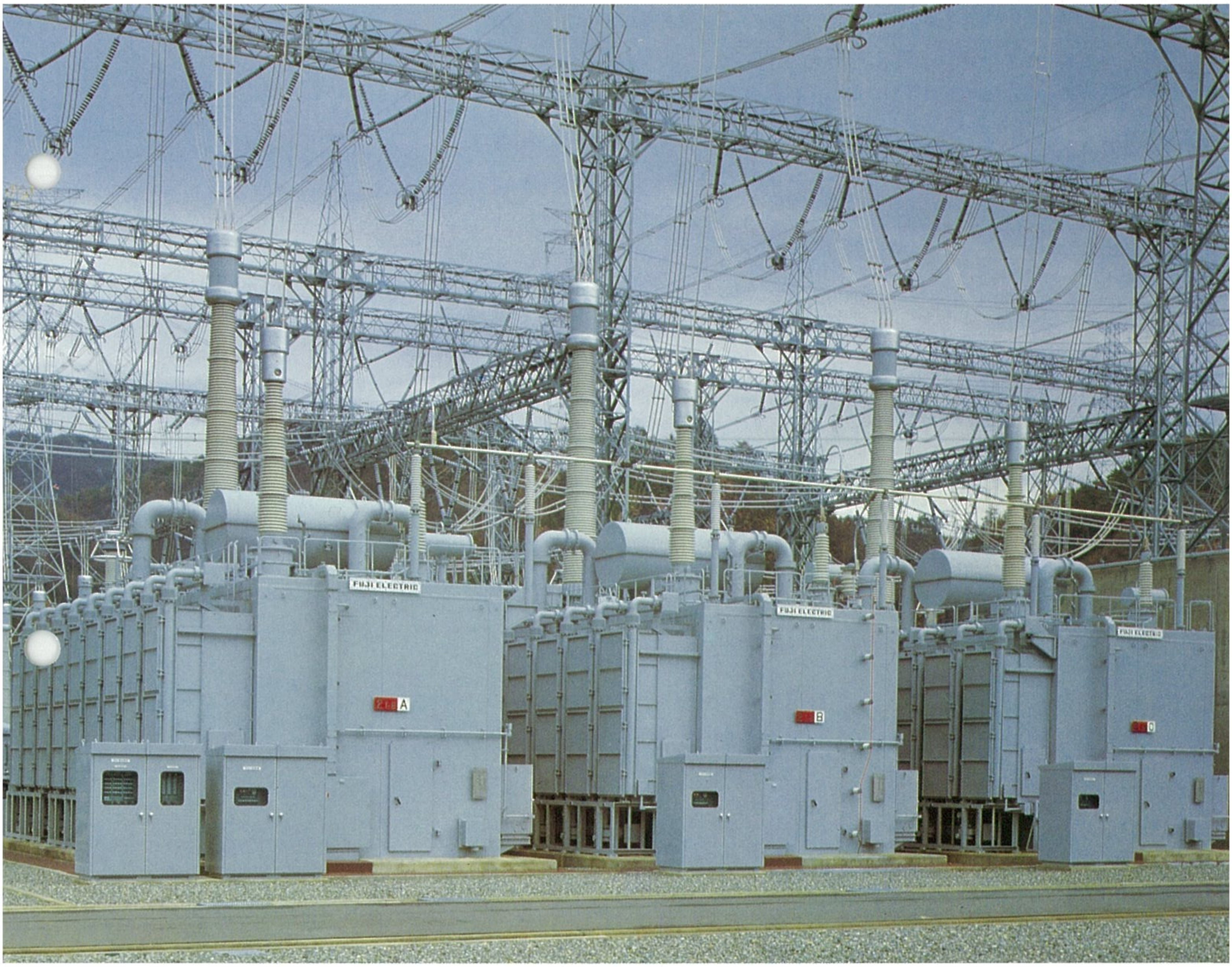
Fuji Electric

Innovating Energy Technology

Large-capacity Transformers



08A1-E-0001

Contents

N89-2838-1

Photo 1 UHV Testing-transformer single phase $\frac{1550}{\sqrt{3}}$ kV 50Hz

Features

Fuji large-capacity transformers are the result of an extensive engineering effort and R & D over many years along with the most advanced and greatly dependable techniques of Fuji plus the technological skills of Trafo-Union AG in West Germany. The transformers are made in a large-scale exclusive shop equipped with new facilities including computers, dust-proof air-conditioning equipment, etc. Fuji has already built and delivered a number of transformers, beginning with the 500kV, 900MVA (bank capacity) on-load tap-changing autotransformer for the Bonneville Electric Power Agency in the U.S., and all of them are successfully operating in the field. The techniques of FUJI have made these transformers superior to those of other firms. The features are as follows.

● Well-arranged core construction

The core is made of top-class Hi-B (high magnetic flux density) oriented silicon steel plate with improved exciting characteristics such as core loss, exciting current, magnetostriction, etc. In order to fully display these characteristics, the core is tightened uniformly with tempered plastic bands and also a core erection equipment is employed, thus making it small-sized and lightweight together with low noise level.

● Winding construction with highly reliable insulation

For the windings of extra high voltage transformers, a high series capacitance disc winding, in which potential oscillation in the winding is suppressed to a minimum when impulse voltage is applied, and an oscillation-free cylindrical layer winding have been adopted. The insulation in the windings, across windings and across winding and ground has been made very reliable as a result of numerous fundamental experiments and with the analysis and improvement of potential distribution and insulation strength by utilizing a computer. Also, all extra high voltage and large-capacity transformers are given a partial discharge test (corona test) to verify the insulation reliability before leaving the plant.

● Great short-circuit resistance of windings

The windings have been designed based on experience including short-circuit strength tests with a number of actual models, and by accurate computer calculation of electromagnetic mechanical force during an external short-circuit. Besides, these windings are tightened securely with a tightening torque corresponding to the electromagnetic mechanical force, together with pretightening treatment. Thus, sufficient short-circuit resistance can be maintained over a long time.

● Assembled style transportation system

With the object of maintaing the high insulation performance obtained at the plant till the time of field erection, and at the same time minimizing the facilities and working days necessary for the field erection, an assembled style transportation system.

● Low noise level

for noise abatement from long ago and has produced the unique enclosure types such as concrete enclosure, prefabrication type multi-enclosure and so on, of which a large number have been delivered. They cut down the noise produced from transformers to as low as 30 to 40dB, and greatly contribute to noise abatement at large-capacity power stations and substations in urban areas.

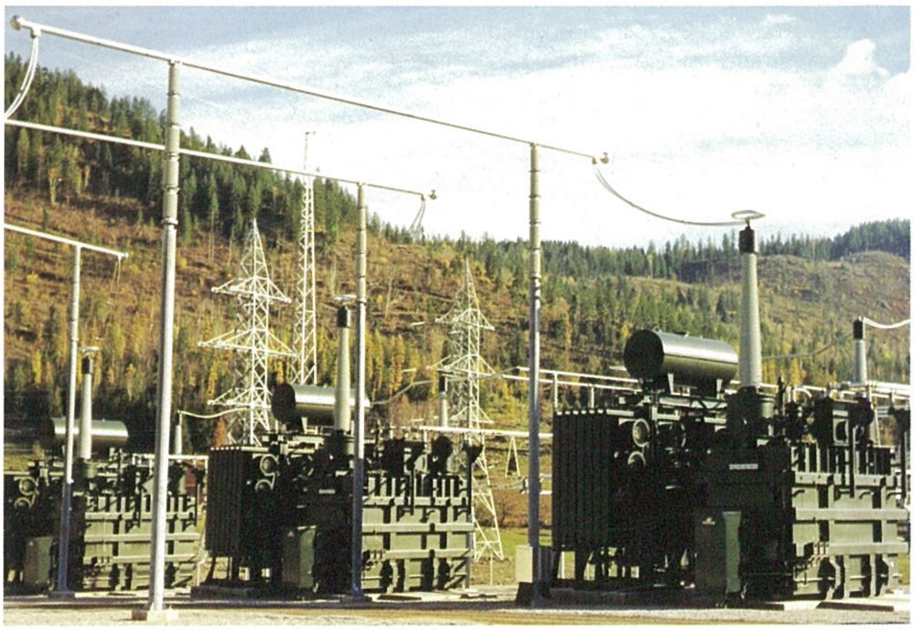


Photo 2 **Extra high voltage outdoor type ONAN/ONAF/OFAF cooling, single phase autotransformer with off-load tap-changer**

60Hz $\frac{5125}{\sqrt{3}}/\frac{242}{\sqrt{3}}/$ 12.6kV,

$\frac{1200}{3}/\frac{1200}{3}/\frac{150}{3}$ MVA

(Bank capacity 1200MVA)

Internal Construction

Core

The core construction is the so-called core type, and three-phase, three-leg core and single-phase, central leg core are used as standards. Further, the hithertomanufactured cores include a single-phase, two-leg one, three-phase, five-leg one, and other specially-constructed cores. The core plates are made of ordinary oriented silicon steel strip, Hi-B (high magnetic flux density) oriented silicon steel strip , etc. For tightening the cores, all main legs are tightened with tempered plastic bands using synthetic resin-impregnated glass tape, and the yokes are secured with a tempered plastic band or center duct tightening bolt system. (Photo 3)

Such tightening systems offer the following advantages:

- Since there are no holes in the core plate, it provides for easy machining and improves the characteristics.
- The core tightening bolts are cooled directly by insulation oil since they pass through the oil duct.
- Because of using the tempered plastic bands, the core plate ends can be tightened securely. Thus, it helps reduce vibration and noise.
- As a result of improving the space factor of core, the transformer can be made compact and lightweight.

The surface of silicon steel plate is inorganic and has great heat resistivity, and besides, it is covered with a film which is stable chemically and possesses high resistance. The core is retained with a unique beam type frame when required, and pre-tightening force and electromagnetic force are borne by the connecting plate of upper and lower frames for preventing undue stress from working on the core, as well as maintaining good no-load characteristics. When machining the core, thorough correction of warp resulting from cutting the steel plate and/or annealing (continuous annealing) for removing strains generated in the cutting process is done with the top-level technological skills in this field. For a large core, a special core erection equipment is used in order to prevent strains from occurring when setting the stacked cores upright. (Photo 4)

Photo 3 Tightening system with tempered plastic bands AC290455

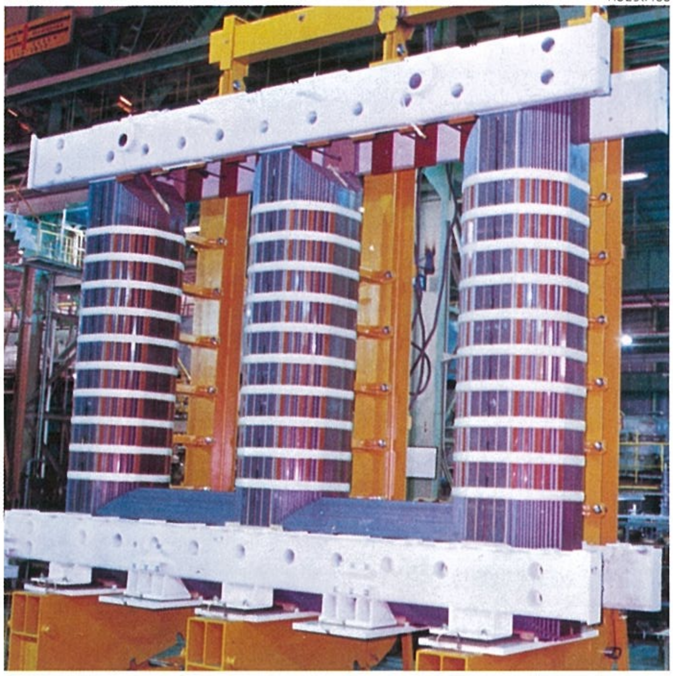


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Photo 4 Core erection equipment AC291508

AC291508

Photo 5 Automatic cutting equipment of core

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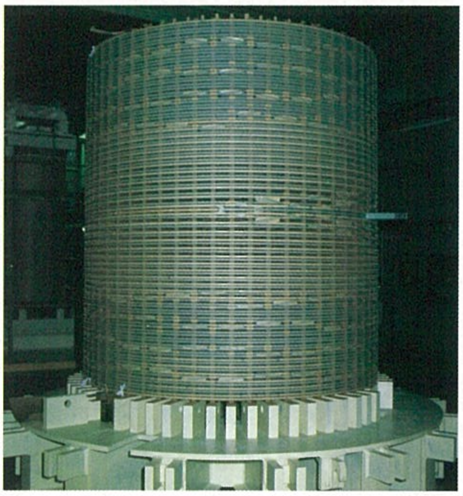

Photo 6 Disk winding

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Windings

Various new windings have been developed in addition to the conventional twin coil disc winding, and according to the purpose of use, the optimum winding is selected from those listed below so that the specific characteristics can be fully utilized. A great quantity of windings have already been manufactured and delivered, and are now operating smoothly.

1) For low voltage and large current;
   - Cylindrical layer winding (using transposed conductor)
   - Helical winding
2) For high voltage and surge protection;
   - High series capacitance disc winding
   - Oscillation-free cylindrical layer winding
3) For wide-range tap;
   - Multi-parallel cylindrical tap winding

As the winding conductor, a transposed conductor has been employed besides the conventional rectangular copper wire to cope with the recent increase in transformer capacity. The transposed conductor is made as follows; with the finely-divided rectangular conductors each insulated with synthetic resin consisting mainly of polyvinyl formal, the odd-numbered conductors are arranged in two rows as shown in Fig. 1, the mutual positions of conductors are transposed in turn at a certain pitch (this is called "transposition"), and with these conductors put together as a unit, the same electric insulation kraft paper as used for ordinary rectangular copper wires is wound thereon for insulation. When this transposed conductor is used, the following merits are available:

- Reduction in stray-load loss in winding
- Prevention of local overheat in winding
- Improvement in characteristics, and accomplishment of light-weight and compact transformers
- Decrease in the number of connecting parts in winding

In high voltage twin coil or single coil disc winding, as shown in Fig. 6, an electrostatic shielding ring is provided at the winding end to ease electric field concentration, and at the same time improve impulse voltage distribution inside the winding and ensure high safety of insulation.

Also, a continuous type winding is employed in principle to reduce the intermediate connection of conductors and better the quality of winding, providing great safety.

For the winding for low voltage and large current, a cylindrical layer winding using the aforementioned transposed conductor or a helical winding is employed according to the magnitude of current. Each of these windings has little stray-load loss and very great mechanical strength. (Fig. 2)

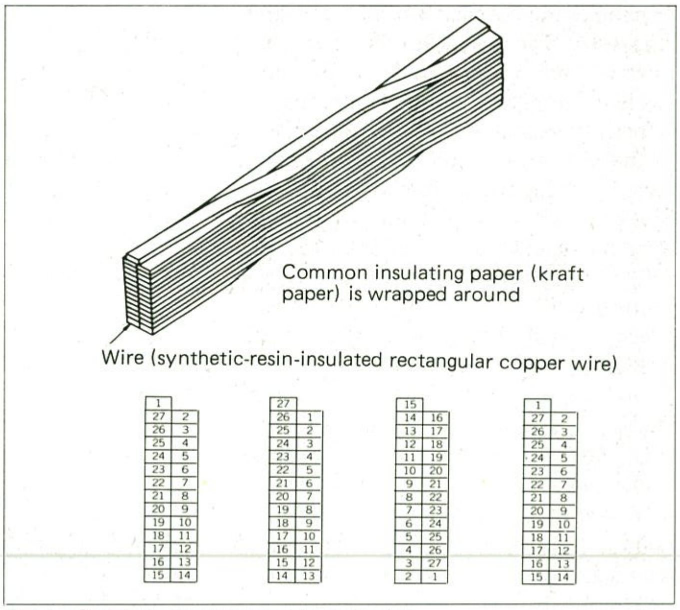
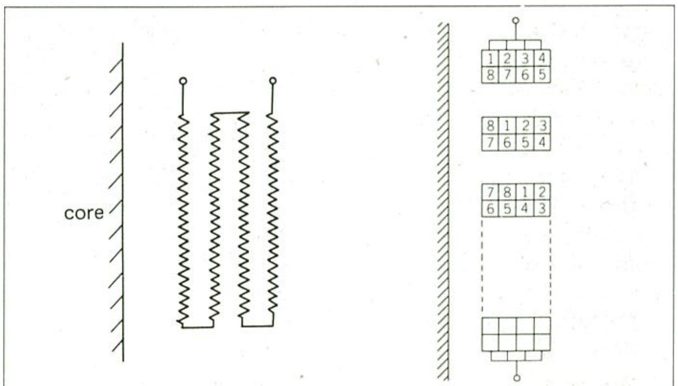
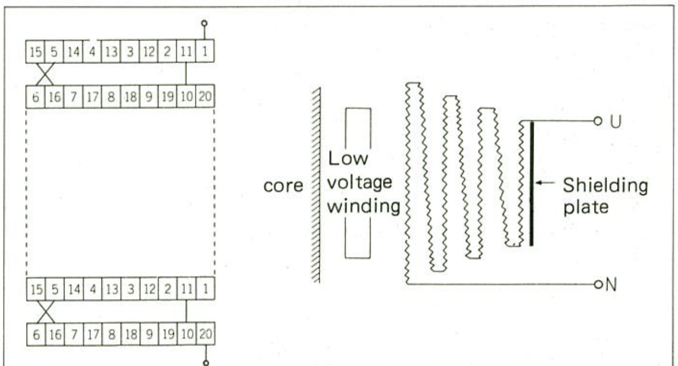


Fig. 1 Continuously transposed conductor



(a) Cylindrical layer winding **(b) Helical winding**

Fig. 2 Winding for low voltage, large current

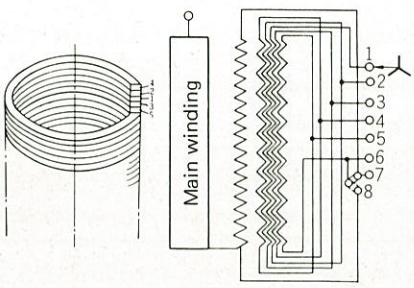


(a) High series capacitance disc winding **(b) Oscillation-free cyrindrical layer winding**

Fig. 3 Winding for high voltage and surge protection

The high series capacitance disc winding is a kind of high series capacitance winding, in which impulse voltage characteristic has been improved by increasing the effective series electrostatic capacitance of the winding considerably with connection across coils intercombined.
When impulse voltage is applied in this winding, whether it is chopped wave or full wave voltage, the voltage distribution is uniform (Photo 7) and no over-voltage is generated thus ensuring uniform insulation at each part in the winding. Therefore, it is well usable for ultrahigh voltage and superhigh voltage windings. Also, when current capacity increases, the effective series capacitance can further be increased by assembling a number of conductors in the winding in the form of a comb, whereby it is suitable even for large-capacity transformers.
The oscillation-free cylindrical layer winding also has a superior impulse voltage characteristic like the high series capacitance disc winding. Since this winding can use the transposed conductor by way of its construction, it is fit for the ultrahigh voltage and superhigh voltage windings with a large current capacity in particular.
As mentioned, Fuji can provide two types of surge-protected windings for ultrahigh voltage and superhigh voltage to enable selecting the optimum winding according to the circumstances such as voltage, capacity, restriction on transportation and so forth.
The multi-parallel cylindrical tap winding is made by putting a few conductors together, winding them cylindrical and connecting in series, as shown in Fig. 4 at any tap position, axial electromagnetic force produced in the winding is very little, and also, because of a close statical connection between conductors, abnormal voltage appearing across taps is significantly small in case of entry of impulsive voltage.

Fig. 4 Multi-parallel cylindrical tap winding



Cylindrical tap winding

Arrangement of windings

Fig. 5 Voltage distribution versus impulse full wave (by computer)

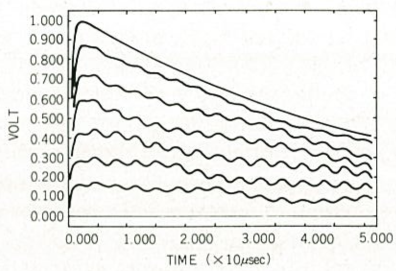
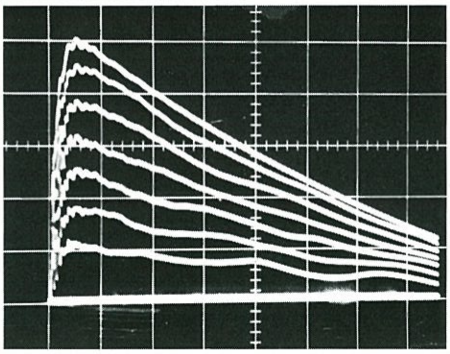
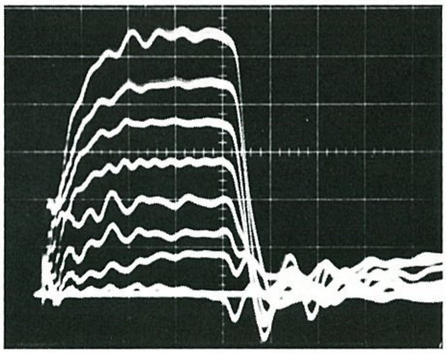


Photo 7 Internal potential oscillogram of high series capacitance disc winding



(a) Voltage distribution versus impulse full wave (by measurement)



(b) Voltage distribution versus impulse chopped wave (by measurement)

Photo 8 Test with analyzer model

Insulation

For insulation across windings, and across winding and ground, a so-called divided oil duct construction (Fig. 6) is adopted which divides the oil gap finely with pressboard barriers. This construction has been established based on the data acquired through continued fundamental research and by following the standards for a sufficient safety factor. Further more, Fuji has succeeded in plotting potential distribution with a computer shown in Photo 9 for ensuring completeness and preventing a partial electric field concentration.

The impulse voltage characteristic was examined at full length in the process of design, based on a number of research results obtained in theoretical analysis with a computer on a model as large as the actual equipment, and tests performed with the utilization of a transient phenomena direct reading unit. As a result, sufficient reliability of insulation has been ensured.

The insulating paper and pressboard used for the windings are dried by a high vacuum drying oven after completion of internal assembly and impregnated with deaerated oil under high vacuum condition. Also, upon completing the transformer, it is subjected to a partial discharge test to be sure that there is absolutely no partial discharge generated, and reliability of insulation is confirmed.

Fig. 6 Divided oil duct insulation construction

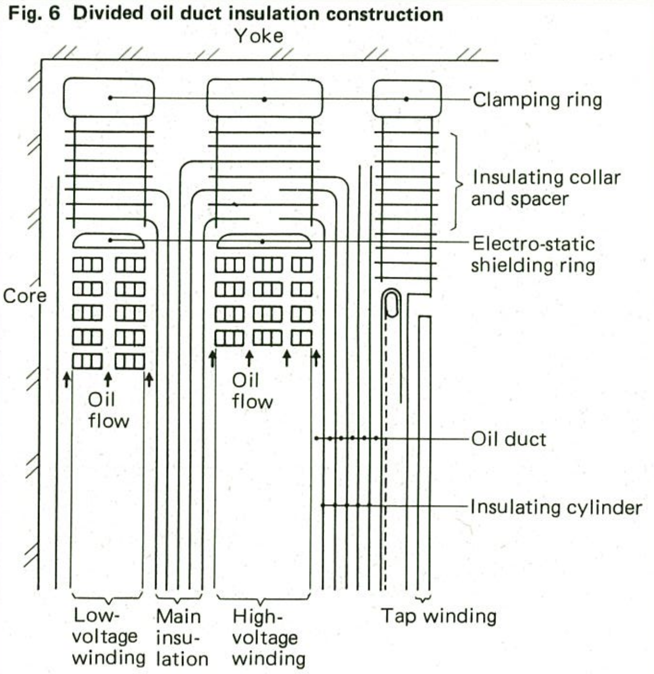


Photo 9 XY plotter

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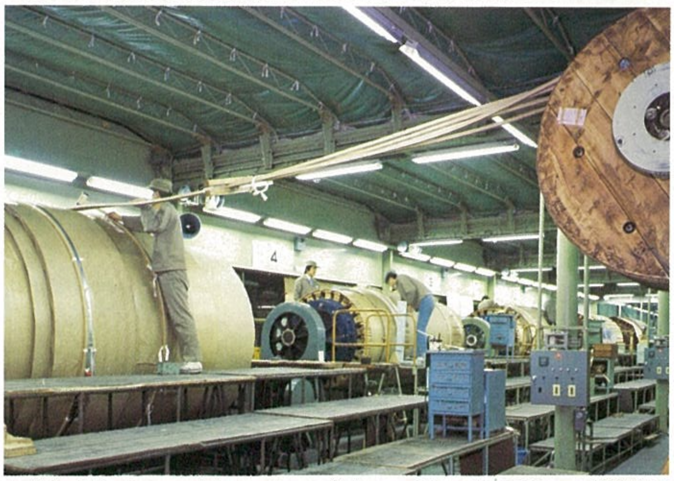
Photo 10 Interior of dust-proof air-conditioned room



▲ **(a) Winding work in dust-proof air-conditioned room** N89-1465-5

▼ **(b) Assembling of active parts in dust-proof air-conditioned room**

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Cooling System

The optimum cooling system will be selected out of the following according to the customer's requirements and also taking into account the transformer capacity and circumstances at the installation site.

1) Oil-immersed self-cooled type
2) Oil-immersed forced-air-cooled type
3) Oil-immersed forced-oil self-cooled type
4) Oil-immersed forced-air forced-oil cooled type
5) Oil-immersed forced-oil water cooled type. . . .(Photo 12)

In a large core, the core internal temperature rise is kept under the limit by providing a cooling oil duct at right angles to the steel plate stacking direction.
For the winding, an oil duct is installed in the coil as required for obtaining a high cooling effect. Especially for a forced-oil transformer having multiwindings, oil flow is measured by making a full-sized section model so that temperature rise at each part of the winding becomes uniform. (Photo 11)

For the self-cooled radiator, a panel type radiator is used as a standard.
For the transformers of more than 50MVA, the forced-oil forced-air-cooled system will be economical. The radiator used for the forced-oil forced-air-cooled type transformers has been furnished with Fuji's unique arrangements for assuring a high cooling effect, and as a result, the cooling device has become considerably compact and loss of auxiliaries has lessened.
The forced-oil self-cooled type is used when intending mainly to minimize noise produced by the cooler. In this case, a noise suppressor is provided for the transformer proper or the transformer is installed indoors, and a self-cooled radiator is installed separately.
The water-cooled type has the merit that it can be installed in a relatively small space, and when good quality cooling water is assured, it will be employed on request.
Water-cooled type unit cooler is installed outside the transformer to facilitage maintenance, checks and cleaning. (Photo 12)

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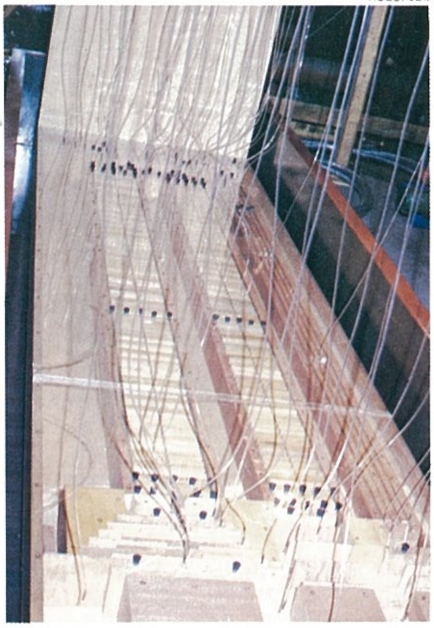

Photo 11 Winding section model for oil flow research

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Photo 12 Forced-oil water-cooled outdoor transformer of three-phase 60Hz 500MVA and 24/432kV

Characteristics and Mechanical Strength

Characteristics

Fuji will make transformers to provide the highest efficiency within the limits where economy is not lost. Because of a great improvement in quality of steel plate and well-arranged core construction, no-load loss is ordinarily not more than 30% of total loss. In relation, to the load loss occupying the majority of the total loss, as a result of employing a transposed conductor, achieving non-magnetization of metal adjacent to the winding, and providing a magnetic shielding of tank inner wall, stray-load loss has been reduced significantly whereby transformers with high efficiency and little loss have been created.

Recently, electric power systems have become steadily larger and the unit capacity of transformers has also increased sharply. The resultant tendency is that transformers are being operated under more gruelling system short-circuit conditions, and such cases have already arisen where it is better to make impedance voltage larger than the standard for keeping the short-circuit capacity as small as possible.

The values of impedance voltage across the primary and tertiary, and secondary and tertiary of a three-winding transformer can be set easily to the value you specify with Fuji's unique built-in reactor.

Table 1 Standard impedance voltage

Nominal voltage [kV]	Impedance voltage [%]
22	8.5
33	8.5
66	9.5
77	9.5
110	10
154	11
187	12
220	13
275	14

Mechanical Strength

Required for transformers is that they be able to withstand a large electromagnetic force attributable to a ground fault and/or short-circuit of lines or loads. For this purpose, it is essential to minimize the force generated and at the same time keep the winding secure so it won't loosen with the force.

Fuji transformers are so arranged as to minimize the axial force by aligning magnetic centers to make the axial discrepancy between windings facing each other zero, and by dividing the tap section into a few blocks.

For a wide range tap, the unique multi-parallel cylindrical tap construction is used so that very little axial force is generated. Also, electromagnetic mechanical force generated in the short-circuit winding is calculated by computer and based on the results of calculation, the short-circuit resistance of the winding itself and pre-tightening force to be applied to the winding are determined. And, careful consideration is given to provide sufficient short-circuit resistance overall. Concerning this, it has been confirmed that the winding is highly reliable form the results of recent tests on short-circuit strength carried out with many model coils and actual transformers.

The winding itself is given a full pre-tightening (Photo 13) and drying treatment and aging of the insulating material due to secular change is done completely to enable many years of usable free of trouble. The winding is clamped securely with a strong coil holder retained by a sturdy frame and connecting plate so that it can sufficiently bear the electromagnetic force generated in the event of a short-circuit.

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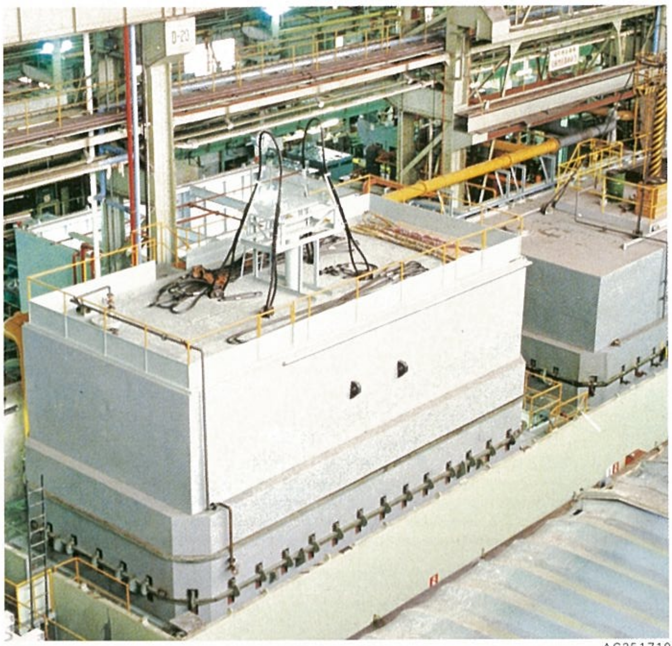
Photo 13 Pretightening of coil

Drying

Photo 14 Vapor phase drying furnace



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The core and coils of the transfomer is dryed by the vapor phase drying method. This is a method to blow kerosene vapor on assembled core and coils in the furnace, and to evaporate moisture in the insulation by the condensation latent heat which is discharged from kerosene vapor during its liquefaction. The winding is uniformly heated up to the inner parts without the intervention of oxygen and at the same time cleaned by liquefied kerosene.
This method has an advantage in obtaining a stable quality of the insulation in a short drying time. (Photo 14)

Assembled Style Transportation

Photo 15 Transformer lifted with 350t gin pole crane

AB290184

Transformers are factory assembled prior to shipment to provide excellent insulation performance when installed in sites.
The Chiba Factory of Fuji possesses an exclusive quay and shipping facilities. Upon completion of shop tests, transformers are carried to the quay by means of air casters and are loaded in ships by gin pole cranes.

Transformers of Various Constructions

Photo 16
Elephant type forced-oil forced-air-cooled on-load tap-changing transformer of three-phase 60Hz, 300/300/90MVA, 275/154/33kV

Photo 17
Transformer directly coupled to SF_6 gas insulated metalclad switchgear

Photo 18
Fully-fitted transportable type transformer with on-load tap-changer of three-phase 50Hz, 10MVA, 64.5/6.9-3.45kV

Elephant Type Transformer

In cases where there is a possibility of transformers being damaged by salt, dust, harmful gas and so on, or where it is necessary to utilize the space more efficiently and/or avoid danger which might come about as a result of the live section having been exposed, it is recommended that an elephant type transformer be employed in which the transformer outlet is directly connected to cables. (Photo 16)
Fuji is prepared to make such a transformer on request.
Fuji manufactured the first 66kV elephant type transformer in Japan in 1959, and subsequently continued to research the insulation construction of elephant section and method of connecting directly to cables. This system is now being adopted positively for ultrahigh voltage large-capacity transformers.

Photo 16

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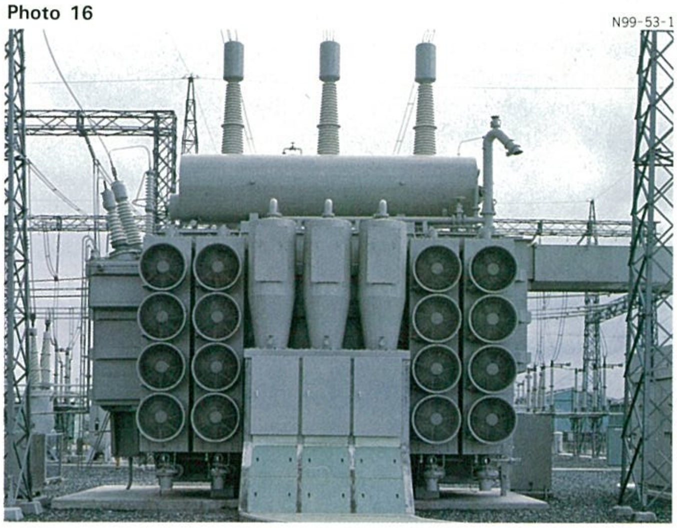

Transformer Directly Coupled to GIS

This transformer is made by connecting an SF_6 gas insulated metalclad switchgear (GIS) with superior arc suppression and insulation performance of SF_6 (sulfur hexafluoride) gas directly to the transformer, for making the electric power circulation equipment compact as well as ensuring high reliability and safety from the social needs accompanying the overpopulated cities. (Photo 17)
In relation to mixing of insulation oil and SF_6 gas, uneven setting, transmission of oscillation and so forth full consideration has been given in the construction of the transformer.

Photo 17

N99-908-13

Fully-fitted Transportable Type Transformer

This transformer eliminates erection work at the site and is convenient for transport. Fuji is also manufacturing such transformers. (Photo 18)
In short, it is transportable in completely assembled status within the limits on rolling stock together. With such accessories as bushing radiator, conservator, etc. kept installed. This type is now manufacturable up to 77kV, 10MVA.

Photo 18

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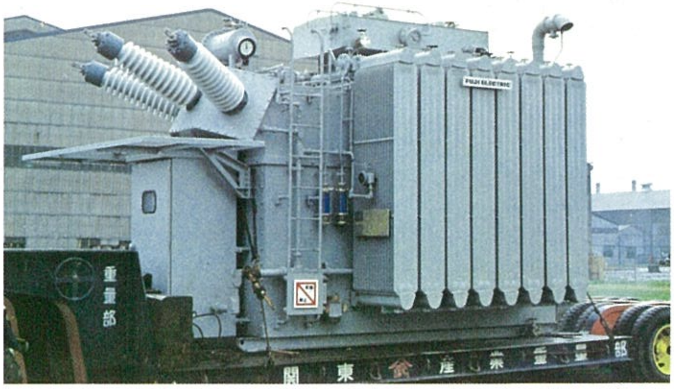

Photo 19
On-load tap-changing low-noise transformer with prefabrication type multi-enclosure, three-phase, 60Hz, 250MVA, 275/77kV, noise level of 53 dB

Photo 20
On-load tap-changing low-noise transformer with prefabrication type multi-enclosure, three-phase, 60Hz, 250/250/60MVA, 220/110/66kV, noise level of 55 dB

Photo 21
Sound-proof concrete enclosure type on-load tap-changing transformer, three-phase, 60Hz, 450/450/135MVA, 275/154/31.5kV, noise level of 55 dB

Low Noise Transformer

These days, there are many cases where large-capacity transformers are installed in the vicinity of residential areas as the demand for electric power increases. As a result, it is being strongly requested to suppress noise produced by the transformers as far as possible, as a part of the countermeasures pertaining to environmental problems. Fuji, in order to meet the diversified requirements for noise suppression of transformers, has already established a series of noise suppression techniques. In particular, Fuji's on-load tap-changing low-noise transformer with prefabrication type multi-enclosure (Photo 19 and 20) and sound-proof concrete enclosure type on-load tap-changing transformer (Photo 21 and Fig.8) are matchless and epoch-making products having the advantage that noise is 25 to 40 dB below the standard level. These are widely used as low noise large-capacity transformers and highly appreciated among users. The transformer noise conforms to the standard noise level provided by NEMA Pub. No. TR1 (Table 3) in principle. Measurement of noise level is made according to NEMA Pub. No. TR1. Transformer noise is such in general that the magnetostriction oscillation of core is transferred to the tank through the oil transmission route and solid transmission route, and it oscillates the tank wall and is dispersed outside as a sound.

In order to reduce the magnetostriction oscillation of core which is the major noise source, the core is made of top-class Hi-B (high magnetic flux density) oriented silicon steel plate with little magnetostriction, and distortion resulting from machining is eliminated by means of a continuous annealing furnace. Also, the core is clamped securely with tempered plastic bands. For preventing the tank from oscillating the tank reinforcements have been arranged properly to negate resonance, and also, oil-proof rubber has been installed between core and tank which prevents solid transmission from core to tank. Further more, the foundation of transformer proper has been separated from that of sound-proof concrete enclosure with antivibration material for reducing noise as much as possible. (Fig. 7)

A vitally important factor to be taken into account when manufacturing a low-noise transformer is how to suppress noise produced by the cooler. For this, Fuji has completed a low-noise fan as a result of development of vanes by which air noise has successfully been reduced and a multi-pole motor series with little magnetic noise. Also, with the development of a low-noise pump and modification of the arrangement of radiating pipes, a superlow-noise forced-air cooler (Fig. 9) of which sound level is 45 dB, or under the conventional level, has been accomplished. This will make it possible to manufacture a forced-oil and forced-air-cooled transformer of 50 dB.

Table 2 shows a series of low-noise coolers.

Photo 19

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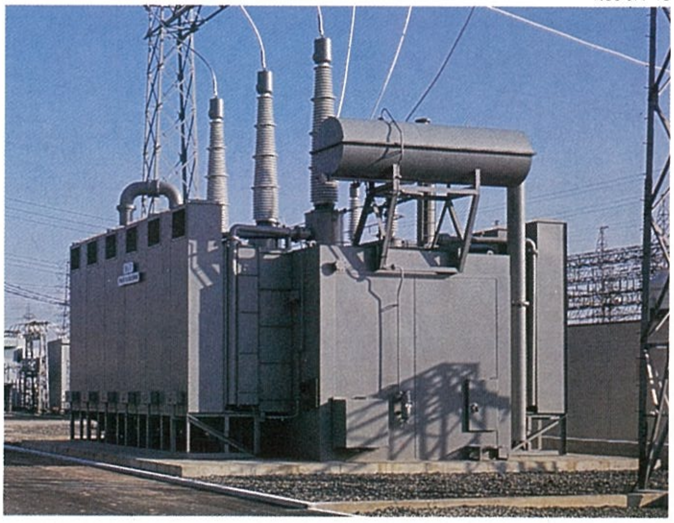

Photo 20

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Photo 21

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Fig. 7 Construction of sound-proof enclosure

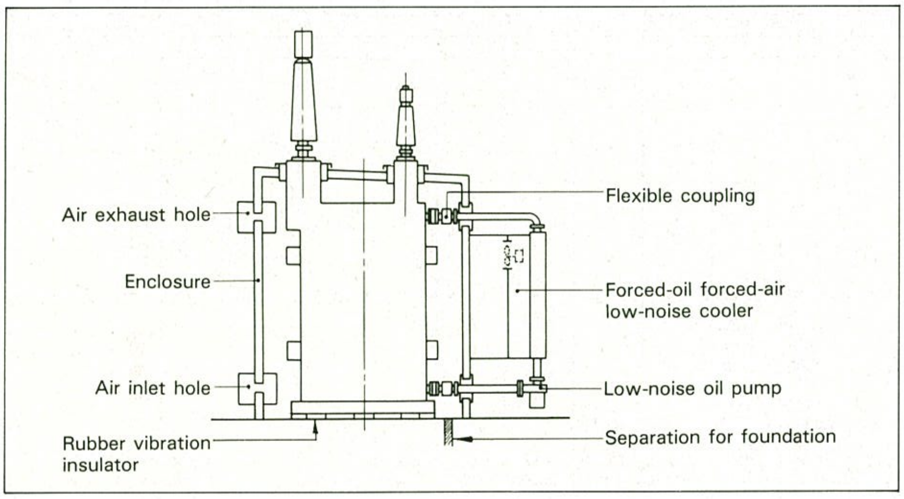


Fig. 9 Construction of forced-oil forced-air cooler for low noise level

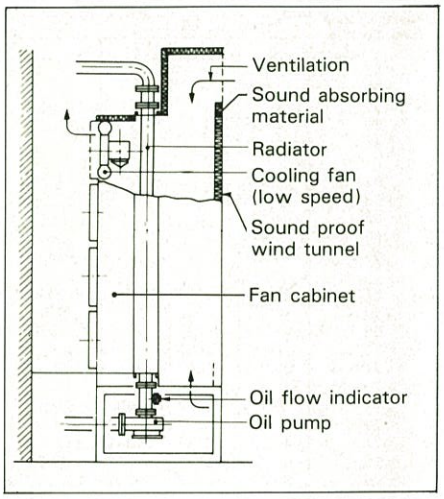


Fig. 8 Construction of sound-proof concrete enclosure

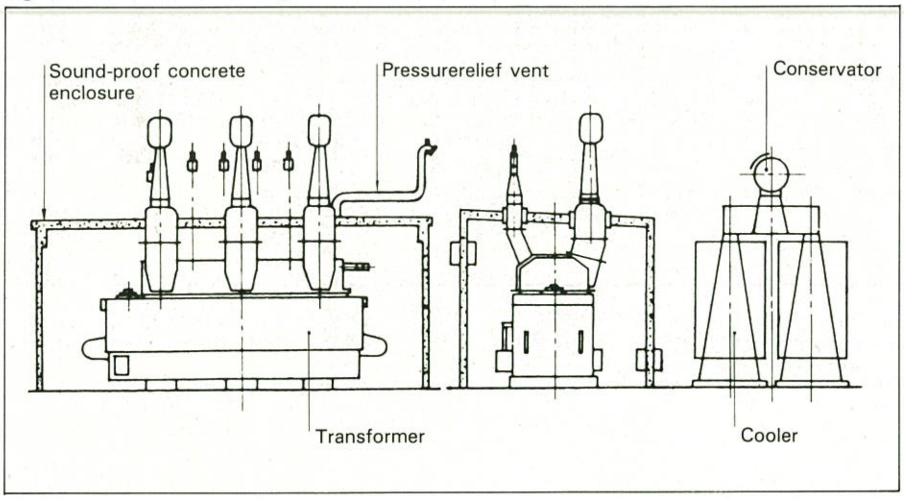


Table 2 Series of forced-oil forced-air coolers (60Hz)

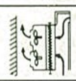
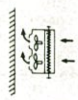
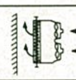
Transformer noise [dB]	Cooler noise [dB]	No. of poles of fan motor [P]	Construction of cooler
50	45	20	
55	50	16	
60	55	20	
65	60	16	
70	65	12	
75	70	10	
80	75	8	
85	80	6	

Table 3 Audible sound levels for oil-immersed power transformers (NEMA Pub No.TR1)

Average sound level, decibels	Equivalent two-winding rating +																	
	350 kV BIL and below			450, 550, 650 kV BIL			750 and 825 kV BIL			900 and 1050 kV BIL			1175 kV BIL			1300 kV BIL and above		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
57	700	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
58	1000	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
59	—	—	—	700	—	—	—	—	—	—	—	—	—	—	—	—	—	—
60	1500	—	—	1000	—	—	—	—	—	—	—	—	—	—	—	—	—	—
61	2000	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
62	2500	—	—	1500	—	—	—	—	—	—	—	—	—	—	—	—	—	—
63	3000	—	—	2000	—	—	—	—	—	—	—	—	—	—	—	—	—	—
64	4000	—	—	2500	—	—	—	—	—	—	—	—	—	—	—	—	—	—
65	5000	—	—	3000	—	—	—	—	—	—	—	—	—	—	—	—	—	—
66	6000	—	—	4000	—	—	3000	—	—	—	—	—	—	—	—	—	—	—
67	7500	6250#	—	5000	3750#	—	4000	3125#	—	—	—	—	—	—	—	—	—	—
68	10000	7500	—	6000	5000	—	5000	3750	—	—	—	—	—	—	—	—	—	—
69	12500	9375	—	7500	6250	—	6000	5000	—	—	—	—	—	—	—	—	—	—
70	15000	12500	—	10000	7500	—	7500	6250	—	—	—	—	—	—	—	—	—	—
71	20000	16667	—	12500	9375	—	10000	7500	—	—	—	—	—	—	—	—	—	—
72	25000	20000	20800	15000	12500	—	12500	9375	—	—	—	—	—	—	—	—	—	—
73	30000	26667	25000	20000	16667	—	15000	12500	—	12500	—	—	—	—	—	—	—	—
74	40000	33333	33333	25000	20000	20800	20000	16667	—	15000	—	—	12500	—	—	—	—	—
75	50000	40000	41667	30000	26667	25000	25000	20000	20800	20000	16667	—	15000	—	—	12500	—	—
76	60000	53333	50000	40000	33333	33333	30000	26667	25000	25000	20000	20800	20000	16667	—	15000	—	—
77	80000	66667	66667	50000	40000	41667	40000	33333	33333	30000	26667	25000	25000	20000	20800	20000	16667	—
78	100000	80000	83333	60000	53333	50000	50000	40000	41667	40000	33333	33333	30000	26667	25000	25000	20000	20800
79	—	106667	100000	80000	66667	66667	60000	53333	50000	50000	40000	41667	40000	33333	33333	30000	26667	25000
80	—	133333	133333	100000	80000	83333	80000	66667	66667	60000	53333	50000	50000	40000	41667	40000	33333	33333
81	—	—	166667	—	106667	100000	100000	80000	83333	80000	66667	66667	60000	53333	50000	50000	40000	41667
82	—	—	200000	—	133333	133333	—	106667	100000	100000	80000	83333	80000	66667	66667	60000	53333	50000
83	—	—	250000	—	—	166667	—	133333	133333	—	106667	100000	100000	80000	83333	80000	66667	66667
84	—	—	300000	—	—	200000	—	—	166667	—	133333	133333	—	106667	100000	100000	80000	83333
85	—	—	400000	—	—	250000	—	—	200000	—	—	166667	—	133333	133333	—	106667	100000
86	—	—	—	—	—	300000	—	—	350000	—	—	200000	—	—	166667	—	133333	133333
87	—	—	—	—	—	400000	—	—	300000	—	—	250000	—	—	200000	—	—	166667
88	—	—	—	—	—	—	—	—	400000	—	—	300000	—	—	250000	—	—	200000
89	—	—	—	—	—	—	—	—	—	—	—	400000	—	—	300000	—	—	250000
90	—	—	—	—	—	—	—	—	—	—	—	—	—	—	400000	—	—	300000
91	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	400000

Column 1: Class* OA, OW and FOW ratings
2: Class* FA and FOA first-stage auxiliary cooling**
3: Straight FOA* ratings, FA* FOA* second-stage auxiliary cooling**

* Classes of cooling (see 2.6.1 of American National Standard C57.12.00-1973).
** First-and second auxiliary cooling (see TR 1-0.02)

+ The equivalent two-winding 55°C or 65°C rating is defined as one-half the sum of the kVA rating of all windings.
# 67 decibels for all kVA ratings equal to this or smaller.

Note) 1. For intermediate kVA ratings use the average sound level of the next larger kVA rating.
2. For column 2 and 3 ratings, the sound levels are with the auxiliary cooling equipment in operation.

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