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Energy Conservation by Introducing “Top Runner Transformer 2014”

Submitted by: Japan Electrical Manufacturers' Association

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ASEAN SHINE

Reducing Losses in Power Distribution through Improved Efficiency of Distribution Transformers (EWG 05 2015A)

Energy Conservation by Introducing "Top Runner Transformer 2014"

28 March 2017 | Jeju, Republic of Korea

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ORGANISERS:

International Copper Association Southeast Asia
Copper Alliance

CSC China Standard Certification

IIEC International Institute for Energy Conservation

JEMA

Introduction

For the Energy Conservation Law Specified Equipment Transformer, the target fiscal years were 2006 for oil-immersed transformers and 2007 for molded transformers. Improvement of 32.8 % in energy consumption efficiency over the old products was attained.

To develop new technologies and new materials for the next generation to enhance the function and performance of equipment, the second criteria were notified in March 2012, **which started a new transformer called Top Runner Transformer 2014**.

In this presentation, we will explain the background of Top Runner Transformer 2014, the outline of the second criteria, and its energy conservation effect.

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1 REASON AND BACKGROUND OF ESTABLISHMENT OF THE SECOND CRITERIA

Reason and Background of Establishment of the Second Criteria

What is the Energy Conservation Law (Act on the Rational Use of Energy)?

- The Energy Conservation Law was established in 1979 triggered by the oil crisis. The purpose is to take measures needed for streamlining the energy use in factories, transportation, buildings, machinery and appliances for effective utilization and securing of fuel resources and to contribute to sound development of the national economy.

Introduction of the Top Runner Standard

- In the revised Energy Conservation Law following the 1997 Kyoto Conference for global warming prevention, “the Top Runner Standard” was established to promote improvement of energy conservation performance for each high energy-consumption equipment, and 31 items are designated currently. **Distribution transformers were designated as the target equipment in 2002, and “the Top Runner Standard” has been applied since 2006.**

2 SPECIFIED EQUIPMENT

Definition in “the Act on the Rational Use of Energy”

Specified equipment

Equipment for which further energy conservation is obligated by “the Act on the Rational Use of Energy” (total 31 items as of March 2017)

Top Runner “method”

Method to determine the energy conservation standard, in which the performance of the product with the highest energy conservation performance among existing products (the top runner) becomes the standard

Three Requirements of Specified Equipment

Specified equipment is defined in the government ordinance as the equipment satisfying the following three requirements

- Act on the Rational Use of Energy (last revision: Law No. 74 of June 24, 2011)
- Article 78 of Chapter 6 Equipment for Machinery and Appliances

  - **Machinery and appliances used in large quantity**
  - **Machinery and appliances consuming a considerable amount of energy**
  - **Machinery and appliances for which improvement in energy consumption efficiency is particularly required**

Transformers were designated as the specified equipment because they satisfied these three requirements.

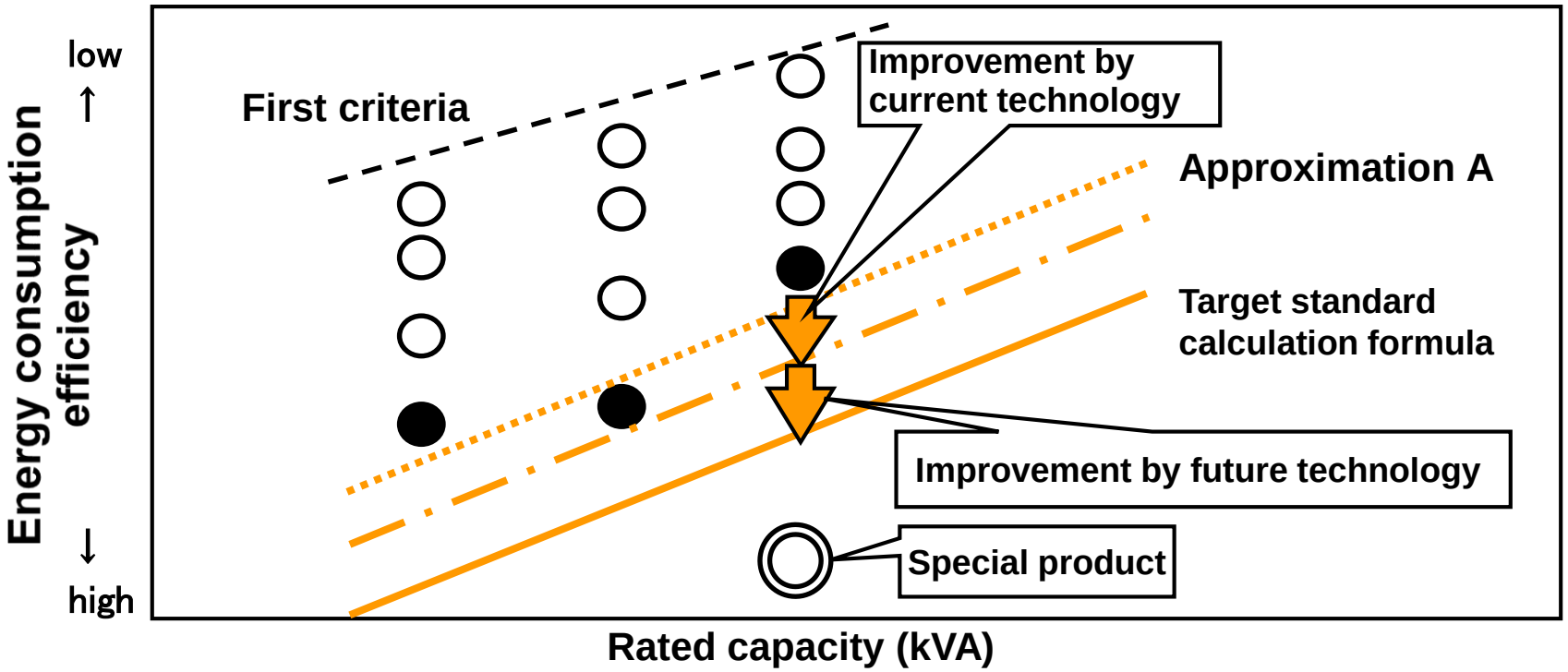
Target Items of the Top Runner Program
(31 items)

1. Passenger car
2. Truck
3. Air conditioner
4. Television receiver
5. Video tape recorder
6. Lighting equipment
7. Copier
8. Computer
9. Magnetic disk unit
10. Electric refrigerator
11. Electric freezer
12. Space heater
13. Gas cooking appliance
14. Gas water heater
15. Oil burning water heater
16. Electric toilet seat
17. Vending machine
18. **Transformer**
19. Jar type rice cooker
20. Microwave oven
21. DVD recorder
22. Routing equipment
23. Switching Routing equipment
24. Combined machine
25. Printer
26. Electric water heater (heat pump water heater)
27. Three phase induction motor
28. Compact self-ballasted LED lamp
29. Heat insulator
30. Sash
31. Double glass

31 items are designated as specified equipment.

What is the Top Runner method?

The Top Runner method is the method that demands a high efficiency using the highest efficiency of the products currently sold as the standard and also considering the future prospective of technology development.



Explanation of Designations

Specified equipment transformer

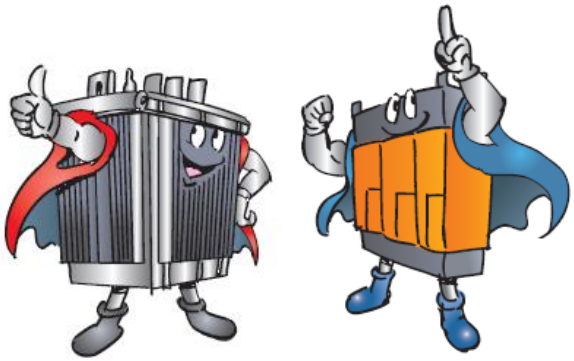
Transformers for which the target standard should be attained according to the notification "Criteria for Judgment of Manufacturers Concerning Improvement of Transformer Performance," in which products not having attained the target yet are also included

Top Runner Transformer

Designation defined by the Japan Electrical Manufacturers' Association as the name of transformers that satisfy the first criteria in specified equipment transformers

Top Runner Transformer 2014

Designation defined by the Japan Electrical Manufacturers' Association as the name of transformers that satisfy the second criteria (target fiscal year: 2014) **in specified equipment transformers**



Designation and Logo of Transformers

Designation: "Top Runner Transformer 2014"

Industry common designation of transformers conforming to the second criteria (target fiscal year: 2014)

Logo: marked on transformer body, catalog, etc.

Energy conservation mark in green

3 REGULATIONS AND LEGISLATION

For Diffusion: Standardization

Issue and revision state of standards related to specified equipment transformers

1. September 2014 Revision of JEM Standard conforming to the second criteria
   - JEM1500 “Standard energy consumption efficiency of oil-immersed transformer conforming to specified equipment”
   - JEM1501 “Standard energy consumption efficiency of molded transformer conforming to specified equipment”
2. May 2013 Revision of JIS for specified equipment
   - JIS C 4304 6kV oil-immersed distribution transformer
   - JIS C 4306 6kV molded distribution transformer

<Main changes>

- Reflection of the second criteria
- Consistency with IEC
- Improvement in maintenance (oil-immersed transformer)

For Diffusion: Legislation

Legislation and institutionalization state related to specified equipment transformers

1. March 2012, Energy Conservation Law, Criteria for Judgment of Manufacturers Concerning Improvement of Transformer Performance (Notification of Ministry of Economy, Trade and Industry No. 71)
   - Criteria
   - Marking, etc.
   - Measuring method for energy consumption efficiency
2. February 2013, Law on Promoting Green Purchasing, Basic Policy on Promoting Procurement of Environmental Conservation Products (cabinet decision)
   - Specified procurement items in Fiscal 2013 and their criteria

     (Transformers whose energy consumption efficiency satisfies the second criteria of the Energy Conservation Law are designated as the specified procurement items. As no tolerance is defined, attention is needed.)

Operation of Specified Equipment

- **Target fiscal year**

  April 2014 (for both oil-immersed and molded transformers)

- **Judgment procedure for conformance to the standard**
  1. Report of annual production (or import) volume, energy consumption efficiency, and weighted average by class
  2. Report of improvement measures when not having attained the conformance

- **Marking**
  1. Marking on catalog, etc.
  2. Marking on product

4 THE OUTLINE OF THE SECOND CRITERIA

NOTIFICATION OF MINISTRY OF ECONOMY, TRADE AND INDUSTRY NO. 71 OF MARCH 30, 2012
"CRITERIA FOR JUDGMENT OF MANUFACTURERS CONCERNING IMPROVEMENT OF TRANSFORMER PERFORMANCE"

Application Target

To improve the efficiency in wider range, not only the standard specifications defined in JIS, etc. but non-standard specifications are targeted.

Excluded products are selected according to the following criteria:

1. Models used for special application (original specifications, special load)
2. Models whose market share is extremely small
3. Models for which measuring methods have not been established technically

[Scope of the target]
Voltage
Primary: high voltage such as 3.3kV, 6.6kV
Secondary: low voltage 100V - 600V
Capacity
Single phase: 10kVA - 500kVA
Three phase: 20kVA - 2000kVA

[Excluded products]
1. Gas-insulated transformer
2. H-type dry transformer
3. Scott-connected transformer
4. Multi-winding transformer (3 windings or more)
5. Single phase of 5kVA or less, or more than 500kVA
6. Three phase of 10kVA or less, or more than 2000kVA
7. Molded light and power common-use transformer
8. Products with secondary voltage of less than 100V or more than 600V
9. Air cooling or water cooling transformer
10. Pole transformer

For distribution transformers, 98.6% of them is targeted.

Classes for Setting a Target

Classes are determined considering physical quantities and functions closely related energy consumption efficiency (total loss).
For transformers, indexes are model, frequency, the number of phase, and capacity.

Class	Type	Phase	Rated freq.	Rated capacity
I	Oil-immersed transformer	Single	50Hz	500kV or less
II			60Hz	500kV or less
III-1		Three	50Hz	500kV or less
III-2			50Hz	more than 500kV
IV-1			60Hz	500kV or less
iV-2			60Hz	more than 500kV
V	Molded transformer	Single	50Hz	500kV or less
Vi			60Hz	500kV or less
VII-1		Three	50Hz	500kV or less
VII-2			50Hz	more than 500kV
VIII-1			60Hz	500kV or less
VIII-2			60Hz	more than 500kV

Classification is the same as the first criteria.

Standard Load Ratio for the Target Standard Value

Basic policy

- When the standard load ratio is set, the followings have to be considered: (1) the value corresponds to actual use conditions, and (2) a sufficient energy conservation effect is attained even if there is a change in the actual load ratio.
- In JIS C 4620 “Cubicle Type High-voltage Power Receiving Facilities,” which is a standard for high-voltage power receiving facilities, the application scope is a capacity of 500kVA or less per transformer. On the other hand, main application of the transformers with a capacity of more than 500kVA is power sources in middle or large scale factories of extra-high voltage consumers.
- Survey of load ratios in 2010

Capacity	Daytime	Nighttime	Average	After improving power factor
500kV or less	36.4%	9.7%	26.6%	11%-42%
more than 500kV	47.1%	29.6%	39.3%	34%-54%

- It needs to be considered that the setting is based on the actual load ratio on one hand, and an energy conservation effect is attained over the entire range of the load ratio on the other. An effective energy conservation standard is determined by selecting an intermediate value as the standard load ratio.

Standard load ratio

The standard load ratio for each capacity is determined as follows:

500kVA or less: 40%

more than 500kVA: 50%

The standard load ratio is the same as the first criteria.

Target Standard Value

Energy consumption of transformers is considered as "total loss (W)," and the target standard value is derived by the Top Runner method in which the most excellent property existing currently at the standard load ratio is determined as the target value.

E: Standard energy consumption ratio (W)

*** Standard load ratio**

500kVA or less: 40%

more than 500kVA: 50%

kVA: Rated capacity of transformer (kVA)

<u>Semistandard specification product</u>

Treated using the calculation formula of the target standard value of the standard energy consumption efficiency for each class multiplied by the following value.

Oil-immersed transformer: 1.10

Molded transformer: 1.05

Classification					Calculation formula of target standard value of standard energy consumption efficiency
Class	Type	Phase	Rated freq.	Rated capacity	
I	Oil-immersed transformer	Single	50Hz	500kVA or less	$E = 11.2 \cdot (kVA)^{0.732}$
II			60Hz	500kVA or less	$E = 11.1 \cdot (kVA)^{0.725}$
III-1		Three	50Hz	500kVA or less	$E = 16.6 \cdot (kVA)^{0.696}$
III—2			50Hz	more than 500kVA	$E = 11.1 \cdot (kVA)^{0.809}$
IV-1			60Hz	500kVA or less	$E = 17.3 \cdot (kVA)^{0.678}$
IV-2			60Hz	more than 500kVA	$E = 11.7 \cdot (kVA)^{0.790}$
V	Molded transformer	Single	50Hz	500kVA or less	$E = 16.9 \cdot (kVA)^{0.674}$
VI			60Hz	500kVA or less	$E = 15.2 \cdot (kVA)^{0.691}$
VII-1		Three	50Hz	500kVA or less	$E = 23.9 \cdot (kVA)^{0.659}$
VII-2			50Hz	more than 500kVA	$E = 22.7 \cdot (kVA)^{0.718}$
VIII-1			60Hz	500kVA or less	$E = 22.3 \cdot (kVA)^{0.674}$
VIII-2			60Hz	more than 500kVA	$E = 19.4 \cdot (kVA)^{0.737}$

Improvement Effect in the Target Fiscal Year

Improvement effect in the target fiscal year

The improvement ratio of the energy consumption efficiency (total loss (W)) in the target fiscal year is expected to be 12.5% compared to the current target standard value on the precondition that the shipment volume and composition by class are the same as those in fiscal 2009.

<Outline of calculation>

1. The energy consumption efficiency (total loss (W)) per unit obtained from the target standard value of the transformers shipped in fiscal 2009 with the weighted average by shipment volume is:
   596.1 W/unit
2. The energy consumption efficiency (total loss (W)) per unit obtained from the target standard value of the transformers expected to be shipped in the target fiscal year with the weighted average by shipment volume is:
   521.8 W/unit

   * The precondition is that the shipment volume and composition are the same as those in fiscal 2009.
3. Improvement ratio of the energy consumption efficiency is:

$$\frac{\text{596.1 W/unit} - \text{521.8 W/unit}}{\text{596.1 W/unit}} = 12.5\%$$

The Top Runner Transformer 2014, combined with the first criteria, will contribute to improvement of 43% in the energy consumption efficiency

Target Fiscal Year

Basic policy

- Model changeover of a transformer is mostly done when the efficiency standard in laws, standards, specifications, etc. is changed. It is generally done every 7 to 8 years. To enhance the energy consumption efficiency substantially, improvement in the efficiency of transformers at least once or twice is required.

Target fiscal year

- The target fiscal year of transformers is determined as the year when 8 years have passed since fiscal 2006, which is the target fiscal year of the current standard for oil-immersed transformer, i.e.,
  the target fiscal year is determined to be fiscal 2014 (April).
- For molded transformers, the target fiscal year was set with a different period from oil-immersed transformers. However, to improve the energy consumption efficiency promptly, as with oil-immersed transformers,
  the target fiscal year for molded transformers is determined to be fiscal 2014 (April).

While the period from the final decision to the target fiscal year was 4 years (molded: 5 years) for the first criteria, the period is as short as 2 years and 3 months for the second criteria.

Measuring Method of the Energy Consumption Efficiency

The energy consumption efficiency of transformers is considered as the “total loss (W).” No-load loss (W) and load loss (W) are measured according to the method specified in JIS C 4304 and JIS C 4306, and the total loss is calculated by the following formula.

$$\text{Total loss (W)} = \text{No-load loss (W)} + \left[\frac{m}{100}\right]^2 \times \text{Load loss (W)}$$

In the above formula, the following values shall be used as ‘m’:

m: standard load ratio

Transformers with a capacity of 500kVA or less: 40 (%)

Transformers with a capacity of more than 500kVA: 50 (%)

The measuring method is the same as the first criteria.

Marking

Marking items

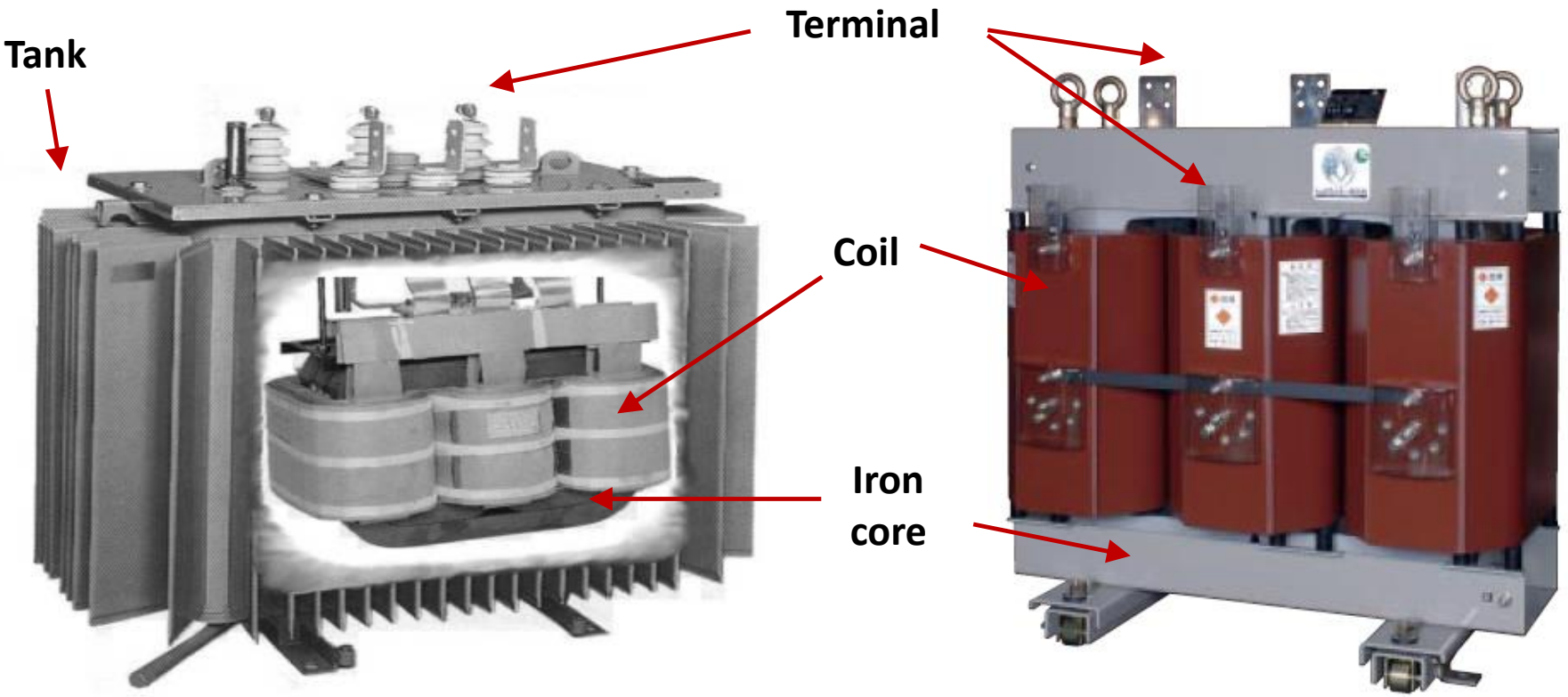
As with the marking items for the energy consumption efficiency of transformers of the current standard, the items a) to j) shown below shall be marked on catalogs showing information related to performance and materials provided by manufacturers, etc. for selection of products.

a) Product name and model
b) Type (structure) of transformer (oil-immersed or molded)
c) Rated capacity (kVA)
d) Number of phase
e) Rated frequency (Hz)
f) Rated primary and secondary voltages (V)
g) Energy consumption efficiency (total loss (W))
h) Standard load ratio (%)
i) Name of standard (standard (JIS or JEM) or semistandard)
j) Name of representative or trade name of manufacturer, etc.

The marking items are the same as the first criteria. It is prescribed that the marking is enforced in April 2014. Overall renewal of catalogs, etc. (or collection of old catalogs) is required.

5 STRUCTURE AND CONSUMPTION ENERGY OF TRANSFORMERS

Structure of Transformer

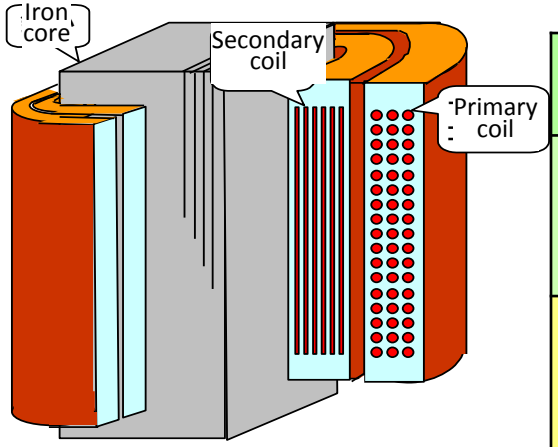


Oil-immersed transformer

Molded transformer

Consumption Energy of Transformers

Loss Reduction



Section view of coil and iron core

Loss and technology to reduce loss

Loss	Site of loss	Main cause of loss	Characteristics	Technology to reduce loss
No-load loss	Iron coil	Magnetic resistance of iron core	Always generated irrespective of load	Improve material Improve core structure Thinner iron core
Load loss	Coil	Magnetic resistance of coil	Proportional to the square of load current	Aluminum -> Iron Shorten winding length Thinner insulator

Improving iron core material

Reduction in no-load loss for higher efficiency is realized by adopting high magnetic flux density directional magnetic steel sheet with enhanced crystal directionality and domain control directional magnetic steel sheet with magnetic domains segmented by surface chase treatment, and improving iron core technology.

Representative properties of iron core material

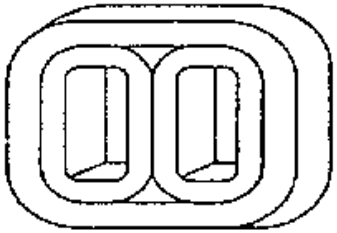
Type of magnetic steel sheet (JISC2553 class No.)	Sheet thickness (mm)	Iron loss (W/kg) at 1.7T, 50Hz
General directional (35G130)	0.35	1.28 (100%)
Highly directional (23P090)	0.23	0.88 (69%)
Magnetic domain control (23R085)	0.23	0.83 (65%)

Top Runner Transformer 2014

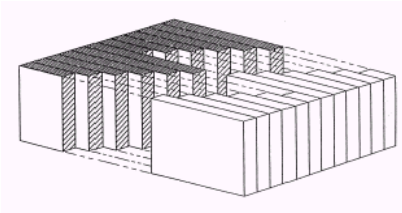
Improving coil (winding technology)

Reduction in load loss is realized by adopting copper with excellent electric conductivity as the winding conductor instead of aluminum used conventionally, and by improved technology of windings with higher density using a thinner insulator. For the coil shape, dimensions are reduced using a multiple square tube.

Improving iron core structure



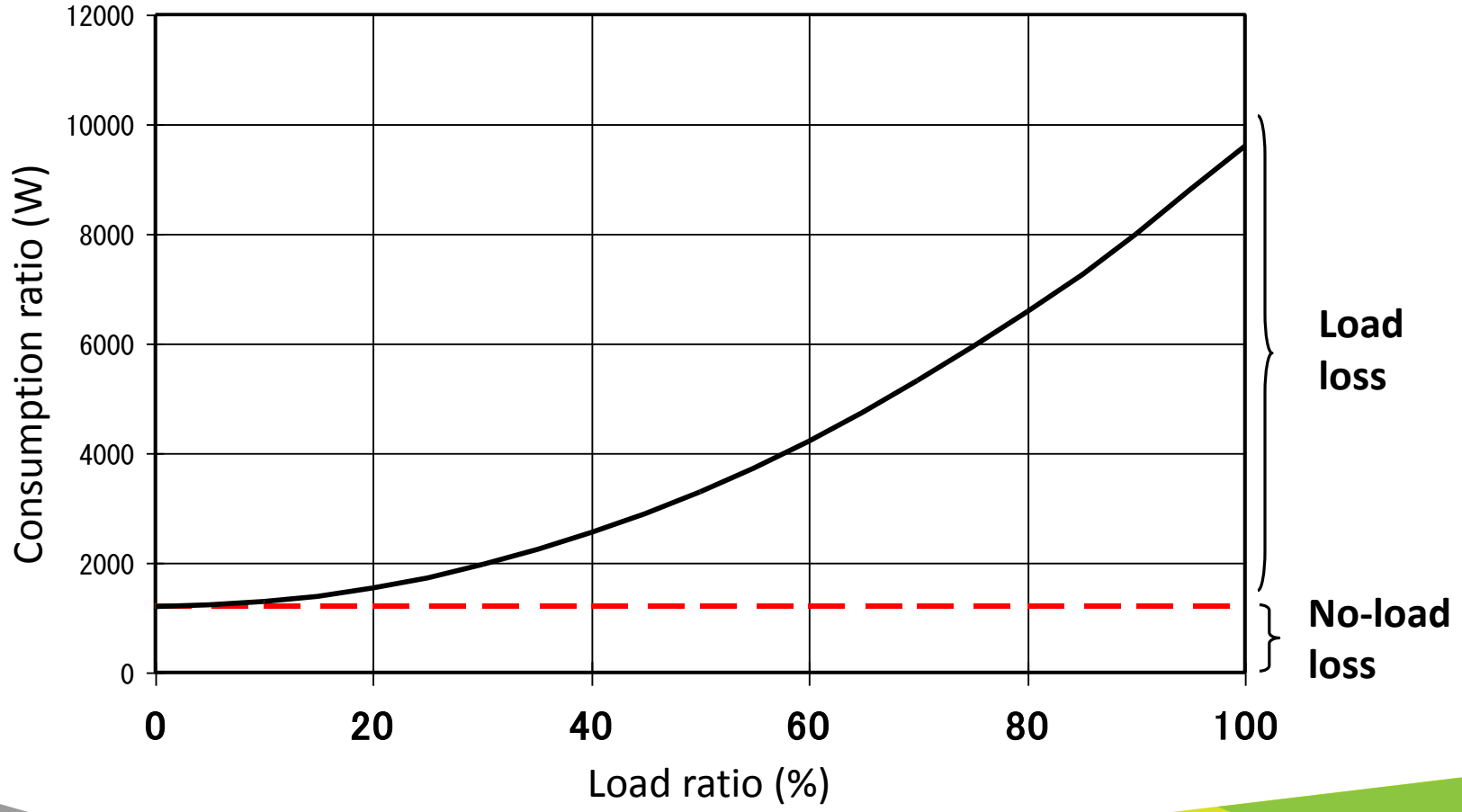
Wound iron core structure



Step-lap structure

Change in Consumption Energy by Load

Energy consumption (total loss) = No-load loss + (Load ratio/100)^2 x Load loss



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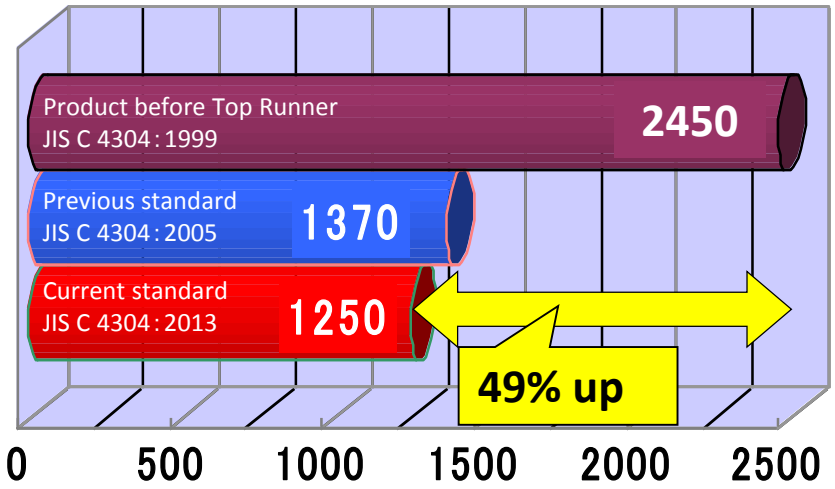
6 COST-EFFECTIVENESS OF INTRODUCTION

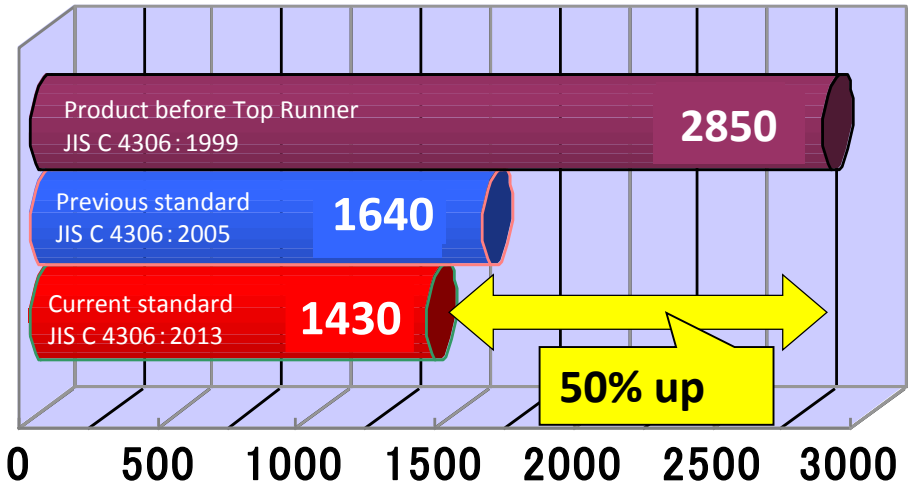
Energy Conservation Effect (1)

Improvement in energy consumption efficiency

Standard load ratio: 40 [%]

Comparison of energy consumption efficiency
Three phase, 50Hz, 500kVA





Oil-immersed transformer

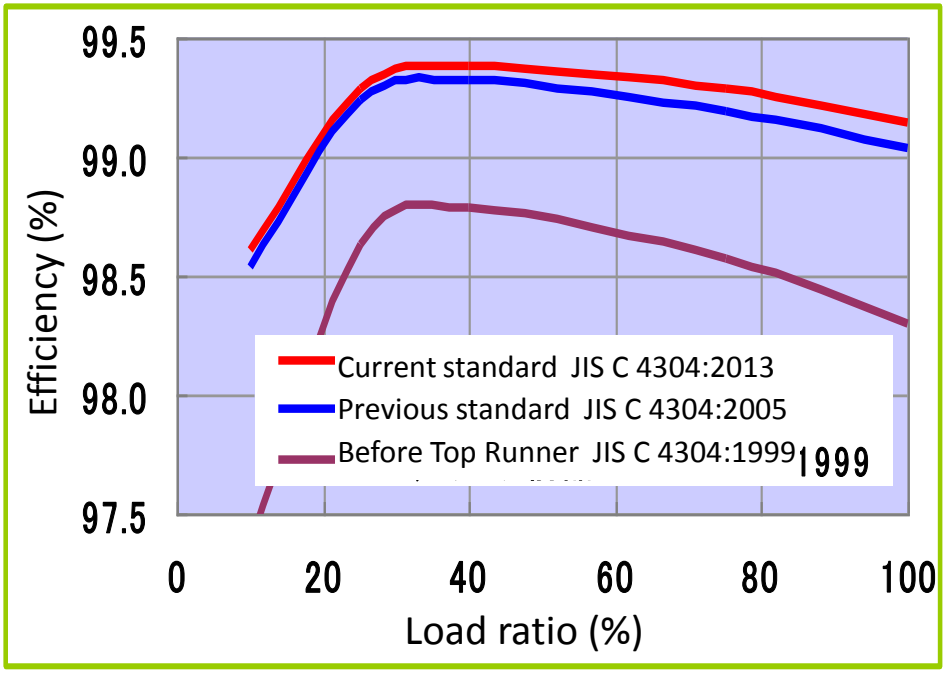
Molded transformer

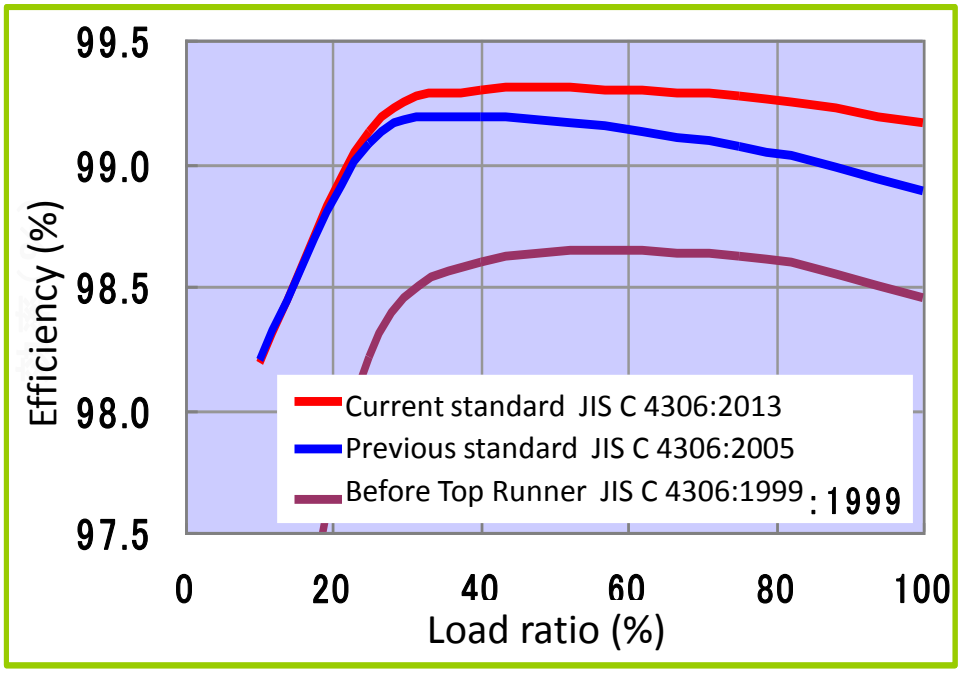
Energy consumption efficiency at standard load (W)

Energy Conservation Effect (2)

Improvement in efficiency at all load ratios

Comparison of efficiency vs. load ratio Three phase, 50Hz, 500kVA





Oil-immersed transformer

Molded transformer

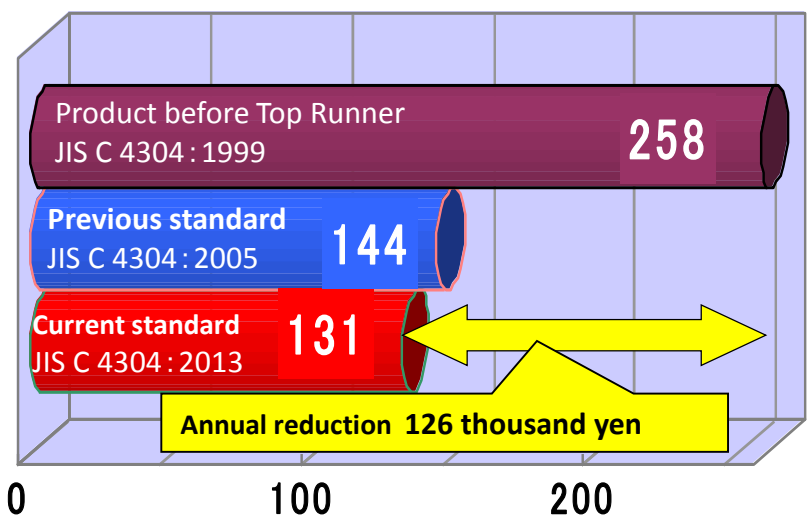
Energy consumption efficiency at standard load (W)

Reduction in Annual Electric Power Charge

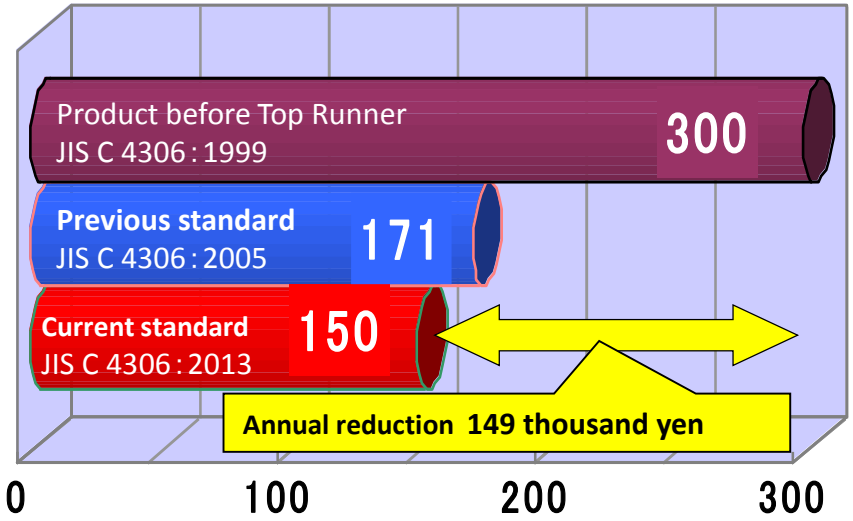
Calculated as unit power charge = 12 (yen/kWh)

Standard load ratio: 40 [%]

Comparison of annual electric power charge Three phase, 50Hz, 500kVA



Oil-immersed transformer



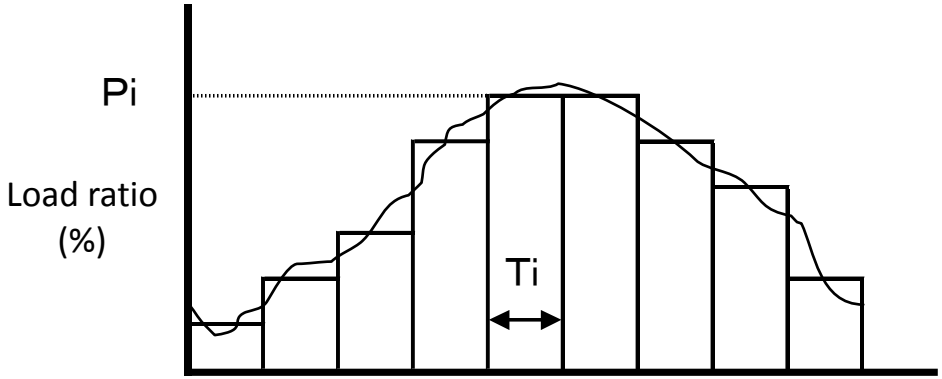
Molded transformer

Electric power charge at standard load (thousand yen)

Formula: Annual power charge (yen) = Energy consumption efficiency (kW) x 24 h x 365 d x Unit power charge (yen/kWh)

Energy Conservation Effect of Transformers Depending on Load Ratio

The total loss of transformers changes depending on the average equivalent load ratio.



Load curve

$$\text{Average equivalent load ratio } Pe\ (\%) = \sqrt{\frac{(P_1)^2 T_1 + (P_2)^2 T_2 + \cdots + (Pi)^2 Ti + \cdots + (Pk)^2 Tk}{T_1 + T_2 + \cdots + Ti + \cdots + Tk}}$$

$Wt = Wi + (Pe/100)^2 \times Wc$

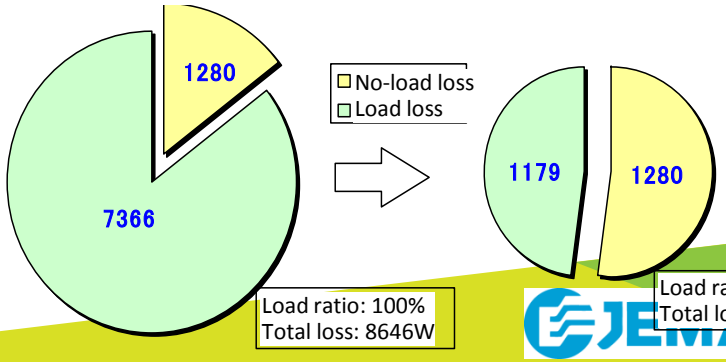
Wt: Total loss (W)

Wi: No-load loss (W)

Wo: Load loss in rated operation (W)

Pe: Average equivalent load ratio (W)

Example: Product before Top Runner, three phase, 500kVA, conforming to JIS4304



7 PROMOTION OF DIFFUSION

Basic Policy for Diffusion

The interim report of the Transformer Criteria Subcommittee recommended the followings for energy conservation:

1. **Efforts of the government**
   From the viewpoint of diffusing transformers with excellent energy consumption efficiency, the government should take measures necessary for diffusion and awareness-raising to promote the efforts of users, manufacturers, etc.
2. **Efforts of the manufacturers, etc.**
   a) Promote technological development for further energy conservation of transformers and make effort to develop products with excellent energy consumption efficiency.
   b) From the viewpoint of diffusing transformers with excellent energy consumption efficiency, make efforts to provide appropriate information so that users can choose a transformer with excellent energy conservation performance and proper capacity in addition to the catalog and instruction manual of the product. For example, show the energy consumption efficiency on a noticeable part of the material provided by manufacturers, etc. for selection of products by users.
3. **Efforts of the users**
   When purchasing a transformer, choose one with excellent energy consumption efficiency and proper capacity, and use the transformer suitably and efficiently for further energy conservation.

Efforts of JEMA

According to the recommendation shown on the previous slide, JEMA promotes the followings for diffusion of Top Runner Transformer 2014.

Promote product development

Establish standard

PR activity
Diffusion activity

***** Efforts other than improving the energy consumption efficiency *****

- **Propose the concept of earthquake-resistance.**
- **Increase commonality of accessories (dial thermometer).**
- **Include an oil scavenging valve or plug as a standard component. (75 - 2000kVA model)**
- **Increase commonality of connection part of the secondary terminal.**

8 SUMMARY

To All the Parties Concerned

With regard to Top Runner Transformer 2014 that contributes to environmental conservation, because a transformer is equipment used in power distribution facilities, understanding and cooperation by business entities concerning construction, electric facilities, design and distribution boards that use a transformer is important. The transformer industry wishes to hear your opinion and will work toward development and commercialization of new transformers. We appreciate it if you cooperate with us so that the users who use a transformer now or plan to use it know the importance of environmental conservation as well as the energy consumption effect, and bear a part for promotion of diffusion.

トップランナー変圧器
2014
2014年度省エネ基準適合品

E O F

Thank you very much for your attention.

The Japan Electrical Manufacturers' Association