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Development of High Energy-efficient Parts-washing System

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◎ Keywords: Prevention of heat loss due to radiation, conduction, etc.

◎ Outline of Theme

The conventional parts-washing system sprinkled heated cleaning liquid and blew off the liquid with compressed plant air. This washing system consumes a lot of energy. Under such circumstances, we have developed a new type of washing system that adopts new washing and drying methods to reduce the energy to heat the cleaning liquid and to blow plant air. This newly developed parts-washing system consumes only half the energy compared to the conventional system. The energy conservation measures we implemented are described below.

◎ Implementation Period of the Said Example

From April 2001 – May 2003

- Planning period: April 2001 – June 2001 3 months in total
- Measures Implementation Period: July 2001 – January 2003 19 months in total
- Measures Effect confirmation Period: February 2003 – May 2003 3 months in total

◎ Outline of the Business Establishment

- Production items: Power units (engines, transmissions) for SUBARU cars
- Number of employees: Approx. 1,750 (Oizumi Plant)
- Annual energy consumption (Oizumi Plant: actual record of FY 2003)
    - Fuel: 7,480 kL/year

- Electricity: 93,053 MWh/year

◎ Process Flow of Target Facility

Shown in the figure below is the production process of the 5-speed automatic transmission (5AT) to which the energy saving measures are taken.

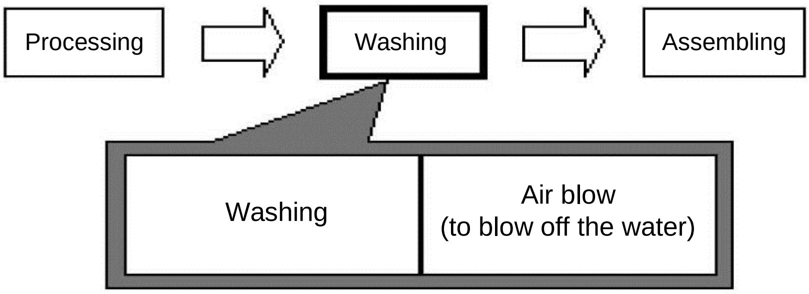


Fig. 1 Process Flow of Target Facility

1. Reasons for Theme Selection

Our Oizumi Plant has been making efforts to achieve the target of reducing energy consumption by more than 30% for newly developed equipment in order to achieve the in-house target described in the “New voluntary environmental plan,” by 2006, which aims to reduce CO_2 emission from the production plants by 6% compared to that in 1990. Under such circumstances, we have started the development of a 5-speed automatic transmission assembly line of new design.

We have conducted a survey of energy (electricity and air) consuming status in our plant that produces 4-speed automatic transmissions (hereinafter referred to as “4AT”). The results show that the processing lines consume 77% and the assembly and operation lines, for which we are responsible, consume 23% of the total energy (Fig. 2-1). We have examined the breakdown of energy consumption and found that the washing system consumes 64% of the energy (Fig. 2-2). Therefore, we have selected energy conservation of the washing system as the most important subject.

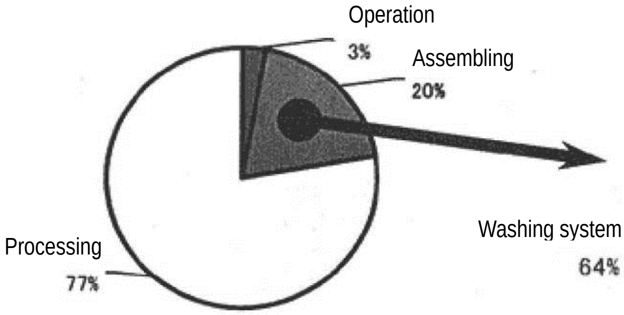


Fig. 2-1 Energy consumption at the 4AT production plant

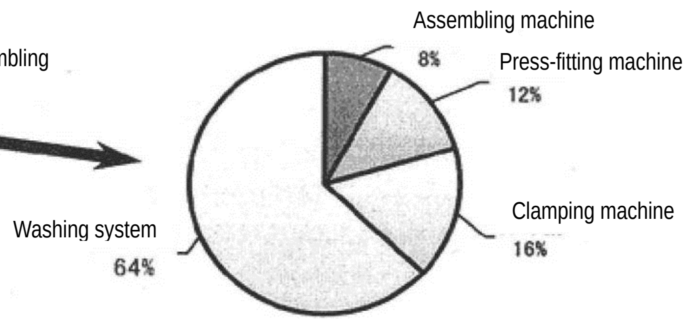


Fig. 2-2 Energy consumption at the 4AT assembly line

Fig. 2 Results of the survey on energy consumption rates

2. Understanding and Analysis of the Current Situation

The main purpose of the parts-washing system located in the assembly line is to remove dust and oil adhered to parts such as gears (hereinafter referred to as “works”). Figure 3 shows the conventional washing system used in the assembly line. It consists of two stations; i.e., the washing station and the air blow station where cleaning liquid attached to the works is blown off.

In the washing station, a large quantity of cleaning liquid is heated in a tank (using an electric heater and steam), pumped up, and sprinkled over the works that are carried by a conveyor belt. The main reasons for heating the cleaning liquid are to improve the detergency and dewatering performance after washing (drying characteristics after washing). In the next air blow station, compressed plant air (generated by the compressors) is blown onto the works so as to remove the water from the works and dry them.

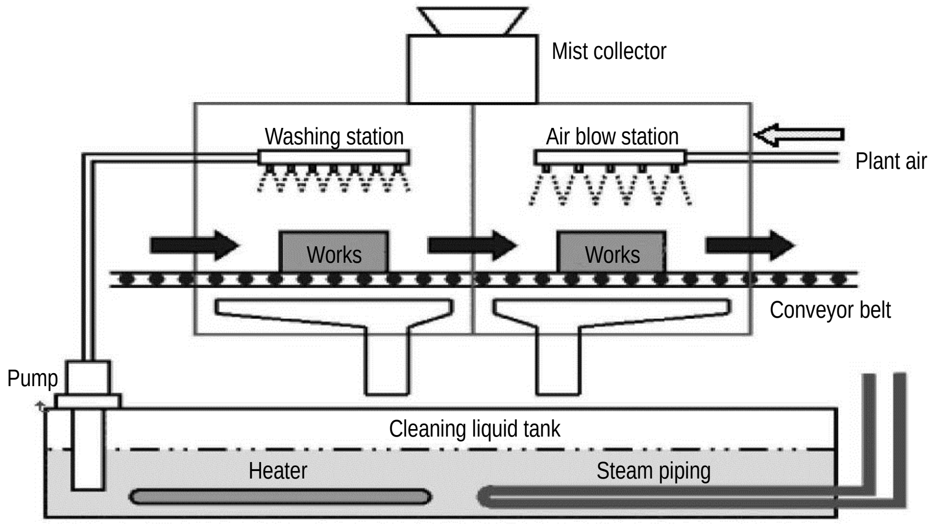


Fig. 3 Outline of the conventional washing system

We analyzed this washing system (Fig. 4).

(1) Washing Station

- Because it is of the circulating type, the cleaning liquid tank is large (800 liters) and, therefore, a large quantity of energy is consumed only to heat the liquid.
- Since heated cleaning liquid is sprinkled over the works, not only the works but also the entire washing room, the suction pump, piping, etc. that do not need to be heated are heated. As a result, significant unnecessary heat loss is generated. It is feared that this practice may deteriorate the environment (surrounding atmosphere) and may be a safety hazard, so that it is necessary to provide heat shields, safety fences, etc. in order to secure safety, which results in cost increase.
- Since heated cleaning liquid is sprinkled over the works, mist is generated. In order to prevent environmental deterioration by the mist, a mist collector (exhauster) must be operated all the time.
- As the mist collector suctions the air, a large amount of heat (latent heat of steam) is removed from the sprinkled hot water in the washing station.

(2) Air Blow Station

- Plant air of approx. 5 m^3 per minute is used to blow off the water from the works. In order to generate this air, 30 kW of electricity is consumed.

- ♦ The air blower discharges compressed plant air. However, the velocity of air flow drops rapidly with increasing distance from the exit due to air resistance.(like shooting a water pistol in water).
- ♦ A large number of nozzles is used in order to blow off the water from the whole works more efficiently, but this usage of plant air is just like throwing it away (the same as air leakage).

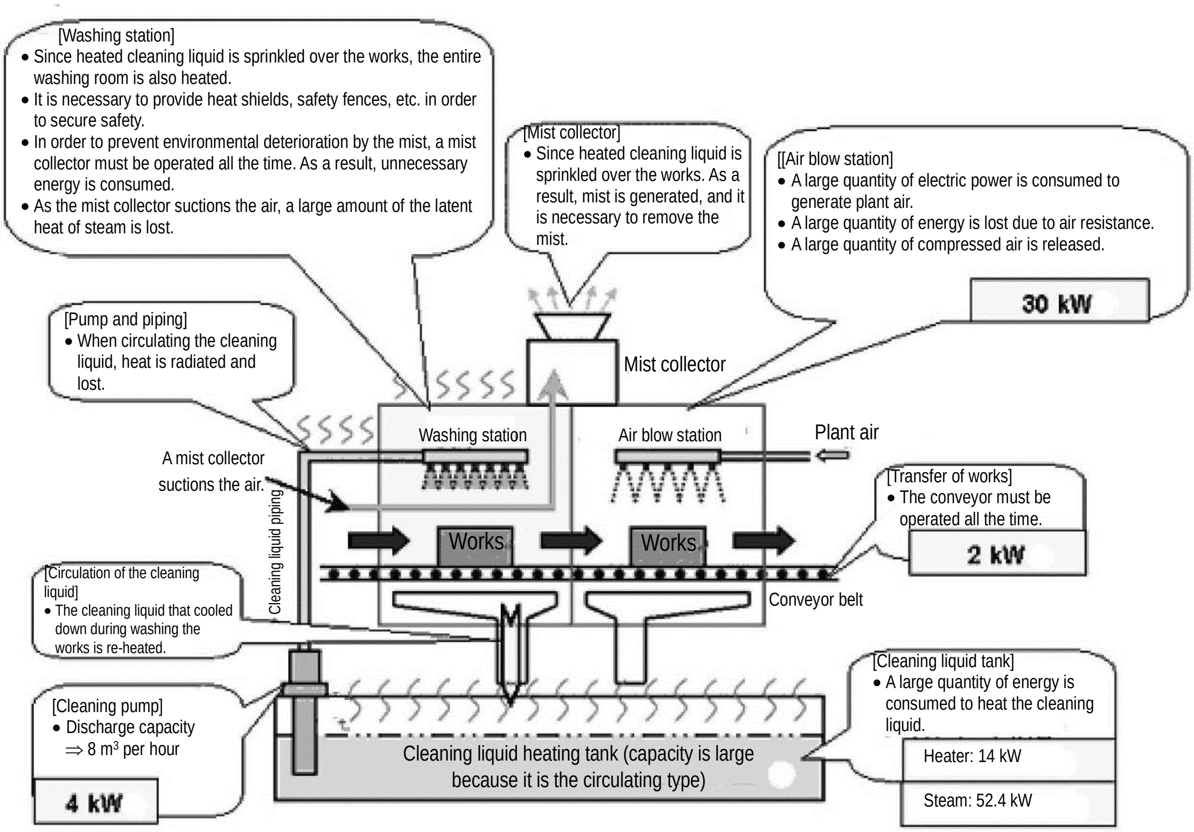


Fig. 4 Energy consumption by the conventional washing system

3. Progress of Activities

(1) Implementation Structure

In order to achieve our target of reducing CO_2 emissions, we started the development of high energy-efficient parts-washing system, which will be a model machine. We examined the specifications for such a washing system that utilizes heat energy efficiently and that discontinues the usage of plant air.

Table 1 shows the time schedule from formulating a plan to its implementation and verification of the effect for the washing system.

Table 1: Time schedule for introducing and operating the washing system

	2001		2002		2003	
	First half	Second half	First half	Second half	First half	Second half
Analysis of the conventional washing system Examination of the improvement plan	→					
Execution of simplified simulation and analysis of effects		→				
Manufacture of the new washing system Re-verification of the improved portions			→	→		
Installation and verification of effects					→	
Application of the same technique to other facilities						→

We examined a wide variety of washing systems, tested our unique ideas, and conducted a simulation to verify the effects before deciding on the final improvement plan.

(2) Target Settings

◎ Effective utilization of heat energy

◎ Discontinuation of the usage of plant air

⇒

We have set the target of reducing energy consumption by the new washing system by more than 50% compared to that by the conventional washing system.
Reduction by more than 0.85 kW

(3) Problems Points and their Investigation

We have determined to abandon fixed ideas and improve the washing system with an innovative concept, and re-examined the washing processes once again.

♦ Washing station

The system of sprinkling heated cleaning liquid is inefficient in terms of heat conductivity to the works.

⇒ Consider discontinuing the system of sprinkling heated cleaning liquid. However, it is necessary to heat the cleaning liquid to improve the performance of degreasing and dewatering.

♦ Air blow station

A certain air flow velocity is required to blow off the water from the works. However, when compressed air is discharged from narrow nozzles as can often be seen in conventional systems, the airflow velocity drops rapidly due to nozzle resistance and air resistance (Fig. 5).

⇒ Review the air blow system. (Discontinue the compressed air blow system because a large quantity of energy is required to generate compressed air.)

⇒ Review the air blow nozzles.

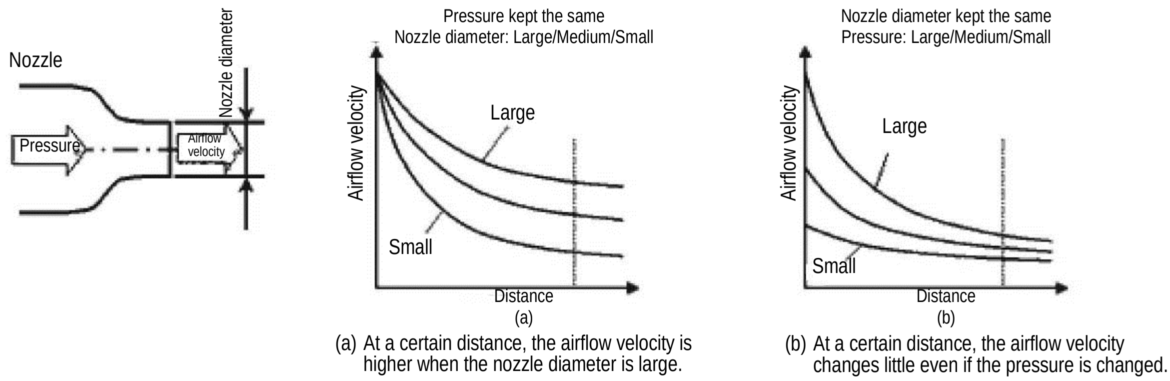


Fig. 5 The relation between air velocity and distance on blowing from air nozzles

* Therefore, it is not necessary to use compressed air for blowing off the liquid from the works. Dewatering can be done with other means if a high airflow velocity can be secured.

In order to solve these problems, we have scrapped the conventional and widely practiced concept of sprinkling heated cleaning liquid over the works and drying them using plant air, and started the manufacture of a parts-washing system with new specifications.

4. Details of Improvement

(1) Reduction of Heat Energy Loss at the Washing Station

The system of sprinkling heated cleaning liquid can accomplish both washing and heating of the works at the same time, but heat energy loss is significant. While we were discussing possible means to solve this problem, we got a hint from our daily life that “we soak in the bath tub to warm ourselves because it takes a longer time to warm ourselves by taking a shower” (Fig. 6), and decided to adopt the system shown below.

◎ Divide the washing station into two stations. (Divide the cleaning liquid tank into the tank containing ambient-temperature liquid and the tank containing heated liquid.)

- In the first station, the cleaning liquid is not heated and is sprinkled over the works (rough washing).

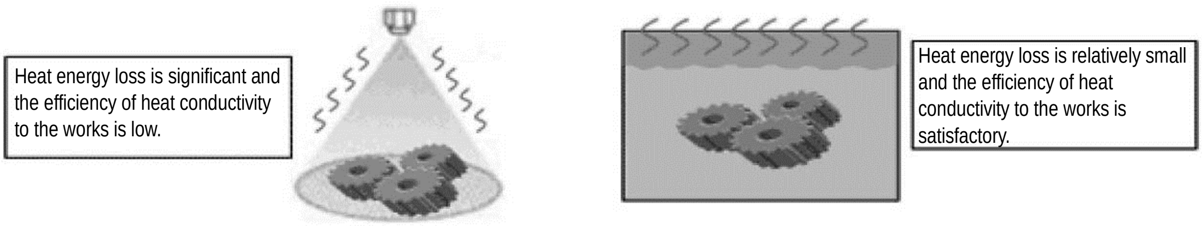
⇒ Radiation heat loss from the entire washing room, suction pump, piping, and the entire equipment can be ignored.

⇒ The generation of steam is reduced and, therefore, it is not necessary to install a mist collector.

- In the second station, the works are dipped in heated cleaning liquid and moved up and down (hereinafter referred to as “dipping”) so as to secure sufficient degreasing and heating.

⇒ By changing the method from sprinkling cleaning liquid over the works to dipping the works, the efficiency of heat conduction to the works improves significantly.

⇒ Since cleaning liquid is no longer circulated, the size of the heating tank can be reduced to the required minimum (from 800 liters to 300 liters). As the quantity of cleaning liquid has been reduced and a temperature drop of the cleaning liquid by circulation can be prevented, the energy required for heating is reduced radically (discontinuation of the electric heater: 14 kW; reduction of energy for generating steam: 28.8 kW).



(a) Sprinkling method (b) Dipping method

Fig. 6 Means to improve the efficiency of heat conductivity

(2) Reduction of Heat Energy Loss at the Air Blow Station

In order to discontinue air blow using compressed plant air, we have decided to adopt the system shown below.

◎ Adoption of the turbo blower system instead of compressed plant air (Fig. 7)

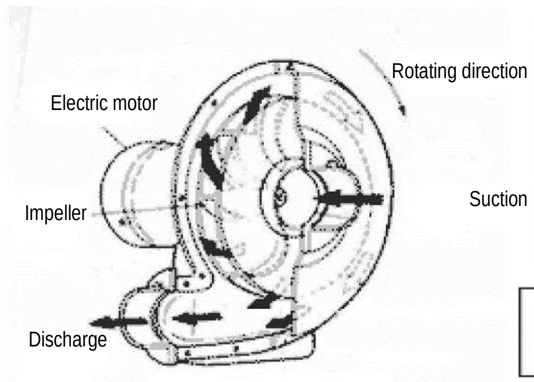
⇒ Increase the air flow rate by making use of the characteristics of the turbo blower to secure an airflow velocity similar to that of plant air.

◎ Thorough care must be exercised to reduce pressure loss in order to generate sufficient airflow velocity at the turbo blower that can provide much less pressure than compressed plant air as before, so that the pipes are made larger (to a duct size) and slit air nozzles are introduced (Fig. 9). In addition, the blower is located directly above in order to minimize the distance between the blower and the nozzles.

⇒ Energy loss due to pipe resistance and air resistance when the air is discharged can be reduced.

⇒ Airflow velocity can be secured by increasing the air flow rate.

As we adopted this system, we could reduce energy consumption significantly while securing dewatering performance equivalent to that of compressed plant air as before (electric consumption for generating compressed plant air: 30 kW → electric consumption by the turbo blower: 5.5 kW).

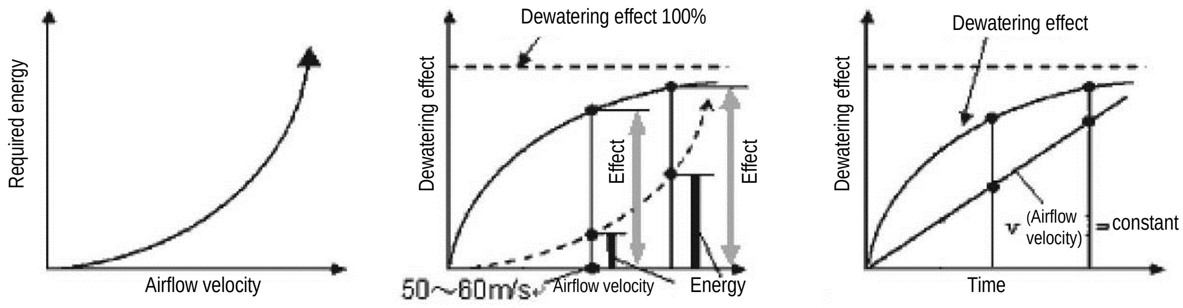


(Outline of the turbo blower)

Air source	Pressure	Flow rate	Evaluation
Plant air (compressor)	○	△	△
Turbo blower	△	◎	○

In the air blow (dewatering) station, the water adhered on the works can be blown off efficiently by increasing the airflow velocity, not the pressure.

Fig. 7 Explanatory chart of the turbo blower



More energy is required to increase the airflow velocity.

More energy is required to increase the airflow velocity, but the dewatering effect cannot be improved as expected. We have found the optimum velocity to secure satisfactory dewatering performance is 50 – 60 meters per second.

In case the airflow velocity is kept the same, the dewatering performance deteriorates if the air is blown at the same location for a long period of time. The dewatering performance can be improved when the works are moved by the nozzles so that all portions of the works are subjected to air blow.

$$v = \sqrt{2g \frac{p}{\gamma}}$$

v: Velocity (m/s) p: Pressure (Pa)
ν : 1.25 kg/ m^3 (specific weight of air)
g: 9.8 meters/s^2 (gravitational acceleration)

[Reference]
The pressure at a velocity of 56 meters per second is 200 Pa (=0.002 kgf/cm^3).

Fig. 8 Dewatering performance

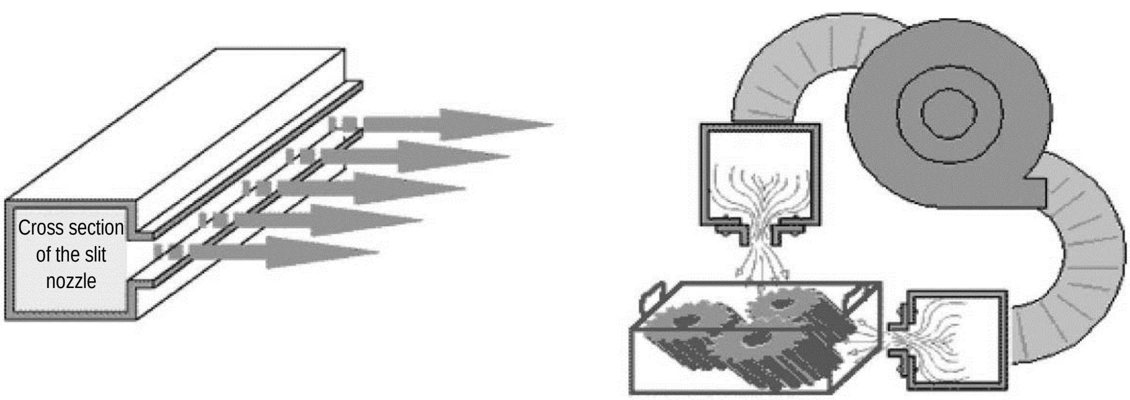


Fig. 9 Slit nozzle and installation model

(3) Other Improvements

◎ We have adopted the carry system by a transfer mechanism to move the works.

⇒ Transfer time of the works without added value can be shortened, which in turn results in a shortened entire cycle time.

◎ We have adopted conveyors moving forward and backward in the sprinkling and washing station and the air blow station, and provided a cylinder that moves up and down in the dipping station in order to move the works repeatedly.

⇒ This new system can wash and dry the works efficiently and the washing accuracy has been improved.

5. Effects of Improvements

Figure 10 shows an outline of the new washing system.

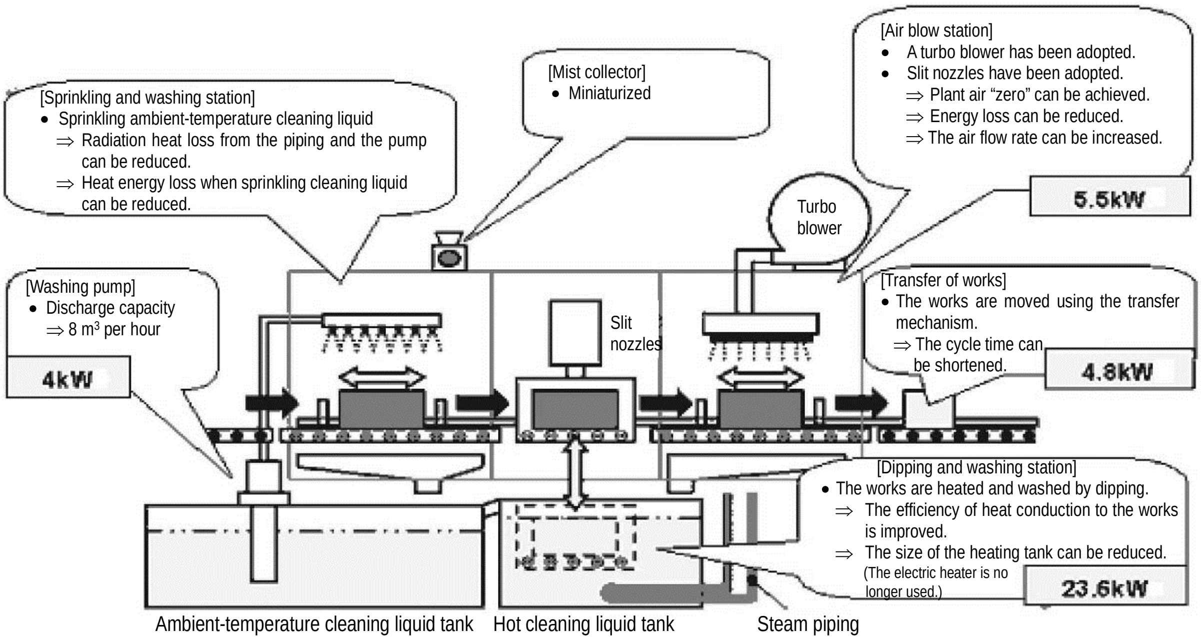


Fig. 10 Outline of the new washing system

Energy consumption by this newly developed washing system is calculated and compared with that of the conventional system.

Table 2 Comparison of energy consumption

Conventional system	1.71 kWh/unit
New system	0.64 kWh/unit

Energy consumption has been reduced by 63% compared to the conventional washing system.

As for capital investment, expenditure for the conveyors which can move forward and backward and for the motors for dipping process can be offset, because the size of the mist collector is reduced, the electric heater is no longer used, and safety precautions such as heat shields and supplementary works can be reduced. So there are no changes in the capital investment.

6. Summary

In order to reduce energy loss in the conventional washing system, we have decided to scrap the conventional method and by changing the basic concept drastically a completely new washing system has introduced. As a result, we could reduce energy consumption significantly. In addition, we could improve not only energy conservation but also the washing and dewatering performance (compared to the conventional washing system) as well as the quality.

When we implemented the improvement measures, we asked ourselves, “Is it really possible to achieve such a target?” .However, we never gave up, kept producing ideas, and spared no efforts to attain the goal. Moreover, we have recognized the fact that this new system was born of a hint from our daily life and that there are hints for improvements everywhere and we will continue to wrestle with the energy conservation activities with confidence. We are very pleased to inform you that we have applied for a patent for this washing system.

7. Future Plans

We will apply this new washing system to other washing machines in an effort to improve the energy consumption of the entire plant. We will not be content with the status quo and will continue to exert our best efforts to further improve energy efficiency and try to achieve the target described in the “New voluntary environmental plan.”