BPA

Japanese Refrigerators Field Testing

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JAPANESE REFRIGERATORS FIELD TESTING

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BONNEVILLE POWER ADMINISTRATION

PORTLAND, OREGON

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EXECUTIVE SUMMARY

Residential refrigerators consume the equivalent of 1700 megawatts (MW) of baseload power in the Bonneville Power Administration (BPA) service area. Japanese manufacturers have designed refrigerator units that appear more energy efficient than some currently available American models. This report summarizes preliminary findings from field testing of 12 refrigerators of Japanese manufacture to evaluate annual kilowatt hour (kWh) use during actual operation. The units have also undergone laboratory testing sponsored by BPA at ETL Testing Laboratories, Inc. in Cortland, New York.

A final report of the project -- due at the end of 1989 -- will correlate in detail the results of field and laboratory tests in comparison to performance ratings determined by the manufacturer.

Test procedures used by Japanese manufacturers are not the same as the Department of Energy (DOE) standard test procedures. This discrepancy makes performance comparison difficult and raises an issue about which test procedure is more realistic. One objective in the field test is to determine the validity of energy consumption ratings obtained by other test procedures.

Data collected during the field test included electricity use, kitchen temperature, number of door openings by user, stored food load, and other user behaviors. Features varied in the various brands and models tested, including capacity, freezer section location, accessories such as ice-maker and water dispenser, and technology such as anti-sweat switches and solid-state controls.

In general, preliminary analysis of the field test shows that under normal household use, the majority (8) of the units are less energy efficient by over 25 percent than indicated by the Japanese manufacturer performance claims, but more energy efficient than indicated by the laboratory tests. However, for four of those twelve units, the field test results did trend toward the level of performance established by Japanese manufacturers. Of the remaining units,

- ° One with an automatic ice-maker showed greater energy consumption in actual operation than indicated by either the Japanese ratings or laboratory tests.
- ° Two units were more energy efficient in the field than indicated by either Japanese claims or laboratory tests.
- ° One unit used more energy in the field than shown by Japanese ratings, but equaled the energy use of the laboratory test.

The energy consumption trend varied according to the volume with the larger units recording the highest energy consumption, as might be expected. The differences in features affected rated energy consumption in both laboratory and field tests. For example, the energy consumption of two units, of identical capacity, one with and one without an ice-maker, was 334 percent greater for the unit with the ice-maker.

The results of the field tests are, therefore, somewhat ambiguous. Further analysis and correlation of results will be included in the final report.

I. INTRODUCTION

Within the BPA service area, residential refrigerators consume the equivalent of 1700 MW of baseload power. To effectively forecast electricity demand, it is important to analyze and to understand energy use characteristics of typical units. Japanese manufacturers have designed and developed products that appear more energy efficient than some American models. Features of the Japanese units include:

- ° varied food load capacities,
- ° larger freezer compartments,
- ° automatic defrosting,
- ° solid-state temperature controls,
- ° multi-zone cooling,
- ° self-mounted cooling units,
- ° high density arc vacuum insulation,
- ° greater interior illumination, and
- ° accessories such as ice-makers and water dispensers.

Some units have as many as four separate doors with four storage compartments, each maintained at different temperatures. Freezer compartments may be at the top, middle, bottom, or side-by-side with the refrigeration sections.

According to a study by the Lawrence Berkeley Laboratory (LBL)¹, units of 16 and 17.3 cubic feet (cf) capacity are popular in the United States, while smaller 10.6 and 10.8 cf sizes are the most popular in Japan. The LBL study also indicated that the 10.8 cf model is very energy efficient in Japan.

¹Meier, A. K., "Energy Use Test Procedures for Appliances, A Case Study of Japanese Refrigerators," May 1987, DOE/BP-63585-1

II. PERFORMANCE TESTING

To determine the average energy consumption of their refrigerators, Japanese manufacturers use test procedures that are different from DOE test procedures. (For details of the two test procedures, see Meier, A. K., "A Case Study of Japanese Refrigerators," May 1987, U.S. Department of Energy, Bonneville Power Administration.) The discrepancies in test procedures make comparison of performance ratings difficult. Questions of difference between Japanese and American user behaviors also arise.

Therefore, BPA sponsored laboratory tests at ETL Laboratory Testing, Inc. (Cortland, New York) to obtain comparative energy use data. The laboratory results indicated energy use of about 40 percent more than the ratings claimed by the Japanese manufacturers. To verify energy consumption, it was also decided to conduct tests under actual operating conditions in residences.

Installation

Twelve refrigerator units were installed in a carefully selected cross-section of residences of BPA employees living in Portland, Oregon and Vancouver, Washington. The brand new units ranged in size from 10.2 cf to 19.6 cf and were identical to those models previously tested in the ETL laboratory environment.

Data Collection

An 18-month monitoring period began in June 1987 for the units first installed. Data collection did not begin simultaneously on all 12 units; however, a full 18 months of data was collected on each unit.

Data collected were:

- weekly kWh consumption;
- number of weekly door openings;
- food load;
- number of uses of associated features such as ice-makers; and
- average weekly kitchen temperature.

The collection of average weekly kitchen temperature, however, covered only a 3-month period from the last quarter of 1988 as it was not a part of the original test design. In addition, some of the recording instrumentation for kitchen temperature had problems.

III. DATA ANALYSIS

The 18-month data were filtered to a 12-month cumulative kWh consumption. Table 1 shows the annual energy consumption of the field tests in comparison with the Japanese ratings and the laboratory test results as well as the percentages of differentiations in energy use. (See Figure 1 also)

In eight units, energy use during the field tests fell somewhere between the lower end use performance claimed by the Japanese manufacturers and the higher end use resulting from laboratory testing. For example:

The 373 annual kWh consumed by the 10.2 cf unit during field operation was 28 percent more than Japanese results and 44 percent less than the laboratory test results.

The 495 annual kWh consumed by the 10.7 cf unit during field operation was 36 percent more than the Japanese test results and 16 percent less than the laboratory test results.

Duplicate Unit Tests

Of the 12 tested units, six were identical pairs of three refrigerator models; namely, two 17.4 cf Hitachi units; two 16 cf National units; and two 19.6 cf SANYO units. In the laboratory test, the energy consumption varied less than six percent among the duplicate units. In the field test, the variation was the same. For the pair of 17.4 cf units, the energy consumption was near the results of the laboratory tests. For the 16 cf and 19.6 cf units, the energy consumption trended toward the Japanese performance ratings. (See Table 2 and Figure 2.)

TABLE 1
ENERGY CONSUMPTION COMPARISON FOR THE REFRIGERATORS TESTED

:-----:									
:	:	:	:No. of	: Size	:Energy use (kWh/yr):	Diff. %	:	:	:
: Brand	: Model	:Features	: Doors	: c/f	:-----:	:	:	:	:
:	:	: (a)	:	:(Liters)	:JAPAN	:Field	: DOE	:JPN	:DOE:
:-----:									
:Hitachi	: R-316kv	: TF	: 3	:10.2(289)	: 292	: 373	: 537	:+28:-44	:
:Hitachi	: R-942SID	:SS(ice sw)	: 2	:14.8(419)	: 1142	: 1863	:1799	:+63:+4	:
:Hitachi	: R-951SB	: SS(sw)	: 2	:17.4(492)	: 986	: 1337	:1365	:+36:-2	:
:Hitachi	: R-951SB	: SS(sw)	: 2	:17.4(492)	: 986	: 1364	:1365	:+38: 0	:
:	:	:	:	:	:	:	:	:	:
:Mitsubishi	:MR4236W	: TF	: 2	:15.0(424)	: 449	: 617	:679	:+37:-10	:
:	:	:	:	:	:	:	:	:	:
:National	:NR306CG-W	: SS	: 4	:10.7(306)	: 365	: 495	:573	:+36:-16	:
:National	:NR346HV-W	: TF	: 3	:11.5(325)	: 376	: 446	:533	:+19:-20	:
:National	:NR434TR-W	: TF	: 2	:14.9(422)	: 449	: 557	:675	:+24:-21	:
:National	:NR455ER-W	: SS	: 3	:16.0(453)	: 792	: 698	:1077	: -13:-54	:
:National	:NR455ER-W	: SS	: 3	:16.0(453)	: 792	: 708	:1077	: -12:+52	:
:	:	:	:	:	:	:	:	:	:
:Sanyo	: 457FBA	: TF	: 2	:19.6(555)	: 704	: 796	:1049	:+13:-32	:
:Sanyo	: 457FBA	: TF	: 2	:19.6(555)	: 704	: 751	:1049	:+7 :-40	:
:	:	:	:	:	:	:	:	:	:
:-----:									

(a) Key: TF=top freezer, SS=side-by-side, ice-automatic ice-maker,
sw=anti-sweat switch

TABLE 2
ENERGY CONSUMPTION COMPARISON OF DUPLICATE UNITS

Brand	Model	Features (a)	Size in c.f. (liters)	Energy use (kWh/year)			
				Laboratory Test		Field Test	
				Unit # 1	Unit # 2	Unit #1	Unit # 2
Hitachi	R-951SB	SS(sw)	17.4(492)	1365	1357	1337	1364
National	NR455ER-W	SS(sw)	16 (453)	1106	1048	698	708
SANYO	457FBA	TF	19.6(555)	1040	1058	796	751

Further data analysis and correlation for the final report may make these results from the three sources -- manufacturer, laboratory, and actual operations -- less ambiguous.

IV. CONCLUSIONS

In each case, the results of the laboratory test failed to confirm the performance ratings assigned by the Japanese manufacturers in their tests. In part, this result could have been due to differences in test procedures used and to associated factors such as variations in user behavior or the ambient temperature.

It was hoped that field tests would provide verification of which measure -- laboratory or manufacturer -- of energy consumption was more realistic in forecasting energy demand of the refrigerator units. However, in most cases, the actual operation of the units substantiated neither the test results from the laboratory setting nor the estimates of energy efficiency forecast by the manufacturers. It has been, however, a mixed variation.

The fact that the duplicate units provided nearly identical data, though placed in different user environments, indicates that the level of energy consumption identified by the field tests is valid.

The results of the field test, when placed in the context of laboratory and Japanese results, also provide a range of like energy consumption for each unit. This result provides a useful tool in forecasting the demand for electricity in the BPA service area.

V. FURTHER ANALYSIS

Definitive results of the coming detailed analysis may complement these tentative conclusions. The analysis will focus on the following questions:

1. On a case-by-case basis, what is the correlation between energy consumption and kitchen temperature?
2. What are the impacts of door openings on energy use?
3. What other variables explain how these units perform in actual conditions?

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Figure 1. ANNUAL kWh USE for 12

Figure 2. kWh USE AMONG

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