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Quality Assurance System of Steel Pipe and Tubes at Kawasaki Steel Corporation

Mikio Niwa, Shigeki Takahara, Naomasa Murai, Yasutoshi Sujita

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Mikio Niwa  
Staff Assistant  
General Manager,  
Technical & Quality  
Control Sec., Tech-  
nology & Production  
Control Dept.,  
Chita Works



Shigeki Takahara  
Staff Manager,  
Technical & Quality  
Control Sec., Tech-  
nology & Production  
Control Dept.,  
Chita Works



Naomasa Murai  
Staff Manager,  
Pipe Control Sec.,  
Technical Control  
Dept., Chiba Works



Yasutoshi Sujita  
Staff Assistant  
Manager, Pipe Control  
Sec., Technical Con-  
trol Dept., Chiba  
Works

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ance system and other related systems at Kawasaki Steel, along with its functions, and discusses the company's efforts to ensure the confidence and understanding of its customers.

The basis of the quality assurance system at Kawasaki Steel lies in correctly understanding customer requirements and specifications and imparting the required quality to products by manufacturing them strictly to these specifications. In this connection, this paper describes, in particular, a computer-based information processing system, a management system for technical specifications and procedures, a tracking system for manufacturing conditions, control of measurement equipment, the management of training and qualification, and technical service activities.

## 1 Introduction

Kawasaki Steel has a history of about 40 years in the manufacture of steel pipe and tubes, which it has produced to date as an essential steel material for various fields of industry. In parallel with its incessant quality improvement activities, as well as improvement of and research into manufacturing techniques and equipment, the company has also established a pipe and tube quality assurance system which has gained an outstanding reputation with customers.

This paper describes the pipe and tube quality assur-

## 2 Basic Concept of Quality Assurance

The basic policy of quality assurance at Kawasaki Steel is to manufacture and supply products that meet the requirements of customers, and to win the full confidence of customers by consistently providing products of the required quality.

The company has established a quality assurance program to realize this policy, the concept of which is as follows:

- (1) Accurate information transmission in all activities from inquiry to product shipment
- (2) Imparting the required quality to products by standardization in the raw material and manufacturing

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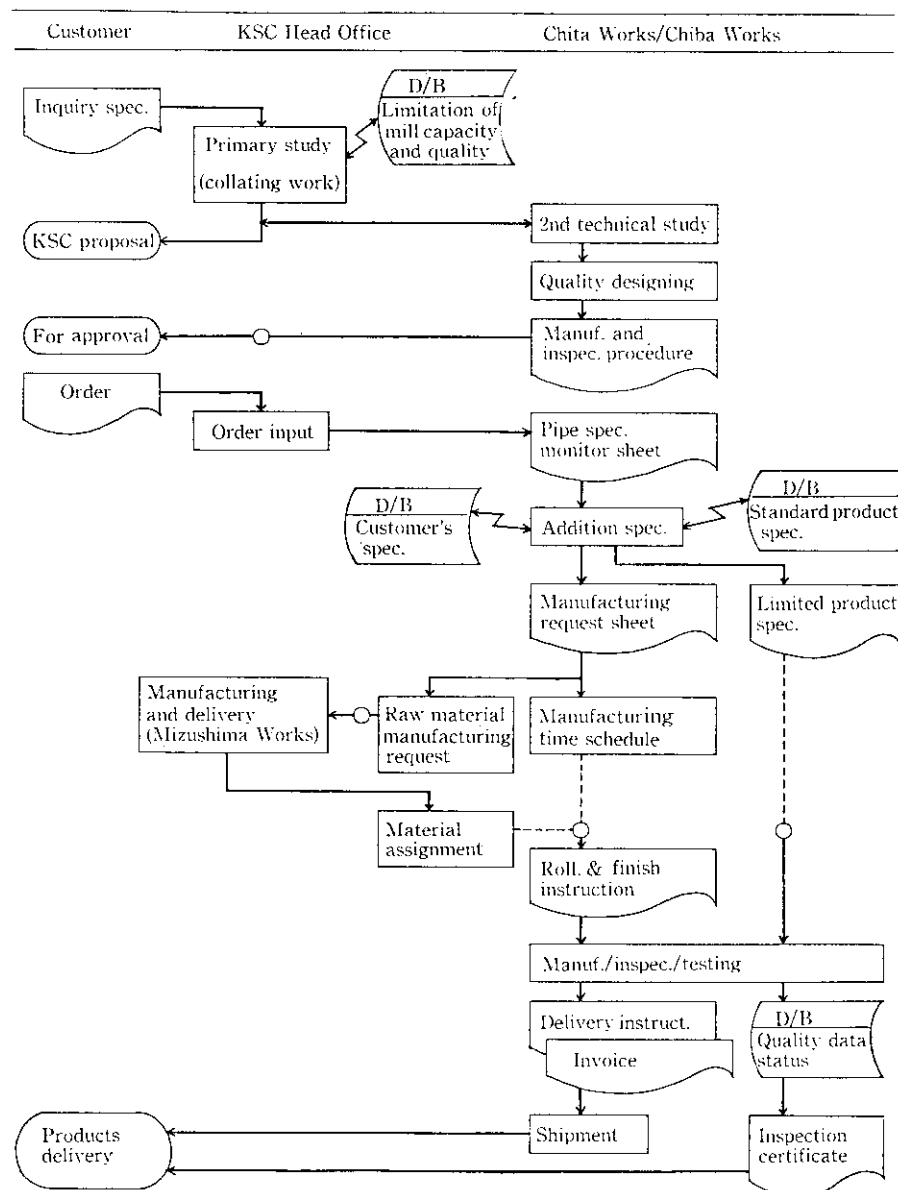
- (3) Quality assurance by inspection of products
- (4) Maintaining and improving equipment and techniques necessary to achieve the required quality
- (5) To audit the production and inspection processes for compliance with the program

Customers naturally demand quality assurance from the standpoint of product reliability; material suppliers must meet this requirements as one of their basic responsibilities as a business. In recent years, the service environment for steel pipe and tubes has become increasingly severe and diverse, and there has been a

### 3 System of Information Transmission from Inquiry to Product Shipment

Computer-based information systems have been fully established by constructing a dedicated high-speed digital network between the head office and all the works and installing optical-cable LANs within each works.<sup>1)</sup>

An outline of information transmission from inquiry to product shipment is given in Fig. 1.



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### 3.1 Preliminary Study of Inquiry

#### 3.1.1 Computer system for preliminary study

A computerized yes-or-no check system is used to obtain an immediate and correct judgment on the possibility of producing products of the quality required by the customer, based on an examination of the customer's quality specifications.

In the computer system for preliminary study, the specifications, dimensions, end uses, processing conditions, and quality specifications required by customers are input from terminals, and producibility is judged with the aid of the computer. At the same time, information on the quality specifications finalized during the preliminary study is stored in computer files; the contents of this information are retrieved when orders are input, and new specifications are added automatically.

The advantages of the computer system for preliminary study include rapid answers, elimination of human fuzziness and error, accurate information transmission through linkage to the specification addition system,

and various information analysis functions. It thus is essential to the company's quality assurance system.

An outline of the computer system flow is given in Fig. 2.

#### 3.1.2 Standardization of process capabilities

The computer judgment on producibility is made by checking the required specifications input from terminals against a standard data base which represents process capabilities and was incorporated on a great deal of technical data used in examining orders by persons in charge of quality design. The number of quality specification items for pipe and tubes is enormous, and the data base is composed of approximately 120 standard constants files.

### 3.2 Order Specification Addition and Manufacturing Instructions

#### 3.2.1 Automatic addition by computer master table of product specifications and order dressing by persons in charge

When an order is input, a pipe specification monitor sheet of the type shown in Fig. 1 is output at the

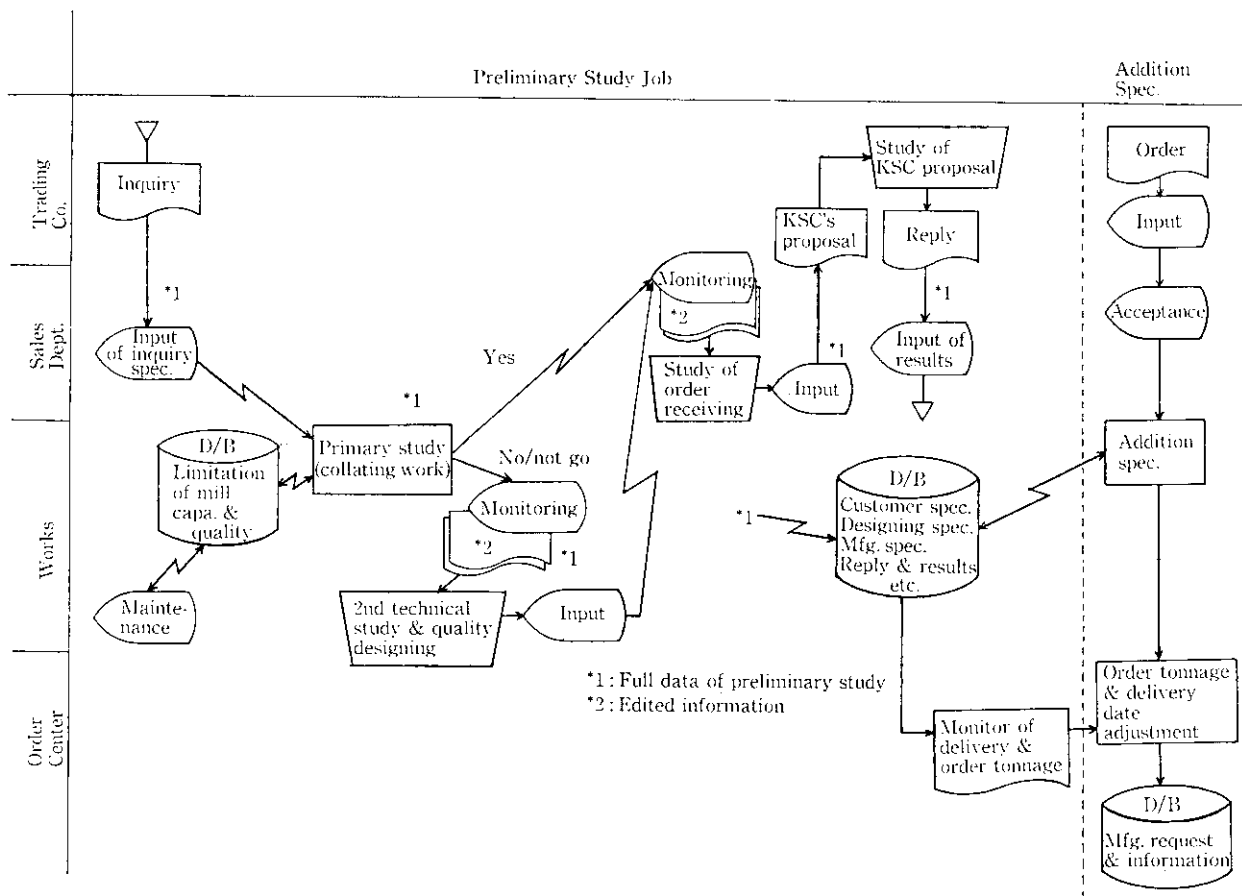


Fig. 2 Schematic diagram of preliminary study job

appropriate station in the works. Customers' specifications finalized in accordance with agreed specifications or prepared for each order are added to orders by persons in charge of products as limited product specifications, in a process called order dressing. The limited product specifications thus dressed are registered in a computer master table of customer's specifications, and the same information is automatically added to repeat orders. Quality characteristics and manufacturing specifications for which there are no special requirements are added from a computer master table of standard product specifications, and all specifications for each order are finalized.

This system ensures correct transmission of order specifications, which in turn form the basis of manufacturing instructions.

### **3.2.2 Issue of limited product specification sheet**

When specification transmission by computer is impossible because of the complexity or special characteristics of the specification, a limited product specification sheet is issued for the individual order. In this case, the identifying number of the limited product specification sheet is incorporated into the order specification and can be output on the manufacturing instruction sheet or on the CRT display, enabling line operators to conduct operation by appropriate reference to the relevant specifications.

### **3.2.3 Orders for raw materials**

When the limited product specifications described in 3.2.1 are dressed, an order monitor sheet including the product specifications is simultaneously output in the manufacturing request sheet shown in Fig. 1, and the necessary raw material order specifications are shown. Orders for raw materials are placed with the raw material processing plants through the Head Office Order Management Dept.

In the raw material processing plants, almost the same order processing procedures as those for pipe and tubes are carried out, and the required quality is imparted to the raw materials in accordance with the raw material order specifications.

### **3.2.4 Manufacturing instructions**

Manufacturing instructions are output by a computer at the appropriate time based on manufacturing schedules. Manufacturing instructions include raw material processing, rolling, finishing, and machining, and material testing. The contents of manufacturing instructions are transmitted by way of CRT display or in the form of instruction sheets to the proper posts based on order specifications, and the required quality is imparted to products in accordance with the manufacturing instructions.

## **3.3 Operation Results and Actual Quality**

### **3.3.1 Control of manufacturing, examination data, and process status**

Operation results from each process are gathered in a computer by input from various sensors or terminals installed at the production lines. If results differ from instructions, comments are made to that effect so that appropriate action to ensure that correct information can be taken.

Production results indicating the status of manufacturing lots can be accessed at any time from system terminals. The progress of the process can be monitored and, at the same time, the details of in-process products can be determined.

Various records of manufacturing and examination are entered in predetermined formats, reviewed by designated examiners, and retained in records for a fixed period of time.

### **3.3.2 Data logging by computer**

The results of various quality-related tests, such as nondestructive examination, dimensional checks, thread examination, visual examination, and weight measurement, and of material tests are input directly from various automatic apparatus or from terminals (computer work stations). Material test results are judged by computer.

Further, manufacturing conditions in pipe-making are logged by the process computer for each piece of pipe. This logging data along with the various records described in 3.3.1 is utilized in the analysis of manufacturing technology, improvement of manufacturing conditions, and quality control.

## **3.4 Material Certification**

Inspection certificates are prepared by a computer after it is ascertained that the results of product examination and testing meet requirements.

The manufacturer's serial numbers entered in the inspection certificate make it possible to match the records of material and pipe manufacturing, examination and testing of materials, and the pipe or tube itself. These principal records are registered in a quality status file and are maintained for reference as necessary.

## **4 Standardization and Standard Control**

### **4.1 System of Standards**

To minimize quality assurance costs, and maintain and improve quality levels, Kawasaki Steel has established company-wide standards for quality management in connection with items of major concern from the viewpoint of quality control.

To achieve the aims of quality control, these quality

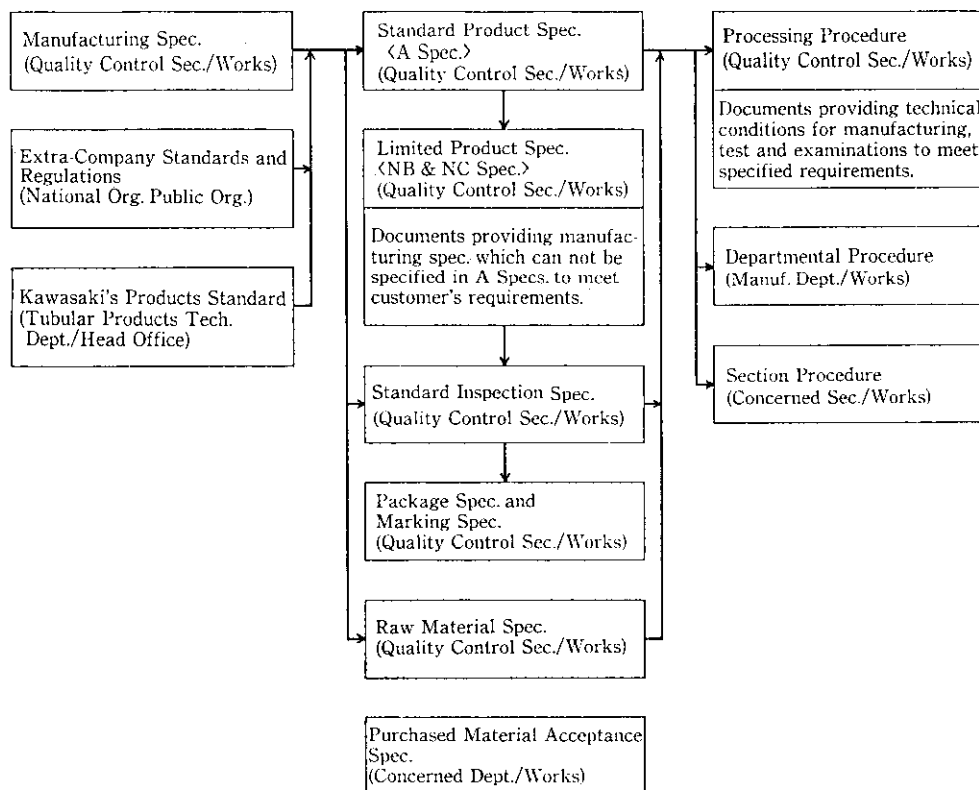


Fig. 3 Kind of specification and procedure and their relation

management standards specify in detail the establishment and maintenance of company Standards and Procedures of an appropriate level, types of Standards and Procedures and their definitions, and matters related to their planning, decision making, distribution, and record keeping.

The types of Standards and Procedures in the manufacture of pipe and tubes and their relationship are shown in Fig. 3.

## 4.2 Standard Management and Maintenance System

### 4.2.1 Ideal state of standard management and maintenance

The works procedures handled by the Technical and Quality Control Section stipulate the specifications of products, quality of products of certified levels, and specified items concerning important technical conditions in manufacturing and examination. They also provide the basis of information for managing the entirety of planning and production control.

To manage and maintain these Standards and Procedures, it is necessary to satisfy the following requirements:

(1) Products of certified quality levels must completely

conform to the relevant standards (JIS, API, ASTM, etc.).

- (2) Revision of the Standards and Procedures to conform to changes in the relevant standards must be easy, and revisions of the Standards and Procedures must be reflected in the whole of the pipe and tube production control system.
- (3) The contents of the Standards and Procedures must correspond perfectly to the contents of computers-recorded data.
- (4) It must be easy to understand the relationships among standards, and good coordination among standards must be maintained.
- (5) For new orders and related regulations, the maintenance of Standards and Procedures and of technical standards for computers must be easy.
- (6) Updated standard sheets must be provided promptly and accurately to related departments.

### 4.2.2 Outline of the system

The standard management and maintenance system conducts affairs related to the revision of Standards and Procedures in the computer system. As is apparent from the conceptual diagram shown in Fig. 4, the operator in the Technical and Quality Control Section establishes and revises Standards and Procedures at terminal

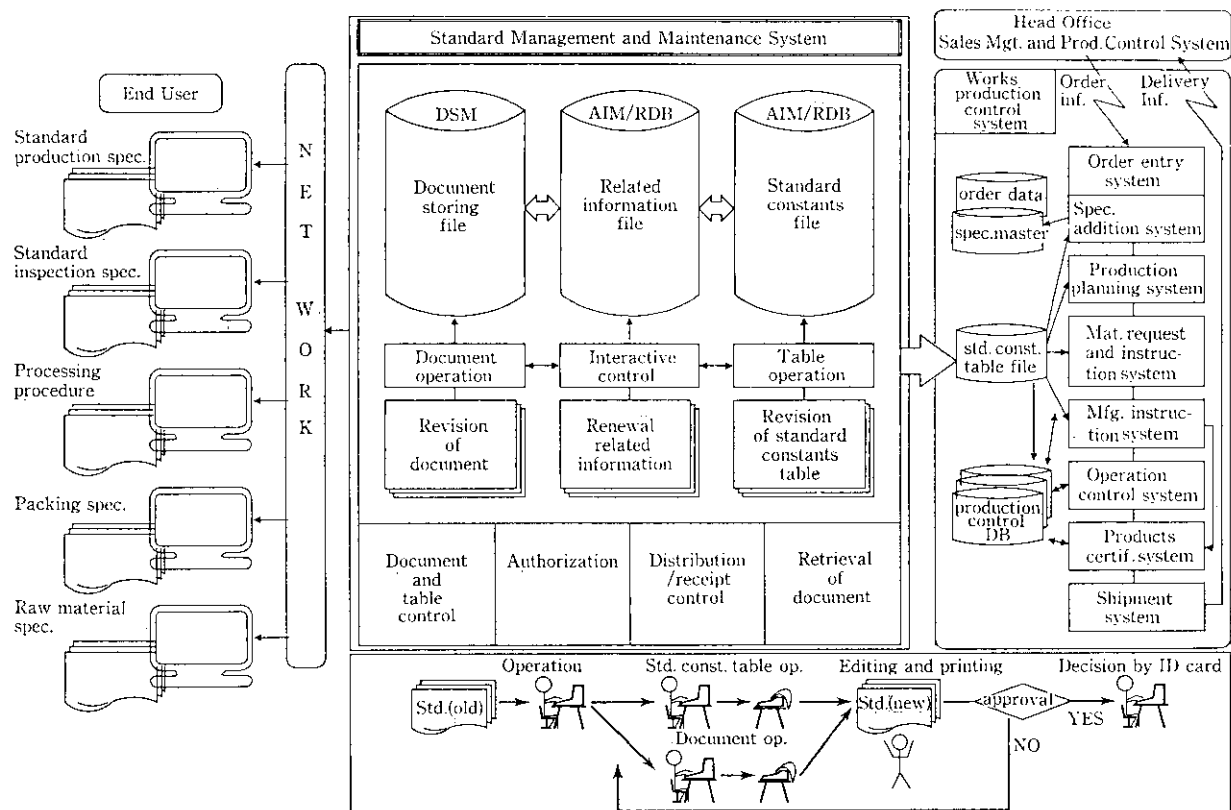


Fig. 4 Schematic of standard management and maintenance system

(CRTs). The information input is retained in the form of standard sheets (documents) and, at the same time, it is stored in a document storage file, standard constants file, and related information file which links the two. The standard constants file is transmitted to the appropriate pipe and tube production control systems for use. Documents in the document storage file are accessible at each office and site office in the works network through the related information file.

The standard management and maintenance system performs affairs related to the revision of standard sheets, including establishment, revision, approval, deletion, filing, mail, mail management, retrieval, reference, retrieval of related information, and output of control sheets.

#### 4.2.3 Features of the system

The most significant feature of this system is the unification of the standard sheets and the standard constants file (unified document and standard constants). "Standard sheets" here refers to handwritten or word processor documents in Japanese which are intended for human use, such as standard product specifications, processing procedures, and standard inspection specifications. The standard constants file is a data list for com-

puter use. Normally, the contents of the standard sheets are translated into a form which can be read by machine and registered in a computer. To unify the two was the most significant task in the establishment of this system. In other words, the unification of the standard sheets and the standard constants was a task aimed at ensuring the compatibility of the standard sheets and the computer standard constants by equating the results of the registering of standard constants and standard sheet preparation in the form of a standard constants list which fulfills the role of the standard sheets. This also reduces manpower requirements by eliminating duplicated work in the revision process.

#### 5 Identification Control and Traceability

One of the basic conditions of quality assurance is accessibility of records of production process for each product item delivered to the customer, and of the results of all tests and examinations carried out.

Kawasaki Steel has established a method of product identification covering the entire manufacturing process from the receiving of pipe materials to the final marking of products. At the same time, the company has also constructed a system for recording manufacturing and

examination data and controlling material test results, as described in 3.3. Data can be accessed at any time as required.<sup>2)</sup>

The identification number used in the manufacture of pipe and tubes is composed of the rolling number and the finishing number (manufacturing number), which is linked to the contract number. This identification number is related to materials, grade symbols, dimensions, roll chance, heat number, and other manufacturing conditions. Markings on products and manufacturing numbers entered on inspection certificates provide access to the manufacturing, examination, and test records of materials and products.

### 5.1 Lot Control in Small-Diameter Pipe and Tubes

In manufacturing processes for small-diameter pipe and tubes, such as heat treatment, nondestructive examination, galvanizing, and threading, working and examination suited to the intended application are conducted at each unit of equipment. Therefore, pipe and tubes between processes are bound in bundles by their identification number for handling. Products are controlled by bundle in the absence of special requirement.

Standards and Procedures and the manufacturing processes selected through consultation with customers are registered in the host computer. When the results of

each process are input, the material progresses to the next manufacturing step. Instructions are given for that process, and at the same time, travelers (in-process product cards) are output from a terminal at the site and attached to the product for identification.

### 5.2 Pipe Tracking System for UOE Pipe

The flow of materials at the UOE line includes pieces of differing sizes and specifications. However, even with pieces of the same dimensions, grades and customer's specifications differ, requiring particular care in giving correct manufacturing and examination instructions. Because such instructions must be given on a piece-by-piece basis, the company has established a complete piece-wise tracking system for the entire line from the start to the completion of pipemaking.<sup>3)</sup>

A process computer monitors the movement of pipe by dividing the entire mill area into about 180 blocks. The concept of the tracking system is shown in Fig. 5.

In making up orders for the actual pipe making process, a pipe number corresponding to a plate number is issued and tracking is conducted based on this pipe number.

Manufactured materials are identified by plate number markings in the processes up to forming, and in the succeeding processes by pipe numbers marked by robots at two points on the external surface of the pipe.

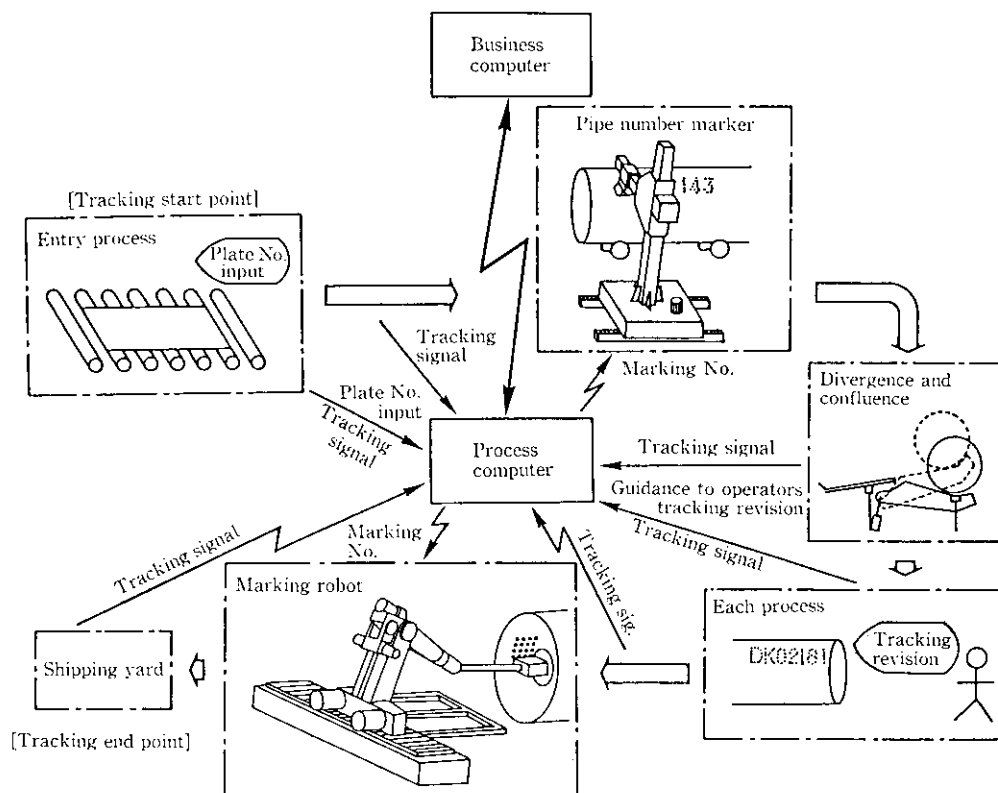


Fig. 5 Pipe tracking system



Tracking begins when a plate number is input from a terminal. When a plate for which no pipemaking instructions have been given is entered, or when a wrong plate number is entered, messages are displayed and the entry is rejected.

When a plate is sent to the next process, signals from sensors are fed to the process computer, allowing the computer to determine the current location of each piece.

This tracking information is displayed on CRTs at each process. By checking the markings on the actual material against the CRT information, the operator can verify the accuracy of tracking.

Automatic tracking covering the entire mill area makes it possible to synchronize operation instructions, the collection of results, and product acceptance with the delivery and discharge of pipe at each process.

### **5.3 Marking of Finished Products**

When products pass all examinations, specified marking items including the identification number are marked on the individual pieces as evidence of acceptance, in conformance with marking standards and product specifications.

## **6 Education, Training and Qualification Control**

Smooth and effective education ensures that Kawasaki Steel's employees possess the knowledge, techniques and skills, and mental attitudes, required of members of the company, Improving the company's human resources while at the same time enhancing its quality assurance activities.<sup>2)</sup>

### **6.1 System of Education and Training**

The company's education program is composed of the following four categories:

- (1) General Education  
General education is conducted by the Labor and Personnel Section. Its main purpose is to impart knowledge required in common by both the technical and general group. Areas covered include basic, administrative, and technical subjects.
- (2) Education and Training for Qualification  
This type of education is conducted to impart the requisite knowledge and techniques in operations where company rules or the regulations of outside bodies require special qualifications.
- (3) Departmental Education and Training  
Departmental education is also conducted in line with each department's needs for quality, technical, safety, and other types of knowledge and skill.
- (4) Education for Quality System Manual Knowledge  
Quality system education is conducted to ensure that quality assurance programs are properly carried out.

In addition, employees are encouraged to participate in technical and scientific programs outside the company and to make presentations and exchanges there.

### **6.2 System for Qualification and Certification**

Examination personnel, test personnel, and those who are engaged in special processes are qualified and certified in accordance with the following provisions and procedures of the company's qualification and certification system in addition to those of official societies:

- (1) Provisions for qualification and certification of NDE personnel by ASNT
- (2) Procedure for qualification, certification, and nomination of personnel involved in examination, testing, and special processes
- (3) Procedure for qualification and certification of auditors

## **7 Control of Testing and Measuring Equipment**

At Kawasaki Steel, the full-time staff conducts high-level control of highly-reliable, ultramodern testing and measurement equipment. Works-wide services, such as purchase, acceptance inspection, and the registry of equipment, guidance in operation and use, periodic inspection and calibration, and record control by EDPS (electronic data-processing system) are carried out, and control standards for this purpose have been established.

The following equipment is classified as measurement instrument's for purposes of quality assurance:

- (1) Instruments used in final judgments on product quality
- (2) Instruments used for measuring control items in the manufacturing process

### **7.1 Traceability to References Standards**

Fixed measuring equipment, examination and testing equipment installed at the site, and portable measuring equipment can be traced to the national standards through in-house practical standards and reference master standards. These reference standards are periodically inspected and certified by national or other official societies.

### **7.2 Identification of Calibration Condition**

The serial number of each testing and measurement equipment is registered and the authorized period of use is controlled. Each device carries a serial number and an available period label to ensure appropriate use within the stipulated period of service.

## **8 Nonconformance Control and Corrective Action**

In all departments where activities for preventing the

recurrence of nonconformance are conducted, quality and techniques are improved by taking measures against nonconformance and correcting nonconforming conditions when they occur.<sup>2)</sup>

Activities for the prevention, correction, and improvement of recurring nonconformities are conducted from the following two perspectives:

- (1) Activities mainly related to manufacturing techniques, such as quality improvement
- (2) Activities mainly related to quality systems, such as systems of operation and standardization

Further, procedures for the identification, isolation, and disposal of nonconforming products, including those for which claims have been made, have been established to prevent the shipment and mistaken use of nonconforming products.

## 9 Internal Audit System

The establishment and maintenance of an appropriate quality system are carried out by objectively diagnosing the conditions of the management and execution of quality control and quality assurance activities, and auditing the achieved quality.

Auditing teams are comprised of a lead auditor and members designated according to the type of audit.

The kinds of internal diagnosis and audits at Kawasaki Steel are as follows; they are carried out both periodically and at irregular intervals.

- (1) Pipe and tube quality control committee meetings
- (2) Internal audits
- (3) Audits by general superintendent
- (4) Company-wide QA survey
- (5) Audit of subcontractors and vendors

## 10 Handling, Storage, and Shipping

Finished products are handled on the basis of manufacturing numbers which are linked to contract numbers. The products are stored for each destination, and shipping instruction sheets in which shipping approval is confirmed in response to shipping requests are issued by the computer.

### 10.1 Pipe and Tube Material Distribution System "CARAVAN"

A total pipe and tube material distribution system called CARAVAN is used at Chita Works. In this system, pallets used exclusively for storage and handling and the under-cab type carrier are adopted, and the position and status of all materials from the end of manufacturing to shipment of the product are monitored in real time, with the computer supplying the most effective and optimum instructions.

Steel pipe and tubes stored on a pallet for each destination in the mill are transported on an under-cab type carrier, which is controlled by a carrier operation sys-

tem, and non-essential handling prior to shipment is eliminated.

In CARAVAN, the use of mobile radio terminal equipment permits control of pipe and tube material distribution in a wide range of operations, including storage and the shipping process.

### 10.2 Storage and Shipping of Large-Diameter Pipe

With large-diameter pipe, address control is applied on a piece-by-piece basis. When pipe is conveyed from the mill to the storage yard, information such as the yard number is entered in a computer, allowing positive identification of the storage location for shipping.

## 11 Quality Improvement and Technical Service

### 11.1 Research and Development

At Kawasaki Steel, the Iron & Steel Research Laboratories of the Technical Research Division are engaged in not only fundamental research, but also quality improvement directly linked to the manufacture and improvement of products and the development of manufacturing techniques.

The Research & Development Planning Decision Committee and Research & Development Committees in the individual works deliberate on research and development activities and the planning, coordination, and progress of work related to the commercialization of products resulting from such activities.

The R&D tasks of these committees include the development of new materials with improved quality and functions, the improvement and development of manufacturing techniques using model mills, joint research with customers and outside research institutes, and quality improvement and new product development to meet customer needs.

In the departments concerned at each works, quality design associated with actual orders and necessary plant experiments and trial production are conducted with the aim of supplying high-quality pipe and tubes and maintaining customer confidence.

### 11.2 Quality Analysis

An integrated quality control system is composed of the control cycle of preliminary study, quality design, quality improvement through production, examination and testing, quality analysis, quality level control, and quality improvement.

Kawasaki Steel has developed and operates open use systems called the FRIEND system and the TOMAS system for gathering and analyzing data on these items. Departments using these support systems perform analyses based on data stored in the host computer, taking advantage of user friendly software to obtain the desired output for non-routine information requests.

Quality data is keyed to manufacturing conditions (piece logging data) through instruction and specification information, and appropriate quality level control is conducted based on quality analysis information. The data is reflected in the achievement of the target quality in subsequent products by means of in-line quality assurance, making it possible to build quality into the product on a continuous basis.

### 11.3 Technical Service Activities

The basic roles of technical service are (1) identifying the product functions required by customers, (2) ensuring that products are used appropriately, (3) providing feedback on the evaluation of products by users and various other kinds of information, and (4) supporting sales activities.

By anticipating customer requirements, technical service activities provide the starting point for building into the product the quality which will fully satisfy performance requirements.

Technical service fills an important role in the development of low-cost functional materials to meet the recent tendency toward quality requirements in which safety and environmental factors are considered, diversification, stricter requirements, and higher performance.

To supply accurate technical information to customers on a daily basis by making available a large stock of technical material, and to meet customer requirements for improvement, Kawasaki Steel has technical service bases in areas where important users are located both at home and abroad.

## 12 Conclusions

This paper has described how Kawasaki Steel imparts excellent quality to pipe and tubes in manufacturing products which customers can use with confidence. The

main points discussed are:

- (1) System of information processing and transmission in all processes from order inquiry to product shipment
- (2) Identification control and traceability in the total manufacturing process
- (3) Education and training of employees and system of qualification and certification
- (4) Control system for test and measurement instruments
- (5) Prevention of occurrence of nonconformance, and corrective activities for nonconformance
- (6) Maintenance of the quality assurance system by well-planned internal auditing
- (7) Quality improvement and technical service based on quality analysis and R&D

At Kawasaki Steel, quality assurance is defined as the effort: "to ensure that the performance required of a product is positively displayed when the product is used by a customer and to win the customer's confidence in its performance."

In the spirit of this definition, and mindful of their responsibility as material suppliers, persons in charge of quality in all department from order receipt to shipping constantly strive to satisfy the requirements of their customers and thus make a positive contribution to industrial activity.

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