ENTRAPMENT OF IMPURITIES INSIDE A COLD TRAP: A PURIFICATION PROCESS FOR REMOVAL OF CORROSION IMPURITIES FROM MOLTEN Pb-16Li

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FEC 2020
28th IAEA Fusion Energy Conference

ABSTRACT

- A wire mesh packing based prototype Cold Trap (CT) is developed for the removal of impurities from molten Pb-16Li.
- The functionality of CT has been assessed continuously for a long duration of ~3500 hours, in the molten Pb-16Li system.
- The deposition of corrosion impurities in the form of Fe-Ni intermetallic has been found on the wire mesh packing of CT.
- The deposition of oxide impurities was also found inside the CT.

BACKGROUND

- Pb-16Li alloy is selected as a candidate breeder and coolant for the liquid metal breeding blanket systems.
- The corrosive nature of Pb-16Li in a high- temperature environment is responsible for the generation of corrosion impurities from the structural materials (Ferritic martensitic steel and austenitic steel) of the system.
- Removal of corrosion impurities from the molten is indispensable for the safe and efficient operation of the liquid metal breeding blanket systems.
- Cold Trap is a purification unit that is used for the removal of impurities from liquid metals.
- Supersaturation of dissolved impurities in the liquid metals and their crystallization are two cardinal processes that drives the functioning of CT.
- A wire mesh arrangements are generally used to facilitate the crystallization of impurities inside CT.

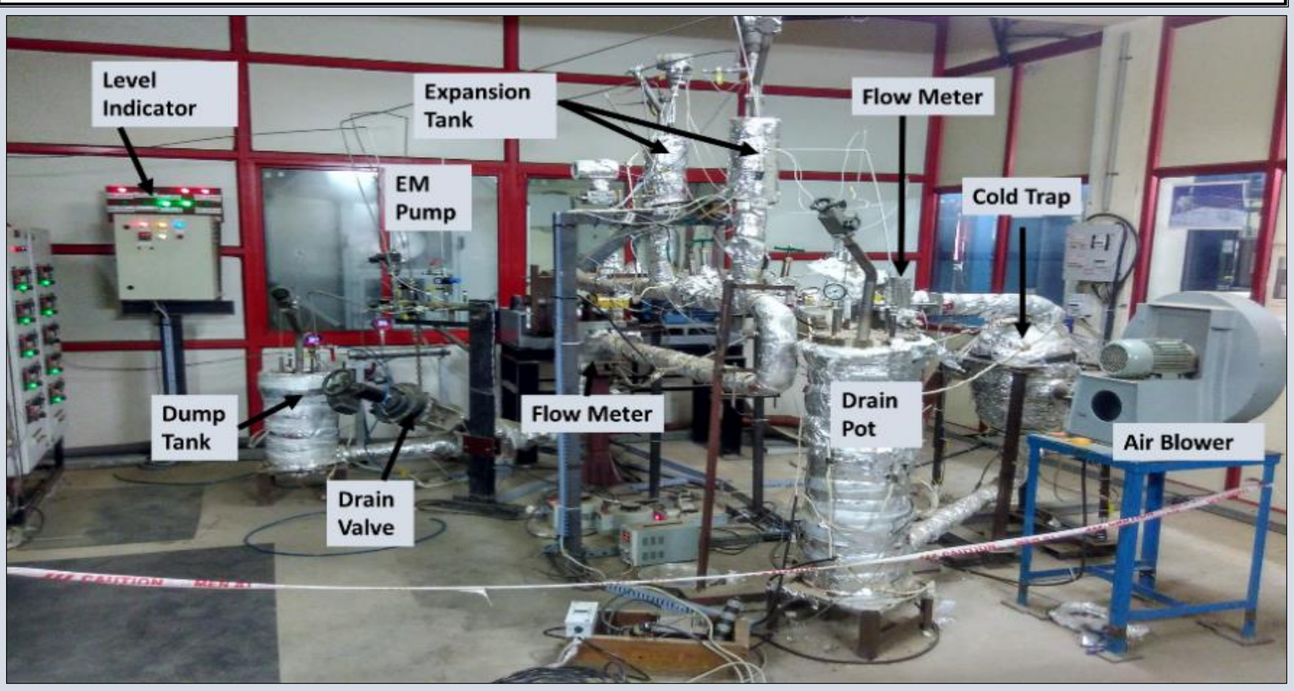
CHALLENGES / EXPERIMENTAL DETAILS

Challenges

- In situ inclusion of impurities in the molten Pb-16Li
- In- situ entrapment of generated impurities
- Liquid metal temperature control inside the CT
- In-situ collection of the Pb-16Li samples from the system

Experimental Details

- The Pb-16Li purification system is a closed loop system with two bypass lines.
- For in-situ inclusion of impurities in the Pb-16Li, an impurity generator having Nickel coupons had been placed in a bypass line.
- In another bypass line, a Cold Trap had been installed for the removal of generated impurities.
- In order to entrap the dissolved impurities, the temperature of molten Pb-16Li inside the CT had been reduced from 350ºC to 270 ºC, through a temperature feedback controlled air blower.
- A sample tank arrangement was used for in-situ collection of Pb-16Li samples at different intervals of the experiment.
- Total ~260 kg of Pb-16Li inventory had been used in the experiment.

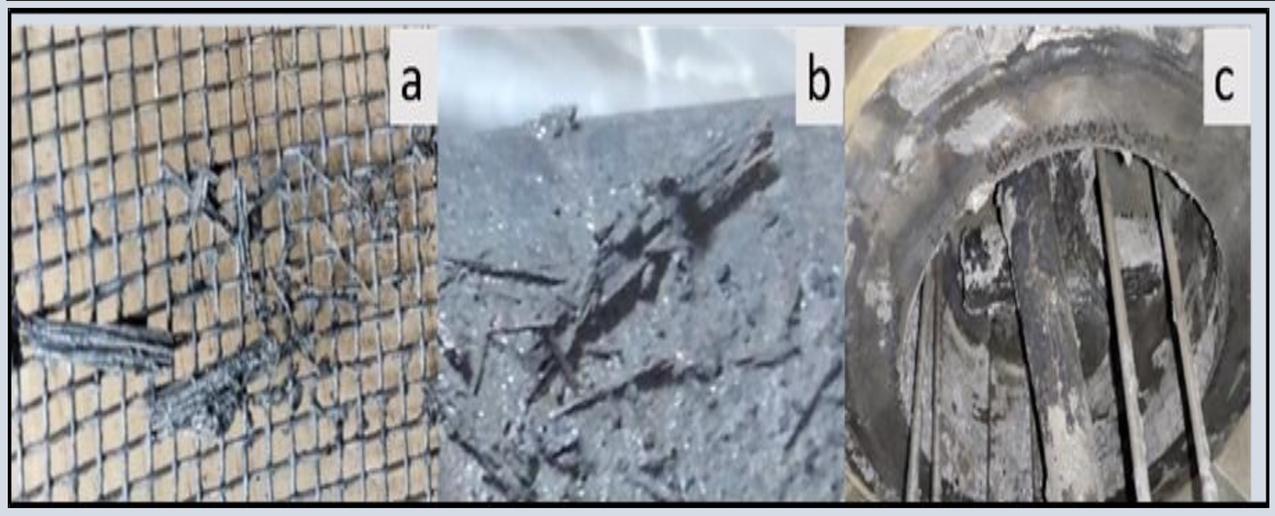


Birds eye view of Pb-16Li purification system at IPR

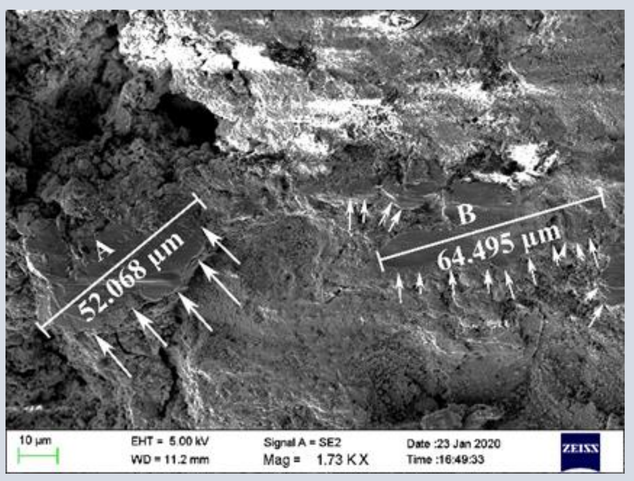
OUTCOME

Characterization Results:

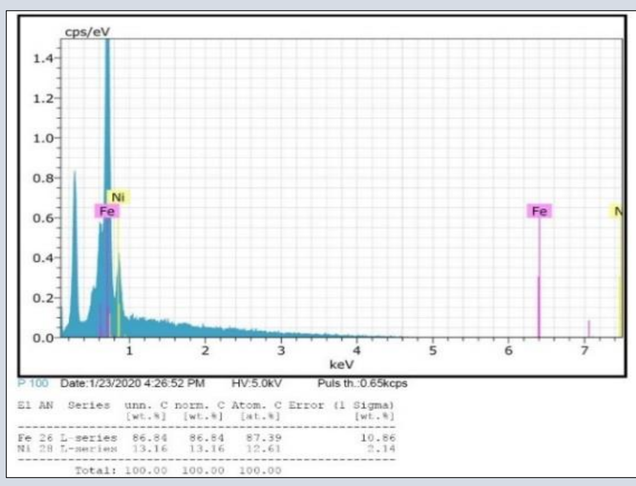
- The corrosion impurities were found to be deposited in a needle shaped crystalline on the wire mesh.
- High concentrations of Iron (Fe) and Nickel (Ni) in the samples deposited on wire mesh of CT confirms the deposition of Fe and Ni impurities on CT mesh.
- The SEM-EDX and XRD analysis of the deposited needles suggest that the micron-size particles (50-191 μm) of iron nickel intermetallic (Ni3Fe and NiFe2O4) are embedded in Pb-16Li matrix.
- The reduction in the concentration of minor elemental impurity such as Copper (~190 ppm to ~50 ppm) was also observed during the CT operation.



Deposition of corrosion impurities on the surface of a) CT wire mesh packing and b) CT outlet pipe, c) deposition of oxide impurities (greyish and black in colour) on interior walls of CT.



SEM micrograph of deposited crystal



EDX analysis results of deposited crystal

ICP-AES analysis result of Pb-16Li samples

Sample Identification	Duration (hour)	Concentration of Impurities (in ppm)	
		Iron (Fe)	Nickel (Ni)
Pb-16Li (fresh sample)	0	10	50
Pb-16Li (main loop)	300	10	50
Pb-16Li (main loop)	1300	10	130
Pb-16Li (main loop)	2900	11	735
Pb-16Li (main loop)	3500	23	950
Pb-16Li (CT internal)	3500	67	2900

ICP-AES analysis result of samples deposited on wire mesh packing

Sample Identification	Concentration of Impurities (in ppm)	
	Iron (Fe)	Nickel (Ni)
Deposited impurity sample	74000	22000

CONCLUSION

- The performed experimental study demonstrated the reliability of a purification system for long duration operation (~3500 hours).
- The removal of impurities from the liquid metal and their entrapment inside the CT had been demonstrated.
- The reliability of active components of the system such as liquid metal pump and air blower was also ascertained in the long duration experiment.
- The characterization of impurities deposited on the wire mesh packing of CT confirmed the significant presence of corroded elements such as iron and nickel in the form of Fe-Ni intermetallics.

ACKNOWLEDGEMENTS / REFERENCES

The authors wish to thank Dr. A.C. Sahayam, NCCCM, Hyderabad for performing the ICP-AES analysis of the samples of experiment which provided an insight to understand the outcomes of the experiments