The Rise and Fall Of Carbon Dioxide Systems

The First Century Of Air Conditioning

This is the fifth article in our special series to commemorate a century of innovation in the HVAC&R arts and sciences.

By William S. Bodinus, P.E.
Fellow/Life Member ASHRAE

Carrier Brunswick sales group, December 1930. The author is seated on the bottom row to the far left.

The application of carbon dioxide (CO_2) refrigeration systems for comfort air cooling reached its highest point in the 1920s. In the early 1930s, new CO_2 refrigerating systems for air-cooling and cold storage applications practically disappeared. The Depression caused a significant reduction in the number of installations and the advent of R-12 for comfort-cooling systems replaced the use of CO_2 as the "safe" refrigerant. During this time, a number of established refrigeration companies manufacturing ammonia compressors also made a line of carbon dioxide compressors. This enabled them to participate in the growing market for comfort cooling.

CO_2 in the 19th Century

In the ASHRAE book *Heat and Cold: Mastering the Great Indoors*, the historical use of carbon dioxide as a refrigerant is explained as follows:

Carbon dioxide (also known as carbonic acid gas and carbonic anhydride) was first proposed as a refrigerant for vapor-compression systems by Alexander Twining, who mentioned it in his 1850 British patent. Thaddeus S.C. Lowe experimented with carbon dioxide for military balloons in the 1860s and recognized the possibilities of using it as a refrigerant. He went on to build refrigerating equipment obtaining British Patent 952 in 1867 and erected an ice machine about 1869 at Jackson, Miss. He also constructed a machine on board a ship for the transport of frozen meat in the Gulf of Mexico. Lowe did not develop his ideas further.

Carl Linde also experimented with carbon dioxide when he designed a machine for F. Krupp at Essen, Germany, in 1882. W. Raydt received British Patent 15475 in 1884 for a compression ice-making system using carbon dioxide. British Patent 1890 was granted to J. Harrison in 1884 for a device for manufacturing carbon dioxide for refrigerant use. Still, the use of carbon dioxide really did not advance until Franz Windhausen of Germany designed a carbon dioxide compressor, receiving British Patent 2864 in 1886. Windhausen's patent was purchased by J&E Hall of Great Britain, who improved it, commencing manufacture about 1890. Hall's carbon dioxide machine saw widespread application on ships, replacing the compressed air machines theretofore used. Carbon dioxide machines were used universally on British ships into the 1940s, after which they began to be displaced by chloroflourocarbon refrigerants. In the U.S., carbon dioxide was used successfully beginning in the 1890s for refrigeration and in the 1900s for comfort cooling. Its principle advocate in the U.S. was Kroeschell Bros. Ice Machine Company, which manufactured systems under patents purchased from the Hungarian Julius Sedlacek."[1]

About the Author

William S. Bodinus, P.E., started his career in air conditioning in 1930 as an engineer with the Brunswick-Kroeschell Division of Carrier Corporation. Having turned 90 this February, he is still actively working as an engineer at E.H. Gustafson Company in Chicago.

Pioneering CO_2 Companies

In 1897, the Kroeschell Bros. Boiler Company had formed a separate company in Chicago for manufacturing CO_2 compressors called Kroeschell Bros. Ice Machine Company. The Kroeschell plant manufactured CO_2 refrigerating compressors, condensers, water and brine coolers, high-pressure CO_2, valves and fittings for cold storage systems. In 1924, Kroeschell merged with the Brunswick Refrigeration Company of New Brunswick, N.J., which manufactured ammonia compressors and appurtenances.

In 1915, Fred Wittenmeier, who had worked in the Kroeschell refrigeration division, resigned and formed another CO_2 refrigeration machine company in Chicago. The Wittenmeier Company manufactured a line of horizontal, double-acting compressors very similar to the Kroeschell line. The company, after ceasing to manufacture compressors in the 1930s, became a refrigeration contractor managed by his son for many years.

The Wolf Linde Company had become a large manufacturer of ammonia compressors in the last quarter of the 1800s and early 1900s and was a lesser factor in the manufacture of CO_2 compressors and CO_2 refrigerating systems. Their big business was ammonia systems for breweries, packing plants and other large cold storage applications. Other companies that manufactured CO_2 machines for air-cooling included the Carbondale Machine Company in Pennsylvania and the American Carbonic Machinery Company.

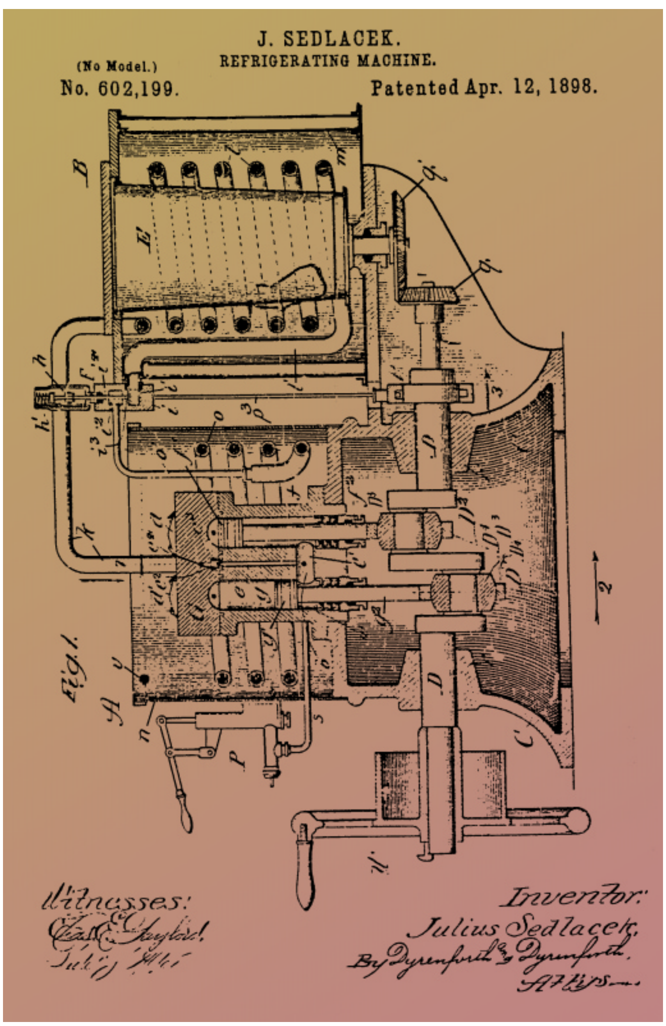
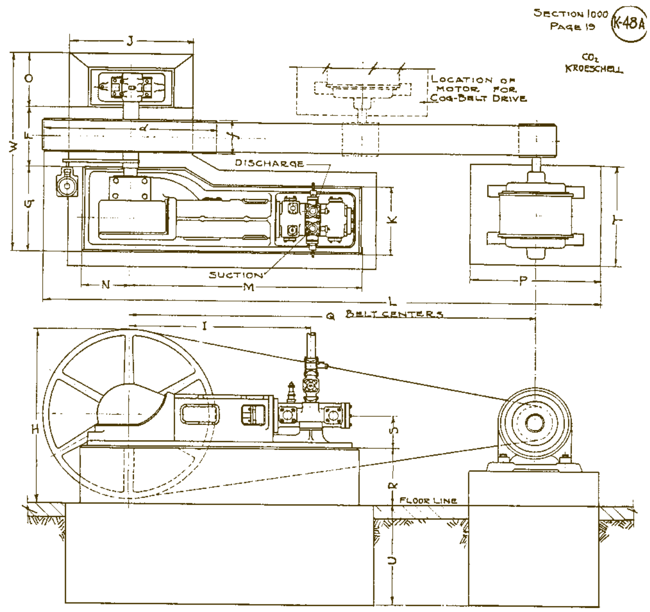


Figure 1: Page from Julius Sedlacek's patent for a refrigerating machine, 1898.



	H-9	H-12	H-15	H-19		H-9	H-12	H-15	H-19
F	17"	24¼"	2'-6	3'-1½"	U	2'-6"	3'-0"	4'-6"	5'-0"
G	2'-7"	2'-11½	3'-8"	4'-2"	W	5'-8	7'-0"	8'-4	9'-10½
H	5'-6"	6'-3"	6'-9"	8'-6"	d	60"	72"	90"	120"
I	5'-0½	6'-3¾	7'-7"	9'-3	f	13"	19"	25"	31½"
J	3'-6"	4'-4"	5'-0"	5'-8"	DISCH	2"	2½"	3"	3½"
K	2'-2"	2'-4½"	2'-9"	3'-1½"	SUCT	2"	2½"	3"	3½"
L	18'-6"	21'-6"	24'-9"	28'-0"	LIQ	¾"	1"	1¼"	1½"
M	6'-7"	8'-0"	9'-6"	11'-6"					
N	17"	20"	2'-0"	2'-4"					
O	20"	23¾"	2'-2"	2'-7"	V	1 9/16"	1 15/16"	2 5/16	2 13/16"
P	4'-0"	5'-0"	6'-0"	6'-0"	VV	52"	83	124	200
Q	14'-0"	16'-0"	18'-0"	20'-0"	X	22½"	30"	37½	47½"
R	2'-0½"	2'-1½"	19"	21"	Y	59"	105	179	310
S	11½"	13½"	17"	21"	Z	58	102	166	280
T	4'-0"	4'-6"	4'-6"	5'-0"					

V = DIA. PISTON ROD - IN INCHES
V-V = WT. PISTON & ROD - IN POUNDS
X = LENGTH CONNECTING ROD - IN INCHES
Y = WT. CONNECTING ROD - IN POUNDS
Z = WT. CROSSHEAD - IN POUNDS

NOTE:
COMPRESSOR SIZES D-E SHOULD NOT BE USED FOR SUCTION TEMPERATURES BELOW +25°F.

DO NOT USE FOR CONSTRUCTION

MARCH-15-1930

Figure 2: Drawing of standard Kroeschell B.D. CO_2 compressors, 1930.

CO_2—The Safe Refrigerant

Kroeschell Bros. Ice Machine Company in the late 1890s promoted CO_2 as a safe refrigerant. Sulfur dioxide (SO_2) and ammonia (NH_3), on the other hand, were extremely noxious. Compression refrigerating plants had to be in remote engine rooms away from people. Also, explosions in ammonia compressors had taken place when extremely high compression ratios existed.

Since carbon dioxide was the only non-toxic, non-flammable refrigerant, it was used in smaller, vertical compressors for cold storage refrigerators and display counters and installed in food markets, hotel kitchens, hospitals, banquet halls, restaurants, large produce public markets and passenger ships. Most of those refrigeration plants cooled calcium chloride and circulated it to the refrigerators.

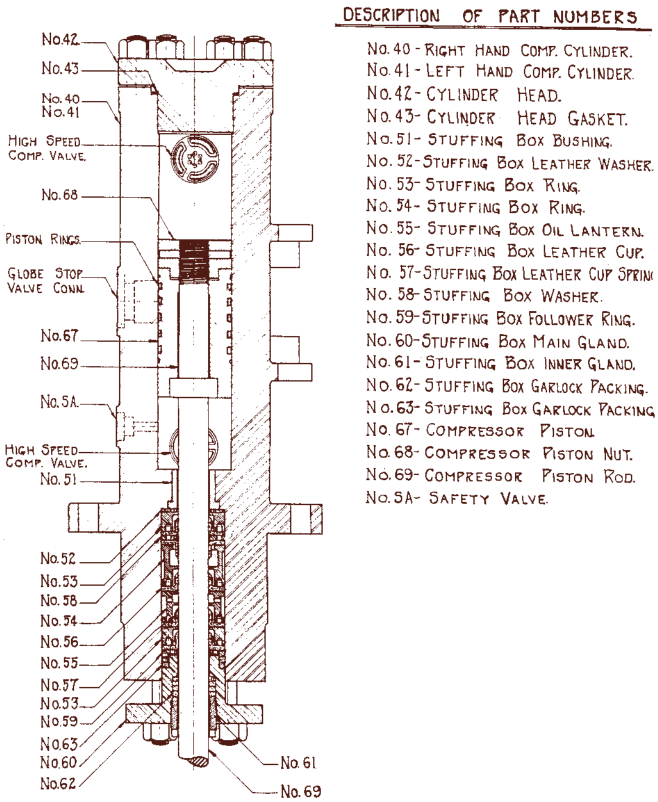


Figure 3: Description of part numbers of an (H) type compressor cylinder. The cross section shows the location of valves, piston and stuffing box; Brunswick-Kroeschell Co., Chicago.

The brine supply temperature was usually about 10°F (–12°C). The cooling elements in the refrigerator boxes were originally galvanized steel pipes mounted on the sidewall or in overhead bunkers. Smaller refrigerators used 1¼-in. (32-mm) iron pipe size coils of a serpentine design with the pipe's bent on 4-in. (102-mm) centers. Large cold storage rooms usually had coils made of 2 in. (51 mm) iron pipe similarly mounted on walls. The calcium brine was circulated through these coils.

In the late 1920s, steel pipe with steel fins about 4- by 4-in. (102- by 102-mm), pressed on the pipes at ½-in. (13-mm) centers, improved the cooling ability. Air circulating fan coil units called cold diffusers also used with banks of plain pipe coils or fin coils were used in the cold storage refrigerator boxes. In a paper written by Fred Wittenmeier in 1916, titled "The Development of the Carbon Dioxide Refrigerating Machine," he refers to a 2-ton (7-kW) CO_2 machine he installed in the Marquette building for cooling a home cellar. At the time, the cost of the CO_2 liquid refrigerant in 50-lb (23-kg) drums was 4 to 5 cents per pound. The price rose to 6 cents a pound in the 1920s and 1930s.

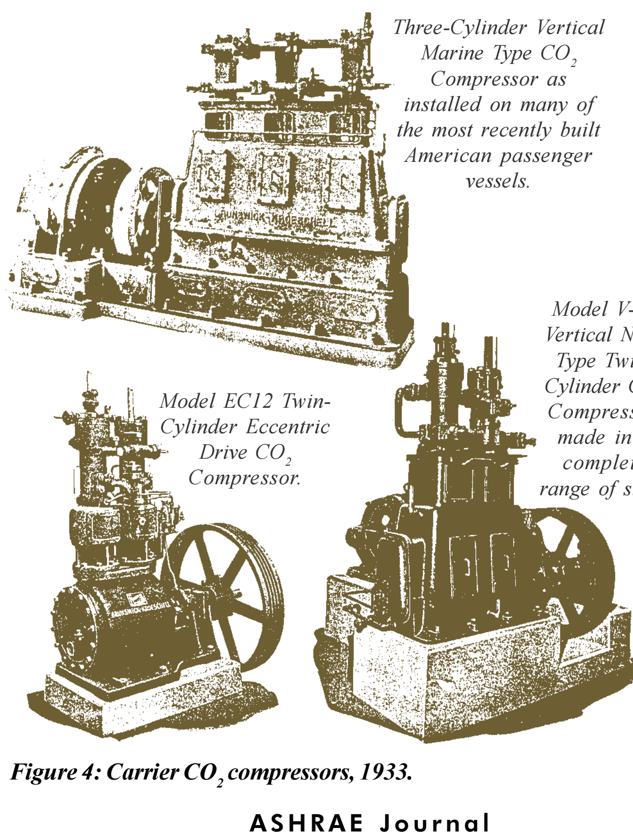
Tank and coil condensers were first used and supplanted by the more efficient double pipe condensers in 1902. Wittenmeier's article states that the small, vertical, cylinder-type compressors of up to 12 tons (42 kW) were shortly followed by the horizontal-type compressors of up to 50-ton (176-kW) size. By 1916, machines were built up to 200 tons (704 kW) each. Wittenmeier refers to his first air-cooling installation, made by Kroeschell Company, using the combination air cooler pipe coil arrangement with direct expansion pipe coil evaporation right in the air washer.

Comfort Cooling in Theatres

The earliest motion picture theaters, such as the Orpheum in Los Angeles, were equipped with direct expansion systems that used CO_2 refrigerating.

Another article by Fred Wittenmeier, which appeared in the July 1922 issue of *Ice and Refrigeration*, addressed cooling of theaters and public buildings. The Kroeschell Company had been well underway in cooling theaters for approximately 10 years before the paper gives some rules of thumb figures for theater cooling, such as 2.5 tons (9 kW) of refrigeration for 1,000 cfm (472 L/s) of air supplied for theaters in the northern states, with 25% added for southern areas. These suggestions of capacity were based on 50% outside air and 25% recirculated air. The evaporator design is based on using 1¼-in. (32-mm) iron pipe coils calculated at 35 feet per ton of refrigeration. The recirculated spray water was to be installed before and after the face of the coils at the rate of 3.5 gpm (0.2 L/s). The evaporating temperature of the CO_2 is suggested at 22°F (–6°C), which is an equivalent pressure of about 30 atmospheres. CO_2 pressure gages for operation often were indicated in atmospheres, with 1 atmosphere being approximately 15 lbs (7 kg).

This high pressure requires heavy steel pipe and fittings to withstand the evaporating pressure of 450 lbs (204 kg) and more as the system's CO_2 pressures equalize. The air velocity



Three-Cylinder Vertical Marine Type CO_2 Compressor as installed on many of the most recently built American passenger vessels.

Model EC12 Twin-Cylinder Eccentric Drive CO_2 Compressor.

Model V-26 Vertical Navy Type Twin-Cylinder CO_2 Compressor, made in a complete range of sizes.

Figure 4: Carrier CO_2 compressors, 1933.

through the evaporator is suggested at 500 fpm (2.5 m/s). The spray water temperature was supposed to be at 58°F (14°C), which was warm enough to prevent the buildup of ice on the coils. The paper recommends a water temperature of 50°F (10°C). If better room air conditions are desired, reheat coils also should be installed. A typical A/C system installed in the French Room in the Congress Hotel in Chicago used this system with resulting room air conditions of 72°F (22°C) and 70% rh.

For theater supply air distribution systems, Wittenmeier's article indicates the floor supply system through mushroom-type outlets is suggested. This was the standard method for heating. In summer, when this type of air cooling was supplied, it was most uncomfortable since a person's lower limbs were very cold due to the supply air being in the 50s. The author remembers suffering the experience personally in theaters in the late '20s and early '30s.

The CO_2 compressors made by Kroeschell starting in 1897 were called "North Pole compressors." The first machines were vertical, twin cylinder, single-acting devices with a water-coiled condenser piping arrangement around the cylinder casing with 1 ton to 6 tons (4 kW to 7 kW) capacity (see *Figure 1*). Horizontal double-acting machines then were developed with 8 tons to 20 tons (28 kW to 70 kW) capacity and in general were patterned after steam engine design. Condensers then were made with a separate tank and coil arrangements.

SIZE		DISP'L. CU. IN. PER REV.	MAX. AND MIN. R.P.M.	+20° SUCTION		+25° SUCTION		+27½° SUCTION		+30° SUCTION		+32½° SUCTION		+35° SUCTION		+37½° SUCTION	
				TONS	H.P.	TONS	H.P.	TONS	H.P.	TONS	H.P.	TONS	H.P.	TONS	H.P.	TONS	H.P.
EC-11	One Cyl. 2x3-1/2"	10.996	200	1.7	3.1	1.8	3.0	1.9	3.0	2.0	3.0	2.1	2.9	2.2	2.9	2.3	2.9
			325	2.6	5.0	2.9	5.0	3.0	4.9	3.2	4.9	3.3	4.8	3.5	4.8	3.7	4.7
EC-12	Two Cyl. 2x3-1/2"	21.992	200	3.4	6.1	3.6	6.0	3.8	6.0	4.0	6.0	4.2	5.9	4.3	5.9	4.5	5.8
			325	5.2	10.0	5.8	10.0	6.1	9.8	6.4	9.7	6.7	9.6	7.0	9.6	7.4	9.4
EC-22	Two Cyl. 2½x4-1/2"	44.178	200	6.5	11.4	7.3	11.4	7.7	11.3	8.1	11.2	8.4	11.1	8.8	11.0	9.4	10.8
			275	9.0	15.6	10.1	15.3	10.6	15.3	11.1	15.4	12.2	15.4	13.4	16.5	14.0	16.2
EC-32	Two Cyl. 3x5-3/4"	81.289	150	9.7	16.2	10.7	16.0	11.2	15.8	11.7	15.7	12.3	15.5	12.9	15.3	13.4	15.0
			225	14.5	24.3	16.1	24.0	16.8	23.7	17.6	23.5	17.8	22.5	18.0	21.4	18.8	21.[illegible]
H9-A	3-1/4x9"	132.067	135	12.9	22.5	14.4	22.4	15.2	22.3	16.0	22.1	16.8	21.9	17.7	21.8	18.6	21.[illegible]
			200	19.2	33.3	21.4	33.2	22.5	33.0	23.7	32.8	24.9	32.5	26.2	32.2	27.5	31.[illegible]
H9-B	3-1/2x9"	155.92	150	17.3	29.9	19.2	29.8	20.2	29.6	21.2	29.4	22.3	29.1	23.5	28.8	24.6	28.[illegible]
			200	23.0	39.9	25.6	39.7	27.0	39.5	28.3	39.2	29.8	38.8	31.3	38.5	32.8	37.9
H9-C	3-3/4x9"	181.55	170	23.1	40.0	25.7	39.8	27.0	39.5	28.3	39.2	29.8	38.8	31.2	38.4	32.8	37.8
			200	27.2	47.1	30.2	46.8	31.8	46.5	33.3	46.1	35.0	45.6	36.7	45.2	38.5	44.5
H9-D	4-1/8x9"	223.29	155			28.3	43.9	29.7	43.7	31.3	43.3	32.9	43.0	34.4	42.6	36.3	41.9
			200			36.5	56.7	38.4	56.3	40.4	55.9	42.4	55.4	44.4	54.9	46.9	54.1
H9-E	4-3/8x9"	253.34	170			35.6	55.2	37.3	54.8	39.3	54.3	41.2	53.9	43.1	53.3	45.5	52.[illegible]
			200			41.9	64.9	43.9	64.5	46.2	63.9	48.5	63.4	50.7	62.7	53.6	61.8
H12-A	4-1/4x12"	305.08	120	27.8	44.0	30.4	43.8	32.0	43.5	33.5	43.2	35.3	42.8	37.1	42.4	38.9	41.8
			164	37.3	60.1	41.5	59.9	43.7	59.5	45.9	59.1	48.3	58.5	50.7	58.0	53.2	57.15
H12-B	4-1/2x12"	346.32	135	35.2	56.8	39.2	56.5	41.2	56.1	43.2	55.6	45.5	55.1	47.7	54.6	50.0	54.1
			164	42.8	69.0	47.6	68.7	50.1	68.1	52.5	67.6	55.2	67.0	57.9	66.3	60.8	65.7
H12-C	4-3/4x12"	389.92	145	43.05	69.3	47.8	68.9	50.3	68.3	52.7	67.7	55.4	67.1	58.0	66.4	60.9	65.4
			164	48.7	78.4	54.1	77.9	56.8	77.3	59.6	76.6	62.6	75.9	65.6	75.2	68.8	73.9
H12-D	5-1/8x12"	459.72	135			52.2	75.2	54.8	74.7	57.6	74.1	60.4	73.4	63.1	72.6	65.8	71.5
			164			63.4	91.4	66.5	90.8	69.9	90.0	73.4	89.2	76.7	88.3	79.9	86.9
H12-E	5-3/8x12"	509.20	145			62.5	90.1	65.6	89.4	68.9	88.6	72.2	87.8	75.5	86.8	78.7	85.5
			164			70.7	101.9	74.2	101.1	77.9	100.2	81.7	99.3	85.4	98.2	89.0	96.7
H15-A	5-1/4x15"	586.44	100	45.0	71.6	50.0	71.2	52.5	70.7	55.1	70.1	57.9	69.4	60.8	68.7	63.7	67.7
			138	62.1	[illegible]	69.0	98.2	72.6	97.5	76.1	96.7	80.0	95.8	83.9	94.9	87.9	93.4
H15-B	5-1/2x15"	649.74	110	55.3	87.9	61.3	87.3	64.4	86.6	67.5	85.9	71.0	85.0	74.4	84.2	78.0	82.8
			138	69.3	110.3	77.0	109.6	80.8	108.7	84.7	107.7	89.1	106.7	93.4	105.6	97.9	103.9
H15-C	5-3/4x15"	716.01	120	66.9	106.3	74.1	105.6	77.8	104.7	81.6	103.7	85.6	102.7	89.8	101.6	94.1	100.0
			138	76.9	122.3	85.2	121.4	89.4	120.4	93.8	119.3	98.4	118.2	103.2	116.85	108.2	115.0
H15-D	6-1/8x15"	820.95	110			77.6	110.5	81.3	109.7	85.4	108.6	89.6	107.6	93.6	106.5	97.5	104.8
			138			97.4	138.6	102.0	137.6	107.2	136.3	112.4	135.0	117.4	133.6	122.3	131.4
H15-E	6-3/8x15"	894.57	120			92.7	132.0	97.1	130.9	102.0	129.7	106.9	128.4	111.6	127.0	116.4	124.9
			138			106.6	151.8	111.7	150.6	117.3	149.1	122.9	147.7	128.3	146.1	133.9	143.7
H19-A	6-1/4x19"	1047.8	80	64.9	100.3	72.1	99.7	75.7	98.8	79.3	98.0	83.3	97.0	87.4	96.0	91.6	94.5
			120	97.4	150.5	106.1	149.5	113.5	148.2	118.9	147.0	125.0	145.5	131.1	144.0	137.4	141.7
H19-[illegible]	6-1/2x19"	1142.91	85	75.7	116.9	84.0	116.0	88.1	115.0	92.3	114.0	97.0	112.8	101.6	111.7	106.5	109.9
			120	106.9	165.0	118.5	163.8	124.4	162.4	130.4	161.0	136.9	159.3	143.5	157.7	150.4	155.1
H19-C	6-3/4x19"	1241.79	90	87.5	135.1	96.9	133.9	101.8	132.8	106.6	131.6	112.0	130.3	117.3	128.9	122.9	126.8
			120	116.7	180.2	129.2	178.6	135.7	177.1	142.2	175.5	149.2	173.7	156.4	171.8	163.9	169.0
H19-D	7-1/8x19"	1397.06	85			102.6	141.9	107.5	140.8	112.9	139.4	118.4	138.1	123.6	136.5	128.8	134.3
			120			144.9	200.3	151.7	198.7	159.4	196.8	167.1	194.9	174.4	192.7	181.8	189.6
H19-E	7-3/8x19"	1505.24	90			117.5	162.4	123.0	161.1	129.3	159.5	135.5	158.0	141.4	156.2	147.2	153.6
			120			155.6	216.6	164.0	214.2	172.3	212.7	180.6	210.6	188.5	208.3	196.3	204.8

Figure 5: Table for tonnage and horsepower for Standard Kroeschell CO_2 compressors.

CO_2 Compressors

The use of carbon dioxide as a refrigerant necessitated heavy-duty construction of refrigerating compressor parts and all cycle components. The evaporation temperature for low temperature application was about 5°F (–15°C) when cooling calcium chloride brine to 15°F (–9°C) or 20°F (–7°C). This 5°F (–15°C) evaporating temperature results in pounds per square inch pressure.

The condensing temperature when cooling tower water was used in summer was often as high as 85°F (29°C) resulting in a gage pressure of 1,240 lbs/in^2. These pressures required the installation of extra heavy steel pipe and forged steel fittings and valves for all field-piping interconnections. Likewise condensers and evaporators had to be designed not only for normal operating conditions but also for the resulting higher equalized pressures in the plant when shut down. The type of pressure gages on the suction and discharge of the compressor often were made to indicate atmospheres. This would tend to take the scare out of indicating the high pressures the system was operating in. For example, if the suction pressure were 340 lbs (154 kg), the atmospheric type gage would read 23, and if the discharge pressure were 1,240 lbs (562 kg), the atmospheric-type gage would read 83.

The compressors, both vertical and horizontal types, were constructed similar to the steam engine designed with the piston firmly fastened to a round, double-acting type steel shaft. A stuffing box arrangement sealed the shaft (see *Figure 3*).

A double valve arrangement would let the suction gas in, then close as the piston moved, and open the discharge position as the piston moved back and forth. Compressors were standing in a vertical

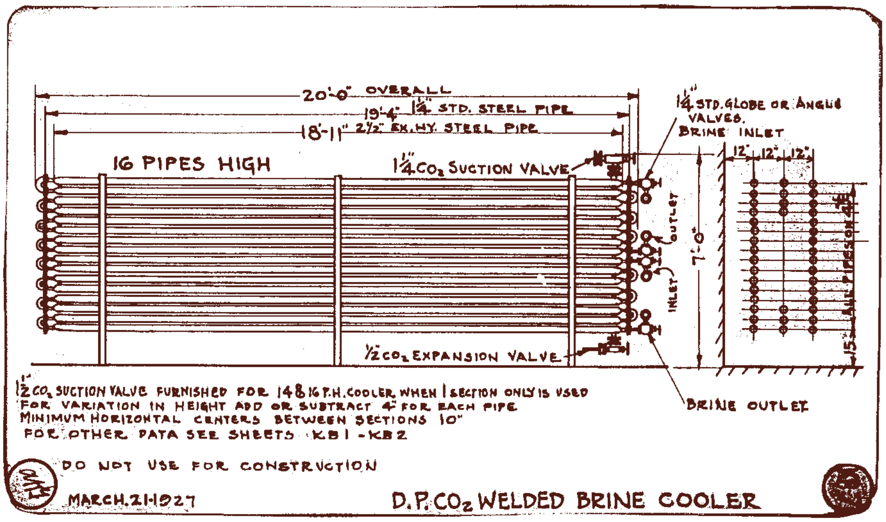


Figure 6: Condenser and brine cooler.

position or horizontal position. The enclosed crankcase design used on a vertical ammonia compressor would require an extremely strong casing if used with CO_2 to withstand the pressures in the system. Therefore, it could not be used (see *Figure 2*). The maximum speed of the small vertical compressors was 325 rpm and the largest horizontal compressors was 120 rpm (see *Figure 4*). *Figure 5* shows machine capacities from 20°F to 37.5°F suction with 75°F condenser water supply.

CO_2 Condensers

The CO_2 condenser was of double pipe construction with a 1¼-in. (32-mm) inner water iron pipe and a 2½-in. (64-mm) outer pipe. The CO_2 refrigerant vapor was condensed in the annular space between the two pipes. The condenser water passed through the 1¼-in. (32-mm) pipe. This type of interchange was highly efficient at the time in comparison with the coil and tank type condenser. The same type and size of double pipe water cooler and brine coolers was also made (see *Figure 6*).

The rule of thumb rating of the double pipe condenser was "one length of 20 ft (6 m) long double pipe condenser was required for one ton of refrigeration." The condensers were installed in banks with stands of 12 to 16 pipes high. Thus, a 100-ton (352-kW) machine would require a minimum of eight stands, each 12 pipes high. The brine coolers were likewise rated on 20-ft (6-m) pipe for 1 ton (4 kW) of refrigeration.

Shell- and tube-type condensers were developed in 1931. These units were made of heavy 8-in. (203-mm) steel pipe for the shell and 1-in. (25-mm) pipe for the tubes.

The evaporator design for comfort air cooling systems consisted of a battery of pipe coils built into a watertight, galvanized 16-gage sheet metal casing. The cooling coils were of 1¼-in. (32-mm) steel pipe made in a serpentine fashion 4 in. (102 mm) on center. CO_2 liquid headers with hand expansion valves (needle-type valves) were connected to the bottom of each stand of coils. A suction header was on the top. A bank of water spray nozzles was on the entering air side and on the top of the pipe coils. Water was supplied to the nozzles from a recirculating pump taking water from the drain pan to the bank of pipe coils, thus cooling the water as well as the air. The bank of coils was often 24 pipes high and 18 rows deep. The size of the coils was calculated on the basis of 35 ft (11 m) of 1¼-in. (32-mm) pipe per ton of refrigeration.

With the advent of aerofin coil in the early 1920s, the bank of coils were made of 1-in. (25-mm) hard copper tubing with approximately 2½-in. (64-mm) copper fins pressed on the tubes of 3/16 in. to ½ in. (5 mm to 13 mm) centers. The depth of the bank of coils was then reduced to 10 or 12 tubes deep. The capacity was then calculated on the basis of 13 ft to 15 ft (0.9 m to 4.6 m) per ton.

An interesting fact, which is illustrated in *Figure 7,* is that the return air is not only mixed with the outside air and then cooled but also part of the return air bypasses the coils to reheat the supply air. This method of recast was called "the bypass system" and carried a U.S. patent. Anyone using the bypass system was charged 5 cent per cfm of total air supplied to the system. The patent was owned by the Auditorium Conditioning

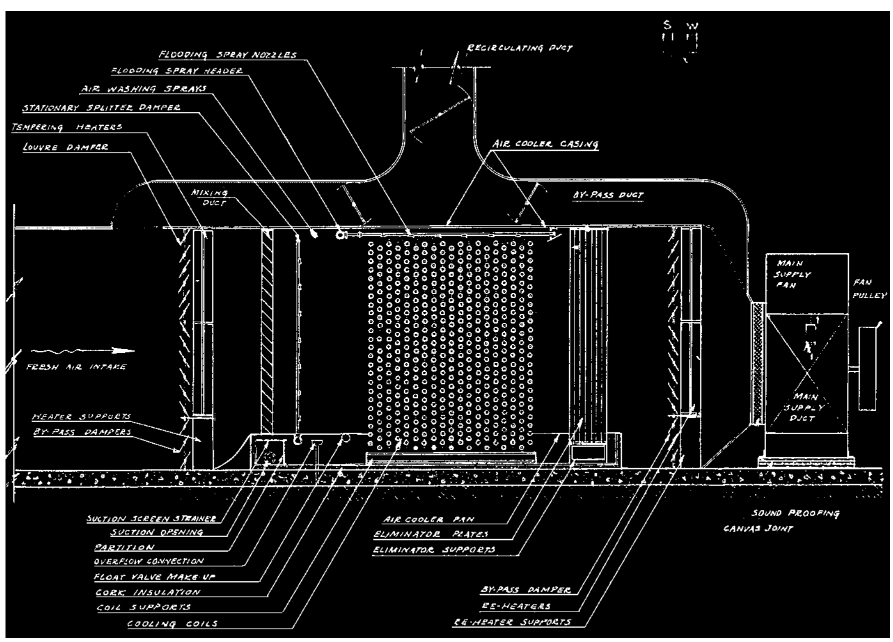


Figure 7: Sketch of D.P. CO_2 welded brine cooler, 1927.

Corporation, a subsidiary of Carrier Engineering Company.

The Decline of CO_2 Systems

As previously stated, the use of carbon dioxide systems was at its peak during the 1920s and the early ’30s. With the advent of fin coils, many small comfort-cooling systems were installed in restaurants, hotel, public spaces, nightclubs, hospital operating rooms, etc., using the small, vertical CO_2 machines built in 3 tons to 20 tons (11 kW to 70 kW). Larger department stores also began to air condition using the horizontal CO_2 machines up to 300 tons to 350 tons (1056 kW to 1232 kW) in the arrangement of duplex compressors directly driven by slow speed synchronous motors.

The last rather large CO_2 system installation was made by Carrier Corporation, using the Kroeschell compressors engineered by the author and installed in the Commonwealth Edison Company in its Chicago headquarters office building where it cooled the lower floors’ public spaces in the years 1935 and 1936. These machines were replaced with centrifugal machines when further cooling of the office building was installed 15 years later.

A recent survey made with the present Kroeschell Engineering Company service department indicates that no CO_2 systems are still in operation in the Chicago area.

However, CO_2 is still used. One recent article described the use of CO_2 in a cascade system with an ammonia system. Another report describes plans by a Japanese automaker to use CO_2 in an automobile air conditioner.

References

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