DOE/NASA CONTRACTOR REPORT

DOE/NASA CR-150871

PRELIMINARY DESIGN PACKAGE FOR RESIDENTIAL HEATING/COOLING SYSTEM - RANKINE AIR CONDITIONER REDESIGN

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Under Contract NAS8-32093 with

National Aeronautics and Space Administration
George C. Marshall Space Flight Center, Alabama 35812

For the U. S. Department of Energy

(NASA-CR-150871) PRELIMINARY DESIGN PACKAGE FOR RESIDENTIAL HEATING/COOLING SYSTEM: RANKINE AIR CONDITIONER REDESIGN (Honeywell, Inc.) 109 p HC A06/MF A01 CSCL 10A

N79-19453

Unclas
G3/44 16433

U.S. Department of Energy

Solar Energy

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SECTION 1
OBJECTIVES

The objectives of the preliminary design review are to:

- Present the iterim design and schedule status of the Residential (3-ton) redesign relative to the proposed concept.

- Discuss problem areas and solutions.

- Define plans for future design and development activity.

SECTION 2
SCHEDULE STATUS

The program is five months into the conceptual design and development phase. The PDR has been moved to April 20th to take advantage of breadboard test results. The initial designs are complete, and development component testing has been initiated.

The Lennox development tasks are on schedule with the exception of the compressor. Poor performance test results combined with a shut down of the York production line have delayed shipment of the modified units and have forced a search for another compressor as backup.

The Barber-Nichols development tasks are on schedule. Testing of the wormgear lubrication system is underway.

See the program schedule Figure 2-1.

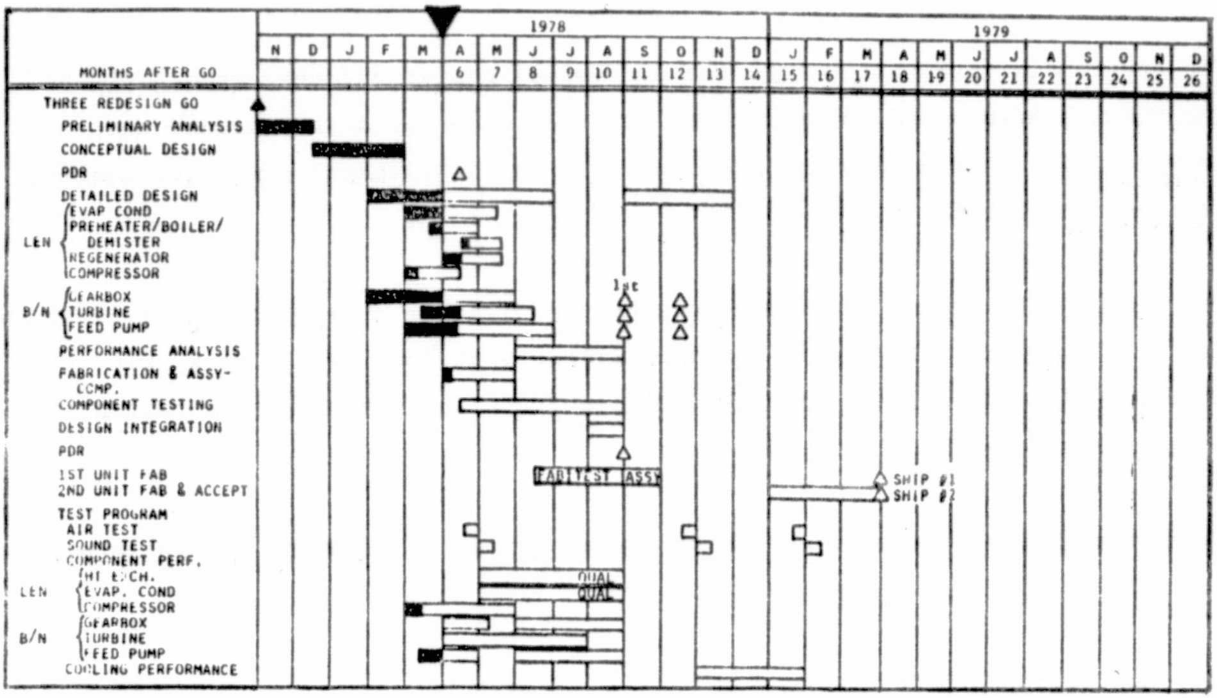


Figure 2-1. Three-Ton Redirect Program Schedule

SECTION 3
SYSTEM BASELINE REVIEW

SINGLE-FAMILY RESIDENTIAL HEATING AND COOLING SYSTEM DESCRIPTION

The proposed system for a single-family residential heating and cooling system is a single-loop, solar-assisted, hydronic-to-warm-air heating subsystem with solar-assisted domestic water heating and a Rankine-driven expansion air-conditioning subsystem. The system is composed of the following major components:

- Liquid cooled flat plate collectors
- A water storage tank
- A passive solar fired domestic water preheater
- A gas-fired hot-water heater
- A gas-fired warm-air furnace with hot-water coil unit
- A rankine-driven direct-expansion air conditioner with auxiliary electric motor and evaporative condenser.
- A tube-and-shell heat exchanger, three pumps, and associated pipes and valving
- A control system
- An air-coiled heat purge unit

The arrangement of components within the system is shown in Figure 3-1. The system consists of a glycol/water collector loop that interfaces with a water storage loop through a tube-and-shell heat exchanger. A domestic hot-water preheat coil is located in the storage tank.

The glycol/water collector loop consists of the solar collectors, the purge coil, pump P1, the Rankine boiler and four control valves as required for the different modes of operation.

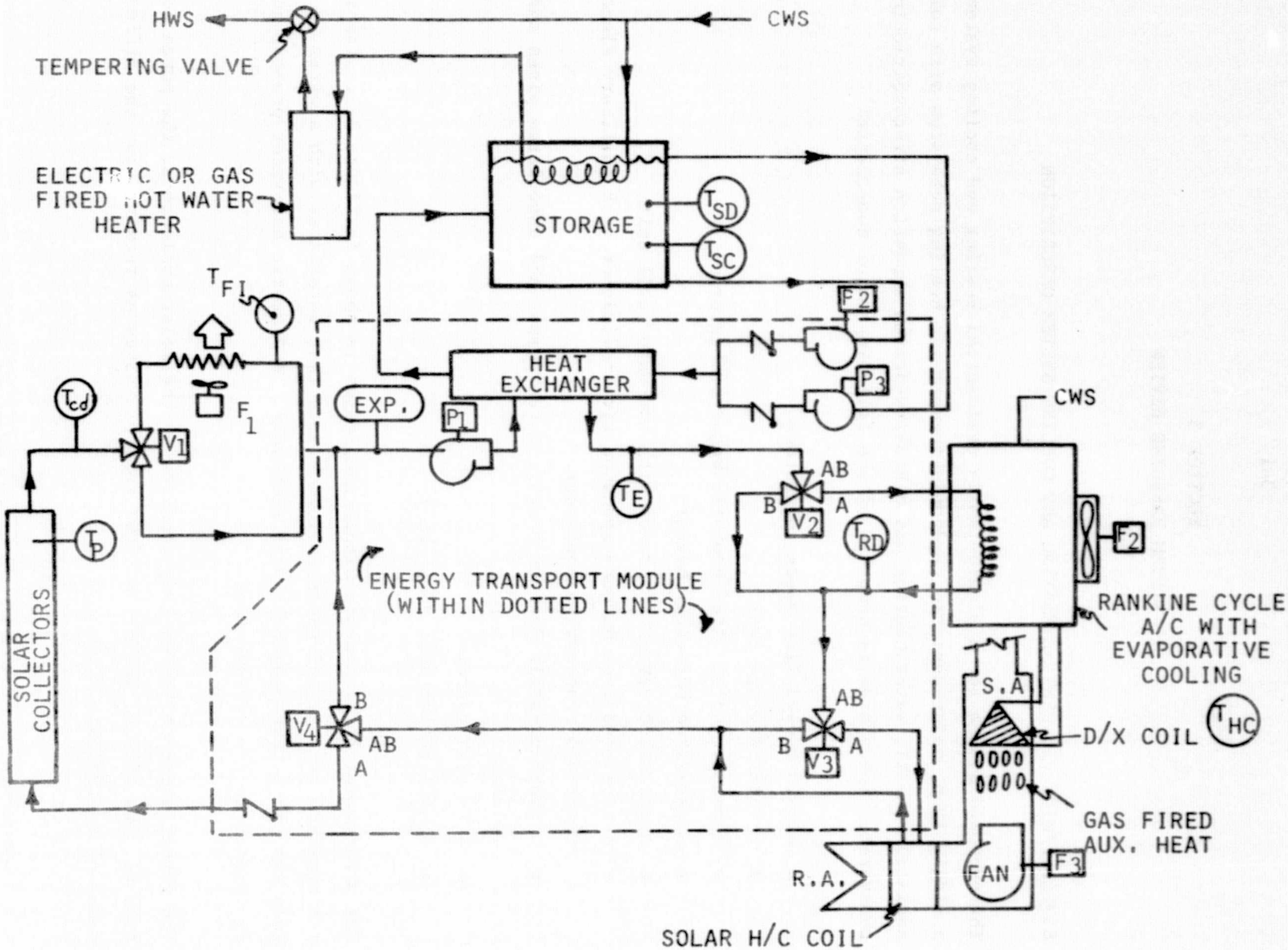


Figure 3-1. Residential Heating and Cooling System

The water storage loop consists of the storage tank, storage pumps P_2 and P_3, and the tube side of the storage heat exchanger.

The system provides 10 modes of operation:

- Direct heating from collectors
- Direct heating from storage
- Direct heating and storage simultaneously
- Auxiliary heating (insufficient solar)
- Rankine cooling from collectors
- Rankine cooling from storage
- Rankine cooling and storage simultaneously
- Electric motor auxiliary cooling
- Domestic hot water preheater
- Purge excess energy.

Heating Subsystem Operation

When solar energy is available and heating is required, the collectors supply heat directly to the furnace through the hot-water coil in the return air duct. Pump (P_1) provides the heat-transfer fluid movement in this loop, and the furnace blower moves the building air through the heat coil. When the heating demand is satisfied, valve V_2 diverts the fluid around the hot-water coil and pump P_2 operates, charging the storage tank by removing water from the bottom, adding energy in the heat exchanger and returning it to the center of the storage tank, thus taking advantage of stratification. During high solar radiation and low heating demand, both heating and storage loop operate simultaneously. If additional energy is still available, the purge coil operates, controlling the downstream temperatures to a preselected value.

When solar energy is not available and heating is required, storage supplies heat to the furnace through the heat exchanger. Pump P_1 drives the outside loop and pump P_3 extracts heat from the top of the storage tank and returns it to the center, again taking advantage of the tank stratification. If the storage tank temperature is not high enough to supply heating, the second-stage thermostat activates the auxiliary furnace until a comfortable temperature is maintained.

Cooling Subsystem Operation -- When solar energy is available and cooling is required, the collectors supply heat directly to the Rankine boiler. Pump P_1 provides the heat-transfer fluid movement. The Rankine drives a high Coefficient-of-Performance (COP) compressor that, in turn, provides conventional direct-expansion cooling. When the cooling demand is satisfied, the system reverts to the storage mode explained in the heating subsystem.

During high solar radiation and low cooling demand, simultaneous cooling and storage is available, using pump P_1 and pump P_2. If additional energy is still available, the purge coil operates by controlling the downstream temperatures to a preselected value. This is an infrequent mode and would occur if coils are oversized for a large heating demand.

When solar energy is not available or is insufficient to operate the Rankine engine at the design horsepower (2. horsepower at 195^{o}F collector outlet), and electric motor will operate the air conditioner independently or to make up the difference between the required horsepower and that supplied by the R/C. Storage is used to supply energy in the same manner as in the heating subsystem. The baseline design uses a constant-speed compressor and, therefore, the electric motor is on-line at all times, supplying the balance of the required horsepower.

SECTION 4
THREE-TON REDESIGN STATUS REVIEW

OBJECTIVES

The primary objective of this effort was to design and develop a marketable single-family cooling subsystem consistent with Lennox manufacturing capabilities and techniques. To achieve this objective, it was first necessary to formulate a design configuration that accomplished a detailed set of objectives relative to the original single-family cooling subsystem. These objectives are:

- Reduce production costs
- Reduce the package size and weight
- Eliminate the cooling tower
- Develop a single-package condensing unit
- Improve system performance
- Reduce maintenance requirements and
- Provide standard Lennox quality and reliability consistent with the advanced design nature of this equipment.

The same team approach on the part of R & D Marketing, and Manufacturing, has been applied to this program that Lennox would normally apply to any product development program.

GENERAL APPROACH

To reduce production costs, the decision was made to fabricate all heat exchangers at Lennox and to attempt to eliminate the boost pump and all best drives.

The decision to fabricate the heat exchangers allows an optimized design, considering performance, cost, and size; and it also creates the possibility of combining components into one compact design. This led to the concept of a single-package preheater/boiler/demister.

Similarly, elimination of the compressor belt-drive required use of a direct-drive rotary compressor, which not only offers the advantages of being compact and low-cost but has been subjected to a modification program to achieve optimum performance and reliability for this application.

Further cost reduction and improved performance is achived by designing a completely new turbine-gearbox utilizing a cantilever, radial-inflow turbine and a high-speed, worm gear configuration.

These design changes have reduced package size and weight; a single-package design is conceivable. The use of a Lennox-fabricated evaporative condenser eliminated not only the cooling tower but also the two-shell-and-tube condensers that served the Rankine and air-conditioning cycles (R/C and A/C).

Except for the turbine gearbox and the feed pump, Lennox is assigned total responsibility for the design and fabrication of all hardware to achieve the following objectives:

- Design for compatibility with Lennox manufacturing methods
- Provide Lennox manufacturing with maximum exposure to the equipment
- Assure minimum package size by eliminating the R/C-A/C module concept.

The turbine gearbox and feed pump are designed and fabricated by Barber-Nichols, who also provides technical support and performance specifications for all additional R/C components.

COOLING SUBSYSTEM OPERATION

Operation

The cooling subsystem consists of two distinct thermodynamic portions, the Rankine-cycle power loop and the air-conditioning loop. The combined RC/AC subsystem is shown schematically in Figure 4-1.

In the Rankine cycle, working fluid is pumped from a water-cooled condenser through a regenerator to the boiler, which extracts heat from solar collector water. The regenerator is a liquid-to-vapor performance improvement heat exchanger operating within the R/C loop. Vapor leaving the boiler is admitted to nozzles that feed a turbine rotor. Turbine exhaust vapor passes through the vapor side of the regenerator and returns to the condenser, completing the Rankine cycle.

Turbine rotational speed is reduced by a gearbox whose low-speed shaft is connected by an overrunning clutch to a motor-generator and air-conditioning compressor. This configuration permits total input power to the A/C loop from the solar-powered R/C. If the R/C system cannot keep up with the cooling demand (i.e., if it is a partially cloudy day), rated cooling can be maintained with the help of the motor.

In the air-conditioning cycle, a compressor receives low-pressure refrigerant vapor from the evaporator (or chiller) and pressurizes it. The high-pressure vapor then enters a water-cooled condenser where the latent heat of vaporization is removed, leaving high-pressure liquid refrigerant. This liquid is allowed to pass through a thermal expansion valve to the low-pressure portion of the loop (i.e., evaporator). The expansion of this high-pressure liquid produces a mixture of refrigerant liquid droplets and vapor at a low temperature (about $45^{o}F$). This low temperature proves sufficient temperature difference to extract heat from air or water, as desired, and thus supplies cooling. The energy taken from the air or water in the cooling process supplies heat of vaporization to the droplets of refrigerant liquid, producing refrigerant vapor. This low-temperature, low-pressure vapor then flows to the compressor, completing the A/C cycle.

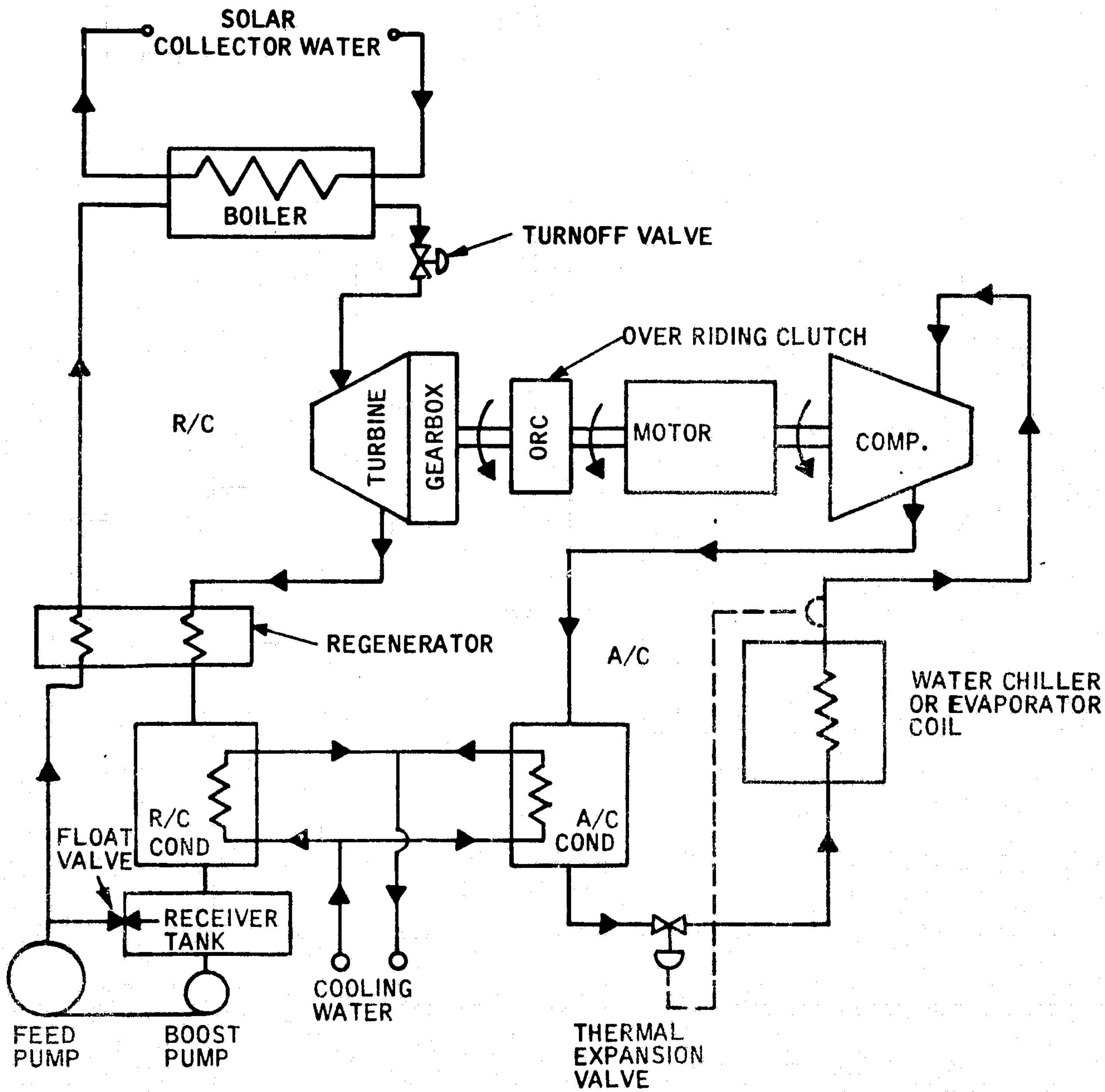


Figure 4-1. General System Schematic for Rankine-Cycle Air-Conditioning System

Working Fluid Considerations Review

Two fluids were originally considered to be viable candidates for use in the Rankine cycle: Refrigerants 113 and 11 (R-113 and R-11). Both are relatively high-molecular-weight fluorinated and chlorinated carbon compounds. Many criteria were used to narrow the large fluid candidate field to these two. The most significant considerations were cycle efficiency, thermodynamic and transport properties, turbomachinery considerations, toxicity, and flammability.

Comparing the two fluids in the temperature range shown in Table 4-1, a 5 percent advantage in cycle efficiency is obtained with R-113. To attain this performance, however, the R-113 requires a regenerator to recover some of the superheat remaining in the turbine exhaust vapor. The R-11 cycle, due to the fluid's thermodynamic properties, contains little or no superheat in the turbine exhaust and so does not require a regenerator.

For the same operating temperatures, R-11 operates at a slightly higher pressure than R-113, as shown in Table 4-1.

Table 4-1. Fluid Operating Temperature Comparison

Heat Exchanger	Fluid	
	R-113	R-11
Boiler pressure at 190°F	47 psia	90 psia
Condenser pressure at 95°F	10 psia	22 psia

This fact favors R-11 because low-pressure condenser systems generally are less attractive from a leakage standpoint.

The same cycle operating conditions also produce different turbomachinery for R-113 and R-11 systems. For the 190°F boiling and 95°F condensing cycle, an R-113 turbine demonstrating 72 percent efficiency and producing three horsepower rotates at 39,000 rpm and is 2.4 inches in pitch diameter, while an R-11 turbine with the same power and efficiency is a 60,000-rpm, 1.6-inch unit. Since gearbox losses increase rapidly with speed, a lower R-113 turbine with the same efficiency is much more attractive. For the three-ton system, the best R/C fluid choice is unquestionably R-113. Its higher cycle efficiency and turbomachinery advantages clearly offset the disadvantages of the regenerator and the below atmosphere condenser.

SIMULATION STUDY AND RESULTS

The original 3-ton Rankine air conditioner design included a comprehensive cycle optimization study. Results of that study are reported in Section 6.11.5 of the heating/cooling PDR document.

The basic cycle was assumed to operate between the temperature limits of the collector-exit design temperature and the temperature of the cooling tower water at 85°F. The design flow rates of the hot source and cold sink were 4 gpm/ton and 3 gpm/15,000 Btu/hr, respectively. A 10°F approach temperature was assumed in both the boiler and the condenser. The pressure loss of the working side was assumed to be 5 percent of the absolute pressure on both the high-pressure side and the low-pressure side of the cycle. The working fluid was R-113 for the 3-ton unit. This choice of working fluid implied the use of a regenerator that had an assumed effectiveness of 0.80. The efficiency of the turbine and pumps were assumed to be 0.72 and 0.50, respectively. This is based on past experience and the analysis described in the turbine and pump sections of this report. The gear-box loss (0.2 horsepower) was included in the analysis, so the design power is the power out of the gearbox. The design power was 1, 2, 3 and 4 hp for the 3-ton unit. Results of this design-cycle computation provided the baseline conditions for the off-design performance calculation.

The off-design computations were carried out for the same conditions as described for the design condition. The plots for the power output and the Rankine-cycle efficiency are shown in Figures 4-2 and 4-3 and design collector-exit temperatures. This represents the typical plot, and the curves for all the other conditions are similar in shape. These curves were used as the input data for the Honeywell simulation program to determine the optimum design temperature and power level. Added to these graphs are curves for a power level of 2.4 horsepower, which was the power selected by the simulation study.

The design parameters selected to guide the first design were:

Solar Water	25% glycol, 190^{o}F @ 4 gpm
Condenser Water	85^{o}F
Rankine HP	2 HP
Rankine Eff.	8%
Motor HP	2
COP (goal)	6
Capacity	36000 Btu/hr

The 3-ton redesign can basically use the same parameters. Honeywell's simulation experience on the Kansas University's 25-ton system pointed out the importance of the Rankine HP to A/C HP relationship and to the importance of minimizing parasitic power.

With this experience, Honeywell conducted a power relationship study, a flow rate study and a COP effect study to determine changes in design parameters.

The Rankine engine size was varied from 0.5 to 2.5 HP. The baseline design parameters were fixed as follows:

Geographical Area	Reno, Nevada
Collector Are	612 ft^{2} @ 30^{o} angle
Solar Water	25% glycol, 195^{o}F @ 3 gpm
Condenser Water	85^{o}F (Evaporative Condenser)

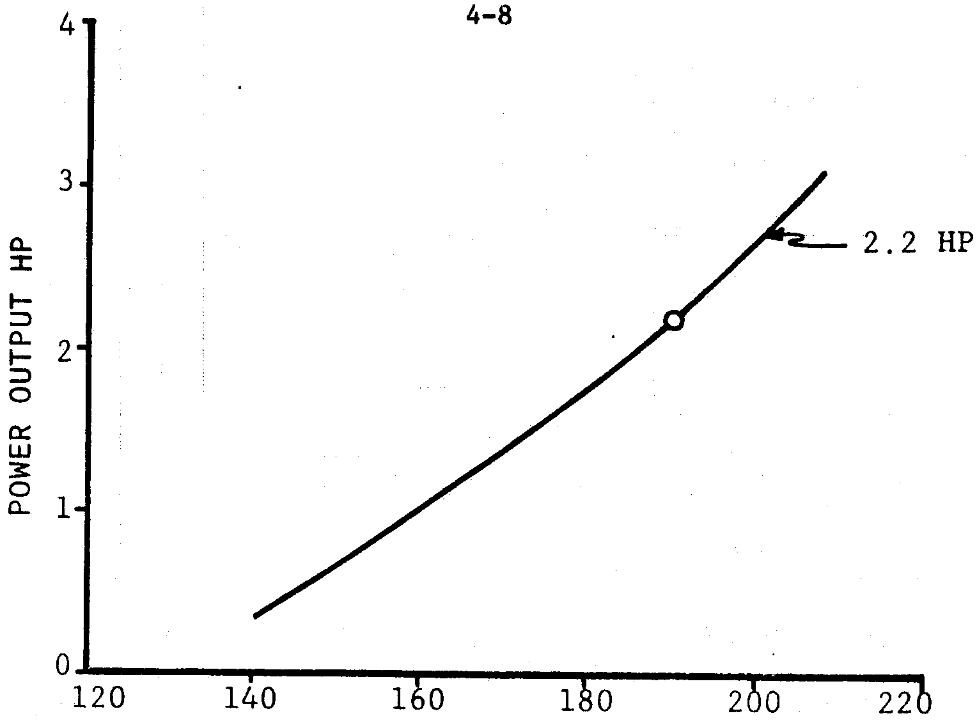


Figure 4-2. Power Output

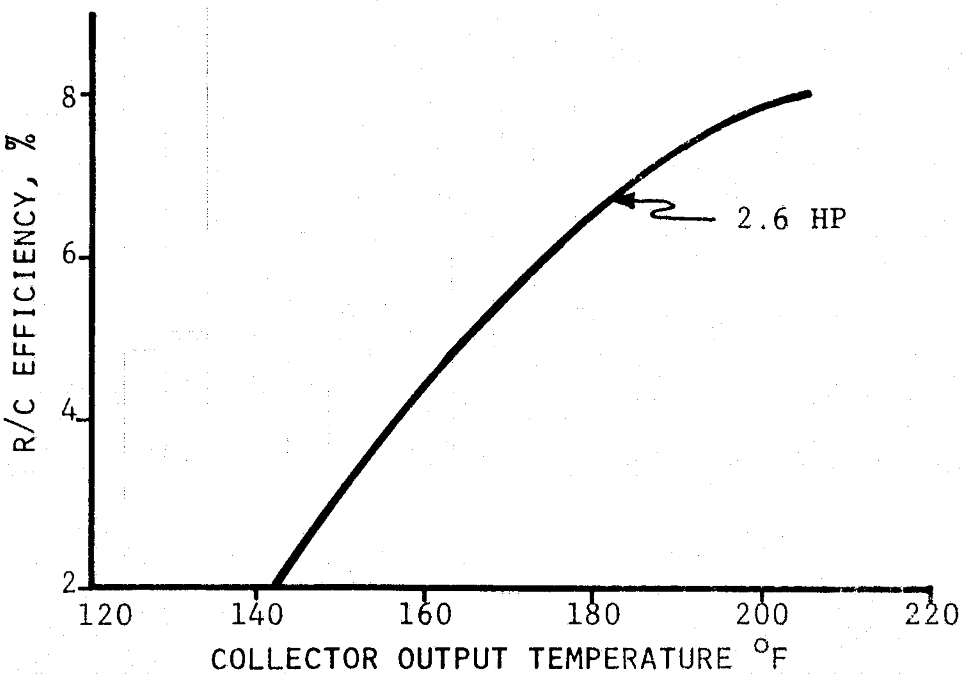


Figure 4-3. Rankine-Cycle Efficiency

Rankine HP (Design)	2.2
Motor HP	2.0
COP	6.0
Capacity	36000 ± 2000 Btu/hr

Results are shown on Figure 4-4. Peak cooling occurred with a 1.1 HP Rankine Cycle. This is the same result that occurred at KU. Apparently the load on most buildings is less than 50% more than 80% of the time that allows the A/C to meet the load with less horsepower. Solar contribution peaks at Rankine input of about half the A/C input because the 1 HP Rankine utilizes energy at a lower rate, allowing it to start earlier, stop later, charge/storage faster and run longer out of storage.

In the case of the 3-ton, designing and fabricating a one HP rankine is impractical because of the relative size of the hardware and the percentage of gear train losses to total output. In addition, a 2 HP rankine provides more downstream applicability and flexibility to larger systems. Therefore, agreement was made to go against the simulation results and build a 2 HP rankine. The same effect (reducing R/C size) can be obtained by reducing the solar water flow as was done at KU. A 30% reduction in flow, 9 gpm to 6 gpm, reduces the cycle efficiency only 5% and the HP 11%. This application philosophy allows the designer flexibility in pump sizing and parasitic power control at no significant loss of solar cooling contribution.

Table 4-2 shows the impact of increasing or decreasing the solar water flow and the impact of a lower COP.

The increased flow gains only 1% in cooling percentage but costs $(12/9)^3$ - 2.37 increase in power required by pump P1. Controlling solar flow relative to economics is site specific but critical to reducing payback. Therefore, the boiler design goal is targeted at 9.

A lower COP of 5.3 (reduced 10%) reduces the solar contribution from 44% to 42% (.5%). This loss is moderately significant and encourages a compressor with as

Table 4-2. 3 Ton Redesign Performance Comparison
Location: Reno Nevada (Modified Lowed)
Collector Area: 612 ft^2

SYSTEM	HEATING LOAD x 10^7 BTU	COOLING LOAD x 10^7	COLLECTOR FLOW, GPM	AIR CONDITIONER COP	RANKINE HP
A (BASELINE)	2.83	7.93	9	5.8	2.2
B (INCR. FLOW)	2.83	7.93	12	5.8	2.2
C (REDUCED COP)	2.83	7.93	9	5.3	2.4

SYSTEM	INPUT TO MOTOR, KW	OUPUT FROM GENERATOR KW	SOLAR CONTRIBUTION		
			HEAT %	COOLING %	WATER
A (BASELINE)	2140	98	90	43	79
B (INCR. FLOW)	2116	91	90	44	78
C (REDUCED COP)	2330	66	90	42	79

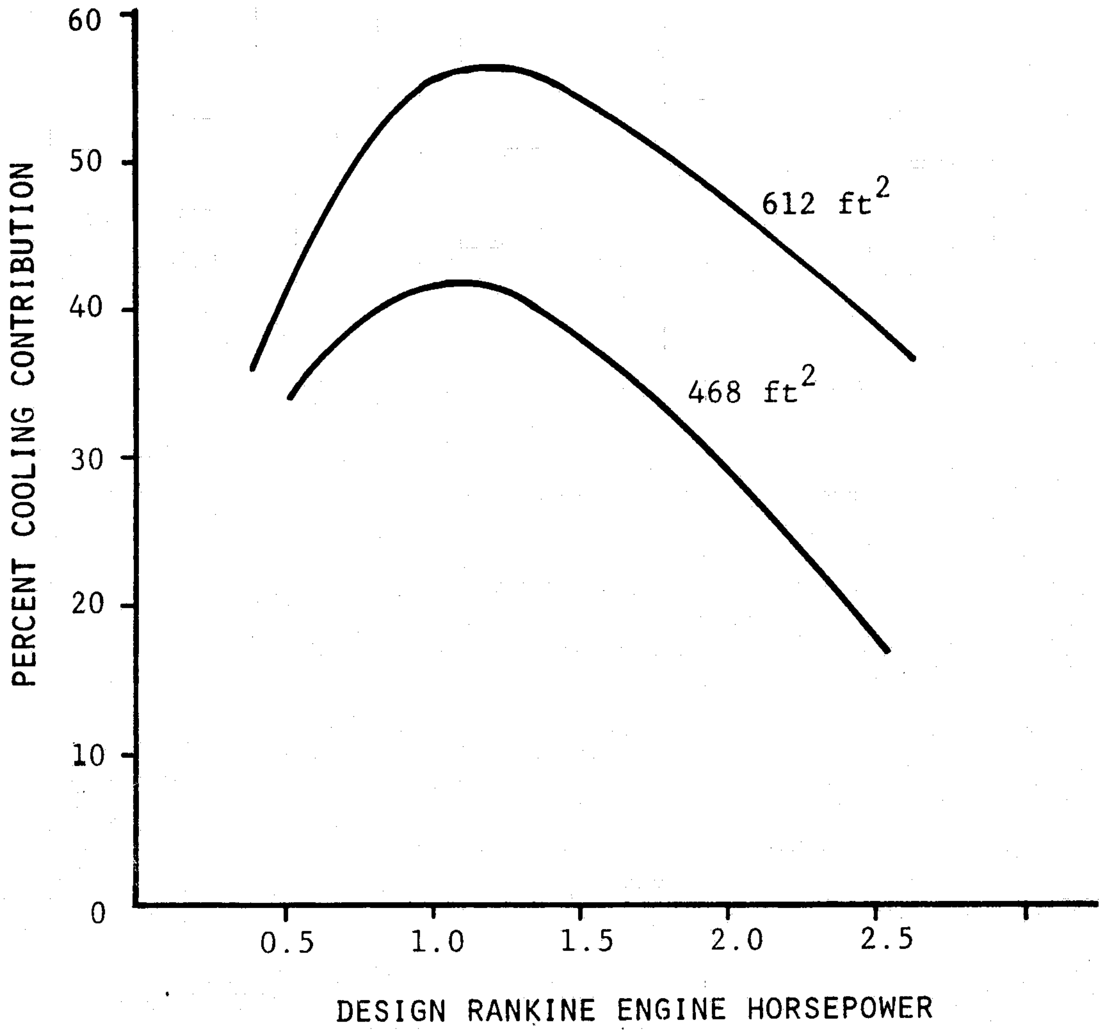


Figure 4-4. Three-Ton, Sacramento 1000-Gallon Storage

high a COP as is practical. Empirical data on various sized compressors indicates the best off-the-shelf performance at 5.1. Modifications should improve the performance to greater than 5.3. COPs of 5.8 or greater are out of reach until an entirely new compressor is designed.

DEVELOPMENT TASK

Evaporative Condenser

Review -- Many factors were considered in arriving at the best method for condensing the Rankine and air-conditioning cycle vapors consistent with maximum system COP, component cost, overall unit size, maintenance, and ease of installation. Condensing equipment commonly vailable includes: air cooled fin-and-tube with associated cooling tower, and evaporative with or without fins.

The comparison chart (Table 4-3) indicates that an evaporative condenser should be thoroughly examined. Obvious advantage are:

- Compact, self-contained, single-package condensing unit
- Maximum efficiency in the vapor cycle Rankine engine and air-conditioning process
- Minimal cost of manufacturing and maintenance.

Table 4-3. Condenser Type Comparison Chart

Consideration	Air Cooled	Water Cooled	Evaporative
Power Requirements per Ton	Highest	Low	Lowest
Condensing Temperature	Highest	Low	Low
Water Tower	No	Yes	No
Water Flowrate (over condenser)	None	3 GPM/Ton	3.7 GPM/Ton
Maintenance	Minimal	Moderate	Moderate
Cost	Least	Most	Medium
Space Required	Extensive	Extensive (with Tower)	Moderate

Ref: Trane Air Conditioning Manual, 1977, pp. 175-176
Refrigeration and Air Conditioning, Jordan & Priester, 1962, pp. 273-275
Refrigeration Fundamentals, ASHRAE, 1971, pp. 439-444

Since two distinct heat transfer processes occur in the evaporative condenser, actual performance and consequently the final effective heat transfer area must be determined by test. Sufficient data is available to estimate the performance by comparing the known values of air-cooled fin-and-tube condensers and water-cooled shell-and-tube condensers.

The size required to reject the heat load for both the Rankine cycle and air conditioner is approximately 10 ft^2 by 12 rows deep of 0.625 O.D. copper tubing using 2400 CFM of air. The fan requires less than 1/5 horse-power differential of 2 psi plus a head of 5 feet, is .08 bhp. Thus, parasitic losses are much lower than with a conventional cooling tower.

Several commercially available evaporative condensers were investigated, but the idea of using one of these is not considered practical because:

- None are available in the size required
- All tended to compromise efficiency for size and cost by using minimum heat transfer surfaces and excessive water pumping rates and air flow.
- Lennox has the capability to design, test, and manufacture an evaporative condenser specifically for the 3-ton cooling subsystem at a favorable cost.

Utilizing a Lennox designed, subcooled Rankine cycle eliminates the potential for pump cavitation and the need for a separate liquid receiver with bypass piping between the outlet of the feed pump and the liquid receiver.

Although exact heat transfer coefficients are not known until the proposed surfaces are tested, the concept is well known and is similar to products currently in use. Figure 4-5 illustrates the proposed concept.

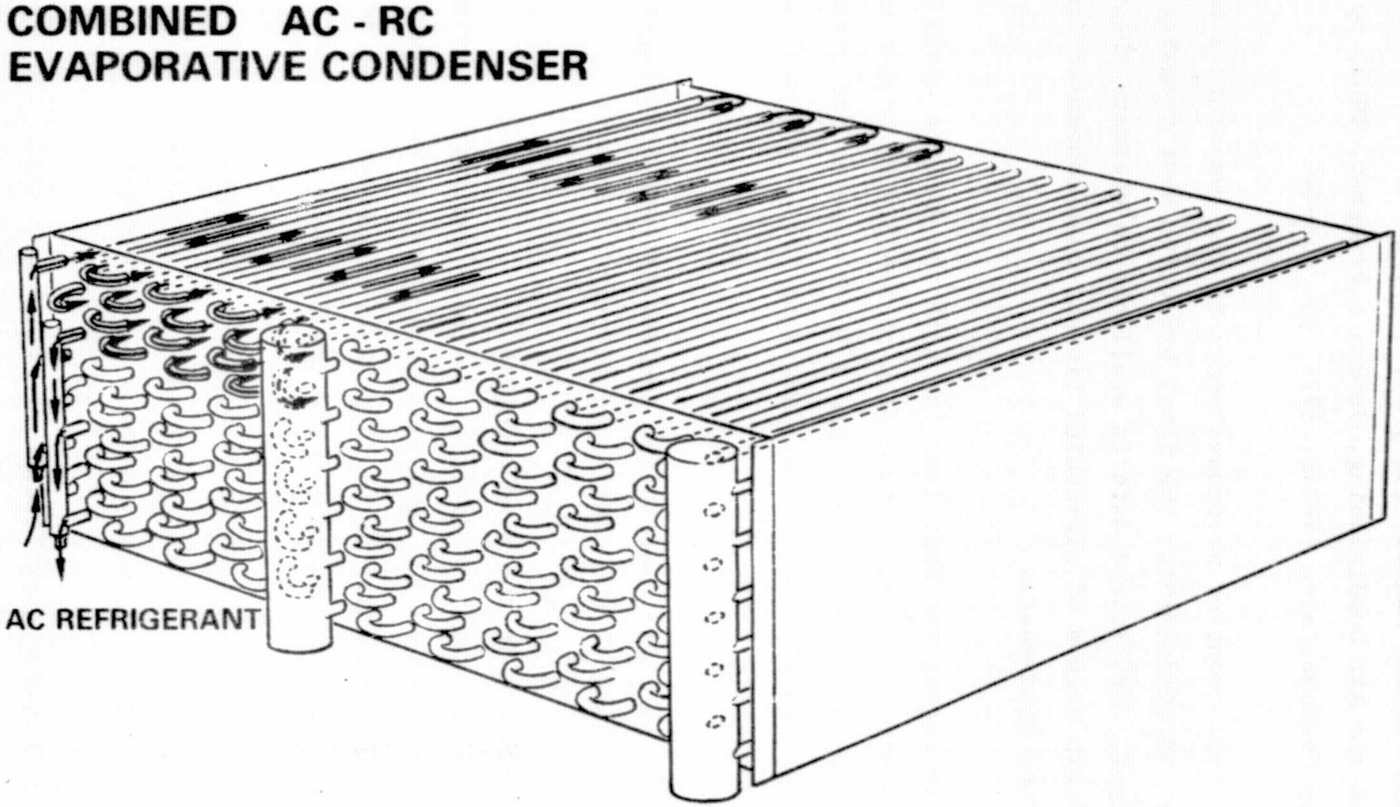


Figure 4-5. Combined AC/RC Evaporative Condenser

Design Status -- Although some literature does exists to predict the performance of an evaporative condenser, there is little data available by which to optimize the design. Such factors as spray water flow rate and air flow rate affect condenser performance as well as pump and fan power. Furthermore, the resulting high values of heat flux dictate a different circuiting technique than is used with conventional air cooled condensers. Therefore, a testing program is required to determine the optimum operating point for a residential sized evaporative condenser.

An evaporative condenser test vehicle has been assembled at Marshalltown. (Figure 4-6). The test vehicle consists of a 22 x 20 inch chamber capable of mounting 4, 6, 8, and 12 row serps of 5/8 inch O.D. copper tubing. The tube pattern is 1.25 inch equilateral triangular centers. A sump at the bottom of the chamber catches the spray water which is then pumped back to the nozzle assembly. Spray water recirculation rate is controlled by a throttle valve while the flow rate is measured by an integrating type meter. Air flow and conditions are controlled and measured by a psychrometric wind tunnel. The above mentioned compressor calorimeter is used to supply superheated refrigerant to the test cell. The water cooled condenser on the compressor is simply disconnected and replaced by the evaporative condenser test cell.

Condenser design points are 125 psia mean condensing pressure (95^{o}F) and 95/75^{o}F entering air conditions. Since the ambient dry bulb is equal to the condensing temperature, there will be no sensible heat transfer and all heat must be transferred by the latent mode. Thus, the sensible heat ratio (SHR) is zero and the maximum attainable psychrometric process line slope (dh/dw) is restricted to the value of the enthalpy of vaporization at the temperature of the evaporating spray water. The spray water, of course, must run at some temperature below the condensing temperature in order to achieve heat transfer out of the tubes and into the water film. Literature and current testing indicate that refrigerant to water temperature differentials as low as 10^{o}F are attainable. This says that spray water will be evaporating at about 85^{o}F with an enthalpy of evaporation (hfg) equal to

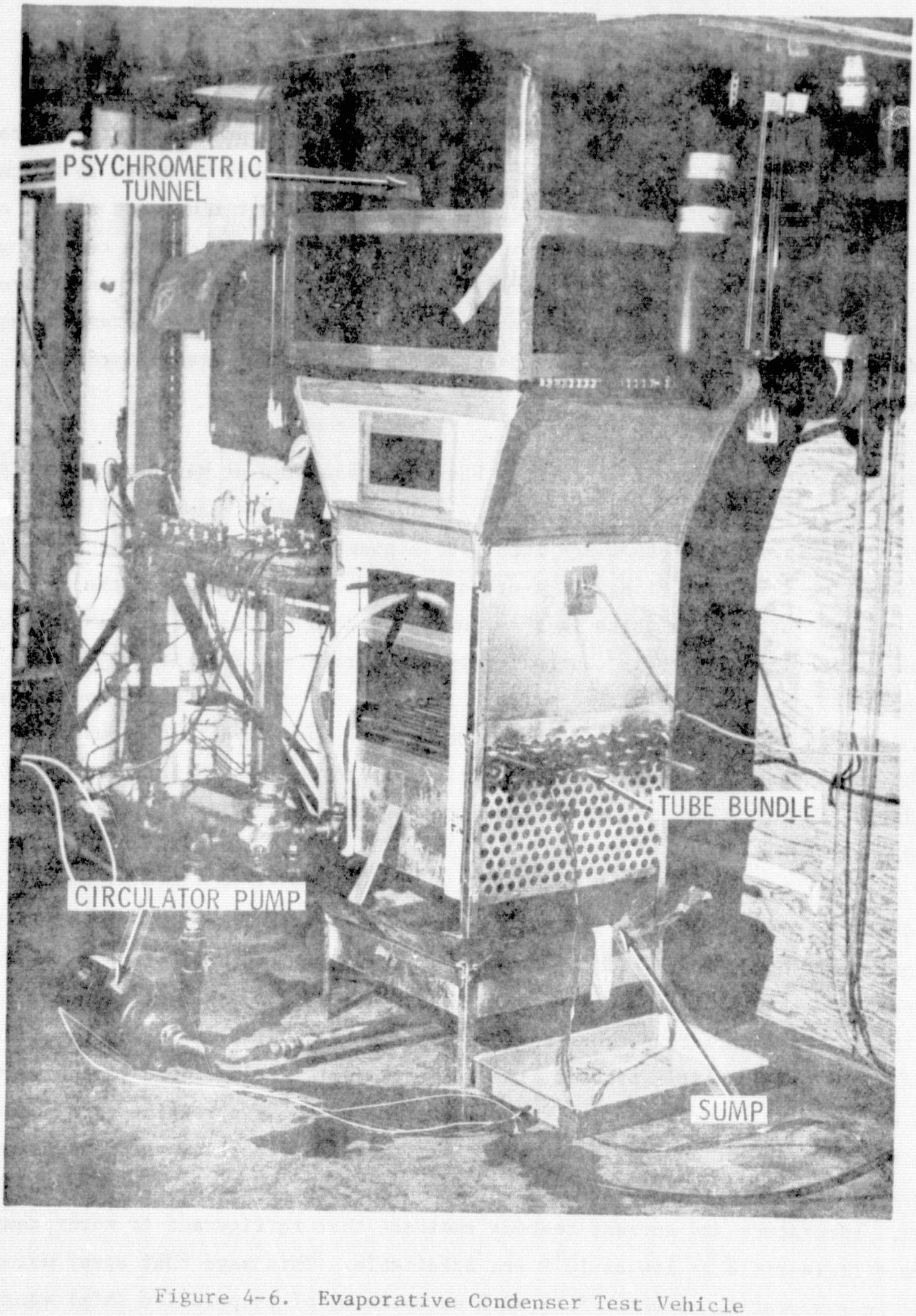


Figure 4-6. Evaporative Condenser Test Vehicle

1045 Btu per pound of water. Thus, the maximum attainable process line slope (dh/dw) will be 1045 $(Btu/lb_a)/(lb_w/lb_a)$. This corresponds to a S.H.R. of -0.05 (Btu/Btu). Furthermore, literature and current testing indicate that by-pass factors as low as 0.1 can be attained. (See Figure 4-7) This results in a useful air enthalpy change of 16.7 Btu per pound of dry air. This says that 860 cubic feet of air must be processed for each 100- Btu's transferred. It also says that 0.96 pounds of water must be evaporated for each 1000 Btu's of heat transferred.

It is not possible, however, to analytically determine the required rate of spray water recirculation, face area, or rows deep to attain the design conditions. Testing is therefore aimed at collecting enough empircal data to enable the selection of the proper spray water rate, face area and rows deep to achieve the design conditions. Test data will also be used to predict system performance on off-design conditions.

At the time of this writing, testing is being done with R-12 for the air conditioning condenser. Once this testing is completed and documented, the vehicle will be converted to test R-113 for the Rankine condenser.

Preheater/Boiler/Demister

Review -- No heat exchanger is commercially available that will combine the functions of the preheater, the boiler, and the demister in a single, compact package; therefore, a new design was proposed. This results in fewer pipe connections, thereby reducing cost, minimizing potential leaks, and reducing energy losses between the boiler and turbine.

Three concepts for a combined preheater/boiler/demister were considered. The first was a pancake coil configuration utilizing concentric tubes. Water flows counter to the R/C working fluid, and the fluid passages are optimized for maximum heat transfer and minimum pressure drop. The pancake is used as a structural member with the most likely location on the bottom or base of the R/C-A/C package.

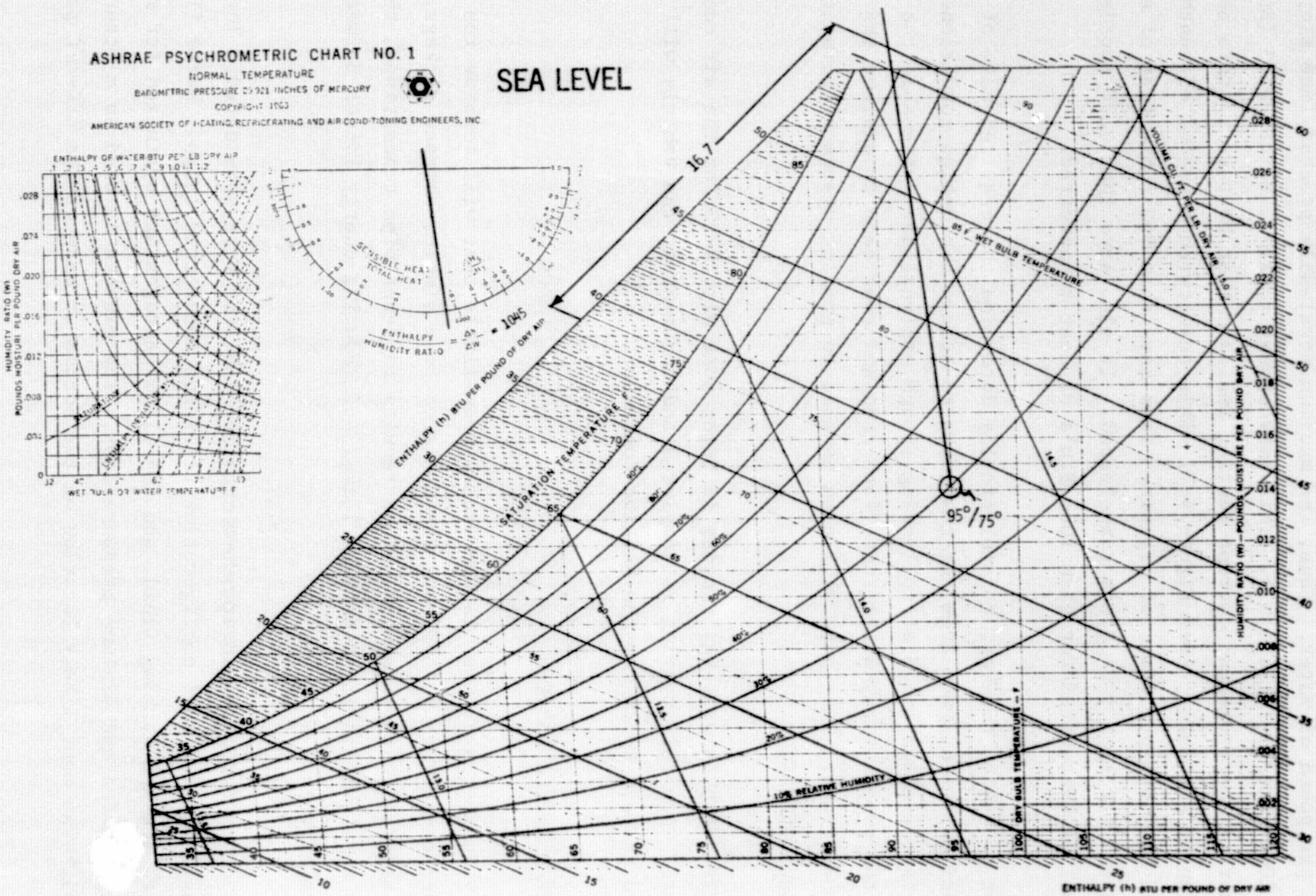


Figure 4-7. ASHRAE Psychometric Chart

Other locations such as the top or side panels are also possible.

The second configuration places the preheater inside the boiler with the cylindrical like outer shell of a normal shell-and-tube configuration. The demister is included in the same shell. This configuration is also used for some of the package structure by mounting other components on it.

The Third configuration utilizes a vapor drum and is similar in concept to a conventional coal-fire steam boiler with the exception that the heat source is hot water. Such a design can be used for one end or wall of the system package.

All of the above concepts have the potential advantage of lighter weight, lower cost, and easier more economical assembly than the conventional procedure of using separate components. Each preheater/boiler/demister uses heat transfer tubing optimized for maximum heat transfer and minimum pressure drop.

Design Status -- Although there are a great many boiler configurations, they can all be categorized under two concepts: flooded boilers and forced convection boilers. Flooded boilers utilize a shell flooded with working fluid in which pool boiling is induced by heated submerged surfaces. In forced convention boilers, boiling takes place as working fluid is pumped through heated tubes or passages. Velocity in these tubes increases as the vapor fraction increases and further contributes to the convection effect.

Several concepts of each type have been considered. Figure 4-8 and 4-9 display examples of flooded and convection designs respectively.

R-113, the working fluid being used, presents several problems not usually encountered with other common refrigerants. The two most noteworthy problems are: 1) the high increase in specific volume upon boiling, and 2) a small change in pressure resulting in a relatively large change in saturation temperature compared to other common refrigerants. The first problem tends to aggravate the second since the higher velocities increase the pressure drop and consequently the temperature drop.

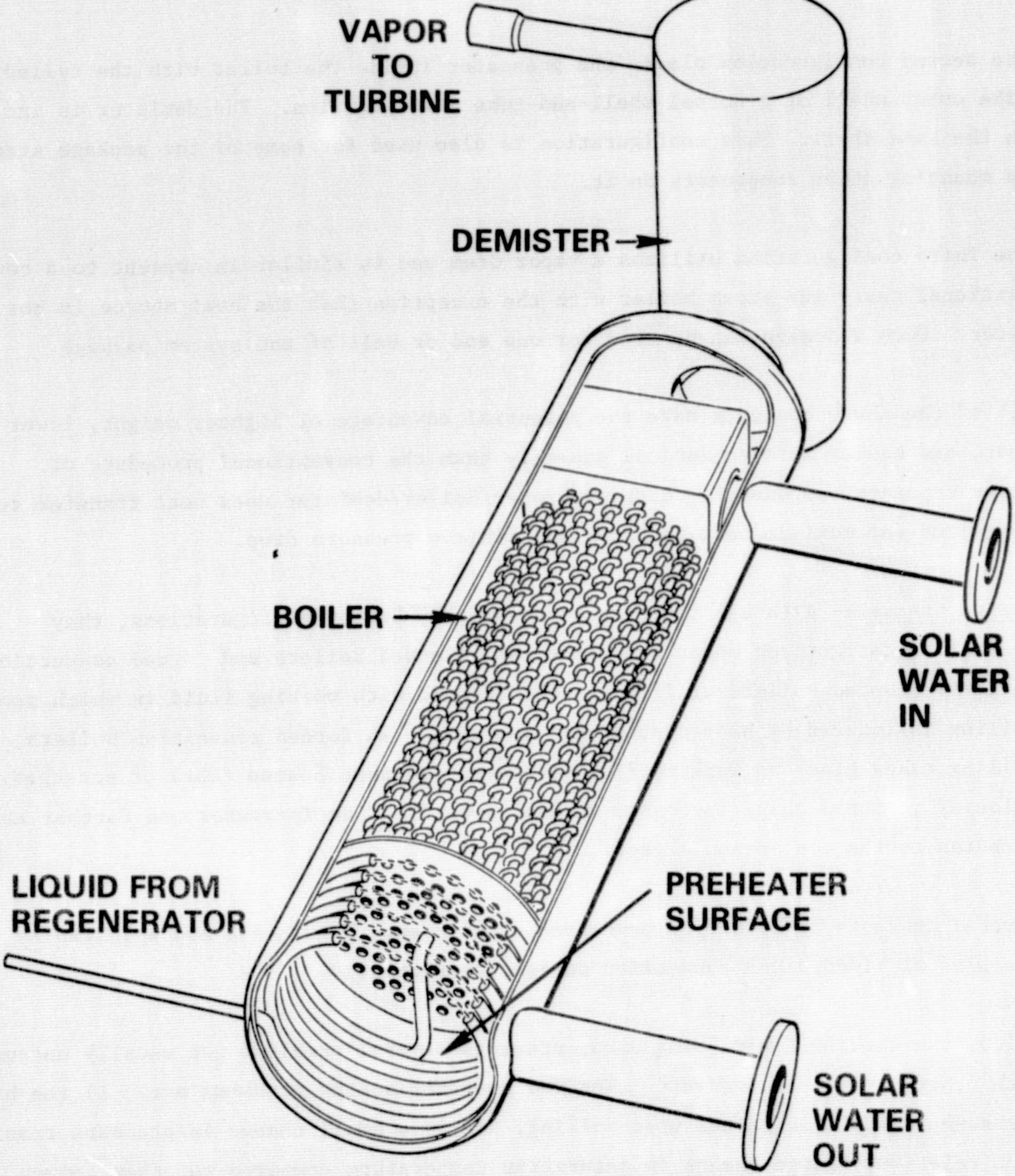


Figure 4-8. Combination Preheater-Boiler-Demister

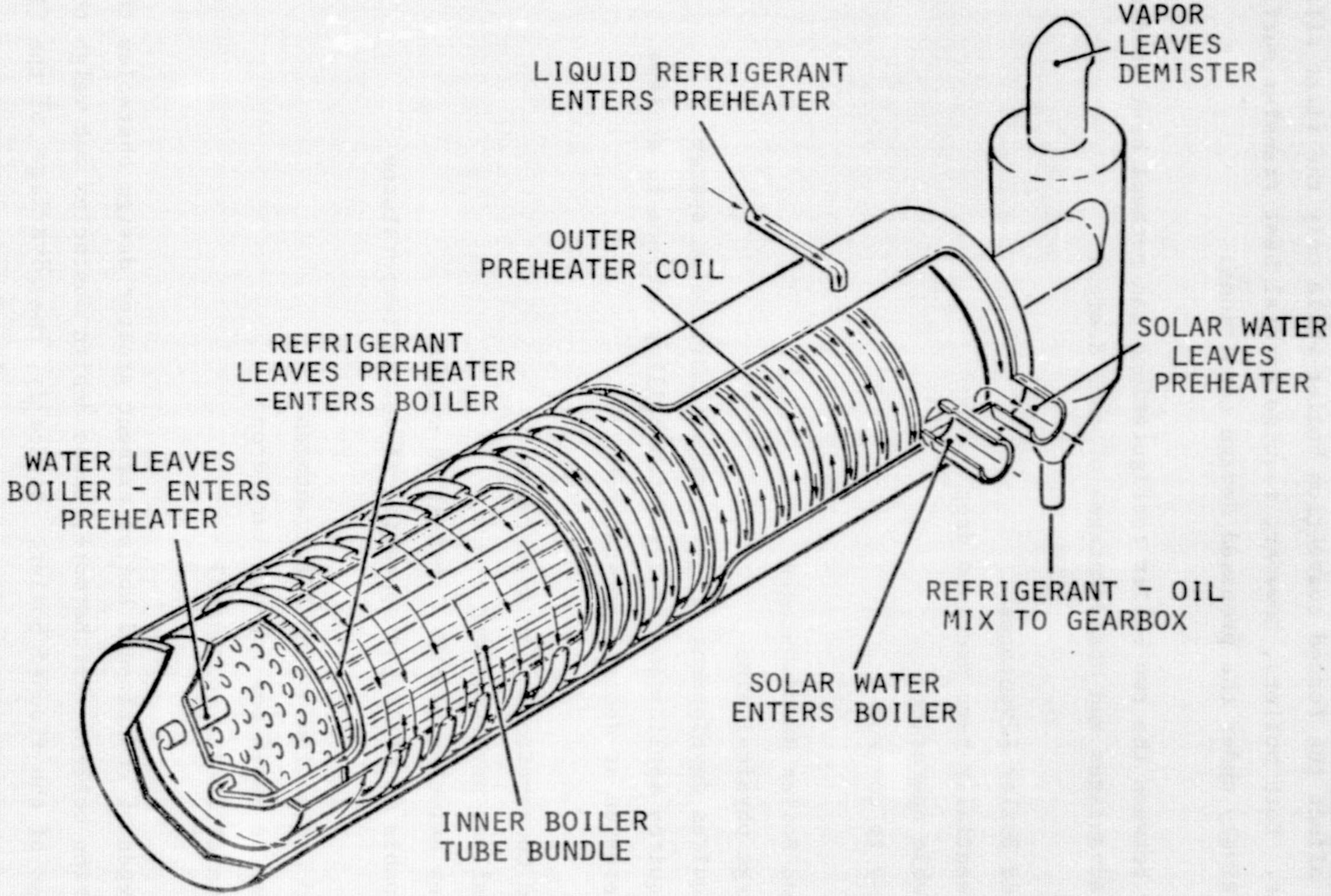


Figure 4-9. Convection Type Boiler

Both problems affect the forced convection boiler while only the first affects the flooded boiler. Both boilers, however, require special heat transfer surfaces to perform effectively under the proposed design conditions.

The tradeoffs between the two boiler configurations can perhaps best be displayed by a list of advantages and disadvantages of each design.

- Flooded Boiler Advantages
  - essentially zero pressure drop
  - stable operation
  - easy to control

- Flooded Boiler Disadvantages
  - large physical size
  - requires development of new gearbox lubrication system
  - requires application of augmented boiling surface to achieve operation at design temperatures

- Forced Convection Boiler Advantages
  - smallest physical size
  - uses existing gearbox lubrication system
  - capable of efficient operation at design temperatures

- Forced Convection Boiler Disadvantages
  - must be optimized for pressure drop
  - more difficult to control

The disadvantages of the flooded boiler present greater design obstacles than those of the convection boiler. Furthermore, these design obstacles out weigh the potential advantages of the flooded boiler. Basically, the advantage of the flooded boiler is its stable operation and ease of control. The zero pressure drop feature really only amounts to an obstacle which does not have to be designed around.

Two of the disadvanatages of the flooded boiler design present some risk. The present gearbox lubrication system will not work with a flooded boiler and would have to be redesigned. The alternate lubrication design has never been tried and would require a certain amount of development time. The augmented boiling surface is also unproven with some experimenters reporting that surface performance degrades with age.

Advantages of the forced convection boiler, on the other hand, tend to outweight the disadvantages. The physical size of the convection boiler is less than half that of the flooded boiler. The convection boiler uses the existing gearbox lubrication system which is a known entity. Like the flooded boiler, the convection boiler also requires an augmented surface to achieve efficient operation at design temperatures. This surface, however, is commercially available and has been demonstrated successful in other applications.

The disadvantages of the convection boiler do not present the risk that those of the flooded boiler do. The problem of optimizing heat transfer against pressure drop is one of running some tests to obtain the necessary empirical data. The problem of controlling a convection boiler is a matter of applying existing knowledge. Techniques similar to those used on the 25 ton system will be used.

In light of the above discussion, effort is being channeled towards the forced convection boiler design. Special boiling tubes with augmented surfaces are currently being shipped to Barber-Nichols in Denver where tests will be conducted to determine the optimum heat transfer to pressure drop ratio.

Boiler design points are 195^{o}F entering mix of 25% glycol-water, 9 gallons per minute flow rate, 178^{o}F mean boiling temperature, and 2 psi boiling pressure drop. The following curve shows the relation of water flow rate and boiling pressure drop to the required UA value of 6400 (Btu/hr $\cdot$ Ft^2 $\cdot$ ^{o}F) is attainable. This says that 40 square feet of heat transfer surface is required. Limiting the boiler tube length to three feet, requires 102 half-inch tubes or 82 five-eighths inch tubes.

The tubes must be restricted in some way to maintain high mass velocities required for the "U" value of 160 (But/hr · Ft^2 · ^oF). The required mass velocity is about 57,000 (Lb/hr · Ft^2). When using the design mass flow of 1040 Lb/hr, the refrigerant cross area must be about 0.018 square feet. Thus, the half-inch tubes must be about 83% obstructed while the five-eighths-inch tubes must be about 87% obstructed. This is most easily accomplished by placing a solid rod of the proper diameter in each tube. An alternate method is to place a second tube inside of each boiler tube and then route glycol-water through the inner tubes as well as over the boiler tubes. The concept greatly increase the ratio of heat transfer surface to heat exchanger volume resulting in a physically smaller heat exchanger. This concept is currently being analyzed for manufacturability and is tentatively considered to be a backup design to the scheme using dead rods in the tubes.

A sketch of the forced convection boiler design appears in Figure 4-9. The heart of the boiler is the tube bundle in the center. Hot water from the collectors is routed through the baffled area within the tube bundle while refrigerant boils inside the tubes. The preheater is a helical coil around the boiler tube bundle. Water leaving the boiler enters the counter flow preheater and runs between the helix on its way out of the boiler. Liquid refrigerant runs inside the helix tube on its way out of the boiler. Liquid refrigerant runs inside the helix tube and is brought close to saturation prior to entering the boiler. Calculations indicate the preheater helix to have a center-to-center diameter of 7.5 inches and a pitch of about 10 turns per foot. The boiler tube bundle will consist of either one-half or five-eighths inch O.D. copper tubing per the dimensions mentioned above.

At this time, the demister will be a separate vessel welded to the end of the boiler. The concept of incoporating the demister into the preheater-boiler shell is being investigated.

Regenerator

Review -- Redesign of the regenerator offers the distinct advantage of direct coupling the turbo-gearbox to the regenerator. This arrangement is compact and provides a structural member for mounting the drive-train, which consists of the turbo-gearbox, the motor, and the compressor. Component assembly is facilitated, and potential sources of refrigerant leaks and oil traps are eliminated. Energy losses are minimized because interconnecting tubing is minimized. Functionally, the heat transfer effectiveness is not improved by the new regenerator, but the manufacturability is improved, resulting in a device that costs considerably less than any presently available and permitting a more integrated package.

Two configuration were to be studied: 1) The turbine is mounted on an outer shell and is direct-coupled to an internal rectangular tube placed between two conventional fin and tube heat transfer surfaces; and 2) the turbine is mounted on an outer shell and is direct coupled to an internal tube placed inside an extended surface spiral tube. In either concept, part of the function of a liquid preheater is incorporated automatically. Development risks are minimal as the proposed designs are similar to existing hardware.

Design Status -- Refrigerant 113, when used as a Rankine cycle fluid, develops enough superheat at the turbine exhaust to require a regenerator for efficient operation. The regenerator desuperheats the turbine exhaust and transfers the heat to the liquid entering the preheater. This reduces the amount of energy rejected by the condenser and required by the preheater. In effect, the regenerator limits the "short-circuit" heat path from the preheater to the condenser.

The regenerator is an interesting heat exchanger in that the two flow streams have identical mass flows. Since one stream is liquid and the other is vapor, some type of extended surface is desirable on the vapor side. Ideally the regenerator should desuperheat the turbine exhaust all the way to the condensing temperature. It is more practical, however, to enter the condenser with a few degrees of superheat. This insures that no condensing occurs in the regenerator which could increase pressure drop and affect turbine performance.

Currently the regenerator is designed to an effectiveness of 55%. This yields a superheat of some 19^{o}F entering the condenser. The current design is capable of being modified to yield higher effectiveness without drastically changing the production technique.

Two regenerator concepts have been examined. The first is a helix of finned tubing wound around a cylindrical baffle (Figure 4-10). The vapor passes through the finned area while liquid runs inside the tubing. Counterflow heat exchange is easily attained and the design is straight forward from a manufacturing standpoint. However, the nature of the design requires the outside shell to be 12 inches in diameter and 14 inches in length.

The other design incorporates a finned tube core inside of a cylindrical shell (Figure 4-11). This design utilizes a bank of small finned tube coils circuited for counterflow. Calculations indicate the outside shell will be 8 inches in diameter and 14 inches in length.

The finned tube core design is presently being analyzed for manufacturability since it represents the smallest size and the design best suited to existing Lennox tooling.

Compressor

Review -- York Automotive Division of Borg-Warner has begun production on a multi-vane rotary compressor that permits direct-drive coupling between the electric motor and the compressor. To achieve maximum efficiency, two modifications to the existing design must be made:

- Add an external oil separater for an efficiency improvement of approximately 5%.
- Eliminate a suction pressure port, which is required to extend the vanes at speeds less than 1500 RPM, for an efficiency improvement of approximately 2%.

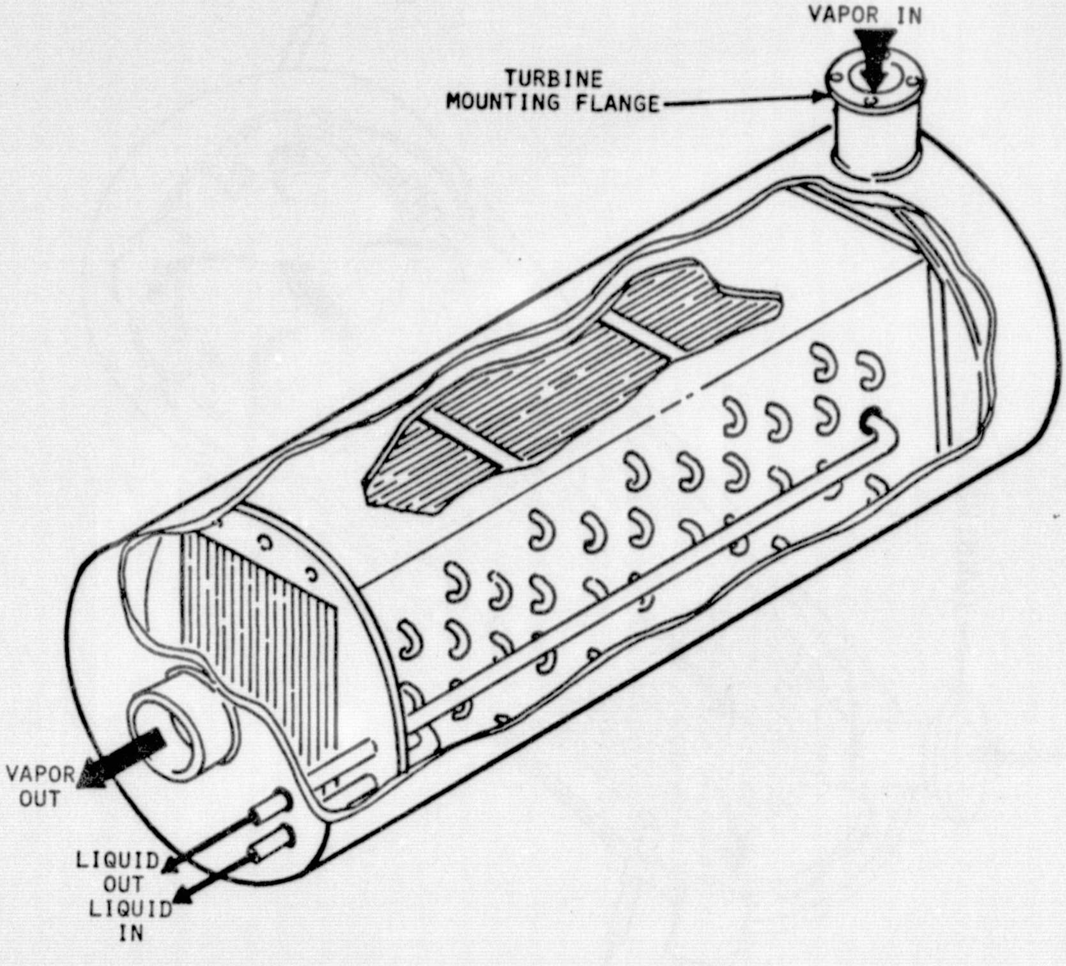


Figure 4-10. Regenerator Finned Tube Core Design

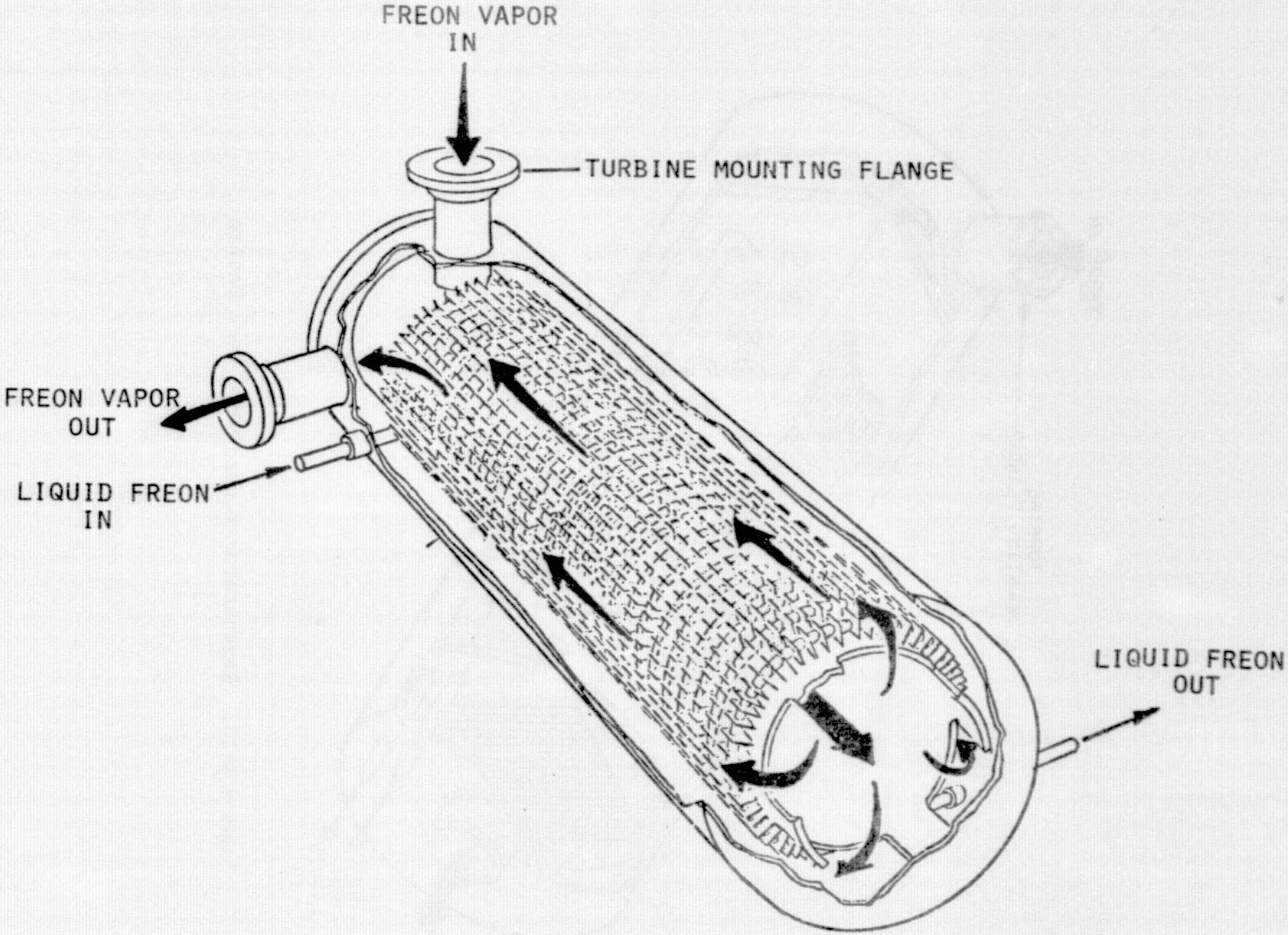


Figure 4-11. Regenerator

These two modifications were expected to result in a compressor efficiency of 72%. If efficiency is increased 4% due to elimination of the belt drive, the total compressor efficiency is approximately 76% compared to 62% for the current belt-driven reciprocating compressor.

The compressor is operating at 1725 RPM (which is compatiable with commercially available 4-pole, high-efficiency electric motors) to achieve a capacity of approximately 36000 Btuh at a COP of about 6.0.

Summary of Advantages:

- Relatively high efficiency--76% direct coupled
- Low cost--approximately $55.00 ($180.00 for current reciprocating compressor)
- Relatively small--7 1/4 long (including 1 5/16" shaft length) x 5 5/8" wide x 5" high
- Light weight and easy to mount with 0.0055" permissible misalignment.

The impact of this compressor on package size, cost, and performance for the 3-ton cooling subsystem is significant. Also, the compressor is a known entity, and minimal technical risk is involved in the applications. Figures 4-12 and 4-13 show the compressor.

Design Status -- The 3-ton redesign calls for the use of the low-cost high-efficiency compressor. A York rotary automotive compressor is specifically named. Automotive compressors are typically half the cost of comparably sized refrigeration compressors. Automotive compressors are also very rugged and built to take a great deal of punishment due to the nature of their application. Until recently, however, efficiency has not been a strong point or even a concern with automotive compressors. Some of the newer designs, such as the York, have been designed for high efficiency. This feature, along with low-cost and rugged design make the compressor an attractive candidate for the cooling subsystem application.

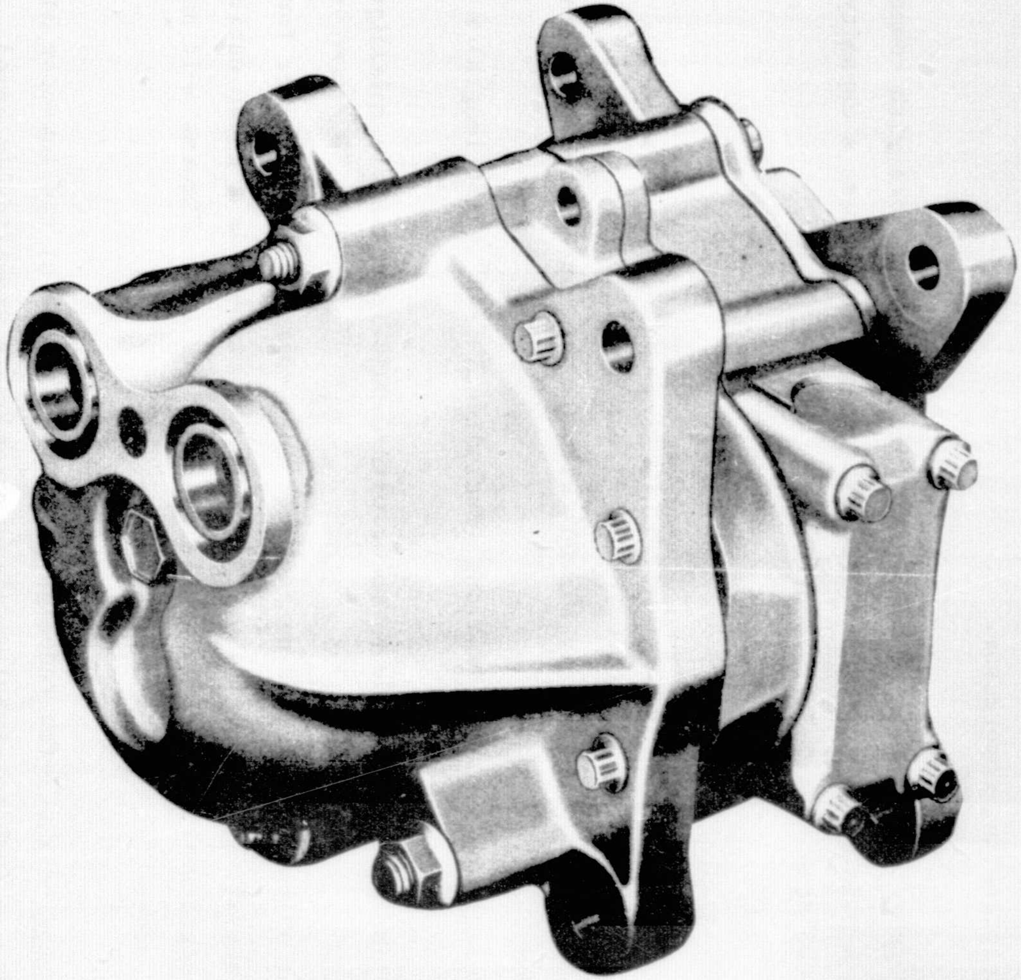


Figure 4-12. Multivane Rotary Compressor

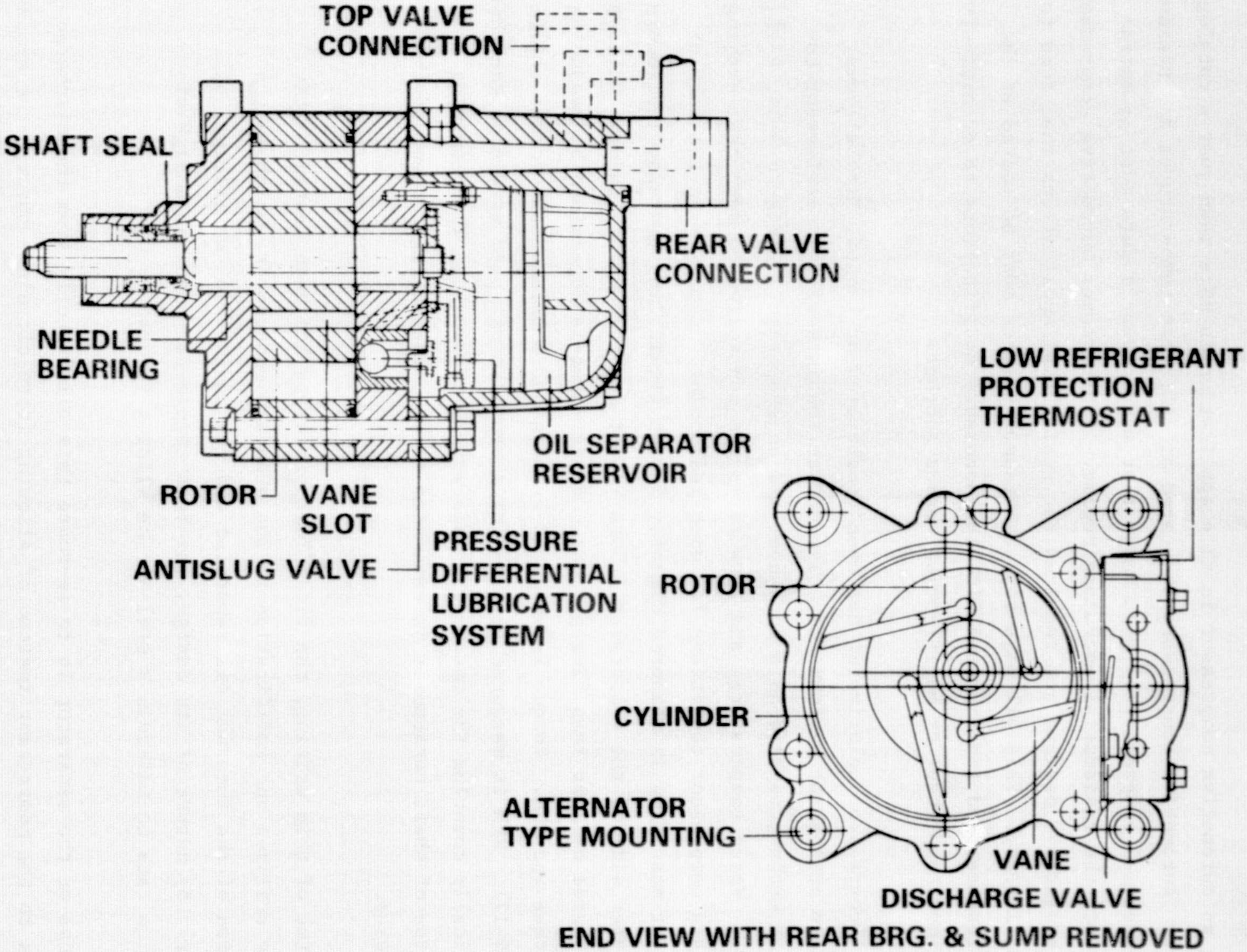


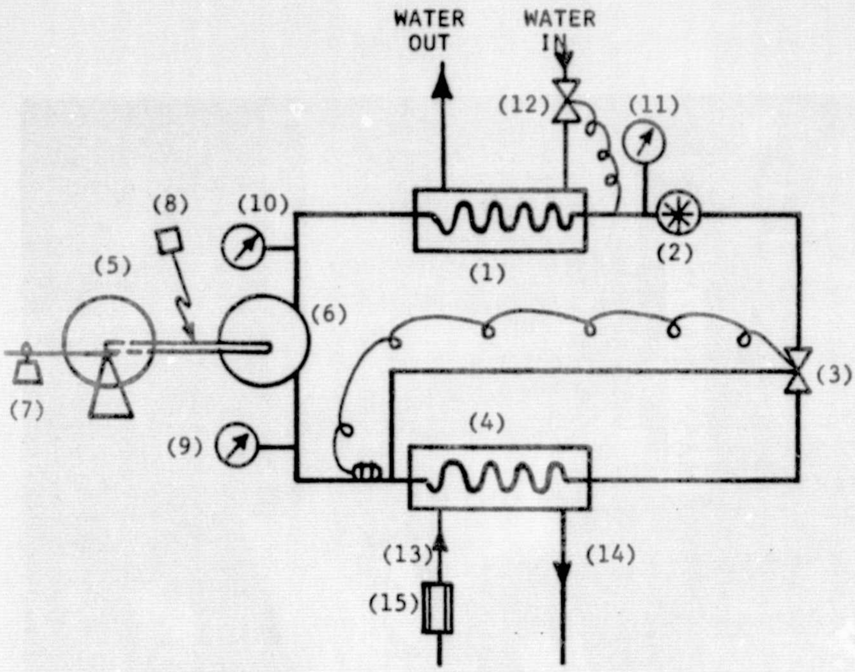
Figure 4-13. Schematic of Multivane Rotary Compressor

Applying an automotive compressor in this application is more than just a catalog procedure. Automotive compressors are rated at different temperatures and pressures than residential compressors. This means that manufactuer's data must be extrapolated into the residential operating regime. Furthermore, automotive compressors contain protective devices not required for residential applications that tend to reduce efficiency. This all says that compressor samples must be tested at the proper pressures and temperatures with the necessary modifications to effectively evaluate one compressor or modification versus another.

A special compressor calorimeter has been constructed at Lennox, Marshalltown, to evaluate compressor performance. The device consists of two refrigerant-to-water heat exchangers used as a condenser and an evaporator. (Figure 4-14, 4-15, and 4-16). Water temperatures and flow rates are controlled to each heat exchanger to maintain compressor conditions for each test point. Capacity in the form of refrigerant mass flow is measured directly in the liquid line and also indirectly on the water side of the evaporator. Data is not recorded unless the two measurements disagree by less than five percent. Power input is determined by measuring shaft torque and RPM. Torque is measured by means of a balance and torque cradle (Figure 4-17). RPM is measured by flashing a synchronous speed strobe on the shaft and physically counting the motor slip rate with a stopwatch. The resulting calculation of shaft horsepower is estimated to be within three percent of the actual value.

At the time of this writing, the first York prototype has been tested. This prototype utilizes one modification to the standard compressor, which is the elimination of the internal oil separator and the addition of an external oil separator. By nature of its design, the York compressor requires a high oil circulation rate to maintain a seal at the sliding joints.

The purpose of the separator is to re-route this oil directly from the discharge line back to the compressor instead of allowing it to circulate through the system where it degrades heat exchanger performance. York believes the external separator



CODE	DESCRIPTION	MEASUREMENTS
1	CONDENSER-WATER COOLED	A. MOTOR
2	MASS FLOW METER	WATTS
3	THERMOSTATIC EXPANSION VALVE	AMPS
4	EVAPORATOR-STEAM HEATED	B. SHAFT
5	CALIBRATED MOTOR	RPM
6	COMPRESSOR ON TEST	TORQUE
7	SHAFT TORQUE DEVICE	C. SUCTION
8	STROBOTACH-SHAFT RPM	TEMPERATURE
9	SUCTION TEMP. & PRESSURE	PRESSURE
10	DISCHARGE TEMP. & PRESSURE	D. DISCHARGE
11	LIQUID LINE TEMP. & PRESSURE	TEMPERATURE
12	HEAD PRESSURE REGULATOR	PRESSURE
13	WATER TEMPERATURE IN	E. LIQUID LINE
14	WATER TEMPERATURE OUT	TEMPERATURE
15	WATER FLOW RATE	PRESSURE
		MASS FLOW
		F. WATER
		TEMPERATURE RISE
		MASS FLOW

Figure 4-14. Compressor Calorimeter

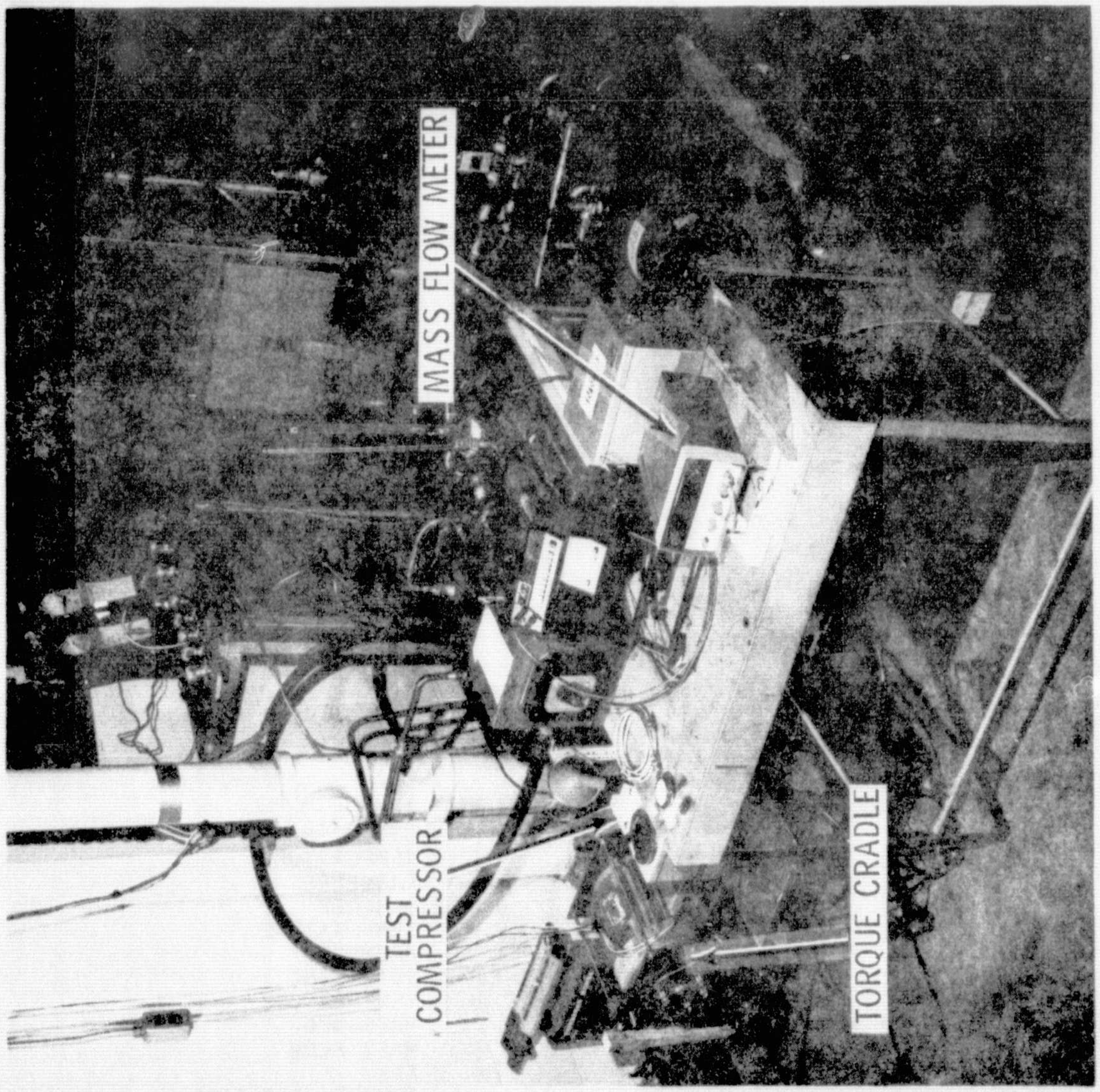


Figure 4-15. Calorimeter - Front View

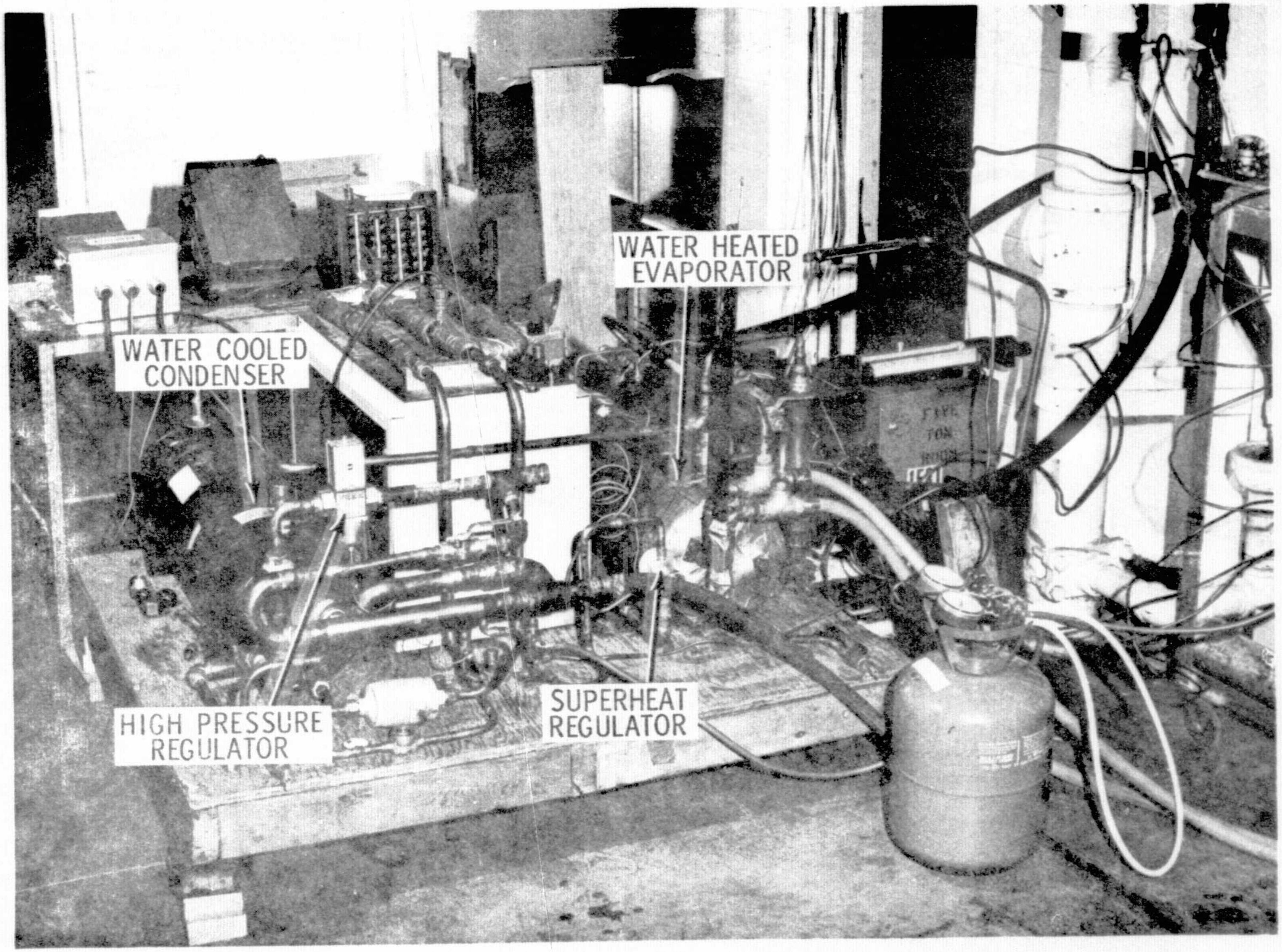


Figure 4-16. Calorimeter - Rear View

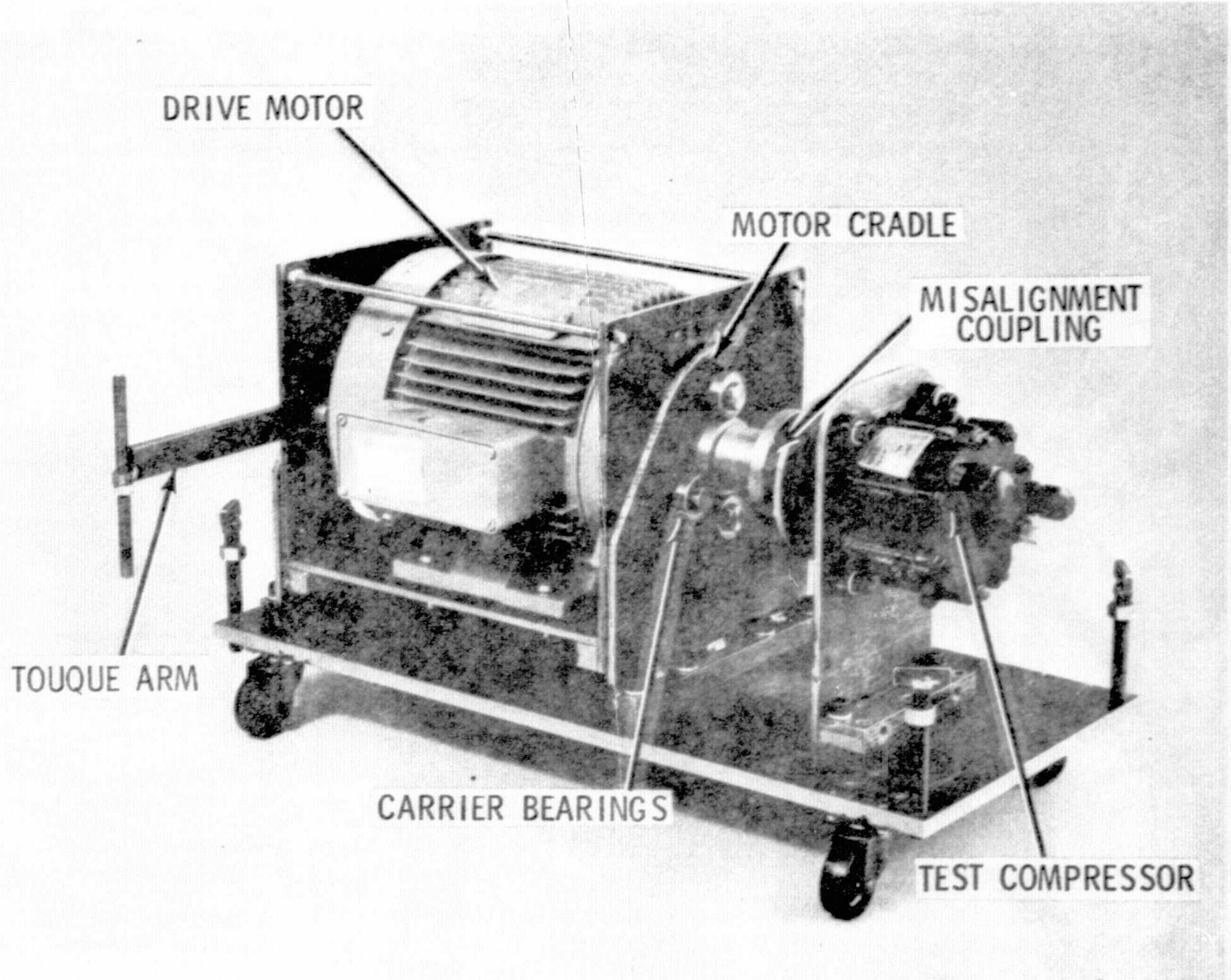


Figure 4-17. Calorimeter Showing Balance and Torque Cradle

will out perform the internal separator and thereby increase compressor performance.

Results of tests performed at Marshalltown on this first prototype appear on Figure 4-18. The data is presented on two sets of curves: (1) shaft horsepower versus suction pressure for lines of constant discharge pressure and (2) refrigerant mass flow versus suction pressure for lines of constant discharge pressure. All data is for 15^{o}F suction line superheat and 1750 shaft RPM.

The compressor design points are 125 psia discharge and 58.4 psia suction pressure with 15^{o}F superheat at the suction port and 1750 shaft RPM. At design point, the data shows a capacity of 680 lb_m/hr with 2.97 horsepower required at the shaft. The design enthalpy change across the evaporator is 56.4 Btu/lb_m resulting in a gross capacity of 38,350 Btu/hr. This yields a design point shaft C.O.P. of 5.10. The compressor efficiency (actual compressor performance over insentropic performance) comes out to be 58%. A stock compressor as well as additional prototypes incorporating further modifications to increase efficiency have been delayed due primarily to York production problems. York estimates production samples to be available again the first week of April, 1978. In light of York production problems and the low efficiency of the first prototype, it has been decided to test one or more alternate compressors as well. Delco-Air and Sanyko are two candidates.

Experience on the 25-ton Trane compressor and now the York compressor indicate that a COP of 6.0 is out of reach for an off-the-shelf compressor. At this point, it would be more realistic to say that a COP of 5.4 is acceptable. Strong consideration will be given by the Lennox compressor design staff to a new design with a COP goal greater than 6.0 prior to mass production.

Gearbox

Review -- The design and development objective is to develop a production turbo-gearbox for small Rankine cycle powered air conditioning systems. The first phase

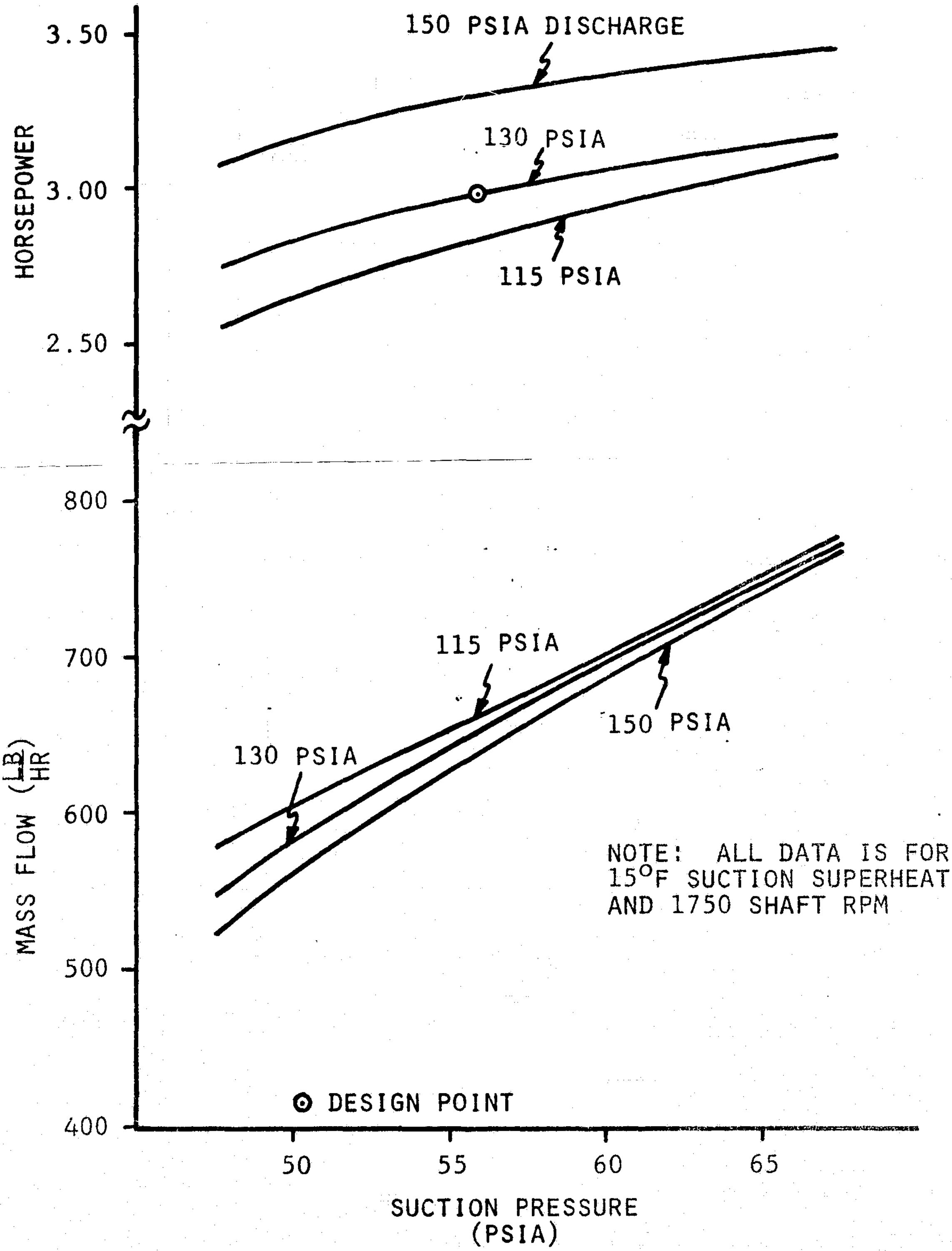


Figure 4-18. First Prototype with External Oil Separator, York VR4912

identifies baseline and development problems associated with high-speed worm gear units lubricated by a refrigerant/oil mixture. During the second phase, a final configuration is selected and detail drawings completed for a prototype gearbox. Production quotations are procured. The third phase involving fabricating prototype hardware for performance and life testing, running life tests plus making necessary adjustments or modifications to establish performance and minimum costs, and making final design hardware for system and field unit testing.

The advantages of a worm gearbox lie in the simplicity and minimum number of parts, making the unit very desirable from a high production standpoint. Figure 4-19 shows the proposed gearbox with turbine. Previous worm gearbox test programs concluded that lubricant distribution and cooling are problem areas that required further development for high-speed use. In reviewing the literature, other development programs have shown that worm gearing is feasible for such service by utilizing positive lubrication systems. Recent developments in gearbox lubrication using refrigerant/oil mixtures indicate that this system may be a desirable approach in solving the above mentioned problem areas. Therefore, the goal of the gearbox program is to determine baseline development problems associated with utilizing high-speed worm gearbox lubricated by refrigerant/oil mixture.

Design Status -- The worm gearbox proposed in the redirect is still considered the baseline. Some initial testing must be done to determine feasibility and design parameters for future design of the final version.

Since design parameters have not been established for the high-speed operation (or are not available in the open literature), these must be determined by development test. This is especially true for the oil-Freon mixture to be used to lubricate and cool the gear box. These tests consist of using a commerically available gear box as a test bed to obtain the desired test results. Mr. Buckingham, a worm gear expert and consultant, recommended ground gears for this application. In production, this step may not be required. The housing has been altered to accept these spray nozzles directed on the worm gear interface. The configuration is such that the gear is below the worm and the spray will fall down onto the gear.

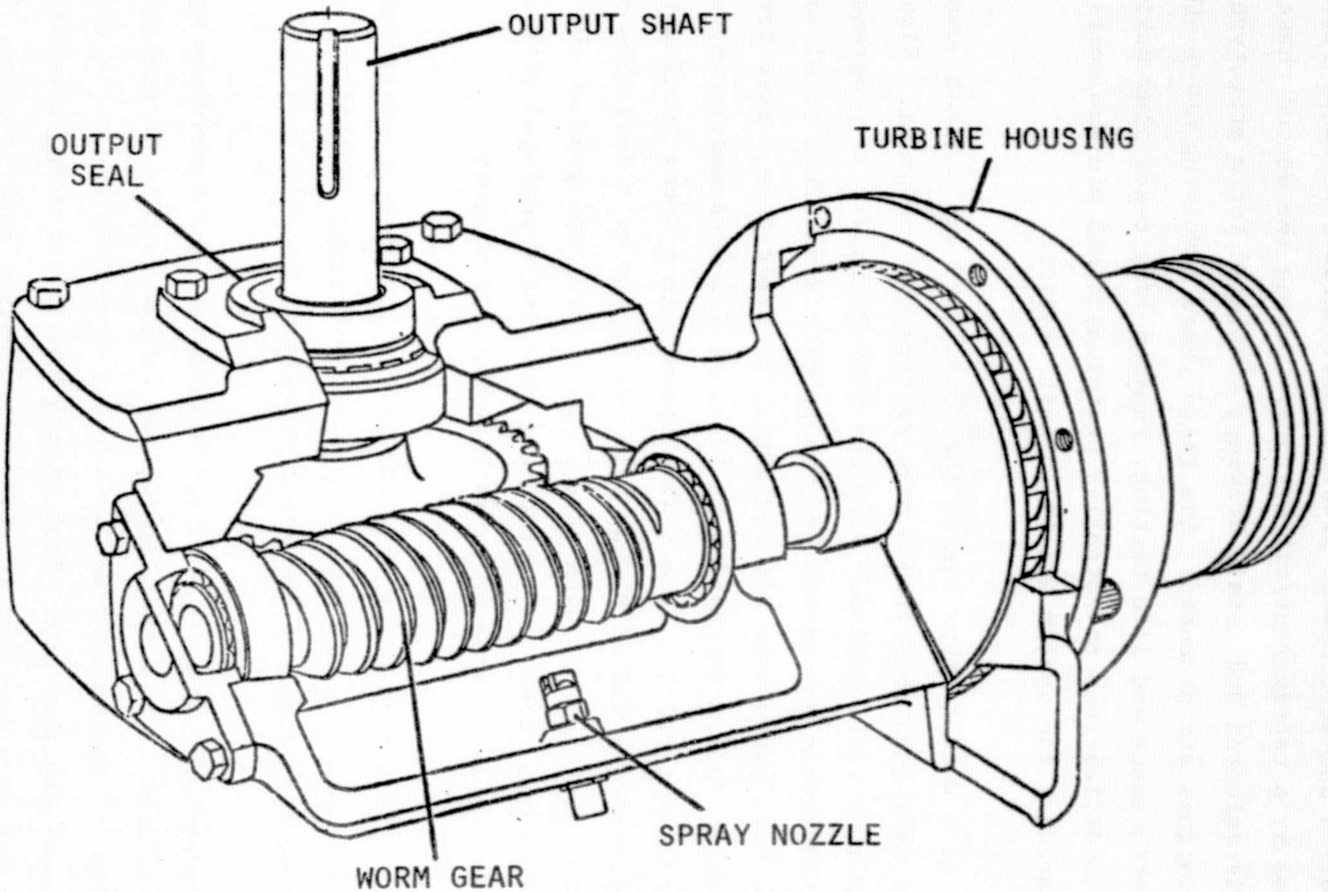


Figure 4-19. Turbo-Gearbox

Three goals are to be achieved in the test: 1) determine feasibility - that is, does the worm survive, 2) determine the amount of cooling - lubrication required, and 3) determine the friction parameters for the worm at high speed. The first goal is the most important. The design challenge is that only a short section of worm contacts the gears. All the friction goes to heating that small section so it must be cooled and lubricated at a sufficient rate. The use of Freon for cooling provides an excellent opportunity for the worm to survive. Once it is demonstrated that the cooling does work, the amount of cooling and nozzles can be optimized. The third goal is to extend the frontiers of knowledge into high-speed worm gear operation by obtaining friction data to optimize the design of the final configuration.

Once the data is available, the final configuration will be designed and fabricated. This unit will then be tested and delivered for installation in the Rankine engine.

The previously tested Milwaukee gear box is considered to be the backup system for the worm box. It is a precision gear box having a very low friction loss (about 0.1 horsepower) similar to the worm gear. A big advantage of the worm box is low cost. The worm drive box has only two shafts, four bearings, and two gears. The Milwaukee has four shafts, eight bearing, and six gears, which, in production, would be reduced to three shafts, six bearings, and four fears. Every effort will be made to delivery a low-cost, operational worm gear box at a gear ratio that optimizes turbine speed and efficiency.

Turbine

Review -- This program includes design, fabrication, and test of an improved turbine for the 3-ton Rankine powered air conditioner. This improved turbine displays a better efficiency than the present unit and also a lower cost potential when produced in quantities of 100,000 per year. The projected efficiency of this unit is 76% after a full development program.

The present turbine is a radial-inflow type with a diameter of 2.7 inches. The improved design is a variation of an axial flow turbine. The blading on the rim points axially rather than radially and is known as a cantilever radial-inflow turbine. This configuration readily lends itself to die casting methods and thus is produced at low cost. In addition, the cantilever bladed turbine has a smaller diameter and larger allowable clearance between the wheel and the housing. This permits use of less critical dimensional tolerances on the exhaust housing, thereby making that part less expensive. Barber-Nichols has had considerable experience in designing and developing this cantilever bladed turbine and also in developing the tooling to produce these in large quantity.

The following items shall be completed in the development of the cantilever turbine:

- Turbine Design Analysis - A detailed turbine design analysis and performance prediction will be conducted with specified fluid conditions. In addition to the basic cantilever turbine, a design analysis of a nozzleless configuration will be considered.
- Design Layout and Detailed Drawings - Based on the turbine layout, an improved estimate of production cost will be evaluated.
- Fabrication.
- Test and Evaluation - The turbine test will be conducted by instrumenting an existing fluid loop. Load will be provided by a calibrated electric motor.

Gearbox losses previously evaluated are included to determine turbine shaft power and overall efficiency. The instrumented fluid loop is used to provide an improved measure of the radial-inflow turbine performance for comparison with the tested efficiency of the cantilever turbine.

<u>Design Status</u> -- Two types of turbine rotors under consideration for this effort are shown in Figures 4-20 and 4-21. Both are radial-inflow, one a full 90-degree flow radial inflow and the second a cantilever bladed radial inflow.

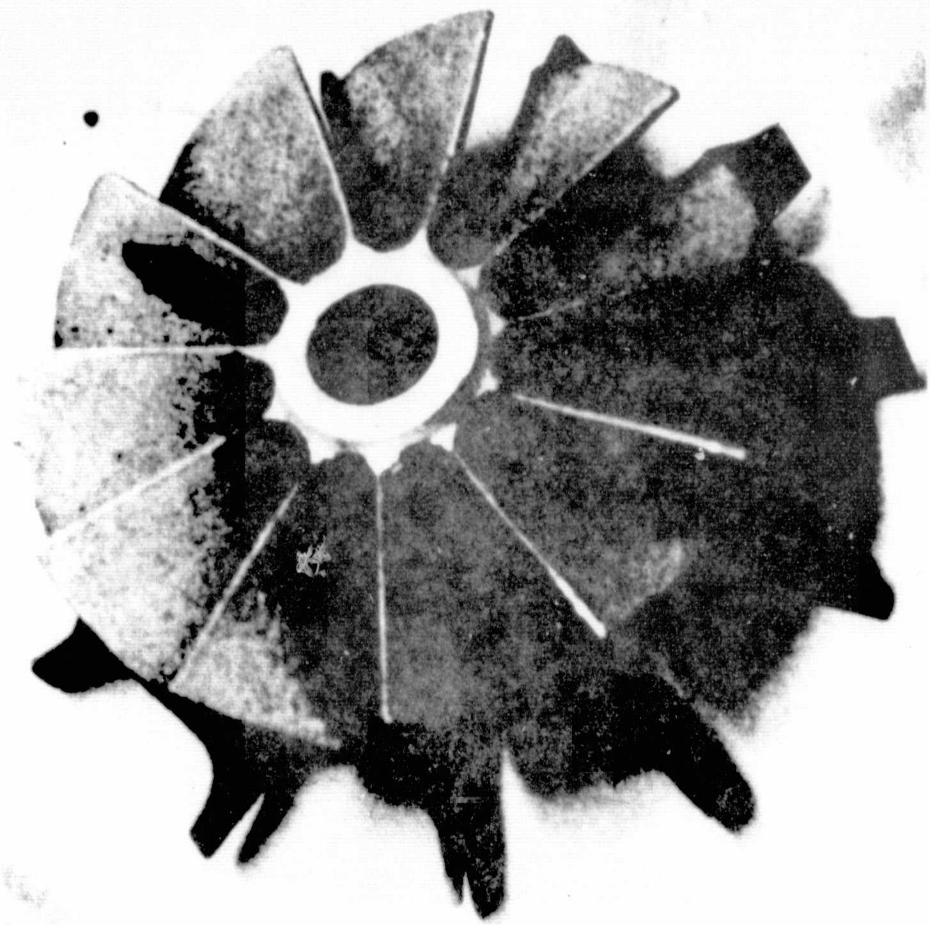


Figure 4-20. Turbine Rotor with 90-Degree Flow Radial Inflow

Figure 4-21. Turbine Rotor with Cantilever Bladed Radial Inflow

Figure 4-20 shows a turbine rotor similar to that found in automobile turbochargers with a diameter of 2.7 inches and fluid turning of 90-degress while flowing through the rotor. Projected efficiencies for a turbine utilizing this rotor type are 73-76% after full development. The projected speed would be around 35,000 rpm. The second type, Figure 4-21, is a variation of an axial-flow turbine known as a cantilever rotor. The blading configuration for the cantilever lends itself to die casting methods and the rotor for this application has a smaller diameter with larger allowable clearances between it and the housing. Production costs for this type is thus potentially very low. Projected efficiencies for the cantilever turbine are 74-77%. The projected speed would be around 28,000 rpm.

The turbines will be tested on the instrumented fluid loop shown schematically in Figure 4-22. The load will be provided by a hydraulically driven motor, and the horsepower out of the gear box will be determined by torque plus speed measurements on the output shaft. Losses through the gear box will be obtained as a function of speed by a direct calibration. Static pressure taps have been located at the turbine inlet, nozzle entrance plenum, nozzle exit, rotor exit, diffuser exit, and turbine exit so improvement areas will be easily isolated. A liquid spray chamber and throttling calorimeter have been included so 0-10% wetness can be introduced and its effect can be evaluated.

The turbine efficiency will be measured for a constant turbine pressure ratio over a range of U/C. where:

$U = N\pi D/720$

N = turbine rotational speed, rpm

D = wheel tip diameter, in.

$C_o = \sqrt{2gJ\Delta H'}$

$\Delta H'$ = overall isentropic head, Btu/lb

Variations in U/C_o for fixed cycle conditions will be accomplished by changing the operating speed of the hydraulic motor. The efficiency measurements will

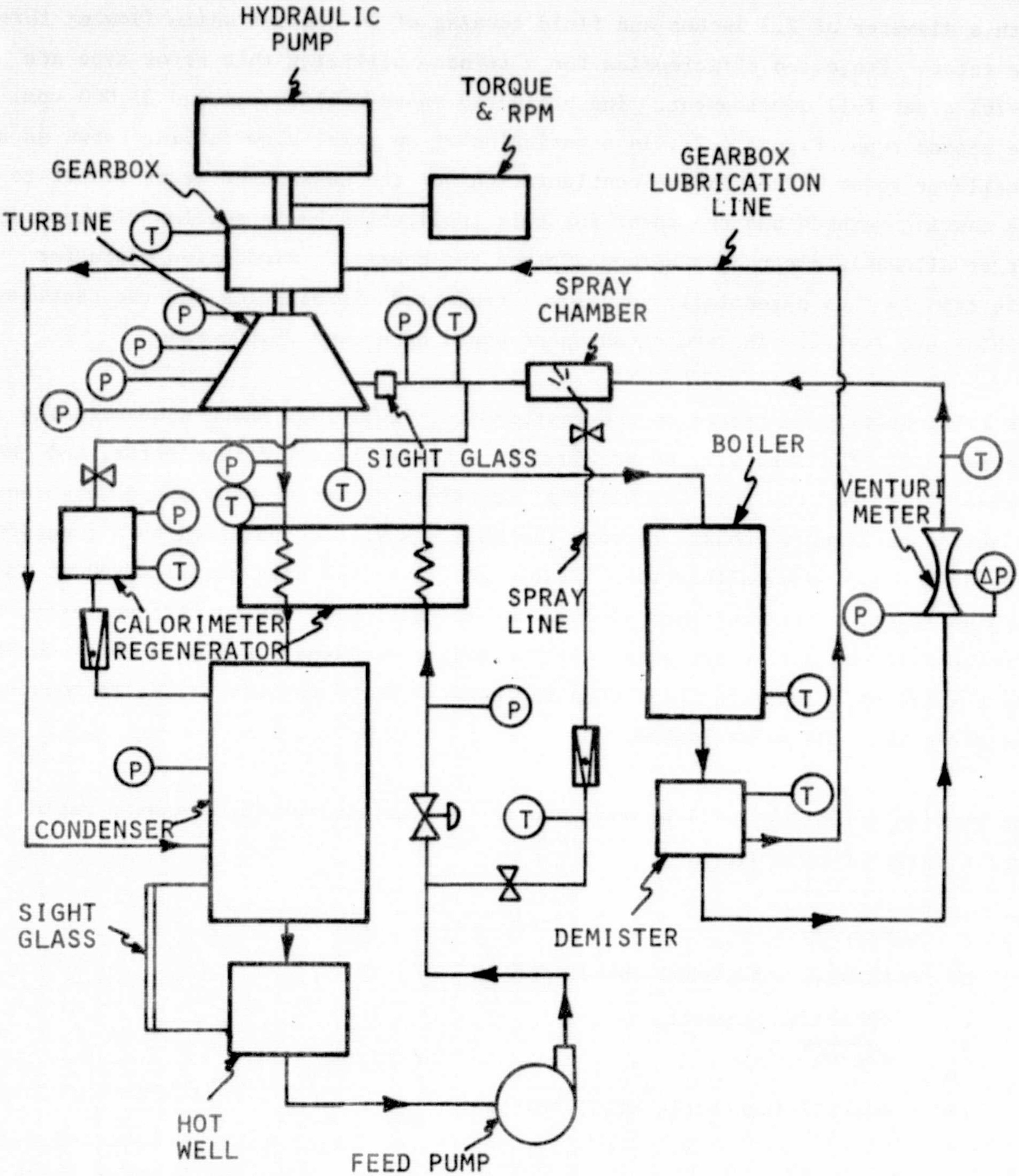


Figure 4-22. HW 3-ton Test Loop

be repeated for a variety of turbine pressure ratios and working fluid inlet qualities. In addition, the turbine arc of admission will be varied by plugging portions of the nozzle block, and its effect on performance will be evaluated.

Similar tests will be conducted on the cantilever bladed turbine wheel. In addition, two different nozzle designs will be tested to determine the performance benefit using more sophisticated nozzels.

A selection will be made between these two designs, and final hardware will be fabricated and delivery for assembly into the Rankine engine.

Rankine Cycle Feed Pump

Review -- The following objectives are to be completed under the feed pump program:

- Develop the concept for a pump driven by expansion of air conditioning fluid.
- Design hardware for the prototype unit.
- Fabricate and test the prototype.
- Redesign, fabricate, and test the preproduction hardware (two units).

The criteria for designing a feed pump that will have a low production cost include ease in manufacturability and the use of a single pump (rather than a boost pump and a feed pump). Additional criteria to be considered are development risk, efficiency, heat required at suction, reliability and maintainability, and startup problems in the cycle.

Design Status -- A number of types of pumps and drive systems were investigated. One system that was eliminated was the pump driven by the air conditioner refrigeration expansion. This idea, proposed in the new direction proposal, was rejected because there was no means of delivering of the power produced by the expander to the pump. In the residential system, the air conditioning expansion takes place at the evaporative coil located in the furnace, and the Rankine engine pump is located outside in the compressor cabinet. Other ideas discarded were: turbine driven centrifugal pumps, plunger drive reciprocating pumps, and a belt driven pump internal to the hermetic system.

Three possible schemes were selected as having potential. All three employ centrifugal type pumps. Figure 4-23 shows that the pump speed, as determined by the drive mechanism, determines efficiency, pump type, and NPSH. The term NPSH refers to the net positive suction head, which is the pressure above that of the saturation pressure required at the inlet side of the pump to prevent cavitation. This is a particularly important parameter in feed pumps for Rankine engines as they must pump the just-condensed (saturated) working fluid as it leaves the condenser. To maintain a low package profile, it is likely that only about one foot NPSH will be available (neglecting subcooling). Refering to Figure 4-23, it can be seen that the pump speed should be below 20,000 rpm from desirable NPSH but should be a high speed for good efficiency. It is possible to get reasonably good low-speed efficiency by using multiple stage. Also, a different type of pump design, called a drag pump can be employed. This will be discussed later.

Figure 4-24 shows the pump size as a function of speed and also the turbine efficiency as a function of speed. The turbine driven pumps could be direct driven with the turbine operating below optimum speed to get proper pump characteristics. However, the turbine performance will be degraded as shown. The pump diameter curve shows that high speed pumps will be an exercise in miniaturization and, therefore, subject to tight tolerances. On the other hand, low speed, single impeller pumps are large and hence expensive due to the size of molds and amount of material.

One possible pump configuration is a flexible shaft driven centifugal pump. The turbine shaft runs at about 30,000 rpm and the worm gear box output shaft runs at 1700 rpm. The pump ideally runs at 10,000 rpm and requires and additional

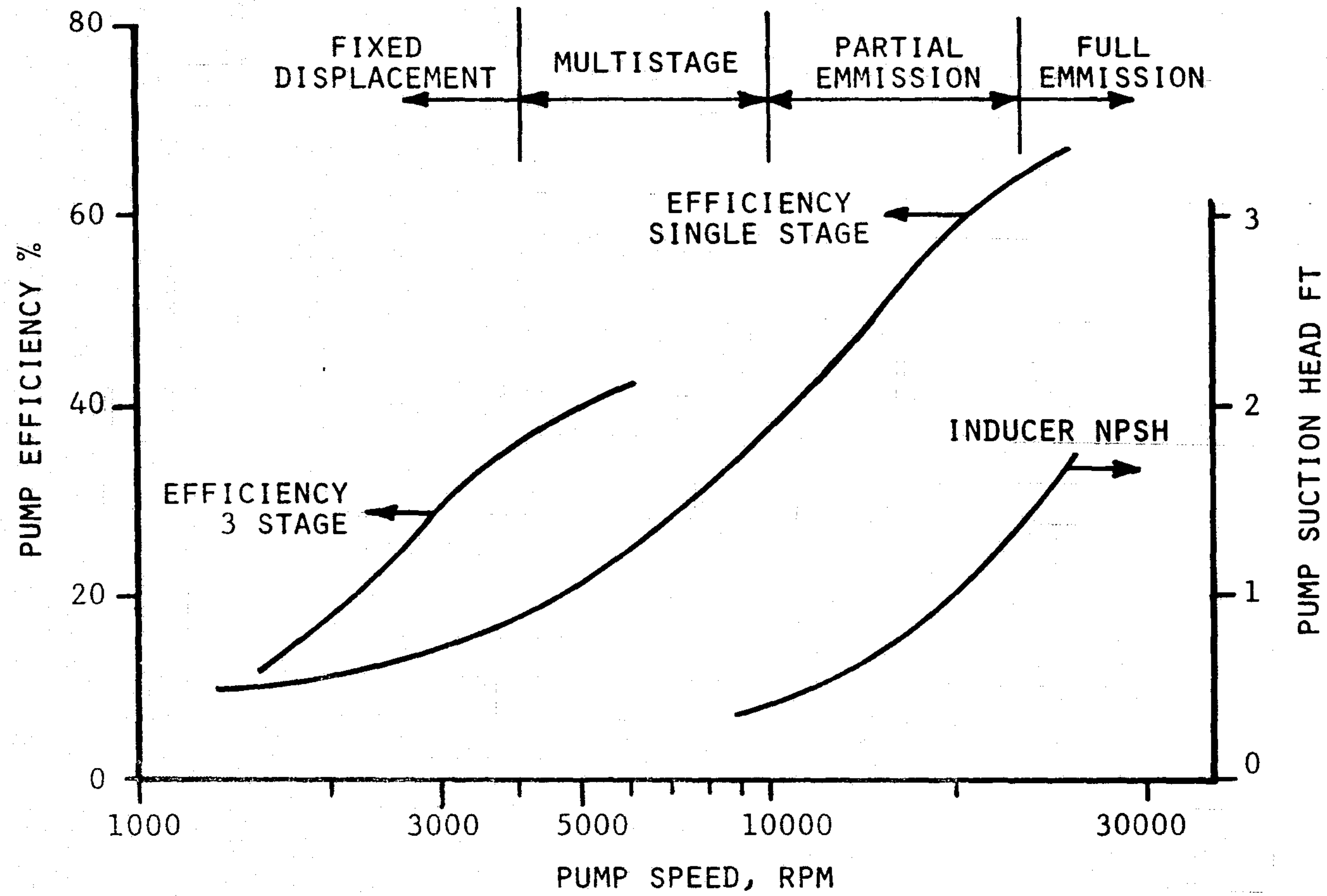


Figure 4-23. Estimated Feed Pump Performance

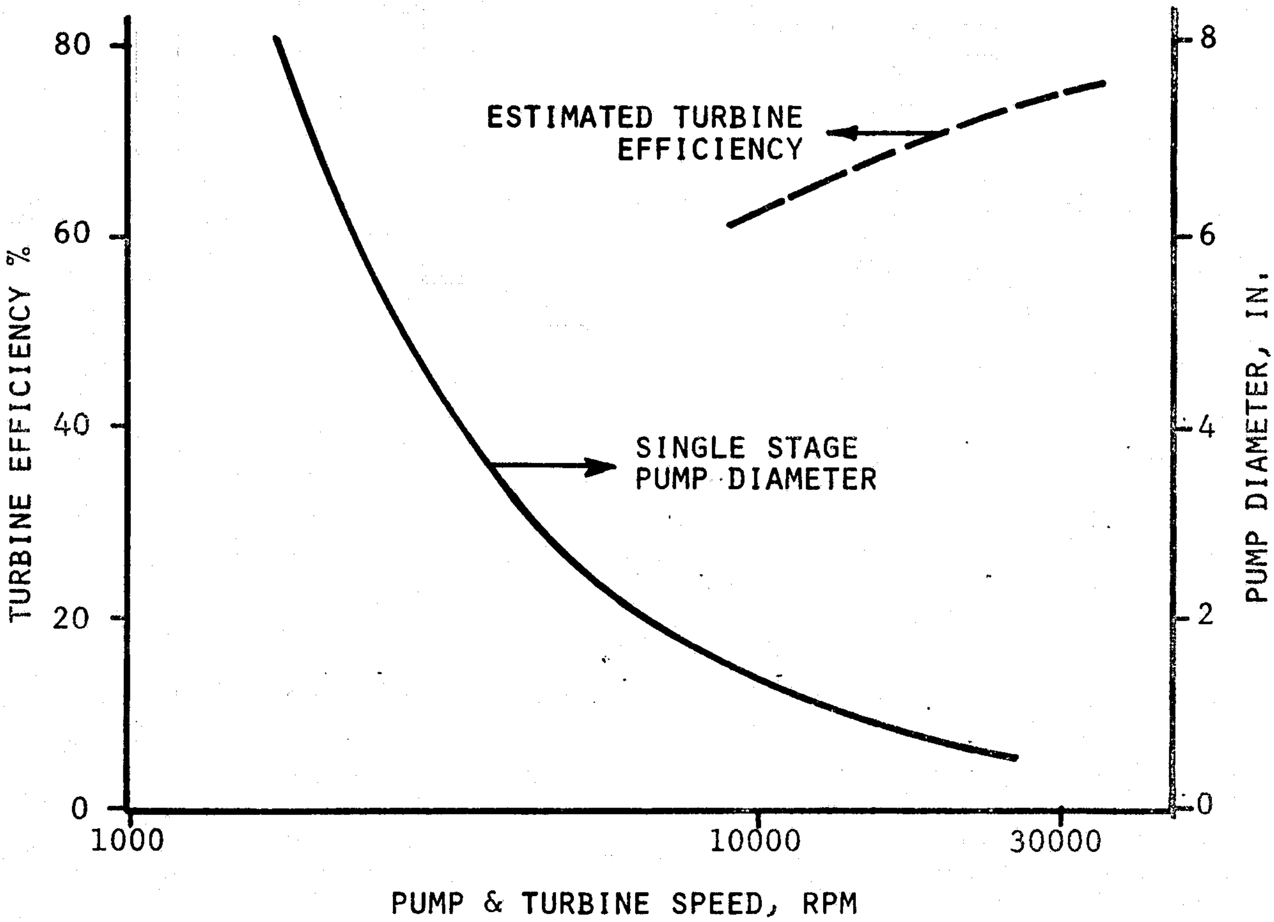


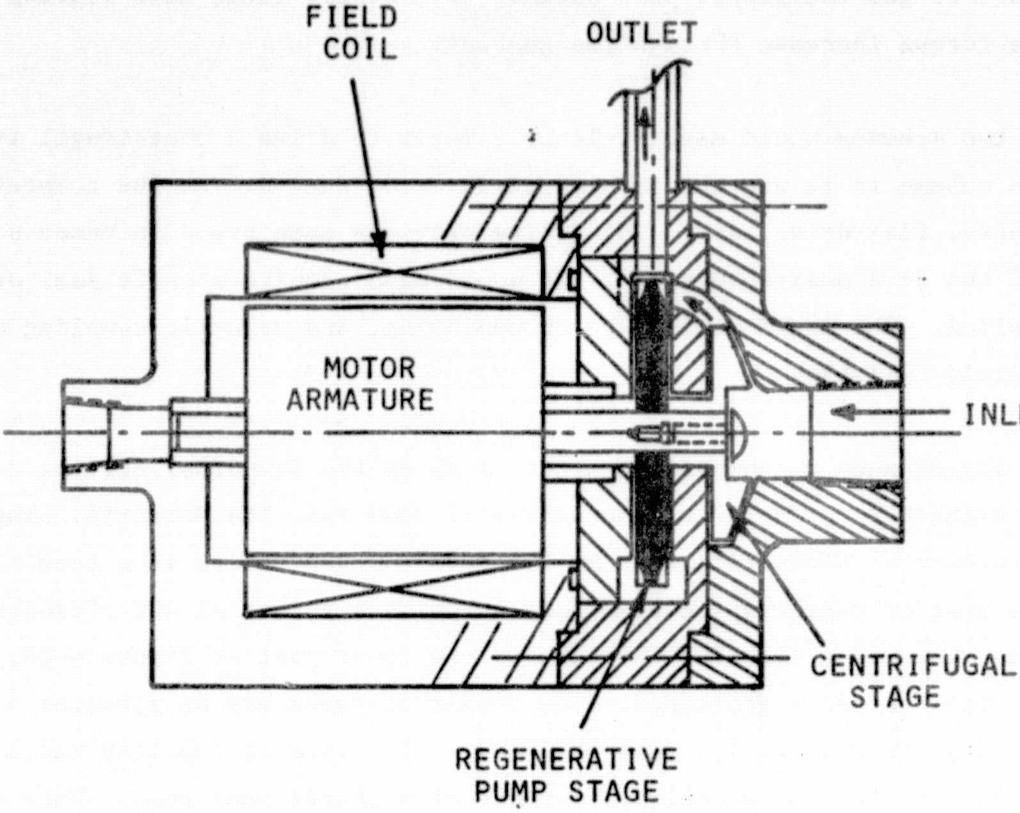
Figure 4-24. Turbine Performance and Pump Speed

set of gears to get the proper pump speed. This system could have startup problems due to the torque increase through the gearing.

The other two schemes would use an electric motor to drive a centrifugal type pump. One scheme is to use the main electric motor that drives the compressor via belts, shafts, flex drive, etc. This drive provides some speed increase so the pump could run at a desirable speed. It would also require a shaft seal or magnetic coupling. The shaft seal is power consuming, and magnetic coupling are not completely reliable.

The third scheme uses a submersible motor (such as the Grundfos) driving a pump. Since the highest motor speed without gears is 3600 rpm, the potential single stage efficiency of a centrifugal pump is low. However, there is a type of pump called the drag or regenerative pump that exhibits a potential 40% efficiency at this speed. This pump impeller is shown on the lower part of Figure 4-25. It is a disk with the edges scalloped. The resulting vanes may be straight or curved. In either case, this is easily mass produced. This type of impeller has a flow pattern such that it acts as multiple stages of a centrifugal pump. Unfortunately, this type of pump has high NPSH requirements and, therefore, needs to be used in connection with a centrifugal stage for boost. This type of pump is shown in the upper part of Figure 4-25 and is the concept that is presently being pursued as the best candidate.

The present cycle configuration predicts a power requirement to drive the pump of .13 horsepower if the pump itself if 40 percent efficient. An analysis is presently underway to do a preliminary design of the centrifugal boost stage and the drag pump stage to determine the pump efficiency. In parallel to this, a search is underway to find a suitable motor. One possible motor is the one used on the 1/6 horsepower Grundfos pump. It has been tested for power output while operating in R-113. The results of these tests are shown in Figure 4-26 and 4-27. It appears that this motor is just marginally sufficient if the voltage is boost on it. How this higher voltage would affect the life expectancy is unknown at this time. The effort to find a different motor is underway. A fallback position would be



DRAG OR REGENERATIVE PUMP STAGE

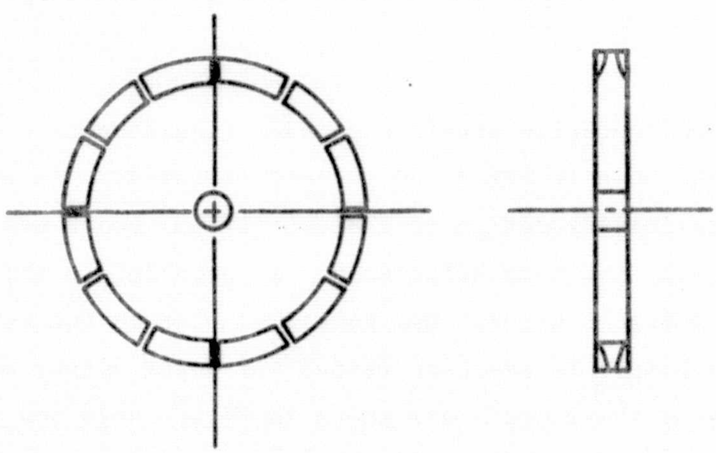


Figure 4-25. Rankine Cycle Feed Pump with Wet Motor

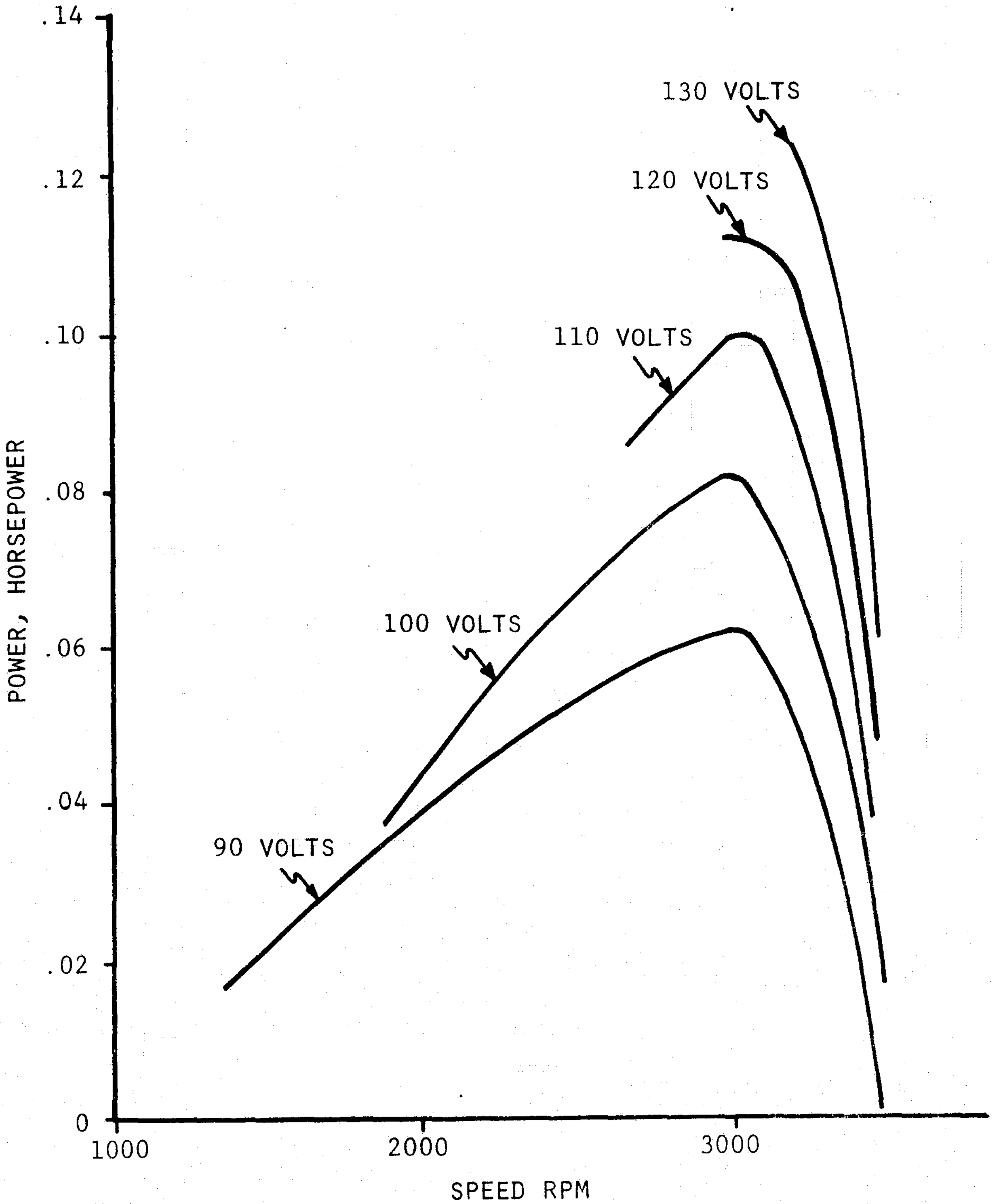


Figure 4-26. Grundfos Up 26-64, Motor Power Output Running in R-113

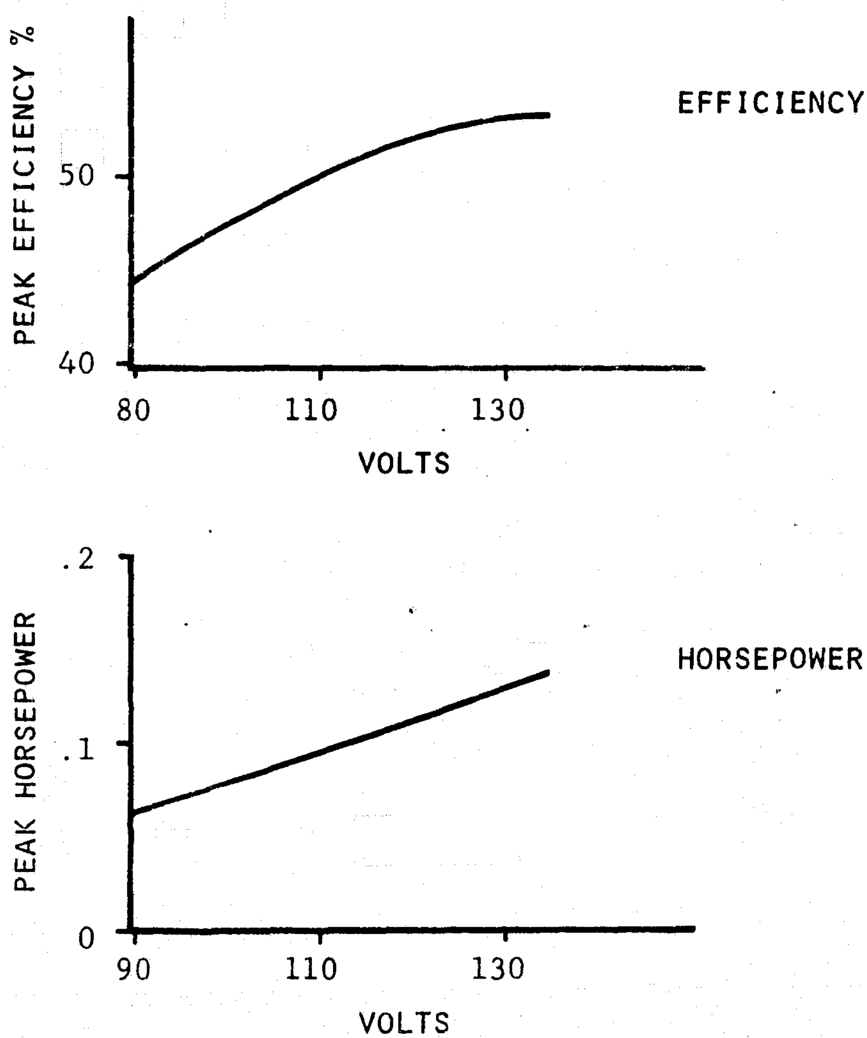


Figure 4-27. Grundfos UP26-64, Motor Running in R-113

to use a submersible water well pump motor; however, these are presently available in 1/3 horsepower or larger.

Presuming that such a motor will become available, the type of feed pump being projected for the Rankine engines will be the centrifugal boost, drag main stage pump shown in Figure 4-25. This should have low cost in large quantities (under $20), excellent reliability, be self-starting, reasonably efficient, and have a fairly low development risk.

Motor/Generator

A 2 1/2 HP GE high efficiency unit operating with 230 V, three-phase input will be used. This motor is similar to that used on the original Rankine air conditioner.

Packaging -- The packaging concept puts the boiler, turbine, motor, compressor, regenerator and condenser in the same package (Figure 4-28). The only remoted component will be the "A" coil. This concept allows for the greatest amount of factory assembly with the least amount of field assembly required. Dimensions are currently figured at 36" high by 42" deep by 72" long. Installed weight of the outdoor section is estimated at 950 lbs.

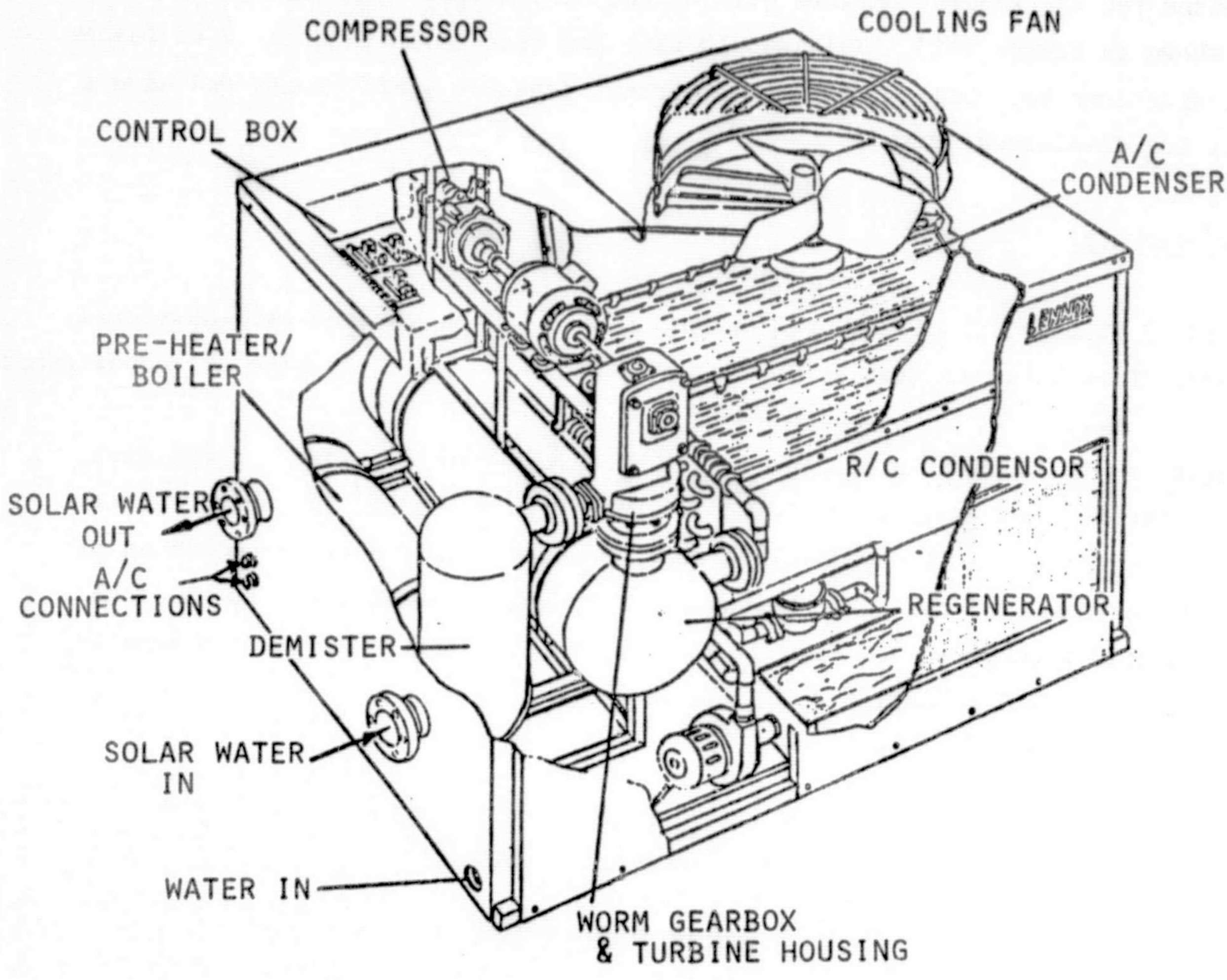


Figure 4-28. R/C Powered 3-Ton Air Conditioning Unit

SECTION 5
MARKETING PLANS

DEALER ORGANIZATION MARKETING

The thrust of Lennox Marketing will be through the dealer organization in the strongest manufacturer-to-dealer relationship in the HVAC Industry. All dealer selection, training, service backup, warranty administration, etc. are provided by the primary manufacturer--Lennox.

The Lennox Marketing Plan was given recognition by the National Environment Systems Contractors Association at it's convention, March 9 in Bel Harbor, Florida.

LENNOX COMMITMENT TO SOLAR

Solar collectors were introduced to our dealer organization in 1975 and a solar domestic hot water heating module in 1976. We are introducing a solar space heating module and collector package in 1978. A study is being made to integrate heat pumps into our solar space heating and domestic hot water packages.

We plan to integrate our Rankine Cycle subsystem into these solar systems in 1979 and 1980, giving us a logical progression of solar products on an integral time scale.

To respond to the demand that is building for solar installations, dealers are installing Lennox sponsored systems and, also, engineered and installed by our more enterprising dealers. Because of this demand, we have been developing a comprehensive training program on solar heating for our dealers.

Figure 5-1 through 5-4 shows a collector array installation on a special section of the Lennox training building, views of the indoor components of this sytem,

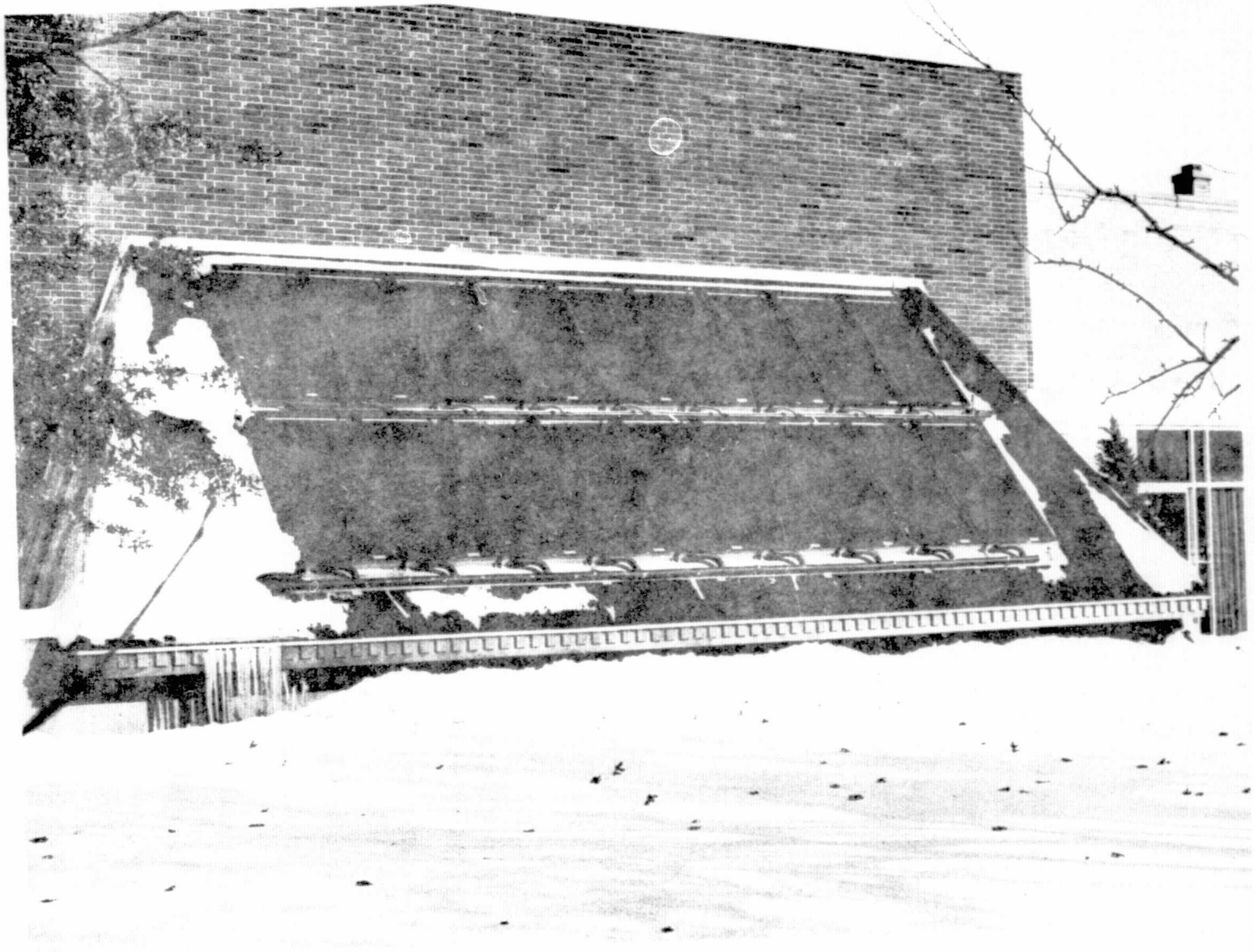


Figure 5-1. Collector Array Installation on Lennox Training Building

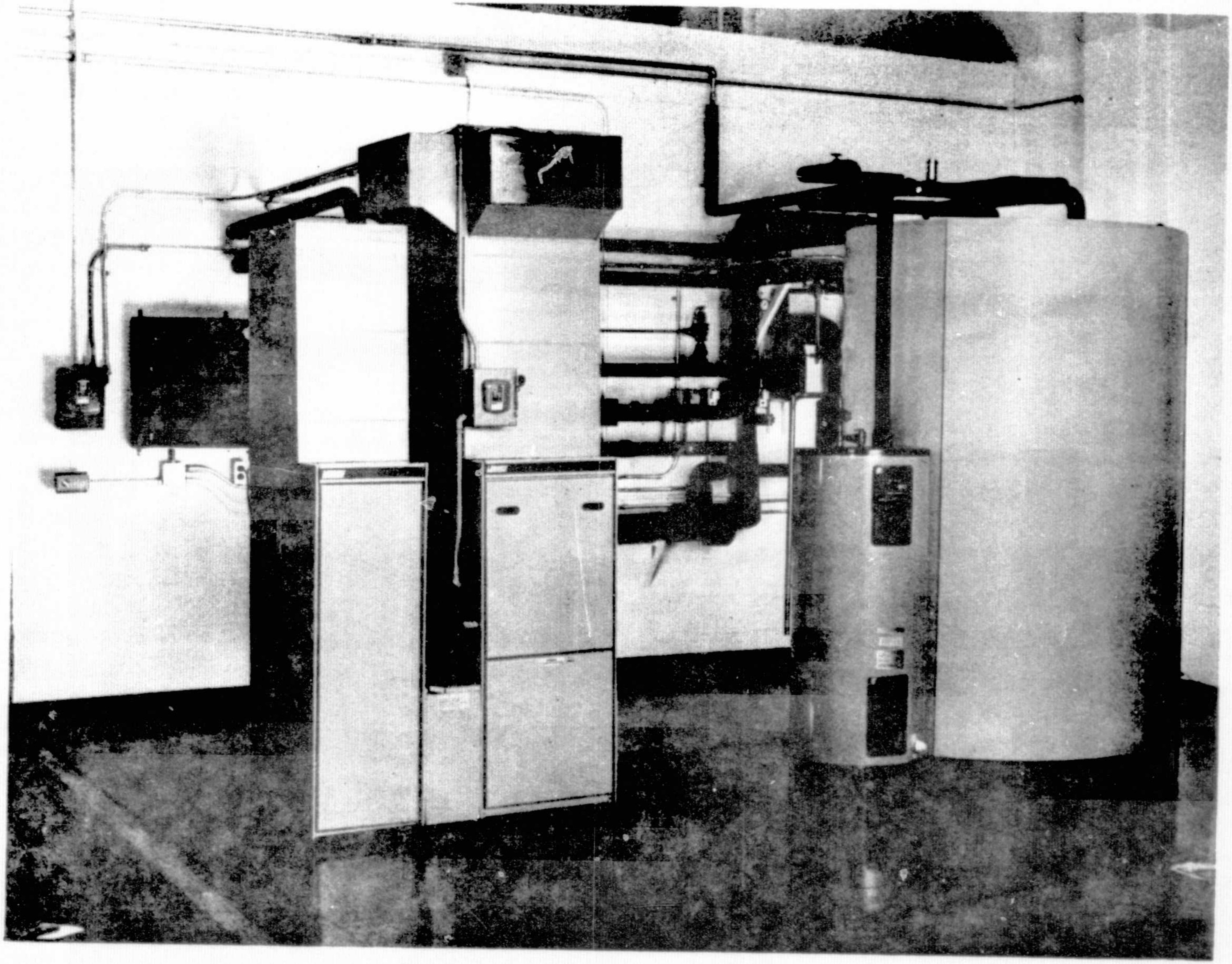


Figure 5-2. Indoor Lennox Solar System Components

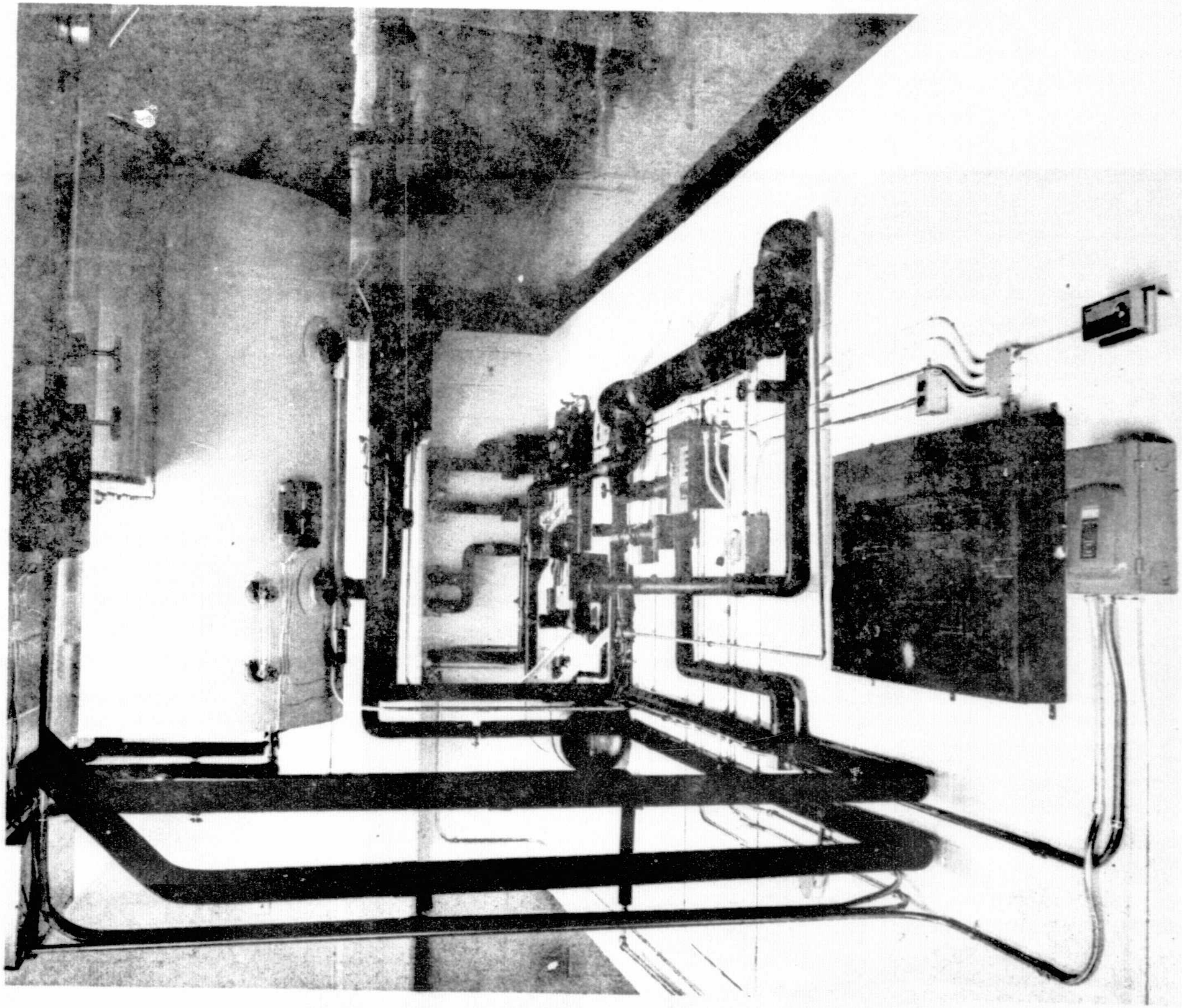


Figure 5-3. Lennox Solar System Indoor Piping Arrangement

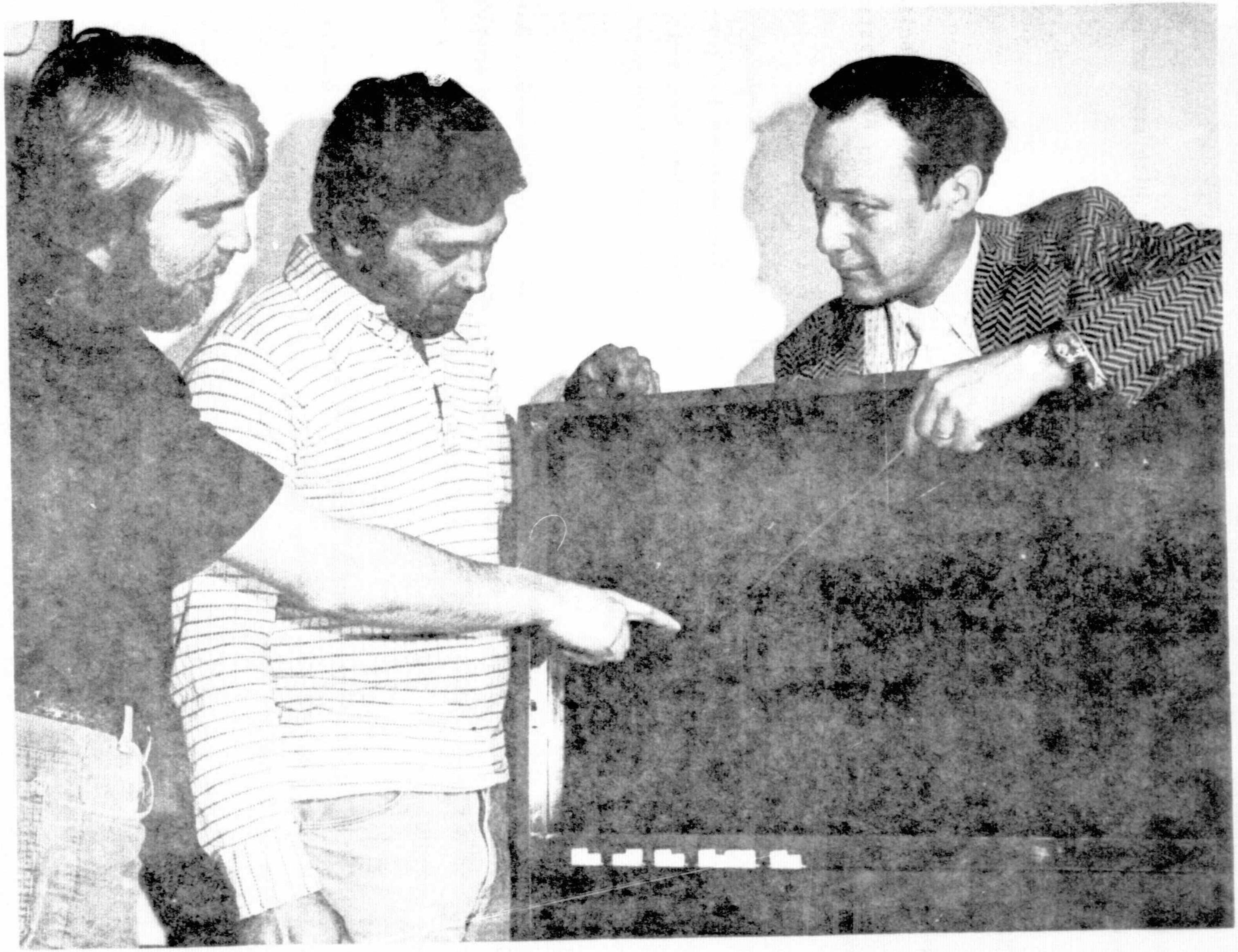


Figure 5-4. Lennox Solar Training Demonstrator

and one of our solar instructors using a solar demonstrator with some of our dealers in an actual classroom situation.

COMMITMENT TO DEALER

Installers of solar systems must be experienced HVAC contractors with a solid background in the theory of heat gain and heat loss calculations, HVAC system design and equipment selection.

The Appendix shows our training course booklets showing the broad scope of Lennox HVAC well-developed and comprehensive basic training program for our dealers. The solar course description booklet also shows the hardware and software, along with the training installation at headquarters that we have developed to assure dealer competence in solar.

As part of our program we have developed a dealer qualification procedure for solar installations using the same approach as that used for heat pump installations. Both require great care in equipment selection and application and in owner education.

Residential solar systems are small size, but, the complexity for the dealer remains. We are developing in-house capability for computer analysis to assist the dealer in equipment selection and life cycle costing.

COST REDUCTION BRIDGE

The Lennox philosophy is to market solar Rankine machines as complete systems, organized into packages or modules that simplify equipment selection and installation. We will be a single source of supply for all components of the complete system.

No HVAC manufacturer has the resources to go from a high-cost prototype direct to production to meet the competitive market immediately.

To meet national goals, HVAC manufacturer's will need help, not only with the development of prototypes, but with a "cost reduction bridge" as well.

The solar Rankine system must necessarily go through continuous engineering simplification to cut costs.

This will require someone to purchase 20 to 30 systems at a time for redesign on an orderly basis:

1) Group A will be first generation
2) Group B will be second generation
3) Group C will be third generation, etc.

The end result will be a system that can be offered on the open market as a top-of-the-line, energy-saving, heat-cool system that is economically viable for a building owner.

By that time, competitive systems and their fuel sources will also be higher priced, thus cutting the cost gap.

The final step in our "cost reduction bridge" will have to be an incentive to ease the burden of initial investment for the private owner:

1) An income tax credit large enough to cover the down payment on the installed system.

2) A minimal or zero property tax increase on the solar system.

3) Depreciation against personal income or some additional tax benefits such as the utilities enjoy because the Rankine solar system is a

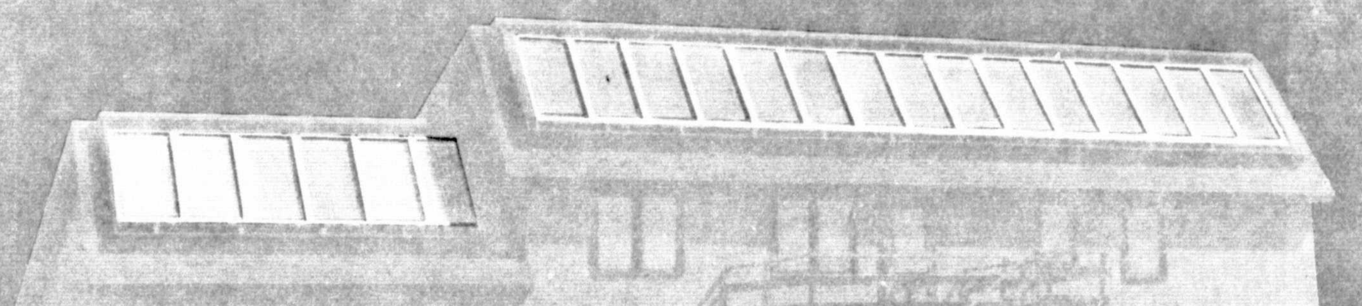
decentralized power plant. As such, the owner needs a method to not only receive a return on his investment, but must enjoy a return of his investment.

The Arab Oil Embargo and now the critical balance of payments problem are forcing us to create a new industry at a pace the private market cannot economically meet. We need all the help we can get. We must communicate effectively. Success is going to depend on the local dealer backed by the private manufacturer. We must all work to make both successful.

APPENDIX A

LENNOX TRAINING MANUALS

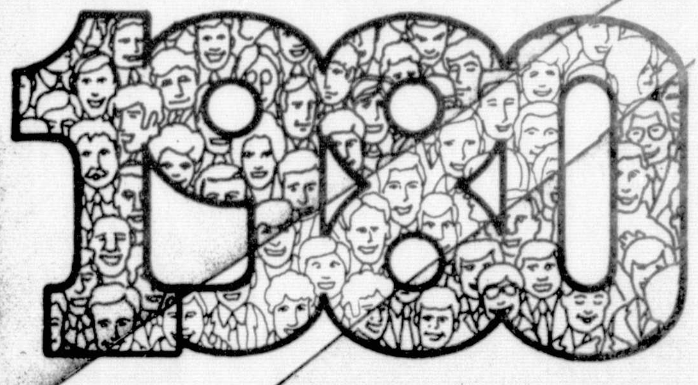
SOMETHING NEW UNDER THE SUN



. . . A SOLAR TRAINING COURSE

BY LENNOX

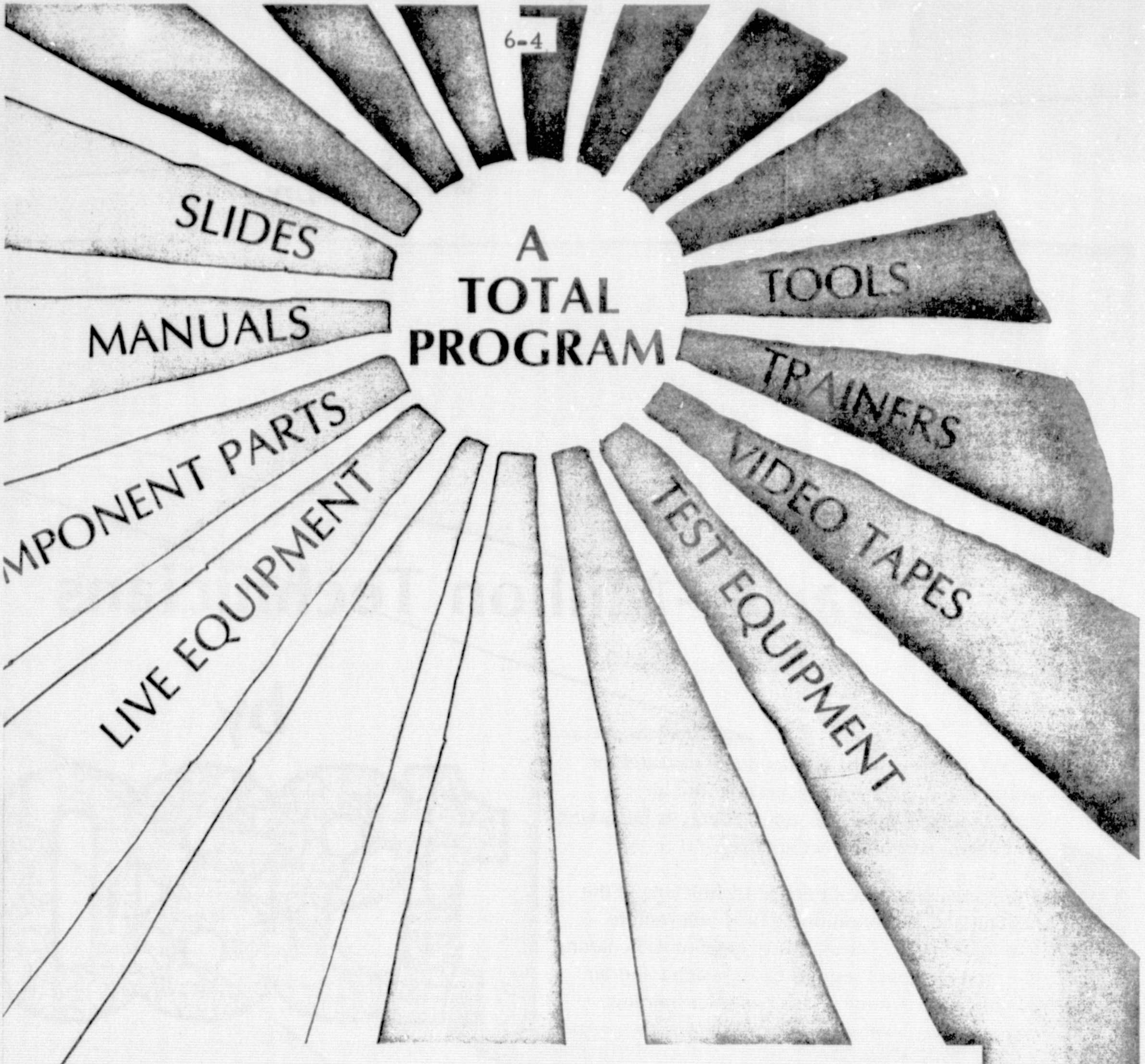
Quarter-Million Technicians by



By 1980 there will be occupational demand for nearly one-quarter million heating and air conditioning technicians. Solar energy is becoming an integral part of this technology.

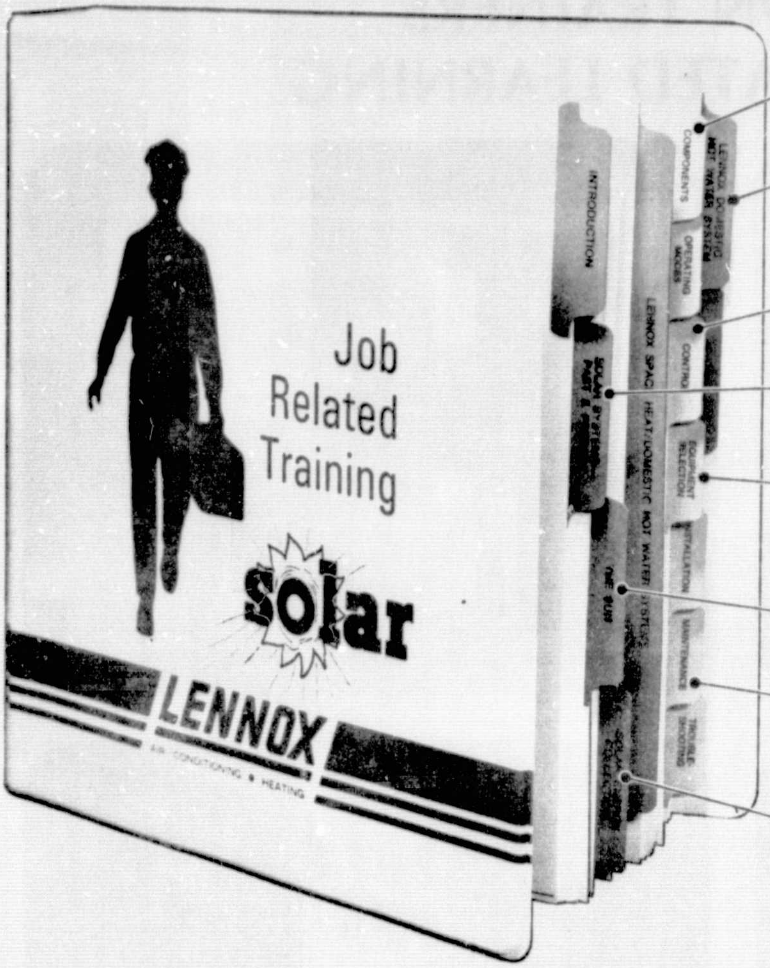
Thousands of the experienced technicians in the heating and air conditioning field will require training in solar. Thousands of newcomers entering the profession will require basic heating and air conditioning training as well as solar training.

Solar education comes *after* thorough training in conventional heating and air conditioning technology. The job market for a "solar" technician without basic heating and air conditioning capability is very limited. However, there is a huge job market for a heating and cooling technician — and the person who has solar added to his training carries a premium value.



Lennox, long a major manufacturer of heating and air conditioning products, is now in the market with solar products. What's more, Lennox has produced a complete training program. At this moment the course is being taught to Lennox salesmen and Lennox dealers. The course will be ready for distribution to the vocational-technical market late 1977. A preview of the course along with hardware and software specifications are included in this brochure.

Textbooks, trainers, slides, video tapes, test instruments, tools and component parts packages are included in the array of training aids. Also, actual solar systems are available for training purposes. From solar system design and installation to service and maintenance, Lennox has a *total* solar heating curriculum.



Space heat and domestic hot water system components are pictured and described individually.

A whole section on solar domestic hot water application acknowledges this huge, emerging market and its occupational opportunities.

Use of color vividly shows fluid flow and electrical action for a variety of system operating modes.

Describes and illustrates solar systems, past and present. Details 53 system designs.

Potentially complex equipment selection and sizing procedures are made simple by using a step-by-step worksheet approach.

Defines types of solar radiation and what effects radiation levels.

Special methods unique to solar system installation, maintenance and troubleshooting prepares students for their work experience.

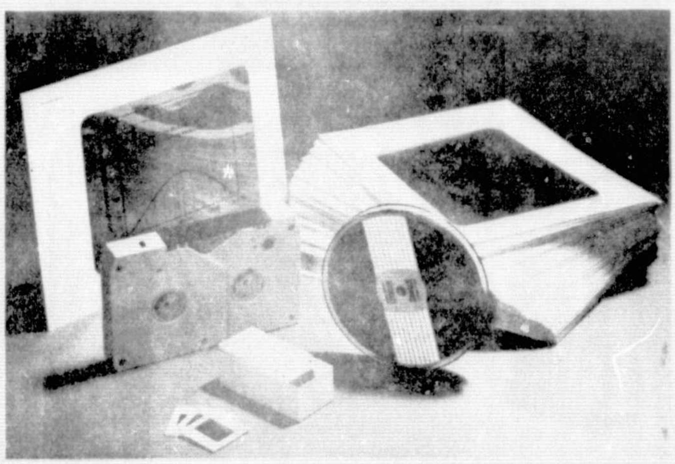
How do collectors work? How is their efficiency measured? This section on solar energy collection describes methods, designs and collector efficiencies.

HERE'S A SOLAR TEXT THAT'S FACTUAL AND READABLE

The Lennox solar text is well illustrated and authentically factual. We make textbook reading a pleasure rather than a grind.

This text captures the student's attention, leading him from the simple to the complex.

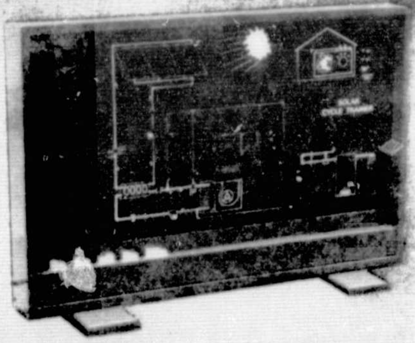
We give the student "need to know" rather than "nice to know" information . . . working techniques and essential theory.



SLIDES AND VIDEO TAPES, TOO

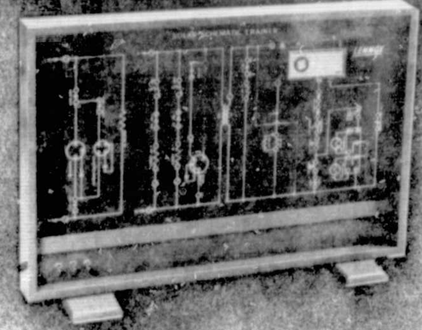
Overhead and 35mm slides match the text, providing a hard-working educational tool. Video tapes demonstrate installation and service procedures.

HANDS-ON TRAINERS FOR JOB RELATED LEARNING



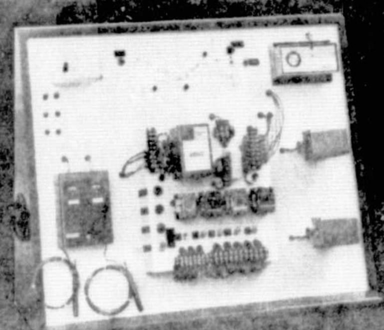
RT-5 SOLAR CYCLE TRAINER

Simulates solar heat hydronic system. Various modes can be programed to show fluid flow and component function. For lecture and self-study.



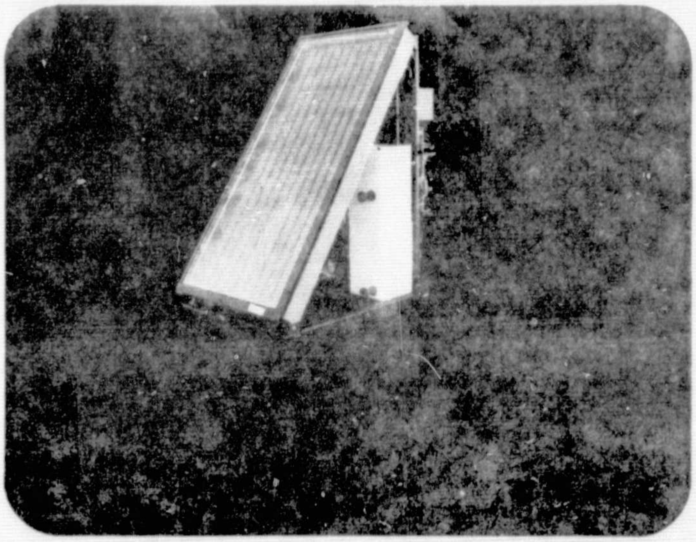
EB-5 SOLAR SCHEMATIC TRAINER

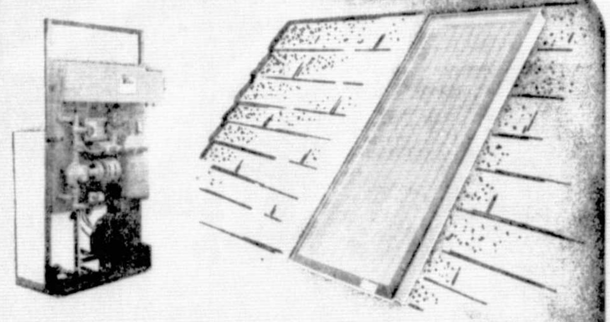
Explains the electrical operation of solar heat, auxiliary heat and electric cooling stages.



ST-17 SOLAR HEAT SERVICE TRAINER

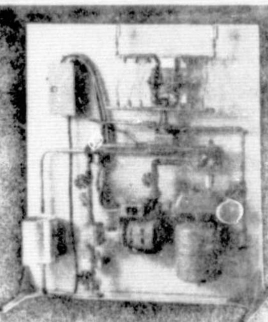
[illegible] normal operation and elec[illegible]





AP-4 SOLAR SYSTEM TRAINER KIT

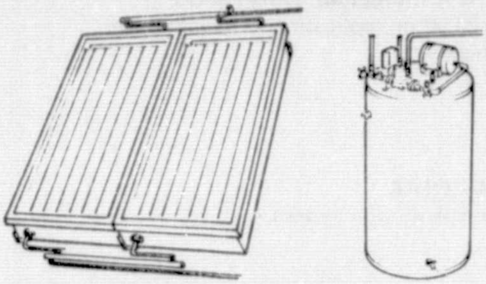
Same system as AP-3. Comes unassembled for student assembly experience. Collector may be located outdoors, remote from the rest of the trainer.

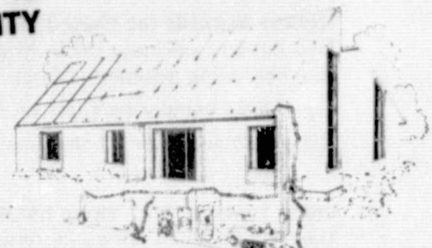


AP-5 HYDRONIC PRINCIPLES TRAINER

A unique trainer that permits the student to observe and direct fluid flow through various solar components. Fundamentals of charging a solar system can also be practiced on this trainer.

LIVE EQUIPMENT FOR JOB RELATED TRAINING





SHS-6 & SHS-18 SPACE HEATING SYSTEMS

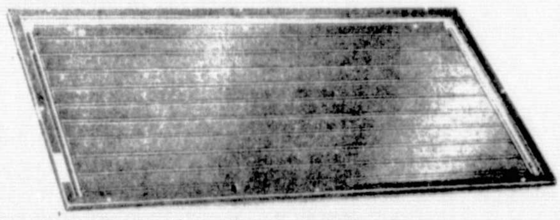
SHS-6 system is complete with 6 collectors and all necessary component parts. It is sized for a school's heating and air conditioning lab. The SHS-18 system is complete with 18 collectors and all necessary component parts. It is sized for the average home, and is especially convenient for student-built homes in a building-trades program. It can also be installed at the school site. Auxiliary heating and solar domestic hot water equipment is available for both of these systems.

SHW-2 DOMESTIC HOT WATER SYSTEM

This is a complete operating system designed to interface with a conventional water heater. Excellent for training while delivering hot water to the classroom. (NOTE: Conventional water heater not supplied with the SHW-2).

LSC18-1S & LSC18-1 COLLECTORS

Solar collectors may be purchased separately and are available in any quantity. LSC18-1S is a single glass collector; LSC18-1 is a double glass collector.



TEST INSTRUMENTS, TOOLS AND PARTS PACKAGES

A solar training program would be incomplete without tools and instruments of the trade. We have assembled test instruments, tools and system components used in solar applications. Our packages make it easier to write funding proposals by cutting tedious research time.

A COMPLETE HEATING AND AIR CONDITIONING CURRICULUM

Lennox has a comprehensive heating and air conditioning curriculum for the voc-tech market, of which solar is just one part. An extensive line of trainers, live equipment and visuals support text materials. The program is divided into several courses or phases to provide a logical learning progression. Courses include:

- Phase I(S) — Basic Maintenance
- Phase II(S) — Full Residential Service
- Phase III(S) — Commercial Installation and Service
- Phase I(HP) — Heat Pump Service & Maintenance
- Phase I(A) — Residential Application
- Phase I(Solar) — Solar Application, Installation, Service and Maintenance.

SOLAR GUIDE SPECIFICATIONS

MANUALS

Student Manuals for Phase I(SOLAR) Lennox Job Related H & A/C Program, Model SP-12
Two binders are included in Model SP-12. Instruction is received in application, installation, service (including troubleshooting), maintenance and cost of operation.

Suggested Quantity for Class of 20 students: 20

Shipping Weight for 20 Students: 220 lbs.

VIDEO TAPES

Video Tapes — 3/4" Phase I(SOLAR) Cassette (1), Model VC-SOLAR
The VC-SOLAR (1) video cassette covers the installation of a typical solar system.

Suggested Quantity for Class of 20: 1

Shipping Weight: 2 lbs.

Video Tapes — 1/2" Phase I(SOLAR) Reel to Reel Video Tape (1), Model VT-SOLAR
The VT-SOLAR video tape covers the installation of a typical solar system. This tape is identical in subject content to the VC-SOLAR cassette.

Suggested Quantity for Class of 20 Students: 1

Shipping Weight: 2 lbs.

SLIDES

35mm slides coordinated for use with Solar Student Manual (SP-12), Model T-6

The slides correspond to the text material for lecture presentation.

Suggested Quantity for Class of 20 Students: 1 set

Shipping Weight: 5 lbs.

Transparencies coordinated for use with Solar Student Manual (SP-12), Model T-7

The T-7 Transparencies are identical in subject content to the T-6 35mm slides.

Suggested Quantity for Class of 20 Students: 1 set

Crated Shipping Weight: 12 lbs.

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TRAINERS

Solar Cycle Trainer, Model RT-5
The RT-5 permits the student to view a simulated solar heat hydronic cycle in a way that is easy to understand. Various operating modes can be programed into the trainer to show the different flow routes and component functions. A series of switches at the front of the trainer are used to program various conditions into the trainer. The proper operating mode of the system then matches the conditions. The switches bring on the cycle in a normal operating sequence.

The trainer pictorially represents the major components and piping of a typical solar heating system. This trainer also includes auxiliary heating, as well as a system air mover. An instructor manual is provided with the trainer.

The gray trainer frame is of sturdy wood construction (Lennox paint No. 98L2080). Clear plastic front protects trainer face from dirt and provides easy maintenance and cleaning. Swivel legs at the trainer base swing out to increase stability or swing in to reduce storage space. A built-in safety interlock switch de-energizes the unit when the trainer back is removed.

Suggested Quantity for Class of 20 Students: 1

Height — 24-1/2"	Shipping Weight: 60 lbs.
Width — 36"	120V, 60 Hz, 2.5 amps
Depth — 4-1/2"	

Solar Schematic Trainer, Model EB-5
The EB-5 helps explain the electrical operation of a first stage solar heat, second stage heat — (auxiliary), cooling system. The trainer removes the confusion students often encounter with wiring schematics.

The multicolor schematic diagram contrasts with the black trainer face background for high visibility. Different colored circuits on the schematic depict both high and low voltage circuitry. Schematic symbols are labeled for easy component identification. Switches located on the front of the trainer permit various parts of the circuit to be lighted and discussed independent of the rest of the circuit. A built-in safety interlock switch de-energizes the unit when the trainer back is removed. The durable wood frame and base are finished with attractive Lennox gray paint (Lennox paint No. 98L2080). The trainer board front is covered with a clear plastic for easy cleaning. Swivel legs at the trainer base swing out to increase stability or swing in to reduce storage space. A detailed instructor manual plus spare bulbs and fuses are provided with the trainer.

Suggested Quantity for Class of 20 Students: 1

Height — 24-1/2"	Shipping Weight: 65 lbs.
Width — 36"	120V, 60 Hz, 1.2 amps
Depth — 4-1/2"	

Solar Heat Service Trainer, Model ST-17

The Solar Heat Service Trainer brings the electrical functions of a solar system to the classroom. The instructor may create one or any combination of eleven faults. These faults are inserted by flipping a switch on the back of the trainer. The student must then approach the trainer, find the fault and suggest a solution as would be done in an actual field situation. Instruments used by the student in troubleshooting the trainer are those used in the field.

Actual solar electrical components are mounted on the front of the trainer. These include sensors, relays, control center and Federal/Pacific fused disconnect switch. The trainer front has a canary yellow (Lennox paint No. 99L3739), bonded mar-resistant finish and the sturdy wood frame is gray (Lennox paint No. 87L2080). The rear panel of the trainer has eleven double-throw 15-amp rating switches, a main power switch and five circuit-protecting fuses in black bakelite fuse holders. This compact trainer has heavy-duty black folding handles on the side for portability. A detailed instructor manual is supplied with the trainer.

Faults which can be created by using the switches on the back panel include:

Blown fuse in disconnect
Defective collector circulation pump
Open lead in thermostat
Uncalibrated temperature sensor
Burned out temperature sensor
Defective blower motor
Open temperature relay
Shorted temperature relay
Open differential relay
Shorted differential relay
Open high temperature limit

Suggested Quantity for Class of 20 Students: 3

Height — 24" Shipping Weight: 85 lbs.
Width — 30" 120V, 60 Hz, 3.0 amps
Depth — 11"

Solar System Trainer, Model AP-3

The AP-3 Solar System Trainer typifies a complete solar heating system. Trainer components include: Lennox solar collector, circulation pumps, control panel with sensors, heat exchangers, storage tank, air separator, air handler, solar heating coil, automatic air vents and thermostat.

The trainer demonstrates how a solar collector absorbs heat. Heat is transferred to the storage tank filled with water. The air mover and solar heating coil are used to disperse the stored heat. Directional valves are used to control flow through the system. As the trainer solar heating system functions, built-in gauges, thermometers and flow meters permit close observation of pressures, temperatures and flow.

The trainer is mounted on a frame and can be wheeled into the sunlight for operation.

Suggested Quantity for Class of 20 Students: 1

Height — 78" Shipping Weight: 750 lbs.
Width — 38" 120V, 60 Hz, 7.5 amps
Depth — 60"

Solar System Trainer Kit, Model AP-4

The AP-4 Solar System Trainer Kit, like the AP-3, typifies a complete solar heating system. Trainer components include: Lennox solar collector, circulation pumps, control panel with sensors, heat exchangers, storage tank, air separator, air handler, solar heating coil, automatic air vents and thermostat.

The trainer demonstrates how a solar collector absorbs heat. Heat is transferred to the storage tank filled with water. The air handler and solar heating coil are used to disperse the stored heat. Directional valves are used to control flow through the system. As the trainer solar heating system functions, built-in gauges, thermometers and flow meters permit close observation of pressures, temperatures and flow.

The differences between the AP-4 and AP-3 are:

1) The AP-4 is a kit that comes unassembled so the student can gain system assembly experience.
2) The AP-4 is stationary and the collector may be mounted remote from the rest of the trainer components. Fifty feet of piping and piping insulation is supplied to accomplish this.

Suggested Quantity for Class of 20 Students: 1

Height — 24" Shipping Weight: 500 lbs.
Width — 38" 120V, 60 Hz, 7.5 amps
Depth — 80"

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Hydronic Principles Trainer, Model AP-5
The Hydronic Principles Trainer teaches fundamental hydronics as it pertains to a solar system. The trainer can be used to teach the following: the use of test instruments, the effect of various pressures in a hydronic system, and the effect of water leaks and air locking in a system. The trainer is also an excellent vehicle to teach the principle used in system balancing. The student will be able to study and observe the operation of circuit setters, water pumps, check valves, air vents, air separators and heat exchangers along with other components. Clear plastic tubing is used in certain areas, permitting the student to view fluid flow through the circuits. This trainer is compatible with student solar software.

Suggested Quantity for Class of 20 Students: 1

Height — 5' Shipping Weight: 150 lbs.
Width — 36" 120V, 60 Hz, 1.2 amps
Depth — 18"

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LIVE EQUIPMENT

Domestic Hot Water System, Model SHW-2
The Domestic Hot Water System consists of a 66-gallon solar energy hot water tank with factory-installed operating components, two single glass solar collectors, and piping to connect the collector to the storage tank. This domestic hot water heating system is supplied with detailed installation instructions for setup in a school laboratory. Equipment is supplied for use by students to practice assembly, maintenance and troubleshooting of separate parts and the complete system. Equipment is compatible with that shown in the student manuals and visuals.

Electrical Characteristics: 115V, 60 Hz, 1-phase

Solar Space Heating System, Model SHS-6
Space heating system consists of 6 solar collectors, heat exchanger, 250-gallon storage tank, solar heat coil, pumps and all components necessary to install a complete system. Installation instructions for setup in a school laboratory are included. Auxiliary heating and domestic hot water equipment is available for this system.

Equipment is supplied for use by students to practice assembly, maintenance and troubleshooting of separate parts and the complete system. Equipment is compatible with that shown in the student manuals and visuals.

Solar Space Heating System, Model SHS-18
Space heating system consists of 18 single glass solar collectors, heat exchanger, 1000-gallon storage tank, solar heat coil, pumps and all components necessary to install a complete system. Installation instructions for setup in a school laboratory or home are included. Auxiliary heating and domestic hot water equipment is available for this system. Equipment is new and is supplied for use by students to practice assembly, maintenance and troubleshooting of separate parts and the complete system. Equipment is compatible with that shown in the students manuals and visuals.

Solar Collector, Model LSC18-1S
The LSC18-1S collector is a single pane high thermal efficiency flat-plate collector applicable to new or retrofit installations.

Specifications:
Nominal Collector Area — 18 sq. ft.
Effective Absorber Area — 15.4 sq. ft.
Ratio Of Usable Absorber Area To Total Surface Covered — 86%
One Glass Cover:
- 1/8 in. Thick
- Tempered, Low-Iron, Clear
- Transmittance — .96

Absorber Coating-Black Chrome On Bright Nickel:
- Absorptivity — .94
- Emissivity — .10
- Stable To 850°F

Absorber Construction:
- Steel Plate
- Copper Flow Tubes — (10) 1/4 in. o.d. (.194 in. i.d.)
- Tube Spacing — 3 in. On Center
- Tube Pattern — "Z" Flow
- Manifold — 1-1/8 in. o.d. (1.079 in. i.d.)

Tube Connections To Manifold:
- ASTM BCuP-3 Brazing Material
- Bond Between Tubes & Steel Plate — 95-5 Solder
- Piping Connections (inlet-outlet) — 1/8-18 fpt

Manifolds & Tubes Pressure Tested:
- To 150 psig Working Pressure

Recommended Flow Rate Thru Collector — .3 to .7 gpm
Collector Fluid Capacity — .3 gal.
Collector Fluid (50-50 Dowtherm SR-1 Equivalent):
SR-1 Data:
- Density — 1.045 g/ml (at 160°F)
- Viscosity — 1.4 centipoise (at 160°F)
- Thermal Conductivity — 0.23 Btu/lb.-°F (at 160°F)
- Specific Heat — 0.85 Btu/lb °F (at 160°F)
- Boiling Point — 232°F
- Freezing Point — minus 34°F

Insulation — Semirigid Fiberglass Board:
- Density — 3.0 lb./ft.^{3}
- Thermal Conductivity — 0.28 Btu in./hr-ft^2 (at 200°F) (R = 12.5)
- Specific Heat — 16 Btu/lb°F
- Maximum Temperature — 550°F (without outgassing)

Collector Shipping Weight (lbs.) — (1/Package)
- LSC18-1S — 143

Collector Net Weight (lbs.)
- LSC18-1S — 123

Solar Collector, Model LSC18-1

The LSC18-1 Collector is a double pane high thermal efficiency flat-plate collector applicable to new or retrofit installations.

Specifications:

Nominal Collector Area — 18 sq. ft.
Effective Absorber Area — 15.4 sq. ft.
Ratio Of Usable Absorber Area To Total Surface Covered — 86%
Two Glass Covers
  1/8 in. Thick
  Tempered, Low-Iron, Clear
  Transmittance — .96
Absorber Coating — Black Chrome On Bright Nickel
  Absorptivity — .94
  Emissivity — .10
  Stable To 850°F
Absorber Construction:
  Steel Plate
  Copper Flow Tubes — (10) 1/4 in. o.d. (.194 in i.d.)
  Tube Spacing — 3 in. On Center
  Tube Pattern — "Z" Flow
  Manifold — 1-1/8" in. o.d (1.079 in. i.d.)
  Tube Connections To Manifold:
    ASTM BCuP-3 Brazing Material
  Bond Between Tubes & Steel Plate — 95-5 Solder
  Piping Connections (inlet-outlet) — 3/8-18 fpt
  Manifolds & Tubes Pressure Tested:
    To 150 psig Working Pressure
Recommended Flow Rate Thru Collector — .3 to .7 gpm
Collector Fluid Capacity — .3 gal.
Collector Fluid (50-50 Dowtherm SR-1 or Equivalent):
SR-1 Data:
  Density — 1.045 g/ml (at 160°F)
  Viscosity — 1/4 centipoise (160°F)
  Thermal Conductivity — 0.23 Btu/lb °F (at 160°F)
  Specific Heat — 0.85 Btu/lb °F (at 160°F)
  Boiling Point — 232°F
  Freezing Point — minus 34°F
Insulation — Semirigid Fiberglass Board:
  Density — 3.0 lb./ft.^{3}
  Thermal Conductivity — 0.28 Btu in./hr-ft^2 (at 200°F)
  (R = 12.5)
  Specific Heat — 16 Btu/lb.°F)
  Maximum Temperature — 550°F (without outgassing)
Collector Shipping Weight (lbs.) — (1/Package)
  LSC18-1-170
Collector Net Weight (lbs.)
  LSC18-1-150

COMPONENT PARTS

Component Parts — Solar Heating, Model CP-8

Includes:
differential controller
aquastat controller
return air limit control
pressure relief valve
plug-in relay
check valve
hand valve
circulation pump
strainer
balancing valve
sensors

Suggested Quantity for Class of 20 Students: 1

TESTING EQUIPMENT

Testing Equipment — Solar Heating, Model LE-8

Includes:
charging pump
pressure gauge
thermometer
circuit setter
readout meter
insolation meter

Suggested Quantity for Class of 20 Students: 1

Tear Here

LENNOX EDUCATION PRODUCTS

a division of Lennox Industries Inc.

Lennox Education Products, 1600 E. Linn, Marshalltown, Iowa 50158 Phone 515/754-4114

Litho U.S.A.

heating-air conditioning technology...

keeping pace with an energy conscious world

LENNOX job related courses in heating and air conditioning

LENNOX HEATING/AIR CONDITIONING TRAINING PROGRAM

The heating/air conditioning industry is commanding more and more attention in view of today's growing energy and environmental concerns. Emphasis is on energy efficient equipment and utilization of new forms of energy (such as solar).

Servicing this equipment is vitally important in an energy-conscious world. Lennox offers a comprehensive heating/air conditioning training program to fulfill this need. The program is divided into several courses or phases to provide a logical learning progression. Courses include:

Phase I (S) — Basic Maintenance
Phase II (S) — Full Residential Service
Phase III (S) — Commercial Installation & Service
Phase I (A) — Residential Application
Phase I (HP) — Heat Pump Service & Maintenance
Phase I (SOLAR) — Solar Application, Installation, Service & Maintenance

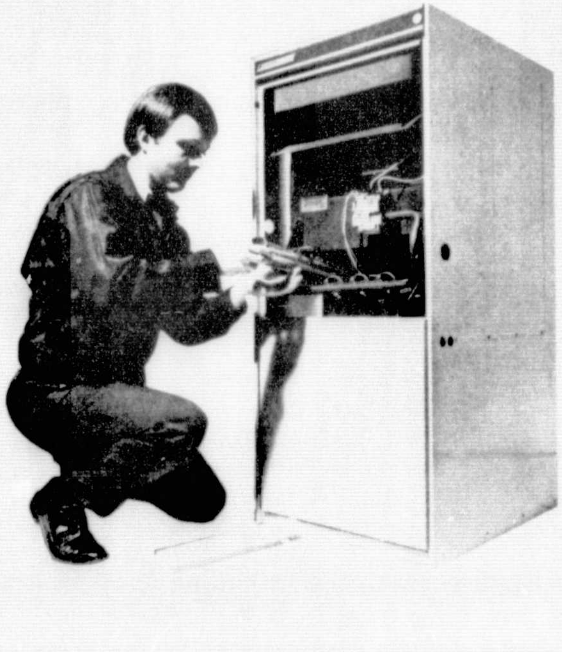
multimedia line

A multimedia line of educational materials has been developed for use in these courses, including manuals, overhead slides, films, video tapes, trainers and live equipment.

manuals are backbone

The manuals are the backbone of the Lennox training courses. They are designed and written in an easy-to-read, graphically pleasant format. Technical information is made easier to comprehend because manuals are written to the eighth and ninth grade reading level (the reading level of most newspapers). Content is low in theory and high in practical knowledge.

A complete line of trainers is compatible with the manuals and enhance the student's understanding of heating/air conditioning. Some trainers are used to visually demonstrate certain things, while others give the student a "hands-on" approach to learning service techniques. Hours of the instructor's time are saved by using these trainers, because the instructor no longer has to spend time "bugging" live equipment. Fuses protect the trainers from damage due to student errors.



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live equipment

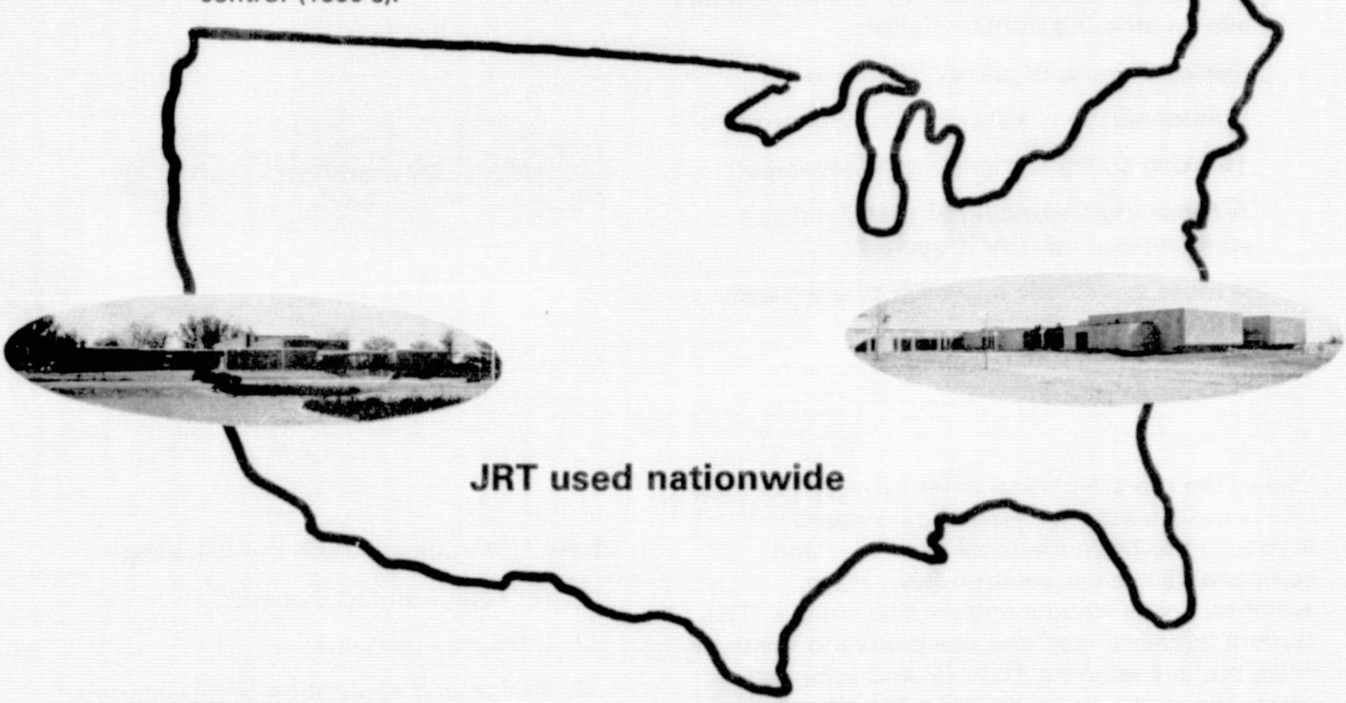
The live equipment offered by Lennox enables the student to work on many of the same units that are encountered in the field. Live equipment gives students an excellent opportunity to apply what they've learned from the other training materials.

slides, films, tapes

Supplementing the manuals, trainers and live equipment are a series of overhead slides, films and video tapes. These closely follow the content of the manuals. The overhead slides are designed so the instructor may mark on them, thus tailoring them to the class situation.

a little about ourselves . . .

Lennox Industries has been a major manufacturer of heating/air conditioning equipment since the turn of the century. Over the years many Lennox innovations have gained industry wide acceptance . . . coal furnaces made of steel (1904), forced air heating (1930's), and multizone climate control (1960's).



About ten years ago, Lennox recognized an acute industry-wide shortage of trained heating/air conditioning service personnel and decided to do something about it. Lennox Job Related Training (JRT) was thus born. Designed primarily for teaching within Lennox, this program has been making its way into vocational technical schools in increasing numbers. Although instruction is with Lennox product, the knowledge can be applied to other brands of heating/air conditioning equipment.

Hundreds of Lennox training programs are located in virtually every state in the nation, as well as many foreign countries. In addition to the voc tech market, colleges, universities, correctional institutions, trade unions and private companies are among our valued customers.

COURSE DESCRIPTIONS

phase I (S) basic maintenance

Phase I (S) is the most important of the phases. In this phase the pattern for the entire program is established. Material learned in Phase I (S) acts as a springboard for Phase II (S). Phase I (S) trains the student to the level of a basic maintenance serviceman. The I (S) graduate is not a full-fledged serviceman, but is capable of correcting minor service problems as well as performing complete service checks on heating (all fuels) and cooling equipment.

Upon completion of Phase I (S), the student has made an amazing transformation:

Self-confidence is greatly increased;

Communications skills are vastly improved;

Thinking ability is more highly developed;

A better understanding of the heating/air conditioning industry is gained;

A more systematic approach to work and learning is developed.

student instantly productive

One of the more technical areas covered in Phase I (S) is basic electricity. Here the trainee is introduced to basic electrical principles and components such as electron flow, fuses, switches, series circuits and parallel circuits. The student learns to read and use meters to measure volts, ohms and amps. Pictorial and schematic wiring diagrams and electrical symbols are also taught.

Phase I (S) manuals teach the following:

1. A "Total Comfort System"
2. Customer relations
3. Design and application of thermostats
4. Heating components and application
5. The combustion process
6. Cooling components and application
7. Basic maintenance — heating (gas, oil and electric)
8. Basic maintenance — (cooling)

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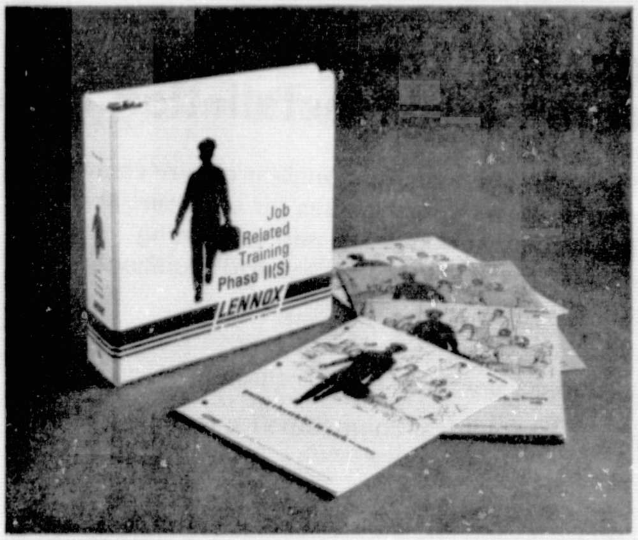
phase II (S)
full residential service



Phase II (S) deals with all procedures required to service and troubleshoot residential equipment — both heating (all fuels) and air conditioning. This phase concentrates heavily on electrical problems. Upon satisfactory completion, the student is qualified to service all residential equipment.

electrical emphasis

In Phase II (S) emphasis is placed on reading and understanding schematic and pictorial diagrams. Eighty percent of all problems in heating and air conditioning equipment are found in the electrical circuits. It is essential, therefore, that a serviceman be totally familiar with all wiring diagrams and how to use them in the troubleshooting procedure.

Phase II (S) manuals teach the following:

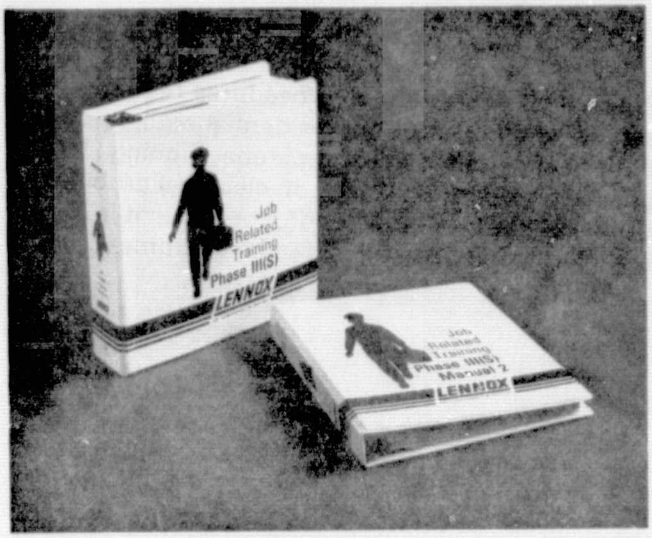
1. Controlling electrical circuits
2. Putting electricity to work — heating (gas, oil and electric)
3. Putting electricity to work — cooling
4. Troubleshooting heating (all fuels) and air conditioning systems
5. Electronic air cleaners

1 or 2 year program

NOTE: Phase I (S) and II (S) comfortably fit into a one year instructional program; I (S) the first semester and II (S) the second semester. By incorporating allied courses such as sheet metal, brazing, drafting, etc., a two year program can be developed. In Lennox schools, Phase I (S) consists of approximately 68 class hours; Phase II (S) 70 class hours.

phase III (S)
commercial installation & service

Phase III (S) covers nomenclature, service and troubleshooting techniques for commercial heating, air conditioning and ventilating equipment. Both single zone and multizone units are studied.



Subject taught in III (S) include:

1. Electrical characteristics featuring three phase power
2. Bearings, motors and blowers
3. Principles of ducted air movement
4. Introduction of outside air into commercial heating and air conditioning systems
5. Commercial cooling systems — compressors, capacity reduction, low ambient kits and timed-off cycles.
6. Heat pumps
7. Duct heaters
8. Power venters
9. Power burners commonly used on most commercial gas heating equipment
10. Flame proving systems
11. Control systems used on commercial gas heating equipment

phase I (A)
residential application

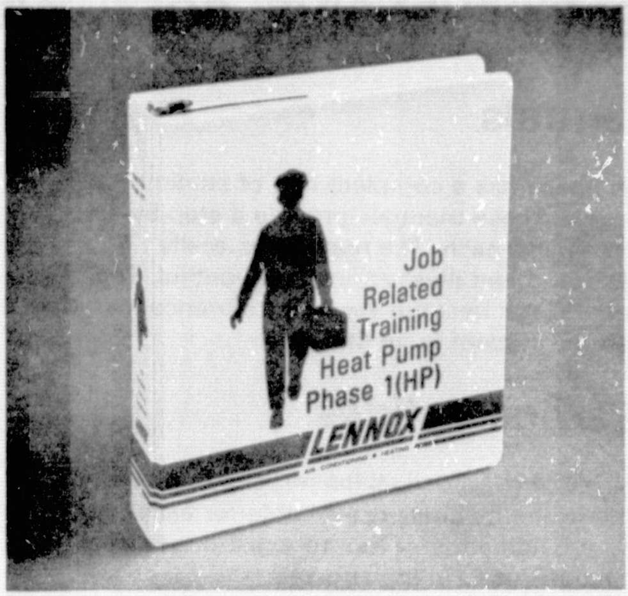
Phase I (A) introduces the student to residential application. Load calculation and equipment selection are stressed. Upon successful completion, the student is capable of figuring most residential application jobs. Methods used follow those of recognized agencies such as NESCA, ARI, ASHRAE and FHA.

Subjects taught in I (A) include:

1. Total comfort systems
2. Description and types of equipment
3. Fundamentals such as heat transfer, etc.
4. Job survey
5. Selecting types of air distribution systems
6. Residential heat loss calculating — simplified method
7. Residential heat gain calculating — simplified method
8. Use of Engineering Handbook for equipment selection and equipment nomenclature
9. Designing air distribution systems — simplified method
10. Pricing of job — equipment, labor, overhead, mark-up, etc.

phase I (HP)
full maintenance & service heat pump

Phase I (HP) provides comprehensive instruction — from the fundamentals of heat pump to advanced service and installation techniques. Lennox heat pump materials and concepts apply to any manufacturer's heat pump.



Material covered in Phase I (HP) includes:

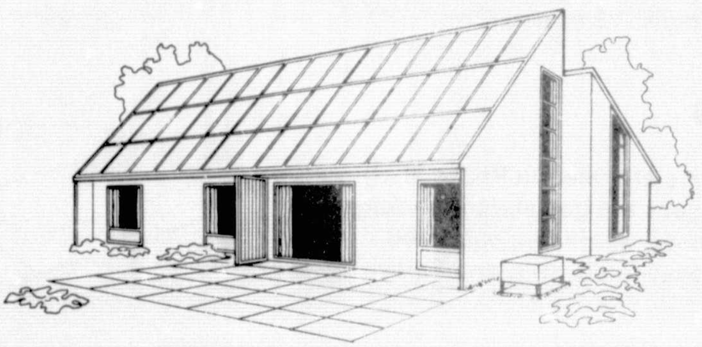
1. Design
2. Maintenance
3. Electricity (electrical function)
4. Troubleshooting sequence
5. Installation
6. Application

phase I (SOLAR)
solar application, installation, service & maintenance

Solar energy has become the talk of the country. It is a virtually untapped resource with vast potential. Lennox has pioneered a complete solar heat system and now offers a practical training course based on this system. Phase I (SOLAR) not only acquaints the student with system design, operation and maintenance, but also cost of operation and the economics of a solar system. Procedures for designing a solar system to the specific application are also taught.

Subjects taught in the Phase I (SOLAR) manuals are:

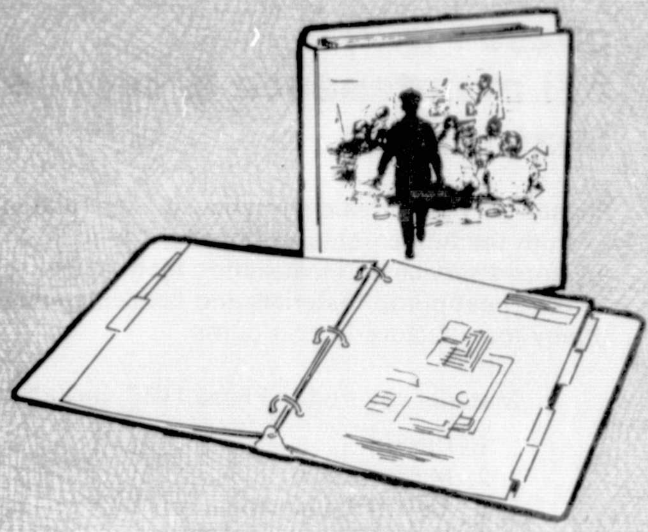
1. The sun
2. Solar systems
3. Lennox solar system
4. Components
5. Transport system
6. Electrical system
7. Design considerations
8. Equipment selection
9. Installation
10. Maintenance
11. Troubleshooting
12. Cost of operation



COMPREHENSIVE SOFTWARE

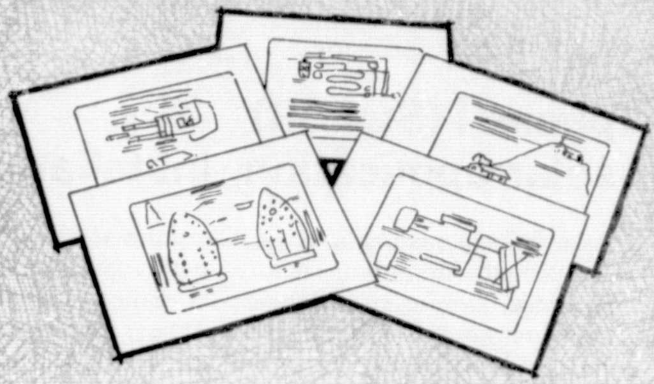
manuals

Each phase has a complete line of student manuals. These manuals provide a step-by-step learning approach. The material is easily understood and illustrations are plentiful. The manuals later become valuable reference material when the student is on the job.



overhead slides

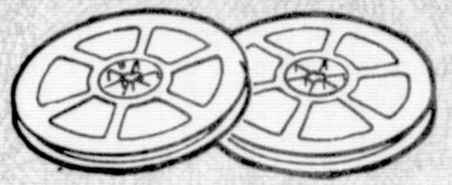
A series of overhead slides relating to material found in the manuals is available for each phase. They provide another tool to expand the teaching techniques used in the courses.



films

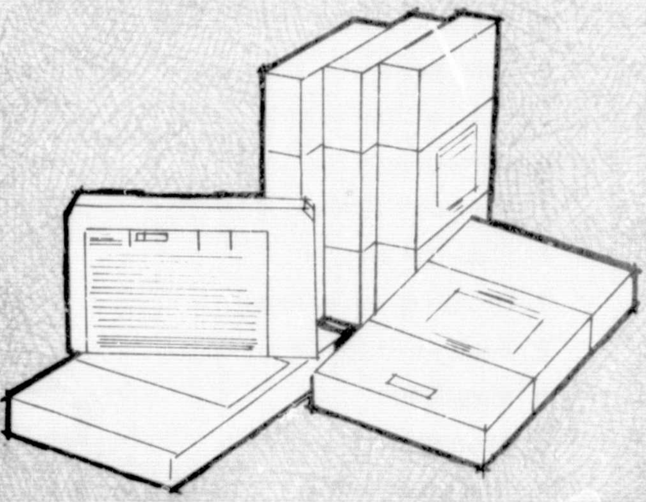
Films augment Phase I (S) and II (S) instruction. The films are:

1. "Search for Total Comfort" — Deals with the subject of home comfort as it relates to heating and air conditioning; a color film done in a humorous vein. Approximate length: 15 minutes.
2. "Design and Development of Hermetic Compressors" — A color film produced in a compressor factory to show how a compressor is designed, developed and produced. Approximate length: 10 minutes.
3. "Oil Burner Service" (audio tape/35 mm slides) 35 mm slides combine with casette sound track to explain the principles of oil burner service. Approximate length: 45 minutes.
4. "Heating-Cooling Specialist" — This entertaining color film portrays industry's need for service personnel and how Lennox Job Related Training seeks to fulfill the need. Approximate length: 12 minutes.



video tapes

A series of video tapes are used in Phase III (S). The subjects of the tapes are gas electric packaged equipment, single-zone; oil electric packaged equipment, single-zone; multizone; and Power Saver equipment.

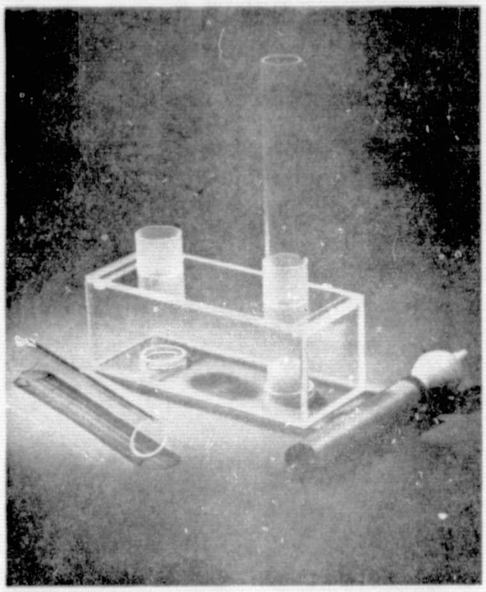


TRAINERS

Trainers add visual and "hands-on" experience to the training program, and are described individually on the following pages.

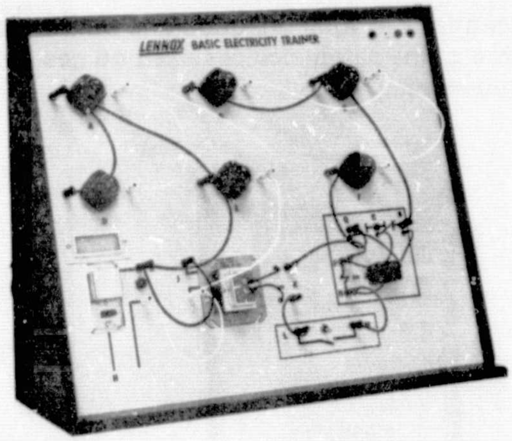
Each trainer is supplied with a detailed instructor manual which explains trainer operation.

Student workbooks are also available for some trainers to facilitate individualized instruction.



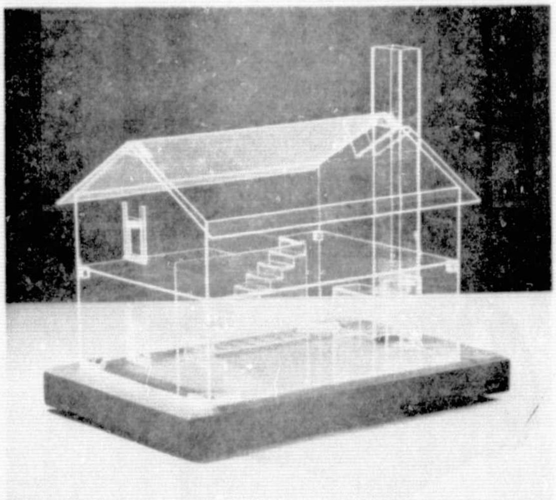
MIP-7 flue and chimney trainer

Flue and chimney principles are demonstrated with this trainer.



ST-2 basic electricity trainer

This trainer is designed to teach the student how to wire and understand all types of basic electrical circuits.

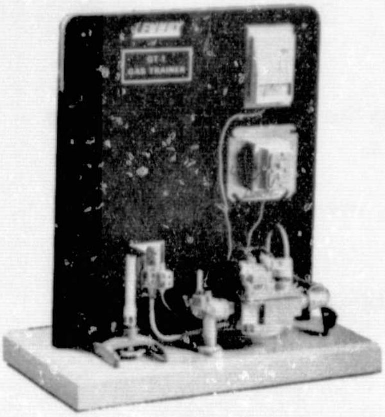


MIP-8 plastic house trainer

Chimney and fireplace effects on draft conditions within a house are shown.

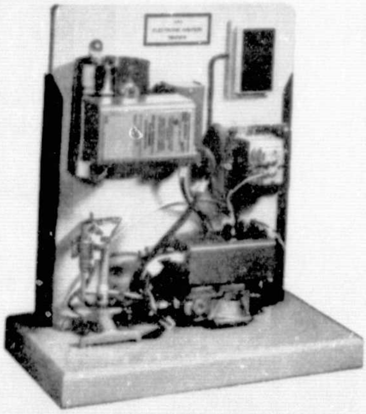
BT-1 bi-metal trainer

Bi-metal principles related to thermostat operation are demonstrated.



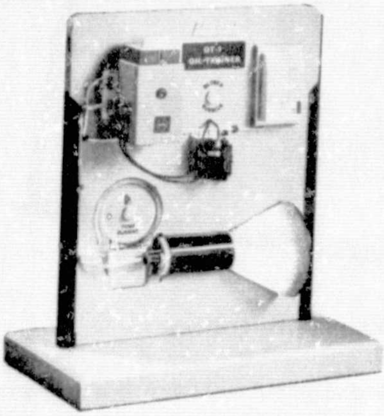
GT-1 gas fundamentals trainer

Demonstrates ignition, good and bad flame, and some of the safety devices used on gas heating equipment.



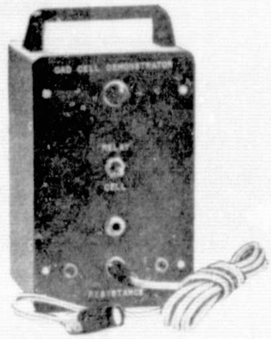
GT-2 gas electronic ignition trainer

Demonstrates electronic pilot ignition and flue damper operation on gas heating equipment.



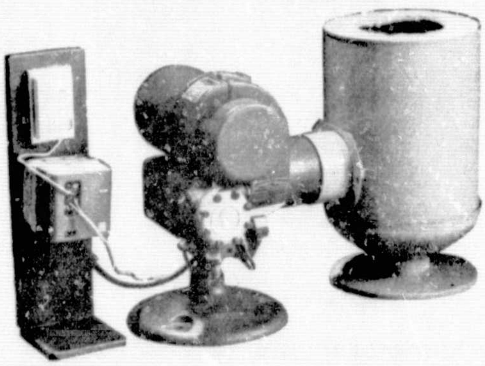
OT-1 oil fundamentals trainer

Oil furnace operation and control are demonstrated with this trainer.



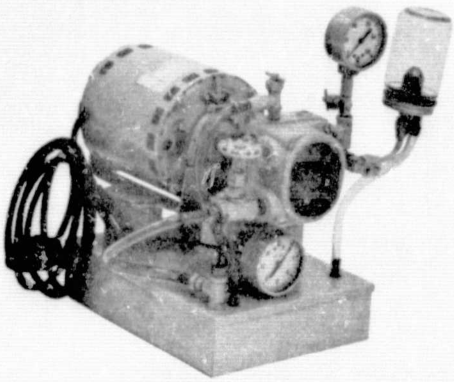
OT-2 cad cell trainer

This trainer teaches the operation of cadmium cell controls in an oil burner.



OT-3 oil burner trainer

Oil flame characteristics can be studied on this trainer.



OT-4 oil pump trainer

This trainer is used to visually demonstrate the operation of a two stage oil pump.

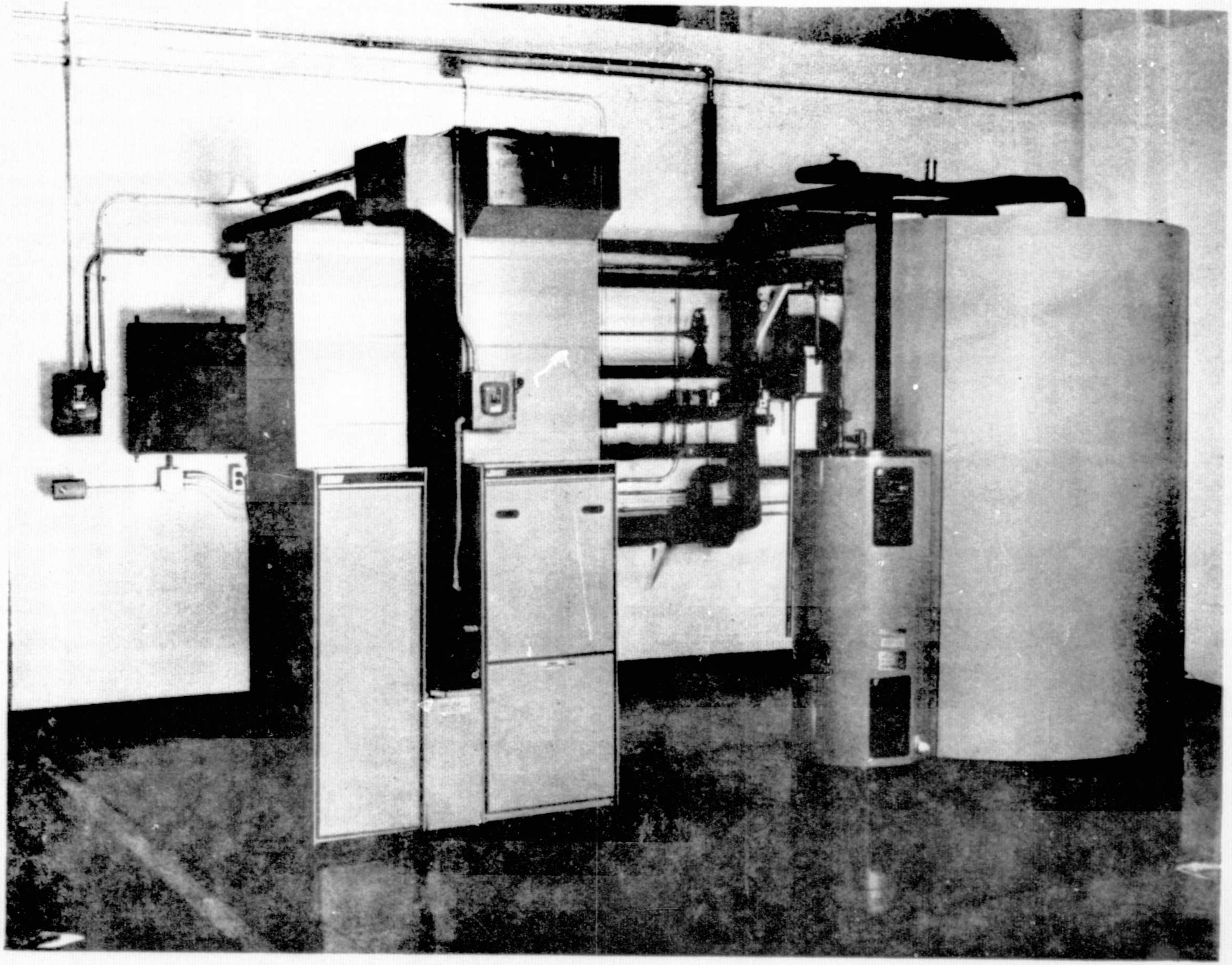
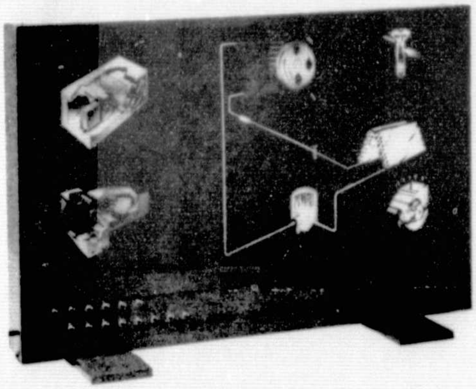


Figure 5-2. Indoor Lennox Solar System Components

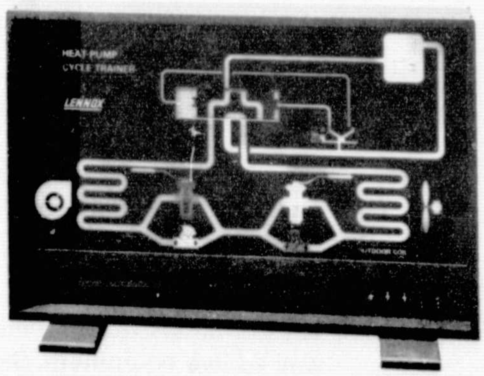


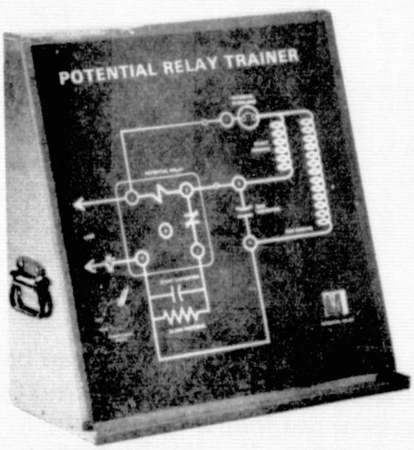
RT-1 refrigeration system trainer

This trainer teaches the air conditioning refrigerant circuit and how the component parts relate.

RT-3 heat pump cycle trainer

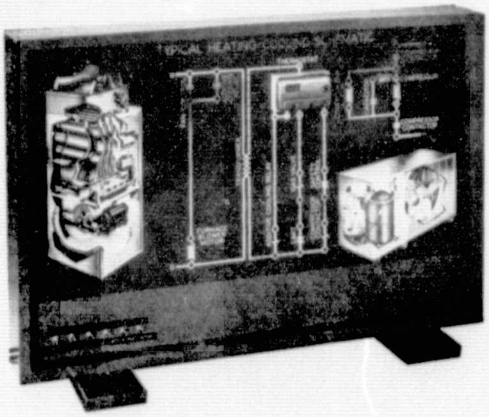
The trainer permits the student to view a simulated heat pump refrigerant cycle.



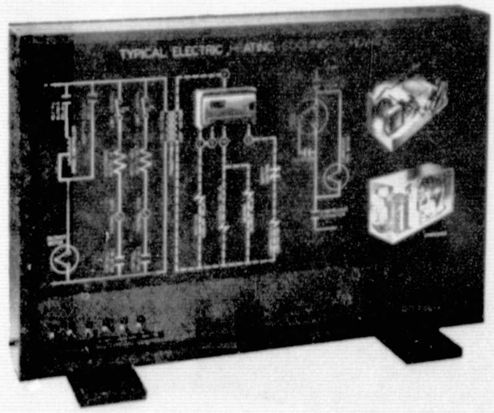


ST-1A potential relay trainer

A difficult control to understand (potential relay) is made simple with this trainer.

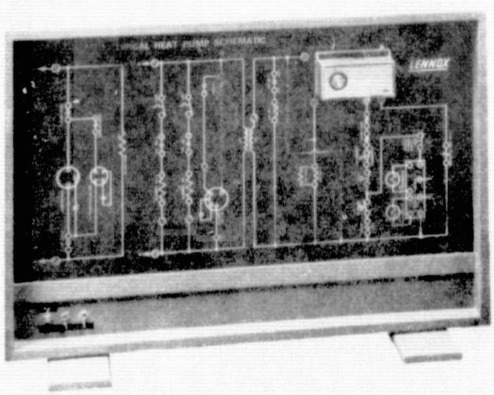


EB-1 heating-cooling schematic trainer (gas)

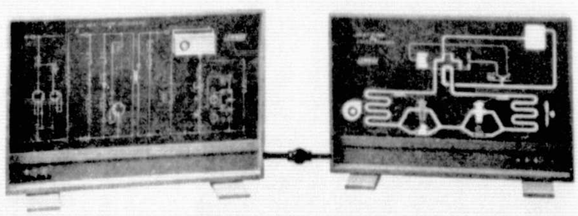


EB-2 heating-cooling schematic trainer (electric)

The EB series of schematic trainers are used to teach the electrical control sequence of heating and air conditioning equipment. As the electrical sequence takes place, various parts of the multicolored schematic light up. This permits the student to concentrate on a particular section of the diagram when it is energized in the circuit. These trainers respond electrically in the same way as live equipment. Switches on the front of the trainers allow the instructor to manually put the trainers through their electrical paces.

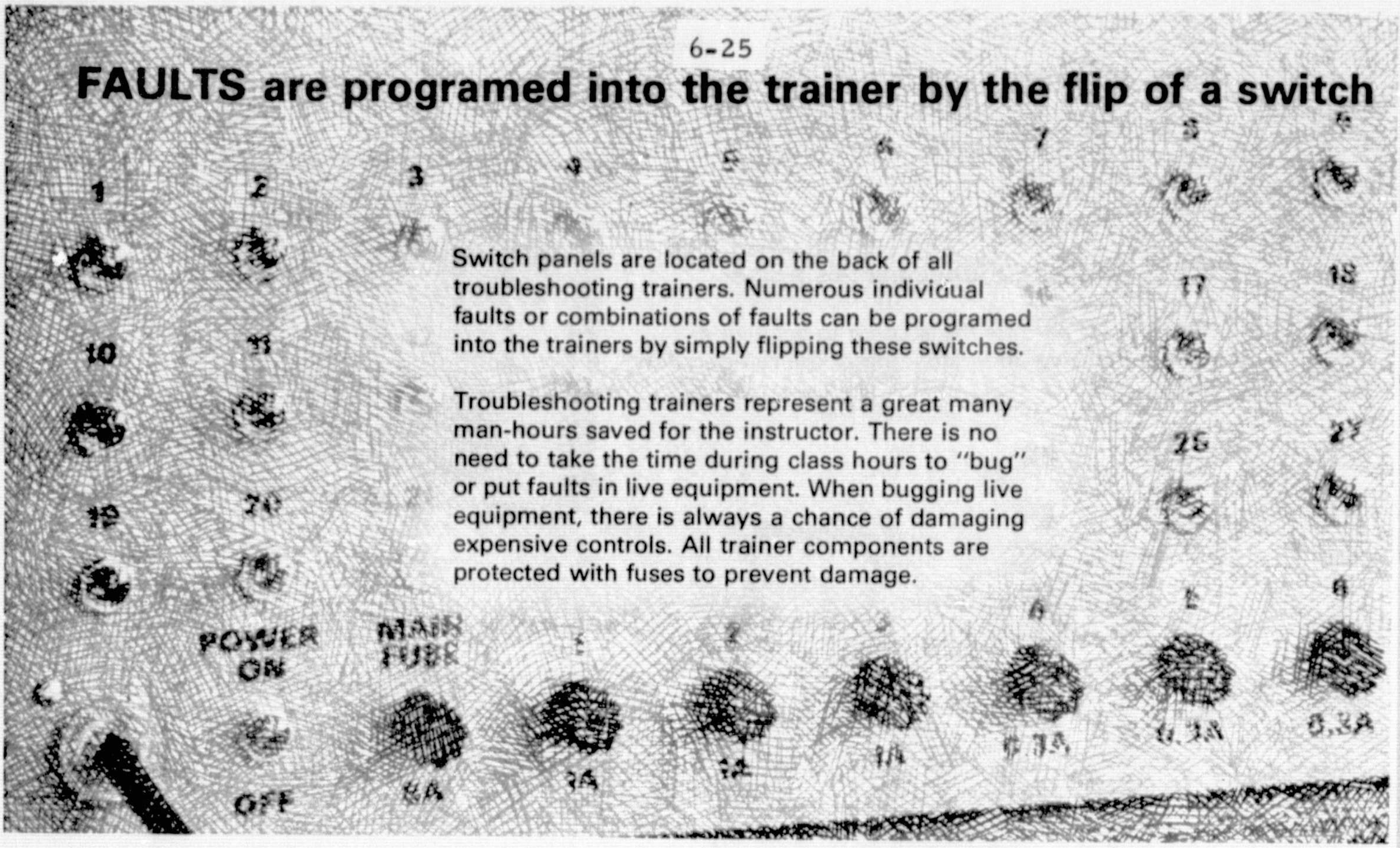


EB-4 typical heat pump schematic trainer



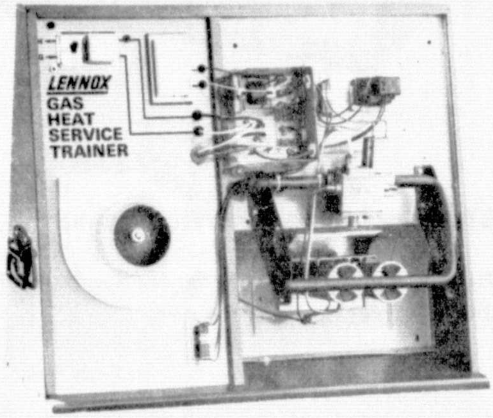
The EB-4 Heat Pump Schematic Trainer can be electrically connected to the RT-3 Heat Pump Cycle Trainer. The student can follow the electrical control cycle and observe how it affects the refrigerant cycle.

FAULTS are programed into the trainer by the flip of a switch



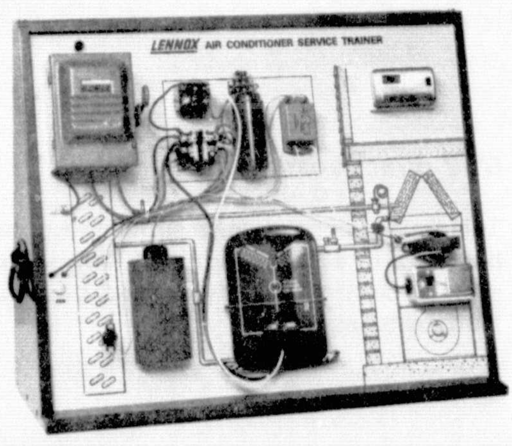
Switch panels are located on the back of all troubleshooting trainers. Numerous individual faults or combinations of faults can be programed into the trainers by simply flipping these switches.

Troubleshooting trainers represent a great many man-hours saved for the instructor. There is no need to take the time during class hours to "bug" or put faults in live equipment. When bugging live equipment, there is always a chance of damaging expensive controls. All trainer components are protected with fuses to prevent damage.



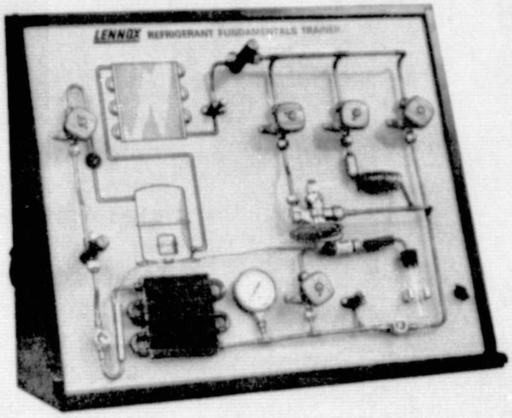
ST-4 gas heat service trainer

This trainer has an actual burner flame and 18 faults that can be switched into the wiring system.



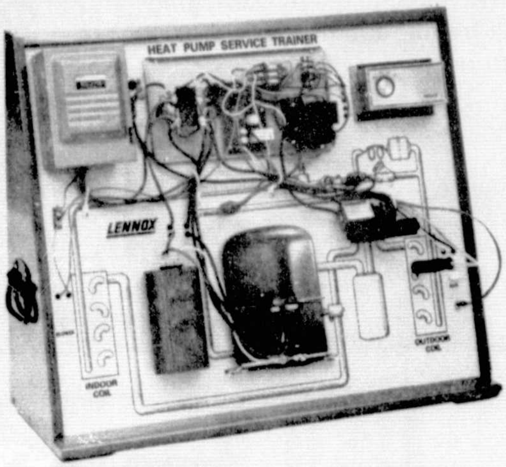
ST-14 air conditioner service trainer

This trainer shows circuitry and electrical function of a typical residential air conditioning system. Thirteen faults may be programed into the ST-14.



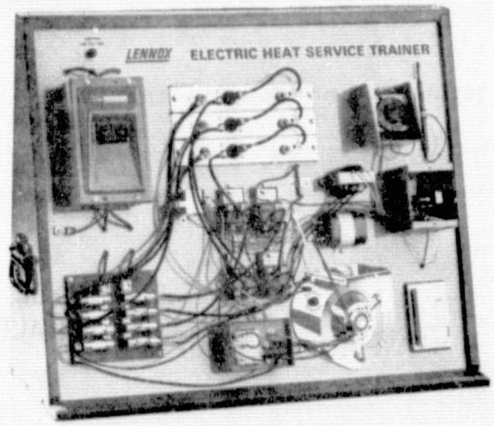
ST-10 refrigerant fundamentals trainer

This trainer permits the student to achieve a comprehensive understanding of the refrigeration cycle.



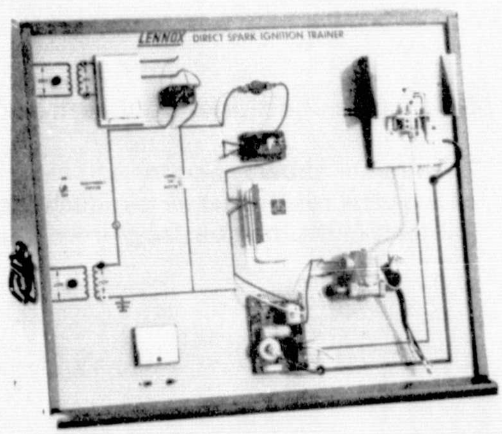
ST-9 heat pump service trainer

When this trainer is put through its heating, cooling and defrosting paces, the student is able to work with components similar to what will be encountered in the field. The trainer has 12 fault switches.



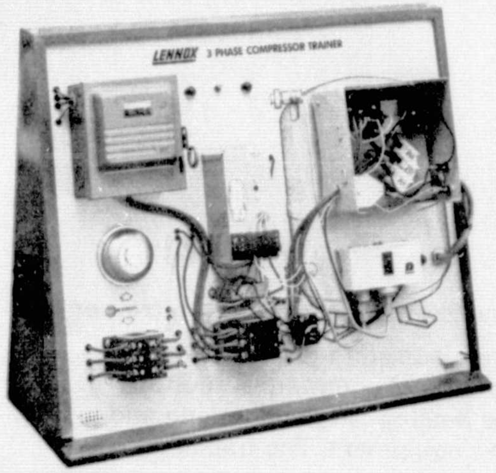
ST-3 electric heat service trainer

Twenty-seven different faults can be switched into this troubleshooting trainer.



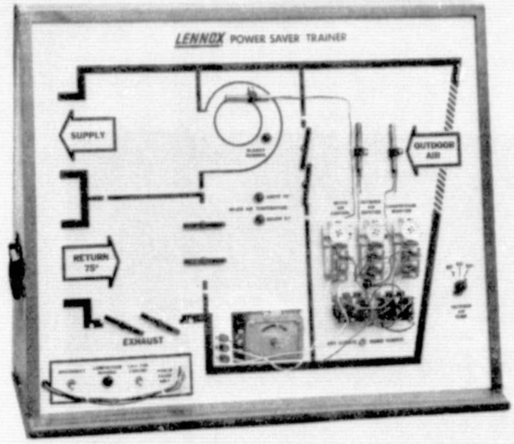
ST-7 direct spark ignition trainer

This trainer consists of a simulated power gas burner, a direct spark ignition flame proving system, control circuitry, control board and nine fault switches.



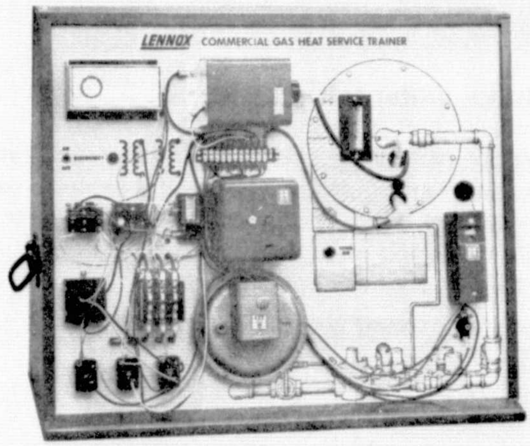
ST-5 three phase compressor trainer

This trainer simulates the operation of a three phase commercial air conditioner. Although the trainer operates on a 120 volt circuit, it provides 208 volt, three phase power. Thirteen faults may be switched into this trainer.



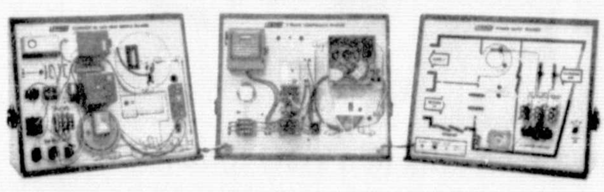
ST-6 Power Saver™ trainer

The Power Saver™ trainer simulates the operation of mixed air temperature control systems generally used on rooftop heating and air conditioning equipment. Eight different faults may be programed into the trainer.

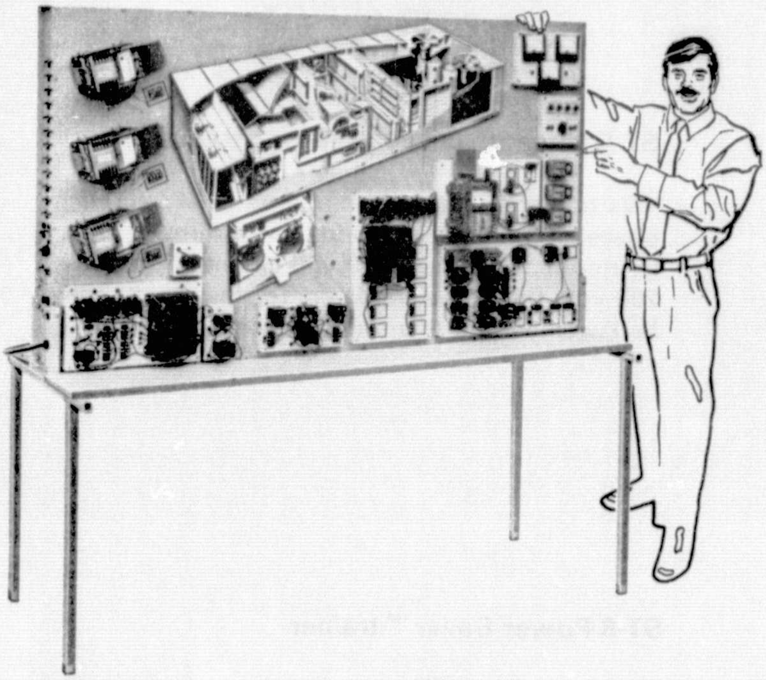


ST-8 commercial gas heat service trainer

The ST-8 Gas Heat Service Trainer simulates the heating operation and associated protective circuitry of a commercial rooftop unit. The trainer has ten fault switches.

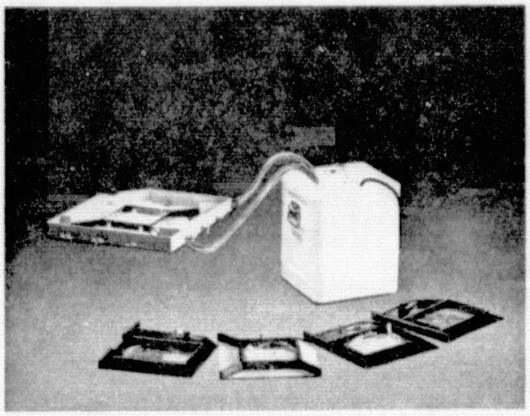


The ST-5, ST-6 and ST-8 can be electrically coupled in several combinations: heating — cooling; cooling — Power Saver™; heating — cooling with Power Saver™. The student has the opportunity to study the interrelationship of one trainer with another. When coupled, these trainers represent a typical commercial unit with heating, air conditioning and Power Saver™ equipment.



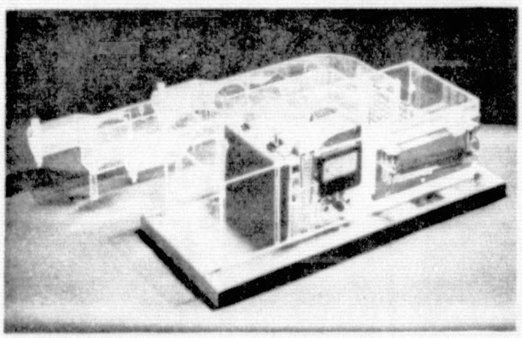
ST-15 multizone control system trainer

This trainer is used to teach a basic understanding of commercial rooftop multizone heating, air conditioning and ventilating equipment. The trainer has 30 fault switches.



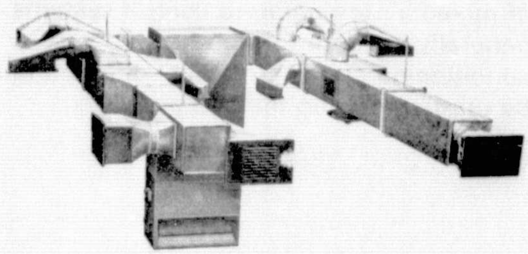
FV-2 flo-vu water table

This important tool is used to visibly demonstrate air circulation in a building. The water table is set on the stage of any standard overhead projector. Specially designed plexiglas inserts fit on the trainer to demonstrate specific flows.



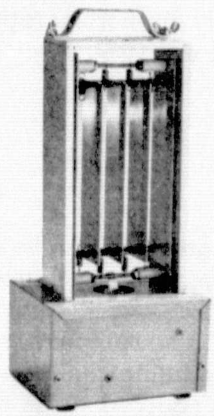
AP-2 air distribution system trainer

The AP-2 is used to acquaint the student with fundamentals of air movement found in typical forced air heating and air conditioning systems.



AP-1 duct system trainer

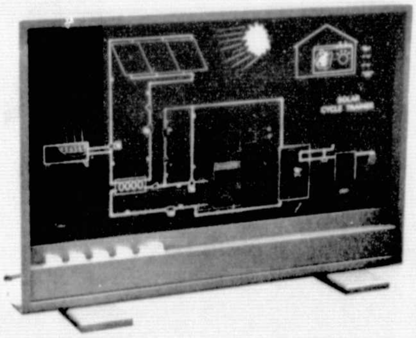
This trainer acquaints the student with good heating and air conditioning system design practices. It consists of two full sized duct systems: one system is properly designed; the other system is poorly designed.



AC-3 electronic air cleaner trainer

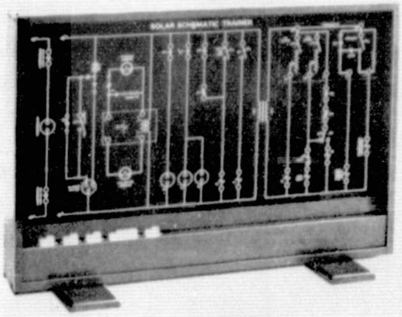
This trainer is designed to visually illustrate electronic air cleaner operation.

solar TRAINERS



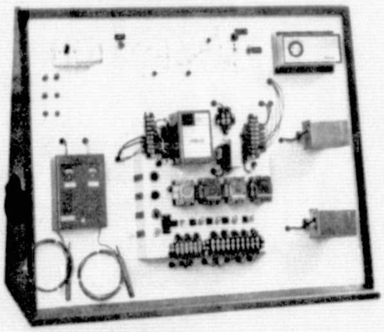
RT-5 solar cycle trainer

Simulates solar heat hydronic system. Various modes can be programed to show fluid flow and component function. For lecture and self-study.



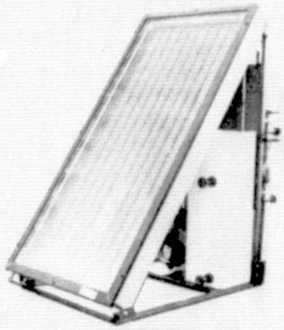
EB-5 solar schematic trainer

Explains the electrical operation of solar heat, auxiliary heat and electric cooling stages.



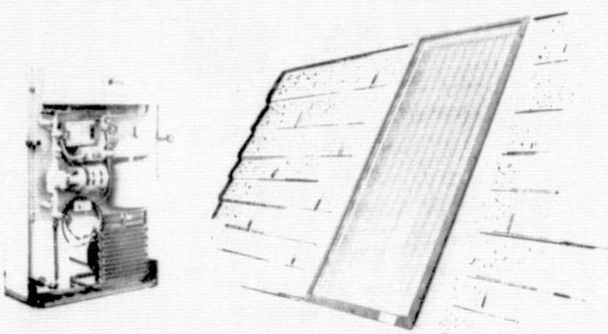
ST-17 solar heat service trainer

Teaches normal operation and electrical troubleshooting for a typical system.



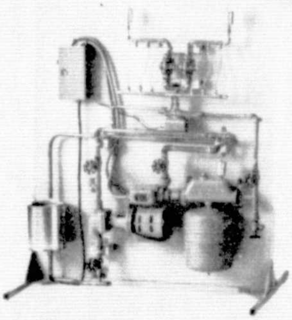
AP-3 solar system trainer

This trainer is a scaled-down working solar heat system. Gauges and thermometers aid the student in understanding solar heat principles. Self-contained and completely portable.



AP-4 solar system trainer kit

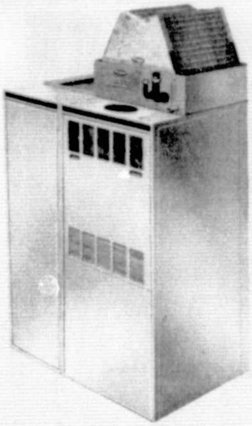
Same system as AP-3. Comes unassembled for student assembly experience. Collector may be located outdoors, remote from the rest of the trainer.



AP-5 hydronic principles trainer

A unique trainer that permits the student to observe and direct fluid flow through various solar components. Fundamentals of charging a solar system can also be practiced on this trainer.

LIVE EQUIPMENT FOR JOB RELATED TRAINING

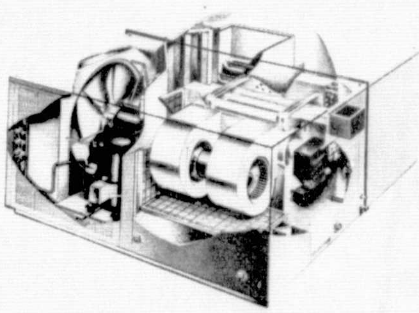


Live equipment is a necessity for student "hands-on" training. The equipment offered by Lennox is an excellent cross section of what will be found in the field: electric, gas and oil furnaces (up-flo and down flo); combination heating and air conditioning units; heat pumps; electronic air cleaners; humidifiers; solar collectors; solar domestic hot water systems; and complete solar space heating systems.

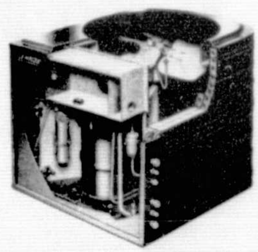
Electric, Gas and Oil Furnaces

Humidifiers

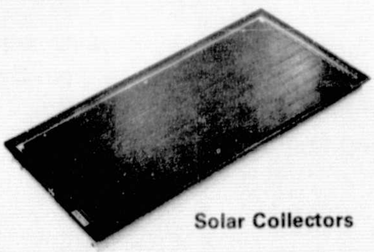
Electronic Air Cleaners



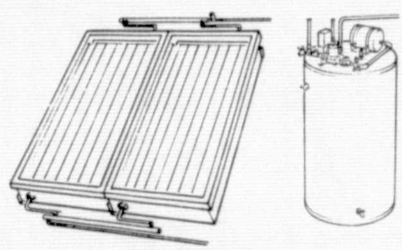
Combination Heating and Air Conditioning Units



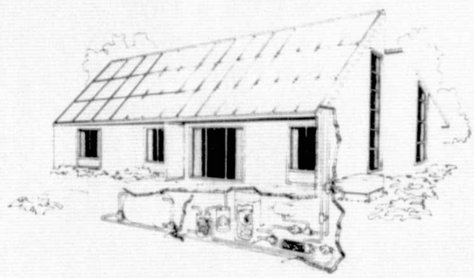
Air Conditioning and Heat Pump Units



Solar Collectors



Solar Domestic Hot Water Systems



Solar Space Heating Systems

WHAT MATERIALS ARE USED IN WHAT COURSE

The following chart lists the course each of the Job Related Training materials are used in.

Model No.	Item	PHASE I (S)	PHASE II (S)	PHASE III (S)	PHASE I (HP)	PHASE I (A)	PHASE I (SOLAR)
FV-2	Flo-Vu Water Table with 5 inserts & accessories	●				●	
RT-1	Refrigeration System Trainer	●					
RT-3	Heat Pump Cycle Trainer				●		
RT-5	Solar Cycle Trainer						●
EB-1	Heating-Cooling Schematic Trainer (Gas)		●				
EB-2	Heating-Cooling Schematic Trainer (Electric)		●				
EB-4	Typical Heat Pump Schematic Trainer				●		
EB-5	Solar Schematic Trainer						●
ST-1A	Potential Relay Trainer		●				
ST-2	Basic Electricity Trainer	●					
ST-3	Electric Heat Service Trainer	▲	●				
ST-4	Gas Heat Service Trainer	▲	●				
ST-5	3 Phase Compressor Trainer			●			
ST-6	Power Saver Trainer (Mixed Air Temperature Control System)			●			
ST-7	Direct Spark Ignition Trainer		●	●			
ST-8	Commercial Gas Heat Service Trainer			●			
ST-9	Heat Pump Service Trainer				●		
ST-10	Refrigerant Fundamentals Trainer	●	▲				
ST-14	Air Conditioner Service Trainer		●				
ST-15	Multizone Control System Trainer			●			
ST-17	Solar Heat Service Trainer						●
BT-1	Bimetal Trainer	●					
GT-1	Gas Fundamentals Trainer	●					
GT-2	Gas Electronic Ignition Trainer	●	●				
OT-1	Oil Fundamentals Trainer	●	●				
OT-2	Cad Cell Trainer	●					
OT-3	Oil Burner Trainer	●	●				
OT-4	Oil Pump Trainer	●	●				
AC-3	Electronic Air Cleaner Trainer	●					
WE-9	Humidifier Trainer (Electric — Solid-State)	●	●				
MIP-7	Flue And Chimney Trainer	●					
MIP-8	Plastic House Trainer	●				●	
AP-1	Duct System Trainer					●	
AP-2	Air Distribution System Trainer					●	
AP-3	Solar System Trainer (Assembled)						●
AP-4	Solar System Trainer (Unassembled)						▲
AP-5	Hydronic Principles Trainer						●
SP-4	1 set Student Manuals Phase I (S) (w/2-1/2" Binder)	●					
SP-6	1 set Student Manuals Phase II (S) (w/2-1/2" Binder)		●				
SP-7	Lennox Service Handbook	●	●	●	●		
SP-8	Instructor Guide I (S) & II (S)	●	●				
SP-9	Student Manual Phase III (S)			●			
SP-10	Student Manual & Worksheets — Application Phase I (A)					●	
SP-11	Heat Pump Manual (w/1-1/2" Binder)				●		
SP-12	Student Manuals Phase I (SOLAR) (w/1-1/2" Binders)						●

● *Standard or required* ▲ *Optional*

(continued on next page)

Model No.	Item	PHASE I (S)	PHASE II (S)	PHASE III (S)	PHASE I (HP)	PHASE I (A)	PHASE I (SOLAR)
F-1	Film "Search For Total Comfort"	●				●	
F-2	Film "Design & Manufacture of Hermetic Compressors"	●	●				
F-3	35mm Slides "Oil Burner Service" with separate Audio Tape		●				
F-4	Film "Heating-Cooling Specialist"	●					
VC-3S	Video Tapes 3/4" Phase III (S) Video Cassettes (4)			●			
VT-3S	Video Tapes 1/2" Phase III (S) Reel to Reel Tapes (4)			●			
VC-Solar	Video Tape 3/4" Phase I (Solar) Video Cassette (1)						●
V.T-Solar	Video Tape 1/2" Phase I (Solar) Reel to Reel Tape (1)						●
T-1	Transparencies Phase I (S), 102 in set	●					
T-2	Transparencies Phase II (S), 91 in set		●				
T-3	Transparencies Phase III (S), 234 in set			●			
T-4	Transparencies Phase I (A), 194 in set					●	
T-5	Transparencies Heat Pump, 61 in set				●		●
T-6	35mm Slides Phase I (SOLAR) (Choose One — Identical Content)						●
T-7	Transparencies Phase I (SOLAR) (Choose One — Identical Content)						●
CP-3	Component Parts — Heating — Gas				●		
CP-4	Component Parts — Heating — Oil	●					
CP-5	Component Parts — Cooling	●					
CP-6	Component Parts — Commercial			●			
CP-7	Component Parts — Heat Pump				●		
CP-8	Component Parts — Solar Heating						●
LE-4	Testing Equipment — Basic Test Equipment Package	●	●	●	●	●	●
LE-5	Testing Equipment — Gas	●	●	●			
LE-6	Testing Equipment — Oil	●	●	●			
LE-7	Testing Equipment — Cooling	●	●	●			
LE-8	Testing Equipment — Solar Heating						●
LT-2	Tools / Heating-Cooling Tool Package	●	●	●	●	●	●
LT-3	Portable Oil Tank	●	●				
GUC	Gas Heating — Electric Cooling — Up-Flo	●	●				
GU	Gas Heating — Up-Flo	●	●				
GD	Gas Heating — Down-Flo	●	●				
GDC	Gas Heating — Electric Cooling — Down-Flo	●	●				
OUC	Oil Heating — Electric Cooling — Up-Flo	●	●				
OU	Oil Heating — Up-Flo	●	●				
OD	Oil Heating — Down-Flo	●	●				
ODC	Oil Heating — Electric Cooling — Down-Flo	●	●				
EU	Electric Heating — Up-Flo	●	●				
EUC	Electric Heating — Electric Cooling — Up-Flo	●	●				
CBH	Electric Heating — Electric Cooling — Horizontal	●	●				
ES	Electric Heating — Multiposition	●	●				
ESC	Electric Heating — Electric Cooling — Up-Flo	●	●				
HP	Heat Pump — Horizontal				●		
HPE	Heat Pump — Electric Heating — Horizontal				●		
EAC-2	Electronic Filter — Cabinet Model w/Auto Wash	●	●				
EAC-7	Electronic Filter — Multiposition Manual Wash	●	●				
WD1-15	Humidifier (Drum Type)	●	●				
WS1-18	Humidifier (Spray Type)	●	●				
GCSS	Gas Heating — Electric Cooling — Single Package - Small			●			
GCSM	Gas Heating — Electric Cooling — Single Package - Medium			●			
GCSL	Gas Heating — Electric Cooling — Single Package - Large			●			
OCSM	Oil Heating — Electric Cooling — Single Package Medium			●			
SHW-2	Solar Domestic Hot Water System						●
SHS-6	Solar Space Heating System (6 Collectors)						●
SHS-18	Solar Space Heating System (18 Collectors)						▲
LSC18-1S	Solar Collector (Single Glass)						●

● *Standard or required* ▲ *Optional*

OTHER ITEMS OFFERED BY LENNOX

component parts packages

The student is able to identify and examine major heating and air conditioning components on an individual basis. The instructor may pass a component around the class at the time it is discussed.

testing equipment

Lennox offers a complete line of testing equipment and tools needed to work on heating and air conditioning trainers and live units. It is important that the student know how to use these tools prior to entering the service profession.

lennox service handbook

Service information on Lennox product is contained in this handbook.

"how to set up a classroom"

This booklet offers tips on setting up a classroom to get the best possible results. Everything from student seating to live equipment and trainer installation (including venting provisions) is discussed.

pretesting program

A pretesting program has been developed for Lennox Job Related Training. Results of this test help determine whether a person has the mechanical aptitude needed to be a successful serviceman. It is recommended this test be given prior to the student entering Phase I (S).

instructor guide — phases I and II (S)

This handbook contains material on Lennox teaching philosophy, course instruction outlines, classroom setup, skill testing, trainer instructor manuals and student trainer workbooks.

instructor training

To aid vocational technical instructors to efficiently and effectively use these many teaching aids, Lennox extends an invitation to attend the Lennox schools. These schools operate in five Lennox plant locations across the United States (Columbus, Ohio; Decatur, Georgia; Marshalltown, Iowa; Fort Worth, Texas; and Sacramento, California). At these schools the voc tech instructor will see a philosophy of teaching that has been so effective within Lennox. A nominal charge is assessed for attending these courses.

FOR MORE INFORMATION on Lennox Job Related Training, write or call Lennox Education Products, 1600 E. Lin
Marshalltown, Iowa 50158, Telephone 515+754-4114

LENNOX

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Form No. SB-785-M1

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