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Examination of the X-Ray Piping Diagnostic System using EGS4 (Examination of the Film and Iron Rust)

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Abstract

In the X-ray piping diagnosis system, the old pipe is taken X-ray photograph, and from the density of the image of the pipe in the film, the thickness of the pipe is measured using the relationship between the density and the thickness.

First, as for the relationship between the density and the absorbed energy in the film, though good agreement was obtained last year, it is improved more by making energy bin smaller in the calculation of EGS4. The reason of the agreement was researched and understood.

Next, using EGS4, the calculation of the thickness of the steel was carried out which is covered with the rust, using the element analysis result of the rust sample that was collected in the old pipe.

When the thickness changes, the rate for the energy absorption of the steel and the rust layer changes. This relationship between the energy absorption and the thickness of the layers is expressed approximately in the formula. It will be reflected on the diagnosis of the pipe.

1 Introduction

Since its development about ten years ago, the X-ray piping diagnostic system used for renewal construction or planning has been an effective and practical system for determining the number of residual years of old piping, more than 500 actual results. The thickness of the wall in an old pipe is estimated using the relationship between steel thickness and film density. However, the system does not work when the density of the steel changes due to the accumulation of rust. Electron Gamma Shower 4 (EGS4) was used to overcome this problem.

2 X-ray Piping Diagnostic System

2.1 System outline

Fig.1 shows the X-ray piping diagnostic system [1]. Old pipe settled in a building is taken X-ray photograph and the film is observed and evaluated whether it is necessary to be analyzed further or not. When it is judged it is no use to analyze because there is no corrosion or so, then the report will be made. When the analysis is necessary because damage seems to be proceeding, films are put in the analysis device and the residual year is computed through the calculation of the thickness of the pipe.

2.2 Main logic

Main logic of the analytical part is shown in Fig.2. Standard pipe that has four-step thickness is set parallel to the pipe that is inspected. On the developed film four points are selected and the curve which is based on the four points is drawn on the thickness and density plane. Most damaged point is selected and the density is measured, the point of density reaches the point of thickness through the density-thickness curve.

There is a weak point in this system because the influence of the rust appeared on the inner surface of the pipe was neglected, because there was no way to get then. And when I knew the existence of EGS4 three years ago, the trial was started.

3 The Improvement of the Spectrum

3.1 Improvement of the spectrum

Fig.3 shows the new X-ray spectrum and the old spectrum obtained last year, which showed good agreement of the energy absorption and the density of the film. The new one is smooth in its shape, and it is adopted in simulation in this paper.

3.2 The agreement of the density of the film and the energy absorption

As for the agreement of the density of the film and the energy absorption of the film, theoretical verification is delayed. An investigation result is described here to make the reason clear [2].

D is expressed approximately as following under conditions stated underneath.

$$D = \log_{10}(I_0/I) = kaN[1 - \exp(-aF)] \tag{1}$$

N: Number of crystallized particles per unit area of the emulsion
a: average projection area of the crystallized particle
k: coefficient $=\log_{10}$e
F: particle fluence

Conditions

1. The incidence angle of charged particles into the film is perpendicular and the scattering and the absorption in the emulsion is neglected.
2. Average area of a crystallized particle is a.
3. The collision between incident particle and crystallized particle surely yields the latent image.

In case F is small, the right side of the equation (1) becomes

$$1 - exp(-aF) \to aF. \tag{2}$$

Therefore D becomes

$$D = ka^2NF \propto F \propto \text{ Absorbed energy} \tag{3}$$

4 Simulation of the Steel with the Rust

4.1 Analysis of the rust

Table.1 shows the result of analysis of rust in the pipe. The rust was collected from the old pipe removed for renewal in the building. Two kinds of pipe were selected, the pipe for the cooling water of air-conditioning and the pipe for supplying water. The supplying water pipe was preferred. Whether it is the representative of all the supplying water pipe, no one knows, and it isn't a problem here.

4.2 The analysis of the X-ray photograph of the steel with rust

The rust was taken X-ray photograph. Fig.4 shows the arrangement of the materials in taking X-ray photograph, X-ray apparatus was moved every time X-ray photograph was taken to set the incidence angle into the film perpendicular. The rust was gathered on the steel block and was enclosed with the plastic plate.

4.3 The simulation of the steel with rust

Fig.5 shows the thickness vs. density of the rust on the X-ray photograph. Two lines are drawn straight, and it seems 3 mm of the rust on the steel of 15 mm can be discriminated clearly, probably 1 mm can be discriminated.

Fig.6 shows the simulation result of the same model that was taken X-ray photograph, but the thickness of the rust changes. It seems every line clearly separated though very long time it took. It shows, by simulation, the difference of rust thickness in 3 mm can be discriminated.

Fig.7 shows the model set up for the next simulation, upper part means X-ray apparatus surrounding the bulb, and the bottom means the film. In the midst steel plate and rust were set.

Fig.8 shows the energy absorption of the film according to the rust thickness change set on the steel plate.

Fig.9 shows the energy absorption, upper part is for rust and lower part is for steel, the top of each bar is shown flat, but in detail it makes curb as shown in Fig.10. But the difference is so small in comparison with the whole.

4.4 The application of the result of the simulation

The simulation result was obtained in the form of energy absorption in the film that occurs in accordance with the thickness change of the combination of steel and rust. It shows, because energy absorption is proportional to the density of the film, that the relationship between thickness of the steel and the rust has been obtained concerning the density of the film. In case when the thickness of the mixture of the steel and the rust is got, which is expressed equivalently in steel with using the main logic, the thickness is divided into two parts, the steel and the rust, using the relationship between them in Fig.6. This is the subject to make practically in the future system making. When another equation is got concerning the thickness of the rust and the steel, then by solving two equations, the thickness of the steel and the rust can be measured.

5 Summary

Followings are got this time.

- A smoother spectrum curve of the X-ray bulb can be got.
- The rust of pipe was acquired and the element was analyzed.
- The rust was placed on the steel plate and the simulation of them was done. Satisfactory resolution could be got.
- The relationship between the thickness of the mixture of rust and steel was obtained using the energy absorption in the film. It shows the possibility of measuring two material layers when another equation of thickness can be got.

Acknowledgement

The author is very grateful to Prof. Hirayama of KEK (High Energy Research Organization) who assisted me in using EGS4.

References

[1] G. Kajiwara, "X-ray piping diagnostic system", *Journal of Testing and Evaluation* **Vol. 26**(1998)346-351.

[2] G. Kajiwara, "EXAMINATION OF THE X-RAY PIPING DIAGNOSTIC SYSTEM USING EGS4 (IN CASE CONSIDERING SPECTRUM OF X-RAY)", Proceedings of the 8th Egs Users' Meeting in Japan, p71.

[3] A. Sekiguchi, "An introduction to Measuring radiation", Tokyo University Press.

Tanble. 1(1) Specific garavity of rust sample.

Usage of pipe	Specific gravity	Bulk specific gravity
Cooling water	4.08	0.66
Water supply	2.03	0.97

Table 1(2) Result of analysis of rust sample (%).

Usage of pipe	O	Fe	Si	Na	C	S	Zn
Cooling water	33.00	56.50	0.03	<0.01	1.56	0.04	5.51
Water supply	27.00	36.90	1.94	0.06	26.00	0.28	2.2

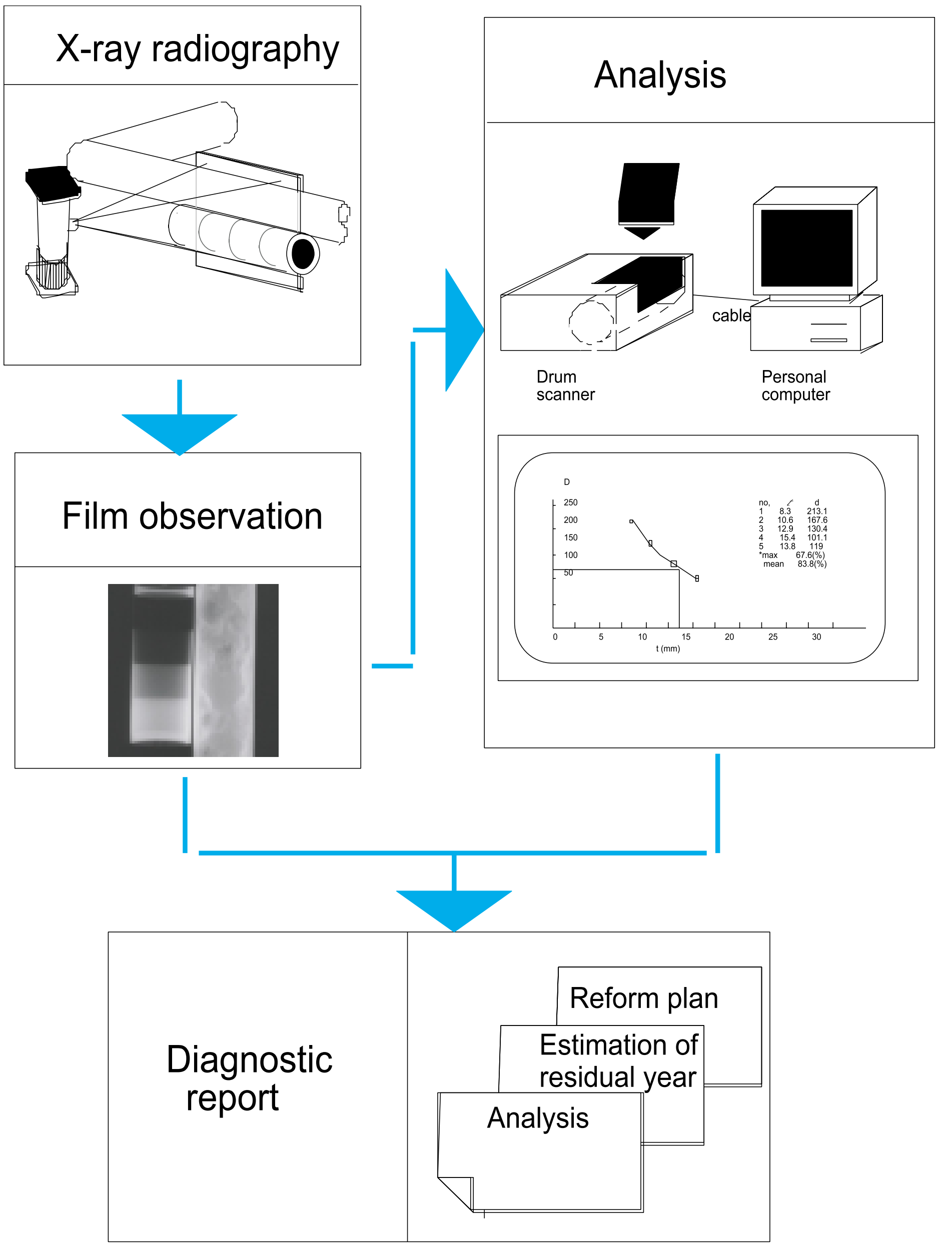
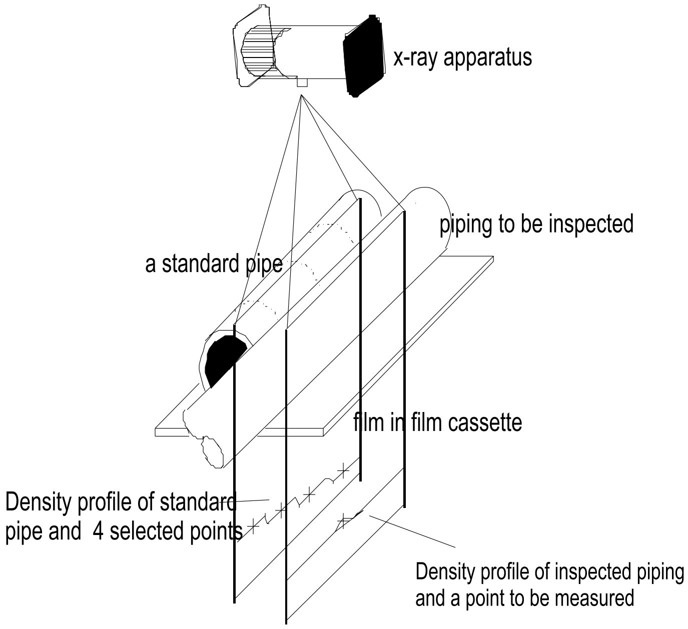
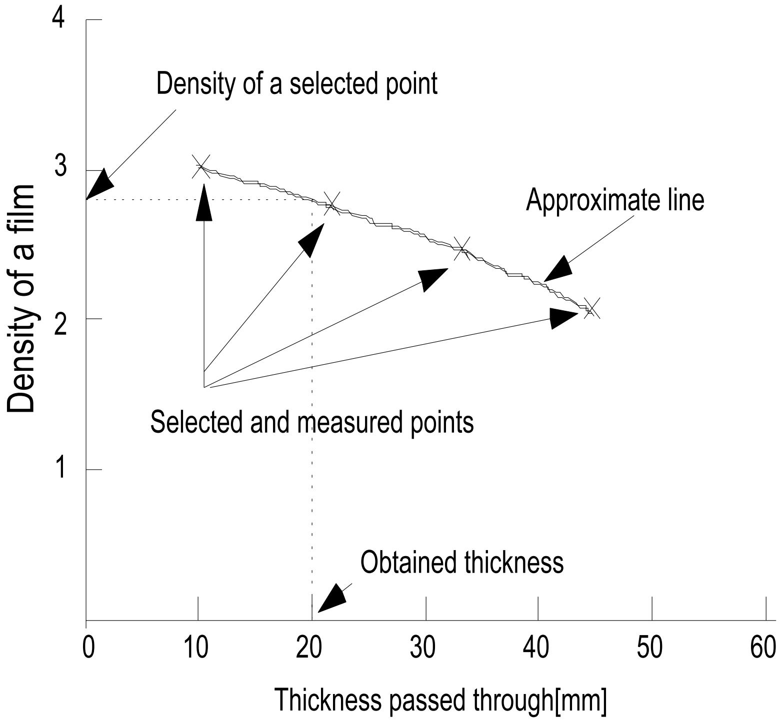


Fig. 1. An outline of X-ray piping diagnostic system



(a) Arrangement of equipment and points on pipes to be measured.



(b) Obtained thickness

Fig. 2. Method of obtaining thickness of corroded piping.

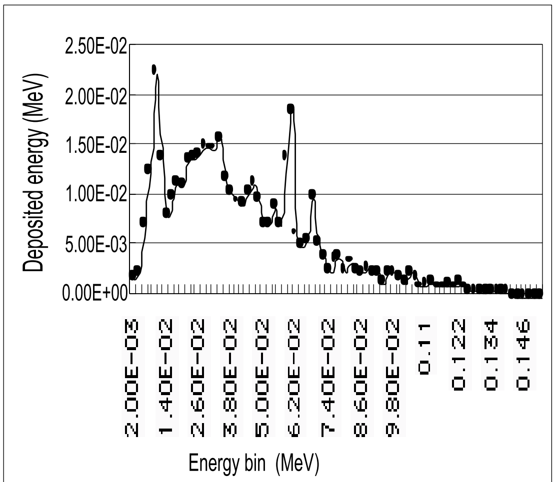


Fig. 3(1). X-ray spectrum at 150 keV (Old)

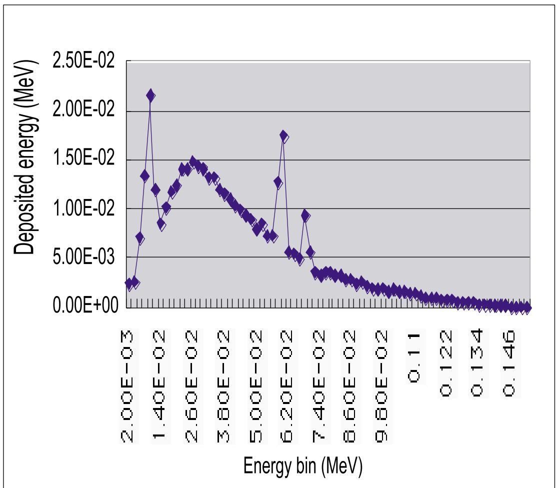


Fig. 3(2). X-ray spectrum at 150 keV (New)

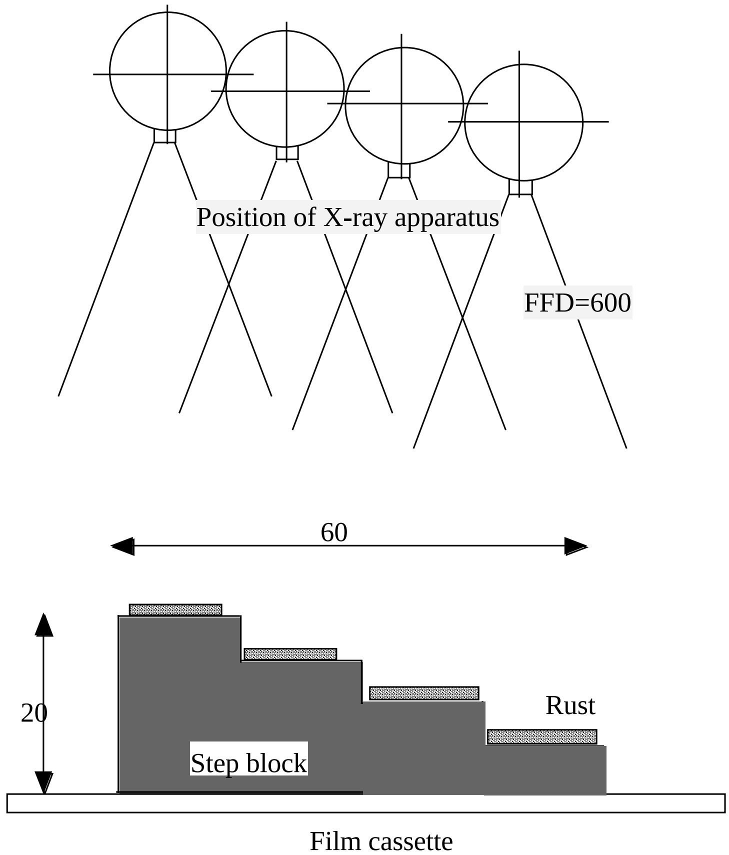


Fig. 4 Arrangement of devices in taking X-ray photograph of rust and steel
unit:mm

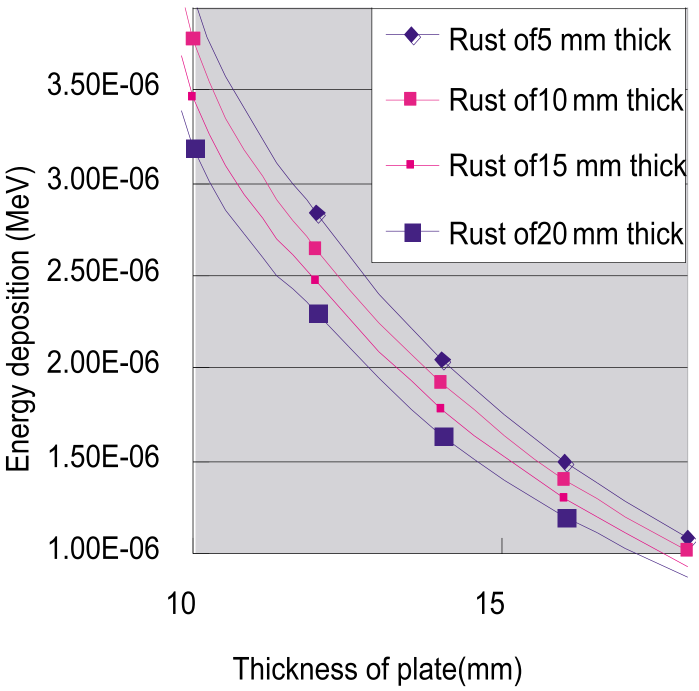


Fig. 6 Simulated energy deposition in steel plate and rust by EGS4 in 500000000 cases.

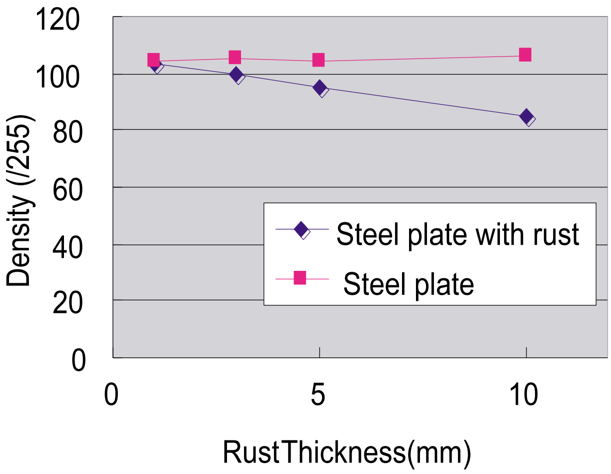
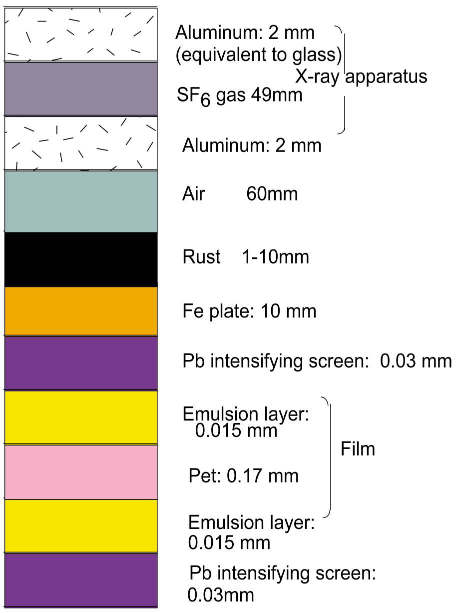
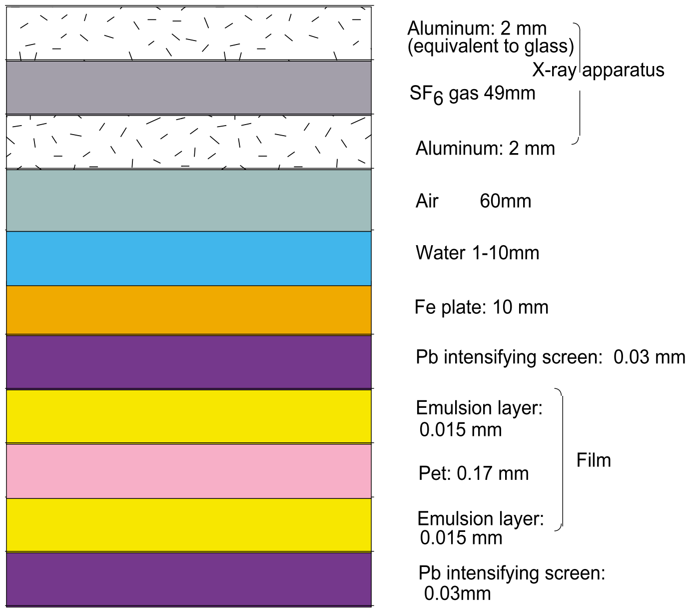


Fig.5 Thickness of the rust placed on the 15 mm steel plate vs. Density of the X-rayed film



Steel and rust.



Fe and Water.

Fig.7 Model structure for simulation .

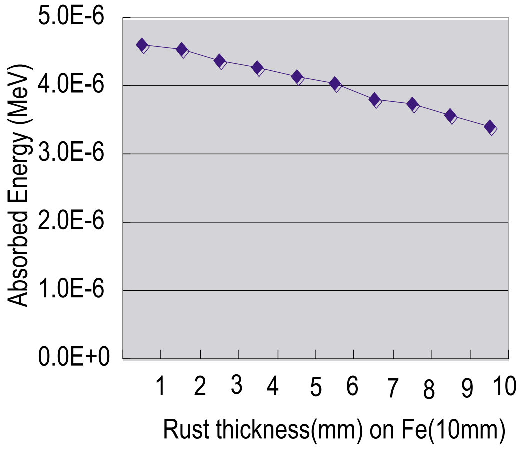


Fig.8 Energy absorption on the film.

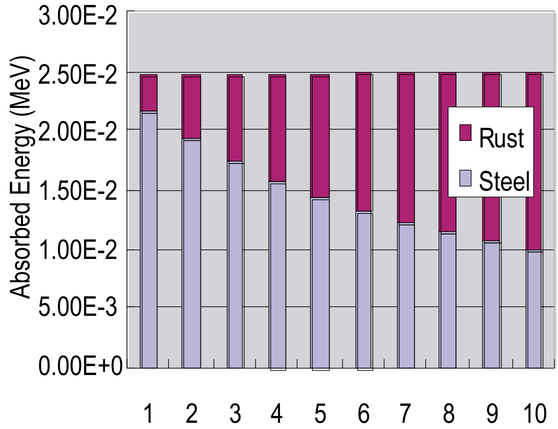


Fig.9 Absorbed energy in Fe and rust.

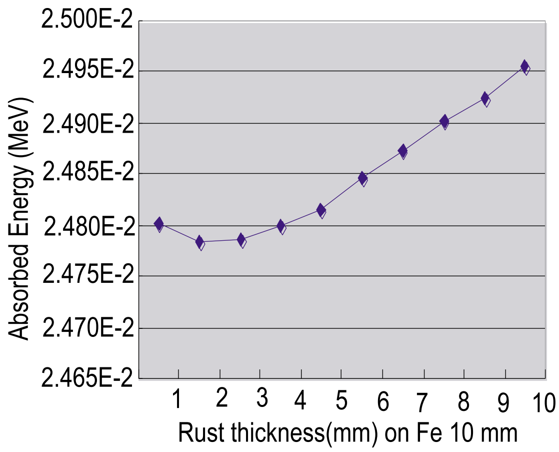


Fig.10 Total energy absorption of Fe and rust.