

# NOISELESS INDUCTION MOTORS

By

Mitsuo Tsukamoto, Eiichi Hoshino,  
(Rotary Machine 2nd Sect., Design Dep't.)

Toshio Arai  
(Motor Sect., Mie Factory)

Eiji Koyasu  
(Rotary Machine 1st Sect., Design Dep't.)

## I. PREFACE

The induction motors are used generally for much purposes and at various places, where it is necessary to get their lower noise in order to make better working circumstances, to decrease the fatigue of the labourers and to raise their working efficiencies. Sometimes induction motors are used as driving machines of refrigerators of a building, especially of a theatre and a hotel, where they are often required their perfect quiet running. They are used lately in the chemical works and in the oil-refining works at the outdoor, and in these cases, they are to show the noiseless character so as not to give the noise disturbance to the surrounding inhabitants.

There are many causes of the noise radiated from a motor, and only hearing the noise to separate each of them is fairly difficult. But nowadays by the development of the acoustic instruments and technics, they are almost analysed and also classified largely into two causes, the magnetic and the mechanical. About the former, the theory which was treated by H. Jordan in Germany having been proved gradually by many experiments, some effective means have been taken to decrease the magnetic noise, such as the selection of the suitable numbers of stator and rotor slots to build the worse harmonic magnetic field, avoiding the resonance of the stator frame, the stator core or the rotor core, skewing and so on.

About the latter, it is considered that the noise occurs at the cooling fan and the rotor, at the other ventilating parts by mechanical frictions. Then to decrease the noise, it is necessary to design so that the air may ventilate effectively, the dimensions, the forms and the numbers of the fan blades may be suitable, the air ducts and the slots of the core may not whistle, and the frame and the other constructive parts may not be resonant to the other mechanical noises. Otherwise, the mechanical

vibration may sometimes be the cause of the noise. In spite of the careful designs considering the magnetic and the mechanical causes, as above mentioned, there is a limit naturally about the lowest noise level of a motor, and to get further quiet motor, it must be taken the variable silencing means.

We were often requested from the customers the most quiet motors, such as that the noise level of them had to be less than 75 phons, so that we endeavoured and researched to get the noiseless motors and got substantial progresses. The noiseless induction motors which we had planned and manufactured were classified generally in four systems as follows;

- (1) Enclosed-ventilated type with silencer, aVR Type
- (2) Water-cooled totally-enclosed type, QR Type
- (3) Direct water-cooled totally-enclosed type, WPR Type
- (4) Pipe-cooled totally-enclosed type, NR Type

In the following chapter, we explain the details and the test results of the noiseless induction motors which we have manufactured.

## II. ENCLOSED-VENTILATED TYPE INDUCTION MOTOR WITH SILENCER

In the Fig. 1 we showed the photograph of a three-phase wound rotor type induction motor used for a refrigerator, its output was 450kW and the speed was 1,500rpm. This is an example of our enclosed-ventilated silencer-mounted type induction motor, and the one equipped in such a quiet place as in a building is normally required the silent running as that its noise level is less than 75 phons. In this machine the ventilating air flows as shown in Fig. 2 and the air canals in the silencer are denoted in Fig. 3. If the output of this type in-

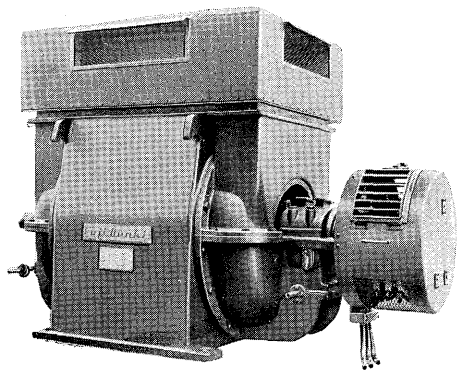


Fig. 1. Silencer type 4 P induction motor

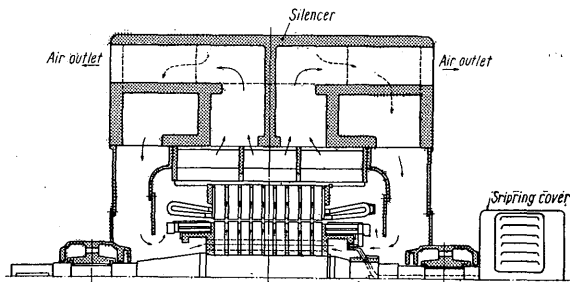


Fig. 2. Section of motor with silencer

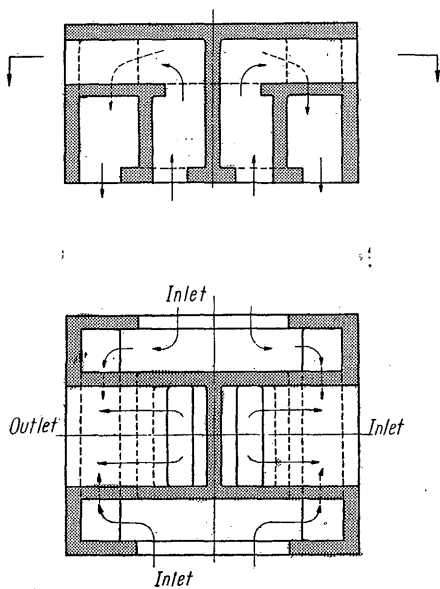
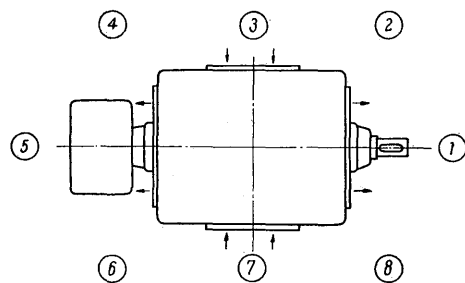


Fig. 3. Silencer

duction motor is relatively small, its standard system is that the ventilating air flows through the opening above the B-side bracket and exhausts through the one above the D-side bracket by the action of the cooling radial fan at the D-side and that the separated silencer boxes are arranged at each opening.

However, being the capacity larger as this motor, the standard system is that the cooling air, unless due to the cooling fan, flows by the aid of the cooling fins attached to the winding clips, from each side of the brackets to the centre of the frame upward. The larger the rotor outer-diameter, the higher its peripheral speed is, the necessity of the cooling radial fan which may be the cause of the noise decreases, so that this ventilating system is effective to diminish the noise. The silencer boxes at each opening of inlet and outlet are incorporated into one, then the outside view is better than the separated and the silencing capacity grows larger due to its wider opening. In the silencer box, the ventilation canals make turns several times as shown in Fig. 3, and the glass-wool walls are stucked as the noise absorber, so that they may display better silencing action. Its bearings are oil-ring lubricated sleeve bearings, so that their friction noise is also less than the ball-bearings', and then, the test results of this motor is such a good character as shown in Fig. 4 as their average value is about 75 phons. This value is the recordable one comparing with its output and speed, which owes to its better ventilating system, better silencer arrangement and construction.



Measuring Point	50 c/s	50 c/s
	Phon	Phon
①	76	78
②	73	75
③	73	75
④	74	76
⑤	74	76
⑥	74.5	76.5
⑦	77	79
⑧	73	75
Average Value	74.5	76.5

Fig. 4. Measured value of noise

### III. WATER-COOLED TOTALLY-ENCLOSED TYPE INDUCTION MOTOR

Fig. 5 is the photograph of 520 kW 3,600 rpm wound rotor type induction motor used for the gasoline pump, and this is an example of our water-cooled totally-enclosed type induction motor. This motor was also the outdoor type, and moreover the pressure-resisting explosion-proof type was necessary, but the requirement was also that its noise level should be less than 75 phons, in spite of its higher speed and special constructions.

Its circulating system of the internal air is shown in Fig. 6. The cooling water flows through the room made in the doubled frame, along which the steel pipes that transfers the heat of internal to air the cooling water are arranged. The internal cooling air circulates through the machine and the pipes by the action of the fan attached at only one side of the motor. The heat losses generated in the stator are conducted through the core, its outer surface and the frame, and transferred to the water. On the other side, those in the rotor are transferred directly to the internal air, which circulates by the cooling fan designed only for them, and then are transferred to the heat exchanging pipes, so that the windage loss of the fan decreases and the mechanical noise diminishes. The stator core are

shrink-fitted in the frame previously laminated and and finished at its outer surface so that the heat resistance at the clearance between the core and the frame may decrease. Because the stator heat losses are conducted directly to the frame, the radial air ducts are not arranged at the stator but at the rotor only and the several air canals are at the shaft. After the internal air flowed through these canals and ducts, it goes to the fan inlet through the air gap and the axial ducts which are specially designed to make easy to flow the air at the top parts of the stator slots. The bearings were oil-ring lubricated water-cooled type sleeve bearings, their rolling noise was also very small, and all the constructive parts were so solid due to its explosion proof constructions, that the test records showed very good noise character as about 75 phons.

### IV. DIRECT WATER-COOLED TOTALLY-ENCLOSED TYPE INDUCTION MOTOR

The 100 kW 1,200 rpm squirrel cage induction motor used for the gasoline pump was the outdoor type pressure resisting explosion proof motor and its noise level had to be less than 75 phons. We adopted for this use the direct water cooled type induction motor as shown in Fig. 7 and in Fig. 8.

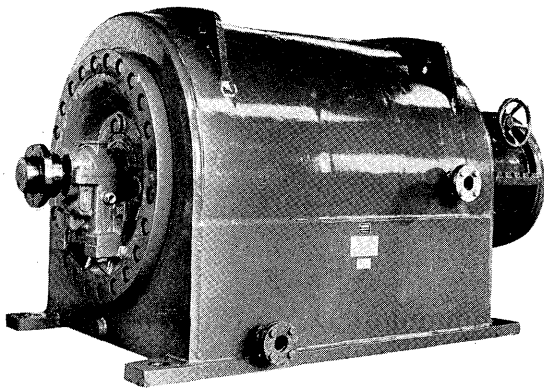


Fig. 5. Water-cooled totally-enclosed type induction motor

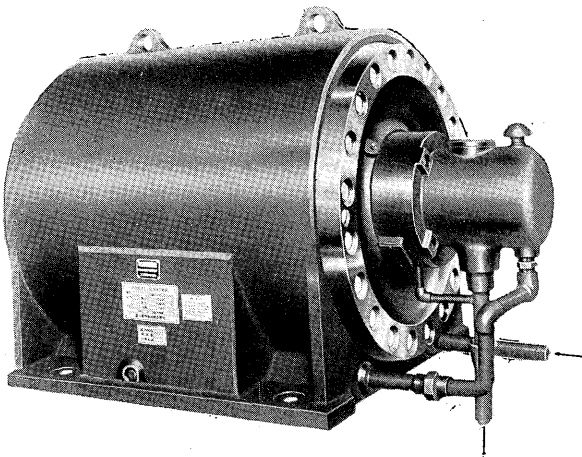


Fig. 7. Direct water-cooled type induction motor

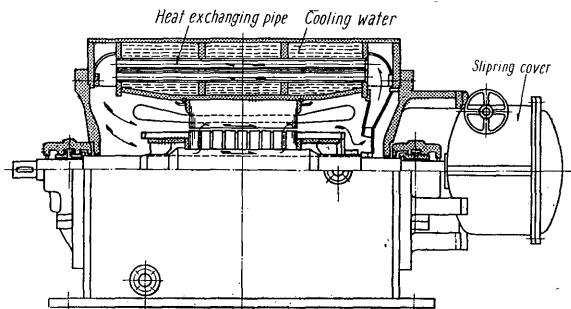


Fig. 6. Section of water-cooled totally-enclosed type motor

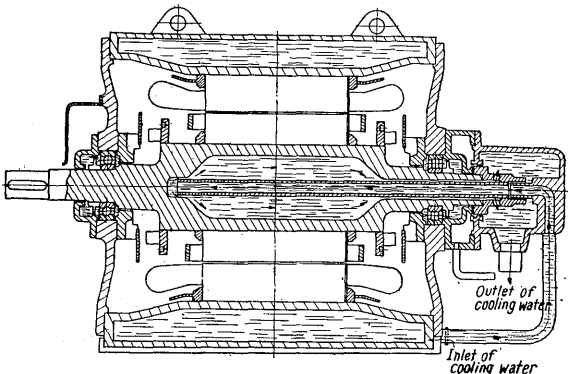


Fig. 8. Section of direct water-cooled type induction motor

About our water-cooled totally-enclosed type induction motor, as formerly explained, only the stator heat losses are cooled by the heat conduction, and the other losses are cooled by the aid of the cooling medium as the air. On the other hand, in the "direct" water-cooled type induction motor which we are now going to explain, almost all of the heat losses are cooled by heat conductions, that is, the cooling water flows through the rooms in the stator frame and in the rotor shaft as denoted by the arrows in the sectional view of Fig. 8. This system is an epoch-making one, of its effective cooling, its constructions and its simplicity, which is firstly invented by Siemens Co. in Germany. In our country, this motor was the first one. Adopting this system, volume of its internal air may be so little and the necessities to attach the internal fan may be so scarce, that the mechanical noise reduces very much. Then the noise which may be radiated from this motor is only the friction noise of rotor and the magnetic noise. The former is, however, isolated by the totally-enclosing frame to the open air, and about the latter the frame is carefully designed and manufactured not to resonant to the magnetic force, so that this type is one of the ideal motor for noiseless use.

Our 100kW motor showed naturally the better noise character and the test results showed 64.5 phons. We believe that this system may be used for much purposes, not only for noiseless uses but also for the other much uses. Because this motor has such good characters as that it may be used at high ambient temperature due to its special cooling system, that it has a simple constructions and may be used easily as the explosion-proof type and as the chemical-resisting type, and that its weight is very light and its dimentions are small.

## V. PIPE-COOLED TOTALLY-ENCLOSED TYPE INDUCTION MOTOR

The draft fan driving motor of 450 kW 900 rpm in Fig. 9 is an outdoor wound rotor type induction motor with explosion-proof slipring cover. It is an example of the pipe-cooled totally-enclosed type induction motor, and its noise level is required to be less than 80 phons. Ventilation system of the motor is shown in the sectional drawing of Fig. 10. As the motor is installed at the outdoor, the protecting cover against rain-drop and the direct rays of the sun is provided. The motor of the pipe-cooled totally-enclosed type is apt to radiate fan noise and ventilation noise outside due to its structure, and it is difficult to reduce its noise level. The motor of Fig. 9 manufactured as an outdoor type noiseless motor is provided with the drip-proof cover to be also available as a silencer. For this

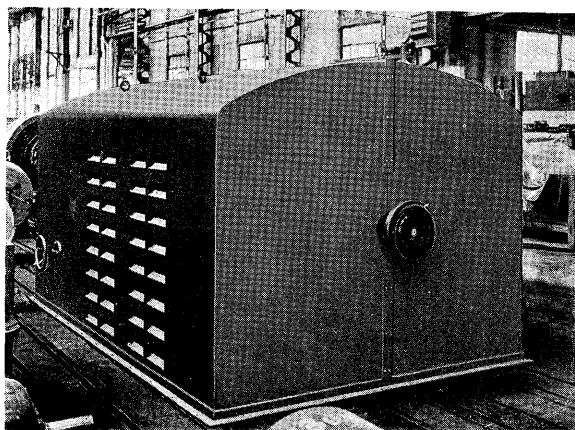


Fig. 9. Pipe-cooled totally-enclosed type induction motor

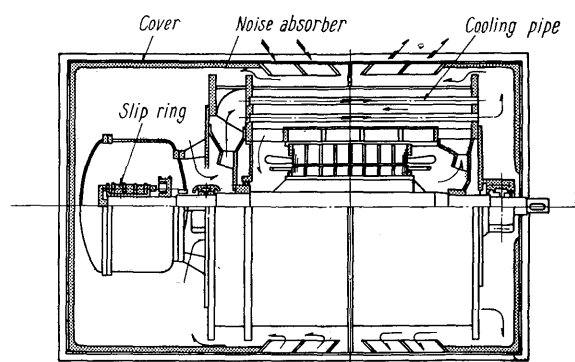


Fig. 10. Section of pipe-cooled totally-enclosed type motor

purpose, comparatively thick glass wool noise absorber is put up inside the cover and makes it absorb the noise generated by the motor as much as possible. Moreover, many bends are arranged by means of the stator frame and the cover in the ventilating circuit to make noise absorption effective. These bends are so carefully designed that they have sufficient area to decrease the velocity of the ventilating air and the ventilation can be carried out without increasing the head of the outer fan. The ventilating fan, the cooling pipe and the other structures are also carefully designed and the velocities of the ventilating air inside the cooling pipe and the duct are reduced to make the dimension of the fan small and to diminish the ventilation noise and the fan noise. Moreover, the resonance of each mechanical part is completely evaded. The dimension of the fan is reduced as much as possible by designing it as high efficiency and high head and decreasing the resistance of the ventilating circuit. Numbers of the fan blades is also suitably selected. By these means mentioned above, the motor of Fig. 9 showed an excellent result of 79 phons.

VI. FUJI SILENT MOTOR

The “silent motor” is the special one of the enclosed ventilated type motors with silencer described in chap II. The silencer of this motor is so effective that the noise level is almost completely reduced as can be said noiseless in practical use. A 150 kw 3,000/3,600 rpm wound rotor type silent motor is shown in Fig. 11 and it has not a brush lifting device and has a space heater. The design was endeavoured to make the noise level below 75 phons and the vibration below 14 $\mu$  and we have got very successful results.

The motor is of box type and has a complicated labyrinth for the ventilating air at the upper part of the box, and glass wool noise absorber is used in this part. In the motor, two small but effective fans are arranged at the both sides of the rotor and each ventilating path is covered with noise absorber.

Cooling air is drawn into the motor through the openings provided at the two sides of the upper box. Then cooling air is led to cool the motor through the air ducts of the core and the ventilating path arranged around the stator core where the noise absorber of U shape (see Fig. 12) is attached. And it flows through the labyrinth and is exhausted from the openings provided at the other

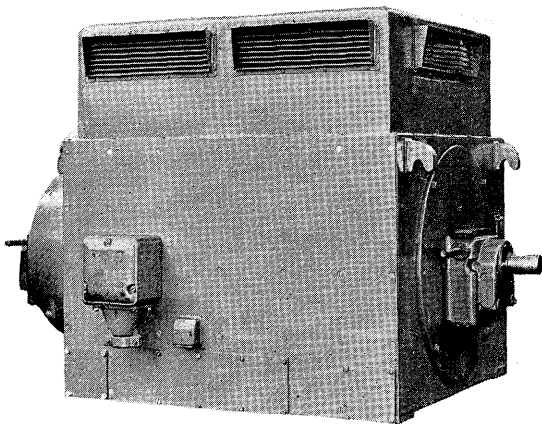


Fig. 11. Fuji silent motor

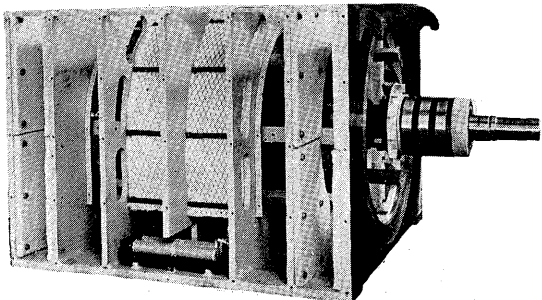


Fig. 12. Main part of Fuji silent motor

two sides of the upper box. By means of this ventilating system, a long path enough to absorb the motor noise can be taken without enlarging the motor size and effective cooling effect is obtained.

The air duct of the core, one of the main sources of the ventilation noise, is carefully designed and the shape of the rotor duct pieces is also selected to get better cooling and to reduce noise.

The bearings of the motor are lubricated by oil rings and cooled by water, as the velocity of the motor is high.

As the motor has not a brush lifting device, materials of the sliprings and the brushes are carefully chosen and cooling of the sliprings and brushes is caved out by providing an separete cooling fan and a ventilating circuit isolated from the inside of the motor. Test results are shown in table 1. The values of the noise given in parentheses were obtained from the test at which a part of the noise absorbers inside the motor was removed. From these test results, it has been confirmed that large parts of the noise absorbers inside the motor can be taken away to keep the noise level about 75 phons.

Table 1. Noise and vibration of Fuji silent motor

(c/s)	(V)	Noise				Vibration (maximum)
		Driving side	Anti- driving	Termi- nal side	Anti- termi- nal side	
50	3,000	6 4 (72.5)	6 6 (76.5)	6 5 (7 4)	63.5 (7 2)	1 0
60	3,000	6 6 (75.5)	6 8 (76.5)	6 7 (7 7)	65.5 (7 5)	1 2

( ) : Noise absorber is partially removed.

VII. CONCLUSION

We described in the foregoing the various types of the noiseless motors manufactured recently. We are confident that the requirement about the noise level can be satisfied by selecting these motors in compliance with service condition. We have intention of endeavouring to meet the request of the customers utilizing the experiences obtained to this day.

Reference  
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