Review of SANS 151:

Suitability for regulating energy in water heaters and allowance for innovations

FINAL

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Executive Summary

The introduction of class B energy efficiency regulation in the VC 9006 in 2016 resulted in wide-spread non-compliance in the water heating industry and affected the export of manufactured products. The definitions and scoping terms used in the standard for fixed electric water heaters (SANS151) and the VC 9006 created confusion on product inclusions. Several changes and modifications have been added and proposed in the regulation and the standard to remedy the situation, but there remains some questions around the suitability of the standard to account for newer technologies and to meet energy-related imperatives.

In this project, a review of the SANS 151 and VC 9006 along with earlier studies of the South African water heater efficiency standards was conducted. The review included comparison to ISO, Australian, EU and US test procedures for relevant comparisons and identifying possible improvements for SANS 151. Key stakeholders were interviewed to determine major problematic portions of the standards. Water heating technologies currently available in South Africa were identified to evaluate scoping issues. This report evaluates the standard by its written logical content, its detail in testing methods and protocol and its energy efficiency consideration in relation to energy labelling and the regulations for national imperatives.

There are several technologies where the scope is unclear or confusing. More important is disagreement between SABS standards writers, NRCS, and SABS Labs on the contended products. The written content of SANS151 and Annex B contain many cases of inconsistent and confusing language or references. Prescriptive design aspects of the standards make it difficult for new technologies to enter the market. A move towards performance based testing is highly recommended. A rigorous review of SANS 151 is suggested and should be done as part of an independent professional rewrite.

The details of the standing loss test is written in ways likely to make the consistent and repeatable results necessary for enforceable standards impossible to achieve. Round robin testing is recommended to improve reliability of results. The relevant appendices of Australian standard AS/NZS 4691.1 should be adopted and modified as a replacement for the standing loss tests in SANS 151.

While class B regulation is a notable step towards energy efficiency labelling for electric water heaters, the standing loss metric is not fit for solar, heat pump and non-electric water heaters. It is recommended to remove the standing loss regulation on non-electric water heaters. Products with small market share should be excluded until empirical evidence can be obtained to justify the regulation.As a next step towards measuring energy efficiency of water heaters, it is essential for energy consumption tests to be used to reflect the actual use in practise and include the energy required to deliver hot water as a service. SABS is encouraged to participate in the international developments of energy efficiency test methods and protocols.

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1. Introduction

The SANS 151 was designed and developed at a time when water heaters that were electrically powered were the only option for domestic use. The move towards using renewable resources has resulted in the water heating market expanding to include newer hot water service topologies, such as point-of-service units and alternative heating methods. This is a similar progression that many other countries face, where each has their own electric water heater standards and either designed new standards for the newer technologies or adopted international ones. An example of this was the major revision of the US water heater energy efficiency test in 2014 to better cover tankless water heaters.

Standards and regulations provide the performance and regulatory requirements to protect consumers and end-users to ensure that products on the market are safe to operate and to align with national imperatives. New technologies being developed are required to comply with these performance and regulatory requirements in order to legally trade on the market.

In the many years that a standard is in service, it undergoes many revisions that are written and amended by different writers and its associated working groups. However, the resulting document should have a consistent style and format that is independent of its individual writers and working groups. Its content should be clear and logical and should not be open to multiple interpretations by its audience. A standard is a document that should stand the test of institutional knowledge and the transfer of knowledge should be in the standard, and not in the memory of individuals in the committees and working groups.

The purpose of this study is to investigate the suitability of the SANS 151 standard for a technologically growing industry. As part of this study, the events following the 2016 regulation of VC 9006 requiring minimum energy performance standards of electric and non-electric water heaters to standing loss tests in SANS 151 will be discussed. This will be discussed as a component of the suitability of SANS 151 to enable innovation in the market. Comparisons with international standards will be provided to determine the suitability of adoption for the South African context. The report provides a set of recommendations and strategic steps for SANS 151 and VC 9006 on the products discussed in the scope of this report and in the context of energy efficiency.

This report does not address issues of governance raised in the Centre for Renewable and Sustainable Energy Studies (CRSES) studies which were also discussed at the Standards and Competition Law Indaba at the end of 2017. (Terblanche, 2018; 2019; Motloba, 2018)

2. Background

The residential appliance Standards and Labelling (S&L) is a national programme of the Government of South Africa administered by the Department of Mineral Resources and Energy (DMRE), supported by the United National Development Programme (UNDP) and the Global Environment Facility (GEF). The cross-cutting nature of the programme necessitates inter-governmental collaboration and cooperation and in this regard the Department of Trade Industry and Competition (DTIC), the South African Bureau of Standards (SABS) and the National Regulator for Compulsory Specifications (NRCS) are key implementing partners.

The S&L project office, with the support and active participation of the above mentioned ministries and national agencies, commissioned this study based on the findings and recommendation of "*A study on the impact of VC9006 and the lack of compliance*" (2019) undertaken by the University of Stellenbosch, which identified deficiencies with the SANS151.

The South African National Standard for Fixed Electric Storage Water Heaters is detailed in SANS 151. This report concerns the pending version of the report, Committee Draft 1, Edition 8.2, (National Committee SABS/TC 075, 2019). The standard covers general aspects, construction requirements, performance requirements, inspection, testing methods, markings and instructions, and provides information in its annexes for materials for construction, test procedures, energy labelling and calculations, quality verification and notes to the purchaser.

SANS 151 is the standard for water heaters. There are several other South Africa National Standards that cover related topics such as installation, maintenance and risks associated with water heaters. Similarly there are standards covering other types of water heaters and components for water heaters. Some of these standards are listed in Table 2.1, additional South African National Standards related to water heaters. This report only addresses SANS 151.

Table 2.1 Additional South African National Standards Related to Water Heaters

SANS 10252-1:2018	Water supply and drainage for buildings Part 1: Water supply installations for buildings
SANS 10254:2017	The installation, maintenance, replacement and repair of fixed electric storage water heating systems
SANS 1352:2012	The installation, maintenance, replacement and repair of domestic air source water heating heat pump systems
SANS 1307:2014	Domestic storage solar water heating systems
SANS 10106:2014	The installation, maintenance, repair and replacement of domestic solar water heating systems
SANS 6211-1:2012	Domestic solar water heaters Part 1: Thermal performance using an outdoor test method

SANS 6211-2:2003	Domestic solar water heaters Part 2: Thermal performance using an indoor test method
SANS 60335-2-21:2000	Safety of household and similar electrical appliances Part 2-21: Particular requirements for storage water heaters
SANS 1352:2012	The installation, maintenance, replacement and repair of domestic air source water heating heat pump systems
SANS 181:2016	Thermostatic controls for electric storage water heaters
SANS 198:2012	Functional-control valves and safety valves for domestic hot and cold water supply systems

The compulsory regulation governing hot water storage tanks for domestic use in South Africa is VC 9006. It is intended to ensure compliance with SANS 151. VC 9006 was issued in 2014 and amended in 2016 (Rob Davies; 2014; 2016). The amendment of VC 9006 in 2016 required all fixed storage water heaters to have a minimum energy efficiency rating of class B when tested in accordance with SANS 151. The inclusion of a class B energy efficiency requirement was perceived to negatively affect the whole water heating industry, in particular, the solar and heat pump water heating systems that are required to be tested under two standards. The results of this have affected manufacturing, export and import industry in South Africa.

NRCS has oversight for all products manufactured in or imported into South Africa as long as those products fall within the scope of the technical regulation. Products produced for export markets only currently are required to meet SANS 151 and VC 9006, as the regulator needs to ensure that these products do not find their way on the local market. The NRCS Act definition of "sell" includes to "... export from the Republic..", this means that any regulation enacted on an exported product that could align to international standards would be beneficial for export trade.

The CRSES completed two studies of VC 9006 and SANS 151 (Terblanche, 2018; 2019). The key findings of these studies was that implementing VC 9006 has created confusion in the market. Some of the issues discussed in the reports are listed here:

- Conflict between standards and regulations (SANS 151 vs VC 9006)
- Alignment with international standards

  The only somewhat similar standard to SANS 151 is AS/NZS 4692.

  "The South African standards for hot water storage tanks, SANS 151, are very similar to AS/NZS 4692. The AS/NZS are drafted in such a way that many of the issues raised by industry in South Africa are fully addressed in those countries. The AS/NZS will be the easiest to align with due to the similarities of the standards and the climate."
- Fixed beverage water boiler units vs 'under the counter geysers'
- Prescriptive design vs. performance testing
- Ambiguities in the testing methodology

  Specifications and tolerances on measuring equipment in the standing loss test are not sufficiently well defined to allow consistent results from independent laboratories.
- System based testing for solar water heaters

3. Approach

This section details the approach taken for this study. The research methodology taken is discussed in Section 3.1. The report layout is provided in Section 3.2. A list of report exclusions are provided in Section 3.3.

3.1. Methodology

To maximise the prospects of an independent perspective and to ensure that the study incorporates national and international experience, practises and trends: 1) A new research team was appointed; 2) Technical expertise and research vigour was prioritised by appointing a university; and 3) An international subject matter expert was included. Moreover, as extensive stakeholder consultation took place in the VC 9006 study it was decided that additional consultation was not necessary. This was based on the following rationale:

- Less than 12 months had elapsed between the two studies with the implication that another round of consultation was unlikely to provide new or material insight.
- Industry would be given an opportunity to provide inputs and comments to the draft report, which have been incorporated in the final version.
- The language used in any standard should allow a layman to understand general sections (objectives, motivation, definitions etc) and technical sections should be clear and unambiguous to a technically competent stakeholder. The scope of a standard determines whether the standard is applicable to a particular product. It is important the scope be clearly written.
- The ability to administer a standing heat loss test on the sole reliance of the SANS151, without having to seek explanations or assistance, is the acid test. The Government of South Africa sees this as a basic and mandatory requirement to encourage a competitive and functional industry.
- Objectivity would be enhanced if the researchers were not biased with the polarised views held by the various market participants.

Interviews, for purposes of clarification, were held with the following implementing partners:

- NRCS: Technical Specialist - Regulatory Research and Development
- SABS: Senior Standards Writer
- SABS: General Manager - Testing)

The only external interview was with an independent consultant, who was previously responsible for testing electric water heaters at SABS, and interviewed as a SABS employee for the VC9006 study. Having worked in both the public and private sector these inputs would be objective, balanced and technically accurate. Additionally, the service consultant does not have any business interests in the manufacturing or installations of electric water heaters which further strengthens the independence of the view provided.

In addition to the interviews, a review of the following set of documents was conducted:

- SANS 151, VC 9006
- Terblanche (2018, 2019)
- A range of international standards, with a focus on AS/NZS 4692.

A review of international standards was conducted for a comparison in the testing protocols, energy-related test methods and specification style and practices that are adopted by other countries and standards organisations for similar domestic hot water services. The goal is to provide a forward-looking strategy for SANS 151 and energy-related domestic water heating regulation to better align towards national objectives.

Of the international standards reviewed, the Australian and New Zealand standard, AS/NZS 4692.1 has the most similarities to SANS 151. These similarities include testing methods, design, construction and more. This is likely that both the Australian and South Africa standards were derived at some point from an earlier British standard. Where the Australian standard is different to SANS 151, it manages to resolve a number of the issues discussed in this report. (Terblanche, 2018)

While the International Organization for Standardization (ISO) has standards for solar and heat pump water heaters, ISO does not have standards for electric resistance water heaters. This report considers the ISO standards for solar and heat pump water heaters. The test accuracies and tolerances were compared to those in the tests from Australia and the United States.

3.2. Report Layout

There are three key areas identified to evaluate SANS 151 and they are provided as follows:

Writing of Standards *(Section 4)*

The confusion of products covered by the SANS 151 and the VC 9006 highlighted by Terblanche (2018, 2019) are investigated through interviews and the written definitions. The content of SANS 151 is evaluated on its readability, logical structure, style and clarity of definitions and scope. Annex B is the focus of the review based on SABS and industry comments. The written content of the materials in Annex B is also evaluated in its clarity of scope such that it should not artificially limit new products on the market. Some miscellaneous comments are provided on the presentation of information in the standards in general.

Testing and Protocols *(Section 5)*

Part of testing and the standards writing is the approach to allowable designs. The difference in approach to prescriptive design and performance testing is discussed in the context of SANS 151. Interviews with SABS representatives mention the "system test type" and "product type" as two different approaches in standards testing. This is interpreted as "systems" and "component testing", and is discussed in the context of solar systems where component testing is most applicable. It is important in the standardisation process that testing methodologies can produce repeatable and reliable results. This is discussed in terms of laboratory accreditation, instrument accuracy, testing protocols and round robin testing.

Energy Efficiency Considerations *(Section 6)*

The energy component of SANS 151 will be discussed separately under energy efficiency considerations, where the history with VC 9006 and its intention will be discussed. The standing loss heat test is evaluated on its fitness for purpose. Broader discussions on solar and heat pump technologies and the ability to measure each type in terms of energy efficiency.

Comments and Recommendations ***(Section 7)***

The recommendations and general commentary on the three topics (Section 4, 5 and 6) are provided in table form and referenced to align with the associated section number.

Strategic Steps ***(Section 8)***

A list of proposed changes and strategic steps are recommended for each of the discussed products in the context of SANS 151 and VC 9006. A process for producing energy-related regulation is suggested for future product considerations.

For ease of referencing, all section references applying to sections from SANS 151 Ed 8.2 (pre-print) will be prefaced with "s", eg. Section s.1 refers to SANS 151 Section 1 labelled "Scope". Sections within an Annex will be prefaced with "s.X", eg. Section s.B.1 refers to SANS 151 Annex B Section 1 labelled "Mild steel containers". Normal sections referencing applies to sections within this report, eg. Section 1 refers to this "Introduction" section. References to sections and Annexes from other standards or documents (i.e. ISO) will be explicitly stated in context.

3.3. Exclusions

This report is not concerned with the general health and safety test methods currently in SANS151. Any recommendations to change or review standards relates only to the writing style and formatting and for the sake of clarity. It should not be interpreted that any recommendation is intended to reduce the quality of current testing practises.

This report does not attempt to make any changes or recommendations on products outside of the original scope of SANS 151. However, other products are discussed in the context of SANS 151 as it currently stands due to the scoping language used either in SANS 151 and/or VC 9006. It is only in this context that products are discussed in this report.

This report does not address whether the risk of legionella should be addressed within SANS 151. The risk of legionella is addressed by other SA standards, specifically SANS 10252-1, *Water supply and drainage for buildings Part 1: Water supply installations for buildings*.

4. Writing of Standards

Standards should be written to be clear and concise and should not include individual writing styles of the writers, but should follow a consistent format. It should not require years of experience with the standard to understand its nuances.

The general sections (scope, definitions, objectives) should be understood by the layman for it to be effectively used. In this case, a very important consideration is that regulators who attempt to develop regulation using the standard need to be able to understand and correctly interpret its scope. Many standards make these sections public-facing to allow the reader to determine whether the standard is applicable before purchasing it.

The technical sections (testing methods and protocols) should be understood by a specialist. The steps required should be clearly indicated. They should be written in a logical and straight-froward manner that allows a lab to determine the performance without any ambiguity or confusion.

This section covers the written aspects in relation to SANS 151 which have an impact on clarity, logical structure, readability and general scope. The topics covered by this section are as follows:

- Clarity in scope: products covered by SANS 151
- Review of Annex B
- Miscellaneous remarks on SANS 151

Each subsection is considered and a set of recommendations provided in critical discussions.

4.1. Clarity in Scope: Products Covered by SANS 151

The scope of SANS 151 and VC 9006 have been questioned in previous reports and have been perceived to cause confusion in the industry. The products covered by these two documents were reviewed; SABS labs, writers and NRCS provided input.

The clarity in scope is considered in SANS 151 in relation to the products that are covered by the standard. It is further expanded in Section 4.2.4 on its materials in Annex B and also discussed in terms of energy efficiency products, in Section 6.3.1.

The types of storage water heaters defined in SANS 151 are cistern type, closed water heater, and open outlet type. As noted by Terblanche, there was no justification for standing loss requirements on any type of water heater other than closed water heaters. (Terblanche, 2018).

> The requirement for class B energy efficiency is largely driven by a study published in 2015, (McNeil, et al., 2015). The experiments conducted in that study and the outcomes are based on standard 150 L hot water storage tanks, made from mild steel for high-pressure systems. No testing was done on SWH, integrated HP, cistern type or similar tanks of various sizes, nor on tanks manufactured from alternative materials such as plastic or copper.

The discussions by Terblanche (2018, 2019) expanded on whether beverage water boiler units and 'under the counter geysers' were included in the scope of SANS 151 and the VC 9006 regulation. SANS 151 defines its scope in Section s.1.1 as follows:

> This standard specifies the characteristics of thermostatically controlled fixed electric storage water heaters intended for indoor and outdoor domestic use and for operation on a.c. supplies at voltages not exceeding 250 V for single-phase and 480 V for other appliances.

According to ACTest (https://www.actest.co.uk/commercial/fixed-appliance-testing/), the definition for fixed relates to the following:

> A fixed appliance is an electrical appliance which is usually connected to the electricity supply via a fused outlet to which the flex is permanently connected.

According to Law Insider (https://www.lawinsider.com/dictionary/domestic-use), the definition for domestic use includes the following:

> Domestic use means the diversion of water by one or more individuals, family units or households for drinking, cooking, laundering, sanitation and other personal comforts and necessities; and for the irrigation of a family garden or orchard not exceeding one-half acre in area.

Two products have been a point of contention with the regulation, the 'under the counter geysers' and fixed beverage water boilers. These two products are discussed in terms of the SANS 151 scoping terms (thermostatically controlled, fixed, electric, storage, domestic use) in Table 4.1 in relation to a conventional electric water heater (geyser). Based on the scoping terms, the two products, that have external plugs, cannot be defined as "fixed". The boiling water dispenser is often used in a commercial setting and therefore does not fit the definition of "domestic use".

Table 4.1: Scoping terms for the SANS 151 definitions of electric water heaters in Section s.1.1 for contended products (gray block indicates a logical "true").

Product	Thermostatically controlled	Fixed	Electric	Storage	Indoor and outdoor	Domestic use
Electric water heater (geyser)	■	■	■	■	■	■
Under/over basin geyser	■		■	■	■	■
Boiling water dispenser	■		■	■	■	

Based on the set of definitions provided and the scoping terms defining each of the hot water products, it can be concluded that they do not fall under the scoping of SANS 151. Interviews with regulators and SABS representatives show the interpretations of whether these products are included or excluded to VC 9006 and SANS 151.

4.1.1. Interviews: Electrical Under/Over Basin Unit

Under/over basin units are small capacity (≤ 50L) electric storage water heaters which are plugged in for electricity. During interviews with SABS Standards, SABS Testing, and NRCS for this report there was disagreement as to whether SANS 151 was applicable for these products. The survey question and a summary of the responses are shown in Figure 4.1 and Table 4.2.

b) Electrical under/over basin unit (Storage $\leq 50l$)

Tick (√) which of the following are applicable:

Cistern type	□
Closed water heater	□
Open outlet type	□
VC 9006	□
SANS 151	□
SANS 1307	□
Other: (Please specify)	________________

Class: A □ B □ C □ D □

Figure 4.1 Sample of Electrical Under/Over Basin Unit Survey Question.

Table 4.2 Summary of Responses to Electrical Under/Over Basin Unit Survey Question.

Institution	**Geyser Type**	**Application of VC 9006**	**Applicable Standards**
NRCS	Closed and open (must have TP valve and mixer for pressure release)	Yes, class B	SANS 151
SABS Standards	Closed water heater	Yes, class B	SANS 151 SANS 1307 (mechanical)
SABS Labs	N/A	No, VC 8055 (Class not applicable)	SANS 60335-2-15 (<15l) SANS 60335-2-75 (>15l)

There is inconsistency in the responses from NRCS and SABS standards writers and labs. This is a cause for concern.

4.1.2. Interviews: Boiling Water Dispenser (Hydroboil)

A similar question for a boiling water dispenser using Figure 4.2 as a visual guide. The responses are provided in Table 4.3.

Figure 4.2: Boiling Water Dispenser (commonly termed "hydroboil").

Table 4.3: Summary of Responses to Boiling Water Dispenser Survey Question.

Institution	Geyser Type	Application of VC 9006	Applicable Standards
NRCS	Closed water heater and open outlet type	Yes, class B	SANS 151
SABS Standards	Closed water heater	Yes, class B	SANS 151 SANS 1307 (mechanical)
SABS Labs	N/A	No, VC 8055	SANS 60335-2-21

There is inconsistency in the responses from NRCS and SABS standards writers and labs. This is a cause for concern.

4.1.3. Critical Discussion

The scope of a standard should clearly describe the products and features which it applies to so there is no confusion as to whether a product is covered by that standard or not. Similarly regulations should only refer to standards that clearly cover the product or test result being regulated. A standard should be reviewed on a regular basis every few years to assure it is still relevant. This review should include the scope. If the range of products on the market has changed, the scope of the standard should be modified to meet the new situation. The market share of new products and their national energy impact should be considered before introducing energy standards and regulations.

For the contended products discussed in Section 4.1 (under/over basin unit and boiling water dispenser) and the confusion over inclusions to SANS 151, the standards provide adequate scoping definitions with the use of "fixed" to exclude products that need to be plugged in. While this term is defined in Section s.3.1.5 as "water heater permanently fixed in a specific location", implying only that it is a permanent fixture. If the meaning of a "fixed appliance" is accepted as provided in Section 4.1, it should be well established in working groups and clarified in the standards. If this definition is not accepted, then a different criteria (such as minimum volume) should be used to clarify the scope. It is also useful to define the term "domestic" in the standard. The difference in interpretations of VC 9006 and SANS 151 standing loss class B MEPS for these two products is problematic.

Regulators, standards writers and labs should achieve consensus over definitions of products and the inclusions or exclusions. The scope and definitions sections of the standard should clearly reflect that consensus. If there is disagreement with the regulatory agencies, then it is no wonder that there is confusion in industry. This is an obvious indication that the scope and definitions should be clearly stated and there should be no ambiguities in interpretations, such that consensus is reached.

4.2. Review of Annex B

From interviews with SABS, the following portions of the SANS 151 that require review are: "...some of the geyser types are not covered in SANS 151 (Annex B material), therefore they cannot be tested and they cannot sell in our market." Interviews with industrial representatives also placed emphasis on Annex B requiring attention.

The structure of Annex B provides a list of materials, construction instructions and tests methods for the material performance (and in some cases the water storage containers). The materials (and liners) and storage container types are listed as the main sections in the Annex, i.e. mild steel container, construction and test of vitreous enamel lined steel storage containers etc. There are twelve sections indicating the materials of container types. Subsections in each of the sections describe specifics of the material or its construction, design requirements (if applicable), joining instructions and performance testing of the material.

Annex B is referenced in Section s.5.2.1, under general material requirements for water container shell. It is referenced for the specifications in relation to corrosion protection of linings under Section s.5.2.2.1, which references Section s.B.2 or s.B.3.

A brief comparison with test methods in Annex B and Section s.7 (The Inspection and Methods of Test) indicates some difference in required testing conditions. Section s.7 states the atmospheric conditions for the test methods that follow. It is not clear in Annex B whether testing conditions in Section s.7 are also required, or if there are any specific test conditions.

The logical structure of Annex B is evaluated on the following criteria:

- Test methods: Referencing
- Test methods: Section levels
- Test methods: Descriptions
- Classifications of Materials and Containers

This review of Annex B concludes with a critical discussion.

4.2.1. Test Methods: Referencing

The review of the logical structure of Annex B takes into account the materials and container types included and the references made to the testing methods required for material performance. A summary of the tests methods required for each material is provided in Table 4.4.

Table 4.4: Summary of test procedures for materials or container types in Annex B (gray block indicates that the test applies to the material through direct reference, yellow block indicates indirect reference).

Test	Vitreous enamel lined steel (s.B.2)	Polyethylene lined steel (s.B.3)	Single shell copper (s.B.4)	Glass-reinforced plastic GRP (s.B.5)	Stainless steel (closed) (s.B.6)	Stainless steel (open/cistern) (s.B.7)	Composite polybutylene and GPR (s.B.8)	Polyethylene cistern (s.B.9)	Polypropylene cistern (s.B.10)	Polypropylene closed (s.B.11)	Stainless steel tubes and polyphthalamide (s.B.12)	Location of test procedure
Solubility of lining material	gray											s.B.2.2
Sample preparation		gray					gray	gray	gray	gray		s.B.3.1.1
Tensile strength		gray					gray	gray	gray	gray		s.B.3.1.2 a - ISO 527-1
Impact energy absorption (Charpy impact)		gray					gray	gray	gray	gray		s.B.3.1.2 b - ISO 179-1
Dimensional stability		gray					gray	gray	gray	gray		s.B.3.1.2 c - ASTM D 1003-13
Environmental stress		gray					gray	gray	gray	gray		s.B.3.1.2 d - ASTM D 1693-13
Resistane to vacuum		gray								gray		s.B.3.3 - Sec s.6.3.1 and s.7.3.4.1
Long term cyclic exposure to hot and cold water		gray		gray			yellow	gray	gray	yellow	gray	s.B.3.4
Visible degradation (by inspection based on long Sec 3.4)				gray								s.B.5.1.2
Life expectancy test				gray								s.B.5.3
Pressure burst test				gray			gray					s.B.5.3.3
Determination of life expectancy				gray								s.B.5.3.4
Metallurgical analysis of material and joints (as requested)					gray	gray						s.B.6.4
Leak (based on life expectancy tests)							gray					s.B.8.1.2
Life-cycle testing (Accelerated pressure cycle test)							gray					s.B.8.2.3
Static pressure hold test							gray					s.B.8.2.4
Thickness consistency								gray	gray			s.B.9.2.1
Creep of the container for long term storage of hot water								gray	gray			s.B.9.4
Resistance fatigue										gray	gray	s.B.11.3.2, s.B.12.3.2 - s.6.3.2
Resistance to hydrostatic pressure										gray	gray	s.B.11.3.3, s.B.12.3.3 - s.6.3.3
Stagnation temperature of the water-filled system										gray		s.B.11.3.5
Long term resistance to pressure and temperature (creep testing)										gray		s.B.11.3.6
Leak test (based on creep test)										gray		s.B.11.3.6.4
Temperature shock											gray	s.B.12.3

General test procedures of material performance are introduced for one material and then also cross referenced from within sections for another material. Two examples are given below.

Example 1: Section s.B.3.4 details a test method for determining the suitability of the lining or container for long term cyclic exposure to hot and cold water storage. This test method is a subsection of Section s.B.3 labelled "Tests of polyethylene lined steel storage containers". The test method is directly referenced for use on four other materials in the additional following sections:

- Section s.B.5.2: Glass-reinforced plastic (GRP)
- Section s.B.9.3: Polyethylene cistern
- Section s.B.10.3: Polypropylene cistern
- Section s.B.12.3.1: Stainless steel tubes and polyphthalamide

The fact that several materials directly reference this test method indicates that it is a general test procedure and it should appear as a separate section item. The fact that the test method is embedded as a subsection of one specific material constitutes a logical inconsistency.

Example 2: Section s.B.3.1 is a set of tests to evaluate the performance of polymeric or polymer materials used for the container or the lining of containers, and in direct contact with water. This section includes a method for ageing the material for test preparation (Section s.B.3.1.1, Material) and performance testing in (Section s.B.3.1.2). Four other materials refer to this procedure as follows:

- Section s.B.8.1.1: Composite polybutylene and glass-reinforced plastic
- Section s.B.9.1: Polyethylene cistern
- Section s.B.10.1: Polypropylene cistern
- Section s.B.11.1: Polypropylene closed

This is a similar logical inconsistency to the one found in Example 1. An additional note for testing the performance of the material in Section s.B.3.1.2 is an embedded reference to Section s.B.3.4 (Long Term Cyclic Exposure to Hot and Cold Water), meaning that any reference to conduct procedures in Section s.B.3.1 indirectly includes the need to perform the long term cyclic exposure routine. The way that these subroutines are written do not show any importance to the embedded tests and could be an unnecessary cause for confusion. As can be seen by the title of Section s.B.3.1, there has been an attempt to generalise the range of materials. The very long title for this section is not aligned to best writing practises.

Taking into account the embedded reference to the long term cyclic testing of hot and cold water test procedure (Section s.B.3.4) increases the number of materials referring to this test method to seven instances. The additional indirect references are indicated in yellow in Table 4.4. The cistern types for polyethylene and polypropylene (Sections s.B.9 and s.B.10) make specific reference to the cyclic hot and cold water test. Therefore, it is referenced twice in these sections.

These two examples are not the only instances of the logical inconsistency in referencing test methods, but are used for illustrative purposes. At first glance of Annex B, it is not clear which materials need to be tested using the method in Section s.B.3.4, nor the importance of this test method.

4.2.2. Test Methods: Section Levels

The section level of test methods indicates the structured location of references for test procedures of a material or container in a section. The type of material or container is situated at the first section level, i.e. Section s.B.x, where Section s.B.1 refers to mild steel containers. The second section level refers to sections with the following format: Section s.B.x.x, and the third section level refers to a format with: Section s.B.x.x.x. From the Examples 1 and 2 in Section 4.2.1, there are inconsistencies in the section labelling for materials with similar test procedures.

The most notable instance in Example 1 is seen with Section s.B.12.3.1 (Stainless Steel Tubes and Polyphthalamide), which is invoked in the third section level. The other materials referencing the test method appear in the second section level. By referencing the same test method at the third section level, indicating to the reader a lesser importance to the test procedure than to other materials.

This is also evident in the second example, references to Section s.B.3.1, the composite polybutylene and glass-reinforced plastic (Section s.B.8) is also in the third section level, whereas the three other materials refer to the test in the second section level. This also implies a lesser importance to the test for composite polybutylene and glass-reinforced plastic.

As mentioned in the section above, there are several indirect references to Section s.B.3.4 as a subsection of another method. This indirect reference is easily missed by an inexperienced or new reader. These two examples are only illustrations of the concept and are not the only instances of this type of inconsistency in Annex B.

4.2.3. Test Methods: Descriptions

The descriptions of test methods differ vastly when compared across materials in Annex B. The test methods are different in terms of style, linearity, number of metrics, pages of text and general clarity.

Example 3: The direct comparison of the descriptions of test methods for two materials Vitreous Enamel Lined Steel (Section s.B.2) and Polyethylene Lined Steel **(**Section s.B.3) is provided in Table 4.5.

Table 4.5: Comparison to test method structure and style (up to the third section level).

Section s.B.2: Vitreous Enamel Lined Steel	**Section s.B.3: Polyethylene Lined Steel**

s.B.2.2 Test to determine the solubility of vitreous enamel linings
s.B.2.2.1 General purpose and principle
s.B.2.2.2 Apparatus
s.B.2.2.3 Test solution
s.B.2.2.4 Test specimens
s.B.2.2.5 Calibration of apparatus
s.B.2.2.6 Test procedure
s.B.2.2.7 Calculation of results
 	
(inclusion of illustrations)
	s.B.3.1 Tests to evaluate the performance of polymeric or polymer materials used for the container or lining of containers, and in direct contact with water
	s.B.3.1.1 Material
	s.B.3.1.2 Performance
	- Par. 1 reference to B.3.4
	- Par. 2 reference to B.3.1.1 and par 1
	- a. Tensile strength test
	- b. Charpy impact verification
	- c. Dimensional stability
	    - 1. VICAT softening point
	    - 2. Environmental stress
	s.B.3.4 Test to determine the suitability of the lining or container for long-term storage of hot water
	s.B.3.4.1. Apparatus
	s.B.3.4.2. Procedure

One metric determined using 1.5 pages of text (if including illustrations 3 pages).	Five metrics determined using approximately 1.5 pages of text.

The test method for Section s.B.2 (Vitreous Enamel Lined Steel) is written in a style that is similar to the scientific method and can be followed in a linear fashion (i.e. step-by-step procedure). It has three sections that differ from other test method descriptions:

- it includes a description of the general purpose and principle
- it includes calibration of apparatus section
- it includes illustrations of the setup.

The description of this test method takes approximately 1.5 pages and the addition of illustrations extends it to roughly 3 pages. The test procedure produces a single metric (the solubility of the lining). The steps are clear and linear, making it easy to follow. The purpose of the test is clearly stated.

The test method for Section s.B.3 (Polyethylene Lined Steel) is written as a set of subsections to determine the general performance of the material. The order of steps are not linearly presented, as an example, under Section s.3.1.2, the logical flow based on the written order of instructions is as follows:

Instruction 1:	carry out cyclic exposure test (s.B.3.4)
Instruction 2:	after ageing in s.B.3.1.1 and completion of hot and cold water tests, confirm the following.
Instruction 3:	a) determine the tensile properties of material before and after exposure…

The term "before and after exposure" in Instruction 3 indicates that measurements of the tensile properties needed to take place before Instruction 1 takes place. It is also implied that ageing of material needs to happen first, but this is also not specified. The style of this set of instructions requires interpretation of the order of steps and for the reader to understand the purpose of test procedures, without it being explicitly stated, in order to follow the test procedures correctly.

The description of the test method in Section s.B.3 takes approximately 1.5 pages of text and produces five performance metrics. It could be considered more efficient in its writing approach than the description of Section s.B.2, although there are some portions of it that could be better clarified. The logical steps that need to be taken to conduct the tests do not appear in a linear fashion. The purpose of the test is implied by its subsections, but it is not clearly stated.

4.2.4. Annex B: Classifications of Materials and Containers

The general trend from the list of materials (and containers) in Annex B moves from general material lining (Section s.B.2-s.B.4) to the explicit addition of container specifications (Section s.B.7-s.B.12). The classifications of materials with relation to geyser design types/containers types and working pressures lacks consistency.

The design types that are relevant to the given materials are indicated in Table 4.6. If the design type is unspecified, it implies that all the design types can be applicable with that material. The fact that design types are added in Section s.B.6 and s.B.7 for the same material (stainless steel) but differing by types starts a trend toward specifying a material and design under a separate material requirement.

Table 4.6: Design types indicated for each material in SANS 151 Annex B (gray block indicates a logical “true”.)

Design type	Vitreous enamel lined steel (s.B.2)	Polyethylene lined steel (s.B.3)	Single shell copper (s.B.4)	Glass-reinforced plastic GRP (s.B.5)	Stainless steel (closed) (s.B.6)	Stainless steel (open/cistern) (s.B.7)	Composite polybutylene and GPR (s.B.8)	Polyethylene cistern (s.B.9)	Polypropylene cistern (s.B.10)	Polypropylene closed (s.B.11)	Stainless steel tubes and polyphthalamide (s.B.12)
Closed (unvented) - max 450l					■					■	■
Open outlet type - max 200l						■					
Cistern type - max 350l						■		■	■		
Unspecified	■	■	■	■			■				

An example provided by SABS of the restrictive scope is an inner lining material that was not covered in Annex B of SANS 151 and therefore could not be adequately tested and is deemed to fall out of scope of SANS 151. The example given by SABS refers to a geyser with a lining that is a material mentioned in the range of materials, but some of the specific detail provided in the sections makes it unsuitable for testing. In this case, the written standards can be considered restrictive as it does not allow for a material that is a variation in construction from an already-accepted set of materials.

The fact that the geyser types are explicitly stated in some types of the material but not for other types of material raises questions on diligence and version control of the standards. Consider the cistern type in Section s.B.10. When a polypropylene material in a closed water heater is developed and attempts are made to include it as the next applicable material, would the material and container type be issued sequentially under s.B.13, or would be the requirements be moved to s.B.11 (closer to its cistern counterpart) and all other materials move down an iteration? This poses a big question around version control and the referencing of materials, as the stakeholders would need to update their mental recall of reference numbers. This conundrum poses the question of whether geyser design should be explicitly stated as separate sections for each material or whether the types should be embedded within the second level referencing.

4.2.5. Critical Discussion

The test methods in Annex B are evaluated on the referencing from other sections, section levels and general descriptions. The test methods are shown to be inconsistent and in some instances illogical. This results in a lack of clarity on the importance of certain procedures for materials and in many instances, it requires the reader to be very familiar with the methods in order to understand the order and procedure to follow.

To address these inconsistencies, a common strategy and framework on how to add new materials and the required testing procedures and performance is required. The strategy refers to deciding what information is important to include for each material, where to include it and how to present it. The framework refers to the section levels and generalised structure within the section. The suite of tests that are required to test the material types towards health and safety requirements should be identified and minimum performance should be determined and traceable. If certain materials are exempt from certain types of testing, it should be explicitly stated with reasoning provided.

From this review, it appears that the testing of polymeric and polymer materials (Section s.3.4) is a commonly referred test. References to it requires some improvement. A possible short term approach of addressing some logical inconsistencies in the short term is suggested below:

A possible short term approach to address some issues raised:
Polymeric or polymer materials (which appear common to many materials) could be placed as a subsection of Section s.6, similar to Section s.6.4 (Metallic Materials of Components Attached to or Removable from the Water Container and in Direct Contact with Water). The test method for performance of polymeric or polymer materials could be provided in as a subsection of Section s.7 (or a separate section in Annex B) with information explicitly stating which Annex B materials need to be tested under it. In Annex B, each polymeric or polymer material could refer to the common test method, wherever it is situated. If there are specific operating conditions or performance criteria, state it within the material subsection where the test method is invoked. An example of this is given in Section s.B.11.3.2, which details the test for resistance to fatigue for polypropylene closed type.

Short term improvements should also include the determination of which testing procedures are required for each material and to provide clarity in the standards (in terms of referencing discussed in Section 4.2.1 and appropriate section levels discussed in Section 4.2..2) where test procedures are invoked. Decisions should be made on whether each material should have its own set of test methods or whether general performance tests be applied. A combination of the two could be applicable with great care, and if similar materials become available and require the direct reference to a test method within a subsection of a different material, a step towards generalisation should be considered. This points towards a discussion on prescriptive design and performance testing, which is presented in Section 5.1.

An additional short term improvement would be the inclusion of purpose and reasoning to test procedures. If no explanation of purpose is provided, attempted changes on the document become difficult as reasons for the numerical specification or design are not traceable.

The long term approach would be to strategise on the structure and framework of Annex B and test requirements. This may include a complete re-writing of certain sections. The framework should also include a guideline or template on how to place and reference the tests in a generalised manner; possibly to group materials by categories. This will allow for a standardisation of the materials and would vastly improve the readability of the Annex. This would also involve the generalisation of the process for adding new materials based on verified the performance requirements of those materials for hot water storage use. The performance tests should allow for generalisation and the operation and output performance levels may differ. Additionally, the standardisation of the test descriptions (as discussed in Section 4.2.3) should be considered. The scientific method approach is a good starting point, albeit, will result in long documents.

4.3. Miscellaneous Remarks on SANS 151

Some general items in the main document of SANS 151 were found during the review that do not fit into the other discussions. They are collected and listed in this subsection.

4.3.1. Circular Logic

Section s.4 provides the permissible working pressures of closed (unvented) systems and excludes 500 kPa without explanation. There is a reference to Annex A, implying more information can be found regarding working pressures. In Annex A, there is a cross reference back to Section s.4. This is circular referencing that adds no value to the reader.

4.3.2. Definitions and Scope

Refinement on some definitions and scope is required. Two such examples are provided:

- TP valve acronym (defined in Section s.3.1.13), which stands for "temperature and pressure" valve is not explicitly described in the definition. While the description mentions "thermal" and "pressure", it requires the reader to interpret its meaning. Should be included in abbreviations.
- "Gas burner" is included in the Scope, but not defined in the Section s.3 (Definitions and Abbreviations). Nor are there any references for efficiency testing of gas burners.

4.3.3. Technical Matters

The symbol for standing loss, S, used in s.A.E (Energy Labelling of Storage Water Heaters) for electric water heaters is derived from the standing loss (Qpr) as determined in s.7.4.3.1.1 (Standing Loss Test Method for Electric Water Heater). Qpr is reported in units of in kilowatt-hours per 24 h. The equation to convert Qpr into S is shown in Equation (4.1).

$$S = Qpr \times 1000/24 \qquad (4.1)$$

Where 1000 is to convert kilowatt to W and 24 is to remove the per 24 h'. Thus the units of S are in watts (W) not in Watts per hour (W/h) as shown in s.E.4.2.1.

It is not clear why Table E.1 (Energy Efficiency Classes of Storage Water Heaters) uses the term S. It would be more direct to rewrite the table to be in terms of Qpr, not S.

When calculating the standing loss in s.7.4.3.2.1.3 (Preparation and Test Start) for the non-electric standing loss test method, the final temperature, Tf, is the maximum temperature in the tank. This means the temperature change over the 12 hours of the test is calculated as the difference from the initial temperature to the maximum tank temperature, not the average tank temperature. The maximum tank temperature at this point is likely to be several degrees above average tank temperature, leading to an unrealistically low standby loss.

4.3.4. SANS 1307

Although out of scope of this report, errors found are reported here for completeness. SANS 1307 (Domestic Storage Solar Water Heating Systems) Section 4.6.1 (Thermal Performance) sets limits on thermal performance as evaluated in accordance with 5.9 (Thermal Properties). Those limits are expressed by Equation (4.2).

$$5 \text{ MJ/d} \leq Q \leq 10 \text{ MJ/d at } H = 20 \text{ MJ /m}^2\text{/d} \quad (4.2)$$

According to 5.9, thermal performance is calculated in SANS 6211-1 (Domestic Solar Water Heaters Part 1: Thermal Performance Using an Outdoor Test Method). In SANS 6211-1, Q is calculated as a formula that includes H and ($T_a - T_c$). ($T_a - T_c$) is the difference in ambient air temperature and cold water supply temperatures. Without specifying the value of ($T_a - T_c$) in SANS 1307, it is not possible to calculate Q. The maximum limit was calculated to prevent unreasonable overheating.

4.3.5. Critical Discussion

These remarks are indications that there are general issues with referencing, clarity in definitions and scope, and technical matters in terms of clarity of units and testing performance criteria. It is an indication that additions to the standards have not been performed in a strategic and consistent manner. In some cases it appears that changes made or fixes are arbitrary in nature.

A long term recommendation would be the consideration of reviewing the entire standard to ensure that there is consistency throughout the document. A strategic framework should be developed to allow for additions to be made in a tactful manner. This should be in line with some of the issues raised in the previous subsections, such as (but not limited to), the purpose is clearly stated and the referencing and section-level structure is clear and consistent.

5. Testing and Protocols

This section covers the laboratory aspect and methods for testing in relation to SANS 151. The topics covered by this section are as follows:

- Prescriptive design vs. performance testing
- Systems and component testing
- Test procedures and standards

Each subsection is considered and a set of recommendations provided in critical discussions.

5.1. Prescriptive Design vs. Performance Testing

Standards are written to assure a product is safe and performs at least as well as mandated. Standards can be written prescriptively or expressed as meeting a certain level of performance. An example of a performance standard is electric water heaters shall meet class B standing loss. An equivalent prescriptive standard in the case of standing loss might be language requiring 50 mm of polyurethane insulation.

Prescriptive design refers to the mandated physical design of a component in regards to the material of construction, the sizing and shape of materials, general arrangement of sub-components, etc. This form of a standard can be much more restrictive in terms bringing new innovations to market. A simple and trivial example is given from Section s.5.2.2.2 (Sacrificial Anodes). “The anode shall be cored with a steel rod of minimum diameter 3 mm” is prescriptive. It is justified in the following statements: “to ensure mechanical and wear strength suitable for the duty it has to perform” and “The anode shall be easily replaceable”. Components too rigorously defined in physical design could limit innovations.

Equivalent performance across technologies that provide the same service are acceptable when rated by testing. Performance testing demonstrates how the component operates under normal conditions and/or tests its limitations.

The tradeoff between specifying prescriptive physical design of a component and specifying the performance of the components comes at a balance between allowing for new innovations and the cost of testing. A prescriptive standard does not require testing, but discourages innovation on the part of manufacturers.

Examples in Annex B of prescriptive design and performance testing shown in Table 5.1 indicate the following:

- Metal-based materials (Sections s.B.4, s.B.6 and s.B.7) have prescriptive design descriptions that point to ISO standards for reliability in quality and expected performance. Performance tests in Table 4.4 indicate a small number of material tests, and some are required by request and do not appear mandatory.
- Polymeric and polymer-based materials (Sections s.B.3, s.B.5 and s.B.8-s.B.11) require performance testing of the materials. The tests are required as there is no reference to ISO standard equivalents and there is much more variability in the products. The suite of tests provide some reliability and trust that the product is fit for purpose.

Table 5.1: Brief overview of materials from Annex B with prescriptive design descriptions and performance testing descriptions.

Standard writing form	Vitreous enamel lined steel (s.B.2)	Polyethylene lined steel (s.B.3)	Single shell copper (s.B.4)	Glass-reinforced plastic GRP (s.B.5)	Stainless steel (closed) (s.B.6)	Stainless steel (open/cistern) (s.B.7)	Composite polybutylene and GPR (s.B.8)	Polyethylene cistern (s.B.9)	Polypropylene cistern (s.B.10)	Polypropylene closed (s.B.11)	Stainless steel tubes and polyphthalamide (s.B.12)
Prescriptive design			■		■	■					■
Performance testing	■	■		■			■	■	■	■	■

If the physical design is rigidly specified, it could result in less requirements to test individual components. However, if the design is fixed without appropriate justification, it could result in the automatic rejection of the adoption of newer and more modern physical designs that do not match those set out in the standard.

Performance testing for individual sub-components, depending on the level of detail tested or accuracy required, could be considered costly in testing due to labour intensity, time taken for each individual test protocol and the possible addition of new equipment.

5.1.1. Critical Discussion

Except in cases where there is a demonstrated need for a prescriptive standard, it is usually better to write standards in terms of performance. As long as the product can meet the required performance criteria, there should be no unnecessary barriers to allowing innovative products to be sold and used. This highlights the need to develop test protocols and performance criteria from first principles and published knowledge.

The level of prescribing component construction and material specifications, such as anodes, should be done with testing performance in mind. A set of performance tests can be provided that would allow for innovations in anode construction and material choice. Simultaneously providing examples of prescriptive designs that are automatically accepted would reduce the burden of testing for those designs that are already known to perform as required.

As indicated by Terblanche (2019):

> "SANS 151 should be reviewed to identify and address inconsistencies and unfair requirements placed on niche and non-'standard water heater' technologies. The standards should be drafted to be fair and inclusive of other technologies. It is also worth considering the approach recommended by the WTO/TBT to regulate based on performance rather than design or descriptive characteristics. Any justification for differentiation and technology specific requirements should be evidence based to prevent unnecessary discrimination." (Terblanche, 2019)

The perception of unfair bias in the standard could be addressed through the design of performance tests. A product tested under a set of performance tests would receive a quantified result of its fitness for purpose. If a product is deemed unfit for purpose or faulty, it should ideally be determined through objective testing based on its performance against an expected set of criteria. Therefore, the performance tests need to be designed carefully to ensure that quality of testing is preserved. The design of such tests is not trivial and would require careful thought in development.

5.2. Systems and Component Testing

A systems based approach to testing means the performance of a system consisting of multiple components must be tested as a single unit. System testing refers to testing the performance of a product assembled from individual components as a single entity, such as an electric water heater. Component testing of the same system would entail tests of the individual components then calculating the performance of the resulting system.

This is a particular concern for custom-designed solar systems, as the collectors, hot water storage tank, pumps, controls and other components are often made by separate manufacturers then installed together as a system. The system designer and installers select the individual components based on the needs of individual installations depending on the expected hot water loads, local climate, and latitude. Different systems may combine different models of collectors with different hot water storage tanks with different configurations and controls. Component testing allows the parts of a system to be tested separately and the performance of the system calculated with algorithms or computer simulation using the performance of the individual parts as input.

The testing burden of a systems based approach can become quite extreme as every different solar water heating system would need to be tested. The cost of each solar water heater system would therefore include the costs of testing. This is compared to the testing cost of standard electric water heaters being spread across an entire model line of potentially many thousands of individual water heaters. This makes system testing an unfair barrier to trade.

Another concern with system testing is that if one component of the system were to cause the system to fail to meet the standard, the entire system must be retested whenever a different component is used. This can even be the case if the component has no impact on the efficiency or performance of the system.

If the test burden is too high the market may be driven to products that are not required to meet the standard or for manufacturers to forego any attempt at compliance.

5.2.1. Critical Discussion

The requirement for system testing is limiting the adoption of solar water heating or at minimum encouraging customers to adopt products that do not meet the standard. Solar water heating systems should be excluded from system testing requirements.

An electric water heater is sold and installed as an entire system. Solar water heaters are commonly sold as a set of individual components. The system is installed in the field from those components. To require an entire solar system to meet SANS 151, including the standing loss test, is an undue barrier to market entry. It would make much more sense to apply only the health and safety requirements in SANS 151 to the hot water storage tank of the solar system.

5.3. Test Procedures and Standards

Repeatable, reliable and robust test procedures for standards are essential for regulatory purposes. Standards will not serve their purpose if the energy efficiency rating of a water heater is not defensible. To accomplish this the test procedure must carefully specify the instruments, the test setup and the test protocol.

5.3.1. Laboratory Accreditation

The measurement instruments must be of sufficient accuracy so the inevitable errors and uncertainties are small enough so that final calculations give certifiable results. Those instruments need to be regularly calibrated. The laboratory must be properly equipped and staff properly trained.

The South African National Accreditation System (SANAS) recognizes how important this is for standards tests and follows international best practice. SANAS qualifies test laboratories according to ISO/IEC 17025:2017 General requirements for the competence of testing and calibration laboratories with documents such as *Technical Requirements* (SANAS, 2019a), *Assessment Plan* (SANAS, 2018a), *Vertical Assessment* (SANAS, 2018b), *Management Requirements* (SANAS, 2019b), and *Assessment Cycle Matrix* (SANAS, 2018c).

5.3.2. Instrument Accuracy

Not only are the competence of the test facility and staff at the facility required, but the test procedure itself must be clear and precise. For example the accuracy and tolerances specified in the test procedure must be stringent enough for the test to yield accurate results. Unfortunately this is not the case in SANS 151. The measurement apparatus listed in Section s.7.4.1, (Apparatus), have no associated tolerances or uncertainty requirements. Nor is there any stipulation of calibration requirements for the measurement instruments.

The general test conditions, equipment and configuration of the set up used for the water delivery and the standing heat loss tests are specified as part of SANS 151. The analogous specifications in AS/NZS 4692.1 are much more detailed and more strictly defined. The relevant appendix in AS/NZS 4692.1 is 7 pages long and contains sections on the test conditions (air temperature and movement, thermal radiation shielding, cold water temperature and pressure, electrical supply), equipment and setup (including the location of 6 temperature probes inside the cylinder), and measurement accuracy.

Table 5.2 compares the instrument tolerances of some of the key measurements in the SANS 151 standing loss test to requirements for those measurements in these other test procedures as follows:

- AS/NZS 4692.1 Appendix B Standardized Test Conditions, B4 Measurement Accuracy and Instrumentation

- US Department of Energy 10CFR430 Subpart B Appendix E, Uniform Test Method for Measuring the Energy Consumption of Water Heaters
- Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Operations Manual for the Residential Water Heater Certification Program

The AHRI certification program provides public representation that the ratings of randomly selected units have been verified by an independent laboratory in accordance with the test procedures. The AHRI certification program complies with requirements of the ISO 17065 (General Requirements for Bodies Operating Product Certification Systems).

Table 5.2: Comparison of Water Heater Instrument Tolerances.

Measurement	**SANS 151 Ed 8.2**	**AS/NZS 4692.1**	**US**	**AHRI Appendix A**
Air and Water temperature	± 3℃	overall uncertainty < ±0.5 K, 95% confidence level. resolution < 0.1 K	accuracy ±0.1 °C precision ±0.06 °C	±0.11 °C (±0.2 °F)
Storage tank temperatures	±1.5℃		accuracy ±0.3 °C precision ±0.14 °C	±0.28 °C (±0.5°F)
Electricity	Not specified	uncertainty ≤ 1%, 95% confidence level resolution ≤ 10 Wh, 1 Wh preferred	accurate to within ±0.5% of the reading	Voltage 1.0 volt Current 0.1 amp

In addition to the requirements on the accuracy of the test instruments, the description of the configuration of the test setup and procedure must be detailed and clear. This is necessary to have a test that can be consistently applied in any accredited laboratory. Otherwise the practices of the laboratory staff will have an undue role in determining the results of the tests.

For a standing loss test, the thermal environment of the water heater being tested is critical. In addition to the tight control of the ambient air temperature, air motion and exposure to thermal radiation must be controlled as well. Without consistent control of these factors, the test results will not be repeatable. These limitations of environmental conditions are clearly described in the Australia standards, but not present at all in SANS 151.

5.3.3. Testing Protocols

The testing protocols written in standards should have sufficient detail for independent accredited laboratories to produce consistent repeatable results. A key determinant of standing loss is the heat content of the water inside the tank. If the water temperature is not measured accurately changes in temperature over the course of the test may mask the actual heat loss.

The Australian and US tests on storage water heaters require six carefully positioned thermal sensors within the tank. For horizontal tanks the Australian standard prescribes the six sensors to be located at distances of 0.14, 0.30, 0.43, 0.57, 0.70, and 0.86 tank diameters above the bottom of the inside of the tank. Horizontal tanks will have significant stratification leading to non-uniform heat loss profiles under a heat loss test. The Australian standard offers a series of options for installing the temperature sensors through the following options (AS/NZS 4692.1:2005):

a) the anodic device opening,
b) any other existing container penetration (e.g., alternative unused hot water outlets or cold water inlets),
c) the pressure-relief valve opening (less preferable),
d) the hot water outlet used for draw-off tests (less preferable); or as a last resort,
e) a special hole made in the tank for the placement of temperature sensors where there is no alternative.

SANS 151 specifies only one location "using a thermocouple placed through as near practicable to the outlet into the upper half of the water in the container."

The ability to consistently and uniformly control water temperature is essential for standing loss tests. The Australian standard recommends an external temperature controller with the ability to control temperature control cut-outs to 1 K or better. SANS specifies using a temperature controller capable of maintaining temperature to within ± 1.5 °C.

SANS has no requirements for determining whether thermal stability has been reached before and is maintained during the 48 hour standing heat loss test. There are no restrictions on what phase of a temperature control cycle (cut-in, cut-out or standby) to end the calculation. This means the energy consumption for one entire reheat cycle could be arbitrarily included or excluded from the calculations. In contrast the Australian standard has very specific guidance on these elements of the test procedure (AS/NZS 4692.1:2005).

The laboratory set up, pipe configuration and level of pipe insulation are not specified for the standing heat loss test for electric water heater in SANS 151. Insulation levels during testing have a very large impact on the final results and need to be clearly defined.

Another protocol crucial for consistency that is not specified is the sampling rate of temperature measurements. The SANS 151 temperature measurements of ambient air and water are described in s.7.4.2 as taken for "the duration of" the test. The way it is written there is no indication of how often the measurement is to be made and recorded.

5.3.4. Round-Robin Testing

A final suggestion to ensure repeatability and reliability of the test protocol is to conduct inter-laboratory reproducibility comparison (round-robin) testing of the same water heater at multiple laboratories. If the test is suitable to task the results from different laboratories should be comparable. Any discrepancies should be evaluated. The language of the standard may need to be improved to remove the source of those discrepancies.

It was as a result of this type of testing within the US with the National Institute of Standards and Testing (NIST) and manufacturers that the AHRI operations manual was developed. A similar project funded by European Committee for Standardization (CEN) focused on evaluation of the standards used and measurement reproducibility of EU laboratories for the application of Ecodesign requirements and labelling of heating and hot water production appliances. (Schweitzer, 2019)

ISO has a set of standards covering accuracy of measurement methods and results. Of these ISO 5725-2:2019 which "amplifies the general principles for designing experiments for the numerical estimation of the precision of measurement methods by means of a collaborative interlaboratory experiment" is probably the most relevant to consult.

5.3.5. Critical Discussion

That a lab is accredited to be able to perform the standing loss test procedures in SANS 151 is only a first step. The standing loss test procedures must specify sufficient accuracy for the instruments and enough detail on the calibration and placement of the measurement instruments and enough clarity on the steps to take in the test procedure that the results are repeatable across staff within laboratories and between laboratories. Otherwise there can be no trust in the results of the testing.

One of the best ways to assure trust in the test procedure is to do interlaboratory comparisons of the standing loss test of the same water heater. This will clearly reveal shortcomings in the standard that need to be revised, such as increasing the accuracy of the measurement equipment and revising the testing protocol so that it can be followed consistently. In addition to SABS Laboratory and Test Africa, water heater manufacturers with laboratories should be invited to participate.

6. Energy Efficiency Considerations

Water heaters use 40% of electricity consumed in the residential sector in South Africa (Hohne et al, 2019). Energy efficiency standards on water heaters are a policy tool that can be used to limit the energy use of water heaters.

This section considers the history of the class B standard and whether a MEPS on standing loss is the most appropriate means of reducing water heater electricity consumption. The topics covered by this section are as follows:

- VC 9006 and SANS 151
- Review of International Water Heater Efficiency Standards
- Comparison of SANS 151 to International Standards

Each subsection is considered and a set of recommendations provided in critical discussions.

6.1. VC 9006 and SANS 151

Energy efficiency regulations relating to domestic hot water storage tanks issued by the VC 9006 in March 2016 caused much disturbance to the industry. This necessitated the clarification of definitions, clarifications to class ratings for different technologies and for a new standing loss test method to account for non-electric units.

According to the NRCS and SABS representatives, the purpose of this compulsory regulation was intended as follows:

- "To save energy by removing inefficient tanks in the South African market."
- "To promote energy efficient products on hot water storage, my understanding was that it would only be applicable to hot water storage with element."
- "...geysers are one of the major consumers of household electricity. So the VC was meant to ensure that there is some savings when the consumption is regulated to be lower."

According to the NRCS, the decision to regulate electric water heaters to class B was based on findings and recommendations in a report by McNeil et al (2015). The decision to extend the class B regulation to non-electric water heaters was based on stakeholder meetings held in 2014/15.

This regulation resulted in the majority of the water heating products becoming non-compliant. The NRCS points out that there was a high level of non-compliance in 2016, specifically from local manufacturers, which made the process of regulating products challenging. Since that time there has been more compliance with the standard. In addition, this regulation caused confusion around the inclusion of non-electric water heating products (solar thermal and heat pumps), which are considered energy efficient due to the reduced usage of electrical energy required for heating.

6.1.1. Subsequent Remedial Action

Since the adoption and later amendment, both SABS and NRCS have continued work to amend the standard and the regulation reduce confusion. This report is based on the draft amended version of SANS 151 which is likely to be finalized in the coming months.

Amendments proposed by SABS to relieve confusion (not yet implemented):

- "Remove pass-fail criteria to the regulation (VC 9006) from standard (SANS 151)."
- "Accommodate other innovative products without compromising standard purpose."
- "Clarification of inclusion/exclusion of non-electric geysers."
- "Alignment of label requirements to the DOE guidelines on labelling."
- New test method proposed for testing standing losses for units that do not have an element (i.e. for solar and heat pump tanks) - supplied in Ed 8.2.
- SABS test labs have reintroduced partial testing of SANS 151 methods to allow manufacturers the opportunity to test during the design phase at reduced cost.

Due to process lead times by the Standards Divisions, not all the above points have been implemented at this time.

Actions taken by NRCS on the changes to regulation to relieve confusion (not yet implemented):

- "To change and clarify scope of the VC."
- "To make changes in the specific MEPS requirement, by requiring class B for electric tanks and class D for non-electric tanks & cistern type."

These proposed amendments are expected to be submitted by the end of March 2020 with implementation expected around November 2020. The approvals of amendments are subject to the Ministers of the DTI (Department of Trade and Industry). Currently, non-electric water tanks considered under class D require an application to the NRCS for a sales permit to continue trade.

6.1.2. Standing Loss for Energy Efficiency

The purpose of the standing loss test is to quantify the ability of a water heater to maintain the temperature of the water in the tank. This effectively evaluates the insulating capabilities of the thermal storage unit.

In Section s.6.6 SANS 151 states the standing loss is determined according to Section s.7.4.3 (Standing Loss Test). That section states the standing loss shall meet the requirements of the national regulation (VC 9006). The standing loss test is one of three tests in Section s.7.4 (Efficiency Tests). The other tests in that section are the Hot Water Output Test and Reheating Time. The results of those two tests must meet the criteria specified in Section s.6.7 (Hot Water Output) and Section s.6.8 (Reheating Time) respectively.

The results of the test for electric storage are expressed in terms of required energy as kWh over a 24 hour period. The criteria for fixed storage water heaters to meet the standing loss test is specified in VC 9006 as class B when tested in accordance with SANS 151. The energy efficiency class of a water heater is determined according to methods specified in Annex E (Energy Labelling of Storage Water Heaters). The method is to convert the standing loss in kWh/24h to standing loss in W.[3] The standing loss (W) and the measured volume are used in Table s.E.1 (Energy Efficiency Classes of Storage Water Heaters) to determine which energy efficiency class the water heater is to be rated at.

Labeling only refers to standing loss and can be considered misleading when considering the energy efficiency of the whole system. A standing loss test does not consider the amount of energy which is used to heat water for use. For many households the energy to make up for the standing loss is only a fraction of the total energy consumed by the water heater.

Figure 6.1 illustrates the comparison of energy consumption of a 150-litre hot water storage tank based on SANS 151 class tables with the fixed temperature gradient (ΔT) of the test procedure in a 24 hour period. This graph shows the energy recovery and standing loss contributions separately. The standing loss class bands (A to G) are represented by the shaded blocks, where class A has the lowest standing losses and class G has the highest. The standing losses represent a fixed (assuming fixed temperature references), passive energy loss to the system. class B has been highlighted due to its relevance in this investigation. The recovery energy ($E_{recovery}$)represents heating water to make up for hot water provided to the user. It is the energy used to heat the water. The recovery energy is a function of the daily volume drawn from the system as provided in Equation (6.1) and is indicated by the linear graph in Figure 6.1. In Equation (6.1), e is the efficiency of heating water. With resistive heating the efficiency is nearly 100%. With solar or heat pumps the efficiency can be larger than 200%.

$$E_{recovery} = e\ \rho V c \Delta T \qquad (6.1)\text{*fix rho}$$

If the total contribution of energy (E_{total}) is considered for the tank in a 24 hour period, it is calculated by adding the recovery energy to the standing loss energy ($E_{standing}$), as shown in Equation (6.2). The percentage of standing loss contribution ($\eta_{standing}$) to the total energy is represented by Equation (6.3). The shaded graphs representing the percentage standing loss contribution for each class band is illustrated in Figure 6.2.

$$E_{total} = E_{recovery} + E_{standing} \qquad (6.2)$$

$$\eta_{standing} = \frac{E_{standing}}{E_{total}} \times 100 \qquad (6.3)$$

To expand on the percentage standing loss contribution in Figure 6.2, if in a 24 hour period, there is no user interaction to the hot water tank (i.e. volume of hot water drawn is zero), then the standing loss energy contributes to 100% of the total energy consumption of the tank. If 150l is drawn from the tank in a day (100% of its rated volume capacity), the standing loss for the upper limit of class B will contribute approximately 15% of the daily energy, whereas the upper limit of class D will contribute approximately 23% of the daily energy.

[3] The units listed for standing loss S in Annex E are not correct. The correct units for S are watts (W).

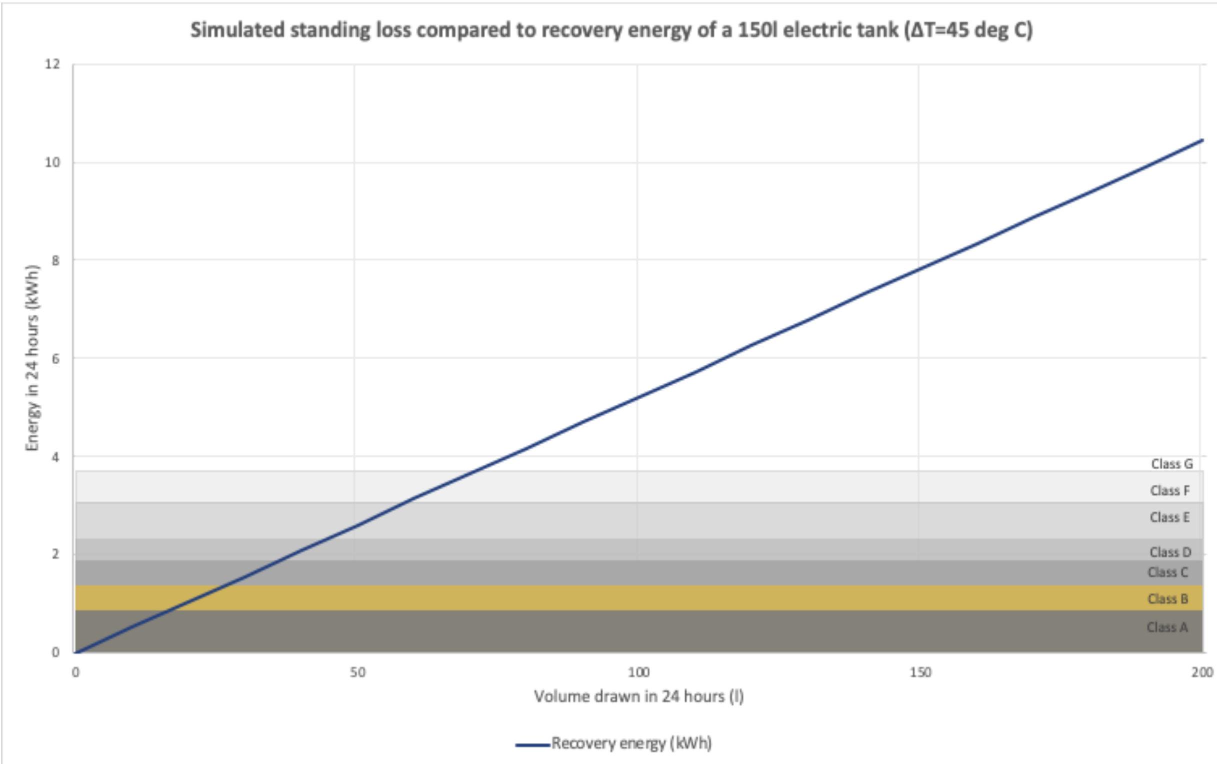

Figure 6.1: Simulated energy consumption of a 150l electric-powered storage tank in comparison to the associated standing loss bands for classes (A to G).

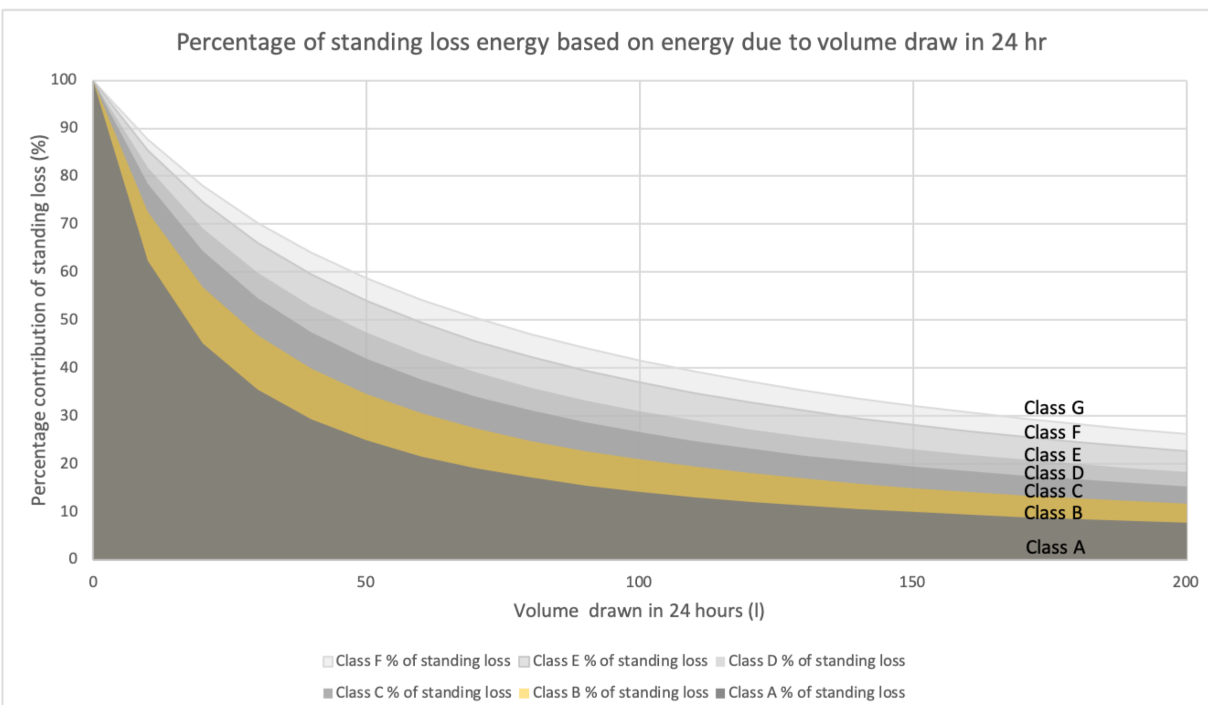

Figure 6.2: Percentage of standing loss energy contribution within 24 hours to the recovery energy from volume of hot water drawn in the same period (class A to class G).

For a well-utilised tank (usage at 100% volume capacity), the fixed standing heat loss contributes a relatively small portion of the total energy contribution of the tank, as can be seen from Figure 6.2. Therefore, the standing heat loss is not a suitable quantity, especially as the only metric, to determine the performance of a tank for energy labelling purposes.

6.1.3. Critical Discussion

Current class labelling based only on the standing loss test does not account for electrical energy consumption required to provide hot water. This means the standing loss can not be used to compare the energy consumption of solar or heat pump water heaters to the energy consumption of electric resistance water heaters. The energy efficiency of solar and heat pump technologies is not measured accurately by standing loss tests. To impose a standing loss requirement on solar and heat pump technologies is unnecessary and creates an additional barrier for trade; the additional testing increases the cost of the product which is passed on to the consumer.

There is no empirical evidence to show whether the regulation has met the desired effect. Sales data of available products on the market were not obtained to produce a detailed market study of sales of hot water products. Speculation from the sales manager of a popular building supplies retailer notes the recent increase in solar sales, with the cited reason due to loadshedding. Anecdotally, it appears that more energy efficient products, such as solar, are being considered more by consumers and the regulatory framework is in place to assist it. It would be beneficial to obtain the quantified impact of this regulation for expected energy savings nationwide.

6.2. Review of International Water Heater Efficiency Standards

This section reviews international standards for water heater efficiency, it does not review standards for health and safety. The types of test procedure and metrics used for water heater efficiency standards vary dramatically among countries. The choice of standard depends on the history and common technologies used for water heating in a country. The initial choice of a test procedure usually depends on the type of technology in common use at the time standards were first adopted. For example water heaters with only a small amount of stored water, such as gas-fired tankless water heaters, can experience cyclic losses for every water draw. This type of loss is not present in storage water heaters. If gas-fired tankless water heaters are not common in a country, there is no reason to adopt a test procedure that includes cyclic losses.

Because of the diversity of history regarding test procedures and standards, the International Organization for Standardization (ISO) does not have many standards for water heater efficiency. The only ISO standards for water heater efficiency are for solar, ISO 9459 (Solar heating – Domestic Water Heating Systems) and heat pumps ISO 19967-1 (Heat Pump Water Heaters Part 1: Heat Pump Water Heater for Hot Water Supply).

6.2.1. Overview of Energy Consumption Tests

The types of performance tests used to rate water heater efficiency include; standing heat loss, cold and hot start, 24-hour simulated use tapping cycle, separate tests of standby, cycling loss and recovery efficiency combined with computer simulation of hot water use. (Waide, 2015) The use of simulation (e.g. using TRNSYS software) to apply the results of component testing is commonly used for solar water heaters.

The test conditions and procedures can lead to significant differences between standards. Cold and hot water temperatures as well as ambient air temperatures are not consistent. Among standards that include hot water draw-offs there is no standard draw pattern. Some of the simulated use tests that include 24 hour draw schedules have more than one tapping pattern. Which tapping schedules to use depends on the capacity of the water heater being tested. Draws in tapping schedules can be defined in terms of the volume of hot water delivered per draw or in terms of the amount of energy delivered per draw.

Another point of difference among standards is whether the energy consumed for heating water is included in the metric. For electric water heaters with resistance elements immersed in water the efficiency of heating water is nearly 100%. If only electric water heaters are covered, applying a standing loss test may be appropriate, even though it doesn't cover the energy used to heat water for use. When electric water heaters are to be rated along with solar or heat pumps, which can have electrical efficiencies well above 100%, a standing loss test is no longer appropriate. At that point the efficiency of the water heater should be the ratio of the energy in the delivered hot water to the energy consumed by the water heater over a typical day.

The effort to have a consistent energy efficiency test for all types of water heating technologies is ongoing. Australia is currently undertaking a study to develop "a new method of testing that is technology neutral, to enable direct comparisons between technologies, and to make it possible to develop technology neutral MEPS." (EECA, 2018) A technology neutral test procedure is also being pursued as part of the Ecodesign requirements for water heaters in Europe. (ECEEE, 2019).

6.2.2. Solar and Heat Pumps

Solar and heat pump water heaters can have daily efficiencies, calculated as the ratio of energy delivered as hot water to electricity use of well above 200%. This is because electricity is not providing all the heat going into the water. For solar, the extra heat is provided by the solar radiation incident on the collector. Electricity is used for pumping water through the collector, operating controls and providing back up heating if it is needed. Heat pump water heaters collect heat from the ambient air around the water heater and pump that heat into water in the tank using a refrigeration cycle. Electricity is used to run the compressor, fans, controls and to provide back up heat if needed.

Because the amount of delivered heat in the hot water is more than the electrical energy used, the efficiency will be above 100%.

6.2.3. Critical Discussion

To adequately compare the energy use for domestic water heating of technologies other than electric water heaters, the standard must move beyond only a standing loss. Many of the international energy efficiency standards for water heaters already are doing this. The EU and Australia have ongoing projects to do this for those regions and should be carefully monitored. South Africa should actively monitor ongoing international efforts to improve water heater efficiency tests. A first step to move beyond a standing loss test could be a simplified 24-hour simulated use test for electric resistance water heaters, then expanding to solar and heat pumps as they become more available on the market.

6.3. Comparison of SANS 151 to International Standards

This report reviews the energy efficiency tests in SANS 151 compared to water heater efficiency standards from the International Organization for Standardization (ISO), the European Union (EU), the United States (US) and the combined Australian New Zealand (AS/NZS) standards. Other standards not readily available in English were not referenced in this report. Future work to update SANS 151 should include reviews of water heater energy efficiency standards in China, Japan, and South Korea in light of the innovative water heater technologies on the market in those countries.

6.3.1. Clarity in Scope

The manner in which the scope of the Australian standard is specified is somewhat unusual and might be useful for SABS and NRCS to consider. The Australian MEPS for electric water heaters is based on a standing heat loss quite similar to the one specified in SANS 151. The Australian standard consists of two parts, AS/NZS 4692.1 (Part 1: Energy Consumption, Performance and General Requirements) and AS/NZS 4692.2 (Part 2: Minimum Energy Performance Standard (MEPS) Requirements and Labelling). Part 2 is referred to in regulations and is used in conjunction with Part 1.

The scope of Part 1 includes the storage component of solar, heat pumps and indirectly heated systems. It further stipulates that it is only for water heaters that use electric resistive heating as the primary energy source. However it concedes the test methods for heat loss are applicable to other water heater types such as solar water heaters and heat pumps. In addition to a scope section, Part 2 has an exclusions section. The exclusion section states that the standard does not apply to “water heaters that use electric-resistive heating to provide less than 50% of the energy supplied in a typical year (e.g., heat pump and solar water heaters)”. The amount of energy supplied in a typical year is to be calculated according to standard AS/NZS 4234 (Heated Water Systems - Calculation of Energy Consumption) which applies to heat pump and solar water heaters as the means to calculate the energy supplied in a typical year.

6.3.2. Standing Loss Test for Water Heaters

The Standing Loss test in SANS 151 has two parts, one for electric water heaters, the other for storage water heater containers and hot water storage tanks not fitted with electric elements.

The standing loss for electric water heaters relies on the existing elements in the tank. For this case the Australian standard AS/NZS 4692.1 is probably the most similar of international tests. Adopting AS/NZS 4692.1 Appendix B (Standardized Test Conditions) and Appendix C (Determination of Standing Heat Loss) with modifications for the electric standing loss test method is probably the most reasonable course of action. AS/NZS 4692.1 addresses many of the issues with the standing loss test of SANS 151.

The choice of international test procedures for a standing loss test for water heaters without electric elements is not as clear. The EU review study of ecodesign and energy labelling for water heaters and tanks identified four different standing heat loss tests for hot water storage tanks in existing European standards. The most promising heat loss test is Annex B (Storage Vessel Performance) in ISO 9459-4 (Solar Heating - Domestic Water Heating Systems - Part 4: System Performance Characterization by Means of Component Tests and Computer Simulation) The heat loss test is somewhat similar to the non-electric standing loss test method in SANS 151 with a different calculation. The criteria for thermal stability in ISO 9459-4 after charging or purging the tank is either Equation (6) or Equation (7) for a 10-minute period:

$$|Tdel - Tin| \leq 0.2 \text{ K} \quad (6)$$

$$d|Tin - Tdel|/dt \leq 0.05 \text{ K} \quad (7)$$

$$|Tdel - Tin| \leq 1 \text{℃} \quad (8)$$

In contrast, the thermal stability for charging the tank in SANS 151 is 12 hours of circulation once the condition in Equation (8) is met.

6.3.3. Future of Water Heater Energy Efficiency Standards

Water heater energy efficiency standards and MEPS are in review or have recently changed in the EU, US and Australia. Experience shows reducing water heater energy use is complicated, to succeed across multiple technologies more than MEPS will be needed, while within a given technology MEPS can be effective.

For at least the past decade the EU has been working on a project to consolidate and harmonize the nearly two dozen different water heater standards in use covering various types of tank and tankless gas water heaters, storage tanks, electric water heaters, heat pumps and solar water heaters. Many of the energy efficiency tests are based on simulated use hot water tapping schedules. The eventual standard is intended to include ratings for parameters such noise, ability to be recycled at end of life, and emissions in addition to energy efficiency. Voluntary energy labels were instituted for all types of water heaters. However the labels have only been widely adopted in the solar water heater sector.

The US metric for water heater efficiency is based on a 24-hour simulated use test. The metric uses site energy, (the energy used at the water heater), not source energy (the total energy counted at the power plant). This leads to different MEPS for water heaters of different fuel types. In an attempt to encourage market adoption of more efficient water heaters (heat pump for electric and condensing level gas water heaters) the MEPS on larger tanks were set at more stringent levels. Instead of increasing the adoption of more efficient large water heaters, that standard has apparently reduced the shipments of large water heaters.

Regional, state and utility activities in the past few years to encourage greenhouse gas emission reductions have increased the attention on heat pumps, The market fraction for solar water heating remains quite small in the US. Because of the increase in renewable electricity generation there is also interest in grid-interactive water heaters that can adjust the use of electricity to better match the variable patterns of electricity production.

Australia has a variety of state regulations and incentives along with a range of water heating technologies including electric, gas (both storage-type and instantaneous), solar and heat pump. There are standing heat loss standards for electric water heaters. The standards for gas storage water heaters include a minimum steady state thermal efficiency, a maximum maintenance gas consumption, and a stratification requirement. There is an average annual coefficient of performance test for heat pumps and solar. (Wilkenfeld, 2009)

6.3.4. Critical Discussion

For clarity in the standards, the energy-related portions should be separated from the health and safety requirements, in a similar approach to the Australian standard, discussed in Section 6.3.1. These portions refer to the following:

- Section s.6.4 (Standing Loss),
- Section s.6.7 (Hot Water Output),
- Section s.6.8 (Reheating Time), and
- Section s.7.4 (Efficiency Tests)

It is recommended to move these sections from the main body of SANS 151 and assemble them into a separate section, annex or new standard to cover only the energy-related aspects of testing electric water heaters. This would clarify the distinction between the energy efficiency tests and the health and safety portions of SANS 151. Energy efficiency regulations could then clearly reference the energy-related tests.

Adopting AS/NZS 4692.1 Appendix B (Standardized Test Conditions) and Appendix C (Determination of Standing Heat Loss) with modifications as appropriate for South Africa may be the best method to address issues with the electric standing loss test method in SANS 151. It includes sufficient detail on instrument accuracy (discussed in Section 5.3.2) and testing protocols (discussed in Section 5.3.3).

It is not necessary at this point for South Africa to adopt standards that cover all types of water heaters. The regulation of non-electric water heaters for energy efficiency is unnecessary (as discussed in Section 6.1.3 and 6.2.2), and it is recommended that non-electric water heaters not be included in the VC 9006 due to additional testing burdens.

If this approach is considered too extreme, one option is to apply the standing loss test only to water heaters that use electricity for more than half of their energy use. Otherwise it is recommended to adopt Annex B (Storage Vessel Performance) in ISO 9459-4 for the non-electric standing loss test method. Table 6.1 shows the options possible for the regulation of solar products. An expanded list of recommendations for each considered technology is provided in Table 8.1 in Section 8. Any technologies with a small share of the market should not be subjected to efficiency standards at this point. As market conditions change, coverage should be expanded, which is discussed further in Section 8.

Regarding Options 2 and 3, South Africa does have a standard for solar, SANS 1307 (Domestic Storage Solar Water Heating Systems - Systems Testing). However, SANS 1307 is a systems test. This means every single different combination of collectors and tanks would have to be tested separately. Both Option 2 (ISO 9459-4 with ISO 9806) and Option 3 (AS/NZS 4234) would avoid that problem. Those methods evaluate the annual energy performance of water heaters using a combination of test results for component performance and a mathematical model to determine standardized annual purchased energy use. For products that could be exported, Option 2 is likely preferable as it would reduce barriers for a larger potential market.

Table 6.1 Possible options for Solar.

<table>
<tr><th>Technology</th><th>Current Status</th><th>Proposed Changes</th></tr>
<tr><td rowspan="3">Solar and solar with electric backup</td><td rowspan="3">VC 9006 Class B SANS 151 ed 8.2 standing loss method.

NRCS proposing Class D for solar, Class B for electric backup.</td><td>Option 1 (Recommended for now):
Remove from VC 9006 and no standing loss test required for non-electric water heaters.</td></tr>
<tr><td>Option 2:
Use ISO 9459-4 Solar heating — Domestic water heating systems — Part 4: System Performance Characterization by Means of Component Tests and Computer Simulation and ISO 9806, Solar energy — Solar thermal collectors — Test methods to determine if more than 50% of yearly energy is from electricity.

If less than 50% of yearly energy is from electricity, no VC 9006 regulation and no standing loss method.

If more than 50% electricity, VC 9006 Class B using Annex B (Storage Vessel Performance) for the non-electric standing loss test procedure.</td></tr>
<tr><td>Option 3:
Use AS/NZS 4234:2008, Heated Water Systems — Calculation of Energy Consumption, to determine if more than 50% of yearly energy is from electricity.

If less than 50% of yearly energy is from electricity, no VC 9006 regulation and no standing loss method.

If more than 50% electricity, VC 9006 Class B</td></tr>
</table>

Longer term it is more important to move towards water heater efficiency standards that include the energy for hot water service. Since the vast majority of water heaters on the market in South Africa are electric storage water heaters, a simplified 24-hour use test, with one morning draw and one evening draw would probably be sufficient.

7. Comments and Recommendations

The comments and recommendations from each of the main sections in this report (Section 4, 5 and 6) are summarised and listed in this section. The comments and recommendations are presented in table format for ease of referencing. The recommendations are divided into short term and long term actions based on the expected time and difficulty of implementing them and are loosely defined with the following criteria:

Short term (ST): Improvements to correct logical inconsistencies, improve trust and reliability in tests, improve clarity in scope and build a process to allow for innovations.

Long term (LT): Improvements to allow for sustainable maintainability, overall readability and better version control of the standards writing process. These recommendations also include solutions that are still in progress by international parties, which would benefit global climate change goals and align better with national imperatives.

The recommendations for Section 4 (Writing of Standards) are presented in Table 7.1 in Section 7.1. The recommendations for Section 5 (Testing and Protocol) are presented in Table 7.2 in Section 7.2. The recommendations for Section 6 (Energy Efficiency Considerations) are presented in Table 7.3 in Section 7.3.

If it is determined that additional resources, skills and/or co-ordination is required to implement and accomplish the listed items, then it is recommended to fund a project by:

- Planning accordingly through annual budgets, and/or
- Seeking international funding mechanisms.

7.1. Recommendations for Writing of Standards

Table 7.1: List of comments and recommendations for the section on writing of standards. These are indicated as short term (ST) or long term (LT) actions. Related sections are provided for ease of reference.

	Comments and recommendations: Writing of Standards	**Section**
4.1	Clarity in Scope: Products Covered by SANS 151	
ST	a) The scope of a standard should clearly describe the products and features which it applies to so there is no confusion as to whether a product is covered by that standard or not.	4.1
ST	b) Regulators, standards writers and labs should achieve consensus over definitions of products and the inclusions or exclusions. The scope and definitions sections of the standard should clearly reflect that consensus.	4.1.1, 4.1.2
4.2	Review of Annex B	
ST	a) Correct parts of the written structure for test methods that are shown to be inconsistent and in some instances illogical.	4.2.1-4.2.3
ST	b) Separate common performance tests for different material categories.	4.2.5
ST	c) Include the purpose of test procedures and reasoning for performance criteria.	4.2.3
ST	d) Provide consistency in corresponding design types relating to materials.	4.2.4
LT	e) A common strategy and framework should be developed on how to add new materials and possibly group into material categories. The required testing procedures and performance criteria should be identified.	4.2.5
4.3	Miscellaneous remarks on SANS 151	
ST	a) Address general issues raised in terms of referencing, clarity in definitions and scope, clarity of units and testing performance criteria.	4.3.1-4.3.4
LT	b) Consider reviewing the entire standard to ensure that there is consistency throughout the document.	4.3.5

7.2. Recommendations for Testing and Protocols

Table 7.2: List of comments and recommendations for the section on testing and protocols. These are indicated as short term (ST) or long term (LT) actions. Related sections are provided for ease of reference.

	Comments and recommendations: Testing and Protocols	**Section**
5.1	Prescriptive Design vs. Performance Testing	
LT	a) Move towards writing standards in terms of performance, except in cases where there is a demonstrated need for a prescriptive standard.	5.1.1
ST	b) Any justification for differentiation and technology specific requirements should be evidence based to prevent unnecessary discrimination.	5.1.1
5.2	Systems and Component Testing	
ST	a) Solar water heating systems should be excluded from system testing requirements.	5.2.1
ST	b) Apply only the health and safety requirements in SANS 151 to the hot water storage tank.	5.2.1
5.3	Test Procedures and Standards	
	a) That a lab is accredited to be able to perform the standing loss test procedures in SANS 151 is only a first step.	5.3.1, 5.3.5
ST	b) Specify sufficient accuracy for the instruments and enough detail on the calibration requirements in the standard.	5.3.2, 5.3.5
ST	c) Clarify placement of the measurement instruments and steps to take in test procedure so results are repeatable.	5.3.3, 5.3.5
ST	d) Perform interlaboratory comparisons of the standing loss test of the same water heater (round-robin testing).	5.3.4, 5.3.5

7.3. Recommendations for Energy Efficiency Considerations

Table 7.3: List of comments and recommendations for the section on energy efficiency considerations. These are indicated as short term (ST) or long term (LT) actions. Related sections are provided for ease of reference.

	Comments and recommendations: Energy Efficiency Considerations	Section
6.1	VC 9006 and SANS 151	
	a) Class labelling based only on the standing loss test does not account for electrical energy consumption required to provide hot water as a service.	6.1.2, 6.1.3
LT	b) Quantify impact of regulation for expected energy savings nationwide.	6.1.3
6.2	Review of International Water Heater Efficiency Standards	
LT	a) To compare energy consumption for domestic water heating across technologies, the standard must move beyond standing loss.	6.2.2, 6.2.3
LT	b) South Africa should actively monitor ongoing international efforts to improve water heater efficiency tests.	6.2.1, 6.2.3
LT	c) Produce a simplified 24-hour simulated use test for electric water heaters.	6.2.1
6.3	Comparison of SANS 151 to International Standards	
ST	a) Separate energy-related requirements of SANS 151 from health and safety.	6.3.4
ST	b) Electric Water Heaters: Adopt with modifications AS/NZS 4692.1 Appendix B and Appendix C for electric standing loss test method.	6.3.2, 6.3.4
ST	c) Heat Pumps: Remove from VC 9006. There is no energy performance test for heat pumps. Until this is developed, heat pumps should not be regulated.	
ST	d) Solar and solar with electric backup: Option 1: Remove from VC 9006 and no standing loss test required.	6.1.3, 6.3.2, 6.3.4
LT	e) Solar and solar with electric backup: *Option 2:* Use ISO 9459-4 to determine if more than 50% of yearly energy is from electricity, then consider a. or b. *Option 3:* Use AS/NZS 4234 to determine if more than 50% of yearly energy is from electricity, then consider a. or b. a. If electricity < 50% of yearly energy, no VC 9006 regulation and no standing loss method.	6.3.4

	b. If electricity > 50% of yearly energy, VC 9006 Class B and adopt with modifications standing loss method in ISO 9459-4 Annex B for non-electric water heater.	
LT	f) Technologies with small market share should not be subjected to energy efficiency standards. Refer to Section 8 for a flow chart on how it could be addressed.	6.3.4, 8.

8. Strategic Steps

In regulating products for energy efficiency, it would be useful to follow a process for effective decision-making. The flow chart in Figure 9.1 presents four steps to determine whether a product and its specific design requires energy efficiency regulation.

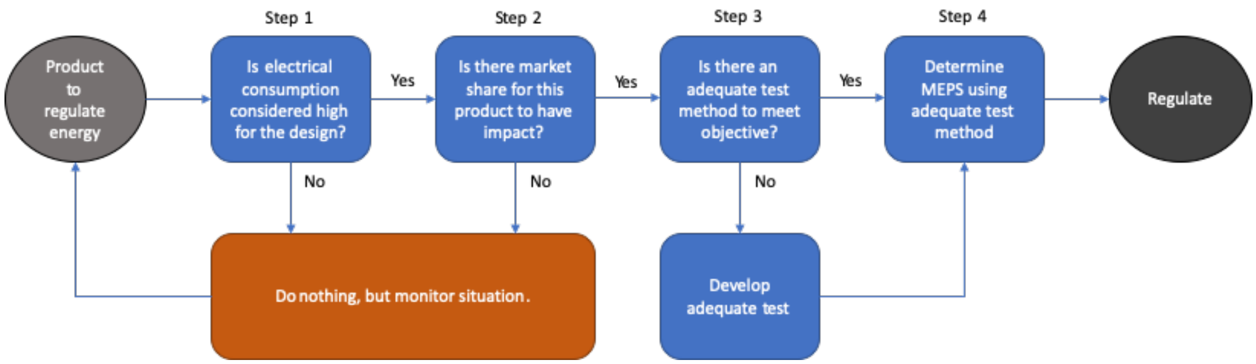

Figure 9.1: Flow chart for product consideration on the grounds of energy efficiency.

Step 1: ***Is electrical consumption considered high for the design?***
This question can be answered through logical reasoning and simulations using scientific models, but should be verified through appropriate testing. The emphasis on this question is on the electrical energy consumption to provide an energy service. Currently, the majority of the South African power grid is supplied by coal. If the situation changes, where photovoltaics or other renewable resources become a larger contributor to the grid, this should be re-evaluated. The Australian standard makes use of a 50% threshold for expected energy use in a year. These thresholds can be refined over time if it is determined that the performance of products could be reasonably improved.

Step 2: ***Is there market share for this product to have impact?***
This question should be answered through an appropriate empirical research such as a market study, for instance, what are the national sales volumes of each product in a year? The impact of the product and its market share should be considered. Hypothetically, if a proposed MEPS on a product could reduce 2% of electrical energy per unit, but it has 80% market share which could result in significant reduction of electrical load on the grid, then it might be important. Additionally, if a proposed MEPS on a product could reduce 40% of electrical energy per product, and it has 10% market share, this could also result in a significant impact. The tracking of increasing market trends could necessitate the preparation of Step 3 and Step 4 for that product.

Step 3: ***Is there an adequate test method to meet the objective?***
This question would refer to the available testing methods within the standards. In context to this report, the standing heat loss test is only appropriate for electric water heaters, and only serves as a proxy parameter for energy efficiency. For non-electric water heaters, more appropriate tests would be required.

This is the reason for recommending a move toward energy consumption tests, which will allow for appropriate testing of non-electric water heating products and the under- and over-basin units.

Step 4: ***Determine Minimum Energy Performance Standards (MEPS) using an adequate test method.*** By this point, the electrical energy consumption and market share have been established. Any MEPS determined for the product would need to ensure a minimum requirement that necessitates the regulatory action, i.e. the national impact on the electrical grid is reduced. This could be accomplished through a simulation with adequate models of products. The regulator needs to determine the level of stringency, based on the lifecycle cost, the combined operating cost and first cost to the consumer and other policy goals such as reduced electrical demand on the grid.

8.1. Strategic Steps: SANS 151 and VC 9006 for products

There are several recommendations made in the use of international standards to support the VC 9006 standing loss testing of electric and non-electric water heaters. According to the NRCS, the products listed below should all be included in VC 9006 and be tested using the standing loss method in SANS 151 ed 8.2. Section 6.1.1 details the proposed action taken by NRCS to amend VC 9006. Based on findings and recommendations in this report, standing heat loss is not an appropriate measure across technologies. Table 9.1 summarises the recommendations for each of the technologies discussed in this report with recommended strategic steps for improving energy regulation for these products.

Table 9.1: Proposed changes to SANS 151 and VC 9006 with strategic steps moving forward.

Technology	**Proposed Changes**	**Strategic steps**
Electric water heater	Remain VC 9006 Class B. Adopt with modifications standing loss method in AS/NZS 4692.1 Appendix B and C. *Recommendation 6.3.b.*	Develop test procedures for total energy consumption, including to heat the delivered water. *Recommendation 6.2.c.*
Under- and over-basin unit	Clarify scope in SANS 151. Exclude from VC 9006 until Step 1 and 2 can be confirmed. *Recommendation 4.1.a.*	Determine impact on electrical demand (Step 1) and current market share (Step 2).
Boiling water dispenser	Clarify scope in SANS 151. Exclude from VC 9006 until Step 1 and 2 can be confirmed. *Recommendation 4.1.a.*	Determine impact on electrical demand (Step 1) and current market share (Step 2).
Heat pumps	Remove from VC 9006 and no standing loss test required for non-electric water heaters. *Recommendation 6.3.c.*	There is no energy performance test for heat pumps. Until this is developed, heat pumps should not be regulated.
Solar and solar with electric backup	***Option 1 (For now):*** Remove from VC 9006 and no standing loss test required for non-electric water heaters. *Recommendation 6.3.d.*	Option 2 or 3 could be considered once the appropriate frameworks have been established.

Electric water heater

No change recommended. The MEPS has been determined from a previous study. Strategic steps include going beyond standing heat loss test to determine energy consumption.

Under- and over-basin unit

Based on responses from working group members, these units are intended to be included in the scope of SANS 151. As discussed, the wording of the scope of the standard should reflect this in a manner that it is not open to interpretation. To determine whether to regulate this product, following the procedural steps in Figure 9.1:

Step 1: Electrical consumption could potentially be problematic. Keeping a small volume of water hot continuously could pose an issue on standing loss energy consumption. This needs to be verified through a measurement on the product.

Step 2: It is not clear what market share these products have. They are available in popular retailers and priced attractively. A market study would need to be conducted to confirm this.

Step 3: Standing loss test is technically possible using AS/NZS4692.1, but difficult. There is no lower volume limit and therefore there is provision to test smaller units. "Test laboratories may elect to use fewer than six temperature sensors where they can demonstrate equivalent results for a particular tank design and temperature control deadband." However there are no directions on how to "demonstrate equivalent results".

Decision: Exclude from VC 9006 until Step 1 and Step 2 can be confirmed to be problematic. There is sufficient rationale to consider this product for energy regulation, but it needs to be justified through empirical findings. Step 3 will need to be confirmed with the SABS test labs that equivalent testing could be accomplished. The largest units found in retailers was 30l, and this could be used as an exclusionary factor in VC 9006.

Boiling water dispenser

Based on responses from working group members, these units are intended to be excluded in the scope of SANS 151. As discussed, the wording of the scope of the standard should reflect this in a manner that it is not open to interpretation. To determine whether to regulate this product, following the procedural steps in Figure 9.1:

Step 1: Electrical consumption could potentially be problematic, as with the unit above. Keeping a small volume of water hot continuously could pose an issue on standing loss energy consumption. These units operate at high temperatures, which has a greater impact on standing losses. This needs to be verified through a measurement on the product.

Step 2: It is not clear what market share these products have. They are very popular in an office or commercial setting and presumed to have high market share. A market study would need to be conducted to confirm this.

Step 3: Standing loss test is technically possible using AS/NZS4692.1, but difficult. There is no lower volume limit and therefore there is provision to test smaller units. "Test laboratories may elect to use fewer than six temperature sensors where they can demonstrate equivalent results for a particular tank design and temperature control deadband." However there are no directions on how to "demonstrate equivalent results".

Decision: Exclude from VC 9006 until Step 1 and Step 2 can be confirmed to be problematic. There is sufficient rationale to consider this product for energy regulation, but it needs to be justified through empirical findings. Step 3 will need to be confirmed with the SABS test labs that equivalent testing could be accomplished. The largest units found in retailers was 25l, and is below the 30l upper volume in the previous example.

Heat pumps
The fundamental principle of the operation of a heat pump is to extract heat from the surrounding air, so it is pulling in additional heat beyond its electrical use. Therefore, by nature it is over 100% efficient. This product should not be regulated until energy performance test procedures are developed for heat pumps.

Solar and solar with electrical backup
Solar water heaters use energy from the sun to heat water. This means that they will use less electricity to heat water than standard electric water heaters. The recommended change is to remove from VC 9006 and not require a standing loss test for non-electric water heaters.

If there is concern about poor performance of some solar systems, use international standards to determine if more than 50% of the system's yearly energy is from electricity. If less than 50% of yearly energy is from electricity, then VC 9006 regulation should not be applicable. If more than 50% electricity is from electricity, VC 9006 Class B should be applicable. Use the storage vessel performance test from the international standards for the non-electric standing loss test.

8.2. Professional rewrite of SANS 151

There are some short term and long term recommendations regarding the suggestions for re-writing the standards, that should not impact on the quality of health and safety currently in the standard. The professional rewrite is suggested in *Recommendation 4.3.b*.

- Incorporate carefully designed performance tests *(Recommendation 5.1.b)*.
- Review relevant international standards for concepts.
- Separate energy-related tests in separate Annex *(Recommendation 6.3.a)*.

9. Conclusion

There are several technologies where the scope is unclear or confusing. More important is disagreement between SABS, NRCS, and SABS Testing on the contended products (such as over/under basin geysers and boiling water dispensers). If all the scoping terms are clearly defined and consensus can be reached on its meaning with relation to an appliance the language in the scope of the standard should reflect that.

The written content of SANS151 and Annex B contain many cases of inconsistent and confusing language or referencing. Some of these are identified in the body of this report. There are some short term recommendations suggested for general clarity and consistency. However, a rigorous review of SANS 151 is suggested and should be done as part of an independent professional rewrite. For energy related regulation, it is recommended to separate energy-related requirements of SANS 151 from health and safety requirements.

The details of the standing loss test including, the measurement equipment specifications, the test configuration and setup, and the protocols of the test procedure itself are written in ways likely to make the consistent and repeatable results necessary for enforceable standards impossible. Round robin testing is recommended for reliability of results. Inclusion of instrument accuracy and measurement tolerances is recommended, and the Australian standard AS/NZS 4691.1 Appendix B & C could be used as guidance. Those standards should be adopted and modified as a replacement for the standing loss tests in SANS 151.

However standing loss is not fit for an energy efficiency metric between technologies. It is not fit for solar, heat pump and non-electric water heaters. It is recommended to remove the standing loss regulation on non-electric water heaters due to the additional costs required that serve as a barrier to trade. Another option is to impose a standing loss test only to water heaters that use electricity for more than half of their energy use. If the standing heat loss test is not removed from VC 9006, then adopt with modifications Annex B (Storage Vessel Performance) in ISO 9459-4 for the non-electric standing loss test method.

No standard is perfect. However, when a regulation makes use of an existing standard to achieve an intended objective, as has been observed with SANS 151 and VC 9006, it is important that several factors to be carefully considered:

- Standard should be clear and unambiguous in its language and writing style (in terms of scoping, definitions, objectives, logic),
- The scope of standards should be clearly written so all stakeholders can agree on product inclusions and exclusions,
- Testing methods and protocols should be clear and rigorous,
- Standards should determine minimum performance without bias,
- Regulation should be developed to meet its intended objectives,
- Regulation should refer to standards in a clear manner that does not cause confusion.

These points have been addressed in this report and a set of short term and long term recommendations have been provided. A significant requirement toward energy efficiency objectives is the development of energy consumption tests for cross-technology evaluations.

Energy consumption tests for water heaters should be reflective of actual use in practise and include the energy required to deliver hot water as a service across technologies. This does not appear in SANS 151, and should be considered. Until such a test is developed, non-electric water heaters should be exempt from any standing loss test or MEPS. However, any type of water heater with a storage tank for hot water should continue to be required to meet all the health and safety requirements of SANS 151. Water heating standards are constantly being revised internationally. It is a strong recommendation for SABS to participate in the international developments of energy efficiency test methods and protocols.

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