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SUBJECT: Investigation of Mechanical Methods of Scale Removal from
HRT Heat Exchangers

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ABSTRACT

Tests were conducted to determine methods of removing scale deposits from the HRT heat exchangers. A mockup of the heat exchanger header was cleared of a deposit of iron rust by reverse flushing at a flow rate below 75 gpm. A tube bundle consisting of 109 1/4 in. O.D. x 0.049 in. wall tubes was plugged with rust. Approximately 80% of these tubes were unplugged by using a 70 psi water pressure differential in combination with vibration from a pneumatic rivet gun. No mechanical method was employed in the tests which could clear the remaining tubes.

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INTRODUCTION

During the operation of the HRT immediately after the dump which terminated Run No. 18, there were indications that the fuel and blanket heat exchangers may have become partially plugged with corrosion scale, which had been removed from the piping and heat exchanger tubing during the dump. A program was initiated to determine; first, if the heat exchangers could be plugged with scale which was assumed to exist and, second, to determine possible mechanical methods of removing this scale. The program was terminated when the actual HRT difficulties were diagnosed to be circulating pump malfunctions.

HEADER TESTS

Since the heat exchanger could possibly plug in either the tube bundle or in the headers, the two regions were investigated independently. A full sized mockup of the header was constructed as shown in Figure 1. Flow through either the inlet or outlet header could be simulated by inverting the mockup. The mockup was piped into a 500 gpm circulating system, Figure 2, which was instrumented to indicate the flow and pressure drop across the mockup. Approximately 25 pounds of iron rust which had been obtained from old steel piping was classified (100% less than No. 6 mesh and 97% less than No. 8 mesh) and loaded into the cooler tank. When the pump was turned on, the inlet header filled with sediment almost immediately as shown in Figure 3. When the header was reversed so that flow was in the opposite direction, the sediment was quickly washed out of the header. The header was then removed and both sides were packed with the iron rust. When the header was reinstalled into the loop and flow started, the outlet header cleared itself even though the inlet header remained plugged. A pneumatic vibrator (Martin Engineering Company Vibrolator No. 51) was installed on the header in an attempt to clear the inlet header also, but there were no beneficial effects observed from the vibration. At this time flow was limited to below 75 gpm as a result of plugging.

UNPLUGGING A SINGLE TUBE

The problem of unplugging a tube was considerably more difficult. Several preliminary tests were conducted using a 3/8 in. O.D. copper tube approximately 18 in. long plugged with iron rust. The sediment had been pulverized and classified to approximate a particle size distribution which was observed in a sample of solids taken from the HRT mockup pressurizer, with particles above No. 10 mesh removed:

- 100% less than No. 10 mesh
- 91% less than No. 30 mesh
- 61.9% less than No. 50 mesh
- 31.5% less than No. 100 mesh
- 21.0% less than No. 200 mesh

When a water slurry of this material was allowed to settle in the 3/8 in. tube, it formed a plug which could not be blown out with either building water or air pressure (approx. 70 psi). It was found that this plug would flow out of the tube under gravity when the tube was vibrated vigorously.

Experiments were made with two types of vibrators, an electric hand vibrator (Burgess Vibrograver) and the pneumatic vibrolator mentioned earlier. Measurements were made of the peak to peak displacement, average velocity, and frequency of the vibrations using a Consolidated Engineering Company Vibration Meter Type 1-117 and Velocity Pickup Type 4-118. The frequency was measured by a vibrating reed type tachometer. The output of the vibration meter was studied on an oscilloscope to determine the wave shapes of the two vibrators. The pneumatic vibrator was found to have a sinusoidal vibration, while the electric vibrator had a saw tooth wave shape as shown in Figure 4.

The peak accelerations produced by the pneumatic and electric vibrators were calculated using the following equations respectively.

$$1. \quad A = \frac{d}{2} W^2 \qquad W = \frac{2\pi f}{60}$$

$$2. \quad A = \frac{V}{0.075 T} \quad (\text{approximate})$$

A = maximum acceleration-ft/sec²

d = peak to peak displacement (from Vibration Meter) ft.

V = average velocity (from Vibration Meter) ft/sec

f = frequency of vibration, cpm (from Reed Tachometer)

T = period of vibration, sec

W = angular velocity, radians/sec

It was found that both types of vibrator would start the plug flowing when the peak acceleration of the vibration reached approximately 5 g.

TUBE BUNDLE

The spare HRE tube bundle, consisting of 109 1/4 in. O.D. x 0.049 in. wall tubes approximately 10 ft long, was set up as shown in Figure 5 in an attempt to unplug an actual heat exchanger. This mocked up the HRT units which contain 251 tubes 3/8 in. O.D. x 0.065 in. wall. The heat exchanger was mounted on a frame which was designed to approximate the natural frequency of the HRT heat exchanger-and-mounting system, which was estimated to be 28 cps. The tube bundle was placed in a vertical position and was filled with the pulverized and classified iron rust mentioned earlier. The dry powder was poured directly into the open tube sheet and packed down with the pneumatic vibrator. The tube bundle was completely filled in this manner. Attempts to unplug the tubing using 70 psi water and the pneumatic vibrator were completely unsuccessful, and the original seepage through the plugged tubes remained constant during the tests. A vibration check was made over the entire range of frequencies (0-7000 cpm) indicating that the maximum acceleration obtainable was 2.2 g. A resonant point was found at a very low frequency, but the acceleration was insufficient to cause the plugs to flow. Attempts were made to use two vibrators at slightly different frequencies, hoping to obtain a beat frequency with a peak acceleration twice that above. However, it was impossible to obtain a beat frequency with the available equipment, and the two vibrators actually seemed to cancel each other. A large air hammer was then tried (No. 80 Boyer Rivet Gun with 307 gram hammer, Chicago Pneumatic Tool Co.) with 70 psi water pressure across the unit, and approximately 80% of the tubes were unplugged. The flow through the tube bundle was metered continuously during the test and the discharge water was examined for rust particles, until there was no increase in flow and no discoloration in the discharge water. No vibration measurements could be taken because of the non-steady state type of vibration produced by the air hammer.

The heat exchanger head was then removed and each tube was checked individually with air pressure. Twenty tubes were found plugged. The head was replaced and several more unsuccessful attempts were made to clear the remaining tubes by the same method.

The heat exchanger was then thoroughly dried in a furnace for approximately 72 hours at 275°F, and attempts were made to clear the bundle by suddenly releasing 200 psig of gas pressure from within the tube bundle, hoping that the sudden expansion of gas might dislodge the particles. When the gas bursts were used with mechanical vibration, rust particles were observed in the discharge, but a final individual tube check indicated that no additional tubes had been unplugged.

Discussions were held with various members of ORNL and manufacturers of ultrasonic cleaning equipment, to determine if ultrasonics might be used to free the tubes. The unanimous opinion was that ultrasonic cleaning would be impractical because of the attenuation of the energy prior to reaching the area of the plug. This was thought to be true whether the energy was introduced into the primary piping or through the steam nozzles.

CONCLUSIONS

Because of the inaccessibility of the HRT tubes, cleaning jets or drills were not investigated. Should the need ever occur, the HRT headers can be cleaned effectively by using a reverse flush technique with some method of removing the solids as they are washed out of the heat exchangers. Reverse flushing with filter systems as shown in drawings TD-D-3679 and TD-D-3662 have been designed for the HRT. Although the tube unplugging tests were not completely successful, it is encouraging that 80% of the tubes were unplugged. The test plugs were probably of a more severe nature than would actually occur since the tube diameter was smaller and tubes were probably more densely packed. Water flushing with vibration seems to be the best approach to mechanical cleaning at this time. If further testing is required, the following recommendations are made:

1. A small tube bundle should be constructed using actual sized tubes of the correct length and supported as in the particular heat exchanger.
2. A properly sized vibrator should be obtained to insure that adequate acceleration can be obtained. Large vibrators can be obtained from the Cannon Vibrator Company or the Cleveland Vibrator Company.
3. An accelerometer with a dynamic recorder should be used to measure the vibrations rather than the velocity-type instrument employed in the above tests, so that non-steady state measurements can be made.
4. The sudden gas expansion technique might be explored at higher pressures.

251 Holes 0.161" Dia.
Drilled on 5/8" Triangular Pitch

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Figure 1
Header Mockup

Figure 2

Heat Exchanger Header Test Loop

Figure 3

Sedimentation of Inlet Header

Figure 4

Time-Displacement Diagram Produced by Burgess Electric Vibrator

Figure 5

Heat Exchanger Unplugging Test

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