2005 Prize of the Chairman of ECCJ

Activity to reduce unit consumption of compressed air by its supply in boundless sync with production

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◎ **Keywords: Electromotive power, Rationalization of heat transformation (Electromotive application equipment, electric heater equipment, etc.)**

◎ Outline of Theme

We pursued to implement the features of Nissan Production Way (NPW), “boundless synchronization with customers and boundless exposure of problems and innovation” and enhance the energy conservation activity that has already been implemented. More specifically, the production site and energy supply section collaborated even closer to expose problems. For supply of compressed air, we sought to realize compressed air unit consumption that is not affected by the production volume, took measures against exposed problems, realized supply of compressed air in sync with production, and decreased the compressed air unit consumption.

◎ Implementation Period of the said Example

- Project Planning Period (October 1st, 2003 – March 30th, 2004, total of 6 months)
- Measures Implementation Period (April 1st, 2004 – April 30th, 2005, total of 13 months)
- Measures Effect Verification Period (May 10th, 2005 – August 31st, 2005, total of 4 months)

◎ Outline of the Business Establishment

- Produced items Automobile manufacturing (TIIDA, MARCH, and CUBE)
- Number of employees 4800
- Annual energy consumption (Actual record in 2004).

Electric power	:	131,231 Mwh
City gas	:	21,513 km3N
Kerosene	:	1,094 kl
Bunker A	:	151 kl

◎ Process Flow of Target Facility

The overall compressed air supply facility that supplies air to all processes throughout the plant is shown below:

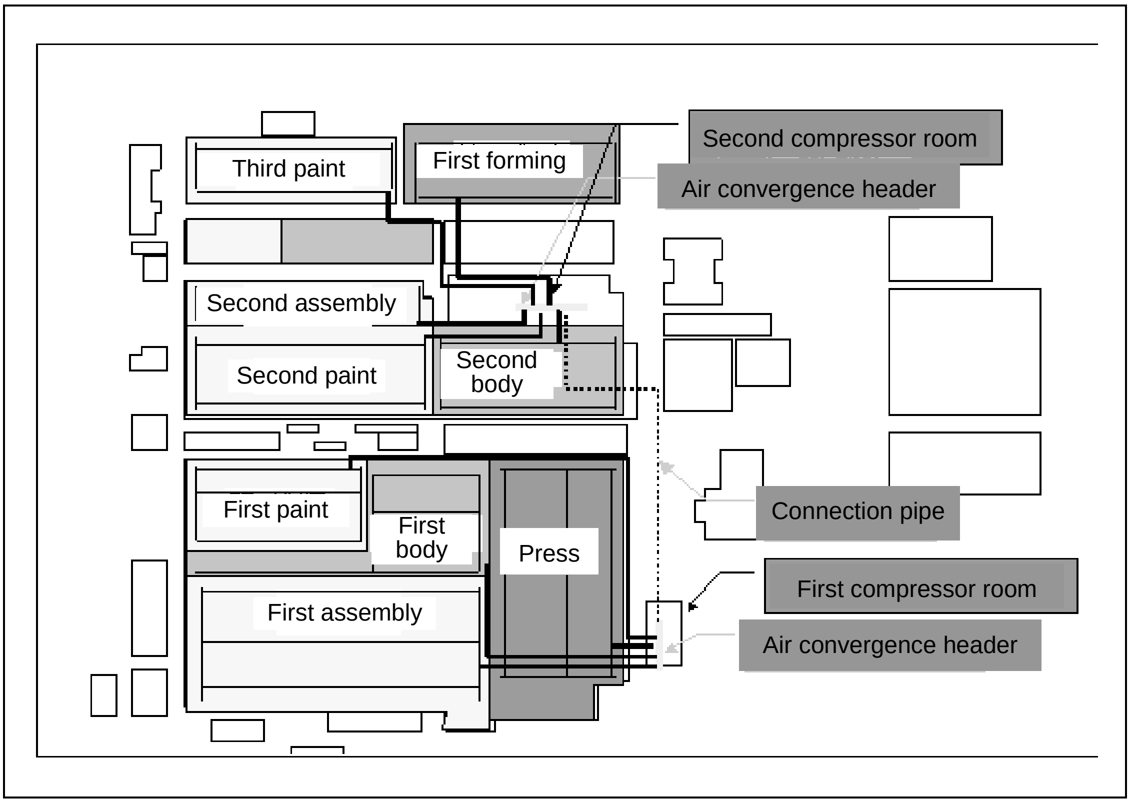

Fig.1 Control of compressed air

1. Reasons for Theme Selection

Power consumption of the air compressors accounts for about 16% of the entire plant, so we have worked on reduction of unit consumption for a long time. (Fig.1) For the unit consumption in 2003, however, while air discharge electricity unit consumption (kwh/m3N) has decreased, unit consumption per automobile (kwh/automobile) is increasing influenced by decreased production. Therefore, we assumed that if compressed air can be supplied according to the production (synchronization), unit consumption should be maintained at a low level with out influence of production volume, which is the way it should be.

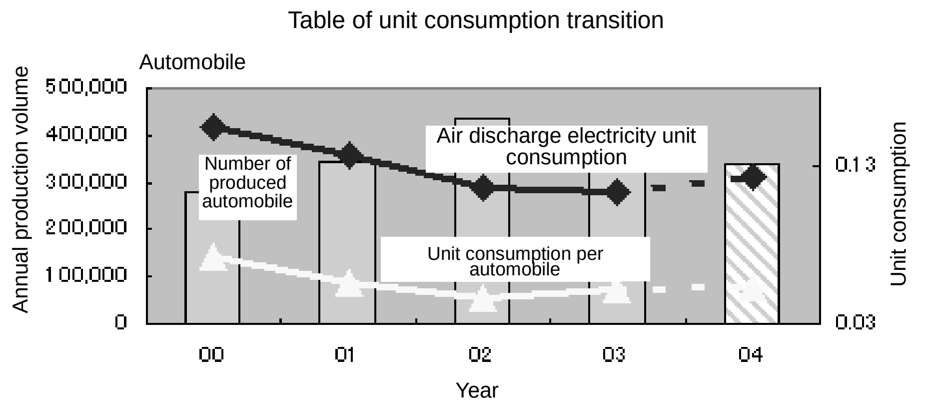

Fig. 2 Transition of air unit consumption

Countermeasures	Year 96	97	98	99	00	01	02	03
Decrease pressure	—			—				
Introduction of tube end pressure control		—						
Introduction of number of operated machines control			—					
Measure to reduce pipe resistance				—				
Measure to close facility primary valves					—		—	
Reduction of air leak						—		
Reduction of air feed time					—			
Setting "no energy day"			—	—	—	—	—	—
Introduction of intermittent air blow				—	—			
Electro-motorization of air equipment								—

Table 1 Measures to decrease air unit consumption

2. Understanding and Analysis of Current Situation

(1) Understanding of Current Situation

1) Outline of compressed air supply facility

Compressors are installed in two compressor rooms. The first compressor room has two high pressure compressors and five low pressure compressors and their total capacity is 3280 kw. The second compressor room has four low pressure compressors and their total capacity is 2190 w.

To supply air, processes are grouped into two systems (high pressure and low pressure) and the air is looped after each process to lower the air feed pressure to the lowest allowable level.

For control,

[1] tube end pressure control to detect tube end pressure for each system and detect the lowest pressure among them,

[2] control of number of compressors to balance load of all compressors installed in the first and second compressor rooms, and

[3] control to operate high pressure compressors at fixed load and use excess air for low pressure using the pressure regulator at the receiver tank are implemented.

This compressed air supply facility, to which such improvements are done, supplies compressed air to virtually all processes in the 500,000 m2 of plant area (14 systems).

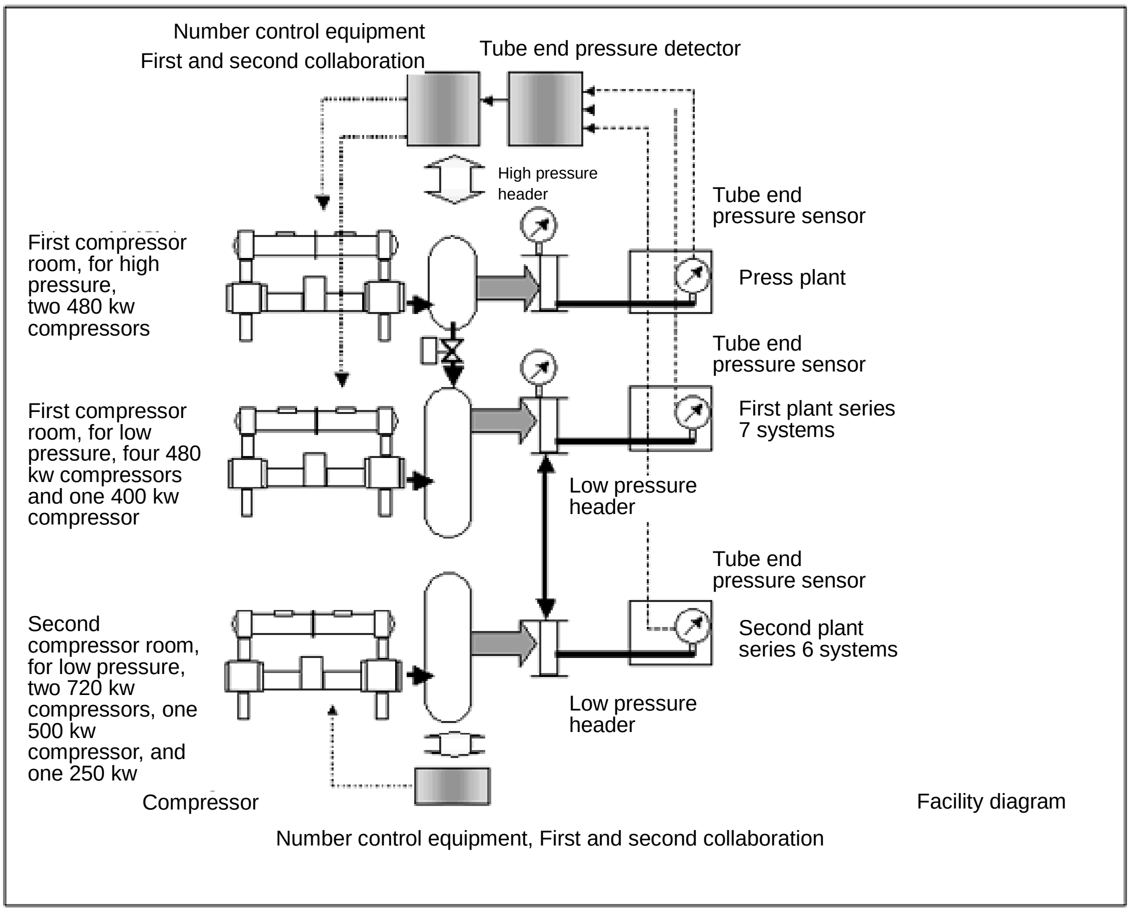

Fig.3 Compressed air system diagram

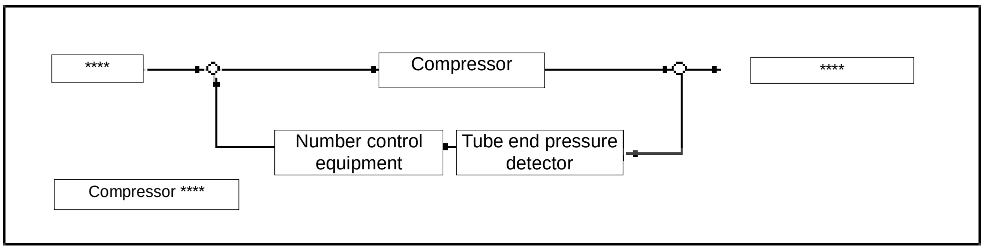

Fig.4 Block diagram of the tube end pressure feedback control

2) Current situation of supplied pressure

Trend according to the record of tube end pressure for each process is shown in Fig.5 and trend according to the record of header pressure is shown in Fig.6.

These suggest the following:

[1] When production is finished, there is a temporary and sharp rise of pressure.

[2] When production is not done, pressure is higher than when production is done.

[3] Tube end pressure differs from process to process, and in some systems, it is higher than the specified pressure.

[4] Header pressure fluctuates widely and is higher than the expected value.

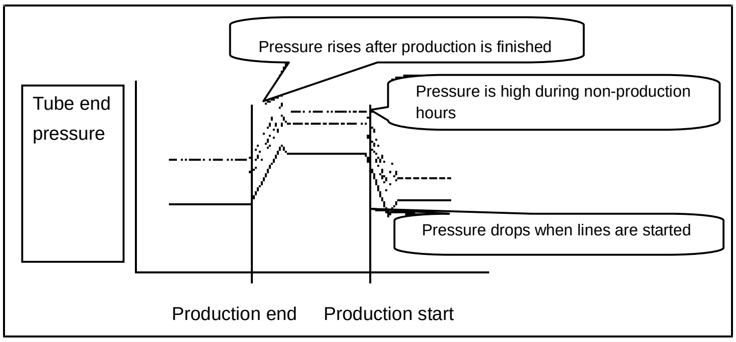

Fig.5 Current situation of the tube end pressure

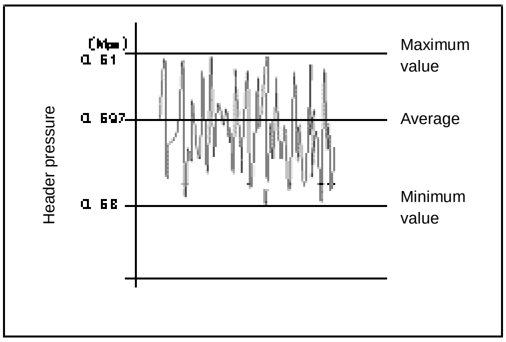

Fig.6 Current situation of header pressure fluctuation

(2) Analysis of Current Situation

The correlation between compressed air flow rate and pressure at the start and end of production is shown in Fig.7. At the end of production, flow rate of compressed air drops rapidly and the pressure rises temporarily. When production is not done, pressure is higher than when production is done because flow rate is less. In addition, at the start of production, flow rate of compressed air rises rapidly and the pressure drops temporarily. As described above, fluctuation of compressed air flow rate causes pressure fluctuation. This fluctuation suggests that demand by production facility and supplier side control are not in sync.

It became clear that there is a major problem that production and supply of compressed air are not in synchronization.

Furthermore, considering this factor and pressure drop, operation pressure is set high, causing energy loss of the compressor shaft power.

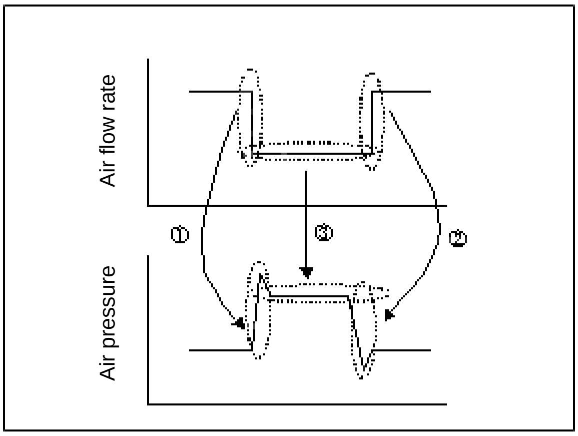

Fig.7 Correlation between air flow rate and air pressure

3. Progress of Activities

(1) Implementation Structure (Family activity)

To synchronize with production, information from the production site is the most important requirement. To discuss supply for the user of the compressed air in more detail in the family activity (manufacturing, maintenance, technology, logistics and energy supply section) that has been already implemented in each process, we decided to establish a regular discussion opportunity to promote this activity.

(2) Target Settings

To achieve the lowest level of unit consumption all the time regardless of production volume and "synchronize supply of compressed air to production to eliminate loss".

{ Less than the average unit consumption in 2002 (the minimum unit consumption when the production volume was maximum), 46.82 (kwh/automobile)
(Equivalent of 12% reduction to 2003).

(3) Problem Areas and Their Investigations

1) Analysis of pressure control when starting/stopping lines

Because the compressed air supply facility supplies air from two locations to the broad area of the entire plant, the supply distance is long, capacity is large, and response on load fluctuation is poor. Therefore, to avoid supply failure due to pressure drop when the pressure fluctuation is large at starting and stopping of the lines, pressure is set rather high and many load adjustment mechanisms are installed. In addition, the base machine is started earlier. Therefore, unload and waiting status is frequently seen, which is a cause of degradation of unit consumption during non-production hours.

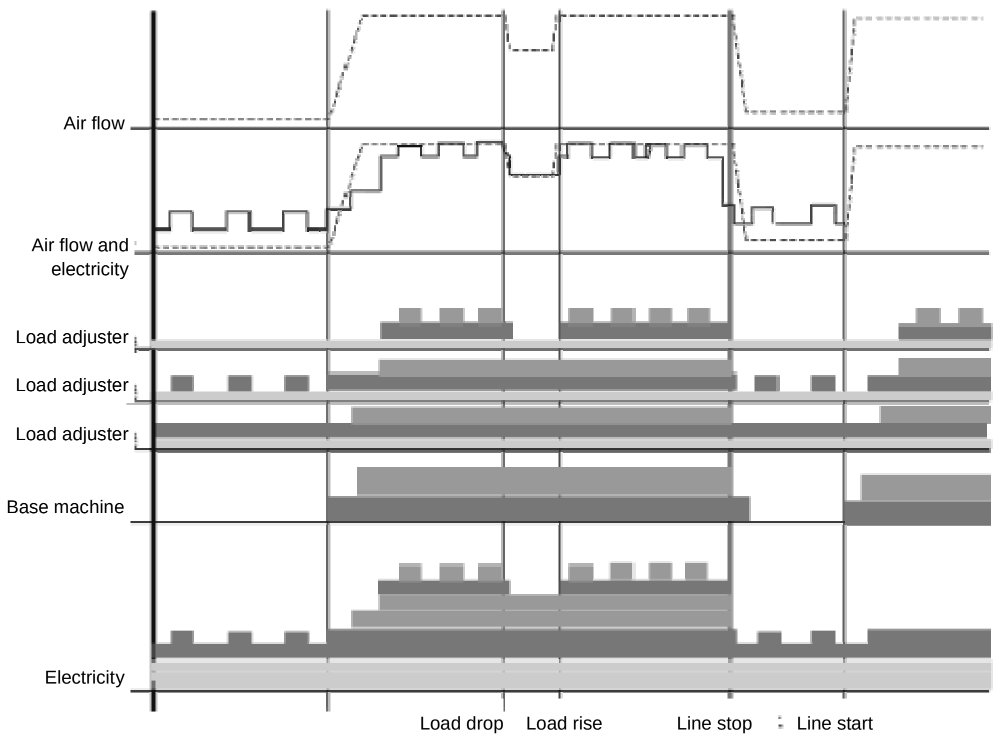

Fig.8 Operation and waiting status of the compressors

2) Clarification of conditions of production side

[1] For production hours, line start and end times are specified for each process according to the Nissan Production Way.

[2] Pressure enough for production is required during production and after production until all facilities are stopped. However, after facilities are stopped, only low pressure air supply is required for facility maintenance and adjustment etc.

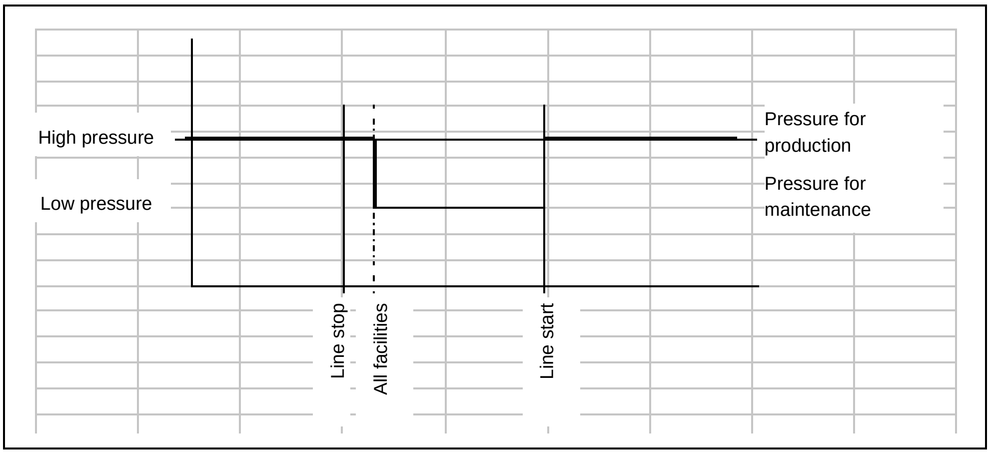

Fig.9 Required pressure

3) Clarification of conditions of production side

Processes are grouped into high pressure systems (press process) and low pressure systems (13 processes). Although all low pressure systems require the same pressure, as shown in Table 2, flow rate varies depending on processes and piping resistance and load situation are also different. In such a situation, low pressure air is currently supplied to all processes by the same system. (Fig.3)

Therefore, although all processes require the same low pressure, compressed air is supplied so that the required pressure is satisfied in the process whose tube end pressure is the lowest, so pressures in other processes are higher than the required pressure.

Process	Guaranteed pressure	Used air (m3N/h)
Press	0.60	2,500
First body	0.55	2,990
First assembly	0.55	3,550
Second body	0.55	1,660
Second assembly	0.55	1,560
First forming	0.55	570
Three areas	0.55	210
Second and third forming	0.55	1,200
General research	0.55	250
Experiment department	0.55	120
First paint	0.50	8,950
Second paint	0.50	6,540
Third paint	0.50	5,640

Table 2 Flow rate and pressure of each process

4) Clarification of problems

[1] Current control using only pressure information cannot appropriately respond to load fluctuation.

[2]There are no mechanisms or facility specifications to control pressure appropriately for each process.

This requires a major improvement of the control system, but because the current control system does not have enough flexibility, we discussed update of the entire system.

4. Details of Measures

To update the entire control system, we considered the following issues that are currently troubling:

To supply compressed air in sync with production, [1] production information should be included in control information to suppress pressure fluctuation doe to production fluctuation. [2] Control supply of compressed air for each process.

(1) Countermeasure 1: Synchronization of Compressed Air Supply Control with Production (Produce as Needed)

・ Feed forward the production information

Plan input based on the production plan and correction based on the change of plan information is established and added to the control information. This allows time management and automatic control of operation of the base load machine and load adjuster in synchronization with production by judging the start and end of production.

As a result, header presser became stable and lower, and unload wait time was decreased.

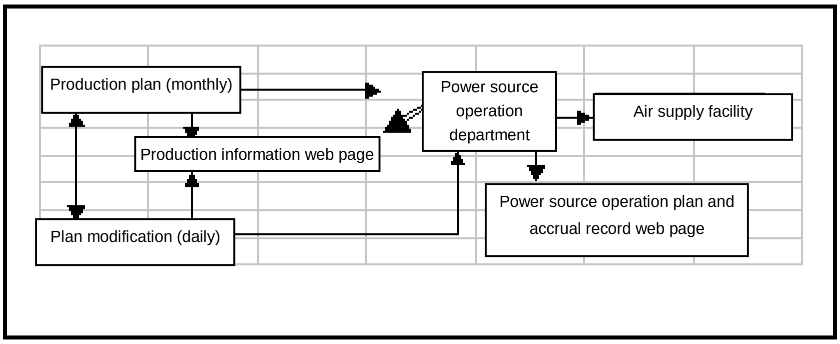

Fig.10 Verification of production information

Controlled compressors

Application	Location	Compressor	Air flow (m3/h)	Capacity (kw)	Method of air flow control		
Low pressure	First	2c Reciprocator	6300	480	Load adjustment	0-50-100%	Start-stop
Low pressure	First	3c Reciprocator	6300	480	Load adjustment	0-50-100%	Start-stop
Low pressure	First	4c Reciprocator	6300	480	Load adjustment	0-50-100%	Start-stop
Low pressure	Second	8c Reciprocator	10530	720	Base load	0-100%	Start-stop
Low pressure	Second	9c Reciprocator	10530	720	Base load	0-100%	Start-stop
Low pressure	Second	11c Screw	6300	500	Base load	0-100%	Start-stop
Low pressure/ High pressure	First	1c Turbo	4250	400	Base load	0-100%	Start-stop
Low pressure/ High pressure	First	5c Reciprocator	6300	480	Load adjustment	0-50-100%	Start-stop
High pressure	First	6c Reciprocator	6300	480	Base load	0-50-100%	Start-stop
High pressure	First	7c Reciprocator	6300	480	Base load	0-50-100%	Start-stop
Low pressure	Second	10c Turbo	5000	500	Single	0-100%	Start-stop

Table 3 Machines that can respond to load fluctuation at line start

(2) Countermeasure 2: Air Supply in Synchronization with Production of Each Section (Feed as Needed)

・ **Supply air in synchronization with production of each process**

We utilized the existing system to measure piping end pressure for each process and modified it to install pressure control valves to the supply pipes to each process so that compressed air that is controlled at the required pressure can be supplied to each process. As such, improvement to feed air at the required pressure to each process in synchronization with production was implemented and loss was eliminated.

In addition, to improve response of control of supplied pressure to each process, control and stability of header pressure is important, so this header pressure information is included in the control.

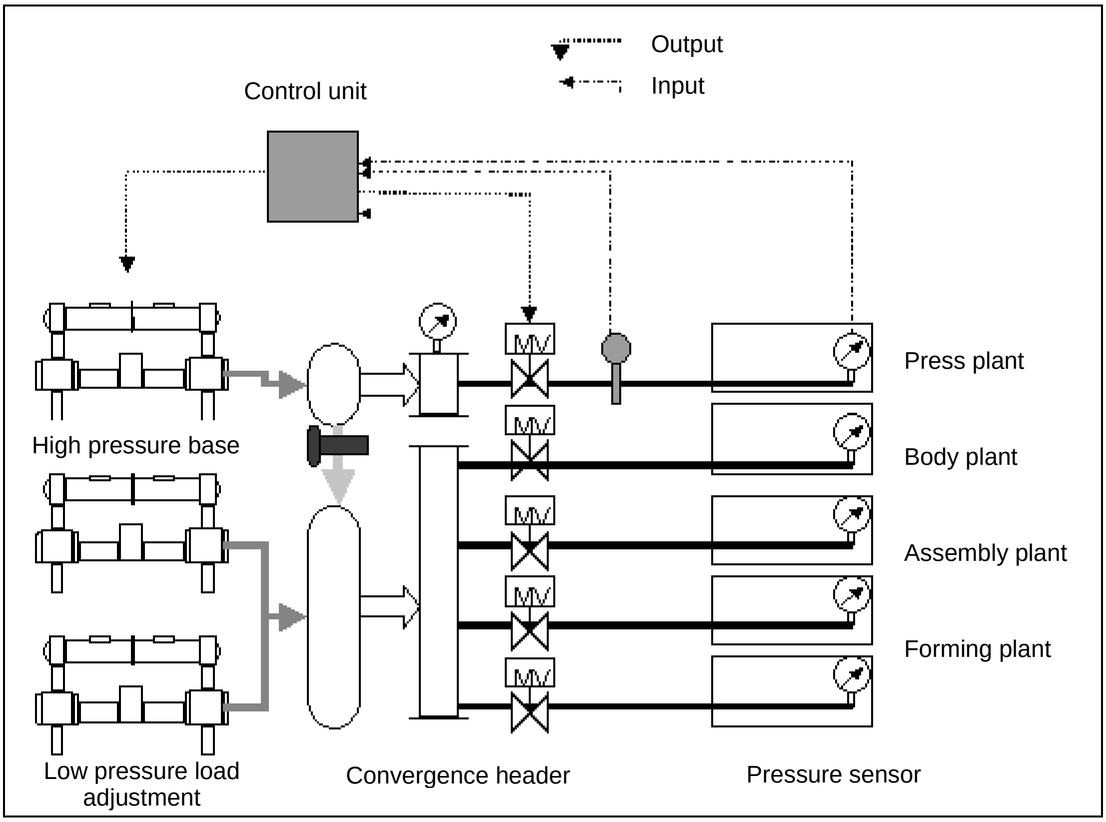

Fig.11 Air feed system for each section

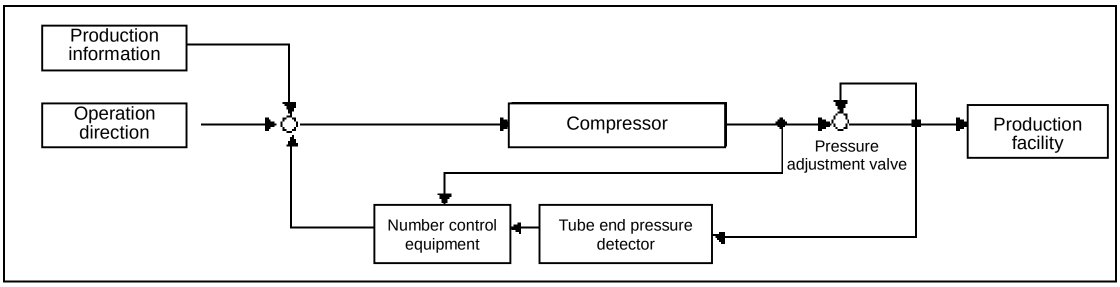

Fig.12 Block chart of production information feed forward

(3) Other Measures (Produce with Minimum Resource)

In the family activity, the following loss improvements were implemented as well as modification of control etc.

[1] Reduction of pipe resistance

- Appropriate dehumidification performance
- Appropriate piping capacity and change of routes

[2] Improvement of measurement equipment

[3] Efforts to appropriate usage and used volume of compressed air when layout is changed or facility is updated.

[4] Reconfirmation of required pressure and correction of tube end position for each process

[5] Countermeasures against leak of compressed air

(4) Addition of Other Measures

(Introduction of steam turbine driven compressors)

1) Boundless pursuit of problems

We have promoted improvement of control and facilities for boundless synchronization with production, but still a lot of compressed air is used during non-production hours as shown in Fig.13. This is the base part (fixed part) of the compressed air supply and a cause to fluctuate unit consumption when production volume is changed. Each process family has discussed how to reduce this fixed part, it was difficult to reduce more.

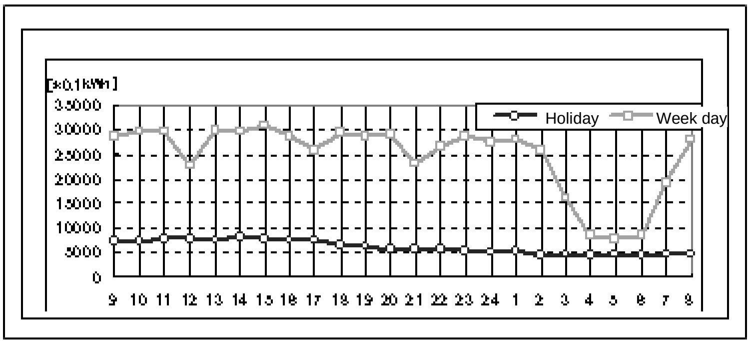

Fig.13 Compressor power for each hour

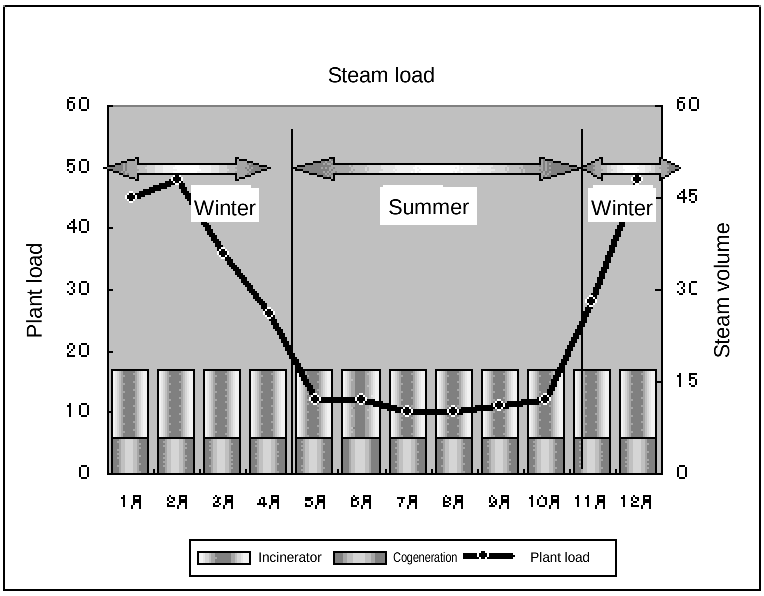

Fig.14 Generated steam and load

2) Change in thinking

To reduce the effect of this fixed part, we discussed whether other excess energy etc. can be used.

As a result, we found that [1] there is excess waste heat recovery in the waste disposal site in summer, and [2] how to use the summer time steam after cogeneration starts operation is undecided, so we discussed introduction of steam driven compressors. During heating period in winter, steam is insufficient, but steam for heating is low pressure, so its pressure is decreased using decompression valves. We discussed utilizing this decompression energy as a source of power for compressors.

The result of simulation indicated investment effect, so we adopted steam driven compressors in the system shown in Fig.15 and used as compressor for the base part. As a result, unit price of compressed air decreased. In this improvement, the amount of used compressed air is unchanged, but compressed air unit consumption was also reduced because of effective use of recovered heat.

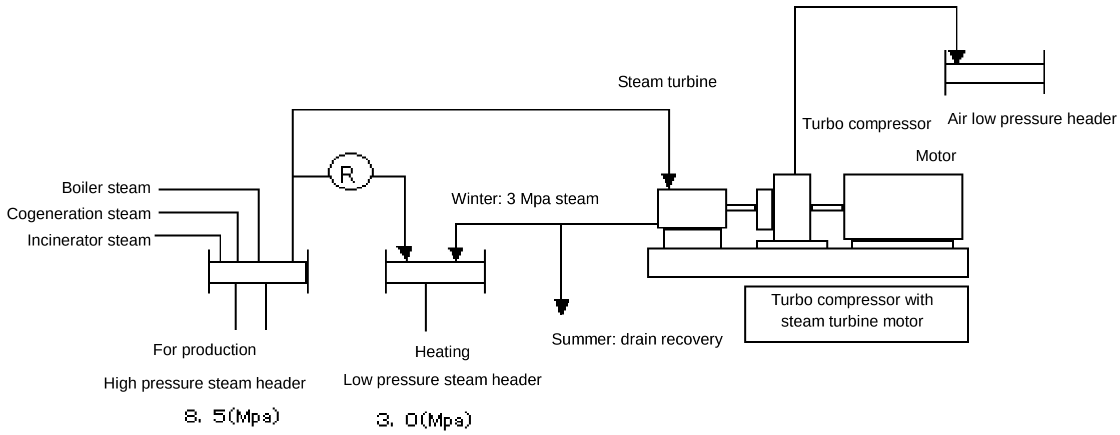

Fig.15 Steam driven compressor

5. Verification of Effects

(1) Reduction of Unit Consumption and Year-round Effect

As a result of the above measures, the actual unit consumption per automobile (kwh/automobile) during May – August of 2005 was 47.99 kwh/automobile, which was 12.6% lower compared to 2003. (Fig.16)

(The number of produced automobiles is fewer and the unit consumption is lower than 2002, when the unit consumption was the lowest. The target is achieved.)

year-round effect: electric charge 27,700 [1,000 yen / year]

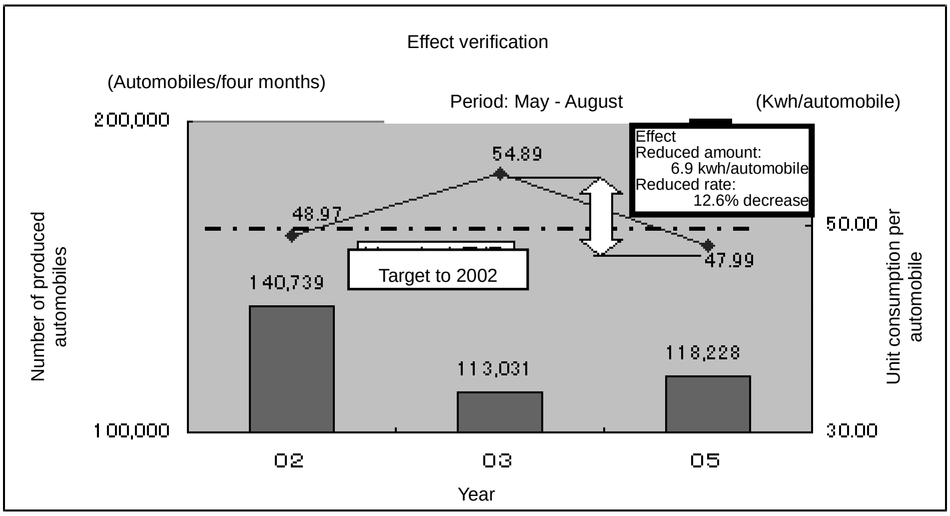

Fig.16 Reduction of unit consumption per automobile

(2) Verification of Unit Consumption Reduction

As shown in Fig.17, for the unit consumption for each hour, unit consumption during production time is more stable and decreased. Also, the unit consumption during non-production time is significantly decreased. (Synchronization of compression air supply with production is improved.) In addition, header pressure became stable and is decreased.

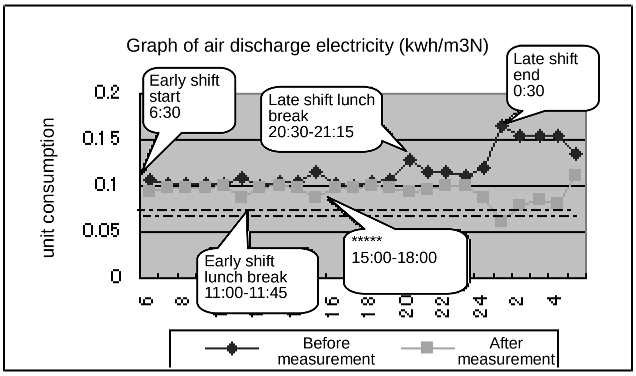

Fig.17 Synchronization with production by improvement of air feed

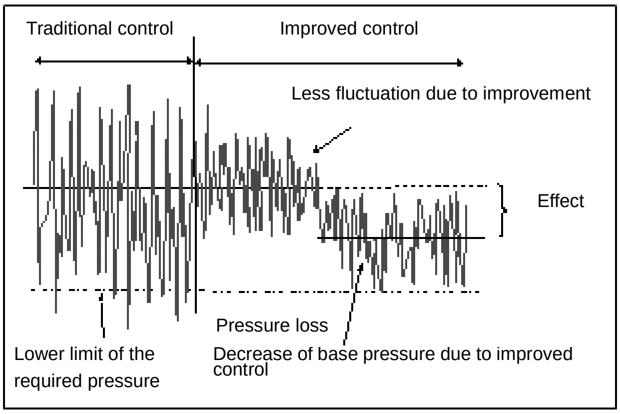

Fig.18 Synchronization with production by improvement of control

6. Summary and Challenges for the Future

- We have implemented improvement according to Nissan Production Way and realized both stabilization of compressed air supply and energy conservation.
- In the future, we would like perform energy conservation check by families at line change or when new facility is introduced using this case as a guide to always synchronize energy supply to the ever changing production processes.