BOILING HEAT TRANSFER OF LIQUID METALS

- Communist China -

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Due to the development of the atomic reactor, there has appeared
apparatus of high coefficient of dynamics with high efficiency, and
also the more frequently used high temperature high pressure techniques
in the chemical industry, which have been drawing attention to the
prospect of using melted liquid metal as a high temperature heatcapaci-
tor. Especially, there are more advantages in using boiling heat
transfer of liquid metals. So far, there is very little research work
done in this aspect, and almost nothing as far as boiling metals under
pressure is concerned.

We have conducted experiments on boiling Hg and Mg under various
pressure. The experimental scope is as follows: Heat load q=5,000 47,000
kcal/m2 hr., pressure p= 1 11 absolute pressure, boiling point tk=355.9
524°C, Prandtl number $P_r$-0.0098 0.0077. The experimental results ob-
tained are summarized as follows:

1. Boiling heat generation of pure Hg under pressure obtained
by boiling Hg subjected to different pressures. Under standard pressure
the thermal coefficient decreases with increases of q, this shows that
$=4850-0.26$ kcal/m2hr°C. This is relatively close to the results ob-
tained by Bromley's film type boiling analysis. Hence, under the stand-
ard pressure, film type of boiling appears under very small value of
heat load. However, the thermal coefficient thus produced is more than
1.5 times greater than that calculated from the formula. When the
pressure is increased, the boiling type changes immediately from film
to nuclear and both heat load q and increase. This can be expressed
by $=Aq^{0.46}$. However, the effect of pressure to is different from
the conventional effect to liquid: pressure increases between 4-11
atms. with continuously decreasing, or $=7q0.46p-0.29$. The charac-
teristic of heat generation of boiling Hg is its close relationship
between its low Pr value and its non-permeability. According to the
recent analysis of Aref'eva and Alad'ev, when the contact angle 140°,
liquid requires very little work to leave the surface of the solid, and
the gas bubbles spread easily through the surface forming film type boiling.

Because of the occurrence of low $P_r$ value, thermal conductivity cannot be neglected, thus the thermal coefficient of the experimental value is much greater than that of the theoretically calculated value. Nuclear type boiling is formed because   is reduced due to the fact that temperature increases with increasing pressure.

2. The boiling heat generation of Mg-Hg. The addition of a small quantity of Mg into Hg can improve the non-permeability of Hg and results in nuclear type of boiling. This property is improved further with additional quantity of Mg. Under the standard pressure, the experimental equation for Hg alloy containing Mg of 0.02% and 0.05% can be expressed by the experimental formula:  $=Aq^n$, i.e., when containing 5.05% of Mg, and under the same value of heatlload, it is 15-50% greater than that of containing 0.02% of Mg.

| Mg Contents | A | N |
|---|---|---|
| 0.02% | 13.7 | 0.43 |
| 0.05% | 2.43 | 0.63 |

This type of permeability affecting the    value has been encountered during our previous experiment on boiling heat transfer of water. Figure 2 shows the experimental results obtained when containing 0.02% of Mg under various pressures, which have no evident effect on the boiling heat transfer of Hg alloy (the widely spread values resulted because of the thermal coefficient of the wall of the tube varied in the lower, middle, and upper parts). This is probably due to the effect on the non-permeability by the addition of Mg which produces a prominent effect on consequently shows very little effect by pressure. Besides, other physical properties are not affected by pressure to any great extent.

Conclusion:

(1) Pure Hg under standard pressure gives the film type of boiling. The experimental value of   is greater than Bromley's theoretical heat transfer value of the film type. Therefore, his equation is not suitable for substances having a low $P_r$.

(2) Pure Hg boiling under pressure gives nuclear boiling characteristics, but the effect of pressure on thermal coefficient is opposite to that of ordinary liquids: between 4-11 atms., pressure increases while   decreases.

The addition of a small quantity of Mg improves the permeability and also heat transfer efficiency, thus enables   to increase. With an increasing amount of Mg,   also increases,   $=Aq^n$ while n also is increasing. When the Hg alloy contains 0.05% of Mg, the property of permeability appears the same as the boiling liquid. The change of pressure

does not affect greatly the heat transfer of the Mg-Hg system. However, under pressure, the nuclear type of boiling is characteristic of the system when containing 0.02% of Mg.

(4) The experimental results cannot be thoroughly interpreted since the theoretical explanation of the relationship of the nuclear type boiling shifting to film type did not consider the effect of permeability variations. It is also necessary to consider the effects of the changes of central density of vaporization and contact angle. The important effect is determined by the permeability between the substance and the heat transfer surface. Permeability is important as far as non-permeable liquids are concerned.

The experimental formulas obtained above for the boiling heat generation under pressure of Hg and Hg alloy can be provided as references for the producing and designing divisions.

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