

Operating Manual

MILLER-NELSON MODEL HCS-401 FLOW-TEMPERATURE-HUMIDITY CONTROL SYSTEM



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OPERATOR'S MANUAL

Miller-Nelson HCS-401

Air Conditioning System (Flow, Temperature, Humidity) For Gas Mask and Filter Testing

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1. BECOMING FAMILIAR WITH THE INSTRUMENT

1.1. What the Instrument Does

The HCS-401 Air Conditioning System (the Instrument) provides conditioned, controlled air flow for laboratory testing where it is desired to direct air of known flow, temperature, and humidity toward a test object. The most common application of the HCS-401 is the challenge testing of gas masks and filters in which air at a known flow rate, temperature, and humidity is laden with toxic chemical vapors and passed through a gas mask (air purifying respirator) or filter to measure its capacity to trap or resist toxic materials.

The Instrument needs to be continuously provided with a source of clean, dry, compressed air and with a source of purified water under a slight pressure. When these inputs are available, the Instrument is able to provide output air at a controlled flow rate, temperature, and humidity selected by the Operator. The flow rate, temperature, and humidity initially selected are monitored via three separate displays (Flow, Temp, RH) and may be modified within specific, allowed ranges by adjusting three separate control knobs (Flow, Temp, RH).

1.2. How the Instrument Works

The control system functions in the following manner.

Air Flow Rate Control

Air received by the Instrument initially passes through a Mass Flow Controller (MFC) that controls air flow in response to the set-point established by the Operator. The MFC controls air flow referenced to standard conditions (25° C, 1 atm) regardless of temperature and pressure variations in the system.

Humidity Control

Following the MFC, air flow passes across the surface of a water reservoir that is heated in response to RH Sensor signals interpreted by the humidity controller. The water heater runs continuously if the humidity is below the set-point established by the Operator (and intermittently as the set-point is approached) to achieve the desired water vapor pressure, and, consequently, the desired absolute humidity in the flowing air stream.

Temperature Control

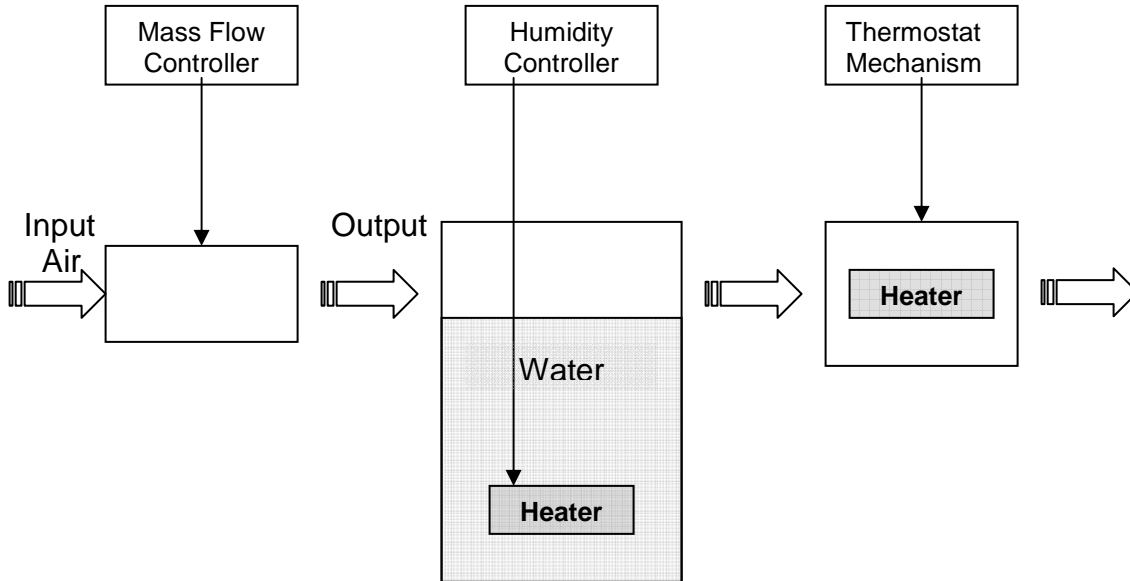
After humidification, just prior to exiting the Instrument, the air stream passes over a cartridge heater that brings the output air to the temperature set-point established by the Operator.

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Figure 1.2
How the Instrument Works



Temperature and Humidity Display

As the air stream leaves the Instrument, two sensors mounted in the Sensor Probe measure the temperature and humidity. In addition to providing feedback signals for temperature and RH control, the readings from the sensors are displayed on the Instrument's Front Panel providing a real-time display of temperature and RH.

Flow Rate Display

A signal from the main Mass Flow Controller is displayed on the Front Panel as a real-time display of flow rate.

Flow, Temperature, and Humidity Analog Outputs

Jacks providing recorder outputs for flow, temperature, and RH are included on the back of the Instrument.

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1.3 Performance and Limitations

1.3.1 Flow Rates that are available with the HCS-401 Instrument

The Miller-Nelson HCS-401 Instrument is available in the following standard “sizes” which are designated by the maximum flow rate obtainable with the Instrument.

20 L/min	50 L/min	100 L/min	200 L/min	500 L/min
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Instruments having other flow rate ratings are available on a custom quote basis.

Since the Mass Flow Controller (MFC) that drives the HCS-401 is most accurate and precise when operated in the upper part of its flow rate range, it is advisable to purchase an Instrument whose maximum flow rate is only slightly higher than the flow rates at which most work is expected to be performed. (See more about MFC accuracy below.)

1.3.2 Steady-State Flow Rate Performance

The available range for flow rate control is as follows:

Lowest Flow Rate	10% of top Flow Rate
Highest Flow Rate	100% of top Flow Rate

MFC accuracy is typically specified as being within $\pm 2\%$ of the maximum flow rate at all flow rates. (See also Specifications, Section 2.1.1).

1.3.3 Steady-State Temperature Performance

Since the HCS-401 controls temperature by heating the input air, the controlled *output temperature must always be higher than the ambient or input air temperature*. Sub-ambient temperatures may be attained by installation of the Cooling Option, a heat-exchange device that cools the output air just prior to the final temperature control.

The available range for temperature control is as follows:

Lowest <i>Controlled</i> Temperature	2°C above Temp of input air or coolant (b)
Highest <i>Controlled</i> Temperature	32°C (c)

(b) if Cooling Option is installed

(c) The instrument can attain temperatures greater than 32°C, but without humidity control

The steady-state accuracy of temperature control is within ± 0.5 °C. (See also Specifications, Section 2.1.2)

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1.3.4 Steady-State Humidity Performance

The available range for humidity control is as follows:

Lowest Humidity	20% above RH of supplied air
Highest Humidity	90% RH at 25°C 65% RH at 30°C 50% RH at 32°C

Since the Instrument controls humidity by adding moisture, output RH will always be higher than input RH. Accordingly, input air must be significantly dryer than the desired output humidity. For best results, input air should be as dry as possible.

The steady-state accuracy of humidity control is normally within ± 3.0 %RH.

1.3.5 Response Time of Instrument in Attaining Steady-State Operations

The Miller-Nelson HCS-401 has been designed to perform experiments at a steady-state. That is, the flow rate, temperature, and humidity are meant to be held constant during an experiment. Consequently, a certain amount of time is required to attain the desired values of flow rate, temperature, and humidity when starting the Instrument or changing from one set of conditions to another.

Typical response times for changes in parameter set-points are as follows:

Flow Rate – up to 1 minute from a cold start; up to 1 minute when transitioning from a high value to a low value.

Temperature – up to 2 minutes from a cold start; up to 5 minutes when transitioning from a high value to a low value.

Humidity – up to 10 minutes to attain high humidity from a cold start; up to 25 minutes when transitioning from a high value to a low value.

NOTE: The time required to attain a new temperature or humidity set-point will be dependent on the flow rate set-point. Attainment of the new temperature or humidity will always be more rapid at higher flow rates compared to lower flow rates. Accordingly, attainment can be accelerated by temporarily adjusting the flow rate set-point to a high value until desired temperature and humidity are attained. This is also useful in the shut down procedure (see Section 4.5.2) in which the humidity display value must attain $\leq 50\%$ RH before shutdown.

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2. PERFORMANCE SPECIFICATIONS

2.1 Operating Ranges and Accuracy at Steady-State

The Miller-Nelson HCS-401 has been designed to perform experiments at a steady-state, holding the flow rate, temperature, and humidity constant during an experiment.

2.1.1 Steady-State Air Flow Rate Performance

The HCS-401 is available in different sizes, each with a distinct maximum flow rate. The basic accuracy specification for flow rate is that the Instrument will control within $\pm 2\%$ of the top (maximum) rate for that Instrument. For example, for HCS-401-100 and HCS-401-200, having top flow rates of 100L/min and 200 L/min, respectively:

HCS-401-200
(Top Flow = 200 L/min)

HCS-401-100
(Top Flow = 100 L/min)

Flow Set- Point (L/min)	Accuracy (L/min)	% Accuracy (%)	Flow Set- Point (L/min)	Accuracy (L/min)	% Accuracy (%)
200	± 4	$\pm 2\%$	100	± 2	$\pm 2\%$
150	± 4	$\pm 3\%$	75	± 2	$\pm 3\%$
100	± 4	$\pm 4\%$	50	± 2	$\pm 4\%$
50	± 4	$\pm 8\%$	20	± 2	$\pm 8\%$
20	± 4	$\pm 20\%$	10	± 2	$\pm 20\%$

2.1.2 Steady-State Temperature Performance

Since the Instrument controls temperature by heating the input air, *the controlled output temperature must always be higher than input air temperature.*

The available ranges for temperature control and associated accuracy are as follows:

Ambient or Input Air Temp	Available Temp Range	Accuracy
18 °C	20-32 °C	± 0.5 °C
20 °C	22-32 °C	± 0.5 °C
22 °C	24-32 °C	± 0.5 °C
24 °C	26-32 °C	± 0.5 °C

If the Cooling Option (see also Section 1.3.3) is installed, the available ranges for temperature control and associated accuracy are as follows:

Coolant Temp	Available Temp Range	Accuracy
0 °C	2-32 °C	± 0.5 °C
5 °C	7-32 °C	± 0.5 °C
10 °C	12-32 °C	± 0.5 °C
15 °C	17-32 °C	± 0.5 °C

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2.1.3 Steady-State Humidity Performance

Since the Instrument controls humidity by adding moisture, output relative humidity will always be higher than input RH.

The available range for humidity control is as follows:

Input Air Humidity (%RH)	Available %RH Range	Accuracy
0%	15-90 %RH	$\pm 3.0\%$ RH
5%	20-90 %RH	$\pm 3.0\%$ RH
10%	25-90 %RH	$\pm 3.0\%$ RH
15%	30-90 %RH	$\pm 3.0\%$ RH

3. INSTALLATION

3.1 Electric Power Input

The Instrument requires a standard USA-style grounded socket providing 115 ± 5 VAC input at current up to 10 amps.

3.2 Air Input

The Instrument requires a source of clean, dry, compressed, filtered air delivered at a constant pressure of 50 ± 10 psi delivered to a port at the rear panel of the instrument via 3/8" tubing. Very high flow Instruments (500 L/min) are supplied with 1/2" air delivery tubing. Low flow instruments (20-100 L/min max. flow) will operate at the lower end of the suggested range (40 psi), while high flow instruments (200-500 L/min max. flow) may require pressures of 60 psi in order to attain maximum flow rates. The compressor must have the capacity to continuously generate the maximum flow rate of the Instrument. If the compressor has other users, their usage must be considered in assessing capacity.

Input air should be 20% lower than the level of relative humidity desired for most experiments. While a compressor will normally dry the air to some degree, an additional drying unit may need to be installed between the compressor and the Instrument to ensure operation at the desired humidity.

3.3 Water Input

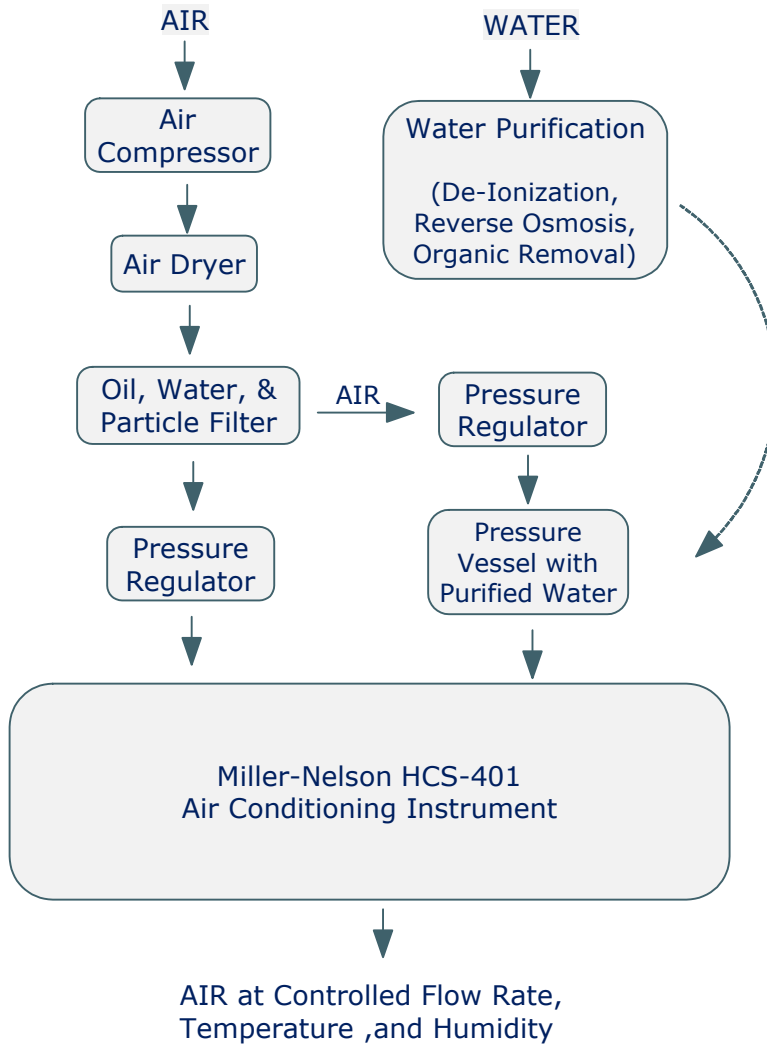
The Instrument requires a source of purified water provided at a constant pressure of 20 ± 10 psi delivered via 1/4" tubing to a port at the rear panel of the instrument. Purified water should be ASTM Type I having resistivity greater than 18 MOhm-cm (conductivity less than $0.06 \mu\text{S/cm}$), and very low organics ($< 100 \mu\text{g/L}$). The Instrument creates humidity by the evaporation of this water. Thus, any impurities dissolved in the input water will remain in the instrument until the Water Reservoir is purged with clean water. If less pure water is used, the Instrument's Water Reservoir should be purged (see Section 3.5.5) more often to remove residue.

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AIR and WATER Inputs Required for Instrument Installation



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3.4 Installation Procedure

3.4.1 Unpack the Instrument and identify the following components:

3.4.1.1 Miller-Nelson Instrument

3.4.1.2 Sensor Probe containing Temperature & RH Sensors

3.4.1.3 Pressure Regulator

3.4.1.4 Polypropylene Tubing, for air and water supply

3.4.2 Retain packing box and foam inserts to protect Instrument in the event that it may need to be transported to another site or returned to the factory.

3.4.3 Place the Instrument on a flat, horizontal surface within a few feet of the required sources of electric power, compressed air, and pressurized water. (See Above) Do not place the Instrument inside a fume hood or in any location where concentrations of chemicals, solvents, acids, alkalis, oils, or corrosives are likely to accumulate.

3.4.4 The Sensor Probe is a gray, tubular assembly (approx. 1" x 6") mounted into a T-shaped assembly containing an adapter for attaching to the Instrument. Note the presence of tiny, fragile temperature and humidity sensors inside the Sensor Probe.

3.4.5 Taking care to protect the fragile sensors from shock or abrasion, install the Sensor Probe into the Instrument by inserting the Sensor Probe adapter into the corresponding adapter on the Instrument rear panel near the port labeled "AIR OUT".

3.4.6 Attach the Sensor Probe's electrical cable to the rear panel of the instrument by screwing the Sensor Probe's threaded electrical cable assembly into the receptacle on the Rear Panel of the Instrument labeled "TEMP RH SENSOR".

3.4.7 Always use **PTFE tape** or other sealant on all **pipe threads** to prevent gas leaks. **NEVER USE PTFE tape or sealant on tube fittings.** (Tube fittings have ferrules and pipe threads do not. Refer to www.swagelok.com for examples.)

3.4.8 Install a shut-off valve and the pressure regulator between the compressed air source and the Instrument. Connect the regulator/filter output to the rear panel of the Instrument using the polypropylene tubing (3/8" or 1/2" OD) at the port labeled "AIR IN". With the Instrument OFF (with no air flow) adjust the air pressure to 50 psi at the pressure regulator. Open the shut-off valve and check for air leaks. If there are leaks, tighten threaded tube fittings and/or redo pipe fittings with PTFE tape or other sealant.

3.4.9 Install a shut-off valve in the pressurized water line, then connect the water line output to the to the Rear Panel of the Instrument at the port labeled "WATER IN" using polypropylene tubing (1/4" OD) provided with the Instrument. Open the shut-off valve and check for water leaks. Use only purified water. (See Section 3.3)

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3.4.10 Install a length of polypropylene tubing (¼" OD) at the rear panel of the Instrument at the port labeled "DRAIN" which can later conduct waste water to a sink or bucket for disposal.

3.4.11 Plug the instrument Power Cord into the grounded 115 VAC receptacle. If only 220 or 240 VAC is available, a voltage converter and plug adapter may be used to reduce the power input to 115 VAC.

3.4.12 Start up the Instrument as directed under Section 4 (Operating Instructions) to verify the success of the installation procedure.

3.5 Warnings and Precautions

3.5.1 DO NOT OPERATE INSTRUMENT without SENSOR PROBE INSTALLED

The Instrument uses its power to heat air and water to attain the temperature and humidity set-points. If the Instrument is turned on while the Sensor Probe is not installed in the Instrument, the Instrument will keep heating continuously, trying to attain the set-points, since the Sensor Probe is not available to report attainment of the set-points. This could cause damage to the Instrument.

An exception is noted in Section 5.3.2 where the Humidity Sensor is calibrated with Sensor Probe outside the Instrument, but only with the temperature and humidity dials set at 000.

3.5.2 General Instrument Care

Insofar as possible, the Instrument should be kept outside of fume hoods and away from chemicals, solvents, acids, alkali, oils, or corrosives. When gases or chemicals are added into flowing systems, they should always be added downstream from the Instrument in such a way that backflow and exposure of the Instrument to chemicals is unlikely.

Take care to avoid dropping or jarring when moving the Instrument from place to place. After installing or moving the Instrument, remove the top and inspect internal components to ensure that no damage has been experienced.

3.5.3 Care of Temperature and Humidity Sensors

The Temperature and Humidity Sensors installed in the Temp/RH Probe are among the most delicate and critical components in the Instrument. They are vulnerable to shock and abrasion, and can be damaged by exposure to chemicals, solvents, acids, alkali, oils, corrosives, or liquid water. Sensors exposed to water should be dried, then re-calibrated.

Care should be taken to protect exposed sensors from shock and abrasion whenever the probe is being installed or removed from the Instrument. When the Instrument is in use, any gases or chemicals other than air or nitrogen should be added to the system downstream from the Temp/RH Probe.

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3.5.4 Water Reservoir Clogging Due to Poor Quality of Water Used

Pressurized water used in the Instrument should be very pure with respect to resistivity and total organics (see Section 3.3). Since water added to the Instrument is vaporized to generate humidity, any salts or other dissolved solids present in supplied water will be left behind in the Water Reservoir as residue, eventually leading to clogging of the water level indicator and the valve that permits entry of fresh water into the Water Reservoir.

3.5.5 Sticky Valves Due to Residue Build-Up in Water Reservoir

Some residue build-up is inevitable. When solid residues build up in the Water Reservoir, they can cause the water shut-off valve to stick leading to over-filling or under-filling of the Water Reservoir. Residue build-up can be ameliorated by periodically purging the Water Reservoir as instructed in Section 6.3 (Purging Water Reservoir to Minimize Residue Build-Up)

3.5.6 Condensation of Water at "cold spots" in the System

The Dew Point, defined as the temperature at which condensation (water liquefaction) occurs in a mixture of water in air, is a function of the water content of the air as follows. This is equivalent to saying that condensation will occur whenever 100% RH is reached.

H ₂ O Conc'n	Dew Point	RH at 25°C	RH at 22°C	RH at 20°C
16.3 mg/L	19°C	71%	84%	94%
17.3 mg/L	20°C	75%	83%	100%
19.4 mg/L	22°C	84%	100%	>100%
20.5 mg/L	23°C	89%	> 100%	> 100%
21.7 mg/L	24°C	94%	> 100%	> 100%

From the Table above, it can be seen that an atmosphere generated by the Instrument to be 75% RH at 25°C will condense at any time or location where its temperature reaches 20°C. Similarly, an atmosphere generated to be 84% RH at 25°C will condense at any time or location where its temperature reaches 22°C.

Thus, independent temperature control must be maintained in the flow path downstream from the Instrument to prevent condensation.

3.5.7 Condensation of Water Inside the Instrument

Condensation of water inside the Instrument can permanently damage the Temperature and RH Sensors contained in the Sensor Probe! Condensation can occur within the Instrument if high humidity is being generated within the Instrument and any part of the Instrument is then cooled.

3.5.7.1 Condensation can occur if the Instrument is turned off in a 22°C room after generating high humidity at 25°C. Preventative Measure: *Turn humidity dial to < 50% RH, then allow Instrument to attain 50% RH on the RH Display before turning off.*

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3.5.7.2 Condensation can occur if the temperature set-point is abruptly changed to a lower temperature after generating high humidity. Preventative Measure: *Turn humidity dial to < 50% RH, then allow Instrument to attain 50% RH on the RH Display before lowering the temperature set-point.*

3.5.7.3 Condensation can readily occur inside the Instrument whenever a high humidity atmosphere is generated at a temperature greater than 25°C. Preventative Measure: *When generating high humidity at any temperature above 25°C, increase the humidity set-point gradually. After operation at high humidity at any temperature above 25°C, first lower the humidity set-point below 50% RH, then lower the temperature set-point only after 50% RH has been obtained on the RH display.*

3.5.8 Air and Gas Leaks

Leaks are always a risk when a gas under pressure is passed through tubing and fittings. Whenever problems are observed with flow, it is advisable to check for leaks using soap solutions, leak detectors, or other testing methods.

It is often the case that gas leaks in the test system downstream from the Instrument can result in a reduction in flow such that the Test is actually being carried out at a flow rate lower than the target flow rate. Clearly, testing at a reduced flow rate is likely to yield erroneous results. As an overall leak detection method, it is advisable to measure the flow rate as far downstream as possible using an independent flow meter to verify that the flow rate at the end of the test system is the same as the flow rate emerging from the Instrument. Any difference in flow rate can be attributed to leaks.

3.5.8.1 Always use **PTFE tape** or other sealant on all **pipe threads** to prevent gas leaks. **NEVER USE PTFE tape or sealant on tube fittings.** (Tube fittings have ferrules and pipe threads do not. Refer to www.swagelok.com for examples.)

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4. OPERATING INSTRUCTIONS

4.1 Turning on All Functions

4.1.1 Make sure all air and water connections are tight. Plug in the Instrument to 115VAC, open all air and water shut-off valves, activate the POWER switch on the Front Panel of the Instrument.

4.1.2 Adjust the flow dial to read 500 (50% of maximum flow rate). Adjust the temperature dial to 250 (25°C), and the humidity dial to 250 (25%RH).

4.1.3 Observe the Front Panel lights and displays. All five Front Panel lights should be lit or blinking.

4.2 Checking-Out Front Panel Light Indicators

4.2.1 STATUS LIGHTS (on left side of Front Panel)

4.2.1.1 Air Flow – Light ON indicates there is sufficient air pressure to feed the Mass Flow Controller. Light OFF indicates there is insufficient air pressure or flow.

4.2.1.2 Water Level – Light ON indicates there is sufficient water in the Instrument's Water Reservoir to drive the humidity controller. Light OFF indicates the Water Reservoir is not yet full.

4.2.1.3 Water Pressure – Light ON indicates there is sufficient water pressure to fill the Water Reservoir. Light OFF indicates there is not sufficient water pressure from the water source to fill the Water Reservoir.

4.2.2 CONTROL LIGHTS (on right side of Front Panel)

4.2.2.1 Temperature - Light ON indicates the air heater is ON in response to the temperature sensor calling for more heat. Light OFF indicates the air heater is OFF in response to the temperature sensor being satisfied. When steady-state control is established, the temperature light should blink ON and OFF regularly.

4.2.2.2 Humidity - Light ON indicates the water heater is ON in response to the humidity sensor calling for more humidity. Light OFF indicates the water heater is OFF in response to the humidity sensor being satisfied. When steady-state control is established, the humidity light should blink ON and OFF regularly.

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4.2.3 If any of the STATUS or CONTROL LIGHTS are not lighted, investigate the cause as suggested by the descriptions above. In most instances, the STATUS LIGHTS not being lighted indicates that either the air or water supply to the Instrument is not adequate due to a blockage or inadequate pressure. CONTROL LIGHTS will not light until all STATUS LIGHTS are lighted.

4.3 Checking-Out Front Panel Displays

4.3.1 The Flow Display Meter indicates the flow rate of air being provided by the Mass Flow Controller. The displayed flow rate should be near to the value obtained by multiplying the flow dial setting (taken as a percent) by the maximum flow rate rating of the Instrument.

4.3.2 The Temperature Display Meter indicates the actual temperature of air as it exits the Instrument and should be near to (but not necessarily identical to) the setting of the temperature dial.

4.3.3 The Humidity Display Meter indicates the actual relative humidity of air being provided by the Instrument and should be near to (but not necessarily identical to) the setting of the humidity dial.

NOTE: Once air exits the Instrument, the absolute humidity (mg H₂O/L of air) has been fixed. However, the relative humidity of air exiting the Instrument and entering the test system downstream from the Instrument will change if the temperature of the test system downstream from the Instrument is different from the air provided by the Instrument. At constant absolute humidity, as temperature decreases %RH will increase. Similarly, as temperature increases, %RH will decrease.

4.4 Adjusting Set-Points to Attain Desired Flow, Temperature and Humidity

4.4.1 Adjust the flow, temperature, and humidity dials until the respective displays read desired values for flow, temperature, and humidity while the STATUS LIGHTS all remain ON, and CONTROL LIGHTS are blinking regularly ON and OFF.

4.4.2 It may be necessary to wait a few minutes for the Instrument to attain steady-state values on the displays, especially for humidity. (See Section 1.3.5)

4.4.3 A final adjustment may be necessary to the flow, temperature, and humidity dials until the exact desired values of flow, temperature, and humidity are shown on the displays on the Front Panel.

4.4.4 Analog outputs to allow continuous recording of flow, temperature, and humidity can be obtained by plugging analog recorder plugs into the jacks on the Rear Panel of the Instrument labeled FLOW (0-5 V.), TEMP (0-2.5 V.), and RH (0-5 V.).

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4.5 Shut-Down Procedure

4.5.1 Adjust the temperature set-point to 250 (25°C) and humidity set-point to 000 (0% RH) and run at a high flow rate until the humidity display value is \leq 50% RH.

4.5.2 When the RH display is less than 50%, Instrument may be turned OFF.

5. CALIBRATION

5.1 General

The Instrument is designed to provide conditioned air for standard testing at a specified flow rate, temperature, and humidity. The reported values of parameters during a test cannot be more accurate than the most recent calibration values of the Instrument. Different types of Calibration Programs may be appropriate for different users who may use the Instrument frequently for official purposes or infrequently for unofficial purposes.

5.2 Flow Rate Calibration

The flow rate of conditioned air from the Instrument is controlled by a single Mass Flow Controller (MFC) which has been factory-calibrated and referenced to 25°C and 1.00 atmosphere of pressure (760 mm Hg, 1.01 bar, 101 kilopascal, 14.7 psi).

Flow rate calibration generally holds constant for long periods of time (years) provided the MFC is not damaged or subject to aerosols or corrosive chemicals. For critical applications, check flow rate bi-annually using an NIST-traceable flow meter. Flow rate calibration and adjustment may be performed by returning your Instrument to the factory. (See Section 7.4)

5.3 Temperature Calibration

The Temperature Sensor is a resistance thermometer that has been calibrated at the factory. Resistance thermometers are subject to drift, especially if wet or damaged, and should be calibrated at least annually. For critical applications, calibrate the temperature sensor weekly or prior to each use as follows.

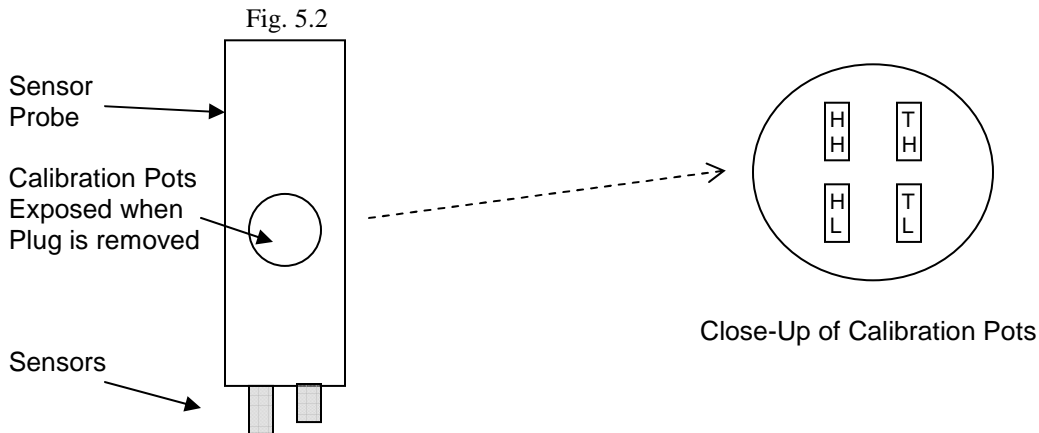
With the Sensor Probe installed in a working Instrument, place an NIST-traceable thermometer inside the Sensor Probe and within 5 mm of the Temperature Sensor. Set the flow dial at 50% of the maximum flow rate. Set the humidity dial at 250 (25% RH). Set the temperature dial at 250 (25.0°C) (or at the temperature at which testing will be performed). After the Instrument has achieved steady-state (as indicated by the temperature and humidity lights blinking ON and OFF regularly), compare the temperature display to the reading of the NIST-traceable thermometer. If the readings differ by more than 0.2°C, adjust Sensor Probe setting as follows:

- (1) Unscrew plastic plug on the side of Sensor Probe exposing four adjustment pots.
- (2) Adjust pot "TL" until the temperature display reading agrees with the NIST-traceable thermometer within 0.2°C.

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5.4 Humidity Calibration

The Humidity Sensor is an electronic sensor that has been calibrated at the factory. This device is subject to drift, especially if wet or damaged, and should be calibrated at least quarterly. For critical applications, calibrate the humidity sensor weekly or prior to each use as follows.

5.4.1 Independent Sensor Calibration (Method A)

With the Sensor Probe installed in a working Instrument, install an NIST-traceable humidity monitor inside the Sensor Probe and as close as possible to the Humidity Sensor. If that is not possible, install the NIST-traceable humidity monitor inside tubing coming directly from the Sensor Probe as closely as possible to the Sensor Probe. Make certain that both Humidity Sensors are at *the same temperature*. Set the flow dial at 50% of the maximum flow rate. Set the humidity dial at the humidity at which testing is to be performed, e.g. 800 (80% RH) or 250 (25.0%) . Set the temperature dial at 250 (25.0°C). After the Instrument has achieved steady-state (as indicated by the temperature and humidity lights blinking ON and OFF regularly), compare the humidity display to the reading of the NIST-traceable humidity monitor. If the readings differ by more than 3%, adjust Sensor Probe setting as follows:

- (1) Unscrew the plastic plug on the side of the Sensor Probe exposing four adjustment pots.
- (2) For calibration in the range 20-50% RH, adjust pot "HL" until the humidity display reading agrees with the NIST-traceable humidity sensor within 1% RH.
- (3) For calibration in the range 50-85% RH, adjust pot "HH" until the humidity display reading agrees with the NIST-traceable humidity sensor within 1% RH.

5.4.2 Absolute Calibration Using Humidity Chamber (Method B)

Remove the Sensor Probe from the Instrument. Set the flow dial at 00% of the maximum flow rate. Set the humidity dial at 000 (0% RH). Set the temperature dial at 000 (0.0°C). With the electrical signal cable still connected to the Instrument, suspend the Sensor Probe in the head space of a humidity chamber (a sealed jar containing a head space above a humidity calibration solution). Close the chamber and agitate the air above the saturated solution for 10-15 minutes to attain equilibrium between the calibration solution and the vapor in the head space of the chamber as indicated by a constant humidity reading on the Front Panel humidity display.

When the chamber has achieved steady-state (as indicated by constant humidity readings on the Front Panel display), compare the humidity display to the standard relative humidity for the particular humidity solution being used. If the readings differ by more than 1%, adjust Sensor Probe setting as follows:

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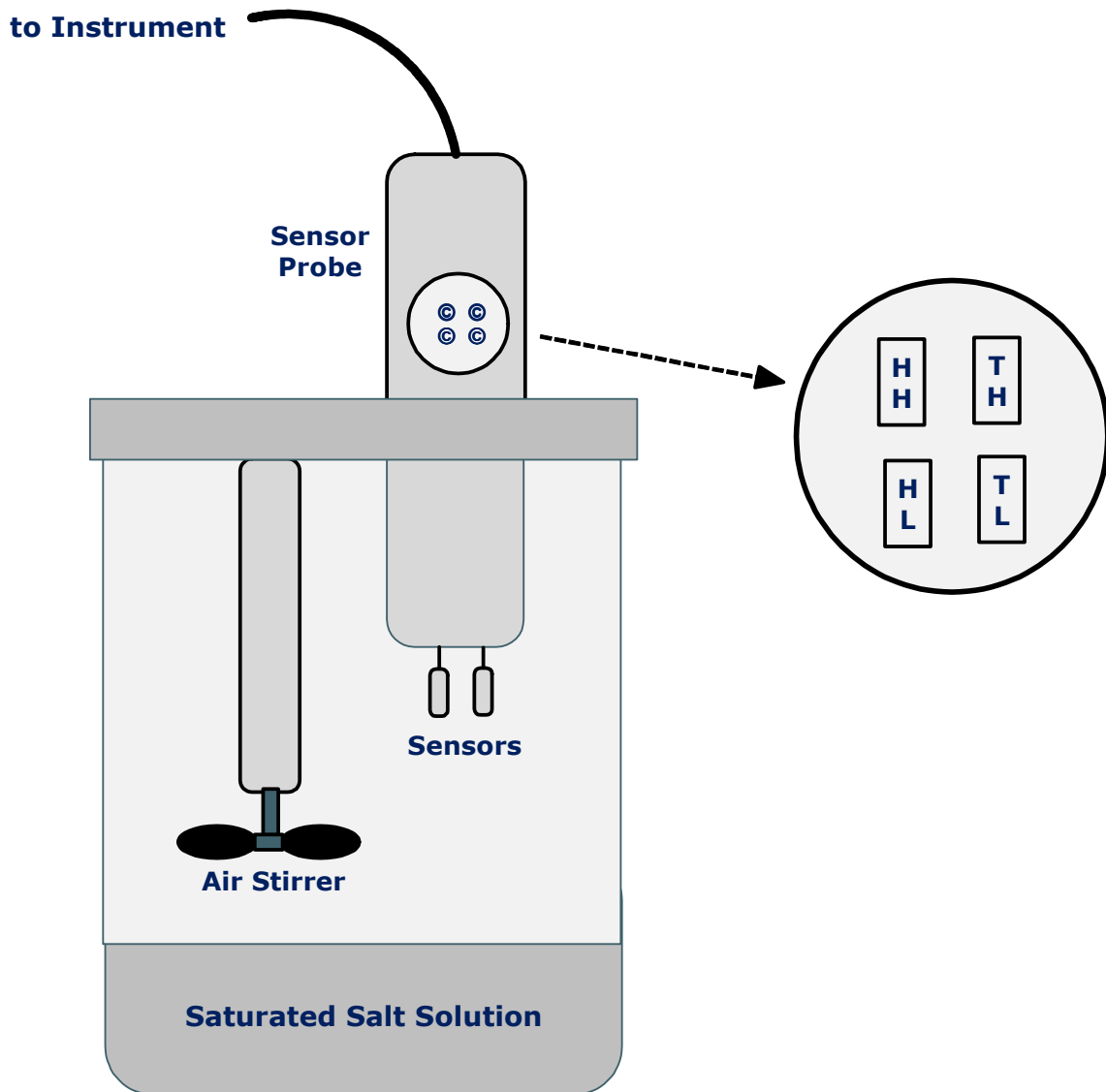
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- (1) Unscrew the plastic plug on the side of Sensor Probe exposing four adjustment pots.
- (2) For calibration in the range 20-50% RH, adjust pot "HL" until the humidity display reading agrees with the NIST-traceable humidity monitor within 1% RH.
- (3) For calibration in the range 50-85% RH, adjust pot "HH" until the humidity display reading agrees with the NIST-traceable humidity monitor within 1% RH.

Locate correct adjustment pot using Figure 5.2 for temperature calibration. A recipe for several humidity calibration solutions is shown in the following Table.

RELATIVE HUMIDITY CALIBRATION



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5.4 Humidity Calibration (continued)

SATURATED SALT HUMIDITY CALIBRATION SOLUTIONS

PERCENT RELATIVE HUMIDITY AT

Saturated Solution of	20°C	25°C	30°C
Lithium Chloride	11.3%	11.3%	11.3%
Potassium Acetate	23.1%	22.5%	21.6%
Magnesium Nitrate	54.4%	52.9%	51.4%
Potassium Chloride	85.1%	84.3%	83.6%

Omega Instruments, Stamford, CT

<http://www.omega.com/temperature/Z/pdf/z103.pdf>

5.4.3 Outsource Calibration (Method C)

Return the Sensor Probe to Assay Technology, Inc. for humidity calibration.
(See Section 7.4)

Complete calibration of air flow, temperature, and humidity along with complete repair of any HCS-401 Instrument can be accomplished at a fixed price (excluding the cost of any replacement parts) by returning the Instrument to the factory. (See Section 7.4)

6. PREVENTATIVE MAINTENANCE

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The Instrument has been shown to operate reliably for long periods of time provided certain maintenance activities are regularly performed.

6.1 Instrument Care

Maintain and use the Instrument in an environment that is kept at a moderate temperature and humidity, and, insofar as possible, is free of aerosols, chemicals, solvents, acids, alkalis, oils, and corrosives.

6.2 Air Cleaners and Filters

Air supplied to the Instrument should be clean and free of aerosols, chemicals, solvents, acids, alkalis, oils, and corrosives. To ensure this, regularly remove and replace any filters or other air cleaning devices installed between the Instrument and its air supply.

6.3 Purging Water Reservoir to Minimize Residue Build-Up

Some residue build-up is inevitable. This can be ameliorated by periodically purging the Water Reservoir. Purge the Water Reservoir by opening the valve labeled "DRAIN" located on the Rear Panel of the Instrument when the Instrument operating (i.e. with the Instrument Power ON and clean pressurized water is continuously supplied to the Rear Panel at the port labeled "WATER IN".) Purge until 1 L. of water is collected or until the last water collected is clear.

6.4 Air Flow Calibration

Perform at least bi-annually using a NIST-Traceable device. (See Section 5. CALIBRATION)

6.5 Temperature Sensor Calibration

Perform at least annually using a NIST-Traceable device.
(See Section 5. CALIBRATION)

6.6 Humidity Sensor Calibration

Perform at least quarterly using a NIST-Traceable device.
(See Section 5. CALIBRATION)

6.7 Periodic Factory Reconditioning

A complete reconditioning (See Section 7.4) of any HCS-401 (including calibration of air flow, temperature, and humidity) plus complete repair of any HCS-401 Instrument can be accomplished at a price guaranteed in advance (*prix fixe*) (*excluding the cost of major replacement parts, if required*) by returning the Instrument to the factory along with an RMA (See Section 9).

7. DEVELOPING A DIAGNOSIS AND REPAIR STRATEGY

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7.1 Multi-Functional Nature of Instrument

The Instrument has been designed to perform reliably for an indefinite period of time, and many have been placed in continuous use for a decade or more. This is remarkable when one considers that its performance includes hydraulic and pneumatic systems as well as electrical and mechanical aspects. When, from time-to-time, as a result of normal wear-and-tear or specific causes, an Instrument ceases to function as desired, the repair can be challenging due to its multi-functional nature.

7.2 Strategy 1 - Typical End User

7.2.1 It is recommended that typical end users will benefit from understanding the ideas contained in the manual in Section 8, INSTRUMENT FIRST-AID AND TROUBLE-SHOOTING, in diagnosing Instrument problems.

7.2.2 In some cases, it is hoped this guidance can lead to immediate, on-site corrections by the end user in either the Instrument or in the way it is being used.

7.2.2 In other cases, a problem may be diagnosed that is beyond the end user's expertise to correct, or the problem may remain undiagnosed.

7.2.3 After one or more calls to the Customer Service Hot Line (1-800-833-1258, ext 4), the end user will be able to determine whether an on-site repair can be made, or whether the Instrument will need to be returned to the factory for repair.

7.2.4 In the event of a return to the factory, please refer to Section 9, RETURNING AN INSTRUMENT TO THE FACTORY FOR SERVICE.

7.2.5 Please refer also to Section 7.4 RECONDITIONED INSTRUMENT PROGRAM.

7.3 Strategy 2 - End User with Access to Special Expertise

7.3.1 Even end users with access to special expertise will benefit from understanding the ideas contained in the manual in Section 8, INSTRUMENT FIRST AID AND TROUBLE-SHOOTING, in diagnosing Instrument problems.

7.3.2 In many cases, this guidance can lead to immediate, on-site corrections by the end user in either the Instrument or in the way it is being used.

7.3.2 In other cases, the problem may remain undiagnosed. In that case, we refer the reader to Section 12, DOCUMENTATION. A review of Instrument drawings and other pertinent sections of this Manual may lead users having high technical expertise to a diagnosis of an Instrument problem leading to an on-site repair.

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7.3.3 To assist in diagnosis of problems, end users with access to special expertise are invited to call the Customer Service Hot Line (1-800-833-1258, ext 4) or our Engineering Department directly at 1-831-417-0622.

7.3.4 End users pursuing on-site repairs may acquire quotations and place orders for repair parts by calling either of the numbers listed above.

7.3.5 In the event of a return to the factory, please refer to Section 9, RETURNING AN INSTRUMENT TO THE FACTORY FOR SERVICE.

7.3.6 Please refer also to Section 7.4 RECONDITIONED INSTRUMENT PROGRAM.

7.4 Reconditioned Instrument Program

A complete reconditioning of any HCS-401 Instrument can be accomplished at a price guaranteed in advance (*prix fixe*) (*excluding the cost of major replacement parts, if required*) by returning the Instrument to the factory along with an RMA (See Section 9) and a purchase order number. The Reconditioned Instrument Program includes the following:

7.4.1 All labor and minor parts required to complete Instrument repair and bring the Instrument to current factory specifications including calibration of flow rate, temperature, and humidity.

7.4.1.2 There will be a separate charge for any major parts that may need to be replaced to bring the Instrument to current factory specifications.

7.4.2 Re-establishment of the Instrument's Limited Warranty for 1 year (excluding the Sensor Probe which has its own Limited Warranty for 3 months).

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8. INSTRUMENT FIRST-AID & TROUBLE-SHOOTING

Below is a list of operating problems (symptoms) that may be observed and a list of possible causes that may aid in diagnosis of problems and point to corrections in the Instrument or in its use.

Table 8.1 SYMPTOMS AND CAUSES

SYMPTOM	Possible CAUSE
Check for Symptoms (A) - (J), in the order given, before doing anything else. Check Cause (1) before Cause (2), and so on.	
A. No power to Instrument	<ol style="list-style-type: none"> 1. Instrument rocker switch turned OFF (front panel) 2. No power to socket plug (check breaker) 3. Blown Fuse (rear panel)
B. Status light OFF - air flow	<ol style="list-style-type: none"> 1. Insufficient pressure or flow from air supply (compressor) 2. Flow switch malfunction (a) (b) (d)
C. Status light OFF - water level	<ol style="list-style-type: none"> 1. Insufficient pressure or flow from water supply 2. Water level switch jammed due to clogging (b) 3. Water flow control valve adjustment (c) 4. Pressure switch malfunction (a)
D. Status light OFF - water pressure	<ol style="list-style-type: none"> 1. Insufficient water pressure or flow from supply 2. Water pressure switch malfunction (a)
E. Temperature control light not blinking ON and OFF	<p><i>If power and all status lights are ON...</i></p> <ol style="list-style-type: none"> 1. Temperature sensor malfunction (a) 2. Heater malfunction (a)
F. Humidity control light not blinking ON and OFF	<p><i>If power and all status lights are ON...</i></p> <ol style="list-style-type: none"> 1. Humidity sensor malfunction 2. Water reservoir heater malfunction
G. NO air flow	<p><i>If power and all status lights are ON...</i></p> <ol style="list-style-type: none"> 1. Mass Flow Controller malfunction (a)
H. Air flow not under control (Displayed value differs from Set-Point)	<ol style="list-style-type: none"> 1. Mass Flow Controller malfunction (a)
I. Air flow not under control (Measured value differs from display value)	<ol style="list-style-type: none"> 1. Air leak in system downstream from Instrument 2. Air leak inside Instrument 3. Mass Flow Controller malfunction (a)
J. Air flow not under control (High flow but displayed value is 000)	<ol style="list-style-type: none"> 1. Mass Flow Controller malfunction (a) 2. Bad connection between PCB and the display meter.

(a) This code indicates the possible malfunction of a component within the Instrument. Call Customer Service at **1-800-833-1258 ext 4** for assistance. You may be referred to the Instrument Engineer. If the problem is not resolved, the end user may choose, either to purchase and replace the possibly malfunctioning component (part), or to return the Instrument for Service as directed in Section 9.

(b) Purge the Water Reservoir as directed in Section 3.5.5 (Purging to Minimize Residue Build-Up in Water Reservoir). Remove the Instrument lid and look into the clear plastic Water Reservoir to see if the water is cloudy. If the water is cloudy, purge until the water appears clear. Use purer water or purge more often.

(c) The water flow control valve is mounted between the WATER IN port on the Rear Panel and the Water Reservoir. Open this valve by 1 or 2 turns to increase the flow of water to the Water Reservoir.

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(d) The flow switch is a clear plastic device containing a metal float mounted in the path between the Mass Flow Controller and the Water Reservoir. With air flow turned OFF, tap the flow switch gently with a screw driver handle to see if the float is merely stuck. If this doesn't solve the problem, the flow switch can be replaced.

9. RETURNING AN INSTRUMENT TO THE FACTORY for SERVICE

9.1 Final Problem Review

Prior to returning an Instrument for repair, review Section 8, Trouble-Shooting and First-Aid and try to determine if the problem can be resolved without returning the Instrument to the factory. Feel free to access Customer Service at 800-833-1258 ext 4 for assistance.

9.2 Obtaining a Return Material Authorization

A Return Materials Authorization (RMA) Number is required, and can be obtained by calling 800-833-1258 ext 4. When you request an RMA No. from the Customer Service Representative, you will immediately be asked to provide the following information.

- HCS Model Number and Flow Rate (e.g., HCS-401-200)
- Serial Number of the Instrument
- Serial Number of the Temperature/Humidity Probe
- Reason for the return
- Purchase Order No. for repair/calibration charges
- Your company contact, ship to and bill to information
- Your company UPS or FedEx Account No., for return shipment (optional)

This number (e.g., MN5088) should be included on all paperwork and written on the outer packing box, when sending the Instrument to the factory.

Upon receipt of your Instrument and inspection by our engineer, a Customer Service Representative will contact you with options and estimates for repair of your Instrument.

In the event that significant repairs are required, a general reconditioning and calibration of the entire Instrument is available for a guaranteed maximum cost for labor and minor parts. The cost of any major parts will be added to this figure.

9.3 Preparing the Instrument for Shipment

The LIQUID RESERVOIR of the Instrument **MUST BE DRAINED COMPLETELY** prior to shipment. This is done by air purging the Water Reservoir by applying air pressure (approx. 25 psi) at the port on the Instrument's Rear Panel labeled "WATER IN", opening the toggle switch on the Rear Panel labeled "DRAIN VALVE", and directing the water emerging from the port labeled "DRAIN" to waste until the last drop of water emerges. Failure to drain all water from the Instrument may cause contamination of the flow controller or other damage to the Instrument.

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Pack the Instrument in its original shipping box with foam inserts or add enough bubble packing to ensure that the instrument is absolutely immobilized in the packing box.

9.4 Shipping the Instrument

Ship by a traceable express service and purchase insurance for the Instrument.

9.4.1 Factory Address

Ship to:

Assay Technology
1382 Stealth Street
Livermore, CA 94551

9.5 Turn Around Time for Repair

Repair/maintenance will be completed in 3 – 8 weeks, depending on the condition of the Instrument upon receipt.

10. LIMITED WARRANTY

The Instrument (with the exception of the Sensor Probe) is provided with a one-year Limited Warranty. The Sensor Probe (Temperature-Humidity Probe, Part No. SJP-200b-2) is provided with a three months Limited Warranty. Factory Reconditioned Instruments and Probes carry the same warranty as a new Instrument or Probe.

Under the Limited Warranty, products are warranted against defects in materials and workmanship. Defective products returned with a Return Material Authorization (Section 9) within the warranty period will be repaired or replaced at the manufacturer's expense. Damage from physical abuse or from exposure to solvents, acids, alkali, oils, corrosives, or water is not covered by this Limited Warranty.

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11. GUIDANCE for CERTAIN APPLICATIONS

11.1 General

Applications below involve typical applications wherein the Instrument provides a controlled flow of conditioned air to which a challenge agent is added in order to test the chemical capacity of air purifying respirators or filters.

11.2 Chemical Challenge Agent Capacity Testing

11.2.1 Air Conditioning Instrument - The Instrument shall be capable of providing a flow of air substantially free of oil or organic contaminants at the specified flow rate (± 1 L/min), temperature ($\pm 2^{\circ}\text{C}$), and relative humidity ($\pm 5\% \text{RH}$). The Instrument shall be calibrated periodically with respect to the accuracy of air flows by a dry gas meter or other absolute method. For systems driven by compressed air, suitable drying, filtration, and pressure regulation shall be applied to the input air.

11.2.2 Challenge Test Flow Path – Delivery tubing, fittings, valves, chambers, and components in the challenge Test Flow Path shall be designed to minimize pressure drop [$\leq 20'' \text{H}_2\text{O}$ (0.05 bar)] and shall be constructed of material which is substantially inert to the challenge agent (e.g. polyolefin, PTFE, glass, or stainless steel).

11.2.3 Temperature and Humidity Monitoring – Temperature and humidity controllers within the Instrument shall be periodically calibrated by a NIST-traceable device. Additionally, temperature shall be monitored by a NIST-traceable device placed near to the Test Article. (NOTES: Temperature and humidity monitors should not be continuously placed in the flow path downstream from the point where challenge agent is introduced due to corrosive effects of agents.)

11.2.4 Challenge Agent Generation (gas) – Where the Agent is a gas (ammonia, cyanogen chloride, sulfur dioxide, hydrogen cyanide, hydrogen sulfide, nitrogen dioxide, phosgene, phosphine), concentrations shall be generated by adding a metered flow of pure gaseous Agent (at a known purity) or a diluted form of gaseous Agent (analyzed gas mixture) into the Test Flow Path upstream from the Test Article at a distance sufficient to provide mixing with the pure air flow. Adding a metered flow of Agent into the Test Flow Path may be achieved by dispensing Agent, or diluted Agent, from a pressurized, regulated cylinder through a mass flow controller or rotameter which has been periodically cleaned and calibrated.

11.2.4.1 Challenge Agent Monitoring (gas) - Where Agent Generation has been achieved by dilution of pure gas or analyzed gas mixture using calibrated mass flow controller or rotameter, verification of the final Challenge Agent Concentration is accomplished by checking for leaks in the system and monitoring the mass flow controller readout or rotameter readings (assuming calibrations, purities, and calculations have been checked). Additional monitoring of Challenge agent Concentration is desirable but optional.

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11.2.5 Challenge Agent Generation (liquid) – Where the Agent is a liquid (carbon tetrachloride, cyclohexane), challenge concentrations shall be generated by adding a metered flow of pure liquid into the Test Flow Path downstream from the air conditioning system and upstream from the entry to the test article. Addition of a metered flow of liquid Agent may be achieved by delivery of pure liquid (or a solution) from a precision gas-tight syringe mounted in a calibrated syringe pump (e.g., Hamilton Model 33 Infusion Pump) through inert tubing and a needle which penetrates a gas-tight rubber septum mounted in the Test Flow Path a sufficient distance upstream from the test article to provide mixing and dissipation of excess heating or cooling arising from the vaporization of liquid. A minimal amount of heat may be directed at the point of liquid addition by heating mantle, tape, or heat gun to vaporize the liquid and/or minimize evaporative cooling.

11.2.5.1 Challenge Agent Monitoring (liquid) - Where Agent generation has been achieved by vaporization of liquid, the verification of final challenge Agent concentration shall be accomplished by monitoring the actual Agent concentration upstream from the test article using an in-line instrument (e.g. calibrated infrared spectrophotometer) or by a wet-chemical analysis of an air sample performed prior to beginning the test.

11.2.6 Test Article and Test Shunt – The Test Article, or its active element (cartridge, etc.), shall be installed in test fixture in such a way that 100% of the flow of Challenge Agent from the Test Flow Path may be directed through the Test Article, or alternately, through a safety cartridge capable of collecting the Challenge Agent for a period of time. This may be accomplished by a Test Shunt comprising a 3-way valve or other switch installed in the Test Flow Path to accomplish shunting the flow of Challenge Agent from safety cartridge to the test fixture once verification of all test parameters has been achieved.

11.2.7 Downstream Monitoring for Breakthrough - Monitoring of the Test Flow Path downstream from the test fixture shall be conducted using a continuous monitoring instrument which has been calibrated at or near the breakthrough concentration. The downstream monitor shall be incorporated in the Test Flow Path only when flow has been switched to the test fixture via the Test Shunt.

11.2.8 Performing the Test – Initially the Test Flow Path shall be directed through the safety cartridge. Once air flow from the air conditioning system has been established at the desired flow rate, temperature, and humidity, Agent Generation shall be commenced with the Test Flow Path directed through the safety cartridge. When verification of the Challenge Agent concentration has been accomplished under Section 11.2.4.1 or 11.2.5.1, the Test Flow Path shall be directed through the test fixture by actuating the Test Shunt. The test begins and the test clock is actuated at the instant the Challenge Agent is directed through the test fixture. The Test continues until the breakthrough concentration is indicated by the downstream monitor.

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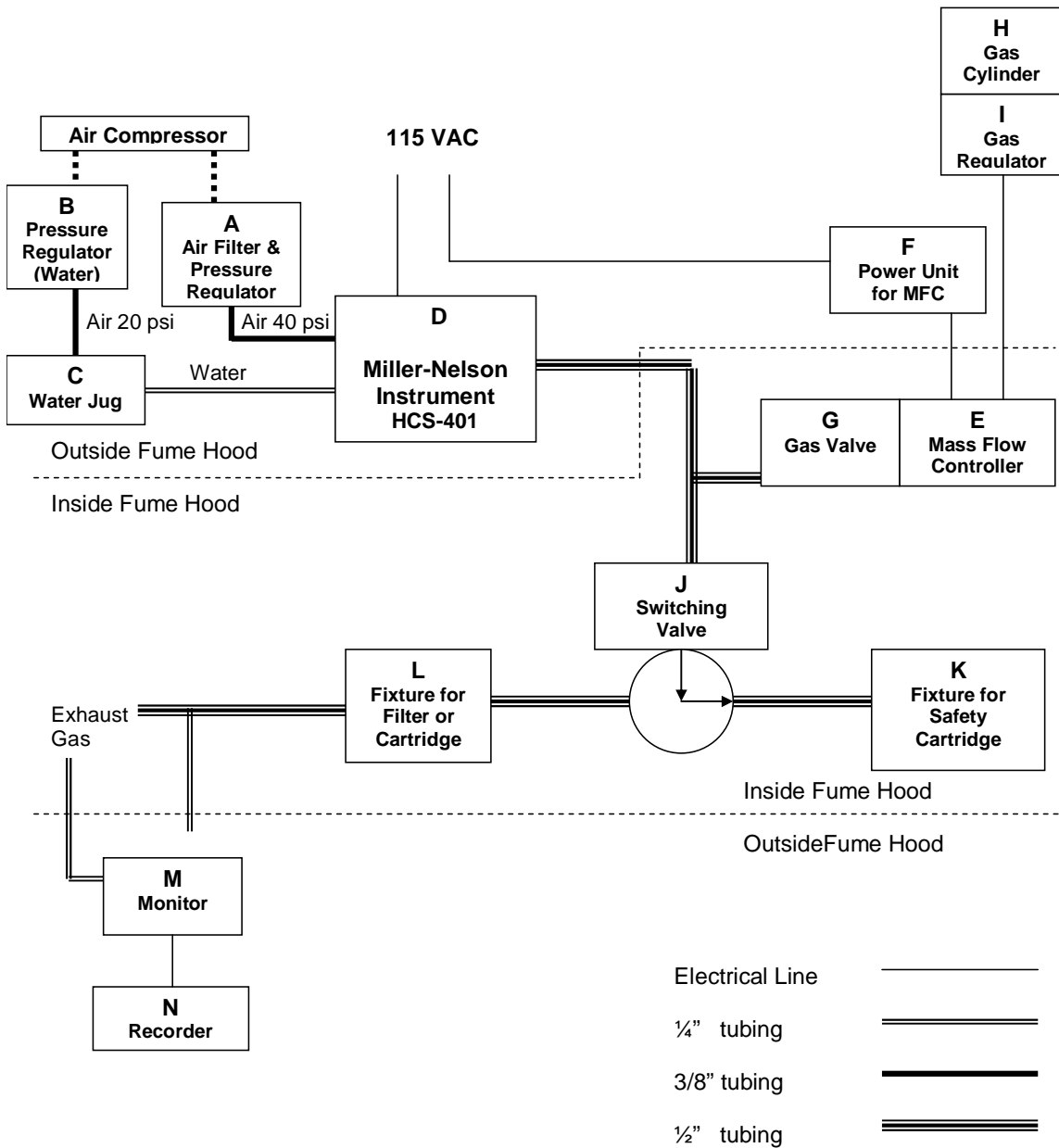
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11.2.9 Timing and Recording Data – A stopwatch may be used for measuring the time between the beginning of the test and the instant that breakthrough concentration is indicated by the downstream monitor. Alternately, a strip-chart recorder or data-logging system may plot the data and keep track of the time.

SCHEMATIC DIAGRAM

Filter or Gas Mask Test



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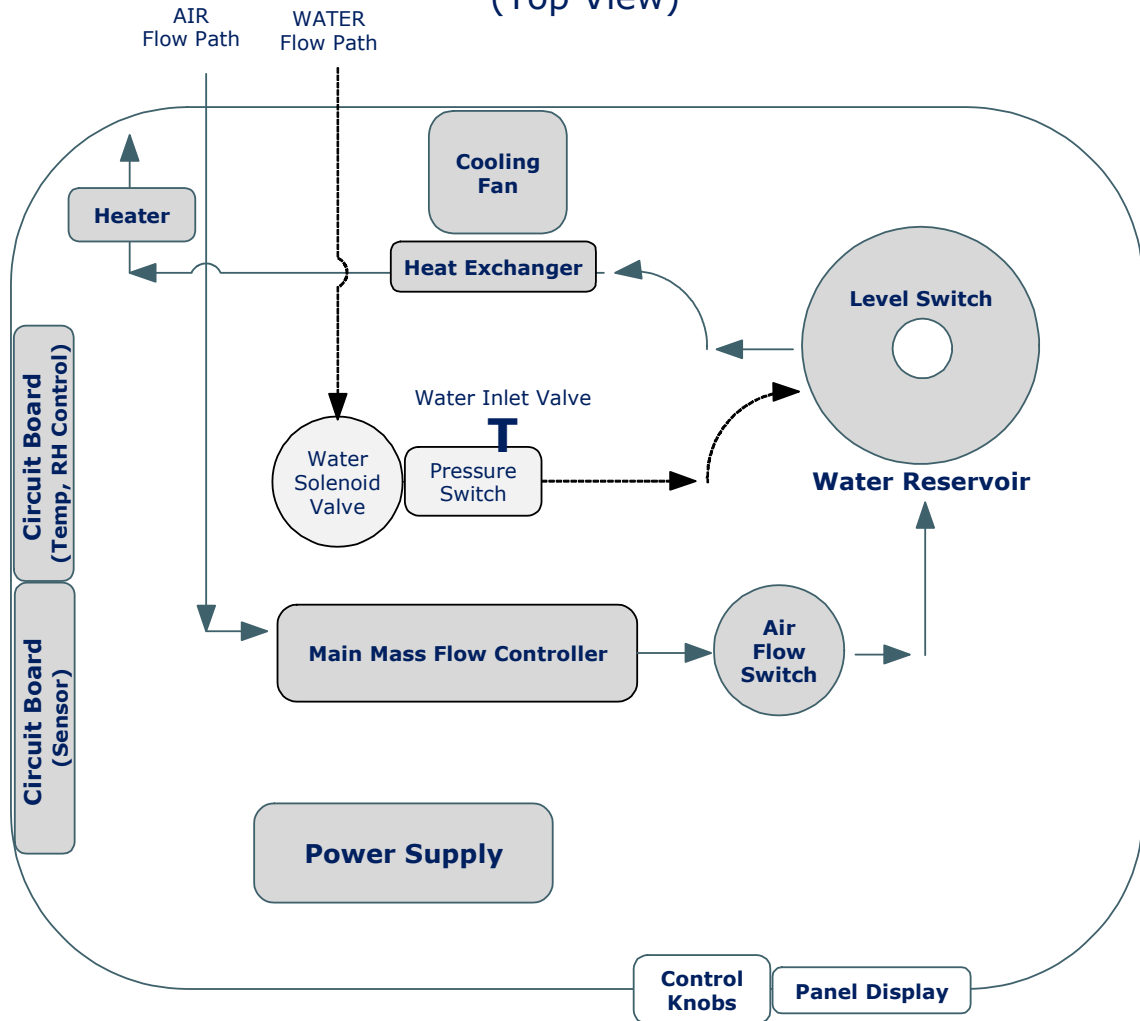
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12. DOCUMENTATION

12.1 Layout of Instrument

Layout of Components Inside Instrument (Top View)



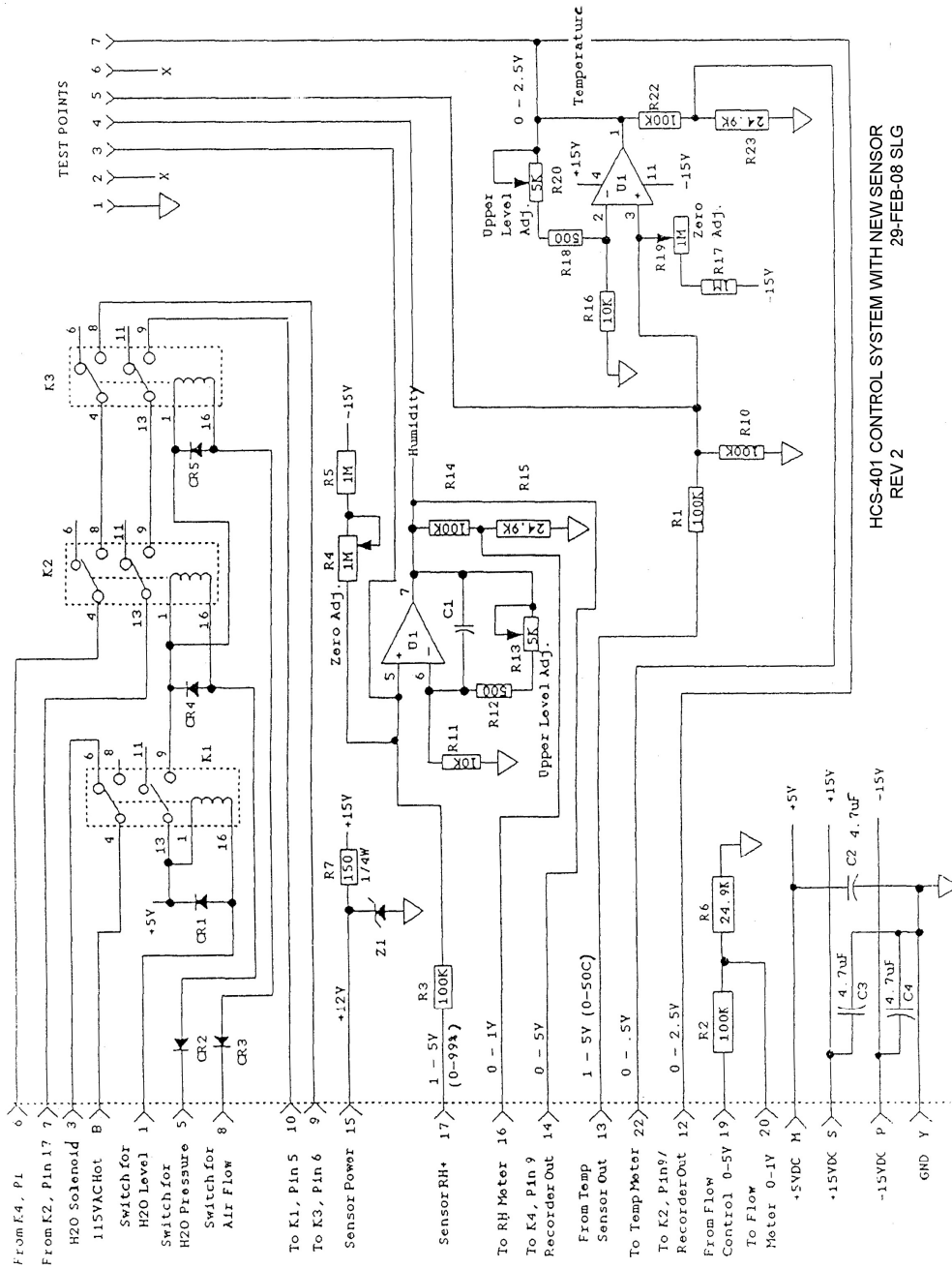
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12.2 Schematic Drawings

CIRCUIT DIAGRAM MAIN INSTRUMENT CONTROL BOARD

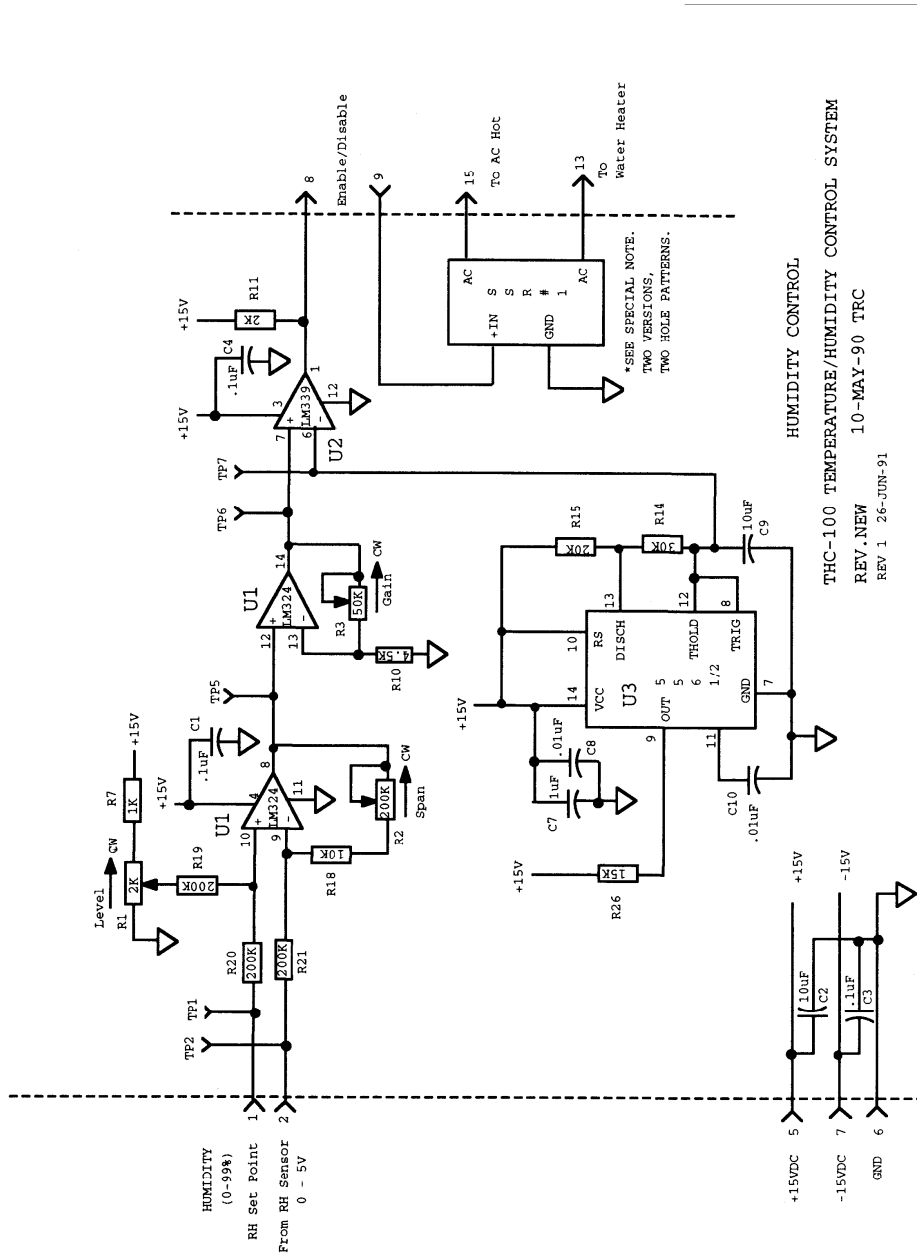


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CIRCUIT DIAGRAM for HUMIDITY CONTROL TEMP/RH BOARD THC-100

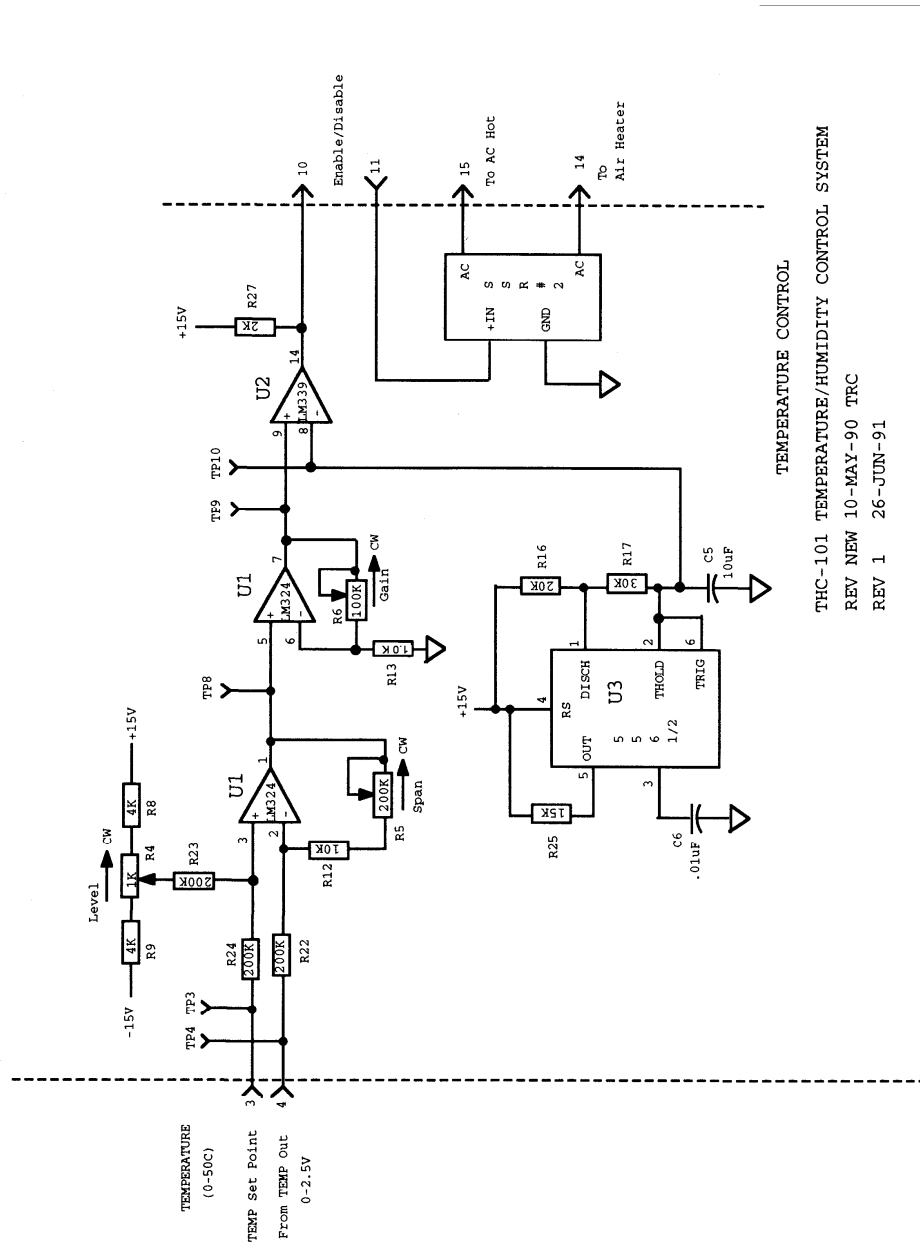


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CIRCUIT DIAGRAM for TEMPERATURE TEMP/RH CONTROL BOARD

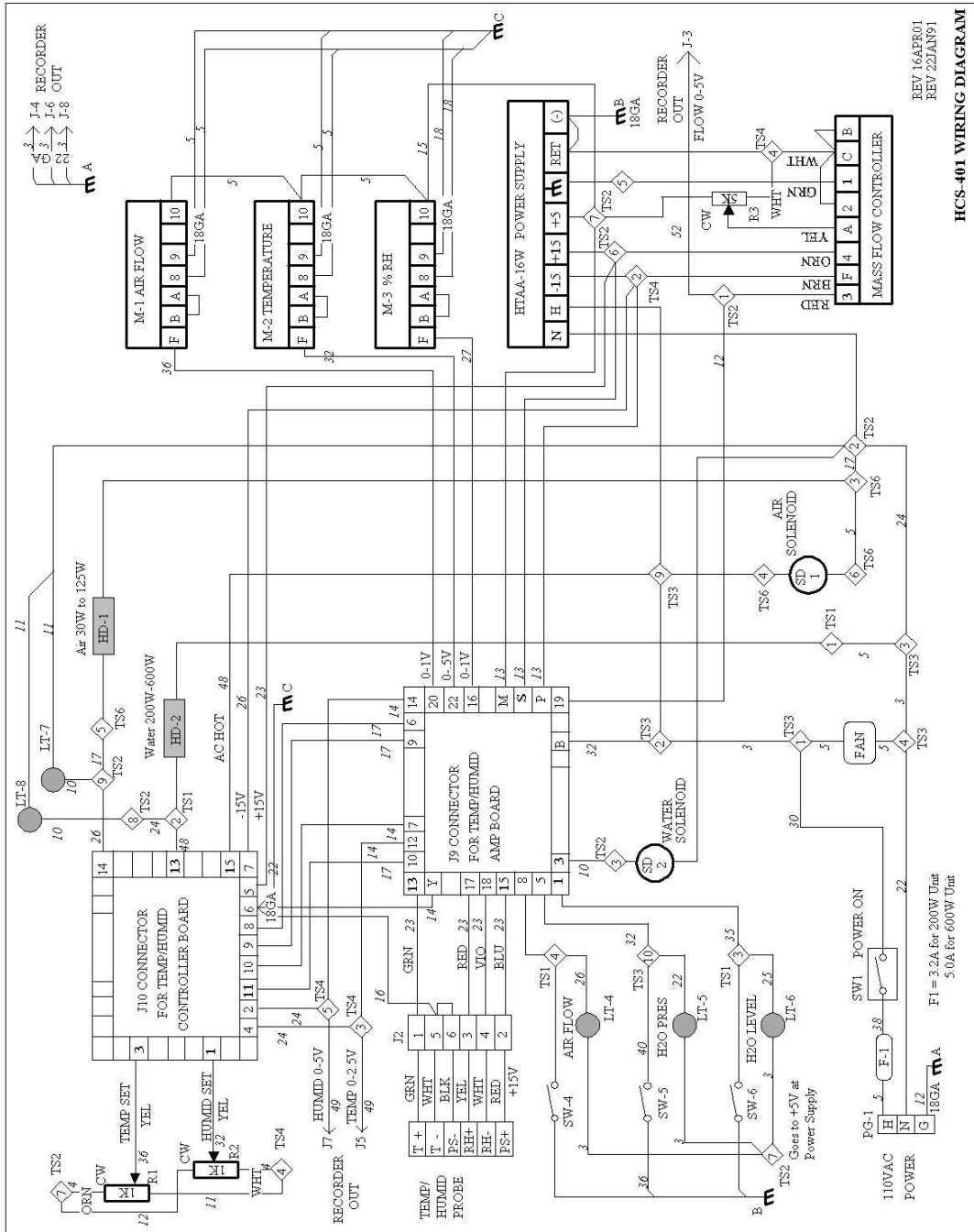


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12.3 Instrument Wiring Diagram



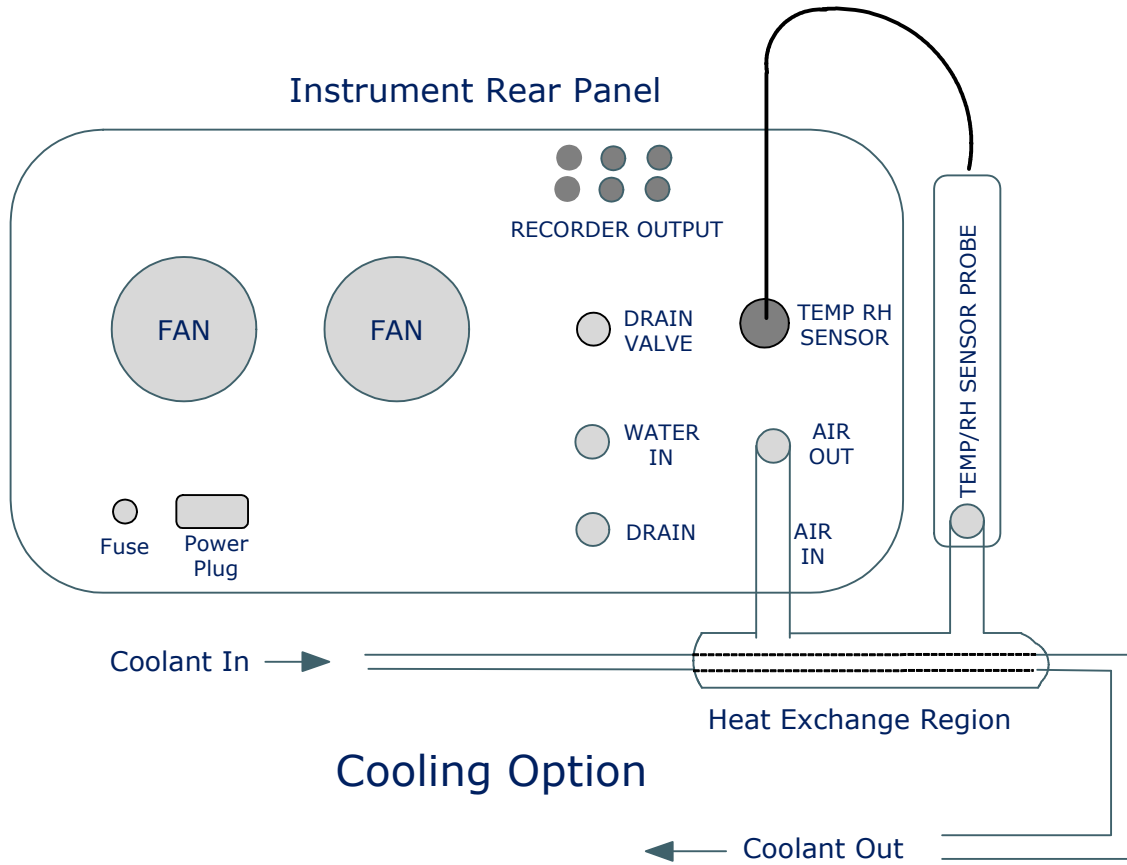
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12.4 Accessories - Cooling Option

Schematic of Cooling Option



DESCRIPTION:

When the Cooling Option is not installed, the TEMP/RH PROBE is installed directly onto the AIR OUT port. The Cooling Option consists of an assembly with two concentric copper tubes interposed between the AIR OUT port and the TEMP/RH SENSOR PROBE.

The outer concentric tube carries the Instrument's output air. Within the Heat Exchange Region, the inner concentric tube, carrying coolant, contacts the outer tube and cools the Instrument's output air as it approaches the TEMP/RH SENSOR PROBE. Temperature control of the cooled air is achieved through feedback provided by the SENSOR PROBE.

A re-circulating laboratory chiller with thermostatic control is recommended as a source of coolant.