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PROJECT OF THE FUEL CYCLE BASED ON THE EXAMPLE OF THE IGNITOR TOKAMAK AT THE RUSSIAN SITE

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Prof. Bruno Coppi and his collaborators have been developing a theory based on an experiment on the ignition of a fusion reaction in a compact tokamak under strong magnetic fields and high plasma density. To carry out this experiment, the tokamak IGNITOR project has been developed [1]. The concept of IGNITOR tokamak based on the using of a strong magnetic field (up to 13 T) and plasma current (up to 12 MA). It will operate with short pulses (of approximately 10 s) and will not have a tritium-breeding blanket. The maximum value of the tritium necessary to provide D-T fusion reaction during 10 s of discharge duration is 0.12 g. The total value of the tritium required for independent operation of the IGNITOR tokamak during one day of experiments (three discharges) is approximately 10 g.
One of the most important systems will be tritium fuel cycle and detritiation systems which provides scientific program of the investigation on IGNITOR-like tokamak. The tritium handling systems shall be technically and cost effective, and allows for effective control of normal and accidental discharge of tritium to the environment.
Table 1. Main Technical Parameters of the Ignitor tokamak [2, 3]
Major radius R 1.32 m Plasma current Ip 11 MA
Minor radii a ⨯ b 0.47 m ⨯ 0.86 m Toroidal field Bt 13 T
Elongation k 1.83 Poloidal current Iθ 8 MA
Triangularity δ 0.4 Average poloidal field 3.5 T
Plasma volume V 10 m3 Edge safety factor qψ 3.5
Plasma surface S 34 m2 RF heating PICRH < 18 MW
Pulse length 4 + 4 s
The offer of the Russian Federation to use the TRINITI site (Troitsk, the Big Moscow region) as the location of a Ignitor tokamak demands a new review of reliability and efficiency of power and technical infrastructure of TRINITI for the stated purposes according to the requirements for use of technologies and costs of realization [3]. This is of high importance for further developments of the Ignitor project. Among the main systems of the technical infrastructure, the fuel cycle systems, including the tritium processing systems, have a principal value not only for supply and recovery from the plasma exhaust of D-T fuel mixtures, but also for ensuring radiological safety of the personnel and environment during normal operation and in the event of an accident [4, 5].
A key condition for the implementation of the scientific program of the IGNITOR project is the ability to operate using DT fuel. The concept of a fuel cycle modification was proposed in [6,7] and based on an analysis of global experience regarding the treatment of tritium.
The provisional approach to the design of a fuel cycle and detritiation systems had been based on technologies used or proposed for other machines, such as JET, ITER, TFTR. A similar activity, to estimate tritium inventory and fuel cycle, is being carried out for DEMO and it will, in the near future, for the new project ARC, the Affordable Robust Compact fusion power reactor. ARC has been recently developed in the US and shares with Ignitor some common concepts, like the use of high-temperature superconductors, high magnetic field and compact dimensions.
Taking into account the 100% research purpose of Ignitor, and the low demand for processing of hydrogen isotopes, a selection of tritium handling and detritiation technologies has to be reviewed, keeping in mind the requirement for cost effectiveness.
The following information was reported earlier [6]:
- the amount of tritium needed to fill the vacuum vessel and fuel system is about 3 g per one discharge or 10 g per one experimental day. This amount presents mobile tritium which can be released inside the building in an accidental event,
- the amount of impurities in plasma exhaust is about 9%, with 3% of these being hydrogen-containing substances (water, methane, ammonia, etc),
- the flow rate of impurities (without residual content of molecular hydrogen) is about 4E-3 mol/h,
- the maximum flow rate of active gas (glow discharge cleaning) is about 5 mol/h. This stream can contain a few tens of parts per million (vppm) of tritium,
- the amount of tritium involved into burning of fusion reaction is estimated as 0.12 g T2.
The presenting concept provides of the supplying, processing of tritium waste and retention of tritium during the implementation of the scientific research program at tokamak IGNITOR. The main task of this work is to develop an engineering concept for the tritium fuel cycle and systems for detritiation of air, water, and solid

tritiated waste when using the IGNITOR tokamak with tritium plasma at the TRINITI site. Based on review of the technologies and arrangements for fuel cycles of experimental fusion reactors, such as JET, TFTR, ITER, an optimized arrangement for the fuel cycle of the reactor Ignitor is proposed. This includes:
1) Storage of pure tritium, deuterium and their mixtures in for of compressed gas in vessels of volume around 10 to 40 l at pressure of 0.4 MPa.
2) Chemical purification of plasma exhaust from gaseous impurities using method of hot getters, e.g. uranium.
3) Separation of hydrogen isotopes by method of replacement gas chromatography.
4) Detritiation of gaseous effluents and air using catalytic conversion of hydrogen containing gases to water vapour followed by detritiation of produced water vapour in wet scrubber.
5) Use of CECE (Combined Electrolyser Catalytic Exchange) technology for detritiation of water streams.
All technologies listed above are well developed in Russia. From our point of view, their application in an integrated matter would ensure good protection of workers, public and environment against exposure to tritium and construction and operation of the fuel cycle and detritiation systems in a cost-effective way.

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