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THE SEVEN LARGE ITER R&D PROJECTS

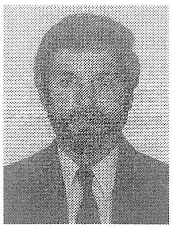
In his Status Report of the ITER EDA to the ITER Council (December '95), Dr. R. Aymar, ITER Director, pointed out that recognizing the need to complete certain key features of the technology R&D for ITER, it had been agreed to highlight and focus the ITER EDA R&D activities in seven critical areas:

Central Solenoid Model Coil
Divertor Cassette
Toroidal Field Model Coil
Blanket Module Remote Handling
Vacuum Vessel Sector
Divertor Module Remote Handling
Blanket Module

Each project includes the development and verification of the full scale manufacturing techniques at the industrial scale. The JCT and Home Teams share responsibility for bringing the projects to fruition. The JCT takes primary responsibility for defining requirements, deliverables, time schedules and milestones; the Home Teams take primary responsibility for R&D implementation including task sharing among the four Home Teams to achieve maximum effectiveness.

The successful and timely execution of these major programmes are vital to the EDA, both for the information that they are due to yield and to provide concrete demonstration of ability to manage a complex interactive schedule of industrial scale technical work within the ITER framework.

In the previous issue of the Newsletter (Vol. 5, No. 8), an article by Dr. D. Maisonnier treated the **Divertor Module Remote Handling Project**. In order to continue in line with this approach, the article overleaf provides an overview of another one of the Seven Large Projects, namely of the **Vacuum Vessel Sector**. The authors of this article are presented below.



In August 1993, Gary Johnson joined the JCT as a member of the VV Group at the Garching JWS, later becoming Group Leader in January 1996.

Prior to joining ITER, he worked on the Atomic Vapor Laser Isotope Separation (AVLIS) program at Lockheed Martin Energy System facilities in Oak Ridge from 1977 to 1985 and at Lawrence Livermore National Laboratory (LLNL) from 1986 to 1993. As the Mechanical Group Leader for the Uranium Separator Section for the AVLIS program at LLNL, he was responsible for the design and fabrication of AVLIS separator components including vacuum vessels, vacuum systems, and special liquid metal handling structures.

He holds a B.S. degree in mechanical engineering from the University of Illinois and an M.S. degree from the University of Tennessee.

Prior to joining the ITER JA Home Team in April 1992, Koichi Koizumi worked on the mechanical design of superconducting magnet systems and joined the ITER CDA as a member of the magnet design group. He started development work on double-walled vacuum vessels at JAERI in 1991 and became VV Group Leader of the JA Home Team in 1992. In July 1995, he became a co-ordinator of the ITER VV Full-Scale Sector Model Project (L3) conducted by the joint efforts of the JCT and the four Home Teams.

He holds an M.S. degree of nuclear engineering from the Hokkaido University.

VACUUM VESSEL SECTOR PROJECT OVERVIEW

by Drs. G. Johnson and K. Koizumi

The ITER vacuum vessel (VV) represents a significant step in size and complexity compared to past fusion reactor vessels. For example, the ITER vessel is ~15 m tall, whereas JET, TFTR, and JT-60 vessels are of the order of 3-5 m tall. The difference in mass is even more striking with the ITER vessel being ~24 times more than the JET vessel (~2600 tons [without shielding] vs. ~110 tons) and ~65 times more than the JT-60 vessel. The increased size alone makes the design more complicated, but additional requirements such as tight manufacturing tolerances, resisting large electromagnetic loads, providing shielding for the superconducting magnets, accommodating natural convection cooling, and remote maintenance requirements make the design even more challenging.

During the conceptual design phase of the vessel it was determined that several design issues could not be resolved except by the construction and testing of large scale models. The most important of these models are the full scale models that make up the Vacuum Vessel large project (L-3).

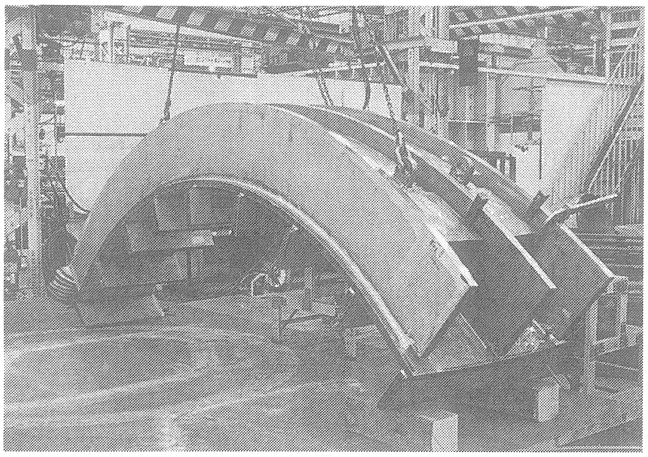
The purpose of the L-3 project is to resolve critical VV issues and provide the inputs required to complete the design. The biggest issues that could not be addressed with small scale models were related to fabrication technology. The most critical of these was the determination of the magnitude of welding distortions, dimensional accuracy, and achievable tolerances. A single sector of the VV weighs ~130 tons (without shielding) and may have as much as 18 tons of weld material. How this welding would affect these parameters could only be accurately determined by building a model at full scale. The achievable tolerances for a sector will impact the positional accuracy of in-vessel components, the required clearances to components on both the inside and outside of the VV, and the design of the field joint used to connect adjacent sectors. Other important objectives of the project are to verify non-destructive inspection (NDI) techniques, demonstrate the feasibility of automatic welding of the VV field joints located at the center-line of the ports, and verify the mechanical and hydraulic characteristics of the double wall design.

ITER VV vs. Full Scale Sector Model

The objective is to make the model as much like the ITER vessel as possible. The current concept is a double wall shell design that is torus-shaped and divided into 20-18° sectors (each sector consists of two 9° half sectors). It is made from SS 316 LN-IG which was selected because of weldability, forming, waste disposal, and cost advantages over other candidate materials. The inner and outer shells are made of welded plates, 40-60 mm in thickness and separated by ribs which space the shells 0.45-0.83 m apart. The space between the shells is filled with plate inserts to provide neutron shielding for the TF coils. Water flows in the space around the inserts to remove nuclear heat deposition both during normal operation by forced convection and during off-normal conditions by natural convection. A sector has three ports which are used for equipment installation and maintenance, diagnostics, utility feedthroughs, and vacuum pumping. The two 9° half sectors allow a sector to be mated to the TF coil at the site, effectively capturing the coil between the ports. After assembling the half sectors and the TF coils, the sectors are joined with each other by field welding at the center plane of the ports during the initial assembly. Considering schedule and budget constraints and the state of the vessel design at the beginning of the project (1995), a model configuration and test plan was developed and finalized. The configuration agreed to at that time continues to match the ITER vessel very well and all objectives are still achievable. The most significant difference between the ITER vessel and the model is the fabrication procedure for the main shell. The current design for ITER is for the vessel to have a continuous inner skin that is completed first allowing welding and inspection access to both sides of this skin before ribs and other components are welded in place. Good access helps assure that this shell (which is the first safety boundary for the reactor) is as high quality as possible. However, for the model this procedure would require that the full size sector (~15 m tall and ~9 m wide) be completed and the assembly shipped to the final assembly/test site. This was determined to be impractical given that the model must be transported by surface roads, so an alternate fabrication procedure (poloidal segmentation) will be used for the model. The advantage of this concept is that the sector can be shipped to the site in smaller pieces and the fabrication schedule can be shortened by maximizing parallel fabrication. A second difference is that only limited areas of the model will be filled with shielding plates. This was done only to reduce cost.

With the above objectives in mind, an outline of the project was developed in mid 1995. The main part of the project would be a **full scale sector model** and would be done by the JAHT. The second part of the project would be a **full scale equatorial port extension** and would be done by the RFHT.

The full scale sector model consists of two 9° half sectors which are designated half sectors A and B. Half sector A being built by Hitachi in Hitachi-city, Japan, is poloidaly segmented into 9 parts (see Fig. 1). Half sector B, being built by Toshiba in Yokohama-city, is poloidaly segmented into 3 parts (see Fig. 2). The two segmentation schemes will help assess the impact of poloidal segmentation on sector tolerances. All detail design and fabrication activities associated with these half sectors are being performed by these two companies under the supervision of the JAHT.



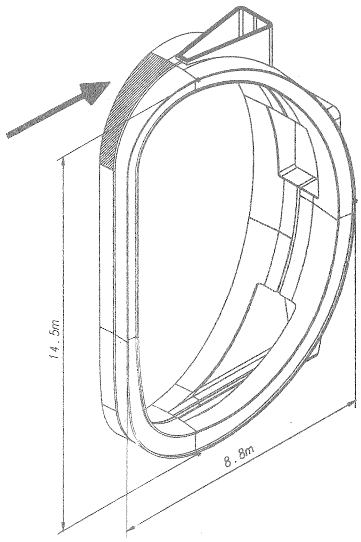


Fig. 1. Upper Curved Section of Half Sector A

Once the half sectors are fabricated, they will be leak and pressure tested, selected areas flow tested, and mechanical tests performed to determine the structural characteristics of the sector. However, the most important test to be performed involves the welding and inspection of the field joint between half sectors A and B. This will involve welding splice plates using the automatic narrow gap-gas tungsten arc welding (NG-GTAW) process and inspecting the joint by the ultrasonic testing (UT) method. Final assembly and testing of the sector model will be done at the Tokai Establishment of JAERI.

Welding Techniques Selected for the Half Sectors

The fact that the model consists of two independent half sectors provided us with the opportunity to test two candidate weld schemes. The technique selected for half sector A is gas tungsten arc welding (GTAW) and electron beam (EB) welding. EB welding will be used in two areas of half sector A. The first area is the weld between the inner shell and the rib. This would be a full penetration weld with the beam coming into the joint from the side. The second area is the weld between the outer shell and the rib. The weld design consists of two individual welds, each ~10 mm wide that are made by passing EBs through the outer vessel shell. This process and joint design have been proposed because of its high welding speed and low distortion relative to other candidate options. GTAW will be used where EB welding is impractical or impossible, for example to weld the poloidal segments together which cannot be done in a vacuum chamber due to size limitations. GTAW is rather slow but produces a very high quality joint. The technique selected for half sector B is GTAW and gas metal arc welding (GMAW). GMAW will be used to make the weld between the rib and the outer shell. The joint is a fillet type formed between the rib and the edge of the outer shell setting on the rib. This technique will result in higher distortions than with EB welding, but has the advantage of not requiring a vacuum chamber and thus can be applied to an assembled sector.

The fabrication of half sectors A and B began in December 1995 by using available material of a slightly different composition (i.e.: SS 316 L) for the initial poloidal blocks. Since that time, all material for the model (~130 tons of SS 316 L+N) has been received and inspected. The fabrication of the inboard poloidal blocks 1 and 2 of half sector A is complete and the inner shell of block 9 has been formed and the ribs welded in place. Welding of the outer shell to the ribs will be completed in November. After poloidal block 9 is completed, blocks 1, 2 and 9 will be welded together to form one of the three main subassemblies of half sector A. This subassembly will be completed in December.

The fabrication of the remaining six poloidal blocks of half sector A (i.e.: blocks 3 through 8) are proceeding in parallel. The material cutting and forming operations for the inner shells and ribs are nearly complete, and preassembly of the ribs onto the inner shells, in preparation for EB welding, is underway.

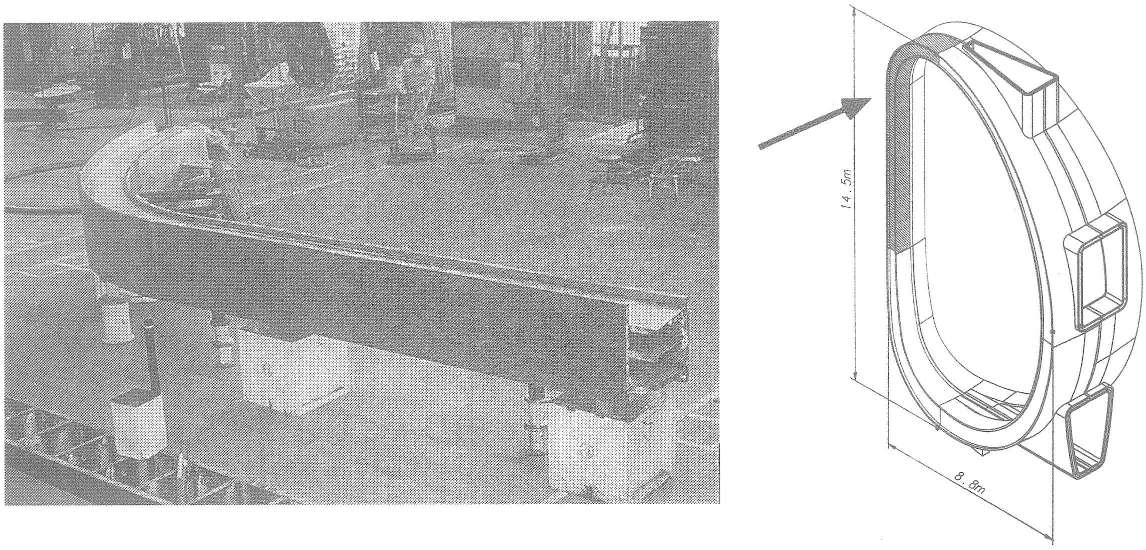


Fig. 2. Upper Inboard Section of Half Sector B

The fabrication of the upper section of half sector B - segment #1 is complete. The inner shell and ribs of the lower section of this segment have been welded together and preparations for welding the outer shell to the ribs are underway. Cutting and forming operations for segment #2 are underway and welding of the ribs to the inner shell will begin in November.

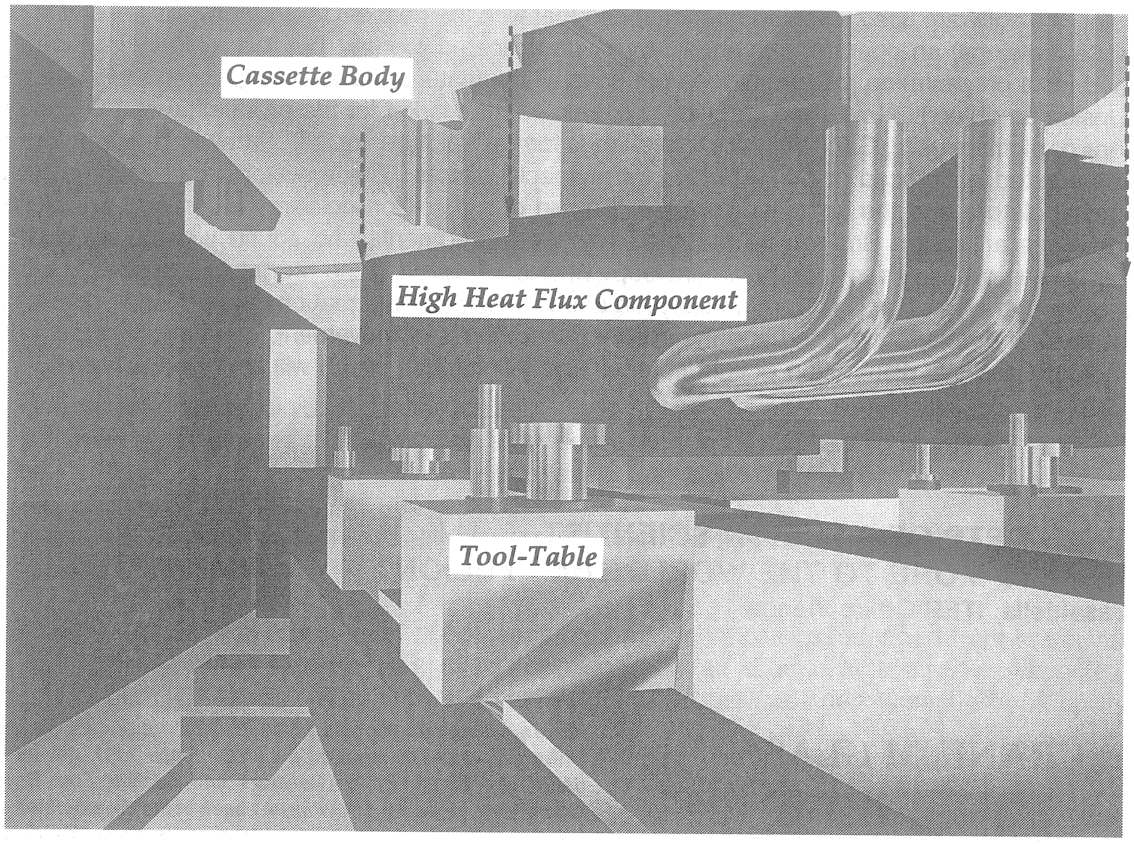
The equatorial port extension is the second part of the L-3 project. The model of this port extension is a full scale double wall assembly 2.2 m wide by 3.4 m tall by 1.5 m long. This model, like the sector model, will be used to develop fabrication technologies for the port extensions. Even though the extension for each port may be of different size and shape, the basic design and fabrication procedure should be common and the technologies developed for the model should be applicable to all extensions. A draft technical specification for the port extension has been reviewed by the RFHT and industrial participants and returned to the JCT for final review and comments. Agreement on the specification is expected in December. The current schedule calls for the design and fabrication to be complete in mid 1997 and testing to be complete in December 1997.

The L-3 project was conceived as the best way to resolve critical VV issues and provide the inputs required to complete the ITER VV design and construction activities. The basic outline of the project was developed in mid 1995 and, by the end of that year, agreements had been reached between the JCT and HTs allowing the project to aggressively move ahead on a very ambitious schedule. Less than a year from the kick-off meeting where details of the project were defined, nearly a third of the sector model is complete and the remaining parts are proceeding without significant technical difficulties. The critical activities associated with final assembly of half sectors A and B will be complete by the end of 1997 and performance testing completed by the end of the EDA. The progress and results to date give us a high level of confidence that the project will be completed on schedule and all objectives will be met.

COMPUTER ANIMATION CREATED FOR ITER

by Drs. A. Antipenkov and D. Mitin, ITER Garching Joint Work Site

On 29 March 1996 at the ITER Garching Joint Work Site, a sequential meeting on the divertor cassettes' remote handling and refurbishment was held. Refurbishment is the process of replacing the worn off plasma facing components. This meeting could have been one of the routine working meetings, if there had one detail been missing: the processes of the components replacement was illustrated by computer animation. The movie was created by the Russian CAD-designer D. Mitin, under supervision of JCT member A. Antipenkov. The quality of the pictures was excellent and the movie was shown on a large screen, complemented by recorded comments by one of the authors, as well as by music. The participants in the meeting were impressed by how easy it had been to explain, with the help of animation, the complex process of cassette refurbishment. The figure overleaf, for example, shows the cassette right in the position in which the replaceable component gets pulled down from the cassette body: the static picture, as you see, is unclear. The same picture with moving details gets immediately understandable.



High Heat Flux Component gets pulled down from the cassette body

Let us recall that the cassette has a steel body serving as a shield and carrying 10 sacrificial "high-heat-flux components", which are affected by plasma particles and neutron flux, and must survive during at least one calendar year (or ~0.1 $MWa.m^{-2}$ neutron load) by means of special coating and an extreme accuracy ($\pm$1 mm) of the alignment. The trickiest part is the attachment of these components of the body. It must maintain the required alignment, be strong enough for high dynamic electromagnetic forces and flexible enough to relieve thermal stresses and provide a reliable vacuum tight coolant pipe connection (these components are fed with water through the body). Due to activated steel of the cassette components, all operations have to be completed remotely with the staff controlling the process looking through the window of a hot cell or on the computer display. The intricate movement of the components and the attachment keys can be much better understood by watching the animation on the screen, but, most important, it helps significantly in developing a system of robots, manipulators and transporters to carry out every operation during maintenance of the cassette, an optimal trace and tool positions, viewing points, etc. Certainly, developing this system would be impossible without full scale modelling of all the processes including construction of specific test platforms. Bearing in mind that, for example, the weight of one divertor cassette is about 25 tons, the expediency to undertake the initial modelling steps with the help of a computer is obvious.

Even the authors of the movie did not expect the effect achieved: the idea of refurbishment described by animation does not require further explanation - it becomes clear for everybody and, moreover, development of the tools for the refurbishment platform is now consistent with the movie.

The Head of the Garching ITER JWS, Prof. R. Parker, said, after having seen the animation: "It would be very useful to have such a movie for the maintenance of all components in the reactor." It should be noted that the positioning of the cassette at its destination in the vessel is even trickier in comparison with the cassette assembly/disassembly. Animated pictures of the handling processes could help to avoid mistakes that are most likely to occur, even when using 3-D drawings, to optimize the system, to develop perfect tractors/tools for the maintenance operation, etc. Unfortunately, there has been too much urgent design work at the JWS, having left no time to respond to this request. D. Mitin has finished his contract with the JCT and is now working at ENTEK in Moscow, but there is still hope that as of the beginning of 1997 it will be possible to carry out this job, at least for the divertor maintenance.

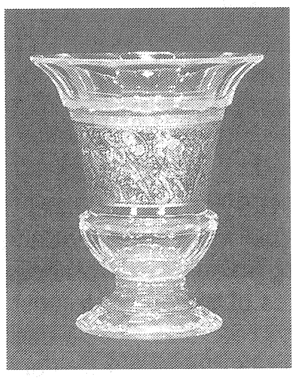
Concerning the software used it should be mentioned that with the help of CATIA (software used at ITER JWSs to generate drawings) an operator can animate very complicated models, but it is a highly intelligent system to be used for a presentation job and it does not have all the features needed (e.g. it cannot locate a viewing camera inside an object). Now there are many systems on the market for the production of 3-D photorealistic animations or pictures using GIF ("graphics interchange format") pictures or DXF ("drawing transfer format") files of models created in Autocad or CATIA, with a lot of special effects. These systems can animate complex or flexible manipulators and the animated pictures dispose of a 1 million colours palette and are of very high resolution. The animation film can be mounted with video fragments and sound with output apart from a computer screen onto a video tape or a hard copy device. Though these programs are usually rather user-friendly, computer animation is still not an easy job to do. The required creation time depends on the creator's skills, the level of the hardware used and the quality (smoothness of movement, number of details, number of screen colours, realistic distribution of light sources and reflections), which will finally be achieved.

HIDDEN FACETS OF A FUSION SCIENTIST - SO THERE IS MORE TO THE WORLD THAN FUSION?

by C. Basaldella, ITER Office Vienna

K. Tomabechi

URANIUM GLASS



ウランガラス

苫米地 顯

Ken Tomabechi was born in Japan in 1929. He graduated from Tohoku University, where he received his Ph.D. Since 1957, he has worked at JAERI and at the Power Reactors and nuclear Fuel Development Corporation in Japan. His work has been in the development of nuclear energy. He has participated in many aspects in this development, including construction of several nuclear reactors, such as JRR-1, JRR-4, and JOYO. He also participated in the nuclear fusion experiment, JT-60. In 1966-1968, he worked at the IAEA Headquarters in Vienna, Austria. In 1988-90, during the ITER Conceptual Design Activities, he served as the Chair of the ITER Management Committee. At present, Dr. Tomabechi works as a research advisor for the Central Research Institute of Electric Power Industry in Tokyo.

Dr. Tomabechi is, at present, member of the ITER Technical Advisory Committee. Further, the ITER Council appointed him in July 1994 as Chair of the Special Review Group to review the technical, social, and the safety and environmental requirements for siting ITER - a task, which was successfully terminated in July 1995 - and as Co-Chair of the Special Working Group, established in December 1995.

On a hot, humid and marvelously lazy morning last summer, I was sitting on the terrace of my friends Gloria and Salo Boekbinder at their house on the most beautiful, but volcano-shaken Caribbean island of Montserrat, enjoying the breathtaking view, ignoring the light smell of sulphur and the slightly intimidating noises of the volcano heard from the distance, when Gloria came back home from her daily shopping tour to the island's little capital Plymouth. Gloria, in the good old days of the ITER CDA, had been Dr. Tomabechi's secretary, when he had served as Chair of the ITER Management Committee at the Max Planck Institute in Garching, Germany. (Gloria swears that her and her husband's decision to go and live on an island at the end of the CDA was no ITER after-effect whatsoever). Gloria was waving a parcel that she had collected at the Plymouth post office. "A gift from Dr. Tomabechi", she explained cheerfully, "apparently he has finished his book!" Since, after eight years with ITER, ITER Newsletter and, so far, 44 issues of the ITER Documentation Series, a publication on fusion, even if written by Dr. Tomabechi - and, on what else should he possibly write a book - would definitely not make me raise from a comfortable chair, I watched Gloria with half-closed eyes unwrapping the book.

I abruptly got up when I saw the cover page. "K. Tomabechi - Uranium Glass" with a stunningly impressive photograph of a Bohemian vase with the characteristic light green shading of uranium glass, pieces of which I first saw at the Museum of Applied Arts in Prague, Czech Republic, and then again, in Venice, Italy, at the glass museum on the glass blowers' island of Murano. When turning the pages, I couldn't believe my eyes.

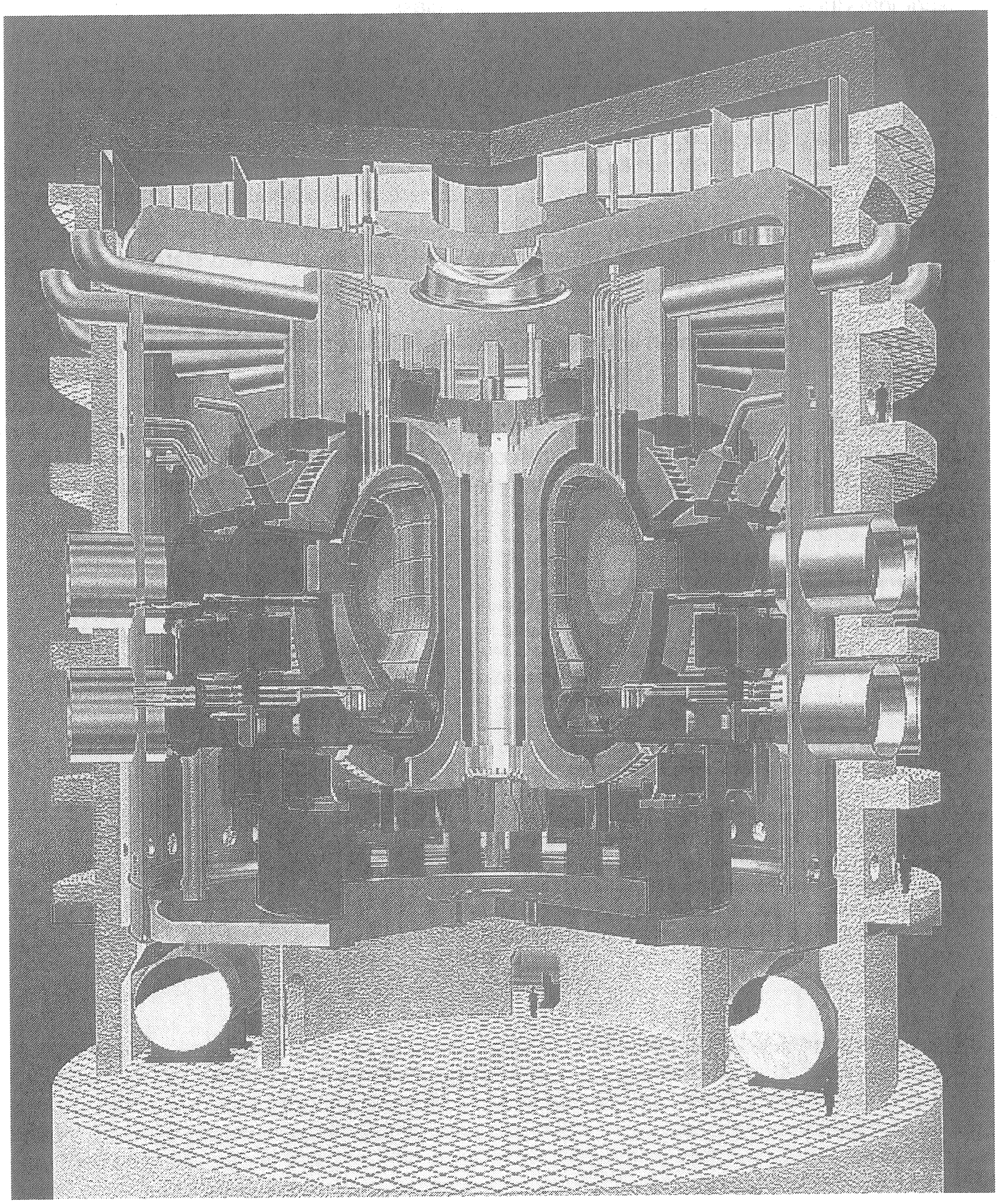
Dr. Tomabechi has "followed the traces of uranium glass" through all the art museums of Europe, the USA and Japan, studying in depth vases, clocks, chandeliers, bowls and even jewellery. He took coloured photographs of the most magnificent pieces of glass in a remarkable quality, complementing his book.

Dr. Tomabechi introduces his readership to the history of glass in general, starting from the manufacturing methods of ancient glass handicrafts and the composition of glass, passing to the discovery of uranium and its use in small amounts for coloring glass, thus achieving the characteristic light green and light yellow shades of unique shine and its fluorescent effect when exposed to ultraviolet light. Scientific details, such as the atomic glass structure and radioactivity, get explained and, finally, the major pieces of art in the various museums are described; and Dr. Tomabechi did not fail to add briefly the historic background of each town where he has visited the museums.

The book was published in Tokyo, Japan, by Iwanami Book Service Center and, as I recently got to know, was already reviewed by M. Vickers in "Nature", UK's famous weekly publication, who stated an "achievement in writing the first book on a material of such scientific, social and aesthetic interest."

The many years of the author's research activities, completely different from "R&D", lead to a wonderful book - congratulations, Dr. Tomabechi!

The experience with Dr. Tomabechi has, of course, taught me one more lesson, apart from the cultural one: it would not - not any more - surprise me at all to discover or to read about absolutely never expected talents of members of our ITER family. Who knows, if next year's Christmas bestseller will be a book on the art of Ikebana by the Council Chairman or....well, let's see.



ISOMETRIC VIEW OF ITER AS SEEN BY THE DESIGNERS

Items to be considered for inclusion in the ITER Newsletter should be submitted to B. Kouvchinnikov, ITER Office, IAEA, Wagramerstrasse 5, P.O. Box 100, A-1400 Vienna, Austria, or Facsimile: +43 1 237762, or e-mail: basaldel@ripo1.iaea.or.at (phone +43 1 206026392).

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