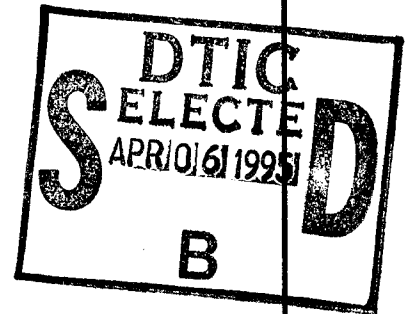


AOARD REPORT

Summary of Visits To Japanese Companies in the Titanium Industry

December 6-17, 1994
Walter H Buttrill
General Electric Aircraft Engines



This summary documents the visit by three and at times four US technologists to certain companies involved in the Japanese titanium industry. The US visitors were Walter H. Buttrill, Sr. Staff Engineer of GE Aircraft Engines, Capt. Paul McQuay of the Asian Office of Aerospace Research and Development, Mr. Tom Broderick, the Technical Area Manager of the Processing Science Group of the Air Force Materials Directorate, and Dr. Daniel Eylon, Professor, Graduate Materials Engineering, University of Dayton. The companies visited were Toho Titanium, IHI, Daido, Sumitomo Sitix, Kobe Steel and NKK. The report gives a brief accounting of each visit and highlights key items of interest at each company. Included are comments by the author about the capabilities of the companies the current presence of these companies in the US aerospace titanium product market and the potential for these companies to increase their presence in that market in the future.

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AOARD Trip Report

Summary of Visits To Japanese Companies in the Titanium Industry
- December 1993 -

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January 15, 1994

Abstract

This summary documents the visit by three and at times four US technologists to certain companies involved in the Japanese titanium industry. The US visitors were Walter H. Buttrill, Sr. Staff Engineer of GE Aircraft Engines, Capt. Paul McQuay of the Asian Office of Aerospace Research and Development, Mr. Tom Broderick, the Technical Area Manager of the Processing Science Group of the Air Force Materials Directorate, and Dr. Daniel Eylon, Professor, Graduate Materials Engineering, University of Dayton. The companies visited were Toho Titanium, IHI, Daido, Sumitomo Sitix, Kobe Steel and NKK. The report gives a brief accounting of each visit and highlights key items of interest at each company. Included are comments by the author about the capabilities of the companies the current presence of these companies in the US aerospace titanium product market and the potential for these companies to increase their presence in that market in the future.

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Introduction

This visit to Japan was the result of an invitation by Dr. Shiro Fujishiro of the Air Force Office of Scientific Research Asian Office of Aerospace Research and Development (AFOSR/AOARD). Dr. Fujishiro asked that I author and present a paper on the hearth melting process technology development work going on at GE Aircraft Engines for the SAMPE Conference on Practical Titanium Alloys. He also indicated that my travel and living expenses could be supported if I were to join with others and review the capabilities of some of the key companies involved in the titanium industry in Japan. The other members of the team were Capt. Paul McQuay also of the Asian Office of Aerospace Research and Development, Mr. Tom Broderick, the Technical Area Manager of the Processing Science Group of the Air Force Materials Directorate, located at Wright-Patterson Air Force Base, and Dr. Daniel Eylon, Professor, Graduate Materials Engineering, University of Dayton. Dr. Eylon was only able to participate in the visits to Toho and IHI. The itinerary for the visit was as follows:

December 6 - Toho Titanium
 December 7-9 - SAMPE Conference
 December 10-11 - Post-SAMPE Discussion Group (Toho & Hakone) December 13 - IHI
 December 14- Daido
 December 15 - Sumitomo Sitix (Osaka) December 16 - Kobe Steel
 December 17 - NKK.

The SAMPE conference will not be discussed as a part of this summary, however there is a very good publication of all the papers that were submitted. This book is available from any of the conference participants. The Post-SAMPE Discussion Group will only be mentioned as it is relevant to some of the general comments and as it contributes to discussion of Toho. (The Post-SAMPE Discussion Group was hosted by Toho and the Japanese Iron & Steel Institute. The discussions were held at the Toho facility and at a resort in Hakone. The group was given a tour of Toho's Chigasaki Plant prior to the discussion session).

At each company that we visited, I presented a summary of the hearth melting process technology development work going on at GEAE, as I had at the conference. The Japanese we spoke to seemed to be aware of this work prior to our visit and also seemed to be very interested in it. They had excellent questions about the work and seemed to quickly come up with some of the key questions surrounding the technology.

General Observations

The Japanese appear to have a natural affinity for accuracy and detail. Probably the most obvious example of this in daily life is their train system and how it operates. The train system in Japan is quite extensive and they are operated to an absolute schedule. Trains would depart and arrive at a given platform within a minute of their scheduled times. This attention to detail on a large scale was also obvious in the industrial settings we visited. At Toho, the titanium ingots are turned on large lathes to prepare the surface of the material for subsequent conversion. I questioned them about the tool being used and the potential for it to break and either stick to the surface of the ingot or worse to become included in the chips which were destined for recycle. They showed me the system they have in place to track the occurrence of tool breakage. They weigh each tool bit before and after use. If a particular tool bit has a weight loss exceeding their threshold they would then down-grade the chips which were generated during that period. I saw page upon page of records for tool bit weight loss; all very small numbers and all very consistent. Each barrel of chips then has a tag on top of the chip corresponding to the classification they have determined from the tool bit weight loss. I viewed numerous barrels and all had the highest classification. In the sponge line, also at Toho, they visually inspect 100% as a part of production and then visually inspect the required 10% (standard aerospace customer requirement) at the inspection department. It was not absolutely clear why they would do this but, I believe that the production people are sufficiently concerned about their ability to produce a quality product that they want to check the product before quality checks the product.

There is substantial production capacity in Japan for titanium sponge, ingot and mill product; however most of the production is in CP titanium products with very little alloyed titanium product. Titanium alloy product is probably less than 15% of total production.

Production activity at the primary producers we visited (Toho, Sumitomo and Kobe) was substantially below capacity. In some facilities they would show us the equipment and we could see that only two thirds or less was operating. This is probably an indication of the general recession more than the downturn in aerospace since they produce little alloy product.

This next observation is a perceived difference between US and Japanese titanium producers. The Japanese titanium producers have a stronger tie to their parent company and in general the parent company is a large successful company, typically a steel company. Toho is tied to Nippon Steel; Kobe is part of Kobe Steel; and Sumitomo has ties to Sumitomo Light Metals and has substantial resources because of Sumitomo's involvement in the silicon wafer business. It appears that the Japanese titanium producers have substantial depth, both technological and financial, offered by their business relationships to other strong Japanese companies. I have not observed similar relationships at any of the US titanium producers with the possible exception of Timet.

The two sponge producers that were visited, Toho and Sumitomo, both use a vacuum distillation process for removal of the residual magnesium in the sponge production process. Until the recent construction of Timet's vacuum distilled production facility, there were no vacuum distillation facilities used in production of titanium sponge in the US and the US has relied primarily on acid leached. (Toho is a business partner in the new vacuum distillation facility at Timet's Henderson NV plant. A Toho gentleman that we met, Mr. Yukio Okura, had lived in Henderson for two years and managed the construction project.)

Visit to Toho Titanium Co., Ltd.

As mentioned earlier we visited Toho on December 6, 1993 and also on December 10, 1993 as a part of the Post-SAMPE Discussion Group. Both visits were to the Chigasaki Plant. This situation was very good for us because it allowed us to have a tour and detailed discussion during the first visit and then when we returned with the larger group we had an opportunity to clarify things we had seen during the first visit.

Contacts during this visit were as follows:

Takashi Fukuyama - Director and General Manager Research & Development, Research & Development Division

Koji Wada - Director Production Division, Corporate Planning Department

Yukio Okura - Managing Director, Production

Masumi Kubo - Assistant Manager, Quality Assurance Section

Masaaki Koizumi - General Manager, Titanium Department

Toshiya Sugai - Managing Director

Michio Hanaki - Senior Metallurgical Engineer, Titanium Department

Susumu Kosemura - Manager Titanium Department, Titanium Division

The original invitation for this visit was from Mr. Fukuyama. Mr. Koizumi provided our tour and appeared to be intimately involved in titanium melting operations. He was also very informed about hearth melting and gave some indications that he felt Toho should have such a facility. As mentioned earlier, Mr. Okura was very involved in the construction of Timet's new vacuum distillation facility.

Toho's Chigasaki Plant produces sponge from rutile and ingots from the sponge. Mr. Okura informed us that concurrent with the construction of the Timet vacuum distillation facility, the Chigasaki Plant also increased its sponge capacity by about 50% with the addition of similar new facilities there. Toho has the capability to make a primary electrode from sponge compacts exceeding 15 tonnes (33,000 lbs.). This

electrode can be triple melted to produce a final melt ingot of the same weight. Several ingots which were in their yard exceeded 50 inches in diameter. This ingot size is larger than any round ingot in the U. S. (Titanium Hearth Technologies, THT, makes slab ingots heavier than this from loose feed material.

In general, I was very impressed with Toho's capabilities. They are a world class titanium sponge and ingot producer.

Visit to IHI Company, Ltd.

The visit to IHI was initiated by my contact with Dr. Hattori. Dr. Hattori is very involved in the GE 90 engine development program. IHI has a significant presence in the turbine engine industry. They are licensed to build numerous turbine engines from GEAE, Pratt & Whitney, and Rolls Royce. It appears that they have had a long and strong relationship with GEAE. The number of GEAE engine programs that they are currently or have been involved in exceeds that of any other engine manufacturer. The facility that we visited was the Tanashi Plant. The primary work at this plant is the production of blades, casings and fuel control accessories. Our time at this plant was spent in discussions and tour of their laboratory facilities. We did not visit the manufacturing areas. The contacts that we made during our visit included:

Hiroshi Hattori - Manager, Materials Technology Dept.
Shoju Masaki Jr. - Manager, Materials Technology Dept.
Sadao Nishikiori - Materials Technology
Takahito Hosokawa - Corporate Director, Technology; Precision Castings Co.
Hirotoishi Ishikawa - Section Manager, Engineering Group; Precision Castings Co.
Koichi Yasuhira - General Manager, Materials Technology

As can be seen from the contact list, Mr. Ishikawa and Mr. Hosokawa were from their casting company. We had originally hoped to visit the casting facilities at Mizuho but since that was not possible they met with us at Tanashi and discussed their casting capability. Mr. Nishikiori gave us a very good summary of the Japanese titanium suppliers that IHI uses to supply titanium for jet engine hardware.

IHI's involvement in the titanium industry is as a consumer of ingot (for castings) and of mill products. The nature of their business has a strong parallel to that of GE's. If GEAE were to identify a "sister" company from Japan I believe it would be IHI.

Visit to Daido Steel Co., Ltd.

The visit to Daido was initiated with Dr. Ohgaki, General Manager, Aerospace Materials Div., however Dr. Ohgaki was not able to meet with us. The people we met with during our visit included:

Susumu Isobe - General Manager, Special Steel Research Lab, R&D Division
Dr. Shiratani - Deputy Manager, Aerospace Materials
Yoshinori Kawatsu - Assistant Manager - Export Section, Aerospace Materials Div.
Toshiharu Noda - Research Engineer, Special Steel Research Lab
Denjiro Otsuga - Manager of Melting Section, Hoshizaki Plant

We met at the Hoshizaki Plant so that we could see their small plasma arc consolidation unit. The primary business of Daido is melting and forging of specialty steels. Daido does not play a major role in the titanium industry, however their plasma arc unit is rather unique and of significant interest. The unit is called the "Plasma Progressive Casting (PPC) Furnace" and is used for consolidation of raw materials. It consists of a chamber with six argon plasma arc torches located at approximately 20 degrees from vertical around the periphery of the head of the furnace chamber. The positions of the torches are fixed relative to the chamber head but the head oscillates in an arc of 120 degrees. The ingot surface resulting from this arrangement is quite porous. The inability to move the torches relative to the chamber head restricts the ability to get the arc near the ingot outside diameter surface. The total power available from the six torches is 540 Kw. The largest ingot that can be cast from this unit is approximately 4,000 lbs.

Although Daido can make titanium ingot, billet and forged product, they have only a very limited presence in this area. Their strength and their participation in the aerospace industry is through their specialty steel products. MA250, AM355, and A286 are primary materials for aerospace products that Daido sells. Daido claims to have 90% of the total specialty steel market. They depend heavily on the automobile industry and consequently are experiencing some tough economic times.

Visit to Sumitomo Sitix Corporation

The visit to Sumitomo Sitix was initiated with Dr. Iseki, Executive Vice President. Our visit was to the headquarters located in Amagasaki, where the titanium production process is located. The people we met with during our visit included:

Junkichi Iseki - Executive Vice President

Atsuo Moriya - Director

Akira Kanai - General Manager, Quality Assurance & Technical Affairs Dept.

Tatsuo Shirai - General Manager, Technical Affairs Dept.

Dr. Takashi Maeda - Senior Research Engineer, Sumitomo Metal Industries

(T. Maeda was not in the meeting at Amagasaki but was met earlier in the trip at the SAMPE conference. Sumitomo Metal Industries provides a sister company relationship for conversion and forging of titanium ingots produced by Sumitomo Sitix. Sumitomo Metal Industries also has substantial ownership in Sitix.) Today's Sumitomo Sitix Corporation has evolved from what was originally Osaka Specialty Steel Manufacturing Co. formed in 1937. In the evolution of corporate identification over the years the name Osaka remained until 1992 when it was changed to Sumitomo Sitix. Sitix is a representation of Si for silicon, Ti for titanium, and X for other. It is meant to reflect their product emphasis; silicon wafers for the electronics industry and titanium for aerospace and commercial applications. The silicon production business has been very strong for Sitix, overwhelming weak titanium production. Dr. Iseki stated that the number of employees involved in titanium production was approximately 200 while 2000 were involved in silicon production.

Sitix produces titanium sponge and titanium ingot. Their process for sponge production is similar to that of Toho and Timet VDP in that it uses vacuum distillation to draw off residual magnesium chloride. Sitix claims a significant advantage in process efficiency by using a closed loop recycle system for magnesium recovery. They reported that their magnesium process loss is less than 1%. They also claim to have reduction and distillation vessels made of a special steel that reduces the iron pick up of the sponge. (Low iron sponge is useful in attaining maximum creep strength in Ti 6242. Teledyne Allvac recently solicited supply of sponge with stringent low iron requirements and Sitix was awarded the contract.) The sponge cake size at Sitix varies with the equipment that is used. The largest sponge cake is approximately 11 tonnes (24,200 lbs.), about 50% larger than the largest sponge cake at Toho. We were able to view a unique piece of equipment for sponge inspection. The concept for the equipment was driven by the need to remove the human element from the sponge inspection. Sitix created a light spectrographic system that would electronically detect color (wave length) and blow a sponge particle of the wrong color into a receiver area. The system was set up over a conveyor belt similar to that used for the conventional visual inspection. They stated that it had not performed as well as they had hoped and that it was not being used for aerospace grade titanium sponge.

Sitix equipment for melting was conventional VAR furnaces similar to several other companies both in the US and in Japan. Their VAR ingot size was not as large as that of Toho's. (Unfortunately my notes don't have their max. ingot size.) Their melting shop was clean and complete, comparing favorably to any I know.

Sitix has an interest in titanium powder. (When RMI stopped sponge production the industry lost a cheap source of titanium powder. RMI would sell the sponge fines that were a natural byproduct of their

process for metal injection molded (MIM) applications. Another source of titanium powder is hydride dehydride (HDH) powder from Toho and other sources; a much more expensive product.) Sitix has a PREP (plasma rotating electrode powder) facility with a capacity of 0.5 tonne per month (1100 lbs/month). They are in the process of installing a new gas atomization facility for powder production. The new facility is designed to use bar or compact as direct feed into an induction melting system. The melt stream would then be fed into a nozzleless gas atomization ring. The facility was under construction during our visit. Its projected capacity is 10 tonnes per month (22,000 lbs/month). This is a very interesting facility, as it appears to have the potential to provide a source for relatively low cost alloyed titanium powder.

Sitix has a small plasma arc furnace that can produce small pilot scale ingots. The ingot size maximum is approximately 150 mm in diameter by 2 m in length, weighing approximately 150 kg. (6" diameter. X 80"; 330 lbs.)

Sitix is certainly a world class titanium sponge and ingot producer. Their facility is among the most advanced facilities known when judged for capacity, efficiency, and attention to process control.

Visit to Kobe Steel, Ltd.

The visit to Kobe Steel was initiated with Dr. Nishimura. Dr. Nishimura is the General Manager of Kobe's Special Metals Research Laboratory which is a part of their Iron and Steel Research Laboratories. His office and the laboratory is located at Kakogawa, however, he met us for our visit at the Takasago Plant. Dr. Nishimura was previously in charge of the Takasago Plant. He became our host for this visit and went out of his way to be sure we were able to see and discuss all things about their plant that were of interest to us. The people we met with during our visit included:

Dr. Eng. Takashi Nishimura - General Manager, Special Metals Research Lab

Dr. Toshio Matsumoto - Technical Manager, Titanium Technical Section

Hiroyuki Morofuji - Manager, Titanium Technical Section

Noriyuki Mitsui - Titanium Melting Section, Manufacturing Department

Atsushi Itoh - Manager, Titanium Melting Section, Manufacturing Department Y. Uozumi - Assistant Manager, Quality Assurance Section, Titanium Division

Tadasu Abumiya - Senior Engineer, Titanium Products Development

Haruki Ohizumi - Technical Director, Takasago Steel Casting & Forging Plant

Kobe's titanium enterprise is a small fraction of the overall production at the Takasago Plant. By far, the Takasago facility's primary business is in steel castings and forgings but they also have a small machinery division and the titanium production at this facility. Kobe does not produce their own sponge. They buy sponge on the open market but appear to have a special relationship with Sitix for sponge. (Toho's primary stock holder is Nippon Steel, a direct competitor with Kobe in the steel segments of their business. The Sitix business chronology lists a cooperative agreement with Kobe as a significant milestone in 1952. Other information acquired outside of these visits indicates Kobe has substantial ownership of Sitix.) Kobe melts sponge, casts ingots and forges those ingots. Although it is not my purpose to describe in detail Kobe's non-titanium production capability, it is noteworthy that Kobe has some of the largest forging equipment available in the US or Japan which is used to forge very large marine engine crankshafts. This equipment and Kobe's titanium technology base would allow Kobe to forge the largest titanium forgings that are made today and positions them to forge parts even larger than any produced today.

The titanium melting and forging facilities at Kobe are extensive. It appeared as though they have at least nine VAR furnaces for titanium melting. The maximum final ingot size is 9 tonne (z 20,000 lbs). This ingot is not a "single stick" but would consist of two primaries joined. The maximum diameter ingot is 1010 mm (z40 inches). At least two of the VAR furnaces are dedicated to aerospace production and are visibly labeled in that manner. Kobe has what I believe is a unique VAR furnace that allows uncompact

particulate feeding. This furnace has a similar advantage as electron beam (EB) and plasma arc (PA) hearth melting furnaces for the consolidation

Visit to NKK

The visit to NKK was initiated with Dr. Ouchi, who is the General Manager of the Materials and Processing Research Center. Our visit was to their facility at Kawasaki. During our visit we met with the following people:

Dr. Chiaki Ouchi - General Manager, Materials & Processing Research Center
Atsushi Ogawa - Metallurgist, Materials Research Department
Masakazu Niikura - Manager Fundamental Laboratory, Materials & Processing Center.

During our visit Atsushi Ogawa, who was our primary host, gave us a tour of their facilities and provided information on SP700 and LT700.

NKK is the second largest steel producer (Nippon Steel is the largest) and as such has tremendous resources. NKK's role in the Japanese titanium industry appears to be that of an alloy developer and application specialist. NKK developed SP700 specifically for super plastic forming applications ("SP"). They designed the alloy to have super plasticity at 700°C, a temperature somewhat lower than the that of the typical titanium alloy, Ti 6-4. SP700 is now being used in several special commercial applications, including watches, hand tools, and mountain climbing equipment. They are also developing an alloy for low temperature ("LT") applications. This alloy named, LT700, is intended to have superior cryogenic properties while maintaining room temperature strength at the 700 MPa (100 ksi) level. A paper given at the SAMPE conference on LT700 was co-authored by Dr. Hattori of IHI. Apparently there is an application for the alloy in an impeller for a rocket motor. (I believe this application is an impeller for a liquid hydrogen pump in the HII Rocket.)

The facilities we viewed during our visit included a small EB furnace used to melt experimental alloys. The furnace was arranged with two EB guns with a total of 250 Kw of power. In comparison, Titanium Hearth Technologies' (THT) large production furnace in the US is arranged with three 600 Kw guns and two 750 Kw guns. While the NKK EB furnace is not useful in production, one can see that it would be ideal in the alloy development environment. The furnace has a 100 mm by 250 mm (4 inch by 10 inch) copper water cooled hearth. The furnace can cast an ingot 200 mm diameter by 600 mm long (8 inches diameter by -24 inches long with a casting rate of approximately 23 Kg per hour (50 lbs. per hour). We also toured their electron microscopy laboratory which contained numerous scanning and transmission electron microscopes. There were four state of the art transmission electron microscopes.

Summary

The Japanese titanium industry is substantially directed at CP applications and as such they have minimal involvement in the US aerospace industry as suppliers of alloy ingot, billet or forgings. They certainly have the capability and the capacity to produce alloy products. They are presently participating in the titanium sponge market in the US and would have a much greater presence if the strength of the dollar were to increase relative to the yen. (This conclusion ignores the influences of sponge produced and sold by countries of the former Soviet Union.) The Japanese companies visited appear to be very strong with significant ties to other large successful industries in Japan providing substantial depth of resources both financial and technological. Of the companies visited Kobe Steel has the largest presence in the aerospace market for alloy products.

It was a pleasure to visit these companies, they are anxious to become partners in the aerospace industry and appear to be well be positioned to do so.