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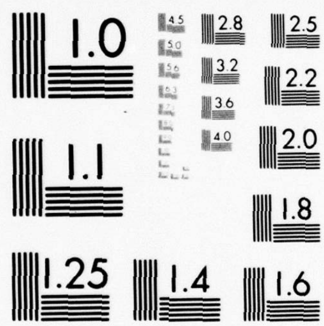

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LEVEL II

PERFORMANCE AND EVALUATION OF CONCEPTS AND DEVICES FOR HEAT RECLAMATION FROM AIR CONDITIONERS, HEAT PUMPS, AND REFRIGERATION EQUIPMENT

S. S. Mohammadi
E. D. Sloan
Colorado School of Mines

August 1978

Final Report

Approved for Public Release; Distribution Unlimited

Prepared for
US Army Facilities Engineering Support Agency
Technology Support Division
Fort Belvoir, VA 22060

Johns Manville Sales Corporation
Denver, Colorado. R+D Center

409601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

(9) Final rept.,

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: FESA-TSD-2057

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle): (6) PERFORMANCE AND EVALUATION OF CONCEPTS AND DEVICES FOR HEAT RECLAMATION FROM AIR CONDITIONERS, HEAT PUMPS, AND REFRIGERATION EQUIPMENT

5. TYPE OF REPORT & PERIOD COVERED: FINAL

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s): (10) S. S. MOHAMMADI [redacted] E. D. SLOAN (COLORADO SCHOOL OF MINES)

8. CONTRACT OR GRANT NUMBER(s): CONTRACT NO. (15) DAAK70-78-D-0002 [redacted] 2

9. PERFORMING ORGANIZATION NAME AND ADDRESS: JOHNS MANVILLE SALES CORPORATION, DENVER, COLORADO

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS: USA FACILITIES ENGINEERING SUPPORT AGENCY, TECHNOLOGY SUPPORT DIVISION, FORT BELVOIR, VA 22060

12. REPORT DATE: (11) AUG [redacted] 78

13. NUMBER OF PAGES: 30

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

15. SECURITY CLASS. (of this report): UNCLASSIFIED

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

(18) USAFESA-TSD (19) 2057

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

(12) 42p.

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

HEAT RECLAMATION, ENERGY CONSERVATION, AIR CONDITIONERS, REFRIGERATION, HEAT PUMPS.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A heat recovery system is described which uses air conditioner or heat pump waste heat for domestic water heating. Current commercial units and field test data are detailed with economic guidelines to aid in choice of a unit. This report enables the reader to determine the cost effectiveness of having such a unit installed. Safety, product warranty, and city and state coding restrictions are discussed. The current and future testing and demonstration plans are cited for the unit.

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SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

TABLE OF CONTENTS

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A heat recovery system is described which uses air conditioner or heat pump waste heat for domestic water heating. Current commercial units and field test data are detailed with economic guidelines to aid in choice of a unit. This report enables the reader to determine the cost effectiveness of having such a unit installed. Safety, product warranty, and city and state coding restrictions are discussed. The current and future testing and demonstration plans are cited for the unit.

II. INTRODUCTION

The concept described is that of recovering the waste rejected heat from central air conditioners for use in domestic water heating. In this concept the condensation of refrigerant is still done by rejecting heat to outside air; however, the desuperheating of the refrigerant at higher temperatures is used to heat water within the residence.

In the same manner the heat recovery system (HRS) may be used with a heat pump above the balance point when it is operating in the heating mode. In both air conditioners and heat pumps the HRS is placed between the compressor and the condenser.

A similar system could be applied to residential refrigeration systems, however, a study done by A. D. Little, Inc.,[1] indicates the areas of concern: (1) longer periods to payback, (2) uncertainties in the reliability of the system and, (3) uncertainties of the impact on the product warranty of the refrigerator. No testing has been done on this concept and further consideration is not given here.

The residential HRS system is a lower limit to payback on initial investment. Commercial HRS systems have invariably better payback periods than do residential systems.

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[1] Design, Development and Demonstration of a Promising Integrated Appliance, A. D. Little, Inc., W. D. Lee, Project Manager, performed for ERDA September 1977.

III. PRECEDENT AND BASIC DESIGN

Initial development of heat recovery units for residential and small commercial use was performed by Florida Power and Light in the early 1960s. A system was designed which is being marketed today, shown in Figure 1, in which water is circulated from the storage hot water tank to a heat exchanger placed between the compressor and condenser of the air-cooled air conditioner. During the operation of the compressor, if the water temperature in the storage tank is below the upper limit, the circulation pump is activated and heat is extracted from the refrigerant, thereby providing water heating. Typically, the refrigerant enters the water heat exchanger at 200-250°F, providing ample temperature for achieving useful water temperatures for domestic purposes (130-140°F).

Another basic design consists of a bayonet-type exchanger in the water heater which is fed by refrigerant circulated from the compressor, eliminating the water pump. This design is no longer being marketed, therefore no further consideration is given to this unit.

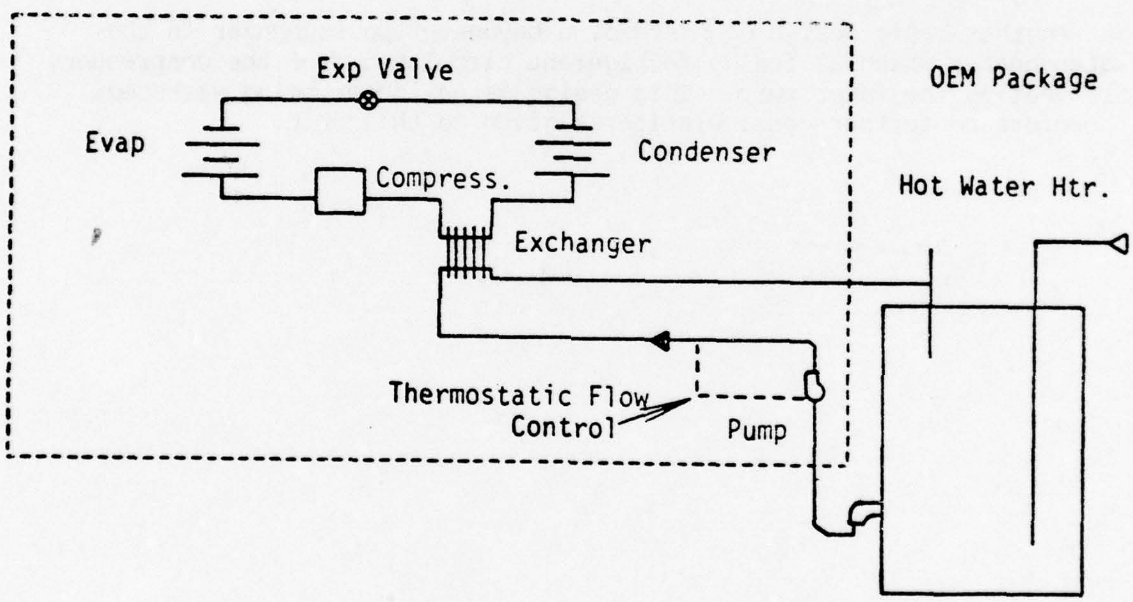

Figure 1. Heat Recovery Water Heating System

IV. METHODS OF ENERGY SAVINGS

A. Heat Recovered from Refrigerant

In a refrigeration cycle, which is the basic cycle used in a refrigerator, air conditioner and heat pump, high temperature refrigerant gas (200-250°F) enters a condensing unit where it exchanges heat with an air or water stream, depending on the condenser design. This heat is normally lost except during the heating modes of a heat pump where it is utilized for space heating.

A.1. Cooling Mode

Typically an air conditioning system with an air-cooled condenser rejects about 16,000 to 17,000 Btu/hr for each ton of cooling capacity. Of this amount 3000 to 5000 Btu/hr of superheat can easily be utilized for water heating. A heat exchanger is installed in the hot gas line between the compressor and the condenser of the air conditioner. Water from the cold water supply to the water heater is circulated through the heat exchanger by a circulating pump. In practice removal of heat from the refrigerant is limited to the superheated region, since the maximum amount of water heated to final utilization temperature can be produced. Furthermore excessive heat removal in the auxiliary heat exchanger causes condensation and results in the formation of subcooled refrigerant in the condensor. This in turn causes choking in the capillary expansion process.

A.2. Heating Mode

During the heating mode of a heat pump since the coefficient of performance[1] is generally higher than 2, each Btu of electrical energy input can generate two or more Btu's of heat which can be utilized for space heating as well as water heating. The mechanism of heat extraction is identical to that of a refrigeration cycle.

B. Compressor Efficiency Improvement

Removal of superheat from the refrigerant causes a reduction in the refrigerant loop temperature which in turn results in lower compressor pressure head. Because of this reduction in head pressure, the compressor operates more efficiently and the electrical demand of the compressor is reduced. Furthermore, lower temperature of the refrigerant loop causes greater temperature driving force in the evaporator which

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[1] Coefficient of performance = $\dfrac{\text{heat obtained}}{\text{electrical energy required}}$

in turn reduces the operation time of the compressor for a given cooling load. The effect of the refrigerant inlet temperature to condenser on the energy efficiency ratio EER (ratio of cooling capacity in Btu/hr to total unit input in watts) of an air conditioner or heat pump for three different outside temperatures is presented in Figure 2. It should be noted that this figure is the result of a computer simulation of an air conditioner/heat pump model (for detailed description refer to A. D. Little report). Normally, even with the HRS, the refrigerant gas inlet temperature to the condenser would never be less than 125^{o}F. The steep portions of the curve represent abnormal operation and may be ignored. As is shown, a drop in the refrigerant inlet temperature to the condenser causes an increase in EER. From an empirical standpoint most manufacturers of heat recovery units claim an efficiency improvement equivalent to 1 to 25% reduction in total energy consumption of compressor.

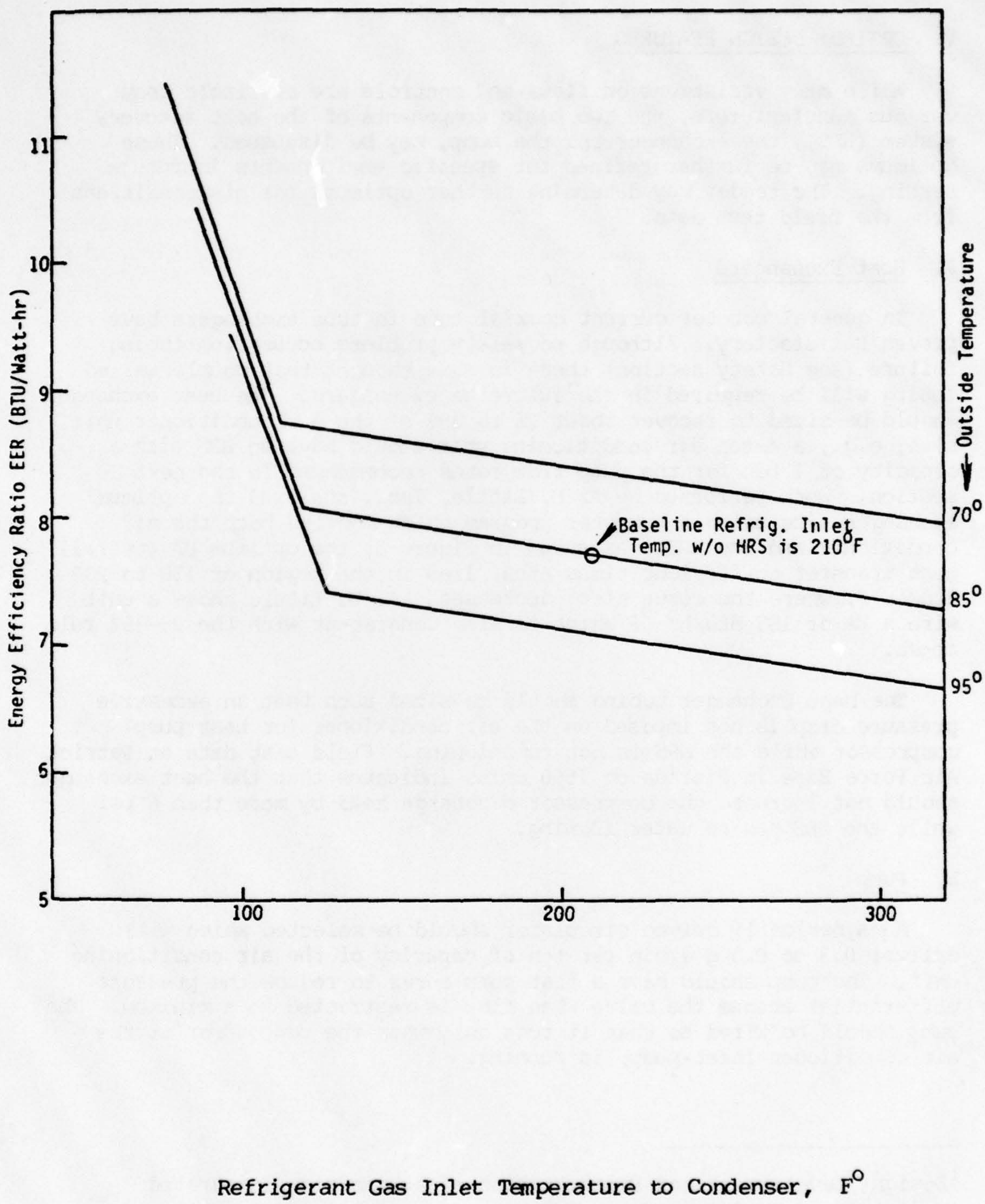

Figure 2. Energy Efficiency Ratio vs. Refrigerant Inlet Temperature to Condenser.

V. OPTIMUM DESIGN FEATURES

While many variations on flows and controls are available from various manufacturers, the two basic components of the heat recovery system (HRS), the exchanger and the pump, may be discussed. These optimums may be further refined for specific environments in future testing. The reader may determine further optimums for his conditions from the field test data.

A. Heat Exchangers

In general counter current coaxial tube in tube exchangers have proven satisfactory. Although no safety problems occur from tubing failure (see Safety section) there is some thought that double walled tubing will be required in the future as exchangers. The heat exchanger should be sized to recover about 25 to 35% of the air conditioner unit size; e.g., a 4-ton air conditioning unit should have an HRS with a capacity of 1 ton for the pump flow rates recommended in the next section. Work performed by A. D. Little, Inc.,[1] analyzed the optimum exchanger size using a computer program which modeled both the air conditioner and the HRS. As shown in Figure 3, the optimum UA (overall heat transfer coefficient times area) lies in the region of 150 to 200 Btu/hr ^{o}F, where the curve slope decreases. A. D. Little chose a unit with a UA of 165 Btu/hr ^{o}F which is also consistent with the 25-35% rule above.

The heat exchanger tubing should be sized such that an excessive pressure drop is not imposed on the air conditioner (or heat pump) compressor while the HRS is not functioning. Field test data at Patrick Air Force Base in Florida on 1500 units indicates that the heat exchanger should not increase the compressor discharge head by more than 6 psi while the HRS has no water flowing.

B. Pump

A magnetically driven circulator should be selected which will deliver 0.3 to 0.5 gal/min per ton of capacity of the air conditioning unit. The pump should have a flat pump curve to reduce the pressure differential across the valve when flow is restricted to a minimum. The pump should be wired so that it runs only when the compressor of the air conditioner (heat pump) is running.

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[1] Design, Development and Demonstration of a Promising Integrated Applicance, A.D. Little Inc., W.D. Lee, program manager, performed for ERDA, September 1977.

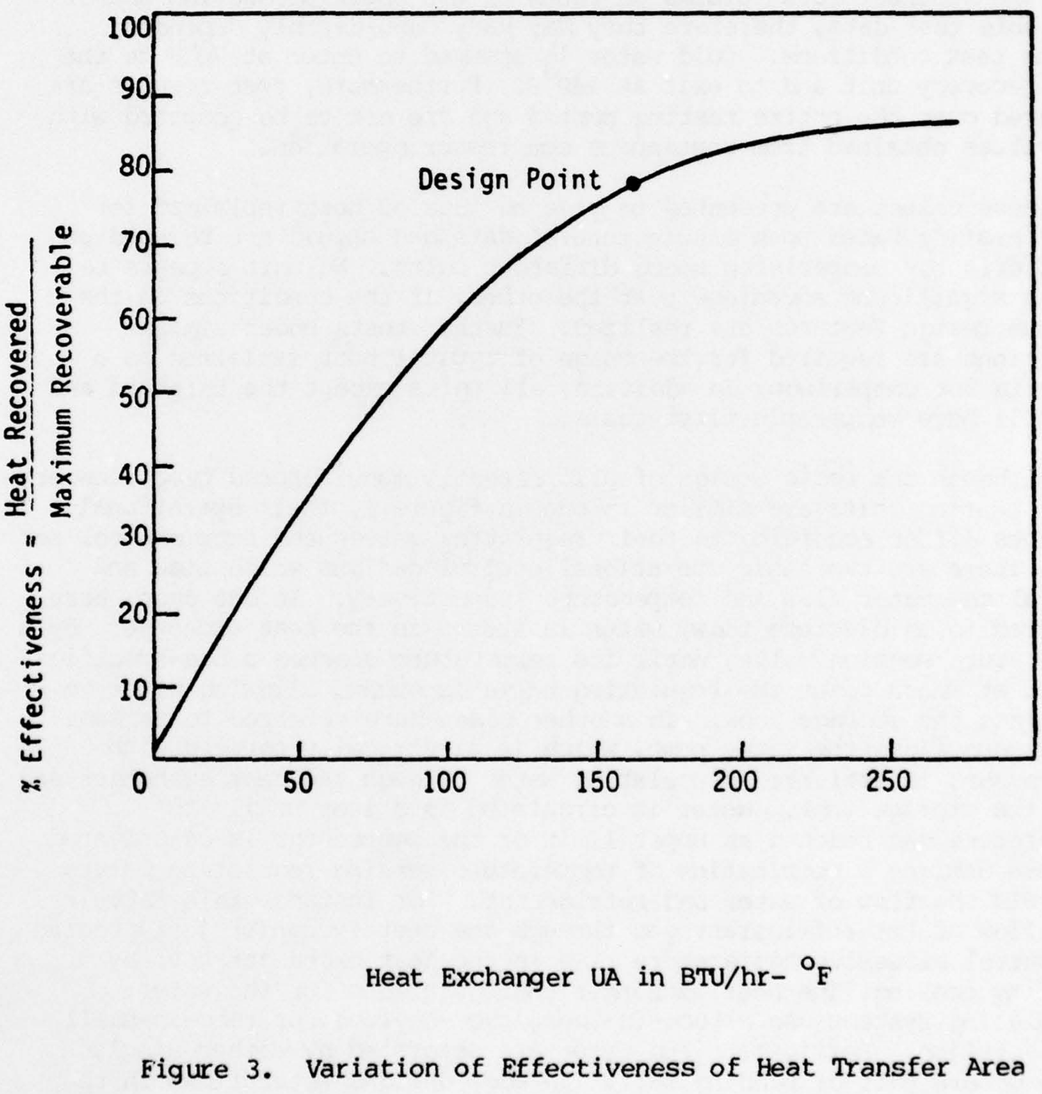

Figure 3. Variation of Effectiveness of Heat Transfer Area

VI. COMMERCIAL UNITS AND DESIGN DIFFERENCES

A summary of the commercially available units and their manufacturers is given in Table 1. Table 2 presents a number of significant features of these units.

The cost of each of the units in Table 2 should not vary appreciably from the $300 - $400 range for a heat recovery unit installed on a 3-ton air conditioner. In Table 2 typical Btu/ton-hr reclaimed refer to the amount of heat which is recovered and utilized for water heating per ton capacity of air conditioning per hour. These figures are obtained from the manufacturers' claims on rates of hot water production and/or available test data, therefore they may vary considerably depending on the test conditions. Cold water is assumed to enter at 70°F to the heat recovery unit and to exit at 140°F. Furthermore, test results are averaged over the entire testing period and are not to be compared with the values obtained from continuous compressor operation.

These values are presented to give an idea of heat reclaimed for water heating based upon manufacturers' data and should not be used as a criteria for comparision among different units. No unit appears to have a significant advantage over the other, if the conditions in the Optimum Design Features are realized. Further tests under similar conditions are required for the usage of typical heat reclaimed as a criteria for comparison. In addition, all units except the Halstead and Mitchell have comparable first costs.

Although the basic design of all presently manufactured heat recovery-water heating units are similar to one in Figure 1, their operational concepts differ according to their regulating valves and pump control set ups. There are two basic operational control designs which time and control the water flow and temperature respectively. In one case, here referred to as discrete flow, water is stored in the heat exchanger, by a temperature sensing valve, until its temperature reaches a pre-specified limit, at which point the regulating valve is opened allowing water to flow into the storage tank. In another case, here referred to as semi-continuous flow, the water pump, which is electrically coupled with compressor, is activated circulating water through the heat exchanger and into the storage tank. Water is circulated in a loop until its temperature has reached an upper limit or the compressor is deactivated. In some designs a combination of temperature sensing regulating valves controls the flow of water and refrigerant. For instance in a Marvair unit flow of hot refrigerant gas through the heat exchanger is regulated to control excessive temperature rise in the heat exchanger thereby limiting scaling. The heat exchanger configurations for the water circulating systems use a tube-in-tube, tube-on-tube, or tube-in-shell configuration. Refrigerant and water are separated by either single wall, double wall or bonding wall. In some designs water flows in the

TABLE 1

COMMERCIALLY AVAILABLE HEAT RECOVERY-
WATER HEATING UNITS

	Unit	Manufacturer	Address
1.	ECU	Energy Conservation Unlimited	Longwood, Florida 32750
2.	HOT-TAP	Energy Conservation Unlimited-Promoted by Arizona Public Service Co.	Phoenix, Arizona 85000
3.	Lectra Saver	Growth Systems Technology Inds., Inc.	Tampa, Florida 33600
4.	H&M HRU*	Halstead & Mitchell	Scottsboro, Florida
5.	Weather King HRU	Weather King, Inc.	Orlando, Florida 32800
6.	Econ-O-Mate	Sun-Econ, Inc.	Ballston Lake, NY 12019
7.	Hot-Shot	Carrier	Syracuse, NY 13200
8.	Heat Grabber	Lynn-Aire Products, Inc.	Decatur, Georgia 30030
9.	Heat Gainer	**W. L. Jackson Mfg. Co., Inc.	Chattanooga, TE 37400
10.	A/C and H.P. Water Heater	Marvair Co.	Coredele, Georgia 31015

* HRU (Heat Recovery Unit)
** No Longer in Production

TABLE 2

COMPARISON OF CURRENTLY AVAILABLE HRS UNITS

UNIT	CONFIGURATION	PRESENTLY AVAIL FROM	SAFETY	OPERATIONAL PROBLEMS	TYPICAL BTU/TON-HR RECLAIMED	INITIAL COST
Econ-O-Mate	Tube-in-shell	Retrofit-OEM	Single wall separates water from ref. water on the outside.	Convoluted design, minimal scaling, continuous flow(CF)[1]	3600-7600	$300-800
ECU	Tube-in-tube helix	Retrofit	Double wall separates water from ref. Ref. on the outside	Convoluted design, minimal scaling. Discrete Flow (DF)[2]	2900-4100	$400-600
Friedrich	Tube-to-tube	Retrofit-OEM	Double wall	Scaling	1700	$350
H&M HRU	Tube-in-tube	Retrofit	Single wall Ref. on the outside	Heat exchanger ends removable for cleaning CF	3300 Btuh/comp. H.P.	$600-900
Heat Grabber	Tube-in-tube	Retrofit	Single wall. Ref. on the outside	Heat exchanger ends removable for cleaning CF	5000	$300
Hot Shot	Tube-in-tube	Retrofit-OEM	Double wall	Scaling a problem CF	2000	$300
Hot Tap	Tube-in-tube helix	Retrofit	Single wall. Ref. on outside	Convoluted design minimal scaling DF	2900-4100	$300-500
Lectra Saver	Tube-in-tube	Retrofit	Single wall. Ref. on outside	Scaling a problem CF	3000-5000	$300
Marvair	Tube-on-tube	Retrofit-OEM	Side by side tubing bonding wall	Scaling a problem CF	N.A.	$300
Weather King	Tube-in-tube	Retrofit-OEM	Single wall. Ref outside	Scaling a problem DF	3700	$350

[1] Semi-continuous flow while compressor is on

[2] Discrete flow design

inner tube and refrigerant in the outer one. This design allows the refrigerant to escape to atmosphere in case of an external tube rupture. If the water is on the outside, however, refrigerant tube failure causes high pressure refrigerant to escape into the potable water. The placement of the refrigerant tube is not crucial because, as discussed in the Safety Section, mixing of refrigerant with water does not seem to cause any health problems.

One of the basic concerns in design is scaling which always exists with heat exchangers. The severity depends on the quality of water (soft or hard), and the water turbulence or mixing patterns. Convoluted wall design of heat exchanger is used in some heat recovery units as a means of enhancing flow turbulence thereby minimizing scale formation. Other designs take advantage of removable exchanger ends for cleaning purposes.

VII. FIELD PERFORMANCE

Evaluation of field performance of heat recovery-water heating units is a difficult task and the results could vary considerably depending on variable weather conditions, and use patterns. The only available residential field test data is summarized in Table 3. Shown here are the claimed energy savings and the supporting field test data which was provided by the manufacturers.

A. Case History

Location: Patrick Air Force Base, Florida

One thousand ECU units and 500 Weather King units have been installed on 2-5 ton heat pump units in military family housings. This represents the largest scale test to date.

Over a period of 1 year, these units have operated essentially with no trouble and with no significant differences in performance. Savings on water heating over a 9-month period are reported to be $16/month based on 3¢/kWh electric cost and 1200 ft^2 residential unit. These units were installed on unitary as well as split systems on heat pump units by Weather King, Florida Air, Bard, Carrier, and G.E. Heat recovery units have all had coaxial exchanger tubing but none with double wall.

Based upon their experiences they have specified the use of a separate storage tank for damping out rapid temperature cycling. Furthermore, at water feeding temperature of 140°F from storage tank the electrical heater should be set at 120°F. They also specify that the rise in compressor discharge head be less than 6 psi with no water flowing through the heat recovery unit. As for heat removal, only the super heat should be reclaimed in order to avoid the capillary expansion problem of slugging. Finally, a safety valve should be installed on the hot water tank with temperature setting at 210°F and discharged to the outside.

B. Operation Problems and Maintenance

There are basically two main problems with all of commercially available units; scaling and freezing. Scaling problem is unavoidable, since water flow, in both discrete flow design and semi-continuous flow design, is periodically stopped, enhancing scale formation. Removable ends on a heat exchanger provide a convenient means of cleaning the heat exchanger. In a non-removable end heat exchanger chemical cleaning is required. Insufficient data is available to specify cleaning frequency due to scaling. Freezing of water in the heat exchanger and connecting lines can be avoided by installing the heat recovery system indoors.

TABLE 3

RESIDENTIAL FIELD TEST DATA

MANUFACTURER	A/C or H.P. CAPACITY	FIELD TEST DATA: Conducted by and/or location	Duration Months	No. of Units	kWh/month* saved or percent savings on water heating
Lynn-Aire	3-ton G.E. H.P.	Electric Mem. Corp Douglas County, GA	5 mo Apr - Aug	1	590
Lynn-Aire	2.5 ton A/C	Georgia Tech	3 hrs	1	—
Lynn-Aire	3 ton A/C	Savannah Elec Pwr Co	4 mo. Aug - Nov	1	410
Energy Conservation Unlimited, Inc.	3 ton A/C	Georgia Power	12 mo.	4	46%
Lynn-Aire	2.5 ton H.P.	Georgia Power	12 mo.	1	51%
Energy Conservation Unlimited Inc. 5	A/C	Alabama Power	24 mo.	8	50%
Energy Conservation Unlimited Inc.	2.5 ton H.P.	Patrick AFB	12 mo.	1000	530
Energy Conservation Unlimited Inc.		Akron, Ohio	6 mo.	—	140
Energy Conservation Unlimited Inc.		Lakeland, Florida	7 mo.	—	500
Sun-Econ	4 ton carrier H.P.	Patrick AFB	12 mo.	500	530
Hot Tap	3.5 ton	Arizona Public Service	12 mo.	3	50%

* Compressor savings not included

Because of the simplicity of design, heat recovery units have little operational problems and their maintenance is rather easy. Results of the test from installation of 1000 ECU units and 500 Weather King units in Patrick Air Force Base in Florida along with the results of tests by Alabama Power, Arizona Public Service, Florida Power, and Georgia Power indicate that these units in their present form have performed with little or no operational problems.

VIII. COST EFFECTIVENESS

A. System Design Selection

The aforementioned study by A. D. Little, Inc., on the economics of a heat recovery system with single tank water storage and dual tank system based on initial costs for new installation indicates that the economics of a single tank system appears to be more favorable. This was determined to be as a result of the increased surface-to-volume ratio of the dual tank system over the single tank system, resulting in greater standby loss.* In practice, however, the results of the field test data from Patrick Air Force Base on 1500 heat recovery units installed indicates the preference of the dual tank system. The additional tank is used for damping out rapid temperature cycling.

B. Economics in Different Climate Zones

Based on an initial added cost of $300 for a heat recovery system, total electrical savings on water heating are used to obtain a payback period. Since total heat recovered is directly related to operating hours, regional annual operating hours of central air conditioners (Figure 4) were used to generate annual savings for different climate zones.

In the aforementioned study by A. D. Little, Inc., the single tank system was used in a computer model in different climate zones to generate potential savings and payback periods on heat recovery units.

The results of this analysis, forecast for year 1990, are presented in Table 4. Columns 1 through 3 are self-explanatory. In column 4, total annual point of use savings is combined water heating savings and compressor efficiency improvement savings for each zone. Column 5 refers to the annual BTU's saved from the installation of a heat recovery system at power plant. Using the payback periods presented in Table 4, which is only applied to central air conditioners, and appropriate modifications for heat pump installation, a simplified regional analysis is developed which justifies or rejects the installation of HRS on central air conditioners or heat pumps.

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*This may not be the case for a tank with greater insulation.

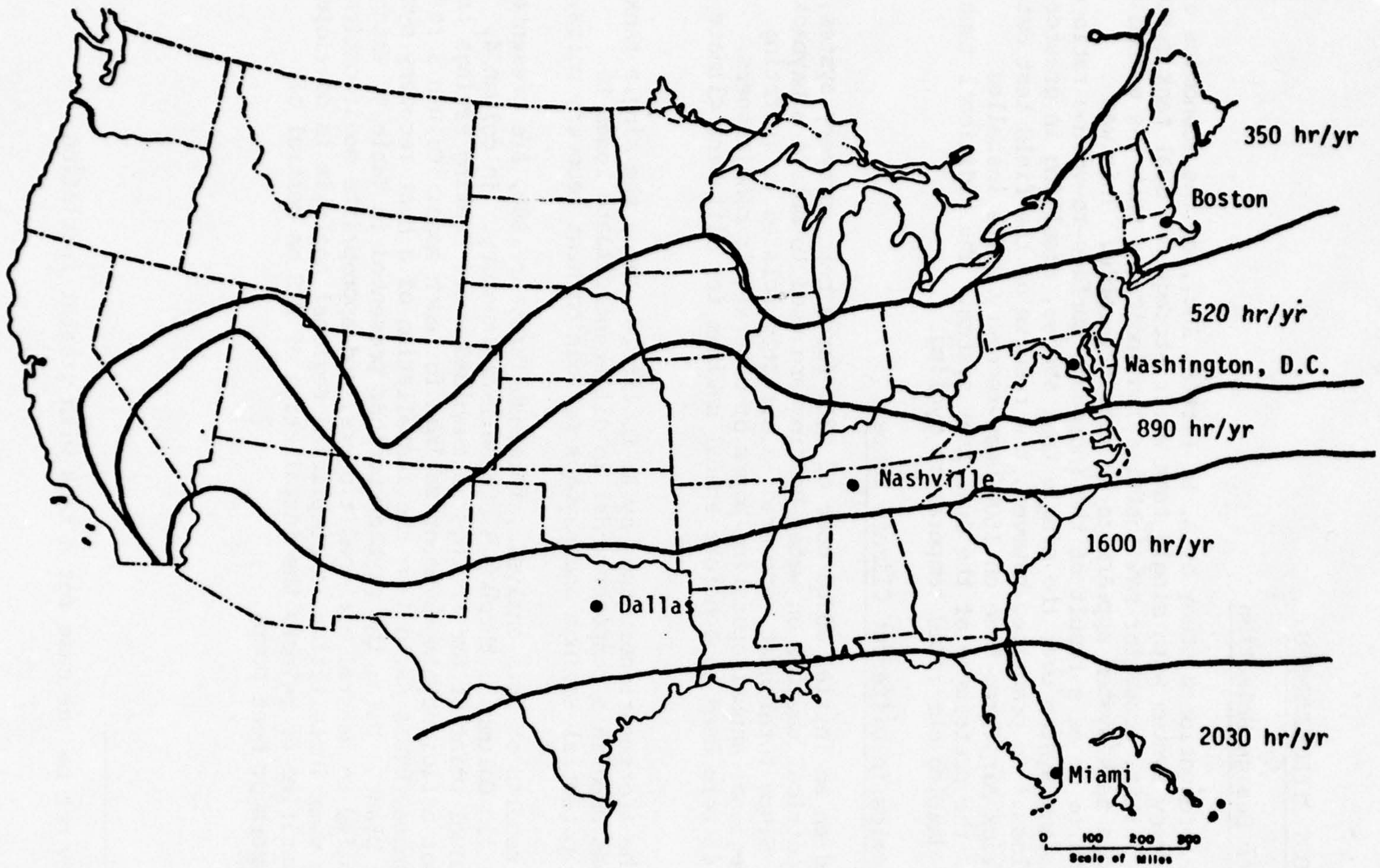

Figure 4. Annual Hours of Operation of Central Air Conditioners by region

TABLE 4

A/C-HRS ENERGY SAVINGS IN DIFFERENT CLIMATIC ZONES[1]
(Cooling Season Only)

BASIS: 3.5 Ton Air Conditioner

$.04 per kWh

Zone Number	Representative City	Baseline Total Annual kWh A/C and Water Heating Without A/C HRS[3]	Cooling Compressor Hours	Annual Point of Use Savings (kWh/year) Total	Annual Point of Use Savings (kWh/year) A/C Portion	Annual Primary Savings (mm Btu/year)	Years to Payback (Added First Cost: $300) Electric Water Heating	Years to Payback (Added First Cost: $300) Gas Water Heating[2]
1	Miami	16,930	2,030	4,271	300	48.5	1.7	4.2
2	Ft Worth	15,230	1,700	3,067	100	34.9	2.4	7.6
3	Nashville	11,400	890	2,340	70	26.6	3.2	10.0
4	Washington	9,700	520	1,330	60	15.1	5.6	17.0
5	Boston	8,893	350	1,300	34	14.77	5.7	16.5
1990 Inventory Weighted Average		13,000		2,538[3]		28.8	3.5	10.6

[1] Electric water heating is 7,260 kWh/year.

[2] Based on the same amount of water heated by air conditioner as the electric water heater plus the 25% credit for the gas recovery efficiency of 80%.

[3] Using heat pumps (heating and cooling), the annual savings could be raised to 4,200 kWh (65% increase), and the years to payback reduced to 1.8 (a 50% reductin). It is anticipated, though, that only one out of five air conditioners will be heat pumps in 1990.

Figure 4 is divided into three regions: Region 1 covering air conditioning use of 890 hr/yr and above (Nashville, Dallas, and Miami) appears to be a favorable region for installation of heat recovery-water heating units. Payback periods vary from 1.7 years to 3.2 years if installed on an air conditioner. Furthermore, payback periods can be significantly reduced if installed on a heat pump. Region 2 covering air conditioning use of 520 hr/yr (Washington, DC) has a questionable economics. Annual savings are to be calculated from the following equation:

Amount savings = A x B x C x D x E where:

$$A = \frac{\text{BTU Savings}}{\text{Ton-hr A/C}}$$

B = electricity cost, $/kwh

C = 0.000293 kwh/Btu

D = Location Factor, Figure 3, A/C hours/yr

E = A/C capacity*

Assumptions: Central A/C
Electrical water heating
Total usage of hot water

Finally, payback period should be estimated from the initial cost, including installation, and annual savings. Typical installation time, based upon the experience of Arizona Public Service Company, is 4 to 6 man hours.

If used with a heat pump, the payback period is reduced but field test data is insufficient to confirm the 50% reduction in payback period cited in Table 4 by A. D. Little. Region 3 covering air conditioning use of less than 500 hr/yr does not appear to have a favorable economics for installation of heat recovery units on central air conditioners. Installations on heat pumps are questionable since economics are dependent on the coefficient of performance of the heat pump, and environmental conditions for various locations in this zone.

Further field test data on installation of heat recovery-water heating units on heat pumps are required in order to clarify the economics.

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*1 to 25% compressor efficiency improvements are not included as a conservative measure.

IX. CURRENT AND FUTURE TESTING AND DEMONSTRATION

Reports from Division of Building and Community System of ERDA, Consumer Products & Technology Branch of ERDA, Office of Energy Conservation of NBS, Center for Building Technology of NBS, Department of Energy and the Federal Trade Commission, indicate that a number of tests are being conducted on heat recovery-water heating units. Standards are being developed which would specify installation codes, labeling, safety requirements, and warranty. The Department of Energy and National Bureau of Standards are currently jointly involved in developing test methodology and evaluating energy recovery on the heat recovery-water heating systems manufactured by ECU, Carrier, Marvair, Sun-Eon and Lynn Aire. This program, under the direction of Dr. Don Walukus (DOE-ORNL) and Dr. Andy Fowell (NBS) will be completed around mid-year 1979. In addition EPRI is currently sponsoring follow-on work by Mr. Richard Merriam of A. D. Little and installation of heat recovery units in southern brewery refrigeration systems. The above tests should establish standard test procedures for rating and specifying heat recovery units. Also these works should establish optimized refrigeration unit control, optimized sizing of the HRS, and the effect of the HRS when used with a heat pump in the northern United States. Figure 5 presents A. D. Little's forecast of the growth of these units with and without support of DOE.

To date, federal and state regulations do not allow manufacturers to claim the energy savings of the HRS as part of the air conditioner energy efficiency. This policy hinders commercialization and should be reconsidered.

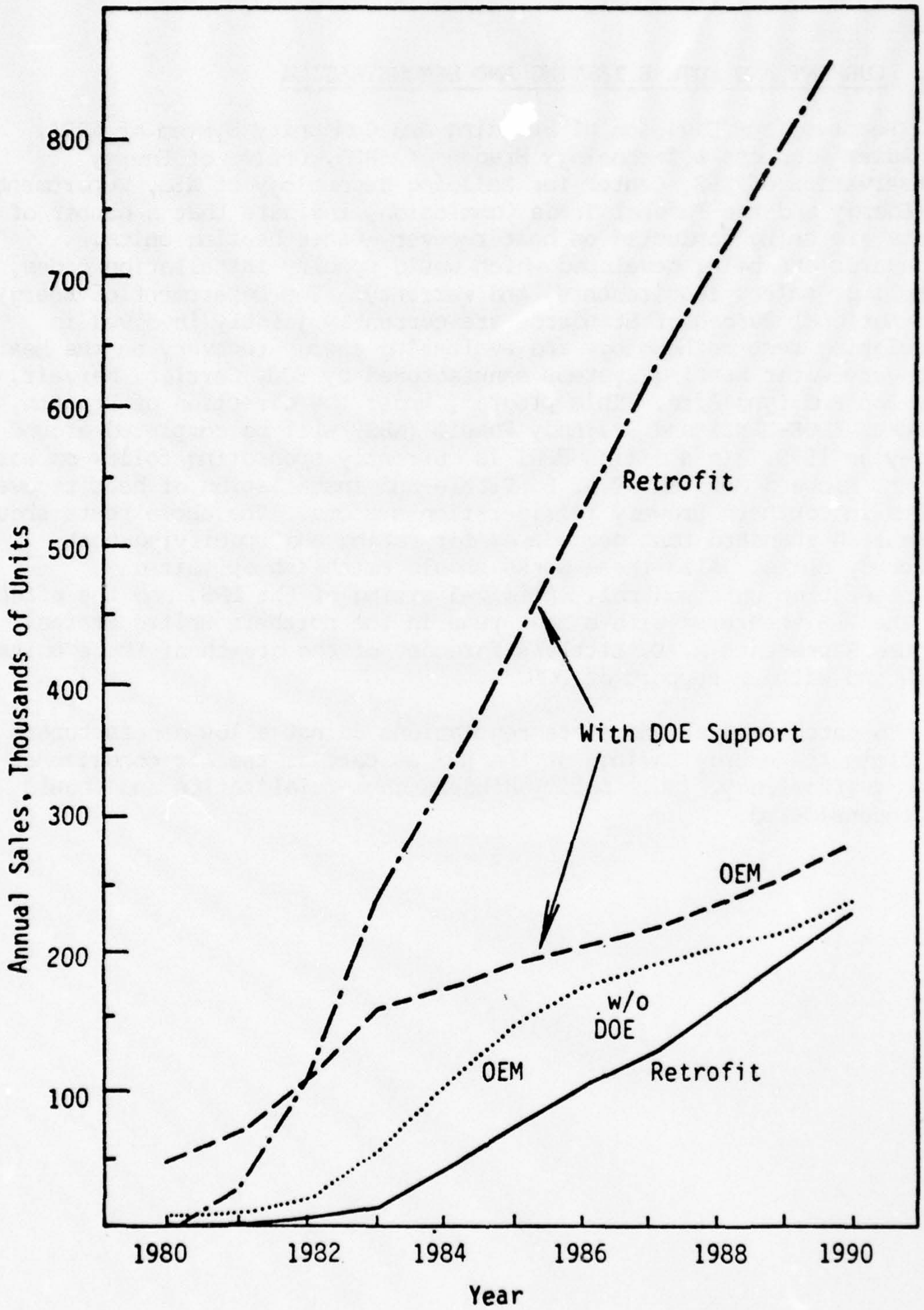

Figure 5. Projected Sales of OEM and Retrofits A/C - HRS With and Without DOE Support

X. SAFETY

Basic concerns in safety are due to either electrical shortage in the unit or a possiblity of a potable water contamination from freon and compressor oil due to a complete exchanger integrity failure.

In the former case, approval by Applied Research Laboratories and compliance with local electrical codes are sufficient for safe operation.

In the latter case studies by Dr. Gibson, of duPont, Drs. Miller and Cowsan of Southern Research Institute, and Sun Petroleum Products Co., indicate that neither the freon nor compressor oil leak (either fresh or burned oil) cause any health problems when leaked into water in a heat recovery-water heating system. Further testing by the Holman/Pyle Company has concluded that microrganisms cannot live in a Freon 22 system and so the danger of contamination is reduced. The Underwriter Laboratory Standard for coil design SA1287 has been used with the Heat Exchanger.

XI. PRODUCT WARRANTY

All presently available heat recovery units are covered for a period of one year by respective manufacturers. Furthermore, no major manufacturers of air conditioners and heat pumps will void their warranty on their units if it is retrofitted with a heat recovery unit as long as it is installed by a qualified technician according to the instructions set forth by the manufacturer of the heat recovery unit.

XII. STATE AND CITY PRODUCT APPROVAL

It should be noted that installation of heat recovery-water heating units is subject to the approval of the local departments of Health and Social Services, Building and Zoning, Safety and Permits, Electric and Water Utilities, and Insurance. A number of the manufacturers of heat recovery units have presently received installation approvals from many local ordinances. Installation in each area should be checked for local approval through the manufacturers.

XIII. CONCLUSIONS

The following conclusions are made based upon this study:

1. The heat recovery system (HRS) does save energy and has a reasonable payback period. It has proved to be simple and trouble free. The number of HRS will continue to grow and may be incorporated as part of normal heat pumps or air conditioners in the near future.

2. Insufficient test data are available to indicate which unit performs better than others, so within optimized equipment guidelines, selection must be based upon economics and availability. HRS rating standards are being determined and comparisons should be available within 2 years.

3. A method is available (described herein) to determine if the unit is economical for each region of the country. Heat pumps operating above the balance point provide better payback than air conditioners using HRS, but insufficient test data are available to quantify the advantage due to the use of a heat pump. For gas water heating, in most cases, the HRS is not justified at this time.

4. Local municipal or state codes should be checked before installation of these units. Toxicity due to Freon 22 or compressor oil is not a problem so safety may be determined through standard testing procedures by Applied Research Laboratories, Underwriters Laboratories, etc., for each unit.

5. All commercial HRS units have 1-year warranty. Insufficient field test data are available to determine longevity. No commercial manufacturer of air conditioners or heat pumps will void their warranty with the installation of an HRS; however, the individual manufacturer should be contacted to determine specific installation instructions.

XIV. RECOMMENDATIONS

Based upon this work the following recommendation is made:

That this report be used only during the interim period until DOE and NBS complete work on comparison and standard generation methods. The DOE-NBS work should be followed closely and their results should be incorporated into any judgements concerning economics or relative merits of the commercial units. No further work should be done until the results of the NBS-DOE tests are known.

XV. LIST OF CONTACTS

Institution	Name	Organization	Phone Number
Government	Eldon Ehlers	EPRI	451-855-2558
	Andy Fowell	NBS	301-921-3748
	Don Walukus	DOE	615-483-8611
	Jim Hildenbrand	NBS	301-921-3892
	Clinton Phillips	NBS	301-921-3741
	David Didion	NBS	301-921-2994
	George Kelley	NBS	301-921-3521
	Bill Walsh	DOE	-
	Larry Fischer	NBS	301-921-3828
	Esher Kweller	NBS	301-921-2938
	L. Raap	DOE	-
Public Service Co.	Tom Morron	Arizona Public Service	602-271-2477
	Nance Louvern	Alabama Power	205-323-5341
	W.J. Patterson	Alabama Power	"
	F.R. Denny	Alabama Power	"
	Jerry Hardin	Georgia Power	404-522-6060
Manufacturers and Consultants	Richard Hibbard	GST Industries	813-621-9459
	Ray Davis	Weather King	305-894-2891
	David Lee	A.D. Little	617-864-5770
	Richard Merriam	A.D. Little	"
	R.H. Neisel	Johns-Manville	303-979-1000
	Bill Simmons	Carrier	315-432-6000
	Reid White	Carrier	"
	Bill Davis	Lynn-Aire	404-377-8646
	Doug Boudry	Marvair	912-273-3636
	C.D. Moreland	Marvair	"
	Otto Nussbaum	Halstead & Mitchell	205-259-1212
	Joseph Mihalz	Sun-Econ Inc.	518-877-7416
	Graham Harris	E.C.U. Inc	305-834-0400
	Edward Wintergalen	Friedrich A/C & Ref Co.	512-225-2000

Addendum to

"Performance Evaluation of Concepts and Devices for Heat Reclamation from Air Conditioners, Heat Pumps, and Refrigeration Equipment"

The Colloid-A-Tron and The Condenser Spray Unit

The Colloid-A-Tron is a device which controls scale precipitation by influencing the size, shape and place of its formation. The Colloid-A-Tron consists of a metallic core inserted into the water stream. It is fashioned by an alloy of copper, zinc, nickel and tin. The core's configuration creates a turbulent water flow that produces an electro-chemical reaction which generates a collodial suspension from mineral ions in water. The colloids are kept suspended in the moving stream of water and don't deposit as scale. This unit, in use since 1969, is patented and manufactured by Century III Corporation, Tucson, Arizona.

The Colloid-A-Tron is effectively used in conjunction with the Condenser Spray Unit (CSU) for saving energy in air conditioners. The CSU works by spraying water on the condenser coils during each on-cycle of the compressor. This spray over the condenser lowers the refrigerant temperature exiting from the coils which causes an improved compressor efficiency. No heat is reclaimed in this unit. The Colloid-A-Tron is used for minimizing scale deposition on the consenser coils.

The Condenser Spray Unit has been marketed since May of 1977, although its test models date back to early 1976. The presently available models of CSU are CSU 3000 and 4000; the former is recommended for use with a 3-ton to 7.5-ton system (or 15 tons split systems with two compressors), while the latter is designed for A/C units up to 15 tons or split systems up to 30 tons.

Energy Saving Economics

To date no test data other than the ones conducted by the manufacturer are available. The manufacturer saving claim of 30%, based on a vendor test which was witnessed by the Tucson Gas & Electric Company, appears to be valid. Based on this figure it appears that the unit can save about 1/2 to 3/4 of the energy saved by a heat recovery water heating unit depending upon the section of the country. Since the installed cost for CSU, (about $400), is comparable to a HWRS unit, the pay-out period for CSU would be 1.3 to 2.0 times as long as that for a HWRS unit.

Using the A. D. Little model of heat recovery systems along with the results of the tests provided by the manufacturer, it appears that up to 6 times the water usage recommended by the CSU vendor will be required.

Warranty

No A/C manufacturer has approved or endorsed the CSU for installation on their unit at the present time. However, marketing research by Century III Corporation indicates that 95% of A/C in use are no longer under warranty.

Operation, Longevity and Code Compliance

The only operational problems inherent with the CSU appears to be a tendency toward slugging; however, the manufacturer adjusts the refrigerant charge to eliminate this problem. A long-term test (>2 yrs.) would be necessary to determine if scaling is a problem. No information was obtained on code compliance.

Conclusions: While no direct test comparisons are available between the CSU and HWRS Systems, preliminary results indicate the following:

1. The CSU unit can save an appreciable amount of energy in air conditioners; however, the energy is not reclaimed in the form of water heating.
2. Pay-out periods on the CSU unit may be from 1.3 to 2.0 times as long as for the HWRS, based upon limited test data for the CSU and extensive test data for the HWRS.
3. Test data for the CSU are so limited that longevity, operational problems and maintenance are uncertain. Furthermore, the possibility of warranty jeopardization is present with the CSU, but does not exist with the HWRS unit.
4. Safety is not a consideration with the CSU unit.

Recommendation: Based upon this study the following recommendations are made:

1. That a direct comparison of the CSU be made to the HWRS System. The most likely place for this to occur is in the current NBS-DOE study mentioned in the main report.
2. That until such tests are made, the HWRS be given preference over the CSU unit.

US Military Academy
ATTN: Dept of Mechanics
West Point, NY 10996

US Military Academy
ATTN: Library
West Point, NY 10996

HQDA (DAEN-ASI-L) (2)
WASH DC 20314

HQDA (DAEN-MPO-B)
WASH DC 20314

HQDA (DAEN-FFP)
WASH DC 20314

HQDA (DAEN-MPO-U)
WASH DC 20314

HQDA (DAEN-MPZ-A)
WASH DC 20314

HQDA (DAEN-MPZ-F)
WASH DC 20314

HQDA (DAEN-MPZ-E)
WASH DC 20314

HQDA (DAEN-MPZ-G)
WASH DC 20314

HQDA (DAEN-RDL)
WASH DC 20314

Director, USA-WES
ATTN: Library
PO Box 631
Vicksburg, MS 39181

Commander, TRADOC
Officer of the Engineer
ATTN: ATEN
Ft Monroe, VA 23651

Commander, TRADOC
Office of the Engineer
ATTN: ATEN-FE-U
Ft Monroe, VA 23651

AF Civil Engr Center/XRL
Tyndall AFB, FL 32401

Naval Facilities Engr Command
ATTN: Code 04
200 Stovall St
Alexandria, VA 22332

Defense Documentation Center
ATTN: TCA (12)
Cameron Station
Alexandria, VA 22314

Commander and Director
USA Cold Regions Research Engineering
Laboratory
Hanover, NH 03755

FORSCOM
ATTN: AFEN
Ft McPherson, GA 30330

FORSCOM
ATTN: AFEN-FE
Ft McPherson, GA 30330

Officer in Charge
Civil Engineering Laboratory
Naval Construction Battalion Center
ATTN: Library (Code L08A)
Port Hueneme, CA 93043

Commander and Director
USA Construction Engineering
Research Laboratory
PO Box 4005
Champaign, IL 61820

Commanding General, 3d USA
ATTN: Engineer
Ft McPherson, GA 30330

Commanding General, 5th USA
ATTN: Engineer
Ft Sam Houston, TX 78234

AFCE Center
Tyndall AFB, FL 42403

Commander, DARCOM
Director, Installation
and Services
5001 Eisenhower Ave.
Alexandria, VA 22333

Commander, DARCOM
ATTN: Chief, Engineering Div.
5001 Eisenhower Ave.
Alexandria, VA 22333

Air Force Weapons Lab/AFWL/DE
Chief, Civil Engineering
Research Division
Kirtland AFB, NM 87117

Strategic Air Command
ATTN: DSC/CE (DEEE)
Offutt AFB, NE 68112

Headquarter USAF
Directorate of Civil Engineering
AF/PREES
Bolling AFB, Washington, DC 20333

Strategic Air Command
Engineering
ATTN: Ed Morgan
Offutt AFB, NE 68113

USAF Institute of Technology
AFIT/DED
Wright Patterson AFB, OH 45433

Air Force Weapons Lab
Technical Library (DOUL)
Kirtland AFB, FL 87117

Chief, Naval Facilities
Engineer Command
ATTN: Chief Engineer
Department of the Navy
Washington, DC 20350

Commander
Naval Facilities Engineering Cmd
200 Stovall St
Alexandria, VA 22332

Commander
Naval Facilities Engineering Cmd
Western Division
Box 727
San Bruno, CA 94066

Civil Engineering Center
ATTN: Moreell Library
Port Hueneme, CA 93043

Commandant of the Marine Corps
HQ, US Marine Corps
Washington, DC 20380

National Bureau of Standards (4)
Materials and Composites Section
Center for Building Technology
Washington, DC 20234

Assistant Chief of Engineer
Rm 1E 668, Pentagon
Washington, DC 20310

The Army Library (ANRAL-R)
ATTN: Army Studies Section
Room 1A 518, The Pentagon
Washington, DC 20310

Commander in Chief
USA, Europe
ATTN: AEAEN
APO New York, NY 09403

Commander
USA Foreign Science and
Technology Center
220 8th St. N.E.
Charlottesville, VA 22901

Commander
USA Science & Technology
Information Team, Europe
APO New York, NY 09710

Commander
USA Army Science & Technology
Center - Far East Office
APO San Francisco, CA 96328

Commanding General
USA Engineer Command, Europe
APO New York, NY 09403

Deputy Chief of Staff
for Logistics
US Army, The Pentagon
Washington, DC 20310

Commander, TRADOC
Office of the Engineer
ATTN: Chief, Facilities
Engineering Division
Ft Monroe, VA 23651

Commanding General
USA Forces Command
Office of the Engineer
(AFEN-FES)
Ft McPherson, GA 30330

Commanding General
USA Forces Command
ATTN: Chief, Facilities
Engineering Division
Ft McPherson, GA 30330

Commanding General, 1st USA
ATTN: Engineer
Ft George G. Meade, MD 20755

Commander
USA Support Command, Hawaii
Fort Shafter, HI 96858

Commander
Eighth US Army
APO San Francisco 96301

Commander
US Army Facility Engineer
Activity Korea
APO San Francisco 96301

Commander
US Army Japan
APO San Francisco, CA 96343

Facility Engineer
Fort Belvoir
Fort Belvoir, VA 22060

Facility Engineer
Fort Benning
Fort Bennning, GA 31905

Facility Engineer
Fort Bliss
Fort Bliss, TX 79916

Facility Engineer
Carlisle Barracks
Carlisle Barracks, PA 17013

Facility Engineer
Fort Chaffee
Fort Chaffee, AR 72902

Facility Engineer
Fort Dix
Fort Dix, NJ 08640

Facility Engineer
Fort Eustis
Fort Eustis, VA 23604

Facility Engineer
Fort Gordon
Fort Gordon, GA 30905

Facility Engineer
Fort Hamilton
Fort Hamilton, NY 11252

Facility Engineer
Fort A.P. Hll
Bowling Green, VA 22427

Facility Engineer
Fort Jackson
Fort Jackson, SC 29207

Facility Engineer
Fort Knox
Fort Knox, KY 40121

Facility Engineer
Fort Lee
Fort Lee, VA 23801

Facility Engineer
Fort McClellan
Fort McClellan, AL 36201

Facility Engineer
Fort Monroe
Fort Monroe, VA 23651

Facility Engineer
Presidio of Monterey
Presidio of Monterey, CA 93940

Facility Engineer
Fort Pickett
Blackstone, VA 23824

Facility Engineer
Fort Rucker
Fort Rucker, AL 36362

Facility Engineer
Fort Sill
Fort Sill, OK 73503

Facility Engineer
Fort Story
Fort Story, VA 23459

Facility Engineer
Kansas Army Ammunition Plant
Independence, MO 64056

Facility Engineer
Lone Star Army Ammunition Plant
Texarkana, TX 75501

Facility Engineer
Picatinny Arsenal
Dover, NJ 07801

Facility Engineer
Louisiana Army Ammunition Plan
Fort MacArthur, CA 90731

Facility Engineer
Milan Army Ammunition Plant
Warren, MI 48089

Facility Engineer
Pine Bluff Arsenal
Pine Bluff, AR 71601

Facility Engineer
Radford Army Ammunition Plant
Radford, VA 24141

Facility Engineer
Rock Island Arsenal
Rock Island, IL 61201

Facility Engineer
Rocky Mountain Arsenal
Dever, CO 80340

Facility Engineer
Scranton Army Ammunition Plant
156 Cedar Ave.
Scranton, PA 18503

Facility Engineer
Tobyhanna Army Depot
Tobyhanna, PA 18466

Facility Engineer
Tooele Army Depot
Tooele, UT 84074

Facility Engineer
Arlington Hall Station
400 Arlington Blvd.
Arlington, VA 22212

Facility Engineer
Cameron Station, Bldg 17
5010 Duke Street
Alexandria, VA 22314

Facility Engineer
Sunny Point Military Ocean Terminal
Southport, NC 28461

Facility Engineer
US Military Academy
West Point Reservation
West Point, NY 10996

Facility Engineer
Army Materials & Mechanics
Research Center
Watertown, MA 02172

Facility Engineer
Ballistics Missile Advanced
Technology Center
PO Box 1500
Huntsville, AL 35807

Facility Engineer
Fort Wainwright
172d Infantry Brigade
Fort Wainwright, AK 99703

Facility Engineer
Fort Greely
172d Infantry Brigade
Fort Richardson, AK 99505

Facility Engineer
Tarheel Army Missile Plant
204 Granham-Hopedale Rd
Burlington, NC 27215

Facility Engineer
Harry Diamond Laboratories
2800 Powder Mill Rd
Adelphi, MD 20783

Facility Engineer
Fort Missoula
Missoula, MT 59801

Facility Engineer
New Cumberland Army Depot
New Cumberland, PA 17070

Facility Engineer
Pacific Northwest Outport
Seattle, WA 98119

Facility Engineer
Oakland Army Base
Oakland, CA 94626

Facility Engineer
Fort Ritchie
Fort Ritchie, MD 21719

Facility Engineer
Vint Hill Farms Station
Warrentown, VA 22186

Facility Engineer
Twin Cities Army Ammunition Plant
New Brighton, MN 55112

Facility Engineer
Volunteer Army Ammunition Plant
Chattanooga, TN 37401

Facility Engineer
Watervliet Arsenal
Watervliet, NY 12189

Facility Engineer
St Louis Area Support Center
Granite City, IL 62040

Facility Engineer
Fort Monmouth
Fort Monmouth, NJ 07703

Facility Engineer
Redstone Arsenal
Redstone Arsenal, AL 35809

Facility Engineer
Detroit Arsenal
Warren, MI 48039

Facility Engineer
Aberdeen Proving Ground
Aberdeen Proving Ground, MD 21005

Facility Engineer
Jefferson Proving Ground
Madison, IN 47250

Facility Engineer
Dugway Proving Ground
Dugway, UT 84022

Facility Engineer
White Sands Missile Range
White Sands Missile Range,
NM 88002

Facility Engineer
Yuma Proving Ground
Yuma, AZ 85364

Facility Engineer
Natick Research & Dev Ctr
Kansas St.
Natick, MA 01760

Facility Engineer
Fort Leonard Wood
Fort Leonard Wood, MO 65473

Facility Engineer
Fort Bragg
Fort Bragg, NC 28307

Facility Engineer
Fort Campbell
Fort Campbell, KY 42223

Facility Engineer
Fort Carson
Fort Carson, CO 80913

Facility Engineer
Fort Drum
Watertown, NY 13601

Facility Engineer
Fort Hood
Fort Hood, TX 76544

Facility Engineer
Fort Indiantown Gap
Annville, PA 17003

Facility Engineer
Fort Lewis
Fort Lewis, WA 98433

Facility Engineer
Fort MacArthur
Fort MacArthur, CA 90731

Facility Engineer
Fort McCoy
Sparta, WI 54656

Facility Engineer
Fort McPherson
Fort McPherson, GA 30330

Facility
Fort George G. Meade
Fort George G. Meade, MD 20755

Facility Engineer
Fort Polk
Fort Polk, LA 71459

Facility Engineer
Fort Riley
Fort Riley, KS 66442

Facility Engineer
Fort Stewart
Fort Stewart, GA 31312

Facility Engineer
Indiana Army Ammunition Plant
Charlestown, IN 47111

Facility Engineer
Joliet Army Ammunition Plant
Joliet, IL 60436

Facility Engineer
Anniston Army Depot
Anniston, AL 36201

Facility Engineer
Corpus Christi Army Depot
Corpus Christi, TX 78419

Facility Engineer
Red River Army Depot
Texarkana, TX 75501

Facility Engineer
Sacramento Army Depot
Sacramento, CA 95813

Facility Engineer
Sharpe Army Depot
Lathrop, CA 95330

Facility Engineer
Seneca Army Depot
Romulus, NY 14541

Facility Engineer
Fort Ord
Fort Ord, CA 93941

Facility Engineer
Presidio of San Francisco
Presidio of San Francisco,
CA 94129

Facility Engineer
Fort Sheridan
Fort Sheridan, IL 60037

Facility Engineer
Holston Army Ammunition Plant
Kingsport, TN 37662

Facility Engineer
Baltimore Output
Baltimore, MD 21222

Facility Engineer
Bay Area Military Ocean Terminal
Oakland, CA 94626

Facility Engineer
Bayonne Military Ocean Terminal
Bayonne, NJ 07002

Facility Engineer
Gult Output
New Orleans, LA 70146

Facility Engineer
Fort Huachuca
Fort Huachuca, AZ 86513

Facility Engineer
Letterkenny Army Depot
Chambersburg, PA 17201

Facility Engineer
Michigan Army Missile Plant
Warren, MI 48089

COL E. C. Lussier
Fitzsimons Army Med Center
ATTN: HSF-DFE
Denver, CO 80240

US Army Engr Dist, New York
ATTN: NANEN-E
26 Federal Plaza
New York, NY 10007

USA Engr Dist, Baltimore
ATTN: Chief, Engr Div
PO Box 1715
Baltimore, MD 21203

USA Engr Dist, Charleston
ATTN: Chief, Engr Div
PO Box 919
Charleston, SC 29402

USA Engr Dist, Detroit
PO Box 1027
Detroit, MI 48231

USA Engr Dist, Kansas City
ATTN: Chief, Engr Div
700 Federal Office Bldg
601 E. 12th St
Kansas City, MO 64106

USA Engr Dist, Omaha
ATTN: Chief, Engr Div
7410 USPO and Courthouse
215 N. 17th St.
Omaha, NE 68102

USA Engr Dist, Fort Worth
ATTN: Chief, SWFED-D
PO Box 17300
Fort Worth, TX 76102

USA Engr Dist, Sacramento
ATTN: Chief, SPKED-D
650 Capitol Mall
Sacramento, CA 95814

USA Engr Dist, Far East
ATTN: Chief, Engr Div
APO San Francisco, CA 96301

USA Engr Dist, Japan
APO San Francisco, CA 96343

USA Engr Div, Europe
European Div, Corps of Engrs
APO New York, NY 09757

USA Engr Div, North Atlantic
ATTN: Chief, NADEN-T
90 Church St
New York, NY 10007

USA Engr Div, South Atlantic
ATTN: Chief, SAEN-TE
510 Title Bldg
30 Pryor St. SW
Atlanta, GA 30303

USA Engr Dist, Mobile
ATTN: Chief, SAMEN-C
PO Box 2288
Mobile, AL 36601

USA Engr Dist, Louisville
ATTN: Chief, Engr Div
PO Box 59
Louisville, KY 40201

USA Engr Div, Norfolk
ATTN: Chief, NAOEN-D
803 Front Street
Norfolk, VA 23510

USA Engr Div, Missouri River
ATTN: Chief, Engr Div
PO Box 103 Downtown Station
Omaha, NB 68101

USA Engr Div, South Pacific
ATTN: Chief, SPDED-TG
630 Sansome St, Rm 1216
San Francisco, CA 94111

USA Engr Div, Huntsville
ATTN: Chief, HNDED-ME
PO Box 1600 West Station
Huntsville, AL 35807

USA Engr Div, Ohio River
ATTN: Chief, Engr Div
PO Box 1159
Cincinnati, Ohio 45201

USA Engr Div, North Central
ATTN: Chief, Engr Div
536 S. Clark St.
Chicago, IL 60605

USA Engr Div, Southwestern
ATTN: Chief, SWDED-TM
Main Tower Bldg, 1200 Main St
Dallas, TX 75202

USA Engr Dist, Savannah
ATTN: Chief, SASAS-L
PO Box 889
Savannah, GA 31402

Commander
US Army Facilities Engineering
Support Agency
Support Detachment II
Fort Gillem, GA 30050

Commander
US Army Facilities Engineering
Support Agency
ATTN: MAJ Brisbine
Support Detachment III
PO Box 6550
Fort Bliss, TX 70015

NCOIC
US Army Facilities Engineering
Support Detachment
Support Detachment III
ATTN: FESA-III-SI
PO Box 3031
Fort Sill, Oklahoma 73503

NCOIC
US Army Facilities Engineering
Support Agency
Support Detachment III
ATTN: FESA-III-PR
PO Box 29704
Presidio of San Francisco, CA 94129

NCOIC
US Army Facilities Engineering
Support Agency
ATTN: FESA-III-CA
Post Locator
Fort Carson, Colorado 80913

Commander/CPT Ryan
US Army Facilities Engineering
Support Agency
Support Detachment IV
PO Box 300
Fort Monmouth, New Jersey 07703

NCOIC
US Army Facilities Engineering
Support Agency
ATTN: FESA-IV-MU
PO Box 300
Fort Momouth, New Jersey 07703

NCOIC
US Army Facilities Engineering
Support Agency
Support Detachment IV
ATT: FESA-IV-ST
Stewart Army Subpost
Newburgh, New York 12250

NCOIC
US Army Facilities Engineering
Support Agency
Support Detachment II
ATTN: FEA-II-JA
Fort Jackson, South Carolina 29207

NCOIC
US Army Facilities Engineering
Support Agency
Support Detachment II
PO Box 2207
Fort Benning, Georgia 31905

NCOIC
US Army Facilities Engineering
Support Agency
Support Detachment II
ATTN: FESA-II-KN
Fort Knox, Kentucky 40121