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DEVELOPMENT OF AUTOMATIC ULTRASONIC TESTING OF WELDS WITH ITS APPROPRIATE DISPLAY SYSTEMS.
DÈVELOPPMENT DE LA CONTRÔLE AUTOMATIQUE ULTRASONORE DES SOUDURES UTILISANT DES SYSTÈMES APPROPRIÉES DE L'EXPOSITION.

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SUMMARY: Four different automatic ultrasonic testing and recording systems have been achieved, contributing to the improvement of quality and reliability of welded structures.

RESUME : Quatre systèmes différentes de la contrôle automatique ultrasonore avec ses enregistreurs convenables ont été accomplies, contribuant à l'amélioration de la qualité et crédibilité des structures soudées.

I. INTRODUCTION

The demand for large welded structures and the safety of these structures is related to variations in the social conditions and the importance of NDI is increasing steadily. However, NDI itself is still a developing technique and increased zeal and effort are required in the future to realize its expectations. Of these, how far the substance of flaws be correctly evaluated by NDI techniques and the establishment of such techniques must be accelerated with regard to deciding the permissible flaw dimensions from fracture mechanics which is in the process of being developed for the evaulation of safety.

In recent years, the development of a method of visually recording and displaying the results of ultrasonic testing, which has replaced the radiographic inspection method as the main flaw detection method of welds, has become urgent. In other words, present ultrasonic flaw detection of welds is primarily manual testing and there are numerous factors governed by the experience and technique of the inspector and there are problems from the standpoints of reproducibility and reliability. The only countermeasure against this is automation of flaw detection. Since the scanning method and its significance are clear, this is not so difficult. The real problems are how to combine scanning suitable for the object to be tested and how to display the results. In conventional ultrasonic testing, emphasis is placed on evaluation centered around the echo amplitude on an A-scope, and efforts toward grasping the substance of flaws which is so necessary are insufficient and development is presently lagging the advances in the field of medicine.

Nippon Steel Corporation is making advances in fabrication and welding of various welded structures, and is also placing emphasis on the development of NDI techniques as a quality and safety guarantee tool and are progressing with research on automation of testing and its appropriate display systems according to the welded objective. The four ultrasonic testing systems which have already been completed and are being utilized in quality control and flaw analysis of welds are outlined heie.

II. OUTLINE OF DEVELOPED TESTING SYSTEMS

II.1. Self-driving automatic testing car

Rationalization and automation of the welding work, especially in shipyards, is being energetically advanced in the construction of the modern shipyard, but we have already cooperated throughout on welding systems for a few shipyards. Of these, there was a demand for the development of a system which permits guarantee of the quality of the parts of large sheet connected by the one-side automatic welding method by ultrasonic testing on the production line and the system was achieved in answering the demand [1].

The most simple method of automation is considered to be the probe holders which can run on guide rails employed in welding work. However, we have developed a system which performs testing automatically by controlling a car mounting all the apparatus and which run by a battery while following the seam contactlessly using the automatic weld tracking system already developed by our company as a method of eliminating power cables and other obstructions and achieving automation. Since the occurence of flaws has been statistically found to be at the bottom half of the bead, a system in which scanning is performed by scanning the two lines from both sides at this important part with only one lateral scan was employed. Furthermore, a simplified recording method in which the output of 4 channels is analog recorded with a single-pen type recorder was employed. For the most serious coupling system in automatic ultrasonic testing, we have succeeded in feeding sufficient and not excessive amount of water (approximately 10 m/l) by the contrivance of an automatic water feeding system from a sealed-type water tank (capacity 20 l). Testing speed is a maximum 5m/min and one seam can be tested within several minutes , the flaws beeing marked. The operation of the test system is shown in Fig. 1.

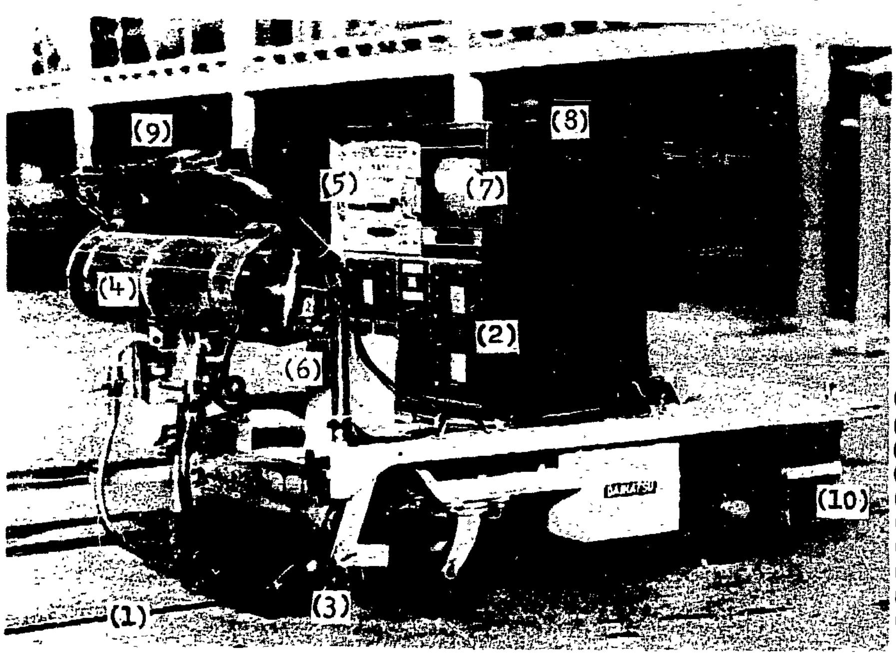
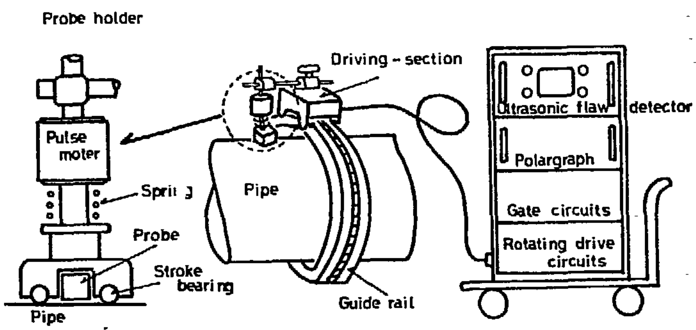


Fig.1 Operating scenes of self-driving ultrasonic testing car.

II.2. Automatic tester of field-welded pipelines

In order to guarantee the safety of pipelines, the importance of NDI of field-welded parts is increasing steadily and , consequently, the trend is toward field-welding which demands ultrasonic testing in addition to conventional radiography. However, at the present time, manual testing is the primary testing method and in order to improve reliability (reproducibility) and work efficiency, studies have been continued and practical prototype testers have been completed based on the judgement that automation of testing is essential [2].

The outline of the equipment is given in Fig.2.



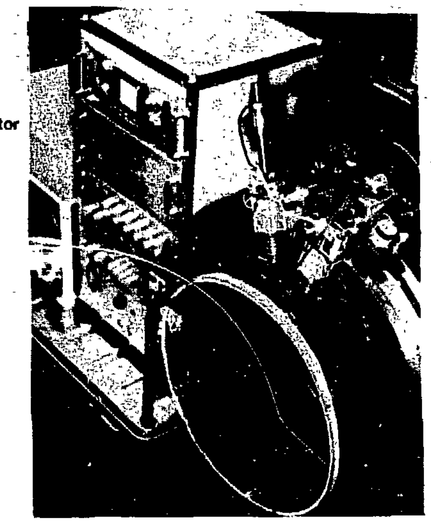


Fig.2 Schematic drawing and operation of automatic ultrasonic flaw detector for pipelines.

A testing system in which testing is performed by four probes in the holders attached to a driving-section travelling on guide rails wrapped around the girth weld with carboxy-methyl cellulose (CMC) painted by brush beforehand as the coupling was employed. In order to facilitate handling, the weight of the guide rail was made light by using aluminum (14.5kg) and measures were taken so that the rail could be easily mounted on and dismounted from the pipe with a hand lever. The probe is in the housing of a gimbal mechanism containing a stroke bearing and a small gap (approximately 0.1mm) is provided between it and the pipe. The probe housing (weight 9kg) is directly coupled to a pulse motor so that rotational scan is performed. This rotational scan is employed for good contact between probes and test pipes, for smooth movement and improved detectability in ultrasonic flaw detection according to the directivity of the weld defect. As a rule there are two probes each at the left and right and the beam path distance is changed and flaw detection is completed in one scan rotation. Flaw detection is performed by electronically switching in one flaw detector and coupling check is also conducted. Recording is carried out by circular graphic display (polargraph) and the position of flaws can be directly viewed. Moreover, the addition of automatic tracking mechanism with a minute displacement to accurately maintain the set beam path distance is also under study.

An example of the test results is given in Fig. 3. This chart is an example of recorded various defects in a 400mmϕ pipe with and without rotational scanning. It can be seen that the detectability is fairly different. Rotational scan is applicable up to a maximum of 480 rev/min (normally 400 rev/min), but variations in the detected

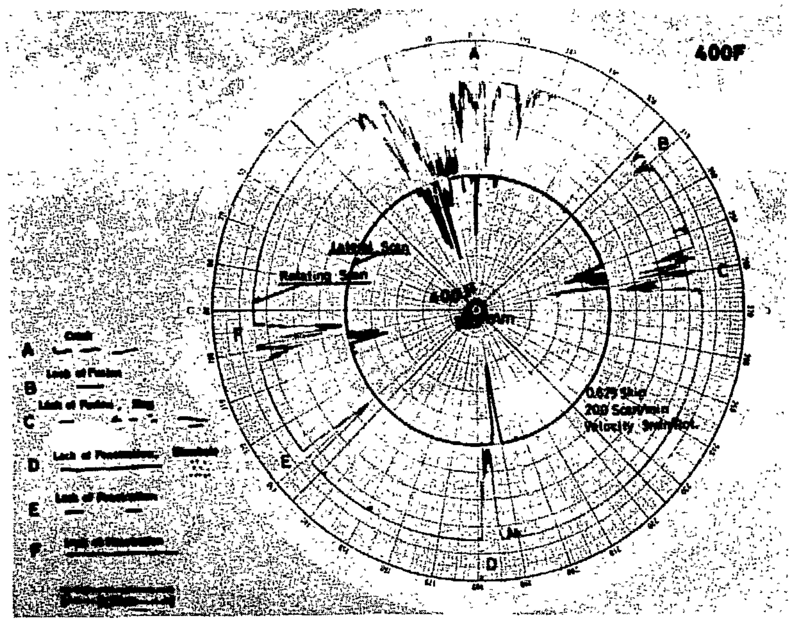


Fig.3 Example of recorded chart of girth weld containing various flaws. (Pipe of 400 mm diam. × 12.7 mm thick.)

value of ±0.5dB pose no practical problems. The same results were obtained at a testing speed of 1m/min, the maximum speed of this system, and a 600mmϕ pipe can be tested in about 3 minutes.

II.3. Fully automatic apparatus with 2-dimensional analogous display

First the type of flaw and then the dimensions (length and height) and location of the flaw related to fracture mechanics are given as known factors from the standpoint of weld flaw evaluation. Concerning judgement of the type of flaw, there are also cases when they can be discriminated to a certain extent by combining flaw detection scannings, but the quantitative and qualitative evaluation of defects is the problem which must be solved in the future. Concerning the dimensions of flaws, comparatively large studies are being conducted on the method of measuring flaw length and preliminary papers have appeared. However, how the actual substance of flaws should be recorded ultrasonically must be studied as much as possible. Therefore, the range which covers the entire weld (including HAZ) is scanned and the result is displayed as a single record figure. However, how recording is to be performed in synchronization with the movement of the ultrasonic probe at this time is a problem. Herein , the development of a system in which records at one to one correspondence can be obtained fully automatically only by initial setting, has been attempted for those objects of which we want to know substances of defects, such as a test piece whose weld defect and strength relation was studied, as precisely as possible.

The block diagram of this system and its operation are shown in Fig. 4. The probes perform square scanning in the directions perpendicular to and parallel to the weld seam and the scan figure is drawn at actual size along with the echo height on an X-Y recorder. That is, the gate of the CRT is shifted in synchronization with the scanning speed of the probe and analog recording is performed with distance-amplitude corrected by means of DAC circuit. Moreover, the pitch of the scan can be arbitrarily changed within the range shown in the figure.

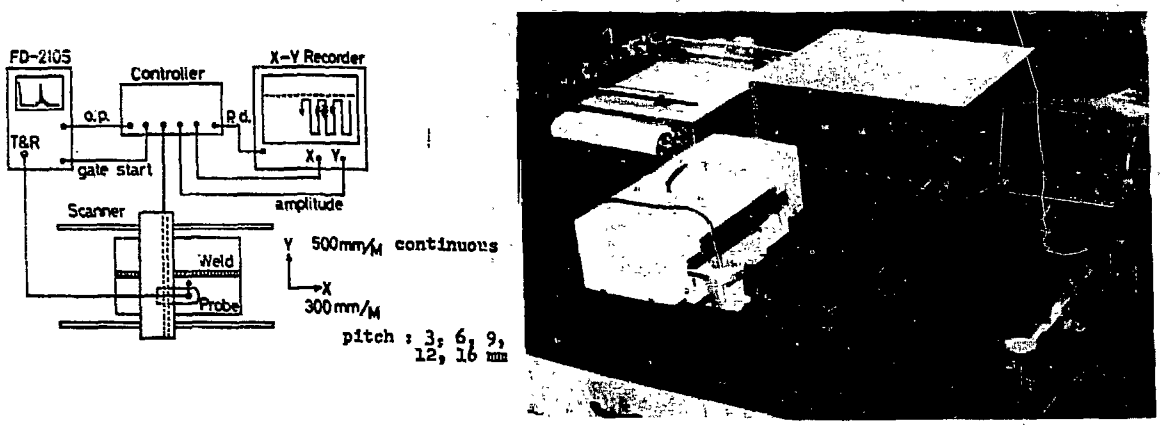


Fig.4 Block diagram and operation of fully automatic flaw detection system with 2-dimentional analogous display.

An example of recording (twice the plate thickness) of incomplete penetration of 9% Ni steel (plate thickness 31mm) and an example of recording of lateral scanning of one line performed in the past are given in Fig. 5.

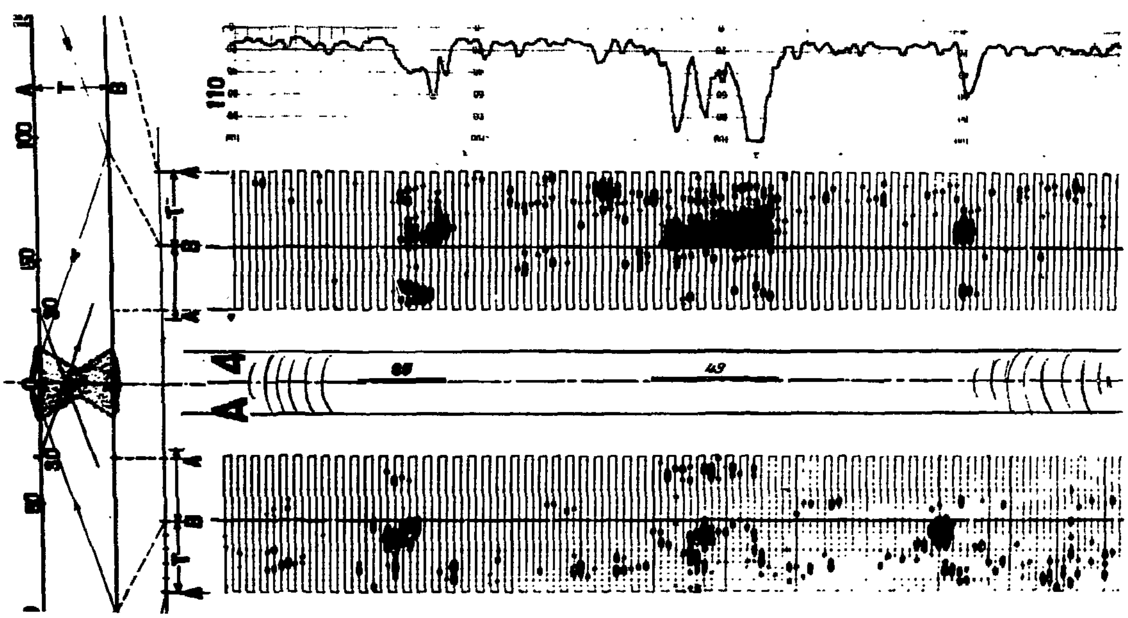


Fig.5 Example of 2-dimensional display chart of weld defects. (incomplete penetration in 9 % Ni steel plate of 31 mm thick)

It is clear that qualitative and quantitative evaluation is fairly distinct [3].

II.4. Quasi 3-dimensional display system

This is basically the same as II.3., but the recording display consists of two views, one being a plane view which corresponds to X-ray film and the other being a cross section view which shows the plate thickness direction distribution of defects. Then, in order to include flaw echo height data, a combination of the method which performs display by a number of plots corresponding to the echo amplitude and a system which performs display on electrical discharge multi pen recording paper with a multiple gate [4] was developed at this time.

The principles of the single probe method of this equipment and the principles applied to the tandem technique are shown in Fig. 6.

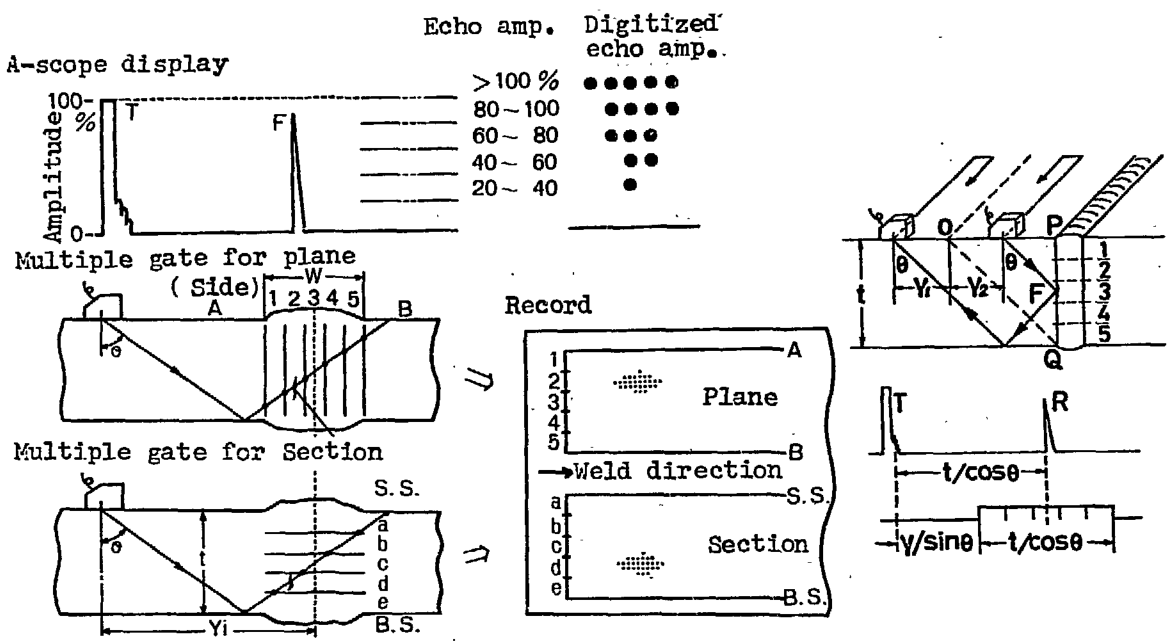


Fig.6 Principle of quasi 3-dimensional display system in case of single probe technique and tandem technique.

An example of flaw recording display with a point plotting X-Y recorder and an electrical discharge pen recorder (120 pens)of a one-side automatic welded plate in shipbuilding material is shown in parallel with an X-ray film in Fig. 7.
Fig. 8 is an example comparing the test results of the narrow gap welded steel plate of 70mm thick by means of the single probe method and tandem technique. That is, the correspondence of the size of the defect recorded by this system and the X-ray or macro etching test is good and, moreover, the position and distribution of the defect can be judged visually. Furthermore, it can be understood that the two methods must be used for detecting thick plate narrow gap welded defects.

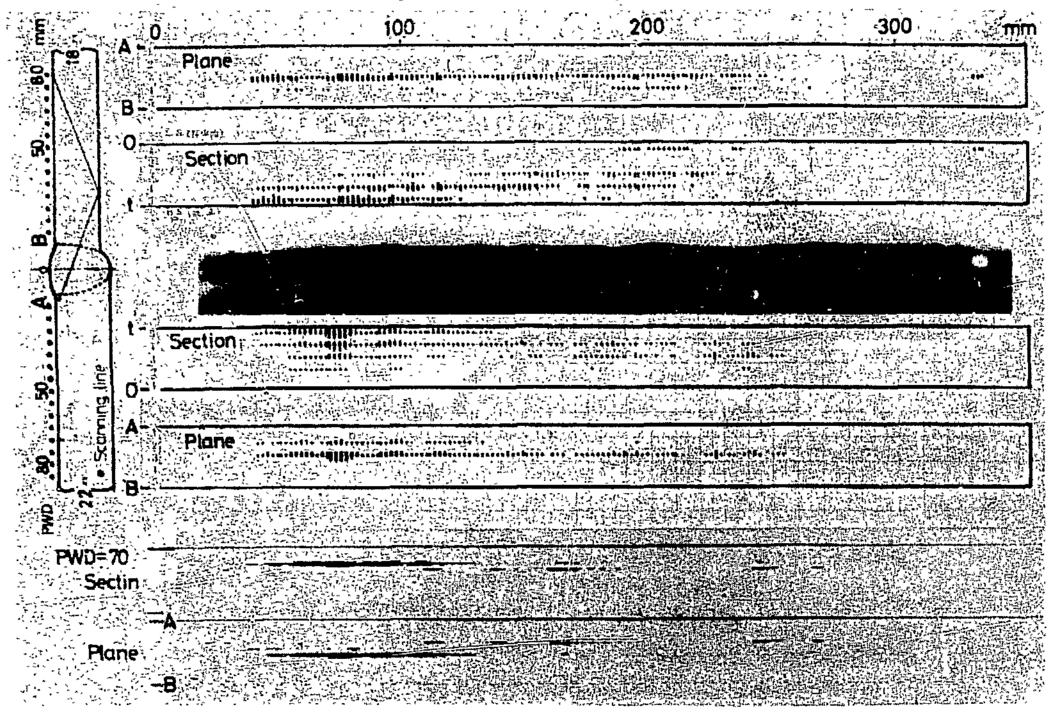


Fig.7 Example of quasi 3-dimentional display chart with point plotting X-Y recorder and electrical discharge pen (120 pens) recorder. (End crack of one-side welded plates)

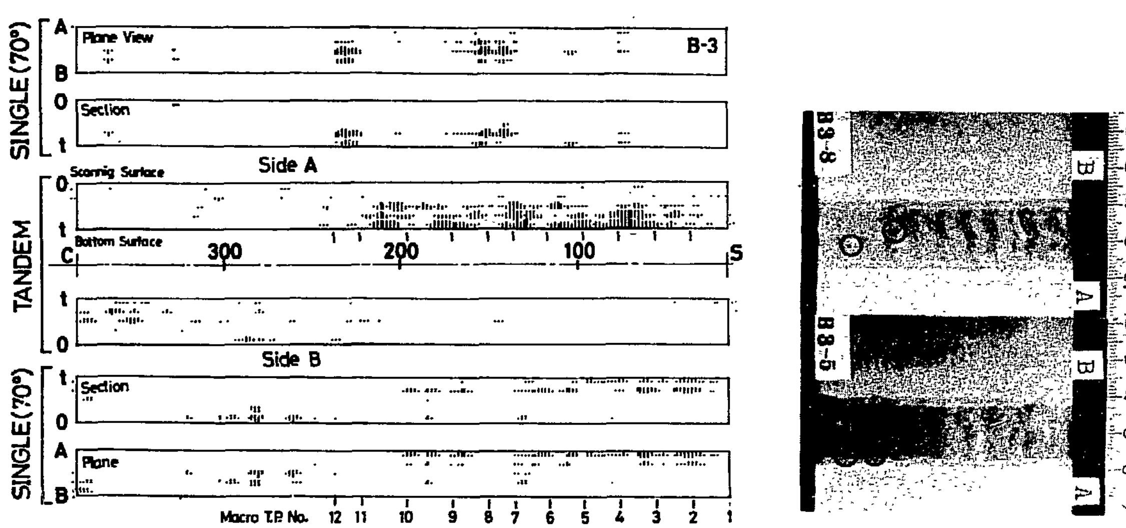


Fig.8 Quasi 3-dimensional display chart of single probe technique and tandem technique for narrow gap welded plate (70 mm) and defect appearance.

III. CONCLUSION

The results achieved with advances in development based on the recognition that the recording and display of the result accompanying the automation of flaw detection is indispensable in order to secure the reliability of ultrasonic testing of welds and its popularization have been described.

In conclusion, the quasi 3-dimensional display system is considered to be the best among the systems which are at present marketed in the world. In the future, the relation between ultrasonic evaluation of various weld defects and its harmfulness should be studied and used as a tool for the safety evaluation of welded structures.

IV. REFERENCES AND NOTES

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