NATIONAL BUREAU OF STANDARDS REPORT

6524

A STUDY OF THE TEST PROCEDURES IN
INTERIM FEDERAL SPECIFICATION AA-R-00211d (Army QMC)
DOMESTIC TYPE, SELF-CONTAINED, ELECTRIC REFRIGERATORS

by

W. F. Goddard and C. W. Phillips

Report to

Mechanical Engineering Division
Headquarters,
Quartermaster Research and Engineering Command
Natick, Massachusetts

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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NBS PROJECT 1003-20-4832 | August 27, 1959 | **NBS REPORT** 6524

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by

W. F. Goddard and C. W. Phillips
Air Conditioning, Heating, and Refrigeration Section
Building Technology Division

to

Mechanical Engineering Division
Headquarters,
Quartermaster Research and Engineering Command
Natick, Massachusetts

IMPORTANT NOTICE

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U. S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

A STUDY OF THE TEST PROCEDURES IN INTERIM FEDERAL SPECIFICATION AA-R-00211d (Army QMC) DOMESTIC TYPE, SELF-CONTAINED, ELECTRIC REFRIGERATORS

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1. INTRODUCTION

In accordance with the request on March 13, 1957, of Mr. J. W. Millard, Research Director, Mechanical Engineering Division, Quartermaster Research and Development Command, U. S. Army, performance tests were made on four nominal twelve cubic foot household refrigerators in accordance with test procedures as set forth in Interim Federal Specification AA-R-00211d (Army QMC). These tests were made to furnish information on the suitability of the test procedures now included in the Interim Federal Specification AA-R-211. Since regular commercial items of an acceptable quality that will assure efficient expenditure of government funds are desired in response to contracts, it was requested that the tests finally recommended should reflect industry practice while still establishing the minimum quality that acceptable commercial items must provide. It was further requested that the four refrigerators procured for test should approximate Type I, as defined in the Interim Specification AA-R-00211d; should be purchased for test through conventional civilian retail sources without disclosure of intended use. Also, to support the final test requirements, the following four areas of investigation were identified for study:

1. Special equipment required for the tests and/or procedures that may not conform to industry practice.

2. Recommendations for changes of test requirements and/or procedures that conflict with industry standards.

3. Time to perform each test.

4. Total time for complete test series.

This report presents the results of the four areas of investigation as stated above. The tests were performed in accordance with the interim specification in all cases except those where,

for some reason, exact conformity was not possible. In these cases, the necessary changes to be made and incorporated in the test procedure were discussed with Mr. Paul Vogel, the project officer representing the Quartermaster Research and Engineering Command. This procedure for revising the tests as the problems presented themselves eliminated the necessity for repeating certain tests.

By agreement with the project liaison officer, this investigation covered only the areas of the specification relating directly to performance tests listed under Section 4.4.

2. DESCRIPTION OF THE TEST SPECIMENS

The four refrigerators used for the tests were all Type I units - units having no frozen food storage compartments as defined for Types III and IV, and equipped for manually-initiated defrost. Each had an ice storage or low temperature storage compartment. The four makes and models are listed below together with descriptive information from the manufacturer's literature.

Admiral DA 1360, as described in Admiral Form A 6412, list price $359.95; rated at a gross storage volume of 13 cubic feet; full-width ice storage freezer chest and drawer; four full-width shelves; twin porcelain crispers; butter and cheese chest in door; four door shelves (1 egg); "Lifeguard" and "Touch-O-Magic" door handle - a means of opening the door from inside in the event of accidental imprisonment and an easy opening outside handle; push button auto-defrost (electric defrost); two ice trays. Fig. 1 and Fig. 2 show the front and back, respectively, of this refrigerator.

Coldspot L 12-A, as described in Sears-Roebuck Form No. RG46-100380, manufactured by the Whirlpool Corporation, Evansville, Indiana; list price $219.00; rated at a gross storage volume of 12.9 cubic feet; full-width ice storage freezer chest and drawer; three full-width shelves; one crisper; four door shelves (1 egg); porcelain enameled interior; safety door latch; on-off-defrost switch; two ice trays. Fig. 3 and Fig. 4 show the front and back, respectively, of this refrigerator.

Fig. 1

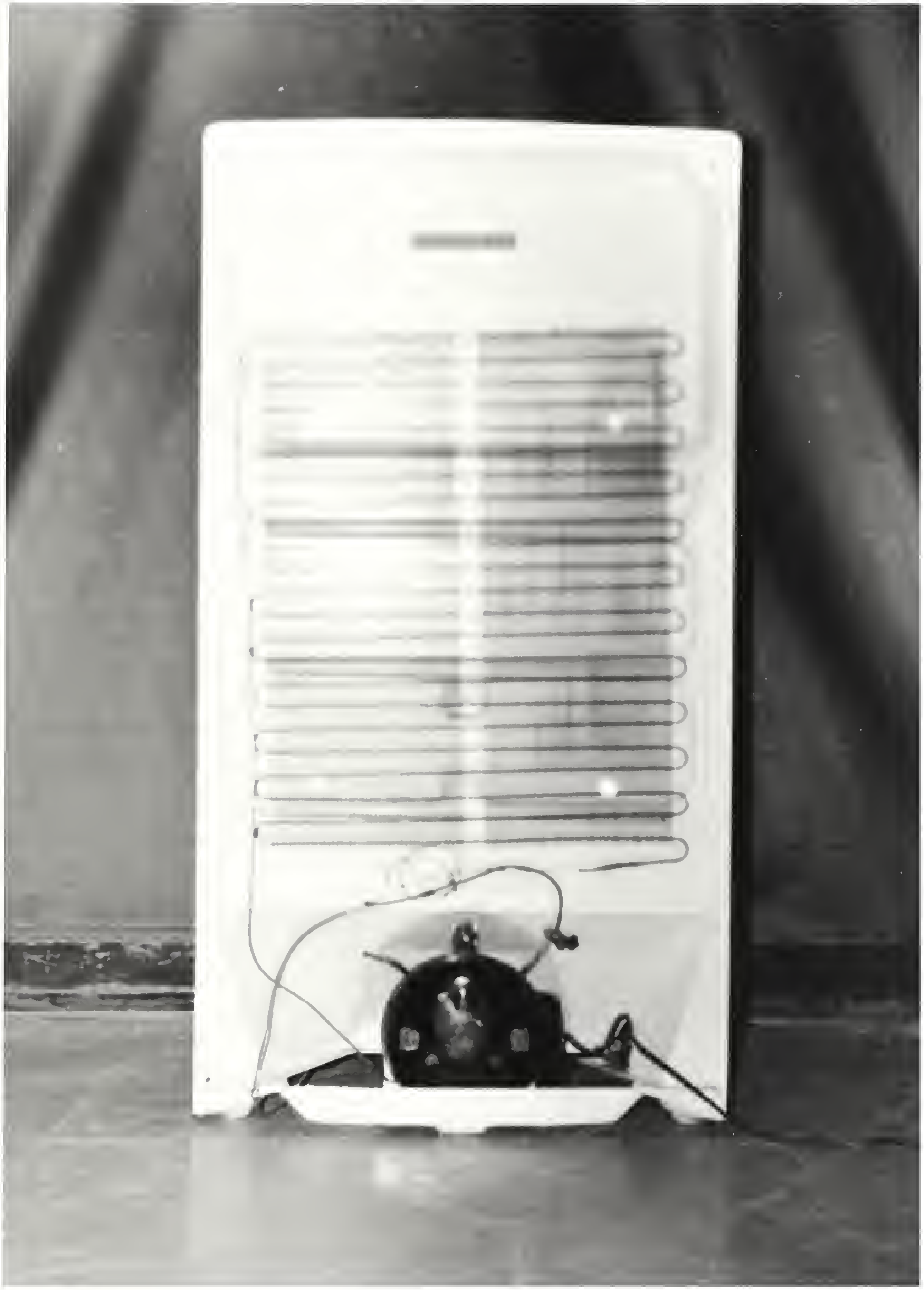

Fig. 2

Fig. 3

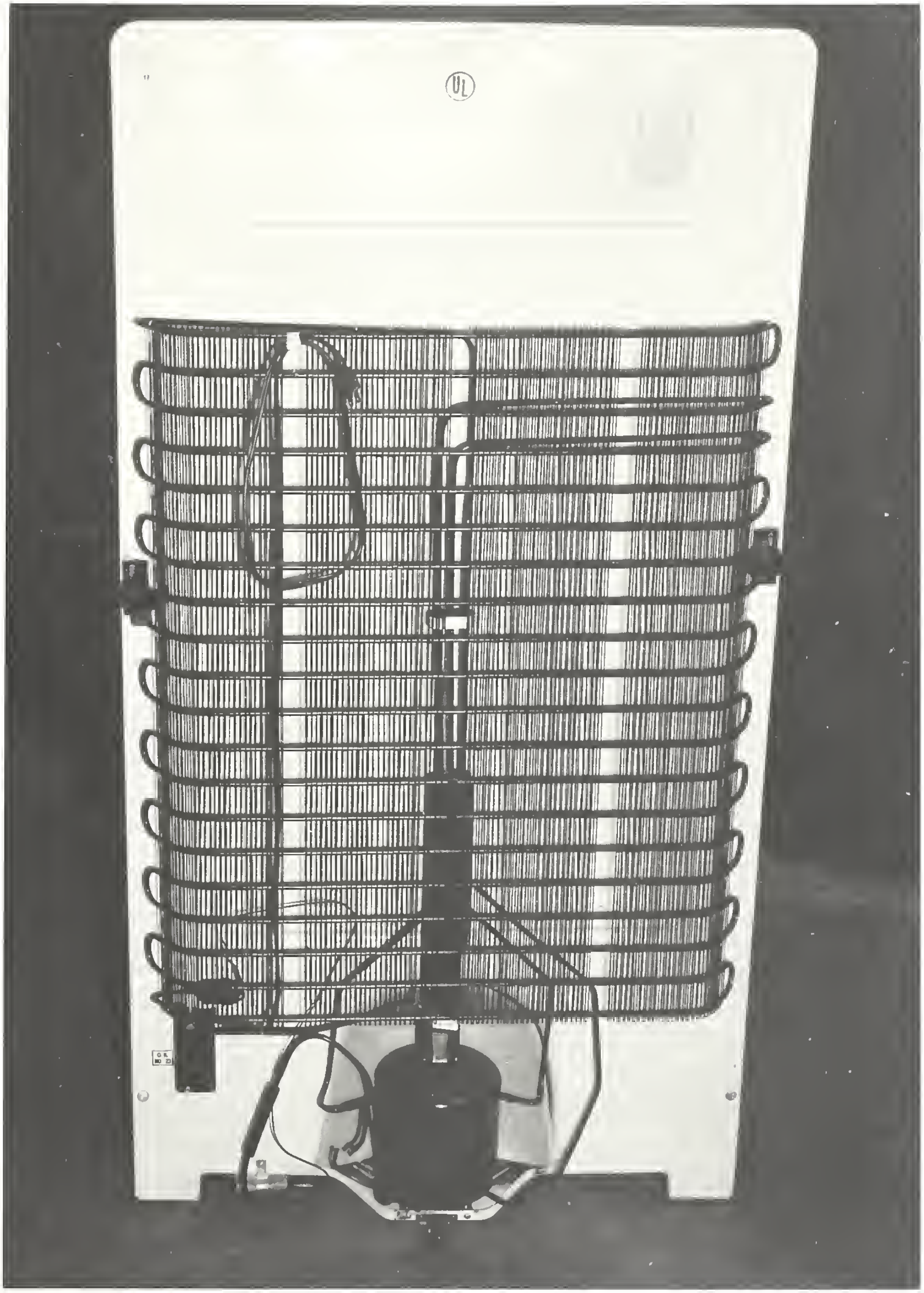

Fig. 4

Frigidaire S-124-57, as described in Frigidaire Bulletin HA-4616; list price \$329.95; rated at 12.4 cubic feet storage volume (NEMA); full-width ice storage freezer chest and drawer; four full shelves and a partial shelf; two porcelain-finished hydrators; butter compartment on door; five door shelves (2 egg); porcelain-finished interior; "Safety-Seal" latch; semi-automatic defrost; three ice trays. Fig. 5 and Fig. 6 are views of this refrigerator.

Westinghouse SK 115, as described in Westinghouse Bulletin 7 DR-0606; list price \$299.95; rated at a gross storage volume of 11.53 cubic feet (NEMA); full-width ice storage freezer chest and drawer; three full shelves; two porcelain-enameled "Humi-drawers"; butter keeper in the door; four door shelves (1 egg); titanium-porcelain enamel interior; on-off thermostat (no defrost position); two ice trays. Fig. 7 and Fig. 8 are views of this refrigerator from front and back, respectively.

As procured, from conventional civilian retail sources without disclosure of intended use, the purchase price for each refrigerator was the list price as given above except for the Admiral, in which case the purchase price was \$201, a reduction of \$158.95 below the list price. This reduction was made by and at the insistance of the seller at the time of pickup when it became known to the seller that the purchaser was the U. S. Government.

The refrigeration systems for all four units were probably typical of current design and construction. All were hermetically sealed. The Admiral and Westinghouse refrigerators used a single refrigeration circuit - compressor, condenser (outside of unit), capillary tube and one evaporator. The Coldspot and Frigidaire refrigerators had, in addition to this circuit, a second refrigerant-cooling circuit. On the Coldspot, it was identified as a "Pre-cooler", and consisted of a 1/4" O.D. copper line running from the discharge side of the compressor, through the upper first four tubes of the condenser and back to the high pressure side of the compressor shell. This "Pre-cooler" tubing can be seen in Fig. 4. On the Frigidaire, a "Superheat Coil", mounted in the compressor compartment under the refrigerator, was connected into a 1/4" O.D. copper line running from the compressor discharge to the high pressure side of the compressor shell. Fig. 9 shows this coil in place as viewed from the front of the refrigerator. These differences in construction of the condenser part of the refrigeration circuit probably affected the length of time involved in the condenser overload test.

Fig. 5

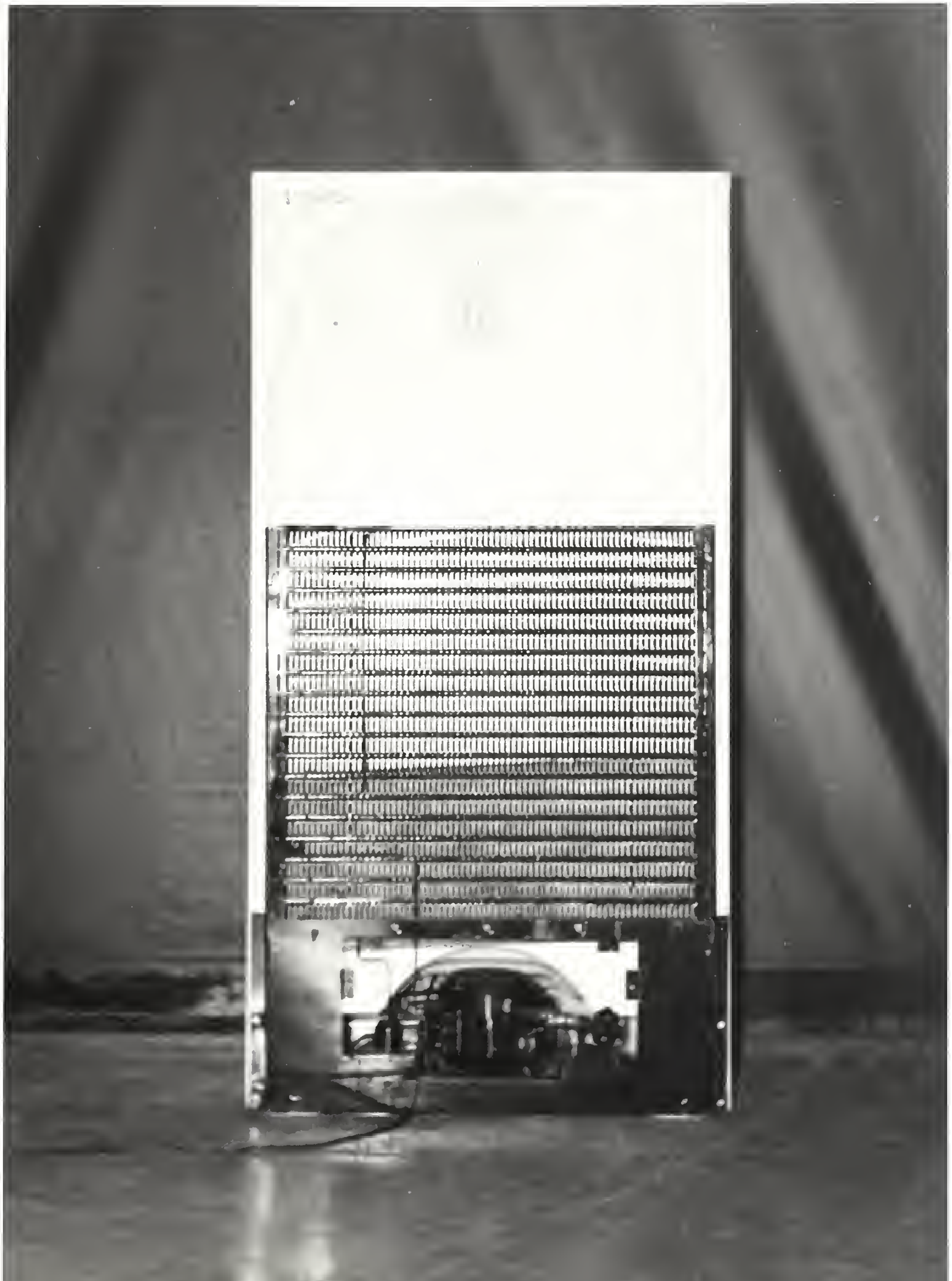

Fig. 6

Fig. 7

Fig. 8

Fig. 9

The several units differed in the method of defrost. Although the defrosting operation in each was manually-initiated, two were equipped with off-defrost-on switches, one with a push button defrost switch, and one had an on-off switch with no marked defrost position. Only one unit, the Admiral, had a means of accelerating the defrost operation - an electric heater element on the evaporator. Three of the specimens were equipped with a means for automatically returning to at least limited operation after defrosting.

These refrigerators were all competitive models intended to represent a cross-section of current industry production. None were "floor" models or "demonstrators." Each unit was removed from existing warehouse stock at the time of purchase. The units were chosen by an NBS representative from the stock available in accordance with recommendation of QMR&E Command as to type. The government was not identified as the purchaser at the time prices were solicited so they probably did not represent normal cost to the government.

3. PROCEDURES AND TEST RESULTS

a. Review of industry practice to determine special equipment or procedures required by the interim specification that may not conform to industry practice.

The formal review of industry practice, upon which the NBS recommendations for the present specification were predicated, was made in 1954, and an informal check made at the time of the work, covered in this report, indicated no outstanding change in industry practices concerning testing equipment or procedures. Nonconformities that do exist between industry practice and the interim specification will probably be found in the method or means of doing the drop test, the door liner test, the test for moisture content of the refrigerant, and the gasket compression test. The need still exists for standardizing these various tests throughout the refrigerator industry.

b. Study to determine what major areas of non-compliance, if any, exist between test requirements of the interim specification and the performance of typical stock refrigerators.

The main purposes of testing the four refrigerators were to determine the suitability of the test procedures incorporated in the interim specification with regard to laboratory techniques and to identify whether or not stock models of current production would comply with the performance requirements of the specification.

Table I summarizes the test results for the four refrigerators and compares these results with the present requirements of the interim specification. An analysis of these test results follows.

Table I shows that all four refrigerators tested were in compliance with part or all of each of the following requirements of Interim Federal Specification AA-R-00211d.

1. Paragraph 4.4.1.2 - Run-in test, 24 hours.

2. Paragraph 4.4.2.1 - No Load Operating Test. Fixed thermostat setting with general food compartment temperature at 39°F, ambient temperature 90°F.

3. Paragraphs 4.4.2.1, 4.4.2.2, 4.4.2.3 - No Load Operating Tests in ambient temperatures of 70°F, 90°F, and 110°F. Minimum permissible food compartment temperature, 33°F.

4. Paragraph 4.4.2.3 - No Load Operating Test at 110°F ambient temperature. Two of the units did not hold the general food compartment temperature below 43°F as required, but all four units operated considerably less than the maximum of 90 percent of the time.

5. Paragraph 4.4.3 - Ice Making Test. Only one unit had the required ice storage capacity. All units froze the required amount of ice in 6 hours.

6. Paragraph 4.4.5.1 - Temperature Change during Cyclic Operation. All units provided less than 6°F change in general food compartment temperature during no-load tests in ambient temperatures of 70°F, 90°F, and 110°F.

7. Paragraph 4.4.5.2 - Minimum Adjustable Range of Refrigeration Temperature Control, 37°F to 43°F. Four of the units provided adjustment below 37°F. Two units could not be adjusted for cyclic operation as high as 43°F.

Table I

SUMMARY OF TESTS OF FOUR REFRIGERATORS

Specification Paragraph Reference: Description of Requirement	Specification Paragraph Reference: Description of Test	Kind of Test	Specification Requirement	Observed Performance of Test Specimens: Frigidaire	Admiral	Westinghouse	Coldspot	Compliance [a]: Yes	No
-	4.4.1.2	24-hour run-in period	-	OK	OK	OK	OK	All	
3.5.1.1	4.4.2.1	No Load Operating Test at 90 F Ambient Temp.	Avg. General Food Compartment Temp. 39 F	39.2 F	39.3 F	39.3 F	39.3 F	All	
3.5.1.1	4.4.2.2	No Load Operating Test at 70 F Ambient Temp.	Min. General Food Compartment Temp. 33 F	34.3 F	33.2 F	40.8 F	38.5 F	All	
3.5.1.1	4.4.2.3	No Load Operating Test at 110 F Ambient Temp.	Max. General Food Compartment Temp. 43 F Max. Operating Time, 90%	45.9 F 51%	44.4 F 68%	47.0 F 42%	44.1 F 58%	 All	All
3.5.2	4.4.3	Ice Making Test, Amt. Frozen in 6 hr[b] Ice Tray Capacity as Supplied by Mfr.	5.25 lb minimum 5.25 lb minimum	6.69 lb 6.69 lb	6.02 lb 4.75 lb	5.40 lb 4.80 lb	5.36 lb 4.40 lb	All F.	 A.W.C.
3.5.3.3	4.4.4.1	Defrosting Test	100% defrosting of evaporator Must initiate limited cooling after defrost	30% Yes	95% Yes	- No	100% Yes	C. F.A.C.	F.A. W.
3.5.1.1	4.4.5.1	Temp. Change in General Food Compartment during Cyclic Operation at No-Load Conditions	Max. Temp. Change 6 F at 70 F ambient " " " 6 F at 90 F ambient " " " 6 F at 110 F ambient	1.70 F 1.95 F 1.95 F	0.75 F 0.60 F 1.10 F	0.90 F 2.95 F 2.50 F	0.85 F 1.30 F 1.40 F	All All All	
3.5.1.2	4.4.5.2	Adjustable range of Refrig. Temp. Control, 90 F Ambient	Min. Adjustable Range, 37 F to 43 F	20.6 - 41.5 F	17.5 - 38.9 F	25.3 - 43.1 F	21.6 - 49.9 F	W.C.	F.A.
3.5.4	4.4.6	Exterior Condensation at 90 F dry bulb 73 - 78% R.H.	None	None	None	None	Hinges and Corner	F.A.W.	C.
3.5.5	4.4.7.1	Comp. Motor Overload Protective Device	Max. Winding Temp. 302 F, Condenser Air Blocked Max. Winding Temp. 302 F, Starting Winding Failed	254 F 127 F	228 F 110 F	208 F 139 F	245 F 153 F	All All	
3.6	4.4.8	Moisture Content of Refrigerant	25 ppm maximum	Charge Lost	7.2 ppm	7.1 ppm	5.7 ppm	A.W.C.	-
3.4.1	4.4.9	Drop Test with Shelves and Trays Loaded	No visible damage from 3" drop, one edge at a time	Slight Damage	No Damage	No Damage	No Damage	A.W.C.	F.
3.8.4.3	4.4.10.1 to 4.4.10.3	Tests of Porcelain Enamel Liner of General Food Compartment	Max. Thickness of Enamel 0.018 in. Min. Reflectance 75% Acid Test shall not Blur Light Image	0.0065 in. 86% OK	0.0065 in. 87% OK	0.0090 in. 88% OK	0.0065 in. 93% OK	All All All	
3.8.4.4	4.4.11.1	Thermal Tests of Door Liner	No Permanent Deformation or Damage at 0 F, 140 F	Cracked at 0 F	Cracked at 0 F	Cracked at 0 F	Cracked at 0 F		All
3.8.6	4.4.11.2	Compression Set of Door Gasket	20% Maximum	10%	25%	25%	25%	F.	A.W.C.
3.8.6	4.4.11.2	Door Gasket Seal	Snug Fit on U.S. Paper Currency	OK	OK	OK	Door Warped	F.W.A.	C.
3.4.5	4.4.11.3	Taste Contamination by Plastics	Shall not Impart Taste to Water or Butter	c	c	c	c	-	-

a. In this column F. standards for Frigidaire; A. for Admiral; W. for Westinghouse; C. for Coldspot

b. Enough additional ice trays were used to provide a minimum ice capacity of 5.25 lb.

c. Standard samples of plastics required for this test, not available from retail sources.

Table II

Time in Hours for Primary Performance Tests

Specification Paragraph	Test	Ambient Condition	Run-In	Stabilize Room	Stabilize Refrigerator	Test	Total Conditioning and Test Time
4.4.9	Drop Test - shelves and trays loaded	Room Temp	0	0	0	1	1
4.4.1.2	Refrigerator Run-In for 24 hours	Room Temp	24	0	0	0	24
4.4.5.2	Refrigeration Temp. Control for 37°F and 43°F	90°F	0	6	12	6	24
4.4.2.1	No-Load Operating Test with general food compartment temp. at 39°F	90°F	0	0	12	12	24
4.4.2.2	No-Load Operating Test with Temp. Control still set at 39°F	70°F	0	6	6	12	24
4.4.2.3	No-Load Operating Test with Temp. Control still set at 39°F	110°F	0	6	6	12	24
4.4.6	Test for Exterior Condensation	90°F 73-78% R.H.	0	8	6	8	22
4.4.4.1	Test of Manually-Initiated Defrost	90°F 80-85% R.H.	0	4	4	24	32
4.4.3	Ice Making in 6 hours	90°F	0	6	8	6	20
4.4.7.1	Compressor Motor Overload: Blocked Condenser	90°F	0	0	3	4	7
4.4.7.2	Compressor Motor Overload: Starter Disconnected	90°F	0	0	3	2	5
4.4.11.1	Thermal Tests of Door Liners at 140°F and 0°F Ambient	140°F 0°F	0 0	14 18	0 0	6 6	20 24
4.4.8	Moisture Content of Refrigerating System	90°F	0	8	1	2	11
		Total time in hours	24	76	61	101	262

8. Paragraph 4.4.7.1 - Motor Overload Protective Device. Operation with condenser blocked. All complied.

9. Paragraph 4.4.7.2 - Motor Overload Protective Device. Operation with failure of starting mechanism. All complied.

10. Paragraphs 4.4.10.1, 4.4.10.2, 4.4.10.3 - Quality of porcelain enamel on interior liner. All complied on maximum enamel thickness, minimum reflectance, and acid resistance.

11. Paragraph 4.4.11.1 - Thermal Tests of Door Liner. All units were undamaged at a temperature of 140°F. All of the original liners failed at a temperature of 0°F.

All four refrigerators tested failed to comply with the following requirements:

1. <u>No-load operation at 110°F ambient temperature.</u> The four refrigerators did not maintain the general food compartment temperature below 43°F as required. Observed temperatures ranged from 44.1 to 47.0°F. This failure was probably due to an inadequate, improperly adjusted, or improperly located thermostat, or inadequate air flow through the manually-adjusted refrigerator temperature control baffles, because none of the refrigerating systems operated more than 68% of the time during this particular test although the specification allows a maximum of 90% operating time.

In literature supplied with each refrigerator, three of the four manufacturers of the specimens tested suggested that the temperature control baffles be used to restrict air flow only at low ambient temperatures. One manufacturer suggested that the baffle be used to restrict air flow at all times except during high ambient temperature. None of the instructions furnished, defined low or high ambient temperatures. The baffles were set to restrict air flow in the no-load tests at 70°F ambient only.

2. <u>Thermal Tests of Door Liner at temperatures of 140°F and 0°F.</u> Although no failures were observed in the door liner of any of the four refrigerators at a temperature of 140°F, all four of the liners failed at 0°F because of cracks which developed and progressed mainly from the holes for the screws used to hold the

liner in place on the door. Fig. 10 through 13 show the failed liners from the Admiral, Coldspot, Frigidaire and Westinghouse refrigerators, respectively.

A new liner was installed in each of the four refrigerators and the test was repeated. Again, no failures were observed at a temperature of 140°F. Three liners failed at a temperature of 0°F. The liner which did not fail, in the Coldspot refrigerator, was installed by a representative from Whirlpool-Seeger Corp., manufacturer of the refrigerator, using screws of a different design from the ones used in the original test. The new screws had a shoulder which prevented excessive pressure on the liner when tightened.

One or more, but not all, of the four refrigerators failed to comply with the following requirements:

1. Ice tray capacity. Only the Frigidaire refrigerator was supplied with sufficient ice tray capacity.

2. Defrosting test. The Westinghouse refrigerator was not equipped with a temperature control having a designated defrost setting. According to the manufacturers' printed instructions, the procedure for defrost was to turn the control switch to "off". Although complete defrosting could be obtained by allowing sufficient time in any room temperature above freezing, the control did not automatically return the system to at least limited operation after defrosting. The Frigidaire refrigerator did not release or melt more than an estimated one-third of the frost on the evaporator before the thermostat returned the system to limited operation 2 3/4 hours after being turned to the defrost setting. The Admiral refrigerator was equipped with a push button defrost switch which did not require changing the normal temperature control setting of the thermostat to defrost the evaporator. It was also equipped with an electric heater on the evaporator to shorten the time required for defrost. The defrost switch returned the refrigerator to normal temperature operation in less than 25 minutes from the time of manual initiation of the defrost operation, leaving a very slight trace of ice at the left front edge of the evaporator. The Coldspot refrigerator defrosted completely in about two hours and returned to limited operation automatically.

Fig. 10

Fig. 11

Fig. 12

Fig. 13

3. Adjustable Refrigeration Temperature control range. All four refrigerators tested held general food compartment temperatures well below 37°F in a 90°F ambient temperature as required but only the Westinghouse and Coldspot models could be adjusted to hold a temperature above 43°F. The Frigidaire and Admiral refrigerators failed this requirement, with general food compartment temperatures at the highest thermostat setting of 41.5°F and 38.9°F, respectively.

4. Exterior condensation. The Coldspot refrigerator failed this requirement. Condensation was observed on the refrigerator surface between the hinges. Condensation was also observed on the lower right side near the gasket closure. This latter condensation was probably caused by failure of the gasket to seal because of a warped door.

5. Drop test. The Frigidaire refrigerator failed this requirement. A permanent twisting of the hinges was observed as a consequence of the drop test. No failures were observed in the other refrigerators.

It is possible that refrigerant system leaks were caused in three refrigerators by the drop test. The Frigidaire refrigerator lost its charge sometime prior to the test for moisture in the refrigerant, which was the last test in the series. The Westinghouse and Admiral refrigerators appeared to contain less than a complete charge of refrigerant at the time of the moisture test. Because of interruptions in the test program, the elapsed time between the drop test and the moisture test for the four refrigerators ranged from three months to more than a year. This elapsed time and the fact that no specific check for refrigerant leaks was made before and after the drop test, make it impossible to state whether or not leaks were caused by the drop test.

6. Compression set of door gasket material. A sample of the door gasket from each of the four refrigerators was tested in accordance with Method B of ASTM D395. For each sample, flat specimens approximately one square inch in area, cut from the gasket, were piled atop one another until a thickness of 0.395 inch was obtained. The test determined the compression set of the material of which the gasket was formed rather than that of the extruded design of the gasket. Three samples failed with a compression set of 25%. The gasket material from the Admiral refrigerator was the only one which complied, having a compression set of 10%.

7. Door Gasket Seal. The Coldspot refrigerator failed this test. The lower edge of the door opposite the hinges did not close sufficiently to effect a gasket seal. Adjustment of the hinges and/or latch did not remedy the situation. After a new liner was installed for the door liner test with special attachment screws, and after readjustment of the latch and hinges, a continuous gasket seal was attained.

Test procedures described in the Interim Specification, which had to be modified in order to conduct the required tests were:

1. Temperature measurement in ice tray compartment. The four refrigerators tested each had a compartment containing the ice cube trays which was identified by the respective manufacturers as a "freezer chest", etc. In a Type I refrigerator, this compartment is not required to be suitable for frozen food storage. Accordingly, the temperature of this compartment was measured by placing two thermocouples in air in the center of the compartment instead of in packages of simulated frozen food as required for Type III and IV refrigerators.

2. Motor overload protective device test. In the test for operation of the motor protective device with the condenser air blocked (Paragraph 4.4.7.1), the overload device on the Frigidaire refrigerator did not function even after several hours of test. The temperature of the windings was determined by measuring their resistance at the time of manual shutdown, repeated at about 30-minute intervals, until four repetitive measurements were obtained. The temperature of the windings was 254°F as determined by this procedure. The Interim Specification does not describe the procedure to be used in the event the overload device does not trip out.

3. Compression set of gasket. The tests for determination of compression set of the door gaskets was made in a manner which determined the characteristics of the material rather than the extruded form of the gasket. Due to a misinterpretation, this was contrary to the test procedure in paragraph 4.4.11.2, which says, "A one-inch section of the gasket shall be compressed ..... in a device described in Method B of ASTM D395 ...." The tests, as performed, were

in non-compliance with two parts of this requirement: (1) a section of the gasket as installed on the refrigerator was not used; and (2) all of Method B of ASTM D395 was used for the test procedure instead of just the device described in Method B of ASTM D395 as stated in the Interim Specification.

4. Taste contamination test for plastics. No tests were made for taste contamination of plastics during this study. Paragraph 3.4.5 requires that none of the plastics used in the refrigerator shall impart odor or taste to food or water. There are many items inside the refrigerators, all of which may be made from different plastics. The test requirement in Paragraph 4.4.11.3 calls for use of a "standard sample" of the plastic to be tested. In view of the fact that these refrigerators were obtained from retail sources, not from the manufacturer direct, no standard samples were available for this test.

5. Time to perform each test. The total time required to complete each performance test on the refrigerators may be divided into three component time periods:

1. Stabilizing the room
2. Stabilizing the refrigerator
3. Test run

These periods ran consecutively. The length of time required to stabilize the room was a function of the equipment used, the room construction, and the degree of condition change required; the time required to stabilize the refrigerator was a function of the refrigerator as a composite unit and the degree of change in ambient conditions required; the test run time was a function of the number of on-off cycles or the time required to assure representative values of the variables observed.

Table 2 presents a break-down of the time required to perform the various phases of the test series on one refrigerator. The order of testing and the time periods involved are not necessarily those listed in the present specification. They are believed to be representative of an average test setup.

It can be seen from Table II that about 262 hours were required to test one refrigerator for compliance with the performance tests in the interim specification which required operation or use of the complete refrigerator. This does not include those secondary tests listed under general performance tests which must be done by means other than actually operating or involving the assembled refrigerator; nor does it include preparation or setup time. These will be discussed under "Time for complete test series."

The time used in stabilizing the various refrigerators varied some from the reported value. However, since there was some overlapping between the time used for room stabilization and refrigerator stabilization, the values reported in Table II are considered representative. The time required for stabilizing room condition would vary with the effectiveness of automatic controls used. The values in Table II were based on automatic control of temperature, manual control of humidity.

6. <u>Time for complete test series</u>. The time required for a complete series of performance tests of one refrigerator under Section 4.4 of the interim specification is summarized in Table III. The time required for complete tests, which includes all phases of performance testing, is divided into three parts:

1. Set-up time

2. Primary performance testing time

3. Secondary testing time

Setup time is defined as that period required to make the specimen ready for a test condition. It includes such items as placing thermocouples, preparing and connecting electrical instruments for the various tests, setting up the moisture determination apparatus, etc. A summary of these items and the time to perform each task is shown in Table IV. Of the total of 32 hours of set-up time shown in Table IV, all but 7 were combined with room or refrigerator stabilizing periods. The variation in set-up time for the several specimens depended on such factors as the degree of access to components in the refrigerators, handle design, thermostat response time, and capability of the person doing the job. The times as listed are representative values. For example, the time required to adapt a door-opener for the defrost test was two hours for one refrigerator with a positive latch as compared to less than an hour for refrigerators with magnetic or easy opening doors.

Table III

Time Required for Complete Test Series*

	Observer Required Hours	No Observer Required Hours	Total Time Hours
Set Up	7	-	7
Run In	-	24	24
Stabilize Room	18	58	76
Stabilize Refrigerator	23	38	61
Actual Test Time	107	-	107
Total Hours	155	120**	275

* Based on Section 4.4 of Interim Federal Specification AA-R-00211d.

** Does not include 168 hours required for test of gasket compression set; includes estimated time for taste contamination tests.

The primary performance testing time was discussed in the previous section (Table II) and is included in this section as part of the time required for a complete test. The 262 hours of primary testing time consisted of two main parts:

1. Time requiring data observation - 101 hours

2. Time necessary for stabilizing, pull-down, etc. - 161 hours

Secondary testing time was that period used in testing those items which did not require operation of the refrigerator as a part of the test. Table V lists the secondary test items and the time

required for each. The greatest percent of the time was that required for the test of the gasket compression set, and was the time required for the gasket to set in the testing device, a period during which no labor charges and minimum overhead charges were involved. This time, 168 hours, is not included in the total time shown in Table III.

Table IV

Set-Up Time for Tests

Item	Task	Time Required, Hours
Installation in room	Placing, leveling, shielding, installing thermocouples, etc.	5
Drop test	Inserting weights on shelves, etc.	2
Defrost	Defrosting and/or drying between condition changes, total for several tests	8*
Thermostat set	Changing settings between condition changes in temp. range, 90°NL, and ice making tests, total for several tests	7*
Handle adapter (Defrost test)	Designing, fabricating, & connecting opener on door handle	1*
Sweat test observation	Wiping unit dry & checking for condensation before actual test	1*
Water for ice making	Preheating water, filling, weighing and placing trays	1*
Overload preparation	Covering & blocking air to condenser	1*
Starter Overload	Disconnecting starter windings	1*
Moisture determination	Connecting sampling tubes and instruments	1*
Gasket compression	Setting up testing instrument	4*
	Total	32

* Can be done during stabilizing periods

Table V

Time Required for Secondary Tests

Test	Item	Observer Required (Hours)	No Observer Required (Hours)
Thickness of Porcelain Enamel	Cabinet & Interior Liner	1	0
Reflectance	Cabinet & Interior Liner	1	0
Acid-Resistance	Interior Liner	1	0
Compression Set	Door Gasket	1	168
Taste Contamination	Butter Dish & Liner	2*	2
	Total	6	170

* estimated

4. DISCUSSION AND CONCLUSIONS

The conclusions based on this study of four refrigerators are limited specifically to requirements referenced in Section 4.4 of Interim Federal Specification AA-R-00211d. Other requirements of the specification were not considered in determining points of compliance, and the times reported for testing do not include times which would be required for determining compliance with these other requirements.

The conclusions are presented in two parts:

1. Time required to perform the tests on a refrigerator.

2. Recommended changes and additions to the specification based on this study.

1. Time required to perform the tests on a refrigerator

The time for the complete series of performance tests for one refrigerator was 275 hours based on the order of testing shown in Table II. It includes 155 hours which required an observer and 120 hours during which conditions were maintained by automatic control. It does not include 168 hours for the test of compression set of the door gasket. It does not include supervisory time or preparation of the test report. It does not include time spent on maintenance or repair of test facilities. The tests were conducted on an around-the-clock basis where necessary.

The order of testing shown in Table II, is recommended to reduce to a practical minimum the number of times conditions must be changed and the abruptness of these changes. It makes use of the drop test first to determine whether or not failure occurs at this point before the other more complex tests are run on the unit. If the run-in test follows, it may be used to check operation of the refrigerator after the drop test.

Use can be made of the stabilizing periods to accomplish tasks which are necessary prior to the tests themselves. The times shown in Tables II through V for the room and refrigerator stabilizing periods are the average values for the four refrigerators used in this study. As test facilities are improved, the time required for stabilizing can probably be reduced somewhat.

For 155 hours of the 275 hours required for testing an observer is needed. In most cases this observer would be one or more persons capable of taking and recording readings; in other cases it would be a person capable of preparing the specimen or changing a condition of the room or specimen. The number of man hours involved will depend on the test facilities, instrumentation, and capabilities of test personnel.

For 120 hours of the 275 hours required for testing, reasonable automatic control can be used to maintain test conditions without personnel in attendance.

Such special equipment as is needed for these tests can be found in any well equipped appliance testing laboratory. The more efficient the test room and equipment is, the sooner proper conditions can be attained, and therefore, both time and cost of the

test will be reduced. Accuracy commensurate with this specification is a part of the normal procedure of any good appliance test setup.

2. Recommended changes or additions to Section 4.4 and referenced requirements of Interim Specification AA-R-00211d based on this study

It should be noted that, of all the tests under Section 4.4, in only two cases did all four of the refrigerators tested fail to comply. One case was the no-load operation at 110°F, where general food compartment temperatures of 44.1°F, 44.4°F, 45.9°F and 47.0°F were observed as compared to a requirement of 43°F maximum. A companion requirement for this test was that the machines should not operate more than 90% of the time. The refrigerators operated, in the same order, 58%, 68%, 51%, and 42% of the time during this test. Since it is probable that a minor change in the temperature control mechanism would bring these units into compliance without exceeding 90% operating time, no change in the requirement is believed necessary.

Fig. 14 and Fig. 15 show operating characteristics of the four refrigerators tested during the no load tests in ambient temperatures of 70°F, 90°F and 110°F. Fig. 15 also shows the effect of the manually-adjusted baffles which were closed in each refrigerator for the no-load tests at 70°F ambient temperature and opened for the no-load tests at 90°F and 110°F ambient temperature.

The second case where all four refrigerators failed to comply concerned the door liners. Although none of the liners failed at a temperature of 140°F during the test outlined in Paragraphs 4.4.11.1, they all cracked around the supporting screw holes as the liners approached a temperature of 0°F. Redesign of the liners, or change of materials, or change of methods by which the liners are attached to the door could probably solve this problem. In a retest of new liners installed in the same refrigerators only three failed. The Coldspot liner did not fail, and, according to the manufacturer's representative who installed the replacement, the only change was in the design of the screws used to fasten the liner to the door. In view of this, and unless it can be shown that storage temperatures of 0°F will not be encountered, the requirement should not be changed.

Since all of the other test requirements were met by one or more of these typical refrigerators, major changes to meet industry practice may not be necessary.

PERFORMANCE OF FOUR REFRIGERATORS DURING NO LOAD TESTS AT 70, 90 AND 110 F AMBIENT. POWER INPUT / 24 HRS, FOOD COMP TEMP, % RUNNING TIME AT 110 F VS AMBIENT TEMPERATURE. BAFFLE OPENED AND/OR CLOSED.

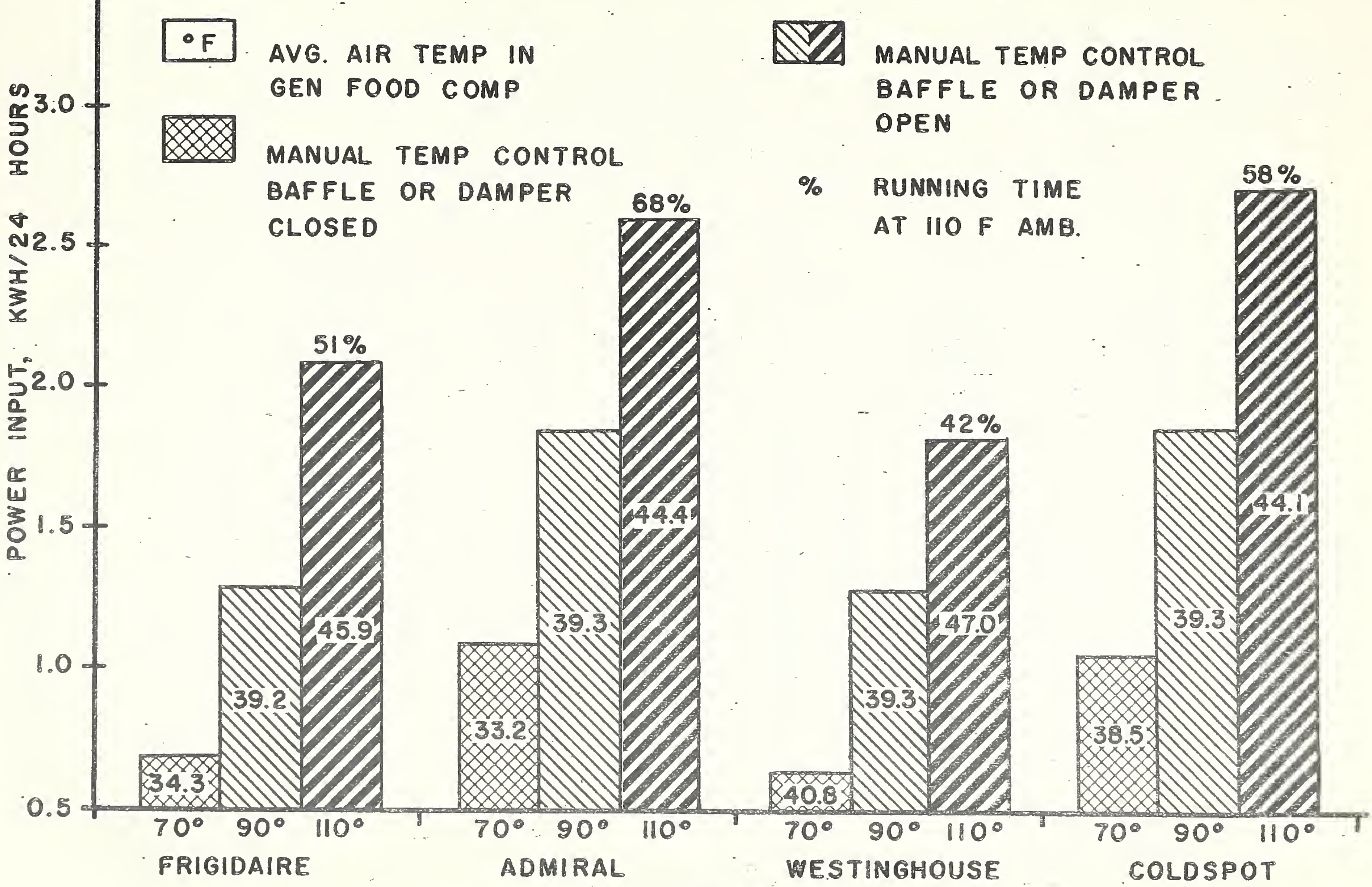

FIG 14

PERFORMANCE OF FOUR REFRIGERATORS DURING NO LOAD TESTS AT 70, 90 AND 110 F AMBIENT TEMPERATURE.

GENERAL FOOD COMP. TEMP. AND LOW TEMP. COMP. TEMP VS AMBIENT TEMPERATURE

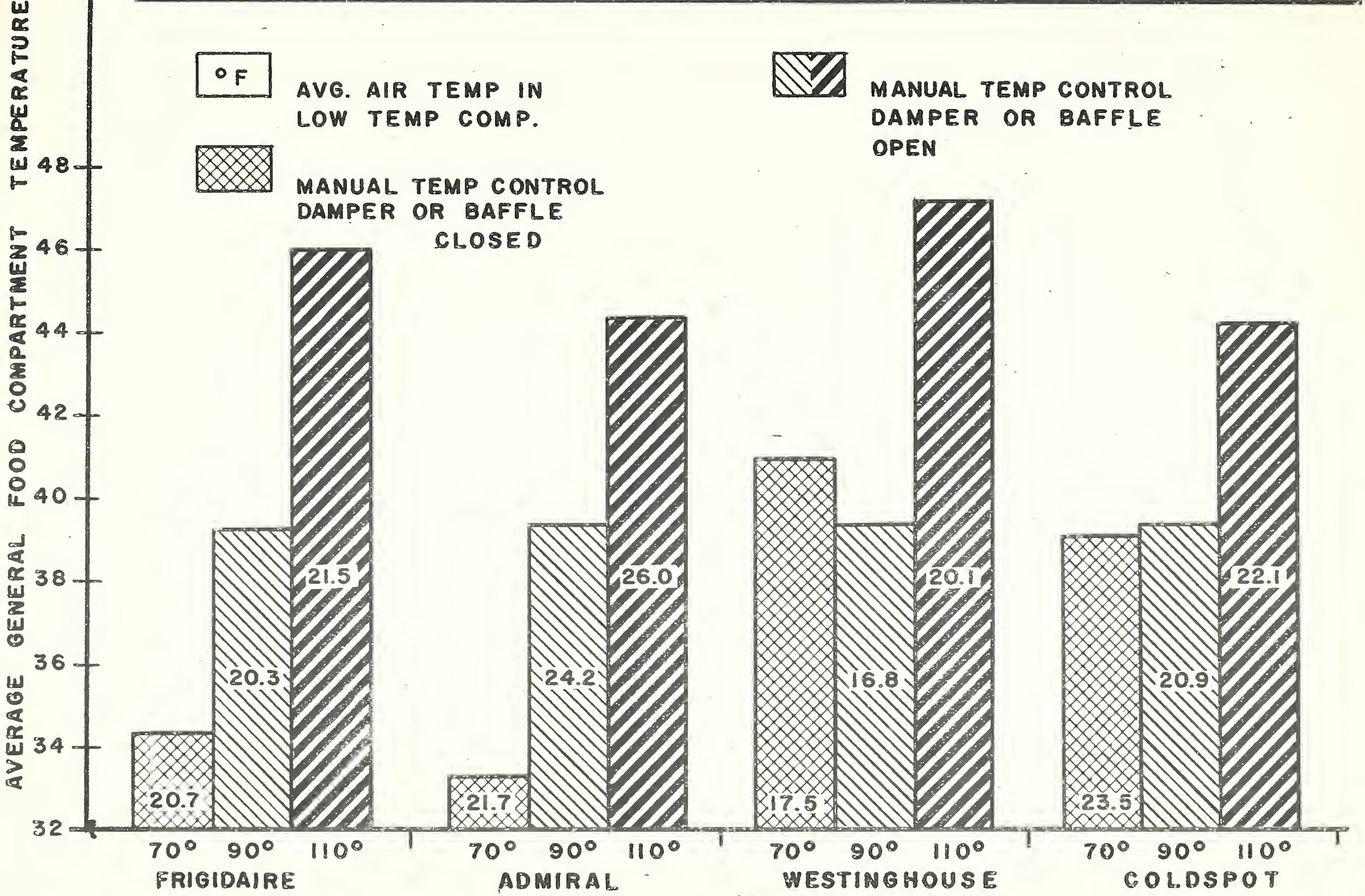

FIG 15

Changes or additions to the specification which may clarify or improve the specification are discussed in the following paragraphs in the order in which they appear in Section 4.4. No review of the other sections of the specification is included, except where items are specifically referenced in Section 4.4.

4.4.1.7 Typographical. Fourth line of first paragraph should read, "......between front and....."

If a temperature requirement is to be included in the specification for the low temperature (ice tray) compartment for Type I and II refrigerators, the means for determining the temperature of this compartment should be included in this paragraph.

4.4.1.8 Add at the beginning of this paragraph, "This test requirement applies to Type III and IV refrigerators only."

4.4.1.9 Typographical. Second line of second paragraph should read, ".....time-integrator."

4.4.2 Instructions for positioning of the temperature control baffles, if used, should be included in this paragraph.

It is our recommendation that the baffle positions remain unchanged throughout the three no-load tests required in 3.5.1.1. The second sentence in paragraph 3.5.1.1 should be changed to read, "Without any change in refrigeration control settings or in temperature control baffle positions, the average......110°F."

4.4.2.1 Change last sentence to read, "Normal ice loads for all types of refrigerators and frozen food loads, prefrozen, for Type III and IV refrigerators shall be......is determined."

4.4.2.2 Change last sentence to read, "The refrigeration temperature control and temperature control baffle shall be set at the same position as for the test at 90°F ambient temperature."

4.4.2.3 Change last sentence to read, "The refrigeration temperature control and temperature control baffle shall be set at the same position as for the test at 90°F ambient temperature."

4.4.4.1 Change the sixth sentence to read, "At the end....in the defrost position <u>recommended by the manufacturer</u>."

4.4.5.1 Change the first sentence to read, "The general..... in Figures 1 through 5, and, for Types III and IV, the frozen..... 4.4.2.1 to 4.4.2.3."

4.4.5.2 Change the second sentence to read, "In two successive tests, with the temperature control set in the first test at the lowest and in the second test at the highest settings......thermostat cycles."

4.4.7.1 Change the first sentence to read, "Each sample...with the heat transfer from the air-cooled condenser and other heat rejecting surfaces restricted.....to function." Add to end of paragraph, "If the compressor motor overload device does not function with the condenser air circulation blocked while the unit is operated continuously for four hours, the resistance of the windings shall not indicate a winding temperature exceeding the specified limit of 302°F at the end of the four-hour period."

4.4.8 Moisture content of refrigerating system. Additional investigation in the general field of moisture measurement may develop more suitable means for this type of determination. Some manufacturers are using small amounts of methanol. A requirement covering this development should be prepared. Until this is done, no change is recommended in the requirement. In paragraph 3.6, the second sentence of the second paragraph should be changed to read, "The refrigerant system.....in excess of 25 ppm by weight as determined......of 4.4.8."

4.4.9 Drop test. Insert a sentence under 4.4 Performance Tests, as follows: "The drop test described in 4.4.9 shall be performed before the run-in period specified in 4.4.1.2 and before any of the performance tests specified in 4.4.2 to 4.4.11 inclusive."

The requirement listed under 3.4.1 should be clarified by changing the last sentence of 3.4.1 to read, "In addition, the refrigerators subjected to this test shall not show any evidence of refrigerant leakage after the drop test or any malfunction in subsequent testing as required in Section 4."

Paragraph 4.4.1.2 should be changed to read, "After the drop test and before starting other performance tests, the......24 hours."

4.4.10.1 and 4.4.10.2 Either delete the reference to Paragraph 3.8.4.2.1 or add 3.8.4.3 and 3.8.4.4.

4.4.11.1 Typographical. Title should read, "Styrene and laminated....plastics."

This paragraph, 4.4.11.1, as written, deals only with the test of door liners. The test as performed under the study covered in this report did not necessitate removal of the door from the refrigerator and as a result, the other plastic components of the refrigerator were also subjected to the ambient conditions of 140°F and 0°F during the door liner test. A permanent warping and deformation of some of the parts such as baffles, door jambs, low temperature compartment doors, etc., was noted at the 140°F temperature. Thermal deformation of plastics is not covered in the tests required under Section 4.4 of the interim specification but is covered by a requirement in Paragraph 3.4.5. It is suggested that the refrigerator be tested as a complete unit under the test conditions required for the door liner. This can be accomplished by changing Section 4.4.11.1 to read, "Thermal Tests. Styrene and laminated thermosetting plastic door liners (see 3.8.4.4) and plastic parts (see 3.4.5) shall be tested as follows:

1. The assembled refrigerator, empty but with all trays, etc., in place, with the door open, shall be permitted to come to thermal equilibrium at 140°F, and then at 0°F. The compressor shall be inoperative for this test.

2. The door shall then be closed and the interior refrigerator temperature permitted to come to steady state at the lowest temperature obtainable with continuous operation of the refrigerating unit in an ambient temperature of 110°F.

3. The door liner and other plastic parts shall be examined for cracks, crazing or permanent distortions."

Change last sentence of paragraph 3.4.5 to read, "Plastics.... 0°F to 140°F." Add new sentence, "Plastic parts shall not craze, crack or permanently distort when tested in accordance with 4.4.11.1."

Change next to last sentence of Paragraph 3.8.4.4 to read, "Styrene......4.4.11.1."

4.4.11.2 Change the title to read, "Compression set of..... rubber door gaskets."

Remove last sentence from 4.4.11.2 and insert in a suitable place in paragraph 3.8.6. Note that it is referenced in the fourth sentence of 3.8.6.

4.4.11.3 Typographical. Title should read, "Taste Contamination."

The wording of this section implies that the test shall be done on all plastic materials in the refrigerator. If this is so, a standard sample as required must be obtained from the manufacturer. The number of tests will vary. The test itself will be difficult because the degree of taste differentiation will vary in an individual and between individuals.

4.4.11.3 Taste contamination. Standard samples of plastic materials shall be given the following taste contamination tests:

a. A standard sample shall be immerged in water in a glass vessel and closed for a period of two hours. A second glass vessel shall be filled with water from the same source and closed. At the end of the two-hour period, there shall be no taste difference in the water from the two vessels.

b. A standard sample, smeared with butter, shall be placed in a glass container and closed for a period of two hours. Some butter, from the same source, shall be placed in a second glass container and closed. At the end of the two-hour period, there shall be no taste difference in the butter from the two containers.

U.S. DEPARTMENT OF COMMERCE
Frederick H. Mueller, Secretary

NATIONAL BUREAU OF STANDARDS
A. V. Astin, *Director*

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