MEETING REPORT

SUMMARY OF THE FOURTEENTH SYMPOSIUM ON FUSION TECHNOLOGY, AVIGNON, FRANCE, SEPTEMBER 8–12, 1986

The 14th Symposium on Fusion Technology (SOFT) was again a focal point for 500 scientists and engineers from America, Asia, Australia, and Europe to present their latest results in this truly high-technology field. The Europeans, among them colleagues from Poland and the USSR, had, of course, the largest group of participants. In reviewing the symposium, a question arose: How is fusion nuclear technology developing?

The old walls of the papal palace in Avignon, France, host of this perfectly organized conference, and Cadarache Tore Supra, a tokamak with a strong innovative impact to industry, were of amazing contrast. The "leitmotiv," or the guiding feature, of this conference was the technology necessary for experimental devices in operation, under construction, or at least in the preliminary design phase. There was no science fiction, no undue extrapolation of a technology of today to the technology for a reactor to be built far beyond the year 2000!

The numbers of contributed papers devoted to the different disciplines were as follows:

1. magnet technology (32)
2. in-vessel components and vacuum systems (29)
3. materials (24)
4. blanket technology (22)
5. high-frequency heating systems (21)
6. data acquisition and control systems (20)
7. tritium handling (18)
8. power supplies (15)
9. neutral beam heating systems (15)
10. experimental systems (13)
11. refueling (8)
12. remote handling (7)
    safety (7)
13. plasma equilibrium (6)
    reactor studies (6).

Analyzing the distribution of contributed papers to plasma technology and technologies related to the next larger devices and to reactors, the ratio is still 2.5 to 1 in favor of plasma technology. There are fields, of course, like experimental systems on the one hand and blanket technology on the other, which were exclusively devoted to one of the areas of fusion technology. In the in-vessel components and vacuum systems section and in the magnet technology section, for example, the blend was 3 to 1 for plasma technology. In the materials section, the ratio was 50 to 50.

Plasma heating, magnet technology, and problems associated with mastering the plasma wall interaction and gas transport were—with 40% of all contributed papers—the areas where most of the engineering work in fusion technology is done today. Long pulse heating systems in the multimegawatt range are going to become standard equipment for most fusion devices. In magnet technology, superconducting systems and magnets for fields on axes between 3 and 10 T are of main interest, and sophisticated thin-wall-sandwiched structures like vacuum-vessel, complex lining systems, mostly made from carbon and pumped limiters, both poloidal and toroidal, are the focal points of in-vessel technology.

In his opening remarks, the director of the French Fusion Program, F. Prevot of the Commissariat à l'Energie Atomique–Cadarache, which hosted the symposium, addressed the amalgamation process of plasma technology and nuclear technology into fusion technology, the subject of this conference since 1960. As the fusion devices are now prepared for tritium operation on the one hand and are growing in complexity because of increasing demands for plasma handling on the other, fusion technology will rapidly expand with greater depth, more coverage of side areas, and more frontier work. Prevot expressed his hope that SOFT will remain an event of cross fertilization of the different fields involved in fusion technology by a balanced program of the most significant results. Here contributions dealing with mutual connections between the different areas ought to be preferred over highly specialized papers, in case the size of the symposium tends to grow too rapidly. In this way, he pointed out, SOFT will remain a market for an exchange of information and experiences, and it will stimulate an orientation to direct research.

In his concluding remarks, R. Toschi complimented the authors of the 14th SOFT because their papers showed a high scientific level and a bold approach without disregarding sound, down-to-earth engineering. Indeed, this time neither philosophical papers nor inventions for an easy way to fusion power were presented. The paper selection committee achieved a remarkable level of quality without compromising quantity.

The European Fusion Technology Program presented by H. H. Hennies has gained momentum rapidly since 1983, whereas the U.S. program, presented by R. J. Dowling, has shrunk somewhat in scope since the last SOFT. Both programs are focused on the technological needs for the next fusion devices: the Next European Torus (NET) in Europe and the Compact Ignition Tokamak (CIT) in the United States. As a result, the seven papers on power reactors dealt with special aspects, such as structural problems of the vessel, fuel cycles, breeding ratios, radiation damage considerations, ignition conditions, and favorable plasma temperatures. Only one paper was of the old style, covering the design of a whole plant.

Hennies addressed the difference between NET and what he called a "physics machine," e.g., CIT, concerning the impact on a technology program. In reality, the said difference will become smaller than Hennies' paper indicates with one exception: In the area of blanket technology, a device like NET has further demands, e.g., neutron-induced stress distribution, as well as corrosion and energy recovery. Since both devices, however, will operate with a deuterium-tritium (D-T) mixture and the physics machine has to be designed and built for nuclear operation, the required technologies have to be developed accordingly. Such a physics machine will be a strong neutron source, and many experiments relevant to blanket technology can be done complementary to those with NET.

Hennies further addressed the important question of an appropriate frame for NET given by the plasma physicist to the nuclear engineers. He confirmed what has been discussed for years in workshops and offices in the United States, namely, that a possibly oversized toroidal magnet, giving both the physicist and engineers more latitude, is not as great a cost penalty as older papers claim.

Many invited papers were devoted to the Joint European Torus' (JET's) extended performance, including higher currents, a new first-wall concept, and a current profile control. Papers were also devoted to the new European devices for toroidal confinement that are under construction. These include the Wendelstein VII-AS, a stellarator; FTU, a high-field tokamak; ASDEX UPGRADE, the large divertor experiment; and the new reversed-field experiment. Finally, a paper was presented on Tore Supra, a new class in large tokamak engineering, with its superconducting coils, superfluid helium technology, fivefold vacuum vessels with aerospace engineering, lower hybrid current drive (LHCD) capability for high currents (in mega-amperes) and densities (5×10^{13} cm^{-3}) and therefore with simple multijunction launchers for LHCD, new klystrons for 3.7 GHz and long pulses on a megawatt level. The visit to the construction site of Tore Supra gave many fusion engineers the good feeling of working in a truly "high-tech" area.

The encouraging results of the Tokamak Fusion Test Reactor (TFTR) at Princeton University and of JET at Culham Laboratory, where both experiments were boosting ion temperatures far beyond the familiar 10-keV milestone, gave a particular thrill to the attendees of the 14th SOFT. All these fine results became possible as a result of the highly developed art of heating a plasma, a subject that was well covered by contributed papers as well as invited papers. Perfectly reflecting the state of the art were papers by A. G. A. Verhoeven on electron cyclotron resonance heating, F. Wesner on ion cyclotron resonance heating, G. Tonon on LHCD, and J. F. Feist on long pulse neutral injection.

The reported 10^{16} deuterium-deuterium neutrons released per second by JET and TFTR made it clear that the innocence of *l'art pour l'art* plasma physics is gone for the large devices and that we have to face the implications of nuclear operation.

The presentation of the preparation of JET for the D-T phase operation may lead to the conclusion that much has to be done before this device is ready for operation. Such a difficulty may be due to the fact that there are almost no tritium engineers with hands-on experience available for the fusion laboratories outside the weapons program. At the present stages of TFTR and JET, there should be dozens of papers at a conference like SOFT dealing with designs and experimental findings related to the tritium storage and delivery systems, the tritium receiving and waste handling, and the reprocessing, as well as the cleanup systems, if one compares the tritium systems with other systems in fusion engineering usually addressed during a SOFT.

Very little, however, was reported on results of engineering work that will be needed very soon. The experimental determination of the kinetic conversion rate of gaseous tritium into HTO by W. Gulden, H. Djerassi, and H. Clerc and the hydrogen extraction from an exhaust gas mixture by M. Charles were the only papers connected to the operation of a tritium plant in the near future. D. Léger gave an invited paper on breeding and reprocessing tritium in a reactor.

Also, the safety and remote handling sections had only a few contributions, although most of these papers were of practical value. For both areas, however, the system engineering features of a whole plant and many details within the community are not yet at a level where fusion could go nuclear with confidence in the near future.

U. Schwarz's invited paper on "Digitized High Power Modulation" was a bridging element between fusion technology and other areas of technology where conditioned variable high power is needed. In his lecture he gave examples of how technological development for fusion helps to harden ordinary industrial products. The papers on the French laser facilities in Limeil and on the research and development for Superphénix demonstrated the high level of French technological involvement in the fields of laser and fast breeder technologies.

Does fusion technology have an innovative power in industry? Today the construction of nearly all fusion devices, test facilities, and, in many cases, even design studies and fabrication tests are handled by companies. No doubt, private industry is strongly involved in fusion technology. Their participation of only 14% in this symposium indicated, however, that fusion technology is, on a global scale, still firmly in the hands of publicly funded institutions. Innovative impact on industrial development means more than supporting routine business in ordering stock items or constructing components according to detailed given designs. Of course the existing experience in fabrication and the availability of developed products are of unsurmountable value when building a device. But only the recognition of demands for and the financial support of novel technologies will lift industry to new horizons. New types of magnets, sophisticated vacuum vessels, and high-power, long-pulse klystrons of 3.7 GHz are examples of developments in France, Italy, and Switzerland. The participation of private industry from these countries in SOFT this time was between 25 and 50%.

The proceedings of the 14th SOFT will be an excellent detailed documentation of specific theoretical and experimental work in all areas of fusion engineering; of achievements in design, construction, and operation of nearly all fusion devices with toroidal magnetic confinement; and of frontier work in fusion engineering.

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November 24, 1986