HVAC&R – A Look Into the Future

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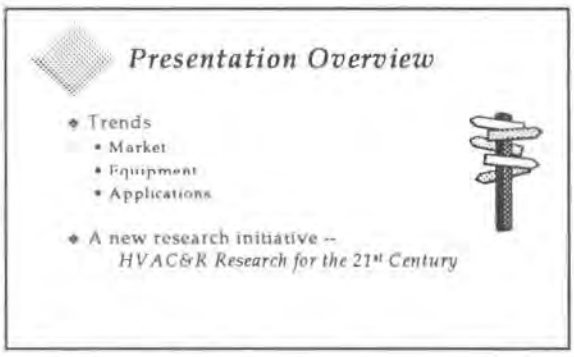
INTRODUCTION

I have been involved the past 8 years with the ARTI Materials Compatibility Lubricant Research (MCLR) program and the ARI R-22 Alternative Refrigerants Evaluation Program (AREP), as well as a number of other small projects executed on behalf of the HVAC&R industry. So, it is with great pleasure that I welcome the opportunity to look into the future and to speak about research for the 21st Century. However, when speaking about research for the twenty-first century, I would like to limit myself to the first 25 years. I guess you can say that I was fully taxed in my imagination to get through that first quarter century, and there was not enough imagination left for the balance of the century. Perhaps some of you in the audience will be able to fill me in later as to how the following 75 years will look.



As an outline of what I will discuss this morning, I will talk about the market trends and drivers, and lead into how these may have an impact on equipment and applications in the future. As a caveat, for this portion of my presentation, I will present possibilities that are not necessarily the views of my employer, industry members, or perhaps even myself. These are things that could occur, but won't necessarily occur, so don't hold me to them. I will then conclude with a description of an industry research program that is just now ramping up.

INDUSTRY DRIVERS

There are a number of drivers affecting our industry today. Currently, the U.S. National Appliance Energy Conservation Act (NAECA; affects unitary residential equipment) and the Energy Policy Act (EPACT; affects larger unitary equipment) are under review, and it is anticipated that new minimum efficiencies will be implemented in the years between 2003 – 2005. Hence, just at the point when industry will be making a serious transition away from R-22, industry will also need to comply with new minimum equipment efficiencies.

We are all familiar with the refrigerant phase-out dates – CFCs are history and HCFCs have dates mandated for them. It is unclear whether the HCFC phase-out dates will be accelerated or whether new regulations will be applied. However, it is likely there will be continued pressures against the use of R-22 in the future.

Additionally, as the result of global warming concerns, we may be facing pressures to restrict HFC usage in the future, or even HFC phase-out requirements. In that case, we in the United States – and other parts of the world – would then be in a quandary as to what the alternative working fluids may be. This will be an area of great concern to us in the future.

International competition has always been a driver and will continue to be a driver. United States manufacturers have about 40% of the world's market. Japanese manufacturers also have about 40% of the world's market ... so we leave 20% of the world market to the rest of the world. However, the rest of the world wants a growing market share just as U.S. and Japanese manufacturers would like increased sales. It is going to make for increasingly heated competition in the future.

Finally there is comfort and health, the real reason that we have a thriving industry today. People wish to buy equipment that provides the comfort and health that they are seeking ... that truly is the driver.

CHANGING BUSINESS CLIMATE

There is also a drastically changing business climate that is occurring, and the market shifts will be fast and significant. We are all aware of the consolidation that is occurring with HVAC&R contractors today, where either they are being bought out or they are selling out. This is resulting in large blocks of well-established and well-capitalized firms that are spreading across the United States. These new firms will have large clout, and will develop a large market

presence that will make it harder for the "mom and pop" contractors to compete.

At the same time, I would anticipate over the next 25 years that the quantity of distributors and the quantity of equipment manufactures will be reduced as well. It could very well be that 25 years from now, instead of having 250 or so manufacturers in the industry, we may be down to half or a third of that. So, in 25 years there may be considerably less people attending a similar plenary session.

The European Unification (EU) is going to be an interesting development as well. If the European countries are able to pull off their grand experiment, it's going to produce a very large market bloc with one currency, reduced internal trade tariffs, a synchronized set of codes and standards ... all encouraging increased trading among the union partners. This process will make it difficult for manufacturers outside of the European Union to compete and sell products within that market bloc if these outside manufacturers do not offer products mirroring those demanded in the EU market.

At the same time, there will be a continuation of technology shifts and technology spin-offs into our industry. Perhaps other industries will come up with new methods that we will adopt. These may be in totally unexpected manners. Others will be more predictable, and perhaps we should be positioning ourselves today to take advantage of the pending changes. As a result of increased communication, we all know that people are able to work out of their homes or satellite offices, and as a result, they don't need to commute to the middle of downtown cities or work in high-rise buildings. That being the case, in 25 years we may not have cities like we have today. And maybe we won't need to sell chillers for large buildings because we may not have the large population centers.

The last two items I would like to discuss in a little more detail as they are significant drivers and they will have a large impact on the HVAC&R market.

SOCIETAL PRESSURES

Indoor environmental quality:

Indoor environment quality (IEQ) will become more important. IEQ is more than just temperature, particulate filtration, humidity and carbon monoxide control. It includes sound, vibration, lighting, air velocity, and contaminant control as well. IEQ will become health- and productivity-based as opposed to comfort-based in the future. I don't know what these health-based or productivity-based IEQ metrics may be, but future HVAC&R equipment will be expected to be responsive to them. However, I do expect that 25 years from now, we will be designing, selecting, operating, and maintaining equipment based on real health, real safety and real productivity feedback.

Environmental impacts:

The next item is environmentally-focused. We are all aware of the ozone depletion issue and we think that it is behind us. We are equally aware of the global warming issue and we know that it is in front of us. Unfortunately, I think the global warming challenge – and what we have to do to rise to that challenge – will be much, much larger than what we had to face for ozone depletion. I hope that we are up to that challenge. Obviously, we are going to see continuing emphasis on refrigerant containment and refrigerant recovery in the future, as well as efficient use of energy.

The Green Party in Europe is very strong and sways decisions in refrigerant choices and equipment selections, hence, its rhetoric in favoring natural refrigerants. Yet, as we have heard these past few days during this conference, it seems to be more than just rhetoric. In Germany, public research funding is discouraged on HFC technologies, but very much encouraged for hydrocarbon applications. In Sweden and Denmark, they will cease R-22 usage after the year 2002 ... no more topping-off existing R-22 equipment. In Austria, they have passed laws requiring that HCFCs cease to be used after the year 2003. In this particular case, Austrian regulations require that R-22 be removed from existing systems and that alternative fluids be utilized. It is obvious that these individual country requirements will have a significant impact on individual industry participants and the type of equipment that they will offer in the future.

Sustainability:

Sustainability will continue to grow support in the future. This means designing for easier recycling (everything will be recyclable) and end-life disposal will be an issue. This implies that the choice in materials that we use today – and those which we will use in the future – will become more and more a recycling issue. Today's HVAC&R equipment, because of its high metallic content – aluminum, steel, copper, bronze – is comprised of 95% recyclable components. However, when we look at some products such as the residential window unit (the window-mounted air-conditioners), we find that they are using more composite materials for strength and durability as well as to assure that the product is lightweight. This implies that aftermarket applications will need to be found for these engineered plastics in 10-15 years so that a disposal problem can be averted.

Germany has initiated a requirement that cars, appliances and air-conditioners must be recycled in a verifiable matter. There are a number of tradeoffs associated with constructing a product designed for ease of disposal somewhere down the line. As an example, since copper contaminates the steel recovery process, Mercedes Benz is looking to replace components containing copper with those made from aluminum. So, here is an instance where a major manufacturer is looking down the road to do today what it can to lessen its burden 15 years from now.

We will also look to use less resources, and to use those resources in a manner that has the least impact on the environment. There is a growing interest to assess the relative impact that the utilization of one component or material selection may have over others. We need to look at how much energy is involved in the extraction, fabrication, shipment, usage, and also the disposal of those components. It is possible that in 25 years there will be rankings for energy consuming equipment – such as air conditioning – in terms of primary power. This could cause

gas technologies to gain favor at the expense of electrically-driven equipment, especially if the ranking includes extraction and energy conversion losses.

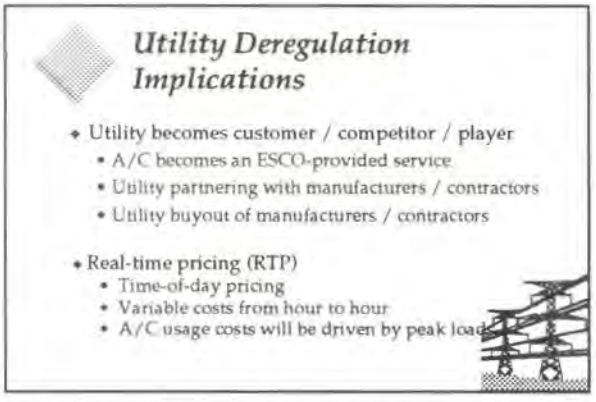
Aging population:

In the industrialized world, the average age of the population is increasing. As supported by a prosperous economic society, older people are more willing and able to afford better comfort and health. Hence, I would expect that we will see increased sales of high-end equipment. However, people in the developing countries have not yet reached the threshold level of having their basic needs taken care of.

Needs of emerging countries:

There is a different set of needs in the developing countries; efficiency may not be the pre-eminent concern with them. Power reliability and power quality concerns may require equipment that is less dependent on the level of site-available electricity. Developing countries may be more interested in equipment that is cheap to purchase, cheap to maintain, and easy to fix. It would be a fortunate coincidence if today's HVAC&R equipment exactly meets the needs of these various regions. Also, due to a lack of established infrastructure in these countries, on-site power generation may be preferred if a reliable electrical grid is missing. Perhaps for this very same reason, developing countries will prefer gas-fired equipment. It is also possible that emerging countries are more likely to consider hydrocarbons or other natural fluids since these countries lack a strong fluorocarbon production base. This will have a profound impact on the global market. As we all know, future sales growth in the HVAC&R industry will be in the developing market. If today's established manufacturers don't offer the products for tomorrow's marketplace, they will lose market share. At the same time, those very same products that have been newly developed for the emerging countries may also be products that enter other markets.

UTILITY DEREGULATION IMPLICATIONS:



The next societal pressure that I would like to look at is associated with utility deregulation. It is a fact that deregulation of the electric utility industry will induce significant changes on how energy is produced, distributed and marketed in the United States. Air-conditioning can become a service rather than a product. A utility or energy service (ESCO) provider can become a supplier of conditioned air. This means that customers may not necessarily own the equipment. It can either be leased to them, or perhaps the customer will merely pay for BTUs of cooling or heating. If this were to happened it would effect a significant change onto the unitary market. The emphasis will go from the customer demanding the least "first-cost" equipment, to the utility or the ESCO demanding equipment that provides the least "life-cycle cost" over the term of a lease. So, what we are looking at is no longer selling

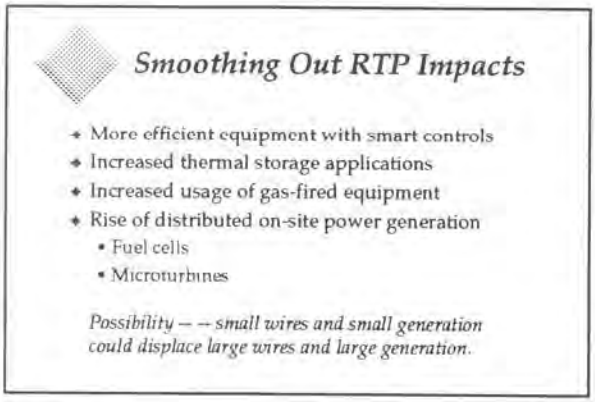
a minimum SEER unit, but perhaps selling a higher value unit that is more reliable, more robust and has better energy efficiency.

While this is going on, there will be great flux. There will be utility partnering with manufacturers and also with contractors, and there will also be a certain amount of utility buyouts of these same manufactures and contractors.

We have all heard that as a result of deregulation, there will be real-time pricing coming our way. This will imply variable cost of electricity, even from hour to hour. It may very well be that when unconstrained demand exceeds available supply, consumers may have to pay a dollar per kWh. However, during off-peak hours – when there is very little utility load – it could very well be that the cost to consumers will be nearly zero for electricity. Obviously, on-peak operation will cost more. The implication is that future consumers may prefer HVAC&R equipment that is optimized for full-load performance and not for part-load performance.

On average, as a result of deregulation, generation cost and generation prices will be lower. However, as we face the uncertainty of global warming regulations, it is possible that retail energy will cost more in the future ... not by scarcity of overall supply, but by governmental regulation.

SMOOTHING OUT REAL-TIME PRICING IMPACTS



So, what will be the industry's response to real time pricing? First, the industry will have to introduce even more efficient equipment so consumers will use less energy during these peak-load operations. Also, we will need to have smarter controls that can sense when the equipment is operating during peak-load, premium time. Perhaps these controls will allow the thermostat to have a higher set-point or prevent the unit from operating during that period of higher-priced electricity.

We will also be seeing in the future an increased usage of thermal storage applications... and I would imagine that we will also see it for residential systems as well. In Tokyo, they are using small tanks (similar to 40 gallon hot water tanks) for thermal storage to allow them to shift part of the residential load into the cheaper evening period. We are likely to see increased usage of gas-fired equipment as customers look for ways to reduce their dependence on electric power generations.

It is also likely that we will see a rise of distributed on-site power generation as customers further look to reduce their electrical dependence. This is especially true in developing countries where there is not ready access to cheap and reliable power. Although not cost-effective today, fuel cells and micro-turbines may become suitable means to overcome electricity distribution shortcomings. It should be noted that these on-site power capabilities are available today. Very

small natural gas turbines, integrated with a compact electrical generator – about the size of a couple of bags of groceries – can produce power in the 25 to 100 kW range (about what an average McDonald's needs).

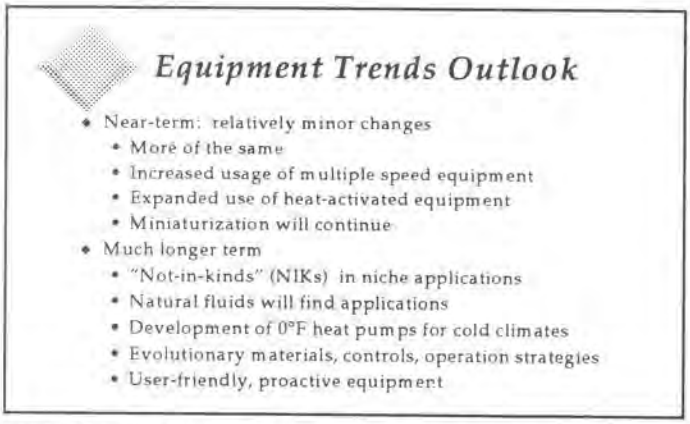
As a result of these trends, especially if you go to distributed on-site power, it can very well be possible that small distribution wires and small generation sets can replace large distribution wires and large generation equipment. What the industry needs to explore is how we will best apply on-site power generation to HVAC&R equipment in the future.

The old rules are rapidly disappearing, the new rules will vary and are subject to constant change.

anonymous

This was a view on the industry drivers and changing business climate. Needless to say, what worked in the past is not likely to be fully satisfactory in the future. The old rules are rapidly disappearing, the new rules will vary and are subject to constant change. Let's look at some possible consequences of this change.

EQUIPMENT TRENDS OUTLOOK



Regarding equipment, it can be said that currently the industry is providing products that are more energy efficient than user requirements. This is obvious when you look at the unitary residential market; the best unitary residential system available today has an efficiency of 18 SEER. However, the efficiency average for unitary systems shipped last year was 11 SEER. For larger building applications, today's most efficient centrifugal chiller has an efficiency of approximately 0.48 kW per ton; the average shipped last year was approximately 0.65 kW/ton. Obviously, the marketplace is not willing to pay the premiums needed to obtain higher efficiency equipment. Hence, in the near-term, I expect relatively minor changes in our market. It will be more of the same. Near-term product offerings will continue to be smaller, lighter, more efficient, quieter, feature laden, good looking, easier to maintain -- all elements of competition within our business.

We also will continue to see increased use of multiple- and variable-speed controls and multiple- and variable-speed motors. There will be an expanded use of heat activated equipment. As evidenced today, there will be more and more interest in desiccant equipment. We will also continue with more miniaturization -- lesser material usage implies lesser cost. Additionally, miniaturization offers opportunities for new applications. As an example, if we can reduce the depth of ductless mini-splits so that they fit within a standard stud depth of an average home, it will make ductless mini-splits more appealing.

Also, as we've heard during this conference, there is a great trend and a great consideration to look at different refrigerants and different applications. There is going to be market differentiation beginning in the next five years. From U.S. speakers we have heard a number of presentations discussing the use of HFC-410A as the long-term alternative to HCFC-22. From Japanese speakers we heard a number of presentations on their diligent investigations on HFC-407C as a long-term alternative to HCFC-22. Hence, it may very well be that soon the marketplace will have two competing refrigerants with very different operating characteristics, which can cause infrastructure and servicing difficulties in the field sometime in the future.

Much longer term, I expect to see non-vapor compression technologies in niche applications. These can include cycles like the carbon dioxide cycle that we have heard about during this conference, in addition to thermoacoustic cooling, adsorption systems, and others. Of the 30-40 different technologies that can be looked at, probably only a half-dozen have any hope of future commercialization. Those cycles will need to be evaluated to ascertain what the limiting technologies are and to explore ways to overcome these difficulties. If today's established manufacturing companies choose not to explore these alternatives, they shouldn't be surprised if specialty companies come on the scene and develop market share with those technologies that may subsequently prove viable.

At the same time, if regulations against HFCs were to be implemented – say, as a result of global warming concerns – it is possible that even the U.S. will deploy equipment that use natural refrigerants. The type of equipment that we would have to develop to use these refrigerants would be very different from today's equipment, and may even entail a cessation of air-to-air unitary equipment that we know today. What we may be looking at are mini centrifugal systems – going to hydronic distribution – as replacements to unitary equipment.

Obviously, for heat pumps to continue to expand their utilization in various different regions of the world, the industry needs to develop a system that can provide heat in very cold climates. So, we need to undertake explorations that lead to heat pumps with satisfactory heating capability for zero degree ambient temperatures.

I expect that in the next quarter century we will see not-in-kind equipment, natural fluid systems, and zero degree heat pumps. This will entail that evolutionary materials, evolutionary controls, and new operation strategies will need to be developed. We will also have to develop more user-friendly proactive equipment. Perhaps cognizant learning controls can adapt to user habits and user idiosyncrasies. This would entail an increased dependence on electronics; which, if we apply with user friendly interfaces, may make it easier for consumers to use their equipment as well as for the installer and the contractors to work with the equipment.

In the future, service people may no longer use the standard manifold gauge and hose sets. Rather, the serviceperson will utilize a "Star Trek-like tri-corder" that records measurements sent by factory-installed transponders located throughout the unit to obtain operating pressures, temperatures, containment levels, and refrigerant circulating composition ... all without having to make direct connections to the equipment.

At the same time, there will be an increased usage of virtual reality in industry endeavors. Use of virtual realty in product design, production line changes, and cause-effect analysis will reduce

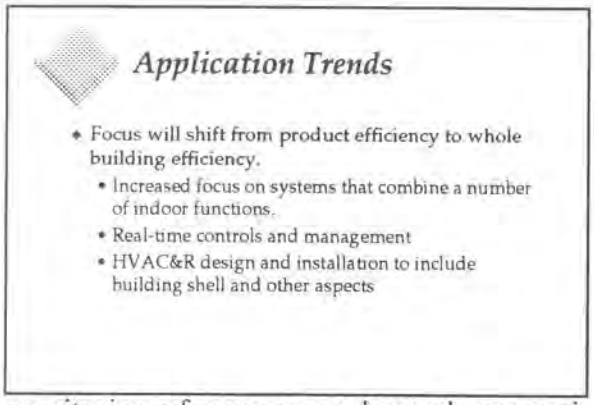
iterations to bring out new products, as well as reduce the risks associated with introducing these new products to market.

As we carry on with today's business, we need to ensure adequate resources are applied for tomorrow's strategic growth. Continued product innovation is our future. Long-term reliance on incremental improvement, to the exclusion of innovation, can become a death-roll of missed opportunities. These opportunities will be application-driven and will have a large impact on the capability and fuctionability of future HVAC&R equipment.

Incrementalism is innovation's worst enemy.

Nicholas Negroponte, MIT

APPLICATION TRENDS



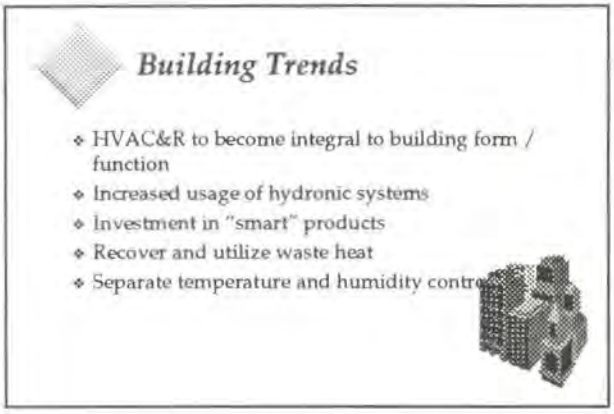
In looking at some of these applications the focus is going to shift from end product efficiency of the unit itself to whole building efficiency. This will entail a more holistic approach. Future industry participants will consider lighting, installation, thermal envelope, window selection, and HVAC&R as a system. There will be an introduction of equipment that will do a combination of indoor management functions. Perhaps there will be unitary rooftop units that will perform energy recovery, on-board monitoring of occupancy demand, contaminant control, and produce hot water in addition to heating and cooling. I see this as being add-on modules where the consumer can mix and match those features needed for various applications.

For residential applications it is likely that an "indoor environmental appliance" will be developed that combines heat recovery, and hot water production with comfort conditioning. This would pull the design away from the installing contractor and bring it back to the factory where equipment manufacturers can exert better quality control while ensuring a better performing unit.

At the same time, we will be seeing more real-time controls that may be able to sense an impending need. Perhaps the building can be informed that a new weather front is approaching and can start compensating in advance. Maybe the house "knows" that occupants are in a car heading home and that it is time to come out of setback and turn-on the front-porch light. Once again, for a deregulated utility market, perhaps real-time controls for real-time pricing.

The industry in the future will design equipment in conjunction with considerations of the building shell and other related components. With more efficient shells, it is possible we can eliminate building perimeter ducts since window condensation is no longer a problem. Therefore, one of the more difficult parts of duct design, the perimeter ducts, is eliminated.

BUILDING TRENDS



In looking at building trends over the next 25 years, it is likely that heating and air-conditioning equipment will become integral to the form and function of the building, not just an adjunct to the building. Perhaps interior walls will be designed to act as heat exchangers. Perhaps for ducted systems, a more energy efficient motive force can be utilized other than fans; maybe convection and conduction can eliminate these fans. Perhaps we can introduce conditioned air under the floor to obtain a better distribution of air throughout the room. Maybe the carpet can serve as a filter where every five to seven years it is either replaced (perhaps in a redecorating effort) or sent out for cleaning.

I already indicated that I expect to see a trend to hydronic systems in residential applications as opposed to the ducted systems that we see today in North America. These are easier to fit to manufactured modular houses, take less space, offer easier quality control of installation (leaks are obvious), and may permit the safe use of hydrocarbon, toxic, or flammable working fluids. Additionally, hydronic systems offer the opportunity to match glide efficiencies and to more easily integrate recovery of building waste energy into the appliance. All this may make it easier to have a more efficient comfort conditioning system in the house.

I also anticipate an increased investment in smart products to meet energy, monitoring and control factors. It can be envisioned that future buildings will have wall sensors that will ascertain and maintain optimum comfort levels for individuals as they move throughout a room. Perhaps home health monitors will be developed that will track individual physical activities while analyzing nutrition and exercise programs. Maybe while you are on your treadmill, the room senses that you are beginning to perspire and reduces supply air temperatures to maintain your comfort. And, obviously, voice-activated products such as lights, air-conditioning, windows, computers, etc. will become commonplace.

The industry will look for ways to recover and utilize waste heat from clothes dryers, dish washers, gray water, etc. in various applications. In residential applications this waste heat has a low-grade energy content, so it will be very challenging to find cost-effective ways to recover this waste energy. But for commercial laundries, hospitals and restaurants, the waste heat has a much higher energy content and there should be ways for us, in a cost-effective manner, to recover that energy.

Finally, it is obvious that we are going to have separate temperature and separate humidity control. By removing moisture in an independent manner, it means that less overcooling, followed by reheat operations, will occur.

SUPERMARKETS IN THE FUTURE

Just what will supermarkets of the future look like? We have already heard in this conference that if we can have better ways of controlling coil frosting – or eliminating it all together – we can have improved case efficiency while maintaining better food preservation. I see this as a trend that will continue and that we will have better control strategies as well.

Another improvement area pertains to the fact that it is very difficult today to re-arrange a store due to fixed piping, fixed drains, and fixed electrical runs. Future innovations will enable faster, easier, more flexible setups in supermarkets. It may be that when you go to the supermarket, you push a button and a display case drops from the ceiling. It may be that you do not pick up your own milk. Perhaps a counter person pulls a milk container from a more energy-efficient cabinet as opposed to a self-use display case.

Also, an increased use of irradiation on fruits, vegetables, dairy goods and other products will reduce the need for refrigeration. This has significant impact on the cooling requirements needed for transport and storage of perishables ... it will very likely shift the operating points for transport and supermarket applications. I see developing countries having a high degree of interest in using food irradiation because it will reduce their dependence on costly refrigeration equipment.

Busy families of the future will be able to scan grocery orders and transmit their needs to the store for delivery the next day. For supermarkets, they can reduce the number of centrally-located stores – usually near high cost residential areas – and place them in areas where people don't want to live. Additionally, they will cease using energy-inefficient display cases in favor of energy-efficient storage cases because point of sale is no longer an issue. They already have the order; stock pickers would merely select the groceries needed against an individual consumer's order.

For the homeowner, it means a savings of at least 60-90 minutes per week ... no need to visit the grocery store. This is something that could be implemented today; there are actually a few small trials ongoing with several U.S. grocery chains. However, they have experienced a couple difficulties. One is that consumers lose a certain amount of comparison shopping ability. How can you compare one product to another if you can't hold the box in you hand and compare ingredients, nutrient content, and claims? How do you compare one steak to another? At the same time, supermarkets have found that virtually all impulse buying has been eliminated. Supermarkets don't profit much from selling milk, eggs and bread ... perhaps a penny or two on a gallon of milk. The profit is on the impulse items – ice cream, candy, cookies, frozen pizzas, etc.

A vision of the future is one thing ...
moving toward that future is another.

Well, that was a vision of the future, which per my earlier caveat may not necessarily be endorsed by any particular organization. In twenty-five years, at the 25th International Compressor Conference at Purdue, perhaps I will be invited back to provide a recap on what did or did not occur. In the interim, let me now tell you about a new research initiative that can be a first step in positioning us for this new and exciting future.

HVAC&R RESEARCH FOR THE 21st CENTURY

Purpose of the Initiative

- Enable HVAC&R manufacturers to offer substantially better equipment in the next decade
  - Higher energy efficiency
  - Improved comfort and health
- Reduce energy consumption in buildings and homes
  - Integrated design: architecture, construction, HVAC, lighting, other energy uses
  - Integrated applications: Controls, equipment, ducts, etc.

We call this new research initiative the *HVAC&R Research for the 21 Century* (21CR). It is being undertaken by the Air-conditioning and Refrigeration Technology Institute (ARTI) on behalf of the air-conditioning and refrigeration industry. It is being supported and endorsed by numerous entities. The purpose of the initiative is to enable equipment manufacturers to offer substantially better systems in the next decade. When we say better, we are talking about higher energy efficiencies and improved comfort and health.

As we began formulating this program, it became obvious that it is not good enough just to have a more efficient green box on the outside of the building. We need to reduce energy consumption in building and homes, and the best way of doing that is to take an integrated approach. We need to look at all the different construction trades used for homes and for commercial buildings, and see what we can do to more effectively integrate HVACR equipment into those applications.

Purpose of the Initiative, Cont.

- Resolve technical hurdles / difficulties
  - Pre-competitive research
  - High-risk investigations
  - Aggressive goals within the individual strategic areas

In moving forward, the 21-CR effort is seeking to foster an environment where technical barriers are identified, solutions investigated, and information shared. At the conclusion of this program, five to seven years from now, we will not be able to put our hands on a 20 SEER heat pump or on an improved chiller. Those are not the goals of the program. The program goals are to provide tools, information, and data so that HVAC&R participants can develop the equipment and services that will be needed in the future.

FIVE STRATEGIC FOCUS AREAS:

We are looking to undertake pre-competitive, high-risk investigations. We have a number of aggressive goals in five strategic areas. The first strategic area listed is to evaluate and investigate novel cycles. These are cycles that are other than the fluorocarbon vapor compression equipment that we use today.

The next item is the ultra-high efficient equipment. What can we do to improve heat exchangers, motor systems, compressors, controls and sensors, air handlers and testing system, pumps and pumps controls? What can we do to make today's products better?

For system integration, we are looking to improve distribution systems, zone control, waste heat recovery, controls/communication, and better integrate HVAC&R systems with building envelope and lighting; again, the integrated approach.

For improved indoor environmental quality, what can we do to enhance the control of moisture and indoor contaminants? How can we reduce transmitted noise? Eliminate drafts? How can we enable people to be more productive and make them more comfortable in the space that they occupy?

The last listed strategic area is environmentally-friendly working fluids. We are looking at refrigerants, lubricants, secondary heat transfer fluids, eutectics, process fluids, etc.

MAGNITUDE OF THE RESEARCH

It is anticipated that this program will be a $35 to $40 million effort over the next 5 to 7 years. There are a number of organizations supporting this effort, and there will be a large number of facilities that will actually be executing the research. Universities, private laboratories, government laboratories and maybe a handful of manufacturers themselves will be interested in undertaking this work. However, it should be noted that it is unlikely that many manufacturers will seek to actively bid on the individual research efforts envisioned for this program. They are too busy today supporting their current product offerings. Basic research, with a time horizon of five-to-ten years, offers too few commercialization prospects. However, being an industry-directed program, HVAC&R participants will be able to more quickly commercialize products that support marketplace needs.

BENEFITS IN UNDERTAKING THE RESEARCH

Benefits in Undertaking the Proposed Research

- Benefits to HVAC&R industry
  - Resolve HVAC&R-related technical hurdles
    - Maintain market dominance
    - Satisfy the needs of the world market
  - Position ahead of the environmental and regulatory challenges on the horizon
  - Strengthen / develop research infrastructure to further support HVAC&R technology

Benefits to HVAC&R industry:
There is a whole host of benefits in undertaking the proposed research. The benefits to the HVAC&R industry are that we will resolve technical hurdles and maintain market positioning with the equipment that the world marketplace demands. It will enable the industry to be positioned ahead of the environmental and regulatory challenges on the horizon. Undertaking the program will also serve to strengthen and develop the infrastructure to further support HVAC&R technology. As a result of the seven-year MCLR program – a very focused 45-project, $11 million research program – industry encouraged a number of universities and private laboratories to support industry research priorities. We encouraged existing contractors to focus on our needs and helped to attract new contractors to undertake work for us, providing for new resources and capabilities that became available for all industry participants.

Benefits in Undertaking the Proposed Research, Cont.

- Benefits to consumers / building owners / general public
  - Greater equipment efficiency
    - Reduced operating costs
    - Reduced CO_2 emissions at the power plant
  - Greater equipment selection and reliability
  - Greater equipment capability and flexibility
    - Electric load leveling
    - Reduction in peak loads
    - Improved comfort levels

Benefits to consumers / building owners / general public:
Obviously, there are a great number of benefits to consumers, building owners, and the general public. Greater efficiencies means reduced operating costs. It means reduced carbon dioxide emissions at the power plant. It implies greater equipment selection and reliability as well as greater equipment capability and flexibility. The consumer ultimately will be the big winner from the 21-CR undertaking.

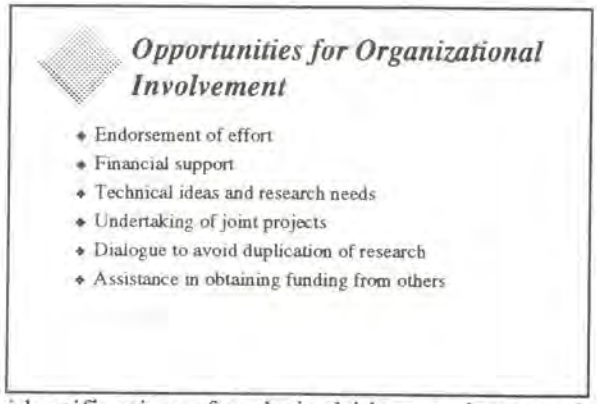
LAUNCHING THE INITIATIVE

Launching the Initiative -- Timetable

1st quarter 1998	21-CR subcommittees were established
2nd quarter 1998	21-CR subcommittees began identifying research needs within their focus areas
4th quarter 1998	Subcommittees finalize initial round of work statements
1st quarter 1999	Steering committee begins to review work statements, prioritize efforts, and authorize the start of specific projects

We have a very aggressive time schedule to match a very aggressive plan. In the first quarter of this year, five 21-CR subcommittees (one for each of the five strategic areas) were established. In the second quarter, the subcommittees held their initial meetings and begun to identify the research needs. Through the balance of this year, the subcommittees will continue to meet to finalize and prioritize the areas of research and prepare work statements. By this time next year, we expect to have a number of research projects underway.

OPPORTUNITIES FOR ORGANIZATIONAL INVOLVEMENT

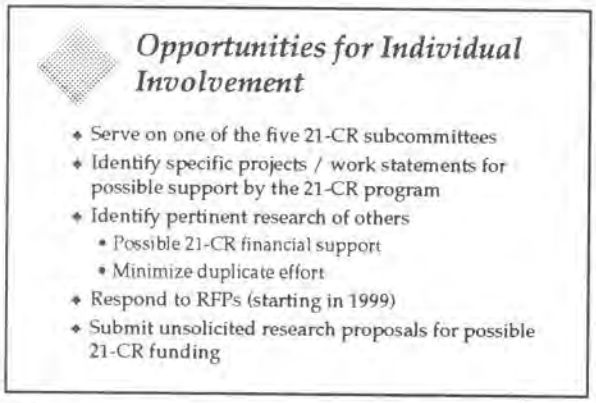


As we move forward with the 21-CR effort, we continue to solicit the involvement of other organizations and seek their endorsement of the effort. If what we do makes sense, we encourage these entities to be involved. We also encourage them to make a financial commitment ... perhaps they can assure that the effort progresses in areas of interest to them.

The most important component, though, perhaps more important than the money, is the identification of technical ideas and research needs. The 21-CR effort is seeking to address the concerns of the entire industry – not just those of the manufacturers', not just those of the servicemen, but those for everyone in the industry. We need the technical ideas and the research needs from all sectors to make this integrated approach a success. In moving forward, we foresee undertaking joint projects with many organizations.

We certainly intend to have dialogs with other entities to minimize the duplication of research as much as possible. However, organizations in of themselves cannot and do not make things happen. It's only the individuals within the organizations that can do that. To each individual in this room, I issue you a challenge and a call to arms. I'm putting you on notice that this program is meant to help you. The success or failure of this program can very well rest on whether you choose to be involved, and do we have lots of opportunities for you to be involved!

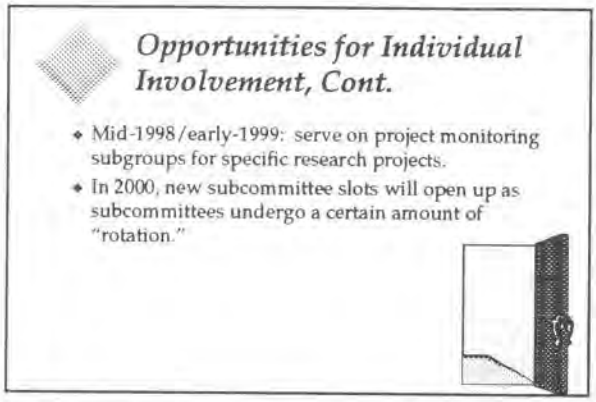
OPPORTUNITIES FOR INDIVIDUAL INVOLVEMENT



Some of you in this room are already serving on one of the five 21-CR subcommittees. Most of those subcommittees are pretty much full at this point, but there are still some key slots to be filled where we are looking for the right experts to bring the missing skills. However, there are other ways for interested industry experts to be involved with the 21-CR effort. We are seeking the identification of specific project needs; this can be as simple as a single paragraph, or a complete work statement.

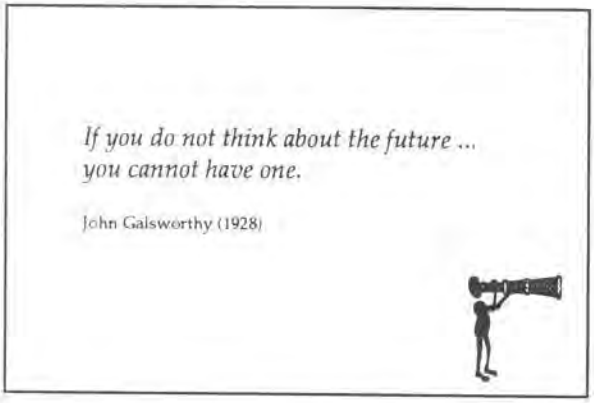
We are also looking for your help in identifying the research of others. We may consider funding those projects that fit within the 21-CR scope. Also, we would like to know about on-going projects to minimize research duplication. During the next few months we will establish a website where we can cross-link with websites of other entities performing investigations of value to the industry. We are looking to make it easier for the whole industry to ascertain what's going on in other organizations. Perhaps the 21-CR website can eventually become a resource for staying abreast of the activities at the many varied research organizations.

Starting in 1999, specific projects will go out for bids, so I would expect that a number of you in this room will be responding to *request for proposals*. Also, I expect a number of you will be submitting unsolicited research proposals. Unsolicited proposals are welcomed, and we look forward to receiving them.



Later this year and into 1999, we will be looking for a whole host of new volunteers to serve on project-monitoring subgroups. The purpose of these subgroups is to ensure that the work statements make sense, review competitive proposals that are submitted in the RFP process, recommend contractor selections, follow the work as it moves forward at the contractors facility, perform on-site reviews, and also review final reports for acceptance. In the year 2000, we will also have new subcommittee slots open up as the subcommittees undergo a certain amount of rotation.

CONCLUSION



As we move into the 21st century, I invite each of you to consider the evolution that will take place within our industry. I encourage you to think about the future and to think of the role that you will play in that future.

I thank you for your attention and will be happy to welcome any questions.