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Challenging Energy Conservation Measures in a *Tofu* Bean Curd Manufacturer in Kochi, Western Japan

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◎ **Keywords**: **Rationalization in conversion of electricity into motive power and heat, etc. (Electric power application equipment, electric heating equipment)**
Rationalization of heating, cooling, and heat transfer (Air conditioning facilities, hot water supply facilities, etc.)

◎ Outline of Theme

For a small to medium-sized manufacturing business such as our company, there are no spare funds available for newly purchasing electric power-saving equipment to promote energy conservation activities. Accordingly, the company positively tackled the implementation of energy conservation without incurring costs by thoroughly making effective use of its existing equipment, through carrying out improvements and modifications and devising usage methods. As a result of effectively using its existing equipment without investing in new equipment, the company succeeded in realizing a 20% reduction in the overall energy usage of the factory until now.

◎ Implementation Period for the Said Example

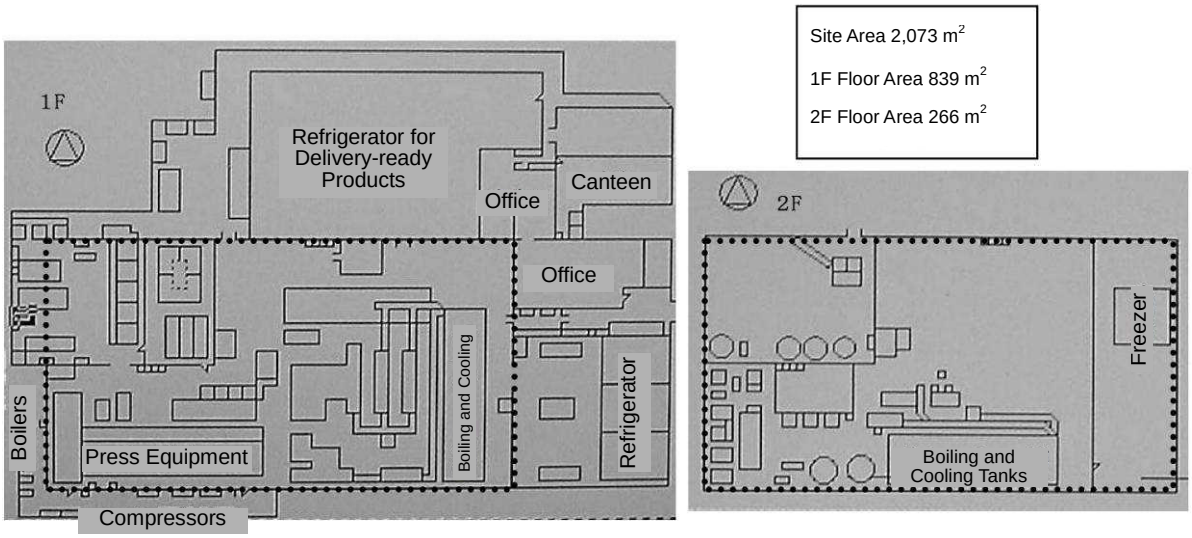
May 2002 – Continuously to the present

- Project Planning Period — May 2002 – Continuously to the present
- Measures Implementation Period — September 2002 – Continuously to the present
- Measures Effect Verification Period — September 2002 – Continuously to the present

◎ Outline of the Business Establishment

- Items Produced — *Tofu* bean curd, and deep-fried *tofu* bean curd manufacture
- No. of Employees — 52 persons
- Non-designated factory

◎ Overview of Target Facilities



1. Reasons for Theme Selection

Our company strives daily to manufacture safe and delicious tofu bean curd including “Deep-sea-water Tofu” that is made with deep-sea water drawn from the ocean off the Muroto Peninsula. In addition, since the company’s establishment, it has utilized “ion water” (electron-charged water) for all the processes in the tofu manufacture. This water is manufactured by ion water generating equipment using infiltrated water from the Shikoku mountain range drawn from 30 meters below the company’s site. The soya beans used as the raw materials for the tofu manufacturing are also 100% non-genetically modified produce, and only Japan-grown soybeans are used, as the company takes particular care to maintain its particular style of tofu manufacture.

Although the current situation of the steep rise in prices of raw materials and fuel costs have greatly exceeded our estimations, we have been striving since 2002 to implement energy conservation activities in order to continue to supply delicious tofu at the same prices. Since no surplus funds are available for investing in equipment, we attempted to realize energy conservation by thoroughly implementing effective utilization of our existing equipment.

2. Progress of Activities

(1) Implementation Structure

An Energy Conservation Promotion Group was created within the entire company to prepare

a structure to allow the planned implementation of a program of actual measures to deepen our understanding of the company's equipment by carrying out investigations into ways of proceeding with energy conservation and the effects, and by implementing study and training.

(2) Understanding of Current Situation

Concerning the implementation of the energy conservation activities, investigations were carried out to determine which fields in our company are actually using large amounts of electric power. Further, by gaining an understanding the current situation, it was to be determined which equipment units will actually allow energy conservation measures to be implemented.

Although we generally understood that equipment that is directly powered by electricity would be using a certain amount of electric power, we were surprised to discover that large amounts of electric power was being used by the compressors, which use electricity indirectly. (Fig. 1)

By determining the priority items for carrying out energy conservation, and beginning little by little from easily implemented measures, we began implementing measures while verifying the effects.

The energy conservation activities that have actually been implemented so far are shown below.

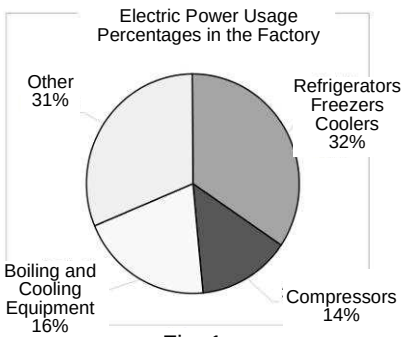


Fig. 1

① In the manufacturing work place, despite the fact that large amounts of compressed air were being used, energy conservation was tackled for the air compressing equipment, which had not been a reduction item subject.

② In our company, an extremely large amount of electric power is used in the summertime, when the peak usage is reached. As this is due to the influence of coolant-related equipment (freezing and refrigeration equipment and air conditioners), the implementation of energy conservation activities was tackled for this coolant equipment.

③ By gaining an understanding of the manufacturing equipment usage situations, we focused our attention on tackling energy conservation of standby electric power that is being wastefully expended.

(3) Analysis of Current Situation

1) Air compressing equipment

- Out of the 5 compressor units, 4 units were operating almost simultaneously approximately once every 10 minutes.
- Because the compressed air appropriate setting pressure has not been determined for each equipment unit, there is an excess setting pressure in the work place.
- The compressed air supply piping to the equipment is thin and long, and water is piled up inside the piping.
- The installation location of the compressors is an extremely hot place. (They are installed beside the boilers.)

2) Coolant-related equipment

- The location where the outside units of the coolant-related equipment are installed are on the roof and on top of the building where they are fully exposed to direct sunlight in locations with high surrounding temperatures.
- Because this equipment is used for the product and raw materials storage locations, 24-hour operation is being carried out.

3) Standby electric power of equipment

- Among the equipment, some units can be used as soon as the power is switched on, while other units can not, requiring time to warm up.
- As the preparation for manufacturing, all of the equipment power is switched on before carrying out the manufacturing preparation.
- In equipment that is using large amounts of electric power, such as the units carrying out heating and cooling, standby electric power is being used wastefully.

4) Reviews of steam equipment

- Review of steam setting pressures and temperatures
- Review of methods of using 2 boiler units.

(4) Target Settings

Taking 2001 as the standard year, a 15% usage reduction was targeted both for electric power and heavy oil five years afterwards, in 2007.

(5) Investigation Items and Details of Measures

1) Air compressing equipment

The operation condition of the 5 compressor units was investigated, and the compressor discharge amounts were compared. (Table 1)

Table 1 Compressor Operation Condition Units: ℓmin. (ANR)

Machine Number (Motor Capacity)	No. 1 Machine (7.5 kw)	No. 2 Machine (7.5 kw)	No. 3 Machine (5.5 kw)	No. 4 Machine (3.7 kw)	No. 5 Machine (7.5 kw)	Total
Usage	332	840	133	297	339	1914
Discharge Amount (Rating)	840	840	630	440	840	3590

According to the comparison between the usage and compressor capacities, it was found that the use of 3 compressors would be sufficient to cover the usage required. However, some equipment units momentarily use large amounts of compressed air. We believed that it would be possible to reduce the number of compressors being used if these peak amounts could be reduced, and we implemented activities to reduce the peak amounts and realize operation of an appropriate number of compressor units.

a. Compressor installation locations and piping changes (Fig. 2)

- Because the compressors were located beside the boilers and their operating efficiencies were being reduced by the rise in the surrounding temperature, their installation locations were moved.
- The compressors were moved to beside the windows and a curtain was used to separate them from the boilers, reducing the surrounding temperatures.
- The piping was arranged in a loop, and the supply piping to the equipment was made thicker and shorter (1F and 2F).

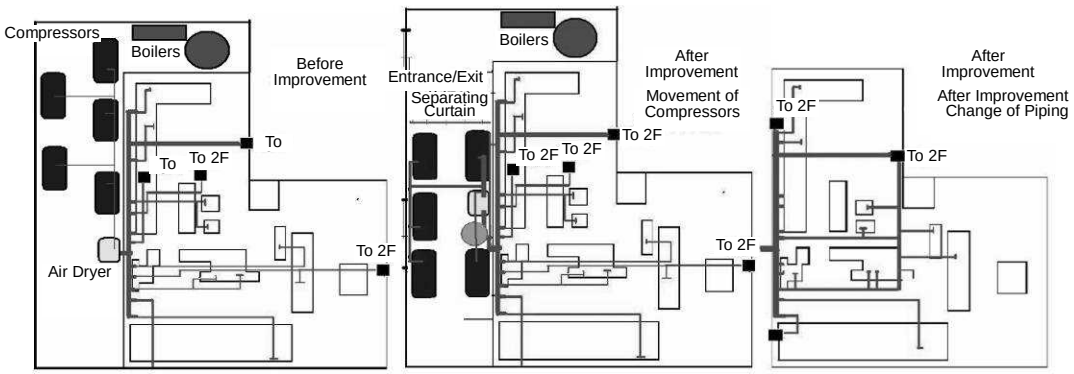


Fig. 2 Compressor Movement and Piping Changes (1F)

b. Repairs of air leakage part

- There were locations at piping joint parts and at cylinders where air was leaking.
- Even small leaks were also carefully repaired.

c. Route changes of tofu press equipment (Fig. 3)

- Out of the maximum compressed air amount used in the factory, approximately 25% is used by the press equipment.
- 15 cylinders with 100 mm diameters operate simultaneously, with pistons reciprocating up and down in a 2-minute cycle time.
- In order to compress the tofu, pressure is required during going down, but pressure is not required during going up.
- A regulator with a check valve was added inside the circuit, and was used to set the required pressure during going up.

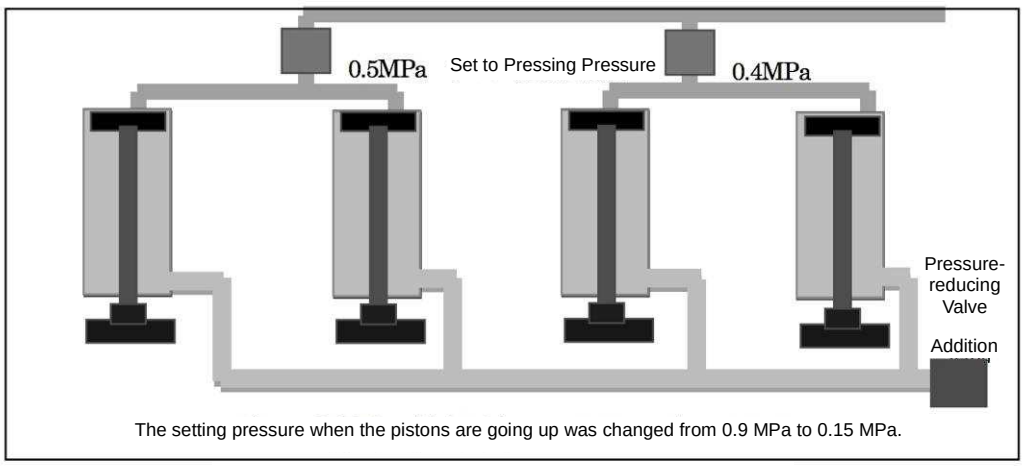


Fig. 3 Press Equipment Improvement

d. Changing the setting pressures to lower pressures

- Due to the implementation of the measures described above, the compressed air usage could be greatly reduced.
- Due to the reduction in the usage, the main supply pressure setting was lowered from between 1.0-0.8 MPa to between 0.8-0.6 MPa.
- The setting pressure for the automatic machines that use the compressed air was reduced from between 0.7-0.5 MPa to between 0.4-0.3 MPa.

e. Result of implementing energy conservation in the air compressing equipment

As a result of implementing the activities, the compressor operation conditions changed to the following. (Table 2)

Table 2 Result of Improving the Air Compressing Equipment Units: ℓmin (ANR)

	No. 1 Machine	No. 2 Machine	No. 3 Machine	No. 4 Machine	No. 5 Machine	Total
Before Improvement	332	840	133	297	339	1941
After Improvement	199	670	Halted	Halted	Halted	869

As a result of implementing energy conservation measures in the air compressing equipment, it was possible to reduce the compressed air usage by more than 50%. The compressor operation was changed to two-compressor operation, and the remaining three units were halted.

Due to the building-up of small energy conservation improvements while effectively using the equipment in the current situation, we were able to achieve a large reduction that exceeded the target amounts, and we were also able to realize operation of the appropriate number of compressor units.

2) Coolant-related equipment

In the cooling structure of the coolant-related equipment, cooling is realized due to the heat exchange between the outside units and the inside units of the room. Regarding the cooling capacity of the coolant equipment, although there will be differences according to the performance of the machines themselves, the installation location of the outside units will also greatly affect the performance.

In the situation of our company, the outside units are installed on the roof and at the south side of the factory. For this reason, the surrounding temperature becomes high, and following the rise in air temperatures in the summertime. Consequently, it can be assumed that the cooling performance of the outside units will be reduced and the consumed electric power will increase.

However, because it was not easy simply to move the outside units or to replace them with new energy-conserving equipment, we tried to see if it would be possible to maintain or improve the performance even when the installation environment is poor by atomizing water to create a mist in the outside units. In order that the water used would not be wasted, the atomizing time was adjusted according to the surrounding temperature using a microcomputer so that only the minimum necessary amount of water would be blown into the units. (Fig. 4 and Fig. 5)

Preparation of the equipment was begun in April to allow verification during the summer of 2003. The connection of the piping to each of the outside units and the creation and mounting of the control equipment was carried out according to plan. In July, the water

atomizing units were installed in the 23 outside units and operation could be started. The installation conditions are shown in Fig. 4.

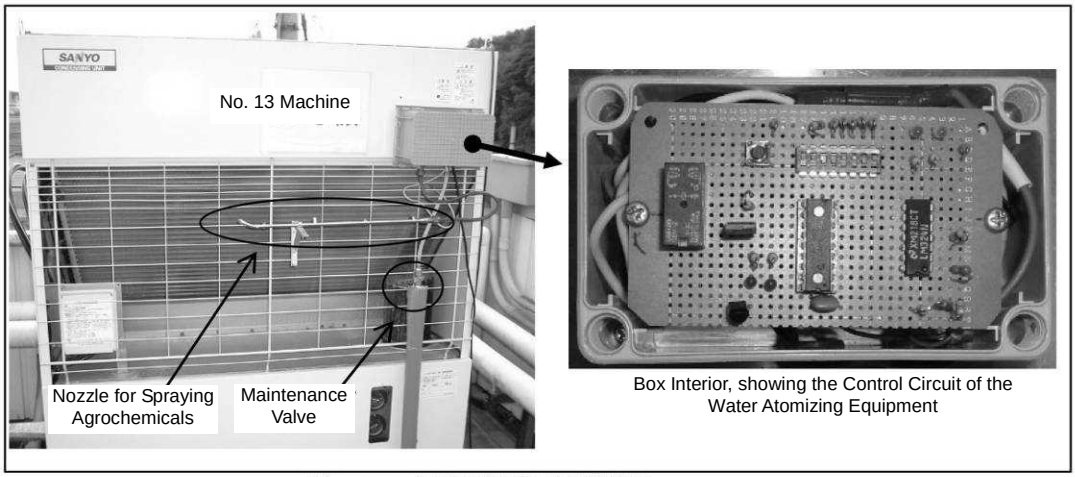


Fig. 4 Water Atomizing Equipment Installation Condition

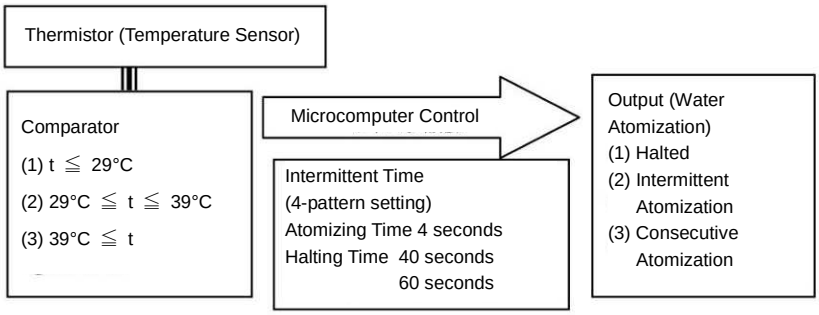


Fig. 5 Control of Water Atomization Equipment

In order to conduct a comparison to determine how much of an effect was being made by the water atomization, wattmeters were installed in each of the outside units each week to investigate the energy conservation effect. The results were as shown below. (Fig. 6 and Fig. 7)

Measurement was carried out in the situation where the water atomizing equipment power was switched off for three days out of every week.

The temperatures described at the bottom of the diagrams are the temperatures measured with a thermometer under the eaves outside the building around noontime, while the electric power amount shows the amount of electric power used in the one day (in kWh). The dark-colored bars in the graph show the electric power amount when the atomizing equipment was being used, while the light-colored bars show the electric power amount on the days when the power of the atomizing equipment was switched off and was not being used.

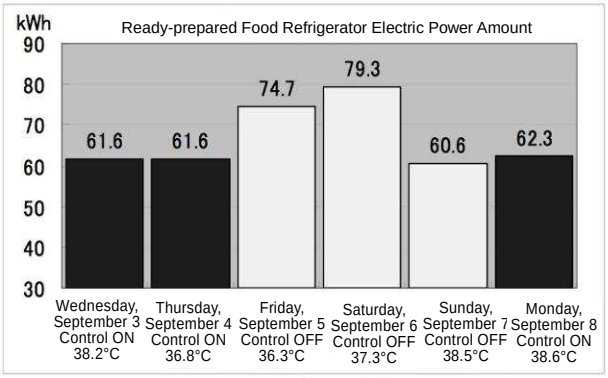


Fig. 6 Ready-prepared Food Refrigerator

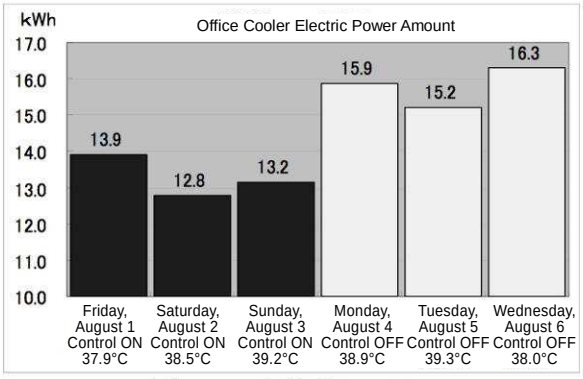


Fig. 7 Office Cooler

The following is the verification of the data for the ready-prepared food refrigerator in Fig. 6. First, because September 7 was a manufacturing holiday, it is considered to be excluded from the subjects for comparison. The electric power amount used in the situation where the atomizing equipment was being utilized was approximately 62 kWh per day. In contrast, when the atomizing equipment was not being utilized, approximately 75 kWh of electric power was used per day, so that an approximately 20% reduction in electric power was being achieved through using the installed atomizing equipment. Concerning September 7, because it was a manufacturing holiday there was almost no opening and closing of the refrigerator doors that occurs frequently during manufacturing. For the dispatch work, door opening and closing is carried out frequently during 30-minute periods in the morning and afternoon each day. For this reason, it can be inferred that the electric power on September 7 is the electric power required to maintain the temperature inside the refrigerator.

For manufacturing days, the results allow confirmation that in the situation where the atomizing equipment was used, even though the door was frequently opened and closed during the manufacturing time approximately the same amount of electric power was used as on September 7, which was a manufacturing holiday.

The following is the verification of the data for the office cooler in Fig. 7.

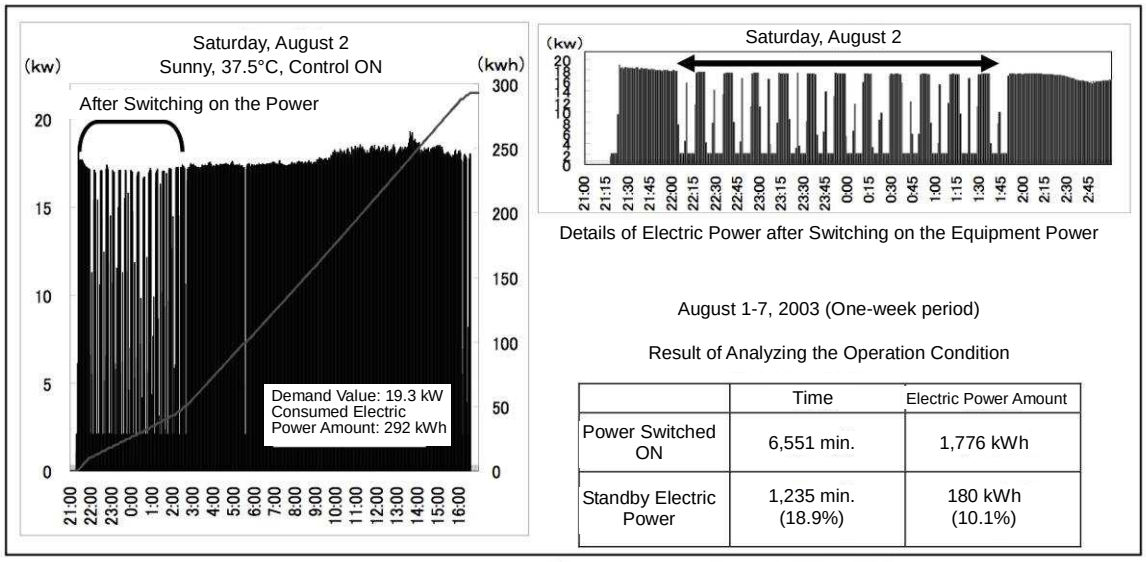
The office cooler is installed inside the warehouse, so that although it is not subject to direct sunshine, it is installed in a location where the flow of air is poor. The way of reading the graph is the same as above, with August 1-3 showing the electric power amounts when the atomizing equipment was being used, and August 4-6 showing the electric power amounts when the atomizing equipment was not being used.

The outside units are installed in a shady location, but even in the situation where the surrounding temperature was not comparatively high, the results still showed a reduction of approximately 15%. As well as achieving the reduction in the electric power, the cooling

performance of the office cooler was increased and the office environment was improved.
Regarding this water atomizing equipment, following the confirmation of the results we conveyed the installation methods to other local small and medium-sized businesses in Kochi prefecture. In this way, not only our company, but many offices in Kochi Prefecture can make practical use of these measures so that the measures implemented by our company could contribute to energy conservation over a wide area.

3) Standby electric power of equipment

In the method used for preparing the manufacturing equipment before the implementation of the energy conservation measures, the person in charge would switch on the power of all the equipment units before carrying out the preparations for manufacturing. This was caused by simplifying the management method, since some of the equipment units require a set temperature to be reached otherwise there would be a danger of manufacturing inferior products due to insufficiencies in heating or cooling.
However, by switching on the power in advance the standby time particularly of larger-sized equipment becomes longer, and it was found that electric power was being used wastefully. This problem was occurring because the time required to reach the set temperature after switching on the equipment power was not precisely understood. Accordingly, we attempted to realize energy conservation by understanding the operating conditions and characteristics of each equipment unit and switching on their power at appropriate timing.



August 1-7, 2003 (One-week period)

Result of Analyzing the Operation Condition

	Time	Electric Power Amount
Power Switched ON	6,551 min.	1,776 kWh
Standby Electric Power	1,235 min. (18.9%)	180 kWh (10.1%)

Fig. 8 Boiling and Cooling Tanks Operation Condition Analysis

The boiling and cooling tanks are the equipment which uses the largest electric power in our

company. After sealing the tofu in packs, two equipment units are operated to carry out heat sterilization and forced cooling. The results of measuring the electric power of this equipment are shown in Fig. 8. Each day, the power was switched on after 9 p.m., and manufacturing started from around 2 a.m. Looking at the graph of the detailed electric power after switching on the electric power, the equipment reaches the setting temperature around 40 minutes after being switched on, and the equipment operation is halted. After attaining the setting temperature, it was found that operation takes place intermittently before manufacturing starts in order to maintain the temperature due to the heat lost through radiation, with the equipment heating up and cooling down.

The time of intermittent operation is the standby electric power, where the electric power is being used wastefully. Considering the ratio of the wasted power as a time, it will be 1,235 minutes per week, corresponding to 18.9% of the time that the power of the boiling and cooling tanks are switched on. It was found that the electric power amount due to this standby electric power was 180 kWh, corresponding to 10% of the electric power amount used.

By measuring and analyzing the electric power, it was possible to understand the time required for the equipment to reach the setting temperature, and the amount of electric power that was being used wastefully. It therefore became possible to set appropriate timing for switching on the equipment so that energy conservation could be realized.

Using the same kind of methods, analyses of the necessary energy and the energy that can be reduced are being carried out for the other manufacturing equipment, such as the packing machines and heating equipment. By reviewing the production control methods, we are implementing energy conservation through continuous accumulated efforts.

4) Steam equipment review

Regarding energy conservation for the boilers, we implemented a thorough review of the usage methods and setting methods without making investments for improving the equipment.

First, we implemented complete management so that the two boilers only operate when required for the minimum time. Supporting the changes in the production amounts for the day, one of the boilers is halted when it is not required. In addition, regarding the steam amount used for heating, reviews were carried out of the setting temperatures and to shorten the times in order to set the appropriate amounts required for each process. By implementing thorough management, we strove to accumulate even small reductions in the steam usage.

As a result of carrying out these kinds of measures, it was possible to realize a 30%

reduction in the heavy oil usage compared to the situation before starting the energy conservation.

(6) Effects Achieved after Implementing Measures

Thorough implementation was made in a systematic manner throughout the company, including the carrying out of reviews of the ways that work had been previously carried out and the equipment management methods. As a result, it was possible to greatly exceed the targets. These are shown in Fig. 9 and Fig. 10.

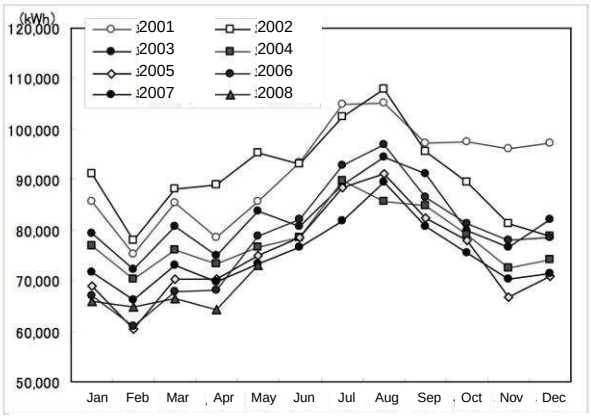


Fig. 9 Changes in Used Electric Power

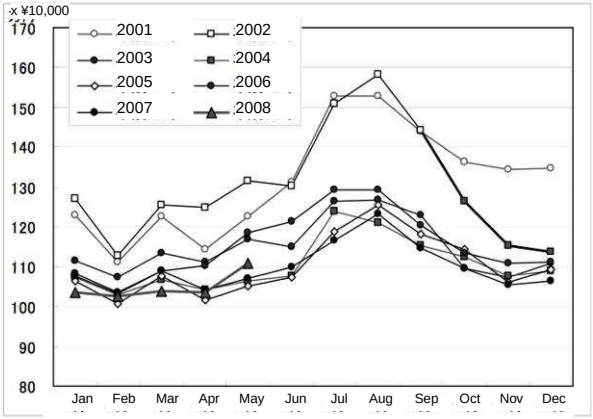


Fig. 10 Changes in Electric Power Costs

	Annual Electric Power Amount (kWh)		Reduction Amount in ¥	A Heavy Oil (L)		Comparison of Manufacturing Units
2001	1, 102, 725	Reduction Amount (%)	Standard	278, 900	Reduction Amount (%)	Standard
2002	1, 090, 550	12, 175 (1%)	¥190,000	233, 500	45, 400 (16%)	95%
2003	985, 184	117, 541 (11%)	¥2,040,000	204, 500	74, 400 (27%)	96%
2004	937, 722	165, 003 (15%)	¥2,550,000	194, 200	84, 700 (30%)	91%
2005	901, 107	201, 618 (18%)	¥2,590,000	189, 600	89, 300 (32%)	87%
2006	939, 303	163, 422 (15%)	¥1,950,000	203, 000	75, 900 (27%)	99%
2007	899, 857	202, 868 (18%)	¥2,620,000	194, 700	84, 200 (30%)	96%

Table 3 Changes in Reduction Numerical Values and Comparison of Manufacturing Units

As shown in Fig. 9 and Fig. 10, since actually beginning to implement activities in September 2002, a large reduction in the electric power amounts has been achieved. In addition, the electric power amount used in the summertime has been reduced to below the electric power amount used in the wintertime before the implementation of the measures.
As shown in Table 3, the reduction amounts for the electric power and heavy oil in 2004 both achieved the targets of 15%. Further, although it is thought there may have been an influence due to the reduction in the number of manufactured units in 2004 and 2005, the accumulated improvements and daily activity implementation allowed the reduction amounts

to be maintained in 2006 and 2007 even though the numbers of manufactured units increased.

3. Summary

In the energy conservation activities carried out this time, an investment of approximately ¥900,000 was made during the initial 2-year period for the purpose of reducing the electric power. As a result of implementing the activities, the investment could be paid off soon due to the effect of reducing the electric power amount throughout the entire plant. The total amount of energy reductions realized until now in electricity and heavy oil has reached approximately ¥32,000,000, exceeding the targets and achieving a large energy conservation effect.

Through implementing the energy conservation activities, the awareness of each one of our employees has grown, and the management and maintenance of the equipment is being thoroughly implemented.

In addition, employees are taking care with the opening and closing of the refrigerator door and the opening and closing of the door of the room where the cooler is located. By compiling graphs of information that operators do not normally see, including the electric power data and reduction amounts in yen, awareness of energy conservation and of costs have also been enhanced, changing the attitudes of employees and resulting in the realization of the results up to the present time.

4. Future Plans

Using the energy conservation activities implemented until now, it was possible to achieve various results initially from the start of activities. The current equipment is in the situation of operating under full capacity nearly every day, and the wear of equipment and machines is also occurring quickly. In order to take care to maintain the attitudes of employees and to avoid consuming energy wastefully, we intend to carry out daily equipment inspections and continue to tackle energy conservation activities involving all our employees.

Lastly, by carrying out these energy conservation activities, we intend to continue contributing to the prevention of global warming.