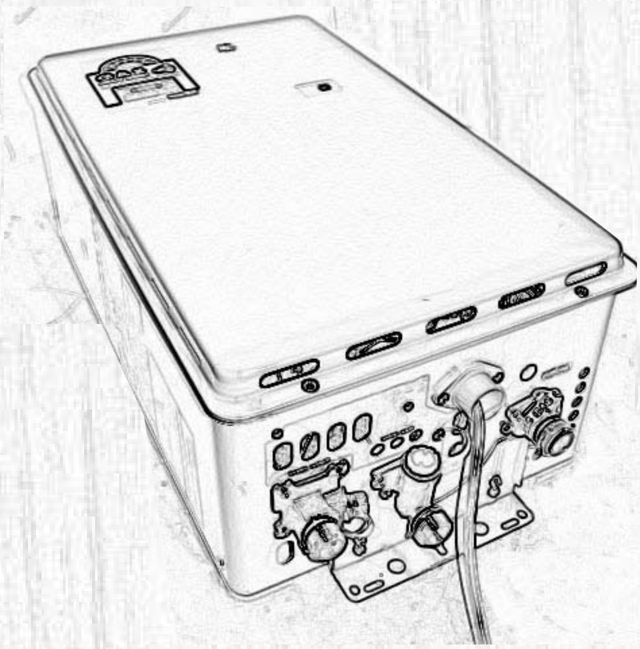
Report No: 2006/12

Gas Water Heater Comparative Testing Round-Robin 2005/06

PART OF THE E3 GAS WORKPLAN

2007 to 2007/08

EQUIPMENT ENERGY EFFICIENCY GAS PROGRAMME



AN INITIATIVE OF THE MINISTERIAL COUNCIL ON ENERGY FORMING PART OF THE NATIONAL FRAMEWORK ON ENERGY EFFICIENCY

October 2006

Abbreviations

AGO	Australian Greenhouse Office
E3	Equipment Energy Efficiency Committee
E3 Gas	Gas Appliance and Equipment Energy Efficiency Committee
MCE	Ministerial Council on Energy
MEPS	Minimum Energy Performance Standards
NATA	National Association of Testing Authorities, Australia
NFEE	National Framework on Energy Efficiency
RIS	Regulatory Impact Statement
TTMRA	Trans Tasman Mutual Recognition Agreement

Australian Government
Department of the Environment and Heritage
Australian Greenhouse Office

Assistant Secretary
Gene McGlynn
Australian Greenhouse Office
Department of the Environment and heritage
GPO Box 787
CANBERRA ACT 2601

A copy of this report can be obtained from www.energyrating.gov.au

Cover design and desktop publishing by Energy Efficient Strategies.

Contents

1 Context

Gas water heaters are a key product identified within the Switch on Gas strategy released in 2004 as part of the National Framework for Energy Efficiency. Governments are collectively looking to regulate the energy efficiency of this product as soon as possible in order to reduce greenhouse gas emissions.

This general goal was foreshadowed in the National Greenhouse Strategy published in 1998. A more refined proposal including possible mandatory performance requirements and a revised gas energy label was released to industry in 2002. Information on previous work undertaken on gas appliances is set out in Annex A.

A key component of any regulatory scheme is the method of measuring performance claims. The existing industry sponsored labelling is underpinned by AS4552 which has been the basis for the current industry operated energy labelling scheme since 1985. However, questions have been raised by key stakeholders concerned about the accuracy and reproducibility of the test method.

The Australian Greenhouse Office proposed a round robin comparative test programme utilising independent NATA accredited gas test laboratories in Australia in order to assess the repeatability and reproducibility of the test method that underpins the current scheme. The basis of this comparative programme was approved by those involved in the relevant Standards Committee AG-001. Industry members agreed to monitor the progress of the round robin.

The aim of the tests was to assess the current status of the test procedure for gas water heaters, AS4552, and to undertake a range of comparative and development tests that would most likely set out the future direction with respect to the development of the test procedure, particularly its suitability as the basis for a future energy regulatory programme for gas water heaters.

A total of 10 units (4 storage and 6 instantaneous water heaters) were obtained in mid 2005 and subsequently tested. The tests undertaken included a range of existing performance tests as specified in standard AS4552 as well as exploratory tests aiming to provide realistic and reliable data on water heater performance. The AGO funded 3 NATA accredited gas test laboratories to undertake the work.

The proposed range of tests to be undertaken, together with broad aims and objectives, were circulated to AG-001 in October 2004. A copy of the testing proposal is attached as Annex B. A range of comments were received from stakeholders, mostly seeking clarifications and refinements to the proposed range of tests.

After initial screening tests were completed, a detailed test schedule was developed for each of the participating laboratories and water heater types. Round robin tests were conducted in late 2005 and early 2006.

This paper does not provide detailed results for individual water heaters. However, it does provide some commentary on the general findings of these comparative and development tests and provides some guidance on areas of the test procedure that require attention during the current revision.

2 Overview of Test Findings

The current standard for gas water heaters (AS4552) determines the annual energy consumption of the appliance for an assumed delivery of 37.7 MJ/day of hot water (nominally 200 litres per day at a 45K temperature rise).

Under AS4552, the key parameters that are used to determine energy efficiency and energy consumption of gas water heaters are:

- for storage systems – the burner efficiency and the maintenance rate;
- for instantaneous systems – the burner efficiency and the startup energy.

These main parameters were measured as part of the round robin tests. The results from each lab varied considerably, in most cases beyond what was initially expected when considering the required measurement accuracy specified in the standard. Many of the key parameters in AS4552, which include burner efficiency for storage systems, maintenance rate and startup energy, all were found to have very much larger than expected inter-laboratory variations and associated uncertainty. In some cases, the observed variations were more than 10 times higher than the theoretical measurement uncertainty.

The large inter-laboratory variation appears to be likely to be caused by one or more possible problems. One key issue is that several tests in the current standard have ambiguities which are known to have a significant impact on the performance measured (laboratories have significant discretion with respect to how the test is conducted in some cases). In other cases, some of the observed variability can be attributed to variations in product behaviour from run to run (this is not a reflection of the laboratories or the test method, but these variations in behaviour need to be understood) – more erratic or difficult behaviour is known to occur in some products that have electronic controls.

There also appears to be issues with the measurement accuracy of some key parameters such as gas consumption (which is a difficult parameter to measure accurately with a high level of resolution as required for some tests such as startup energy) and other test measurements such as temperature and electrical energy, which should be fairly straight forward in normal circumstances, but the type of equipment used and its fundamental accuracy and calibration can create problems if not rigorously checked and carefully implemented.

The variations in the measurement of key parameters used for energy labelling between the participating laboratories were clearly unacceptable and resulted in significant variations in estimates of the key performance parameters for gas water heaters such as annual energy consumption. These variations also meant that there were significant differences between the claimed and measured star rating index in some cases.

The test method however was found to work satisfactorily in relation to the overall uncertainty of burner efficiency measurements for instantaneous gas water heaters. In other words, the measured variation in efficiency for each instantaneous unit when tested to the standard in each laboratory was within the theoretical uncertainty range. The relatively good inter-laboratory agreement on the instantaneous water heater burner efficiency is expected as this test involves very large continuous gas consumption under steady state conditions which can be measured with reasonable accuracy.

More detailed discussion on the results is included in Annex C.

3 Future Testing

These results call into question the capacity of the present test method to support a regulatory programme where suppliers would not be permitted to market product unless they can demonstrate compliance with the specified regulatory performance levels. Before AS4552 can be used as a basis for the government regulation of energy efficiency of gas water heaters, significant work needs to be undertaken to ensure that the measurement of the key parameters for energy efficiency can be determined within acceptable limits.

Under standards committee AG-001, Working Group 11 was reformed in mid 2006 to tackle the task of revising the test methods. Key stakeholders from government, industry and test laboratories are participating through the standards process to improve the test method in a timely manner. The detailed results from the round robin tests will be used to guide WG11 in their review of the standard.

There are a number of related issues regarding gas water heaters that will need to be addressed as part of the revision to the test method and the related energy labelling and MEPS programme once the basic test method has been revised. Some of these are discussed in Annex E.

4 What are the Key Parameters Measured for Gas Water Heaters

A number of parameters are used to determine the annual energy consumption of gas water heaters. These are set out in Annex D. The annual energy consumption is used to determine the star rating of the product as set out in Table 1 below.

Base energy consumption for a 1 star water heater is 28,900 MJ/year. This is the estimated energy consumption of a storage water heater that just meets that maximum permitted maintenance rate value and the minimum permitted burner efficiency. These values were set when the star rating system commenced in the late 1980's.

The star rating system is set to provide an additional star for each 7% reduction in annual energy consumption (ie for each 2023 MJ/year reduction in energy). Note that unlike electrical appliance star ratings, the step sizes for gas water heaters remain equal through the progression from 1 star to 6 stars. The energy delivered under the test method is 200 litres of water at 60ºC (temperature rise of 45K from a nominal 15ºC supply temperature), which is 37.7MJ per day or 13,761 MJ per annum. The overall annual product efficiency can be estimated from 13,761 divided by the annual energy consumption estimated from the equations in Annex D.

Table 1: Annual Energy Consumption and Star Rating

Stars	Annual Energy MJ/year
1	<28,900
2	<26,877
3	<24,854
4	<22,831
5	<20,808
6	<18,785

Source: AS4552

5 What was Tested in the Round Robin?

A total of 10 water heaters were acquired from five different suppliers. As indicated in Table 2, the storage capacity of the 4 storage test units ranged between 155 and 175 litres with thermal inputs between 32.5 MJ/h and 42 MJ/h. The rated output of the 6 instantaneous types was between 12.5 litres/min and 21 litres/min delivery with thermal inputs between 130 MJ/h and 195 MJ/h. The claimed star ratings of the ten gas water heaters ranged between 3.0 and 5.7.

With the exception of one storage water heater model, which was damaged in transit between laboratories, all assessments at each laboratory were performed on the same individual appliance. The test standard followed was AS 4552-2000 (AG 102-2000) Gas water heaters - and the following specific clauses were tested:

- 3.4 to confirm the specified thermal input,
- 4.1.2 storage type only in order to ensure the integrity of key design features necessary for satisfactory combustion performance, and
- 5.3/5.19 to determine thermal efficiency and energy label/star rating.

In addition, a range of other investigative tests were undertaken as outlined in Annex B.

Table 2: Overview of 10 water heaters tested

Water Heater	Type	Capacity	Thermal Input (MJ/h)
A	Storage	175 litres	32.5
B	Storage	160 litres	40.0
C	Storage	160 litres	42.0
D	Storage	155 litres	40.0
E	Instantaneous	12.7 l/min raised 40ºC	60.0

Water Heater	Type	Capacity	Thermal Input (MJ/h)
F	Instantaneous	12.6 l/min raised 40ºC	167.0
G	Instantaneous	12.5 l/min raised 40ºC	160.0
H	Instantaneous	21.0 l/min raised 25ºC	160.0
I	Instantaneous	16.3 l/min raised 25ºC	130.0
J	Instantaneous	16.0 l/min raised 40ºC	195.0

6 What Further Work is Required

While the tests conducted to date have clarified many issues, there are many issues that still require further work.

The main area that needs refinement is an energy delivery test. This needs to be based on hot water that can be delivered by the product. This could be a repeated test to determine energy delivery capability – this would be a good measure of energy service capability of water heaters and their suitability for different household sizes.

A range of other issues need to be considered when determining in use energy consumption of gas water heaters. These are listed for reference:

- Typical pressure-temperature relief valve hot water loss was found to be consistent with expansion of water – this is an issue that needs to be taken into account when the hot water storage unit is under practical operation.
- Cold water temperature – the impact was in line with expectations but would need to check that changes in supply temperature can be accurately reflected in draw-off tests versus modelling of performance.
- A full list of parameters to be measured to allow accurate measurement are under development and will be included as part of the test method development.

7 Next Steps

Energy efficiency regulators are ready to assist the gas water heater industry to improve the existing test method. Under standards committee AG-001, Working Group 11 was reformed in mid 2006 to tackle the task of revising the test methods. Key stakeholders from government, industry and test laboratories are participating through the standards process to improve the test method in a timely manner. The detailed results from the round robin tests will be used to guide WG11 in their review of the standard.

Some aspects of the standard can be refined using the round robin results while some tests may need to be completely revised. It is also likely that some new parameters (such as the energy service capacity of the water heater) will need to be included in a revised test method. An important aspect will be to ensure that parameters determined under the revised water heater test are able to provide an accurate estimate of water heater energy consumption under normal use conditions.

As part of the development work within WG11, some additional tests will be undertaken to clarify particular issues of interest. However, the body of data that has been collected during the round robin will provide a valuable resource during the current revision of the test method. Detailed data will be released to WG11 as particular issues of interest are investigated during the revision process.

The target is for a public comment version of a revised standard with all the new performance parameters finalised to be available by mid 2007. The latest date acceptable to government agencies will be for the final version of the standard to be published by the end of 2007.

References

AS 4552-2005 (AG 102) *Gas fired water heaters for hot water supply and/or central heating.* Available from www.standards.com.au

AS/NZS62301-2005, *Household electrical appliances - Measurement of standby power* (IEC 62301, Ed. 1.0 (2005) MOD). Available from www.standards.com.au

Switch On Gas - Australia's strategy to improve the energy efficiency of gas appliances and equipment 2005-2015, E3 Gas. Report 2004/14. Available from www.energyrating.gov.au

Switch on Gas – Revised Work Plan 2007 - 2007/08, E3 Gas, Report 2006/11, October 2006. Available from www.energyrating.gov.au

Switch on Gas - Work Plan 2005/06 - 2007/08, E3 Gas, April 2005, Report 2005/10. Available from www.energyrating.gov.au

Standby Product Profile - Instantaneous Gas Water Heaters (Standby Report sb2004/04). Available from www.energyrating.gov.au

Driving Energy Efficiency Improvements to Domestic Gas Appliances, E3 Gas discussion paper, 2003. Available from www.energyrating.gov.au

Energy Labelling & Minimum Energy Performance Standards for Domestic Gas Appliances, Mark Ellis & Associates et al, for E3 Gas, November 2002. Report 2002/17. Includes responses from GAMAA and the AGA. Available from www.energyrating.gov.au

MEPS Profile - Commercial Water Heaters. Report for E3 in 2001 examines MEPS options for a range of commercial water heater types including gas, electric and boiling water units. Available from www.energyrating.gov.au

Top Energy Saver Award (TESAW) - Award winning appliances. Criteria for gas appliances available from www.energyrating.gov.au

Artcraft Research, *Appliance Performance Labelling In Australia and New Zealand,* Report 2006/08, prepared for E3 committee, August 2006. Available from www.energyrating.gov.au

ANNEX A - Background to Current Developments

An important part of the National Greenhouse Strategy, formulated and adopted by all Australian Governments in 1998, is to expand and enhance product energy efficiency initiatives under the Equipment Energy Efficiency programme (now called the E_3 programme). The overall responsibility for these initiatives lies with the Ministerial Council of Energy (MCE).

Discussions between the government and the gas appliance industry on appliance efficiency issues have been ongoing for many years. In 2002 the E_3 programme commissioned Mark Ellis and Associates to undertake a review of gas appliance efficiency in Australia. The report titled “Energy Labelling & Minimum Energy Performance Standards for Domestic Gas Appliances” was released in November 2002 (Report 2002/17).

The broad objective of this study was to assess the appropriateness of the development and application of minimum energy performance standards (MEPS) for domestic gas appliances. Further, the study was to investigate and report on the effectiveness of the current gas labelling scheme and the potential for amendment to generate greater incentive for the provision of more energy efficient appliances. The purpose of this scoping study was to develop a comprehensive assessment of firstly whether any government action is necessary and if so, to recommend the most appropriate course of action and report on the implications of any action.

The version of this report on the website includes comments and a response on the report from the Australian Gas Association and the Gas Appliance Manufacturers’ Association of Australia.

The recommendations for gas water heaters were to introduce a government regulated mandatory MEPS and energy labelling scheme. A target MEPS level was also proposed which would be broadly equivalent to the MEPS levels set for gas water heaters in the USA from 2004.

A discussion paper called “Driving Energy Efficiency Improvements to Domestic Gas Appliances” was released in July 2003. The recommendations of this paper, which were supported by industry stakeholders, have been endorsed by the Ministerial Council on Energy which has now given a commitment to regulate gas appliance efficiency primarily to drive improvements to higher levels than has so far been achieved with current energy labelling schemes.

Subsequently, a paper titled “Switch on Gas”, which sets out Australia’s strategy to improve the energy efficiency of gas appliances and equipment in the period 2005-2015, was released in December 2004. A detailed work plan for “Switch on Gas” was released in April 2005 and an updated version was released in October 2006.

These documents are all available from www.energyrating.gov.au in the electronic library.

ANNEX B - Round Robin Approach

This annex provides a copy of the broad terms of reference for the gas water heater round robin that was circulated to the gas industry and standards committee for comment in mid 2004.

General Principles

The objective of the gas water heater standard should be to measure the key performance characteristics of the water heater (including energy service delivery and energy performance) so that its performance can be assessed under a range of conditions but with minimal additional testing required. In a limited way this approach is already included within AS4552 with respect to determination of daily energy consumption.

In this case the water heater's key performance parameters such as heat loss (storage), burner efficiency and startup energy (instantaneous) are used to estimate daily and annual energy consumption for a set hot water delivery. The most expedient way to achieve this objective is to measure the key performance parameters under controlled conditions in a way that is suitable for use within a simulation model which can be used to estimate performance under any expected condition. To achieve this, the tests have to cover representative conditions and the parameters determined have to be sufficiently precise to allow accurate simulations. The purpose of these development tests is to confirm, at least in part, that this approach is both feasible and suitably accurate when compared to actual usage.

Storage Water Heaters – Key Issues

The following issues need to be examined as part of the testing schedule:

- Capacity – both stored volume or delivered energy are used at present but the pros and cons of these require further investigation.
- There is a requirement that hot water delivery be >70% of the nominal capacity for a 6K drop. Leaving the burner off for this test may be unrealistic for larger input models and the relevance of this requirement needs to be reviewed.
- How do we deal with variable thermostats and actual temperature operation under different conditions?
- Performance under periods of no use: some models appear to have a large deadband (allowed to have 14K) and can sit for long periods without a boost recovery of the burner. Need to examine the storage temperature when there is no use and examine if there is a need for other requirements regarding storage temperatures (see AS3498 for minimum storage temperatures).
- Make sure that the test procedure can deal with electric boost element options and powered flue systems or other electric input.
- Make sure that the test procedure can deal with heat exchanger type gas fired systems and combination hydronic and hot water systems (combi boilers)

Storage Water Heaters – Proposed Test Schedule

The following investigative tests are proposed:

- Measure and compare static capacity, hot water delivery and mixed hot water delivery (refer to electric storage method), examine impact of leaving the burner on during drawoff.
- Examine the impact of drawing off various volumes of water and the recovery within the storage water heater and compare this with the existing recovery efficiency method – examine alternative ways of determining the heat contained in the water and to make the recovery test more robust.

- Document the behaviour of thermostats during normal operation and examine the impact on performance and whether there are alternative options for control of the water heater during tests (and the importance on measured parameters).
- Alternative heat loss measurements to be examined: these include heat loss at standard condition (65°C), at maximum temperature, and the value of doing a decay type test where the tank is allowed to cool (with and without pilot).
- Examine tank storage temperatures under a period of prolonged inactivity.
- Need to devise a set of test measurements for gas storage units to characterise the heat exchanger performance and burner efficiency as well as heat losses from the tank to allow accurate modelling to be developed.
- Undertake a realistic drawoff profile and check whether this can be realistically simulated (eg US or EN test procedures).
- Look at losses from PTR valves as well (hot water lost through expansion)

Instantaneous Water Heaters – Key Issues

- Startup energy – look at areas for improvement in this test element. Examine splitting the test into unstable and stable components for determination of water usage, energy and efficiency. A single test could then be used for startup and steady state efficiency.
- Many instantaneous water heaters now have variable rate burners and their output temperature can be controlled. Some units are programmed to not exceed 50°C, so this needs to be considered in the test method. Performance under different flow rates also needs to be examined.

Instantaneous Water Heaters – Proposed Test Schedule

- Identify startup and steady state as two components of each starting event: measure data for say a minimum of 10 seconds (look at existing data) or until temperature and output is stable – for startup and steady state need to quantify litres of water, energy in and energy out to determine all necessary parameters.
- Develop a matrix of flow rates and temperature rises (get both steady state and startup parameters for each combination available). Look at maximum flow rate, minimum and an intermediate rate to determine key performance parameters. Examine range of deliver temperatures for units with user programmable controls.
- Examine the issue of cold water temperature and its impact on instantaneous performance.
- Need to devise a set of test measurements for gas instantaneous units to characterise the heat exchanger performance and burner efficiency as well as startup to allow accurate modelling to be developed

ANNEX C - Key Findings from the Tests Conducted under AS4552

Energy Storage and Delivery

In the case of gas storage tanks, a key parameter is the energy stored in the tank and which can be delivered to the user. The recovery time is also of importance.

The current method in AS4552 involves temperature measurement of drained water from the tank once it achieves a desired thermostat temperature (measured at the level of the thermostat sensing element). Draining the water can be difficult and the temperature measurement is potentially quite inaccurate, especially when this has to be integrated with volume. The time taken to perform the test will affect the results. See separate notes on problems associated with determination of water volume.

This measurement is a key parameter in the determination of recovery efficiency for gas storage water heaters.

A more workable and reliable test is likely to be based on a draw-off (eg until the outlet temperature falls to a specified temperature, or a specified volume is delivered) and recovery of the water heater. This could be based on the hot water delivery test for electric storage water heaters. This test could be tested sequentially several times to get a repeatable result. It would provide a good measure of the energy storage capability of the water heater, the recovery period and the recovery efficiency of the total system. It is far more realistic than the current AS4552 test method as the water heater is required to be installed and operate normally.

The exploratory tests found that determination of the tank temperature during the test via inserting temperature probes at specified positions in the tank is fraught with difficulty and is nearly impossible in some tank designs and configurations. So, based on the test experience, this approach is not recommended in the revision of AS4552.

Recovery Efficiency – Storage Water Heaters

All laboratories did AS4552 recovery burner efficiency test for the storage water heaters. The test results show that while the theoretical uncertainty of measurement of thermal efficiency of a storage water heater in the standard (as written) is of the order of 2%, the inter-laboratory tests showed an overall uncertainty of the order of 4%. The general conclusion is that the test as written is too vague and appliance behaviour can affect results in some cases. A number of factors will contribute to this inter-laboratory variation, such as differences in water volume and tank temperature measurements.

This test is rather contrived and is unlikely to reflect actual performance of the product during normal use. Far more reliable results have been obtained with repeated full tank drawoffs down to a termination temperature of 42°C through normal plumbing connections with immediate reheating. This type of test provides good information on the delivery capacity of the unit and is far simpler for laboratory personnel to perform. The initial result has to be discarded as the product has not reached thermal equilibrium. However, a full tank drawoff does not reflect the marginal recovery efficiency that occurs under normal use with partial drawoffs. Under these conditions many tanks will “stack” (temperatures increase towards the top of the tank) which can reduce recovery efficiency and increase heat losses.

Static Capacity of Storage Tank

This parameter is required under AS4552-2000 Clause 5.1.1 and in the AS4552-2005 version under Clause 6.6. Essentially the measured storage tank capacity must be within ±5% of the nominal capacity claimed by the manufacturer.

This parameter showed significant variation between claimed and measured values. It was found that, in general, measured volume was usually at the maximum permitted tolerance limit.

The efficiency test method does not specify whether the tank is to be tipped to extract the water volume. On average more than 10% of the total tank volume is below the cold inlet and could not be easily drained in many cases. There are various other anomalies or ambiguities regarding volume measurement that need to be resolved if this parameter is to be retained in the test method. This parameter is of little practical value on its own in the gas water heater test method as it does not reflect the capability of the water heater. However, the total volume of water in the tank may be of some interest for subsequent calculations.

Maintenance Rate – Storage Water Heaters

The maintenance rate is essentially the standing losses of a storage type appliance. An appliance is allowed to operate under the control of its thermostat (in isolation from any water connections) for an extended period in a "fixed" ambient temperature and the heat input required to maintain the tank at a certain temperature is measured. The tank's temperature rise (measured at a single point in the centre of the tank) above the actual ambient temperature achieved is used to correct the energy consumed back to a standard value of temperature rise.

Thermostat deadbands (bandwidth), thermostat temperature setting and water heater behaviour have all been found to substantially affect maintenance rate in a non-linear way. Even though maintenance rate is of the order of 20% to 40% of total water heater consumption, the inter-laboratory uncertainty is around 10 times higher than the theoretical error for maintenance rate when considering real lab results. This means that in practical terms the total error in annual energy consumption from maintenance rate measurements is of the order of 7% of the total annual energy based on the current test method.

If heat losses and corresponding energy consumption are to be evaluated in a similar fashion to that currently described, this will require a revised method of test which is far more prescriptive, in particular regarding the following aspects:

- description of how and where the ambient conditions are measured;
- the tolerance within which these conditions are maintained;
- adequate shielding of appliances from radiation and air movement;
- setting of thermostat.

An alternative may be to conduct a range of actual drawoff tests and to estimate maintenance rate from parts of these tests rather than through a prescriptive separate test where the product appears likely to enter a "non-use" mode.

Start-up Test – Instantaneous Water Heaters

The start-up energy is an important parameter which is required for instantaneous water heaters. The start-up energy typically makes up around 10% of total water heater annual energy consumption. So it is a small but significant contributor to total energy consumption.

The start-up test was found to be one of the most difficult tests to perform in AS4552. Instantaneous water heaters have very high gas flow rates and the current criteria (gas energy consumed to reach 90% of equilibrium temperature) is of the order of a few seconds. The accuracy and resolution of all instruments used is critical for this test. The point where measurements are terminated can be highly variable, even on a single water heater, as all parameters are rapidly changing at this point. Gas flow rates often exceed 200 MJ/hour for a short period of this test.

The inter-laboratory results confirm problems with start-up energy both in terms of repeatability and reproducibility of results. The actual uncertainty between labs is more than 10 times the theoretical uncertainty for this parameter. One of the key factors that affects the uncertainty was found to be product behaviour. One product tested that is known to be highly stable in its behaviour showed an uncertainty in the reproducibility of the start-up energy measurement of the order of 4% (which is still higher than the theoretical uncertainty, but in the realms of acceptability). However the uncertainty in start-up energy in products that are known to be very complex (or erratic) in their behaviour was of the order of 20% of the measured value. This is probably primarily due to complex controls (negative feedback control algorithms with respect to gas rates and water temperature etc, step wise modulating gas flow rates, start-up characteristics and operating sequence). A secondary factor is likely to be the resolution of gas volume measurements. The test is of relatively short duration and the uncertainty can be large, with gas volume requiring careful interpolation of data. Special care is required when using normal gas metering equipment for this test (eg starting and ending the test on a whole gas meter revolution).

An alternative test approach to determine start-up energy is to run the water heater to steady state with rapid sampling and integration of all parameters so that start-up parameters can be determined. The water and energy that is disregarded (if any) can then be calculated. It is likely that this test would have to be performed multiple times to provide a result of acceptable accuracy.

A limitation of the current method is that all energy delivered up to a 90% temperature rise is discarded. This may be valid for some applications, but not necessary all hot water end uses. The current test method does not calculate wasted water (cold water discharged through the appliance before an acceptable temperature is reached). This is becoming an important aspect of these water heater types and it needs to be quantified.

Several repeat tests on a range of representative temperature settings (possibly also gas rate and/or water flowrate extremes) may also be required as the startup energy may also vary with outlet water temperature and flow rate. The tests were performed as part of the test programme and results appear to be promising although there is still some work to do before a satisfactory method is finalised.

An area of some importance where there is little data is the frequency and duration of starts that could be expected for a range of normal drawoff profiles. Frequent short duration hot water drawoffs will be more difficult and inefficient for an instantaneous gas water heater. If the time between drawoffs is short, some residual heat may also be present. Interactions of instantaneous gas water heaters with clothes washers (which typically fill in small multiple drawoffs during load sensing) requires some investigation.

Thermal Efficiency – Instantaneous Gas Water Heaters

Thermal efficiency for instantaneous water heaters is the key parameter that determines energy consumption and overall energy efficiency and star rating of the product. For this parameter, the laboratory variation was close to theoretical uncertainty – of the order of 2%. For most products in a steady state condition, the outlet temperatures are relatively stable and the gas flow rates are high which means that an accurate determination of the required parameters can be readily obtained.

While the test as written is probably adequate in general terms, there are some aspects of the test method that could be tidied up to make results even better and to remove ambiguities. For this parameter, the method only requires fine tuning. However, data also needs to be recorded for high and low flow rates and minimum and maximum temperature rises; the standard currently only records data for the maximum gas rate (nominally maximum flow rate and temperature rise).

Electrical Energy Measurements

Most instantaneous gas water heaters now have mains power electrical connections. The electrical energy consumption during the test and in standby has to be determined. The standby energy consumption (with the current designs and standby levels) dominates the overall electrical energy measurement in AS4552. However, the total electrical energy is generally small compared with total gas energy.

Surprisingly, for this parameter there was a large difference between labs – the inter-laboratory uncertainty was more than 10 times theoretical uncertainty (which has a value of around 1%). Even though this is a measurement of minor importance, it is a parameter that can generally be measured with very low uncertainty given the correct instrumentation. It appears that the difference in laboratory measurements is probably due to a combination of low resolution metering being used (where in some labs they may not be equipped with necessary equipment to precisely measure power levels of a few Watts), and no definition in AS4552 describing just when an appliance is deemed to be in a standby mode. In the revision of the standard the exact state of the appliance for each measurement needs to be defined and appropriate instrumentation for small power loads also needs to be specified. Reference to AS/NZS62301 for all low power measurements is recommended.

ANNEX D - Key Parameters to Determine Annual Energy Under AS4552

The algorithm used to determine the Annual Energy Consumption (A_E) of a gas water heating appliance, from which the Star rating is directly derived, depends on the type of appliance, i.e. whether it is of the storage or instantaneous type. The algorithms used are shown below.

Equation 1 Storage water heater AEC algorithm.

$$A_E = \left[\frac{W_D \times 100}{E} + \left(24 - \frac{W_D \times 100}{R \times E}\right) \times M\right] \times 365$$

Where A_E = Annual energy consumption (MJ/year)
W_D = Water heat content (MJ) = 37.67
E = Thermal efficiency (%)
R = Gas consumption (MJ/h)
M = Maintenance rate (MJ/h)

Equation 2 Instantaneous water heater AEC algorithm.

$$A_E = \left[\frac{W_D \times 100}{E} + \left(24 \times P + N \times S + Q_e \times 3.6\right)\right] \times 365$$

Where A_E = Annual energy consumption (MJ/year)
W_D = Water heat content (MJ) = 37.67
E = Thermal efficiency (%)
P = Pilot gas rate (MJ/h)
N = Number of draw-offs per day = 19
S = Start up heat capacity per draw-off (MJ)
Q_e = Daily electrical consumption (kWh)

A number of quantities require determination in order to calculate the A_E.

ANNEX E - Future Considerations for AS4552

The general approach used in AS4552 is to determine key performance parameters using bench tests to measure particular key attributes of the water heater under defined conditions and then to use these parameters to estimate the energy consumption for a particular task (delivery of 37.7 KJ of hot water per day). While the concept of using key performance parameters to determine the energy consumption for a specified task has merit (in that the task can be varied as required), the test method as written is known to have substantial limitations. The bench tests conducted on water heaters in the standard are somewhat contrived and in some cases are known be a poor representation of the behaviour of the product under normal use. Issues such as the use of lower output temperatures and flow rates for instantaneous gas water heaters and the behaviour during partial drawoffs for storage systems (eg stacking, where the temperature profile of water in the tank becomes non uniform) are not covered to any extent by the current test methods. Clearly, the standard needs to have a test method that is repeatable and reproducible but also which provides a reasonable estimate of energy consumption of water heaters under the typical range of use that product is likely to encounter.

A related limitation of the standard is that there is no acknowledgement of the energy service capability of each water heater type. Small storage systems are compared to large storage systems for the same energy delivery task as are small and large instantaneous systems. While most gas water heaters can supply many times the assumed delivery task in AS4552 in a typical day, there are limitations on the volume of hot water that can be delivered in a single event or the flow rate that can be sustained which needs to be reflected as part of the capability of each unit and its suitability for small, medium or large households.

A significant limitation of the current labelling system is that the information displayed on the energy label shows only a single hot water task (37.7 MJ per day). It is known that many users may on average require less hot water than this while others may require more. Given the complex interactions and variations in the design of gas water heaters, the relative efficiency for different types and designs is likely to change ranking for hot water deliveries that are smaller and larger than the value assumed on the current energy label. Therefore the energy label would be of more consumer relevance if information such as total energy consumption and efficiency for smaller and larger tasks were also shown.

Gas Appliance and Equipment Energy Efficiency Committee

The Gas Appliance and Equipment Energy Efficiency Committee consists of the following member organisations:

Australian Greenhouse Office, Department of the Environment and Heritage

Department of Industry, Tourism and Resources

NSW Department of Energy, Utilities and Sustainability

Office of the Chief Electrical Inspector Victoria

Sustainability Victoria

Electrical Safety Office, Queensland Department of Industrial Relations

Queensland Department of Energy

Western Australian Department of Consumer and Employment Protection

Western Australian Sustainable Energy Development Office

South Australian Office of the Technical Regulator

Tasmanian Office of Energy Planning and Conservation, Department of Infrastructure, Energy and Resources

ACT Office of Sustainability, Chief Minister's Department

Northern Territory Department of Infrastructure, Planning and Environment

New Zealand Energy Efficiency and Conservation Authority

Energy Safe Victoria

Department of Transport, Energy and Infrastructure (SA)

New Zealand Ministry of Environment