15680-3

MECHANICAL DESIGN MANUAL SUMMARY SHEET

Date: July 18, 1996

Subject: Chiller Selection

Description: Criteria and guidelines for the selection and application of electric liquid chillers.

CSI Sections: 15681-15730

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ELECTRIC LIQUID CHILLER SELECTION

Introduction

The Consulting Engineer's ability to expalin product lines, evaluate their uses, and apply them correctly in field, is justification of his own existance.

In the last seven or eight years chiller design has changed greatly . ARI full load efficiencies of 0.55 kW/Ton has become very common and Integrated Part Load Values (IPLV) have become a more routine selection paramater. Given the greater energy efficiencies seen with today's chillers, the designer needs to look more closely at plant peripheral power consumption (i.e. pumps and fans) for an overall plant efficiency.

Along with improving overall efficiencies, the transition from CFCs to alternative refrigerants has also had a great deal of impact on current chiller designs. HCFC-123 (R-123) has replaced R-11 in low pressure machines while HFC-134a (R-134a) has become the leading alternative for R-12 in medium pressure machines. While R-123 has acted as almost a drop in replacement, R-134a has required a great deal of improvements in compressor technology along with the need for the development of synthetic oils.

Selection of the correct chiller which best suites an application requires the Engineer to compare efficiencies, compressor design, and shell design, as well as a machines ability to best meet the user's realistic expectations for operation and maintenance. It is always important to first define these expectations and then tailor your selections to find a machine(s) that best matches those desires.

Products

Reciprocating - Air-cooled, range from 20 - 100 tons in capacity, average efficiency of 1.1 kW/Ton.

Helical Rotary - (Screw) Water-cooled, ranges of 125 - 675 Tons and 1000 - 1250 tons. Larger custom machines can be field assembled up to 10,000 Tons, R22 high pressure machines. Use a screw compressor with a slide valve for capacity control. Efficiencies down to .57 kW/Ton in the smaller machines and .60 kW/Ton in the larger ones can be expected. A pump out unit is required and refrigerant can be stored in either heat exchanger bundles with the provision of isolation valves.

Centrifugal - Water-cooled, range from 350 - 10,000 tons, low pressure machines using R123 or medium pressure R134A. Design uses a constant speed impeller with inlet vanes for capacity control. Efficiencies down to .55 kW/Ton can be expected. Aa pump-out unit is required to remove refrigerant in all models, however the low pressure machine's heat exchangers do not have the ability to act as storage vessels. Some manufacturers offer an engine driven drive line from 400 - 2,000 Tons.

Sizing

The installed air-conditioning coil capacity is the basis for selection of chiller size. An internal *building* diversity factor can be taken in most VAV systems relative to occupancy and orientation. In single building systems a diversity of 80% may be common. The designer needs to be aware of building use and outdoor air requirements, prior to making selections in schematic and design development phases of the project. Campus and district systems may also use a *site* diversity since buildings may have different orientations, uses, and hours of occupancy; their peaks do not coincide. This may also be 80% at times.

While diversities may be used to reduce plant capacity, the designer must also consider that the system itself adds load to the plant. An open drive motor will add heat to the space, while a hermetically sealed will subtract from the chiller capacity. Pump and transmission heat should also be considered. A single building may see a 5% increase and campus systems up to 15% that must be considered in sizing the chiller.

Refrigerants

We are constantly faced with questions on which refrigerant should be used, if any. Questions on toxicity, flammability, and possible phase-outs of refrigerants are always being asked.

Ozone depletion and global warming hve been identified as an environmental concern. Earth's protective ozone layer is deteriorating due to chlorine emissions. Global warming is the entrapment of the sun's heat in the atmosphere, resulting in a warming of earth's climate.

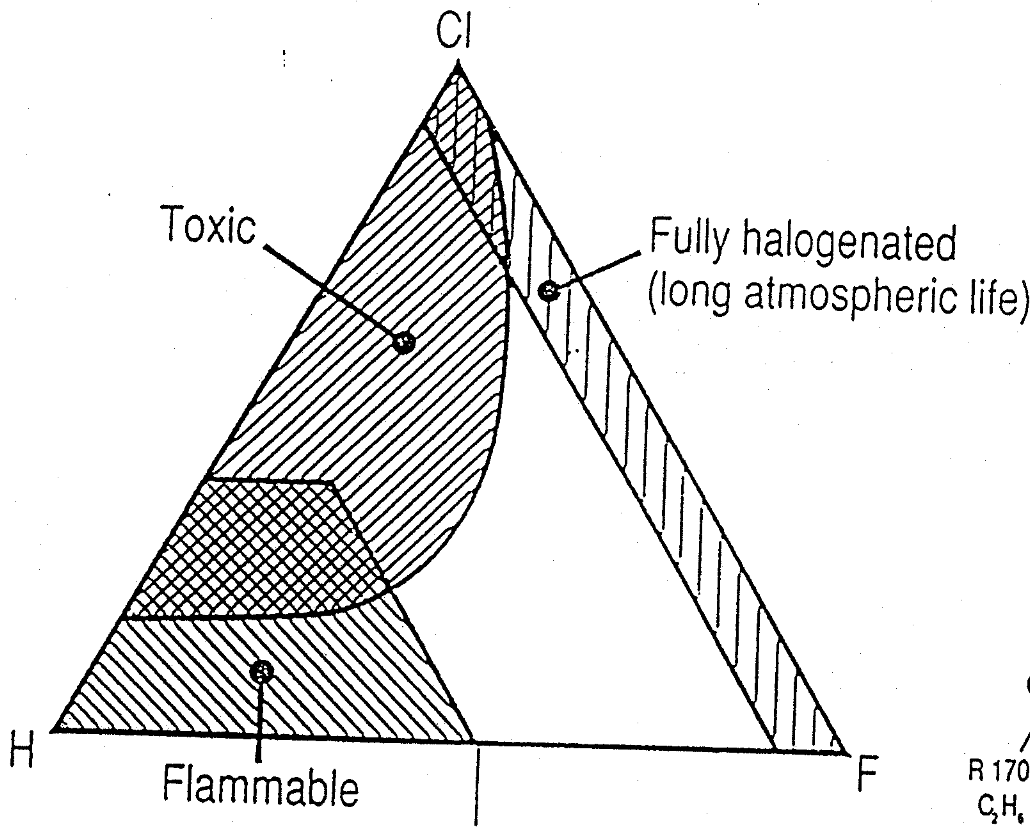
The Montreal Protocol agreement mandated the phaseout of CFC (ie.. fully halogenated refrigerants) production by January 1, 1996. The U.S. Environmental Protection Agency implemented the Clean Air Act Amendments of 1990 which legislate domestic phaseout of CFCs in compliance with the Montreal Protocol schedule. Since alternative refrigerants such as HCFCs (R22 &123) contain less ozone-damaging chlorine, their phase-out schedule would not be as quick.

The Montreal Protocol was updated in 1995 to reduce the growth cap of HCFCs from a rate 3.1% to 2.8%. HCFC production is scheduled to be phased out by 2020, except for a 0.5% allowance till 2030 for servicing existing equipment. The Clean Air Act may impose fines for the intentional venting of CFCs and HCFCs during servicing, maintenance or disposal of refrigeration equipment. As of 1995 the venting of HFCs was also prohibited in regards to potential global warming.

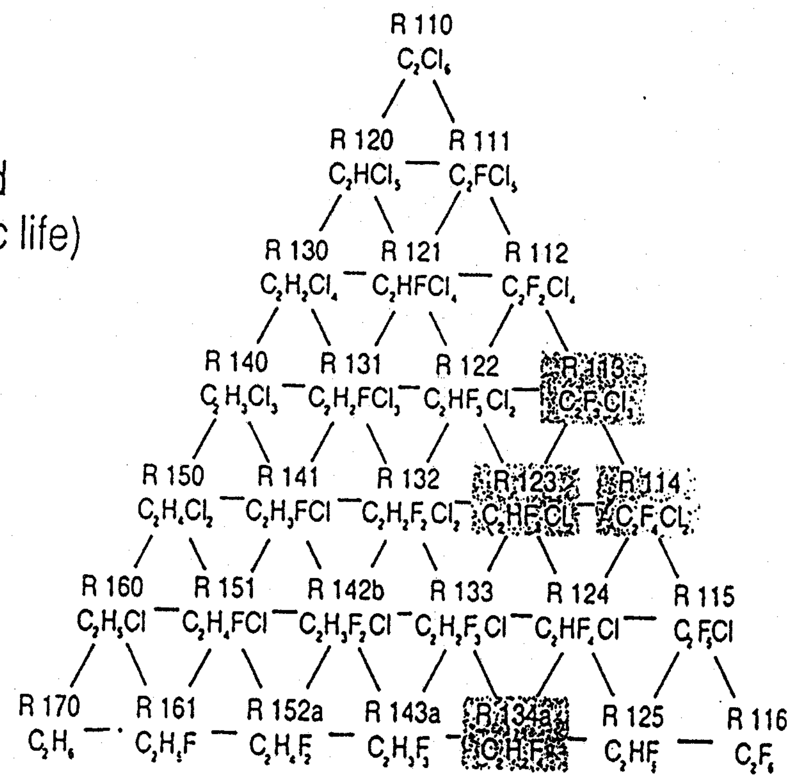
The major concerns in selecting alternative refrigerants have been; chemical behavior, thermodynamics, health and safety, environmental impact, and cost. Refrigerants are composed mainly of one or two carbon atoms and various combinations of chlorine, fluorine, and in some cases, hydrogen. Rrefrigerants containing too much hydrogen are flammable, while those with high chlorine levels tend to be toxic. For example HCFC-123 is a good replacement for CFC-11, however, it approaches the toxicity range of the chemical matrix.

The American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE) provides Standard 15-1994 , a safety code for mechanical refrigeration. Refrigerant sensors are required for all electric chillers. Sensors associated with HCFC-123 are required to be much more sensitive than with other refrigerants. Group B1 refrigerants also have more stringent ventilation requirements than those in A1. Higher costs associated with these safety devices must be anticipated.

HCFC-123 is used in negative pressure machines which require purge systems to evacuate air and moisture. HCFC-22 and HFC-134a operate in positive pressure systems which do not require such purge systems. An additional benefit to HCFC-22 and HFC-134a high pressure machines is that, with the provision of isolation valves and a pump-out unit, the refrigerant can be stored in the heat exchanger shells.



Cl
Toxic
Fully halogenated
(long atmospheric life)
H
Flammable
F



R 110
C_2Cl_6
R 120
C_2HCl_5
R 111
C_2FCl_5
R 130
$C_2H_2Cl_4$
R 121
C_2HFCl_4
R 112
$C_2F_2Cl_4$
R 140
$C_2H_3Cl_3$
R 131
$C_2H_2FCl_3$
R 122
$C_2HF_2Cl_3$
R 113
$C_2F_3Cl_3$
R 150
$C_2H_4Cl_2$
R 141
$C_2H_3FCl_2$
R 132
$C_2H_2F_2Cl_2$
R 123
$C_2HF_3Cl_2$
R 114
$C_2F_4Cl_2$
R 160
C_2H_5Cl
R 151
C_2H_4FCl
R 142b
$C_2H_3F_2Cl$
R 133
$C_2H_2F_3Cl$
R 124
C_2HF_4Cl
R 115
C_2F_5Cl
R 170
C_2H_6
R 161
C_2H_5F
R 152a
$C_2H_4F_2$
R 143a
$C_2H_3F_3$
R 134a
$C_2H_2F_4$
R 125
C_2HF_5
R 116
C_2F_6

TYPICAL REFRIGERANT SAFETY LEVELS

TEST	REFRIGERANT (PPM) CFC11	HCFC123	HCFC22	HFC134a
AEL Allowable Exposure Limit	1,000	30	1,000	1,000
LC50 (lethal concentration in air at which half the test population perished after 4 hours)	26,000	32,000	308,000	600,000
Cardiac Sensitization (concentration at which heart palpitations begin to occur)	5,000	20,000	50,000	75,000
NOEL (no observed effect level)	10,000	<300	10,000	60,000

LESS RISK & LIABILITY →

As reported by the Program For Alternative Fluorocarbon Toxicity Testing (PAFT)

SAFETY GROUP

	Lower Toxicity	Higher Toxicity
Higher Flammability	A3 Propane	B3
Lower Flammability	A2 R-142b, 152a	B2 Ammonia
No Flame Propagation	A1 R-11,12,114,500,134a, 22	B1 R-123, SO_2

Components

Compressor

Stages-Stages of a compressor effect compressor size mostly. An R-123 machine with a sinfle stage compressor is almost 3'-0" taller than a two stage machine of similar size (based on a 500 ton machine). Multi-stages do offer more efficiency with the application of an intercooler and by injecting hot gas inbetween stages to reduce compressor work.

Transmission-Low pressure machines are direct coupled operating at 3600 rpm while high pressure machines use single ratio speed increasers to run at closer to 12,000 rpm. Speeds very with compressor designs.

Inlet vanes/Slide Valves - regulate the amount of refrigerant that is drawn from the evaporator into the compressor. The inlet vanes are followed by a diffuser. Inlet vanes provide capacity modulation from 100% down to as low as 10% in some machines. Capacity reduction is also governed by ECWT or condenser water relief. Without lower ECWT the unit may surge or you may see refrigerant stall.

Motors

Open Drive - The open-drive does show a shorter motor life based on motor manufacturer curves. This is an effect of operating at higher ambient temperatures. The other draw-back is shaft-seals. Manufacturers have not perfected a means of collecting the oil lost lubricating the seals. Presently an "oil recovery system", a plastic tube and a milk jug, is placed on top of the chiller and is required to be periodically emptied. This usually isn't done by the operator and oil saturates the insulation of the chiller.

Hermetic - hermetic motor is a philosophy of longer motor life as it is running in a cooler environment. The draw-back to hermetics is that a "motor burnout" will contaminate the refrigerant requiring complete replacement. Manufacturers sometimes state that the refrigerant may not need to be replaced depending on the extent of motor burn, however, the motor manufacturers state that once the refrigerant/oil coolant for the motor is even slightly tainted, this will shorten motor life and may even facilitate additional motor losses. Frequency of motor burnouts is very small. KJWW has not experienced any hermetic motor loss

Other

Engine-driven
Turbine

Heat Exchangers

Shells - low pressure machines (HCFC-123) do not have rated shells. HFC-134a and HCFC-22 machines have ASME certified construction. Differences in shell design can be seen in end sheet configurations and water box designs.

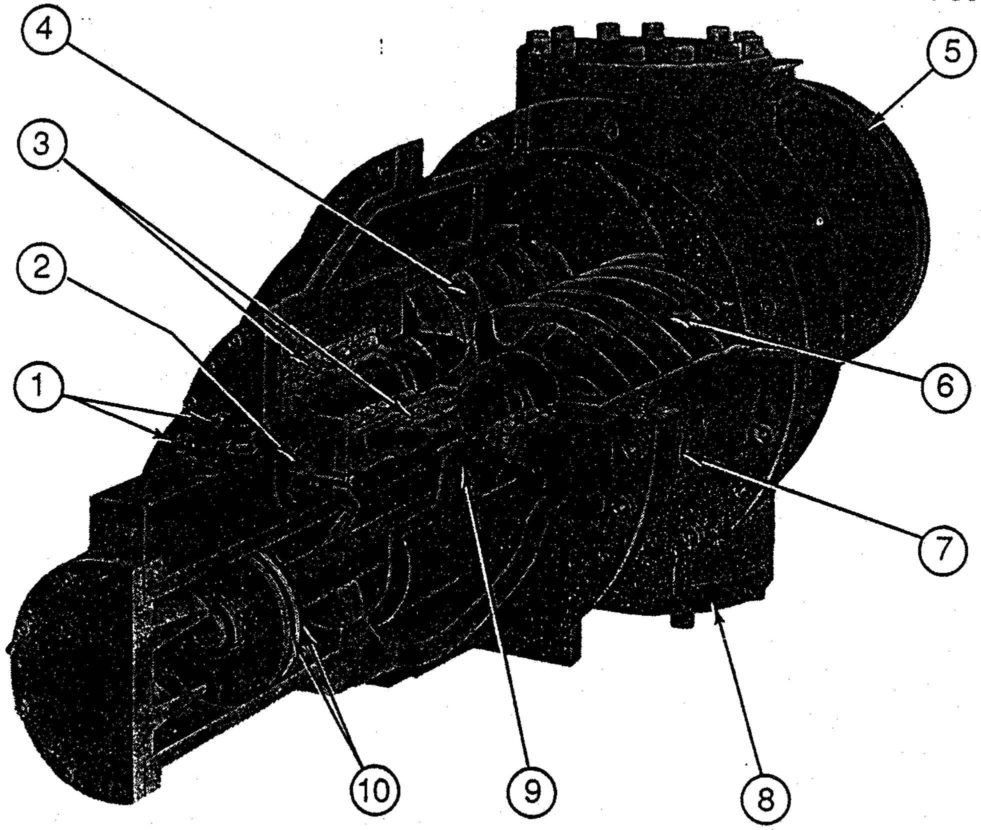
Tubes- smooth bore, enhanced, and super enhanced tubes are available. Standard tube diameters are 0.28 with 0.35 as an option. Cupronickel and titanium is also available for special applications.

Peripheral devices

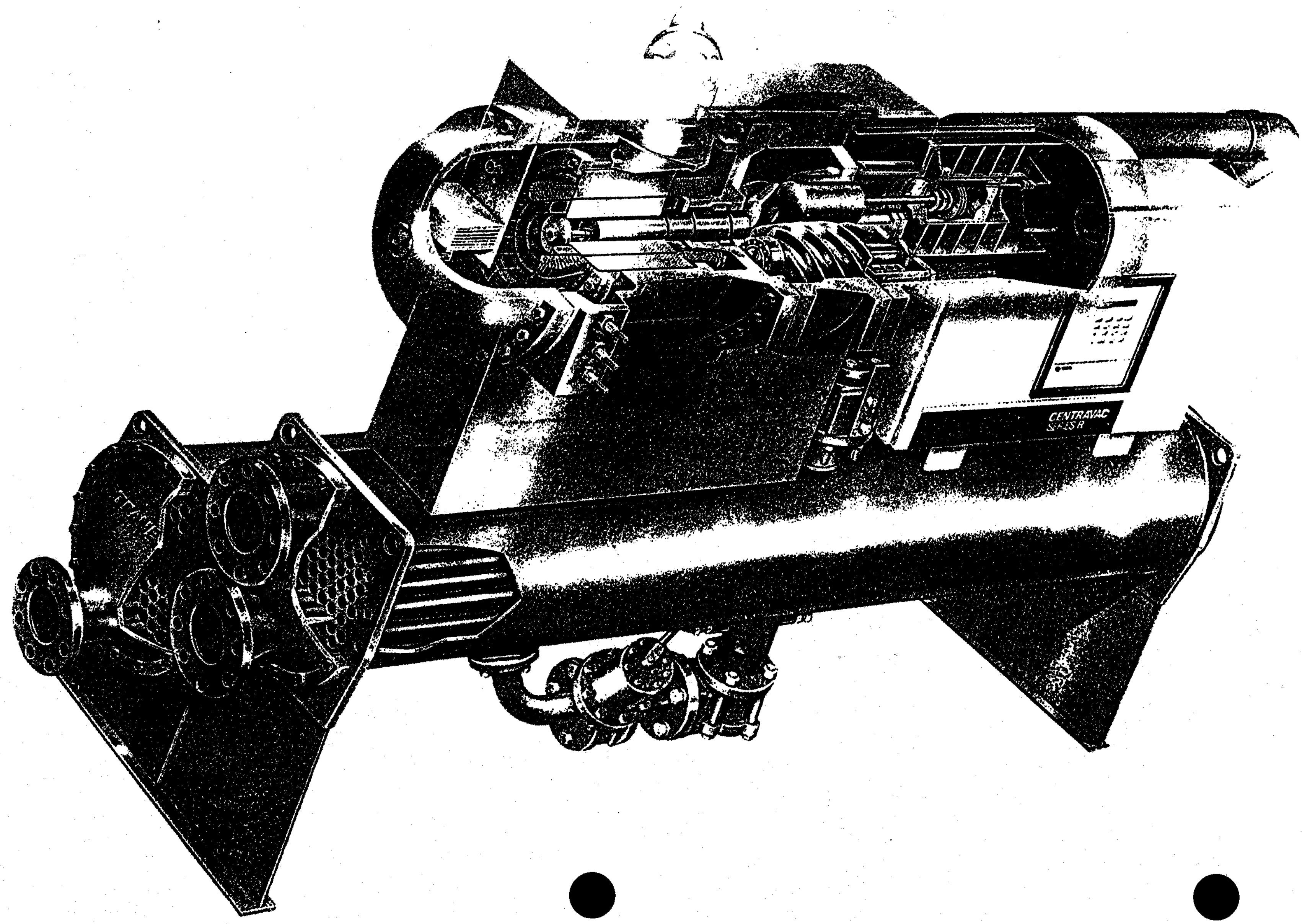
Purge units- Are required on low pressure machines. Low pressure machines tend to create a vacuum once shutdown drawing in moisture along with air. The purge unit vents this air along with traces of refrigerant. High efficient purge units have efficiencies close to .0005. The purge units are generally unit mounted. A shell heater can also be installed for shutdowns of long duration (winter) to keep the shell pressures somewhat positive.

Pump Out Units- Are require for all machines to remove the refrigerant for sservice. High pressure machines do allow the ability to store refrigerant in the heat exchangers, while a separate vessel is required for low pressure machines (could be 55 gal. drums).

SCREW COMPRESSOR COMPONENTS

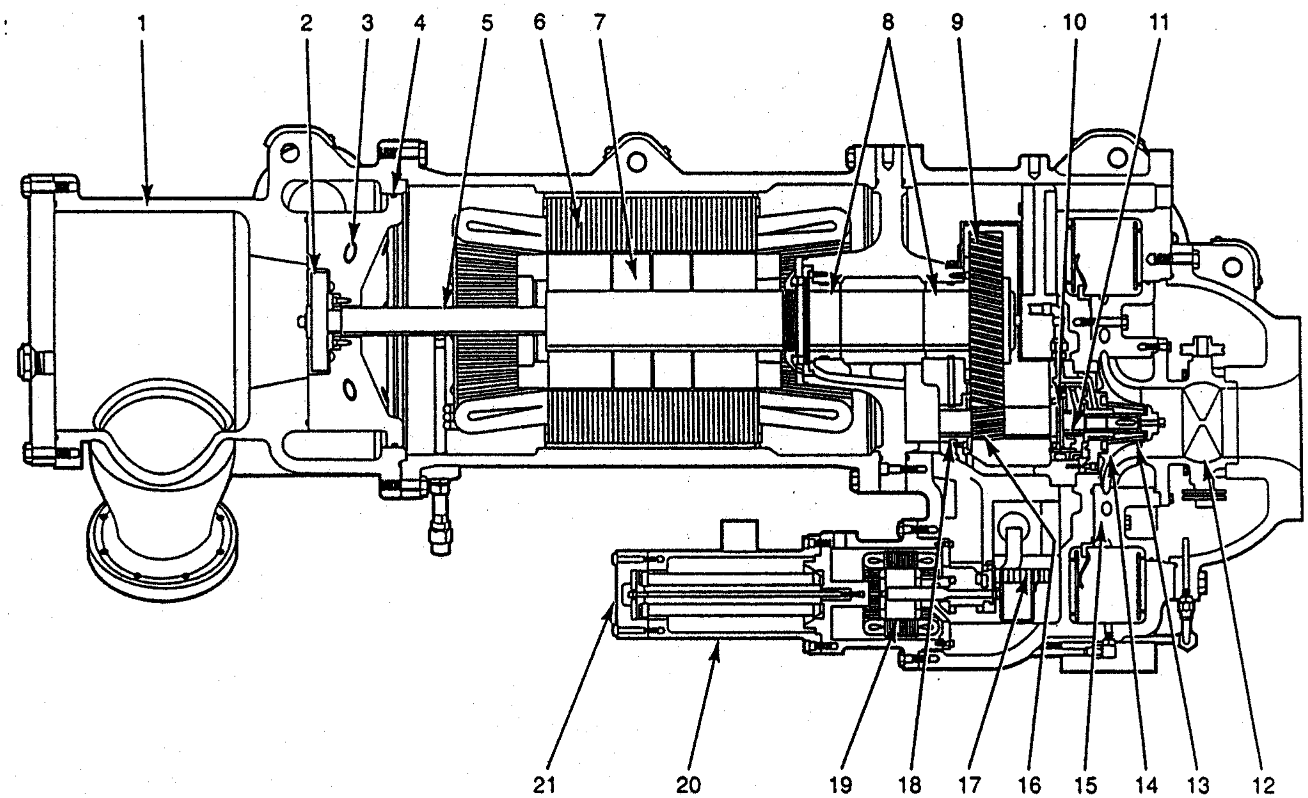


1 — Control Oil Lines
2 — Capacity Control Solenoid Valve
3 — Discharge Bearing Assemblies
4 — Male Rotor
5 — Semi-Hermetic Motor
6 — Female Rotor
7 — Rotor Oil Injection Port
8 — Suction Inlet Flange
9 — Capacity Control Slide Valve
10 — Slide Piston Seals


CENTRAVAC

Machine components

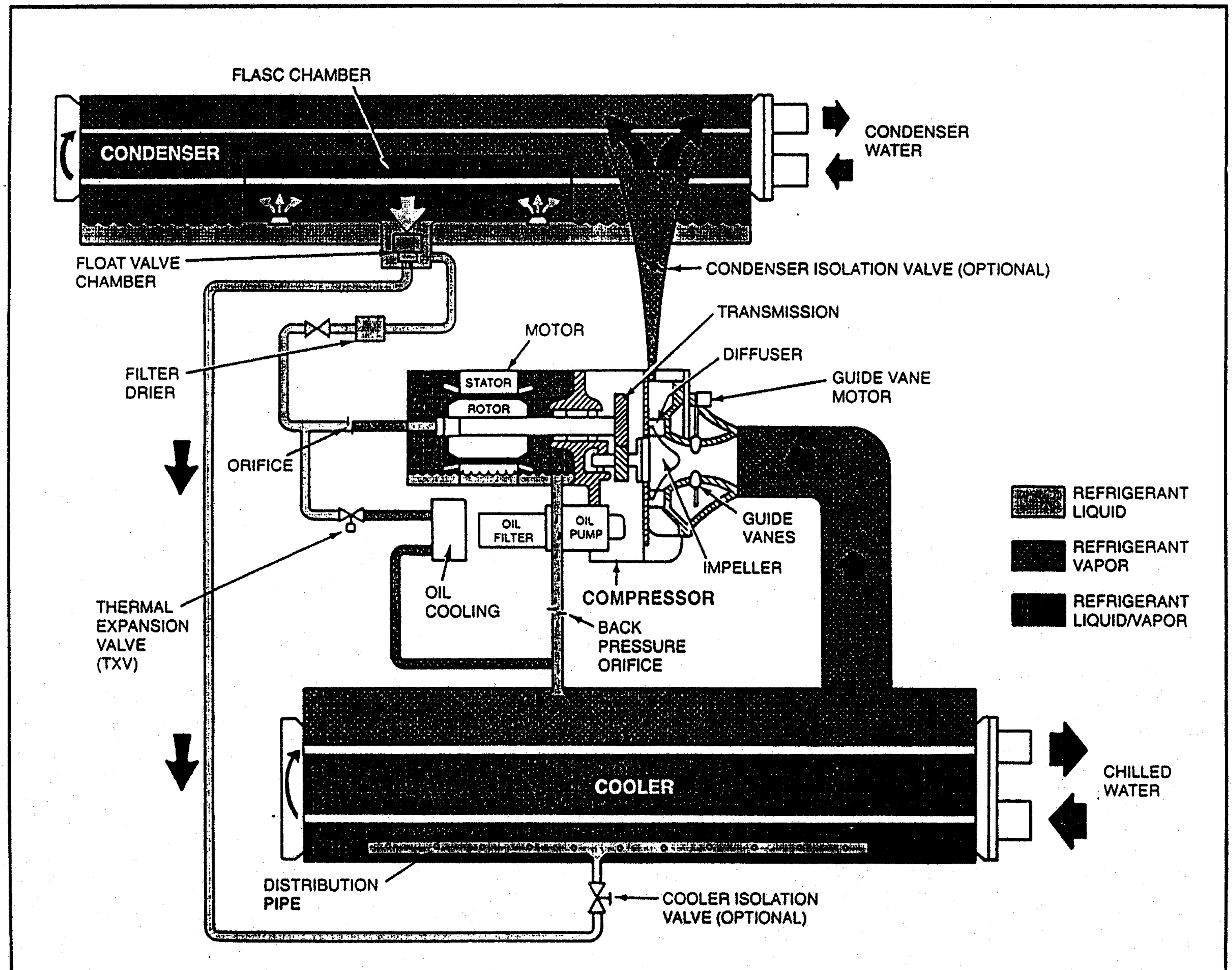
COMPRESSOR COMPONENTS*



LEGEND

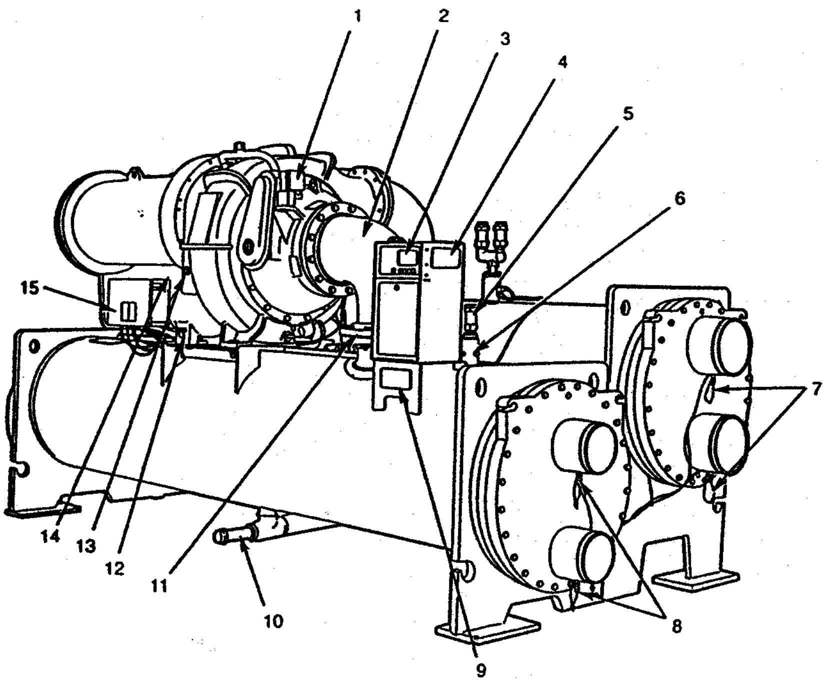
1 — Turbine Housing
2 — Turbine Wheel
3 — Turbine Nozzles
4 — Turbine Nozzle Block
5 — Motor Shaft Extension
6 — Motor Stator
7 — Motor Rotor
8 — Motor Shaft Journal Bearings
9 — Low Speed Bull Gear
10 — High Speed Shaft Thrust Bearing
11 — High Speed Shaft Journal Bearing
12 — Variable Inlet Guide Vanes
13 — Impeller Shroud
14 — Impeller
15 — Pipe Diffuser
16 — High Speed Pinion Gear
17 — Oil Heater
18 — High Speed Shaft Journal Bearing
19 — Oil Pump Motor
20 — Oil Filter
21 — Oil Filter Cover

*Items 1 to 5 apply to 19XRT only.


FLASC CHAMBER
CONDENSER
CONDENSER WATER
FLOAT VALVE CHAMBER
CONDENSER ISOLATION VALVE (OPTIONAL)
TRANSMISSION
MOTOR
DIFFUSER
GUIDE VANE MOTOR
FILTER DRIER
STATOR
ROTOR
ORIFICE
OIL FILTER
OIL PUMP
GUIDE VANES
IMPELLER
REFRIGERANT LIQUID
REFRIGERANT VAPOR
REFRIGERANT LIQUID/VAPOR
THERMAL EXPANSION VALVE (TXV)
OIL COOLING
COMPRESSOR
BACK PRESSURE ORIFICE
COOLER
CHILLED WATER
DISTRIBUTION PIPE
COOLER ISOLATION VALVE (OPTIONAL)

Machine component

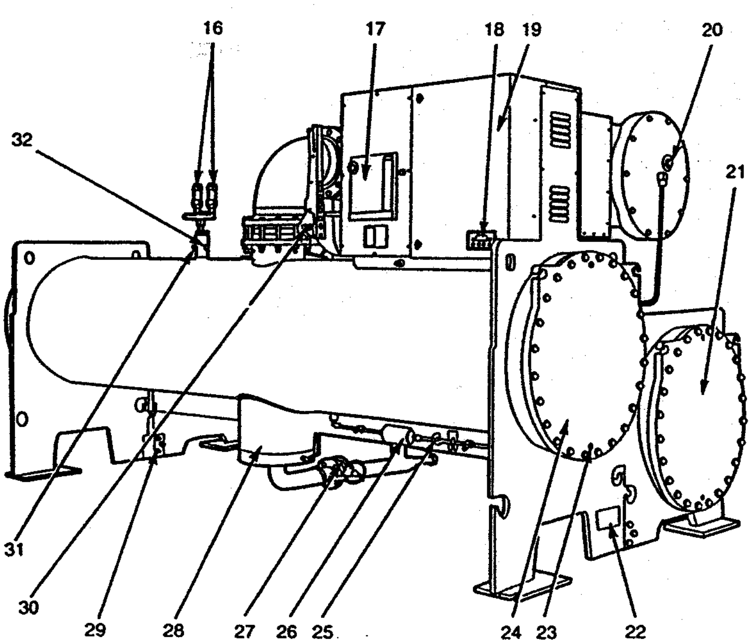
FRONT VIEW



LEGEND

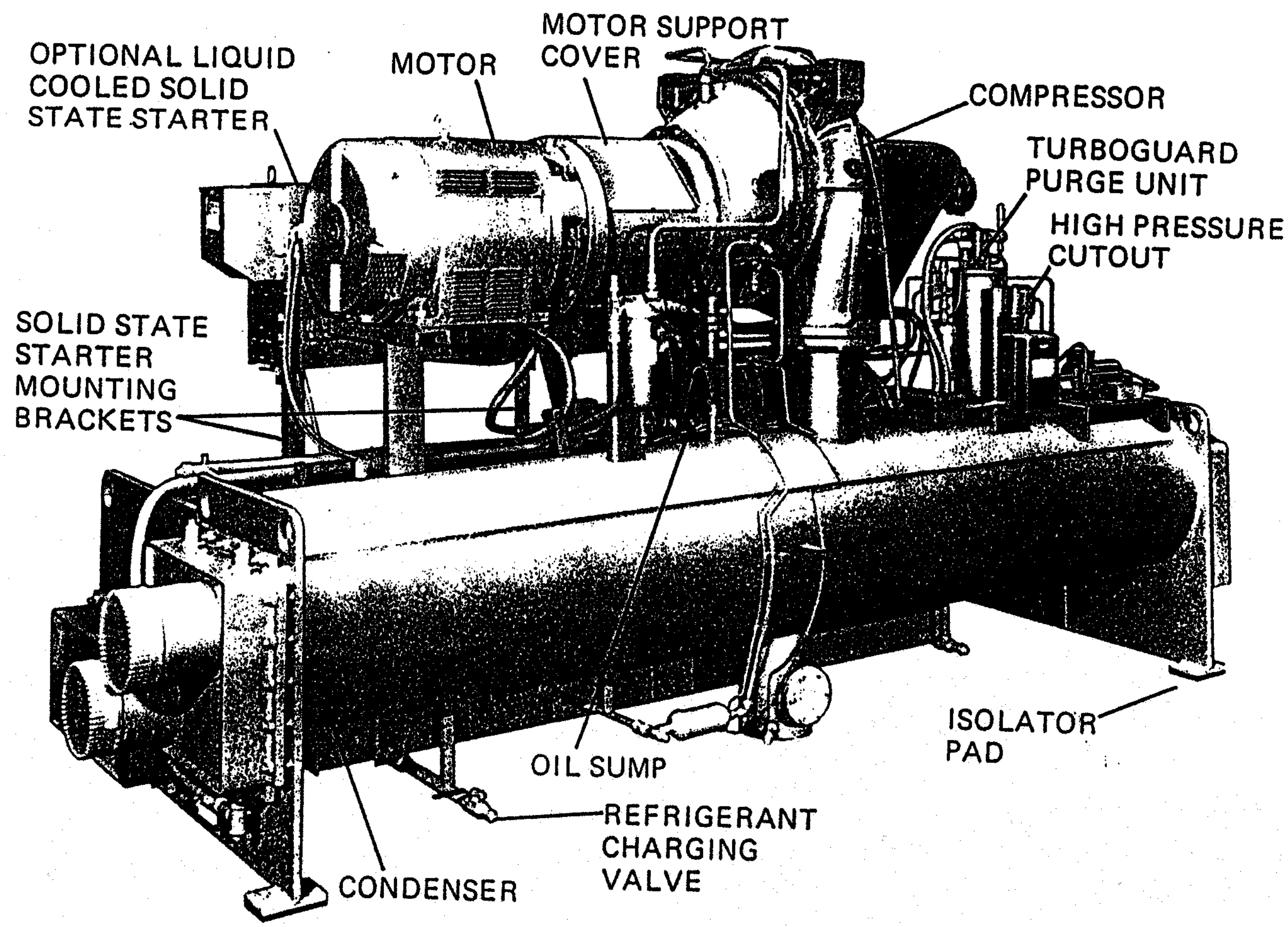
1 — Guide Vane Actuator
2 — Suction Elbow
3 — Local Interface Display Control Panel
4 — Machine Identification Nameplate
5 — Cooler, Auto Reset Relief Valve
6 — Cooler Pressure Transducer
7 — Condenser In/Out Temperature Thermistors
8 — Cooler In/Out Temperature Thermistors
9 — ASME (American Society of Mechanical Engineers) Nameplate, Cooler
10 — Refrigerant Charging Valve
11 — Typical Flange Connection
12 — Oil Drain Valve
13 — Oil Level Sight Glasses
14 — Refrigerant Oil Cooler (Hidden)
15 — Auxiliary Power Panel

REAR VIEW

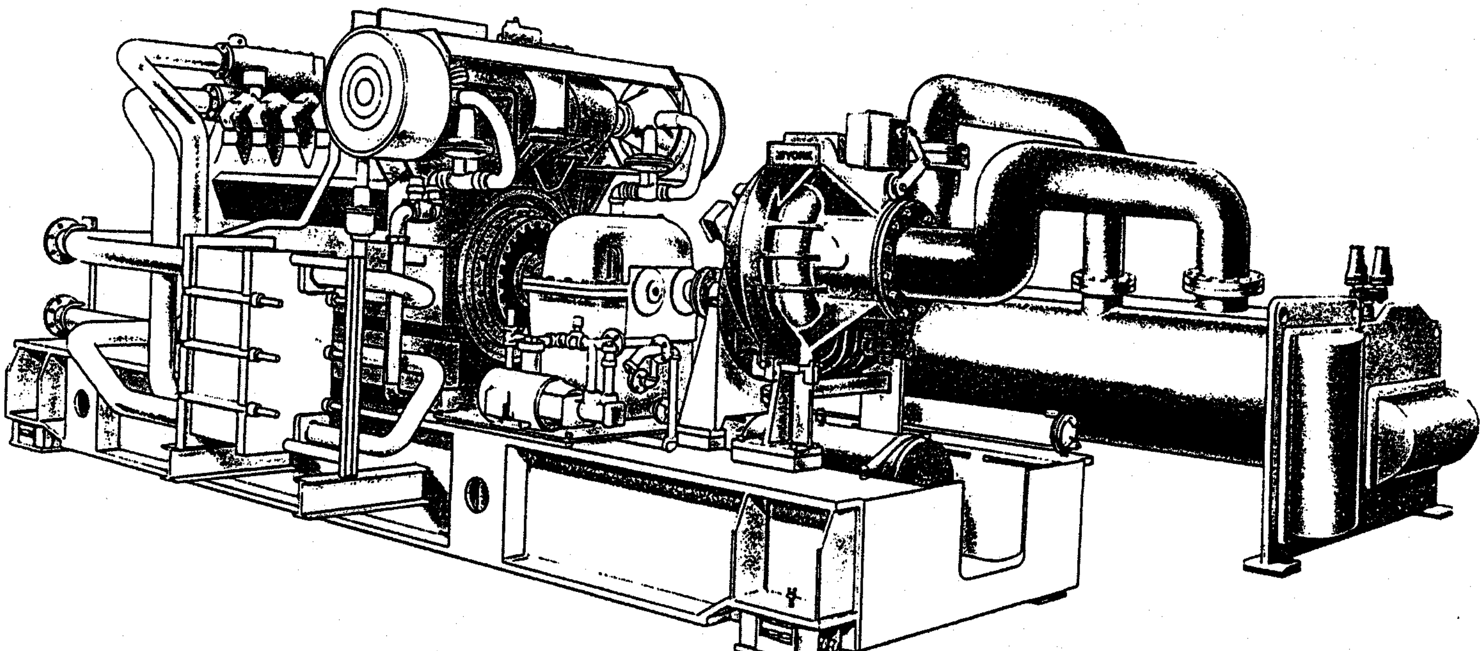


LEGEND

16 — Condenser Auto. Reset Relief Valves
17 — Motor Circuit Breaker
18 — Solid-State Starter Control Display
19 — Unit-Mounted Starter (Optional), Solid-State Starter Shown
20 — Motor Sight Glass
21 — Cooler Return-End Waterbox Cover
22 — ASME Nameplate, Condenser
23 — Typical Waterbox Drain Port
24 — Condenser Return-End Waterbox Cover
25 — Refrigerant Moisture/Flow Indicator
26 — Refrigerant Filter/Drier
27 — Liquid Line Isolation Valve (Optional)
28 — Linear Float Valve Chamber
29 — Vessel Take-Apart Connector
30 — Discharge Isolation Valve (Optional)
31 — Pumpout Valve
32 — Condenser Pressure Transducer


OPTIONAL LIQUID COOLED SOLID STATE STARTER
MOTOR
MOTOR SUPPORT COVER
COMPRESSOR
TURBOGUARD PURGE UNIT
HIGH PRESSURE CUTOUT
SOLID STATE STARTER MOUNTING BRACKETS
ISOLATOR PAD
OIL SUMP
REFRIGERANT CHARGING VALVE
CONDENSER

GAS-ENGINE-DRIVE CHILLERS



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