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Final Report

Options for Reducing Refrigerant Emissions from Supermarket Systems

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SUMMARY

This report was prepared to assist personnel responsible for the design, construction and maintenance of retail food refrigeration equipment in making knowledgeable decisions regarding the implementation of refrigerant-emissions-reducing practices and technologies. The report first characterizes the design of typical supermarket refrigeration systems and focuses on why these types of systems have high rates of refrigerant emissions. Three case studies also are provided of companies that have successfully implemented emission-reducing practices and technologies. The report concludes with a discussion of a variety of technical and procedural options that can be applied to existing systems and in new construction.

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ABBREVIATIONS AND ACRONYMS

ANPRM	Advance Notice of Proposed Rule Making
ARI	Air-conditioning and Refrigeration Institute
ASHRAE	American Society of Heating, Refrigerating and Air-conditioning Engineers
CAAA	Clean Air Act Amendments
CFC	Chlorofluorocarbon
DX	Direct Expansion
EMS	Energy Management System
EPR	Evaporator Pressure Regulator
FMI	Food Marketing Institute
GWP	Global Warming Potential
HCFC	Hydrochlorofluorocarbon
HFC	Hydrofluorocarbon
NPV	Net Present Value
ODP	Ozone Depleting Potential
ODS	Ozone Depleting Substance
SCAQMD	South Coast Air Quality Management District
SNAP	Significant New Alternatives Program
UNEP	United Nations Environment Programme

CHAPTER 1
Characterization of Supermarket Refrigerant Emissions

The purpose of this chapter is to:

- Review the legal requirements that pertain to refrigerant emissions and the impact of those requirements on the supermarket industry;
- Identify the basic causes of refrigerant emissions in supermarket refrigeration systems; and
- Discuss options that supermarket owners have to control refrigerant emissions and their associated costs.

1.1 Background

The Montreal Protocol, an international treaty to reduce the use of ozone-depleting substances (ODSs) was signed in 1987. The Protocol required all signatory parties to begin reducing their production of ODSs on a national level. Later amendments to the Protocol further restricted ODSs, calling for a complete phaseout of the production of CFCs and other ODSs. EPA has used its authority under Title VI of the Clean Air Act Amendments (CAAA) of 1990 to develop regulations to phase out the production of CFCs and HCFCs, including the refrigerants most favored for supermarket use, CFC-12, CFC-115 (a component in the blend R-502), and HCFC-22. The CAAA also required EPA to develop regulations that require refrigerant recycling and to approve new refrigerant substitutes.

The Phaseout of Production and Consumption of Class I Substances (CFCs), administered by the EPA, includes a progressively declining cap on the total national production and importation of CFCs. The cap on CFC production will continue to decrease annually until December 31, 1995. After 1995, other than in very limited circumstances, production and importation of CFCs will be prohibited. (Reference: CAAA, Section 604, 1990) The phaseout of HCFC-22 is scheduled to begin in the year 2004, with production scheduled to cease in the year 2020. Congress has also instituted an escalating excise tax on virgin CFCs and CFC-containing blends, which is administered by the IRS.

Prices of CFCs have risen since the beginning of the phaseout on production in large measure because of the decreasing supply of CFC refrigerants and the increasing taxes. Taxes on virgin CFCs are scheduled to continue to increase until production ceases at the end of 1995. After this date, prices of CFCs are likely to escalate more rapidly because of the expected decrease in availability of replacement CFC refrigerants. Availability of CFCs after the phaseout date is largely dependent on the rate of refrigerant recycling and the demands of other sectors, in particular mobile air-conditioners.

In 1993, EPA issued regulations mandating the recycling of ODSs entitled **The National Recycling and Emission Reduction Program** (also known as the Recycling Rule). (Reference: CAAA, Section 608, 1990; and Federal Register, May 1993) These regulations became effective June 14, 1993 and require persons working on refrigeration and air-conditioning systems containing ODSs to maximize the recapturing and recycling of ODSs during the maintenance, service, and disposal of these systems. Specifically, the Program prohibits the intentional venting of these substances and requires the use of refrigerant recovery devices prior to servicing or disposing of ODS-containing equipment. The regulations were designed to maintain the availability of CFCs as long as possible without additional production through reuse and containment of existing CFCs. The main provisions of the rule that most affected the supermarket industry were:

- mandatory recovery of refrigerant during equipment service;
- required certification of technicians; and

- requirements for leak repair of systems with refrigerant charge sizes of 50 pounds or more.

The first provision, recovery of refrigerants, affects all departments of supermarket facilities operations. Engineering personnel now have an additional reason to specify valves to isolate refrigerant in the systems, valves to access the refrigerant, and components to allow refrigerant to be pumped into the receiver during service. Maintenance personnel need to carefully schedule service to include the extra time required to recover refrigerant. Operations personnel also have extra motivation to increase preventive maintenance to avoid the longer downtimes should equipment require service. Furthermore, portable refrigerant recovery devices must be supplied for all service trucks, with larger devices made available for large recovery jobs.

As of November 14, 1994, technicians are required to pass an EPA-approved certification test in order to handle or purchase ODS refrigerants. For many companies the expense of certification is significant. However, for technicians to pass the test they must be knowledgeable of the effects that refrigerant emissions have on the atmosphere. Certified technicians that are conscientious are likely to take actions to prevent refrigerant emissions, and thereby minimize the cost of recharging with increasingly expensive ODS refrigerants. In this way some of the costs of certification can be recuperated.

The requirements for leak repair of systems with large charges will affect almost all companies, as most supermarket systems piped out of a remote equipment room contain at least 50 pounds of refrigerant. These requirements will be a challenge for some companies to meet. However, since the cap on leakage rates was set at 35 percent of the total charge contained by each system, the imposition of additional hardships beyond that already imposed by the economics of the refrigerant market will not likely be substantial. If a store is actually leaking in excess of the amount allowed by law, simple and cost-effective measures can usually be taken to reduce the leakage rate to compliance levels; moreover, savings from reduced CFC usage will likely exceed compliance costs.

On February 15, 1994 EPA announced its final **Significant New Alternatives Policy (SNAP) Rule**, which establishes the structure by which the Agency evaluates substitute chemicals and processes for their potential effects on human health and the environment. (Reference: CAAA, Section 612, 1990; and Federal Register, March 1994) This rule lists the substitutes that EPA has reviewed and found to be acceptable or unacceptable in key industrial use sectors, including supermarket refrigeration and air-conditioning. At present, the list of substances approved by EPA for commercial refrigeration use includes the refrigerants HCFC-22, HFC-134a, HFC-227ea, ammonia, and the blends R-401A, R-401B, R-402A, R-402B, R-404A, R-406A, R-407A, R-407B, R-408A, R-409A, and R-507. (Reference: Federal Register, March 1994 and August 1994) EPA will update the list as new chemicals are submitted and evaluated.

Impact on the Supermarket Industry

In prior years when CFCs were thought to be environmentally harmless, the price of refrigerants was such that it was uneconomical (from the company's perspective) to expend resources locating and repairing less severe refrigerant leaks when working with supermarket refrigeration equipment. Choosing between recharging a system and finding and repairing a leak was an economic decision. In many instances it was less expensive to recharge. These practices resulted in the release of thousands of tons of ODS refrigerants annually.

Design and construction of these systems reflected a similar economic philosophy. Prevention of refrigerant emissions was only one of many design criteria evaluated in planning store layouts. Compromises were constantly made between engineering design, economics, and store ambiance.

The prohibition on refrigerant venting has now added a legal aspect to the issue of refrigerant emissions. Responding to the situation, many refrigeration engineers, construction mechanics, and maintenance personnel have become more aware of the impact of their equipment specifications and operating procedures on refrigerant emissions. Some company executives have educated themselves on the issue, and have encouraged changes in operating procedures by their staff. More and more supermarkets are now investing resources to control refrigerant leaks from their refrigeration systems.

Emissions of CFCs are recognized as harmful because of the resulting ozone depletion. As a result, many supermarkets adopted a double-pronged approach of reducing leakage from existing CFC systems in conjunction with moving to alternative refrigerants. At the time of the issuance of the original ODS Phaseout regulations in 1990, the only alternative available on the market was HCFC-22. Most supermarkets began to move towards the use of HCFC-22 immediately, but only in medium-temperature (non-frozen) applications.

The use of HCFC-22 posed major problems in low-temperature applications; even though HCFC-22 had been used in prior years in these applications, low-temperature HCFC-22 equipment had not been manufactured for a generation. As a result, new equipment had to be developed to handle the stresses imposed by HCFC-22 in this application. At the same time, refrigerant manufacturers were aggressively developing non-CFC refrigerant options such as HFCs to replace CFC-12 and R-502 in supermarket applications.

Two kinds of refrigerant alternatives were eventually developed by the manufacturers: interim and long-term. The interim refrigerants were designed to be used as replacements to CFCs in existing equipment and were composed of blends of HCFCs and other chemicals. The long-term options were designed to be used in new equipment and had some potential as retrofit refrigerants; the long-term options were composed of various HFCs.

Many of the HFC-based long-term options tend to have large Global Warming Potentials (GWPs).[1] Consequently, supermarkets that are focused on environmental protection are now exercising considerable care in their choices of refrigerants and equipment designs. Moreover, instituting practices to reduce ODS emissions now will have an added environmental benefit of reducing emissions of HFC-based refrigerants as they are applied in supermarket systems.

1.2 Sources of Refrigerant Emissions

Refrigerant emissions from supermarket refrigeration systems are affected by (1) original equipment design and construction, (2) maintenance and repair practices, and (3) corporate policy. This section qualitatively describes:

- how the design and construction of equipment can influence refrigerant emission levels during normal operation;
- how maintenance and repair personnel can impact whether the systems they care for are leaky or leak-tight; and
- how a company's policies have a indirect influence on emission levels.

A quantitative evaluation of these items is provided in Chapter 5.

1.2.1 Equipment Design and Construction

Supermarket refrigeration systems operate on the commonly-used vapor-compression thermodynamic cycle. This cycle produces cooling by circulating a refrigerant through various components in which the refrigerant alternately absorbs heat from a refrigerated space and then rejects the heat to a warmer space. The cycle requires four basic components:

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[1] The GWP of a chemical is an indicator of its estimated contribution to the environmental problem of global warming. Chemicals that have a greater ability to absorb and emit infrared radiation are likely to have greater GWPs than those which do not. Furthermore, chemicals that have long atmospheric lifetimes, such as HFCs, are also likely to have greater GWPs than those which do not.

- the evaporator coil (located in the walk-in box or display case), in which the liquid refrigerant boils off at a low temperature under low pressure as it absorbs heat from the refrigerated space;

- the compressor (located on the compressor rack or condensing unit), which increases the pressure and temperature of the refrigerant gas, enabling it to liquify at a high temperature;

- the condenser coil, which liquifies the refrigerant by rejecting heat from the hot, high-pressure refrigerant gas to a cooling medium that can be either air, in the case of an air-cooled condenser (typically located outside the store) or water, in the case of a shell-and-tube condenser (typically located inside the store); and

- the expansion valve (located immediately before the evaporator coil), which reduces the pressure of the liquid refrigerant, enabling it to boil at the low temperatures required in the refrigerated space.

In addition to the four basic components, other components are also required to make the system operate smoothly. These components include:

- piping, to connect all of the components together;

- a receiver, to allow refrigerant from the system to be stored when not required;

- suction liquid accumulators, to prevent liquid refrigerant that fails to boil off in the evaporator or suction line from entering the compressor;

- control and shut-off valves, to divert refrigerant to where it is needed and stop or throttle refrigerant flow as required;

- refrigerant filters and driers, to protect system components from damage from moisture and other impurities that have remained in the system after construction or that have developed in the system over time;

- an oil management system, which returns oil driven out of the compressor back to the crankcase of the compressor; and

- electronic and mechanical controls to provide safe, efficient, and effective operation of the entire system.

Heat reclamation coils may also be included in the system to preheat air in the air handling unit or water for the domestic hot water. These coils remove useful heat from the hot refrigerant gas discharged from the compressors, thereby increasing energy efficiency.

1.2.1.1 Piping

In theory, refrigeration and air-conditioning systems indefinitely recycle their refrigerant charge for reuse and should not require additional refrigerant to operate properly for their entire useful lives. For example, each year thousands of domestic refrigerators and window air-conditioners are retired to the landfill with the original refrigerant charge intact. It should be stressed, however, that these self-contained appliances contain refrigerant tubing lengths of 50 feet or less and therefore are appreciably less prone to the refrigerant emissions associated with the long piping lengths of the large commercial equipment found in supermarkets.

It is because of the long piping lengths and their associated large numbers of joints and connections that refrigerant emissions in commercial refrigeration systems are so difficult to control. With many connections and miles of piping to design, build and maintain, supermarket facilities personnel face a big challenge in controlling refrigerant emissions. Furthermore, the heat, vibration, and high pressures developed during the refrigeration cycle only exacerbate any existing leakage situation. The estimates in Table 1.1 below represent the quantity of refrigeration equipment required to operate a mid-sized full-service supermarket. (Reference: Bittner, 1992)

The type of refrigerant piping used in supermarkets is designed to be much stronger than required to counteract the internal pressures to which it is typically subjected. As a result, refrigerant leaking directly from undamaged piping is uncommon. However, emissions of refrigerant from piping can result from the following scenarios:

- by locating piping in unprotected high-traffic areas, on top of cooler boxes or display cases, resulting in possible crushing;
- by using hot refrigerant gas to defrost evaporator coils, causing piping to rapidly expand and contract approximately 1,000 times annually for the life of the equipment, resulting in metal fatigue of the pipe;
- by improperly securing field piping, compressor rack piping, or capillary tubes on pneumatic pressure controls, resulting in abrasion from vibrations or thermal expansion and contraction; and
- by improperly mounting or securing condenser or heat reclaim piping, resulting in abrasion from vibrations or thermal effects and exacerbating galvanic corrosion.

Any failures occurring in refrigerant piping can result in catastrophic loss of the entire refrigerant charge. In general, piping located on the compressor rack or condensing unit is very vulnerable to catastrophic failure because of the high levels of vibration transmitted from the compressors. Furthermore, piping located on the high-pressure side of the compressor is the most vulnerable to catastrophic failure because it is subjected to the same high levels of vibration as well as high temperatures and gas pulsation.

TABLE 1.1
PIPING AND CONNECTIONS REQUIRED IN A MID-SIZED SUPERMARKET

Equipment	Piping Length (Miles)[a]	Number of Connections
Display Fixtures	6.8	6,400
Air-cooled Condensers	4.4	3,600
Heat Reclaim and DX Air-conditioning Coils	1.4	1,200
Evaporator Coils (Walk-in Coolers and Freezers)	1.2	2,100
Compressor Racks	0.1	1,200
Field Piping	4.0	1,700
TOTAL	17.9	16,200

[a] 1 mile = 1.609 km

1.2.1.2 Piping Joints and Connections

As shown in Table 1.1, an average supermarket contains over 16,000 joints and connections. Emissions from piping connections and component connections are much more common than from the actual piping; moreover, emissions tend to occur continuously, as opposed to all at once. Connections come in three types:

- **Brazed** connections are typically found in long runs of field piping and on return bends on heat exchangers such as evaporator and condenser coils. They are the most leak-resistant of connections, but take longer to assemble and disassemble.

- **Flanged** connections can typically be found on non-piping components, such as replaceable-core filter-driers or the end bells of semi-hermetic compressors. These type of connections lend themselves to easy disassembly, but are high-maintenance and leaky due to the fact that gaskets or O-rings are required.

- **Screwed or flared** connections are typically found on high-service items, such as controls and expansion valves. These types of connections are the most leaky of the three, and poor construction is the chief cause of the leakage.

1.2.1.3 Valves

Releases from valves can also be significant. Not only do valves leak from flare or flange connections used in their installation, but also from external ports on the valves. Schrader valves are among the greatest offenders. These types of valves are used for attaching pressure gauges and for refrigerant transfer to/from refrigeration systems. Valve caps are sometimes constructed of plastic instead of gasketed brass, and consequently the valves leak even when capped. Common practice for some mechanics is to leave the caps off altogether, increasing the leakage rate.

Another substantial source of refrigerant leakage is the expansion valve. Typically these valves come with flared connections for ease of installation. When the valve is repeatedly subjected to freezing and thawing many times, ice can form in the threads of the valve, causing the flare to unseat and resulting in a steady-state leak.

Finally, relief valves on supermarket systems are nearly always found to be leaky, due to the their mode of operation and type of construction. Receiver-mounted relief valves are constantly subjected to high refrigerant pressures and are vulnerable to contamination and corrosion. In addition, these types of valves frequently do not reseat completely following a pressure relief event.

1.2.1.4 Seals and Other Sources

After many years of use, the seals on open-drive-type compressors eventually become leaky due to misalignment of the drive shaft entering the compressor. These seals can become a large source of steady-state refrigerant emissions as they age and deteriorate.

Galvanic corrosion at the junction of dissimilar metals is also a frequent problem with certain components made of metals other than copper, such as steel. This is usually the case for suction accumulators and suction filters. Places where dissimilar metals come into contact need to be monitored closely for leakage.

1.2.2 Operations and Maintenance (O & M) Practices

The historically low cost of replacement refrigerants has been the primary reason that the refrigeration industry had favored low-first-cost designs over low-emission designs. As a result, many O & M personnel lacked training in low-emissions practices. However, more and more O & M personnel are becoming aware of the impact their operating procedures have on refrigerant emissions through additional education and training.

This transition away from old practices has been neither smooth nor easy for those in the trade who do not believe that supermarket systems can be low-emitting. Skill levels in the refrigeration trade are now becoming more critical to a company's "bottom line" and more companies are now investing in additional educational and training opportunities for their O & M personnel. Additional education and training will have the largest benefit in cases where mechanics can be sufficiently relieved from system repair duties so that time is available to engage in thorough preventive maintenance. Finally, when maintenance personnel are held personally accountable for refrigerant consumption, they often discover ways to reduce refrigerant consumption while simultaneously managing their other responsibilities in an effective manner.

1.2.3 Corporate Policies and Practices

Corporate policies and practices to protect supermarkets' investment in refrigeration equipment and to ensure cost-effective operations should be evaluated to ensure that they do not hinder the development of a program to reduce refrigerant emissions. Since an emissions reduction program requires changes in operating procedures by nearly all facilities departments, persons attempting to implement such a program may encounter resistance from individuals who do not fully understand the entire issue.

Policies and practices should be evaluated with an eye toward removing all institutional barriers. For example, to conduct an emissions reduction program most effectively, a company must be willing to expend the necessary resources to fully integrate the operations of its various facilities departments. This implies providing a vehicle to resolve conflicting needs between departments for limited resources. Additionally, maintenance contractors should be required to account for refrigerant consumption as part of any new contract. The environmental and financial benefits of investing resources in improving engineering, construction, and maintenance practices might also be evaluated. Furthermore, corporate education of all involved parties may result in personnel becoming motivated to improve practices or seek information on emissions-reducing technologies.

Companies can take measures to become more vertically-integrated so that ideas developed by internal O & M staff on new or improved emissions reduction methods will more likely to be relayed to people who can effectively act on those ideas. As a result, problems that can be solved by simple design or manufacturing changes will be corrected more quickly.

In addition to moving towards greater vertical integration, improving communications with maintenance contractors is also a vital component of a corporate policy in the implementation of an emissions reduction program. Obtaining specific knowledge of CFC refrigerant and equipment inventories and refrigerant emission levels is a prerequisite to planning a program strategy; contractors can lend assistance in this area. Companies that know the actual monetary costs of refrigerant emissions are in a good position to justify expending resources to improve their situation. Furthermore, contractors that must provide regular refrigerant recharging reports are likely to take steps to improve the emissions situation without prompting by the client company.

Operating procedures sanctioned during the era of inexpensive refrigerants by persons in positions to influence refrigerant consumption, (e.g., equipment manufacturers, system designers, installers) are becoming outmoded in the new era. Efforts to improve policies and procedures may inspire the motivation to solve these potential problems:

- Lack of specific information on replacement refrigerant costs because these costs can be buried in other operations costs;

- Lack of action on equipment manufacturers' part to improve product design to reduce refrigerant emissions because communication between departments in supermarket companies on equipment problems can be somewhat less than optimal;

- Lack of priority given to leak detection and repair by O & M departments because cost-effectiveness of potential emissions reduction measures has not yet been demonstrated within the company.

1.3 Options for Preventing Refrigerant Emissions

Supermarket companies ultimately can best reduce their refrigerant emissions by implementing a variety of technological options, in addition to fostering greater coordination and communication between their engineering, construction, and maintenance teams. Stressing accountability for refrigerant emission control within each department is also extremely important to the success of an emissions reduction program. By coordinating their efforts, supermarket personnel can reduce and prevent emissions in all facets of a piece of refrigeration equipment's life cycle, including the initial design and construction and the subsequent maintenance and repair of the equipment. Supermarkets can reduce CFC emissions specifically by simply removing the CFC refrigerants from the systems and replacing them with alternative refrigerants. However, supermarkets must always keep in mind the environmental implications of their refrigerant choices. For example, the use of non-CFC refrigerant alternatives that have lower energy efficiencies than other viable alternatives will result in higher levels of pollution generated at most power plants. In addition, some alternatives have high direct GWPs, an issue that has already led to their restricted use in some foreign markets.

This section describes quantitatively some options to prevent refrigerant emissions in the design, construction, operation and maintenance of supermarket refrigeration systems. A quantitative evaluation of these options is provided in Chapter 5.

1.3.1 Equipment Design and Construction

Refrigerant emissions can be controlled by following certain guidelines. If the design team incorporates those guidelines into its specifications and if the construction department or contractor follows those specifications as written, then supermarket refrigerant emissions can be reduced significantly. In Chapter 5 of this report, estimates of refrigerant emissions reductions through implementing individual technologies range from 3 to 25 percent.

1.3.1.1 Design

The engineering team occupies a position of considerable influence over refrigerant emissions yet may receive little feedback on its designs from construction and maintenance personnel for various reasons. If allowed to monitor the success of its existing designs in reducing emissions, the engineering team can help prevent the occurrence of future refrigerant emissions.

Refrigeration systems that are designed for ease of service, operation and construction will more likely be well built and maintained, thus reducing future service events and their accompanying refrigerant emissions. Improved design practices will inevitably lead to smoother equipment operations, saving the company money on refrigerant and energy costs.

Guideline 3, a publication of the American Society of Heating, Refrigerating, and Air-conditioning Engineers (Reference: ASHRAE, 1990), provides solid, basic advice on system design, construction, operation, and service practices. The content of this Guideline should be incorporated into engineering practices and specifications as a critical component of an emissions reduction program.

Feedback on system design problems received from the construction and maintenance teams can be used by engineers to improve designs and specifications. Recurrent system component problems can then be communicated to equipment manufacturers. Manufacturers can then begin to develop improved equipment designs and a better-manufactured product. Providing this kind of feedback may enhance quality assurance within the manufacturer's facilities, and eventually lead to less frequent equipment failures and smaller levels of refrigerant emissions.

1.3.1.2 Construction

Construction departments and contractors can reduce refrigerant emissions from the equipment they build by carefully following engineering specifications and providing feedback to engineering on design improvements. By following exemplary construction practices, a climate of mutual respect between departments can be created.

Since local codes regarding refrigeration installations rarely exist, some construction personnel may be unaware of the special workmanship needs of these systems, and as a result, may "cut corners." In addition, some technicians may be insufficiently trained in good installation practices. Some good practices that construction staff can adopt include:

- supporting and securing piping properly to minimize vibration and stress;
- using brazing alloys of sufficient silver content to construct emissions-resistant systems;
- using dry nitrogen or other inert gas to minimize oxidation during brazing, greatly reducing future maintenance problems resulting from contaminated refrigerant and oil;
- purging piping after construction with high pressure compressed air or nitrogen to remove contaminants such as dirt and metal filings;
- rigorously checking for leaks before allowing piping to be covered by walls or floors; and
- using flared fittings only when absolutely necessary.

Finally, the quality of the construction is also dependent on the quality of the materials used.

1.3.2 Operations and Maintenance Practices

Proper operations and maintenance practices are also critical to maintaining low levels of refrigerant emissions. A comprehensive preventive maintenance program that includes thorough leak detection and repair can spell the difference between a store with high emissions and one with minimal emissions. As shown in Chapter 5 of this report, improvements in operations and maintenance practices can result in emissions reductions of 5 to 40 percent.

Store operations and maintenance personnel have the responsibility to be aware of recurring problems resulting in refrigerant emissions and to relay their observations to engineering and construction personnel. If maintenance service is provided on a contract basis, potential abuses in performing unwarranted maintenance work can be avoided by using "fixed-cost" maintenance and service contracts. These types of contracts also provide an incentive to the contractor to minimize refrigerant leaks because contractors will net higher profits if (1) direct costs of replacing refrigerant are reduced and (2) system repairs that are side-effects of low refrigerant charges are reduced.

Operations and maintenance technicians must have the proper training and the proper tools to perform the tasks necessary to reduce emissions. Training requirements include:

- recognition of the importance of good preventive maintenance;
- ability to keep a good maintenance log;
- ability to properly operate leak detection and refrigerant recovery devices; and
- knowledge of low-emission refrigerant management techniques.

The tools service technicians must possess in the CFC transition era include portable recovery devices and a portable leak detectors (cordless types are more likely to be frequently used). Moreover, these tools can only be effectively utilized if sufficient time is provided to use them.

Maintenance and service technicians that value preventive maintenance are likely to devote more time preventing repairs to avoid potential "midnight repair runs." One excellent method of reducing the frequency of service events that conscientious technicians employ is to keep an updated maintenance log, recording service events and refrigerant recharging events as they occur. By doing so, technicians can determine whether the problems they encounter are systemic or random. They can then work on reducing the systemic problems by determining if the fault lies with design or construction of the system or if increased preventive maintenance is the solution to the problem.

Other store personnel can assist in the endeavor to reduce emissions as well. Quick checks of refrigerant levels and telltale "oil-spotting" (indicating that oil and refrigerant are leaking) can be performed by any person working in the store. Store personnel can also be trained to be aware of signs of low refrigerant charges, such as poor temperature maintenance in display cases. Including non-technical store personnel in the emissions reduction program is but one of a variety of options available to store owners to reduce refrigerant emissions.

1.3.3 Non-CFC Refrigerants

Supermarkets that adopt the dual strategy of moving to alternative refrigerants and reducing leakage from existing refrigeration systems realize a dual environmental benefit. Not only are these supermarkets reducing emissions of gases implicated in ozone depletion, but of gases implicated in global warming as well. New alternatives to replace ODS refrigerants have become increasingly more accepted as additional successful field tests have been completed. However, many of these refrigerants are composed of blends that may separate under certain circumstances. In the event of refrigerant leaks, the composition of these blends may significantly deviate from the originally composition and have a resultant negative impact on refrigerant cooling performance and energy efficiency.

Prior to the CFC phaseout, CFC-12 and R-502 had been used in supermarkets almost exclusively because of their excellent properties as refrigerants at the temperatures required in supermarkets refrigerators and freezers. CFC-12 had been commonly used in medium-temperature applications (0° F to 32° F [-18° to 0°C] evaporator temperature) and R-502 in both medium- and low-temperature (-40° F to 0° F [-40° to -18° C]) applications. Of all the non-flammable, non-toxic refrigerants developed in the pre-phaseout era, CFC-12 and R-502 had the best properties for supermarket applications, operating under positive pressures and with good energy efficiency. In addition, maintaining positive pressures is important to prevent air from leaking into many kinds of refrigeration systems, but is critical in supermarket systems because of the large number of potential leak sites. A low refrigerant charge caused by refrigerant leaking out does much less damage to a system than a buildup of moist air caused by air leaking in.

The CFC phaseout forced the supermarket industry to quickly seek and implement alternatives to CFC-12 and R-502, resulting in the temporary re-adoption of an old supermarket refrigerant, HCFC-22, for both medium-temperature and low-temperature applications. Industry recognized that HCFC-22 was only an interim solution, as this refrigerant also had an ozone-depleting potential (ODP), albeit a much smaller one than CFC-12 or R-502. However, industry had no choice but to proceed with HCFC-22 and HCFC blends until non-ODS refrigerant alternatives were developed and placed on the market.

Contacts with several major refrigerant manufacturers revealed that at the time of this report many refrigerant blends are available on the market for either new or retrofit applications; many more are undergoing testing. The contacts also revealed that the single-component refrigerants HCFC-22 and HFC-134a were available from numerous manufacturers. As mentioned previously, refrigerants listed on the EPA SNAP list include HCFC-22, HFC-134a, HFC-227ea, ammonia, and the blends R-401A, R-401B, R-402A, R-402B, R-404A, R-406A, R-407A, R-407B, R-408A, R-409A, and R-507. Following is a summary of many of the refrigerants that have been developed for use in supermarket refrigeration applications by various companies.

Allied-Signal

This manufacturer produces the HFC-based blend AZ-50, and also co-produces the HCFC-based blends MP-39 and MP-66 with DuPont.

- AZ-50 (R-507) is a blend designed to replace R-502 in new and retrofit applications.
- MP-39 (R-401A) and MP-66 (R-401B) are retrofit substitutes for CFC-12.

Both of these blends are presently commercially available and are SNAP-listed.

DuPont

DuPont offers the blends MP-39, MP-66, HP-80, HP-81, and HP-62 for supermarket applications. All of its blends contain HCFCs, except for HP-62, which contains HFCs only.

- MP-39 (R-401A) and MP-66 (R-401B) are retrofit substitutes for CFC-12.
- HP-80 (R-402A), HP-81 (R-402B) and HP-62 (R-404A) are retrofit substitutes for R-502. HP-62 is also recommended as a refrigerant in new applications.

All blends are commercially available and SNAP-listed.

Elf Atochem

This company has developed three substitute blends for supermarket applications. Two of the blends are based on HCFCs: FX-56 (R-409A), and FX-10 (R-408A). The other blend, FX-70 (R-404A) is based on HFCs.

- FX-56 is a blended substitute for CFC-12 for retrofit applications.
- FX-10 is an HCFC-based retrofit alternative to R-502. FX-70 is an HFC-based alternative to R-502 for new equipment; the refrigerant also has potential in retrofit applications.

FX-10, FX-56 and FX-70 are all currently available and have been approved by the SNAP program.

Great Lakes

This company has developed and is presently testing a replacement for CFC-12 consisting of HFC-227ea and HFC-152a. The blend will not be commercially available anytime in the near future.

ICI Americas

This manufacturer has developed two HFC-based blends: Klea 407A (R-407A) and Klea 407B (R-407B).

- Klea 407A (the refrigerant formerly known as Klea 60) is a substitute for R-502 and is designed to be used in retrofit applications only.
- Klea 407B (the refrigerant formerly known as Klea 61) is also a substitute for R-502. This blend is recommended for use in new equipment applications only.

Both of these alternatives are becoming widely commercially available. Both are SNAP-listed.

ICOR International

This company has developed R-406A, a blended substitute for CFC-12. This refrigerant is intended to be a drop-in replacement and may be substituted for CFC-12 without any hardware changes, according to the manufacturer. The blend consists of HCFC-22, HCFC-142b, and isobutane. This refrigerant has been approved for listing under EPA's SNAP program.

National Refrigerants

A blend made by Rhone-Poulenc, Isceon-69L (R-403B), is commercially available exclusively from this distributor. This blend is a substitute for R-502 and is intended to be a "drop-in" replacement. It may be substituted for R-502 without any hardware changes, however National Refrigerants recommends that the system be "cleaned up" first by changing the oil and the filters prior to operating systems with this refrigerant. The blend consists of HCFC-22, propane and perfluoropropane. This refrigerant has been evaluated for listing under EPA's SNAP program and has been categorized as "proposed unacceptable" because other refrigerants are available for this application that do not contain perfluorocarbons. (Reference: Federal Register, September 1994)

1.3.4 Summary of Equipment-related Alternatives

Companies have three basic choices regarding the disposition of their existing equipment that influence their choices of alternative refrigerants. They can:

- maintain the equipment on CFCs as long as possible;
- retire their equipment, replacing it with non-CFC equipment; or
- retrofit their equipment to alternative refrigerants.

The concerns regarding maintaining equipment on CFCs have been discussed in previous sections. These include assuming the risk of not being able to obtain replacement refrigerant, incurring escalating costs for replacement refrigerant, and potentially harming the environment through emitting refrigerant from the system. These are all good reasons to make systems more leak-resistant if a company chooses to proceed with this option for certain pieces of equipment.

Companies can also retire their equipment, either as a result of a remodel, equipment failure, or a proactive CFC phaseout campaign. New equipment that uses alternative refrigerants is available for both medium- and low-temperature applications. Alternative HFC-based refrigerants approved for use in new equipment by some manufacturers include HFC-134a, R-507, and R-404A. HCFC-22-using equipment is widely available for both low- and medium-temperature applications.

Besides replacing refrigeration systems with new non-CFC systems, supermarkets also have the option to continue to use their existing equipment by retrofitting it to various substitutes. Table 1.2 summarizes information regarding the alternatives to CFCs that can be used in new or retrofit supermarket systems. Some substitutes described in the section above do not appear in the table because the refrigerant is not commercially available.

1.3.5 Comprehensive Corporate Refrigerant Management

The supermarket companies that are most successful at reducing refrigerant emissions have become that way as a result of careful planning involving all of the teams responsible for providing refrigeration to the stores: engineering, construction, and maintenance. By coordinating the actions of these teams through encouraging better communications between the teams, companies can ensure that their refrigerant emission levels will continue on a downward trend.

To institute a comprehensive corporate refrigerant management program, a company must first take stock of current practices. A thorough evaluation will determine which of its activities promote or at least do not detract from the goal of reducing and eventually eliminating CFC refrigerant consumption. One good way to improve the information collection is to provide incentives for personnel to become better informed about the corporate refrigerant situation and the available emissions control options.

Other actions must be taken to move along an emissions reduction program. Company executives controlling the management of supermarket facilities play a critical role in implementing an emissions reduction program. Corporate executives can become more aware of the atmospheric effects and monetary costs of their refrigerant emissions. Several methods to boost awareness include:

- appointing a corporate refrigerant manager;
- beginning a program to record amounts of and reasons for refrigerant consumption;
- improving the quality of communications between departments (for example, better communications between operations and maintenance (O&M) personnel and engineering and design (E&D) personnel could lead to low-cost, easy-to-maintain equipment designs); and
- gathering available information on the effects of CFC emissions on the stratospheric ozone layer and distributing it to decisionmakers and implementation staff.

Personnel who work directly with the equipment such as equipment designers or installers may be in a position to significantly influence a company's rate of refrigerant consumption directly. However, they too must become aware of effective measures they can take to reduce emissions. Their awareness can be improved through aggressive information collection. Materials presently available include:

- information available through supply houses;
- information available through contractors;
- information available directly from equipment and refrigerant manufacturers, including advertising in trade publications promoting emissions-reducing technologies;
- EPA-developed information packets and fact sheets; and
- articles in professional and trade journals.

TABLE 1.2
REFRIGERANT ALTERNATIVES FOR SUPERMARKETS

ODS Refrigerant	Evaporator Temperature[2]	Non-CFC Substitute	ODP[3]	GWP[4]
CFC-12	All	(Baseline)	1.0	7100
CFC-12	Medium and Low[4]	HFC-134a	0	1200
CFC-12	Medium	R-401A	0.033	1017
CFC-12	Low	R-401B	0.036	1116
CFC-12	Medium and Low	R-406A	0.052	1618
CFC-12	Medium	R-409A	0.044	1340
R-502	All	(Baseline)	0.332	4365
R-502	Low	R-402A	0.019	2648
R-502	Medium	R-402B	0.030	2252
R-502	Medium and Low	R-404A	0	3520
R-502	Medium and Low	R-407A	0	2990
R-502	Medium and Low	R-407B	0	3195
R-502	Medium and Low	R-408A	0.024	3295
R-502	Medium and Low	R-507	0	3600
CFC-12, R-502	Medium and Low[5]	HCFC-22	0.05	1600

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[2] A medium temperature evaporator is required to refrigerate fresh foods. A low temperature evaporator is required to refrigerate frozen foods.

[3] ODP denotes the refrigerant's Ozone Depletion Potential, referenced to CFC-11. GWP denotes the refrigerant's Global Warming Potential, based on a 100 year time horizon and referenced to CO_2 as a baseline (value of 1.0). Hydrocarbons are assumed to have a GWP of 3.0. (Reference: Derived from CAAA, Section 602, 1990; and UNEP, 1992.)

[4] Retrofits of low-temperature CFC-12 systems to HFC-134a may result in unacceptable losses in cooling capacity (up to 30 percent).

[5] Retrofits of low-temperature R-502 systems to HCFC-22 may result in unacceptable losses in cooling capacity (up to 20 percent).

After some evaluation, corporate executives may need to resolve cross-departmental problems to achieve effective refrigerant management. Furthermore, additional internal funds may need to be redirected to facilities departments for use in reducing long-term operating costs through an emissions reduction program. The large potential impact of reduced operating costs on the traditionally low profit margins of this competitive business may justify such an investment. In addition, such a program might be turned into another advantage for the company as well. A high-visibility "green grocer" campaign could be launched which promotes the company's efforts in reducing ODS and greenhouse gas emissions through a refrigerant emissions control and CFC refrigerant phaseout program and an energy use reduction program.

Facilities executives may need to adopt other creative methods to gain approval and funding for any new programs they wish to implement. These tactics may include:

- implementing pilot projects to demonstrate the cost-effectiveness of new technologies and new operating procedures;
- emphasizing the potential for store disruptions or high refrigerant costs if measures to reduce emissions are not taken;
- emphasizing the strategic competitive importance of the technologies; and
- building a refrigerant consumption reduction team including people in the legal, financial, environmental, engineering, construction, and maintenance departments.

By taking initial small steps to get quick results and building a team involving important decisionmakers, program managers have a better chance of success than attempting to conduct the program alone.

CHAPTER 1 REFERENCES

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CHAPTER 2
Case History - Hannaford Brothers Company

Hannaford Brothers Company, a chain of 95 supermarkets operating in northern New England and upstate New York under the trade names Shop 'n Save, Sun Foods, and Martins, has adopted a proactive stance on the CFC phaseout issue. The company's approach to reducing CFC emissions from its refrigeration systems consists of two parts. First, the company is removing CFC refrigerants from its systems by retrofitting its existing stock of refrigeration equipment to accommodate alternative refrigerants. Second, the company is in the midst of a program to significantly reduce leakage of all types of refrigerants from its refrigeration equipment.

The company's goal was to eliminate its use of all CFCs by September 1994. The company has already eliminated its purchases of virgin CFC refrigerants as a result of its CFC phaseout program. Any replacement refrigerant required by the remaining CFC systems now comes from the store of refrigerant recovered during retrofit activities. The company's CFC phaseout program has proceeded smoothly. CFC-12 was eliminated from all the company's refrigeration systems by the end of 1993 through retirement or retrofit of the CFC-12 refrigeration equipment. The company then pursued a phaseout of R-502. As of May 1994, this refrigerant has already been totally eliminated from eight stores, with retrofits partially complete in 39 other stores.

Consumption of R-502 and alternative refrigerants has been reduced by an aggressive leak detection and repair program which augments the company's regular preventive maintenance program. As a result, Hannaford has reduced refrigerant emissions to near-zero in many stores. The company's refrigerant emissions reduction program has also reduced net operating costs. The program stresses involvement and accountability by all departments responsible for the stores' refrigeration systems including store design, construction, and maintenance. The company's outside maintenance contractors have also been made accountable for the refrigerant used in the stores.

The head of the company's CFC phaseout and leak reduction program is Tom Mathews, Hannaford's Facilities and Energy Manager. It is his belief that the company's efforts to reduce refrigerant emissions have given them a competitive advantage -- first, because the company's environmental actions are appreciated by their customers and, second, because the operating costs have been reduced by requirements for less replacement refrigerant.

2.1 Engineering the Emissions Out

Refrigerant emissions are known to be the result of both regular operating leakage and catastrophic releases. Hannaford controls many of these emissions through regularly scheduled leak inspections and prompt repairs. Once equipment is built, leaks can only be reduced by inspection and repair. However, by careful design from the beginning, equipment can be configured to eliminate factors or components which in standard systems would be prone to catastrophic leaks.

When CFC refrigerants were low-priced and thought to be environmentally harmless, Hannaford stayed competitive with low-first-cost refrigeration system designs. Over time, however, Hannaford has modified its design practices. In developing its program to "engineer the emissions out," Hannaford carefully examined practices where it could most effectively reduce its leaks. It identified several major factors contributing to refrigerant leakage:

- System designs that required large numbers of joints and connections, each a potential leak site,

- The hot-gas method of defrosting cooling coils which created many opportunities for leaks to occur,

- Construction specifications that did not ensure clean leak-free systems,

- Equipment manufacturers that did not offer low-emission designs,
- The maintenance department which had no regular leak detection and repair program, and
- Maintenance contractors that operated under contracts that indirectly discouraged efforts to control refrigerant leakage.

2.2 Loop Piping Designs

In decades past, Hannaford engineers had used conventional designs in the construction of store refrigeration systems. Although effective, these conventional designs shared a common flaw: each refrigerated case or cooler box required a set of refrigerant pipes running from the common header pipes in the mechanical room to the cooling coil in the refrigerated space. For the average Hannaford store, this meant that installation of 50 to 60 sets of pipes was required to provide cooling to all of the refrigerated spaces. Each set required a substantial number of connections and joints and consequently included potential sites for a leak to occur.

In an effort to reduce the number of long pipe runs and correspondingly large number of connections, Hannaford began in 1985 to implement "loop piping." The innovative system design required far fewer joints than conventional designs. In essence, loop piping entailed extending two common pipes from the compressor racks out into the store area to all of the refrigerated systems. The inlet and outlet of each cooling coil was then connected to the common pipes with a short run of connecting piping. Moreover, the common pipes, with their larger size and sturdier construction, tended to be much more resistant to breakage from the movement of the building as it settled than the smaller pipes used in former designs. Hannaford estimates that loop piping saved the company about two-thirds of the total piping length and two-thirds of the fittings. In addition, refrigeration installation costs decreased about 30 percent compared to conventional designs.

2.3 No More Hot-Gas Defrost

The company had been using the hot gas discharged from its compressors to defrost its cooling coils. Although this method worked quickly, it had several drawbacks.

- The method required the compressors to operate with high discharge pressures for defrost purposes year-round instead of allowing the discharge pressures to fall with the outside air temperature in the cooler months, preventing the company from capturing significant energy savings.
- Additional components and piping were required to install a hot-gas defrost system, increasing the number of potential leak sites. In addition, this type of defrost made loop piping more difficult.
- Thermal expansion, contraction and stress degradation of valves, piping, and connections were a consequence of the characteristic sudden changes in temperature, eventually resulting in leaks.

Over time, Mr. Mathews' objections to the use of hot-gas defrost grew. He discontinued its use after observing that, on average, releases of refrigerant of at least 100 pounds were occurring about four times a year per parallel rack. Mr. Mathews instead began to specify electric resistance heaters to defrost the company's freezers. The electric defrost method proved to be more effective than the hot-gas method and required less refrigerant charge. Hannaford also began to institute a demand-defrost scheme that eliminated unnecessary defrost cycles. Overall, Hannaford's operating costs averaged 15 to 18 percent lower for the new defrost method.

2.4 Improved Construction Practices

Hannaford's engineering department has instituted many changes to improve the quality of the refrigeration equipment installations. To prevent refrigerant leakage, the company mandates rigorous pressure testing of the refrigeration systems following their construction, ensuring system integrity. To reduce the presence of contaminants left in the systems after installation and increase the strength of the piping connections, the engineering specifications were also changed to include:

- mandatory use of nitrogen or other inert gas during brazing operations to prevent internal oxidation of the piping from contaminating the systems,
- mandatory installation of filters upstream of all expansion valves to protect the valves from clogging with any particulate left in the system, and
- mandatory use of solder containing at least 15 percent silver to ensure strong, leak-resistant connections.

Hannaford's strategy to prevent unnecessary service expenditures has resulted in reduced operating costs with only marginally increased construction costs. Its philosophy is that by building clean, dry, and tight refrigeration systems to start with, it can concentrate its operations and maintenance resources on inexpensive preventive maintenance rather than on expensive repairs.

2.5 Improved System Component Designs

As an additional part of its program, the company worked with its equipment manufacturers to develop lower-emission products. Hannaford now requires that display cases be equipped with expansion valves with sweat-type connections instead of flare-type because the company has had several problems with leaky flare connections on expansion valves. Compressor racks are now ordered with special steel capillary tubing for pressure controls instead of copper, because steel has better resistance to stress failure, abrasion, and breakage.

Hannaford's choice of air-cooled condensers is also significant. The company requires that all condensers purchased be modular units with tubing bundles less than five feet long, have side-mounted tubing headers, and have large, low-tip-speed fans. Condensers of this type have fewer problems with emissions because chafing of the condenser tubing is reduced. In addition, condenser fan mountings have less chance of shearing off from vibration and puncturing the condenser tubing.

Hannaford has obtained good results by maintaining open lines of communication with its equipment manufacturers. Mr. Mathews commented that in his experience, manufacturers can often be persuaded to improve their products, particularly when pushed by customers that constitute at least one percent of their business. Given Hannaford's significant purchasing power and the competitive refrigeration systems components market, manufacturers do listen when Hannaford has a suggestion.

2.6 Improved Maintenance Practices

Hannaford has been taking steps to improve its maintenance program since 1987. The company realized that in order to effectively reduce its refrigerant emissions, the people performing maintenance on the stores would have to be committed and enthusiastic participants in the program. Crucial to improving Hannaford's maintenance program was getting across to its mechanics that a zero-emissions store was not only practical, but practicable.

The implementation of EPA's no-venting rule and refrigerant recycling regulations added some urgency to the situation. Upon the issuance of the regulations, Hannaford's management reemphasized the need to reduce refrigerant emissions to maintenance staff. The company believed that it could eventually reduce refrigeration system problems to the point where its increasing number of stores could be maintained by the same number of mechanics for the same labor-hours. In the end, the company's belief was confirmed. By performing leak detection and repair as a regular and important part of their job, Hannaford's mechanics were able to reduce total maintenance costs. Although regular labor hours remained the same, "middle-of-the-night" repair runs and nuisance calls were significantly reduced, and replacement refrigerant costs were reduced as well. Mr. Mathews also reports that the company's systems now run better and more efficiently.

Hannaford's maintenance mechanics are required to perform four to eight hours of leak detection and repair per store per month. In addition, one overall leak inspection of all systems is required each week. Of those hours, the mechanics spend 90 percent of the time searching for and gaining access to leaks. Hannaford eased its mechanics' leak-checking burden considerably by purchasing battery-operated leak detectors. Leak detectors that required electrical cords had proved to be cumbersome and were not well utilized. Hannaford's new leak detectors are capable of detecting CFCs, HCFCs, and HFCs, important for a company that plans to invest heavily in HFC-based technology.

The remainder of the time is usually spent correcting problems with flanged and flared connections. This usually entails tightening valve packings and replacing seals. Occasionally, mechanics will find a leaking brazed connection. Although very few brazed connections leak refrigerant, when located, they must be removed and replaced, requiring about two hours of a mechanic's time. In aggregate, however, the mechanics spend far more time reducing leakage from non-brazed connections.

Hannaford's mechanics spend a great deal of time trying to prevent catastrophic losses of refrigerant. This entails careful inspections of the high-temperature, high-vibration locations in the system, where catastrophic refrigerant emissions are most likely to occur. In particular, the compressor racks are carefully inspected for loose clamps, excessive vibration, and tube chafing. These kinds of conditions may precede a major release of refrigerant.

2.7 Incentives for Contractors

In its review of its refrigerant management methods, Hannaford scrutinized the way its maintenance contractors operated. The company began to require that contractors provide a periodic refrigerant replacement report and discovered that maintenance contractors operating under service-only contracts that allowed them to bill Hannaford for replacement refrigerant tended to have high refrigerant consumption, while contractors operating under fixed-cost service-and-preventive-maintenance contracts had much lower refrigerant consumption.

Hannaford consequently began to specify that all new contracts be of the fixed-cost service-and-preventive-maintenance type. Now that its contractors have the incentive and the means to keep refrigerant in the systems, the company is realizing significant financial benefits from its reduced replacement refrigerant costs. Last year, Hannaford observed significant reductions in refrigerant consumption for those contractors that were switched over to fixed-cost contracts. Moreover, these consumption reductions were obtained in a very cost-effective manner.

2.8 Program Results

As a result of its comprehensive refrigerant management program, Hannaford has reduced its consumption of all new refrigerants by 44 percent from last year and consumption of R-502 by 54 percent. Overall, Hannaford has reduced its total refrigerant consumption by 80 percent in eight years, while at the same time doubling its number of systems requiring refrigeration.

CHAPTER 3
Case History - Shaw's Supermarkets

Shaw's, a chain of 88 stores operating in four states in the New England area has generated some significant results in its mission to reduce refrigerant emissions from its stores. The company is working diligently to streamline its policies and programs to reduce refrigerant emissions and resulting dependence on market supplies of CFCs.

Shaw's benefits from its affiliation with the supermarket trade group, the Food Marketing Institute (FMI). John Seaburg, Shaw's Vice President of Engineering and Construction, previously was Chairman of the Energy and Technical Services Committee and is currently active on the Alternative Refrigerants Task Force. Joining FMI, according to Mr. Seaburg, is a good way to become better informed about state-of-the-art methods of managing both CFC and non-CFC refrigerants and equipment, and the latest new products and developments in the industry.[6]

3.1 An Emissions Reduction Program

In the early stages of the development of his company's CFC elimination program, Mr. Seaburg quickly realized that by attempting to retrofit or replace all of Shaw's CFC refrigeration equipment with HCFC-22 technology, the company would incur high costs in the first years of the program. Shaw's determined that a program to immediately reduce leakage from the chain's refrigeration systems in conjunction with a long-term program to retrofit and replace the equipment would be more cost-effective. In addition, by starting an emissions reduction program immediately, the company gained several advantages.

- The company saved the cost of retrofitting many of its pieces of existing refrigeration equipment by both reducing CFC consumption of the equipment and using refrigerant recovered during retrofits to service the equipment. This was the optimal strategy for equipment that was still useful, but was not a good candidate for retrofit, as its life could be prolonged inexpensively until natural retirement.
- The company gained additional time to formulate its policy on long-term alternative refrigerants while awaiting the development and testing of long-term refrigerants. At the time, many refrigerant alternatives were still under development and most non-CFC equipment was not available.
- The company blunted the effects of the escalating prices of replacement refrigerant by reducing demand for replacement refrigerant.
- The company prepared for possible future regulations regarding levels of emissions from supermarkets by developing methods to reduce emissions.

In addition to moving to alternative refrigerants cost-effectively, Shaw's had three other objectives for its emissions reduction program: first, complying with regulations on refrigerants; second, ensuring product integrity to keep customers coming to the stores; and third, improving the overall quality of the facilities departments in general.

Shaw's needed its refrigerant consumption to match its available supply of refrigerant to assure uninterrupted equipment operation. The company planned to accomplish its goals through "the five Rs," by:

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[6] FMI's Energy and Technical Services Committee has published some CFC phaseout guidelines for supermarket facilities departments entitled <u>1994 FMI Alternative Refrigerant Guidelines</u>. Updates are added as new information becomes available.

- **reducing** refrigerant leaks to the atmosphere through leak detection and maintenance programs,
- **recovering** refrigerant during equipment service, retrofit, and retirement,
- **recycling** refrigerants within the business, saving money over the cost of virgin refrigerant[7],
- **reclaiming** recovered refrigerant of unknown quality to ARI Standards through a trusted reclamation company, and
- **reusing** refrigerants as much as possible.

Shaw's assessed its existing infrastructure to determine what practices and conditions could be improved to reduce or prevent refrigerant emissions. It determined that improvements could be made in all of its facilities departments, including engineering, construction, and maintenance. The company also believed that purchasing a computer program that could monitor its refrigerant consumption and log maintenance events could help minimize refrigerant emissions.

3.2 The Maintenance Manager

The company already had been recording its CFC consumption on an individual store basis. However, with the availability of refrigerants becoming an increasing concern for the company, Shaw's recognized the need to track refrigerant usage at the system level. It could then concentrate its efforts on both its highest-leaking stores and systems, maximizing its available resources. The company also recognized the need to monitor its service events to better troubleshoot refrigeration system problems. Shaw's consequently located and enlisted the aid of a company that had developed a computer program that performed both of these functions.

The program's capabilities also extended to forecasting refrigerant needs, helping the company plan its equipment conversions and replacements so that its overall costs from new refrigerant purchases could be reduced. The initial cost for the program seemed high, at $7,500 for a single terminal and $30,000 for a networked system of five terminals. Shaw's opted for a networked systems, and it paid for itself in less than one year. The program required no additional labor to update its database because it interfaced directly with Shaw's accounting program. The information the accounting clerks had been entering from service invoices into the accounting system for years now had a dual function.

The program was designed for companies with multi-site operations, such as grocery chains and could track refrigerant movement and leakage by location. At any time, an operator could log on to the database and query the program on various topics, such as equipment servicing histories and refrigerant recharging histories. Furthermore, the operator could prioritize database searches by type of event. This capability allowed Shaw's to troubleshoot and monitor its equipment from the office to optimize its service and preventive maintenance strategies.

3.3 Underground Piping

Shaw's had been experiencing problems with piping that was located in exposed spaces. When Shaw's piped all of its systems above ground, piping had occasionally been damaged by store personnel in the normal course of store operations. In an effort to prevent possible risk to employees and damage to unprotected piping and connections, Shaw's began the practice of locating refrigerated system piping in trenches under the floor slab. As a bonus, the installation cost of locating piping underground has so far been less than the cost of locating the piping overhead.

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[7] Excise taxes do not apply to recycled refrigerant.

However, locating piping underground presented a potential problem to maintenance personnel, as any leakage from underground piping or connections could require demolition of the floor slab to locate the leak. Shaw's came up with a solution to both increase access to the piping and decrease the probability of a leak. The company specified that any tubing located underground must be of the soft-drawn type. This type of tubing could be installed in 50 foot continuous lengths. To ensure the accessibility of the required connections, the company specified for service pits to be constructed every 50 feet as well.

3.4 Stationary Leak Detectors

As a further control on its refrigerant emissions, Shaw's also began to monitor in-store air for the presence of refrigerant, employing stationary leak detectors in many stores. The manufacturer of Shaw's refrigeration controller and energy management system (EMS) offered this capability as an option on its equipment for an additional five percent premium on the price, and Shaw's accepted its offer. Shaw's now had the capability to monitor refrigerant leakage continuously. Each system is set up to monitor eight points in the stores -- three in the compressor room, four in the main pits, and one in the duct that returns air from the store to the air handler. Whenever a sensor detected a significant leak, it sent a signal to an alarm company, who in turn contacted Shaw's maintenance department.

Shaw's needed to periodically adjust the sensitivity of the leak detectors because they gave off numerous false alarms at the outset. For instance, soon after installation, the leak detectors were sensing small quantities of naturally-occurring methane in the backfill of the main pits and sounding an alarm. Fine-tuning of the system resulted in fewer false alarms, but the system did require some time to calibrate.

The installation of these units has resulted in significant benefits for Shaw's. In one incident, one of Shaw's contractors insisted that a problem existed with one of the refrigeration systems, but that it was not due to refrigerant leakage. Because Shaw's had this remote monitoring capability, it was able to show evidence to the contrary. In addition, if refrigerant is emitted from a leakage point prior to the leak becoming catastrophic, the system can alarm the maintenance department immediately so that maintenance personnel can repair the leak and avoid a major refrigerant loss.

3.5 Charge Reduction

To reduce the impact of catastrophic leaks, Shaw's makes efforts to reduce the system refrigerant charge size in its designs. The company employs four design features that reduce charge size. These features are:

- remote headers,
- heat reclaim pump-out,
- split condensers, and
- condenser bypass.

Shaw's was aware that it had been using large amounts of piping to construct its systems. But after seeing an eye-opening report on the actual length of piping and number of connections required to build a conventionally-designed store, the company was determined to improve its design practices. Shaw's decided to reduce the overall piping length by reducing the number of pipes coming out of the compressor room and extending the main suction and liquid lines out into the store in locations central to the systems serviced. Remote headers were then attached to collect and distribute refrigerant for short branch lines serving individual refrigerated spaces. Not only did this design reduce refrigerant charge by approximately 15 percent, but Shaw's contractors reported that it saved 10 to 15 percent on piping installation costs.

In examining its practices, the company identified another way to improve on conventional designs. With its previous design, after completion of a heat reclamation cycle, refrigerant had remained stagnant in the heat reclaim coil and piping. The improved design called for the addition of an electrical circuit and components to pump the refrigerant out of the heat reclaim system after cycle completion. This modification helped maximize the utilization of refrigerant in the system.

In the winter months, when refrigerant requirements were maximal and the compressed refrigerant was more easily condensed back into liquid and required fewer condenser tubes to reject the heat of evaporation and compression, Shaw's took the opportunity to install apparatus to valve off sections of the condenser, thereby saving an additional 15 percent of the charge.

Another wintertime savings opportunity was the fact that it occasionally got so cold that the refrigerant condensed entirely back to liquid within the heat reclamation coil. A system was designed to sense this condition and then valve off and pump the refrigerant out of the condenser. This feature allowed Shaw's to reduce charge size by an additional five to 10 percent.

3.6 Eliminating Capillary Tubes

In its quest to further improve its operating procedures, Shaw's investigated the occurrences in which it had lost the most refrigerant from its systems. The company observed that failed capillary tubes were frequently at fault, with five to ten percent of these devices leaking significant amounts annually. These tubes were subject to large amounts of vibration, being typically mounted in close proximity to the compressors. If they failed, the entire refrigerant charge would be lost within minutes.

The company began to investigate where it could eliminate the need for capillary tubes. It found that in many instances, other technologies could be used. For example, electronic oil and pressure sensors could be used, thereby eliminating the need for a pneumatic-type control that required capillary tubes to transmit pressure to a controller. Not only could electronic controls greatly reduce refrigerant emissions, they could also act as inputs to the EMS, allowing remote monitoring of system conditions, a great help in remote troubleshooting.

In applications where the company could not find suitable electronic substitutes, it applied a technology used in aerospace applications that was a good alternative to capillary tubes. This technology was a type of polymer hose supported on the outside with braided steel hose. This product was not only compliant, so that it could make the sharp bends required by its application, but vibration- and abrasion-resistant as well because of its tough steel outer shell. Although the polymer inner hose was slightly permeable to refrigerants on the order of a few ounces per year, it could prevent virtually all emissions resulting from capillary tube failures.

3.7 Improving Maintenance

Shaw's had already been recovering most of its refrigerant during service operations by either pumping refrigerant into the receiver or into another compressor rack in the mechanical room. After the issuance of the EPA's recycling regulations, however, Shaw's recovery program became even more efficient as the company purchased portable refrigerant recovery devices for all of its service mechanics.

Shaw's had found that the best way to reduce the costs of a leak reduction program was to coordinate the activities of the in-store personnel with the maintenance personnel. For example, to check whether an expansion valve or cooling coil in a case is leaking, product must first be removed from the case to access the refrigeration components. Shaw's tries to schedule its leak detection activities to coincide with routine case cleaning to minimize labor requirements.

The maintenance department convinced in-store personnel to let it handle all operational problems with the cases and cooler boxes by promising and delivering quick call response times. If a case is severely frosted, store employees now know not to attempt to remove the ice with an ice pick, but to call maintenance immediately.

When Shaw's must contract out service work to maintenance contractors, it chooses the company from a select list of preferred contractors who have all been specially trained. The company expended great effort in educating its contractors to do things meticulously and properly. This effort includes regular formal instruction on procedures and schedules for service items, e.g., refrigeration system oil changes and refrigerant leak detection and repair. The company urges the contractors to work towards a fixed budget and to do everything possible not to exceed the budget.

3.8 Results of the Program

Shaw's CFC phaseout program is doing quite well due to the success of its emissions reduction program. To date, Shaw's has two stores in which it has eliminated ozone-depleting refrigerants from all of the refrigeration equipment, and twelve stores in which CFC-12 has been completely eliminated.

The company has reduced total chain-wide consumption of CFCs by 44 percent of its 1988 levels, at the same time adding about eight new stores each year. Its refrigerant recovery, recycling and reclamation program has allowed it to reuse over 3,000 pounds* of refrigerant since 1990. On average, annual refrigerant purchases have been reduced 18 percent by using recycled product. At this year's current cost per pound, this amounts to about $45,000.

Finally, according to its computerized maintenance manager and refrigerant tracking program, Shaw's has reduced its annual refrigerant system leakage by 29 percent (or approximately 6,000 pounds) over the last two years.

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* 1 lb = 0.454 kg

CHAPTER 4

Case History - Jitney-Jungle Stores of America

Jitney-Jungle Stores of America, a chain of 108 stores operating in six states throughout the South has launched an ambitious program to reduce its consumption of CFCs and other refrigerants. The company's approach includes a comprehensive refrigerant leak detection and repair program as well as a rapid transition to alternative refrigerants through equipment conversion and replacement. The company has been removing CFC refrigerants from its systems by converting its existing stock of refrigeration equipment to accommodate alternative refrigerants and replacing older, leakier, inefficient equipment with state-of-the-art non-CFC equipment.

In 1991 James Riley, Jitney-Jungle's Vice President of Engineering began to collect information on his options to reduce and eventually eliminate refrigerant consumption in Jitney-Jungle's stores. He formed a team of advisors including people with good knowledge of the company's existing systems as well as people with good knowledge of the new refrigerant and equipment alternatives. The team began with some test conversions to HFC-134a, R-402A, and R-404A, and quickly built up the confidence to convert an entire store to HFC-134a and R-402A. Using the experience gained from the first non-CFC conversions and installations, the company began to implement a program to eliminate its purchases of virgin CFC refrigerants by the end of 1995, using only the store of refrigerant recovered during conversion activities to satisfy the needs of its remaining CFC systems.

4.1 Refrigerant Conservation Opportunities

To accomplish its goal of eliminating all purchases of virgin refrigerant, the company devised a program to conserve refrigerant by reducing emissions resulting from all phases of its operations. It first identified and assessed those practices in engineering, service, and maintenance where opportunities existed to make practical, effective changes. It identified several factors directly contributing to refrigerant emissions:

- A commonly-used receiver design that required larger-than-necessary amounts of refrigerant, resulting in extra emissions in the event of a catastrophic failure;
- A commonly-used refrigerant expansion valve design that resulted in predictable yet preventable refrigerant emissions;
- System designs and maintenance practices that resulted in conditions leading to high system operating temperatures and pressures, making systems more susceptible to failure;
- Service operations in which mechanics were sometimes too busy to conduct effective leak detection and repair, and were thus occasionally forced to settle for topping off systems with refrigerant to keep the stores operating; and
- Installation practices in which systems were sometimes left without optimal component-isolation or refrigerant access facilities.

4.2 Vertical Full-charge Surge Receivers

In its assessment, the company questioned why its compressor racks were always furnished with horizontal flow-through receivers instead of vertical surge receivers, which had been available for many years. The company asked its rack manufacturers to rework their arrangement of rack components so that vertical receivers could be used.

Vertical receivers offered three benefits over horizontal receivers, because of the latter type's smaller horizontal area. First, and most importantly, vertical receivers required smaller quantities of refrigerant to maintain the same depth of liquid as a horizontal receiver. Second, vertical receivers consumed less floor space, allowing for a more compact arrangement of system components, and thus a smaller compressor rack. Third, by installing a vertical receiver in a "surge" arrangement instead of a "flow-through" arrangement, free subcooling of the liquid refrigerant that occurred in the winter months could to be preserved, as less mixing occurred between the newly-condensed, cold refrigerant and the warmer refrigerant stored in the receiver inside the store, thereby saving energy.

4.3 All-sweat Thermostatic Expansion Valves

After becoming aware of the problems it was having with refrigerant leaks from its flare-type thermostatic expansion valves, the company decided to investigate the use of the newly-available sweat-type (brazed) valves. After some initial successes with the technology, the company decided to require that all new display cases be equipped with sweat-type expansion valves instead of flare-type. Although this design made it more difficult to remove expansion valves for service reasons, the company has noticed a very significant reduction in emissions from this particular component. In addition, the brazed valves include external strainers in order to make the valves easier to clean in the event that particulate matter clogs the valve.

4.4 Improved Mechanical Room Conditions

In discussions between the engineering department and the maintenance department, it was determined that systems which operated with the highest pressures and temperatures were among those systems with the most maintenance problems related to refrigerant emissions. Therefore, an effort was made by both engineering and maintenance personnel to keep pressures and temperatures down.

Engineering personnel made special efforts to increase ventilation, ensuring that compressor room ventilation was adequate to control heat gain. In addition, the largest size compressor head cooling fans available were specified to be installed on each new compressor to be put into service as well as those compressors which had problems with overheating. Departing from standard industry practice, head cooling fans were specified for compressors operating in the medium-temperature range, reducing the amount of heat to which all of the stores' systems were subjected. In addition, monitoring sensors were installed in those stores containing electronic refrigeration controller/monitors so that Jitney-Jungle could obtain detailed performance data on systems, such as temperatures and pressures at various key points.

Maintenance personnel took special care to make heat transfer from the systems as efficient as possible, ensuring that condenser surfaces were cleaned regularly, ventilation fans and controls were operating properly, and systems were monitored more closely to detect heat-related problems. During regularly-scheduled major inspections equipment operations were restored to original engineering specifications to optimize the utility of the heat- and pressure-controlling design features.

4.5 Improved Service and Maintenance Program

The CFC phaseout has been a time of tremendous change for the company's maintenance department. For environmental and financial reasons, the company needed to conserve its existing refrigerant supply. A refrigerant tracking system was implemented and leak detection and repair practices were improved to augment the company's existing preventive maintenance program. As a result, the company believes it can reduce refrigerant emissions to insignificant levels by the end of 1994.

Since November 1993, construction and maintenance personnel have been responsible for helping maintain a refrigerant accounting log by filling out a short form at the company's centralized depot before picking up refrigerant to replace refrigerant used during service operations. The form reflects all charging events, and includes the date, the quantity used, the reason for recharging, and the location of the leak, if any.

In order to keep the stores' refrigeration systems operating while reducing refrigerant emissions levels, additional maintenance personnel were hired. As a result, each mechanic can now conduct 20 to 30 hours of leak-checking and repair per month. Mr. Riley remarked that the biggest issue he faces in continuing his emissions reduction program is not retraining his staff, but focusing on those procedures that conserve the most refrigerant. As a result of his efforts, the mechanics now employ several methods to control system leaks, including fluorescent dyes, soap-and-water bubbling solutions, and halogen torch-type leak detectors. To further aid in locating and eliminating emissions, the company has purchased electronic leak detectors for all of its mechanics and refrigerant recovery units for all of the maintenance trucks as well.

Two mechanics have been assigned to a leak elimination task force to perform leak checks and repairs full-time, with two more to be added to the task force soon. To reduce leaks in a single store, one of the mechanics on the task force typically requires one to two days to leak-check and complete repairs on a store containing dedicated single-compressor refrigeration systems, and two to three days on a store containing parallel compressor racks. Indications are that the increased operating costs for the preventive maintenance efforts have been more than offset by the reduced requirements for replacement refrigerant.

4.6 Installation of Isolation and Access Valves

To aid in the recapturing of refrigerants, the company has begun to specify the installation of isolation and access valves on all large or frequently-serviced components, such as condensers, heat reclaim coils, solenoid valves, and filters. Now when repairs are conducted on these components, refrigerant charges can be isolated within the component and accessed for removal, significantly reducing both downtime for recovering the refrigerant charge and any emissions associated with managing the recovery of a large amount of refrigerant. Bypass piping is now typically installed around filters so that filter cores can be replaced without removing systems from operation.

4.7 Reducing Emissions during Conversions

An important consideration that has surfaced in converting to the new refrigerants and lubricants is material compatibility. For example, some valves that were leak tight with the original CFC refrigerant and mineral oil were found to leak with R-402A. This problem involved only a single model made by a single manufacturer, but it did heighten the company's awareness of the differences between the old and new refrigerants and lubricants. The leaky valves were replaced, and the problem was solved. Typically, besides the lubricant and filter/driers, the company does not need to replace any of its refrigeration system components during conversions for refrigerant compatibility reasons.

Another concern was the moisture-absorbing characteristics of the polyol ester lubricant used with some of the new refrigerants. Typical practices used for charging mineral oil systems could not be applied when using the new lubricant, since the polyol ester lubricant would quickly absorb moisture from exposure to the air. This condition could eventually have led to significant emissions resulting from system damage from moisture contamination. The way the company solved this problem was to install access valves on compressors to minimize exposure of the lubricant to the air when charging the system with the new lubricant. Clearly-marked clean evacuated charging cylinders were then used for transporting the new type of lubricant. The cylinder was charged with the polyol ester lubricant by weight, and pressurized with a blanket of dry nitrogen to prevent moisture from seeping in as well as assist flow out of the cylinder once the charging valve was opened. After charging with the new lubricant, systems were immediately evacuated.

The company also takes other measures to ensure that the systems stay clean and dry during conversions. Prior to a conversion, systems are flushed thoroughly with the new lubricant and filters are replaced with types containing materials compatible with the non-CFC refrigerant. As a result of these efforts, the systems become much cleaner inside and require less contaminant-related maintenance. In addition, all leaks are repaired and the systems are "tuned-up" to engineering specifications to ensure good conversion success. Following the completion of a conversion, the company's project managers use a very detailed quality assurance checklist to verify that the refrigeration systems have been installed according to engineering specifications.

4.8 Reducing Emissions through Equipment Replacements

When Jitney-Jungle is considering replacing some of its older CFC equipment, leakage rates of the existing equipment are a prime consideration. If the system has a history of excessive leakage, the company will replace the system with a state-of-the-art non-CFC system equipped with leak-resistant components. All components deemed minimally acceptable for use in the field are then evaluated on their potential for leaks before being specified for installation. For example, the use of a certain pressure-regulating valve was rejected since it had six more potential leak sites than another valve considered otherwise equivalent in operation. By considering leakage rates among other factors, the company can recover some of the cost of retiring the system from reduced costs of maintenance, energy, and refrigerant.

CHAPTER 5
Emission-Reducing Technologies and Practices

5.1 Introduction

Supermarket facilities personnel have many technical and procedural options to reduce refrigerant emissions in the construction, modification, service, or repair of refrigeration systems. This chapter gives a detailed analysis of those options.

Technologies covered in this chapter include new and retrofit system components that can:

- prevent damage to system components from accidents, compressor vibration or gas pulsation;
- resist refrigerant leakage better than standard components;
- maintain internal system cleanliness and dryness to reduce maintenance and repair requirements;
- manage refrigerant charges more effectively, enabling refrigerant charges to be reduced during regular operations, or isolated and accessed during service procedures; or
- monitor refrigerant concentrations continuously from remote locations.

Operating procedures discussed in this chapter include:

- refrigeration system construction procedures to prevent or reduce emissions; and
- maintenance and service procedures that cost-effectively reduce emissions.

5.2 Emission-reducing Technologies for New and Retrofit Construction

Refrigerant emissions are best avoided by specifying emissions-reducing options in the design phase. Most options are best implemented in the initial construction of the systems; others can be cost-effectively implemented as retrofit measures. ASHRAE Guideline 3 contains good advice on methods to reduce emissions, and a summary of its contents should be included in the design specifications for all new supermarket construction. (Reference: ASHRAE, 1990)

The FMI CFC Task Force has stated its position on new equipment: "New installations should be made with particular attention to piping design and installation of valves and accessories to minimize refrigerant emissions and permit proper servicing of equipment." In addition, "...any refrigeration system known to have a history of excessive refrigerant emissions should be replaced with [a new system]." (Reference: FMI, 1991) Clearly, supermarket engineering leaders have had concerns about the ways in which new systems are being designed and maintained.

Although all types of emissions of currently viable supermarket refrigerants should be avoided for global warming reasons, of prime importance is avoiding emissions of ODS. The most effective retrofit strategy for reducing ODS emissions is simply the application of non-ODS refrigerants in the existing system. However, this option may require replacement or re-adjustment and fine-tuning of some components, such as compressors, electrical components, expansion devices, suction riser piping, and lubricant and refrigerant charges. The cost to retrofit an average U.S. supermarket of 42,000 square feet* to HFC-based refrigerants would be approximately \$35,000 (\$0.83/ft^2); to retrofit to HCFC-based interim refrigerants would be approximately \$25,000 (\$0.60/ft^2). (Reference: FMI, 1994)

Other less-expensive strategies for reducing emissions of any type of refrigerant can also be implemented, and these options are discussed below. These options reduce emissions in one of several manners, including:

- reducing system damage from accidents, vibration or pulsation;
- replacing or substituting for other higher-emitting technologies;
- keeping systems clean and dry and thereby reducing future maintenance requirements to a certain extent;
- effectively managing the refrigerant inside the system to optimize utilization of refrigerant or to isolate or access refrigerant during service operations; or
- monitoring store air for refrigerant on a continuous basis.

5.2.1 Technologies to Control Damage from Accidents, Vibration and Pulsation

Protecting system components from damage due to vibration or accidents is vital to reducing refrigerant emissions. Frequently, sudden large emissions can be traced back to excessive system vibration or pulsation. Uncontrolled vibration and pulsation generally cause pipes to flex, abrade, and eventually fail due to metal fatigue or wear, resulting in accidental releases. Large emissions can also result when pipes are located in high traffic areas. Even with the best precautions, pipes located in these types of spaces are likely to eventually suffer concussion, abrasion, or other types of damage and consequently fail. Listed below are some specific measures designed to minimize damage to system components which would otherwise result in refrigerant emissions.

Piping Clamps. Certain types of piping clamps greatly reduce the possibility of catastrophic events, such as broken discharge lines. Clamps should be equipped with vibration-resistant fasteners, such as locknuts or castle nuts with cotter pins. Clamps should also be equipped with resilient inserts to protect the piping from the steel clamp. These types of clamps ensure that piping will not come loose during normal service, thus preventing excessive vibration. This measure is easy and inexpensive to retrofit on existing systems.

Integral Vibration and Pulsation Eliminating Devices. The decision to use devices to eliminate compressor vibration and gas pulsation affects both engineers and construction personnel. These devices include vibration eliminators, baffle plates, and mufflers and are used to control vibration/pulsation in both suction and discharge lines. Whenever engineers specify the use of these devices, installation personnel should take care that the devices are securely mounted at the opposite end of the compressor connection, and are mounted parallel to the compressor shaft, except for baffle plates which are mounted between the compressor and the discharge service valve. (Reference: FMI, 1991) These technologies can be retrofitted at moderate cost.

Improved Piping Designs. Both engineering and construction personnel should seek information on proper piping design. For example, a service bulletin available from a major compressor manufacturer offers good guidance to system designers and installers. (Reference: Carlyle, 1989) This bulletin discusses topics critical to vibration-resistant system design such as piping practices to avoid structural resonances, forced vibration, and acoustical resonances. The bulletin provides in-depth coverage of this topic beyond the scope of this report.

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* 1 square foot = 0.0929 square meter

By becoming familiar with the circumstances under which vibration can damage systems, designers and installers can identify potential problems with field piping and take action to prevent system damage. Chronic problems with pre-fabricated systems should be noted and the information relayed back to the equipment manufacturer. Difficulties with field piping should be discussed with both engineering and construction personnel. Problems can usually be corrected at moderate cost.

Underground Piping. The practice of locating piping in trenches under the floor slab benefits the environment and the company by both reducing emissions and saving money. This practice should be implemented with care. Engineers should emphasize the future serviceability of piping connections in their designs. They should also consider the possibility of future remodeling that includes modification of the piping as well as pest control. Retrofits that employ this option are relatively expensive.

5.2.2 Technologies to Replace or Substitute for High-emitting Technologies

Several substitute technologies have been developed to replace older high-emission technologies. Listed below are some of the more important options to replace or substitute for typically-used components.

All-sweat Expansion Valves and Filters. The use of flared connections on expansion valves and liquid filter/driers usually results in unnecessary emissions and system downtime. Repeated cycles of thermal expansion and contraction inevitably lead to flare connections unscrewing. When possible, display cases and evaporators for walk-in boxes should be installed with sweated expansion valves. Due to the fact that expansion valves are a frequently-serviced item, incremental costs to retrofit this technology are quite low.

Frost-proof Flare Nuts for Expansion Valves. The condensation that typically forms on thermostatic expansion valves can turn to ice within the flare nut threads. Since the ice has no path of escape in typically-designed flare nuts, over repeated cycles, the ice can eventually cause the flare nut to crack. Frost-proof flare nuts have a unique design that allows the ice a path of escape, ensuring greater system integrity. In addition, this technology provides an option for those who prefer the flexibility of a flare connection, but also want lower emissions. Incremental costs associated with this option are low.

Elimination/Avoidance of Hot Gas Defrost. As noted earlier, the hot gas method of defrosting evaporator coils has the drawback of thermal stress degradation of components. Consequently, other defrosting methods should be used, (e.g., time-off, electric-resistance or fan-reversal). Retrofits to these methods, however, are often not cost-effective unless conducted in conjunction with a complete case and/or cooler box replacement.

Low-emission Condensers. Typically-designed condensers occasionally suffer problems with tube chafing as a result of gas pulsation. In addition, condenser fan mountings can shear off from vibration and corrosion and puncture the condenser tubing. Emissions associated with condenser leaks can be a very significant percentage of the total charge, so great care should be taken in selecting features of new condensers. Condensers designed to minimize bearing stress on tubing bundles have proven effective in preventing refrigerant emissions. Condensers equipped with large, low-tip-speed fans are also a good defense against emissions. Retrofits involving this low-emission condensers are usually expensive to conduct; however, incremental costs may not be that great considering the likelihood of additional emissions associated with older condensers that have a history of leakage.

Steel capillary tubes. Because copper capillary tubes are subject to large amounts of vibration, they can easily become damaged and fail if installed or maintained incorrectly, and are cited frequently as the cause of many fugitive and catastrophic emissions. New compressor racks equipped with pneumatically-operated pressure controls could be provided with capillary tubing made of steel instead of copper, because of its better resistance to stress failure, abrasion, and breakage. This technology is very cost-effective to retrofit. However, these types of capillary tubes still require proper securing and require mechanical connections.

Electronic Controls. If possible, capillary tubes should be eliminated altogether, and should be replaced by electronic oil and pressure controls. Not only can electronic controls greatly reduce refrigerant emissions, but they can also act as inputs to a computerized refrigeration controller (RC) or energy management system (EMS), allowing remote monitoring of system conditions and permitting remote system troubleshooting. If an RC or EMS is being installed in a new or existing store, serious consideration should be given to the application of electronic pressure controls to get the best utility out of the system. This option has low incremental costs to retrofit, given that systems are usually out of operation whenever a capillary tube has failed, and installation time is not especially long.

Braided steel hose. In applications where suitable electronic substitutes do not exist, braided steel hose is another viable alternative to copper capillary tubes. This product is compliant and has good vibration-resistant characteristics. Although the polymer inner hose may be slightly permeable to some refrigerants on the order of a few ounces per foot per year, it can prevent virtually all catastrophic emissions resulting from capillary tube failures. Like steel capillary tubing, retrofits to this technology are also cost-effective.

Dual Relief Valves with Rupture Discs. Relief valves are a safety requirement for any type of system containing liquid under pressure. Dual-relief installation is a particularly effective method, where two relief valves are connected in parallel with a three-way shut-off valve. This type of configuration allows one relief valve to be serviced or removed while the system is still being protected by the other relief valve. Each relief valve should be capable of protecting the system, but only one relief valve should be permitted to shut off at a time. This configuration can be built-up, or purchased as a single module. When installed in conjunction with a rupture disk, this configuration can practically eliminate fugitive emissions. Due to the large amount of labor involved in removing a relief valve, retrofits are usually cost-effective only in the event of a failure of the old relief valve, or when failure seems imminent due to corrosion.

5.2.3 Technologies to Maintain System Cleanliness and Dryness

It is difficult to estimate the savings that can be attributed to implementing measures to maintain system cleanliness and dryness due to the diffuse but positive effect this condition has on nearly all system operations. Nevertheless, a clean and dry system is very desirable. By removing moisture, acids, and particulates, these measures can significantly reduce the frequency of non-routine servicing.

Oversized Filter/Driers. To compensate for the possibility of errors in construction procedures that can result in system contamination, oversized in-line replaceable-core filter/driers should be used where practicable. Since these filters have a large capacity and cross-sectional area, pressure drop is minimized and the large amounts of contaminants can be handled with ease. Furthermore, since the filter core can be replaced, systems can be kept in top shape following any procedure that involves breaking the integrity of the system. This technology entails a moderate cost to retrofit, but when installed with brazed connections, it is a substantial improvement over small existing filters with flare connections.

Upstream Filters. The use of filters upstream of all expansion devices further reduces system problems, preventing any particulate matter or ice from clogging the expansion valves. Implementation of this technology prevents many of the problems that make expansion valves one of the most frequently-serviced components in a refrigeration system. When one considers the many occasions that system integrity will be broken over the lifetime of any typical system (e.g., case remodels, component service), the use of upstream filters can provide inexpensive protection to the system. Given the substantial number of expansion valves in any given store, retrofits to this technology should be undertaken only when incremental costs can be minimized, (i.e., when the system is already out of service for another reason.)

5.2.4 Technologies to Effectively Manage Refrigerant

Systems with the capability to manipulate the internal location of the refrigerant often have lower emissions than other systems. Not only does this capability allow charge sizes to be reduced (an advantage in the event of an unforeseen catastrophic release), but it also speeds up the process of recovering refrigerant, thereby minimizing the temptation to some technicians to vent refrigerant to expedite a repair job.

Listed below are some measures that can help to reduce required charge size, or isolate and access refrigerant during service operations.

Pump-down Capability. System designs that incorporate components to control the location of refrigerant in the refrigeration system enable mechanics to break system integrity during repairs without having to remove the entire charge. Pump-down capability requires a receiver large enough to contain the entire charge of the system. The receiver must also be capable of being isolated through the presence of isolation valves.

Isolation and Access Valves. Designers should anticipate locations where systems will benefit from the installation of isolation and access valves, and specify these items to be installed in the proper locations. Applied system-wide, this small degree of foresight will reap large benefits for the company through reduced refrigerant recovery time. In many instances, Schrader valves provide the function of access valves. In cases where Schrader valves are applied, the valves should be connected to the system with brazed connections and gasketed metal caps should be used. For existing systems lacking access or isolation valves, the necessary valves should be installed during service operations that require removal of the charge. As part of an improved leakage prevention program, these types of valves should be checked regularly as they may leak at the stem.

Charge-reducing Measures. Efforts should also be made to decrease the system refrigerant charge size to reduce the impact of catastrophic leaks. Several system designs, including remote headers, heat reclaim pump-out, split condensers, condenser bypass, and loop piping can reduce required charge size. These measures are not cost-effective in retrofit situations.

- <u>Remote headers</u>. Parallel rack charge reduction can be achieved by reducing the number of pipes coming out of the compressor room. Designers can reduce charge sizes and piping installation costs by specifying the use of remote headers to collect and distribute the refrigerant contained in the individual systems' suction and liquid lines.

- <u>Heat reclaim pump-out</u>. To maximize the utilization of the refrigerant contained in a system, the refrigerant should be pumped out of all components not actively functioning. The incorporation of a control circuit and components to pump the refrigerant out of heat reclaim systems after cycle completion is a worthwhile investment to reduce required charge size.

- <u>Split condensers</u>. In the winter months, when systems utilize the most refrigerant and require the least amount of condenser surface, charge size reduction can be accomplished by installing the necessary equipment to automatically valve off sections of the condenser. In this way, pressure can be maintained to feed the expansion valves adequately, with much less refrigerant required to flood the active condenser surface.

- <u>Condenser bypass</u>. In some parts of the country, ambient winter temperatures are cold enough for refrigerant to condense entirely back to liquid within the heat reclamation coil. Components able to sense this condition and valve off the condenser can be installed to allow systems to operate with even smaller charge sizes.

- <u>Loop Piping</u>. Like the remote header design, loop piping reduces charge size as well as the number of connections and joints by extending common pipes from the compressor racks out into the store area.

5.2.5 Refrigerant Leakage Monitoring Technologies

Stationary Refrigerant Leak Monitoring Devices. These units typically have alarm capabilities and make use of multiple sensors applied at strategic locations throughout the store. Use of these units to detect leaks and assist in dispatching service personnel to the site can minimize the loss of refrigerant. These units have the potential to be a valuable complement to a leak detection and repair program that includes regular system inspections. Whether these units will be a good value for a particular company, however, depends on the maintenance and service support structure for the stores. These types of units require that sensors be carefully located to provide the best protection and properly calibrated to minimize false alarms.

Many manufacturers of electronic refrigeration controller systems offer leak monitoring capabilities at a premium over the price of a regular controller. However, stand-alone refrigerant monitors are also available on a new or retrofit basis. These devices may be particularly effective if installed in stores known to have high refrigerant leak rates.

5.2.6 Summary Tables

Tables 5.1 and 5.2 list most of the above emission control options along with industry estimates of the impact on refrigerant emissions and approximate value of implementing each of the options. (Reference: Bittner, Burdwood, Mathews, Twisdale) Some options, such as the options to increase system cleanliness and dryness, were not included because of the difficulty in estimating benefits due to the diffuse effects these conditions have on system operations.

Each option was assumed to be implemented on two hypothetical typical remote compressor racks: one three-compressor R-502 low-temperature parallel rack (8 systems) containing a 500 pound charge, and one single compressor CFC-12 medium-temperature rack containing a 100 pound charge.

A range of incremental capital costs for each option was then calculated based on information collected from equipment manufacturers. (The incremental capital cost is defined as the difference in cost between new equipment with the emission control option and industry-standard equipment, including initial cost, installation and commissioning.) A zero value in the incremental capital cost column indicates that the option is the same cost or less expensive than the industry standard.

The net present value (NPV) of the option over its lifetime was then calculated based on the following assumptions:

- a 20 year lifetime;
- an internal value of capital of 7 percent; and
- the option is implemented as a sole emissions reduction measure.

Three different refrigerant prices were used in developing the NPV estimations to show the sensitivity to increases in refrigerant price. In addition, to show the sensitivity to higher levels of baseline refrigerant emissions, a multiplier of 3.0 was applied to the expected reduction in emissions to generate a range of NPVs at each refrigerant price point. To maintain conservative values, calculated NPVs do not include the value of business lost for equipment downtime due to loss of refrigerant charge, decreased required maintenance, or avoided labor to recharge refrigerant following a leak event.

The simple formula shown below was used to generate the values in the following tables:

$$NPV = PV(ERE \times RP) - EC$$

where:

- NPV is the net present value of the option;

- PV is the present value of the cash flow from reduced emissions;
- ERE is the expected reduction in emissions in pounds per year;
- RP is the refrigerant price; and
- EC is the cost of the option.

5.3 Emissions-reducing Operating Practices

The practices involved in constructing, maintaining, servicing, and retiring refrigeration systems have a significant bearing on the amount of refrigerant consumed by the system in the long-term. Emissions-reducing procedures involving construction personnel include:

- use of proper brazing practices;
- use of proper pipe securing practices;
- use of proper construction quality assurance practices; and
- use of portable leak detectors.

Tables 5.3 and 5.4 list some of these emission-reducing control options for construction, service and maintenance personnel along with industry estimates of the cost (including labor), impact on refrigerant emissions, and approximate value of implementing each of the options. As in the previous section, two hypothetical typical remote compressor racks were assumed to incorporate each of the measures in isolation. In addition, all assumptions are consistent with the previous tables. It is important to note that several of the control options would be shared among several independent refrigeration systems in each store (or many stores, in the case of portable leak detectors); therefore, the costs are assumed also to be shared.

5.3.1 Construction Practices

Construction practices can significantly affect the emissions levels from refrigeration equipment. The success of engineering system design improvements that reduce emissions depends heavily on the care taken during system construction. Discussed below are some practices that can be cost-effectively implemented in the construction of refrigeration systems to reduce emissions.

Brazing practices. Proper methods of joining components together can greatly enhance the leak resistance of joints as well as protect the entire refrigeration system. To reduce the required number of connections, piping runs should be as direct as possible, and full lengths of pipe should be used when feasible. To eliminate the formation of oxides during brazing operations, a cylinder of nitrogen or other inert gas should be attached to the section being brazed, and the valve cracked open slightly to allow a small quantity of the protective gas to flow through the section and displace any air. To increase the strength of the connections, solder of sufficient silver content should be used to ensure strong, leak-resistant connections. For most applications, solder containing at least 15 percent silver is appropriate.

Pipe securing practices. The method used to secure piping is critical to preventing emissions, especially the large emissions associated with broken discharge lines. Technical bulletins dealing with such problems are available through some equipment manufacturers.[8] The use of piping clamps is usually the easiest and most effective way to correct vibration problems. In general, piping must be clamped to a structure that has sufficient stiffness to be effective, or else vibration resonance problems may occur, causing

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[8] Various companies, including Carlyle, Copeland, Hussmann, and Trane, have produced technical bulletins that discusses vibration problems with piping.

TABLE 5.1
COSTS AND BENEFITS OF LEAK REDUCTION TECHNOLOGIES - PARALLEL THREE-COMPRESSOR LOW-TEMPERATURE R-502 RACK (8 SYSTEMS), 500 POUND CHARGE

Option	Typical Range of Incremental Capital Cost (Dollars)	Expected* Reduction in Emissions (% of charge per year)	Range of Lifetime Net Present Values of Implementing Option (Dollars)		
			$7.50/lb	$15/lb	$22.50/lb
Clamps with castle or lock nuts	0	5	27	54	80
Discharge mufflers	25-65	5	-38 to 2	-11 to 29	15 to 55
Baffle plates	15-30	5	-3 to 12	24 to 39	50 to 65
Vibration eliminators	5-45	5	-18 to 22	9 to 49	35 to 75
Proper piping design	0	6	33 to 96	66 to 193	100 to 289
Underground piping	0	4	24 to 71	47 to 141	71 to 212
All-sweat TXVs and filters	0	5	29 to 87	58 to 174	87 to 260
Frost-proof flare nuts for expansion valves	0	5	27 to 80	54 to 161	80 to 241
Avoidance of Hot Gas Defrost	0	8	44 to 132	88 to 264	132 to 395
Low emission condensers	0-150	9	-104 to 138	-58 to 276	-12 to 415
Steel cap tubes	30-40	3	-25 to 15	-10 to 60	5 to 105
Braided steel hose	35-40	3	-25 to 10	-10 to 55	5 to 100
Electronic controls	0	3	15 to 45	30 to 90	45 to 135
Dual-relief valves	80-100	5	-73 to -53	-46 to -26	-20 to 0
Remote headers	0	4	24 to 71	47 to 141	71 to 212
Loop piping	0	4	24 to 71	47 to 141	71 to 212
Heat reclaim pumpout	120-170	5	-143 to -93	-116 to -66	-90 to -40
Split condensers	250-350	5	-323 to -223	-296 to -196	-270 to -170
Condenser bypass	300-500	5	-473 to -273	-446 to -246	-420 to -220
Stationary leak monitors	150-275	25	-141 to -16	-7 to 118	127 to 252

* In interpreting the values for the expected reduction in emissions, a certain degree of caution must be used: the values are independent estimates for each option implemented in isolation; implementing several options would not give reductions equal to the summation of the individual reductions because many options are co-dependent with other options.

TABLE 5.2
COSTS AND BENEFITS OF LEAK REDUCTION TECHNOLOGIES - SINGLE-COMPRESSOR MEDIUM-TEMPERATURE R-12 RACK, 100 POUND CHARGE

Option	Typical Range of Incremental Capital Cost (Dollars)	Expected* Reduction in Emissions (% of charge per year)	Range of Lifetime Net Present Values of Implementing Option (Dollars)		
			$7.50/lb	$15/lb	$22.50/lb
Clamps with castle or lock nuts	0	5	5	11	16
Discharge mufflers	25-65	5	-60 to 20	-54 to -14	-49 to -9
Baffle plates	15-30	5	-25 to -10	-19 to -4	-14 to 1
Vibration eliminators	5-45	5	-40 to 0	-34 to 6	-29 to 11
Proper piping design	0	5	5 to 16	11 to 32	16 to 48
Underground piping	0	3	3 to 11	6 to 21	10 to 32
All-sweat TXVs and filters	0	4	4 to 13	9 to 26	13 to 39
Frost-proof flare nuts for expansion valves	0	4	4 to 13	9 to 26	13 to 39
Avoidance of Hot Gas Defrost	0	5	5 to 16	11 to 32	16 to 48
Low emission condensers	0-150	22	-126 to 71	-103 to 141	-79 to 212
Steel cap tubes	30-40	14	-25 to 15	-10 to 60	5 to 105
Braided steel hose	35-40	14	-25 to 10	-10 to 55	5 to 100
Electronic controls	0	14	15 to 45	30 to 90	45 to 135
Dual-relief valves	60-80	5	-75 to -55	-69 to -49	-64 to -44
Stationary leak monitors	50-90	25	-63 to -23	-36 to 4	-10 to 30

* In interpreting the values for the expected reduction in emissions, a certain degree of caution must be used: the values are independent estimates for each option implemented in isolation; implementing several options would not give reductions equal to the summation of the individual reductions because many options are co-dependent with other options.

TABLE 5.3
COSTS AND BENEFITS OF OTHER LEAK REDUCING OPTIONS - PARALLEL THREE-COMPRESSOR LOW-TEMPERATURE R-502 RACK, 500 POUND CHARGE

Option	Typical Range of Incremental Capital Cost (Dollars)	Expected* Reduction in Emissions (% of charge per year)	Range of Lifetime Net Present Values of Implementing Option (Dollars)		
			$7.50/lb	$15/lb	$22.50/lb
Use of Portable Leak Detectors	2-4	16	82 to 169	167 to 341	253 to 512
Use of 15 percent solder	0-20	5	7 to 27	34 to 54	60 to 80
Use of refrigerant accounting system	10-20	16	66 to 161	151 to 333	237 to 504
Improved preventive maintenance	0-200	40	14 to 268	229 to 536	443 to 804
Fixed-price maintenance contracts	0	16	86 to 171	171 to 343	257 to 514

* In interpreting the values for the expected reduction in emissions, a certain degree of caution must be used: the values are independent estimates for each option implemented in isolation; implementing several options would not give reductions equal to the summation of the individual reductions because many options are co-dependent with other options.

TABLE 5.4
COSTS AND BENEFITS OF OTHER LEAK REDUCING OPTIONS - SINGLE-COMPRESSOR MEDIUM-TEMPERATURE R-12 RACK, 100 POUND CHARGE

Option	Typical Range of Incremental Capital Cost (Dollars)	Expected* Reduction in Emissions (% of charge per year)	Range of Lifetime Net Present Values of Implementing Option (Dollars)		
			$7.50/lb	$15/lb	$22.50/lb
Use of Portable Leak Detectors	1-2	16	82 to 169	167 to 341	253 to 512
Use of 15 percent solder	0-20	5	7 to 27	34 to 54	60 to 80
Use of refrigerant accounting system	10-20	16	66 to 161	151 to 333	237 to 504
Improved preventive maintenance	0-70	40	14 to 268	229 to 536	443 to 804
Fixed-price maintenance contracts	0	16	86 to 171	171 to 343	257 to 514

* In interpreting the values for the expected reduction in emissions, a certain degree of caution must be used: the values are independent estimates for each option implemented in isolation; implementing several options would not give reductions equal to the summation of the individual reductions because many options are co-dependent with other options.

noise and transmitting vibration to other refrigeration system or building elements. Clamps should be oriented to constrain the maximum motion of the piping, (e.g., if the direction of maximum motion is vertical but the piping is clamped horizontally, the clamp will be less effective, and may even exacerbate the problem). Improper constraint may induce excessive stress that can increase the likelihood of piping breakage.

Quality assurance practices. Prior to placing any refrigeration system into service, the systems should be rigorously pressure tested first to ensure system integrity. A preliminary rough leak test should consist of pressurizing the system to one-half of operating pressure with dry nitrogen and then using a soap-and-water solution to produce bubbles at leak sites. Safety controls and relief valves first should be removed and their orifices plugged before conducting the test. Once it is determined that gross leakage has been eliminated, a more thorough evaluation can be conducted by fully pressurizing the system and applying the soap-and-water solution again. A final pressure test would entail using a mixture of dry nitrogen and a small quantity of the HFC refrigerant intended for use. Portable electronic leak detectors can then be used to locate any remaining leaks.

Once all leaks are eliminated, the system should then be subjected to a standing vacuum test. This test involves multiple evacuations down to progressively lower vacuum levels to remove moisture and non-condensible gases, breaking the vacuum each time with dry nitrogen. Removal of all water vapor is crucial to successfully applying HFC refrigerants and the polyol ester lubricants used with them, due to their high affinity for water. Upon the third evacuation, the system should be allowed to stand for 12 hours and the pressure monitored to verify system integrity.

Following this test, the system can be recharged with nitrogen slightly over atmospheric pressure and the driers, safety controls, and relief valves installed. After completion of component installation, the system should be evacuated once more and then charged with refrigerant.

5.3.2 Repair Service and Preventive Maintenance

Both repair service and preventive maintenance are critical elements in a program to minimize emissions from refrigeration systems. Personnel working in these areas should not underestimate the impact their practices can have on reducing operating costs and protecting the environment.

System Servicing

For equipment containing more than 50 pounds of refrigerant, EPA regulations limit total leakage to 35 percent of total charge per year. This accounts for the majority of equipment installed in U.S. supermarkets. Leakage can be reduced in a cost-effective manner through a carefully constructed strategy for system service and repair. As a result, the practice of regular and thorough leak inspection and repair not only helps comply with the law, but also provides the best value to the supermarket.

Like the recommendations made for design personnel in section 5.2, service technicians can improve their practices by following recommendations made in ASHRAE Guideline 3. (Reference: ASHRAE, 1990) These recommendations are briefly listed below.

- Only properly trained personnel should engage in system servicing or refrigerant handling.
- Per the provisions of the Clean Air Act, ODS refrigerants are not to be vented to the atmosphere for any purpose other than for accepted service practices that result in de minimis emissions (e.g., attaching service gauge hoses).
- Causes of refrigerant emissions should be found and remedied prior to recharging any system. Following leak repair, systems should be retested to verify repair integrity. Systems should be replaced if losses continue even after applying good maintenance practices.

- Periodic testing of both refrigerant and oil for contaminants is critical to assessing system health and avoiding service events.
- Compressor oil should be degassed prior to removing it from the compressor to reduce the concentration of dissolved refrigerant.
- Refrigeration systems that have suffered a motor burnout may be contaminated with carbon or sludge. The oil should be examined to determine the extent of the contamination. In the event of a severe burnout, ODS refrigerant must be transferred to an business that performs refrigerant reclamation or disposal.

Preventive Maintenance

Companies can reduce their overall maintenance costs while protecting the environment through the implementation of practices that reduce emissions as part of an overall preventive maintenance program. Other goals that can be attained from this type of preventive maintenance program include:

- reduced unscheduled maintenance in general;
- reduced replacement refrigerant costs; and
- better and more efficient system performance.

Preventive maintenance programs geared towards reducing emissions would benefit from including the following items:

- a system charging and maintenance log;
- regular walk-through system inspections;
- regular major system inspections;
- impromptu inspections; and
- reassessment of existing maintenance agreements with external contractors.

System charging and maintenance log. Diligently maintaining a log of refrigerant and oil transfers and repair procedures is essential to assess the integrity of the refrigeration systems as well as to track the movement of refrigerant throughout the company. This log should be kept on an individual equipment basis and include the operating charge as well as all additional recharges. The log should also indicate both regular and unscheduled service and all items inspected or repaired. Companies should consider making it a requirement for contractors or in-house maintenance personnel to provide a periodic refrigerant replacement report that summarizes the activities in each store.

Alternatively, companies can purchase software to track the refrigerant. Computer programs exist that not only track refrigerant movement, but also monitor equipment service events to identify problem systems. Some programs can also interface directly with certain accounting programs and save on labor to track refrigerant.

Regularly scheduled walk-through inspections. Maintaining control over refrigerant expenses is extremely difficult without regular leak detection and repair. A system inspection schedule for all stores should be established, setting aside a minimum number of hours each week or month for inspection and repair activities. In addition, the schedule should include both major and minor inspections. Companies that already conduct regularly scheduled inspections should weigh the costs and benefits of increasing the frequency and rigor of these inspections.

Walk-through inspections should include (at a minimum) a visual inspection for refrigerant leaks in both the compressor room and the sales area. Portable battery-operated electronic leak detectors provide additional protection against refrigerant emissions if visual inspections fail to indicate remaining leaks. In addition, factors that could result in future leaks should be identified, such as loose connections, pipe or capillary tube chafing, or excessive vibration within the high-temperature, high-vibration parts of the equipment.

Flanged and flared connections should receive particular attention at the time of the inspection. Valve packings and service valve caps should be inspected and tightened if loose. Brazed connections should also receive some attention, if time permits. In addition, system "vital signs" should be monitored during a walk-through inspection. These "vital signs" include oil levels, pressures and temperatures, refrigerant levels, and compressor suction and discharge pressures.

Major Inspections. At least once a year, the refrigeration systems in each store should undergo a major inspection. In addition to those activities conducted during walk-through inspections, the system should be shut down temporarily to carefully inspect the condition of all components in the system and the coil surfaces should be cleaned. Cleaning coil surfaces not only helps to maintain system efficiency through improving heat transfer but also reduces system pressure, decreasing the potential for leaks. After the system is put back into operation, vital signs (pressures and temperatures) should be noted and entered into the log as a basis for comparison.

Impromptu Inspections. If technicians have sufficient time between assignments, they should be encouraged to conduct an impromptu walk-through inspection of the refrigeration systems. These types of inspections have the lowest cost of any type of preventive maintenance measure and can possibly result in the prevention of significant refrigerant emissions.

Outside contractors. As part of an overall review of the maintenance program, contracts with contractors should also be reviewed. If the review indicates that the contractor does not have proper incentive to find and repair refrigerant leaks, the contract should be revised and renegotiated. Compensation for contractors should become contingent on the contractor providing periodic refrigerant replacement reports.

Having a list of preferred contractors who have been trained in company procedures is of great benefit to an emissions reduction program. Educating contractors should be considered essential to keeping the actions of the contractor consistent with the mission of the supermarket. Educational curricula should include formal instruction on procedures and schedules for service items (e.g., refrigeration system oil changes and refrigerant leak detection and repair).

5.4 Analysis of Data on Refrigerant Emissions

In order to estimate the impact of various emission controls, experts in supermarket engineering and maintenance were contacted and asked to provide any data collected in this area. (Reference: Bittner, Burdwood, Mathews, Twisdale) To support the experts' judgments, ICF conducted research in the area of refrigerant leakage from typical systems to estimate independently the impact of implementing emissions-reducing measures on these systems.

In two previous reports, researchers had been largely unsuccessful in obtaining measured data on emissions from supermarkets. (Reference: Harrison et al., 1995; Rand, 1979) Research conducted for this report confirms the scarcity of available data in this area; however, two sources of recorded data were located.

The first source of formal data was a midwestern supermarket chain that provided refrigerant recharging reports. The second source was the South Coast Air Quality Management District (SCAQMD), which provided system recharging auditing records from several retail food companies falling within its jurisdiction.

Emissions reductions ideally would have been estimated from a large population that included a variety of companies, stores, configurations of refrigeration units, leakage rates, service practices, and contractor/in-house maintenance and engineering support arrangements. Analysis of such a population would have been more statistically rigorous than the present analysis. However, these kinds of data were not volunteered and may not exist.

5.4.1 Midwestern Chain Recharging Reports

One midwestern chain volunteered data on all of its refrigeration equipment. These data were collected for the entire chain over a period of one year and were aggregated at the sub-system level. The data were provided already in summarized form, and only a slight analysis was required. Some background information on the chain is listed below.

- It operates 110 stores averaging 34,000 square feet each.
- Refrigeration for each store is mainly provided by two or three large parallel compressor racks. The chain maintains approximately 300 of these racks.
- Each rack averages 65 horsepower* and services approximately 15 systems.
- The grand total refrigerant charge contained in all of its stores is approximately 270,000 pounds.
- The chain's remote refrigeration equipment required recharging 287 times in 1992.
- The annual leakage rate for the chain is relatively low – 15 percent of total charge in 1992.

The chain maintains this low emissions rate by requiring that several procedures be followed by its contractors.

- All equipment must be installed per the chain's written specifications.
- All equipment must be able to maintain a 500 micron (67 Pa) vacuum for 24 hours before charging is permitted.
- Refrigerant loss reports must be filled out for contractors to receive reimbursement for services rendered.
- Receiver inspections are conducted routinely.
- Systems installed in last three years use all-sweat expansion valves. To date, none of these valves have experienced any leakage.

Data provided on a subsystem basis for the chain's remote equipment included the total amount of refrigerant released and the number of service calls for recharging refrigerant. From these data, the average amount released per service call was calculated. An analysis of the data reveals several interesting phenomena. The analysis showed a high correlation between the total amount of refrigerant released and the number of service calls for recharging refrigerant. However, the release amount per service call showed little correlation with the average release per service call, suggesting that, in general, large releases had only a small impact on total refrigerant recharges.

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* 1 Horsepower = 0.746 kW

Of the 18 subsystems, two in particular dominated total refrigerant releases, accounting for over one-third of all emissions: the condenser and hot gas defrost subsystems. This observation is not particularly surprising, given the severe conditions under which these two particular subsystems must operate. Ranking third on the list, thermostatic expansion valves (TXVs) accounted for another 10 percent of total releases. Releases from TXVs are generally considered to be substantial for many companies in the industry, and the company providing these data is no exception.

These three subsystems also ranked at the top for number of service calls involving recharging, suggesting that for these subsystems, regular inspections to minimize number of service calls would be particularly useful in minimizing refrigerant loss. The condenser and hot gas defrost subsystems also had high average emissions per service call (ranking in the top half of all subsystems), indicating that for these two subsystems, design improvements targeted at reducing large emissions could also have an impact on overall emissions.

Liquid line solenoid valves, service valves and stem packings, and pressure controls ranked fourth through sixth for total refrigerant releases. These same three subsystems also ranked among the top six for number of service calls involving recharging, but had average to low rankings for average release amounts per service call. This observation suggests that increasing the number of preventive maintenance leak inspections to reduce the number of service calls would be the action most likely to minimize total releases for these subsystems.

The subsystems ranked at the very top for average refrigerant releases per service call were, in order, receiver relief valves, discharge header tubing, suction line tubing, liquid line tubing, and evaporator coils. However, all of these subsystems were ranked in the lower half for total amount of refrigerant released, reinforcing the previous assertion that large releases have only a small impact on this chain's total refrigerant consumption.

These observations suggest that this chain can reduce refrigerant consumption most effectively by focusing on subsystems that are most frequently serviced, and not on subsystems that have the highest average emissions per service call. Table 5.5 summarizes the company's recharging experiences at the subsystem level.

TABLE 5.5
REFRIGERATION SUB-SYSTEM RELEASES AT A MIDWESTERN SUPERMARKET CHAIN

Subsystem	Total Amount of Refrigerant Released (lbs)	Percentage of Total Emissions and (Rank)	Number of Service Calls for Recharging Refrigerant	Percentage of Total Number of Calls and (Rank)	Release Amount per Service Call (lbs) and (Rank)
Condenser[1]	6,410	17 (1)	47	16 (1)	137 (9)
Hot gas defrost[2]	6,163	17 (2)	44	15 (2)	140 (8)
Expansion valves	3,879	10 (3)	35	12 (3)	111 (14)
Liquid line solenoid valves	2,494	7 (4)	22	8 (5)	113 (12)
Service valves, stem packings	2,285	6 (5)	27	9 (4)	85 (18)
Pressure controls[3]	2,120	6 (6)	19	7 (6)	112 (13)
Not properly charged[4]	1,930	5 (7)	13	5 (9)	148 (6)
Suction line tubing[5]	1,875	5 (8)	9	3 (11)	208 (3)
Liquid line tubing[6]	1,555	4 (9)	8	3 (13)	194 (4)
Evaporator coils	1,470	4 (10)	8	3 (12)	183 (5)
Discharge header tubing	1,327	4 (11)	5	2 (14)	265 (2)
Compressor fittings, oil lines	1,265	3 (12)	14	5 (7)	90 (16)
Heat reclaim[7]	1,240	3 (13)	14	5 (8)	89 (17)
Receiver relief valves	1,110	3 (14)	4	1 (15)	278 (1)
Sight glasses	1,084	3 (15)	9	3 (10)	120 (11)
Demand cooling valves[8]	430	1 (16)	3	1 (17)	143 (7)
Braided hoses	367	1 (17)	3	1 (16)	122 (10)
Filters and driers	227	1 (18)	3	1 (18)	92 (15)

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[1] Includes circuit-splitting piping, solenoid valves, check valves, 3-way valves, flooding valves, fan controls, and condenser tubing.

[2] Includes check valves at evaporator, EPR valves, hot gas solenoid valves, and liquid line differential valves.

[3] Includes capillary tubes and flare connections on pneumatic controls.

[4] Includes improper winter charging and miscellaneous leakage where no significant leaks were found.

[5] Includes suction lines from evaporators to suction header.

[6] Includes liquid lines from liquid header to evaporators. Note that in one event a single underground liquid line released 450 pounds.

[7] Includes check valves, 3-way valves, heat reclaim tubing.

[8] For HCFC-22 applications only.

5.4.2 South Coast Air Quality Management District Audit Reports

The South Coast Air Quality Management District (SCAQMD) is a California government agency responsible for regulating air pollution in Southern California. In 1991, the agency issued a regulation, Rule 1415, that provides for the monitoring of commercial refrigeration systems. As a result of the requirements of Rule 1415, retail food companies operating in the jurisdiction of the SCAQMD are required to record:

- the amount of and reason for refrigerant being charged into any refrigeration system, and
- the annual refrigerant leakage status of each refrigeration system on the premises, including non-leaking systems.

Refrigeration system audit reports already part of the public record were provided by SCAQMD for this analysis. A total of 440 recharging and leak testing events were included in the reports from 56 different stores representing 20 different businesses. A statistical analysis of the data provided in the records indicates that refrigerant emissions from commercial refrigeration systems in the SCAQMD jurisdiction were approximately eight percent of total charge in 1993.

Methodology

A general statistical characterization of leak events could inform supermarkets on whether to focus their emission-reduction resources on improving maintenance practices (more effective in preventing fugitive emissions) or improving system designs (more effective in preventing catastrophic emissions). An earlier survey on emissions from retail food stores concluded that refrigerant consumption results almost exclusively from catastrophic releases. (Reference: Harrison et al., 1995) The analysis conducted for this report attempted to test the findings of the earlier survey.

Supermarket systems are generally recharged upon inspection or when the remaining charge falls below a critical level (approximately 20-40 percent of total charge for parallel-compressor racks and 40-70 percent for single-compressor racks, depending on individual system characteristics). As a result, one would expect to find a pattern in the percentages of refrigerant recharge required upon discovery. In this analysis, for each documented recharging event, the total amount of refrigerant recharged was divided by the total system charge. The resulting fraction was called the recharging percentage. These recharging percentages were then separated into decile categories (i.e., 0-9%, 10-19%,...) and the populations within each decile category were then analyzed separately from the larger population.

If parallel-compressor-type equipment predominated and recharging amounts fell primarily within the first four deciles, one might suspect that leaks could be primarily classified as fugitive, at least in frequency. This supposition was validated in the ICF study.

An attempt was made to reconcile the findings with actual field practices. Recharging events falling within the first two deciles could be explained by fugitive emissions that were caught in the early stages by regular or chance inspections. Recharging events falling within the third and fourth deciles would likely indicate that sources of fugitive emissions were not found until system performance of parallel racks was impaired from insufficient refrigerant. Recharges within the next three deciles (40 to 70 percent) could be explained by declining system performance of single-compressor racks. Recharges of 100 percent almost certainly would be the result of a catastrophic leak. Table 5.6 details some findings from the statistical analysis.

The preponderance of recharging events involved refrigerant amounts less than 40 percent of total system charge. A smaller number of events involved refrigerant amounts from 40 to 67 percent of total system charge. A very small amount of events involved total system recharges. One interesting finding was that no events involved recharging amounts from 67 to 99 percent of total system charge; however, this finding may have more to do with the small population size than leakage characteristics of refrigeration systems in general.

Further analysis suggested that not only do fugitive emissions occur more often than catastrophic emissions, but they also account for more aggregate refrigerant loss. Total recharges occurred in only 2 percent of recharging events, and accounted for only 8 percent of total refrigerant consumption. One would expect to find a preponderance of total charge releases and resulting recharging events if the conclusion of the previous survey was correct -- that emissions result almost exclusively from catastrophic releases. (Reference: Harrison et al., 1995) The results of the analysis conducted for this report, however, contradict the conclusion of the earlier survey.

Further, the analysis suggests that most leaks reported by auditors were high-side leaks; few occurred on the low-side. Leaks involving the condenser almost invariably resulted in major, if not total charge loss. A final analysis of the data revealed that, other than from condensers, leakage rates from any other component may range from a very small percentage of the charge to the entire charge.

Caveats

Several circumstances surrounding the data provided should be considered in attempting to extrapolate the findings to supermarket refrigeration equipment in general.

- Industry-wide data were not available to perform a comprehensive statistical analysis.
- The population analyzed was small.
- The nature of the maintenance practices in the SCAQMD jurisdiction other than leak repair was not reported in the audits.
- The accuracy and completeness of the data reported under the auditing requirements is unknown.
- The figure calculated for the leak rate of the population is not unachievable, but is quite low compared to the rest of the industry; however, the figure could indicate that emission-reducing measures are already being implemented in the SCAQMD jurisdiction.

TABLE 5.6
STATISTICAL ANALYSIS OF SCAQMD AUDIT REPORTS

Item	Percentage recharged											
	None	1-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100
Number of Events[9]	287	68	16	17	16	7	14	5	0	0	0	10
Most Frequent Leak Sources		TX PL CT SH DS BR EV	HR CT VP FD FT RE SS PL	CT FT TX HR	TX FT CO PH	CO FT HR BR	PH FT CT	BR PH				CO DS HR GH
Aggregate Number	287	117				26						10
Percentage of total population	65	27				6						2

BR	Brazed Connection	FT	Flare, TXV	SH	Schrader Valve
CO	Condenser Piping	GH	Gasket, High-Side	SS	Suction Service Valve
CT	Capillary Tube	HR	Heat Reclaim Piping or Valve	TX	TXV, problem unspecified
DS	Discharge Service Valve	PH	Piping, High-Side	VP	Valve Packing
EV	Evaporator Piping	PL	Piping, Low-Side		
FD	Flare, Drier	RE	Relief Valve		

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[9] An event is defined as either a recharge or an audit indicating no leaks.

CHAPTER 5 REFERENCES

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