RECENT ACTIVITIES IN ACCELERATOR CONSTRUCTION AND STF CRYOMODULE

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Abstract

Since being founded in 1910, Hitachi, Ltd. has been providing a wide lineup of products and services in fields ranging from consumer home electronics to social infrastructure. The corporation has conducted a wide range of activities in the field of particle accelerators as well.

This paper describes Hitachi's contributions to the history of accelerator construction, major devices recently handled by Hitachi, and its efforts in developing STF cryomodules as part of recent R&D oriented toward the International Linear Collider (ILC).

EFFORTS IN ACCELERATOR CONSTRUCTION

Hitachi's development of particle accelerators began at the dawn of Japan's peaceful use of nuclear power. After electrostatic accelerators, electron linacs and other devices were developed for basic research, a small, special-purpose design group was established at a Hitachi Works. For more than four decades since then, the group has been engaged in constructing various accelerator systems ranging from small laboratory equipment to those in large national projects.

Hitachi joined accelerator construction projects conducted by universities and national research institutes from the R&D stage, and has been acquiring technology and developing the accelerator business. Figure 1 shows the projects handled so far. Starting with magnets and pattern power supplies for KEK's proton synchrotron (PS), the corporation has been involved in many large accelerator projects launched by KEK, the National Institute of Radiological Sciences (NIRS), the Institute of Physical and Chemical Research (RIKEN), the Japan Atomic Energy Agency (JAEA), and other organizations.

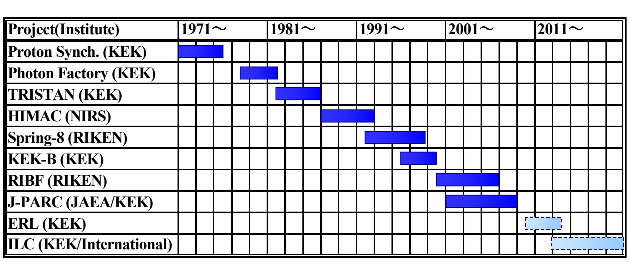

Figure 1: Hitachi's efforts in accelerator construction.

While handling the main magnets and related power supply systems in these projects, the corporation has been working on various superconducting magnets, beam ducts, vacuum systems, beam monitors, cryogenic systems, various power supplies, control systems, and related equipment.

They have also been making system-based efforts. Amid the craze for small SORs for semiconductor manufacturing, which began during the latter half of the 1980s, Hitachi constructed a small synchrotron in its own laboratory and has been engaged in system development. By enhancing this technology, the corporation has been working on equipment ranging from systems for the basic research addressed in those days to multipurpose or medical accelerator systems in recent years.

EXAMPLES OF RECENT ACCELERATOR CONSTRUCTIONS

The following are recent major examples of the accelerator projects handled thus far.

RIBF (RIKEN)

RIKEN's RI-Beam Factory is now the world's most powerful heavy-ion accelerator system, which accelerates heavy particles up to those of uranium at 70% of the speed of light, then collides the particles against a target to generate RI-Beams. [1]

Hitachi has manufactured superconducting sector magnets — the most important component of the superconducting ring cyclotron SRC — now in the final stage of three cyclotrons arranged to accelerate particles in multiple stages. Figure 2 shows a general view of the SRC.

The sector magnets of the SRC consists of the following components: superconducting main coils, superconducting trim coils, radiation shields, warm poles, vacuum vessels and beam chambers, and iron yokes. There are six sets of main coils, which are pool-cooled superconducting coils wound with aluminum-stabilized NbTi conductors. At a rated current of 5,000 A, these coils generate a central field of 3.8 T and accumulate a total energy of 240 MJ. The manufacture of these coils takes advantage of the technology for manufacturing large superconducting coils, which the corporation has been cultivating in applying nuclear fusion and other technologies. On the other hand, the 24 superconducting trim coils are designed to ensure field quality. To combine the thinness of the coils with their high rigidity, the corporation has adopted a conductive cooling system that is used in detector magnets and similar devices. Various other leading-edge superconducting and cryogenic technologies are employed, including a structure that thermally insulates the superconducting coils from the room temperature portion, while maintaining the coils at a specified positional precision in the small space within the vacuum vessel.

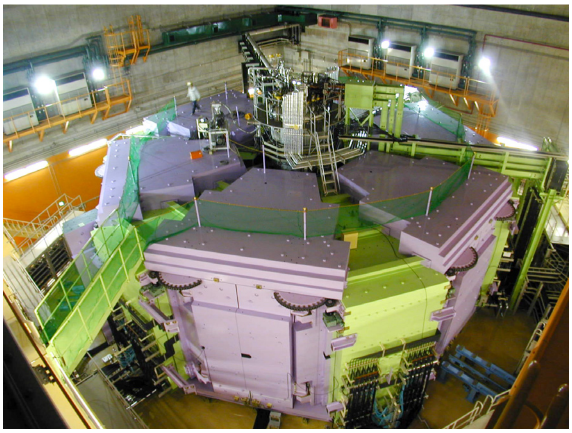

Figure 2: General view of the SRC.

J-PARC (JAEA/KEK)

The accelerators at the Japan Proton Accelerator Research Complex (J-PARC) consists of a linac about 330 meters in overall length, a rapid cycle 3-GeV synchrotron having a circumferential length of about 350 meters and a 50-GeV synchrotron with a circumferential length of about 1,570 meters. [2] Hitachi has conducted technical development in conjunction with JAEA and KEK, and manufactured the main equipment for J-PARC, whose required specifications are of the world's highest level.

The equipment manufactured by Hitachi for J-PARC includes the Radio Frequency Quadrupole linac (RFQ) of the first stage accelerator, the pulse power supply facility for the linac, and the main magnets for both the 3-GeV and 50-GeV synchrotrons.

The RFQ's acceleration energy is 3 MeV and its electrodes are machined with a precision of tens of micrometers. Figure 3 is a photo of an RFQ that has just been installed.

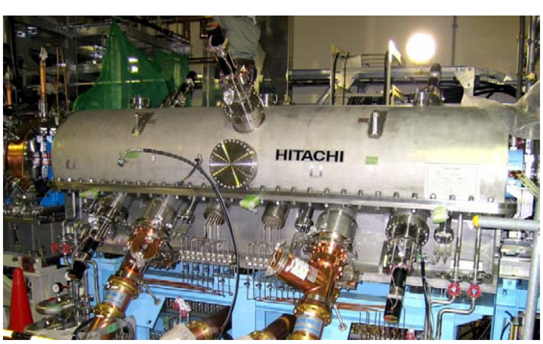

Figure 3: RFQ as installed.

Magnets have been manufactured in large numbers with large sizes and high functionality. Table 1 lists the magnets handled by Hitachi.

Table 1: Magnets for the 3-GeV and 50-GeV synchrotrons (manufactured by Hitachi)

Synch.	Type	Qty.	Weight	Magnetic field	Frequency
3GeV	B	25	38t	1.2T	25Hz
	Q	60	11t	18T/m	
	SX	18	2.2t	$18.6T/m^2$	
	Bump	10	5.8t	0.2T	
50GeV	B	97	33t	19T	0.3Hz
	Q	216	12t	18T/m	

The main magnets for the 3-GeV synchrotron is characterized by AC loss when energized with a 25-Hz sine wave. To counter that effect, the corporation has employed a conductor of aluminum stranded wire based on the technology for power transmission lines. The bending magnet is 3.4 meters in overall length and weighs 38 tons, and therefore among the world's largest magnets. Figure 4 is a photo of the bending magnet.

Figure 4: Bending magnet for the 3-GeV synchrotron.

Hitachi has manufactured one of the world's largest resonance power supplies for the 3-GeV synchrotron to excite the main magnets mentioned above. Moreover, the corporation has manufactured three types of ten bump magnets for the incidence bump system. To achieve high frequency characteristics, it consequently applied an electromagnetic steel plate 0.1-mm thick in large magnets for the first time ever.

The bending magnets and quadrupole magnets for the 50-GeV synchrotron are similar to those for the 3-GeV synchrotron, and among the world's largest laminate magnets in terms of both size and flux density generated. These magnets have entailed extreme difficulties in securing assembly precision due to their sizes and weights, but have achieved the specified field performance.

Synchrotron System

The synchrotron system is now widely used in various fields such as fundamental scientific research and medical application. Hitachi delivered the multi-purpose accelerator to Fukui Prefectural Government as a whole system as illustrated in Figure 5. Then, Hitachi delivered the proton beam therapy system to the University of Tsukuba for medical use. Based on this system, Hitachi also delivered the latest proton beam therapy system to M.D. Anderson Cancer Center in the United States and its commissioning at the site has almost been finished successfully.

Figure 5: Multi-purpose accelerator with synchrotron and tandem.

MANUFACTURING THE STF CRYOMODULE

As part of its R&D oriented toward the International Linear Collider (ILC), KEK is constructing a superconducting RF test facility (STF). The STF cryomodule consists of two cryostats based on the TESLA design, each about six meters long, cavities, dual radiation shields, and related equipments. Each cryostat can house four 9-cell cavities, each one meter in length.[3] Figure 6 shows the cross section of the cryostat.

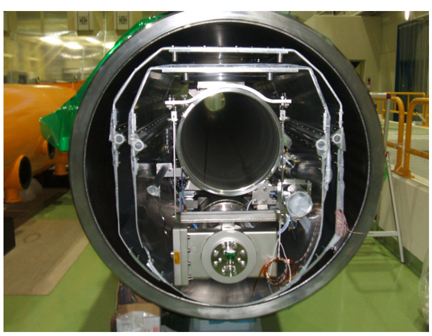

Figure 6: Cross section of the cryostat being assembled.

Hitachi manufactured the components of the cryostats and carried out the final assembly of STF cryomodule at KEK's building. [4]

The equipment to be cooled with helium, that is, the GRP, cavities, cryogenic piping, and dual radiation shields as assembled together into one unit, is called the "cold mass." The cold mass was assembled by suspending the GRP onto a special-purpose assembly jig and mounting the components around it. In that assembly process, different groups of personnel handle the different components. Consequently, tasks to be handled by Hitachi and those handled by KEK and other manufacturers were conducted in a mutually telescopic manner. To proceed efficiently with the work, it is therefore very important to coordinate processes and procure parts in advance between the groups. KEK installs the cavities, wire position monitors (WPM), coaxial cable, and other parts. The assembled cold mass is then carefully inserted into the vacuum vessels by using a different special-purpose jig and fixed by using support posts to complete the assembly of one of the cryostats.

Both cryostats are transported into the underground tunnel beneath the building, and then undergo final assembly. After the cryogenic piping is connected and the some remaining components are installed, the vacuum vessels are closed. This completes the assembly of the STF cryomodule. Figure 7 shows the completed STF cryomodule.

Figure 7: STF cryomodule as completed.

Having been installed, this device is being prepared by KEK in preparation for evaluation testing as an R&D system as of May 2007.

SUMMARY

By constructing a variety of accelerator equipments, Hitachi has thus far been developing and establishing the technologies for manufacturing the related components. We were able to share valuable knowledge and expertise particularly well through the manufacturing and assembly of the STF cryomodule as part of R&D currently in progress. We intend to extend this to large accelerator projects to be launched in the future, and help promote the implementation of such projects as the future ILC constructions.

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