

## **Effects of Sleeving Closed Feedwater Heaters**

Stanley Yokell  
MGT Inc.  
Boulder, Colorado

And

Carl F. Andreone  
Reading, Massachusetts  
Member of the MGT Informal Consulting Network

### **Introduction**

The process of sleeving closed feedwater heaters is the insertion of thin tubes (sleeve material) into the existing inlet tubes of a feedwater heater then expanding the inserts into the tubes. The expanding process produces a residual interfacial fit pressure between the sleeve OD and tube ID. Typical sleeve thicknesses are in the range 0.01-inch to 0.03-inch thick, depending upon material of construction and thickness of the original tubes.

Sleeving has long been used in power generation heat tubular heat transfer equipment to reduce the prospect of inlet-end erosion. Because of the need to keep existing equipment operating as long as possible, sleeving the inlets of closed feedwater heaters and steam surface condensers is increasingly widespread in the power generation industry. More recent developments have been restoring tubes to service that have been plugged because of perforations in discreet, identifiable locations and restoring tubes to service that have been plugged because their walls have become so thin that continued operation presents a hazard of failure.

Sleeves may also be used to bridge failures in discreet location of tubes that are otherwise intact. An example of such bridging is when a tube endures a circular crack just beyond the inner face of the tubesheet either in the transition from expanded to

unexpanded length. Sleeving is also used to repair nuclear steam generators. Although the principals that apply are the same, this paper does not discuss sleeving steam surface condensers or nuclear steam generators.

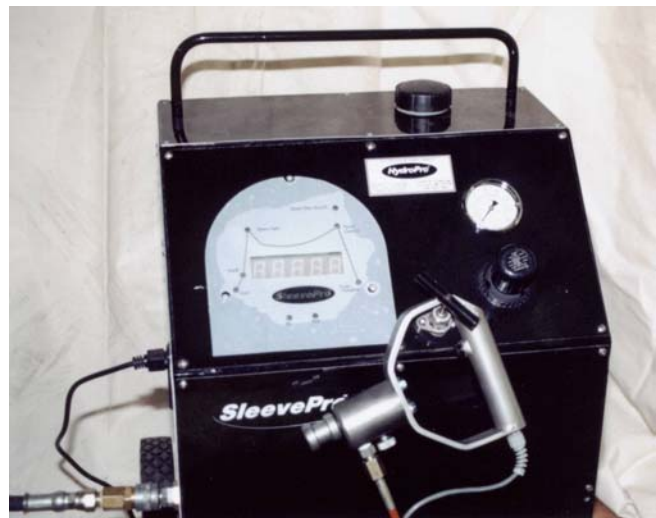
### **Objectives of this Paper**

The objectives of this paper are as follows:

1. To describe the methods and equipment used to sleeve feedwater heater tubes.
2. To describe the effects of inserting sleeves on the performance of the feedwater heater.

**Forcing a ball through the sleeve.** The earliest method for bridge sleeving steam surface condensers was to force a ball through the sleeve. There were two disadvantages: (1) tight contact between the outside of the sleeve and inside of the tube was seldom uniform, and (2) lack of control of the sleeving process could bulge the tube between baffles and supports, which made retubing difficult.

**Roller expanding.** For many years, the principal method of fastening sleeves into tubes has been roller expanding. Some sleeves were also welded to the tubes at their sleeve outlet ends. It is necessary to establish the adequacy of rolling the sleeves into the tubes by experimentally correlating rolling torque with sleeve-to-tube



**Figure 1 The ®SleevePro expanding system**  
(HydroPro, Inc., San Jose, Calif. and Bourbon

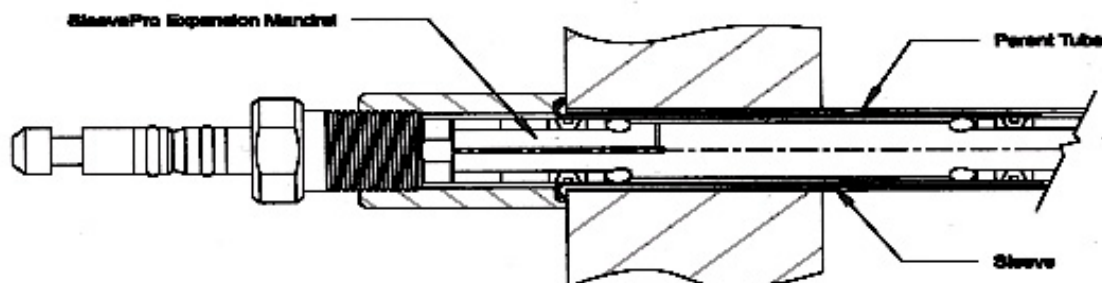
tightness. This is because since typical sleeves are only about 0.010 to 0.030-inch thick, deducing percent wall reduction of sleeves is impractical. Torque controls on rolling equipment produce less precise information than do controls on hydraulic sleeving equipment and hydraulic methods have been developed to surmount this problem.

**Hydraulic expanding.** Control of hydraulic expanding pressure is far more precise than control of rolling torque. Consequently there is less risk of overexpanding and causing the tube to bulge between supports and baffles. Hydraulic sleeve expanding pressure is best determined experimentally using mock-ups. Unlike rolling equipment, in which torque may drift from the original setting, hydraulic expanding equipment maintains the set expanding pressure within tolerances of  $\pm 1.25$  to  $\pm 2.5\%$  depending upon the yield strength of the sleeve.

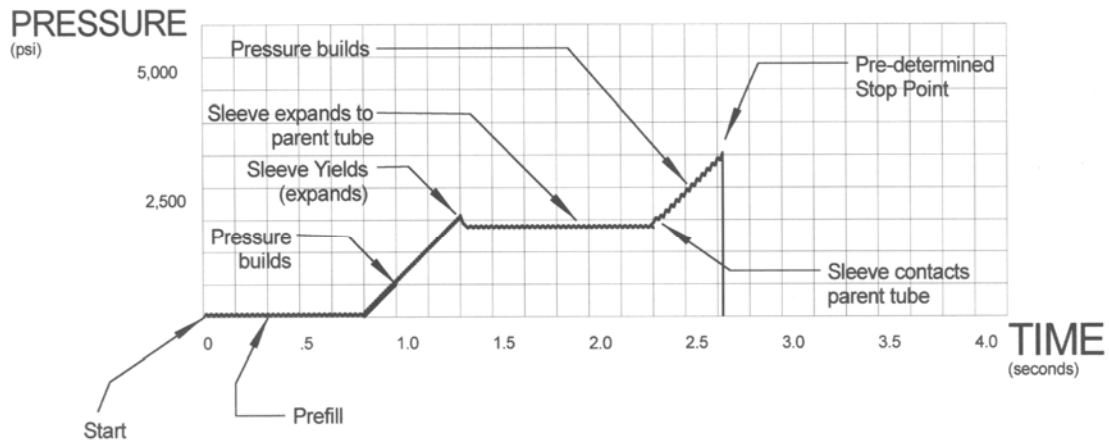
### Hydraulic Sleeving Equipment

Figure 1 show the very advanced HydroPro ®SleevePro strain control system. The system tracks the stress/strain curve of the sleeve allowing electronically sensing the points at which the sleeving material yields and makes contact with the parent tube. After the sleeve contacts the parent tube, the system controls additional water volume to limit the radial expansion of the sleeve and parent tube, thus creating a tight interfacial fit by utilizing the elastic capacity of the parent tube. (See Figure 2.)

Figure 3 shows the pressure path during sleeving with the SleevePro system.



**Figure 2** @SleevePro mandrel inserted in sleeve before expanding (HydroPro, Inc., San Jose, Calif. and Bourbon, Missouri)



**Figure 3, Pressure path during sleeving with the @SleevePro system (HydroPro, Inc., San Jose, Calif. and Bourbon, Missouri)**

1. Calculate the pressure drop and heat transfer for normal (new) conditions.
2. Calculate the pressure drop and heat transfer for the number of tubes to be sleeved.
3. Calculate the pressure drop and heat transfer after the proposed number of tubes is sleeved.

The following gives the details of these calculations.

### Estimating Pressure Drop for Sleeving

Pressure drop in a tube is the sum of entry and exit losses of feedwater into and out of the tube end and friction losses in the straight lengths and U-bend turns. Usually, when the purpose of sleeving is to prevent tube end erosion, the sleeves are short and there is sufficient pressure drop available so that any increase resulting from sleeving does not materially affect the operation. When plugs are removed and tubes restored to service by full length sleeving, the pressure drop is substantially reduced from that of the plugged condition.

In the wide world of shell-and-tube heat transfer, pressure loss calculations typically consider the entrance and exit losses to be one velocity head. The HEI Closed

Feedwater Heater Standards use this concept to give the equation for Tube Entrance and Exit Losses used in this paper<sup>1</sup>. The following is based on the HEI method. It has been modified for the single pass flow that applies to sleeving in either single pass or two-pass U-tube designs. For multipass designs except two-pass U-tube designs, multiply equation (1) by the number of passes  $N_p$ .

$$\Delta P_E = \frac{1.448 \times 10^{-9}}{C} K_t \left( \frac{W}{A_t} \right)^2 \quad (1)$$

Where

$\Delta P_E$  = Pressure Drop resulting from tube entrance and exit losses, psi

$A_t$  = Flow area inside tubes, in<sup>2</sup>

$C$  = Density correction factor based on average water operating temperature.

Figure 3a of the HEI Closed Feedwater Heater Standards has a curve of density correction factor versus temperature<sup>1</sup>. For inlet water temperatures below 100 °F, use a correction factor of 0.99. For higher temperatures refer to Fig. 3a of HEI CFH Standards. For sleeves in the inlet pass that extend a short distance behind the tubesheet very little error is introduced by using the inlet temperature. For full length sleeves in the inlet pass, assume that the temperature at the turnaround will be the inlet temperature plus half the temperature rise in the heater. Then set the average as the average between the inlet and turnaround temperature.

$K_t$  = Loss correction factor for tube configuration = 1.6 for tubes welded or expanded into tubesheet with approximately 1/8-inch protrusion and 1.3

---

<sup>1</sup> Equations for the variation of water density  $\rho$  with temperature are not provided in this paper in the interest of following the methods of the HEI Standards with which power plant engineers are familiar.

for tubes flush with the tubesheet with slightly rounded entrance. (See Fig. 3b of HEI CFH Standards.) The purpose of the HEI loss correction factor  $K_t$  is to account for tube ends that protrude from or lie below the surface of the tubesheet face. If the tubes are not welded into the tubesheets but are expanded only and trimmed flush, use a value of 1 for  $K_t$ .

$N_p$  = Number of passes except for two-pass U-tube designs.

$W$  = Cooling water flow, lbs/hr.

To calculate the pressure drop resulting from sleeving, first calculate the exit/entrance losses in the tubes before sleeving based on the tube flow area. Then calculate it based on the sleeve flow area. Subtract the pressure drop before sleeving from the pressure drop after sleeving to get the increase resulting from sleeving. If you define  $A_s$  as the flow area inside the sleeve and  $\Delta P_s$ , as the pressure drop due to sleeving you can modify equation (1) to give the calculation directly from equation (1a) as follows.

$$\Delta P_s = \frac{1.448 \times 10^{-9}}{C} K_t W^2 \left[ \left( \frac{1}{A_t} \right)^2 - \left( \frac{1}{A_s} \right)^2 \right] \quad (1a)$$

Where

$A_s$  = Flow area in sleeves, in<sup>2</sup>

For multipass designs except U-tube two-pass designs, multiply equation (1a) by the number of passes  $N_p$ .

(Classical theory would suggest using 1.7 velocity heads for entrance and exit losses. It would produce the following equation.

$$\Delta P = 1.7 \frac{V^2 \rho}{2g \cdot 144} \quad (2)$$

Where

$\Delta P$  = Pressure Drop, psi

$V$  = Flow velocity in sleeves, ft/sec

$\rho$  = Density, lb/ft<sup>3</sup>

$G$  = Gravitational Constant = 32.2 ft/sec<sup>2</sup>)

To the entrance/exit losses add the effect of the length of the smaller diameter sleeve length on the pressure drop. Estimate this by multiplying the specification sheet pressure drop by the length of sleeve divided by the total straight length of tube times (tube ID/Sleeve ID)<sup>1.8</sup>.

This is shown in equation 3

$$\Delta P_{SL} = \Delta P_{Spec} \frac{L_S}{L_t} \left( \frac{A_t}{A_s} \right)^{1.8} \quad (3)$$

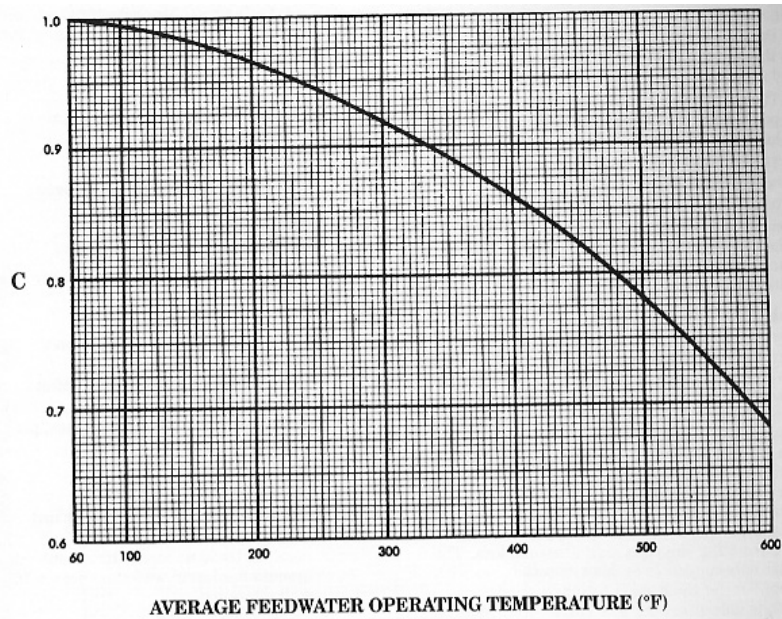
Where

$\Delta P_{SL}$  = Pressure drop in straight length of sleeve, psi

$\Delta P_{Spec}$  = Pressure drop shown on specification sheet, psi

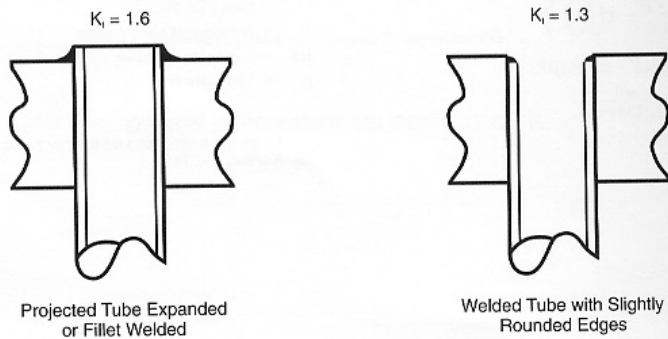
$L_S$  = Straight length of sleeve, in.

$L_t$  = Total straight length of tube legs, in. (For U-tube construction includes straight lengths in the inlet pass and neglects turnarounds.)



DENSITY CORRECTION FACTOR

Fig. No. 3a



LOSS CORRECTION FACTOR FOR TUBE CONFIGURATION

Fig. No. 3b

F

ull

These figures are copied from the HEI Closed Feedwater Heater Standards, 6<sup>th</sup> Ed., March 1998 by Permission of the Heat Exchange Institute, Cleveland, Ohio.

length sleeves are often installed in only some of the tubes to restore previously plugged tubes to service. Since returning the tubes to service reduces the pressure drop much more than the increase in pressure drop from sleeving, estimating the pressure drop due to sleeving is not unwarranted.

### **Heat Transfer Improvement with Full Length Sleeving**

Oxide films on the sleeve exteriors and tube interiors and areas of possibly incomplete contact between sleeves and tubes increases the overall resistance to heat transfer. The resistance of the barrier between tube and sleeve is called *contact resistance*. Reduction in the amount of recovered duty is the result of additional resistance to heat transfer of the sleeve metal wall and the contact resistance. Based on the authors' examination of unpublished data provided in confidence, contact resistances appear to be about as follows: 0.011 hr-sq ft deg F/Btu for Stainless Steel type 304 tubes sleeved with SS 304 sleeves, 0.0013 hr-sq ft deg F/Btu for Admiralty Brass tubes sleeved with 90-10 Copper-Nickel, 0.0046 hr-sq ft deg F/Btu for Admiralty Brass Tubes sleeved with SS 304 sleeves, and 0.0026 hr-sq ft deg F/Btu for <sup>TM</sup>Monel tubes sleeved with Monel sleeves. Readers should be aware that the listed contact resistances have not been established by extensive testing. These estimated resistances indicate that for austenitic stainless steel tubes sleeved with stainless sleeves and for admiralty brass tubes sleeved with 90-10 copper nickel sleeves, recovery of surface is about 89% effective; for Monel tubes sleeved with Monel sleeves, recovery is about 80% effective; and for admiralty brass tubes sleeved with austenitic stainless sleeves, recovery is about 70% effective.

To estimate the heat transferred by tubes recovered by sleeving, add the resistance of the sleeve metal and the contact resistance to the sum of the resistances (reciprocal of

the overall coefficient) and invert to estimate the overall film coefficient of the zones in which the sleeves are installed. The additional heat transferred is then the product of the outside surface of the recovered tubes times the LMTD in the zones times the estimated overall coefficient.

If the sleeve metal is the same material as the tube, estimate the sleeve metal resistance by multiplying the tube metal resistance by the ratio of sleeve metal thickness to tube wall thickness. For sleeves of a material that are not the same as that of the tubes multiply the proportioned result by the ratio of the tube thermal conductivity to that of the sleeve.

### Example Calculations<sup>2</sup>

The data used in the following examples (Tables 1, 2 and 3) have been obtained or derived from a Manufacturer's data sheet, drawings and ASME Code Section II Part D, Properties.

<b>Table 1 Specimen Calculation of Thermal Effects of Sleeving Feedwater Heaters</b>		
Client		
Date		
Job No. & Equipment No.		
<b>*Data to Change from Example for Other Heaters</b>		
<b>Information Obtained or Derived from Data Sheet, Drawings and ASME Sec. II Part D</b>		
*Tube Material	SA688TP304N	From Manufacturer's Data Sheet
*Total No. U-tubes	1941	From Manufacturer's Data Sheet
*OD, in.	0.625	From Manufacturer's Data Sheet
*Thickness, in.	0.057	From Manufacturer's Data Sheet
*Straight length, in.	391	From Manufacturer's Data Sheet
*Thermal conductivity, Btu/hr ft °F	10.40	From ASME Code Sec. II Part D
Tube Unit surface, sq ft/ft	0.1636	From HEI Closed FWH Standards P62
Surface/straight leg sq. ft	5.331	(Straight length/12)(tube unit surface)
*Steam inlet saturation temp., °F	411.30	From Manufacturer's Data Sheet
*Drains outlet temp., °F	377.30	From Manufacturer's Data Sheet
*Inlet feedwater temp., °F	367.30	From Manufacturer's Data Sheet
*Outlet feedwater temp., °F	413.30	From Manufacturer's Data Sheet

<sup>2</sup> Spreadsheets for use in these calculations may be downloaded from [http://www.mgt-inc.com/tips/Technical\\_Tips\\_Vol\\_1\\_4.html](http://www.mgt-inc.com/tips/Technical_Tips_Vol_1_4.html)

<b>Table 1 Specimen Calculation of Thermal Effects of Sleeving Feedwater Heaters</b>				
Temperature rise, °F	46.00	<b>Outlet - inlet temperature</b>		
Terminal Temp Diff, °F	-2.00	<b>From Manufacturer's Data Sheet</b>		
Drains Cooling Approach	10.0	<b>Drains outlet - FW inlet temp</b>		
*Feedwater flow, lb/hr	4939829	<b>From Manufacturer's Data Sheet</b>		
<b>Zone (All Data Taken from Manufacturer's Documents)</b>		<b>Desuperheat</b>	<b>Condense</b>	<b>Subcool</b>
*Total Effective Surface, sq. ft./ From Manufacturer's Data Sheet	21018			
*Surface in zone, sq. ft. <b>From Data Sheet</b>		1979	16576	2463
No. Tubes in Zone <b>From Data Sheet</b>		1941	1941	1941
Zone Length, ft <b>From Manufacturers Drawings</b>		6.25	52.2	7.75
*LMTD, Deg F <b>From Data Sheet</b>		213.9	16.3	21.4
Resistances, hr-sq ft °F /Btu		<b>From Manufacturer's Data Sheet</b>		
*Tube side fouling <b>From Data Sheet</b>		0.00025000	0.00025000	0.00025000
*Tube side film <b>From Data Sheet</b>		0.00030600	0.00031000	0.00031800
*Tube wall <b>From Data Sheet</b>		0.00055500	0.00055500	0.00055500
*Shell side film <b>From Data Sheet.</b>		0.00977900	0.00040000	0.00093700
*Shell side fouling <b>From Sheet</b>		0.00030000	0.00000000	0.00030000
Sums of resistances		0.01119000	0.00151500	0.00236000
Overall HT Coefficient, U, Btu/hr-sq ft °F <b>1/sum of resistance</b>		89.4	660.1	423.7
Duty=UA(LMTD), total/zonal	238290000	37835000	178155000	22300000
*FW Av Sp. Ht, Btu/lb, <b>Calc. From Data Sheet</b>	1.049	<b>Total duty/(FW flow x FW temperature rise)</b>		
<b>Note: FW Av Sp. Ht. May be Different from Steam Table Value</b>				
<b>Sleeve information</b>				
Material <b>From Data Sheet</b>	SA688TP304			
Sleeve Thickness, in.,	0.028	<b>As Decided with Sleeving Contractor</b>		
*Thermal conductivity, Btu/hr ft °F	10.40	<b>From ASME Code Sec. II Part D</b>		
<b>Effect of plugging</b>				
No. of Plugged tubes in DSH and DC	100	<b>From Plug Map</b>		
No. of full lengths to be sleeved	100	<b>Decided By Utility</b>		
Plugged Surf, sq. ft. tube unit surf. X zone length x No. plugged		102.3	854.0	126.8
Duty decrease, Btu/hr <b>U x plugged surf. x LMTD</b>		1954537.5	9188164.8	1149705.9
Total duty reduction, Btu/hr	12292408.2	<b>Sum of plugged zonal surfaces</b>		
FW out temp decrease, °F	2.37	<b>Total duty reduction/FW flow</b>		
FW out temp with 100 plugged tubes, °F,	410.93	<b>Original out temp. - FW out temperature decrease</b>		
TTD with 100 plugged tubes, °F	0.37	<b>Steam inlet temp. - plugged tube out temperature</b>		
DCA with 100 plugged tubes, °F	10.5	<b>DCA + (FW temperature rise x duty decrease/duty)</b>		
<b>Effect of sleeving recovery of plugged tubes</b>				
Additional resistances in sleeved tubes, hr-sq ft °F /Btu				
*Sleeve metal	0.0.0002726			
*Contact resistance, hr-sq ft-°F	0.0011000			
Sum zone sleeve metal and contact resistance		0.0013726		0
Sum zone resistances, hr-sq ft deg F/Btu**		0.0125626		0.0023600
Zone Us, Btu/hr-sq ft deg F <b>1/ sum zone resistance</b>		79.6		423.7
Restored duty, Btu/hr <b>zone Us x zone surface X LMTD</b>		1740979	9188164.8	1149705.9
Total restored duty increase, Btu/hr	120788497	<b>Sum of restored zone duties</b>		

<b>Table 1 Specimen Calculation of Thermal Effects of Sleeving Feedwater Heaters</b>			
Total duty decrement w sleeved tubes, Btu/hr	-2135591	Restored duty - no plug duty	
Total duty with sleeves, Btu/hr	238076441	Sum no plug duty + decrement	
Calc. FW out temp, deg. F (Sp. Ht. calc. basis)	413.26	Sleeved duty/(FW flow x Sp. Ht.)+Inlet FW temp.	
TTD with 100 full sleeved tubes, °F	-1.96	Steam. Inlet sat. temp - sleeved FW out temp.	
DCA w 100 sleeved tubes, °F	10.5	DCA +(drains out - FW in)/(rest./original duties)	
<b>**Note: Usually only the DSH is sleeved. If the DC tubes are sleeved insert the same number of sleeved tubes for the DC as for the DSH.</b>			

<b>Table 2 Specimen Pressure Drop Calculation, 100 Tubes Sleeved with Full Length Sleeves</b>			
Company		Date	
Job No.			
#No. of Passes to be Sleeved	1		
<b>Fill in *Data from Mfr's. Data Sheet to Change from Example</b>			
*Number of U tubes	1941	From Mfr's. data sheet	
*Estimated Average U-bend Length, In.	13.6	From U-tube schedule	
*Total Estimated Straight Length, in.	774	Include length in tubesheet	
*Estimated Average Total Tube Length, In.	787.6	U-bend + straight lengths	
*Data Sheet Tube Side Pressure Drop, Psi	16.30	From Mfr's. data sheet	
*OD of Tubes	0.625	From Mfr's. data sheet	
*Wall thickness, in.	0.057	From Mfr's. data sheet	
ID of Tubes, in.	0.511	Tube OD - 2 x tube wall	
Flow Area/Tube, sq. in.	0.205	$(\pi/4)$ x square of tube ID	
Total Tube Flow Area, A <sub>t</sub> , sq. in.	398.1	Inside flow area x No. of tubes	
No. of Tubes to be Sleeved in One Pass	100	Sleeving plugged tubes	
*Sleeve Length, in.	774	Length of sleeve	
*Sleeve Thickness, in.	0.010	Thickness of sleeve	
Sleeve ID, in.	0.491	Sleeve OD - 2 x sleeve wall	
Flow Area/Sleeve, sq. in.	0.189	$(\pi/4)$ x square of Sleeve ID	
Total Sleeve Flow Area, A <sub>s</sub> , sq. in.	18.9	Inside flow area x No. of sleeves	
Flow Area Reduction Due to Sleeving, sq. in.	1.6	No. to be sleeved x area diff.	
*Flow Quantity, lb/h, W	4939829	From Mfr's. data sheet	
Feedwater Inlet Temperature, °F	367.3	From Mfr's. data sheet	
Feedwater Outlet Temperature, °F	413.3	From Mfr's. data sheet	

<b>Table 2 Specimen Pressure Drop Calculation, 100 Tubes Sleeved with Full Length Sleeves</b>		
Average FW Temperature in Sleeved leg, °F	401.8	<b>0.75 x outlet + 0.25 x inlet temps</b>
**Density Correction Factor, C, Fig. 3a, HEI CFS	0.86	<b>From HEI chart</b>
K <sub>t</sub> , Fig. 3b HEI CFS	1.6	<b>From drawing and HEI figure</b>
Exit/Entrance ΔP After Sleeving	0.41	<b>HEI calculation</b>
Exit/Entrance ΔP Before Sleeving	0.40	<b>HEI calculation</b>
Increase Due to Entrance/Exit, Psi	0.003	<b>Before - after ΔP</b>
ΔP in Straight Lengths, Before Sleeving, Psi	15.90	<b>Total ΔP - entrance and exit ΔP</b>
ΔP in Straight Lengths, After Sleeving, Psi	16.814	
Total ΔP After Sleeving, Psi	16.817	<b>Sum sleeved + entrance and exit ΔP</b>
Increase in ΔP Due to Sleeving, Psi	0.932	<b>Sum straight + entrance and exit ΔP</b>
<b>#For full length sleeving only 1 if inlet pass only, 2 if inlet and outlet pass are sleeved</b>		
<b>*Values to change for new calculation.</b>		
<b>**Use inlet temperature for short sleeves, average outlet leg temperature for full length sleeves.</b>		

<b>Table 3 Specimen Pressure Drop Calculation, All Inlet Tubes Sleeved with Short Sleeves</b>		
Company		Date
Job No.		
#No. of Passes to be Sleeved		1
<b>Fill in *Data from Mfr's. Data Sheet to Change from Example</b>		
*Number of U tubes	1941	From Mfr's. data sheet
*Estimated Average U-bend Length, In.	13.6	From U-tube schedule
*Total Estimated Straight Length, in.	774	Include length in tubesheet
*Estimated Average Total Tube Length, In.	787.6	U-bend + straight lengths
*Data Sheet Tube Side Pressure Drop, Psi	16.30	From Mfr's. data sheet
*OD of Tubes	0.625	From Mfr's. data sheet
*Wall thickness, in.	0.057	From Mfr's. data sheet
ID of Tubes, in.	0.511	Tube OD - 2 x tube wall
Flow Area/Tube, sq. in.	0.205	( $\pi/4$ ) x square of tube ID
Total Tube Flow Area, A <sub>t</sub> , sq. in.	398.1	Inside flow area x No. of tubes
No. of Tubes to be Sleeved in One Pass	1941	Sleeving inlet tubes
*Sleeve Length, in.	18	Length of sleeve
*Sleeve Thickness, in.	0.010	Thickness of sleeve
Sleeve ID, in.	0.491	Sleeve OD - 2 x sleeve wall
Flow Area/Sleeve, sq. in.	0.189	( $\pi/4$ ) x square of Sleeve ID
Total Sleeve Flow Area, A <sub>s</sub> sq. in.	367.5	Inside flow area x No. of sleeves
Flow Area Reduction Due to Sleeving, sq. in.	30.6	No. to be sleeved x area diff.
*Flow Quantity, lb/h, W	4939829	From Mfr's. data sheet
Feedwater Inlet Temperature, °F	367.3	From Mfr's. data sheet
Feedwater Outlet Temperature, °F	413.3	From Mfr's. data sheet
Average FW Temperature in Sleeved leg, °F	401.8	0.75 x outlet + 0.25 x inlet temps
**Density Correction Factor, C, Fig. 3a, HEI CFS	0.885	From HEI chart
K <sub>t</sub> , Fig. 3b HEI CFS	1.6	From drawing and HEI figure
Exit/Entrance $\Delta P$ After Sleeving	0.47	HEI calculation
Exit/Entrance $\Delta P$ Before Sleeving	0.40	HEI calculation
Increase Due to Entrance/Exit, Psi	0.070	Before - after $\Delta P$
$\Delta P$ in Straight Lengths, Before Sleeving, Psi	15.90	Total $\Delta P$ - entrance and exit $\Delta P$
$\Delta P$ in Straight Lengths, After Sleeving, Psi	16.366	
Total $\Delta P$ After Sleeving, Psi	16.014	Sum sleeved + entrance and exit $\Delta P$
Increase in $\Delta P$ Due to Sleeving, Psi	0.489	Sum straight + entrance and exit $\Delta P$
<b>#For full length sleeving only 1 if inlet pass only, 2 if inlet and outlet pass are sleeved</b>		
<b>*Values to change for new calculation.</b>		
<b>**Use inlet temperature for short sleeves, average outlet leg temperature for full length sleeves.</b>		

## **Acknowledgements**

The authors wish to thank the Heat Exchange Institute for permission to copy figures from the HEI Closed Feedwater Heater Standards. The authors also acknowledges the thoughtful review conducted by Bruce Schafer of Framatome ANC of Lynchburg, Virginia.

## Reference

---

<sup>i</sup> Standards for Closed Feedwater Heaters, 6<sup>th</sup> Ed., March 1998, the Heat Exchange Institute, Cleveland, Ohio.