Concepts of the power exhaust and divertor design have been developed, with a high priority in the preconceptual design phase of the Japan-Europe Broader Approach DEMO Design Activity (BA DDA). A common critical issue is the large power exhaust in the main plasma and divertor by the radiative cooling with impurity seeding. (i) Different power exhaust concepts in the main plasma and divertor have been developed for JA and EU DEMOs, and divertor operations were systematically determined by simulations (SONIC and SOLPS-ITER). In addition, effect of the different geometry on the plasma detachment was compared for comparable exhaust power of $P_{\text{sep}} \sim 150 \text{ MW}$. (ii) Integrated designs of the heat removal components and cassette structures have been developed. (iii) Both divertor designs are adequate to handle the peak heat loads on the target ($q_{\text{target}}$) of $10 \text{ MWm}^{-2}$ level under neutron irradiation condition. These approaches will provide important case-studies for future improvement of their DEMO designs.

**Power exhaust concept and Divertor simulation:**

Power exhaust scenarios and divertor designs have been developed in JA[A] and EU[B], where the total heating powers ($P_{\text{heat}} = 435$ and $457 \text{ MW}$) are comparable. JA-DEMO ($R_p/a_p = 8.5/2.42 \text{ m}$, $P_{\text{fusion}} = 1.7 \text{ GW}$) challenges the divertor concept appropriate for high power handling ($P_{\text{sep}} \sim 255 \text{ MW}$, $P_{\text{sep}}/R_p \sim 30 \text{ MWm}^{-1}$) and ITER-level radiation fraction in the main plasma ($f_{\text{rad}} = P_{\text{main}}/P_{\text{heat}} \sim 0.4$) for the steady-state plasma performance ($H_{98} = 1.3$, $\beta_N = 3.4$) higher than ITER. On the other hand, EU-DEMO ($R_p/a_p = 9.1/2.9 \text{ m}$, $P_{\text{fusion}} = 2 \text{ GW}$) challenges reducing the divertor coverage due to increasing the tritium breeding blanket volume with employing ITER-level $P_{\text{sep}}/R_p \sim 17 \text{ MWm}^{-1}$ ($P_{\text{sep}} \sim 150 \text{ MW}$) as well as increasing $f_{\text{main}}$ to $\sim 0.67$ with ITER-level $H_{98} = (1.1)$ and $\beta_N = (2.6)$ by high-Z (Kr, Xe) and Ar seeding.

![Figure 1: Divertor geometry and simulation mesh for (a) JA-DEMO, (b) EU-DEMO.](image-url)
increasing local $T_{dive}$ and $T_{divi}$ as shown in Fig. 2(b,c). For the baseline and the higher $P_{sep}$ cases, the divertor operation is acceptable. For the lower $f_{rad+div}$ case, high $n_{sep}^e \geq 2.3 \times 10^{19}$ m$^{-3}$ is required.

The EU-DEMO divertor removed the baffles, and only covered the target plate near the strike point, which was rather open and disadvantage for neutral compression compared to those of ITER and JA-DEMO. The peak $q_{target}$ and $T_{dive}$ appeared near the separatrix, and the plasma performance was recently simulated for the baseline and severe ($200$ MW) cases as shown in Fig. 2(d). While reduction in $q_{target}$ ($\leq 10$ MWm$^{-2}$) is achieved in relatively low $f_{rad+div}$, further increases of $f_{rad+div}$ (>0.75 and >0.9 for the baseline and severe cases, respectively) are required to reduce $T_{dive}$ lower than 5 eV for minimizing target erosion at large plasma fluence. Feasible divertor operation is expected for the ITER-like $P_{sep}/R_p$ case.

For comparison, plasma performance in the JA-DEMO divertor with the same $P_{sep}$ -150 MW was simulated; a partial plasma detachment was produced even at lower $f_{rad+div}$ >0.6, and the peak $q_{target}$ was reduced to $\leq 7$ MWm$^{-2}$. Figure 2(e) shows that $T_{dive}$ at the attached region is increased to ~20 eV comparable to EU DEMO, but net erosion is not severe due to lower fluence. These results suggested that long leg divertor (1.6m) is appropriate for both DEMO baseline concepts, and the closure divertor geometry is more efficient for the large power exhaust.

**Figure 2:** JA-DEMO: (a) peak $q_{target}$ at outer target for three series of $P_{sep}$ and $f_{rad+div}$ against $n_{sep}^e$. Profiles of (b) $T_{dive}$, $T_{divi}$, $n_{divi}^e$, (c) integrating heat load components for open square in (a) higher $P_{sep}$ series. EU-DEMO: (d) $T_{dive}$ and $q_{target}$ for $P_{sep}=150$, 200 MW against $f_{rad+div}$. (e) comparison of JA and EU DEMOs: $T_{dive}$ for comparable $P_{sep} = 150$ MW.

**Design concept and issues of the DEMO divertor**

Application of the ITER target technology, i.e. tungsten (W) armor and Cu-alloy heat sink (pipe), and appropriate cassette structure to high neutron irradiation condition in DEMO have been developed for both designs. Particularly, material property degradation of the CuCrZr pipe and Cu-interlayer is anticipated at the neutron dose of 1-2 dpa. For the JA-DEMO divertor, neutron irradiation to the CuCrZr pipe is reduced by the closure geometry as shown in Fig. 3(a), and the high temperature water of $T_{coolant} = 200$ °C is used to reduce the irradiation embrittlement. RAFM (F82H) steel pipe is used for the heat sink for the baffles, dome and reflectors. Since the neutron irradiation on the CuCrZr and the interlayer will be higher in the open geometry of the EU divertor (Fig. 3(b)), high heat flux components reinforcing the ITER technology based on W and Cu-alloy have been developed [C], and recently tested successfully in a high-heat flux facility under repeating 20 MWm$^{-2}$ with $T_{coolant}$ of 130°C. Lifetime issues of Cu-alloy and RAFM steel of the DEMO divertor are summarized. Common and specific issues in their design concepts such as their cassette structures (RAFM steel) and nuclear heat cooling are also shown.
Figure 3: Divertor designs (a) J-A-DEMO: targets, baffles, reflectors and dome, cooling pipes incorporated in cassette. (b) EU-DEMO: targets, liner and coolant manifold in cassette.


Affiliation
National Institutes for Quantum and Radiological Science and Technology (QST)

Country or International Organization
Japan

Primary authors: Dr ASAKURA, Nobuyuki (National Institutes for Quantum and Radiological Science and Technology (QST)); Prof. HOSHINO, Kazuo (Graduate School of Science and Technology, Keio University); Dr HOMMA, Yuki (National Institutes for Quantum and Radiological Science and Technology (QST)); Dr VORPAHL, Christian (EUROfusion Programme Management Unit); Dr SUBBA, Fabio (Politecnico di Torino); Dr UTOH, Hiroyasu (National Institutes for Quantum and Radiological Science and Technology (QST)); Dr SOMEYA, Youji (National Institutes for Quantum and Radiological Science and Technology (QST)); Dr KAKUDATE, Satoshi (National Institutes for Quantum and Radiological Science and Technology (QST)); Dr SUZUKI, Satoshi (National Institutes for Quantum and Radiological Science and Technology (QST)); Dr SAKAMOTO, Yoshiteru (National Institutes for Quantum and Radiological Science and Technology (QST)); Dr HIWATARI, Ryoji (National Institutes for Quantum and Radiological Science and Technology (QST)); Dr SICCINIO, Mattia (EUROfusion Programme Management Unit); Dr FEDERICI, Gianfranco (EUROfusion Programme Management Unit); Dr YOU, Jeong-Ha (Max Planck Institute for Plasma Physics)

Presenter: Dr ASAKURA, Nobuyuki (National Institutes for Quantum and Radiological Science and Technology (QST))

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