INFORMATION FLOW AND LEARNING IN NEW PROCESS DEVELOPMENT: CONSTRUCTION PROJECT IN THE STEEL INDUSTRY

by

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ABSTRACT

New production line development requires many kinds and many
levels of information during the process, but such information is not
always well organized or easy to access. In many cases, it belongs
to the people outside of the project team as know-how or sometimes
it has been lost in the history of the organization. Then we often
experience difficulties in getting the necessary information.

In these days, new production lines are usually highly
integrated and sophisticated. Development of such kind of production
line requires good understanding of existing production lines and
available new technologies. In this process, it is important to keep
good information flow for the success of the project and it is
crucial to accumulate these information in accessible way for the
company's future projects.

In this thesis, I use the concept of "sticky information" (von
Hippel, 1990) and examine the sources of stickiness and solutions in
the cases of Kawasaki Steel's No.3 and No.4 Continuous Annealing
Line development projects. From the microscopic analysis, many
features of stickiness problem are revealed. At the later part of this
thesis, we analyze problem solving and problem identification
issues from the standpoint of stickiness of information.

The ultimate purpose of this study is to provide a basic frame
work to design and manage the project team which can easily
transfer and accumulate the information in it.
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Chapter 1 Introduction

1.1 Importance of Information Transfer in New Production Line Development Project

Meaning of new production line development

Many companies try to improve competitive position through development of new production line. Therefore it has important strategic meaning.

Generally speaking, new production line development project is regarded as an innovation process. Introduction of a new production line often tries to achieve radical change which is difficult to get from incremental improvement of existing production lines. Even if it does not have ambitious target, just to introduce new technology from external innovator requires some sort of technological or organizational changes in the existing factory. In this meaning, new production line development project is an innovative process.

However this preconception may be misleading. When we develop new production line, we should not overlook the importance of the continuity of the technological change. Before the new production line is developed, there has been a long history of continuous improvements in the company. Some of these improvements may not be applicable to the new production line because of the difference of the process. However, generally speaking, there are still many improvements which are theoretically applicable to new production line. If we fail to transfer such accumulated improvements to the new production line, we lose much of invisible assets and we have to work hard just to reach to the same level of improvement as existing production lines have already
achieved. Definitely, we need to transfer accumulated improvements into new production line.

However it is not enough to bring accumulated improvements to the new production line because new production line development is an opportunity to make a fundamental improvement. There tend to be some problems in existing lines, which are well known but can not be solved because they require to make fundamental changes of the machine or software and we cannot afford to do it because of the amount of the cost or the time to modify the production line. New production line development project provides an opportunity to solve such problems.

We can summarize these three points as follows:

- New production line development is an opportunity to make radical change.
- New production line development is based on the accumulated incremental improvements.
- New production line development is an opportunity to solve fundamental problems which was given up in the existing production lines.

If we want to increase the competitiveness by development of new production line, it is necessary to take all these three aspects into account and try hard to maximize the result of each activities. In the following sections, main difficulties related to these three features are discussed.

New production line development as an innovation

Whenever a new production line is developed, some sort of technology transfer should occur. Technology may be transferred
from R&D section, equipment maker or other plant to a new factory. However, such technology transfer is not always easy. Such situation is explained by von Hippel as the "stickiness of data." (von Hippel 1990)

Why innovation is sticky? Because introduction of innovation does not mean just to bring new machine in the plant. But innovation often requires the receiver to have different type of knowledge or skills. Or it may change the way of business and require to change the organizational structure. Or it may even requires to change the fundamental concept of the business or value system. Innovation requires to transfer or develop these environment in order to work successfully. If we look at this problem from the point of view of information transfer, introduction of innovation requires to transfer many pieces of sticky environmental information. Therefore we have to consider sticky information issue to make a successful introduction of innovation.

New production line development on the base of accumulated improvements

Accumulated incremental improvement is one of the most important invisible assets for the company. It is the source of the competitive advantage. If we could transfer it into new factory, we could accelerate the "learning curve" and shorten the start-up period. However, sometimes such kind of know-how is difficult to transfer. This is also a "sticky data".

Why it is sticky? It is rare to build the identical lines. Unless we build the perfectly same line, we cannot copy the line, then we have to apply the wisdom of the past into new line. But it is difficult to do. There are some reasons. Sometimes those improvements are optimum solutions in the specific context. They are not always general solutions, therefore, they may not work in the different settings. In other case, the background reason of the
solution may be forgotten or the original design document may be lost. Unless we know the reason of the first success, we can't make sure to succeed in the second application. It seems to be strange to forget or lose such important information, but it can happen because this kind of improvement is not a single event. In many cases, production line has been continuously changed to improve and these improvements are done by multiple generation of staffs. We can find when and what kind of modification was done from the historical record but it is difficult to understand why and how these modifications was designed. This is the reason why continuous improvements are sticky to the existing production line.

**New production line development as a fundamental improvement**

New production line development is a chance to make a fundamental change in the process, which was not feasible in an old production line because of the constraints of cost or time. In such case, people in the old production line often forget the existence of the problems. "It is no use crying over spilt milk." Then the information of fundamental problems becomes sticky data because nobody mention the existence of the problems to the people of the development team for the new production line. Though development of new production line is a chance to make a fundamental change, fundamental problems tend to be forgotten and we may overlook the chance to improve it.

All these three features of the new production line development mentioned above are related to the problem of how to transfer the "sticky data". Then it is important to study the development of a new production line from the stand point of information transfer.
Know how of new production line development

In addition to the design information, the know how of new production line development is also a very important information. To complete a large scale development project in limited time, limited budget and limited manpower, it is necessary for a manager to have a good managerial skills (know-hows). Project management is not an easy job which can be done by everybody. Such kind of managerial skills (or know-hows) are also sticky data and it should be transferred to the next generation.

Another kind of information which is necessary to administrate development project is the knowledge of related law, regulations, company rules etc. Transfer of this kind of knowledge is relatively straightforward. However, since it requires a large amount of knowledge to cover everything, there must be some mechanism to enhance the learning.

As we have seen above, to succeed in the development of new production line, it is necessary to solve many sticky information problems.

Kawasaki steel situation

Sticky information problem is also important for the company for many other reasons. Just like other company, Kawasaki Steel has many problems which are caused by the fact that technology is sticky to people.

(1) Problem of Technology Transfer

One problem is that unless we can transfer technology effectively, our options to assign jobs to people becomes very limited. When we move a person who has sticky data, the data itself may be taken away with him from the section where he belonged. That makes it difficult to move a talented person even if it is
appropriate from the career making point of view. This problem becomes more difficult to solve when the total number of stuffs is reduced to increase the productivity of engineers. The more talented a person is, the more necessary he is for the section and the more difficult it becomes for him to be involved in a rotation. The only way to solve this problem is to unstick information from him and to keep only information in the section and to free him.

There is another problem which is caused by the development cycle of a new production line. In the steel industry, there is a long development cycle for new production lines. This cycle may exceed ten years. In this situation, generation gap becomes problem. Some generation had many new production line developments when they were young, but once the peak of new production line development had gone, there was a long period which did not have major new production line developments. The generation who were young in this period did not have chance to learn how to develop a new production line. It was very difficult for the organization to maintain the ability to pursue new production line developments. But after some years later, the other development peak came, however capability and know-how to pursue the development was partly lost by the time and people who had experiences in the developments had retired or transferred to other sections. In such situation, it is also important to unstick data from people and to transfer know-how to the next generation.

By the way, it is often said that user involvement is a very important factor for the successful development of a new production line. However, needs of the operators or maintenance people are very sticky to them, therefore even if we involve them in the development team, the information of their needs is not necessarily transferred to the engineers. Here again sticky information problem is important. To cope with this problem, some people say that it is necessary for equipment department staffs to learn operation much
more. The bottom line of this idea is that it is easier for the engineers to learn operation needs by themselves than for the operators to explain their needs explicitly to the engineers. But how can engineers learn operation? Operators acquired these information from their experience. Should we assign engineers to the production line to acquire same knowledge from experience? This problem is still left to be studied, but it is apparently one kind of stickiness problem about how to transfer sticky user information to the engineers.

Another related issue is that Engineering Department of Kawasaki Steel has focused on the business of transferring operational know-how so far. Theoretically there are three kinds of know-how in the company: know-how of operation, know-how of new product development, and know-how of new production line development. The second and third type of know-hows belong to staff sections. While we don't want to sell the second type of know-how; know-how of new product development, because we want to keep our competitive advantage, we can sell the third type know-how: know-how of new production line development. In order to develop a new production line, it is not enough to go to the equipment makers and buy latest technology. It is necessary to understand the existing production methods in the company, to understand the new technology, and to modify the new technology in order to fit the existing plant environment. Usually this type of engineering is not provided by outside engineering firms but rather should be done internally. But this work requires to deal with many kinds of sticky information. If we could develop the know-how to deal with the "sticky information" problems and to transfer the "sticky information" effectively, we can create an another kind of business chance to sell "know-how of new production line development".
(2) Technology Transfer to Armco Steel Corporation

Kawasaki Steel has started joint venture with Armco to operate Armco Steel Corporation (ASC) in the U.S. To make this venture successful, it is necessary to put both companies' know-how together and to create new know-how tailored for the venture. However if information is sticky to human, we have to transfer many people to ASC, but, after we have reduced number of engineers in recent recession, we don't have enough people to transfer. It is very important to unstick data from people and transfer sticky information efficiently to ASC.

(3) Organizational problem of Equipment Department

Whenever the recession came to Japanese economy, it was always discussed how to reduce the number of supporting staffs. In such arguments, mainly two ideas were dominant. One was to make a central equipment department in Tokyo headquarter and pool smaller number of staffs there and send them to the factory when new production line development was necessary. The other idea was to divide the equipment department into two groups, one was planning group and the other was implementation groups. By this division of the work, it would become possible to average out the peak and bottom of the project work and could avoid staffs to be fixed in one project for one or two years. To think these problems we have to consider the consequence of each measures on the transfer and accumulation of know-how (sticky data). If we adopt first option, it may be difficult for the central engineering department to understand operation needs and update the knowledge of continuous improvement which is done in the plant. If we adopt second option, it may be difficult for the design group engineers to get the feed back of his design, and also difficult for the implementation groups to understand what was the reason of the design. These policy have a strong effect on the information transfer and accumulation in the
company, therefore it should not be discussed only from the efficiency point of view.

How to unstick data.

As we have seen above, it is very important for a new production line development project and for the company to unstick the information and transfer it to a new production line. This is the reason why I choose this subject for the theme of thesis.

In this thesis, I will examine the two of the subsequent major new production line developments of CAL (Continuous Annealing Line) in Kawasaki Steel Chiba Works from the sticky data standpoint of view and try to generalize it to be applicable to the future projects.

My goal is to find the effective way to unstick data and to create a database which can be applied to the future projects. But how to make usable data base (not as a cut flower, but as a flower with root) is a challenging problem.

1.2 Comment on No.3 CAL and No.4 CAL Project

This research is based on the development projects of CAL (Continuous Annealing Lines). I will briefly explain the background of this research using the rest of this chapter.

What is CAL?

Final stage of steel sheet production is CAL. After steel sheet is rolled by cold strip mill, the material becomes very hard and brittle because of the metallurgical change of the material during the process. To change this property, it is necessary to do heat treatment (annealing). In old days, steel coils were piled up and
large bell shape furnace was placed to cover them and treatment was done inside of the bell shape furnace. To complete this process, it took over a week.

CAL (Continuous annealing line) was developed to improve the productivity of this annealing process. It has two uncoilers (payoff reel) and welder in the entry section and connect the end of the first coil to the top of the next coil and treat them continuously in the Nitrogen filled large furnace.

The first CAL was developed for tin plate, because thin and narrow plate was easy to be treated continuously and the tendency of the products treated by CAL to be harder than batch furnace was welcomed by tin plate user. But it was difficult to develop sheet CAL to produce thick and wide steel sheet for cars and steel furnitures, which is processed by deep drawing by user.

History of CAL in Kawasaki

Kawasaki Steel build their first CAL in Chiba Works (No.1 CAL) in 1960s. It was tin CAL. The maker of furnace was Mitsubishi Heavy Industry.

The second CAL (No.2 CAL) was build in Chiba Works more than ten years ago. It was multipurpose CAL which can produce both tin and sheet plate. Kawasaki was late to start to develop sheet CAL and this CAL had a strategic purpose to develop sheet CAL technology in addition to the increase of tin plate production capacity.

After then Kawasaki build their first large capacity sheet CAL in Mizushima Works (Mizushima No.1 CAL). To transfer the No.2 CAL know-how, young engineer Mr. Iida was sent to Chiba Works and studied it.
No.3 CAL project

About two year after completion of Mizushima No.1 CAL, No.3 CAL was constructed in Chiba Works' the No.2 Cold Strip Mill. It was a first large capacity sheet CAL in Chiba and first CAL for the No.2 Cold Strip Mill. (No.1 and No.2 CAL were build in the No.1 Cold Strip Mill). To transfer Mizushima know-how, Mr. Kiihara and Mr. Mega were transferred from Mizushima plant to Chiba. Mr. Kiihara had been an operation manager of Mizushima No.1 CAL since just after the line had been put into operation. Mr. Mega was originally Chiba Works engineer and transferred to Mizushima Works to help test run of Mizushima No.1 CAL and since then he had been involved in initial trouble shooting of the line.

There had been not many large scale investments in Chiba No.2 Cold Strip Mill because large portion of the investments for sheet product was concentrated on Mizushima Works. But because Chiba No.1 Cold Strip Mill was the only tin plate plant of Kawasaki Steel, there were many new production line developments in that plant. Therefore, there were not many equipment department staffs who were used to large scale developments in the No.2 Cold Strip Mill group, then No.3 CAL project was formed mainly by the people who had experience of the No.1 Cold Strip Mill's developments.

In addition to it, because there was no CAL in the No.2 Cold Strip Mill before No.3 CAL, there were no operators who had experience in operation of CAL in the No.2 Cold Strip Mill. To transfer the know-how of CAL operation, several operators were transferred from the No.1 Cold Strip Mill to the No.2 Cold Strip Mill.

Just after No.3 CAL finished its test run, No.4 CAL's development project was approved by the board of directors. Then many equipment department staffs were transferred from No.3 CAL project to No.4 CAL project.
No.4 CAL Project

No.4 CAL was the third tin CAL in the No.1 Cold Strip Mill. But it was more integrated line than earlier two lines. In old plant, the heat treated coil was sent to separate temper mills, however, No.4 CAL integrated mill in it and could finish all processes necessary to be done before packaging. The other difference was that it was designed to be operated at the speed of maximum 1000 meter per minutes (mpm), while No.2 CAL, which had been the fastest CAL in the world, was operated at the maximum speed of 720 mpm. (It means approximately 40% speed up.) In addition to it, the customer needs became to require much thinner and more tender materials, which were much more difficult to produce.

Though there were many challenges in No.4 CAL project, there were many advantages for it. One was that No.3 CAL had just been developed and many members of No.4 CAL project had experience of that project, then they could learn from its experience. In addition to it, the schedule could be managed very well because equipment department section's staffs had just experienced No.3 CAL project and could anticipate what would occur in the project.

The other advantage for No.4 CAL was that there were many talented foremen and leaders in the No.1 Cold Strip Mill and because manufacturing section's manager of No.4 CAL project had been managing the plant, he could involve many talented people from the No.1 Cold Strip Mill floor.

1.3 Structure of this thesis

In this chapter, we discussed overview of many sticky information issues in the new production line development project and in the general context of the company. In addition to it, brief
explanation of the project was given to provide background knowledge.

In the second chapter, we will examine related works from literatures and then briefly discuss the stickiness problem and new production line development.

In the third chapter, we will focus our discussion on the information transfer. First simple information transfer model is introduced and according to it sources of stickiness are discussed. Then we will examine the data gathered from the real development projects.

In the fourth chapter, we will discuss how to cope with the stickiness problem. Since there are many sources of stickiness, there are many methods to cope with the problem. We will attack this problem from both theoretical point of view based on the discussion of different sources of stickiness and empirical point of view based on the data.

In the fifth chapter, we will approach the problem from different angle. We will discuss about the information flow in problem solving and discuss stickiness problem in the problem solving process.

In the sixth chapter, we will examine some practical techniques to cope with stickiness problem. (Of course, there is no general solution to this problem, therefore the techniques discussed here will be focused on specific problems.)

In the last chapter (chapter 7), we will review the sources and solutions of stickiness problem and discuss what was learned from the conceptual, and managerial point of view.
Chapter 2  New Production line Development and Concept of Sticky Information

2.1 Stickiness

Information which is vital for innovation or problem solving is not always easy to transfer. Eric von Hippel said, "Much data in fact have 'sticky' qualities that make them hard or impossible to replicate and diffuse to remote sites." He listed numbers of reasons for the stickiness. "Some of these have to do with the volition of the data possessor, who may simply be unwilling to allow 'proprietary' data to be replicated or transferred for reasons of private advantage.....Other factors have to do with how the data are encoded or embodied in a person, organization, or object, with how they are indexed, and with the compatibility between data transmitter and receiver." (von Hippel, 1990)

New production line development is very important to increase the competitiveness of the company. In such kind of development project, we have to cope with many forms of stickiness of the information. Let us examine couple of examples.

In many cases, such project is accompanied with technological change (innovation), but the original idea developed by R&D or outside vender is not easily transferred into new plant or equipment. M. Tyre explained this fact as follows: "'Implementation is innovation.' [Leonard-Barton, 1987] .....Introducing new manufacturing technology is not simply a question of implementing a well-developed solution, but of managing a problem solving process to adapt existing ideas and create new solutions within a particular environment [Tyre, 1988; Kazanjian and Drazin, 1986; Rice and Rogers, 1980]" (Tyre 1989) To adapt new idea to new environment, it is necessary to transfer the design information from original
developer to the problem solver and it is also necessary to transfer factory environment information from factory to the problem solver. However, such information tends to be "sticky" to the people who know it.

On the other hand, new plant or equipment is not necessarily completely "new". On the contrary, it should be built on the company's accumulated know-hows. But it is not an easy task to transfer many know-hows accumulated in the company to the new plant or equipment. In some cases, such know-hows may be accumulated in many different people who had developed, operated or maintained the existing plants or equipments. In another cases, the existing plants or equipments has been changed many times in the past and nobody have the complete knowledge of the "real" situation of the plant or equipment. In either cases, data is "sticky" to the person or machine.

As shown above, we have to deal with sticky data in the project for new production line development. To gather sticky data itself is not an easy task but, in the practical sense, it is not enough to transfer sticky data to the project. Even if we succeed to transfer sticky data, unless we use it effectively, it is useless. In the broader definition, data is not really transferred or unstuck unless it is effectively used. Therefore, in this report, I will treat those cases, in which data were transferred but not used, as a part of sticky data problems.

2.2 Two phase model of the new production line development project

New production line development project can be divided into two different phases. One is "Design, manufacturing and implementation" phase and the other is "Test run and start up" phase. The main difference between these two phases is whether the real
machine exists or not. In the first phase, there is no machine, therefore the most important problem is how to transfer sticky information to the designers and how to communicate sticky information between designers. In the second phase, since there is a machine in the plant, the most important information is sticky to the machine and the problem is how to bring related sticky information effectively to the machine side and solve the problem.

It is often considered that design phase is the most creative time and the rest of the project is just carry out the plan. However, in reality, the test run and start up phase is as important as design phase. Because of the complexity of the new plant or equipment, it is almost impossible to do perfect design, therefore many problem solvings are left until the plant or equipment is built. The test run is not only to find and to solve the manufacturing errors or implementation mistakes, but also to find and to solve design problems.

In addition to it, there exist windows of opportunity to change (Tyre and Orlikowski, 1990) and once we failed to fix problems while the window is open, it becomes very difficult to fix it later. Therefore we have to consider not only how to transfer sticky information but also how to transfer it timely.

From the information point of view, the first phase is the time to gather sticky information from many different sources and synthesize it into one design of plant or equipment. In this phase, many pieces of information are integrated into "mental model of the plant or equipment" and optimization is done on this "mental model" because actual plant or equipment is not built yet and no one can verify the design until it is assembled. Therefore, there may exist difference between "mental model" and "real" plant and equipment. By definition, "mental model" is very sticky to the designer though it is described in the drawing or program, etc because no documents
have the all information of the "mental model", there is always background information which is not written in documents.

In such "mental model" of the plant or equipment, each part is treated as an ideal function and complicated interactions are often overlooked or deliberately ignored. This may cause problem when the real machine is build because in the real machine, each part has not only ideal function but also unexpected side effect.

In addition to it, if there are more than one designer are involved, they may have different "mental models" of the plant or equipment and each of them may work hard to improve their own "mental models". In this case, it is difficult to find inconsistency of the design because each "mental model" is sticky to the designer and is not visible to the others.

As shown above, the first phase create sources of troubles inherently. The second phase is the time to modify the "real" machine or software to be close to the ideal "mental model". At the same time, many contradictions in the "mental model" are solved. During this phase, both the "mental model" and "real" machine or software are changed and "realistic design" is achieved.

In this phase "mental model" is sticky to the designers and "real" machine information is sticky to the machine, therefore there must be some mechanism to bring both sticky data together. Tyre's "forum" (Tyre 1989) or "templating" (Tyre and von Hippel 1991) concepts are methods to cope with this problem. (We will discuss these methods later.)

Since there are two different phases in the construction project, we have to treat stickiness problem differently in these two phases.
Stickiness found in phase 1

In this phase, main concern is how to find, unstick, transfer, and apply sticky data into the design (or "mental model"). From this point of view, there are four major sources of stickiness.

(1) **Stickiness caused by complexity of data**

It is often the case that necessary information is very complex and it is not useful to transfer only one part of information. Such case occur when the information is consisted of large set of systematic knowledge or it is consisted of set of intuitive judgements which are acquired by experience. In either cases, data is very sticky to the person who have the information.

Generally speaking, in such case, it is very time-consuming to try to unstick data from the person. Von Hippel made a hypothesis, "If data needed by a problem-solver are sticky, related problem solving activity must move to and among loci of sticky data -- perhaps repeatedly as problem-solving proceeds." (von Hippel, 1990) Actually in such kind of project work, following two ways of problem-solving are preferred: (1) Move design task to the person who has sticky data. or (2) Move person with the sticky data into the project. In either way it is avoided to transfer sticky data and just result of the design is applied to the new plant or equipment.

However these approach are not always applicable. First of all, availability of such kind of experts becomes problem. They may be too busy to assume part of the design responsibility of the project. On the other hand, the independence of the parts of the design becomes another problem. If the design is dependent on the design of other parts, it is not feasible to separate one part of design work and ask experts to do it.
(2) Stickiness related to the information transfer channel

When design require many pieces of information from many different sources, it is not feasible to bring all experts in the project, therefore it is necessary to unstick data and transfer it to the project team.

Even if the information is simple enough to be transferred, it is still difficult to actually transfer it. Sources of stickiness related to this area are; (1) Filter or Barrier of sender and/or receiver. (2) Compatibility or incentive. (3) Poor transfer method.

In any cases, "face to face" communication is powerful to transfer data efficiently. However it is not always enough because it may not be possible to unstick all information in the limited time frame.

In this case, involving the person who has sticky data into the project may be a good solution. By involving these people into the project, we can increase his/her concentration and commitment into the problem. ("Forum" concept in Tyre, 1989) In addition to it, we can expect the higher probability of transferring sticky data by simply increasing exposure time of the sender to the receiver. The longer the two people work together, the more possible it becomes that the sticky data is transferred "by chance".

Related to this issue, geographic location has significant impact on the communication (effectiveness of information of transfer). T. Allen studied this issue and proposed to have "non-territorial office". (T. Allen, 1977) When we design a project team, we have to think about not only formal matrix organizational structure but also geographical location of the project team.
(3) Lost data

In practical sense, it is useless if the transferred data is not used appropriately. It is no use blaming each other; "I have told you!.

Generally speaking, the timing of the receiving of the data and the timing when it is required for design does not always match. Therefore the information is stored for some period and then applied to the design of the production line. However if there are too much information to handle (and it is often the case with real construction), some pieces of information will be lost. Even if the information is written on the paper, it may be buried in a huge pile of documents.

To avoid this it is necessary to create a good filing system. Or at least it is necessary to understand the priority of the data and not to lose important informations.

(4) Windows for design

Just like "there exists a relatively brief 'window of opportunity' to explore and change the technology following initial implementation" (Tyre and Orlikowski 1991), there also exists "windows for design" in the design stage. During the design stage, all design parameters are not fixed at one time, but they are gradually fixed one by one according to the interrelation between each parameters and time necessary for manufacturing of each parts. Once we fail to change the design while the "window is open", the cost and time loss to change will increase significantly.

Then we have to concern not only the data itself but also the timing of the data transferred.

Experienced engineers understand the relation of each design parameter and understand the timing when the window is closed for
the specific design parameter. Then "experience" is one solution. The other solution may be "systems thinking" (Senge, 1990) If we have the clear model of the project, we may be able to judge the timing of the events.

Stickiness found in phase 2

Stickiness found in this phase (test run and start up) is mainly related to the stickiness to the new plant or equipment. Many problems which were difficult to predict during the design stage reveal in this stage. Unforeseen interactions between multiple components' designs are often found in this phase.

During this period the most powerful tool to solve the problem is "learning from experience." (Tyre and von Hippel, 1991) By observing the real situation, we can understand the complex situation and we can also understand the problems regardless what background we have.

The one best thing to have real machine is that it "automatically sort(s) relevant from irrelevant details". (Tyre and von Hippel, 1991) Tyre and von Hippel called this effect as "templating". (We will discuss pros and cons about this method in Chapter 6.)

The difficulty of this phase is that "there exists a relatively brief 'window of opportunity' to explore and change the technology following initial implementation, after which the technology and its context of use tend to congeal." (Tyre and Orlikowski, 1991) Therefore if we want to take advantage of the "templating", we have to move quickly before the window close. One solution is "creating forums for change" (Tyre, 1989). However if we want to move quickly, there must be some techniques to increase the speed of problem identification. We will discuss this in Chapter 6.
Chapter 3 Information Transfer and Stickiness of Information

To develop a new production line, it is necessary to assemble many kinds of information (or know-hows) from different sources in or out of the company. However, these pieces of information are not freely transferred. They are sticky to the person or the machine or the location. Therefore, it is important for the development project to unstick data from the sources.

In this chapter, we will examine the different sources of stickiness from the information transfer point of view. First we will introduce simple information transfer model and discuss the stickiness problems caused by each of the element of information transfer model. Then we will examine the cases of two new production line development projects using this framework. Finally we will check how many cases of stickiness problems are reported for each source of stickiness in the real projects.

3.1 Information transfer model

Fig. 3-1 shows our simple information transfer model.

First of all, there are sender and receiver. Sender has information which is useful for the receiver. This information may be a type of information which can be written on a paper or may be a type of information which can not be written on a paper explicitly (tacit knowledge).

There is a information transfer channel which is consisted of Information transfer method, filter and barrier. Information transfer method may be a meeting or telephone conversation or letter exchange, etc. Both sender and receiver have filter on the information transfer channel. Let us define "filter" as an obstacle
which works selectively according to the contents of the information. Purpose of the filter is to select relevant information from many other irrelevant information and/or protect the sender or receiver from the loss caused by undesirable information transfer. Then sender and receiver monitors the contents of the information transferred and try to control the flow of information. Barrier is another obstacle mainly placed by receiver. Let us define "barrier" as an obstacle which works selectively on the specific sender. Sender's credibility or receiver's prejudice can create barrier. The feature of the barrier is that the same information can be sticky or not based on the fact who sends the information.

There is a information storage. Information is not necessarily transferred at the desirable timing for the receiver. The purpose of this storage is to keep the information temporally until it will be used. As shown in the Fig. 3-1, this storage tends to overflow in the real project work, therefore, there is a risk that important information is lost while it is waiting to be used.

In the real project, there are multiple senders and receivers involved and network is formed. However when we pick up the each element, this simple information flow model can be applied.

Fig. 3-1 Simple information flow model
3.2 Stickiness problem caused by each element of information transfer.

(1) Stickiness caused by the nature of information

The first type of stickiness is stickiness caused by the nature of the information. This is caused by the "complexity" of the information. This type of stickiness is further divided into two categories.

(1-1) Systemic knowledge

This type of stickiness is caused by the nature of the information when it is part of a large set of systemic data. To use such information, it is necessary to have whole set of systemic data. It is not only useless but also dangerous to use only part of the data. "Little knowledge being a dangerous thing." For example, If we decide what kind of coating materials to use to protect the roll which is to be used in high temperature, we should not select the material only by the applicable design temperature but we have to consider many other aspects; thermal shock, fragility, wear out, roughness of the coated surface, etc.

There are two ways to cope with this type of stickiness. One is to transfer whole set of knowledge and the other is to transfer the job to the person who has the knowledge.

The first solution: transferring whole set of knowledge is theoretically possible but difficult to do. If we try to ask the person who has the information (expert) to teach his knowledge to one of the project member, it may be possible but it will take long time. It is not feasible to do it for the short term project work. In addition to it if the student is not enough qualified, he may learn only the part of the information. It is dangerous.
It may be good idea to ask expert to write an easy manual about his knowledge. However, it is tedious for him to write everything he knows\textsuperscript{1}. Even if he writes everything patiently, the document contains too much informations and it becomes very difficult for the novice reader to judge which information is relevant to his problem.

It may be easier for the user of the information to build expert system with the help of information technology, but it requires long time and huge amount of money to build it. Is it feasible to invest in such expert system which may be used only several times? (There are not so many opportunities to develop new plant.)

As shown above, it is not feasible to try to transfer whole set of knowledge to the project and this is the source of stickiness of this type of information. However, it may be possible to transfer the whole set of knowledge by transferring the expert himself. This means to involve him as a member of project team. This is the perfect solution to solve the stickiness problem. We do not have to worry about the stickiness of the data. Data comes with the person. However, it is not always possible to involve expert in the project. Generally speaking, such expert is a scarce resource for the company, then he is not always available. In addition to the availability, there is another problem. When we ask expert to do the job, the information may not be transferred to the other members in the project team. In such case, if some problem occurs in that area later, nobody in the project can solve it and we have to ask the expert to help again.

\textsuperscript{1}It may not be possible for the expert to write every thing on paper because his knowledge may not be organized in the manner which enables him to write sequentially or systematically. When he face real problem, it will trigger his memory to retrieve data. However, without such trigger, it may be difficult for him just to write every thing on a piece of white paper.
Then it may be better to transfer just the "result" of the problem solving. This means that if it is impossible to transfer the "information" to the project, just transfer the "task" to the source of the information. By dividing the large task into separate small tasks, it may be possible to "subcontract" the task which require the whole set of the knowledge of the expert. The weakness of this approach is that if the task cannot be "separated" perfectly and it is necessary to interact with the rest of the design work, it will hinder the efficiency of the expert job. Then this method is applicable only to the limited cases.

The other possible way to transfer just the "result" is to imitate the similar design. However, there is few identical design for the production line, then some kind of modification is necessary to apply past design and if it is done poorly, it creates a risk of causing problems later. One of the realistic solution for this problem is to ask expert to check the design\(^2\) or ask him to created standard design, which is useful even if it is applicable for limited range of specification.

(1-2) Intuitive judgement (Tacit knowledge)

Another type of stickiness cased by the nature of the information is that the information itself is very vague and difficult to describe in words or pictures. Intuitive judgement of the experienced people is the typical example of this type of stickiness.

Experienced people can make a better judgement in a shorter period of time. There is no doubt that they have some kind of information accumulated through their experience. But it is difficult to explain it explicitly. In this case it is impossible to unstick data

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\(^2\)It may be more useful to ask him to check the situation or assumption. But to do so, it is necessary to transfer "sticky data" to the expert. It may be another problem.
from him, therefore we have to transfer the person to the project or to transfer the job to the person or to imitate the past design (or use the standard design) However, each solution has the same problems mentioned in the "Systemic Knowledge" section.

(2) Stickiness caused by the nature of the problem

Stickiness can be caused by the nature of the problem. It is caused by the complexity of the problem. There are two kinds of complexity of the problem. One is related to the structure of the interrelation of the system. The other is related to the structure of the organization of the project team.

(2-1) Complex phenomena

Stickiness which belongs to this category is caused by the complex interaction of the elements of the system. It is not too much to say that any one of the design task is related to the other design and we cannot decide or change it without affecting other parts. The problem is that it is not always easy to find which parts are affected by the specific design. If we fail to predict the interaction of multiple design factors, it will cause the problem later.

Although it is difficult to foresee all interactions of the design factors, they reveal once the design is realized as the physical equipment. Problems caused by mismatch of interrelated design factors are found during the manufacturing, assembly, installation, test run, or start-up period.

The important feature of this type of stickiness is that it is sticky to the plant and it is sticky to the timing. Because of the complexity, it is difficult to understand the problem and solve it without seeing the real phenomena (or real machine), therefore it is sticky to the plant. It also sticky to the timing, because it is
difficult to foresee all the problems by the design informations such as drawing or print out of the program, therefore we have to wait until the design is realized.³

To cope with this problem, it is necessary to be "careful" in designing, of course, but it is not possible to prevent all problems by just being careful. Experience may be helpful to foresee more problems up front. The systems thinking or simulation (includes mental simulation) may also useful. However, there still would remain many problems undetected in the design phase. One of the most important task of the test run and start up (or ramp up) is to find and solve these problems. However, "there exists a relatively brief 'windows of opportunity' to explore and change the technology" (Tyre and Orlikowski, 1991), therefore if we fail to solve the problems, it becomes very difficult to solve it later. Then, this type of stickiness is difficult to solve because it is difficult to foresee and once the problem is found, it also requires to be solved in limited time span.

(2-2) Complexity of interdepartmental tasks

This type of the stickiness is almost same as the "Complex Phenomena" mentioned above. However it has additional difficulty caused by the organizational boundary. Some problems are not only complex by themselves but also related to the several organizations in the project. For example, the change in the machine design will affect the layout of the sensor and it will affect the control program and this will affect the design of the control panel. In such case, the complexity is enhanced by the organizational structure, because the cause and result occur at the different sections of the

³In other words, we can say,"we have to wait until the window opens." Regarding to this window concept (Tyre, 1990), we have to remember that "the window will close again."
organization and the necessity of the communication between the
different sections makes the problem more difficult to foresee.

The approach to cope with this kind of problem is same as the
"Complex Phenomena" case mentioned above.

(3) Stickiness caused by the nature of the information
transfer channel

Even if the information is simple enough to be unstuck from
the source, sometimes the nature of the channel for information
transfer prevents it from being transferred.

(3-1) Transfer method

The most simple case is that the difficulty of information
transfer is caused by the selection of the improper information
transfer method. For example, drawing may be a good way to
communicate between mechanical engineers but it is not proper to
communicate with electrical engineer. The other example is that
even if we can not make the maker's engineer understand the
machine trouble by more than one hour's telephone conversation, it
is easy to make him understand by showing the machine and explain
it at the machine side.

As indicated by above examples, it is necessary to select
transfer method carefully to enhance the efficiency of the
communication. And it depends on the nature of the information to be
transferred and the nature of the background knowledge or training
of the sender and receiver. However, it is well known that the "face
to face" communication is one of the most powerful solutions.

(3-2) Geographical separation

Geographical separation affects the information transfer in
two ways. One is that it limits the selection of communication
methods; that is that geographical separation disable to use the "face to face" communication and force us to use less effective method; such as telephone, facsimile, mail etc. The other is that it reduces the interaction of the sender and the receiver because of the low efficiency of the transfer method.

(3-3) Filter

In addition to the problem caused by the transfer method itself, the sender or receiver also creates difficulties of the information transfer. One of the source of the difficulties is the "filter" and the other is the "barrier".

Both of them are related to the judgement of the sender or receiver whether or not to process the information. In this report, we will distinguish filter and barrier. Filter is the judgement which is based on the contents of the information and works selectively according to the contents. On the other hand, barrier is the judgement based on the prejudice or relationship of the sender and receiver, then it works consistently related to the fact who is the sender or receiver, rather than the nature of the information itself.

Three types of filter on the sender side are found ... this research. One is the case that sender misunderstand the needs of the receiver and did not think it is relevant data. The second case is that the sender has some reason that he is not willing to send the specific data, which often happen in the case of information related to failure. The third case is that sender forgets the existence of the information. For example, people often forget to mention too familiar things.

There also two kinds of filter on receiver side found in this research. One is the case when the receiver is reluctant to receive the specific information. For example, the information which will cause the design change will face strong reluctance from the
designer at the later stage of the design. The other case is that the receiver has a strong preconception and will not believe the new information which contradicts it.

Some of these filters can happen simultaneously. It will make the situation even worse.

It is difficult to remove these filers. It is also difficult for the sender or the receiver to know that the other party has filter in his channel. One of the effective way to find and to remove these filters is to put both people together, which enable to use the face to face communication, and increase the time of the contact and richness of the information transfer channels. If we can put both of them in the project team, it is best because it increase the chance of data transfer and it also change the stand point and create mutual interest. Even if we can only put both of them in the same building, it will help a lot because it enables both of them to chat each other. The other way is to include the third party in the communication. It will increase the possibility that the filter is found by chance. However, these methods rely on the chance, in which the information transfer happens by chance. Therefore, we cannot expect them to work always.

(3-4) **Barrier**

Though filter works selectively on the base of the contents of the information, barrier works selectively on the base of the historical relation between sender and receiver. First, there is a historical barrier which is created by the bad past performance of the sender. Once somebody caused serious trouble in the past, it is difficult to retrieve the trust again. In such circumstances, receiver is not willing to listen to the sender. Second, there is a barrier which is created by the attitude of the sender who always sends too much trivial information. In this case, receiver gets tired of the flood of low priority information and he reduces his attention to the
particular sender to the lower level. The third type of barrier is caused by the less familiarity between the sender and receiver. When they meet for the first time, they cannot communicate well. It is because their psychological distance is far. All of us experience, when we meet somebody for the first time, we have trouble to find what to talk and we tend to talk general topics only, however, once we get used to each other, we feel comfortable to talk much more detail. The same thing happens in the business. If it is the first meeting, the talk tends to focus on the prepared, relatively formal agenda and it is rare to talk about related but informal issues. It is difficult to get rich information in the first meeting.

To cope with these problems, it is necessary to establish good relation between sender and receiver. However, it is easy to say but difficult to do. Especially it is difficult to manage. It is useful to try to open our mind. But how can we manage to do it?

One alternative way is to change the setting. It sometimes works to include a member who belonged to the outside of the usual setting, (for example, to bring a person from a different plant), who does not have specific prejudice. But he may be educated the norm by other members, then it dose not always work.

The other way is to put different people in one project. By doing this, the communication between people increase and it may be possible to overcome the barrier.

Anyway this issue is very difficult to handle because it deeply related to the human nature.

(4) Stickiness caused by the mismatch of sender and receiver

Even if all problems mentioned above are cleared, there still exists some problems which is related to the mismatch of sender
and receiver. The main feature of this type of the problem is that it depends on the combination of sender and receiver. Therefore, if we change either the sender or the receiver and leave every other conditions same, the information could be transferred easily.

(4-1) Knowledge compatibility

The compatibility problem occurs when a sender and a receiver have different backgrounds (for example, different discipline, different level of capability or different level of experience etc.). Machine drawing is a very powerful communication tool between mechanical engineers but it is not appropriate to communicate between a mechanical engineer and an electrical engineer.

To cope with this problem, there are three ways. One way is to use face to face communication. The second way is to talk at machine side. The third way is cross education.

The face to face communication is powerful solution. If compatibility problem occurs during face to face communication, the sender can easily detect it and change the way of communication. For example, if the receiver seems to have difficulty to understand a mechanical drawing, the sender can draw some schematic views on the paper and explain it to the receiver.

While face to face communication is very powerful way of communication, it is not always applicable because it requires to bring sender and receiver to the same physical location. Then if both of them live in different towns, it is time consuming and expensive. (However in many cases it pays off.)

The second way: machine side meeting is also a very powerful solution. Seeing is believing. If we can see the real machine, we can explain very complex situation no matter what kind background we have.
However this way has the same problem as the face to face communication because it is one special kind of face to face communication. In addition to it, there is another problem for it. It is impossible to do "machine side meeting" until the real machine is constructed, then it cannot be used at the design stage. However it is one of the most powerful ways of the communication during the installation, test run and start up period.

Closs education is also a good solution. Teach electronics to mechanical engineers and teach mechanical engineering to electronics engineers. It is a fundamental way to eliminate the compatibility problem because it aims to create compatible people.

The problem of this method is that it requires long time and investment in education. In addition to it, it is necessary to teach majority of the engineers. One compromise is to educate small number of engineers and let them work as interpreters, but it is a less efficient way.

(4-2) Incentive

Incentive of sender and receiver have effects on the information transfer. Apparently there are two cases when incentive matters. First, when sender dose not have incentive or do have negative incentive to send information, it becomes sticky. The typical case is that the information is related to the past failure of the sender. If the sender was asked about the past failure, he may be willing to share the lessons. However, if he is not asked about it, he may not talk about it by himself.

The opposite thing happens when receiver will suffer some kind of extra cost by accepting the transferred information. For example, if the sender is the customer of the new equipment and the receiver is the maker of it and assume both of them are talking about the final approval of the design, the receiver dose not want to
listen any comments about their design which require design changes, all they want to listen is the only one word; "approve". In such situation, if the customer says, "If you change the position of the motor to the opposite side of the machine, it will become more easy for maintenance", this information would be neglected.

The other example of the receiver side's lack of incentive is related to the fact that on-the-job training is the most efficient way of training. If we teach the know-how of the production line development to the newly hired engineers in the class room, many of them start to sleep. Even if they dose not sleep and take note enthusiastically, they will forget it soon. It is partly because they does not have strong incentive to get the information. However, if they are assigned to the new production line development project, they have strong incentive to learn and they are willing to listen to the senior engineers and actually learn a lot from them.

(5) Other kind of problems

There are some other issues which are related to the effectiveness of information transfer.

(5-1) Transferred but not used information

If some information is transferred but it is not used, it has no practical value. However in the new production line development project, there are too much information to handle and sometimes important information is forgotten and failed to be used. There are two main reasons for this problem; one is the huge amount of information to be handled. The other is that the information transfer and its use occur at the different timing. The former is obvious. If we receive too much information, very important information may be buried by a mass of less important information. The latter is related to the concept of "window of opportunity for design", which means each design parameters has a relatively narrow timing to be fixed or
changed and each piece of related information can only be used at that timing. Therefore, if the piece of information is received too late after the timing, it cannot be used. To the contrary, if the piece of information comes too early before the timing of use, the receiver has to store the information and in this case there is a risk that the information will be lost.

Good filing system may be one solution. But it is not enough that the information is filed neatly. It should be easy to use. Unless it is used, the information becomes "sticky to the file". To avoid to miss the timing, there must be some kind of "automatic alarm" which let us know the timing comes (M. Tyre in personal conversation, 1991). One difficult problem to develop such "alarm" is that its timing cannot be predetermined to the specific day. It should be determined by the context of the other design progresses. To do this, we have to know the logic when "the window of opportunity for design" opens, but it still to be left for the future study.

One compromise is to manage the information with priority and to avoid to lose "important" information. However, it still have a problem how to know which information is really "important".

(5-2) Update of information

Another kind of problem occurs from the "duality of information". The real know-how information of the production equipment is embodied in the machine. At the same time construction information or modification information is left to the persons who did the work or in the documentation of the project. When we want to get the information, it is much easier to get it from the person or documents than from the machine itself. However, the equipment may be modified several times later, then the information accumulated in person or document may not represent the real situation of the equipment. Then we have to
develop some mechanism to update the information perfectly or we have to do reverse engineering on our own equipment. Either way is difficult to do with 100 % accuracy.

(5-3) Unpredictable effect

There is one different type of problems which make the situation more difficult. That is a synergy effect. When we design a work team, we implicitly expect to have some synergy effects between the members. However such kind of effect is difficult to predict or control. Therefore, if we control the information transfer too tightly, we may get the high efficiency in the designed way of communication but we may lose opportunity to get synergy effects. If we want to enhance the synergy effect, we have to put "irrelevant" people together and to create relaxed atmosphere, but it tends to end up less focused and low productive meeting. Therefore some balance is necessary.

3.3 Case study -- Stickiness in the new production line development

In this section, we will examine the concept of stickiness of information in the context of the real construction projects.

Original data was based on the author's experience of two large scale production line development projects of steel making plants. From these projects' experience many descriptive data which are related to the information issues have been extracted. (See Appendix for full data.)

We will examine and analyze the concept of stickiness of information by using these descriptive data. This chapter is divided into nine sections according to the types of the stickiness of information.
A. Complexity of information

Information becomes sticky when it is complex.

A-1 Systemic knowledge

When the information is backed up by large amount of systemic knowledge and if it is difficult to separate it from the rest of the background knowledge, it becomes sticky.

Case example: Case #3F-2

Rollers in the furnace should have special coating to prevent surface defect of the strip (product). This technology had been developed and accumulated in maintenance department in Chiba Works. Mr. Kasai, assistant manager of maintenance section, was the key person of this technology. I asked him to write specification of coating for No 3CAL's furnace.

Historically, this technology was developed by maintenance section, because after Chiba's No.2 CAL had been put into operation, the surface defect of the products caused by the small projection built on roll surface became major quality problem and to solve this problem the coating technology was developed by maintenance section.

To decide the specification of roll coating for No.3 CAL, wide range of knowledge of the coating materials was necessary, (for example, characteristics of materials, applicable temperature, resistance to the thermal-shock, the surface roughness after coating, etc.) It was difficult to transfer all of these pieces of information to me, while it was easy to transfer the furnace specification information to Mr. Kasai because he knew the existing CALs very well then he had background knowledge to understand the new CAL.

In this case, roll coating specification was decided by the expert who was not a member of the project. The reason was that the task require systemic knowledge while the task had a few interrelations between other tasks.

The task to write roll coating specification requires the following knowledge; (1) environmental specification: furnace temperature, strip temperature, temperature change ratio, contents of surrounding gas, (2) functional specification: surface roughness,

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4 His office was located from 2 or 3 miles away from the construction site.
life of the coating, hardness of the coated surface, (3) information of characteristics of materials: applicable temperature, resistance to the thermal shock, chemical reaction with the surrounding gas, resistance to the ware out, (4) process knowledge: how to control surface roughness, range of the producible roughness of the alternative process, (5) quality control knowledge: what kind of tests to require, (6) administrative information: budget, schedule.

Among these information, project team had (1) environmental specification, (2) functional specification, and (6) administrational information. All these information were less sticky, less tacit and less interrelated; they could be written on a piece of paper and they could be decided from the fundamental specification of the furnace without interaction with design of other parts.

The expert had (3) information of characteristics of material, (4) process knowledge, and (5) quality control knowledge. These information were not tacit because it is possible to write down these information on paper at least theoretically. (Actually subset of these information was written on pieces of paper as a specification document for purchasing.) However it was not easy to transfer these information to the project, pertly because there were no text books which had these information, and partly because it was difficult to use these information appropriately. Let's examine these points further.

The expert had systemic knowledge, however it was stored "systematically" in his head not in the notebook. He had acquired these information during his long career. He may have studied part of his knowledge from coating technology handbook. He may have learned part of his knowledge from bitter experience of failure. He may have acquired part of his knowledge from presentation of the vendors. There might exist separate documents each of which contained pieces of these information but there was not a single document which had as systemic information as he had. It might be
possible for the project to find and study all these information and solve the problem by themselves, but it was not practically feasible and not efficient way to accomplish the mission.

What if the expert had written down every thing he knew on a text book? It might have been still difficult for the project team to do the task because it would have been difficult to use the knowledge appropriately. The expert knowledge was not a specific knowledge which was only applicable to the CAL project. It was rather general knowledge which could be applied to the continuous casting equipment, tension reel machine, scrap press machine, etc. Then even if the expert knowledge had been written on a handbook, it would have been still as difficult for the nonexpert to use it appropriately as user’s manual of a personal computer, because it would have had too much information which were irrelevant for him and he could have not known where to read to get the answer.

In this case, the expert knowledge were sticky because of its systemic nature, while the project knowledge was transferable. In addition to it, the task could be neatly separated from other project work. (As far as his specification meets all design requirements, and could be implemented within budget and time limit, there was no interference between that task and rest of the project tasks.) Then it was a good strategy to transfer the task not the sticky information.

There was one risk to transfer task not information. That is if some problem happened later, nobody in the project could solve it because they just got a solution not a way to solve it, then they had to ask the expert to solve it again. However in this case the expert was a maintenance section staff and after the line was constructed, it would become his job to take care of the line trouble, then there was no problem. (However it was a special case. It cannot be generalized.)
A-2 Intuitive judgement (Tacit knowledge)

When the information involves tacit knowledge, it also becomes sticky.

Case example: Case #3F-9

The profile of the furnace roll was important know how and it differed from line to line. I asked Mr. Oota, assistant manager of our project, who was a staff of the No. 2CAL, to decide it. He decided it based on Mizushima's design and modified it with No. 2CAL's experience.

There were no established theory to determine roll shape. It is decided by try and error. And it was regarded as one of the most important know-how in CAL design and kept secret to the out of the company. Mr. Oota had experience of designing it because one of the most important task of manufacturing engineer was to decide the roll shape whenever new products or new operation method was introduced in existing CAL.

There was no quantitative model to design roll crown, but the qualitative relation between roll crown and line trouble was known. If the crown was too small, the strip would start snaking at the high speed operation. If the crown was too large, the strip would collapse at the high temperature section. The risk is enormous. Once such kind of trouble occurred, it would take long time and huge amount of money to fix it because it would require to pull out many rolls from the furnace, to remove expensive coating, to reshape them, to apply coating, and to install them into the furnace again.

In this case there was no quantitative model to design roll crown, but the qualitative relation between roll crown and line trouble was known. Given it was impossible to design theoretically and there was no identical line to imitate, the best way to reduce the risk was to ask expert who had experience of design of roll crown for other line. He might make bad design but the probability of his success in design was higher than that of other people who did not have experience.

In such case the expert could use the design of the other line as a base and then try to modify the design to meet the special need of the specific line. The direction of the modification was clear because we had qualitative model, but in order to decide how much he should modify it, he had to make intuitive judgment. He seemed to have intuitive model of the sensitivity of the modification of the
design to the performance. Such intuitive model is tacit and difficult to transfer to the others.

In this case the project had an expert in it and he solved the problem.

Following case is another one which is related to the tacit information issue. In this case the information is much more closer to art than science.

**Case example: Case #3G-6**

Entry and delivery section’s success determined by the accumulation of small cares in the design and test run because the main trouble in this section is that strip is caught on the frame of the machine or slit between conveyers. Such trouble can only been solved by careful examination of layout, and problem detection and modification during the test run.

Because there is no theory in this field, an experienced mechanical engineer is necessary. In No.3 CAL, Mr. Nemoto was very good at such task. He designed entry section and used special conveyer to handle scrap but we failed to use that kind of conveyer in delivery section because it was designed by young engineers (Mr. Muramoto and I) and did not know it. After we found that he used special conveyer in the entry section, we complained him why he did not teach us but it was a commonsense for him and he could not imagine that we did not know it.

The main difficulty in the entry and delivery section of the CAL was that in both section the strip was not continuous and we had to handle the free end strip, while most part of the line dealt the strip in continuous manner. Such free end could have many shape and tended get into any narrow slit and stuck there. Therefore the most difficult thing to design in the entry and delivery sections were how to prevent strip jam.

The only known rule was "Don't make any gap. Strip goes into surprisingly narrow gap and jams." and "Keep the pass line wide open. If you put beam, pipe or whatever, strip stick to it and jams."

Experienced people know many trouble cases and solutions, then they can avoid such problems or easily fix them.

Can such expertise be transferred to others? The answer is Yes and No. Each element of good design such as special conveyer good to handle scrap could be listed in documentation and make it standard design. In this sense, it is Yes. But we can't transfer the ability to detect potential problems intuitively. In this sense, it is No.

In this case there was no quantitative model to solve the problem. The qualitative model (or rule of thumb) is, "Don't make any
gap. Strip goes into surprisingly narrow gap and jams." and "Keep the pass line wide open. If you put beam, pipe or whatever, strip stick to it and jams." It was almost impossible for young engineer to apply these rules because it was too vague. He just ignored it or became paranoia.

Experienced engineers could judge whether the design was acceptable or needed modification to prevent jamming. They seemed to have mental models to judge what kind of gaps will cause trouble or how much clearances were necessary for the specific point of the line. Such model is tacit and therefore sticky.

To deal with this problem, project team were consisted of experienced engineers and young engineers and assign experienced engineers to entry and delivery sections. The solution was same for this case as "the roll crown case": to involve expert.

In both cases above, involvement of the expert was apparently the easiest way to solve the problem. But it is not always possible to do it because the appropriate experts may not always be available. In such case, is it possible to ask external expert to solve the problem? It depends on how much information should be transferred to the external expert. Generally speaking, it is more difficult to transfer the task to the expert than the systemic knowledge case because we cannot select the necessary data to transfer; we don't know what kind of information is necessary to do "intuitive" decision. It means we have to transfer as much information as possible to the expert and such information may include "sticky information" but it is difficult to do by definition.

The other alternative is to ask expert to be a part time member of the project. It reduces the load of expert compared with the full time involvement and it increases the easiness of information transfer compared with the external consulting case. It seems to be a good solution, but we have to be careful because it
may have the weakness of both methods. (It may end up with consuming unexpectedly large amount of expert's time and may create confusion caused by insufficient level of communication between project members.)

B. Complexity of problem

Information becomes sticky not only when the information itself is complex but also when the problem is complex.

B-1 Complex phenomena

There are some problems which are inherently complicated and difficult to solve them before they actually occur. Example below indicate the stickiness of information which is caused by the complexity of the problem.

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**Case example : Case #4M-3**

We had a trouble of dropping rolls from roll changer in No.3 CAL project and I was very careful to prevent such kind of trouble in No.4 CAL. During the design period, I found a possibility of pushing out the rolls when roll changer moved toward the mill in the preparation sequence of roll changing(See Fig. 3-2) and added sensor (See Fig. 3-3) to stop the machine whenever it detected rolls on the track.

But during the test run, this sensor cause a trouble to stop the flow of sequence just before roll changer reached in front of the mill because at that position the sensor of the roll changer detect the roll which was placed in the mill and it automatically stopped the sequence. To solve this problem we changed the use of this sensor as an start condition (not as an operation condition)

But unfortunately it could not prevent the accident which happened later. That accident occurred when operator put new rolls on the pull out position on the roll changer by mistake and started the roll changing sequence. (See Fig. 3-4) This was exactly the same problem which I predicted earlier. However the interlock logic did not work because the sensor did not detect the roll at the start timing because the roll was place slightly out of the sensor's range. Soon after it started to push out the rolls, it detected them but because we changed the logic not to work after it started, it could not prevent the accident. After we learned lessons from this accident, we changed the sensor to the one with longer sensing range and changed the logic to stop the machine whenever sensor detected the roll up to the point where it reached very close to the mill and detect the roll in the mill.
The situation described in this case is a little complicated. First, design team found the potential problem from their past experience. (Problem identification Level 1) Then they added sensor and interlock logic to prevent it from happening. (Problem solving Level 1) However, they found the problem of the machine to stop in front of the mill. (Problem identification Level 2) They tried to solve this problem by simply changing the logic. At that time, they thought it should be start condition\(^5\) not operation condition\(^6\) because they simply believed that if there was no roll when the machine started, it could not happen that suddenly roll appeared on the way of the machine. (Problem solving Level 2). Unfortunately, they experienced the accident and found their logic was not strong enough to prevent the problem. In this case if the sensor was placed a little closer to the roll, it could have detected it. But if the success or failure of the logic depends on the subtle position of the sensor, it is not reliable enough to use in the factory environment. (Problem identification Level 3) To solve this problem fundamentally, they change the sensor to the one with longer sensing range and changed the logic to stop the machine anytime until it reached close enough to the mill. (Problem solving Level 3)

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\(^5\)Start condition is a interlock which only applied when the machine starts. Then once the machine starts, even if the condition changes and condition of interlock is established, it will not affect the machine.

\(^6\)Operation condition is a interlock which is applied always during the machine is moving. Then whenever the interlock condition is established, it stops the machine immediately.
1. Initial Position

2. Move toward the Mill

3. Catch the rolls

4. Pull out the rolls

5. Move back
Fig. 3-2 Roll change sequence

Fig. 3-3 Sensor to detect rolls

Fig. 3-4 Situation of the accident

Operator put new rolls here by mistake.

1. Initial Position

Work rolls were pushed out and hit the ground.

2. Move toward the Mill
Throughout these problem solving, the fundamental problem was same but the level of the problem solving was different. At the first stage they found the problem and solved it at the functional level. The character of this level's problem solving is that it is function oriented (or surface level). If event "A" is the problem, put sensor to detect it and prevent event "A" from occurring. (Level 1 problem solving.) Then at the second stage, the real situation revealed the imperfect part of the logic. Their original solution was so simple that it caused unexpected side effect. Then they modified the solution to adapt to the reality. The character of this level's problem solving is that it incorporate the complexity of the problem, for example side effect of the solution, interference of the components, etc. (Level 2 problem solving) At the final stage of the problem solving (Level 3 problem solving), the reliability or stability matters. In the real situation, the system are exposed to the many fluctuation factors, for example human error, precision of the installation, environmental change etc. Definitely the system have to keep its function regardless of these changing factors. The character of this level's problem solving is that robustness of the system matters.

Let us summarize this argument from the stand point of complexity of the problem. First level problem solving is simple functional level. Second level of problem solving deals with systemic (or logical) complexity. Third level of problem solving deals with the complexity caused by the fluctuating environment.

When we think a problem in our head, we tends to think it at the functional level and try to think is as simple as possible. It is difficult to check every possible interferences or side effects in our head. We are not good at exploring around many possible cases in our mind. In addition to it, we tends to neglect the fact that the real world does not move as designed. When we design a interlock logic,
we assume that the sensor always detect the signal, but in the real world it can fail to detect the signal by many external factors. It is almost impossible to understand all these factors in our mind and solve the problem.

The higher (or "deeper") the level of problem solving is, the more difficult to anticipate it at the design stage. Some of the higher (or "deeper") level problems may be solved by the experience, creativity or contingency at the earlier stage. However quite a few of them would remain until the test run or real operation stage.

### B-2 Organizational complexity

#### Case example: CASE #4D-3

In No.3 CAL test run, we experienced that after we started to use oiler (the machine to spray oil on the surface of steel plate to prevent stain), the strip tended to slip after shear cut. It caused the measuring error of the strip position and the trouble to separate the top of the next coil from the scraps.

In No.4 CAL design, we (mechanical engineers and electronics engineers of Kawasaki Steel) decided to put additional set of pinch rolls and measuring rolls to improve the accuracy of the gate switching. (See Fig.3-5) This decision was announced to both machine maker and electronics control vendor. But electronics vendor's engineers did not use the sensor on measuring rolls for shear cut control on their own decision. The reason was that electronics control vendor used subcontractor for the shear control and both of them wanted to have separate sensor for their use. The electronics vendor's engineer decided to use measuring rolls' sensor for shear control, pinch rolls' sensor for strip positioning control. But our original intention was to use measuring rolls' sensor (which can measure more accurately) for strip positioning control to improve the accuracy of gate switching.

Though we knew the problem and installed measuring rolls, electronics vendor's engineer made a decision from different point of view and we could not utilize the No.3 CAL experience.

In this case the source of the problem was organizational complexity. First Kawasaki Steel's engineers knew the problem and decided to add the measuring rolls to the design and this decision was announced to the electronics vendor's engineer. But he had his own problem to solve. He needed to have separate sensors for the control of the machine. Then he found there was extra sensor and
decided to use it for the shear control purpose and he used another sensor for his own use. If he had understood Kawasaki Steel engineers original intention very well, he may not have used it.

This case illustrate that if there are multiple decision makers are involved in the project and information (or decision) is transferred from one to the other, it may be changed because of the different priority, different value, different needs or different level of understanding.

![Fig. 3-5 Schematic Diagram Around Shear](image)

From the mechanical engineers point of view, he noticed the problem and he enforced the solution to the machine maker but he could do nothing to the electric control vendor because it was out of
his control. In this situation, solution overlapped different organization and no one could control both of them. Under such condition it was difficult to ensure the decision was carried out properly. Unfortunately in the case presented in this section, one of the organization failed to enforce it or changed their mind and the effort of the other organization was wasted.

C. Filter and barrier

In the preceding two sections, we dealt with the stickiness caused by the nature of the information or problem. In this section, we deal with the stickiness caused by the filter or barrier\(^7\) of the sender and/or receiver.

C-1 Filter of sender: Misunderstood relevancy

Information will not be transferred if the sender think it is irrelevant to the receiver without contingency. The following case illustrates this situation.

| Case example : Case #4G-16 |

During the test run, one hydraulic valve broke. When we opened the casing, we found that the inside of the valve had corroded. Then someone remembered that he saw this valve stand was flooded in heavy rain during the installation. This information was not reported because he did not recognize the significance of the information. (He thought it did not matter because the specification of the valves were water proof.) After this trouble, we checked all valve stands which had possibility to be flooded according to his memory and found a few valves which had corrosion and replaced them.

In this case, the person, who saw that the valve stand was flooded by water, did not recognized the significance of the event and did not transferred information to others. Of course, he thought

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\(^7\)In this report, "filter" and "barrier" are used differently. "Filter" works selectively on the base of the contents of the information. "Barrier" works selectively to the specific sender or receiver.
it was extraordinary situation but he thought it did not matter because the valves were water proof type. As far as the (possible) sender does not recognize the importance of the data, it will not be transferred.

Similar thing often happens when people go to see an expert and try to get advice, the amount of information which is stored in the expert's head is enormous. Then experts tends to give information which seems to him to be relevant to the listener. Information will not be transferred unless the sender thinks it is relevant to the receiver.

C-2 Filter of sender: Reluctance

Another type of stickiness is caused by the reluctance of the sender to send a specific type of information. The following case illustrate this kind of situation.

**Case example : Case #3F-6**

Mr. Kaihara (who was one of the No.3 CAL project member) was an assistant manager of Mizushima No.1 CAL when that line started its operation. He knew that at the beginning stage of Mizushima No.1 CAL there were many minor explosion at the pilot burner (though these problems were solved later.) Mizushima's pilot burner was a premix type, in which fuel gas and air was premixed sent to the each burner. Then when burners were not adjusted well, they could cause such troubles. We decided to use nozzle-mix type burner which had separate piping for fuel gas and air to the nozzle to avoid this problem. (However, it increased the amount of piping which caused increase of construction cost and time.)

In this case, Mr. Kaihara had hand on experience of Mizushima No.1 CAL project, therefore he knew the initial trouble about pilot burners. However unless he brought this information to the project, it was difficult to get such kind of information because nobody

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8In this case, the sender himself was a receiver when he saw that the valve stand was flooded. At that time, he had failed to receive the information as important information which should be transferred to the others.
wants to talk about his trouble or failure. If the failure and trouble is very serious and causes a significant damage to the company, it is difficult to hide it and everybody knows it. But if the trouble or failure is minor and has been solved at early stage, such information tends to be kept secret locally or at least is not reported officially to the headquarter (because it is not necessary to report it if it has been solved.) In such case, information becomes very sticky because sender is very reluctant to send it, while such kind of information is most useful for the receiver.

In the specific case shown above, this information was brought by the insider who had been a member of previous project and then was assigned to the new project. He had a strong motivation to transfer the information because he did not want to repeat the same problems. Generally speaking, if we want to get such kind of information, it is useful to involve former project member in the new project or to learn such information through personal relation from the insider. However it is difficult to get such information from regular official route.

C-3 Filter of sender: Given up problem

Sometimes information becomes sticky just because the sender cannot remember the information explicitly. The following case shows this type of problem.

Case example : Case #3F-7

Mr. Kaihara noticed that Mizushima No.1 CAL's layout of staircases was not good for operators to walk around. They were not placed on the routine machine examination route, therefore operators had to go forward and back to find staircases. Although it was very inconvenient for operators, we did not hear this complaint from operators when we visited Mizushima plant. Since I could learn this information from Mr. Kaihara, I decided to be careful to layout stairs to improve the movement of people.

In this case, the information was sticky and might be available only from Mr. Kaihara who noticed this problems. Because once the line was put into operation, operators started to think the situation
as given. Of course they might feel uncomfortable about the situation but they didn't report it because they knew that it was impossible to change whole structure. It was no use crying over spilt milk. Therefore they could not recall the fact when new construction project members visited the plant.

In addition to it, even if new construction project members were given a plant tour, they could not notice it because these problems only could be found by the people who always walked around the plant. The tourist who just walked through the plant with guide would never find them. Mr. Kaihara noticed the problem when he took over that line and he tried to fix it but he couldn't. From this experience he remembered the problem very well and could transfer the information to Chiba's No.3 CAL (the new plant).

This case shows that if the problem is daily but difficult to solve, people get used to it or give up to change it, then such information becomes sticky because it is difficult to remember and difficult to transfer when somebody visited them. In this case, only Mr. Kaihara could tell the information because he did not get used to it and remembered it very well.

**C-4 Filter of receiver: Reluctance**

If the sender tries hard to send some information, sometimes receiver is reluctant to receive it. The following case shows this type of stickiness.

**Case example : Case #3G-5**

When we wanted to change the design of the machine to improve operability or maintainability, maker's engineer often said that it was impossible to do it. In such case, the best way to persuade them was to show them the way to solve the problem. Of course we did not design by ourselves but it was very important that we could show them a conceptual design. It was not necessary to be a precise drawing. Schematic diagram written by free hand was often useful enough. If we could show them the fundamental idea to solve the problem and if they agreed with it, they worked hard to make it real solution. However if we did not have an idea about how to solve it and just ask them to solve it from
the scratch, they tended to reply that though they tried hard to solve it, it was impossible to do it.

One of our job was to transfer our requirement (user information) to the reluctant receiver (maker engineer). Maker engineers did not like to change their original idea or design because of the time constraint, budget constraint, or simply not knowing the importance of the information. If we wanted to remove reluctance in receiver side we had to prove the feasibility and advantage of our idea, however to do this it was necessary for us to have high engineering ability.

This case shows that if information has negative impact to the receiver (for example it will cause extra cost or effort), the receiver becomes reluctant to receive it and information becomes sticky. The problem is that this judgement tends to be done according to the receiver side's needs regardless the importance of the information to the total system performance.

In the case above, they tried to reduce such reluctance by providing feasible solution with the information. In more general situation, this kind of stickiness should be considered with the motivation or incentive of the receiver.

C-5 Filter of receiver: Preconception

When receiver has strong preconception, new information which seems to be duplication tends to be ignored. Following case shows such kind of situation.

Case example : Case #3G-9

In No.3 CAL project, the delivery section and the mill section were purchased from different makers. At the first design, the path level (the level of the strip path from floor) was decided to be 1000 mm. But during the mill design, we change the level to 1100 mm to make it easy to design. On that time I failed to change the path level of the delivery section and could not find the mismatch of the levels until installation.

The reason why I could not find that I failed to transfer the information was that it was very fundamental specification and once we started the design, I never checked it again, while almost all drawings had path level written on them. I did not have any doubt about it and did not try to check it. (Strong preconception)

The another reason was that the two section was purchased from different makers and drawings were drawn by each of them only for each of the section. Therefore, no
This case shows that once a receiver established strong preconception, he will not accept the related information and check it. Many pieces of information which indicate the existence of the problem appeared on the drawings many times but he did not have any doubt about his preconception and overlooked them.

C-6 Filter of both sender and receiver

If both of the sender and the receiver think that one kind of information is not necessary to be transferred, it will never be transferred. Following case shows this type of problem.

Case example : Case #3F-10

Large fan of the furnace broke during the test run because of poor design. This fan was purchased by Mitsubishi Heavy Industry, who build the furnace section, from small fan maker, which had already bankrupted by the time of trouble. After this trouble, Mitsubishi checked all other fans' design and replaced almost all fans.

We (Kawasaki Steel engineers) never tried to check the detail design of fans because we regarded them as established units which could be purchased as an functional unit ( just like pumps or cylinders or bearings ) We did not asked Mitsubishi people about whom they purchased those fans from. Even if Mitsubishi had informed us the name of the fan maker, we could not judge whether it was acceptable or not. We trusted MHI's selection of the fan maker. However after the trouble, some people criticized us why we did not controlled the Mitsubishi's purchase decision. As a hindsight, we thought we should have checked it. If we had known that they bought them from very small companies, we could have asked them to check the design thoroughly, at least.

This case shows that if both of the sender and the receiver think that one kind of information (the name of the fan maker) is not necessary to transfer, it will never be transferred but such judgement is not always good and some important information may be missed to be transferred.
C-7 Barrier on receiver

Sometimes information transfer becomes difficult because receiver do not want to listen to specific sender (barrier). The following case shows this situation.

Case example : Case #3F-3

Regarding coating technology, Chiba Works had used Union Carbide as only supplier because the competitor, Tokaro once had quality trouble in the past and since then nobody dared to try to use them as supplier. On the other hand Mizushima Works preferred Tokaro because of the good service and low price. Mr. Kaihara, manager of manufacturing group of No 3CAL project, who came from Mizushima Work, initiated comparison study of both companies' coating material with Mr. Kasai, the key person of Chiba Work's coating technology. As a result, No 3CAL adopted both types of coating and reduced the cost by competition.

This case shows that once a barrier is created by past trouble caused by the specific sender, it is difficult to overcome the barrier. In this case, this barrier was broken by one manager who did not have such prejudice but until that time the vender could not transfer information about their new technology and improved performance over the barrier.

C-8 Incentive of sender

If the sender does not have strong willingness to transfer the information, it becomes sticky.

Case example : Case #4G-2

Makers' engineers are talented to do accurate design work, however sometimes make big mistakes in the assumption level. We always try to check their assumptions, rather than detail design. (There is no time and no capability to check every details.) But in these days, sometimes they make mistake in design. Mr. Narumi said that in old days, there were good checking system in the maker. Many managers checked the mistakes before final design sent to us. But in these days, they reduced the number of designers and managers do not check at all. They just sign. They should be shamed that many careless mistakes are found by customers.

This change made the check more difficult because the drawing which was not checked by anybody other than the designer was not easy to read. In old days, during the
drawing was checked by many people, the vague description was changed and additional section sight was drawn. Then the drawing became easy to read. The other problem was that the person who drew it couldn't find mistake as well as the other person. Then the quality of the drawing went down and it contained many mistakes, which made it more difficult to read.

In this case, maker tried to increase the productivity of the engineer and reduced the number of people who checked the design. This caused that the drawing became more difficult to read and sticky data became much more sticky to the person who designed it.

C-9 Incentive of receiver

If the receiver does not have incentive to receive the information, it also becomes sticky.

Case example : Case #4G-9

In Kawasaki, a construction project had been thought to be the best chance to educate young engineers, because they learn seriously and they were exposed to good chances to learn from many experts who gather in the projects.

The problem is there are not so many big projects to educate all new engineers.

This statement is related to the fact that it is difficult to teach young engineers in the class room training. If the receiver is not serious about receiving the information, it is difficult to transfer it.

C-10 Credibility of the sender

The credibility of the sender is one of the important factors of the source of the stickiness. Following case shows this situation.

Case example : Case #4G-3

If we tried to avoid the same problems of existing line in the new design and if we didn't know the theoretical cause of the problem, we had to guess and took risk to try to do something. In such situation, operators and manufacturing engineers often provided us good information and assumption of causal relation but we couldn't !00% rely on their suggestions because sometimes their assumptions were superstitious and often their solution was just try to put some equipment and to remove it if it did not work. Such approach caused cost up and was harmful because it consumed the space and effort to be
devoted to more useful equipment. Then we had to be careful to find the true meaning of their suggestions. But the most difficult thing was to pick up a very important piece of information from the many pieces of superstitious information.

If someone always say less important thing, nobody listen to him carefully. However very important user information tends to be buried in the flood of superstitious information. Since it is difficult to keep our mind always open, important information may be overlooked.

**C-11 Psychological distance**

The relationship between sender and receiver has effect on the stickiness of the information.

I often experience whenever my mother in law call my house by telephone, I can talk with her friendly but I found the amount of the information is not large. To the contrary, I am always surprised how much information my wife gets from short telephone conversation with her.

**Case example : Case #4G-18**

When we designed utility pipeline for No.4 CAL, we had to check our company's rule for utility design which was decided by Utility Group in energy department. In that time I asked Mr. Nakajima one of our project member who belonged to Energy Technology Section of energy department to check the rule. Energy Technology Section and Utility Group were totally different sections while both of them belonged to energy department. However, because I did not have any acquaintance in the Utility Group, I thought it was easier to ask Mr. Nakajima to check it. He was very corporative and gave me an answer within the day.

In the above case, the difficulty of the information transfer depends on the relationship between sender and receiver. Mr. Nakajima was a member of the same department and staid in the same large room with the Utility Group. Therefore it was relatively easy to get the information. If sender and receiver have intimate relationship, it is easy to get information but if they are stranger, it is difficult to transfer the same information.
D. Knowledge compatibility

Same information can be sticky or not, depending on the nature of the sender or receiver. In this section we examine this type of problem.

D-1 Knowledge compatibility

If sender and receiver have different background, some kind of information becomes sticky.

Case example: Case #3F-12

In No. 3CAL project, we contracted with Mitsubishi Heavy Industry (MHI) to do joint research to develop new thermal control method for CAL, however the result was not very good. Because MHI’s representatives were control engineering researchers and tried to apply latest control theory without thinking the nature of the production line. On the other hand, our representatives were not all control engineers and very skeptical about the theory and required to apply more simple logic. Both of them could not reach agreement at the most fundamental level and spent time arguing and finally made compromise which both of them were not satisfied with.

Mitsubishi people could not convince Kawasaki people. They believed that their theory should be useful in this case. They might think it was too technical to explain us or they simply believed in the theory because the new theory was one kind of fashion those days and was applied to many fields and proved to be useful. On the other hand Kawasaki people rejected Mitsubishi people's idea basically intuitively. Kawasaki people’s intuition might have been prejudice or superstition, however I believed that Kawasaki people had sensed some kind of truth intuitively because in spite of the different engineering backgrounds, all of the experienced and best engineers in Kawasaki thought the model which was proposed by Mitsubishi people was not applicable to their production line.

It made the problem more complicated that the validity of the theory can only be proved after it was developed and put into operation, therefore, both of them argued the problem with no answer.

In this case both of them had strong belief but could not transfer the information to others because of the difference of the background. Generally speaking, it is difficult to transfer information between people who have different background and training.
E. Transfer method

Stickiness of information can be caused by the transfer method.

E-1 Difficulty caused by the limitation of transfer method

Each transfer method has its own limitation on the richness of transferred information.

Case example: Case #4E-2

In the test run we used transceiver or intercom to communicate from machine side to the electric room where Hitachi’s software engineer debugging. The communication was extremely difficult because we had different engineering background, we were geographically separated and we communicated through verbal communication only. (We couldn’t draw picture, we couldn’t point the machine.) Whenever we found difficulty to make the software engineer understand the problem, we asked him to come to the machine side and showed him the situation and explained it to him. It was the fastest way to do the job.

Even if we want to send the same information, the selection of the transfer method has a strong effect on the efficiency of the information transfer, which is equal to the stickiness of the information.

E-2 Geographical separation

Geographical separation also increase the stickiness of the information.

Case example: Case #3G-10

In No.3 CAL project, the construction site was far from the equipment department building (approximately 30 minutes drive), then we built temporarily office next to the construction site. Both mechanical and electrical section people moved in the building but instrument section people refused to come. As a result, we could not get good communication with that group and whenever we coordinated the layout of pipes and cables, instrument section people failed to get necessary space and caused us to do the coordination job again later.
Geographical separation increase the stickiness of the information.

F. Transferred but not used

Even if the information is successfully transferred to the receiver, it sometimes is not used effectively. Unless it is not used, it is same as that the information is not transferred at all.

F-1 Limited capacity of the receiver -- overflow

If there is too much information to handle, selection of the information occurs.

Case example : Case #4G-7a

Mr. Narumi and I often talked on the way home that in such construction, we had to find the crucial problems efficiently and focus to attack them because without selecting the problems, there were too much problems to solve. To do this we had to widely open our eyes and check the project in the total point of view and to judge which problems were important. Narrow viewers tended to focus on trivial problems and failed to find much fundamental and crucial problems. Mr. Ida said we could neglect small problems at the design stage because they could be fixed at the test run but we couldn't leave fundamental problem because it could be fatal.

This comment shows that if there is too much information, it is important to select them according to the importance of the information. However if we view this comment from different stand point, it means that even if the information is transferred, it will be selected because of the limited capacity of the receiver. In this process there is a risk that some information which is important to the sender is abandoned by the misjudge of the receiver. This situation is shown in the following case.

Case example : Case #3M-4

Mr. Ida told me that it was necessary to have bellows cover over the air cylinder rods in the mill to protect it from environment. I requested to the maker to apply this rule and kept it in my mind but failed to find that there was one cylinder which did not have cover on its rod and it caused trouble after the line started operation.
There were many cylinders in the mill and covers were not explicitly drawn on the assembly drawing, therefore we always write our comment to the maker like: "All cylinders in the mill should have cover over the cylinder rods." Then we relied on the maker's engineer to make sure every cylinder really had covers. However, they failed to apply the rule to all cylinders because there were too much cylinders and too much things to take care of. I think both maker designer and I did not recognized the importance of this information. It seemed to be just one of many pieces of information for us and I think this was the reason of the failure.

This case shows if we fail to recognize the importance of the information, it tends to get less attention and tends to be failed to be used.

F-2 Lost information: too long to keep

If the information is kept for long time before actually used, it tends to be lost during waiting period. Following case shows such situation.

Case example : Case #4G-13

In No.3 CAL we failed to use the special type of conveyer for the delivery section while it was used in entry section because of the lack of the knowledge. In No.4 CAL, I remembered the failure very well and informed it to Mr. Shiota (one of the managers of our project who oversaw the design of delivery section) and also to the chief engineer of the maker but again we failed to use that kind of conveyer because I told it at the very beginning stage of the project and they forgot the information during the design. In addition to it, they used the No.3 CAL's drawings as reference and copied No.3 CAL's bad feature.

In this case the first information was lost and the second wrong information was adopted because the first information was significant to me but it was just one of many information for them. On the contrary, the second (wrong) information was given in the final drawing of No.3 CAL and they thought it was credible. I think they often refereed to it during their design job. In such situation, they might not imagined that there were some points to be improved.

This case shows that it is difficult to keep information for long time until it is really used. But the time period is not the only determinant factor which affect loosing of information because people who has the hands on experience about the information will not forget it easily, it is the person who learned it as a knowledge that tends to forget it. The latter does not know the importance of
the information. Therefore, it is important to transfer the
information with the importance, priority or reasoning information.

F-3 Expensive to verify

If the information is difficult to verify, it cannot be used for a
important decision.

Case example : Case #3F-16

When we designed the No.3 CAL, we knew that NKK (second largest steel maker
in Japan) used direct flame burner for their CAL. We knew that that type of burner had an
advantage: because it did not have radiant tube, its response became very high. However
there might be weakness that it might affect the chemical characteristics of the strip surface
because the exhaust gas of the burner contacted the strip. We were very curious about the
technology but it was necessary to built test furnace to test it, which meant that it would
need a lot of money and time. Then we decided not to consider it.

If it requires a lot of money or efforts to verify the
information, the possibility of the data to be used goes down
because we have to think about the trade off between the cost and
the (expected) benefit of the information.

G. Timing

Timing of the information transfer has significant impact on
the usefulness of it.

G-1 Timing: different timing of generation and use of the
information

If the timing of the generation of the information and the
timing of its use are different, the information needs to be stored
somewhere. The following case shows successful storage of the
information.

Case example : Case #3M-1

Mr. Ida told me that bridle rolls should be made by centrifugal casting pipe instead
of rolled plate which does not have uniform surface around welding line. He learned this
In this case, the information was generated long time before it was applied to the design of the new line and this time gap was filled by a manager who remembered the old fact. Generally speaking, if the timing of the generation of the information and the timing of the use is different, there should be some kind of storage function of the information or it will be lost.

Human memory of experienced people may be one solution but it is not reliable because if the project group does not have such expert in it, it becomes difficult to get such information.

Diffusion of such know how is difficult because when the information is generated, the potential user of the information does not know that they will need the information later. Without strong motivation, it is difficult to remember information, therefore such kind of information is only well remembered by those limited number of people who have hands on experience.

One solution of this problem is standardization. Whenever such kind of information generated, we can make new standard and make sure that others follow this standard. The problem of this solution is that standard does not really transfer the sticky information itself but it just transfer the solution. Original information has not only the solution but also the information of environment, reasoning, and assumptions related to the solution, but standard does not have such information. Therefore it is difficult to adapt it to new environment adequately.

**G-2 Timing: Windows for design**

There is a narrow windows of opportunities for design changes during the whole design process. If the information miss such
timing, it will be wasted or should be stored until the next project. This fact also creates a difficulty of information transfer.

**Case example: Case #3M-3**

Mr. Kaihara said that it was difficult to pick up old rolls from the roll changer of the mill because of the narrow clearance and low precision of overhead crane. Then we designed roll guide for roll changer but it did not work because putting the rolls into guide itself was difficult because of the narrow clearance.

I found this fact later and tried to solve the problem but I found that if we wanted to solve this problem fundamentally at that timing, it was necessary to change whole design of the mill structure. It was impossible because many detail design of the mill had already been done by the time and we could not afford to abandon all these works and do the whole design work again.

We started the design of the roll changer later than the design of the housing structure of mill, then we did not start to conceder the way to make the roll handling easier until we start to design the roll changer. However we found it later that it was difficult to improve the situation effectively without changing the clearance of the roll changer but if we wanted to do so we had to change the mill structure itself, which meant to change almost all design which had been finished by that time. We could not afford to do so. We found it later that the design schedule itself was not good. We should have considered design of the roll changer when we designed mill housing. When we designed the mill housing, we fixed the important parameter for roll changer design without noticing the fact explicitly.

This case shows two important things. First, there exists narrow windows of opportunities for design and if we miss the timing, it is difficult to change it later. Second, even if the information is transferred, it can be wasted by the misjudge of the timing to use.

Let's examine the first point. Existence of window of opportunities for design means that timing of the information transfer is as important as information itself. If the information is brought after the timing, it is simply useless. If it is brought earlier than the timing to use, it has to be stored until the timing comes but it means that there is a risk that the information will be lost.

The second point makes the situation more complicated. It means that if we want to use one kind of information, it is
necessary to know the other kind of information that is timing information of the window of opportunities for each design factors. Experienced engineers have such information. This kind of information is one of the very sticky ones.

G-3 Difficulty to transfer information up front

The preceding sections are related to the timing issue on the receiver side, but there is also timing issue on sender side. It is difficult for sender to transfer all information up front.

Case example: Case #3F-11

Whenever we had difficult design problems, Mitsubishi people brought their laboratory people with them and we could consult them. They were experts of that field and very helpful, however, their first suggestion was often off the point because of wrong assumptions or unacceptable assumptions of usage of the machine. But after we talked with them, they understood the situation and provided us good solution.

The interesting thing was that it was very easy to find the fundamental mistake during the meeting with them while we could not find any problems in the report before we meet them. (Even Mitsubishi's chief engineer could not find the mistake which he could have known to be wrong but he should have read the report because he signed his name on it.) Meeting was the most important way to understand each other.

On the other hand we could not give them what kind of assumption is acceptable before they write their report, because we didn't know what kind of analysis they would do and what kind of assumptions they would need. We could not prevent wasting their efforts to write first report and every time they had to rewrite their report.

This case shows two reasons why sender cannot provide all information up front. One is that they need some cue to remind information, therefore meeting is very useful method to get information. The other is that they do not know which information is relevant to the receiver. We have already discussed the latter in the section of "C-1 Filter of sender: Misunderstood relevancy", therefore we will discuss the former here.

If the sender needs cue to remind the information and send it, it becomes difficult to transfer information up front. If this fact is combined with the window issue, it can create big trouble, because
the sender may not be able to provide the information at the best timing regarding to the windows of opportunities for design, then it may be wasted.

This cuing issue is related to the effectiveness of the face to face communication and the effectiveness of the learning by experience because both of them are powerful partly because they are full of cues for the sender to remind information.

H. Unpredictable effect

Though it is not directly related to the stickiness of the information, there are some unpredictable effects which make the management of information transfer difficult.

H-1 Synergy effect

If there are more than one sender or receiver involved in the site of information transfer (for example meeting), sometimes unexpected synergy effect occurs.

Case example : Case #3F-13

We contratced the inside lining of the furnace to the Kawasaki-rozai, one of our subsidiary companies. The expert of the company proposed the latest way of lining (block method), which was fastest to construct and would make the lining less deteriorated after long period. At that time Mitsubishi Engineer was trying to reduce the heat loss caused by the circulation of the gas within the lining layer. When we talked about the new lining construction method, Mitsubishi Engineer brought his problem and we found that we could solve his problem by putting additional layer between blocks in the new construction method.

In this case, new solution was found by synergy effect but this synergy effect was not got by design. If both of the makers did not attend the same meeting, such kind of synergy did not occur. The difficulty is that we cannot design such kind of synergy to occur. Even if we put many different kinds of people together, synergy effect does not necessarily occur always. Without synergy effect,
meeting with too many people tends to be low efficient. If we want to improve specific kinds of information transfer, we should separate the sender and receiver from others and make them concentrate on that issue. Therefore, we have to think the trade off between the efficiency of the meeting and the synergy effect.

I. Update of information

Another type of practical issue is how to keep the information updated.

I-1 Duality of the information

One source of the problem of update of information is that machine can be changed after it is build but the information is not necessarily be updated at this timing.

<table>
<thead>
<tr>
<th>Case example : Case #3G-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generally speaking, large equipment makers such as Mitsubishi or Hitachi have constructed many lines all over the world and accumulated know how. Therefore when we request to change their design, they often say that they have always constructed in this way. However, even if their equipment was poorly designed and be modified after initial operation, they don't know it. Incremental improvement is done by the users and there is no official channel for the makers to get this kind of information and no necessity or benefits for the users to do it.</td>
</tr>
</tbody>
</table>

This case shows that when the machine is first built, the information and the machine are consistent, but since then whenever the machine is modified, the original information and real machine becomes more inconsistent. In such case it is very dangerous to believe the original information. This problem is caused by the duality of information. Machine itself has perfect set of information in it but this information is not easy to get. (For example if we want to know the dimension of one part, we have to take the machine into peaces and measure it.) Therefore it is sticky to the machine. On the other hand, information generated at the construction is easier to transfer. (For example it is written in documents or drawing which
can easily be transferred. Or it is stored in human memory and we can just ask him.) However this information is not necessarily updated when the machine is modified. The machine can be changed without changing the information and if we want to keep the information always updated, it requires extra efforts.

### 3.4 Data analysis -- Source of stickiness of Information

Before closing this chapter, let us check how many cases were categorized in each type of stickiness in the descriptive data.

Table 3-1 shows how many cases fell into each type of stickiness. From this table we can pick up the sources of stickiness problem which appeared most frequently.

<table>
<thead>
<tr>
<th>Type</th>
<th>Number of Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-2: Tacit knowledge</td>
<td>8 cases</td>
</tr>
<tr>
<td>B-1: Complex phenomena</td>
<td>8 cases</td>
</tr>
<tr>
<td>A-1: Systemic knowledge</td>
<td>7 cases</td>
</tr>
<tr>
<td>E-1: Inadequate transfer method:</td>
<td>6 cases</td>
</tr>
<tr>
<td>F-1: Buried information:</td>
<td>6 cases</td>
</tr>
<tr>
<td>C-2: Filter of sender: reluctance</td>
<td>5.5 cases</td>
</tr>
<tr>
<td>G-3: Can't transfer information up front:</td>
<td>5 cases</td>
</tr>
</tbody>
</table>

This result shows that top three major source of stickiness are all related to "complexity". Complexity is caused by the nature of the information, therefore it is difficult to reduce the stickiness. Then problem of "transfer method" and receiver's "overflow" problem follows. These problems are controllable, therefore we have to take these issues into account when we design project team. Next frequent problem was "reluctance". In the cases, this problem was often solved by insider involvement or personal connection to the insider, but this problem may be solved by the managerial effort. There should be culture to share the information and make the information as common assets. To achieve this, it is necessary to
change the evaluation system and create some mechanism to handle and accumulate this type of information. There are many things to do for creative management. The last major source was "can't transfer information up front". This can be solved by experience.

Table 3-2 and Fig. 3-6 summarizes how many cases fell into each group of stickiness. From this data, we can compare the sources of stickiness on the category level. The data shows that "Filter or Barrier" creates problem most frequently. Then both "complexity of information" and "complexity of problem" follow. Next three categories, "transferred but not used", "Transfer method", "Timing", have almost same weight.
<table>
<thead>
<tr>
<th>Why sticky</th>
<th>What is the consequence</th>
<th>DATA TYPE</th>
<th>Number of Cases</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. Complexity of Information</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A-1 Systemic Knowledge: Require to transfer systemic knowledge or wide range of knowledge, though which is not systematically documented</td>
<td>Difficult to transfer whole set of knowledge. Design with partial knowledge is dangerous.</td>
<td>S</td>
<td>7 [3]</td>
<td>7 [3]</td>
</tr>
<tr>
<td></td>
<td>(Ex. The case that information generated by try and error should be applied to different setting.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A-2 Tacit knowledge: Require intuitive judgement of experienced person.</td>
<td>If unexperienced person do the same judgement, the probability of getting right answer becomes lower</td>
<td>I</td>
<td>2</td>
<td>8 [1]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>I&amp;S</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>S</td>
<td>5 [1]</td>
<td></td>
</tr>
<tr>
<td><strong>B. Complexity of problem</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B-2 Organizational complexity: Source or destination of information is not single</td>
<td>May fail to transfer the information throughout the organization</td>
<td>S</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S &amp; I</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td><strong>C. Filter or Barrier</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-1 Filter of sender: Misunderstood relevancy. (Think it is irrelevant information.)</td>
<td>Information is not given</td>
<td>I</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>C-2 Filter of sender: Reluctant to send (Ex. Reluctant to send information of Failure.)</td>
<td>Information is not given and same failure repeated</td>
<td>I</td>
<td>5.5 [1]</td>
<td>5.5 [1]</td>
</tr>
</tbody>
</table>

---

9 See the Note at the end of this table for the meaning of symbols.
10 See the Note at the end of this table for the meaning of [i].
11 See the Note at the end of this table for the meaning of fraction number.
<table>
<thead>
<tr>
<th>Why sticky</th>
<th>What is the consequence</th>
<th>DATA TYPE</th>
<th>Number of Cases</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-3 Filter of sender: Given up problem</td>
<td>Information is not given and same failure repeated</td>
<td>I</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>(Recognition of the problem Forget the existence of the problem which can't be solved.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-4 Filter of the receiver: Reluctant to receive</td>
<td>Receiver tries to avoid receiving the information.</td>
<td>IS</td>
<td>1 [1]</td>
<td>2 [2]</td>
</tr>
<tr>
<td>(Received information causes cost to the receiver Ex. require redesign etc.)</td>
<td></td>
<td>1 [1]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-5 Filter of the receiver: Strong preconception</td>
<td>Receiver is preoccupied by some idea and will not believe new information which contradicts it.</td>
<td>I</td>
<td>3 [1]</td>
<td>3 [1]</td>
</tr>
<tr>
<td>C-6 Filter of both sender and receiver: Misunderstood relevance. (Ex. Both of them think it is not necessary or useful to transfer the information.)</td>
<td>Couldn't predict the potential trouble</td>
<td>I</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>C-7 Historical barrier on receiver side</td>
<td>Overlook the opportunity to improve</td>
<td>S</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>C-8 Weak incentive for the sender (Ex. Lack of incentive for sender side to make the information easy to understand.)</td>
<td>Document without example or drawing without enough section views or detail drawing.</td>
<td>IS &amp; S</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>C-9 Weak incentive for the receiver to understand and keep information: Class room education vs. on the job training</td>
<td>We can't teach construction know-how by class room education because listener is not interested in it and can't understand the importance of the information, then it will be easily forgotten.</td>
<td>IS</td>
<td>1</td>
<td>3 [1]</td>
</tr>
</tbody>
</table>
Table 3-1  Source of stickiness problem in the cases.  (continued)

<table>
<thead>
<tr>
<th>Why sticky</th>
<th>What is the consequence</th>
<th>DATA TYPE</th>
<th>Number of Cases</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-10 Credibility of the information source:</td>
<td>If the information source often send superstitious or fault information, credibility of the source is deteriorated and good information from that source tends to be overlooked.</td>
<td>I</td>
<td>2 [1]</td>
<td>2 [1]</td>
</tr>
<tr>
<td>C-11 Psychological distance: Unfamiliarity of sender and receiver</td>
<td>Only &quot;coordination&quot; type of communication is done and &quot;information&quot; and &quot;inspiration&quot; type of communication does not occur. Even &quot;coordination&quot; type information suffer from low efficiency</td>
<td>I&amp;S S</td>
<td>2 [1]</td>
<td>3 [1]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>D. Knowledge compatibility</th>
<th>2 [0]</th>
<th>2.4%</th>
</tr>
</thead>
<tbody>
<tr>
<td>D-1 Knowledge Compatibility: Difficult to transfer information between people with different background, culture, and value</td>
<td>Both of them were not willing to accept information</td>
<td>S I</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>E-1 Transfer method</th>
<th>8 [1]</th>
<th>9.8%</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-1 Inadequate transfer method: Difficult of transferring information caused by the transfer method (Ex. It is difficult three dimensional movement with drawing.)</td>
<td>Two dimensional drawing is not suitable to transfer movement or usage information. It is difficult to explain everything with drawing.</td>
<td>S I</td>
</tr>
<tr>
<td>E-2 Geographical separation: (Different location of the source of information and receiver.)</td>
<td>If the receiver is separated from the source of information, the amount and quality of the information is reduced.</td>
<td>S I&amp;S</td>
</tr>
</tbody>
</table>
Table 3-1  Source of stickiness problem in the cases.  
(continued)

<table>
<thead>
<tr>
<th>Why sticky</th>
<th>What is the consequence</th>
<th>DATA TYPE</th>
<th>Number of Cases</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>F. Transferred but Not Used</td>
<td>Important information is buried by too much less important information, which causes receiver to oversee very critical information</td>
<td>I</td>
<td>4 [3]</td>
<td>6 [3]</td>
</tr>
<tr>
<td>F-1 Buried information:</td>
<td></td>
<td>S&amp;I</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Too much information</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Ex. Too much information</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>overflows the capacity of</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>receiver.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F-2 Lost information:</td>
<td>Information which is not generated by themselves but just taught by somebody tends to be lost in a long period</td>
<td></td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Too long to keep</td>
<td>Even if written document remained, it may not be referred.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difficult to keep</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>transferred information for a long time.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F-3 Expensive to verify</td>
<td>Can’t afford to check it because of the cost or the time necessary to verify it and give up.</td>
<td></td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

G. Timing

<table>
<thead>
<tr>
<th>Why sticky</th>
<th>What is the consequence</th>
<th>DATA TYPE</th>
<th>Number of Cases</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>G-1 Timing problem:</td>
<td>Maintenance information should be kept somewhere until next construction but during long period it may be lost</td>
<td>S&amp;I</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Different timing of</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>generation of the</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>information and needs of</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>the information.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G-2 Timing: Window for</td>
<td>If the receiver failed to use the information at the proper timing, it becomes useless</td>
<td>C for S</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>design</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Information should be</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>transferred and handled at</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>the proper timing.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G-3 Can’t transfer</td>
<td>Once the first design is finished many problems pointed out and new informations remembered and transferred to the maker. They had to redesign.</td>
<td>S</td>
<td>5 [1]</td>
<td>5 [1]</td>
</tr>
<tr>
<td>information up front</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Ex. Can’t remember</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>relevant information in an</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>abstract argument.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 3-1  Source of stickiness problem in the cases. (continued)

<table>
<thead>
<tr>
<th>Why sticky</th>
<th>What is the consequence</th>
<th>DATA TYPE</th>
<th>Number of Cases</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>H. Synergy effect</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H-1 Unpredictable</td>
<td>&quot;Inspiration&quot; type of communication is difficult to design</td>
<td>S</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>synergy effect</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

I. Update of Information

| I-1 Update: Quality of the information | Real information is encoded in the machine and knowledge is copy of it. Then if information is updated whenever machine is modified, it becomes false. | I&S       | 2 [2]          | 3 [2] |
| Difficulty in keeping track of modification |                                                                                             | S         | 1              |       |

NOTE

Type of information
I: Information for Problem Identification.
S: Information for Problem Solving.
C: Complementary information

Number in [] indicate the number of cases of general comments; for example the comment which has the notion of "generally speaking..." or "such kind of problem often happened..." or "It was a rule of thumb for project work...." General comment can be a aggregation of several cases then the number of cases may have the higher significance than it appears.

Fraction: When there were two candidates of problem types and difficult to determine which should be assigned, 0.5 point is assigned to both of them.
Table 3-2  
Source of stickiness: Summary

<table>
<thead>
<tr>
<th>Category</th>
<th>Number of Cases</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Complexity of Information</td>
<td>15</td>
<td>18.3%</td>
</tr>
<tr>
<td>B. Complexity of problem</td>
<td>10</td>
<td>12.2%</td>
</tr>
<tr>
<td>C. Filter or Barrier</td>
<td>26</td>
<td>31.7%</td>
</tr>
<tr>
<td>D. Knowledge compatibility</td>
<td>2</td>
<td>2.4%</td>
</tr>
<tr>
<td>E. Transfer method</td>
<td>8</td>
<td>9.8%</td>
</tr>
<tr>
<td>F. Transferred but not used</td>
<td>9</td>
<td>11.0%</td>
</tr>
<tr>
<td>G. Timing</td>
<td>8</td>
<td>9.8%</td>
</tr>
<tr>
<td>H. Synergy effect</td>
<td>1</td>
<td>1.2%</td>
</tr>
<tr>
<td>I. Update of information</td>
<td>3</td>
<td>3.7%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>82</strong></td>
<td><strong>100.0%</strong></td>
</tr>
</tbody>
</table>

Fig 3-6  
Source of stickiness in the cases
Chapter 4  How to Cope with Stickiness Problem

4.1 Solution for each type of source of stickiness

As we have seen in the chapter 3, there exist diversified sources of stickiness. This implies that there are different types of solution for different sources of stickiness. In this section, we will examine what kind of solutions were used in the cases and discuss advantages and disadvantages of them.

Table 4-1 (from pp.108 to pp.115) shows the sources of stickiness problems and how they were solved in the cases. Let us examine this table item by item.

A. Complexity of Information

This category focuses on the complexity of the information which is used in problem solving.

A-1 Systemic knowledge

This type of complexity makes it difficult to transfer the expert knowledge to the project member because partial knowledge is not useful or even dangerous to use. This type of information should be transferred as a set not as a piece. If we want to transfer this type of knowledge, it is necessary to do systematic education. It requires very long period of time to reproduce an expert.

In this situation, short term solution is either "Involve the experts in the project and let them design." or "Separate task and send it to the expert." Both of them avoid to transfer sticky systemic knowledge.
Expert involvement seems to be easiest way to solve the problem. However the main obstacle is the availability of the expert. Generally speaking, real experts are scarce resource in many companies. Part time involvement may reduce the load but still it fixes the scarce resources to the project. This solution is a luxurious solution.

On the other hand, "send task" solution seems to be better. It does not occupy experts time. Experts can be located at the central office and can be shared by multiple projects. But it is not always easy to "separate the task from other project works and send it to the expert." If the task has many interrelationship with the rest of the project work, it is not a good strategy to ask external expert to solve it because it will increase the overhead of communication because his job should be well coordinated with the rest of the project. Another difficulty is that if the task requires sticky information of the environment of the task, it is difficult to transfer the necessary information to the expert. Therefore this solution is applicable only when the task has little interrelationship with the rest of the task and the task does not require sticky information of the environment where it works. There are not so many tasks which can clear these conditions.

A-2 Tacit knowledge

If the tacit knowledge is necessary to solve the problem, it is difficult to transfer the knowledge to the project member because in many cases the expert himself cannot explain his knowledge in explicit way. This kind of knowledge can only be acquire by experience. Therefore, in the short term, we have to ask expert to solve the problem. In this sense, situation is similar to the systemic knowledge case.

Theoretically, there are two ways to let expert to do it, like systemic knowledge case; "Expert involvement" or "Send task to the
expert". However there were no cases in the descriptive data which used "send task" solution for tacit knowledge problem. This may be because it is difficult for the project member to judge what kind of input is necessary for the person who use tacit knowledge to solve the problem or because people who solve the problem with tacit knowledge needs tacit input and it is difficult to send "tacit input" to the expert.

In the descriptive data, there were seven cases which used "expert involvement" for the tacit knowledge problem. Another feature found in the descriptive data was that expert with tacit knowledge brought to the project not only "information for problem solving", but also "information for problem identification". This is one advantage of "expert involvement". We can expect higher chance of problem identification by the expert when he is involved in the project than when he is located in the central office and just solve the problem which is sent to him. However there exists availability problem, too. When appropriate expert is not available, it is necessary to "gather information as much as possible" and solve the problem by ourselves. (It is one kind of a gamble.) One such case was reported in the descriptive data.

B. Complexity of problem

Not only the complexity of the information but also the complexity of the problem causes stickiness of the information transfer.

B-1 Complex phenomena: Too complex to predict

When the problem is related to the complex phenomena, it is difficult to predict what will happen, then it is difficult to send related information beforehand.
In such case, "machine shows the problem" which we overlooked. When we put the machine in the real working environment, it automatically find the mismatch between the designers assumptions and environment. Tyre and von Hippel call it "templating". (1991) The main drawback of this method is that it shows the problem at the final stage of the project and sometimes it is too late to fix the problem fundamentally, then we are forced to make compromise. In spite of this drawback, templating is a very powerful way of identifying information mismatch.

Another way is to "learn from other line's experience". Generally speaking, even if the project involves radical innovation, there are some similarity between new production system and existing production system. Therefore we can learn from similar line's experience. It is especially important when the existing line could not find the problem at the design stage and machine showed it later but it was too late to change the machine and people gave up. In such case, we should avoid the same kind of trouble in the new production system. We can not excuse ourselves that the problem was too complex to predict because it had been clear from the other line's experience. The drawback of this method is that this kind of experience is not automatically shared by all members in the organization. Unless we make effort to share the experience, the experience remains to be only a personal experience rather than a organizational experience. Involvement of the experienced people is one solution of this problem but is does not solve the personalized experience problem directly. If we want to create "learning organization", we have to invent the way to share the personal experiences and make them as organizational experiences.

B-2 Organizational complexity: Source or destination of information is not single

The complexity of the problem can be created by artificially. When the organizational structure is too complex or it does not fit
the problem structure, the information can become sticky. For example the problem solving requires the coordination of more than one division of the company the same solution becomes more sticky to implement than the case where it is related to only one division.

There was not a good solution to this problem in the descriptive data. The existence of the mismatch was "shown by the machine". But if we want to find it earlier, we have to make special effort for the coordination work or we have to design the project team not to have many overlapped jobs.

C. Filter or Barrier

When neither the information nor the problem is complex, we still have stickiness problem caused by the filter or barrier of the sender and/or receiver.

C-1 Filter of sender: Misunderstood relevancy.

When sender misunderstands that some information is not relevant to the receiver, he will not transfer it. Then it becomes sticky to the sender. To solve this problem, there are two ways. One is to "get the information by chance from the sender". The other is "get the same information from different sender." Let us think about the former solution. The source of the problem was that the sender suppress the information transfer. Then it is possible to get the information by chance through chattering or through the conversation related to other problems. The drawback of this method is that it is not reliable. We cannot expect to get information "by chance".

The latter solution; "get the same information from different sender" is a good solution when there are multiple persons who have same information. It is often the case in the real life. Then the good strategy is to try to get the information from multiple persons
because the source of the problem was sender's misunderstanding therefore other sender may not have the same filter.

In the descriptive data, there was one case where information was transferred by the maintenance people rather than a maintenance staff because maintenance people did not think whether the information was related to the new project or not before he transferred it.

There was another data where the information was failed to be transferred but the problem was shown by the machine. Here again, templating was very reliable and worked as backup of the other method.

C-2 Filter of sender: Reluctant to send

Information becomes sticky when sender does not want to transfer it to others. This tends to happen when the information is related to the failure of the sender. This type of stickiness is difficult to overcome. In the data, there were many cases where this type of problems were solved by the "Involvement of the insider". This solution is very effective because the source of the stickiness was the disincentive to the sender to transfer the information but if he is a member of the project for the new production line development, he has a strong incentive to transfer the information because he does not want to repeat the same mistake. This is the reason why it is better to involve the members of former project because he can bring not only the experienced skill to do the job but also insider information which tends to be sticky.

Another solution was to "get the information by chance through the face to face communication." This is also useful because we may remove the reluctance of sender through a friendly face to face conversation. It is difficult to get the same information through letters or facsimile. Face to face communication is very important
though it is time consuming and expensive when the sender and receiver are not located in the same place.

C-3 Filter of sender: Given up problem

When the problem is difficult to solve, people often get used to live with the inconvenience. In such case people tends to forget the existence of the problem, then the information about the problem becomes sticky especially when we try to get it through a short interview.

To cope with this problem, "insider involvement" and "get information through face to face communication" were used. Both of them use the face to face type communication and try to increase the possibility of the information transfer by increasing the time to talk it. The drawback of this method is that it is not reliable, there is no guarantee that we can get the information through these methods.

C-4 Filter of the receiver: Reluctant to receive

There may be a reluctance on the receiver's side. When we take the sender's point of view and if we want to send the information but it will cause some kind of loss to the receiver, we can expect the first reaction of the receiver is reluctance. This often happens when we want to improve the machine design from the user's point of view, maker's engineers tends to have a reluctance to listen to us, no matter how large improvement is expected by the design change, simply because it will cause him a significant loss when he have to redesign many parts.

To remove this reluctance, sender have to "send value added information" to reduce the load of the receiver to use the information.
Chapter 4  How to Cope with Stickiness Problem

C-5 Filter of the receiver: Strong preconception

If the receiver has a strong preconception, he may stop to get information related to the issue. For example we do not check the house number when we come home every day, but we might have checked it when we moved in the house for the first time. If the receiver strongly believes in wrong information, it will hinder the flow of correct information. Then information related to the matter becomes sticky.

It is difficult for the receiver to solve this problem by himself. In the descriptive data, there were two methods which solved this problem. One was "Machine shows it." The other was "Other person recognize the problem." The latter solution shows the effectiveness of team work.

C-6 Filter of both sender and receiver: Misunderstood relevance.

Sometimes misunderstanding of the relevance occurs both sender and receiver at the same time. In such case, information becomes very sticky and difficult to change the situation. This happened in the descriptive data and it was solved only by "machine shows it."

C-7 Historical barrier on receiver side

Up to this point, we have examined about "filter" problems. In our definition filter is the obstacle of information transfer which affects information transfer selectively on the base of the contents of the information. Here we have another type of obstacle: "barrier". As we have defined in the previous chapter, barrier affect the information transfer on the base of who is the sender. For example, if the sender caused a serious trouble in the past, receiver will not listen to him again. Barrier is formed by the historical record or prejudice.
It is difficult to remove this kind of obstacle. In the descriptive data, this type of problem was solved by "putting people of the different culture together", which means that people who were transferred from different factory did not have "barrier" and caused to do reevaluation of the sender.

C-8 Weak incentive for the sender

If the sender does not have a strong incentive, information tends to be sticky to him. Weak incentive of the sender is similar to the reluctance of the sender but the former does not accompany sender's loss, while the latter accompanies it. Therefore the obstacle is not as strong as that of the reluctance case.

Interestingly, in the descriptive data, the solution used for the "weak incentive" case and "reluctance" case were same. In both cases, "Insider involvement" and "Face to face communication" was used.

C-9 Weak incentive for the receiver to understand and keep information

When receiver does not have strong motivation to get the information, the information becomes sticky. In the descriptive data, this problem was mentioned related to the comparison of effectiveness of the class room lecture type training and on the job training. When the trainee had strong motivation, the effectiveness of the training increased.

C-10 Credibility of the information source

If the sender's credibility is low, the information send from this sender tends to be neglected. In this sense, "low credibility" is a moderate form of "barrier". The main difference is that in the "barrier" case, information form the sender is always rejected, however, in the "low credibility" case, information from the sender
is accepted but tends to be lost or abandoned when the receiver overflows.

This problem may be solved by the effort of both sender and receiver. In the descriptive data, the solution for the sender was to "increase the quality of the information" and the solution for the receiver was to "remove prejudice and open mind". This solution seems to be obvious. The problem is how to do this. This is an important managerial problem.

C-11 Psychological distance: Unfamiliarity of sender and receiver

Geographical distance is a big obstacle for the information transfer, but the "psychological distance" is as difficult as geographical distance to overcome.

In this case, "insider involvement" is useful again. He has easy access to his original group and enhance the information transfer. Another solution found in the descriptive data was also on the same line: "Use personal network". When we think about the information transfer such kind of informal (or personal) information transfer should be taken into account.

D. Knowledge compatibility

D-1 Knowledge Compatibility

It is difficult to transfer information between people with different background, culture, and value. To overcome this problem, "Machine side demonstration" was used in the descriptive data. Seeing is believing. It is a general method to transfer information.

Another solution: to have "interpreter" was suggested but it was not really applied in the case. However it is a reasonable solution. To do this, manager should plan to provide cross functional training. It is very important these days because production system
becomes more integrated and its performance depends more on the system performance rather than components' performance.

E. Transfer method

E-1 Inadequate transfer method

Difficulty in transfer of information may be caused by the transfer method. To overcome this problem, we have to find best way to transfer the information. In the descriptive data, two methods were used. One was "machine side meeting". The other was "face to face meeting". What is the best solution may depends on the nature of the information to be sent. But "face to face" communication may be one of the general type solution while it costs time and money.

E-2 Geographical separation

Geographical separation causes obstacles for the information transfer. This field is well studied by Tom Allen (1977). In the descriptive data, there were cases which used "collocation" as solution to improve information transfer.

F. Transferred but not used

Unless the transferred information is used effectively, the transferred information has no practical value. Therefore, we have to consider the problem: "transferred but not used" as one of the important problem of information transfer.

F-1 Buried information: Too much information

When receiver has too much information to process, he may overflow. It often happens in the new production line development because project period is always short and developer has to handle
many problems simultaneously because rapid development is a one of the key factor of competitive advantage.

When overflow is inevitable, we have to find the way to save important information from losing. To do this, receiver has to have "priority" to handle the information and sender needs to "send the information with priority information" to affect the receiver's judgement of priority and make his information survive.

The problem is how to judge the importance of the information. Some times it requires another information (complementary information) to judge the importance of the information. For example, if we have difficulty to decide the design parameter of the machine, we can make temporary design and fix it later when it will not cause significant delay or cost up. But to make this decision, it is necessary to be able to judge whether it will cause significant problem later or not and this judgement need experience (tacit knowledge).

F-2 Lost information: Too long to keep

If information is transferred too early before it actually is used, it may be lost before used. To cope with this problem, it is good to "send the information at the correct timing" but the difficulty is that it is necessary to know when is the correct timing. It is extremely difficult for the sender to know it. The other solution is to "keep information in a good filing system" but the difficulty of this solution is that success or failure of the filing system does not only depend on the design of the system but also depend on the efforts to maintain it.

F-3 Expensive to verify

When the information is expensive to verify, it tends to be abandoned. In this case, we have to think of the trade off between
the expected benefit to get when the information is applied and the cost to verify it.

G. Timing

Timing has important effect on the effective use of transferred information.

G-1 Timing problem: Different timing of generation of the information and needs of the information

When the timing of the generation of the information and the needs for it is different, there must be some buffer to keep the information. It is especially important when there is a long time gap between the generation and use of the information. Maintenance information belongs to this category. Maintenance information is very important information for the new production line development but in many cases, when the existing line's problem was solved by the maintenance department, the new production line's development team did not exist yet and it would be formed many years later. In such case, even if the maintenance people thought that same mistake should be avoided in the future, he could not transfer the information simply because he did not know to whom he should tell it.

In the descriptive date, this kind of problem was solved by the "involvement of the people who knows the information" (in this case the maintenance people). This is a passive solution because it rely on the memory of the person who experienced the existing line's trouble. It is difficult to diffuse the information widely in the company by this solution because it relies on the human memory but the number of the people who have this information is limited and it will becomes the bottle neck of the diffusion.
There is not a good way to keep this kind of information as a common database but it is a very important theme of the research for managers.

G-2 Timing: Window for design

There exists windows for design. If we miss the timing to use the information, it lose the value. The problem is how to find the right timing to use the information. To know this timing, it is necessary to understand the interrelation of the many design decisions of the project. It is one kind of tacit knowledge. This requires experience. The natural solution is the "involvement of the people who have experience". This is one of the important information which can be transferred by the involvement of experienced people.

G-3 Can't transfer information up front

In the project work, we often experience that the some important information are not available up front and when it becomes available, it causes many design changes. It is a waste of time and efforts. But it is almost impossible to send all information up front simply because we do not know which information will be necessary to design.

To cope with this problem, many methods were used in the descriptive data. One method was to "use preliminary design as a base of discussion". It is easier to find wrong assumptions of preliminary design and correct it than to list up correct assumptions from scratch. Through the preliminary design, both sender and receiver can learn what kind of information is necessary to solve the problem.

Another solution is "use other line's experience as prototype". If there are similar line, we can learn from it. By doing this, we can reduce the necessity of preliminary design and improve the
efficiency of the engineering work. But how can we "learn" from other line? Usually the easiest way is the "involvement of the experienced people".

"Do first and then think" is alternative solution. Unless we start to solve the problem, we don't think it hard enough and our understanding will not become deep enough. Then we should start anyway and gradually we can understand the problem well. It is a practical way to cope with this problem.

Another contradicting tactics is "leave the problem. It will become easier to solve it later." Some problems are difficult to solve at the early stage of the project because there are many undecided factors and if we force to solve it we have to make too many assumptions. In such case it is wise to leave the problem and solve it later. The difficulty is how to judge which problem should be "left" and which problem should be "done first". To decide, we have to judge the relative easiness of the problem solving between now and later. This requires experience (tacit knowledge).

H. Synergy effect

H-1 Unpredictable synergy effect

We sometimes experience unpredictable synergy effect when we "put different type of experts together". The problem is that we do not know what we should do if we want to facilitate this effect. The solution is not just "put all experts together in every meeting" because it will increase the meeting time and consume the experts' time which should be used for creative work. The real problem is what kind of people we should put together and how to maximize the total output of the project. We have no answer yet but it is an interesting theme for the future research.
I. Update of information

I-1 Update: Duality of information

Information of the existing production line is useful for the development of new production line. This information was generated when the old line was developed. The problem is the information of the existing production line does not necessarily reflect the real situation of the line, while it represented exactly the real situation of the machine when it was build.

If we fail to update the information, we may make a wrong decision based on the wrong information and may end up to repeat the same mistake as the old production line's project team did.

Though it is important to update the information, it is difficult to do it. It is difficult to maintain document updated whenever the machine is modified because the person who modify the machine has little needs to maintain the document because his main concern is to improve the machine which he takes care of, not to improve the future machine. Even if people decided to make great effort to maintain the document, if one person fail to change the document after he modified the machine, this one incident ruin the credibility of the document. Even if the document is perfectly maintained, information stored in the memory of the former project team member may not be updated and this wrong information may be transferred from person to person.

There are many pitfalls related to updating issue. All of them are caused by the duality of the information. There is not a perfect solution to this problem yet.
Table 4-1  Source of stickiness problem and how it was solved.

<table>
<thead>
<tr>
<th>Why sticky</th>
<th>What is the consequence</th>
<th>How it was (or should have been) unstuck.</th>
<th>DATA TYPE</th>
<th>CASE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-1 Systemic Knowledge: Require to transfer systemic knowledge or wide range of knowledge, though which is not systematically documented</td>
<td>Difficult to transfer whole set of knowledge. Design with partial knowledge is dangerous.</td>
<td>Involve the experts in the project and let them design.</td>
<td>S(^{12})</td>
<td>3G-3 [3G-13] [4G-11] [4G-12]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Separate task and send it to the expert.</td>
<td>S</td>
<td>3F-1 3F-2 4G-15</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>A-2 Tacit knowledge: Require intuitive judgement of experienced person. (Ex. The case that information generated by try and error should be applied to different setting.)</td>
<td>If unexperienced person do the same judgement, the probability of getting right answer becomes lower</td>
<td>Involve expert in the project and ask him to solve it. (Expert decision may not be the optimal solution but his possibility to get optimal solution is higher than others.)</td>
<td>S</td>
<td>3F-9 3M-2 3G-6 4D-1 4G-5 4G-6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Separate task and send it to the expert.</td>
<td>S</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gather information as much as possible</td>
<td>IS</td>
<td>4M-1</td>
</tr>
</tbody>
</table>

\(^{12}\)See the Note at the end of this table for the meaning of symbols.  
\(^{13}\)See the Note at the end of this table for the meaning of [ ] or ( ).
Table 4-1  Source of stickiness problem and how it was solved. (Continued)

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<tbody>
<tr>
<td><strong>B. Complexity of problem</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>B-1 Complex phenomena: Too Complex to predict.</td>
<td>Overlook side effect. Get unintended result</td>
<td>Machine shows it. (Do it with imperfect information and fix it later, but sometimes it becomes too late.)</td>
<td>3M-6</td>
<td>3F-4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Learn from similar line's experience</td>
<td>4M-3</td>
<td>4G-17</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4M-4</td>
<td>[4G-19]</td>
</tr>
<tr>
<td>B-2 Organizational complexity: Source or destination of information is not single</td>
<td>May fail to transfer the information throughout the organization</td>
<td>Machine revealed the problem. (But sometimes too late.) To prevent this type of problem, strong coordination is necessary.</td>
<td>S</td>
<td>4D-3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>S &amp; I</td>
<td>3G-9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>C. Filter or Barrier</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>C-1 Filter of sender: Misunderstood relevancy. (Think it is irrelevant information.)</td>
<td>Information is not given</td>
<td>Get the first hand information from worker who don't have such hypothesis. But it is not reliable because it works by chance.</td>
<td>3M-6</td>
<td>3F-4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Machine showed it.</td>
<td>4D-1</td>
<td>4G-16</td>
</tr>
<tr>
<td>C-2 Filter of sender: Reluctant to send (Ex. Reluctant to send Information of Failure)</td>
<td>Information is not given and same failure repeated</td>
<td>Involve insider in the project</td>
<td>3F-5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Get information (by chance) through face to face communication.</td>
<td>3F-6</td>
<td>3F-14</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3F-15</td>
<td>[4G-1]</td>
</tr>
</tbody>
</table>

(Continue on next page)

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14See the note at the end of this table for the meaning of (1/2)
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<thead>
<tr>
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<tbody>
<tr>
<td>C-3 Filter of sender: Given up problem (Recognition of the problem Forget the existence of the problem which can’t be solved.)</td>
<td>Information is not given and same failure repeated</td>
<td>Insider involvement.</td>
<td>I</td>
<td>3F-7</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>I</td>
<td>3F-8 (1/2)</td>
</tr>
<tr>
<td>C-4 Filter of the receiver: Reluctant to receive (Received information causes cost to the receiver Ex. require redesign etc.)</td>
<td>Receiver tries to avoid receiving the information.</td>
<td>Send value added information. (Sender has to reduce the cost for receiver.) Ex. make feasible and concrete requirement</td>
<td>I</td>
<td>S</td>
</tr>
<tr>
<td>C-5 Filter of the receiver: Strong preconception (Ex. Both of them think it is not necessary or useful to transfer the information.)</td>
<td>Receiver is preoccupied by some idea and will not believe new information which contradicts it.</td>
<td>Real machine shows the truth</td>
<td>I</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-6 Filter of both sender and receiver: Misunderstood relevance.</td>
<td>Couldn’t predict the potential trouble</td>
<td>Machine showed it. (Change the way of thinking. --After making trouble in No.3 CAL, We checked it very carefully in No.4 CAL)</td>
<td>I</td>
<td></td>
</tr>
<tr>
<td>C-7 Historical barrier on receiver side</td>
<td>Overlook the opportunity to improve</td>
<td>Put people of different culture in a project. (Bring people who don’t have barrier.)</td>
<td>S</td>
<td></td>
</tr>
</tbody>
</table>

(Continue on next page)
Table 4-1  Source of stickiness problem and how it was solved. (Continued)

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<tbody>
<tr>
<td>C-8 Weak incentive for the sender (Ex. Lack of incentive for sender side to make the information easy to understand.)</td>
<td>Document without example or drawing without enough section views or detail drawing.</td>
<td>Compensate it by face to face meeting or ask to improve the information to be more user friendly</td>
<td>I</td>
<td>4G-2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Insider involvement.</td>
<td>I&amp;S</td>
<td>3M-1</td>
</tr>
<tr>
<td>C-9 Weak incentive for the receiver to understand and keep information: Class room education vs. on the job training</td>
<td>We can’t teach construction know-how by class room education because listener is not interested in it and can’t understand the importance of the information, then it will be easily forgotten.</td>
<td>Increase motivation of receiver. Educate young engineer by on the job training. Machine side demonstration. Hands on experience.</td>
<td>S</td>
<td>4M-2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>I</td>
<td>(4E-5; 4G-9)</td>
</tr>
<tr>
<td>C-10 Credibility of the information source:</td>
<td>If the information source often send superstitious or fault information, credibility of the source is deteriorated and good information from that source tends to be overlooked.</td>
<td>Sender side: increase the quality of information to send and improve credibility. Receiver side: remove prejudice and open mind to new information</td>
<td>I</td>
<td>[4G-3]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(4G-14)</td>
</tr>
<tr>
<td>C-11 Psychological distance: Unfamiliarity of sender and receiver</td>
<td>Only “coordination” type of communication is done and “information” and “inspiration” type of communication does not occur. Even “coordination” type information suffer from low efficiency</td>
<td>Involve insider from the potential source of the information</td>
<td>S&amp;I</td>
<td>3G-7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Use personal network</td>
<td>I&amp;S</td>
<td>[3G-8]</td>
</tr>
</tbody>
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<tr>
<td><strong>D. Knowledge compatibility</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D-1 Knowledge Compatibility:</td>
<td>Both of them were not willing to accept information</td>
<td>Necessary to have &quot;interpreter&quot; who can understand both of the &quot;language&quot;.</td>
<td>S</td>
<td>(3F-12)</td>
</tr>
<tr>
<td>Difficult to transfer information between people with different background, culture, and value</td>
<td></td>
<td>Machine side demonstration.</td>
<td></td>
<td>4E-2</td>
</tr>
<tr>
<td>(Ex. It is difficult three dimensional movement with drawing.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>E. Transfer method</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E-1 Inadequate transfer method:</td>
<td>Two dimensional drawing is not suitable to transfer movement or usage information. It is difficult to explain everything with drawing.</td>
<td>Machine side meeting.</td>
<td>S</td>
<td>[3G-4]</td>
</tr>
<tr>
<td>Difficulty of transferring information caused by the transfer method</td>
<td></td>
<td>Easy to explain at the machine side. Seeing is believing. Hands on demonstration</td>
<td>S</td>
<td>3M-5</td>
</tr>
<tr>
<td>(Different location of the source of information and receiver.)</td>
<td></td>
<td></td>
<td>I</td>
<td>4F-4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>I</td>
<td>4E-2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Face to face meeting.</td>
<td>I</td>
<td>3F-11</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>S</td>
<td>(4E-1)</td>
</tr>
<tr>
<td></td>
<td>If the receiver is separated from the source of information, the amount and quality of the information is reduced.</td>
<td>Move to the &quot;locus&quot; of the sticky data. Collocation.</td>
<td>S</td>
<td>[3G-10]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>I&amp;S</td>
<td>4G-8</td>
</tr>
</tbody>
</table>
Table 4-1  Source of stickiness problem and how it was solved. (Continued)

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<th>CASE</th>
</tr>
</thead>
<tbody>
<tr>
<td>F. Transferred but Not Used</td>
<td>Important information is buried by too much less important information, which causes receiver to oversee very critical information</td>
<td>[Receiver's point of view] Receiver should select information according to the importance (or value) of the information. Sometimes it is necessary to go and hunt critical information.</td>
<td>I</td>
<td>[4G-7a] [4G-7b] [4G-7c] (4G-14)</td>
</tr>
<tr>
<td>F-1  Buried information: Too much information.  (Ex. Too much information overflows the capacity of receiver.)</td>
<td>[Sender's point of view] Information should be transferred with priority information</td>
<td>S&amp;I S&amp;I</td>
<td>(3M-4) (4G-13)</td>
<td></td>
</tr>
<tr>
<td>F-2  Lost information: Too long to keep  Difficult to keep the transferred information for a long time.</td>
<td>Information which is not generated by themselves but just taught by somebody tends to be lost in a long period. Even if written document remained, it may not be referred.</td>
<td>Send information at the correct timing. Make the information more easy to remember. Information transferred with reasoning or background information might last longer. Written information in compatible way to the receiver last long. (Ex. drawing for designer)</td>
<td>S&amp;I S&amp;I</td>
<td>(4F-1) (4G-13)</td>
</tr>
<tr>
<td>F-3  Expensive to verify</td>
<td>Can't afford to check it because of the cost or the time necessary to verify it and give up.</td>
<td>Tradeoff between cost and expected effect. If additional information which shows the validity of the information is available, people think it worthwhile to spend money and/or time for it.</td>
<td>3F-16</td>
<td></td>
</tr>
</tbody>
</table>
### Table 4-1  Source of stickiness problem and how it was solved. (Continued)

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<th>DATATYPE</th>
<th>CASE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>G. Timing</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G-1 Timing problem: Different timing of generation of the information and needs of the information. (Information should be transferred and handled at the proper timing.)</td>
<td>Maintenance information should be kept somewhere until next construction but during long period it may be lost</td>
<td>To involve the person who have knowledge of the information [Systematic database might be useful]</td>
<td>S&amp;I</td>
<td>3M-1</td>
</tr>
<tr>
<td>G-2 Timing: Window for design</td>
<td>If the receiver failed to use the information at the proper timing, it becomes useless</td>
<td>Involvement of experienced people. Another information (timings information: that is &quot;what kind of information is necessary and applicable at each stage of project&quot;) is necessary to use the information.</td>
<td>C for S</td>
<td>(3M-3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>C for S</td>
<td>4F-2</td>
</tr>
<tr>
<td>G-3 Can't transfer information up front (Ex. Can't remember relevant information in an abstract argument.)</td>
<td>Once the first design is finished many problems pointed out and new informations remembered and transferred to the maker. They had to redesign.</td>
<td>Use preliminary design as a base of the argument [If we could make prototype data base, it might be useful]</td>
<td>S</td>
<td>3F-11</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>S S</td>
<td>4F-3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4F-5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Use other line's experience as prototype</td>
<td>S</td>
<td>[4G-4]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Do first, then think. Early contact with maker and make time for the further improvement of design</td>
<td>S</td>
<td>4G-7a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Leave the problem. It will become easier to solve it later.</td>
<td>S</td>
<td>4G-7a</td>
</tr>
</tbody>
</table>

### H. Synergy effect

<table>
<thead>
<tr>
<th>Why sticky</th>
<th>What is the consequence</th>
<th>How it was (or should have been) unstuck.</th>
<th>DATATYPE</th>
<th>CASE</th>
</tr>
</thead>
<tbody>
<tr>
<td>H-1 Unpredictable synergy effect</td>
<td>&quot;Inspiration&quot; type of communication is difficult to design</td>
<td>Put different type of expert together (in a meeting)</td>
<td>S</td>
<td>3F-13</td>
</tr>
</tbody>
</table>

(Continue on next page)
Table 4-1  Source of stickiness problem and how it was solved. (Continued)

<table>
<thead>
<tr>
<th>Why sticky</th>
<th>What is the consequence</th>
<th>How it was (or should have been) unstuck.</th>
<th>DATA TYPE</th>
<th>CASE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Update of information</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difficulty in keeping track of modification</td>
<td>Real information is encoded in the machine and knowledge is copy of it. Then if information is updated whenever machine is modified, it becomes false.</td>
<td>It requires special mechanism and effort to update the complete information of the machine</td>
<td>I&amp;S</td>
<td>[3G-1]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>I&amp;S</td>
<td>[4G-10]</td>
</tr>
<tr>
<td></td>
<td>Get information from personal network.</td>
<td></td>
<td>S</td>
<td>4D-2</td>
</tr>
</tbody>
</table>

NOTE
Type of information
I: Information for Problem Identification.
S: Information for Problem Solving.
C: Complementary information
Type of solution
Case No with () means it was not solved in the real case and is judged that type solution could have solved the problem.
Case No. with [] indicate that the case was a general comment; for example it has the notion of "generally speaking....." or "such kind of problem often happened......" or "It was a rule of thumb for project work......" This distinction is important when we count the number of cases in some category because general comment can be a aggregation of several cases then it should have the higher significance.
When there were two candidates of problem types and difficult to determine which should be assigned, I just assigned 0.5 points and indicated with (1/2) after the case number.
4.2 Category of solution type

In the previous section we examined many solutions for the stickiness problem according to the type of the sources. As we have noticed, there are some solutions which appear in several sources. In this section, we will focus on the type of the solution rather than the source of the stickiness. Data is rearranged according to the solution in Table 4-2.

4-2-1. Categories

Solution are grouped by their nature or similarity as follows;

I. Techniques to find problems

This group of the solution focuses on the problem identification. There are three solutions involved in this category.

I-1. Machine shows it. (Templating)
I-2. Learn from similar line's experience.
I-3. Other person recognize the problem.

II. Technique to find relevant information

There is only one solution which belongs to this category.

II-1. Do preliminary design and use it as a base of argument.

III. Techniques to use expert knowledge

This group of solution focuses on the effective use of the expert knowledge. There were five solutions which belong to this category.

III-1. Send task to expert.
III-2. Expert Involvement (1) [Expert who has information for problem solving.]

III-3. Expert Involvement (2) [Expert who has complementary information: Ex. Experienced people]

III-4. Expert Involvement (3) [Expert who has information for problem identification: Insider involvement]

III-5. Gather information as much as possible.

Expert involvement was divided into three groups according to what kind of information was transferred by the expert. First type of expert brought information which was used directly for the problem solving. This type of expert had data base (systemic or tacit) to solve the problem.

Second type of expert brought complementary information which is necessary to use the database type information. This type of information is typically brought by the people who have experience of similar project. (Of course this type of expert also brings information for problem solving or information for problem identification.)

Third type of expert brought information for problem identification. This type of information was transferred by the insiders.

Distinction among expert, experienced people, and insider is not important. One person can be expert and experienced and insider at the same time. The important point is that when we try to solve the stickiness problem by expert involvement, we have to think which type of information we want to transfer and what kind of people may have the information.
IV. Techniques to enhance the effectiveness of information transfer

This group of solution focuses on the way of information transfer. There are four solutions which belong to this category.

IV-1. Get information through face to face communication.
IV-2. Machine side meeting or demonstration.
IV-3. Get information through personal network.
IV-4. Interpreter who can understand multiple discipline.

V. Techniques to increase the possibility of occurrence of information transfer by chance

This group of solution focus on the information transfer by chance. In the real life, we cannot control everything. We often get important information by chance. Therefore it is worth to think the method to increase the probability of the information transfer by chance. There are three solutions which belongs to this category.

V-1. Put people of different culture together (in a project).
V-2. Put different type of expert together (in a meeting).
V-3. Collocation.

VI. Techniques to increase the possibility of effective use of transferred information

This group of solution focuses on the effective use of the transferred information. There were five solutions which belong to this category.

VI-1. Remove prejudice and open mind to new information. (Receiver or Manager of receiver)
VI-2. Increase motivation of receiver. (Manager of receiver)
VI-3. Send high quality information or value added information. (Sender)
VI-4. Information selection by importance. (Receiver)
VI-5. Send information with priority information. (Sender)

VII. Timing issue

Finally this group of solutions focuses on the timing issues. There are three solutions which belong to this category.

VII-1. Send information at the correct timing.
VII-2. Do first, then think.
VII-3. Update information (with special effort).
Table 4-2  Solution of stickiness problems

<table>
<thead>
<tr>
<th>No.</th>
<th>Solution</th>
<th>Applied type of problem</th>
<th>Case No.</th>
<th>Type of info.</th>
</tr>
</thead>
<tbody>
<tr>
<td>I - 1</td>
<td>Machine shows it. (Templatimg)</td>
<td>B-1. Complex phenomena: Too complex to predict</td>
<td>3M-6, 4F-4, 4M-3, 4M-4</td>
<td>S&lt;sup&gt;15&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B-2. Organizational complexity</td>
<td>4D-3, 3G-9</td>
<td>S&lt;sup&gt;16&lt;/sup&gt; &amp; I</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C-1. Filter of sender: Misunderstood relevancy</td>
<td>4G-16</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C-5. Filter of the receiver: Strong preconception</td>
<td>3G-9</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C-6. Filter of the sender and receiver: Misunderstood relevance</td>
<td>3F-10</td>
<td>I</td>
</tr>
<tr>
<td>I - 2</td>
<td>Learn from similar line's experience</td>
<td>B-1. Complex phenomena: Too complex to predict</td>
<td>3F-14, 4D-1, 4G-17, [4G-19]&lt;sup&gt;17&lt;/sup&gt;</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G-3. Can't transfer information up front.</td>
<td>4F-3, 4F-5</td>
<td>S&lt;sup&gt;18&lt;/sup&gt;</td>
</tr>
<tr>
<td>I - 3</td>
<td>Other person recognize the problem</td>
<td>C-5. Filter of the receiver: Strong preconception</td>
<td>[4G-2], 4G-20</td>
<td>I</td>
</tr>
</tbody>
</table>

II. Technique to find relevant information.

| 11 - 1 | Use preliminary design and use it as a base of argument | G-3. Can't transfer information up front. | 3F-11 | S |

(Continue on next page)

<sup>15</sup>See the Note at the end of this table for the meaning of symbols.
<sup>16</sup>In these cases, the information to be transferred was S type information but failed to be used. Machine revealed this failure.
<sup>17</sup>In these cases, it was difficult to transfer S type information because I type information lacked.
Table 4-2  Solution of stickiness problems (continued)

<table>
<thead>
<tr>
<th>No.</th>
<th>Solution</th>
<th>Applied type of problem</th>
<th>Case No.</th>
<th>Type of info.</th>
</tr>
</thead>
<tbody>
<tr>
<td>III-1</td>
<td>Send Task to Expert</td>
<td>A-1 Systemic knowledge</td>
<td>3F-1</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3F-2</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4G-15</td>
<td>S</td>
</tr>
<tr>
<td>III-2</td>
<td>Expert Involvement (1)</td>
<td>A-1 Systemic knowledge</td>
<td>3G-3</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td>[Expert who has information for problem solving.]</td>
<td></td>
<td>[3G-4]</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>[4G-11]</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>[4G-12]</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A-2 Tacit knowledge</td>
<td>3F-9</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3M-2</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3G-6</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4D-1</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4G-5</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4G-6</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>[4G-12]</td>
<td>S</td>
</tr>
<tr>
<td>III-3</td>
<td>Expert Involvement (2)</td>
<td>G-2. Timing: Window of design</td>
<td>(3M-3)</td>
<td>C for S</td>
</tr>
<tr>
<td></td>
<td>[Expert who has complementary information: Experienced people]</td>
<td></td>
<td>4F-2</td>
<td>C for S</td>
</tr>
<tr>
<td>III-4</td>
<td>Expert Involvement (3)</td>
<td>C-2 Filter of sender:</td>
<td>3F-5</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td>[Expert who has information for problem identification: Insider involvement]</td>
<td>Reluctant to send</td>
<td>3F-6</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3F-14</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3F-15</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4G-1</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td>User (Operator)</td>
<td>C-3. Filter of sender:</td>
<td>3F-7</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Given up problem</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Maintenance Staff</td>
<td>C-8. Weak incentive for the sender</td>
<td>3M-1</td>
<td>I &amp; S</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Maintenance Staff</td>
<td>G-1. Timing problem:</td>
<td>3M-1</td>
<td>S &amp; I</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Different timing of</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>generation of the</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>information and use of</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>it.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>People in existing line</td>
<td>C-11. Psychological</td>
<td>(3G-7)</td>
<td>S &amp; I</td>
</tr>
<tr>
<td></td>
<td></td>
<td>distance: Unfamiliarity</td>
<td>(3G-8)</td>
<td>S &amp; I</td>
</tr>
<tr>
<td></td>
<td></td>
<td>of sender and receiver.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>III-5</td>
<td>Gather information as much as possible</td>
<td>A-2 Tacit knowledge</td>
<td>4M-1</td>
<td>I &amp; S</td>
</tr>
</tbody>
</table>

(Continue on next page)
### Table 4-2 Solution of stickiness problems (continued)

<table>
<thead>
<tr>
<th>No.</th>
<th>Solution</th>
<th>Applied type of problem</th>
<th>Case No.</th>
<th>Type of info.</th>
</tr>
</thead>
<tbody>
<tr>
<td>IV-1</td>
<td>Get information through face to face communication. (But it is not reliable because in many cases it works by chance.)</td>
<td>C-1 Filter of sender: Misunderstood relevancy.</td>
<td>3F-4</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C-2 Filter of sender: Reluctant to send</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>C-3. Filter of sender: Given up problem</td>
<td>3F-8 (1/2)</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C-8. Weak incentive for the sender</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>E-1. Inadequate transfer method.</td>
<td>4G-2</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td>Machine side meeting or demonstration</td>
<td>D-1. Knowledge compatibility.</td>
<td>4E-2</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td></td>
<td>E-1. Inadequate transfer method.</td>
<td>[3G-4]</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3M-5</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4F-4</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4E-2</td>
<td>I</td>
</tr>
<tr>
<td>IV-3</td>
<td>Get information through personal network.</td>
<td>C-11. Psychological distance: Unfamiliarity of sender and receiver.</td>
<td>4G-18</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td></td>
<td>I-1 Update of information</td>
<td>4D-2</td>
<td>S</td>
</tr>
<tr>
<td>IV-4</td>
<td>Interpreter who can understand multiple discipline.</td>
<td>D-1. Knowledge compatibility.</td>
<td>(3F-12)</td>
<td>S</td>
</tr>
</tbody>
</table>

### V. Techniques to increase the possibility of occurrence of information transfer by chance.

<table>
<thead>
<tr>
<th>No.</th>
<th>Solution</th>
<th>Applied type of problem</th>
<th>Case No.</th>
<th>Type of info.</th>
</tr>
</thead>
<tbody>
<tr>
<td>V-1</td>
<td>Put people of different culture together (In a project).</td>
<td>C-7 Historical barrier on receiver side</td>
<td>3F-3</td>
<td>S</td>
</tr>
<tr>
<td>V-2</td>
<td>Put different type of expert together (in a meeting).</td>
<td>H-1. Unpredictable synergy effect.</td>
<td>3F-13</td>
<td>S</td>
</tr>
<tr>
<td>V-3</td>
<td>Collocation</td>
<td>E-2. Geographical separation</td>
<td>3G-10</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4G-8</td>
<td>I&amp;S</td>
</tr>
</tbody>
</table>

(Continue on next page)

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19See the Note at the end of this table for the meaning of fraction number.
Table 4-2  Solution of stickiness problems (continued)

<table>
<thead>
<tr>
<th>No.</th>
<th>Solution</th>
<th>Applied type of problem</th>
<th>Case No.</th>
<th>Type of info.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VI-1</td>
<td>Remove prejudice and open mind to new information <em>(Receiver or Manager of receiver)</em></td>
<td>C-10. Credibility of the information source.</td>
<td>[4G-3] (4G-14)</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VI-2</td>
<td>Increase motivation of receiver <em>(Manager of receiver)</em></td>
<td>C-9. Weak incentive for the receiver</td>
<td>[4M-2] (4E-3) (4G-9)</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VI-3</td>
<td>Send high quality information or value added information <em>(Sender)</em></td>
<td>C-4 Filter of the receiver: Reluctant to receive</td>
<td>[3G-2] (3G-5)</td>
<td>I</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

VII. Timing issue.

| VII-1| Send information at the correct timing | F-2. Lost information: Too long to keep. | (4F-1) (4G-13) | S & I       |
|      |                                          |                                        |              |              |
| VII-2| Do first, then think | G-3. Can’t transfer information up front. | [4G-4] (4G-7a) | S           |
|      |                                          |                                        |              |              |
| VII-3| Update information (with special effort.) | I-1 Update of information. | [3G-1] (4G-10) | I & S       |

(Continue on next page)
Table 4-2   Solution of stickiness problems (continued)

NOTE
Type of information
I: Information for Problem Identification.
S: Information for Problem Solving.
C: Complementary information

Type of solution
Case No. with () means it was not solved in the real case and is judged that type solution could have solved the problem.
Case No. with [] indicate that the case was a general comment; for example it has the notion of "generally speaking......" or "such kind of problem often happened......" or "It was a rule of thumb for project work......" This distinction is important when we count the number of cases in some category because general comment can be a aggregation of several cases then it should have the higher significance.
When there were two candidates of problem types and difficult to determine which should be assigned, I just assigned 0.5 points and indicated with (1/2) after the case number.
4-2-2. Data analysis

Let us examine the use of the solutions in the descriptive data.

Table 4-3 shows how often each type of solution was used. Table 4-4 shows summary number of the cases of stickiness problem in each categories and Fig. 4-1 shows the same data in the pie graph. From this graph we can understand that "Category 3: Techniques to use expert knowledge" has the largest number of cases. Then "Category 1: Techniques to find problems", "Category 4: Techniques to enhance the effectiveness of information transfer", and "Category 6: Techniques to increase the possibility of use of transferred information" follows.

Table 4-5 and Fig 4-2 shows solution used for more than one categories. This shows that following three solutions are most versatile: "Machine shows it", "Expert involvement (I type)", "Face to face communication". If we do not distinguish the expert's type, the number of the categories which can be solved by the expert involvement will increase more. And also if we include "machine side meeting" as one kind of "machine shows it" or "face to face", the number for these solutions will increase.

Table 4-6 shows solution which solved more than two cases and Fig 4-3 shows the top six solutions which solved most problems. It shows that "expert involvement (I type and S type)" is heavily used. The rest of the solutions were as follows: "Machine shows it", "Learn from similar line", "Machine side meeting", "Face to face communication". Interestingly all of top six solutions are also solutions which solved more than two categories (versatile solutions).
Table 4-3  Solution of stickiness problems in each categories (Summary)

<table>
<thead>
<tr>
<th>No.</th>
<th>Solution</th>
<th>Number of applied categories of stickiness</th>
<th>Number of problems solved</th>
<th>Number of cases in each info. type</th>
</tr>
</thead>
<tbody>
<tr>
<td>I - 1</td>
<td>Machine shows it. (Templating)</td>
<td>(B-1, B-2, C-1, C-5, C-6)</td>
<td>9</td>
<td>17 [2] cases</td>
</tr>
<tr>
<td>I - 2</td>
<td>Learn from similar line's experience.</td>
<td>(B-1, G-3)</td>
<td>6 [1]</td>
<td></td>
</tr>
<tr>
<td>I - 3</td>
<td>Other person recognize the problem.</td>
<td>(C-5)</td>
<td>2 [1]</td>
<td></td>
</tr>
</tbody>
</table>

II. Technique to find relevant information.

| II - 1 | Use preliminary design and use it as a base of argument. | 1 (G-3) | 1 | S = 1 |

III. Techniques to use expert knowledge | 25 [5] + (2) cases |

| III-1 | Send Task to Expert | 1 (A-1) | 3 | S = 3 |
| III-3 | Expert Involvement (2) [Expert who has complementary information: Experienced people] | 1 (G-2) | 1 + (1) | C for S = 1 |
| III-4 | Expert Involvement (3) [Expert who has information for problem identification: Insider involvement] | 5 (C-2, C-3, C-8, C-11, G-1) | 9 [1] + (1) | I = 6 |
| III-5 | Gather information as much as possible | 1 (A-2) | 1 | I & S = 1 |

(Continue on next page)

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20See the Note at the end of this table for the meaning of symbols: I,S,C.
21See the Note at the end of this table for the meaning of [ ] and ().
Table 4-3  Solution of stickiness problems in each categories (Summary) (Continued)

<table>
<thead>
<tr>
<th>No.</th>
<th>Solution</th>
<th>Number of applied categories of stickiness</th>
<th>Number of problems solved</th>
<th>Number of cases in each info. type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IV. Technique to enhance the effectiveness of information transfer.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IV-1</td>
<td>Get information through face to face communication.</td>
<td>5 (C-1, C-2, C-3, C-8, E-1)</td>
<td>4 + (1)</td>
<td>I = 4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>S = 1 (1)</td>
</tr>
<tr>
<td>IV-2</td>
<td>Machine side meeting or demonstration</td>
<td>2 (D-1, E-1)</td>
<td>5 [1]</td>
<td>I = 3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>S = 2 [1]</td>
</tr>
<tr>
<td>IV-3</td>
<td>Get information through personal network.</td>
<td>2 (C-11, I-1)</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>IV-4</td>
<td>Interpreter who can understand multiple discipline.</td>
<td>1 (D-1)</td>
<td>1 [1]</td>
<td>S = 1 [1]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>V. Techniques to increase the possibility of occurrence of information transfer by chance.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V-1</td>
<td>Put people of different culture together (In a project).</td>
<td>1 (C-7)</td>
<td>1</td>
<td>S = 1 [1]</td>
</tr>
<tr>
<td>V-2</td>
<td>Put different type of expert together (in a meeting).</td>
<td>1 (H-1)</td>
<td>1</td>
<td>S = 1 [1]</td>
</tr>
<tr>
<td>V-3</td>
<td>Collocation</td>
<td>1 (E-2)</td>
<td>2</td>
<td>S = 1 [1]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>I &amp; S = 1</td>
</tr>
<tr>
<td></td>
<td>VI. Techniques to increase the possibility of use of transferred information.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VI-1</td>
<td>Remove prejudice and open mind to new information (Receiver or Manager of receiver)</td>
<td>1 (C-10)</td>
<td>1 [1] + (1)</td>
<td>I = 1 [1] + (1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VI-2</td>
<td>Increase motivation of receiver (Manager of receiver)</td>
<td>1 (C-9)</td>
<td>2 [1] + (1)</td>
<td>I = 0 + (1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>S = 2 [1]</td>
</tr>
<tr>
<td>VI-3</td>
<td>Send high quality information or value added information</td>
<td>2 (C-4, C-10)</td>
<td>3 [3] + (1)</td>
<td>I = 2 [2] + (1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>S = 1 [1]</td>
</tr>
</tbody>
</table>

(Continue on next page)
Table 4-3  Solution of stickiness problems in each categories (Summary) (Continued)

<table>
<thead>
<tr>
<th>No.</th>
<th>Solution</th>
<th>Number of applied categories of stickiness</th>
<th>Number of problems solved</th>
<th>Number of cases in each info. type</th>
</tr>
</thead>
<tbody>
<tr>
<td>VI-4</td>
<td>Information selection by importance (Receiver)</td>
<td>1 (F-1)</td>
<td>3 [3] + (1)</td>
<td>1 = 3 [3] + (1)</td>
</tr>
<tr>
<td>VI-5</td>
<td>Send information with priority information (Sender)</td>
<td>1 (F-1)</td>
<td>0 + (2)</td>
<td>S &amp; I = 0 + (2)</td>
</tr>
</tbody>
</table>

VII. Timing issue.

<table>
<thead>
<tr>
<th>No.</th>
<th>Solution</th>
<th>Number of applied categories of stickiness</th>
<th>Number of problems solved</th>
<th>Number of cases in each info. type</th>
</tr>
</thead>
<tbody>
<tr>
<td>VII-1</td>
<td>Send information at the correct timing</td>
<td>1 (F-2)</td>
<td>0 + (2)</td>
<td>S &amp; I = 0 + (2)</td>
</tr>
<tr>
<td>VII-2</td>
<td>Do first, then think</td>
<td>1 (G-3)</td>
<td>2 [1]</td>
<td>S = 2[1]</td>
</tr>
<tr>
<td>VII-3</td>
<td>Update information (with special effort.)</td>
<td>1 (I-1)</td>
<td>2 [2]</td>
<td>I &amp; S = 2 [2]</td>
</tr>
</tbody>
</table>

NOTE
Type of information
I: Information for Problem Identification.
S: Information for Problem Solving.
C: Complementary information
Type of solution
Number with [] indicate that the case was a general comment; for example it has the notion of "generally speaking......" or "such kind of problem often happened......" or "It was a rule of thumb for project work......" This distinction is important when we count the number of cases in some category because general comment can be an aggregation of several cases then it should have the higher significance. This type of case is included in the total case count.
Number with +() means it was not solved in the real case and is judged that type solution could have solved the problem. This type of case is not included in the total case count.
Caution When there were two candidates of problem types and difficult to determine which should be assigned, I just assigned 0.5 points and added with other case numbers.
Table 4-4 Number of stickiness issues in each categories

<table>
<thead>
<tr>
<th>Techniques</th>
<th>Number of cases</th>
<th>Total</th>
<th>Solved</th>
<th>Not solved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category 1</td>
<td></td>
<td>17</td>
<td>17</td>
<td>0</td>
</tr>
<tr>
<td>Category 2</td>
<td></td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Category 3</td>
<td></td>
<td>27</td>
<td>25</td>
<td>2</td>
</tr>
<tr>
<td>Category 4</td>
<td></td>
<td>13</td>
<td>12</td>
<td>1</td>
</tr>
<tr>
<td>Category 5</td>
<td></td>
<td>4</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Category 6</td>
<td></td>
<td>15</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>Category 7</td>
<td></td>
<td>6</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>83</strong></td>
<td><strong>72</strong></td>
<td><strong>11</strong></td>
</tr>
</tbody>
</table>

Fig 4-1 Distribution of stickiness issues in each categories

- Category 1: Techniques to find problems
- Category 2: Technique to find relevant information
- Category 3: Techniques to use expert knowledge
- Category 4: Techniques to enhance the effectiveness of information transfer
- Category 5: Techniques to increase the possibility of occurrence of information transfer by chance
- Category 6: Techniques to increase the possibility of use of transferred information
- Category 7: Timing issue
**Table 4-5** Solution used for more than one categories

<table>
<thead>
<tr>
<th>Method</th>
<th>Number of categories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machine shows it.</td>
<td>5</td>
</tr>
<tr>
<td>Expert involvement (I type)</td>
<td>5</td>
</tr>
<tr>
<td>Face to face communication</td>
<td>5</td>
</tr>
<tr>
<td>Learn from similar line's experience.</td>
<td>2</td>
</tr>
<tr>
<td>Expert involvement (S type)</td>
<td>2</td>
</tr>
<tr>
<td>Machine side meeting</td>
<td>2</td>
</tr>
<tr>
<td>Get information through personal network</td>
<td>2</td>
</tr>
<tr>
<td>Send high quality information</td>
<td>2</td>
</tr>
</tbody>
</table>

![Bar chart showing the solution used more than one categories](chart.png)

**Fig. 4-2** Solution used more than one categories
Table 4-6  Solution which solved more than two cases

<table>
<thead>
<tr>
<th>Method</th>
<th>Number of problems solved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expert Involvement (S type)</td>
<td>11</td>
</tr>
<tr>
<td>Machine shows it.</td>
<td>9</td>
</tr>
<tr>
<td>Expert Involvement (I type)</td>
<td>9</td>
</tr>
<tr>
<td>Learn from similar line.</td>
<td>6</td>
</tr>
<tr>
<td>Machine side meeting</td>
<td>5</td>
</tr>
<tr>
<td>Face to face</td>
<td>4</td>
</tr>
<tr>
<td>Send high quality info.</td>
<td>3</td>
</tr>
<tr>
<td>Info. selection by priority</td>
<td>3</td>
</tr>
<tr>
<td>Others</td>
<td>33</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>83</strong></td>
</tr>
</tbody>
</table>

Fig. 4-3  Top six solutions solved most problems
Chapter 5  Problem Solving and Stickiness of Information

5.1 General flow of information for problem solving

Problem solving is not a single step action. There are many different levels of understanding of the problem and problem solving. To solve a problem, first, we have to know the existence of the problem. After we notice the problem, we have to understand the problem and find what kind of information we need and whom we should ask or where we should search for the information. Then we have an option whether we solve the problem by ourselves or ask somebody else to solve it. And if we decided who solve it, we have to transfer necessary information to the solver and solve it. As shown above, problem solving can be seen as a flow of actions and it can be divided into several stages and in each stages different types of information are required to solve the problem.

Fig 5-1 shows the general flow of information for problem solving. As shown in the figure, it can be divided into six different stages. First stage is "Problem Identification." Without knowing the existence of the problem, we can't solve it. Second stage is "Relevant Information Identification." At first stage, we find the existence of problem but we can not start to solve the problem because our understanding of the problem is not deep enough. It is necessary to understand the problem and find what kind of information is (or might be) necessary to solve the problem. In this sense, this second stage can be included in the problem identification stage in a broader definition. But at this stage human insight is necessary, while problem identification itself can be done by just observing the breakdown of the machine.
1. **Problem Identification**
   "I don't know the existence of problems."

2. **Relevant Information Identification**
   "I don't know what kind of information to gather."

3. **Information Source Identification**
   "I don't know whom I should ask or where to search for information."

4. **Decision**
   "Who should solve the problem?"
   "Which is relatively easier?"

5. **Information Collection**
   "How to transfer the information?"

6. **Effective Use of Information**
   "Information was transferred but it was not used effectively."

**Note:**
*1: Information for Problem Identification
*2: Complementary Information
*3: Information for Problem Solving

Fig. 5-1 Flow of Information for Problem Solving
Third stage is "Information Source Identification." At this stage we already know the problem and necessary information, but it is necessary to know who has (or might have) the information or where the information is (or might be) located. In some cases, this stage is skipped because it may be very obvious for us. But sometimes, it is very tough to find the source of the information. In such case, we have to find additional information (complementary information) to identify to locus of the information. To do this, we often talk with experts or experienced people about the problem or go to the library and try to find related literature.

These first three stages may not be straightforward. We begin from very primitive or superficial understanding of the problem, then we start to do try and error to get the information. Through trying to identify the relevant information or information source, our understanding of the problem becomes deeper and/or we may find another more fundamental problem than the original one. Therefore, these three stages can be an iterating process. In the Fig. 5-1, the arrow going back from stage two or three to the stage one shows this movement. (Evolutionary way of problem identification.)

The fourth stage is "Decision." When we find the locus of the information, it is not always necessary to solve the problem by ourselves. In many cases, it is easier and more reliable to ask expert to solve the problem. In this case there are several alternative ways to do this. We may separate the task from the rest of the project work and send it to the expert, or we may ask the expert to participate the project in part time basis or full time basis. If it is difficult to ask others to solve the problem by ourselves, we have to gather information and solve the problem. Which alternative way is the best? It depends on the relative stickiness of the expert information and context information. We will discuss this problem later.
The fifth stage is "Information collection." It is difficult to transfer the sticky information by definition. There is not a single way to "unstick" the information. But there are some measures to cope with this problem depending on what type of stickiness we want to reduce.

The last stage is "Effective Use of Information." We tend to think that when we transfer the information, it is over. But, there are many cases we failed to use the information effectively and waste the opportunity to solve the problem in practical work. If we really want to solve the problem, we have to keep this problem in our mind. In such occasion, people tend to say, "I have told you!" But there are fundamental reasons why people forget or fail to use the information effectively. Unless we solve this problem, all of the previous efforts end up in vain.

This is the general description of flow of information for problem solving. We will discuss what kind of methods exist and are useful in the following sections. But before we move to the discussion, let us discuss the type of information a little bit.

There are three types of information: (1) Information for problem identification, (2) Information for problem solving, (3) Complementary information.

First type of information is relatively straightforward. We need information to identify the problem. Sometimes this information is generated by checking the design. Sometimes we can learn it from the experience of similar project. Some times we fail to find the problem and it reveals at the test run when machine fails to work properly or breaks down, at the worst case.

Second type of information is "Information for problem solving." Many kinds of information related to problem solving belong to this category. It can be the knowledge of the materials used in the
machine, or behavior of the operators, or intuitive judgement of the expert, or mathematical model of the problem, or solution used in the similar lines, and so on.

Third type of information is "Complementary Information." This type of information does not contribute to the problem solving directly but it is necessary in the process of the problem solving. For example, the knowledge of who has (or may) have the "information for problem solving" is this type of information. The other example is the "timing information". It is important to know when we should decide and can change the design parameters because there exists windows for design. We will discuss this issue later.

5.2 How stickiness relates to problem solving?

Let us examine Fig. 5-1 again. In the right side of the chart, the dominant type of information necessary in each stage is indicated by symbols: "I", "S", "C".

At stage one, "I" type (information for problem identification) is necessary by definition. Sometimes this information is very sticky. When problem is complex, existence of the problem is not obvious. It may be difficult to predict at the design stage because no one knows the whole system. (Fragment of information is distributed over the project members and is sticky to the owner of the information.) Then the most powerful way to find the problem is to wait until the machine is built and to see whether it works or not. In this case, information is sticky to the machine. Sometimes experienced people can find problems intuitively at the design stage. But this skill is not easy to teach, therefore unless such kind of experienced people are available, we can not enjoy the benefit of this method. It is sticky to the experienced people.
At the second stage, to identify the relevant information, we need "I" type information. At this stage, we have to examine the problem carefully and understand the problem. To do this we need wide rage of technical knowledge. In many cases, necessary information is not limited in one technical field, therefore transfer of technical information between the different kind of expertise is necessary. But this is one of the sticky information transfer. ("I" type information.) On the other hand, experienced people are good at finding relevant information. This kind of know how to find information is also sticky to the experienced people. ("C" type information.)

At the third stage, "C" type information is necessary to identify the source of information. The knowledge of many supporting issues are important. For example, if we know who is the expert of the field, we can easily get information from him. In many cases, senior engineers know many other experts in the company and easily find the appropriate person to ask question. This type of information is sticky to the experienced people. Another example is that, if we have got used to the library, it is easy to find necessary information but when we use the library for the first time, it was difficult to figure out how to find useful information from the huge amount of books. Know how to use the index system of the library is sticky to the person who experienced it in the past.

At the fourth stage, decision of who should solve the problem is done based on the relative stickiness between the expert knowledge and the task information. Then we try to find which is easiest; to send the task to the expert or to bring the expert to the project or to transfer expert knowledge to the project member. We will discuss this issue later.

At the fifth stage, "S" type information should be transferred to the problem solver. In this stage, it is needless to say that we
have to cope with stickiness of information. There are many kinds of source of stickiness as we have examined in chapter 3.

At the sixth stage, we need "C" type information to use information effectively. If we miss the window of opportunity to use the information, the information has no value any more. But the knowledge when we should use the information is sticky information itself. Experienced people know it. On the other hand, it is necessary to know the relative importance of the information and use the information according to the priority especially when there are too much information to be handled. But again the knowledge to judge the priority is sticky to the experienced people.

Based on this overview, we will examine the each stage of problem solving and the methods to cope with the stickiness problem in the following section.

5.3 Flow of information for problem solving and methods to cope with the stickiness problem

Stage 1: Problem Identification -- Techniques to identify the problem

Information of the problem existence is very important because once we know the existence of problem, we can make our effort to gather information necessary to solve the problem. However unless we know the existence of the problem, we can't initiate our effort and fail to prevent the problem from occurring and when we find the problem, it is too late to solve it.

Though it is very important, it is very difficult to identify the problem. We don't know what is the relevant information to indicate the existence of the problem.
(a) Templating -- Machine shows it

There are many methods to identify the existence of the problem. The most certain method is "templating" (Tyre and von Hippel, 1991). Machine shows the existence of problems regardless of the ability of the developer.

When we put the machine into the plant environment, it shows problems. Until we do this, it is difficult to know which information is relevant and where exists the mismatch but once we do this, all relevant information are sort out automatically and we know the existence of the problem from troubles. Tyre and von Hippel (1991) studied this effect and named it as "Templating".

In the new production line development project, templating starts to work when the assembly of the component machines starts and continues until test run and ramp up period.

Though templating is powerful, it tends to identify the problem at later stage of the project. However the earlier the problem is identified, the more options we have to solve the problem and we can solve it by the cheaper way. When the problem is identified too late, there are too many constraints and our option is limited and available solution tends to be expensive.

(b) Prototype (or pilot line)

To avoid this problem, prototype (or pilot line) can be used. This is one kind of "templating" in a broader sense.

There are many levels of the perfection of prototype (or pilot line). If the prototype (or pilot lint) is exactly same as the final products (or process), it works best and would reveal almost all problems. However even a rough model could be very useful, while it will reveal limited amount of problems. If it is well focused to the
very important features of the product (or process) and if it can identify the problems which are difficult to solve later, it is worth to do.

The problem of this method is that it is expensive and time consuming if we want to improve the fidelity of the prototype (or pilot line), while it can save more money and time when it succeeds to find the problem earlier. This is the reason why it is not very popular in practical production line development. There is a tradeoff between risk of the failure and cost of prototype (pilot line).

(c) Simulation and model

Cheaper method on the same line is the use of model. It can be computer model or plastic model or mockup or even mental modeling, depending on the situation.

The main feature of the modeling is that it is build on the knowledge and assumptions of the designer, therefore it can not find the assumption level problems. For example, even if we use FEM (Finite Element Method) model to analyze the strength of the structure, if we use the wrong data for the material property, the result becomes irrelevant to the real structure. Though it has the fidelity risk, it can identify the problem related to interrelation of the components, which we tends to overlook. In this sense, modeling helps us to get new insights of the problem.

(d) Expert involvement

To find the assumption level problem, it is useful to have other person to check the assumptions. In this case, we assume that the person who checks the assumptions has expert knowledge (systemic knowledge or tacit knowledge) in that field. In this sense, this is one kind of expert involvement. Experts usually provide us "S" type information but they also contribute to the project with their problem identification capability.
The drawback of this method is that it is not always reliable. To identify problems effectively, it is necessary for the expert to understand the environment information of the problem, but it is time consuming. If the expert makes a judgement with incomplete knowledge, the result is not reliable. Expert can overlook the problem because of the lack of the information.

(e) Learn from past experience

Another kind of expert, who has the experience of other line, is useful. In many production line development cases, there are many similarities to the existing lines, therefore the experience of the similar line is useful. The person experienced problems in the existing line can find similar problems in the design of the new production line. If the problem has been solved already in the existing line, he can provide even the solution or information of who solved the problem.

User involvement is one of more general type of this expert involvement. He may not identify the problem directly but he can provide information of their experience and helps the designer to identify the problem.

Existing line’s experience is not necessarily limited to the past experience. We can use the existing line as a prototype (or pilot line). If we carefully examine the situation of the existing lines or do some experiment in them, we may identify the potential problems in the new line. This type of "use of existing line's experience as a prototype" often appeared in the cases.

The problem of this method is that the identified problem is sometimes important, but sometimes superstitious because the past problems in the existing lines did not necessarily solved by theoretical analysis but rather fire fighting ways.
Stage 2: Relevant Information Identification

In some cases, we know how to solve the problem instantly when we identify the problem. In such case, this stage is skipped. However, in some cases, we don't know how to solve the problem or we don't know at all how to approach the problem. This can happen in the case where problem is identified by the "template" type of identification methods. Many of us may have an experience of being at a loss in front of a broken machine.

When we don't know how to solve the problem, we usually ask somebody who may have a similar experience or go to the library and search literature. We may make some assumptions and create simple model to explain the situation and do some experiment. The main purpose of these activities are to increase the understanding of the problem.

Unless we understand the problem well enough, we cannot start problem solving. Professor Marcie Tyre said that one student visited her office and said, "I'm interested in your program. Tell me about management of technology." She tried to answer his question but could not make him quite satisfied. The problem was he did not ask her right question, and then she could not answer what he really wanted to know. However the real problem was not his way of asking, but rather the level of his understanding. Unless he knew well what he wanted to know, he could not ask "right question" and he could not get "right answer".

(a) Supervision by senior people

As shown above, we now understand the main feature of this stage is "understanding of the problem". Then what can we do to facilitate this process? In real life, we can ask expert or senior people to consult our problem or our supervisors may help us. Then it
is one of the important tasks of managers to provide such kind of help to his subordinates.

(b) Use of preliminary design

Another important way is to use preliminary design as a base of discussion. It is difficult for us to understand the problem on a abstract discussion. It is much easier to make preliminary design and find the problems or weakness of it and improve it. In this manner we can improve the understanding of the problem.

Anyway, we have to understand the problem well, then we can figure out what kind of information is necessary to solve the problem.

Stage 3: Information Source Identification

In some cases, it may be obvious for us whom we should ask or where we should search to find necessary information. In some cases, "related information identification" and "information source identification" occurs simultaneously. But still in some cases, we have to find the source of information. For example we can think of the following cases; the case in which we are sure that the problem could be solved by computer simulation but we don't have an expert in our company or the case in which we may have established a FEM model to solve the problem but material property data at high temperature is not available, etc.

(a) Use of personal network

Generally speaking, experienced people know whom to ask in the company. Personal network has important roll in such cases.
(b) Role of the "gate keeper" in stage 3

Allen (1977) found that in many organizations, there are some key technical persons who maintain the latest technical information and provide consultation to colleagues. He called this kind of person as a "gate keeper". Though gate keeper is an important information source, one of the other important aspects of gate keeper is visibility. If we know who is the gate keeper, we do not have to worry about stage 3 problem. We just go to see the gate keeper and ask him. Even if he does not have the information, he can easily identify the right person to ask through his past experience and wide personal network. Therefore visibility of the gate keeper makes the stage 3 (identification of information source) easier.

Up to this point, we have concentrated on the problem and information identification issues. We may regard all these three stages (Stage 1 to Stage 3) as problem identification in a broader definition, but many problem identification methods do not always give us the stage 2 or 3 information. Then it is better to consider them separately.

Stage 4: Decision -- Who solve the problem?

If we know or can predict the existence of the problem and if we know the location of the information, we can choose appropriate strategy from the following alternatives.

(a) Ask Expert to solve part of the project task

If the task can be separated from the rest of the tasks with minimum interference, we can ask external expert to solve the task. The advantage of asking expert to solve it is that we can avoid the difficult task; to unstick expert information which is sticky to him.
In stead of transferring sticky information of expert, problem is transferred. This method is useful when the information, which is necessary to solve the problem, is sticky to the expert and the information to define the problem is not sticky to the project. The important points are (1) whether the task can be separated from the rest of the tasks with minimum interrelationships or not, and (2) whether the task can be described explicitly or not.

(b) Expert involvement ("S" type)

If the task can not be separated from the rest of the tasks and has many interferences, we cannot ask external expert to solve the problem because the overhead of coordination work becomes too much. If the task itself can not be explicitly described, for example the task requires expert's diagnosis of the situation or project members don't understand what kind of information is necessary to solve the problem or information, which is necessary for the task, is intuitive judgements of some members of the project, we cannot ask external expert to solve the problem, either.

In such case, expert's information is sticky to the expert and information of the problem is also sticky to the project. This is the case where expert involvement as a member of project (full time or part time base) is one of the best solutions. By doing so, we can avoid to send both of sticky informations: expert information and problem information. The disadvantage of this solution is that it is feasible only when the expert is available. This method require to allocate very scarce resource: expert's time. If the problem can be solved by part time base, it will lessen the burden to the expert, but it depends on the scale of the problem and stickiness of the information related to the task.

In this case, the sticky information brought by the expert is "S" type information, therefore let us call this as "S" type expert involvement.
(c) Expert involvement ("C" type)

People who have experience of new process development can be called one kind of expert. The important point is that experienced people have timing information or system interrelationship information (complementary information) in addition to expert knowledge of the production system. Timing information or system interrelationship information is very important to use other information effectively because there exist windows of design in the development. If we miss the timing when the windows are open, we can't use the information effectively. For example, in the case 3M-3, the existence of roll handling problem had been known since very beginning of the project, but this knowledge did not produce improvement in the project because they failed to examine this problem at the proper timing and when they started to conceder this problem, it was too late (the window had been closed).

Timing information is sticky because it requires to have deep understanding of the project work. To understand timing, we have to know the interrelationship of each tasks of the project work. This interrelationship could be written on paper but it would be a very large scale network chart. (In this sense, timing information has systemic knowledge type of stickiness.) Experienced people understand this relationship from their experience of former projects.

This type of expert can judge the priority of the tasks and information because he has the timing information and the interrelationship information. Then he can select important information effectively when there are too much information to handle.
The important feature of this type of expert is that he brings "C" type information, therefore let us call this as "C" type expert involvement\(^{22}\).

(d) Expert involvement (insider)

Expert is not necessarily an expert of problem solving but he can provide insider information. One of the most popular insider is a user. User involvement is very useful to get the environment or user behavior information. Another type of insider is the member of the former development project. Involvement of this type insider is very useful to get the information of failure (or difficulty) in the former project or know-how type of information. Other type of insider is the maintenance staff or maintenance people. Involvement of this type of people is very useful to get the information of the update of the existing line and the information of frequent troubles in the existing line. Any way, these insiders have specific type of sticky information which is difficult to access for the outsiders.

The difference of this type of expert (insider) involvement from other types of expert involvement is that insiders work as sources of information and they do not necessarily solve the problems by themselves.

(e) Go and try to get first hand information

If we cannot separate task or involve people who have sticky information. We have go and try to get information which is located outside of the project. In this case we cannot avoid the problems of transferring sticky information. We will examine the techniques to do this in the next section.

\(^{22}\)We can expect I type expert involvement as an analogy. It appeared in Stage 1 Problem identification section (d) (pp. 140).

- 147 -
Stage 5: Information collection

(a) Technique to enhance the effectiveness of information transfer

In this section, we will examine the techniques to enhance the effectiveness of information transfer. (Some of these techniques are also applicable to the I type information transfer for problem identification stage. We did not discuss information transfer method issues in the stage 1 argument. It is included in this section.)

(a-1) Face to face communication

Face to face communication is very powerful because it has many cues and it can transfer necessary information very efficiently in the interaction of the sender and receiver. The other advantage is that it can transfer information which the sender originally does not intend to transfer. This feature is helpful especially for the problem identification purpose.

(a-2) Machine side meeting or demonstration

Machine side meeting or demonstration is one kind of face to face communication. However it is more powerful because it can use demonstration. Seeing is believing. Demonstration is especially useful when the knowledge compatibility is the obstacle of the information transfer.

(a-3) Get information through personal network

In many cases, the same information becomes more sticky through the official channel than personal channel. For example, information related to the past failure is more difficult to obtain from the official route than from personal conversation. Another example is that if we request some information to the other department through official route, they will answer exactly what was asked but if we have a friend in the department, he may ask us
the reason of the request and he will give us the best information we need, not just what was asked. Through personal network, we can get the information which fits our needs better and has more rich contents.

(a-4) Interpreter

If we have a difficulty to transfer information because of the knowledge compatibility problem, it is helpful to have an "interpreter" who knows both of the different knowledge bases and translate the information into different "language".

(b) Techniques to increase the possibility of occurrence of information transfer by chance

When we think of information transfer, we tends to think it in deterministic way and try to control it. But in reality, some information is transferred by chance because unless we know the existence of the information, we can't make effort to get it. This type of information transfer is useful especially for the problem identification. While information is transferred by chance, it is important for us to try to increase the possibility of the occurrence of information transfer.

(b-1) Put people of different culture together in a project

If the people of the same culture (or background) living together, they tends to have similar ways of thinking and tends to have same kind of filter or barriers. To break such kind of obstacles, it is useful to put people of different culture together.

(b-2) Put different type of expertise together in a meeting

If we put different types of expertise together, synergy effect may occur. But sometimes it merely causes conflict between different groups. Therefore it is a very difficult managerial issue,
but we can’t afford to forget it because if we can get the synergy effect, it may create a great benefit.

(b-3) Collocating

We discussed the importance of putting different type of people together above but we did not discussed how to put them together. One way is put them in a project. Another way is to do joint meeting of different people. But there is another way to do this, that is collocating. Different types of people are located in a same building but they are not necessary to belong to the same project.

Collocating is a very powerful method to increase the information transfer. It is useful to increase both of problem identification and problem solving type of information transfer. To enhance this, there are techniques including the design of the building. This issue was studied well by Tom Allen (1977).

Stage 6: Effective use of information

(a) Techniques to increase the possibility of use of transferred information

Even if the information is transferred, it is not sure whether it will be used properly or not. Transferred information may be discarded by the receiver by some kind of prejudice or it may be lost simply because the receiver overflows.

(a-1) Long term solution for fundamental problem

(1) Remove prejudice and open mind

If the receiver has prejudice or preconception, he may misjudge the value of the information and discard it. To prevent this problem, it is necessary to remove prejudice and keep our mind open
to the new information. It is easy to say but difficult to do. However we should not forget managerial effort to do this.

Sometimes it is useful to change the person in order to remove the prejudice. Rotation is one of the powerful managerial leverage.

(2) Send high quality information or value added information

If we send information and want to make sure that it will be used properly, we have to make effort to send high quality information or value added information. "High quality" means that information is correct and non-trivial. "Value added" means that the information should be accompanied by the feasible method of application. It is important when we want to send information of problem identification and want receiver to solve the problem. In such case, receiver tends to be reluctant to accept the fact. However if we can provide feasible solution or key to the solution, the receiver will accept the information more easily.

(3) Increase motivation of the receiver

If we can increase the motivation of the receiver, the possibility of use of the information will increase. The method to increase the motivation differs from case to case. Following examples are picked up from the case.

Create trust. Remove barrier. This method is useful when there is filter or barrier on the receiver side.

OJT training. This is an example to improve the motivation of the receiver.
(a-2) Short term solution for overflow problem.

(1) Information selection by importance (Receiver side)

When there are too much information to be used and receiver overflows, it is important for the receiver to select information by importance. When we judge the importance, we have to take into account following factors: (1) Importance of the impact on the performance or operatability or maintainability of the line. (2) Difficulty of the fixing problem later. (Timing issue.)

(2) Send information with priority information (Sender side)

If we see the same problem (too much information problem) from sender's point of view, it is important to send information with priority information and make sure that important information will not be discarded by mistake. One way to do this is to explain the sender's need or situation to the receiver and let him understand it.

The difficulty is that sender tends to overvalue his information and all information tends to be highest priority. If we really want it work, we have to evaluate the value of the information carefully.

(b) Related issue -- Timing

Timing issue is one of the important issues related to the effectiveness of information transfer. Let us examine a couple of issues related to timing problem.

(b-1) Send information timely -- Window of design

There exists windows of opportunities for design. If we miss the timing it becomes very difficult and expensive to change the design later. Therefore, the information which is sent too late had little value and it may not be used.
To the contrary, if the information is sent too early, there is a risk that the information will be forgotten or lost by the receiver. In this case, the information may not be used, either. To send information too early is also reduce the possibility of the effective use of the information.

The lesson we learned here is "Don't send it too late. Don't send it too early". But the difficulty is that sender does not know the timing information of the receiver. Therefore practical way is to send the information early enough and occasionally ask the receiver about the progress and monitor his activities. The drawback of this way is that it is time consuming and require managerial efforts of the sender.

(b-2) Do first, then think -- Fix it later

Another timing issue is that some information are difficult to get up font but relatively easy to get it later. Then if we can wait for a while, it may reduce cost, time, and effort to get the information. The problem is how to judge which problem can be left for the later solution. To judge this problem, it is necessary to know the interrelationship of the tasks.

(b-3) Information updating

The last issue was the updating of information. If we forget the fact that information can be different from the real situation because the real world can change without updating the information, it will cause troubles. This problem often happens in the case of the drawing or other documents which were created at the initial construction timing and failed to be maintained at the later modifications. It can happen not only in the written documents but also in the human memory. Experts memory may not always be updated on the later changes of the situation.
5.4 Data analysis and Discussion

In this section we will analyze the descriptive data. We focus on what kind of solution appeared in each stage of the problem solving. To do this, the table of solution of stickiness problem discussed in the chapter 4 was rearranged according to the problem solving flow. (Some solution was used in multiple stages of problem solving, in this case the solution was listed in all of these stages and cases were divided into each stages according to the contents.) (See table 5-2 which is placed at the end of this section: pp.163 - 167)

Aggregate data analysis

Table 5-1 and Fig. 5-2 show the numbers of cases listed in each stages. This shows that more than half of the descriptive data is related to the stage 1, i.e. problem identification. This shows the importance of the problem identification in the project work.

Another feature of the data is that there are very few cases reported related to stage 2 and 3. This is because that stage 2 and 3 are not recognized explicitly in the real life, but rather created in order to facilitate the conceptual analysis of the different problem identification methods.

Stage 4, 5, 6 have approximately same weight in the data but stage 6 is different from others. Cases related to the stage 6 are eleven and four of them (36%) were not solved. This unsolved ratio is very high compared to the other stages (while stage 5 is 20%, others are less than 10%). This shows that even if the information is transferred, it is not always used effectively and there is not a good solution to cope with this problem.
Fig. 5-2  Distribution of cases in each stages of problem solving

Table 5-1  Number of cases in each stages of problem solving

<table>
<thead>
<tr>
<th>Stage</th>
<th>Number of cases</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Solved</td>
<td>Not solved</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stage 1</td>
<td>48</td>
<td>57.1%</td>
<td>43</td>
<td>51.2%</td>
<td>5</td>
</tr>
<tr>
<td>Stage 2</td>
<td>1</td>
<td>1.2%</td>
<td>1</td>
<td>1.2%</td>
<td>0</td>
</tr>
<tr>
<td>Stage 3</td>
<td>0</td>
<td>0.0%</td>
<td>0</td>
<td>0.0%</td>
<td>0</td>
</tr>
<tr>
<td>Stage 4</td>
<td>14</td>
<td>16.7%</td>
<td>13</td>
<td>15.5%</td>
<td>1</td>
</tr>
<tr>
<td>Stage 5</td>
<td>10</td>
<td>11.9%</td>
<td>8</td>
<td>9.5%</td>
<td>2</td>
</tr>
<tr>
<td>Stage 6</td>
<td>11</td>
<td>13.1%</td>
<td>7</td>
<td>8.3%</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>84</td>
<td>100.0%</td>
<td>72</td>
<td>85.7%</td>
<td>12</td>
</tr>
</tbody>
</table>
Let us examine each stages in the Table 5-2 more detail.

Stage 1: Problem Identification

"Machine shows it" type solution appeared often in the data (9 out of 48 cases = 18.8%). It was powerful in many types of problem (It was applied to five categories). Especially it was useful for both of the complexity type problem. (Complex phenomena and Organizational complexity.) It was the only solution other than "learning from other line", used in the case for complexity problem.

"Learn from similar line's experience" is also powerful for the complexity problem. ("Can't transfer information up front" problem is one kind of complexity problem because it is caused by the complexity and large amount of information involved and unless we defined the related area, we can't judge which information is important for the receiver.)

Involvement of the experts who have tacit knowledge is useful because they can identify the problem intuitively. This skill is hard to transfer to the others, therefore involvement of them is useful.

Another type of expert who is desirable to be involved is the person who has insider information. There are ten cases reported in this category. This shows the importance of the past experience to identify the problem. It also shows that such kind of experience seems to be difficult to diffuse in the organization other than the "insider involvement".

Other person can identify the problem which was difficult for the person in charge because of the problem related to his filter: Strong preconception.

Up to this point, all these problem identification methods are somewhat focused on the mechanism of finding problems. There is
other group of solutions used in the cases. The feature of this group is its focus on the information transfer.

"Get information through face to face communication" is the most frequently used method. (Four cases in five categories.) The next most frequently used method was "Machine side meeting and demonstration" and "Information selection by importance". (Both of them have three successful cases.) The former is useful because of the efficiency of the information transfer. The latter is focused on the effectiveness of the use of transferred information. "Collocation" is a well-known method to enhance the communication of the information by chance. And there are many other methods related to the removal of filter or barrier listed in the table.

Interesting finding is that if we want to improve the problem identification capability, we have to consider two things: First, we have to find right person (or right mechanism), who has necessary knowledge and capability, and bring him/her into the project. Second, we have to enhance the communication between the team members because it is necessary to bring multiple pieces of information held by different persons together to identify the problem.

Stage 2: Relevant Information Identification

"Use of preliminary design" was the only method reported in the cases. Until we start to try to solve the problem, we don't know how to approach it. But once we start preliminary design, it becomes clear what we know and what we do not know. It is one powerful way to deepen our understanding of the problem. It is especially useful when multiple people are involved in the problem solving and each has piece of necessary information. In such case, potential information sender cannot send his information to the rest of the
group unless he recognize that his piece of information is relevant to the problem.

This is one of the way to unstick the sender information. We can't transfer information until we know it is related. But to know it, it is necessary to start to think and increase the understanding of the problem.

It often happens when we make preliminary design and bring it to the meeting, somebody find fundamental problems in it relating to the wrong assumption. Then we have to bring it back and do the whole design again. It seems to be a waste of time. We think, "He should have told me earlier." But he could not. By the help of the preliminary design, both sender and receiver can increase the level of understanding and reach to the level to start discussion. Preliminary design is not a waste.

Stage 3: Information Source Identification

This type of problem did not appear in the cases. May be in the case where a large company working with a large vendor, only if we can identify necessary information, we can manage to find the expert who has this kind of information in either companies. Then this kind of problem did not occurred in the case.

Though there was no case reported, my hypothetical case was as follows, though we know the existence of the problem and what kind of information was necessary, we could not find the source of information and gave up to solve the problem. However later we found the data by chance when we were reading somebody else's report and regret that we did not asked him. Such kind of problem can happen when communication in the company is not good or there is no gate keeper who know the technology in the company.
Stage 4: Decision

There are many cases (14 out of 84 cases) which are related to expert involvement decision. As discussed in the section 5.3, the decision whether we solve the problem or ask expert to do it is based on the relative stickiness between the expert knowledge and project information related to the problem. Let us examine the data to find this trade off.

"Send task to expert" solution was used only in the cases where the source of the stickiness was "systemic knowledge". In such case, though expert knowledge is difficult to transfer, it is relatively visible what kind of knowledge he has and what kind of information is necessary to use his knowledge. This is the reason why "send task to expert" solution was used only for "systemic knowledge" type problem. In the cases "send task" solution was not popular, maybe because of its limited applicability.

On the other hand, "expert involvement" was used both "systemic knowledge" and "tacit knowledge" cases. It is difficult to find what kind of information is necessary for the expert who will do the intuitive judgement based on his tacit knowledge. In this case, it is necessary for the expert to come to the project and find necessary information.

When we think of expert involvement, different type of experts should be involved to bring different types of information. If we try to get some kind of knowledge (systemic or tacit), we should involve the expert who has such kind of knowledge. If we try to get the complementary information such as timing of design or judgement of priority, we need to involve the expert who has the experience of similar type of project work.
Stage 5: Information collection

Information transfer of the sticky information is difficult by definition. Therefore there is not a single solution. There are two different approach for this problem; one is "try to enhance the effectiveness of information transfer", the other is "try to increase the possibility of the information transfer by chance."

(a) Techniques to enhance the effectiveness of information transfer.

Face to face is powerful information transfer method. In the descriptive data, almost all information transferred by face to face was I type (therefore listed in Step 1). I believe there should have been many cases which were not reported but used face to face to transfer S type information. The fact that only I type information transfer cases were reported means that I type information is difficult to transfer other than face to face because "problem identification" requires many relevant information especially it was done at the design stage of the project.

Machine side meeting is also popular way which can be used in both Stage 1 (I type information) and Stage 5 (S type information) but it can only be possible after the machine is built. It is one kind of face to face communication, however it includes machine therefore it is much more powerful. It can overcome the compatibility problem. How should manager do to utilize this feature? It is good to put developer and user together and locate the activity at machine side. This is the main idea of M. Tyre's "forum" concept (1989). In the construction case, test run team is one kind of forum.

Personal network is also used to get S type information. It is more powerful for S type information than for I type information
because when we know the locus of the information and if there is stickiness in the official channel, it is clever to go around it by using personal network, however if we do not know the locus of the information, it is not sure that information can be get through personal network.

Interpreter might be useful to overcome the knowledge compatibility problem but only one failed case was reported.

(b) Techniques to increase the possibility of occurrence of information transfer by chance.

To increase the possibility of occurrence of information transfer by chance following three methods were used: "put people of different culture in a project", "put different type of expertise in a meeting", or "collocation of related divisions". The main point of these method is "mixture of the different people". Manager should consider this in the project team formation, project location decision, or meeting design.

Stage 6: Effective Use of Information

If the transferred information is not used effectively, all efforts done to transfer the information are wasted. There are two types of methods used in the cases.

(a) Techniques to increase the possibility of use of transferred information

Methods in this category are specially focused on the overflow problem. From receiver's point of view, "information selection by priority" is a good to cope with overflow problem because he can avoid to lose important information by mistake. From sender's point of view, he have to "send information with priority" is important because he want to influence receiver's priority judgement.
(b) Timing issue

"Send information at the correct timing" is important to cope with the "windows of design" issue and "too long to keep" issue, but it is difficult or sender to judge the timing because only receiver has the timing information (complementary information). This is the reason that though two cases of "send information at the correct timing", both of them are failure cases. It shows that it is difficult for the sender to solve the timing issue. One practically possible solution is a follow up strategy: send the information as fast as possible and occasionally call the receiver and ask the progress. The drawback of this strategy is it consume time and efforts of sender and sender can not afford to do this for many cases of information.

"Do first, then think" is a practical wisdom, because problem solving is a revolutionary process and we can not always do the right thing at the first time. Then what should we do? Should we wait until all information become available? This strategy suggest "don't wait" because we can revise later when the information becomes available. It is useful when we think that until we start to think the problem seriously, we can not understand the problem, however there is a risk to do it in haste and limit our options.

"Update of information" is related to a different type of problem. It indicates that unless we make effort to keep information updated, the information we got with great efforts can be a wrong information.
Table 5-2  Solutions of stickiness problems applied in each stages of problem solving

<table>
<thead>
<tr>
<th>No.</th>
<th>Solution</th>
<th>Applied type of problem</th>
<th>Case No.</th>
<th>Type of Info.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>[9]</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>+(5) cases</td>
<td></td>
</tr>
<tr>
<td>Stage 1: Problem Identification</td>
<td></td>
<td>43</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 - 1</td>
<td>Machine shows it.</td>
<td>B-1. Complex phenomena:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(Templatting)</td>
<td>Too complex to predict</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>B-2. Organizational</td>
<td>3M-6</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>complexity</td>
<td>4F-4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4M-3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4M-4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>C-1. Filter of sender:</td>
<td>4D-3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Misunderstood relevancy</td>
<td>3G-9</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>C-5. Filter of the receiver:</td>
<td>4G-16</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Strong preconception</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>C-6. Filter of the sender</td>
<td>3G-9</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>and receiver:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Misunderstood relevance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 - 2</td>
<td>Learn from similar lines'</td>
<td>B-1. Complex phenomena:</td>
<td>3F-14</td>
<td></td>
</tr>
<tr>
<td></td>
<td>experience.</td>
<td>Too complex to predict</td>
<td>4D-1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4G-17</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>4G-19</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>G-3. Can't transfer</td>
<td>4F-3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>information up front.</td>
<td>4F-5</td>
<td></td>
</tr>
<tr>
<td>1 - 3</td>
<td>Expert Involvement</td>
<td>A-2 Tacit knowledge</td>
<td>4G-5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>[Expert who has tacit</td>
<td></td>
<td>4G-6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>knowledge]</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(Continues on next page)

\[23\]See the Note at the end of this table for the meaning of symbols.

\[24\]In the case, the information to be transferred was S type information but failed to be used. Machine revealed the failure.

\[25\]See the Note at the end of this table for the meaning of () and ()

\[26\]It was difficult to transfer S type information because the I type information lacked.
Table 5-2  Solutions of stickiness problems applied in each stages of problem solving (continued)

<table>
<thead>
<tr>
<th>No.</th>
<th>Solution</th>
<th>Applied type of problem</th>
<th>Case No.</th>
<th>Type of info.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>[Expert who has information for problem identification: Insider involvement] Former PJ member</td>
<td>C-2 Filter of sender: Reluctant to send</td>
<td>3F-5</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3F-6</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3F-14</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3F-15</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4G-1</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td>User (Operator)</td>
<td>C-3. Filter of sender: Given up problem</td>
<td>3F-7</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td>Maintenance Staff</td>
<td>C-8. Weak incentive for the sender</td>
<td>3M-1</td>
<td>I&amp;S</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G-1. Timing problem: Different timing of generation of the information and use of it.</td>
<td>3M-1</td>
<td>S&amp;I</td>
</tr>
<tr>
<td></td>
<td>People in existing line</td>
<td>C-11. Psychological distance: Unfamiliarity of sender and receiver.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>[3G-7]</td>
<td>S&amp;I</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>[3G-8]</td>
<td>I&amp;S</td>
</tr>
<tr>
<td>1-5</td>
<td>Other person recognize the problem.</td>
<td>C-5. Filter of the receiver: Strong preconception</td>
<td>[4G-2]</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4G-20</td>
<td>I</td>
</tr>
<tr>
<td>1-6</td>
<td>Get information through face to face communication.  (But it is not reliable because in many cases it works by chance.)</td>
<td>C-1 Filter of sender: Misunderstood relevancy.</td>
<td>3F-4</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C-2 Filter of sender: Reluctant to send</td>
<td>3F-8</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(1/2)27</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>C-3. Filter of sender: Given up problem</td>
<td>3F-8</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(1/2)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>C-8. Weak incentive for the sender</td>
<td>4G-2</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td></td>
<td>E-1. Inadequate transfer method.</td>
<td>3F-11</td>
<td>I</td>
</tr>
<tr>
<td>1-7</td>
<td>Machine side meeting or demonstration</td>
<td>D-1. Knowledge compatibility.</td>
<td>4E-2</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td></td>
<td>E-1. Inadequate transfer method.</td>
<td>4F-4</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4E-2</td>
<td>I</td>
</tr>
<tr>
<td>1-8</td>
<td>Collocation</td>
<td>E-2. Geographical separation</td>
<td>4G-8</td>
<td>I&amp;S</td>
</tr>
</tbody>
</table>

(Continues on next page)

27See the Note at the end of this table for the meaning of fraction number.
Table 5-2 Solutions of stickiness problems applied in each stages of problem solving (continued)

<table>
<thead>
<tr>
<th>No.</th>
<th>Solution</th>
<th>Applied type of problem</th>
<th>Case No.</th>
<th>Type of Info.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - 9</td>
<td>Remove prejudice and open mind to new information (Receiver or Manager of receiver)</td>
<td>C-10. Credibility of the information source.</td>
<td>[4G-3]</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(4G-14)</td>
<td></td>
</tr>
<tr>
<td>1 - 10</td>
<td>Send high quality information or value added information (Manager of receiver)</td>
<td>C-4 Filter of the receiver: Reluctant to receive</td>
<td>[3G-2]</td>
<td></td>
</tr>
<tr>
<td>1 - 11</td>
<td>Increase motivation of receiver (Manager of receiver)</td>
<td>C-9. Weak incentive for the receiver</td>
<td>(4E-3)</td>
<td></td>
</tr>
<tr>
<td>1 - 12</td>
<td>Send high quality information or value added information (Manager of receiver)</td>
<td>C-10. Credibility of the information source.</td>
<td>[4G-3]</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(4G-14)</td>
<td></td>
</tr>
<tr>
<td>1 - 13</td>
<td>Information selection by importance (Receiver)</td>
<td>F-1. Buried information: Too much information</td>
<td>[4G-7a]</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>[4G-7b]</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>[4G-7c]</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(4G-14)</td>
<td></td>
</tr>
<tr>
<td>1 - 14</td>
<td>Gather information as much as possible</td>
<td>A-2 Tacit knowledge</td>
<td>4M-1</td>
<td>I&amp;S</td>
</tr>
</tbody>
</table>

Stage 2: Relevant information identification.

1 cases

Stage 4: Decision

(Continues on next page)
Table 5-2  Solutions of stickiness problems applied in each stages of problem solving (continued)

<table>
<thead>
<tr>
<th>No.</th>
<th>Solution</th>
<th>Applied type of problem</th>
<th>Case No.</th>
<th>Type of info.</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 - 1</td>
<td>Get information through face to face communication.</td>
<td>E-1. Inadequate transfer method.</td>
<td>(4E-1)</td>
<td></td>
</tr>
<tr>
<td>5 - 2</td>
<td>Machine side meeting or demonstration</td>
<td>E-1. Inadequate transfer method.</td>
<td>[3G-4]</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3M-5</td>
<td>S</td>
</tr>
<tr>
<td>5 - 3</td>
<td>Get information through personal network.</td>
<td>C-11. Psychological distance: Unfamiliarity of sender and receiver.</td>
<td>4G-18</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td></td>
<td>I-1 Update of information</td>
<td>4D-2</td>
<td>S</td>
</tr>
<tr>
<td>5 - 4</td>
<td>Interpreter who can understand multiple discipline.</td>
<td>D-1. Knowledge compatibility.</td>
<td>(3F-12)</td>
<td></td>
</tr>
<tr>
<td>5 - 5</td>
<td>Put people of different culture together (In a project).</td>
<td>C-7 Historical barrier on receiver side</td>
<td>3F-3</td>
<td>S</td>
</tr>
<tr>
<td>5 - 6</td>
<td>Put different type of expert together (in a meeting).</td>
<td>H-1. Unpredictable synergy effect.</td>
<td>3F-13</td>
<td>S</td>
</tr>
<tr>
<td>5 - 7</td>
<td>Collocation</td>
<td>E-2. Geographical separation</td>
<td>3G-10</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4G-8</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>S &amp; S</td>
<td></td>
</tr>
</tbody>
</table>

Stage 6: Effective use of information

<table>
<thead>
<tr>
<th>No.</th>
<th>Solution</th>
<th>Applied type of problem</th>
<th>Case No.</th>
<th>Type of info.</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 - 1</td>
<td>Increase motivation of receiver (Manager of receiver)</td>
<td>C-9. Weak incentive for the receiver</td>
<td>4M-2</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>[4G-9]</td>
<td>S</td>
</tr>
<tr>
<td>6 - 2</td>
<td>Send high quality information or value added information (Sender)</td>
<td>C-4 Filter of the receiver: Reluctant to receive</td>
<td>[3G-5]</td>
<td>S</td>
</tr>
<tr>
<td>6 - 3</td>
<td>Send information with priority information (Sender)</td>
<td>F-1. Buried information: Too much information</td>
<td>(4M-4)</td>
<td>S &amp; I</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(4G-13)</td>
<td>S &amp; I</td>
</tr>
<tr>
<td>6 - 4</td>
<td>Send information at the correct timing</td>
<td>F-2. Lost information: Too long to keep.</td>
<td>[4G-1]</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(4G-13)</td>
<td>S &amp; I</td>
</tr>
<tr>
<td>6 - 5</td>
<td>Do first, then think</td>
<td>G-3. Can't transfer information up front.</td>
<td>[4G-4]</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4G-7a</td>
<td>S</td>
</tr>
<tr>
<td>6 - 6</td>
<td>Update information (with special effort.)</td>
<td>I-1 Update of information</td>
<td>[3G-1]</td>
<td>I &amp; S</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>[4G-10]</td>
<td>I &amp; S</td>
</tr>
</tbody>
</table>

(Continue on next page)
Table 5-2  Solution of stickiness problems applied in each stages of problem solving (continued)

<table>
<thead>
<tr>
<th>Type of information</th>
<th>Case No.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>I:</td>
<td></td>
<td>Information for Problem Identification.</td>
</tr>
<tr>
<td>S:</td>
<td></td>
<td>Information for Problem Solving.</td>
</tr>
<tr>
<td>C:</td>
<td></td>
<td>Complementary information</td>
</tr>
</tbody>
</table>

Type of solution
Case No. with (0) means it was not solved in the real case and is judged that type solution could have solved the problem.
Case No. with [I indicate that the case was a general comment; for example it has the notion of "generally speaking......" or "such kind of problem often happened......" or "It was a rule of thumb for project work......". This distinction is important when we count the number of cases in some category because general comment can be a aggregation of several cases then it should have the higher significance.
When there were two candidates of problem types and difficult to determine which should be assigned, I just assigned 0.5 points and indicated with (1/2) after the case number.
5.5 Summary

In this chapter, first, we discussed the flow of information for solving and how to cope with the stickiness problem in each stages, and then we examined the case data according to these categories.

From the data analysis, we found that more than half of the data was related to the problem identification stage and information for problem identification (I type information). To facilitate this process, there were two groups of methods used. One group focused on the capability of external resources, represented by "Machine shows it (templating)" and "Expert involvement". The other group focused on the information transfer aspect, represented by "Face to face communication" or "Machine side meeting". (Among these issues, we will discuss templating issue again in the next chapter.)

There were few data reported related to the second and third stages. However when we use the templating for problem identification, generally, it does not provide us any information other than the existence of the problem. Then these stages are very important and creative parts of the problem solving.

Relating to stage four, many cases which used involvement of some kind of expert. Interesting point found in the cases was that there were different types of experts involved for the purpose to get different types of information. We need not only the expert who has technical knowledge but also experts who have complemental information or insider knowledge of the existing plants. For the success of the project, we have to have balanced mix of these different type of experts. This point is very important when we design a project team.
We found many different measures to cope with stickiness problem to enhance the efficiency of information transfer. Because there are diversified sources of stickiness, there were many measures to cope with them. However generally speaking, personal contact is preferred than formal channel and face to face type of communication is more often used than memos.

At the stage six, we found that transferred information is not always used effectively and there were not successful methods to prevent waste of information. When we want to improve the total efficiency of information transfer, we have to devote much more managerial efforts to this problem. As one of special case of this problem, we will discuss about timing issue and windows of technological change in the test run in the next chapter.
Chapter 6  Related Issues

In this chapter, we will discuss some topics which are related to the stickiness issues but not well discussed in the previous chapters. First, we will examine a method for problem identification, especially focusing on templating. Then we will discuss second topics: timing issue, especially focusing on the management of test run period.

6.1 Templating: Powerful tool for problem solving

It is ideal that new equipment is perfectly debugged and ready for use by the time when it is sent to the plant. In the reality, it is not easy to solve all problems up front. This fact often cause the conflict between developer and plant people. Tyre and von Hippel (1991 draft) explained this problem from the stand point of information theory and why it is easier to identify the problems once the new equipment is placed in the plant environment. They called this phenomena as "templating". According to them, the features of the "templating" are as follows;

(1) "The transfer of information in rich, physical form"
(2) "The direct, physical comparison of problem space and proposed solution,"
(3) "Clear, visual signalling of misfits and where they occur."

The superiority of templating were explained by the sticky information concept.

Design information is sticky to the designer. However if we move the machine which embodies this sticky information to the plant, we do not have to hassle to unstick data from designers.
Environment information is sticky to the plant. It is difficult to pick up every features of plant environment and transfer them to the lab, but it is easier to bring the new machine into the environment.

To ensure the matching of the machine to the plant environment, it is necessary to deal with stickiness caused by complexity; It is difficult to know which feature of the machine should be matched by which environmental conditions because both of them are consisted of huge amount of information. Then main problem is if it is impossible to transfer all information, how to sort relevant data from huge amount of seemingly irrelevant data.

They found through the research of problem solving at the plant, "Almost all of the problems were unrecognised because developers lacked information about factory and use characteristics was incomplete." Importantly it was not caused by the laziness of the developer to understand the plant, but it occurred "despite multiple efforts to identify and transmit necessary information." Their research showed how difficult it is to transfer plant information to the lab and always people regret it afterwards, "It would have been easy to convey information ..... , if anyone had thought to do so." (Tyre and von Hippel 1991)

From the practical point of view, it is not admirable thing to find problems (especially fundamental problems) after the machine is made. Though template is powerful way to identify problems, it is may be regarded as a one sort of "necessary evil". Practically, it is regarded as the most important ability for a developer to predict and to prevent such kind of mismatch. Then how to do it?

One solution is to assign experienced engineers to the job. Experience (especially of developer but occasionally of user) is useful mechanism to find potential problems. They know what kind of problems tend to occur in the plant. It is often the case that
experienced engineers know production site very well. They learned it from bitter failure experiences in the past. Sometimes experienced engineers are good interviewers to get plant information from the operators. They can cue the operators by "What if" questions.

Another common solution is the use of safety margins. Designers know that anything can happen in the plant, then they usually allow large safety margin in their design. In this sense production equipments are always over specification\textsuperscript{28}. (I think this is the reason why "Table 2 - (3) Information on physical factory environment" (in their report) problem was not observed in the real case.\textsuperscript{29})

I. Problem identifying and Problem solving

"The transfer of the machine into operation in the user context was a very powerful and efficient way" to identify the problems. Although it shows the existence of the problem, it does not always indicate the source of the problem. Diagnosis and problem solving requires another mechanism.

\textsuperscript{28}In the steel plant, all sensors have very strong protectors. Then if we want to put small sensor; one inch by two inches, we need as large as three inches by four inches space to install it because it needs strong protector made of 1/8 inches thickness steel plate. When I was a newly hired engineer, I found such excessively strong protector in the plant for the first time and asked why it should be so strong to the experienced engineer. He answered, "Without such protector, it will soon break. Why? Because operators step on the sensors when they try to remove jammed steel from the line."

\textsuperscript{29}Since new machine has large safety margin in its design, mismatch problem tends to be caused by the existing facility side. For example, If the power supply of the factory is not sufficient, whenever some machines move at the same time, machine fails to work correctly. To solve such problem, we have to modify the existing facility, not new machine itself.
Different problem solving patterns were observed in their research. These patterns were determined by what kind of sticky information was necessary. Then if the problem required the information sticky to the lab, problem solving pattern showed "go and back" movement between plant and lab.

Although "go and back" mode of problem solving seems to be reasonable from the information theory, it is inefficient and time consuming way for problem solving. I think "templating" concept is much more powerful if it is conceded with "forum for change" concept (Tyre 1989) and "rapid test run" (or aggressive test run) concept. If the information is sticky to the location (= lab), go and back is inevitable. However in many cases it is sticky to the person. In this case it is efficient to gather lab people and plant people and do test jointly for certain period of time. (creating forum)

II. "Expert-as-template"

Expert can sort relevant information from the plant environment. In this sense he is a template to sort information from huge plant information. But he is not a rigid template, naturally, before he solves the problem, he has many hypotheses about causal effect relation and he is not quite sure which hypothesis is the correct answer. Then he (and his hypotheses) is simultaneously templated by the plant environment (or reality). (We may call it double templating or simultaneously templating, etc.)

This may be one of the reason of the iterating movement of problem solving between lab and plant. (In this case the person who has hypotheses is in the lab. Then messenger has to go and back every time new hypothesis is tested.) To facilitate the process, forum is the best. Collocation of expert (who has hypotheses) and plant environment speeds up the iteration.
III. What to do to enhance templating?

It is not enough to send machine to the plant environment. Just putting the machine in the plant does not identify problems automatically. To activate problem identification, it is necessary to try to apply "template" aggressively because unless we try to use untested functions or situations, problems will not be identified.

When we think about "the window of opportunity for technology change" (Tyre and Orlikowski 1991), it is critical to find problems as early as possible while window is open. We cannot afford to wait until all problems are found contingently. Then we have to apply "template" aggressively, creatively and systematically.

IV. Is it a good strategy to send machine to plant early?

As shown above, "templating" is a powerful way to identify complex problems. But what is the managerial implication of it? Can we say, "OK! We don't have to worry about plant environment during design. Just finish our work and sent it to the plant, then we can do problem solving efficiently."

Is it a good strategy to send machine to plant early?

If we think about the "windows of technological change", it is not good to leave too much problems to the test run because we have a risk to run out of time before we can solve all problems which are found by "templating."

We also have to be careful about the impact of premature technology on the plant people. If it takes too long to perform well, plant people easily lose their enthusiasm and start to regard the project as a failure. Here is another kind of windows of opportunity; "windows of opportunity of acceptance". Then we should keep the number of problems to be solved at the site minimum.
Another problem of the "templating" is the cost of the problem solving. Generally speaking, the later the problem is found, the more money and time is necessary to solve it. The hypothetical relation between cost of problem solving (includes money and time) and timing of problem solving is shown in Figure 1. Apparently, "templating" reduce the cost of problem identification, however it increase the cost of problem solving. Then we have to consider the trade off between both the cost of problem identification and the cost of problem solving. If we are too optimistic or naive to leave fundamental problem until templating, we have a risk that even the problem is found, we can not fix it because it is too late to change the design.

![Diagram of cost of problem solving](image)

Fig. 6-1 Model of cost of problem solving (cost of change) and timing

How can we select the problems which should be solved earlier. One parameter is how sensitive the cost of problem solving is to the time. If the design is related to the fundamental and
interrelated one, the sensitivity is high. To the contrary, if the
design is related to the supplemental and independent one, the
sensitivity is low. For example, the design of the furnace structure
is the former case because if we change it we have to change the
machine layout and we have to redesign piping route and cable route.
The design of the safety fence is the latter case because it can be
added or modified at the site without changing the design of other
parts.

V. Simulation/Prototype

If we take the cost of problem solving into account, we need to
solve some problems at relatively earlier stage of the development.
In such case, are there any tools which can be used as substitution
for "templat ing"? Even if they are not perfect as "templat ing", they
may be useful for the case which has high cost sensitivity to the
timing of problem solving.

One way is the use of model. In the design of the nuclear
reactor or chemical plant, plastic model is often used as the
problem solving (and more importantly problem finding) tool. Resent
development of computer technology enables us to do the problem
solving on the CRT. Many CAD program has a function of interference
check.

Another way is the use of "rapid prototype." (von Hippel 1990)
This idea is try to develop not perfect but fundamentally correct
prototype rapidly and ask user to use it and get feed back.

In addition to them, meeting is a very useful method of
problem finding. In the design review meeting or control flow review
meeting, what we are really doing is "mental modeling." In such
meeting, each people has his/her own mental model of the equipment
and testing it in the hypothetical environment. People bring their
past experience and check their model will work or not in that hypothetical environment.

Although these "modeling" methods are not as powerful as "templating" because of the low fidelity, they are powerful if we cannot afford to wait until we can use template. When we try to decide the strategy of problem solving, we always have to take the trade off between the cost of problem identification and the cost of the problem solving into consideration.

VI. Note: Many other issues which were not mentioned in the paper.

• Templating is powerful because it reveals the problem which was not consciously recognized by the designer. This is the main advantage of the templating. Mental simulation do not have this function. Meeting may be between both of them. It is a mental simulation by multiple person, then it can provide new insights to the designer which he did not recognize.

• Why all problems can not be solved up front? One cause is the complexity of the problem and lack of the information of the drawing. Drawing does not convey all information. It conveys only the information which designer wanted to draw on it. Therefore it is impossible to find problems which designer did not recognize or at least have some kind of question about it. CAD program can help to solve this problem. It often has a function to check interference of the parts.

The other issue is that user's information is limited to the specific environment, therefore it is not always applicable to a new machine because it has different environment.
"Developers do not have to know how users value specific aspects of machine operation and how they will use the equipment -- this is conveyed in the process later" (Tyre and von Hippel, pp 16) This comment may be too strong. We do need to avoid problem at site, because it cost time and money. User involvement may be necessary to reduce the number of problems found after machine is built.

Operators or manufacturing engineers tend to ask to change the machine at the late stage of project. It always require rework and cost time and money. Sometimes we can't change it simply because it is too late.

6.2 Test Run and Windows for Technological Change

I. Concept of window for technological change

Tyre and Orlikowski described "window for technological change" concept in their report. (1991) This concept explains the fact that "there exists a relatively brief "window of opportunity" to explore and change the technology following initial implementation, after which the technology and its context of use tend to congeal." This concept is very powerful because it can explain many real problems.

People who experienced introduction of new facility may have such kind of experiences but it is not useful to learn this general tendency from experience, because once such problem occurs, it is too late to cope with it.

In this report, I will examine the "window" concept in the Kawasaki Steel No.3 and No.4 CAL construction projects and try to explain the implication of this concept in test run.
I-1 Unused automatic control mode.

We have many production lines which are operated by manual control mode while there is automatic control mode. When we ask the operators why they do not use automatic control mode, the common answer is that the reliability of the automatic control mode is very low. Then we have to ask the second question why such convenient function is not improved to be reliable enough. Operators cannot answer this question but they can say, "I don't know. But we can operate the line without it."

There is a tendency that once operators learned and got used to the manual operation, they tended not to try to use automatic operation mode. In No.3 CAL project, Mr. Kaihara said that if we wanted to force operators to use automatic control mode, we had to remove handles and switches from operation room.

I-2 Untested function

We realized the fact that those functions which were not tested in test run would not be used forever. We knew there were many machines dismantled form the production line in two or three years after the construction. In many cases, such machines had never used or used only at the start up period. They were premature and nobody took care of them after the construction.

Whenever I see such kind of situations, I always wonder whether such functions are fundamentally unnecessary function and developed by mistake or not. In many cases, the design concept was challenging at the construction time and significant time and effort was invested in the development. At least in development stage, these were not unnecessary functions.

Why such kind of innovative functions were abandoned after construction? It seems that only small amount of additional efforts
are necessary to save it, compared with the significant efforts invested in development stage.

I-3 Bureaucratic rules

I experienced that after the line was put into operation, it suddenly became difficult to modify the line. During the test run, I could modify the machine within a few days (even in a few hours) by writing a piece of memo or by calling maker's managers on telephone, but if the line started its operation, I had to write formal request accompanied by drawing and had to gather many signatures to get authorization. Even after this tedious process, I had to wait one or two weeks until the modification is done\textsuperscript{30}.

These experiences suggest that there is a "window of opportunity" (Tyre and Orlikowski, 1991) and once we miss it, it becomes difficult to recover later.

II. Why window exists

Why such "window" exists? What kind of change will occur in the technological or organizational environment when "window" closes.

There are three kinds of fundamental reasons for the windows. First, there is a change related to the resource allocation process. Second, there is a change in difficulty and risk accompanied with the modification. The more progress is made in the test run, the more difficult and risky a modification becomes. Third, there is a intended change in the organization before and after the start of the operation.

\textsuperscript{30}Is it a bad thing? It may be good to keep stability. It is a good method to prevent mistake. There is a trade off between flexibility and risk. In the test run, flexibility has priority, but in the operation, stability and risk management is more important.
II-1 Resource allocation

a. Time

Once the line starts its operation, production becomes the first priority and all of the available time is allocated to it until the production quota is filled. Generally speaking the line becomes too busy to do experiments for the further improvement (or unfinished test run.)

b. Money

Short after the line starts its operation, the construction account is closed and after then whenever we make modification, we must ask maintenance section to approve to use their budget or get separate budget from the headquarters for large modification.

The same problem occurs in the maker side. They also close their construction account shortly after the operation of the line. Before that time, they have certain amount of money to fixed the production or design problems found at the construction site. However, once their account closed, it becomes very difficult for them to produce parts for the modification. Then they becomes extremely reluctance to admit the necessity of change.

c. Manpower

Sooner or later the disintegration of the project team will occur after the production line starts its operation. The timing depends on the shortage of total manpower in each of the

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31 In Tyre and Orlikowski's report (1991), this is listed in the first factor; "The tension between production requirements and adaptive activities."

32 This account has large amount of money and is relatively flexible account. Use of the money is not strictly controlled item by item.
department. If the are severe need for manpower, the team will soon be disintegrated. On the contrary, if the needs of manpower is not high, the team are left for a relatively long period.

When a member of the project is transferred to other project, it means that project lose the sticky information relating to his job and also lose the effective connection with the maker. Many information related to his job is sticky to the person and it is not easy for the rest of the project to cover the vacancy. This situation is described in the Tyre and Orlikowski report (1991). But we cannot underestimate the second factor: the loss of connection with the maker. Even if the person is assigned another job, it does not affect the contract relationship with the maker officially. But the other person who does not know the circumstances of the machine design has a difficulty in negotiation with the maker or take long to make decision. It reduces the efficiency and create reluctance for change in both companies. (Same kind of sift of man power occurs in the maker, too.)

d. Change in value and priority of resource allocation

After the line was put into operation, the first priority is placed on the production. But at the beginning stage, the efficiency of the line is not high enough, then the emphasis on production means the emphasis on continuity of production because when the production line's efficiency is low, the only way to increase the production amount is to keep the line running. At this stage, the most precious thing is the time. Then people in the operation section tends to cut maintenence or modification time to make up the delay of the production.

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33In Tyre and Orlikowski report (1991), this is listed in the fourth factor; "The erosion of enthusiasm and group cohesion over time."
Under such kind of circumstances, the easiest and the fastest solutions (band aid solutions) are valued, the fundamental solutions are not sought and in many cases, multiple solutions are tried simultaneously to solve one problem. These way of problem solving does not contribute to the increase of knowledge because we can not find which solution worked, and reduces opportunities of further improvements.

II-2 Fundamental difficulty and risk

Modification of the complicated system are always accompanied with "a significant risk that a seemingly straightforward adaptation would balloon into a major project. Further, users recognized the potential to make a mistake that would cause greater problems than the one they were trying to fix." (Tyre and Orlikowski, 1991)

a. Fragility

We had this kind of experience during the test runs of No.3 and No.4 CAL projects. I thought software was fragile like glasswork, if we try to fix a small part of it, whole thing may break.

This risk is much larger in software than in hardware. I think it is caused by the fact that software is much more difficult to decode (or to unstick the information from it). Because it is difficult to visualize the whole structure of the software, the information about software is more sticky to the programmer who wrote it. One of the electrical engineer said that he envied mechanical engineers because source machine trouble can be understood by watching the machine but the source of software trouble is rare to be found just reading the program.

This fragility of the system discourage the user to try to modify it.
Chapter 6  Related Issues

b. Integration

Integration of the system makes it more difficult to modify a part of it. There is a complicated interrelation between the components and/or operating environments. It creates uncertainty in modification of the system and discourage the user to do it. (Tyre and Orlikowski 1991)

In addition to it, the complexity of the system grows larger approaching the end of the test run and makes it more difficult to modify the system.

II-3 Test run: a process for stabilization

a. Step by step reduction of uncertainty

The principal purpose of the test run is to reduce uncertainty from the line and freeze it. To achieve this goal, project team work very hard for a long period. (In No.3 and No.4 CAL project, test run continued for four months.) During this period, test run teams attack the problem from very elemental function to the sophisticated function. They have to fight with the fragility problems every day and endure the frustration of a seesaw game (go forward one step, and pushed back one step). Through this process, they can increase the rigid (or stable) part step by step. Who can blame them because they don't want to go back to the uncertain situation, especially at the final stage of the test run?

b. Bureaucracy

After the line is put into operation, bureaucracy starts its function. It requires established procedures to do any tiny modification to the line. It is designed to prevent failure but not to enhance creativity. Bureaucracy is a mechanism of stabilization.
The purpose of the organization is different from test run and operation. In the construction project, the creativity and challenging spirit is most valued and the project team is organized to enhance it. However, in the operation, the stability is more important and the organization is formed to ensure it. As a result, after the test run the "window" is closed intentionally.

III. Test run strategy

III-1 No.3 CAL's problem and No.4 CAL's strategy

a. Aggressive test run in No.3 CAL and its problem

We knew that it is very difficult to change after operation and we tried aggressively to test every functions during the test run in the No.3 CAL project. As a result, we could finish the test run one week prior to the schedule and with the record of significantly low rate of break down during the test run. We thought we made a great success in the test run.

However, we had a big trouble six months later. At that time, the production amount reached to high level and the cooling sections capacity was almost full. In this situation, the cooling buckle problem occurred. To prevent this problem, operators had to reduce the line speed and it became the bottleneck of the whole line.

To cope with this problem, old project members were called back and formed special task force. But they had their own jobs at that time. (Many members were assigned to the No.4 CAL project and they were very busy.) The production quote was high at that time and there were little time to be used for experiment. The production priority was very high and even team members gathered at the operation room on time to do an experiment, we always kept waiting until the production quote was filled and experiment tended to start at midnight.
These circumstances deteriorated the efficiency of the work significantly. Then it took longer to fix the problem than we had expected.

b. Lessons from No.3 CAL and its application in No.4 CAL

No.3 CAL's experience taught us the importance of finding the potential bottleneck as soon as possible. The later the problems are found, the more it becomes difficult to solve them.

In No.4 CAL project, we tried hard to run the line at maximum capacity as early as possible. For example, even if we could not keep to run the line at 100% speed continuously, we tried to run it even for a few minutes.

By this effort we found that there were two major problems to achieve the maximum speed. And we could solve them before such a high speed was really required.

c. No.4 CAL rapid max test

In No.4 CAL, we employed a "rapid max" strategy to avoid the same problem as No.3 CAL. This strategy is very powerful to cope with the "window" problem. It will be discussed more deeply in the following section.

III-2 Test run strategy: rapid max test

a. Why rapid max test

Generally speaking, the test run was considered to be the period to check the fundamental functions and maximum capacity should be tested during the start up period. We believed that max capacity test cannot be done during test run because it requires that all of the supporting functions work perfectly to achieve the maximum speed or capacity and such condition only occurs at the end of start up period.
However such strategy created a danger of leaving the large problems hidden until the production amount increased. This means that large problems tends to be left hidden until window was closed. However it was very difficult to solve those problems after the window was closed. This is the reason why I place emphasis on rapid max test strategy.

Of course, it is impossible to keep the line running at the maximum capacity for long period at the early stage of start up. It can only be done in limited condition; for example, do the test during a short period or do the test in only one part of the line and keep the rest of the line idol, etc. In this sense, "rapid max test" is not perfect, but very useful way to detect potential problems.

b. Model of the rapid max test

Rapid max test reduces the total start up time. This situation is explained in Fig. 6-2.

Let us assume that we want to start up the production line as planed "start up curve" (Fig. 6-2.(a)). However at the planing we do not know there are fundamental problems which will be revealed at certain performance levers (or load levels): L1 and L2. And each problems need certain amount of time (T1, T2 days) to be solved. These times can be shorten by special efforts but it is difficult to reduce them significantly because these times consist of problem identification, problem solving, design, manufacturing of replacing parts, installation of them and test, each of which require certain amount of time.

Then actual star up curve will become like Fig. 6-2 (b). Up to the performance (or load) level L1, the start up can be done on schedule. But when it reaches L1 level, hidden problem reveals and we have to spend extra time T1 days to solve it. After we solve the first problem, we can continue the start up according to the original
start up curve's pace, however it is already delayed by T1 days. Then another hidden problem reveals at performance (or load) level L2 and we have to spend additional time T2 to solve the problem. When we finish the start up period, we find that we were behind the schedule by T1 + T2 days.

On the other hand, if we adapt rapid max strategy we can avoid such delay. With rapid max strategy, we always try to make a champion data at the early stage of start up. For example, we try to increase the line speed as much as possible every day. Of course we cannot achieve such a high level performance for a long time or in a stable manner. Nevertheless we continue to challenge the top speed. By this rapid max strategy, hidden problems reveal earlier than usual. (Fig. 6-2 (c)) Then we don't have any delay in the start up schedule, while we spend same amount of time to solve these problems.

Without such kind of strategy, delay in schedule is inevitable. Therefore we can shorten the total amount of start up time.

III-3 Early start up vs early stabilization

Early start up and early stabilization does not have the same meaning. However, sometimes both concepts are used in mixed way to explain the good performance of a construction project.

Early start up means that the short start up period to achieve the designed line capacity in stable manner. On the contrary, early stabilization means that the line is operated in stable manner (that means it is operated without difficulties) shortly after the test run. In the latter case, it is possible to be stable at the 60% capacity level.
Fig. 6-2 Rapid max test model
Early stabilization does not necessarily mean early start up. It rather tends to be related to the late start up, because if people prefer the stability, the line tends to be stabilized at lower level and once it is stabilized at lower level, the window is closed and it becomes more difficult to achieve the higher level later. Early stabilization is early closing window.

To achieve the early start up, we have to endure the uncertainty just before we achieve the maximum capacity. To make it easier, we have to find large problems as early as possible by rapid max strategy and save time to solve it.

Operators or manufacturing engineers are trained to maintain the stability of the line and tend to select early stabilization strategy. Then we have to create a mechanism to prevent this.

III-4 Test run concept -- importance of start up period

Conceptually the life of the line is divided into two period: construction and operation. Test run is included in the construction and regarded to be the last part of it. On the other hand, start up period is included in the operation and it is controlled by operators. (See Fig. 6-3 (a))

The reason why start up is considered to be the part of operation is that during this period the operators get used to the new production line and many operational parameters are standardized and samples are shipped to the customers to get approvals. These tasks are operational department's tasks then it is thought to be a part of operation.

However, "window" point of view, this start up period is very important for detecting the large problems and fixing them. Then we have to change our perception and understand the start up period as the third period which does not belong to the construction or the operation. (See Fig. 6-3 (b))
Chapter 6 Related Issues

(a) Conventional View

Window is open but busy to fix basic problems. Learning by use and fix it.

(b) New View

Fig. 6-3 New View of Start Up
At least until this period will finish, project team should not be disintegrated and they should take initiative to find large problems of potential bottlenecks. The earlier the problems are found, the more time is left for solving them.

IV. What is the implication of window concept?

As shown above, "window" concept has a significant impact on test run strategy. However in this section, let us examine other implication of window concept.

IV-1 What can be done.

After we recognize the existence of "a relatively brief 'window of opportunity' to explore and change the technology following initial implementation" (Tyre and Orlikowski, 1991), what can we do to cope with this situation. There are three reactions.

a. Do as many change as possible while the window is open.
   b. Try to keep window open as long as possible.
   c. Figure out the way to reopen it.

Let us examine these strategies.

IV-2 Keep the window open strategy

Length of the start up time is not the solution. (Tyre and Orlikowski, 1991) Even if we are allowed to use long time for start up, the window may be closed before the end of the period. Then it is not easy to control the time of window open.

IV-3 Reopen strategy

If it is really necessary to reopen the window, it is possible to do it. We can create project team and stop the operation for a
necessary period. However, such kind of reopen is very expensive, especially for large problems. Large problems require longer modification period and larger scale modification. It is also risky. If we start to modify the complex system, some unpredictable things can happen and create a significant risk of schedule slippage or additional cost.

Anyway, If we could avoid the situation which requires to reopen the window, it would be happy for us. If one fails to exhaust major problems while window is open, it is necessary to reopen it. However, most important thing is to find as many problems as possible while window is open.

Especially finding potential large problems during window is open is very important. (If we could do it, we may keep the window open a little longer or schedule to reopen it.)

IV-4 Large problem vs. small problem

It is not necessary to solve every problems. If we take into account the risk accompanied with modification, there is a level where diminishing return becomes dominant. In such case strategical ignorance is important.

However we cannot overlook large problems. Large problems are often problems which cause bottlenecks in the production line and reduce the performance of the line. Some large problems are related to the quality problems and reduce the production amount which can be shipped. Anyway it is most important to find large problems earlier in the start up period.

IV-5 Combination of rapid max strategy and "Kaizen"

As far as we solve the large problems in the start up period, we can continuously improve the performance by solving smaller problems later.
After the line is put into operation, the stability of the operation becomes very important. On the other hand, to make improvement it is necessary to change the status quo. To balance these contradicting requirement, the idea of "Kaizen" is useful. "Kaizen" concept solves this problem by separating the activity into four phases and repeating them continuously. This idea is explained by PDCA cycle. Through this cycle the stability is ensured by standardization and continuous improvement is achieved by cyclic repetition of the PDCA cycle.

I think this idea is a powerful solution to reopen the window cyclically and to keep making improvement. Once such kind of activity becomes custom of the organization, many organizational and individual forces to close the window may be reduced.

Though "Kaizen" concept is useful to solve small problems continuously, large fundamental problems should be solved at the start up period, because to solve them, it is necessary to mobilize more resources than those for "Kaizen" activities. Regarding large problems, the window still closes at the early stage of start up. Then, the combination of rapid max test strategy and "Kaizen" is necessary. These two methods complement each other.

V. Conclusion

The main point of this section is that it is necessary to find and solve large problems at the early stage of start up because it is difficult to reopen the large window. The basic idea is that we can reopen smaller windows much easier than larger windows.

However what can we do if we fail to find and solve all large problems up front. If the problem is very important, we have to reopen the window or even cut the wall to create new window. But such action always require high cost. The later the problems are
found, the more expensive it becomes to solve them. Then some kind of trade off is considered.

User experience is a very rich source of information. (Tyre and Orlikowski 1991) But special effort is necessary to utilize it because once the windows are closed, it is too expensive to reopen them and many informations are wasted.

The other way to save the information is to find a way to accumulate it until next construction and use them as know-how. But we have to solve sticky data problems: how to unstick and how to accumulate user information.
Chapter 7  What Was Learned from This Research?

7.1 Implication of information flow on innovation

As we have discussed in Chapter 1, successful new production line development should have all three features: (1) It includes innovative ideas, but (2) it also based on accumulated know-how, and, in addition to it, (3) it achieves fundamental improvements which had been given up in the existing lines. To achieve these different requirements, it is necessary to have different types of information flow.

To achieve first goal, first, it is necessary to transfer work environment information to designer, and then, to transfer designer's ideas (new concepts and assumptions of design) to the plant.

To achieve second goal, it is necessary to gather know-hows accumulated in the many different locations in the company and integrate them into one design. To transfer know-how, it is not enough to imitate the way of work at the superficial level, but rather to understand the reason of the know how. In this sense, we have to transfer "know-why" rather than "know-how".

All these kinds of information mentioned above are very sticky when we want to transfer to the development team. The first step to
cope with this problem is to understand the sticky nature of the information transfer in the new production line development project.

7.2 Sources of stickiness and how to unstick in the new production line development

We created a simple model of information transfer and discussed sources of stickiness according to the each element of the model, and then, we examined descriptive data gathered from two new production line development projects. (Chapter 3)

We found the most frequent sources of stickiness are as follows:

1. Filter or Barrier 31.7%
2. Complexity of information 18.3%
3. Complexity of problem 12.2%
4. Transferred but not used 11.0%
5. Transfer method 9.8%
6. Timing 9.8%

Category 1 and 5 are stickiness related to the nature of information transfer channel. Category 2 and 3 are stickiness related to the complexity of the information or problem. Both of them are predicted by von Hippel in his report. (1990) The value of this research is that we took microscopic stand point and have broken them down into many subcategories. It is important because each of subcategory has different reason of stickiness and different nature of stickiness, therefore we have to attack them with different methods for each subcategory.

Another interesting finding is that there is a large group of cases where information was transferred but not used effectively. This is interesting because many academic researches have fundamental assumptions that if we succeed to transfer the
information, the problem is solved and the information should be used effectively. However, this research shows that it is not enough to transfer information, but we have to make sure that the transferred information is used effectively, because unless it is used effectively, the information has no value to the project. To solve this problem, we have to consider timing issue and overflow problems.

In Chapter 4, we discussed the most frequently used solutions and advantages and limits of them. Top six most effective (or versatile) solutions are as follows:

1. Expert involvement (S type) 13.3%
2. Machine shows it 10.8%
3. Expert involvement (I type) 10.8%
4. Learn from similar line 7.2%
5. Machine side meeting 6.0%
6. Face to face communication 4.8%

As we have discussed earlier, different sources of stickiness require different types of solution. Therefore it seems to be funny to list solutions according to just the number of cases solved. It may be criticized as comparing apples and oranges on the same base. But this list is still interesting to consider.

If we examine this list from problem identification's point of view, there are three main methods in the list. First solution is "machine shows it." This is very powerful as Tyre and von Hippel argued in their "templating" concept. (1991) But this method has a drawback that it finds the problem at the last stage of the project as we discussed in the Chapter 6. Of course it is valuable to identify problem even if it is impossible to solve it now, because we can use that knowledge in the next project. However from the project members' point of view, it matters whether they can successfully solve the problem in their project or not. Therefore, people try to
find other methods to identify the problem up front. To do this "expert involvement (I type)" and "learn from similar line" is used as often as "templating". This is very interesting because while experts are often viewed as data base or source of problem solving capability, they have another important role, problem identification, in the real projects.

The other interesting thing is that though it is not emphasized in the academic literatures, it is important to "learn from similar line" in the real life. No matter how radical the innovation is, it is rare that it changes everything of the existing production method. As far as there is some commonality in the new and the old technology, why don't we learn from existing line? It is a commonsense for practical people (at least in Japan). The data showed importance of this point.

Another interesting aspect of this list is that solution 5 and 6 are related to how to increase the effectiveness of communication. The result supports the common sense that "face to face communication" is the best way to communicate. "Machine side meeting" is one kind of "face to face communication" but it is more powerful because it can use demonstration of the real machine. Effectiveness of this method supports Tyre's "forum" concept (1989).

7.3 Managerial meaning

What are the managerial meanings of these findings?

7.3.1 Project design

When we think about project team design, we always think, "Bring right people and let them do". But who are the right people?
What kind of capability or information we expect from them? We can answer these questions from information flow point of view.

Let us examine the solutions and list up the cases when expert was used to solve the stickiness problem.

1. When we want to learn from the person who has experience of the other line. (Especially when there are filter of sender related to reluctance.)

2. When we want to know of the history of trouble shooting in the company and try to apply that wisdom to the new line.

3. When we need systemic knowledge or tacit knowledge of the expert to solve the problem.

4. When we face complex problem and need experienced people to understand the complicated situation.

5. When we want to judge the priority of the information because we have too much information to handle.

6. When we want to judge the timing to use the information (or to solve the problem). [windows of opportunities for design]

7. When we don’t know where to start to solve problem.

What kind of experts are required in the above list? The first type is the expert who has some kinds of sticky knowledge. [#1 to 3 in the list.] For example expert who has the knowledge of other existing production line, or who has the historical knowledge of troubles in the existing production line, or who has systemic or tacit knowledge. The main feature of this type of experts is that they serve as a database for the problem solving. People who is called as "living dictionary" or very experienced operators who know everything about the production are the typical example of the experts who belong to this type.

The second type is the expert who has the insight of the problems related to the specific technological area. [#4 in the list] This type of insight is developed by the long experience in that technological area. The main difference between this type and the
first type is that this type people contribute problem solving capabilities to the project. The first type (database type) expert does not necessarily solve the problem by himself. This often happen when we involve operators in the project. They provide rich information about real production but, in many cases, they do not solve the problem by themselves. In order to solve the problem, it is necessary to have second type expert who has the insight of the problem and can interpret the meaning of the operators' comments and apply them to the problem solving.

The third type is the **expert who has insight of the project management.** [#5 to 7 in the list.] For example, expert who can judge the priority of the problems, or who can judge the timing of problem solving, or who can judge how to approach the problem.

One important thing is that these types are based on the nature (or function) of the expertise and it does not necessarily mean that each person should belong to one type. In many cases, talented people have two or three types of nature (or function) at the same time.

When we design a project team, we have to gather appropriate mix of expertise to fill the different types of necessity mentioned above. When we say "expert involvement", we tend to forget that there many different types of "expert" exist. We always have to try to think which expert can bring what kind of knowledge or capability to the project and try to avoid putting same kind of expertise.

7.3.2 Project management

Stickiness of information requires special attentions of the project managers.
(1) **Timing issue**

As we have seen, transferred information is not necessarily used effectively. (This unexpected result is one of the important finding of this study.) One of the main obstacle of the effective use of the information is the timing issue (or "windows of opportunity" issue). They are further divided into two issues. One is how to identify the problem timely (while the windows are still open). The other is how to know when we should use the information. The latter is solved mainly by the involvement of the experienced people as mentioned above.

The former problem is discussed in Chapter 6. Though "templating" is a very powerful method for problem identification, it tends to show us the problem too late, therefore we have to use other methods, for example prototype (or pilot plant), models, simulation, expert involvement, and learning from similar line.

(2) **Information transfer**

The other thing which managers have to think is how to improve the effectiveness of information transfer. There are some techniques to improve it.

First, managers have to think geographical location of the project. It affects the efficiency of information transfer. Therefore project team have to be located near to the major source of sticky information. The problem is that the types of the information necessary for the project are different according to the progress of the project, therefore the location of the major source of sticky information changes. We need to change the location of our project to meet this change of the location of the major source of sticky information. [von Hippel, 1990]
The second point is that one of the most effective way to transfer sticky information to the project is to involve experts. As we have discussed, important managerial point is that there are different kinds of expert for different kinds of information, therefore we have to have good mix of people in our project.

Test run or ramp up period is as critical as design period to determine success or failure of the project. To manage this period, "creating forum" (Tyre, 1989) is very powerful. To make it sure that we could solve major problems before the windows close, "rapid max test" is useful. (Chapter 6)

7.3.3 Information flow and organizational learning

(1) Personalized information and organizational learning.

We have discussed that it is rare to develop totally new production line but there are many similarities between the new production line and existing production lines. Therefore we have to use the past experiences in the company but the problem is that these experiences are not "organizational learning" but rather aggregation of "personal learning".

It is important for both organization and people to unstick the information and make it common knowledge. From the organization point of view, it would increase the efficiency of technology transfer from the existing production lines to the new production line. And also it would enable to transfer technology from generation to generation. From the people's point of view, it would relieve them from "trap of expertise". The more the person has know-hows, the more important he becomes to the department but it prevents him from moving to the other department and he will have difficulty to be promoted in the general managerial ladder. It is good for people to unstick the information and to be freed from it for the sake of his career making. (Of course, he may not want to share his know-how
with others to keep his value as an expert higher than other's. This is a narrow view of the expert because unless he shares his know-how with others, he will not get other's know-how. It may be OK if the competition is limited within the company, but in the reality, by doing this, he and his company will lose competitiveness in the global competition.)

In the case study of the new production line development projects, expert (or experienced people) involvement is often used as a solution. It seems to be a very easy solution for managers. All they have to do is "just bring right people". But the real problem is how to make sure that we have right people in our organization when we need them. It is a long term managerial issues. We have to think how to educate people. If these experts' capabilities can only be gained by experience, how to create the chance for the next generation to gain it is important problem. These are tough questions but we have to think well for the long term success.

Learning from similar line's experience is also powerful solution, but how to "learn"? In many cases, similar line's information was brought by the insider or acquired by face to face communication. Both of them rely on the human memory as information storage and human to human contact as information transfer method. The problem is these methods are not good for diffusion of the information widely over the organization because information is sticky to the limited number of people and if they are not available, we can not transfer information. Is it possible to unstick these information and to make database which is accessible for all projects? We know it is not an easy task but if we can do it, it is wonderful. Thinking about such data base, it is not enough to list all incidents in the existing line with its cause, consequence and solution because these troubles or solutions are dependent on the certain environment, but if we add the background information to the database, it would be applicable to the other lines.
We need some kind of database to keep information to achieve "organization learning". But to do so, we have to find the way to unstick the data from person and to store them in a accessible form. In addition to it, we have to find way to update the information. This problem is difficult but if it were achieved, it would have a large impact on the efficiency of new production line development.

7.4 Summary

In this thesis, we used "sticky information" concept (von Hippel, 1990) and analyzed real new production line development cases deeply. Although this study is based on only two projects, total 67 descriptive data were gathered. Through this microscopic analysis, we found interesting natures of "sticky" information and we improved our insight about it.

While "sticky information" concept is useful, it is somewhat loose concept and it includes many kinds of problems related to information transfer. It may be well divided into several sub-concepts. This thesis provides one proposal for this area of research.

While this thesis has a value as a first step toward this direction, further research is necessary. It would be interesting to know if the situation is same in the different industries or different scale of the development projects, or whether there are difference of the stickiness problems between new product development and new process development.

Another interesting but difficult field of study is that given the sticky nature of information, what we can do to create data base to keep information as "organizational knowledge", or what is the best way to "educate" expert efficiently. Study of the stickiness of the information will provide us the base of such study but there is still a long way to reach this goal.
REFERENCES


Tyre, Marcie and Wanda J. Orlikowski, "Creating Windows for Technological Change in the Production Environment", January 1991, MIT Sloan School of Management, Cambridge, MA

von Hippel, Eric, "The Impact of 'Sticky Data' on Innovation and Problem-Solving", April 1990, WP #3147-90-BPS, MIT, Cambridge MA
Appendix Descriptive Data

Descriptive data used for this thesis was based on two new production line development projects: No.3 CAL and No.4 CAL project. Each data has an identification number, whose first character indicate the project ("3" for No.3 CAL project, "4" for No.4 CAL project), second character indicate the related section of the project ("F" for furnace, "M" for mill, "D" for delivery section, "E" for electric system, "G" for general), third character after "-" is a serial number.

At the end of this appendix, there is a summary table of these data.

Descriptive Data of No.3 CAL Project

Furnace Section

3F-1 New type of burner was developed prior to the project to increase the capacity of each burner. Our project involved energy department staff who was a member of the development as an expert, and I asked him to write specifications for purchase of the burner. (For No.3 CAL project more than 200 burners were used in furnace section.)

The reason why I asked him to do so was that it was easier for him to do it than I. I thought it would take too long to learn the result of the development and to write it by myself. Report was published by the developing group but I couldn't use the report to write purchasing specification because both of them had different focus. Report was focused on new findings but purchasing specification had to exhaust all informations to define the system. (For example, it had to include capacity of each burner, air pollution
specification, list of items to be purchased, and so on.) It required whole set of background knowledge. If I wrote it by myself, I couldn't be sure that everything was included.

This might be a example of stickiness of information to the person and taking advantage of involving people to get information efficiently.

<table>
<thead>
<tr>
<th>Type of problem:</th>
<th>A-1. Systemic knowledge</th>
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<tbody>
<tr>
<td>Solution:</td>
<td>Separate task and send it to the expert</td>
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</table>

3F-2 Rollers in the furnace should have special coating to prevent surface defect of the strip (product). This technology had been developed and accumulated in maintenance department in Chiba Works. Mr. Kasai, then, assistant manager of maintenance section, was the key person of this technology. I asked him to write specification of coating for No 3CAL's furnace.

Historically, this technology was developed by maintenance section, because after Chiba's No.2 CAL had been put into operation, the surface defect of the products caused by the small projection built on roll surface became major quality problem and to solve this problem the coating technology was developed by maintenance section.

The furnace temperature of No.3 CAL was higher than the existing furnace and we feared that usual coating material would last or not. Mr. Kasai and Mr. Kaihara cooperated to do the laboratory test and selected new coating material for high temperature zone.

To decide the specification of roll coating for No.3 CAL, wide range of knowledge of the coating materials was necessary (for example, characteristics of materials, applicable temperature,
resistance to the thermal-shock, the surface roughness after coating, etc.) It was difficult all of these pieces of information to transfer to me while it was easy to transfer the furnace specification information to Mr. Kasai because he knew existing CAL very well so then he had background knowledge to understand new CAL. [Systemic knowledge]

Mr. Kasai was a gatekeeper of coating technology in our plant. We got sticky data by involving him.

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<tr>
<th>Type of problem:</th>
<th>A-1. Systemic knowledge</th>
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<tr>
<td>Solution:</td>
<td>Separate task and send it to the expert</td>
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</table>

3F-3 Regarding coating technology, Chiba Works had used Union Carbide as only supplier because the competitor; Tokaro once had quality trouble in the past and since then nobody dared to try to use them as supplier. On the other hand Mizushima Works preferred Tokaro because of the good service and low price. Mr. Kaihara, manager of manufacturing group of No 3CAL project, who came from Mizushima Work, initiated comparison study of both companies' coating material with Mr. Kasai, the key person of Chiba Work's coating technology. As a result, No 3CAL adopted both type of coating and reduced the cost by competition.

I think this is a good example to show there is a stickiness of data caused by history. Once one made a serious mistake, no one would hear him later and it create barrier of the flow of information.

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<thead>
<tr>
<th>Type of problem:</th>
<th>C-7. Historical barrier on receiver</th>
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<tr>
<td>Solution:</td>
<td>Bring people who don't have barrier</td>
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</table>
There were many troubles caused by bearing of furnace rolls in No 2 CAL. (Bearing nuts became loose after a long period of operation and then bearing moved from original position and finally touched the casing and broke down.) It was a big problem for the maintenance section but I did not know these troubles until one leader of maintenance workers (Mr. Ishibashi) was assigned to our project. He knew that these troubles occurred in No.2 CAL but not in No.1CAL. Maintenance department peoples tried many things to prevent these troubles but could not stop them. (Some people said that they were caused by rough job of the workers which means that they didn't fastened nuts properly.) I learned from my boss (Mr. Ida), who designed the No. 2CAL, the fact that since No.2 CAL was built, the design to support the bearing had been changed to improve the maintainability. Finally, I found that in No.2 CAL's design, bearing became loose because of thermal expansion of the shaft and I changed the design to prevent it.

This is an example of the stickiness of data to the section. For the maintenance people, the information of the existence of the problem was common sense but it was not well known in equipment department because it was regarded as a problem in the quality of maintenance jobs not as a design problem.

Misunderstanding of sender omitted the information to be sent to receiver, because sender (engineers in maintenance section) thought that the information was irrelevant to the receiver. However, Mr. Ishibashi did not have such judgement. He suffered from the problem and wanted it to be solved no matter who was responsible for it.
Mr. Kahiara, who came from Mizushima plant, brought us an information that Mizushima’s No.1 CAL was lacking heating capacity and that was one of the reason why they could not produce enough amount of products as designed. Once the furnace was built, it was difficult to increase heating capacity. Therefore we carefully checked the basic assumption of calculation of heating capacity and decided to have relatively large margin in capacity design. In addition to it, we tried to have balanced margin all over the line not to create bottle neck.

Furnace section was designed by Mitsubishi Heavy Industry (MHI). All of the Kawasaki CALs’ furnace were designed by MHI because in Japan there were fixed partner to build CAL, which was the result of the history of development: Kawasaki was later to develop CAL than Nippon Steel and NKK. Since Nippon Steel design CAL by themselves and NKK chose Tyugai Furnace as a partner, MHI also wanted partner to get into this market, then Kawasaki and MHI decided to work together. Since then these two companies always worked together even when MHI sold CAL to foreign steel maker as far as CAL was concerned. This relationship helped to accumulate know how in both side. Both of the companies had knowledge of previous projects.

Mr. Kahiara had been a plant manager of the Mizushima’s No.1 CAL. Though he did not belonged to the construction project, he took over the line after it got into operation and he had to deal with many initial troubles. He might not know every reason of the designs but he knew very well about the weak points of original design.
I think this is a good example of the success of transfer of sticky data by moving people. Because many people do not want to talk much about initial troubles because they were often "stupid" troubles and they thought it was OK as far as it "had been solved" then there were no reason to advertise "their own faults".

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<th>Type of problem:</th>
<th>C-2. Filter of sender: Reluctance</th>
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<td>Solution:</td>
<td>Insider involvement</td>
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3F-6 Mr. Kaihara (who was one of the No.3 CAL project member) was an assistant manager of Mizushima No.1 CAL when that line started its operation. He knew that at the beginning stage of Mizushima No.1 CAL there were many minor explosion at the pilot burner (though these problems were solved later.) Mizushima's pilot burner was a pre-mix type, in which fuel gas and air was premixed and sent to the each burner. Then when burners were not adjusted well, they could cause such troubles. We decided to use nozzle-mix type burner which had separate piping for fuel gas and air to the nozzle to avoid this problem. (However, it increased the amount of piping which caused increase of construction cost and time.)

This is also an example of sticky data which had been brought by Mr. Kaihara. It was sticky to the Mizushima NO.1 CAL project because these troubles were not officially reported.

Information of such small problem which had been solved is one of the most sticky data. If the problem is serious and took long to be solved, it can't be hidden and becomes famous (or notorious) and then everybody understand the problem. But the problem is small and has already been solved, it is not necessary to announce it to the public.
Mr. Kaihara noticed that Mizushima's CAL's layout of staircases was not good for operators to walk around. They were not placed on the routine machine examination route, therefore operators had to go forward and back to find staircases. Although it was very inconvenient for operators, we did not hear this complaint from operators when we visited Mizushima plant. Since I could learn this information from Mr. Kaihara, I decided to be careful to layout stairs to improve the movement of people.

This information is also sticky and might be sticky to Mr. Kaihara who noticed this problems. Because once the line put into operation, operators think the situation as given. Of course they may feel uncomfortable about the situation but they don't report it because they know that it is impossible to change whole structure. It is no use crying over spilt milk. And even if we visited the plant we may not notice it because these problems only can be found by the people who always walk around the plant. The tourist who just walked through the plant with guide would never find them.

Mr. Kaihara noticed the problem when he took over that line and tried to fix it but couldn't. From this experience he remembered the problem very well and could transfer the information to Chiba's No.3 CAL.

Although we received the information and tried to avoid same trouble, we could not get the satisfactory result because we tried to check the layout of stairs and made many minor modification during the detail design but there had been many constraints already and we could not change the layout fundamentally. From this experience, I
could design satisfactory design in No.4 CAL by taking into account these factors at the very begging stage of design.

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<tr>
<th>Type of problem:</th>
<th>C-3. Filter of sender: Given up problem</th>
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<tr>
<td>Solution:</td>
<td>Insider involvement</td>
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</table>

3F-8 I heard that there were some rolls which could not be changed without cutting the column of the furnace structure in Mizushima's CAL. I decided to check the design of No.3CAL and found same problem, then changed the design.

I forgot from whom I received this information. I think I heard this story when I visited Mizushima plant. At least I received this information directly from person who is related to the Mizushima plant then I can say that I received it as a first hand information.

I think that I received the information by chance. Before I visited Mizushima Works, I heard that in Mizushima maintainability was not well considered, then I tried to ask maintenance people what kind of trouble they had. I think I received this information during such conversations.

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<th>Type of problem:</th>
<th>C-3. Filter of sender: Given up problem</th>
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<tr>
<td></td>
<td>C-2. Filter of sender: Reluctance</td>
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<tr>
<td>Solution:</td>
<td>Face to face: Go and get first hand information</td>
</tr>
</tbody>
</table>

3F-9 The profile of the furnace roll was important know how and it differed from line to line. I asked Mr. Oota, assistant
manager of our project, who was a staff of the No. 2CAL, to decide it. He decided it based on Mizushima's design and modified it with No. 2CAL's experience.

There were no established theory to determine roll shape. It is decided by try and error. And it was regarded as one of the most important know-how in CAL design and kept secret to the out of the company. (We didn't let Mitsubishi Heavy Industry know it.) Mr. Oota had experience of designing it because one of the most important task of manufacturing engineer was to decide the roll shape whenever new products or new operation method was introduced in existing CAL.

There were no quantitative model to design roll crown, but the qualitative relation between roll crown and line trouble was known. If the crown was too small, the strip would start snaking at the high speed operation. If the crown was too large, the strip would collapse at the high temperature section. The risk is enormous. Once such kind of trouble occurred, it would take take long time and huge amount of money to fix it because it would require to pull out many rolls from the furnace, to remove expensive coating, to reshape them, to apply coating, and install them into the furnace again.

This is also an example of sticky information. It is sticky because it requires accumulation of experience (or information) and it is decided by intuitive way. These skill is difficult to transfer because the database itself is not explicitly descriptive and decision process is vague. For example the information is just like, "too large crown causes buckling but too small crown causes snaking" but no one can say the boundary amount of crown numerically. It could not be determined by theory and intuitive judgement was required.
3F-10 Large fan of the furnace broke during the test run because of poor design. This fan was purchased by Mitsubishi Heavy Industry, who build the furnace section, from small fan maker, which had already bankrupted by the time of trouble. After this trouble, Mitsubishi checked all other fans' design and replaced almost all fans.

We (Kawasaki Steel engineers) never tried to check the detail design of fans because we regarded them as established units which could be purchased as an functional unit (just like pumps or cylinders or bearings) We did not asked Mitsubishi people about whom they purchased those fans from. Even if Mitsubishi had informed us the name of the fan maker, we could not judge whether it was acceptable or not. We trusted MHI's selection of the fan maker. However after the trouble, some people criticized us why we did not controlled the Mitsubishi's purchase decision. As a hindsight, we thought we should have checked it. If we had known that they bought them from very small companies, we could have asked them to check the design thoroughly, at least.

_The information that Mitsubishi purchased fans from very small company and it actually bankrupted was sticky to Mitsubishi. They didn't have incentive to inform it to us and we weren't interested in such detail of their activity._

Type of problem: C-6. Filter of both sender and receiver: misunderstood relevance

Solution: No. -- Machine told
Whenever we had difficult design problems, Mitsubishi people brought their laboratory people with them and we could consult them. They were experts of that field and very helpful, however, their first suggestion was often off the point because of wrong assumptions or unacceptable assumptions of usage of the machine. But after we talked with them, they understood the situation and provided us good solution. (Non the less, we added some safety margin on their suggestions to make final decision.)

We always asked them to write assumptions in their report. We didn't care whether they refuse to give us specific formula or theory to be used to solve the problem, but we always insisted to check the assumptions of their analysis.

The interesting thing was that it was very easy to find the fundamental mistake during the meeting with them while we could not find any problems in the report which was sent to us prior to the meeting before we meet them. (Even Mitsubishi's chief engineer could not find the mistake which he could have known to be wrong though he should have read the report because he signed his name on it.) Meeting was the most important way to understand each other.

On the other hand we could not give them what kind of assumption is acceptable before they write their report, because we didn't know what kind of analysis they would do and what kind of assumptions they would need. We could not prevent wasting their efforts to write first report and every time they had to rewrite their report. (In No.4 CAL project we could speed up this process because we could use No.3 CAL's report as a prototype.)

This example shows that it is useful to be able to access to the experts who had sticky information. But to transfer our sticky data (acceptable assumptions of calculations) it is necessary to
check written report (one kind of prototype) and meet together (face to face communication).

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<tr>
<th>Type of problem (1):</th>
<th>G-3. Can't transfer information up front</th>
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<tr>
<td>Solution (1):</td>
<td>Use Prototype</td>
</tr>
<tr>
<td>Type of problem (2):</td>
<td>E-1. Inadequate transfer method</td>
</tr>
<tr>
<td>Solution (2):</td>
<td>Face to face communication</td>
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</table>

3F - 12 In No. 3CAL project, we contracted with Mitsubishi Heavy Industry (MHI) to do joint research to develop new thermal control method for CAL, however the result was not very good. Because MHI's representatives were control engineering researchers and tried to apply latest control theory without thinking the nature of the production line. On the other hand, our representatives were not all control engineers and very skeptical about the theory and required to apply more simple logic. Both of them could not reach agreement at the most fundamental level and spent time arguing and finally made compromise which both of them were not satisfied with.

Mitsubishi people could not convince Kawasaki people. They believed that their theory should be useful in this case. They might think it was too technical to explain us or they simply believed in the theory because the new theory was one kind of fashion those days and was applied to many fields and proved to be useful. On the other hand Kawasaki people rejected Mitsubishi people's idea basically intuitively. Kawasaki people's intuition might have been prejudice or superstition, however I believed that Kawasaki people had sensed some kind of truth intuitively because in spite of the different engineering backgrounds, all of the experienced and best
engineers thought the model which was proposed by Mitsubishi people was not applicable to their production line.

It made the problem more complicated that the validity of the theory can only be proved after it was developed and put into operation, therefore, both of them argued the problem with no answer.

*Both of them had strong belief but could not transfer the information to others.*

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<tr>
<th>Type of problem</th>
<th>E-1. Knowledge compatibility</th>
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<td>Solution</td>
<td>No. (Good interpreter was necessary)</td>
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</table>

**3F-13** We contracted the inside lining of the furnace to the Kawasaki-rozen, one of our subsidiary company. The expert of the company proposed the latest way of lining (block method), which was fastest to construct and would make the lining less deteriorated after long period. At that time Mitsubishi Engineer was trying to reduce the heat loss caused by the circulation of the gas within the lining layer. When we talked about the new lining construction method, Mitsubishi Engineer brought his problem and we could solve his problem by putting additional layer between blocks in the new construction method.

Mitsubishi engineer had the information related to the cause of the low efficiency. Kawasaki-rozen’s expert had the information of different way of lining. We modified the latter idea of the new lining method by putting special layer between blocks to solve the former problem identified by Mitsubishi. In this case combining both ideas provided new method to solve both problems. This synergy effect was not got by design. Because they did not have direct relationship
between themselves (because both of them contracted directly to Kawasaki Steel), it was not necessary to put them together in one meeting. At first we wandered whether we should put them in the same meeting or we should have separate meetings. Finally, we decided to put them in the same meeting partly because we were too busy to have two separate meetings and partly because we were afraid of failing to transfer important information between them.

We could add insulate layer between blocks to improve the efficiency. This was the synergy effect of the meeting.

This is an example to show that it is useful to put people together when each of them have sticky data because sometimes we can get unexpected synergy effect of two sticky data.

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<tr>
<th>Type of problem</th>
<th>H-1. Synergy effect</th>
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<tr>
<td>Solution</td>
<td>Put different type of people together</td>
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</table>

3F-14 Mr. Kaihara brought the information that in Mizushima No.1 CAL, motor power of the guide rolls and seal rolls were not enough and they often "tripped" (circuit breaker broke down because of excess load) and caused problems.

These rolls are not designed to touch the strip always. But if the strip vibrate, these rolls guide the strip not to touch the frame of the furnace and get scratched.

The original design idea was that because these roll are not always touch the strip, it was not necessary to have strong motor to drive strip but small motors which could keep the rolls running were enough. However Mizushima's experience revealed that once the strip
started vibration and touched the roll the small difference of the speed of them created force to rolls and motors would trip by over load easily and it created occasional interruption of operation because we could not leave the roll stop in the furnace because once the roll stopped, the temperature difference of the roll surface would cause the roll to bend and it would break the roll.

The original design concept seemed to be reasonable. But actually it was not right. The real operation revealed the problem.

The failure information was brought by Mr. Kaihara. If he did not bring the information, I am not sure we could get the information from other source.

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<tr>
<th>Type of problem</th>
<th>C-2. Filter of sender: reluctance and B-1. Complex phenomena</th>
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<tbody>
<tr>
<td>Solution</td>
<td>Insider involvement and Learn from other line’s experience.</td>
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</table>

3F-15 Mr. Kaihara brought the information that in Mizushima No.1 CAL’s test run, the density of oxygen in the furnace did not go down and had hard time to find pin hole of the furnace after they started hot run. (final stage of test run, which was done with heating up the furnace) To prevent this problem, we did the leak test thoroughly. As a result, we could shorten the start-up time.

The information of the difficulty in test run was useful to prevent the same problem. If we can transfer this kind of information of experience efficiently, we can increase our performance. However there was no benefit for the sender to transfer the information. They could be reluctant to show that they
had troubles in the test run especially when the trouble seemed to be able to be prevented for the others.

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<th>Type of problem</th>
<th>C-2. Filter of sender: reluctance</th>
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<tr>
<td>Solution</td>
<td>Insider involvement</td>
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3F-16 When we designed the No.3 CAL, we knew that NKK (second largest steel maker in Japan) used direct flame burner for their CAL. We knew that that type of burner had an advantage: because it did not have radiant tube, its response became very high. However there might be weakness that it might affect the chemical characteristics of the strip surface because the exhaust gas of the burner contacted the strip. We were very curious about the technology but it was necessary to build test furnace to test it, which meant that it would need a lot of money and time. Then we decided not to consider it.

Some information becomes sticky because of the cost to verify it.

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<th>Type of problem</th>
<th>F-3. Expensive to verify</th>
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<tr>
<td>Solution</td>
<td>No. (trade off between cost and expected effect)</td>
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</table>

Mill section

3M-1 Mr. Ida told me that bridle rolls should be made by centrifugal casting pipe instead of rolled plate which does not have uniform surface around welding line. He learned this fact when he had been a staff of maintenance section. In those days, there was a
quality trouble caused by the surface condition of the welding line of the bridle rolls.

Mr. Ida started his career in maintenance section and then moved to equipment department and participated and managed many construction work in Chiba No.1 Cold Strip Works. He was regarded to be the No.1 person for the construction work in this field because he had both management skill and detail knowledge of machines.

*Mr. Ida knew this information from his past experience in the maintenance section. But such kind of data was sticky to the maintenance section. (Because for the maintenance section, the problem had been solved and the diffusion of the technology was not their job.)*

*There is another problem which is related to timing. There was a large gap between the time when maintenance know-how was created and the time when new line was constructed. Therefore, information must be accumulated somewhere until next construction. In this case, the information remained in Mr. Ida's memory. But if he did not remembered it, we would have failed to use the know-how which had been generated before.*

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<th>Type of problem (1):</th>
<th>Solution (1):</th>
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<td>C-8. Less incentive for sender</td>
<td>Insider involvement</td>
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<th>Type of problem (2):</th>
<th>Solution (2):</th>
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<tr>
<td>G-1. Timing: different timing of generation and use of the information</td>
<td>Human memory (insider involvement)</td>
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3M-2 We asked Mr. Yamashina, who had been an operator staff of existing plant and was assigned to No.3 CAL project at
detail design phase, to design the spray pattern of lubrication liquid and to decide the nozzle series number, because he had know how.

These patterns could be relatively easily changed by operators and also it was very important to get the high quality products, therefore, operator staffs often tried new patterns and established know-how in existing plants.

*Such expert information (know-how) was not or could not written in document. The easiest way to get it was to assign people who had know how in our project.*

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<tr>
<th>Type of problem:</th>
<th>A-2. Tacit knowledge (know how)</th>
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<td>Solution:</td>
<td>Expert involvement</td>
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3M-3 Mr. Kaihara said that it was difficult to pick up old rolls from the roll changer of the mill because of the narrow clearance and low precision of overhead crane. Then we designed roll guide for roll changer but it did not work because putting the rolls into guide itself was difficult because of the narrow clearance.

I found this fact later and tried to solve the problem but I found that if we wanted to solve this problem fundamentally at that timing, it was necessary to change whole design of the mill structure. It was impossible because many detail design of the mill had already been done by the time and we could not afford to abandon all these works and do the whole design work again.

We started the design of the roll changer later than the design of the housing structure of mill, then we did not start to conceder the way to make the roll handling easier until we start to design the roll changer. However we found it later that it was difficult to improve the situation effectively without changing the clearance of
the roll changer but if we wanted to do so we had to change the mill structure itself which meant to change almost all design which had been finished by that time. We could not afford to do so. Therefore the design schedule itself was not good. We should have considered design of the roll changer when we designed mill housing. When we designed the mill housing, we fixed the important parameter for roll changer design without noticing the fact explicitly.

(We learned this lesson from No.3 CAL and we could avoid such king of the problem by considering roll changer simultaneously when we designed mill housing in No.4 CAL.)

*During the design process some important information may not available because it will be decided later or some important parameter is decided without noticing it. In such case, data became sticky to time because of the schedule constrain we can't change it.*

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<thead>
<tr>
<th>Type of problem</th>
<th>G-2. Timing; Window for design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solution</td>
<td>Failed. (receiver should know when the information can/should be used)</td>
</tr>
</tbody>
</table>

3M-4 Mr. Ida told me that it was necessary to have bellows cover over the air cylinder rods in the mill to protect it from environment. I requested to the maker to apply this rule and kept it in my mind but failed to find that there was one cylinder which did not have cover on its rod and it caused trouble after the line started operation.

There were many cylinders in the mill and covers were not explicitly drawn on the assembly drawing, therefore we always write our comment to the maker like: "All cylinders in the mill should have cover over the cylinder rods." Then we relied on the maker's engineer to make sure every cylinder really had covers.
However they failed to apply the rule to all cylinders because there were too much cylinders and too much things to take care of. I think both maker designer and I did not recognized the importance of this information. It seemed to be just one of many pieces of information for us and I think this was the reason of the failure.

Even if the sticky data was transferred to the maker's engineer it is sometimes difficult to realize it, because it requires careful application over long period of time. Sometimes the information may be buried by other informations. Sometimes the receiver may have different priority from the sender and may neglect the information.

The person who had bitter experience of failure never forget if but the person who got the information as just a knowledge may forget it.

<table>
<thead>
<tr>
<th>Type of problem</th>
<th>F-1. Buried information (Too much information)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solution</td>
<td>Failed. (receiver should have priority system not to forget important information)</td>
</tr>
</tbody>
</table>

3M-5 In the test run, only three operators were assigned to mill section. Then, after the line was put into operation and operators were divided into four groups to form three sifts, one group did not have "expert of mill". That group was afraid of changing the rolls of the mill and tried to avoid it because they could not be sure whether the roll changing machine was working well or not.

Even if the sticky data was transferred efficiently by face to face and hands on experience in the test run, it was still sticky and did not diffuse into the other operators easily.
Table:  

<table>
<thead>
<tr>
<th>Type of problem</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-1. Transfer method; adequate diffusion problem.</td>
<td>Face to face communication at machine side and hands on experience.</td>
</tr>
</tbody>
</table>

3M-6 When we designed the spray pattern, I did not recognize that the mist of the oil flowed in the mill housing and condensed on the surface of the structure in the mill, which dropped on the surface of the strip and caused quality trouble. I realized it after we started operation and watched the mill standing by it for more than half a day.

*Such kind of complicated phenomena is difficult to predict. The real situation only can teach us.*

<table>
<thead>
<tr>
<th>Type of problem</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-1. Complex phenomena</td>
<td>Machine showed it.</td>
</tr>
</tbody>
</table>

General comment

3G-1 Generally speaking, large equipment makers such as Mitsubishi or Hitachi have constructed many lines all over the world and accumulated know how. Therefore when we request to change their design, they often say that they have always constructed in this way. However, even if their equipment was poorly designed and be modified after initial operation, they don't know it. Incremental improvement is done by the users and there is no official channel for the makers to get this kind of information and no necessity or benefits for the users to do it.
Original design concept is sticky to the maker of the equipment but the improvement information is sticky to the user, then maker may make same mistake again and again.

Here, duality of the information is also the problem. Information of the real situation is encoded in the machine but it is not easy to decode it. Then, we have to keep information separately, but when we modified the machine, we tend to fail to update the information.

<table>
<thead>
<tr>
<th>Type of problem</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>I-1. Update of the information</td>
<td>Gather modification information as well as original design information</td>
</tr>
</tbody>
</table>

3G-2 Makers' engineers have detail knowledge of design of the equipments but don't know how they are used. They tends to think function first and often forget to care about operability and maintainability. In addition to it, they represent their company then they try to reduce cost and some times sacrifice the durability or even performance. Our task as equipment department engineers is to guide them to the optimal design from the stand point of user not maker.

If the value systems of the two party are different, some information, which is important for one party but not important for the other, becomes sticky.

<table>
<thead>
<tr>
<th>Type of problem</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-4. Filter of receiver: reluctance</td>
<td>Sender made effort to transfer the information</td>
</tr>
</tbody>
</table>
3G-3 No.3 CAL first adopted CRT operation in our company, in which many switches and handles were replaced by the touch input device on CRT. To make the operators get used to the concept, we let them design what kind of information was displayed on the CRT and in which screen they appeared. Through these work, they got used to new way of operation before test run.

By involving the user, we could put sticky data into design. In the design of CRT, it is important to know what information they need and what kind of parameter they use in different operation situations. We could avoid to transfer such complex information by involving operators.

However, they could not taken into account every situation. Later, after the line was put into operation, they found that when they change mill rolls, they have to go and back in two separate CRT screen and they regretted their design. [No.4 CAL's operator heard this problem and could avoid it by changing the design.]

This arrangement made it possible to transfer operators' sticky information into the CRT graphic design and get operators used to the new concept: CRT operation at the same time.

By user involvement, we could avoid to transfer sticky information: operators' "use and preference", but operators themselves failed to apply all of their information and found problems later when they started real operation.

<table>
<thead>
<tr>
<th>Type of problem :</th>
<th>A-1. Systemic knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solution :</td>
<td>User involvement</td>
</tr>
</tbody>
</table>
Appendix:  Descriptive Data

**3G-4**  We usually include all start up maintenance people at the installation stage and let them supervise it and in the test run each engineer who designed the machine becomes section test run leader and work with maintenance people. During this period many information is transferred from engineers to maintenance people.

Such information can't be transfer efficiently from classroom lecture because they get bored and we may forget to tell everything. But to survive the test run together, we can transfer not only the knowledge but also design concept. And sometimes we can modify the machine taking into account maintenance peoples' ideas.

*The same information can be sticky or less sticky by the method applied to transfer the information.*

<table>
<thead>
<tr>
<th>Type of problem</th>
<th>A-1. Systemic knowledge and E-1. Transfer method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solution</td>
<td>Machine side communication and hands on experience</td>
</tr>
</tbody>
</table>

**3G-5**  When we wanted to change the design of the machine to improve operability or maintainability, maker's engineer often said that it was impossible to do it. In such case, the best way to persuade them was to show them the way to solve the problem. Of course we did not design by ourselves but it was very important that we could show them a conceptual design, which was not necessary to be a precise drawing. Schematic diagram written by free hand was often useful enough. If we could show them the fundamental idea to solve the problem and if they agreed with it, they worked hard to make it real solution. However if we did not have an idea about how to solve it and just ask them to solve it from
the scratch, they tended to reply that though they tried hard to solve it, it was impossible to do it.

One of our job was to transfer our requirement (user information) to the reluctant receiver (maker engineer). Maker engineers did not like to change their original idea or design because of the time constraint, budget constraint, or simply not knowing the importance of the information. If we wanted to remove reluctance in receiver side we had to prove the feasibility and advantage of our idea, however to do this it was necessary for us to have high engineering ability.

Electrical engineers usually place whole in one contract, which include design, manufacturing of hardware, software, installation and test run, with large electrical maker. Mechanical engineers often criticized them that they are technically dependent to the makers and it affect their mentality to be dependent on and rely on them, then they tended not to try to find the solution by themselves and sometimes fail to persuade maker's engineers to reflect our (user) needs.

*To remove the reluctance of the maker's engineer to listen to us, it is necessary to have our own information source and ability to show the way to solve the problem, and convince them that we are the important source of the information and they have to listen to us.*

<table>
<thead>
<tr>
<th>Type of problem</th>
<th>C-4: Filter of the receiver: Reluctance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solution</td>
<td>Send value added information</td>
</tr>
</tbody>
</table>

**3G-6** Entry and delivery section's success determined by the accumulation of small cares in the design and test run because
the main trouble in this section is that strip is caught on the frame of the machine or slit between conveyers. Such trouble can only been solved by careful examination of layout, and problem detection and modification during the test run.

Because there is no theory in this field, an experienced mechanical engineer is necessary. In No.3 CAL, Mr. Nemoto was very good at such task. He designed entry section and used special conveyer to handle scrap but we failed to use that kind of conveyer in delivery section because it was designed by young engineers (Mr. Muramoto and I) and did not know it. After we found that he used special conveyer in the entry section, we complained him why he did not teach us but it was a commonsense for him and he could not imagine that we did not know it.

The main difficulty in the entry and delivery section of the CAL was that in both section the strip was not continuous and we had to handle the free end strip, while most part of the line dealt the strip in continuous manner. Such free end shape could have many shape and tended get into any narrow slit and stuck there. Therefore the most difficult thing to design in the entry and delivery sections were how to prevent strip jam.

The only known rule was "Don't make any gap. Strip goes into surprisingly narrow gap and jams." and " Keep the pass line wide open. If you put beam, pipe or whatever, strip stick to it and jams."

Experienced people know many trouble cases and solutions, then they can avoid such problems or easily fix them.

Can such expertise be transferred to others? The answer is Yes and No. Each element of good design such as special conveyer good to handle scrap could be listed in documentation and make it standard design. In this sense, it is Yes. But we can't transfer the ability to detect potential problems intuitively. In this sense, it is No.
Each solution by the expert is transferable but the ability to predict the potential problem is very sticky.

The data itself is not sticky but the knowledge (or sensitivity to find) the existence of the problem is sticky.

<table>
<thead>
<tr>
<th>Type of problem</th>
<th>A-2. Tacit knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solution</td>
<td>Expert involvement</td>
</tr>
</tbody>
</table>

3G-7 No. 3CAL project was consisted of strangers from stand point of the existing No.2 Cold strip mill plant. Then we could not get operation information from that plant and our main source of information was Mizushima plant. Then this project seemed to be isolated from the existing plant. I think this might be the cause of late approval gathering from the customers because the lest of the organization (especially marketing section) was not prepared well when construction of No.3 CAL was finished.

Unless we have good communication net work, the ordinary data can become sticky data.

<table>
<thead>
<tr>
<th>Type of problem</th>
<th>C-11. Psychological distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solution</td>
<td>Failed. (Involvement of the existing plant might be useful)</td>
</tr>
</tbody>
</table>

3G-8 Both Mr. Kaihara and Mr. Mega had good network with Mizushima plant. Mr. Mega got many operation information (for example operation parameters or real usage of equipment etc.) Mr. Kaihara sometimes asked Mizushima people to do special experiment for us.
If we have some member who came from different section of the company, we can enjoy to get important information relatively easily from their original section.

Moved people act not only as a source of information but also provides a window to the source of information.

<table>
<thead>
<tr>
<th>Type of problem</th>
<th>C-11. Psychological distance</th>
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<tbody>
<tr>
<td>Solution</td>
<td>Insider involvement</td>
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</tbody>
</table>

3G-9 In No.3 CAL project, the delivery section and the mill section were purchased from different makers. At the first design, the path level (the level of the strip path from floor) was decided to be 1000 mm. But during the mill design, we change the level to 1100 mm to make it easy to design. On that time I failed to change the path level of the delivery section and could not find the mismatch of the levels until installation.

The reason why I could not find that I failed to transfer the information was that it was very fundamental specification and once we started the design, I never checked it again, while almost all drawings had path level written on them. I did not have any doubt about it and did not try to check it. *(Strong preconception)*

The another reason was that the two section was purchased from different makers and drawings were drawn by each of them only for each of the section. Therefore, no matter how carefully I checked the drawing of one maker, I could not find the mistake. The only way to find the problem was to put two makers' drawings together and to compare them. *(Organizational complexity)* However I did not try to do it because I did not have any doubt about it. *(Strong preconception)*
Unless the person have any doubt, he cannot find the mistake even if all necessary informations are in his hand.

If the information is divided into multiple sources of components, it is difficult to find the problem.

<table>
<thead>
<tr>
<th>Type of problem</th>
<th>C-5. Filter of the receiver: Strong preconception.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solution</td>
<td>Machine showed</td>
</tr>
</tbody>
</table>

3G - 10 In No.3 CAL project, the construction site was far from the equipment department building (approximately 30 minutes drive), then we built temporally office next to the construction site. Both mechanical and electrical section people moved in the building but instrument section people refused to come. As a result, we could not get good communication with that group and whenever we coordinated the layout of pipes and cables, instrument section people failed to get necessary space and caused us to do the coordination job again later.

Physical distance hinder the communication. Though Tom Allen said that coordination type communication will take place regardless the distance simply because it is necessary, such physical separation reduce the efficiency of communication.

<table>
<thead>
<tr>
<th>Type of problem</th>
<th>E-2. Geographical Separation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solution</td>
<td>Collocation</td>
</tr>
</tbody>
</table>
Descriptive Data of No.4 CAL Project

Furnace section

4F-1  Since the No.3CAL we started to use special roll which embodied sensor in it. It was designed by us and purchased from one roll maker. When we developed this roll in No.3 CAL project, we instructed the detail way of production and precision request to the roll maker, however, we did not repeated same procedure carefully in No.4 CAL project because we ordered the roll to the same maker. But this time, they changed the production procedure thoughtlessly and did not informed it to us and caused a trouble.

We thought the information of the No.3 CAL’s design should be kept in the maker but actually they forgot it. I think it might be caused by the fact that in No.3 CAL project we taught the reason why that part should be build in certain way but they might have not fully understood it or even if they had understood it at that time, such information which was taught by somebody and not thought by themselves might be easily forgot.

Even if we could transfer sticky data to maker, sometimes it is difficult to keep it in the maker because it was not first hand information, which is generated by themselves, then relatively easily lost. On the contrary, if we got or generated the information with our own effort, we would not forget it. A cut flower can’t last long. If the flower has root, it can last and have seeds for next generation. (Compatibility of the information.)

| Type of problem | F-2. Lost information: Too long to keep |
4F-2 In No.4 CAL we took floor layout and stairs layout into account from the very beginning stage of the design because we could not make them optimized in No.3 CAL project, in which we started to consider them in detail design and could not make fundamental change because of many constraints. Although there were no detail design drawing, we could predict what kind of factors would conflict from No.3 CAL's experience. And we could make satisfactory design.

In No.3 CAL case [3F-7], we could not use the sticky information fully because we did not know the timing or interdependence information of the design factors. But in No.4 CAL, we got both data and could utilize it.

<table>
<thead>
<tr>
<th>Type of problem</th>
<th>G-2. Timing: Window for design</th>
</tr>
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<tbody>
<tr>
<td>Solution:</td>
<td>Use the information while the</td>
</tr>
<tr>
<td></td>
<td>window is open.</td>
</tr>
</tbody>
</table>

4F-3 In No.4 CAL project, we could speed up the capacity design stage because we could use the No.3 report as prototype. Then we could concentrate on the different points only.

In No.4 CAL both Kawasaki and Mitsubishi people had the same background experience of No.3 CAL, then we could reduce the amount of sticky data to be transferred. In addition to it, the effort to make the reason of design clear in No.3 CAL decreased the stickiness of the No.3 CAL information and made it easier to be transferred.
**Type of problem:** G-3. Can't transfer information in abstract argument

**Solution:** Use existing line as prototype

### 4F-4

In No.4 CAL furnace design, we made many windows to see the inside of furnace. And they were very helpful to solve the snaking problem at the test run.

When I did research of the existing line as a part of new engineer training, I had frustration that I could not see what happened in the furnace. We knew something wrong happened to the products in the furnace but we could not identify the point of the trouble. It made the research extremely difficult and I decided to make many windows for the new line.

*Furnace tends to be a large black box. But when we have to solve problem, it is necessary to have windows to see. If we want to learn from real operation situation, it is necessary to have means to see the situation or measure the data.*

**Type of problem:** E-1. Transfer method

**Solution:** Create windows to look into the furnace.

### 4F-5

In No.3 CAL construction, roll makers did not keep the promised shipment date and we had to re-schedule many times and had big difficulties to keep the final construction dead line. To avoid the same problem, in No.4 CAL I controlled the roll makers (the same makers as No.3 CAL) very tightly and required the makers to
report me the progress every other week regularly. And in this project we did not have any serious shipment delays.

The information that these makers were tends to be loose at schedule was difficult to get until we actually to the job with them. Once we knew the fact, we could cope with that problem by acting cleverly.

From the No.3 CAL experience, I knew that the roll makers tends to be loose about shipment day and could avoid the same problem.

<table>
<thead>
<tr>
<th>Type of problem</th>
<th>G-3. Can't transfer information up front.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solution</td>
<td>Use other line's experience</td>
</tr>
</tbody>
</table>

Mill section

4M-1 Operators said that in the TPL (existing temper mill), the guide rolls layout was not good to prevent shape defect problem, but did not know how to change the layout because there was no theory to explain the relationship between guide roll layout and the defect. Then we guessed the reason and designed according to the assumption. It was one kind of gamble.

I talked with operators who had worked in the TPL mill, manufacturing engineer, and Mr. Narumi (one mechanical engineer of our project and had modified other existing mill than TPL within one year before). Each of them told me the past story and gave me advice. I tried to take these points into account and designed the layout. But I thought it might be too risky to fix the design from these informations, then I designed it at least we could change the diameter of the rolls in the future.
When not all necessary informations are available, we have to generate the best solution with the limited information and have to have some safety margin or flexibility of the future modification in design.

In this example, information of the existence of the problem was known however information of the solution was not transferable because it was solved not theoretically but by try and error in the existing line.

<table>
<thead>
<tr>
<th>Type of problem</th>
<th>A-2. Tacit knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solution</td>
<td>Gather information as much as possible and make it easier to change in the future to reduce the risk.</td>
</tr>
</tbody>
</table>

4M-2 Supervisor, who was sent from Ishikawajima Harima Heavy Industry (IHI), often said that he couldn't even carry screw driver with him when he was sent abroad as a supervisor, however in our plant he himself help us to tune or fix machine. In Japan, even I [mill section's test run leader] went into the machine, getting dirty with grease on my cloth and help the workers.

He said that if a supervisor try to fix something by himself, the union people complain about it. But in Japan, I had to do the nasty job first because it was the way to show the leadership. If I do it first, everybody follow me.

He said it was tedious to teach the workers in foreign construction site how to tune the machine. He could have finished the job within the time he spent to teach it.

Can we call such way of instruction as technology transfer? It depends on the attitude of the worker who was taught by him. If the
worker tries to understand and improve his skill, the technology can be transferred but if he regards it as a instruction and do just as ordered, the transferred technology will soon be lost.

When we built No.4 CAL, we always assigned one of the best maintenance men to do the job with maker's supervisor to learn their skill and to understand the new equipment.

Information transfer itself is very important, but it is more important to have a mechanism to keep it in the organization. We have to consider the length of period before the information is lost.

This case also shows that hands on demonstration is useful method to unstick data.

<table>
<thead>
<tr>
<th>Type of problem</th>
<th>C-9. Incentive of the receiver</th>
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<tbody>
<tr>
<td>Solution</td>
<td>Machine side demonstration and hands on experience.</td>
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</tbody>
</table>

4M-3 We had a trouble of dropping rolls from roll changer in No.3 CAL project and I was very careful to prevent such kind of trouble in No.4 CAL. During the design period, I found a possibility of pushing out the rolls when roll changer moved toward the mill in the preparation sequence of roll changing and added sensor to stop the machine whenever it detected rolls on the track. But during the test run, this sensor cause a trouble to stop the flow of sequence just before roll changer reached in front of the mill because at that position the sensor of the roll changer detect the roll which was placed in the mill and it automatically stopped the sequence. To solve this problem we changed the use of this sensor as an start condition (not as an operation condition) But unfortunately it could not prevent the accident which happened later. That accident occurred when operator put new rolls on the pull out position on the
roll changer by mistake and started the roll changing sequence. This was exactly the same problem which I predicted earlier. However the interlock logic did not work because the sensor did not detect the roll at the start timing because the roll was place slightly out of the sensor's range. Soon after it started to push out the rolls, it detected them but because we changed the logic not to work after it started, it could not prevent the accident. After we learned lessons from this accident, we changed the sensor to the one with longer sensing range and changed the logic to stop the machine whenever sensor detected the roll up to the point where it reached very close to the mill and detect the roll in the mill.

Even if we could predict the problem and transferred the information, complicated situation may prevent to utilize it.

<table>
<thead>
<tr>
<th>Type of problem</th>
<th>B-1. Complex phenomena</th>
</tr>
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<tbody>
<tr>
<td>Solution</td>
<td>Failed to predict.</td>
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<tr>
<td></td>
<td>Machine showed it.</td>
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</tbody>
</table>

4M-4 In the No.4 CAL roll changer design, we compared whether cableveyor or cable reel to choose as power supply method. At that time, we thought both of them were technically indifferent and chose the cable reel which was maker's original design. However, when we had noise trouble on the sensor line later, we found that with cable reel it was impossible to change the sensor cable to improve the sealing performance. If we had selected the cableveyor, it would have been very easy to change sensor line later. We did not realized that when we selected the cable type, we had limited our capability to cope with the noise problem.

One decision may have significant impact on other decision later. But such relationship tends to be very difficult to predict.
Once we experience such trouble, it is easy to understand the relationship.

<table>
<thead>
<tr>
<th>Type of problem</th>
<th>B-1. Complex phenomena</th>
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<tbody>
<tr>
<td>Solution</td>
<td>Failed to predict problem</td>
</tr>
<tr>
<td></td>
<td>Machine showed it</td>
</tr>
</tbody>
</table>

Electric system

4 E - 1 No.4 CAL adopted "Mika System", which was newly developed programming tool. With "Mika System", programmer could write program in flow diagram not in special machine language and program itself could be monitored on operation room's graphical display as a flow diagram. The sequence of the program which was processed at the time could be displayed on the CRT by changing color of the flow diagram.

It was a very good concept, however, the compiler which generate machine code from block diagram was very poor. It appeared to take 30 minuets to compile. It was not acceptable because during test run we had to continuously change program to remove bugs.

Hitachi, the vendor of electric system for No.4 CAL was very eager to use new "Mika System" in No.4 CAL from their marketing needs and decided to do test run during day time by fixing machine code program by hand and change the flow diagram according to the result of test during the night. It cost Hitachi by increasing the number of engineers. In addition to it, the poor communication inside Hitachi caused large confusion in test run. The night shift engineers tried to fix the test run problem from just reading memo which was written by day shift engineers but they could not understand well and they could not fix the problem or introduced another problems in
the program. We had frustration every morning to find that the machine which became to move last night stopped to move again.

*The debug information was sticky to the software engineer in the day shift and it was difficult to transfer it to the night shift engineer who was supposed to apply it to the original software.*

<table>
<thead>
<tr>
<th>Type of problem</th>
<th>E-1. Transfer Method</th>
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<tbody>
<tr>
<td>Solution</td>
<td>Face to face communication</td>
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</tbody>
</table>

4E-2 In the test run we used transceiver or intercom to communicate from machine side to the electric room where Hitachi's software engineers were debugging. This communication was extremely difficult because we had different engineering background, we were geographically separated and we communicated through verbal communication only. (We couldn't draw picture, we couldn't point the machine.) Whenever we found difficulty to make the software engineer understand the problem, we asked him to come to the machine side and showed him the situation and explained it to him. It was the fastest way to do the job.

*If the data was sticky because of the insufficient transfer channel, the best way to transfer is to bring people to the source of the data. Seeing is believing.*

<table>
<thead>
<tr>
<th>Type of problem</th>
<th>E-1 Inadequate transfer method and D-1 Knowledge Compatibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solution</td>
<td>Machine side communication and Demonstration</td>
</tr>
</tbody>
</table>
4E-3 Though electric engineers knew that electric maker (Hitachi) failed to keep the shipment date of motors in No.3 CAL project, they failed to control the maker again and caused a significant delay in installation schedule in No.4 CAL project.

In No.3 CAL project, we could manage to meet the final dead line and then they might not have taken the problem seriously. In addition to it, the know-how of project management tends to be seen lower level skills than theoretical engineering job. But in reality, the success or failure of the project depends on accumulation of such "low level" know-hows because if we fail to leave enough time for test run, the line have to start operation with many bugs and it will deteriorate the performance of the line seriously.

*If the person does not have an intention to learn, he cannot learn from experience.*

<table>
<thead>
<tr>
<th>Type of problem</th>
<th>C-9. Incentive to learn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solution</td>
<td>Failed to learn from the lesson</td>
</tr>
</tbody>
</table>

**Delivery Section**

4D-1 The operators on No.4 CAL project found that the edge of the coil of No.3 CAL was not beautifully aligned but it was a very important quality item for the steel sheet for tin plate. Mr. Narumi thought the distance between reel and the last roller before the reel was the key factor to determine the shape of the edge of the coil. Then we tried to minimize this distance in the design of No.4 CAL.

Though the causal relation was not clear but we could try to do as much as possible to prevent the problem.
We could know the existence of the problem from No.3 CAL. Once we know the problem, we could make some assumption and try to solve the problem.

<table>
<thead>
<tr>
<th>Type of problem(1) [Problem Identification]:</th>
<th>B-1. Complex phenomena</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solution (1):</td>
<td>Learn from other line's experience</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type of problem(2) [Problem Solving]:</th>
<th>A-2. Tacit knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solution (2):</td>
<td>Expert's intuition</td>
</tr>
</tbody>
</table>

4D-2 There were two dominant designs to treat scrap of side trimmer. (Side trimmer was a machine to trim the edge of the strip and to make the coil width as the specification. From this machine approximately from one quarter to a half inch width's strip was generated as a scrap.) One was a scrap press and the other was a scrap baller. When we built No.3 CAL, we knew that scrap press of TPL (existing line) often causes trouble and we decided to adopt scrap baller. But scrap baller had a difficulty to operate automatically. When we built No.4 CAL, we knew that the fundamental problem of TPL's scrap press had been solved by maintenance section. Then we decided to adopt scrap press.

Both Mr. Nakamura and Mr. Shiota knew the fact that the problem of scrap press in TPL was solved. I think it was because that Mr. Nakamura was a manager of maintenance section before he was assigned to this project and Mr. Shiota was one of the members of the initial construction of TPL, then he might be consulted by the maintenance engineer before he modified it.
The information of the existing line should always be updated. If we use the old information, it may mislead us.

<table>
<thead>
<tr>
<th>Type of problem</th>
<th>I-1. Update of information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solution</td>
<td>Get information form personal network.</td>
</tr>
</tbody>
</table>

4D-3 In No.3 CAL test run, we experienced that after we started to use oiler (the machine to spray oil on the surface of steel plate to prevent stain), the strip tended to slip after shear cut. It caused the measuring error of the strip position and the trouble to separate the top of the next coil from the scraps.

In No.4 CAL design, we (mechanical engineers and electronics engineers of Kawasaki Steel) decided to put additional set of pinch rolls and measuring rolls to improve the accuracy of the gate switching. This decision was announced to both machine maker and electronics control vendor. But electronics vendor's engineers did not used the sensor on measuring rolls for shear cut control on their own decision. The reason was that electronics control vendor used subcontractor for the shear control and both of them wanted to have separate sensor for their use. The electronics vendor's engineer decided to use measuring rolls' sensor for shear control, pinch rolls' sensor for strip positioning control. But our original intention was to use measuring rolls' sensor (which can measure more accurately) for strip positioning control to improve the accuracy of gate switching.

Though we knew the problem and installed measuring rolls, electronics vendor's engineer made a decision from different point of view and we could not utilize the No.3 CAL experience.
Even if we could unstick the information and could transfer into machine design, we failed to enforce it.

<table>
<thead>
<tr>
<th>Type of problem</th>
<th>B-2 Organizational complexity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solution</td>
<td>Failed. (Strong control and coordination was necessary)</td>
</tr>
</tbody>
</table>

General comment

4G-1 The major difference between No.3 CAL and No. 4CAL project was that in No. 3 CAL case, manufacturing sections' manager (Mr. Kairara) and engineer (Mr. Mega) came from Mizushima Works and knew the (hidden) problems of Mizushima No.1CAL, however in No.4 CAL project, approximately half of the engineers came from No.3CAL project and knew its problems very well.

For example, we knew that No.3 CAL's structure had vibration problem caused by the sharing machine and had to reinforce it during test run. No.4 CAL used concrete base for that machine to avoid same problem.

What kind of sticky information we can get easily is determined by what kind of people we can transfer.

<table>
<thead>
<tr>
<th>Type of problem</th>
<th>C-2. Filter of sender: Reluctance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solution</td>
<td>Assign former project member to new project</td>
</tr>
</tbody>
</table>

4G-2 Makers' engineers are talented to do accurate design work, however sometimes make big mistakes in the
assumption level. We always try to check their assumptions, rather than detail design. (There is no time and no capability to check every details.) But in these days, sometimes they make mistake in design. Mr. Narumi said that in old days, there were good checking system in the maker. Many managers checked the mistakes before final design sent to us. But in these days, they reduced the number of designers and managers do not check at all. They just sign. They should be shamed that many careless mistakes are found by customers.

This change made the check more difficult because the drawing which was not checked by anybody other than the designer was not easy to read. In old days, during the drawing was checked by many people, the vague description was changed and additional section sight was drawn. Then the drawing became easy to read. The other problem was that the person who drew it couldn't find mistake as well as the other person because he knew what was written on the drawing and he never actually saw it carefully and failed to find the fact that it was written in different way from what he intended. Then the quality of the drawing went down and it contained many mistakes, which made it more difficult for us to read.

*In these days, they try to increase the productivity of the engineer and reduced the number of people who check them. This caused that sticky data becomes much more sticky to one person who designed it and making the check more difficult.*

<table>
<thead>
<tr>
<th>Type of problem</th>
<th>Solution</th>
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</thead>
<tbody>
<tr>
<td>C-8. Sender's incentive to make the information easy to understand and C-5. Filter of the receiver: Strong preconception</td>
<td>Check the drawing other than the designer.</td>
</tr>
</tbody>
</table>
4G-3 When we tried to avoid the same problems of existing line in the new design and if we didn’t know the theoretical cause of the problem, we had to guess and took risk to try to do something. In such situation, operators and manufacturing engineers often provided us good information and assumption of causal relation but we couldn’t rely on their suggestions because sometimes their assumptions were superstitious and often their solution was just try to put some equipment and to remove it later if it did not work. Such approach caused cost up and was harmful because it consumed the space and effort to be devoted to more useful equipment.

Then we became very skeptical about what they said and tried to be careful to find the true meaning of their suggestions. But the most difficult thing was to pick up a very important piece of information from the many pieces of superstitious information.

**Some information is superstitious information.**

*Superstitious information reduce the credibility of the other information from the same source. (It increase the stickiness.)*

<table>
<thead>
<tr>
<th>Type of problem:</th>
<th>C-10. Credibility of the sender</th>
</tr>
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<tbody>
<tr>
<td>Solution:</td>
<td>Sender: increase the quality of the information.</td>
</tr>
<tr>
<td></td>
<td>Receiver: remove prejudice.</td>
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</tbody>
</table>

4G-4 Generally speaking, in our way of equipment purchasing, the detail specifications had not decided at the contract day. After we chose the maker, we started to discuss detail of line specifications and changed them whenever it was necessary. The reason why we did in this way was that it was difficult to fix detail specification without starting design work. If we tried to avoid
design change and to contract with detail specification, we had to do engineering work before we could contract, but it would have taken longer to finish the whole construction period. Our way was best to reduce the total construction period by avoiding preliminary engineering work.

When we constructed No.3 CAL the economy was recession and it gave us bargaining power, therefore we did not bothered by the cost increase caused by design change. However, when we constructed No.4 CAL, the economy was at the peak and makers were very aggressive to make larger profit and always required us to pay extra money for design change.

It shows that our way was sometimes good and sometimes but in the construction cost point of view. But it enabled us to reduce the project period, because we could start to talk with the maker just after our concept design and budget was approved.

Some data is available only after some degree of engineering. Then it will take too long if we try to contract after every information become available.

<table>
<thead>
<tr>
<th>Type of problem:</th>
<th>G-3. Can't transfer information up front.</th>
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<tbody>
<tr>
<td>Solution:</td>
<td>Early contact with maker.</td>
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</table>

4G-5 Mr. Narumi was a very experienced mechanical engineer and could find structural weakness without calculation. Young engineers could not imitate it. They had to calculate or even use FEM program to get the same answer.

It may be one of the most difficult sticky information (know-how) to transfer.
**4G-6** Because of the short construction period, we had to start civil work before we finished the design of each machines or even final layout in both No.3 and No.4 CAL projects. In such situation, we had to decide rough shape of foundation and start to dig the ground and during that time we decided basic load and civil engineers design foundation. Many jobs were done simultaneously and everything was based on anticipation.

Such kind of job can only be handled by experienced engineers because the basic requirement drawings sent from machine makers often included fatal mistakes because it also based on anticipation. Mr. Nemoto (in No.3 CAL) and Mr. Narumi (in No.4 CAL) could find these mistakes just look at the foundation drawing without machine drawing and checked makers' designers and let them amend the design.

*This is also one of the sticky data which belongs to experienced engineers.*

**4G-7a** Mr. Narumi and I often talked on the way home that in such construction, we had to find the crucial problems efficiently and focus to attack only important one because if we did not select the problems, there were too much problems to solve. To do this we had to widely open our eyes and check the project in the wider point
of view and to judge which problems were important. Narrow
viewers tended to focus on trivial problems and failed to find much
fundamental and crucial problems. Mr. Ida said we could neglect
small problems at the design stage because they could be fixed at
the test run but we couldn't leave fundamental problem because it
could be fatal. (Actually it was a good strategy to leave less
important problems, because it was easier to identify and solve
problems later when many related information became available.)

*When we think about the stickiness of the data in construction
project, we have to think about the time constraint of the project. If
we could not solve all problems, we should not spend time to get
sticky data to solve less important problems.*

<table>
<thead>
<tr>
<th>Type of problem</th>
<th>Solution</th>
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<tbody>
<tr>
<td>F-1. Buried information and</td>
<td></td>
</tr>
<tr>
<td>G-3. Can't transfer information up front.</td>
<td>Select important problems. Leave less important problems until it becomes easier.</td>
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</table>

**4G-7b** During the project, we were too busy to solve all
problems. Every time we had to choose some problems to neglect, we
tried to think whether they could be solved later with minor
changes, which did not require too much money or too long time to complete.

*We select information to use according to the value of
information when we overflow. The value of the information is
judged by the receiver.*
4G-7c My favorite story to talk with Mr. Narumi was the fallacy of perfectionist. The person who tries to get 100 points in the examination often ends up with 70 points because he can't abandon any problems to get 100 points and spend too much time to solve very difficult problem which has only 5 points, then he has no time to solve other easier problems. On the other hand, the person who try to pass the examination starts to solve from easiest problems to the most difficult problem. Fist of all he can secure to pass the examination and then he can increase the score incrementally and at last he finds that he has solved almost all problems and get 95 points. (and sometimes get 100 points.) We liked this story very much and often talked each other about the nature of the project work.

*How to judge the relative importance of the problems? It might require other kind of sticky information or skill.*

4G-8 Mitsubishi Heavy Industry (MHI) decided to reduce construction cost and construction time. They sent their chief
designer of this project to the construction site and kept him staying there during the installation and test run.

By staying at the construction site, he could increase the communication with the installation people and user (Kawasaki Steel people), then he could increase the amount of sticky data to make decision. He could reduce the misunderstanding of the problem. He could get some practical advice from the installation experts. He could get the quick response from the customer and sometimes get compromise from customer to use alternative solution, because we (customer) could understand whole picture of the problem: problem itself, constraint of schedule, problem related to installation, cost and time to manufacture related parts, etc.

It was useful for Mr. Fukada to move to the "locus" of sticky data.

<table>
<thead>
<tr>
<th>Type of problem</th>
<th>E-2. Geographical separation</th>
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<tbody>
<tr>
<td>Solution</td>
<td>Move to the construction site.</td>
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</tbody>
</table>

4G-9 In Kawasaki, a construction project had been thought to be the best chance to educate young engineers, because they learn seriously and they were exposed to good chances to learn from many experts who gather in the projects.

The problem is there are not so many big projects to educate all new engineers.

On the job training is very powerful to educate young engineers. Is it possible to transfer same quality of sticky data in other way?
Type of problem: C-9. Incentive of receiver
Solution: On the Job Training.

4G-10 Generally speaking, know-how of the construction or improvement is sticky to the person who developed it and sometimes the designer himself forget it later. On the other hand, the know-how is fixed in the machine itself.

To mobilize this information, it is necessary to update the drawing but it requires special effort to keep the drawing updated whenever modification is done. If the drawing is not updated, nobody rely on it because it is dangerous to imitate old (and wrong) design. When I was assigned to the equipment department, senior engineers taught me, "Check the real machine. Don't trust the drawing."

But even drawing is updated perfectly there is another problem. When we transfer it to the other plant, it is necessary to imitate the design perfectly because if we change it, it can cause problem. However, there is no identical line exist, then we have to modify the original design without knowing the real underlining reason of the design. It tends to cause serious troubles.

It is necessary to understand the fundamental reason of the original design. To do this, it might be useful to have comments of the designer in the drawing. (It might be good to have electric filing system which can handle both drawing and technical information as a related database.)

Design information is left in the factory in two ways. One is as a sticky data to the person who designed it, but it diminishes with time. The other is as a sticky data to the machine, but it is difficult to decode (or understand), therefore it is not very useful for the next
generation people who want to apply it to other plant or modify the machine.

Some people may argue it can be solved to write report or documentation properly. But these information are not usable if they are buried by thousands of pages of documents. How to keep the information in a usable form is most important problem.

<table>
<thead>
<tr>
<th>Type of problem</th>
<th>Solution</th>
</tr>
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<tbody>
<tr>
<td>I-1. Update of the information</td>
<td>No good way.</td>
</tr>
</tbody>
</table>

4G-11 There were many standards and specifications regarding to the products. For example, we had a contract to put red paper in the coil to indicate the place where the welding point was. Before No.4 CAL, such paper was put by hand but we had to develop automatic machine to handle this requirement in No.4 CAL. Any way, there were many such requirements regarding products, and they were written in standards but if we didn't have the manufacturing engineer who knew these rules well, we had to spend long time to check these rules and might have made mistakes by ignorance.

Even if there is written document, it is much more efficient to get information from person who know it very well. Because related information often is buried within many irrelevant informations.

<table>
<thead>
<tr>
<th>Type of problem</th>
<th>Solution</th>
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<tbody>
<tr>
<td>A-1. Systemic knowledge</td>
<td>Expert involvement</td>
</tr>
</tbody>
</table>

4G-12 We learned operators' way of doing job from operator members of our project. For example they said they always check the edge of the coil before they put it into the line because if
the coil had a crack, it would break in the line and cause a big trouble. After we learned these things, we tried to design the layout of machines to facilitate or at least not to disturb these activities.

Experienced operators had many knowledge of important phenomena. For example, after the coil was divided and finished winding at the tension reel at delivery section, the end of the coil often slipped and fell down from the top of the coil and cause trouble and he said it was very important to stop the reel within certain degree from the vertical line. Then we took it into our specification of the control logic to Hitachi.

Another example was that they knew the behavior of the scrap from trimming machine well and had experience of improving the guide of the scrap of existing machine. They suggested the shape of the guide plate and we adopted it.

*Operators had observed many phenomena from their experience. They were one of the important source of information.*

<table>
<thead>
<tr>
<th>Type of problem</th>
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<tr>
<td>A-1. Systemic knowledge and Tacit knowledge</td>
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<table>
<thead>
<tr>
<th>Solution</th>
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<tbody>
<tr>
<td>Expert involvement</td>
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</table>

4G-13 In No.3 CAL we failed to use the special type of conveyer for the delivery section while it was used in entry section because of the lack of the knowledge. In No.4 CAL, I remembered the failure very well and informed it to Mr. Shiota (one of the managers of our project who oversaw the design of delivery section) and also to the chief engineer of the maker but again we failed to use that kind of conveyer because I told it at the very beginning stage of the project and they forgot the information during the design. In addition
to it, they used the No.3 CAL's drawings as reference and copied No.3 CAL's bad feature.

In this case the first information was lost and the second wrong information was adopted because the first information had a strong impression to me but it was just one of many information for them. On the contrary, the second (wrong) information was given in the final drawing of No.3 CAL and they thought it was credible. I think they often refereed to it during their design job. In such situation, they might not imagined that there were some points to be improved.

*The way of the information transfer determined the life of the information.*

| Type of problem          | F-1. Buried information: Too much information and  
|                         | F-2. Lost information: too long to keep  
| Solution                | Failed. (Transfer the information at right timing.)

**4G-14** In No.4 CAL, operators gave us too much informations for us to handle. It overflowed us. But not all information was important data.

*If there too much less important informations to be handled, important information may be buried between them and foreseen.*

| Type of problem          | F-1. Buried information: too much information  
|                         | C-10. Credibility of the sender  

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Appendix  Descriptive Data

| Solution: | Failed (Increase the receiver capacity or decrease the number of the less important information to be sent.) |

4G - 15 When we designed No.4 CAL, Mr. Matsumoto, who was an expert of lubrication technology in maintenance section, created and offered us the standard of selection of flexible tube for hydraulic system. We could just send copies of the standard to machine makers and we could transfer the maintenance know-how into No.4 CAL.

When we constructed No.3 CAL, there were many types of flexible tube used in existing line and we had to investigate the performance of the different types of tubes to select.

The reason of the existence of different types of tubes was partly because Kawasaki people used special type of tubes which was not industrial standard historically, and at sometime someone think it was not economical and introduced industrial standard types of tubes.

*If some expert investigates sticky informations and standardizes it, it increase the efficiency of the project team.*

| Type of problem: | A-1 Systemic knowledge |
| Solution:       | Standard was written by an expert. |

4G - 16 During the test run, one hydraulic valve broke. When we opened the casing, we found that the inside of the valve had corroded. Then someone remembered that he saw this valve stand was flooded in heavy rain during the installation. This information
was not reported because he did not recognize the significance of the information. (He thought it did not matter because the specification of the valves were water proof.) After this trouble, we checked all valve stands which had possibility to be flooded according to his memory and found a few valves which had corrosion and replaced them.

*That information was sticky because the person who saw it did not recognize the importance of it. He might not imagined it would cause trouble later.*

<table>
<thead>
<tr>
<th>Type of problem :</th>
<th>C-1. Filter of the sender:</th>
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<tbody>
<tr>
<td></td>
<td>misunderstood relevance.</td>
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</table>

| Solution         | Machine showed it.        |

**4G-19** During the No.4 CAL projects, No.4 CAL operators were sent to No.3 CAL for training for a few weeks. Through this experience, operators found that No.3 CAL's design of CRT operation had some problems. For example, they found that when they try to do the roll change in mill section, they had to go and back in two CRT pictures. The source of the problem was that No.3 CAL's CRT design was based on the function. Therefore, there were separate screens for the control of the roll changer and for the control of the mill. However, during the flow of the roll change job, it was necessary to check the mill parameters. To prevent this problem, in the No.4 CAL design, the mill parameter informations were included in the roll changing screen.

*No.4 CAL could use the information of No.3 CAL project to improve the design. In this case, information was brought by the operators who were sent to No.3 CAL as trainees for a few weeks.*
Type of problem: B-1. Complex phenomena
Solution: Learn from similar line's experience

4G-18 When we designed utility pipeline for No.4 CAL, we had to check our company's rule for utility design which was decided by Utility Group in energy department. In that time I asked Mr. Nakajima one of our project member who belonged to Energy Technology Section of energy department to check the rule. Energy Technology Section and Utility Group were totally different sections while both of them belonged to energy department. However, because I did not have any acquaintance in the Utility Group, I thought it was easier to ask Mr. Nakajima to check it. He was very corporative and gave me an answer within the day.

It is much faster to get the information through personal network than through official channel.

Type of problem: C-11. Psychological distance
Solution: Use the personal network

4G-19 In No.4 CAL projects, the operators (not engineers) wrote many comments on the check back drawings. While checking the drawing, they remember many troubles in the past experience and they wrote them down on the drawing. These comments were very helpful for me to understand the operation.

I wanted to get same kind of information from the maintenance people, but we had only four maintenance people in our project and they were very busy to help the installation. Then I had to give up and had to use my imagination to improve the maintainability.
The check back drawing worked as a prototype. If we can improve the design during this stage, it will shorten the start up period and will increased the total performance of the line.

<table>
<thead>
<tr>
<th>Type of problem</th>
<th>B-1. Complex phenomena</th>
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<tbody>
<tr>
<td>Solution</td>
<td>Use similar line's experience</td>
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</tbody>
</table>

4G-20  In the early stage of planning of No.4 CAL, we asked manufacturing engineers whether inspection line was necessary for No.4 CAL or not. Then he answered that it was not necessary. However, after our budget was fixed, he found it was necessary. It caused us trouble.

The reason was that he had been assigned to the TPL (one of the existing line), which did not have a inspection line. This experience made him believe that inspection line was not necessary for No.4 CAL. However, in the existing line whenever such kind of inspection was necessary they brought the coil to another line and borrowed the equipment. Such kind of arrangement was difficult for No.4 CAL. (This problem was found by operators who were assigned to No.4 CAL project. They knew it because they themselves did that work.) Then we had to add this equipment.

Even manufacturing engineer make a fundamental mistake about what kind of inspection was necessary.

<table>
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<th>Type of problem</th>
<th>C-5. Filter of the receiver: Strong preconception</th>
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<tbody>
<tr>
<td>Solution</td>
<td>Found by operators</td>
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<tr>
<td>Case No.</td>
<td>Short description of problem</td>
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<tr>
<td>---------</td>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>3F-1</td>
<td>To write purchase specification of burner</td>
</tr>
<tr>
<td>3F-2</td>
<td>To write purchase specification of coating</td>
</tr>
<tr>
<td>3F-3</td>
<td>Nobody listened to the vendor who had caused trouble in the past.</td>
</tr>
<tr>
<td>3F-4</td>
<td>Bearing trouble information was not transferred.</td>
</tr>
<tr>
<td>3F-5</td>
<td>Problem of the other line (furnace capacity)</td>
</tr>
<tr>
<td>3F-6</td>
<td>Problem of the other line (burner trouble)</td>
</tr>
<tr>
<td>3F-7</td>
<td>Bad layout of the staircase in existing line.</td>
</tr>
<tr>
<td>3F-8</td>
<td>Maintainability</td>
</tr>
<tr>
<td>3F-9</td>
<td>Roll profile</td>
</tr>
<tr>
<td>3F-10</td>
<td>Bad design of fan</td>
</tr>
<tr>
<td>Case No.</td>
<td>Short description of problem</td>
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<tr>
<td>3F-11</td>
<td>Check of the assumption of the design</td>
</tr>
<tr>
<td>(3F-12)</td>
<td>Control method dispute</td>
</tr>
<tr>
<td>3F-13</td>
<td>New insulation design</td>
</tr>
<tr>
<td>3F-14</td>
<td>Motor power design</td>
</tr>
<tr>
<td>3F-15</td>
<td>Leak test trouble</td>
</tr>
<tr>
<td>3F-16</td>
<td>New type burner</td>
</tr>
<tr>
<td>Case No.</td>
<td>Short description of problem</td>
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<tr>
<td>3M-1</td>
<td>Roll manufacturing process</td>
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<tr>
<td>3M-2</td>
<td>Spray pattern design</td>
</tr>
<tr>
<td>(3M-3)</td>
<td>Roll changer design</td>
</tr>
<tr>
<td>(3M-4)</td>
<td>Cylinder rod cover</td>
</tr>
<tr>
<td>3M-5</td>
<td>Roll changing experience</td>
</tr>
<tr>
<td>3M-6</td>
<td>Spray mist</td>
</tr>
<tr>
<td>[3G-1]</td>
<td>Maker's design information</td>
</tr>
<tr>
<td>Case No.</td>
<td>Short description of problem</td>
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<tr>
<td>[3G-2]</td>
<td>User's needs</td>
</tr>
<tr>
<td>3G-3</td>
<td>Design of CRT operation</td>
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<td>3G-4</td>
<td>Information transfer to the maintenance people</td>
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<tr>
<td>3G-5</td>
<td>Information for the improvement for the user</td>
</tr>
<tr>
<td>3G-6</td>
<td>Entrance &amp; Delivery section design</td>
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<tr>
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<td>Know how of machine tuning.</td>
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<td>Roll changer trouble.</td>
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<td>Drawings not checked by other than the designer</td>
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<td>Losing credibility by keep saying superstitious information.</td>
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<td>Contract maker with vague specification.</td>
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<td>Finding the structural weakness without calculation</td>
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<td>Problem selection</td>
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<td>4G-8</td>
<td>Engineer at construction site.</td>
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<td>Update of drawing.</td>
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<td>Overflow of receiver</td>
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<td>Flexible tube standard</td>
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<td>Utility pipeline specification.</td>
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<td>Operators comment on the drawing.</td>
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<td>4G-20</td>
<td>Inspection line</td>
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**Note:** Case No. with () indicate that the sticky problem was not solved therefore there is a solution which "should / could have solved" the problem in the solution column.

Case No. with [] indicate that the case was a general comment; for example it has the notion of "generally speaking......" or "such kind of problem often happened......" or "it was a rule of thumb for project work......". This distinction is important when we count the number of cases in some category because general comment can be a aggregation of several cases then it should have the higher significance.

When more than one type of problem was listed in one box, it means that it was difficult to decide which was the cause of the problem. In such case, counting of the case becomes fraction number.