I

# A new Concept of Building Frame Production System Intended for Mass Production System Structure

Une nouvelle conception d'un système de production en série pour la construction métallique

Ein neues Konzept eines Fertigungssystems für die Massenherstellung im Stahlbau

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## 1. PREFACE

Steel Structural Industry such as shipbuilding, bridges and steel frame industry have been recognized what is called industry which requires an intensive labor power. This is due to the fact that they cover a huge structure and require much transportation of materials or half-fabricated materials in the manufacturing process, and that problems to achieve mechanization and automation in the manufacturing process have been generally founded quite hard in the respect of the variety and/or working periods of structure only because steel frame industry relies chiefly on the production to order.

However, the wave for industrialization in the developed countries has brought forth the material improvement in our daily life and an increase of National Income has reached to 10% through 20% yearly and the ratio of labor cost into the production cost was going up. It will be the present situation that characteristics as an intensive type of industry are gradually apt to be out of sight.

Therefore, these steel structural industries have made every possible effort to reduce the cost for their own survival and development, that is, they have tried to save the production periods as shortly as possible and to cut down the labor power by means of mechanization and automation, and to find out their final and ideal production system into that of mass production. In short, it means that they try to emerge from an intensive labor industry.

As far as the matter of mechanization and automation are concerned, they have been thought and developed from the point of an anticipation for economic effect in the mere manufacturing process or of the demand for keeping the quality required only for some manufacturing process. When we try to design the production-to-order system into mass production system, we must pay such attention as it might be done to have not only a direct effect on the individual manufacturing process but also an indirect effect on the system itself and this will occupy a very important factor when we value the investing effect.

This report makes it clear how we should think in order to transfer non-mass production system, which can be seen in the production to order such as bridge and steel frame industry, into mass production system and what part it plays in the mechanization and automation.

## 2. PRODUCTION-TO-ORDER SYSTEM AND MASS PRODUCTION SYSTEM

### 2-1. Types of Production System

As shown in P-Q chart of Muther, they are divided into three types:-

(A) Zone ..... Line Production
(B) Zone ..... (A) or (B) or Combined Production
(C) Zone ..... Process Production

The type of production method are in the following:-

(a) Type of Order ..... Production in advance or Production to order
(b) Type of Shape or Form .... Continuously or Solely
(c) Type of Quantity ..... Much or Less

The study to decide the most moderate method by judging that actual production system belongs to any of the above classification has not be done so far and therefore been still remained unsolved as one of the most important subject.

At present we have a firm recognition that the pattern of most effective production system is of mass production system, and believe that we can raise up to the maximum the productive quantity per labor unit by line production system.

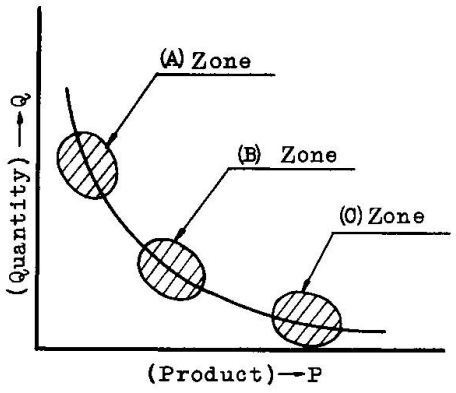



Fig. 2.1 P-Q Chart

### 2-2. Characteristics of Mass Production System

In the field of Steel Structure, the definition of "Same Kind" should be considered from the point of "Shape or Form" and "Production Process". In general we will not be able to expect much structures with the same kinds of shapes or forms, however, in order to realize the above expectation, it goes without saying that the existence of market demand must be one of the terms to be realized or otherwise we should work out to call for the demand, producing standard type of products-whose details are lined up hereunder- more economically, but those are comparatively less in quantities in the field of steel structure.

*** Type ship, Normalized residential apartment, Gymnasiums, Bonded Warehouse, Oil storage tank which are chiefly required for economy but appearance.

In our country there has increased year by year the demand for steel frames of high-rise buildings and therefore, the matter of mass production in the fabrication of building frame, which have never been thought so far, has been rapidly on the focus one of these years.

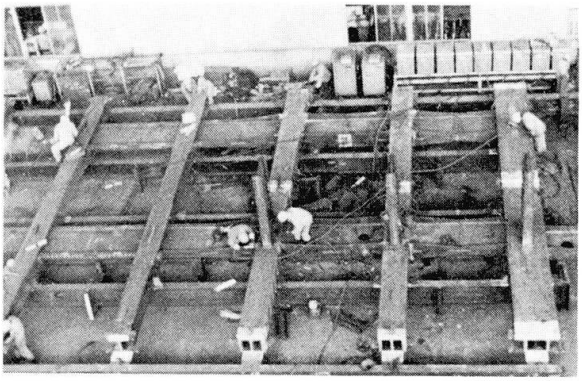


Photo. 2-1; View of Assembly for KEIO PLAZA HOTEL Building Frame

As we might be well aware, KEIO PLAZA HOTEL in Tokyo is the highest skyscraper in Japan, and we can admit the effect of mass production in this fabrication, however, the most extinguished example is refer to the fabrication of building frame in World Trade Center Building in New York City, U.S.A.. We can point out the specialized assembling line for column members which Pacific Car & Foundry Corp had executed in the fabrication of this building frame. However, such example will not be seen much in view of overall demands and this will not be recognized as general.

We can say that it is one of the most effective approach to understand the scope of same kinds of materials so widely, such as to intend to produce each different kinds of materials in the common production process. In the field of products which do not require much process of fabrication, a good pattern for manufacturing process cannot be seen enough, and we make it possible to regard even many different materials as same kinds of materials as far as this type of structure is concerned. The matter is the balance of loading in the fabricating process, and it is not too much to say that this is the sole key for approaching to the way of mass production. In short, the step to mass production system in the steel structure could be summerized in Figure 2-3.

As you can see from the figure, you will find out line (A) and line (B). As for line (A) there exist many a restricted condition beyond manufacturers disposition and human control, but regarding line (B) we will be able to integrate such products as are not considered in general as mass production type into the production system with characteristics of mass production system, analyzing unit work into elements such as work unit and combining each work unit.

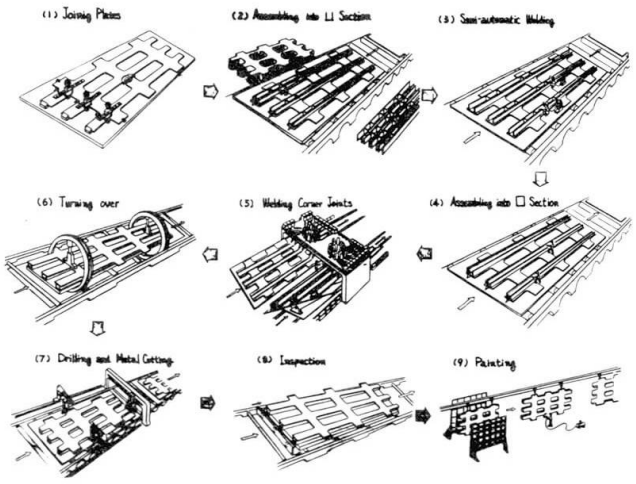



Fig. 2-2; Specialized Assembling Line for N.Y., WTC Building Column

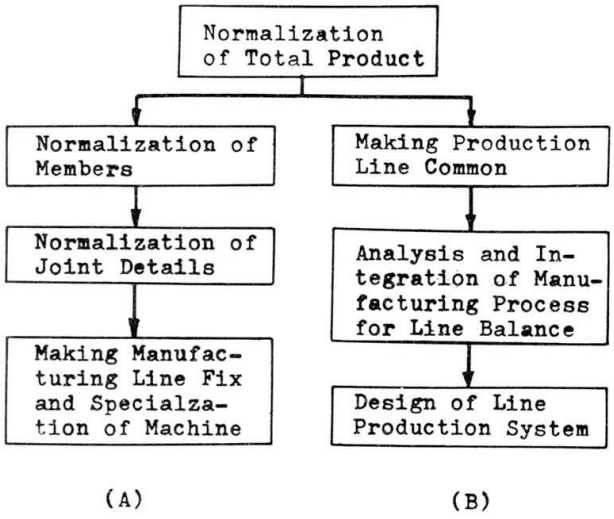



Fig. 2-3; Process to Mass Production System

## 3. IN ORDER TO ADAPT MASS PRODUCTION SYSTEM INTO PRODUCTION-TO-ORDER SYSTEM

### 3-1. Approach for the Efficiency of Production-to-order

We can consider the method to produce individual products by means of the most effective (or efficient) production system. When we summarize the problems on the productivity, the followings will be raised;-

(a) There will be no enough time to design the most proper production system for individual projects.

(b) Even though the design of the most optimum production system be possible, we should be in need for our serious decision in order to install machines practically in view of an excellent productivity by the investment.

(c) Since each different materials from fabricating process and loading are mixed in the same production line, fabricating or transporting machines and spaces can be generally without any consideration of each relations, and products already in line will be resulted in putting between machines and spaces, which cause the equality of loading difficult.

(d) Therefore, on our viewing some project from the point of production flow, it is not continuous and occurs the loss of time which will be allowance time resulted from an ill production planning.

It must be necessary to solve these problems in order to obtain a high efficiency, that is, (a) to increase the ratio of direct working time (b) to balance the capacity of work stage and to decrease the quantities of half-made products in the manufacturing process, and Line Production System is now widely recognized as one of the best method to obtain the effective production system.

New conception to produce steel structure most efficiently is to design line production system in considering each different individual members from shapes or fabrication process to be same kinds and much quantities of members, which will lead to good productivity. Line production system means to perform each working process at the constant cycle of time, that is, to make it tactful.

At the present stage it will be important to make a cycle time of work constant, and therefore, it must be recommended to divide each unit work into elements and itemize it into the level of work unit, and to recognize them as new unit work. In case you analyze and integrate unit work, you must not overlook that fabricating sequence is already decided as restricted condition because work unit is fabricated into any given shape or form, not to be independently existed in the working process. Therefor, process of analyzing through integration must be necessary to meet with the fabrication sequence, and require to shorten performance time and/or to decrease operation of machine, and then as a result to operate more than two machines per head. Mechanization and automation help to raise the efficiency of production system and lead to high productivity by investment.

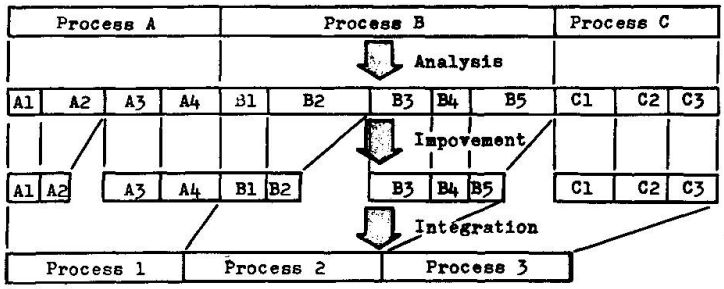



Fig. 3-1; Technique for Balancing

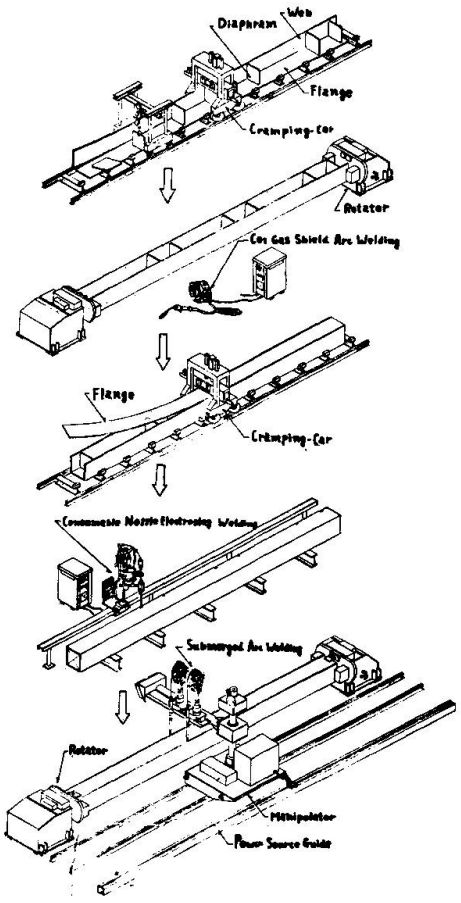



Fig. 3-2; Assembling Line of Box Colomn

## 3-2. Design of Production Line

Design to turn production to order into production line is to make line balancing, and it will be easier in the similar products, and easier in half-made products than in the final products. Therefore, in the design of production line, you should combine the following two methods properly;-

(1) to classify structural members into similar structural pattern, and make fabrication process tactful among those category

(2) among different structural pattern, to gather each similar members under the stage of such fabrication as any given shapes is not still appeared, and complete tactful production line.

Take building frame for example, you can classify structural members into Box section, Cross section, I section, H section and Circular section, and put a practical member of building frame in the above mentioned pattern and fabricate each members under the desired production process. You can consider Cross section as similar member as H section in the stage of I section from which Cross section can be formed. You'll admit that Box section will be the similar with H & Cross section under the comparison of performance process, and then make it possible to operate apparently different members with different structural sections in the common production line up to some working process. In the building frame you can prepare for sub-assembly line which various pattern such as column shaft, beam joint bracket, I type beam and Honeycomb beam and design line as shown in Figure 3-2 and it makes possible that you can turn production to order system into line production system.

## 3-3. Example for Tact System in the Fabrication of Building Frame

For tubular structure we have already started in our factory the execution of line production by tact system for assembling work in 1968, and that is, as you can see from Table 3-1, we have designed the assembling line including welding work by analyzing assembly work into each work unit and organizing new unit work. As the result, in necessity for keeping the balance of cycle time, semi-automatic $CO_2$ short arc welding method was adopted instead of prevailing stick welding, and the ratio of workers in assembling and welding have become

| Number of Unit Work | | Three Dimensional Assembly | Two Dimensional Assembly |
|---|---|---|---|
| Preparation Works | 1-1 | Recieving work order sheet | Same as the left |
| | 1-2 | Keeping assembly bin in order | |
| | 1-3 | Drawing on assembly bin in full scale | |
| | 1-4 | Gathering materials for jig | |
| | 1-5 | Preparation of materials for jig | |
| | 1-6 | Assembling and welding jig | |
| | 1-7 | Inspection of the jig | |
| | 2-1 | Gathering handy members like gusset | Same as the left |
| | 2-2 | Transporting them into assembly bin | |
| | 2-3 | Examining unsupplied members | |
| | 2-4 | Gathering and dispatching them | |
| | 2-5 | Transporting them into assembly bin | |
| Repeated Works | 3-1 | Transporting tubular main cords into the jig | Same as the left |
| | 3-2 | Fixing them mechanically to the jig | |
| | 3-3 | Transporting sub-assembled block into the jig | |
| | 3-4 | Fixing them to the main cords by tag welding | |
| | 3-5 | Transporting lattice members into the jig | |
| | 3-6 | Fixing them to the main cords by tag welding | |
| | 3-7 | Transporting plane block assembled in above 3-1 to 3-6 process to the three dimensional assembly bin ( Repeating above 3-1 to 3-7 process ) | The works are not done in case of two dimensional assembly |
| | 3-8 | Transporting plane block into the jig | |
| | 3-9 | Fixing them mechanically to the jig | |
| | 3-10 | Transporting lattice members into the jig | |
| | 3-11 | Fixing them to the block by tag welding | |
| | 3-12 | Transporting handy members into the jig | |
| | 3-13 | Fixing them to the block by tag welding | |
| | 3-14 | Marking the places where uncommon members attach | |
| | 3-15 | Transporting them to the jig | |
| | 3-16 | Fixing them to the block by tag welding | |
| | 3-17 | Marking the block mark | |
| | 3-18 | Transporting assembled block to welding place | Same as the left |
| | 3-19 | Welding one side | |
| | 3-20 | Turn block over | |
| | 3-21 | Welding another side | |
| | 3-22 | Transporting welded block to finishing place | |
| | 3-23 | Measuring strain caused by welding | |
| | 3-24 | Removing strain ( by gas heating ) | |
| | 3-25 | Measuring residual strain | |
| | 3-26 | Transporting finished block to stock yard | |

Table 3-1; Example of Analysis into Unit Work (Assembly of Tubular Structure)

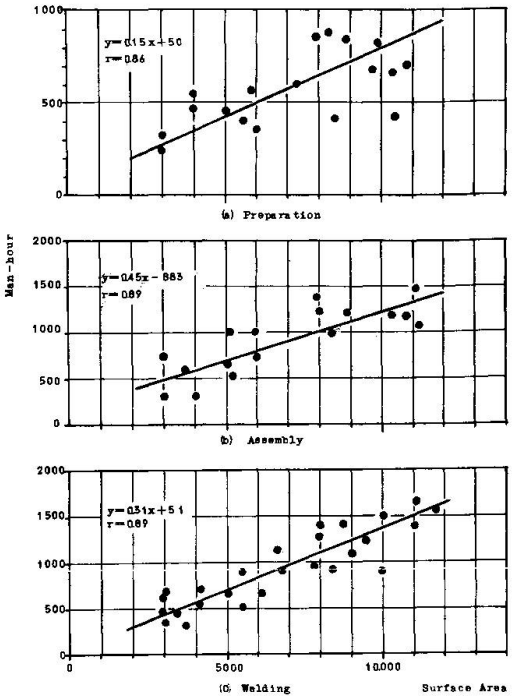



Fig. 3-3; Relation Curves of Man-hour/Surface Area (Truss)

1:1 below as compared with the past 1:1.2, and we have succeeded in using surfaced area of building for calculating reliable performance cycle time at an early stage. Fig. 3-3 shows the relation curve of man-hour/surface area for every fabrication process.

## 4. MECHANIZATION AND AUTOMATION UNDER THE FABRICATION STAGE

In the mass production system, preparation work for assembly such as marking, cutting and drilling must be automaticalized because its purpose is to level fabricating time to different fabricated members from working quantities. By this work, you'll be able to decrease the kinds of members and increase the quantities in respect of working process, and to turn into the mass production pattern in the long run.

### 4-1. Marking and Cutting

In the production control system marking and cutting have a quite important meaning. That is, they are situated in the first working process in the shop work and, in another word, they are in working process by which plates, angles and other materials are devided in various pieces, and free from the common roles. Originately in the modernized production line, marking work, which is to mark on the template made in mold loft, should be excluded. However, when final product is not similar in shape or form, it will very often make assembling work impossible to adopt no-marking system, except that you are intending to turn into line production by the (B) method shown in Fig. 2-3. Overall adoption for no-marking production system requires complete N/C assembling work and at present stage this adoption seems to be still early in time in view of efficiency of investment.

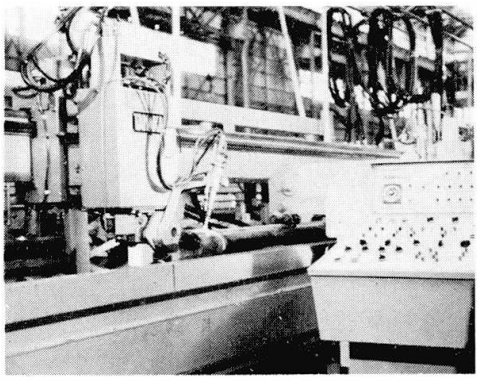


Photo. 4-1; N/C Pipe Cutter

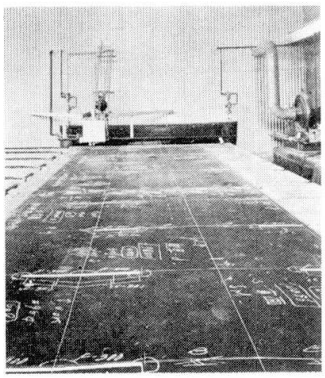


Photo. 4-2; EPM of Magnifying Type

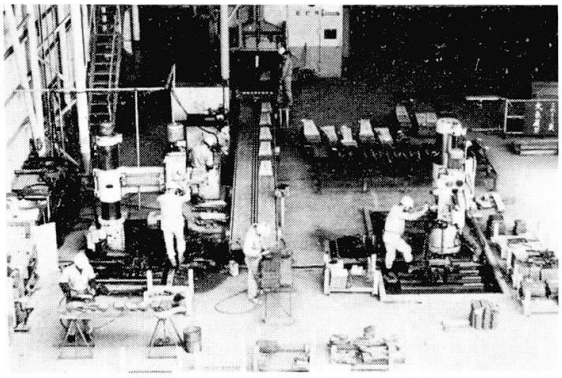


Photo. 4-3; EPM-Cutting-Drilling Sub-System

(a) No-marking and cutting in the steel pipe

The method of automatic cutting introduced by "Introductory Report" of Dr. F. Faltus shows an example of "PICOM" which was developed by our factory, and this machine is made so as to pick up the data, which control directly cutter from the drawings and to cut the pipe without any marking process, and recently numerically controlled. Details about production system by "PICOM" will be reported in a later Chapter.

(b) Electro Print Marking (EPM)

EPM system has been used in shipbuilding industry one of ten years. For the time being, this is only for the purpose of obtaining scrap percentage and size of fabrication lot as key plan, and therefore, magnified project method using reduced scale drawing has been chiefly used, however, in the fabrication of building frame template drawn in full scale is used because exactitude to be required is not available due to the fact that marking line is so thick.

EPM system was originately adopted under the developing procedure before reaching to no-marking cutting system which has used numerically controlled cutting and generally, adoption of N/C machine will bring its economicality, therefore, EPM system will be considered to be adopted only because of its being economical for the time being. Recently, the prevailing of automatic drafter have help to raise up distinguishedly the productivity of drafter-EPM system. Photo. 4-3 shows the sub-system of EPM-cutting-drilling in our writer's factory, and this EPM system has made it possible to transport less small members of materials in factory. This EPM system sures to help to equalize the working time for each members of materials which have individual marking load, and makes a line balance in such system possible.

4-2. Drilling

Drilling time is corresponding to the pieces of holes, and recently multi-axis drilling and N/C drilling make it possible to eliminate the individuality with fabricated members. Furthermore, in the field of production of building frame, movement to normalization of joint pattern in designing section so as to decide bolt hole by section of structural members make it possible to decrease the selection of hole pattern.

One of these years rolled H shape has now been utilized as material for building frame and we have developed N/C multi-drilling machine (H-COM) in our factory in order to automaticalize drilling operation against H-shaped steel. The change of working contents brought by this machine is in Figure 4-2.

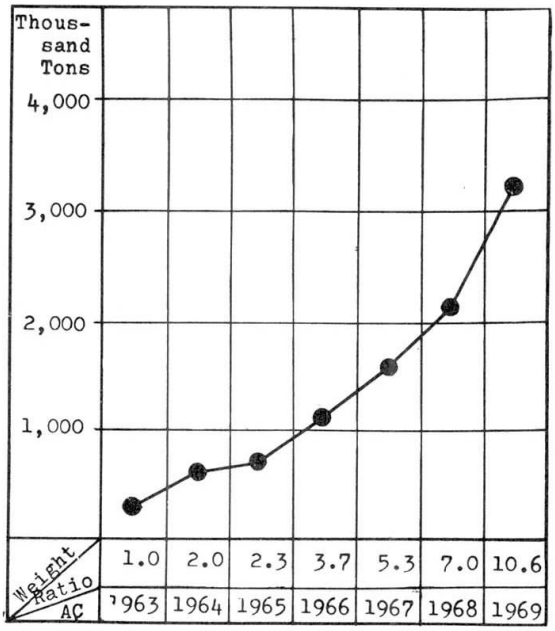



Fig. 4-1; Transition of annually Produced Weight of Rolled H Steel in Japan

H-shaped raw material is put in the drilling machine in the first working process, and in accordance with program (punched tape) in advance, drilling work is automatically performed. In viewing this process from the point of mass production, we have only admitted that the automation of drilling work has resulted into line production which can decrease the waiting loss time in unit work in the fabrication process from raw material to completion, but it has another important meaning that different line of hole group could be fabricated at the same time and variety of fabricated members are lost by N/C, and as a result we could turn into same kind of work which have same process and also normalized hole group to minimize programing.

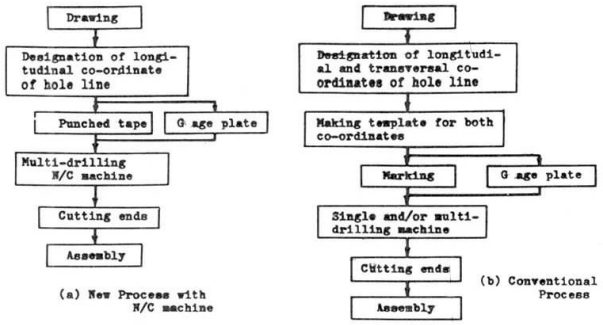



Fig. 4-2; Change in Preparation Process for H-shape brought by the Use of N/C Machine

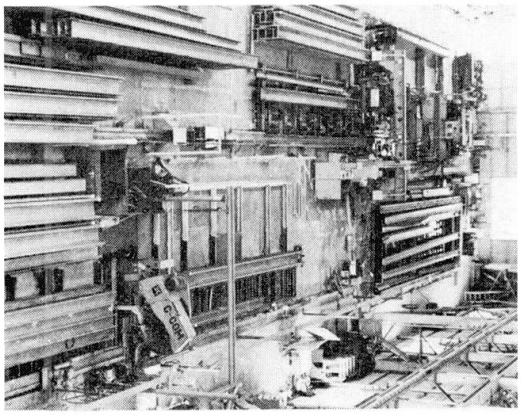


Photo 4-4; Drilling and Cutting Line for H-shape

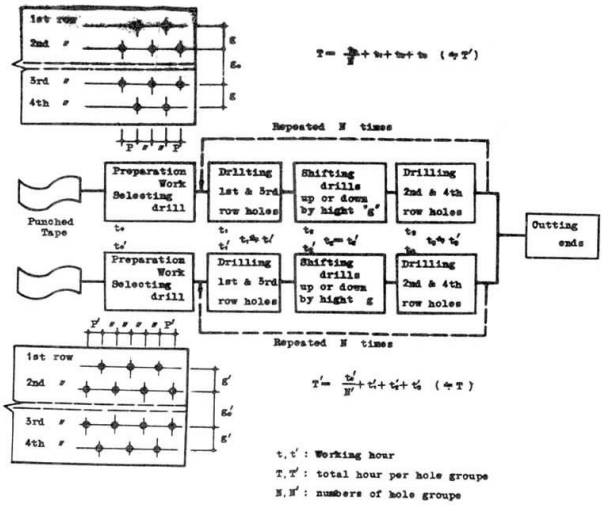



Fig. 4-3; Drilling Time per Hole Group When Drilled by N/C Machine

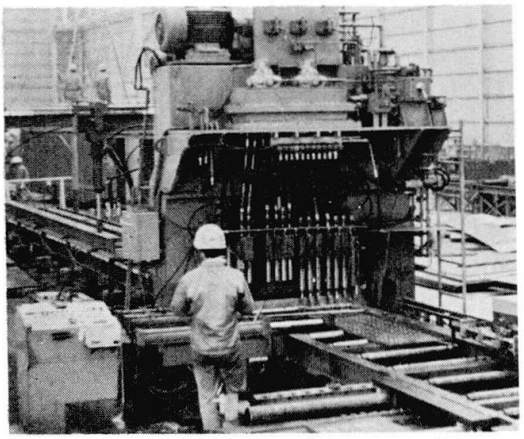


Photo. 4-5; N/C Drilling Machine for Splice Plate (S-COM)

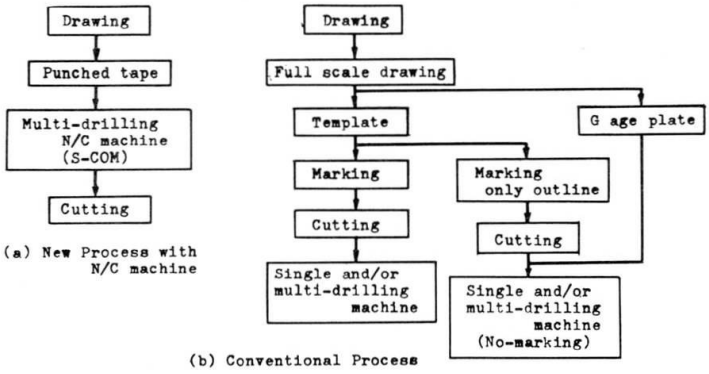



Fig. 4-4; Change in Manufacturing Process for Splice Plate Brought by the Use of N/C Machine

Drilling work on the splice plate is not quite different from the above mentioned H-shaped materials, and rather easier than the latter, because of drilling on flat plate. In case we should use drilling machine "S-COM" which is a specialized machine for splice plate, we could consider all the splice plate as the same kind, because the difference from the diameter and distributing line of bolt holes could not be regarded as individual.

## 4-3. Welding

In the field of steel structure welding is one of the important works to guarantee the structure's quality, and at the same time in the constitution of the production cost together with assembling work. To make this welding work automatic and to save the time help to obtain the fixed quality and shorten production periods.

There will be too broad to report about the automation of welding, and we would like to introduce you a few example here. In the automation of welding, normalization of joint details will be the condition in advance, and if the joint details will be normalized, then automation of welding will be possible. Detailed matter on this normalization will belong to theme II, Design Concept.

(a) Example for automation of fillet welding

(1) Simultanious welding for both fillet joints of flange and web plate of I beam. (See Photo. 4-6)

(2) Fillet welding for common joint of box frame using automatic tandem head MIG. (See Photo. 4-7)

(3) Fillet weld using gravity stick weld. (See Photo. 4-8)

(4) Automatic vertical fillet welding. (See Photo. 4-9)

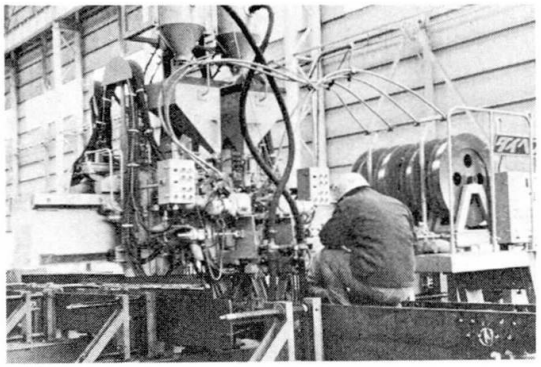


Photo. 4-6

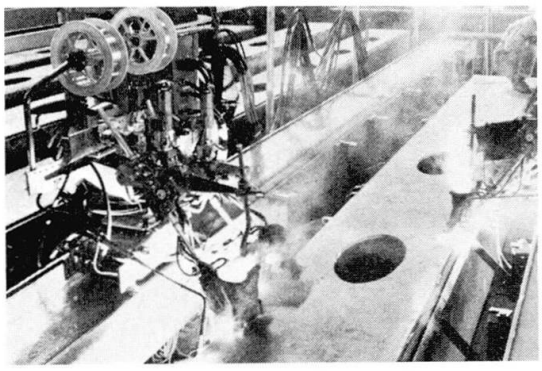


Photo. 4-7

Photo. 4-8

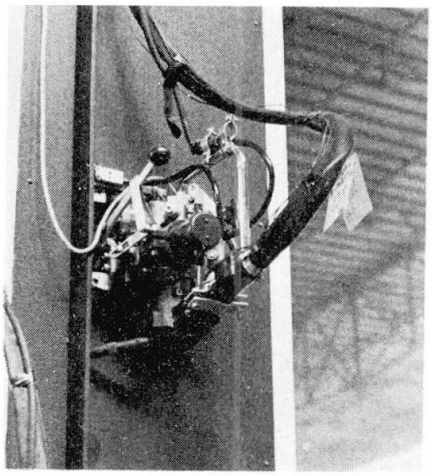


Photo. 4-9

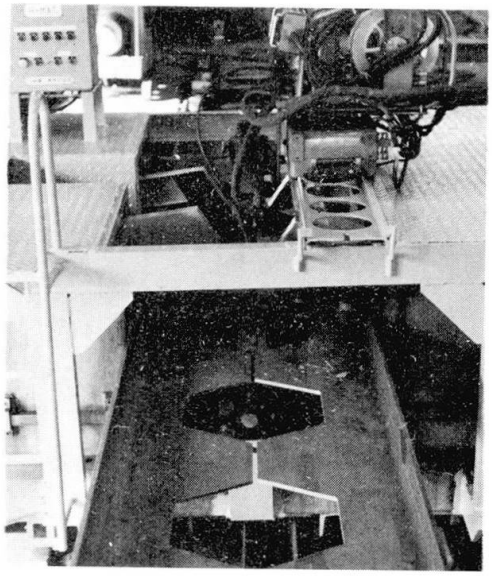


Photo. 4-10

(b) Automatic welding for butt joint.

(1) One side automatic $CO_2$ gass shielded welding for square butt joint. (See Photo. 4-10)

(2) Automatic vertical welding for square butt joint. (See Photo. 4-11)

(3) Automatic weld for V butt joint. (See Photo. 4-12)

## 5. EXAMPLE FOR PRODUCTION SYSTEM INTENDED FOR MASS PRODUCTION TYPE

Building frame will be divided for its kind into the following table, and each optimum production system will be adopted. From the point of mass production system, in case of high rise building, same structure will be extended even toward the hight, and in the industrial building such as rollmill factory, same structure will be extended toward the length, therefore, it will be possible to design the structure intended for mass production and to install the specialized production facilities economically.

We have already introduced a good example of mass production system about block by WTC Building in N.Y., and this example also applies to mass production about floor structure at the stage of designing, however, the realization of mass production about floor structure will be at the mercy of transportation and located situation. (See Photo. 5-1)

Recently honeycomb beam has been used for the purpose of saving weight and/or others, and we have the following production line with automation in our factory for fabricating this beam. (See Fig. 5-1)

Photo. 4-11

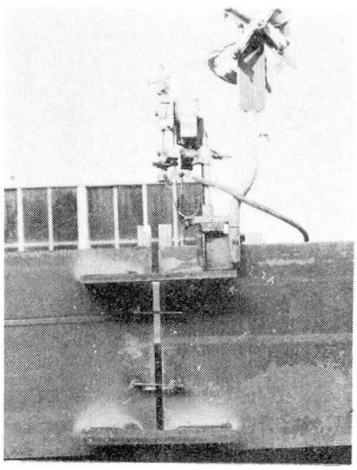


Photo. 4-12

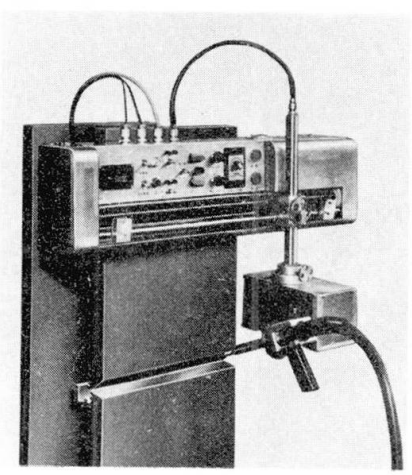
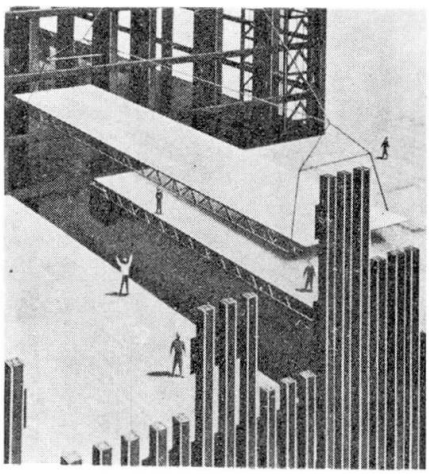


Photo. 5-1



| Kinds of Building | Type of Building Frame | Note |
|---|---|---|
| Office<br>Hotel<br>Apartment | I sectional Beam<br>H sectional Column<br>Box sectional Column<br>Cross sectional Column<br>Circular sectional Column | Multi-storied Rahmen<br>Manufacture is repeated toward their hight. |
| Mill<br>Warehouse | Truss Girder<br>I Beam<br>Truss Column<br>Box sectional Column<br>Tubular Column<br>Cross sectional Column<br>H sectional Column | Single-storied Rahmen or Truss<br>Manufacture is repeated toward their length. |

5-1. Production System in High-rise Building Frame Using Specialized Fabricating Machine. (See Fig. 5-2)

5-2. Production System in Tubular Structure Using No-marking Cutter. (See Fig. 5-3)

Production system of steel pipe in tubular structure will have the following procedure in general.

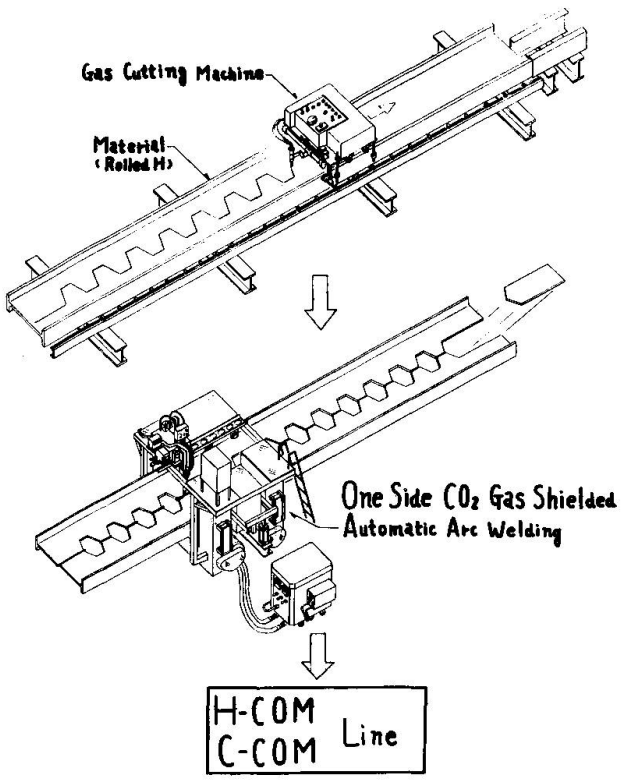



Fig. 5-1; Assemblying Line for Honeycomb Beam

Full scale drawing and expansion ---Marking template---Marking center line to steel pipe---Marking---Manual cutting

but it became possible to simplify work unit and produce massively by the use of PICOM. We have adopted tact system into making line production type possible, which led to the level-up of productivity. In the past it required approximately 150 to 200 H/TON (Man-hour/Ton) in the fabrication cost, but even since the development of pipe cutter it decreased down to 25 to 30 H/TON at present. The above simplification resulted into that of designing and the figure of pieces per ton, which show the difficulty of manufacturing decreased from 200 pieces through 300 pieces per ton to 50 through 100 pieces per ton.

## 6. POSTSCRIPT BY THE WRITER

It is true that every manufacturers who receive orders have tried to seek for the most proper pattern of production system in each own way and manner as if they are groping something in the dark. Recently, after the analysis of mass production system from the concept "System Structure" they have recognized that it will be possible to turn into mass production system by looking for the common process from production system for individually different type of products.

In our factory we have been making an effort to put all sub-system automatic, since we believe automation of the work will be the key for transfering into mass production system. It will go without saying that higher productivity will be obtained not by the improvement of individual work but by the design of total system. We have always intended for the design of total system through the automation and numerical control of individual sub-system, and we believe that it will not require long time before designing of total system will be completed.

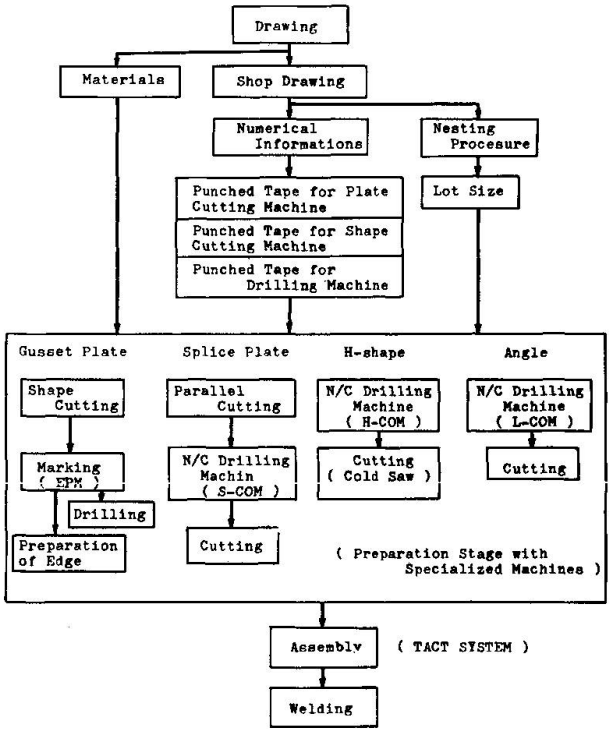



Fig. 5-2; Production System in High-rise Building Frame

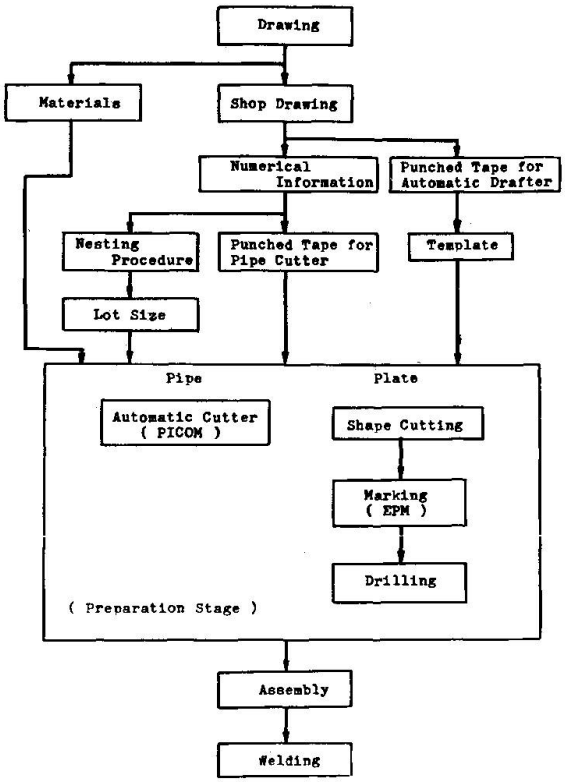



Fig. 5-3; Production System of Steel Pipe in Tubular Structure

## References

Tanaka, M. "How to Make Production System Effective"

Muther, R. "Systematic Layout Planning"

Yamauchi, K. and Kamei, T. "Future Prospects for Steel Skeleton.Fabrication"

Aono, I. and Kamei, T. "Procedures for Fabricating Tubular Members"

Mundel, M.E. "Motion Study Research"

Ohba, H. Yamauchi, K. and Murata, Y. "Automation of Manufacturing Process for Steel Structures"

Murata, Y. "The Highest Building in the World, The W.T.C. Building in N.Y. City"

SUMMARY

In production system we recognize standard patterns caused by the relation between Products and Quantities, ,and assign production to order as process production. It is obvious for line production pattern to be highly productivity, so we are looking for the way to line production system by analyzing each processes at various levels and integrating them to balance the process tactfully, and introduce in this report our examples based on mechanization and automation which we think a very good improving method for balancing lines.

RESUME

Nous reconnaissons parmi les systèmes de production les applications normalisées causées par la relation entre produit particulier et de série et nous adaptons les productions exigées au processus de fabrication. La condition première de la fabrication à la chaîne est, bien entendu„ une haute productivité; c'est pourquoi nous étudions la fabrication à la chaîne en analysant chaque processus sous différents angles et en la réintégrant exactement dans le système. Dans ce rapport, nos exemples sont basés sur la mécanisation et l'automation. Nous croyons avoir ainsi une bonne méthode pour se représenter les lignes directrices.

ZUSAMMENFASSUNG

Beim Fertigungssystem anerkennen wir die Standardausführungen, die zwischen dem Verhältnis von Erzeugnis und Menge bestehen und ordnen die verlangte Erzeugung dem Produktionsprozess zu. Für Fliessfabrikation ist selbstverständlich hohe Produktivität Voraussetzung, wir verfolgen daher die Fliessfabrikation durch Analyse jedes Vorganges unter verschiedenen Gesichtspunkten und deren genau abgewogene Einführung in den Vorgang. Im vorliegenden Bericht stützen sich unsere Beispiele auf Mechanisierung und Automation, welche nach unserem Dafürhalten eine sehr gute und verbesserte Methode für die Richtlinien darstellen.

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