Redesign of a Problematic 3-Fluid Plate and Frame Heat Exchanger.

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Abstract

A 3-Fluid plate and frame heat exchanger uses cooling water to reduce the exiting temperature of air and oil from a compressor. The cooling water causes fouling within the heat exchanger which reduces the heat transfer capability. When the heat transfer gets too low, the exchanger requires chemical cleaning. The cleaning process requires an outside company to clean due to the welded structure of the heat exchanger. Replacement of these exchangers is required when the cleaning is no longer effective. The purpose of this project is to replace the exchanger with a more cost-effective system.

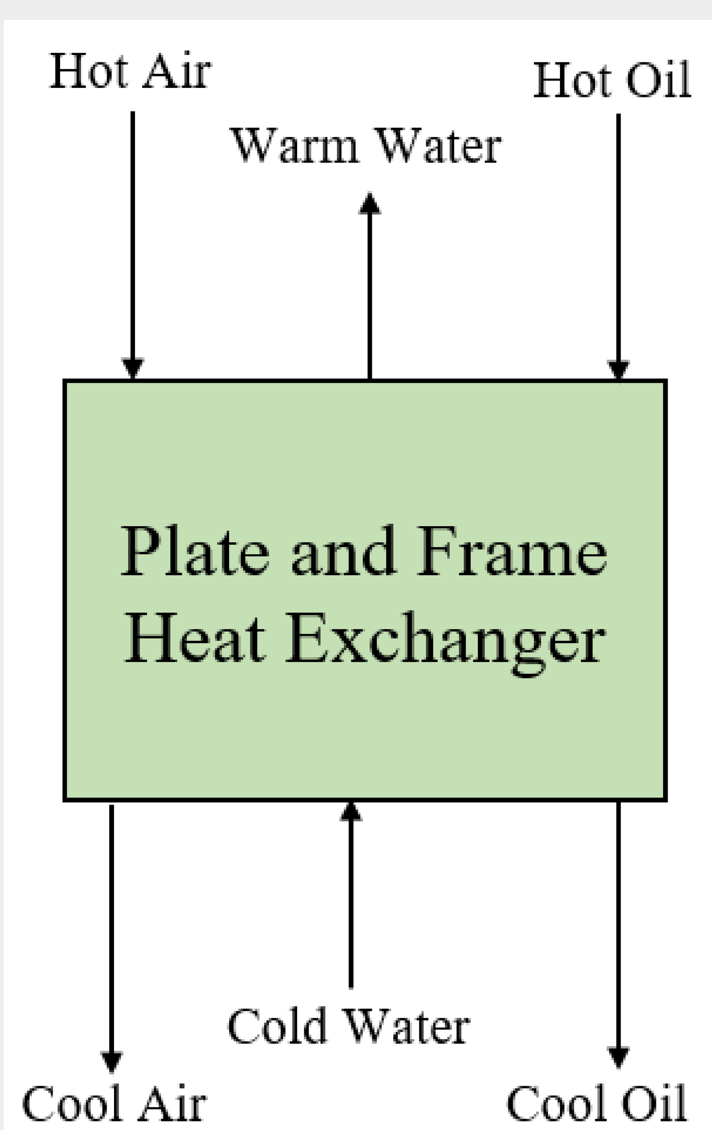

Figure 1: Simplified Block Flow Diagram of Current System.

Contents	Temperature In (˚F)	Temperature Out (˚F)
Water	72	109
Oil	117	107
Air	140	87

Table 1: Temperature Profile of the System.

Proposed Design

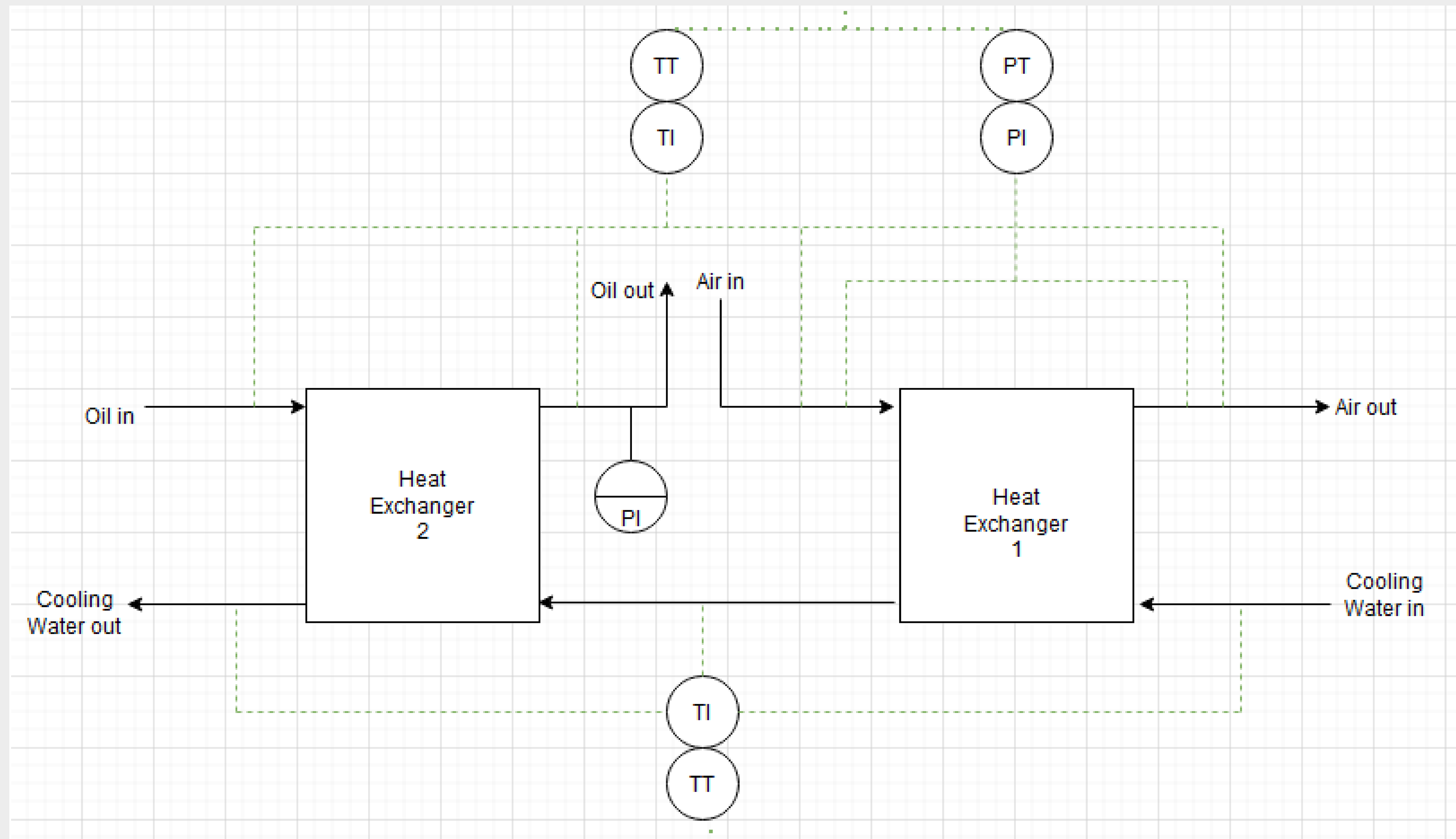

Figure 2: Process and Instrumentation of New Heat Exchanging System. **This diagram contains pressure gauges that may not currently exist on the system.** Finding the pressures could allow the system to be defined for a thermodynamic modeling approach.

The reason for switching to a two heat exchanger system is for ease of analyzing. The algorithm used to determine the design of the new heat exchangers is shown below.

Energy Balance

$$Q_{water} = Q_{oil} + Q_{air} \qquad Q = \dot{m} C_p \Delta T$$

Step 1: Find oil flow rate

Step 2: Guess Number of Plates (n) → $S = \frac{n}{2} * W * b$ → $v_{h,c} = \frac{\dot{m}_{h,c}}{\rho_{h,c} * S}$

Step 3: $h_c = 0.4 * \frac{k_c}{D_e} * Re^{0.64} * Pr^{0.4}$ & $h_h = 0.4 * \frac{k_h}{D_e} * Re^{0.64} * Pr^{0.4}$

Step 4: $U = \frac{1}{\frac{1}{h_c} + \frac{\Delta x_{plate}}{k_{plate}} + \frac{1}{h_h}}$ → $NTU = \frac{U * A}{C_{min}}$

Step 5: $NTU = \frac{T_{in} - T_{out}}{\Delta T_{LM}}$

Step 6: Iterate n until $NTU = NTU$

$W = Plate\ Width$ $\quad b = Plate\ Gap$ $\quad D_e = 2b$

$NTU = Number\ of\ Transfer\ Units$ Subscript h and c denote hot and cold streams.

Calculations

The final specifications for the heat exchangers are detailed in Table 2. **The surface area of the plates in the new design has not changed from the current system.** U values were found using an assumed ratio based on the fluid contents.

System	U $\frac{BTU}{ft^2 * hr * °F}$	# of Plates
Current Exchanger	705.7	70
New Air Exchanger	91.8	125
New Oil Exchanger	615.6	135

Table 2: Design Parameters for the New System.

The deliverables are the two spreadsheets with the design and economic calculations. An example economic analysis is shown below with assumptions of initial costs, cleaning rates, interest, and lifetime.

Buying Option	Net Present Value ($)
Replacing Current System	-86,000
Buying New System	-69,000
Money Saved	17,000

Table 3: Example Economic Analysis.

Conclusions

Ultimately, the best way to improve the heat exchanging process after the compressor is to further define the system and purchase heat exchangers with removable plates for pressure washing. Pressure washing should mitigate the cost of chemical cleaning. The economic analysis and design of the new exchangers includes the cheaper oil, which also reduces cost.