

## TITANIUM INDUSTRY IN JAPAN

Kokichi Takahashi

Kobe Steel, Ltd.  
Kobe, Japan

Today, there lie a large number of crucial problems on the international scene such as energy shortage, hyperinflation and heightened tension, thus creating an unfavorable environment to all of us. The Japanese titanium industry, however, is in an unprecedentedly active condition. The supply cannot meet the demand despite all efforts to increase production by each titanium manufacturer since last year. In 1976 when the last conference was held in Moscow, we were severely damaged by the first oil crisis and were at the bottom of a business depression with an operation of less than 60% of the capacity. We feel as if the depression was a dream, for the present condition is so brisk.

In the history of titanium production, though titanium was expected to be the third metal next to iron and aluminium, its application was limited to a structural material for aircrafts and parts of aero engines as well as corrosion-resistant material for equipment in the chemical industry. Titanium did not have a stable demand to serve as base cargo. This made the industry easily and greatly affected by the business fluctuations, and what is worse, slumps were long and booms were short. The history of the industry was the history of hardships.

Thanks to the continuous efforts made by the people committed to the industry, the time has come when titanium takes a great step forward. Titanium is now expected to play an increasingly important role in overcoming various problems the major industrial nations in the world now face, such as "resource-saving", "energy-saving" and "protection of natural environment".

Taking aircrafts as an example, the total number of passengers has shown remarkable increases in recent years and we have entered the age of mass transportation with airbuses. In addition to the increased demand for titanium due to the appearance of large aircrafts and the increase in the production of aircrafts, the necessity to produce light-body planes and jet engines of high fuel efficiency or to achieve low noise had further increased the demand for titanium. Titanium is also used in the place of conventional copper alloy for the surface condensers of steam turbines at some thermal and nuclear power stations in coastal zones. This conversion of the materials to titanium is now widely observed in the world as one of the measures to enable operation of high efficiency at the power plants, without causing environmental pollution. It has been proved that titanium is best suited for the requirements of the time.

The heightened demand for titanium made it considered to be a valuable metallic material of high value. Japan has been playing a very important role as one of the few producers of titanium among industrialized countries. The beginning of the production of sponge titanium in our country dates far back to 1952. We have nearly thirty years of the experience of production and export. The progress is shown in the figure. Ten years from 1960s to 1970s was the decade of hardships with many difficulties appearing one after another. The depression in 1976 to 1977 made the turning point and everything has been getting better since then. Last year, in 1979, the historical high yield of 13,200 tons was recorded and a further increase in production is expected this year and next year as the series of large scale investment in plants and equipment since last year began to contribute to the production. It is expected to yield 17,000 to 18,000 tons in the year 1980 and 22,000 to 23,000 tons in 1981, making record high yield every year. Such a large volume of production is expected to ease or solve the serious shortage of sponge titanium, that we are currently experiencing. If demand cannot be met with the increased production,

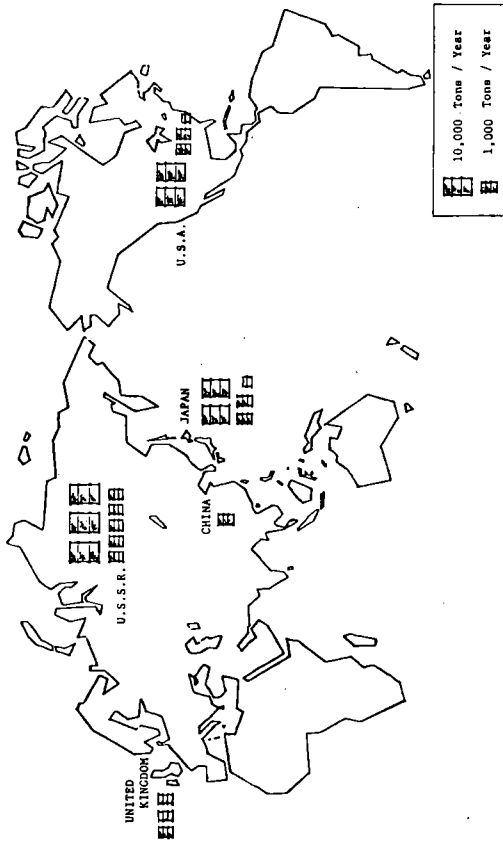


Fig. 1 Production capacity of titanium sponge in the entire world ('80)

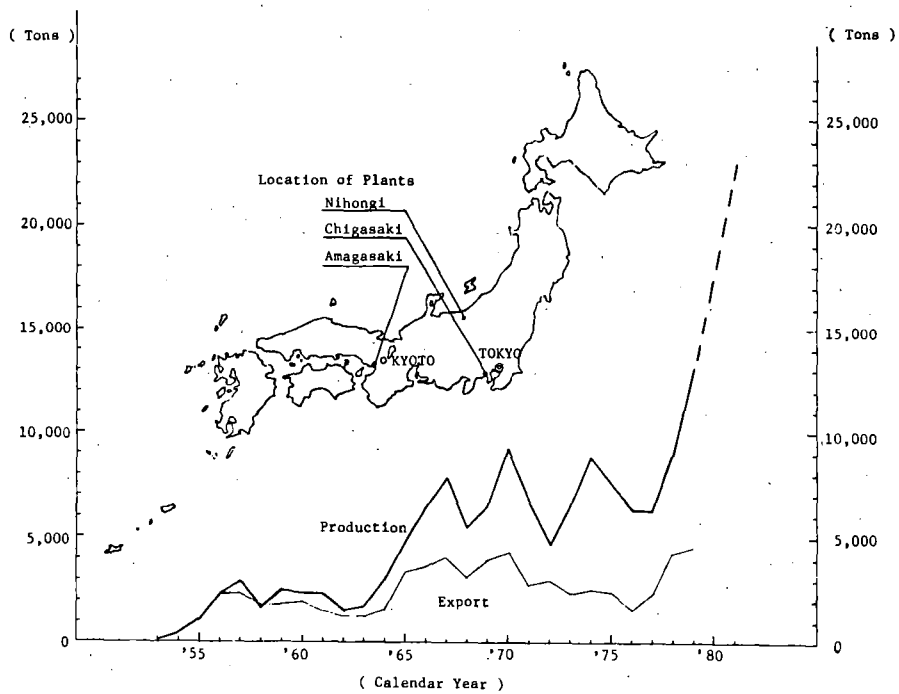


Fig. 2 Titanium sponge production in Japan

we have to study the next measures to take in order to perform the responsibility as a supplier.

The production of titanium mill products dates back to 1955. I understand titanium has been developed as "metal for aircrafts and space industries" in the industrialized nations in Europe and America, while in Japan, titanium has been developed as corrosion-resistant material for chemical industry. Much effort has been made to establish low-cost mass-production technology and to explore demand so as to apply titanium to seawater cooled heat exchangers in place of copper or nickel base alloys. Excellent results have been obtained in the utilization of steel production facilities. This is the main characteristic of Japan as compared with other industrialized countries. Most of the titanium mill products are commercially pure rolled titanium products for non-aerospace industries. The production of titanium alloys for the aerospace industry shares only a few percent or less of the total production. The production of alloys for aircrafts will gradually increase in accordance with the increase of domestic production of the aircraft bodies and jet engines.

Like the production of sponge titanium, the production of titanium mill products has been remarkably increasing these few years, establishing a new record every year, with 2,700 tons in 1977, 3,600 tons in 1978 and nearly 5,000 tons in 1979. Thin wall welded titanium tubings and its material, cold rolled titanium strip in coil have made especially remarkable progress.

The rapid expansion of production and demand within these two years was made possible thanks to the progress of technology. The development of production technology enabled mass-production and reduced the production cost. This development made it possible to expand demand for titanium, substituting other materials like copper alloys and carbon graphite.

In Japan, rutile and ilmenite, the material ores, are imported from Australia and South Africa. The technology to produce synthetic rutile of more than 95% titanium oxide contents from ilmenite has also been established. As you know quite well, Kroll process or Hunter process is normally applied for the production of sponge titanium from titanium oxide. The former adopts magnesium reduction and the latter sodium reduction. In Japan, Kroll process is mainly used and a part of sponge titanium is produced by Hunter process. Great efforts have been made for improvement of production technology of sponge titanium to cope with the great fluctuations of demand and with rising cost of energy (Photo. 1). Approximately 30,000 kWh of electricity is necessary to produce 1 ton of sponge titanium by Kroll process. Requirement of such amount of electricity is a great problem in Japan where dependence on thermal power generation is quite high. Electrolysis of magnesium chloride requires the most electricity in Kroll process. Up to now, 17,000 to 20,000 kWh electricity was needed to yield 1 ton of magnesium. In Japan, the capacity of some electrolysis cells has been increased from 40,000 to 100,000 A (Table 1) and electricity consumption is being reduced to approximately 13,500 kWh. The vacuum distillation process, where sponge titanium and magnesium chloride are separated, requires a large amount of electricity second only to that of electrolysis. In order to save energy in this process, vacuum distillation is conducted without any cooling after reduction of  $TiCl_4$  (titanium tetrachloride) with magnesium. It is reported that this improvement enabled 800 to 1,000 kWh energy saving for distillation of 1 ton of sponge titanium.

Table 1 Performance data in  $MgCl_2$  electrolysis

Current	80	kA
Cell voltage	5.7	V
Rate of operation	99.5	%
Current efficiency	93.2	%
Production	808	kg/day
Sludge quantity	30	kg/ton-Mg
$Cl_2$ concentration	98.0	%
Cell life	20~25	Months

Enlargement of batch size has been zealously studied to achieve higher productivity. The size is now being enlarged from the conventional 1.5 to 2 tons to about 5 tons.

In Japan which has small territory, tight environmental control is adopted. Thirty percent of the total investment in plants and equipment is spent to construct various waste treatment facilities (Photo. 2).

Titanium ingot is produced by the consumable electrode arc melting process. Five to eight tons of ingot is usually produced (Photo. 3). Scrap is also largely made use of in order to reduce the cost of commercially pure titanium products as well as to effectively utilize resources. Scrap is added to melted titanium, and the rate of addition has reached more than 30%. Recently plasma beam melting has also been applied to the production and the method is to be authorized by the Japan Industrial Standard (JIS) before long (Photo. 4).

The manufacturing process after the production of ingot is done by steel production facilities. Large ingot is processed into slab or billet by a press or a slabbing and blooming mill (Photo. 5 and 6). As for the production of commercially pure titanium cold-rolled strip, which is mass produced, slab is processed to hot strip coil by a hot tandem mill (Photo. 7 and 8), then cold rolled by a cold tandem mill (Photo. 9) or a Sendzimir mill (Photo. 10) and lastly vacuum annealing (Photo. 11) is performed (Photo. 12). Thin wall welded titanium tubing (Photo. 13), which is the main product among commercially pure titanium products, is produced on the automatic forming line (Photo. 14 and 15) with TIG (Tungsten Inert Gas) welders using cold rolled coil. While ASTM requires annealing after tubing, thin wall welded titanium tubing is used as welded in Japan. Broad and thick titanium plates for surface condenser tube plate are produced by means of heavy plate mill for steel (Photo. 16).

Wide utilization of steel producing facilities has improved the productivity of titanium and explored new demands (Photo. 17).

Here, I would like to explain how titanium is used and what kind of demand exploration is conducted.

The largest application is seen in a large heat exchanger with thin wall welded titanium tubing. Aluminium brass tubing was conventionally used for desalination plants and the surface condensers of thermal and nuclear power stations (Photo. 18). This aluminium brass tubing is being replaced by titanium tubing.

Since 1965, efforts have been made to utilize titanium tubing for the surface condensers of the thermal power stations. On the initial stage titanium tubing as used only in the air extraction section where the corrosion environment was severe. Recently, however, titanium tubing is widely used for the whole surface condenser. Titanium is used not only as tube material but also as tube plate material in Japan and leak-free surface condenser of high reliability is made by means of seal welding. Unlike other countries, titanium tubing is used as welded as mentioned before, and the wall is usually 0.5 mm thick in Japan (0.7 mm in other countries). Furthermore, operational experiments are carried out in oil tankers so as to apply titanium tubing to surface condensers for ships. Exploration of demand for titanium tubing as a heat transfer tubing material for desalination plants has been made in Japan since more than a decade ago. Large-scale application of titanium in this field was materialized at Al Jubail plant (Photo. 19) in Saudi Arabia and some other plants, which is an epoch-making phenomenon. Titanium is also generally adopted as heat exchanger tubing, using seawater as cooling water, at petroleum refineries and steel plants. With the increase in application of thin wall welded titanium tubing, unexpected local corrosion and hydrogen absorption were sometimes experienced. These problems, however, have been solved technologically. A considerable amount of titanium thin sheet is also used for plate type heat exchangers (Photo. 20 and 21) which are used to cool and recycle cooling industrial water with seawater in large vessels, at nuclear power stations and coastal steel plants. The anode in sodium chloride electrolysis (Photo. 22) was once made of carbon graphite, which is now replaced by titanium with excellent corrosion

resistance. Utilization of titanium yielded such merits as automization and stabilization of operation of the plants.

Titanium is also indispensable in the petro-chemical industry which made remarkable progress after World War II. Production facilities for acrylic fiber (Photo. 23), urea (Photo. 24), acetaldehyde and acetone cannot be operated without C.P. titanium and corrosion-resistant titanium alloys. For example, 5% tantalum alloyed titanium, which was indigenously developed in Japan, is used without fail for the nitric acid recovery process at acrylic fiber production facilities. Another typical example is the application of 0.15% palladium alloyed titanium at acetaldehyde or acetone production plants, in order to prevent crevice corrosion by high temperature and high concentration chloride catalyzer.

Titanium is applied not only to chemical plant equipment but also to medical equipment. A centrifugal separation rotor for blood (Photo. 25) is an example of the utilization of corrosion-resistance and high strength to weight ratio of titanium alloys.

Castings are also produced and used for pumps and valves and radial flow mixer of total weight of 300 kg (Photo. 26 and 27). Production technology for thin walled castings with complicated feature has been developed and established.

Using high strength to weight ratio, titanium is also applied to connecting rods and intake and exhaust valves for cars (Photo. 28). It is also used as a material for the printing hammer of an ultra-high speed line printer.

Titanium is broadly utilized in cameras, bicycles (Photo. 29), cistern for an aquarium, sporting goods (Photo. 30), a tone arm for a disk player (Photo. 31) and vibration plates of a radio speaker, making use of its light weight and corrosion-resistance.

Future utilization of titanium and titanium alloys is expected to be in aerospace field in Japan. Though aircrafts (Photo. 32) and fuel chambers for booster rockets for artificial satellite (Photo. 33) have been made of titanium alloys, much remains to be studied in terms of production and utilization of high strength titanium alloys. Development of jet engines (Photo. 34) and STOL (Photo. 35) with the jet engines are now being conducted. Demand for high strength titanium alloys are expected to increase in Japan in the near future as it did in other countries. Titanium alloys with properties of corrosion-resistance and high strength to weight ratio are also being used for steam turbine blades for a generator (Photo. 36 and 37) and for deep submergence vehicles (Photo. 38). Titanium alloys with their excellent properties at a cryogenic temperature are used for the rotors of super conducting generators and super conducting wire (Photo. 39) used for magnetically levitated trains (Photo. 40).

Finally I would like to give some future outlook of the titanium industry.

Titanium was once considered as a metallic material for aerospace equipment or a "metal for air". In the later 1970s, it obtained a position as "metal for earth" and development of titanium as a "metal for sea" has begun in the 1980s. In this way, the application of titanium seems to be expanding. As mentioned above, the role of titanium as a "metal for air" will become more active, but the role as a "metal for earth" has just begun to be established, and we are now expecting its future development as a "metal for sea". From the international point of view, large projects for the development of oceanic resources and energy might give titanium another field of application.

Titanium is now in its youth with much possibility for the future. There have been sharp fluctuations in demand in the past and it is our duty to lay a track for stable growth. Though the titanium industry in Japan is enjoying an unprecedented boom, the users feel much anxiety due to the imbalance between supply and demand and rapid price hike resulted from shortage of sponge titanium. The problems should be solved without delay. With understanding of the present situation, the Japanese titanium industry is determined to make utmost efforts to secure stable supply in terms of both volume and price and to meet the demand.

The Japanese titanium industry would like to perform its responsibility as a major provider of titanium, seeking for long-term and sound development of titanium production.

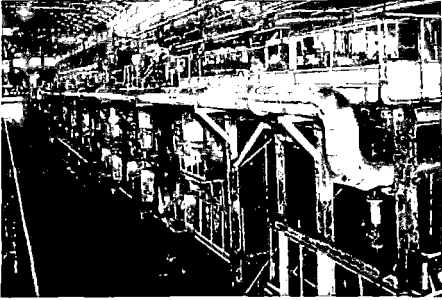


Photo. 1 Titanium tetrachloride reduction furnace  
(OSAKA TITANIUM CO., LTD.)

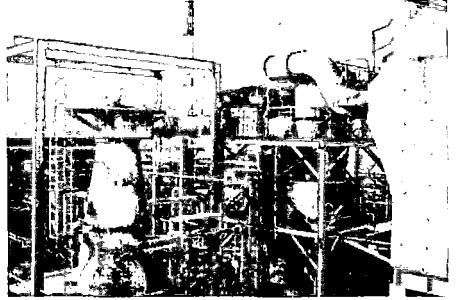


Photo. 2 Pollution-control equipment  
(OSAKA TITANIUM CO., LTD.)

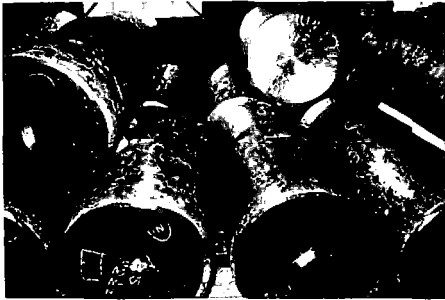


Photo. 3 Ingots (5tons)

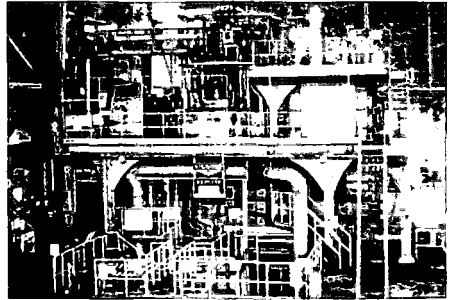


Photo. 4 Plasma beam furnace (3.5tons)  
(NIPPON STAINLESS STEEL CO., LTD.)



Photo. 5 Ingot (8tons)  
3,000ton oil hydraulic forging press

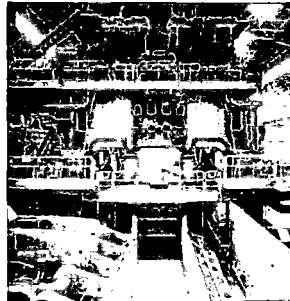


Photo. 6 Slabbing mill

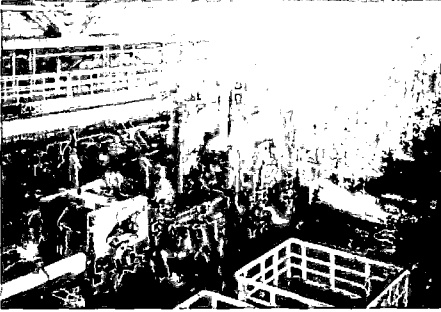


Photo. 7 Hot tandem mill  
(SUMITOMO METAL INDUSTRIES, LTD.)



Photo. 8 Hot rolled strip

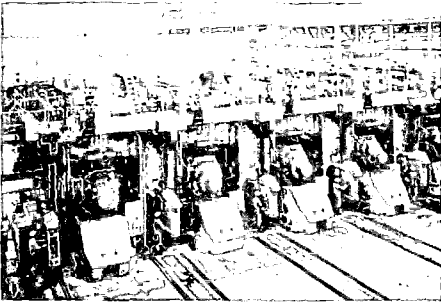


Photo. 9 Cold tandem mill

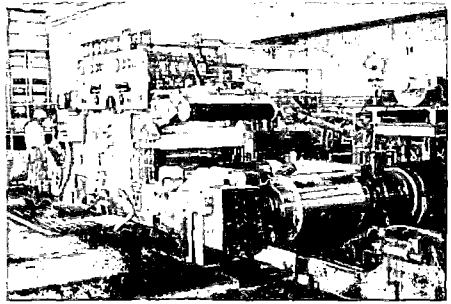


Photo. 10 Sendzimir mill  
(NIPPON STAINLESS STEEL CO., LTD.)

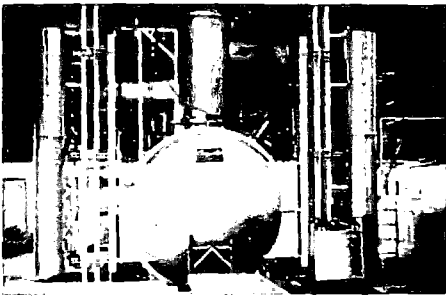


Photo. 11 Vacuum annealing furnace

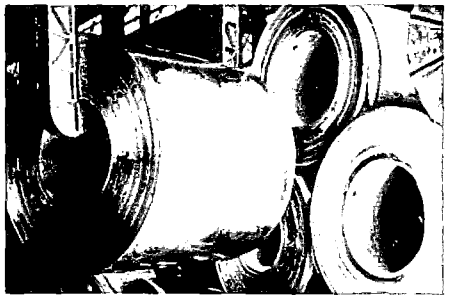


Photo. 12 Cold rolled strip



Photo. 13 Thin wall welded tubes

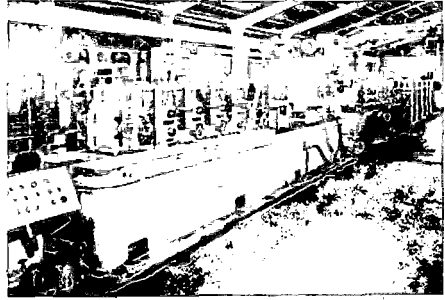


Photo. 14 Tube forming and welding line  
(SUMITOMO METAL INDUSTRIES, LTD.)

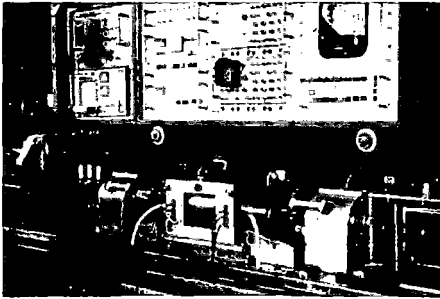


Photo. 15 Ultrasonic and eddy current testing  
equipment

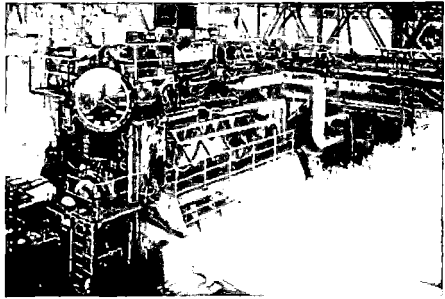


Photo. 16 Plate mill

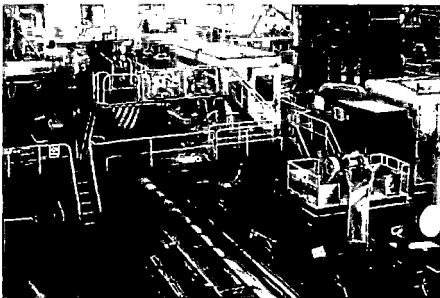


Photo. 17 Ugine sejournet mill  
(SUMITOMO METAL INDUSTRIES, LTD.)

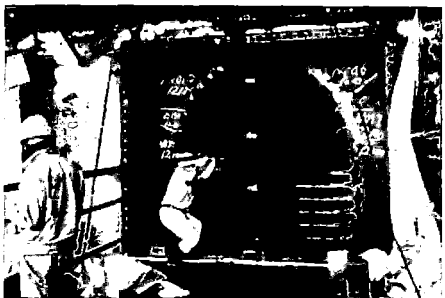


Photo. 18. Installation of titanium tubing  
at Fukushima nuclear power station  
(with the courtesy of TOSHIBA CORPORATION)

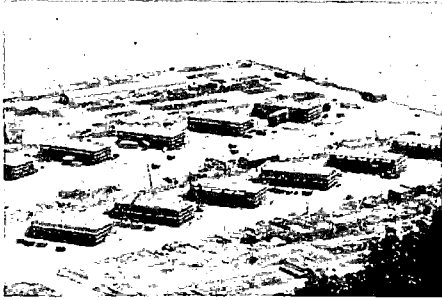


Photo. 19 Desalination plant for Al Jubail, Saudi Arabia  
(with the courtesy of  
MITSUBISHI HEAVY INDUSTRIES, LTD.)

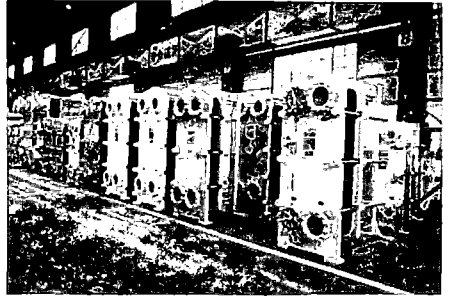


Photo. 20 Plate type heat exchanger  
(with the courtesy of  
KYOTO MACHINERY CO., LTD.)

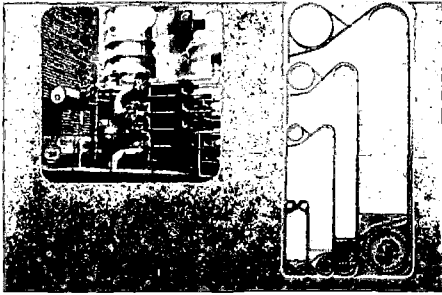


Photo. 21 Plate type heat exchanger  
(with the courtesy of HISAKA WORKS, LTD.)

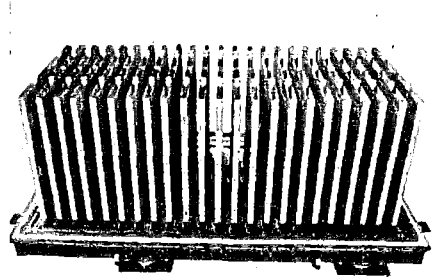


Photo. 22 DSE™ electrode for chlor-alkali cell  
(with the courtesy of  
PERMEREK ELECTRODE, LTD.)

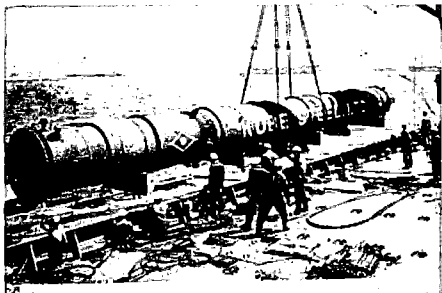


Photo. 23 Titanium lined urea reactor

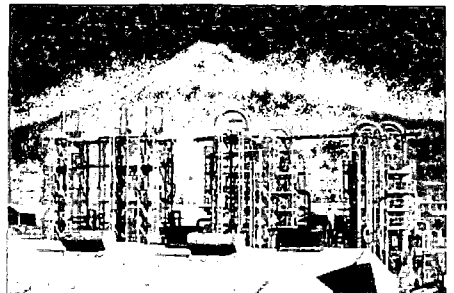


Photo. 24 Acrylic fiber plant  
(with the courtesy of  
ASAHI CHEMICAL INDUSTRY CO., LTD.)

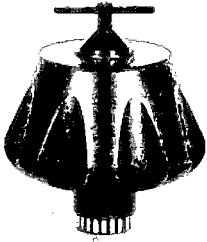


Photo. 25 Titanium alloy rotor for automatic preparative ultracentrifuges (with the courtesy of HITACHI KOKI CO., LTD.)

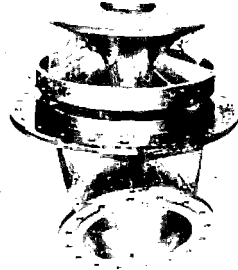


Photo. 26 Titanium cast radial flow mixer (VACUUM METALLURGICAL CO., LTD.)



Photo. 27 Ti-6Al-4V cast impeller (VACUUM METALLURGICAL CO., LTD.)

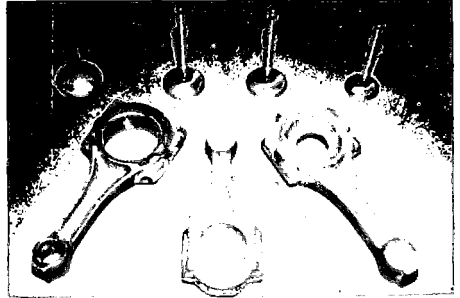


Photo. 28 Valves and connecting rods for automobile engine

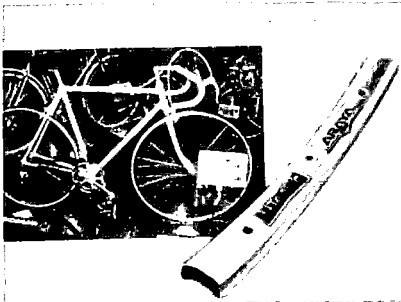


Photo. 29 Bicycle (with the courtesy of ARAYA INDUSTRIAL CO., LTD.)

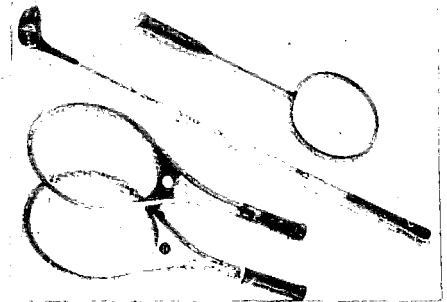


Photo. 30 Sporting goods (NIPPON MINING CO., LTD.)

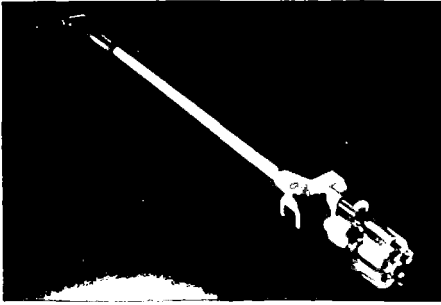


Photo. 31 Audio accessory for disk player (tone arm)  
(NIPPON MINING CO., LTD.)

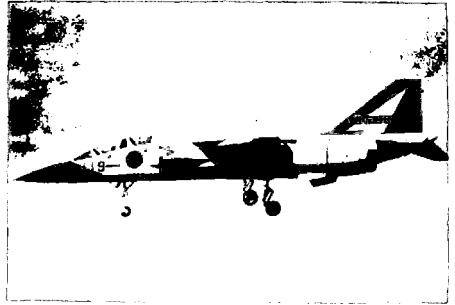


Photo. 32 Trainer (T-2)  
(with the courtesy of JDA)

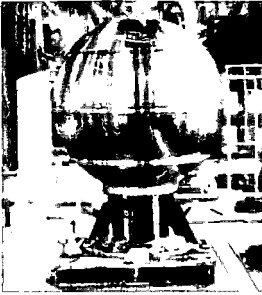


Photo. 33 Spherical rocket motor case  
(with the courtesy of  
NISSAN MOTOR CO., LTD.)

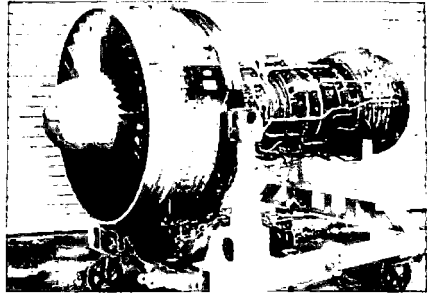


Photo. 34 FJR710 turbofan engine  
(with the courtesy of AIST)

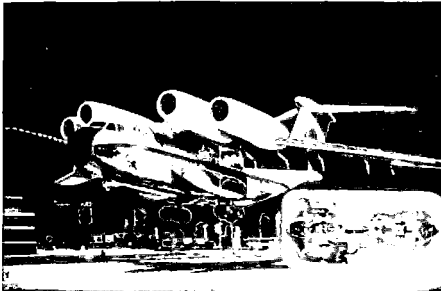
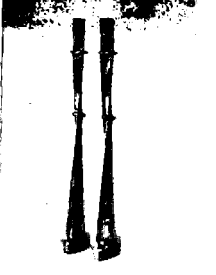


Photo. 35 STOL (short take-off and landing)  
(with the courtesy of AIST)



<b>23" LONG TITANIUM ALLOY BLADE</b>	
OPERATING SPEED	1,680 RPM
BLADE LENGTH	584.2
BASE DIAMETER	1.987
TIP SPEED	177
MATERIAL WEIGHT	1.4 BLADE
LOADING	17.4

Photo. 36 Steam turbine blade  
(with the courtesy of  
MITSUBISHI HEAVY INDUSTRIES, LTD.)

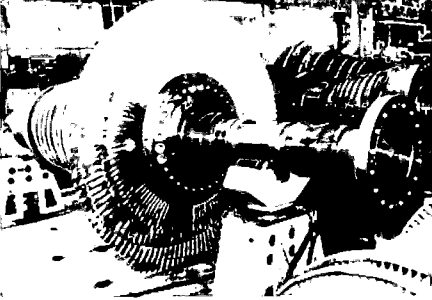


Photo. 37 Steam turbine  
(with the courtesy of  
MITSUBISHI HEAVY INDUSTRIES, LTD.)



Photo. 38 Deep submergence vehicle  
(with the courtesy of  
MITSUBISHI HEAVY INDUSTRIES, LTD.)

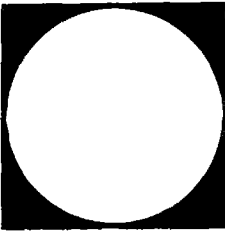


Photo. 39 Super-conducting wire

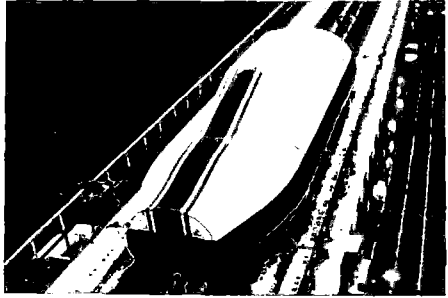


Photo. 40 Magnetically levitated train  
(with the courtesy of JNR)