Practical Issues Resulting From Having Different Energy Performance Test Standards For Domestic Refrigerators

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Overview

- ***An ideal test standard***
- ***Lessons Learned from R&D Efforts at The University of Auckland***
- ***Issues and difficulties with current test standards***
- ***Ideas of how they can be "rectified"?***
- ***Future work to be done...***

An *IDEAL* Test Standard ...

- **Three Features (?)**
  - **Repeatable - door openings**
  - **Reproducible - same result in other labs,**
  - **Inexpensive**

$$\boxed{E_{lab} \approx E_{in-field}}$$

- **Results applicable to different climates/users**
- **Consumer can make cost effective decisions**
- **Possible to forecast electricity demand**
- **Encourages product "innovation" and "free trade"**

Current Test Standards...

- Energy consumption results differ from one standard to another due to --
  - different test ambient temperatures and relative humidities
  - compartment internal air temperatures
  - food loading
  - door openings
- Unfair comparisons of refrigerators from different regions by media
- Current test procedures have major weaknesses...
- Systematic comparisons between different test standards - currently no conversion algorithms!

Test Standards and Their Differences

General testing requirements for various test standards

Cabinet Type	Parameters	AS/NZS	ISO	ANSI	JIS#	CNS
Testing Parameters	Ambient (T_A -°C)	*32±0.5°*	*25±0.5°*	*32.2±0.6°*	*15/30±1°*	*30 ±1°*
	Relative Humidity	-	*45 -75 %*	-	*75±5%*	*75±5%*
	Door Openings	*No*	*No*	*No*	*Yes*	*No*
All – Refrigerator	Fresh-Food (T_{FF} - °C)	*3 ±0.5°*	*5°*	*3.3 °*	*3±0.5 °*	*3 ±0.5°*
Refrigerator - Freezer	Fresh-Food (°C)	*3 ±0.5°*	*5°*	*7.2 °*	*3±0.5°*	-
	Freezer (°C)	*-15±0.5°*	*-18°*	*-15°*	*-18±0.5°*	*-18±0.5°*
Freezers	Freezer (T_{FR})	*-15±0.5°C*	*-18 °C*	*-17.8 °C*	*-18±0.5°C*	*-18±0.5°*
Energy Measurement Period		*Lesser of 1 kWh or 16h operation*	*≥ 24 h*	*3h<t <24h 2 or more cycles*	*= 24 h of testing*	*= 24 h of testing*

73% of the consumption is weighted at an ambient of 15°C and 27% at 30°C.

R&D Efforts at the University of Auckland ...

- **Effect of different variables on Energy Consumption**
- **Cabinets were divided into two sets to assess-**
  - **reliability and repeatability of test data**
  - **variability in energy consumption in the same model by the same manufacturer**

Tested models and their reference numbers

Cabinets	Set 1	Set 2	Features
All-Refrigerators	C190_1	C190_2	Frost-free
	C270_1	C270_2	Frost-free
	C370_1	C370_2	Frost-free
Refrigerator-Freezers	N169_1	N169_2	46+108 L
	N249_1	N249_2	46+181 L
	N375_1	N375_2	85+278 L

General Testing Requirements

Cabinets	Testing Parameters	AS/NZS	ISO	Variation (AS/NZS) I	II	III
	Ambient (T_A)	32±0.5 °C	25 ±0.5 °C	32±1 °C	25 ±1 °C	10 ±1 °C
	Relative Humidity	-	45 -75 %	40 - 80±5%	40 - 80±5%	40 - 80±5%
All-Refrigerator	Fresh-Food (T_{FF})	3 ±0.5 °C	5 °C	3 ±0.5 °C	3 ±0.5 °C	3 ±0.5 °C
	Door Openings	No	No	No	No	No
	ΔT ($T_A - T_{FF}$)	29°C	20°C	29°C	22°C	7°C
Refrigerator - Freezer	Freezer (T_{RF})	≤-15°C	≤-18°C	≤- 15°C	≤ - 15°C	≤ - 15°C
	Door Openings	No	No	No	YES[$]	No
	ΔT ($T_A - T_{FR}$)	>47°C	>43°C	>47°C	>40°C	>35°C

[$] Two door-opening schemes were used for refrigerator-freezers as discussed.

Testing Scheme For R/Fs

Refrigerator-Freezers

- ISO: food packs in freezer but no door openings
- JIS: No food loads but door openings of both the compartments
- Current approach: load both the compartments and test with door openings of both the compartments

- Test empty cabinets with “no” door openings at AS/NZS 25/3°C
- Food packs in freezer but empty food compartment and test at AS/NZS 25/3°C
- Food packs in freezer + water bottles (~22% volume) in food compartment and test at AS/NZS 25/3°C
- Both compartments loaded + door openings as per JIS, and
- Both compartments loaded BUT with *Real* door openings scheme.

Door Opening Schemes

Door Opening for the Japanese Industrial Standard

Type		Rate	No. of Openings	Opening Time
All-Refrigerator		Every 12 Min	50	10 s #
Refrigerator -Freezer	Fresh-Food Compartment	every 12 Min	50	10 s #
	Freezer Compartment	every 40 Min	15	10 s #
Freezer		every 40 Min	15	10 s #

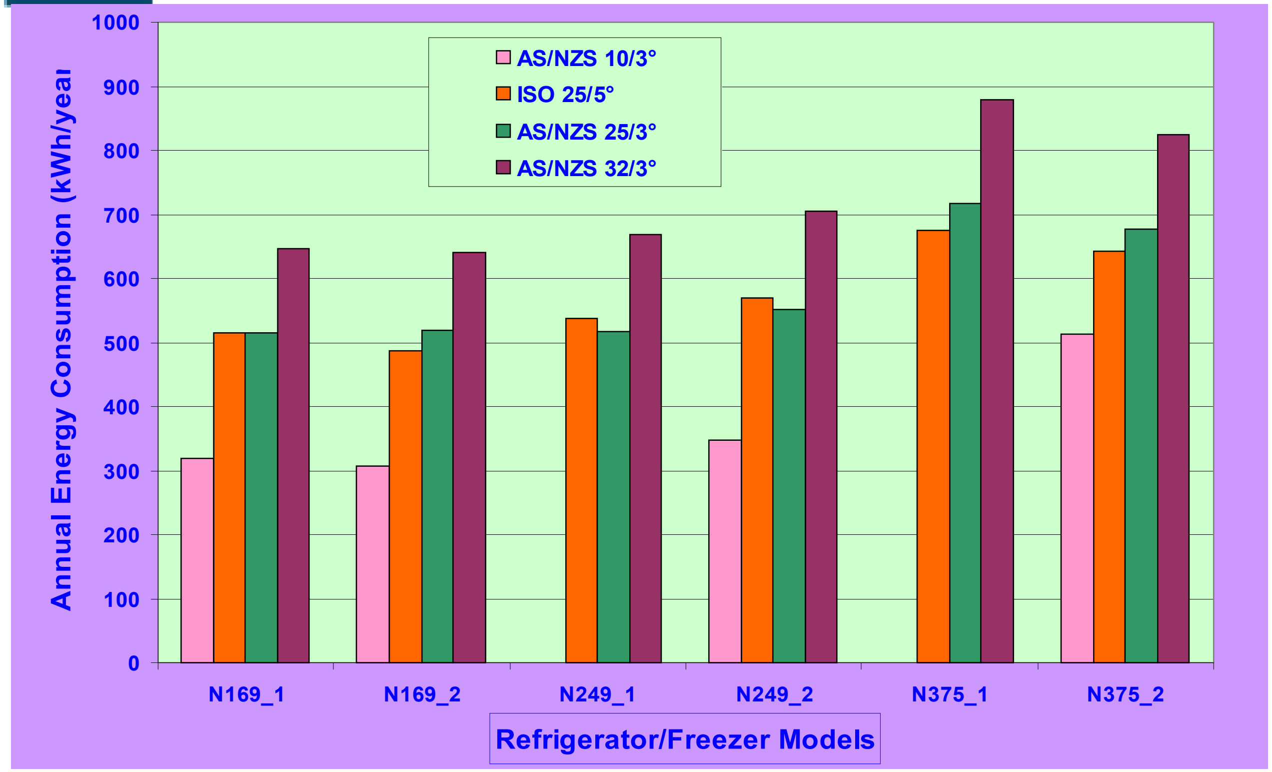
#The doors were fully opened at 90° for 10 s (during first 10 hours of testing).

Real Door Opening Scheme for AS/NZS

Times during The day $	Time period	Door Openings		Total Openings	
		F. Food	Freezer	F. Food	Freezer
Breakfast	0 – 2 hours	10 min.	40 min.	12	3
Morning	2 – 4 hours	20 min.	60 min.	6	2
Lunch	4 – 6 hours	15 min.	60 min.	8	2
Afternoon	6 – 8 hours	20 min.	60 min.	6	2
Dinner	8 – 11 hours	10 min.	40 min.	18	4
Evening	11 – 14 hours	12 min.	40 min.	15	4
Total	Openings	in 24	Hours	65	17

$ The doors were fully open for 10 s and testing was done for at least 24 hours.

R/Fs(1) - ANZS Vs. ISO



AS/NZS Vs. ISO

- For N169_2 and N375_2; AS/NZS 32/3° is 19% and 24% higher than AS/NZS 25/3° and ISO 25/5°
- ISO 25/5° is about 6% lower than AS/NZS 25/3°

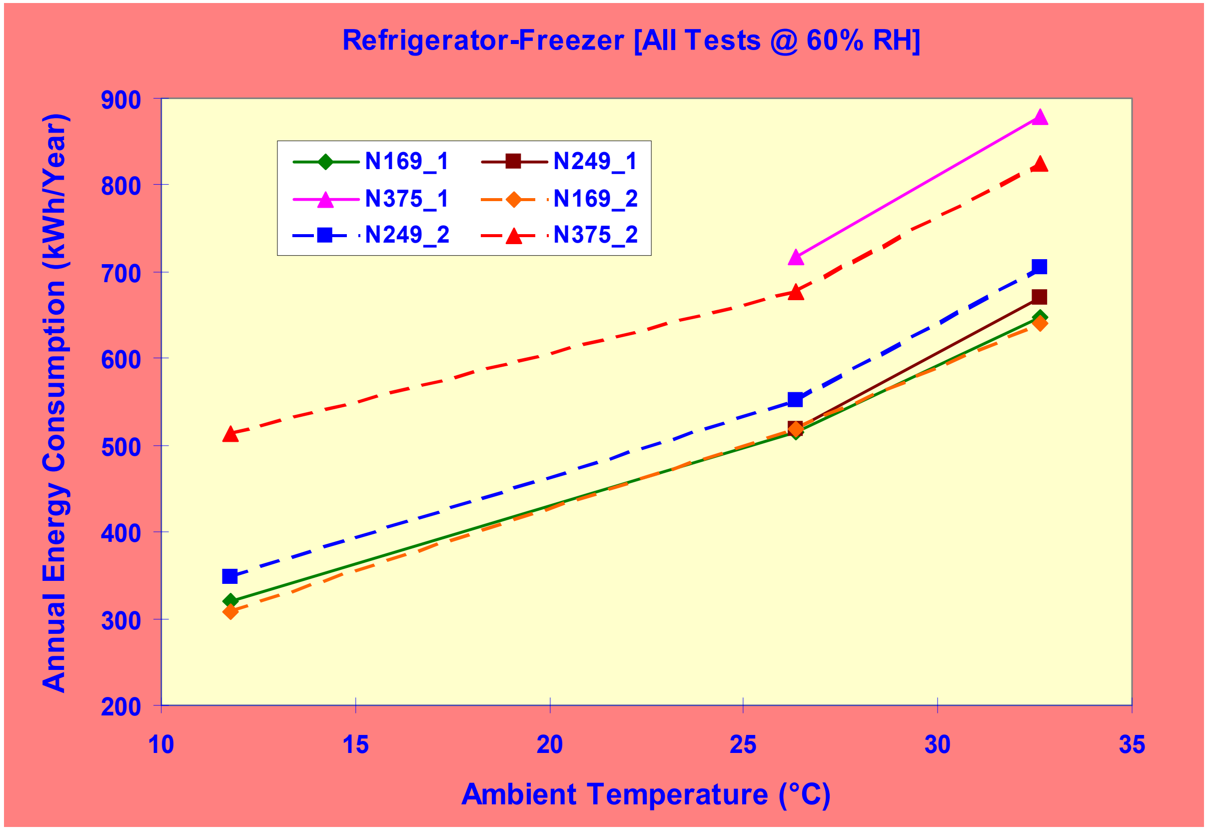
Cabinet Size

- For AS/NZS 32/3°, energy increases by 10% and 28% as size increases from 154 to 227L; and from 227 to 363 L respectively.

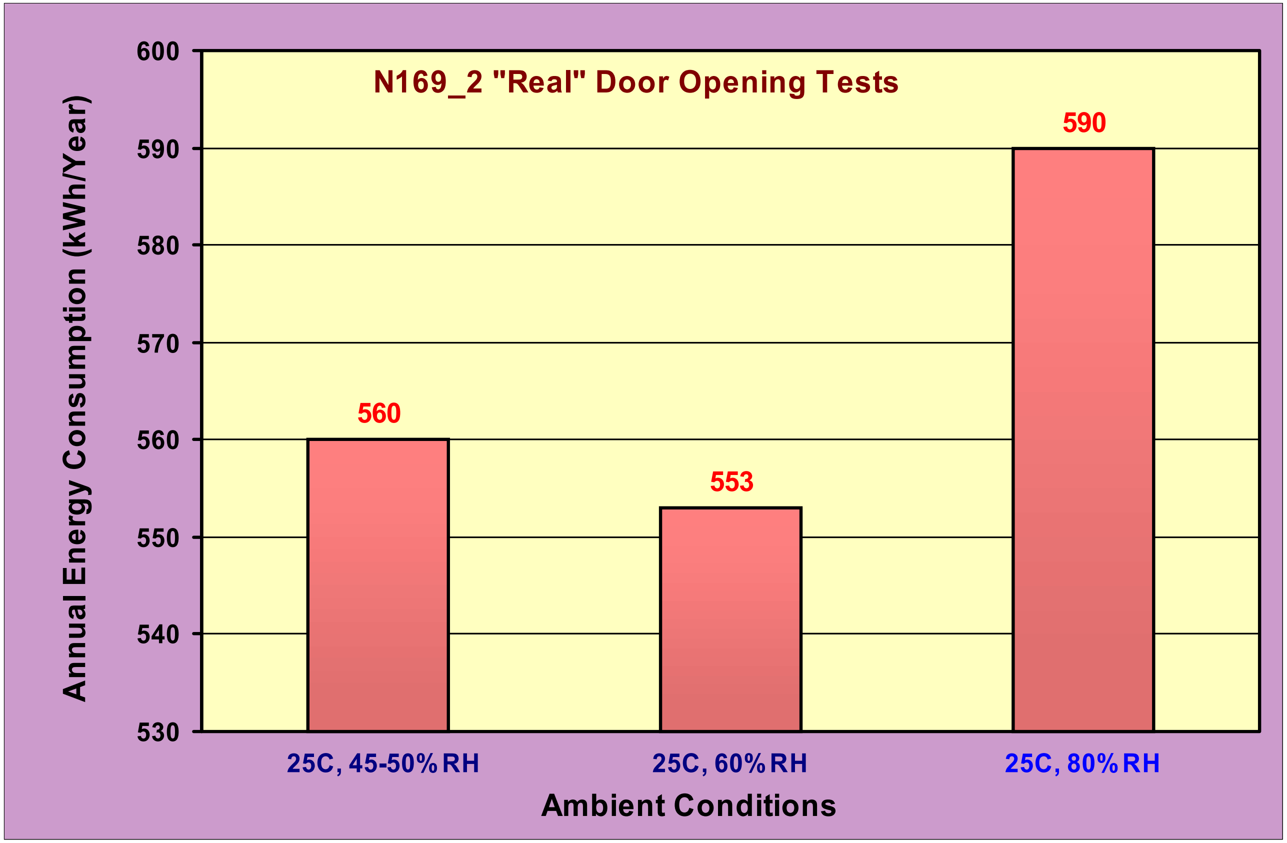
R/Fs(2)- Ambient Temp.

Ambient Temperature

- Relative humidity=60%
- Energy consumption increases by
  - 40% as T ? from 10° to 25°C
  - 20% as T ? from 25° to 32°C
  - 50% as T ? from 10° to 32°C
  - these variations are very similar to all-refrigerators



R/Fs(3)- Relative Humidity

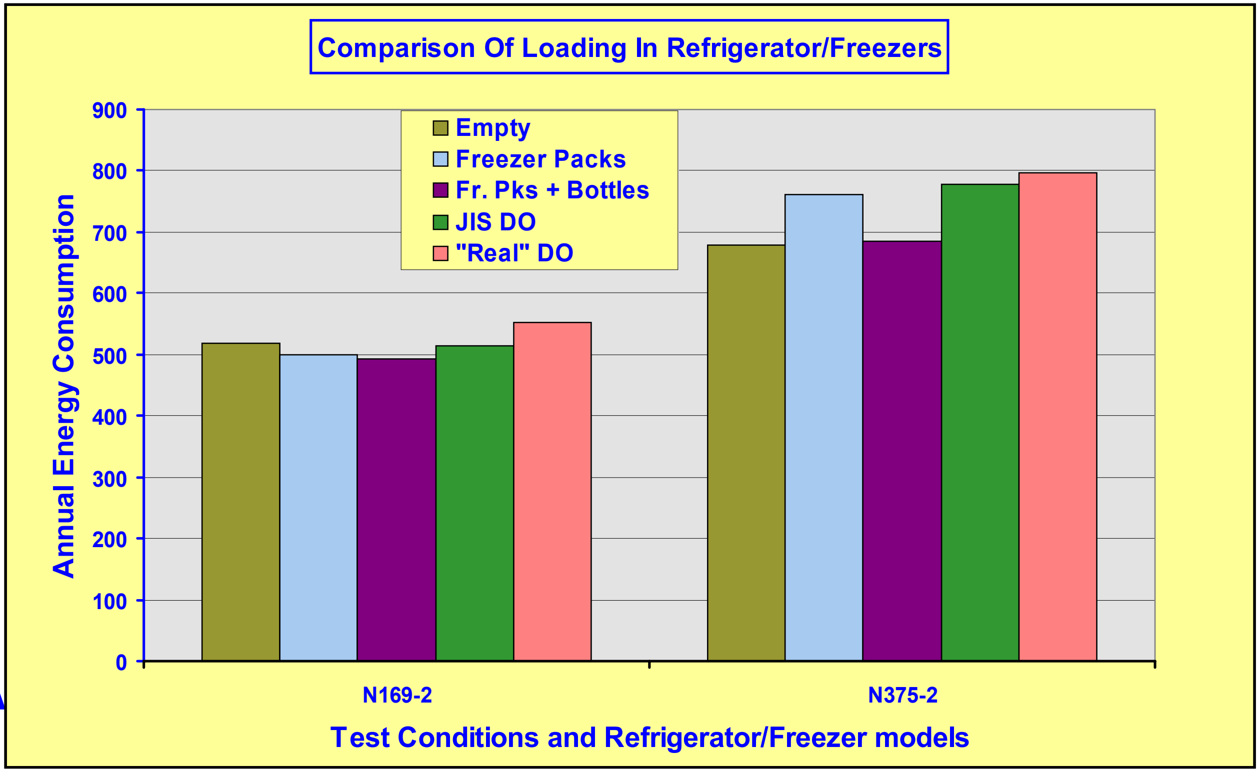


Energy Consumption increases by less than 5% with RH.

R/Fs(4) - Door Openings

EC for N169_2

- ***Real DO*** **> JIS by 6.5%**
- **Real *DO* > AS/NZS 25/3° (food packs and bottles) by 10.5%**
- ***Real DO*** **< AS/NZS 32/3° (closed door; no food) 16%**
- **Meier ~ 15% in USA**
- **EECA ~ 25% in NZ**



Re-capping

- ***Refrigerator/Freezers***
  - *EC in Real DO is about 7% more than JIS,*
  - *EC in ANZS32/3° is 24% and 20% more than ISO 25/5° & AS/NZS 25/3°,*
  - *EC in AS/NZS 32/3° is about 15% more than Real DO at AS/NZS 25/3°,*
  - *EC in AS/NZS 32/3° is about 25% (in NZ) and 10% (in Australia) more than in-field use energy.*

Issues With Current Test Standards (1)

- **Current Test Procedures are Obsolete!**
  - **Can't accommodate "smart" advancements in refrigerator technology e.g.**
    - **microprocessor controllers,**
    - **variable speed compressors,**
    - **adaptive defrost heaters etc.**
  - **Microprocessors may command R/Fs to operate through Internet and/or at night for demand side management!**
- **New generation test procedures are required, which MUST capture both the hardware and software performance - Alan Meier (Berkley)**

Issue (2): Externalities

- **Separate testing of export models**
  - **Expensive and time consuming**

- **Hypothesis that "European Union" R/Fs are more efficient than locals or others?**
  - **Quite the contrary (!) because EC of a R/F in AS/NZS or ANSI is about 20% more than ISO because**
    - **AS/NZS or ANSI are more "stringent" standards**
    - **External heat load is much higher, so that the cabinet is more efficient to meet those specifications.**

- **Imported model may NOT work in Darwin due to high ambient conditions as opposed to ISO's temperate classification?!**

Issues (3): Algorithms

- **Actual Performance**
  - Don't help the consumer-
    - Either to make cost effective decisions to buy a product,
    - or make electricity demand forecasts, because

$$E_{label} \neq E_{in-field}$$

- **Urgent need to develop Conversion Algorithms to**
  - Avoid "cost and time" intensive testing on every model,
  - Facilitate 'free trade' among various economies,
  - Assess R/F performance under different in-service conditions,
  - Help consumer to make 'cost' and 'performance' effective decisions,
  - Enable electricity demand forecasts

Issue (4): Refrigerants

- **It is claimed that HCs (iso-butane) are not necessarily better than R134a at low evaporating temperatures but are better at high temperatures**
  - **This means that a cabinet (using iso-butane) may consistently perform better in ISO than AS/NZS or ANSI**
    - » **less heat load**
    - » **high evaporating temperature**
  - **This raises two issues-**
    - » **Energy Consumptions would be specific to the refrigerant used,**
    - » **Energy consumption conversion from one standard to another may be difficult using "traditional" approaches.**
  - **Specific conversion algorithms may need to be developed.**

Issue (5): Harmonisation of Test Standards

- **Compartment Temperatures: Most Standards use**
  - » -18°C for the freezer except AS/NZS (-15°C)
  - » 3°C for the food compartment except ANSI and ISO (5°C)
  - » All standards should use -18°C (freezer) and 3°C (fresh food).
- **Food Packs In Frost Free R/Fs In ISO-**
  - » Unstable conditions, especially with frequent defrosts (~10 h apart!)
  - » "warmest" food pack temperature for energy calculation-
    - leads to freezer running a lot colder (~ -22°C)
  - » Two recommendations-
    - Freezer should be tested unloaded, and
    - "Average" temperature of -18°C should be used to be consistent with other standards

Issue (6): Ambient Temperature And Door Openings

- **Most standards specify a "static" test at a single ambient temperature with 'doors' closed**
  - **"unsatisfactory results" because-**
    - » **high ambients (in AS/NZS or ANSI) crudely compensate for door opening loads since kitchens rarely exceed 20°C,**
    - » **This compensation is less realistic as cabinet insulation is improved -**
      - **well insulated cabinets that perform well in AS/NZS would be less impressive in the "real world" use,**
      - **slope of EC Vs $T_{ambient}$ differ for each model type,**
      - **cabinets optimised around a "static" point may be less impressive at other ambients,**
    - » **door openings have poor repeatability and are expensive.**
  - **Therefore, a new standard should be evolved that has the realism of JIS (with door openings) PLUS the simplicity of AS/NZS.**

A Generic Approach

Total Energy Consumption

$$E = E_{amb} + E_{process} + E_{defrost} + E_{other}$$

Ambient heat load due to ?T

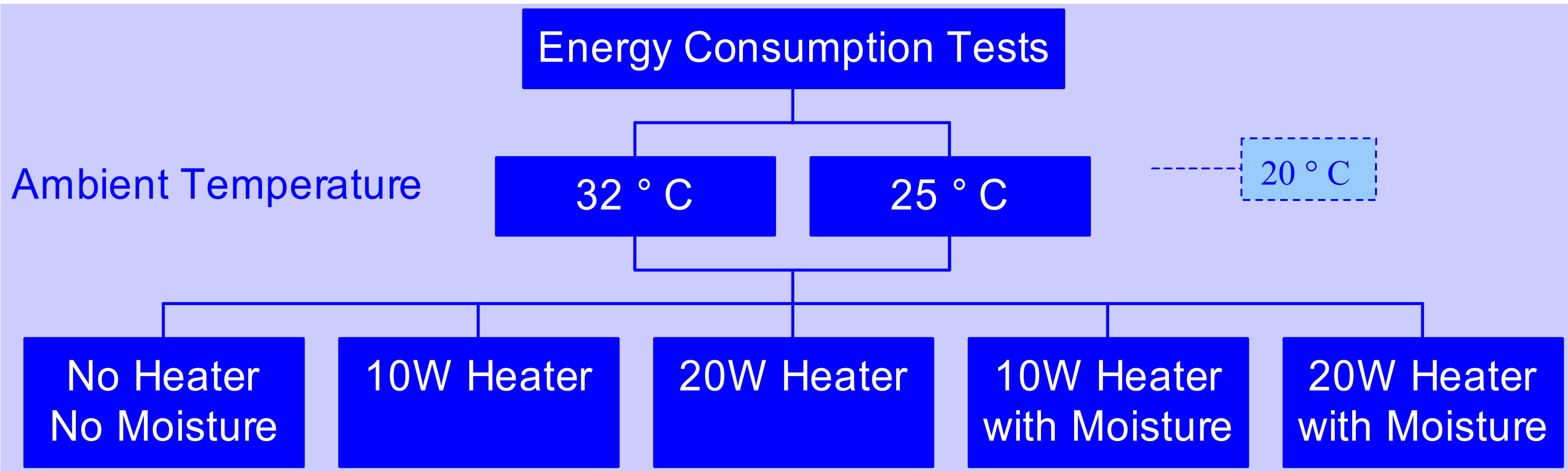
Air Infiltration + warm food

Defrost heater

Anti-sweat heaters, lights, switches

External Loads

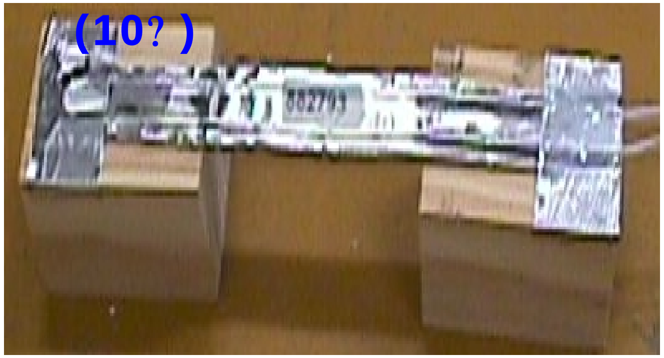
Testing Approach

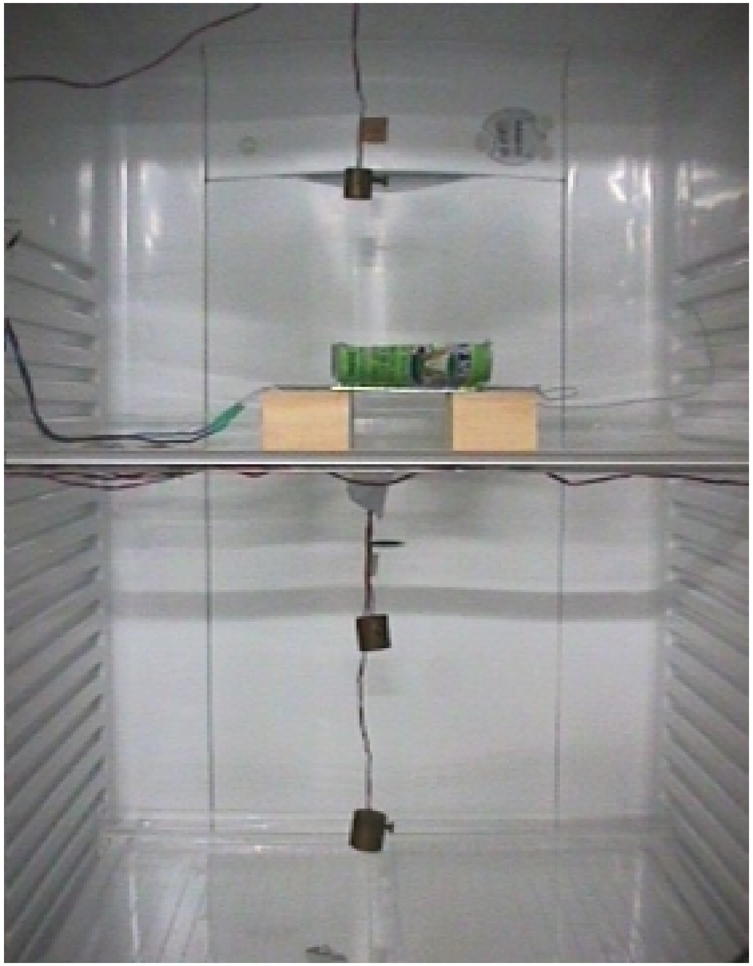


- Total of 48 Energy Consumption Tests
- Extrapolate results for lower ambients (say 20ºC).

Experimental Setup

Resistance Heater (10?)

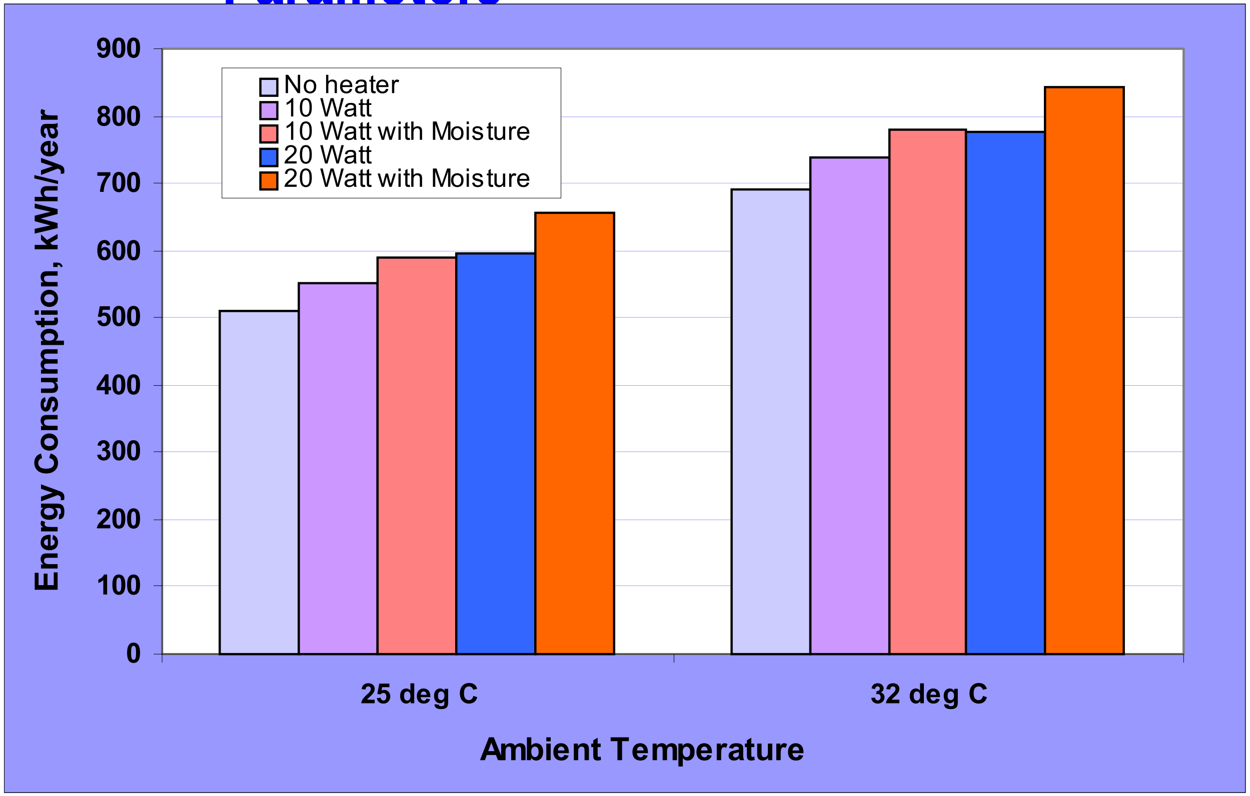




Effect of Testing Variables

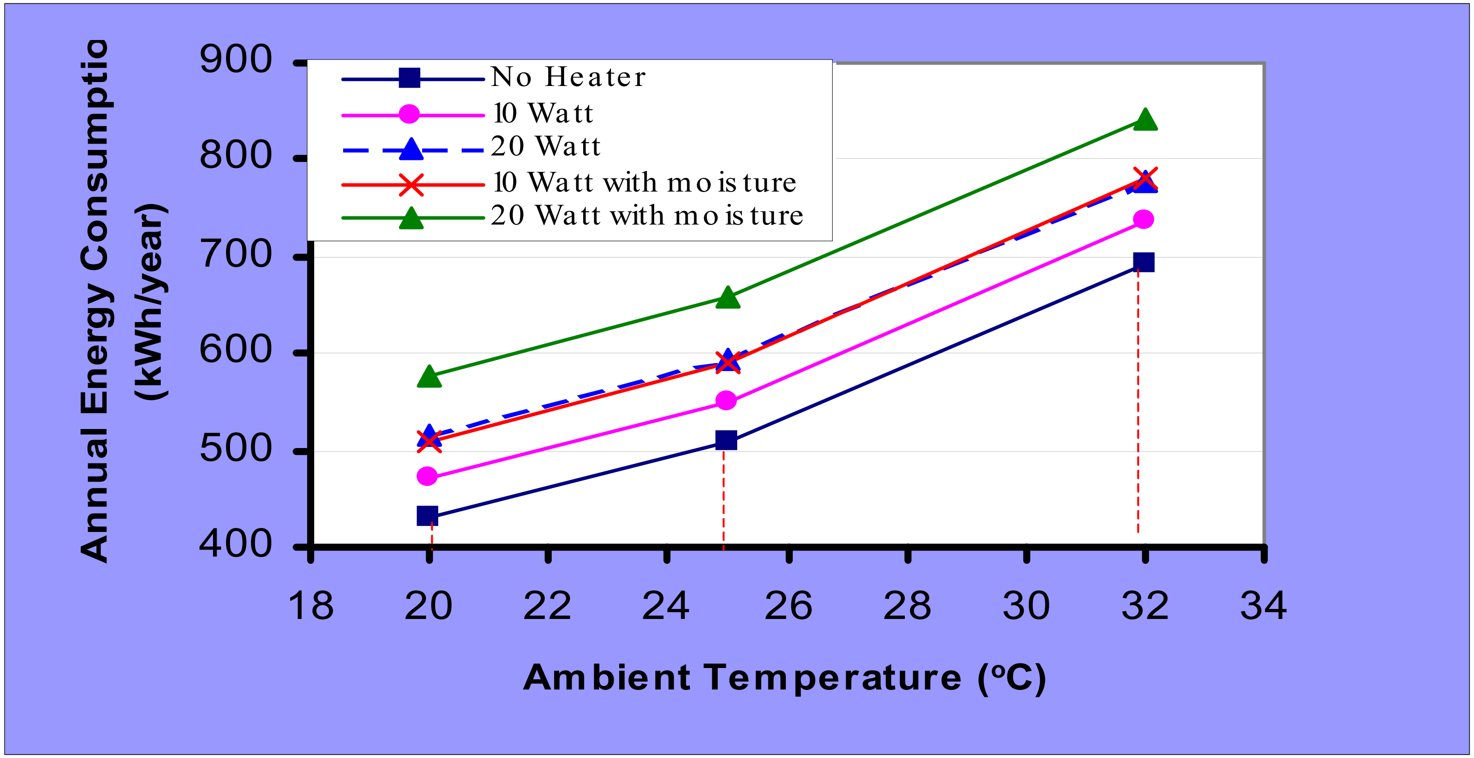
Annual Energy Consumption for Various Parameters

- EC is about 25% higher at 32°C.
- EC increased by about 7.5% with every 10W additional heat load.
- EC with (10W + moisture) = EC with (20W).



Effect of Testing Variables

Annual Energy Consumption with Various Parameters



? 75% of EC at 32°C = EC at 20°C with 20W heater

Future Direction ...

- **Closed door tests at lower ambients with additional heat load are demonstrated to be very useful for MEPS**
- **R&D is required to**
  - **Formulate a test procedure that is simple, repeatable, reproducible and inexpensive,**
  - **Design closed door tests that can yield energy consumption - a *true representative* of the in-field data (as shown here)**
  - **Develop EC Vs $T_{ambient}$ profiles for different cabinet models**
  - **Develop Energy Consumption Algorithms**
- **New standard is needed - with the realism of *Real door openings of the* JIS plus the simplicity of AS/NZS**
  - **Harmonised standards for reasons of free trade,**
  - **New standards MUST capture both the hardware and software performance**

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