

# NiDI

Nickel  
Development  
Institute

---

## Application of INCO coloured stainless steel in Japan

---

*by M. Yoshino*

---

---

*NiDI Technical Series No. 13,005*

Contents

	Page
1. Introduction .....	1
2. Production .....	3
3. Properties of Coloured Film (Table 1-10) .....	6
4. Improvement in Colouring Technology .....	6
4-1. Pre-Treatment .....	6
4-2. Precise Colour Control .....	6
4-3. Multi-Colouring .....	7
4-4. Continuous Colouring .....	7
4-5. Hardening .....	8
4-6. Anti-Fingerprint Device .....	9
5. Application Example .....	10
5-1. Roofing/Siding Application (Photo 1-9) .....	10
5-2. Interior Application (Photo 10-22) .....	10
5-3. Exterior Application (Photo 23-26) .....	11
5-4. Bathtub Application (Photo 27-30) .....	11
5-5. Other Applications .....	12
(1) Ornamental Use (Photo 31-33) .....	12
(2) Tableware (Photo 34-35) .....	12
(3) Sign (Photo 36) .....	12
(4) Continuous Coloring (Photo 37-38) .....	12

The material presented herein has been prepared for the general information of the reader and should not be used or relied upon for specific applications without first securing competent advice.

While the material is believed to be technically correct, the Nickel Development Institute, its members, staff, and consultants do not represent or warrant its suitability for any general or specific use and assume no liability or responsibility of any kind in connection with the information herein.

The drawings and photographs are for illustrative purposes only, and their inclusion does not constitute or imply any endorsement of

## 1. Introduction

It has long been known that stainless steels can be coloured by treatment in a hot solution containing chromic and sulfuric acids or in a hot alkaline solution containing oxidizing agents. Many trials have been made for commercializing the above processes. However, coloured film obtained by the above processes was found to be too soft and porous to give adequate wear and abrasion resistance.

In early 1972, INCO announced that it had developed a new colouring process easily applicable to commercial scale production. The process was based on such technical innovations as exploitation of the electrochemical method for precise colour monitoring and incorporation of hardening treatment to improve abrasion resistances. INCO's announcement created a great sensation among the stainless steel industry.

In the same year, a license for the INCO colouring process was granted to Nippon Kinzoku, the first licensee in Japan. Since then, licensees have increased in number as follows:

Nippon Kinzoku Co., Ltd.

3-1, Marunouchi 3-chome, Chiyoda-ku, Tokyo

Nippon Metal Industry Co., Ltd.

1-1, Nishishinjuku 2-chome, Shinjuku-ku, Tokyo

Nippon Steel Corporation

6-3, Otemachi 2-chome, Chiyoda-ku, Tokyo

Takasago Tekko Co., Ltd.

10-24, Osaki 1-chome, Shinagawa-ku, Tokyo

Nippon Yakin Kogyo Co., Ltd.

5-8, Kyobashi 1-chome, Chuo-ku, Tokyo

Nisshin Steel Co., Ltd.

4-1, Marunouchi 3-chome, Chiyoda-ku, Tokyo

Tokyo Metal Art Co., Ltd.

1-3-4, Motogo, Kawaguchi-shi, Saitama Pref.

Morifuji Giken Kogyo Co., Ltd.

7-14, Obata 3-chome, Moriyama-ku, Nagoya

Cleanup Corporation

22-22, Nishinippori 6-chome, Arakawa-ku, Tokyo

After receiving the license, extensive pilot plant tests were performed aimed at quicker commercialization.

In spite of aggressive efforts by the licensees, it was three years until the INCO process for coloured stainless steel made its commercial debut in Japan. It was not until the construction of Reiyukai Shakaden in 1975 that coloured stainless steel became established. Since then the use of coloured stainless steel has increased rapidly in both volume and applications.

In November 1976, sponsored by INCO and its licensees in connection with The Japan Stainless Steel Association, a "Coloured Stainless Steel Information Day" was held in Tokyo to increase awareness of coloured stainless steel among the related industries.

At exhibition hall of the convention, various coloured samples were displayed and technical lectures were given on properties, fabrication and applications of coloured stainless steel.

The convention was well attended by architectural designers, interior/exterior designers, fabricators, metal finishers and press reporters, covering almost all areas of the architectural industries.

The success of the convention was of great help for further promotion of coloured stainless steel in Japan.

Since the first commercial production in 1975, coloured stainless steel has been finding a variety of exterior and interior applications.

Compared with earlier products, current applications are requiring more designed and patterned colours.

To meet customers' requirements which tend to become more and more severe, continuous improvements in colouring technology have been made.

## 2. Production

As shown in Fig.1, commercial production of INCO coloured stainless steel began in 1975 and within two years it recorded production of 170,000 square meters in 1977. This steep increase was due mainly to the application early in 1976 of decorative panels to stainless steel bathtubs.

Stainless steel bathtubs, as shown below, quickly gained currency replacing plastic or enamel coated steel bathtubs. Its market share reached almost 50% in 1982. However, with the change of demand which has tended to shift toward more luxurious materials, stainless steel bathtub market has started to show a gradual decline since 1985.

Bathtub output in Japan ('000 Unit)				
	Stainless	Others (1)	Total	SS Market Share(%)
1970	38	1,540	1,578	2.4
1971	69	2,000	2,069	3.3
1972	130	2,430	2,560	5.1
1973	200	2,890	3,090	6.5
1974	320	1,910	2,230	14.3
1975	510	1,561	2,071	24.6

(Adoption of coloured stainless as decorative panel)

1976	↓ 734	1,514	2,248	32.7
1977	769	1,315	2,048	36.9
1978	828	1,151	1,979	41.8
1979	843	1,160	2,003	42.1
1980	834	1,017	1,851	45.1
1981	738	831	1,569	47.0
1982	744	785	1,529	48.7
1983	720	761	1,481	48.6
1984	682	738	1,420	48.0
1985	623	715	1,338	46.5
1986	607	731	1,338	45.4
1987	562	756	1,318	42.6
1988	515	787	1,302	39.6
1989	437	776	1,213	36.0

(1) Plastic, enamel coated steel and enamel coated cast iron (excluding wooden bathtubs)

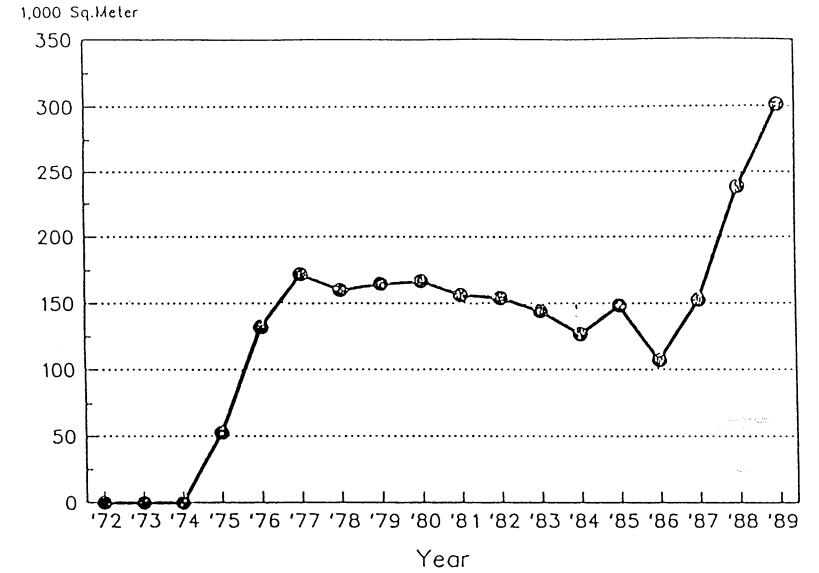


Fig. 1 Output of INCO Coloured Stainless in Japan

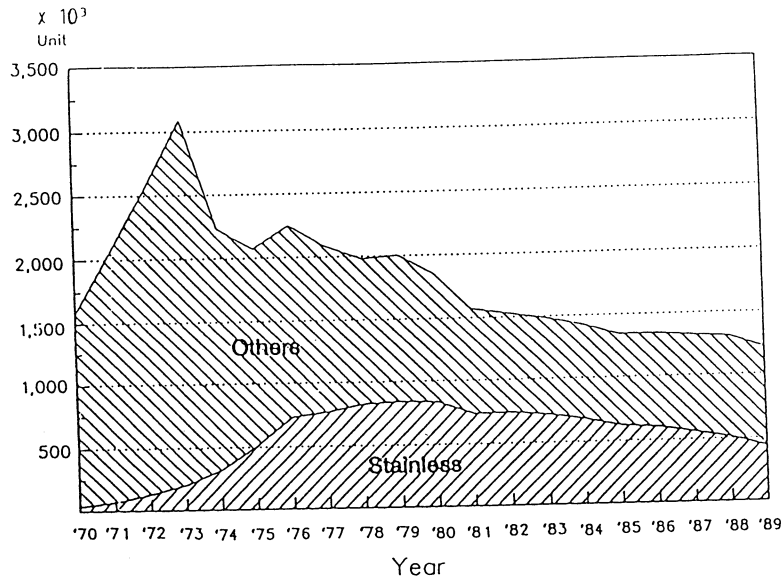


Fig. 2 Bathtub Production in Japan

Supported by the application of stainless steel to bathtubs, production of coloured stainless steel showed a remarkable increase in late 1970's. However, due to the sharp decline in housing construction, output of stainless steel bathtubs declined from 1981 although its market share increased. Since it was the biggest market for coloured stainless steel, production of coloured stainless steel was directly affected. On the other hand, architectural applications have been increasing steadily. This offset the decline in the bathtub market. As a result, production of coloured stainless remained flat for about nine years from 1978 to 1985.

Since 1986 building construction has been very active in most big cities all over Japan. Thanks to this booming architectural market, demand for coloured stainless steel for elevator panels, interior and exterior applications has dramatically increased. This booming situation is continuing. It is fortuitous that the continuous colouring processes has been developed to meet this increasing demand.

### 3. Properties of Coloured Film

Various tests were made to evaluate corrosion, heat and abrasion resistance of coloured stainless steel. As shown in Table 2 - 11, coloured and hardened stainless steel shows as good performance as uncoloured stainless steel or anodized aluminum.

### 4. Improvement in Colouring Technology

Extensive research has been carried out to improve colouring technology based on the INCO process as described below:

#### 4-1. Pretreatment

A slight difference in the surface condition gives detrimental variations in colour. For Bright Annealed Finish Type 304 stainless, the variation is often seen as a stripe pattern. In order to obtain a uniform color, the surface condition should be uniform prior to colouring. For control of the surface conditions the following methods were developed:

For Type 304 stainless steel

Anodic electrolysis in 5-50% H<sub>3</sub>PO<sub>4</sub> solution at 5-50 C and 0.5-3.0 A/dm<sup>2</sup>

(Japanese Pat. Appl. No. 51-47545)

(Japanese Pat. Appl. No. 51-131431)

For Type 430 stainless steel

Anodic electrolysis in Cr<sub>2</sub>O<sub>3</sub> 200 g/l, H<sub>2</sub>SO<sub>4</sub> 200 g/l at 25 C and 1.0 A/dm<sup>2</sup> for 2-3 min.

(Japanese Pat. Appl. No. 51-120939)

#### 4-2. Precise Colour Control

The colour is produced by immersing the stainless steel in a hot solution of chromic and sulfuric acids. The desired colour is obtained by measuring the potential increase from the colour starting point. On a commercial production line, it is not always easy to measure the exact potential of the colour starting point.

In addition, measurement of the potential increase does not always give 100% satisfactory result because fluctuation of the potential at the colour starting point gives a slight variation in colour. To overcome these difficulties in commercial production, the following controls were applied:

- Incorporation of a micro computer system for measuring colour starting potential  
(Japanese Pat. Appl. No. 55-125278)
- Use of an equation reflecting the effect of colour starting potential  
(Japanese Pat. Appl. No. 51-47544)  
(U.S. Pat. No. 4,026,737)

#### 4-3. Multi-Colouring

Multi-colour effect can be obtained by using an appropriate masking method. However, it is not practical for commercial production because masking and stripping of the masking resist are costly and, in addition, colouring should be repeated according to the number of colours required.

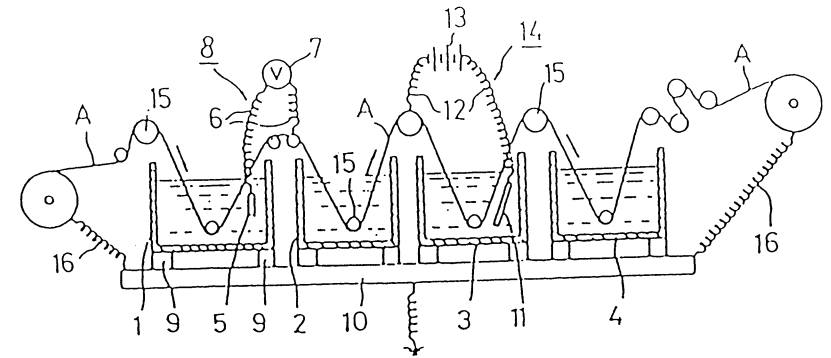
Processes recently developed are based on the fact that colour effect is different depending on surface finishes. In these processes, prior to colouring, stainless is pretreated chemically and/or mechanically to give different surface finishes according to the pattern required. Then, multi-colouring is obtained by one immersion in the solution.

(Japanese Pat. Appl. No. 52-69828)

(Japanese Pat. Appl. No. 51-30545)

#### 4-4. Continuous Colouring

For productivity increase, continuous colouring processes have been developed recently. The following is a schematic example of the continuous colouring process.



- where, A: Stainless coil
- 1: Colouring tank
  - 2: Water rinsing tank
  - 3: Hardening tank
  - 4: Water rinsing tank
  - 5: Reference electrode
  - 6: Lead wire
  - 7: Potentiometer
  - 8: Potential measurement unit
  - 9: Insulation
  - 10: Foundation
  - 11: Anode
  - 12: Lead wire
  - 13: Direct current source
  - 14: Cathodic electrolysis system
  - 15: Guide roll
  - 16: Earthing

#### 4-5. Hardening

Aiming at further increase of abrasion resistance, addition of selenium ions (Japanese Pat. Appl. No. 52-139634) or molybdenum ions (Japanese pat. Appl. No.

50-15750) into the hardening solution were tried, but were not commercially applied.

#### 4-6. Anti-Fingerprint Device

One of the problems with decorative use of colour stainless steel is the fingerprint. To be free from this problem, coating with silicon oil plastic film were tried but none was successful because the thin film coating affects the colour tone. Vacuum spattering of fluorides or silicates (Japanese Pat. Appl. No. 52-44740) was also tried but this is costly and also changes the original colour tone. Currently, use of fluorocarbon resin is being tried. Since very thin coating thickness is obtainable with the resin, the effect on colour tone is minimal compared with other coating processes.

## 5. Application Example

### 5-1. Roofing/Siding Application

There is a steady demand for coloured stainless steel for roofing/siding applications.

INCO coloured stainless steel gives not only the economy of free maintenance but also special colour effects which cannot be obtained by other materials.

Photo 1 shows black coloured sidings of "Reiyukai Shakaden" which was constructed in 1975 and still is the biggest single application using 18,500 m<sup>2</sup> of black coloured stainless panels for roofings and sidings.

Photo 2 shows blue coloured stainless roofing of a gymnasium.

Photos 3 and 4 show applications of blue coloured roofing.

Photo 5 shows blue coloured roofing used by a golf course in Chiba Prefecture. Black coloured Hair-line finish is used for the roofing of an entrance hall (Photo 6).

Photos 7 to 9 show use of fabricated and patterned coloured stainless roofing.

### 5-2. Interior Application

Herein INCO colour is finding a variety of applications. Rather than single colour, highly designed or patterned colour effects are used since uniqueness or individuality is needed in this application.

Photo 10 shows gold coloured stainless ceiling panels at the meeting Hall of "Reiyukai Shakaden", where 4,800 m<sup>2</sup> of panels are used.

Panels were coloured first, then, press-formed. Shown in Photo 11 is also the ceiling of a meeting hall of "Shitennoji". In the multi-colour ceiling, Sanskrit relating to buddhism is designed. The multi-colour effects are obtained by one colouring process.

Photo 12 shows side wall of the "Shitennoji" meeting hall. After blue colouring, patterns were given to the panels by etching.

A special three dimensional effect is obtained by the combination of colouring and etching.

Photo 13 shows a ceiling application in a lobby in a company club. Panels were blue coloured and partly stripped to give a special effect.

Photo 14 shows a successful use of red colour on a hair-line finish stainless, which gives a graceful and composed atmosphere.

As can be seen in Photo 15, combination of black colour on a hair-line finish and blue colour with etched BA finish panels give a subtle effect. Gold colour on a mirror polished sheet gives a specially gorgeous effect (Photo 16).

Photo 17 shows a rainbow effect obtained by arranging the colour tones.

Photo 18 shows the inside of the Coloured Stainless Exhibition House which was recently constructed for demonstration of coloured stainless, where every possible application is displayed.

Use of coloured stainless steel for elevator surrounding applications is increasing. In this application, finely designed patterns with multi-colours and etching effects are required as shown in Photos 19 - 22.

### 5-3. Exterior Application

Because of the character of this application, multi-colour is rarely used.

Photo 23 shows an application of gold colour on hair-line finish. Photos 24 and 25 show a gold colour on mirror polished stainless.

Use of red colour on hair-line finish is shown in Photo 26. As can be seen in these photos, hair-line has the effect of producing subdued tones.

### 5-4. Bathtub Application

As was mentioned the development of the stainless bathtub greatly contributed to the expansion of coloured stainless in Japan.

Use of coloured stainless in this application was not dominant as in 1970's but continues to provide a large market. Currently the bathtub application contributed about 25% of the total coloured stainless market whereas it was more than 60% during the peak period from 1978 to 1985.

Because of its nature of massproduction, silk screen and photo-etching techniques are fully employed in this application.

Some examples are shown in Photos 27-30. Photo 27 shows a blue coloured panel with flower pattern by etching. The combination with etching gives effective variations in colour.

Photo 28 shows an example of simpler design. The dark blue colour is accented attractively by gold colour line.

Multicolour examples are given in Photos 29 and 30. The multicolour effect is obtained by single immersion in the solution.

### 5-5. Other Applications

#### (1) Ornamental use

Coloured stainless is used for purely ornamental purposes. Photos 31 and 32 show picture plaques of coloured stainless exploiting highly sophisticated multi-colouring techniques. Photo 33 shows an ornamental display composed of stainless panels with various colours.

#### (2) Tableware

Coloured stainless is also used for such household applications as tableware, compotes, coasters etc.

Photo 34 shows a gift set of spoon and fork.

Photo 35 shows compotes.

The thread pattern etching gives an attractive colour variations. Press forming was made after colouring.

#### (3) Sign

Though the quantity is very small at present, stainless signs are used here and there such as at shops, stations, offices, etc. An example is given in Photo 36, which uses black colour with etched letters.

#### (4) Continuous colouring

With the development of the continuous colouring process, mass-production of coil colouring is now applicable commercially. Efforts are being made to develop a new market for coil products. Items considered most promising are angles and sections for housing applications. Shown in Photos 37 and 38 are coloured stainless coils and their formed products.



Table 1. Copper Accelerated Acid Salt Spray Test (CASS)

ASTM B368-68 (520 hrs)

Test Material		* Corrosion Rating			Colour
Metal	Finish	Uncoloured	Coloured	Coloured & Hardened	
Type 304	2B	○	△	◎	Gold
Type 304	BA	○	△	◎	Green
Type 304	Buffed	○	△	◎	Blue
Type 430	Buffed	△	X	◎	Blue
A1-1100	D-300	-	XX	-	Bronze
A1-1100	Asada Process	-	XX	-	Bronze

\* ◎ very slight corrosion  
 ○ No change  
 △ ↓  
 X ↓  
 XX severe corrosion

(Nippon Steel Data)

Table 2. Salt Spray Test

JIS Z2371-63 (1,000 hrs)

Test Material	Treatment	Appearance after Test
Type 304 BA	Uncoloured	No change
	Coloured & Hardened	No change
A1-1100	D-300	Slight corrosion
	Asada Process	Slight corrosion

NaCl 5 ± 1%  
 pH < 6.5  
 Temp 35 ± 2°C  
 Spray Pressure 0.7 - 1.8 kg/cm<sup>2</sup>

(Nippon Steel Data)

Table 3. Dry & Wet SO<sub>2</sub> Atmospheric Corrosion Test

(200 hrs)

Test Material		* Corrosion Rating			Colour
Metal	Finish	Uncoloured	Coloured	Coloured & Hardened	
Type 304	BA	△	-	○	Blue
Type 304	Buffed	△	-	○	Blue, Gold, Red
A1-1100	D-300		△-X		Bronze
A1-1100	Asada Process		△-X		Bronze

\* Corrosion Rating

○ No change  
 △ ↓  
 X severe corrosion

SO<sub>2</sub>: 500 ppm  
 Temp: 24-48°C (60 min. cycle)  
 Moisture: 80-100%

(Nippon Steel Data)

Table 4. Pitting Corrosion Test

5% FeCl<sub>3</sub> Soln. at RT

Test Material		* Corrosion Rating			Immersion Time (hr)
Metal	Finish	Uncoloured	Coloured	Coloured & Hardened	
Type 304	2B	X	-	◎	1
Type 304	BA	X	-	◎	48
Type 304	Buffed	X	-	◎	72
Type 430	Buffed	XX	-	○	1
A1-1100	D-300	-			48
A1-1100	Asada Process	-	◎		48

\* Corrosion Rating

◎ slight pitting  
 ○ ↓  
 X ↓  
 XX heavy pitting

(Nippon Steel Data)

Table 5. Corrosion Resistance to Acid and Alkaline Solutions

Material	Acid or Alkaline	Conc.(%)	Temp.(°C)	Immersion Time	Appearance after Immersion
Type 304 Coloured & Hardened	H2SO4	10	35	48 hrs	No change
	HC1	10	35	48 hrs	Colour faded away
	HNO3	10	35	48 hrs	No change
	NaOH	10	35	20 min.	No change
Anodized A1-1100	NaOH	10	35	140 sec.	Colour faded away

(Nippon Steel Data)

Table 6. Corrosion Resistance to Various Chemical Agents

Agent	Conc.(%)	Temp.(°C)	Time(hr)	Colour		
				Green	Amber	Black
Cement Water	-	50	50	○	○	○
		100	10	△	△	△
Sodium Carbonate	5	50	50	○	○	○
		100	10	○	○	○
Caustic Soda	5	50	50	○	○	○
		100	10	○	○	○
Salt Water	10	50	50	○	○	○
		100	10	○	○	○
Detergent (Neutral)	5	50	50	○	○	○
		100	10	○	○	○
Aceton	100	RT	200	○	○	○
Lacquer Thinner	-	RT	200	○	○	○
Trichloroethylene	-	RT	200	○	○	○
Soy Bean Sauce	-	100	10	○	○	○

○: No change in colour

△: Slight change in colour

(Tokyo Metal Art Data)

Table 7. Atmospheric Corrosion Test in Contact with Mild Steel

(Material: Type 304 coloured & hardened)

Exposure Time	Remark
30 - 60 days	Red rust on coloured S.S. was easily wiped out by wet cloth. No change in colour.
90 - 120 days	Difficult to remove red rust but no change in colour.
150 days	Red rust was removed using 2% HNO3 soln. No change in colour.
180 days	Red rust was removed by 2% HNO3 but the rust was penetrated into the colour film.

(Tokyo Metal Art Data)

Table 8. Heat Resistance of Coloured Stainless

(Material: Type 304 coloured & hardened)

Testing Condition	Colour		
	Blue	Brown	Black
Boiled Water x 500 hr	○	○	○
150°C air x 100 hr	○	○	○
200°C air x 100 hr	○	○	○
250°C air x 100 hr	(1)	(2)	(3)

Remark, ○: No change in colour

(1) Slightly turned to yellowish colour.

(2) Slightly turned to yellowish brown colour.

(3) Slightly turned to brownish colour.

(Tokyo Metal Art Data)

Table 9. Scratching Test

Scratch testing machine: Erichsen Type 318

Scratching Material Load (g)	Plastic			Copper (Hv93)			Steel (Hv201)		
	250	500	1,000	250	500	1,000	250	500	1,000
Type 304 Coloured & Hardened	◎	◎	◎	○	△	△	△	X	X
Anodized A1	◎	◎	◎	○	○	○	△	△	X

Remarks, ◎: No damage  
○: Very slight damage  
△: Slight damage  
X: Severe damage

(Nippon Kinzoku Data)

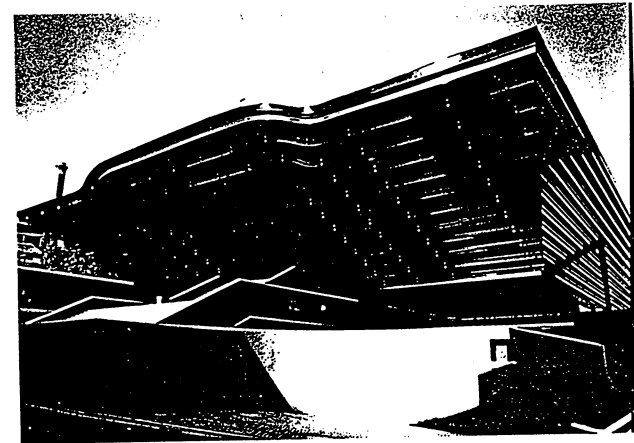


Photo 1. Reiyukai Shakaden (Tokyo)  
by courtesy of Nippon Kinzoku Co., Ltd.

Table 10. Abrasion Test

Rubbing test using a plastic rubber  
Load: 100 gram  
Material: Type 304

Colour	Rubbing Cycle (until the coloured film is removed)	
	Coloured	Coloured & hardened
Blue	30 - 80	800 - 1,300
Gold	80 - 130	1,000 - 1,500
Reddish Purple	100 - 150	1,500 - 1,800
Green	100 - 150	1,500 - 1,800
Dark Brown	130 - 180	1,600 - 2,000
Black	150 - 200	1,600 - 2,000

(Tokyo Metal Art Data)

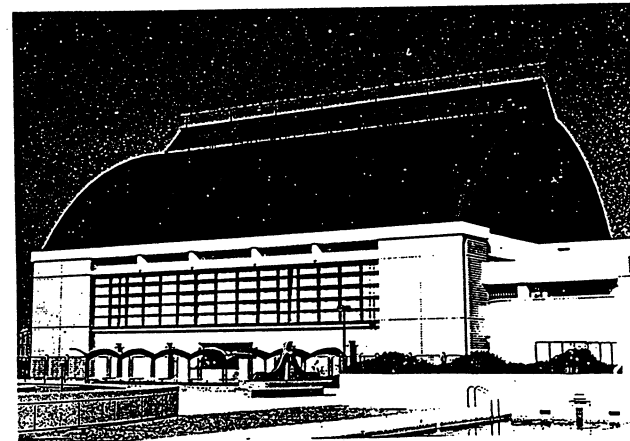


Photo 2. Tokai-Mura Gymnasium (Ibaragi Pref.)  
by courtesy of Cleanup Corp.