COOLING TOWERS

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FOREWORD

Ten or 12 years ago, the proposal to air condition a projected large office building in London was regarded by those concerned with mild astonishment as well as with pleasure. It was remarkable then that any firm should wish to give their staff such controlled conditions, and go to the expense of installing mechanical cooling. The prospect of having a relatively new and complex engineering problem to solve was exciting.

Today, air conditioning is commonplace, and its complexities have to be understood and mastered by many engineers. A revolution has overtaken the heating and ventilating industry which it is, in fact, no longer, but has become in the space of a few years the heating and air conditioning industry. As such, numbers of new techniques have to be learned by the engineers concerned, of which water cooling for refrigerant condensing is one. Cooling towers are now as common and as new as pumps were on heating systems 50 years ago. This book should be very useful in spreading the knowledge of cooling towers, their fundamentals, their selection, installation and maintenance.

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PREFACE

The study and application of refrigeration and air conditioning has expanded considerably over the past decade. This is particularly true in the United Kingdom, where the increasing incidence of tall buildings of light construction with the desire for cleaner internal conditions, and the special requirements of certain modern processes such as in the pharmaceutical, plastics, and the computer and electronics industries, has led to air conditioning being considered as a necessity where, perhaps, little need existed before. As a result, air conditioning has also come to be expected, no longer being classed as a luxury, while cooling equipment is an essential feature of many industrial processes.

This expansion has been aided by some excellent books which include texts on cooling towers, such as those by McKelvey and Brooke, and by Jackson; the application of the cooling towers themselves, however, has not been given the consideration which it deserves.

As a result of the increasing use of air conditioning and refrigeration plant, a situation has been created in industry in which engineers and contractors, trained substantially in the principles of heating and ventilation only, have found themselves launched into the theory and application practice followed previously only by refrigeration engineers, whilst the latter have become more frequently and deeply involved in the arts of air movement and conditioning than was previously the case. Furthermore, in many industries, cooling principles are now being used for the first time, thus opening up new fields for the use of such equipment.

This book aims to fill a need, more widely felt than merely in the heating and ventilating industry, to present, as concisely as possible, the many aspects of application of cooling towers so that the busy engineer and student alike can easily use it as a quick work of reference. To this end, check lists and charts are incorporated as an aid to coherence of thought and rapid analysis of data.

After a brief comparative chapter on the various types of tower, the theoretical treatment is included more as a lead into the subject, to lay a foundation for the chapter on testing, than as a complete course on the theory. The keen student, and the engineer, it is hoped, will turn to the bibliography to select texts for deeper reading on the theoretical principles. Likewise, the chapter on construction and materials aims to provide a general background rather than a deep study of the subject, so that the process of selection and application may be based on a knowledge of the practical problems which face the cooling tower designer.

Specification and selection are dealt with in some detail, as is the integration of the tower into the cooling water piping circuit and control scheme. Much of the material which is included in these sections, it is believed, has not been so presented previously. Also included is a chapter on the particular aspect of noise relating to cooling towers, since this subject becomes of increasing concern as our equipment is installed in ever closer proximity to spaces where quietness and peace are demanded. The authors believe that this aspect has not been sufficiently covered in other texts on cooling towers, and that as a consequence, engineers and users alike have tended to accept a lower standard than necessary in the belief that the subject was too complicated to be studied in detail in relation to cooling tower location; frequently a user contends with a higher noise level than is reasonable, or the tower location is changed to another site which is often less suitable and less conducive to good performance.

Effective water treatment to maintain the cooling water, the piping system, and the tower itself in good condition is another subject which has been so often viewed as complicated chemistry, or as a magic brew known only to the specialist. The authors have aimed to set out the principles and a formal set of requirements against which the designer and user can measure the protection given to each and *every* system which incorporates a cooling tower. Particular mention is made of the need to employ specialist knowledge in the form of a water treatment service, but this does not obviate the necessity for careful assessment of the proposals for treatment based on a general knowledge of the principles and practice involved, and the effects which result from a given form of treatment.

In the end, the proof of the pudding is in the eating, and although a full scale test is beyond all possibility on almost any site, the authors have endeavoured to set out a reasonable basis for establishing the performance of a cooling tower by means of a relatively straightforward test procedure, coupled with analysis of the empirical results based on the theoretical principles developed in the earlier chapter.

Finally, preventive maintenance, precautions against fire, and observance of water bye-laws are discussed; details relating to vortices, air entrainment, and many other considerations involved in the use of cooling towers in air conditioning and refrigeration are all backed up by clear reference to the bibliography.

Space does not permit us to list all the people who have helped towards the preparation of this work. Whereas in the text contributions of material from various companies is recorded in acknowledgement, and several names are mentioned in appreciation of very full and time consuming assistance, the authors also wish to convey their grateful thanks to all those who have so freely given help and encouragement, in the hope that they also will gain a little satisfaction if a useful and successful book emerges as a result of all our efforts.

London and Birmingham J. D. GURNEY, I. A. COTTER
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CHAPTER 1

CLASSIFICATION OF EVAPORATIVE WATER COOLING EQUIPMENT

It is unfortunate that the correct selection and application of cooling towers to serve refrigeration plant is too frequently given scant attention, particularly where the refrigeration equipment is associated with an air conditioning system. So often, in this situation, the cooling tower becomes "nobody's baby", and yet, as the ultimate instrument in providing a heat sink for the system, it deserves better study than it usually receives.

The rest of the system is carefully designed, using well-known methods, but investigation suggests a spasmodic and incoherent approach to the cooling tower, with little knowledge of the principles involved, and no perception of the impact which the limitations and requirements of the site location can have on the suitability of a given tower selection.

In the past, of course, there has been little necessity to make a deep study of refrigeration cooling water systems. Only in the last few years, during which time the extent of air conditioning has spread enormously in the United Kingdom, has space become so limited and expensive that compact high performance equipment has been necessary; where, previously, a small number of manufacturers offered towers substantially similar in layout, to clients with adequate space in which to install units of more than ample performance rating, we now have a wide range of different materials and arrangements all basically suitable for the task, but each in its turn more or less ideal for a given project, according to the various limitations imposed by structure and location in the modern environment.

Air conditioning can be considered as the addition of refrigeration to the heating and ventilation of a building in order to provide cooling and dehumidification, that is, to extract heat and moisture from the conditioned space; the extraction of heat occurs at the air coil, and the refrigerant, or the chilled water, as the case may be, conveys this heat away from the conditioned area. Ultimately, this heat is discharged elsewhere either usefully, in the form of reheat, or for heating at another point as in a heat pump, or is discharged into the atmosphere as a waste product. It is for this last purpose that the cooling tower may be used, so that the heat is dissipated under low grade conditions.

There are means other than a cooling tower to provide cooling for a refrigeration plant: direct cooling of the refrigerant by passing air through the condenser itself; use of an evaporative condenser, which can be described as a cross between an air cooled condenser and a cooling tower; or by water from ponds, lakes, rivers, and swimming pools, or process water. Thus, we may well ask:

WHY USE A COOLING TOWER?

At the refrigeration plant, the heat is dissipated in the refrigerant condenser, which is usually air or water cooled; each is a relatively cheap medium. The physical characteristics are such that heat transfer between two gases through the walls of a separating tube or vessel is more difficult, and requires greater heat transfer surface than between a liquid and a gas. The cost of heat transfer surface is high, thus an air cooled condenser may cost two or three times that of a water cooled unit.[16]

Furthermore, in an air cooled condenser, it is normally only economic to cool the refrigerant to within 10°F of the dry bulb (d.b.) temperature, whereas the combination of shell and tube condenser and evaporative water cooling tower can operate at least 5°F below these conditions; a reduction of 5°F in mean condensing temperature can save up to 10 per cent. in refrigeration compressor design running horsepower.

With the growing trend for compact plant, largely due to the increasingly high intrinsic value of any space given up to plant rather than to offices and productive capacity, the small size of the shell and tube condenser is a valuable asset. In addition, of course, large air cooled condensers are difficult to control, and usually unacceptable to planning authorities, whilst the trend towards architectural treatment of the complete building in urban areas makes a large condenser aesthetically undesirable; as we shall see later, water cooling towers can be treated in such a manner as to turn them into architectural features instead of eye-sores.

At the same time, there is every advantage in the use of a packaged refrigeration water chilling plant in which all refrigeration connections and pipe runs are installed and tested in the factory. The running of refrigeration piping on site to air cooled and evaporative condensers, with the inherent danger of enclosing dirt and moisture, plus the difficulties which long pipe runs present in terms of refrigerant migration and oil return, make the packaged water cooled plant all the more attractive.

Other sources of cooling such as ponds, lakes, and rivers are all convenient in a given situation, but all also have a common feature in being a convenient receptacle for rubbish, leaves, and bird droppings; as a consequence filtering, cleaning, and restriction of algae growth are major problems which can impose a high maintenance cost on this type of cooling medium. In addition, the cooling capacity of a lake or pond is not capable of prediction to any degree of accuracy, so that there must be a certain element of risk unless the water surface area is considerable. The use of harbour or river water nearly always raises problems associated with entrainment of mud, which settles in the cooling system, and is very difficult to remove.

Although water may be so cheap and plentiful that a once-through system may be used for the small condenser, in the case of mains water a very real cost would accrue. In a typical case, the cost of mains water may be perhaps 2s. 6d. per thousand gallons, whilst local authority drainage charges could equal this sum; it will be seen that for large plant, the annual cost of running water to waste would considerably exceed the owning/operating cost of suitable cooling towers.

Thus, while water is used for preference, efforts are made to re-cool and re-use it by means of evaporative water cooling towers.

DEFINITION

A cooling tower is an enclosed device, designed for the evaporative cooling of water by direct contact with air.

COOLING TOWER NOMENCLATURE

Before discussing each group of towers in detail, it will be as well to define those of the terms which will be used which are not necessarily self-explanatory.

Cooling Tower Range

The difference in temperature between the water onto and water off the tower; for 90°F inlet and 75°F outlet water temperature, the range is 15°F.

Cooling Tower Approach

The difference in temperature between the water off the tower and the design air inlet wet bulb (w.b.); for 75°F water outlet and 65°F w.b. air inlet, the approach is 10°F.

Drift or Carry-Over

The spray droplets which are picked up by the air-stream and carried by it out of the tower.

Blowdown, Bleed or Purge

Is the water removed from the circulating system to prevent the build-up of dissolved solids or of harmful concentrations from the atmosphere.

Make-up

Is the water which must be added to the circulating system, from the mains or, possibly, some other source, to compensate for that lost due to evaporation, carry-over and purge.

Forced Draught

The system used in mechanical-draught towers whereby the air is forced into the tower by a fan.

Induced Draught

The system used in mechanical-draught towers whereby the air is drawn through the tower by a fan.

Packing or Fill

The material which forms the heat transfer surface within the tower, and over which the water is distributed in its passage down the tower.

Water Distribution

The arrangement whereby the water is conveyed to all parts of the packing at the top of the tower.

Casing or Cladding

The facing material which surrounds the packing, and retains the water within the tower.

GENERAL CLASSIFICATION

Devices for the evaporative cooling of water fall into a series of groups, as follows, strictly, not all of these are cooling towers, but they are included in order to present as complete a picture as possible.

Group 1—Ponds, (a) cooling, (b) spray.
Group 2—Natural draught or atmospheric frames, (a) spray-filled, (b) wood fill.
Group 3—Natural draught chimney towers.
Group 4—Mechanical draught towers, (a) forced draught, (b) induced draught.
Group 5—Ornamental fountains and special aesthetic treatments.

Comparison of Types of Evaporative Water Cooler

This book is concerned with the types of cooling tower normally used in conjunction with air conditioning and industrial process equipment; of these classifications, mainly mechanical draught towers are in general use in the UK on such applications. As an alternative, spray ponds are sometimes used, and may be installed on the roof of buildings, while ornamental devices are of interest for sports arenas, restaurants, and various areas given over to public entertainment. All five groups are described briefly in the following table, while a more detailed study will be made of mechanical draught towers.

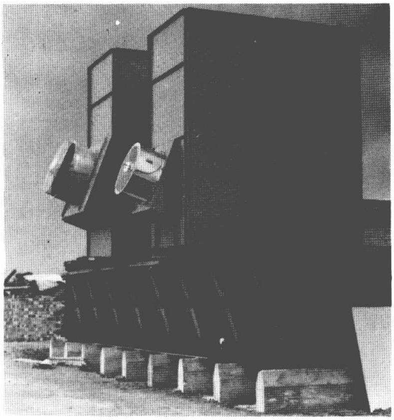


Fig. 1.1—Two forced draught steel shell panel construction coolers.

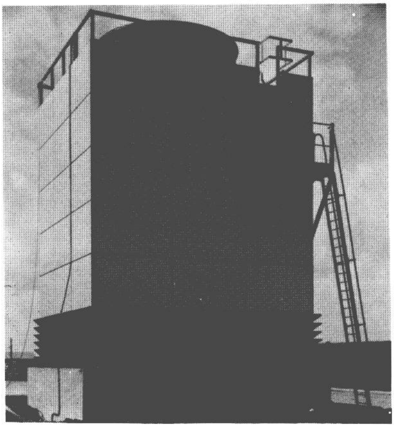


Fig. 1.2—Induced draught tower with glazed asbestos casing.

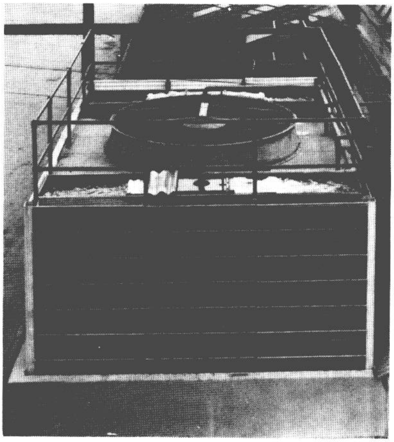
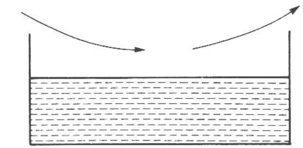
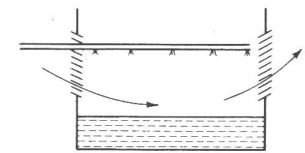


FIG. 1.3—Cross flow induced draught tower.

Group	Type	Description and Remarks	Sketch
1	(*a*) Cooling Pond	Simplest and cheapest form of water cooling. Cooling occurs partially from contact between air and water at the surface, with resultant evaporation, and partially from transfer of heat to pond walls and floor. Cooled water is drawn off at one end and return water enters at the other. Simple to construct but very space-consuming and involves expensive excavation. Little make-up necessary—but greater than with a mechanical draught tower. Serious contamination likely but readily visible. Very low rate of heat transfer. Poor approach to air wet-bulb temperature. Precise cooling performance not readily determined.	
	(*b*) Spray Pond	A pond with sprays mounted several feet above the surface, surrounded by louvred fencing to reduce loss through carry-over. More compact than cooling pond—may be installed on roof-tops. Low installation and maintenance costs. Better performance than ponds without sprays but limited performance compared with towers since water/air time of contact is small. High water loss in winds, with consequent nuisance. Tends to collect foreign matter. Unreliable performance results from fouling of spray nozzles.	
2	Atmospheric Towers	Air movement through tower is mainly dependent on wind; water falls in crossflow to horizontal movement of air; partial counterflow effect from convection currents produced by warm water. Long low-maintenance life due to lack of mechanical parts. Recirculation of used air does not occur. Tower of tall and narrow construction, therefore a high pumping head is necessary. Unobstructed location is necessary. Tower must face prevailing wind. Secure anchorage required against winds due to tall construction. Risk of fog to leeward of tower. Water temperature varies with wind velocity and direction.	