# MHD TECHNOLOGY FOR THE PRODUCTION OF Pb – Li EUTECTIC ALLOYS

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**Introduction.** The lead-based Pb–Li eutectic with low melting temperature has been chosen as a promising blanket material for thermoelectric fusion reactors (for example, in breeding blanket test facilities). For the production of this material, the main problem is a great difference in densities of the both components (Pb and Li). They differs in more than 20 times, therefore, an intense mixing of the melt is obligatory. Under these conditions to make use of MHD methods is very topically: wide possibilities of MHD effects allow to find and realize rational mixing regimes, to ensure quality of eutectic alloy, homogeneity of its chemical composition.

The phase diagram of the binary system Li–Pb is well known and shown in Fig. 1 [1] – the necessary material is an eutectic mixture with 15.8 atomic % lithium (0.625 weight %) and low melting point $T_{\mathrm{m}} = 235°\mathrm{C}$. This mixture consists of compound LiPb that is dissolved in pure lead.

We must mention that the problem of precise Li concentration in the eutectic mixture was under discussion [2] – previously it was assumed that the eutectic point is 17.0 atomic % Li (0.68 weight %). However, in practice it is not of great importance. The alloys with a chemical composition that a little differs from the eutectic one also are suitable for the operation of a blanket [3] (for example, hyper-eutectic compositions with at. % Li $\leq 18.0$, $T_{\mathrm{m}} = 254°\mathrm{C}$).

In the report, an applied MHD stirrer and technologic experiments on Pb–Li eutectic production are described.

**1. MHD inductor-stirrer.** An important problem is an insufficient uniformity of the produced eutectic materials due to the following reasons: 1) insufficient homogeneity of the melt; 2) non-uniform distribution of binary alloy

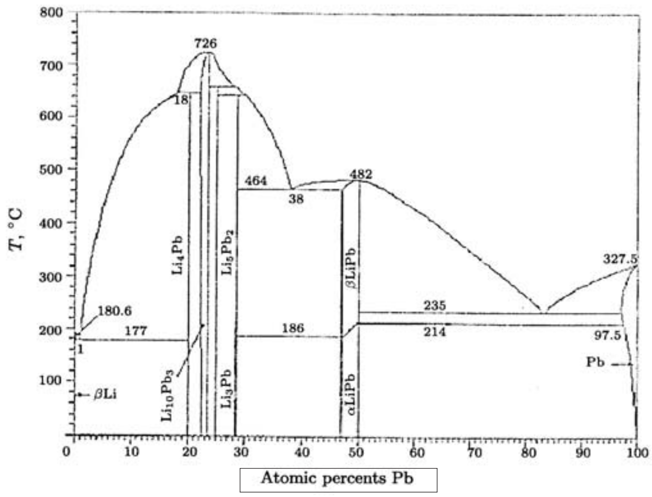


*Fig. 1.* Phase diagram of Li–Pb system.

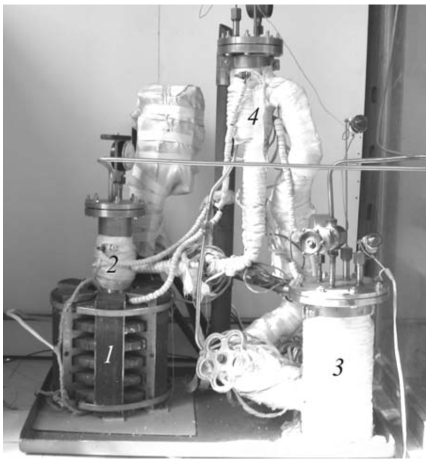


*Fig. 2.* Experimental equipment for the production of Pb15.8Li eutectic. *1* – MHD inductor – stirrer, *2* – crucible – reactor, *3* – Li tank, *4* – Li dozer.

components during solidification. In order to achieve required uniformity of the alloys, at the Institute of Physics, University of Latvia a three-phase stirrer (Fig. 2) was designed, produced and used in experiments – it induces an intense mixing of the melt during the process of liquid eutectic mixture production. The stirrer is a cylindrical inductor, generating a downwards directed travelling magnetic field. Inside the stirrer a cylindrical stainless steel crucible-reactor is placed, it is the working zone, where the process of eutectic production takes place. Dimensions of the inductor: outer diameter 240 mm, inner diameter 100 mm, height 224 mm; feeding voltage 36 V. The capacity of working regime is approximately 2 kW, velocity of melt motion 0.4-0.5 m/s.

**2. Realized technological scheme (Fig. 2).**

- Part of the crucible-reactor of inner diameter 60 mm is filled with a fixed amount of pure lead (free of oxides). The lead is melted and immediately after the stirring of the liquid metal is started. The melting as well as all further described processes in the Li systems and inside the reactor take place in an inert atmosphere of argon or in vacuum.
- The lithium is melted in a Li tank, then pure lithium (from the lower part of the tank) is pumped to a dozer, where necessary amount of liquid Li is kept (0.625% of common $\mathrm{Pb} + \mathrm{Li}$ weight).
- This amount of lithium is gradually, over an extended period of time, injected into the volume of the moving lead. The MHD stirrer generates velocity fields, so preventing the tendency of Li to float-up. The best stirring regimes are as follows: the melt along the rims of the crucible flows upwards but in the centre downwards.
- The chemical reaction, providing PbLi formation, takes place and after mixing of this chemical composition with pure lead the Pb15.8Li eutectic molds.
- During the reaction, the temperature of the melt rapidly rises but at intense stirring its increase can be limited $\leq 200^{\circ}$C that prevents formation of hard melting intermetalites. Soon after the reaction the temperature regime in the whole volume of PbLi and Pb mixture becomes even, $T$ is approximately by $100^{\circ}$C higher than the lead temperature before Li injecting.
- The liquid mixture with $T \approx 400$–$430^{\circ}$C is intensely stirred during 30–40 minutes. Then the MHD stirrer is switched off, but the melt is still held for one hour at $T \approx 400^{\circ}$C. Then the warming of the crucible stops and the obtained eutectic alloy gradually solidifies (inside the crucible or after its delivery to an ingot form).

The volume of every eutectic portion is 5–6.5 kg; it is limited by the dimensions of the working zone – the inner diameter of the crucible is 60 mm and the height of the MHD inductor-stirrer is 224 mm. As continuation, it results in designing equipment with about 10 times larger efficiency.

**3. Achievement of MHD technology – homogeneous composition of the eutectic material.** The surface of produced ingots was practically pure, free of oxides a.o.

For a more precise analysis, samples $\sim 20$ mm long and $\sim 100$ mm$^2$ in cross-section were cut out from different places of the ingot. Two kinds of analysis were performed:

- X-ray phases study: it showed that in the ingot volume there are no local crystal structures, so all chemical composition of PbLi is dispersed in a lead matrix;
- analysis of the chemical composition of the produced material: the amount of Li was defined in a following way – mechanically scrubbed samples were for some second placed in $HNO_3$, rinsed with spirits and dried; then each sample was divided in two parts; a weighted part was being solved in warm diluted $HNO_3$ to a concentration of $\sim 1$ mg/ml. The method of atomic absorption was used, based on a selective Li-lines lamp. The accuracy was estimated at 0.02% level.

In order to estimate the chemical composition homogeneity, the data about the distribution of Li atomic % are compared for three ingots produced by different technologies:

- in Fig. 3 METEAUX-SPECIAUX technology [3];
- in Fig. 4 the analysis results of Jost-Hinrich Stachov Metalhandel ingot; the authors of the report did it by the method that is described previously;
- in Fig. 5 our MHD technology.

| Probes, no. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Atomic, % | 20.4 | 19.6 | 22.9 | 16.1 | 16.0 | 16.1 | 18.0 | 18.8 | 18.2 | 14.8 | 20.5 |

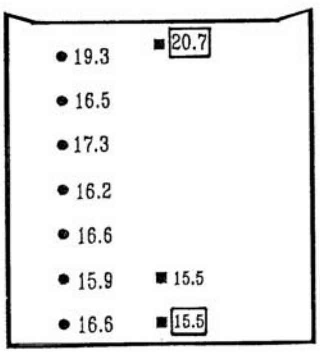


*Fig. 3*

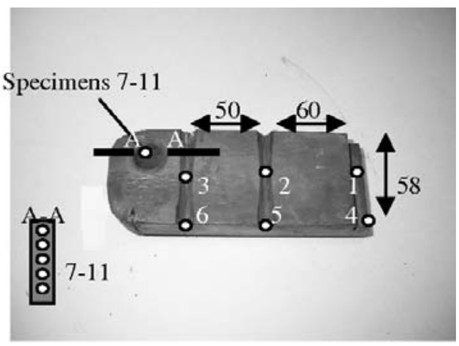


*Fig. 4*

*Fig. 3.* METEAUX-SPECIAUX 11 kg bar. The distribution of Li at. % in the ingot volume [3].

*Fig. 4.* Part of the Jost-Hinrich Stahov Metaldandel ingot. The distribution of Li at. % is shown in table.

| | | at. % Li |
|---|---|---|
| 1. | METEAUX-SPECIAUX [3], 1993 | 18.1±2.6 (14.4 %) |
| | other ingot, data in [4], 1988 | 17.2±0.8 ( 4.7 %) |
| 2. | Jost-Hinrich Stachov Metalhandel, 2003 | 19.4±3.5 (17.1 %) |
| 3. | Institute of Physics UL, MHD technology, 2004 | |
| | first ingot, | 15.8±0.2 (1.3 %) |
| | second ingot | 16.1±0.2 (1.2%) |

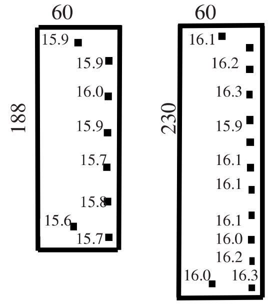


*Fig. 5.* Two cylindrical ingots produced by the MHD technology. The distribution of Li at. %.

Resume about the arithmetical average at.% Li and maximum deviation of this % (for every ingot):

The advantage of MHD technology is obvious.

**4. Conclusion.** The MHD technology for the production of Pb15.8Li eutectic alloy of proper quality has been worked out at the Institute of Physics, University of Latvia. Testing of this technology has demonstrated that during the process of eutectic production it is very important to initiate an intense mixing of the liquid melt. For such task, MHD methods turned out almost suitable – the purity and a significant chemical homogeneity of the Pb–Li eutectic alloy have been achieved.

**REFERENCES**

1. H. Ihle and C. Wu. Chemical thermodynamics of fusion reactor breeding materials and their interaction with tritium. *Journal of Nuclear Materials*, vol. 130 (1985), no. 3, pp. 454–464.

2. P. Hubberstey, T. Sample and M.G. Barker. Is Pb–17Li really the eutectic alloy? A redetermination of the lead – rich section of the Pb–Li phase diagram (0.0 < $x_{\mathrm{Li}}$(at %)< 22.1). *Journal of Nuclear Materials*, vol. 191–194 (1992), part 1, pp. 283–287.

3. H. Feuerstein, L. Hörner, J. Oschinski and S. Hor. Behavior of lithium in Pb–17Li systems. In *Proceedings of International Conference on Liquid Metal Systems* (Karlsruhe, Germany, 1993).

4. J. Dekeyser, J.L. Walnier and L. Auffret. Starting experience on the use of Pb–17Li in a forced convection loop. *Fusion Technology*, (1988), pp. 1160–1166.