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Ammonia Packaged Units an Alternative to CFCs

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AMMONIA PACKAGED UNITS
AN ALTERNATIVE TO CFC'S

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AMMONIA PACKAGED UNITS - AN ALTERNATIVE TO CFC'S

The phaseout of the fully halogenated CFC's is an opportunity for the ammonia refrigeration industry to grow into markets previously dominated by CFC refrigerants and equipment that uses the CFC's. Typically the small single load outdoor applications utilized CFC equipment due to significant capital cost advantage over ammonia.

While there may be less concern with higher cost since the CFC's ultimately will not be available, it would in my opinion be advantageous if it can be shown to the marketplace that ammonia systems need not be two, three or even four times the cost of small unitary CFC refrigeration systems. Then the ammonia refrigeration industry will have the competitive advantage of having a well established low cost refrigerant, and have competitively priced equipment hopefully with no more than a 10 to 25% premium for comparable features. Many people will give a ball park cost of $2,500 to 4,000/TR for a central ammonia plant When a packaged DX R-22 unit might cost 500 to $750/TR, (excluding installation) this is a big difference

This paper will focus on three concerns to the marketplace (Designers, Owners, & Contractors) when applying ammonia to three typical refrigeration applications. These three applications are:

- Rooftop mounted air cooling units - direct ammonia.
- Rooftop or outdoor mounted HVAC Units for use in office buildings using water or glycol chillers to assure no refrigerant leak into air stream
- Outdoor installation of larger glycol chillers and/or icebuilders for larger office buildings or industrial applications where ammonia inside the building may be politically undesirable.

The three concerns that are at issue when designing, installing and operating a refrigeration system are:

- Design issues relative to application of ammonia refrigeration systems in an outdoor environment.
- Equipment package costs and installation costs.
- Operating and maintenance cost issues.

These are the issues that will be discussed in detail in the rest of this paper.

The reasons for considering outdoor refrigeration vs indoor applications include:

- Safety of Building Occupants - minimal risk of exposure to high concentrations of refrigerant in the event of a leak.
- Protection of Goods stored in buildings from exposure to a refrigerant in the event of a leak. Example - food storage warehouses.
- Lower Installed Cost
  - avoid need for building envelope @ $50 to $60/sq. ft.
  - avoid need for ventilation systems and refrigerant leak detection system which can typically be $20,000 plus

DESIGN ISSUES RELATIVE TO OUTDOOR INSTALLATIONS OF THREE APPLICATIONS.

- Environmental Issues

Three major areas of concern must be addressed when considering an outdoor environment.

- Oil used in the compressor (either rotary screw or reciprocating) must be able to perform its function when the compressor is started up and during normal operation.
- Removal of heat of compression methods must be reviewed for suitability in outdoor environment. With reciprocating compressors - oil cooler and heads require cooling, with rotary screw compressors - oil cooler requires cooling.
  - Suggest refrigerant cooled heads and oil cooler on reciprocating compressors.
  - For screw compressor use refrigerant oil cooler. This avoids need for a closed loop fluid cooler.
- The type of condenser selected will dictate review of its suitability for year round operation and requirements for winterizing. Water cooled and evaporative condensing require consideration of potential freeze-up, air cooled condensers don't have this problem but operate at higher condensing temperatures, which over a fifteen (15) year lifecycle can result in higher operating costs that will approach three times the original CFC equipment package cost.

As an example Table V at the end of this paper shows the estimated operating costs of Ammonia and R-22 systems with aircooled and evaporative condensers. The annual operating cost difference is $7,630 Over fifteen (15) years this would cost $115,000 compared to the R-22 package cost for a compressor condenser unit only at $40,000 for a 100 TR unit.

- With evaporative condenser - sump heaters, low water temp cutout, and winterized design are items that must be considered.

The evaporator depending on which type is used, may or may not have any unique design concerns relative to outdoor installation.

Direct Cooling Evaporators

Air units and silos have no unique concerns with ammonia outdoor applications vs CFC.

Indirect Cooling Evaporators

Water/glycol chillers and ice builders have problems relating to potential freeze-up of the secondary refrigerant in an outdoor environment, that must be addressed regardless of whether the refrigerant is ammonia or freon.

- Compressor Selection

Both commonly used types of compressor, reciprocating and rotary screw can be applied equally well to the outdoor ammonia application. Each has to be evaluated as to what considerations need to be addressed with the outdoor environment.

Screw Compressors

- Oil sump heaters suggested
- Oil cooling, if glycol it must be set up for correct design temp for area (-40°F in Northern parts of United States)

Reciprocating Compressors

- Oil sump heaters suggested
- Refrigerant cooled heads and oil cooler suggested in lieu of glycol cooling (avoids cost of closed loop fluid cooler)

Single vs Multiple Evaporators

By far the most common application of rooftop packages is for dedicated loads. The application to multiple loads dictates certain design considerations for either ammonia or CFC.

With multiple loads a receiver and suction trap are often required and further complicates control requirements. It is suggested additional features such as level controls, sight glass and possibly independent control of the loads and compressor condenser be included.

- Refrigerant Charge

While traditional ammonia refrigeration systems have large refrigerant charges, it is because these systems typically are large capacity central systems.

A look at Table I shows a comparison of five systems with capacities in the 30 to 160 TR range for R-22 and ammonia systems. The charges ranged from 35 lb to 400 lb (except for the icebuilder). The range is due more to the existence or lack of components in the package than due to which type of refrigerant.

It can be seen that very small refrigerant charges can be achieved if the package designer keeps this in mind.

The receiver, if included, can increase by 40% to 100% the package refrigerant charge. Similarly, if the load (whether a chiller or air unit) refrigerant charge is included this can significantly increase the package charge.

There is definitely some added refrigerant charge when going to flooded evaporators as opposed to DX that will affect either type of refrigerant package.

Table II shows the percentage of total package refrigerant charge that each component contributes for a chiller package. The evaporator at 36% in the case of this flooded ammonia chiller was the largest percentage. The second largest component was the receiver at 31%. As attempts are made to reduce package refrigerant charge the receiver becomes an obvious item to focus on. It is really not required in single load packages and in this case if eliminated could reduce the charge by 30%.

To reduce the evaporator charge may require some compromises. Larger tube diameters and close packing of tubes will reduce the charge but may affect the chiller performance. The option of using a spray chiller with the ammonia still in the shell but not flooded, or going to a falling film, plate style chiller can reduce the refrigerant charge of the evaporator. In the case of an air unit coil, circuit design and tube diameter can help minimize refrigerant charge but may be accompanied by added refrigerant side pressure drop and this will have to be compromised to an acceptable balance.

Package piping charge can be reduced most effectively by reducing pipe lengths which is done by making compact packages. Ability to maintain the package must be watched. Smaller pipe sizes can reduce refrigerant charge but carries a definite penalty in pressure drop which can increase operating costs.

A good equipment package designer can by being aware of these factors reduce the package charge 30-50%.

EQUIPMENT PACKAGE COSTS AND INSTALLATION COST

- Comparison between R-22 and ammonia packages for different types of applications.

The major difference in pricing that has been observed is not so much due to the refrigerant, but the quality and type of components that make up the package. If a hermetic compressor is acceptable to an owner the cost of an R-22 package mass produced can be purchased as glow as $350/TR for a water cooled package. As soon as you decide you want the quality and ruggedness of an industrial refrigeration open drive reciprocating compressor, an R-22 package price jumps up to the 500 to $650/TR range.

Table III shows seven (7) different types of ammonia and R-22 packaged refrigeration systems. The uninstalled package costs ranged from 400 to $1,410/TR. This range is primarily due to the different applications (chiller, icebuilder, air units) and different types of compressors rather than the type of refrigerant. In the case of a water or glycol chiller having an open reciprocating compressor and water cooled condenser, the R-22 package was $850/TR compared to $890/TR for the ammonia package, a 5% difference. Comparing the R-22 and ammonia icebuilder packages, they are $1,395/TR and $1,410/TR respectively, a 1% difference. Note the R-22 icebuilder package has a hermetic compressor vs the ammonia package with an open compressor.

Comparing the R-22 semi-hermetic air cooled condensing unit with an ammonia condensing unit with open reciprocating compressor and evaporative condenser, both for air unit application, we find $400/TR and $750/TR respectively. Most of this difference is due to the type of components being significantly different. The open drive reciprocating compressor is a significantly higher cost component compared to a semi-hermetic compressor. All welded steel piping for ammonia vs copper piping in the R-22 package also affects cost

Thus comparing equal <u>quality</u> and types of <u>compressor</u> and <u>condenser</u> virtually has no effect on price. As mass production of ammonia packages becomes more common it is expected the cost of ammonia packages could drop below equivalent R-22 packages due to the inherent advantages of ammonia over R-22. These advantages are lower surface area required on evaporators and condensers, smaller pipe sizes, and lower CFM/TR for ammonia. Typically these translate to approximately <u>20%</u> less surface area, <u>50%</u> smaller pipe cross sectional area, <u>3%</u> lower CFM/TR.

<u>Avoided building costs when using outdoor packages.</u>

- <u>Equipment Room</u>

The most obvious advantage of using an outdoor package, is the avoided cost of the enclosure or building. When an addition to an existing production facility is required, code requirements dictate fire rated walls. This usually dictates concrete block walls. Building costs for this type of construction run $50 to $60/SF. If you can build a stand-alone building for the refrigeration system you could spend as low as $36 to $40/SF for a metal building. Based on past experience a well designed refrigeration equipment room will require 2 to 2.5 SF/TR depending on the capacity of system. This translates into $70 to $150/TR that can be saved using an outdoor package.

- <u>Ventilation Requirement</u>

A continuous ventilation system or refrigerant detector activated ventilation system is required by building codes for attached equipment room. This cost can run between $5,000 to $20,000 depending on the size of the refrigerant charge in the system.

Another advantage of the rooftop packages is avoiding the cost and maintenance of long field piping runs from the equipment room to the evaporator.

<u>OPERATING AND MAINTENANCE COSTS</u>

- <u>Electrical Operating Costs</u>

Typically the rooftop packaged refrigeration systems have been R-22 or R-12 air cooled systems. Comparing ammonia with R-22, both air cooled and with a fan coil evaporator the system KW/TR might be 1.38 for ammonia and 1.55 KW/TR for R-22 or a 12.5% difference. Table IV shows a comparison of R-22 and ammonia for three (3) types of condensing for a 35 to 40 TR package with a fan coil evaporator.

The use of an ammonia package over an R-22 package can give a definite operating cost advantage of 12.5 to 15% depending on type of condensing used. At 6 cents/KWH and for a 100 TR load this equates to approximately $1/HR advantage at <u>design conditions</u>. An annual $2,400/YR for a 4000 hour/YR load is the estimated difference in operating the two (2) systems, when taking into account that during most of the year we have lower condensing temperatures and thus lower average operating costs.

There is a real advantage to considering a package outdoor ammonia system with evaporative condenser over an R-22 aircooled condenser. Table V compares the annual operating cost of these two (2) systems and shows a $7,630/YR operating cost difference. Note that much of the difference here is due to the type of condensing.

All of the above operating costs are based on a reciprocating compressor in the package.

<u>Maintenance Issues</u>

Electrical costs unfortunately are not the only concern. In a recent plant visit discussing the maintenance history of some R-22 rooftop hermetic package condensing units for 40° cooler application the following situation was found.

Total DX R-22 Units	24
Total Refrigeration Load	660 TR
Average Unit Size	20-30 TR
Age of Units	10-15 yrs.
% units down for repair at any time	15 to 25%
Annual Refrigerant Loss	2000 to 3000 lbs/YR
Maintenance Staff Required to Repair Units	One man full-time

Table VI shows a detail breakdown of the estimated operating and maintenance cost for this plant. At current R-22 costs this system was using approximately $2,500 to $4,500/YR for refrigerant.

The parts cost was estimated at between $10,300/YR and $18,000/TR. The manpower costs for an internal employee with benefits and overhead costs were running close to $50,000/YR. The maintenance costs overall are estimated to run between 95 and $110/TR/YR.

Thus with electrical and maintenance costs this total is running between to 320 to $335/TR. This is close to 75% to 100% of the capital cost of the equipment package to begin with.

An ammonia package does not eliminate all maintenance costs. However their traditional materials of construction are heavy duty set up for industrial application and long life. It is expected that for a similar environment the above case with rooftop ammonia packages would have an annual operating and maintenance cost of $190 to 210/TR.

At most the premium capital cost for an industrial quality ammonia package over a hermetic R-22 package might be $300 to $400/TR which could be paid for in two (2) years of operating cost savings in this example.

The overall purpose of refrigerating a cooler was not being achieved 15 to 25% of the time up to Quality Control Room temperature standards. This in many cases simply cannot be tolerated. If the maintenance program were improved to meet temperature requirements 95 to 98% of the time an even higher cost would have been incurred.

If the maintenance was not being done in house the annual manpower costs alone would have been closer to $90,000 vs $50,000 at typical service rates. Plus expenses and markup on parts, would be higher than in-house maintenance thus raising the overall maintenance costs by as much as 50%.

<u>Summary</u>

Ammonia and R-22 are very similar refrigerants in terms of application temperatures and pressures. Yet there are some inherent advantages ammonia offers that can provide the refrigeration user a lower cost of ownership. Outdoor applications minimize the capital cost of a refrigeration system. By considering a marriage of the two (2) advantages - an <u>outdoor</u> <u>ammonia</u> package, a significantly lower cost of ownership can be offered to the refrigeration user.

It is believed that in the current climate of concern with the CFC refrigerants, ammonia outdoor packages at a slight capital cost premium can be offered as a very cost effective alternative to the traditional CFC packages. The prices shown in the attached tables for ammonia packages are based on custom built-up packages.

Ammonia is a tried and proven refrigerant. There is nothing unique about this application, its been done many times before now. We do have a challenge however, to make the demand for this alternative large enough that we can ultimately reduce the <u>ammonia</u> <u>outdoor</u> <u>package</u> cost below R-22 package costs thru mass production and standardization. This goal of a lower cost package can be achieved in theory due to the inherent advantages ammonia has over R-22 or R-12. It is believed the only reason we do not currently see that cost advantage is because of lack of volume and because we are also comparing two different levels of quality of the packages in most cases. Namely the industrial vs commercial quality components including hermetic vs open drive compressors and different levels of sophistication in controls. Plus most industrial refrigeration ammonia systems include suction accumulators and receivers that simple DX freon packages do not include.

In conclusion it is the author's opinion that a cost effective viable alternative exists today for application where traditional unitary CFC packages were applied. This alternative is the Ammonia Packaged Refrigeration Unit.

TABLE I

Refrigerant Charge

Comparison of Selected Jobs for R-22 and Ammonia

System ID	Appplication	Refrigerant	System Capacity (TR)	Refrigerant Charge (LB)	Comments
I	Water Chiller	R-22	103	160	No Receiver Incl. Chiller
II	Glycol Chiller	R-22	83	150	No Receiver Incl. Chiller
III	Glycol Chiller	NH3	40/120[1]	170	Excludes Rec. No Load
IV	Glycol	NH3	80/160[2]	330	No Rec./Incl. Chiller
				155	Without Chiller
V	2 Air Units	NH3	79	510	Includes Rec. No Load
VI	Ice Builder	NH3	64	5000	Includes ice coil refrig. charge.
VII	Ice Builder	R-22	84	88	Ice Coils have glycol in them.
VIII	One Air Unit	R-22	23	35	Condensing unit only.

TABLE II

Package Refrigerant Charge of an Ammonia Chiller

% of Total Charge by Component

Component	% of Total Charge
Evaporator	36
Suction Accumulator	None
Condensor	16
Receiver	31
Package Piping	17
	100%

[1] Future capacity of package by adding compressor and condensing capacity.

[2] Same as footnote 1.

TABLE III

Refrigeration Package Costs
(Excluding Installation For Packages Shown in Table I)

System ID	Refrigerant	Operating Conditions	Capacity (TR)	Package Descriptions	Cost ($/TR)
I	R-22	42° CW 75°/90°	103	Water chiller, hermetic comp. indoor design, water cooled, cooling tower cost not incl., major MFR.	350
II	R-22	42° CW 30°/95	83	Glycol chiller, open recip compr. indoor design, water cooled, cooling tower cost not incl., builtup pkg.	850
III	NH3	30°/93	40	Glycol chiller, open recip compr outdoor design, evap cond., evap. cond. price incl., built-up pkg. Expandable to 120TR	1250
IV	NH3	30°/95°	80	Glycol chiller, open recip compr outdoor design, water cooled, cooling tower cost not incl., built-up pkg.	890
V	NH3	20°/95° 50°/95°	28 + 51 = 79	Compressor/condensor pkg., open recip compr. outdoor design, evap. cond., evap. cond. cost incl., built-up pkg. (Two Suction Temp.)	715
VI	NH3	20°/95°	64	Ice builder pkg. 1000 TR-HR, open recip. comp. outdoor design, evap. cond., evap. cond. cost incl., built-up pkg.	1410
VII	R-22	10°/95°	84	Ice builder pkg. 1000 TR-HR, hermetic compr. outdoor design, water cooled, cooling tower cost not incl., major MFR.	1395
VIII	R-22	30°/116°	23	Compressor/condensor pkg. for HVAC, semi-hermetic comp. outdoor design, air cooled condenser, major MFR.	400

TABLE IV

Comparison of Electrical costs for 40° Cooler Application

Comparing Refrigerants

	Ammonia (KW/TR)	R-22 (KW/TR)	Difference KW/TR	%
Air Cooled Condenser (30°/113°)	1.38	1.55	.17	12.5
Water Cooled Condenser (30°/95°)	1.04	1.20	.16	15
Evaporative Condenser (30°/95°)	1.02	1.17	.15	15

Comparison of Types of Condensing

	% Difference
Ammonia Air Cooled vs Water Cooled	32%
Ammonia Air Cooled vs Evaporative Condensor	35%
R-22 Air Cooled vs Water Cooled	29%
R-22 Air Cooled vs Evaporative Condensor	32%
R-22 Air Cooled vs Ammonia Evaporative Condensor	52%

TABLE V

Operating Cost of a 100 TR Load

(6 cents/KWH, 4000 HR/YR)

	Ammonia	R-22	Difference	
Air Cooled Condenser	19,870	22,300	2,430	
Water Cooled Condenser	14,980	17,280	2,300	
Evaporative Condenser	14,690	16,850	2,160	
R-22 Air Cooled vs Ammonia Evaporative Condenser				7,630

TABLE VI

Maintenance and Operating Costs
For Plant with 24 R-27 DX Units (Air Cooled)
Compared to Ammonia (Evaporative Condenser)

	R-22 (Air Cooled)	Ammonia (Evap. Cond.)
Refrigerant Loss	$ 2,400 - 4,500/YR	$100/YR
Manpower - Maintenance	50,000/YR	$25,000 to $30,000/YR
Parts (Estimated)	$10,300-$18,100	$ 3,300 to $11,500/YR
TOTAL	$62,700-$72,600/YR 660 TR	$28,400 to $41,600 660 TR
Total Maintenance Costs	$95 to $110/TR/YR	$43 to $ 63/TR/YR
Electrical Costs (Based on Table V)	$225/TR/YR	$147/TR/YR
Total Operating and Maintenance Cost	$320-$335/TR/YR	$190 to $210/TR/YR

THE IMPACT OF COMPACT HEAT EXCHANGERS ON REFRIGERATION TECHNOLOGY AND CFC REPLACEMENT

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