

Country: Republic of Korea

Technology: Distribution Transformers

Sub Category: Dry and liquid filled

Introduction

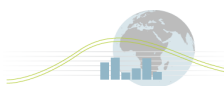
The first stage in the Mapping and Benchmarking process is the definition of the products, i.e. clearly setting the boundaries that define the products for use in data collection and analysis. This ensures the comparison between the participating countries is done against a specific and consistent set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

The summary definition for this product is:

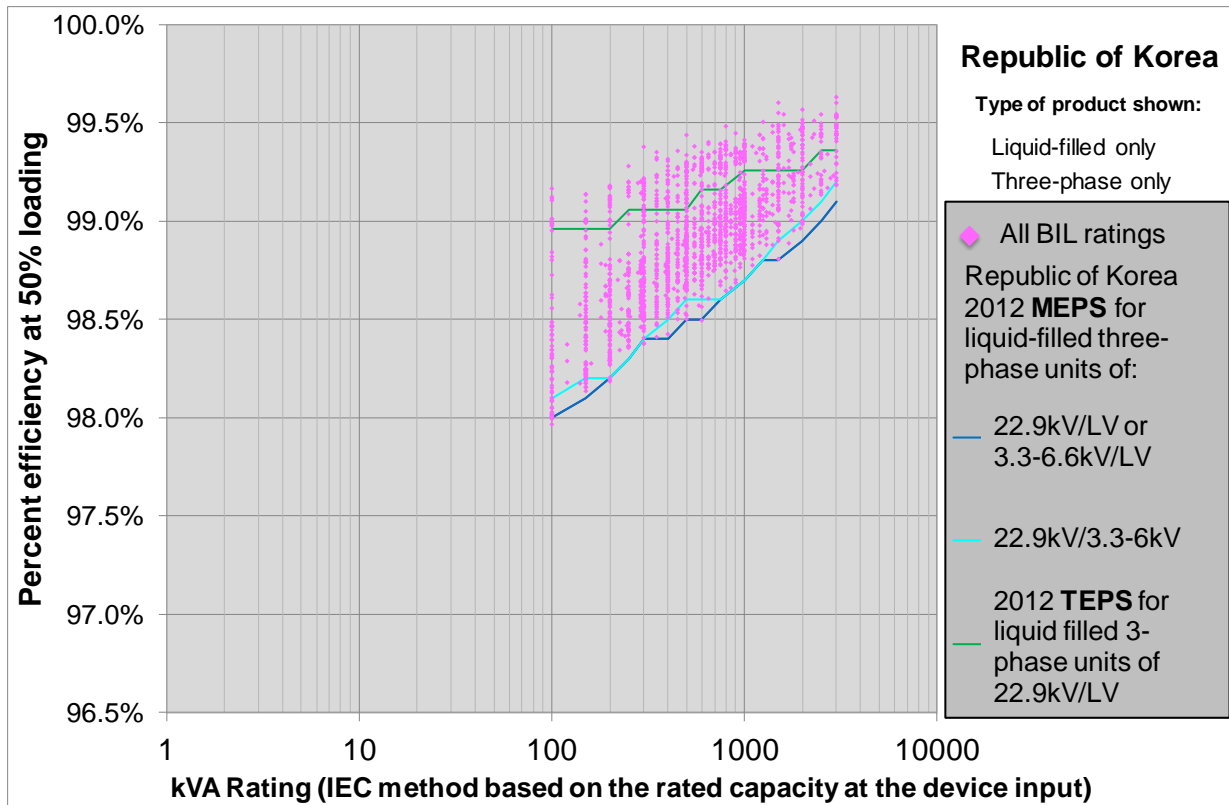
M&B Category	Description
Definition and Scope	<p>Transformer means a static piece of apparatus with two or more windings that, by electromagnetic induction, transforms a system of alternating voltage and current into another system of alternating voltage and current usually of different values and at 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.</p> <p>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.</p>
Characteristics of interest to the analysis	<ul style="list-style-type: none"> • 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	<p>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.</p>

The detailed product definition can be found at the Annex website:

<http://mappingandbenchmarking.iea-4e.org/matrix?type=product&id=15>



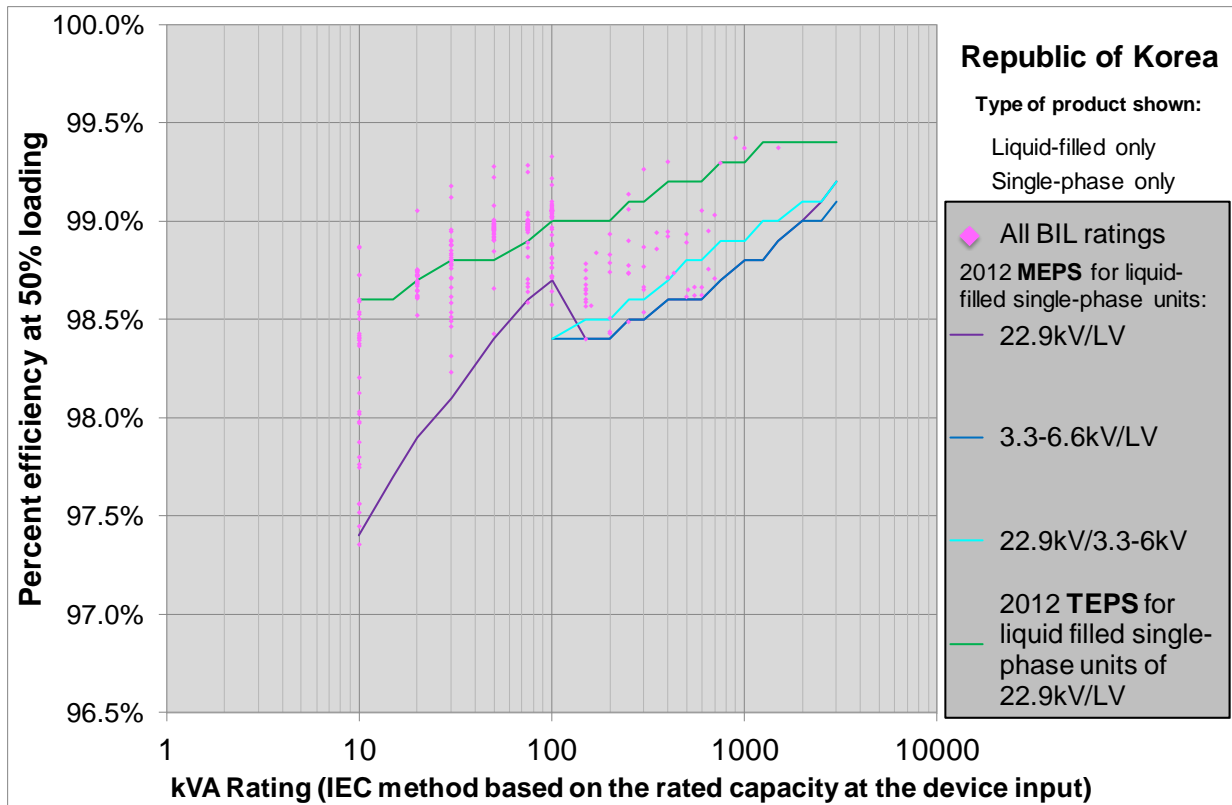
Percentage efficiency at 50% loading for distribution transformers in the Republic of Korea: Three-phase liquid-filled transformers



Key notes on graph (see notes section 1)

- The source of data for this graph is KEMCO in October 2013 from the mandatory government registration database. Manufacturers are required to register transformers in the capacity range 100kVA to 3000kVA.
- This graph shows performance data for 1843 distribution transformers (representing 88% of liquid-type models in the dataset)
- The percentage efficiency requirement is calculated at 50% load, which is measured in accordance with the following four standards: (a) KS C 4306 - Single high voltage cover bushing transformers; (b) KS C 4311 - Dry-type transformer; (c) KS C 4316 - Two bushing type pole transformer for 22.9 kV and (d) KS C 4317 - Distribution transformers not more than 3MVA for 22.9kV. The Korean test standards are 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 60Hz with ratings from 100 to 3,000 kVA.
- Products are shown for all voltage classes of liquid-filled distribution transformers.
- TEPS = Target Energy Performance Standards and represents a level of ambition in energy-efficiency that the government wishes to promote through its incentive schemes. Only the TEPS that applies to the most common models is plotted but, as described in the notes, there are also TEPS for 22.9kV primary / 3.3-6.6kV secondary and 3.3-6.6 kV primary / low voltage secondary.
- All of the models shown in the database meet the MEPS requirements.

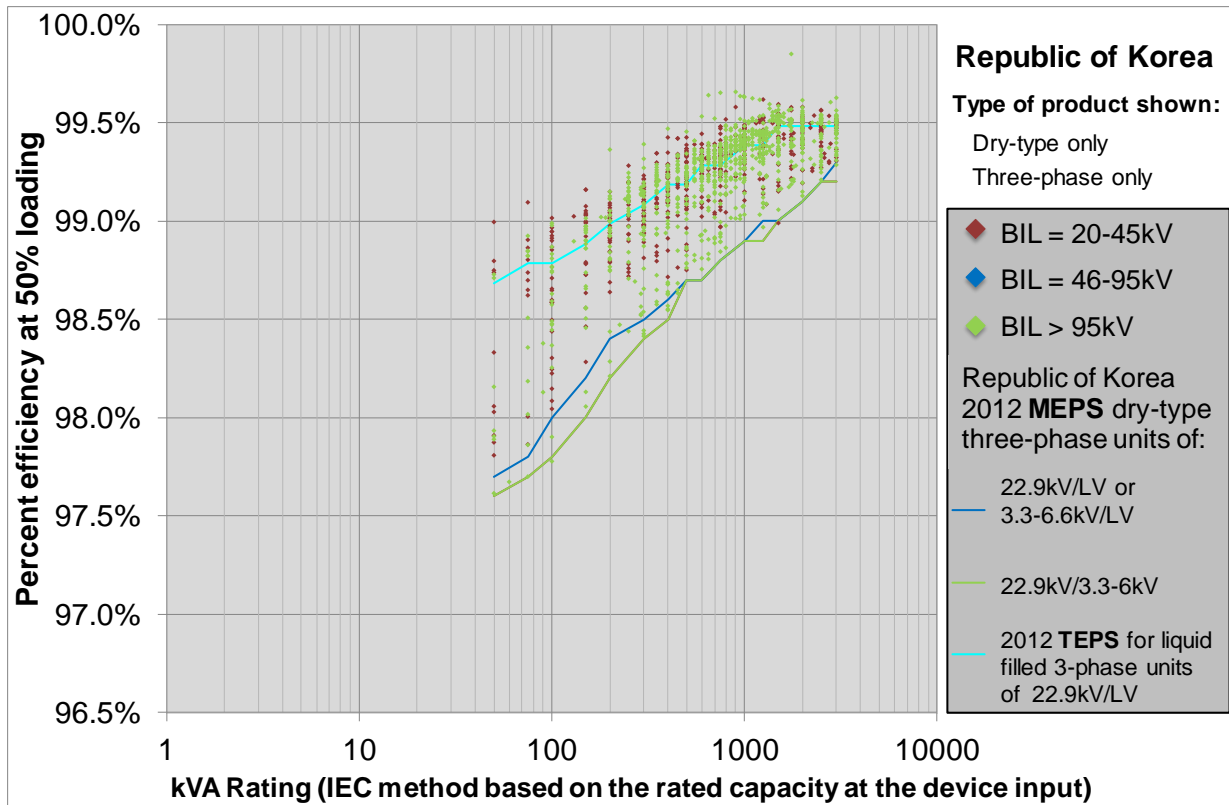
Percentage efficiency at 50% loading for distribution transformers in the Republic of Korea: Single-phase liquid-filled transformers



Key notes on graph (see notes section 1)

- The source of data for this graph is KEMCO in October 2013 from the mandatory government registration database. Manufacturers are required to register transformers in the capacity range 100kVA to 3000kVA.
- This graph shows performance data for 261 distribution transformers (representing 12% of liquid-type models in the dataset)
- The percentage efficiency requirement is calculated at 50% load, which is measured in accordance with the following four standards: (a) KS C 4306 - Single high voltage cover bushing transformers; (b) KS C 4311 - Dry-type transformer; (c) KS C 4316 - Two bushing type pole transformer for 22.9 kV and (d) KS C 4317 - Distribution transformers not more than 3MVA for 22.9kV. The Korean test standards are 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 60Hz with ratings from 10 to 3,000 kVA.
- Products are shown for all voltage classes of liquid-filled distribution transformers.
- TEPS = Target Energy Performance Standards and represents a level of ambition in energy-efficiency that the government wishes to promote through its incentive schemes. Only the TEPS that applies to the most common models is plotted but, as described in the notes, there are also TEPS for 22.9kV primary / 3.3-6.6kV secondary and 3.3-6.6 kV primary / low voltage secondary.
- All of the models shown in the database meet the MEPS requirements.

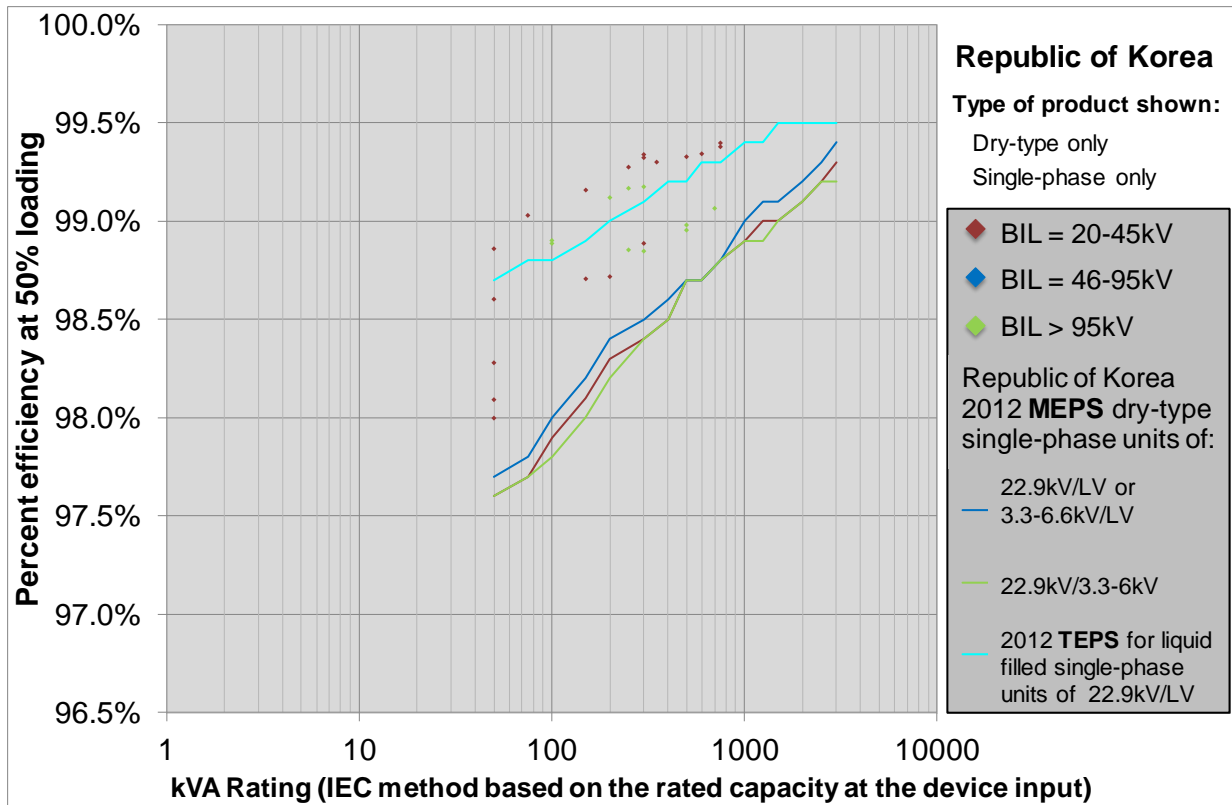
Percentage efficiency at 50% loading for distribution transformers in the Republic of Korea: Three-phase dry-type transformers by BIL rating



Key notes on graph (see notes section 1)

- The source of data for this graph is KEMCO in October 2013 from the mandatory government registration database. Manufacturers are required to register transformers in the capacity range 100kVA to 3000kVA.
- This graph shows performance data for 1440 distribution transformers (representing 98% of dry-type models in the dataset)
- The percentage efficiency requirement is calculated at 50% load, which is measured in accordance with the following four standards: (a) KS C 4306 - Single high voltage cover bushing transformers; (b) KS C 4311 - Dry-type transformer; (c) KS C 4316 - Two bushing type pole transformer for 22.9 kV and (d) KS C 4317 - Distribution transformers not more than 3MVA for 22.9kV. The Korean test standards are 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 60Hz with ratings from 50 to 3,000 kVA.
- Korea has different efficiency requirements for different transformer voltages which are shown on the graph. The models included in the database are differentiated by Basic Impulse insulation Level (BIL) rating range, in a way that is consistent with the different insulation ratings in North America.
- TEPS = Target Energy Performance Standards and represents a level of ambition in energy-efficiency that the government wishes to promote through its incentive schemes. Only the TEPS that applies to the most common models is plotted but, as described in the notes, there are also TEPS for 22.9kV primary / 3.3-6.6kV secondary and 3.3-6.6 kV primary / low voltage secondary.
- All of the models shown in the database meet the MEPS requirements.

Percentage efficiency at 50% loading for distribution transformers in the Republic of Korea: Single-phase dry-type transformers by BIL rating



Key notes on graph (see notes section 1)

- The source of data for this graph is KEMCO in October 2013 from the mandatory government registration database. Manufacturers are required to register transformers in the capacity range 50kVA to 3000kVA.
- This graph shows performance data for 28 distribution transformers (representing 2% of dry-type models in the dataset)
- The percentage efficiency requirement is calculated at 50% load, which is measured in accordance with the following four standards: (a) KS C 4306 - Single high voltage cover bushing transformers; (b) KS C 4311 - Dry-type transformer; (c) KS C 4316 - Two bushing type pole transformer for 22.9 kV and (d) KS C 4317 - Distribution transformers not more than 3MVA for 22.9kV. The Korean test standards are based on the IEC method with rated capacity at the device input.
- The products shown in this graph are all single-phase dry type and operate at 60Hz with ratings from 50 to 3000 kVA.
- Korea has different efficiency requirements for different transformer voltages which are shown on the graph. The models included in the database are differentiated by Basic Impulse insulation Level (BIL) rating range, in a way that is consistent with the different insulation ratings in North America.
- TEPS = Target Energy Performance Standards and represents a level of ambition in energy-efficiency that the government wishes to promote through its incentive schemes. Only the TEPS that applies to the most common models is plotted but, as described in the notes, there are also TEPS for 22.9kV primary / 3.3-6.6kV secondary and 3.3-6.6 kV primary / low voltage secondary.
- All of the models shown in the database meet the MEPS requirements.

Major Policy Interventions (see notes section 2)

In July 2012, Korea adopted mandatory efficiency standards for liquid-filled and dry-type distribution transformers. Korea establishes minimum performance efficiency requirements and then sets a higher level of efficiency and requires that manufacturers meet that level before they can market the product as highly energy-efficient. The higher energy-efficiency level is referred to as the 'Target Energy Performance Standard' or TEPS.

Mandatory performance requirements

Mandatory standards¹ covering three types of distribution transformers exist in Korea:

- Dry-type distribution transformers, single-phase and three-phase from 50-3000 kVA
- Liquid-filled distribution transformers, single-phase and three-phase from 10-3000 kVA, setting a minimum efficiency requirement at 50% loading separately for single-phase and three-phase.

Korea also states that if the kVA capacity is not contained in the table, then the user shall apply linear interpolation to determine the efficiency of the model.²

High efficiency performance requirements

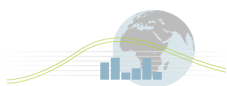
In addition to the MEPS level, Korea also sets a higher level of efficiency called a "Target Energy Performance Standard" (TEPS) and requires that manufacturers meet that level before they can market the product as highly energy-efficient. The TEPS apply to the same scope of coverage as the MEPS.

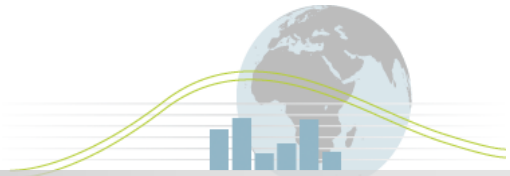
Labelling of distribution transformers

Korea also has a label that they use for distribution transformers which provides the percentage efficiency in a very clear way, helping to inform consumers and support the monitoring, verification and enforcement process.

¹ See http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/66

² In case that capacity of transformer is in the defined values of the table above, based on the standard number shall be rounded off to two decimal places after using interpolation. For example, in case of 130kVA 22.9kV/440V 3-phase liquid-filled transformer, linear interpolation shall be applied based on the defined capacity and standard (100kVA 98.0% and 150kVA 98.1%) as shown: 130kVA efficiency = $98\% + (130 - 100) \times (98.1 - 98.0) / (150 - 100)\% = 98.06$. It shall then be rounded off so that 98.1% shall be energy efficiency standard applicable to a 130kVA transformer.

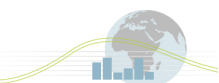




Cultural Issues (see notes section 3)

The market channel for electric utilities in Korea is generally direct, with the majority of utilities placing orders directly with distribution transformer manufacturers. When placing an order, generally the electric utility usually provides a specification, including the value it places on future core and coil losses over the life of the transformer. This cultural market issue tends to get manufacturers to develop custom designs in their contract bids, reflecting the customer's performance requirements and the dynamic costs of material, equipment, and labour at a transformer manufacturer's facility.

The delivery channel for commercial and industrial customers can be complex, working through intermediaries such as stocking distributors and electrical contractors. Electrical contractors typically purchase transformers using specifications written by themselves or by agents. Some larger industrial customers buy transformers directly from distributors or manufacturers based on specifications drafted by in-house experts.



Notes Section 1. Percentage Efficiency Graphics

1.1 Test methodologies, Performance Standards

1.1.1 Test Methodology

The standardisation process in Korea follows the basic principles for standards development outlined by the International Organization for Standardization (ISO), the IEC and the World Trade Organization (WTO) Technical Barriers to Trade Agreement (TBT). The Korean Agency for Technology and Standards (KATS) oversees the development of national Korean Standards (KS), coordinating input from public and private sector stakeholders through KATS' technical committees. KATS also acts as an accreditation body for laboratories. There are over 20,000 published Korean Standards.

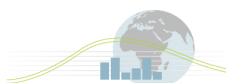
As discussed in the energy-efficiency measures report, Korea has adopted MEPS and Top Energy Performance Standards (TEPS) to help transform their market to use high-efficiency transformers in the electricity transmission and distribution system. Starting in July 2012, Korea established these requirements to promote more energy-efficient transformers. The requirements are based on a percentage efficiency that is calculated at 50% load, which is measured in accordance with the following four standards:

- KS C 4306 - Single high voltage cover bushing transformers
- KS C 4311 - Dry-type transformer
- KS C 4316 - Tow bushing type pole transformer for 22.9 kV
- KS C 4317 - Distribution transformers not more than 3MVA for 22.9kV

Within these standards, the regulations cross-reference the measurement methodologies that are published in the IEC 60076 standards, which have been adopted without modification (i.e., "identical") as national Korean Standards (KS). KS C IEC 60076-1, Power transformers – Part 1: General, corresponds to IEC 60076-1:1993 and is identical to that standard. KS C IEC 60076-11, Power transformers – Part 11: Dry-type transformers, corresponds to IEC 60076-11:2004 and is identical to that standard.

1.1.2 Performance Metrics

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.



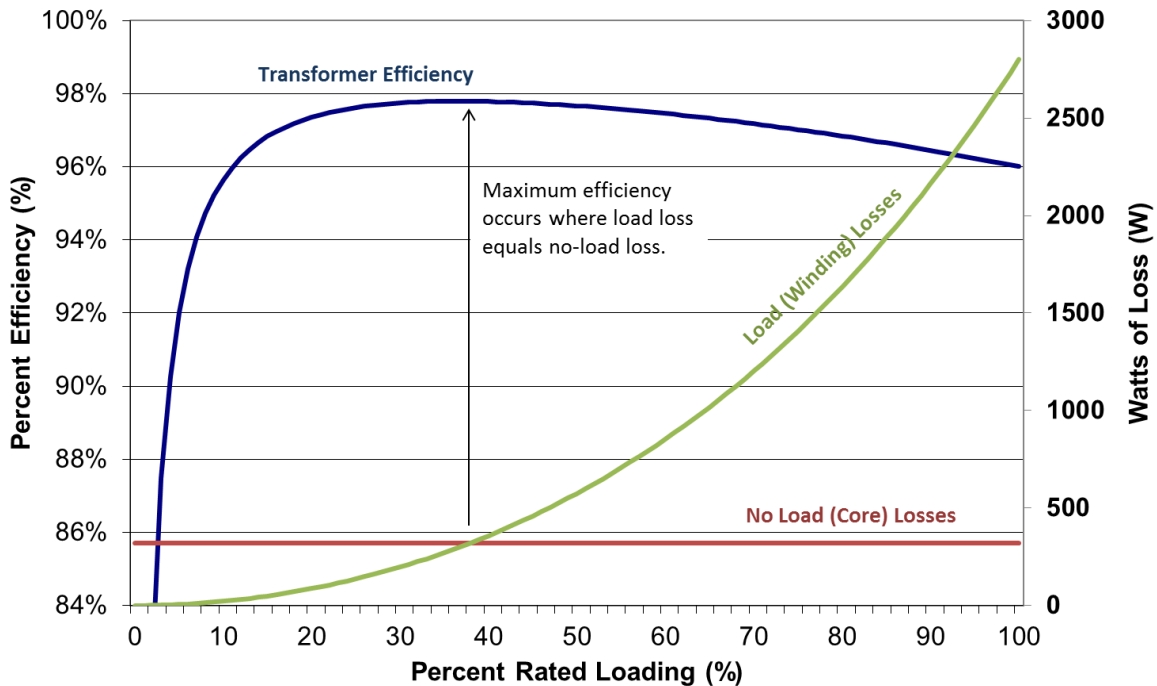


Figure A. Illustration of Relationship Between Losses and Efficiency

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 the Republic of Korea there is a product efficiency labelling scheme which communicates the efficiency of the transformer to the end-user. The following figure is a screen capture of the Korean label for distribution transformers. It must be 7cm (length) x 7cm (height), but it can be adjusted slightly, given in its location.



Figure 1. Korean Label for Distribution Transformers

All products must meet the relevant mandatory minimum standard.

1.3 Data sources and limitations

The data was provided by KEMCO in October 2013 from the mandatory government registration database. Manufacturers are required to register transformers in the capacity range 10kVA to 3000kVA.

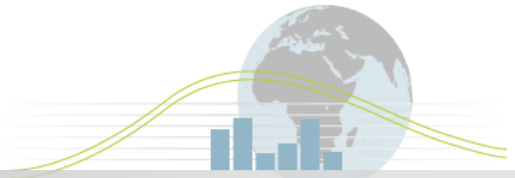
The Korean data set consists of 3,572 products from an unknown number of manufacturers (data was anonymous). 59% of liquid type (1,468 dry; 2,104 liquid) and 92% 3-phase (289 single; 3,283 three). kVA ratings in the source dataset are based on the input rated power (IEC system). BIL ratings range from 75 kV to 200 kV and products operate at 60Hz. The data set included the overall energy efficiency percentage, along with coil and core losses at 50% load.

It is assumed that this data set is highly representative of the Republic of Korea market because it is a mandatory registration scheme.

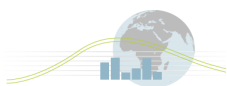
1.4 Data manipulation and specific limitations

All Republic of Korea data was assumed to have been declared in accordance with the IEC test method and efficiency at 50% load was used as the basis of graphics in this report - no manipulation was required. 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 in order to make a comparison to the different BIL ratings in other countries (e.g., USA, Canada, Australia).
- The Korean database was provided with both the percentage efficiency at 50% loading and the losses in the core and coil at 100% loading. All of the percentage



efficiency ratings were rounded to one decimal place, meaning a unit with a 98.22% efficient performance was rounded to 98.2%. However, by rounding everything to one tenth of an efficiency point, a lot of the richness of the data was not shown. To address this problem, the percentage efficiency was calculated using the IEC method and the reported core and coil loss to several decimal places. This enabled greater visibility in terms of the efficiency of the transformers across the database.



Notes Section 2. Major Policy Interventions

The minimum performance requirements and high-efficiency performance labelling requirement took effect from July 2012. The efficiency of the transformer is measured at 50% load, in accordance with Korean National Standards: KS C4306, KS C4311, KS C4316 and KS C4317. Korea’s electricity system operates at 60Hz.

In their tables of efficiency values, Korea designates the “MEPS” requirement for the Minimum Energy Performance Standard and the “TEPS” requirement for the Target Energy Performance Standard. Both values are presented in the tables below. Korea also states that if the kVA capacity is not contained in the table, then the user shall apply linear interpolation to determine the efficiency of the model. Transformers that were sold prior to the effective date and special purpose transformer (e.g., multi-winding transformers with more than 3 windings, etc.), primary and secondary low-voltage transformers and transformers which have been repaired are not subject to the MEPS and TEPS requirements.

Table 1. Korean MEPS and TEPS for Single-Bushing Distribution Transformers from 2012, measured at 50% load.

kVA	13.2kV Primary / 230 V Secondary	
	Single-Phase MEPS (% efficiency)	Single-Phase TEPS (% efficiency)
10	98.3	98.7
20	98.5	98.8
30	98.7	98.9
50	98.8	99.0
75	98.8	99.1
100	98.9	99.2

* Note: Testing according to KS C4306.

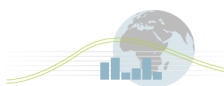


Table 2. Korean MEPS and TEPS for 3.3-6.6kV Dry-Type Distribution Transformers from 2012, measured at 50% load.

kVA	Dry-Type, 3.3-6.6 kV Primary / Low Voltage Secondary			
	Single-Phase MEPS (% efficiency)	Single-Phase TEPS (% efficiency)	Three-Phase MEPS (% efficiency)	Three-Phase TEPS (% efficiency)
50	97.7	98.7	97.7	98.7
75	97.8	98.8	97.8	98.8
100	98.0	98.9	98.0	98.9
150	98.2	99.0	98.2	99.0
200	98.4	99.0	98.4	99.0
300	98.5	99.1	98.5	99.1
400	98.6	99.2	98.6	99.2
500	98.7	99.3	98.7	99.3
600	98.7	99.3	98.7	99.3
750	98.8	99.3	98.8	99.3
1000	99.0	99.4	98.9	99.4
1250	99.1	99.5	99.0	99.5
1500	99.1	99.5	99.0	99.5
2000	99.2	99.5	99.1	99.5
2500	99.3	99.5	99.2	99.5
3000	99.4	99.5	99.3	99.5

* Note: Testing according to KS C4311.

Table 3. Korean MEPS and TEPS for 22.9kV Dry-Type Distribution Transformers from 2012, measured at 50% load.

kVA	Dry-Type, 22.9 kV Primary / Low Voltage Secondary			
	Single-Phase MEPS (% efficiency)	Single-Phase TEPS (% efficiency)	Three-Phase MEPS (% efficiency)	Three-Phase TEPS (% efficiency)
50	97.6	98.7	97.6	98.7
75	97.7	98.8	97.7	98.8
100	97.9	98.8	97.8	98.8
150	98.1	98.9	98.0	98.9
200	98.3	99.0	98.2	99.0
300	98.4	99.1	98.4	99.1
400	98.5	99.2	98.5	99.2
500	98.7	99.2	98.7	99.2
600	98.7	99.3	98.7	99.3
750	98.8	99.3	98.8	99.3
1000	98.9	99.4	98.9	99.4
1250	99.0	99.4	98.9	99.4
1500	99.0	99.5	99.0	99.5
2000	99.1	99.5	99.1	99.5
2500	99.2	99.5	99.2	99.5
3000	99.3	99.5	99.2	99.5

* Note: Testing according to KS C4311.

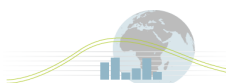


Table 4. Korean MEPS and TEPS for 22.9kV Dry-Type Distribution Transformers from 2012, measured at 50% load.

kVA	Dry-Type, 22.9 kV Primary / 3.3-6.6 kV Secondary			
	Single-Phase MEPS (% efficiency)	Single-Phase TEPS (% efficiency)	Three-Phase MEPS (% efficiency)	Three-Phase TEPS (% efficiency)
50	97.6	98.7	97.6	98.7
75	97.7	98.8	97.7	98.8
100	97.8	98.8	97.8	98.8
150	98.0	98.9	98.0	98.9
200	98.2	99.0	98.2	99.0
300	98.4	99.0	98.4	99.0
400	98.5	99.1	98.5	99.1
500	98.7	99.2	98.7	99.2
600	98.7	99.3	98.7	99.3
750	98.8	99.3	98.8	99.3
1000	98.9	99.4	98.9	99.4
1250	98.9	99.4	98.9	99.4
1500	99.0	99.5	99.0	99.5
2000	99.1	99.5	99.1	99.5
2500	99.2	99.5	99.2	99.5
3000	99.2	99.5	99.2	99.5

* Note: Testing according to KS C4311.

Table 5. Korean MEPS and TEPS for Low Voltage Liquid-Filled Distribution Transformers from 2012, measured at 50% load.

kVA	Liquid-Filled, 3.3-6.6 kV Primary Low Voltage Secondary			
	Single-Phase MEPS (% efficiency)	Single-Phase TEPS (% efficiency)	Three-Phase MEPS (% efficiency)	Three-Phase TEPS (% efficiency)
100	98.4	99.0	98.0	99.0
150	98.4	99.0	98.1	99.0
200	98.4	99.0	98.2	99.0
250	98.5	99.1	98.3	99.1
300	98.5	99.1	98.4	99.1
400	98.6	99.2	98.4	99.2
500	98.6	99.2	98.5	99.2
600	98.6	99.2	98.5	99.2
750	98.7	99.3	98.6	99.3
1000	98.8	99.3	98.7	99.3
1250	98.8	99.4	98.8	99.4
1500	98.9	99.4	98.8	99.4
2000	99.0	99.4	98.9	99.4
2500	99.0	99.4	99.0	99.4
3000	99.1	99.4	99.1	99.4

* Note: Testing according to KS C4316, KS C4317.

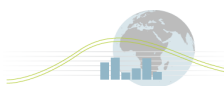


Table 6. Korean MEPS and TEPS for 22.9kV Liquid-Filled Distribution Transformers from 2012, measured at 50% load.

kVA	Liquid-Filled, 22.9kV Primary / 3.3-6.6 kV Secondary			
	Single-Phase MEPS (% efficiency)	Single-Phase TEPS (% efficiency)	Three-Phase MEPS (% efficiency)	Three-Phase TEPS (% efficiency)
100	98.4	99.0	98.1	99.0
150	98.5	99.0	98.2	99.0
200	98.5	99.0	98.2	99.0
250	98.6	99.1	98.3	99.1
300	98.6	99.1	98.4	99.1
400	98.7	99.2	98.5	99.2
500	98.8	99.2	98.6	99.2
600	98.8	99.2	98.6	99.2
750	98.9	99.3	98.6	99.3
1000	98.9	99.3	98.7	99.3
1250	99.0	99.4	98.8	99.4
1500	99.0	99.4	98.9	99.4
2000	99.1	99.4	99.0	99.4
2500	99.1	99.4	99.1	99.4
3000	99.2	99.4	99.2	99.4

* Note: Testing according to KS C4316, KS C4317.

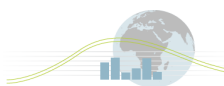
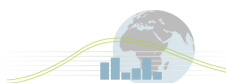
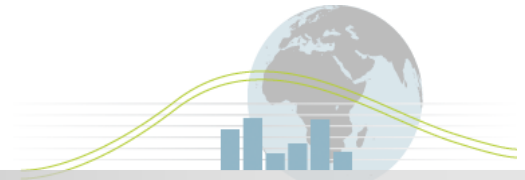


Table 7. Korean MEPS and TEPS for 22.9kV Liquid-Filled Distribution Transformers from 2012, measured at 50% load.

kVA	Liquid-Filled, 22.9kV Primary / Low Voltage Secondary			
	Single-Phase MEPS (% efficiency)	Single-Phase TEPS (% efficiency)	Three-Phase MEPS (% efficiency)	Three-Phase TEPS (% efficiency)
10	97.4	98.6		
15	97.7	98.6		
20	97.9	98.7		
30	98.1	98.8		
50	98.4	98.8		
75	98.6	98.9		
100	98.7	99.0	98.0	99.0
150	98.4	99.0	98.1	99.0
200	98.4	99.0	98.2	99.0
250	98.5	99.1	98.3	99.1
300	98.5	99.1	98.4	99.1
400	98.6	99.2	98.4	99.1
500	98.6	99.2	98.5	99.1
600	98.6	99.2	98.5	99.2
750	98.7	99.3	98.6	99.2
1000	98.8	99.3	98.7	99.3
1250	98.8	99.4	98.8	99.3
1500	98.9	99.4	98.8	99.3
2000	99.0	99.4	98.9	99.3
2500	99.1	99.4	99.0	99.4
3000	99.2	99.4	99.1	99.4

* Note: Testing according to KS C4316, KS C4317.





Notes Section 3. Cultural Issues

No additional notes.

