STUDIES ON ALGORITHM DEVELOPMENT FOR ENERGY PERFORMANCE TESTING

STUDY 1 - SELECTION OF PRODUCT GROUPS

ASIA-PACIFIC ECONOMIC COOPERATION

APEC Energy Working Group

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STUDIES ON ALGORITHM DEVELOPMENT FOR ENERGY PERFORMANCE TESTING

STUDY 1 - SELECTION OF PRODUCT GROUPS

Prepared by Lloyd Harrington
Energy Efficient Strategies, Melbourne, Australia

with assistance from

Dr Paul Waide
PW Consulting, Manchester, UK

FINAL REPORT, 30 November 2001

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APEC Secretariat
438 Alexandra Road
#14-00 Alexandra Point
Singapore 119958

Tel: +65 2761880
Fax: +65 2761775

Email: info@mail.apecsec.org.sg
Website: http://www.apecsec.org.sg

Foreword

This project entitled *Studies On Algorithm Development for Energy Performance Testing* is one of a number of projects managed by the APEC Energy Working Group to address the requests of APEC Energy Ministers to strengthen cooperation on energy efficiency standards.

The Energy Working Group is one of ten APEC working groups. Its goal is to maximise the energy sector's contribution to the region's economic and social well being through activities in five areas of strategic importance:

- energy supply and demand,
- energy and the environment,
- energy efficiency and conservation,
- energy research, development and technology transfer, and
- minerals and energy exploration and development.

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The electronic version of this report is in PDF format and has been formatted for double sided printing on A4 paper, with all odd pages on the right hand side and all even pages on the left.

This report is Study 1 - Selection of Product Groups. There are three other components to the *APEC Algorithm project* as follows:

- Study 2: Study of algorithms for domestic refrigeration appliances
- Study 3: Study of algorithms for air conditioners
- Study 4: Survey of industry and regulators

Energy Efficient Strategies

Warragul, Australia, November 2001

EXECUTIVE SUMMARY

General conclusions

A wide range of electrical products are regulated for energy efficiency within APEC member economies. This list is even more extensive if economies outside of APEC are also considered. Given the lack of harmony among the existing energy consumption and performance test procedures, industry is likely to incur a significant cost through reduced access to markets and additional testing in order to meet local regulatory energy efficiency requirements.

This study has examined the main electrical product groups that are regulated for energy efficiency with a view to assessing whether a "conversion algorithm" is feasible and desirable. While making this assessment, products for which algorithms are inappropriate or unnecessary have also been identified.

In its simplest form, a conversion algorithm is a simple adjustment factor that could allow a measure of energy and/or performance under one test procedure to be converted to an equivalent and comparative value under a different test procedure, without the need for additional retesting. In its most complex form, an algorithm could be a modelling algorithm consisting of a computer model that is used to simulate a product's performance and energy consumption under a range of conditions, including different test procedures, or conditions of actual use (in a factory or household, for example).

In general, depending on the product, it is recommended either that test procedures be aligned (i.e. that significant differences between them be removed) or that a conversion algorithm be developed (i.e. that the existing local test procedures be retained, but that a method or procedure be developed which can accurately convert between them). For some specific products it is recommended to both align test procedures and develop conversion algorithms. This is because although there are significant differences between the existing test procedures for these products, none of them are very well suited to predicting local energy consumption and efficiency levels. Under these circumstances it can be more appropriate to develop a harmonised test procedure that is designed for use with an algorithm to convert performance results under standard test conditions into more representative values under local conditions. For a few products, no action is recommended because there is unlikely to be a significant restriction in trade due to energy efficiency requirements.

Products recommended for alignment

As a general rule, where alignment is recommended, it is in accordance with the relevant international standard for the product. However, there are a number of cases where there is currently no suitable international standard, or where the published international standard is inadequate to be recommended for alignment within APEC. In these cases a specific strategy is proposed. The recommendations for each product for which alignment within APEC is recommended are summarised below. Products that are recommended for both alignment and modelling algorithm development are indicated by the symbol **.

Household refrigerators and freezers **

The recommendations for refrigerators and freezers are:

- to actively work on the ISO refrigerator test standard to improve its reproducibility and its applicability to a range of refrigerator technologies (especially frost-free systems) and configurations;
- to work towards the universal use of ISO volume measurement procedures (while acknowledging that the current ISO definitions need to be refined);
- to undertake work within ISO to improve the treatment of unusual compartment types and configurations;
- to improve the ISO test procedure treatment of smart technologies (especially for adaptive defrosting technologies, but also for variable-speed compressors);
- to actively move towards alignment of key elements of the refrigerator test procedure, such as those concerning materials (test packs), measurement instrumentation and tolerances, volume measurements and standardised internal temperature conditions (and measurement methods) for energy consumption measurement;
- to examine ways to incorporate key usage elements (humidity and defrosting, and user-introduced food loads) into a basic test method with a view to building up information for an improved combined testing–modelling approach;
- to undertake serious investigations with regard to options for developing a modelling algorithm for refrigerators and freezers;
- depending upon feasibility, to work towards establishing consensus regarding the longer-term vision for the combined use of a single harmonised test procedure with an energy consumption modelling algorithm, in order to eliminate arbitrary differences in the test procedures while allowing the generation of energy performance results that are more representative of local circumstances.

Automatic icemakers

It is recommended that, where a test procedure for the performance of automatic ice-makers is necessary, APEC member economies align with the requirements of ASHRAE 29. If necessary, this could also be developed into an international standard.

Commercial refrigeration equipment

It is recommended that APEC works towards the development of a suitable international test method (or methods) for these products. The relevant published ASHRAE, CAN/CSA and European standards should be used as the initial basis for such an international standard. The main test procedures that should be considered as the potential basis for an international standard, according to product type, are:

- remote refrigeration: CAN/CSA-C657, ANSI/ASHRAE 72 and ANSI/AHSRAE 117 (equivalent to CAN/CSA) and draft European Standard prEN 441;
- self-contained refrigeration: CAN/CSA-C827, ANSI/AHSRAE 117 (equivalent to CAN/CSA) and draft European Standard prEN 441;

- vending machines: CAN/CSA-C804, ANSI/AHSRAE 32.1 (equivalent to CAN/CSA).

Air conditioners and heat pumps **

The recommendations for air conditioners are:

- to provide some effort and resources into eliminating the currently somewhat arbitrary (but mostly small) differences in test conditions and tolerances for testing of air conditioners and heat pumps within APEC member economies. Aligning to ISO5151 T1 (and ISO13253 and ISO13256 as applicable) would appear to be a feasible option, while acknowledging that ISO approaches and definitions need to be refined in some cases over the longer term;
- to work gradually towards the development and adoption of an international coding system of definitions for air conditioners within APEC member economies, in order to assist with the uniform treatment of air conditioning products in a regulatory sense;
- to undertake further investigations into the feasibility of developing a full simulation model for air conditioners as a medium-term goal (including a calibration process against physical tests). Such an approach should make particular reference to the accurate estimation of performance under standard rating conditions (for comparative and regulatory purposes), simulation of actual usage under a range of climates, and more realistically and accurately assessing the performance of variable-speed drive compressor systems under conditions of actual use (e.g. a range of part load conditions).

Other air conditioners

The recommended strategy for other more "non-conventional" air conditioner types (e.g. water-sourced heat pumps, ground-sourced heat pumps and closed-loop heat pumps) is essentially the same as for conventional air conditioners: alignment of the test elements as far as possible in the first instance to the relevant ISO standards (e.g. ISO13256). Modelling algorithms can be developed if these prove successful for conventional air-to-air heat-exchanger products. Such algorithms for non-conventional air conditioners may be possible, but these are more likely to be complex for product types such as ground-source and water-source heat pumps.

Dehumidifiers

At this stage there is no international test method for the performance of dehumidifiers; however, it is understood that AHAM will be proposing its test method (AHAM DH-1) to IEC TC59 as the basis for a new international standard in the near future. It is recommended that the development of this new IEC standard, which will provide a good basis for future alignment, be supported by APEC.

Electric motors

IEC now appears to have resolved the outstanding technical issues associated with a new international standard for motors and will soon publish a standard (a full revision of IEC60034.2) that characterises motors over a range of conditions and which is accurate and competent. This new standard will be equivalent to the historically superior North American motor test procedures (NEMA MG 1-1987 and ANSI/IEEE 112-1984 Method B). It is recommended that APEC considers using this new IEC standard as a suitable basis for future standard alignment once published.

Lighting equipment

The following recommendations are made for lighting products:

- active alignment with IEC standards for lighting products, other than fluorescent lamp ballasts;
- closer examination of the adequacy of IEC standards for HID and quartz-halogen systems for energy efficiency regulatory purposes (noting that these products are currently subjected to minimal regulation, but that regulation is likely to increase);
- encouragement of APEC participation in the development of a new IEC standard for the measurement of fluorescent lamp ballast efficacy based on the published standard AS/NZS4783.1-2001.

Clothes washers

The recommendations for clothes washers are for:

- active participation in IEC committee SC59D to assist in the development of a relevant international clothes washer performance standard, noting that IEC has recently formed a working group called "Global Application of IEC60456" to achieve such a goal;
- medium-term alignment to the IEC standard when this is deemed acceptable. In the meantime a number of disparate clothes washer test methods are likely to remain in place.

Clothes dryers **

IEC61121 could eventually provide a suitable international test procedure for clothes dryers once some of the outstanding technical issues are resolved, especially the current energy correction methodology. The basic test elements of the IEC standard could form the basis of a suitable standard for alignment within APEC. It is recommended that APEC instigates more widespread international participation in the IEC clothes dryer standard committee to ensure that it is applicable within APEC.

Substantial retesting because of local variations in initial moisture content could be avoided if the generic performance algorithm approach for clothes dryers can be refined and accepted. It is recommended that this area of development receives some significant effort over the next few years. Once such a test methodology becomes available, it is recommended that APEC considers the feasibility of alignment with this approach. Therefore, the development of a separate conversion algorithm is probably neither necessary nor recommended for this product (however, the generic approach may be considered as an algorithm in itself).

The recommendations for clothes dryers are for:

- active participation in IEC committee SC59D to assist in the development of a relevant international clothes dryer performance standard;
- inclusion of a more accurate energy consumption measurement method into the IEC standard and the elimination of the current inaccurate energy correction method;
- development over the longer term of a more generalised IEC dryer standard that could accurately estimate energy consumption over a wide range of initial moisture contents (in effect a partial modelling algorithm based on test measurements);
- medium-term alignment with this generalised IEC standard/algorithm when this is deemed acceptable, which would then allow for a range of initial moisture contents to be used in local or regional standards to better reflect local usage conditions.

Dishwashers

The recommendations for dishwashers are for:

- active participation in IEC subcommittee SC59A to assist in the finalisation and maintenance of a relevant international dishwasher performance standard;
- short- to medium-term alignment to the IEC test method once published.

Office equipment and consumer electronics

APEC should coordinate approaches to the measurement of standby energy consumption for its various voluntary and mandatory programs in operation or under consideration. APEC member economies with a direct interest in standby energy consumption should actively participate in the new IEC TC59 project to examine test methods for the determination of standby losses. Development of an algorithm at this stage is not considered likely, nor is an investigation into the feasibility of an algorithm recommended.

Power transformers

Given that there are few differences in the test methods used in North America (NEMA TP1, NEMA TP2, ANSI/IEEE C57.12.91, ANSI/IEEE C57.12.90, CAN/CSA-C802.1-00, CAN/CSA-C802.2-00) and IEC standards (IEC60076 and IEC60726), it is recommended that APEC considers using the IEC standards as a suitable test method for future alignment for power transformers. North America should be encouraged to actively participate in the relevant IEC committee to ensure that the IEC test method adequately meets its testing requirements.

Industrial fans

It is recommended that where a test procedure for the performance of industrial fans is necessary, APEC member economies generally align with ISO5801.

Pumps

It is recommended that where a test procedure for the performance of pumps is necessary, APEC member economies generally align with ISO2548 and ISO3555.

Products recommended for conversion or modelling algorithm

The recommendations for each product for which the development of a conversion algorithm within APEC is recommended are summarised below. Products that are recommended for both alignment and modelling algorithm development are indicated by the symbol **. For these products, the detailed recommendations are included above.

Household refrigerators and freezers **

Full recommendations for algorithm development for refrigerators and freezers are given above (page vi). A full discussion of the background to and options for refrigerator and freezer algorithms is contained in Section 5.2.1.2 (page 23).

The results of *Study 2: Study of algorithms for domestic refrigeration appliances* (which also forms part of this project) should also be considered in the light of these recommendations.

Air conditioners and heat pumps **

Full recommendations for algorithm development for air conditioners and heat pumps are given above (page vii). A full discussion of the background to and options for air conditioner and heat pump algorithms is contained in Section 5.3.1.2 (page 28).

The results of *Study 3: Study of algorithms for air conditioners* (which also forms part of this project) should also be considered in the light of these recommendations.

Electric water heaters

A full discussion of the background to and options for electric water heater algorithms is contained in Section 5.6.1.2 (page 39).

The prospects for alignment of water heater test procedures appear to be poor. The only feasible option appears to be the development of a modelling algorithm that would allow accurate modelling and characterisation of a wide range of climate conditions and usage patterns. Such a computer model already exists and is in the process of being developed into an international standard (refer to AS4234). APEC should provide active assistance in this development, particularly with regard to the specification of input requirements for conventional water heater types. It may be necessary to specify a standard set of tests to measure the key attributes of a water heater for such an algorithm, but these tests are likely to be no more onerous (often less onerous) than current test methods for water heaters. Such measurements may form part of an international standard.

Clothes dryers **

Full recommendations for algorithm development for clothes dryers are given above (page viii). A full discussion of the background to and options for clothes dryer algorithms is contained in Section 5.6.3.2 (page 43).

Products for which no specific action is recommended

Products for which there is no recommended action within APEC for the time being are listed below.

Ranges & ovens

It is recognised that there are some problems associated with the IEC international test method (IEC60350) for ranges and ovens at this stage. Given that the level of regulation for this product is relatively low, no specific action is recommended at this stage. However, Canada might wish to consider more active participation in the relevant IEC committee to improve the international test method so that it is suitable for alignment within APEC, should this be required in the future.

Microwave ovens

The IEC standard for microwave oven performance (IEC60705) is generally considered competent and ought to be suitable for alignment within APEC should a test method be required. Given that the level of regulation for this product is relatively low, no specific action is recommended at this stage.

Vacuum cleaners

The IEC standard for vacuum cleaner performance (IEC60312) is generally considered competent and ought to be suitable for alignment within APEC should a test method be required. However, given that the level of regulation for this product is relatively low, no action is recommended at this stage.

Irons

The IEC standard for iron performance (IEC60311) is generally considered competent and ought to be suitable for alignment within APEC should a test method be required. However, given that the level of regulation for this product is relatively low, no action is recommended at this stage.

Other products

Other products for which no specific recommendations for action have been made include:

- electric space heaters;
- boilers;
- furnaces;

- rice cookers;
- pool heaters.

Other recommendations

For the above recommendations to be effective, it would be necessary to institute and maintain a system by which those responsible for energy efficiency standards in each APEC member economy are kept informed of all developments on such standards within APEC and international forums. APEC project EWG 1/2001T (Energy Standards Information Development) represents a start, but a more long-term system ought to be instituted.

In particular, the participation of APEC member economies in ISO and IEC work ought to be encouraged and facilitated.

Future work

The product groups for which there is the greatest need or potential for developing algorithms are refrigeration appliances and air conditioners. These are covered in greater detail in Studies 2 and 3 of this project. Work on algorithm development is also recommended for water heaters and clothes dryers. Study 4 investigates the acceptability of the concept of algorithm use with various stakeholders, including regulators. The results from these studies need to be taken into account before planning future work in detail.

Whether or not algorithm development proceeds, there will still be a need for the longer-term alignment of standards, preferably based on international standards that have been appropriately influenced by APEC member economies.

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Glossary

APEC – Asia Pacific Economic Cooperation

APEC's Osaka Action Agenda – see Chapter 2.1.1

Comparative energy labelling program – the application of labels to appliances and equipment that allow potential buyers to compare the energy efficiency and/or energy consumption of different models.

Cooling only – air conditioner that can only cool, usually of the vapour compression type, although other types are possible (absorption, evaporative).

COP – coefficient of performance; a measure of the efficiency for an air conditioner, usually in the heating mode (EER now defines cooling efficiency). Units can vary, but SI/metric units are Watts/Watt.

CTI – APEC Committee on Trade and Investment

EER – energy efficiency ratio: a measure of energy efficiency for an air conditioner in the cooling mode. Units can vary considerably – typically Watts/Watt, BTU/Watt hour or kCal/Watt hour. Care is required when comparing these variables. SI/metric units are Watts/Watt.

EES – Energy Efficient Strategies (lead author for Study 1)

EGEEC – APEC Expert Group on Energy Efficiency and Conservation

Endorsement labelling program – an endorsement is a voluntary label which indicates to potential buyers that a product meets a certain efficiency standard or is part of a "high efficiency" group, but does not directly compare efficiency against other models in the market.

EQV – term used to compare test procedures indicating that two procedures are equivalent in technical content but not fully identical in presentation i.e. with minor technical deviations that do not render unacceptable anything that was acceptable under the terms of the other standard .

Heat pump – an air conditioner of the vapour compression type which is primarily configured to operate as a space heater rather than a cooling device.

IDT – term used to compare test procedures and indicates that they are technically identical – i.e. any deviations are editorial changes that do not alter the technical content of the standard and do not change the clause structure and numbering.

M – Mandatory program (law or regulation)

MAPA – APEC leader's Manila Action Plan (see Chapter 2.1.2)

MEPS – minimum energy performance standard, also called minimum energy efficiency standard (or just "Standards") in some economies. Products cannot be legally sold unless they meet the specified level of energy efficiency.

MFD – multi-function devices – usually combination of printer/fax/scanner and/or copier.

NAFTA – North American free trade agreement (Canada, Mexico, USA)

NEQ – term used to compare test procedures and indicating that two procedures are not equivalent in terms of their technical content although they are based on (or related to) each other i.e. the test procedures contain significant technical and editorial deviations which make them incompatible.

Reverse cycle air conditioners – an air conditioner of the vapour compression type that can heat or cool by internal reversal of the refrigeration process.

SCSC – APEC Sub-committee on Standards and Conformance

SEER – Seasonal Energy Efficiency Ratio: usually a composite weighted average of energy efficiency for a reverse cycle air conditioner over a range of heating and cooling tasks. Often involves part load testing. Sometimes may apply just to cooling only air conditioners over a range of part and full load conditions. Widely used in North America and Japan.

SGES – APEC Steering Group on Energy Standards

T12, T8, T5 etc. – dimensional specification of tubular fluorescent lamps in eighths of an inch: e.g. T12 is 1.5 inches diameter (38mm) while T8 is 26mm and T5 is 16mm.

UC – Under consideration (not implemented).

1 INTRODUCTION

1.1 Background

Internationally there is a recognised need to raise the efficiency of energy use, and to this end many APEC member economies have introduced regulatory requirements such as minimum energy performance standards (MEPS) or energy performance labelling for selected products. Not all APEC member economies require MEPS or labelling for all energy using products (some economies require none) and for most products different requirements apply in different APEC member economies. The lack of compatible energy efficiency regulatory requirements, especially where different test procedures are used to determine energy and performance, means that there is potentially an additional cost to trade in energy using products.

This project is one of a series of projects managed by the APEC EWG Expert Group on Energy Efficiency and Conservation (EGEEC) to address the requests of APEC Energy Ministers to strengthen cooperation on energy efficiency standards. The Expert Group reports to the APEC Energy Working Group.

1.1.1 Project objective

One of the objectives of the EGEEC is to foster the development and use of energy performance test result conversion algorithms, with the aim of avoiding expensive multiple testing of appliances to different test standards when those appliances are subject to different energy performance requirements in various economies.

The objectives of this project are to confirm the identity of the products for which the development of test result conversion algorithms would be appropriate, practicable and realistic, and to determine the features of those algorithms. A subsequent project would be needed to facilitate the development of each product test conversion algorithm.

1.1.2 APEC Energy Working Group

The Energy Working Group (EWG) is one of nine APEC working groups. Its goal is to maximise the energy sector's contribution to the region's economic and social well being through activities in five areas of strategic importance:

- energy supply and demand,
- energy and the environment,
- energy efficiency and conservation,
- energy research, development and technology transfer, and
- minerals and energy exploration and development.

1.1.3 General situation

There is a recognised need to raise the efficiency of energy use, and to this end some individual APEC member economies have introduced regulatory requirements concerning the minimum energy performance or energy performance labelling of selected products. These requirements are often different in each economy and therefore have the potential to impose an additional cost on the trade of energy using products.

1.1.4 APEC Energy Ministers declaration

The Energy Ministers of the APEC member economies have issued a declaration noting both the important role of energy efficiency standards in accomplishing energy efficiency goals and the scope for reducing the cost of trade in products which are subject to them. The EGEEC has been asked to "work towards the establishment of bases for the direct comparison of the outcomes of testing to different standards so that the need for testing to multiple standards can be reduced or removed" (APEC Energy Ministers, Sydney meeting – details are given in SGES 2000).

Specifically, the project is expected to lead to a strengthening of the open multilateral trading system by enabling recognition of the results of a single test instead of requiring multiple testing, and will thus be in line with Section B of Part One of APEC's Osaka Action Agenda.

1.1.5 Previous work

In 1999, EES (with assistance from a range of consultants) completed a project entitled *Review of energy efficiency test standards and regulations in APEC member economies* (Project 03/98T, Publication Number: APEC #99-RE-01.5) (EES 1999). This study documented the energy labelling and MEPS programs in operation or proposed in APEC member economies for electrical products and also documented in detail the test procedures used for these programs. It also reported the international test methods published by ISO and IEC and made an initial assessment of the prospects for alignment of test procedures within APEC.

A number of other recent projects also examine test procedures in detail and include some brief consideration of the issue of test procedure conversion algorithms as follows:

- Symposium on Domestic Refrigeration Appliances (NZ) (EES 2000)
- Colloquium on Technical Issues of Minimum Energy Performance Standards (ballasts and air conditioners) (APEC 1999)
- Technical colloquium on energy efficiency testing procedures for motors, refrigerators and air conditioners (AGREE 1997)
- MEPS testing for refrigerators in Australia (units were tested to ISO, AS/NZS and US test methods) (summary in Harrington 2001).

1.2 Project brief – Study 1: Selection of Product Groups

The main output of this project is a detailed report to identify products for which the development of testing algorithms would be appropriate, noting that the form, potential accuracy and purpose of algorithms may be different for each product group.

The scope of the study is limited to electrical appliances and equipment and does not cover safety or non-energy related products or requirements. The study is applicable to all 21 APEC member economies.

The scope of work was as follows:

- Undertake the study, including familiarisation with previous work by EWG relating to the topic;
- Identify product groups for which the use of test result conversion algorithms may be appropriate (and those for which algorithms are inappropriate or unnecessary).

There are three other components to this APEC Algorithm project as follows:

- Study 2: Study of algorithms for domestic refrigeration appliances;
- Study 3: Study of algorithms for air conditioners; &
- Study 4: Survey of industry and regulators.

1.3 Approach to the project

This current study on algorithms is intended to address a distinct aspect of the second request of ministers above, in terms of options which will enable conversion between existing test methods ("bases of comparison of the outcomes of testing to different standards"), in contrast to alignment of test procedures. The study assesses each product group in some detail and assesses the prospects and needs (or not) for algorithms.

The primary task (as defined in the brief) is to "identify product groups for which the use of test result conversion algorithms may be appropriate (and those for which algorithms are inappropriate or unnecessary)".

A three-phase approach was used for the project:

1. research and information gathering;
2. a review of existing material with respect to conversion algorithms and an assessment of the potential for the development of suitable algorithms for products within the project scope, based on the elements of the main test procedures for each product and the existence of suitable tools.
3. analysis and synthesis, structured along product lines.

The authors have used their extensive knowledge and contacts to build on the work that has already been done on test procedure conversion algorithms (both within APEC and elsewhere) to ensure identification of the key product groups where the use of algorithms may be appropriate to reduce the energy testing costs associated with trade.

1.3.1 Products covered

The prospects for energy test procedure conversion algorithms were considered for a wide range of product groups. A far as possible, all electrical products that are regulated for energy efficiency within APEC have been included, as follows:

- Household refrigerators and freezers
- Automatic icemakers
- Commercial refrigeration equipment
- Air conditioners and heat pumps
- Other ("non-conventional") air conditioners
- Dehumidifiers
- Electric space heaters
- Electric motors
- Lighting equipment
- Electric water heaters
- Clothes washers
- Clothes dryers
- Dishwashers
- Office equipment and consumer electronics
- Power transformers
- Boilers
- Industrial fans
- Pumps
- Furnaces
- Cooking products
- Vacuum cleaners
- Pool heaters
- Irons

This report only covers electrical appliances and equipment. Numerous APEC member economies have or are considering regulations covering gas, oil and/or wood-burning equipment. These are not in the scope of the study and are not covered in this report.

1.3.2 Structure of report

The structure of the report is as follows:

Chapter 1 outlines the brief and the approach to the study.

Chapter 2 provides detailed background information on the history of actions within APEC to align test procedures and how this project on the feasibility of conversion algorithms for energy using products came into being.

Chapter 3 outlines the distinction between the alignment of test procedures and the use of a conversion algorithm. It explains the strengths and weaknesses of each approach and sets out criteria for when each should be considered.

Chapter 4 gives a brief overview of the energy using products to which energy efficiency regulations are applicable in the APEC member economies. The program requirements are described in more detail in EES (1999) and EES (2001).

Chapter 5 presents the main findings of the project in the form of an appraisal of the suitability of energy test procedure conversion algorithms for each product type. The prospects for alignment are also considered for each product and recommendations on how to reduce barriers to trade are also suggested.

Chapter 6 lists the references used in the report and lists the key product test procedures cited.

Annex A contains a reproduction of the APEC “Guide for Alignment”.

1.4 Project team & acknowledgements

The project was led by Mr Lloyd Harrington, principal of Energy Efficient Strategies (Australia). Mr Harrington coordinated the project, carried out much of the primary research and analysis, analysed the standards for many of the products, and assembled and edited the report. Energy Efficient Strategies was responsible for printing and distribution of the report in paper and electronic formats.

Dr Paul Waide, the principal of Paul Waide Consulting (United Kingdom), carried out the research and analysis for several of the products and assisted in the preparation of the report and editing. Kerry Munro of PW Consulting also assisted with editing.

The project team gratefully acknowledges the assistance of all those who provided information regarding each of the APEC member economies.

The team also gratefully acknowledges the assistance, guidance and direction of the APEC Secretariat in Singapore, especially Dr Helena Gaytan, Ms Daphne Ho, Mr Yang Yafei and Mrs Anita Douglas, and of the Project Overseer, Eur. Ing. David Cogan of the Energy Efficiency and Conservation Authority, New Zealand.

2 APEC HISTORY ON ALIGNMENT ISSUES

2.1 Background

The Asia-Pacific Economic Cooperation (APEC) was established in 1989 in response to the growing interdependence among Asia-Pacific economies. APEC began as an informal dialogue group; it has since become the primary regional vehicle for promoting open trade and practical economic co-operation.

There is a substantial amount of documentation and dialogue that has lead to this current project: *Studies On Algorithm Development For Energy Performance Testing*. This chapter provides a brief overview of the history that has lead to an investigation of algorithms by the Energy Working Group. More information can be obtained from various APEC reports including APEC (1997) (a copy is included as Appendix A), Nordicity (1997), EES (1999) and SGES (2000).

2.1.1 Osaka Action Agenda

In November 1994, at Bogor, Indonesia, APEC leaders came together to "chart the future course of [their] economic co-operation" in order to "enhance the prospects of an accelerated, balanced and equitable economic growth" through the APEC region. This meeting spawned the Bogor Declaration that conceptualised the vision of an open trading system in the Asia Pacific region. APEC leaders implemented this vision through the Osaka Action Agenda at their 3rd meeting in Osaka Japan in November 1995. The Osaka Action Agenda was a template for future APEC work that laid out some of the common goals of APEC members. Essentially, the Agenda represented the three pillars of trade and investment liberalisation, their facilitation, and economic and technical cooperation. It stressed that for the APEC region to achieve sustained economic development, APEC member economies had to pursue activities in each of these areas.

The Agenda laid out nine General Principles that APEC member economies could apply in order to meet the long-term goal of free and open trade and investment no later than the year 2010 in the case of industrialised economies and the year 2020 in the case of developing economies. The Agenda expected that each APEC economy would develop its own action plan and that these action plans would elaborate on steps needed in order to achieve the objectives including both concerted unilateral action to be taken in line with issue-specific guidelines and collective actions.

Standards and Conformance was one of the areas that the agenda targeted. The Agenda set out four goals under the heading of Standards and Conformance that a chosen APEC forum would be asked to pursue. These goals were to:

1. Ensure the transparency of the standards and conformity assessment of APEC member economies.
2. Align APEC member economies' mandatory and voluntary standards with international standards.
3. Achieve mutual recognition among APEC member economies of conformity assessment in regulated and voluntary sectors.

4. Promote co-operation for technical infrastructure development to facilitate broad participation in mutual recognition arrangements in both regulated and voluntary sectors.

The Osaka Guidelines also called for each APEC economy to participate actively in international standardisation activities and called for APEC member economies to increase the harmonisation of their standards.

2.1.2 Manila Action Plan for APEC

At their 4th meeting in Manila, Philippines in November 1996, APEC Leaders drafted The Manila Action Plan (MAPA). MAPA focused on the trade liberalisation and investment objective set out in the Osaka Action Agenda. The Action Plan sought to "reduce the cost of doing business by liberalising trade, eliminating unnecessary administrative burdens and bringing down technical barriers to trade through the use of new technologies and/or cost-efficient processes."

MAPA set out eight key undertakings as necessary in order to meet this objective. One of the undertakings dealt with Standards and Conformance. The undertaking stressed the need to "conclude mutual recognition arrangements on conformity assessment for standards and alignment with international standards." MAPA then linked each undertaking with a set of activities needed to complete the scope of the undertaking.

Standards and conformance related activities included ensuring the transparency of standards and conformity assessment in APEC member economies and the need for voluntary sectors to enter into Mutual Recognition Agreements (MRAs) in co-operation with regional specialist bodies.

The action plan also called for the alignment, by 2000/2005 (industrialised countries/developing countries), of mandatory and voluntary standards with international standards. In particular, MAPA emphasised the need to align standards on electrical and electronic appliances (air conditioners, televisions, refrigerators, radios and their parts, and video apparatus), food labelling, rubber gloves, condoms and machinery.

The APEC Committee on Trade and Investment (CTI) established a Sub-committee on Standards and Conformance (SCSC) by the Declaration of an APEC Standards and Conformance Framework (November, 1994). Its principle objectives are to:

- encourage alignment of members' standards with international standards;
- achieve mutual recognition among APEC member economies of conformity assessment in regulated and voluntary sectors;
- promote co-operation for technical infrastructure development in order to facilitate broad participation in mutual recognition arrangements in both regulated and voluntary sectors; and
- ensure the transparency of the standards and conformity assessments of APEC member economies.

2.1.3 Alignment of test standards within APEC

Following the Manilla Action Plan for APEC, the Sub-committee on Standards and Conformance (SCSC) published their report entitled *Guide for Alignment of APEC Member Economies' Standards with International Standards* (APEC 1997). This provides direction to APEC member economies on processes for alignment of their test procedures. The document has been included as Appendix A of this report.

2.2 Background on algorithms

The Energy Ministers of the APEC member economies met for the first time in Sydney, Australia on 28-29 August 1996. At this meeting, the Ministers recognised that an APEC multilateral framework might provide an opportunity to overcome impediments to trade related to the use in the APEC region of differing energy efficiency standards (i.e. test procedures used to measure the energy efficiency of a product). It was felt that this could be done without affecting the integrity of individual economies' standards. Rather, reducing the negative trade implications of energy-efficiency test procedures would facilitate the greater use of energy efficiency programs with their associated energy and environmental benefits. Ministers instructed officials from member economies to work together to achieve the benefits of increased cooperation on energy standards through the following actions:

- develop firm proposals for establishing a base on which mutual acceptance of accreditation of energy efficiency testing facilities and the results of test performed at these facilities can be achieved;
- work towards the establishment of bases of comparison of the outcomes of testing to different standards so that the need to test to multiple standards can be reduced or removed;
- develop a general policy framework that would allow for the progressive development and implementation of harmonised standards on a bilateral or multilateral basis, and product by product, as technical details are established and mutually agreed upon.

The APEC Energy Working Group created the Steering Group on Energy Standards (SGES) to carry out the above tasks related to energy standards. The SGES was always intended to be a temporary group and once the above-listed tasks were completed, the SGES would have completed its mandate. SGES held its last meeting in March 2000 and handed over its remaining tasks and recommendations for implementation to the Expert Group on Energy Efficiency and Conservation (EGEEC).

SGES activities culminated in the design of a general policy framework. The purpose of the framework is to provide a structure that will help guide future energy-efficiency standards related work within APEC member economies. The framework draws upon the findings of the *Review of Energy Efficiency Test Standards and Regulations in APEC Member Economies* (EES 1999) and the results of several APEC sponsored workshops.

In its final report, SGES recommended “adoption of a three-pronged, product-by-product, approach to the greater alignment of test procedures within APEC member economies” (SGES 2000), in particular:

1. to adopt a common test procedure from procedures used in the region, where this is feasible;
2. to influence the development of procedures so that they are in a form suitable for member economies; and
3. to develop algorithms to convert results between existing member economies' test procedures.

SGES recommended that Ministers agree the above elements should be implemented on a progressive, multilateral or bilateral basis. The pace of implementation would vary by economy depending on the particular circumstances.

One of the projects developed by SGES prior to its disbandment was the initiation of this study on the potential for algorithms to reduce testing costs and allow translation between different test procedures (point 3 above).

3 ALIGNMENT AND ALGORITHMS

Clearly, there is a huge range of test procedures in use within APEC member economies. While there is a degree of similarity and even harmonisation in some areas and for some products, there is generally a complex mix of requirements in force. This obviously has the potential to, and most likely already is, restricting free trade between APEC member economies.

3.1 Practical application of alignment and algorithms

3.1.1 What is alignment?

Alignment is where test procedures become so similar that they effectively become equivalent. Alignment or equivalence does not mean that all elements of a test method are necessarily identical (although identical test methods of course qualify as equivalent or aligned as well), but it does mean that the overall result, in terms of energy and performance, will be the same in practical terms. Aligned standards may have small differences in tolerances, set points, some materials and methodologies where these do not unduly affect the overall result. Aligned standards may also be of a dissimilar format and layout.

Even though APEC leaders have directed APEC member economies to align their test standards to international standards, there are some outstanding issues. More often than not, international standards committees draw expertise from a narrow base of economies. Many committees which cover energy and performance of products draw heavily from European economies, while input from outside of Europe (including from APEC member economies) is often minimal, or even non existent. While it is fair to say (and it is often said) that many of these standard committees are dominated by Europe, it is also fair to say that few APEC member economies (or those from other regions) provide any significant input or resources into many of the relevant areas. So there are some practical and political issues regarding alignment with international test procedures published by IEC or ISO that need to be addressed. Having said this, ISO and IEC test procedures are the only internationally accepted test procedures and are the only formal international bodies developing test procedures where APEC member economies can have a direct input in their development

3.1.2 What is an algorithm?

In its simplest form, a conversion algorithm is a simple adjustment factor which could allow a measure of energy and/or performance under one test procedure to be converted to an equivalent and comparative value under a different test procedure without the need for additional retesting. In its most complex form, an algorithm could consist of a computer model which is used to simulate the performance and energy consumption under a range of conditions, including different test procedures, or conditions of actual use (say in a factory or household). In principle conversion algorithms could range between being very simple to being very complex in nature. The required complexity of an algorithm is merely a reflection of the complexity of the test procedure itself and the characteristics, design and operation of the product. It would also depend on the type of task or energy service delivered by the product. Algorithms can be well suited in circumstances where there is a need to take into account usage profiles for a particular product and where this is likely to vary widely in different parts of the world.

Conversion algorithms, where feasible, will provide reduced testing costs for manufacturers, which will in turn reduce the costs of trade. The reduction of testing costs through the application of conversion algorithms could also save energy by lowering the barriers to the free trade of the most efficient products across APEC member economies. However, the development of conversion algorithms that are accurate and reliable is not simple for some products and probably not even necessary or feasible for others.

3.1.3 Benefits of alignment and algorithms

The development of suitable conversion algorithms has, in effect, the same impact as the alignment of test procedures – it avoids having to retest an exported product to a range of local test procedures. So really, either alignment of test procedures or development of suitable conversion algorithms provides an acceptable outcome in terms of APEC policy requirements and future directions (provided that economies accept the results of a conversion algorithm as credible).

In summary, the alignment of test procedures and the development of conversion algorithms both achieve the same net effect. These are to:

- facilitate international trade;
- decrease testing and approval costs for manufacturers;
- allow the free movement of the most efficient products (noting that products with a low energy efficiency may be barred if they do not meet local MEPS levels);
- facilitate international comparisons; and
- assist in the diffusion of advanced energy saving technologies.

3.2 Alignment versus algorithm

Alignment and algorithms both have the same benefits – they facilitate trade by reduction of testing costs. In some ways, developing an algorithm is even more attractive than alignment: it allows free trade of products, but allows local test procedures (and the associated energy program activity) to be retained with little or no change, thus providing much better program continuity. This is an important issue – the resistance to test procedure “change”, however small the change may be, can be enormous, as manufacturers have often made huge investments around production facilities which already meet the requirements of the various energy programs in which they are required to participate. Governments have also often made large investments in the development and enforcement of local test procedures and therefore can be reluctant to change (institutional inertia). However, an outward looking manufacturer will quickly see the advantages of a flexible system that allows exports to flourish without the need for extensive retesting.

In cases where there is a particular product test procedure that is clearly superior to others and is already "generic" to the extent that it characterises products to the level that is necessary, alignment would tend to suggest itself as the preferable medium term option, as opposed to the development of conversion algorithms. However, it is only worth aligning to a test procedure that is technically superior and competent – aligning to a poor test procedure serves little purpose.

Conversion algorithms have the added advantage of being able to provide a more accurate estimate of the impact of local usage patterns, better ranking of products under conditions of actual use and may also allow the retention of local or traditional test conditions in many cases. They would also facilitate direct international comparisons, which are of increasing importance in a world of global trade.

3.2.1 When is alignment preferred over algorithms?

Alignment is generally preferred when:

- there is a well accepted and highly regarded international or regional test procedure for a product and that this is widely used (or has the potential for widespread application); and
    - the test procedure provides sufficient information to characterise the product's performance under typical usage conditions (i.e. the operation of the product is a simple on/off or the test procedure measures performance over a range of loads or outputs); or
    - the test procedure and/or the product performance parameters are so complex that it is not possible to predict changes in performance with changes in use or conditions.

3.2.2 When are algorithms preferred over alignment?

Algorithms are generally preferred when:

- there are a number of test procedures for a particular product and none is superior to the others;
- there is a significant trade in the product and widespread requirements for testing for regulatory purposes (and therefore a need for retesting which can increase the cost of trade);
- the pattern of use or other external factors such as climate significantly affect the performance and/or energy consumption of the product but these effects can be readily characterised through known adjustment or scaling factors or through simulation;
- it is possible to characterise the performance of the product in a repeatable and reproducible manner (through known adjustment or scaling factors or through simulation) so that the performance under a range of test procedures can be accurately estimated.

An algorithm may be based on data or measurements that are not contained in any existing test procedure. Therefore, to use or develop an algorithm it may be necessary to conduct a test or series of tests that do not align with any existing test procedures or to apply an existing test procedure but to include additional measurements or data collection. While this may appear more onerous at face value, the collection of some additional data at the time of testing may obviate the need for retesting to many other test procedures. In some cases, the same tests can be conducted and made suitable for use in an algorithm merely by recording some additional measurement points during the tests. Sometimes algorithms may require the recording of physical data (e.g. physical dimensions, component design) that is not normally collected during energy tests to assist in the simulation of results.

3.2.3 Special benefits associated with algorithms

Where algorithms are able to take accurately into account the impact of climate and/or the impact of user behaviour, they can provide additional benefits. For many products actual use profiles can have a large impact on energy consumption and to a lesser extent performance. A good example of this type of product is water heaters. So where energy efficiency is regulated for these types of products it is usually necessary to specify a "standard" or "typical" usage profile. This makes application of this type of test procedure very difficult in economies that have different usage profiles. Even within a single economy, the reality is that a "typical" usage profile is based on an average value: there will in fact be a wide range of actual uses (typically something resembling a normal distribution or sometimes a skewed distribution). An algorithm which accurately takes into account usage will be able to predict energy consumption under both "standard" usage profiles (contained in test procedures) and also under actual conditions (or a range of actual conditions). This ability can be very useful for the modelling and estimation of actual end use energy consumption for certain products (e.g. load forecasting and energy policy development).

Another area where algorithms can provide additional benefits is where the performance and/or energy consumption of a product is affected by temperature (and hence climate). A good example of these types of products are refrigerators, freezers and air conditioners. Again, test procedures for these products usually specify a single test temperature for the determination of energy consumption and performance. In reality, a set of conditions which are applicable to one economy will not necessarily be applicable to others, especially considering the range of climates found across APEC. Even within some economies such as Australia and the USA, there is a wide range of climates which makes the application of test procedures to temperature sensitive products difficult. In these cases temperature based algorithms are ideal to minimise retesting while adequately meeting the needs of differing climatic regions around the world.

Of course, algorithms that can estimate the impact of usage patterns and climate can be powerful tools for modelling end use energy consumption as well as for regulatory purposes.

All product energy test procedures are compromises between the need to develop a reproducible, inexpensive and widely applicable test procedure and the need for the test procedure to represent local operating conditions and usage and hence to replicate local energy consumption levels. Typically test procedures will apply a single set of operating conditions in order to give simple reproducible results which can be used for rating and comparison purposes; however, as has already been mentioned, local climatic and usage conditions can vary significantly even within an economy and therefore the energy results produced by a standard energy test are only ever an idealised representation of the actual *in situ* energy consumption. For this reason it may be most appropriate to aim to develop test procedures which provide enough information to enable a conversion algorithm to be "primed" while simultaneously giving enough information to enable products to be directly compared under "standardised" conditions. The widespread adoption of this philosophy would enable all relevant product test procedures to be aligned to a single test procedure which would produce the minimum information required to apply a energy consumption conversion algorithm. This could then be applied to determine average *in situ* energy consumption levels within a given economy or region. The adoption of this view for selected products would imply that the optimal approach is not to choose between aligning test procedures or using a test procedure conversion algorithm but rather to align test procedures *and* use a conversion algorithm. This would enable the test procedure to be applied in a manner relevant to local requirements.

3.2.4 Acceptance of algorithms for regulatory purposes

If conversion algorithms are to be developed, they need to be credible, accurate and robust. In addition, there needs to be some agreement, at least in principle, for regulators to consider the use of such approaches should they prove to be successful. If regulators cannot or will not consider the use of such conversion algorithms, their development will be largely in vain, except for data analysis projects and international comparisons. Some issues regarding the practical application of algorithms for regulatory purposes are outlined in Chapter 5.

It is important to note that a separate study entitled *Studies on Algorithm Development for Energy Performance Testing: Study 4: Survey of industry and regulators* has been undertaken in parallel with this report. This separate study examines in more detail the responses from regulators within APEC to the concept of conversion algorithms. This study should also be reviewed when considering issues associated with the acceptance of conversion algorithms by industry and regulators.

Many economies regulate products. Unless there is some sort of plan or agreement within APEC on how to move forward, there is unlikely to be any progress in this area. Yet, APEC leaders have in fact agreed to some level of alignment in test standards by 2010/2020 (APEC 1997). For this to happen, there needs to be either acceptable test procedures which are worth aligning to or the development of credible conversion algorithms that are acceptable to regulators. There is little point in aligning with a standard that has a poor technical base or is unsuitable for local application.

A problem area in international standards development is that the composition of international standards committees tends to be mainly derived from manufacturers and to a lesser degree material suppliers and test laboratories. Ironically, there is often a low level of input from regulatory agencies, who in fact are often charged with the ultimate use and application of these test procedures. If international standards are to become more relevant, regulators will need to provide coherent input and ongoing development resources into these areas. This applies to both international standards development and the development of algorithms that may be used for regulatory purposes.

3.3 Important issues for alignment and algorithms

There are a range of issues that need to be considered when either aligning test procedures or developing algorithms.

3.3.1 Few international test procedures are "generic"

Despite the best intentions and efforts of standards committees and their members, the reality is that few of the commonly used international test procedures are in a form that could be considered to be "generic", in that they can characterise the product under a range of typical uses. For some products, such a "generic" test procedure is quite feasible, but for others, the prospects of a generic test procedure are probably poor. In these cases, a conversion algorithm may be a more suitable option.

3.3.2 Climate considerations

Climatic considerations are critical for some products (especially air conditioners and refrigerators, and to some extent water heaters), and this is generally poorly handled in the existing test procedures for these product types. These products, which can have widely varying temperature performance coefficients for different models, are usually tested under a single static temperature condition, which is neither representative nor facilitates the estimation of performance under other conditions (including actual use). Of course, "actual use" and a "representative test point" can never be developed – consider an economy such as Australia which has climate zones ranging from cool temperate to humid tropical; a single test condition can never be representative of such a range. For such products, a complex conversion algorithm (i.e. computer model) is probably the only feasible long term option in terms of the elimination of retesting costs, which are substantial under the current regulatory regimes.

3.3.3 New "smart" products

The increasing prevalence of electronic controls in appliances and equipment will make testing more complicated and less repeatable. Features such as fuzzy logic, automatic programs and sensors (water level, load detection) and sensors for soil and dirt are becoming common. Electronic controls can sometimes even tell when they are being subject to a standard test and under a worst case scenario, they could be programmed to alter the behaviour of the product to give more favourable results than during actual use, which is potentially misleading for consumers. It is therefore important that test procedures move with the times to ensure that these smart products don't outsmart the test procedures.

A related issue is that where a test procedure specifies a single test point, it is well known that manufacturers tend to optimise for that test point rather than for real consumer use. This is of little service to the consumers who are supposed to be helped by programs such as energy labelling and MEPS. Examining energy and performance over a range of conditions (which would typically need to be done in the development of a conversion algorithm) means that there is no advantage for manufacturers to optimise to a single test condition, hence products would hopefully become more versatile and better optimised for real use.

4 OVERVIEW OF PRODUCTS REGULATED FOR ENERGY EFFICIENCY IN APEC

This section takes a brief look at products that are regulated for energy efficiency and gives some insight regarding the potential scope of application of algorithms for different product groups. Clearly, if products are not regulated for energy efficiency, or if energy efficiency is of no interest for voluntary programs or consumer information, then the development of conversion algorithms is likely to be of little interest.

The important product groups for alignment and algorithms will be those where there is a large trade and a high degree of regulation for energy efficiency. Within this group, the main products of interest for algorithm development will be those where:

- there is a lack of harmonised test procedures but where there is potential for successful algorithm development to reduce testing costs; and/or
- climate or actual use varies substantially between economies (or within economies) and an algorithm offers the potential to tailor standardised test measurements to actual use and/or local climatic conditions.

4.1 Overview by product

EES (1999) gives a succinct overview of each of the major product categories with regard to the level of trade, the degree of regulation and the status of international test procedures. A summary of this review, which has been updated for this report, is shown below. More details can be found in Chapter 3 of EES (1999). Details on the actual program requirements in each APEC economy can be found in Chapter 2 of EES (1999) with additional data for non-APEC member economies in EES (2001).

4.1.1 Refrigerators

- large world trade
- large number of different test procedures
- widely regulated across APEC member economies
- no test procedure is clearly superior to others.

4.1.2 Air conditioners

- large world trade
- mostly similar test procedures, but with many small variations
- widely regulated across APEC member economies, some product categories require seasonal performance and part load figures (which require multiple tests)
- ISO test procedure is used widely but is currently inadequate for modelling actual use, a range of climatic conditions, seasonal performance or part load operation (especially inverter models).

4.1.3 Electric motors

- large world trade
- mostly similar test procedures, but with some significant differences (mainly treatment of stray losses, reference core temperatures)
- regulations apply in some APEC member economies, many under consideration
- IEC test procedure is used widely but currently inadequate. IEEE approach used in NAFTA is the superior test methodology. IEC is currently being aligned with IEEE.

4.1.4 Lighting products

- large world trade
- mostly similar test procedures, mainly based on IEC performance standards, but with some significant differences with respect to measurement of efficacy of ballasts.
- regulations apply in some APEC member economies, some under consideration.
- IEC test methods for lamps and other components are adequate. IEC test procedures for lighting equipment are widely used but as yet there is no suitable IEC standard for the determination of ballast efficacy. There is a need to develop a new IEC ballast test procedure based on the superior methods now used in North America and Europe for determination of efficacy. This issue has been canvassed within APEC at the Colloquium on MEPS held in Korea (APEC 1999) and subsequently a suitable test method for ballast efficacy for use within APEC has been developed and published in Australia and New Zealand as AS/NZS 4783.1. This should be proposed as the basis for a new IEC standard.

4.1.5 Electric water heaters

- small but growing world trade
- many different test procedures, wide range of temperature requirements, main test methods cover both static and draw-off tests. Task type tests (with user draw-off) are essential for non electric technologies but these types of tests tend to be specific to a particular economy and are not widely applicable. Test procedures need to cover multiple fuels in many cases. Impact of part day (off peak) electric energisation profiles is poorly handled in most test procedures.
- regulations apply in many APEC member economies and are under consideration in some.
- current IEC test procedure is currently inadequate (only provides static heat loss measurement for electric types). It would be preferable to consider electric, gas, solar and heat pump systems on a comparable basis.

4.1.6 Clothes washers

- large world trade

- wide range of test procedures, some home grown and others derived from IEC
- regulations apply in some APEC member economies, some under consideration
- IEC test procedure is currently inadequate with respect to performance of top loading machines. Wide range of work is under way within IEC to address all aspects of the test, but it will be some time before all major issues have adequately progressed. IEC is probably the best of the existing test methods but needs wider international input.

4.1.7 Dishwashers

- moderate world trade (trade is increasing between North America and Europe)
- three main test procedures – IEC, AHAM, US DOE (also now CENELEC for Europe)
- regulations apply in some APEC member economies, no more are proposed
- the current published IEC test procedure (dated 1981) is inadequate with respect to performance. Wide range of work is under way in IEC with respect to all aspects of the test with input from Europe, North America and Australasia – good progress to date. New “international” IEC test method is expected shortly.

4.1.8 Clothes dryers

- small world trade
- two main test procedures – IEC and AHAM (US DOE)
- regulations apply in some APEC member economies, no more proposed
- IEC test procedure is currently inadequate with respect to performance. Needs improvement in the area of energy correction. Also needs to be made more generic to allow the estimation of energy consumption over a wide range of initial moisture contents without the need for retesting. Some work under way in IEC, but progress is slow. Most existing dryer test procedures (including those in North America) have the same inadequacies.

4.1.9 Office equipment and consumer electronics

- huge world trade, relatively short life, fast turnover, rapid change in technology
- few formal test procedures
- regulations apply in few APEC member economies but widely covered by voluntary programs
- there may be a case for the standardisation of some aspects of the testing of these products (e.g. instrumentation and accuracy). Most common measurement is for standby electricity consumption. Some IEC work is under way for standby measurement methods for various products.

4.2 Other data sources

To obtain a wider international feel for the degree of regulation of products for energy efficiency around the world, some data has been extracted for a report entitled *Energy Labelling and Standards Programs Throughout the World* (EES 2001), which in turn has drawn on the APEC study entitled *Review of energy efficiency test standards and regulations in APEC member economies* (EES 1999). Information on the program details in each APEC economy (such as exact scope and technical requirements for labelling and MEPS) are available in EES (1999).

Energy Labelling and Standards Programs Throughout the World (EES 2001) covers a wide range of economies, including a number that are not within APEC. The data is believed to be up to date as of late 2001. The report (EES 2001) provides data sources for further information for each economy and is available for download from www.energyefficient.com.au under documents.

Table 1: Summary of Labelling Programs by Product and Economy

Product	Argentina		Australia		Brazil		Bulgaria		Canada		Chile		China		Costa Rica		European Union		Hong Kong		Hungary		India		Indonesia		Iran		Israel		Jamaica		Japan		Korea		Lithuania		Mexico		New Zealand		Norway		Philippines		Poland		Romania		Singapore		Switzerland		Chinese Taipe		Thailand		U.S.A.	
Type of Label	Comparative	Endorsemen	Comparative	Endorsemen	CoVparative	Endorsemen	Comparative	Endorsemen	Comparative	Endorsemen	Comparative	Endorsemen	Comparative	Endorsemen	Comparative	Endorsemen	Comparative	Endorsemen	Comparative	Endorsemen	Comparative	Endorsemen	Comparative	Endorsemen	Comparative	Endorsemen	Comparative	Endorsemen	Comparative	Endorsemen	Comparative	Endorsemen	Comparative	Endorsemen	Comparative	Endorsemen	Comparative	Endorsemen	Comparative	Endorsemen	Comparative	Endorsemen	Comparative	Endorsemen	Comparative	Endorsemen	Comparative	Endorsemen	Comparative	Endorsemen	Comparative	Endorsemen	Comparative	Endorsemen	Comparative	Endorsemen	Comparative	Endorsemen	Comparative	Endorsemen	Comparative	Endorsemen
Air Conditioner - Central			V						V	V																									M				M		V											V							M	V
Air Conditioner - Room			M	V	V	M			M						M				V								M		M				M		M				M	V	V				M							V				V	V	V	M	V
Air conditioners, Single-packaged central & heat pumps			V						V																										M				M		V																		M	V
Air Conditioner - Split System			M	V					V										V																M						V				M											V			M	
Ballasts						M				V			V		M																				M				M													V						V	M	V
Boilers																																				V																							M	V
Clothes Dryers			M	V			M		M								M		V		M																M				V		M				M		M			V	V							V
Clothes Washers			M	V		M	M		M								M	V	V		M								M						M		M		M		V		M	V			M		M			V	V			V		V	M	V
Clothes Washer Dryers Integrated			M				M		M								M				M																M				V		M				M		M				V							V
Computers				V						V								V																V		V						V		V								V		V		V		V		V
Copiers				V						V								V		V														V		V						V		V										V						V
Dishwashers			M	V			M		M	V							M	V			M								M								M				V		M	V			M		M				V						M	V
Fans																													V																															
Fax Machines				V						V								V																V		V						V		V										V		V				V
Freezers	M		M	V	V	M	M		M					V	M		M	V			M								M		M		M				M				V		M	V	M		M		M				V			V			M	
Furnaces									V																																																		M	
Heat Pumps			M	V					V																										M						V			V															M	V
Lamps		V				M	M			V				V	M		M	V		V	M	V		V					V				M		M	V	M						M				M	V	M			V	V			V		V	M	V
Microwave Oven																																				V																				V				
Monitors				V						V								V																V		V						V										V		V		V				V
Motors										V					M									V												V				V												V						V		
Multi Function Devices (MFD)				V						V								V																V								V												V						V
Printers				V						V								V																V		V						V		V										V		V				V
Pumps																																				V			M																					
Radio Rcvr/Rcdr																		V																																				V						V
Ranges/Ovens									M						M									V					M																															V
Refrigerators	M		M	V	V	M	M		M		?	?		V	M		M	V	V		M			V	V		M		M		M		M		M		M		M	V	V		M	V	M		M		M			V	V			V	V	V	M	V
Scanners				V														V																V								V												V						V
Solar Water Heating																													M																															
Heaters- Gas Central			V	V					V																																																		M	
Heaters- Space			V	V					V																				M						M																								M	
Televisions																		V						V									M			V				V				V										V		V				V
Transformers																																																								V				V
VCRs and/or DVDs																		V																		V								V										V						V
Water Heaters			V	V						V					M									V					M												V											V				V			M	

Legend: M - Mandatory Label V - Voluntary Lal ? - Label Status Unknown ▭ - APEC economies

Table 2: Summary of MEPS by Product and Economy

Product	Australia	Bulgaria	Canada	Chile	China	Columbia	Costa Rica	European Union	Hungary	India	Iran	Israel	Japan	Korea	Malaysia	Mexico	Philippines	Poland	Romania	Russia	Saudi Arabia	Singapore	Switzerland	Chinese Taipe	Turkey	U.S.A.
Air Conditioners - Central	M		M													M										M
Air Conditioners - Room			M		M		M			V		M	T	M		M	M			M	?	M		M		M
Air conditioners Large, heat pumps & condensing units	M		M																							M
Air conditioners, Packaged terminal and heat pumps	M		M																							M
Air conditioners, Single-packaged central & heat pumps	M		M																							M
Air conditioners, Split-system central and heat pumps	M		M													M	M			M						M
Ballasts			M		M	M	M	M					T	M	M		M							M		M
Boilers			M					M						M		M									M?	M
Clothes Dryers			M																				?			M
Clothes Washers			M		M			V				M		M		M		M					?			M
Clothes Washers/Dryer Integrated			M																							M
Computers													T	M						M			V			
Copiers													T	M									V			
Dehumidifiers			M																							
Dishwashers		M	M					V				M								M			?			M
Fans					M							M												M		
Fax Machines														M									V?			
Freezers	M	M	M				M	M	M			M							M?	M			V?			M
Furnaces			M																				V?			M
Hard-disk Drives													T													
Heat Pumps			M																							M
Icemakers			M																							
Irons					M																					
Lamps		M	M			M	M					M	T	M		M										M
Monitors														M						M			V?			
Motors	M		M	M?			M								M	M								M		M
Pool heaters																				M						
Printers														M						M			V?			
Pumps																M										
Radio Rcvr/Rcdr					M			V						M						M						
Ranges/Ovens			M				M					M								M			V?	M?	M?	
Refrigerators	M	M	M	M?	M		M	M	M	V	M		T	M		M		M	M?	M			V?	M		M
Rice Cookers					M																					
Scanners														M						M						
Solar Water Heating						M						M														
Space Heaters			M									M						M								M
Televisions					M			V					T	M						M			V?			
Transformers			M													M										
VCRs								V					T	M									V?			
Water Heaters	M		M				M	V				M				M				M				M		M

Legend: M - Mandatory Standar V - Voluntary Standard T - Target Program ? - Standard Status Unknown

(shaded) - APEC economies

5 ASSESSMENT OF THE SUITABILITY OF ALGORITHMS BY PRODUCT TYPE

5.1 Background

This section looks at each product type within the scope of the study and examines the major differences in test procedures used to regulate products within APEC member economies. An assessment is then made whether algorithms are a suitable option to reduce testing costs and if possible the basis or approach for such an algorithm is identified. Recommendations are made for further work to reduce testing costs for the product type.

5.1.1 Application of algorithms

In its simplest form, a "conversion algorithm" takes the results of a test and modifies it in line with differences in operating parameters to indicate the result that would be obtained if tested in accordance with a different test regime. As a simple example, it may be reasonably assumed that the heat loss from a storage water heater is directly proportional to the difference in temperature between the hot water and the external ambient environment so a simple scaling factor may be possible.

Preferably, any inaccuracies introduced by the application of such an algorithm should be small compared with the errors associated with testing.

If the accuracy of the algorithm is a bit less than a re-test under different conditions, the use of the algorithm may still be acceptable if a margin of uncertainty is applied. For example, the energy performance as predicted using a conversion algorithm may need to be several percent better than the MEPS cut-off that the product is attempting to meet.

In the case of a modelling algorithm, the accuracy required may depend to some extent on regulatory needs. For comparative performance ratings, or for indicating the likely in-service energy use, the accuracy need only be of a similar order to that of testing. For more precise classification purposes (proving compliance with a MEPS, or rating for an energy labelling class) a greater accuracy may be necessary, or a security or uncertainty margin may be applied.

In some cases, there may be a need to balance the conflicting requirements of algorithm simplicity and accuracy.

5.2 Refrigeration Products

5.2.1 Household refrigerators and freezers

It is important to note that a separate study entitled *Studies on Algorithm Development for Energy Performance Testing: Study 2: Study of algorithms for domestic refrigeration appliances* has been undertaken in parallel with this report. This separate study examines in more detail the issues associated with refrigerator and freezer algorithms and makes a more thorough technical assessment of algorithm options for this product type. This study should also be reviewed when considering issues associated with the development of algorithms for this product.

5.2.1.1 Product overview

Refrigerators and freezers are produced in very large numbers and there is a significant and growing inter-regional trade in finished products. This pattern is reinforced as manufacturers are increasingly moving beyond their traditional market boundaries and are either exporting their products, or more commonly, are initiating manufacture in target export markets. Some APEC member economies use the ISO test procedures that are also used in Europe but there are a large number of economies that either use totally different test procedures or use procedures that only partially concur with ISO. None of the existing test procedures is clearly superior to the others and each represents trade-offs between ease of use, repeatability and reproducibility, cost and realistic representation of performance during actual use.

Many APEC member economies, as is the case around the world, regulate refrigerators and freezers for energy efficiency or include these in energy related programs. Refrigerators are probably the most regulated product within APEC (and in the world) with respect to energy efficiency and yet are also the product that has the most complex and diverse range of test procedures (sometimes with valid reasons) and therefore possibly has the worst prospects for either alignment or conversion algorithms. Refrigerators are one of the most common products, both in businesses and households, and are one of the most affected in terms of energy consumption with respect to climatic and temperature conditions, which vary considerably by region. It is also a product that is difficult to characterise in terms of energy consumption and performance under actual use conditions and under different test procedures.

5.2.1.2 Overview of main product test procedures and major issues

The main differences in the major test procedures for refrigerators and freezers are for the choice of ambient temperature used for the steady state energy test, the interior design operating temperatures, the method of measuring the interior operating temperatures, whether frozen food compartments are loaded or not and whether door openings are included or not. The interior and exterior temperatures specified in the test procedures influence refrigerator energy consumption in two ways. Firstly, the thermal load to be extracted from the cabinet is directly proportional to the difference between the exterior (ambient test temperature) and interior temperatures in the cabinets. Secondly, the evaporation and condensation temperatures, which have a strong influence on the efficiency of the refrigeration cycle, are dependent on the interior and ambient test temperatures respectively.

The ambient test temperature is 25°C in ISO (or 32 °C if the unit is rated as a tropical class appliance), 32.2 °C under ANSI/AHAM and 32°C in AS/NZS. In Japan energy consumption used to be tested at two ambient temperatures (15°C and 30°C) and a weighted average value taken (the so called original JIS Method A, although the current JIS Method C uses a single ambient temperature of 25°C). Chinese Taipei and Korea use an ambient temperature of 30°C.

Significant differences also exist in the nominal interior temperatures such that under ISO and JIS (Method C) the frozen food compartments are either -6°C, -12°C or -18°C, while in the ANSI/AHAM the frozen food compartment is -17.8°C for a separate freezer but only -15 °C for a frozen food compartment within a refrigerator-freezer. Fresh food temperature also vary: +5°C for ISO and JIS (Method C), and +3°C for AS/NZS, JIS (Method A), Chinese Taipei and Korea and some products in the US (all refrigerators) and +7.22°C for other products in the USA.

Furthermore, these internal design temperatures are not directly equivalent because the definition of how the temperature is attained differs between the various test procedures. The ISO test procedures specify that the temperature of a 3 or 4 star freezer compartment must not exceed -18°C at any time (except during defrosts) in any one of the test packs that are loaded into the freezer compartment to provide thermal ballast during testing. In practice this means that the average freezer compartment temperature is typically -21°C. The ANSI/AHAM and AS/NZS test procedures measure the average freezer compartment temperature when the freezer is empty and thus would typically record a value some 3 degrees different to ISO and JIS for the same freezer compartment. Similar differences exist with the other procedures.

There are also other significant differences in major test procedures such as:

- differences in volume measurement procedures;
- minor differences in test room set-up and instrumentation;
- differences in freezer test pack composition (ISO versus North America) and whether or not these are used for energy consumption tests;
- a variety of rules regarding user adjustable controls and interpolation for energy consumption determination;
- the use of door openings (or not) for energy consumption testing;
- a lack of rules concerning how to deal with sub-compartments or unusual compartment types within the ISO standard;
- significant differences in non-energy operational test requirements e.g. temperature tests and pull down tests, that can have an important impact on the configuration of the appliance and its performance during the energy test.

Another key issue is the treatment of auxiliary energy loads and in particular the defrosting system. None of the existing procedures reward intelligent adaptive defrost systems correctly, for example, and there are some significant differences in how the initiation of the defrost cycle is treated within the test cycle. This is important as adaptive defrost is becoming a common feature within frost-free products and may dominate the frost-free market within 10 years.

A more comprehensive overview of all the current refrigerator test methods and related issues can be found in EES (2000) and Harrington (2001).

5.2.1.3 Recommended approach to reduce testing costs

The current refrigerator and freezer test procedures have varying levels of reproducibility and repeatability but are not likely to be very accurate at reflecting actual average in-use performance, even within a single economy's borders. To be able to achieve this would require a much more extensive characterisation of the refrigeration system under a broad range of operating conditions coupled with an algorithm that is primed using data of actual local usage practice and conditions. Nor is there any simple or straight forward method of converting results between test procedures as they currently stand – existing test procedures collect far too little information on the performance and characteristics of the refrigerator or freezer to be of use in estimating performance under other test methods.

For refrigerators and freezers, the way forward, at least in the short term, is unclear and most likely difficult. The differences in test procedures are so significant and the number of economies involved is so large, that the prospects of alignment are small, at least in the short term.

Furthermore, on a technical level all of the existing test procedures have strong and weak points in certain areas and none is clearly superior to any other. This would tend to mitigate against alignment to any one of the existing procedures as they currently stand. There is also a huge amount of institutional (industry, government and regulator) inertia associated with existing test procedures for refrigerators in many economies (e.g. regulations for energy labelling and MEPS); this also makes the prospects for changes somewhat remote in the short term.

The prospects of developing a satisfactory conversion algorithm that could be used to convert energy and related performance values from one test procedure into those applicable under another are slim because of the lack of required data currently gathered in any of the existing test procedures. The problem is especially acute for refrigerators with multiple compartments operating at different design temperatures such as refrigerator-freezers. To have any hope of knowing what coefficients should be applied in a conversion algorithm it would be necessary to know whether the product uses a single cooling loop or multiple loops and this isn't always apparent to those conducting the testing (unless destructive tests are performed). Despite this, it would make sense to develop and apply a conversion algorithm aimed at converting energy consumption results measured under any particular test procedure into more representative values for specific local conditions. The current test procedures involve an unhappy compromise between being reproducible, which is necessary for regulatory and comparative performance purposes and being representative, which is important for consumer information and for evaluating real *in situ* energy consumption levels. The result is that all of the currently used test procedures make unacceptable simplifications regarding the typical usage conditions and hence give misleading energy consumption results. A combination of alignment to a single optimised test procedure and the use of a conversion algorithm to adjust the energy results to give a better indication of local energy use would have the benefit of minimising testing costs and the associated non-tariff trade barrier that multiple testing represents while giving a better indication of the likely *in situ* energy consumption in a specific region or local economy.

Ultimately, a conversion algorithm (most likely a rather complex computer model with extensive calibration through physical tests) is the only medium term prospect to avoid (at least in part) the myriad of test methods that currently exist. However this is a complex and significant task and would require substantial resources merely to establish feasibility, let alone get it to an acceptable level of performance for regulatory purposes. A parallel study to this one (Study 2) examines the technical prospects for refrigerator algorithms in more detail.

Without a strong push from policy makers and other stakeholders, a short-term alignment in refrigerator test procedures seems unlikely. Nonetheless there are many elements where alignment would make good sense and make development of an algorithm simpler. Further investigations should be undertaken into both simple and more complex computer modelling options for refrigerators to determine their feasibility as algorithms for use with refrigerator test procedures. More extensive use of a test procedure with dual energy temperature test points and controlled internal heat loads may provide some insight and data to assist with modelling and algorithm approaches.

The recommendations for refrigerators and freezers are:

- to actively work on the ISO refrigerator test standard to improve its reproducibility and its applicability to a range of refrigerator technologies (especially frost-free systems) and configurations;
- to work towards the universal use of ISO volume measurement procedures (while acknowledging that the current ISO definitions need to be refined);
- to undertake work within ISO to improve the treatment of unusual compartment types and configurations;
- to improve the ISO test procedure treatment of smart technologies (especially for adaptive defrosting technologies, but also for variable-speed compressors);
- to actively move towards alignment of key elements of the refrigerator test procedure, such as those concerning materials (test packs), measurement instrumentation and tolerances, volume measurements and standardised internal temperature conditions (and measurement methods) for energy consumption measurement;
- to examine ways to incorporate key usage elements (humidity and defrosting, and user-introduced food loads) into a basic test method with a view to building up information for an improved combined testing–modelling approach;
- to undertake serious investigations with regard to options for developing a modelling algorithm for refrigerators and freezers;
- depending upon feasibility, to work towards establishing consensus regarding the longer-term vision for the combined use of a single harmonised test procedure with an energy consumption modelling algorithm, in order to eliminate arbitrary differences in the test procedures while allowing the generation of energy performance results that are more representative of local circumstances.

5.2.2 Automatic icemakers

The only APEC economy to regulate automatic icemakers is Canada. These products are primarily commercial in nature. The testing requirements are contained on CAN/CSA-C742 and these are harmonised with US requirements in ASHRAE 29. At this stage there is no international test method for the performance of automatic icemakers. It is recommended that, where a test procedure for the performance of automatic icemakers is necessary, APEC member economies align with the requirements of ASHRAE 29. If necessary, this could also be developed into an international standard. While development of an algorithm may be possible, this appears to be unnecessary at this stage and work on an algorithm is not recommended.

5.2.3 Commercial refrigeration equipment

The only APEC economy to regulate commercial refrigeration products is Canada, however, a number of other economies are considering regulation of these products (e.g. Australia). There are also some guides on performance and energy consumption of commercial refrigeration products used by the US government under their Government Energy Management Program (GEMP). The main commercial refrigeration product categories are:

- remote refrigeration – large scale open or closed display cabinets where the compressor system is located remotely from the cabinet (coffin display cabinets or glass door cabinets typically found in supermarkets);
- self contained refrigeration – where the refrigeration system is housed in a single package (e.g. glass drink display cabinets found in smaller retailers);
- vending machines – stand alone units for indoor or outdoor use.

The main test procedures for these products are:

- Remote refrigeration: CAN/CSA-C657, ANSI/ASHRAE 72 and ANSI/AHSRAE 117 (equivalent to CAN/CSA) and draft European Standard prEN 441;
- Self contained refrigeration: CAN/CSA-C827, ANSI/AHSRAE 117 (equivalent to CAN/CSA) and draft European Standard prEN 441;
- Vending machines: CAN/CSA-C804, ANSI/AHSRAE 32.1 (equivalent to CAN/CSA).

At this stage there is no international test method for the performance of commercial refrigeration. Given that there is likely to be some trade in these products between Europe, North America, Japan and Australasia, it is recommended that APEC work towards the development of a suitable international test method (or methods) for these products. The relevant published ASHRAE, CAN/CSA and European standards should be used as the initial basis for such an international standard.

While development of an algorithm may be possible, this appears to be unnecessary at this stage and work on an algorithm is not recommended.

5.3 Space conditioning equipment

5.3.1 Air conditioners and heat pumps

It is important to note that a separate study entitled *Studies on Algorithm Development for Energy Performance Testing: Study 3: Study of algorithms for air conditioners* has been undertaken in parallel with this report. This separate study examines in more detail the issues associated with air conditioner algorithms and makes a more thorough technical assessment of algorithm options for this product type. This study should also be reviewed when considering issues associated with the development of algorithms for this product.

5.3.1.1 Product overview

Room air conditioners are traded in large volumes internationally and despite differences in market traditions and product types are usually essentially the same or very similar around the world. The inconvenience and expense of re-testing has led to some concerted efforts to align the testing practices and rating conditions required within the different test procedures which in turn has led to a high degree of commonality among them. However, many small differences continue to exist, and in practice these will usually oblige a manufacturer to re-test their products if they wish to sell them in a different member economy to their own. A draft of the *Study of algorithms for air conditioners* confirmed that, because of the only minor differences between the energy test procedures used for room air conditioners, the reported cooling capacity and energy consumption results are only likely to differ by a few percent between the different test procedures currently used in APEC member economies. The main exception to this finding are the treatment of split room air conditioners in the NAFTA economies as these are defined as central air conditioners under NAFTA regulations and hence are tested using a seasonal energy efficiency rating (SEER) rather than just a single rating condition as applies elsewhere or as applies for window mounted room air conditioners in NAFTA. Some economies only require testing to ISO condition T1 while NAFTA and Japan require SEER testing (e.g. multiple loadings and test conditions) for some products.

In some areas major differences exist between the test procedures used in certain member economies, which is as much a result of differences in how identical products are classified, as it is through fundamental differences in the test conditions and testing practice. There appears to be a strong case for the complete alignment of product definitions used in test procedures and efficiency regulations, as the existing differences in definitions currently constitute arbitrary barriers to the free flow of goods that are not prerequisites of the energy performance policy objectives. The development of an international coding system would assist considerably in this matter.

5.3.1.2 Overview of main product test procedures and major issues

The main rating conditions used to rate the cooling capacity of room air conditioners is almost, but not quite, aligned among the various APEC member economy test procedures. This has probably occurred partly by default (through the partial or full adoption of ISO), but is also partly the result of efforts to try and develop products with a common rating basis. However, there is certainly a case to remove the need for expensive re-testing, and even redesign, in order to sell a given product among member economies, which now exists in some cases.

For room air conditioners in the cooling mode, the majority of member economies have essentially adopted the ISO5151-1994 T1 test condition for air to air appliances, although sometimes with minor differences caused by rounding to the nearest whole number on the Fahrenheit or Celsius scale and sometimes with different test tolerances.

There is more variation in heating capacity and energy performance conditions among the member economy test procedures. The principal reason is the change in the rating condition between the old ISO-R859 (withdrawn in 1994) and the current ISO5151-1994 test procedures. Many economies did not revise their test procedures after

ISO5151 replaced ISO-R859 in 1994 and hence have kept the 21°C indoor dry-bulb condition as opposed to the 20°C condition specified in ISO5151. The new ISO condition also introduced indoor wet-bulb requirements that were not specified in the old test procedure. It may be that those member economies that have not adopted the newer ISO conditions have technical objections to the new conditions, but it is more likely that it is due to institutional (and regulatory) inertia leading to delays in redrafting the procedures.

There is no theoretical reason why these small differences could not be fully aligned where there is sufficient institutional impetus to overcome them, but this would require a full review of the differences (not just those directly associated with energy performance testing), agreement on the optimum approaches and values and then a decision to fully align. Perhaps the simplest option would be to fully align to the ISO5151-1994 T1 test condition for cooling performance testing and to align tolerances in both the test temperatures and the declared EER and cooling capacity performance values. A draft of the *Study of algorithms for air conditioners* confirmed that the differences in rated performance under the different test procedures in use throughout APEC member economies were minor but still significant enough to require retesting in many cases. The development of a conversion algorithm would be practicable for these products; however, as there are no substantive technical differences between the main cooling mode testing condition used in the APEC member economies, it probably makes more sense to fully align the procedures to the ISO5151 T1 test condition. The *Study of algorithms for air conditioners* also confirmed that the cooling capacity and energy results were more sensitive to differences in the indoor wet bulb temperature conditions than the indoor dry bulb conditions and this confirms the need to accurately set indoor wet bulb conditions in the test procedure. Thus there is a strong recommendation to align to the ISO5151 test condition in the short term.

In the longer term this will not be sufficient. None of the existing test procedures is capable of giving a realistic representation of average in use performance (in either absolute or relative terms) and thus there is considerable need to improve the quality of all the procedures in the medium term.

The major shortcoming of the ISO test method(s) for air conditioners is their inability (or lack of a requirement) to provide information on energy consumption and efficiency at part load. While this is not a major issue for the majority of air conditioners (with single speed compressors), it does dramatically understate the likely relative operating efficiency of units that use multi-speed or variable speed compressors. Air conditioners typically only spend a small proportion of their normal operating hours at rated capacity under normal *in situ* usage conditions. For those units with a single speed compressor, the nominal efficiency at part load will be similar to full load, as the compressor cycles on and off in response to the thermostat control. However, for multi-speed compressors or those which use a variable speed drive (e.g. inverter systems), the apparent efficiency will increase substantially under part load conditions (although the condenser and evaporator size remains constant, the relatively smaller compressor output at part load increases the overall refrigeration system efficiency).

Inverter systems now dominate the market in Japan and they are gaining a significant market share in many other APEC member economies, so this is a very real issue. Some APEC member economies (Japan, USA, Canada) have part load testing requirements (sometimes tests at several load conditions are required such as for SEER), these are not done in a way that can be used to characterise the machine's operation under a range of actual conditions.

Even in the case of air conditioners that have fixed speed compressors, using a single steady state rating condition is an over simplification of reality, but for variable speed drive units, this is a very serious limitation. The EER of a variable speed drive air conditioner (or of multi-speed drive units) is strongly dependent on the cooling capacity such that the peak performance often occurs at about 60% of the rated cooling capacity, which is itself often about 75% of the maximum achievable capacity. The EER might typically vary by a factor of 2 or more across this range, which allows a wide margin for preferential selection of the rated cooling capacity for best EER performance. This issue alone presents a number of regulatory issues and questions.

Another very serious limitation of the current test procedures is their inability to address the air handling performance of the air conditioner, which has a large impact on the actual effective cooling performance of the appliance. This issue has been avoided due to the complexity of summarising real life air flow situations and because of practical difficulties in creating a repeatable and reproducible test addressing cool air distribution. There are also some important associated issues with testing at altitude and the appropriate corrections that should be applied to compensate results.

5.3.1.3 Recommended approach to reduce testing costs

The current air conditioner test procedures are reasonably reproducible and repeatable, but do not come very close to reflecting actual in-use performance in different economies. Even those member economies that have modified the international test procedure to better reflect their local circumstances are not likely to have achieved conditions that either resemble real average in-use air conditioner energy consumption within their own economies or that necessarily correctly rank average in-use energy efficiency. To achieve this would require a much more extensive characterisation of the system under a broad range of operating conditions coupled with an algorithm and precise knowledge of actual local usage practices and conditions. The *Study of algorithms for air conditioners (Study 3)* has gone some way toward identifying the minimum range of operating conditions that would need to be tested to enable this system characterisation to be attained although there are some outstanding issues to be clarified.

Given that air conditioners, while being complex in terms of their detailed operation and design, are relatively simple devices that collect energy and shift it from one space to another under a limited range of conditions and given that the physics of their operation is well understood (refrigeration engineering), this type of product does lend itself to algorithm development. In fact a number of simulation models of varying complexity already exist for air conditioners.

The most appropriate "algorithm" option for air conditioners is probably a mixture of modelling (simulation of the key performance and construction characteristics) combined with physical testing of the unit to calibrate or align the simulation model with measured test data (actual performance). There are a number of computer models for air conditioners that are used to simulate energy and performance of air conditioners and there is also extensive testing of air conditioners. What appears to be missing is the linking of the two aspects to provide a much more flexible and accurate tool for both energy regulations, modelling and analysis. Alignment to the current standard rating point (say T1 for cooling) could be used as the basis for much of the calibration process needed to "prime" the computer model and this would also give added comfort and security of this approach for regulatory purposes as T1 testing is commonly required for energy labelling and/or MEPS. The provision of data on the construction of the unit and basic well known performance data (such as a compressor performance map) to enable calibrated simulations means that the incremental testing and data requirements are small. In fact, such a modelling approach could substantially reduce the testing required in those cases where a number of tests are required (e.g. part load tests for inverters and seasonal energy efficiency rating tests in North America for larger systems and in Japan).

It is reasonable to assume that the development of such an algorithm would enable a fully international test method to be adopted that could be applied to reflect performance under local usage circumstances far more realistically than any single set of weighted steady state conditions could do. It could also be used to estimate performance and energy under most of the standardised rating conditions found in test procedures today. If nothing else, the development of such an algorithm or simulation model would enable the magnitude of differences in the rated performance resulting from the differences in existing local test procedures to be quantified and for the impact of differences in individual parameters to be evaluated. In fact this has already been addressed to a large degree in the *Study of algorithms for air conditioners (Study 3)*, however, the continuation of this type of analysis is also likely to aid informed debate about test procedure alignment issues and the consequences of modifying any particular parameter. The computer modelling approach would also enable the impact of trade-offs caused by desirable simplifications of the test procedure against system characterisation accuracy to be quantified, that would substantially aid the discussions on how best to optimise development of the international ISO5151 test procedure as a basis for simulation calibration.

The recommendations for air conditioners are:

- to provide some effort and resources into eliminating the currently somewhat arbitrary (but mostly small) differences in test conditions and tolerances for testing of air conditioners and heat pumps within APEC member economies. Aligning to ISO5151 T1 (and ISO13253 and ISO13256 as applicable) would appear to be a feasible option, while acknowledging that ISO approaches and definitions need to be refined in some areas over the longer term;
- to work gradually towards the development and adoption of an international coding system of definitions for air conditioners within APEC member economies, in order to assist with the uniform treatment of air conditioning products in a regulatory sense;
- to undertake further investigations into the feasibility of developing a full simulation model for air conditioners as a medium-term goal (including a calibration process against physical tests). Such an approach should make particular reference to the accurate estimation of performance under standard rating conditions (for comparative and regulatory purposes), simulation of actual usage under a range of climates, and more realistically and accurately assessing the performance of variable-speed drive compressor systems under conditions of actual use (e.g. a range of part load conditions).

5.3.2 Other air conditioners

There are a number of other more "non-conventional" air conditioner types that are regulated for energy efficiency in APEC member economies, mainly in North America. These products include water sourced heat pumps, ground sourced heat pumps and closed loop heat pumps. Canadian and US standards are based on ASHRAE 37 test methods. These products have a limited marked world wide, but are traded between the major markets of North America, Europe and Japan.

There are strong moves in North America to align their testing regimes with ISO standards where these are available. A discussion on recent moves for water sourced heat pumps is provided in Ellis (2000). This alignment work with ISO test methods needs to be encouraged across APEC.

As for conventional air conditioners, algorithms for non-conventional air conditioners may be possible but these are more likely to be complex for product types such as ground source and water source heat pumps.

The recommended strategy for non-conventional air conditioner type is essentially the same as for conventional air conditioners: alignment of the test elements in the first instance and algorithms can be developed if these prove successful for conventional air to air heat exchanger products.

5.3.3 Dehumidifiers

The only APEC economy to regulate dehumidifiers is Canada. The testing requirements are contained on CAN/CSA-C749 and these are harmonised with US requirements in ANSI/AHAM Standard DH-1. At this stage there is no international test method for the performance of dehumidifiers. However, it is understood that AHAM will be proposing their test method to IEC TC59 as the basis for an international in the near future. It is recommended that the development of this new IEC standard, which will provided a good basis for future alignment, be supported by APEC.

5.3.4 Electric space heaters

The only APEC economy to regulate electric space heaters is the USA while Korea is considering regulation. The US requirements are for comparative energy labelling, primarily against gas and oil heaters. This product category includes resistive space heaters but does not include heat pumps which are covered under air conditioners.

There is an IEC standard for space heaters (IEC60675), but it is not clear if this is widely used. For electric resistive space heaters, there is effectively no difference in energy efficiency between products (all electrical energy is converted to heat), so these products are unlikely to be regulated widely for energy efficiency. If a test method is required, ideally this should be based on an agreed international test method with a view to alignment of requirements. There appears to be little point in developing an algorithm for this product type.

The only complication is that where a labelling program is required to cover similar products for multiple fuels (such as in the USA), electric systems need to be compared to other fuels on a consistent basis. In this regard, alignment to a competent multi-fuel test procedure would be the best option (the current US method has an assumed heating profile so this may be problematic for international adoption), but this is beyond the scope of this study. Algorithms for this product may be useful for estimating performance and energy consumption for a number of heating profiles when using fuels other than electricity (as burner efficiency for oil and gas products will vary with ambient conditions, output capacity and output profile).

5.4 Electric motors

5.4.1 Product Overview

Motors are products which are already traded widely on the international market.

While only a few APEC member economies currently regulate motors on the basis of energy efficiency (mostly larger three phase motors, but also small single phase motors in some cases), there are many economies that are considering energy efficiency regulations or related programs for motors. In addition, the declaration of motor efficiency (at full and/or part load) is a widely quoted and sought piece of information in the market place by suppliers and purchasers and is used in a range of voluntary programs such as Motor Challenge (USA) and in EURODEEM (European high efficiency motor database – see http://energyefficiency.jrc.cec.eu.int for more details).

5.4.2 Overview of main product test procedures and major issues

The four main test procedures for motors which are in use in the world are:

IEC60034-2A Rotating electrical machines - Part 2: Methods for determining losses and efficiency of rotating electrical machinery from tests

NEMA MG 1-1987, Motors and Generators, Revision No. 2

ANSI/IEEE 112-1984, Test Procedure for Polyphase Induction Motors and Generators (Method B) (IEEE has several methods: A, B, C, E, E1, F and F1)

JIS C4210 Low voltage three phase squirrel cage motors for general purpose (see also JEC 37)

The IEEE and NEMA methods are equivalent and either is generally acceptable for use in North America, so there are in fact only three main methods of test. While much of the content of these three main test methods is similar, there are some key differences, which are discussed below.

The losses in an induction motor, the most common type, comprise: stator copper loss; rotor losses; iron losses; windage and friction loss; and additional load loss (also commonly called stray loss). The two main parts of an induction motor are the stator (static) and the rotor (turning).

The main losses are outlined below:

- stator I^2R losses: stator copper losses are determined from the resistance of the stator at its temperature of operation;
- rotor I^2R losses: rotor losses are obtained from the air gap power and the slip (which should be corrected to the specified stator temperature) and depend on the conductivity of the rotor material;

- stator and rotor iron losses (also called core losses): are from eddy currents and hysteresis losses in laminations and depend on the flux density and frequency. Iron core losses are thought to be nearly constant in the stator for a given voltage, while rotor iron core losses are negligible at rated load. Iron losses for the stator are obtained from a no load test;
- windage and friction losses: depend on the speed and sometimes the direction of the motor. They are also obtained from a no load test;
- stray losses (also called additional losses): these are not well understood, but in fact are those losses which are in addition to the losses determined above. They are believed to be made up of (1) flux pulsation losses in the rotor and stator teeth, (2) surface losses in the rotor and stator (negligible) due to space harmonics in the stator and rotor, (3) I^2R losses in rotor cage due to rotor currents induced by the harmonics of the flux density.

The main differences in the IEC, JIS and IEEE test procedures are outlined below.

Instrumentation accuracy
There are some differences in the instrument accuracy required under JIS, IEC and IEEE.

Sequence of Testing
JIS and IEC do not specify a sequence of test. IEEE tests are to be undertaken in order of rated load temperature test, test under load and no-load test.

No-load Stabilisation
IEC and JIS contain no requirement for stabilisation prior to measurement, although this is common sense and widely practiced. IEEE requires stabilisation of temperature and input power before readings are taken (less than 3% variation of input power for successive readings taken at half hour intervals). Stabilisation before measurement decreases windage and friction loss variability.

Reference temperature for stator I^2R losses
IEC and JIS correct the measured stator temperature to the rated temperature of the insulation class ratings (Class A to 75^{o}C, Class B to 95^{o}C, Class F to 115^{o}C, Class H to 130^{o}C) for the determination of stator I^2R losses (rather than determine these at the actual stator operation temperature). The IEEE method uses the actual temperature in the stator during a load test for determination of stator I^2R losses, corrected to an ambient temperature of 25^{o}C. The IEC and JIS method means that if a motor is well designed and the stator runs "cool", it obtains no advantage under the test procedure as the stator losses are adjusted back up to the rated stator winding temperature for the insulation class of motor. Under the IEEE procedure, a lower stator temperature during actual use will be reflected in lower stator losses under the test procedure, which is more reflective of actual use.

Reference temperature for iron losses
IEC and JIS do not specify a reference temperature for measurement of iron losses. As the sum of the iron and stator losses are determined from the no load test, an increase on the stator losses from the increase in reference stator temperature will mean that the iron losses are underestimated during normal use when using IEC or JIS. IEEE determines the no-load test losses at actual temperature of operation, which means that the balance between stator losses and iron losses will be more accurate.

Reference temperature for rotor I^2R losses

JIS and IEC do not specify a reference temperature for measurement of rotor I^2R losses. IEEE corrects the value of slip for each load point back to an ambient temperature of 25°C using the ambient corrected value for the stator I^2R losses. The impact of this difference is somewhat unclear, but the IEEE method is thought to be more accurate.

Additional or stray losses

As noted above this is the most significant difference between the test methods. JIS/JEC assume that additional losses are 0% for all motor types and sizes. IEC assume that additional losses are 0.5% of the rated input for all motor types and sizes. IEEE Method B determines the additional losses through a series of direct torque measurements at various loads. A regression of the measurements is used to estimate the additional losses. The IEEE method is thought to be an accurate method of assessing additional losses for motors.

Interestingly, apart from the specified order of testing, some stability requirements and the requirement for direct torque measurements, the practical differences between the test methods are minimal. Most of the differences resulting from the use of differing reference temperatures are in calculations undertaken at the completion of the testing rather than differences in the tests themselves. The IEC test method nominally only requires an efficiency test at rated load, but most suppliers undertake and provide efficiency measurements at 75% and 50% of rated load as these values are widely by customers during motor selection.

Most analysts regard the IEEE method (with the direct measurement of stray or additional losses) to be the superior test method of the main international methods (AGREE 1997, Batheld & Kline 1997, Renier et al 1998, Van Voy 1997). More detailed papers on motor efficiency can be found in de Almeida et al (1997), in particular the paper by Van Voy et al (1997) compares induction motor efficiency test standards.

In late 1997, IEC initiated a new work item to review the IEC test procedure for motors with a view to considering the IEEE procedure and adopting the superior approaches that were applicable. There has been a long and involved process of drafting and redrafting of a new international standard since that date, but a committee draft for voting (document IEC 2G/118/CDV) was finally passed in October 2001, which means that a new IEC standard will soon be issued as a Final Draft International Standard (FDIS). The resulting standard is very similar to the approach to IEEE with the exception that it allows "additional" losses to be either measured as per the IEEE Method B or estimated or "assigned" using an equation. The equation for estimating additional losses varies with rated output and has been set at the high end of what is expected on the market, so a manufacturer with low additional losses has a strong incentive to measure these directly using the IEEE or new IEC method. The estimation method was inserted essentially at the request of the Europeans who were concerned at the significant cost increase of tests under the proposed direct measurement method, as torque has to be accurately measured under the IEEE procedure (which requires more sophisticated and expensive instrumentation).

Interestingly, the joint Australian/New Zealand Standard AS/NZS 1359.5:2000 contains parallel MEPS and high efficiency requirements for motors tested by the two different methods. These were produced using an unpublished conversion algorithm. In this case, the algorithm was used to adjust the target efficiency, rather than the test results.

5.4.3 Recommended approach to reduce testing costs

IEC now appear to have sorted out the outstanding technical issues associated with a new international standard for motors and will soon publish an international standard that characterises motors over a range of conditions and that is accurate and competent. It is recommended that APEC consider using this standard as a suitable test method for future alignment for motors.

Motors are relatively unusual, in that the new IEC test method is already suitable for a range of purposes and conditions and the test method already “characterises” the product to the extent that is required in the market place for normal use (e.g. measures load factor and efficiency for a wide range of load outputs). Therefore, the development of a conversion algorithm is not necessary nor recommended for this product.

5.5 Lighting equipment

5.5.1 Product overview

Lighting products are widely used in all sectors of the economy and there is already a huge international trade in these products and their components. The main types of equipment that are already regulated on the basis of energy efficiency are fluorescent lamps (mainly linear lamps, some compact fluorescent lamps), fluorescent lamp ballasts (the most common product regulated for efficiency) and some incandescent lamp. A number of economies are also considering energy efficiency regulations for these products. High intensity discharge (HID) lamps (e.g. sodium or mercury vapour, metal halide) appear not be directly regulated for efficiency at this stage (as they are mainly used in industrial or outdoor applications and their efficiency is generally quite high in any case: but some economies are considering regulation), nor are (surprisingly) quartz halogen systems widely regulated (these are very widely used in residential and commercial sectors and in fact have relatively poor energy efficiency: again, some economies are considering regulation).

Lighting products are generally relatively simple in nature and their main modes of operation are straight forward. The main parameters of interest are light output and power input and the system is usually on or off. There are no complicated programs to consider and the ambient conditions have only a minor marginal impact on the product performance. While there are dimming systems and occupancy sensors which affect actual operation, these systems are well understood and are not usually included in regulatory or voluntary requirements for energy efficiency. Lighting quality (distribution of light) is an issue for some product types, although this is difficult to quantify in some cases and it rarely forms a regulatory requirement for efficiency. Other important lighting issues are the colour rendering index and the apparent light colour, although IEC and CIE standards cover these attributes more than adequately.

5.5.2 Overview of main product test procedures and major issues

Generally speaking, there is widespread use, either directly or through the adoption of local "clone" versions, of the IEC standards for the measurement of lighting performance. It appears that these standards are generally well regarded with respect to design, construction and performance of lighting components. Efficacy measurements for lamp components are well specified within IEC and these methods are widely accepted. Despite this, some APEC member economies do not appear to use these IEC standards, but the reasons for this are unclear. This may warrant further investigation.

The issue of efficacy of fluorescent lamp ballasts is not addressed directly within any of the IEC standards, although most of the required information regarding reference ballasts and lamps and measurement of various parameters is contained in the relevant ballast and lamp performance standards. However, a methodology for the determination of efficacy of ballasts is critical as this product is widely regulated and the best approach is not necessarily "logical or obvious" to a non-expert in lighting performance. The absence of an IEC test method is probably partly a case of lack of understanding or appreciation by the relevant IEC committees of how their standards are used on a day to day basis. It is also probably the result of a history of concentration on the performance of lighting components and their standardisation (e.g. construction, strength, size and dimensions, operation voltage and power, light output and so on) rather than concern with respect to efficacy.

North America, out of necessity, has developed it own approaches to the measurement of lamp and ballast efficacy which appear to be technically competent. The approach is generally in line with the approaches for measuring the efficacy of fluorescent systems that have been more recently developed in Europe (although the details and performance parameters are quite different). A number of APEC member economies are developing or searching for an appropriate method for measurement of ballast efficacy.

The technical difficulty for fluorescent systems is that for some ballast/lamp circuit types (mainly those without a starter and those used with high frequency ballasts) is that it is not possible to accurately determine the lamp power or ballast power directly. The approach that is taken in North America and now Europe is that the relative light output and total power circuit power for a test lamp and ballast is compared to a reference system. This seems to be the most reliable method of measuring ballast efficacy. This approach is critical for high frequency systems (where the light output for a given lamp power input increases significantly) if they are to be compared on a fair and equitable basis to low frequency systems (ferromagnetic ballasts).

There would appear to be an opportunity for the IEC to develop a new international test method for the measurement of the efficacy of ballasts. This could be done with both the input from the major APEC member economies as well as Europe to develop a truly international test procedure. The existing methods in Europe and North America could be used as a basis for the development of the new standard. There are not likely to be many controversial issues, although minimum requirements for ballast lumen output may generate some discussion (historically these are generally higher in Europe than North America).

Australia and New Zealand have recently issued a test method for the determination of ballast efficacy (AS/NZS 4783.1-2001) which is based broadly on the European method but has been made more general so that it covers the requirements of the North American test procedures. This approach was discussed and generally agreed within an APEC forum at the Colloquium on Technical Issues of Minimum Energy Performance Standards (APEC 1999) held in Korea in 1999 and these discussions essentially spurned the development of the new AS/NZS standard. APEC should consider sponsoring the development of a new IEC standard for the determination of energy performance and efficacy of fluorescent lamp ballasts using the recently published AS/NZS standard as an initial discussion draft. This would complement the current suite of IEC lighting performance standards for lamps and ballasts. Once developed, this standard could be nominated as a suitable test method for future alignment within APEC.

If a suitable IEC standard can be successfully developed for ballast efficacy, this test method would be already suitable for a range of purposes and conditions and would "characterise" the product to the extent that is required in the market place. Therefore, the development of a conversion algorithm is probably not necessary or recommended for this product.

5.5.3 Recommended approach to reduce testing costs

The following recommendations are made for lighting products:

- active alignment with IEC standards for lighting products, other than fluorescent lamp ballasts;
- closer examination of the adequacy of IEC standards for HID and quartz-halogen systems for energy efficiency regulatory purposes (noting that these products are currently subjected to minimal regulation, but that regulation is likely to increase);
- encouragement of APEC participation in the development of a new IEC standard for the measurement of fluorescent lamp ballast efficacy based on the published standard AS/NZS4783.1-2001;
- development of an algorithm at this stage is not considered likely nor is investigation into the feasibility of an algorithm recommended.

5.6 "Wet" household appliances

So called "wet" products are of four types: water heaters, clothes washers, dishwashers and clothes dryers. Each of these products are examined briefly.

5.6.1 Electric water heaters

5.6.1.1 Product overview

Electric water hearers are used in many APEC member economies, although the ownership does vary substantially by member economy, ranging from negligible to well over 50% in the residential sector. The level of trade in water heaters is not all that high as they are generally large bulky items with a relatively low manufactured value. However, many of the manufacturers have global operations and the level of trade is likely to increase with more liberalised trade arrangements world wide.

Electric water heaters, being a product that consumes large amounts of a premium energy source (electricity), are often regulated where their use is common. The range of test procedures varies both in the details (typically reflecting local storage temperatures and ambient temperatures) and general approach, with some economies using a static heat loss test (no hot water drawn off) with others using dynamic drawoff tests of specified temperatures and volumes over a set period. Within the test procedures for electric water heaters there is almost no alignment within APEC member economies (not even within NAFTA economies). Water heater test procedures are typical "home grown" in that that they seem to rarely draw on IEC tests or any other international method and almost always reflect "local conditions".

The IEC test method for water heaters is a static standing heat loss test, and while probably adequate for one particular class of product (electric storage models), is of little (obvious) value to economies like the USA which regulates a range of fuel types (electric resistance, heat pump, gas, oil) and requires a common test procedure across these product types. A task or draw-off test is usually required for non-electric water heater types. It is important to note that total energy use for a water heater is primarily affected by the volume of hot water delivered, so actual usage profiles are critical for comparing and ranking hot water systems. Of course usage profiles vary throughout the world (as do hot water storage temperatures, ambient air temperatures and cold water inlet temperatures, all of which impact on total energy consumption of water heaters). For electric water heaters the main technical difference between models is the level of insulation (i.e. heat loss, although stratification in storage systems is of some importance), while for non-electric types other factors such as burner efficiency and start up characteristics also play a role in total energy consumption.

5.6.1.2 Overview of main product test procedures and major issues

On the face of it, the prospects for alignment of water heater standards are poor. Many product types are regulated, test procedures are many and varied and there is a real need to cover product groups beyond simple electric storage models (such products are outside the scope of this study, but they are still relevant in a practical sense). The standard simple heat loss approach currently used in the IEC is of little direct value in most cases when considered in isolation. But the more complex methods used (e.g. drawoff tests in the USA), while perhaps reflecting more accurately local use and conditions and providing better product coverage (but both of these points are debateable), means that these particular test methods are largely irrelevant to most other economies and climates and offer a poor option for APEC wide alignment.

Water heaters would appear to be an ideal candidate for the development of an algorithm. While the modelling required for a water is reasonably complex (thermodynamic heat flow modelling with the ability to characterise temperature stratification within the tank during drawoff and heating recovery characteristics, as well as radiant and convective heat losses), the physics of these systems is generally very well understood and modelling is reasonably practical and accurate. Modelling of systems which have a strong interaction with the environment (e.g. heat pump models, solar water heaters), is somewhat more complex but has also been successful.

There are a number water heater simulation models available around the world. Work undertaken in Australia, primarily for the modelling and rating of solar water heaters under AS4234, has resulted in the development of a computer model that can accurately characterise a wide range of water heater technologies, including electric storage systems, gas instantaneous and gas storage systems and solar and heat pump systems.

Actual tests on a range of solar and conventional systems has shown that the Australian model provides a very accurate estimate of the task energy consumption (for any weather or climate pattern, any drawoff pattern and any energisation profile). The Australian model can also be used to accurately simulate different test procedures such as static heat loss tests under different conditions and pre-defined drawoff tests.

This Australian model could be used as a basis for APEC member economies for the measurement of energy consumption and energy efficiency of water heaters. The data requirements for conventional electric systems are minimal and can be determined from simple tests, together with key physical characteristics (it is likely, for example, that tests under IEC60379-87 could provide some of the necessary input data for electric storage water heaters, as could any other static heat loss test e.g. CSA/CAN standards or AS/NZS standards, as long as the precise test condition was documented). Heat pump and solar systems require a greater range of physical tests under controlled or known outdoor conditions to determine the required input and performance variables, but this is quite manageable. While some additional documentation and software development may be necessary before it is ready to be publish as an international standard, the basic modelling engine appears to be sound and robust and suitable for widespread application.

5.6.1.3 Recommended approach to reduce testing Costs

The prospects for alignment of water heater test procedures appear poor. The only feasible option appears to be the development of a modelling algorithm which will allow accurate modelling and characterisation of a wide range of climate conditions and usage patterns. Such a computer model already exists and is in the process of being developed into an international standard. APEC should provide active assistance in this development, particularly with regard to the specification of input requirements for conventional water heater types. It may be necessary to specify a standard set of tests to measure the key attributes of a water heater for such an algorithm, but these tests are likely to be no more onerous (often less onerous) than current test methods for water heaters. Such measurements may form part of an international standard.

5.6.2 Clothes washers

5.6.2.1 Product overview

Clothes washers appear to be regulated in a number of APEC member economies, as well as Europe. The ownership of clothes washers is high in most APEC member economies, but the energy consumption varies considerably due to local cultural factors (wash temperature, frequency of use). There is certainly a large trade in clothes washers within the APEC region and around the world. Most European machines heat water internally (using electricity) while most machines from elsewhere in the world (i.e. most of APEC) use external hot water where this is necessary. European machines are predominantly of the drum type (front loading), while types such as agitator and impeller predominate within APEC (although drum machines are available in most economies and are increasing their market share in

North America). Some new clothes washer technologies such as bubble wash, ozone and nutator technologies have appeared in recent years, but these are still only fringe technologies. The advent of these new technologies has created some interesting challenges for clothes washer performance testing.

Test procedures used in APEC member economies are a mix with some obviously "home grown" while others have drawn on IEC methods but these have been adapted for local conditions, cultural influences and differing technologies and (particularly types of washers and wash temperatures). A few economies use IEC methods without modification (or are considering this approach), but more often than not have to develop separate approaches to cover top loading machines which until recently have not been covered by the IEC test method. The measurement of performance also varies substantially, with NAFTA economies not measuring performance at all (some even test without a load for some products, although has recently changed), while IEC, JIS and AN/NZS use a range of different approaches to assess the washing performance.

5.6.2.2 Overview of main product test procedures and major issues

The washing process in a clothes washer is a complex one (a combination of chemical and mechanical action which is affected by water temperatures, water hardness, soil type, detergent composition and so on) and it is extremely unlikely that a conversion algorithm or computer model would be able to accurately characterise the performance and the energy consumption of a clothes washer (it may be possible to estimate energy consumption of a clothes washer for different wash temperatures based on a single test, but it is not possible to estimate the wash performance for these temperatures except through direct measurements). So the prospects for a conversion algorithm are very poor, if not negligible.

This suggests that efforts for clothes washers should concentrate on alignment of test methods. However, as noted above, the IEC standard is still in the development stage with respect to its treatment of top loading systems (as well as some of the other performance measures). In its current form, the IEC standard is not really worthy of alignment in the short term. On the other hand, even it its current form, it is probably superior to many of the test procedures currently in use in APEC member economies.

The IEC standard for clothes washers (IEC60456) was, until recently, developed wholly within Europe, and as such, was only really applicable for drum (front loading) machine types used in hard water areas. Recent work on the standard has meant that there is now at least a detergent and methodology that is applicable to non-drum machines (top loaders, which probably constitute the vast majority of clothes washers in the world), although there are many issues still to be resolved. There is much work to be done in the IEC on the alignment of various aspect of the test procedure such as water hardness and detergent composition, both which substantially affect the washing performance. One of the issues is whether separate reference detergents should be used for drum systems versus non-drum systems (agitator, impeller) and whether the IEC reference system (based on drum technology) is applicable to non-drum machines.

Encouragingly, IEC subcommittee 59D (laundry products) in 2001 formed a working group to look at the application of IEC60456 to all clothes washer types around the world. The working group, called "Global Application of IEC60456" will be looking at all test elements with a view to ensuring that materials, methodologies and assessment systems are universally applicable.

Other performance elements of the IEC standard are worthy of consideration, such as spinning and rinsing performance (although there are some questions regarding reproducibility of this latter test). The severity of washing index used in Australia to measure the harshness of the mechanical action is also an important consideration for non-drum machines (a similar test can be found in the Japanese standard).

There are many local and cultural factors which impact on the clothes washer performance and energy consumption: use of external hot water, water hardness, local detergent composition, program selection, wash temperature, typical load composition. While it is possible (even necessary) to specify all of these variables in an IEC or other international test procedure, this necessarily will move the test method away from “actual use”. It is yet to be determined whether the correct ranking of machines (such as is required for energy labelling or MEPS) could be achieved using “unrealistic” and highly standardised test conditions found in clothes washer test procedures. Probably the biggest area of difficulty is the use of different wash temperature across (and within) APEC member economies and the consequent impact on wash performance and energy consumption. It is not really possible or desirable to control this element of the test.

There are certainly benefits to aligning to a methodology such as the IEC, even if this means that there is some retesting required for aspects such as wash temperature. At least the approaches and materials required by a test laboratory would be consistent.

5.6.2.3 Recommended approach to reduce testing costs

The recommendations for clothes washers are for:

- active participation in IEC committee SC59D to assist in the development of a relevant international clothes washer performance standard, noting that IEC has recently formed a working group called “Global Application of IEC60456” to achieve such a goal;
- medium-term alignment to the IEC standard when this is deemed acceptable. In the meantime a number of disparate clothes washer test methods are likely to remain in place;
- development of an algorithm at this stage is not considered likely nor is investigation into the feasibility of an algorithm recommended.

5.6.3 Clothes dryers

5.6.3.1 Product overview

Clothes dryers are not all that common within APEC member economies except in USA, Canada, Australia and New Zealand. These in fact are the only economies that regulate clothes dryers for energy efficiency (NZ is voluntary at this stage but is expected to be mandatory shortly). Clothes dryers are of course common in Europe as well (although that has not been examined for this report) and these products carry an energy label in that region.

5.6.3.2 Overview of main product test procedures and major issues

There are currently two major approaches used for clothes dryers: the AHAM style of approach and the IEC approach. In fact, the two test methods are not so different from each other and are certainly not irreconcilable. The major differences include different initial moisture contents, operation into the cool down period (or not), and some differences in test load composition. AHAM specifies the bone dry method for determining load mass, while IEC allow both the bone dry and conditioned mass methods.

All of the dryer performance methodologies currently in use (including IEC) do not adequately or consistently correct the energy consumption to a target final moisture content (except in AS/NZS standard which deals with this issue specifically). The repeatability error (within the same laboratory) in energy consumption arising from this poor methodology is potentially as high as ±8% from this issue alone, which makes existing methods largely unacceptable for regulatory purposes. This issue needs to be redressed within IEC but progress over recent years has been poor. The current AS/NZS method should be adopted in IEC or a more generic universal test methodology should be developed (see discussion below).

A related issue is the treatment of timer dryers versus autosensing (or dryness sensing) controlled models. These are not handled in a consistent manner in the major methodologies (except AS/NZS). This also needs to be addressed.

There are a range of other small differences in dryer standards such as ambient test room temperature and humidity, allowable tolerances, clothes load composition and the like, but these differences have only a minor impact on the overall performance measurement. There is a strong argument to at least harmonise the basic test procedure elements and materials for clothes dryer testing. Apart from the method for estimating energy consumption, the IEC standard could form an acceptable basis for an international standard for clothes dryers.

The energy service provided by a clothes dryer is relatively straight forward – energy (usually heat) is used to remove moisture from a damp clothes load. Theoretically, the parameters being measured can be determined to a high degree of accuracy – mass, time and energy (usually electricity but sometimes also gas). Interestingly, there is little disagreement in international circles regarding the definition of “dry clothes” so this can be defined in an international test procedure with some confidence. The only parameter that is likely to change from economy to economy is the initial moisture content of the clothes load (which is dependent on the average spinning performance of clothes washers used in a particular economy). Therefore it is important to have a test procedure that is able to deal with this variable in a way other than retesting at every likely initial moisture content. Clearly the average spin performance of clothes washers in each member economy varies substantially. The range of initial moisture contents specified in current dryer test procedures varies by a factor of up to 2, which is merely a reflection of the local clothes washer stock.

If a methodology can be developed that can estimate the energy consumption of a clothes dryer accurately for a range of initial moisture contents, this would effectively be able to serve as a generic international standard. While such an “algorithm” is quite feasible, it will be necessary to change the measurement approach in the major methodologies to better characterise the performance of the clothes dryer over a range of initial moisture contents. This involves segmenting the drying curve into its component parts – start up characteristic, linear drying portion (down to about 30% moisture) and the non-linear tail. By characterising each of three parts of the performance curve, the clothes dryer energy consumption (the major performance variable of interest) can be accurately estimated for a wide range of initial moisture contents. Ongoing work in this area is under way within IEC and it is hoped a suitable and accurate methodology can be developed within the next few years.

5.6.3.3 Recommended approach to reduce testing costs

IEC61121 could eventually provide a suitable international test procedure for clothes dryers (once some of the outstanding issues are resolved, especially the current energy correction methodology). The basic test elements of the IEC standard could form the basis of a suitable standard for alignment within APEC. It is recommended that APEC instigate more widespread international participation in the IEC clothes dryer standard committee to ensure that it is applicable within APEC.

Substantial retesting because of local variations in initial moisture content could be avoided if the generic performance algorithm approach can be refined and accepted. It is recommended that this area of development receive some significant effort over the next few years. Once this test methodology is available, it is recommended that APEC consider the feasibility of alignment with this approach. Therefore, the development of a separate conversion algorithm is probably not necessary or recommended for this product (however, this generic approach may be considered as an algorithm in itself).

The recommendations for clothes dryers are for:

- active participation in IEC committee SC59D to assist in the development of a relevant international clothes dryer performance standard;
- inclusion of a more accurate energy consumption measurement method into the IEC standard and the elimination of the current inaccurate energy correction method;
- development over the longer term of a more generalised IEC dryer standard that could accurately estimate energy consumption over a wide range of initial moisture contents (in effect a partial modelling algorithm based on test measurements);
- medium-term alignment with this generalised IEC standard/algorithm when this is deemed acceptable, which would then allow for a range of initial moisture contents to be used in local or regional standards to better reflect local usage conditions.

5.6.4 Dishwashers

5.6.4.1 Product Overview

Dishwashers are not all that common within APEC member economies except in USA, Canada, Australia and New Zealand (although there is growth in the ownership of this product in Japan and Korea). In fact these first 3 economies are the only ones in APEC that regulate dishwashers for energy consumption (NZ is voluntary at this stage but will have mandatory requirements shortly; Korea is preparing regulations at the moment). Dishwashers are of course common in Europe as well (although that has not been examined for this report) and they carry an energy label in that region. Japan has a significant dishwasher market but this is not regulated for efficiency at this stage.

There is a growing international trade in dishwashers and this is likely to be substantial within a decade. The design of dishwashers from Europe and North America are still quite different, although globalisation of the market means that there is a gradual convergence in the design and performance of dishwashers. Trade between Europe and North America is increasing. There are a range of dishwasher test procedures currently in use, and there are some significant differences between these. However, there has been a strong push for development of a true international test method for dishwashers which is now close to fruition.

5.6.4.2 Overview of main product test procedures and major issues

Currently there are three main approaches to testing dishwashers – old IEC60436-1981 used in Australia and New Zealand (but now modified significantly due to its technical limitations), the AHAM method used to assess performance (with a heavy soil load but mostly used for comparative performance testing in the USA) and the US DOE method specified in CFR430, which has no soil on the load for energy consumption testing. Europe is now using a regional standard CENELEC EN50242 (based on the German DIN performance standard but modified somewhat) which has also deviated substantially from the old IEC60436-1981, and this method also has a soiled load for testing.

As for clothes washers, prospects for the development of conversion algorithms for dishwashers are poor. The washing process is complex and is affected by a wide range of variables. It is unlikely that energy consumption or performance under different test conditions or using different soils or materials could be accurately predicted.

Due to the lack of active work since its publication, IEC 60436-1981 has fallen behind in its ability to adequately assess the performance of dishwashers now on the market. Dishwashers are starting to be equipped with adaptive controls that adjust performance in response to soil loads, so it is becoming necessary to test units for energy consumption with a soiled load to get a result that is reflective of actual use. The increasing requirements for accurate performance assessment (in terms of repeatability and reproducibility) for various programs now also means that a new approach is required.

There has been ongoing work within the IEC since 1996 to address the major issues associated with the IEC dishwasher test procedure. This has been progressing slowly and steadily and in 2001 a committee draft (IEC 59A/102/CD) was issued for public review. This draft received few significant technical comments from IEC members and it is expected that a committee draft for voting (CDV) will be issued early in 2002. Given the active involvement of Australasia, Europe and North America in the development of this revised IEC60436, it is hoped that this will soon provide a suitable international test procedure for dishwashers. Once this test method is available, it is recommended that APEC align with this test methodology. Therefore, the development of a conversion algorithm is not necessary or recommended for this product.

5.6.4.3 Recommended approach to reduce testing costs

The recommendations for dishwashers are for:

- active participation in IEC subcommittee SC59A to assist in the finalisation and maintenance of a relevant international dishwasher performance standard;
- short- to medium-term alignment to the IEC test method once published;
- development of an algorithm at this stage is not considered likely nor is investigation into the feasibility of an algorithm recommended.

5.7 Office equipment and consumer electronics

5.7.1 Product overview

The sales of office equipment and consumer electronics around the world is enormous and there is already a huge trade in these products, both within APEC member economies and internationally. The other special attributes of these products is that their life is generally quite short (of the order of 3 to 6 years) and ownership levels are high and growing (both in the commercial and household sector) so the stock turnover is therefore generally very fast (at least in comparison with most commercial, industrial and household equipment). The pace of change of technology for these products is also very fast, which makes regulation difficult, but it also makes it difficult for test procedures to keep up.

While few APEC member economies regulate these products directly in terms of energy consumption, there are numerous programs such as Energy Star (used in many economies directly or indirectly) and the Japanese Top Runner program, which set out requirements and specifications for some of these products. The other important point is that many of these products are built for a world market, so therefore (by and large) they have uniform specifications the world over. Hence it has been necessary to take a global approach through programs like Energy Star.

Energy efficiency specifications for these products tend to focus on the energy consumption in standby modes, although other modes are of some interest for these products in some cases. The range of products in this category is quite large and growing: computers and computer peripherals (peripherals, scanners, modems etc), photocopiers, fax machines, telephones and answering machines and home entertainment equipment (TVs, VCRs, DVD players, stereo systems and individual components etc.). The range of equipment is quite diverse and this presents some problems with dealing with this product group in a coherent fashion.

5.7.2 Overview of main product test procedures and major issues

Currently test procedures for these products are not all that well specified (often in the form of guidelines rather than formal published international test procedures), but these appear to be adequate for the moment. In most cases, the tests required are relatively straight forward and the equipment and methodology not overly complicated, although the methodology and equipment specifications are important if power measurements below 10 Watts are to be determined with accuracy.

Where the standby mode is to be measured, the main issue is definition of the relevant standby modes themselves. Some equipment types have complex internal operations and controls and all possible modes may not be obvious to uninformed users or even test houses.

There is probably no need for a conversion algorithm given the largely uniform approach for testing these products to date. The other issue is that much of the measurement required for these products relates to standby or sleep mode energy consumption, rather than the energy consumed during normal operation (therefore measurement of performance is not required). There is increasing international interest in the assessment and limitation of standby energy consumption for a wide range of electronic equipment (e.g. 1 Watt program within the IEA) which will also impact on these products. Standby measurements apply to a range of other product types as well (e.g. off mode of many household appliances such as clothes washers, clothes dryers, dishwashers, air conditioners).

There is an argument that there needs to be some formalisation of the test methods used to determine standby energy consumption for office equipment and consumer electronics. Issues such as standardised temperature and humidity, consistent approach to dealing with rated voltage and frequency ranges, adequate instrumentation (noting that often power consumption levels are very small and that the current waveforms are complex, requiring sophisticated measurement equipment for energy) and generalised approaches for determining what is to be measured for new and unusual product types.

Obviously such work would need to be international and would require input from major stakeholders (e.g. Energy Star partners, Japan, IEA, European Group for Efficient Appliances). It is unclear whether such work should progress inside or outside of the IEC. The European Commission has given CEN and CENELEC a mandate to develop test methods for the measurement of standby energy consumption for a range of products covered by regulations or voluntary agreements in Europe.

A new project within TC59 (household appliances) was approved in October 2001 to develop test methods for the measurement of standby for a wide range of appliances (not specifically office equipment or home electronics). This test method is likely to be applicable to a range of product types outside of the scope of TC59 as well. It is hoped that this group will undertake much of the work required to satisfy the European Commission mandate on standby. APEC member economies should consider contributing to this work. There is also work progressing rapidly in the USA with regard to measurement of standby in response to announcements made by President Bush earlier in 2001, so this should also be monitored.

5.7.3 Recommended approach to reduce testing costs

APEC should coordinate approaches for the measurement of standby energy consumption for their various voluntary and mandatory programs in operation or under consideration. APEC member economies with a direct interest in standby energy consumption should actively participate in the new IEC TC59 project to examine test methods for the determination of standby losses. Development of an algorithm at this stage is not considered likely nor is investigation into the feasibility of an algorithm recommended.

5.8 Miscellaneous equipment

This section lists a range of miscellaneous equipment which are regulated by at least one APEC economy. As a general rule the number of economies that regulate these products are few. Given the low level of regulation of these products and the limited number of test procedures for energy and performance, the general approach recommended for these products is alignment of test procedures where efficiency requirements and associated testing requirements are likely to form a barrier to trade.

5.8.1 Power transformers

A number of APEC member economies now regulate for transformer efficiency (Canada, Mexico) and several are considering regulations or have voluntary programs (Australia, Chinese Taipei, USA). The main test procedures for power transformers are listed below.

Table 3: Power Transformer Test Procedures

AS 2374-1997	Power Transformers
AS 2735	Dry-Type Power Transformers
IEC 60076-1993	Power Transformers
IEC 60726	Dry-Type Power Transformers
NEMA TP1-1996	Guide for Determining Energy Consumption for Distribution Transformers (US)
NEMA TP2-1998	Standard Test Method for Measuring the Energy Consumption of Distribution Transformers (US)
ANSI/IEEE Standard C57.12.91-1979	IEEE Standard for Test Code for Dry-Type Distribution and Power Transformers.
ANSI/IEEE Standard C57.12.90-1993	IEEE Standard Test Code for Liquid-Immersed Distribution, Power and Regulating Transformers and IEEE Guide for Short-Circuit Testing of Distribution and Power Transformers
Canadian Standard C802.1-00	Minimum Efficiency Values for Liquid-Filled Distribution Transformers
Canadian Standard C802.2-00	Minimum Efficiency Values for Dry-Type Transformers

The North American test methods (NEMA and CSA) are all equivalent. The Australian method is equivalent to the IEC method. A brief assessment and comparison of IEC and NEMA methods has revealed that the main differences are:

- the values nominated for temperature correction for copper (234.5 in TP-2 vs. 235 in IEC 60076);
- the acceptable tolerance for losses (± 3% in TP-2 versus +10% total losses or +15% of each component loss provided that tolerance for total losses is not exceeded in IEC 60076);
- the treatment of reference temperatures may also differ in some cases.

However, these differences are small and unlikely to substantially impact on the test results.

Given there are few differences in the test methods used in North America and IEC, it is recommended that APEC consider using the IEC standards as a suitable test method for future alignment for power transformers. North America should be encouraged to actively participate in the relevant IEC committee to ensure that the IEC test method adequately meets their testing requirements.

The IEC test method is already suitable for a range of purposes and conditions and the test method already "characterises" the product to the extent that is required in the market place for normal use (e.g. provides efficiency over a range of power outputs). There are already standardised approaches for adjusting efficiency and output of transformers at different ambient temperatures (these approaches are widely used in the power distribution engineering sector). Therefore, the development of a conversion algorithm is not necessary nor recommended for this product.

5.8.2 Boilers

Boilers are regulated or are subject to voluntary programs in Mexico, USA and Korea. However, the main focus of these programs is on fuels other than electricity (mainly gas and oil). As for electric space heaters, there is effectively no difference in efficiency between electrical products (all electrical energy is converted to heat), so these products are unlikely to be regulated widely for energy efficiency. If a test method is required, ideally this should be based on an agreed international test method with a view to alignment of requirements. There appears to be little point in developing an algorithm for this product type.

The only complication is that where a labelling program is required to cover similar products for multiple fuels (such as in the USA), electric systems need to be compared to other fuels on a consistent basis. In this regard, alignment to a competent multi-fuel test procedure would be the best option, but this is beyond the scope of this study. Algorithms for this product may be useful for estimating performance and energy consumption for a number of heating profiles when using fuels other than electricity (as burner efficiency for oil and gas products will vary with ambient conditions, output capacity and output profile).

5.8.3 Industrial fans

China and Chinese Taipei are currently the only APEC member economies to regulate industrial fans for energy efficiency. The main relevant international test method for this product is ISO5801, although some US test methods are also used (AMCA210 and AMCA300). It is recommended that, where a test procedure for the performance of industrial fans is necessary, APEC member economies align with ISO5801. AMCA should be encouraged to ensure that their standards are aligned as far as is possible (and that ISO take into account North American requirements for industrial fans). While development of an algorithm may be possible, this appears to be unnecessary at this stage and work on an algorithm is not recommended.

5.8.4 Pumps

Mexico is currently the only APEC economy to regulate industrial pumps for energy efficiency, although Korea and the USA have voluntary labelling programs. The main relevant international test methods for this product are ISO2548 and ISO3555. It is noted that Mexico specify requirements for deep well pumps and at this stage there is no relevant international standard for this product. It is recommended that, where a test procedure for the performance of pumps is necessary, APEC member economies align with ISO2548 and ISO3555. While development of an algorithm may be possible, this appears to be unnecessary at this stage and work on an algorithm is not recommended.

5.8.5 Furnaces

Furnaces are regulated for MEPS and/or energy labelling in Canada and USA. However, the main focus of these programs is on fuels other than electricity (mainly gas and oil). As for electric space heaters, there is effectively no difference in efficiency between electrical products (all electrical energy is converted to heat), so these products are unlikely to be regulated widely for energy efficiency. If a test method is required, ideally this should be based on an agreed international test method with a view to alignment of requirements. There appears to be little point in developing an algorithm for this product type.

The only complication is that where a labelling program is required to cover similar products for multiple fuels (such as in the USA), electric systems need to be compared to other fuels on a consistent basis. In this regard, alignment to a competent multi-fuel test procedure would be the best option, but this is beyond the scope of this study. Algorithms for this product may be useful for estimating performance and energy consumption for a number of heating profiles when using fuels other than electricity (as burner efficiency for oil and gas products will vary with ambient conditions, output capacity and output profile).

5.8.6 Cooking products

This section deals with a number of cooking products that are regulated for energy efficiency or are covered by some type of voluntary program. Cooking products are notoriously difficult with regard to achieving aligned test procedures, as differences in cultural factors can have a substantial influence on the performance of the product and these are difficult to replicate in a test procedure.

5.8.6.1 Ranges/Ovens

A review of test procedures for cookers can be found in EES (1999 – Annex G1). MEPS and labelling for ovens and cooktops are mandatory in Canada. There are some differences between the Canadian method (CAN/CSA-C358) and the IEC method (IEC60350). Some experts feel that the IEC standard as published has significant problems that need to be resolved before it could be recommended for alignment within APEC. The requirements for Korea and Chinese Taipei have not been determined for this report.

Given that the level of regulation for this product is relatively low, no specific action for this product is recommended at this stage. However, Canada might wish to consider more active participation in the relevant IEC committee to improve the IEC test method so that it becomes suitable for alignment within APEC, should this be required in the future.

5.8.6.2 Microwaves ovens

Microwave ovens are subject to voluntary energy labelling programs in Korea and Chinese Taipei. There are no mandatory regulatory programs for microwave ovens within APEC or in any other parts of the world. It has not been possible to determine the testing methods used for microwave ovens in Korea and Chinese Taipei. However, the IEC standard for microwave oven performance (IEC60705) is generally considered competent and should be suitable for alignment within APEC should a test method be required. Given that the level of regulation for this product is relatively low, no action for this product is recommended at this stage.

5.8.6.3 Rice cookers

China regulates rice cookers for MEPS. No other economy in the world regulates this product. It has not been possible to determine the basis of the test method for rice cookers. There is no international test method for rice cookers. Given that the level of regulation for this product is relatively low, no action for this product is recommended at this stage.

5.8.7 Vacuum cleaners

Russia regulates vacuum cleaners for MEPS. No other economy in the world regulates this product. It has not been possible to determine the basis of the test method for vacuum cleaners. The international test method for vacuum cleaners is IEC60312. The IEC standard for vacuum cleaner performance is generally considered competent and should be suitable for alignment within APEC should a test method be required. However, given that the level of regulation for this product is relatively low, no action for this product is recommended at this stage.

5.8.8 Pool heaters

Russia regulates pool heaters for MEPS. No other economy in the world regulates this product. It has not been possible to determine the basis of the test method for pool heaters. There is no international test method for pool heaters (although ISO12596 does cover installation guidelines for solar pool heaters). Given that the level of regulation for this product is relatively low, no action for this product is recommended at this stage.

5.8.9 Irons

China regulates irons for MEPS while Russia has voluntary MEPS for irons. No other economies in the world regulate this product. It has not been possible to determine the basis of the test method for irons in China and Russia. The international test method for irons is IEC60311. The IEC standard for iron performance is generally considered competent and should be suitable for alignment within APEC should a test method be required. However, given that the level of regulation for this product is relatively low, no action for this product is recommended at this stage.

6 REFERENCES

6.1 Papers and reports

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6.2 Standards

Only standards cited in this report (directly or indirectly) are listed below. A full listing of test standards in use within APEC can be found in EES (1999). Standards are grouped by the bodies that develop the standards. Within each body, standards are listed in number order. Bodies listed in this section are:

AHAM – Association of Home Appliance Manufacturers (USA)

AMCA - Air Movement and Control Association, International

AS – Australian Standards

ASHRAE – American Society of Heating, Refrigerating and Air-Conditioning Engineers Inc.

CAN/CSA – Canadian Standards Association

CNS – Chinese National Standards of Chinese Taipei

EN – European Norms

IEC – International Electrotechnical Commission

IEEE – Institute of Electrical and Electronics Engineers

ISO – International Standards Organisation

JIS – Japanese Industrial Standards

KS – Korean Standards

NEMA – National Electrical Manufacturer’s Association (USA)

NZS – New Zealand Standards

6.2.1 AHAM – Association of Home Appliance Manufacturers (USA)

Web site: http://www.aham.org

AHAM DH-1 Performance of Dehumidifiers

AHAM DW-1 Performance Evaluation of Dishwashers

AHAM HRF-1 Electric Refrigerators and Electric Refrigerator-Freezers & Freezers

6.3 AMCA - Air Movement and Control Association, International

Web site: http://www.amca.org

AMCA 210 Laboratory methods of testing fans for aerodynamic performance rating

AMCA 300 Reverberant room method for sound testing of fans

6.3.1 AS – Australian Standards

Web site: http://www.standards.com.au

AS/NZS 1359.5: Rotating electrical machines – general requirements – Part 5: Three phase cage induction motors – high efficiency and minimum energy performance standards requirements.

AS/NZS 2040.1: Performance of household electrical appliances - Clothes washing machines - Energy consumption and performance

AS/NZS 2442.1: Performance of household electrical appliances - Rotary clothes dryers - Energy consumption and performance

AS 2374: Power transformers - General requirements (there are 7 parts)

AS 2735: Dry-type power transformers

AS4234: Solar water heaters - Domestic and heat pump - Calculation of energy consumption

AS/NZS 4474.1: Performance of household electrical appliances - Refrigerating appliances - Energy consumption and performance

AS/NZS 4783.1: Performance of electrical lighting equipment – ballasts for fluorescent lamps: Part 1 – Method of measurement to determine energy consumption and performance of ballast-lamp circuits.

6.3.2 ASHRAE – American Society of Heating, Refrigerating and Air-Conditioning Engineers Inc.

Web site: http://www.ashrae.org

ASHRAE 29: Methods of testing automatic icemakers

AHSRAE 32.1: Methods of testing for rating bottled and canned beverage vending machines

ASHRAE 37: Methods of testing for rating unitary air conditioning and heat pump equipment

ASHRAE 72: Method of testing open refrigerators

AHSRAE 117: Method of testing closed refrigerators

6.3.3 CAN/CSA – Canadian Standards Association

Web site: http://www.csa.ca

CAN/CSA-C360-98 Test method for measuring water and energy consumption of automatic household clothes washers

CAN/CSA-C361-92 Test method for measuring energy consumption and drum volume of electronically heated household tumble-type clothes dryers

CAN/CSA-C657-95 Energy performance standard for commercial refrigerated display cabinets and merchandisers

CAN/CSA-C742-98 Performance of automatic icemakers and ice storage bins

CAN/CSA-C749-94 Performance of dehumidifiers

CAN/CSA-C802.1-00: Minimum Efficiency Values for Liquid-Filled Distribution Transformers

CAN/CSA-C802.2-00: Minimum Efficiency Values for Dry-Type Transformers

CAN/CSA-C804: Energy Performance of Vending Machines

CAN/CSA-C827-98: Energy Performance Standard for Food Service Refrigerators and Freezers

6.3.4 CNS – Chinese National Standards of Chinese Taipei

CNS 9577-89 Method of Test for Electric Refrigerators and Freezers

6.3.5 EN – European Norms

European Committee for Electrotechnical Standardisation web site: http://www.cenelec.be

prEN 441: Medium and low temperature self contained refrigeration cabinets

EN 50242: Performance of household dishwashers

6.3.6 IEC – International Electrotechnical Commission

Web site: http://www.iec.ch

IEC 60034-1: Rotating electrical machines - Rating and performance

IEC 60034-2A: First supplement : Rotating electrical machines - Part 2: Methods for determining losses and efficiency of rotating electrical machinery from tests (excluding machines for traction vehicles)

IEC 60064: Tungsten filament lamps for domestic and similar general lighting purposes- Performance requirements

IEC 60076-1: Power transformers - Part 1: General (there are several parts)

IEC 60081: Double-capped fluorescent lamps - Performance specifications

IEC 60311: Electric irons for household or similar use - Methods for measuring performance

IEC 60312: Vacuum cleaners for household use - Methods of measuring the performance

IEC 60350: Electric cooking ranges, hobs, ovens and grills for household use – Methods for measuring performance.

IEC 60379: Methods for measuring the performance of electric storage water-heaters for household purposes

IEC 60436: Methods for measuring the performance of electric dishwashers

IEC 60456: Clothes washing machines for household use - Methods for measuring the performance

IEC 60675: Household electric direct-acting room heaters- Methods for measuring performance

IEC 60705: Methods for measuring the performance of microwave ovens for household and similar purposes

IEC 60726: Dry-type power transformers

IEC 60901: Single-capped fluorescent lamps - Performance requirements

IEC 60921: Ballasts for tubular fluorescent lamps- Performance requirements

IEC 60929: A.C.-supplied electronic ballasts for tubular fluorescent lamps - Performance requirements

IEC 60969: Self-ballasted lamps for general lighting services. Performance requirements

IEC 61121: Tumble dryers for household use - Methods for measuring the performance

IEC 61231: International lamp coding system (ILCOS) - Covers all lamp categories. Coding for the main lamp types is specified.

IEC 61341: Method of measurement of centre beam intensity and beam angle(s) of reflector lamps

6.3.7 IEEE – Institute of Electrical and Electronics Engineers

(North America)

Web site: http://www.ieee.org

ANSI/IEEE 112-1984: Test Procedure for Polyphase Induction Motors and Generators, Institute of Electrical and Electronics Engineers, New York, NY 10017 (Method B) (also available as NEMA MG1)

ANSI/IEEE C57.12.91: IEEE Standard for Test Code for Dry-Type Distribution and Power Transformers

ANSI/IEEE C57.12.90: IEEE Standard Test Code for Liquid-Immersed Distribution, Power and Regulating Transformers and IEEE Guide for Short-Circuit Testing of Distribution and Power Transformers

6.3.8 ISO – International Standards Organisation

Web site: http://www.iso.ch

ISO2548: Centrifugal, mixed flow and axial pumps - Code for acceptance tests - Class C

ISO3555: Centrifugal, mixed flow and axial pumps - Code for acceptance tests - Class B

ISO5151: Non-ducted air conditioners and heat pumps - Testing and rating for performance

ISO5155: Household refrigerating appliances - Frozen food storage cabinets and food freezers - Characteristics and test methods

ISO5801: Industrial fans - Performance testing using standardised airways

ISO7371: Household refrigerating appliances - Refrigerators with or without low-temperature compartment - Characteristics and test methods

ISO8187: Household refrigerating appliances - Refrigerator-freezers - Characteristics and test methods

ISO8561: Household frost-free refrigerating appliances - Refrigerators, refrigerator-freezers, frozen food storage cabinets and food freezers cooled by internal forced air circulation - Characteristics and test methods

ISO12596: Swimming-pool heating systems - Dimensions, design and installation guidelines

ISO13253: Ducted air-conditioners and air-to-air heat pumps - Testing and rating for performance

ISO13256-1: Water-source heat pumps - Testing and rating for performance - Part 1: Water-to-air and brine-to-air heat pumps

ISO13256-2: Water-source heat pumps - Testing and rating for performance - Part 2: Water-to-water and brine-to-water heat pumps

6.3.9 JIS – Japanese Industrial Standards

Japanese Standards Association web site: http://www.jisc.org

JIS C4210: Low voltage three phase squirrel cage motors for general purpose

JIS C9606: Electric Washing Machines (performance and safety)

JIS C9607: Household Electric Refrigerators, refrigerator-Freezers and Freezers

6.3.10 KS – Korean Standards

Agency for Technology and Standards web site: http://www.ats.go.kr

KS C9305-1996: Household Electric Refrigerators, Refrigerator-Freezers and Freezers

6.3.11 NEMA – National Electrical Manufacturer's Association (USA)

Web site: http://www.nema.org

NEMA MG 1: Motors and Generators, Revision No. 2—May and November 1989, September and November 1990, January and March 1991, National Electrical Manufacturers Association, Washington, DC 20037

NEMA TP1: Guide for Determining Energy Consumption for Distribution Transformers

NEMA TP2: Standard Test Method for Measuring the Energy Consumption of Distribution Transformers

6.3.12 NZS – New Zealand Standards

Web site: http://www.standards.co.nz

See AS (Australian Standards) for standards published jointly.

6.3.13 USA

Web site: http://www.gpo.gov

10 CFR Part 430 – US Code of Federal Regulations: Energy Conservation Program for Consumer Products

16 CFR305 – US Code of Federal Regulations: Rule concerning disclosures regarding energy consumption and water use of certain home appliances and other products required under the energy policy and conservation act (''appliance labelling rule'')

US EPA Energy Star web site: www.energystar.gov

APPENDIX A: APEC GUIDE FOR ALIGNMENT

The text of the APEC “Guide for Alignment” has been reproduced in this report for information purposes.

GUIDE FOR ALIGNMENT OF APEC MEMBER ECONOMIES' STANDARDS WITH INTERNATIONAL STANDARDS
Asia Pacific Economic Cooperation
Subcommittee on Standards and Conformance, APEC Committee on Trade and Investment
APEC #96-CT-03.3 - 1997 APEC Secretariat

Foreword

The APEC Sub-Committee on Standards and Conformance (SCSC) was formed in November 1994 to promote cooperation among member economies on standards and conformance to facilitate trade in the region. One of the objectives of the APEC SCSC is to achieve alignment of member economies' standards with international standards by the year 2010 for developed economies and 2020 for developing economies. This would lead to the convergence of standards among member economies to facilitate trade flows.

This Guide was developed to recommend actions that APEC SCSC member economies should take to align their standards with international standards. It was developed by the APEC SCSC in cooperation with the Pacific Area Standards Congress (PASC). A working group comprising Standards Australia and Japan Industrial Standards Committee, which represented the PASC Standing Committee, and Singapore, which represented the APEC SCSC, was established to undertake the project. The Guide was accepted by the APEC SCSC and endorsed by the Committee on Trade and Investment in August 1996.

At the same time that this Guide was being developed, the working group also undertook a consolidation and revision of the ISO/IEC Guides 3 and 21, which provide guidance on identifying the degree of equivalence with and indicating deviations from international standards. The draft revised Guides were submitted to]SO for consideration. The revision and consolidation of ISO/IEC Guides 3 and 21 are being undertaken by]SO/IEC. When this work is completed this APEC Guide may need to be revised.

1 Introduction

Alignment of APEC member economies' standards with international standards will help to reduce costs, facilitate trade and improve the efficiency of administrative processes related to trade. International standards generally reflect the best experience of manufacturers, trade organizations, purchasers, consumers, testing laboratories, regulatory authorities and other interested parties worldwide and cover common needs in a variety of countries. Therefore, the broader alignment of member economies' standards with international standards is an important element for promoting trade in the Asia Pacific region.

2 Scope

This guide gives member economies recommended actions to be taken in aligning member economies' standards with international standards. It is recommended that the methods listed in the ISO/IEC Guides 3 and 21 be used.

3 Definitions

In this Guide, "International Standards" means:
a) ISO and IEC, and also
b) Standards published by other international bodies listed in the ISO/IEC KWIC (Keyword-in-context) Index of international standards. See Annex 1.

Member economies' standards" means:
a) Voluntary standards developed or adopted by member economies' standards bodies that are members of relevant international standards bodies such as ISO/IEC; or,
b) Where members of relevant international standards bodies do not exist, voluntary standards recognised by the governments of the respective economies as their official standards.

"Alignment with International Standards" means to adopt international standards as member economies' standards with:
- as few technical deviations as possible, taking into account the specific conditions and needs of each member economy;
- deviations clearly identified, and; - a general explanation of the deviations with their reasons provided.

Actions for Alignment

(1) Evaluation of International Standards

The first step in preparing or revising any member economies' standards should be a thorough review of international or draft international standards with the aim of adopting the most appropriate, while taking into account the following factors:

- Is the international standard or draft international standard being considered applicable to the specific situation of a member economy?
- Does the international standard reflect the latest technologies? (Note that existing standards may reflect old technologies but new or revised standards may be in the process of preparation).
- Is the international standard used in practice in other countries?

(2) Adoption of International Standards

To achieve alignment with international standards, it is recommended that the relevant international standards be adopted as the member economies' standards to the maximum possible extent by using the methods described in the ISO/IEC Guides 3 and 21.

(3) Elimination of Deviations from International Standards

Deviations from international standards can exist because international standards may not meet all the needs of member economies for the following reasons:

a) International standards may be limited in scope since they are developed on a consensus basis that generally reflects the common needs of those countries involved in the standardizing process, and some criteria may not be covered because consensus could not be reached.

b) Specific conditions of member economies may not be adequately addressed by international standards for reasons that include an insufficient level of protection, fundamental climatic or geographical factors and fundamental technological problems. These are recognised by the World Trade Organization Agreement on Technical Barriers to Trade (WTO TBT) and the Agreement on the Application of Sanitary and Phytosanitary Measures.

Notwithstanding the above, deviations of member economies' standards from international standards should be removed whenever possible.

(4) Clear Identification of Deviations

For transparency, it is recommended that the degree of equivalence be identified and any deviations from the international standards, and reasons for the deviations, be clearly indicated. The ISO/IEC Guides 3 and 21, as well as other relevant ISO/IEC Guides, gives guidance on how to do this.

(5) Participation in International Standardization Activities

It is recommended that representatives from member economies participate positively and co-operate closely in international standardization activities to influence the contents of international standards so as to make them suitable for adoption in the region.

In order to achieve this goal, representatives from member economies are encouraged to:

- consult with each other regarding common requirements and put forward these requirements to the relevant international technical committees for consideration;
- where there are no applicable international standards, after consultation amongst member economies, propose new work items and provide draft requirements for inclusion in the new international standards;
- participate actively in the activities of relevant international standards bodies, and
- undertake the role of secretariat of relevant technical committees and subcommittees particularly where new international standards of benefit to the region are being prepared.

(6) Cooperation with Specialist Regional Bodies

To promote alignment with international standards and participation in international standardization activities, it is recommended that member economies seek assistance from their standards bodies, PASC and other relevant specialist regional bodies.

Annex 1
INTERNATIONAL ORGANIZATIONS LISTED IN THE ISO/IEC KWIC INDEX OF INTERNATIONAL STANDARDS

Name	Official Acronym
International Bureau of Weights and Measures	BIPM
The International Bureau for the Standardization of Man-made Fibres	BISFA
Codex Alimentarius Commission	CAC
Customs Co-operation Council	CMCCID
International Commission on Illumination	CIE
International Special Committee on Radio Interference	CISPR
International Atomic Energy Agency	IAEA/A1EA
International Air Transport Association	IATA
International Civil Aviation Organization	ICA010ACI
International Commission on Radiation Units and Measurements, Inc.	ICRU
International Dairy Federation	IDFIFIL
International Electrotechnical Commission	IEC/CEI
International Federation of Library Associations and Institutions	IFLA
International Institute of Refrigeration	HR/I1F
International Labour Organization	lLO/OlT
International Maritime Organization	IMO/OMI
International Olive Oil Council	100C/C01
International Commission on Radiological Protection	ICRIP/C1PR
International Organization for Standardization	ISO
International Telecommunication Union	ITUMIT
International Office of Epizootics	OlE
International Organization of Legal Metrology	OlIVIL
International Vine and Wine Office	OW
International Union of Railways	UIC
United Nation Educational, Scientific and Cultural Organization	UNESCO
World Health Organization	WHO/OMS
World Intellectual Property Organization	WIPO/OMPI

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438 Alexandra Road
#14-00, Alexandra Point
Singapore 119958
Tel: +65 2761880 Fax: +65 2761775
Email: info@mail.apecsec.org.sg
Http://www.apecsec.org.sg

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