Technological empowerment:
creating local knowledge with calculating practice

[Purpose]

The purpose of this study is to reassemble the process of knowledge construction in terms of measurements and calculations and to indicate the empowerment process enabled by the management mechanism that encompasses measurements and calculations.

[Design / methodology / approach]

In order to analyze the case of Material Flow Cost Accounting (MFCA), we have employed the discussion on the relationship between inscription, knowledge and reference(Latour, 1999) and insight from accumulations of inscriptions (Latour, 1987). We collected and analyzed data on the FY2010 implementation of MFCA in the painting process of Yamashina plant, Nippon Denki Kagaku Co., Ltd.,(NDK) by action research and participant observation. Our analitical focus is of the detailed level of measurements and calculations practice conducted in MacKenzie (2009), Garcia-Parpet (2008), and Latour (1999).

[Findings]

First, this study shows that the technology of calculation enables the construction of localized practical knowledge by setting up objects of measurements and calculations dexterously. Rather than taking the dichotomous worldview of technological practice and social practice, we grasped the implementation of MFCA as a field of knowledge formation in the actor world created by measurement and calculation practices. Second, as a result, this study also shows that embedding calculating practices within management system programs can have an effect of empowerment. Local knowledge that was generated for each diverse context created power for autonomous actions, and at the same time, the aspect of uniformity of calculation inherent in the program acted for the control of the organization.

[Originality / value]

First, this paper clarifies the organizational process of knowledge-power, which is created with measuring and calculating. In conventional studies on accounting and knowledge-power, a calculative device is embedded in the social relationship between the surveillant and the governed person and is enclosed in the web of accountability; on the other hand, in this paper, by focusing on the interrelationship between the calculable object and the measurer, we view accounting-as-a-calculation-device as one of the actors forming the network of knowledge-power relationship. Second, we have shown the process

of technological empowerment. Conventional studies on empowerment discuss technological empowerment from the viewpoints of social structure and psychology. In contrast, by paying attention to measuring and calculating practice, we have shown, in this study, a form of empowerment in which the technology of calculation itself defines a creation of knowledge to enable a change in the power relation without a grasp of the knowledge and skill that would come with the delegation of power. At the same time, measurements and calculations, which had been conventionally overlooked and embedded in the process of participation, have been re-evaluated in terms of organizational meaning in their practices.

[Keyword]

inscription, knowledge, MFCA (Material Flow Cost Accounting)

Introduction

The paintings and objet created by Joan Miró would try to describe more than what is inscribed and formed in them. However, it is next to impossible to reproduce not only the dusty air felt by the skin when walking around the arable land but also the rut you feel on the soles of your feet, the mixture of smells from livestock and grains, and the collection of unorganized sounds that fill in the ambience. In the same manner, accounting numeric figures intend to convey massage in their inscriptions more than the relationships of profits, incomes, and costs. However, the techniques of skilled workers actually working in factories, the advanced technologies hidden in materials, and employee morale are, though important in the management decision-making process, not reflected in such figures.

As Roberts (2009) warned on intelligent accountability, we need to direct our attention to the relationship between numerical values that constitute accounting practice and the real world not described by them. Rather than capturing things not described in accounting figures as the context that affects it, we need seriously to take the ambiguity, of which separates accounting from other things. As Latour (1999) described the moment at which the boundary between forest and savannah is drawn in the hybrid world, accounting figure are constructed in the hybrid relationship.

The very moment at which it is generated provide us an opportunity to consider the meaning of the substance being cut off into numerical values. With regard to integration environment and economy, analyzing accounting as objectified information depicting efficiency is not enough. If researchers did not direct their attention to the contact point at which practice is integrated with accounting in the hybrid calculation space, business and environment would be still separated.

Rather than trying to grasp issues in the world where “environment,” “calculation techniques,” and “accounting” are objectified, we should take it that constitutive actions are chained and connected to each other in hybrid practice. With focusing on technology we could witness the the dexterity to link nature and society, which have been demarcated from each other. In contract theory as well as governability or institution, calculative practice has so far been discussed while dichotomously contraposing the issues of technology and the issues of humans. However, because a technological aspect in calculating practice itself stays the basis of society, environmental problems cannot be solved if we overlook the interaction of calculating practice and humans’ practice.

Thus far, there has been a great deal of research about the social composition of accounting (e.g., Hopwood, 1987; Miller & O’Leary, 1987, 1993). As measurement and calculatve technologies have come to be increasingly embedded in hybrid practice (Miller et al., 2008), measuring and calculating practices have come to be intricately embedded in organizational lives. Accounting, which has measures to transform problems insoluble within the existing economic framework into things that can be solved (Callon, 2009), is likely to be positioned at the forefront of resolving the dichotomy of problems. MFCA (Material Flow Cost Accounting) and CFP (carbon footprint of products) are neither abstract and idealistic calculating technologies nor the technology of governability constructed in the political context (Miller & O'Leary, 1994). Rather, they are technological devices to perform the integration of the environment into the economy while forming a network of actors.

In the hybrid world, frameworks for measurements and calculations are tactfully designed. MFCA visualizes material loss that has been overlooked in the existing management framework and connects management and the environment to each other (Kokubu and Nakajima, 2008; ISO, 2011). It, as well as other management schemes like TQM of QC activity, is programmed to encompass measurement practices and calculations. In these management schemes, how to express practices in numerical terms will become an important issue for solving problems in existing management frameworks. In addition, generating numerical figures provides a more diversified range of information and contact points than does utilizing given numerical figures. Therefore, in order to understand the importance of digitization and calculations in management schemes, it will be more important to understand the action of digitization and the process of forming an actor’s cognitive framework at the same time (Vollmer et al., 2009). However, in conventional studies on accounting, preparer of numerical information and the practice of generation of such information have been often left outside the scope of analysis or, at leaset, have been paid less attention.

Further, such matters as measurements and calculations often tend to be concealed in the concept of “participation” in accounting practice. As is pointed out in studies on the process of empowerment in relation to accounting (Johnson, 1992) and in introductions of accounting methods (Shields, 1995), the participation of the organization’s members is a promotional factor of such activities; subjective commitment can be said to be a key element for smooth management. However, information on individual effort has been ambiguous in studies on participation, and therefore, individual processes and elements have been overlooked as objects of consideration. Still further, the effect of accounting and calculative actions on members of the organization has also been overlooked in this regard.

Accounting is composed of a variety of numerical figures, and the practice of generating numerical figures is repeated over and over again in daily accounting practices. Moreover, accounting created in that manner characterizes society and organizations (Hopwood et al., 1987). One of the ways to think about the effects of accounting on an organization and its members is to track back to the moment when numerical figures are generated. At that point, the generation and social composition of such numerical figures will be made clear in relation to knowledge formation.

As Latour points out, the practice of calculation, that is, a series of actions to transform objects into inscriptions such as numerical figures and to create the relationship of inscriptions in a different space, forms the philosophical foundation of knowledge construction as a matter of reference.

> “Knowledge does not reflect a real external world that it resembles via mimesis, but rather a real interior world, the coherence and continuity of which it helps to ensure.” (Latour, 1999, p.58).

That is to say, (scientific) knowledge is reflecting the steadiness inherent in a measuring device that enables digitization or symbolization when inscriptions make references. Therefore, knowledge depends on technology for measurements and is characterized by the configuration of the technology.[1] However, “problems” that require technology for

[1] Knowledge is not only what is shown externally through inscriptions but also what is learnt implicitly through physicality. Moreover, such knowledge is thought to have effects in the context of empowerment. A cognitive framework on the basis of which we will conduct our inquiry cannot be realized only by understanding the rationality indicated by numeric figures and reflecting the rationality on the actual status; sensitivity to generated numeric figures is also considered to constitute an important part of the cognitive

measurements and calculation are not necessarily apparently present as given. Knowledge is formed during the process of problematization within a network of measuring devices and other actors (Miller & O'Leary, 1993). When inscriptions are generated, reference are performed after trials are repeated, such as selection of appropriate technology and application of technology to the real world (Latour, 1999).

In this paper, we will, by tracking trials of such references in accounting practices, analyze the process of knowledge construction as well as the effects on a cognitive framework of organizational members. The purpose of this study is to reassemble the process of knowledge construction from the aspects of measurements and calculations and clarify the process of empowerment facilitated by technological device.

To achieve its purpose, this paper is composed as follows. In the next section, through a review of discussions on empowerment on management accounting, issues to be addressed in the paper will be outlined. With regard to the empowerment issue arising in relation to management accounting, we refer to the problem that the processes of measurements and calculations are concealed within the concept of "participation." In the third section, we discuss the relationship between calculating practices and knowledge construction to clarify the study's framework of analysis. As Latour (1999) points out, measurement and calculation actions attempt to construct knowledge through their inherent steadiness and continuity, while the knowledge can be the source of organizational change (Quattrone & Hopper, 2001) and control through its diversity and uniformity. In the fourth section, we inquire into the case of the implementation of MFCA in the electrostatic coating process of Nippon Denki Kagaku Co., Ltd.(NDK) to analyze the relationship between empowerment and calculation practices. In the fifth section, we discuss the case, and in the sixth section, we summarize the discussion.

Accounting and empowerment

Empowerment aims at encouraging the autonomous activities of the organizational members. To activate organization with empowering the members previous studies highlight two issues: the transfer of power to employees, including the delegation of authority, and controlling the empowered employees. In the context of management accounting in particular, the idea of empowerment is discussed in contrast with hierarchy and accountability relationship. Rather than presenting specific work procedures or coordinating interdependency, empowered workers is expected carry out the organizational

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framework. However, since the purpose of this paper is to clarify the roles technology plays in empowerment, our analysis will involve a consideration of these limitations.

purpose with eliminating problems autonomously (Johnson, 1992).

Delegation of authority is one possible measures for empowerment. As pointed out by Conger and Kanungo (1988), however, delegation of authority is not a sufficient condition for empowerment. The socio-structural conditions of organizations need to be improved (Spreitzer, 1995). In order for empowerment to work well, it is necessary not only to change the organizational structures of authority and responsibility but also to encourage subordinates use their power; as such, it becomes important to transfer to the subordinate employees such strategic resources as information along with authority (Bartlett & Goshal, 1997). This kind of condition can be achieved not just by direct transfer but also by personnel development through provision of opportunities for learning (Heller, 1992).

It is also claimed that in addition to making changes in organizational structures, the psychology of employees should be well considered so that they can clearly recognize that they have been granted power (Thomas & Velthouse, 1990). It is important to establish mechanisms that make employees recognize themselves as powerful; however, mere slogans with no provision of substantial information, knowledge, or skills will nullify the effect of empowerment (Forrester, 2000).

It is of course important to set up conditions in which such subordinates are able to use power. What is often overlooked, however, is that a larger framework of control is necessary as well in order for management through empowerment to take effect. Simons (1995) points out that in order to manage an organization through the use of empowerment, it is necessary both to clearly represent the management vision and to present rules for actions. In addition, it is useful to make additional use of conventional types of control systems.

To achieve organizational goal with empowered members, it is also necessary to create an environment in which subordinates and employees can discover problems and develop the abilities and skills required to solve them. These conditions are prepared by transfer of strategic and managerial resources including information and provision of opportunities for learning. In addition, it is necessary to consider psychologically encouraging subordinates and employees recognize the shift in power status. Empowerment can be said to address all of these issues comprehensively.

In the context of empowerment mentioned above, accounting can be deemed to change the content of information provided and the method of information provision, and to change and influence matters related to authority and accountability. In contrast to this, however, focusing on measurements and calculations, we have shown in this paper a form of empowerment not in which knowledge and skills are grasped as provided with delegation of authority but instead in which technology of calculation itself defines knowledge creation and enables changes in control and power. That is, by focusing on the action of the calculations embedded in the management program, calculations are set to cause changes in power.

Although empowerment has been also discussed in accounting studies, accounting usually are treated as obstructive or promotional factor. Constructive role of accounting in the empowerment process has not been clearly discussed. In other words, accounting has been studied solely as an attachment to organizational phenomena (Justesen and Mouritsen, 2011). By focusing on the measurement and calculation practices that compose accounting, which we will discuss in the next section, we will be able to clarify the action of accounting to enable empowerment, which has been often buried within the concept of participation. As a result, as understanding of local phenomena deepens in knowledge construction, problems will be discovered and an environment for developing abilities to solve them will be established, and, further, it will be possible to discuss the role that “programmed” measurement and calculation schemes play in the area of control.

As with many other methods of business management, MFCA supports managerial decision making and improvement activities as an information provision tool, and the effects of the use of MFCA on areas such as organizational change (Numata, 2007) and interorganizational relations (Anjo, 2007) have been so far discussed. One of the effects is the enforcement of frontline workers through MFCA, which can be deemed to be empowerment. To understand the the process of empowerment with MFCA in this study, we do not simply ascribe the problem to engineers’ participation in the process of establishing MFCA—we discuss the matter of knowledge construction through the processes of measurement and calculation. In the next section, we will, therefore, by analyzing the relationship between calculations and knowledge construction, present the analytical framework of this study.

Process of knowledge construction through calculations

Translation is a core concept of the actor-network theory (ANT) developed by Latour (2005). The ANT represents the idea of understanding the network connecting actors as major constituents as the whole rather than interpreting individual components of society as independently existing. Here, what matters is how to grasp the relationship between actors, and one of the focusing points of analysis is translation.

Translation is the process of affecting the interests of other actors by applying transformation to their meanings and to the physical layouts, and it can be realized by replacing, connecting, interfering or drift (Latour, 1999). When we regard accounting calculations as translation processes, we can understand that it is possible to apply transformation to the structures of the interests of other actors, thereby making it possible for us to explicitly grasp their roles (Justensen & Mouritsen, 2011).

The sociology of translation was originally created in the process of understanding scientific knowledge through fieldwork in the laboratory; Latour attaches special importance to the fact that increased actor connections lead to the emergence of fact builders. From the point of view of accounting, accounting method can be regarded as forming a network by connecting actors within and outside the organization(Briers and Chua, 2001; Mouritsen et al, 2009). Going beyond the scope of normal responsibility and authority relationship, the scope of actor connections enables a finer analysis of how each actor feels and behaves through translation.

Additionally, in sociology of translation actors are not necessarily limited to human beings (Latour, 1987). All things that can apply a kind of transformation to other actors, such as accounting systems, computer monitors and measuring instruments to weigh raw materials, can be actors. In other words, in the actor-network space in which nonhuman (including accounting calculation methods) is regarded as actors, interactive relationships between humans and nonhuman can be grasped.

An important note about translation is that objects that have been translated emerge in the forms of symbols and numeric figures, and, as such, may have different possibilities than they had before. Because this point is given special importance in the sociology of translation, such forms of expression as symbols and numeric figures are referred to as "inscriptions", and their roles in the formation of actor-networks have been analyzed. The results of accounting calculations are nothing but inscriptions, and therefore, in the ANT, it has been deemed possible to analyze accounting phenomena focusing on actions of measurements and calculations.

Inscriptions are the results of transformation of objects of measurements into symbols and numeric figures (Latour, 1999), and symbolized actors can, for example, be moved to columns in an Excel spreadsheet for calculations, which makes it possible to rearrange their properties and to make inscriptions form knowledge through their newly developed relationships to affect other actors. That is, when a certain phenomenon is translated into inscriptions, these inscriptions generate a new knowledge, which may change their relationships. When discussed in the context of MFCA, the following sections will analyze the way that what has been only abstractly grasped in terms of resource productivity can now be translated into numeric figures (inscriptions) in MFCA to form a new knowledge and the way the new knowledge will affect the people concerned and penetrate into the organization.

The construction of inscriptions is also concerned with the relationship between symbols and the objects of their reference as indicated by the expression “how do we pack the world into words” (Latour, 1999, p.24). That is to say, information indicated by symbols should not be grasped as independent from the cognitive capacity of a person who receives it but should be understood as a cognitive framework created by interactions between a person who receives information and symbols (Vollmer et al., 2009). Therefore, it is important to understand the process of knowledge construction by following the trail of actions of reference of objects by symbols.

When objects are transformed into symbols, they are incorporated into spaces that measuring devices inhabit. Measuring devices such as weighing scales, tape measures, and thermometers quantify the object, transforming its properties into weight, length, and temperature along with their respective scale for measurement. In the same manner, accounting methods transform the object along with their predetermined rationality such as labor productivity and resource productivity that exist in their behind. The action of transforming the object into symbols in this manner is the “way of keeping something constant through a series of transformations” (Latour, 1999, p.58), and the constancy exists in the interior of the measuring device as an actor.

This is one of the sources of the constructive role of measuring devices including accounting. The process of quantifying the object simultaneously defines the cognitive framework of a user of the numeric figures to form certain knowledge. Here lies the significance of grasping accounting calculations as an actor. Knowledge constructed with accounting practice is interconnected with organizational change and it facilitate diversified organizational practices (Quattrone and Hopper, 2001).

In MFCA calculation, actual activities tinged with materiality and specificity in individual production processes are cut off from the aspect of physical quantity through the use of a weighing scale and a surveying instrument and are expressed as inscriptions while their original relationships are maintained. If viewed from the place where original information existed, information can, once it has been transformed into inscriptions, be deemed to have been reduced in space, because such inscriptions could, for example, be addressed at a meeting room away from the factory. Physical-quantity information is fitted into the framework of MFCA and is summarized as a balance of input and output to generate new inscriptions, which will, being accepted as a new knowledge by people concerned, alter their understanding of the organization.

When inscriptions are thus connected to objects of measurement, they are given specific meanings to form certain knowledge. Moreover, this process of forming knowledge goes on while affecting the interactions of actors. Understanding this aspect is none other than part of the organizational accounting practices proposed by Hopwood. In the next section, we will analyze through a review of specific cases the way inscriptions generated by MFCA create knowledge and affect actors.

Construction of local practical knowledge

1. Material Flow Cost Accounting (MFCA)

MFCA was originally developed in Germany and was introduced to Japan in 2000; since then, it has rapidly spread all over Japan with strong support from the Ministry of Economy, Trade and Industry (Nakajima and Kokubu, 2008). After MFCA was deliberated for ISO standardization as proposed by Japan, it came to be issued in 2011 as ISO14051.

After introduction to Japan as a project of the Ministry of Economy, Trade and Industry (Ministry of Economy, Trade and Industry, 2002), MFCA underwent a remarkable development. It is defined as a "major tool for calculating the costs of both the products and waste resulting from the production of specific kinds of products by tracing the material flow throughout the corporate activities on quantity and cost bases" (Nakajima and Kokubu, 2008, p. 17) and has attracted attention as an important method of environmental management accounting for achieving compatibility between the environment and the economy in corporate activities. The purpose of MFCA is to conduct a proper calculation of the costs of waste, the data from which are then used to provide incentives for lessening the environmental load, lowering costs, and promoting improvement activities (Kokubu, 2008).

MFCA is a new method that was developed throughout the 2000s. Studies on it can be divided into two groups: studies on problem solving using its calculation techniques and related development potential and case studies of its implementation in corporations. The former group of studies includes those on the positioning of MFCA as an accounting system (Nakajima and Kokubu, 2003); those on the experimental combination of methods of measuring environmental impact, such as life cycle assessment with MFCA, (Kokubu and Shimogaki, 2008); those that discuss the possibility of using MFCA in supply-chain management (Higashida, 2010); and those that discuss effective MFCA systematization in management (Nakajima, 2010). The other group of MFCA case studies comprises theses written primarily by businesspeople in large corporations that introduce success stories about MFCA implementation in corporations such as Canon (Aki, 2007), Sekisui Chemical

Co., Ltd. (Numata, 2007), Mitsubishi Tanabe Pharma Corporation (Kono, 2007), and Sanden (Saito, 2007). There are also a few case studies on the implementation of MFCA in small and medium businesses (SMBs) (Shimogaki, 2008).

Thus, there have been many conventional studies on MFCA's calculation techniques and on successful cases of its implementation, but the way that MFCA has been understood and disseminated across organizations in ever-changing organizational practices has not been fully discussed.

2. Case company

In this section, we descriptively analyze the case of MFCA implementation in Nippon Denki Kagaku Co., Ltd. (NDK)'s FY2010 electrostatic coating process, which involved manufacturing electronic substrates and circuit boards. NDK, with capital of 100 million yen and 191 employees, had been selected as an object company for the "Kyoto Study Group for MFCA"[2] project to support MFCA activities from FY2008 to FY2010; MFCA was introduced in three of NDK's manufacturing processes in Kyoto Prefecture.

NDK introduced MFCA in its precision sheet-metal process in the first year of the empirical trial project, in the chemical copper-plating process in the second year, and in the electrostatic coating process in the third year. Given the results of the first and second years, the third year saw the understanding and dissemination of the calculation method across the site as a particularly important issue.

The authors were involved in MFCA implementation at NDK for three years. For this study, we notified the company of the purpose of our participation as part of our action research and supported their implementation of MFCA as advisers. The authors participated in nine official company meetings, from November 2010 through March 2011. Each meeting took two to three hours, and all meetings were tape-recorded and transcribed. During our action research, we were authorized to gain access to internal information as needed, and these data have been used in our analysis.

3. Implementation of the MFCA Project and their problems

In this paper, we analyze the MFCA project in FY2010. However, before describing the calculation activities as MFCA's process of knowledge construction, let us first establish the issues we were aware of in the 2008 and 2009 MFCA projects and those of the MFCA

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[2] As one of the measures taken by local authorities to spread MFCA, Kyoto Industrial Support Organization 21 supported the empirical trial project implemented by the Kyoto MFCA Study Group for three years beginning in FY2008. Throughout this project, MFCA has been introduced at three NDK sites in Kyoto Prefecture.

implementation for the painting process, based on the results of the previous projects.

NDK introduce MFCA in its precision sheet-metal process in 2008 and in its chemical copper-plating process in 2009. Because in addition to large-item small-scale production, the qualities and specifications of raw materials to be inputted are different among products in the precision sheet-metal process, the MFCA implementation focus in the first year was on simplifying the method of grasping the physical quantities. In the second year, because MFCA was being introduced in the chemical copper-plating process with chemical reactions, we attempted to grasp the physical quantities through the verification of long-term data by using both estimated and measured values. Thus, we tried to reduce the company’s MFCA implementation burden by simplifying the method of calculating loss—for example, by narrowing the range of objects to be measured according to their features and manufacturing processes.

At NDK, material loss had been calculated through the implementation of MFCA; thus, the usefulness of MFCA as a tool for loss calculation had been confirmed. However, in the face of constraints such as fluctuations in the number of orders received and customer demand for quality requirements, insufficient loss reduction was achieved in FY2008 and FY2009. In the implementation of MFCA in the electrostatic coating process for FY2010, therefore, top management requested tangible improvements. In addition, the vice-manager of Quality Assurance Environment Management expressed a strong demand for loss reduction, saying, “We would like to carry through all the projects to the very last to achieve a reduction of loss.”

Furthermore, with weight placed on calculating loss in the MFCA implementation in the first and second years, NDK gave top priority to simplifying calculation practices by receiving support from external professionals and using calculation tools. It had been pointed out that this policy had helped prevent the calculation principle from penetrating throughout the organization. In fact, the vice-manager said that “from the time we start to collect data for the implementation of MFCA, we need to bear in mind the steps to follow to improve advancements in visualization; if not, the visualization of MFCA will go forward alone with other things left behind.” In other words, even when loss was quantified, the data were not well connected to organizational practices.

Under these circumstances, MFCA was introduced in the electrostatic coating process for FY2010. The process was carried out in the Yamashina factory of NDK and was said to have generated losses, particularly in paint and energy. Although it had been intuitively understood that the painting process generates comparatively greater material loss, that loss had not been specifically grasped in cost terms; thus, improvement activities were not going forward.[3] The painting line is composed of a number of processes, and MFCA was implemented (as shown in Fig. 1) with a focus on the electrostatic coating and baking and drying processes.

In the following section, we will first explain the selection of a measurement method as the prerequisite for translation through MFCA and then conduct a descriptive analysis of two activities as specific translation processes: the calculation of a material balance for the quantification of paint deposition efficiency and the analysis of film thickness in visualizing the material modes.

4. Selection of a Measurement Method: Prerequisite for Translation

Not all of the paint sprayed in the electrostatic coating process is deposited over the target's surface; much of it dissipates in the atmosphere. In addition, undeposited paint is collected and precipitated in the water tank to produce a large volume of sludge, later scrapped as waste: "We see by intuition where waste is generated, but we hesitate to take action, being at a loss for what to do to reduce waste," said the vice-manager of Quality Assurance and Environmental Management. Thus, although it had been recognized that waste was being generated, what was required to elucidate the structure of waste generation and improve it remained to be solved.

Therefore, in order to measure the amount of resource waste, it was determined that we should analyze the efficiency of the use of paint in the electrostatic coating process by using MFCA. It was regretted that in the previous two MFCA projects, the visualization of material loss did not lead to reductions in waste. The vice-manager of Quality Assurance and Environmental Management specified that, "Data should be collected on the premise that it will be used in the future for improvement."

Fig. 1 Flow Diagram of the Painting Line

The continuity of data collection and improvement activities was recognized as an issue requiring solution. At the start of this project, it was thought that one of the causes of the gap generated between loss calculation and improvement activities was the method of collecting the material data. This also involved the problem of MFCA's knowledge

[3] Because material loss in the painting process was recognized as an important object of improvement, painting was suggested to be a candidate for MFCA implementation for the first year. However, because priority was placed at that time on demonstrating the visualization of material loss through MFCA, MFCA implementation was shelved because its calculation of quantity was deemed too complex.

construction. Therefore, in order to grasp as a material flow the efficiency of paint coating on item surfaces (i.e., how much of the paint sprayed through the nozzle was coated on the target surfaces), the calculation of the material balance and the analysis of the material distribution were conducted in parallel.

The MFCA analysis was carried out in reference to the solid content of paint as the main material. For the acquisition of material flow data, measurements of the weights of members before and after painting (quantifying the efficiency of paint deposition) and measurements of the film thicknesses of the coated material (analyzing film thickness) for a prescribed number of products were taken. In the following section, through quantifying the efficiency of paint deposition and analyzing the coating thickness, we will analyze the types of translations that MFCA performed and the kind of knowledge constructed by the numeric figures (inscriptions) obtained through the translations.

5. Quantification of the Efficiency of Paint Deposition: Translation into Material Balance

The efficiency of paint deposition was calculated by measuring the weights of the materials before and after painting, thus measuring how much of the inputted paint was turned on products. In order to account for paint dispersed in the electrostatic coating process in the framework of MFCA calculation, it was necessary to translate the paint deposited on materials and the paint absorbed into the water tank as waste into positive and negative products, respectively. This means that the physical change in the paint occurring in the field is translated by MFCA into a material balance that can be shared by users in a meeting room.

It was difficult to compare liquid poured into a spray tank from an 18-liter metal can with a thin coating film that can be seen only with difficulty on a metal surface. Six people on the staff, including the vice-manager of Quality Assurance and Environmental Management (a leading promoter of MFCA) and the authors, gathered in the conference room of NDK. The only navigational map we had was the MFCA framework saying that we should convert material flow into quantity and separate inputted material into positive and negative products. In this process, metal plates of various shapes, sizes, and thicknesses were processed, and grasping their material flow required the conversion of objects. Here, MFCA operated as an actor.

Viewing the process through the MFCA framework, the paint as a positive product was deposited as a thin coating film on the metal plates, and as a negative product, one part of the paint was the sludge in the water tank, another was the solid matter stuck on the interiors of the exhaust ducts, and still another was the paint stuck on the wire used to hang metal plates. We had no choice but to give up selecting waste as the quantitative object of our measurement because it was almost impossible to identify which part of liquid became waste when it was sprayed. Therefore, we decided to calculate the material balance by comparing the inputted raw materials with the positive products.

At that time, what appeared before us as the first question was whether we could know the quantity of the thin coating films in thickness or weight. The vice-manager of Quality Assurance and Environmental Management noted that distribution of thicknesses of the coating films differed due to the distance from the central point. This did not mean, however, that the chance to knowing the physical quantities of the positive products was totally closed. The nonuniformity of the coating films provided us with a chance to understand the material flow in the electrostatic coating process in two different ways.

Accordingly, we attempted in parallel to measure the material balance by weight as well as to grasp the material flow as the distribution of coating thicknesses.[4] First, in order to identify the correspondence between input and output, we chose the same types of products   The weight of the paint on a metal plate is very slight; in order to equalize the fractional errors for all the metal plates, the weights of the grouped parts before and after painting were compared with each other.

As is the case with many companies that use MFCA, numeric figures for positive and negative products became stronger substances in the field by being connected to more actors (Latour, 1999). The three kinds of parts, which are different in size and shape, can be considered as actors here. In the electrostatic coating process, painting was conducted by using reciprocators. It was expected that the loss ratio would change depending on the size of each material. Measurements were conducted for the three kinds of members, all of which were different in size and shape. The paint deposition efficiency ratios for the three kinds of parts, in descending order of superficial area size, were 33.2%, 25.67%, and 9.45%.

The results of our analysis, based on the compared material weights, are shown in the table in Fig. 2: (1) the weights of materials before and after painting, (2) the weight of the paint inside the water tank before and after painting, (3) the weight of the solvent portion in the water tank modified and summed up, and (4) the paint deposition efficiency ratio.

Fig. 2 Measurement of Paint Deposition Efficiency Ratio in the Painting Process

[4] With regard to analyses of specific cases, this section analyzes the measurement of the material balance; in the next section, we analyze the distribution of film thicknesses. This does not mean there is a temporal order between the two analyses. In fact, the analyses were conducted in parallel while overlapping.

These three different types of numeric figures are inscriptions resulting from translations, from which new knowledge will begin to be generated. These inscriptions, the figures of which were different according to the sizes of parts, were projected on the screen in NDK's meeting room, which we were using as our laboratory. Particles of paint dispersed in the atmosphere in the work site were translated as a pattern of transition in quantities. Thus, a visualized space was created through which participants in the MFCA meeting had to go in order to grasp resource productivity. As Latour (1999) points out, multiple inscriptions, if superposed on one another, increase the level of confidence much more than a single inscription, and this was the case here.

At this stage, for the staff of NDK and us, the paint was no longer a liquid dissolved in thinner, nor a thin coating material on a metal plate. It was transformed into numeric figures and points on a graph showing a pattern displayed on the screen of a computer and projected on the screen in the meeting room.

NDK staffs work with paint in the field every day. However, the we are more familiar with inscriptions of paint on an Excel spreadsheet than the they are. At this stage, the network of relationships in the painting process was thus transformed through MFCA. The numeric figures on the Excel spreadsheet indicated not just the quantity of paint but also the resource productivity within the MFCA framework.

This translation enables us larger degree of freedom. Unlike changes in the paint used in actual work in the field, the quantity of paint as inputted material, positive products, and negative products can be easily manipulated on an Excel spreadsheet. With regard to the numeric figures indicating the physical quantities related to paint as an object of measurement, Fig. 3 shows how, when the paint deposition ratio is changed from the current 30% to 50%, the quantity of paint changes accordingly. Likewise, a change in the amount of money required can be converted into a target for improvement activity in the electrostatic coating process.

Fig. 3 Simulation of Improvement Effect in the Electrostatic Coating Process

Enjoying this degree of freedom in the use of those numeric figures in the meeting room (or laboratory) was of cardinal importance to NDK staff and us. The simulation did not just evaluate the effect of loss improvement. It can also form a new framework of understanding at the local manufacturing site from the viewpoint of a change of material flow in the paint. In other words, the abstract concept of resource productivity was made knowable through an understanding of how numeric figures can change and of the effect to be expected by improving the numeric figures calculated as material loss.

By sharing paint as converted into symbols together with the method of changing material flow through increasing or decreasing the numeric figures of loss on the screen in the meeting room, the staff and we were able to share a calculation-based attitude about the material. In the process of adding an altering pattern of paint to the outline map of MFCA, indicating the inputs and outputs, the NDK staff came to understand MFCA in their own related processes. This implies a knowledge construction through MFCA and its pervasiveness among its users.

6. Analysis of Film Thickness and Understanding of the Process: Translation of Modes of Material

In parallel with grasping the material balance in the process by comparing the weights of the materials before and after painting, we also tried to understand the material flow in the electrostatic coating process by analyzing film thicknesses. The vice-manager of Quality Assurance and Environmental Management explained that film thicknesses were different from each other. Unlike in plating processing, a simultaneous and uniform processing of the surfaces of the metal plates could not be obtained in the electrostatic coating process.

Metal plates were carried from right to left by conveyors and were sprayed by paint sprayers moving up and down by reciprocators. Paint ejected from the nozzle heads spread in a radial pattern; when the target distance of approximately ten or more centimeters was reached, the distribution of paint seemed to become gradually thinner from the center to the periphery. At the same time, paint was attracted to the sides of the electricized parts.

The other goal of our evaluation of the change of material in the electrostatic coating process was to convert the spatially complex movement of material into inscriptions of numeric figures, the purpose of which was to understand material loss from the viewpoint of film thickness. As in our analysis of the relationship between positive and negative products by weight, film on the surfaces of members was a positive product, and paint dispersed into the atmosphere was a negative product.

We have so far learned the balance of positive and negative products through variations in weight, but we have also analyzed why material loss occurred. We no longer need to know the volume of all positive products, nor do we need to pay any attention to the relationship between paint coated on the plate and liquid paint in the tank. Our attention has been attracted to spatial modes of paint over the brief period of time from the spray of the paint from the nozzle to partial paint deposition on the parts surfaces or paint dispersion into the atmosphere.

First, sprayed paint was translated as the distribution of its coating thicknesses. The sample plate onto which paint was sprayed over the surface in a radial pattern was used as a sample of the distribution of paint. The paint-sprayed plate was carried into the meeting room, and the graph of the distribution of film thicknesses (see Fig. 4) was displayed there as well. Paint spread all over sample plates in a radial pattern, converted into film thicknesses, provided us with new guidelines for the evaluation of material flow. Two line graphs of film-thickness distributions in vertical and horizontal directions showed angled forms with the highest values at the center, sterically reflecting the trend of film thickness.

Here, however, the fluctuating thicknesses of paint film were not taken as the problem in themselves. Inscriptions of the film thicknesses (see Fig. 4) were confined to a specific phenomenon of paint dispersion on the plane surface, thereby separating the movement of paint ejected from the spray nozzle from the flow of time and reducing the space from the three- to the two-dimensional. By setting up the boundary from which film thicknesses formed by sprayed paint could be seen as outside a set standard, a range indicating numerical distances from the center where the equipment functioned effectively was defined. Then, by overlapping this range with the other two-dimensional space—the broader range within which the paint was sprayed by the equipment—modes of paint that were seemingly complex as inscriptions displayed on the screen were conveyed into the laboratory room. This was the very moment when the other framework for grasping material flow was formed. Here, in the same way as formerly, we superimposed a plural number of inscriptions to form a framework for understanding. This framework for understanding was formed by MFCA, the knowledge was shared by people concerned, and measures for improvement came to be considered.

The range over which the paint was sprayed had been determined by the size of the inputted parts and the marginal area set up for the equipment. To be more specific, the spray area was known by the size of the member as detected by a sensor and the degrees of the margins set up in the vertical and horizontal directions. One degree of the scale equals 5 cm; if margins of four degrees are set up in each direction and a 30-cm side (900 cm^2) of the member is selected, then paint is sprayed within a range of 70 cm × 70 cm (4,900 cm^2). This means that paint is sprayed over an area more than five times larger than the surface area of the member. This overspraying should receive special attention when improvements are sought.

NDK followed the margin degrees recommended by the maker at the time when the equipment was introduced. By looking at the process in the realm of calculations with attention focused on the material, we were able to understand the process from the viewpoint of resource productivity, thereby triggering improvements in conventional practices.

Fig. 4 Analysis of Paint Film Distribution

Epilogue: behavioral changes in the field

As regards information on resource productivity that has been shown through MFCA analysis, its feasibility for improving the production process has been investigated in consideration of constraints other than resources management issues. Among the issues discussed from various angles were those on the operation status of the belt conveyor as production management activities, the method of application of paint by the spray heads as quality assurance, and thermal energy in the drying furnace and paint features as production technology. For issues that could not be solved only by management resources within the company, a consultant on painting technology was invited to carry out an analysis of the process.

A solution with the highest feasibility is an investment in spray-coating equipment, because one of the technological issues that the consultant pointed out was that the electrostatic three-dimensional painting equipment did not function properly. Because electrostatic painting was originally expected, the extra amount of paint to be sprayed was set and actually applied. However, this part of this core technology barely functioned at all. Therefore, it was the case that resource productivity was translated from the analytical issue of modes of painting to the issue of equipment.

Although this issue is insoluble by on-site management activities such as production and quality management and production technology, the site manager and the manager in charge of environmental conservation are trying to find a solution to the issue by accessing equipment makers to collect general and technology information for analysis. As is suggested in discussions of MFCA in other companies (Nakajima and Kokubu, 2008; Kokubu and Kitada, 2012), the cognitive framework for resource productivity of MFCA presenting issues beyond the scope of on-site business management has come to generate autonomous activities among the managers of NDK.

Discussions

The process of knowledge construction in the case of MFCA implementation at NDK as shown in the preceding section can be made clear in nature by focusing on the diversity and uniformity generated by calculations. First, from the viewpoint of diversity, MFCA is a mechanism to evaluate productivity based on the basic framework of analysis of the relationship between the input and output of materials. As was seen in the case of the electrostatic painting process, MFCA attempts to generate numeric figures reflecting local relationships in practical situations to accordingly construct knowledge.

Practices of calculations as knowledge for a better understanding of the local situation have given power to lower managers. Knowledge generated just by superposing inscriptions created a center of calculation (Latour, 1987) in the NDK meeting room, empowering managers as well as enabling autonomous activities as the center of discretion (Munro, 1999).

Thus, the implementation of the new accounting method as the practice of measurements and calculations can be interpreted as a transformation of power relations. By converting the matter of introduction of a tool into the matter of knowledge/power construction or alteration, accounting need not continue to be treated as knowledge and technology accompanying the delegation of authority in the context of empowerment, and accounting practices need not be kept buried in the concept of "participation" for adjustment of psychological aspects. From this, the process of empowerment that calculations possess was made apparent.

On the other hand, the technology for measurements and calculations has affected organizational management through empowerment from the aspect of the uniformity inherent in itself as well. Practical knowledge built up as an actor world of accounting systems such as MFCA (Quattrone, 2009) is itself a reification of the concept of resource productivity that MFCA includes in its program and clearly shows the direction for organizational control. In actuality, institutional aspects to enable organization and individual behaviors suited to accomplishing ends have been formed not as communication in the forms of slogans and support but as rationality in the calculation program.

Summary

In this study, we have clarified the process of constructing the cognitive framework of accounting numerical figures together with accounting as a local practical knowledge through analyzing the case of MFCA implementation at NDK. This implementation process can be seen as a scheme of empowerment for organization members' autonomous behavior, but enabling practices in compliance with environmental conservation at local sites is not its sole function. Practices can be vary at each local site but at the same time be uniform in space because of the action of the self-controlling aspect (Power, 2007) inherent in such a management program as accounting (Quattrone, 2009). Through adaptation to local conditions, measurers come to be able to gain specific practical knowledge, and, in addition, conformity ensures system performance.

In this paper, the following two points have become apparent through our analysis. First, this study shows that the technology of calculation enables the construction of localized practical knowledge by setting up objects of measurements and calculations dexterously. Rather than taking the dichotomous worldview of technological practice and social practice, we grasped the implementation of MFCA as a field of knowledge formation in the actor world created by measurement and calculation practices. Second, as a result, this study also shows that embedding calculating practices within management system programs can have an effect of empowerment. Local knowledge that was generated for each diverse context created power for autonomous actions, and at the same time, the aspect of uniformity of calculation inherent in the program acted for the control of the organization.

The contributions of this paper can be summarized in the following two points. First, this paper clarifies the organizational process of knowledge-power, which is created with measuring and calculating. In conventional studies on accounting and knowledge-power, a calculative device is embedded in the social relationship between the surveillant and the governed person and is enclosed in the web of accountability; on the other hand, in this paper, by focusing on the interrelationship between the calculable object and the measurer, we view accounting-as-a-calculation-device as one of the actors forming the network of knowledge-power relationship. Second, we have shown the process of technological empowerment. Conventional studies on empowerment discuss technological empowerment from the viewpoints of social structure and psychology. In contrast, by paying attention to measuring and calculating practice, we have shown, in this study, a form of empowerment in which the technology of calculation itself defines a creation of knowledge to enable a change in the power relation without a grasp of the knowledge and skill that would come with the delegation of power. At the same time, measurements and calculations, which had been conventionally overlooked and embedded in the process of participation, have been re-evaluated in terms of organizational meaning in their practices.

Finally, let us refer to the following two points as limitations of our analysis in this paper. One is that the setting condition of our analysis was too narrow. If we had selected cases in which we could discuss the dexterity of setting the objects of calculation in consideration of organizational contexts and the relationship between social context and focus on the environment, we would be able to analyze the cases along more dimensions. The other is that it will be necessary to carefully consider whether the metaphor of knowledge that reflects the steadiness and continuity inherent in the measuring equipment appropriate for scientific and explicit knowledge is valid in the context of empowerment.

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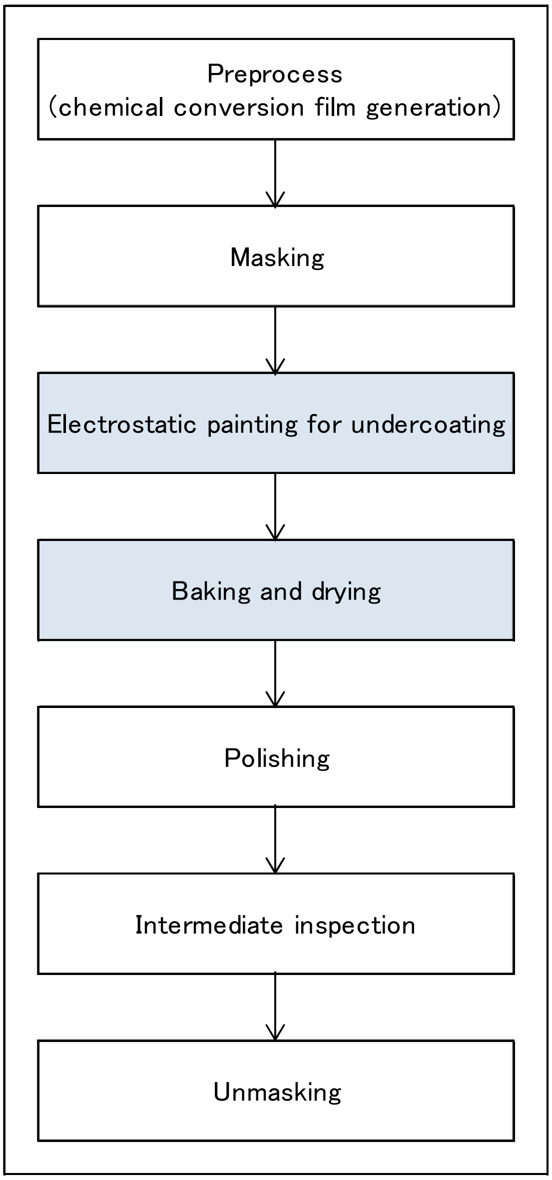
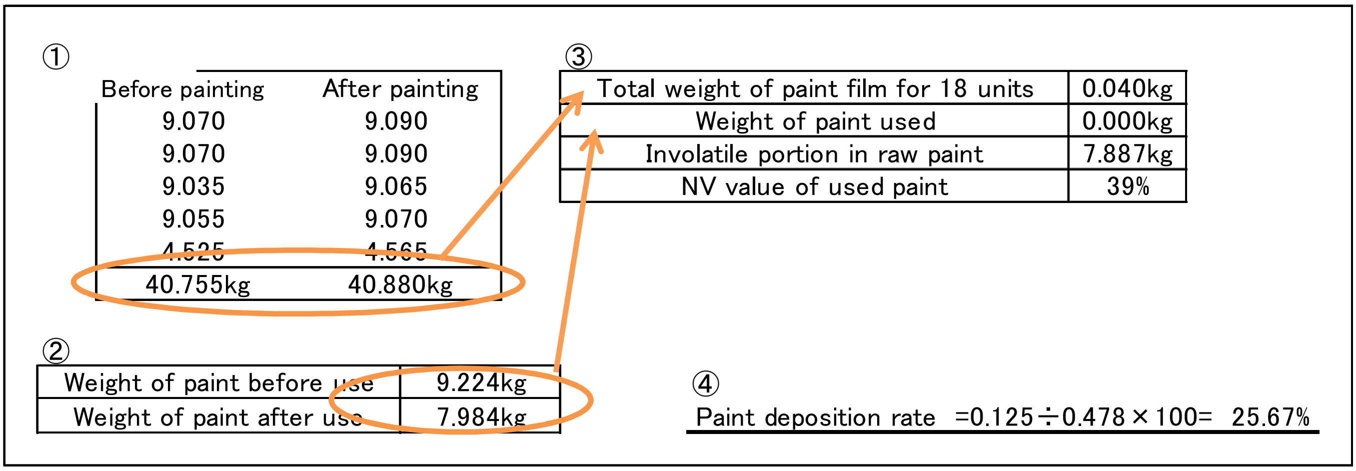
Fig. 1 Flow Diagram of the Painting Line



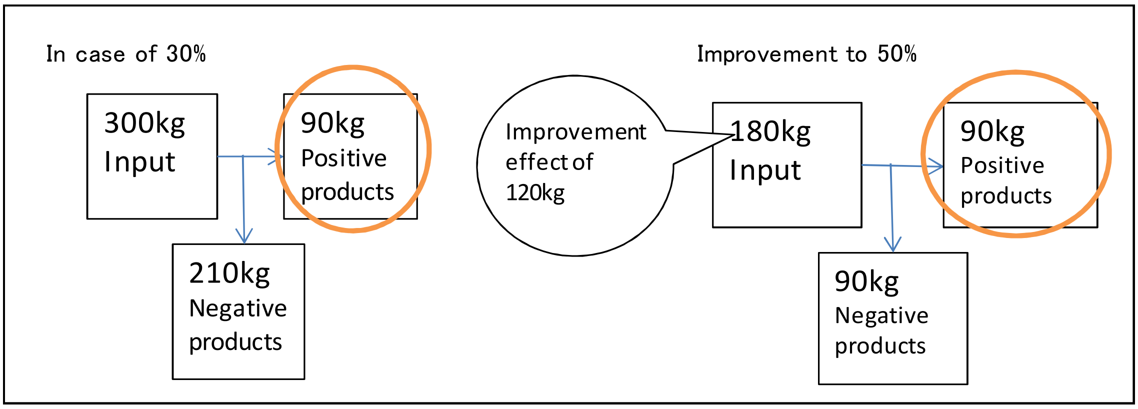
(Prepared by the authors)

Fig. 2 Measurement of Paint Deposition Efficiency Ratio in the Painting Process



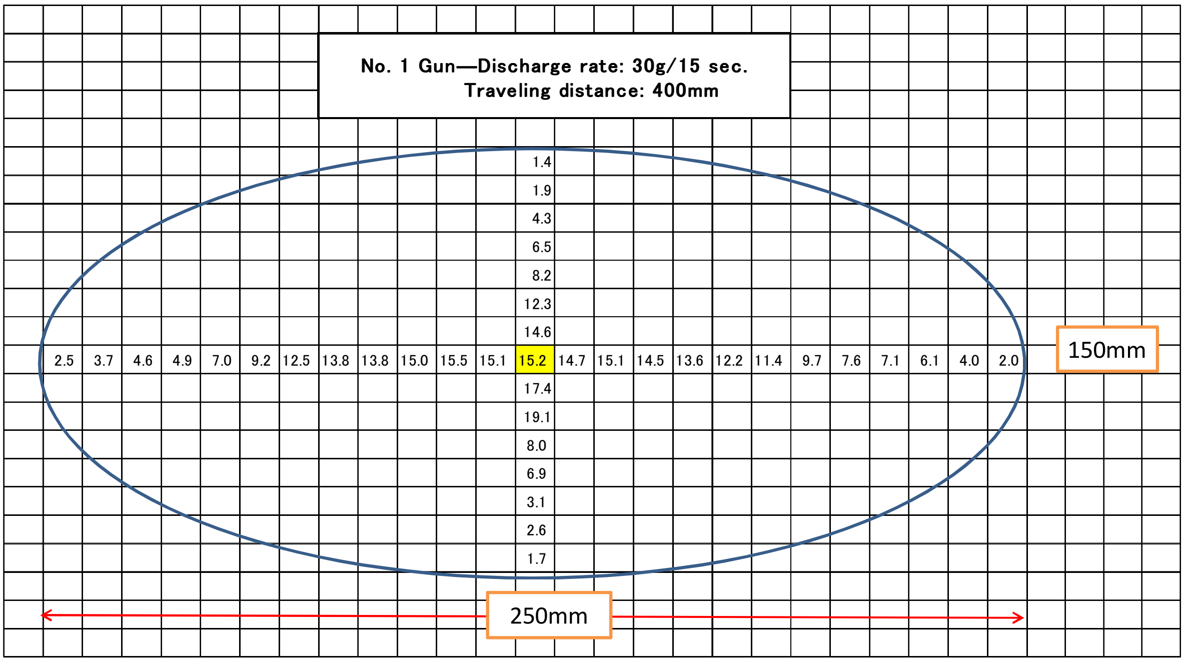
(Partly modified by the authors based on internal documents of Nippon Denki Kagaku)

Fig. 3 Simulation of Improvement Effect in the Electrostatic Coating Process



(Prepared by the authors)

Fig. 4 Analysis of Paint Film Distribution



(Partly modified by the authors based on internal documents of Nihon Denki Kagaku)