Because of continuing interest in the problems of controlling boiler tube corrosion when burning wastes, an extra unscheduled discussion without formal papers was arranged for Monday evening, May 24.

About 200 attended this unscheduled session which was planned to bring out the available current knowledge and experience on corrosion in boilers. In many ways, the Waste-to-Energy (W→E) corrosion problem is following the coal-ash corrosion situation in utility boilers of 25 years ago. However, there the research of many finally seemed to isolate the culprit as being alkali iron tri-sulfates at very high steam temperatures. The solution there was to pull back on steam temperatures to about 1040 F and to modify the flow of secondary air along the furnace walls to reduce the amount of SO$_3$ formed within the slag layers deposited on the tubes. Also, shields were tried to protect the tubes from the action of the sulfates.

Today, the W→E corrosion problem appears to be both from molten chlorides on the tube surface and chemical reaction of chlorides trapped deep in the ash deposit.

W→E plants began operating first in Europe in the 60's and from the start some corrosion was experienced. Those plants escaping corrosion generally operate below 500 F steam temperature. But many operate above 800 F steam temperature with varying degrees of annoying but acceptable corrosion.

Care in operation probably has as much effect as anything in minimizing corrosion attack. Many plants, some in the U.S. and some in Europe, have found that too vigorous use of soot blowers exposes cleaned surfaces to rapid attack. This indicates that the deposit on the tubes may be generally considered to be protective. However, recent research indicates that if the deposit gets too hot, the chlorides melt or decompose and attack the metal. Often the most rapid corrosion seems to come from excessive burning rates or from internal scaling caused by loss of control of boiler water quality. With the caliber of staff often available in W→E plants, good control of water quality is more difficult than in much larger electric utility plants.

Good furnace mixing is important, but whether reducing conditions are in themselves a cause has not been confirmed. Even in an oxidizing atmosphere the conditions beneath the ash deposit may be reducing.

A recurring theme in the remarks made during this session was that adequate shredding accompanied by metals separation should give better combustion, better furnace mixing and reduce tube attack by metallic contaminants. Whether the additional benefit of resource recovery can economically offset the considerable maintenance cost of most shredders remains to be demonstrated.

Against the common practice of protecting furnace wall tubes above the grate with silicon carbide covering held in place by welded studs, a contrary view expressed was that this not only impairs heat transfer but conceals potential spot failures of tubes caused possibly by internal tube scaling.

Corrosion probe tests supported by EPA have shown that high chromium alloys used at just the most vulnerable points in superheaters could extend tube life by a factor of 10. Aluminum-silicon coatings also show promise but they are difficult.
to apply in a manner that provides a sufficiently dense layer to be impervious to penetration by the furnace atmosphere.

In summary, above 500°F steam temperature some corrosion can be expected but a number of European plants operate above 800°F with corrosion rates that are tolerable. Operation is extremely important to avoid, at any time, even temporary overheating of the tubes. This is much more difficult to prevent with refuse than with oil or coal, hence diligent operator skill is required.

Those contributing principally to this discussion were C. O. Velzy, R. E. Sommerlad, A. L. Plumley, Dale Vaughan, Eric Smith, Vaughn Mansfield, and Dick Engdahl.

The following references are pertinent:

REFERENCES


COMMENTS by R. S. Rockford

In accordance with your request, I have reviewed your draft of the minutes of the corrosion session at the recent Solid Waste Processing Conference session at the recent Solid Waste Processing Conference in Boston. My comments follow: —

Your statement—“but many operate above 800°F steam temperature with varying degrees of annoying but acceptable corrosion. Another statement made—a number of European plants operate above 800°F with corrosion rates that are tolerable.”

I question the point that many operate above 800°F with varying degrees of tolerable or acceptable corrosion. I would say that in many instances, success, when operating above 800°F has been coupled with operation in specially designed combination fired units (combination of fossil and waste firing). I believe it should be pointed out that many of the units operating at high temperatures in Europe are firing refuse in combination with fossil fuels.

Your statement—“Good furnace mixing is important but whether reducing conditions are in themselves a cause is debatable.”

I have received the impression that there has been general agreement among authorities that alternating oxidizing and reducing atmospheres is one of prime causes of furnace corrosion and can be the of the causes of superheater corrosion.

Statements were made in the first and fourth paragraphs on Page 2 concerning water treatment.

I believe any operator of a modern high duty waterwall boiler must recognize that good water treatment is mandatory and internal scale cannot be tolerated regardless of the fuel fired. We are doing no one a favor by trying to design around poor operating practice in this regard.

Your statement—“Operation is extremely important to avoid, at any time, even temporary overheating of the tubes.”

It is unclear what point you meant to make here, however, I got the impression you are implying that you can get overheating of furnace tubes due to high heat input. Strictly speaking, with the relatively low heat inputs per square foot in these big furnaces I would not expect overheating of the furnace tubes from flame impingement alone. However, improper feedwater treatment can result in poor boiler water conditions which can cause internal scale with overheating of the tube metal at normal heat inputs. Flame impingement could, however, create an oxidizing and reducing atmosphere in the vicinity of the waterwall tubes which could cause corrosion on a tube. If you elevated the tube temperature due to scale inside the tubes the corrosion rate would probably be greatly accelerated.
At the meeting you asked for my comments concerning the use of shields to protect superheater tubes. I pointed out that shields had been used successfully in Europe including the Edmonton, Ivry and Stuttgart Plants and that we had tried them selectively at Nashville. At Nashville, they proved effective in reducing the corrosion tendency and based on this experience they will be used there in the future to help protect the first two rows of superheater tubes (next to the furnace outlet).

You are to be commended for initiating this special corrosion session. It was handled beautifully, some excellent thoughts were expressed and it proved to be of major interest judging from the attendance.

In reply to Robert Rochford

Thanks very much for your careful comments on the Boston Corrosion Session Summary. However, three of your points, I'm sorry, didn't get into the summary:

1. Discussion of those units in Europe using combination firing with fossil fuels. I know only of Essen and Munich. I'd say many more such as Dusseldorf, Zurich and Ivry operate above 800°F on straight refuse. Nevertheless, it would have been good to bring in the combination concept.

2. Importance of clean waterside. You are so right that we must not try to design around poor water treatment.

3. Overheating. It would be so much clearer if I'd have said, "overheating of the deposit." You are right that with clean water the free flowing water tube cannot become overheated. What can become overheated is the chloride layer in the deposit. For that reason, long flames and flame impingement are to be avoided.

I now see that one major shortcoming of our interesting evening was that we didn't clarify the argument over reducing conditions.

The preponderant evidence seems to say that we never have reducing conditions in a furnace, but if a char particle burns while against a tube, there is localized reduction. More important, the conditions within the deposit can often be reducing.

I'm glad to know that the tube shields have helped at Nashville. After you have had some more experience there, I'd be interested in having some data on average shield life at various locations.

DISCUSSION by Eric H. Smith

BOILER WATERWALL TUBE CLEANLINESS

The presence of a very thin scale on the inside of the tube can increase the metal temperature of the area of the tube exposed to the flame several hundred degrees leading to blistering and eventual rupture. It is exceedingly difficult to damage a perfectly clean tube having adequate circulation.

A boiler operating at 680 psig (4680kPa) with a water temperature of 502°F (261°C) would have a maximum metal temperature only about 50°F (28°C) higher with clean tubes but with scale in the tubes this might go to 1000°F (538°C) with subsequent failure.

Those units where steam is condensed and returned to be reused as feed water should presumably have better records than those where contaminated condensate and make up is required. Extreme precautions in the design and operation of the water conditioning equipment is required in the latter case.

EFFECT OF WATER CONDITION ON SUPERHEATER

Boiler water purity must be of a high order to hold down solids carryover which over a short or long period can accumulate and thereby increase tube metal temperature which in the presence of a reducing atmosphere would lead to corrosion of the tube metal.

OXIDIZING ATMOSPHERE NECESSARY IN GAS ENTERING SUPERHEATER

This is a necessity if corrosion is to be avoided. 02 recorders are a necessity and the writer believes that operation at 150% excess air, where pollution control equipment is adequate, would lead to an increase in plant running time which would more than offset the lower efficiency. In many instances the lower efficiency is of no consequence because at least some of the output must be condensed in the plant itself.

PLACEMENT OF OVERFIRE AIR JETS

Care must be taken in the placement of side overfire air jets. Low velocities are desirable, since it is possible to suck flame toward a side or front...
waterwall due to aspirating eddies at the point where the jet enters the furnace.

WIDER FURNACE IN BURNING ZONE.

It is desirable to widen the stoker and furnace as much as 18" (450 mm) each side (3¾"-0" (900 mm) total) where the refuse feeding grate section ends. The fuel bed is then thinner at the sides and a reducing flame next to the walls is avoided.

Comment on Discussion by Herbert I. Hollander

This ad hoc session prompted by Dick Engdahl resulted in an excellent interchange of views in this area of concern.

There is still much to learn regarding cause and effect relationships since the simplistic rationalizations and conclusions are obviously not applicable across the board.

Metal wastage in thermal energy systems is not a phenomena unique to refuse fired systems. Through the years there have been many horror stories of major and not so major problems even with unfired heat transfer vessels no less those firing waste fuels of production or the conventional fossil fuels — coal and residual oils in particular.

It is not unusual to have two and even three "identical" units in the "same" plant, utilizing the "same" fuels, perform differently and encounter operational and maintenance problems of different severity.

Although usually done almost instinctively — comprehensive correlations of refuse firing experiences should be made with the fossil fuel experiences and thereby the apprehensions expressed and precautions advocated be placed in broader perspective since expedient conclusions can not be all inclusive.

Obviously there is significant divergence of views and interpretations of the observations and data — and the real significance thereof.

Provisions have been and are being made in designs of systems and operating programs to avoid or minimize these problems, among others.

Although too frequently taken for granted, it has been found that improving and rigorously maintaining boiler water quality will avoid deposition of an insulating layer of material on the inside of the tube, thereby significantly improving or eliminating troublesome tube metal wastage. This is especially critical in the furnace areas of high heat flux. As essential, albeit less detectable, is the obvious need and attainment of intimate contact with clean surface of "sufficient” heat transfer medium (water, steam, thermal fluid, air etc) to maintain the desired level of system performance and reliability. The circulation rate, velocity, flow pattern and transitional change-of-state of the “fluid” within the tube have a major influence on the heat transfer and tube metal cooling effectiveness.

The prudent design, (and therefore perhaps the most expedient in the final analysis) would be "more than just adequate” to ensure complete fuel/air mixing and ample retention time in the primary combustion zone. Generous flame travel and low gas velocities are necessary to minimize entrainment, avoid combustion beyond the furnace and possible deposition and buildup of semi-plastic ash. This applies to all fuel firing systems especially those burdened with ash whether of a fouling nature or not, particularly where combination fuel firing will be practiced.

There are few situations where the quality of the fuels and the character of the ash can be assured for the practical life of the system. Therefore, the system design must provide configurations of the combustion chamber, convection sections and particularly their interfaces to successfully contend with the spectrum of fuel characteristics likely to be encountered. The initial cost premium, if any, is in reality miniscule when compared to; — the value of the fuel to be consumed even in a few years of operation no less the practical life of the facility — the material and labor cost, and loss in production resulting from a forced outage of the system.

There are of course other factors influencing cause and effect relationships including operating modes, system control and responsive monitoring programs.

It is very apparent that no individual or firm has all of the answers. Even those practitioners who have had to wrestle with these circumstances are perplexed all too frequently.

Compromise should only be made with full awareness of the elements of exposure — commercial expediency can become a costly rationalization. In today’s purview of environmental concerns and resources conservation (i.e. materials, energy, monetary and human), there is little latitude for the uninitiated and naive.

The determination to press for progress will persist since otherwise there will be stagnation and decay.