organize several European-US workshops.

Jack Connor (Culham) agreed to co-ordinate the European TTF and maintain contacts with the US TTF, with help from Francesco Romanelli (Frascati), Jan Weiland (Chalmers University) and Friedrich Wagner. They would coordinate workshops, disseminate information, organize the biannual European meeting and, jointly with the European topic coordinators, propose European contributions to the US meetings. J.W. Connor and B. Carreras belong to the Confinement and Transport ITER Expert Groups so the results of TTF activity can be fed into the ITER framework to avoid duplication.

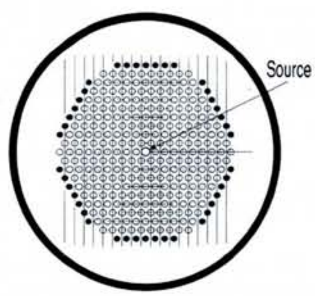
The support of laboratory Directors in Europe is being sought. As it is hoped that the initiative will harness the undoubted strength of the European Fusion Programme to solve the grand challenge of understanding the cause of anomalous transport in magnetic confinement devices, F. Wagner reported the outcome of the Göteborg discussion to the European Programme Committee last September. General approval was given and terms of references suggested. The European collaboration must take full account of the ITER physics and Expert Group activity to avoid duplication; appropriate dissemination of knowledge must occur; working structures must incorporate all EURATOM Fusion Associations as well as JET; additional travel costs must be kept low, the organizational overhead minimized and activity concentrated at the working level.

The Topic Coordinators are: edge turbulence (Hidalgo, Madrid), core transport and turbulence (Romanelli, Frascati), physics of short timescales in transport (Cordey, JET), perturbative transport (Jacchia, Milan), and stellarator-tokamak comparisons (Stroth, Garching).

J.W. Connor, *Culham Laboratory*

Elegant Demonstration Successful

The sub-critical reactor assembly used for demonstrating the energy amplifier comprises 270 Al-clad bars of natural uranium immersed in demineralised water with a neutron spallation source at the centre. The assembly is normally used in Madrid for teaching purposes.



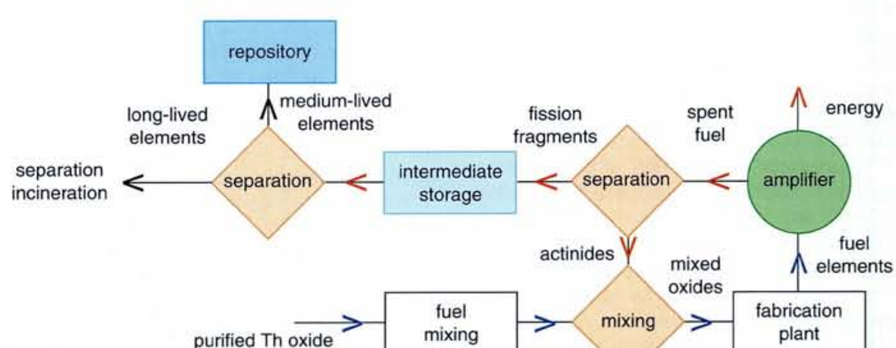
It is just over a year since C. Rubbia, CERN's former Director-General, made headlines by proposing an energy amplifier — a nuclear reactor based on an accelerator-driven sub-critical assembly with thorium as the breeder fuel. Neutrons produced by spallation multiply *via* fission reactions in a fuel-moderator medium to give an overall energy gain. The main advantages, apart from sub-critical operation, lie in: the use of thorium (inexhaustible on the human scale; little plutonium production so reduced risk of nuclear proliferation); the production of much less transuranic actinide waste than conventional nuclear reactors; mainly existing technologies unlike other hybrid systems for energy production.

His group found resources to check calculations experimentally using well-established but nonetheless elegant techniques. The results were presented in detail by Professor Rubbia at CERN in early December. A spallation target, placed at the centre of a sub-critical assembly comprising 3.6 tonnes of natural uranium encased in aluminium tubes and immersed in water, was irradiated by a low-intensity proton beam produced by CERN's Proton Synchrotron beam over a two-week period. Observed temperature increases of the order of a mere 0.01 °C (since the device only generated 1 W to minimise radioactive waste production) correlated with measurements of fission fragments. Assumed cross-sections and approximate analytical solutions were verified and the estimated energy gain of 30 agreed with the results of a Monte-Carlo simulation.

On the analysis side, the window of opportunity for the amplifier approach is narrowing as the group rediscovers various technological, environmental and commercial restraints. A practical system delivering 10^8 to 10^9 W would operate in a different regime where transmutations modify significantly the evolution of cascades (thus allowing the required breeding of a Th fuel with a long burn-up period). Studies have been extended from the original graphite and water-cooled systems based on thermal and epithermal neutrons to systems involving fast neutrons with lead coolant. This allows a higher gain which is not flux limited, thus avoiding the need for several accelerators. But it also means that one is now discussing larger (1 GW), more exotic reactors working closer to criticality. Fuel regeneration has also become more complicated: established processes to separate out long-lived actinides need improving, and economic considerations suggest storing short-lived fission products while concentrating processing on the long-lived, high-mobility varieties.

On the accelerator side, the experiment demonstrated that there is no point in going beyond about 1 GeV proton energies. The analysis so far indicates that useful systems may also involve fairly modest currents ($\approx$ 10 mA, roughly an order-of-magnitude less than for the high-intensity linac-based fission schemes being proposed for various applications of transmutation — see *EN*, August 1995, p. 135). So some existing cyclotron designs may be suitable, notably isochronous ring cyclotrons with C-separated magnets of the type operating at the Paul Scherrer Institute. Overall, the economics of the fast-neutron option appear favourable, but a detailed analysis is needed.

Professor Rubbia aims is to remain an experimentalist at heart by seeking support for a pilot facility involving a larger reactor assembly, fuelled this time with thorium, to once again verify calculations (a proposal along these lines is expected shortly).



A possible fuel cycle for the energy amplifier. Fuel reprocessing is limited by the efficiency of separating out the actinide fission products. For cost-effectiveness, medium-lived fission products may be stored, with costly processing reserved for long-lived elements.