Effective cell constant would be greater than 100. Previous cell constant retained.	Incorrect or contaminated standard used for calibration.	Redo calibration using correct or fresh standard. Refer to *Troubleshooting* section.
E1.4	Range-switching error.	Gap between ranges.	Electronic calibration adjustment needed.
			Turn automatic range-switching off; manually switch between ranges.
E1.5	Temperature compensator (TC) is off-scale.	Sample outside of TC operating range of -10 °C to 210 °C.	Use manual temperature compensation.
			Check TC connections or install TC.
E1.6	Input is at maximum.	The internal A/D (analog-to-digital) converter is at the top of the scale. The analyzer cannot measure higher at this range.	If conductivity input is in manual range switching, change to automatic range switching so that the analyzer can automatically shift up to the next input range.
			If conductivity input is already on range 4, then the analyzer is at the limit of it's measuring capability. Use a different sensor with a higher cell constant.
E1.7	Conductivity shows negative value.	Linear temperature compensation constant (LTCC) is set to high.	Determine a lower LTCC to use to correctly compensate for temperature. A typical value is 2.00 (for 2% change per °C).

Error	*Description*	*Causes*	*Solutions*
CA1.9	Display shows OFL.d.	Conductivity value too high for the LCD display; eg. the display units are µS/cm and the conductivity is higher than 9,999 µS/cm.	Change the display units from µS/cm to mS/cm in [cond] [unit].
0.00	No conductivity measurement.	Sensor resistance has saturated the measuring capability of the analyzer.	Open circuit; sensor not connected.
			Sensor with different cell constant should be used.

Error Messages for Temperature

Error	*Description*	*Causes*	*Solutions*
E2.1	Temperature reading off-scale; less than -10 °C.	Temperature is lower than -10 °C.	Verify process and sensor location.
		Electronic calibration needed.	Follow procedure in *Hardware Alignment* section.
E2.2	Temperature reading off-scale; greater than 210 °C.	Temperature compensator (TC) not attached.	Attach temperature compensator.
			Turn off temperature input. Follow *Input On/Off Switch* procedure in *Software Configuration* section.
			Connect resistor to TC terminals to simulate a constant temperature. Refer to *Hardware Alignment* section.
		Temperature is higher than 210 °C.	Verify process and sensor location.
		Electronic calibration needed.	Follow procedure in *Hardware Alignment* section.

Caution Messages for Alarms

Caution Number	*Description*
CA7.6	Alarm A, High alarm
CA7.7	Alarm A, Low alarm
CA7.8	Alarm A, Deviation alarm
CA7.9	Alarm A, Fault alarm
CA8.6	Alarm B, High alarm
CA8.7	Alarm B, Low alarm
CA8.8	Alarm B, Deviation alarm
CA8.9	Alarm B, Fault alarm

SENSOR INSTRUCTIONS

Preparation for use

1. Moisten the sensor body with tap water and remove the lower plastic storage cap. Keep the storage cap for future use. Rinse the exposed conductivity elements with tap water.
2. For first time use, or after long term storage, immerse the tip of the sensor in a conductivity standard for 30 minutes. This wets the conductivity electrodes and prepares them for stable readings with test solutions.

NOTE: *IC Controls sensor's are shipped dry. These electrodes are often ready for use immediately with a typical accuracy of ± 2% conductivity without calibration. It is recommended that the sensor be soaked in standard plus calibrated using an appropriate conductivity standard in order to achieve optimal results.*

Calibration for Conductivity

Overall system accuracy is maintained by calibrating the sensor and analyzer together in a concentration close to the expected sample concentration. The cell and analyzer can generally be calibrated in two of four typical ranges: 0 µS/cm to 100 µS/cm, 0 µS/cm to 1 000 µS/cm, 0 µS/cm to 10 000 µS/cm, and 0 µS/cm to 100 000 µS/cm.

IC Controls has available conductivity calibration kits which conveniently package all necessary calibration supplies. These kits are available as P/N A1400051 (low conductivity; cell constants 0.01/cm and 0.02/cm), P/N A1400052 (medium conductivity; cell constants 0.1/cm to 5.0/cm) and P/N A1400053 (high conductivity; cell constants 10/cm to 50/cm).

Where to Perform Conductivity Calibrations

A suitable place to conduct a calibration is at a counter or bench with a sink in an instrument shop or laboratory. However, IC Controls' conductivity calibration kits are kept small and portable so that they can be taken to installation sites, together with a bucket of water (for cleaning/rinsing) and a rag or towel (for wiping/drying).

NIST Traceable

IC Controls QC's manufactured conductivity standards using NIST (National Institute of Standards and Technology) materials. Certificates of traceability to NIST are available as P/N A1900333.

Sensor Storage

Short term: Rinse the sensor electrodes in deionized water, allow to dry and store dry.

Long term: Rinse the sensor electrodes in deionized water, allow to dry, cover sensor tip with the plastic shipping cap and store dry.

Monthly Maintenance

A monthly maintenance check is recommended by grab sample calibration since the sensor is typically installed in the process and not easy to remove. Whenever possible, calibration using a conductivity standard close to the process conductivity value is suggested.

Follow the appropriate calibration procedure in *Conductivity Calibration* section. Keep a log of the cell constant at each monthly calibration.

Yearly Maintenance

Follow the monthly maintenance procedure. Check the cell constant log. If the cell constant has changed more than 20% over the past year, it may need to be chemically cleaned - follow the *Chemical Cleaning of Sensor* procedure.

O-rings and teflon-sealing ferrules should be replaced on conductivity sensor models 402, 403, 414, and 425.

The condition of electrical connections in 400 junction boxes should be examined for signs of corrosion and tight connections; replace if corroded.

The condition of the safety cables on model 403 sensors should be examined for rust or bent mounting screws. Replace if deterioration shows.

Restoring Sensor Response

Mechanical Cleaning of Sensor

The sensor will require cleaning if sludge, slime, or other tenacious deposits build up in the internal cavities of the sensor. Wherever possible, clean with a soft brush and detergent. General debris, oil films and non-tenacious deposits can be removed in this way.

For flat-surface sensors, use a potato brush and a beaker or bucket of water with a good liquid detergent. Take care not to scratch the electrode surfaces. Internal cavities of standard sensors can be brushed with a soft ¼ inch diameter brush.

Plastic body sensors should be washed using a soft cloth ensuring all wetted areas are cleaned. This will return their appearance to like-new condition and remove sites for buildups to occur.

Check the sensor calibration against a conductivity standard and calibrate if necessary. If the sensor is still not responding properly, proceed to the *Chemical Cleaning of Sensor* procedure, otherwise, return the sensor to the process.

Chemical Cleaning of Sensor

Obtain a supply of IC Controls' conductivity sensor cleaning and conditioning solution, P/N A1100005, or as available in conductivity chemical cleaning kit P/N A1400054.

NOTE 1: *A suitable place to do chemical cleaning is at a counter or bench with a laboratory sink with a chemical drain where waste is contained and treated before release.*

NOTE 2: *IC Controls' kits are kept small and portable so that they can be taken to installation sites, together with a bucket of water (for rinsing) and a rag or towel (for wiping/drying). Waste materials, particularly acid leftovers, should be returned to the laboratory sink for disposal.*

CAUTION: *Use extra caution when handling cleaning solution as it contains acid.* **Wear rubber gloves and adequate facial protection when handling acid.** *Follow all P/N A1100005 MSDS safety procedures.*

a) Set up the cleaning supplies where cleaning is to be performed. Lay out the sensor cleaning brush, syringe, cleaning and rinse solutions, plus the beakers and sensor if already at hand.
   NOTE: *Ensure your cleaning solution beaker is on a firm flat surface since it will contain acid.*

b) Remove the conductivity sensor from the process and examine it for deposits. Use the sensor cleaning brush with tap water to loosen and flush away any deposits within the cell measurement area. Detergent can be added to remove oil films and non-tenacious deposits. Hard scales and other tenacious deposits may require chemical cleaning.

c) **CHEMICAL CLEANING -** Fill a beaker ¾ full of cleaning and conditioning solution P/N A1100005, or for flow-through sensors with internal passages, seal one end to form a container inside the sensor body.

d) Lower the conductivity cell into the center of the beaker until the top hole is submerged, or pour the solution in until the flow sensor is full.

e) Keep removing and re-immersing the sensor until the sensor electrodes appear clean. Stubborn deposits can be worked on with the brush and syringe to squirt cleaner into hard to reach areas.
CAUTION: *Use great care when brushing and squirting acid*. **Wear rubber gloves and facial protection.**

f) Rinse the cleaned sensor thoroughly in tap water and squirt with deionized water to rinse before calibrating.

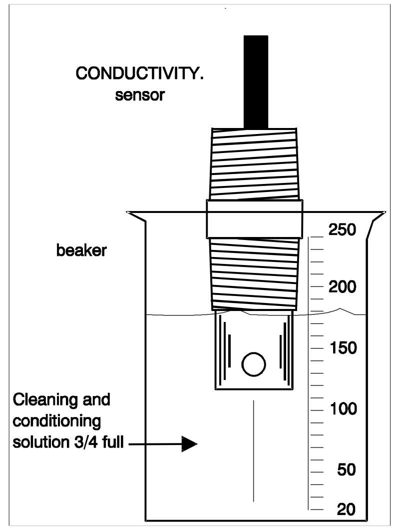


Illustration 17: Chemical cleaning

g) Check the sensor against a conductivity standard near full scale. If the sensor is still not developing the proper cell constant ± 5% (or reading near the standard value), clean again, proceed to troubleshoot or replace the sensor.

h) A clean, rinsed and dried conductivity sensor should read near zero in air. If it does not, troubleshoot the sensor, wiring, and analyzer.

If the sensor cannot be returned to good condition, it may need to be replaced. The cell constant, as calculated by the analyzer, should be within 25% of the original or intended value stamped on the sensor.

NOTE: *If none of the above procedures succeed in restoring your sensor response, it is near the end of its useful life and should be replaced.*

Alternatively, available acids can be used such as nitric acid, hydrochloric acid, or sulphuric acid. Nitric acid is preferred as it has no chlorides to corrode stainless steel. Acid concentrations between 0.5% acid and 10.0% acid (approximately 50% dilution of concentrated acid) can typically be used, depending on the severity of the application.

4 mA TO 20 mA OUTPUT SIGNALS

Two assignable 4 mA to 20 mA output channels are provided. The user may configure the analyzer to determine which input signal will be transmitted by each 4 mA to 20 mA output channel. Each output channel can be independently configured to transmit a conductivity or a temperature signal.

The output channels function independent of each other. Each output channel has a separate on/off switch and adjustable low and high span (or scale) adjustments. This makes it possible, for example, to transmit two conductivity signals, each using separate high and low adjustments.

To adjust the output span or output window for conductivity or temperature signals, set [LO] to correspond to the low end of the scale or 4 mA output, and set [HI] to correspond to the high end of the scale or 20 mA output. The analyzer will automatically scale the output according to the new settings.

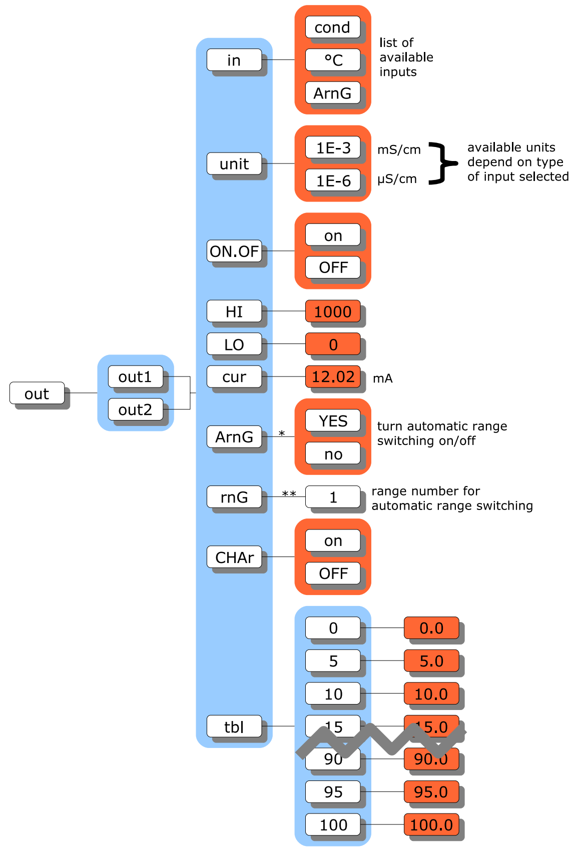


Illustration 18: Output menu

Reversing the 4 mA to 20 mA Output

The low scale setting will normally be lower than the high scale setting. It is possible to reverse the output or "flip the window" by reversing the settings of the low and high scale.

Simulated 4 mA to 20 mA Output

Select [cur] from the output menu to display the output current in mA that is presently being transmitted by the output signal. The display will be updated as the output signal changes based on the input signal and the program settings. From here, one can watch the output respond to the change in the input signal. This is useful for verifying program settings and for testing the hardware calibration.

To simulate a different 4 mA to 20 mA output signal, press *ENTER* to access edit mode. Edit the displayed mA value to display the desired output needed for testing the output signal. Press *ENTER* to select the displayed value. The output signal will be adjusted to put out the desired current. This process can be repeated as often as necessary.

The output signal is held at the displayed level until the program leaves this part of the menu.

Units for Outputs

The output menu will be using different units for its settings, depending on the input selected. Select [unit] from the output menu to display the units in use for this output. The [unit] setting affects the LO and HI settings.

For conductivity, the [unit] selection can be set to[1E-6] for microsiemens, µS/cm, or [1E-3] for millisiemens, mS/cm.

For temperature, the [unit] selection can be set to [°C] for degree Celsius, or [°F] for degree Fahrenheit.

Decimal Places for Conductivity

The number of decimal places for high and low conductivity output can be adjusted to 0, 1, or 2 decimal places. Select [cond] [dEc] from the menu.

Automatic Range Switching

Automatic range switching enhances the resolution capability of the 4 mA to 20 mA output. An application could track the conductivity input from 0 mS/cm to 500 mS/cm. When the conductivity level drops below about 50 mS/cm, a typical recorder would be able to show very little resolution (refer to illustration 20).

With automatic range switching in effect for output 1, the output will adjust automatically over 4 ranges, moving from range 1 which is 100% of full scale to range 4 which is 0.1% of full scale. This means that with a full-scale setting of [HI] = 500 mS/cm, the output will automatically switch down to 0 mS/cm to 0.05 mS/cm or 0 µS/cm to 50 µS/cm on the fourth range. The actual numbers depend on the setting of the [HI] value and is user-adjustable.

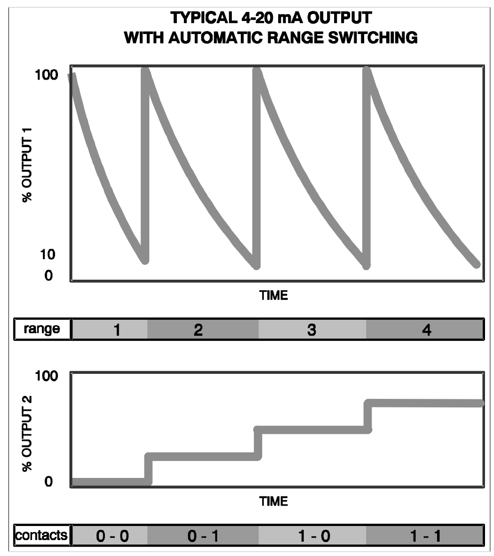


Illustration 19: Output with automatic range

A hysteresis is built into the output logic to avoid having the output switch between ranges too frequently, thereby painting the chart recorder. The output will not switch downscale until the output reaches 9.5% of the current scale. The output will switch upscale again when the output reaches 100% of the current scale.

Enabling Automatic Range Switching

Only output 1 has auto-range available. From the menu select [out] [out1] [ArnG], then edit the setting to show [YES]. With auto-range enabled, the range currently being used can be determined by selecting [out] [out1] [rnG] from the menu.

Example of Range Switching

Illustration 19 shows the effect of using automatic range switching on the 4 mA to 20 mA output. Illustration 20 shows the conductivity level decreasing with no resolution at the low levels. The upper graph of illustration 19 depicts the 4 mA to 20 mA staying within 10% to 100% of scale by switching ranges in output 1. The lower graph shows the 4 mA to 20 mA of output 2, reflecting the range in effect on output 1.

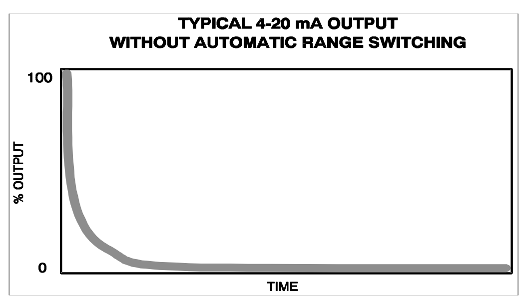


Illustration 20: Output without range switching

To achieve results similar to those in illustration 19, use the settings in Table 5.

Setting	***Output 1***	***Output 2***
[in]	[cond]	[ArnG]
[ON.OF]	[on]	[on]
[LO]	0	1
[HI]	500	5
[unit]	[1E-3]	
[ArnG]	[YES]	

Table 5: Output settings

Using the Alarm Contacts

The alarm contact method uses the two alarm contacts to distinguish between ranges. With two contacts, there are four possible combinations. The on/off combinations for the A and B contacts are shown in Table 6.

To use the alarm contacts for range indication set [CONF] [AL] [AL.A] [Func] to [rnG].

While the relay contacts are being used for remote range indication of output 1 range, the alarms will continue to function, ie. LED indication and alarm caution messages in the SAMPLE frame plus IC Net alarms. It is not possible to use the relay contacts for alarm indication and range indication at the same time.

Using the Second 4 mA to 20 mA Output

A more versatile method for indicating the range number for output 1 remotely is to use output 2. The following settings for output 2 will transmit the range number: [in] = [ArnG], [ON.OF]= [on]

Range Number	***Output 1; % Full Scale***	***Output 1; Conductivity (mS/cm)***	***Output 2; mA***	***Relay Contacts***
1	100	500	4.00	A=0, B=0
2	10	50	8.00	A=0, B=1
3	1.0	5.0	12.00	A=1, B=0
4	0.1	0.5	16.00	A=1, B=1

Table 6: Example of range switching

Range Number	***LO = 0 HI = 4***	***LO = 1 HI = 4***	***LO = 4 HI = 1***	***LO = 4 HI = 0***
OUT2=OFF	4.00	4.00	4.00	4.00
1	8.00	4.00	20.00	20.00
2	12.00	9.33	14.67	16.00
3	16.00	14.67	9.33	12.00
4	20.00	20.00	4.00	8.00

Table 7: Using output 2 for range indication

Also, set the [HI] and [LO] parameters to indicate which values represent 4.00 mA and 20.00 mA. Table 7 shows the relationship between the range number and some of the possible LO/HI settings.

Output Characterization

The 455 analyzer has user-programmable output characterization that is off by default but can be turned on by the user. Output characterization could be used to provide more accurate control over an output device such as a non-linear ball-valve - the output could be customized to meet specific application needs. A 21-point output table allows the user to specify the behavior of the output in increments of 5% of the uncharacterized output signal. The table links uncharacterized output values to desired output values allowing a wide variety of non-linear behaviors to be described with high resolution.

Each of the two outputs has its own independent characterization capability.

Example: Bi-linear output

Goal: Record the conductivity input between 0 µS/cm and 500 µS/cm, while giving 80% of the scale to the area between 0 µS/cm and 100 µS/cm. The purpose is to give maximum recorder resolution to the main area of interest, which is 0 µS/cm to 100 µS/cm, yet still maintain a record of the times that the conductivity would go over this limit.

If output characterization were not available, the [LO] and [HI] could still be set to 0 µS/cm and 500 µS/cm respectively, but the area of interest from 0 µS/cm to 100 µS/cm would occupy only 20% at the bottom of the scale. To correct this, the center of the scale will be 'expanded' and the high area will be 'shrunk'.

To achieve the desired output characterization, the 21-point characterization table and the high and low settings need to be defined.

1. Set the boundaries for conductivity output; [LO] = 0 µS/cm and [HI] = 500 µS/cm. The characterization table will now automatically characterize the output so that 0% = 0 µS/cm and 100% = 500 µS/cm.
2. It is probably easiest to draw or sketch the characterization curve before entering any table values. A blank worksheet has been provided in *Appendix B*. This worksheet can be copied and can also serve as documentation for your analyzer setup.
3. The characterization curve for the example is shown in illustration 21. For reference, the conductivity values corresponding to the uncharacterized output are shown at the top of the diagram. There are three points on the graph that are of most interest.
   a) 0% output corresponds to the [LO] setting of 0 µS/cm and 4.00 mA output.
   b) 'Normal' 100% output corresponds to the [HI] setting of 500 µS/cm and 20.00 mA output.
   c) At 100 µS/cm, 80% output is required.
4. Once the points of interest are identified, plot them on the graph and connect them with straight lines.
5. The column marked "% characterized output" can now be filled in by reading the coordinates off the graph. For example, to find the required table value for "10", locate 10 on the horizontal scale, follow the line up until it hits the curve. The table value is the value on the vertical axis, in this case 40. Refer to the arrows in illustration 21.
6. Once the columns in the table have been completed, enter the table values in the program. Select [tbL] from the output menu, then enter each output value. All 21 points must be entered - values cannot be skipped. Table 8 illustrates the completed table for the example.
7. To activate output characterization, set [CHAr] in the output menu to [on].

% Uncharacterized Output	*Uncharacterized 4 mA to 20 mA Output*	*% Characterized Output*	*Corresponding Conductivity (µS/cm)*	*Corresponding 4 mA to 20 mA Output (characterized)*
0	4.00	0.0	0 (LO) (a)	4.00
5	4.80	20.0	25	7.20
10	5.60	40.0	50	10.40
15	6.40	60.0	75	13.60
20	7.20	80.0	100 (c)	16.80
25	8.00	81.3	125	17.00
30	8.80	82.5	150	17.20
35	9.60	83.8	175	17.40
40	10.40	85.0	200	17.60
45	11.20	86.3	225	17.80
50	12.00	87.5	250	18.00
55	12.80	88.8	275	18.20
60	13.60	90.0	300	18.40
65	14.40	91.3	325	18.60
70	15.20	92.5	350	18.80
75	16.00	93.8	375	19.00
80	16.80	95.0	400	19.20
85	17.60	96.3	425	19.40
90	18.40	97.5	450	19.60
95	19.20	98.8	475	19.80
100	20.00	100.0	500 (HI) (b)	20.00

Table 8: Characterization for Bi-Linear Example

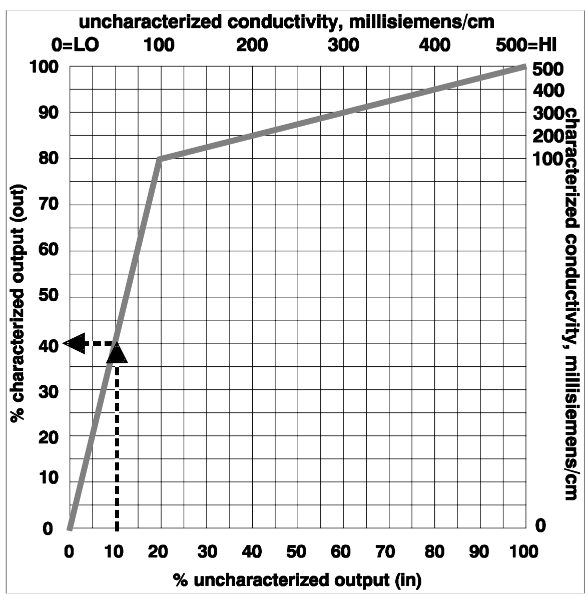


Illustration 21: Bi-linear output characterization

ALARM FUNCTIONS

Two alarms, alarm A and alarm B, are a standard feature. Each alarm has an alarm contact associated with it which can be used for remote alarm indication or for control functions. The two alarms function independently of each other. Either alarm can monitor the conductivity or the temperature input.

Each alarm features an adjustable set-point, user-selectable alarm type, adjustable differential (also called hysteresis), unit selection, and an on/off switch. The alarm types which are available are high, low, deviation, and fault. Alarms can be set anywhere between 0 µS/cm and 9 999 µS/cm *or* 0 mS/cm and 9 999 mS/cm for the conductivity input or –10 °C and 210 °C for the temperature input. The differential is adjustable from 0 µS/cm to 100 µS/cm *or* 0 mS/cm to 100 mS/cm.

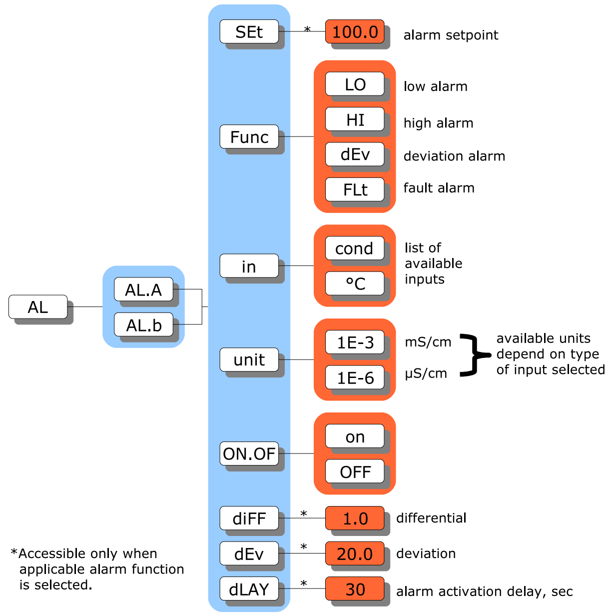


Illustration 22: Alarm menu

Use of Relay Contacts

By default, the relay contacts will be used to indicate alarm conditions. If there is an alarm condition then it will be indicated using both the LED and the relay contact. This function of the relay contacts can be selected by setting [CONF] [AL] [AL.A] [FUNC] and [CONF] [AL] [AL.b] [FUNC] to [AL]. If another use is selected for the relay contacts then the alarm cannot simultaneously use the contact, however, the alarm function continues using the LED, display messages and serial communication.
The relay contacts can also be used for remote indication of range number for the first 4 mA to 20 mA output, PID pump pulse outputs, PID time proportional control, etc..

Alarm Indication

The A and B LEDs on the front panel show the current state of each alarm and alarm contact. In addition, an alarm condition for an input will cause the sample display for that input to alternate with the alarm function, either [LO], [HI], [dEv], or [FLt]. This way the operator can quickly determine which alarm caused the alarm condition (alarm A or alarm B LED lighted), and the type of alarm. An LED that is "blinking" or "on" shows the alarm condition. The status of the relay contact can also be determined at a glance as it is activated when the LED is "on" and deactivated while the LED is only "blinking" or "off". The alarm LED will "blink" while the alarm override is in MANUAL because this situation deactivates the alarm contacts.

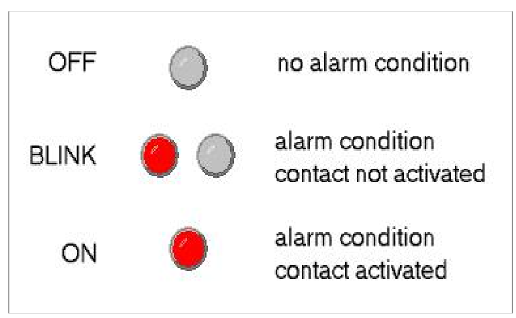


Illustration 23: Alarm status , alarm LEDs

Each alarm will simultaneously generate a caution number in the error menu. Refer to *Caution Messages for Alarms* in section entitled *Error Messages* for a description of each alarm caution. The alarm cautions will not cause the error LED to come on because the error LED only comes on if there are any errors. To view alarm caution(s) using the error menu, select [Err] from the main menu, then use the *Up* or *Down* arrow key to scroll through the list of errors and cautions, if any.

Alarm Override

For normal alarm operation the alarms are said to operate in auto-mode. If the operator wishes to intervene and switch off the alarm contacts temporarily while attending to a problem, the alarms can be switched to manual override using the *MANUAL* key.

In AUTO mode: The green AUTO LED is on and the analyzer alarms will activate and deactivate the relay contact as programmed. Press the *MANUAL* key to temporarily deactivate the alarm contacts.

In MANUAL mode: The green AUTO LED will blink. The relay contacts are deactivated, but the alarm LEDs continue to indicate alarm condition(s). Press the *AUTO* key to return to AUTO mode immediately and reactivate the relays. If no key is pressed for 15 minutes, the 15-minute timeout will return the alarms to AUTO mode.

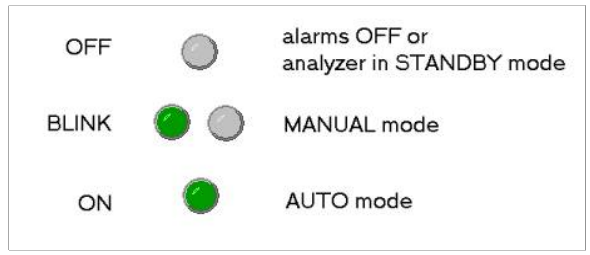


Illustration 24: Alarm override status, AUTO LED

Wiring and NO/NC Contacts

The alarm contacts for alarms A and B may be wired as normally open or normally closed. By default, the analyzer assumes the alarm contacts are wired normally open. A normally open alarm contact will be inactive if there is no alarm condition and will be active when there is an alarm condition. If the program configuration and the wiring for each alarm do not match then the incorrectly configured alarm contact will generate an alarm when there is no alarm condition and vice versa.

Refer to illustration 2 for the configuration menu. Select [CONF] [AL] from the menu.

Delayed Activation

Alarm relay activation, by default, is immediate upon alarm condition, or may be delayed. Delay gives the operator a chance to correct alarm situations before the relay contacts activate, or can eliminate alarms based on temporary or spurious change in the process.

The delay time is programmable by the operator. To change or view the delay time, select [dLAY] from the alarm menu. The default value of 0 seconds is for immediate contact activation. The delay time can be set from 0 s to 9 999 s.

Deviation Alarm

A deviation alarm is practical when the process is expected to stay within a certain range. An alarm will be set if the input deviates too far from a set-point. Please note that the [dEv] frame only shows up in the menu after the alarm function has been changed to deviation alarm since it would have no effect for a high, low, or fault alarm.

Example:
If the conductivity is expected to stay between 100 μS/cm and 200 μS/cm, then we would set [in] to [cond], [Func] to [dEv], [SEt] to 150, and [dEv] to 50. Effectively, a high alarm at 200 μS/cm and a low alarm at 100 μS/cm has been set.

The differential setting will continue to function as for high and low alarms.

High or Low Alarm

A high alarm is set when the value of the conductivity or temperature rises above the set-point and is cleared when the conductivity or temperature drops to below the set-point minus the differential (refer to illustration 25). A low alarm is set when the value of the conductivity or temperature drops below the set-point and is cleared when the conductivity or temperature rises to above the set-point plus the differential (refer to illustration 26). The differential has the effect of setting the sensitivity of the alarm. The differential provides a digital equivalent of a hysteresis.

A two-stage alarm can be implemented by choosing the same alarm function, ie. high or low alarm, for both alarms, but selecting different set-points.

Example:
The conductivity of a critical process may not drop to below 50 µS/cm. Use alarm B as a low alarm set at 50 µS/cm and use alarm A as an advance warning device by configuring it as a low alarm set at 100 µS/cm. When alarm A is activated there is still time left to take corrective action.

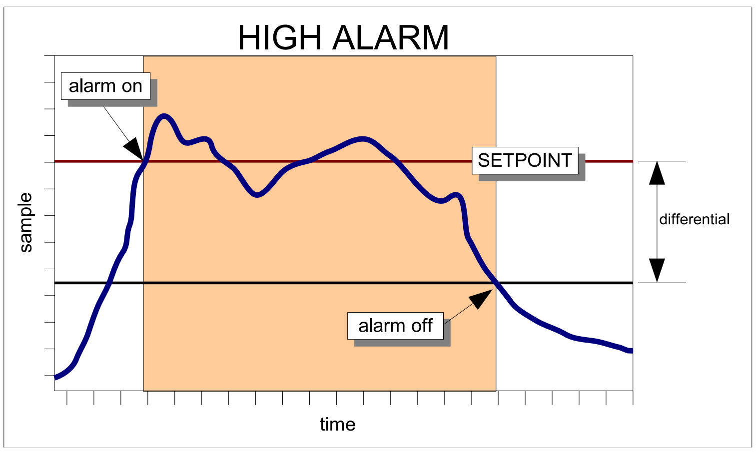


Illustration 25: High alarm

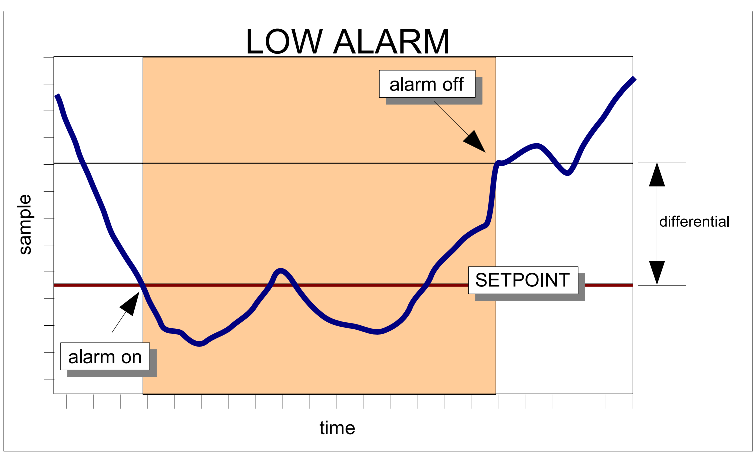


Illustration 26: Low alarm

Fault Alarm

A fault alarm for an input will be set when anything goes wrong with that input. Something is wrong with an input if the input is off-scale or an unacknowledged error message exists for that input. Caution messages do not cause a fault alarm.

To use an alarm as a fault alarm, select [FUNC] from the alarm menu, then select [Flt]. To enable the alarm, make sure the on/off switch is set to [on]. Also, set the input in the alarm menu to the desired input, either conductivity or temperature.

The set-point and differential for the alarm have no effect when the alarm is used as a fault alarm.

Using Alarms for On/Off Control

The alarms can also be used for process control - the alarm contacts will then function as on/off signals for switches controlling a valve, pump, motor, etc.. The set-point determines the control point of the system and the setting of the differential controls the amount of corrective action before a controlled shut-off occurs. Examples of high and low control using the alarms are shown in the following illustrations.

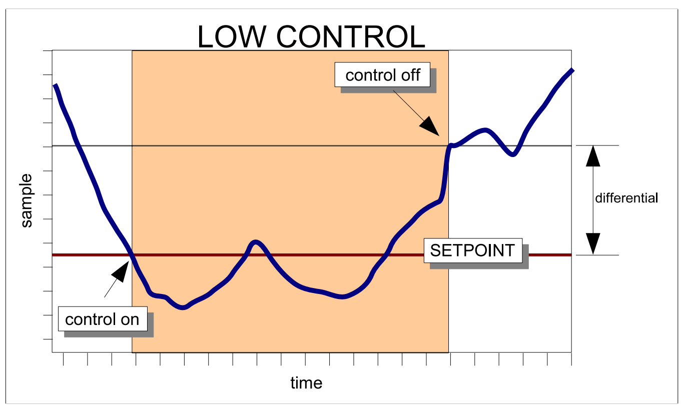


Illustration 27: Low control

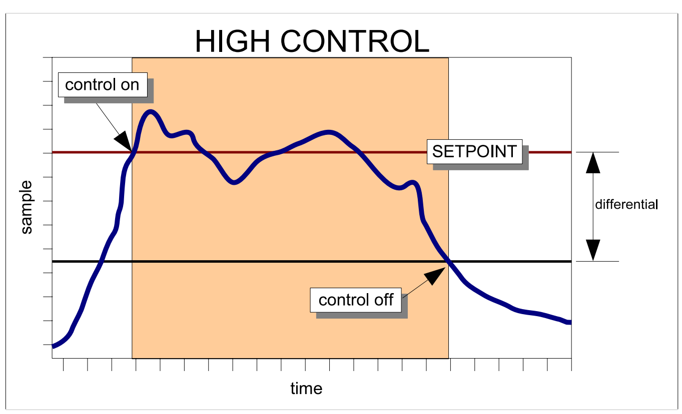


Illustration 28: High control

CONFIGURATION OF PROGRAM

The 455 analyzer has been designed with ease-of-use in mind. In most cases the analyzer factory configuration will handle the application and no configuration of the analyzer is necessary.

Relay Contacts; NO/NC

The 455 program by default assumes the relay contacts are wired normally open. A normally open relay contact will open if there is no alarm and will be closed by the microprocessor when there is an alarm condition. If the program configuration and the wiring do not match the incorrectly configured relay, it will generate an alarm when there is no alarm and vice versa.

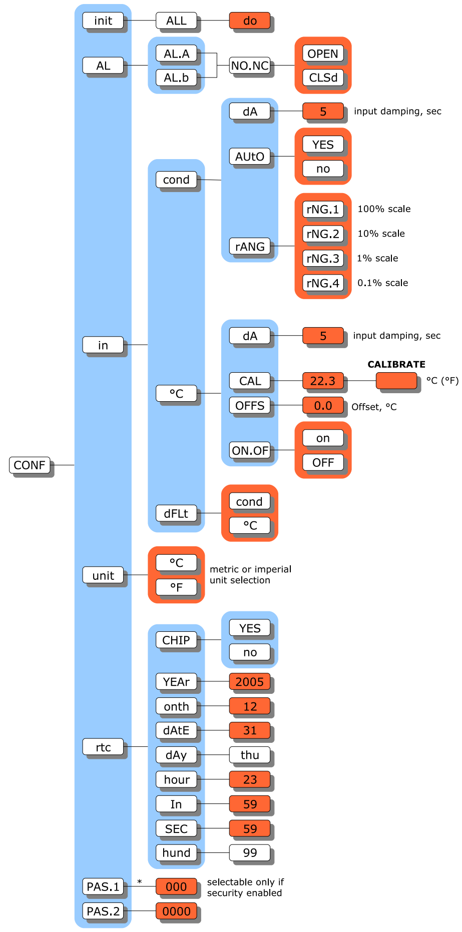


Illustration 29: Configuration menu

Auto-Ranging Conductivity

The analyzer program allows the user to select either manual or automatic ranging. By default, the analyzer will automatically switch between ranges. Refer to the section entitled *Automatic Range Switching* for further details.

Re-initializing All Settings

Occasionally it may be desirable to reinitialize all of the program settings to bring them back to default. Executing an initialization will cause the analyzer to reset all the program variables and settings to factory defaults.

Parameters such as the output signal settings, alarm settings, and the program configuration will need to be re-entered if they were different from the factory default settings.

Select [CONF] [init] [ALL] from the menu. The display will flash [do]. Nothing will happen if you press *CANCEL* or *SAMPLE*. The analyzer will re-initialize only when the user presses *ENTER*.

Password Security

The factory default is no security. No password security should be necessary if you are the only user and no protection of settings is needed. Password security should be implemented for critical applications where program settings may only be changed by authorized personnel.

For minimal security, IC Controls advises that the user set a level 2 password. Leaving the level 1 password at "000" gives the operator complete access to all areas of the program but does not allow settings to be changed in the configuration menu. With minimal security in place, unauthorized users are prevented from enabling password security.

Appendix A describes how to enable or disable security.

Temperature Input Calibration

Refer to the *Electronic Hardware Alignment, Alignment of Temperature Input Circuit* section for the procedure on calibrating the temperature input.

TROUBLESHOOTING

When trying to determine what the problem is with a conductivity loop, there are a few simple steps to follow:

Isolating the Problem

FIRST: Write down the symptoms.

a) conductivity reading

b) temperature reading

c) conductivity cell constant in analyzer

d) sensor cell constant on the label

SECOND: Separate the sensor from the analyzer so that the problem can be isolated.

Disconnect the sensor from the analyzer at the terminal block - it is much easier to test and determine if the problem is in the conductivity sensor or in the analyzer this way.

THIRD: See if the analyzer reads correctly without the sensor.

a) With sensor leads removed, the analyzer should read 0 µS/cm or mS/cm, depending on units selected, or close to zero.

b) Insert a 1 000 ohm, 1% resistor across the sensor cell connection and a second one across the sensor TC connections.
NOTE: *If the temperature reading is approximately 0 °C (or 32 °F), then the analyzer looks alright.*

c) Change the analyzer cell constant setting to 1.00 and TC to manual, set at 25 °C.
NOTE: *If the conductivity reading is approximately 1 000 µS/cm (or 1.00 mS/cm), then the analyzer looks alright.*

d) If the reading is far from 1 000 µS/cm, perform a calibration with [Cal] set to 1 000 µS/cm and note the calculated conductivity cell constant in [CELL].

e) When finished, set TC back to auto and remove both resisters.

FOURTH: Problem isolated

If the [CELL] is within 10% of 1.00, then the analyzer appears OK. If the analyzer is OK, then the problem is likely with the sensor. If the [CELL] is greater than 10% out, the problem may be in the analyzer.

Troubleshooting Hints

Slow Response
Typically due to excessive sample line length and low flow, producing long sample transport lags. Resolve by adding a fast-flow loop with the sensor in a short side stream, or by shortening the line.

Slow response can also be caused by a buildup of dirt in the sample line. In this case, the problem may be alleviated by changing the take-off point or by installing a knock-out pot. Alternatively, a dirty-water sample system may be needed.

Readings consistently low or spike low
Characteristic of bubbles in the sample line passing through the sensor or hanging up in the sensor. Review the installation instructions provided with the conductivity sensor.

Readings gradually falling

The analyzer can no longer be calibrated properly. This problem is typical of scale or sludge/slime deposits in the sensor - the sensor will need to be cleaned. Refer to the *Yearly Maintenance* procedure in this manual or in the sensor manual.

Readings at maximum

"+Err" message under all conditions. First verify that the analyzer is displaying conductivity using mS/cm units. The analyzer will display "+Err" if conductivity is above 9 999 μS/cm with μS/cm units selected for the display. This condition is indicated by CA1.9.

If unit selection is not the problem, then either the sensor is shorted or there is a problem with the wiring/analyzer setup. This condition is indicated by E1.6. Test for shorts by disconnecting sensor from analyzer and checking impedance between black and white leads with sensor in air. Insulation value should exceed 1 MΩ (megaohm) if sensor OK.

If the sensor is OK, then substitute resistors for the sensor to test the wiring and the analyzer. If the problem persists with the resistors in place then it is an analyzer problem. Use the following formula or consult the table below for resistance values to use.

$$resistance(\Omega)=\frac{cell\ constant \times 10^6}{\mu S/cm\ of\ solution\ at\ 25°C}$$

If the sensor tests OK, i.e. no shorts as per above test procedures, and the analyzer and wiring work OK with substitute resistors as in table 9, but the "+Err" message and E1.6 still occur when the analyzer and sensor are hooked up and placed in service, then the conductivity is too high for the cell constant used. Resolve by determining the actual conductivity and selecting a new conductivity sensor with the correct cell constant.

Elevated readings on low conductivity

The analyzer reads high at the low end of the range. In some cases, the analyzer will give a low reading even with the conductivity sensor in air. Large zero signals are indicative of a wiring problem. Look first at shielding between leads and ensure the shield is connected to the analyzer shield terminal rather than electrical ground. Other known causes include incorrect cable or cable lengths too long for the application.

Where the elevated zero is small, it is likely due to cable resistance/capacitance and can be zeroed out using the air zero calibration procedure.

Conductance (μS)	***Resistance (Ω); 1.0/cm cell constant***	***Resistance (Ω); 0.1/cm cell constant***
1	1 000 000	100 000
10	100 000	10 000
100	10 000	1 000
1 000	1 000	100
10 000	100	10
100 000	10	1
1 000 000	1	0.1

Table 9: Resistance values for simulation

ELECTRONIC HARDWARE ALIGNMENT

Alignment of Conductivity Detection Circuit

1. Install a 700 Ω resistor between electrode drive and sense; TB200 terminals 1 and 3.
2. Set the conductivity input to manual range and switching on range 3. From the menu, select [CONF] [in] [cond] [AUTO] and change the setting to [no] (no auto ranging). Then select [CONF] [in] [cond] [rANG] from the menu and set the range to [rNG.3].
3. Set up a precision volt meter, Fluke 8050A or equivalent, to read 4.000 VDC. Use sensor shield connection, TB200 terminal 2 as common, and left side of R212. Refer to drawing D5920093 (Rev.1.9). Adjust electronic standardize with blue trim-pot VR200 at left edge of board for a reading of 4.000 VDC which is approximately 600 mV peak-to-peak square wave.
4. Set the analyzer to manual temperature compensation and set the manual TC temperature to 25 °C. Set manual temperature compensation by selecting [cond] from the menu. If the analyzer displays [Auto], press *ENTER* to go into edit mode, and press *Down* arrow key to display [SEt], then press *ENTER*. Press *Right* arrow key to display the manual TC temperature. Change this temperature to 25 °C.
5. With multimeter common on TB200, terminal 2 (sheild); adjust to 4.85 VDC ± 0.005 VDC, TP202 (or pin 1 of U203), using VR201 blue span adjust potentiometer just to left of pin1.
6. Return conductivity input to automatic range switching by selecting [CONF] [in] [cond] [Auto] from the menu and changing the [no] setting to [YES].

Alignment of Temperature Input Circuit

The temperature input can be adjusted both by making electronic adjustments and/or by having the program compensate for differences in offset. Both procedures are described below. The temperature input of the 455 microprocessor analyzer requires a 1 000 Ω TC in the sensor.

Adjusting Electronic Calibration

1. Remove the offset calculated by a previous software calibration of the temperature input. Select [CONF] [in] [°C] [OFFS] from the menu and edit the offset to read 0.0.
2. Set up a precision multimeter, Fluke 8051A or equivalent, to read VDC.
3. Use TB200, terminal 2, as common. Refer to drawing D5920093 (Rev1.9). Place a 1 000 Ω 1% resistor across T+ and T- terminals. Adjust blue trim-pot VR202, located at the top-right side of TB201, for a reading of 0.200 V at TP203.
4. Place a 1.74 kΩ 1% resistor across T+ and T- terminals. Adjust blue trim-pot VR203, located at the top-right side of U203, for a reading of 4.80 V at TP203.
5. Close the case and press *SAMPLE* followed by the *Down* arrow key to display the temperature reading.
6. Re-insert the 1 000 Ω 1% resistor and adjust VR202 until the display reads 0.0 °C ± 0.1 °C.
7. Re-insert the 1.74 kΩ 1% resistor and adjust VR203 until the display reads 195.0 °C ± 0.2 °C.

Software Calibration

To do a software calibration of the temperature input, the correct temperature needs to be known.

1. Select [CONF] [in] [°C] [CAL] from the menu. The actual temperature as measured by the temperature sensor will be displayed. Edit the displayed value to the known correct temperature. Press *ENTER* to leave edit mode, then *SELECT* to start the calibration.
2. The current temperature will be shown using a flashing display. When the input appears to be stable, press *ENTER* to set the new temperature. The software offset for the temperature input will be adjusted automatically.
3. The calculated offset in degrees Celsius can be viewed by selecting [CONF] [in] [°C] [OFFS] from the menu. Whenever the hardware alignment is 'correct', the offset will be 0.0. The displayed offset can be edited.

Calibration of 4 mA to 20 mA Outputs

Use one of the following two approaches to get the analyzer to output the desired current level, and then make electronic adjustments to calibrate the output.

Approach 1: Simulated 4 mA to 20 mA Output (Self Calibration)

1. Select [cur] from the output 1 menu to display the present output current in mA. The display will be updated as the output current changes based on the input signal and the program settings.
2. To simulate a different 4 mA to 20 mA output signal, press *ENTER* to select edit mode. Use the arrow keys to display the desired output needed for testing the output signal. Press *ENTER* to select the displayed value. The output signal will be adjusted to put out the desired current. This process can be repeated as often as necessary to output different signal levels.
3. The output signal is held at the displayed level until the program leaves this menu selection. Make calibration adjustments while the analyzer shows the output at 20.00 mA.
4. Repeat the above steps for output 2.

Approach 2: Use Voltage Source to Adjust Input

This faster calibration approach requires a voltage source for the input.

1. To calibrate output 1, set [in] = [°C]. Input a low enough signal to cause analyzer to indicate [- Err]; the analyzer will output 4.00 mA. Reverse the polarity or input a high enough signal to cause the analyzer to indicate [+ Err]; analyzer will output 20.00 mA.
2. Repeat step 1 for output 2.

Tip: *Both outputs can be simultaneously calibrated if you set [in] = [°C] for both inputs.*

Adjusting Electronic Calibration

1. The outputs are isolated from the main circuit, therefore, measurements are made with common at the output 2 terminal, TB304.
2. Measure output 1 ‘zero’ at TP301 (pin 8 of U304) while output 1 is outputting 4.00 mA. The reading should be between -0.870 VDC and -1.250 VDC. Adjust #2 voltage with VR300.
3. Change analyzer output to 20.00 mA; switch multimeter to mA and measure + terminal of output 1, at TB303, and adjust VR301 so that the current reads 20.00 mA. Return analyzer output to 4.00 mA and trim actual output to 4.00 mA using VR300. Check again at 20.00 mA and repeat adjustments until satisfied.
4. Measure output 2 'zero' at TP300 (pin 7 of U304) while output 2 is outputting 4.00 mA. The test point should read between -0.870 VDC and -1.250 VDC. Adjust #2 ‘zero’ voltage with VR302.
5. Change output at output 2 to 20.00 mA; switch multimeter to mA and measure + terminal of output 2, at TB304, and adjust VR303 (span pot) until the current reads 20.00 mA.
   NOTE: *Zero and span are very wide range adjustments which show small interactions. Recheck zero and span to confirm good calibration.*
6. If so desired, all software settings can be returned to factory default condition by following the procedure in *Configuration of Program; Re-initializing All Settings*.

Testing Relay Outputs

1. Relay output operation can be verified by testing for contact closure or continuity at each relay. To activate a relay, select [CONF] [NO.NC] [AL.A] from the menu. Press *ENTER* to go into edit mode, then press the *Up* or *Down* arrow key to change the normally open/normally closed configuration from open to closed. Press *ENTER* to accept the new value. A closed contact should open and an open contact should close.
2. Repeat step 1 for for the Alarm B contact.
3. If so desired, all software settings can be returned to factory default condition by following the procedure in *Configuration of Program; Re-initializing All Settings*.

DISPLAY PROMPTS

[1]	Actual cell constant (multiplication factor 1)
[100]	Cell constant x100
[1E-3]	Conductivity units in millisiemens per centimeter; (from E-3 = milli)
[1E-6]	Conductivity units in microsiemens per centimeter;(from E-6 = micro)
[ACC.*n*]	Access level for security. Displayed after password entered by user
[AL]	Alarms
[AL.A]	AlarmA
[AL.b]	Alarm B
[AUto]	Automatic ranging of conductivity input; yes/no switch
[ASCI]	ASCII serial output log
[BAud]	Baud rate for serial communications
[°C]	Temperature in degrees Celsius; use metric units
[CAL]	Calibrate analyzer
[CELL]	Cell constant
[CHAr]	Output characterization on/off
[CHIP]	Chip: Is this analyzer equipped with a real-time clock chip?
[CLr]	Clear the internal data log
[cnt]	Count of number of readings in internal data log
[CLSd]	Normally closed alarm contact
[cond]	Conductivity input
[CONF]	Configuration of program menu
[Cont]	Continue internal data log when buffer full
[cur]	Signal output in mA, or current
[dA]	Input damping, in seconds
[dAtE]	Date: Real-time clock setting for day of the month (1-31)
[dEc]	Decimal places
[dEv]	Deviation alarm
[dLAY]	Alarm activation delay
[do]	Do: press *ENTER* to execute the reset/clear action
[donE]	Done: Reset/clear action has been taken
[Err]	Error or warning number
[Er.94]	RAM checksum failed. Some settings may be lost
[°F]	Temperature in degrees Fahrenheit; use imperial units
[FLt]	Fault alarm
[FrEq]	Frequency of internal data log updates in seconds
[FULL]	Full: What to do when internal data log is full; continue or stop
[HI]	High alarm; high limit (20 mA) for 4 mA to 20 mA output window
[Hold]	Output hold during calibration
[hour]	Hour: Real-time clock setting
[hund]	Hundredth of a second: Real-time clock display
[iLOG]	Internal data log
[in]	Input OR Minute: Real-time clock setting
[LO]	Low alarm; low limit (4 mA) for 4 mA to 20 mA output window
[NodE]	Node number for IC Net communications
[NO.NC]	Normally open/Normally closed
[OFF]	Off
[OFFS]	Offset

[ON]	On
[ON.OF]	On/off switch
[onth]	Month: Real-time clock setting
[OPEN]	Normally open alarm contact
[out]	Output menu
[out 1]	First 4 mA to 20 mA analog output channel
[out 2]	Second 4 mA to 20 mA analog output channel
[PAS.1]	Set password 1, operator access
[PAS.2]	Set password 2, complete access
[PASS]	Enter password to change access level
[rANG]	Analyzer conductivity input range selection
[rnG]	Range number
[rtc]	Real-time clock
[SEC]	Seconds: Real-time clock setting
[SEr]	Serial communications menu
[SEt]	Setpoint: Select manual temperature compensation
[StAr]	Start internal data log
[StOP]	Stop internal data log
[tbL]	Characterization table
[unit]	Display/setting of units
[YEAr]	Year: Real-time clock setting

GLOSSARY

Cell constant describes enclosed volume between electrodes in the conductivity sensor. Units are cm^{-1}. Higher cell constants produce higher analyzer ranges; lower cell constants produce lower ranges.

Conductivity the amount of electrical current that flows through a liquid. Generally reported as microsiemens per centimeter (µS/cm) or millisiemens per centimeter (mS/cm).

EPROM Erasable Programmable Read Only Memory. The EPROM chip holds the program which determines the functioning of the 455 analyzer. Replacing the EPROM chip with a chip containing a new or an updated program changes the way the analyzer functions. The EPROM chip is programmed by the manufacturer.

Hysteresis the reading at which an alarm is turned on is not the same reading at which the alarm is turned off again. This phenomenon is referred to as the hysteresis.

LED Light Emitting Diode. LEDs are used as on/off indicators on the front panel of the 455.

LTCC (Linear Temperature Compensation Constant) The default LTCC of 2.0 adjusts the conductivity reading by 2.0 % per degree Celsius so that the effective conductivity at 25 °C can be displayed.

mho the reciprocal of ohm; ohm spelled backwards. The equivalent of mho is siemens, which is the modern naming for this unit.

microsiemens (µS/cm) unit of conductivity. Micro is the metric prefix meaning *one millionth.*

$$\mu S/cm = \frac{1}{10^6\, ohm \cdot cm} = 10^6\, siemens/cm$$

millisiemens per centimeter (mS/cm) unit of conductivity. 1 millisiemens per centimeter = 1 000 microsiemens per centimeter. Milli is the metric prefix meaning *one thousandth.*

Menu he series of prompts which determine the layout of the program used by the analyzer.

Microprocessor an integrated circuit (chip) which executes the program on the EPROM chip and controls all the input/output functions.

NC Normally closed

NO Normally open

Normally closed each of the alarm contacts can be wired and configured as normally open or normally closed. A circuit which is wired normally closed will be closed (i.e. the external device wired to it is turned on) when the analyzer is not powered.

Normally open a circuit which is wired normally open will be open (i.e. the external device wired to it is turned off) when the analyzer is not powered.

On/Off control control response in which the contact is either fully on or fully off.

RAM (Random Access Memory) Memory in a RAM chip can be both written to and read from. The contents of RAM will disappear as soon as the RAM chip loses power. The RAM chip has a battery backup device which preserves the contents of the RAM chip for a considerable time even if the analyzer is turned off. All settings are stored in RAM.

siemens per centimeter (S/cm) unit of conductivity

$$S/cm = \frac{1\, ohm}{cm}$$

TC Temperature compensator

Temperature compensation correction for the influence of temperature on the sensing electrode. The analyzer reads out concentration as if the process were at 25 °C or 77 °F, regardless of actual solution temperature.

Appendix A — Security

The analyzer has a built-in password protection system. This security system is disabled by default and does not need to be enabled if no password protection is necessary. If you choose not to enable the password protection system then the user will have unrestricted access to all analyzer settings available through the menu as described in this manual.

Having security disabled gives the user the same access to the program as being at access-level 2 at all times.

With security enabled anyone can view settings anywhere in the program. When you do not have proper access rights, the program will display [PASS] for 2 seconds, indicating that a proper password must be entered before being allowed to proceed.

This appendix contains instructions for setting passwords in the configuration section of the menu. Daily usage of the analyzer by the operator does not require knowledge of setting passwords in the configuration section since all passwords are entered by selecting [PASS] directly from the main menu.

Access-level	***Description***
0	View only access to all settings
1	Access to all settings except for configuration menu. **Usage:** operator access, no changes can be made to configuration and passwords cannot be changed.
2	Access to all settings. This gives the same program access as when password security is not enabled. Passwords can be changed. **Usage:** installation, management.

Table 10: Security access levels

ENTERING A PASSWORD

With security enabled, select [PASS] from the main menu. The analyzer will display [0000]. Use the arrow keys to display your level 1 or level 2 password, then press *ENTER*. The program will display [good], followed by your access level before returning to the main menu. If an incorrect password was entered, the program displays [bAd] instead. Refer to illustration 30 flow chart to determine how the program validates a password.

You will now have level 1 or level 2 access for as long as you are working with the analyzer. The access level will automatically be restored to level 0 after no key has been pressed for 15 minutes. This 15-minute timeout will also return to display the main sample.

It is good practice to return the analyzer to level 0 access (or level 1 access if password 1 is set to "000") when you have finished using the analyzer. This is accomplished by selecting [PASS] from the main menu, then pressing *ENTER* with [0000] displayed.

ENABLING PASSWORD SECURITY

When security is disabled, both password 1 and password 2 are set to "0000." Security is enabled by setting password 2 to a non-zero value.

Level 2

Select [CONF] [PAS.2] from the menu. The analyzer will display [0000]. Use the arrow keys to change the display to the desired password for level 2. You can press *SAMPLE* at any time to safely cancel password entry. Press *ENTER* to enter the password into memory and to enable password security. The analyzer program automatically returns to the configuration menu.

With only password 2 set to a non-zero value, level 2 access is required to make changes in the configuration menu but all other settings are unprotected. Effectively the user will always have at least level 1 access.

Level 1

At this point, password 1 is still “000.” You may optionally enable operator access control or level 1 security by changing the level 1 password from “000" to a non-zero value. Change the password by selecting [CONF] [PAS.1] from the menu, then entering an appropriate 3-digit password.

RECORDING YOUR PASSWORDS

You may want to write down the passwords you set and store them in a secure place. Once a password has been set, there is no way to redisplay it. Since passwords are set in the configuration menu, level 2 access is required to change either password. If you have forgotten the level 2 password, there is no simple way to regain access to the analyzer. Contact the factory if you find yourself locked out of the analyzer.

DISABLING PASSWORD SECURITY

Password security can be disabled by setting the level 2 password to “0000.” In order to change the password you must first have level 2 access to the program.

Select [CONF] [PAS.2] from the menu, then press *ENTER* when the program displays [0000]. Both passwords 1 and 2 are set to “0000" and security is now disabled. The main menu will be changed to exclude the [PASS] frame , and the configuration menu will no longer have the [PAS.1] frame.

PASSWORD EXAMPLE - A QUICK TOUR

With security disabled, select [CONF] [PAS.2] from the menu. Set the level 2 password to “0002". Select [CONF] [PAS.1] from the menu. Set the level 1 password to ”001." Security is now enabled.

Select [PASS] from the main menu. Press *ENTER* with [0000] displayed. The analyzer will display [ACC.0] to indicate we are now at access level 0.

Try changing the output 1 low setting. Select [out] [out1] [LO] from the menu. The current value will display. Press *ENTER* to go into edit mode. The analyzer will display [PASS] for 2 seconds because we need to enter a password first. Level 1 security is needed to change this setting.

Select [PASS] from the main menu again. Change the displayed value to [0001], which is the level 1 password. Press *ENTER*. The analyzer will display [good], followed by [ACC.1], indicating that the password is valid and that we now have level 1 access.

Try changing the output 1 low setting again. You will find that this time we can go into edit mode unhindered.

Select [PASS] from the main menu again. Enter the level 2 password, which is “0002.” We are going to set the level 2 password to “0000” again to disable password security. Password 2 is found in the configuration menu and therefore requires level 2 access before it can be accessed. Select [CONF] [PAS.2] from the menu. Press *ENTER* with [0000] displayed. Both passwords are set to “0000” again and password security is disabled.

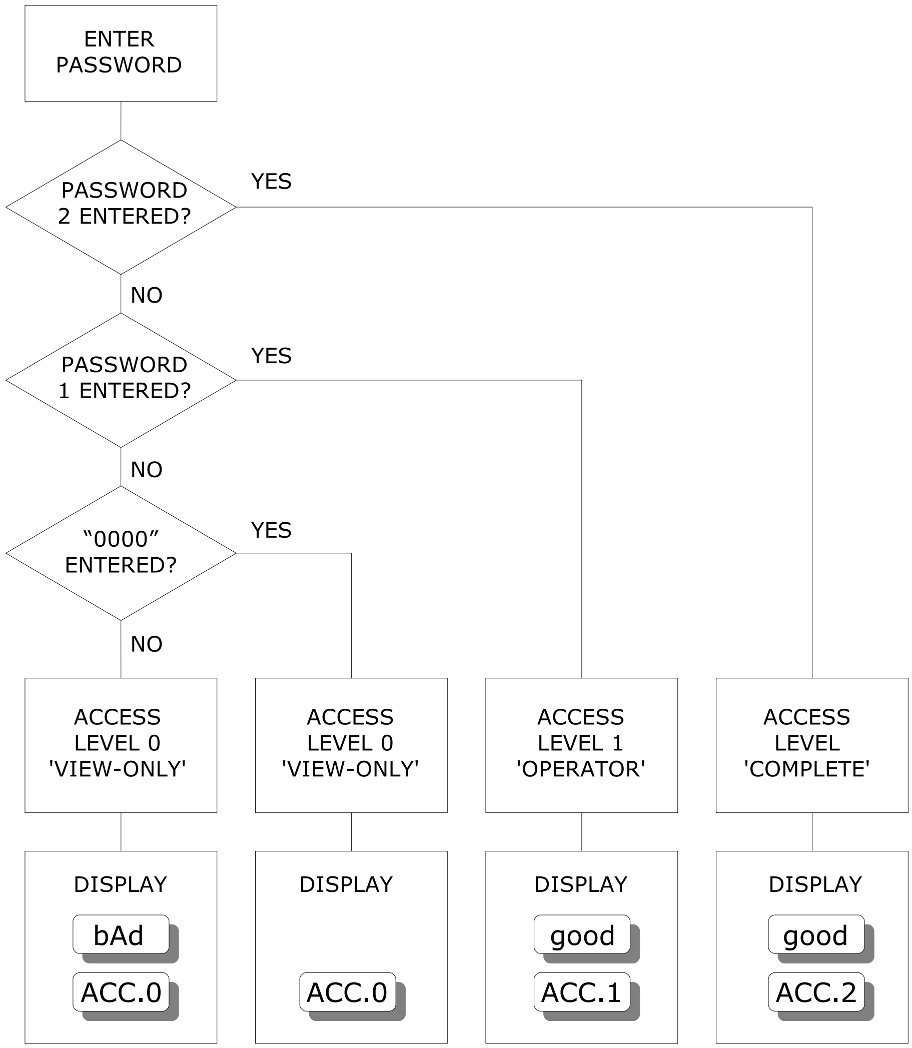
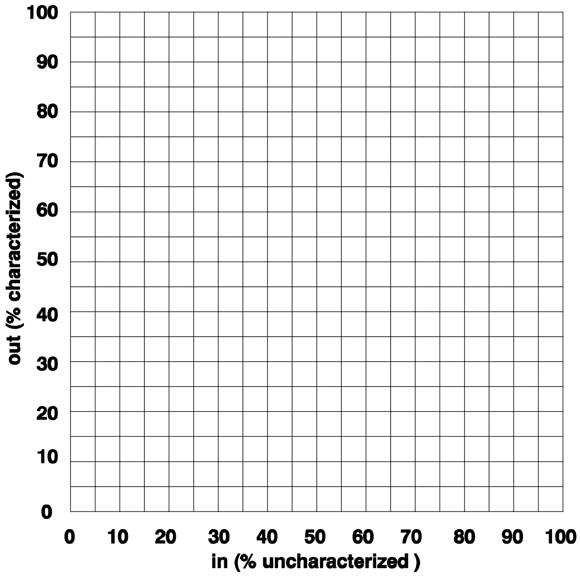
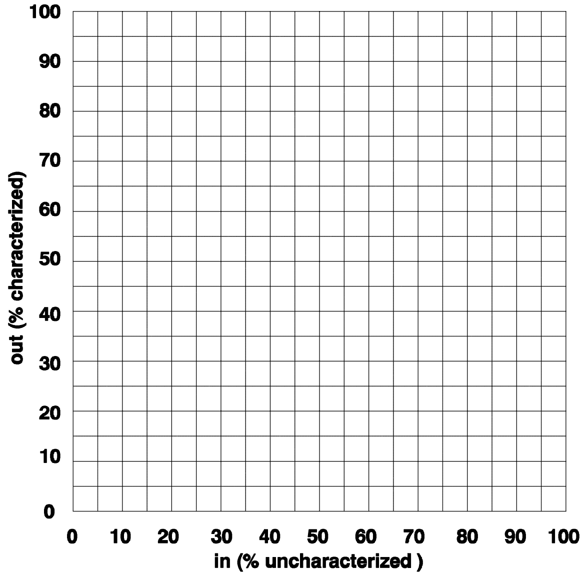


Illustration 30: Password logic

Appendix B — Output Characterization





% Uncharacterized Output	*% Characterized Output*	*Input units (eg. mS/cm, °C)*	*4-20 mA output*
0		LO	4.00
5			4.80
10			5.60
15			6.40
20			7.20
25			8.00
30			8.80
35			9.60
40			10.40
45			11.20
50			12.00
55			12.80
60			13.60
65			14.40
70			15.20
75			16.00
80			16.80
85			17.60
90			18.40
95			19.20
100		HI	20.00

Appendix C — Parts List

Part Number	Description	Drawing Number
	455 conductivity analyzer	
A9051010	455 power PCB	D5920093
A9051009	455 display board	D5980176
A9141010	455 case, complete	D4830022
A9201014	16-wire interconnect cable, two-end	
A9160024	0.25 A microfuse	
A9160035	3 A microfuse (used with option -51; timer)	
A3200070	Hardware set; 4 each of standoff, lock washer, 4-40 nuts	
A2500201	Panel mounting kit	D4950054
A2500255	Pipe/wall mounting kit	D4950053
	400 J-box, wall mount type	
A1201514	Weatherproof, wall mount J-box (only)	
A9120050	Terminal strip, 6 CKT	
	400 J-box, pipe top, explosion proof type	
A2101513	Explosion proof J-box (only)	
A9120098	Terminal strip, 6 CKT	
	Interconnect cable to 400 interface	
A9200000	Conductivity cable, 4 conductor with shield	D5920095
	Consumable Supplies	
A1400051	Low conductivity calibration kit for cell constants 0.01/cm to 0.2/cm, 1 year supply	
A1400052	Medium conductivity calibration kit for cell constants 1.0/cm to 5.0/cm, 1 year supply	
A1400053	High conductivity calibration kit for cell constants 10.0/cm to 50.0/cm, 1 year supply	
A1400054	Conductivity chemical cleaning kit, 1 year supply	
A1100161	100 µS/cm conductivity standard, 500 mL (A11000161-6P for 6-pack)	
A1100162	1 000 µS/cm conductivity standard, 500 mL (A11000162-6P for 6-pack)	
A1100163	10 000 µS/cm conductivity standard, 500 mL (A11000163-6P for 6-pack)	
A1100164	100 000 µS/cm conductivity standard, 500 mL (A11000164-6P for 6-pack)	
A1100192	Deionized rinse water, 500 mL (A11000192-6P for 6-pack)	
A1100005	Cleaning and conditioning solution, 500 mL (A11000005-6P for 6-pack)	
A1100007	Plastic, 100 mL graduated cylinder (for sensor cell constant 0.01/cm)	
A1100020	Plastic, 250 mL beaker	
A1100016	Sensor cleaning brush, ¼ inch	
A7400031	Syringe, 120 mL	

Appendix D – Default Settings

The following program settings are the default settings for the analyzer. New analyzers will have these settings unless the setup has already been customized for your application.

Outputs

	Output 1	**Output 2**
Input to be transmitted	conductivity	temperature
Low setting	0.00	0.0
High setting	1000	100.0
ON/OFF switch	ON	ON
Units	[1E-6] µS/cm	° C

Alarms

	Alarm A	**Alarm B**
Input for alarm	conductivity	conductivity
Alarm function	High	Low
ON/OFF switch	OFF	OFF
Set-point	900	100
Differential	10.0	10.0
Units	µS/cm	µS/cm

Global units

metric units, temperature in degrees Celsius

Alarm contacts

Configured normally open

Security

Not enabled

Temperature compensation

Automatic TC using temperature input. Linear temperature compensation constant set to 2.0% change per degree Celsius

Input signal damping

Signal damping for:

$$Conductivity = 5\ seconds$$
$$Temperature = 5\ seconds$$

Appendix E – Serial Output

RS485 can be used to send ASCII format serial pH and temperature (default frequency is 60 seconds), or as a two-way communication port for remote operation if an interface format program is available. No special software is needed on the computer to receive ASCII data. The ASCII data port function can be turned on/off and controlled from the internal data log menu; both ASCII and serial must be on.

Data transmitted by the analyzer is in simple ASCII format. No special software is needed on the computer to receive the ASCII data, only an ASCII terminal program such as Hyperterminal on MS Windows systems. The 656 continuous output consists of four data fields containing input values separated by commas. Each line of data is terminated by a linefeed/newline. Comma-separated fields make it easy to import the data into other programs for analysis, for example, into a spreadsheet.

Wiring and Enabling

1) It is good practice to first turn off the analyzer and the computer before connecting a serial cable.
2) Wire the RS485 cable into the terminal block TB1 located on the display board. Refer to illustration 31. Connect pin1 RD(A) to pin 3 TD(A) and connect this to terminal A on TB1 in the analyzer. Connect pin2 TD(B) to pin 9 RD(B) and connect this to terminal B in the analyzer. Connect earth or shield at one end only!
3) Turn on the analyzer and the computer.
4) Configure the analyzer for the desired baud rate. Select [SEr] [baud] from the menu. Baud rates from 1200 to 38400 baud can be selected, the default is 9600 baud. For RS485 systems with automatic send data control the lowest baud rate that can be used is 9600.
5) To enable serial transmission by the analyzer, set the serial ON/OFF switch to ON; select [SEr] [ON.OF] and edit to display [on].
6) Turn on ASCII output; select [iLOG] [ASCII] and edit to display [on].

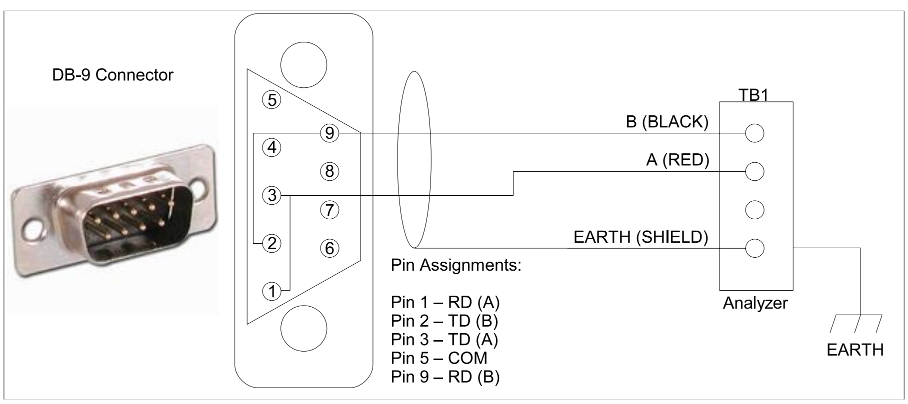
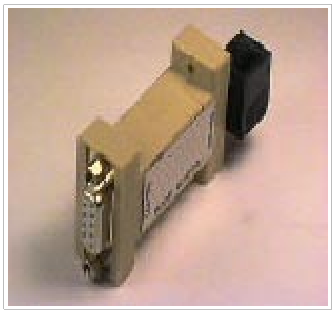


Illustration 31: RS485 wiring

Portable Laptop Hookup



RS232 to RS485 Converter

The P/N A7900015 is a port-powered, half-duplex RS232 to RS485 converter. The unit supports two-wire RS485 communications. The converter handles the enabling and disabling of the transmitter. This works regardless of the operating system or program you are running. The RS232 side has a DB9 female connector. The RS485 side has a six-position RJ11 connector.

Illustration 32: Port-powered RS232 to RS485 converter

Material List:

- P/N A7900015, RS232 to RS485 converter
- P/N A2500192, 10 foot cable with RJ11 connector at one end, data wires at other end

Installation:

1) It is good practice to first turn off the analyzer before connecting a serial cable.
2) Bring the RS485 cable into the analyzer through the center hole. Wire the RS485 cable into the terminal block TB1 located on the display board. Connect the black to terminal B, red to terminal A, and the clear to EARTH.
3) Connect the converter to a free COM port on your laptop computer.
4) Insert the cable's RJ11 connector into the converter.

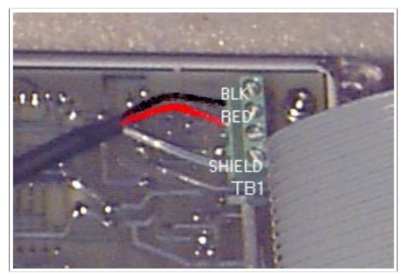
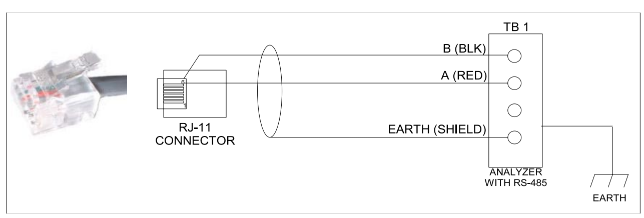


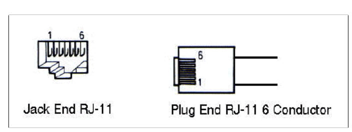
Illustration 33: Wiring RS485 cable

Making a Custom Cable:

A cable has been provided with the adapter. If this cable is not long enough, use the following information to create your own cable. Connect shield at one end only.

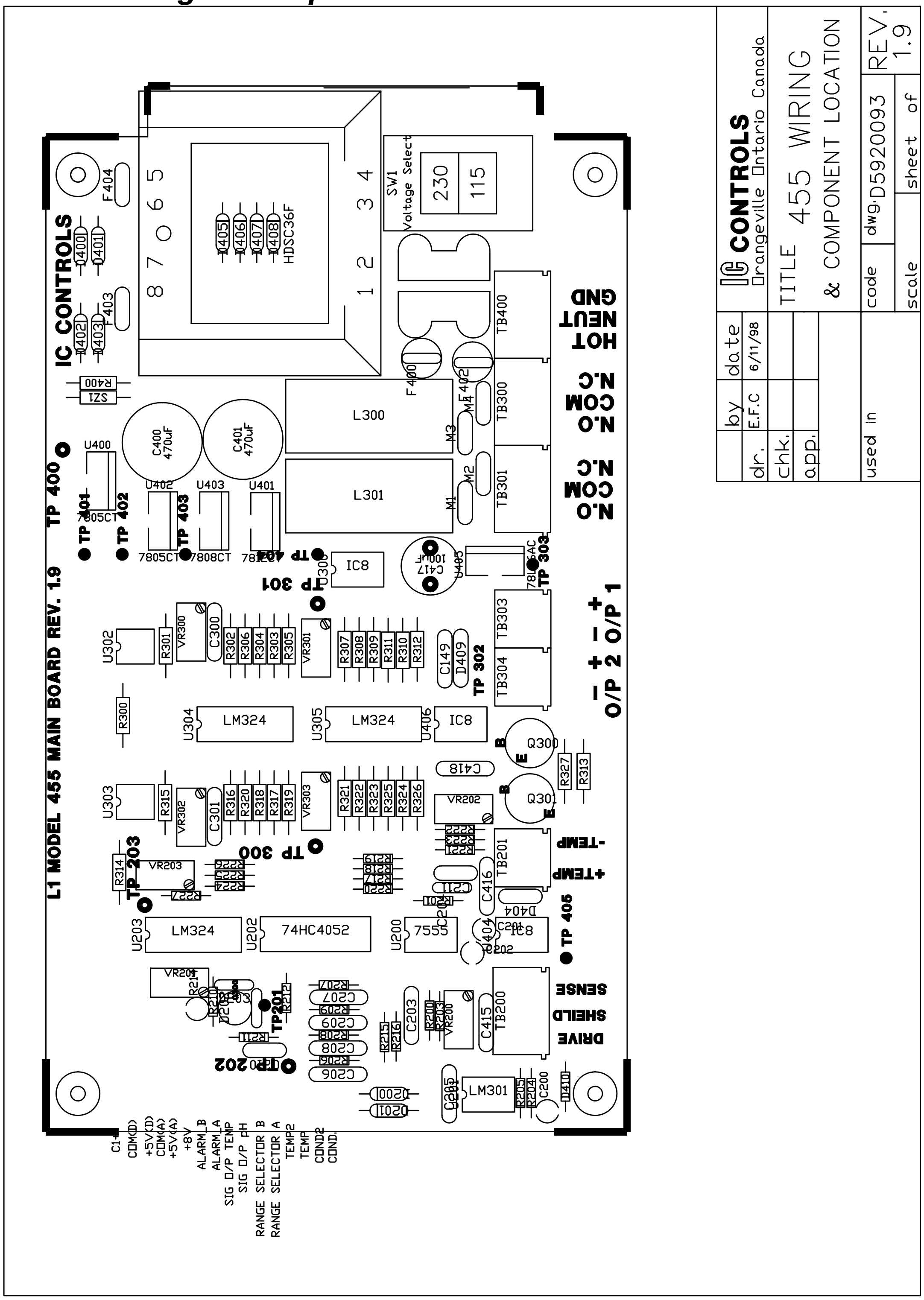
Converter Signal	*RJ11 Pin Number*
Data A (-)	2
Data B (+)	5
Signal Ground	4



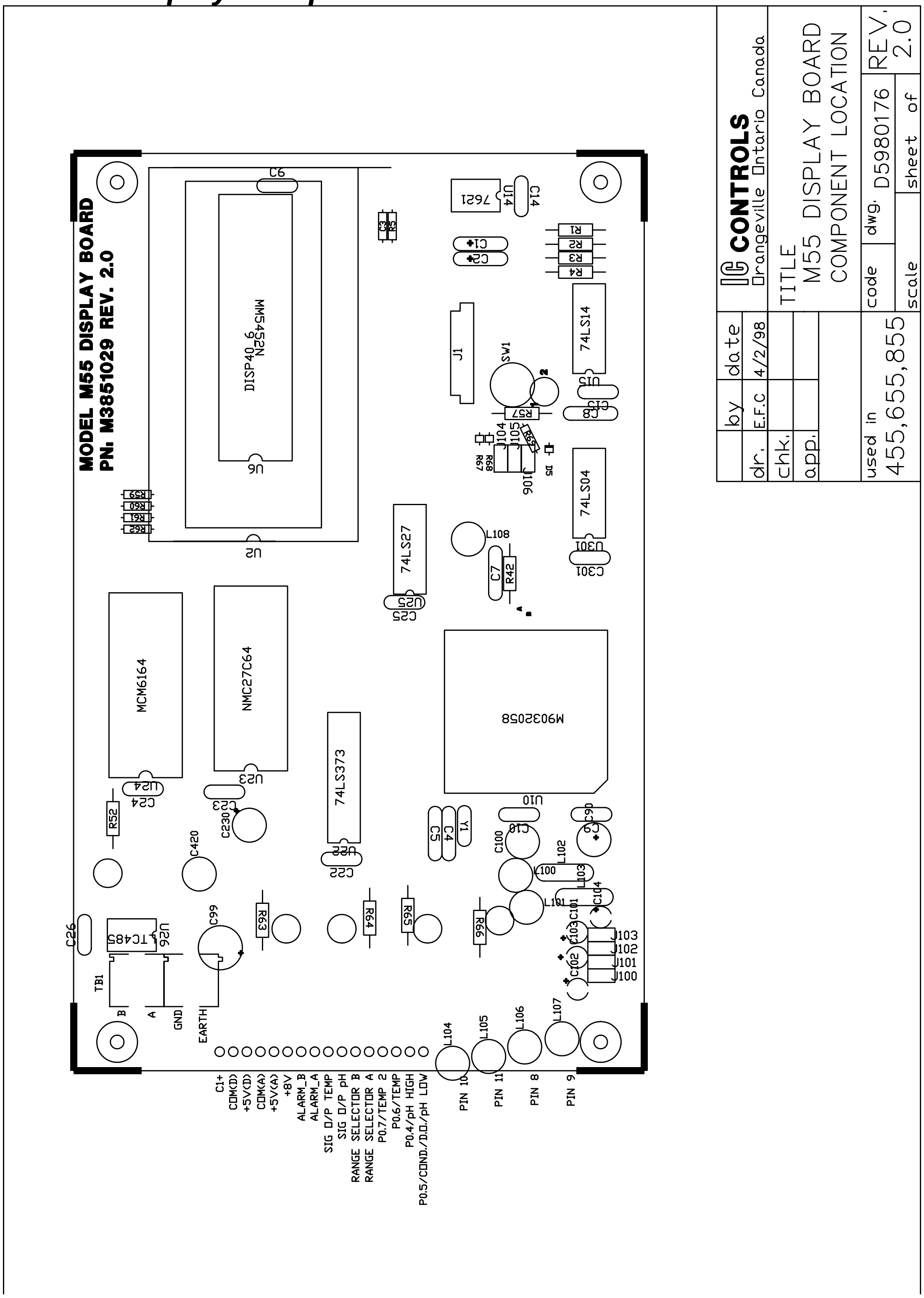


DRAWINGS

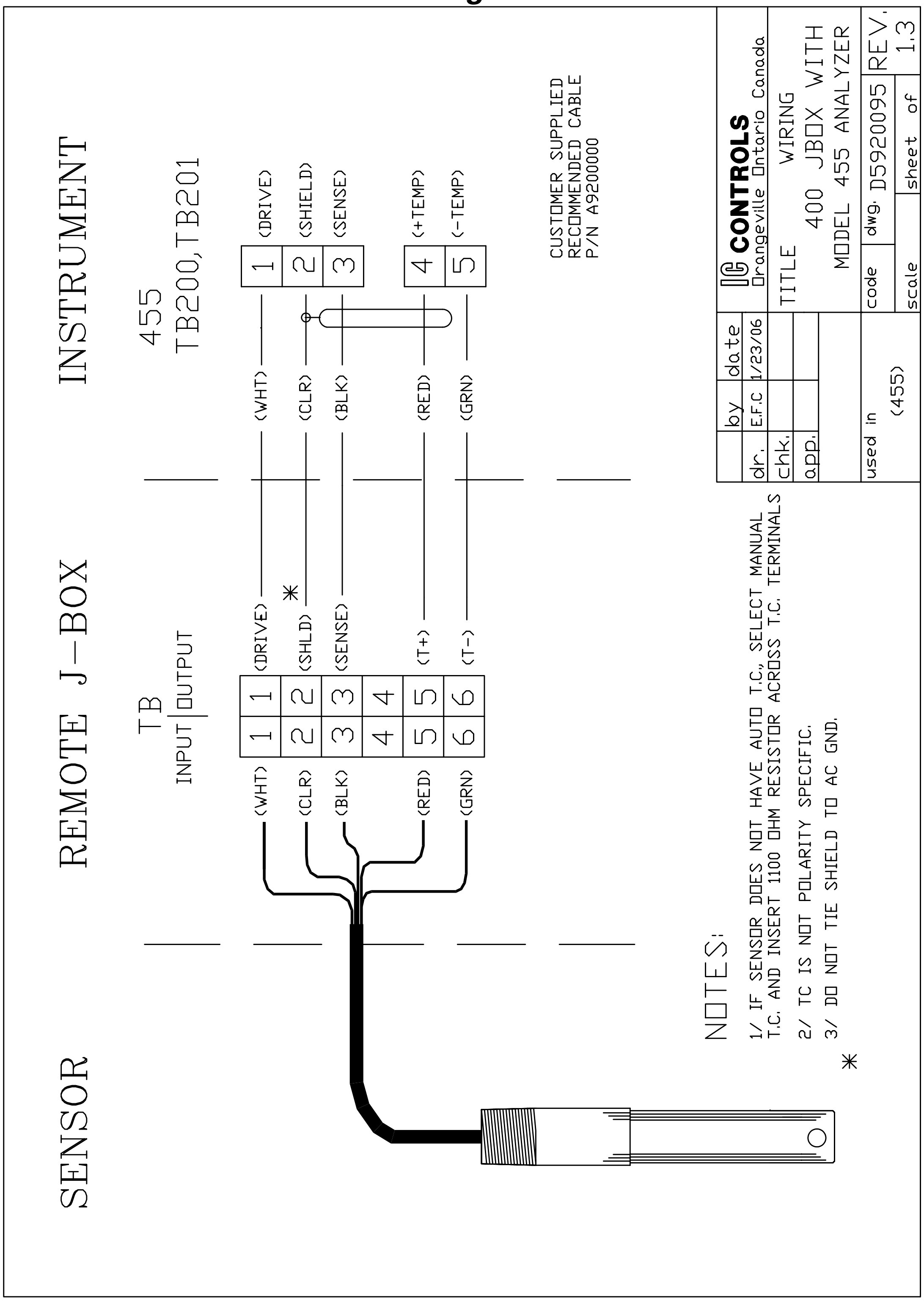
D5920093: Wiring & Component Location



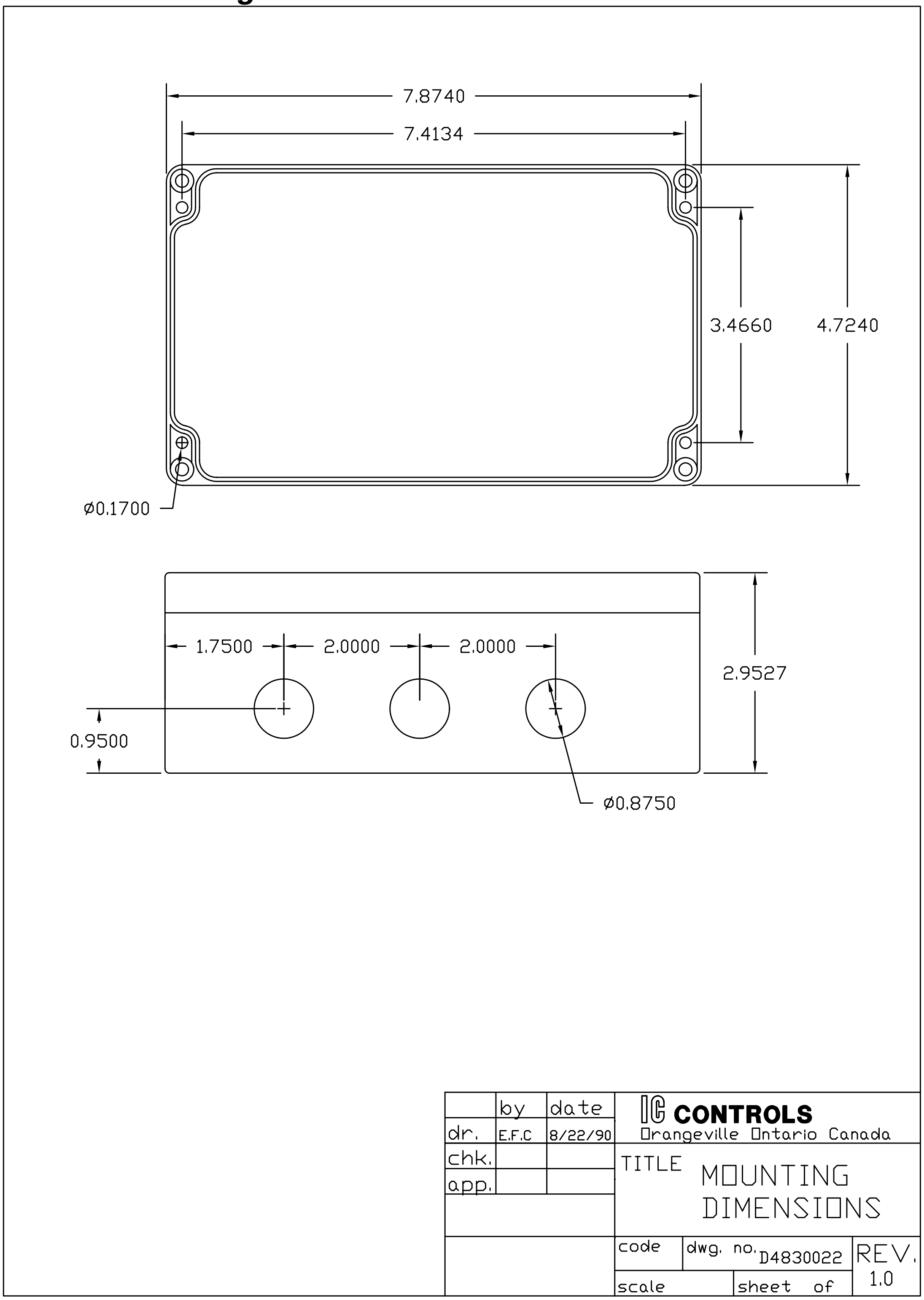
D5980176: Display Component Location



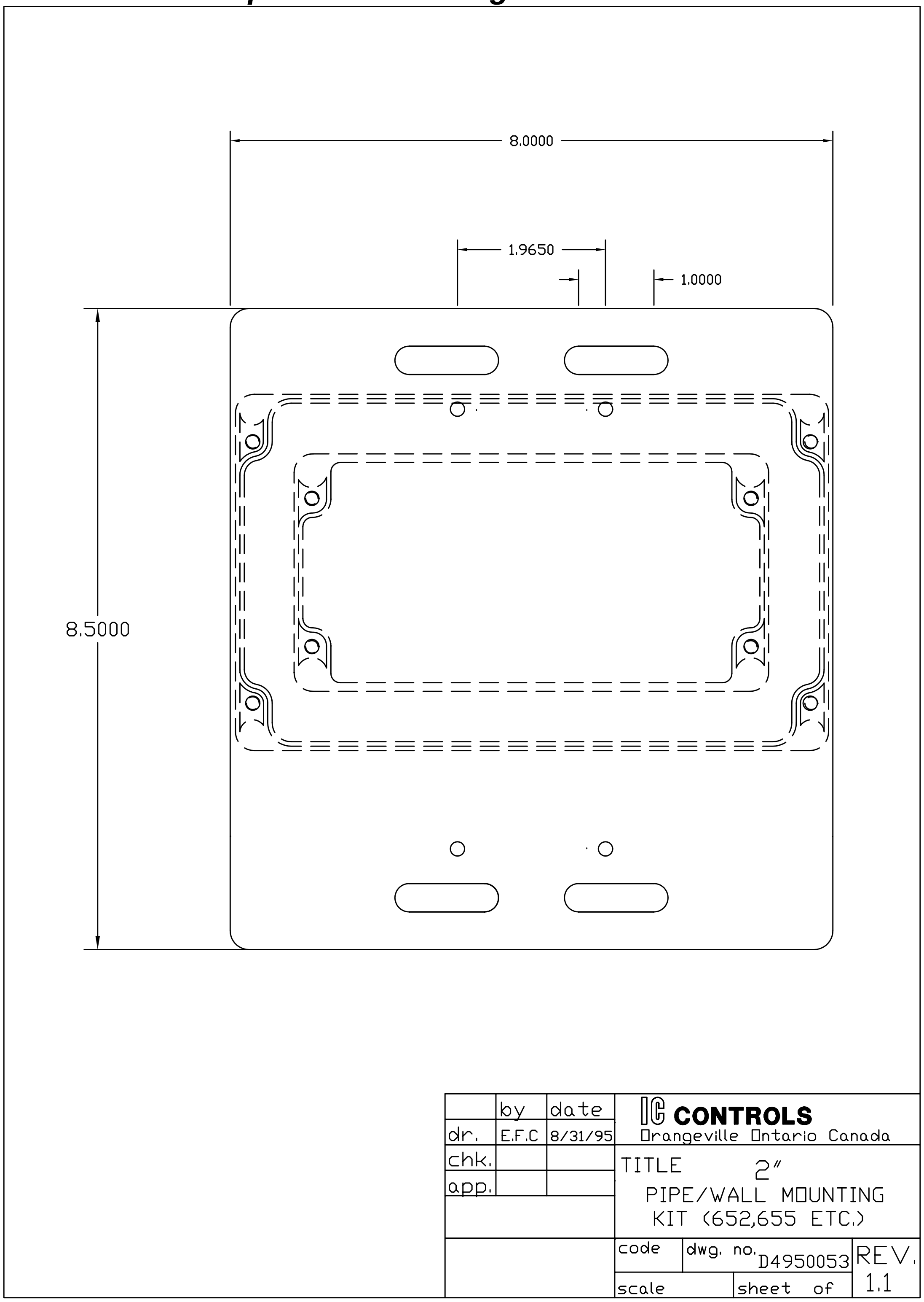
D5920095: 400 Junction Box Wiring



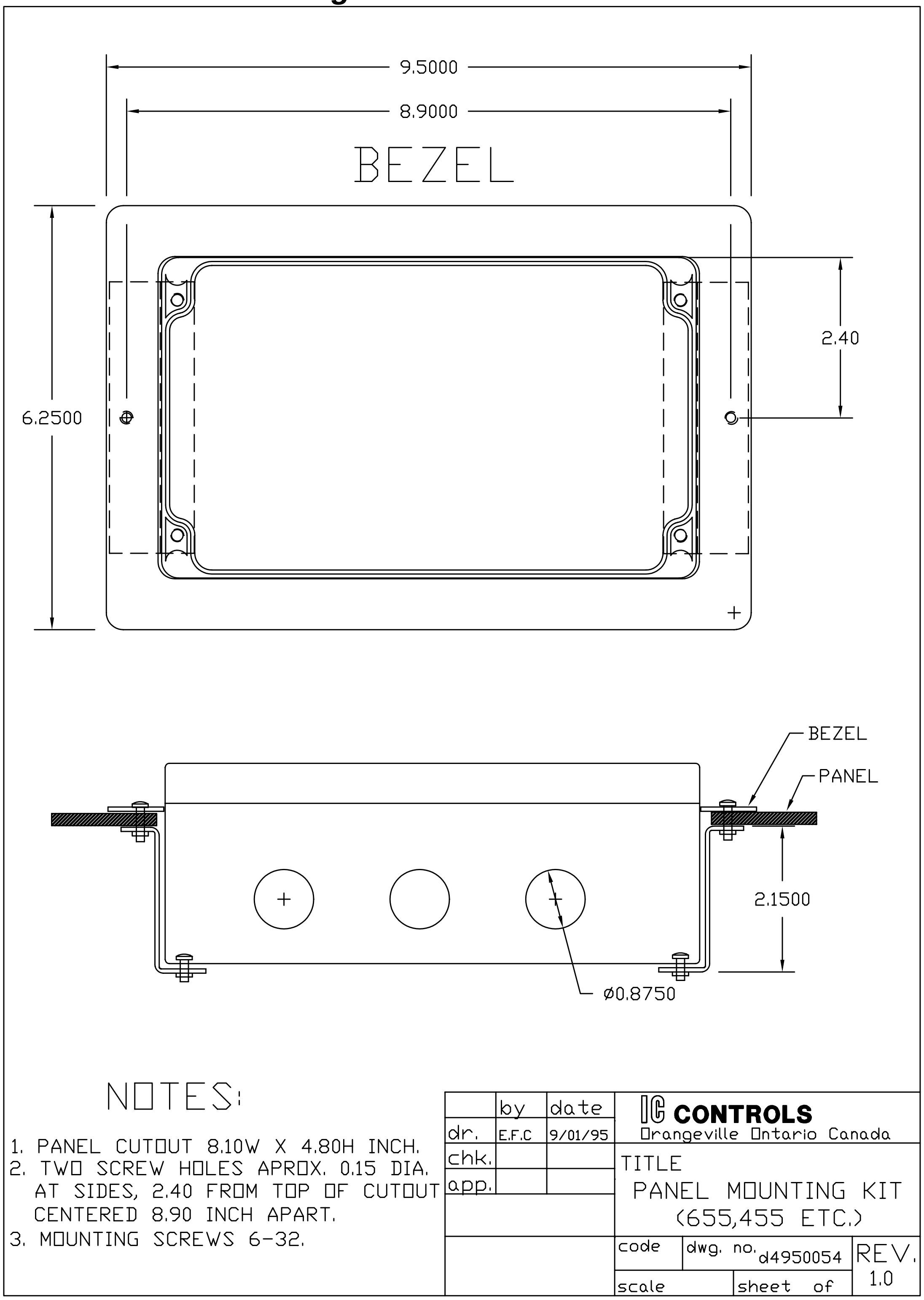
D4830022: Mounting Dimensions



D4950053: 2 inch Pipe/Wall Mounting Kit



D4950054: Panel Mounting Kit



INDUSTRIAL PRODUCTS WARRANTY

Industrial instruments are warranted to be free from defects in material and workmanship for a period of twelve (12) months from the date of installation or eighteen (18) months from the date of shipment from IC CONTROLS whichever is earlier, when used under normal operating conditions and in accordance with the operating limitations and maintenance procedures in the instruction manual, and when not having been subjected to accident, alteration, misuse, or abuse. This warranty is also conditioned upon calibration and consumable items (electrodes and all solutions) being stored at temperatures between 5 °C and 45 °C (40 °F and 110 °F) in a non-corrosive atmosphere. IC CONTROLS consumables or approved reagents must be used or performance warranty is void. Accessories not manufactured by IC CONTROLS are subject to the manufacturer's warranty terms and conditions.

Limitations and exclusions:

Industrial electrodes, and replacement parts, are warranted to be free from defects in material and workmanship for a period of three (3) months from the date of installation or eighteen (18) months from the date of shipment when used under normal operating conditions and in accordance with the operating limitations and maintenance procedures given in the instruction manual and when not having been subjected to accident, alteration, misuse, abuse, freezing, scale coating, or poisoning ions.

Chemical solutions, standards or buffers carry an "out-of-box" warranty. Should they be unusable when first "out-of-box", contact IC CONTROLS immediately for replacement. To be considered for warranty, the product shall have an RA (Return Authorization) number issued by IC CONTROLS service department for identification and shall be shipped prepaid to IC CONTROLS at the above address.

In the event of failure within the warranty period, IC CONTROLS, or its authorized dealer will, at IC CONTROLS option, repair or replace the product non-conforming to the above warranty, or will refund the purchase price of the unit.

The warranty described above is exclusive and in lieu of all other warranties whether statutory, express or implied including, but not limited to, any implied warranty of merchantability or fitness for a particular purpose and all warranties arising from the course of dealing or usage of trade. The buyer's sole and exclusive remedy is for repair, or replacement of the non-conforming product or part thereof, or refund of the purchase price, but in no event shall IC CONTROLS (its contractors and suppliers of any tier) be liable to the buyer or any person for any special, indirect, incidental or consequential damages whether the claims are based in contract, in tort (including negligence) or otherwise with respect to or arising out of the product furnished hereunder.

Representations and warranties made by any person, including its authorized dealers, distributors, representatives, and employees of IC CONTROLS, which are inconsistent or in addition to the terms of this warranty shall not be binding upon IC CONTROLS unless in writing and signed by one of its officers.

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