Kansai University Review of Business and Commerce
No. 10 (March 2008), pp. 57-86

The New Development of Material Flow Cost Accounting (MFCA): MFCA analysis in Power Company and Comparison between MFCA and TPM (Total Productive Maintenance)

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1. Development of Material Flow Cost Accounting

In April 2007, Japanese Government (Ministry of Economy, Trade and Industry) had decided to propose the guideline of MFCA, "Environmental management – Material Flow Cost Accounting-General principles and framework", as New Work Item Proposal (NWIP) to ISO/TC207 (ISO 14000 families), and then this was proposed formally on the 16th of November 2007[1].

Material Flow Cost Accounting (MFCA) was introduced to Japan in 2000, and approximately 8 years have passed as at fiscal 2007. During this period, nearly one hundred of Japanese companies introduced MFCA as an experiment, and actualized material losses (negative products) in manufacturing processes, and the usefulness of MFCA which provides management information enhancing resource productivity has started to be found in corporate practice[2]. In MFCA, (actually occurring) waste of materials hidden in the old standards is made newly "visualized" by manufacturing process such as by machine, and cost evaluation is carried out as negative products as well as good products (positive products), in application of the concept of mass balance. As a result, manufacturing costs are represented as a composition of positive products and these negative products, and the ratio of positive and negative product costs ratios are clearly shown in Figure 1.

Figure 1 is an example prepared on the basis of the previous experiences. Firstly, negative product costs are 26% in "Cost Structure of Positive and Negative Products" in the right half of the Figure 1. In the past, even where a usual product yield exceeds 95%, it is not rare

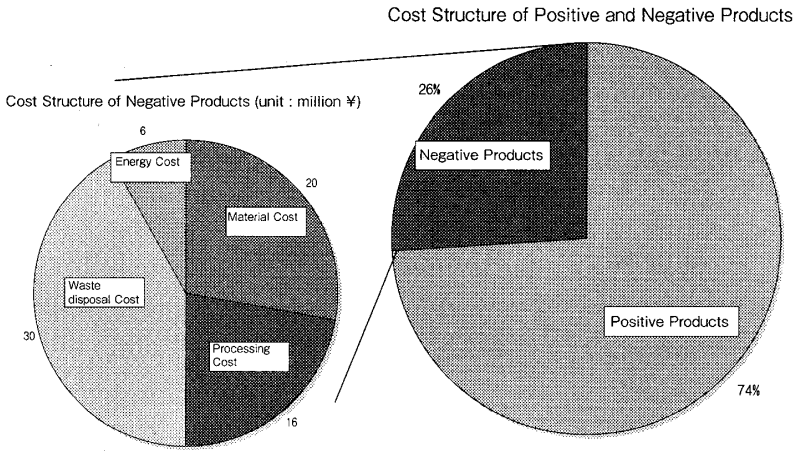

Figure 1 New Cost Structure clearly shown by MFCA

that negative products costs exceed 26% of the total product manufacturing costs as shown in Figure 1, and the ratio of this negative product cost is not particularly large[3]. In addition, it is possible to grasp the occurrence of these negative products by material cost, processing cost, waste disposal cost and energy cost with MFCA, as the structure of negative product costs can be clearly shown in the right half of Figure 1. In this example, a cost evaluation amount is shown by each item. In MFCA analysis, the quantity of materials of negative products which occur in the manufacturing process in such production process is understood, and the cost evaluation amount on the basis of that is shown by the place of occurrence systematically by Flow Cost Matrix of MFCA. Accordingly, measures to reduce negative products will be examined and executed, while estimating the effect against accurate costs, using material quantity information and cost information by place and material concerning negative products.

The most important point in the examination of this improvement measure is not reduction of cost amounts. Cost information is data to measure the priority order in management decision making or the effect against investment costs, and the direct target is material (loss) comprising negative products. For example, if materials (for material loss) comprising negative products can be reduced at the material quantity level, the processing cost which is the cost evaluation amount of these negative products can be reduced. In addition, because

waste (emission) is reduced, waste disposal cost will also be reduced. However, from the viewpoint of concrete expenditure costs, even where wastes are reduced on the same condition, processing costs apportioned to negative products will only be evaluated as processing costs of good products, and expenditure costs will not necessarily be reduced. Compared to this, in cases of waste disposal costs, expenditure costs themselves will be reduced.

Regarding energy costs, in the present MFCA it is usual to estimate an electric power usage quantity or a consumed electric power bill within the scope of its corresponding amount similarly to processing costs, and calculate pro rata for positive products and negative products on the basis of the weight proportion of material, for example. Energy cost comprising negative product cost in this case means that it is possible to evaluate that manufacturing is made using this amount of energy cost, and it does not indicate an amount corresponding to its material loss of the input energy quantity.

Nevertheless, energy such as electric power is deemed to be one of the materials in MFCA in the definition concerning materials of IMU (Institut für Management und Umwelt, Augsburg Germany) which developed MFCA[4]. Accordingly, energy is considered to be a physical element comprising products (positive and negative products) similarly to general materials. There have been several times to discuss about this matter with IMU. However, it appears that no theorization of energy flow and concrete analytical method have been established in such a case.

In particular, energy such as electric power will be input in that place (for example, a machine) and does not comprise part of a good product but will be completely consumed. Accordingly, if energy is classified into materials, all input energy will become so-called negative products in MFCA. On the other hand, if the part of the energy which drives a machine and processes a positive product comprises a positive product, the quantity of input electric power will be apportioned pro rata for a positive product and a negative product. At present, consumed electric power quantity is apportioned into a

positive product and a negative product in many cases, using the weight quantity proportion of materials from mass balance information of positive and negative products. However, in this method only the electric power quantity is apportioned to negative products, and the input quantity itself is not reduced by raising a positive product ratio, similarly as with processing costs and waste disposal costs explained above. Accordingly, it is necessary to clarify a loss of the input quantity itself in order to reduce the input quantity itself (per production unit) on the basis of the viewpoint of MFCA. On this point, the project team have measured an actual power ratio of manufacturing equipment and computed improvement room of electric power and an annual reducible amount (electricity bill) after improvement and carried out examination of an improvement measure on the basis of energy loss analysis and the effect against costs in an MFCA project at NIPPON PAINT CO., LTD. in the IGES Kansai Research Centre[5]. However, the examination ended on the phase of trial, because the technology to measure individual electric power consumption timely, and time and expenses required for its measurement and the effect seen (an economic aspect) as a result of the measurement were not yet relatively attractive for corporations.

However, such analysis of energy by understanding energy as a material has started to draw attention as a new subject of consideration of the environment such as emission of CO_2 and reduction of expenditure cost. It has started to be considered important as a subject of management, apart from the relationship with the level of energy cost to manufacturing cost. In this way, in line with the increase in the degree of management, subjects which had been managed as part of the general matters and only by a rough estimate have become required to be understood by quantity of occurrence and place, and further by cause. MFCA based on mass balance will exhibit usefulness as a database, a system of physical (mass) information, which will become required as a new subject.

The author have examined the possibility of MFCA analysis in the electric power business to construct the basis of MFCA analysis particularly in electric power as a basic research for MFCA analysis

concerning energy in manufacturing industry. As mentioned earlier, the need for the reduction of CO_2 emissions has made reduction of energy consumption an important corporate issue. However, for example, where electricity is generated from fossil fuels, it is difficult to store electric power with present technology. It is therefore more effective to use it as generated power, once it is generated. In addition, for example, CO_2 is not emitted at a place where electric power is consumed, but CO_2 is emitted at the time of electric generation at a power station of a power company. How to effectively utilize generated electricity with specified CO_2 being emitted is therefore an issue of manufacturing industry. From a social viewpoint, the author therefore carried out MFCA analysis of electric power generation in electric power business and energy flow (including energy conversion from energy resource to electric power) in sending and distributing electric power.

In addition, improved points of resource productivity are basically discovered by applying MFCA, but the difference from the previous management concerning production management is questioned especially in practice in many cases. Concerning the difference from the yield of products, if 100 kg of material is input for a product and a product is completed, the (product) yield is 100%, and even if the material contained in the product weighs 80 kg, 20 kg of material loss will not be actualized in a usual yield management[6]. However, for example, the present state or improvement points concerning a material yield which are discovered with MFCA in study meetings, etc. for the introduction of MFCA to the actual spot in corporations are already the subject of measurement management in TPM (Total Productive Maintenance), and company staff's reaction is why it is discussed now or there is a question of what is the difference between TPM and MFCA. In addition, they pay attention to what is going on in corporations which have succeeded by MFCA and why. This point is examined in Section 3.

2. Energy analysis in Material Flow Cost Accounting

Analysis concerning energy is one of the important research issues

in the future development of Material Cost Flow Accounting (MFCA), and CO_2 exhaust reduction is expected to be increasingly important, and analysis and reduction of energy consumption is considered to become the most important issue in environmental management as well. In this Section, reduction of energy consumption, which is a basic research of MFCA analysis of electric power manufacturing process of electric power business, can be located as a basic research into the reduction at an in-process, which is manufacturing, and not the reduction in the place, where it is consumed, as an end-of-pipe. However, a clear point is that the plant itself is huge and the quantity of the data and its kinds are diverse. In addition, data is not sorted out for MFCA analysis. The present phase is a basic research where data is understood and input and output are confirmed in MFCA.

Efforts have been made to enhance the electric power generation efficiency rate such as development of and investment in new facilities in the past. Whether or not it is possible to discover environmental management accounting information in the electric power business from processing information such as material flow and energy flow is currently under examination. It is expected that when this research is advanced, environmentally friendly energy in a true sense will be discovered and a life cycle to purchase and use material, which is environmentally friendly power, will be realized.

2-1. Energy analysis in Material Flow Cost Accounting and its background

As explained above, energy, for example, electric power is supplied to a machine and consumed as soon as the machine becomes in operation if the electric source is on. It does not flow after it is supplied. Therefore, people have attempted to understand a consumed electric power quantity at an input place (for example, at a machine and facility). However, it is not usual to measure the power consumption quantity per machine, but it is only possible to measure per power meter set up at a house or a floor, if any, on a monthly basis. There are usually no records per hour or per machine at all. Accordingly, in introduction cases of MFCA, a method to estimate figures from monthly data and existing data is usually adopted.

Nevertheless, reduction in the emissions of global warming gases such as CO_2 has started to be given priority as a management issue in recent years. In addition, interest has been extended to energy saving in a manufacturing process and some companies have started to carry out detailed measurement of consumed electric power in their manufacturing processes. The project team carried out sample measurement in the process which was the subject of research in the MFCA research project at NIPPON PAINT CO. LTD. by making consumed electric power at machines and facilities the time axle (also by applying to the state of operation). Analysis of the electric power ratio, etc. in this experience clarified that the part corresponding to the electric power consumed for the function of a machine itself out of the input electric power was smaller than estimated. For example, in cases of an old machine, depreciation has completed, and people think that production is carried out with a machine with nil cost. However, it was clarified that there are some cases where replacing a new facility is cost effective, when the cases are reanalyzed from the viewpoint of electric power consumption.

In this way, where examination of an analysis model is carried out in accordance with the definition that electric power is a material while further carrying out the research concerning electric power consumption in the manufacturing industry, there must be a concept of "Green Electric Power" in the sense that the electric power is generated at a lower environmental load, as green procurement of raw materials. In addition, it is true that power is input and consumed in the manufacturing process, and does not flow after that, but there is a flow of energy from the energy resource through its generation, transmission, distribution to consumption as a product as an industrial product. Because of my awareness of this issue, the author decided to carry out this research, considering that it might be possible to provide useful environmental management accounting information by analyzing with MFCA, by deeming that the electric power business is a process of manufacturing a product, which is electric power.

2-2 Possibility of Material flow Cost Accounting in Electric Power Business

Electric power enterprises are private companies, but they have a strong public interest ethos. Their most important mission is therefore the safe and stable provision of electric power. They had carried out their business not under free competition but as a monopolistic enterprise in a region before the liberalization of electric power, which started in the year 2000. In such a background, there is no concept that they understand the manufacturing process to actualize and reduce costs as manufacturing business of industrial products with the purpose of the so-called profit orientation, but they are understood and managed as plant facilities and their operation and systems. However, needless to say, they have systematic management information as an electric power business, as they have a mission that they pursue energy efficiency and economy.

Nevertheless, the author intend to understand this as a manufacturing process of an industrial product and, in addition, the author intend to carry out MFCA analysis. For example, information concerning the state of operation of each facility is recorded rigidly and in detail. However, in the manufacturing process of an industrial product, it appears that naturally the information system is not designed to totalize or understand manufacturing information of the product (electric power) by the so-called process in MFCA and information systems to be used for production management[7]. In addition, regarding costs, they do not calculate cost information by process to utilize their results as management information in particular. This is because of the characteristics of the line of the electric power business, and not a defect of necessary information for their operation.

Accordingly, firstly, it is necessary to understand input and output of material by dividing the manufacturing process of electric power into several manufacturing processes from the starting point of input of energy resources to the exit from an electric power station (the so-called sending end), and for example setting up their manufacturing processes as a material quantity centre of MFCA. Concretely, this means to extract data that can be used for MFCA from the data group

which is operated and managed.

Figure 2 shows the main changes of material in the electric power manufacturing process. In MFCA, mass balance is applied to each process. For example, coals are put into a boiler, which is combustion equipment, as in Figure 2 and vapor of a high temperature and high pressure is generated. The input is therefore coals, which are the same material that has been used, but the output is heat caused by combustion, and more specifically it is water vapor. In addition, this water vapor is a positive product. This water vapor, which is a positive product, does not contain any part of the coals as its composition element. It is therefore necessary to prepare mass balance information different from that in the past.

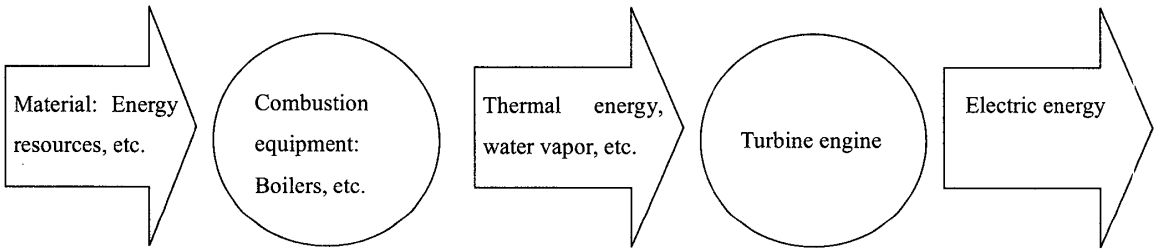

Figure 2 Transformation of flow material in electric power business

Next, Figure 3 shows mass balance and energy balance (proposal) in the electric power business. Figure 3 is incomplete, but it is a table showing the figures measured both by mass balance and energy balance of input and output in the combustion by a boiler.

In mass balance, CO_2, other exhaust airs (sulfuric oxides: SOx, nitrogen oxides: NOx, water, etc.) and ashes will be the output[8]. A positive product is thermal energy, and let us consider that thermal energy is bonded with water as water vapor.

Accordingly, firstly, the author will analyze on the basis of mass balance with MFCA. Where coals are perfectly combusted, coal (C) and hydrogen (H) will not remain as they are, but will be emitted as CO_2 and water. In this case, the part left as remains from a ton of carbon and hydrogen is considered to be material loss. 20 tons of

Input	Mass balance	Output
Coal	Combustion: CO_2 and water	
Breakdown: carbon (C) and hydrogen (H) 80t	Breakdown: carbon and hydrogen	79t
non-combustible component (water, etc.) 20t	Residual exhaust: ash and exhaust air	
	Breakdown: carbon and hydrogen	1t
	Impurities	20t
Pure water 1,000t	Pure water and water vapor	1,000t

Input	Energy balance	Output
Energy quantity of 100 tons of coals 100%	Change to pure water (water vapor)	85%
	Exhaust heat from an external wall and a chimney of a boiler	15%

Figure 3 Mass balance and energy balance of electric power business

impurities included in ashes or emitted from coals as exhaust gases are also material loss.

Next, let us look at energy balance, and calculate the thermal quantity of such coals, and let it be 100(%). Then, it is possible to calculate an estimated amount of heat of water vapor on the basis of the produced quantity of water vapor, which is an output in the boiler process, and the temperature. For example, if exhausted heat from an external wall and a chimney of a boiler is let to be 15%, this 15% will be energy loss.

In this way, it is necessary to analyze the part of a boiler which is a combustion engine both in mass balance and energy balance. In addition, it is considered to be possible to actualize a material loss by condition and simultaneously it is also possible to actualize a structural loss in such a process as well, by measuring a material loss by lot, assuming that one generation is one lot and not as a theoretical value or rough estimate.

2-3. Examination of the possibility of an analysis of a thermal power station with Material Flow Cost Accounting

In a consultation survey with power businesses this time, the author decided to study as to whether or not it is possible to introduce MFCA analysis in an electric power business which has actual experience in industrial products in the past and, in addition, as to what sort of usefulness can be discovered, where an analysis is carried out.

According to a literature[9], it is pointed out that the technology of controlling turbines and generators was nearly completed in thermal power generation, but there are many research issues in boiler control, and mainly control of the temperature of vapor from a boiler to a turbine is an unresolved issue. If control is completed in cases of turbines and generators as stated in this literature, the performance of a machine itself will decide the efficiency. Because the facility is always replaced by a state-of-the-art one when it is up-dated, it is considered to be difficult to find any material loss which actually enables technological improvement. However, it is considered necessary to carry out a survey on the actual state of operation and examine whether or not the maximization of the efficiency is always achieved by its method of operation.

The occurrence of waste by the control of the temperature of vapor from a boiler to a turbine is estimated. On this point, the author therefore considered it necessary to examine whether or not a loss is actualized, depending on whether or not data per control or per power generation unit (by power generation order) is available.

As a result, the author carried out a survey on the possibility of MFCA analysis, making a thermal power station (coal) as the subject of research. Concerning details of the survey, the author carried out a survey on a power generation process and material flow from an energy resource to a sending end to understand the process, and simultaneously, the author carried out a consultation survey on the location and details of data with respect to input and output within the process.

As a result of an examination based on data, the author had a general view of a series of processes of usual thermal power generation shown in Figure 4. The Figure shows approximate figures. The 100% of energy quantity which existed in coals input for thermal power generation is processed (conversion) into electric power energy at a yield of 39%, and is further reduced to 37% after a loss of 2% in distribution.

Furthermore, it is necessary to analyze how usefully the value of the product, which is the power at a yield of 37%, is realized by a consumer (such as a factory and a family home). On this point, future examination is required through the supply chain to consumers.

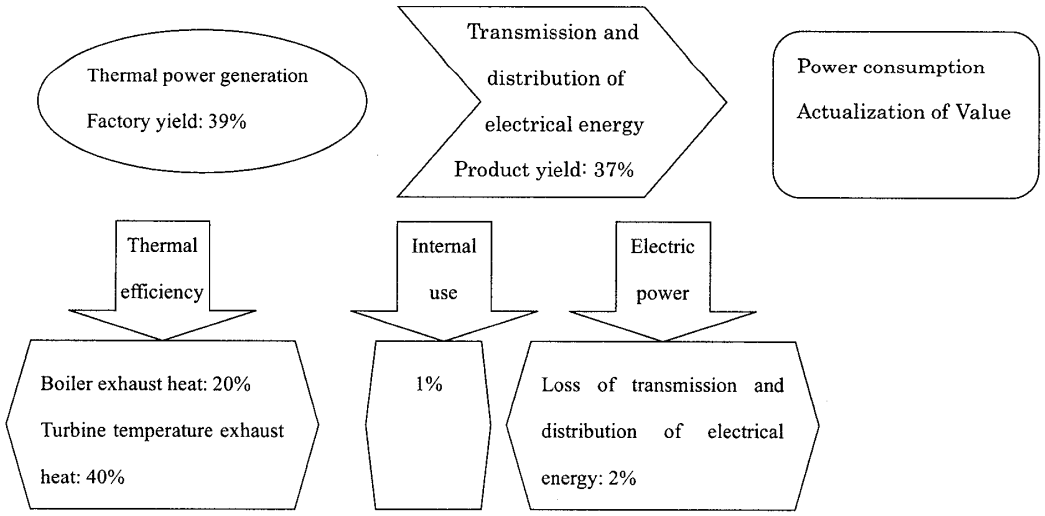

Figure 4 General view of material loss in electric power manufacturing process

In addition, to understand such a material loss in the actual quantity of the material in the thermal power generation process, it is necessary to prepare mass balance information for each process. A graphic screen to monitor an information system at a power station shows the existing data, which are data in an operation daily log (operating time, generating power quantities, transmitted power quantities, fuel consumption quantities and fuel calorific value) and general daily log (waste quantities, water and drainage quantities). In addition, as a Figure of a manufacturing process, an energy flow chart is shown by

graphic information for monitoring. It is also possible to analyze the efficiency relation by the operation daily log, etc. It is possible to separate out the best practice and improvement subject in the efficiency relation data using this operation daily log. Furthermore, it is considered to be possible to sort out manufacturing information by lot with reference to the graphic screen information for monitoring.

It is possible to carry out benchmarking by supporting decision-making on the distribution of management resources for technological research and development and facility investment from the viewpoint of the merger of technological knowledge and management, and simultaneously, by separating out the best practice from the viewpoint of environmental management accounting where not only the economy but also the reduction of environmental load are integrated by carrying out a survey on the actual situation where each power station is considered to be a factory, and not merely citing general theories.

In this way, this is still basic research into the introduction of MFCA. However, the author consider it possible to succeed in presenting a case, using environmental management accounting information which enhances both the economy and the environment which are seen in general manufacturing business in line with the steady and sure evolution of research in the future.

2-4. Conclusion

This study is only on the phase of basic research to find out whether it is possible to introduce MFCA. In some cases a new finding is made by carrying out follow-up surveys on a flow of a product by making the material of input and output as the key, like general introduction cases of MFCA. In addition, the author carry out the examination also from the viewpoint of the actualization of the process from the viewpoint of the environmental load, for example, emission of CO_2 and its reduction, to find out whether or not it is possible to find environmental management accounting information which has not been utilized as management information in a power business.

For example, development of power generation facilities is a joint

development with a heavy electric machinery maker. A turbine engine, called "Factor T" made by TOSHIBA CORP., is mentioned as an example of the environmental efficiency index[10]. In this example, a turbine engine launched in June 2006 achieved 1.88 against a turbine engine launched in 2000[11]. Miniaturization and higher efficiency were achieved. For example, the amount of emission of CO_2 was reduced by approximately 240 tons at the time of manufacturing, and by 1,700 tons at the time of usage respectively. In this survey the author have considered that there are actually usage conditions at the time of usage that are not reflected at the time of designing the engine such as change in the order of priority for usage which reflects the efficiency which does not necessarily agree to the initial usage plan or the efficiency of the combination of other engine or that of old and new facilities, because of a number of restrictive conditions. The author consider that it is possible to find out a possibility of further improvement by the efforts of the maker and the further cooperation with the power enterprise, which is the user. The author also consider that business process analysis with MFCA will be effective in the systematization of losses, which is the basis of its improvement.

In this basic research of MFCA in a power business, it is clear from Figure 4 that the enhancement of the product yield, which is 37%, is a major issue from the viewpoint of waste of energy. In particular, the total loss of the boiler exhaust heat and turbine temperature exhaust heat is approximately 60%, and the question is how to reduce this energy loss. Power companies are naturally making efforts to reduce energy loss, but it is a fact that there is a technological limitation. For example, it is considered that the most important social priority issue is not reduction of energy loss at family homes but that at the time of power generation. Furthermore, needless to say, how to use electric power energy which can be obtained only after making a loss of this size is the most important issue.

3. Significance of Material Flow Cost Accounting for existing production management

Material Flow Cost Accounting (MFCA) enables a loss hidden in

the cost or the standard in the past to be exposed by measuring and understanding it by mass balance and clarifying it at a material quantity level. Then, cost evaluation will be carried out with the clarified loss (material quantity) as a negative product, and it will be processed as information useful for decision making in management. An improvement measure to eliminate this waste will be examined and executed on the basis of this processed MFCA information.

By the way, when the author give such explanation on the spot, some company staff says that to find out this waste and eliminate it has been done in the past and is still being done, as if they were wringing water out of a dry towel, and it is impossible to do more. For example, company staff often says to the author, "We have introduced TPM (Total Productive Maintenance), but what is the difference between TPM and MFCA? Is it possible to use TPM and MFCA together?" In the background of this question, there is a critical or doubtful evaluation of MFCA as in what is new in MFCA compared to the existing production management. In this Section, the author would like to discuss the relationship with TPM.

For example, Figure 5 is a table showing TQM with TPM for comparison to which the characteristics of MFCA are added to each item under classification.

Firstly, it is understood that the purpose of TQM is the same as that of TPM. The purpose of MFCA is the same, but it is considered that MFCA has an element of extension of the scope from a local or an individual enterprise to a number of divisions or the relationship between more than two enterprises.

In addition, the different aspect is that the subject of management is (product) quality in the case of TQM compared to facilities in the case of TPM, but that of MFCA is material (material resources).

The means of the achievement of the purpose are explained to be the realization of "making the workplace clean, and facilities of "nil disaster", "nil fault", "nil breakdown"[12], while the means of MFCA is the

minimization of material in the realization of value.

In training company staff, TPM makes company staff good at facilities with an emphasis on facility technology and conservation skills, while MFCA carries out human development for the purpose of the realization of maximum resource productivity by understanding the whole of the product flow or business flow systematically.

Accordingly, unlike TQM and TPM, the centre of which is small group activities, MFCA tends to be developed to be applied to the

Classification	TQM	TPM	MFCA
Purpose	Improvement of characters of Corporations (Enhancement of business performance and making a cheerful office)		+ Realization of environmentally friendly 'product development' industry
Subject of management	Quality (On the side of output and the results)	Facilities (On the side of input and the cause)	Material (Process, cause and results)
Means to achieve the purpose	Systematization of management (systematization and standardization) Inclination towards software	Making the actual spot and the actual thing what they should be Inclination towards hardware	Visualization of mass balance Inclination towards information
Human development	Centering on management technique (QC technique)	Centering on specific technologies (Facility technologies and conservation technologies)	Centering on product development (Thought, erasure of preconceived ideas)
Small group activities	Voluntary circle activities	Unification of job duty activities and small group activities	Integration of the process from the start to the end of product manufacture
Aim	Quality of PPM order	Downright elimination of loss and waste Direction towards zero	Maximization of resource productivity Direction towards ultimate zero

Figure 5 Comparison of characteristics between existing production management techniques and those of MFCA[13]

whole of the factory and the whole of the company, and further to business flow (industrial flow) including downstream and upstream.

Lastly, it is explained that the target of TQM is to minimize the faulty rate per 1 million units, and that of TPM is to make a loss or waste zero. On this point, it is considered that MFCA is that same as in that its target is to make the waste of material ultimate zero.

This paper will consider the theoretical common elements and difference between TPM and MFCA in the next Section onwards.

3-1. Theoretical common elements of TPM and MFCA

TPM is interpreted, defined and executed on an individual basis at each enterprise and each factory, apart from the basic definition, which will be explained below. The reason why the form of TPM varies depending on users is that such a form derives from the type of business and the type of product, and TPM activities are also prescribed at present in accordance with the items of the issues and the targets of each enterprise and factory. Accordingly, the actual TPM is carried out in a number of different forms, and the definition and purpose which are its basis are theoretically formulized and explained. Firstly, we will have a look at its common elements with MFCA by theoretically analyzing TPM.

According to the Japan Industrial Management Association (2002, 290p. to 291p.), the purpose of TPM is "to promote the modernization of facility management and development of facility management techniques", and defines TPM to the whole company in the following 5 items:

1) Construction of the characters of a corporation to aim for ultimate pursuit of production system efficiency.
2) Prevention of losses from occurring such as nil disaster, nil fault and nil breakdown for the lifecycle of a production system
3) Participation in all divisions such as development, production, sales and management
4) Participation of all from top to the employees standing in the front line

5) Production conservation activities to achieve zero loss by duplicating small group activities.

The following five items are listed below as basic principles on the basis of the above definitions:

1) Making profitable characters of an enterprise: utilization of conservation prevention, prevention conservation and improvement conservation
2) Prevention philosophy: planning participation management and human respect
3) Participation of all members of a committee: Emphasis on management where facilities themselves are made out so that a loss may not occur, with emphasizing the actual spot.
4) Principle of the actual spot and actual thing: making zero loss
5) Automation and making factories without workers

Compared to the above, MFCA is explained by citing the following 5 points as the characteristics and the effect of the Japanese version[14] of MFCA at the time of the introduction of MFCA.

1) Application Quotation of mass balance (mass balance table) to a process with a factory
2) Material loss analysis of a manufacturing line per manufacturing group
3) Visualization of material flow
4) Cost evaluation of material cost (manufacturing cost)
5) On-the-spot improvement, and improvement of manufacturing method and evolution towards production reform

MFCA is a tool where mass balance (mass balance table) and cost calculation (measurement of economy) are integrated and resource productivity and economy are merged. In addition, MFCA functions as a health diagnosis tool of an enterprise (CT scan: photographing of computer faults), and a corporation will know its actual figure at each manufacturing process which the corporation itself did not know (accurately) with "surprise (the number of waste cases and their sizes)". As a result, MFCA will function as a management information tool which will induce improvement and management reform on the

actual spot, and works as an invigorator and an activator, but does not work as a treatment drug as waste will not become zero by introducing MFCA.

TPM on the basis of facility management and MFCA on the basis of material flow both have a relatively wide scope of management and are naturally defined as social activities. In addition, both have a purpose of achieving zero loss. The subjects of their management and measurement are different, as one is facilities and the other is material (flow and stock), but their purposes are both zero loss.

If you look at losses in TPM, there are the seven major losses in facilities, which are 1) breakdown, 2) programme, and adjustment, 3) edged tools, 4) cutting up, 5) short time breakdown 6) slowdown in speed, and 7) faults and readjustment. The purpose of TPM is how to reduce these seven major losses. However, the efficiency of the primary unit is also explained as an issue[14], and the difference (material quantity loss) between raw materials weight and product weight is defined as a yield loss as in MFCA. In addition, it is also explained that losses include all kinds of losses such as a mould which includes energy loss and subsidiary materials, and loss while repairing tools.

The difference between TPM and MFCA will be explained in the next Section. However, there is no difference between them in a theoretical definition in that material such as raw materials and energy are included in the subjects of losses, and it may be misunderstood that the only difference of MFCA is its name.

Nevertheless, the most important issue of TPM is structural analysis and reduction of facility loss, and the loss in the primary unit mentioned above is not for material flow analysis but for checking an improvement ratio of input material weight per unit of product. Concerning a loss of a mould or that of repair tools including for subsidiary materials, it is explained to measure the improvement ratio of the input value in money[16]. From the above, it may be understood superficially that material loss is measured and managed by setting

up a scope in a general sense of reducing all kinds of wastes in TPM. However, the centre point and a focus point are considered to be completely different.

3-2. Difference between TPM and MFCA: Through the practical observation

Regarding the difference between TPM and MFCA, and in particular not as the scope of the subject of management, but as defining the target in carrying out each, clearly the difference is that the answer in the case of TPM is facilities and that in the case of MFCA is material (flow and stock).

Because of this difference, it can be said that there is an essential difference between material quantity loss in TPM as defined in the wording in a text and material loss in MFCA. By the introduction of MFCA, positive and negative flows of material have been clarified, and as a result, it is possible to compute the difference between input weight and product weight as in cases of the quantity material loss called in TPM. However, MFCA is a technique to see input and output of material by input material of all input materials, which comprise not only raw materials but also subsidiary materials, and it is not a technique to see the deviation from the standard value or design value.

In MFCA, waste (emission) is taken as a negative product, and its process (occurrence) is clarified, and its emission from a factory, et al. is taken as shipping of a product in a sense, and its information is systematized as management information. Accordingly, a product is always recognized, as a system where two types of products, a negative product and a positive product, are produced. This clearly represents a view of a production process essentially different from the conventional view of a production process. In this way, MFCA is a production management information system on the basis of a new view of a production process. It is therefore possible to understand that it is the same as TPM if such information is added to the conventional production management information. However, such a way of understanding does not mean more than that data exists as

points.

When MFCA is actually introduced, in most of the cases 90-95% of the information necessary for MFCA already exists including the actual spot readings. However, that does not mean that MFCA exists in the existing production management system. In MFCA it is a fact that in some cases in the past precious information was only recorded and was left as it was or was erased after confirming that it was recorded. In other words, systematized information did exist in MFCA, but the theory or structure (MFCA) which systematizes it was lacking.

Then, the question is why unnecessary data was measured. The answer on this point is that such data is necessary at the time of designing a plant or for the purpose of quality guarantee, and that it therefore exists for confirmation, and is not used for production management (production flow) as main data. In most cases, information other than information necessary for such a section or person in charge is not jointly used at all. In general, the information relating to production yield management is usual production management information, and the difference between the standard data and the actual data is managed at a product or a finished product level. Furthermore, the relationship between the number of finished products and the time limit of delivery is considered to be the most important, and in some cases an actual value is automatically prepared with intermediate stock as a buffer to always achieve a superficially high produce yield.

TPM does not have a structure to actualize such a present state, and it can be constructed by clarifying the flow and stock of material by MFCA and carrying out cost evaluation.

In addition, in TPM defective goods, inferior goods, etc. are considered to be a major loss (one of the seven major losses) in production. Behind this, It is considered that there is an assumption that a product weighing 100 will be produced against an input of material weighing 100, or an assumption that the design value is clear

as a system of responsibility of a hierarchical business administration but that it is irrelevant to whether the business model itself is right or wrong. In a little more detail, it is not information which produces innovation of a product or a production method. It can be said that TPM is information suitable for an enterprise but MFCA is a borderless expanded system of business information (economic information) originating from the inside of MFCA.

The author would like to refer to the communication function of MFCA within the whole of the enterprise as a separate aspect. Data totalized by MFCA is collected or measured systematically on the basis of product flow. Accordingly, cross-sectional information is required. It has been said that there is a cross-sectional organization or close communication as a basis of a Japanese style manufacturing method. However, the actual situation is that they are separated from each other on the basis of the system of responsibility, and in particular responsibility by job system is clear, but data is considered to be rarely jointly used for a flow throughout the manufacture of a product. Execution and responsibility in TPM are on the basis of small group activities. However, there is no view which covers the whole stage as is seen in MFCA. Accordingly, what is required before and after a

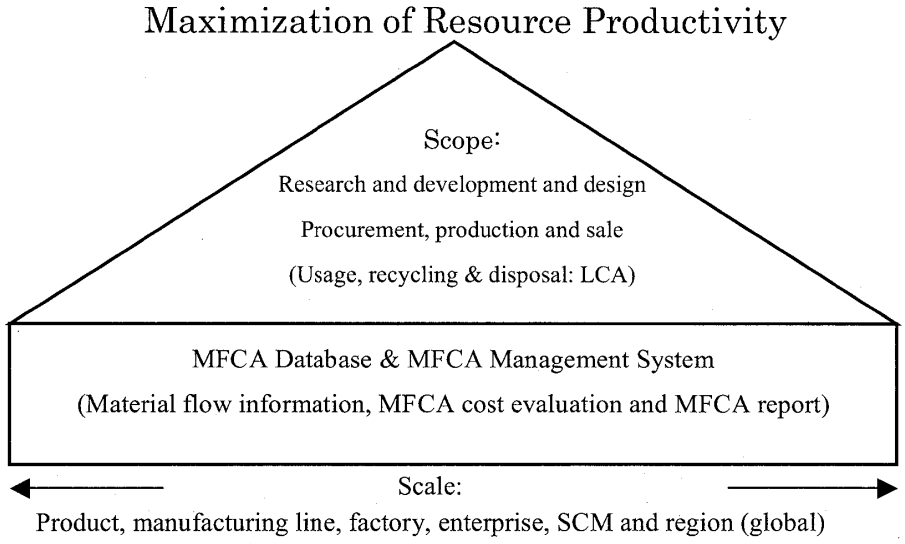

Figure 6 Expansion of Scale & Scope in MFCA

process becomes impossible to manage, and local maximization and efficiency will therefore be targeted using the assumption of it.

Compared to this, as shown in Figure 6, it is possible to expand the scope of MFCA within an enterprise from research and development to usage and disposal, and there is such a strong tendency. There is no restriction in the scale of information to a product or individual enterprise. Furthermore, the unit of measurement of MFCA is not a monetary value including private profit but the quantity of material. It is therefore possible to develop it to a supply chain or an area. It is possible to realize the enhancement of resource productivity on a global scale concretely and effectively through corporate activities by expanding in this way.

Material quantity and costs used in MFCA are the common language for corporate management. This has expanded a field of vision of each system, and made issues common to both by opening issues rather than hiding them, thus leading towards a resolution.

Lastly, TPM has a strong aspect of on-the-spot management, but MFCA is a database. For example, it is possible for the person responsible for management to provide data (visualization) to understand the present state accurately. In TPM, job duty activities and small group activities in production activities are unified, but they are all improvement activities for each actual spot. On the other hand, the cost matrix produced by MFCA is not a product processed by others' evaluation with respect to how manufacturing is carried out as a whole, but it is possible to understand and evaluate the state of production on the basis of objective data, which is material quantity. It is possible to activate an actual spot by the president's visit to the actual spot and it is possible for the president to understand the present state by so doing. However, it is difficult to understand and evaluate constantly. In addition, to obtain cost information is time consuming. MFCA information which presents the present state is relatively quickly available. It is also clear as positive and negative product information. Cooperation with information technologies and systems will be necessary in the future. However, this does not appear

to be difficult to achieve.

3-3. Summary

This paper explained TPM and MFCA by focusing on the difference between them, but it is not my intention to discuss which is the superior system. It is considered that in reality it is useful to utilize both TPM and MFCA as systems supplemental to each other. For example, Canon uses MFCA in a positive manner as a management tool for cross sectional management which is impossible by the conventional TPM, etc. by linking job site type environmental guarantee activities and MFCA. As a result, Canon succeeded in achieving a waste reduction of 40% compared to last year at one of its offices[17]. Such waste disposal cost appears to have been reduced by several million yen per annum. Canon introduced MFCA as a tool for job site type environmental guarantee activities, and enhanced resource productivity dramatically at an actual spot directly connected with manufacturing, and not the reduction of "paper, rubbish and electricity". This means there was a discovery of a wasteful process in manufacturing which had not been found by the conventional production management technique.

This is another matter, but people sometimes notice that their improvement target (priority order) which used to be decided on the basis of a standard such as a product yield was wrong, and change their order of improvement. The rank of an improvement item which used to be in a lower rank will be raised, but this also means that the order was corrected by having found a hidden cost.

In this way, in some cases a loss which was not discovered by existing production management is newly discovered by MFCA or it is discovered that there was a hidden loss in a loss which had already been discovered. It is true that all is covered when expressed in words, but the way of thinking that material loss in MFCA covers all may be the same as if one declares that one is omniscient and omnipotent, if the author may borrow the words of a certain corporate manager.

4. Conclusion

As a new evolution of Material Flow Cost Accounting, This paper discussed two points in particular, which are the possibility of MFCA in an electric power business in relation to energy and the relationship with TPM which is an existing production management technique.

Concerning the possibility of MFCA in an electric power business, the author started with understanding the manufacturing process of energy and reconfirmed the product yield and loss of energy. As is understood and recognized as common knowledge in the electric power business, it is important to establish management decision making information for individual enterprises and socioeconomic improvement by clarifying material flow and energy flow and using material (including CO_2) quantity of a loss and cost information in inter-industry relations in the future. In this sense, the author consider that this study is at the starting point.

In addition, concerning the relationship between TPM and MFCA, companies tend to understand that the scopes of both are basically the same, when theoretically explained. But the fact is that their contents and quality are different. It is clear that the degree of importance in their management purpose and real image clarified by data are completely different in the actualization of a material loss in material flow in MFCA and the material quantity loss in yield management by primary unit explained in TPM.

It is considered that the reason behind this is that because the proportions of labour costs and facility costs to the total cost are large, business administration is considered important, which makes TPM developed and evolved. There is no argument on this point. However, for example, if material quantity loss concerning raw material is included in the scope of TPM, it is not evolved as a tool or a system which analyzes the material quantity loss systematically. Analysis of a disparity by comparing a design value or standard with actual values or improvement is a major function of MFCA, and the subject is the value (the total value) of all materials including supplementary

materials and material quantity and its occurrence are not the subjects. The important point is a matter of judgement of the degree of importance. The management tool is evolved for the most important issues respectively, and it can be said that MFCA is a management tool that focuses on the corporate issue, resource productivity, which has not been necessarily previously considered important. Accordingly, both or the existing management technique and MFCA are in a mutually supplementary relationship.

Nevertheless, although it is a mutually supplementary relationship, the essential difference is MFCA is superior to the conventional management tool in providing minute data, required precision and the degree of extension of the system. In other words, it can be interpreted to give a greater load to enterprises. It is considered that it is a remaining issue that such a load of data collection will be explained by useful information derived from MFCA.

By the way, not only the possibility of the proportion of costs and the opportunities to improve costs but also the importance of resource productivity will become increasingly important in this century of the environment, and it will be understood not as a mere index but as a market participation qualification in similar importance to quality.

MFCA functions as a new useful management system which induces the enhancement of new resource productivity by actualizing material loss which has been previously hidden behind management data or neglected. Some success cases at corporations in reducing raw materials or waste disposal costs have been described. Information to be publicly announced or draws attention at that time is money value information such as a cost reduction amount. The usefulness of MFCA is certainly to make corporations recognize the size of their economic loss and induce their corporate activities to improve that by carrying out cost evaluation of material loss. Nevertheless, the figure clarified by MFCA is the proportional loss to a negative product weight and input resource at a material quantity level as shown in the right half. Figure 7 shows an example where a negative product has a weight proportion of 75%. The past MFCA projects were to convert

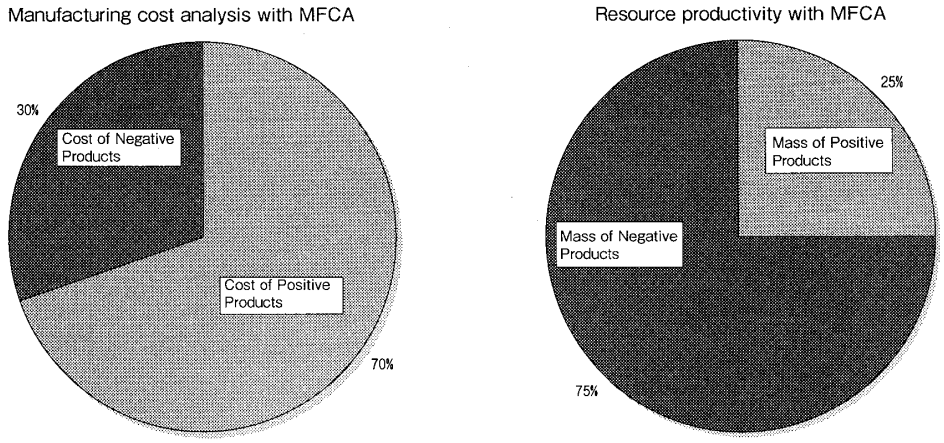

Figure 7 Manufacturing cost proportion and mass proportion of a positive product and a negative product in MFCA

raw data into cost matrix information (cost evaluation) which is shown on the left half on the basis of the above resource productivity information and show the size of the cost (the thought that there is no waste against the thought that waste is zero yen), and attempt to review corporate activities in the past. However, if you look at the right half compared with that, the reality that it is impossible to make a product without using four times more resources is a very problematical state from the viewpoint of environmental management. The differential of an economic value makes such a paradox. But it can be said that this is the most important issue from the viewpoint of the earth (resource). It is considered that products with the highest resource productivity are the valuable products of the highest quality by clarifying this state in manufacturing products in the future. the author consider that MFCA will be utilized as a strategic management tool in future corporate management in this sense, too.

Notes

1. After the voting process, this NWIP was formally approved in March, 2008. This NWIP will be discussed in working group in ISO/TC207 about three years, and will be published as new international standard in ISO 14000 families.

2. Corporations which publicly announce results of the introduction of MFCA include Tanabe Seiyaku Co., Ltd. (at present, Mitsubishi Tanabe Pharma Corporation), CANON INC and NITTO DENKO CORP, etc.
3. Similarly, if you look at the material cost out of positive and negative product costs, it is not rare that material cost of negative products becomes nearly 30% of the total material cost of product manufacturing, even if the product yield exceeds 90%. Accordingly, Figure 1 shows a case of a large waste disposal cost.
4. A discussion paper published by IMU (Institute für Management und Umwelt, Augsburg Germany) in February 2001 defines that energy will be included in material on MFCA. (See Nakajima and Kokubu (2002), p.200.)
5. For more details, see IGES Kansai Research Center (2003), pp.73-76.
6. "not be actualized" herein means that although it is known that material yield management is not 100% in design yield management and standard management, material loss is not managed clearly as it has deviated from the management target as a part which is impossible to manage or it is tacitly understood.
7. This does not mean that there is no information or data, but, for example, it is not always systematized as management data or a report. This can be considered to be the same for all business lines, as additional works occur when mass balance information is collected in a number of business lines from the viewpoint of MFCA.
8. Although water, which is the origin of water vapor, is also input, water is considered to change to water vapor without waste. The water therefore is ignored to make explanation here easy.
9. See Matsumura and Hirayama (2005), p.1.
10. See TOSHIBA CORP. (2007), p.20.
11. See TOSHIBA CORP. (2007), pp. 1-2.
12. See Nakajima and Shirase (1992), p.11.
13. See Nakajima and Shirase (1992), Table 1.6 in p.11, added a column for MFCA.
14. IMU in Germany which first developed MFCA introduces MFCA applied to the whole company as its basis on the assumption of ERP (Enterprise Resource Planning) such as SAP and Oracle. Compared to this, the MFCA project first introduced in Japan in 2000 was for a manufacturing process or product manufacturing. MFCA had therefore been developed for relatively small-scaled manufacturing processes and was named as "Japanese style MFCA" in order to be differentiated from MFCA (German style) in Germany. Japanese style MFCA has been developing by merging with improvement activities on the spot, which Japanese companies are good at.

15. Nakajima and Shirase (1992), pp.38-39.
16. Nakajima and Shirase (1992), p.47.
17. Anjo (2006), p.49.

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(This work was supported in part by MEXT (or JSPS). KAKENHI:18530366)