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FTP/4-4Ra & FTP/4-4Rb & FTP/4-4Rc: Status of LLCB TBM R&D Activities in India; Activities on the Helium Cooled Lithium Lead Test Blanket Module for ITER; Current Progress of Chinese Solid Breeder TBM

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FTP/4-4Ra: Status of LLCB TBM R&D Activities in India
The development of Lead-Lithium Ceramic Breeder (LLCB) blanket is being performed as the primary candidate of Indian Test Blanket Module (TBM) program towards DEMO reactor. The LLCB TBM will be tested from the first phase of ITER operation (H-H phase) in one-half of a ITER port no-2. Neutronic calculations for the above design of LLCB TBM blanket have been carried out to estimate tritium production rate and radial profiles of nuclear heating in the blanket. The thermal-hydraulic analysis have been carried out for both serial flow and parallel flow of PbLi . Based on this analysis LLCB design has been optimized. To study the MHD effects, lab scale liquid metal MHD experiments has been performed to understand MHD phenomena in complex flow geometries and to generate relevant MHD database for validation of MHD numerical code. Safety analysis has been carried out for the safety licensing of LLCB TBM system for ITER. A set of four reference accidents has been identified for complete LLCB TBM System. An in-house customized computer code is developed and through these deterministic safety analyses the prescribed safety limits are shown to be well within limits for Indian LLCB-TBM design and it also meets overall safety goal for ITER. Lead-Lithium loop construction involves development of critical components like electromagnetic pump, heat exchanger, recuperator, cold trap, flow meter, pressure transmitters etc. Series of experiments on compatibility of Pb-Li with candidate structural materials Indian specific RAFMS have been attempted to study corrosion effects. Two parallel experiments were conducted in Pb-Li buoyancy loop and in a electromagnetic pump pump driven loop in the presence and absence of magnetic field. The specimens were characterized using analytical tools such as Optical microscopy, Scanning electron microscopy, energy dispersive X- ray (SEM/EDX), EPMA. Lithium Titanate development is under progress through two techniques (1) Solid state reaction (2) Chemical solution based technique. Extruder Spherodization process was adopted for preparation of spherical pebbles. RAFM Steel development in India is based on the chemical composition of the conventional P91 steel is modified by substitution of highly radioactive element molybdenum by tungsten and niobium by tantalum. This paper will provide present status of TBM related R&D activities in India.

FTP/4-4Rb: Activities on the Helium Cooled Lithium Lead Test Blanket Module for ITER
This paper gives an overview of the activities carried out at CEA concerning different aspects of the module and the associated systems (TBS –Test Blanket System): system engineering and configuration management, compliance with existing regulation, conceptual design, manufacturing and assembling of subcomponents, testing programme, instrumentation needs, ancillary systems, maintenance in ITER port cell and transport of irradiated waste.

FTP/4-4Rc: Current Progress of Chinese Solid Breeder TBM
The helium-cooled/solid breeder with the pebble bed concept has been adopted in Chinese ITER test blanket modules (TBM) design. The structure dimension of HCCB TBM design is based on 1/2 ITER test port divided vertically. In order to reduce the effects of magnetic field ripple, the design was updated with reduced RAFM steel mass. The arrangement of pebble beds in the sub-module is changed from the original transverse direction to the current vertical direction. In this updated design, each sub-module has cooling plates fed in parallel by high pressure Helium. Flow-rates of He coolant are controlled by the coolant bypass system between first-wall and sub-modules. Updated design were exhibited that the coolant flow of FW has been changed from the toroidal direction to the poloidal direction; and every 3 coolant channels are to form a cooling loop, and there

are 9 loops in total inside the FW. Moreover, a modification for sub-module has also considered, the number of tritium breeding zone and neutron multiplier zones consist of 2 zones and 3 zones, respectively. Some test facilities including electro-magnetism test facility and helium test loop are being built in China. Relevant R&D on the key issues of the tritium system, RAFM steel structure material, function materials including the solid tritium breeder and neutron multiplier as well as the tritium permeation barriers, are being conducted in China. Chinese Low-activated Ferritic/martensitic steel, CLF-1, as TBM structural materials is developing towards industrially level. Exploration study of neutron multiplier Be pebbles fabrication technology has been done. Be pebbles are produced by the rotating electrode process (REP). The lithium orthosilicateas tritium breeding materials of HCCB TBM have been fabricated at laboratory level. The design of a test helium loop working at high pressure (8MPa) and high temperature (550℃) prior to TBMs installation in ITER have been completed. In addition, Chinese HCCB TBM will be tested in Port #2 with the India Liquid Lithium Ceramic Breeder (LLCB) TBM simultaneously. Two TBMs and its associated ancillary systems will be integrated on the same Port as well as interfaced with ITER buildings and systems.

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