2006 Prize of Director General of Regional Bureau of Economy, Trade and Industry

Conservation of Energy through Heat Integration of Multiple Equipment

Idemitsu Kosan Co., Ltd., Tokuyama Refinery
Integration Project

◎ **Keywords: Rationalization of heating, cooling and heat transmission**
Recovery of exhaust heat for use

◎ Outline of Theme

In order to attain energy conservation targets at the refinery, discoveries and improvements were sought from working focused on the issue of effective mutual use of heat among multiple equipment (hereinafter referred to as the “heat integration”). A lateral project team was formed within the refinery to implement activities. The team collected numerous technical information from specialist organizations both inside and outside the company and conducted considerations. As a result, technical issues were resolved smoothly and it was possible to realize a large scale heat integration energy conserving modification, which includes effective use of low grade heat.

◎ Implementation Period for the said Example

- Period for formulation of plan: April 2003 through December 2003 Total of 9 months
- Period for implementation of action:
  January 2004 through October 2004 Total of 10 months
- Period for verifying effectiveness of action:
  January 2005 through March 2005 Total of 3 months

◎ Outline of the Business Establishment

- Production items: Liquefied petroleum gas, gasoline, kerosene, light oil, heavy oil
- Number of employees: 278 persons (as of April 1, 2005).
- Annual energy consumption (record for FY2005): 474,298 kiloliters (crude oil equivalent)

◎ Process Flow of Target Facility

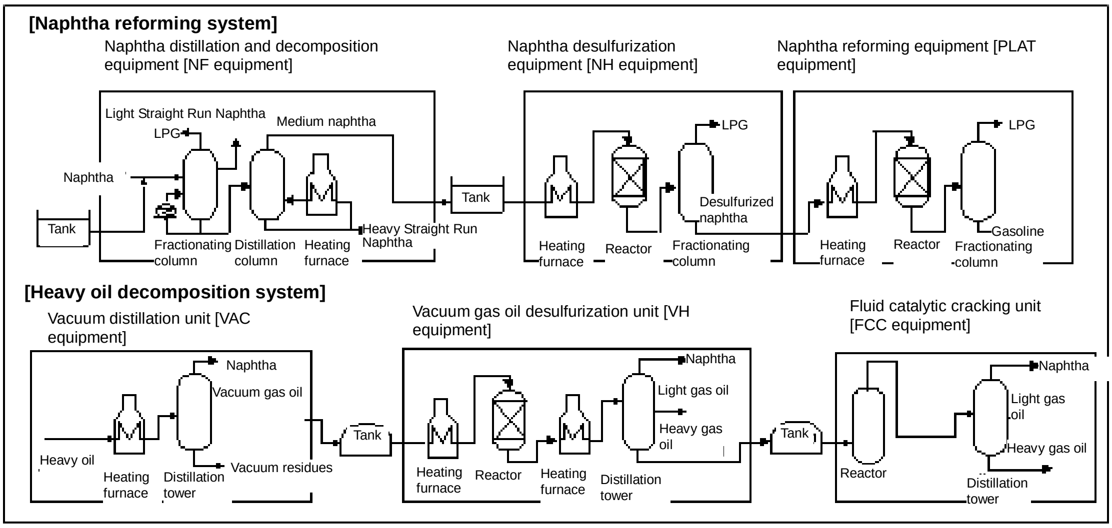

Figure 1: Process for intended facility

1. Reasons for Theme Selection

Crude is refined at this refinery, to produce petroleum products such as gasoline, kerosene and light oil etc. It was recognized that optimization through operational improvements and facility improvements of individual equipment was approaching the limit and for this reason, the concept was switched to optimization for individual system segments, categorized according to their purposes in the recent years, to undertake consideration of various issues.

Against such backdrop, the energy conservation by heat integration, intended for the naphtha reforming system and the heavy oil decomposition system, were considered for this project.

2. Understanding and Analysis of Current Situation

(1) Understanding of Current Situation

Equipment belonging to these two systems that were considered for the project comprised 60 % of all fuel consumptions at the refinery. Realizing effective heat integration, therefore, mean that major energy conservation can be attained.

1) Naphtha reforming system

Processes at the refinery can be divided broadly into categories of distillation, desulfurization and reforming, and refining operations are performed by respective equipment. Products discharged from this individual equipment are cooled down as they are temporarily stored tanks. Furthermore, the heating of raw material oil (on charge side) and Riboira heating (on rRiboira side) are both performed by a single heating furnace with the NH equipment, as shown in Figure 2. Since both combustion heat amounts differ (the current difference in heat amount is derived from the difference in temperature of exhaust gases, which is 320 degrees Celsius), thermal expansion of the center wall takes different rates at both side, therefore the deference of combustion heat amount has collapse constraints of the wall. This is an issue that had to be resolved for the safety considerations, as well as for the purpose of energy conservation.

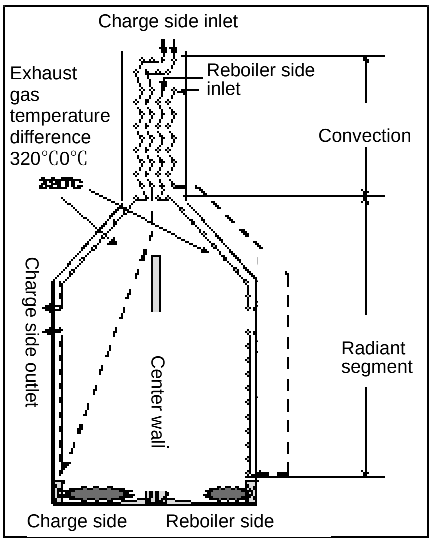

Figure 2: Heating furnace structure of NH-equipment

2) Heavy oil decomposition system

As with naphtha reforming system, the product here is also cooled down and temporarily stored in tanks. Furthermore, no effective means to utilized excessive heat was found for this system, which is basically an excess heat system.

(2) Analysis of Current Situation

The most effective measures of heat integration for both the naphtha reforming system and the heavy oil decomposition system are to reuse heat of products without cooling them by bypassing storage tanks which are located between equipments (hot charge). There are, however, a number of problems for simply connecting pipes. Some of the representative issues are described below:

- The process must be reconsidered, since the thermal balance of the next equipment would be changed when the products send to the next equipment without cooling. A consideration is needed to figure out a way to recover heat brought in by the hot charging.
- When the distance between equipment is considerable, careful consideration is needed with regards to heat radiation losses and pipe installation costs.

In addition to aforementioned problems, issues pertaining to individual systems were analyzed, as described below:

1) Naphtha reforming system

The center wall structure of the NH equipment is comprised of stacked bricks. The difference in the combustion heat amount between the charge side and the Riboira side creates difference in thermal expansion of the center wall, causing it to collapse as mentioned above. When the wall collapses, emergency stop is obviously necessary with the equipment and there is also a potential for suspension of operation over a long period of time until repairs are completed, which makes this prospect a critical problem. The difference in combustion heat amount at the present is generated from the “increased load of raw material oil heating due to soiling of raw material oil heat exchanger” and the “reduced load for Riboira heating due to energy conserving operations by reducing pressure in distillation tower. The flow diagram of the NH equipment is shown in Figure 3.

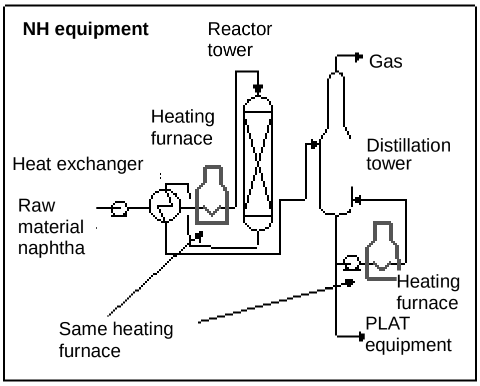

Figure 3: NH equipment flow diagram

2) Heavy oil decomposition system

The segment subject to hot charging is located in between equipments such as VAC-VH and VH-FCC. The distance between VAC and VH equipment is in the immediate vicinity but the distance between VH and FCC equipment is about one kilometer. Since pipe installation costs would be quite considerable, a consideration was made to perform hot charging between the VAC and VH equipment. There is however no measures to effectively recover and utilize heat when hot charging are performed between the VAC and VH equipment. Ordinarily consideration is made to generate steam when there is excessive amount of heat and supplied to other equipment, however, the amount of steam on the premises will be excessive in summer, making it ineffective. For this reason, some brain racking was conducted and following three proposals were made:

- Use the heat to preheat raw materials for the VAC equipment.
- Use the heat to preheat raw materials for the VH equipment.
- Use the heat to preheat air for the heating furnace.

3. Progress of Activities

(1) Implementation Structure

The Integration Project Group was launched with the members of the Operations Section, who are thoroughly familiar with the equipment subject to the project, as well as those of the Engineering Works Section, who are in charge of facility management and the Engineering Section, who are in charge of facility planning. The decision was made to request for cooperation as needed from technical personnel at the Petroleum Technology Center in head office who provide specialized technical assistance, as well as those at the Facility Management Center. Plans and records of activities are shown in Table 1.

Plan Actual record

Table 1: Schedule table

Item	2003 April	2003 July	2004 January	2004 July	2005 January
Understanding current status					
Analyzing current status					
Considering strategies					
Implementing activities					
Understanding effects					

(2) Target Settings

Target: 10,000 kiloliters per year (crude oil equivalent).

The target was set extremely high, as this amount corresponds to 2.5 % of energy consumption at the entire refinery.

(3) Problem Points and Their Investigation

1) Heat integration for naphtha reforming system

a. Hot charging of NF equipment

Although it is not shown in the process for the facility subject to implementations of the project, an atmospheric distillation unit for distilling crude oil was located in the upstream segment of the NF equipment and maintained the temperature of the product to 40 degrees Celsius and lower to prevent firing of the tank. The temperature of the product at the inlet of the cooling vessel was 80 degrees Celsius and considerations were made to see whether or not there were any measures to recover this heat, which was transferred by hot charging, for effective use by the entire NF equipment.

b. Hot charging between NF and NH equipment

The load on the heating furnace was larger on the charge side and lower on the Riboira side, as mentioned earlier. The charge side was therefore reduced by hot charging, contracting the gap in temperature of the heating furnace and bringing the whole situation towards a better direction. As a result of considering further reduction of pressure in the distillation tower, however, it was discovered that the difference in the load on the heating furnace was in the increasing tendency, which led us to the conclusion that a fundamental measure had to be implemented to the main unit of the heating furnace.

[Problems and considerations of heating furnace]

At the risk of becoming repetitious, it should be pointed out that the problem here was that the center wall would collapse. As a preventive measure, reinforcement could be implemented to prevent collapsing, however, with such a measure, the foundation of the heating furnace must also be reinforced at the same time, which results in an enormous cost that was equivalent in amount to rebuilding the entire furnace. Modification of a tube was therefore considered as a different measure. Specific implementation is shown in Figure 4.

In order to balance off the load on the Riboira side, the tube at the convection segment was completely removed so that heating is performed entirely with the radiant segment. Since the load was reduced by hot charging, it was decided to remove a portion of the tube in the convection segment of the charge side also. The overall number of tubes was reduced and as a result the temperature of gas at the outlet of the heating furnace did rise, but since the NH heating furnace is equipped with an exhaust gas recovery facility, no increase in energy consumption occurred after the modification.

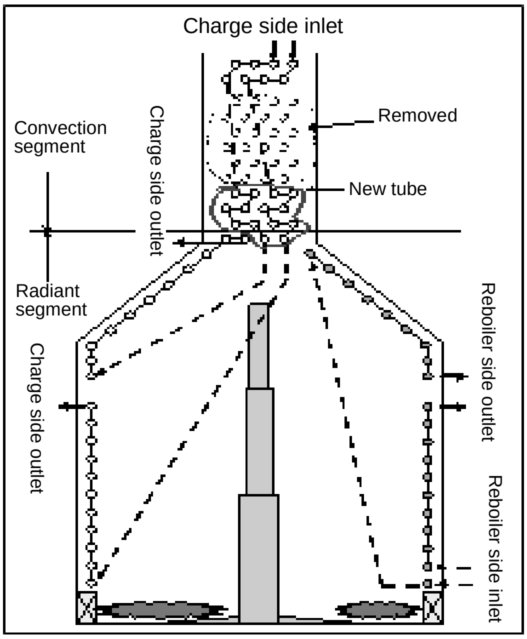

Figure 4: Preventive measure for heating furnace of NH equipment

c. Recovery of heat from raw material oil of PLAT equipment

Through the modification, it became possible to hot charge partly in the NF equipment, but other raw materials from the storage tank were passed without preheating. On the other hand, the raw material oil heat exchanger of the PLAT equipment is a high performance plate-type heat exchanger, which is capable of preheating materials at a constant temperature without dependence of raw material temperature, as shown in Figure 5. For this reason we focused our attention on the raw material oil of the PLAT equipment as raw material oil preheating fluid for the NF equipment and conducted a study on its effectiveness and potentials.

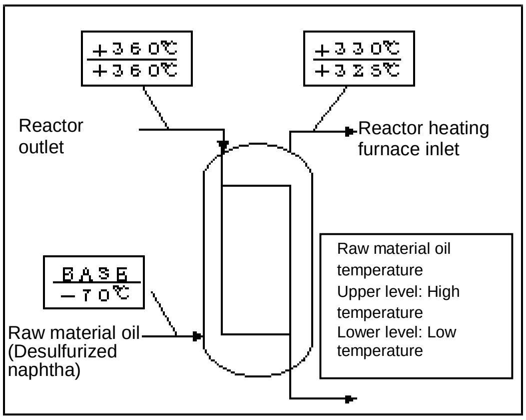

Figure 5: Raw material oil heat exchanger for PLAT equipment

2) Heat integration for heavy degradation system

a. Hot charging between VAC and VH equipment

Similar to the naphtha reforming system, considerations pertaining to hot charging were conducted for this system as well. The heat recovery flow for the VH equipment is shown in Figure 6. Since not all heat could be recovered when the temperature of the raw material oil in the VH equipment rose with the hot charging, the amount of heat exhausted through disposal in the cooling vessel for heavy gas oil increased as a result.

Although the temperature of the heavy gas oil at the inlet of the product cooling vessel could be raised to about 160 degrees Celsius by hot charging, since the temperature range is still relatively low, it merely amounted to the “low level heat”, recovery from which is difficult. Considerations were initially made on preheating of raw material at the VAC and VH equipment, but we reached the conclusion that there is no effective use as the heat temperature level was low. We then considered preheating the air for the heating furnace by using heavy gas oil, but this had to be abandoned since there is a potential threat of heating furnace exploding if the fluid leaks into the air for the heating furnace. When we were almost ready to give up on finding any effective modification ideas, an unanticipated concept was proposed by a member, which suggested that if generated steam is used for preheating the air for the heating furnace should be possible to implement modifications that are both safe and efficient. We then decided to pursue this strategy.

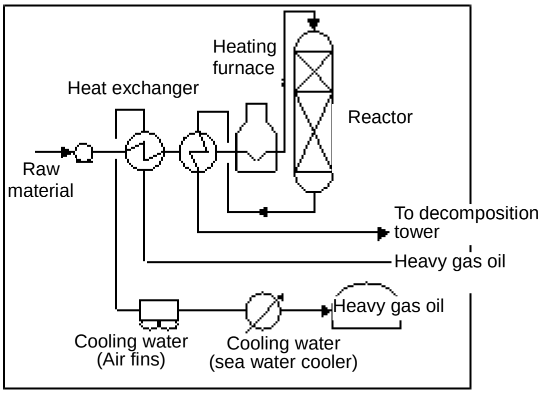

Figure 6: VH equipment heat recovery flow

4. Details of measures

(1) Heat Integration Modification of Naphtha Reforming System

The measure involved installation of heat exchanger and modification of piping as shown in Figure 7, as well as remake of convection as already shown in Figure 4. The specific details are as follows:

[1] Installation of a piping that channels a part of raw material naphtha to the NF equipment directly from upstream equipment (hot charging of NF equipment).

[2] Installation of a piping that channels the product to the NH equipment directly from the NF equipment (hot charging between NF and NH equipment).

[3] Enhancement of raw material oil heat exchanger of NH equipment.

[4] Modification of tubing on heating furnace of NH equipment.

[5] Installation of heat exchanger for raw material oil preheating of NF equipment (heat recovery from raw material oil of PLA plant).

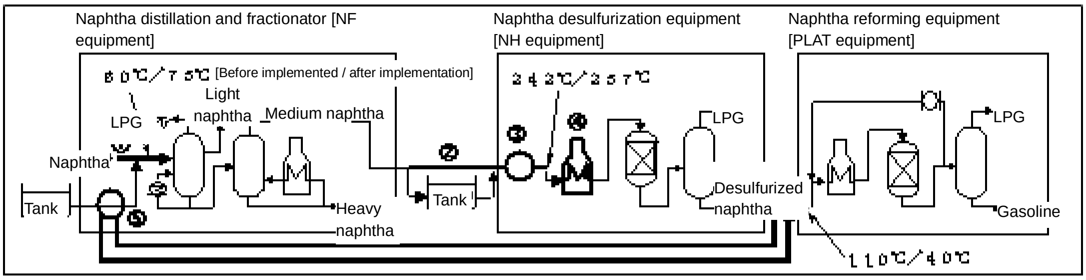

Figure 7: Heat integration modification of naphtha improvement system

Furthermore, the difference in load on the charge side and the reboiler side of the heating furnace of the NH equipment could be narrowed done to reduce the gap in temperature from 320 degrees Celsius before modification to 143 degrees Celsius after modification, thereby avoiding the danger of the center wall collapsing.

(2) Heat integration modification of heavy oil decomposition system (Figure 8)

A measure involving installation of heat exchanger and air preheater, as well as modification of piping was implemented. Furthermore, the heat exchanger of the VAC equipment was enhanced in order to strength the raw material oil preheating capacity of the equipment on its own. The specific details are as follows:

[1] Enhancement of raw material oil heat exchanger of VAC equipment.

[2] Installation of piping for directly transfer of product from VAC and VH equipment (hot charging between VAC and NH equipment).

[3] Installation of heat exchanger for generating steam from excessive heat of heavy gas oil for use in preheating of air for combustion in heating furnace.

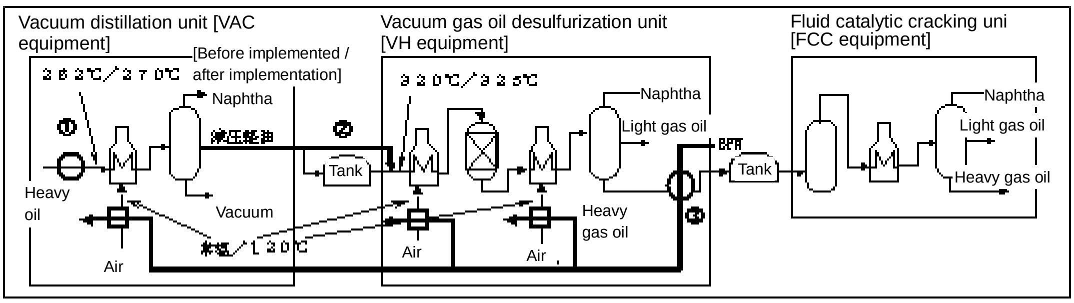

Figure 8: Heat integration modification of heavy oil decomposition system

The steam generating system mentioned in [3] is shown in Figure 9 and the air preheater is shown in Figure 10. A closed system was adopted to recover and reuse condensed steam after preheating air.

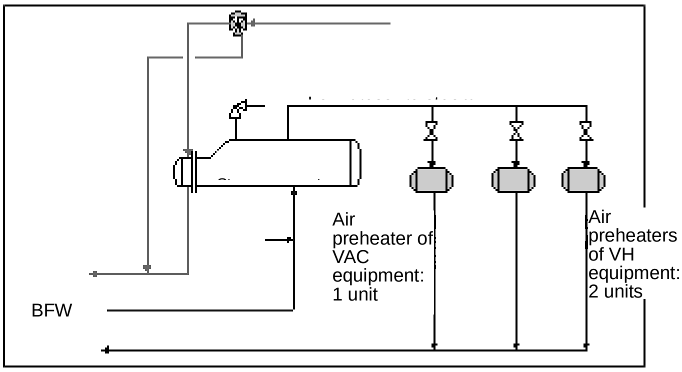

Figure 9: Steam generating system

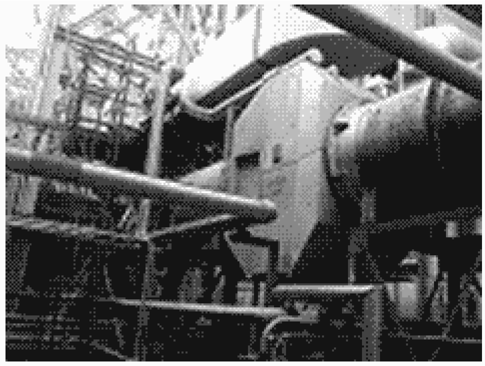

Figure 10: Air preheater

5. Effects achieved after Implementing Measures

(1) Heat Integration for Naphtha Reforming System

The energy conservation effect of naphtha reforming system is shown in Table 2 and the load reduction effect of heating furnace for naphtha desulfurization equipment is shown as an example in Figure 11. The load reduction effect is represented in fuel consumption unit (amount of fuel gas consumed per charging of NH equipment). There was approximately 15 % reduction after implementing the modification work.

Table 2: Energy conservation effects of naphtha reforming system

	Planned value Kiloliters per year (crude oil equivalent)	After modification Kiloliters per year (crude oil equivalent)

Load reduction of reboiler on distillation tower of NF equipment	3,170	3,150
Load reduction of heating furnace in NH equipment	2,880	4,040
Total	6,050	7,190

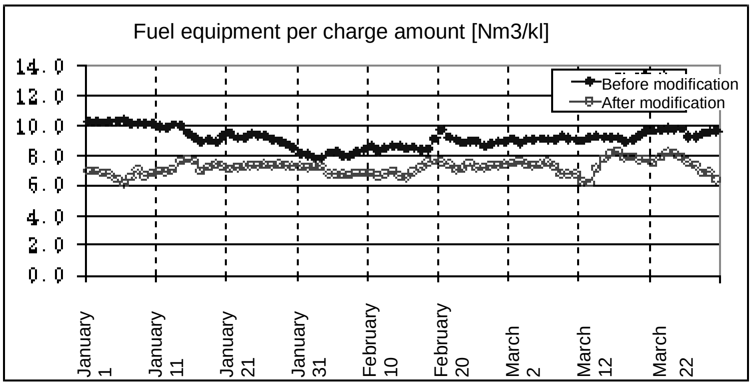

Figure 11: Change in fuel consumption unit for heating furnace of NH equipment

(2) Heat Integration for Heavy Oil Decomposition System

The energy conservation effect of heavy oil decomposition system is shown in Table 3 and the load reduction effect of heating furnace for reactor of the VH equipment is shown as an example in Figure 12. The load reduction effect is represented in fuel consumption unit (amount of fuel gas consumed per charging of VH equipment), as was the case with the NH equipment. There was approximately 20 % reduction after implementing the modification work.

Table 3: Energy conservation effects of crude oil decomposition system

	Planned value Kiloliters per year (crude oil equivalent)	After modification Kiloliters per year (crude oil equivalent)
Load reduction of heating furnace in VAC equipment	2,210	2,750
Load reduction of heating furnace for reactor in VH equipment	1,310	1,360
Load reduction of reboiler for distillation tower of VH equipment	1,000	1,390
Total	4,520	5,500

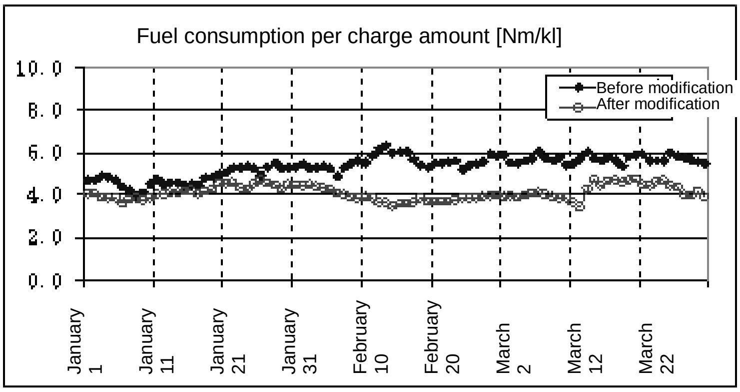

Figure 12: Change in fuel consumption unit for heating furnace of reactor in VH equipment

We were able to attain the energy conservation effect of the entire equipment subject to implementation conducted by the project, as described thus far, of 7,190 + 5,500 = 12,690 kiloliters per year (crude oil equivalent). This was an impact that amounts to 3.1 % of total energy consumption at the refinery, exceeding the planned 2.5 % target. The years payback, calculated from total cost of implemented modification work, was approximately four years. We believe that we were able to implement a superior modification work that is recoverable in a relatively short period of time.

6. Summary

We switched our concept from the conventional optimization of individual equipment to the optimization of multiple equipments in system units and persisted with our efforts even when problems presented technically high obstacles to conserve a significant amount of energy through the implementation of heat integration between multiple equipment. We believe that this project was a thoroughly satisfying venture and provided us with an opportunity to improve the energy conservation technologies of our personnel on site and to reach another level of awareness by achieving significant energy conservation results.

7. Future Plans

Implementation of modification conducted by this project does not complete all efforts that spring out of the concept for optimization of multiple equipments. We intend to undertake further actions to discover new measure to deal with energy conservation issues by broadening our scope.

There is no end to conservation of energy. Reduction of carbon dioxide emissions and environmental load are under greater scrutiny nowadays. We intend to have each individual personnel on site continue making efforts for improving energy conservation technologies and undertaking activities to discover and promote energy conservation issues with new concepts each and every day.