EFFECT OF USAGE CONDITIONS ON HOUSEHOLD REFRIGERATOR-FREEZER AND FREEZER ENERGY CONSUMPTION

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ABSTRACT

A study was made of an automatic- and a manual-defrost refrigerator/freezer combination, and an upright and a chest freezer to measure the effect on energy consumption of five variable usage conditions: thermostat setting, ambient temperature, food load, door-opening frequency, and relative humidity. No evaluation was made of the effect of frost build-up.

Ambient temperature and thermostat setting were found to have considerably greater effect on energy consumption than door-opening and relative humidity changes for the specimens tested.

Key Words: Appliance labeling; energy use; household freezers; household refrigerators; refrigerator.

1. INTRODUCTION

The work described in this report was performed by the Mechanical Systems Section of the Building Environment Division of the National Bureau of Standards (NBS) for the Product Systems Analysis Division, also of NBS.

The object of this project was the determination of the relative magnitude of importance of several variables likely to influence the energy consumption of household refrigerator-freezers and freezers.

The variables considered were as follows:

1. Thermostat setting
2. Ambient temperature
3. Presence of food load
4. Door opening frequency
5. Relative humidity

No evaluation was made of the effect of frost buildup on the manual-defrost refrigerator.

Four types of units, an automatic and a manual-defrost refrigerator-freezer (hereafter called "refrigerator") and an upright and a chest freezer were tested to determine whether the effect of these variables would differ for various types of refrigerators and freezers. The four units were manufactured by three different companies.

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2. DESCRIPTION OF TEST SPECIMENS

The automatic-defrost refrigerator had a net volume of 0.42 m^3 (14.7 cubic feet), 0.30 m^3 (10.48 cubic feet) for fresh food and 0.13 m^3 (4.24 cubic feet) for frozen food. Exterior dimensions were approximately 162 cm (64") high x 76 cm (30") wide x 71 cm (28") deep. The freezer compartment was located above the refrigerator compartment with a separate door. Separate controls were provided for the freezer and refrigerator compartment temperatures, with markings of A to E and 1 to 9, respectively. The refrigerator compartment control was the thermostat governing compressor operation. The freezer compartment control was a damper or baffle directing more or less air to the refrigerator compartment. The electric defrost was initiated by an electric timer after every 5 hours, 33 minutes of compressor operation. The same timer terminated the defrost after a 27-minute defrost period. The temperature of the defrost heater was limited by an attached bimetallic sensor. Both condenser and evaporator were equipped with fans.

The manual defrost refrigerator had a net volume of 0.38 m^3 (13.6 cubic feet), 0.28 m^3 (9.83 cubic feet) for fresh food and 0.10 m^3 (3.76 cubic feet) for frozen food. The exterior dimensions were the same as those of the automatic-defrost refrigerator. This refrigerator had a condenser fan but not an evaporator fan. The freezer compartment was located above the fresh food compartment with a separate door. A single control was provided for freezer and refrigerator compartment temperatures. This control was a thermostat with anticipator governing compressor operation. This refrigerator was described by the manufacturer as cycle defrost. This was achieved by isolating the refrigerator from the freezer compartment and recommending that the refrigerator thermostat be set warm enough so that the mean cyclic evaporator temperature was above 0 C (32F). The refrigerator compartment would then stay frost free although the separate freezer would need manual defrosting.

Both refrigerators were equipped with electric resistance antisweat heaters around the doors. Neither has a switch allowing their optional use.

The manufacturer's recommended voltage for both refrigerators was 115V.

The upright freezer had a net volume of 0.45 m^3 (15.9 cubic feet), exterior dimensions were approximately 80 cm (32") wide x 74 m (29") deep x 165 cm (65") high. No evaporator or condenser fans were provided. The evaporator surface was incorporated in three full-width grille-type shelves. The condenser was a grille-type surface attached to the back of the cabinet. There was no provision for thermostat adjustment by the owner. The manufacturer's recommended voltage was 120V.

The chest freezer had a net capacity of 0.29 m^3 (10.3 cubic feet). Exterior dimensions were 89 cm (35") high x 81 cm (32") wide x 77 cm (30 1/3") deep. Neither condenser or evaporator fans were provided. The evaporator tubes were bonded to the inner liner, providing a cold wall construction. The condenser tubes were similarly bonded to the outer liner. A two-position (normal and cold) thermostat was provided. There were no intermediate thermostat positions between these two settings. The manufacturer's recommended voltage was 120V.

3. TEST PROCEDURE

3.1 Instrumentation

All temperatures were measured by copper-constantan thermocouples connected to an indicating potentiometer or, alternatively, a strip-chart recording potentiometer. Thermocouple locations for measurement of interior and ambient temperatures were in accordance with American National Standards Institute (ANSI) B 38.1 [1]. A 75% freezer loading of chopped frozen spinach in 280 g (10 oz.) packages installed and instrumented according to ANSI B 38.1 was used for the simulated load tests.

Energy consumption was measured by watthour meters in the main power line to each refrigerator or freezer.

Compressor running times were measured by a time clock attached across the compressor main winding terminals.

Spot readings of line voltage were made throughout the test series.

3.2 General Test Conditions

Tests were run at two nominal ambient temperatures, 32.2 C (90 F) and 23.9 C (75 F). The tests at 32.2 C (90 F) were performed in accordance with the guidelines of Association of Home Appliance Manufacturers (AHAM) HRF-2-ECFT-1974 [1]. Some of the tests at 23.9 C (75 F) were also performed in accordance with this same standard for comparison purposes, but most of this series were made under simulated usage conditions.

Some tests were made under conditions that would closely approximate expected household conditions. Tests were also performed to determine energy consumption using the methods given in AHAM HRF-2-ECFT-1974 [1]. Although time limitations made it impossible to perform all the tests on all the units, sufficient tests were performed to make a comparison between the different test conditions.

Tests were performed with freezer compartments empty and with freezers and freezer-section shelves loaded to 75% of their capacity.

Most of the tests at an ambient temperature of 23.9 C (75 F) involved door openings - the door-opening schedules are given in the descriptions of the individual tests.

Two relative humidity levels, 40% and 60%, were employed during the door-opening tests in a 23.9 C (75 F) ambient temperature.

All tests were run on the NBS house power supply, which averaged 120 volts.

Antisweat heaters were connected and in operation during these tests since none of the test samples were provided with a manual switch for the heaters.

All test refrigerators and freezers were broken in by several days running in accordance with the requirements of ANSI B 38.1 [2], prior to testing.

The term "steady-state" as applied to tests in this report indicates that the test conditions had been allowed to stablize for a period of time sufficient to insure repeatability before data were taken. A "steady-state" test in which the refrigerator cycled on its thermostat would have repeatable temperature excursions and repeatable on-off cycles; and the energy consumed during each cycle would also be repeatable.

4. TEST RESULTS

4.1 Refrigerator Tests

The two refrigerators were tested simultaneously in the same laboratory area. The various tests are summarized in Tables 1 and 2.

For the first five tests, performed June 5 through June 14 on the automatic-defrost refrigerator, the recorded average refrigerated compartment and freezer compartment temperatures do not include the temperature excursion during defrost. The energy consumption for this refrigerator is given both with and without defrost energy included. Standard HRF-2-ECFT-1974 [1] requires that the average freezer compartment temperature not include the temperature excursion during defrost and that the energy consumption include energy used to defrost. The later tests of this unit, from June 20 on, include the effect of defrost in both recorded temperatures and energy consumptions to more closely simulate household conditions.

The determination of energy consumption by the graphical interpolation method of Standard HRF-2-ECFT-1974 [1] is shown in Figure 1 for the dual-control, automatic-defrost refrigerator and Figure 2 for the single-control, manual-defrost refrigerator. This energy consumption determined by the uniform, repeatable procedure of Standard HRF-2-ECFT-1974 [1] provides a basis for comparison against which the results of the non-standard tests performed under simulated usage condition can be compared. Data points taken on June 14 are included in these figures to show the comparative effect of freezer-compartment loading.

Tests from June 20 on were performed in a nominal 23.9 C (75 F) ambient temperature. These tests were all performed with the freezer compartment loaded. On June 20, in a nominal relative humidity of 60% simulating a summer condition, a usage test was performed in which both refrigerator and freezer doors were opened 24 times during an 8-hour day. These door openings were performed in 3 one-hour groups of 8 openings per group, simulating usage for breakfast, lunch and dinner. The length of door opening was 10 seconds and the spacing between individual openings in a group was 8 minutes. The doors were opened approximately 90 degrees. On June 21, the above test was repeated except that only the refrigerator doors were opened and the freezer-compartment doors were kept closed. On June 22, a closed-door test was performed for comparison with the test in a 32.2 C (90 F) ambient temperature on June 14.

On June 25, 26 and 27, the above test schedule was repeated at a lower relative humidity, 40%, simulating winter operation.

For the final test on June 28, both freezer and refrigerator doors were opened simultaneously for 10 seconds at 8-minute intervals for 3 consecutive hours and the doors left shut the following 5 hours. The top lines of data recorded for June 28 in Tables 1 and 2 present the average temperatures and power consumptions recorded during the 3 consecutive hours of repeated door opening. The bottom lines of data for this same day present the average power and temperature for the 8-hour period of 3 hours of door openings followed by the 5-hour recovery period with the door shut.

4.2 Freezer Tests

The freezers were loaded to 75% of capacity with boxes of frozen, chopped spinach and were instrumented as described in ANSI B 38.1 [2] prior to testing. Data for all freezer tests are summarized in Tables 3 and 4. The two freezers were tested simultaneously.

The first test performed, on July 2, was a measurement of the steady-state energy consumption in a 23.9 C (75 F) ambient temperature. On July 3 this was repeated at a nominal 32.2 C (90 F) ambient temperature. On July 5 the test was repeated because the ambient temperature was a little too low for the test on July 3.

The chest freezer had a two-position (normal and cold) thermostat, while the upright freezer had a fixed thermostat. The above tests were performed on the normal thermostat position on the chest freezer. Examination of the test data indicated that this position was inadequate for long-term frozen food storage. The tabulated average freezer compartment temperature was approximately -13.9 C (7 F). The warmest thermocouple, installed in the middle of one of the frozen spinach packages, frequently reached -9.4 C (15 F). For this reason the remainder of the tests of this freezer were performed with its thermostat in the cold position.

The initial steady-state on July 2 in an ambient temperature of 23.9 C (75 F) was repeated July 10 with the thermostat of the chest freezer moved to its cold setting.

On July 11 and 12 two door-opening tests were performed. These were to simulate light and heavy usage of the freezers. The light-usage schedule was 12 door openings during an 8-hour day spaced into 3 groups such that 4 door openings occurred in the morning, 4 at lunch time, and 4 in the evening. Each door opening lasted 10 seconds and the door openings in a group were spaced 8 minutes apart.

The heavy-usage schedule was similar except that the number of door openings in each group was doubled. That is, each one of the three groups consisted of 8 door openings, 8 minutes apart, with each opening lasting 10 seconds.

The final two tests, on July 17 and 18, were closed-door, steady-state tests in ambient temperatures of 23.9 C (75 F) and 32.2 C (90 F). These tests differed from the previous steady-state tests in that the product load was removed from the freezers. The air temperatures within the empty freezers were measured by unweighted thermocouples and, in the case of the chest freezer, the thermostat was set to the cold setting as explained above.

5. DISCUSSION OF TEST RESULTS

The following discussion evaluated the effects of the principal variables studied:

5.1 Ambient Temperature. Ambient Temperature had a major effect on energy consumption. The following table summarizes the energy consumption at 23.9 C (75 F) and 32.2 C (90 F) for the items tested:

	A 23.9 C (75 F) Closed Door Energy Consumption, kWh in 24 hrs	B 32.2 C (90 F) Closed Door Energy Consumption, kWh in 24 hrs	B-A Increase for 8.3 C (15 F) ΔT, kWh in 24 hrs	(B-A)/A Increase for 8.3 C (15 F) ΔT, %
Automatic-Defrost Refrigerator	4.80	6.53	1.73	36
Manual-Defrost Refrigerator	2.86	3.94	1.08	38
Upright Freezer	4.70	5.78	1.08	22
Chest Freezer	2.14	3.05	0.91	42

The refrigerator energy consumptions listed are the data taken on June 14 and June 24 reported in Tables 1 and 2. On both of these two days the freezer compartments were loaded and the thermostat settings identical.

The freezer energy consumptions listed are the data taken on July 17 and July 18 reported in Tables 3 and 4. On these two days the freezers were unloaded and the thermostat settings were identical.

5.2 Thermostat Setting. The freezers did not provide variable thermostat settings, since one had a non-adjustable thermostat and the other a two-position thermostat, with the warmer position too warm for extended storage of frozen food.

The refrigerators had thermostats which could be adjusted beyond the desirable range of temperatures for food storage.

Assuming that a refrigerated-compartment temperature outside the range of 0 C (32 F) to 4.4 C (40 F) would be unacceptable and that a freezer-compartment temperature above -12.2 C (10 F) would also be unacceptable, the following range of energy consumptions can be taken from Figures 1 and 2:

32.2 C (90 F) Closed Door
Energy Consumption of Refrigerators, kWh in 24 hrs.

	Maximum	Minimum	% Difference
Automatic-Defrost Refrigerator	6.5	5.0	26
Manual-Defrost Refrigerator	3.9	3.2	17

The maximum energy consumption for the automatic-defrost refrigerator occurred at an average freezer-compartment temperature of -22.6 C (-8.6 F) and an average general food-compartment temperature of 3.1 C (37.5 F). The average freezer-compartment and general food compartment temperatures for minimum energy consumption for this refrigerator were -12.2 C (10 F) and 4.4 C (40 F) respectively. For the manual-defrost refrigerator, the maximum energy consumption occurred at the average freezer-compartment and general food-compartment temperatures of -16.3 C (6.9 F) and 3.6 C (38.5 F), respectively.

The above data on storage temperatures for maximum and minimum energy consumption were obtained for an ambient temperature of 32.2 C (90 F) and an empty refrigerator. Thus the magnitude of the maximum and minimum values should not be considered typical of a usage condition; the percent variation is probably slightly less than that which would occur in a normal ambient temperature.

5.3 Refrigerator Loading (no door usage). One test was performed for comparison between the loaded and unloaded condition of the refrigerators. This was the test at an ambient temperature of 32.2 C (90 F) performed on June 14 with the same temperature settings that were later used for the tests at an ambient temperature of 23.9 C (75 F). This data point is plotted on Figures 1 and 2. The loading had little effect on the manual-defrost refrigerator but produced an increase in the energy consumption of the automatic-defrost refrigerator. This would seem reasonable since the manual-defrost freezer compartment was of cold-wall construction while the automatic-defrost freezer compartment depended on forced-air circulation from the common evaporator coil which it shared with its refrigerator compartment.

A more direct comparison was performed on the two freezers. Closed-door 23.9 C (75 F) tests were performed on these on July 10 loaded, and on July 17, unloaded. The data taken from Tables 3 and 4 are summarized below:

Freezer Energy Consumption, kWh in 24 hrs.
[Doors Closed, Ambient Temperature of 23.9 C (75 F)]

	Loaded	Unloaded	% Difference
Upright Freezer	3.86	4.70	20
Chest Freezer	2.21	2.14	-3

The small effect of loading on the manual-defrost refrigerator and chest freezer as opposed to the relatively large effect on the power consumption of the automatic-defrost refrigerator and upright freezer indicates that the effect of this variable cannot be generalized. Cold-wall freezer construction minimizes the effect of loading, whereas other design features, such as dependence on air circulation to maintain temperature, increase the difference.

Loading also tends to raise the average compartment temperature because of poorer temperature distribution. This is particularly true for food packages near unrefrigerated surfaces such as those in the door shelves of the upright freezer compartments and the topmost package in the chest freezer which was directly below the unrefrigerated door.

5.4 Door Openings. The energy consumption of refrigerators and freezers associated with prescribed door opening schedules was determined for the following table by calculating the time-weighted average of the energy consumption measured during an 8-hour heavy (24 openings) door-opening schedule with 16 hours of closed-door steady-state operation at the same temperature and humidity.

Daily Energy Consumption of Refrigerators and Freezers With and Without Door Opening in an Ambient Temperature of 23.9 C (75 F)

	Relative Humidity %	Energy Consumption, w/Door Openings, kWh in 24 hrs	Energy Consumption, w/Closed Door, kWh in 24 hrs	Difference %
Automatic Defrost Refrigerator	60	5.16	4.80	7
	40	5.08	4.82	5
Manual Defrost Refrigerator	60	2.98	2.86	4
	40	2.85	2.69	6
Upright Freezer	50	4.18	3.86	8
Chest Freezer	50	2.21	2.21	

The increase in energy requirements for door opening was less than 10% in all cases and averaged 6%.

Note that the chest freezer results in the above table show no increased load on this unit as a result of door opening.

Both the steady-state and door-opening tests for the automatic-defrost refrigerator include the energy required by defrost. Comparison of the entries in the percent difference column indicates no significant difference between the automatic-defrost and the manual-defrost refrigerators in their response to the door-opening schedule used at either humidity level at which they were tested.

Tests were also performed on the two refrigerators in which the freezer doors remained shut but the refrigerator doors were opened according to the same door-opening schedule as was used when both freezer and refrigerator doors were opened simultaneously. These tests are recorded in Tables 1 and 2 for June 26. No appreciable difference was observed between the energy consumption measured with the refrigerator doors only being opened and both the refrigerator and freezer doors being opened under the same schedule of door use. The freezer door opening apparently had no effect on power consumption because of its small size and because it was 75% loaded, which further reduced the volume available for air exchange.

5.5 Relative Humidity. Steady-state and door-opening tests were performed in an ambient temperature of 23.9C (75F) at two relative humidity levels--60% simulating summer operation and 40% simulating winter operation. These tests are summarized in the table in Section 5.4 on the effect of door openings. The variation in relative humidity had little effect on the energy requirement involved in door openings over closed-door operation. The steady-state energy consumption of the automatic-defrost refrigerator did not change with the relative humidity variation; however, the energy requirement for steady-state operation of the manual-defrost refrigerator did change and was approximately 5% higher at 60% RH than at 40%.

5.6 Defrost. The energy consumption for the automatic-defrost refrigerator with and without defrost

power included is shown in Table 1 for the closed door tests in an ambient temperature of 32.2 C (90 F). The energy requirement for defrosting averaged less than 9% of the total refrigerator energy consumption for the closed-door tests.

The small difference in energy consumption between the tests performed with door openings at 40% and 60% relative humidity indicates that the small amount of ice that can accumulate on the evaporator between timed defrosts as compared to the mass of the evaporator does not significantly affect the defrost energy.

An automatic-defrost refrigerator normally requires an evaporator remote from the refrigerated space. Cold air is blown by an evaporator fan from this remote evaporator to the refrigerator and freezer compartments to provide cooling. Moisture within the refrigerator condenses on this eveporator since it is the coldest area in the circulating air stream. Since the evaporator is remote it may be heated, with the evaporator fan turned off, to the 4 C (40 F) normally required for defrosting without heating the food storage compartments. The use of the evaporator fan increases the energy consumption by the amount required by the fan motor plus the extra energy required by the refrigeration system to remove the fan heat from the refrigerated space. Although a defrost cycle may result in a small increase in energy consumption over that of normal operation, the presence of the evaporator fan is responsible for the major difference in the energy consumption between automatic-defrost and manual-defrost refrigerators. Other factors tending to increase the power consumption of automatic-defrost refrigerators above manual refrigerators would be those associated with top-of-the-line versus basic appliances such as larger size, automatic ice-cube makers, chilled water dispensers, etc.

6. CONCLUSIONS

The observed effects of the variables studied were as follows:

1. Increasing ambient temperature from 23.9 C (75 F) to 32.2 C (90 F) increased daily energy requirements from 22% to 42% in closed door tests.
2. Thermostat adjustment within a usable range of temperatures increased daily energy requirements 17% and 26% for the two refrigerators tested.
3. Loading freezer compartments with a simulated food load resulted in energy requirement changes of -3% and +20% for the two refrigerators tested, depending on refrigeration system design and control characteristics as described in Section 5.3.
4. A reasonable simulated-usage schedule of door openings on the refrigerators and upright freezer increased power consumption approximately 6%. It had little or no effect on the energy requirements of the chest freezers.
5. Tests at relative humidity levels of 60% and 40% showed little or no difference in door-opening loads, but in one case the higher relative humidity increased steady-state energy requirements 5%.
6. Automatic defrosting of the one refrigerator with this feature required little additional energy, less than 9% more than would otherwise have been used. Although the power required for a defrost cycle may be small, the addition of an automatic-defrost feature may require design changes which substantially increase a refrigerator's energy consumption, as is discussed in Section 5.6.

7. REFERENCES

[1] Association of Home Appliance Manufacturers (AHAM) Standard No. HRF-2-ECFT, Test Procedure to Determine the Freezer Temperature and Energy Consumption of Household Refrigerators, Combination Refrigerator-Freezers and Freezers.

[2] American National Standard B 38.1-1970, Methods of Testing for Household Refrigerators, Combination Refrigerator-Freezers, and Household Freezers.

Table 1 - Summary of Automatic-Defrost Refrigerator Tests

Date of Test	Average Ambient Temp.,C(F)	Average Relative Humidity%	Refrigerated Compartment, Avg.Temp.,C(F)	Freezer Compartment, Avg.Temp.,C(F)	Refrigerated Compartment, Thermostat Setting	Freezer Compartment, Thermostat Setting	Product Load	Door Openings	Compressor Run Time %	Average Power Consumption Without Defrost W	Average Power Consumption With Defrost W	Energy Consumption With Defrost kWh in 24 hrs.
6/5/74	32.8 (91.0)	35	3.4 (38.2)	-14.2 (6.4)	3.7	8 2/3	No	No	63	198	206	4.94
6/6/74	32.5 (90.5)	35	3.1 (37.5)	-22.6 (-8.6)	Coldest,9	Coldest,E	No	No	100	273	272	6.53
6/7/74	33.0 (91.4)	44	-1.3 (29.7)	-11.8 (10.7)	Coldest,9	Warmest,A	No	No	59	190	203	4.87
6/10/74	32.2 (90.0)	43	5.8 (42.5)	-6.2 (20.8)	Warmest,1	Warmest,A	No	No	45	143	157	3.77
6/11/74	32.9 (91.2)	29	6.3 (43.4)	-19.9 (-3.8)	Warmest,1	Coldest,E	No	No	81	237	238	5.71
6/14/74	32.7 (90.0)	42	5.3 (41.5)	-18.4 (-1.1)	3	Coldest,E	Freezer,75%	No [a]	100	276	272	6.53
6/20/74	24.4 (76.0)	64	5.0 (41.0)	-17.2 (1.1)	3	Coldest,E	Freezer,75%	8,8,8Both Doors	78		244	5.86
6/21/74	24.4 (75.9)	63	5.1 (41.2)	-17.7 (0.2)	3	Coldest,E	Freezer,75%	8,8,8Refr.only	77		245	5.88
6/24/74	23.7 (74.6)	59	4.4 (40.0)	-17.2 (1.1)	3	Coldest,E	Freezer,75%	No	62		200	4.80
6/25/74	24.6 (76.2)	42	5.1 (41.4)	-17.4 (0.7)	3	Coldest,E	Freezer,75%	8,8,8Both Doors	75		233	5.59
6/26/74	24.6 (39.5)	43	4.2 (39.5)	-18.1 (-0.5)	3	Coldest,E	Freezer,75%	8,8,8Refr.Only	77		242	5.81
6/27/74	24.6 (76.3)	42	4.3 (39.8)	-17.2 (1.0)	3	Coldest,E	Freezer,75%	No	60		201	4.82
6/28/74	24.6 (76.2)	43	7.0 (44.6)	-16.7 (1.9)	3	Coldest,E	Freezer,75%	23 Continuous [b]	83		282	6.77
6/28/74	24.6 (76.3)	43	5.7 (42.2)	-17.0 (1.4)	3	Coldest,E	Freezer,75%	23 + Recovery [c]	72		231	5.54

a. 24 door openings were performed in 3 groups of 8 as described in Section 4.2.

b. 23, 10 second door openings were performed at 8 minute intervals.

c. The door opening schedule of b. was followed, after which the unit was left shut and unit performance recorded until temperature and energy consumption returned to the values observed prior to the door opening series.

Table 2 - Summary of Manual-Defrost Refrigerator Tests

Energy Consumption kWh in 24hrs	Date of Test	Average Ambient Temp.,C(F)	Average Relative Humidity,%	Refrigerated Compartment Avg.Temp.,C(F)	Freezer Compartment Avg.Temp.,C(F)	Thermostat Setting	Product Load	Door Openings	Compressor Run Time %	Average Power Consumption W
3.67	6/5/74	32.4 (90.3)	35	1.6 (34.9)	-14.5 (5.9)	4.5	No	No	60	153
5.21	6/6/74	32.9 (91.3)	35	-7.5 (18.5)	-21.8 (-7.2)	Coldest,9	No	No	100	217
3.17	6/10/74	32.7 (90.9)	43	3.6 (38.5)	-13.9 (6.9)	Warmest,1	No	No	49	132
3.94	6/14/74	32.7 (90.8)	42	1.5 (34.7)	-14.1 (6.6)	2.5	Freezer,75%	No [a]	67	164
3.22	6/20/74	25.1 (77.1)	64	2.6 (36.6)	-13.9 (6.9)	2.5	Freezer,75%	8,8,8Both Doors	51	134
3.22	6/21/74	25.0 (77.0)	63	2.9 (37.2)	-13.3 (8.1)	2.5	Freezer,75%	Refr. only	48	134
2.86	6/24/74	23.8 (74.8)	59	0.2 (32.3)	-14.7 (5.5)	2.5	Freezer,75%	No	45	119
3.17	6/25/74	24.9 (76.9)	42	2.2 (36.0)	-14.4 (6.1)	2.5	Freezer,75%	8,8,8 Both Doors	51	132
3.02	6/26/74	25.1 (77.1)	43	2.7 (36.9)	-13.2 (8.2)	2.5	Freezer,75%	8,8,8 Refr. Only	43	126
2.69	6/27/74	24.8 (76.7)	42	2.6 (36.6)	-12.8 (8.9)	2.5	Freezer,75%	No	39	112
3.91	6/28/74	24.9 (76.8)	43	1.6 (34.9)	-14.4 (6.1)	2.5	Freezer,75%	25 Cont. [b]	63	163
3.14	6/28/74	24.9 (76.8)	43	2.0 (35.6)	-13.9 (7.0)	2.5	Freezer,75%	25 + Recovery [c]	49	313

a. 24 door openings were performed in 3 groups of 8 as described in Section 4.2.

b. 23, 10 second door openings were performed at 8 minute intervals.

c. The door opening schedule of b. was followed, after which the unit was left shut and unit performance recorded until temperature and energy consumption returned to the values observed prior to the door opening series.

Table 3 - Summary of Upright-Freezer Tests

Date of Test	Average Ambient Temp.,C(F)	Avg. Relative Humidity, %	Avg. Freezer Compartment Temp.,C(F)	Product Load	Door Openings	Compressor Run Time, %	Average Power Consumption W	Energy Consumption kWh in 24hrs
7/2/74	24.5 (76.1)	40	-18.0 (-0.4)	75%	No	47	164	3.94
7/3/74	31.3 (88.3)	36	-18.6 (-1.4)	75%	No	71	232	5.57
7/5/75	33.2 (91.8)	29	-19.2 (-2.6)	75%	No	81	259	6.22
7/10/74	23.5 (74.3)	56	-17.3 (0.8)	75%	No	43	161	3.86
7/11/74	23.3 (74.0)	47	-17.4 (0.6)	75%	4,4,4*	49	178	4.27
7/12/74	23.3 (74.0)	47	-17.7 (0.2)	75%	8,8,8*	57	201	4.82
7/17/74	23.8 (74.9)	43	-19.3 (-2.8)	No	No	54	196	4.70
7/18/74	32.8 (91.9)	40	-20.8 (-5.5)	No	No	71	241	5.78

*Either 12 or 24-door openings performed in 3 groups as described in Section 4.2.

Table 4 - Summary of Chest-Freezer Tests

Date of Test	Average Ambient Temp., C(F)	Avg.Relative Humidity, %	Avg. Freezer Compartment Temp., C(F)	Thermostat Setting	Product Load	Door Openings	Compressor Run Time, %	Average Power Consumption W	Energy Consumption kWh in 24hrs
7/2/74	24.5 (76.1)	40	-14.0 (6.8)	Normal	75%	No	37	74	1.78
7/3/74	31.3 (88.3)	36	-13.7 (7.3)	Normal	75%	No	46	91	2.18
7/5/74	33.1 (91.8)	29	-13.6 (7.5)	Normal	75%	No	55	105	2.52
7/10/74	23.5 (74.3)	56	-16.4 (2.5)	Cold	75%	No	50	92	2.21
7/11/74	23.3 (74.0)	47	-17.7 (0.2)	Cold	75%	4,4,4*	50	91	2.18
7/12/74	23.3 (74.0)	47	-16.4 (2.4)	Cold	75%	8,8,8*	49	92	2.21
7/17/74	23.8 (74.9)	43	-19.4 (-2.9)	Cold	No	No	49	89	2.14
7/18/74	32.8 (91.1)	40	-19.5 (-3.1)	Cold	No	No	73	k27	3.05

*Either 12 or 24-door openings performed in 3 groups as described in Section 4.2

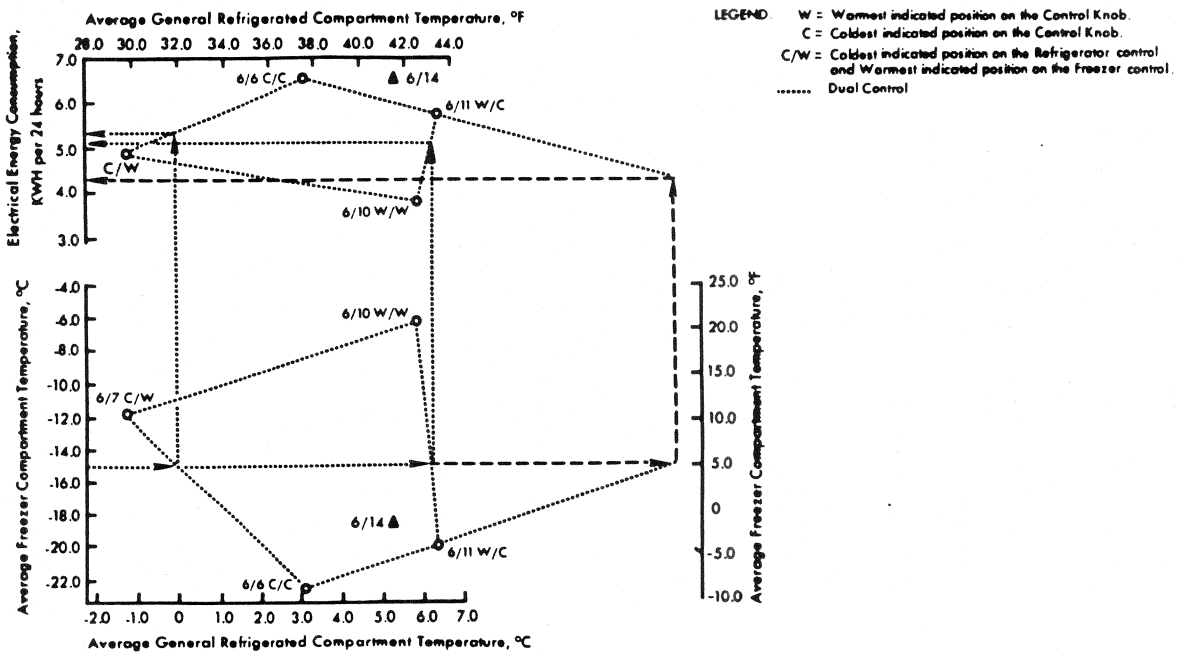

Fig. 1 Energy consumption tests of automatic defrost refrigerator in an ambient temperature of 32.2C (90 F)

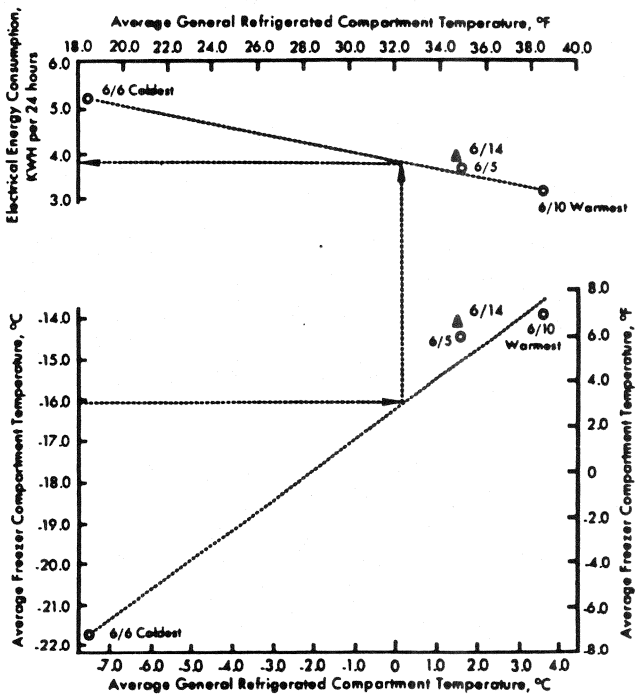

Fig. 2 Energy consumption tests of manual defrost refrigerator in an ambient temperature of 32.2C (90 F)