of the various materials in series comprising the section. The overall permeance of an insulated section is equal to the reciprocal of the overall resistance.

The discussion and equations presented above and in Chapter 23 for estimating water vapor flow provide a design procedure only which is based on several assumptions. Forces other than water vapor pressure, such as hydraulic pressure, absorption, adsorption, hygroscopicity and capillarity, affect water vapor flow and cause moisture migration. These various forces are interrelated but the actual relationship is very complex, and has not been expressed in a simple way for design use.

Fortunately, in many cases consideration of water vapor pressure differences alone can be used to obtain a fairly accurate calculation of the water vapor flow. This consideration is useful in designing vapor barrier systems or in preventing the possibility of condensation within a given insulated section.

Water vapor may also be transferred as part of a moving air stream caused by convection currents or air infiltration. This means of water vapor transfer is similar to that of transfer of heat by air leakage, and in many instances it constitutes the major means.

TYPES OF VAPOR BARRIERS

Water vapor barriers may be classified as structural, membrane, or coating barriers.

Structural barriers include rigid sheets, such as reinforced plastics, aluminum, stainless steel; and rigid insulation types which are relatively impervious to water vapor flow due to their physical structure and composition. These barriers usually are fastened in place by mechanical means, and also have provision for vapor sealing at joints.

Membrane barriers include metal foils, laminated foil and treated papers, coated felts and papers, and plastic films or sheets. Such barriers are flexible and are supplied in roll form or as an integral part of the insulation. Accessory materials are required for sealing joints.

Coating barriers may be of the semi-fluid *mastic* type, the more fluid (paint) type arbitrarily called *surface coatings*, or the hot melt type. Their basic composition may be asphaltic, resinous or polymeric, with or without pigments and solvents as required to meet design condition. Application may be by spray, brush, trowel, roller, dip or mop, depending upon type of coating and insulation.

Properties

A water vapor barrier does not necessarily *stop* the flow of vapor, but serves as a medium of control to *reduce* the rate and volume of flow.

In refrigeration and air-conditioning applications, and in buildings, water vapor barriers are applied to thermal insulation on cold pipes, ducts, refrigerated enclosures, and structures. Their function is to prevent accumulation of water within the insulation or construction. By retarding water vapor transmission, water vapor barriers help to (1) keep the insulation dry, and reduce the heat load requirements for the cooling system; (2) prevent structural damage by rot, corrosion, or the expansion effect of freezing water, and (3) reduce paint problems on exterior wall construction.

In addition to the rate of water vapor transmission, other properties of barriers are important, depending upon the type of barrier, and its application. These properties include mechanical strength in tension, shear, impact and flexure; adhesion; elasticity; thermal stability; fire and flammability resistance; inertness to other deteriorating elements; and ease of fabrication, application and joint sealing. The permeance of various building materials and several water vapor barriers is given in Table 1, Chapter 23.

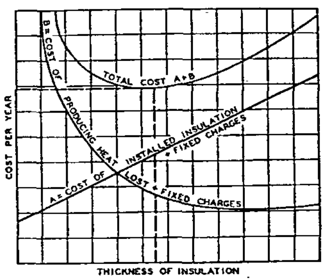

Fig. 3 . . . . Determination of Economic Thickness of Insulation

EFFECTIVENESS OF VAPOR BARRIERS

The effectiveness of any vapor barrier in preventing water accumulation depends upon its permeance and also on its location within the insulated section. It is to be emphasized that the vapor barrier must be applied to the surface exposed to the higher water vapor pressure. For most applications this will be the warm side. Under conditions of *reversible* water vapor flow, the selection and location of water vapor barriers require special study and treatment.[13]

The effectiveness of a barrier system may be greatly reduced if openings, even though very small, exist in the barrier. Such openings may be caused by poor workmanship during application, poorly sealed joints and edges, insufficient coating thickness, improper caulking and flashing, uncompensated thermal expansion, mechanical forces, aging, and other forms of deterioration.

PART III: ECONOMIC THICKNESS OF INSULATION

The costs involved in insulating either heated or refrigerated equipment, air conditioned rooms, pipes, ducts, tanks, and vessels are of a magnitude to warrant careful consideration of type and quantity of material to be used. The economic thickness is that which will pay for itself over a given period of time while producing a specified return on capital expenditure. At this thickness the sum of the annual cost of heat loss or heat gain and insulation is a *minimum*. As the thickness of insulation increases the annual cost of heat loss (or heat gain) decreases, but the annual cost of insulation (first cost multiplied by a percentage for fixed charges) increases. The sum of the two costs will first decrease with increasing thickness of insulation, and then, depending on operating conditions, will increase beyond a certain thickness (see Fig. 3). Therefore, the thickness at which the sum of the costs is a minimum, is the most economical. (See also Reference 14.)

The cost of heat gain or heat loss is the cost of producing the heating or cooling effect for a year, and includes operating costs, such as water, power for the compressors, and maintenance.

The cost of insulation should include the initial installed cost plus the fixed charges including interest, maintenance, and depreciation based on the expected life of the facility.

Other factors which may modify purely economical considerations are: (1) the need to avoid surface condensation;

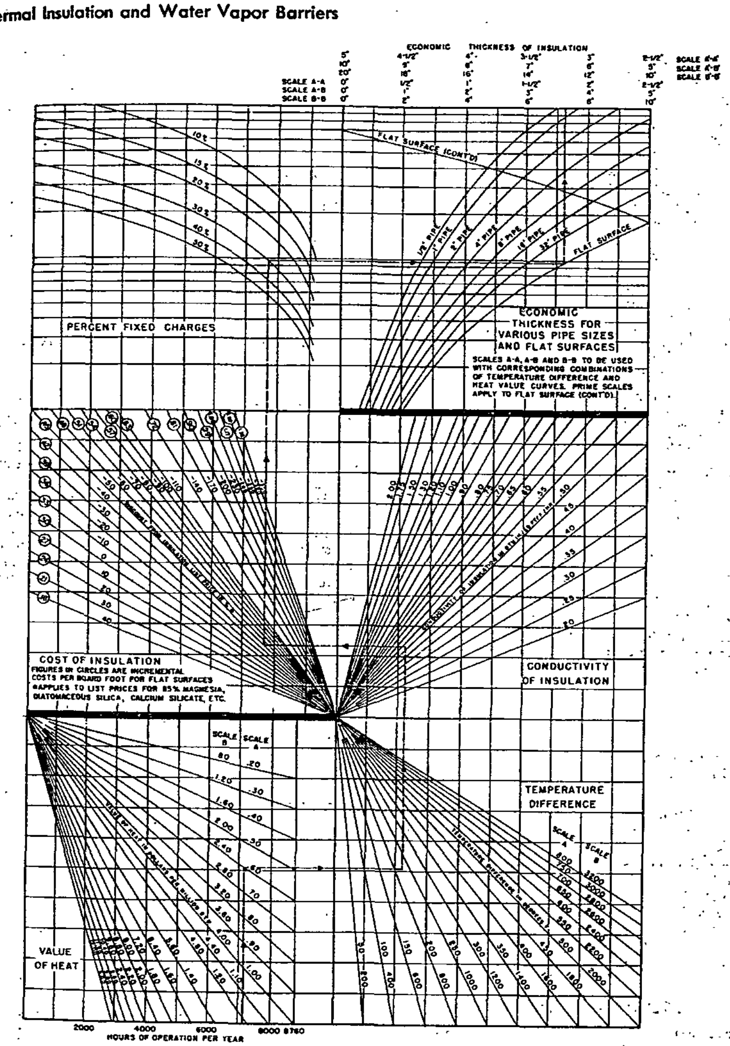

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Fig. 4 . . . . Chart for Determining Economical Thickness of Pipe Insulation