KAWASAKI STEEL TECHNICAL REPORT No.5 (May 1982)

Development of Lime-based Powder Reagent for Injection Desulfurization of Hot Metal in Torpedo Car

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Synopsis :

Lime-based reagent with fine grain size and improved fluidity has been developed for hot metal desulfurization using the torpedo car (top) injection method. With the optimization of both the powder size and the C, CaF2 and CaCO3 contents in the reagent, lime reaction efficiency is improved far higher than the level reported in counterpart documents. This desulfurization method does not lead to resulfurization which usually occurs during the hot metal teeming into torpedo cars into which calcium carbide has been injected for desulfurization purposes. The effect of CaCO3 content in the reagent on ηCaO and the absence of resulfurization is theoretically explained on the basis of uniform mixing time of hot metal in torpedo cars and the analysis of torpedo slags taken before and after the desulfurization. The high value of η CaO and the absence of resulfurization have contributed to lowering the unit consumption cost of the lime-based reagent to roughly one-half of that of carbide. Also, the choice of suitable lining material for torpedo cars (MgO-C for slag line and Al 2 O3-SiC for the remaining part) and an increased frequency of torpedo car utilization have reduced the lining cost for lime desulfurization to about 80% of that for the carbide desulfurization. The lime-based reagent replaced calcium carbide in August 1979 at the No.3 Steelmaking Shop at Chiba Works.

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Lime-based reagent with fine grain size and improved fluidity has been developed for hot metal desulfurization using the torpedo car(top) injection method. With the optimization of both the powder size and the C, CaF_2 and $CaCO_3$ contents in the reagent, lime reaction efficiency is improved far higher than the level reported in counterpart documents.

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The high value of η_{CaO} and the absence of resulfurization have contributed to lowering the unit consumption cost of the lime-based reagent to roughly one-half of that of carbide. Also, the choice of suitable lining material for torpedo cars (MgO-C for slag line and Al_2O_3 -SiC for the remaining part) and an increased frequency of torpedo car utilization have reduced the lining cost for lime desulfurization to about 80% of that for the carbide desulfurization. The lime-based reagent replaced calcium carbide in August 1979 at the No. 3 Steelmaking Shop at Chiba Works.

1 Introduction

Since hot metal desulfurization is very effective in improving the productivity of steelmaking furnaces such as open hearth furnaces and converters, various methods of hot metal desulfurization have been studied and put into practical use. Of these methods, the torpedo car injection desulfurizing method is excellent for processing a large quantity of hot metal in a short time and achieving high utilization efficiency of the desulfurizing reagent; hence the number of plants employing this method is increasing. Kawasaki Steel Corporation's Chiba Works installed the ATHtype torpedo car injection desulfurizing equipment at the time of constructing No. 6 Blast Furnace and No. 3 Steelmaking Shop, and started desulfurization utilizing calcium carbide (hereafter called "carbide") as reagent in 1977. Since then, the utilization efficiency of carbide (η_{CaC_1} ****) has gradually improved^{1,2)} as a result of optimization of the reagent injection rate and the quantities of carbon in the reagent and of the substance (CaCO₃) for stirring-gas generation. However, carbide was expensive because its production required a large quantity of electric power, and improvement in the above-mentioned η_{CaC_1} had almost reached its limit. In about mid-1978, therefore, the authors started the development of a lower-cost desulfurizing reagent that would replace carbide.

Lime has a thermodynamic potential to desulfurize

**** $\eta^{\times} = \frac{\{[\%S]_0 - [\%S]_f\} \times 1000}{[CaO \text{ or } CaC_2 \text{ Consumption } (kg/t)]}$									
M_{CaO}, M_{CaC_2} :	Molecular respectively	weight	of	CaO	and	CaC ₂ ,			

^{*} Originally published in Kawasaki Steel Giho, 14 (1982) 1, pp. 1-9

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hot metal down to low sulfur concentration^{3,4}), and can be a cheap desulfurizing reagent; but because of its slow reaction rate, lime, hitherto, was never used widely as a desulfurizing reagent on an industrial scale. Particularly in the top injection desulfurization, reagents mainly comprising quick-reacting carbide were frequently used. The present studies were aimed at developing a low-cost injection desulfurizing reagent by accelerating the reaction rate of lime. This objective was successfully accomplished within about two years, with the desulfurization cost greatly reduced by replacing carbide with this new desulfurizing reagent. This paper reports the progress of the development by dividing it into three stages.

2 1st Stage—Determination of Composition of Desulfurizing Reagent

2.1 Preliminary Examination

To improve the desulfurization rate, it is effective to use fine lime powder so as to increase the hot metallime powder interface. However, lime powder lacks fluidity and sometimes causes hanging and pulsation, resulting in clogging of the lance. This tendency grows as the lime powder becomes finer. To solve this problem, various methods for improving the fluidity of lime powder were examined on a laboratory scale, and it was found that addition of MHPS (methyl hydrogen polysiloxane, a kind of silicone oil) was effective. As shown **Fig. 1**, MHPS reduces the angle of repose of lime powder and improves its fluidity with a very small addition, compared with calcium stearate which



Fig. 1 Changes in the lime powder's angle of repose by addition of MHPS (methyl hydrogen polysiloxane) or calculum stearate

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is a typical surface active agent. For the addition of MHPS, there is an optimum value, and if it is exceeded, the angle of repose will increase.

Desulfurizing reaction by lime is said to progress at the diffusion-controlled rate in the solid phase⁵⁾, and therefore, the sulfurizing reaction of lime powder will be accelerated if addive X is added to lime powder to form low melting portions on the surface layer of lime³⁾. To select the ingredient X which would be the most suitable for this purpose, a desulfurization test was conducted by adding 3 g/kg-hot metal of "CaO + X" powder in 5 kg of hot metal, which was melted in the graphite crucible and maintained at 1 350° \pm 20°C, and by mixing them with an impeller. If the desulfurizing rate is analyzed by the rate equation of Kawai et al.⁵⁾, it was found that rate constant K_s (104 %/min) was 0.3 for CaO only, 1.2 for 90 %CaO-10%Na₂CO₃, 2.0 for 95%CaO-5%Na₃AlF₆, and 2.5 for 95%CaO-5%CaF₂, indicating that K_s increased when various types of flux components were added to lime. From these test results, fluorite which was found most effective was used in the actual furnace test.

In view of our experience in carbide desulfurization during 1977-1978, it was determined that the composition of the desulfuring reagent of highest η_{CaC_2} was 59%CaC₂-27%CaCO₃-15%C, where CaCO₃ generates gases by pyrolysis and mixes hot metal and slag vigorously, and C maintains the interior of the torpedo car in a reducing atmosphere, thereby respectively contributing to enhancing the value of η_{CaC_3} . On the basis of this experience and the results of the above-mentioned examination, an actual furnace test was conducted on a lime-based desulfurizing reagent with a small addition of MHPS and mainly comprising $60\%(95\%CaO-5\%CaF_2)-25\%CaCO_3-15\%C$.

2.2 Actual Furnace Test

Table 1 shows injection conditions of the desulfurizing reagent compared with those by Hoesch method⁶). Although the quantity of the carrier gas was as small as 10 N/ per kg of the desulfurizing reagent in this test, stabilized injection of the lime-based desulfurizing reagent was possible owing to the fluidity enhancing effect of MHPS explained earlier. Then a test was conducted on injection of the desulfurizing reagent by changing the grain sizes of lime powder and the contents of fluorite, C, and CaCO₃ in the desulfurizing reagent.

Fluorite addition and lime grain size:

Changes in η_{CaO} were obtained by changing α in composition (60 - α)%CaO-25%CaCO₃- α %CaF₂-15%C from 0 to 3 and 5% and by changing the grain size of lime powder from **C**(-28 mesh) to **M**(-60

•	This work	Hoesch CaO		
Desulfurizer	CaO,CaCO ₃ ,CaF ₂ ,C,Surfactant			
Hot metal	260 · 340 t	150 t		
Carrier gas	$N_2 = 5 N l/t \cdot min$	Natural gas 28 N l/t min		
Injection rate	0.5 kg/t•min	0.5 kg/t·min		
Gas/Solid	10 N <i>l</i> /kg	56 N <i>l</i> /kg		
Lance angle (below horizontal)	65 -70 degree	90 degree		

 Table 1 Conditions of injection desulfurization for this work compared with those for Hoesch method⁶⁾



Fig. 2 Dependence of η_{Ca0} for desulfurization from [%S] = 0.045 to [%S] = 0.015 on the content of CaF₂ in the reagent or on grain size of lime powder (C: -28 mesh, M: -60 mesh, F: -200 mesh)

mesh) and F(-200 mesh) in composition 55%CaO-25%CaCO₃-5%CaF₂-15%C. The results are shown in Fig. 2. In this paper, η_{CaO} was obtained by considering that CaO which was generated by the pyrolysis of CaCO₃ in the desulfurizing reagent would also contribute to desulfurization. Fig. 2 indicates that as the fluorite addition increases, η_{CaO} is improved. However, when the melting loss of refractories is taken into consideration, the suitable addition of fluorite is 3 to 5%. On the other hand, when the grain size of lime powder is changed from C to M, η_{CaO} improves by about 2%. If the grain size is further lowered to F, however, η_{CaO} will conversely be reduced.

The reason for the above may be explained as follows: The critical diameter of lime powder, which penetrates into hot metal by piercing through nitrogen bubbles when it is injected into hot metal, has been



Fig. 3 Increase in η_{CaO} with increasing carbon content in lime-based reagent

calculated as 1.4 μ m by the theoretical equation of Engh et al.⁷⁾ The weight percentage of portions having diameters smaller than the critical diameter is 12% for the **M** size, but is as large as 44% for the **F** size. Therefore, when **F** size lime powder is injected into hot metal, the percentage of lime powder which adheres to the surfaces of nitrogen bubbles and floats over the hot metal will increase. As a result, the hot metal-lime powder interface will become smaller than the case of **M** size lime powder, thereby lowering the η_{CRO} value.

C addition:

The value of η_{Ca0} increases, as shown in Fig. 3, when β in composition $(70 - \beta)$ %CaO-25%CaCO₃-5%CaF₂- β %C is increased from 0 to 5, 15, and 20%. In order to find out the reason for this, gas samples were taken from the torpedo car which was in the process of being injected with desulfurizing reagent of $\beta = 5, 20\%$. The gases contained 17 % CO₂ and 0.21 % O₂ (average of n = 9) for $\beta = 5\%$, and 6.9% CO₂ and 0.01% O₂ (average of n = 3) for $\beta = 20\%$, showing decreases in CO₂ and O₂ values. Thus it is considered that η_{CaO} increases, because the increased C content in the desulfurizing reagent increases reducibility of the atmosphere inside the torpedo car. Namely, the simple and low-cost "C mixing" will produce the same effect as does the Hoesch method⁶ which uses natural gas as the carrier gas.

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Energy density, $\dot{\epsilon}$ (W/t)

Fig. 4 Time required for completed mixing of melt in torpedo car during injection of desulfurizing reagent

CaCO₃ addition:

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When γ in composition $(80 - \gamma)$ %CaO- γ %CaCO₃-5%CaF₂-15%C was increased from 25% to 35%, η_{CaO} increased from 11.4% to 13.3%. This is attributable to the increase in the mixing effect by the CO gas which is generated by equation (1).

$$2CaCO_3 + [Si] \longrightarrow 2CaO + SiO_2 + 2CO \qquad (1)$$

In order to investigate the mixing effect by the CO gas, a Cu tracer was added to hot metal under processing and the time (t_{mix}) required for the tracer to be uniformly distributed was measured in respect of carbide-based and lime-based desulfurizing reagents. The results are shown in Fig. 4. The broken line in the figure indicates the value calculated by eq. (2) shown below obtained from the results of t_{mix} measurements in various secondary refining processes of molten steel.

 $t_{\text{mix}} = 800 \dot{\epsilon}^{-0.4} \text{ (sec)} \cdots (2)$ $\dot{\epsilon}: \text{ Mixing energy density (Watt/ton)}$

The reason for the large measured value of t_{mix} in the test shown in Fig. 4 compared with the above calculated value is that the torpedo car used in the test had a shape disadvantageous for mixing, compared with the ladle used to obtain eq. (2). When a comparison is made at the same ϵ value, t_{mix} for the lime-based reagent is larger than that for the carbide-based one. The reason for this, which was proved by the water model test, is that since the consumption of the limebased desulfurization reagent is greater, slag on the surface of hot metal increases and disturbs mixing. It is advisable, therefore, to increase the addition of CaCO₃ to the lime-based reagent than to the carbidebased reagent (27% CaCO₃: refer to Par. 2.1).

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Fig. 5 Desulfurization curves with changing initial sulfur concentrations (this work: lime-based reagent, Hoesch: lime)

2.3 Summary of Actual Furnace Test

Since the preceding section clarified that the highest η_{CaO} value was obtained by the 45%CaO-35%CaCO₃-5%CaF₂-15%C composition, the number of tests on this composition was increased. The results are shown in Fig. 5.

The desulfurizing reagent obtained by the present studies shows a much better efficiency, especially in the low-S concentration area, than the efficiency

obtained by Hoesch method⁶ which until now has been considered the most efficient lime desulfurization method. As shown in Fig. 5, the newly developed desulfurizing reagent can desulfurize down to 0.002% S, and it has now become possible to manufacture extremely low sulfur steels such as line pipe steels highly resistant to hydrogen-induced cracking, as and when necessary, by combined use of the desulfurizing reagent and molten steel desulfurization.

3 2nd Stage—Half-step Use of New Desulfurizing Reagent

3.1 Iron Loss and Temperature Drop

Although the new desulfurizing reagent showed a higher η_{Cso} value than in the conventional lime-based desulfurizing reagent, the consumption of the former was about twice as great as that of the carbide-based desulfurizing reagent, and thus iron loss to slag was anticipated. Consequently, iron content in slag after desulfurization was investigated for both carbide-based and lime-based desulfurizing reagents. As a result, iron content of slag after lime desulfurization was found to be about one-half that after carbide desulfurization and it was confirmed that iron loss due to the use of the lime-based desulfurizing reagent would not increase.

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Temperature drop by lime desulfurization was 17°C, while that by carbide desulfurization was only 10°C.

3.2 Changes in S Concentration during Hot Metal Transportation

When hot metal was charged to the torpedo car, resulfurization of 0.012% occurred in the case of carbide desulfurization, but as the utilization ratio of the lime-based desulfurization increased, the quantity of resulfurization decreased as shown in Fig. 6, and when the utilization ratio exceeded 40%, resulfurization changed to desulfurization. Similarly, a



Fig. 6 Relation between changes in sulfur concentration, ΔS , of hot metal during tapping into torpedo car and ratio of lime desulfurization heats to total desulfurization heats



Fig. 7 Lime desulfurization vs. carbide desulfurization--Hot metal S concentration from BF tapping to BOF charging

0.002% resulfurization occurred when hot metal after carbide desulfurization was charged from the torpedo car to the charging ladle, whereas no such resulfurization occurred in the case of lime desulfurization heats.

Fig. 7 shows the transition of S concentration, when hot metal of [%S] = 0.040 at BF tapping is charged into the converter at [%S] = 0.015. The figure indicates that desulfurization load during lime desulfurization heats is lower by 0.019% than that during carbide desulfurization heats, which constitutes a great advantage of lime desulfurization. In the following, the reasons for changes in S concentration during transportation are examined from the results of investigation of slag compositions.

Sulfide capacity (C_s) of slag is defined by

When an MnO term is added to the experimental formula of C_s by Venkatradi et al.⁹⁾ by referring to the value of C_s of the two-dimensional system of MnO-SiO₂ and MgO-SiO₂, the following equations are obtained:

$$\log C_{s} = -5.54 + 1.35B \dots (4)$$

$$B \equiv \frac{(\%CaO) + 1.42(\%MnO) + 0.69(\%MgO)}{0.93(\%SiO_{2}) + 0.18(\%Al_{2}O_{3})} \dots (5)$$

From eq. (3) and free energy (ΔG°) for sulfur dissolution into hot metal, the equilibrium distribution of sulfur (K_s) between slag and hot metal can be expressed by



Fig. 8 S distribution between slag and hot metal as a function of slag basicity

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Fig. 8 shows the relation between B and (%S)/[%S]which was measured at the BF runner and pre-desulfurization torpedo car. The solid line in the figure is the equilibrium value which has been obtained by substituting into eq. (6) the value of P_{o_i} which was determined by the combustion reaction equilibrium of C at $P_{co} = 1$ atm and T = 1.773K. In Fig. 8, the calculated value of the slope of the relation between Band $\log (\%S)/[\%S]$ shows good agreement with the empirical value, and this indicates that the sulfur exchange between slag and hot metal during transportation of hot metal has reached an equilibrium under a certain value of P_{o_i} . Further examination is required, however, to determine which is the governing factor of the absolute value of P_{0_1} , a_0 of hot metal, a_{FeO} of slag, or gaseous phase P_{O_2} .

When the torpedo car receives hot metal, [%Si] decreases by an average 0.03%, and silica of 0.64 kg/tis generated as a result of oxidation of the stream by air. Values of concentration of CaO, SiO₂ and Al₂O₃, which constitute the main ingredients of pre-desulfurization slag, shown in Table 2 give fairly good agreement with calculated values which have been obtained on the assumption that the above-mentioned silica of 0.64 kg/t is uniformly mixed with post-desulfurization slag of 4.5 kg/t which is still remaining inside the torpedo car. The value of (%S) after uniform mixing of post-desulfurization slag of 4.5 kg/t and silica of 0.64 kg/t is calculated as 5.49% [= $6.28 \times 4.5/(4.5)$ + 0.64)] for the torpedo car after carbide desulfurization and as 3.51% [= $4.02 \times 4.5/(4.5 + 0.64)$] for the torpedo car after lime desulfurization. On the other hand, equilibrium (%S) with respect to 1.68 which is the value of B obtained from the actually measured slag composition is 3.92%. Since an apparent equilibrium is established between slag and hot metal as explained earlier, S which corresponds to 1.57% (5.49% - 3.92%) shifts from slag to hot metal inside the torpedo car after carbide desulfurization, thereby causing a 0.008% resulfurization. Through similar calculation, it is found that a 0.002% desulfurization occurs inside the torpedo car after lime desulfurization. These calculation results clearly explain the trends of test results shown in Figs. 6 and 7 (0.012% resulfurization for carbide desulfurization and 0.005% desulfurization for lime desulfurization).

Efficiency of lime utilization for desulfurization (η_{CaO}) is 13.3% even after improvement by the present studies, i.e., 1/3 of η_{CaC_2} . When the values of S concentration in hot metal before and after desulfurization are aligned between carbide and lime desulfurization, the quantity of lime required for desulfurization is 2.6 times (= $3W_{CaO}/W_{CaC_1}$) the quantity of carbide required for desulfurization. However, the consumption of the desulfurizing mixiture is increased in carbide desulfurization as mentioned in this section, in order to compensate for resulfurization which occurs during transportation of hot metal. Therefore, when the values of S concentration of hot metal at BF tapping and at converter charging are aligned between carbide and lime desulfurization, the consumption of lime is only 1.8 times that of carbide.

4 3rd Stage—Use of Lime-based Desulfurizing Reagent in Operation Step

4.1 Selection of Refractories for Torpedo Car

In the past when the carbide-based desulfurizing reagent was used, the slag line of the torpedo car was lined with high-alumina bricks and the remaining parts of the torpedo car were lined with chamotte bricks. Fig. 9 shows a comparison of the wear condition of refractories between lime desulfurization (lime desulfurization utilization ratio: 61%) and carbide desulfurization using the torpedo car of the abovementioned specification. When lime desulfurization is employed, wear of refractories was severe at the slag line and upper part of the torpedo car. The reason for this may be that lime desulfurization forms high basic slag and consequently low melting-point compounds such as anorthite (CaO·Al₂O₃·2SiO₂) and gehlenite $(2CaO \cdot Al_2O_3 \cdot SiO_2)$ become liable to grow on the working faces of bricks, thereby accelerating wear.

	Averaged Composition (%)						р
	CaO	SiO ₂	Al ₂ O ₃	MnO	MgO	S	
BF slag	41.4	33.8	14.6	0.7	7.3	1.10	1.39
Before desulfurization	48.2	31.7	7.2	2.1	1.6	3.92	1.68
After CaC ₂ desulfurization	51.6	21.9	6.0	1.9	1.4	6.28	2.58
After CaO desulfurization	59.6	22.3	5.1	0.5	0.9	4.02	2.81

 Table 2
 Average composition of blast furnace slag and torpedo car slags before and after desulfurization treatment

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Fig. 9 Wear line contour of lining of a torpedo car used for lime (61%) and carbide (39%) desulfurizations (right) compared with that for carbide desulfurization (left)



Fig. 10 Steep increase in wearing rate of high-Al₂O₃ lining compared with low and rather constant wearing rate of MgO-C lining with increased lime desulfurization ratio

On the basis of experience shown in Fig. 10, selections were made from refractories suitable for lime desulfurization. First, when MgO-C bricks were used at the slag line, melting loss at this portion was greatly decreased, as shown in Fig. 10. Since the wear rate of MgO-C bricks is controlled by oxidation of C, it is desirable to minimize the frequency of intermediate repairs. Then, Al_2O_3 -SiC bricks were used for the hot metal stagnating zone and the hot-metal-ceiling contact zone which were subject to wear and deterioration, in order to strike a balance with MgO-C bricks that were less or damaged by heat. Further, the frequency of torpedo car utilization was increased to decrease oxidation of C contained in MgO-C by atmospheric air at idling time of the torpedo car. Consequently, the unit consumption of refractories for the torpedo car was greatly reduced from 1.08 kg/t for carbide desulfurization to 0.69 kg/t for lime desulfurization.

4.2 Temperature Drop during Hot Metal Transportation

A very important aspect of energy-saving measures is to minimize the temperature drop during hot metal transportation. Particularly when MgO-C refractories having a higher heat transfer coefficient were used, it was necessary to prevent an increase in temperature drop due to the use of MgO-C refractories. In order to find out effective measures for this purpose, a simplified model was first made to estimate the quantity of the temperature drop.

For this estimation, a linear heat transfer formula was used, and the heat transfer coefficient at the external surface of the torpedo car was taken as a sum of the convectional heat transfer coefficient (= 15 kcal/m²·h·°C) and the radiant heat transfer term in which the radiation coefficient was approximated to

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Fig. 11 Comparison of measured and calculated temperature decrease, ΔT , of hot metal between teemings into and dischargings out of torpedo car

unity. When a torpedo car was empty, heat radiation occurred from the interior of the torpedo car owing to the syphon effect, and the heat transfer coefficient at the internal surface at this time was taken as 0.6 kcal/ $m^2 \cdot h \cdot °C$. The quantity of thermal radiation from the internal surface is strongly dependent upon the heat conductivity of refractories and is practically free of the error in the above-mentioned heat transfer coefficient.

Changes in steel-shell temperatures with the passage of time were measured at positions corresponding to MgO-C and Al₂O₃-SiC bricks, respectively, and the values of thermal conductivity of the refractories were determined so that calculated values would agree well with measured values. These values of thermal conductivity were used in calculating the quantity of the temperature drop (ΔT) of hot metal between receiving it to and discharging it from the torpedo car. The resultant calculated values agreed well with measured values (see Fig. 11). Then, through the use of a torpedo car which was lined with refractories for lime desulfurization of a new specification obtained by the abovementioned method, the quantity of temperature drop (ΔT) was calculated as a function of the empty time and filled-up time of the torpedo car, and Fig. 12 was obtained. This figure indicated that increasing the frequency of torpedo car utilization was greatly effective in decreasing ΔT , and efforts were thus made to increase the frequency of torpedo utilization with the additional objective of reducing the wear of MgO-C mentioned in the preceding Section. As a result, the frequency of torpedo car utilization was increased from 2.7 times/day in March, 1979 to 3.6 times/day in 1980, thereby decreasing ΔT by 14°C. Through conversion from carbide to lime, a decrease of ΔT by 4°C was accomplished owing to the effect of increasing

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Fig. 12 Calculated temperature decrease, ΔT , of hot metal as a function of filled-up and empty times of torpedo car and observed decrease in ΔT obtained by the increase in frequency of torpedo car utilization

the frequency of torpedo car utilization, although desulfurizing reagent consumption rose and ΔT increased as a result of a rise in refractory heat content.

4.3 Expansion of Lime Desulfurization Ratio

After refractories suitable for lime desulfurization were determined, conversion from carbide to lime progressed smoothly and practically completed in August, 1980. Through this conversion it was possible to cut the desulfurization cost by about 50% and the refractory cost by about 20%.

5 Conclusion

A low-cost injection hot-metal desulfurizing reagent with lime as a main ingredient was developed in three stages.

Improvement in the fluidity of lime powder by a small addition of methyl-hydrogen-polysiloxane rendered stabilized injection possible. The optimum composition of the lime-based desulfurizing reagent was determined as 45%CaO (-60 mesh)-35%CaCO₃-5%CaF₂-15%C by means of an actual furnace test while changing the contents of CaF₂, C, and CaCO₃ in the desulfurizing reagent and the grain size of lime powder. The efficiency of lime utilization for desulfurization was 13.3%, when

the lime-based desulfurizing reagent was used for desulfurizing from [%S] = 0.045 to [%S] = 0.015.

- (2) When the carbide desulfurizing reagent is used, resulfurization rate reached 0.012% and 0.002% at receiving hot metal to and discharging it from the torpedo car, respectively. When the lime desulfurizing reagent is used, desulfurization rate is 0.005% at receiving and no resulfurization occurs at discharging. Therefore, if the values of S concentration at BF tapping and converter charging are aligned between lime and carbide desulfurization, lime consumption corresponding to 1.8 times the carbide consumption will be sufficient.
- (3) As torpedo car refractories for lime desulfurization, MgO-C and Al_2O_3 -SiC were selected for use at the slag line and other parts, respectively. Through improvement in the torpedo car utilization rate, the temperature drop was less in the lime desulfurization than in the carbide desulfurization, in spite of an increased unit consumption of the desulfurizing reagent and the necessity of using basic refractories.

On the basis of the above-mentioned results, conversion from carbide desulfurization to lime desulfurization was practically completed in August, 1980. Through this conversion, it was possible to cut the cost of the desulfurizing reagent by about 50% and the refractory cost by about 20%.

The 1st stage of the present studies was jointly conducted with Chiba Works of Nippon Lime Limited.

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