RECENT ON-LOAD TAP CHANGING POWER TRANSFORMER

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I. INTRODUCTION

It is customary to use on-load tap changing transformer up to the bank capacity of approximately 50,000 kVA. The number of this type of transformers manufactured by the Company, has reached 240 by the end of 1957. It is provided with a so-called Jansen switch which operates at high speed by means of spring.

II. IRON CORE

The so-called silicon sheet steel that has been used for a long time is now being replaced by cold-rolled silicon sheet steel (orient core) having small iron losses and exciting current.

Orient core Z_{11} or Z_{12} of Yahata Iron Works possesses characteristics equal to those of Armco M–6X and M–7X (Table 1).

For the orient core, to exhibit its superior characteristics, annealing process for complete elimination of strain from the silicon sheet steel must be performed.

Fig. 1 illustrates the annealing furnace with the temperature distribution of 800°C inside the furnace which is being watched by the use of thermocouples.

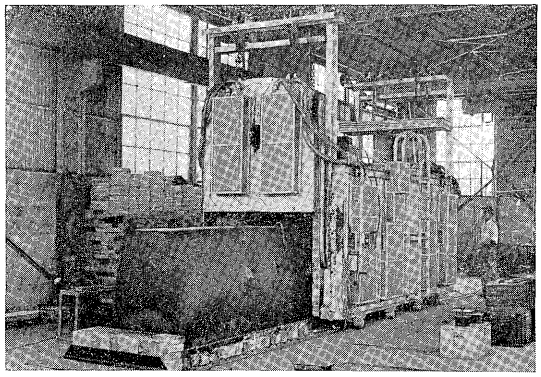

Fig. 1. Annealing furnace for oriented core

III. WINDINGS

The standard system is to bring the tap to the neutral point of the star connection (Fig. 2a) with three Jansen switches placed together on one insulating porcelain bushing (Possible due to very small interphase voltage).

Since there are several conductors to be led out, the tapped windings are put together and arranged on the outside of the main winding (Fig. 2b).

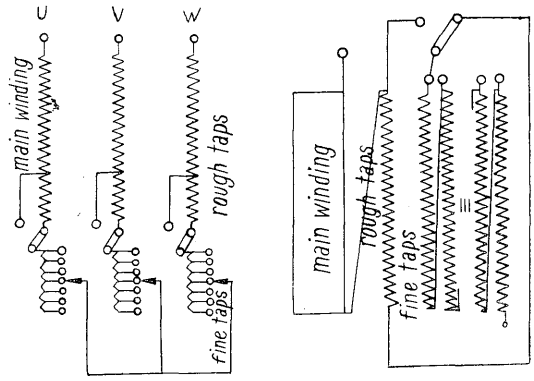

Fig. 2. Connecting diagram of on-load tap changing transformer

(a) To bring the tap to the neutral point of the star connection

(b) Winding arrangement

The double coils shown in Fig. 3a are used for the main winding for voltage less than 66 kV and the lightning-proof single coil shown in Fig. 3b for voltages of 110 and 154 kV.

The double coils used is the ordinary type and needes no description.

The single coil has the inside and the outside of each coil tied together as shown in the figure and has an advantage over the double coils in that the voltage between the coils is approximately a half that of the double coils.

As shown in Fig. 2b, the tap windings consist of rough and fine taps. In the fine taps, the coils having the same number as the taps are cylindrically wound upward in parallel. Thus, any one of the

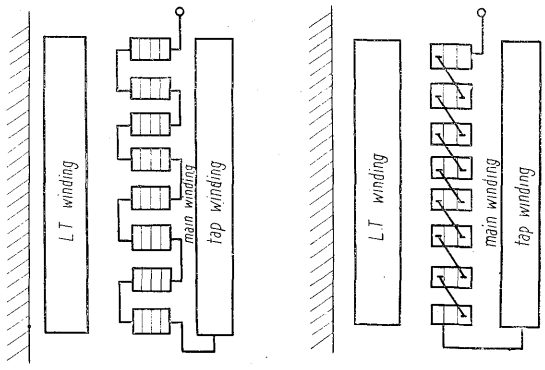

Fig. 3. Type of winding

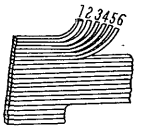

Fig. 4. Cylindrical tap

taps is made to pass similarily through from the top to the bottom of one layer. (See Fig. 4)

The tap windings, wound in this manner, have excellent characteristics for mechanical strength against short-circuits and surge voltage.

Since the low tension windings, main high tension winding, and the tap windings are concentrically wound to the same height, and together with the fact that the taps pass through uniformly from the top to the bottom in the fine tap windings, leakage flux in horizontal direction is small (because of small unbalance in ampere-turns) and the mechanical force produced in the axial direction during short-circuits is also extremely small. Thus, the windings are mechanically strong and possess a high safety factor.

Since the tap windings have a considerable large electrostatic capacitance to ground, no dangerously abnormal voltage is produced, as is proven by the surge voltage test, in which, when voltage is impressed on the three circuit terminals with the neutral point ungrounded, the rise in potential at the neutral point was founded to be suppressed to less than 10%.

IV. ON-LOAD TAP CHANGER

The change-over process of one of the taps in Jansen switch is illustrated in Fig. 5. Although the time it takes to move the tap from the initial position "a" to the position "f" at the end of one tap changing motion is approximately 5 seconds, operated either manually or electrically; it is only 4 cycles from the position "b" i.e. from the moment the main contact separates to the position "f".

The rating of the switch is 600 A; but, the current is transferred at first, from the main contact to the auxiliary contacts and divided into small currents of approximately 100 amperes each before breaking. Therefore, arcs produced are greatly reduced.

The current distribution in the auxiliary contacts is similar to that of the anode balancer of mercury rectifier.

The contacts have been proved by life test to withstand 30,000 times of switching operation.

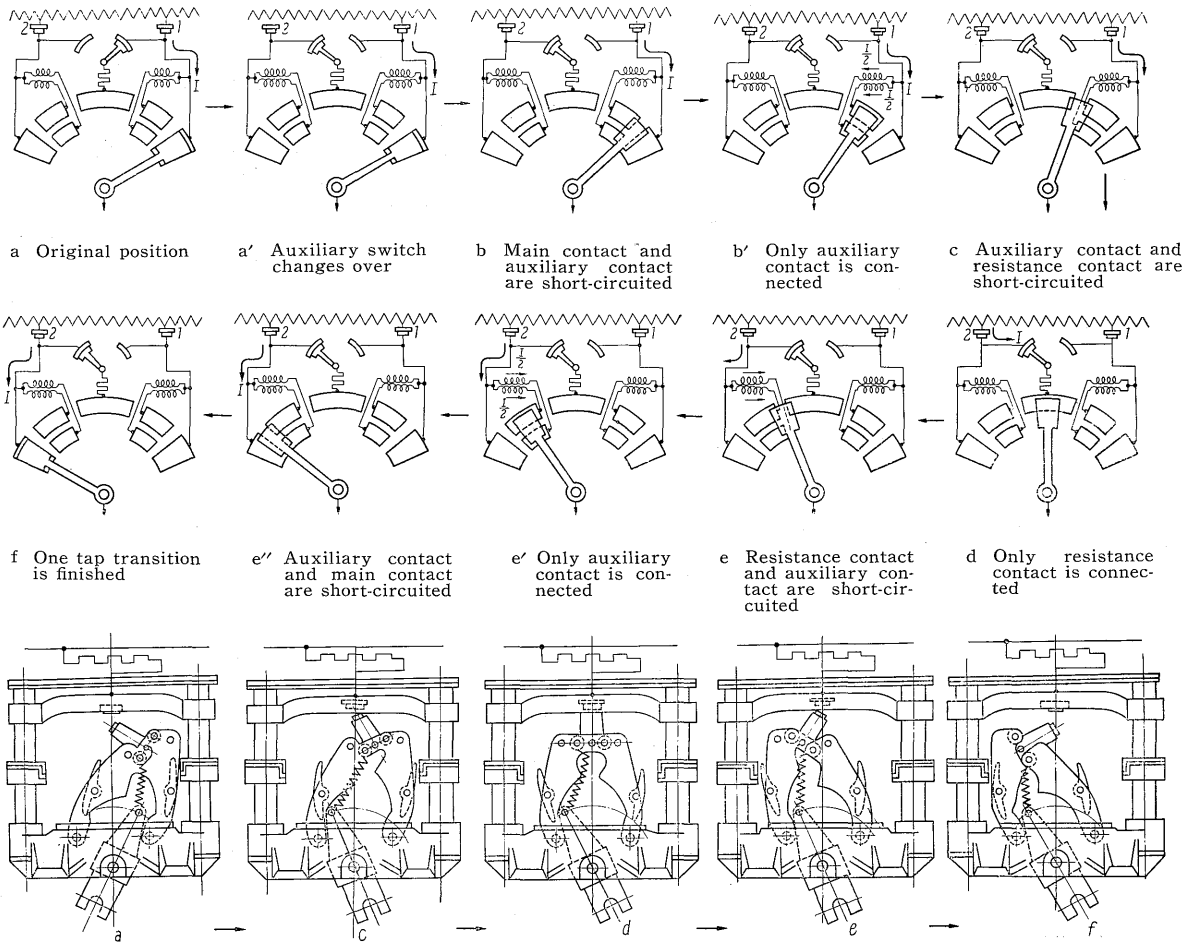

Fig. 5. Change-over process of one of the taps in Jansen switch

The oil, in which the switch is immersed, is completely separated from the main body ; but, since the oil becomes contaminated from the arcs it is recommended to be replaced every 20,000 times of switching operations.

The number of switching operations is registered on a call meter.

V. SEALING, PACKING, ETC.

(1) Sealing :

Those of perfectly sealed nitrogen construction to avoid complications encountered in the nitrogen enclosed equipment are also adopted for 3-phase, 60 kV, 10,000 kVA transformers and are manufactured in a large quantity. For output of this magnitude, the sealed construction is being gradually standardized and for equipment of larger output, the same construction will be adopted in the near future.

A nitrogen expansion chamber is provided to maintain the pressure exerted to the tank by the changes in temperature and load to a suitable value.

(2) Packings ;

As for the packings, basic experiments and research have resulted in the use of nitrile rubber obtained by polymerizing butadiene and acryl nitrile in a ratio determined by the Company. *1

This nitrile rubber is made into suitable shapes and by the skilfull use of the stopper, perfect oil seal is maintained.

(3) Fuji Nox Insulation Oil ;

There have been cases where, instead of the nitrogen enclosed equipment, Fuji Nox insulation oil, having equal anti-oxidizing property was used. For transformers below 6,000 kVA, the use of Fuji Nox insulation oil is cheaper as compared with the cost of nitrogen enclosed equipment.

(4) Fuji Synclor : (Used in special cases)

Non-inflammable synthetic oil (Fuji Synclor) is made from diphenyl chloride and chloro benzene. The Company was the foremost to enter into research and manufactured this product ahead of the competitors. The research and the experiments are still continued. *2

To compare this oil with mineral oil, dielectric breakdown tests such as, one minute dielectric strength test by alternating current, short period breakdown test, impulse puncture test, impulse creepage flashover test, etc. were conducted on both the synthetic and the mineral oil and pressboards impregnated with these oils under the same condition.

The results showed that the Fuji Synclor is superior to the mineral oil in all respects.

(5) Noise : *3

Generally, the standard noise level is as shown in Table 2. Double-walled tank filled with rockwool is employed whenever the installed location requires much lower noise level. By this method, 12～13 db can be lowered. Further reduction of approximately 30 db is possible by completely surrounding the transformer with the concrete walls.

VI. EXAMPLES OF MANUFACTURED TRANSFORMERS

The on-load tap changing transformers manufactured during 1956 and 1957 are listed in Table 3.

(1) Fig. 6 shows 154 kV, 30,000 kVA on-load tap changing transformer. It is a forced-oil, fan-cooled type having the following specifications :

Impedance	11%
Efficiency	99.24%
Gross weight with oil	137 tons
Vol. of oil	50 kl

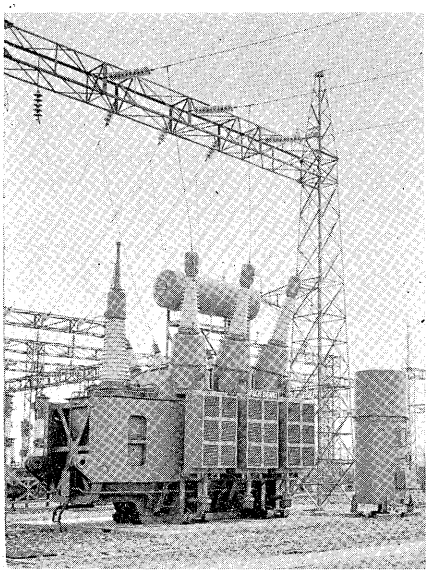

Fig. 6. 154 kV, 30,000 kVA on load tap changing transformer

Fig. 7 is a photograph of the above transformer in transportation and shows a truck type tank (Schnabel) having 12 wheels and 130 tons loading capacity (Shiki 160). Transporting weight is 79 tons with temporary cover and with nitrogen enclosed.

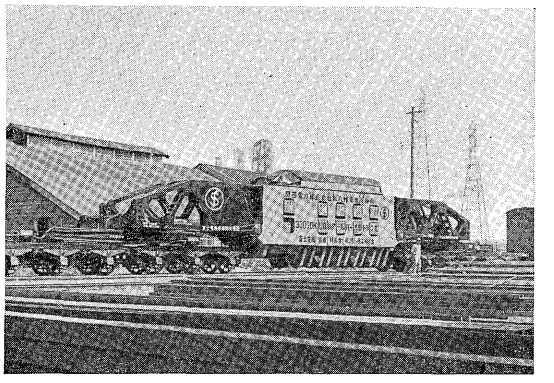

Fig. 7. Transporting style

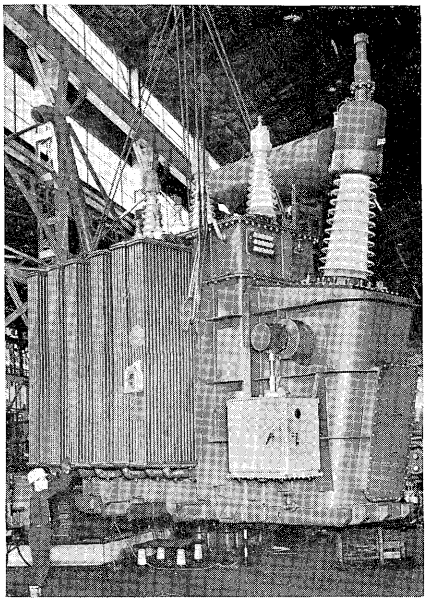

Fig. 8. 77 kV 10,000 kVA on load tap changing transformer

(2) Fig. 8 shows 77 kV, 10,000 kVA on-load tap changing transformer of oil-immersed, self-cooling type having the following specifications :

Impedance 7.5%
Efficiency 99.04%
Gross weight with oil .....44.5 tons
Vol. of oil .....17.7 k*l*

Fig. 9 shows assembling operation of the transformer.

(3) Single phase transformers are also manufactured. Fig. 10 is an example of banked 30,000 kVA oil-immersed, self-cooled transformers(three 10,000 kVA single phase transformers) with the following specifications :

Impedance 7.5%
Efficiency 99.31%
Gross weight with oil .....35.5 tons
Vol. of oil .....11.1 k*l*

(4) Fig. 11 shows 66 kV and 6,000 kVA oil-immersed, self-cooled on-load tap changing transformer with the following specifications :

Impedance 7.5%
Efficiency 98.91%
Gross weight with oil ..... 40 tons
Vol. of oil ..... 15 k*l*

This transformer is a nitrogen enclosed type, constructed for offering convenience in transportation by trailer.

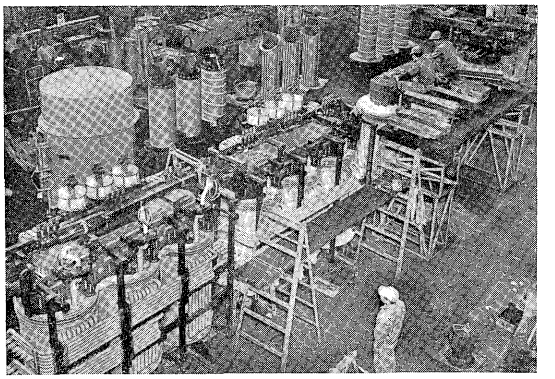

Fig. 9. Assembling operation of 10,000 kVA transformer

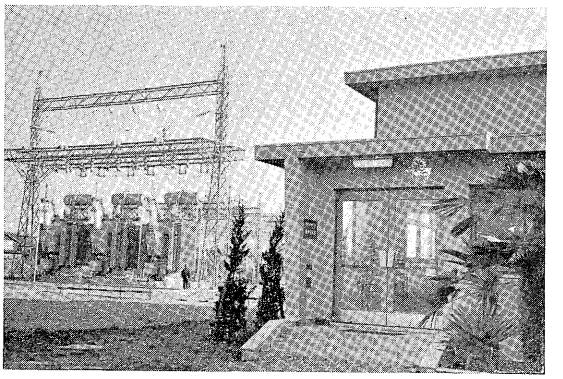

Fig. 10. Banked 30,000 kVA three 10,000 kVA single phase on-load tap changing transformer

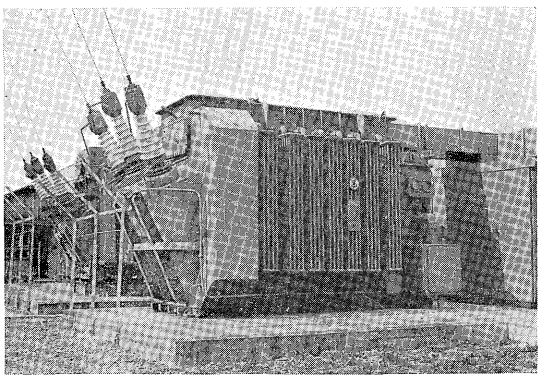

Fig. 11. 66 kV, 6,000 kVA nitrogen enclosed type on-load tap changing transformer

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Fuji Denki Review Vol. 3, No. 3, 1957
*2. Noboru Iseki
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*3. Toshihiko Ito
Fuji Denki Review Vol. 4, No. 1, 1958