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Outline of New Quench and Temper Facility for Small Diameter Tubing

Takeo Doi, Toshihisa Taue, Tadashi Nishihara, Shiro Hatakeyama, Yoshikazu Kitahaba, Hiroaki Kondo, Keiichiro Takitani, Haruho Niwa

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Takeo DOI** Toshihisa TAUE** Tadashi NISHIHARA**
Shiro HATAKEYAMA** Yoshikazu KITAHABA** Hiroaki KONDO**
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1 Foreword

Since the first oil crisis in 1974, exploration of oil and natural gas has been actively carried out in various regions of the world. Consequently, in the field of "oil country tubular goods (OCTG)," the demand has been increasing year by year, particularly for higher quality goods. To meet this situation, Chita Works of Kawasaki Steel Corporation completed an OCTG plant in 1977 for integral operation from heat treatment to thread-cutting of casing and line pipes.

Subsequently in November, 1979, Kawasaki Steel's Chita Works completed a new quench and temper facility for tubing and drill pipes, thereby establishing an integral manufacturing system for casing and tubing. This report reviews the outline of the quench and temper facility for tubing (refer to **Photo. 1**).

2 Purpose and Outline of Facility

The purpose and outline of the quench and temper facility are described below:

(1) Establishment of high quality OCTG quench and temper system
The new quench and temper system has made it possible to manufacture high grade tubing and drill pipes having H_2S sour corrosion resistance, CO_2 sweet corrosion resistance, and high strength and high toughness and also to manufacture pipes with extra thick upset portions. These products are quite fit for use in increasing deeper oil wells and severer environment. Further, in order to meet an increased demand for premium joint tubes, a mass production system of these high grade OCTG have been established through selection of materials having excellent quench and temper characteristics and the adoption of Kawasaki Steel's unique heating system and water tank type inside/outside quenching system.

(2) Establishment of quality assurance system
A very strict quality assurance system has been established with the help of on-line installation of NDI equipment such as an ultrasonic tester and magnetic particle tester for pipe ends, the use of the tracking system for all-line lot control, increased accuracy in temperature control, and adoption of operational data logging.

(3) Energy and Labor Saving
Energy saving has been positively promoted by the development of the upset portion rapid heating device, selection of optimum reheating temperatures and reduction in furnace idle time with the use of computer for reheating furnace control, and improvement in heat insulation through the extensive use of ceramic wool. Drastic labor saving has also been achieved by the introduction of independent computers for measuring, quality control and various conveyors and by almost full automation of individual facilities.

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** Chita Works
*** Research Laboratories

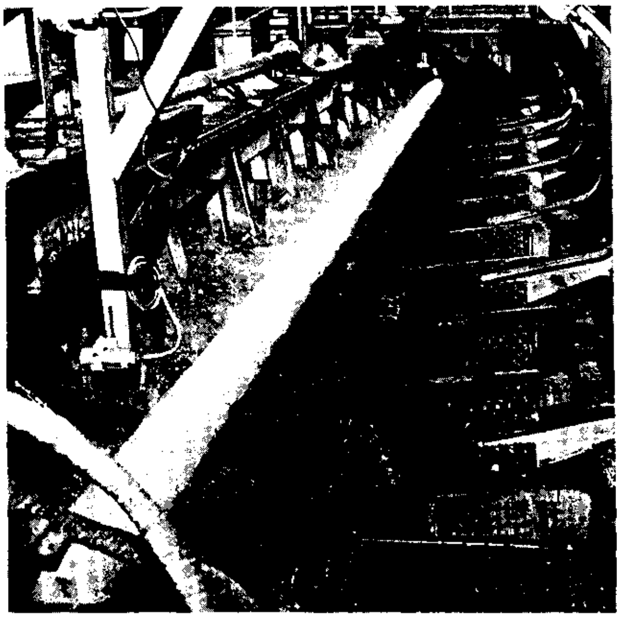


Photo. 1 Water tank type inside/outside quenching facility

3 Facility Specification

Fig. 1 shows the manufacturing and inspection process of the new quench and temper facility for tubing, and **Table 1** shows available pipe sizes for the facility and its capacity.

Products to which the facility is applicable include tubing, drill pipes and some kinds of casing such as API 5A, 5AC, and 5AX, and premium joint pipes such as HYDRIL, and ATLAS BRADFORD, etc.

For the quench and temper furnaces (i.e., the austenitizing furnace and drawing furnace), LPG-burner-type walking beam furnaces have been adopted, and for the quenching device, a water-tank-type inside/outside cooling system has been adopted.

For the cooling bed, an air-cooling rake-type cooling bed is used, and for the straightener, an upset pipe straightener with 2-1-2-1 transverse roll arrangement is employed.

The NDI device used for pipe portion is an upset tube ultrasonic tester of the tube rotating type, and for upset portion, a magnetic particle tester.

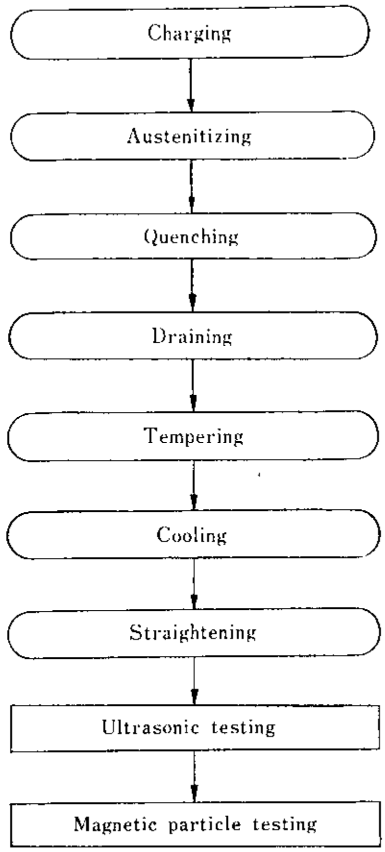


Fig. 1 Manufacturing and inspection process

Table 1 Available pipe sizes and capacity

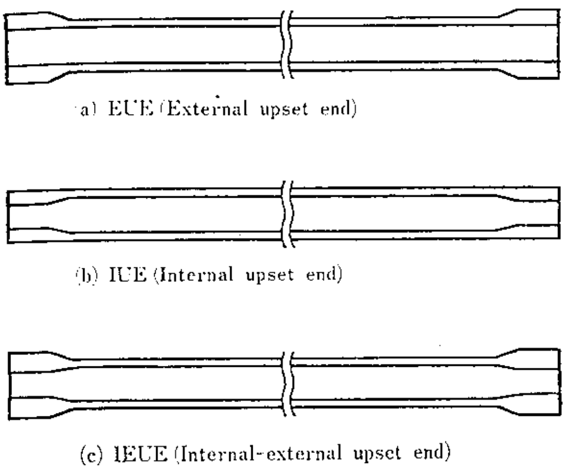
Item	Specification	
Diameter	Pipe body	48.3-139.7 mm
	Upset portion	Max. 148 mm
Wall thickness	Pipe body	3.68-16.0 mm
	Upset portion	Max. 35 mm
Length	5.5 10.5 m	
Capacity	10 t/h, 6 000 t/month	

4 Features of Quench and Temper Facility

4.1 Rapid Heating Equipment for Upset Portion

Most of the materials to be treated by the quench and temper facility are upset pipes, as shown in **Fig. 2**. When pipes are reheated in the ordinary reheating furnace, time required for reheating the thickest-walled upset portion is used as a standard for the time required for reheating. Consequently, the pipe body excluding the upset portion is retained at a high temperature zone longer than necessary. This will have adverse effects on the quality of the pipe reheated and involve a waste of energy.

In order to solve these problems, a rapid heating equipment for the upset portion only has been developed and installed inside the furnaces used in the quench and temper facility. **Figs. 3** and **4** show cross sections of the upset portion rapid heating equipment



(a) EUE (External upset end)

(b) IUE (Internal upset end)

(c) IEUE (Internal-external upset end)

Fig. 2 Types of upset end

for the austenitizing and drawing furnaces, respectively. As a result of installing the equipment, remarkable rapid heating effects have been observed as shown in **Figs. 5** and **6**, resulting in about 10% improvement in productivity.

4.2 Quenching Device

In order to improve the quench severity of the upset portion, the quench facility is provided with a water-tank-type inside/outside quenching system which is unparalleled in the world for small diameter pipe use.

Fig. 7 shows the cross section of the quench water tank. The pipe to be quenched is fed into the water tank in a slightly inclined state and retained in a horizontal position. Its external surface is cooled by water jetted in 4 directions (at 90° pitch) along the

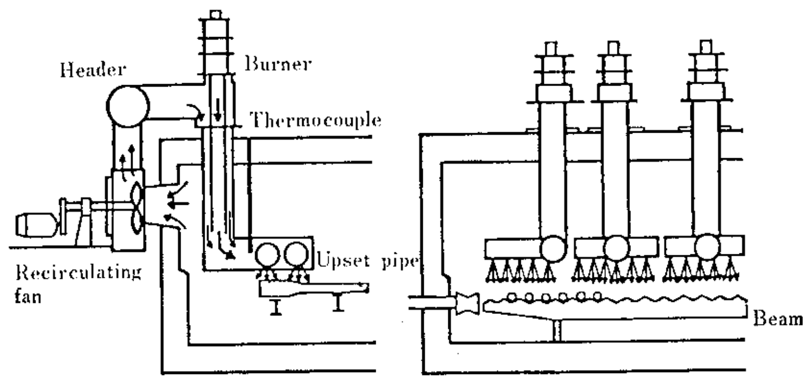


Fig. 3 Rapid heating equipment for upset portion in the austenitizing furnace

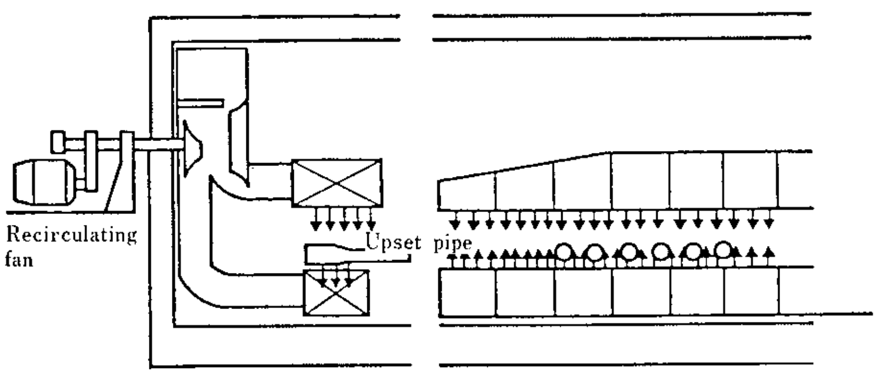


Fig. 4 Rapid heating equipment for upset portion in the drawing furnace

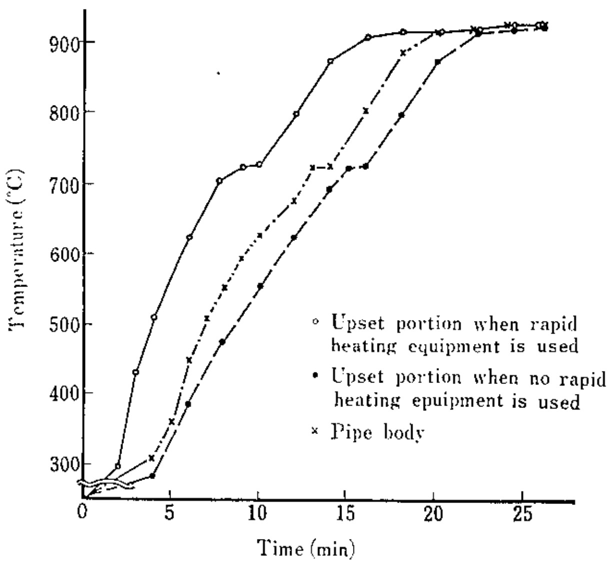


Fig. 5 An example of actual heating curve at the austenitizing furnace (measured by thermocouple inserted in the pipe body and upset portion)

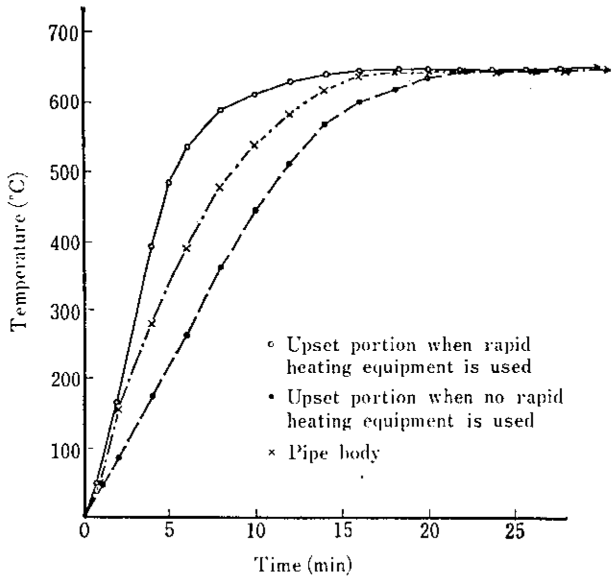


Fig. 6 An example of actual heating curve at the drawing furnace (measured by thermocouple inserted in the pipe body and upset portion)

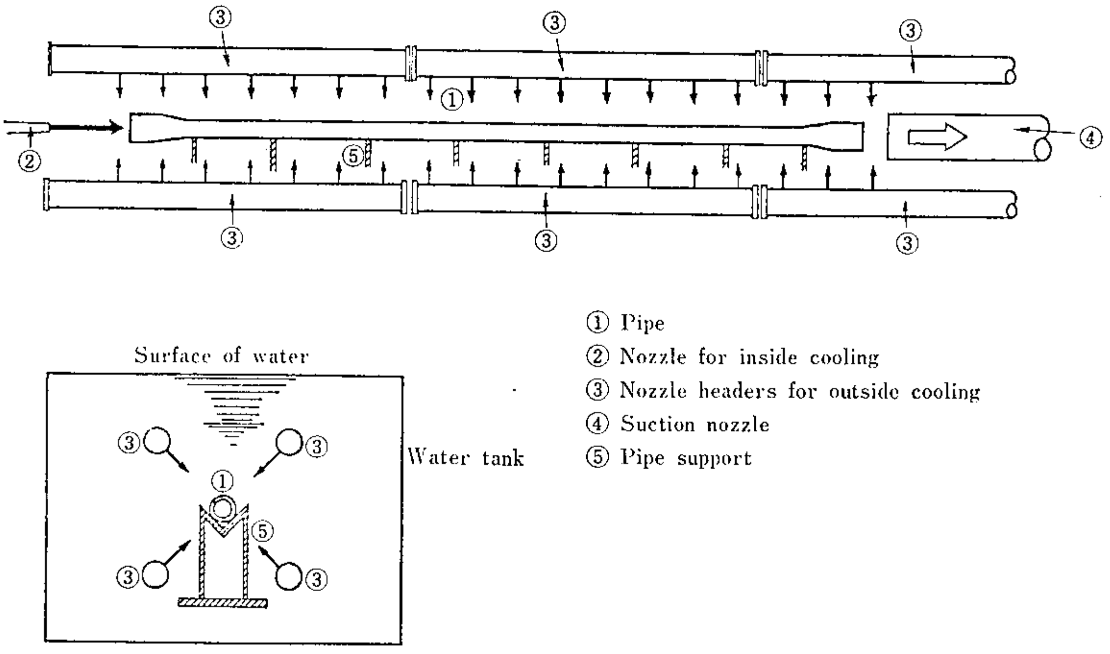


Fig. 7 Quenching unit

circumference and its inside is forced-cooled with high pressure water jetted from the internal cooling nozzle.

A suction nozzle installed on the opposite side of the internal cooling nozzle directly sucks in and discharges cooling water which has become hot by passing through the internal surface of the pipe. With this arrangement the lengthwise bending of the pipe is prevented which is caused by the localized increase in temperature of water in the water tank.

4.3 Hot Air Recirculating Fan

With the object of controlling temperature deviation within $\pm 5°C$, the soaking zone of the drawing furnace is divided into 3 sub-zones in the lengthwise direction, and each sub-zone is provided with a hot air recirculating fan as shown in **Fig. 8**.

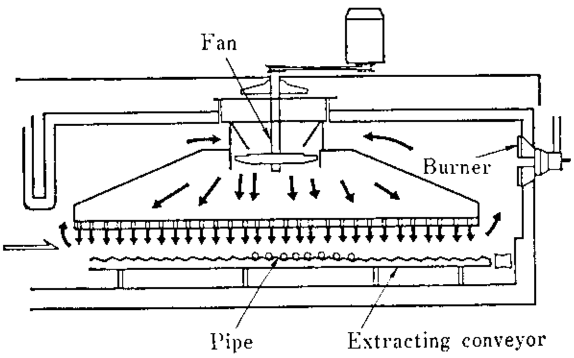


Fig. 8 Recirculating fan of the soaking zone in the drawing furnace

5 Quality Control System

To attain the highest level quality control with the minimum number of personnel, 4 microcomputers and 1 process computer have been introduced into the quench and temper facility. An outline of these computers is given below.

5.1 Transfer Control

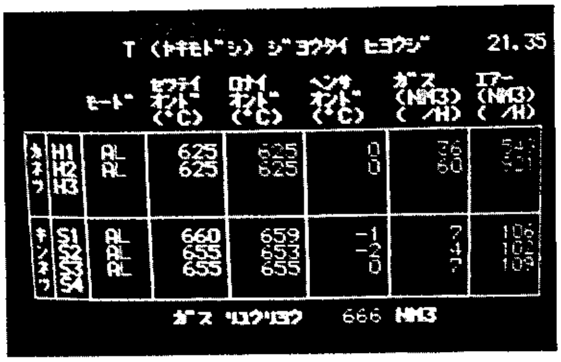
Two MELPLAC units manufactured by Mitsubishi Electric Co., Ltd. have been installed.

One unit exercises a series of transfer controls from the austenitizing furnace to the ultrasonic tester, and the other unit minimizes the overhang lengths of pipe ends inside the furnace and at the cooling bed and controls the stopping position of the upset portion to prevent it from riding over the beam.

5.2 Furnace Operation and Pressure Control of Water for Quenching

Two MICREX units manufactured by Fuji Electric Co., Ltd. have been installed. They control furnace temperatures and combustion and residual oxygen quantity in the austenitizing and drawing furnaces as well as pressure of quench cooling water.

Photo. 2 shows an example of the CRT screen under control operation.



Temperature of drawing furnace

Photo. 2 Illustration of digital direct control

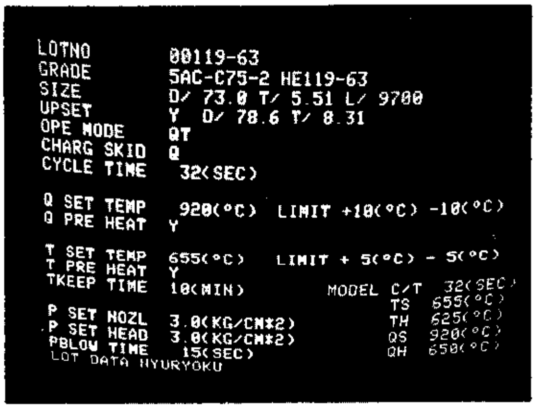
5.3 Data Logging System

The following operations are performed by HIDIC-80 manufactured by Hitachi Co., Ltd..

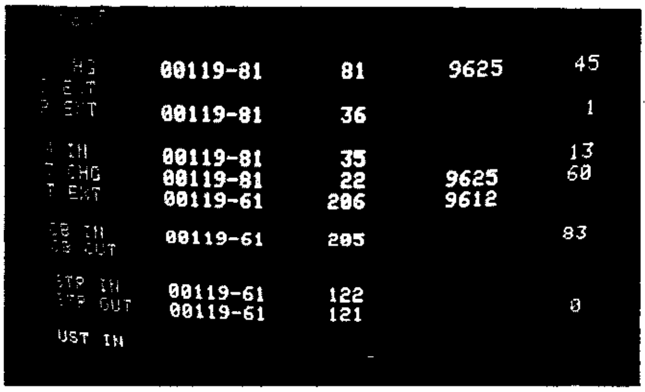
(1) The system tracks each length of pipe throughout the line in order to obtain logging data for extraction temperatures and holding time of each furnace and to give a decision of acceptance or rejection.
(2) It displays information on such items as lot No., pipe No. etc. for the pipe which passes through the inlet/outlet of each equipment (see **Photo. 3**).
(3) It logs data such as the furnace condition, quench water condition and unit fuel consumption at intervals of 10 min., 1 hr. and 8 hr.
(4) It measures the length of each pipe at the austenitizing furnace inlet, and sets the pipe length to the MELPLAC every time at the inlets of the austenitizing furnace, drawing furnace and cooling bed.
(5) In order to minimize the idle time of the furnace during size changing and temperature alteration, it schedules time for setting alterations of the austenitizing and drawing furnaces and locks the pipe insertion into the inlet of the austenitizing furnace before the expiry of the pre-determined time.

5.4 Nondestructive Inspection Device

As a nondestructive inspection device, an ultrasonic tester is directly connected to the quench and temper continuous processing line for quickly feeding back the quality condition. This device is capable of passing



(a) Picture of input data



(b) Picture of lot tracking

Photo. 3 Illustrations of lot tracking

through the upset portion by means of the opening mechanism of the probe setting arm and detecting notches to a depth of 5% of the wall thickness on both the internal and external surfaces. Defects at the upset portion that cannot be detected by the ultrasonic tester are detected by the magnetic particle tester at the subsequent step.

6 Product Quality

6.1 Quench Hardenability

Fig. 9 shows the hardness distribution of as-quenched tubing material which consists of 0.25%C, 1.35%Mn steel to which a minute quantity of B is added. Excellent quench hardenability is one of the most important properties required of OCTG. As shown in **Fig. 9**, even thick-walled tubing has uniform and sufficient Martensite hardness over the entire thickness by means of inside/outside quenching and the proper chemical composition design. Besides its quench hardenability, the material is suitable for API tubing in terms of quench cracking and sulfide stress corrosion cracking resistance, and is employed as a common material for C-75, L-80, N-80, C-95 and P-105 tubing.

6.2 Tensile and Impact Properties

Figs. 10 and **11** show the tensile and CVN impact properties of API tubing, respectively. API tubing consists of C-75, L-80, N-80 and P-105 specimens and their dimensions are $2^7/_8$ in. (73.0 mm) O.D. × 0.217 in. (5.51 mm) thick.

These figures indicate that the products are highly uniform in hardness and their notch toughness at low temperatures is excellent.

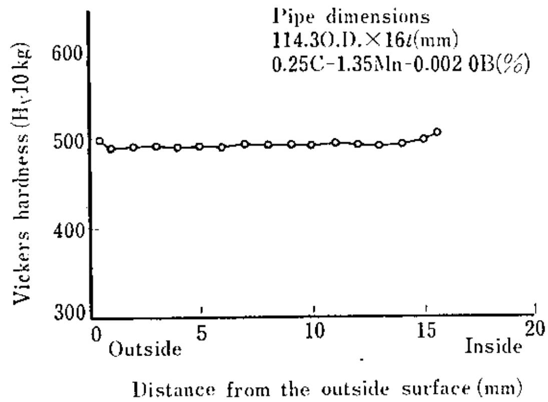


Fig. 9 Hardness distribution of as-quenched pipe

6.3 Sulfide Stress Corrosion Cracking Resistance

Very important qualities required of steel material for sour oil and gas well tubing are sufficient quench hardenability and high temperature tempering characteristics. The new quench and temper facility has been designed by paying sufficient consideration to these two points. **Table 2** shows examples of SSC threshold yield strength obtained by the constant load tension test set forth by the NACE standard.

6.4 Dimensional Stability

In general, when a steel pipe undergoes quench and temper treatment, its roundness and straightness usually show some variations.

Fig. 12 shows the results of measuring the outside diameter of a steel pipe which has been quenched and tempered by the new facility and then straightened.

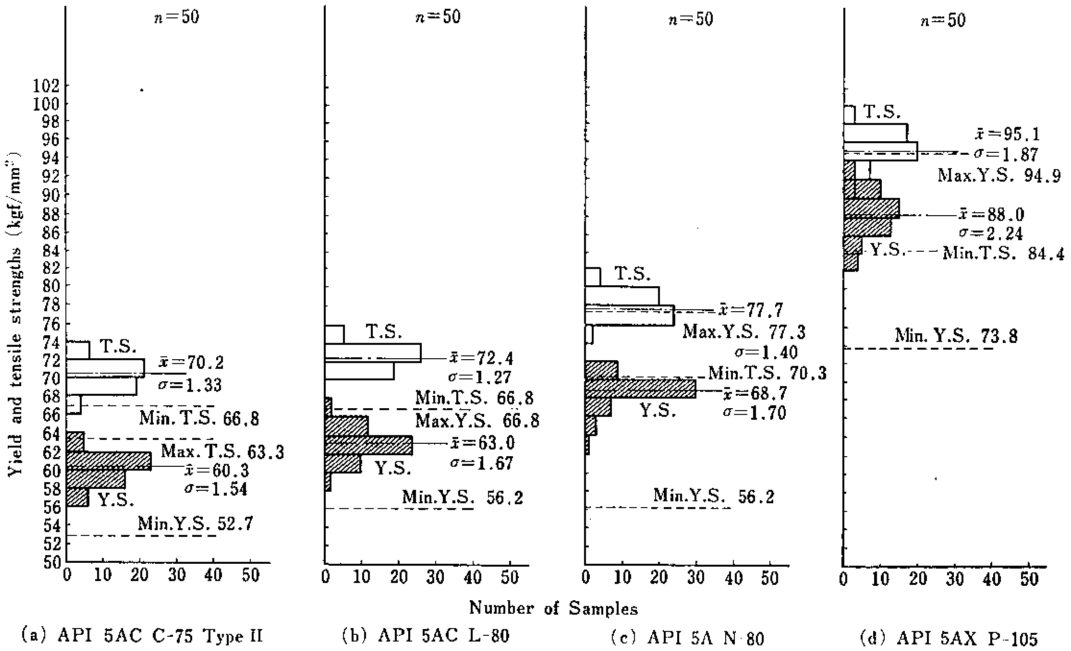


Fig. 10 Results of API tensile test

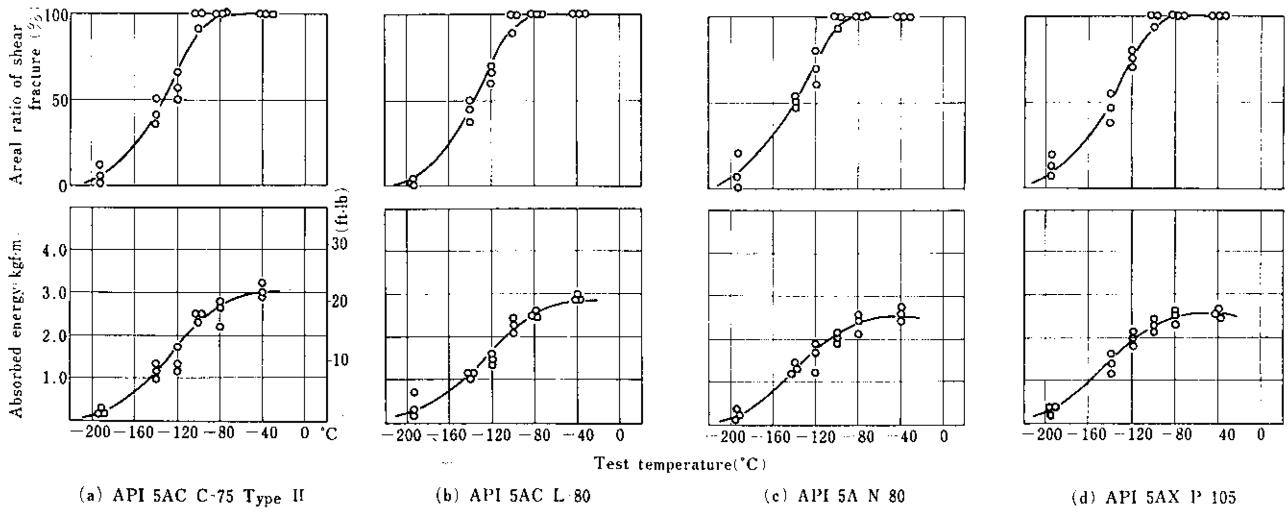


Fig. 11 Results of Charpy impact test

Table 2 SSC threshold yield strength of anti-SSC tubings

Standard	Size	SSC threshold/ specified min. yield strength(%)
API 5AC C-75 Type II	3½"O.D.×0.375 in t	100
L-80	〃	95
KO-90SS	〃	95

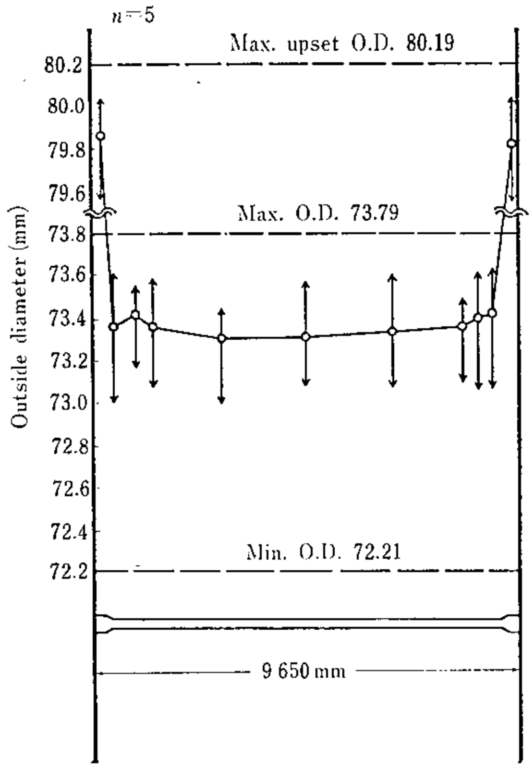


Fig. 12 Outside diameter of $2^7/_8$ in. N-80 upset tubing after quenched at 920°C and tempered at 600°C

The figure indicates that dimensional accuracy has been obtained which fully meets the API standard. As for bending of the pipe, excellent straightness has been obtained by improvements in quenching conditions and the straightening method.

7 Conclusion

Upon its completion in November, 1979, the new quench and temper facility was immediately put into operation and attained, as early as in December, 1979, an excellent operating rate exceeding 80%. Since then it has been continuing to operate smoothly and has delivered excellent products to the world market, thereby receiving very high evaluation from many users.

In prospect of an ever-increasing demand for OCTG in the future, extension of the OCTG producing line including installation of an unpsetter facility is actively in progress in order to supply OTCG of still higher quality.