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Panel Discussion Part-1

Case Studies of Material Flow Cost Accounting

Introductory Research on Material Flow Cost Accounting
IGES Kansai Research Center Research Project

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As a part of its "Business and the Environment Project," IGES Kansai Research Center is promoting the research and development of practical tools to help facilitate the internal management of companies engaged in environmental management as sustainable management. In social scientific studies, field research whose outcomes can be widely applied in the real world is as important as academic research. What is essential in making an academic theory applicable to actual business activities is to study its feasibility and usefulness through fieldwork so that we may understand issues to be solved and propose measures for improvement. IGES holds bimonthly workshops under the title of "Study Meeting on Environmental Accounting for Corporate Management," hereinafter referred to as the IGES Corporate Management Workshop. The objective of the workshop is to provide researchers, who are developing the most advanced theories, and corporate staff who could apply those theories in their business, opportunities to exchange their opinions, facilitating experimental research. Nippon Paint Co., Ltd. and Shionogi & Co., Ltd., members of the workshop, joined the project introduced below.

In order to promote research on MFCA theory, research based on literature and materials available both in Japan and overseas is of course important. In addition, we should apply the theory and tools in real business management in Japanese companies to study its usefulness and understand the issues to address. We therefore included the introductory application of the MFCA system to Japanese companies in the IGES 2002 research project.

IGES asked for cooperation from Nippon Paint in December 2001 to analyze their production by the MFCA since the company had shown its interest in a lecture on the MFCA theory given at one of the IGES Corporate Management Workshops. Nippon Paint and IGES then repeatedly had preliminary meetings, followed by MFCA investigative meetings including a study tour of a Nippon Paint plant during the period from the end of December 2001 to January 2002. By the end of the series of the investigative meetings, one of the production lines was chosen to participate in the experimental research.

In April 2002, an IGES research team gave an explanatory session on the MFCA theory to a plant manager, the staff in charge of production lines, Environmental Quality Headquarters and Finance & Accounting Department. In the session held at the Osaka plant of Nippon Paint, staff in charge of each step of the production process asked questions regarding a specific work procedure of the selected production line, helping us to understand issues to address in applying the MFCA theory in actual management. In addition, we discussed scheduling of the project, the objective of the MFCA introduction, a flowchart to show outcomes of the research and how to use data to be collected.

In April 2002, the IGES research team visited the Environmental Management Unit at Shionogi headquarters to explain the outline of MFCA and the planned experimental research. Questions about specific items were brought up at this exploratory session such as differences between the MFCA and Shionogi’s existing system including environmental management information, advantages gained by introducing the MFCA system, and additional time or costs required for research cooperation. There had been two examples of MFCA being introduced to pharmaceutical companies in the past: one by IMU in Germany, which created the MFCA concept and the other by the Japan Environmental Management Association for Industry (at Tanabe Seiyaku, Co., Ltd.) under a commission from the Japanese Ministry of Economy, Trade and Industry. IGES set its objective in the research at Shionogi to address new environmental issues in the MFCA system based on the outcomes from the former two examples.

After obtaining Shionogi's approval for the experimental research, we held a meeting in May 2002 to create a comprehensive plan, including selection of a plant and line to join the research. Responding to Shionogi's proposal, IGES selected a pharmaceutical product manufactured at the Kanegasaki Factory that included the entire production process from drug substance manufacturing, to formulation and packaging. Based on detailed explanation about the selected production line from Shionogi and consideration of the scientific characteristics and annual production schedule of this drug, data collection times and scope of research data were decided. The Ministry of Health, Labor and Welfare regulates that pharmaceutical companies should make detailed data of physical flow. IGES, therefore, was to collect very detailed data at the chemical compound level, limited to the manufacture of one lot of the target product.

Case Study I : Nippon Paint Co.,Ltd.

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1. Company Profile

For 122 years, since its initiation in 1881, Nippon Paint[1] has been a leading manufacturer in the Japanese paint industry developing, manufacturing and selling various types of paints and coatings for automobiles, buildings, industrial equipment, ships and other products in various sectors. As of March 31, 2002, they had 27,712 million yen in capital, 192,467 million yen in consolidated net sales and 4,515 employees.

The company has eagerly addressed environmental issues and has been an active member of the Japan Responsible Care Council since its foundation in 1995. In March 1999, it was the first company in the Japanese paint industry to acquire ISO14001 certification for all Japanese facilities. In addition, the company also formed its environmental management policy, building a worldwide cachet as an environment-conscious company that contributes to environmental protection and reduction in resource and energy consumption. Their basic policy is as follows:
"Through its offering of color and design services, as well as its endeavors to develop better ways to protect our natural resources, Nippon Paint is determined to fulfill its responsibility of beautifying and conserving the global environment. By enhancing the environmental awareness of all its employees, Nippon Paint is initiating a corporate-wide effort to promote environmental commitment."

The company has also established environmental management targets to be achieved by 2005: the targets are for environmental conservation activities and energy and resource saving; and to provide products and services with an aim of developing products and technologies that minimize environmental load.

2. Project overview

2.1 Meetings prior to implementation of the project

In December 2001, IGES researchers visited the Osaka Plant to explain MFCA to the related division staff members and to take a plant study tour. As it is important for the project staff members to understand MFCA prior to its introduction, a meeting was held to clarify points of implementation.

Among the problems posed in the meeting, the issue regarding data collection had to be solved immediately. As the Osaka Plant is located next to the head office, the project team members visited the plant as frequently as they needed and swiftly found proper solutions through close and frequent communications with related plant workers in charge of process flow. Through such bilateral communications, many proposals were presented from the plant workers. In this way, two or three meetings between the IGES researchers and the project team members were held each month.

The data collection sheet, including flowcharts, was prepared by the Accounting Department and it took several months for preparation. This sheet was well designed and very easy to use, with illustrations and pictures showing processes and tasks of the manufacturing line to be surveyed in detail. Taking into consideration the manufacturing plan of the related product, a trial test was carried out in July, followed by improvement of the sheet, and the beginning of a three-month period of data collection in August.

1) For further detailed corporation profile, please refer to http://www.nipponpaint.co.jp/

MFCA was first introduced to the water-based paint manufacturing line in the Osaka Plant. MFCA covers material cost, system cost, distribution/waste disposal cost and energy cost. The manufacturing line is composed of five processes: mixture, dispersion, dissolution, filtration and filling. In the first process mixture, a dozen types of raw materials including water, pigments, additives and resin are mixed. In the dispersion process, the grain size is made equal. In the dissolution process, additives are poured and stirred. In the fourth process filtration, impurities are removed from the finished product. In the final process filling, the finished product is placed into 18-L containers.

To carry out the project to introduce Material Flow Cost Accounting (MFCA), the following team has been organized.

Project team members:

Head office (3):

Environmental Quality Headquarters

Accounting Department

Factory (14):

Manufacturing Section

Center of Engineering

Safety and Emergency Section

2.2 Data collection

In principle, material-related data was collected through actual measurement, while labor and other costs were collected from financial data.

In calculating material cost, the data written in the work control form (manufacturing indication form) was not used, but all raw materials used in each process was weighed and the cost was calculated by multiplying the weight by the price of each material.

The system cost includes labor cost, depreciation cost and other expenditures. The data related to the system cost was collected from financial data. As more than two products are manufactured in a single manufacturing line, the depreciation cost and other expenditures of the product to be surveyed were calculated according to the specified rule. The labor cost was calculated based on the record of individual work time for each process. In the survey conducted this time, only the cost directly relating to the manufacturing work was taken into account. (The cost necessary for auxiliary work was excluded.)

The main delivery/waste disposal cost is the cost for disposing of packages and containers of purchased raw materials. It was calculated by multiplying the weight (kg) by unit disposal cost. The general delivery cost was excluded.

The energy cost was calculated by multiplying the integrated energy consumption of each machine in each quantity center by unit power cost. As every quantity center was not equipped with watt meters, sample data was collected using power measuring devices.

2.3 Preparation of flowcharts including data

1) Flowchart (material cost)

As the manufacturing line surveyed is also used to manufacture other products, the machines and tools are washed after each process has been completed.

After materials were mixed with water in a tank in the quantity center during the mixture process, shown in Fig. 2.1, it is transferred to the subsequent dispersion process and the tank is washed with water. The drainage (water used to wash the tank including a small amount of material residue) is stored for reuse the next time washing of the same type of product is required.

From the mixture process through to the final filling process, pipes were used to connect each process. As products that complete each process are transferred via the pipes, no leaks occurred. Also, no paint is left in the pipes as paint adhering to the inside of the pipes is extruded with a utensil (called a pig) following the filling process.

As a result, in the water-based paint manufacturing line, a very small amount of material loss (final waste) was generated. What little fine powder was generated from powdered materials during the mixture process was collected with a dust collector and recycled as materials. Only a small amount of residue that could not be collected or adhered to the dust collector became waste.

2) Flowchart (system cost)

The system cost of each quantity center is shown in Fig. 2-2. The depreciation cost related to the manufacture of water-based paint (survey target of this project) was calculated according to the specified rule.

3) Flowchart (delivery/waste disposal, energy costs)

In Fig. 2-3, the energy cost is shown in the upper boxes and waste disposal cost shown in the lower boxes.

4) Flow cost matrix

In Fig. 2-4, the amount invested in each quantity center is shown above the material loss in the middle of the figure.

- Material loss cost ratio: 0.127%
  (total material loss cost/total costs)
- Final waste cost ratio: 0.137%
  (disposed material loss/total material cost)

These ratios, derived from MFCA, show that water-based paint is manufactured with only a small amount of material loss.

2.4 Another application of MFCA -a study of power consumption loss-

The purposes of this project were to verify that material and cost losses of the water-based paint manufacturing line are nearly zero, as expected, and to fully understand MFCA procedures for further applications to other manufacturing lines in the company.

Furthermore, we discussed a new application for MFCA. With the aim of minimizing environmental load, power consumption was analyzed and studied through MFCA. First, power consumption for each machine was measured. As the number of power measuring devices was limited, the power of one machine was measured only once. By measuring power consumption during two or more batches of operations, the entire related manufacturing line was sampled. The power consumption during one batch of operations for a machine was then estimated. We discussed the practical use of the data for MFCA.

So far, the power consumption of each machine had been measured, but the problem of how to link the data with MFCA as an environmental management accounting data had not yet been solved. Simply speaking, the question was what the measured power consumption data should be compared against when calculating energy loss.

In this project, the power factor was used as a solution. The power factor, as shown by the following equation, is the ratio of electric power consumed to activate the functions of each machine to input power.

$$\text{Power factor}(\%) = \frac{\text{Electric power consumed to activate machine functions (W) (effective power)}}{\text{Voltage (V)} \times \text{electric current (A) (apparent power)}} \times 100$$

The power factor of each machine was calculated based on the data obtained using measuring devices. In several cases, lower power factors than the standard power factor of 85% were obtained. It is considered logical for MFCA to calculate and collect data for power loss and its cost for each machine and each quantity center and to use them for minimizing power loss. Power loss is obtained using the following equation: apparent power × (1 - power factor) = power loss

1) Possibility of reduction in power consumption loss

We examined how we might reduce power consumption loss, which is found by calculating the operating power consumption for each machine and the power factor. Reduction in power consumption loss leads to cost reduction.

Calculations of possible annual cost reduction resulting from reduction in power consumption loss

Electricity rates are roughly divided into a basic charge and a power charge. Each charge is calculated as shown below:

Basic charge = (unit cost/kW) × (contract demand) × (modified power factor)

Power charge = (consumed power) × (unit power cost/kWh) ± (adjusted fuel charge)

The basic charge, a fixed cost that consumers must pay, is calculated based on contract demand. When contract demand is lower than 500 kW, the highest value from the past year (including the current month that related electric rates are paid) among the maximum actual demand measured each month, is used for the calculation. The maximum demand was the maximum value of average demand for 30 minutes in a month. On the other hand, the power charge is a fluctuating cost that consumers pay based on the amount of power they consume.

Accordingly, to reduce electric costs, contract demand and consumed power should be reduced. In this project, power consumption for each machine was measured.

		①	②	③	④	⑤	⑥	⑦	⑧	⑨
					③／②	③÷0.85	⑤－②	①×⑥/60/1,000	⑦×8.5 ※	⑧×20says×12months
Manufacturing machines	Process	Operation time per day (min.)	Apparent power (W) (input power)	Effective power (W)	Power factor	Apparent power calculated based on the standard power factor (85%)	Possible power reduction (W)	Possible power reduction per day (W)	Possible cost reduction per day (yen)	Possible annual cost reduction (yen)
Machine A	Dispersion	300	4,000,000	3,100,000	0.78	3,647,059	352,941	1,765	15,000	3,600,000
Machine B	Dispersion	300	370,000	222,000	0.60	261,176	108,824	544	4,625	1,110,000
Machine C	Dispersion	300	200,000	110,000	0.55	129,412	70,588	353	3,000	720,000
Machine D	Dispersion	420	1,000,000	800,000	0.80	941,176	58,824	412	3,500	840,000
Machine E	Filtration	240	350,000	122,500	0.35	144,118	205,882	824	7,000	1,680,000
Machine F	Filling	300	100,000	30,000	0.30	35,294	64,706	324	2,750	660,000
Machine G	Filling	360	110,000	44,000	0.40	51,765	58,235	349	2,970	712,800
Machine H	Filling	420	90,000	36,000	0.40	42,353	47,647	334	2,835	680,400
Machine I	Common	360	950,000	665,000	0.70	782,353	167,647	1,006	8,550	2,052,000
Total				5,162,240		6,034,706	1,135,294	6,834	50,230	12,055,200

※ Unit power cost/kWh

As a result, in several cases, the power factor was found to be lower than the standard 85%. Improvement of the power factor is considered to lead to a reduction in contract demand and consumed power. For an effective investment, investment efficiency must be appraised by estimating the amount of investment needed for improvement and expected cost reduction achieved by the investment. The power factor of the machines with higher investment efficiency should be improved sooner.

The following table shows the actual power consumption for each machine, power factors, power to be reduced and annual cost to be reduced.

First, the power factor of each machine (④) was calculated based on the apparent power (②) and the effective power (③) obtained through actual measurement. Second, the difference between the apparent power calculated based on the standard power factor (85%) (⑤) and the real apparent power (②) was obtained. This is shown in (⑥) as possible power reduction. Next, the possible cost reduction per day (⑧) is estimated by multiplying the possible power reduction per day (⑦), calculated based on the possible power reduction (⑥), by unit power cost (8.5 yen/kWh: applied by Kansai Electric Power Co., Inc. on and after October 1, 2002). Furthermore, possible annual cost reduction (⑨) was estimated (operation days per month: 20). Through the project, the following was found: in total, 12,055,200 yen in power costs will be reduced annually. Machine A specifically, will reduce 3,600,000 yen in power costs (the highest amount among machines A to I).

With regard to the basic charge, theoretically, the maximum demand is considered to be reduced by improving the power factor, followed by a decrease in contract demand per year. If contract demand is reduced by 100 kW a month, for example, the basic charge is estimated to be reduced by 2,136,000 yen per year. (100 kW × 1,780 yen <unit cost for basic charge per kW applied by Kansai Electric Power Co., Inc. on and after October 1, 2002> × 12 months)

To most effectively improve the power factor, reductions in power cost resulting from a reduction in consumed power, and reductions in the basic charge resulting from a reduction in contract demand, should be taken into account. It is important to start improving the power factor from the machine that the largest amount of power cost and basic charge can be reduced.

2) Estimating investment recovery period

Installation of condensers, employment of high-efficiency motors and other various methods will lead to an improvement in power factors. Effect and necessary cost vary depending on method. The corporation should survey the investment efficiency of each machine and give priority to the machines with higher investment efficiency when improving the power factor. Investment efficiency was studied based on the investment recovery period.

The table shows the power cost-related investment recovery period, calculated based on the amount of investment needed for power factor improvement. Among machines A to I, machine F has the highest investment efficiency: 1.5 years, and machine A has the lowest: 5 years. If reduction in the basic charge resulting from reduction in contract demand is taken into account, the investment recovery period will become shorter.

Currently, to prevent global warming, reduction in CO_2 emissions are a pressing need. Various schemes, such as an emission trading scheme and the introduction of a CO_2 tax, have been considered. As these plans may lead to a cost increase, a reduction in power consumption becomes increasingly important. When such reductions for future possible cost increases is taken into account, the investment recovery period becomes shorter; accordingly, machines that have been considered not worth the investment may prove worthy. It is important for the company to determine its investment based on its payable amount, investment recovery period, and future trends.

From the viewpoint of power factor improvement, we studied the possibilities for a reduction in power consumption loss. The amount of investment and the results (amount of reduction) will vary depending on methods of improving the power factor. Cost reduction estimates based on the difference between the actual measured power factors of each machine and the power factor achievable by improvement, will be very useful information for the company that must decide to invest or not to invest.

2.5 Future issues to be addressed

The scope of material costs to be measured was discussed. When determining the loss of input materials, should residues left in a container be measured as a material loss? Should powder dust that is collected by the whole factory be measured as a material loss of each process? In the former case, if the amount of residue in a single operation is minute, residues of two or more operations are collected and measured. In the latter case, we contended that when substances are difficult to measure and the data is important, estimated values are employed. The powder dust of each process, for example, is calculated by dividing the monthly average amount of powder dust by production amount. In addition, one type of substance can be surveyed separately by purpose and origin to properly determine the cost. Take water for example. Water used as a material is studied separately from water for washing.

Manufacturing machines	Process	Possible annual cost reduction (yen)	Investment amount (yen)	Recovery period (years)
Machine A	Dispersion	3,600,000	18,000,000	5.0
Machine B	Dispersion	1,110,000	2,000,000	1.8
Machine C	Dispersion	720,000	1,500,000	2.1
Machine D	Dispersion	840,000	2,500,000	3.0
Machine E	Filtration	1,680,000	5,000,000	3.0
Machine F	Filling	660,000	1,000,000	1.5
Machine G	Filling	712,800	1,300,000	1.8
Machine H	Filling	680,400	2,000,000	2.9
Machine I	Common	2,052,000	4,000,000	1.9
Total		12,055,200		

Next, the meaning of time was discussed in measuring energy and system costs. In other words, when studying energy and system costs, does the time only mean the duration that the machines operate manufacturing products, or does that include idle time? Time will be dealt with depending on machine type and conditions. The same issue was discussed for delivery and labor costs.

We also concluded that to obtain useful information about electric power, it was significant to measure electric power consumption for each machine. We decided to do the measurement. As a result, we found that this measurement allows comparisons between the measured value of power consumption and power factor, and this can provide useful information for decision making regarding investment in machines.

The manufacturing line, the research target of this project, has been known as a line with little material loss. Through the introduction of MFCA, this fact was numerically verified. In addition, by comparing detailed measured data, such as power consumption of each machine, with theoretical values and then analyzing them, new improvements were discovered. The knowledge of this research will be applied to other manufacturing lines, which will lead to the improvement of manufacturing lines and processes of the whole plant.

Furthermore, the method to link MFCA information to (external) environmental accounting is an important issue to be discussed in the future.

Flow Chart (material cost)

Nippon Paint

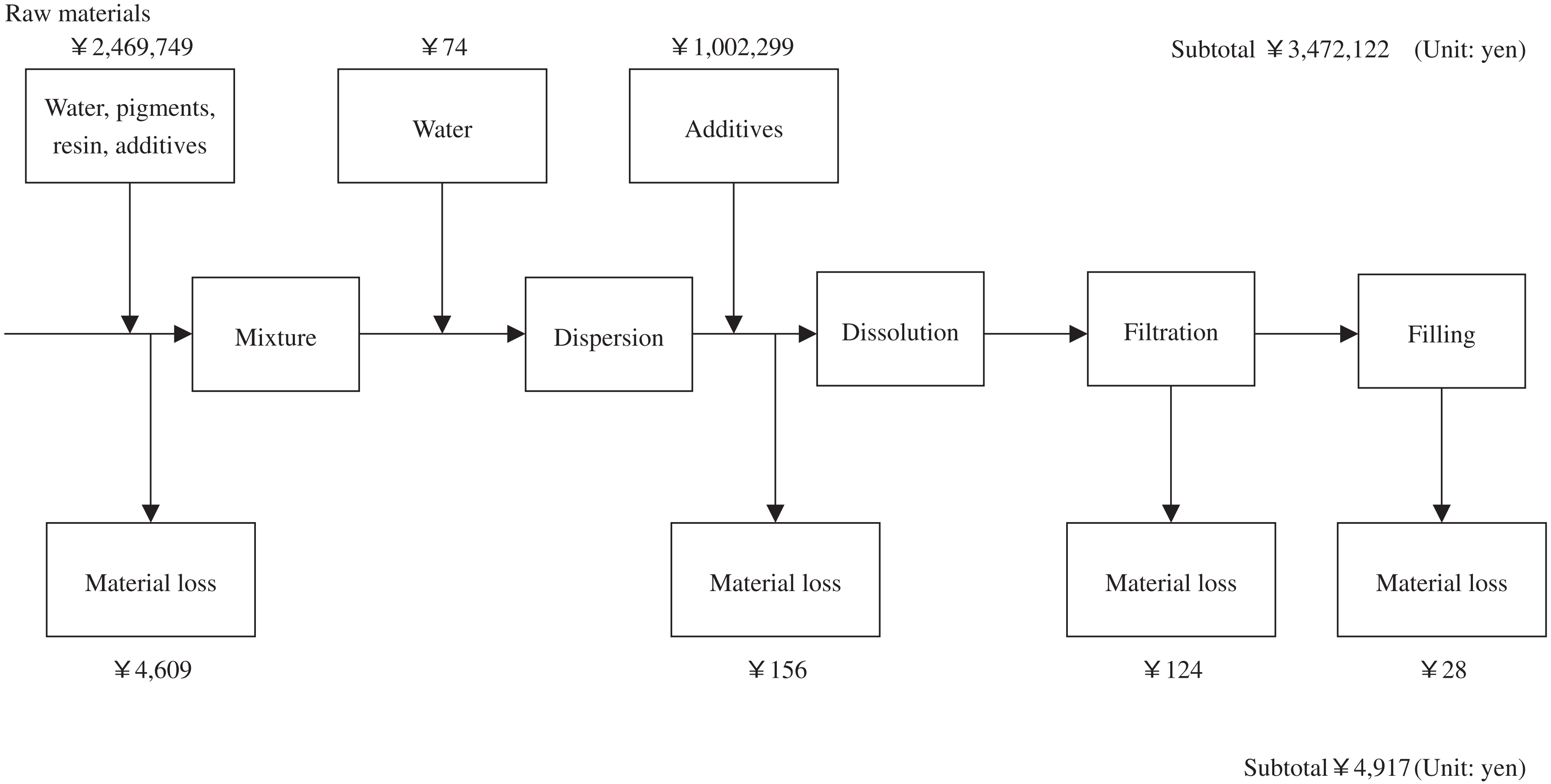

Fig. 2-1 Nippon Paint Material Flow Cost Flow Chart

Flow Chart (system cost)
Nippon Paint

(Unit: yen)

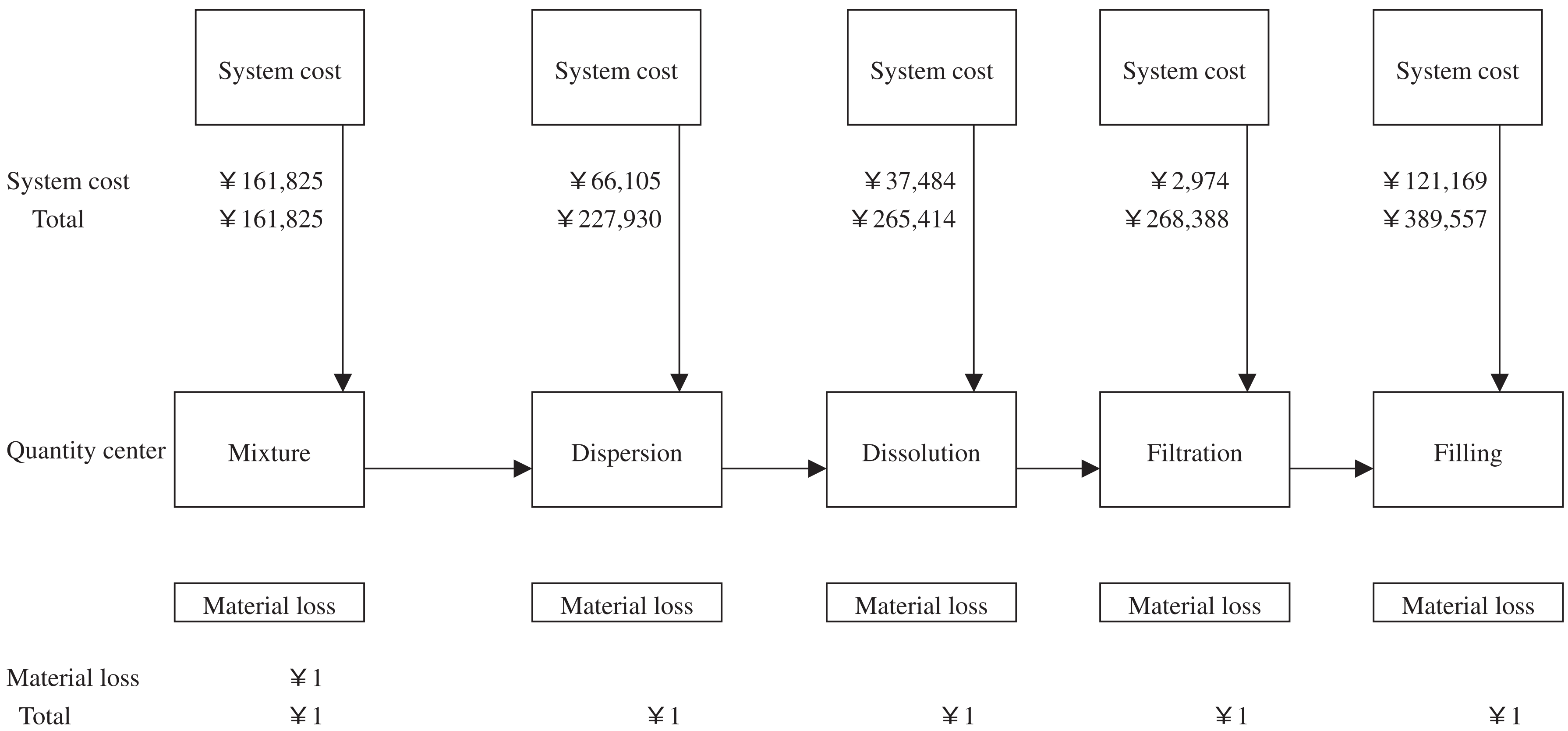

Fig. 2-2 Nippon Paint System Cost Flow Chart

Flow Chart (delivery/waste disposal･energy costs)

Nippon Paint

(Unit: yen)

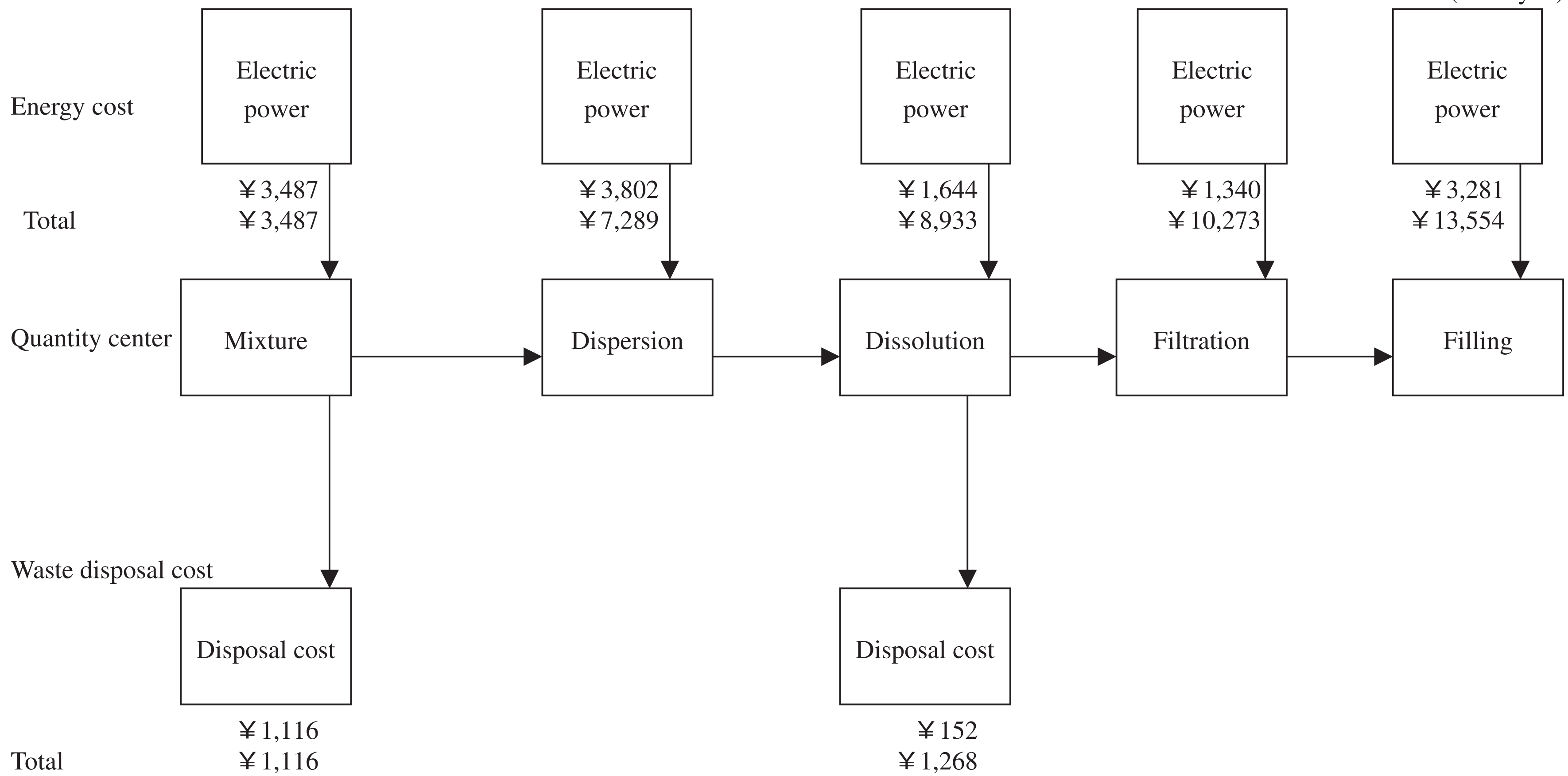

Fig. 2-3 Nippon Paint Delivery/Waste Disposal･Energy Costs Flow Chart

Flow Cost Matrix
Nippon Paint

(Unit: yen)

Quantity center	Mixture	Dispersion	Dissolution	Filtration	Filling	Total
Input						
Material cost	¥2,469,749	¥ 74	¥1,002,299	¥ 0	¥ 0	¥3,472,122
System cost	161,825	66,105	37,484	2,974	121,169	389,558
Energy cost	3,487	3,802	1,644	1,340	3,281	13,554
Subtotal	¥2,635,061	¥ 69,981	¥1,041,427	¥ 4,314	¥124,450	¥3,875,233
Material loss						
Material cost	¥4,609	0	156	124	28	4,917
System cost	1	0	0	0	0	1
Waste disposal cost	1,116	0	152	0	0	1,268
Subtotal	¥5,726	0	308	124	28	6,186

	Material cost	System cost	Energy cost	Waste disposal cost	Total
Product	3,467,205	389,556	13,554	0	3,870,315
Material loss	4,917	1	0	0	4,918
Packaging	0	0	0	1,268	1,268
Total	3,472,122	389,557	13,554	1,268	3,876,501

Material loss cost ratio 0.127% (total material loss cost/total costs)
0.137% (disposed material loss/total material cost)

Fig. 2-4 Nippon Paint Flow Cost Matrix

Case Study II : Shionogi & Co., Ltd.

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1. Corporate Profile

Since its establishment in 1878, Shionogi & Co., Ltd.[1] has continuously supplied pharmaceutical products for medicinal and other uses. Its company policy, "Shionogi constantly strives to provide medicine of the best possible kind essential for protection of the health of the people", was established in 1957. According to its corporate information as of the end of March 2002, the company has 21,279 million yen in capital, annual sales of 206,403 million yen, and 5,237 employees. Through its conscientious attitude toward science and its conduct based strictly on ethics, the company strives to fulfill its responsibility in the best possible way as a company that operates in areas closely related to the life and health of the people.

The company's effort in environmental conservation is milestoned by its establishment in 1971 of its emissions treatment policy for preventing pollution and its establishment in 1994 of Shionogi's Basic Environmental Policy. In addition, the company defined the goals of its company-wide environmental activities in Phase 1 of the Environmental Protection Plan in 1995 and Phase 2 of the Environmental Protection Plan in 2000. Shionogi, as it operates in the pharmaceutical field, strives to protect the global environment, prevent pollution, safeguard people, and reduce environmental impact.

Harmonious relationship with society is one of the aims expressed in Shionogi's Basic Environmental Policy. In the context of this aim, the company has been actively disclosing its environmental information in the form of environmental reports since 2000. Shionogi believes that for the company to perform its environmental activities effectively and efficiently with limited resources, it must have a tool that facilitates the evaluation and validation of the effectiveness of such activities. The company, therefore, has introduced the concept of environmental accounting to its activities since its first publication of environmental data in an environmental report.

The company regards Material Flow Cost Accounting (MFCA) as a useful means for corporate management in the context of environmental accounting. In the recent trial project, the company implemented MFCA as a means for reducing its environmental impact and production cost at one of its factories, where the entire pharmaceutical production process was subdivided into the processes of synthesis, formulating, and packaging. The project team included the following members:

Project team configuration:

Head office	
Environmental Management Unit	2 people
Accounting and Financial Dept.	1 person
Factory	
Factory Chief	3 people
Drug substance personnel	3 people
Formulating and packaging personnel	2 people
Energy (utilities) personnel	1 person
Logistics and warehouse personnel	1 person

2. Project

2.1. Preliminary activities

The preparations and examination for the trial implementation of MFCA started in July, 2002. In

1) For more information about the company, visit their Web site at: http://www.shionogi.co.jp/index_e.html

late July, the team visited the Kanegasaki Factory to explain the trial project and to study the production processes on site.

1) Discussions before the factory visit

On-site observation of material flow is essential for the introduction of MFCA. However, the Kanegasaki Factory, the target of our study, is located in Iwate Prefecture, a considerable distance from the company's head office at Osaka, as well as from the IGES Kansai Research Center at Kobe. This made it difficult for the research team to pay frequent visits to the factory. The research team decided to visit the factory only once. The research team, before visiting the factory, obtained as much information as possible through hearings from Shionogi's Environmental Management Unit at its head office. Through repeated meetings, the team learned the details of pharmaceutical production processes using existing flow charts and identified issues that would require on-site investigation.

In these meetings, we learned about three categories of values that could be used for calculating the mass balance at each quantity center. These are: measured values; standard values (target values) derived from measured values; and theoretically-derived ideal values. We discussed these categories of values and their suitability in material loss calculation. Generally, at a chemical company, it is possible to keep track of both the theoretically-derived ideal values and the experiment-based standard values. For the present project, we decided to include the ideal values in the scope of our analysis. We also discussed the system cost such as electric and other utility costs, depreciation cost, and labor cost, in order to define the portion of such costs that should be included in our analysis.

Concurrently with these discussions that preceded our visit to the factory, Shionogi's Environmental Management Unit at head office used existing data to produce prototype MFCA flow charts. They gave some special features to the flow charts to improve their usefulness in our research project. For example, tracing the original materials from the products of chemical reactions was made easier.

2) On-site meeting (factory visit)

In late July, the research team visited the Kanegasaki Factory with data prepared at the preliminary meetings. At the factory, we walked through the production processes in the order given in the flow charts, receiving explanations from the people in charge of each process. We collected information and summarized them as we discussed with the factory personnel the points raised at the preliminary meetings. At the same time, we were made aware of some issues that would require further examination. This experience of actually seeing the production processes allowed us to understand the flow charts in a three-dimensional way, helping us to clarify issues. Additional issues were raised at the factory as we looked at the utility supply facilities, warehouse (storage/logistics) facilities and waste disposal /recycling facilities. In our discussions about the material loss calculation, we came to an agreement that measured values should reflect losses by quality control sampling and losses by accidents.

We revised the flow charts based on the results of these discussions. In this process, actual values were clearly distinguished from estimated values (interpolated /extrapolated values). We produced new flow charts for utility cost and system cost.

3) Review meetings

For three months after the factory visit, we held meetings roughly on a monthly basis to continue our discussions based on the revised flow charts and newly-collected data. From November, we started to meet approximately twice a month to complete the flow charts inclusive of cost data and to identify issues that required further examination. We completed the cost-inclusive flow charts in early January. We held several meetings to produce the presentation data from the complete material flow data prior to our presentation at the international symposium on January 31.

The most important issue discussed in our meetings was the evaluation of costs for the products of chemical reactions. When chemical reactions are involved, it is arguable whether it is appropriate to calculate the cost based on the mass ratio as is done usually in MFCA. Considering the chemical compositions of purchased raw materials and the nature of chemical reactions that take place in the production processes at Shionogi, we came to the conclusion that it would make the evaluation more useful for corporate management decision making if we evaluated the cost of different materials not simply by their mass ratios, but in consideration of how the raw materials, purchased by Shionogi, were manufactured. Making such a consideration in the evaluation would require information from the suppliers, such information as the cost of materials used to produce the materials supplied to Shionogi. Thus, the feasibility of expanding the scope of MFCA to include the entire supply chain became another topic that required further exploration.

Our trial project covered the manufacturing flow of one particular pharmaceutical product, comprising a serial production process of drug substance manufacturing, formulating, and packaging. We investigated all the processes from the importing of materials to the factory to the export of products from the factory. We investigated the sewage processing facilities as well. The material flow data per batch was calculated from data of plural batches.

The complete production process is composed of three processes. The first is a drug substance manufacturing process for the synthesis of a drug substance; the second is a formulating process for molding the drug substance into tablets or granules; and the third is the packaging process. We defined several quantity centers for each process. The manufacturing process included quantity centers at the points of reaction, extraction, separation, drying, and so on; the formulating process at the points of palletizing, molding, and so on; the packaging process at the points of filling, packaging, boxing, and so on.

In our effort to determine the mass balance at different points in the production process, we took advantage of a large amount of existing data on the material quantities, which had been recorded and summarized by Shionogi for different purposes. Such data was readily available because pharmaceutical manufacturers are required to produce a "manufacturing control standard code" and other documents defined in the "Good Manufacturing Practice (GMP)" issued by the Japanese Ministry of Health, Labor and Welfare. In addition, Shionogi had master formulas that described details of production processes and defined mass balance for each production process in terms of the names and quantities of input and output materials. Shionogi was experienced in the process of revising the mass balance information with changes in the production process. For the implementation of MFCA, however, it was necessary to enable matching between output materials and input materials.

In the trial project, our task was to complement existing data with newly-collected data and then reevaluate the existing mass balance information using MFCA. Since Shionogi's master formula documents contained data on material quantities only, we strived to find possibilities for further improvement (Kaizen) by associating the outputs with the inputs and their costs using the MFCA methodology.

2.2. Data collection

With regards to the manufacturing, transportation, storage, waste disposal, and sewage processing, we collected data on the material flow, material cost, energy consumption/cost, and labor cost. With regards to the production facilities, we collected data on the depreciation cost, repair/maintenance cost, and the cost for consumables.

Before calculating the material cost, we determined the material flow in different production processes beginning with input materials, referring to the material balance information in the master formula documents and complementing it as required by measured values or values estimated from theoretical values. The material cost of the products of composition or decomposition that arise in the production process was initially calculated from the cost of input materials based on the mass ratio, as is usually done in MFCA. The validity of this method, however, was a subject that required further examination during the project. In areas where no data existed, we collected data during the project. For example, we collected data on the weight of packaging materials that were used with the input materials and later discarded.

With regards to the energy consumption and utility cost associated with production, we sorted out data on the consumption of resources such as electricity, water, and steam. At the same time, we evaluated the energy consumption associated with the transportation and storage of raw materials, intermediate products, and end products by measuring the amount of energy consumed by trucks, forklifts, elevators, refrigerators, and so on. Labor cost was determined separately for the individual areas of drug substance manufacturing, formulating, packaging, waste disposal, sewage processing, and transportation. In addition, we collected records on the facility's depreciation cost, repair/maintenance cost, cost for consumables, and commission for having the waste disposed.

The mass per lot in drug substance manufacturing differs from the mass per lot in formulating and packaging. When combining different sets of data to prepare the basic data for MFCA, the material quantity and cost data pertaining to formulating, packaging, and utilities were adjusted to match the mass per lot in drug substance manufacturing.

2.3. Creating flow charts with data

In MFCA, it is basic to trace the flow and stock of materials within a company starting from the input materials that were brought to the company. Even though this approach is characteristic of MFCA, its validity is questionable when the production process involves chemical reactions; the question is whether it is appropriate or not to always evaluate quality product and material loss in terms of input materials. One of the aims of our project was to address this open question about the MFCA technique.

If the production process involves the emission of carbon dioxide (CO_2), for example, the application of MFCA theoretically requires the evaluation of the carbon dioxide in terms of the input materials that contained its components, carbon (C) and oxygen (O). In cases where a chemical reaction produces output materials that are entirely different in physical properties from the input materials, the calculation of material cost for quality product and material loss becomes problematical. We addressed this problem in our project and found a way toward its solution.

MFCA can make available a wide range of information that was not available before, among which is the information about the generation of carbon dioxide. With MFCA, it is possible to identify the locations at which the carbon dioxide is generated, measure the amounts of carbon dioxide generated at these locations, and determine the costs thereof. Such environmental information is valuable for a company in determining its strategy for overall and local reduction of carbon dioxide emission.

Figure 1: Material cost flow chart

In the flow chart, the drug substance manufacturing process is broken down into the processes of synthesis, post-processing, and purification, for each of which we defined a quantity center. Even though it may seem in the flow chart as if each of these processes had its own retrieval process, there exists in reality only one integrated retrieval facility for the entire drug substance manufacturing process.

Figure 2: System cost flow chart

The system cost includes the facility's depreciation cost, repair/maintenance cost, cost for consumables, and labor cost. We identified the system cost and distributed it by the material cost.

Figure 3: Utility and waste disposal cost flow chart

The utility cost includes the costs of electricity, steam, water, and the fuel for vehicles used for transportation inside the premises.

Figure 4: Flow cost matrix

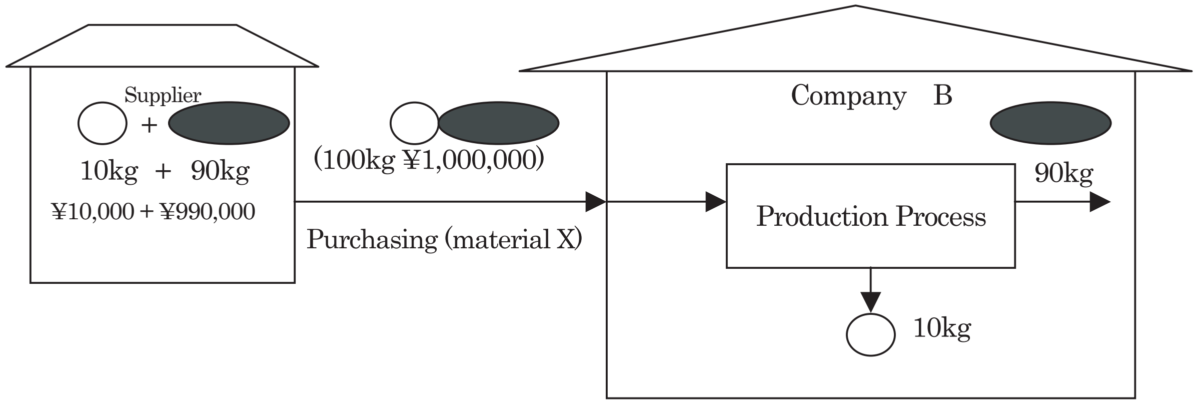
2.4. Evaluation of the implementation results

1) Calculation of material cost in cases that involve chemical reactions

In the given case, 100kg of material X purchased for 1,000,000 yen yields 90kg of quality product and 10kg of material loss. If we are to distribute the material cost of 1,000,000 yen by the mass ratio, the cost associated with the quality product and the cost associated with the material loss are 900,000 yen and 100,000 yen respectively.

However, in chemical industry, the purchasing cost of input materials is decided and negotiated with the supplier in consideration of their compositions. In the given case, for example, the material "○" serves only as the protector of the material "⬬" and its actual price is as low as 1,000yen per 1kg. In a case like this, it is inappropriate to distribute the material cost by the weight ratio. The cost associated with the material loss (the cost of the later-discarded material "○") should be corrected to 10,000 yen per 10kg.

We followed this principle in our trial project. Even through we traced all the discarded materials back to their sources; we determined their costs not by their weight but their estimated purchasing prices based on their composition.



This approach required information about production processes at suppliers. Thus, our project revealed the need for and potentiality of expanding the scope of MFCA to the entire supply chain.

2) MFCA information (unit: thousand yen)

	Material cost	System cost	Utility cost	Waste disposal cost	Sum
Product	8,866	2,196	115	—	11,177
Material loss	3,150	145	11	28	3,335
Material loss breakdown: Recycled	1,417	—	—	—	1,417
Material loss breakdown: Abandoned	1,734	—	—	—	1,734
Sum	12,017	2,341	126	28	14,511

Material loss rate:
26.2% (material loss cost per total material cost)
Abandoned material rate:
14.4% (abandoned material cost per total material cost)
Material loss cost rate per gross costs:
23.0%

The conventional method of material control at Shionogi has been to measure the actual yield and compare it with the standard yield in terms of quantity. This comparison is done for each end product in the drug substance manufacturing process, formulating process, and packaging process. MFCA allowed the company to understand the yield with cost broken down to processes. The company may use this process-based cost information to improve its processes.

3) Process-by-process measurement of carbon dioxide production and its significance

a. Effects of the Kyoto Protocol and the obligation of industry to reduce their carbon dioxide emission

In June, 2002, Japan ratified the Kyoto Protocol. Under the Kyoto Protocol, which will come into effect soon, Japan is obliged in the period between 2008 and 2012 to reduce its global warming gas emission by 6% from its 1990 figure. The Guideline of Measures to Prevent Global Warming defines Japan's step-by-step legislative approach toward achieving this reduction. The Guideline defines the period up to 2004 as Step 1, the period dedicated to the evaluation and review of various measures. Concrete measures will be enforced in the Step 2 period from 2005.

Following the effectuation of the Kyoto Protocol, especially from the outset of the Step 2 period, the reduction of carbon dioxide and other global warming gas emissions will be an important issue for corporate management. For a company to be able to make evaluations about concrete measures, it will have to produce a main inventory of carbon dioxide emission in different sectors of its activities. According to the GHG Protocol, which aims at standardizing the methods adopted by corporations for calculating and reporting their emissions, companies should make a distinction of emission sources of different categories. Sources and causes of direct emission, for example, should be divided into the following categories: production of electricity, heat, or steam; physical or chemical manufacturing processes; transportation of raw materials, products, wastes, or employees; and temporary emission sources.

For a company to be able to promote global warming countermeasures without losing their competitiveness through extraordinary expenditures, it has to be aware of the maximum amount expendable for various measures including the sales or purchase of a portion of the emission allowance. Each company must pursue economical efficiency when carrying out measures for reducing its emission of global warming gases. Comprehensive evaluation of various measures in terms of economy is a prerequisite for decision making.

b. Control and evaluation of carbon dioxide emission by material flow charts

Generally, a major proportion of carbon dioxide emission in corporate activities is associated with the use of energy. In the steel industry, cement industry, and some other industries, however, a large amount of carbon dioxide is generated from reactions taking place in production processes, which must be measured and reduced. Even in other industries, there are many physical and chemical processes that produce carbon dioxide.

It is certainly significant to consider the application of MFCA to such production processes in order to control carbon dioxide generated in each process. When applying MFCA to such processes involving chemical reactions, it is important that we analyze the input materials down to the molecular level. In the trial project, we traced the origins of the quality product and its material loss all the way back to the molecules of the input materials using source material identification numbers.

Combining cost data and quantity data with MFCA enabled cost-wise evaluation of carbon dioxide emission.

2.5. Issues for further exploration

In the trial project, we determined the amount of carbon dioxide generated by chemical reactions at different points (quantity centers) in the production process by using material flow charts and identified the origin of carbon dioxide at each of the points in terms of the input materials that included the carbon which reacted with oxygen to produce the carbon dioxide.

In the trial project, we calculated the material cost associated with the resulting carbon dioxide based on the purchasing cost of the input materials that contributed to its formation, even though MFCA generally demands the cost of input materials distributed to the cost of quality product and material loss be based on the mass ratio. If we were to follow this convention in MFCA, the cost calculation for the products of chemical reactions would have required the distribution of input material cost according to the molecular weight of their elements. We questioned the appropriateness of this method when the process involved a chemical reaction that totally changed the physical properties of the materials. If such common products as H_2O and CO_2 are formed in a chemical reaction involving an expensive input material, for example, the distribution of input material cost by molecular weight would attach them a cost much higher than their ordinary manufacturing cost or purchase cost. Another problem with this cost distribution method is that it can largely give different costs for the same substance if it is derived from different input materials or different purchasing prices. The usefulness of information resulting from this cost distribution method in corporate management, therefore, is questionable. Therefore, we deemed it more appropriate to choose a cost distribution method based not on the molecular weight, but on the manufacturing method and cost of the associated input materials.

In MFCA, carbon dioxide is definable as one of the output materials from a production process involving a chemical reaction. MFCA, therefore, allows a company to locate the sources of carbon dioxide and identity its quantity and costs. Such information is valuable because it can help the company make an intelligent decision about environmental management.

In the trial project, we paid attention to the carbon dioxide produced in the production process by reactions involving raw materials. Our project has successfully demonstrated the MFCA’s ability to supply information that helped the company make environmental management decisions. With regards the reduction of carbon dioxide emission. MFCA can help the company identify its location or sources, as well as its quantity and associated costs.

We believe that more detailed and more useful environmental management information can be made available in future by adding quantity data and cost data about carbon dioxide emissions from other categories: emissions caused by energy use, transportation, and so on. Even though every company is already making efforts to obtain data about its own emission of chemical substances to the air and water under the Pollutant Release and Transfer Register (PRTR) and other requirements, it is rare that a company has data on the cost associated with emissions in addition to data on the quantity of the emissions. We expect further applications of MFCA to include substances other than carbon dioxide and the use of resulting information for cost-efficient implementation of eduction measures.

Our experience in the trial project that applied MFCA to a production process involving chemical reactions has shown that correct financial evaluation of such a process should involve the evaluation of upstream and downstream processes, or even of the entire supply chain. The availability of information about upstream processes is particularly important because it enables the feedback of useful information to upstream suppliers. The implementation of MFCA to the entire supply chain will be an important step that should be taken in the near future for simultaneous pursuit of economic and environmental efficiency.

We expect the MFCA flow charts to be used in the near future as a valuable tool for gaining environmental management information and a reference for tasks such as the analysis of measured and theoretical values, comparison with and analysis of financial accounting data, and the examination of Kaizen plans.

Our trial project addressed the new challenge of using MFCA for obtaining data about carbon dioxide and other global warming gas emissions, the importance of which has rapidly increased in recent years. For a company that handles materials that produce such gases through a chemical reaction, a MFCA system can be help in locating the sources of emission and quantifying the amount of emission at different locations. Such data is useful for a company when it has to decide on global warming gas reduction measures or about the sales or purchase of a portion of the emission allowance. The supply of such data is one of the most important tasks in our ongoing research about MFCA, successful execution of which will contribute to the national project for global warming gas reduction.

Figure 1 Material cost flow chart (unit: thousand yen)

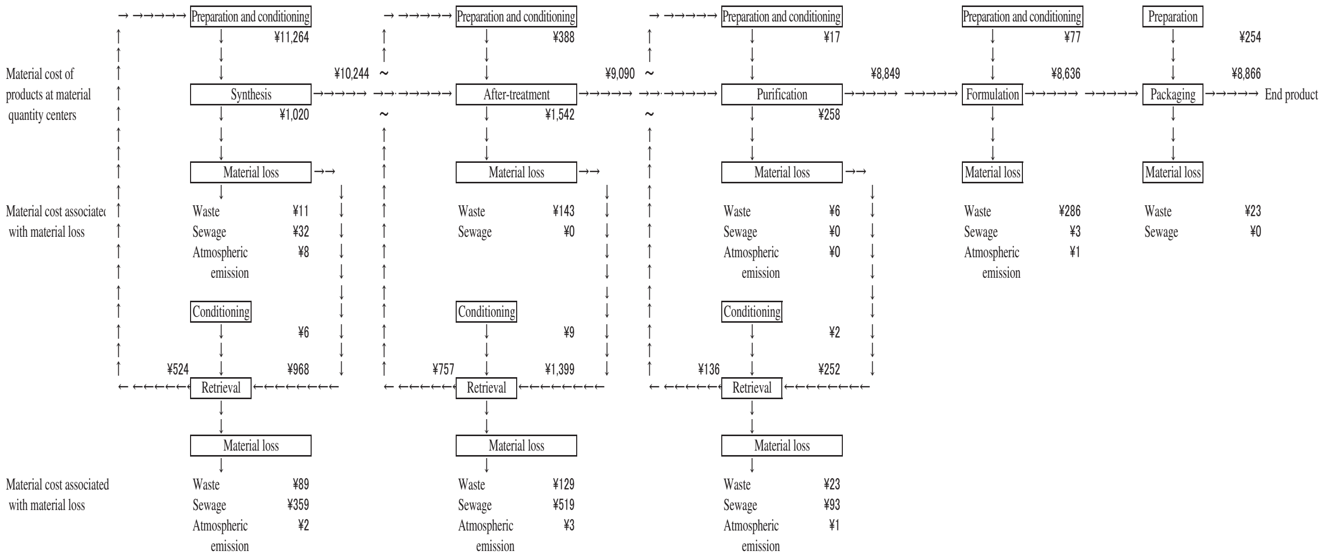


Figure 2 System cost flow chart (unit: thousand yen)

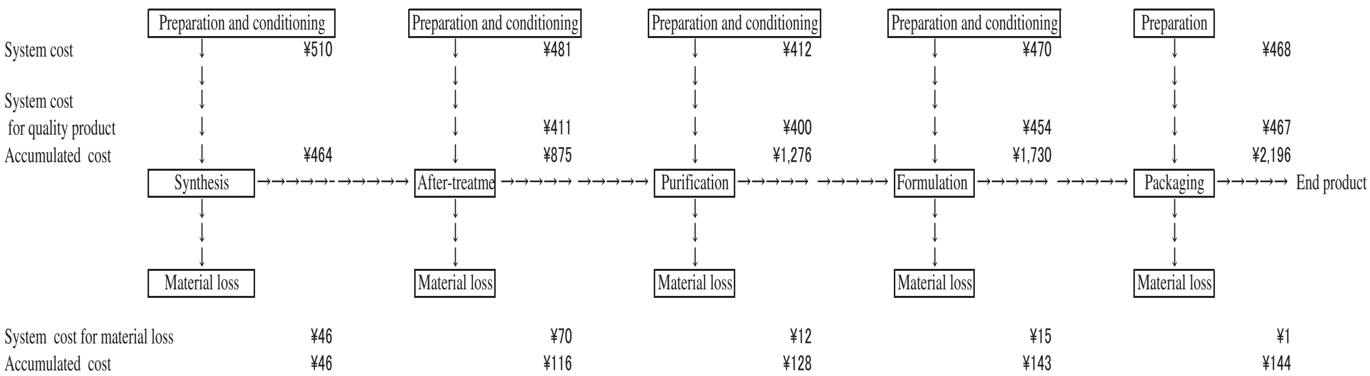
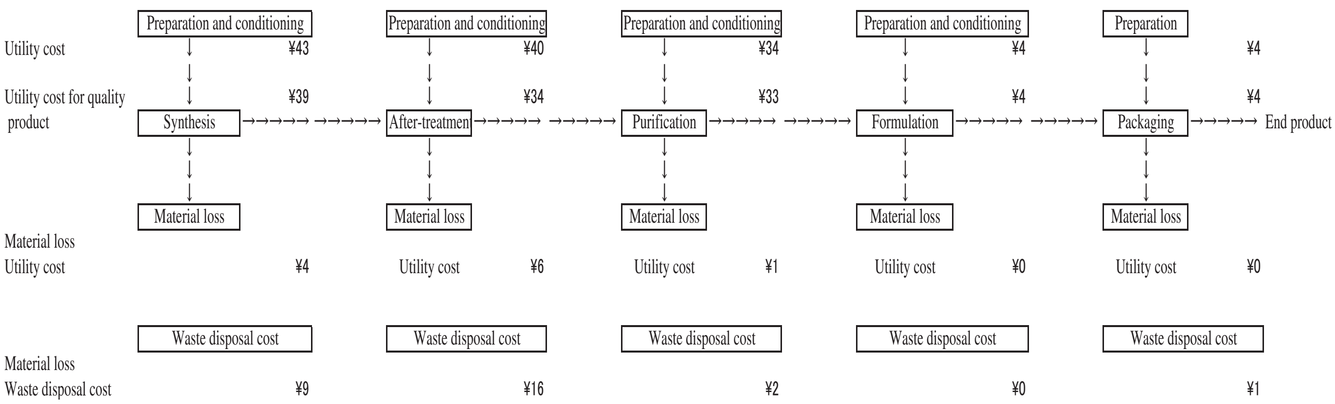


Figure 3 Utility and waste disposal cost flow chart (unit: thousand yen)



Case Studies of Material Flow Cost Accounting

Figure 4-1 Flow cost matrix (unit: thousand yen)

Synthesis → → After-treatment → → Purification → → Formulation → → Packaging → End product

	Synthesis	After-treatment	Purification	Formulation	Packaging
Input:					
Material cost	¥11,271	¥397	¥19	¥77	¥254
System cost	¥510	¥481	¥412	¥470	¥468
Utility cost	¥43	¥40	¥34	¥4	¥4
Subtotal	¥11,823	¥918	¥466	¥550	¥726
	¥0	¥0	¥0	¥0	¥0
Material loss:	¥0	¥0	¥0	¥0	¥0
Material cost	¥1,026	¥1,552	¥260	¥290	¥23
(recycled)	¥524	¥757	¥136	¥0	¥0
(abandoned)	¥503	¥795	¥124	¥290	¥23
System cost	¥46	¥70	¥12	¥15	¥1
Utility cost	¥4	¥6	¥1	¥0	¥0
Waste disposal cost	¥9	¥16	¥2	¥0	¥1
Subtotal	¥1,085	¥1,643	¥275	¥305	¥25

Figure 4-2 Flow cost matrix (unit: thousand yen)

	Material cost	System cost	Utility cost	Waste disposal cost	Sum
Quality product	8,866	2,196	115	–	11,177
Material loss	3,150	145	11	28	3,335
Material loss breakdown: recycled	1,417	–	–	–	1,417
Material loss breakdown: abandoned	1,734	–	–	–	1,734
Sum	12,017	2,341	126	28	14,511

Material loss rate: 26.2% (Material loss cost per total material cost)
Abandoned material loss rate: 14.4% (Abandoned material loss cost per total material cost)
Material loss rate per gross costs: 23.0% (Material loss cost rate per gross costs

	System cost	Utility cost	Waste disposal
Synthesis	510	43	9
After-treatment	481	40	16
Purification	412	34	2
Formulation	470	4	0
Packaging	468	4	1

	Input	Quality product	Abandoned waste and emission	Recycled
Synthesis	11,271	10,244	503	524
After-treatment	397	9,090	795	757
Purification	19	8,849	124	136
Formulation	77	8,636	290	0
Packaging	254	8,866	23	0