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Impact of New Refrigerant Regulations on Postharvest Cooling[1]

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New regulations and taxes intended to protect the earth's atmosphere are increasing the cost and reducing the supplies of refrigerants needed to operate your refrigeration systems. Chlorofluorocarbons (CFCs), the most widely used chemicals for refrigeration are being phased out in an effort to decrease damage to the ozone layer as well as reduce the global warming effect of gasses released into the atmosphere.

OZONE DEPLETING REFRIGERANTS

The furor over conventional refrigerants has been caused by concern that these chemicals destroy the ozone layer, the uppermost level of the earth's atmosphere. Ozone reflects ultraviolet (UV) radiation, which causes skin cancer in humans and can disrupt the growth of marine plants and animals. The bad guys are CFCs (chlorofluorocarbons), including R-12, R-11, R-115, which do the most damage to the ozone layer. They are extremely stable, which is good from a refrigeration perspective, but bad because they do not break up until they come in contact with high intensity solar radiation some 35 miles above the earth's surface. When they break up, chlorine atoms are released which fracture ozone molecules.

Another category of refrigerants which damage the ozone layer, but to a much lesser extent, are HCFCs (hydrochlorofluorocarbons). They break up much faster and at lower levels in the atmosphere, compared to CFCs, so that less chlorine reaches the outer ozone layer. Included in this group are R-22 (used in most all residential and small commercial air conditioning systems), and a group of new refrigerants (sometimes referred to as low ozone depleting refrigerants) that are being used as substitutes for the CFCs. The use of these refrigerants will reduce the damaging effect on the ozone layer, but will eventually have to be replaced with refrigerants having a zero depletion rate.

Several worldwide efforts, starting with the 1987 Montreal Protocol, are moving to reduce and eliminate CFCs and HCFCs. Based upon these initiatives, the US Clean Air Act has mandated that no more CFCs will be manufactured after December 1995 and that HCFCs will begin reduction in 1996 and be completely phased out by 2030. It also imposes stiff fines for venting CFCs and HCFCs into the atmosphere. The only CFCs that will be available beginning in 1996 will be those that are recovered and remanufactured. Recovery and recycling equipment are becoming big businesses.

A group of refrigerants known as azeotropes are mixtures of halocarbons (CFCs, HCFCs and HFC) and are numbered in the 500 series, such as R-500, R-501, and R-502. Unfortunately, most of these have a high ozone depletion rating since they are mixtures containing CFCs. For example, R-502, an important

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low temperature refrigerant is a mixture of R-22 (HCFC) and R-115 (CFC) and will soon be in short supply due to the early phase out of CFCs.

NONOZONE DEPLETING REFRIGERANTS

Another category of refrigerants are called HFCs (hydrofluorcarbons) which contain no chlorine and thus have no damaging effect on the ozone layer. Included in this group is R-134a a new refrigerant that is being used as a replacement for R-12.

Other refrigerants are classified as inorganic and include ammonia, water and nitrogen, which do not damage the ozone layer.

Although never used extensively in the US as refrigerants, hydrocarbons such as methane, propane and butane are good refrigerants except for their flammability; and they do not deplete the ozone layer. Some work is underway to modify these refrigerants to make them non/less flammable.

Ozone depletion ratings have been assigned to each refrigerant and are based on the amount of chlorine in the refrigerant and how fast they break down. R-12 is used as the standard since it has the most detrimental effect on the ozone layer and other refrigerants are compared to it. For example, R-502 has a depletion level rating which is 30% that of R-12, while R-22 has an ozone depletion rating only 5% that of R-12. CFCs have the highest depletion level ratings with HCFCs being much less, in the order of 10% that of CFCs, while the other categories of refrigerants (HFCs, inorganic and hydrocarbons) have a zero rating. Ozone-depleting refrigerants are now subject to a tax tied directly to their depletion level rating.

GLOBAL WARMING

Another environmental concern is the global warming effect of refrigerants discharged into the atmosphere. It has been estimated that during the 1980's, CFCs released to the atmosphere were responsible for 24% of the human-caused future global warming effect. This contribution is second only to the 55% share from carbon dioxide emissions during this period. Table 1 shows the global warming potential of several refrigerants compared to carbon dioxide. For example, one pound of R-12 discharged to the atmosphere would have the same effect on global warming as 7100 pounds of carbon dioxide over a 20 year time period. However, some of the HCFs which will replace CFCs are not much better. In fact, it is estimated that some of the replacement refrigerants will actually increase the global warming effect since the efficiency of some of these systems will be less, thus requiring the burning of more fossil fuel and more generation of carbon dioxide. The likelihood of less efficient systems will be much greater during the transition period in which "drop-in" replacement refrigerants are used in existing equipment as compared to completely new systems designed for the new refrigerants.

Table 1. Global warming potentials of trace gases relative to CO_2

Trace Gas	Global Warming Potential Integration Time Horizon		
	20 years	100 years	500 years
Carbon Dioxide	1	1	1
Methane	63	21	9
Nitrous oxide	270	290	190
CFC-11	4500	3500	1500
CFC-12	7100	7300	4500
CFC-113	4500	4200	2100
CFC-114	6000	6900	5500
CFC-115	5500	6900	7400
HCFC-22	4100	1500	510
HCFC-123	310	85	29
HCFC-124	1500	430	150
HCFC-141b	1500	440	150
HCFC-142b	3700	1600	540
HFC-125	4700	2500	860
HFC-134a	3200	1200	420
HFC-143a	4500	2900	1000
HFC-152a	510	140	47

REVIEW OF IMPORTANT REFRIGERANTS

There are many choices for refrigerants available -- some are currently in use or available and some will come on line in the future. The following is a discussion of some of the important refrigerants which

may help you in making management decisions concerning your refrigeration systems.

- R-12 - a miracle chemical when it was first formulated in 1930s, it is now viewed as the worst of the ozone busters. It sets the standards for ozone depletion level with a score of 1. One of the family of CFCs, R-12 can be used for low to medium temperature applications. It is very stable, nontoxic, nonflammable, very compatible with lubricating oils, nonreactive with materials used in refrigeration systems, and has fairly good thermodynamic properties. Manufacturing is scheduled to halt at the end of 1995. After this, these chemicals will only be available in remanufactured or recycled forms. Several "drop-in" replacement refrigerants are becoming available for R-12 (R-134a is one of them). The conversion can be relatively simple in that very little equipment must be changed and you do not have to be extremely careful in changing the oil. You must get most of the mineral based oil out and replace it with a new type synthetic oil made for the specific refrigerant that you will be using.

- R-22 - is a HCFC that has only 5% of the ozone depletion effect of R-12. HCFCs are much less stable than CFCs; they break up at lower levels of the atmosphere where they do far less damage. R-22 is most efficient for mid-level chilling and air conditioning systems. It can be used for lower temperature applications but some problems with lubrication may develop. Production levels of R-22 will be frozen in 1996 with complete elimination by 2030. It is relatively easy to switch from R-22 to ammonia if you have a compressor engineered for both (required pipe size and compressor loads are similar) but you must switch copper and bronze fittings to steel.

- R-502 - this is a mixture of R-22 and R-115 designed to make R-22 work better at low temperature applications. It is getting hard to find as production of R-115 winds down, it is on the same phase out schedule as R-12. R-502 has an ozone depletion level one-third that of R-12. It is easy to convert from R-502 to R-22 since normally only the expansion valves need to be changed. However, R-22 will not perform as well at low temperature application as R-502.

- Ammonia (R-117) - is used in large refrigeration plants and is much cheaper than CFCs and HCFCs. Apparently, ammonia does not damage the ozone; however, it is flammable and toxic to humans. The problem with toxicity is lessened since it is self alarming in that it smells so bad that you know it is coming. Ammonia also has the disadvantage of attacking copper and brass as well as requiring special arrangement for oil circulation. However, ammonia has the best thermodynamic properties of any common refrigerant. Due to its toxicity and flammability, it can not be used in a direct system, but must use an intermediate heat transfer fluid, usually water. This means that the evaporator (cold coil) can not be located directly in the air stream or come in contact with food products. An indirect system is not usually a disadvantage for cooling produce and may be used as an advantage. For hydrocooling systems it is not an issue since they are indirect by design. For air cooling, indirect systems are slightly less efficient since two heat exchange processes must occur. However, they have the advantage of thermal storage (water or ice) which could make the overall cooling process more efficient and more capable of handling varying cooling loads. Also, water-to-air heat exchangers result in higher humidity air. Ammonia systems may have a higher initial cost, partly due to the added cost of indirect systems, but usually have a longer life and lower total costs over the life of the system. Also, ammonia has an ozone depletion rating of zero.

- Substitute Refrigerants (Low Ozone Depleting) - to distinguish the new "drop-in" refrigerants from the old Freons (a DuPont brand name). DuPont is using a new trade name Suva. The depletion level potential of these chemicals is very low, at or slightly less than the level of R-22. Suva MP-39 and 66 are formulated to replace R-12 and Suva HP-80 and 81 to replace R-502. These substitute refrigerants are reported to perform with no reduction in capacity or efficiency. In contrast, new equipment specifically designed for use with R-134a can be more efficient than its R-12 counterpart. A slightly different compound R-69 manufactured by Rhone-Poulenc, is also designed to replace R-502.

- Substitute Refrigerants (Non Ozone Depleting) - R-134a is a hydrofluoracarbon (HFC) with an ozone depletion rating of zero which has been developed to replace R-12 and is now being used in automobile air conditioners. A direct switch to R-134a in a system designed for R-12 is reported to result in a 10-15% decrease in refrigeration

capacity. There are other HFCs such as R-125 engineered to replace R-122 and R-143a designed to replace R-502. Suva HP-62 is also a replacement for R-502. Since all of these refrigerants are HFCs, they have an ozone depletion rating of zero.

SEAL LEAKS AND CONSERVE REFRIGERANT

Regardless of the type of refrigerant used, a concerted effort to eliminate leaks should be made. This will reduce your operating costs as well as avoid potential legal action. Since July 1, 1992 it has been illegal to discharge ozone depleting refrigerants into the air. Initially the Environmental Protection Agency (EPA) was most concerned with intentional venting usually done by repairmen who would empty a system prior to servicing it. Now under the authority of the clean air act they are looking for leaky systems. Leaks may be monitored through purchases of refrigerants. Contractors suspect that they may soon be required to account for the use of the refrigerants. Future regulations may require that you give a reason for purchasing refrigerants, such as enlarging a system. Stiff fines are associated with the EPA regulations. For example, a fine up to $25,000 can be assessed for unlawful release of a CFC and a $10,000 reward can be made for reporting a violation.

The financial incentive to plug leaks is likely to increase. Historically it was cheaper to just periodically refill a leaking system but that has changed. Ozone depleting refrigerants are now subject to a tax tied directly to their depletion level rating. For instance, every time the tax on R-12 increases by $1 the tax on R-502 jumps 30 cents. The tax on R-12 jumped to $5.35 per pound in 1995 and will increase $0.45 per year until year 2000. This rapid increase in price causes concern about illegal imports of CFCs. Refrigeration industry officials have recently reported numerous offers to purchase CFCs at prices well below even the amount of federal excise tax. Miami customs agents report that illegal refrigerants are second only to drugs. The new "drop-in" refrigerants designed to replace CFCs are expensive, but are becoming cheaper than the CFCs as the tax increases. A 25-ton system might contain between 100 and 300 pounds of refrigerant, making the cost of refrigerant a major item.

As refrigerants get more expensive, the incentive to clean and reuse them will increase. There are many refrigerant recovery systems being marketed today. An owner can recover and reuse refrigerant as long as it is used in a system he/she owns; refrigerant can not be sold or transferred to another owner, under current regulations.

MANAGING YOUR REFRIGERATION SYSTEMS

It is expected that many owners of refrigeration systems will face immediate refrigerant shortages in 1996 which may lead to higher prices and difficulty obtaining CFCs, ordering delays for retrofit parts and new equipment, and temporary or total shut downs. Some manufacturers have already reported a tripling of their delivery cycles, up to six months. No doubt all of this is confusing and frustrating to you as an owner or manager of refrigeration systems. Crisis can be avoided by proper planning and immediate action.

Rule 608 (National Emissions Reduction Program) of the Title VI Clean Air Act of 1990 requires minimal record keeping when CFC and HCFC refrigerants are present. You should have the following files in your records:

- Records of refrigerant purchases.
- A copy of your recovery equipment certification form.
- Records of employee training.
- Records of recovered refrigerant.
- Facility equipment serviced and services performed.
- Records of leak detection.
- Records of refrigerant disposition.
- An environmental policy statement.

The written policy should state that your company and all its employees will obey all laws applicable to this industry and that any employee who knowingly vents CFC or HCFC will be terminated.

Suspicions are growing on the part of regulators due to the fact that little refrigerant is coming in for reclamation and that only a small portion of the certified recovery equipment has been purchased. Some fines have been levied, but not nearly what could be. "No records" is not an excuse.

The EPA suggests the following measures as a means of getting started with a practical approach to managing refrigerants.

1. Designate a CFC/HCFC manager.
2. Inventory, track and manage existing refrigerant stocks.

3. Quickly develop and implement an action plan. Under this action plan you could recycle and conserve refrigerants, reduce leaks, retrofit equipment with substitutes and replace equipment when economically feasible.

Suppose that you determine that a given system has roughly ten years of useful life remaining. Should you retrofit the system with a new substitute refrigerant or should you replace the system with a completely new refrigeration system. It is suggested that you need to know the following items to make this decision.

- Know current events, including ozone depletion, climate change, international activities and clean air act.
- Become familiar with existing EPA regulations, including phase out and tax on CFCs/HCFCs, prohibition of venting and leakage, and recycling rule.
- Become familiar with the substitute refrigerants and new equipment using new refrigerants.
- Know your own equipment, including hours of usage, maintenance and repair history, schedule for recommended overhaul, ventilation rates in equipment room, refrigerant availability and cost, and total number of refrigeration systems under your management.
- Know the energy implications, including energy cost, current and future taxes, efficiency of your equipment, efficiency of new equipment, your cooling load requirements, and energy efficiency rebates or other incentives from utilities companies.
- Know the environmental and safety implications of refrigerant options.
- Know your building or plant modernization schedule.

SUMMARY

A manager must have a good understanding of refrigerants and refrigeration systems in order to make wise decisions for the future. Because regulations and the refrigerants themselves are still in such a state of flux, there is no good map for planning ahead. This is particularly true if you are adding refrigeration now. Converting from one refrigerant to another may require replacement of expensive components and lubricants. Also, a refrigeration system usually loses efficiency and/or useful life when a substitute refrigerant (one for which the system was not designed) is used. Many of the new refrigerants are less stable, more corrosive and less compatible with lubricants than were the conventional refrigerants. Therefore, one can expect that new refrigerants and new systems will experience more breakdowns and require more maintenance than the conventional systems which were developed over a long period of time. It normally takes 5-10 years to design, develop and test new refrigeration equipment.

If after consulting with your refrigeration experts, you are uncertain of which direction to take, you might consider a compromise such as purchasing a R-22 system but using steel instead of copper so that the refrigerant could be converted to ammonia in the future at a very low cost. Some codes will not currently allow the use of ammonia but may change as the CFCs and HCFCs are phased out. You may also want to keep in touch with EPA regulations through their EPA Ozone Hotline (800-296-1996).