moisture levels is extremely important to permit adequate observation and data analysis.

The testing of *paper and textiles* of necessity must be carried out under rigidly maintained temperature and humidity conditions as variations, particularly in their moisture content, will have a considerable effect on physical characteristics, etc.

In the same category should be considered *rubber compounds* which are extremely susceptible to small variations in the surrounding air temperature and relative humidity. A few degrees difference in air temperature significantly affects stress values, tensile strength and ultimate elongation. A 2 percent variation in the moisture content of the sample, possible with a few percent increase or decrease in the room's relative humidity, will change tensile strength 200 to 400 psi. Since test results would thus vary widely throughout the country, the U. S. Government originally established optimum values for each test, for various compounds, and these values have been generally accepted by the rubber industry. These values were obtained by testing samples at 77 F and at constant relative humidity.

*Bacteriological and plant growth rooms*, as well as *dry boxes* and *environmental chambers* must also be rigidly maintained at determined moisture levels in order to permit testing of processes or products under a wide range of possible usage conditions. Environmental rooms and chambers can be maintained by use of sorption dehumidifiers under the range of humidity from zero to essentially 100 percent, depending on the accuracy available from the control instrumentation.

*Testing of window-type air conditioners* has been greatly accelerated and simplified by the use of sorbent dehumidifiers to regulate humidity levels. Frequently, the sorption unit is used in conjunction with heating and cooling coils to provide the required dry-bulb temperatures.

Humidity conditioning has become an indispensable tool in establishing standard environments for testing, rechecking, and repairing electronic navigation and fire control instruments before installation with several aircraft manufacturers. While humidity control is a vital element in instrument production and calibration, it also enables highly skilled personnel to work more comfortably and thus more efficiently on instruments being checked.

## APPLICATIONS FOR DRYING AT ELEVATED PRESSURE

### Preservation of Materials

Generally, materials in storage are preserved at essentially atmospheric pressure but there are a limited number of applications for the preservation of stored materials at elevated pressures, particularly where the dried media is an inert gas surrounding the material to be stored. These applications would include materials which would deteriorate when subjected to either high relative humidity or oxygen content in the surrounding media. The drying of high pressure air which is subsequently reduced to a range of 5 to 10 psig has been used most effectively in pressurizing coaxial cables to eliminate electrical shortage causing interference in telephone lines due to moisture infiltration. This same principle, but at somewhat lower pressures, is also used in wave guides and radomes to prevent moisture film on the envelope, etc.

### Process Drying of Air and Other Gases

The drying of air and other gases in refineries, chemical plants, power stations, etc., has long been an essential factor toward efficient plant operation, quality control, etc.

Drying of *instrument air*, particularly in areas where the air lines are run outdoors and exposed to temperatures below the dew-point of the air leaving the aftercooler, to a level of −40 F, will prevent condensation or freeze-up in the instrument control lines. Not only is continuous trouble-free operation assured, but considerable savings in instrument repair and down time is also realized. Most industrial processes cannot tolerate inaccurate instrument control.

The drying of *plant air* used for pneumatically operated valves, tools and other equipment is necessary in areas where the piping is exposed to low ambient temperatures in order to prevent condensation and freezing. In addition, the use of dry air prevents rusting of the air lines which produce abrasive impurities which cause excessive wear on tools, etc. Use of dry air for these purposes will considerably reduce maintenance and replacement costs.

Drying of industrial gases or fuels such as *natural gas* has been accepted as a necessary step in the industry. For example, fuels including natural gas are cleaned and dried before storage underground to assure that valves and transmission lines will not freeze from condensed moisture during extraordinarily cold weather when the gas is most needed. Propane likewise must be clean and dry to prevent ice accumulation. Other gases, such as bottled oxygen, nitrogen, hydrogen, and acetylene must have a high degree of dryness. In the manufacture of liquid oxygen and ozone, the weather air supplied in the particular process must be clean and dry.

Drying of air or inert gas for *conveying of hygroscopic materials* in either liquid or solid state is mandatory to insure continuous, trouble-free plant operation. Normally, gases for this purpose are dried to a −40 F dew point.

*Purging and blanketing operations* in the petro-chemical industry depend on the use of dry inert gas for reduction of explosive hazards, reaction of chemicals with moisture or oxygen, etc.

### Testing of Equipment

Dry, high pressure air is used extensively for testing of refrigeration condensing units to insure tightness of components and prevent moisture infiltration. Similarly, dry inert gas is used in testing of copper tubing, and coils to prevent corrosion or oxidation. The manufacture and assembly of transistors and other electronic components require exclusion of all moisture, and final testing in dry boxes must be carried out in moisture free atmospheres. The simulation of dry high altitude atmospheres for testing of aircraft and missile components in wind tunnels require extremely low dew-point conditions.

### Liquid Phase Drying

Use of solid adsorbents offers an economic method for removing water from liquid hydrocarbons where high purity is desired and water content is relatively low. This is of particular value for many organic liquids in the petrol-chemical industry. Among liquids which can be dried with good results are: Benzene, toluene, xylene, butane, propane, trichlorethylene, Refrigerants 11 and 12, and methyl chloride.

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CHAPTER 79

# OWNING AND OPERATING COSTS

*Fixed Charges, Amortization, Interest, Taxes, Insurance, Rent, Maintenance Costs, Labor for Operation, Energy Costs, Constant Loads, Electric Refrigeration, Heat-Operated Refrigeration, Water Costs, Heating*

THE total cost for the use of heating, ventilating, and air-conditioning systems may be divided into two classifications. The first of these is the relatively fixed and unvarying expense of ownership, and the second is the variable and somewhat controllable expenditure for actual operation of the equipment. Owners and prospective purchasers of this equipment are particularly concerned with both since the actual expenditure is generally predicated upon the possible return on the investment resulting from increased patronage, greater efficiency on the part of the employees, meeting of competition, or the improvement and maintenance of quality in a manufactured product. These costs may be grouped under four headings: (1) *Fixed Charges*, (2) *Maintenance Costs*, (3) *Labor for Operation*, (4) *Energy Costs*, and (5) *Water Costs*.

## FIXED CHARGES

Fixed charges are the annual expenses arising from the ownership of the installation, including use of the owner's money, and protection of the equipment in the form of insurance. Such costs are usually unchanged from year to year regardless of whether the equipment is in or out of service. Fixed charges may be grouped under five headings: (1) *Amortization*, (2) *Interest*, (3) *Taxes*, (4) *Insurance*, and (5) *Rent*.

### Amortization

As air-conditioning equipment becomes older, its ability or capacity to perform present and future service is reduced. Provision must be made for the owner to recover each year a portion of the initial value of the equipment as an expense to be charged against revenue, or to amortize the cost. This decrease in the value of property is usually determined by an accountant or engineer using some theoretical method and will depend upon (1) the total first cost, and (2) the amortization period.

The total first cost of an installation is the actual capital expenditure required to buy and install the air-conditioning, heating, or ventilating system ready for operation. It represents the first cost of the equipment combined with additional costs incurred because of the installation of the system.

The first cost of air-conditioning, heating, or ventilating systems includes the following:

1. Heat producing equipment including boilers, burners, controls, etc.
2. Heat distributing equipment including direct radiation, piping, etc.
3. Air handling equipment including fans, air heaters, air conditioners, filters, controls, etc.
4. Air distribution system including ducts, outlets, grilles, etc.
5. Refrigerating equipment including piping, pumps, etc
6. Water conservation devices including towers, evaporative condensers, etc.
7. Insulation of pipes, ducts, and equipment.
8. Building alterations, furring-in ducts and pipes, structural work, electrical work, plumbing, fees, permits etc.

To estimate the first cost of any system prior to installation, the best procedure is to determine the heating and cooling load, and then after thorough engineering study, select the type of system. The installed cost of systems will vary widely, depending upon the type of equipment selected, and the design of the distribution system, equipment and labor costs in the locality, demands for the particular installation, etc. A reasonably approximate cost may be determined for a selected design in a given locality from the sum of the estimated unit costs of the component parts of the system. A reasonably precise estimate of the cost of the components may be obtained from cost records of recent installations of a comparable design, or from quotations submitted by manufacturers and contractors.

Approximate costs are given in Table 1 for mechanical air-handling systems including heating and cooling coils for distributing 1½ cfm per square foot of floor area and refrigeration equipment based upon a requirement of one ton for every 333 sq ft of floor area. Different types of service demand may change the floor area per ton of refrigeration and air volume per square foot between wide limits and, consequently, the table should be used with caution.

Other first costs may be incurred because of the installation of the air-conditioning or heating and ventilating system. These will include such items as electrical work, plumbing, miscellaneous piping, building alterations, cutting, patching, furring-in of ducts or pipes, foundations, structural supports, remodeling or redecorating after installation, consulting engineer's fees, licenses, and permits. As these costs vary widely no approximations are practicable. Therefore, each case must be considered individually. If a quotation can be secured from a manufacturer or contractor covering the complete job, it will usually include the items that have been mentioned.

The length of the amortization period to be used depends upon (1) the type and remaining life of the building or space for which the system is to be used; (2) the type of equipment to be employed as a part of the system; (3) the character of the business; (4) lease or ownership conditions; and (5) the taxing authorities.

Depreciation, due to deterioration or obsolescence, must be considered in arriving at the amortization period. Maintenance and deterioration usually have the effect of offsetting one or the other. If a long depreciation period is to be used, then the item for maintenance, repair, and the replacement of wearing parts must be greater than for a short depreciation period.

In determining the length of the amortization period, the