Ammonia Refrigeration & Scenario in Industrial Refrigeration

By

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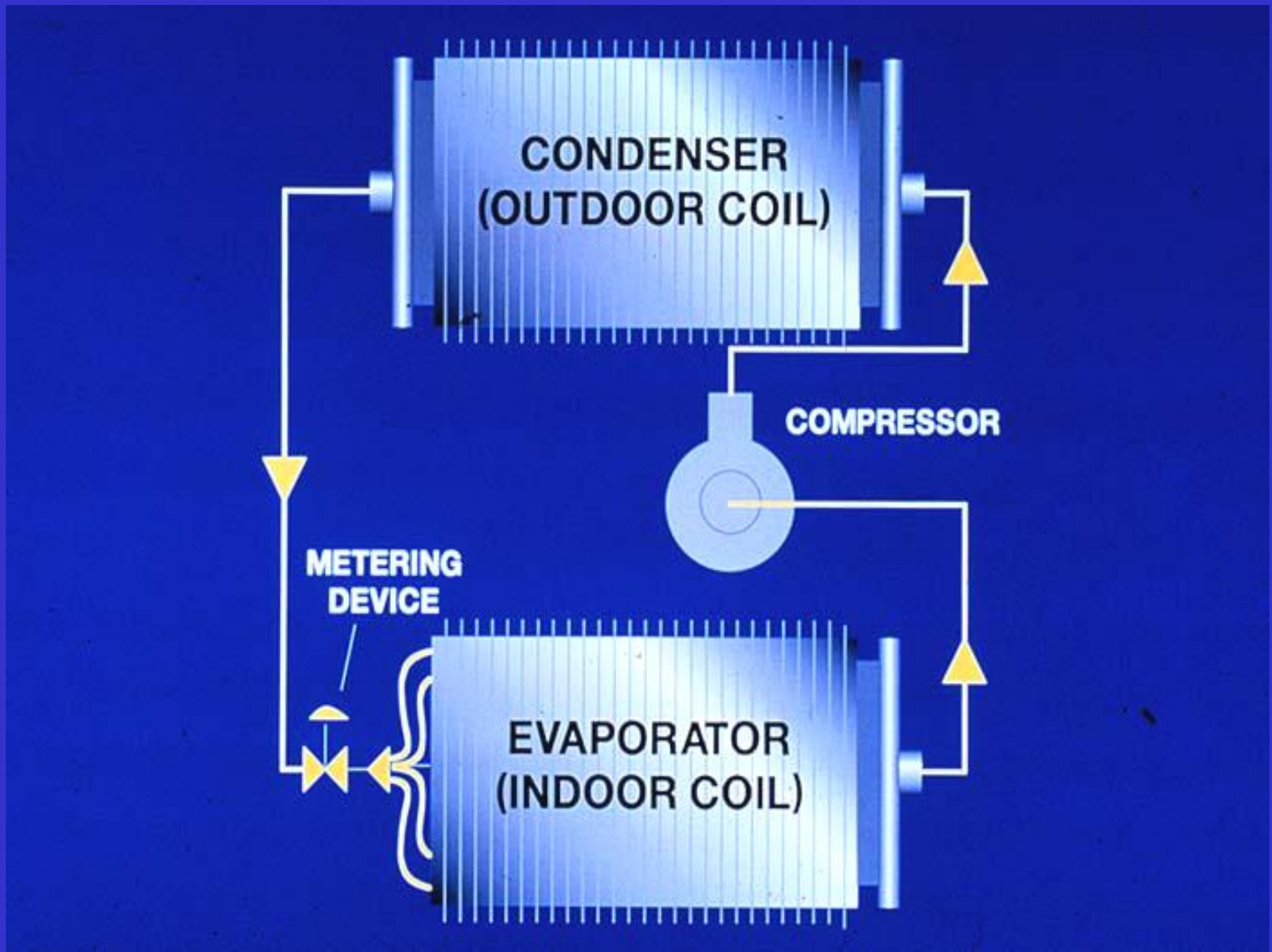
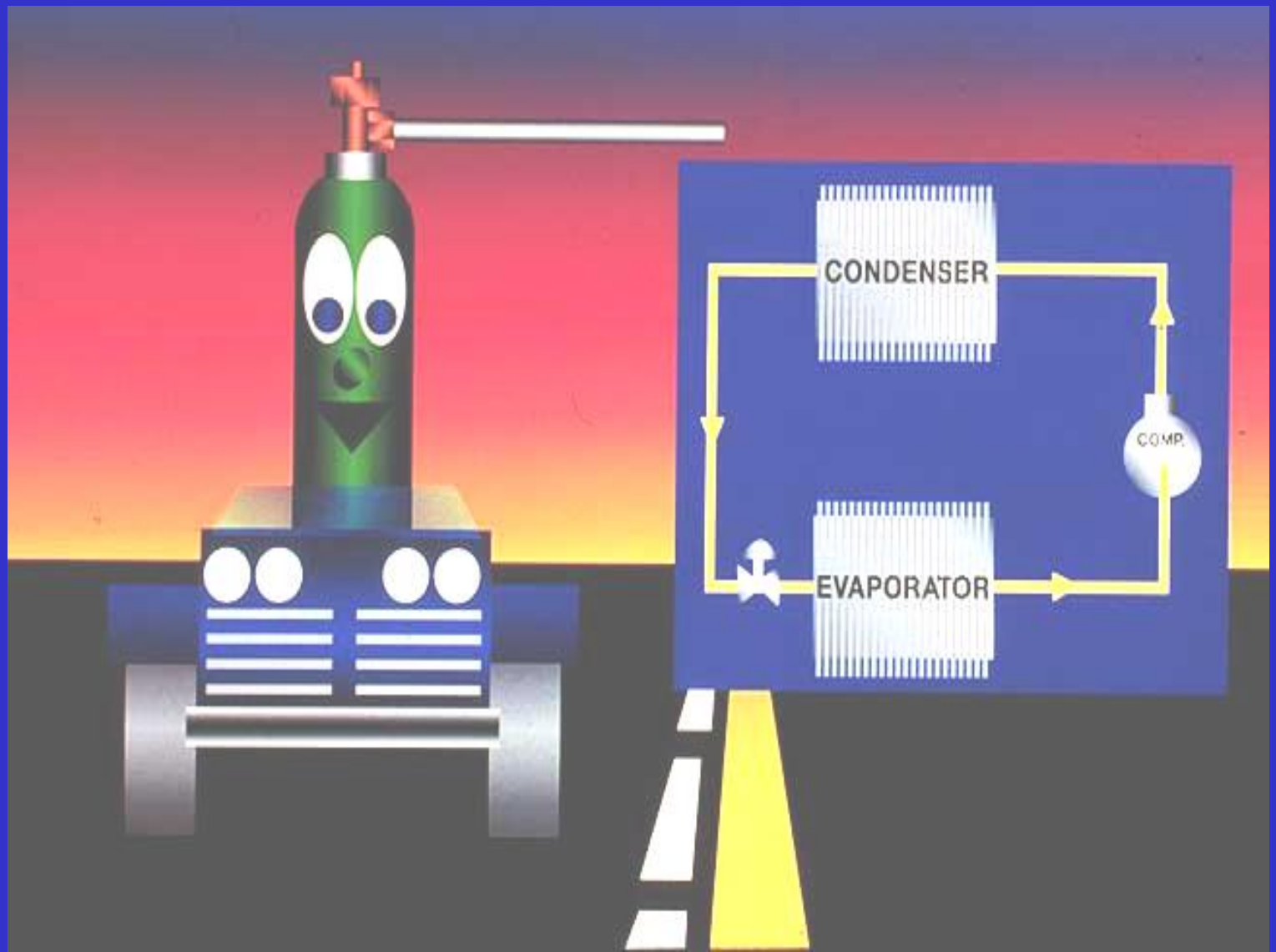
ASHRAE Fellow Life member

5th March 2014

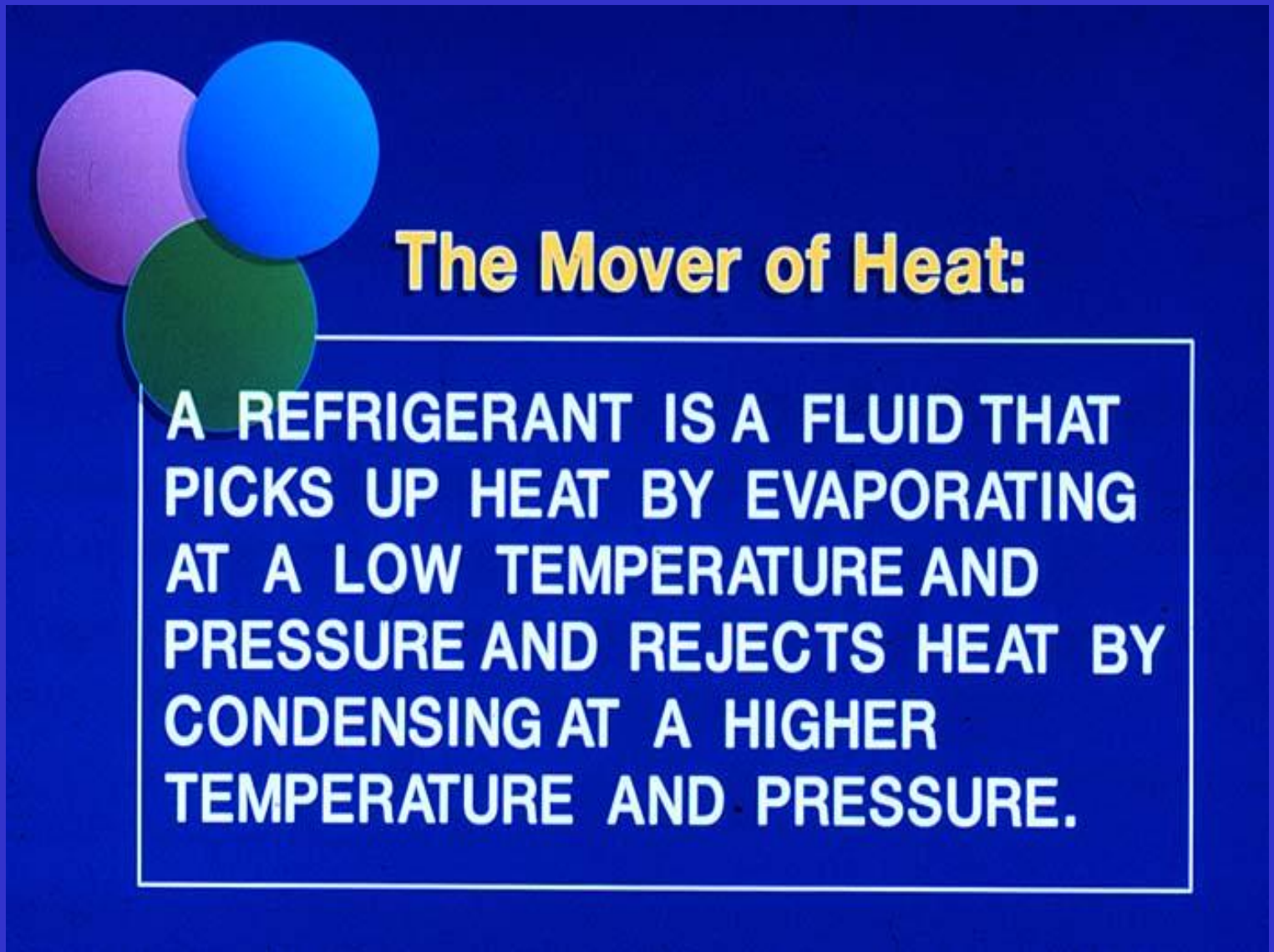
Basic Components Of A Refrigeration System



Refrigerant Flow Path



Refrigerant ?



REFRIGERANT EVALUATION PROCESS

1. ENVIRONMENT
2. PERFORMANCE
3. ENERGY EFFICIENCY
4. TOXICITY/SAFETY
5. FLAMMABILITY
6. MATERIAL CPMPATIBILITY
7. STABILITY
8. COST

THERMAL/PHYSICAL PROPERTIES

- BOILING POINT
- DISCHARGE TEMPERATURE
- DISCHARGE PRESSURE
- SPECIFIC VOLUME
- DENSITY
- LATENT HEAT OF VAPORISATION
- COMPRESSOR DISPLACEMENT
- HORSE POWER PER TON
- COP

Ammonia Refrigeration & Scenario in Industrial Refrigeration

Why Ammonia ?

5th March 2014

Reasons for Selecting Ammonia Refrigerant

- **ODP-0**
- **GWP < 1**
- **Atmospheric Life- 0.01 years**
- **Natural Refrigerant**
- **Highest Efficiency-Better Heat Transfer Properties**
- **Easier Oil Management**
- **Low Cost-Easy Availability**

STANDARD DESIGNATIONS OF REFRIGERANTS

ASHRAE STANDARD 34

METHANE SERIES			
NUMBER	**CHEMICAL FORMULA**	**CHEMICAL NAME**	**SAFETY CODE**
R11	CCL_3 F	TRICHLORO FLUROMETHANE	A1
R12	CCL_2 F_2	DICHLOROFLUROMETHANE	A1
R22	$CHCLF_2$	CHLORODIFLUOROMETHANE	A1
ETHANE SERIES			
R113	CCL_2FCCLF_2	TRICHLOROTRI FLU ROETHANE	A1
R114	$CCLF_2CCLF_2$	DICHLOROTETRAFLUROETHANE	A1
R123	$CHCL_2$ CF_3	DICHLOROTRIFLUROETHANE	B1
R 134a	CH_2FCF_3	TETRAFLUROETHANE	A1
PROPANE SERIES			
R290	$CH_3CH_2CH_3$	PROPANE	A3
ZEOTROPIC BLENDS (% BY MASS)			
R404A	R125/ R143a / R 134a	(44/ 52 / 4)	A1/A1
R407C	R32/ R125 / R134a	(23 /25 / 52)	A1/A1
R41 OA	R32/ R125	(50 / 50)	A1/A1

contd...

STANDARD DESIGNATIONS OF REFRIGERANTS

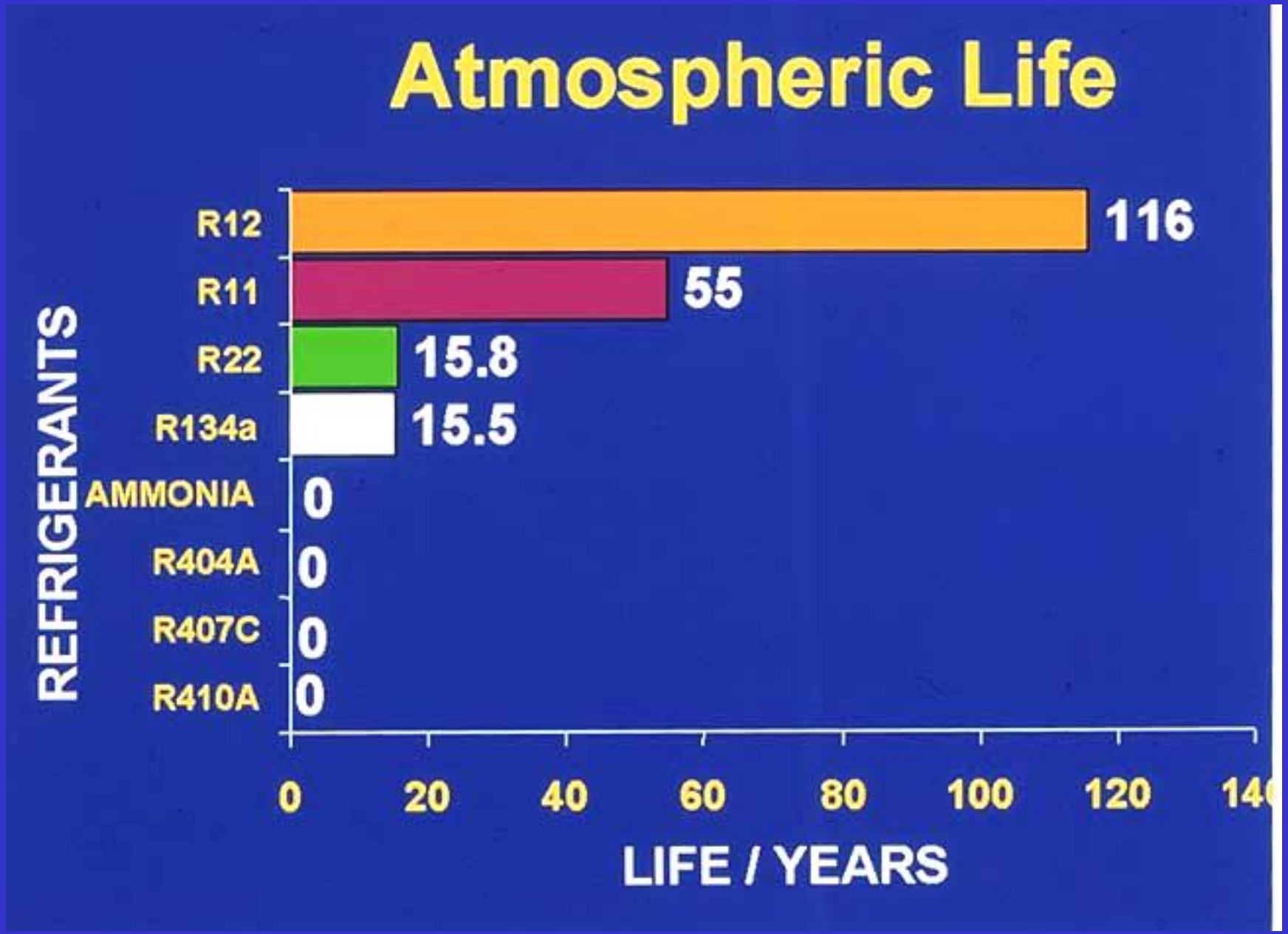
ASHRAE STANDARD 34

contd...

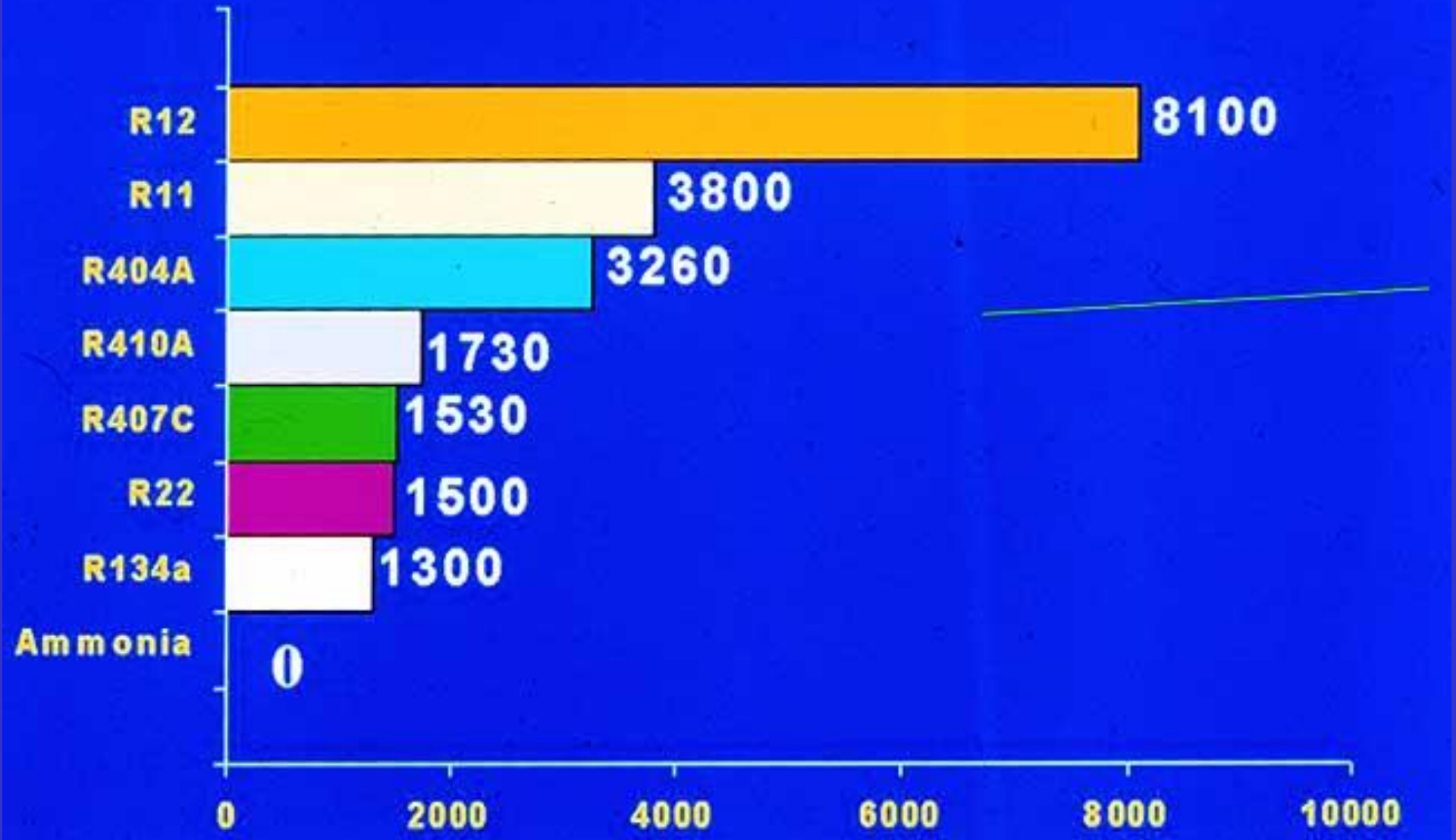
NUMBER	CHEMICAL FORMULA	CHEMICAL NAME	SAFETY CODE
AZEOTROPIC BLENDS			
R500	R12/ 152a	(73.8 / 26.2)	A1
R502	R22 / R 115	(48.8 / 51.2)	A1
HYDROCARBON			
R600	$CH_3CH_2CH_2CH_3$	BUTANE	A3
R600a	$CH(CH_3)_3$	METHYLE PROPANE	A3
INORGANIC COMPOUNDS (NATURAL REFRIGERANTS)			
R717	**NH_3**	**AMMONIA**	**B2**
R718	H_2O	WATER	A1
R744	CO_2	CARBON DIOXIDE	A1
R764	$S0_2$	SULPHUR DIOXIDE	B1

Ozone Depletion Potential

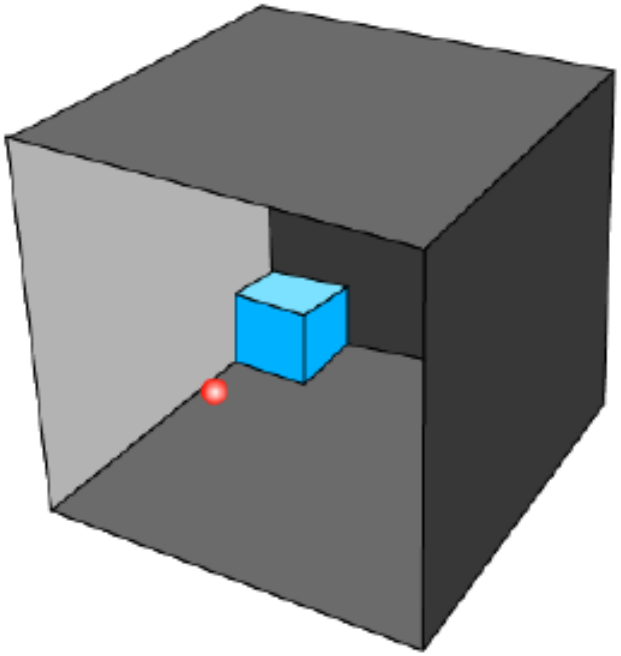
- **Capacity of molecule to destroy stratospheric ozone measured relative to the ODP of R11 as 1.0**


Atmospheric Life
REFRIGERANTS
R12
R11
R22
R134a
AMMONIA
R404A
R407C
R410A
116
55
15.8
15.5
0
0
0
0
0
20
40
60
80
100
120
LIFE / YEARS

Global Warming Potential



PER YEAR IN THE WORLD



All ammonia in nature
(1 → 3) x 1.000.000.000 ton

Produced by Man
(100 → 120) x 1.000.000 ton

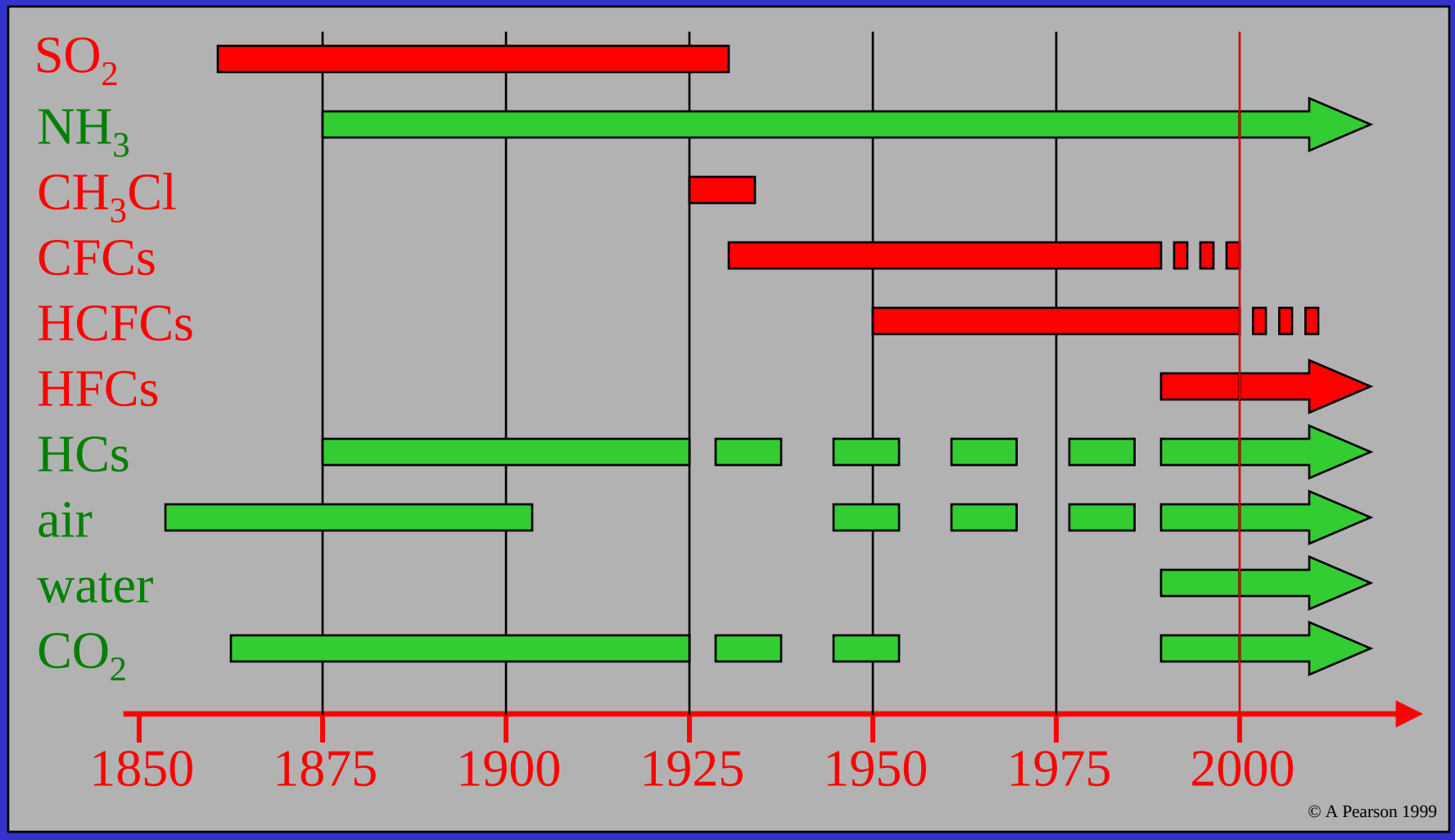
Ammonia used as refrigerant
(3→ 5) x 100.000 ton

Natural Refrigerants

(Zero ODP & Ultra-low GWP Refrigerants)

- **Hydrocarbons (HC-290, HC-600a)**
- **Ammonia (R-717)**
- **Carbon Dioxide (R-744)**
- **Water (R-718)**
- **Air**

Refrigerants Time-line



PHYSICAL PROPERTIES

TOXICITY	HOW MUCH HOW LONG
FLAMABILITY	
EXPLOSIVENESS	
ODOUR	PUNGENT DETECTABLE-5PPM ONWARDS
LEAKAGE TENDENCY	LESS LOSS-PURGING/LEAKS 8.2CFT/LB AGAINST1.2CFT/LB FOR R-22
MOISTURE TOLERENCE	IMMENSE-AQUA/AMMONIA
OIL MISCIBILITY	IMMISCIBLE

ASHRAE Standard 34.1-2013-Toxicity/Flammability

Flammability in Air @ 60°C & 101.3 kPa	ASHRAE Standard Safety Group	
Higher Flammability LFL or $ETFL_{60} \leq 100$ g/m^3 OR HOC ≥ 19 MJ/kg	A3	B3
Lower Flammability LFL or $ETFL_{60} > 100$ g/m^3 & HOC < 19 MJ/kg	A2	B2
Lower Flammability LFL or $ETFL_{60} > 100$ g/m^3 & HOC < 19 MJ/kg with a maximum burning velocity of ≤ 10 cm/s	A2L	B2L
No flame Propagation	A1	B1
Flammability in Air @ 60°C & 101.3 kPa	Lower Toxicity OEL ≥ 400PPM	Higher Toxicity OEL < 400 PPM

LFL = Lower Flammability Limit
$ETFL_{60}$ = Elevated Temperature Flame Limit @ 60°C
HOC = Heat Of Combustion, OEL-Occupational Exposure Limit

FLAMABILITY /EXPLOSIVENESS

- HARD TO IGNITE/ STABLE COMPOUND
- TEMPERATURES UPWARDS OF 450 Deg C DISOCIATES AT NORMAL PRESSURES.
- FLAMABLE LIMITS 16 TO 25 % VOLUME IN AIR
- IGNITION ABOVE 651 Deg C
- CLASSIFIED- NON FLAMABLE-US COAST GUARD & TRANSPORT DEPERTMENT.
- GROUP II BY ASHRAE 15.70 CODE
- BS 4434-95 ALLOWS UPTO 2.5 KG CHARGE ANYWHERE CLASSIFIED AS **B2**

Toxicity

5 PPM	**Onwards Detectable**
25 PPM	**Detected by most – no health hazard exposure 10 – 15 years**
100 PPM	**No dangerous effects, minor irritation.**
400 – 700 PPM	**Irritation Eyes, Nose, Mucous . Lead to dryness**
1700 PPM	**Cough, Cramp, Serious Irritation, Injuries**
2000 PPM	**Can Lead to Death**
7000 PPM	**Lethal within few minutes**

THE GASES LIGHTER THAN AIR

HYDROGEN	H2	0.07
HELIUM	He	0.14
METHANE	CH4	0.55
AMMONIA	NH3	0.59
HYDROFLUORIC ACID	HF	0.59
NEON	Ne	0.70
HYDROCYANIC ACID	HCN	0.93
CARBON MONOXIDE	Co	0.97
NITROGEN	N2	0.97

Comparison of Various Refrigerants

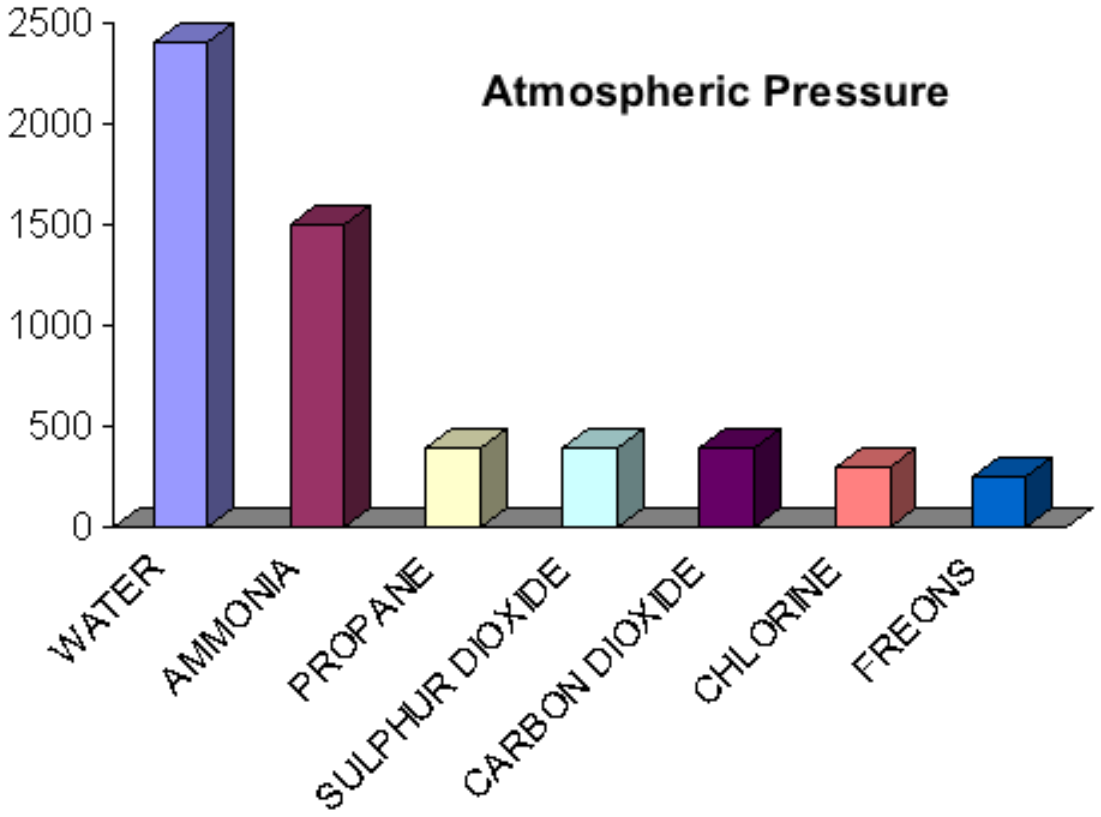
ASHRAE Fundamentals 2009 Table 9-29.9

Table 9 Comparative Refrigerant Performance per Ton of Refrigeration

Refrigerant No.	Chemical Name or Composition (% by mass)	Evaporator Pressure, psia	Condenser Pressure, psia	Compression Ratio	Net Refrigerating Effect, Btu/lb	Refrigerant Circulated, lb/min	Liquid Circulated, gal/min	Specific Volume of Suction Gas, ft^3/lb	Compressor Displacement, gal/min	Power Consumption, hp	Coefficient of Performance	Compressor Discharge Temp., °F
170	Ethane	233.2	672.8	2.88	69.5	0.81	0.35	0.541	3.27	0.489	2.7	121.73
744	Carbon dioxide	326.9	1041.4	3.19	57.3	0.51	0.10	0.269	1.03	0.257	2.69	157.73
1270	Propylene	51.9	189.1	3.64	123.0	0.46	0.11	2.081	7.12	0.295	4.5	107.33
290	Propane	41.5	155.9	3.76	119.5	0.47	0.12	2.502	8.73	0.292	4.5	96.53
502	R-22/115 (48.8/51.2)	49.7	190.3	3.83	45.6	1.25	0.13	0.814	7.59	0.306	4.38	100.13
507A	R-125/143a (50/50)	55.0	211.6	3.85	47.4	1.20	0.14	0.814	7.31	0.321	4.18	94.73
404A	R-125/143a/134a (44/52/4)	52.9	206.0	3.89	49.1	1.16	0.14	0.860	7.45	0.318	4.21	96.53
410A	R-32/125 (50/50)	69.3	271.5	3.92	72.2	0.77	0.09	0.873	5.04	0.298	4.41	123.53
125	Pentafluoroethane	58.5	226.4	3.87	36.7	1.51	0.16	0.631	7.12	0.327	3.99	87.53
22	Chlorodifluoromethane	42.8	172.2	4.02	69.9	0.81	0.08	1.248	7.58	0.287	4.66	127.13
12	Dichlorodifluoromethane	26.3	107.5	4.09	50.3	1.12	0.10	1.479	12.43	0.284	4.7	100.13
500	R-12/152a (73.8/26.2)	31.0	127.1	4.09	60.1	0.94	0.10	1.504	10.54	0.284	4.66	105.53
407C	R-32/125/134a (23/25/52)	41.8	182.7	4.38	70.2	0.81	0.09	1.289	7.80	0.298	4.5	118.13
600a	Isobutane*	12.8	58.5	4.58	113.5	0.50	0.11	6.524	24.30	0.288	4.62	85.73
134a	Tetrafluoroethane	23.6	111.2	4.71	63.6	0.89	0.09	1.945	12.90	0.290	4.6	98.33
124	Chlorotetrafluoroethane*	12.8	64.3	5.03	50.7	1.11	0.10	2.741	22.81	0.287	4.62	85.73
717	Ammonia	34.1	168.5	4.94	474.3	0.12	0.02	8.197	7.34	0.282	4.76	209.93
600	Butane*	8.1	41.0	5.05	125.6	0.47	0.10	10.325	36.04	0.292	4.74	85.73
11	Trichlorofluoromethane	2.9	18.1	6.25	67.0	0.84	0.07	12.317	77.52	0.264	5.02	109.13
123	Dichlorotrifluoroethane	2.3	15.8	6.81	61.2	0.93	0.08	14.279	99.21	0.274	4.9	91.13
113	Trichlorotrifluoroethane*	1.0	7.8	7.71	52.7	1.04	0.08	26.940	209.02	0.268	4.81	85.73

*Superheat required.

LATENT HEAT


Atmospheric Pressure
2500
2000
1500
1000
500
0
WATER
AMMONIA
PROPANE
SULPHUR DIOXIDE
CARBON DIOXIDE
CHLORINE
FREONS

Comparison at -20^0 F/+95 ^{0}F

Refrigerant	Capacity-TR	Shaft Power	HP/ TR
R 717	104.4	245.2	2.349
R-22	104.7	264.9	2.530
R134a	53.8	148.6	2.762
R404A	97.9	290.8	2.970
R 507	102.2	302.3	2.958
R410A	151.5	415.3	2.741

Ammonia Refrigerant v/s R-22

1. **Specific heat of liquid is 4 times - 4 to 1**
2. **Latent heat of vaporization is- 6 to 1**
3. **Liquid thermal conductivity is -5.5 to 1**
4. **Viscosity is less- 0.8 to1**
5. **Liquid density is less - 0.5 to 1**

Field of Applications

1. Ice Plants-commercial/amusement centers
2. Cold storages-Fruit/Vegetables/meat/Fish/Seeds/Dry fruits
3. Freezing of foods-Fish/meat/Fruits/Vegetables
4. Breweries/ Dairies
5. Chemical/Dyestuff –process cooling
6. Concrete cooling-Dams/Roads/Runways
7. Water Chillers-Air conditioning
8. Thermal storages-Heat Pumps
9. Super markets-Ammonia/CO2 cascade
10. Industrial Process/Fertilizer plants
11. Bottling Plants-Coca Cola/Pepsi

Comparison R404a V/S Ammonia For cold room Design

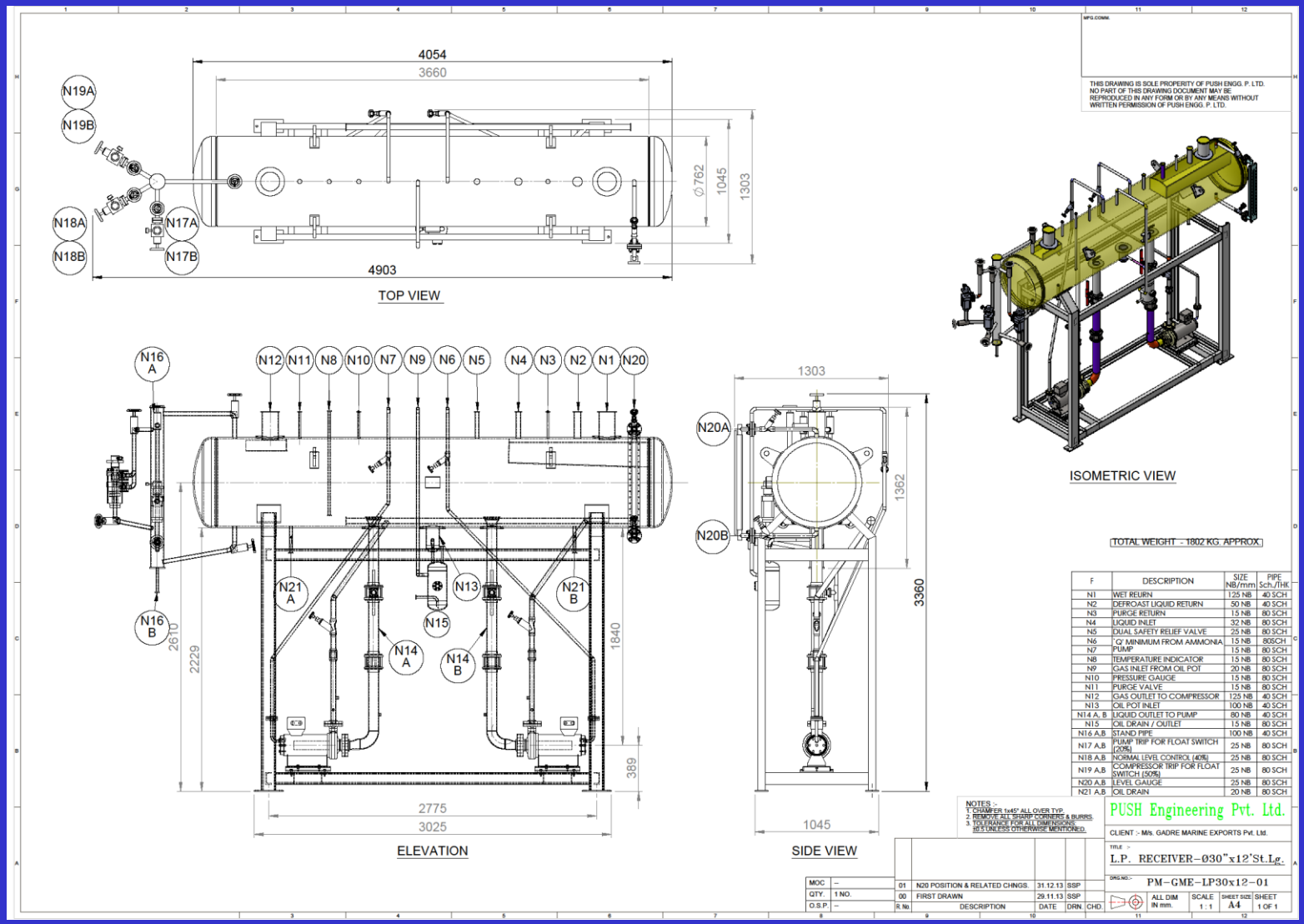
Basis-3 Rooms, Each 12mx24mx9m-Sotage 500 Ton each Temperature -20^0 C, For storage of Frozen Products, Refrigeration load 3x42kW=126kW

R404a-Air Cooled	R717-Ammonia-Water cooled
2units per Room screw compressors-6nos. Power 22.7 kW each with air cooled condenser	Two stage reciprocating compressor 4 cylinder, 1 No 54.4 kW power
Evaporator Star Coolers Model 2383, each 2 Fans -999W, with electric defrost each with 18 kW heaters	Evaporator Star coolers-2383-3fans 0.5kW, gravity flooded, water defrost
Piping, controls, gas insulation etc	Evaporative condenser-200 kW heat rejection, Receiver, piping, gas, controls ,insulation etc.
Total cost without Duty 74,90000	Total cost 4234000+ standby compressor motor
Total power with out defrost 117.3 kW	68.5 kW

Recent Trends

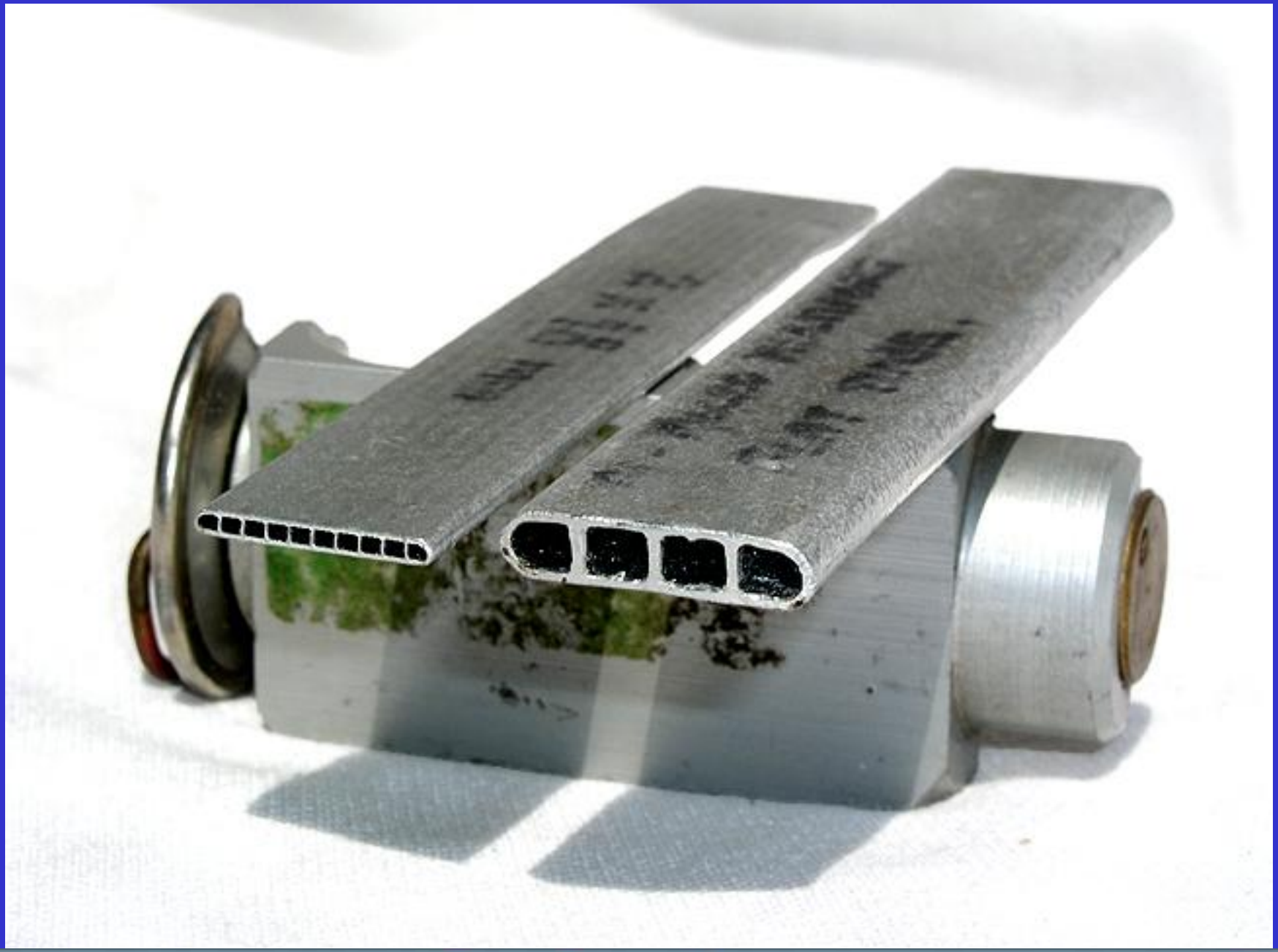
1. Semi Hermetic Compressors with aluminum windings
2. High Speed screw compressors-3600 RPM
3. Low Charge systems with high side Float
4. Use of PHE foe condenser/Chiller
5. Air Cooled Ammonia systems with wet pads
6. Direct Expansion systems using miscible oils
7. Ammonia-CO2 Cascade for Super markets
8. Heat pump applications
9. Ammonia blends with DME to reduce toxicity

Pump Circulation overfeed Design systems



F	DESCRIPTION	SIZE NB/mm	PIPE Sch./THK
N1	WET REURN	125 NB	40 SCH
N2	DEFROAST LIQUID RETURN	50 NB	40 SCH
N3	PURGE RETURN	15 NB	80 SCH
N4	LIQUID INLET	32 NB	80 SCH
N5	DUAL SAFETY RELIEF VALVE	25 NB	80 SCH
N6	'Q' MINIMUM FROM AMMONIA	15 NB	80SCH
N7	PUMP	15 NB	80 SCH
N8	TEMPERATURE INDICATOR	15 NB	80 SCH
N9	GAS INLET FROM OIL POT	20 NB	80 SCH
N10	PRESSURE GAUGE	15 NB	80 SCH
N11	PURGE VALVE	15 NB	80 SCH
N12	GAS OUTLET TO COMPRESSOR	125 NB	40 SCH
N13	OIL POT INLET	100 NB	40 SCH
N14 A, B	LIQUID OUTLET TO PUMP	80 NB	40 SCH
N15	OIL DRAIN / OUTLET	15 NB	80 SCH
N16 A,B	STAND PIPE	100 NB	40 SCH
N17 A,B	PUMP TRIP FOR FLOAT SWITCH (20%)	25 NB	80 SCH
N18 A,B	NORMAL LEVEL CONTROL (40%)	25 NB	80 SCH
N19 A,B	COMPRESSOR TRIP FOR FLOAT SWITCH (50%)	25 NB	80 SCH
N20 A,B	LEVEL GAUGE	25 NB	80 SCH
N21 A,B	OIL DRAIN	20 NB	80 SCH

ECO Mesh Ammonia Air cooled condenser



EXIT

Aluminum Coolers

Modern Packaged Ammonia Systems

- New design (PHEs or spray type shell & tube evaporator)
- Liquid injection system
- Better efficiency (>30%) than HFC134a
- Less charge (0.02 to 0.5 kg/kW) for dry and flooded evaporation
- Higher discharge pressure (up to 40 bar)
- Safety level increased significantly towards “zero leak”
- Used in Europe for both display cabinets and space conditioning

Ammonia for A/C and Commercial Refrigeration

- Ammonia A/C with central plants
- Ammonia display freezer cabinets
- Independent circuits
- Secondary refrigerants used
- Risk free AC&R

PACKAGE CHILLER

AIR COOLED AMMONIA PACKAGE CHILLER

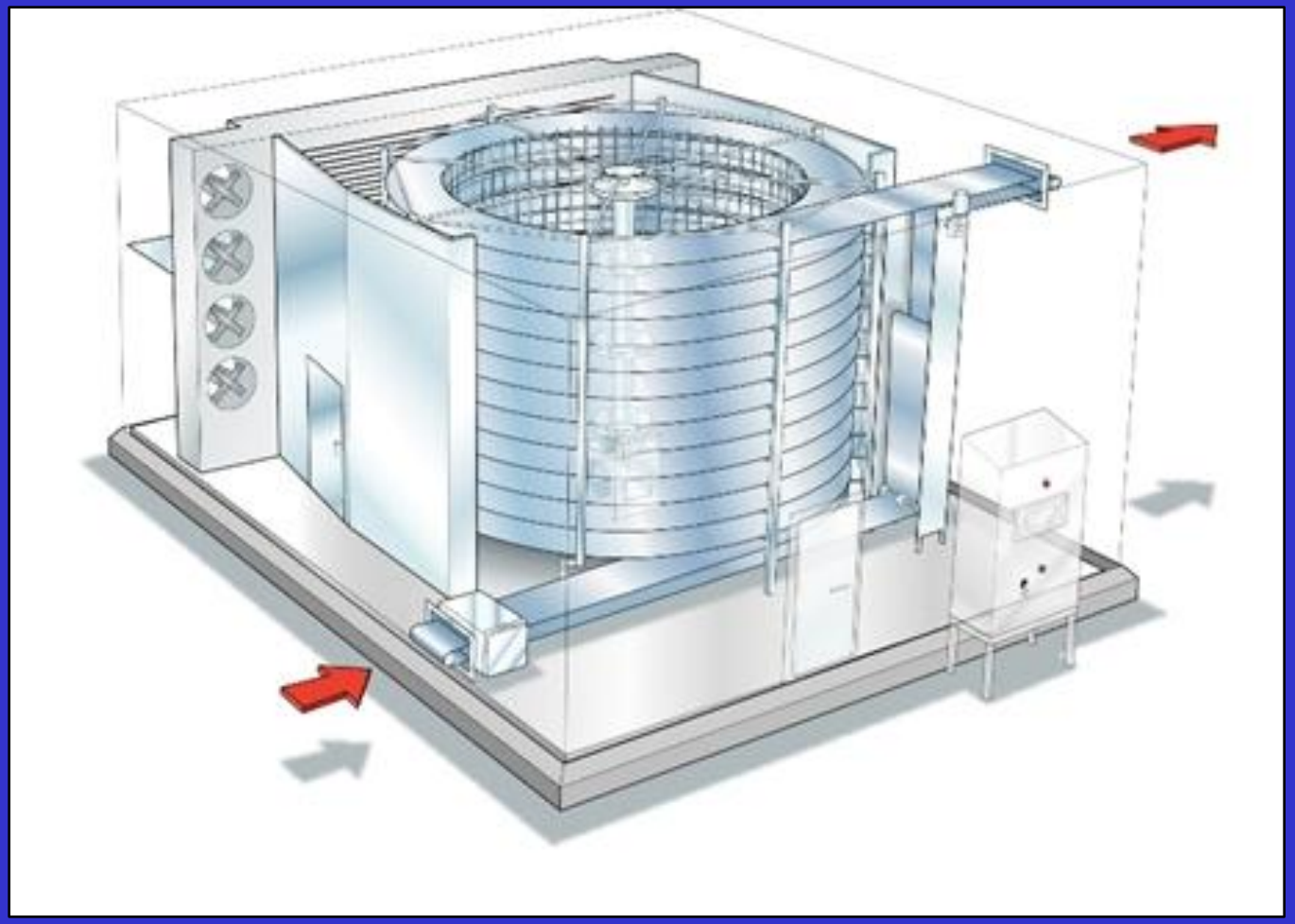
WATER COOLED PACKAGE CHILLER-SCREW COMPRESSORS & PHE CONDENSER/COOLER

WATER CHILLER USING RECIPROCATING COMPRESSOR & ENCLOSED PHE CONDENSER/COOLER

PACKAGE MILK CHILLER WITH 'U' TUBE ACCUMULATOR

Falling Film Water Chiller

SPIRAL FREEZER



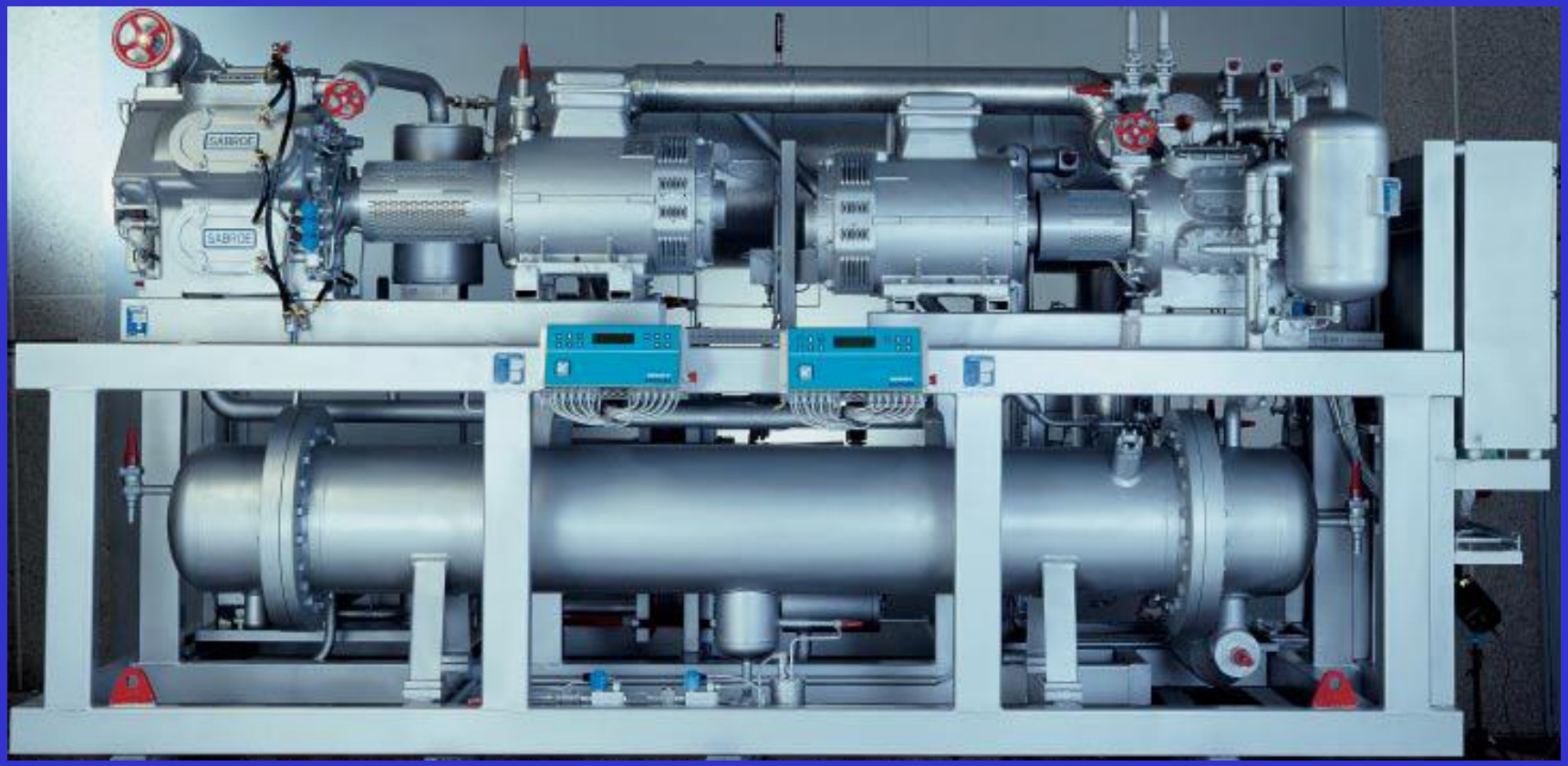
IQF

IQF

SPIRAL FREEZER

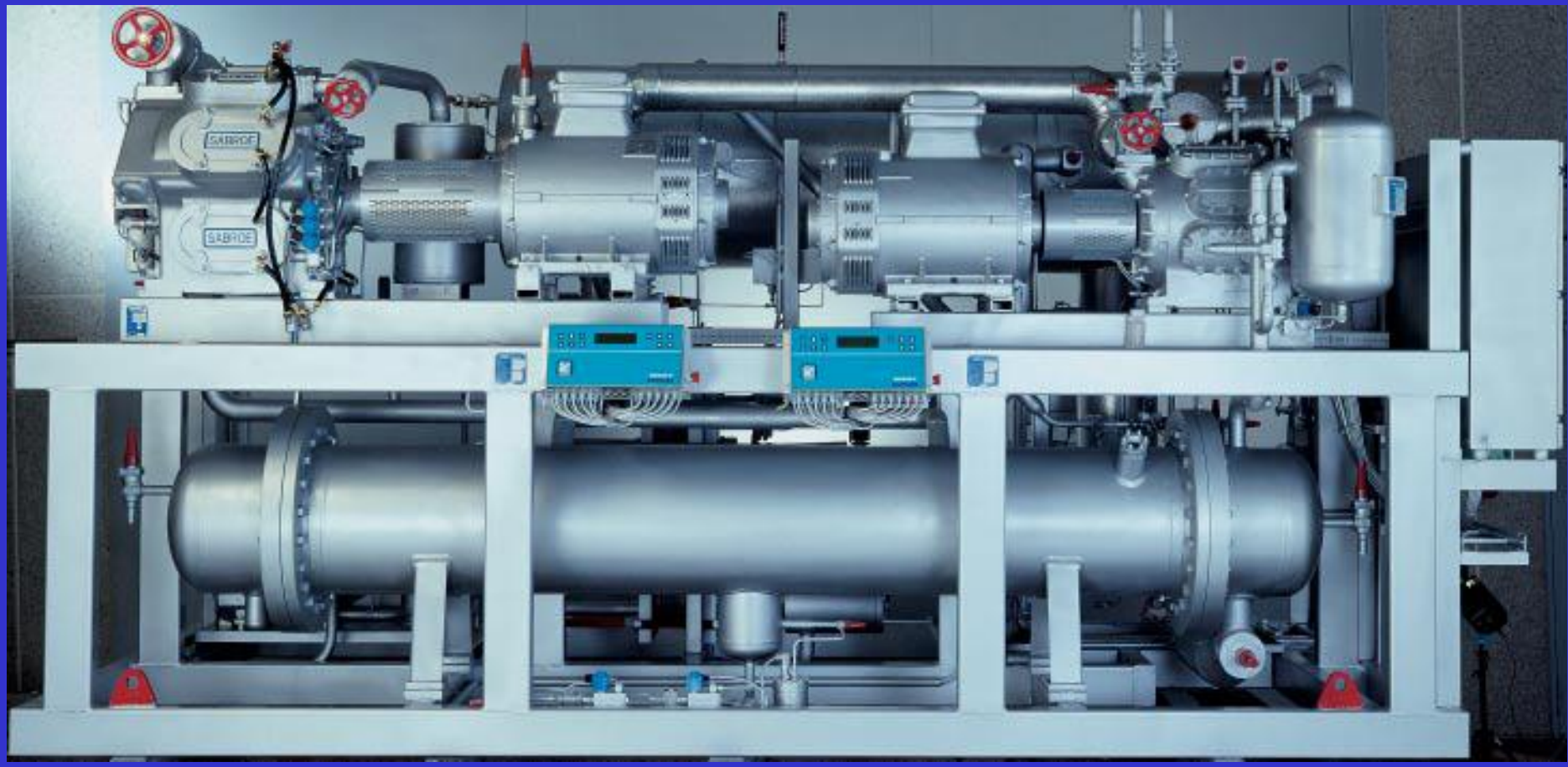
PLATE FREEZER

CO2 Ammonia Cascade



AMMONIA-CO2 BRINE SYSTEM –FRUIT STORAGE-HOLLAND

AMMONIA CHILLER AT HEATHROW AIRPORT



AMMONIA-CO2 BRINE SYSTEM –FRUIT STORAGE-HOLLAND

AMMONIA -CO2 CASCADE

Thank you

Any Questions ?

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