Introduction to the DATS Fouling Monitor Technology

The **D**eposit **A**ccumulation **T**esting **S**ystem (**DATS™**) Fouling Monitor is a microprocessor based, data acquisition system designed to control, monitor and record all parameters necessary to perform heat transfer analysis. As deposits (scaling, microbial slime, sediments) accumulate, the tube surface becomes thermally insulated, and the change in Heat Transfer Resistance (HTR) is electronically recorded. Changes in HTR due to corrosion and corrosion products may also be detected.

The **DATS™** system is designed to simulate the geometry and heat flux of a shell and tube heat exchanger, where the cooling fluid circulates on the tube side. An electrical heating element is mechanically bonded to the exterior side of a customer specified tube, and simulates heat application by the shell side fluid or gas. Precise measurements of the thermal gradient across the fluid-tube-heater system establishes the heat transfer relationship. In this way, the **DATS™** Fouling Monitor is used to determine the effect(s) of fouling deposits on heat transfer (i.e. condenser efficiency).

Specific operating conditions such as surface temperature, heat load and flow rate are adjusted on the **DATS™** to match specific components of the cooling water system (main condenser). All collected data is stored in the **DATS™** microprocessor and may be periodically transferred to a personal computer for analysis.

The **DATS™** is also equipped with four auxiliary 4-20 mA transducer signal inputs. These may be used with any customer selected transducer, but are typically connected to water quality measurement instruments which are relevant to the phenomena under study (i.e. pH, conductivity, chemical residuals, differential pressure).

Using these principles, the **DATS™** allows the customer to analyze fouling for specific process conditions, and generates information necessary for efficient fouling management programs.

The **DATS™** has been used to:

1. Determine the rate and extent of fouling.

2. Evaluate physical and/or chemical treatments for fouling control.

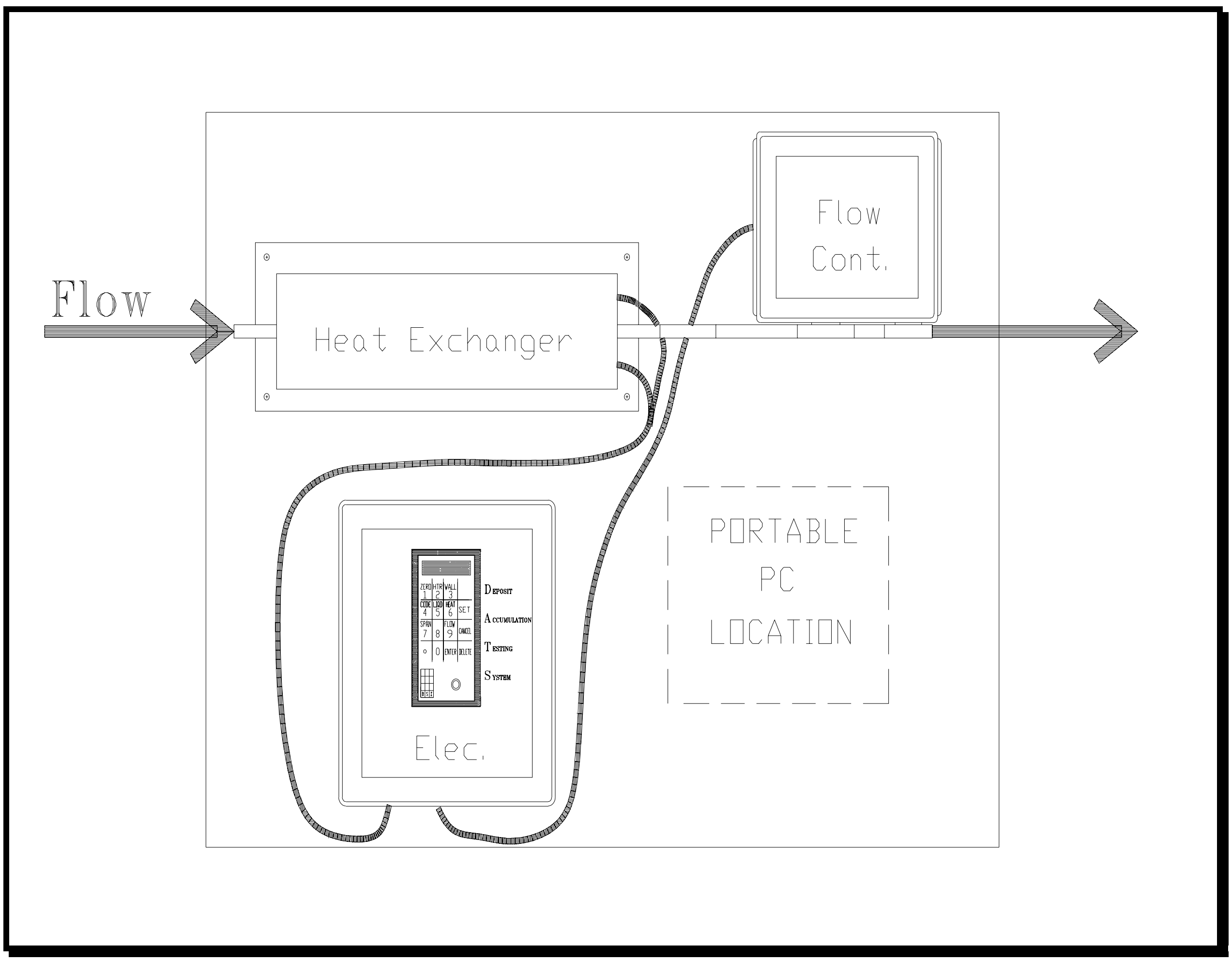
3. Optimize fouling control feed rates and cleaning schedules.

4. Continued monitoring of treatment effectiveness.

5. Monitor improvements in utility heat rates.

6. Evaluate condenser retube materials.

A typical **DATS™** component configuration is shown in Figure 1. The components of the **DATS™** may be placed on a table horizontally or mounted vertically.



The essential on-site requirements for installing the **DATS™** system, i.e. fluid connections, electrical connections, and equipment mounting are:

1) Nylon reinforced tubing, plastic pipe, or similar fluid line (sizes to fit standard tube OD's - e.g. 0.625", 0.875", 1.00")

2) Compression fittings for tube connections, if required

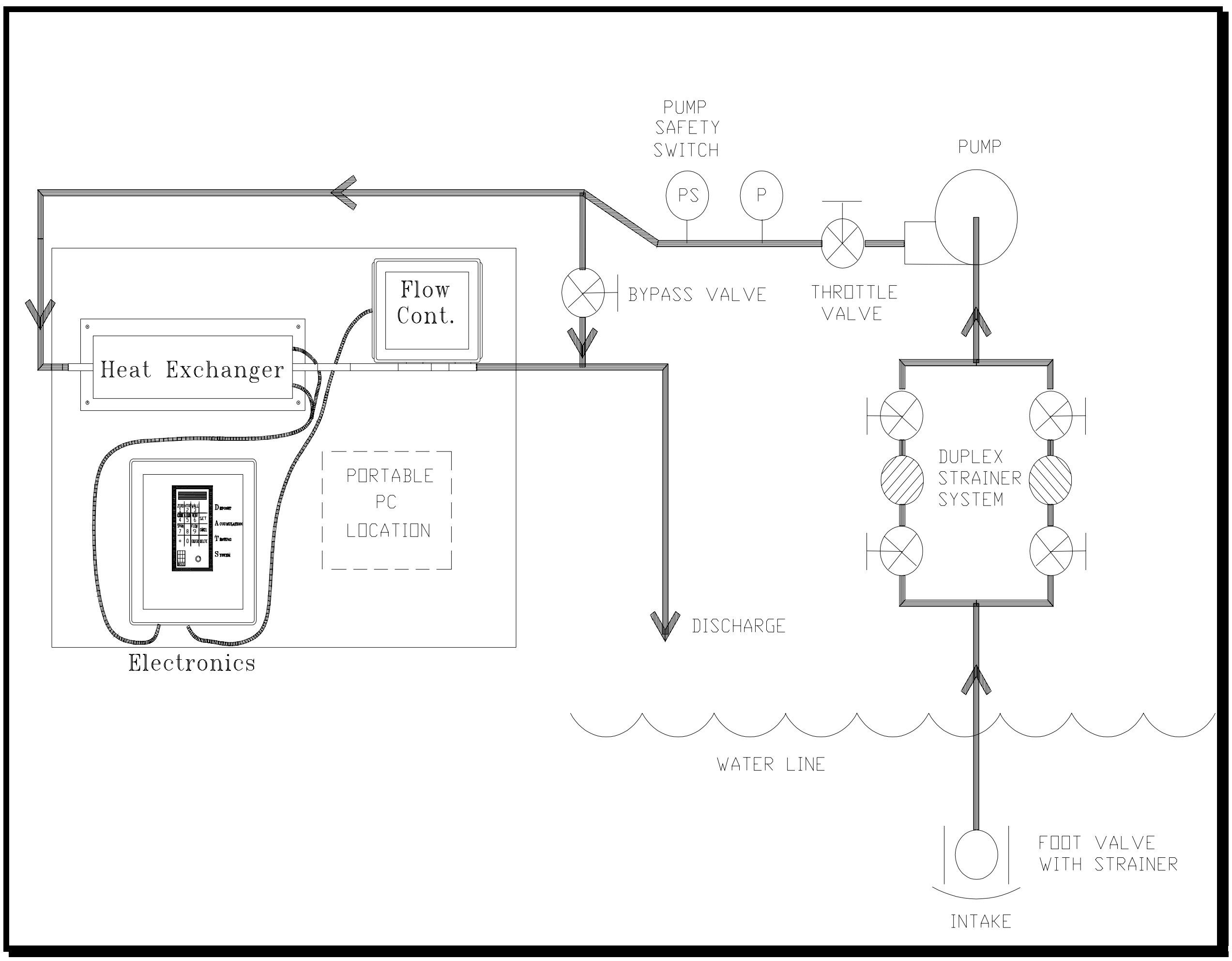
3) Gate-type isolation valve

4) Bypass valve

5) 115 VAC/15 amp (220 VAC/7.5 amp) dedicated service power supply

6) "Unistrut" (or similar mounting framework), or desk top for equipment support

7) An IBM PC/XT/AT or BIOS compatible computer(clone) for data retrieval and analysis, with a graphics card and serial port



Applied Heat Calculation

(Range: 250 - 4500 Btu/hr **[**75 - 1320 Watts**]**)

The **DATS™** Applied Heat is calculated from the desired or designed heat flux (condenser flux) and heat exchanger tube dimensions as follows;

DATS™ Applied Heat = Condenser Design Heat Flux x **DATS™** Heat Exchanger Surface Area

Heat flux = Btu/hr-ft^2 **[**Watts/m^2**]**

Surface Area = Heated Surface area of heat exchanger tube
= π x D x L

where:

π = 3.1415
D = O.D. of tube in ft **[**m**]**
L = heated length of tube in ft **[**m**]**

∴ **For English Units**

Surface Area (ft^2) = 3.1415 x (O.D. (inches) x 1/12) x 5/12

= 0.1091 x (O.D. (inches))

∴ **For Metric Units**

Surface Area **[**m^2**]** = 3.1415 x O.D.**[**m**]** x l **[**m**]**

= 3.1415 x (O.D.**[**cm**]** x 1/100) x 12.7/100

= 0.00399 x (O.D. **[**cm**]**

With the applied heat calculated, the set points for flow velocity and applied heat may then be set. Flow must be initiated prior to the setting of applied heat.

Data Interpretation and Calculations

General Principles

The following guide explains the general principles involved in calculation of **DATS™** parameters and in interpretation of data collected. The following assumptions have been made:

- Water, or fluid with similar characteristics is circulating in the system.
- Uniform radial steady state heat transfer.
- A fully developed thermal and hydrodynamic boundary layer exists in the tube.
- Fluid temperature range between 32 - 180 °F **[**0 - 82°C**]**.
- Reynolds numbers between 10,000 - 100,000 (e.g. fluid properties similar to water).

a. Heat Transfer Resistance:

The geometry and physical relationship of the elements within the Heat Exchanger are shown in Figure 8.

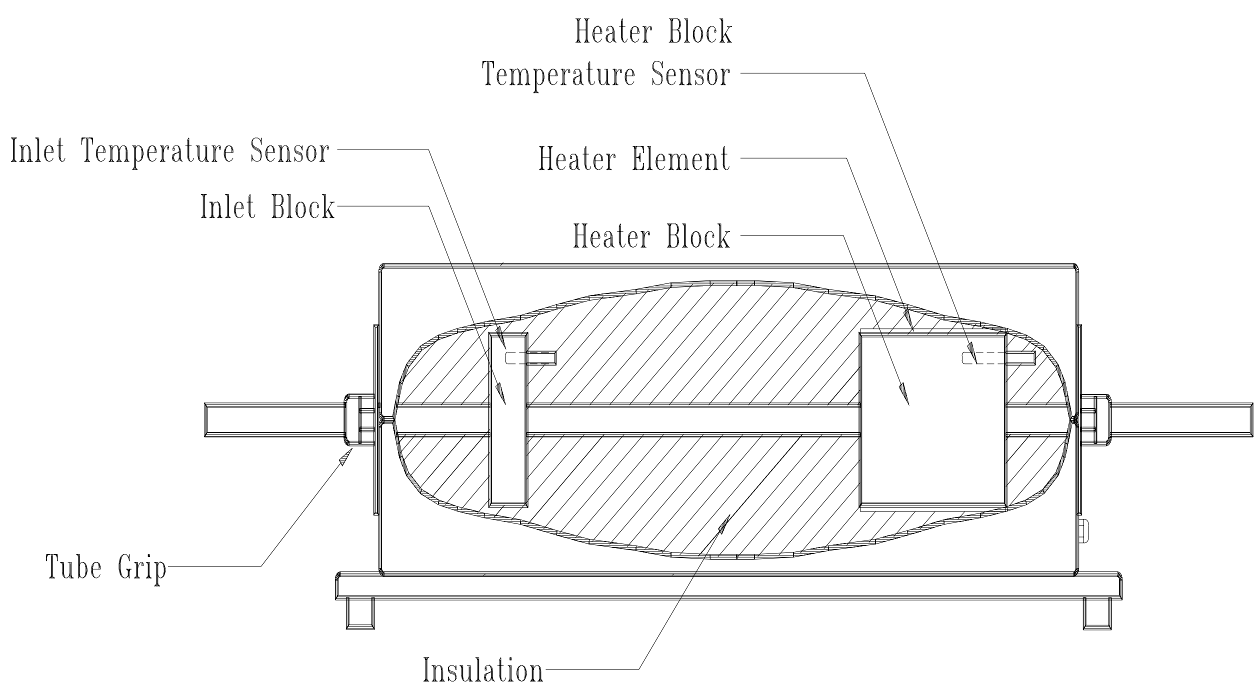


Figure 8. DATS™ Heat Exchanger

The **DATS™** calculates the Heat Transfer Resistance (HTR) from the following equation:

$$HTR_{total} = A \frac{(T_{block} - T_{water})}{Heat}$$

where:

HTR_{total} = Total Heat Transfer Resistance ($hr\text{-}ft^2\text{-}^oF/Btu$, **[**$m^2\text{-}^oC/Watt$**]**)
Area = Tube outside surface area (ft^2, **[**m^2**]**)
T_{block} = Heater block temperature (^oF, **[**^oC**]**)
T_{water} = Water temperature (^oF, **[**^oC**]**)
Heat = Applied heat (Btu/hr, **[**Watts**]**)

b) Wall Temperature:

Wall temperature is defined as the temperature of the tube inside wall (beneath any fouling layer which may develop), and is calculated by the relationship:

$$T_{wall} = T_{block} - (Heat * Constant)$$

where:

T_{block} = Temperature (^oF, **[**^oC**]**) of the heater block at a radius of 0.719 inches **[**1.826 cm**]**

The Constant is developed from an empirical relationship of the convective heat transfer coefficient, which is a derivation of the Colburn equation, and the measured total HTR.

$$HTR_{conv} = \frac{d}{0.023*Re^{0.25}*Pr^{1/3}*k} = \frac{A}{Constant}$$

where:

Re = Reynolds number
Pr = Prandtl number
k = Thermal conductivity of water ($Btu/hr\text{-}ft\text{-}^oF$, **[**$Watts/m\text{-}^oC$**]**)
d = Tube inside diameter (ft,**[**m**]**)

When the **DATS™** HTR is zeroed initially , the convective heat transfer coefficient is automatically calculated, the constant is calculated, and the wall temperature relationship is established.

c) Zero Heat Transfer Resistance:

Zero heat transfer resistance is a constant which is subtracted from the Total Heat Transfer Resistance:

$$HTR_0 = HTR_{ti} - HTR_c$$

where:

HTR_0 = Zero HTR value, calculated for a clean tube. This value is automatically subtracted from future HTR values

HTR_{ti} = Initial total HTR for a clean tube (includes the HTR for the heater block)

HTR_c = Convective heat transfer resistance

d) Water Temperature Compensation:

The convective heat transfer coefficient is also used to compensate for water temperature and flow velocity changes. Total HTR is the sum of the convective HTR and the conductive HTR. The convective heat transfer equation calculates the convective component. The conductive component of the heater block and tubing is assumed to remain constant. When the **DATS™** has been properly zeroed and is operational, the fixed heat transfer resistance measured at the start of the experiment is automatically subtracted from the total current heat transfer resistance.

Thus, the complete **DATS™** HTR equation becomes:

$$HTR = HTR_t - HTR_0 - HTR_c$$

where:

HTR = Differential HTR

HTR_t = Total current HTR

HTR_0 = Total conductive HTR with a clean tube

HTR_c = Total convective HTR with a clean tube.

The differential HTR is set to zero during the **DATS™** Zero/HTR operation. With time, the HTR increases due to the change in the conductive HTR which corresponds to the changes in fouling deposit HTR. Variation in HTR due to water temperature or flow velocity variations may cause some variation in heat transfer resistance's values. This may be due to transient (non steady-state) behavior, or to limitations of the convective heat transfer equation.

Data Interpretation

The data calculated by the **DATS™** may be used to evaluate the efficiency, reliability and economic feasibility of various fouling control techniques for the system under test. The deposit HTR determined by the **DATS™** may be used to estimate the percent cleanliness based on the design CLEAN heat transfer coefficient of the process equipment (condenser or heat exchanger). This is a simple method of estimating the performance degradation of a fouled heat exchanger.

For example;

assume the design heat transfer coefficient (U_{design})
(from HEI standards) =

650 Btu/hr-ft^2-^{o}F

The deposit HTR determined by the **DATS™** after six weeks =

0.0005 hr-ft^2-^{o}F/Btu

Fouled HTR (HTR_{fouled}) = ($1/U_{design}$) + **DATS™** HTR

= (1/650) + 0.0005 (hr-ft^2-^{o}F/Btu)

= 0.00154 + 0.0005

= 0.00204 hr-ft^2-^{o}F/Btu

Fouled heat transfer coefficient (U_{fouled}) = $1/HTR_{fouled}$

= 1/0.00204

= 490 Btu/hr-ft^2-^{o}F

Therefore:

% Cleanliness = (490/650) * 100

= 75.47%

This is a simple calculation which gives some indication of the reduced capacity or efficiency of the heat exchanger. More complex methods must be used to obtain a realistic understanding of the economic impact of fouling in a particular situation.

Please specify the tube metallugy and dimensions when ordering a new or replacement tube:

Replacement Tube, 3' Section, 1008 Carbon Steel	200-001
Replacement Tube, 3' Section, 1010 Carbon Steel	200-002
Replacement Tube, 3' Section, 1018 Carbon Steel	200-003
Replacement Tube, 3' Section, 1020 Carbon Steel	200-004
Replacement Tube, 3' Section, 304 Stainless Steel	200-005
Replacement Tube, 3' Section, 316 Stainless Steel	200-006
Replacement Tube, 3' Section, 316L Stainless Steel	200-007
Replacement Tube, 3' Section, 70/30 Cu-Ni	200-008
Replacement Tube, 3' Section, 90/10 Cu-Ni	200-009
Replacement Tube, 3' Section, Admiralty Brass	200-010
Replacement Tube, 3' Section, AL6X	200-011
Replacement Tube, 3' Section, Aluminum Brass	200-012
Replacement Tube, 3' Section, Copper	200-013
Replacement Tube, 3' Section, Titanium	200-014

Outside Diameter Sizes (standard):

1.0 inch	[2.54 cm]
7/8 inch	[2.2225 cm]
¾ inch	[1.905 cm]
5/8 inch	[1.5875cm]
.551 inch	[1.4 cm]

Wall Thickness Sizes (standard):

.028 inch	[.711 mm]
.035 inch	[.889 mm]
.049 inch	[1.2446 mm]
.065 inch	[1.651 mm]
.083 inch	[2.1082 mm]

Other sizes and materials may be available on special order.

The above information was excerpted from the DAT2 and 3 users manual for informational purposes. For specific information regarding either unit, please address questions directly to BSI.