

SMC-TR-96-11

USER MANUAL FOR REFRIGERATION SYSTEM MONITOR

Ullrich Hesse, PhD

Spauschus Associates, Inc.
300 Corporate Center Court
Stockbridge, GA 30281

May 1996

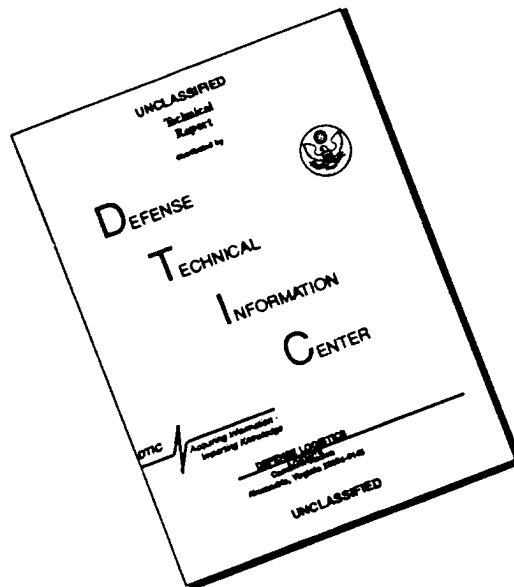
Prepared for:
SMC/SDFE, Los Angeles Air Force Base, CA 90245-4683
Under Contract No. F29601-94-C-0013

Approved for Public release; distribution is unlimited

19960625 207

DTIC QUALITY INSPECTED 1

DISCLAIMER NOTICE



THIS DOCUMENT IS BEST QUALITY AVAILABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

This report has been reviewed and is approved for publication. Publication of this report does not constitute approval or disapproval of the ideas or findings. It is published in the interest of STINFO exchange.


DELLA B. HINESLEY
Project Officer


STEVEN M. SODERQUIST
Chief, Systems Effectiveness

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.				
1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE May 1996		3. REPORT TYPE AND DATES COVERED Final; Feb 94 - Apr 96
4. TITLE AND SUBTITLE User Manual for Refrigeration System Monitor			5. FUNDING NUMBERS F29601-94-C-0013	
6. AUTHOR(S) Ullrich Hesse				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Spauschus Associates, Inc. 300 Corporate Center Court Stockbridge, GA 30281			8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) SMC/SDFE 160 Skynet Street Suite 2315 Los Angeles AFB, CA 90245-4683			10. SPONSORING / MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES				
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for Public Release; Distribution is Unlimited			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) A refrigeration system monitor has been developed which will provide an early warning that a refrigeration or air-conditioning system is experiencing internal problems. The monitor separates non-condensable gases from the flowing refrigerant and provides an external signal when a significant amount of gases have been collected. The presence of these non-condensable gases indicates that one or more problems are developing, including incomplete evacuation, suction side leaks and compressor bearings operating in a boundary lubrication regime. The type of gas collected is indicative of the specific malfunction. This document provides detailed instructions for the user regarding installation and operation of the monitor.				
14. SUBJECT TERMS Refrigeration, Air conditioning, Monitor, Non-Condensable gas, Refrigeration system monitor			15. NUMBER OF PAGES 17	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT UL	

GENERAL INSTRUCTIONS FOR COMPLETING SF 298

The Report Documentation Page (RDP) is used in announcing and cataloging reports. It is important that this information be consistent with the rest of the report, particularly the cover and title page. Instructions for filling in each block of the form follow. It is important to *stay within the lines* to meet *optical scanning requirements*.

Block 1. Agency Use Only (Leave blank).

Block 2. Report Date. Full publication date including day, month, and year, if available (e.g. 1 Jan 88). Must cite at least the year.

Block 3. Type of Report and Dates Covered. State whether report is interim, final, etc. If applicable, enter inclusive report dates (e.g. 10 Jun 87 - 30 Jun 88).

Block 4. Title and Subtitle. A title is taken from the part of the report that provides the most meaningful and complete information. When a report is prepared in more than one volume, repeat the primary title, add volume number, and include subtitle for the specific volume. On classified documents enter the title classification in parentheses.

Block 5. Funding Numbers. To include contract and grant numbers; may include program element number(s), project number(s), task number(s), and work unit number(s). Use the following labels:

C - Contract	PR - Project
G - Grant	TA - Task
PE - Program Element	WU - Work Unit Accession No.

Block 6. Author(s). Name(s) of person(s) responsible for writing the report, performing the research, or credited with the content of the report. If editor or compiler, this should follow the name(s).

Block 7. Performing Organization Name(s) and Address(es). Self-explanatory.

Block 8. Performing Organization Report Number. Enter the unique alphanumeric report number(s) assigned by the organization performing the report.

Block 9. Sponsoring/Monitoring Agency Name(s) and Address(es). Self-explanatory.

Block 10. Sponsoring/Monitoring Agency Report Number. (If known)

Block 11. Supplementary Notes. Enter information not included elsewhere such as: Prepared in cooperation with...; Trans. of...; To be published in.... When a report is revised, include a statement whether the new report supersedes or supplements the older report.

Block 12a. Distribution/Availability Statement. Denotes public availability or limitations. Cite any availability to the public. Enter additional limitations or special markings in all capitals (e.g. NOFORN, REL, ITAR).

DOD - See DoDD 5230.24, "Distribution Statements on Technical Documents."

DOE - See authorities.

NASA - See Handbook NHB 2200.2.

NTIS - Leave blank.

Block 12b. Distribution Code.

DOD - Leave blank.

DOE - Enter DOE distribution categories from the Standard Distribution for Unclassified Scientific and Technical Reports.

NASA - Leave blank.

NTIS - Leave blank.

Block 13. Abstract. Include a brief (*Maximum 200 words*) factual summary of the most significant information contained in the report.

Block 14. Subject Terms. Keywords or phrases identifying major subjects in the report.

Block 15. Number of Pages. Enter the total number of pages.

Block 16. Price Code. Enter appropriate price code (*NTIS only*).

Blocks 17. - 19. Security Classifications. Self-explanatory. Enter U.S. Security Classification in accordance with U.S. Security Regulations (i.e., UNCLASSIFIED). If form contains classified information, stamp classification on the top and bottom of the page.

Block 20. Limitation of Abstract. This block must be completed to assign a limitation to the abstract. Enter either UL (unlimited) or SAR (same as report). An entry in this block is necessary if the abstract is to be limited. If blank, the abstract is assumed to be unlimited.

Table of Contents

<u>Section</u>	<u>Title</u>	<u>Page</u>
1.0	General Purpose	1
1.1	Functional Principle of the Monitor	2
1.2	The Components of the Monitor	4
1.2.1	Separation Unit	6
1.2.2	Controller	6
1.2.3	Additional Equipment	7
1.3	Installation	7
1.4	Calibration	9
1.5	Operation	9
1.6	Sampling for Analysis	10
1.7	Limitations of Application	11
1.8	Detailed Views of Separation Unit	12
1.9	Material Lists for the Monitor	14

Figures

<u>Figure</u>	<u>Title</u>	<u>Page</u>
1	Section of the Separation Coil	2
2	Schematic View of Separation Unit Installed Parallel to the Discharge Line	3
3	Separation Unit	4
4a	Front View of the Controller	5
4b	Rear View of the Controller	5
5	Schematic View of the Connection to the Refrigeration Cycle	8
6	Arrangement for Sampling	11
7	Different Views of the Separation Unit	12
8	Different Interior Views of the Monitor	13

1.0 GENERAL PURPOSE OF THE MONITOR

The non-condensable gas (NCG) Monitor is designed to separate non-condensable gases from the flowing refrigerant in a refrigeration or air-conditioning system.

Non-condensable gases are undesirable in a refrigeration system under normal operation conditions, and their appearance is an indication of possible future system failures. Sources for non-condensable gases and their composition are:

- incomplete evacuation resulting in air, nitrogen or argon as non-condensable gases;
- low side leak resulting also in air, nitrogen or argon as non-condensable gases;
- motor / compressor stress reaction products :
 - a) from motor insulation resulting in CO, CO₂, N₂, .. as non-condensable gases;
 - b) from lubricant resulting in H₂, CH₄, C₂H₆, or CO and CO₂ for POE lubricants as non-condensable gases;
 - c) from lubricant / bearing failures resulting in H₂ as non-condensable gases;
 - d) from refrigerant reaction resulting in CO₂, HCl, HF.

In any case, the appearance of non-condensable gases is an indication of improper operation. The purpose of the non-condensable gas Monitor is

- to collect these non-condensable gases;
- to indicate that non-condensable gases have been collected;
- to provide a sample of the non-condensable gases for analysis.

Improper operation of the refrigeration or air-conditioning system will be indicated by the non-condensable gases collected by the Monitor, and steps can be taken at an early stage to avoid severe failures such as motor burn out or excessive increase of lubricant acidity and associated failures.

1.1 Functional Principle of the Monitor

The collection of the non-condensable gases is a separation process. The separation of the non-condensable gases from the circulating refrigerant takes place in a separation coil as shown in Figure 1.

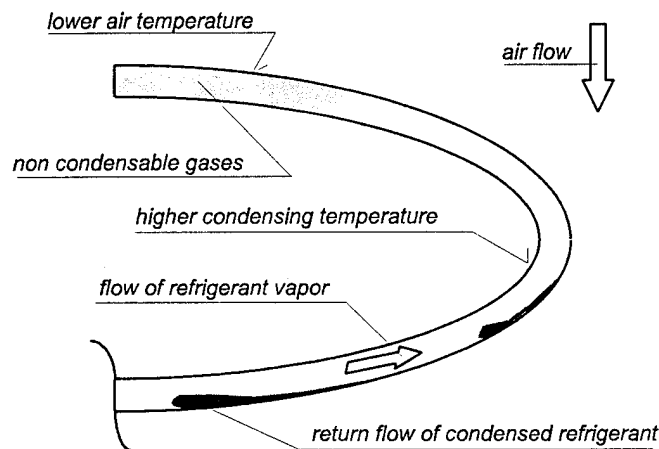


Figure 1: Section of the Separation Coil

Small amounts of refrigerant vapor at condensing pressure and temperature are constantly liquified in the coil. The coil is cooled by the same air, or air of lower temperature than is used for condensation of the circulating refrigerant in the condenser. The non-condensable gases will remain in the coil and collect at the top end. Once non-condensable gases are collected, the refrigerant condensation process will cease in this (top) section of the coil. Thus, with interrupted heat flow from the top section of the coil to the air, the temperature measured at this section of the coil will reduce to the air temperature. In the remaining (lower) section of the coil, where no non-condensable gases have collected, the temperature of the coil will remain at the higher condensing temperature.

The separation coil is part of the separation unit schematically shown in Figure 2. In this unit an additional coil is used for desuperheating and partial condensation of the hot discharge gas. A sight glass is used to control the flow and to confirm existence of two phase flow.

The needle valve is used to adjust the flow rate in a way that sufficient two phase flow will occur in typical operation conditions. Once this valve has been set, further adjustments are not necessary.

Only a small fraction of the total circulating refrigerant mass is condensed in the separation coil, since for proper operation, it is sufficient to feed only a fraction of the discharge gas through the separation unit of the Monitor (which encloses the separation coil). The separation unit of the Monitor is installed parallel to the discharge line between the compressor and the condenser or to a part of this discharge line.

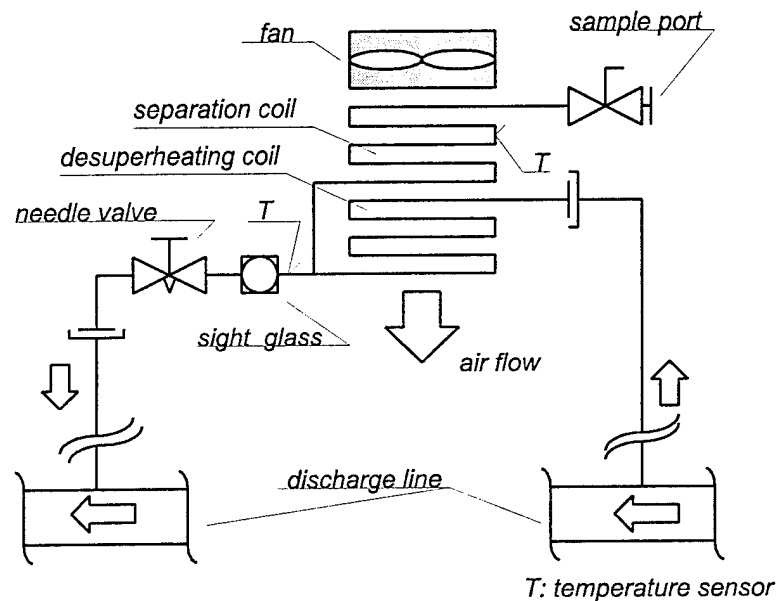


Figure 2: Schematic View of Separation Unit Installed Parallel to the Discharge Line

Two temperature sensors are installed in the separation unit. One is to determine the temperature at the upper part of the separation coil, and the other is installed at the end of the desuperheating coil close to the sight glass to determine the saturation temperature.

If the difference between the temperature measured at the separation coil and the temperature at the other sensor exceeds a certain level for a certain period of time, a collection of non-condensable gases will be indicated by the Monitor controller. Further increase in temperature difference and time will produce an audible alarm.

1.2 The Components of the Monitor

The Monitor consists of two major parts:

- the separation unit shown in Figure 3 and
- the controller shown in Figures 4a and 4b.

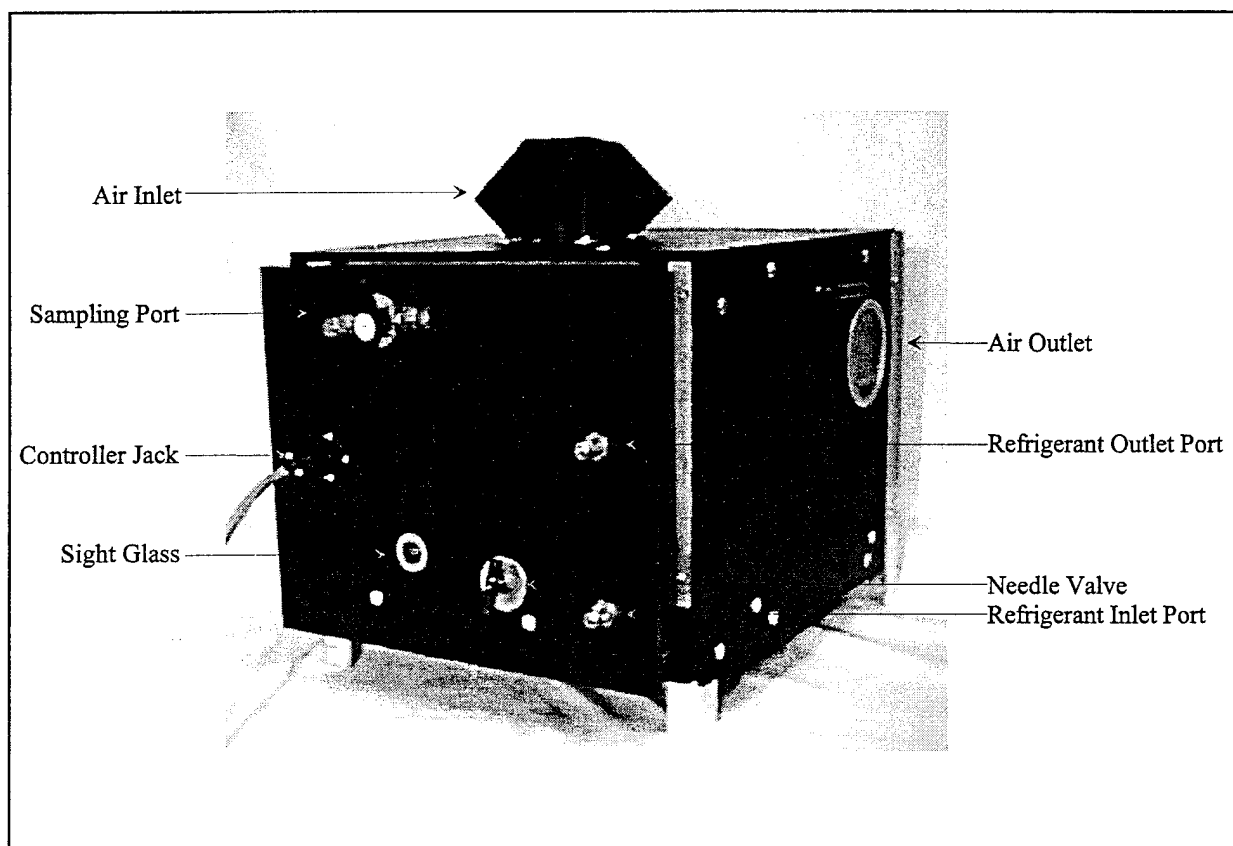


Figure 3: Separation Unit

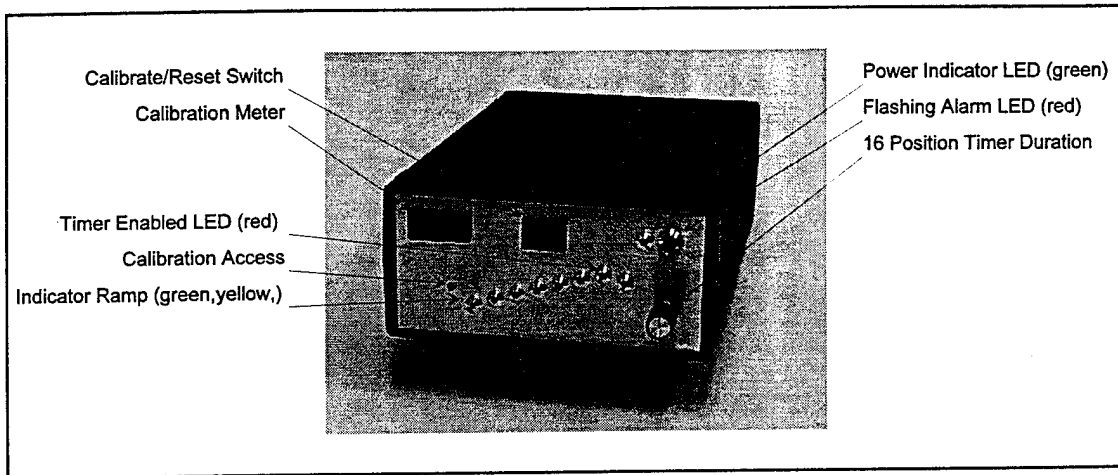


Figure 4a: Front View of the Controller

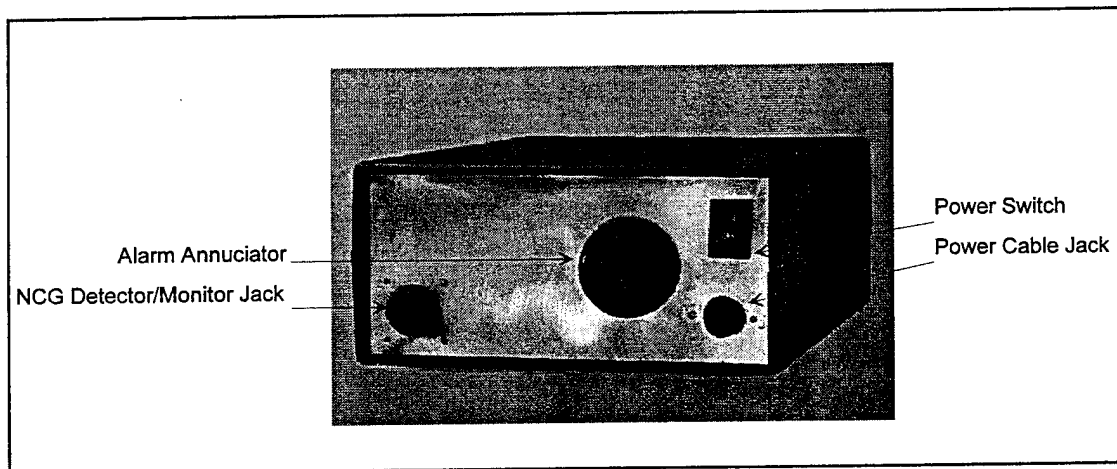


Figure 4b: Rear View of the Controller

1.2.1 Separation Unit

The separation unit as shown in Figure 3, contains the following components:

1. the separation coil for the separation of the non-condensable gases (1/4" stainless steel tubing);
2. the desuperheating column for desuperheating and partial liquefaction of hot discharge gas from the compressor (1/4" copper tubing);
3. the sight glass for visual control of two phase flow;
4. the needle valve as flow restrictor;
5. the refrigerant inlet port (1/4" male flare fitting) as connection port to the compressor side of the discharge line, or to a by-pass section of the discharge line;
6. the refrigerant outlet port (1/4" male flare fitting) as connection port to the condenser side of the discharge line, or to a by-pass section of the discharge line;
7. the fan for air circulation;
8. a thermostatic switch and a temperature sensor to control the airflow through the fan (or to take the fan out of operation if the discharge temperature is low, and thus avoid full condensation in the desuperheater coil);
9. an air intake port;
10. three air outlet ports (right side, left side, rear);
11. temperature sensor (type Motorola MTS102) to determine the temperature at the upper part of the separation coil;
12. temperature sensor (type Motorola MTS102) at the end of the desuperheating coil to determine the saturation temperature;
13. jacks for connection of the sensors and the power supply with the controller;
14. sliding platform for easy maintenance.

1.2.2 Controller

The controller as shown in Figure 4, contains the temperature sensor signal processor. The temperature sensors have a linear response to temperature. The signals received from the two sensors are processed in the following order:

- Individual sensor 20 dB amplification.
- Analog differential 20 dB amplification.

- Variable amplification of 17 to 27 dB.
- Positive response limiter and minimum threshold conditioner .
- Variable trigger-point ladder detector with visual output.
- Count-down timer with 16 preset periods, pause, and reset

An indicator ramp of green and yellow LED's on the front panel of the controller housing indicates increasing or decreasing signal level. A red LED indicates when the timer has been enabled. A flashing red alarm light on the front panel and an audible alarm annunciator are actuated to indicate collection of sufficient non-condensable gases to warrant alarm conditions. The timer duration can be selected with a 16 position switch on the front panel.

A single switch on the front panel is used for calibration (left position) and reset (right position). A digital meter facilitates calibration.

Power switch, power cable jack, and separator unit jack are installed on the rear side of the controller housing.

1.2.3 Additional equipment

A 12V DC power supply is supplied with the Monitor as well as a 15' cable for the connection between the separation unit and the controller. The power supply operates from 115 VAC power.

The refrigerant piping needed for the installation of the separator is standard equipment, and must be provided on-site by the user.

1.3 Installation

The separation unit must be installed close to, and between, the refrigeration system compressor and condenser. A schematic view is given in Figure 5. The inlet port must be connected to the discharge line close to the compressor or directly to the compressor; 1/4" O.D. copper tubing is sufficient. This line must be insulated to prevent condensation in the tubing due to excessive heat loss.

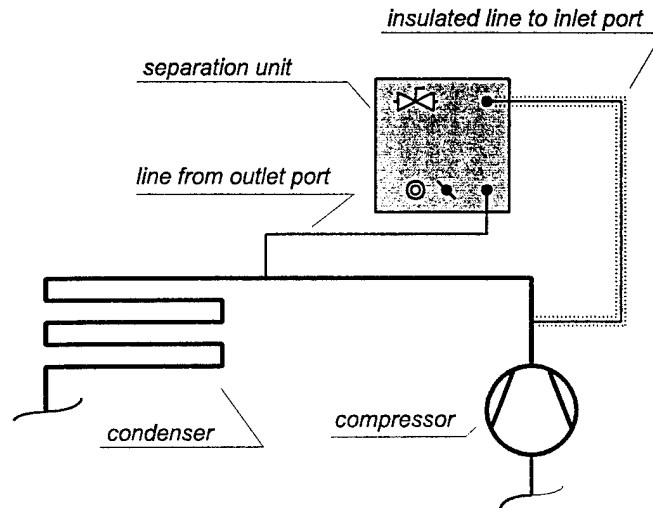


Figure 5: Schematic View of the Connection to the Refrigeration Cycle

The outlet port must be connected to the discharge line near the condenser inlet; again 1/4" O.D. copper pipe is sufficient, but insulation is not needed on this connecting line. The bypassed part of the discharge line should not be too short as a certain small value of pressure drop is needed to establish sufficient flow through the separation unit.

It is important for the Monitor to be physically positioned above the system connection points, in order to insure proper flow of refrigerant.

It is recommended that the needle valve of the separation unit be fully open during leak testing, evacuation and filling. Proper refrigerant reclaim, leak testing, evacuation and charging methods must be adhered to according to Federal guidelines.

The temperature of the cooling air at the air intake must be the same or lower than the temperature of the air cooling the condenser.

The controller and the separation unit must be connected with the connection cable and the controller connected to the power supply.

1.4 Calibration

Due to the need for an isothermal environment, it might be necessary to calibrate the Monitor before the installation of the separation unit. The calibration is done according to the following procedure:

1. The separator unit and the controller should be placed in an isothermal area.
2. Install cables and turn on detector.
3. Let stand in the environment for 1 hour.
4. Push and hold calibration switch (Figure 4a) to the left.
5. If reading on the calibration meter (Figure 4a) is between +10 and -10 the unit is ready for use.
6. If reading is greater than +10 or less than -10, while holding the calibration switch to the left, adjust the meter reading with a screw driver through calibration access hole on front panel.
7. Allow 3 minutes for stabilization and repeat from step 5.

1.5 Operation

After the Monitor has been installed and calibrated as described, it is ready for operation. Set timer logging function for one of the 16 possible durations as shown in Table 1 (position E, 1800 minutes, is a good starting position). Pushing the reset toggle (right) will initialize the time accumulator. When the differential temperature exceeds the preset limit (which has been factory set and requires no adjustment), the timer runs until the alarm sounds or the temperature falls below the limit. In the latter case, the elapsed time reading is discontinued until the limit is once more exceeded.

The presence of non-condensable gases is visually indicated by an ascending ramp of LED's (see Figure 4a). The topmost LED (red) is tied to the timer function, and the alarm condition is indicated by a pulsing siren and a flashing red LED. This indicates an appreciable quantity of non-condensable gases has been collected and can be captured for analysis. Purging without analysis is not recommended since valuable information will be lost, in addition to an intentional venting of refrigerant gas to the atmosphere.

Table 1: Timer Settings and Durations

0	1	2	3
7 SEC	13 SEC	26 SEC	52 SEC
4	5	6	7
105 SEC	211 SEC	7 MIN	13 MIN
8	9	A	B
28 MIN	56 MIN	112 MIN	225 MIN
C	D	E	F
450 MIN	900 MIN	1800 MIN	3600 MIN

1.6 Sampling for Analysis

The sampling port has a 1/4" male flare fitting connection. The sampling arrangement as shown in Figure 6 must be connected to this sampling port. The sampling procedure is:

1. Connect the sampling unit (3" to 5" 1/4" tube with two hand valves) to the sampling port of the separation unit;
2. Leak test;
3. Connect the second hand valve to a vacuum pump;
4. Evacuate the arrangement, while the hand valves of the sampling arrangement are both open and the sampling port valve on the Monitor is still closed;
5. After evacuation, close the valve connected to the vacuum pump;
6. Open the sample port valve on the Monitor;
7. Quickly close the hand-valve on the sampling unit;
8. Close the sample port valve on the Monitor;
9. Disconnect the sampling unit from the Monitor and the vacuum pump. Securely cap the flare fittings.

For analysis and evaluation of results Spauschus Associates, Inc. may be contacted.

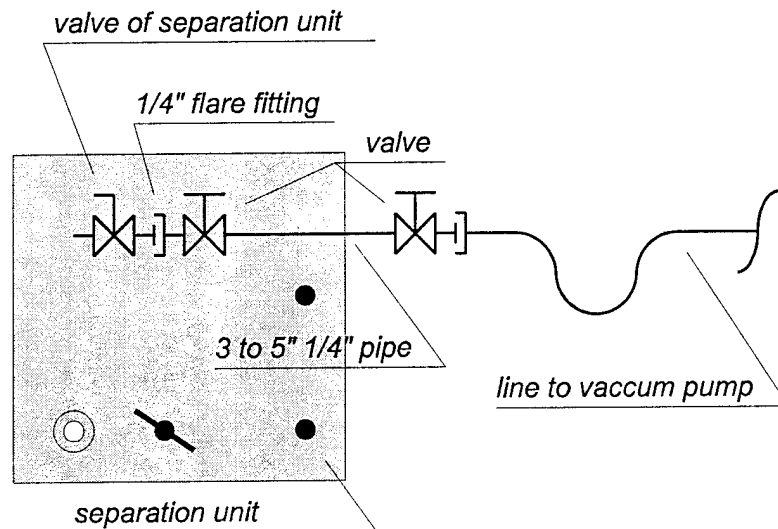


Figure 6: Arrangement for Sampling

1.7 Limitations of Application

This Monitor has been developed for air cooled refrigeration systems operating with single component refrigerants. For operation with refrigerant mixtures which show a significant temperature glide during evaporation and condensation, or for operation with liquid cooled units contact:

Spauschus Associates, Inc.

300 Corporate Center Court

Stockbridge, GA 30281

Tel.: 770 507 8849

Fax: 770 507 9247

1.8: Detailed Views of Separation Unit

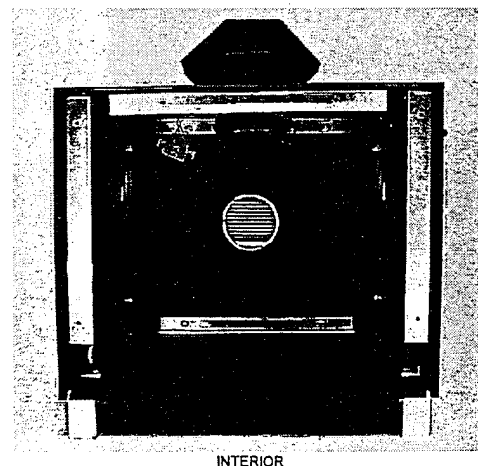
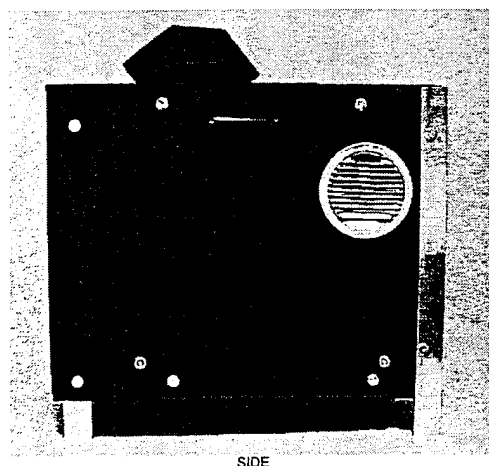
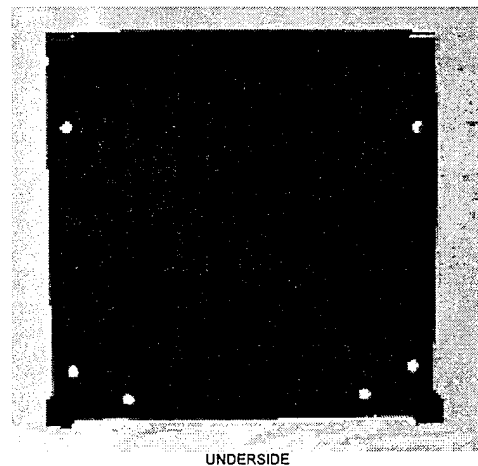
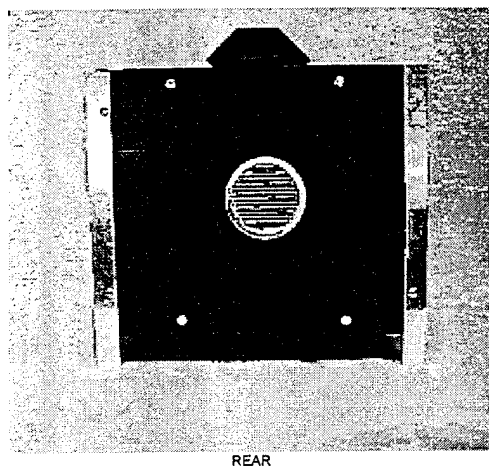
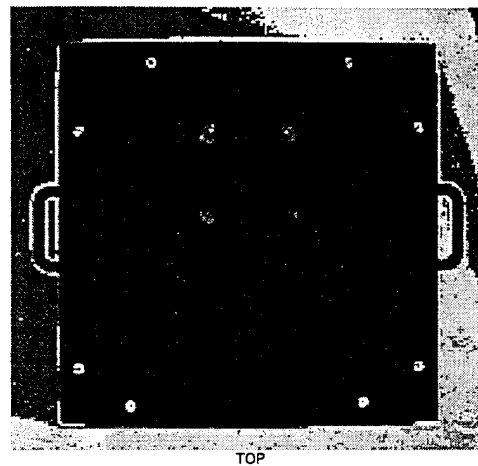
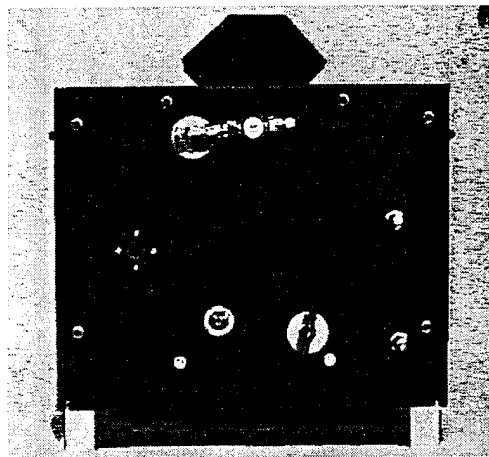
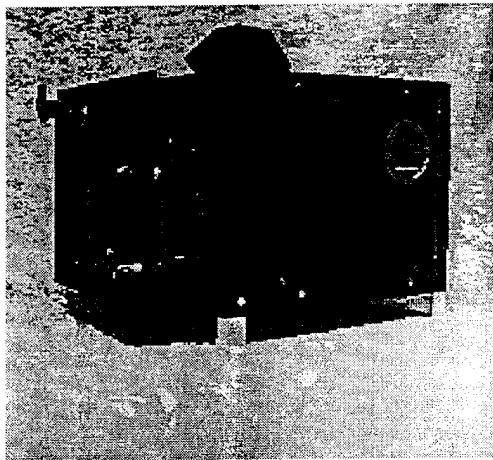
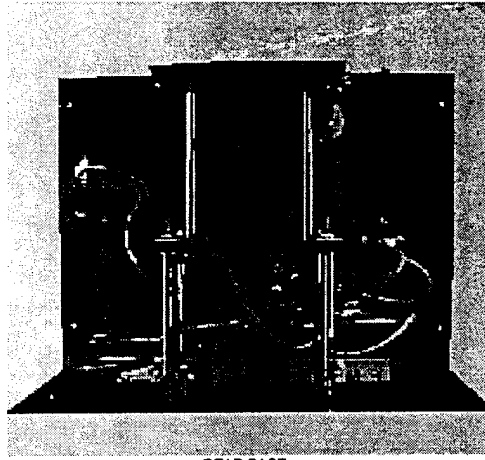


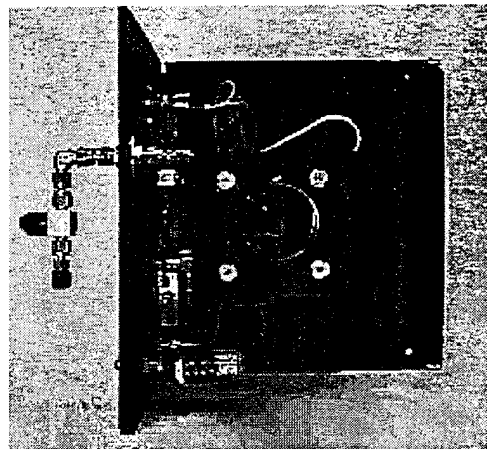
Figure 7: Different Views of the Separation Unit



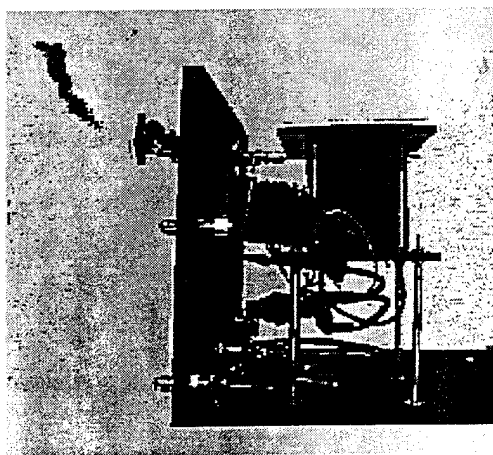
HOUSING W/SLIDING BASE



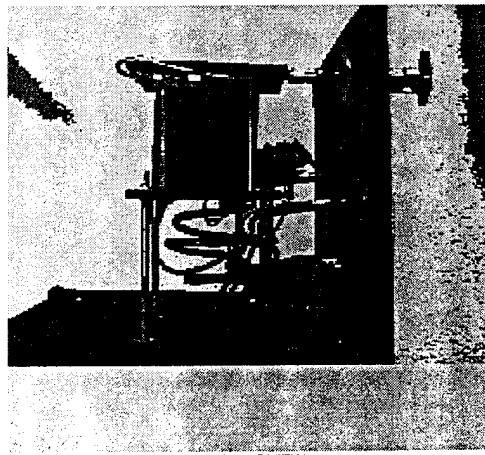
REAR BASE



TOP SPIRAL VIEW



LEFT SIDE VIEW



RIGHT SIDE VIEW

Figure 8: Different Interior Views of the Monitor

1.9: Material Lists for the Separation Unit and Controller

Table 2: SEPARATOR UNIT HOUSING MATERIALS LIST		
Qty	Part Description	Vendor
Components		
6 ft ²	PVC Sheets (6 mm thickness)	U. S. Plastics
1	3" Diameter Vent Cap	Home Depot
3	3" Diameter Louvers	Home Depot
1	Papst Variofan (Model # 8412 GMV)	Allied Electronics
2	Carrying Handles	Home Depot
4	Teflon Spacers	Home Depot
1 male/ 1 female	4 Conductor Molex Connector	Radio Shack
1 set	Runners (1' length)	Home Depot
Fasteners		
48	3/8" Screw Posts	Home Depot
8 ft.	1/8" X 3/4" Aluminum Angle	Home Depot
5 ft.	1/8" X 1" Aluminum Angle	Home Depot
6	8/32" Socket Cap Screw @ 1/2" length	Home Depot
6	8/32" Finishing Washers	Home Depot
8	8/32" Machine Screw Nuts	Home Depot
4	8/32" Machine Screws @ 1" length	Home Depot
Components		
2.5 ft.	1/4" O.D. Stainless Steel Tubing	Supelco
5.5 ft.	1/4" O.D. Copper Tubing	Henri's Hardware
1 ft.	1/8" O.D. Stainless Steel Tubing	Supelco
1	Negative Temp. Coefficient Thermistor	Allied Electronics
1	Temperature Controller	Allied Electronics
1	3" PVC Pipe	Home Depot

Table 2: SEPARATOR UNIT HOUSING MATERIALS LIST

Qty	Part Description	Vendor
1	Sporlan Moisture & Liquid Indicator (1/4" SAE Flare Male X 1/4" SAE Flare Female)	United Refrigeration
1	NUPRO Plug Valve (316 SS 1/4 " Swagelok)	Georgia Valve
1	NUPRO Screw Bonnett Needle Valve	Georgia Valve
4 ft.	8/32" Threaded Rod	Henri's Hardware
Fasteners		
2	Brass AN Bulkhead Union (1/4" Flare to 1/4" Swagelok)	Georgia Valve
3	1/2" X 1 1/2" Fender Washers	Home Depot
4	8/32" Machine Nuts	Home Depot
2	1/4" Port Connectors	Georgia Valve
4	1/4" Nut	Georgia Valve
1	1/4" AN Adapter with nut	Georgia Valve
8	8/32" Anchor Nuts	Home Depot
12	8/32" Washers	Henri's Hardware
1	1/4" to 1/8" Reducing Union	Georgia Valve
1	316 SS AN Bulkhead Union (1/4" Flare to 1/4" Swagelok)	Georgia Valve
4	SAE 1/4" Flare Nuts	Henri's Hardware
1	SAE 1/4" Flare Tee	Henri's Hardware
1	316 SS 1/4" Swagelok Union Elbow	Georgia Valve
1	316 SS 1/4" Swagelok to Flare AN Union	Georgia Valve
1	1/2" Copper Pipe Holder	Home Depot

Table 3: Controller Parts List

Qty	Part	Description
Probes		
2	MTS102	Silicone Temperature Sensor
Board 1		
1	LM324	Quad Low Power Operational Amplifier
1	AD830	High Speed Video Difference Amplifier
1	HE722A0610	Reed Relay DPST-NO with diode suppressor
1	1k Potentiometer	15 turn
1	100k Potentiometer	15 turn
1	100 Ω	1%
1	499 Ω	1%
4	1 k Ω	1%
1	2k Ω	1%
3	10 k Ω	1%
1	20 k Ω	1%
1	100 k Ω	1%
1	1 M Ω	10%
1	.1 μ Farad	Tantalum
2	.01 μ Farad	Tantalum
Board 2		
3	LM339	Quad Comparator
16	100 Ω	10%
11	10 k Ω	10%
1	1 k Ω Potentiometer	15 turn
Board 3		
1	LM339	Quad Comparator
1	MC14536BCP	Programmable Timer
2	HE722A0610	Reed Relay DPST-NO with diode suppressor
2	100 Ω	10%
2	301 Ω	10%
5	5.11 k Ω	10%
1	10 k Ω	10%
1	51.1 k Ω	10%

Table 3: Controller Parts List

Qty	Part	Description
1	75 k Ω	10%
1	.22 μ F	Tantalum
Face Plate		
1	Binary Coded Hexadecimal Switch	Grayhill 26 series switch
1	DPM-1	3 ½ Digit Subminiature Meter
1	SPDT Switch	Momentary Rocker Switch
5	Green LED's	
2	Yellow LED's	
2	Red LED's	
1	Flashing Red LED	
Rear Plate		
1	Piezo Annunciator	4-28vdc 3-18ma
1	On/Off Switch	Rocker Switch
1	5 Pin Din Jack	
1	Amp Jack	Series 2 11-8
Miscellaneous		
1	Case	
3	Pc Baords	
6	Buss Bars	
1	WRI 2731 Power Supply	+5v, -12v, +12v @47-63Hz & 95-250vac
1	Connecting Cable (Amp)	25ft