Lab Fouling Test Unit Implementing Phase Microwire Test Cards

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Introduction

Fouling, the accumulation of unwanted carbon based deposits on the surface of process piping, is studied using an autoclave based Fouling Test Unit (FTU).

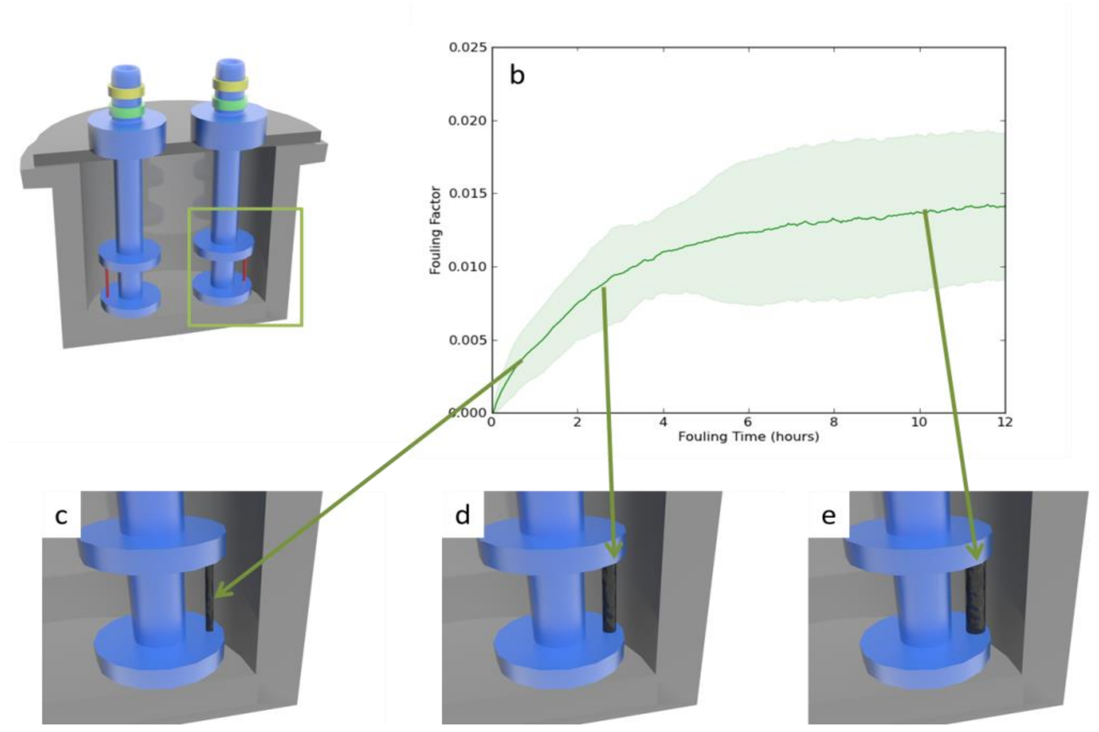
Fouling build-up reduces heat transfer from the metal surface to the process fluid. The FTU measures this heat transfer and correlates it to the rate fouling build-up in situ during testing.

Tests were conducted using Vacuum Tower Bottoms (VTB) samples and comparisons were made between deposits on the wire in the laboratory FTU using a clamped wire and on a micro wire assembly using Scanning Electron Microscopy (SEM).

The effect of using a much smaller wire assembly was explored and the results showed no significant disadvantage to using a much smaller wire dimension.

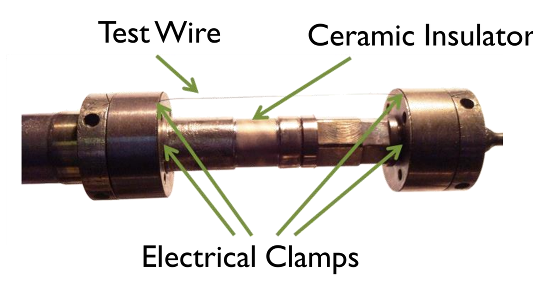
Experimental Conditions & Goals

1. Employ the FTU to simulate plant conditions and investigate the key variables for controlling fouling in heat exchanger applications.
2. Explore the effect of a new wire geometry and the use of a micro wire assembly on fouling measurements.
3. Identify and optimize fouling mitigating chemical additives.



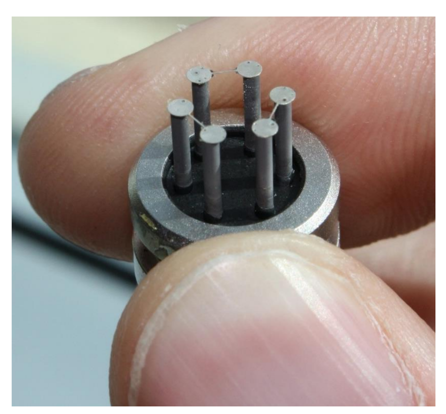
FTU testing uses a heated wire to provide a hot metal surface in a heated and stirred autoclave reactor. As fouling forms on the heated wire the measured fouling factor increases providing a precision continious measurement of the fouling build-up process. Temperature of the process fluid is kept at 500^{0}F while the heated wire is kept at 950 ^{0}F. Autoclave stirring is designed to provide a uniform flow field across the wire durring testing. The autoclave is held under a pressurized head of nitrogen at 200psi. Each run includes an initial slow heating rate used to calibrate the test wires and fit their resistance vs. temperature measurements to an ex-situ obtained calibration up to 1000 ^{0}F.

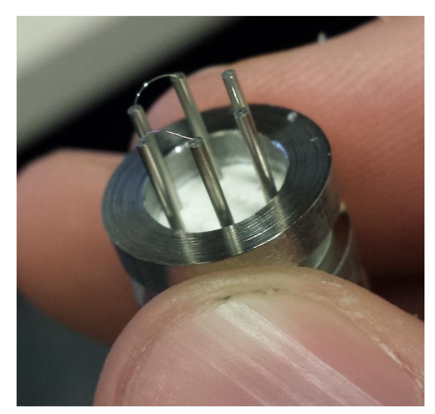
Fouling Testing



In the traditional Athlon FTU the test wire is held firmly between two electrically isolated clamps that are connected with a four wire electrical connection. A fresh section of clean wire is mounted before each run and after each run the wire is removed from the clamps for analysis.

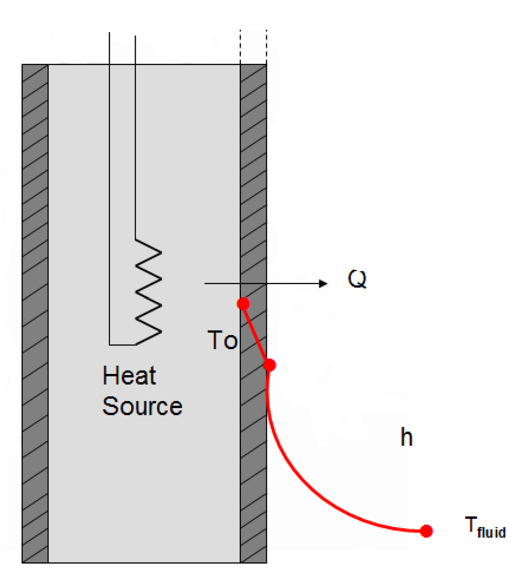
Using the micro wire assembly three test wires are positioned between pins of a high pressure feedthrough. Shown below to the left is a feedthrough with micro wires electroplated onto the pins. Below to the right is another method of fixing the wires involving spot welding.

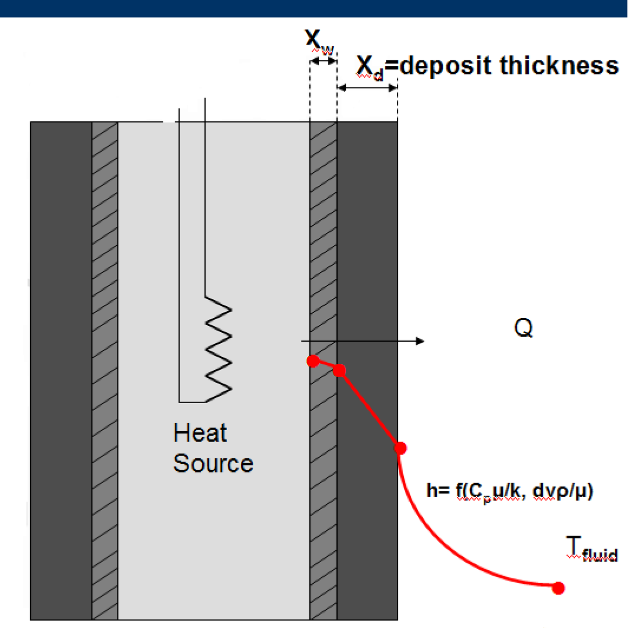




These micro wires are incorporated with a high pressure feedthrough that can operate at 900F (left) and 1000F (right). The test wires are each connected to a four point electrical connection that allows for their resistance to be precisely monitored as they are electrically heated.

Heat Transfer Theory





$Q_c = U_c A_c \Delta T_c$

r_1=pipewall resistance $=X_w/K_w$

r_2=fluid film resistance $=1/h$

$R_{total} = 1/r_1 + 1/r_2$

$1/U_c = (X_w/K_w + 1/h)$

$Q_f = U_f A_f \Delta T_f$

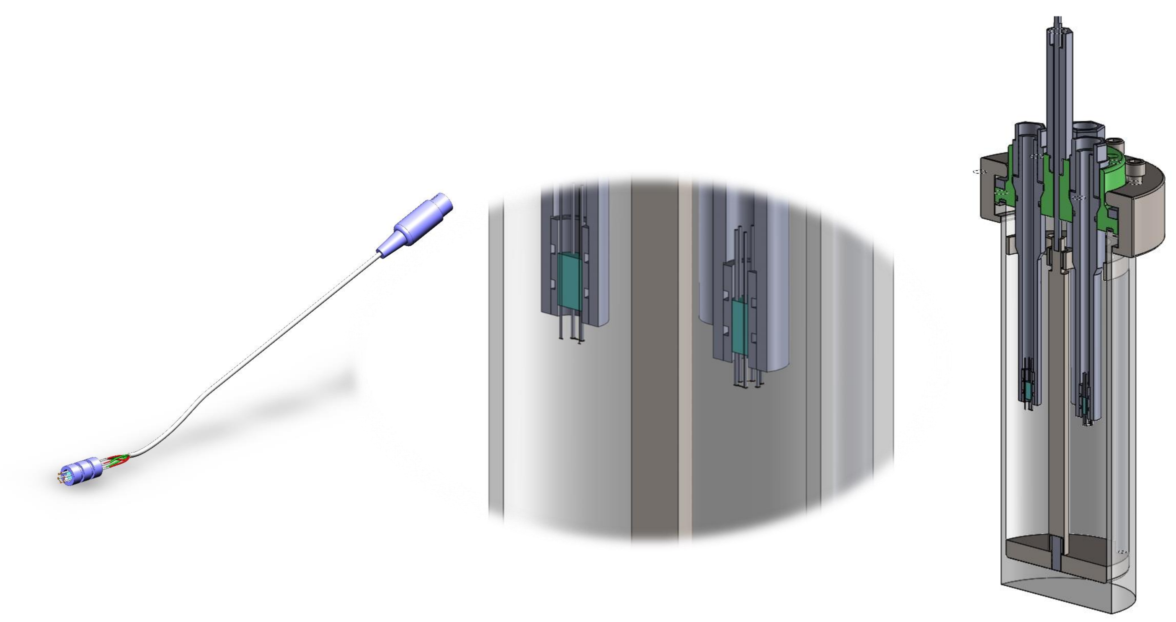
$1/U_f = (\underbrace{X_w/K_w + 1/h}_{1/Uc} + X_d/K_d)$

$FF = 1/U_f - 1/U_c$

By measuring the initial temperature of the wire, the initial heat flux from the wire and then monitoring the heatflux from the wire as the temperature of the wire is held constant the Fouling Factor of the deposited coke layer is measured.

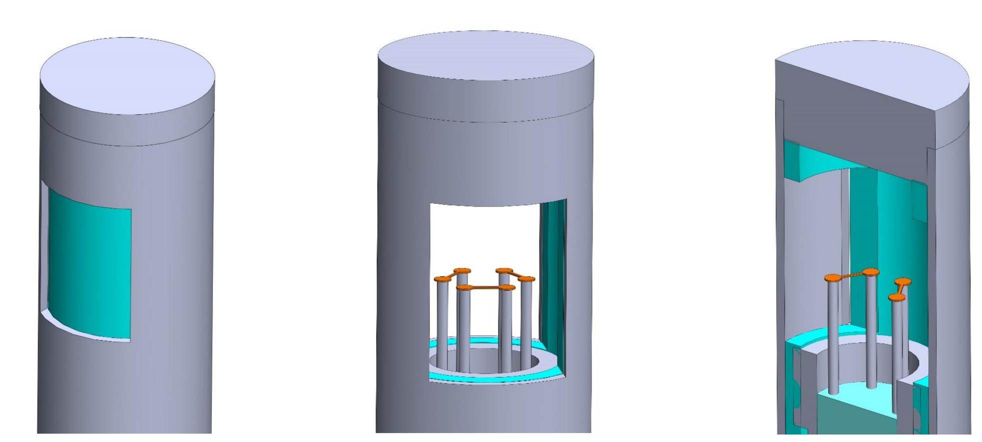
Microwire Incorporation into FTU

Incorporating four test cards into the existing Athlon Solutions FTU allows for 12 different fouling temperature/time combinations so be conducted in a single test setup. Installation of the test cards is done with a simple pressing tool and electrical contacts are made with a four wire electrical connector with four contacts per test wire in solution.



Microwire Incorporation in Field

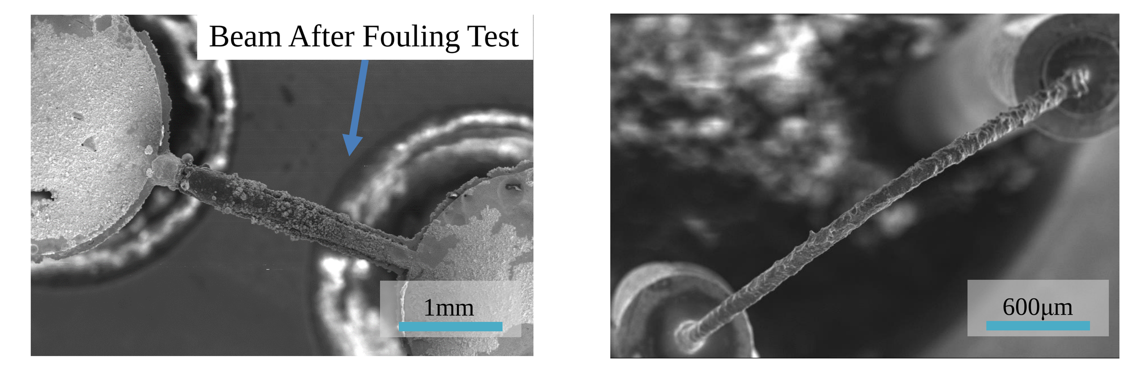
The Microwire test card can be incorporated into a retractable probe with a sliding window for implementation in the field. The window is opened to allow for test fluid to flow past the sensor. The window can then be closed to allow for a controlled environment fouling test to be conducted with known static fluid conditions. On the left is the probe with the sampling window closed. In the middle is the window open exposing the wires to the flow. On the right is a cross section showing the wires in a closed probe.



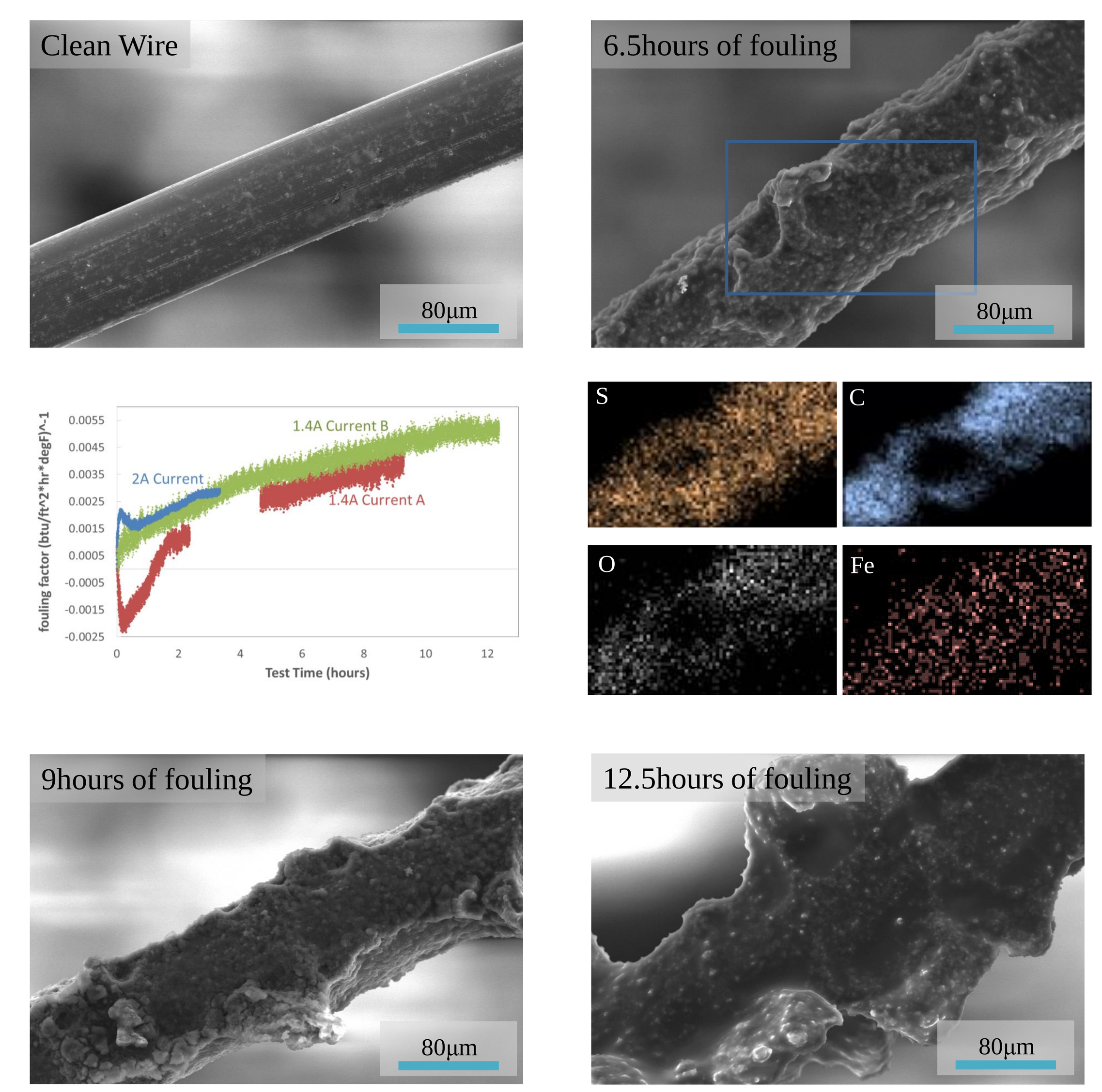
This retractable probe can be inserted into the fluid flow using an assembly similar to an ER corrosion probe where the probe can be removed from the flow using an isolation valve. After three long term fouling tests have been conducted the probe will be removed and a new Microwire test card will be installed allowing for an additional three fouling tests.

Fouled Microwires

Two styles of micro wires were tested in 500°F Atmospheric Bottoms. The wires were heated using a constant current (1.4A) to obtain a starting temperature of approximately 750°F. To the left is an image of a fouled 100µm wide x 20 µm thick nickel beam electroplated onto the pins of a feedthrough. To the right is an image of a fouled 86 µm diameter 316 stainless steel wire.



The fouling formed uniformly on the wires allowing for a good measurement of fouling with time not effected by varying thickness of the deposit. With longer fouling times tested the deposit was significantly thicker. EDX maps show the fouling to me mainly made of carbon with some content of sulfur and iron.



Conclusions

1. **Fouling rates can be characterized using the Athlon FTU**
2. **The Phase Sensors Microwire test card increases the density of test wires allowing for multiple tests to be done on a single high pressure feedthrough.**
3. **Electrical current required for fouling can be dramatically reduced by reducing the diameter of the test wire and reducing the flow rate experienced by the wire.**

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