crew and equipment, demand too much heat to be supplied in this manner. The recovery of heat from waste gases is therefore imperative. In airplane operations light weight is a more important requirement than in any other type of transportation. Noise should be reduced to a minimum and combined use may be made of material for insulating and noise reduction.

REFERENCES

RAILWAY PASSENGER CARS

Report on Performance and Cost of Operation of 1937 Internal Combustion Engine Mechanical Compression Equipment for Air Conditioning Railroad Passenger Cars, by Division of Equipment Research, *Association of American Railroads*, May 1, 1937.

Report on Relative Performance of Air Filters, by Mechanical Division, *Association of American Railroads*, January 15, 1938.

Air Conditioning of Railroad Passenger Cars, by L. W. Wallace and G. G. Early, Jr. (*A.S.M.E. Transactions*, November, 1937).

Passenger Car Cooling Methods, by Kenneth Cartwright (*Refrigerating Engineering*, February, 1936, p. 83 and March, 1936, p. 158).

Diesel Drive for Passenger Air Conditioning, by J. R. Hornaday (*Refrigerating Engineering*, March, 1942, p. 139).

Railroad Air Conditioning, by Gordon T. Wilson (*Refrigerating Engineering*, May, 1943, p. 323).

BUSES AND AUTOMOBILES

Bus Heating, by E. T. Todd and F. O. Gadd (*Heating and Ventilating*, Dec. 1946, p. 83).

Air Conditioning of Automobiles and Buses, by L. W. Child (*Society of Automotive Engineers Journal*, June, 1938).

Bus Air Conditioning, by Jerry Hicke (*Heating, Piping and Air Conditioning*, October, 1938, p. 639).

Bus Air Conditioning, by A. J. Mallinckrodt and Lars Hanson (*Refrigerating Engineering*, June, 1939, p. 388).

Problems in Air Conditioning Automobiles, by F. J. Linsenmeyer (*Society of Automotive Engineers Journal*, July, 1939).

AIRPLANES

Comfort in High Altitude Flying, by D. W. Tomlinson (A.S.H.V.E. TRANSACTIONS, Vol. 47, 1941, p. 57).

Heat Exchangers for Aircraft, by Arthur J. Hess (*Refrigerating Engineering*, September, 1944, p. 192).

Heating and Ventilating for Transport Airplanes, by B. M. Brod (A.S.H.V.E. TRANSACTIONS, Vol. 52, 1946).

Comfortization of Aircraft, by Albert A. Arnhym, (Pitman Publishing Corp., New York, 1945).

Refrigeration for Air Conditioning Pressurized Transport Aircraft, by B. L. Messinger, (*Heating and Ventilating*, January, 1946, p. 63).

Chapter 49

MARINE HEATING, VENTILATION, AIR CONDITIONING

General Considerations, Ship Construction Features, Factors Affecting Design, Ventilation Requirement for Various Types of Space, Air Conditioning Space Treatment, Typical Air Conditioning Systems, Types of Refrigerating Systems, Dehumidification, Ship Insulation

THE importance of adequate shipboard heating, ventilation, and air conditioning arrangements cannot be overemphasized. Installations must be designed to keep the passengers comfortable and the operating personnel physically and mentally fit. The provision of satisfactory living and working conditions is one of the most economical means of keeping a high morale.

GENERAL CONSIDERATIONS

A ship must be self-sufficient and provide for all human needs. Facilities must be limited to the minimum space and weight practicable to conserve dead weight and to increase the pay load. The pay load may be expressed in terms of cargo carrying ability, passenger carrying capacity, fighting strength, or towing ability.

Conditions in living spaces must permit adequate rest and comfort. Passenger accommodations must be treated to provide service and living conditions similar to those afforded by the various classes of hotels. Many of the expedients used ashore for this purpose are not applicable afloat. For instance, all living quarters aboard ship cannot be located at a distance from the power plant, but must often have boundaries in common with heat producing spaces. The thermal conductivity of shipbuilding materials such as steel, copper, brass, etc., is many times the value for building materials used ashore, and this, together with concentrated arrangement of equipment, produces a difficult heat transfer and insulation problem. Furthermore, the use of portholes, windows, skylights, and similar openings is greatly restricted in marine applications because of the necessity for strength, water-tightness and protection from the sea in foul weather. During wartime, the utility of portholes, windows, and skylights is greatly restricted because they must be fitted with light-excluding devices.

Mechanical ventilation is absolutely necessary for most shipboard spaces to enable the crew to operate the vessel, to prevent the accumulation of objectionable combustible and toxic gases, and to preserve stores and cargo. Shipboard equipment must also be reliable inasmuch as specialized servicing facilities are not available at sea and failure during an emergency may jeopardize the vessel's safety. Adequate spare parts form an integral part of all equipment furnished. Experience has demonstrated that *simple* and *foolproof* heating, ventilating, and air conditioning arrangements are essential for satisfactory service. The only variation between ship and shore applications is that emphasis is placed on different practical aspects of the design.

SHIP CONSTRUCTION FEATURES

The seaworthiness of a vessel is increased by subdividing the main hull space into a number of watertight compartments, so arranged that the vessel