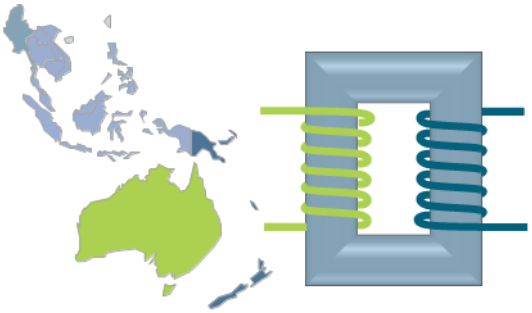


Country: Australia

Technology: Distribution Transformers

Sub Category: Dry and liquid filled

Introduction

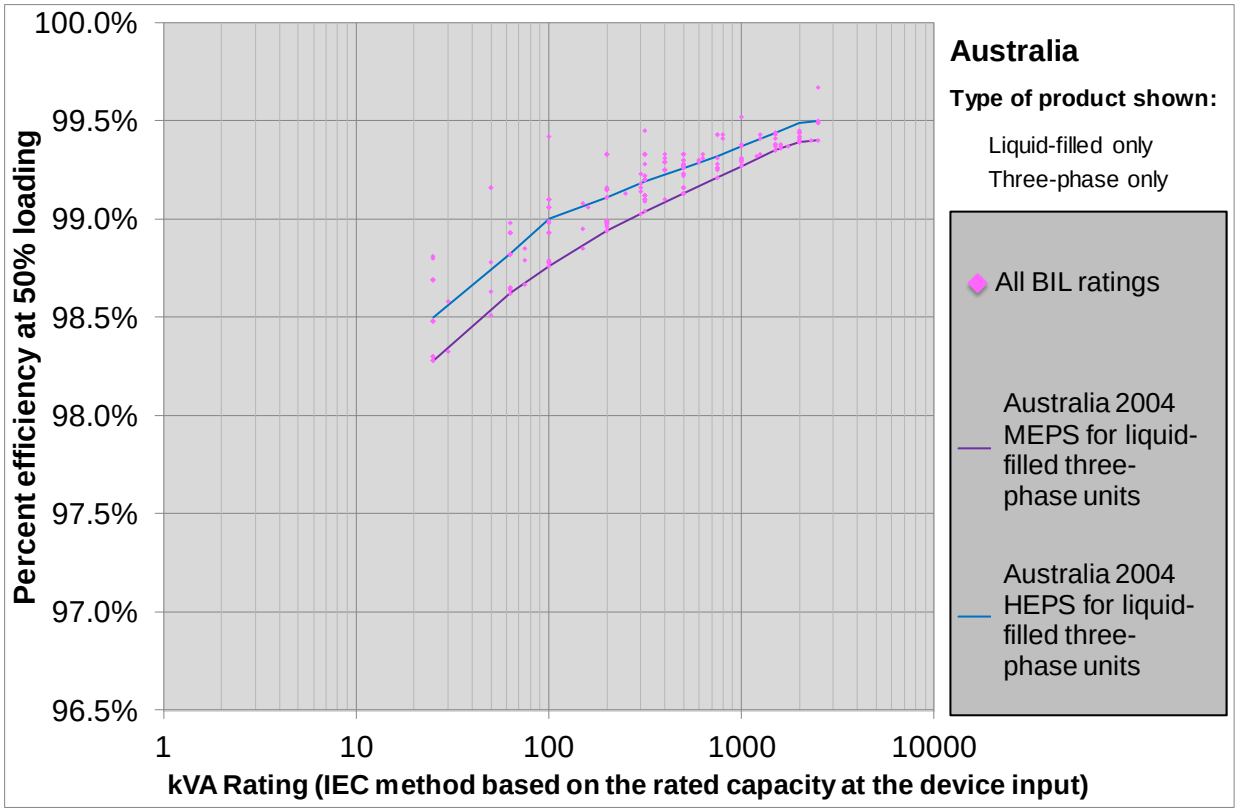
The first stage in the Mapping and Benchmarking process is the definition of the products, i.e. clearly setting the boundaries that define the products for use in data collection and analysis. This ensures the comparison between the participating countries is done against a specific and consistent set of products.

The summary definition for this product is:

M&B Category	Description
Definition and Scope	**Transformer** means a static piece of apparatus with two or more windings that, by electromagnetic induction, transforms a system of alternating voltage and current into another system of alternating voltage and current usually of different values and at the same frequency for the purpose of transmitting electrical power. A **distribution transformer** takes voltage from a primary distribution circuit and steps down to a secondary distribution circuit. Products included within scope of this analysis are distribution transformers including oil-immersed and dry-type, single-phase and three-phase, rated from 10 to 3150 kVA, with a primary voltage of 36kV or less, and designed to operate at 50 or 60 Hz.
Characteristics of interest to the analysis	• Type of cooling - liquid-filled (e.g., mineral oil) or dry-type (air-cooled) • Operating frequency, usually 50Hz or 60Hz • Number of phases: single-phase or three-phase • Power handling capacity (i.e., the kVA rating) • Voltage class, based on the primary winding insulation level • Designed for installation on a pad, a pole, or other
Exclusions	Special purpose transformers are excluded from the scope, including: instrument transformers, rectifier transformers , furnace transformers, auto-transformers , grounding transformers, starting transformers, testing transformers, welding transformers, explosion-proof transformers , underground mining transformers, and submerged transformers.

The detailed product definition can be found at the Annex website:
http://mappingandbenchmarking.iea-4e.org/matrix?type=product&id=15

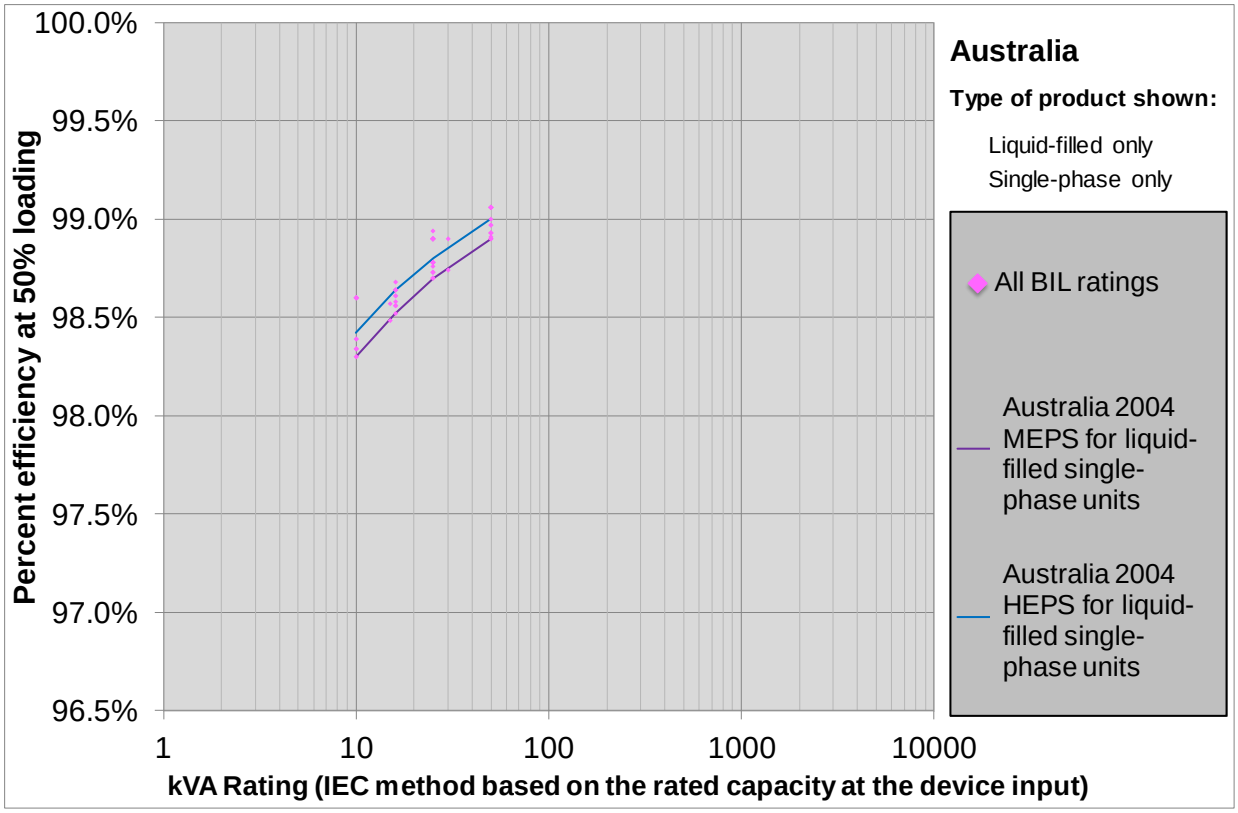
Percentage efficiency at 50% loading for distribution transformers in Australia: Three-phase liquid-filled transformers



Key notes on graph (see notes section 1)

- The source of data for this graph is the Australian federal government registration scheme.
- This graph shows performance data for 259 distribution transformers (representing 78% of liquid-type models in the dataset)
- The test methods used to determine compliance with MEPS for distribution transformers are AS2374.1-1997 Power Transformers and AS2735-1984 Dry Type Power Transformers, based on the IEC method with rated capacity at the device input.
- The products shown in this graph are all three-phase liquid filled and operate at 50Hz with ratings from 25 to 2,500 kVA.
- Products are shown for all voltage classes (Basic Impulse insulation Levels - BIL), as the Australian efficiency regulation does not differentiate between product classes of liquid-filled distribution transformers by primary voltage.
- HEPS = High Efficiency Performance Standard which represents an aspirational level set in 2004 that is meant to be indicative of a possible future MEPS requirement, and is a level that manufacturers are allowed to use to market and promote their products if they meet or exceed it.
- All of the models in the database meet the MEPS requirement.

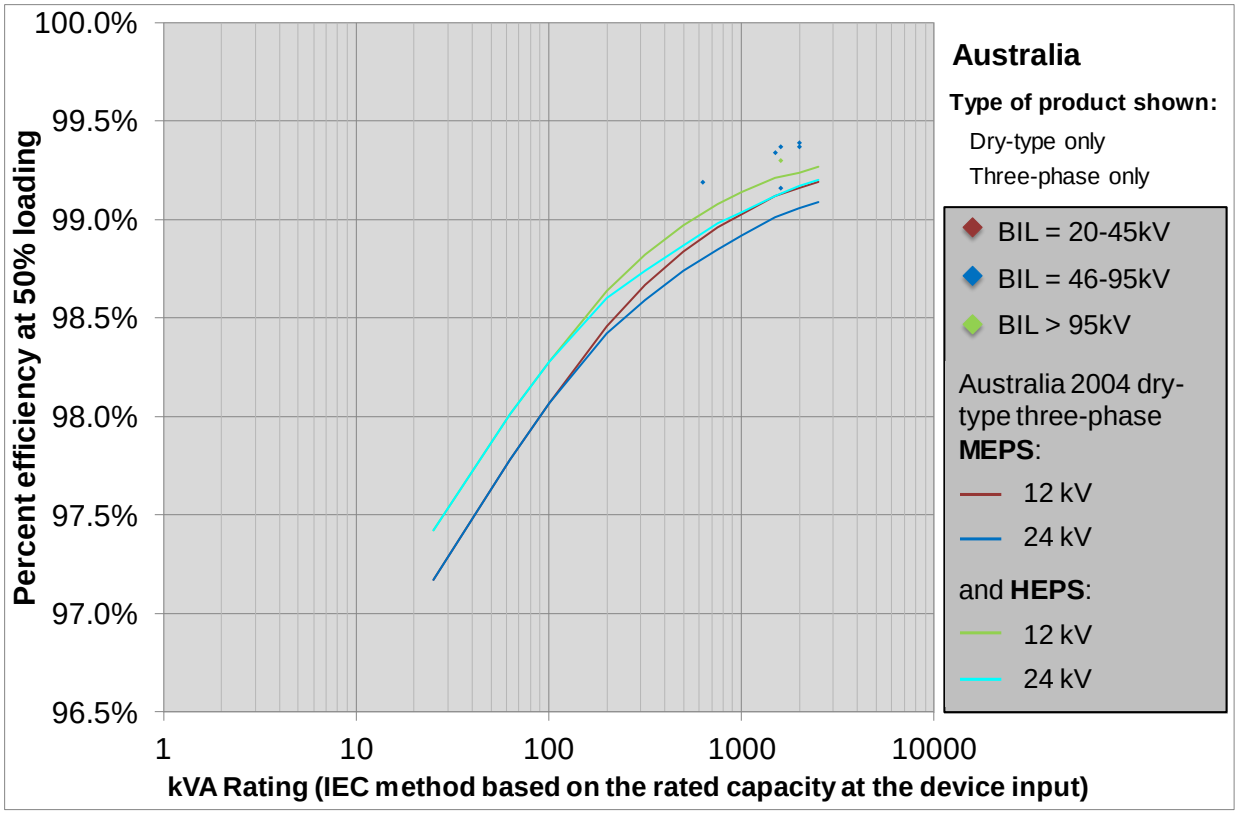
Percentage efficiency at 50% loading for distribution transformers in Australia: Single-phase liquid-filled transformers



Key notes on Graph (see notes section 1)

- The source of data for this graph is the Australian federal government registration scheme.
- This graph shows performance data for 72 distribution transformers (representing 22% of liquid-type models in the dataset)
- The test methods used to determine compliance with MEPS for distribution transformers are AS2374.1-1997 Power Transformers and AS2735-1984 Dry Type Power Transformers based on the IEC method with rated capacity at the device input.
- The products shown in this graph are all single-phase liquid filled and operate at 50Hz with ratings from 10 to 50 kVA.
- Products are shown for all voltage classes (Basic Impulse insulation Levels - BIL), as the Australian efficiency regulation does not differentiate between product classes of liquid-filled distribution transformers by primary voltage.
- HEPS = High Efficiency Energy Performance Standards which represents an aspirational level set in 2004 that is meant to be indicative of a possible future MEPS requirement, and is a level that manufacturers are allowed to use to market and promote their products if they meet or exceed it.
- All of the models in the database meet the MEPS requirement.

Percentage efficiency at 50% loading for distribution transformers in Australia: Three-phase dry-type transformers by BIL rating



Key notes on Graph (see notes section 1)

- The source of data for this graph is the Australian federal government registration scheme.
- This graph shows performance data for 10 distribution transformers (representing 100% of dry-type models in the dataset)
- The test methods used to determine compliance with MEPS for distribution transformers are AS2374.1-1997 Power Transformers and AS2735-1984 Dry Type Power Transformers based on the IEC method with rated capacity at the device input.
- The products shown in this graph are all three-phase dry type and operate at 50Hz.
- The MEPS levels shown span from 25 to 2,500 kVA, although the models shown in the graph range from 600 to 2,000 kVA.
- Products are differentiated by Basic Impulse insulation Level (BIL) rating range, as the Australian regulatory requirements are differentiated according to the primary voltage which is indicative of the BIL rating.
- HEPS = High Efficiency Performance Standard which represents an aspirational level set in 2004 that is meant to be indicative of a possible future MEPS requirement, and is a level that manufacturers are allowed to use to market and promote their products if they meet or exceed it.
- All of the models meet the MEPS requirement.

Major Policy Interventions (*see notes section 2)*

The main policy measure promoting energy-efficient distribution transformers in Australia is the establishment and maintenance of Minimum Energy Performance Standards (MEPS) and High Efficiency Performance Standards (HEPS).

Mandatory performance requirements

Australia has mandatory energy performance standards[1] for liquid-filled and dry-type distribution transformers with power ratings from 10 kVA to 2500 kVA intended to be used on 11 kV and 22 kV networks. Effective since 2004, the MEPS are set out separately for single phase and 3-phase transformers with minimum efficiency values at 50% of rated load in AS 2374.1.2.

High efficiency performance standards

Covering the same scope as the mandatory requirements, the HEPS represent an aspirational, voluntary level set in 2004 that is meant to be indicative of a possible future MEPS requirement, and is a level that manufacturers are allowed to use to market and promote their products if they meet or exceed it.

[1] See http://www.energyrating.gov.au/products-themes/industrial-equipment/distribution-transformers/meps/

Cultural Issues (*see notes section 3)*

Electricity markets in both Australia and New Zealand have separated the electricity operational businesses of investing in and maintaining distribution wires (distribution business) from the wholesale purchase and sale of electricity to consumers (retail business). Retailers pay a fee for the use of the wires to deliver electricity to their customers and retailers also pay for all the losses incurred. Distribution operators, therefore, bear no costs associated with the losses on their network, and thus are not motivated to choose transformers that cost-effectively reduce losses. Instead, the main focus of the distributors is cost-reduction and reliability.

Power distribution networks in Australia are regulated by the Australian Energy Regulator (AER). The AER has recently considered regulating for incentives to optimise losses at the investment stage. After consultation the AER decided against such an approach for want of evidence of a significant departure from optimality at present.[2] This assessment is probably correct for the time being. Until about ten years ago, transformer selection was optimised for losses in public sector utilities. There is some anecdotal evidence that commercial pressures in the corporatised and privatised distribution businesses are starting to drive efficiency levels down through increased use of low efficiency imported equipment. The current impact of this trend is small but the cumulative effect will be apparent in future.

Outside of the comparatively large electric utility market, in the commercial buildings sector, the separation between the investor/builder who makes the transformer purchasing decision and the ultimate user can be a barrier to achieving an optimal level of efficiency. In the industrial and mining sector, aversion to risk is a factor that biases decisions in favour of low capital equipment and low efficiency.

Also relevant are existing contracts for supplying equipment, such as products already held in storage as spares and consulting engineers who use previous design specifications. Decisions based on these criteria can be rational from the perspective of the individual decision-maker but may incur higher societal costs as circumstances change.

[2] "Review of Minimum Energy Performance Standards for Distribution Transformers", Equipment Energy Efficiency Program, Consultation Regulatory Impact Statement, May 2011.

Notes Section 1. Percentage Efficiency Graphics

1.1 Test methodologies, Performance Standards

1.1.1 Test Methodology

The test methods used to determine compliance with MEPS for distribution transformers are AS2374.1-1997 Power Transformers and AS2735-1984 Dry Type Power Transformers. Certain product types are exempted (refer to AS2374.1.2-2003).

Thus the relevant Australian test methods are:

- AS 2374.1-1997 Power Transformers, Part 1: General
- AS 2735-1984 - Dry-Type Power Transformers

The standard, AS 2374.1-1997 is based on and includes the full text of IEC 60076-1:1993.

1.1.2 Performance Metrics

Mandatory energy performance levels are contained in the Australian Standard AS2374.1.2:2003, and apply to single and three-phase, dry type and oil immersed transformers. High Efficiency Standards have also existed since1 October 2004, where distribution transformers that meet more stringent performance levels than MEPS (also specified in AS2374.1.2:2003) have been allowed to be promoted as “High Power Efficiency Transformers”.

Thus the relevant Australian standard for performance metrics is:

- AS 2374.1.2-2003: Power Transformers Part 1.2: Minimum Energy Performance Standard (MEPS) requirements for distribution transformers

Efficiency is a measure of the power consumed by a transformer, and it is determined in part by the sum of the core losses and winding losses experienced by the transformer. The efficiency of a transformer varies across the range of loading points that a transformer may experience in its lifetime. The measured efficiency of a transformer operating at 80% of rated load (where winding losses are likely to dominate) will probably be different to the efficiency of a transformer operating at 20% of rated load (where core losses are likely to dominate). Figure A (for a three-phase 75 kVA dry-type transformer) shows the efficiency curve relative to the watts of core and winding loss. This figure shows that the efficiency curve varies over the loading points, with its peak occurring where the core losses are equal to the winding losses.

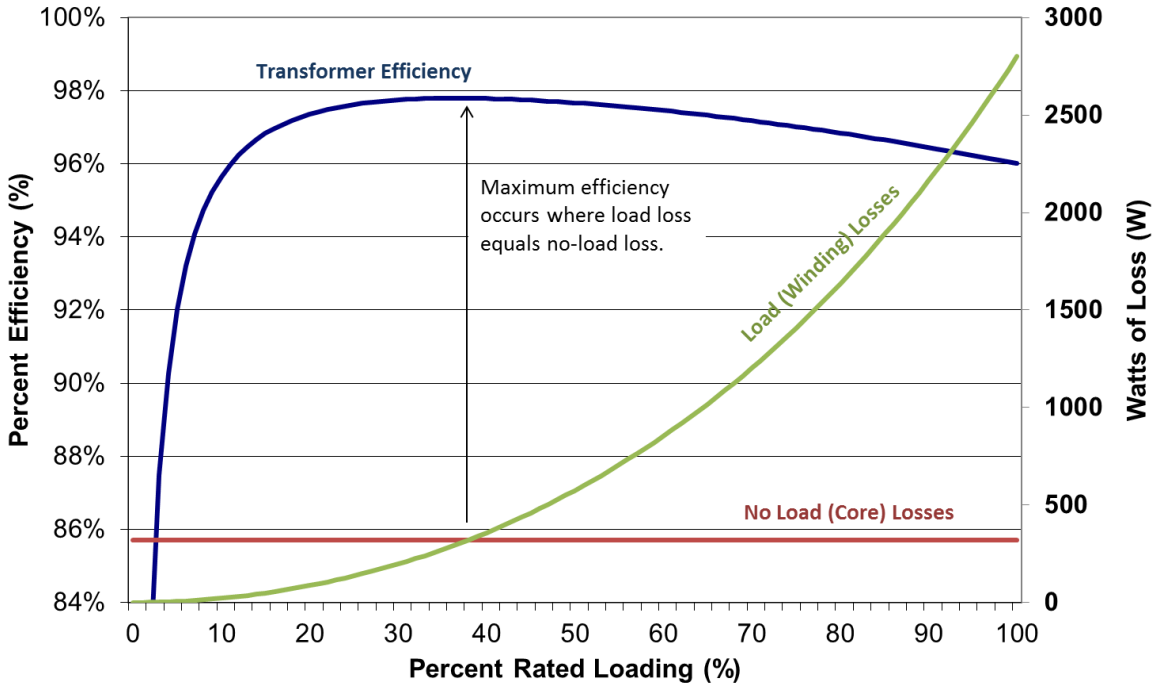


Figure A. Illustration of Relationship Between Losses and Efficiency

The equation used for determining efficiency for transformers under the IEC testing standards is:

$$IEC\ Definition\ Efficiency = \frac{(Power\ Input - Losses)}{(Power\ Input)}$$

For the purposes of this analysis, the efficiency is declared at 50% of the rated maximum load of the distribution transformers.

1.2 Product Classifications

In Australia there are no product efficiency labelling classifications for distribution transformers - all products simply have to meet the relevant mandatory minimum standard.

1.3 Data sources and limitations

The source of data for this analysis is the Australian federal government registration scheme, data was downloaded 30 July 2013 from: http://reg.energyrating.gov.au/comparator/product_types/38/search/comprehensive/?expired_products=on&paginate_by=20&wrapper_search=&model_number=&rated_output=&phase=&network_voltage=

The data set consists of 348 products from 11 different manufacturers. 95% of liquid type (16 dry; 332 liquid) and 79% 3-phase (72 single; 276 three). kVA ratings in the source dataset are based on the input rated power (IEC system). All products have a BIL rating of 75 kV and operate at 50Hz. The data set included only the overall percentage efficiency and does not include coil or core losses.

It is assumed that this data set is highly representative of the Australian market because all models sold in Australia must be registered in this database. Any regulated product offered for sale after 1 October 2004 must be registered with a State regulator unless the supplier can prove that they were manufactured or imported prior to this date. Registration may be lodged for transformers or families of transformers with comparable specifications and performance characteristics. In order to register you will need to provide information about the characteristics and performance of your transformers.[3]

1.4 Data manipulations and specific limitations

All Australian data was assumed to have been declared in accordance with the IEC test method and IEC based efficiency at 50% load was used as the basis of graphics in this report. The specific steps in data cleaning were:

- Dual voltage distribution transformers were classified according to their highest voltage group (this corresponds with the insulation rating of the primary which will lower the efficiency).
- Medium-voltage dry-type transformers were classified into the following BIL classes: 20-45 kV; 46-95 kV and >96 kV.

[3] Reference for this registration requirement in Australia: http://www.energyrating.gov.au/wp-content/uploads/Energy_Rating_Documents/Fact_Sheets/Industrial_Equipment/Distribution_Transformers/distribution-transformer-registration-fact-sheet.pdf

Notes Section 2. Major Policy Interventions

Further details of the performance requirements are given below and in the tables on the following pages:

Mandatory performance requirements

The Standard, AS2374.1.2:2003/Amdt1-2005, Power Transformers: Part 1.2: Minimum Energy Performance Standard (MEPS) Requirements for Distribution Transformers, was published in March 2003 and took effect on 1 October 2004. The standard provides a minimum efficiency level that all products manufactured after 1 October 2004 must meet or exceed to be placed on the market in Australia.

It should be noted that Australia is currently conducting an analysis of reviewing and potentially revising the requirements on distribution transformers, with a preliminary impact assessment report published in May 2011. The draft revision under consideration proposes a number of changes to the scope of transformers that would fall under the future revised regulation:

1. Extending coverage to include both distribution and generation transformers.
2. Increasing the upper limit of kVA rating from 2500 kVA to 3150 kVA.
3. Extending the range of network voltages covered to include all voltages less than 36kV.
4. Extending the frequency to cover 50 and 60 Hz.
5. Removing the exemption on gas filled transformers.

Voluntary performance requirements

In addition to the MEPS levels, the Standard, AS2374.1.2:2003/Amdt1-2005, Power Transformers: Part 1.2: Minimum Energy Performance Standard (MEPS) Requirements for Distribution Transformers, also contains a set of High Efficiency Performance Standard (HEPS) levels. The HEPS level allows the easy identification of high efficiency performing products, and gives manufacturers an indication of where the next level of efficiency requirements could be in the future. Transformer importers and manufacturers may promote and use voluntary HEPS that are detailed in the standard.

The following tables present the performance requirements for the MEPS and HEPS.

Table 1. Australian Efficiency Regulations for Liquid-Filled Distribution Transformers from 2004, measured at 50% load.

Liquid-filled 50 Hz	kVA Rating	Percent Efficiency at 50% Loading	
		MEPS (2004)	HEPS (2004)
Liquid-Filled Single Phase (and SWER[4])	10	98.30	98.42
	16	98.52	98.64
	25	98.70	98.80
	50	98.90	99.00
Liquid-Filled Three Phase	25	98.28	98.50
	63	98.62	98.82
	100	98.76	99.00
	200	98.94	99.11
	315	99.04	99.19
	500	99.13	99.26
	750	99.21	99.32
	1000	99.27	99.37
	1500	99.35	99.44
	2000	99.39	99.49
	2500	99.40	99.50

* NOTE: For intermediate power ratings the power efficiency level shall be calculated by linear interpolation.

Table 2. Australian Efficiency MEPS Regulations for Dry-Type Distribution Transformers from 2004, measured at 50% load.

Dry-Type 50 Hz	kVA Rating	Percent Efficiency at 50% Loading	
		MEPS Um=12kV (2004)	MEPS Um=24kV (2004)
Dry-Type Single Phase (and SWER[5])	10	97.29	97.01
	16	97.60	97.27
	25	97.89	97.53
	50	98.31	97.91
Dry-Type Three Phase	25	97.17	97.17
	63	97.78	97.78
	100	98.07	98.07
	200	98.46	98.42
	315	98.67	98.59
	500	98.84	98.74
	750	98.96	98.85
	1000	99.03	98.92
	1500	99.12	99.01
	2000	99.16	99.06
	2500	99.19	99.09

* NOTE: For intermediate power ratings the power efficiency level shall be calculated by linear interpolation.

[4] Single Wire Earth Return (SWER) or single wire ground return is a single-wire transmission line for supplying single-phase electrical power from an electrical grid to remote areas at low cost. Its distinguishing feature is that the earth (or sometimes a body of water) is used as the return path for the current, to avoid the need for a second wire (or neutral wire) to act as a return path.

[5] Single Wire Earth Return (SWER) or single wire ground return is a single-wire transmission line for supplying single-phase electrical power from an electrical grid to remote areas at low cost. Its distinguishing feature is that the earth (or sometimes a body of water) is used as the return path for the current, to avoid the need for a second wire (or neutral wire) to act as a return path.

Table 3. Australian Efficiency HEPS Levels for Dry-Type Distribution Transformers from 2004, measured at 50% load.

Dry-Type 50 Hz	kVA Rating	Percent Efficiency at 50% Loading	
		HEPS Um=12kV (2004)	HEPS Um=24kV (2004)
Dry-Type Single Phase (and SWER[6])	10	97.53	97.32
	16	97.83	97.55
	25	98.11	97.78
	50	98.50	98.10
Dry-Type Three Phase	25	97.42	97.42
	63	98.01	98.01
	100	98.28	98.28
	200	98.64	98.60
	315	98.82	98.74
	500	98.97	98.87
	750	99.08	98.98
	1000	99.14	98.04
	1500	99.21	99.12
	2000	99.24	99.17
	2500	99.27	99.20

* NOTE: For intermediate power ratings the power efficiency level shall be calculated by linear interpolation.

[6] Single Wire Earth Return (SWER) or single wire ground return is a single-wire transmission line for supplying single-phase electrical power from an electrical grid to remote areas at low cost. Its distinguishing feature is that the earth (or sometimes a body of water) is used as the return path for the current, to avoid the need for a second wire (or neutral wire) to act as a return path.

Notes Section 3. Cultural Issues

No additional notes.