

Introduction of nugget profiler

Make 10, June, 2010

Revision: 27, Mar, 2024

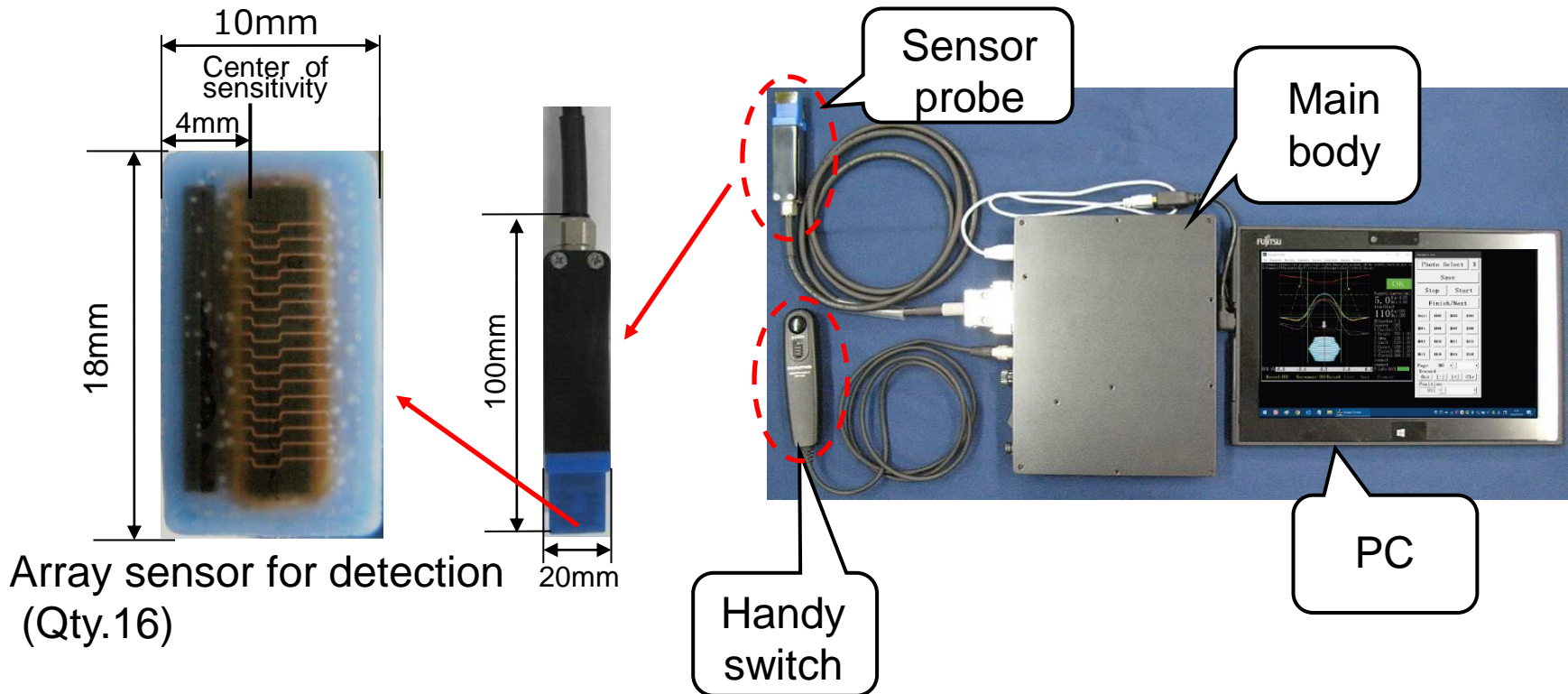


Nippon Kouatsu Electric Co., Ltd.

1 . Equipment composition

This equipment is composed of the following four parts.

- Main body (including PC) : hardware control, function of preparation of exciting voltage pattern.
- Tablet PC : data analysis and man machine IF functions.
- Sensor probe : generating magnetic flux and data acquisition functions.
- Handy switch : trigger function of inspection data recording.

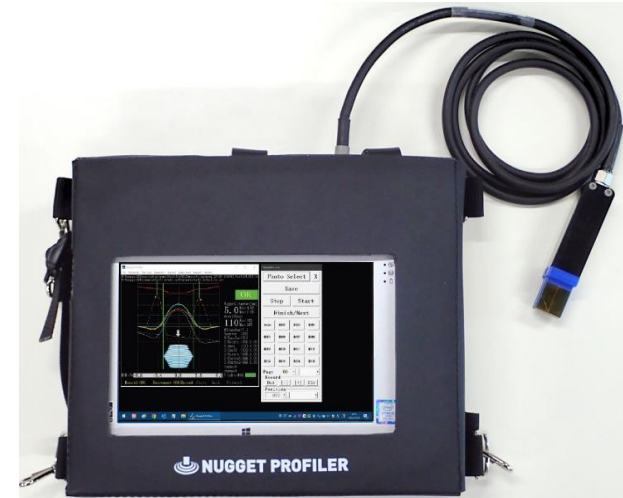


2 . What is a Nugget Profiler?

A machine to inspect spot welds using magnetism.

Features:

1. A nugget can be quantified.
- 2. Needs no gel, water or other medium.**
(Ultrasonic method requires some medium such as gel or water.)
- 3. Can distinguish between nugget and cold-joint (pressure weld).**
4. A sensor is applied lightly and inspected.
5. The inspection speed is around 4 seconds per weld point.
6. Automatically save results to electronic file (traceability).
7. The powered is a battery.



It is an inspection machine
which can quantify the nugget of spot welding easily.

It is possible to check whether welding at the same position maintains constant quality

3 . Comparison with other inspection methods

	Nugget profiler	Ultrasonic type	Driver check (DC) chisel test
The contents of detection	The amount of change of metallographic structure	Distance to the changing point of acoustic impedance	Mechanical strength
A thing to be examined	Only iron	Iron, Nonferrous metal	Iron, Nonferrous metal
Area which can be inspected.	○ The part which does not have a convex around an inspection side (Contact area size is 18x10mm)	◎ : Single type ○ : Array type	△ Area where tool cannot be inserted is impossible.
Quantification of a nugget	○	× : Single type △ : Array type	×
Distinction with Cold-joint	○ (comparison of a value in fixed quantity)	△	○
Damage to the test object	None	Wiping of water and oil is required. =>Metal corrosion	A bend occurs. Tapping-back is necessary. =>Metal fatigue
Inspection of three sheets	△ (Inspection from surface and back side)	○	△ (Inspection from surface and back side)
Application to High-tension steel	○	○	△(Those with a possibility of cracking a welding part.)
Inspection time	○	△	◎
Traceability	○	○	×

4. Change in steel materials

4.1. Change in phase by steel material temperature

Item	Ferrite phase	Austenite	Martensitic phase
SEM image and crystal structure			
Characteristics	<ul style="list-style-type: none"> • Room-temperature crystal structure • Body-centered cubic lattice crystal structure • Soft • Ferromagnetic (strongly attracted by a magnet) = Low magnetic resistance 	<ul style="list-style-type: none"> • High-temperature crystal structure • Face-centered cubic lattice crystal structure • Excellent toughness and ductility • Non-magnetic (not attracted by a magnet) 	<ul style="list-style-type: none"> • Dense needle crystal structure • Body-centered cubic lattice crystal structure • Hard but brittle • Paramagnetic (weakly attracted by a magnet) = High magnetic resistance

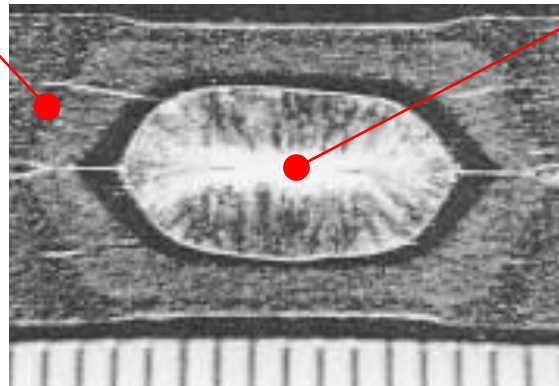


Figure: Photo of weld cross section

5. Inspection theory outline and sensor structure

Know-how

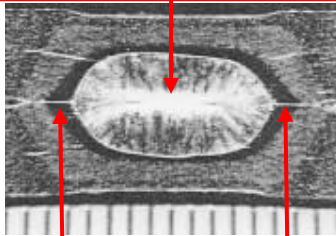
The magnetic sensor contains two types of coils:

- (1) Exciting coil: Serves as an electromagnet, which produces magnetism.
- (2) Sensing coil: Converts produced magnetic flux into electrical signals, which are then sent to the device.

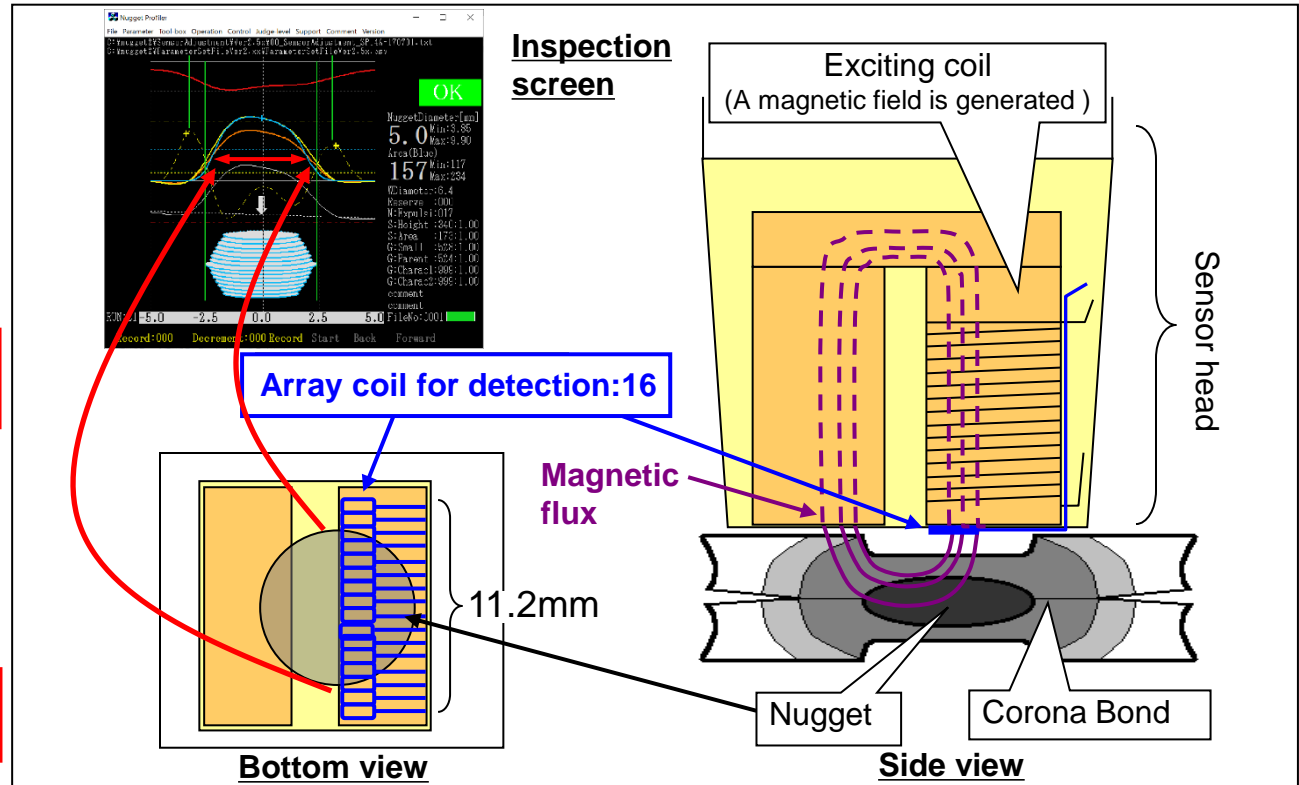
It obtains difference in magnetic resistance between the weld and base metal using 16 detection coils and plots it on a waveform chart.



[Nugget]
Magnetic resistance = High



[Nugget circumference]
Magnetic resistance = Low



Coil requires welded part (indentation) + two pieces on left and right side (base metal part)

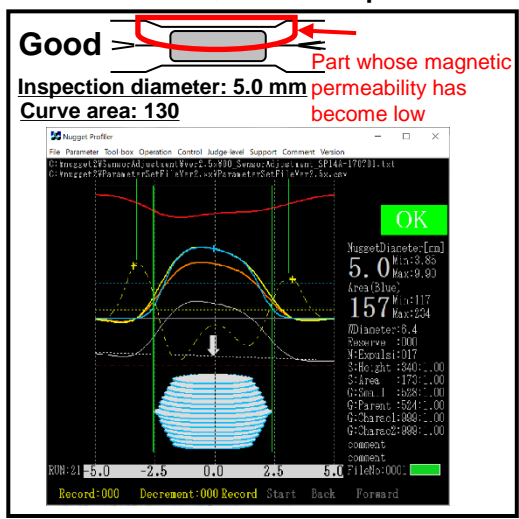
6 Comparison of welding

6.1 Comparison of welding quality and inspection result values

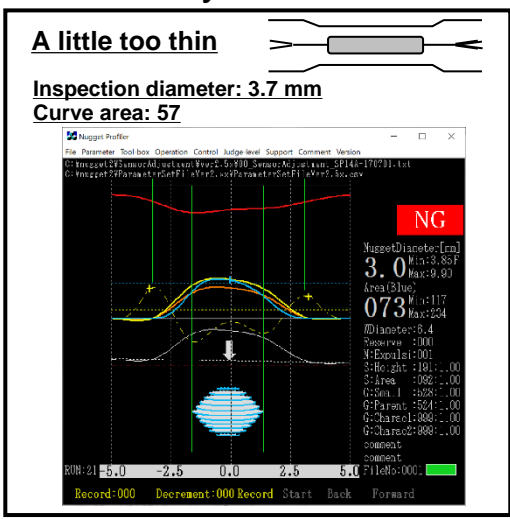
The red circle between the two sheets in the figure below indicates the part whose magnetic permeability has actually become low.

The inspection results show that the obtained curve varies depending on the welding quality.

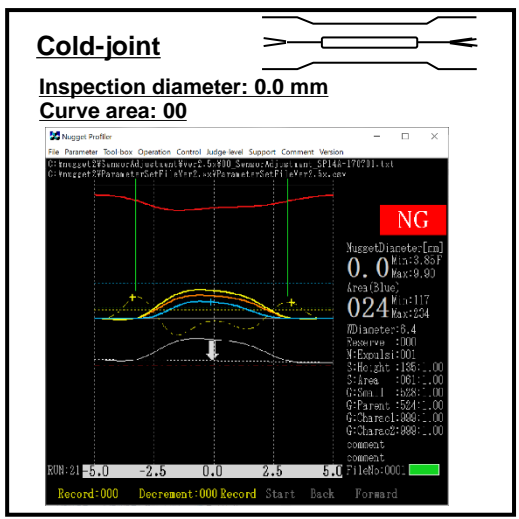
Therefore, it is required to control not only the diameter but also the curve size.



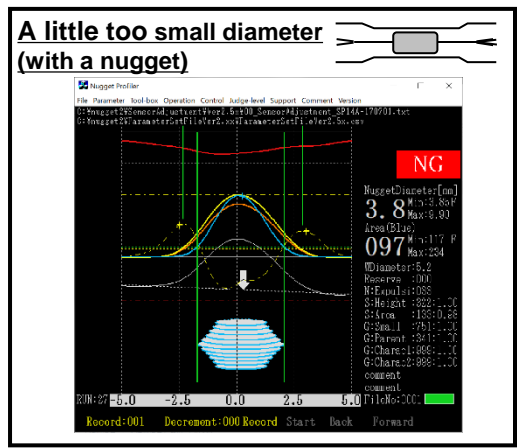
The curve height becomes lower.



The curve height becomes lower.



The curve width becomes narrower.



7 Determination of pressure welds and nuggets

Based on the detected values obtained in the previous page, the analysis result (inspection wave form) is shown below in inspecting the NG product (cold-joint) and OK product (nugget).

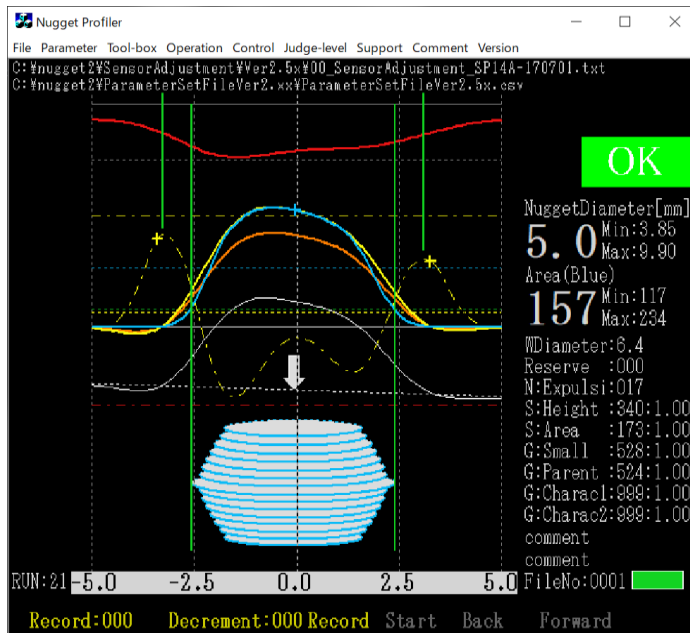
The "difference" at the bottom of the table below is the analysis result. This is the difference value between the yellow wave and orange wave.

- In case of inspecting NG product => The form of blue wave (Difference) is flat or low crest.

- In case of inspecting OK product => The form of blue wave (Difference) is high crest.

* The height of blue wave and the judgment of OK/NG product are set in parameter based on the destruction test.

Inspection screen (in case of inspecting OK product)



* The red line estimates the surface shape.

	OK part (nugget)	NG part (cold-joint)
Macro picture (Cut cross section view)		
Weak magnetic field Inspection screen: orange wave		
Strong magnetic field Inspection screen: yellow wave		
Difference Inspection screen: blue wave *Analysis result		

○Comparison of OK and NG products

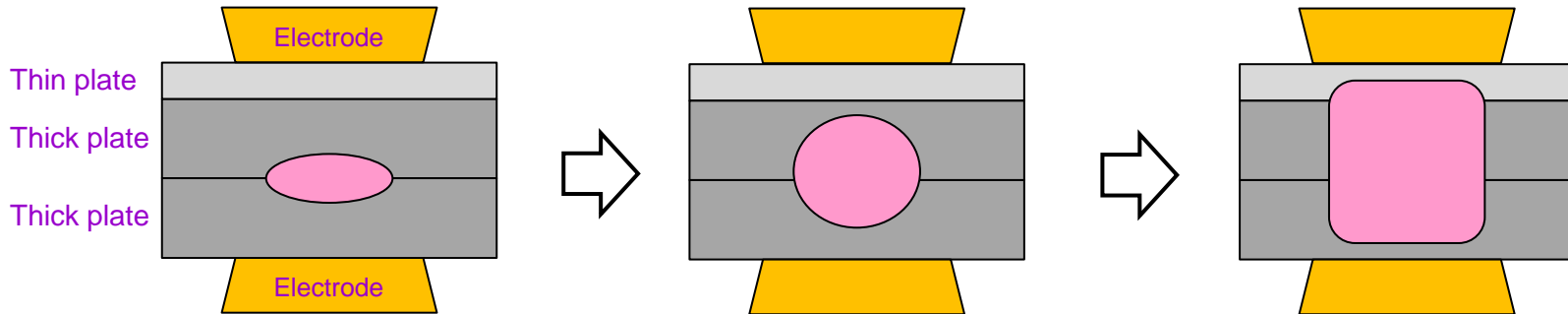
Item	OK	NG
Macro photo		
Status	Melt solidification	Cold joint
Change	Enough change (Martensitic phase)	Inadequate change
magnetic resistance	Slightly low	Low
Inspection waveform	<p style="text-align: center;">High</p>	<p style="text-align: center;">Low</p>

○Items with changing magnetic resistance

Item	S/N	Strong magnetic field	Weak magnetic field
Shape change (bending, pressing, etc.)	Noise	Acquisition	Acquisition
Pressurization (during spot welding)	Noise	Acquisition	Acquisition
Heating (no change in structure)	Noise	Acquisition	Acquisition
Organizational change	Signal	Acquisition	Non-acquisition

8. Supplement: Welding three plates

When welding three plates, a nugget is formed as follows:

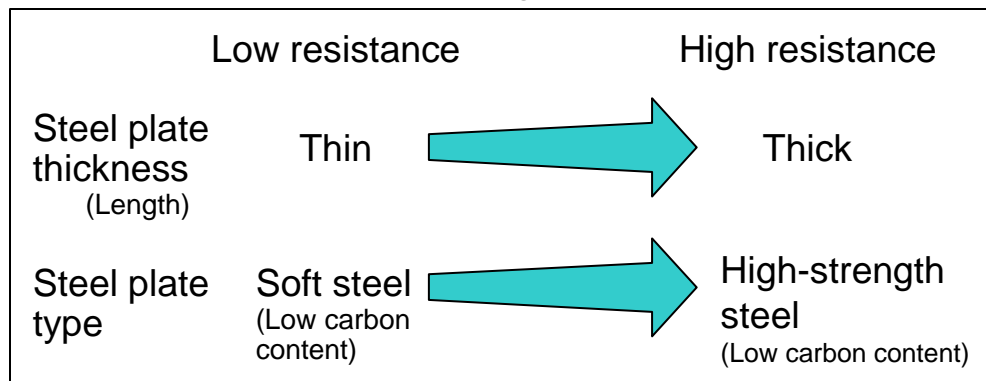


Process of nugget formation when welding three steel plates

- A nugget is first formed between thick plates, and then reaches to an area between thin and thick plates.
 - Between high-strength steel plates, and then between soft steel and high-strength steel plates
- The nugget formation starts from an area with high electric resistance.

Source:
Literature in weld engineering
Volume 35 (2017) No. 1, etc.

○ Electric resistance depending on steel plate thickness and type



$$R = \rho \frac{l}{A}$$

R = Electric resistance
 ρ = Electric resistivity
 l = Length
 A = Sectional area

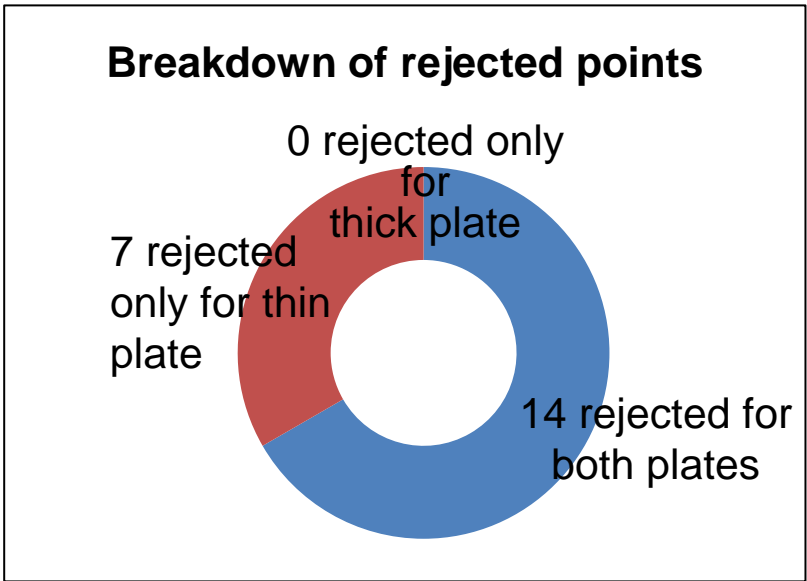
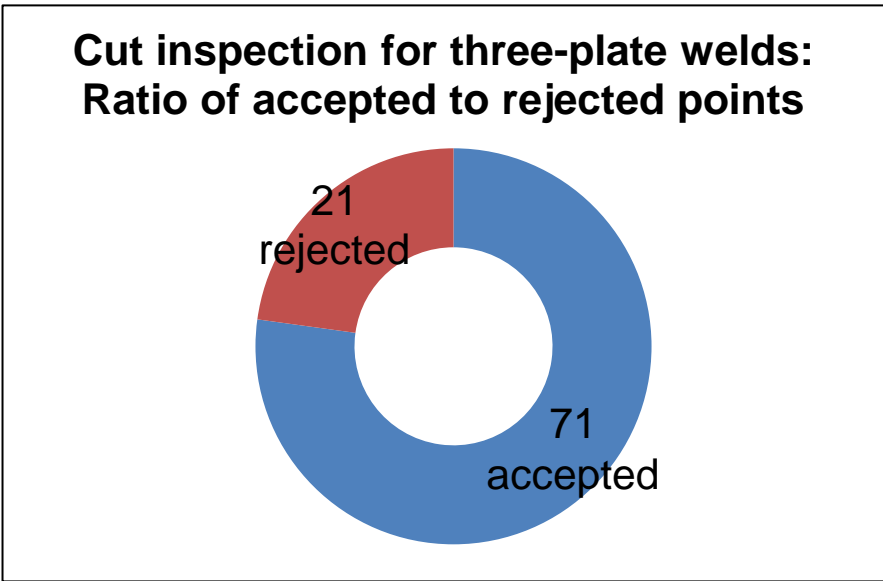
Steel type

Carbon steel (with 0.1% C: equivalent to S10C) ... 14.2
 Carbon steel (with 0.2% C: equivalent to S20C) ... 16.9
 Carbon steel (with 0.4% C: equivalent to S40C) ... 17.1

Electric resistance
(μΩ·cm)

8. Supplement: Welding three plates

We cut and inspected 92 three-plate weld points to check the welding status.



Cut inspection:

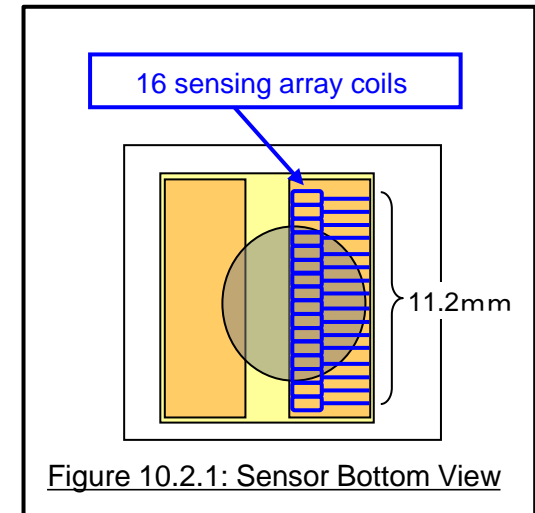
A cut inspection is a method to break a sample actually and measure the weld system.

9. Summary of sensor

The magnetic sensor, which is the main component of Seam Seeker, is energized by direct current blocking (a patented Nippon Kouatsu proprietary technique).

This technique is capable of inducing a much larger electromotive force compared to the conventional alternating current (sine wave) method, providing the following advantages:

1. High performance: Changes in the steel microstructure characteristics (tensile strength, total elongation and hardness) can be detected.
2. Smaller size: 16 array sensors are provided within a space of approximately 11 mm.



10 . Equipment specifications

Model	NPH03A	NPH03B
Dimensions(excluding protrusions)	230(w)×195(D)×50(H)mm	285(w)×205(D)×70(H)mm
Weight	1.91kg	2.32kg
PC(Display size)	Surface Go 10inch	TOUGH PAD 10inch
Welding inspection part	Inspection welding diameter	3 mm to 7 mm [Indentation diameter 8mm or less; Effective sensor width: 11 mm] (The equipment may support the ranges other than the above. Please inquire us.)
	Specimen sheet thickness (Thickness of one inspection side)	0.7 to 2.3 mm (The equipment may support the ranges other than the left. Please inquire us.)
	Materials	Ultra high tensile strength steel plate High tensile strength steel plate Mild steel plate (Two mild steel plates are handled individually.)
	Specimen sheet surface treatment	No treatment, electrogalvanizing, hot-dip galvanizing (As for the aluminizing, please inquire us.)
	Number of specimen mating sheets	Two sheets, three sheets (Inspection from both sides are necessary.)
	Sensor edge material	FR
	PC	Data storage
Setting of inspection condition		Set in the inspection screen. (The setting contents can be stored in the file.)
Judgment method		OK/NG judgment, The diameter of a presumed nugget, Growth degree
Option		Navigation mode, Inspection record management
OS		Windows10
Operation temperature range	5°C to 40°C (41°F to 104°F)	
Operation humidity range	Up to 80%RH (No condensation occurs.)	
Power supply	Two kinds of power supplies selectable. (1) AC85V to 240V, 0.5A (2) Battery (8 size AA Ni-MH battery)	

Please note that the product specifications are subject to change without notice for improvement.

APPENDIX