JT-60SA Newsletter

No. 100, May 2018

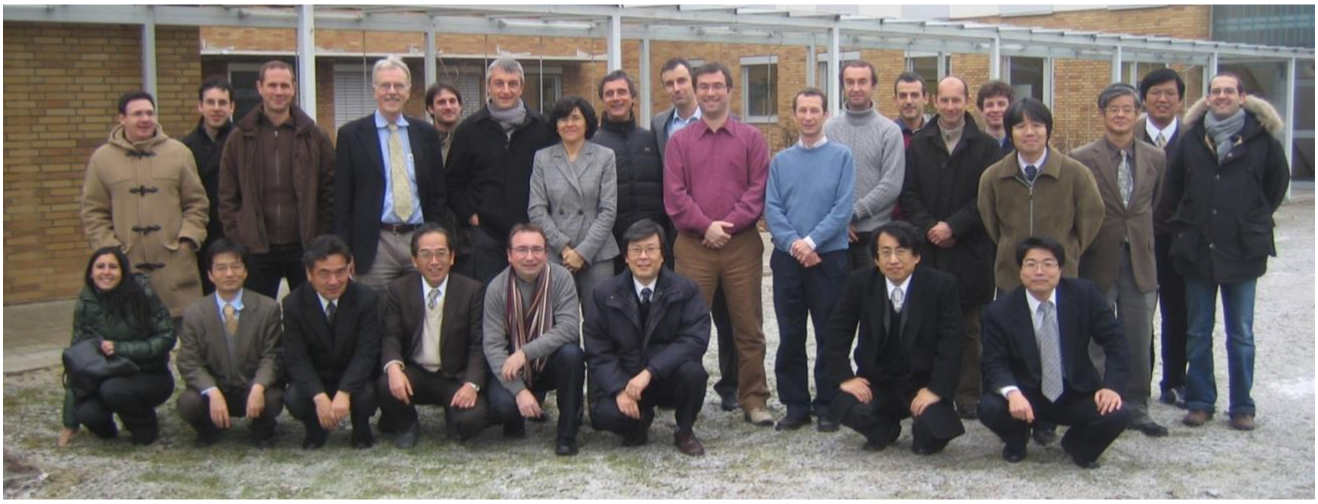
1. Head line

Introduction to the No.100 celebratory issue

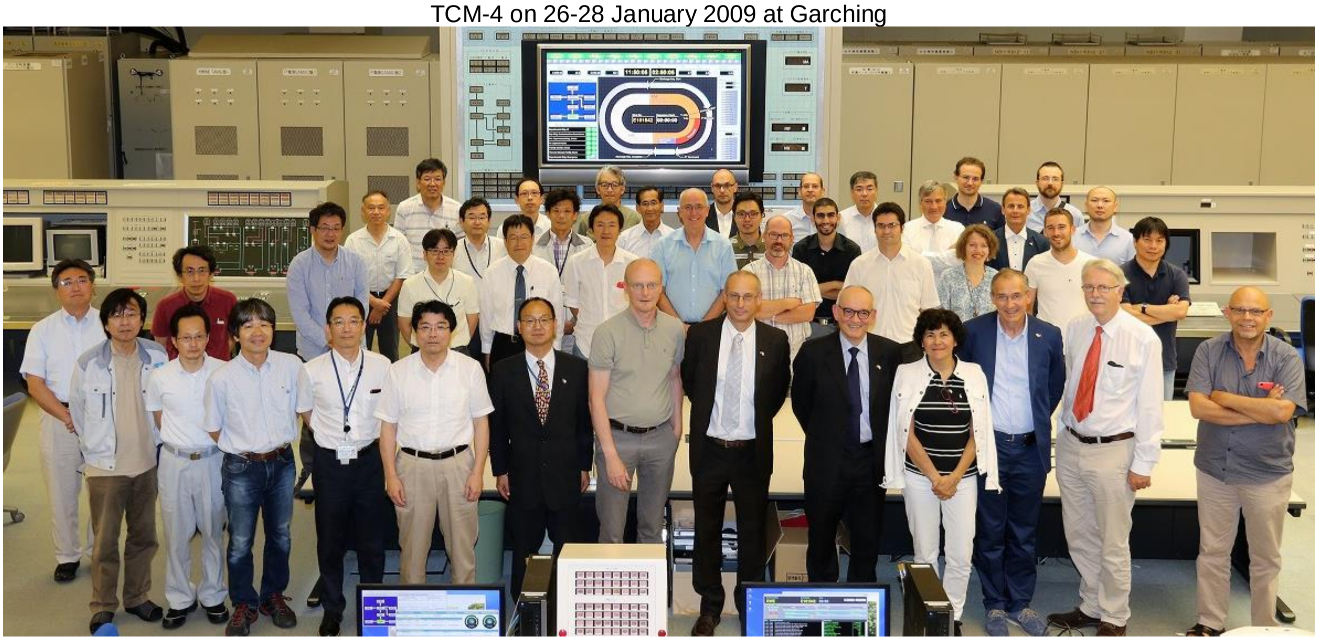
The JT-60SA Newsletter was started in January 2010 to keep the stakeholders informed about progress with the project. It was begun as a pdf, distributed to an emailing list, but after a year this now seemingly old-fashioned method was superseded by an online version with the pdf file and an RSS link embedded, to reach a much wider audience. The newsletter is now regularly read by more than 100 different viewers worldwide, outside the many home viewers at Fusion for Energy (F4E), the EU voluntary contributors, and the National Institutes for Quantum and Radiological Science and Technology (QST).

Each month the project team newsletter editor in Japan puts together a skeleton based on what is currently newsworthy, and what articles they have previously stimulated from the project's contributors. After a check for balance in the project team, this skeleton is circulated for outline approval of the Home Team project managers. A rough final version is then polished by the editors in Europe and Japan, and circulated for final project manager approval, and the electronic version is then prepared in Europe, and finally carefully checked editorially in Europe and Japan, and synchronized with the pdf version produced in Japan, before the final joint release of both, just after the start of the month.

With the JT-60SA Newsletter now reaching its 100th edition, it is an excellent opportunity to celebrate the achievements the newsletter has reflected over the last 8 years. The JT-60SA project is now at the peak of the full assembly phase, and this special issue showcases the key changes that have been made over the years, with contributed articles by the PL, PMs, DPMs, EU voluntary contributors and JA HT TROs covering their personal view about the history, highlights, current status, and future challenges.



TCM-4 on 26-28 January 2009 at Garching



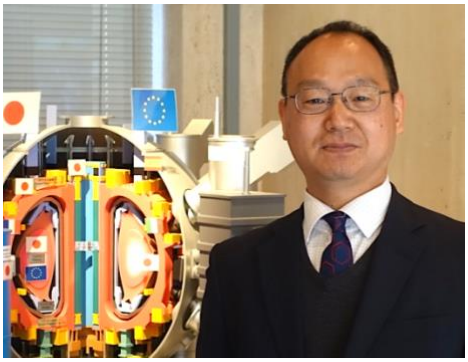
TCM-28 on 5-6 July 2017 in Naka

2. News

Contribution from PL, EU and JA PMs

Congratulations on the 100th memorial issue! We started the JT-60SA Newsletter from January in 2010 to share the status of the project among the JT-60SA team members and widely disseminate the activities to the world. It was not easy at the beginning of the project to collect the 7 articles every month, and the Project Team members and I sometimes had to take a photo in and out of the Naka site to find something attractive. As the project proceeded, such worries have been resolved and changed to the pleasure of receiving lots of articles contributed from each Home Team. The Newsletter is edited in an example of joint work in dedicated and encouraging collaboration between Garching and Naka.
In particular, Spears-san and his assistants in Garching, and first Sato-san and now Kawashima-san and their assistants in Naka are really appreciated. Without their enthusiasm and efforts, it would not have been continued without any break. I hope the Newsletter will continue to work and evolve as a bridge to connect all the Integrated Project Team members in Europe and Japan, and further open the door to the world.

[by Shinichi Ishida, PL (21 Jun. 2007~30 Jun. 2014)]



I myself appeared for the first time in the JT-60SA Newsletter in issue No. 54 in June 2014, when I joined the Project Team of the Satellite Tokamak Programme as Project Leader (PL). Since then, in order to directly witness the progress of the Project, I have visited a lot of institutes and manufacturers in Europe and Japan responsible for procurement of components and systems of JT-60SA, some of which are also shown in this Newsletter's articles. The JT-60SA Newsletter provides a valuable record to the public of the progress in a nuclear fusion project. Its mission is quite important, because nuclear fusion is still not so well known in the field of science and technology in spite of extensive outreach activities. Looking over archived Newsletter articles up to now will show you the steady advance of the JT-60SA Project with the lapse of time: how various components and systems of the superconducting tokamak JT-60SA have been designed, tested, manufactured, delivered, assembled and commissioned, how assembly buildings and plant facilities have been constructed or refurbished, at the QST Naka site in Japan to accommodate facilities, and how efforts of so many people have been devoted to this project. Development of fusion energy is quite challenging work. Lots of technological issues have occurred even in seemingly simple components because of its state-of-the-art nature. JT-60SA contributors including people in research institutes, universities, laboratories, manufacturers and so forth have always engaged in such issues seriously. In the big smiles of the group photos taken at the various workshops shown in the Newsletter articles, I strongly feel their confidence and pride for having overcome difficulties and fulfilled responsibilities. At the time when this memorial issue is being published, assembly of the last (18th) toroidal field (TF) coil is being carried out. Most of the components and systems are already delivered to the QST Naka site waiting for their turn. Now is the time to appreciate the efforts exerted by numerous JT-60SA team members for so many years. Although publication of the next memorial issue, No. 200, is far in the future, I am sure it will contain articles showing the remarkable achievements of JT-60SA taking the initiative in promoting the ITER project and designing DEMO reactors. I am really looking forward to reading it.

[by Hiroshi Shirai, PL (1 Jul. 2014~26 Apr. 2018)]

I am very happy to work in this Project. In these 10 years, I learned a lot in this Project. I found so many friends in this Project. I enjoyed a lot of beer in this Project. (I needed to write a lot of reports ….) The Integrated Project Team of JT-60SA put together by Europe and Japan is a very strong team in which all the team members share the same objectives, milestones, issues, and ways to solve problems based on mutual trust. In particular, I deeply respect European colleagues. Their strong efforts cover procurement of each component. They are always thinking about assembly and operation. I have confidence that JT-60SA will reach its first plasma in September 2020, and, after that, JT-60SA will become the strongest experimental device for ITER and DEMO. This device is constructed for young fusion researchers who are taking leading roles of ITER and DEMO. I deeply hope they will enjoy many challenges in JT-60SA. Our tokamak operation starts soon.

[by Yutaka Kamada, PL and JA PM at present]

The JT-60SA project, formally started with the signature of the Broader Approach (BA) Agreement in 2007, immediately had to face 2 important challenges. The first related to the initial mismatch between its conceptual design and the available budget, the second regarded instead the relatively unclear management model which had to be employed for the project implementation. The 2 matters are of course related, as the cost and the management model, particularly for complex projects, are strongly correlated. In order to have a serious possibility of success, it was therefore immediately visible to stakeholders that both issues had to be solved before industrial suppliers could be engaged in fabrication of long lead items. This had to be done, and quickly; therefore the preparatory work done in years 2008 and 2009 were key to the present achievements.

The design had to be optimized aiming to maintain the main plasma performance targets, for example plasma current and pulse duration, while reducing the foreseen cost. This was achieved by revisiting the whole system architecture, re-optimizing the device aspect ratio, simplifying the design of magnet, cryostat, cryoplant, power supplies and pretty much all systems. In some sense, this effort was also instrumental in building a cohesive team, built by committed individuals from many organizations in Europe and Japan and focussed on what was shaping as the common goal. At the same time, attention had to be devoted in developing a reasonably efficient management model, coherent with the BA Agreement, which would allow individuals from several organizations to collaborate using a common set of rules. In a relatively short time a set of processes, the Common Quality Management Systems, were developed and agreed upon, moreover a set of common collaboration tools were also put in place. Once this groundwork was roughly completed, the implementation work could eventually start on a fairly solid basis, allowing the committed individuals from all European and Japanese institutions to co-operate. In time, difficulties and successes not only forged the shape of the device but also the “JT-60SA Culture”, a set of values which transcend barriers between nations and institutions and which is now an asset as important as the hardware built together.

[by Pietro Barabaschi, Deputy PL and EU PM at present]

3. News

EU HT highlights

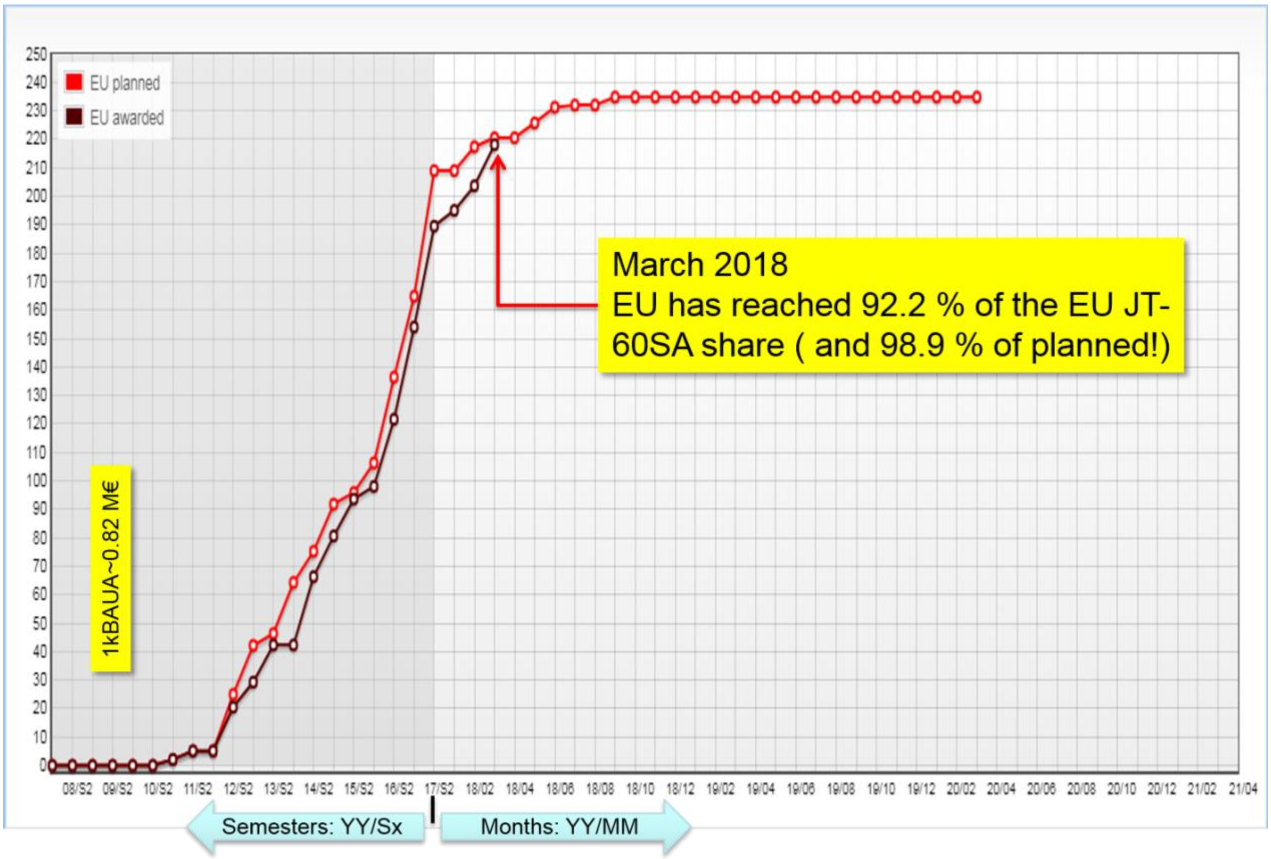
The 100th issue of the JT-60SA Newsletter marks a moment in time in which the great efforts in design, manufacturing, testing, and logistics, bring results at an accelerated pace. March 2018 marked the achievement of what is, for the European contribution to JT-60SA, one of the most remarkable milestones. The last of the 18 Toroidal Field coils (TFCs) passed acceptance tests at the QST Naka site on 27 March and is now in final assembly. This achievement marks more than 9 years of design, technological development, manufacturing and full-scale testing which involved several Institutions and laboratories (F4E, CEA, ENEA and SCK•CEN), and many industries all over Europe and even in Japan.

Since the beginning of 2018, in less than 3 months, F4E delivered 5 TFCs to the JT-60SA site. This was possible thanks to the strong acceleration in the delivery of the last TFCs by CEA and ENEA in the final quarter of 2017. The CEA Saclay Cold Test Facility kept a sustained pace, the result of constant improvements which reduced the testing times well below 20 days per coil. Meanwhile the Pre-Assembly team was able to match the Cold Test Facility feats by producing in the same time interval a fully preassembled, carefully measured and nicely packed coil. The rest is a story of careful coordination and ‘extreme’ logistics with land, maritime and air transports tuned like clockwork.

But looking back our path is marked by milestones that, of course, we don’t forget: the great achievement of the Cryostat, fully supplied by CIEMAT with excellent quality and ahead of schedule, the successful and timely completion of the supply of the High Temperature Superconductor Current Leads（HTS-CLs) (by KIT), the successful tests of the first part of the Superconducting Magnets Power Supplies (SCMPS) (by CEA), of the Switching Network Units (SNU) (by ENEA) and of the Cryoplant (by CEA) fully installed and operational since December 2016, of the Quench Protection Circuits (QPC) (by CNR-RFX) ready since 2015 and opening the way to European on-site installation at the QST Naka site.

On 31 March 2018, F4E (and Europe!) has, for the first time reached 98.9% of the planned commitments: we are on schedule, perfectly aligned for the final approach to the first plasma in September 2020.

[by Enrico Di Pietro, EU Deputy PM (DPM) at present]



March 2018, EU has reached 98.9% of the planned commitments

4. News

Contributions from the European Voluntary Contributors

CEA - Toroidal Field Coils, Cryoplant and Power Supplies

CEA as Voluntary Contributor endorsed the commitment taken by the French government for a contribution to the JT-60SA project which included:

- the manufacturing of 10 Toroidal Field coils using components (casing and conductors) provided by F4E,
- the design and construction, with SCK•CEN, of the cold test facility aiming at testing the 20 Toroidal Field coils at nominal operation conditions (4.5 K, 25.7 kA), as well as the performance of these tests - the tests included the most severe event that can be encountered in a superconducting magnet which is the resistive back transition, called a quench,
- the design, manufacturing, installation and commissioning at the QST Naka site of the Cryogenic System aiming at cooling at operation temperature the superconducting magnets, structures, thermal shields, current leads and the cryopumps of JT-60SA,
- five superconducting magnet power supplies,
- the manufacturing of the mechanical structures (gravity supports and Outer Intercoil Structures) dedicated to the assembly of the magnetic field system.

CEA was given by F4E the task to perform in Europe before shipment to Japan the assembly of the TF coils with their respective Outer Intercoil Structures. To achieve all these goals, CEA has mobilized highly skilled CEA professionals all along this last decade and has contracted with specific industrial companies, such as Air Liquide Advanced Technologies, Alstom-Belfort (meanwhile: General Electric), SDMS, Alsyom, Jema and LGM, who proved to be efficient and reactive during the manufacturing. Based on its expertise in the field of design and operation of the large superconducting tokamak Tore Supra, the CEA contribution, focussed on the procurement of some of the most critical components of the JT-60SA Cryomagnetic System, allowed it to address new major scientific technical and industrial challenges and provided an opportunity to reinforce very fruitful collaborations within Europe and with QST. This provides the basis for developing further these common efforts towards magnetic fusion success with the next goals, such as the preparation of the startup and operation of JT-60SA and the implementation of the JT-60SA research programme, which will be, along with ITER, one of the major fusion challenges in the next decade. *[by Jean-Claude Vallet]*

ENEA - Toroidal Field Coils, TF coil casings and Power Supplies

ENEA, as an in-kind contributor to the project JT-60SA, is in charge of the procurement of 10 toroidal field (TF) superconducting coils, 20 TF coil casings, part of the Power Supply and 4 Switching Network Units (SNUs).

ASG Superconductors (ASG, Genoa) manufactured the TF coil according to the contract signed in 2011. Development of innovative prototype systems and equipment, both for constructive solutions and for the definition of manufacturing procedures, has been realized. The manufacturing includes integration of the winding pack into a structural steel casing. Care has been devoted to defining the chamfer to comply with the strong welding requirements. Following the achievement of the dummy double pancake (DP), the manufacturing started and 10 TFCs have been completed by April 2018.

ENEA commissioned in 2012 Walter Tosto (WT, Chieti) to fabricate 20 coil casings. The qualification programme validated the manufacturing processes, such as vibration stress relief treatment, welding and ultrasonic phased array, using mock-ups representative of straight and curved legs. The full procurement was completed in July 2017.

A contract for SNUs was signed in October 2012 with OCEM (OCEM ET, Bologna). Innovations included implementing the switch by an electronic static circuit breaker in parallel with the electromechanical bypass switch. Relevant tests were performed on an SNU in the Frascati Tokamak Upgrade facilities in 2014. Finally, the 4 SNUs were assembled for operational tests in final configuration. The 4 SNUs reached Japan in October 2016.

ENEA, through a contract signed in August 2013 with Poseico (Genoa) and Jema (Spain), procured 4 AC/DC converters for the central solenoid (CS), 2 AC/DC converters for the Equilibrium Field (EF) coils, 2 AC/DC converters for the Fast Plasma Position Control Coils (FPPCC), and 6 converter transformers. The complete systems of SCMPSs were delivered to Japan in December 2017.

[by Antonio Cucchiaro]

Attendees to TCM 23 in Genoa, September 2015

CIEMAT – The Cryostat

The JT-60SA cryostat is a large vacuum vessel made up of type 304 stainless steel which encloses the tokamak providing the vacuum environment to reduce thermal loads on the components at cryogenic temperature.

Due to functional purposes, the cryostat has been divided into 3 large assemblies: the Cryostat Base (CB), the Cryostat Vessel Body Cylindrical Section (CVBCS) and the Top Lid. CIEMAT was in charge of the design and manufacturing of the CB and CVBCS.

The CB comprises 3 sub-assemblies, the so-called lower structure (split in 3 sectors), the double ring (also split in 3 sectors) and the inner cylindrical shell made in a single piece. The 7 pieces are fully welded structures in which partial tolerances must be kept on each sub-assembly. The CVBCS is built by cylindrical sections connected by truncated-conical elements. It consists of a single-shell vessel (34 mm thick for shielding purpose) externally reinforced with 20 mm thick ribs. Bolted flanges connect the different sectors of the vessel body, sealed by thin non-structural welds performed from inside/outside the cryostat.

The CB total weight is 253 t, 12 m external diameter and 2.9 m height with requirements in total tolerances of ± 2 mm in height, ± 4 mm in external diameter and ± 0.25 mm flatness on machined surfaces. The CVBCS total weight is 175 t, 13.47 m maximum external diameter and 10.95 m height with also very tight tolerances: ± 4mm in height, ± 4 mm in radius on the main flanges and ± 0.25 mm flatness on machined surfaces. The cryostat shell has a tolerance of ± 10 mm in radius and the centre of the ports must maintain its absolute position within a tolerance of ± 8mm. The CB was manufactured by the Spanish company IDESA S.A. and assembled in-situ in 2013, while the CVBCS was manufactured also by the Spanish company ASTURFEITO S.A. and sent to the QST Naka site in November 2017. *[by José Botija]*

Cryostat Base (CB) and Cryostat Vessel Body Cylindrical Section (CVBCS)

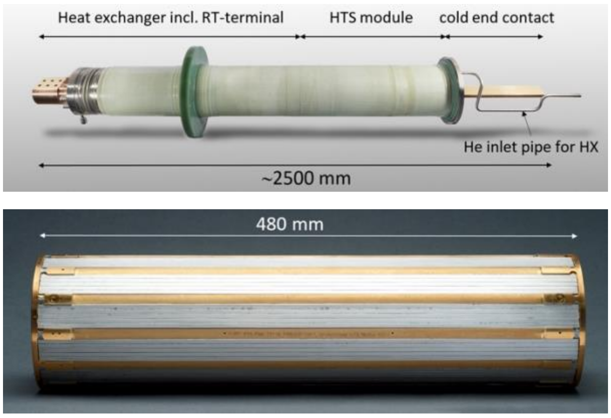
KIT - High Temperature Superconductor Current Leads

The Karlsruhe Institute of Technology (KIT) agreed to construct and test high-temperature superconductor (HTS) current leads for the JT-60SA superconducting magnet system. In total 6 HTS-CLs for 25.7 kA for the TF coils and 20 HTS-CLs for 20 kA for the PF and central solenoid (CS) coils were needed. In addition, the acceptance tests of the HTS current leads were performed at cryogenic temperature and full operating currents in the dedicated cryogenic test facility CuLTKa at KIT. After the signatures of the procurement arrangement between Europe (F4E) and Japan (JAEA*) and the agreement of collaboration between KIT and F4E in February 2010, a detailed design of both types of current leads was carried out and finally agreed between KIT, F4E and JAEA.

The basic design of the HTS CL follows the construction and experience from those provided for the W7-X project: a resistive copper heat exchanger with the electrical contact at room temperature covers the temperature range from room temperature to 60 K and is actively cooled by a flow of 50 K helium. An HTS module (Bi-2223 in AgAu matrix) covers the temperature range from 60 K to 4.5 K and is cooled by heat conduction from the low temperature contact. The low temperature connection to the superconducting feeder at 4.5 K includes a Nb_3Sn insert to reduce the resistive losses at 4.5 K.

Parallel to the detailed design, the procurement of material and half pieces was carried out. The manufacturing of the HTS current leads started in 2014. All HTS current leads were tested in CuLTKa with the last test in July 2017. All these acceptance tests of the TF and PF HTS current leads were conducted without any problem and the results were within the expectations. The experience of the personnel at KIT ensured a smooth execution of the project within the allocated time and budget.

[by Reinhard Heller]



TF HTS current lead (top) and HTS module (bottom)

Two PF HTS-CLs installed in test facility CuLTKa

HTS-CLs for PF11 to PF20 after arrival at QST

CNR - Consorzio RFX – The Quench Protection System and the Resistive Wall Mode Power Supplies

The Italian National Research Council (CNR), acting through Consorzio RFX, has contributed to the JT-60SA project with 2 systems: the Quench Protection Circuits (QPC) for the superconducting coils and the Power Supply System for the resistive wall mode (RWM) control (RWM-PS).

For the QPC, the function of the protection system for the superconducting coils is to fast-discharge the stored energy in the case of a quench or other faults. Each QPC is composed of a Hybrid mechanical-static Circuit Breaker (HCB) consisting of a mechanical ByPass Switch (BPS) for conducting the continuous current, in parallel to a Static Circuit Breaker (SCB) based on an Integrated Gate Commutated Thyristor (IGCT) for current interruption, plus a backup protection with explosive actuated CB. The nominal currents to be interrupted and the maximum reapplied voltages are 25.7 kA and 2.8 kV for the toroidal field coil QPCs and ± 20 kA and ± 5 kV for the poloidal field coil QPCs. The HCB design was the result of an R&D programme carried out since 2006 to identify innovative solutions for the interruption of high dc current, able to improve the maintainability and availability of the QPC. The procurement was signed in December 2009 and successfully completed in summer 2015 on time and on budget. The installation and commissioning activities, the first experience of joint work between Europe and Japan at the QST Naka site, were successfully carried out also thanks to the very fruitful collaboration.

Figure 1 summarizes key steps of the QPC procurement and Figure 2 gives a panoramic view of the final installation at the QST Naka site.

Figure 1: QPC scheme and main components in the centre, from the left to the right: signing of the QPC procurement, qualification factory type tests on the prototypes, visit of the Project Leader at Nidec ASI premises, system delivery at the QST Naka site, installation and commissioning phase, training and closure meeting of the contract and procurement.

Figure 2: Panoramic view of the final installation of QPC units in a power supply hall of JT-60SA plant

For the Power Supply system for Resistive Wall Mode (RWM) control, the whole RWM control system (coils, power supplies and control) went through several steps of optimization (Figure 3). The final coil configuration consists of 3 toroidal rings of 6 coils placed on the plasma side of the stabilizing plate, inside the vacuum vessel; the coils are individually fed by dedicated power amplifiers, controlled in real time.

A key aspect highlighted by the physics studies was the need for a very fast reaction of the control system to prevent an excessive growth of the plasma instabilities and to limit the power required for their control. The main requirements for the power amplifiers were a peak current of 300 A, output voltage of 240 V, bandwidth of 3 kHz and a latency shorter than 50 µs. The fulfillment of such fast dynamics was addressed via an R&D programme, which led to an innovative design solution adopting hybrid Silicon-Silicon Carbide (Si-SiC) semiconductor for the power amplifiers and to the development of a new sophisticated inverter on-board control. The procurement was finalized in 2015, after the detailed design and development and test of prototypes, and the system is presently in an advanced phase of manufacturing, with the delivery to Japan expected in autumn 2018.

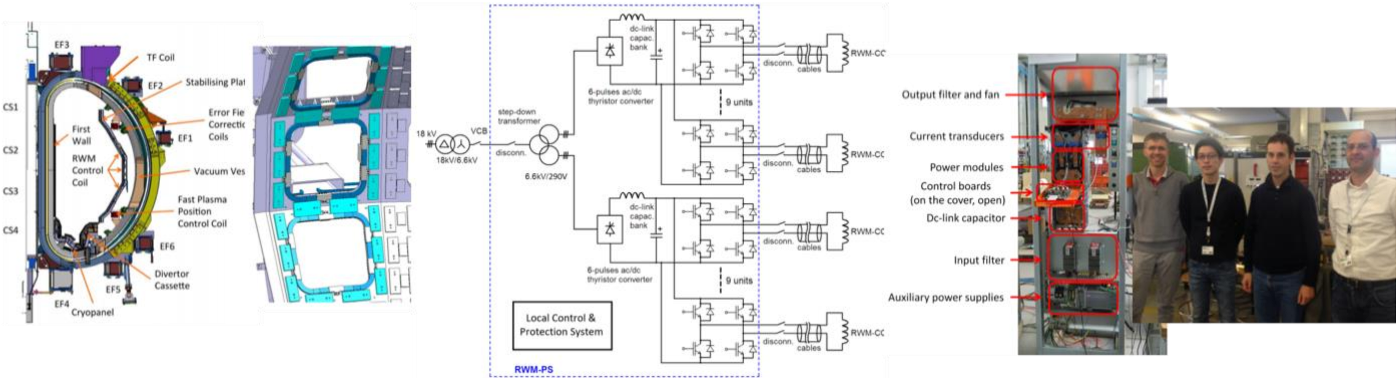


Figure: 3 From teft to right: layout of the JT-60SA in-vessel components, in-vessel sector coils for RWM control, scheme of the Power Supply system for RWM control, prototype of the key component of the system, and witnessed qualification type tests.

The work in the near future will involve the QPCs first in the integration with the PS sub-systems and then in the integrated commissioning. The validation of the models developed during the design phase will be an important task since they can be used for better understanding the systems behaviour during the integration in JT-60SA and to study possible upgrades. Outcomes from the operation of these systems, useful for ITER and DEMO, are also expected. *[by Elena Gaio]*

SCK•CEN (Belgium) - The Toroidal field coils cold test cryostat

The 18 Toroidal Field Coils for JT-60SA had to be individually tested at cryogenic temperatures and at the nominal current in a test cryostat. This cryostat was provided as an in-kind contribution by Belgium and was developed jointly with CEA-Saclay in France. The vessel is large, oval shaped, with an overall length of 11 m, a width of 7.2 m and a height of 6.5 m. To reduce the heat load to the coils, the cryostat is covered by LN_2 cooled thermal shields. In addition to the cryostat, 3 test frames for the coils, the valve box vessel and the insulation vacuum system were also provided by Belgium (in particular by the Belgian company Ateliers de la Meuse (ALM), with the support of Centre Spatial de Liège (CSL) under supervision of SCK•CEN).

The main requirements for the test of the TFCs can be summarized by "test like you operate" and can be summarized by:

- insulation vacuum better than 10^{-3} Pa;
- nominal current 25.7 kA;
- nominal temperature 5 K;
- temperature margin before quench about 7.5 K.

To minimize the helium refrigerator needs, thermal insulation by liquid nitrogen shielding is mandatory.

Manufacturing and assembly of these large and heavy parts, the total weight being about 60 t, were performed on time. Not only the flanges were machined (Figure 1) to guarantee the needed vacuum quality, but also the TF coil test adaptor interfaces, to ensure exact positioning of the coil interfaces to the test facility. After machining, all thermal shields were installed and connected in series. The cryostat and auxiliaries were first factory tested and then transported to CEA Saclay in France where the cold tests have been performed (one can see the cryostat at its official inauguration in Saclay, Figure 2). All tests were carried out in the cryostat without problem. *[by Vincent Massaut]*

Figure 1: Cover flange machining, see operator on right for scaling

Figure 2: Visit of the Broader Approach Steering Committee (BASC-13) to Saclay

*The responsibility of the Japan Atomic Energy Agency (JAEA) regarding fusion research and development was transferred to QST from Apr. 2016.

5. News

JA HT highlights: Issues and Solutions

The Satellite Tokamak Programme (JT-60SA Project) started on 21 June 2007. The JA Home Team (HT) had 2 critical issues at that time: the procurement of Vacuum Vessel (VV) and the sharing of Cryostat procurement.

To begin with, the JA HT prepared the Procurement Arrangements (PAs) for the PF Coil Conductor and the VV. The PAs for the PF Coil Conductor and the VV were signed on 4 October 2007 and 28 January 2008 respectively. However, the specification and the configuration model of the TFC were not yet fixed. The conceptual design of the TFC in 2007 allowed to foresee such problems as hollow NBI ports and unacceptable NBI tangential ports, which caused interference between the TFC structure and the VV NBI ports. Therefore, a Hold Point was set in the VV PA that “the sizes of Vacuum Vessel Body and Ports will be fixed according to the progress of detailed design of TFCs and plasma physics assessment”. Meanwhile, the JA HT signed 2 contracts on the VV procurement on 19 March 2008 in line with the Broader Approach (BA) budget plan for the JA HT activity, which were the procurement of plate material for the VV and the fabrication of the VV. This meant that the extra cost must be paid for by the JA HT. After that the TFC design was fixed in line with the Integrated Design Report (IDR) in November 2008. The issue was successfully solved.

The second issue was the technical problem of Cryostat manufacturing based on the sharing of the Cryostat procurement agreed in 2007. The EU HT was responsible for the design and the manufacturing of Cryostat base (CB) and body including the top lid without ports. The JA HT was responsible for the design and the manufacturing of Cryostat ports and the openings for port holes in the Cryostat body. In this case, it was hard to avoid deformation of the machined parts. The JA HT prepared the detailed procedure of the Cryostat assembly at the QST Naka site. Then the procedure was discussed between the groups, widening the scope to allow for the possibility of the port hole opening being made at the factory in Europe. The final tolerances achievable and cost implications were studied by the EU HT and the JA HT including the CIEMAT team. As a result, a sharing change request for the Cryostat was approved by the PL and PMs. In order to solve the technical problem of port hole opening and stub welding, it was proposed that the sharing of port hole opening and stub fabrication/welding should be changed from Japan to Europe. As a trade-off for the sharing change, it was proposed that the procurement of the vessel body material (SS304 plates with Co < 0.05 wt%) and the top lid should be changed from Europe to Japan.

Fortunately, the 2 critical issues were completely solved in close cooperation with the EU HT. The JA HT deeply appreciates the cooperation and the contribution to the JT-60SA Project by the EU HT. *[by Akira Sakasai, JA DPM (1 Apr. 2016 ~ 31 Mar. 2018)]*

News

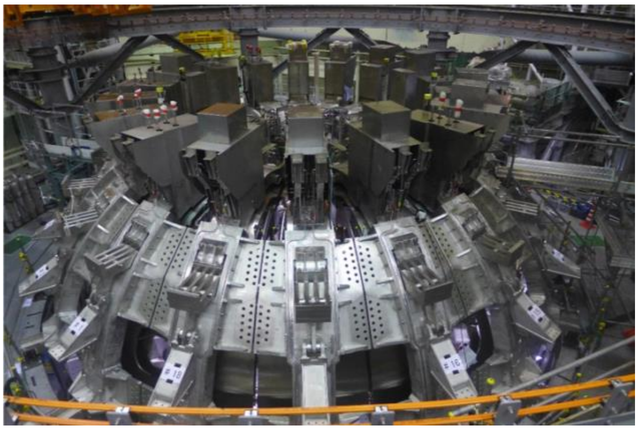
Contributions from the JA HT TROs

JT-60SA Assembly including VV, TS, and In-vessel

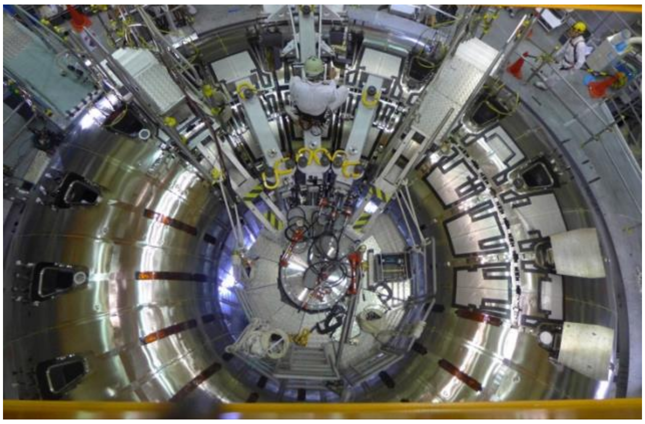
The JT-60SA assembly started on 28 January 2013. Seven pieces of cryostat base (CB) arrived at the port of Hitachi on 16 January 2013. After customs clearance, the 7 pieces were transported 1 per day at 3:00-4:00 am from the port of Hitachi to the QST Naka site. As the beginning of the JT-60SA assembly, the first assembly work of the CB was published via news release on 28 January 2013. The assembly of the CB was completed with high accuracy in March 2013.

After that, the lower Equilibrium Field (EF) coils (EF4, EF5, EF6) were temporally placed on the CB in January 2014. The assembly of 340-degrees of the VV with double wall structure was completed in August 2015. And the Vacuum Vessel side Thermal Shield (VVTS) assembly was completed in November 2016. The TFC assembly started in December 2016, and 17 TFCs were installed by the end of March 2018.

The 18th TFC and the final sectors of VV and VVTS together were lifted up and placed into the 20-degree opening on 20 April 2018. The welding connection of the final VV sector will start in May 2018. The upper EF coils (EF1, EF2, EF3) will be transported in July 2018 and installed. Then the installation of In-vessel components (magnetic sensors, first wall graphite tiles, upper diverter tiles) will also start in autumn 2018. *[by Akira Sakasai*



18th TFC and the final sectors of VV and VVTS together are placed onto the 20-degree opening



The VVTS final sector was adjusted to the neighbor VVTS sectors by couplers before the final sector assembly

PF Magnet and Magnet Shared Components

The superconducting Poloidal Field (PF) coils of JT-60SA consist of 4 modules of the Central Solenoid (CS), and 6 Equilibrium Field (EF) coils. The EF coils are large diameter coils. For example, the diameter of EF1 is 12 m. Because it was very difficult to transport large EF coils from the manufacturer's factory to the QST Naka site, we started with the construction of a factory for EF coil manufacturing at the QST Naka site. We also constructed the conductor manufacturing building, and a 600 m long conductor production line. Figure 1 shows the start of construction of the coil manufacturing building on 28 July 2008 (almost 10 years ago!). The JT-60 Magnet System Group was established at the QST Naka site on 1 October 2008. The building was completed on 30 March 2009 as shown in Figure 2. We also made a contract with Mitsubishi Electric Corporation for the manufacturing of PF coils in 2008. The first PF conductor was produced in the conductor manufacturing building on 5 March 2010 (Figure 3). QST and Mitsubishi Electric Corporation developed the coil manufacturing tools, and started the manufacturing of EF4 which is the smallest coil at Mitsubishi's factory. Then, we transported the EF4 and coil manufacturing tools on 27 April 2012 to the coil manufacturing building. We started the onsite manufacturing for the remaining 5 EF coils, and finished it in August 2016. EF 4, 5, and 6 are shown in Figure 4. As a result of the establishment of the manufacturing method, high-circularity EF coils were achieved. Regarding the CS, we already finished the production of 4 CS modules. We will start the integration of the 4 modules soon. The CS will arrive at the QST Naka site this winter. We also fabricated 3 Coil Terminal Boxes (CTB) and 11 Valve Boxes (VB). The PF magnet and Magnet Shared Components will be completed in this (financial) year.

[by Kaname Kizu]

Figure 1 Start of construction of coil manufacturing building

Figure 2　Building was completed

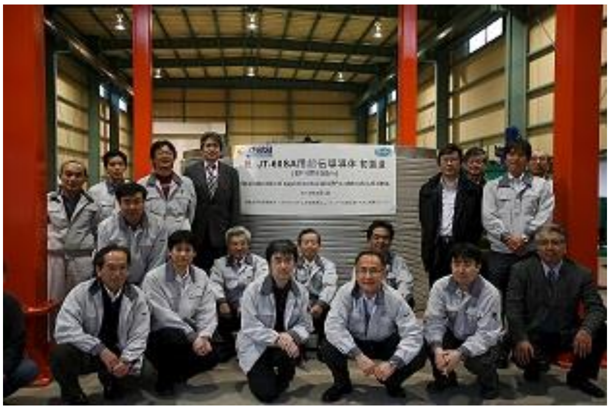


Figure 3 First PF conductor

Figure 4　Manufacturing of EF 4, 5, and 6

Magnet Power Supply

Most of Magnet Power Supplies are procured by Europe, according to the procurement arrangement based on the Broader Approach Agreement between Europe and Japan. At this moment, all power supplies except the RWMPS have been delivered to the QST Naka site and the site acceptance tests of the Quench Protection Circuits (QPC) procured by Consorzio RFX, the switching network units for the central solenoid (SNU-CS) procured by ENEA and the SCMPS (for TF, EF2, EF3, EF4 and EF5) procured by CEA have already been completed successfully. The installation and test for the SCMPS (for CS1, CS2, CS3, CS4, EF1, EF6 and Upper/Lower Fast Plasma Position Control Coil FPPCCs) procured by ENEA are now in progress.

For the above European on-site activities, Japan arranged some infrastructure and power devices for site acceptance test of European components. These included the auxiliary power supply system, DC feeder, water cooling system for the power supplies, H-MG (HITACHI Motor-Generator), AC circuit breakers, and the cables/pipes between European and Japanese components. In addition, Japan fabricated the SNU-EF and the ByPass Switch (BPS) of the Booster PS as new PS devices. Moreover, Japan managed the ground transportation for European components between the port of entry in Japan and the QST Naka site. These Japanese activities were started from FY2013 and the above activities were completed by FY2017.

As the next step, we plan mainly to install the supervisory control system including interlock and to start the signal cabling (optical and metallic) between European power supplies and the Japanese control system. After all the installation and modification of the Power Supplies and its control system are completed, we plan to start PS internal combination testing using a Dummy Load.

[by Katsuhiro Shimada]

(a) DC feeder fabrication (inside)

(b) DC feeder fabrication (outside)

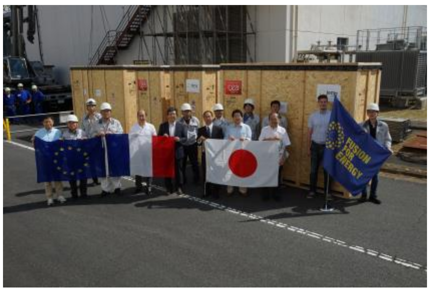
(c) Water Cooling System for PFCPS

(d) SNU-EF

(e) H-MG overhaul

(f) Cabling and piping work for SCMPS

(g) QPC ground transportation
(Carry-in work at Naka site)



(h) SCMPS ground transportation
(Arrival at Naka site)

(i) SNU-CS ground transportation
(Inspection at Yokohama port)

JT-60SA NBI system

The NBI development group at the QST Naka site has developed the JT-60SA negative ion source where 500 keV, 22 A, D- ion beams are produced for 100 s. The pulse duration time is only extended from 10 s of the previous value in JT-60U. Through a neutralization of negative ion beams, 10 MW D_0 beams are expected to be injected into JT-60SA. In order to realize such powerful beams with long pulse duration, the JT-60 negative ion source has been modified, improving the voltage holding capability for stable high-energy acceleration, reducing the grid power loading to an allowable level, and controlling the temperature of plasma grid for a stable long-pulse production of the negative ions. As shown in Table 1, the achieved parameters (energy, beam current, pulse duration time) independently fulfill the requirements for JT-60SA. After these independent tests, combination tests such as a 500 keV acceleration for 100 s are being done. *[by Masaya Hanada]*

Table 1 Design value and achievement obtained from JT-60 negative ion source

Parameter	Design Value in JT-60SA	Achievement
Energy	500 keV	500 keV, 2.8 A
Beam current	22 A（Current density: 130-170 A/m^2）	32 A, 10 keV, 1 sec 15 A, 10 keV, 100 sec
Pulse duration time	100 sec	100 sec, 15 A, 10 keV

ECRF System

The electron cyclotron range of frequency (ECRF) system is one of the significant devices for the success of the first plasma. The system consists of a dual frequency gyrotron, a wide frequency band waveguide transmission line and a launcher to inject radio frequency (RF) power into the plasma. The required RF oscillation frequencies are 110 GHz and 138 GHz. Based on the development programme of the dual frequency gyrotron, the first dual frequency gyrotron for JT-60SA has been manufactured and tested. The operation of 1 MW-100 sec at both frequencies was successfully performed in FY2014. This gyrotron can also oscillate at 82 GHz (so it is actually triple-frequency), which can be expected to be useful for plasma start-up assist and wall cleaning. The oscillation of 1 MW-1 sec at 82 GHz was successful in FY2015. The dual frequency gyrotron is now ready for the first plasma.

The capability of injecting 1.6 MW RF beams with both toroidal and poloidal steering is required for the launcher. The schematic drawing of the launcher is shown in Figure 2. It consists of 2 waveguides running in parallel, 2 small movable mirrors placed in front of the waveguide outlet and a large fixed curved mirror installed underneath. The small mirror travels back and forth in the radial direction to steer the beams poloidally and is also rotated along the axis of the driving shaft to steer the beams toroidally. The advantage of this launcher is to eliminate flexible cooling tubes in the vacuum environment of the JT-60SA tokamak resulting in the reduction of the risk of water leakage in vacuum. The full-scale mock-up of the mirror steering structure was manufactured (see Figure 3), in which the movable mechanism consisting of the drive shafts and LM guides with MoS_2 composite solid lubricant was installed. Cyclic rotation (10^4 cycles) and linear motion (10^5 cycles) tests were carried out and both cyclic motions were achieved as required, with the conclusion that the steering mechanism for the movable mirrors has now been successfully developed. *[by Koji Takahashi]*

Figure 1: Dual frequency gyrotron

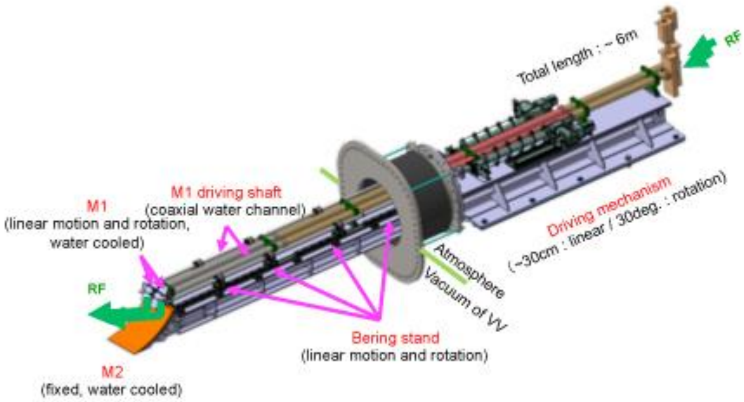


Figure 2: Schematic drawing of ECRF launch

Figure 3: Full scale mock-up of mirror steering structure

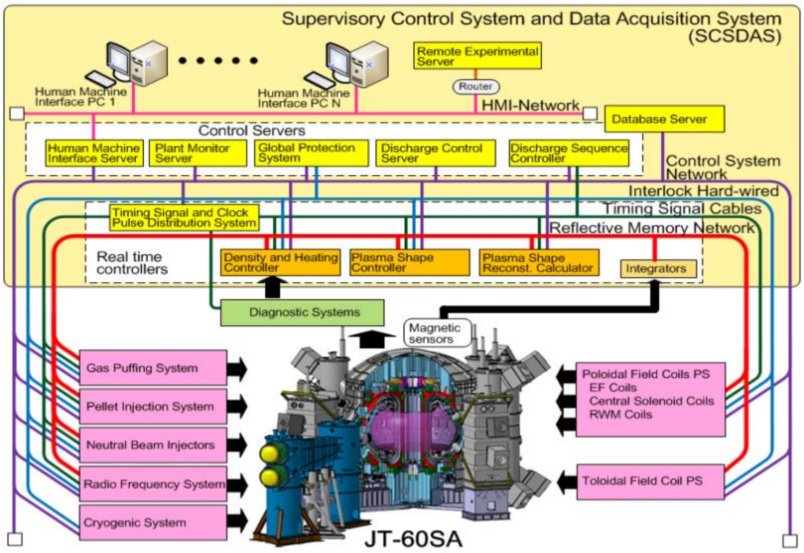
SCSDAS system

The SCSDAS (Supervisory Control System and Data Acquisition System) manages all control systems in JT-60SA. The SCSDAS is mainly composed of the several servers with functions of discharge sequence management, plant data monitoring, discharge parameter input functions, and real-time control. We have completed the development of the basic discharge sequence execution function of the SCSDAS.

Currently, the replacement of the SCSDAS development system by the real system, as well as signal cabling between the controllers, are in progress. In parallel, we are revising the safety protection interlock table from the viewpoint of safe device operation prior to installation of the interlocking logic in each system PLC (Programmable Logic Controller). After completion of the safety protection interlocking system implementation, the combination test with SCSDAS will be performed. Then, we are going to carry out the internal linkage test inside the SCSDAS before the individual linkage test with other facilities.

In this fiscal year, we are preparing the SCSDAS and other facilities in order to start the individual linkage test.

[by Yoichi Kawamata]



(a) Cunfiguration of the SCSDAS

(b) Real-time controller

(c) Huge monitor in central control room

(d) Safety protection interlocking system

7. Local
Editorial Note

The JT-60SA Newsletter happily reached No.100. I appreciate the JT-60SA Integrated Project Team members, and the Satellite Tokamak Programme Project Team members for their greate contribution and support for the JT-60SA Newsletter. I am grateful also to the people of the neighbouring cities, towns and villages for their kind cooperation on the local articles.I am thankful also for being blessed with excellent editorial staff, Spears-san, Petra-san and Nakamura-san.
Every article showed the latest achievements of the project in each monthly period and they were all impressive. Please come back to the JT-60SA Newsletter website and enjoy them at any time, then you can surely trace this historic project. See you on the site soon.

[by Hisato Kawashima]

Since it began in January 2010, I've enjoyed trying to improve the standard of English in the reports without losing their international charm (mostly trading excessive French definite articles for missing Japanese ones), enhancing technical clarity and accuracy where necessary, and making the transition from pdf to online electronic version in 2011. My Project Team colleagues always ensured we had enough material, although one time I did have to steer us away from an article about a pet dog, only to have to admit defeat when the "year of the dog" came round in January 2018! Congratulations to all contributors, and many thanks to my editorial colleagues , without whose patience we would not have such a good record of our project.

[by Bill Spears]

When I started more than 7 years ago the newsletter became one of my first tasks. And since then it has a special place in my heart. I have been amazed to see the progress of the project and have also learnt a lot about the technical side. It is nice to see the readiness of people when it comes to writing articles.
I am grateful to our Japanese colleagues, Kawashima-san and Nakamura-san (and all having worked on the newsletter so far), for the smooth cooperation. I would like to thank Bill Spears for his help and continuous support. It is a pleasure working in such an atmosphere. I am looking forward to reporting on further progress of the project and the first plasma!

[by Petra Rancsik]

Regrettably, I left the JT-60SA Project in March 2018. I am grateful to all of the newsletter readers for patiently waiting for the newsletter issue every month. In addition, I thank all of the contributors who were so kind to help me with understanding and translating technical and scientific contents through my 3-year-engagement.
When I saw the advertisement for this editor position, I instantly decided to apply for this rare opportunity to witness an historic challenge for mankind. Actually, I was able to attend many achievements. It was a great honour to be one of the JT-60SA project members.
It is surprising that I worked on one third of 100 issues. My job couldn't be successful without Spears-san's leadership and Petra-san's cooperation. Spears-san continuously guided me and improved the quality of the articles. Petra-san always gave priority to generating the web version, even when she had delivery of her 2 babies. Thanks. Finally, Kawashima-san is always a great chief to produce the Newsletter every month without any suspension. Only he could achieve this. Thanks to him, anybody can recall every moment of this historic JT-60SA Project and it is so valuable.

[by Shinya Nakamura (1 Apr. 2015 ~ 31 Mar. 2018)]

8. Calendar

4 - 8 June 2018
7th Research Coordination Meeting (RCM-7)
Naka, Japan

27 - 28 June 2018
30th Technical Coordination Meeting (TCM-30)
Naka, Japan

1 - 6 July 2018
45th European Physical Society Conference on Plasma Physics (EPS 2018)
Prague, Czech Republic

16 - 21 September 2018
30th Symposium on Fusion Technology (SOFT 2018)
Giardini Naxos, Italy

22-27 October 2018
27th IAEA Fusion Energy Conference (FEC 2018)
Gandhinagar, India

Contact Us

The JT-60 Newsletter is released monthly by the JT-60SA Project Team.

Suggestions and comments are welcome and can be sent to newsletter@jt60sa.org.

For more information, please visit the website: http://www.jt60sa.org/.