75 and 80 F with ± 1 F deg tolerance. The relative humidity conditions generally maintained are between 45 and 50 percent. Cleaning of the air is generally obtained by both impingement and electrostatic type air filters. Not only must the parts be accurate and clean, but the workers' hands must not impart moisture or dirt to the accurate and delicate parts and surfaces such as jewel bearings and stems which ride in these bearings. Air conditioning has made important contributions towards the increase in accuracy of modern instruments.

Drafting Rooms

Drafting rooms are air conditioned for both precision manufacture and work efficiency. In the first place, designs which are pictured on drawings have to be drawn to scale. In many plants the drawings or reproductions of the drawings are used as templates for the manufacture of working tools or parts, especially in the aircraft industry. Here temperature and humidity control prevent variations in size and distortion in shape. Concerning work efficiency, it has been proven that draftsmen turn out more and better work where uniform air conditions are maintained, and where perspiration and dirt are not allowed to affect the drawing. Conditions in drafting rooms are generally kept at normal comfort levels, usually at 75 F and 50 percent rh with normal variations.

Since drafting rooms are often large, open spaces, special attention has to be given to air distribution. Uniform conditions should be obtained over the room whether near the outside walls or far from them. As draftsmen usually lean over their work, special attention has to be given to keeping the space free from drafts on the backs of their necks.

Aspirating types of air outlet grilles are recommended. Air movements at the working height should not exceed 10 to 30 ft per min. If the room is large or has two or three exposures, it should be zoned.

Blackout Plants

Wartime blackout and other modern windowless plants have generally been one-story buildings extending over large areas. As a result, different methods for air conditioning have been developed. Two general methods have resulted: (1) the conventional method using a central machinery room, or building where a chilled medium and a heating medium have been produced and pumped to many air-handling units, each of which would handle an individual area or zone; (2) the zone-unit system. Cooling machinery, suitably sized for each zone, is located at that zone. The heating equipment may be located at the zone or at a central location. The zone unit system saves one heat exchange as the cooling can generally be done by the direct method. Other advantages are the saving in first and operating cost of such auxiliary equipment as pumps and insulated piping. Both of these methods have been used extensively in these large-area, single-floor plants. The air-handling units for each zone are generally located in roof trusses or in penthouses on the roof.

These air-conditioned factories proved themselves during the war and also since the war for different purposes. The experience confirmed the basis on which they were originally designed and especially the air conditioning. They definitely showed (1) better and more uniform quality of product, (2) increase in production due to conservation of workers' health and energy, (3) reduction of accidents due to fatigue and (4) less absenteeism.

Mining

The heat and humidity encountered in mines may cause higher body temperatures and acceleration of pulse, injurious to productiveness. Dust from mining processes endangers health of workmen; gases, sometimes poisonous or explosive, must be removed. It has been found economical and desirable to air condition gold mines by machinery located at the outdoor level or at lower levels. This permits working of lower levels of mining.

The Rand Mine, in South Africa, uses an air circulation of 400,000 cfm and 7500 gal of water per min circulated to a spray pond. Fans lead to a duct system which enters the vertical shaft 100 ft below the surface. The refrigeration system in this mine has three 750 ton centrifugal machines and a dehumidifier 50 ft × 16 ft wide. The average depth of a gold mine in the vicinity is 4000 ft.

It is believed that mining can be carried on as far below the surface as 12,000 ft, if air conditioning can be provided economically. This means an increase in revenue in the South African mines of $100,000,000 in the value of gold available for every increase of 200 ft in depth. If the depth goes 6000 ft more, three billion dollars worth of gold may become available.

Wet-bulb temperature is the guide to mine conditions; a wet-bulb of 92 F with a velocity of 50 ft per min is the minimum requirement. In the case of a mine producing 150,000 tons monthly at 6000 ft, the heat load appears to be 70,000,000 Btu per hr.

Three methods of cooling are possible: (1) surface refrigeration consisting of a plant to cool air and force it down from the top; (2) underground refrigeration plant (for example, one installation, 6400, ft below the surface, cools 8000 tons of air per day to a maximum temperature of 83 F); (3) compressed air operation of machinery in the mine.

Air conditioning to temperatures below normal by means of well water and refrigeration is practiced in certain coal mines in this country, where trouble is experienced in warm weather with falling roofs. There are various theories as to why roofs are more likely to fall in warm weather, such as (1) the effect of temperature variation on expansion of rocks, (2) weakening of roof material due to wetting, and (3) unknown chemical action. A single set of fans with an air-washer type of cooler was used in the first of the coal mines devoting attention to this problem in 1931. Later a mine in Indiana set up a dehumidifier arrangement by installing sprays in a brick-lined chamber at the foot of the main vertical shaft. Air was blown by motor-driven fans through a course in the horizontal shafts. Water for cooling purposes was available from a flooded, unused portion of the mine, and, after use, was pumped from the spray to another abandoned portion. Temperatures of 50 F were reported in both cases.

Motion Picture Studios

Modern movie stages are large, insulated buildings; the soundproofing makes other treatment necessary for satisfactory occupancy. Lighting, the greatest contributor of heat within, is variable as to amount and duration, and must be correctly controlled. Size and number of sets are variable and create individual problems, and both the number and types of persons on a sound stage play their parts in relation to air conditioning.

High-salaried personnel, often in costume, demand comfort while working. Less time is lost in make-up retouching and less delay brought about by perspiration-dampened costumes, when sets are properly cooled.

An air-conditioning system should have the ability to heat, cool, ventilate, and clean. Stages are generally maintained at 75 F and 50 percent rh, with temperature settings above and below, at the option of the occupants. Floor distribution of air has the advantage of more economical removal of rising heat

but the disadvantage of placing set construction and personnel too near the source of cooling. Overhead distribution has the advantage of better temperature distribution but is less economical in the removal of rising heat from lights.

Film making demands precision manufacture, and air conditioning is necessary. This application is treated more fully in Chapter 30.

Optical Goods

Modern optical instruments such as bomb sights, range finders, telescopes, binoculars, cameras, etc., require extreme care in manufacture in order to obtain optical accuracy. The fundamental part of such devices is the lens. The lens must be ground and polished. In this process, the accuracy required is such as to make air conditioning necessary. The air must be dust-free and temperature constant. The wax in which the lenses are imbedded must be firm. The polishing rooms must be free from air-borne dust and impurities. When the component lenses are assembled into groups, they must be free of dirt and perspiration marks, and the cement must be maintained under constant conditions.

The conditions generally maintained are similar to those in other manufacturing processes, such as 80 F dry-bulb temperature and 50 percent rh. To get the desired cleanliness of air, combinations of impingement and electrostatic air cleaners are often used.

Abrasives

In the precision manufacture of abrasive materials such as sand paper and abrasive wheels, controlled conditions of temperature and humidity contribute much to manufacturing efficiency and quality. Precision depends in many cases on grinding operations, and accurate grinding calls for a high-grade grinding wheel. The quality of the grinding wheel depends in part upon the air conditions under which it is manufactured and used.

Abrasive wheels are normally bonded with materials such as bakelite, clay, hard rubber or sodium silicate; in some cases hygroscopic. Abrasive grains are added when bakelite is in liquid form; the room temperature is controlled to insure constant consistency. When the bonding material is of ceramic clay, relative humidity control prevents lumping of the clay. Unless used (and stored) in an atmosphere free of excessive humidity, deterioration of the wheel will take place. The usual air conditions for the manufacture of abrasives are 78 F dry-bulb temperature and 50 percent rh.

Clay Modeling Rooms

In the automotive industry (and in other industries, as well) clay models of future designs are used extensively. Such models are costly and must be preserved until they have served their purpose. Dry-bulb temperatures of approximately 75 F and relative humidities in the 40 to 60 percent range are used in these rooms.

PART II: LABORATORIES AND TESTING FACILITIES

Laboratory and testing facilities are spaces arranged, equipped and environmentally controlled for experimental and study work. These may be enclosures within a room, one or more rooms in a building or an entire building devoted to particular research, development or testing activity. Such facilities are employed by industrial, educational and governmental agencies for scientific and medical study and for industrial product development.

Environmental requirements for these facilities relating to the regulation of temperature, humidity, pressure, air motion, air cleanliness, sound and vibration are attained and affected by the application of air conditioning, ventilation and refrigeration processes. In order to develop the design of these processes to fulfill required conditions, it is important that requirements are explicitly stated and fully understood. Requirements necessary for design determinations are: (1) design conditions, (2) thermal loads, (3) time during which conditions are to be maintained, (4) air flow rates, (5) air flow patterns, (6) contaminant control, and (7) sound and vibration limits. The definition of these requirements requires close communication between the designer and researcher and a responsibility on the part of the designer to obtain all necessary information and convey to the researcher's full understanding the performance capabilities and limitations of the intended design.

DESIGN CONDITIONS

Exhaust requirements for laboratory and testing facilities for the conveyance of contaminants to the atmosphere require the treatment of large quantities of outdoor air. Selection of outdoor design conditions, therefore, materially affects the size and cost of refrigeration and steam facilities. One degree Fahrenheit difference in outdoor design wet-bulb temperature involves approximately 0.375 tons of cooling capacity per 1000 cfm of outdoor air. Outdoor design data for each locality if not available in standard design references, therefore, should be obtained from local weather bureau or airport weather records. For comfort air conditioning, outdoor conditions commonly employed in the locality or those equalled or exceeded in weather records 5 percent of the time are satisfactory for cooling load computations. For spaces with specified maximum or maintained indoor states, maximum values of outdoor conditions should be applied.

Indoor conditions should be defined in terms of dry-bulb temperature, wet-bulb temperature, or relative humidity with specified tolerances for each value. Indication should be obtained on whether a stated set of conditions represent limiting values or levels to be maintained. For variable temperature rooms corresponding humidity requirements for the specified dry-bulb range should be obtained or an indication whether humidity levels are to be selectively available for any value within the specified dry-bulb range.

HOURS OF OPERATION

The periods during which specific indoor states are to be maintained in particular laboratory spaces bear directly on whether such spaces will be served by individual ventilation, air conditioning and refrigeration systems operable at any time of the day or year or by central plants operating on common daily and seasonal schedules. A system designed to continuously maintain and limit the dry-bulb temperature of an interior laboratory space when operating at a dew point of 55 F or less requires mechanical refrigeration which automatically operates whenever the outside dry bulb exceeds 55 F. It is erroneous to assume that, because a system serving such space operates on 100 percent outdoor air, it will be capable of fulfilling conditions during the winter season without mechanical refrigeration. A dry-bulb temperature of 55 F is frequently exceeded during the winter months. Requirements relating to the hours and seasonal periods during which specified conditions are to be maintained should be specifically expressed.

THERMAL LOADS

Transmission, solar, lighting, and occupant room sensible and latent load components are supplemented in laboratories