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**THE OAK RIDGE REFRIGERANT MANAGEMENT PROGRAM**

by

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**Abstract**

For many years, chlorofluorocarbons (CFCs) have been used by the Department of Energy's (DOE) Oak Ridge Y-12 Plant in air conditioning and process refrigeration systems. However, Title VI of the Clean Air Act Amendments (CAAA) and Executive Order 12843 (Procurement Requirements and Policies for Federal Agencies for Ozone Depleting Substances) signed by President Clinton require, as policy, that all federal agencies maximize their use of safe, alternate refrigerants and minimize, where economically practical, the use of Class 1 refrigerants. Unfortunately, many government facilities and industrial plants have no plan or strategy in place to make this changeover, even though their air conditioning and process refrigeration equipment may not be sustainable after CFC production ends December 31, 1995.

The Y-12 Plant in Oak Ridge, Tennessee, has taken an aggressive approach to complying with the CAAA and is working with private industry and other government agencies to solve tough manufacturing and application problems associated with CFC and hydrochlorofluorocarbon (HCFC) alternatives. Y-12 was the first DOE Defense Program (DP) facility to develop a long-range Stratospheric Ozone Protection Plan for refrigerant management for compliance with the CAAA. It was also the first DOE DP facility to complete detailed engineering studies on retrofitting and replacing all air conditioning and process refrigeration equipment to enable operation with alternate refrigerants. The management plan and engineering studies are models for use by other government agencies, manufacturing plants, and private industry.

This presentation identifies some of the hidden pitfalls to be encountered in the accelerated phase-out schedule of CFCs and explains how to overcome and prevent these problems. In addition, it outlines the general issues that must be considered when addressing the phase-out of ozone depleting substances and gives some "lessons learned" by Y-12 from its Refrigerant Management Program. Discussion topics include requirements for developing a refrigerant management plan and establishing priorities for cost-effective compliance with the CAAA, as well as ways in which employees can be empowered to develop a comprehensive refrigerant management plan. The result of this employee empowerment was a cooperative labor-management effort that is beneficial for Y-12, DOE, and the environment.

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## Introduction

For many years chlorofluorocarbons (CFCs) have been used in air conditioning and refrigeration systems designed for long-term use. Title VI of the Clean Air Act Amendments (CAAA) provided regulations to reduce and prevent damage to the earth's protective ozone layer. In 1987, 24 industrial countries met in Montreal, Canada, to mandate regulations governing the production of CFCs. They set a goal of achieving a 50% reduction of 1986 production levels by the year 2000 (see Fig. 1). In 1990, the same countries represented at Montreal met again, declaring a complete CFC phase-out by the year 2000. The Clean Air Act was passed by Congress in October 1990, establishing a schedule for U.S. companies to comply with the new phase-out dates. The Montreal Protocol and the Clean Air Act were revised in 1992 because CFCs escaping to the atmosphere were contributing to the destruction of the stratospheric ozone layer at an increasing rate. Then-President George Bush mandated an accelerated schedule for the production phase-out of all ozone depleting substances by December 31, 1995.

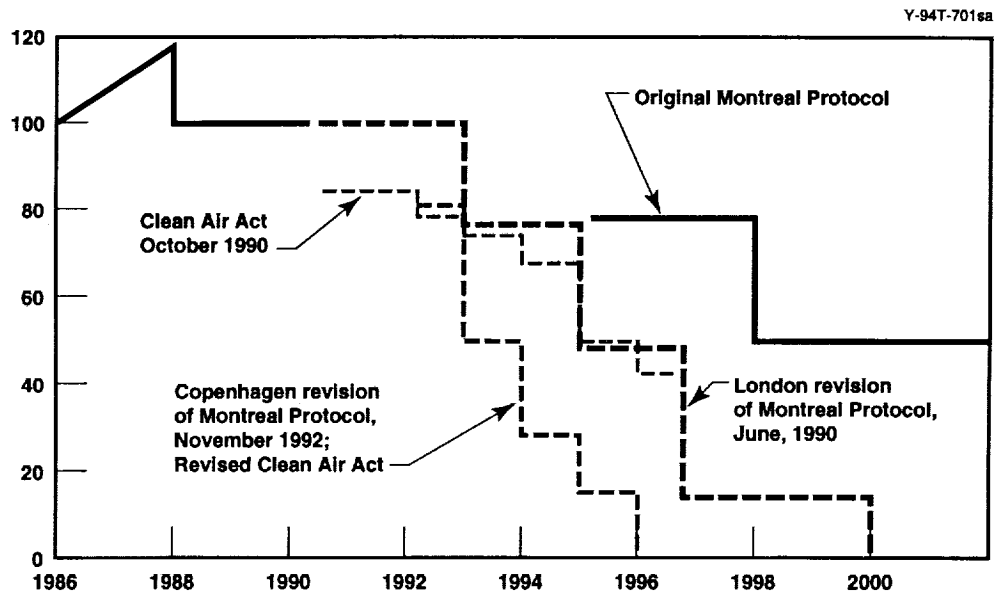


Fig.1. Percentage of 1986 CFC production.

The U.S. is the largest consumer and producer of CFCs in the world (see Fig. 2). Air conditioning and refrigeration account for approximately one-third of the U.S. yearly consumption (see Fig. 3). President Bill Clinton has advocated development of "green technologies" and has developed an early phase-out schedule for hydrochlorofluorocarbons (HCFCs). In his first State of the Union address in February 1993, the President outlined new environmental technology initiatives to accelerate environmental protection. The Senate has recently passed the National Environmental Technology Act, a part of the Administration's broad new technology policy outlined in "Technology for America's Economic Growth: A New Direction to Build Economic Strength." One of Vice President Al Gore's Reinventing Government proposals is the Clean Industry Initiative to promote the development of environmentally friendly refrigerants. The Vice President has also written a book that includes chapters devoted to the cause-and-effect relationship between ozone depletion and global warming.

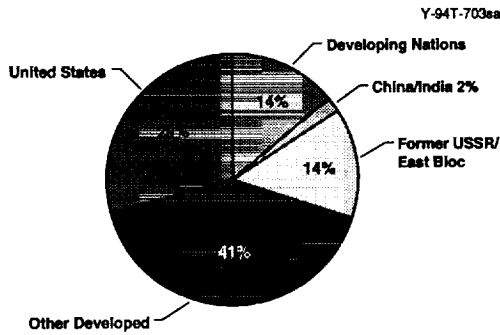


Fig. 2. Approximate consumption of CFCs by country and region.

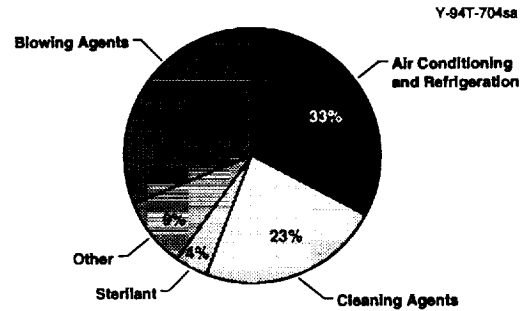


Fig. 3. Estimated United States End Uses of CFCs.

DuPont, the largest producer of CFCs in the world, will stop production of all CFCs in 1994. Halons are scheduled to be phased out by 1994. Production of all other Class 1 CFCs will stop December 31, 1995. In addition, the Environmental Protection Agency (EPA) proposes reducing the production limit of CFCs such that 1995 production can be only 15% of the 1986 level. DuPont had planned to stop CFC production in 1994; however, the EPA asked DuPont to continue production of CFC-12 through 1995 to supply the automotive market. The cost of converting equipment to non-CFCs is staggering, and the cost impact could slow down economic growth in the next 4-5 years if not managed properly. Forecasters believe that in 1996 the United States will still have the following equipment running on CFCs:

- 160 million refrigerators,
- 125 million motor vehicle air conditioners (MVACS),
- 5 million commercial refrigeration systems, and
- over 58,000 large commercial and industrial chillers.

This equipment is valued at over \$125 billion. The switchover to non-CFC refrigerants must be carefully managed to prevent an extra economic burden from falling on individuals, companies, and the entire U.S. economy. The EPA estimates the 1996 demand for CFCs will be approximately 48 million pounds; however, no supply will be available. Manufacturers have already said they will be unable to meet the near-term demand for new units and retrofit equipment or to provide sufficient supplies of CFC alternatives to meet the demand. To compound the problem, the alternative refrigerants now being introduced into the market are only interim replacements that will also be phased out in the future.

Conservation measures (recycle and recovery), conversion, and compliance with the CAAA have been slow in coming. The EPA, the Air-Conditioning and Refrigeration Institute (ARI), and the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) have all issued warnings about potential shortfalls of CFCs. A leading refrigerant manufacturer predicts "near chaos" unless more equipment owners start planning and engineering before production is halted in 1995. Rising prices, a "black market," and cooling outages seem inevitable. One expert forecast that "some equipment owners will have stocks of CFCs to see them through, but thousands of building owners, tens of thousands of businesses and industrial companies, and millions of homeowners and auto owners will have no stocks of CFCs." Chiller manufacturers also warn: "Do nothing and you may soon have a chiller (or air conditioning equipment) with no refrigerant." These warnings are ominous and should be taken seriously if we are to maintain our current life style and quality of life. In Economics 101, it is taught that a dollar spent today will cost less than a dollar spent tomorrow. This axiom is still true, and companies that convert to non-CFC alternatives today will not spend as much or be caught in the last-minute panic the experts warn against.

A misconception exists in government and private industry that choosing an alternative refrigerant is a risky proposition. Officials in these areas think that, if they wait long enough, a low-cost "drop-in" replacement will be invented to rescue them and make the problem go away. All alternative refrigerants

have undergone extensive testing for toxicity, fire protection, personal exposure limits, and almost every other health/safety issue before being approved for testing and evaluation by the EPA.

The new alternatives do have some limitations but are considered safe if handled properly; however, they may be slightly less efficient than the refrigerants they replace. This efficiency loss will generally not affect operations because most systems have been over-designed with built-in excess capacity to allow for future expansion. In some cases, the new refrigerant (e.g., HFC-134a) is actually more efficient than the old refrigerant if a complete retrofit is performed on the chiller. The good news is that EPA's Significant New Alternative Program (SNAP) has helped develop and test over 100 new alternative refrigerants. The bad news is that they have found no "drop-in" energy-efficient replacements that simply require draining the old refrigerant and filling a system with a new refrigerant.

Even with alternative refrigerants, equipment room ventilation still must be modified to comply with the new ASHRAE Standards 15 and 34 adopted by most code authorities. Installation of oxygen depletion and halocarbon refrigerant sensors may also be required. Some service organizations will not work in a facility until the sensors have been installed. The current HCFC-123 (CFC-11 replacement) threshold limit value (TLV) of 10 ppm is being re-evaluated by the American Council of Government Industrial Hygienists (ACGIH) and could be raised to 30–100 ppm. Some alternate refrigerants being tested have flammability problems and low flash points, but they will probably never be approved by the EPA, Factory Mutual, National Fire Protection Association, or the ACGIH for manufacture and sale to the general public.

Industry estimates indicate that almost all government agencies and private businesses think a refrigerant management plan is necessary and a good idea, but just over 50% have such a plan! Unfortunately, the government has no national plan or strategy in place. Heating, ventilation, and air conditioning (HVAC) system owners and building managers should not expect any relief or last-minute reprieve from the government. Such amenities as air conditioning and refrigeration, commonly taken for granted, may not be sustainable when CFC production is halted and no new materials are available to replace them.

### **What Have We Done?**

The Department of Energy's (DOE) Y-12 Plant has taken an aggressive approach to comply with the CAAA and was the first Defense Program (DP) facility to develop a long-range Stratospheric Ozone Protection Plan. This plan provides administrative controls to minimize plant emissions of ozone depleting substances, maximize the use of ozone-friendly alternatives, and achieve cost-effective compliance with EPA's CAAA requirements. The plan is a model for government agencies, manufacturing plants, and private industry facilities.

As part of the plan, recycle and recovery programs were implemented several years ago. The "lessons learned" are available to other organizations upon request. Y-12 was also the first DOE DP facility to request line-item funding for retrofitting and replacing all air conditioning and refrigeration equipment to achieve compliance with the CAAA. The necessary detailed engineering studies were completed for converting all HVAC systems, chillers, and refrigeration equipment to operate with alternate refrigerants. Oak Ridge has maintained efficiencies and capacities to minimize any upstream power plant emissions. Where practical, some equipment will be retrofitted to reduce project costs and the impact on the government's shrinking budget. Several interim capital construction projects are currently in progress to install both high-efficiency purge units and pressurization/leak detection units on low-pressure chillers.

Personnel training and refrigerant recycling were identified early as the easiest and least expensive methods for implementing CAAA compliance efforts. In the early 1990s, the Y-12 Plant procured several portable refrigerant recycle units to purify refrigerant in direct-expansion (Dx) air conditioners and MVACs. Several hand-held leak detection units were also procured to find equipment leaks and implement a leak detection program. With only minimal investment (about \$4,000–\$6,000 each for the recyclers and only \$300–\$400 for the hand-held detectors), reduced emissions were noticed immediately. These units were so successful that additional larger, EPA-approved, portable recycle units were procured for use on all chillers and large building air conditioning systems. The combination of recycling and leak detection

programs reduced Y-12 CFC emissions by more than 58% from 1992 to 1993. Simultaneously, in-house training programs were developed, and an interactive television hook-up was recently initiated with local community colleges to train students about the CAAA and certify technicians in the various EPA refrigeration classifications. Automotive mechanics were certified by the EPA for work on MVACs, and refrigeration mechanics were certified in all four EPA refrigeration categories. Other training programs were developed to include courses on the proper operation of most recycle/recovery equipment and a management awareness course for engineers, HVAC system owners, and building managers.

In addition, several inexpensive administrative controls were implemented to help reduce emissions and comply with the CAAA. Engineering procedures and specifications were revised to prevent procurement of equipment that uses CFCs. A procedure was initiated that required the review/approval of all purchase requisitions for CFCs and HCFCs. Procedures were also developed for the removal and storage of refrigerants from equipment and appliances before disposal, and plans were initiated for procurement of storage and recovery tanks to stockpile excess refrigerants. Specifications for fleet vehicles were modified so that the air conditioning systems would be compatible with or operate using alternate refrigerants. In a large plant such as Y-12, communications and old habits were the hardest barriers to overcome. Employee training and administrative controls made an immediate impact on awareness of the problem—reducing CFC emissions—and employees were empowered to correct problems.

### **Equipment and Strategy Used**

A task team, drawn from several divisions within the Y-12 Plant, was charged with establishing a strategy and guidelines for an economical conversion to alternative refrigerants. Additional tasks included setting priorities for worker health and safety considerations, energy efficiency, considerations for long-term operation, development of short-term and long-term strategies for compliance, and development of criteria for evaluating existing equipment. Input was requested from almost every division, including accounting; development; engineering; utility operations; fire protection; health, safety, environment and accountability; industrial hygiene; health physics; and the refrigeration mechanics' union. This diversity was necessary and very important because the retrofit/replacement of equipment for use of alternate refrigerants turned out to be more complex than anyone ever envisioned. Industrial hygiene concerns about ventilation and union concerns about worker health and safety when working with or around the new refrigerants were only some of the issues to be resolved. The resulting criteria were used to formulate a \$13.6 million FY 1996 Line Item Project for retrofitting and replacing all HVAC systems and chillers in the Y-12 Plant. The team developed the following strategy and criteria for converting to alternative refrigerants:

1. Retrofit or replace only equipment containing a charge of 10 lb or greater. A study determined that the retrofit costs for equipment with a charge less than 10 lb would exceed the replacement costs and value of the equipment. For economic reasons, it was decided that equipment with less than a 10-lb charge should not be retrofitted or converted to the new alternative refrigerants. This smaller equipment (generally 5 tons or less) will be handled on a case-by-case basis. In general, it will be left in service until the end of its service life or until leaks develop, at which time it will be either shut down or replaced.
2. Equipment over twenty years old, and critical equipment less than twenty years old but with a bad leak-rate history, would be replaced. Leak rates and efficiency are the biggest factors in determining replacement—not age or maintenance history. Coincidentally, the oldest equipment generally has the highest leak rates. Most equipment over twenty years old is inefficient with efficiency ratings greater than 1.0 kW per ton. Most new chillers with alternative refrigerants have efficiencies of 0.60 kW per ton or less.
3. Equipment less than twenty years old without bad leaks would be retrofitted to use new, alternate refrigerants. Some CFC-11 hermetic chillers will lose about 2%–5% efficiency and 10%–15% capacity in converting to HCFC-123. Retrofitting must include new O-rings and gaskets. The hermetic motor must be replaced so the winding insulation will be compatible with the refrigerant. The impellers will need reworking to minimize losses in efficiency and capacity. Conversion from CFC-12 to HFC-134a is somewhat easier and could result in a slight efficiency gain. Conversion to HFC-134a requires flushing

of the lubrication system several times and switching to a polyolester lubricant instead of the mineral oil previously used. In order to increase operating pressures, gears must be replaced on chillers, and the pulleys and belts must be changed on Dx units.

4. Equipment with HCFC-22 and MVACs would not be retrofitted or converted. Small, through-the-wall air conditioning equipment, freezers, water fountains, and refrigerators will remain in use until their service life is over or they incur leaks, at which time they will be either shut down or replaced.
5. Where practical, all environmental chambers and all process and walk-in coolers with a refrigeration system containing 10 lb or more of refrigerant would be retrofitted. Coolers and environmental chambers with less than a 10-lb charge would remain in place until they reach the end of their service life or develop leaks, at which time they will be either shut down or replaced. Coolers and environmental chambers are a special problem because many are custom built. Some of the cabinets must be torn apart to install new compressors. After the market was researched, no stock, off-the-shelf units appeared to be available that would exactly fit the openings and meet operating requirements. Most new coolers and chambers would have to be specially designed and built, which is expensive. It is difficult to justify installing a new unit unless it directly supports a process or production system.
6. Shut down the oldest equipment with the worst leaks, excess capacity, and lowest utilization. The air conditioning and refrigeration mechanics generally know which equipment has the worst leak rates. Implementation of a centralized, PC-based refrigerant tracking system can identify and quantify leak rates. Such a tracking system costs only \$350–\$450, and it is invaluable for auditing and tracking refrigerant usage by individual pieces of equipment. In addition, building and chiller load profiles should be analyzed, incorporating planned expansions and future uses. Existing capacities need to be evaluated to determine if the equipment is actually required or if it should be shut-down.
7. Chill water lines should be extended to replace building air conditioning units where economically practical.
8. Monitors should be installed in each equipment room and chiller building, and the ventilation systems should be modified to comply with ASHRAE Standards 15 and 34.

### **Refrigeration Equipment**

Equipment to be retrofitted or replaced having a charge greater than 10 lb of refrigerant fell into three basic categories:

- I Chillers** – CFC-11, CFC-12, and HCFC-22
- II Direct Expansion (Dx) Air Conditioners** – CFC-12 and HCFC-22
- III Coolers and Environmental Chambers** – CFC-12, CFC-502, CFC-503, and HCFC-22

In Category I, Y-12 plans to replace six hermetic chillers and two open-drive chillers with a total cooling capacity of 4,525 tons. The equipment ranges from an old 200-ton unit up to 1,100-ton units and includes two low-temperature machines. Nineteen chillers with a cooling capacity of 20,300 tons will be retrofitted to operate on the new alternate refrigerants. Due to downsizing, several areas within the plant were shut down, and nine old chillers were taken out of service.

In Category II, three Dx building air conditioners will be replaced with units that operate on HCFC-22. Two Dx units will be replaced with chilled water handlers, and three CFC-12 Dx units will be retrofitted to operate on HCFC-22.

In Category III, 15 environmental chambers, 4 walk-in coolers, and 1 process cooler will be converted from CFC-12 to HCFC-22. Two process coolers will be converted to HFC-134a, and seven environmental chambers will be converted from CFC-502/503 to a non-CFC refrigerant (possibly DuPont Suva HP-62).

Preliminary estimates indicate retrofitting and replacing the equipment in Categories I, II, and III will produce an annual savings of approximately 2,658,000 kilowatt hours of electricity and \$125,500 when completed. This savings will be achieved with no loss in capacity. The converted equipment will emit considerably less refrigerant to the atmosphere, and, as a result, less refrigerant will be procured for replacement. It is estimated that future refrigerant procurement costs could be reduced for an added savings of \$50,000-\$60,00 per year. The impact on stratospheric ozone depletion due to the retrofit and replacement program will be even more dramatic (See Table 1). Preliminary calculations indicate ozone depletion from emissions would be reduced approximately 99.69% after the retrofit and replacement project is completed. The combined energy savings and environmental improvement make this a win-win situation.

Equipment with less than 10 lb of refrigerant were the most difficult to locate and identify and the most time consuming to inventory. Some task team members were shocked to see how many appliances and small through-the-wall units were involved. This equipment included 165 refrigerators and freezers; 132 ice machines, drinking fountains, and water coolers; and 1,375 small air conditioners and through-the-wall units. These units are relatively inexpensive and will be replaced or shut down at the end of their service life or when leaks occur.

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1992 Ozone Depletion From Emissions					
Refrigerant Type	Emissions In Pounds	X	ODP Number	=	Ozone Depletion Factor
CFC-11	10,000	X	1.0	=	10,000
CFC-12	90	X	0.95	=	86
HCFC-22	3,025	X	0.05	=	151
CFC-113	200	X	1.07	=	214
CFC-114	5,100	X	0.8	=	4,080
CFC-502	30	X	0.2	=	6
<b>TOTAL</b>					<b>14,537</b>
Estimated Ozone Depletion After Retrofit and Replacement					
HCFC-123	1,000	X	0.02	=	20
HFC-134a	90	X	0.0	=	0
HP-62	30	X	0.0	=	0
HCFC-22	500	X	0.05	=	25
<b>TOTAL</b>					<b>45 (99.69% reduction)</b>

Table 1. Impact on Ozone Depletion.

### Lessons Learned

The following summary of the lessons learned by the Y-12 Plant may be used to help a company or government agency make the tough decisions about converting to alternate refrigerants:

1. Formulate a task team from various departments and service organizations and obtain management support for its findings.
2. Develop a schedule and establish a budget to support the task team findings.
3. Involve the equipment manufacturer in planning at the earliest stage and consult with a service contractor or consulting engineer to work closely with the manufacturer.
4. Focus on life-cycle operating costs, equipment availability, and energy efficiencies based on integrated part-load values and applied part-load values rather than refrigerant choices.
5. Participate with the contractor and manufacturer to determine when and how to convert.

6. Develop a management awareness training course and worker certification program and include the hourly employees or maintenance contractor as part of the team.
7. Initiate a leak detection and a recycle/recovery program and contain, contain, contain.
8. Develop an inventory of all air conditioning and refrigeration equipment and refrigerant stocks.
9. Plan to phase in, over a period of several years, replacement and conversion for large complexes using multiple chillers and building air conditioning equipment where replacement costs can be high and not easily funded in one lump sum.
10. Do not wait until December 31, 1995, to start a program and make decisions about converting.

### **What Should The Conversion Plan Include?**

Some basic criteria must be included in any conversion and retrofit plan as good management practices and to help make it succeed. These criteria will provide management control over the implementation process and help ensure fiscal responsibility. In addition to incorporating the lessons learned at Y-12, a plan should include:

- A long-term phase-out schedule for CFCs and a budget for the conversion plan.
- A designated CFC Manager (or CFC Czar) in upper management who will champion the plan and help in the budgetary process.
- Procurement of recycle/recovery equipment and immediate implementation of a leak detection program—recycle, conserve, conserve.
- Tracking of refrigerant usage and procurement at a central location where information can be readily accessed.
- An inventory of all equipment and refrigerant stock and setting of priorities for converting equipment.
- Development of written policies and defined procedures for procurement, handling, storage, and use of refrigerants.
- Evaluation of equipment life, performance, and efficiency, and an analysis of existing needs and future requirements.
- An engineered solution to retrofit or replace equipment, determined with more than one manufacturer's recommendation.
- Clearly defined monitoring, health and safety, reclamation, and disposal procedures so everyone involved has a clear understanding about who is responsible, what should be done, and how to do it.
- Maximization of equipment retrofitting to conserve cash flow and assurance that equipment room ventilation meets ASHRAE standards.