B-14.4.2 Evaluation of important measures in the heat utilization sector

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Approximately 50% of the total energy supply in Japan has been consumed as thermal energy. On the other hand, approximately 60% of the primary energy supply has been lost as waste heat. Therefore, full utilization of thermal energy would be important to promote the energy conservation and to contribute to the global environmental protection technologies. In this research, concerning to utilization of unused waste heat, the possibility of heat recovery from the water including fouling, such as calcium carbonate, is studied. The classification of fouling, the investigation of the quantity of total recoverable energy, the deterioration of the performance of heat exchanger are studied and the reduction of global warming by the heat recovery is estimated. Concerning to the research of a new Energy Flow Map, total amounts of energy consumption(Industry-use, Transportation-use, and Public-use) are listed from a human-life point of view. This table is classified into 5 main categories which are Clothing, Food, Home, Job/School, and Society/Service. Those are classified into some items further. Energy utilization which are manufacturing energy, manufacturing energy of raw materials, energy loss, and energy release into environment include loss of energy transformation were calculated and listed. Energy consumption were calculated from the statistics of energy utilization and the table of industry utilization. These values were compared with 5,150W which is the average energy consumption at 1991. So far 3,800W is classified approximately, but 25% is still unknown. After this, we are trying to reduce unknown value by making the most of the table of industry utilization.

Key Words Heat Recovery, Fouling ,Heat Exchanger, Energy Flow

1. Introduction

Approximately 50% of the total energy supply in Japan has been consumed as thermal energy. On the other hand, approximately 60% of the primary energy supply has been lost as waste heat. Therefore, full utilization of thermal energy would be important to promote the energy conservation and to contribute to the global environmental protection technologies. In this research, concerning to utilization of unused waste heat, the possibility of heat recovery from the water including fouling, such as calcium carbonate, is studied. The classification of fouling, the investigation of the quantity of total recoverable energy, the deterioration of the performance of heat exchanger are studied and the reduction of global warming by the heat recovery is estimated. For making an energy flow map from the viewpoint of end use, the energy consumption relating the daily life, industrial products and the production of materials, have been categorized into five. Energy utilization which

are manufacturing energy, manufacturing energy of raw materials, energy loss, and energy release into environment include loss of energy transformation were calculated and listed. Energy consumption were calculated from the statistics of energy utilization and the table of industry utilization.

2. Possibility of heat recovery from waste heat

In the research of heat recovery from waste heat, we investigated the total amount of energy which can be recovered from waste heat of ironworks. We also developed the experimental apparatus for clarifying the process of fouling attachment on the heat exchanger surface in order to predict the reduction of heat exchanger performance and observed the process of the attachment of Calcium Carbonate scale on the heat exchange surface. We developed the numerical calculation code which can simulate t the process of the attachment of Calcium Carbonate scale on the heat exchange surface and investigated the effect of several parameter like velocity, thickness of liquid film on the fouling process. We also compared between experimental results and numerical results. Moreover, reduction of global warming by both hot water and vapor energy transportation systems is evaluated roughly considering system infrastructure, electric power in running and so on.

2.1 Investigation of the total amount of recoverable energy from waste heat

In investigation of the total amount of energy which can be recovered from waste heat, we investigated waste heat in ironworks. Total amount of waste heat in ironworks is about 5240 MW , whose standard is 15 ℃, and total amount of energy not recovered is about 4400 MW[1]. Main part of unused waste energy is the heat of cooling water for slug and its total energy is about 1140 MW and its average temperature is 80 ℃. Exhaust of coke oven also has much quantity of heat and its averaging temperature is about 200 ℃. Therefore, we consider the heat recovery of waste heat whose temperature 80 ℃ and 200 ℃.

2.2 Prediction of the reduction of heat exchanger performance by fouling

The cooling water for slug is around 80℃ in average and includes much crystal materials like Calcium Carbonate and Silica since high temperature slug is cooled directly by water. Therefore, we have fouling problem when we exchange the heat from the cooling water. In this research, we investigated the mechanism of scale attachment on heat exchanger experimentally and numerically in order to develop the fouling attachment model. In experimental analysis, we investigated the process of Calcium Carbonate scale attachment on the surface of heat exchanger when the liquid including Calcium Carbonate flows in film. This experimental apparatus consists of heating section, controlling system and so on. We flows the liquid including Calcium Carbonate on the surface of heating section in film, and measured the thickness of liquid film by capacitance meter and measured pH on both liquid surface and the surface of heating section and the temperature of the liquid. The results reveal that crystallization of Calcium Carbonate generates near the exit of liquid film and on the surface of the heating section.

We also analyzed numerically the process of Calcium Carbonate scale attachment on the surface of heat exchanger considering gas and ions diffusion in the liquid when the liquid including Calcium Carbonate flows in film. In the numerical analysis, the conservation equations of ions, conservation equations of electrons and diffusion equations of ions

were solved on the boundary conditions of the surface distribution of pH which were measured in the experiment. We calculated the distributions of ions when no crystallization occurs and crystallization occurs on the surface of heat exchanger. And then, we compared the numerical results with the experimental ones, and they agreed well in the pH distribution. Though we could not measured the rate of crystallization, the numerical results coincides in the rate of crystallization qualitatively. These shows that this numerical simulation can predict the rate of crystallization in some degree.

2.3 Reduction of global warming by energy transportation system

We roughly estimated reduction of global warming when we transport the heat energy of waste heat whose temperature is 80 ℃ by hot water energy transportation system The system condition as follows. We have much waste heat whose temperature is 80 ℃. The exit temperature of the heat supplying side is 75 ℃ and the supplying heat energy for the heat demand side is 10 MW. In the heat demand side , we assumed that 60 ℃ hot water is made from 20 ℃. In this case, the system efficiency is 0.792. We estimated the reduction of global warming by energy transportation system. We considered heat exchanger, steel pipe and pump as initial investment and only materials in heat exchanger and steel pipe. Table 1 shows that energy transportation system utilizing waste heat has more effect on the reduction of global warming even when we considered usage of the initial investment and the running system.

Next, we investigate both the system efficiency and the economics of energy transportation systems when we assumed that heat energy which is recovered from waste heat of 200 ℃ is transported by hot water energy transportation system and vapor transportation system. We assumed the system condition as follows. The temperature of vapor waste heat is 200 ℃, the supplying heat energy for the heat demand side is 29.1MW (25Gcal/h). The exit temperature of the heat supplying side is 183 ℃. Heat supplying time is 1200 hour per year and the system is maintained keeping the temperature. Figure 1 shows the system efficiency and the average system efficiency as a function of the distance in the case of the pipe radius of 600 mm.

Concerning to the cost of hot water energy transportation system and vapor energy transportation system, we considered the cost of heat exchanger, pipe section, (including construction) and pump system (including running cost). Figure 2 shows that total cost of the hot water energy transportation system and the vapor energy transportation system as a function of distance. Though Table 2 shows that energy transportation system utilizing waste heat has more effect on the reduction of global warming even when we considered usage of the initial investment and the running system, the figure shows that the cost of infra structure is big problem. Therefore, the energy transportation system

Table 1 Reduction of global warming by hot water energy transportation system

	Quantity	Unit of CO_2 release[2)]	Reduction of global warming
Stainless steel	83 ton	3.273 (kg/kg)	-233.3 ton
Steel pipe	1452 ton	1.3 (kg/kg)	-1887.6 ton
Urethane	25 ton	3.375 (kg/kg)	-83.9 ton
Electric power	14.3 (MWh/day)	0.4218 (kg/kWh)	-6 ton/day
Heat output	240 (MWh/day)	0.4218 (kg/kWh)	101 ton /day

utilizing waste heat has much effect on the reduction of global warming if we don not consider the cost.

3. New energy flow map

We made a new Energy Flow Map, in order to describe the ratio of thermal utilization to energy utilization. This is a energy consumption table not only based on each utilization in ordinary life, but made from viewpoint of consumer. Total amounts of energy consumption(Industry-use, Transportation-use, and Public-use) are listed from a human-life point of view in Table 2. The table is classified into 5 main categories which are Clothing, Food, Home, Job/School, and Society/Service. Those are classified into some items further. Energy utilization which are manufacturing energy, manufacturing energy of raw materials, energy loss, and energy release into environment include loss of energy transformation were calculated and listed. Energy consumption were calculated from the statistics of energy utilization and the table of industry utilization.[3] These values were compared with 5,150W which is the average energy consumption at 1991. So far 3,800W is classified approximately, but 25% is still unknown. After this, we are trying to reduce unknown value by making the most of the table of industry utilization.

In current analysis for thermal utilization, cocking and refrigeration are 1% respectively at Food category, cooling/heating and gas/water are 4% respectively at Home category. Therefore total amount of thermal utilization is 10%. This amount is approximately equal to energy consumption of car at home. This analysis showed that in thermal utilization, we can contribute greatly to the reduction of the energy consumption which is increasing gradually now. For example, we can use high performance heat pump or waste

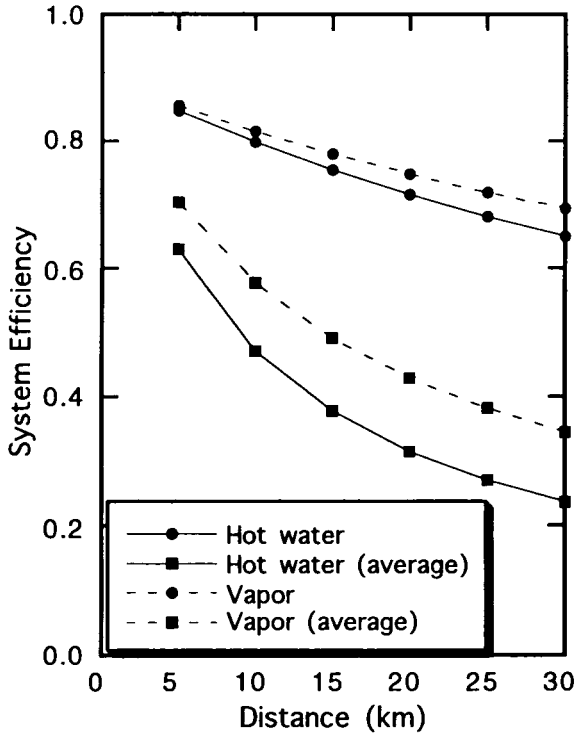

Fig. 1 System efficiency as a function of distance

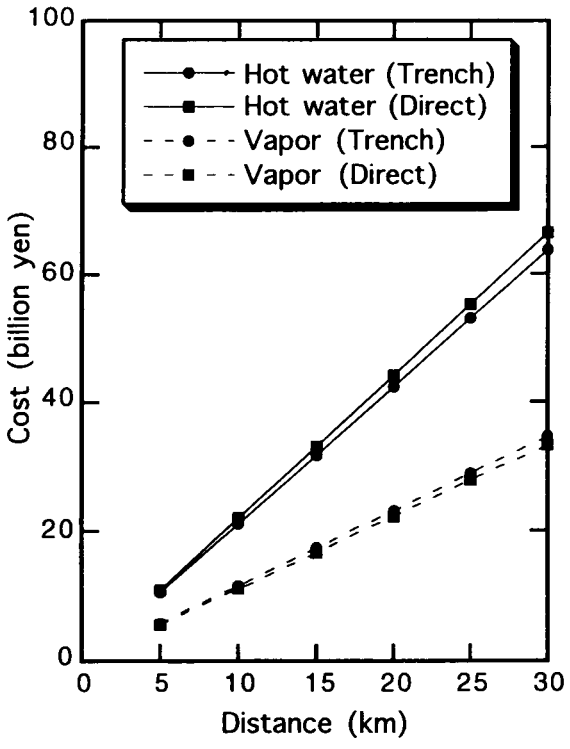

Fig. 2 Cost as a function of distance

heat to cooling/heating and gas/water system. This is the first time to be made the table from viewpoint of consumer. The table is highly evaluated. It is easy for consumer to understand the amount of energy consumption.

Table 2 The analytic table of energy consumption based on ordinary life

	Energy consumption (W)	Manufacturing energy + That of raw materials (W)	Energy release · Energy loss Transformation loss (W)	Sub total (W)	Total (W)
Clothing					
Clothes, Bedding	—	68	18	86	137
Washing(Laundry, Iron, Dryer)	16	31	31	51	
Food					
Food(Vegetable, Fruit, Frozen food)	—	90	38	128	
Cooking(Gas range, Microwave, Rice cooker, Dishwasher)	44	2	13	59	296
Refrigeration(Refrigerator)	15	6	29	50	
Eating out(Restaurant)	33		26	59	
Garbage	0			0	
Home					
House(Detached house, Condominium)	—	148		148	
Car(Family car)	437	90		527	
Heating/Air conditioning	142	9	44	195	
Gas/Water(Bath, Washbowl)	173	—	25	198	
Light	17	—	32	49	1,576
TV, VCR, CD-Stereo, Computer, Hair dryer	102	5	194	301	
The other electric power	—				
Makeup, Taking care of children		102	56	158	
Publication(Newspaper, Book)					
Job/School					
Building(Electricity, Gas, Water, Photocopy)	162	327	143	652	
	56	31		87	869
Commutation, Public transportation (Bus, Train, Taxi)	35			35	
Business trip, Travel(Airplane, ship)	53		42	95	
Hotel					
Society/Service					
Transportation, Communication(Cargo, Mail,	324			324	
Delivery, Garbage truck, Moving,	87		68	155	
Tel, Fax)	45		36	81	918
Shopping(Department store, Supermarket)	15		12	27	
		103		103	
Medical service	—	92		92	
Entertainment(Movie)		136		136	
Road					
River, Sewerage, Waterworks					
Park, Residential area, Harbor, Agricultural engineering, The others					
Unknown Part	568		786	1,354	1,354
Total			1,593		5,150

After this, we call this table as the analytic table of energy consumption based on ordinary life. This table will be used to have more active discussions and feel energy as one component of ordinary life.

4. Concluding remarks

In this research, concerning to utilization of unused waste heat, the possibility of heat recovery from the water including fouling, such as calcium carbonate, is studied. The classification of fouling, the investigation of the quantity of total recoverable energy, the deterioration of the performance of heat exchanger are studied. Moreover, reduction of global warming by both hot water and vapor energy transportation systems is evaluated roughly considering system infrastructure, electric power in running and so on. The result reveals that the energy transportation system utilizing waste heat has much effect on the reduction of global warming if we don not consider the cost. For making an energy flow map from the viewpoint of end use, the energy consumption relating the daily life, industrial products and the production of materials, have been categorized into five. Energy utilization which are manufacturing energy, manufacturing energy of raw materials, energy loss, and energy release into environment include loss of energy transformation were calculated and listed. Energy consumption were calculated from the statistics of energy utilization and the table of industry utilization. These values were compared with 5,150W which is the average energy consumption at 1991. So far 3,800W is classified approximately, but 25% is still unknown. After this, we are trying to reduce unknown value by making the most of the table of industry utilization.

Reference

(1)Unused Energy in Ironworks、Nihon Tekkou Renmei.
(2)Inaba et al., Kankyou kanri, Vol.31, No.6 1995
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