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Development of a High-Efficiency, Automatic-Defrosting Refrigerator-Freezer

Phase II—Field Test

Volume III—Executive Summary and Task Reports

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December 1982

Work performed for

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DEVELOPMENT OF A HIGH EFFICIENCY, AUTOMATIC-DEFROSTING REFRIGERATOR-FREEZER

PHASE II - FIELD TEST

VOLUME III - EXECUTIVE SUMMARY AND TASK REPORTS

RICHARD F. TOPPING

December 1982

Report Prepared by

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under

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for

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Oak Ridge, Tennessee 37830

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Raymond H. Bohman was responsible for the design and manufacture of the ESTR-18D high efficiency refrigerator at Amana Refrigeration, Inc., assisted by Robert L. Harrison and Donald Alba. Charles V. Mueller was in charge of the market test and arrangements with Price's, Inc., the Amana distributor in Norfolk, Virginia, the location of the field test.

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Useful technical inputs and program guidance were received from the Oak Ridge National Laboratory technical monitor, Edward A. Vineyard.

ABSTRACT

This report describes the second phase of the development of a high-efficiency, automatic-defrosting, refrigerator-freezer, sponsored by the U.S. Department of Energy (DOE) and subcontracted by Oak Ridge National Laboratory.

Following the successful completion of Phase I (design, construction, and laboratory testing of a 16 ft^3 high efficiency refrigerator-freezer prototype), Phase II was initiated to evaluate sales potential and in-home performance as a necessary step in creating a product that was both manufacturable and marketable. Arthur D. Little, Inc., continued as principal contractor to Oak Ridge National Laboratory with Amana Refrigeration, Inc., subcontractor. Twenty-five pilot production 18 ft^3 units using prototype tooling were produced on the assembly line to confirm the feasibility of full-scale production. These units were then used in a market and field test program in which consumer appeal and in-home performance were assessed. The market evaluation confirmed that refrigerators incorporating high-efficiency features at added cost are saleable and that large capacity, automatic-defrosting, refrigerator-freezers will continue to capture a large portion of the market in the years ahead. The field test confirmed the in-home energy saving potential of a high efficiency, automatic-defrosting refrigerator-freezer utilizing advanced design features such as optimized, thick-wall, foam insulation and a two-evaporator refrigeration system. Results showed an average energy savings of 60% compared to a baseline unit of conventional design.

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DEVELOPMENT OF A HIGH-EFFICIENCY, AUTOMATIC-DEFROSTING REFRIGERATOR-FREEZER

EXECUTIVE SUMMARY

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1. INTRODUCTION

This report summarizes Phase II of the development of a high-efficiency, automatic-defrosting, refrigerator-freezer by Arthur D. Little, Inc., and Amana Refrigeration, Inc. Following the successful completion of Phase I (design, construction, and laboratory testing of a 16 ft^3, high-efficiency, refrigerator-freezer prototype), Phase II was initiated to evaluate the manufacturing implications, sales potential, and in-home performance of the high-efficiency refrigerator concept as a necessary step in creating a viable commercial product. In Task 1 of Phase II, 25 pilot production units were manufactured on the assembly line to confirm the feasibility of full-scale production. In Task 2, these units were used in a market and field test program in which consumer appeal and in-home performance were assessed. The market evaluation confirmed that refrigerators incorporating high-efficiency features at added cost are saleable and that large capacity, automatic-defrosting, refrigerator-freezers (over 16 ft^3) will continue to capture a large portion of the market in the years ahead. The field test confirmed the energy saving potential of a high-efficiency, automatic-defrosting, refrigerator-freezer utilizing advanced design features such as optimized thick-wall foam insualtion and a two-evaporator refrigeration system. Results showed an average energy savings of 60% compared to a baseline unit of conventional design. This savings was substantially higher than predicted by the DOE, 90°F, closed-door test, hereafter referred to as the DOE test, and suggested that further testing is needed to investigate the comparative effects of in-home usage on conventional and high-efficiency designs.

2. SPECIFICATIONS AND MANUFACTURING APPROACH

2.1 Comparison of Designs

Early in Phase II it was decided to produce 18 ft^3 units for the performance test, since Amana already had an energy efficient 16 ft^3 model in production, but was considering near-term replacement of the current 18 ft^3 top mount model. The 18 ft^3 cabinet was designed using essentially an identical layout to the 16 ft^3 prototype, except for the larger dimensions required for increased capacity. The Phase I and Phase II cabinet specifications are compared in Table 1. The 32 in. width was maintained from the Phase I design and the height and depth increased to incorporate the added capacity.

A computer model developed in Phase I predicted only a 15% increase in heat leak for the Phase II cabinet. Therefore, it was concluded that the Phase I refrigeration system components could be retained in the Phase II design with little change in overall performance. The Phase I control system, including a 48 hour defrost timer, was also retained.

Table 1

PROTOTYPE CABINET SPECIFICATIONS

I. Insulation Thickness (in)

	Freezer Compartment				Fresh Food Compartment		
	Side	Front	Back	Top	Side	Front	Back
Phase I	3.00	2.50	3.00	3.00	2.25	2.50	2.25
Phase II	2.88	2.44	2.91	2.88	2.13	2.44	2.00

II. Heat Flow (BTU/hr)

	Freezer	Mullion	Fresh Food	Gasket	Wedge	Total
Phase I	43.08	13.28	68.39	41.90	10.06	176.71
Phase II	49.37	10.47	85.33	39.17	19.10	203.44

III. Adjusted Volumes (ft^3)

	Freezer	Fresh Food	Total	Volume Ratio
Phase I	3.60	12.22	15.82	.30
Phase II	4.39	13.80	18.19	.32

IV. Exterior Dimensions (in)

	Height	Width	Depth
Phase I	65	32	32
Phase II	66	32	33

A double gasket on the freezer door was not considered due to concern about ice blockage in field usage. The freezer door liner was designed, however, with provision for an inner "wiper" gasket along the bottom edge of the door if it became evident during testing that freezer gasket heat leak was excessive.

2.2 Additional Testing of the Phase I Prototype

Because of the uncertainties concerning dual compartment temperature control and airflow system performance, the Phase I prototype underwent additional laboratory testing and analysis before the Phase II detailed design was finalized.

- Cabinet Temperature Control Testing. The Phase I prototype control system used a thermostatic control on the cold plate to cycle the compressor and another thermostatic control in the freezer to control the freezer fan. Amana observed premature compressor shutdown due to cut-out of the fresh food compartment thermostatic control. It was determined that a sudden increase in refrigeration capacity in the fresh food evaporator (cold plate) resulting from shutdown of the the freezer fan caused rapid cooling of the temperature control sensor located on the cold plate. To alleviate this situation, a small thermal resistance was added to the temperature sensor. Amana recommended that Arthur D. Little, Inc., perform diagnostic tests on the test unit to confirm proper control before finalizing the control system design for the Phase II units. Using an electric heat source to simulate heavy usage, Arthur D. Little, Inc., found the control system performance over a range of ambient temperatures to be acceptable, and proposed no changes to the Phase I prototype control.

- Airflow tests. Measured values of airflow and CFM/Watt were significantly lower than desired for the Phase I prototype, and degraded overall refrigerator performance. Testing was conducted on a plastic model of the mullion flow path and results indicated that 3.2 CFM/Watt was achievable by smoothing the flow path and enlarging the air intake slot to reduce inlet pressure drop, thereby increasing the flow rate of the propeller fan for the same fan motor power. These modifications were incorporated in the Phase II freezer air system design. A better than expected improvement was achieved as shown in Table 2.

TABLE 2. AIRFLOW TEST RESULTS

		Phase I	Phase II
Fan airflow	=	19.5 CFM	47.4 CFM
Fan power	=	16 Watts	11.8 Watts
CFM/Watt	=	1.2	4.0

2.3 Performance Testing of the Phase II Design

Three pre-prototype 18 ft^3 units were built. Actual measured energy consumption in the DOE test was 2.03 kWh/day which resulted in a DOE Energy Factor (EF) of 10.14 and a yearly operating cost on the 1980 Federal Trade Commission label of $37.

In addition to energy consumption measurements, one prototype was subjected to dynamic usage (door opening) tests in a 90°F, and 65% relative humidity test room, (Gulf States test). Refrigeration performance was acceptable; however significant condensation was observed on the top surface of the fresh food compartment. The decision was made to install, during production of the field test units, a small electric heater on the top surface of the fresh food compartment which could be activated by a service technician in the field to control this condensation if it became a significant problem.

2.4 Manufacturing Approach

Amana chose to treat the Phase II unit as it would any new model for production. In this way, all of the normal procedures for procurement, inspection, and inventory control could be used, making the manufacture of this model less disruptive to the normal flow of manufacturing processes than otherwise might be expected.

The pilot production run was performed to anticipate any problems with manufacturability. By utilizing all available sets of parts, a total of 36 units were completed. After testing and modification, 25 units for the field test were selected to fill the color mix desired. After final inspection and crating, these units were ready for shipment to Norfolk, Virginia, the site selected for the home usage tests.

Because of the uniqueness of this model design, Amana elected to conduct a series of tests in their "hot rooms" where all performance characteristics could be tested and measured against expected criteria as determined through the prototype testing program. The test plan included these tests:

(1)	Continuous operation (compressor control shorted) in a 90°F ambient for thermal balance	All Units
(2)	Cycling tests - no door openings, 90°F ambient, mid-control settings	All Units
(3)	Sound tests including frequency scans	7 Units
(4)	Exterior condensation tests (sweat) in a high humidity chamber	2 Units

In addition, three units were tested for energy consumption in accordance with the DOE test procedure. The annual energy input for this model had been previously estimated by tests on pre-production prototypes. This testing served to confirm the earlier energy testing within 1%.

The thermal performance tests proved to be quite encouraging. The 36 units exhibited a very acceptable degree of uniformity, particularly in freezer and fresh-food temperatures and run-time characteristics. Table 3 summarizes the cycling performance of the 36 units in a 90°F ambient with no door openings. Tests were conducted with the anti-sweat heater switch set at "extra high," the compartment controls both at mid-position, and no simulated food load.

Table 3

ESTR-18D PILOT PRODUCTION PERFORMANCE RESULTS

Operating Characteristic	Average	Range	Standard Deviation
Freezer Temperature (°F)	+2.5	-1.2 to 5.0	1.2
Fresh Food Temperature (°F)	+36.8	33.2 to 39.6	1.6
Energy Input (kWh/day)	2.217	1.93 to 2.56	0.1505
Compressor Cycles (per day)	13.89	7.7 to 22.7	3.12
Compressor Run Time (%)	48.06	42.5 to 57.6	3.32

2.5 Instrumentation

The field test units were equipped during production with temperature, door opening, and power consumption instrumentation. The temperature and door opening sensors were installed so that any unusual problems encountered in the test could be investigated by connecting these sensors to a data logger placed in the test home.

3. FIELD TEST

3.1 Market Test

The market test was divided into two separate efforts; a consumer preference survey to evaluate the general attitude of consumers towards high-efficiency refrigerators, and a retail sales test to gauge the appeal of the ESTR-18D on the salesroom floor.

3.1.1 Consumer Preference Survey

In-depth, in-store interviews were conducted at retail outlets in Norfolk, Virginia, in which prospective refrigerator purchasers were asked detailed questions pertaining to their overall refrigerator selection and buying process. Unfortunately, because of slow sales during the survey period, only 62 interviews were completed out of a planned 200; therefore, the results were not as conclusive as desired. However, a factor analysis done on the raw data revealed some interesting facts:

- Consumers at the time of the survey were generally replacing their old refrigerator with a larger capacity unit. Rising energy prices and heightened consumer energy consciousness were not affecting this historical trend.

- Most purchases were to satisfy immediate needs; fast delivery was imperative.

- More than half the respondents said they would pay a premium of $100 if they could save this amount on their electric bills over a period of two years.

- Although a large segment thought that an energy-saving refrigerator should be priced higher, there was a sizable group who thought that prices should be comparable or even less.

- Frost-free operation was the most important feature in terms of consumer preferences.

3.1.2 Retail Sales Test

A sales test was next conducted to assess the consumer appeal of the high-efficiency, ESTR-18D unit. A rather elaborate plan was necessary to allow "sale" of the test units, yet retention of them for the field test, while keeping the sales test accurate and uncompromised. It was concluded that the best approach would be to offer all of the high-efficiency and baseline units for sale in a conventional manner. The retail salesmen and customers would be told nothing of the upcoming field test or the experimental nature of the high-efficiency model. At the end of the sales test period, purchasers would be contacted, asked to participate in the field test, and given their purchase price back; thus allowing the manufacturer to regain title to the test units. To encourage participation, a financial incentive would be offered. Units not placed in this manner would be placed into appropriate homes directly by the local Amana distributor.

Prior to the sales test, the high-efficiency unit was introduced to the retail salesforce as a new, limited-production, unit for which Norfolk had been chosen as the first test market. A special display

was set up by Amana using three 18 ft^3 automatic-defrost, top-mount units; their basic TR-18D model; their full-feature TC-18D unit; and the high-efficiency ESTR-18D model which offered a feature level between the other two. The customer was offered the choice of the feature-packed TC-18D unit for an $80 cost increase, or the high-efficiency ESTR-18D unit with fewer extra features for $110 over the cost of the basic TR-18D model.

Initially, five ESTR-18D units were sold. During a weekend promotion, the price was lowered $60 and five additional units were sold. Total sales of high-efficiency units accounted for 28% of all sales of 17 ft^3 through 19 ft^3 units for the participating retail stores during the six-week sales test. Sales personnel reported that the response towards the high-efficiency unit was quite positive. The types, ages, sizes, and incomes of the families who purchased the ESTR-18D represented a good cross-section. The veteran sales manager responsible for the sales test predicted that all the ESTR-18D units would have been sold if the test had been in a normal sales period.

3.2 Field Test

- Test Site. At the completion of the retail sales test, all purchasers of the ESTR-18D refrigerators agreed to participate in the field test. The remainder of the high-efficiency and baseline test units were placed into homes by the local distributor. A total of 24 high-efficiency and 23 baseline units comprised the field test sample.

  Every month, participants were asked to list any abnormalities experienced in their refrigerator usage such as absence from home, visitors, etc., as well as operational difficulties experienced with their unit. These comments were collected by program personnel when they visited each site to read the instrumentation indicating the month's energy consumption. The data collector also observed the refrigerator control settings, quantity of food stored, and any obvious malfunctions. The data was analyzed to calculate the average energy consumption for the high-efficiency and baseline samples, identify possible service difficulties or design defects, and detect abnormal usage patterns that could possibly affect the energy consumption of the two models.

- Field Test Results. Twelve months of data, beginning in August, were collected. The results of the field test for each month are shown in Figure 1 and compared with the energy consumption measured using the DOE test

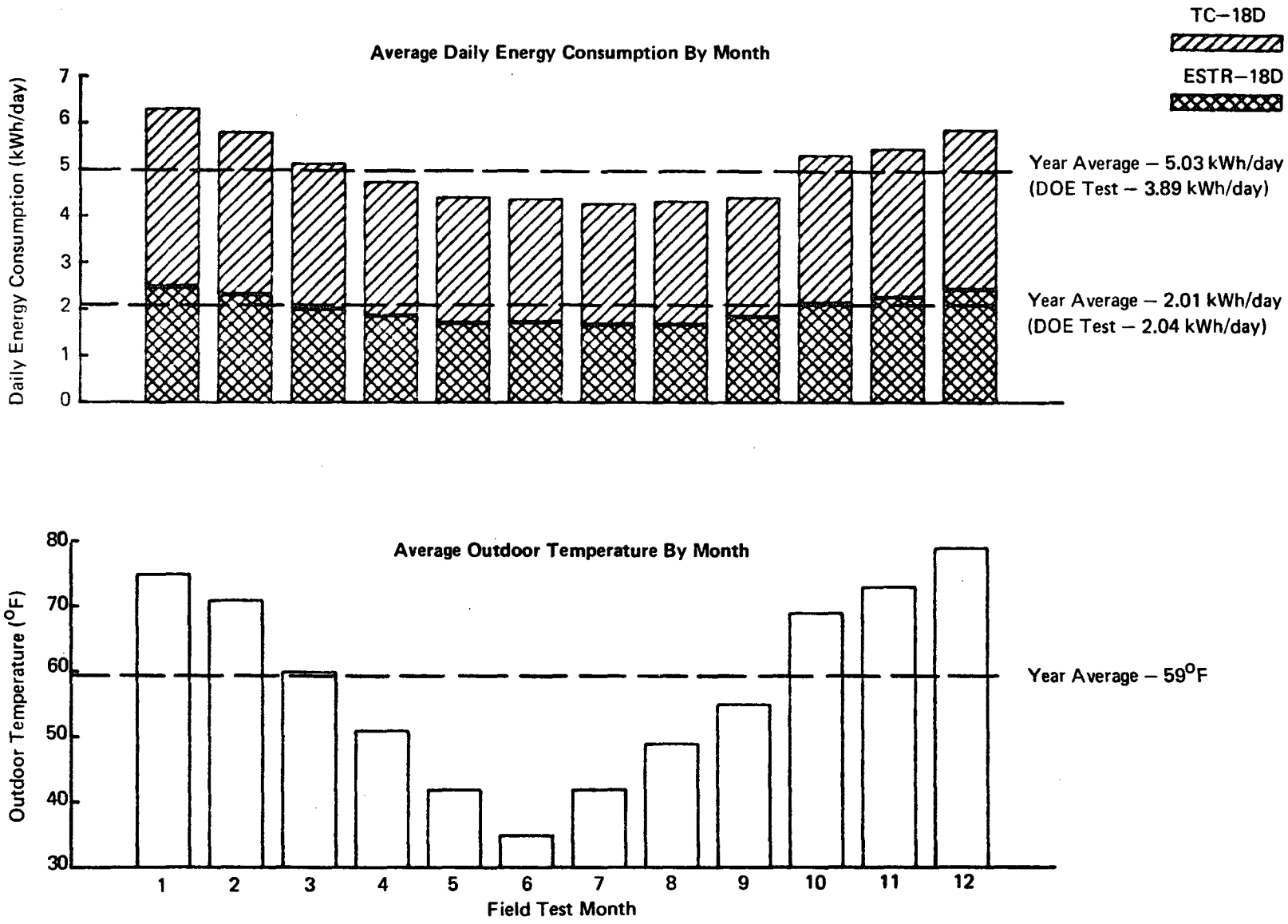

FIGURE 1. FIELD TEST ENERGY CONSUMPTION AND OUTDOOR AMBIENT TEMPERATURE

procedure. It is interesting to note that the DOE test predicted the energy consumption of the new technology, ESTR-18D unit very well, but substantially underestimated the electric usage of the conventional TC-18D. Prior to this test, it had been suggested that because of the heavy cabinet insulation and rather low capacity refrigeration system, the DOE test might underpredict the energy consumption of the ESTR-18D in actual home usage. However, this field test data indicates that the low heat-leak cabinet with twin-evaporator, when compared to a unit of conventional design, demonstrated more energy savings in actual usage in many of the homes than predicted by the DOE test. However, this field test data represents a limited sample; for conclusive results, a much larger sample size is required.

Figure 1 also shows that the energy usage for both units correlates with trends in average outdoor temperature. Unfortunately, indoor ambient temperature was not measured, but indoor temperature does tend to vary with outdoor temperature, although to a lesser degree. This data suggests that the relatively high temperature and humidity experienced in Norfolk in the summer, coupled with ordinary household usage patterns, imposed a stringent operating environment on the refrigerators. The high-efficiency ESTR-18D performed better than the TC-18D, demonstrating an average yearly 60% decrease in energy consumption over the baseline unit compared to 47% predicted by the DOE test.

Attempts to derive correlations of energy consumption versus usage parameters such as number of persons in the household, food load, refrigerator settings, etc., proved unsuccessful because of data scatter and the relatively small sample size. Refrigerator energy consumption varied widely from month-to-month and unit-to-unit in actual home usage.

4. BENEFITS DERIVED FROM THE PROGRAM

During Phase II, Amana decided, as a result of this program, to develop a commercial version of the energy efficient ESTR-18D for its model line. The consumer and nation benefitted from the accelerated commercialization and availability of a large capacity, automatic-defrost, refrigerator-freezer with superior energy efficiency.

In retrospect, this program demonstrated that a participating manufacturer in a government-sponsored program of this type can expect to develop increased expertise in these areas:

- Product Design
- Product Performance Experience
- Marketing Efforts
- Manufacturing Techniques

The following paragraphs describe how Amana used the information gained from this program in the development of their TSC-18E high-efficiency refrigerator-freezer.

- Product Design Parameters. Experience with the field test model led to several modifications in the design of the TSC-18E. Difficulties with the installation of some units led Amana to consider means to reduce the front-to-rear depth for the commercial version. This was accomplished by reducing the insulation thickness of the door and using a bottom-mounted, fan-cooled condenser. An early field complaint concerning bottle space on the top shelf led to adjustable cantilever glass shelves for the commercial version and reports during the field test of excessive moisture in the crisper area prompted Amana to alter the condensate drain system.

- Product Performance Experience. Evaporator-fan noise was an early problem discovered in the testing of the ESTR-18D field test units. This problem was resolved by redesign of the mounting bracket, use of softer resilient mounting grommets, and incorporation of spring-loaded thrust washers in the motor bearing system. Tests conducted on the field-test prototypes indicated a higher than desirable refrigerant pressure drop through the cold plate during operation. The cold-plate refrigerant circuit was subsequently redesigned for the commercial version. Several other minor changes in the compressor mounting and tube routing were made for the commercial version as a result of experience gained with the field units.

  During the field test, surface condensate (sweat) was reported on both the exterior and interior of the ESTR-18D. This led Amana to redesign the anti-sweat heaters used in the mullion section and on the fresh-food compartment top panel. The heater wattage was increased to allow the customer better control of heavy sweating using the "energy saver" switch.

- Marketing Effort and Experience. The market testing reinforced Amana's decision to commercialize the ESTR-18D. Their conclusion from that effort was that low energy consumption is an important product

attribute in attracting sales, but the cost premium that the public will pay is less clear.

- Manufacturing Techniques and Experience

  The ESTR-18D had the largest ABS plastic liner ever fabricated at Amana. The lessons learned in the process of producing these liners and in the subsequent assembly of them into refrigerator cabinets aided the development and early introduction of the commercial version.

  The opportunity for Amana to assess the manufacturability of the ESTR-18D prior to a production commitment for a similar product was an important benefit. Several changes that improved manufacturability and processing were incorporated into the new design. Assembly facility and material handling modifications were also instituted.

5. CONCLUSIONS AND RECOMMENDATIONS

The Phase II field test of the 18 ft^3 high-efficiency ESTR-18D confirmed the energy saving potential in actual home usage of a high-efficiency, automatic-defrost, refrigerator-freezer utilizing advanced design features such as optimized thick-wall foam insulation and a two-evaporator refrigeration system. Results showed an average energy consumption of 2.01 kWh/day--a savings of 60% compared to the TC-18D baseline unit of conventional design.

The field test also uncovered performance differences between the ESTR-18D and TC-18D not adequately explained by the standard energy rating test. It suggested a need for an investigation of the effects of various usage parameters on power consumption. This study would help to determine whether established steady-state performance tests, such as the DOE test, will continue to provide an acceptable rating method for refrigerators in light of the new, high-efficiency technologies being introduced in some models.

A market evaluation performed as part of this program confirmed that refrigerators incorporating high-efficiency features at added cost are saleable and that large automatic-defrost, refrigerator-freezers will continue to capture a large portion of the market in the years ahead.

No serious design deficiencies in the high-efficiency model appeared. The unit provided substantial energy savings while providing the same service as a refrigerator-freezer of conventional design.

DEVELOPMENT OF A HIGH-EFFICIENCY, AUTOMATIC-DEFROSTING REFRIGERATOR-FREEZER

TASK 1 REPORT
SPECIFICATIONS AND MANUFACTURING APPROACH

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SPECIFICATIONS AND MANUFACTURING APPROACH

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1. INTRODUCTION

Following the successful completion of Phase I (design, construction, and laboratory testing of a 16 ft^3 high efficiency refrigerator-freezer prototype), Phase II was begun in February 1979. The primary purpose for Phase II was to evaluate the manufacturability, sales potential, and in-home performance of the high-efficiency refrigerator concept as a necessary step in creating a viable commercial product. The Task 1 plan called for the manufacture of 25 pilot production units on the assembly line as a basis for possible full-scale future production. As in Phase I, Arthur D. Little, Inc., continued as principal contractor to Oak Ridge National Laboratory with Amana Refrigeration, Inc., subcontractor. Both participants demonstrated their support and enthusiasm by participating in program cost sharing.

In Phase I, a survey of food consumption and storage trends, family size, and consumer buying habits led to a forecast of 1985 sales-weighted average capacity of approximately 16 ft^3 and identification of the top-mount, automatic-defrosting refrigerator-freezer as the projected sales leader. To meet this market demand, a 16 ft^3 top mount was selected as the baseline for the Phase I design and development. However, in Phase II, an 18 ft^3 unit using Phase I technology was chosen for performance testing since the larger model better fit Amana's new product development efforts and market. Because of its similarity to the 16 ft^3 design, this report describes only the additional research necessary to produce the 18 ft^3 model.

2. SPECIFICATIONS FOR THE PILOT REFRIGERATOR-FREEZER

Design specifications were first prepared for the Phase II high efficiency 18 ft^3 model.

2.1 Comparison of Designs

Early in Phase II it had been decided to produce 18 ft^3 units for the high test, since Amana already had an energy efficient 16 ft^3 model in production, but was considering near-term replacement of their current 18 ft^3 top mount. Therefore, prospects for commercialization of the high-efficiency design were better using the larger unit. The 18 ft^3 cabinet was designed using essentially an identical layout to the 16 ft^3 prototype, except for the larger dimensions required for increased capacity. The Phase I and Phase II cabinet specifications are compared in Table 1.1. The freezer-to-fresh food adjusted volume* ratio is approximately the same for the two units. Insulation thickness values reflect total cabinet wall thicknesses minus shell

*Adjusted volume is the gross internal volume corrected to reflect useful space. Volume occupied by shelves, door dikes, ducts, trim, etc., is deducted using standard procedures adopted by industry (ASHRAE Standard 13-69).

Table 1-1

PROTOTYPE CABINET SPECIFICATIONS

I. Insulation Thickness (in)

	Freezer Compartment				Fresh Food Compartment		
	Side	Front	Back	Top	Side	Front	Back
Phase I	3.00	2.50	3.00	3.00	2.25	2.50	2.25
Phase II	2.88	2.44	2.91	2.88	2.13	2.44	2.00

II. Heat Flow (BTU/hr)

	Freezer	Mullion	Fresh Food	Gasket	Wedge	Total
Phase I	43.08	13.28	68.39	41.90	10.06	176.71
Phase II	49.37	10.47	85.33	39.17	19.10	203.44

III. Adjusted Volumes (ft^3)

	Freezer	Fresh Food	Total	Volume Ratio
Phase I	3.60	12.22	15.82	.30
Phase II	4.39	13.80	18.19	.32

IV. Exterior Dimensions (in)

	Height	Width	Depth
Phase I	65	32	32
Phase II	66	32	33

and liner material. Insulation is polyurethane foam except for a polystyrene foam block in the mullion.

The cabinet heat leak data shown in Table 1-1 was calculated using a cabinet heat load computer program developed in Phase I.**

Since the model calculated only a 15% increase in heat leak, it was concluded that the Phase I refrigeration system components (compressor, condenser, freezer evaporator, cold plate) could be retained in the new cabient with little change in overall performance. The control system, including a 48-hour defrost timer, was also retained.

The 32 in width was maintained from the Phase I design and the height and depth increased to provide added capacity. Concern was expressed by Amana because the 33 in depth precludes the use of the unit in some kitchens. At the expense of some energy savings, a forced convection bottom-mounted condenser could have been used in place of the static back-mounted condenser to reduce the depth. It was decided, however, that the 33 in depth would be maintained in order to achieve minimum energy consumption, and that consumer reaction should be monitored closely to determine if that depth would significantly limit the ultimate market for the energy saving refrigerator.

The double gasket used on the freezer door in Phase I was eliminated due to concern about ice blockage in field usage. Test results from Phase I had indicated that a well-designed throat area with small clearances substantially reduces the benefit of the double gasket, especially when considering the added cost, complexity, and possible reliability problems. The freezer door liner was designed, however, with provision for an inner "wiper" gasket along the bottom edge of the door if it became evident during testing that freezer gasket heat leak was excessive.

2.2 Additional Testing of Phase I 16 ft^3 Prototype

Early in Phase II, uncertainties concerning dual compartment temperature control and airflow system performance were identified by Amana; therefore the 16 ft^3 Phase I prototype was shipped to Arthur D. Little, Inc., for comprehensive laboratory testing and analysis before finalizing the Phase II detailed design.

2.2.1 Cabinet Temperature Control Testing

The Phase I prototype control system used a thermostatic control on the cold plate to cycle the compressor and another thermostatic control in the freezer to control the freezer fan. The system was

**For a complete description of the Phase I prototype development see: Development of a High Efficiency Automatic Defrosting Refrigerator/Freezer, Phase I Design and Development, Final Report, Volume II - R&D Task Reports, by W. David Lee, ORNL/Sub-7255/2, U.S. Department of Energy, Washington, D.C., February 1980.

designed so that in a typical cycle, the freezer load would first be satisfied. The fan would then stop, terminating cooling in the freezer, but the compressor would continue to operate until the fresh food refrigeration load was satisfied by the cold plate.

During Phase I testing, Amana observed premature compressor shutdown due to cut-out of the fresh food compartment thermostatic control after freezer fan shutdown. The sudden increase in refrigeration capacity in the fresh food evaporator (cold plate) resulting from the freezer fan shutdown caused rapid cooling of the temperature control sensor located on the cold plate. To alleviate this situation, a small thermal resistance (standoff) was added to the temperature sensor. No premature fresh food control cut-out was then observed in 90°F closed door tests, but Amana recommended that heavy usage tests be performed on the test unit to confirm proper control before finalizing the control system design for the Phase II units.

In tests conducted at Arthur D. Little, Inc., an electric heat source was utilized to simulate heavy usage. Control system performance over a range of ambient temperatures was found to be acceptable, and no changes to the Phase I prototype control were proposed. However, dynamic usage (door opening) tests were recommended for the Phase II prototype to further investigate the suitability of the control system for actual production models utilizing the two evaporator concept.

2.2.2 Airflow Tests

To investigate the freezer forced air system performance, airflow was measured by a hot wire anemometer at the inlet of a 22 in. long x 1 in. wide duct which was constructed over the mullion inlet air slots of the 16 ft^3 prototype in order to obtain uniform, measurable airflow. The test was conducted with the compressor operating, the fresh food compartment door closed, and the freezer door open. The measured velocity distribution was fairly uniform, although a low velocity region was identified near the center of the mullion slot. Measured values of airflow and CFM/Watt were significantly lower than desired for the prototype, however, and hurt overall refrigerator performance. Further testing was conducted on a plastic model of the mullion flow path and the results indicated that 3.2 CFM/Watt was achievable by smoothing the flow path and enlarging the air intake slot to reduce inlet pressure drop and thereby increase the flow rate of the propeller fan for the same fan motor power. These modifications were incorporated in the Phase II freezer air system design. A better than expected improvement was achieved as shown in Table 1-2.

Table 1-2

AIRFLOW TEST RESULTS

		Phase I	Phase II
Fan airflow	=	19.5 CFM	47.4 CFM
Fan power	=	16 Watts	11.8 Watts
CFM/Watt	=	1.2	4.0

2.3 Performance Testing of the Phase II Design

Three pre-prototype 18 ft^3 units were built in the Amana model shop; two were retained at Amana for development testing and one was shipped to Arthur D. Little, Inc., for diagnostic evaluation. Actual measured energy consumption using the DOE test was 2.03 kWh/day which resulted in a DOE Energy Factor (EF) of 10.14 and a yearly operating cost on the 1980 Federal Trade Commission label of $37.*

A comparison of the performance of the Phase II design (designated the ESTR-18D) with other currently available units is presented in Table 1-3. The improvement over the current Amana product (TC-18D) is dramatic:

Table 1-3

ENERGY CONSUMPTION COMPARISON

Model	FTC Label Number ($/Year)	EF (Ft^3/kWh/day)	Energy Usage (kWh/Yr)	California Standard (kWh/Yr)
ESTR-18D	37	10.14	744	1477
TC-18D	71	5.37	1321	1488
Industry Range (18 ft^3)	45 to 88	--	--	--

In addition to energy consumption measurements, one prototype was subjected to dynamic usage (door opening) tests in 90°F and 65% relative humidity test room (Gulf States test). Refrigeration performance was acceptable; however significant condensation was observed on the top surface of the fresh food compartment. Although this phenomenon is common in conventional cold plate (partial automatic defrost) models, it was decided that users should be monitored for negative reaction during the field test. The decision was also made to install electric heaters on the top surface of the fresh food compartment which could be activated by a service technician in the field to control this condensation if it became a significant problem.

3. MANUFACTURING APPROACH

Amana chose to treat the Phase II prototype as it would any new model for production. In this way, all of the normal procedures for procurement, inspection, and inventory control could be used, making the manufacture of this model less disruptive to the normal flow of manufacturing processes than otherwise might be expected.

*Based on a cost of electricity of $.0497/kWh.

In reviewing the parts list, it became apparent that the component parts for this model could be grouped into six categories:

1. Extended use items. This category included those parts that were common to other models in Amana's line. In addition to fasteners and hardware, such items as door handles and handle pads, crisper pans, meat pans, control escutcheons, egg trays, ice trays, and dairy door were included in this group. This category of parts was immediately available at any time, and presented no procurement problems.

2. "Off-the-shelf" purchased parts. This category of parts was unique to this model, but was readily available as off-the-shelf items that required little or no modification to meet the requirements of the model. Examples were the compressor, fan motor, defrost timer, refrigerator control, freezer control, and defrost terminator. These parts were available with only a moderate lead time.

3. Purchased parts produced by special set-up or minor modification of standard tooling. The parts grouped into this category were unique to this model, but could be produced from tooling that made similar items for other Amana models. Minor tool modifications or special set-ups generally were all that was required to enable the vendor to produce the unique part. Examples of parts in this category included the evaporator, cold plate, wire and tube static condenser, shelving, defrost heater, anti-sweat heaters, exterior door trim, door shelf retainers, door gaskets, wire harnesses and shipping carton. Moderate lead times and tooling or set-up changes were required, which easily met the time restraints of the project.

4. Parts manufactured from Amana tooling and modified to the model's requirements. The basic tooling to produce parts in this category existed, but rework or modification was needed to make the part acceptable for this model. Normally, tools are modified to produce a new part, but in this project it was more economical to rework the part since only 40 to 50 sets were needed. Parts in this category included the cabinet bottom, compressor support rails, crisper pan cover, ice tray tunnel and toe grille. Procurement of the basic parts in this category was fairly easy; however, adequate model shop time for rework was a matter of concern to Amana.

5. Parts fabricated using a special set-up on Amana tooling. Here again the basic tooling to produce the parts existed, but a special set-up was required to produce exactly what was required. Examples of parts in this category included the cabinet wrapper, cabinet back panel and the cabinet door panels.

6. Parts requiring new tooling to produce. Parts in this category could not be produced by any of the above methods. New temporary tooling was needed. The objective was to produce the needed number of usable parts with minimum investment in tooling. At a conference between Amana and Arthur D. Little, Inc., responsibility for procuring tooling and parts was apportioned as follows:

Arthur D. Little, Inc.

Drain Block (EPS plastic molding)

Drip Tray, Evaporator (Aluminum stamping)

Fan Shroud, Evaporator (Injection molded ABS plastic)

Breaker Molding, Mullion (Injection molded ABS plastic)

Refrigerator Top Panel (Aluminum stamping)

Center Mullion (Fabricated steel)

Lower Mullion (Fabricated steel)

Amana

Food Liner (Vacuum formed ABS plastic)

Door Liner, Freezer (Vacuum formed ABS plastic)

Door Liner, Refrigerator (Vacuum formed ABS plastic)

Freezer Compartment Floor (Vacuum formed ABS plastic)

Drain Cover (Aluminum stamping)

Fan Motor Mounting Plate (Aluminum stamping)

Fan Motor Mounting Bracket (Fabricated steel)

Foaming Fixtures, Cabinet (Fabricated steel)

Tool procurement and parts delivery were on schedule for all parts except the injection molded items and the EPS mold. Severe technical and contractual difficulties with the tooling vendor delayed delivery of those parts beyond the planned May 1980 production date. When delivery was finally made, pilot production was rescheduled and ultimately completed in late October 1980.

The pilot production run was accomplished using standard techniques used at Amana. Twenty-five units were designated for the performance test. Ten additional units were planned for program back-up, local field test, engineering tests, in-house display, etc. Manufactured parts and subassemblies were prepared as a group. Cabinet weldments were then introduced into the assembly line at key points for assembly operations that required the use of equipment located there. Such operations included foaming, electrical harness testing, refrigeration system hook-up and brazing, evacuation, charging, and final testing. Other assembly operations were generally conducted off-line in repair areas by a small staff of skilled technicians and assembly-line personnel. All products received the standard quality control checks and qualification tests. Using these techniques, the assembly operation was completed in approximately one week. By utilizing all available sets of parts, a total 36 units were finally completed. After testing and modification, 25 units for the performance test were selected to fill the color mix desired. These were then returned to the assembly line for final inspection and crating. By the end of October, 1980, the units were ready for shipment to Norfolk, Virginia, the site selected for home usage tests.

4. ENGINEERING AUDIT TESTING

The normal test procedures used for performance qualification of Amana refrigerators were also used for the ESTR-18D. Each unit was operated for 25 minutes on an electrified conveyor prior to reaching the test station. At the test station the unit's input in watts was measured and air temperature in the freezer compartment recorded. Additional control function checks, defrost system checks and electrical system integrity checks were made.

Normally, 10% to 15% of each day's production are also given a five-hour (minimum) thermal performance test where temperatures in both the freezer compartment and fresh food compartment are monitored and recorded on strip chart recorders. At the completion of the test, the pull down and cycling characteristics of the unit on test can be checked and compared to norms for that particular model. For the ESTR-18D, since norms had not been established, all units were given the five-hour thermal performance test.

Because of the uniqueness of this model design, Amana elected to conduct a series of tests in their "hot rooms" where all performance characteristics could be tested and measured against expected criteria as determined through the prototype testing program. The test plan included these tests:

(1)	Continuous operation (compressor control shorted) in a 90°F ambient for thermal balance	All Units
(2)	Cycling tests - no door openings, 90°F ambient, mid-control settings	All Units
(3)	Sound tests including frequency scans	7 Units
(4)	Exterior condensation tests (sweat) in a high humidity chamber	2 Units

In addition, three units were tested for energy consumption in accordance with the DOE test procedure. The annual energy input for this model had been previously estimated by tests on pre-production prototypes. This testing served to confirm the earlier energy testing within 1%.

The thermal performance tests proved to be quite encouraging. The 36 units exhibited a very acceptable degree of uniformity, particularly in freezer and fresh-food temperatures and run-time characteristics. Table 1-4 summarizes the cycling performance of the 36 units in a 90°F ambient with no door openings. Tests were conducted with the anti-sweat heater switch set at "extra high," the compartment controls both at mid-position, and no simulated food load.

Table 1-4

ESTR-18D PILOT PRODUCTION PERFORMANCE RESULTS

Operating Characteristic	Average	Range	Standard Deviation
Freezer Temperature (°F)	+2.5	-1.2 to 5.0	1.2
Fresh Food Temperature (°F)	+36.8	33.2 to 39.6	1.6
Energy Input (kWh/day)	2.217	1.93 to 2.56	0.1505
Compressor Cycles (per day)	13.89	7.7 to 22.7	3.12
Compressor Run Time (%)	48.06	42.5 to 57.6	3.32

Initial sound testing uncovered more variability in sound performance than desired. As a result, a minor modification was made in the evaporator fan motor mounting to correct the problem. This modification was made to all units.

5. INSTRUMENTATION

The performance test units were equipped during production with temperature, door opening, and power consumption instrumentation. Arthur D. Little, Inc., designed and built the electronic kilowatt-hour meters for measuring energy consumption. The temperature and door opening sensors were installed so that any unusual problems encountered in the performance test could be investigated by connecting these sensors to a data logger placed in the test home. Table 1-5 lists the locations of the thermocouples in the ESTR-18D.

Table 1-5

ESTR-18D THERMOCOUPLE LOCATIONS

1. Freezer Evaporator Inlet.
2. Freezer Evaporator Outlet.
3. Freezer Compartment.
4. Refrigerator Evaporator Inlet.
5. Refrigerator Evaporator Outlet.
6. Refrigerator Compartment.
7. Condenser Inlet.
8. Condenser Mid-Point.
9. Condenser Outlet.
10. Precooler Outlet.
11. Compressor Inlet.
12. Ambient Air.

Note: All thermocouples with the exception of Nos. 3, 6, and 12 are mounted on the refrigeration system tubing. Numbers 3 and 6 are free-standing and measure compartment air temperatures. Number 12 is free-standing and measures ambient (room) air temperature at the lower front grille.

DEVELOPMENT OF A HIGH-EFFICIENCY, AUTOMATIC-DEFROSTING REFRIGERATOR-FREEZER

TASK 2 REPORT
FIELD TEST

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FIELD TEST

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1. INTRODUCTION

This report describes the second task of Phase II in which the market potential, consumer appeal, and in-home performance of a high-efficiency, automatic-defrosting refrigerator-freezer was assessed. A complete description of the design, manufacture, and specifications of the 18 ft^3 field test unit, designated the ESTR-18D, is contained in the Task 1 report. This Task 2 report begins with the market evaluation of the ESTR-18D conducted prior to in-home testing and concludes the Phase II effort with general observations on the field test results and recommendations for further work.

The field test was planned to accomplish the following objectives:

1. Determine the energy savings of the high-efficiency design when compared to a conventional, automatic-defrost top-mount under actual field use conditions.

2. Assess the reliability of the high-efficiency design, and reveal any design deficiencies before possible full-scale production.

3. Clarify buying patterns and evaluate the consumer appeal of high-efficiency, automatic-defrosting, refrigerator-freezers.

It was decided that a one-year field test of 25 high-efficiency and 25 baseline top-mount refrigerator-freezers would meet objectives 1 and 2 above; a consumer preference survey and retail sales test would be used to gather information to meet objective 3. Norfolk, Virginia was chosen as the site for the field test, because hot, humid summer weather conditions were desired to reveal design deficiencies, and because an enthusiastic commitment was received from the local Amana distributor.

Of the 36 high-efficiency units produced in the pilot production run, 25 were chosen for the field test. Twenty-five conventional Amana TC-18D top-mount, 18 ft^3 refrigerator-freezers, similar in internal appearance to the ESTR-18D, were selected as baseline units for comparison. Both sets of units were shipped to Norfolk in preparation for the field test.

2. MARKET TEST

The market test was divided into two separate efforts; a consumer preference survey to evaluate the general attitude of consumers

towards high-efficiency refrigerators, and a retail sales test to gauge the appeal of the ESTR-18D on the salesroom floor.

2.1 Consumer Preference Survey

In-depth, in-store interviews were conducted at retail outlets in Norfolk in which prospective refrigerator purchasers were asked detailed questions pertaining to their overall refrigerator selection and buying process. Mid-Atlantic Research, Inc., a market survey firm, was selected as the subcontractor to conduct these interviews. The schedule called for interviewers to be in four retail outlets during peak weekend traffic periods in late August and early September, 1980.

Unfortunately, because of slow sales during the survey period, only 62 interviews were completed out of a planned 200; therefore, the results were not as conclusive as desired. However, a factor analysis done on the raw data by Arthur D. Little, Inc., revealed some interesting facts:

- Consumers at the time of the survey were generally replacing their old refrigerator with a larger capacity unit. Rising energy prices and heightened consumer energy consciousness were not affecting this historical trend.

- Most purchases were to satisfy immediate needs; fast delivery was imperative.

- More than half the respondents said they would pay a premium of $100 if they could save this amount on their electric bills over a period of two years.

- Although a large segment thought that an energy-saving refrigerator should be priced higher, there was a sizable group who thought that prices should be comparable or even less.

- Frost-free operation was the most important feature in terms of consumer preferences.

The complete report on this survey, including the questionnaire used, is included as Appendix A of this report.

2.2 Retail Sales Test

A sales test was conducted from January 8 through February 15, 1981 at selected retail outlets in Norfolk, to assess the consumer appeal of the high-efficiency ESTR-18D unit. A rather elaborate plan was necessary to allow "sale" of the test units, yet retention of them for

the field test, while keeping the sales test accurate and uncompromised. It was concluded that the best approach would be to offer all of the high-efficiency and baseline units for sale in a conventional manner. The retail salesmen and customers would be told nothing of the upcoming field test or the experimental nature of high-efficiency model. At the end of the sales test period, purchasers would be contacted, asked to participate in the field test, and given their purchase price back; thus allowing the manufacturer to regain title to the test units. To encourage participation, a financial incentive would be offered. Units not placed in this manner would be placed into appropriate homes directly by the Amana local distributor.

Prior to the sales test, the high-efficiency unit was introduced to the retail salesforce as a new, limited-production unit for which Norfolk had been chosen as the first test market. A special display was set up by Amana using three 18 ft^3 automatic-defrost, top-mount units; their basic TR-18D model; their full-feature TC-18D unit; and the high-efficiency ESTR-18D model which offered a feature level between the other two. The customer was offered the choice of the feature-packed TC-18D unit for an $80 cost increase, or the high-efficiency ESTR-18D unit with fewer extra features for $110 over the cost of the basic TR-18D model. Figure 2-1 is a sample of the promotional literature prepared for the sales test.

Initially, five ESTR-18D units were sold. During a weekend promotion, the price was lowered $60 and five additional units were sold. Total sales of high-efficiency units accounted for 28% of all sales of 17 ft^3 through 19 ft^3 units for the participating retail stores during the six-week sales test. Sales personnel reported that the response towards the high-efficiency unit was quite positive. Consumers generally did not react negatively to the large, deep cabinet. Several commented favorably on the thick door; they liked the heavy, quality feel. The types, ages, sizes, and incomes of the families who purchased the ESTR-18D represented a good cross-section: several retired families, enlisted Navy and Coast Guard personnel, a Navy Commander. The veteran sales manager responsible for the sales test for the Amana distributor predicted that all the ESTR-18D units would have been sold if the test had been in a normal sales period since, from his perspective, the unit demonstrated universal sales appeal.

3. FIELD TEST

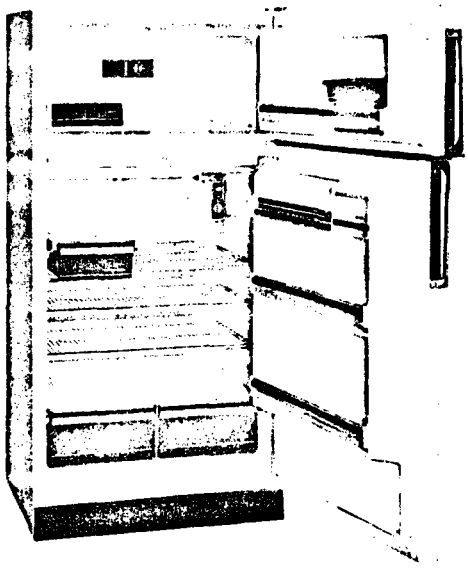
3.1 Test Site

At the completion of the retail sales test, all purchasers of the ESTR-18D refrigerators agreed to participate in the field test. The remainder of the high-efficiency and baseline test units were placed into homes by the local distributor. The field test agreement shown as Table 2-1 was signed by all participants. A total of 24 high-efficiency and 23 baseline units constituted the test sample.

FIGURE 2-1. PROMOTIONAL SALES LITERATURE

Amana® Super Energy Saver

18.0 Cubic Foot "Twin System" Refrigerator/Freezer



Only $37 Per Year Operating Cost*

Amana gives you fantastically efficient performance with:

TWIN SYSTEM DESIGN

- FREE O' FROST™ FREEZER means no defrosting ever.
- AUTOMATIC DEFROST REFRIGERATOR
  Moist cold refrigerator compartment minimizes food dehydration so foods stay moist even if left uncovered.

COMPUTER OPTIMIZED INSULATION SCHEDULE
Puts insulation where it's needed most to reduce operating costs: 2¼ inches around the refrigerator; 3 inches around the freezer; and 2½ inches in the doors.

*According to U.S. government test procedures, estimated yearly operating costs for this refrigerator amount to only $37 per year. Your cost will vary depending on your local energy rate and how you use the product. The current industry range of estimated yearly cost of operation is $45 to $88.

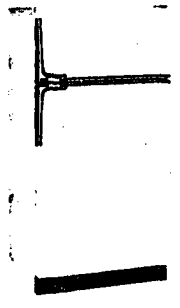
Amana. gives you more than efficiency, you get the convenience features that have made Amana refrigerators famous:

BIG CAPACITY REFRIGERATOR —
13.80 cubic feet
Tough ABS inner door and food compartment liner are easy to clean. Glide-out shelves keep everything within reach. See-thru meat pan and crispers, and butter compartment are conveniently located.

BIG CAPACITY FREE O' FROST™ FREEZER —
4.22 cubic feet
Completely automatic. 48 hour defrost interval, made possible by Amana's "Twin System" design, makes it energy efficient.

STOR-MOR® REFRIGERATOR AND FREEZER DOORS
Keep most often used foods where they are easy to reach.

DURABLE, ATTRACTIVE STYLING
Textured steel doors hide fingerprints and minor scratches. Acrylic enamel cabinet finish resists stains, chipping and cracking. The luxurious look of fine wood accents complement crisp styling.



Dimensions in Inches

Height	66
Width	32
Depth	33 3/32
Depth with doors removed	28¼

Specifications subject to change without notice.

Enjoy big capacity and big savings with the Amana Super Energy Saver.
Backed by a century-old tradition of fine craftsmanship.

Form No. 0603X
Printed in U.S.A.
T2

©1980, Amana Refrigeration, Inc.
Amana, Iowa 52204

A Raytheon Company

Table 2-1

AMANA FIELD TEST AGREEMENT

AGREEMENT between Amana Refrigeration, Inc., of Amana, Iowa, 52204 (Amana Price's, Inc., of Norfolk, Virginia, 23517 (Price's) and the field test product user identified below (User).

Amana, through the cooperation of its representative, Price's, wishes to test the Product identified below under home-use conditions and User desires to have the Product installed in his or her home for actual usage. In consideration of this, it is agreed as follows:

1. Amana will install the Product at the location identified below for actual usage by User for a period of approximately twelve months. Usage shall be at no cost to User other than necessary cost of electricity and/or other utility services required for operation of the Product.

2. The continuation of this, or future tests of Products by User is expressly conditioned upon User's full cooperation and assistance in promptly supplying information and completing any questionnaires which may be requested by Amana including the following:

   a. Participating in an in-depth, in-person consumer survey approximately midway through the test period; and

   b. participating in a similar survey at the conclusion of the test period.

3. User will permit Amana to install monitoring equipment, to make month inspections, repairs, and alterations of the Product and the monitoring equipment at reasonable times and upon prior notification by Amana.

4. User will notify Amana immediately of any difficulties associated wit the Product by telephoning the following Amana representative:

   Ron Conuers
   Vice President, Service
   Price's, Inc.
   1900 Monticello Avenue
   Norfolk, VA 23517
   Telephone: (804) 627-5571

5. The Product and monitoring equipment are Amana's property and will not be removed from the designated home without prior written permission of Amana's representative designated in paragraph 4 above.

6. User shall not alter the Product or the monitoring equipment in any way without the prior specific written authorization and direction of Amana.

7. Product details and specifications, the reasons for the test, and the Product experience during the field test are proprietary to

Amana and in no event shall User discuss or reveal same to any other person, firm, or organization including the retail dealer from whose store the Product was delivered and his or her salespersons.

8. Upon reasonable notice, User or Amana may terminate the field test period and Amana will remove the Product and monitoring equipment from the location. The obligations of paragraphs 7 and 11 survive any termination.

9. Amana makes no warranty, express or implied, with regard to performance or otherwise of the Product provided under this Agreement.

10. Amana accepts responsibility for any damages incurred by User as a result of the installation or the operation of the Product and the monitoring equipment other than that resulting from misuse or abuse of the Product or of the monitoring equipment by the User.

11. At the conclusion or termination of the test period, Amana will, at its option, either offer the Product for sale to User at a price of $500.00 or offer the User $100.00 credit towards the purchase of any Amana product purchased from Price's, Inc. within ninety days of the conclusion or termination of the test period.

PRODUCT_____

PRODUCT SERIAL NO._____

MODEL NO._____

_____
Field Test Product User

Date_____

Location_____

_____

APPROVED
AMANA REFRIGERATION, INC.

By_____

Date_____

APPROVED
PRICE'S, INC.

By_____

Date_____

RWH/jm
12/80

Information on the test site (household size, member's ages, refrigerator location, air conditioning use, etc.) was collected using the form shown as Table 2-2. Results are presented in Table 2-3.

Every month, participants were asked to use the form shown as Table 2-4, to list any abnormalities experienced in their refrigerator usage such as absence from home, visitors, etc., as well as operational difficulties experienced with their unit. These comments were collected by personnel from Mid-Atlantic Research, Inc., the subcontractor chosen to collect the field test data, when they visited each site to read the instrumentation indicating the month's energy consumption. The data collector also observed the refrigerator control settings, quantity of food stored, and any obvious malfunctions and recorded this data on the form shown as Table 2-5. The data was analyzed by Arthur D. Little, Inc, to calculate the average daily energy consumption for the high-efficiency and baseline samples, identify possible service difficulties or design defects, and detect abnormal usage patterns that could possibly affect the energy consumption of the two models.

3.2 Field Test Results

Initial pretest instrumentation readings were taken in late July 1981 so that the following month, August, began the 12-month field test. The results of the field test for each month and test site are presented in Table 2-6. In Table 2-7, the field test results are compared with the energy consumption measured using the DOE test procedure. It is interesting to note that the DOE test predicted the energy consumption of the new technology, ESTR-18D unit very well, but substantially underestimated the electric usage of the conventional TC-18D. Prior to this test, it had been suggested that because of the heavy cabinet insulation and rather low capacity refrigeration system, the DOE test might underpredict the energy consumption of the ESTR-18D in actual home usage. However, this field test data indicates that the low-heat-leak cabinet with twin-evaporator, when compared to a unit of conventional design, demonstrated more energy savings in many of the homes than predicted by the DOE test However, it should be emphasized that this field test data represents a limited sample. For conclusive results, a much larger sample size is required.

Figure 2-2 shows that the energy usage for both units correlates with trends in average outdoor temperature. Unfortunately, indoor ambient temperature was not measured, but indoor temperatures do tend to vary with outdoor temperatures, although to a lesser degree.

The average daily energy consumption for both refrigerator models was initially higher than predicted by the DOE test, but showed a monthly decrease from August to December, a steady period during the winter months, and a monthly increase through the late spring and summer

Table 2-2

HOUSEHOLD PROFILE

Test Location (No.): _____

Unit: TC
ESTR

As I already mentioned, an interviewer from Mid-Atlantic Research, Inc., will be visiting your house once a month during the test period to read the meter on your refrigerator and talk with you for a few minutes about your experience with the test unit. In addition to the monthly data, the following information is needed to serve as a background for the test data.

Name of head of household: _____

Address: _____

Home telephone number; _____

1. Who is the person the interviewer should contact for the monthly interview?

   _____(Name)

2. Is there another telephone number, besides your home phone, where you/this person can be reached during the day?

   _____(Tele. No.)

3. Which time of day is best to call you (this person)?

   At home: _____

   At other number: _____

4. How many adults are living in this household? _____

5. How many children are currently living with you? _____

5a. How many of these are between fourteen and eighteen? _____

5b. How many are between nine and thirteen? _____

5c. How many are between four and eight? _____

5d. How many are under age four? _____

6. How many adults are generally home during the day? _____

7. Apart from special holidays or vacations, are there certain times during a typical year where some of the family members are absent for a month or longer?

1 YES
2 NO

If "YES":
Who is that and what time span is involved?

_____

_____

8. To the best of your knowledge do you anticipate having to move your household away from the larger Norfolk area?

1 YES (Consider purchase of a different model)
2 NO

9. The efficiency of a refrigerator is greatly influenced by family vacations, large parties and other unusual events. To help us understand possible fluctuations in the efficiency of your unit, the Monthly Recording Sheets are provided and we'd appreciate your recording to let us know about any such events.

10. Where will the test refrigerator be located?
1 Kitchen
2 Hallway
3 Other (describe)

_____

10a. Is that area heated in the winter?
1 YES
2 NO

10b. Is that area air conditioned during the summer?
1 YES
2 NO

If "YES"
10c. Is it a central air conditioning system or a local room air conditioner?
1 Central
2 Local

11. Finally, I'd like you to think back to your purchase decision and tell me what features made you decide to buy this particular unit. What things did you like about it and what things didn't you like?

_____

_____

12. Are there any features you would have liked to have but couldn't buy with this unit?

1 YES
2 NO

If "YES"
12a. Which ones? (Write in.)

_____

_____

Thank you for your answers.

Person taking this profile: _____

Date: _____

Table 2-3
FIELD TEST SAMPLE CHARACTERISTICS (ESTR-18D)

Test Site #	Adults	Children (Ages) 14-18	9-13	4-8	0-4	Total No. of Persons	Type of Air Conditioning	Icemaker
01	2				1	3	Room	
02	2					2	Room	✓
03	5					5	Room*	
04	2					2	Room	
05	2					2	None	
06	3					3	Central	
07	2		1		1	4	Central	
08	2	2	1			5	Central	✓
09	2					2	Room	✓
10	2				2	4	Central	✓
11	3		1			4	Room	✓
12	2			1		3	Room*	
13	2					2	Room	
14	3	3				6	None	
15	3					3	Central	
16	2					2	Central	
17	2		2	2		6	Central	✓
18	2	3	1			6	Central	✓
19	2					2	Central	✓
20	2					2	Central	✓
21	2					2	Central	
22	2		1			3	Central	
23	4					4	Room	✓
24	Unit not placed							
25	2		1			3	Room	

*Used occasionally.

Table 2-3 (Continued)
FIELD TEST SAMPLE CHARACTERISTICS (TC-18D)
(Continued)

Test Site #	Adults	Children (Ages) 14-18	9-13	4-8	0-4	Total No. of Persons	Type of Air Conditioning	Icemaker
26	2		2		1	5	Room	
27	3					3	Central	✓
28	2			1		3	None	
29	2					2	Room	
30	2	2				4	Room	✓
31	2			2		4	None	
32	2		1	1		4	Room	
33	3	2				5	None	
34	2	1			1	4	None	✓
35	2					2	Central	
36	2		3		1	6	Central	✓
37	2	1	1			4	Central	
38	1					1	Central	
39	4	2				6	Room	✓
40	2					2	None	
41	2			2		4	Central	✓
42	2			2	1	5	Room	✓
43	2					2	Central	✓
44	2		2			4	Room	✓
45	2					2	Central	✓
46	2	2			1	5	Central	✓
47	2	1				3	Central	✓
48	Late participant - not surveyed							
49	Unit not placed							
50	Unit not placed							

Table 2-4

MONTHLY RECORDING SHEET FOR YOUR AMANA REFRIGERATOR

Please keep these forms near your refrigerator. They will help you remember any unusual circumstances which may happen during the course of a month.

Start a new list each month and give it to the person who will read the meter on your refrigerator at the end of the month. (The numbers on this meter relate to the cooling efficiency of the unit.)

IF YOU HAVE ANY PROBLEMS OR QUESTIONS ABOUT THE UNIT, CALL:

Ron Conyers
PRICE'S INC.
Telephone: (804) 627-5571

IF YOU HAVE ANY QUESTIONS ABOUT THE MONTHLY METER READINGS, CALL:

Donald J. Messmer
MID-ATLANTIC RESEARCH, INC.
Telephone: (804) 253-4432

---

1. Were there any unusual circumstances which happened this month?

1 YES
2 NO

These could relate to such things as:

a. Changes in the number of people in the family.
Changes in the number of people at home during the day.
Changes in the amount of food (parties or similar).

b. Changes in the performance of the refrigerator.

If "YES"; please write in:

_____

_____

_____

2. Did you have any service call(s) this month?

1 YES
2 NO

If "YES"
What was the nature of the problem? (Please write in.)

_____

Has the problem been fixed to your satisfaction?

1 YES
2 NO

If "NO"
What still needs to be taken care of?

_____

_____

Date_____ Name_____

Table 2-5

MONTHLY MONITOR

INTERVIEWER: Call a few days in advance of the monitoring day and ask for the time of day when the responsible person will be at home. Remind him/her to complete their Monthly Recording Sheet.

House _____ Test Location # _____

Telephone No. (Home) _____ (Work) _____ Model: 1 TC
2 ESTR

Person to speak to: _____ Address: _____

Time and day of appointment: _____ _____

COMPLETE THIS SECTION BY INSPECTION

	a.	b.	c.
1.	Last Reading _____	New Reading _____	Change _____
	Month/Day _____	Month/Day _____	
	Meter at _____	Meter at _____	_____

(Affix new sticker with new reading and today's date near meter.)

2. Temperature Control in fresh food compartment set at: _____

3. Temperature control in freezer compartment set at: _____

4. Check fresh food compartment for any water drops:
   1 No water accumlated
   2 Some water accumlated
   3 Excessive amount of water

4a. Where is this water accumulated? (Describe location.)

_____

5. Fresh food compartment is:
   1 Empty
   2 Normal
   3 Very full

6. Freezer is:
   1 Empty
   2 Normal
   3 Very full

ASK RESPONDENT

7. Now I'd like to collect your monthly recording sheet. In addition to what you you have recorded, are there any particularly good things you would like to mention? (Write in.)

_____

_____

8. And are there any unfavorable things you'd like to mention about your refrigerator? (Write in.)

_____

_____

9. Do you know of any family vacation or unusual events coming up within the next four weeks which could present problems with the next meter reading?

1 YES
2 NO

If "YES," record the circumstances.

_____

_____

Be certain the household's recording sheet is completed and signed and attach it to this form. Also, DON'T LEAVE BEFORE AFFIXING A NEW STICKER TO THE REFRIGERATOR.

Thank you for your participation in this study and I'll call you again a few days before _____ (month/day) to arrange for a convenient time for the next meter reading.

Interviewer's Name _____

Table 2-6

FIELD TEST RESULTS (ESTR-18D)

MONTH	Average Daily Energy Consumption (kWh/day) by Month												
	1	2	3	4	5	6	7	8	9	10	11	12	
Test Site #													
01	2.86	2.24	2.08	1.96	1.72	1.81	1.78	1.87	1.99	2.23	1.83	1.87	
02	2.50	2.34	1.88	1.65	1.49	1.58	1.54	1.56	1.81	2.09	2.33	2.57	
03	2.28	1.95	1.89	1.84	1.66	1.73	1.72	1.76	1.83	2.18	2.23	2.42	
04	1.96	1.91	1.85	1.84	1.74	1.66	1.65	1.68	1.93	2.43	2.33	2.46	
05	2.48	2.89	2.23	1.91	1.80	1.94	1.83	1.78	1.94	2.08	2.19	2.77	
06	3.53	2.96	1.87	1.62	1.51	1.47	1.41	1.45	1.66	2.59	3.43	3.30	
07	-*	-	-	-	-	-	-	-	-	-	-	-	
08	2.64	2.43	1.95	2.13	2.03	2.02	2.01	1.87	1.99	2.27	2.64	2.74	
09	-	-	2.12	1.77	1.72	1.61	1.63	1.61	2.09	2.55	2.84	2.76	
10	2.29	1.89	1.77	1.74	1.58	1.60	1.57	1.56	1.69	2.03	1.77	1.90	
11	-	-	-	-	-	1.90	1.84	1.98	2.22	2.29	2.47	3.23	
12	2.97	2.56	2.60	2.54	2.45	2.25	2.13	2.20	2.11	2.13	2.17	2.42	
13	-	2.24	1.94	2.27	1.84	1.70	1.67	1.78	2.01	2.26	2.33	2.44	
14	3.16	2.80	2.38	2.20	1.76	1.91	1.89	1.80	1.98	2.55	2.64	3.01	
15	2.41	2.25	2.06	2.36	1.97	2.38	1.61	1.67	1.76	2.21	2.19	2.06	
16	1.58	1.58	1.45	1.42	1.42	1.40	1.40	1.32	1.38	1.60	1.77	1.80	
17	2.92	2.55	1.90	-	-	-	-	-	-	1.89	2.17	2.48	
18	2.13	2.61	2.15	1.75	1.68	1.67	1.63	1.47	1.85	2.23	2.46	2.19	
19		2.71	2.44	-	-	1.76	1.85	1.83	2.01	2.01	2.07	2.15	
20	2.24	1.99	2.05	1.95	1.78	1.63	1.71	1.76	1.91	2.20	2.28	1.94	
21	-	-	-	-	-	-	-	-	-	-	-	-	
22	1.91	1.75	1.55	.96	.83	.82	.76	.67	.95	1.24	1.58	2.10	
23	2.37	-	-	-	-	-	1.96	1.80	1.97	2.03	2.15	2.80	
24	-	-	-	-	-	-	-	-	-	-	-	-	Year Average
25	-	-	1.75	1.54	1.57	1.64	1.53	1.58	1.62	1.86	1.81	2.05	
Mean	2.48	2.31	2.00	1.86	1.70	1.72	1.67	1.67	1.84	2.13	2.26	2.43	2.01
Std. Dev.	.49	.41	.28	.37	.32	.32	.28	.30	.28	.31	.41	.43	
Sample Size	17	18	20	18	18	20	21	21	21	22	22	22	
Range Low	1.58	1.58	1.45	.96	.83	.82	.76	.67	.95	1.24	1.58	1.80	
Range High	3.53	2.96	2.60	2.54	2.45	2.38	2.13	2.20	2.22	2.59	3.43	3.30	

* - indicates questionable data reading or instrumentation failure.

Table 2-6 (Continued)

FIELD TEST RESULTS (TC-18D)

MONTH	Average Daily Energy Consumption (kWh/day) by Month 1	2	3	4	5	6	7	8	9	10	11	12	Year
Test Site #													
26	6.21	5.57	4.48	4.57	4.63	4.39	-	-	-	-	-	-	
27	-	-	-	-	-	-	-	-	-	-	-	-	
28	6.74	5.68	5.12	4.78	4.55	4.41	4.35	3.99	3.23	4.09	3.91	5.16	
29	5.80	5.35	4.02	3.48	3.3	3.28	3.30	3.30	3.53	4.15	4.73	5.12	
30	8.10	7.01	6.00	5.96	5.0	4.86	5.33	4.96	5.34	6.77	6.72	5.37	
31	6.59	5.44	5.15	4.30	4.0	3.95	4.36	4.50	4.81	5.37	6.02	7.76	
32	4.98	4.96	4.62	4.60	3.59	3.34	3.36	3.56	3.66	5.04	5.32	5.49	
33	8.79	7.53	7.03	6.18	6.45	6.36	6.09	6.38	6.53	7.46	7.67	8.38	
34	6.41	5.83	5.54	5.32	4.32	4.36	3.07	3.33	3.65	4.94	4.80	5.38	
35	5.64	5.17	4.72	4.39	4.21	4.18	4.03	4.08	4.24	5.05	5.13	5.60	
36	6.42	6.00	5.43	5.41	4.9	5.02	5.02	5.24	5.37	6.57	5.85	6.38	
37	6.39	-	-	-	4.53	4.06	4.11	4.29	4.88	5.47	5.72	6.09	
38	5.80	5.41	5.37	5.23	5.11	5.24	5.18	5.30	5.46	5.88	5.60	5.82	
39	5.63	5.05	3.85	3.49	3.44	3.73	3.36	3.49	3.68	5.24	5.74	6.69	
40	-	-	-	-	-	-	-	-	-	4.51	5.30	5.88	
41	-	-	-	-		-	-	-	-	-	-	-	
42	5.40	5.25	4.28	4.10	4.19	4.12	4.21	4.27	4.11	4.29	5.33	5.35	
43	-	-	-	-	-	-	-	-	-	-	-	-	
44	6.68	6.71	5.88	5.18	4.86	5.13	4.69	4.68	-	-	-	-	
45	-	-	-	-	-	-	-	-	4.01	4.30	4.22	4.36	
46	6.50	6.61	6.64	5.31	4.41	4.37	4.04	4.56	4.59	5.78	5.13	4.95	
47	5.33	5.46	4.00	3.54	3.28	3.30	3.03	3.19	3.37		-	-	
48	-	-	-	-	4.59	-	4.91	-	-	-	-	-	Year
49	-	-	-	-	-	-	-	-	-	-	-	-	Total
50	-	-	-	-	-	-	-	-	-	-	-	-	
Mean	6.31	5.81	5.13	4.74	4.41	4.37	4.27	4.32	4.40	5.31	5.45	5.86	5.03
Std. Dev.	.96	.76	.94	.84	.76	.80	.85	.87	.93	.99	.91	1.03	
Sample Size	17	16	16	16	18	17	18	16	16	16	16	16	
Range Low	4.98	4.96	3.85	3.48	3.28	3.28	3.03	3.19	3.23	4.09	3.91	4.36	
Range High	8.79	7.01	7.03	6.18	6.45	6.36	6.09	6.38	6.53	7.46	7.67	8.38	

Table 2-7

ENERGY CONSUMPTION COMPARISON OF THE HIGH-EFFICIENCY AND BASELINE UNITS

Model	FTC Label Number ($/Year)*	DOE Test Values			Field Results (kWh/day)	Difference (kWh/day)
		Energy Factor (ft^3/kWh/day)	Energy Usage (kWh/Yr)	Energy Usage (kWh/day)		
ESTR-18D	37	10.03	749	2.04	2.01	0.03 (-1%)
TC-18D	71	5.37	1421	3.89	5.03	1.14 (29%)

*Based on $0.0497/kWh

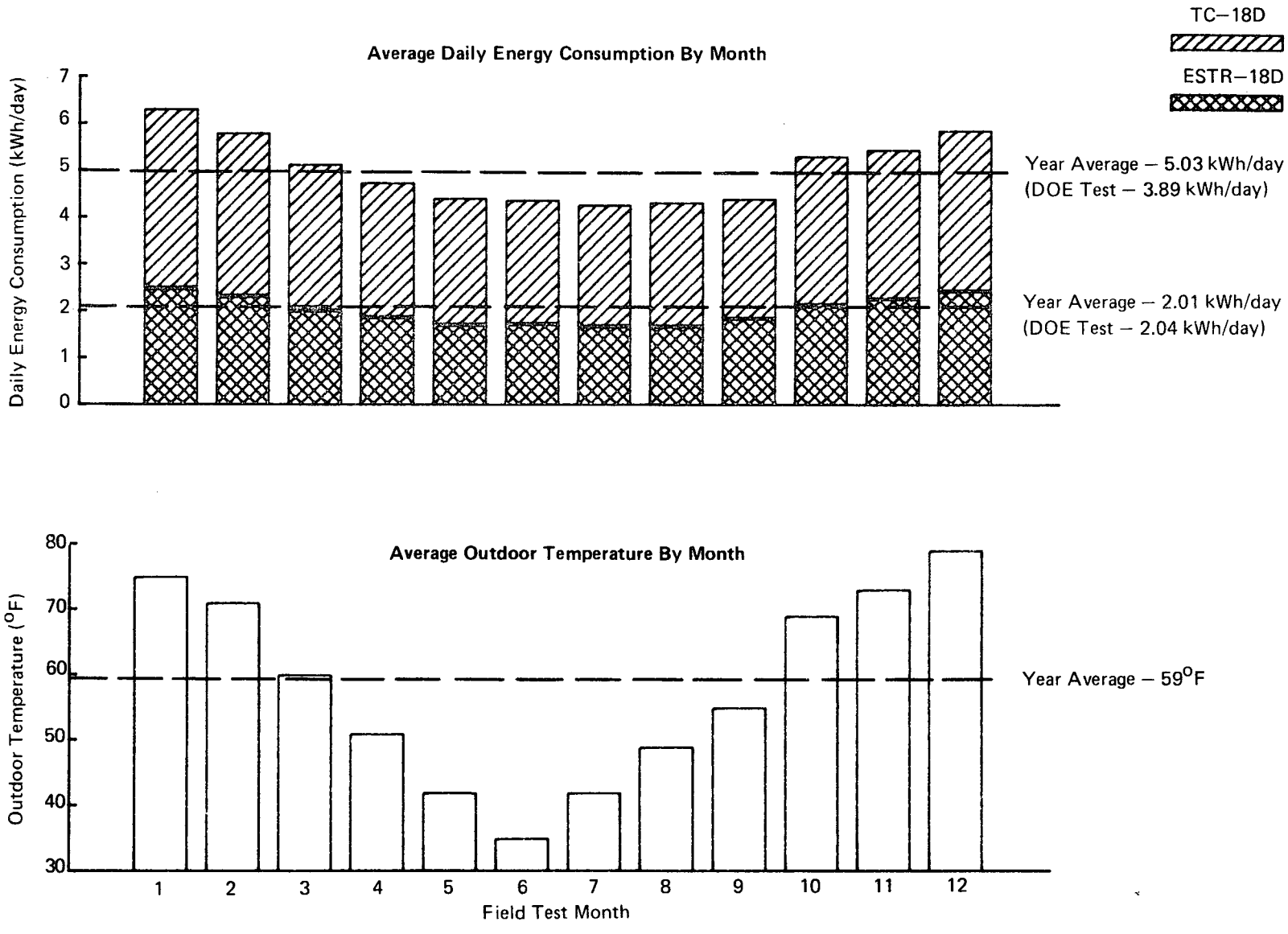


FIGURE 2-2. FIELD TEST ENERGY CONSUMPTION AND OUTDOOR AMBIENT TEMPERATURE

months. This data suggests that the relatively high temperature and humidity experienced in Norfolk in the summer, coupled with ordinary household usage patterns, imposed a stringent operating environment on the refrigerators. The high-efficiency ESTR-18D performed better than the TC-18D, demonstrating an average yearly 60% decrease in energy consumption over the baseline unit compared to 47% predicted by the test procedure.

Attempts to derive correlations of energy consumption versus usage parameters such as number of persons in the household, food load, refrigerator settings, etc., proved unsuccessful because of data scatter and the relatively small sample size. Refrigerator energy consumption varied widely from month-to-month and unit-to-unit in actual home usage.

4. BENEFITS DERIVED FROM THE PROGRAM

During Phase II, Amana decided, on its own initiative, to develop a commercial version of the energy efficient ESTR-18D for its model line using the technical and marketing information gained, as well as the insights and skills developed during the course of this program. The consumer and nation subsequently benefitted from the accelerated commercialization and availability of a large capacity, automatic-defrost, refrigerator-freezer with superior energy efficiency.

In retrospect, this program demonstrated that a participating manufacturer in a government-sponsored program of this type can expect to develop increased expertise in these areas:

- Product Design
- Product Performance Experience
- Marketing Efforts
- Manufacturing Techniques

The following sections describe how Amana used the information gained in these areas in the development of their TSC-18E high-efficiency refrigerator-freezer. Amana believes that the benefits accrued from this project range from improved product design capability to the development of marketing insight that would otherwise have had to be guessed at. Though difficult to quantify, these benefits were nonetheless important to the follow-on project in which a commercial version of the model was produced.

4.1 Product Design Parameters

The overall cabinet size and front-to-rear depth of the ESTR-18D had been an early concern. While the Norfolk results did not identify

this as a crucial problem, difficulties with the installation of several engineering field test units led Amana to consider means to reduce the front-to-rear depth for the commercial version. This was accomplished by reducing the insulation thickness of the door by 1¼ in. and using a bottom-mounted, fan-cooled condenser in place of the wire and tube static condenser attached to the back panel. As an additional feature, the fan-cooled condenser allowed "built-in" or "recessed" applications. A total depth reduction of 2¼ in was realized.

An early complaint concerning bottle space on the top shelf led to adjustable cantilever glass shelves for the commercial version. Reports during the field test of excessive moisture in the crisper area prompted Amana to alter the condensate drain system. The final commercial design replaced the internal defrost water drain channel with an external drain tube, and thus eliminated a source of moisture in the cabinet.

4.2 Product Performance Experience

Evaporator-fan noise was an early problem discovered in the testing of the ESTR-18D field test units prior to their shipment from the factory. This problem was resolved by redesign of the mounting bracket, use of softer resilient mounting grommets, and incorporation of spring-loaded thrust washers in the motor bearing system. These changes were also included in the commercial model.

Tests conducted on the field-test prototypes indicated a higher than desirable refrigerant pressure drop through the cold plate during operation. The cold-plate refrigerant circuit was subsequently redesigned for the commercial version. Several other minor changes in the compressor mounting and tube routing were made for the commercial version as a result of experience gained with the field units.

During the field test, surface condensate (sweat) were reported on both the exterior and interior of the ESTR-18D. This led Amana to redesign the anti-sweat heaters used in the mullion section and on the fresh-food compartment ceiling panel. The maximum heater wattage was increased to allow the customer better control of heavy sweating using the "energy saver" switch.

4.3 Marketing Effort and Experience

The market testing has been described in detail in a previous section of this report. Amana's conclusion from that effort was that low energy consumption is an important product attribute in attracting sales, but the cost premium that the public will pay is less clear.

4.4 Manufacturing Techniques and Experience

While the fabrication of single-piece food liners for refrigerators and freezers using ABS plastic sheet was not a new process for Amana,

the ESTR-18D had the largest liner ever attempted. As such, it presented some problems in achieving acceptable material thickness and strength. The lessons learned in the process of producing these liners and in the subsequent assembly of them into refrigerator cabinets aided the development and early introduction of the commercial version.

The opportunity for Amana to assess the manufacturability of the ESTR-18D prior to a production commitment for a similar product was another important benefit. As a result of Amana's previous experience with the field test unit production run, several changes that improved manufacturability and processing were incorporated into the new design, and assembly facility and material handling modifications were also instituted.

5. CONCLUSIONS AND RECOMMENDATIONS

The Phase II field test of the 18 ft^3 high-efficiency ESTR-18D confirmed the in-home energy saving potential of a high- efficiency, automatic-defrost, refrigerator-freezer utilizing advanced design features such as optimized thick-wall foam insulation and a two-evaporator refrigeration system. Results showed an average energy consumption of 2.01 kWh/day--a savings of 60% compared to the TC-18D baseline unit of conventional design.

The field test also uncovered performance differences between the ESTR-18D and TC-18D not adequately explained by the DOE test. It suggested a need for an investigation of the quantitative and comparative effects of various usage parameters (such as temperature, humidity, food load, door openings) on power consumption. The results of this study would help to determine whether established steady-state performance tests, such as the DOE test, will continue to provide an acceptable method for ranking refrigerators, in light of the new, high-efficiency technologies being introduced in some models.

A market evaluation performed as part of this program confirmed that refrigerators incorporating high-efficiency features at added cost are saleable and that large automatic-defrost refrigerator-freezers will continue to capture a large portion of the market in the years ahead.

No serious deficiencies in the high-efficiency model appeared. The design promises to provide energy efficient operation while providing the same service as a conventional automatic-defrost refrigerator-freezer. Some customer education may be necessary, however, to deal with the added moisture that can be present in the refrigerator compartment due to the use of the cold-plate evaporator.

APPENDIX A

CONSUMER PREFERENCES CONCERNING ENERGY EFFICIENT REFRIGERATORS

1.0 SUMMARY

Consumer needs and wants were studied in a consumer survey in preparation for the home testing of an energy-saving refrigerator-freezer developed by Arthur D. Little, Inc., and Amana Refrigeration, Inc., under contract to DOE. Price's Appliance Stores of Norfolk, Virginia, was chosen for the interviews.

- Consumers are still increasing the size of their refrigerators.

- Most purchases are to satisfy immediate needs; fast delivery is imperative.

- The top ten most important items in terms of needs and wants rank as follows:

  - Frost-free feature
  - Vegetable and meat trays of sturdy material
  - Particularly heavy insulation in walls and doors
  - Low operating cost
  - Specific outside dimensions
  - Rollers
  - Adjustable shelves
  - Very large freezer
  - Specific color
  - Energy saver (saves $50 to $100 over three to four years)
  - Low noise level

- The factor analysis shows these markets to cluster into two large segments and nine relatively small segments.

- The largest market segment wants what is called the <u>basic</u> refrigerator:

  Well-known national brand
  Heavy insulation on walls and doors
  Large freezer
  Specific color desired
  Low operating cost

  - Low operating cost is an item new to the definition of a basic refrigerator. In keeping with this cost concern, more than half of the respondents would pay a premium of $100 if they could save this amount on their electric bills over a period of two years.

- The second largest segment consists of people who are interested in the <u>technical features</u> which are energy conserving, over and above their need for low operating costs. In contrast to the first segment, they are interested in the technology, not merely in lower costs. This segment looks for the following in a refrigerator:

Energy saving features (saves $50 to $100 on electric bills)
Humidity control
Energy efficient electric components

- Although a large segment thinks that an energy saving refrigerator should be priced higher than other refrigerators, there is a sizeable group who thinks that the price should be comparable or even less.

- The factor analysis clusters then split into smaller segments. The convenience segment, the third largest segment, considers the following items important:

  Automatic door closing
  Interior size
  Freezer light
  Specific outside dimensions

- The fourth largest segment is concerned with shelf configurations.

- A segment worth mentioning is the frost-free segment. Although only in eighth position, it is important to know that frost-free nevertheless is the most important feature in terms of people's needs and wants, and therefore a pricing strategy for frost-free is critical.

- Care should be taken in using the factor analysis alone, because generally there should be four to five times as many respondents as attributes. In this study there were only twice as many respondents as attributes.

2.0 RESEARCH PROCEDURES

2.1 Field Work

Our plan called for 200 interviews with refrigerator shoppers in four different stores. We anticipated interviewing in June and July when refrigerator sales are high; however, because of delays in manufacturing, we were forced to wait until August. In August, shopping patterns changed and shoppers for refrigerators were hard to find. The findings in this report are based on 62 interviews.

2.2 Methodology

The questionnaire designed for this study appears in Appendix A-1. Among other questions, the respondents rated the importance of a list of 31 attributes describing features of a refrigerator. The results were factor analyzed and yielded a number of population segments which demonstrate individual needs and wants.

Factor analysis should best be done with three to four times as many responses as attributes. Because sample size (62 responses) were only twice the number of attributes, the results of this factor analysis should be used with caution.

Factor analysis is a statistical procedure used to attempt to discover the few factors that may underlie and explain the interrelationship among a large number of variables. It can be helpful in pointing out relationships among observed values that are not obvious.

In this study, a large inventory of attributes was developed describing refrigerator features. The consumer was asked to rate each feature by degree of importance in the purchase decision process for a particular refrigerator. Based on these importance ratings, the factor analysis groups together features that are highly interrelated; it reduces the large inventory to a smaller set of attribute dimensions called factors or segments.

In this study, the computer identified 11 such factors. For example, the analysis showed that those respondents who said it was very important that their refrigerator be "a well-known national brand" also tended to place high importance on "heavy insulation on walls and door," "a large freezer," "specific color desired," and "low operating cost." Those who tended to agree with these statements were labeled as consumers wanting the "basic refrigerator," i.e., the type the average consumer expects to find.

Generally, those who agreed with one of the statements under each of the 11 factors (in Table A-1.2) agreed with the other statements in that factor, and those who disagreed with one tended to disagree with the others.

The Factor Loadings in Table A-1.2 show how closely the attributes are related to the underlying factors. Attributes with a loading of .50 or less, although somewhat related to a factor, were excluded from consideration.

Thus, the heavy loadings of "energy saving features," "electric bill savings," "humidity control," and "energy efficient electric component" on Factor 2, indicate that the factor involves an underlying general interest in mechanical/technical elements. The researcher looks at the commonality among the attributes and assigns the factor a name or label. Attributes that show "no load" are not related to any of the 11 factors; they stand by themselves. Table A-1.2 also shows an "Average Attribute" column with ratings from 4.6 to -3.2. These ratings relate to the average measurement obtained on the importance scale of +5 to -5 in Question 18 of the questionnaire. For example, respondents assigned an average importance of 3.2 to the attribute "Well known national brand." Note that Table A-1.1 relates to the same measurements; instead of the average rating it shows the percentage of respondents who selected a +5 rating for the attribute.

The Importance Rating in Table A-1.2 indicates how much the whole sample likes or dislikes the factor. It answers the question: Is there one factor or group of factors that are very important to the respondents? The importance score in this study indicates that the top two factors, with a score of 17.4 and 13.8, are relatively important.

2.3 Sample Composition

Sixty-two interviews were conducted with shoppers who examined large refrigerators (16 ft^3 or larger). In about half of the cases, husband and wife shopped together and answered jointly. In 25 interviews the respondent was a novice at purchasing a refrigerator. Another 25 people last shopped for such an item more than 10 years ago. The great majority were homeowners. Several landlords were shopping for refrigerators for apartments they rented; they were more concerned with functional aspects (price, serviceability) and less concerned with appearance.

3.0 DETAILED FINDINGS

The questionnaire in Appendix A-1 has been structured as a reporting vehicle with percentages next to the answer categories. A synopsis of the most relevant points follows:

- People were shopping for refrigerators because:

  29% The old one broke
  27% New home does not have one
  18% Old one is not efficient

- About half the shoppers needed to have their new refrigerator at home within the next eight days; 25% said they could wait eight weeks or longer.

- Unprompted dislikes about the currently owned refrigerator were:

  40% Mechanical and other problems
  19% Current one too small
  16% Not automatic defrost
  15% Current one too old

- For 52% of the respondents their new refrigerator will be larger; one-third would choose a size of 19-21 cubic feet. On the average, shoppers would pay $641 with an upper limit of $684. (Tables A-1.3 and A-1.4 show the distribution of the prices quoted.)

- Only 16% know how much they pay in electricity each month for their refrigerator; 63% expect the new refrigerator to have lower operating cost.

- The energy guide labels (mandatory after May 19, 1980) were not affixed to the units from prior stock. There was confusion in people's minds between an "Energy Guide" label and the manufacturer's "Energy Saver" label. The latter, in some cases, was felt to be a marketing gimmick and not believable. Nevertheless, 52% thought it was very important that their new refrigerator be an energy saver and another 37% thought it was somewhat important.

- Forty-eight percent did not know if energy-saving refrigerators were priced higher than non-energy savers. Those who noticed a price difference quoted an average differential of approximately $95. (See Table A-1.5 for details.) While 45% thought a higher price for an energy saver is justified, there were also 51% who believed it should be priced lower.

- With respect to achieving savings on their electric bill in return for a higher purchase price, most respondents better related to a yearly savings of $48 than a monthly savings of $4 on their electricity bills. The group was split approximately in half; one segment was quite willing to pay an extra $100 in the purchase price to save on their electric bill, the other was not sure.

- In 90% of the households the refrigerator is kept in the kitchen; 65% of the homes have space limitations particularly for width and height. (See Tables A-1.6 through A-1.8 for details.)

APPENDIX A-1

THE QUESTIONNAIRE AND SUPPORTING TABLES

THE QUESTIONNAIRE

Research Study Among Shoppers

INTERVIEWER: SPEAK TO PERSONS WHO EXAMINED LARGE REFRIGERATORS (16 CU. FT. OR LARGER).

Hello, I'm (name) from Mid-Atlantic Research.

We are doing a study among shoppers to find out about their preferences with regards to refrigerators. I'd like to ask you a few questions and I'm definitely not selling anything.

1. First, why are you looking at refrigerators today? (Why do need to buy one?) (DO NOT READ CATEGORIES.)

(Multiple answers)

29%	Old one broke
18	Old one is not efficient
5	Need larger size
0	Need extra features
27	New home does not have one
21	Other (Specify)_____
10	Just browsing
0	Don't know

1a. How soon do you need a new refrigerator?

47%	Within next 8 days
8	Within next 2 weeks
8	Within next 4 weeks
10	Within next 8 weeks
15	Later than that
12	Don't know

2. What are the things, if any, that you dislike about your current refrigerator or what things give you problems with it? [WRITE IN.] (Multiple answers).

15%	Too old
19	Too small
40	Mechanical/other problem
16	No automatic defroster
11	Other (freezer on bottom/side-by-side/no shelves)
13	No problem/nothing/no refrig.
8	Don't know

3. What would be the most important two or three features a new refrigerator must have if you were to buy it today?

26%	Defroster/no frost
37	Size--bigger
21	Shelves--glass/adjustable
11	Appearance--color/textured front
10	Inside feature--meat tray/place for eggs on door
27	Ice maker--automatic ice maker
18	Other--coils enclosed/freezer on top/capacity
34	Good general--good quality/saves energy/good service/price

4. What size refrigerator would you be likely to buy; that is how many cubic feet would it have?

19%	Less than 18 cubic feet
27	18 cubic feet
32	19-21 cubic feet
10	22 cubic feet
7	More than 22 cubic feet
3	Other (Specify)_____
2	Don't know

4a. Will your new refrigerator be larger or smaller than the one you currently have or will it be about the same size?

52%	Larger
13	Smaller
31	About the same
4	Don't know

5. And how much would you expect to pay for this size of refrigerator with the important features you just mentioned?

See Table A-1.3

5a. What would be the upper limit you think you would pay?

See Table A-1.4

6. Do you know about how much you pay in electricity each month to operate your refrigerator?

16%	YES
84	NO

If "YES"

6a. What is that amount?

70%	Under $10
10	$10 - $12
0	$13 - $14
10	$15 - $18
0	$20 - $25
10	More than $25
0	Don't know

7. Do you think if you bought the new refrigerator you are looking at, this operating cost would be about the same, or would it be higher or lower than the refrigerator you now have?

13%	Higher
63	Lower
19	About the same
5	Don't know

7a. Why do you say that? [DO NOT READ CHOICES.]

Operating Costs Higher
(Sample size = 8)

New one:

50%	Is larger
38	Has more features
0	Will be used more
0	Is less efficient
13	Other (Specify)
0	Don't know

Operating Costs Lower
(Sample size = 47)

New one:

40%	Is smaller
0	Has less features
0	Will be used less
62	Is more efficient
34	Other (Specify)
0	Don't know

Operating Cost is the Same

New one is larger, but:

0%	Has less features
0	Will be used less
67	Is more efficient
17	Other (Specify)
17	Don't know

New one is smaller, but:

50%	Has more features
0	Will be used more
0	Is less efficient
0	Other (Specify)
50	Don't know

New one is the same size:
(Sample size = 4)

50%	All same features
25	Other (Specify)
25	Don't know

8. Have you noticed that some of the refrigerators are called "Energy Savers"?

82%	YES
18	NO

9. What, in your opinion, distinguishes an Energy Saver from a regular refrigerator? (Multiple answers.)

23%	Use less electricity/less operating cost
32	Insulation--foam insulation/better insulation
5	Not different--promotional gimmick/built same
8	Mechanical--compressor/ventilation
7	Better engine
13	Other misc.--Thermo coating/sep. temperature control/etc.
37	Don't know/not reported

10. If you were to buy a new refrigerator how important do you think it would be that this refrigerator be an Energy Saver? Would you say:

23%	Extremely important
29	Very important
36	Somewhat important
10	Very unimportant
2	Don't know

11. Did you notice by any chance, whether the Energy Savers are priced about the same as the regular refrigerators or are they priced differently?

45%	Difference - ASK Q. 12 & Q.13
7	Priced the same
48	Don't know

IF "Difference" in Q. 11

12. If "Different", is that higher or lower?
(Sample size = 28)

82%	Higher
4	Lower
14	Don't know

13. Compared to a regular model of the same size, approximately how much was that price difference?

See Table A-1.5

14. The Federal Trade Commission requires that labels be attached to all refrigerators to show the energy consumption and cost of operation compared to similar units. Have you noticed any such labels?
[THESE ARE CALLED "ENERGY GUIDES]

68%	YES
32	NO

15.	If a refrigerator is particularly low in energy consumption would that, in you opinion, justify a higher initial purchase price on that unit or should all refrigerators be priced comparably regardless of their energy consumption?	45%	Higher price justified
		27	Should be price comparably
		13	Don't know
		15	Priced less

15a. Why do you say that?

(See Appendix A-1-1

16.	Assume for a moment that your choices had come down to two refrigerators of the same size and one of them, an Energy Saver, had a purchase price which was $100 higher than the other one. If you could save $4.00 per month on your electricity bill by buying the more expensive Energy Saver, how likely would you be to do that when you buy a new refrigerator now? Would you say you would be [READ].	31%	Extremely likely
		24	Very likely
		15	Somewhat likely
		13	Somewhat unlikely
		11	Very unlikely
		6	Don't know
17.	What if the initial price for an Energy Saver was $50 higher than for a regular refrigerator and you could save $1.00 per month on your electricity bill. How likely would you be to buy such an Energy Saver when you buy a new refrigerator now? Would you be [READ].	19%	Extremely likely
		23	Very likely
		18	Somewhat likely
		18	Somewhat unlikely
		16	Very unlikely
		6	Don't know

18. Now, I'd like to read you a list of attributes that a refrigerator might have. Please tell me how important each attribute would be in your decision for selecting a particular refrigerator. We'll use a scale from minus five to plus five with minus five meaning the attribute would be very unimportant in your decision and plus five meaning it would be extremely important in your decision to select a particular refrigerator--and you can select any number between minus five and plus five. (Hand respondent Card 1.) Here is a picture of this scale (see Table A-1.1)

First, how important is it to you that . . . .

The price be at or below the price you indicated as your upper limit?	-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
It has an ice maker?	-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
It has provision to add an ice maker later?	-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
It has a large meat keeper?	-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
It be of certain outside dimensions so as to fit where you want to put it?	-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
It has a certain interior size (i.e., certain cubic feet)?	-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
It has energy saving features?	-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
It has a very large freezer (four cubic feet or more)?	-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
It has particularly heavy insulation in walls and door?	-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
If it is an energy saver, the additional $50 or $100 be saved in your electric bill within three to four years?	-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
It has "frost free" feature?	-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
It has low operating cost?	-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
It has an egg holder in the door?	-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
Shelves have particular configuation (spaced correctly)?	-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
Shelves be adjustable for any configuration you want?	-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5

First, how important is it to you that . . . .

It has a freezer compartment at the bottom rather than on top?	-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
It has a utility compartment in door?	-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
It has a freezer compartment on the side rather than on top or bottom?	-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
It has the specific color you want or need?	-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
Vegetable and meat trays are of sturdy material?	-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
It be a well-known national brand rather than a little-known brand?	-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
It has rollers so you can easily move it out from the wall or refrigerator space?	-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
It has humidity control so food won't dry out?	-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
It has an ice water tap so you can get ice or water anytime without opening doors?	-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
It has a heated butter keeper?	-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
It has a light in freezer compartment?	-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
It has an automatic door closer?	-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
It has energy efficient electrical components?	-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
It has see-through doors to view inside contents without opening door?	-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
Decorative panels can be added to the front of the product?	-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5
It has low noise level.	-5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5

19. And to complete the interview, here are a few more questions for background purposes only:

A.	Including yourself, how many people are living in your household?	8%-1; 18%-3; 10%-5; 42%-2 19%-4; 3%-6
B.	How many of these are: between eighteen & fourteen between thirteen and ten under ten	10%-1; 3%-2; 0%-3; 2%-4; 86%-0 8%-1; 2%-2; 0%-3; 0%-4; 90%-0 16%-1; 11%-2; 3%-3; 0%-4; 69%-0
C.	Do you live in a house or apartment?	82% House 11 Apartment 7 Other (Specify)_____ 0 Don't know
D.	Approximately how large is your kitchen? What are the dimensions?	See Table A-1.6 (Actual sq. ft.)
E.	When did you last buy a refrigerator?	3% Less than 2 years ago 8 2-5 years ago 7 6-7 years ago 3 8-9 years ago 16 10-12 years ago 24 Longer than 12 years ago 39 Never 0 Don't know
F.	What size of refrigerator do you currently have?	53% Less than 18 cubic feet 13 18 cubic feet 16 19-21 cubic feet 8 22 cubic feet 5 Larger than 22 cubic feet 2 Other (Specify)_____ 3 Don't know
G.	In which room/area do you now have your refrigerator?	90% Kitchen 0 Hallway 2 Basement 8 Other (Specify)_____ 0 No answer

H.	Is that also where you'd place your new unit?	95%	Yes
		5	No
I.	If "No" where would you place your new one?		_____
J.	Are there any space limitations concerning the height, width or depth of the area where your refrigerator has to fit? [ASK FOR EACH: HEIGHT, WIDTH, AND DEPTH]	65%	Yes ASK Q. Ja
		35	No

If "YES", ask:

Ja. Is this for the height, width, or depth?

	YES	NO	Don't Know
Height	73%	20	8
Width	78%	13	10
Depth	33%	53	15

If, "Yes" to height, width or depth:

(See Tables A-1.7, A-1.8, A-1.9)

L.	Before you came here today in which other places, if any, have you shopped for a refrigerator recently?	3%	Department Store
		48	Mass Merchandise (Sears, Penny's etc)_____
		2	Hardware Store
		13	Appliance Store
		40	Shopped here or other places
		6	Other
M.	Is there any literature or other sources you may have consulted for information about the type of refrigerators available? Which ones?	36%	Yes
		65	No

N. And finally, here is a card with age and income categories. [HAND RESPONDENT CARD 2]. Please tell me the letter of the category which includes your age.

Age Category (Table A-1.10)

A.	0%	E.	18%
B.	15	F.	10
C.	21	G.	13
D.	23	H.	2 Refused

O. And please tell me the number of the category which includes your income.

Income Category			
1.	0%	5.	21%
2.	5	6.	13
3.	8	7.	24
4.	19	8.	10

INTERVIEWER COMPLETE THE FOLLOWING:

RESPONDENT'S SEX: MALE 5%
FEMALE 50%

DATE OF INTERVIEW: _____ STORE _____

TIME OF INTERVIEW _____
(AM/PM)

I certify this is a complete and honest interview taken in accordance with my instructions.

INTERVIEWER'S SIGNATURE: _____

Table A-1.1

Rank Order of +5 Importance Ratings

Respondents %	Feature
84%	Frost-free feature
63%	Vegetable & meat trays are of sturdy material
60%	Particularly heavy insulation in walls and doors
60%	Low operating cost
57%	Certain outside dimensions to fit in
52%	Has rollers to move it around
50%	Shelves adjustable
44%	Has very large freezer
42%	Is an energy saver (save $50-$100 over 3-4 years)
42%	Has low noise level
40%	Has humidity control
39%	Has egg holder in door
37%	Well-known national brand
37%	Energy efficient electrical components
34%	Priced at or below my upper limit
31%	Has large meat keeper
27%	Has an ice maker
24%	Has energy saving features
24%	Has light in freezer compartment
24%	Has automatic door closer
23%	Shelves have particular configurations
19%	Provision to add ice maker later
16%	Freezer compartment on side
10%	Freezer compartment at the bottom, not top
8%	Ice water tap
5%	Heated butter keeper
5%	See through doors
2%	Decorative panels

Table A-1.2

REFRIGERATOR--NEED CONCEPT ANALYSIS

Rank	Importance		Factor Loading	Average Attitude
1	17.4	Well-known national brand	.77	3.2
		Heavy insulation walls/doors	.63	3.8
		Large freezer	.62	2.8
		Color you want	.60	2.7
		Low operating cost	.57	4.1
2	13.8	Energy saving feature	.77	2.5
		Electric bill savings	.69	3.1
		Has humidity control	.65	3.0
		Energy efficient electric component	.65	2.6
3	11.7	Has auto door closer	.69	1.2
		Certain interior size	.68	3.5
		Has light in freezer	.65	1.6
		Outside dimension fit	.54	3.1
4	10.2	Shelves adjustable	.83	3.5
		Shelves with particular configuration	.83	1.9
5	7.6	Egg holder/door	.72	2.1
		Meat trays/sturdy	.65	4.3
6	7.0	Price at/below limit	.84	2.9
7	3.5	Freezer at bottom	.82	-1.8
		Utility compartment/door	.53	1.6
8	2.8	Frost-free feature	.86	4.6

Table A-1.2

REFRIGERATOR--NEED CONCEPT ANALYSIS

(continued)

	Importance		Factor Loading	Average Attitude
9	1.8	Has ice maker	.86	0.8
		Add ice maker later	.83	0.5
10	-1.2	See-through doors	.80	-3.2
11	-1.9	Has an ice water tap	.76	-2.2
		Heated butter keeper	.76	-2.4

The following attributes were excluded because they failed to achieve a factor loading greater than .50.

Low noise level (3.3)
Has rollers (3.3)
Freezer compartment on side (-0.5)
Decorative panels can be added (-2.6)
Large meat keeper (2.0)

Factor loading cutoff = .50

Sample size = 62

Table A-1.3

Amount Expected to Pay for the Refrigerator

The Respondent is Likely to Buy

Amount ($)	Number of Mentions	All Respondents Who Answered (%)	Cumulative (%)
325	1	1.9	1.9
350	1	1.9	3.7
400	7	13.0	16.7
450	3	5.6	22.2
500	10	18.5	40.7
530	1	1.9	42.6
550	1	1.9	44.4
560	1	1.9	46.3
600	3	5.6	51.8
650	3	5.6	57.4
700	7	13.0	70.3
799	1	1.9	72.2
800	5	9.3	81.4
849	1	1.9	83.3
900	1	1.9	85.1
950	1	1.9	87.0
1000	7	13.0	99.9
	54		

Mean = 641.0
Standard Deviation = 202.6
Median = 600.0

Table A-1.4

Upper Limit of Amount Expected to Pay for the Refrigerator the Respondent is Likely to Buy

Amount ($)	Number of Mentions	All Respondents Who Answered (%)	Cumulative (%)
325	1	2.0	2.0
350	1	2.0	4.1
400	3	6.1	10.2
450	1	2.0	12.2
500	9	18.4	30.6
550	5	10.2	40.8
560	1	2.0	42.8
600	4	8.2	51.0
650	3	6.1	57.1
700	6	12.2	69.4
800	2	4.1	73.4
900	3	6.1	79.6
950	1	2.0	81.6
1000	6	12.2	93.8
1100	2	4.1	97.9
1400	1	2.0	100.0
	49		

Mean = 684.4
Standard Deviation = 233.6
Median = 600.0

Table A-1.5

Price Difference Expected to Pay for

An Energy Saving Refrigerator

Amount ($)	Number of Mentions	All Respondents Who Answered (%)	Cumulative (%)
15	1	8.3	8.3
50	2	16.7	25.0
79	1	8.3	33.3
100	5	41.7	75.0
106	1	8.3	83.3
150	1	8.3	91.6
200	1	8.3	100.0
	12		

Mean = 95.8
Standard Deviation = 45.6
Median = 100.0

Table A-1.6

Size of Respondent's Kitchen

Amount (Sq. ft.)	Number of Mentions	Total Respondents Who Knew This Measure (%)	Cumulative (%)
30	1	2.1	2.1
40	1	2.1	4.2
45	1	2.1	6.4
63	1	2.1	8.5
64	1	2.1	10.6
80	3	6.4	17.0
84	1	2.1	19.1
90	1	2.1	21.2
92	1	2.1	23.3
96	1	2.1	25.5
100	3	6.4	31.8
108	1	2.1	34.0
112	2	4.3	38.2
120	10	21.3	59.5
144	3	6.4	65.9
160	2	4.3	70.1
168	2	4.3	74.4
180	3	6.4	80.7
200	1	2.1	82.9
216	2	4.3	87.1
240	2	4.3	91.4
252	1	2.1	93.5
260	1	2.1	95.6
300	2	4.3	99.9
	47		

Mean = 138.9
Standard Deviation = 64.4
Median = 120.0

Table A-1.7

Maximum Width Available In Respondent's Home

For a Refrigerator

Amount (in)	Number of Mentions	Total Respondents Who Knew This Measure (%)	Cumulative (%)
25	1	5.0	5.0
30	2	10.0	15.0
32	6	30.0	45.0
34	3	15.0	60.0
35	1	5.0	65.0
36	4	20.0	85.0
37	1	5.0	90.0
38	1	5.0	95.0
68	1	5.0	100.0
	20		

Mean = 35.1
Standard Deviation = 8.1
Median = 34.0

Table A-1.8

Maximum Height Available In Respondent's Home

For a Refrigerator

Amount (in)	Number of Mentions	Total Respondents Who Knew This Measure (%)	Cumulative (%)
29	1	5.6	5.6
58	1	5.6	11.1
60	1	5.6	16.7
63	1	5.6	22.2
64	2	11.1	33.3
65	2	11.1	44.4
66	2	11.1	55.5
67	3	16.7	72.2
68	3	16.7	88.9
69	1	5.6	94.4
76	1	5.6	100.0
	18		

Mean = 63.9
Standard Deviation = 9.2
Median = 66.0

Table A-1.9

Maximum Depth Available In Respondent's Home

For a Refrigerator

Amount (in)	Number of Mentions	Total Respondents Who Knew This Measure (%)	Cumulative (%)
24	1	14.3	14.3
25	2	28.6	42.9
27	1	14.3	57.1
28	1	14.3	71.4
29	1	14.3	83.7
30	1	14.3	100.0
	7		

Mean = 26.9
Standard Deviation = 2.1
Median = 27.0

Table A-1.10

AGE CATEGORY			INCOME CATEGORY		
A.	0%	Under 20	1.	0%	Under $6,000
B.	15	21 - 25	2.	5	$6,000 - $9,999
C.	21	26 - 30	3.	8	$10,000 - $13,999
D.	23	31 - 39	4.	19	$14,000 - $19,999
E.	18	40 - 49	5.	21	$20,000 - $24,999
F.	10	50 - 59	6.	13	$25,000 - $29,999
G.	13	60 or older	7.	24	$30,000 and over
H.	2	Refused	8.	10	Refused

APPENDIX A-1-1

VERBATIM ANSWERS CONCERNING PRICE OF ENERGY-SAVING REFRIGERATOR-FREEZER

Q. 15a. -- Higher price justified (45% of respondents)

"Well it depends - I got to get my money's worth. We want to keep the Vepco (electric) bill low."

"I don't know."

"In the long run you would save money."

"Well, if it costs more to make."

"You could recover the additional cost in lower Vepco bills."

"Depends on quality of materials used."

"In the long run you will save money."

"We are all being asked to save energy."

"Making it would cost (more)."

"New features brings prices up $25 to $50."

"Money paid back from saving energy."

"In the long run you save money."

"Refrigerator would have more value. Anything that would save on electric bill would help."

"Priced according to what offers."

"You would capture the expense over a period of time."

"You could get the money back."

"It takes more to make energy refrigerators."

"Depends on how much higher; you have to be able to recover the extra cost."

"Making it up in monthly Vepco costs."

"Refrigerators last a long time, so you could figure out how long it would take to recover the cost."

"It would be a better refrigerator all around. GE is a mighty nice refrigerator."

Q. 15.a -- Higher price justified (45% of respondents)

"It would seem logical to pay more for a more efficient refrigerator."

"Average 18 years life for refrigerator, so would recover the cost plus save extra."

"If it saves on energy it's worth it."

"Should be built better."

"You save and everyone saves. It's a good goal."

"Electricity is saved."

Q.15a. -- Should be priced comparably (27% of respondents)

"Experimental models now, so could be priced higher; but eventually should be priced the same."

"Money is a consideration with us - the energy saver doesn't cost that much more to build and higher price isn't justified - we just can't afford the extra money right now."

"Technologically, we should produce consumer goods at the same price - costs should not be passed on. Moderate price difference is justified (second thought)."

"Higher price would defeat the purpose."

"I think they should be making them more efficient."

"Everybody should be equally concerned."

"Don't know."

"Doesn't cost that much more to make."

"Save so little per month, should be priced the same; all refrigerators should be made the same."

"I don't feel I would want to pay for it."

"More people would be likely to buy them."

"It's a Catch 22; Vepco rates will always change - Vepco rates saved, but higher monthly refrigerator payments will offset the savings."

"Economy; to encourage us to save energy."

"Everyone should be saving energy - energy efficiency should be part of the package."

"A refrigerator is a refrigerator and I don't think there is much difference between one or the other."

"People will more likely buy a cheaper unit."

"Counterbalance - any how we want to buy things or sale."

Q.15a. -- Priced less (15% of respondents)

"Wouldn't justify higher price - wouldn't get it back in electricity. 50¢/month is probably all we would save anyhow."

"I don't believe the new 'efficient' refrigerators really do that much."

"First, energy saving is unimportant; you pay what you have to pay for electricity; if anything, they should be less if they want us to save energy."

"People should make things to conserve energy and place them within everyone's price range."

"We should be conserving energy; manufacturers should encourage us."

"Like the EPA rating - running the machine not the same cost, as the rating says."

"Buy to fit my needs; features I want are more important than a $2 - $3 per month savings."

"Refrigerators can't be at same price; energy efficient ones should cost less."

Q.15a. -- Don't know (13% of respondents)

"It depends. Looking at total package - features, service, etc. - energy is not the only concern."

"It depends. I wait to buy things, wait till the breakdown, then I need it in a hurry. So things like energy consumption I don't look at."