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F. V. Honnold
United Technologies Carrier Corporation

OPENING ADDRESS BY FRED V. HONNOLD

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Every two years, we gather to share with each other a portion of what we've learned about compressors since the last meeting.

We also learn at these conferences just how much we don't yet know.

Our professional curiosity is stimulated and we return from West Lafayette energized and determined to probe even deeper into the arcane field we've chosen for study.

In the intervening time, we focus our thoughts sharply on screws, scrolls, rotaries, recips and centrifugals. We concentrate on improving seals and tolerances; improving valve or port designs; creating better gas paths; eliminating losses . . . the list goes on and on.

We live and breathe compressors.

Today I'm asking that we widen our vision -- looking beyond the narrow confines of our science to some larger issues that affect each of us in this room both on a personal and professional basis.

The fact is, they are issues we couldn't avoid even if we wanted.

Many of you are familiar with the American fable of Rip Van Winkle, the rural New Yorker who laid down one afternoon for a nap and woke up 20 years later in a vastly changed world. I'm sure that similar tales exist in almost every culture.

Although we, as engineers, work in a world of facts and scientific proof, who among us has not engaged in such fantasy? We all have asked ourselves what problems our children's children will face and how will they be solved.

Fortunately, or unfortunately, depending on how you view change, the world is changing at such a pace that we won't have to wait 20 years to find out.

Consider global warming.

Mathematical models sophisticated enough to digest and analyze the complexity of the earth's atmosphere and oceans completely, do not exist.

Neither does scientific consensus on global warming.

The Environmental Protection Agency is projecting a 3 degree centigrade increase in the earth's overall temperature by the year 2100. This could result, they say, in devastating coastal flooding as sea levels rise as much as 3 feet.

Others say CO-2 and other "greenhouse gases" in the atmopshere have nearly doubled in the last 100 years, but global temperatures have risen only a half degree centigrade -- way below other projections.

The various hypotheses have yet to be proven, but concern over the accumulation of these "greenhouse gases" -- carbon dioxide, methane, oxides of nitrogen and sulfur, and CFCs -- appears likely to result in legislation or regulation that will restrict their generation and release.

Consider atmospheric ozone depletion.

Besides being viewed as a "greenhouse gas", we're all aware of the role CFCs are believed to play in reducing levels of atmospheric ozone.

Two weeks ago in London, the United Nations Environmental Programme confirmed a total ban on CFC production by the turn of the century.

There will be a future reassessment to see if such a ban is achievable by 1997.

Those attending the UNEP conference agreed that HCFCs, like 22 and 123, are essential if the CFC phaseout is to succeed. But there also was agreement that even these compounds should be phased out by 2040 at the latest and by 2020 if possible.

There are other concerns lurking in the future, as well.

Consider the dwindling of finite energy reserves and increased electricity demand.

When those of us in developed countries flip on a wall switch, we expect electricity to flow, and it almost always does. But as the demand for electricity inches closer to the available supply, the threat of shortages appears more and more likely.

I attended a conference last month at which a major southern U.S. electric utility announced incentives for its large commercial and industrial customers to <u>reduce</u>, or at least shift to off-peak periods, their consumption of electricity.

In itself, that isn't too startling. Utilities have been promoting off-peak usage for years. But the size and intensity of their efforts have increased.

Rebates for the purchase of energy-efficient equipment are increasing, and no longer are utilities promoting new ways for their customers to use as <u>much</u> electricity as they can.

Some other speakers at the conference presented scenaria that I think shocked a few people in the audience.

The Electric Power Research Institute anticipates that 200 new medium-sized power plants will need to be built in the U.S. within 10 years to add an additional 100 gigawatts of generating capacity.

But, EPRI said, only 75 gigawatts of generating capacity are planned between now and the year 2000.

Even some of that additional capacity is in doubt as utilities face increased pressure from the public and regulators to justify each new generating plant.

The puzzle becomes even more complex as you consider the interplay among these issues.

The worldwide demand for electricity is steadily increasing.

Growth of demand is even greater in developing countries where urbanization increases energy consumption as societies shift focus from agrarian to industrial.

But meeting that demand for electricity contributes to those other problems.

Coal, in the U.S. and elsewhere, is the fuel of choice to generate that electricity.

According to the North American Electric Reliability Council, coal now generates about 43.5 percent of electricity in the U.S.

By 2000, the Reliability Council expects the percentage to fall to 41.4 percent. Regardless, coal will continue to be used far more than other fuels.

But burning coal generates greater amounts of carbon dioxide as well as oxides of nitrogen and sulfur -- all of which contribute to the threat posed by global warming.

Sulfür emissions, or course, contribute to acid rain, an environmental concern I hadn't mentioned earlier.

The push to eliminate CFCs has added another variable to the equation.

As compressor engineers, we know that most of the non-CFC refrigerants under study as possible substitutes or alternatives offer less cycle efficiency -- thus drawing more electricity input for the same output.

Add to this the efficiency penalty created by the elimination of CFC-blown insulating foam from refrigerator and freezer walls.

Of course, burning natural gas is a cleaner way to generate electricity and more natural gas is being used for that purpose, but methane is even more efficient than CO-2 at trapping heat. Stricter regulation of methane releases during production and transportation may hinder the development of gas-powered generating plants.

There are other alternatives, such as nuclear generation, solar and clean, renewable hydro-electric power, but they have their problems, too .

After the Chernobyl accident in 1987, the safety of nuclear power plants around the world is being called into question.

Both Japan and France are committed to expanding their use of nuclear power, but Sweden plans to phase out nuclear plants by 2010.

Spain, as well, has a five-year moratorium on the construction of new nuclear plants. A recent public opinion poll showed that only 30 percent of the Spanish populace favored nuclear power.

Even hydro has its problems.

The proposed "Three Gorges" project in the People's Republic of China would include a 600-foot-high dam across the Yangtze River that would provide 18 gigawatts of electricity. The dam is attractive to a country that relies mainly on coal-burning power plants.

But the social consequences would be staggering. More than a million people would be displaced from their homes. The lake created behind the dam would engulf some of the country's most scenic areas.

The news just keeps getting worse.

I wish I could paint a brighter picture of our earth's future, but doing so would be inaccurate. These problems are real and they cannot be ignored.

I assume by now you've begun to sense the direction in which I'm heading.

The air conditioning and refrigeration industries contribute to these problems. And even though issues like global warming, ozone depletion, and dwindling natural resources cannot easily be reduced to more human dimensions, we, as individual compressor engineers, must believe that we can play a significant role in their solution.

And now is as good a time as any to place one more obstacle in our path -- the requirements of the various markets we serve.

While we're keeping an eye on energy efficiency for the sake of our environment, we can't forget about things like cost, reliability, low sound levels and comfort that our customers expect.

Remember:

- Compressors dominate air conditioning system cost.
- Compressor failures dominate system repair costs.
- Compressor sound levels also dominate air conditioning and refrigeration system sound levels.

Where do we start?

The problems of global warming and dwindling natural resources available for electricity generation both hinge on increasing the efficiency with which the world uses energy.

In the air conditioning and refrigeration industries, that means increasing the efficiency of our systems and processes. And since improving compressor efficiency is generally more cost effective than increasing heat exchanger efficiency, the responsibility falls heavily on our shoulders.

We've already come a long way. Compressor efficiencies in the last 20 years have increased nearly 60 percent from 7 to 11 EER by reducing losses from friction, heat transfer, leakage and motors.

But the way people look at air conditioning and refrigeration systems is changing and will demand more of us. Let me give you some examples.

As a means of shifting peak demand so that they can postpone the construction of new generating capacity, utilities are waking up to the potentials of thermal storage.

A San Diego developer recently received more than $400,000 from a utility because he agreed to install an ice storage system to cool a 30-story office building and hotel complex.

Other utilities are paying for feasibility studies to see if thermal storage is a viable alternative to builders.

Some say thermal storage uses <u>more</u> energy because lower suction temperatures are required to make sub-freezing brine as opposed to chilled water at 6 degrees centigrade..

But the real savings will come when we combine ice storage with a cold air delivery system.

In standard air distribution systems, air is cooled to around 12 degrees C. But air cooled to 7 degrees reduces the volume of air needed. That means smaller ducts and reduced fan horsepower. When compared with a conventional system, cold air systems can reduce electricity consumption by 50 percent.

But these ice storage / cold air systems will really come into their own when we develop compressors with higher efficiencies at lower suction temperatures.

The focus is not only on ice storage.

Heat recovery has long been popular with commercial and industrial users, but with energy costs rising, it will also spread into the residential sector with products that integrate space cooling with domestic water heating.

Integrated products demand stronger compressors.

With the increased reliability and cost effectiveness of digital electronic controls, we also find that zoning is making a comeback in commercial systems and spreading into the residential systems.

Using energy only where and when it is necessary to maintain comfort saves our customers money, but to be effective, it requires compressors that operate efficiently over a broader range of load conditions.

So how do we get there?

I'm sure most of us have conceptualized the ideal compressor. It would have:

No valves
No torque pulses
No bearing wear
No compression chamber leakage
No heat transfer in compression
No lubricant
No over or under pressure
Minimum dynamic imbalance
Capacity matching the load

Few moving parts

Minimum sound

And intelligence

The rotating-type compressors our industry has embraced recently already possess some of these ideal characteristics. Better dynamic balance and fewer parts. Screws and scrolls don't have valves and only minimum torque pulses. But the ideal is still far ahead of us.

The papers we'll hear at this conference will move us closer to those ideals.

o We already are looking at new materials that hold the promise of improved efficiency, robustness, reliability, and reduced costs.

The cast iron and aluminum we've had around for years is good stuff and metallurgists keep making better alloys. Because of their low cost, we're bound to keep using them as substrates.

But the wear and abrasion resistance we need we'll probably get from ceramic coatings. Reliability will increase. Not only will our customers be happier, but the number of scrapped compressors out there will reduce the volume of CFCs and HCFCs released into the atmosphere.

Metallic and non-metallic composites, especially in screw and scroll compressors, will help us attack the leakage problems inherent in both systems. Abradable coatings that seat with each other may help us reduce both leakage and friction.

And when we do that, we increase efficiency.

Air conditioning and refrigeration system manufacturers spend millions of dollars each year to improve the heat transfer characteristics of our coils.

New materials, some variation of those same coatings, will help us eliminate the unwanted heat transfer within a compressor that steals efficiency.

Until now, the oil-less compressor has pretty much been a dream. But with new bearing materials, that dream is within our grasp.

Not only will compressor reliability be greatly enhanced with no lubrication system to fail, but overall system efficiency will improve as oil stops circulating with refrigerant through heat exchangers.

Oil-free compressors start looking even better when you consider the effects that some CFCs substitutes have on traditional lubricants.

o We are advancing the idea of designing electronic controls and sensors into the compressor rather than adding them as afterthoughts. Coupled with variable-speed capabilities, efficiency and reliability will improve dramatically.

Variable-speed drives offer exceptional opportunities for efficiency improvement because they allow us to more "easily" approach achievable system SEERs over 20.

Compressor efficiency increases because the variable-speed drive allows it to operate at lower pressure ratios.

When the system is operating at below maximum load, as it does most of the time, the throttled-down compressor reduces refrigerant flow.

In effect, that oversizes the evaporator and condenser coils to improve heat transfer and efficiency.

With permanent magnet, electronically commutated motors, some of the losses common to induction motors no longer exist because current isn't being used to create a field in the rotor. More efficient motors also dump less heat into the suction gas, multiplying their impact on overall compressor efficiency.

As I mentioned earlier, zoning in both residential and commercial applications calls for compressors that operate over a wider range.

Is there any reason, given the sophistication of future electronics, that we couldn't see speed variations of 30 to 1?

We're also talking about intelligence in compressors -- intelligence that lets them adapt to changing conditions, protect themselves better and diagnose their own ailments.

As a compressor ages and capacity degrades because of wear, an intelligent compressor could increase its speed to compensate. If it sensed refrigerant flooding, it would reduce speed and signal the fan motor to increase airflow over the evaporator coil.

The possibilities are limited only by our imagination and the very real marketplace constraints that require real value for money.

o Advances in manufacturing processes, such as near-net-shape casting and more precise machining, will also help us create better compressors.

Near-net-shape molding operations already have permitted the substitution of a plastic material for steel in the rotors of a twin-screw air compressor.

The challenge is to apply near-net-shaping to achieve large manufacturing cost savings for screw rotors and scroll elements in air conditioning and refrigeration compressors.

Near-net-shaping, through molding, casting or powdered metal techniques, can have a huge implication for tooling costs. Imagine eliminating $5 worth of capital depreciation from the cost of each small compressor.

We also need to improve the accuracy of our final machining. Screw rotors today are machined to tolerances of + or - 20 microns. That needs to be cut in half to stop leakage and realize full efficiency.

While maintaining accuracy, we also need to increase the speed at which metal is removed to control costs.

Computer-compensated machine tools will soon offer real-time feedback during <u>all</u> compressor machining processes so adjustments can be made without sacrificing time.

o More sophisticated computer modeling and simulation techniques will allow us to improve efficiency, reliability and cost before a cutting tool ever touches metal -- or plastic.

As Ray Cohen has pointed out before, it really wasn't too long ago that we even began to fully understand what was happening inside a compressor.

It wasn't until about 1960 that modern engineering methods were first applied to analyze compressor operation. With electric resistance strain gauges and piezoelectric pressure transducers, we began to gather the measurements and analytical tools we needed to develop today's mathematical models and simulations.

Today, those computer simulations are proving their worth as we optimize designs long before they are committed to metal.

Computer simulation tools are now being used to eliminate rotor chatter in twin-screw compressors. The computer can analyze variation after variation until the right rotor profile is achieved.

Purdue is now working on computer simulations that correlate a screw compressor's internal pressure pulsations with radiated sound.

When you consider the volatile regulatory environment in which we operate, these simulation tools give us the flexibility we need to respond to what may seem like overnight changes in policy. They help us shorten the time needed to progress from concept to finished product. Their importance will increase as regulatory and market demands shorten product life cycles.

Standing up here in front of the world's foremost compressor experts is like, as the American expression goes, preaching to the saved. There's not much I can tell you that you don't already know.

But if anything has become clear from this quick and admittedly superficial discussion of today's compressor technology, it's that none of us can be expected to know or do it all. In fact, such an attitude is dangerous.

The rapidity of change doesn't allow time for mistakes if we're to be successful. We need to look beyond our own workstations and involve others in the process of creating compressors.

Do we think about :

- Parts availability
- Inventory requirements
- Weight requirements
- Tolerance capability of machine tools

- Factory layout
- Fabrication cost
- Capital depreciation

Have we taken manufacturing variables into account in assessing performance?

The resolution of any technical problem, like shell vibration, can seriously affect factory throughput.

And more than manufacturing is involved. We need to consider product applications, life-cycle cost, capital investments and the applied cost over the life of the product.
This is an organizational challenge, not a technical one. But its importance can't be underestimated.

Like self-abrading coatings on moving parts, we must make sure we maintain intimate contact with other parts of our organizations or our customers' organizations. For just as we understand technical matters unknown to them, they are aware of market and regulatory forces we may not have considered.

When we tie all of this together -- new materials, powerful electronics, precise manufacturing techniques, computer simulation and the willingness to work with others, we'll achieve results that benefit our institutions, our companies, even our individual countries.

And, as I suggested earlier, our advances in compressor technology will have a broader effect.

I've done some figuring to see if I couldn't quantify what impact our efforts to improve compressor efficiency might potentially have on our planet.

Admittedly, they are rough calculations based on simple assumptions, but they illustrate my point.

Let's assume that we've develolped a new 30,000 BTU scroll compressor. New materials have reduced friction and leakage losses to a minimum. Electronics have given it variable speed and adaptive powers.

For the sake of argument, let's give it an EER of 12.5. That's 20 percent over what most compressors of this size achieve today. Over a 20-year operating life, that's a savings of 20,000 kilowatt hours. You also should remember that this compressor will maintain its efficiency longer.

What does this mean in terms of saved resources?

In today's power plants, it would take 7,000 kilograms of coal to generate that many kilowatts.

What does it mean in terms of greenhouse gases?

Burning that much coal creates about 20,000 kilograms of CO-2. Multiply the savings from one compressor by the number of compressors produced year after year and you'll see that we can have a significant impact on the problems facing our world. There also are other environmental benefits I haven't calculated.

Reduced size means less raw material. That avoids energy consumption at primary levels like mining and smelting. Lighter weight also reduces transportation costs and fuel consumption.

New materials and designs will soon allow us to substitute non-CFC refrigerants without any efficiency penalty.

Lower total costs will make the system more affordable. That's of real concern to those in developing nations to whom refrigeration can sometimes be a matter of life and death.

Insertion of these new technologies also has met our customers' demands for comfort, quiet, reliability and low cost.

I don't always remember what I read on bumper stickers, but I saw one recently in Ithaca, N.Y. whose message has stayed with me. It said simply:
"Think globally, Act locally." . . . "Think globally, Act

locally."

That's not a bad attitude to adopt in a world beset by problems that threaten to overwhelm us with their scope and complexity.

Issues like global warming, ozone depletion, the steady erosion of natural resources and the needs of millions in developing countries do seem overpowering. And there are no simple solutions, no miracle cures.

But they will be resolved.

> Resolved by people with the breadth of vision to acknowledge these problems exists;
>
> By people with the clarity of vision to see their role in creating solutions;
>
> By people, like you, willing to focus their special talents and energy on a single aspect of the larger puzzle.

I hope some of the insights we gain during this conference will move us closer to those solutions.

Thank you.