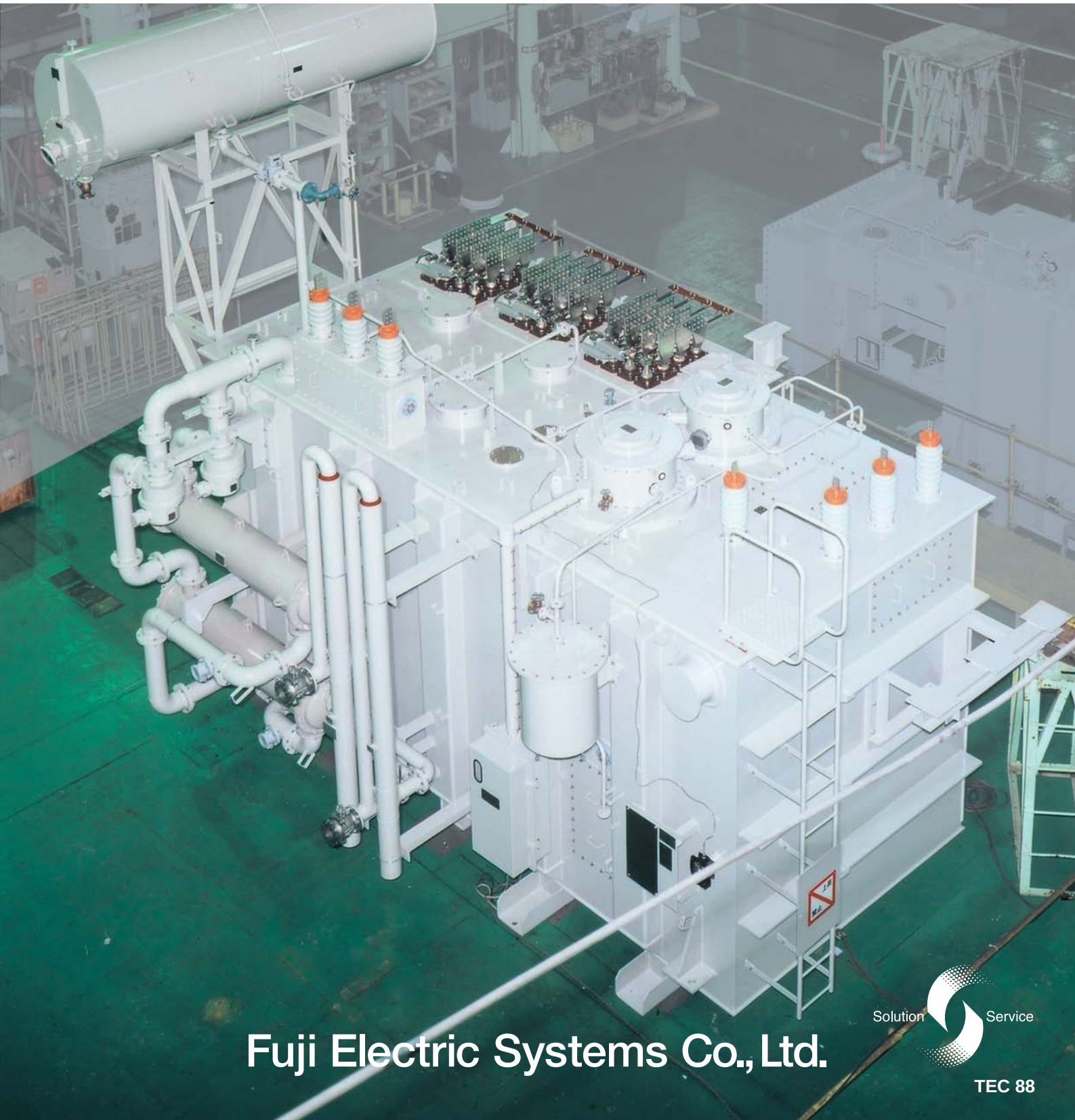
e-Front runners

Electric Furnace Transformers



Fuji Electric Systems Co., Ltd.

Solution Service

TEC 88

Fuji's Furnace Transformers promise customers optimum performance based

Fuji Electric began the production of electric furnace transformers in 1929, and had belivered 463 units totaling 9,441MVA as of March 2002. The transformers are produced at a special, large factory equipped with state-of-the-art equipment such as dustproof air-conditioning equipment (clean room). Our transformers are backed by continuing research and development in the latest technologies.

Features of electric furnace-use equipment

Highly frequent load interruption

Steel making arc furnaces and certain kinds of ferroalloy smelting furnaces require dozens of interruptions a day. When the furnace capacity is large, direct power receiving from 60kV, 70kV, or higher power systems is more economical and power loss can be decreased.

Power-factor correction and harmonics filter capacitor

In an electric furnace, AC power flows at a low voltage and high current. Since a slight reactance in the circuit will have a great influence, the power-factor is normally 70 to 85% and so a power-factor correction device is necessary. When the arc changes during furnace operation or in DC furnaces, harmonics are generated by the rectifier itself, and so equipment that will decrease such harmonics is necessary.

Flicker compensation

In steel making arc furnaces, flicker occurs due to the voltage fluctuation of the power system caused by the arc changes during furnace operation. Hence, most large furnaces are equipped with flicker compensators.

Series reactor

To enable flicker compensation and stable operation, a series reactor can be inserted.

Advantages of electric furnace transformer

Optimum core construction

The laminated cores are built up of grain-oriented silicon steel plate that has excellent magnetic characteristics such as iron loss, exciting current, and magnetic distortion. To make full use of these excellent magnetic characteristics, the cores are securely and equally clamped by reinforced insulating cylinders and wedges, thus achieving a lighter and more compact construction.

Winding construction suitable for low-voltage and high-current

Multi-parallel twin coil disc windings are adopted for the secondary windings. Sufficient transfer between parallel conductors makes the current distribution between parallel conductors uniform, so load loss is reduced and local overheating avoided. Hence, these windings are ideal for low-voltage high-current application.

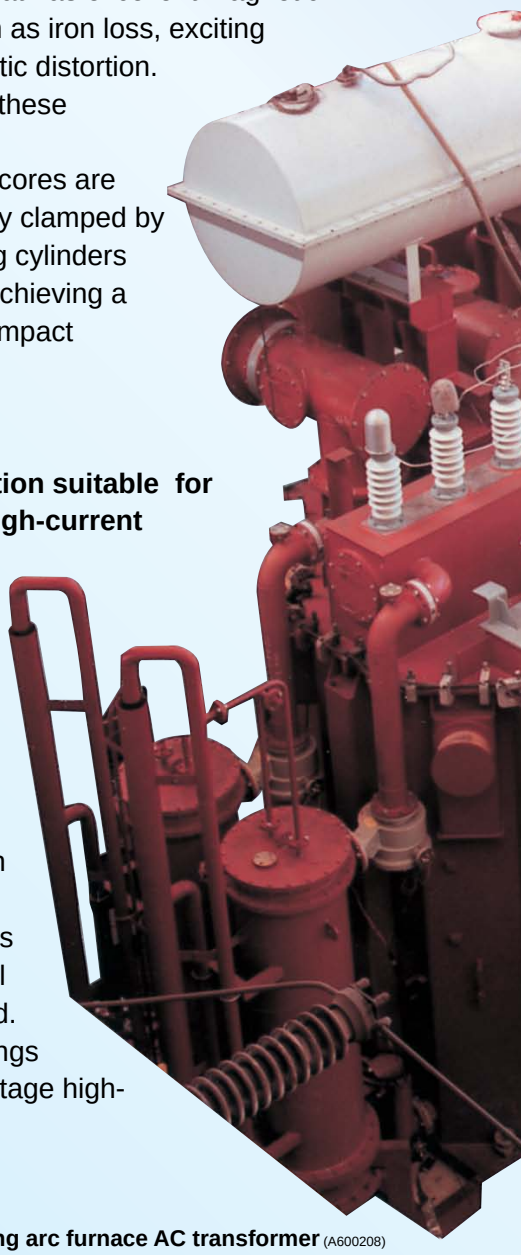
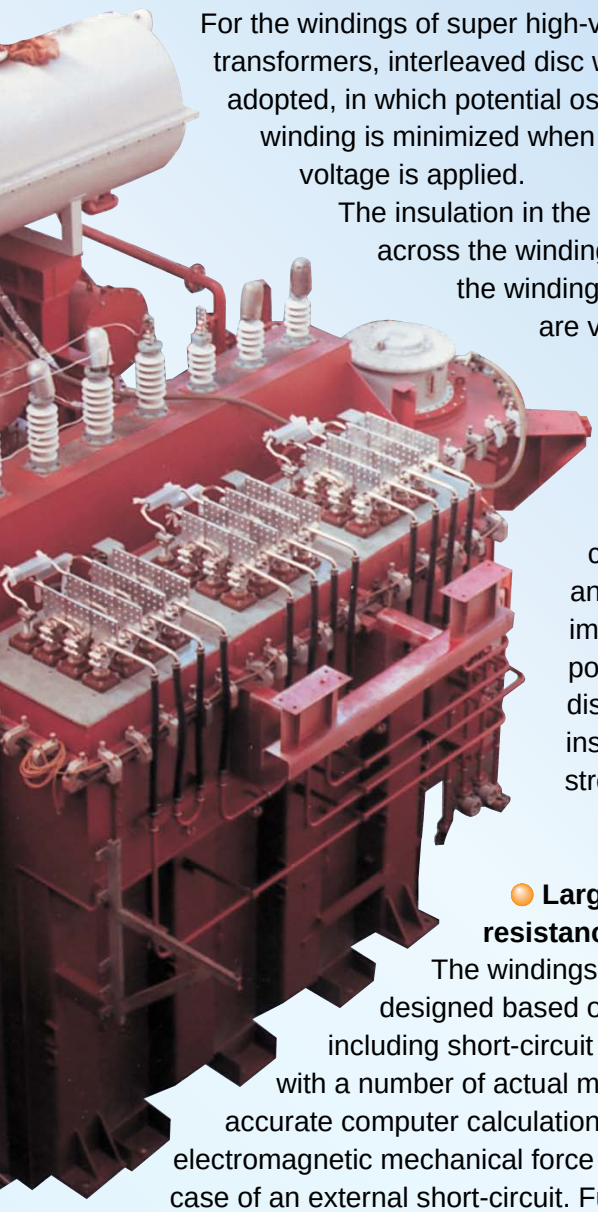


Photo 1 Steel making arc furnace AC transformer (A600208)

on our wealth of experience with electric furnace facilities.

Applicable furnaces
- Steel making arc furnace (AC, DC)
- Ladle refining furnace
- Ferroalloy smelting furnace
- Special furnace (graphitizing furnace, ash melter, carbon silicon reactor, etc.)



Winding construction with highly reliable insulation

For the windings of super high-voltage transformers, interleaved disc windings are adopted, in which potential oscillation in the winding is minimized when an impulse voltage is applied.

The insulation in the windings, across the windings and across the winding and the ground are very reliable, thanks to numerous fundamental experiments as well as computer analysis for improving the potential distribution and insulation strength.

Large 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 the electromagnetic mechanical force generated in case of an external short-circuit. Furthermore, these windings are tightened securely with a tightening force corresponding to the electromagnetic mechanical force, together with pre-tightening treatment, ensuring, that sufficient short-circuit resistance is maintained over a long time.

Highly reliable, high quality transformer

It is very important to prevent the insulating surfaces from being contaminated by moisture and dust during internal assembly, because this contamination would affect the insulation reliability. Thus, all stages including insulator processing, winding and assembly are carried out in a dustproof air-conditioned room, where special measures are taken to prevent dust being produced by moving machinery and overhead cranes, and vacuum cleaners are used as well. These measures result in highly reliable, high quality transformers. After assembly, strict drying as well as vacuum oil treatment to ensure complete impregnation is carried out in a vacuum drying oven.

Highly frequent, reliable on-load tap changer

Fuji was the first in the world to develop a vacuum bulb type on-load tap changer based on the resistance changeover system. The on-load tap changer has an expected service life of more than one million electrical operations and five million mechanical operations.

Optimum oil preservation system according to environment

The best suited oil preservation system from open type, rubber-cell type, and diaphragm-sealed type can be installed according to the environmental conditions and the cooling system.

Voltage Regulation System and Connections System

For the steel making arc furnace, the furnace transformer's secondary voltage must be greatly changed to control the input power to the furnace according to the melting and smelting periods of scrap. Similarly, for the smelting furnace, because of furnace internal resistance, production control and forming of self-baking electrodes, the secondary voltage has to be changed. In general, the ratio of maximum to minimum secondary voltage is required to be high value such as 2:1 or 3:1.

Output voltage regulating method

Direct system : Method to obtain various secondary voltages by changing over the equivalent taps provided on the primary side (Table 1, 1).

Indirect system : A series transformer is installed on the secondary side, and a tertiary winding (tap winding) is wound on the main transformer (Tables 1, 3 and 4). The taps of the tertiary winding are changed over to regulate voltages applied to the primary side of the series transformer, thereby changing the secondary induced voltage of the series transformer to obtain the desired output voltage.

Photo 2 DC transformer for steel making arc furnace

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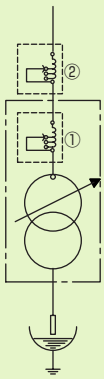
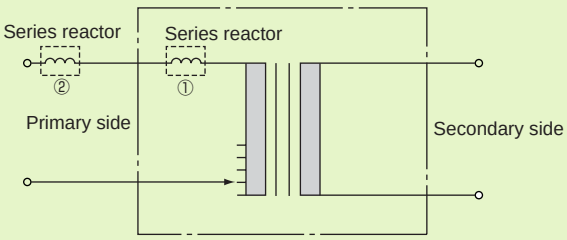
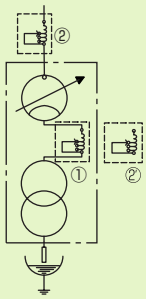
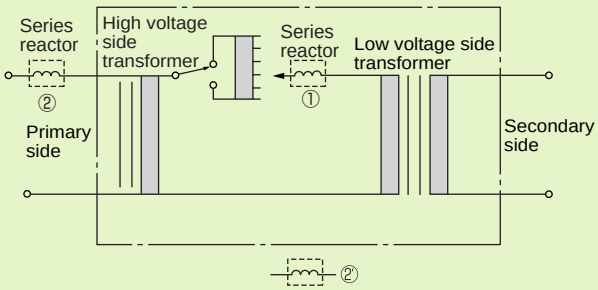
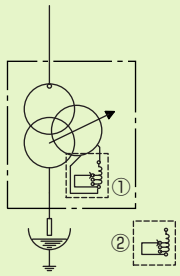
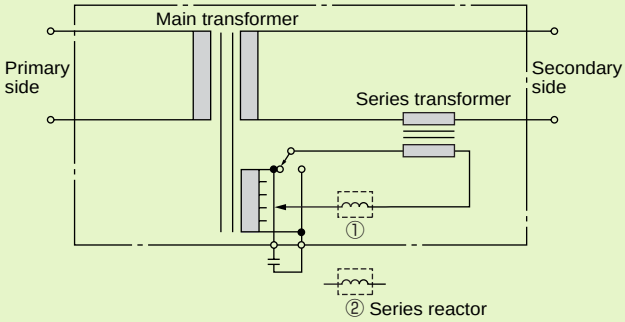
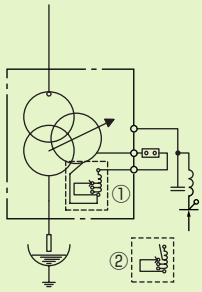
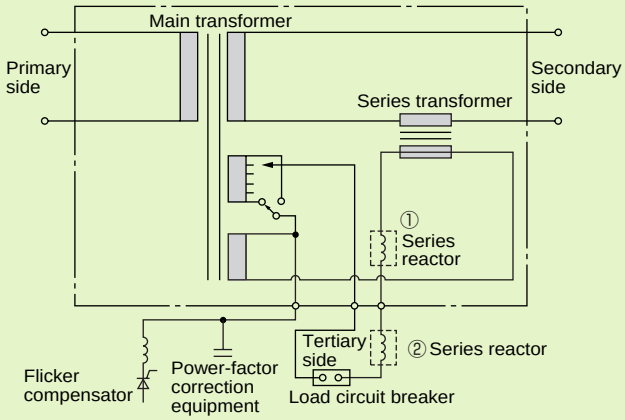
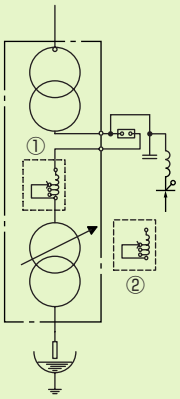
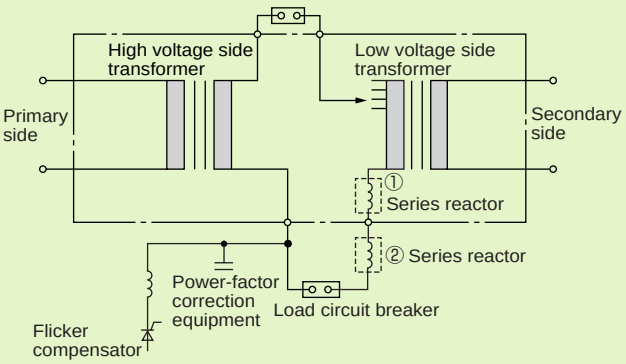
Table 1 Output voltage regulating method

Single-line diagram	Internal connection system of transformer	Features and operating conditions
1 Direct system 		**Operating conditions** 1) The voltage regulating range should be comparatively narrow (approx. 2:1). However, if required, the voltage range can be widened by $\sqrt{3}$ times by changing the primary winding to △-⅄ connection. 2) The tap voltage steps do not have to be equal values. 3) The primary voltage should be 77kV or less. 4) The power-factor correction and harmonics filter equipment, flicker compensator and series reactor should be connected on the primary side. **Features** 1) The one-core, two-windings construction is an economical arrangement. 2) The power loss is small. 3) The impedance is low.
2 Auto-transformer built-in direct system 		**Features** 1) Applicable to transformers of insulation class, Class 30 or less (BIL 200kV or less) with a wide tap regulating range. 2) The power-factor correction and harmonics filter equipment, flicker compensator and series reactor can be connected on the primary side ② or secondary side ①, ② of the high voltage side transformer.

Single-line diagram	Internal connection system of transformer	Features and operating conditions
3 Indirect system  	 	**Features** 1) The series transformer permits the voltage regulating range to be chosen freely. 2) An arbitrary primary voltage can be selected. 3) The tap voltage step is equal. 4) The power-factor correction and harmonics filter equipment, flicker compensator and series reactor (built-in type ① and external connection type ②) can be connected to the tertiary side.
4 Indirect system  	 	**Features** 1) The series transformer permits the voltage regulating range to be chosen freely. 2) Since the load interruption is carried out on the tertiary side, the primary voltage can be reduced by one step from 60 to 200kV. 3) The power-factor correction and harmonics filter equipment, flicker compensator and series reactor (built-in type ① and external connection type ②, can be connected to the tertiary side. The equipment can also be connected to the fourth windings depending on the voltage and capacity, instead of to the tertiary windings, if necessary.
5 Step-down transformer built-in direct system  	 	**Operating conditions** 1) Since two transformers with the same capacity must be housed in the same tank, the facility becomes large and heavy. There should be no restriction on transportation and installation space. **Features** 1) Although the features are the same as item 4 above, the primary side circuit can be completely isolated from the secondary side circuit by the load circuit breaker.

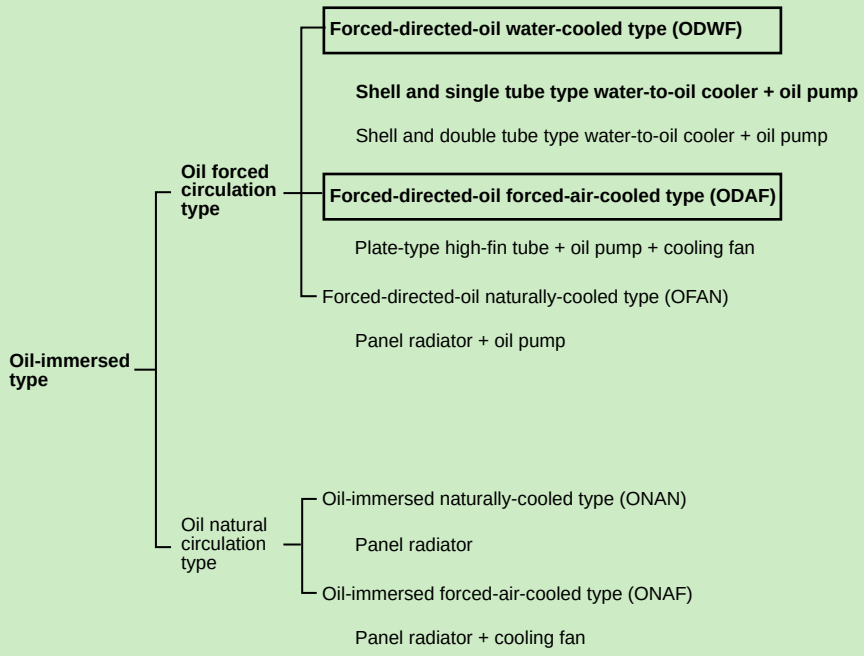
Mechanical Strength

The key characteristics of furnace transformers are sufficient robustness to withstand the large electromagnetic forces caused by the frequent short-circuits inside the furnace, load fluctuations, or short-circuit of the winding. The windings should be sufficiently tightened to resist these forces and not become loose. Generated electromagnetic forces also should be suppressed as much as possible.
Fuji furnace transformers are carefully manufactured so as to minimize the axial magnetic forces, by matching the magnetic centers of the individual windings to make the axial displacement between the mutual windings zero, and also by distributing the tap winding section into several blocks.
In the case of wide range voltage regulation, using multi-parallel cylindrical tap windings makes the axial electromagnetic forces almost negligible. Electromagnetic forces generated at short-circuited windings are calculated by computer, and based on the result, the short-circuit strength of windings themselves and pre-tightening force given to the windings are determined. Hence, meticulous measures are taken to ensure excellent strength. The reliability of windings and short-circuit strength have also been confirmed with many model coils and actual transformers.
Sufficient pre-tightening and drying treatment of windings are performed to minimize the aging of insulating materials so that trouble-free operation is ensured for many years. The windings are tightened with the connecting plates and strong windings presses supported by hard frames, so the windings can easily withstand the electromagnetic force generated when a short-circuit occurs.

Cooling Method

The optimum cooling method can be selected according to the customer's requirement, taking into account the transformer's capacity and installation location.

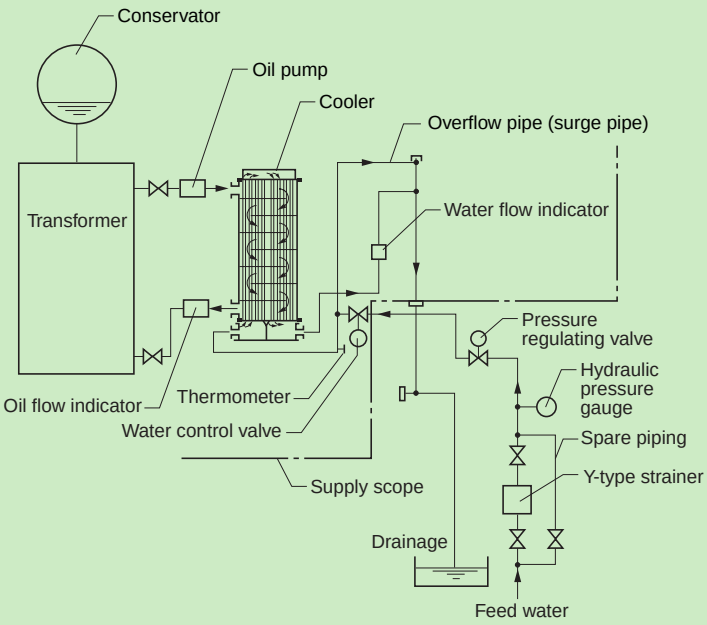
Fig.1 Cooling method



In the above figure, the two types enclosed by ▭ are mostly adopted. Fuji's standard is shown in boldface.
For the large-sized core, the temperature inside the core is kept within the limit by providing cooling oil ducts at right angles to the laminating direction of the core plates.
Oil ducts are also installed in the windings, if necessary, to increase cooling effect. For most large-capacity transformers having multi-windings, forced-oil cooling is employed to avoid local temperature rise.

The forced-directed-oil water-cooled type (ODWF) requires less space and is most suitable for furnace transformers that must be placed adjacent to the furnace. The water pressure of Fuji's single tube type water cooler is always kept lower than the oil pressure by providing an overflow pipe (surge pipe) at the inlet of the water cooler. In case the heating tube is damaged by corrosion, water penetration into transformer is prevented. A double tube type water cooler is also available by special request.

Fig. 2 Piping diagram of forced-directed-oil water-cooled type (ODWF) cooler (single tube type water cooler)



Feature

The water pressure of Fuji's single tube type water cooler is always kept lower than the oil pressure by providing an overflow pipe (surge pipe) at the inlet of the water cooler. In case the heating tube is damaged by corrosion, water penetration into transformer is prevented.

Photo 3 External view of water-cooled type cooler

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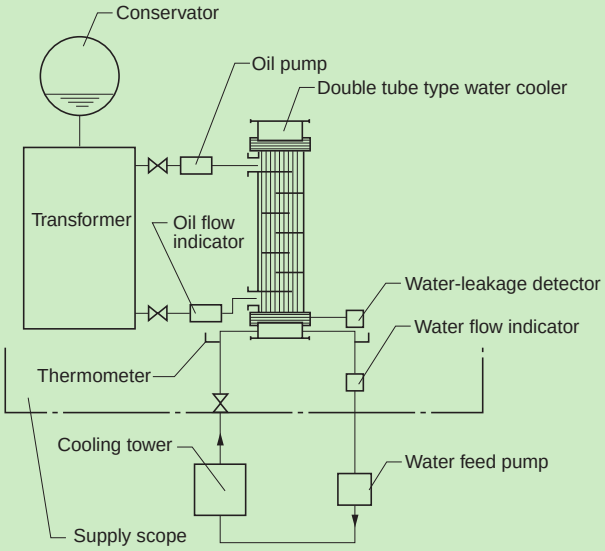
Fig. 3 Piping diagram of forced-directed-oil water-cooled type (ODWF) cooler (double tube type water cooler)



Feature

In case of a double tube type cooler, even if the heating tube on the water side is damaged by corrosion, watertightness is maintained by the heating tube on the oil side. The leaked water from the gaps between the double tubes is vented into the air so that water penetration into the transformer is prevented. A detector is provided to detect the water-leakage.

Principle of double tube type water-cooled type cooler

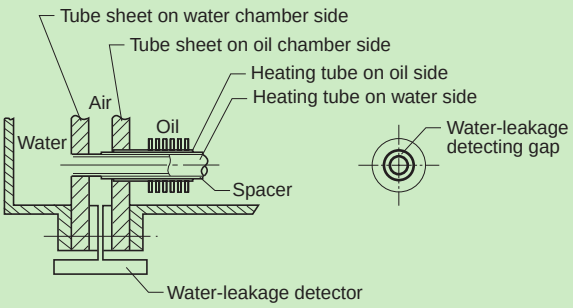
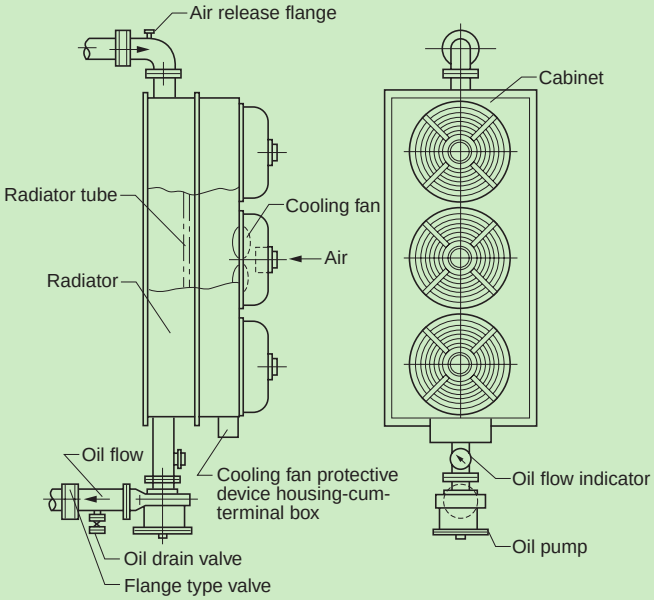


Fig. 4 Forced-directed-oil forced-air-cooled type (ODAF) cooler



Core Construction

Fuji's standard core types are classified into two types: three-phase three-leg core type and single-phase central-leg core type. Special construction types, including single-phase two-leg type and three-phase five-leg type, are also available.
Core plates are made of grain-oriented silicon steel plate, which offers improved magnetic characteristics such as iron loss, exciting current, and magnetic distortion. A tightening method combining reinforced insulating cylinders with wedges improves the core space factor and makes the transformer compact.
The principle point where a reactor is different from a transformer is that each phase has one winding and there is a gap in the magnetic circuit.
A series reactor is generally connected to the circuit in series to limit the short-circuit current of the circuit. In electric furnace equipment, a series reactor might be installed to suppress the flicker phenomenon generated from the arc furnace. In such a case, an air-core type series reactor, in which the reactance change is small against load currennt, is usually adopted. Air-core type reactors do not have iron core legs in the winding and the winding inside is a complete gap. Fig. 5 shows a typical example of its structure.
In the air-core type, shielded cores with stacked silicon steel plates are adopted to prevent the magnetic flux from heating the tank and other metal portions. Meanwhile, the proportion of the core mass of the air-core type is smaller compared with that of a transformer. To smoothly absorb the magnetic flux generated from the winding into the core, non-oriented silicon steel plates are used for the upper and lower shielded cores, and are tightened hard and optimally by tightening bolts in the piling direction.

Photo 4 External view of core before winding insertion

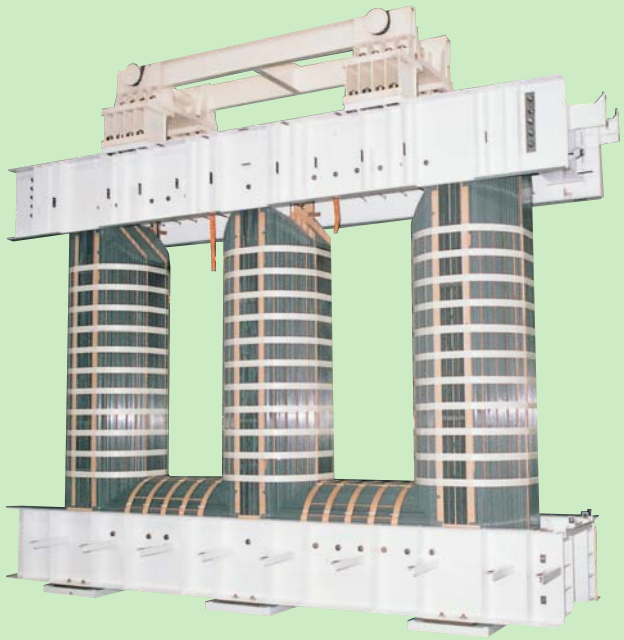


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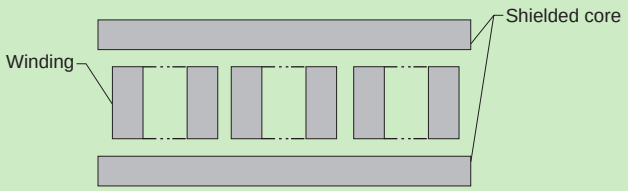
Fig. 5 Three-phase air-core type

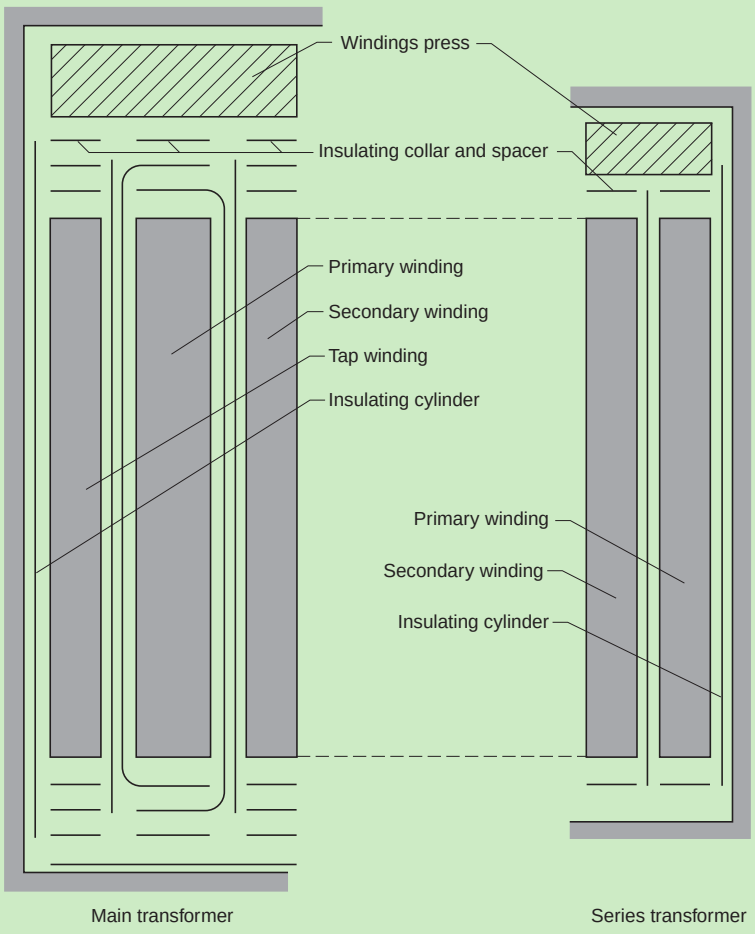


Winding Construction

The highly reliable, excellent performance windings are designed and manufactured, taking the following aspects into account.

- Windings are coaxially arranged.
  In this method, each winding is arranged coaxially against the core.
  In general, secondary low-voltage, high-current windings are arranged mostly outside. This allows easier draw-out and connection of high-current leads, resulting in more secure working (Fig. 6).
- To increase the short-circuit resistance, a unique winding construction is adopted and sufficient pre-tightening treatment and drying for the winding itself are applied.
  Adequate pre-tightening treatment and drying improve the strength against electromagnetic forces caused by frequent short-circuits inside the furnace, load variations, and short-circuits at line ends, and minimize the aging of insulating materials as well.
- Windings are usually wound continuously, reducing the number of connecting points of the conductors, for improved performance and reliability.
- As winding conductors, in addition to the conventional copper wires, flat aluminum wires are employed to reduce stray load loss, improve performance, and reduce the mass and size.

Fig. 6 Cross section of coaxially arranged windings



Winding construction

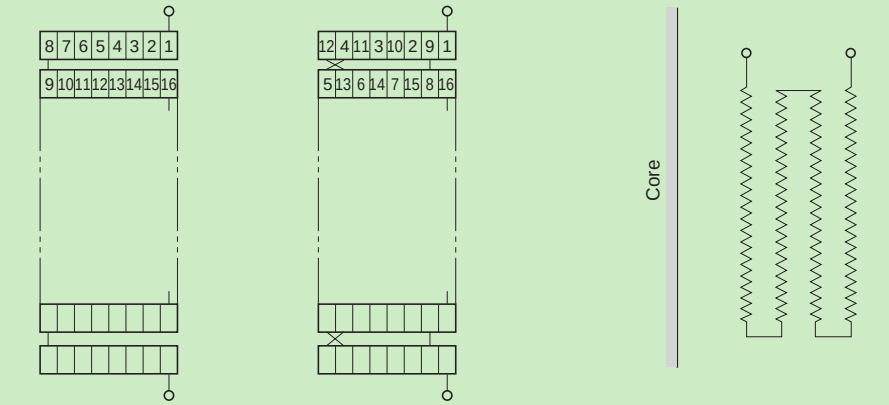
In addition to the conventional twin coil disc winding, the following various new types of winding constructions are adopted in furnace transformers depending on equipment requirements.

- For high-voltage windings
  - Twin coil disc windings
  - Interleaved (high series capacitance) disc windings
  - Cylindrical layer windings
- For low-voltage high-current windings
  - Multi-parallel twin coil disc windings
  - Helical windings
- For wide range tap windings
  - Parallel cylindrical layer tap windings

The twin coil disc windings (Fig. 7a) are wound continuously without any connecting points in the windings. When multi-parallel type conductor connection is required, these conductors are transferred at suitable points to reduce the circulating current between conductors.
The interleaved (high series capacitance) disc windings (Fig. 7b) are wound with the connection between windings interleaved with each other. The remarkably increased effective series electrostatic capacitance of the windings improves the impulse voltage characteristic. Even if an impulse voltage is applied, the voltage distribution inside the winding remains almost even and no overvoltage occurs in any part of the windings. Hence, these windings are ideal for ultrahigh voltage windings, having uniform insulation reliability at each part in the windings.
Cylindrical layer windings (Fig. 7c) show good impulse voltage characteristics similar to the interleaved (high series capacitance) disc windings.

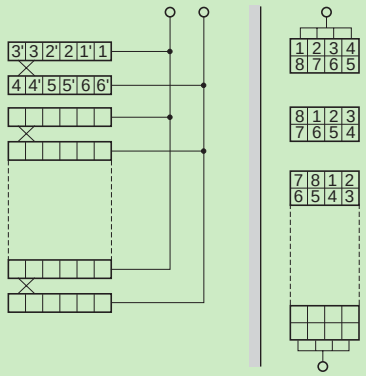
The multi-parallel twin coil disc windings (Fig. 8a, Photo 5) are constructed by axially stacking multiple twin coil disc windings. Various measures are taken both to improve the voltage imbalance between windings located in parallel and to eliminate local overheating inside the windings. When the indirect voltage regulation method is used, the windings, having a numerical "8" shaped construction, are continuously wound over the main transformer and the series transformer.
Helical windings (Fig. 8b) are used for high current windings with relatively high voltage. The windings can be made to have small stray load loss and extremely large mechanical strength by selecting the number of conductors connected in parallel depending on the current value.
The parallel cylindrical layer tap windings (Fig. 9) are made by winding several conductors on a cylinder and connecting them in series. The windings feature a very small axial electromagnetic force produced in the windings at any tap position.
A series reactor is inserted in the circuit in series to suppress flicker. Several kinds of reactance, which are not constant, are needed for the reactor. Hence, the reactor winding is a tap winding corresponding to several kinds of reactance. For the winding structure, twin coil disc winding is usually used. The tap is drawn out from the coil connecting part of the outer section of the winding.
Although a non-energizing part occurs depending on the tap position, the winding configuration is such that the non-energizing part is arranged in the center of the winding to suppress potentioal oscillation of the non-energizing part.

Fig. 7 High voltage windings



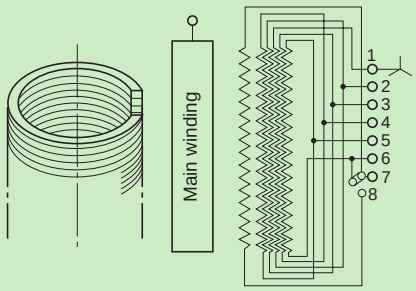
a) Twin coil disc winding
b) Interleaved (high series capacitance) disc winding
c) Cylindrical layer winding

Fig. 8 Low-voltage high-current windings



a) Multi-parallel twin coil disc winding
b) Helical winding

Fig. 9 Parallel cylindrical layer tap winding



Cylindrical tap winding
Winding arrangement

Photo 5 Multi-parallel twin coil disc windings

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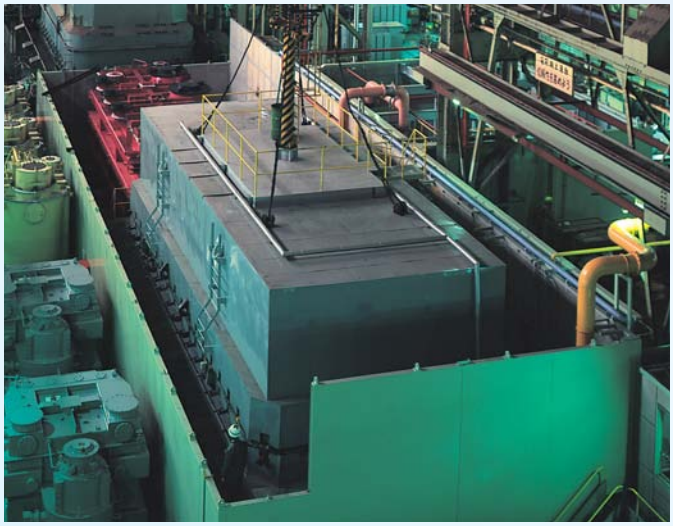
Insulation and Drying

Insulation

A divided oil duct construction, which finely divides the oil gap with pressboard barriers, is adopted for the insulation between the windings, and between the windings and the ground. This is based on data acquired through continued fundamental research and design with careful attention to safety standards.
Furthermore, in the ultrahigh voltage class, a computer calculates the potential distribution to avoid local electric field concentration, thus achieving a uniform field density. Concerning impulse voltage characteristics, computerized theoretical analysis on an actual-size model is performed, and experiments using a device for direct-reading transient phenomena have been made. In the design process, characteristics are studied in detail to ensure that insulation reliability is secured. The insulating paper and pressboard used for windings are pre-tightened and dried just before being put into the iron core, then dried thoroughly in a vapor drying oven after assembly, and the windings are impregnated with degassing oil under high vacuum.

Photo 6 Large size vapor drying oven



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Drying

The windings are alone pre-tightened and dried just before being mounted on the core to ensure the stability of dimensions and shape of the windings. The windings are tightened by the specified force, and are then subjected to vacuum heating-drying treatment.
Next, the internal part of the transformer whose core and winding assembly has been completed is subjected to vacuum heating-drying with a solvent in a vacuum vapor drying oven (Photo 7). Completion of drying is judged by measuring the insulation resistance, tan δ, the dew point and the transformer winding temperature. Because the insulation materials are re-tightened hard after they have completely shrunk by means of efficient pre-tightening, drying and vapor drying, the windings will not further shrink due to aging when in service.
When the transformer has to be dried on site due to restrictions on transportation, the hot circulating oil vacuum drying method is adopted, which requires simple equipment and can obtain good drying effect.

Photo 7 Pre-tightening and drying treatment of windings

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Termination

High voltage side

There are three types of leading-out terminals from inside the transformer. Each type has different features in terms of economy, maintenance and safety.

- **Ordinary type bushing**

A single type bushing or condenser bushing, conforming to JEC-183, IEC Pub. 137, and ANSI C76.1 are employed. The selection of suitable bushing type depends on the insulation class at the end of lines, current rating, or contamination level.

- **Elephant type bushing (including GIS direct-coupled type)**

Elephant bushings are most suitable for furnace transformers because cables are directly led into the transformer tank, no live sections are exposed, and a compact transformer can be realized, which reduces the installation space and eliminates maintenance risks. Fuji normally uses the air type construction when the insulation class at the ehd of lines is Class 30 or less (BIL 200kV or less) or the oil-immersed type when the insulation class is Class 60 or more (BIL 350kV or more).

Photo 8 shows a special elephant type unit directly coupled to SF_6 gas insulated switchgear (GIS), which makes the electricity distribution facility more compact.

- **Bus duct type**

This is a type of bushing where the ordinary type bushing and connecting conductors are covered by an air-duct, which is frequently used for Class 30 or less (BIL 200kV or less) transformers as there as there is no danger on security.

Photo 8 GIS direct-coupled elephant type bushing

N99-937-4

Photo 9 Ferroalloy furnace transformer-use ordinary type bushing

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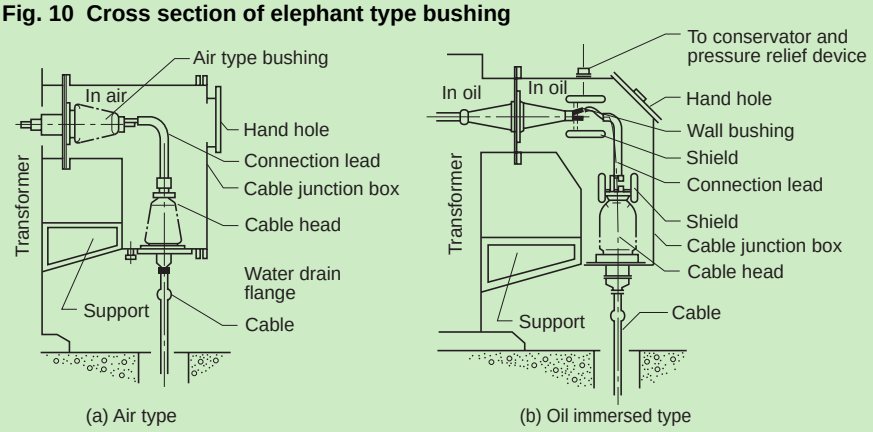
Photo 10 Oil-immersed elephant type bushing

N99-541-13

Fig. 10 Cross section of elephant type bushing



Low voltage side

The terminal structure on the secondary side of the furnace transformer has a remarkable feature on the lead-out of the high current. Fuji has developed various types of terminals, depending on electric furnace construction or other requirements. Terminals for high current can be classified into two types according to cooling method. In both methods, positive and negative terminals are led out close to each other, to minimize inductance and reactance.

● **Naturally-cooled flat-bar terminal**

The terminals are made of either electric copper or aluminum plate. Unsaturated polyester resin is used for the partition plate in the straight-through part of the conductor. The current is limited to a maximum of 13kA for each conductor plate. The terminals are modularized depending on the current (Photo 13).

● **Water-cooled type terminal**

The water-cooled type terminals are made of U-shaped seamless thick copper tube, in which the cooling water flows. Super high currents can be easily led out by increasing the parallel number of terminals. Fuji's standard model is provided with terminal top end fixtures as shown in Fig. 11 and Photo 11. We also have terminals that are cooled by common cooling water, directly connected to furnace side water-cooled conductors (Photo 12), as well as terminals that connect to the low-voltage high-current windings inside the transformer, as shown in Photo 14. Each phase is led out in a delta (△) connection with an equal distance between each lead.

Photo 11 Water-cooled type terminal

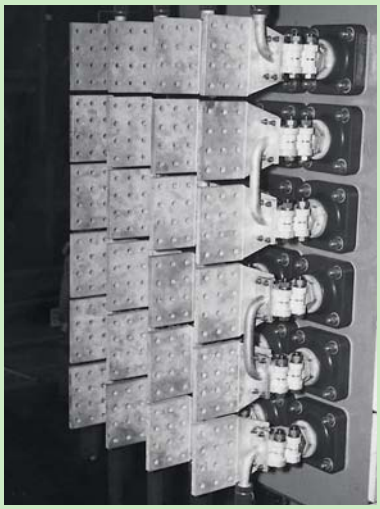


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Photo 12 Water-cooled type terminals directly connected to the furnace side water-cooled conductor

(Each terminal of upper/lower and right/left side is led out close to each other as a positive/negative terminal.)

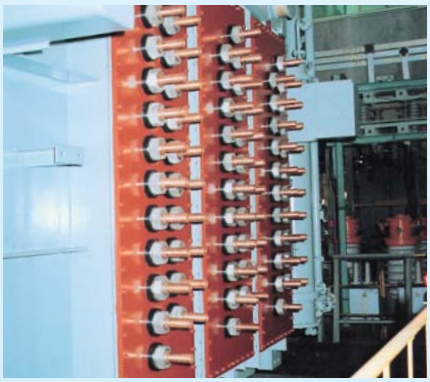

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Photo 13 High-current naturally-cooled flat-bar terminals

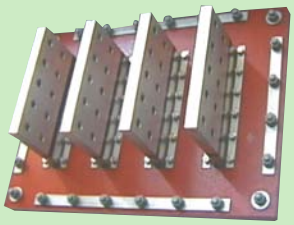
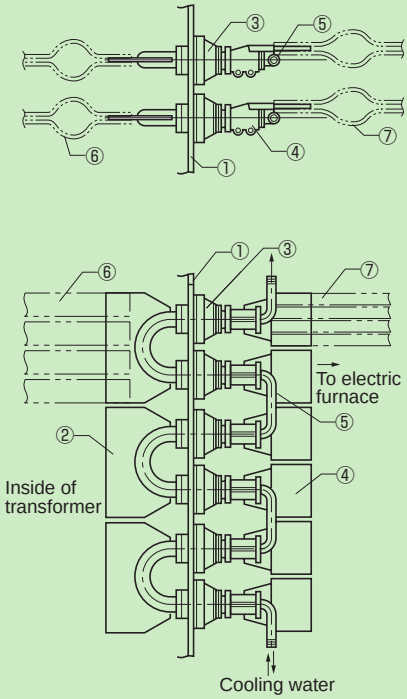
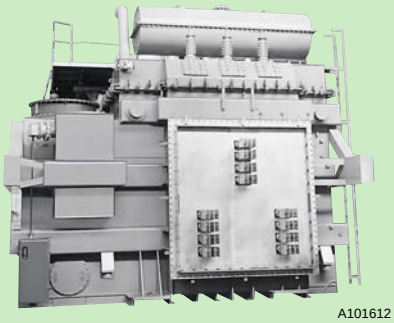


Fig. 11 Water-cooled type terminal structure



① Tank wall
② Internal connecting conductor
③ Epoxy resin insulator
④ Terminal top end fixture
⑤ Cooling water pipes
⑥ Internal flexible conductor
⑦ External flexible conductor

Photo 14 Arc furnace transformer with close-delta connection inside the transformer



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Accessories

Accessories for large-capacity electric furnace transformers (above 5,000kVA) and their features are as follows.

Table 2 List of accessories (●: standard accessory)

Division	Name	Oil preservation system			Remarks
		Open type	Rubber-cell type	Diaphragm type	(Making/breaking current: for 100V DC, time constant 7ms)
Standard accessories	Name plate	●	●	●	Installation on high voltage side as standard
	Cooling equipment	●	●	●	Cooling fans, oil pumps, oil flow indicators and water flow indicators are provided, depending on the cooling system.
	Radiator valve	●	●	●	For naturally-cooled radiators, only the lower valve is attached.
	Conservator	●	●	●	
	Dehydrating breather	●	●	●	
	Bushing (secondary terminal)	●	●	●	Ordinary type bushing, elephant type, bus duct type and salt water resistant type (naturally-cooled, water-cooled)
	Grounding terminal	●	●	●	Will be installed on the main tank, on-load oil-purifier and arrester as standard. Kinds and dimensions of grounding wires: clamping type structure, compressed type
	Terminal box for auxiliary circuit	●	●	●	Terminal box containing all input and output terminals of fans, pumps and measuring instruments
	No-voltage tap changer or on-load tap changer	●	●	●	On-load tap changer includes a motor drive mechanism. No-voltage tap changer: Manual operation on the main tank cover, operation from floor level, motor drive operation, tap position indicator system and operating power source.
	Buchholz relay	●	●	●	Equipped with "NO" (normally open) contact at 1st and 2nd step. Contact rating: 0.5A at open/close and continuous current 5A
	Dial type thermometer	●	●	●	Equipped with max. indication needle and "NO" contact. Contact rating: 0.1A at open/close and continuous current 1A
	Dial type oil level indicator	—	●	●	Equipped with "NO" contact at lower limit. Contact rating: 0.5A at open/close and continuous current 5A
	Oil gauge	●	—	—	
	Oil drain valve	●	●	●	With oil check plug
	Lifting lug	●	●	●	
	Oil-impregnation valve	●	●	●	
	Jack boss	●	●	●	
	Base	●	●	●	
	Surge suppressor	●	●	●	
Optional accessories	Pressure-relief device				Equipped with "NO" contact. Contact rating: 0.5A at open/close and continuous current 15A
	Bank name plate				
	Main circuit terminal				Types and dimensions of compressed type terminal
	Bushing type CT, built-in CT				Rating: 100A or over at 6kV
	Bus duct flange				
	Cable junction box				Elephant type bushing
	On-load oil-purifier				For Jansen type on-load tap changer. Used to improve the insulation reliability of the diverter switch chamber and reduce the number of power failures during maintenance. Not required for VS-LTC.
	Short-circuiting device for diverter switch				Dummy insert for main circuit when diverter switch is removed.
	Oil piping				Used for pressure-relief device
	Oil pressure relay				
	Alcohol thermometer				
	Resistance bulb				
	Foundation bolt				
	Ladder				
	Safety flap for ladder				
	Wheel				Selection of flanged wheel or flat wheel, rail gauge moving direction and directional change of 90˚.
	Winding temperature indicator				Contact rating: 0.5A at open/close and continuous current 15A
	Oil flow indicator				
	Water flow indicator				
	Secondary conductor support frame plinth				
	Oil circulation pump and motor				

Oil Preservation System

The volume of insulation oil sealed in the transformer changes according to its temperature change and/or transformer load change. The conservator is a device that deals with its volumetric change. Conservators are classified into three types according to construction: open type, rubber-cell type and diaphragm-sealed type. Fuji will supply conservators that are best suited for the environmental conditions and cooling method.

● Open type

Because the surface of the transformer oil is in direct contact with the air in the conservator, a dehydrating breather (silica gel) is mounted on the air side of the conservator to remove the moisture in the air, to prevent water from mixing in the oil. It is necessary to periodically collect the insulating oil for checking tan δ, overall oxidization, and withstand voltage (Fig. 12).

● Rubber-cell type

The insulation oil is sealed by a rubber-cell in order not to make contact with the air, thus avoiding oxidation of the oil. The volume of the rubber-cell varies according to oil expansion and shrinkage (Fig. 13).

● Diaphragm-sealed type

This isolates the insulation oil from the air by inserting a diaphragm between the insulation oil and air. The diaphragm has extremely low permeability against air. Once the insulating oil is degassed, its additional treatment and replacement are not necessary, thus simplifying maintenance (Fig. 14).

Photo 15 Rubber-cell type

N99-2570-2

Fig. 12 Open type

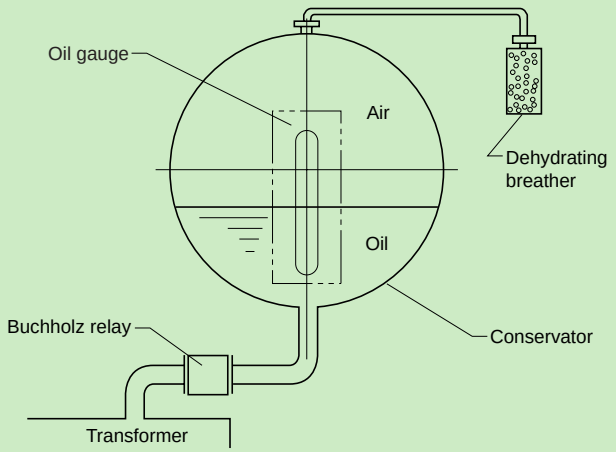


Fig. 13 Rubber-cell type

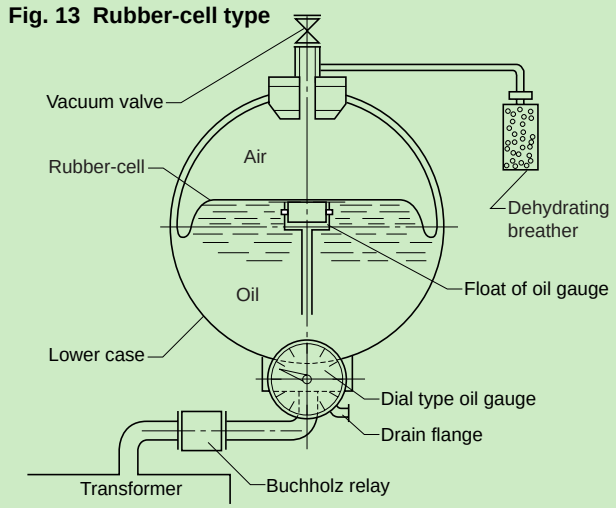
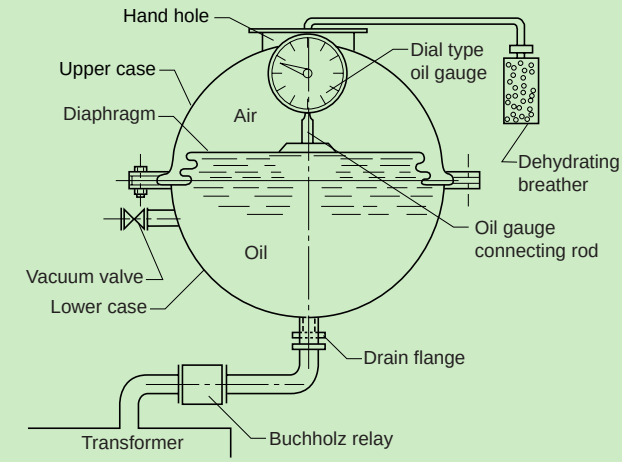


Fig. 14 Diaphragm-sealed type



On-Load Tap Changer

To regulate the input power of an electric furnace, the secondary side tap voltage of the furnace transformer has to be changed over. This changeover is frequently made at on-load, and could occur from dozens of times a day to more than 100 times. This changeover frequency is extremely high compared with that of general-use power transformers, and so a highly reliable tap changer that withstands such frequent changeover is essential.
Fuji provides two types of tap changers: the Jansen type on-load tap changer and a vacuum bulb type on-load tap changer. The latter was invented by Fuji and has an expected service life of more than one million electrical operations and does not require an on-load oil-purifier.

Features

1. Wide variation
   From small capacity to ultra large-capacity transformers, Fuji offers a wide variety of tap changers.
2. Excellent performance, high reliability
   Excellent performance and high reliability are guaranteed based on verification by severe characteristic tests and life test, plus a wealth of experience.
3. Resistor type change-over method
   A compact tap changer is achieved by employing a current limiting resistor.
4. Easy maintenance and inspection

Comparison of permissible changeover times [Unit: million times]

	Vacuum bulb type	Jansen type
Mechanical life operations	300	80
Electrical life operations	100	20
Auxiliaries	20	20

Photo 16 Vacuum bulb type on-load tap changer (VS-LTC)

AC337618

Photo 17 Diverter switch of vacuum bulb type on-load tap changer (VS-LTC)

AC349312

Transportation

Fuji adopts a suspension bridge type freight car for transporting large-capacity transformers. As a result, the high insulation performance obtained at the time of completion at the factory is retained without degradation until locally assembled at site, and the assembly equipment and days required at site are also saved. This method is remarkably effective and has already been used for the delivery of more than 200 units. We use our own freight car, the Shiki 280 (for 165 ton), and a unique vehicle type tank. The method can also be used for furnace transformers having a special structure.
It is also easy to draw out the transformer after the factory test to the quay using an air bearing car and load it into the freighter (Photo 18).

Photo 18 Transformer lifted

DK10970

Photo 19 Transformer loaded onto barge

DK0082

Photo 20 Transformer loaded into ship

DK0083

Reference Items

Number of transformers, application	
Installation location	● Indoor or outdoor ● Specify if such places subject to damage from salt water, dust, poisonous gas, vibration and shock should be considered.
Number of phases	● Three-phase, single-phase
Frequency	● 50Hz, 60Hz
Rated capacity	
Rated voltage and tap voltage	● Rated primary voltage, secondary tap voltage, number of tap steps (Specify the full capacity tap voltage and reduced capacity tap voltage.)
Tap-change system	● On-load or no-voltage ● Jansen type or vacuum bulb type
Connection	● Specify Delta (△) or Wye (人) standard connection (for three-phase only). (Open type or closed type)
Type of ratings	● Continuous rating or short-time rating (If short-time rating is required, specify the ratio of overload operation, overload time, and load cycle condition.)
Oil preservation system	● Open-type, rubber-cell type, diaphragm-sealed type. Specify one of these types.
Cooling method	● Oil-immersed naturally-cooled type (ONAN), forced-directed-oil forced-air-cooled type (ODAF), forced-directed-oil water-cooled type (ODWF) (Specify cooling water temperature, water quality.) Maximum temperature of the medium
Operating condition	● Ambient temperature: 40℃ or below, altitude: 1000m or less
Transporting condition	● Specify size and weight (mass) limitation during transportation, if any.
Installation condition	● Specify size and weight (mass) limitation while installing transformer, if any.
Other conditions	● Specify primary terminal lead-in method, secondary terminal lead-out method, applicable standard (e.g. IEC, ANSI), etc.

Fuji Electric Systems Co., Ltd. / Slogan symbol

Solution Service

The slogan symbol is based on Fuji Electric Systems' Solution & Service motto, and "S" that symbolizes them.

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