

Table 2 Selected Characteristics of Wide-Range Heat Transfer Fluids

Property	Fluid						Dewaxed Kerosene
	Water	60% Ethylene Glycol + H ₂ O	Ref-1120 Trichloroethylene	Ref-11	Methanol	Ref-30 Methylene Chloride	
Boiling Pt. F	212	223	+88 to 190	75	147 to 151	104	309
Freezing Pt. F	32	-60	-124	-168	-144	-142	-120
Density at 68 F	1.0	1.08	1.46	1.49	0.79	1.33	0.80
Specific Heat at 68 F	1.0	0.82	0.23	0.21	0.60	0.27	0.50
Viscosity, cp at 68 F	1.0	4.7	0.58	0.44	0.59	0.44	0.4*
at -40 F	—	185	1.17	0.98	1.9	0.88	1.45
at -100 F	—	—	2.08	1.8	5.0*	1.60	5/10*
Thermal conductivity at 68 F	0.346	0.225	0.06	0.06	0.12	0.09	0.07*
Heat carrying ability Btu per (sq) (gpm) (F deg)	500	368	165	156	239	183	200
Turbulent heat transfer at -40 F, % ^b	—	5.3	33.5	34.9	35	44.5	24.8

* These values are estimated.

^b Based on heat transfer of water flowing at velocity of 50 fpm.

can be used and offer the advantages of a rapid response because of their low thermal mass. All types of electric heaters require the use of proper insulation and protection against moisture. Generally speaking, temperature test chambers (dry bulb control) may use open wire resistance heaters although condensation at low temperature may produce excessive moisture and corrosion on the heaters. Humidity chambers should include a sealed type of heating system such as the metal sheathed tubular heater with terminals brought to the exterior of the chamber structure to guard them against the humidity and breathing effects of cycling. Salt-spray chambers are usually heated by an indirect means such as circulating heated water or air around the outside of the chamber shell outside the salt-fog atmosphere. Heaters for sand and dust chambers must use sheathed heaters which have good resistance against the erosion of the high velocity sand and dust. Explosion-proof testing chambers contain an explosive fuel and air mixture. Heaters must have temperature limiting devices on the sheath with terminals extended to the outside to prevent ignition of the mixture.

Altitude and space chambers present very special heat problems. Arcing between terminals under vacuum conditions must be guarded against. It is general practice to bring the terminals to the outside of the vacuum space through a vacuum tight fitting. The reduced convective heat transfer of a heater under vacuum must be considered in the design to prevent burnout. Thermally and mechanically bonding of sheathed heaters to the exterior wall of the vacuum structure has been successfully used to avoid some of these problems. Internal forced convection heating is usually suitable up to about 50,000 ft of altitude (approximately 0.1 atmosphere).

Indirect heating is also very suitable for environmental

chambers. Hot water, steam, brines, and oils can be used in coils in various configurations. These heating systems are particularly applicable where very close tolerances must be provided within the system because complete modulation can be used. Modulation control is also used in electrical resistance heating systems by means of use of power proportioning equipment. Hot water recirculating systems and steam systems can be used with relatively standard design approaches. Complete drainage of the coils and piping within the chamber must be assured if the chamber will be operated below freezing. Proper water treatment should be provided.

Many brines and heat exchange fluids which are not limited to the temperature ranges of water or steam are available. No one fluid for the commonly required wide ranges of environmental test equipment (such as -100 F to +500 F) is available at present. Most chemical brines present some problems of viscosity, toxicity, flammability, chemical reaction with the piping and other limitations. Any heat exchange fluid must be carefully evaluated for limitations.

The above discussion is primarily concerned with non-radiant heating systems used to duplicate the conditions found in storage and transportation and when a protective housing is provided around the equipment. Radiant type heating systems are required to simulate situations such as sun exposure wherein both the heat flux density and the wave length are important and more commonly in equipment which is exposed to radiation from some high temperature source. Radiant sources used in environmental chambers vary from exposed nichrome wire heaters to specialized equipment such as arc lamps and mercury Xenon lamps used to simulate sunshine in outer space. Since the wave length of the source is a function of its temperature, the conditions to be simulated

must be understood before a suitable radiant heat source can be designed. Where the problem is simply to produce high watt density on the product to be tested, bare nichrome wires, sheathed heaters, carbon and silicon carbide rod heating elements and similar devices can be used. Tubular quartz heat lamps are often suitable for very rapid heat-up conditions. Carbon arc and mercury Xenon lamp temperatures produce wave lengths which will simulate the wave length of sunshine in outer space. Sunshine at sea level is usually simulated by the use of mercury vapor lamps or combinations of tungsten filament heat lamps to produce the proper wave length and watt density. Radiant heating systems may be required to produce heat densities in excess of 125 kw per sq ft. Careful design of the chamber structure, proper support of the heating elements, and the location of the heating elements are required to prevent problems due to the mechanical and thermal stresses which result from large temperature differentials and rapid heat-up and cool-down cycles.

Humidification

Common means of raising the relative humidity within a test enclosure include direct introduction of low pressure steam, vaporizing water by electric immersion heaters in an open evaporator, and direct atomizing water sprays alone or in combination with electric heaters to aid vaporization of the spray.

Steam and vapor generators are best used for producing high humidities at temperatures well above ambient since considerable sensible heat is introduced. Control of steam may be modulating or on-off. With the latter, anticipation is suggested to minimize over-run due to a too rapid rise in moisture content. When self-contained steam generators are used, they should include a low water cut-off device, suitable pressure relief valves, and other safety devices. Make-up water should be provided from a distilled or demineralized source.

Atmospheric pressure vapor generators operating at atmospheric pressure are commonly used when it is desirable to produce test conditions of 95 ± 5 percent relative humidity at temperatures between 100 and 160 F. Protection against immersion heater burnout is mandatory for good design.

For production of high humidities at temperatures near and below ambient temperature some form of water spray is best due to the adiabatic cooling effect upon evaporation. Although water spray systems do not have as rapid response as steam, this is no disadvantage at lower temperatures where the humidity ratio is low. By controlling the temperature of the sprayed water, both humidification and dehumidification can be achieved with a single system. Heating and cooling means may be located either inside the conditioning spray plenum or externally in the recirculating water circuit. Very close control of humidities is possible with such a design approach. Distilled or demineralized water is suggested because tap water may be contaminated. Recirculating spray systems should be periodically flushed out because of possible contamination of equipment or test parts from the air stream.

Air Movement

All types of fans and air movers are used in test chambers. Special problems include the effects on the fan characteristics of widely varying air densities due to extreme temperature and altitude simulations. The combined high humidity and temperature conditions made equipment protection necessary against special corrosion and mechanical stress. Consideration must also be given to protection of the drive from the en-

vironment. Propeller, axial flow, or centrifugal fans are most generally employed. Positive displacement or multi-stage turbine type blowers are used to obtain the necessary total pressure for ram air simulation under altitude conditions. Drives for internally mounted fans must be located externally when extreme conditions are encountered in the air stream. To eliminate corrosion and minimize heat transmission, stainless steel shafts are commonly used. In almost all instances, a vapor seal is required to eliminate or minimize transmission to or from the ambient air. If internal bearings are used, they must withstand the full range of environmental conditions with a reasonable life expectancy. Altitude chamber fan shafts must be equipped with vacuum tight shaft seals.

Air distribution within the workspace of the test equipment is important in order to produce uniform gradient conditions throughout the test space and good control system response. Frequently, close temperature gradients specified for air circulation rate and distribution will complicate the control problem. Air densities may vary almost three to one in temperature test chambers, and more than fifty to one in altitude test chambers. Therefore, motor sizing and speed control of fans require careful attention.

The air flow for a specific gradient is directly proportional to the net heat gain or loss in the works pace and inversely proportional to the permissible temperature gradient and density of the air.

Usually the air volume must be increased at elevated temperatures due to the lower density. The circuit pressure drop will be approximately proportional to the air density. Therefore, the system balance points should be determined from the fan characteristic curves for various operating range conditions in the chamber.

Dehumidification

Low humidity conditions with controlled dew points above freezing usually are produced by mechanical refrigeration cooling and electric reheating because most environmental chambers require mechanical refrigeration for extended dry-bulb temperature range control. For production and control of humidity conditions requiring dew points below freezing and continuous operation, either dual evaporators alternately defrosted or automatically regenerating desiccant dehumidifiers are used. If an enclosure is sufficiently vapor tight, and there is no internal latent load, a sufficiently large evaporator to handle the frost build-up due to initial latent load may be an acceptable solution.

Ram air coolers which simulate the cooling air supply for electronic airborne equipment at controlled temperature, humidity, and altitude conditions present special dehumidification problems. If 100 percent outdoor air is required, it is best handled by a wet coil which removes a large part of the moisture just above freezing, followed by a set of parallel alternately defrosted evaporators. For ram air-simulators in a closed loop arrangement, simpler systems are possible if the cooling of air does not involve dehumidification.

When using certain liquid or solid desiccants in very high or low dry-bulb ranges, mechanical refrigeration cooling may be required for precooling or after-cooling. In such systems, a portion of the chamber air is continuously withdrawn by an auxiliary blower and passed through the drying agent and any necessary precooling or after-cooling coils.

ALTITUDE AND SPACE SIMULATORS

For many years altitude chambers have been common equipment in environmental laboratories. These have cus-