Table 17 .... Effect of Temperature on Capacity*
(Constant Compressor Displacement—4 cfm.)

Evap. Temp. F	Capacity—Btu per Hour, Condensing Temperature, F: 60	80	100	120
Refrigerant 12				
−20	5,240	4,790	4,320	3,841
0	8,280	7,590	6,890	6,160
20	12,590	11,580	10,550	9,470
40	18,510	17,080	15,620	14,090
Refrigerant 22				
−20	8,672	7,987	7,279	6,536
0	13,518	12,479	11,402	10,277
20	20,303	18,782	17,203	15,553
40	29,553	27,386	25,139	22,789

* See Reference 16 for Refrigerant 12 data, Refrigerant 22 values calculated using tables in Chapter 20.

Table 18 .... Effect of Temperature on Theoretical Horsepower per Ton*

Evap. Temp. F	Condensing Temperature F: 60	80	100	120
Refrigerant 12				
−20	1.03	1.36	1.76	2.24
0	0.70	0.99	1.33	1.73
20	0.43	0.68	0.97	1.31
40	0.20	0.42	0.67	0.95
Refrigerant 22				
−20	1.03	1.37	1.77	2.24
0	0.71	1.01	1.34	1.74
20	0.44	0.69	0.98	1.32
40	0.20	0.42	0.67	0.97

* See Reference 16 for Refrigerant 12 data. Refrigerant 22 values calculated using tables in Chapter 20.

Table 19 .... Relative Safety of Refrigerants

Refrigerant No.	Refrigerant Name	ASA-B9 Safety Code Group	Underwriters' Laboratories Group Classification	Explosive Limits in Air % by Volume
50	Methane	3ª	5b	4.9 to 15.0
14	Tetrafluoromethane	1ª	6ª	Nonflammable
1150	Ethylene	3ª	5b	3.0 to 25.0
744A	Nitrous Oxide			Nonflammable
13	Monochlorotrifluoromethane	1ª	6*	Nonflammable
170	Ethane	3	5b*	3.3 to 10.6
744	Carbon Dioxide	1	5*	Nonflammable
13B1	Monobromotrifluoromethane	1ª	6	Nonflammable
290	Propane	3	5b*	2.3 to 7.3
22	Monochlorodifluoromethane	1	5a**	Nonflammable
717	Ammonia	2	2*	16.0 to 25.0
500	...	1	5a	Nonflammable
12	Dichlorodifluoromethane	1	6*	Nonflammable
40	Methyl Chloride	2	4*	8.1 to 17.2
601	Isobutane	3	5b	1.8 to 8.4
764	Sulfur Dioxide	2	1*	Nonflammable
600	Butane	3	5*	1.6 to 6.5
114	Dichlorotetrafluoroethane	1	6*	Nonflammable
21	Dichloromonofluoromethane	1	4–5†	Nonflammable
160	Ethyl Chloride	2	4a*	3.7 to 12.0
11	Trichloromonofluoromethane	1	5*	Nonflammable
611	Methyl Formate	2	3*	4.5 to 20.0
30	Methylene Chloride	1	4a*	Nonflammable
113	Trichlorotrifluoroethane	1	4–5‡	Nonflammable
1130	Dichloroethylene	2	4*	5.6 to 11.4

* Underwriters' Laboratories Report MH-2375.
** Underwriters' Laboratories Report MH-3134.
† Underwriters' Laboratories Report MH-2630.
‡ Underwriters' Laboratories Report MH-3072.
ª Unofficial.

Table 20 .... Underwriters' Laboratories Classification of Comparative Hazard to Life of Gases and Vapors

Group	Definition	Examples
1	Gases or vapors which in concentrations of about ½ to 1 percent for durations of exposure of about 5 minutes are lethal or produce serious injury.	Sulfur Dioxide
2	Gases or vapors which in concentrations of about ½ to 1 percent for durations of exposure of about ½ hour are lethal or produce serious injury.	Ammonia, Methyl Bromide
3	Gases or vapors which in concentrations of about 2 to 2½ percent for durations of exposure of about 1 hour are lethal or produce serious injury.	Carbon Tetrachloride, Chloroform, Methyl Formate
4	Gases or vapors which in concentrations of about 2 to 2½ percent for durations of exposure of about 2 hours are lethal or produce serious injury.	Dichloroethylene, Methyl Chloride, Ethyl Bromide
Between 4 & 5	Appear to classify as somewhat less toxic than Group 4.	Methylene Chloride, Ethyl Chloride
	Much less toxic than Group 4 but somewhat more toxic than Group 5.	Refrigerant 113
5a	Gases or vapors much less toxic than Group 4 but more toxic than Group 6.	Refrigerant 11, Refrigerant 22, Carbon Dioxide
5b	Gases or vapors which available data indicate would classify as either Group 5a or Group 6.	Ethane, Propane, Butane
6	Gases or vapors which in concentrations up to at least about 20 percent by volume for durations of exposure of about 2 hours do not appear to produce injury	Refrigerant 12, Refrigerant 114, Refrigerant 13B1

Safety

The characteristics of a number of refrigerants are summarized in Table 19 with respect to toxicity and flammability. In ASA Standard B9.1-1964, refrigerants are classified in three groups, depending on the hazard. Group 1 refrigerants are considered the least hazardous and Group 3 the most hazardous. The Underwriters' Laboratories' Classification system is based on acute toxicity tests on guinea pigs. The significance of the Underwriters' Groups is shown in Table 20.

LEAK DETECTION

The detection of leaks in refrigeration equipment is a major problem for both manufacturers and service engineers. Several methods of leak detection will be described.

Electronic Detector

The electronic detector is widely used in the manufacture and assembly of refrigeration equipment. The operation of the instrument depends on the variation in current flow due to ionization of decomposed refrigerant between two oppositely-charged platinum electrodes. This instrument can be used to detect any of the halogenated refrigerants except Refrigerant 14. It is not recommended for use in atmospheres containing explosive or flammable vapors. Some other vapors, such as alcohol and carbon monoxide, may interfere with the test.

The electronic detector is the most sensitive of the various leak detection methods, reportedly capable of sensing a leak of 1/100 oz per year of Refrigerant 12, or approximately 1×10^{-6} cc per second.

A portable model is available for use in field testing. Other models are available with an automatic balancing system which corrects for refrigerant vapors that might be present in the atmosphere around the test area.

Halide Torch

The halide torch has been used for many years as a fast and reliable method of detecting leaks of halogenated refrigerants. Air is drawn over a copper element heated by a methyl alcohol or hydrocarbon flame. If halogenated vapors are present, they will be decomposed and the color of the flame will change to bluish-green. Although not as sensitive as the electronic detector, this method is suitable for most purposes.

Bubble Method

The object to be tested is pressurized with air or nitrogen. A pressure corresponding to operating conditions is generally used. The object can be immersed in a water bath and any leaks detected by observing the formation of bubbles in the liquid. Addition of a detergent to the water will decrease the surface tension and prevent escaping gas from clinging to the side of the object and will promote the formation of a regular stream of small bubbles. Kerosine or other organic liquids are sometimes used for the same reason. A solution of soap or detergent can be brushed or poured onto joints or other spots where leakage is suspected. Leaking gas will form soap bubbles which can be readily detected.

Detection of Ammonia and Sulfur Dioxide Leaks

Ammonia can be detected by burning a sulfur candle in the vicinity of the suspected leak or by bringing a solution of hydrochloric acid near the object. If ammonia vapor is present, a white cloud or smoke of ammonium sulfite or ammonium chloride will be formed. Ammonia can also be detected with any indicating paper which changes color in the presence of a base.

Sulfur dioxide can be detected by the appearance of a white smoke when aqueous ammonia is brought near the leak.

The presence of leaks can also be determined by pressurizing or evacuating and observing the change in pressure or vacuum over a period of time. This is a good practice in checking on the tightness of a system but is of little help in locating the point of leakage.

EFFECT ON CONSTRUCTION MATERIALS

Metals

The halogenated refrigerants can be used satisfactorily under normal conditions with most of the common metals, such as steel, cast iron, brass, copper, tin, lead and aluminum. Under more severe conditions, the various metals will affect such properties as hydrolysis and thermal decomposition in differing degrees. The tendency of metals to promote thermal decomposition of the halogenated compounds is in the following general order:

(Least decomposition) Inconel < 18-8 stainless steel < nickel < copper < 1340 steel < aluminum < bronze < brass < zinc < silver (most decomposition).

This order is only approximate and exceptions may be found for individual compounds or for special conditions of use. The effect of metals on hydrolysis would probably be similar.

Magnesium, zinc, and aluminum alloys containing more than 2 percent magnesium are not recommended for use with halogenated compounds where even trace amounts of water may be present.

Methyl chloride should never be used with aluminum in

Table 21 .... Swelling of Elastomers in Liquid Refrigerants at Room Temperature[17]

Refrigerant No.	Refrigerant Name	Linear Swell, Percent: Buna N	Buna S (GR-S)	Butyl (GR-I)	Natural Rubber	Neoprene GN	Thiokol FA
11	Trichloromonofluoromethane	6	21	41	23	17	2
12	Dichlorodifluoromethane	2	3	6	6	0	1
13	Monochlorotrifluoromethane	1	1	0	1	0	0
21	Dichloromonofluoromethane	48	49	24	34	28	28
22	Monochlorodifluoromethane	26	4	1	6	2	4
30	Methylene Chloride	52	26	23	34	37	59
40	Methyl Chloride	35	20	16	26	22	11
113	Trichlorotrifluoroethane	1	9	21	17	3	1
114	Dichlorotetrafluoroethane	0	2	2	0	2	0
600	Butane	1	8	20	16	3	0