DENSO NEWS CONFERENCE REMARKS

2002 SAE World Congress, March 4, 2002

“Looking Toward the Future – CO_2 Refrigerant”

RICHARD SMITH
Director, Climate Control Engineering
DENSO International America, Inc.

We, at DENSO, are extremely proud of our status as the automotive world’s global leader in air conditioning systems. As Mr. Fukaya noted in his remarks, we take even more pride in the fact that we have achieved that status while honoring a serious, steadfast, superceding commitment to the environment.

This, as you know, is not always, if ever, a simple balancing act – the progression of automotive engineering and the safety of the environment. The balance becomes even more delicate, more sensitive, when you add the weight of corporate fiscal responsibility. Again, we, at DENSO, stand proudly on our record. We have shown, and continue to show, we believe, an ability to regard all three – engineering, the environment and fiscal responsibility -- with the same concern and care.

– more –

In direct regard to automotive climate control systems, which is today's subject, DENSO is quite efficiently and energetically pursuing the goal of developing an automotive climate control system that meets – or exceeds – current engineering standards and demands, those being:

- One: Smaller and more powerful,
- Two: Easily adaptable, and
- Three: Above all else, of course, environmentally better.

In regard to the current generation of vehicles, those with conventional internal combustion engines, DENSO continues its mission of reducing the environmental impact of the R-134a-based air-conditioning system by specifically targeting improvements in efficiency and weight, which, in turn, reduce power consumption and, ultimately, decrease environmental impact.

Society, or course, demands, and rightly so, continued progress toward development of systems that are completely benign to the environment. We are leading that march, too.

Thus, for the near-term, next generation of hybrid and idle-stop vehicles, DENSO has developed electrically powered A/C systems and alternative means of cabin heating. It wasn't so long ago that the automotive industry discovered that R-12-based air-conditioning systems posed two serious threats to the environment:

- One: Ozone depletion.
- And, two: Global warming.

DENSO, as you may recall, was at the forefront of the global conversion from R-12, an ozone-depleting refrigerant, to R-134a, an ozone-safe refrigerant. We received an EPA award in 1993 citing our work. We took great pride in seeing one of our customers – Toyota – become the first automaker to convert its fleet to R-134a, also in 1994.

– more –

We still are hard at work, trying to improve the current R-134a system through development of more efficient heat exchangers -- DENSO currently manufactures the smallest, lightest, most efficient heat exchangers in use – and by reducing refrigerant leakage through developing better system hoses and fittings.

But we knew, too, even then – and even now, while working to better the R-134a system -- that the conversion to R-134a would, ultimately, lead only to short-term success. We knew that we needed to look even further into the future:

- Toward a generation of new vehicles and their new demands.
- Toward a new generation of systems.
- Toward an air-conditioning system run on CO_2.

Why CO_2? Two reasons, mainly.

- One: CO_2 is a refrigerant that exists in nature and has a negligible effect on the environment.
- Two: CO_2 also is a good working fluid not only for cooling systems, but also for heat-pump systems. That potential tied perfectly into the next generation of vehicles, those with electric or hybrid engines, which cannot draw cabin heat from an internal combustion engine.

While the conversion to R-134a was a significant step, basically one refrigerant was replaced by another, albeit a much safer one, using fundamentally the same system components. But if that was a step, converting to a CO_2 system could well prove to be one of those, quote-unquote, giant leaps.

As previously noted. CO_2 – or carbon dioxide -- is a refrigerant that exists in nature. It is not toxic and does not damage the ozone. In effect, its potential for harm is negligible. Indeed, its Global Warming Potential, or GWP, is less than one-one thousandth than that of R-134a.

– more –

In addition to the GWP benefit of CO_2, the air-conditioning cycle with CO_2 displays a promising benefit in total global warming impact compared to current R-134a systems. The Total Equivalent Warming Index, or TEWI, is a measure of overall system operation impact. We believe that we can achieve about a 35 percent global warming impact benefit by 2005.

After the conversion to R-134a, industry researchers began seeking the next generation refrigerant. And DENSO has been at the forefront of the effort.
It is important to note that SAE, too, has been actively involved in this effort, specifically by sponsoring summer ride-and-drive symposiums in Phoenix – in which DENSO has participated -- as well as by sponsoring an Alternative Refrigerants Cooperative Research Effort. DENSO has supported that initiative both with funding and with our advanced components

Researchers examined numerous alternative refrigerant possibilities. Propane, for example, was one. Most possibilities were discarded. CO_2 emerged as the favored candidate. Today, we are at the point where we can say that development of a CO_2 system is ready for the next step: actual vehicle applications.

This adaptive use of CO_2, it should be noted, is not entirely new. In May 2001, DENSO began manufacturing CO_2-driven applications for Japanese domestic hot-water heating utilizing a heat-pump system.

It is interesting to note, that in those applications, the CO_2-driven water-heating system used one-third the amount of power required by a conventional natural gas heater system.

– more –

Here's how this all works:

The diagram behind me describes the CO_2 refrigeration cycle. You will note that it employs basically the same cycle as the R-134a adaptation. This is known as a vapor compression cycle.

The system works basically like this: A gas cooler, which corresponds to a conventional condenser, cools CO_2 refrigerant discharged from the compressor, and, in this application, heats the water supply. Next, the thermal expansion valve, or TXV, condenses a part of the CO_2 refrigerant as a result of adiabatic expansion.

The refrigerant completes the cycle by absorbing heat from the ambient air and returning to the compressor, ready to transfer the heat to the water.

Once, again, as noted previously, the hot-water system use of CO_2 has shown significant benefits – a 30 percent reduction in power consumption and a 50 percent reduction in emissions. One reason the CO_2 system is so attractive in Japan is that natural gas in Japan is 10 times as expensive as it is here. The bottom line? This product offers Japanese residential consumers a five-year payback. And, because CO_2 is benign to the atmosphere, the product also offers significant and obvious environmental benefits

Now for the automotive applications.

This slide depicts the basic system components. Again, the basic cycle is the same as current R-134a cycle -- a vapor compression cycle, with two fundamental differences.

First, because the operating pressure of a CO_2 system is 10 times higher than that of the R-134a system, the system requires significantly different construction – different heat exchanger construction, different materials for hoses and gaskets. Every component needs to be re-engineered.

– more –

Second, the automotive application requires an internal heat exchanger to obtain the efficiency targets previously mentioned. The highly positive side is that the effects on global warming are greatly reduced – and that is, indeed, the bull's eye on the target. In application, the CO_2 system fundamentally met or bettered the R-134a system for cooling capacity. It still, however, lags the best R-134a system in power consumption or drag on the engine, as previously shown in the TEWI chart, be it an internal combustion engine or an electric or hybrid motor.

Our goal at DENSO is to make the CO_2 system as efficient as our future ``top level'' target for the R-134a system. The CO_2 system requires additional development before mass application, but it is ready for specialized use. For example, DENSO has developed a CO_2 air-conditioning and heat-pump system jointly with Toyota for its fuel cell hybrid vehicle the Toyota FCHV-4, which employs a hermetically sealed electric compressor, resulting in good sealing performance, a simple structure and easy installation.

The CO_2 system is perfect for an electric vehicle or an electric-hybrid vehicle, such as the FCHV-4, which cannot use the heat generated from a conventional internal combustion engine to heat the vehicle cabin. A quick note, here: On March 26th, Toyota will make a presentation of this application on the FCHV-4 at the Earth Technologies Forum in Washington DC.

Pictured behind me on the diagram, now, is the air-conditioning and heat pump system to be employed in the FCHV-4. The system can be switched between the heating and cooling modes by opening and closing by-pass valves. In the cooling mode, the CO_2 refrigerant circulates through the evaporator, cooling the vehicle cabin air. In the heating mode, it circulates through the interior gas cooler, heating the air.

– more –

Basically, what we have with CO_2 is single-system operation for heating and cooling, as opposed to the dual-system operations required on current vehicles. In the CO_2 system, both heating and cooling systems use the same components and the same coolant – CO_2. In current systems, cooling is generated by use of a refrigerant; heat is generated with engine coolant.

Because today's engines have become so efficient, especially the small gasoline or direct inject diesel engines, there is insufficient waste heat to provide adequate passenger comfort. But the CO_2 heat pump provides a comfortable cabin environment in the heating season, as shown here. The dashed line shows the heating performance of a conventional engine-coolant system for the one-liter class vehicle popular in Japan and Europe.

This heating performance is quite insufficient, as our counterparts in the engine community have made great strides in improving the efficiency of these small engines.

Through this research, DENSO has developed system components, including a hermetic-type electric compressor, a gas cooler, a unique accumulator tank that includes an internal heat exchanger, and an evaporator. Because the accumulator is integrated with the internal heat exchanger and the expansion valve, the structure of the CO_2 system becomes simple and is easy to install in the vehicle. Each component is designed to enable resistance to high operation pressure, which is a characteristic of CO_2 operation.

While all of these developments are encouraging and promising, problems still remain – technologically and in infrastructure. Regarding the former: Engineers must address the issues of the CO_2 system's higher pressure, larger potential for leakage and low coefficient of performance.

– more –

Other issues, these of the infrastructure category, include: the handling of CO_2 in air-conditioner system maintenance; safety; availability; logistics; servicing and maintenance, and SAE standards. Indeed, the SAE sub-committee will be meeting tomorrow to continue their work in this area. Of course, DENSO is an active participant.

In summary, before the CO_2 air-conditioning system can enter the mainstream mass-production marketplace, the following issues must be resolved – cost-reduction; weight reduction; reliability improvement; and, more importantly, adequate provision of service and maintenance equipment, and clear, standardized procedures for safe handling of CO_2 systems for service and maintenance.

These issues are too difficult and too far-reaching to be handled by one company. In order to continue the progress, DENSO needs the assistance of other automakers, other air-conditioning system suppliers and other governments worldwide. This is a monumental task, to be sure. But it also is one that we believe is well worth the potential benefits to the industry, and, most importantly, to the environment.

We, at DENSO, look forward, as always to the special challenge of helping lead the way.

# # #