

STEAM AIR COILS DESIGN AND DRAINAGE

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The physical and performance demands of dry kiln operation place severe requirements on steam-air coils and drainage systems

Although HEAT TRANSFER efficiency is a primary concern, the equally important service factors of LONG MAINTENANCE-FREE LIFE, REPAIRABILITY, CLEANABILITY, and DRAINAGE can be satisfied only through close attention to materials and construction. All factors must be considered to insure fast heat up, maximum thermal efficiency, minimum downtime, and maximum productivity.

HEAT EXCHANGE rate varies directly with coil surface area in contact with air (Figure 1). Extended surface fins attached to tubing multiply surface area hundreds of times reducing necessary coil size. The preponderance of fin surface renders tube surface, thickness, and material insignificant as a factor in heat transfer.

CORRECTION FACTORS FOR TUBE MATERIAL

<u>TUBE MATERIAL</u> <u>COMPARISON</u>	<u>WALL THICKNESS</u>	<u>OVERALL "U" FACTOR</u>
COPPER	0.049 IN	1.000
CU/NI 70/30	0.049 IN	0.991
90/10	0.049 IN	0.991
CARBON STEEL	0.083 IN	0.988
STAINLESS STEEL	0.049 IN	0.988

Fin material has a greater effect on heat transfer.

HEAT TRANSFER OF IDENTICALLY CONSTRUCTED COILS

<u>MATERIALS</u>	<u>OVERALL "U" FACTOR COMPARISON</u>
CARBON STEEL TUBE/CARBON STEEL FIN	1.00
STAINLESS TUBE/STAINLESS FIN	0.69
STAINLESS TUBE/ALUMINUM TUBE	1.10
CARBON STEEL TUBE/ALUMINUM FIN	1.14
COPPER TUBE/ALUMINUM FIN	1.18

The best compromise among efficiency, strength, and cost suggests aluminum fins on carbon steel pipe.

FIN TO TUBE BOND greatly affects heat transfer also. How much of the tube is in direct contact with fins and how tightly the contact is made and sustained determines how fast heat flows from tube into the fin and how well efficiency is maintained through innumerable heat up and cool down cycles.

TENSION WOUND "L" FOOT fins provide excellent sustainable performance (Figure 2). A Schedule 40 pipe is devarnished and lightly knurled to slightly roughen the surface. The same machine pulls a thick aluminum fin strip through dies to form an

"L" shape with a foot width equal to the fin pitch. This fin is helically wound in counter rotation to produce a tension wind along the length of the tube. The slight tube roughness grasps the slightly softer fin foot and the ends are tacked to the tube. The fin foot is in tight secure contact with the total tube surface. The resultant bond provides excellent heat transfer which will persist through all manner of service conditions and temperatures through 400 degrees Fahrenheit.

TENSION WOUND "KEYFIN" is suggested between 400 and 750 degrees (Figure 3). The machine gouges a helical groove in the pipe and tension winds a straight fin strip into the groove. Simultaneously the tube metal displaced by the gouging is peened back against the fin securely fixing it in place.

WELDED FIN attachment is used above 750 degrees.

LONG MAINTENANCE-FREE LIFE is fostered by a prudent choice of header and tube materials and the method of bonding them.

To promote heat transfer, a slightly turbulent air flow across the coil is preferred. The helical fin wind promotes this. Additionally, centrifugal fans induce a natural pulsating air flow. The combination of continuous turbulence and pulsation constantly flexes the coil tubes, and the points of flexure and resultant stress are the TUBE TO HEADER JOINTS. Thick and strong tube and header materials and firm resilient bonds are needed to prevent material fatigue breaks and joint fractures (Figure 4).

Schedule 40 pipe for tubes and headers of Schedule 40 pipe or 1/4-inch formed steel plate welded together form strong secure joints. The use of similar materials eliminates the possibility of galvanic corrosion at these joints.

Unlikely repair is easily done by rewelding. This is accomplished without eliminating any precious fin surface.

The NUMBER OF TUBE TO HEADER JOINTS is minimized by using large diameter pipe for tubes. Large diameter tubes permit large diameter fins which result in less fins, less tubes, and less tube to header joints to fail (Figure 5).

Larger and less fins also means wider fin and tube spacing less likely to retain particulate matter. CLEANABILITY is enhanced by both wide spacing and strong thick fins and tubes.

DRAINAGE of condensate and non-condensable gases (AIR) immediately and continuously is critical to maximum sustained heat transfer.

"Air" accumulating in steam reduces the temperature of the steam. Unremoved "air" and condensate form films on the tube surfaces which are insulating barriers to heat transfer. The sum of these effects is a slowing down of heat flow and a reduction in efficiency as much as 50%.

Gravity flow of condensate in the tubes must be promoted. Wherever possible, tube orientation should be vertical or else tubes should be pitched downward from the inlet header to the outlet.

"Air" will flow through a tube only if a positive pressure differential and vapor flow velocity is maintained in the direction of the coil outlet. This is the task of the drainage system, and to do this consistently, all coils should be trapped

individually. A single trap draining a single header common to a number of coils will not guarantee proper drainage conditions.

Identically constructed coils have variations in cross sectional area and natural differences in pressure drop. Coils in parallel in an air flow face will not have equal air flows, and therefore will not have equal condensing rates. Unequal condensing rates mean unequal pressure drops. The lesser pressure drop of the lighter loaded coils permits steam flow into the common outlet header. This raises header pressure above outlet pressure of the coils with higher loading and pressure drop. The result is steam flow into both ends of these coils and the trapping of "air" in these tubes. This accumulating "air" reduces temperature and insulates against heat transfer. Efficiency is reduced.

The solution is a separate trap for each coil. The discharge of these traps can dump into a common header without detriment.

STEAM TRAP SELECTION criteria further illustrate the need to evacuate "air" and condensate continuously and at steam temperature.

A Union Carbide report entitled "Study of Energy Consumption in Process Steam Traps" suggests that the type of steam trap can affect the efficiency of a heat exchanger. Four different traps were used to drain the same exchanger. The amount of steam consumed while draining with each trap was measured and compared.

<u>TRAP TYPE</u>	<u>STEAM USAGE COMPARISON</u>
HIGH CAPACITY IMPULSE	1.00
F&T	1.08
FREE FLOATING BALL	1.08
INVERTED BUCKET	0.92

They estimated that the change from Impulse to Inverted Bucket resulted in a steam cost savings of \$1.1 Million/yr.

Thermostatic sub-cooling traps were not considered. A Union Carbide plant in Canada had tried them and experienced vapor binding of the exchangers by non-condensable gases. Traps which back up and cool condensate can result in inefficient operation.

Retention of condensate in coils to cool it before discharging turns them into combination steam and hot water heaters. Water gives up its heat only half as fast as steam, and it drops in temperature as it does. The water seal formed by the retained water won't let "air" pass through to the trap and out of the system. This further reduces the steam temperature and insulates against heat transfer. The total result is a drastic reduction in heat transfer rate. Steam pressure must be sharply increased to regain the required heat transfer. This is inefficient.

"Air" in a steam system comes from the carbonates and bicarbonates in all make-up waters. When water is boiled, these compounds liberate carbon dioxide gas which carries over into the system with the steam. This is the primary constituent of the efficiency robbing "air."

As a gas, carbon dioxide will not corrode metal. If it is below steam temperature in contact with cool condensate, it will dissolve and produce CARBONIC ACID. This radically reduces the condensate pH and causes corrosion in the steam system.

Inverted Bucket traps with large or thermic vents will remove both condensate and air continuously at steam temperature.

THE DRAINAGE SYSTEM should promote a positive pressure drop across the coil, and not permit backup of condensate and/or "air" at any time.

CONSTANT STEAM PRESSURE AND ON-OFF CONTROL

A vacuum breaker should be installed at the inlet to each coil. When steam is shut off, the residual steam in the coil will condense collapsing pressure into a vacuum which will prevent drainage or, in extreme cases, suck condensate into the coil from the condensate return lines. The vacuum breaker will open to permit gravity flow to and through the trap into the vented condensate return.

Condensate permitted to lie in the system can freeze, cause corrosion and cause water hammer damage when steam is turned on again.

A thermostatic air vent at the coil outlet assists the trap in "air" removal.

MODULATED STEAM PRESSURE WITH VENTED RETURN BELOW TRAP

A new charge of lumber requires quick temperature rise and rapid evaporation. As evaporation progresses, heat requirements diminish, and required steam pressure is reduced to reduce steam temperature commensurately. Since the steam/temperature curve is not linear, steam pressure decays more rapidly than heat requirements. Large amounts of steam are still being condensed and a vacuum forms in the coil although a small steam pressure still exists at the inlet. Condensate removal stops.

The vacuum breaker now should be moved to the coil outlet. This will break the vacuum and allow condensate to flow by gravity to and through the trap and down into the vented return.

MODULATED STEAM PRESSURE WITH PRESSURIZED OR OVERHEAD RETURN

Back pressure at the outlet of a trap from any source lowers the differential across the trap and the capacity. At some relatively high steam pressure and condensate flow, the drop across the trap will become zero and flow will stop.

To permit continued drainage, the inlet of a second trap called a "Safety Drain" is tapped into the coil discharge pipe physically above the main trap inlet. When flow stops and condensate backs up, it will flow into the Safety Drain and out and down into an open drain or into a vented receiver. From there it may be pumped back to the boiler.

THE SAFETY FACTOR used to size traps will vary with each type of control.

For constant pressure or on-off control, apply a 3 to 1 safety factor to the maximum condensate flow to determine

maximum required trap capacity. Select a trap which has this capacity at the maximum pressure differential.

For modulating steam pressure operation between 0 and 15 psig., apply a safety factor of 2 to 1, and select a trap with the required capacity at 1/2 psi differential.

For modulating steam pressure operations between 15 and 30 psig., apply a safety factor of 2 to 1, and select a trap with the required capacity at 2 psi differential.

For modulating steam pressure operation above 30 psig., apply a safety factor of 3 to 1, and select a trap with the required capacity at 1/2 the maximum pressure differential.

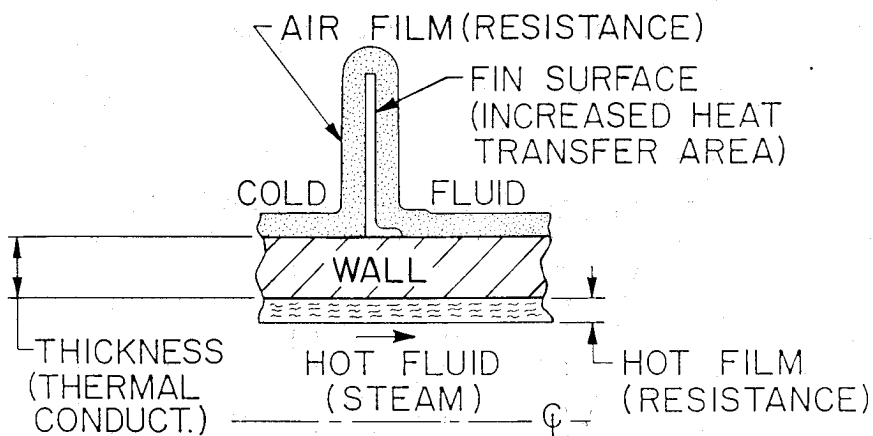


Figure 1. Finned Tube Heat Transfer

1. PIPE BUFFED AND KNURLED
2. PIN WOUND UNDER TENSION
3. TEMPERATURE UP TO 400°F

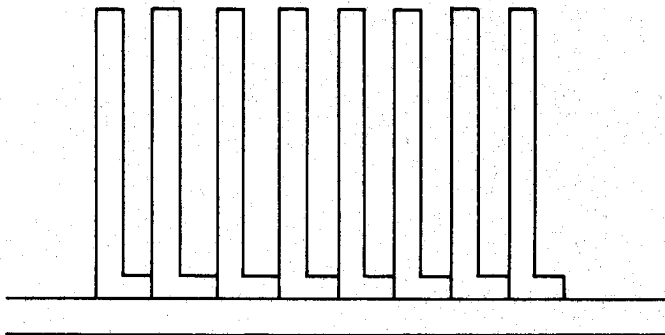


Figure 2. Tension Wound "L" Foot

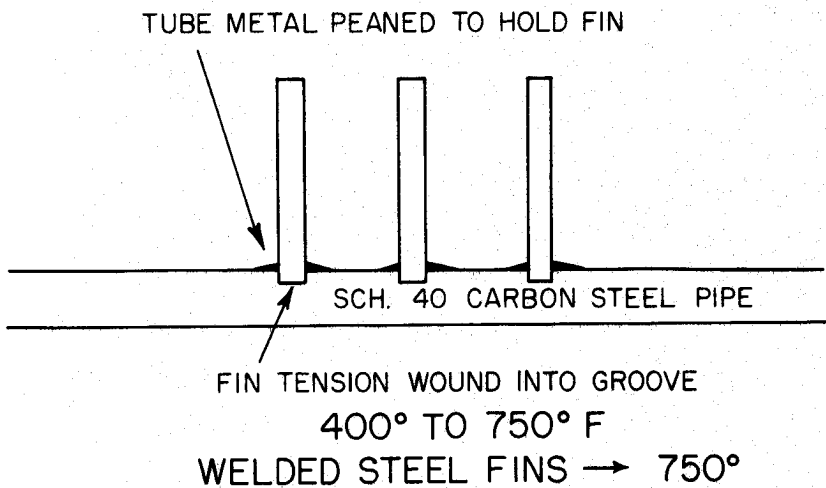


Figure 3. Keyfin Tension Wound

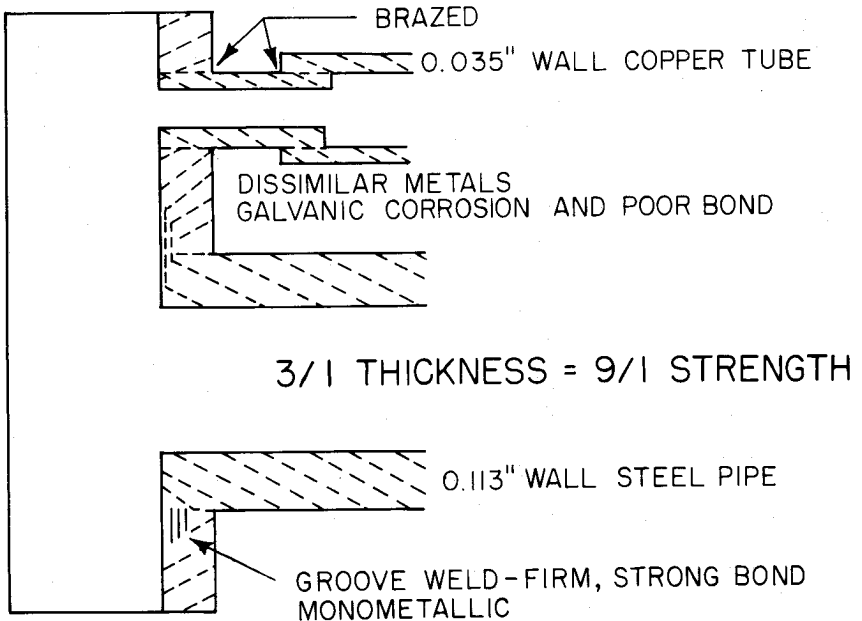


Figure 4. Tube to Header Joints

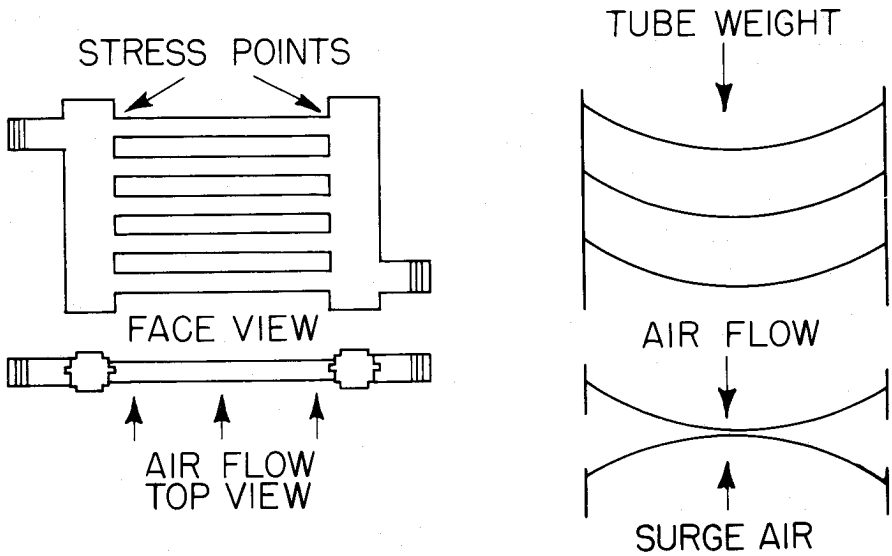


Figure 5. Coils Under Stress