275 KV 230,000 KVA "FAHRBAR" POWER TRANSFORMER FOR HIGASHI OSAKA SUBSTATION OF KANSAI ELECTRIC POWER CO., INC.

By

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I. PREFACE

Our Company have completed the first "Fahrbar" (truck type) power transformer before other makers in Japan. and this met with a favourable criticism of all fields. Since then, the development of the assembled transportation of the transformer is remarkable and recently almost of the large capacity transformer are "Fahrbar" type ones. And 10 years has passed since oscillation-free type concentric layer windings having excellent characteristics for extra high voltage transformer was completed. In these years, our Company have manufactured this type of transformers above 50 sets in quantity and over 3,500 MVA in total capacity.

As the oscillation-free type windings display the excellent features in higher voltage, they must be most suitable for the 400 kV class transformer which will be adopted in near future in Japan.

275 kV, 230,000 kVA transformer that our Company have now completed for Higashi Osaka Substation of Kansai Electric Power Co., Inc. are of "Fahrbar" type adopting above described oscillation-free type concentric layer windings in the high voltage side. And for the transport of the transformer we employed new Shiki 600—capacity 240 tons, 24 axes—special "Schnabel wagon". As we adopted, for the schnabel type wagon, movable side bearer system which is the first trial in Japan, we introduce outline of the wagon in the following sections, also.

Fig. 1 shows the outer view of the 275 kV, 230,000 kVA transformer at site.

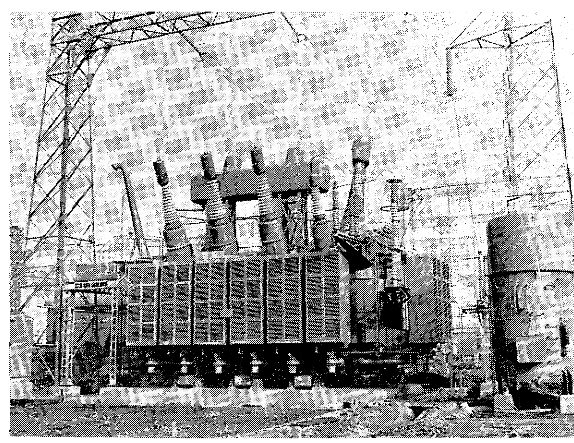

Fig. 1. 230,000 kVA transformer at site

II. RATINGS, WEIGHTS AND DIMENSIONS

Type :	3 phase, core type, outdoor use, oil-immersed forced oil circulation with air blast cooling, "Fahrbar" type
Frequency :	60 c/s
Voltages :	Primary side, F 275–F 262.5–R 250 kV 人 with earthed neutral
	Sencodary side, 147 kV 人 with neutral resistor
	Tertiary side, 15.4 kV Δ
Insulation level :	Primary side, BIL line side 1,050 kV, Neutral point 400 kV, graded insulation
	Secondary side, BIL line side 750 kV, Neutral point 550 kV, graded insulation
	Tertiary side, BIL 150 kV
Capacity :	Primary, 200,000 kVA
	Secondary, 200,000 kVA
	Tertiary, 60,000 kVA
Weight :	Total, 348 t
	Oil, 67,000 l
Dimensions :	12,400 mm × 7,200 mm × 9,600 mm (width × depth × height)
Outline :	Shown in Fig. 2

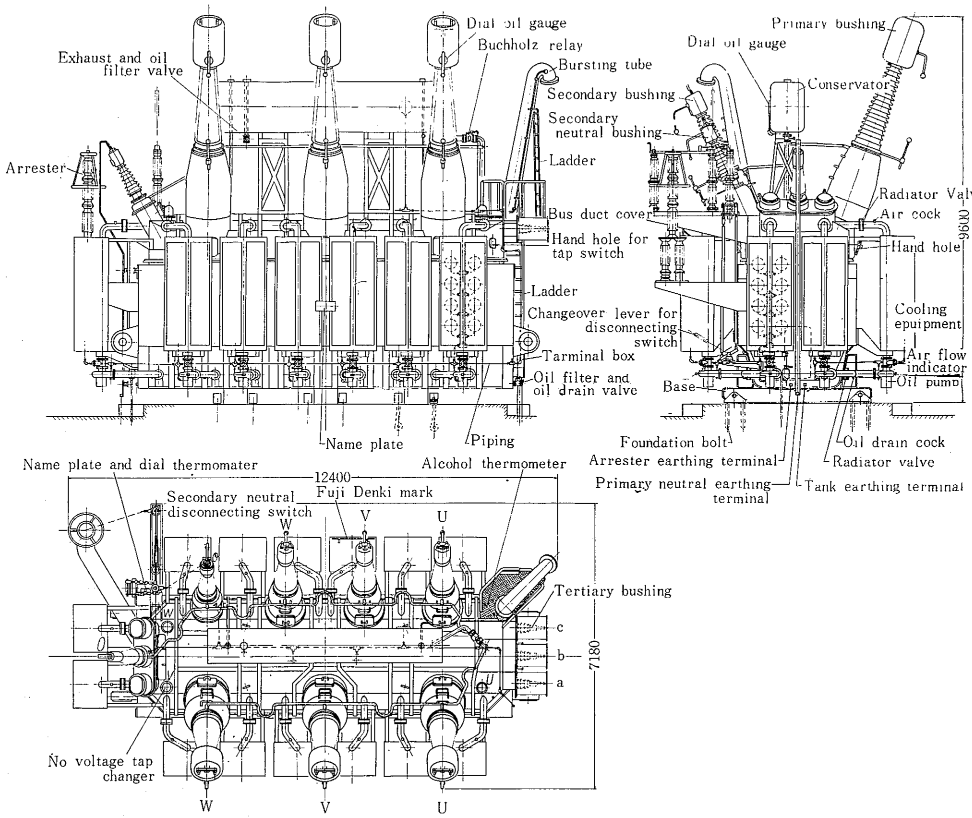

Fig. 2. Outline dimension

III. INTERIOR CONSTRUCTION

1. Core

Assembled transportation by the railways is limited on the dimensions, hence we employed five leged construction for the core. For the core materials M-6X grain oriented electrical sheets produced by Armco Co., Ltd. are used, and in order to utilize excellent rolling direction magnetic characteristics 45° overlapping joints are adopted. As the magnetic characteristics of the sheets are deteriorated by the mechanical strain, relevant annealing process is necessary after straining works, such as bolling, cutting and so on.

However mechanical strain is not limited to only the chance of manufacturing process. During operation axial electromagnetic force, which eccured in the windings according to the short-circuit accident, effects to the core yoke through the core clamping devices, on this case, the strain will occur and magnetic characteristics will be deteriorated. For long years the friction force of the overlapping parts is reduced by slight shrinkage of the frame insulation and as the result of this there is a fear of producing the gap on this jointing parts. Our Company have adopted the construction that these axial electro-magnetic forces may not effect.

2. Windings

Primary, Secondary and Tertiary windings are concentrically arranged in order as shown in Fig. 3. According to its voltage and current our standard winding construction is adopted for each winding. For Tertiary large current cylinder form block winding, for Secondary single coil, and for Primary oscillation-free type concentric layer winding which has a linear impulse voltage distribution in the winding, are adopted. Single coils are not provided with static shield plates which are troublesome in the manufacturing process, and possesing excellent impulse voltage characteristics, and further ordinally voltage acrossed on the oil ducts among coils are only one half of the former twin coil. On the other hand, oscillation-free type concentric windings are with construction of concentric cylinder type, and internal impulse voltage oscillation

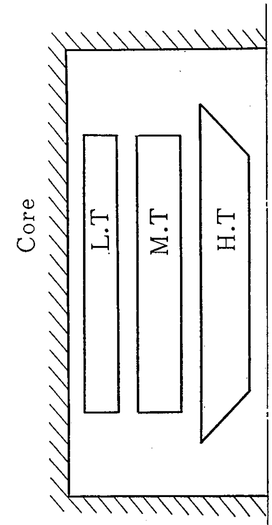

Fig. 3. Arrangement of windings

does not occur and radial direction leakage flux of every taps are very little because on the neutral side, i.e. earthed layer coils, three tap coils are wound in parallel and arranged dispersively.

Then the winding constructions have a feature that the axial direction electromagnetic force due to external short-circuit is very small.

3. Others

For the jointing parts of high voltage and middle voltage terminal lead polygon contacts are used in order to execute assembled transportation and shorten the erection priod. A polygon contact is developed for connecting of the cable head of the Fuji elephant type transformer to the transformer proper, and the connection is enough only by inserting the contact into the winding lead.

With increasing of the unit capacity of transformers, leakage ampere turns also increase, hence increasing of the stray loss in the core-frame or other metalic parts are naturally presumed. Therefore, deep consideration for the suitable arrangement of the construction and the election of materials was paid and we aimed to reduce the stray loss. Fig. 4 shows interior views of transformer. Fig. 5 shows the fore press of the M.T. winding and super large capacity high vacuum drying tank, degree of vacuum 10 μHg, is shown in Fig. 6.

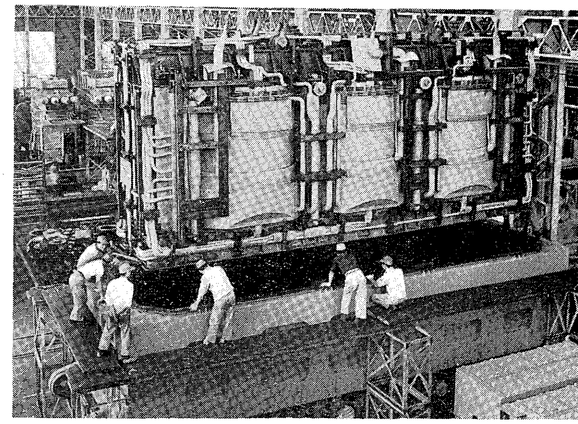

Fig. 4. Interior view of transformer

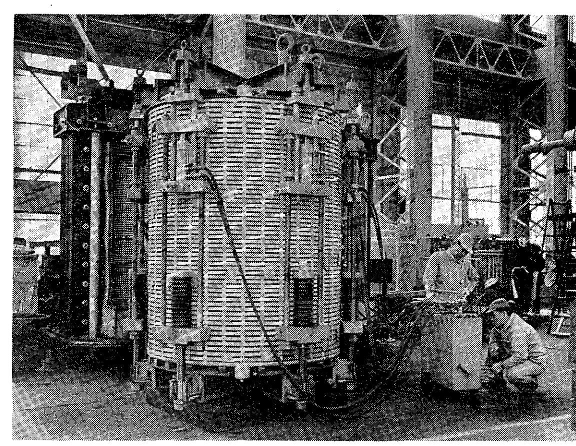

Fig. 5. Fore press of M.T. winding

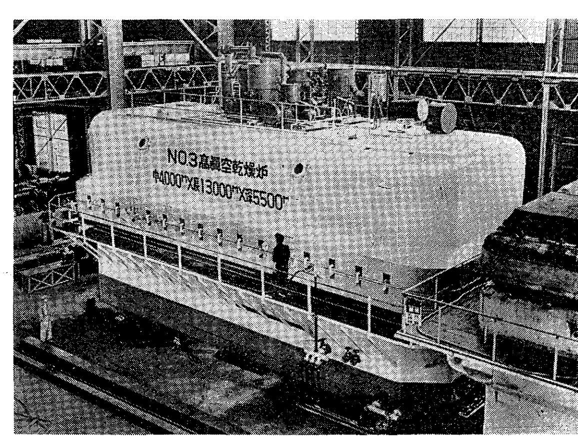

Fig.6. High vacuum drying tank

IV. EXTERNAL CONSTRUCTION

1. Tank

On the transportation, as well known, weight and dimensions are limited. With the increasing of the capacity the limitation, especially dimensions, becomes strict due to the problem of deviation on transportation and the height of center of gravity.

The tank is wagon type having maximum dimensions to the limit as shown in Fig. 7. The connecting system of this tank to the schnabel wagon is just same as the former wagon type, but weight transfer mechanism under set condition to the schnabel wagon is differed from the former one. Namely, box formed main frames are arranged upper and lower position, bottom beams are connected to the lower frame and withstand a total weight of interior, and upper and lower frames are interconnected with vertical auxiliary beams which withstand several tens μHg of degree of vacuum.

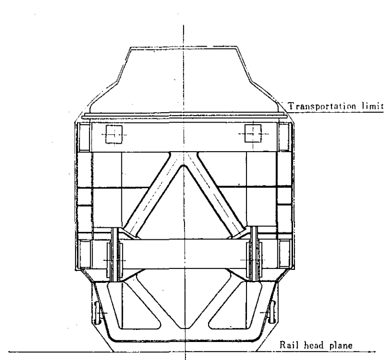

Fig. 7. Limit of truck of J.N.R.

As to the transfering of the stress, both tension force on the lower beams and compression force on the upper beams are directly transfered to the schnabel, then over stress concentration is avoided and stress distribution is uniform.

During the manufacturing, tank was rotated freely with special designed supporting jig and we adopted down-cast welding system, hence welding process was easy and its reliability was improved and the erection manufacturing period was shortened. Inspection of surface failure was executed over all process, and careful manufacturing was also executed, namely, detecting the crack and stress releaf annealing of welded parts.

Fig. 8 shows the 150% over load test, and in this test stress distribution and strain was measured by wire resistance strain gauge. And for the data of future design deformation of accelerative force by transporting was measured. Fig. 9 shows the tank under working of supporting bearing boss of hinge.

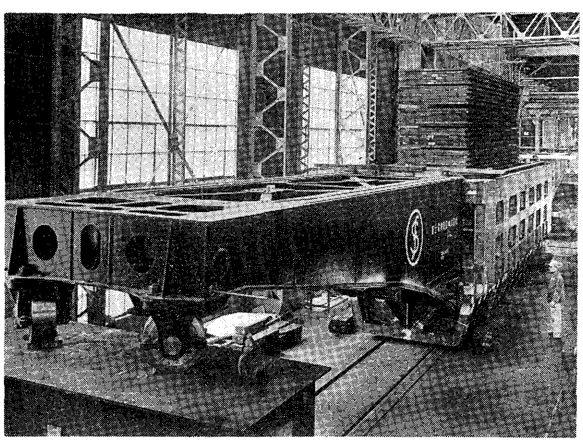

Fig. 8. View of load test

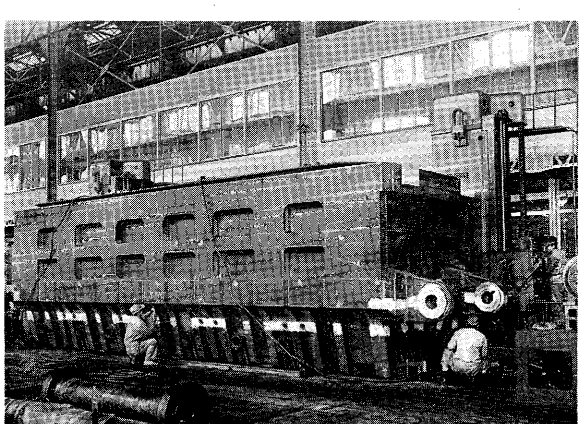

Fig. 9. Wagon type transformer tank

2. Others

In order to accomodate five leg core, the length of the tank and cover becomes longer than the case of three leg core, but they have ample strength against the several tens μHg of degree of vacuum, the vibration is small beyond expection, and noise is only 89 phon for the NEMA standard 92 phon.

Nitrogen gas sealing equipment is float tank type and their action is inspected always with alarm contact attached to the float tank.

A Buchholz relay is employed for the detecting and protecting of the transformer interior faults.

V. COOLING

In generally forced oil circulation forced air cooled system is adopted for large capacity transformer. However, with increasing of the capacity radiated loss from the unit surface of coil is more increasing, and the temperature difference between oil and winding becomes large. Therefore the cooling equipment must increase over the increasing of capacity.

Following formula shows the temperature difference θ between coils and oil.

$$\theta = W\left(\frac{1}{\alpha} + \frac{\delta}{\lambda}\right)$$

where W: Quantity of heat radiation per unit surface
α: Heat transfer coefficient on a boundry between coil surface and oil
δ: Thickness of insulating paper of coil
λ: Heat conductivity of insulating paper

In the above formula second term in the parenthesis is decided according to the insulation composition, hence "α" shall be large to decrease "θ". "α" has a relation with oil speed passing through the cooling oil duct of coil and becomes large by increasing of oil speed. However, in the range oil flow is steady flow, increasing of "α" is not so expected even if oil flow is increased over some limit. Hence increasing oil speed over some limit will result increasing of head loss of cooling equipment and power loss. For the reason of this, before manufacturing of this transformer we made the real size model of winding and tested oil flow inside of windings and execute a experiment of adjusting oil flow. As the result of this model test we got the most suitable oil speed in the coil and considering the necessary circulating oil quantity and maximum cooling effect for the oil speed, we adopted 14 sets of unit cooler system cooling equipment. Every one set of cooling equipment is composed of one oil pump and eight cooling fans and oil flow meter is attached. Fig. 10 shows the oil flow experiment.

VI. TRANSPORTATION

The transformer was transported by the Shiki 600—capacity 240 ton, 24 axes—special "Schnabel wagon" which was produced by Nippon Sharyo Seizo Kaisha Ltd. for ultra large capacity transformers. Fig. 11 shows the dimensions of Wagon.

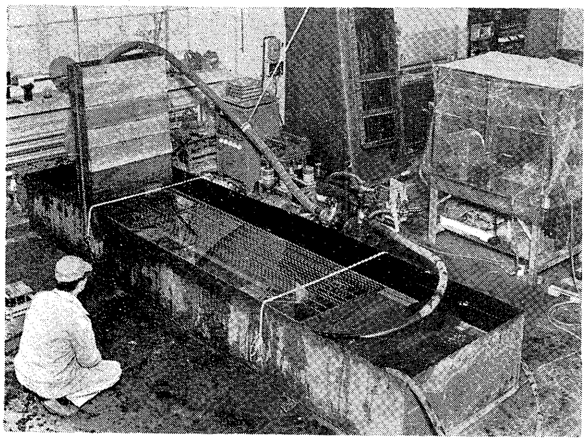

Fig. 10. Oil flow experiment

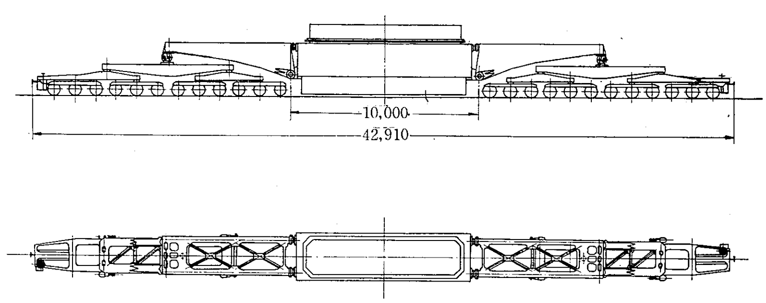

Fig. 11. Shipping dimension of SHIKI-600 transporting

Transformer being large capacity, weight and dimensions will increase remarkably, hence the limit of transporting weight and dimensions and the height of center of gravity of the transformer will become a important problem. With increasing of the weight, transit of the center of gravity will be large due to the superelevation of the curve, and there will be a fear of overturn to the inner side of rail. On the railway transportation allowable load of one axes is limited to be under 14 tons, so with increasing of weight the number of axes must increase. On the other hand, increasing of numbers of axes will result enlarging of the car length, deviations on the curve will be enlarged and then allowable transporting width will be decreased.

Thus, with increasing of transformer weight, two contradicted requirements appear, such as lowering the height of center of gravity and decreasing the width of the transformer.

The new special "Schnabel wagon" has manufactured under considering of these two special requirements.

Advantages which are obtained by adopting this construction are: the height of center of gravity being higher than the former type by 300 mm, deviations of 10 m long transformer at radius carvature 100 m being reduced by one hundred and several tens mm. In other words, removing the yoke from the core during transportation to lower the center of gravity is now no necessary and three leg transportation is available that could be transported as five leg core in the former type. And allowable width of the transformer also extended than former limit by about 300 mm. That is to say, with same dimensions of transformer interior the distance between tank and windings can be extended by one hundred and several tens mm. Considering 200 kV class transformer having a 400 mm insulation distance, it is understand how this has important meaning.

Specifications of Shiki 600 special Shcnabel Wagon are as follows:

Weight	94.8 tons
Load	240 tons
Length unloaded	32.910 mm
Loaded 10 m long transformer	42.910 mm
Maximum width (unloaded)	2,770 mm
Maximum height from the rail head (unloaded)	3.478 mm

VII. CONCLUSION

As described in preface, we Fuji Denki have completed first "Fahrbar" power transformer before any other makers in Japan, and this system have been favoured by all fields. Then we have had much interest in this field, and have continued effort of improvement.

Adopting of oscillation-free type winding which is suitable for extra high voltage directly grounded graded insulation system is epock making in the world and we achieved our special position in the transformer manufacturing field.

By adopting this oscillation-free type winding we will apear our excellent features in the field of extra high voltage transformer which capacity is growing up larger and larger and especially in the field of 400 kV class transformer which will be realized in near future in Japan.