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VAPOR TRAP

Solvent Capture and Recovery

Instruction Manual

RVT100, RVT400, RVT4104

Refrigerated Vapor Traps

Savant

Savant Instruments

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NOTE: For safety, pay particular attention to instructions marked with the CAUTION symbol (⚠) throughout this manual.

1.0 DESCRIPTION

Savant RVT-series Refrigerated Vapor Traps are reliable, easy-to-use, compact benchtop traps for solvent vapor condensation and collection. Mechanically refrigerated vapor traps replace dry ice/methanol traps, and are the easiest, most practical, and safest way to protect high-vacuum, rotary vane oil pumps in a vacuum system.

Solvents are removed from samples during vacuum evaporation with a SpeedVac® Concentrator, or during rotary evaporation in conjunction with the Vacutron® Solvent Recovery System, and are collected in the CFC-free Refrigerated Vapor Trap. Solvent vapors pass into a Glass Insert Trap and condense on its walls, preventing the vapors from reaching the oil-sealed vacuum pump (component SpeedVac® systems), or from escaping a rotary evaporator (Vacutron system). When used in conjunction with the Savant VaporNet® controller, Savant RVT-series traps provide levels of solvent recovery equal to the most elaborate liquid nitrogen traps.

The three available models differ in trap chamber capacity and in approximate operating temperature as follows:

	Trap chamber capacity	Operating temperature
RVT100	1 liter	-55°C
RVT400	4 liters	-55°C
RVT4104	4 liters	-104°C

The RVT4104 uses a cascade, dual-compressor refrigeration system, displays the trap temperature, and can control power to the vacuum pump.

CAUTION: **To assure safe operation and best results, read this manual in its entirety before operating this instrument. Improper operation can damage the trap or your vacuum pump.**

2.0 INSTALLATION

Receiving. Inspect the shipping carton upon receipt. If the carton is damaged in any way, **do not accept delivery**. Call Savant at 1-800-634-8886, 516-249-4600, or (Fax) 516-249-4639.

Unpacking. Carefully remove the instrument from its shipping carton. Lift and carry with two people, holding the unit securely underneath with both hands. Compare the packing list to the box contents. If there is a discrepancy, call Savant at 1-800-634-8886, 516-249-4600, or (Fax) 516-249-4639.

Inspection. Inspect the unit for any damage that may have occurred during shipment. Should there be damage, report it to the carrier and contact Savant immediately. Make sure the carrier inspects the damage and leaves an inspection report. Register claims for shipping damage against the carrier or his agent. Save the shipping carton in the event a return is necessary.

2.1 SITE PREPARATION

The trap is typically placed on a bench top at least 26 inches (66 cm) deep and located near a power outlet of the required voltage. The outlet must have a rating of at least 15 A for 120 V operation, or 10 A for 240 V operation. The trap draws high current when first switched on; therefore, other high-powered equipment, or equipment that will be affected by a momentary drop in power, should not be placed on the same circuit as the trap. The refrigerated trap and SpeedVac® or Vacutron System may also be installed on a sturdy mobile cart, such as Savant's Deluxe Convenience Cart.

Provide adequate ventilation. Savant refrigerated traps are air-cooled and require at least 4 inches (10 cm) of clearance for ambient air suction. The RVT100 and RVT400 draw air inward from the right side. The RVT4104 draws air from the left side. **Ambient temperature must not exceed +90°F (+32°C) during operation.**

2.2 OTHER COMPONENTS

The following accessories are ordered separately:

- **Glass Insert Trap.** Order GIT100 (1-liter glass trap) for the RVT100; order GIT400 (4-liter glass trap) for the RVT400 and RVT4104. The Glass Insert Trap is quickly exchanged between runs and is easy to clean. Having several Glass Insert Traps available permits refrigerated trap operation while other Glass Insert Traps are being cleaned.

- **CryoCool® Heat Transfer Fluid.** A permanent, safe, efficient, and economical alternative to methanol or ethanol. CryoCool® does not evaporate, has very low water absorption, is non-flammable (requires no special storage), is odorless, and is non-toxic. Order SCC1 for a 1-liter bottle; order SCC5 for a 5-liter bottle.

In addition, Savant offers a complete line of other components required for drying, including vacuum tubing kits and Quick-Fit Connectors to enable rapid exchange of Glass Insert Traps.

2.3 PREPARING FOR OPERATION

Switch the trap **OFF.** Connect the power cord to the receptacle on the right side of the instrument. Plug the trap into an appropriate wall outlet.

CAUTION: **Before connecting the Refrigerated Vapor Trap to an outlet, check voltage, frequency, and amperage to be sure they match the power requirements indicated on the label on the right side (left side for RVT4104) of each instrument. (RVT100, RVT400: 120 V AC / 60 Hz, 4 A; 240 V AC / 50 Hz, 2 A. RVT4104: 120 V AC / 60 Hz, 12 A, 240 V AC / 50 Hz, 6 A) If there are questions, please consult an electrician.**

- As a safety feature, units are equipped with a three-prong grounded plug that fits a grounding-type power outlet. Consult an electrician to replace outlet if necessary. **Do not defeat this safety feature by modifying the plug.**

- These units are "FOR INDOOR USE ONLY". Avoid operating in areas of excessive humidity or extremes of temperature.

RVT4104 users can plug the vacuum pump into the outlet on the left side of the RVT4104 and leave the vacuum pump switched on; the RVT4104 will control power to the vacuum pump, insuring that the pump is **ON** only when the trap has reached its operating temperature.

Pour CryoCool® Heat Transfer Fluid into the stainless steel trap chamber. For the RVT100, use 200 ml; for the RVT400 and RVT4104, use 800 ml. A line scribed in the wall of the stainless steel trap indicates the minimum appropriate level of CryoCool® when the Glass Insert Trap is not present. If the chamber already contains CryoCool®, add more CryoCool® until the level reaches the scribed line.

Carefully place a clean Glass Insert Trap into the chamber so that the end with the glass elbows (ports) faces up. As you press the glass trap into the chamber, the level of CryoCool® rises. Verify that the final CryoCool® level is 10 to 15 mm below the rubber seal. If the level is low, carefully pour more CryoCool® into the chamber while holding down the Glass Insert Trap.

Immediately wipe clean any CryoCool® that spills onto the rubber seal.

Fit the white insulating cover over the Glass Insert Trap to secure the trap in the chamber. Attach the vacuum tubing of the drying apparatus (SpeedVac® or rotary evaporator) to the intake port of the Glass Insert Trap. (The elbow that leads to the glass tube down the center of the trap is the intake port.)

Quick-Fit Connectors are used on each port of the Glass Insert Trap. These fittings are the black assemblies at the end of the clear plastic vacuum tubing. Unscrew and remove the hex clamping nut (Figure 1). Remove the spacer from the hex clamping nut, noting its orientation. Slide the hex clamping nut onto the elbow so that its hollow end faces outward. Insert the spacer so that its flat face **faces outward.** This flat face will press against the O-ring. Slide the O-ring over the port and into the hex nut. Now slide the rest of the Quick-Fit assembly over the port and screw it together with the hex clamping nut. Hand-tightening is adequate; **DO NOT** use a wrench. **Never simply loosen the hex nut and force the Quick-Fit fitting onto the tubing. This can damage the O-ring, and prevent a good vacuum seal.**

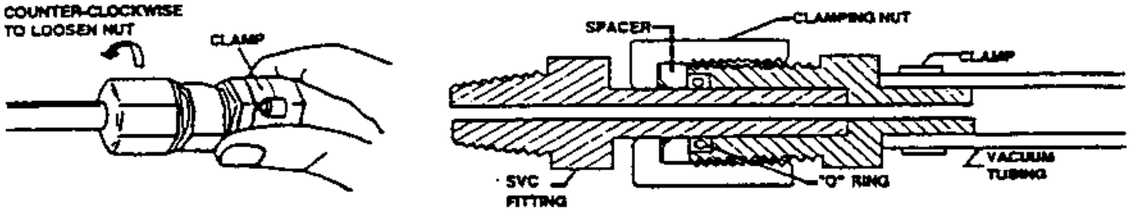


Figure 1. Quick-Fit Connector.

3.0 OPERATION

All models. After preparing the unit as described in Section 2.3, switch it **ON.** The power switch, located on the front panel (RVT100, RVT400) or on the left side (RVT4104) of the instrument, illuminates when on.

Immediately verify by touch that the trap is drawing air through the vent on the right side (left side for RVT4104). If you cannot feel the air suction, switch the trap OFF (O) at once. Operating the trap without a working fan, or with the air flow blocked, will damage the refrigeration system.

It may take up to 30 minutes (90 minutes for RVT4104) for the trap fluid to reach its operating temperature. When this occurs, you may begin drying operations as outlined in the instruction manual of your drying apparatus.

The RVT100, RVT400, and RVT4104 Refrigerated Vapor Traps are designed to operate continuously and may be left on for extended periods. Be sure to regularly check the Glass Insert Trap and empty it as required. For maximum efficiency, replace with clean trap when half full.

RVT4104. The RVT4104 displays trap temperature and pump power status. When you switch the RVT4104 **ON**, all front panel display LED segments are lighted for a few seconds as a test. When the unit starts up, the trap temperature is displayed. On start-up, the display typically indicates the ambient temperature. When the trap temperature reaches -85°C, the RVT4104 activates the vacuum pump. The RVT4104 features a "Pump On" light that illuminates whenever power is being applied to the vacuum pump. Ultimately, the trap temperature typically indicates a temperature of -104°C or colder. **During operation, the trap temperature may rise because condensing and freezing solvent vapors transfer heat into the trap.**

The RVT4104 occasionally displays "CO" (Compressor Off) in place of the trap temperature. This indicates that the RVT4104 has deactivated its compressors for several minutes to equalize refrigerant pressures. This feature provides safety and optimum trap operation.

4.0 SPECIFICATIONS

COLD TRAPS	RVT100	RVT400	RVT4104
Operating Temperature*	-55°C	-55°C	-104°C
Capacity	1 liter	4 liter	4 liter
Dimensions (WxDxH)			
Inches	13.5 x 23.5 x 12.0	13.5 x 23.5 x 12.0	20.0 x 26.0 x 13.0
Centimeters	34.3 x 59.7 x 30.5	34.3 x 59.7 x 30.5	50.8 x 66.0 x 33.0
Shipping Weight			
Pounds	55	60	150
Kilograms	25	27	68
Power Requirements	120 V AC / 60 Hz, 4 A 240 V AC / 50 Hz, 2A	120 V AC / 60 Hz, 4 A 240 V AC / 50 Hz, 2 A	120 V AC / 60 Hz, 12 A 240 V AC / 50 Hz, 6 A

* Depends on ambient temperature, line voltage fluctuations, and load capacity.

5.0 ACCESSORIES

GIT100	Glass Insert Trap for RVT100
GIT100BV	Glass Insert Trap with built-in Bleeder Valve for RVT100
CP100	Closure Plate for RVT100 when not using GIT
GIT400	Glass Insert Trap for RVT400 or RVT4104
CP400	Closure Plate for RVT400 or RVT4104 when not using GIT400
SCT120	Chemical Trap
DC120A	Disposable Cartridge for SCT120 when trapping acid and water vapors
DC120R	Disposable Cartridge for SCT120 when trapping radioactivity and organic solvent vapors
FDC206	Freeze Drying Chamber with 6 intake ports and 6 valves
SCC1	CryoCool® Heat Transfer Fluid (1 liter)
SCC5	CryoCool® Heat Transfer Fluid (5 liters)
VN100	VaporNet® Controller for SpeedVac® component systems
CC120/DX	Deluxe Convenience Cart

6.0 WARRANTY AND LIABILITY STATEMENTS

All Savant products (excluding glassware) are warranted against defects in material and workmanship for one year after the date of delivery to the original purchaser. Savant's warranty is limited to defective materials and workmanship, and does not cover incidental or consequential damages.

Savant will repair free of charge any aparatus covered by this warranty. If a new component fails to work, Savant will replace it, absorb all charges, and continue the one-year warranty period. Warranty work is subject to our inspection of the unit. No instruments, equipment, or accessories will be accepted without a Return Material Authorization (RMA) number issued by Savant. Costs of shipping the unit are not covered under warranty. The warranty obliges you to follow the precautions in this manual.

When returning apparatus that may contain hazardous materials, you must pack and label them following U.S. Department of Transportation (DOT) regulations applying to transportation of hazardous materials. Your shipping documents must also meet DOT regulations. **All returned units must be decontaminated and free of radioactivity.**

Use of this equipment in manners other than those specified in this manual may jepardize personal safety. Under no circumstances shall Savant be liable for damages due to the improper handling, abuse, or unauthorized repair of its products. Savant assumes no liability, express or implied, for your use of this equipment.

APPENDIX I
TROUBLESHOOTING AND MAINTENANCE

Replenishing CryoCool® Heat Transfer Fluid. When cold, CryoCool® condenses water vapor from the air and develops a build-up of ice. Periodically, the CryoCool® must be refreshed if:

- you see an ice build-up on the stainless steel trap walls;
- the Glass Insert Trap rises above its usual position, indicating an ice build-up beneath; or
- the refrigerated trap seems to be losing efficiency.

Shut off the unit in the case of ice build-up and allow the ice to melt. Remove the fluid by aspiration or pipetting, and add fresh CryoCool® to the trap, as described in Section 2.3, **PREPARING FOR OPERATION.**

To reuse CryoCool® that has a layer of water, transfer it to a container and place it in a freezer until the water freezes. The liquid fraction is CryoCool®, which can be reused. Decant off the CryoCool® and dispose of the ice.

Vibration. If the trap vibrates excessively, have the line voltage checked with a voltmeter. The voltage should be above 108 V for 120 V units and above 209 V for 240 V units.

CAUTION: **Low line voltage may cause thermal overload of the unit.**

Maintenance. Savant Refrigerated Vapor Traps require proper air flow for ventilation. At least every 3 months, clean the condenser grille on the right side of the unit (left side for RVT4104). Dust and dirt on the grille can block air flow. **Turn the trap off before cleaning so that dust and dirt are not drawn into the unit.** Use a vacuum cleaner with a brush attachment, or purge the condenser with compressed air.

The refrigeration system in the trap is hermetically sealed and does not require maintenance.

SAVANT SERVICE MANUAL — 24-Jan-92 draft
by Spike

RT-100 and RT-400 Single-Stage Refrigerated Traps

CONTENTS

Preface

This manual explains how to detect, diagnose, and correct malfunctions, to the component level, in the Savant RT100 and RT400 refrigerated traps. It is written for Savant manufacturing personnel and for Savant field service personnel. It is also available to trained customers who wish to perform their own maintenance.

The manual is designed to provide a step-by-step procedure for generalists to evaluate a unit. Later sections also give more applied information, such as solutions to specific problem reports, and detailed theory.

Organization. All Savant service manuals are divided into these parts:

- Part 1, Theory of Operation, describes the unit's purpose, principles of design, and sequence of operation. Part 1 describes the diagnostic tools that are built into the unit.
- Part 2, Service Procedures, shows how to determine whether a unit has failed, how to identify and replace the faulty component, and how to perform other required maintenance procedures.
- Part 3, Tables, provides specifications for each model. These specifications include acceptable measurements for each measurable parameter, and specifications and characteristics of the component subsystems and fluids. Part 3 also lists order numbers for spare parts for each model.
- Technical drawings appear at the end of the manual.

Service notes, updating this manual, will be issued from time to time by Savant. Service notes will reflect important changes in procedures or production. Each service note will replace or add specific pages to this manual. Insert these pages into the manual as specified. Discard any replaced pages.

Each service note will have as its first page a change history, including it and all previous service notes. Place the first page of the service note just after the cover page of this manual, to show that the manual incorporates that and all previous service notes.

PART 1

THEORY OF OPERATION

1.1 The Application

The Savant RT100 and RT400 refrigerated traps apply low-temperature (-60°C) refrigeration to a glass insert trap for the purpose of removing by condensation vapors from gases that pass through the glass insert trap.

The RT100 and RT400 are similar in theory, and differ primarily in the capacity of the glass insert trap.

1.2 Theory of Operation

The units use a typical single-stage refrigeration system with a compressor and a closed supply of refrigerant. The compressor circulates the refrigerant to an evaporator, where the refrigerant changes to the gaseous phase and absorbs heat; and to a condensor, where the refrigerant changes to the liquid phase and gives off heat. The evaporator is a copper tube braised to the interior walls of the stainless steel trap.

1.3 Sequence of Operation

When the unit is switched on, the rocker switch illuminates, the fan at the rear of the unit begins operating, and the compressor starts. Unlike the Savant two-stage refrigeration systems, there is no delay in compressor operation in the RT100/RT400. The compressor and fan run at all times that the unit is powered on.

1.4 Overview of Maintenance

The unit has a single function from the customer's standpoint: to achieve and maintain the specified temperature at the stainless steel trap.

In servicing the unit, removing the cover gives you access to these sources of information:

- o Visual inspection of the unit for obvious flaws;
- o Observation of the operating status of the compressor; and
- o Observation of the fan.

In addition, a pair of wires is accessible from the underside of the unit, below the stainless steel trap. This red and blue wire is a T-type thermocouple contained in the refrigeration system evaporator, braized to copper tubing around the stainless steel trap. By attachin these thermocouple leads to a temperature gauge, you can read the true temperature of the trap.

Since the unit does not have refrigeration access valves, you cannot check internal refrigerant pressures, except when recharging a system.

You typically treat a subassembly failure by replacing the subassembly. However, if the refrigeration system fails, you may be able to repair it by recharging it with refrigerant. A correct charge is critical because efficient operation requires an exact amount of liquid refrigerant.

PART 2

SERVICE PROCEDURES

2.1 Safety Precautions

The following hazards exist in servicing any refrigeration unit:

- The unit uses AC power, and some of the service procedures in this chapter require operation with the cover off, exposing power lines. This raises the risk of electrical shocks. The refrigerated trap should only be plugged into a circuit protected by a Ground-Fault Interruptor (GFI). This minimizes injury from shock. In addition, you should not touch exposed wires at all without first unplugging the unit.

- All refrigerants are potential asphyxiants. All maintenance on the refrigerated traps should be performed in a well-ventilated area. If it becomes necessary to discharge or recharge a refrigeration stage, this operation should be performed only by personnel that Savant trains and certifies.

2.2 Environmental Checks

Before servicing any unit, always check the environment for conditions that could cause a failure:

1 Verify that the ambient temperature is 75°F or below. The Savant refrigerated traps are not rated for operation in hotter environments. Verify that the unit is not in direct sunlight and that it is located with 12 inches of space at the rear of the unit for ventilation. Verify that the unit is level. Level operation is important to ensure proper flow of refrigerant. If necessary, move the unit to a more suitable location.

2 Visually inspect the condensor fins at the rear of the unit for accumulation of dust or dirt. With the unit switched off (to avoid drawing dust or dirt into the unit), brush off any accumulation. Accumulations of dust or dirt on the fins reduce the unit's ability to exhaust heat to the atmosphere.

After taking these steps, return the unit to normal operation to see if they corrected the problem.

2.3 Recommended Service Equipment

- Temperature meter suitable for attachment of T-type thermocouple
- Capacitance checker
- Clamp-on ammeter
- Blade and Phillips screwdriver
- Other hand tools (wrenches, pliers, wire cutters, and so on)
- Electronic refrigerant leak detector

Additional service equipment for recharging a refrigeration system:

- Vacuum pump (capable of achieving vacuum below 25 microns) and electronic vacuum gauge
- Two-gauge manifolds with charging hoses
- Oxygen/acetylene torch with proper brazing tip and brazing supplies
- Flaring and swaging tools for 1/4, 5/16, and 3/8 (outside diameter) tubing
- Tubing cutter
- Pinch-off tool
- Regulated supplies of dry nitrogen and of R-13B1 refrigerant

2.4 Troubleshooting Aids

The only informational aid in the unit is the thermocouple wire discussed in Section 1.4.

2.5 Troubleshooting Sequence

Plug the unit into an operating electrical outlet of the proper voltage and switch the unit on. These things should immediately occur:

- The power switch should illuminate.
- The fan should begin operating.
- The compressor should start.

You need not remove the cover to detect proper start-up. The fan is faintly audible and can be seen through the condenser at the rear of the unit. If any of the above fail to occur, correct the problem as described in Section 2.6.

Extract the thermocouple wires. The thermocouple wires are located next to the insulated trap cylinder. The factory sometimes wedges these wires between the trap cylinder and the insulated capillary tube. The wires may be accessible from the underside of the unit. If they are not, remove the cover as described in Section 2.5a. Connect the thermocouple wires to a T-type temperature gauge to monitor the trap temperature. Monitor the displayed temperature until it reaches -60°C. If this takes over 1 hour, consult Section 2.9.

2.5a Cover Removal

Use a Phillips screwdriver to remove the 2 screws on each side of the RT100, near the base of the unit. (On the RT400, there are 3 screws on each side.) Remove two additional screws at the rear of the unit.

Lift the cover straight up until it clears the internal components of the refrigerated trap.

2.6 Start Sequence Failures

Any failure in the start sequence should be corrected before proceeding further.

<u>Problem 1: Neither the fan nor power switch light operate.</u> This indicates a problem in the power circuit.

- o Verify that the power cord is firmly plugged into both the outlet and the unit.

- o Verify that the outlet into which the unit is plugged is active, typically by plugging another appliance or device into it. There could be a problem with the fuse or circuit breaker that supplies the electric outlet.

  A blown fuse or circuit breaker indicates an underlying problem, which is not corrected by replacing the fuse or resetting the circuit breaker. Therefore, after restoring the circuit, restart the unit and monitor it closely to see if the fuse blows again.

  If so, trace the wiring harness, visually or with an ohmmeter, for shorts between the power wires (black, white, and green). Isolate and test for shorts the filter capacitor, power switch, and fan. Electrically analyze the compressor (see Section 2.10). Check for shorts or a frozen compressor rotor.

- Visually inspect the wiring harness for any loose wires.

Problem 2: The fan does not operate or the light on the power switch does not illuminate. These problems are easily localized.

- If the fan does not operate, visually inspect the wiring harness connections to the fan. Use an AC voltmeter to ensure that the fan is receiving power. Unplug the unit, then disconnect and replace the fan.

- If the light on the power switch does not light, but the unit otherwise operates correctly, you can replace the power switch.

2.7 Suspicious Temperature Readings

Since the RT100/RT400 do not have a temperature readout, the user does not often report an inappropriate temperature reading. More often, the user reports a general failure to produce cooling. The service person may detect inappropriate temperature readings by using the thermocouple wires with a temperature meter.

Problem 3: The meter shows room temperature.

If this is the only problem with the unit (that is, if the trap is getting cold despite the temperature reading), then it indicates a failure of the trap thermocouple.

- Be sure you attached the thermocouple wires to the temperature meter correctly. Connecting the thermocouple backward produces readings above 0°C.

- Test the thermocouple's resistance. A reading above 2 megohms means the thermocouple is bad or there is a loose connection in the wiring. If you cannot find and repair a break in the wiring, you must service the trap without this temperature information. Use instead a mercury thermometer to measure trap temperature.

Problem 4: The meter reads -60°C, but the user says the trap is not cold enough (or does not produce the desired effect in the apparatus).

A user may report that the refrigerated trap is ineffective despite the fact that you observe a reading of -60°C. The most likely cause of this failure is user misapplication of the unit. Any use of the trap in an apparatus applies heat to the trap. If the unit is overloaded, the trap temperature will rise or the trap will be inefficient. In particular:

- o Analyze the cryo-coolant (the liquid the user pours into the stainless steel trap to convey heat away from the glass insert trap). Visually check for ice in the coolant. Also check the specific gravity of the coolant. The Instruction Manual tells the user to purify the coolant periodically.

- o Analyze the condition of the glass insert trap. Trapped vapors remain in the glass insert trap as ice or liquid. Removing and cleaning the glass insert trap is also a routine operation that the Instruction Manual calls for. Operating the unit without a fresh glass insert trap makes it inefficient.

2.8 Failure to Refrigerate

The refrigerated trap should cool the stainless steel trap to the operating temperature within 1 hour (on both the RT100 and RT400). If the user reports that it takes longer to cool the trap, or that the trap never cools to the rated temperature, first be sure you have checked these causes:

- o Be sure the unit is operating in a proper environment, as described in Section 2.2.

- o Verify that the unit is being used properly, as described under Problem 4.

If there is no external explanation for the problem, you must evaluate the performance of the refrigeration system.

Problem 5: The compressor is not operating.

Immediately when you switch on the unit, the unit should start the compressor to draw heat away from the trap.

- o Remove the wires attached to the compressor. Verify that the terminals are free of corrosion.

- o Perform an electrical analysis of the compressor as described in Section 2.10.

2.9 Poor Cooling Performance

A refrigeration stage can lose cooling power due to disturbance of, or impurities in, the copper tubing. Normal wear on the compressor may also be the problem.

Problem 6: The trap temperature is cold, but does not reach -60°C, even when you are placing no load on the system.

This indicates reduced capacity of the refrigeration system.

<u>Solution.</u> Reduced capacity can be caused by oil lodging in the refrigerant tubing. The first corrective operation should be to leave the unit off overnight. This lets the oil settle; the pressure differentials when you restart the unit drive the oil back to the compressor.

If the unit continues to show reduced efficiency, refrigerant may be starting to leak, or a compressor may be starting to wear out. Physically analyze the refrigeration system (see Section 2.11).

2.10 Electrical Analysis of a Compressor

Electrical analysis of a compressor is called for whenever the unit is receiving power but the compressor does not operate.

1 Make sure the unit is unplugged.

2 Use a Phillips screwdriver to remove the electrical housing from the compressor.

Discharge the capacitor before proceeding. If you recently switched off the unit, the capacitor may retain a charge.

3 Ensure that all wires within the housing are securely attached. If any are not, reconnect them according to the wiring diagram and retest the unit.

4 Detach the capacitor from terminals 11 and 13. Examine the capacitor: The hood separates during certain failures to prevent explosion. If the hood is separated or ajar, or if there is any discoloration, replace the capacitor.

Use a capacitance tester to test the capacitor. If the reading differs substantially from its labeling, replace the capacitor.

5 Pull off the relay--the square black component with terminals labeled 10 through 14. Test the relay with an ohmmeter. There should be virtually 0 ohms between terminals 10 and 11 when the relay is upright. When the relay is upside-down, there should be an open circuit between terminals 10 and 11. If the relay fails these tests, replace it.

If you replace either the capacitor or the relay, then replace both. They are inexpensive and a failure in one may degrade the other. Each replacement compressor ordered from Savant includes both the capacitor and relay.

Locate the three prongs where the relay was attached. They are in this configuration:

```
Run  o      o  Start

         o
       Common
```

6 Measure the **run winding** resistance between the Run and Common terminals. Also measure the **start winding** resistance between the Start and Common terminals. Correct values are in the table in Section 3.1. If the observed reading differs substantially from the correct value, replace the compressor.

7 Ensure that all three terminals are open circuits with

respect to ground (the green wire attached to the housing). If any terminal is shorted to ground, replace the compressor.

If all components pass their tests, reattach the relay and all wires and replace the housing over the electrical terminals.

You can also test the compressor free-running current. You should do this especially if the unit blows fuses:

8 Attach a clamp-type ammeter to the red or orange wire connected to terminal 10. Start the unit and read the current. The correct free-running current is specified in Section 3.1. If the reading is substantially greater than the specified current, then the compressor may have a frozen rotor or bad relay or capacitor.

Any time you replace the compressor, you must recharge the system, as described in Section 2.12.

2.11 Physical Analysis of a Refrigeration System

Physical analysis of a refrigeration system is called for when the compressor is operating but cooling does not occur. Recharging the system (see Section 2.12) is required in most cases of failure, and may be required simply to detect the cause of the failure.

1 Switch off the unit and allow time for the entire apparatus to warm to room temperature. Then restart it. If the unit now cools properly (that is, if the failure is intermittent) then the likely cause is an oil blockage. If the problem recurs, flush and recharge the system. Oil blockage typically occurs when a unit is moved to another location.

2 Check for refrigerant leaks. All Savant refrigeration systems use pressurized, hydrocarbon-based refrigerants to transfer heat from one place to another. In practice, sudden leaks do not occur. If a system begins to fail because of a refrigerant leak, you can detect gas in the vicinity of the copper tubing. We recommend the use of an electronic leak detector. If you detect a leak, seal it and recharge the system as described in Section 2.12.

Some electronic leak detectors detect the glue used to attach the insulation to the capillary tube. If your leak detector gives you a large number of false positive readings, we recommend the use of a fluorescent gas leak detector, such as the Teltale product of Stewart Hall Chemical Corporation.

No leak detector will detect a leak if the test occurs after all the refrigerant has escaped. In this case, pressurize the system with 100 pounds of nitrogen, with a pressure gauge attached. A loss of 0.5 pound of pressure over 15 minutes suggests a leak.

If a leak is not detected at this point, leave the manifold attached and start the unit for no more than 15 minutes. Look at the pressure gauge on the manifold. A jumpy gauge, a total absence of head pressure or suction pressure, or head pressure over 300 psi, indicates a failure of a valve in the compressor; replace the compressor. Excessive vacuum (25" Hg) on the suction-side gauge indicates a blockage in the capillary. Remove the capillary and visually examine both ends for a blockage. Physically remove the blockage or replace the capillary.

3 If there is no refrigerant leak and the failure is not intermittent, the compressor may be worn out, so that its pumping has no effect. Replace the compressor and recharge the system with new refrigerant, as described in Section 2.12. Use the electronic leak detector to verify the integrity of all new joints.

4 An improper charge of refrigerant can also make a refrigeration stage fail. There is no practical way to detect an improper charge except to recharge. If, following steps 1 and 2 above, you have replaced the compressor, you will give the stage a proper charge afterward. You may test the compressor and find you can reuse it.

2.12 Recharging a Refrigeration System

Intentional discharge or recharge of a refrigeration stage must be performed only by personnel that Savant trains and certifies.

Overview. The tubing of a refrigeration stage contains a refrigerant under pressure. The refrigerant switches between the gaseous and liquid phases when the unit is operating. The refrigerant is not consumed during the unit's operation, so it lasts indefinitely, unless (1) there is a leak in the tubing, or (2) you replace a component such as the compressor. In these two cases, you must recharge the system. This means you must add fresh refrigerants at the specified pressures.

The refrigerant must circulate freely in the tubing to transfer heat efficiently. Whenever you open the system, take great care that foreign matter such as dirt does not enter the tubing. Whenever you cut or splice copper tubing, deburr the inside of the tube and carefully remove all loose matter.

Whenever you open the system, moisture from the air enters the tubing. Microscopic imperfections in the interior surface of copper tubing can hold moisture. The traps do not include dryers to remove this moisture. Therefore, before any recharge, you must thoroughly purge the system. You cannot just apply vacuum; as you decrease the vapor pressure, evaporating the water, you also lower the pressure differential, so that the vapor leaves the system more slowly. Therefore, you must also flush the system with nitrogen. The procedure below includes these steps.

Do not perform the following procedure without receiving permission from the factory. You must specify which Savant-certified personnel will be performing the procedure.

Procedure. Follow these steps to recharge a system.

DISCHARGE

1 Sever the charging stubs below the existing pinch points. Braise to each stub a new piece of 1/4-inch copper tubing.

   You may now smell burnt refrigerant. If so, or if you replaced a compressor that burned out, there may be burnt compressor oil in the lines that will be hard to remove and may cause problems later. In this case:

   - Replace as much copper tubing as is feasible
   - Perform the following PURGING procedure several times
   - If feasible, replace the entire unit

2 Flare the new tubes to a combination vacuum and charging manifold. This manifold has hand valves and hose ports for connection to the refrigeration system, a vacuum system, and a tank of refrigerant or nitrogen.

PURGING

3 Connect the vacuum pump to its hose port on the manifold. Connect a tank of dry nitrogen to the other port. Open the hand valve to the vacuum. Evacuate the refrigeration system to 100 microns or less. Also open the hand valve to the nitrogen, although the tank valve is closed. This evacuates the hose to the nitrogen.

4 Shut off the vacuum and apply nitrogen to give the system a static charge of 10 psig. Then shut off the nitrogen.

5 Start the compressor. Run the compressor until it is warm (15-30 minutes). This circulates the nitrogen throughout the system, to mix any remaining water or impurities with the nitrogen. It also agitates the compressor oil to free any dissolved impurities.

6 Shut off the compressor and apply vacuum again.

7 Connect the refrigerant tank. Use the vacuum to purge the hose to this tank. The amount of air in an unpurged hose is sufficient to produce an improper charge. Do not simply use refrigerant to blow air out of the hose. This wastes refrigerant and it does not eliminate moisture from the hose.

8 Evacuate the system to 30 microns and maintain this vacuum level for at least 12 hours.

CHARGING

9 Since you are typically returning to the unit after a 12-hour absence, verify again the vacuum level.

10 Shut off the vacuum, refrigerant, and access valves.

11 Open the high-side and low-side valves. Open the valve for the refrigerant. Use the main panel valve to charge the system to the specified pressure. Shut the valve when the pressure is achieved.

The Specifications in Section 3.1 specify the refrigerant to use and the correct pressure level. All pressures are psig (pounds per square inch above atmospheric pressure).

FINISHING

12 Pinch off and seal the high and low charging stub.

13 Use the electronic leak detector to test for leaks, particularly at the new seals.

14 Test the unit's performance. (If you operate the unit with valves attached, you will note a slight decrease in the charge, since some refrigerant dissolves in the compressor oil. Do not add more refrigerant to compensate for this.)

SECTION 3

TABLES

3.1 Specifications

	RT100	RT400
TARGET TEMPERATURE	-60°C (-76°F)	-60°C (-76°F)
115 volts:		
Resistance of "start" winding	4.0 ohms	4.0 ohms
Resistance of "run" winding	1.9 ohms	1.9 ohms
Free-running current	2.3 amps	2.3 amps
Current when rotor is locked	20 amps	20 amps
220 volts:		
Resistance of "start" winding	13.1 ohms	13.1 ohms
Resistance of "run" winding	10.7 ohms	10.7 ohms
Free-running current	1.6 amps	1.6 amps
REFRIGERANT CHARGE	R-13B1 @ 76 PSIG	R-13B1 @ 82 PSIG
OPERATING PRESSURE AT SPECIFIED TEMPERATURE		
Suction	10" Hg	5" Hg
Discharge	235 PSIG	235 PSIG

3.2 Spare Parts Order Numbers

	RT100	RT400
Capillary tube assembly	094-1019-00	094-1019-00
Compressor assembly (115 VAC)	M60-0008-01	M60-0008-01
(220 VAC)	M60-0008-02	M60-0008-02
Condensor	094-6017-00	094-6017-00
Dryer, see strainer		
Evaporator assembly	094-1010-00	093-1002-00
Fan motor (115 VAC)	M60-0014-01	M60-0014-01
(220 VAC)	M60-0014-02	M60-0014-02
Power switch (115 VAC)	E90-0065-01	E90-0065-01
(220 VAC)	E90-0065-02	E90-0065-02
Relay: (Compressor relay is part of Compressor assembly)		
Seal (trap top seal)	094-6032-00	093-6007-00
Strainer, oil	M60-0029-01	M60-0029-01

SAVANT SERVICE MANUAL 18-Dec-92

RT490, RT4104, RVT4104
Refrigerated Traps

CONTENTS

Preface

This manual explains how to detect, diagnose, and correct malfunctions, to the component level, in the Savant RT409, RT4104, and RVT4104 refrigerated traps. It is written for Savant manufacturing personnel and for Savant field service personnel. It is also available to trained customers who wish to perform their own maintenance.

The manual is designed to provide a step-by-step procedure for generalists to evaluate a unit. Later sections also give more applied information, such as solutions to specific problem reports, and detailed theory.

The manual does not explain how to repair individual components, such as circuit boards. Failed circuit boards can be returned to Savant, where the Service Department uses customized testers to determine whether the board can be repaired and returned to service. Other components should not be returned to Savant.

Organization. All Savant service manuals are divided into these parts:

- Part 1, Theory of Operation, describes the unit's purpose, principles of design, and sequence of operation. Part 1 describes the diagnostic tools that are built into the unit.
- Part 2, Service Procedures, shows how to determine whether a unit has failed, how to identify and replace the faulty component, and how to perform other required maintenance procedures.
- Part 3, Tables, provides specifications for each model. These specifications include acceptable measurements for each measurable parameter, and specifications and characteristics of the component subsystems and fluids. Part 3 also lists order numbers for spare parts for each model.
- Technical drawings appear at the end of the manual.

Service notes, updating this manual, will be issued from time to time by Savant. Service notes will reflect important changes in procedures or production. Each service note will replace or add specific pages to this manual. Insert these pages into the manual as specified. Discard any replaced pages.

Each service note will have as its first page a change history, including it and all previous service notes. Place the first page of the service note just after the cover page of this manual, to show that the manual incorporates that and all previous service notes.

PART 1

THEORY OF OPERATION

1.1 The Application

The Savant RT490, RT4104 and RVT4104 refrigerated traps apply low-temperature refrigeration to a glass insert trap for the purpose of removing by condensation vapors from gases that pass through the glass insert trap.

The three trap models are similar in theory. The RT490 achieves a low temperature of -90°C. The RT4104 and RVT4104 use a different compressor and refrigerant to achieve a low temperature of -104°C. The RT4104 and RVT4104 are identical in their service implications except that they take different charges of refrigerant; see Section 3.1.

1.2 Theory of Operation

The units use a cascade refrigeration system to produce the required low temperatures. This means that two independent refrigeration systems are interconnected within the unit:

- The **first-stage system** is the refrigeration system that rejects heat directly to the atmosphere, using an air-cooled condenser.

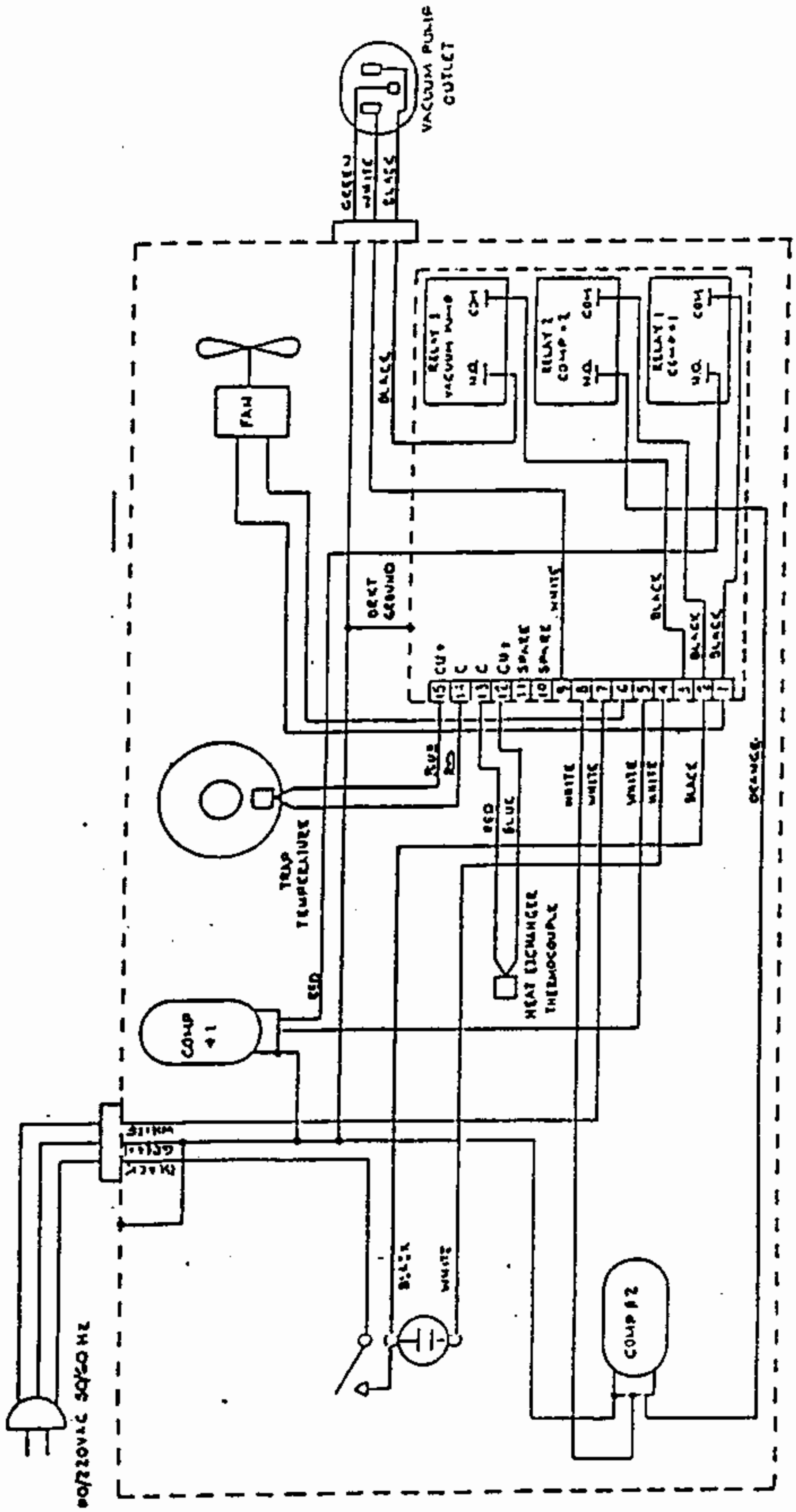
- The **second-stage system** is the refrigeration system that creates the low temperature within the stainless steel trap. This system rejects heat into the first-stage system.

Each stage is a typical refrigeration system with a compressor and a closed supply of refrigerant. The compressor circulates the refrigerant to an **evaporator**, where the refrigerant changes to the gaseous phase and absorbs heat; and to a **condensor**, where the refrigerant changes to the liquid phase and gives off heat.

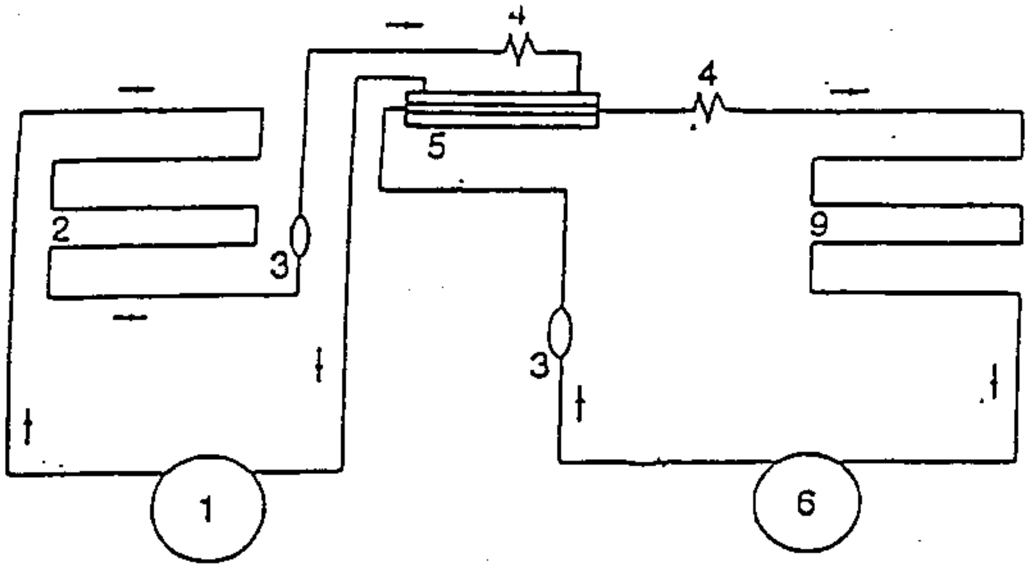
A tube-in-tube heat exchanger called the **cascade heat exchanger** serves as the evaporator of the first-stage system and the condenser of the second-stage system. The cascaded systems combine to transfer heat from the stainless steel trap, through the cascade heat exchanger, to the atmosphere.

The cascade design achieves lower temperatures than comparable single-stage designs can achieve. (A single-stage design would require the use of refrigerant at pressures approaching 500 psi, which creates technical problems.)

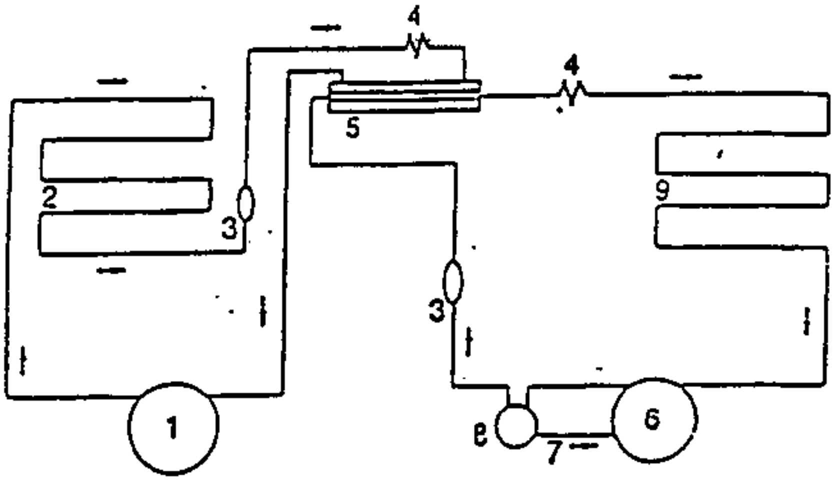
A circuit board senses internal temperatures, controls and synchronizes the two stages, and drives an indicator panel that displays temperatures.



RT490/RT4104 SCHEMATIC



RT490 Schematic



RT4104 Schematic

<u>Legend:</u>

1 First-stage compressor
2 First-stage condensor
3 Filter/dryers
4 Metering devices
5 Heat exchanger (condensor of the second stage in direct contact with the evaporator of the first stage)
6 Second-stage compressor
7 Oil return line to second-stage compressor (RT4104 only)
8 Oil separator (RT4104 only)
9 Second-stage evaporator

1.3 Sequence of Operation

The refrigerated trap's circuit board contains electronic logic that controls the sequence of operation.

When you turn the unit on, the indicator panel reads ±1.8.8 for ten seconds. This verifies every light and digit segment on the panel.

After an additional 20-second delay, the first-stage compressor starts. In five to ten minutes, the first stage cools the heat exchanger to a temperature where the second-stage system can function. The operation of the second stage transfers heat from the stainless steel trap to the heat exchanger, warming the heat exchanger. The heat exchanger set point and the operating behavior differ between the units:

- RT490: When the heat exchanger reaches -27°C, the second-stage compressor starts. At this point, both refrigeration systems are operating. When the heat exchanger reaches 0°C, the second stage shuts down until the heat exchanger again cools to -27°C.

- RT4104, software versions V1.14 and before: When the heat exchanger reaches -15°C, the second-stage compressor starts and the first-stage compressor stops. When the heat exchanger reaches 0°C, the first-stage compressor switches on until the heat exchanger again cools to -15°C. If the heat exchanger should instead continue to warm, then when it reaches +5°C, the second stage shuts down until the heat exchanger returns to -15°C.

- RT4104, software version V1.15 and later, and RVT4104: When the heat exchanger reaches -15°C, the first-stage compressor stops. Fifteen seconds later, the second-stage compressor starts. The second-stage compressor runs alone until the heat exchanger reaches -5°C. At that point the first-stage compressor switches on and both compressors are running until the heat exchanger again cools to -15°C. Then the procedure in this paragraph repeats.

  During the initial operating cycles (before the system has cooled), the heat exchanger will tend to continue rising; when it reaches +3°C, the second-stage compressor switches off and the cycle repeats: The unit operates only the first-stage compressor and waits for the heat exchanger to cool again to -15°C, as it does when the power is first switched on.

This cycling can occur 5-10 times before the trap reaches the specified temperature, depending on the contents and initial temperature of the stainless steel trap.

When the trap reaches about -80°C, the unit switches on the electric outlet at the rear. The user typically plugs the vacuum pump in here so that it will not operate until the trap is cool enough to catch corrosive vapors. These vapors would damage the vacuum pump if they reached it. The LEDs on the front panel that indicate pump status should always reflect the state of this electric outlet.

Delays in activating the compressors are normal. The unit imposes a 15-second delay between switching one compressor and switching another. This minimizes effects on the power line.

Every 4 hours, the unit switches off both compressors for 1 to 3 minutes. This overrides normal operation and is independent of the temperatures. The indicator panel shows "CO" for "Compressors Off" during this time to show that the deactivation is deliberate. Switching off the compressors lets any oil in the refrigerant lines drain back to the compressors.

1.4 Overview of Maintenance

The unit has a single function from the customer's standpoint: to achieve and maintain the specified temperature at the stainless steel trap.

In servicing the unit, removing the cover gives you access to these sources of information:

- Visual inspection of the unit for obvious flaws;
- Observation of the operating status of the two compressors;
- Observation of the fan and status lights; and
- The temperature reported on the indicator panel.

You can direct the unit to report internal temperatures on the indicator panel. You can test points on the circuit board to isolate a problem to a subassembly, such as a single compressor. You can use meters to test the electrical characteristics of a subassembly.

Since the unit does not have refrigeration access valves, you cannot check internal refrigerant pressures, except when recharging a system. However, you can assess the status of the refrigeration systems by reading temperatures of the inlet and outlet of the heat exchanger and the evaporator.

You typically treat a subassembly failure by replacing the subassembly. However, if a refrigeration system fails, you may be able to repair it by recharging it with refrigerant. A correct charge is critical because efficient operation requires an exact amount of liquid refrigerant.

PART 2

SERVICE PROCEDURES

2.1 Safety Precautions

The following hazards exist in servicing any refrigeration unit:

- The unit uses AC power, and some of the service procedures in this chapter require operation with the cover off, exposing power lines. This raises the risk of electrical shocks. The refrigerated trap should only be plugged into a circuit protected by a Ground-Fault Interruptor (GFI). This minimizes injury from shock. In addition, you should not touch exposed wires at all without first unplugging the unit.

- All refrigerants are potential asphyxiants. All maintenance on the refrigerated traps should be performed in a well-ventilated area. If it becomes necessary to discharge or recharge a refrigeration stage, this operation should be performed only by personnel that Savant trains and certifies.

An additional hazard to the equipment is as follows:

- The circuit board and indicator panel contain electronics that can be damaged by static electricity (by giving it a shock). When removing a circuit board, always hold it by the sides. Persons doing extensive maintenance on circuit boards should be grounded, such as by wearing wrist straps. When shipping a circuit board, always enclose it in a static-protective bag.

2.2 Environmental Checks

Before servicing any unit, always check the environment for conditions that could cause a failure:

1. Verify that the ambient temperature is 75°F or below. The Savant refrigerated traps are not rated for operation in hotter environments. Verify that the unit is not in direct sunlight and that it is located with 12 inches of space at the rear of the unit for ventilation. Verify that the unit is level, even when the stainless steel trap is filled with cryo-coolant. Level operation is important to ensure proper flow of refrigerant. If necessary, move the unit to a more suitable location.

2. Visually inspect the condensor fins at the rear of the unit for accumulation of dust or dirt. With the unit switched

off (to avoid drawing dust or dirt into the unit), brush off any accumulation. Accumulations of dust or dirt on the fins can degrade the unit's ability to exhaust heat to the atmosphere.

After taking these steps, return the unit to normal operation to see if they corrected the problem.

2.3 Recommended Service Equipment

- Volt-ohm meter (VOM)
- Capacitance checker
- Clamp-on ammeter
- Blade and Phillips screwdriver
- Other hand tools (wrenches, pliers, wire cutters, and so on)
- Electronic refrigerant leak detector

Additional service equipment for recharging a refrigeration system:

- Vacuum pump (capable of achieving vacuum below 25 microns) and electronic vacuum gauge
- Two-gauge manifolds with charging hoses
- Oxygen/acetylene torch with proper brazing tip and brazing supplies
- Flaring and swaging tools for 1/4, 5/16, and 3/8 (outside diameter) tubing
- Tubing cutter
- Pinch-off tool
- Regulated supplies of the following gases:
  --Dry nitrogen
  --R-13B1 refrigerant
  --R-290 instrument-grade propane
  --R-502 refrigerant
  --R-503 refrigerant

2.4 Troubleshooting Aids

The circuit board and indicator panel give you much troubleshooting information:

- Lights on the circuit board show the status of the three relays:
  CR15 monitors RLY3, which operates the vacuum pump outlet.
  CR14 monitors RLY2, which operates the second-stage compressor.
  CR13 monitors RLY1, which operates the first-stage compressor.

- You can get temperature readings from the second-stage system output from the heat exchanger (the warm side). Attach a jumper to the P6 header. Now the indicator panel intermittently shows the heat exchanger temperature. The decimal points light up during this display. For example, if the display alternates between "-104" and "-.5.7." then it indicates a trap temperature of -104 and a heat exchanger outlet temperature of -57°C. After servicing the unit, move the jumper to the P5 header (or remove it entirely) for normal operation.

- After verifying that the unit switches the compressors correctly, it is sometimes helpful to detach the wires from relays RLY1 and RLY2 and attach toggle switches so that you can operate the compressors manually.

  Do not operate the second-stage compressor manually for long periods of time with a warm heat exchanger (above -5°C). You could build up sufficient refrigerant pressure to damage the unit.

2.5 Troubleshooting Sequence

Plug the unit into an operating electrical outlet of the proper voltage and switch the unit on. These things should immediately occur:

- A red light inside the power switch should light up.

- The fan should begin operating.

- For the first four seconds of operation, the indicator panel should read: ±1.8.8.

You need not remove the cover to detect proper start-up. The fan is faintly audible and can be seen through the condenser at the rear of the unit. If any of the above fail to occur, correct the problem as described in Section 2.6.

Remove the cover and attach the P6 jumper (described in Section 2.4) in order to monitor the unit's normal operation. The second-stage compressor should switch on within a minute of start-up and the LED labeled CR13 should light up. If it does not, refer to Section 2.8.

Within 10 minutes, the heat exchanger temperature (displayed with decimal points lit) should start to drop. If the display does not show a temperature drop or gives erratic readings, refer to Section 2.7. When the heat exchanger is cold enough (a reading of -.2.7. on the RT490, or -.1.0. on the RT4104/RVT4104), the second-stage compressor should switch on and the LED labeled CR14 should light up. If this fails to occur, consult Section 2.8.

Continue monitoring temperature until the stainless steel trap cools to the specified temperature. If this takes over 4 hours, consult Section 2.9. If the vacuum pump outlet fails to switch on when the stainless steel trap gets sufficiently cold, consult Section 2.10.

2.6 Start Sequence Failures

Any failure in the start sequence should be corrected before proceeding further.

Problem 1: Neither the indicator panel, fan, or power switch light operate. This indicates a problem in the power circuit.

- Verify that the power cord is firmly plugged into both the outlet and the unit.

- Verify that the outlet into which the unit is plugged is active, typically by plugging another appliance or device into it. There could be a problem with the fuse or circuit breaker that supplies the electric outlet.

  A blown fuse or circuit breaker indicates an underlying problem, which is not corrected by replacing the fuse or resetting the circuit breaker. Therefore, after restoring the circuit, restart the unit and monitor it closely to see if the fuse blows again.

  -- If it blows immediately, trace the wiring harness, visually or with an ohmmeter, for shorts between the power wires (black, white, and green). Isolate and test for shorts the filter capacitor, power switch, and fan.

  -- If it blows approximately 1 minute after power-up, electrically analyze the first-stage compressor (see Section 2.11). Check for shorts or a frozen compressor rotor.

  -- If it blows approximately 15 minutes after power-up, perform the same tests on the second-stage compressor.

- Visually inspect the wiring harness for any loose wires.

Problem 2: The fan is running and the power switch is lit, but part or all of the indicator panel does not light up.

Within a minute after you switch on the unit, CR13 should light up and you should hear the first-stage compressor switch on. This verifies that the circuit board is producing the required voltages and is in control of the unit; proceed to Problem 3. If it does not occur, it indicates a problem with the circuit board:

- Visually inspect the board for burned components or discoloration indicating that a component has overheated. If you find any, return the circuit board to Savant, indicating this as the problem.

- Visually inspect the wiring harness. Ensure that there are no loose black, white, or green wires.

- Check the fuse (labeled F1) on the circuit board. If the filament is blown, switch off power to the unit, replace the fuse, restart the unit, and continue testing. If the new fuse blows, return the circuit board to Savant, indicating this as the problem.

- With the unit switched on, use an AC voltmeter to verify that the line voltage is present between terminals 1 and 4 of the main circuit board connector (P2). If it is not, use the AC voltmeter to trace backward to the power outlet and locate the discontinuity. If AC power is present at the circuit board but the circuit board is not performing any control operations, return the circuit board to Savant for repair.

- To give Savant a more specific problem report, measure DC voltages on the header labeled P7.

  - Pin 1 (the pin closest to the white dot) is ground.
  - Pin 2 should read +5v with respect to ground.
  - Pin 3 should read -5v with respect to ground.
  - Pin 10 should read +5v with respect to ground.

  (Pins 2 and 3 supply power to the electronics on the circuit board. Pin 10 is on a separate circuit that supplies the relays.)

  If all voltages are within 0.5 volt of their specified levels, return the circuit board to Savant and report a failure of the electronics on the board. If any voltage is more than 0.5 volt out of specification, return the circuit board to Savant and report a power supply failure.

Problem 3: The indicator panel is bad. (The preceding section eliminates the circuit board as the source of the problem.)

The ±1.8.8 pattern displayed on the indicator panel for the first four seconds of operation tests each segment of the panel. Any other pattern indicates a problem that you should correct first, so that incorrect readings do not mislead you later.

- If some but not all of the segments light up, the problem is definitely a bad indicator panel; replace it.

- If none of the segments light up, ensure that the indicator panel is connected to header P4 on the circuit board. If it is connected, unplug it and plug in a known-good indicator panel and cable assembly. If the new one works, the problem was in the indicator panel or the cable. (Substituting one component at a time can locate the problem more precisely. You can also verify cable continuity with an ohmmeter.)

  If a known-good indicator panel does not light up when plugged into header P4 on the circuit board, it indicates a failure on the circuit board. Return the circuit board to Savant, indicating a problem controlling the indicator panel.

<u>Problem 4: The fan does not operate or the light on the power switch does not illuminate.</u> These problems are easily localized.

- o If the fan does not operate, visually inspect the wiring harness connections to the fan. Use an AC voltmeter to ensure that the fan is receiving power. Unplug the unit, then disconnect and replace the fan.

- o If the light on the power switch does not light, but the unit otherwise operates correctly, you can replace the power switch.

2.7 Suspicious Temperature Readings

Consult this section if the user reports inappropriate temperature readings on the indicator panel. (The previous sections cover general failures of the indicator panel. Be sure before proceeding that all segment lights of the indicator panel are working, in order to avoid incorrect readings.)

<u>Problem 5: The display always shows room temperature.</u>

If this is the only problem with the unit (that is, if the trap is getting cold despite the temperature reading), then it indicates a failure of the trap thermocouple.

- o Inspect the wires attached to pins 14 and 15 of the main circuit board connector (P2). Reconnect the wires if either is detached. Be sure that the red wire is attached to pin 14 and the blue wire is attached to pin 15, as shown in the wiring diagram. Connecting the thermocouple backward produces readings above 0°C.

- o Detach the thermocouple from pins 14 and 15 and test its resistance. A reading above 2 megohms means the thermocouple is bad or there is a loose connection in the wiring. If you cannot find and repair a break in the wiring, the user must read temperature with an external thermometer or replace the trap.

If the thermocouple resistance is good, return the circuit board to Savant, indicating a failure to sense trap temperature.

Problem 6: The display shows low temperature, but the trap is not cold enough (or does not produce the desired effect in the apparatus).

A user may report that the refrigerated trap is ineffective despite the fact that the indicator reports the specified low temperature. The most likely cause of this failure is user misapplication of the unit. Any use of the trap in an apparatus applies heat to the trap. If the unit is overloaded, the trap temperature will rise or the trap will be inefficient. In particular:

- Analyze the cryo-coolant (the liquid the user pours into the stainless steel trap to convey heat away from the glass insert trap). Visually check for ice in the coolant. Also check the specific gravity of the coolant. Over time, the cryo-coolant absorbs moisture from the air. The Instruction Manual tells the user to replace the coolant periodically.

- Analyze the condition of the glass insert trap. Trapped vapors remain in the glass insert trap as ice or liquid. Removing and cleaning the glass insert trap is also a routine operation that the Instruction Manual calls for. Operating the unit without a fresh glass insert trap makes it inefficient.

- If the apparatus is in working order, inspect the trap thermocouple physically and electrically as described under Problem 5.

Problem 7: The displayed temperature is erratic.

The circuit board senses trap temperature and displays a new reading every few seconds. Each displayed temperature should differ by no more than 1° from the previous temperature. When the trap is cooling, the indicator panel displays each temperature number on its way down to the specified temperature.

If the displayed temperature jumps around (for example, if successive readings change by 2 or more degrees), it may indicate a grounding or wiring problem.

- Verify that the thermocouple wires attached to pins 12 through 15 are tight.

- Examine each location where a green wire is attached to the circuit board or to the chassis. Ensure that the connection is tight, that a star washer is present between the terminal and the circuit board and chassis, and that there is no corrosion. Also be sure you have verified the DC voltages on the circuit board, as discussed under Problem 2.

- If ground and DC connections read satisfactorily, then a failure in either the trap or on the circuit board can cause erratic temperatures. (If the reported temperature is generally correct but erratic, the problem is more likely to be on the circuit board. If the reported temperature is inaccurate as well as erratic, the problem is more likely to be in the trap.)

Disconnect the trap thermocouple from pins 14 and 15 of P2. Attach a known-good thermocouple of the same type. If the reading is still erratic, return the circuit board to Savant indicating erratic readings of trap temperature. If the reading is now stable, then the thermocouple (or the wires to it) is bad. If you cannot locate and repair the thermocouple, the user must read temperature with an external thermometer or replace the trap.

- If the user reports erratic displays involving the decimal points, it is likely that during previous servicing of the unit, someone left the jumper connected to the header labeled P6 (see Section 2.4). Remove the jumper to return the indicator panel to normal.

2.8 Failure to Refrigerate

The refrigerated trap should cool the stainless steel trap to the operating temperature within 4 hours. If the user reports that it takes longer to cool the trap, or that the trap never cools to the rated temperature, first be sure you have checked these causes:

- Be sure the unit is operating in a proper environment, as described in Section 2.2.
- Verify that the unit is being used properly, as described under Problem 6.

If there is no external explanation for the problem, you must determine how the first and second refrigeration stages are interacting. You can isolate the failure to one stage. The first stage must cool the heat exchanger before the second stage starts to operate.

To get information on the heat exchanger's performance, attach a jumper to P6, as described in Section 2.4.

Problem 8: No compressors are operating.

Within a minute after you switch on a warm unit, the unit should activate the first-stage compressor to draw heat away from the heat exchanger.

- Verify that the LED labeled CR13 is lit. If it is not, then return the circuit board to Savant, indicating an electronic problem in the activation of the first-stage compressor.
- If CR13 is lit but the compressor is not operating, then the circuit board is calling for but not achieving compression. Remove the wires attached to relay RLY1. Verify that the terminals are free of corrosion. Measure the resistance across the terminals. If the resistance is not zero, return the circuit board to Savant, reporting a failure in relay RLY1.
- If the resistance is zero, reattach the wires and ensure that they are well seated. If the compressor still does not come on, analyze the first-stage compressor as described in Section 2.11.

Problem 9: The first-stage compressor is operative, but second-stage is not. (The indicator panel reports adequate cooling of heat exchanger.)

The first-stage system cools the heat exchanger. When you put a jumper on P6, the unit reads the temperature of the heat exchanger. When this temperature reaches a certain level (-15°C for the RT4104/RVT4104; -27°C for the RT490), the circuit board activates the second-stage compressor.

Failures can include:

1 The first-stage system could fail to provide cooling
2 The electronics could fail to sense that cooling is occurring
3 There could be a failure in starting the second-stage system

- Ensure that the jumper is on P6. Switch on the unit and allow about 15 minutes for the heat exchanger to cool. During this period, verify using the indicator panel that the heat exchanger is cooling.

  If the heat exchanger reads -.1.5. for the RT4104/RVT4104, or -.2.7. for the RT490, but the second-stage compressor does not come on, follow a procedure like the one for <u>Problem 8:</u>

- Verify that the LED labeled CR14 is lit. If it is not, then return the circuit board to Savant, indicating an electronic problem in the activation of the second-stage compressor.

- If CR14 is lit but the compressor is not operating, then the circuit board is calling for but not achieving compression. Remove the wires attached to relay RLY2. Verify that the terminals are free of corrosion. Measure the resistance across the terminals. If the resistance is not zero, return the circuit board to Savant, reporting a failure in relay RLY2.

- If the resistance is zero, reattach the wires and ensure that they are well seated. If the compressor still does not come on, analyze the second-stage compressor as described in Section 2.11.

<u>Problem 10: The first-stage compressor is operative, but the second-stage is not. (The indicator panel does not report cooling of heat exchanger.)</u>

If the heat exchanger temperature (the value displayed with decimal points) does not decrease for several minutes, the unit may be unable to sense the heat exchanger temperature. The key is to determine whether the temperature reading is accurate. Follow a procedure like the one for <u>Problem 5:</u>

- Inspect the thermocouple wires attached to pins 12 and 13 of the main circuit board connector (P2). If either is loose, reconnect it and retest the unit.

- Detach the thermocouple wires and test the resistance through the thermocouple. A reading above 2 megohms means the thermocouple is bad or there is a loose connection in the wiring. Locate and repair it.

- If the thermocouple is good, check that the board can read the thermocouple accurately by attaching the other thermocouple: Temporarily move the wire from pin 14 of P2 to pin 13, and move the wire from pin 15 to pin 12. Now the trap temperature should read out as the heat exchanger temperature. If the trap temperature reads inaccurately when you connect that thermocouple to pins 13 and 12, return the circuit board to Savant, indicating a failure to sense heat exchanger temperature.

The above procedure establishes that the indicated temperature is accurate. Reconnect the thermocouples to the proper terminals and check for physical problems:

- Evaluate the first-stage refrigeration system as described in Section 2.12.

- Use the extra thermocouple (HE IN) to detect an obstruction of the heat exchanger, as discussed in Section 2.13. On the RT490, you can replace the heat exchanger. (On the RT4104 and RVT4104, it is within the trap block.)

2.9 Poor Cooling Performance

A refrigeration stage can lose cooling power due to disturbance of, or impurities in, the copper tubing. Normal wear on the compressor may also be the problem.

Problem 11: The trap temperature fluctuates between the specified temperature and about -70°C, even when you are placing no load on the system.

This indicates reduced capacity of the second-stage refrigeration system. The second-stage system can achieve the operating trap temperature, but cannot maintain it.

Solution. Reduced capacity of the second-stage system can be caused by oil lodging in the refrigerant tubing. The first corrective operation should be to leave the unit off overnight. This lets the oil settle; the pressure differentials when you restart the unit drive the oil back to the compressor.

If the unit continues to show reduced efficiency, refrigerant may be starting to leak from the second-stage system, or a compressor may be starting to wear out. Physically analyze the second-stage system (see Section 2.12).

On the RT490, you can replace the capillary tube of the second stage. Do so before replacing the compressor or recharging the second-stage because of reduction of capacity. Obstruction of the capillary may be the cause of the problem. (On the RT4104 and RVT4104, the capillary tube is in the trap block.)

2.10 Vacuum Pump

A user may report problems in the switching of the vacuum pump. You can simplify diagnosis of these problems in the following ways:

- o Follow the procedures in Section 2.7 and 2.8 to establish that the trap is being cooled to the specified temperature and that the indicator panel displays the correct trap temperature.

- o Unplug the vacuum pump and plug in a lamp or light bulb to make the trap's operation of the electrical outlet more obvious.

Problem 12: The vacuum pump is never on.

The steps of this analysis are comparable to Problem 8, where the first-stage compressor does not switch on:

- o If the trap is not reaching the specified temperature, solve that problem first. Once the system becomes capable of cooling the trap, it may begin switching on the vacuum pump.

- o Verify that the LED labeled CR15 is lit. If it is not, then return the circuit board to Savant, indicating an electronic problem in the activation of the vacuum pump outlet.

- o If CR15 is lit but the vacuum pump or light bulb does not come on, then the circuit board is calling for but not achieving activation. Remove the wires attached to relay RLY3. Verify that the terminals are free of corrosion. Measure the resistance across the terminals. If the resistance is not zero, return the circuit board to Savant, reporting a failure in relay RLY3.

Problem 13: The vacuum pump is always on.

- o Ensure that the vacuum pump was indeed plugged into the switched outlet of the refrigerated trap, rather than directly into a separate power outlet.

- o Switch the refrigerated trap off. If the vacuum pump or light bulb remains on, there is a short circuit in either relay RLY3 or in the wiring harness. Unplug the wires from the terminals of RLY3, unplug the vacuum pump or other appliance plugged into the refrigerated trap, and use an ohmmeter to locate the short.

- o Let the trap warm to room temperature, so that the trap should deactivate the vacuum pump. (To accelerate the process, replace the cryo-coolant with fresh coolant at room temperature.) Switch the unit on. The LED labeled CR15 should be off, since the trap is now too warm for the vacuum pump to come on. If the LED is on, return the circuit board to Savant, indicating a logic failure in the operation of the vacuum pump. (If the LED is off but the vacuum pump is on, it indicates a short circuit in relay RLY3 or in the wiring harness. Follow the instructions in the previous paragraph.

2.11 Electrical Analysis of a Compressor

Electrical analysis of a compressor is called for whenever the LED on the circuit board is lit but the compressor does not operate.

1 Make sure the unit is unplugged.

2 Use a Phillips screwdriver to remove the electrical housing from the compressor.

Discharge the capacitor before proceeding. If you recently switched off the unit, the capacitor may retain a charge.

3 Ensure that all wires within the housing are securely attached. If any are not, reconnect them according to the wiring diagram and retest the unit.

4 Detach the capacitor from terminals 11 and 13. Examine the capacitor: The hood separates during certain failures to prevent explosion. If the hood is separated or ajar, or if there is any discoloration, replace the capacitor.

Use a capacitance tester to test the capacitor. If the reading differs substantially from its labeling, replace the capacitor.

5 Pull off the relay--the square black component with terminals labeled 10 through 14. Test the relay with an ohmmeter. There should be virtually 0 ohms between terminals 10 and 11 when the relay is upright. When the relay is upside-down, there should be an open circuit between terminals 10 and 11. If the relay fails these tests, replace it.

If you replace either the capacitor or the relay, then replace both. They are inexpensive and a failure in one may degrade the other. Each replacement compressor ordered from Savant includes both the capacitor and relay.

Locate the three prongs where the relay was attached. They are in this configuration:

```
Run  o     o  Start

         o
       Common
```

6 Measure the **run winding** resistance between the Run and Common terminals. Also measure the **start winding** resistance between the Start and Common terminals. Correct values are in the table in Section 3.1. If the observed reading differs substantially from the correct value, replace the compressor.

7 Ensure that all three terminals are open circuits with respect to ground (the green wire attached to the housing). If any terminal is shorted to ground, replace the compressor.

If all components pass their tests, reattach the relay and all wires and replace the housing over the electrical terminals.

You can also test the compressor free-running current. You should do this especially if the unit blows fuses:

8 Attach a clamp-type ammeter to the red or orange wire connected to terminal 10. Start the unit. Manually activate the compressor with a toggle switch or wait until the point in the sequence where the unit tries to activate the compressor. Then read the current. The correct free-running current is specified in Section 3.1. If the reading is substantially greater than the specified current, then the compressor may have a frozen rotor or bad relay or capacitor.

Any time you replace the compressor, you must recharge the system, as described in Section 2.14.

2.12 Physical Analysis of a Refrigeration System

Physical analysis of a refrigeration system is called for when the compressor is operating but cooling does not occur. Recharging the system (see Section 2.14) is required in most cases of failure, and may be required simply to detect the cause of the failure.

1 Switch off the unit and allow time for the entire apparatus to warm to room temperature. Then restart it. If the unit now cools properly (that is, if the failure is intermittent) then the likely cause is an oil blockage. If the problem recurs, the solution is to flush the second stage with R-11 and recharge the second stage (oil blockage usually occurs in this stage). Oil blockage typically occurs when a unit is moved to another location.

2 Check for refrigerant leaks. All Savant refrigeration systems use pressurized, hydrocarbon-based refrigerants to transfer heat from one place to another. In practice, sudden leaks do not occur. If a system begins to fail because of a refrigerant leak, you can detect gas in the vicinity of the copper tubing. We recommend the use of an electronic leak detector.

If you detect a leak, seal it and recharge the system as described in Section 2.14.

Some electronic leak detectors detect the glue used to attach the insulation to the capillary tube. If your leak detector gives you a large number of false positive readings, we recommend the use of a fluorescent gas leak detector, such as the Teltale product of Stewart Hall Chemical Corporation.

No leak detector will detect a leak if the test occurs after all the refrigerant has escaped. In this case, pressurize the system with 100 pounds of nitrogen, with a pressure gauge attached. A loss of 0.5 pound of pressure over 15 minutes suggests a leak.

To find a leak in a refrigeration stage that has exhausted all its refrigerant, pressurize the system with 20 psi of R-12 or R-503 (for detection by the electronic leak detector) and add nitrogen to a total pressure of 50 psi. It should now be possible to localize the leak using the electronic leak detector.

If a leak is not detected at this point, leave the manifold attached and start the unit for no more than 15 minutes. Look at the pressure gauge on the manifold. A jumpy gauge, a total absence of head pressure or suction pressure, or head pressure over 300 psi, indicates a failure of a valve in the compressor; replace the compressor. Excessive vacuum (25" Hg) on the suction-side gauge indicates a blockage in the capillary of that stage. If you can find a blockage in an accessible part of the capillary, you may be able to relieve it, but this is not usually cost-effective; at this point, you would return the unit to Savant.

3 If there is no refrigerant leak and the failure is not intermittent, the compressor may be worn out, so that its pumping has no effect. Replace the compressor and recharge the system with new refrigerant, as described in Section 2.14. Use the electronic leak detector to verify the integrity of all new joints.

4 An improper charge of refrigerant can also make a refrigeration stage fail. There is no practical way to detect an improper charge except to recharge. If, following steps 1 and 2 above, you have replaced the compressor, you will give the stage a proper charge afterward. You may test the compressor and find you can reuse it.

2.13 Additional Thermocouples

Two thermocouples have already been discussed:

- Connected to terminals **12 and 13** is a sensor for the first-stage system at the output of the heat exchanger.
- Connected to terminals **14 and 15** is a sensor for the second-stage system at the inlet to the refrigerated trap.

There are two other thermocouples stowed in the unit that provide additional troubleshooting information:

- The one labeled **B** senses the Bottom (the outlet) of the evaporator assembly.
- The one labeled **HE IN** senses the first-stage system at the input to the heat exchanger.

<u>To use these thermocouples,</u> detach the wires normally connected to terminals 14 and 15 and attach the thermocouple of interest. The temperature reading on the indicator panel (when the decimal points do not appear) is the desired reading. **Do not disturb the wires connected to terminals 12 and 13.** Doing so prevents the unit from sequencing properly. (You can also read the thermocouples with a voltmeter. They are all T-type (copper/constantan) thermocouples. Convert millivolts to degrees C using a physics handbook.)

The temperature differences between these thermocouples and the normally-attached thermocouples measure the performance of the refrigerated trap and the heat exchanger.

Difference across trap. The difference in the two readings from the stainless steel trap indicates the adequacy of the charge of the second-stage system:

- o The output (B) is normally 5-10°C warmer than the inlet, if there is no load on the trap (the coolant is at the operating temperature).
- o If the differential is 10°C or more, the second-stage system may have lost some charge or the unit may not be on a level surface.
- o If the output (B) is colder than the inlet, the second-stage system is overcharged and must be recharged as described in Section 2.14.

The difference fluctuates when the unit is in the process of cooling the stainless steel trap or the coolant. At these times, the reading is meaningless.

Difference across heat exchanger. The first-stage inlet to the heat exchanger (HE IN) is normally 5° colder than the outlet. As above, the reading is only meaningful when the entire trap has cooled to the operating temperature. If the inlet is warmer than the outlet, it could indicate an improper charge within the heat exchanger.

2.14 Recharging a Refrigeration System

Intentional discharge or recharge of a refrigeration stage must be performed only by personnel that Savant trains and certifies.

Overview. The tubing of a refrigeration stage contains a refrigerant under pressure. The refrigerant switches between the gaseous and liquid phases when the unit is operating. The refrigerant is not consumed during the unit's operation, so it lasts indefinitely, unless (1) there is a leak in the tubing, or (2) you replace a component such as the compressor. In these two cases, you must recharge the system. This means you must add fresh refrigerants at the specified pressures.

The refrigerant must circulate freely in the tubing to transfer heat efficiently. Whenever you open the system, take great care that foreign matter such as dirt does not enter the tubing. Whenever you cut or splice copper tubing, deburr the inside of the tube and carefully remove all loose matter.

Whenever you open the system, moisture from the air enters the tubing. Microscopic imperfections in the interior surface of copper tubing can hold moisture. The traps do not include dryers to remove this moisture. Therefore, before any recharge, you must thoroughly purge the system. You cannot just apply vacuum; as you decrease the vapor pressure, evaporating the water, you also lower the pressure differential, so that the vapor leaves the system more slowly. Therefore, you must also flush the system with nitrogen. The procedure below includes these steps.

It is convenient to disconnect the red and black wires attached to relay RLY1, and disconnect the orange and black wires attached to relay RLY2. Attach each pair of wires to a toggle switch. This lets you operate each compressor manually.

Do not perform the following procedure without receiving permission from the factory. You must specify which Savant-certified personnel will be performing the procedure.

Procedure. Follow these steps to recharge a system. If you are recharging both systems, recharge the second-stage system first.

DISCHARGE

1 Sever the charging stubs below the existing pinch points. Braise to each stub a new piece of 1/4-inch copper tubing.

You may now smell burnt refrigerant. If so, or if you replaced a compressor that burned out, there may be burnt compressor oil in the lines that will be hard to remove and may cause problems later. In this case:

- Replace as much copper tubing as is feasible
- Perform the following PURGING procedure several times
- If feasible, replace the entire unit

2 Flare the new tubes to a **combination vacuum and charging manifold.** This manifold has hand valves and hose ports for connection to: the first stage, the second stage, a vacuum system, and a tank of refrigerant or nitrogen.

PURGING

3 Connect the vacuum pump to its hose port on the manifold. Connect a tank of dry nitrogen to the other port. Open the hand valve to the vacuum. Evacuate the refrigeration stage to 100 microns or less. Also open the hand valve to the nitrogen, although the tank valve is closed. This evacuates the hose to the nitrogen.

4 Shut off the vacuum and apply nitrogen to give the system a static charge of 10 psig. Then shut off the nitrogen.

5 Start the system's compressor. (The compressor for the other stage should be off.) Run the compressor until it is warm (15-30 minutes). This circulates the nitrogen throughout the system, to mix any remaining water or impurities with the nitrogen. It also agitates the compressor oil to free any dissolved impurities.

6 Shut off the compressor and apply vacuum again.

7 Connect the refrigerant tank. (If this system takes two refrigerants, connect the first tank.) Use the vacuum to purge the hose to this tank. The amount of air in an unpurged hose is sufficient to produce an improper charge. **Do not simply use refrigerant to blow air out of the hose.** This wastes refrigerant and it does not eliminate moisture from the hose.

8 Evacuate the system to 30 microns and maintain this vacuum level for at least 12 hours.

CHARGING

Complete the charging procedure for one stage before starting on the other stage.

9 Since you are typically returning to the unit after a 12-hour absence, verify again the vacuum level.

10 Shut off the vacuum, refrigerant, and access valves.

11 Open the high-side and low-side valves of one stage. Open the valve for the refrigerant. Use the main panel valve to charge the system to the specified pressure. Shut the valve when the pressure is achieved.

The Specifications in Section 3.1 specify the refrigerant to use and the correct pressure level. All pressures are psig (pounds per square inch above atmospheric pressure).

12 If charging the second stage, apply the second refrigerant. Attach **the same hose** to the second refrigerant tank. Use vacuum to purge the hose again before applying the second refrigerant.

The specified pressure for the second refrigerant is the **total pressure** the system should have after adding the second refrigerant, in psig. (The amount of the second refrigerant to add is therefore the difference between the two specified pressures.)

FINISHING

13 Pinch off and seal the high and low charging stub.

14 Use the electronic leak detector to test for leaks, particularly at the new seals.

15 If charging both systems, repeat the above steps for the other system.

16 Test the unit's performance. (If you operate the unit with valves attached, you will note a slight decrease in the charge, since some refrigerant dissolves in the compressor oil. **Do not add more refrigerant to compensate for this.**)

SECTION 3

TABLES

3.1 Specifications

	RT490	RT4104/RVT4104
TARGET TEMPERATURE	-90°C (-130°F)	-104°C (-155°F)
FIRST-STAGE COMPRESSOR		
110 volts:		
Resistance of "start" winding	4.0 ohms	4.0 ohms
Resistance of "run" winding	1.9 ohms	1.9 ohms
Free-running current	2.3 amps	2.3 amps
230 volts:		
Resistance of "start" winding	13.1 ohms	13.1 ohms
Resistance of "run" winding	10.7 ohms	10.7 ohms
Free-running current	1.2 amps	1.2 amps
SECOND-STAGE COMPRESSOR		
110 volts:		
Resistance of "start" winding	4.0 ohms	3.6 ohms
Resistance of "run" winding	1.9 ohms	1.6 ohms
Free-running current	2.3 amps	3.2 amps
230 volts:		
Resistance "start" winding	13.1 ohms	14.5 ohms
Resistance of "run" winding	10.7 ohms	9.2 ohms
Free-running current	1.2 amps	1.6 amps

REFRIGERANT CHARGE	RT490	RT4104	RVT4104
First stage	R-502 @ 105 PSIG	R-13B1 @ 125 PSIG	R-13B1 @ 100 PSIG
Second stage, refrigerant #1	R-290 @ 10 PSIG	R-290 @ 0 PSIG	R-290 @ 0 PSIG
Second stage, second charge (total pressure)	R-503 @ 55 PSIG	R-503 @ 48 PSIG	R-503 @ 53 PSIG
OPERATING PRESSURE AT SPECIFIED TEMPERATURE			
First stage suction	0" Hg	2" Hg	2" Hg
First stage discharge	175 PSIG	220 PSIG	200 PSIG
Second stage suction	15" Hg	21" Hg	20" Hg
Second stage discharge	75 PSIG	50 PSIG	50 PSIG

3.2 Spare Parts Order Numbers

Except where noted, all parts apply to all three models.

	115 VAC	220 VAC
Capacitor: part of Compressor ass'y		
Capillary tube assembly, RT490 *		
first-stage system	083-1008-00	083-1008-00
second-stage system	083-1009-00	083-1009-00
Circuit board, RT490	082-1005-01	082-1005-02
Circuit board, RT4104/RVT4104	082-1005-03	082-1005-04
Compressor assembly	M60-0008-01	M60-0008-02
except RT4104/RVT4104 2nd stage:	M00-0020-01	M00-0020-02
Dryer, see strainer		
Evaporator, see Trap assembly		
Fan motor	M60-0014-01	M60-0014-02
Heat exchanger, RT490 *	083-1010-00	083-1010-00
Motor, see Fan motor		
Power switch	E90-0065-01	E90-0065-02
Printed circuit, see Circuit board		
Relay:		
Compressor relay is part of Compressor assembly		
Relays CR1 through CR3 are part of Circuit board		
Seal (trap top seal)	093-6007-00	093-6007-00
Strainer, oil	M60-0029-01	M60-0029-01
Trap assembly (RT490)	083-1004-00	083-1004-00
Trap assembly (RT4104/RVT4104)	082-1004-00	082-1004-00

* On the RT4104/RVT4104, this part is inside the trap assembly, listed above.