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FIELD TESTING ENERGY-SAVING HERMETIC COMPRESSORS IN RESIDENTIAL REFRIGERATORS*

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Abstract The design of an energy saving compressor for low back pressure applications is reviewed. Calorimeter performance results are stated for two sizes of the efficient design and compared with performance test results for a standard compressor. Power consumption of a refrigerator-freezer is given with a standard compressor and with the energy saving compressor. The preparation of the refrigerators used in the field test are discussed along with the criteria used in selecting the instrumentation for the project. Results of the energy saving compressor in the field test along with a comparison to a standard production compressor are presented. Some conclusions are drawn, based on the data, in relation to important factors in residential refrigerator power consumption.

Keywords Energy, Refrigerator, Compressor, Hermetic, Testing, Residential, Calorimetry.

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ABSTRACT

The design of an energy saving compressor for low back pressure applications is reviewed. Calorimeter performance results are stated for two sizes of the efficient design and compared with performance test results for a standard compressor. Power consumption of a refrigerator-freezer is given with a standard compressor and with the energy saving compressor. The preparation of the refrigerators used in the field test are discussed along with the criteria used in selecting the instrumentation for the project. Results of the energy saving compressor in the field test along with a comparison to a standard production compressor are presented. Some conclusions are drawn, based on the data, in relation to important factors in residential refrigerator power consumption.

INTRODUCTION

Following the design of a highly efficient compressor an extensive demonstration program was undertaken. There was several major areas in the demonstration program, a pilot production of the compressor was undertaken, a life test of fifty samples was begun, a pilot run of a refrigerator using this compressor is planned, and a field test to gather energy information is being conducted. It is the reporting of the field test experience and resulting data that is the primary purpose of this paper.

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The field test was conducted with a total of forty refrigerator-freezers. Half of the refrigerator-freezers had a total volume of about 21 cubic feet. The remaining twenty units had a volume of approximately 18 cubic feet. In each of the two volume sizes, ten refrigerators used a standard efficiency compressor and ten units were prepared with the energy saving compressor. All refrigerators were placed into household environments. Energy consumption data will be collected for one year.

COMPRESSOR DESIGN

A highly efficient hermetic compressor was designed in capacities to fit low back pressure applications. The primary intended applications were refrigerators, freezers, and refrigerator-freezers. Significant design changes were made to the induction motor, flow restrictions or losses, lubrication system, and re-expansion volume of the compressor.

In the efficient design, a four pole permanent split capacitor motor was utilized. Although four pole motors tend to be less efficient than two pole motors, the inclusion of the running capacitor brought the efficiencies to an acceptable level. The motors were wound with copper wire to avoid the higher losses of aluminum wire. Additionally, a low loss steel was used in the motor construction. Four pole motors operate at a synchronous speed of 1800 r.p.m. on a 60 cycle per second source, while two pole motors run at 3600 r.p.m. synchronous from the same source. The primary advantage then becomes not the comparable motor efficiency but the motor speed. Operating at half the speed means that there will be half the number of valve openings and pressure pulsations. It is the reduced losses associated with the fewer openings that make a four pole motor an advantage. A further advantage of the reduced speed was a decrease in frictional losses in the bearings. This improvement shows up as reduction in power consumption.

Enlarged suction ports contributed to a reduction of the flow loss within the compressor. A low loss plastic suction muffler was also included. Discharge port diameters were also increased to minimize flow losses. Unlike eliminating other restrictions, there is a negative effect on compressor efficiency when enlarging the discharge ports. Since the discharge reed is on the opposite side of the valve plate an increase in discharge port volume is also an increase in re-expansion volume. Restrictions were also reduced

in the discharge line by increasing its diameter. In the discharge muffler inlet tube a neck down was eliminated making a further contribution to the efficiency. All of these changes while reducing restrictions also had an adverse effect on noise. The refrigerant gas flows through the compressor in a less damped manner. Had the operating speed of the compressor not been reduced the increase in noise probably would have been unacceptable.

A redesigned crankshaft insured adequate lubrication, of the bearing surfaces, at the lower speeds. In order to insure lubrication of the piston and reduce blow by the piston ring, oil which had previously been allowed to flow to the compressor shell was diverted to the bore.

Piston ring wall thickness was increased to displace refrigerant gas in the ring groove of the piston. This contributed directly to a reduction in re-expansion volume and an improvement of compressor efficiency.

COMPRESSOR PERFORMANCE

All of the energy saving compressors used in the field test were tested to determine refrigerating capacity and power consumption. Testing was done by the secondary refrigerant calorimeter method. This is a primary test method contained in an ASHRAE Standard. No confirming tests were conducted so the compressor cannot be said to be tested in accordance with the ASHRAE Standard. Since it is the primary method that is used for rating and reporting purposes, the data is valid but unconfirmed.

Tests were conducted with an evaporator temperature of -10°F and a condenser temperature of +130°F. During the test air was forced over the compressor at 90°F. Suction gas was held at 90°F. Liquid refrigerants were maintained at 115°F or less but in calculating the capacities the liquid was corrected to 90°F. Table 1 gives the performance data for the compressors used in the field test.

REFRIGERATOR-FREEZER DESCRIPTION

The refrigerators used in this test had the freezer located on the top. Foam insulation was used in these units. The condensers are cooled by forced air. Temperature control for the freezer section is accomplished by a thermostatic control. A mechanical dampener is used to vary flow of cold air to the

provisional compartment. An automatic defrosting system is also included in these units. The evaporator is defrosted by means of an electric heater. A timer is used to start a defrost cycle for every six hours the compressor has operated. An anti-sweat heater, which is switchable, is also found on these units.

REFRIGERATOR-FREEZER TEST DATA

Preceeding the field test energy consumption tests were run in accordance with the AHAM standard. The difference was .62 KWH/24 Hr. between the standard and energy saving compressors in the 18 Ft^3 refrigerator as can be seen by comparing Figures 1 and 2. In the 21 Ft^3 size the energy saving compressor used .32 KWH/24 Hr. less than the standard compressor. This difference can be seen by comparing Figures 3 and 4.

It is interesting to note what effect a small increase in refrigerating load can have on power consumption. In the 18 Ft^3 machine the difference was .58 KWH/24 Hr. with the anti-sweat heater off. When the test was conducted with the anti-sweat heater on the difference in power consumption increased to .66 KWH/24 Hr. This shows what a small increase in the required refrigeration can mean in terms of power consumption. The same situation can be seen in the 21 Ft^3 units by observing Figures 3 and 4.

FIELD TEST PREPARATION

Forty refrigerators were taken from inventory for the field test. No special preparation was given to the units. Since there had been a minor problem in the pilot production of the special compressors, calorimeter tests were conducted to insure the normal performance of the compressors used in the field test. Compressors were then installed in the refrigerators. An energy recording circuit was installed in the unit. A questionnaire was prepared so that background information could be gained on the field test participants. A postcard was also made so that the participants in the test could mail in their power consumption readings monthly. Also recorded on the postcard was the ambient temperature of the test site.

In planning the field test much thought was given to power consumption measurement. We desired an inconspicuous set up so that the user would not continually be aware that they were participating in a field test program.

The use of a watt-hour meter was eliminated because of its size and the difficulty the user might have in reading it. After a search of available equipment we settled on a pulse initiator which would trigger an electro-mechanical counter. The counter was mounted in the toe grill of the refrigerator-freezer so that it would not be noticable in the household. Mounting in this fashion presented only a minor inconvenience in reading the counter.

To insure accurate and correct data from the field test units a check was made on the pulse initiator and counter. After installation in the unit an initial counter reading was made. The refrigerator-freezer was then plugged in and allowed to run for a minimum of 24 hours. During this time a standard kilowatthour meter was also recording the power consumed. A comparison was made and a correction factor was assigned to each unit. This correction factor is then used to arrive at the actual power consumed each month. The typical correction factor is less than five percent. In order to guarantee comparable results only one kilowatthour meter was used for the comparison.

CONCLUSIONS

From the data presented in Tables 2, 3, 4, and 5 it can very easily be seen that the energy saving compressor does permit a refrigerator-freezer to operate on less power than a standard compressor. This we did not find surprising. What was unexpected, however, was the fact that in all of the test groups the refrigerators used significantly less power than was indicated by the AHAM test, as can be seen in Table 6. The average monthly data is presented graphically in Figures 5 and 6.

A closer examination of the data in Tables 2 through 5 shows that in both the 18 Ft^3 and 21 Ft^3 groups there were users of the standard compressors that achieved power consumption readings as low as those found in the energy saving compressor groups. Some users of the energy saving compressors in both 18 Ft^3 and 21 Ft^3 used more power than the average use of the standard compressor in that group. It becomes fairly obvious that usage can be as important as design in real world energy conservation.

As we began to examine which factors were most accountable for energy usage, it became apparent that ambient temperature is the main ingredient. Apparently, less significant but still influential is the number of door openings. Some of the units were used as auxiliary or secondary units. In

some of these units ambient temperatures were average indicating the probable influence of door openings. The most surprising factor was family size. We had expected that larger families would use much more power than smaller households. While family size may still be a factor it is not overly significant.

It is important to remember that the data presented here is for a fall and winter period. We do expect higher power consumption numbers when warmer readings are included. Even these power consumption figures will be less than AHAM estimates.

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ACKNOWLEDGMENTS

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TABLE 1

PERFORMANCE OF COMPRESSORS USED IN FIELD TEST

Type	Capacity	Power Consumption	Energy Efficiency Ratio
Production 18 Ft^3	850 BTU/Hr.	218 Watts	3.9 BTU/WHr.
Energy Saving 18 Ft^3	800 BTU/Hr.	163 Watts	4.9 BTU/WHr.
Production 21 Ft^3	1050 BTU/Hr.	269 Watts	3.9 BTU/WHr.
Energy Saving 21 Ft^3	1000 BTU/Hr.	208 Watts	4.8 BTU/WHr.

TABLE 2

21 FT^3 HIGH EFFICIENCY PERFORMANCE TEST DATA (KWH/24 Hr.)

Serial No.	Sept.	Oct.	Nov.	Dec.	Cumulative
35179	3.26	3.17	2.50	2.18	2.72
35167	--	2.27	2.02	2.04	2.10
35182	3.01	2.94	2.89	2.24	2.76
35160	3.23	3.43+	3.43	*	3.38
35650	2.89	2.89	2.39	2.46	2.68
35159	--	1.84	1.79	1.88	1.84
35158	--	--	--	3.18	3.18
36831	--	--	--	3.23	3.23
Averages	3.10	2.76	2.50	2.46	2.74

-- Indicates unit not under test. * Indicates unit under test. Card not received.

TABLE 3

21 FT^3 STANDARD EFFICIENCY PERFORMANCE TEST DATA (KWH/24 Hr.)

Serial No.	Sept.	Oct.	Nov.	Dec.	Cumulative
35705	3.39	3.63	3.75	3.59	3.62
35648	--	3.49	2.69	3.26	3.05
35708	2.88	2.88	2.26	2.13	2.53
35645	3.46	2.70	2.35	2.43	2.76
35647	3.75	3.59	3.57	2.92	3.45
35663	3.50	3.32	3.59	3.74	3.54
35703	--	1.97	2.42	2.23	2.19
35671	--	--	--	3.26	3.26
Averages	3.40	3.08	2.95	2.95	3.05

-- Indicates unit not under test.

TABLE 4

18 FT^3 HIGH EFFICIENCY PERFORMANCE TEST DATA (KWH/24 Hr.)

Serial No.	Sept.	Oct.	Nov.	Dec.	Cumulative
36823	2.16	1.93	2.05	2.02	2.05
36830	1.88	1.30	1.11	1.26	1.38
36829	2.21	1.79	1.73	1.60	1.82
36850	3.32#	3.19#	1.74	1.74	1.74
37341	2.01	1.77	1.61	1.50	1.76
37340	1.73	1.51	1.72	2.13	1.78
36819	--	2.36	2.45	2.85	2.55
36832	--	--	--	1.85	1.85
36763	--	--	--	1.77	1.77
Averages	2.00	1.78	1.77	1.86	1.86

-- Indicates unit not under test. # Indicates data not included in cumulative or average.

TABLE 5

18 FT^3 STANDARD EFFICIENCY PERFORMANCE TEST DATA (KWH/24 Hr.)

Serial No.	Sept.	Oct.	Nov.	Dec.	Cumulative
36834	2.82	2.18	2.17	2.06	2.32
36825	1.65	1.18	1.09	1.40	1.30
36833	--	2.40	2.31	2.09	2.26
36960	2.67	2.15	*	*	2.36
39199	3.47	2.37	2.30	2.44	2.66
36940	3.55	3.40	3.55	3.52	3.51
37370	3.63	3.23	2.86	2.38	3.04
36958	3.35	3.37+	3.37	3.15	3.31
37374	--	--	2.84	2.87	2.86
37361	--	--	--	3.89	3.89
Averages	3.02	2.54	2.56	2.64	2.75

— Indicates unit not under test. * Indicates unit under test. Card not received.

+ Indicates card not received. Assumed usage, same as subsequent month.

FIGURE 1

ENERGY CONSUMPTION PER AHAM HRF-2-EGFT

Energy Saving Compressor 18 Ft^3 Refrigerator

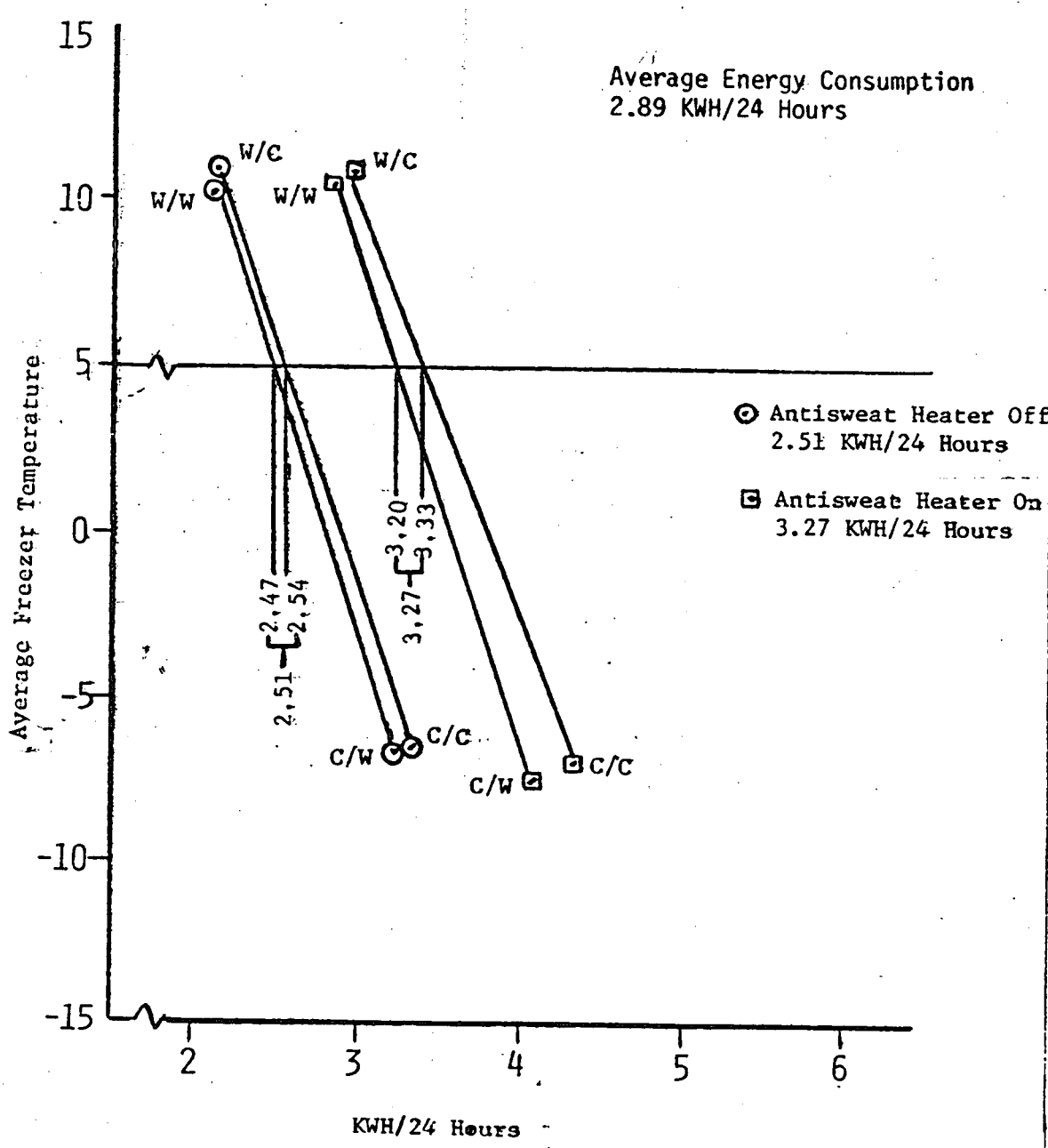


FIGURE 2

ENERGY CONSUMPTION PER AHAM HRF-2-ECFT

Standard Compressor 18 Ft^3 Refrigerator

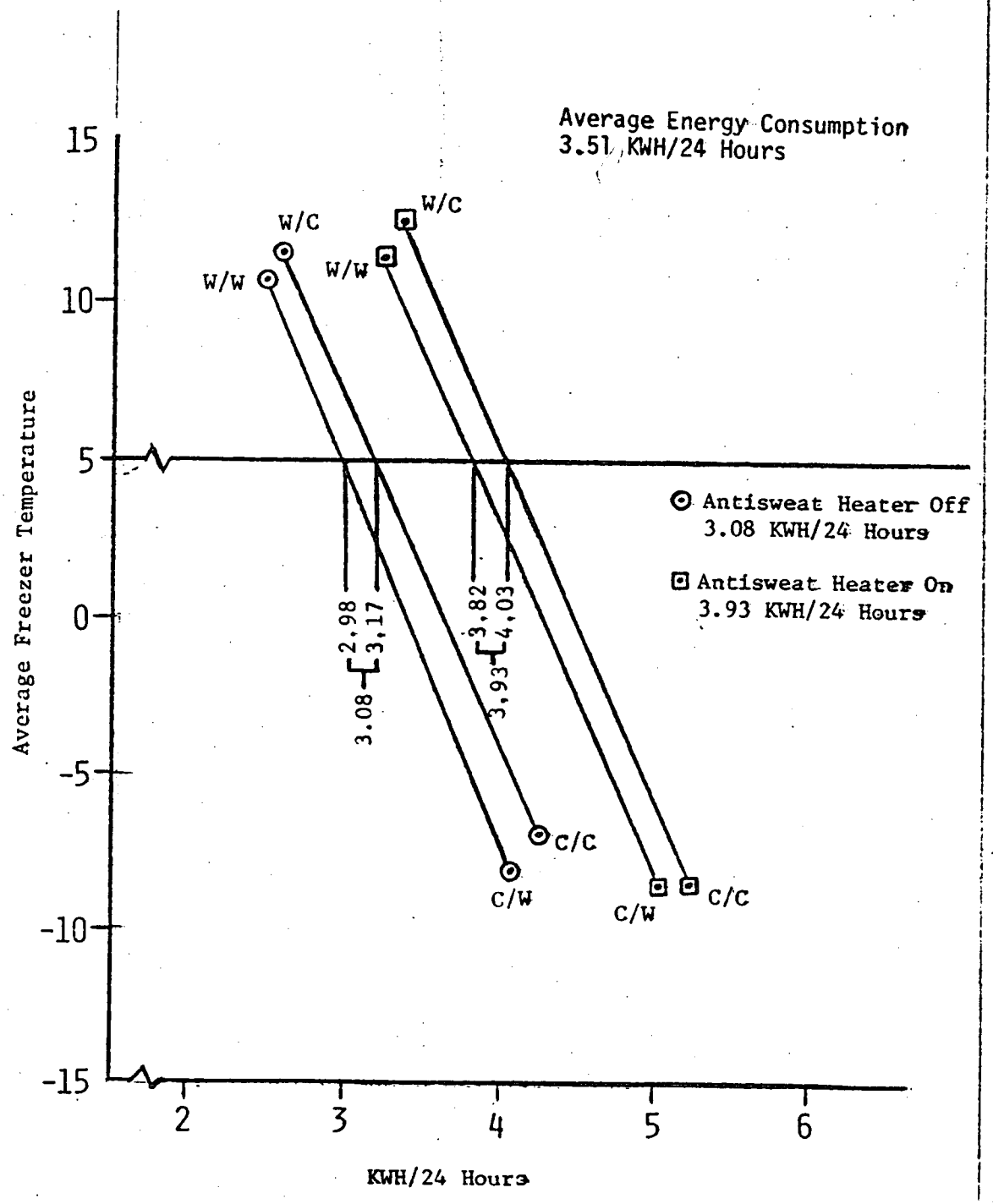


FIGURE 3

ENERGY CONSUMPTION PER AHAM HRF-2-ECFT

Energy Saving Compressor 21 Ft^3 Refrigerator

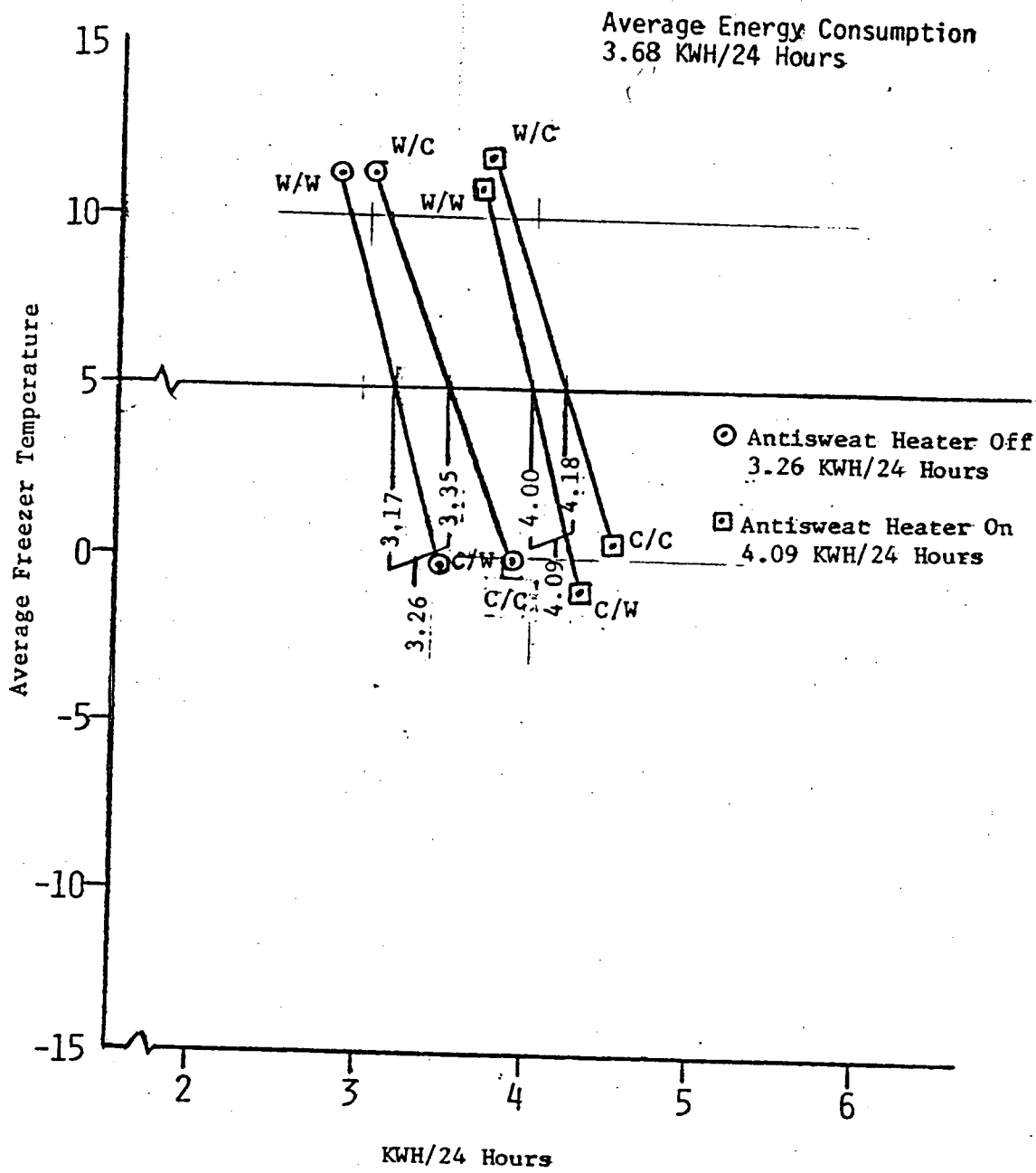


FIGURE 4

ENERGY CONSUMPTION PER AHAM HRF-2-ECFT

Standard Compressor 21 Ft^3 Refrigerator

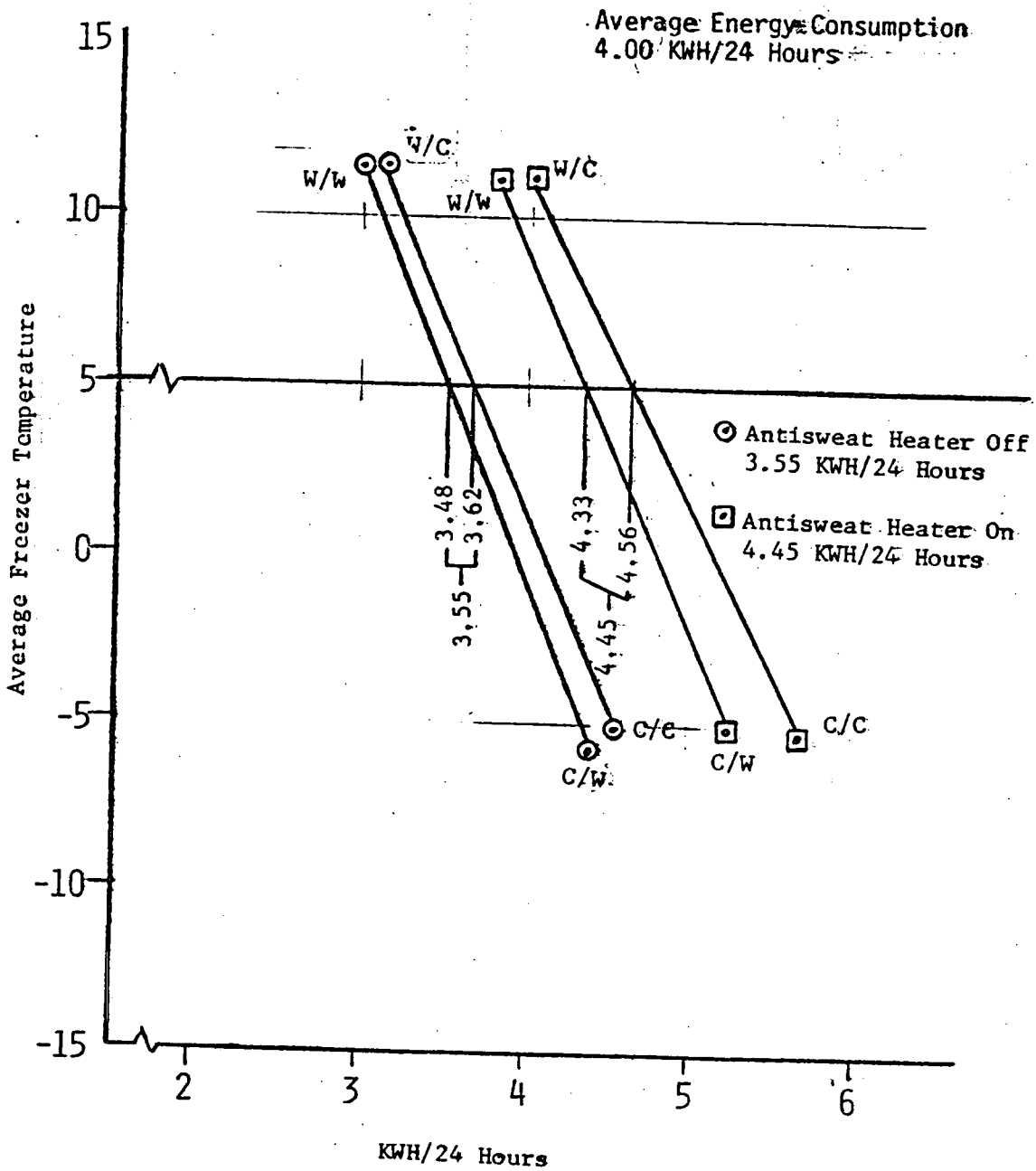


FIGURE 5

18 FT^3 PERFORMANCE TEST DATA

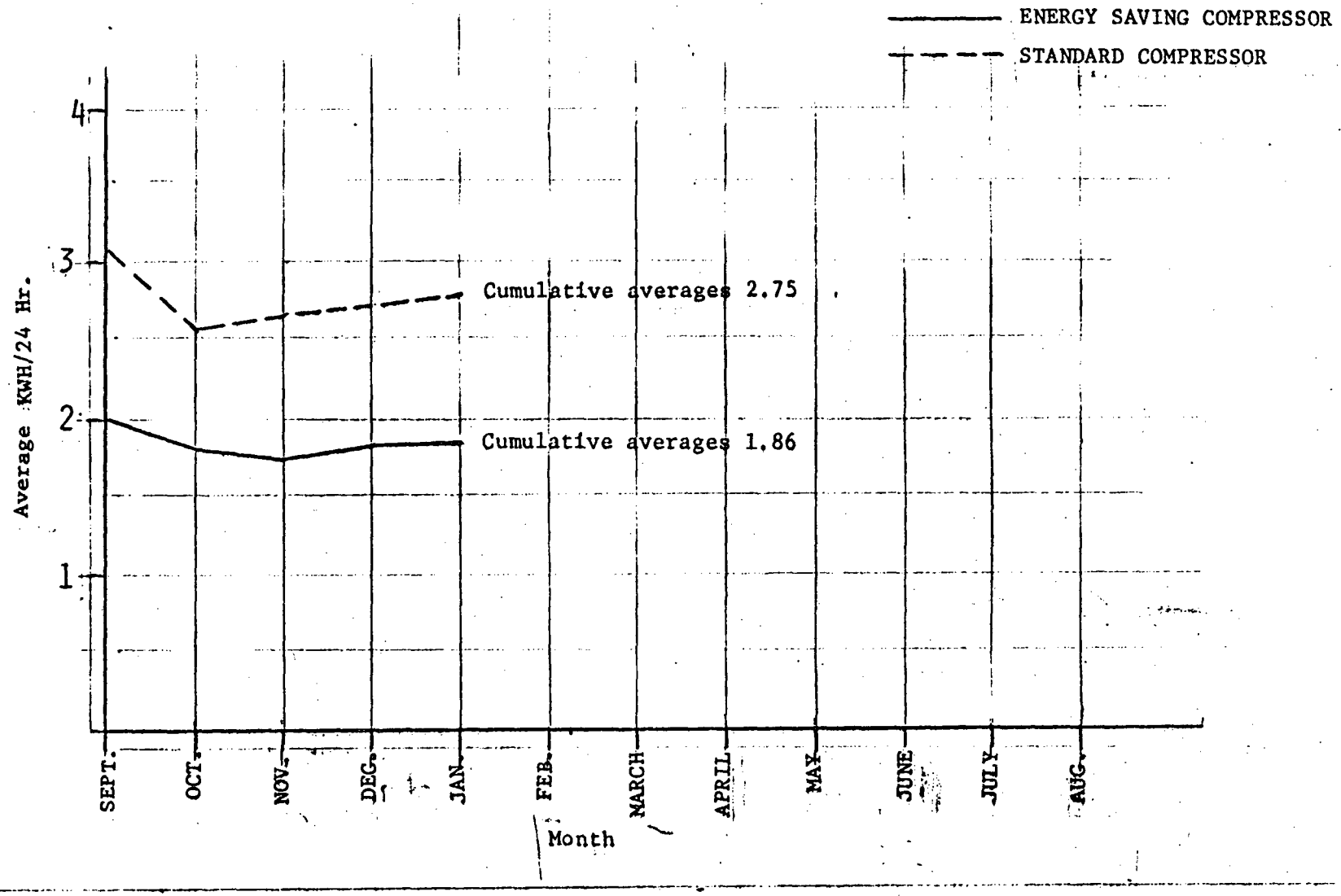
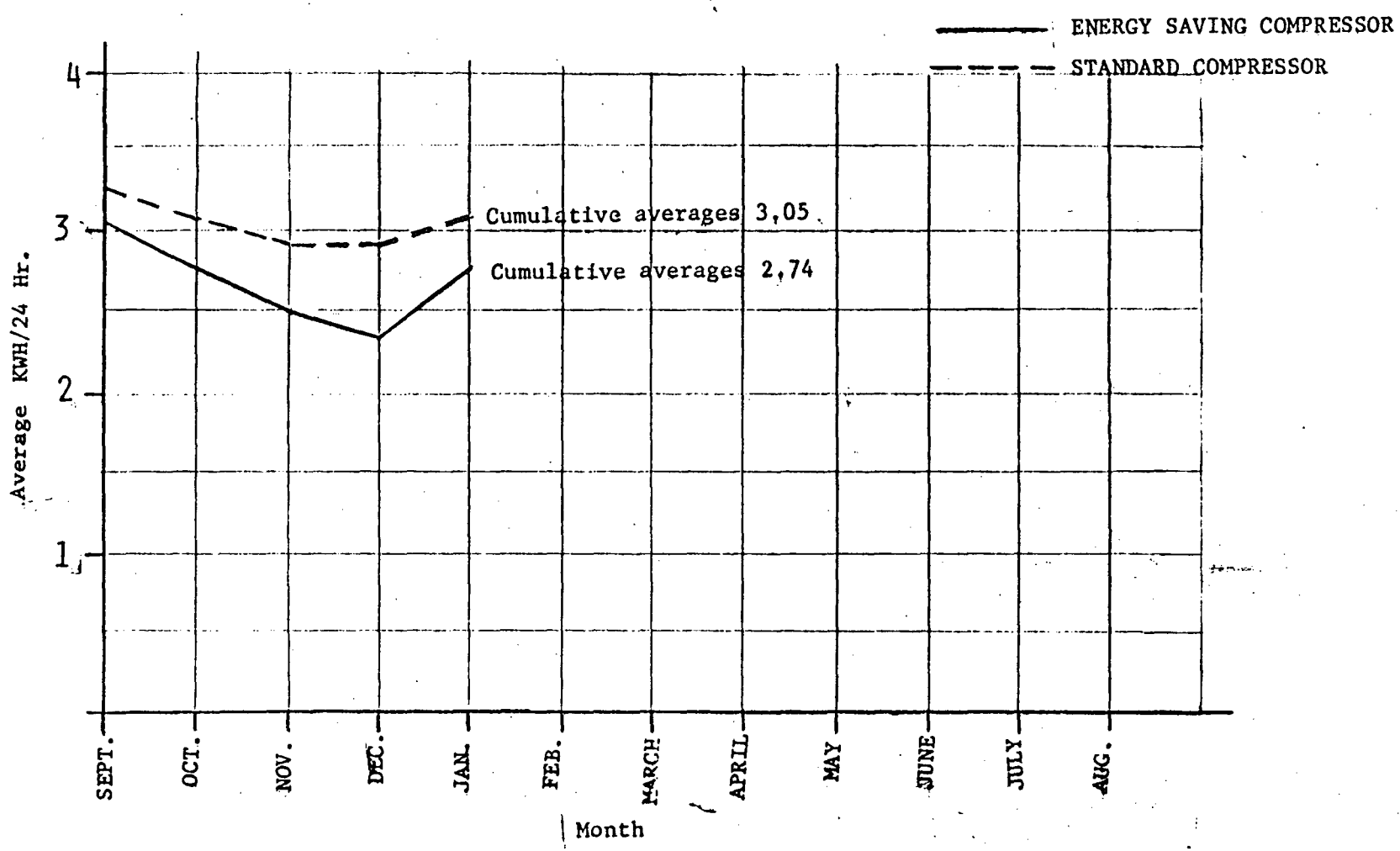


FIGURE 6

21 FT^3 PERFORMANCE TEST DATA