



WOLVERINE TUBE HEAT TRANSFER DATA BOOK

4.1. Heat Exchangers with High-Finned Trufin Tubes

4.1.1. Areas of Application

It is frequently the case that one fluid in a heat exchange process has a much higher film heat transfer coefficient than the other, under the conditions of the given problem. Thus, water very commonly gives a value of 1000 to 1500 Btu/hr ft²°F, whereas air at atmospheric pressure usually gives a value of about 10.

The consequence of this imbalance is that the size of the heat exchanger is almost completely controlled by the necessity of providing a large area in contact with the poor heat transfer medium. Often, the best way to provide this area without unduly increasing the overall size of the heat exchanger is to use banks of high-finned tubes such as shown in Fig. 4.1, with the poor heat transfer medium flowing across the finned surface and the other fluid inside the tube.

High-finned Trufin is used in a wide variety of services, but the large majority of applications are for transferring heat to atmospheric air. Air has become increasingly important as the ultimate medium for rejecting waste heat, for a variety of reasons. In some areas, water is altogether lacking. Even when available, water may be too costly, or require too much treatment to minimize fouling or corrosion, or require too much reprocessing before it can be discharged to the environment. And in some situations, air is preferable to even readily available water as a cooling medium. The final result is a rapidly increasing need for heat exchangers specifically designed to handle, and transfer heat to, large quantities of air.

In these exchangers, air is blown across banks of finned tubes, picking up heat from the stream on the tube-side, which is correspondingly cooled. The hot air is then usually dispersed into the atmosphere and the heat dissipated by mixing. Equipment designed for this purpose is commonly called an air-cooled heat exchanger or air cooler, and to some extent this term has become a generic term for most high-finned Trufin apparatus. However, it is important to remember that high-finned Trufin has a variety of other applications, as this section will indicate.

Typically, in an air-cooled exchanger, the fluid on the tube-side may be a process liquid that needs to be sensibly cooled before going to storage or to the next step in the process, or the tube-side fluid may be a vapor that must be condensed. Further, the vapor may be originally superheated above its saturation temperature so that it needs to be de-superheated before condensation takes place. The vapor may be essentially a single component, or it may be a mixture of several components, not all of which are necessarily condensable. Subcooling of the condensate may also be performed in air-cooled equipment.

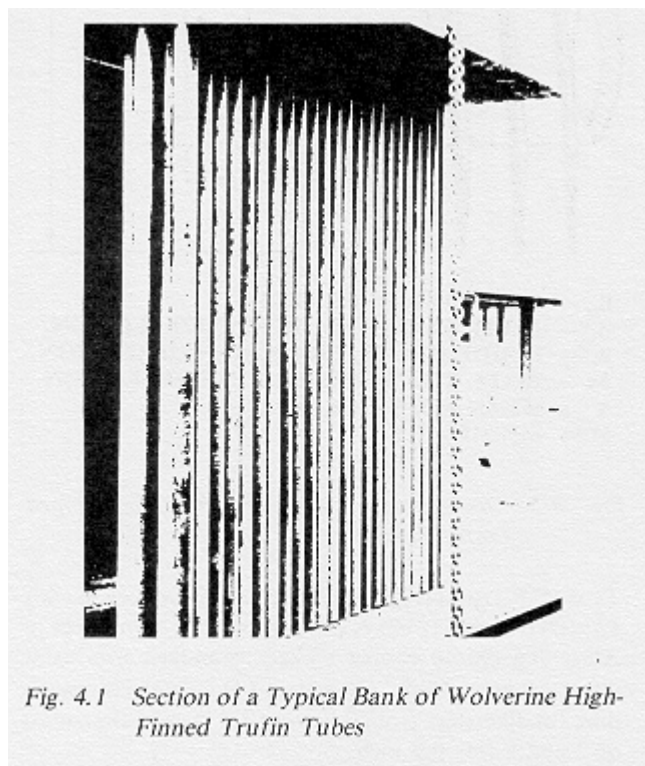


Fig. 4.1 Section of a Typical Bank of Wolverine High-Finned Trufin Tubes



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In the cases cited above, the cooling process was direct, in the sense that the heat was transferred directly from the process fluid, through the tube wall and fins, to the air. *Indirect* air cooling is also used. In this arrangement, the process streams are actually cooled in shell and tube heat exchangers with a closed water loop as the intermediate coolant. The water is then cooled in air-cooled heat exchangers. This arrangement allows the use of generally more compact water-cooled equipment in the immediate vicinity of the process units with ultimate heat rejection accomplished to the atmosphere with air-cooled equipment on the periphery of the plant. The quality of the intermediate coolant can be controlled to minimize corrosion and fouling problems. The equipment and piping arrangement is more extensive and complicated, and the temperature of the process fluids cannot be reduced as low as for the direct cycle.

The indirect cycle can be very useful if air temperatures get so low as to cause the process fluids to freeze up or get exceedingly viscous upon direct cooling. The intermediate fluid in the indirect cycle can be a water-glycol mixture so chosen that it will not freeze under the most extreme conditions encountered. The temperature of the intermediate fluid can be controlled by bypassing a portion of it around the coolers, or by shutting down some or all of the fans.

In addition to its use in rejecting heat from process plants, high-finned Trufin may also be used to reject heat from power plants (both direct and indirect cooling cycles have been proposed and constructed), and refrigeration and air-conditioning systems. In another application - space heating systems - it is the warm air off of the tubes that is the desired product; the heat source may be either condensing steam or a hot liquid inside the tubes.

There are, finally, two applications areas in which the atmospheric air is the heat source rather than the heat sink. In the first of these, air is used to supply heat to a process fluid, either to sensibly warm it or to vaporize it. There is only a limited temperature range over which atmospheric air may be cooled, since if the fin surface temperature drops below the dew point of the air and below 32°F (0°C), ice will form on the fins and can rapidly lead to a restricted air flow and possible mechanical damage to the tube. In the other application, it is the cooled air (for air-conditioning or refrigeration) which is of interest, the cold sink being a boiling refrigerant or possibly a sensibly heating brine.

In principle, the air-side calculations (i.e., on the tube bank finned surface) are the same for all of the above applications, though the specific ranges of parameters vary widely. However, the tube-side calculations are quite different, and are covered in other sections of this manual.

4.1.2. High-Finned Trufin

All high-finned Trufin made by Wolverine has *integral* fins. That is, the fins are raised from the base tube metal in a fabricating operation so that the final tube and its fins are one piece of metal, except for the Trufin Type L/C which has an internal liner of a different metal. But here also, the outer tube and the fins are a single piece of metal.

Integral finning ensures the maximum thermal efficiency of the tube since there is no possibility of the fins becoming partially or totally separated from the tube metal by environmental corrosion at the base of the fin or by repeated expansion and contraction in operation or by mechanical damage in handling.

There are several different types of Wolverine high-finned tubes manufactured. The descriptions given below are intended only to indicate the major features of each type and certain general classes of applications that each lends itself to. Certain limitations of material availability and construction features are also indicated. For a detailed listing of sizes available, tolerances, material specifications, ordering information, etc., see Section 6.

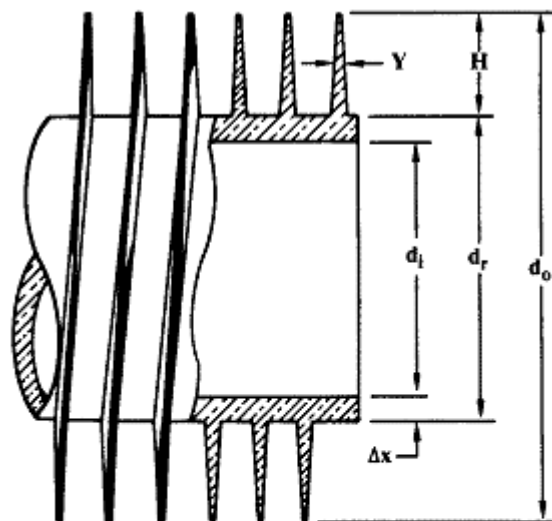


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Fig. 4.2 defines the major geometrical parameters common to Wolverine high-finned tubes. Type H/F Trufin (Fig. 4.3) is normally produced in alloy 122 (DHP copper) but is also available in some sizes of Alloy 706 (90/10 copper nickel). Standard size inside diameters range from 5/16 in. to 1 1/4 in. with corresponding fin diameters from 0.9 in. to 2.2 in. and fin counts of 7 and 9 fins per inch.

Type H/R Trufin (Fig. 4.4) is produced in 3003 aluminum. Standard root diameters range from 3/8 in. to 1 in. with corresponding fin diameters from 0.9 in. to 1.9 in. and standard fin counts of 5, 7, 9, and 11 fins per inch. Type I/L Trufin (Fig. 4.5) has internal longitudinal fins as well as helical fins on the outside. It is available only in 3003 aluminum and has the same fin configurations as Type H/R aluminum.

Type L/C Trufin (Fig. 4.6) is a duplex finned tube in which the outer tube is integrally finned 3003 aluminum with the same outside fin configuration similar to Type H/R aluminum. The inner tube may be of any material including copper, admiralty, copper nickels, low carbon and stainless steels. The dimensions of the inner tube are standard dimensions for heat exchanger tubes. Type L/C Trufin is used when corrosion or pressure considerations require the use of a special material in contact with the process fluid. The aluminum assures good heat conductance through the fins into the air, as well as excellent resistance to atmospheric corrosion.



d_o — DIAMETER OVER FINNS.
 d_r — ROOT DIAMETER OF FINNED SECTION.
 d_i — INSIDE DIAMETER OF FINNED SECTION.
 Δx — WALL THICKNESS OF FINNED SECTION.
 Y — MEAN FIN THICKNESS.
 H — FIN HEIGHT.

Fig. 4.2 Geometrical Parameters for High-Finned Trufin Tubes.

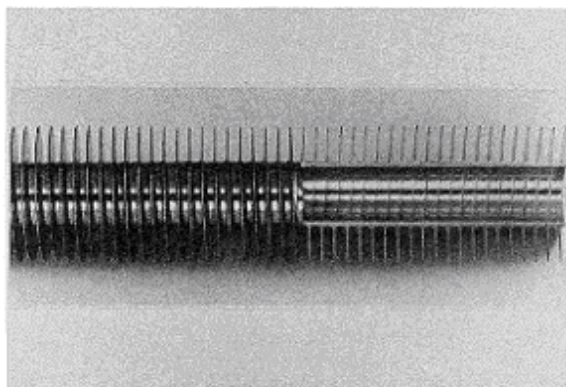


Fig. 4.3 Wolverine Trufin Type H/F

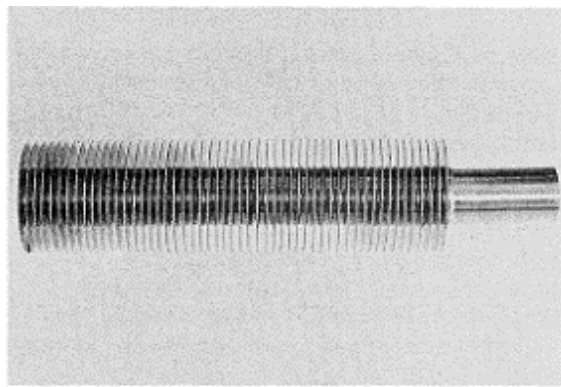


Fig. 4.4 Wolverine Trufin Type H/R



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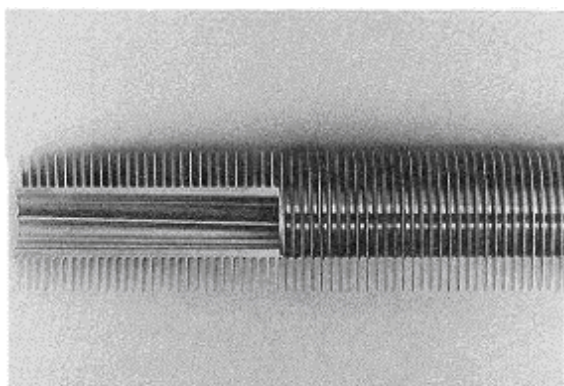


Fig. 4.5 Wolverine Trufin Type I/L

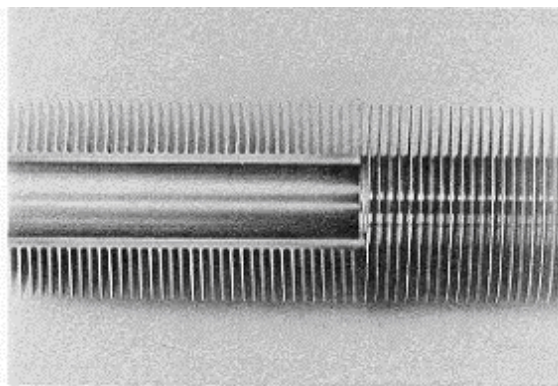


Fig. 4.6 Wolverine Trufin Type L/C

4.1.3. Description of Equipment

1. *Basic Arrangements.* Most large air-cooled heat exchangers are essentially composed of a shallow (3 to 8 rows) tube bank across which a large quantity of air is blown or drawn at relatively low velocities by large fans. Two different configurations are shown in Figs. 4.7 and 4.8.

Fig. 4.7 shows a horizontal tube, forced draft arrangement, in which the fan is mounted below the tube bank and blows air upwards past the tubes. This configuration is commonly used for both cooling liquids and condensing vapors; especially in the latter case, the tubes may be slanted 2° or 3° downwards in the direction of flow to facilitate drainage of the condensate from the tube. The forced draft arrangement is mechanically attractive: the fan and drive may be supported directly on the ground with a fairly short shaft, easing stress and vibration problems and simplifying maintenance. However, the hot air leaves the top of the unit at a fairly low velocity and may tend to recirculate through this or nearby units and raise the inlet temperature, reducing the unit capacity.

Fig. 4.8 shows the horizontal tube, induced draft arrangement. Induced draft produces generally more uniform airflow across the bundle and projects the hot air plume more positively into the atmosphere, reducing recirculation problems. However, in the arrangement shown, fan and driver are more difficult to secure and maintain, and the fan loses efficiency in handling the less-dense hot air.

An alternative arrangement places the driver below the bundle, connected by a long shaft to the fan above the bundle; however, tubes must be left out of the bundle to allow the shaft through, with consequent bypassing problems and loss of surface, not to mention potential shaft vibration problems.

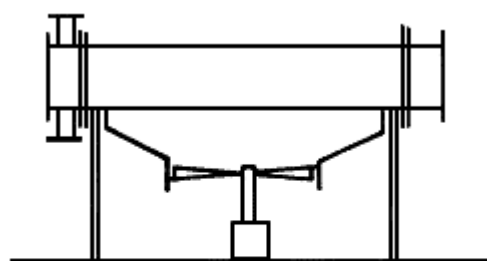


Fig. 4.7 Arrangement of a Typical Horizontal Tube Air-Cooled Exchanger with Forced Draft.

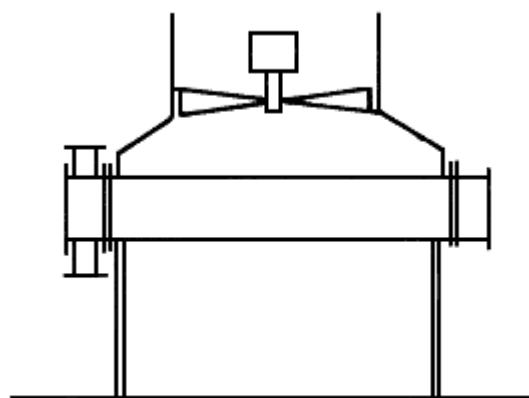


Fig. 4.8 Arrangement of a Typical Horizontal Tube Air-Cooled Exchanger with Induced Draft.



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2. *Tube Bundle Construction.* The tubes are always arranged in a triangular layout or (less commonly) a rotated square layout, as shown in Fig. 4.9. Inline arrangements are never used because a major portion of the air can flow through the bundle in the clear channel between the tips of fins on adjacent tubes and mix only very poorly with the heated air flowing through the fin field. The effect is to reduce the apparent heat transfer coefficient to approximately half of that of a triangular array. (Refs. 1,2) Even in the staggered layouts the tubes are put as close together as possible without having the tubes vibrate against each other in normal operation. Typically, the tip to-tip clearance is 1/4 in.

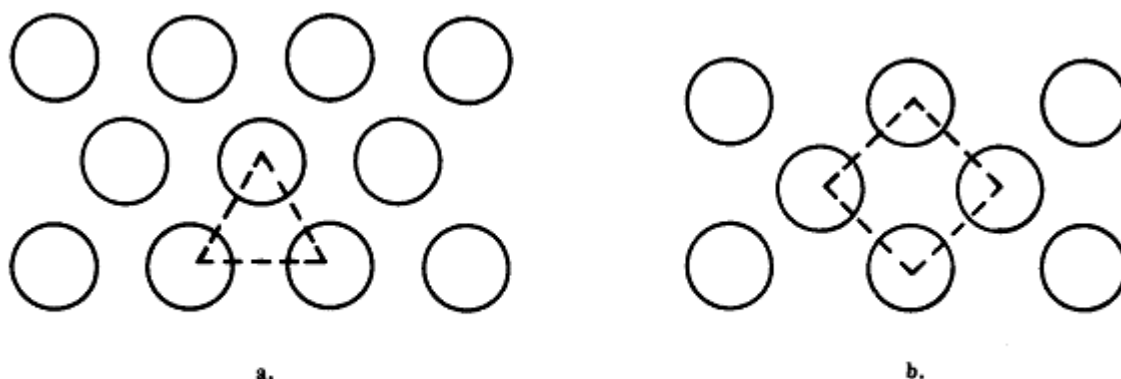


Fig. 4.9 Finned Tube Unit Cell Geometries: a) Equilateral Triangular Layout b) Rotated Square Layout

Usually the tubes are inserted in box-type headers, Fig. 4.10. The tubes may be expanded into and/or welded to the tube sheet. In the simple box header, the flanged cover plate may be easily removed, exposing the ends of all of the tubes for inspection, leak testing, cleaning, replacement, rerolling or rewelding, or plugging. The integrally welded box header is designed for higher pressure operation; any operations on the tubes are carried out by removing the inspection plugs and working through the inspection hole.

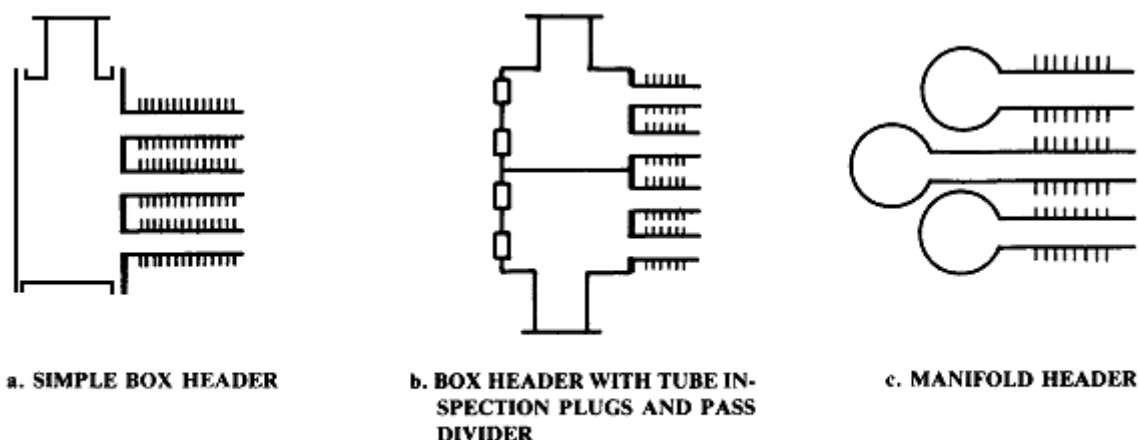


Fig. 4.10 Typical Headers for Air-Cooled Exchangers; a) Simple Box Header with Flanged Cover Plate, b) Integrally-Welded Box Header with Tube Inspection Plugs and Pass Divider, c) Manifold for High Pressure on Tube-Side.

A minimum of three rows of tubes is used in tube banks; the usual maximum is eight rows, though occasionally up to 12 are employed. The greater number of rows of tubes is used where a relatively small



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airflow is required. Generally in this case the tube-side fluid is at high temperature and the air temperature can increase over a correspondingly greater range.

In certain applications (e.g., condensation, especially multi-component mixtures) the tube bank is arranged for single pass; that is, the process fluid is introduced at one end and flows in parallel through all of the tubes in the bundle to the other end, where it exits from the exchanger. For other applications (e.g., cooling of a liquid over a wide temperature range), it is often better to let the tube side fluid flow back and forth through the tube rows making two, three, or occasionally more passes through the exchanger and across the air stream. In this case, the tube side fluid always starts at the top tube row and with successive passes, moves to lower tube rows in order to approximate as closely as possible countercurrent flow. The flow path is controlled by pass dividers or partition plates in the headers, as illustrated for a two pass unit in Fig. 4. 10b. Usually an integral number of tube rows (one or two) is taken for each pass, but by using vertical as well as horizontal dividers it is possible to split rows into fractional rows per pass, as shown in Fig. 4.11. However, in order to make room for the plates it may be necessary to omit tubes or distort the layout, which may result in air bypassing. Also, tube-side fluid distribution may be non-uniform. Since the assumptions may not be satisfied, such arrangements should not be used when close temperature approaches are called for.

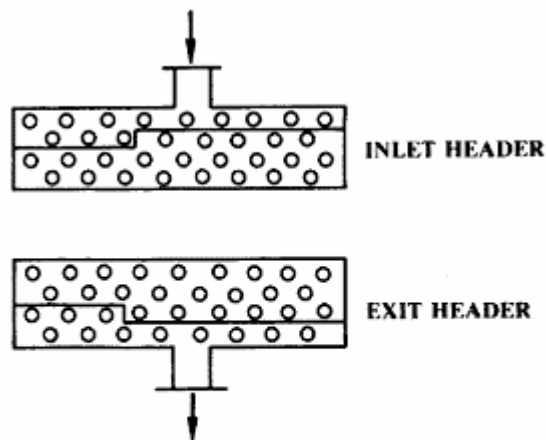


Fig. 4.11 Diagram of Possible Pass Divider Arrangement for Three Equal Passes in a Four Row Bundle

If the distance between headers is greater than about 4 to 6 feet, it is necessary to provide periodic tube support plates, through which the tubes pass with only enough clearance over the fin diameter to allow the tubes to be inserted easily during assembly. To provide a bearing surface for support, the space between fins may be filled (for the distance of a few fins) with a low melting alloy such as a solder cast in place or by a wraparound shroud, or the support plate may be made thick enough to hold several fins.

The bundle is held together and stiffened by side members of appropriate size and shape (commonly U-channels) bolted or welded to the headers and the support plates and to the legs or tower support structure. The clearance between the outermost tubes and the side members should be as small as possible to minimize air bypassing. Auxiliary features such as plenums, shrouds, louver systems, and screens are fastened to the main structural members for support.

3. *Fans and Drivers.* Next to the tube bundle itself, the fan and its driver are the most important elements of the air-cooled exchanger. The fans are invariably axial flow propeller type, with four or six blades, up to 24 feet in diameter (larger ones are available). Especially in the larger sizes, adjustable pitch blades are used. Maximum static pressure is limited to one inch of water, with one half inch of water pressure drop a common design specification.

The fan blades are often made of plastic if the air temperature does not exceed 175°, which includes many induced draft applications. Aluminum blades are usable up to around 300°F and steel at higher temperatures. Tip speed should not exceed about 12,000 ft/min in the larger sizes; apart from strength considerations, fan noise increase rapidly at higher speeds.



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Both electric motor and steam turbines are used as drivers, either direct or indirect. In isolated locations, engine drivers can be used. For indirect drive, V-belts or reduction gears are used; temperature limitations must be observed in induced draft positioning. Hydraulic drives are also used.

In estimating fan power requirements, a combined fan and driver efficiency of 60 percent is reasonable, with a range from 50 to 75 percent. In view of the many options open for fans and drives and the specialized nature of the field, detailed information and recommendations should be sought from the manufacturer for each application.

4. *Other Components.* Fan rings, shrouds and plenums are always used on air-cooled exchangers to guide the airflow and minimize peripheral escape, bypassing, and recirculation of air. There seems to be no general body of information available on design practices in these areas, and reasonable attention to the mechanics of airflow is probably sufficient to avoid catastrophic problems.

A coarse screen underneath the fan is commonly used as a safety precaution in forced draft units where there is any possibility that people or animals may get close to the fan and also to protect the fan and tube bundle from ingesting flying debris.

A variety of techniques and equipment is used to ensure that the process fluid does not freeze in the tubes under conditions of low air temperature. First, the fans can be shut off: as a rough rule of thumb, an air-cooled heat exchanger will transfer about one-third as much heat with the fans off. Second, louvers may be installed under the tube bank to further restrict airflow. Third, it is possible to arrange for some of the fans to be reversible and deliberately recirculate some of the warm air that has passed through the bundle back through the bundle into the fresh air supply. Fourth, some bundles have a separate row of tubes underneath the main bundle into which steam can be bled to warm the incoming air.