

Fig. 15 Oil-ash corrosion of ferritic alloys as a function of temperature

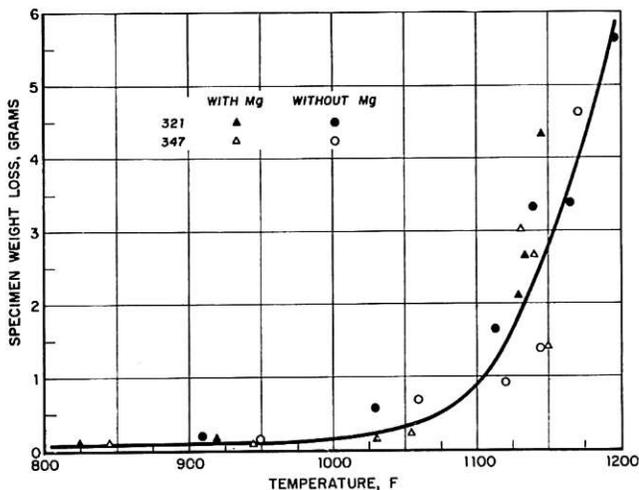


Fig. 16 Oil-ash corrosion of austenitic alloys as a function of temperature

low-temperature corrosion and deposits are possible. More testing is necessary to measure the benefits to be obtained.

An accurate evaluation of reduction in high-temperature corrosion was not made; oil-ash deposits produced during the addition of magnesium metal, however, contained from 30 to 40-percent magnesium oxide and had melting points in the neighborhood of 2700 F compared to 1100 to 1300 F for ordinary oil-ash deposits. It is highly unlikely that a deposit with a melting point of 2700 F would be corrosive at operating tube temperatures. More testing is planned.

### Acknowledgments

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## DISCUSSION

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One of the first noteworthy points in this interesting paper is the finding that a conventionally designed and built oil-fired boiler furnace can be adapted to operation with as little as 2 percent excess air at full load without much more trouble than a modification of the combustion controls. When we first began hearing about low excess air in Europe, most American operators were pessimistic about trying to approach stoichiometric conditions because they expected problems in metering fuel to each burner and in adjusting air dampers. It might be feasible elsewhere, but it just wouldn't be practical here. Yet the boiler described in this paper is reported to operate without difficulty and with a clear stack. And so one lesson we have learned at first hand is that operation with low excess air need not necessarily call for a major redesign of a plant and special training of selected operators. It may be done more simply than had been thought possible a year or two ago.

Another important point is the extremely small quantity of additive necessary to produce a significant decrease in the amount of  $\text{SO}_3$  reaching the air heater. As shown in Fig. 4, the already low values of  $\text{SO}_3$  at full load when operating at about 0.5 percent  $\text{O}_2$  were reduced further by a factor of three by adding 12 lb per hr of metallic magnesium to the furnace. This is enough, as the authors state, to react with 40 lb of  $\text{SO}_3$  to form magnesium sulfate. That they reported a reduction of 57 lb per hr of  $\text{SO}_3$ , then, points to other actions, for it is quite improbable that  $\text{MgO}$  in the flue gas and on surfaces can approach quantitative reaction with  $\text{SO}_3$ .

Scavenging atomic oxygen by the magnesium metal may be a part of the story, as the authors suggest, but this argument would be much stronger if the magnesium were added as a metallic vapor to mix thoroughly with the flue gas. The relatively poor contact between even 50-mesh magnesium particles and any atoms of oxygen if present would be expected to be poor. Further, atomic oxygen exists in flames; but recombination occurs rapidly, and it is questionable whether any atomic oxygen still exists in the flue gas by the time the gas reaches the point where the magnesium is added. Still another argument against this mechanism is the fact that the magnesium is more effective when added high in the furnace rather than at the burner level. If atomic oxygen scavenging is indeed occurring with magnesium, the magnesium should have been more effective when added to the flame than when introduced essentially after combustion is completed.

Work at Battelle for the ASME Committee on Corrosion and Deposits has confirmed the importance of atomic oxygen in producing  $\text{SO}_3$  in flames. It also shows that this reaction must occur within the flame itself. For example, in a typical experimental flame, the atomic oxygen level was 16 parts per million in the visible flame, but it dropped to zero only 0.03 in. beyond the flame envelope. It is this atomic oxygen that reacts with  $\text{SO}_2$  to produce the  $\text{SO}_3$  formed by flame reactions. For these reasons, it appears likely that any reduction in  $\text{SO}_3$  observed by the

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authors when magnesium was added high in the furnace did not come from the removal of oxygen atoms by the magnesium.

A more likely explanation for the effectiveness of the MgO, beyond its neutralizing SO<sub>3</sub>, is the old concept of destroying the surface catalytic activity of the superheater elements. Periclase, the common mineral form of MgO, has a density of 3.58, so the 19.9 lb of MgO formed by burning 12 lb of magnesium would occupy a volume of just less than 0.1 cu ft. Assuming that half the MgO produced was deposited on the superheater, the layer would form at the rate of 0.0005 in. per hr on 1000 sq ft of surface. Allowing for reaction with SO<sub>3</sub>, erosion and reaction with the oil ash, and removal by spalling, this might still provide enough MgO to serve as an effective mask for the otherwise catalytic superheater surface.

Practically, of course, an operator is not concerned about the mechanism by which a beneficial treatment functions. He is concerned only with results. But those who are charged with devising better techniques tomorrow than exist today must constantly be asking questions about "how" and "why." Thus this paper is of great interest to them as well as to the practical operating engineer, for it gives more bits of evidence that, in the long run, will aid in controlling this expensive and annoying problem of corrosion and deposits.

### Authors' Closure

The authors appreciate the comments of Mr. Reid on this work. Subsequent work supports his observation that scavenging of atomic oxygen by magnesium may not be the principal mechanism for reducing SO<sub>3</sub> formation. A study of the amount of SO<sub>3</sub> formed in various sections of the boiler has yielded the following results:

SO<sub>3</sub>, ppm (at 185 mw and 2.5 percent excess air)

	Before Sec. SH	Before Primary SH	Before AH
Without Mg	3	12	32
With Mg	3	3	7

It was found that the amount of SO<sub>3</sub> formed in the furnace (as measured before the secondary SH) was the same for a given load and excess air, regardless of whether or not magnesium was being added. Only after magnesium had been added for several hours were reductions in SO<sub>3</sub> concentration noted at the primary SH and air heater inlets. These results indicate that:

(a) When operating the test boiler at low excess air most of the SO<sub>3</sub> in the flue gas is formed catalytically in the convection passes rather than by the reaction of atomic oxygen with SO<sub>2</sub>.

(b) As suggested by Mr. Reid, the reduction in SO<sub>3</sub> concentration by the addition of Mg is probably due to the coating of catalytical surfaces with magnesium oxide.

Additional data on high temperature corrosion were obtained after the paper was printed and were included in the oral presentation. Fig. 17 is a plot of corrosion versus temperature for TP-321 and 347 austenitic alloys showing the results of three one-month tests. The upper curve represents operation with normal excess air, the intermediate curve with low excess air, and the lower curve with low excess air plus magnesium addition. These data support the assumption that had adequate coverage of additive been obtained, corrosion of high temperature metal surfaces would have been reduced substantially.

Low excess air operation with magnesium was effective in reducing high temperature corrosion to negligible quantities. Thus, as has been demonstrated by other investigators, magnesium oxide will alleviate high temperature corrosion.

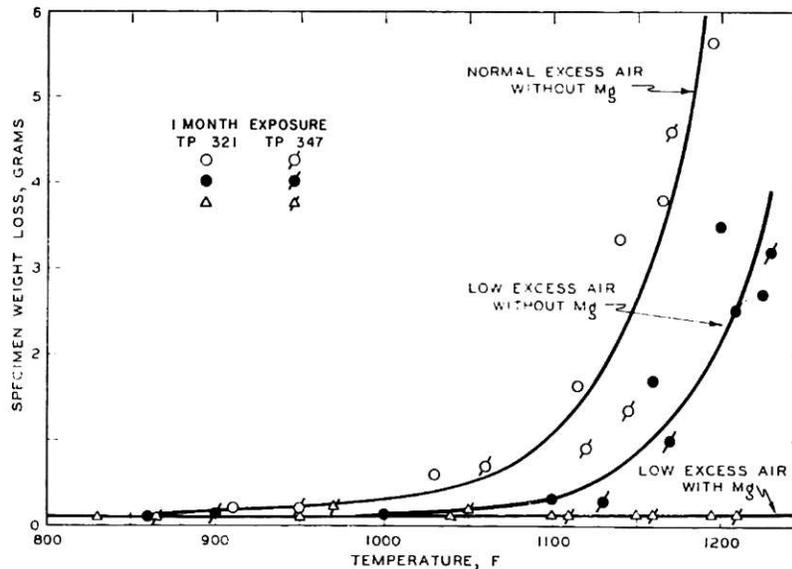


Fig. 17 Wastage versus temperature