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JAPAN ASSOCIATION OF CORROSION CONTROL

Pipe Renewal Technology to Prolong Water Supply Pipe Works

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Abstract

We define anti-corrosion technology, for the corrosion problem which formed inside of steel pipes for cold and hot water supply pipes and air-conditioning water pipes by reducing corrosion to passive state magnetite by using NMR(Nuclear Magnetic Resonance) phenomenon, is NMR Method. We present Practical examples which had exerted effect by NMR Method, and review the difference of the effects under the different conditions of pipe works.

KEYWORDS:Corrosion($FeO(OH)$), Passive state, Magnetite(Fe_3O_4), Black body radiation, Electromagnetic wave(micro wave), Paramagnetic resonance, Fe ion content, Weight percentage of magnetite, Improve the clogging, Hydrated electron

1 Introduction (Definition of NMR Method)

Water flows pass through "NMR Method equipment" which is installed outside of steel pipes for cold and hot water supply pipes and air-conditioning water pipes, and receives electromagnetic wave (microwave) of specific wavelength which arises from the combination of blackbody radiation from "NMR Method equipment" and the free electron method laser. The microwave

breaks up clusters of water molecules for about 6 hours, using resonance phenomena of electron and proton of the hydrogen of the water molecule. The smaller-size clusters of water molecules are moved in the pipes by the energy of pressure pumps or the energy of gravity, the water molecules run into each together, and electron detachment(hydrated electron) is induced. the process is similar to the phenomenon in thundercloud. The hydrated electrons reduce corrosion to magnetite, so Fe ion content in the water is reduced. In addition, the hydrated electrons

scale down the blockage of corrosion in the pipes, withhold from erosion by corrosion, and prolong water supply pipe works.

Usually, water supply pipe works are made of iron. Iron (*Fe*) of the pipe is oxidized by oxygen (*O*₂) and water molecule (*H*₂*O*), come to corrosion (*FeO(OH)*), enlarge the volume, and arise the blockage inside pipe. When hydrogen electrons are supplied to the corrosion, water molecules contained the corrosion are detached by hydrogen electrons, and the corrosion is reduced to magnetite which is solid and small-size. So erosion by corrosion of water supply pipe works is stopped and the pipe works are prolonged.

1.1 Basic theory about Black Body Radiation

In the late 19th century, Planck, physicist in Germany, assumed that the energy levels of a harmonic oscillator are equally spaced, not range continuously, as shown in Fig.1^{*1}

This is the basement of blackbody radiation theory.

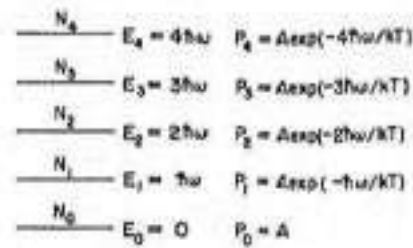


Fig. 41-5. The energy levels of a harmonic oscillator are equally spaced: $E_n = n\hbar\omega$.

$$\begin{cases} h : \text{Planck constant} = 6.62606876 \times 10^{-34} (J \cdot s) \\ \hbar : h/2\pi \end{cases}$$

For the reason, the harmonic oscillator can take up energies only $\hbar\omega$ at a time.

After calculating energy distribution $I(\omega)$ from blackbody radiation on the premise of this theory, we get this formula.

$$I(\omega) = \frac{\hbar\omega^3}{\pi^2 c^2 (e^{\hbar\omega/kT} - 1)} \quad (1)$$

$$\begin{cases} k : \text{Boltzmann constant} = 1.3806503 \times 10^{-23} (J/K) \\ c : \text{Light velocity} = 2.99792458 \times 10^8 (m/s) \end{cases}$$

According to this formula(1), even when frequency ω comes to large enough, the term in denominator $e^{\hbar\omega/kT}$ gets larger exponentially than ω^3 in numerator, and $I(\omega)$ converges. Therefore, distribution of $I(\omega)$ becomes like Fig.2.

*2

*1 Fig.1 is quoted from Reference[5] The Feynman Lectures on Physics Volume I

*2 Fig.2 is quoted from Reference[7] The Feynman Lectures on Physics Volume III

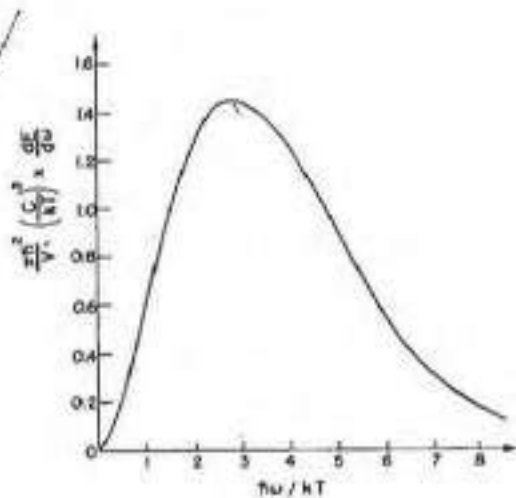


Fig. 4-10. The frequency spectrum of radiation in a cavity in thermal equilibrium, the "blackbody" spectrum.

These formula(1) and Fig.2 are Planck's law of frequency spectrum of blackbody radiation.

1.2 Basic Theory of Electromagnetic Wave (Maxwell Equations)

In 19 century, Maxwell, physicist in England, defined electromagnetic wave as the phenomenon such that electric field and magnetic field proceed together at light velocity, and wrote Maxwell equations which are time-dependent.

$$\begin{cases} \nabla \cdot E = \frac{\rho}{\epsilon_0} \\ \nabla \times E = -\frac{\partial B}{\partial t} \\ \nabla \cdot B = 0 \\ c^2 \nabla \times B = \frac{j}{\epsilon_0} + \frac{\partial E}{\partial t} \end{cases} \quad (2)$$

$$\begin{cases} E : \text{Electric field}(V/m) \\ \rho : \text{Density of electric charge}(C/m^2) \\ \epsilon_0 : \text{Permittivity} \frac{10^7}{4\pi c^2}(F/m) \\ B : \text{Magnetic flux density}(N \cdot m/A) \\ j : \text{Electric current density}(A/m^2) \end{cases}$$

Such a phenomenon that electric field and magnetic field proceeds in space in obedience to these Maxwell equations, is principle of electromagnetic wave. It is shown like Fig.3^{*)}.

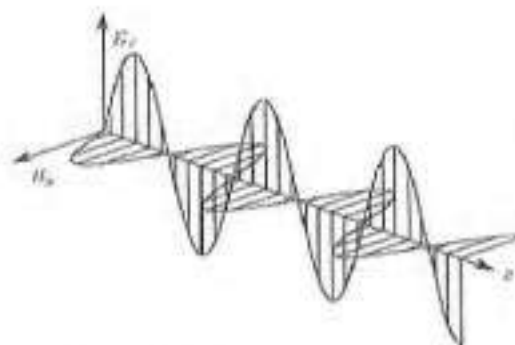


Fig.3 Electromagnetic wave proceeding z direction

1.3 Difference between Nuclear Magnetic Resonance and Paramagnetic Resonance

Normal NMR method is, mainly, used to analyze the structure of organism. Applying magnetic field to sample artificially(usually more than 2 Tesla; more than 20 thousands Gauss), irradiating radiofrequency wave, to

^{*)} Fig.3 is quoted from Reference[12] Electromagnetics.

arise nuclear spin. Measuring and analysing spin echo which comes back from the sample after irradiation finishes, and analysing the structure of the sample from the data of spin echo.

The method of ESR(Electron Spin Resonance) is normally apply high magnetic field to sample. But in some cases that don't apply magnetic field and measure in earth's magnetic field. The electromagnetic wave to irradiate is in the spectrum of microwave, and the method uses 10^3 times larger than normal NMR method, seeing wavelength and frequency.

There is a phenomenon, "The hyperfine structure in hydrogen", which takes absorption and emission of energy by interaction of nuclei and electron. Hydrogen in atomic state has two ground-state energies, which are brought about by interaction of nuclei and electron and differ in minute level. This is such a phenomenon that, when ground-state energy of hydrogen atom is excited from low one to high one, it absorbs specified wavelength of microwave, and when ground-state energy of hydrogen atom goes from high one to low one, it emit the same wavelength of microwave. In astronomy, the phenomenon is normally used for observe astronomic observation. This is the phenomenon which is brought about by interaction of nuclear spin and electronic spin, and this is resonance phenomena which arise

without applying magnetic field.

Nuclear magnetic resonance phenomena by NMR Method equipment is thought to be a phenomenon which is similar to hyperfine structure in hydrogen, in the points that electromagnetic wave of microwave spectrum is irradiated to hydrogen atoms which are contained in water molecules and induces paramagnetic resonance.

1.4 Mechanism to emit single-wavelength by spontaneous emitted radiation (Basic Theory about Spontaneous emission and Laser)

As the method to ingenerate microwave, the above-mentioned blackbody radiation is well known method from ancient days, such as carbonization of wood(more than 800 °C), manufacturing of clay(more than 1200 °C). Using these method, ingenerate electromagnetic wave by blackbody radiation after manufacturing.

However, conventional methods ingenerate electromagnetic wave in wide range wavelength, as the distribution of Fig.2. When wide range wavelength is generated, electromagnetic wave weaken by interaction between different phases.

On the other hand, NMR Method equipment generates single wavelength, using such a similar way which is usually called

laser.

1.4.1 Laser of spontaneous emission

Laser of spontaneous emission generates electromagnetic wave using low energy, but the electromagnetic wave contains various wavelenghtes.⁴⁾

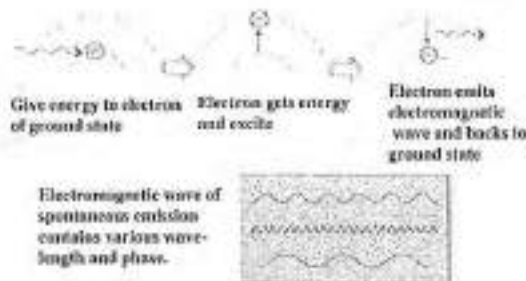


Fig.4. Laser of spontaneous emission

1.4.2 Laser of induced emission

Laser of induced emission generates electromagnetic wave of single wavelength, but this laser requires strong light source, so external energy is necessary.

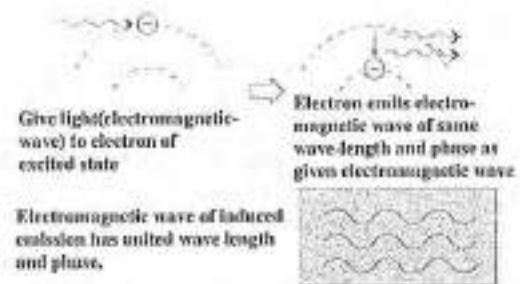


Fig.5. Laser of induced emission

1.4.3 Laser of free electron

There is laser of free electron, which generates electromagnetic wave of single wavelength using blackbody radiation. NMR Method equipment is starting from the idea.

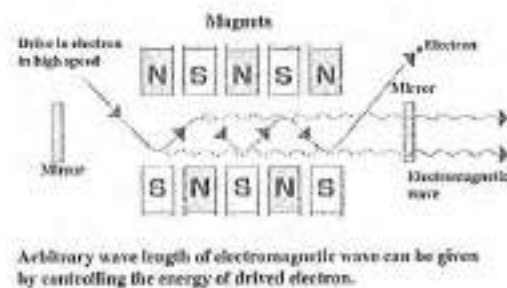


Fig.6. Laser of free electron

1.5 Mechanism of NMR Method equipment

NMR Method equipment, which contains material of blackbody radiation that was made by sintering powder mix of 23 kinds of metals and combines many layers of mag-

⁴⁾ Fig.4~Fig6 are quoted from Reference[10] Illustrations of general knowledge of electromagnetic wave

netic materials with many holes that has the effect of laser of free electron to gather the microwave from the blackbody radiation material to specific wavelength, is installed on the outside of steel pipe.

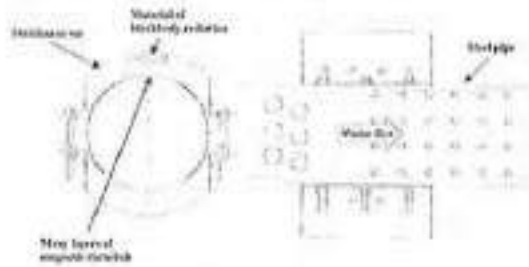


Fig.7. NMR Method equipment

NMR Method equipment bring out in resonance phenomenon using specific wavelength electromagnetic wave (microwave) to nuclei and electron in hydrogen atom of water molecules which go through inside steel pipe. By the resonance phenomenon, condition of clusters of many water molecules changes to the exited state condition of smaller ones. When the water on such condition is moved by the energy of pressure pumps or something, water of exited state condition going through in steel pipe emits electrons, similar to the phenomenon of electric discharge(thunder) which is generated when exited state cluster of water moves in thundercloud. These hydrated electrons changes corrosion($FeO(OH)$) which has occurred in steel pipe to magnetite Fe_3O_4 , stops erosion of corrosion and prolong the life of steel

pipe works.

2 Result

2.1 Corrosion which had formed inside of a water supply steel pipe of one way flow of water, was reduced to magnetite.

2.1.1 The result of measurement of all the Fe ion content in the sample water from the water supply steel pipe in the building of Hokkaido Industrial Research Institute of Japanese Government

The equipment of NMR method (name of the commodity is NMR Pipetector) was installed on the outlet steel pipe (inner diameter size is 100mm) of an elevated tank on the building of Hokkaido Industrial Experimental Laboratory. The sample water which was not used during the night for more than 10 hours, was taken in the morning, and Table 1 and Fig.8 show the result of water examination of the sample water. It indicates that corrosion($FeO(OH)$) has formed in the water supply steel pipe, and it had dissolved into the water during the night. However, all the Fe ion content of the sample water decreased to 0.423mg/l in 2 months after the installation of the equipment. Further-

more, as the result of water examination of the sample water, in 4 months after the installation, all the Fe ion content decreased to 0.262mg/l.

Table 1. Measurement result of all the Fe ion content in the sample water of Hokkaido Industrial Research Institute's building before and after the installation of the equipment.

Time	Quantitative	All Fe ion content (mg/l)
Before installation	0.760	0.760
2 months after installation	0.420	0.420
4 months after installation	0.262	0.262

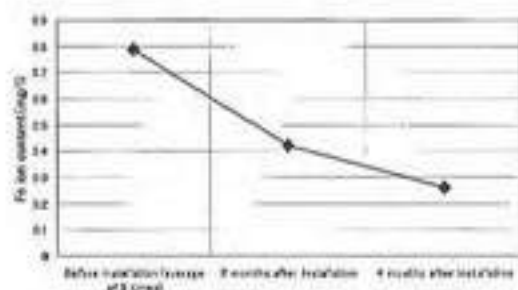


Fig. 8. Changes of all the Fe ion content in the sample water of Hokkaido Industrial Research Institute's building before and after the installation of the equipment.

2.1.2 The result of measurement of all the Fe ion content in the sample water from the water supply steel pipe in the building of Medical Center Hospital of Japanese Red Cross Society.

The equipment of NMR method (name of the commodity is NMR Pipetector) was installed on the outlet steel pipe (inner diameter size is 200mm) of an elevated water tank of the building in the testing area. The sample water which was not used during the night for more than 10 hours, was

taken in the morning from the faucet of the outpatient baby room, and Table 2 and Fig. 9 show the result of the water examination of the sample water. Before the installation of the equipment, the result of the water examination showed that all the Fe ion content was 2.00mg/l. It indicates that corrosion ($FeO(OH)$) had formed in the steel pipe of the water supply of the building, and it had dissolved into the water during the night. However, all the Fe ion content of the sample water decreased to 0.48mg/l in 2 weeks after the installation of the equipment, and all the Fe ion content of the sample water showed 0.49mg/l in 4 weeks after the installation, and then, all the Fe ion content of the sample water decreased to 0.27mg/l in 6 weeks after the installation of the equipment.

Table 2. Measurement result of all the Fe ion content in the sample water of Medical Center Hospital of Japanese Red Cross Society.

Time	Quantitative	All Fe ion content (mg/l)
Before installation	2.00	2.00
2 weeks after installation	0.48	0.48
4 weeks after installation	0.49	0.49
6 weeks after installation	0.27	0.27

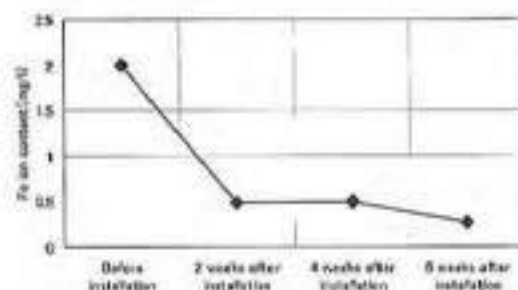


Fig. 9. Changes of all the Fe ion content in the sample water of Medical Center Hospital of Japanese Red Cross Society.

2.2 Corrosion($FeO(OH)$) formed inside of a hot-and-cold water steel pipe of an air conditioner with circulating flow of the same water, was reduced to magnetite(Fe_3O_4).

2.2.1 The result of examination of weight percentage of magnetite(Fe_3O_4) which was existing in the rust formed inside of the hot-and-cold water steel pipe of the air conditioner

The equipment of NMR method (name of the commodity is NMR Pipetector) was installed on the outlet steel pipe (inner diameter size is 200mm) of the hot-and-cold water generating machine, in which all of the hot-and-cold water circulating passes through. Table 3 and Fig.10 show the measurement results of the weight percentage of magnetite(Fe_3O_4) in the rust formed inside of the branch steel pipe (inner diameter size is 80mm). The weight percentage of magnetite(Fe_3O_4) in the surface of the rust which was contacting with water, was 2.2% before the installation of the equipment. However, the weight percentage of magnetite(Fe_3O_4) in the rust increased to 14.4 % in 3 months after the installation of the equipment. Furthermore, the weight percentage of magnetite(Fe_3O_4) increased

to 53.4% in 6 months after the installation, and it increased to 72.9% in 12 months after the installation of the equipment.

Table 3. Measurement result of the weight percentage of the magnetite in the rust of the air-conditioner's steel pipe.

Time	Weight percentage of magnetite (Fe ₃ O ₄) (%)
Before installation	2.2
3 months after installation	14.4
6 months after installation	53.4
12 months after installation	72.9

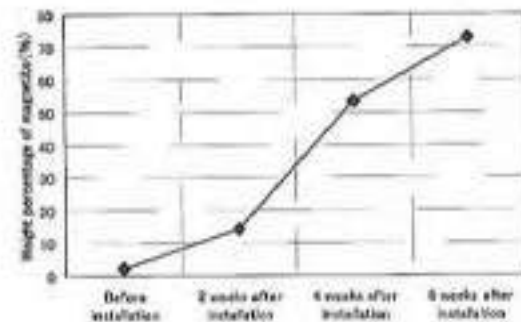


Fig. 10. Changes of the weight percentage of magnetite (Fe_3O_4) in the rust of the air-conditioner's steel pipe of Foundation Wakabadai Administration Center's building.

3 Difference of Effect by Installation Condition

3.1 Difference of Effects by Diameter of the Pipe

We confirmed and demonstrated, by test of stopping erosion of corrosion by reducing corrosion inside steel pipe works to magnetite by NMR method, that NMR Method is available to use under the conditions which inside diameter at the installing point are from 40mm to 200mm.

All 53 results of the test are classified by inside diameters like this table.

Table 4. Test results of 53 cases

Diameter of pipe	Number of cases
40mm and below	4
50mm~100mm	36
125mm~150mm	11
200mm	2
Total	53

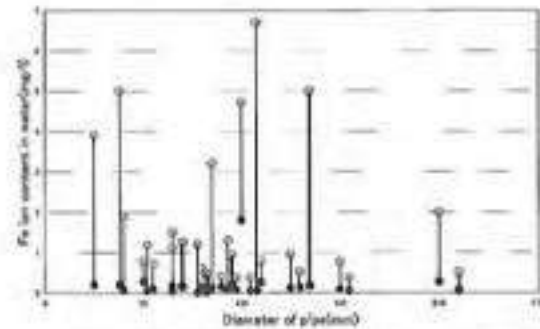


Fig. 11 Relation between diameter of pipe and Fe ion content in water

3.1.1 Relation between Diameter of Pipe and Decrease of Fe Ion content in Water (29 test results)

The relation between diameters of steel pipes and results of decrease of Fe ion content in the water was like this table.

Table 5. Test results of 29 cases

No.	Name of the building	Diameter of pipe (mm)	Fe ion content before installation (mg/l)	Fe ion content after installation (mg/l)
1	White Stone kindergarten	40	3.1	2.5
2	Yokohama City Hall	100	3.1	2.8
3	Yokohama City Hall	100	2.0	1.5
4	White Stone kindergarten	40	3.2	2.5
5	White Stone kindergarten	40	3.2	2.5
6	Yokohama City Hall	100	3.3	2.8
7	Yokohama City Hall	100	3.2	2.5
8	Yokohama City Hall	100	3.2	2.5
9	Yokohama City Hall	100	3.2	2.5
10	Yokohama City Hall	100	3.2	2.5
11	Yokohama City Hall	100	3.2	2.5
12	Yokohama City Hall	100	3.2	2.5
13	Yokohama City Hall	100	3.2	2.5
14	Yokohama City Hall	100	3.2	2.5
15	Yokohama City Hall	100	3.2	2.5
16	Yokohama City Hall	100	3.2	2.5
17	Yokohama City Hall	100	3.2	2.5
18	Yokohama City Hall	100	3.2	2.5
19	Yokohama City Hall	100	3.2	2.5
20	Yokohama City Hall	100	3.2	2.5
21	Yokohama City Hall	100	3.2	2.5
22	Yokohama City Hall	100	3.2	2.5
23	Yokohama City Hall	100	3.2	2.5
24	Yokohama City Hall	100	3.2	2.5
25	Yokohama City Hall	100	3.2	2.5
26	Yokohama City Hall	100	3.2	2.5
27	Yokohama City Hall	100	3.2	2.5
28	Yokohama City Hall	100	3.2	2.5
29	Yokohama City Hall	100	3.2	2.5

We indicated the relation of 29 test results between diameters of steel pipes and Fe ion content in the water on Fig. 11. ○ indicates Fe ion content in the water before installation, and ● indicates Fe ion content after installation.

3.1.2 Relation between Diameter of Pipe and Increase of Weight Percentage of Magnetite (7 test results)

The relation of 7 test results between diameter of steel pipes and results of increase of weight percentage of magnetite was like this table.

Table 6. Test results of 7 cases

No.	Name of the building	Diameter of pipe (mm)	Weight percentage of magnetite before installation (%)	Weight percentage of magnetite after installation (%)
1	White Stone kindergarten	40	0.2	0.2
2	Yokohama City Hall	100	0.2	0.2
3	White Stone kindergarten	40	1.2	1.5
4	Yokohama City Hall	100	3.0	3.3
5	Yokohama City Hall	100	3.0	3.3
6	Yokohama City Hall	100	3.0	3.3
7	White Stone kindergarten	40	20.1	20.3

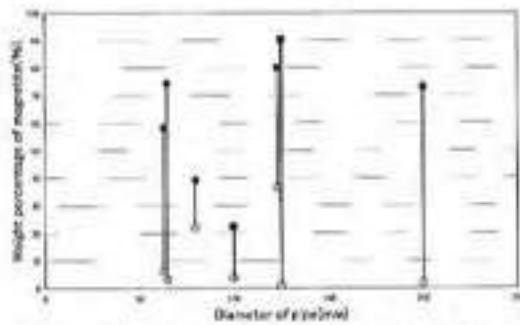


Fig. 12 Relation between diameter of pipe and weight percentage of magnetite

We indicated the relation of 7 test results between diameter of steel pipes and weight percentage of magnetite. ○ indicates weight percentage of magnetite before installation, and ● indicates weight percentage of magnetite after installation.

3.1.3 Relation between Diameter of Pipe and Decrease of Corrosion Blockage in the part of joint (18 test results)

We studied about changing of corrosion to magnetite by looking the decrease of corrosion blockage using the phenomenon that the volume of rust become less than one of tenth when red rust ($FeO(OH)$) is reduced magnetite(Fe_3O_4).

The relation between diameter of pipe and decrease of corrosion blockage in the part of joint.

Table 7. Test results of 18 cases

	Name of the building	Diameter of pipe (mm)	Decrease of corrosion blockage (%)
1	Sensai Bldg construction	80	36.3
2	Yamanashi Bldg construction	100	34.3
3	Shanrei Bldg construction	80	33.6
4	Yamanashi Bldg construction	80	33.3
5	Chubu Bldg construction	100	33.1
6	Seiwa Bldg construction	100	30.7
7	Osaka Bldg construction	100	33.1
8	Osaka Bldg residence	70	33.6
9	Osaka Bldg Bldg construction	100	34.1
10	Chubu Bldg construction	80	33.5
11	Seiwa Bldg construction	100	31.8
12	Seiwa Bldg construction	70	31.1
13	Shizuoka Bldg construction	70	31.3
14	Osaka Bldg construction	70	30.3
15	Osaka Bldg construction	100	30.3
16	Osaka Bldg construction	80	30.7
17	Osaka Bldg construction	100	30.1
18	Osaka Bldg construction	100	30.8

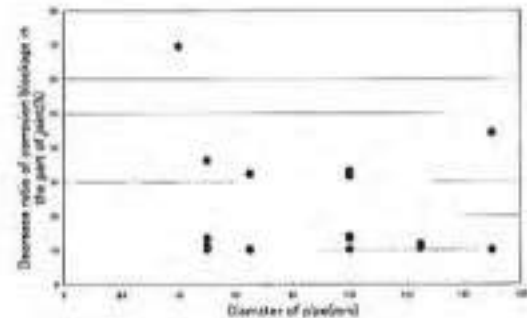


Fig. 13 Relation between diameter of pipe and decrease of corrosion blockage in the part of joint

We indicated the relation of 18 test results between diameter of pipe and decrease of corrosion blockage. We plotted each test results on the graph, whose horizontal axis is diameter of pipe(mm) and vertical axis is decrease ratio of corrosion blockage in the part of joint(%).

3.2 Difference of effect by distance

We confirmed and demonstrated, by test of stopping erosion of corrosion by reducing corrosion inside steel pipe works to magnetite by NMR method, that NMR method is available to use under the conditions which

distance between installation point to effective point is under 150 meter.

All 53 results of the test are classified by distance like this table.

Table 8. Classification for distance

Distance from installation point	Number of cases
Under 10 meters	2
11 meters ~ 20 meters	17
21 meters ~ 30 meters	14
31 meters ~ 40 meters	3
41 meters ~ 50 meters	11
Total of below 50 meters	47
51 meters ~ 100 meters	4
100 meters	2
Total	53

3.2.1 Relation between distance and decrease of Fe ion content in water (29 test results)

Relation between effective distance and decrease of Fe ion content in water was like this table.

Table 9. Test results of 29 cases

No	Name of the building	Distance (m)	Fe ion content before installation (mg/l)	Fe ion content after installation (mg/l)
1	Shake Zonta residential	22	6.1	6.04
2	Y. Watarai Ware in Zonta	24	4.0	1.8
3	Sumino Red Cross Medical Center	25	2.8	0.12
4	Yama University	26	1.2	(Under 0.0)
5	Shimizu National Research Institute	28	0.102	0.102
6	RIKEN SD Agency	28	0.5	(Under 0.0)
7	1st City High School	300	4.25	0.12
8	Yamamoto Jr. School	28	2.8	0.2
9	Shimizu (Industrial) company	31	5.5	0.2
10	Shizuoka University Institute	31	0.1	0.11
11	Shizuoka Sea City Hospital	34	0.27	0.21
12	Shimizu City Middle Primary School	100	3.2	0.12
13	Kajima Blue Stone residential	25	0.23	0.17
14	Chuo University	25	0.25	0.12
15	Shizuoka University	27	1.21	0.22
16	Shizuoka Univ. Lab.	28	0.12	0.11
17	SHIMIZU	28	0.28	0.21
18	Japan Red Cross Association Shimizu	28	0.23	0.22
19	Shizuoka University	28	0.2	0.22
20	Shizuoka University Research Co., Ltd.	28	0.25	0.22
21	Shizuoka University Hospital	28	4.24	0.12
22	Shizuoka University	28	0.25	0.12
23	Shizuoka University	28	0.1	0.21
24	Shizuoka University	28	0.2	0.22
25	Shizuoka University	28	0.2	0.22
26	Shizuoka University	28	0.2	0.22
27	Shizuoka University	28	0.2	0.22
28	Shizuoka University	28	0.2	0.22
29	Shizuoka University	28	0.2	0.22

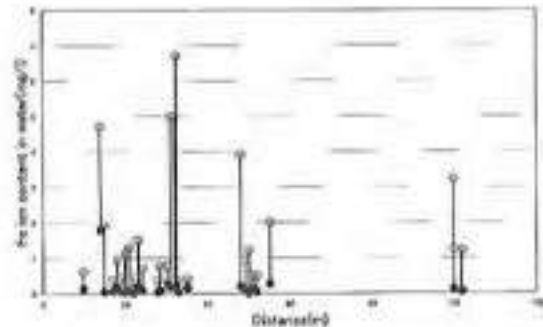


Fig. 14. Relation between distance and Fe ion content in water

We indicated the relation of 29 test results between effective distance and Fe ion content in the water on Fig.14. ○ indicates Fe ion content in the water before installation, and ● indicates Fe ion content after installation.

3.2.2 Relation between Effective distance and Increase of Weight Percent of Magnetite (7 Test Results)

Relation between effective distance and increase of weight percentage of magnetite was like this table.

Table 10. Test results of 7 cases

No	Name of the building	Distance (m)	Weight percentage of magnetite before installation (%)	Weight percentage of magnetite after installation (%)
1	Shake Zonta residential	22	0.2	20.1
2	Shizuoka University	28	0.2	12.2
3	Yama University	26	1.2	16.2
4	Shizuoka University	28	0.2	16.2
5	Shizuoka University	28	0.2	16.2
6	Shizuoka University	28	0.2	16.2
7	Shizuoka University	28	0.2	16.2

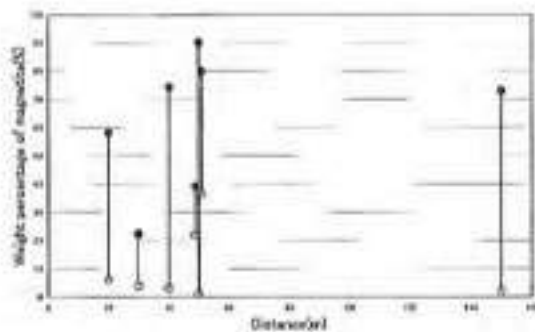


Fig. 15 Relation between distance and weight percentage of magnetite

We indicated the relation of 7 test results between effective distance and weight percentage of magnetite. \circ indicates weight percentage of magnetite before installation, and \bullet indicates weight percentage of magnetite after installation.

3.2.3 Relation between Effective distance and Decrease of Corrosion Blockage in the part of Joint (18 test results)

Relation between effective distance and decrease of corrosion blockage in the part of joint was like this table.

Table 11. Test results of 18 cases

	Name of the building	Distance (m)	Decrease of corrosion blockage (%)
1	İstanbul İhtisatı evleri	28	26.2
2	Yeni Bursa evleri	118	44.3
3	İstanbul Bursa evleri	28	28.9
4	İstanbul evleri	28	32.3
5	Osman Evleri evleri	28	33.1
6	İstanbul evleri	48	31.7
7	İstanbul evleri	20	19.4
8	Osman Evleri evleri	80	18.4
9	İstanbul evleri	30	14.1
10	İstanbul evleri	30	13.5
11	İstanbul evleri	20	11.8
12	İstanbul evleri	20	11.1
13	İstanbul evleri	20	11.3
14	İstanbul evleri	20	10.3
15	İstanbul evleri	10	10.3
16	İstanbul evleri	20	10.3
17	İstanbul evleri	10	10.1
18	İstanbul evleri	50	10.0

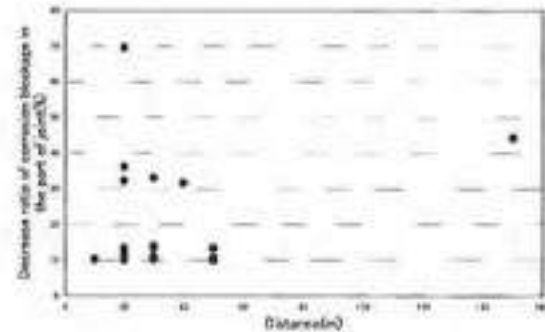


Fig. 16 Relation between distance and decrease of corrosion blockage in the part of joint

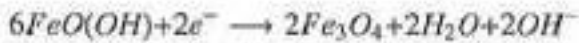
We indicated the relation of 18 test results between effective distance and decrease of corrosion blockage. We plotted each test results on the graph, whose horizontal axis is effective distance(m) and vertical axis is decrease ratio of corrosion blockage in the part of joint(%).

4 Discussion

It is well known that a galvanized steel pipe, which is very popular to use for a water supply pipe and hot-and-cold water pipe of the air-conditioner, easy to lose coated zinc layer inside of the pipe in 4 or 5 years after being built, and the steel inner surface of the pipe is oxidized by water and oxygen that dissolved into the water, and formed corrosion($\text{FeO}(\text{OH})$). This corrosion($\text{FeO}(\text{OH})$) has made a red water problem since old days, because this corrosion($\text{FeO}(\text{OH})$) is easy to dissolve and spread in the water, so all the Fe ion content in the water increased when the water is kept inside of the pipe for

a long time without being used, and it makes the red water problem. However, there was no solution of the corrosion and red water problem until today. This NMR method proved that when the corrosion($FeO(OH)$) was changed to magnetite(Fe_3O_4) which is not solved into the water, the corrosion and red water problem were solved.

The reaction formula of reduction is as follows.



5 Conclusion

In case of all of 29 test of decrease of Fe ion content in water, the corrosion($FeO(OH)$) which had formed in galvanized steel pipe of water supply pipes and dissolved into the water, were decreased step by step after the installation of the equipment of NMR method equipment(name of commodity is NMR Pipetector), and finally all the Fe ion content decreased to the level that there was no corrosion($FeO(OH)$) formed inside of the pipe. It indicated that corrosion($FeO(OH)$) was changed to different type of crystal which is insoluble and difficult to spread into the water. It is very difficult to think about other component or crystal

except for magnetite(Fe_3O_4). This indicates that the reaction of reduction occurred and, at the same time, new form of corrosion($FeO(OH)$) was prevented, because it was proved by continuous decrease of all the Fe ion content in the sample water after the installation of the equipment.

In case of the inside of the hot-and-cold water pipe of the air-conditioner in which the same water was circulated, the corrosion($FeO(OH)$) which formed inside of the steel pipe was reduced to magnetite(Fe_3O_4) by installing NMR method equipment(name of commodity is NMR Pipetector). This was proved by the increase of the weight percentage of magnetite(Fe_3O_4) in the rust formed inside of the steel pipes of all 7 tests after the installation of the equipment.

Using data of all 53 test results, We verified about the relation between diameter of pipe(below 200mm) and decrease of Fe ion content in water, the relation between diameter of pipe and increase of weight percentage of magnetite, and the relation between diameter of pipe and decrease of corrosion blockage in the part of joint. Although there are some spread of data, all 53 test result proved to reduce corrosion in the pipe to passive state magnetite and accomplish stopping corrosion in the pipe. Additionally, we verified also about the relation between effective distance(under 150m) and

decrease of Fe ion content in water, the relation between effective distance and increase of weight percent of magnetite, and the relation between effective distance and decrease of corrosion blockage in the part of jointing. These results proved to reduce corrosion in the pipe to passive state magnetite and accomplish stopping corrosion in the pipe. Accordingly, it was proved that NMR method is expected to be effective to almost all buildings, when flow-rate is more than certain amount to produce hydrated electron to reduce.

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