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Selection and costing of heat exchangers Air-cooled type

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THE PREPARATION OF THIS DATA ITEM

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The costing data were provided by Graham Manufacturing Ltd and were collected by Mr P. Bansil, under the supervision of Dr C.D.R. North and Prof. G. F. Hewitt.

The person with overall responsibility for the work in this area is Mr S.J. Pugh, Head of Thermofluids Group.

SELECTION AND COSTING OF HEAT EXCHANGERS AIR-COOLED TYPE

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SELECTION AND COSTING OF HEAT EXCHANGERS

Air-cooled type

1. NOTATION AND UNITS

		Units	
		SI	British
A	heat transfer surface area of heat exchanger (related to external bare tube area)	m^2	ft^2
c_p	specific heat capacity	J/kg K	$\text{Btu/lb } ^\circ\text{F}$
C	cost per unit $\dot{Q}/\Delta T_m$	£/(W/K)	$\text{£/(Btu/}^\circ\text{F)}$
C_L	cost of labour per unit $\dot{Q}/\Delta T_m$	£/(W/K)	$\text{£/(Btu/}^\circ\text{F)}$
C_M	miscellaneous cost per unit $\dot{Q}/\Delta T_m$	£/(W/K)	$\text{£/(Btu/}^\circ\text{F)}$
C_t	tube costs per unit $\dot{Q}/\Delta T_m$	£/(W/K)	$\text{£/(Btu/}^\circ\text{F)}$
CR	cost ratio, see Section 7	—	—
$CR_{1.65}$	cost ratio for change to 1.65 m bundle	—	—
$CR_{6.1}$	cost ratio for change to 6.1 m bundle	—	—
$CR_{9.1}$	cost ratio for change to 9.1 m bundle	—	—
CR_{15}	cost ratio for change to 15 m bundle	—	—
$CR_{3/4}$	cost ratio for change to $3/4$ in tubing	—	—
CR_{ext}	cost ratio for change to extruded tubes	—	—
F_T	logarithmic mean temperature difference correction factor	—	—
h	specific enthalpy	J/kg	Btu/lb
$\dot{M}$	mass rate of flow	kg/s	lb/h
$\dot{Q}$	heat load of exchanger	W	Btu/h
U	overall heat transfer coefficient	$\text{W/m}^2\text{K}$	$\text{Btu/h ft}^2\text{ }^\circ\text{F}$
ΔT	temperature difference	$\text{K or } ^\circ\text{C}$	$^\circ\text{F}$

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x factor in Equation (4.4) — —

Subscripts

c, h refer to cold and hot stream respectively

in, out refer to values of parameter at inlet to and outlet from heat exchanger respectively

lm logarithmic mean

m mean

2. PURPOSE AND SCOPE OF THIS DATA ITEM

This Data Item is one of a group on the selection and costing of heat exchangers. The first Item in the group, ESDU 92013⁴, provides a means of selecting, from a wide range of exchanger types, those feasible for a particular duty. Its objective is to provide the *process designer* with a simple and rapid method of selecting between the feasible types, and subsequently of obtaining rough cost estimates. Such estimates are often required well before the actual configuration of the equipment is decided.

This Item extends the costing data for air-cooled exchanger types, accounting for design parameters for which single 'standard' values were previously assumed.

In the procedure outlined in the ESDU 92013, the first step is to select feasible types of heat exchanger on the basis of thermal and hydraulic requirements, compatibility with fluids and operating conditions (for example temperature and pressure), maintenance, availability, space and weight, and fouling characteristics. Having established a list of feasible types, the next stage is to cost them and then to select a heat exchanger (and its associated circuitry) having the lowest cost. It is recognised that the cost calculations in such procedures are of limited accuracy and that quotations for more than one type of exchanger should be sought if the costs are similar (that is within 20-50%).

In the costing method used in ESDU 92013 costs are expressed in terms of C , the cost per unit $\dot{Q}/\Delta T_m$ where $\dot{Q}$ is the heat load (heat transferred from the hot to cold fluid in the heat exchanger per unit time), and ΔT_m is the mean temperature difference, corrected for heat exchanger configuration. A further summary of the method is given in Section 4. For a given exchanger type, a 'standard' set of design parameters is chosen. However, costs are often highly dependent on variations in these design parameters, even for a constant value of $\dot{Q}/\Delta T_m$, and particularly for tubular exchangers such as air-cooled and shell-and-tube types. Simple correction factors are suggested; for instance, it is suggested in ESDU 92013 that stainless steel exchangers would be 1.5 times the cost of carbon steel exchangers. However, the use of such simple correction factors is of doubtful validity. For instance, it is self-evident that the ratio of costs for a stainless steel exchanger to that for a carbon steel exchanger would vary with the relative importance of the material content with respect to labour content, which would increase as the size of the exchanger increased.

In this present Item the specific case of the air-cooled heat exchanger is investigated further, with an attempt to develop correction factors to the table for the 'standard' parameters in order to produce more realistic costings over a wider range of configurations. ESDU 94013 provides similar extended data for the other tubular heat exchanger case, namely shell-and-tube types.

The objective of this present Item is to provide the process designer with the means of establishing an approximate cost. Normally, the process designer will specify the duty of an air cooled heat exchanger. Thermal design then follows, leading to the establishment of a configuration which can then be mechanically designed and, ultimately, costed. However, there is an increasing requirement for the process designer to establish the approximate cost of process equipment before the detailed design sequence is entered. This allows choices to be made between alternatives at an early stage of development of the process flow sheet.

Methods for costing air-cooled heat exchangers are available in the literature. For instance, Smith³ considers a variety of factors which influence cost relative to a fixed configuration. This approach is useful if the configuration is known *a priori*, but lacks the attraction for rapid costing of the C-value method, where the specific configuration is not required.

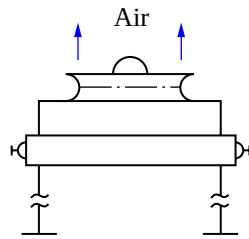
Another important consideration for air cooled heat exchangers is that of the overall optimisation. Air-cooled heat exchangers require fan power to move the air and are often quite large, occupying sizeable plots of often expensive land. Thus, it could be argued that optimisation should be on the basis of annual costs (taking account of power and annual land costs) rather than capital costs. Though the approach is eminently sensible, it is the experience of heat exchanger vendors (as exemplified by the vendor who provided the present data) that buyers of air-cooled heat exchangers usually concentrate on capital costs with the aim of minimising initial investment, and in this present study has also concentrated on capital costs. Optimisation of air cooled heat exchangers taking account of land and power costs is discussed by Saunders².

In this Item, various constructional features of air-cooled heat exchangers are considered (Section 3) and the basis of the costing method is discussed (Section 4). Sections 5 and 6 discuss costs for the “standard” type of configuration and Section 7 discusses the effect of variations from this standard, specifically the effects of tube type, bundle length and noise reduction.

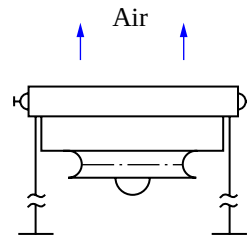
3. CONFIGURATIONS OF AIR-COOLED HEAT EXCHANGERS

The air cooled heat exchanger consists of a bundle (or bundles) of externally-finned tubes which are mounted in a frame and terminated at each end by a header. Air is blown over the tube bundle(s) by means of single or multiple fans. Sketch 3.1 shows the various ways in which the fans and bundles can be arranged. These alternative designs may be reviewed as follows.

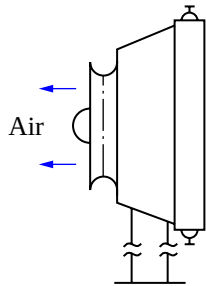
- (a) **Horizontal, induced draught:** A typical unit of this type is shown in Sketch 3.1a and Figure 1a. This type has a number of advantages. The escape velocity of the air from the fans is typically up to 10 m/s, and this makes the unit less susceptible to crosswind than the forced draught design ((b) below). The upper plenum provides protection against rain or hail storms (which assists controllability) and also protects the bundle from solar radiation (which can significantly affect the heat load in hot countries, typically by 10 – 15%). Much more uniform air flow distribution is achieved than with the forced draught unit. The main disadvantage of this type is that the fan has to be mounted in the hot efflux air stream. This limits its use to low process temperatures (below 70°C, say). Furthermore, access to control louvres (see below) is more difficult.
- (b) **Horizontal, forced draught:** This is the most popular layout. A typical unit is shown in Sketch 3.1b and Figure 1b. Here the fan is in cool air and this allows much higher process temperatures to be used. Since the air passing through the fans is cooler, the power consumption for a given mass flow is lower. The erection procedure is simpler and bundles can be removed for cleaning and repair much more easily than for the induced draught type. However, compared with the induced draught type, air flow distribution is much less uniform. Furthermore, the escape velocity of the air from the top of the bundle is low, making the unit susceptible to crosswind effects, including external recirculation around the unit. This problem is accentuated by proximity to tall structures. Unless screens or louvres are fitted, the top of the unit is open to the atmosphere. This presents a problem with process control, since sudden squalls of rain or hail can dramatically change the performance. Also, the bundle is exposed to solar radiation, which can give rise to a significant rise in heat load in hot countries.
- (c) **Vertical, induced draught:** Here, the bundle is mounted vertically (see Sketch 3.1c), which minimises plot area and allows the unit to be mounted directly on columns (for example, on column reflux condensers). Fan temperature problems similar to those described above for the horizontal induced draught type can occur; and vertical units are also particularly prone to crosswind effects.



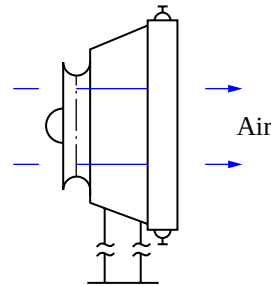
(a) Horizontal induced draught



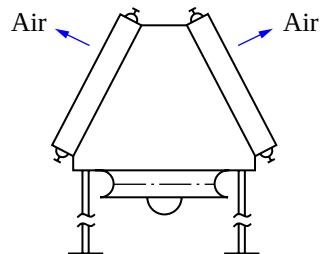
(b) Horizontal forced draught



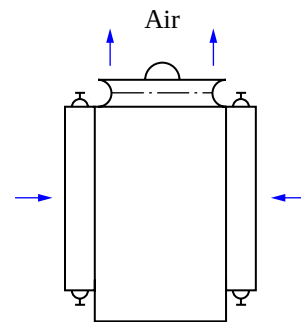
(c) Vertical induced draught



(d) Vertical forced draught



(e) A-frame, forced draught



(f) Cell type, induced draught

Sketch 3.1 Fan and bundle arrangement for air-cooled heat exchangers