VENTILATING DUCTS OF CONCRETE SOUND-PROOF ENCLOSURE OF TRANSFORMER

By

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I. PREFACE

To reduce the noise of transformer core and that of the cooling fan has been a problem of long standing. The latter is overcome for a time being by changing the method of cooling, but the former is still an unavoidable problem and much information as to the study of the countermeasure and the practical use of it has been proposed. This article presents a method of preventing radiation of noise from steel core by enclosing the transformer with sound-proof walls made of a material that absorbs much of the acoustic transmission loss.

One of the typical methods by utilizing acoustic transmission loss of wall that is widely used heretofore may be installing transformers in a sound-proof housing. This however, gives always some difficulties as to the transformer cooling and in consequence, it makes an extensive increase in cost of cooling plant as well as the transformer housing. The radiator is nothing but an inferior noise radiating body compared with the transformer tank and there is practically no reason in most cases to keep them in the sound-proof wall. The purpose of noise suppression may be sufficient if a wall that is made similar to the transformer housing be placed between the transformer tank and the radiators around it. This wall may be either of steel plate or concrete plate. The enclosure made of steel plate, in other words, the basic structure of sound-proof tank may be as shown in Fig. 1.

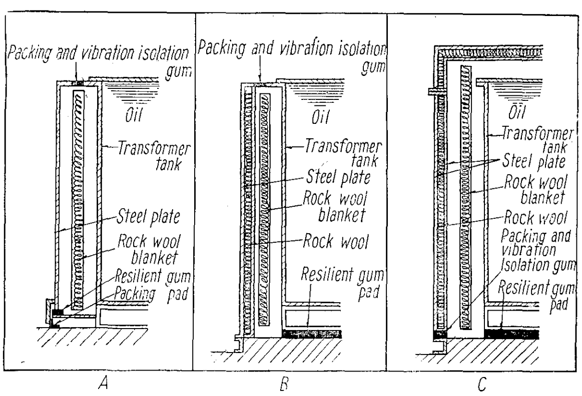

Fig. 1. Typical construction of sound-proof tank

The Fuji Electric Mfg. Co. has made many transformers of low noise disturbance that are similar to Fig. 1A. For instance, the transformer in Fig. 2 shows the structure of sound-proof tank

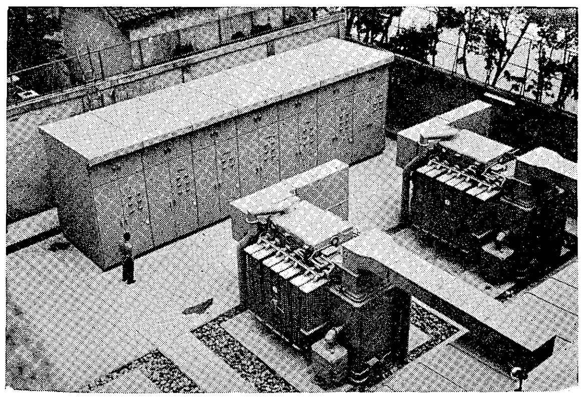
Fig. 2. Completely assembled transportation type load ratio control transformer 3 ph. 60 c/s 20 kV 6,000 kVA, noise level 55 phon

the construction of which is of very restricted proportions since the transformer is of a fully assembled and portable type and yet the noise reduction is 12 db. The Fig. 3 shows a low noise level transformer which is a trial manufacture of the Fuji Electric Mfg. Co. The sound-proof tank is made similar to that of Figs. 1B and C. Fig. 4 shows the appearance of structure ♯1 of Fig. 3. In the structure ♯2 of Fig. 3, the noise suppression effect is found to be about 13 db, while in the structure ♯1, it is raised up to 20 db. (The value of db is measured according to the JIS noise level meter scale A). The method of noise prevention by means of sound-proof tank may be applicable to many transformers in future since its effect is large and is adaptable to transformers of any working conditions. On the other hand, the sound-proof tank, being of very complicated structure, requires much time in fabrication and assembly and also the cost of materials will upset the practicability. As the principal material of sound-proof tank steel plates are adopted. An investigation has been made if it can be replaced by concrete

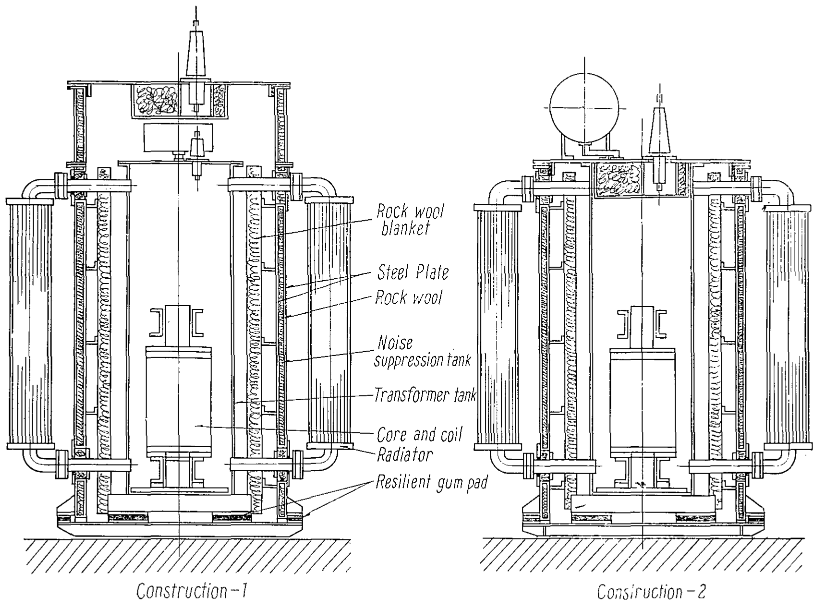

Fig. 3. Section sketch of experimental low noise level transformer with sound-proof tank

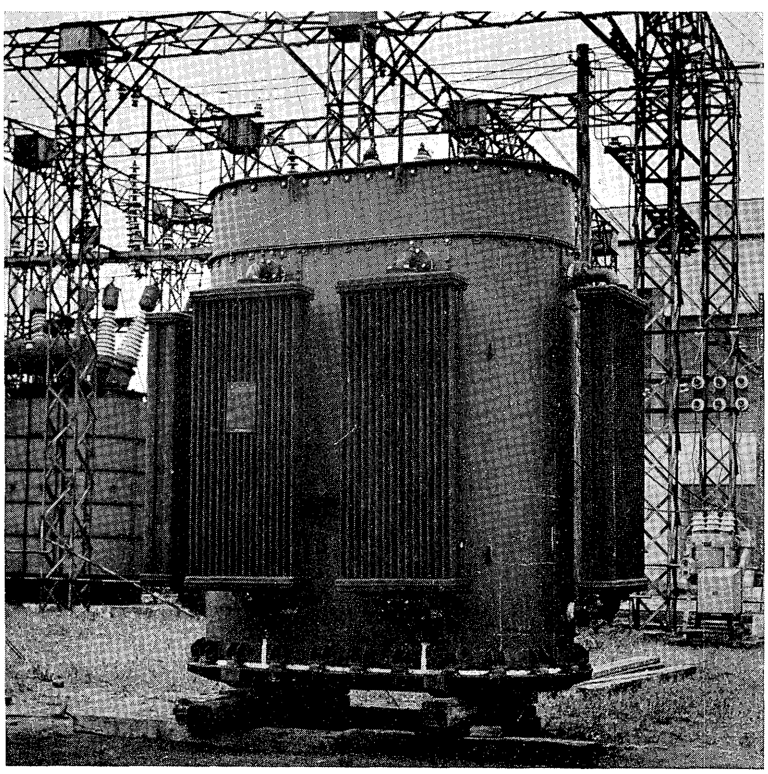

Fig. 4. External view of low noise level transfomer (Fig. 3 C-1) 3 ph. 50 c/s 30 kV 3,200 kVA

plate—the sound-proof enclosure of concrete. The weight of the concrete plate of 150mm thick is equivalent to that of 50 mm thick steel plate. As the cost of cement is much cheeper than that of steel, it is a great advantage to use it instead of steel.

In case of sound-proof housing, it has been a practice to draw out the high voltage lead of transformer by the use of a wall bushing. If the transformer bushings be made in common use with the wall bushings as in the case of sound-proof tank as shown in Fig. 5, it not only saves the wall bushings but also the size of concrete enclosure. For instance, in a case of 140 kV transformer, the height of housing may be reduced to half. The radiators are arranged on the outside of the housing the same as in a case of sound-proof tank. One of the side wall is made open for transformer entrance and after the transformer is installed the opening is shut tightly by cement blocks with mortar finish. An up-to-date transformer of high reliability gives no trouble in such enclosure. For monitoring the transformer, the telemeter or other instruments can be provided on the outside wall and transformer operators have no need of entering the housing. However, as the tap changing operation can be made easier inside the enclosure, it is more reliable to make an access into the enclosure and it is necessary to provide a small sound-proof door and a certain space to permit simple work to be done inside. The space is conducive to sound-proof purpose but the temperature control may sometimes become an obstacle to the sound-proof effect of enclosure. The main portion of transformer heat loss is taken away by

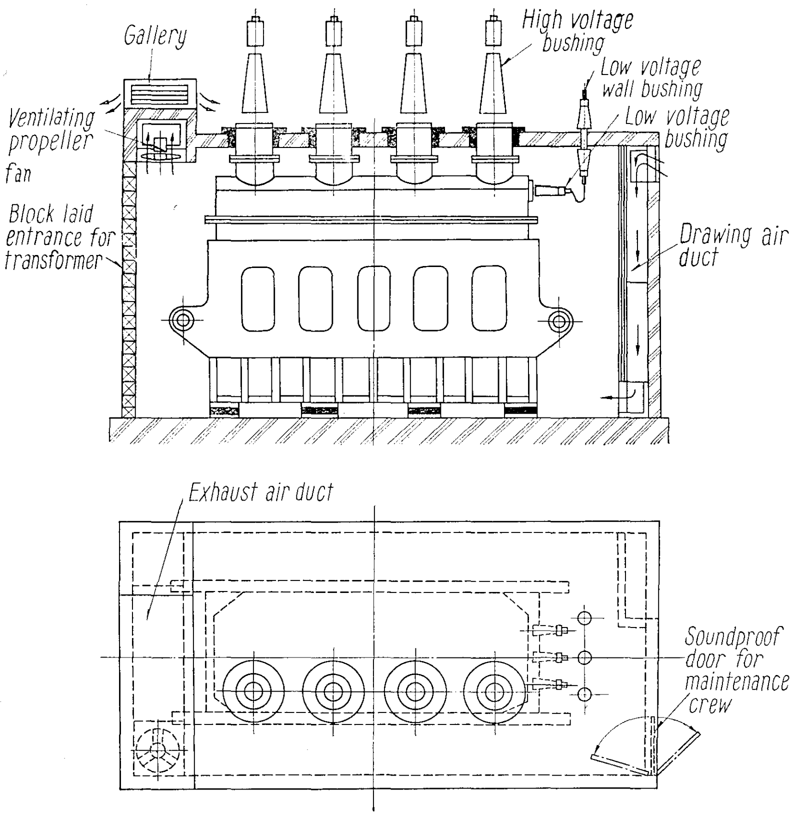

Fig. 5. Section view of low noise level transformer with concrete enclosure

radiators but a small portion of heat is radiated inside the enclosure from the transformer tank. For instance, in the case of a large transformer of 40–150 MVA in the concrete enclosure, to keep the room temperature below 45°C against the maximum oil temperature of 75°C, the cooler capacity must be ample enough to absorb 30–50 kW of heat. For saving the cooler capacity and holding down the rise of the sound pressure inside the enclosure, it is more profitable to cover at least 2/3 of the tank surface by heat insulators such as rock-wool to an extent not to interfere with maintenance. Considering the room cooling by ventilation, to keep the room temperature not higher than 10°C above the outside temperature, the volume of air 50–90 m³/min may be necessary even if the heat insulators cover the tank surface. A natural draft by means of air duct or the use of heat exchanger can be considered, but here a forced draft system through a sound-proof air duct is suggested.

It is, however, questionable whether a relatively short air duct prevents noise which is the strongest low frequency sound such as 100∼120 cycles in the case of transformers without lowing the soundproof effect of the cement enclosure. In order to examine this, a test was conducted on a model air duct of 60 kV 45 MVA transformer, made in a similar size to an actual duct. The result was found satisfactory.

II. CONSTRUCTION OF NOISE ABSORBING AIR DUCTS

Clean outdoor air is taken from the upper end and drawn in on the floor as shown in Fig. 5. The drawing air duct is arranged vertically and air is made to flow on the floor. An air exit is provided on the ceiling opposite side of the inlet opening and an exhaust fan is placed there. The exhaust air duct is arranged horizontally. The inlet and outlet openings are placed with distance as much as possible. An air duct lined with noise absorbing material is more effective when built oblong instead of square in section. In construction of enclosure, it is an usual practice that the length of exhaust side is made short as its sectional area comes near to square, witch makes noise absorption difficult compared to that of the inlet side. The test was made on

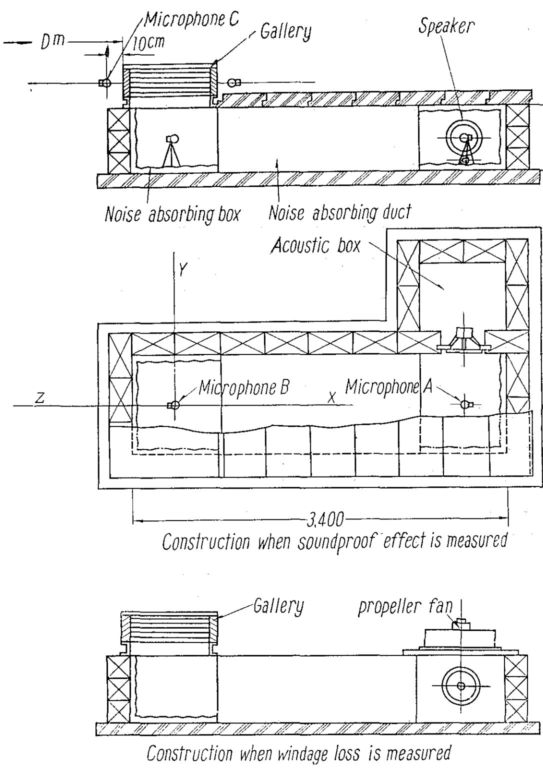

Fig. 6. Exhaust duct model for ventilating system of concrete enclosure

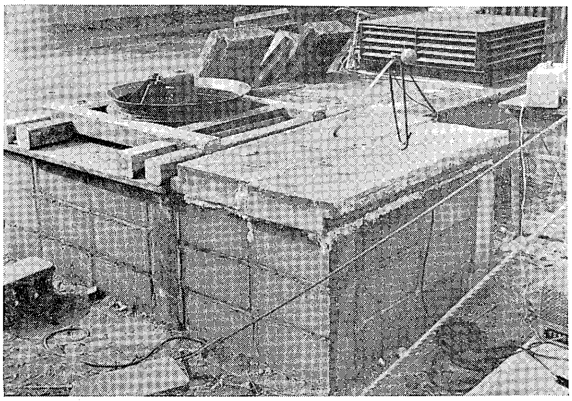

Fig. 7. View of exhaust duct model, testing on air flow losses and volume

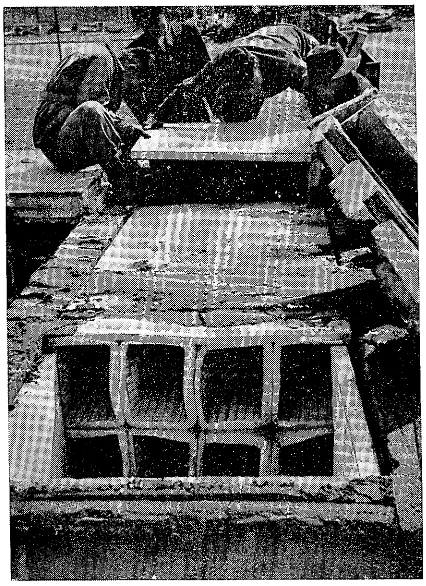

Fig. 8. View of exhaust duct model, inserting cell type noise absorbing dust

the exhaust duct. Figs. 6, 7, and 8 show the models of exhaust ducts. The models which are built conveniently for the test purpose, show slight difference in sound and in appearance of air inlet but as the air duct goes outdoor through 3 elbows of 90°, the condition will be the same with an actual installation. The air duct is placed on a concrete foundation of 120 mm thick and the roof made of heavy concrete blocks. A sound source speaker is placed on one end of the air duct. On the back of the speaker, a sound box is mounted which is made of blocks of the same material as the side block. The sound box is to boost up radiation effect of low sound. On the exhaust opening, a steel gallery of area approximately 1.5 times of duct section is placed. Noise absorbing boxes are placed at both ends of air duct and at the curved portion of the ducts. One of 3 kinds of sound absorbing ducts is placed on the middle part where the duct is straight. The Noise absorbing box is a plywood made square box with two sides open. The inside of it is lined with rock-wool blanket of 50 mm thickness covered by steel net and cheese cloth. The noise absorbing duct is made of galvanized steel plates and inside of which is lined with rock-wool blanket of 25 mm thickness. In order to increase sound-proof effect, varied shapes of similar noise absorbing materials are made of steel wire or the punching metal to sectionalize the inner space of the ducts. All rock-wool blankets are covered by cheese cloth. A cell type noise absorbing duct is the one used popularly and placed cross-wise along the air flow in the duct. A maze type noise absorbing duct divides the duct into four at a right angle to air flow and makes their width to conform with the wave length of $\frac{1}{4}$ of 100 cycles and the length $\frac{1}{4}$ of 200 cycle wave length, the air flow proceeding in zig-zag ways. This type increases resistance to air flow but the sound-proof effect is great. A wave type duct is the one partitioned by noise absorbing walls of waved shape which is of one wave length of standing wave shape in parallel with the air flow. The three sorts of ducts are all made in 1,800 mm length. The gap between the outsides of noise absorbing boxes and ducts and outer shell of the air duct is filled with wet sand to prevent sound leakage.

III. OUTLINE OF EXPERIMENT

As shown in Fig. 6. for the measurement of the sound-proof effect a microphone A is placed right in front of the speaker, microphone B is placed below the gallery in the air duct, and the microphone C on the exterior of the air duct. All frequencies of

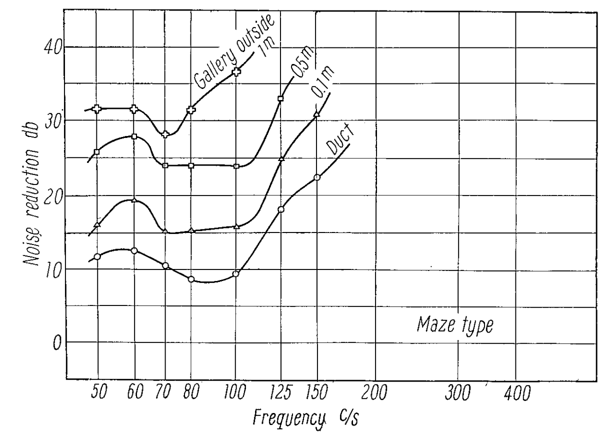

Fig. 9. Test data of maze-type noise absorbing duct

sine wave sound are measured. Figs. 9, 10 and 11 show the results of wave measured. In the curves, the one that is marked "duct" shows the value of reduced sound by means of noise absorbing duct indicated by the difference of microphone A & B.

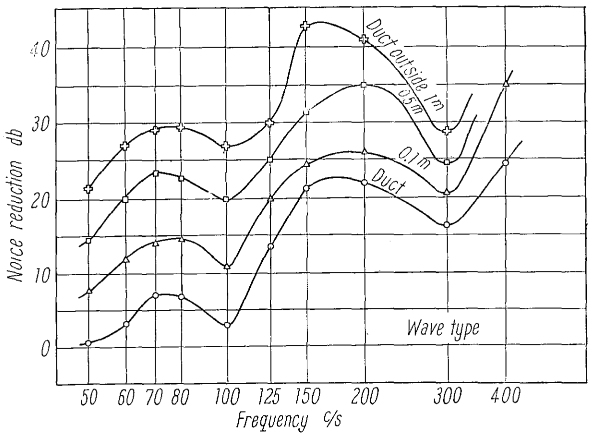

Fig. 10. Test data of wave-type noise absorbing duct

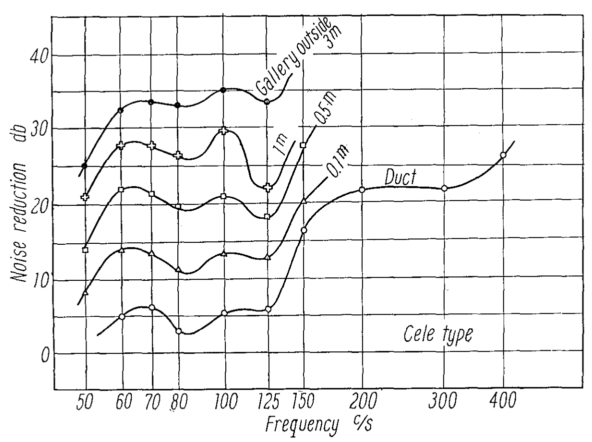

Fig. 11. Test data of cell-type noise absorbing duct

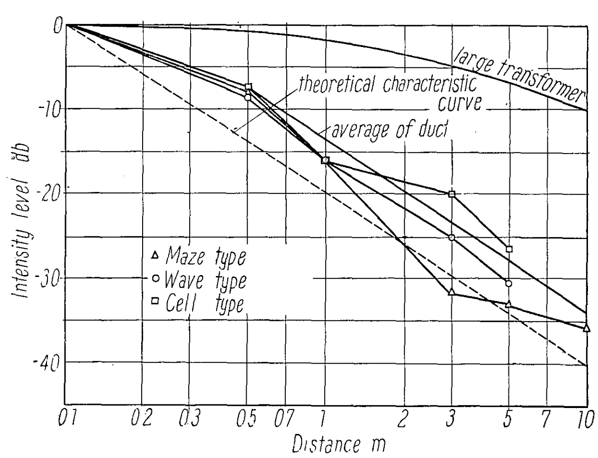

Fig. 12. Attenuation versus distance characteristics of emitted noise from duct outlet

Also marked the gallery 10 cm, 50 cm—indicate the value of reduced sound at the point of 10 cm, 50 cm apart from the gallery face of the exterior of the air duct, being the average value of 3 directions X.Y.Z. shown in Fig. 6. Fig. 12 shows the attenuation charateristics of noise leaking from the gallery according to the distance and the value is plotted based on 100 cycles.

In a duct of such a length as to the extent of the air duct tested, when the noise absorbing duct alone is taken up, the sound reduction effect in case of low tone below 100 cycles is very small as anticipated.

For instance, in the case of 100 cycles it is 9.5 db for the maze duct, 3 db for the wave type duct and 5.5 db for the cell type duct.

On the otherhand, for the high sound 200 cycles, a remarkable effect beyond anticipation is available : over 30 db in the case of maze type and 20 db in both wave and cell type ducts. For higher sound than 200 cycles, the sound-proof effect becomes far better, and the noise leakage from nearby the sound boxes on the duct outer shell is bigger than the noise leakage from the gallery ; and besides the noises from other sources affect to make the measurement impossible.

The sound-proof effect is found efficient in the noise absorbing duct and on the bent portion at both ends. In addition, it includes attenuation by a reflection of part of energy when the sound spreads to atmosphere from the duct. The measured value at 10 cm apart from the gallery includes this effect. Suppose the difference of noise weakening between the value measured in the duct and that measured at 10 cm from the gallery be the indication due to the forgoing reason ; then when the sound is 100 cycles, the maze type indicates 6.5 db, the wave and cell type indicates 8 db.

Another important fact of the sound-proof effect of the duct may be the following phenomena. The noise radiated from the duct opening is attenuated along the distance greater than that from the noise source, i.e., the transformer or the sound-proof enclosure. As shown in Fig. 15, the noise radiated from the gallery is similar to that radiated from the point sound source, and the attenuation is greater than in the case of a transformcr having a large radiating surface. Fig. 12 shows the attenuation of noise in 100 cycles. When measured at 10 cm distance, the difference of attenuation in propagation between the enclosure (the large transformer in Fig. 12 showed noise attenuation level 10 db measured at 10 m) and the air duct (35 db at 10 m) is found to be 25 db. This shows that if noise troubles come in question at 10 m distance from the enclosure, the attenuation on that point will be 25 db regardless of the reduced noise in the air duct. In other words, if the enclosure has sound-proof effect of 35 db, the air duct itself may all right as long as it has reduction of noise above 10 db. This proves that either one of three types of noise absorbing ducts can give sufficient margin as far as the effect is concerned. However, the wave type ducts may be considered best because of its material, ease of construction and windage loss.

The test on the windage loss and on the volume of air flow is conducted as shown in Figs. 6 and 7 and the following results are obtained using a propeller fan of vane dia. 600 mm 1,410 rpm 0.42 kW power.

Table 1. Test result of windage loss

	Volume of air flow m^3/min	Water head loss mm
Maze type duct	98	17.7
Wave type duct	129	10.2
Cell type duct	137	9.3

The volume of air flow is calculated from a mean velocity measured at 20 points on the gallery surface. The water head loss is measured through a small hole made on a fan mounting plate. In an actual case windage loss of the air drawing duct is to be added to that of the exhaust duct, which makes the use of propeller fan unsuitable for the maze type duct.

IV. CONCLUSION

It has been proved from the above test that a doubt whether a sound-proof effect a concrete enclosure will be spoiled by the ventilating ducts is cleared up. In case transformer noise be required to reduce the level about 30 db below than according to the JEM standard, a concreate enclosure is good enough. The method of using a sound-proof tank to reduce noises as much as possible and an insufficient portion being made up by an attenuation effect of a building is not to be used. Furthermore, if the noise reduction of 10–20 db be required, a concrete enclosure together with a sound-proof tank may solve the trouble.