arc furnace were recognized. As a result of increase of the hydrogen susceptibility of liquid steel, caused by rapid deoxidation of the steel at that stage, the hydrogen in the furnace hearth, in residual oxidizing slag as well as in added materials, such as, lime, deoxidizers and carburizing materials, was considered to enter easily into steel.

Oxygen and hydrogen in molten steel on the stage, were found to vary with intimate correlations. Ratios of $[H]^2 \times [O]$ at the end of oxidation and that at the earlier stage of reduction of the same heat had almost the constant values, although the values $[H]^2 \times [O]$ had a wide range according with the melting conditions.

- Studies were also made on the relations of $[H]$ at tapping of a basic electric arc furnace to P_{H_2O} in various specifications of the steel. The lower carbon the steel had, the higher effect of P_{H_2O} on $[H]$ at tapping were in the average recognized.

HYDROGEN IN MOLTEN STEEL—PART II

(Several experiments on behavior of the hydrogen in molten steel)

Shigeki Sawa

Synopsis

Behavior of the hydrogen in liquid steel melted in a 35 KVA high frequency induction furnace was studied.

Fig. 1. Sampling devices for hydrogen in liquid steel.

About 4 kg of carbon steel or Ni steel was melted in a alumina crucible with glass slag or in a magnesia crucible with basic slag. Water vapor or H_2 gas was blown over to the slag surface or bare metal surface, and variation of $[H]$ was studied by means of a new vacuum sampling device as shown in Fig. 1 and vacuum fusion analysis.

Fig. 2. Al_2O_3 crucible heat.

Fig. 3. Basic heat.

Fig. 4. Amounts of hydrogen accumulated in the vacuum sampling tubes relating to the total hydrogen contents of the specimens.

Some typical heats of the experiments are shown in Fig. 2 and Fig. 3. In Fig. 4 relation of the amounts of H_2 accumulated in the vacuum sampling tube to the total hydrogen in the specimens are plotted. From these observations, the following conclusions were obtained.

1. The hydrogen in liquid steel tended to escape from the surface of the steel bath to atmosphere, and the tendency was intensified when the steel had a high hydrogen value.
When the liquid steel was covered by the slag layer, $[H]$ enriched by H_2 or H_2O seemed to decrease to some extent, while it decreased rapidly when the slag was taken off and molten steel surface was exposed to air.
2. Basic slag seemed to let H_2O pass more easily than the glass slag. By H_2O vapor blowing over to the slag surface, $[H]$ increased to more than 15 cc/100 g within a few minutes if the slag was basic, while in the case of glass slag, $[H]$ increased to about 10 cc/100 g.
3. Small addition of the Ti in liquid steel prevented H_2 from escaping from the specimens during and after solidification.
4. As to the relation between $[H]$ and P_{H_2O} in atmosphere, the author suggested the following theory:

Equations presented by D.J. Carney, J. Chipman and N.J. Grant¹⁾,

1).....Basic Open Hearth Steelmaking AIME (1951) 686

$$[\text{H}]\% = 1.35 \times 10^{-3} \sqrt{P_{\text{H}_2\text{O}}/a_0} \quad \text{at } 1600^\circ\text{C} \quad \dots\dots\dots (2)$$

could not be applied as they are when the molten steel was exposed to atmosphere containing H_2O vapor $P_{\text{H}_2\text{O}}$, because $P_{\text{H}_2\text{O}}$ on the surface layer of the steel was considered to be not the same as $P_{\text{H}_2\text{O}}$ in the atmosphere.

Gas composition on the surface layer of the liquid steel was considered to shift keeping equilibrium with composition of the surface layer of the liquid steel. These are probably a concentration gradient from the surface to the deep part of the liquid steel according with velocities of reactions and diffusions. Also, it was considered that there was a concentration gradient of CO , CO_2 , H_2 , H_2O , O_2 and N_2 in thin layer of gas phase on the surface of the liquid steel. The compositions of the gas phase varied continuously from the "composition in equilibrium with the compositions of the liquid steel surface" to the "composition of atmosphere."

Relation of $[\text{H}]$ and $P_{\text{H}_2\text{O}}$ in atmosphere should be determined under steady condition when there was an equivalent flow of diffusion of H_2O and H_2 in the central directions through that intermediate gas phase which was found between the surface of the liquid steel and the atmosphere.

Suppose that thickness of the intermediate gas phase was so thin that its temperature could keep as same as liquid steel, that diffusion constants of H_2 and H_2O in the gas phase was as same as in air and that their temperature coefficients could be applied to 1600°C , the steady condition at 1600°C as to $[\text{H}]$ and $P_{\text{H}_2\text{O}}$ should be as follows:

$$P_{\text{H}_2}(P_{\text{H}_2\text{O}} - P_{\text{H}_2\text{O}}) = D_{\text{H}_2\text{O}}/D_{\text{H}_2} \div 0.36$$

$$[\text{H}]\% = 0.0027 \sqrt{P_{\text{H}_2}}$$

$$P_{\text{H}_2\text{O}}/P_{\text{H}_2} \cdot [\text{O}]\% = 3.95$$

$$[\text{H}]\% = 1.62 \times 10^{-3} \sqrt{P_{\text{H}_2\text{O}}/(1 + 1.42[\text{O}]\%)} \quad \dots\dots\dots (3)$$

Where P_{H_2} , $P_{\text{H}_2\text{O}}$ are partial pressure of H_2 and H_2O on the surface of liquid steel, $P_{\text{H}_2\text{O}}$ is the partial pressure of H_2O in atmosphere.