4- Thermoacoustics: Too bulky, low volumetric efficiency. Heating mode a serious complication. Pressurized system safety concerns. No appropriate machines in production, expensive. Peltier thermoelectric devices are an almost ideal combination of size, weight, reliability, cost, and simplicity for the VTSW application. All of the other approaches entail significant tradeoffs, including much lower efficiency in the case of Ranque-Hilsch tubes.

THERMOELECTRIC VTSW

Once it was determined that thermoelectrics were the best way, overall, to go, it was then time to determine the overall layout of the system. In order to make the system as simple, compact, and inexpensive as possible, it was determined that a single Peltier device would be capable of pumping the maximum heat dictated by an estimate of the most acceptable additional continuous electrical load for such a function. This was estimated at between 50-75 watts input power. Fig. 1 is a photo of VTSW Prototype No.1.

Fig. 2

Given careful system design and a resultant COP, (Coefficient of Performance), of .50, a single Peltier thermoelectric device will pump half of the input power rating from the cold side to the warm side, or apx. 25-37.5 watts. In order to make the most of the available heat pumping capacity, and concentrate the available cooling power, (heating mode is a different story because the efficiency of the Peltier device in heating mode is more than twice as good as in cooling mode, on average, so the overall VTSW system was optimized from the beginning with cooling mode taking precedence), was to limit the total area of the wheel grip being cooled, thereby reducing the cooling load in order to favorably match it up to the practically available cooling power in order to produce the most acceptable cool-down time and final temperature.

Fig. 3

The power rating of the thermoelectric heat pumping system effects the amount of heat that must be rejected from the warm side in cooling mode. This affects the size, weight, cost, and noise level of the fan and heat exchanger used to cool the warm side. For maximum efficiency, the warm side should be as cool as possible while operating in cooling mode because overall system ΔT, as well as absolute temperature, will determine system efficiency.

Fig. 4

Another important consideration is VTSW system noise. In order to minimize noise, it is necessary to minimize the air flow rate of the auxiliary fan blowing air over the auxiliary heat exchanger. In order to do this, it is necessary to maximize efficiency and minimize heat pumping requirements.

The heat pipe chosen for the VTSW is made of thin wall copper tubing with a sintered wick on the inside wall. The sintered wick allows the pipe to be bent without damage to the inside wall wicking structure or separation of the wick from the inside wall. The pipe is vacuumed out and ~5-10.0 ml of distilled water are added while maintaining the required vacuum. Water performs very well since it has a relatively high specific heat and latent heat of vaporization. It is also preferred because it is non-flammable and is relatively inexpensive.

It is definitely not desirable to have a flammable liquid inside the heatpipe, which is in close proximity with the airbag assembly. Being that the water in the heatpipe is in a fairly strong vacuum, the freezing point is reduced below the normal freezing point of water under standard conditions, so freezing and subsequent stalling of the heatpipe under very low temperature ambient conditions is avoided. If it is necessary to certify the system for extremely low temperature operation, a small amount of methanol can be added to the water charge to further reduce the freezing point under vacuum without entailing any fire hazard. The only effect of the addition of alcohol will be a proportional reduction in the net heat of vaporization with increasing alcohol/water ratio.

The auxiliary heat exchanger is the heat exchanger that carries system input power I2R heat plus heat pumped across the Peltier junction, away from the warm side of the device in cooling mode.

In heating mode, the auxiliary heat exchanger absorbs heat from ambient air at a heat exchanger temperature below ambient air temperature because the auxiliary side of the device drops below ambient temperature when input power polarity is reversed. Heat absorbed by the auxiliary heat exchanger in heating mode is pumped across the device to what has now become the warm side. Input power I2R is additive in this mode, hence the COP is always higher in heating mode than in cooling mode.

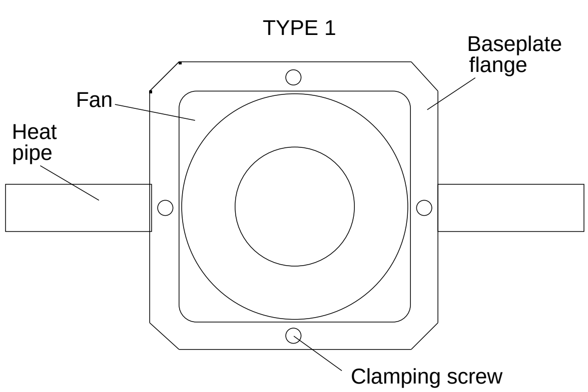

Fig. 5

The first VTSW prototype, Type 1, has a single standard Peltier device with a square footprint, (Figs. 5 & 6).

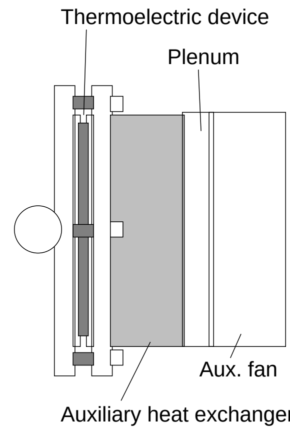

Fig. 6

This was not optimal because heat has to travel from the far outside edges of the device and the clamping baseplates of the heatpipe assembly and the auxiliary heat exchanger to the heat pipe, creating a higher than desired temperature gradient along the way.

The Type 2 VTSW thermoelectric assembly was a compromise between Type 1 and Type 3 originally, and was discontinued in favor of Type 3.

The second VTSW prototype, shown in Figs. 2-4, was built for Daimler-Benz to demonstrate the advantages of the Type 3 configuration and to demonstrate transparent packaging within an existing production steering wheel with airbag and horn assembly. The performance of the Type 3 assembly was noticeably better than the Type 1, getting colder faster in cooling mode, and warmer faster in heating mode.

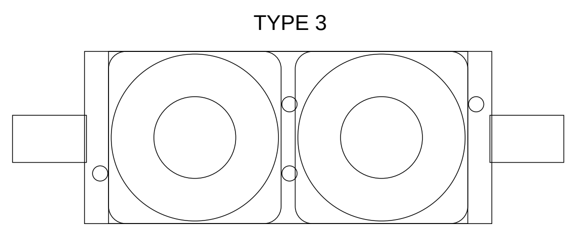

Fig. 7

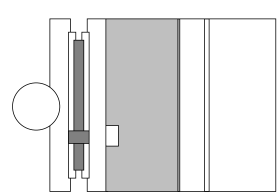

Fig. 8

Figs. 7 & 8 show the Type 3 VTSW thermoelectric assembly, which is wider and shorter. This accomplishes three things:

1- More of the heat pipe area is used for thermal transfer to and from the thermoelectric device and the heatpipe. The heatpipe power rating is based upon heatpipe material, wall thickness, diameter, wick characteristics, working fluid, length, characteristics of any radii or variations in cross-section, input area, and output area.

2- The maximum distance from the heatpipe baseplate outside edge, as well as from the auxiliary heat exchanger baseplate outside edge, to the heat pipe is significantly reduced.

3- The shorter, wider thermoelectric assembly is easier to package within existing steering wheels.

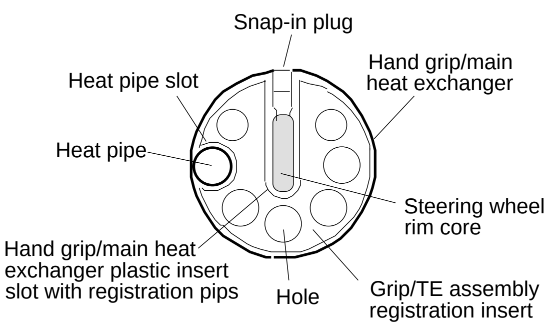

Fig. 9

The ability to cool and heat the steering wheel quickly is another requirement dependent to a great extent on system efficiency and heat pumping load. Fig. 9 is an end view of a molded plastic insert that fits inside each grip, and is designed to minimize heat leak from inside the steering wheel rim and the reinforcing ring into the copper hand grip heat exchangers so that the available thermoelectric cooling power and minimum possible cool-down time are focused on cooling down primarily the hand grips. These plastic inserts also serve to clip the hand grip heat exchangers to the steering wheel grip reinforcing ring, which may be essential for some steering wheel designs with leather wrapped grips and/or rims, as opposed to wheels where the heat pipe/grip assembly is molded into the plastic body of the wheel, which is molded over a metal reinforcing spoke and ring. A narrow snap-in plug closes the slot gap after assembly. If the variable temperature areas of the steering wheel are wrapped with leather, it is best to use the thinnest leather that is practical in order to optimize cool-down and warm-up times.

The heat pipe assembly may be molded into the steering wheel, leaving a thin skin of plastic covering the hand grip heat exchanger sections, before assembling the thermoelectric device, auxiliary heat exchanger, and auxiliary fan.

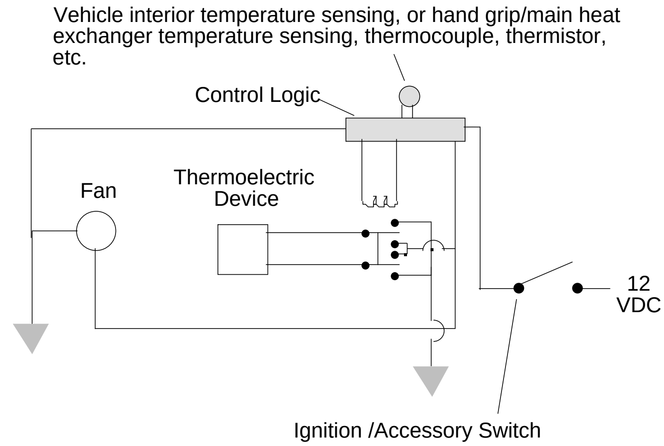

Fig. 10

Fig. 10 shows a basic VTSW control schematic, which includes a temperature sensor and control logic that controls VTSW mode as a function of ambient air temperature. The control logic determines the position of a double pole double throw switch, which determines power input polarity to the thermoelectric device. The control logic also controls power to the auxiliary fan.

Figs. 11 and 12 show the Type 3 thermoelectric assembly of Figs. 7 and 8, but with a significant difference. The assembly of Figs. 11 and 12 uses plastic or metal clips instead of screws to clamp the assembly. The advantages of this arrangement are:

1- Heat leak via clamping screws from the hot side to the cold side is significantly reduced, which enhances efficiency in cooling mode. The material that enables this new approach to thermoelectric system assembly is called “Thermaphase” and has half the thermal impedance of thermal grease at a contact pressure of only 2.25 psi. This enables the use of metal or plastic clips instead of screws. So, in addition to enhanced efficiency from reduced heat leak, efficiency is further improved because of the lower R-theta, or thermal impedance, of the new Thermaphase thermal interface material.

2- Manufacturing and assembly complexity is reduced, reducing assembly time and cost. Drilling and tapping screw holes, and the possibility of under-torqued or unevenly torqued clamping screws is eliminated, improving quality control. Eliminating screw holes is particularly significant when making brazed folded fin type heat exchangers because the need to EDM the screw holes is eliminated.

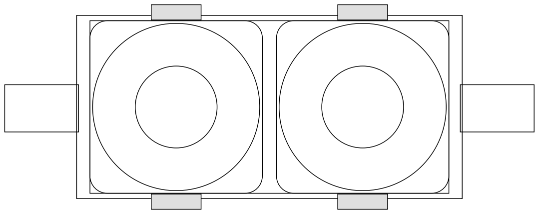

Fig. 11

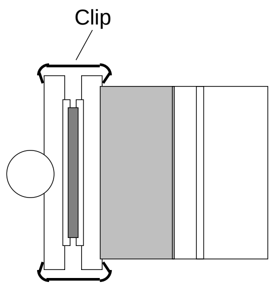

Fig. 12

Fig. 13 shows an “air slip-ring”. It is called a slip-ring because it is analogous to an electrical slip-ring, however it conveys air instead of electricity. The purpose of this optional component is to enhance performance and efficiency of the VTSW in applications where it is feasible to fit it. The air slip-ring requires a small diameter air conduit inside the steering column housing, and allows the air conduit inside the steering column housing to remain stationary while conveying air to the auxiliary heat exchanger, which rotates with the steering wheel. The air flow cross section of the air slip ring, and the air conduit inside the steering column housing, need not be more than about 6.0 cm2.

The air slip ring allows air to be blown from the evaporator/heater air box to the auxiliary heat exchanger in the VTSW by a small vaneaxial blower located inside the air box. This means that, in cooling mode, with the vehicle air conditioning running, air that is below ambient temperature is blown from the air box through the conduit in the steering column housing up to the air slip-ring, and into the auxiliary heat exchanger, as shown in Fig. 14, which is a side elevation view of the assembly. When air is supplied to the auxiliary heat exchanger at a temperature below ambient when the VTSW is in cooling mode, the efficiency, power, and performance of the VTSW will be enhanced.

Likewise, when the VTSW is in heating mode, and air is supplied from the heater in the air box to the auxiliary heat exchanger in the VTSW at a temperature above ambient, VTSW performance, efficiency, and power will be enhanced.

Another advantage of the air slip ring with remote blower is that, although the tubeaxial fans shown in Figs. 11 & 12 can be very quiet, the air slip ring with remote vaneaxial blower can reduce noise even further by placing the blower inside the vehicle HVAC air box, given adequate spectrum analysis and air duct tuning to avoid blower/duct/slip ring resonances.

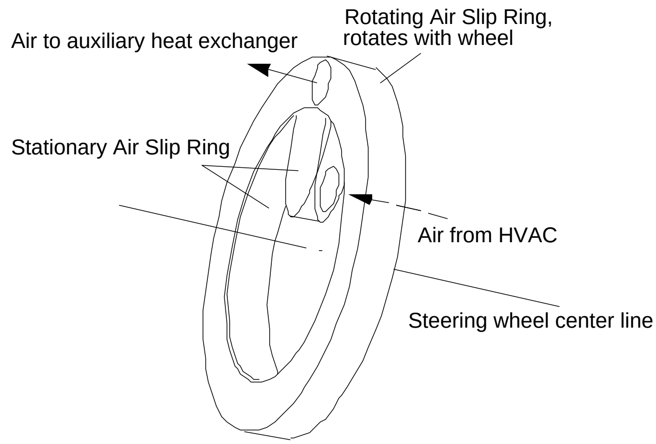

Fig. 13

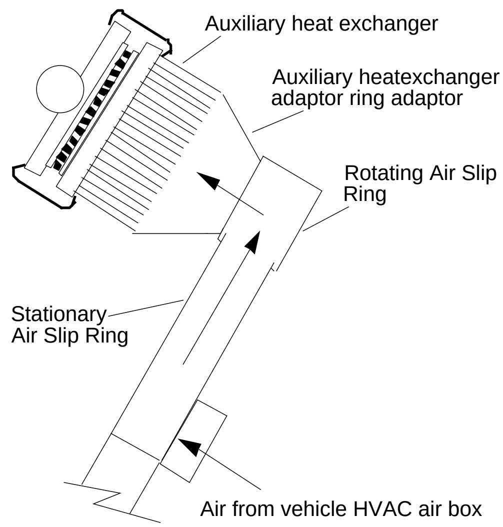

Fig. 14

Figs. 15, 16, and 17 are thermographs of VTSW prototype No.1 in cooling and heating modes. Fig. 15 shows VTSW 1 in cooling mode, with the cooler colors representing lower temperatures and the warmer colors representing higher temperatures.

Fig. 15 shows a temperature of apx. 75.0° C on the red areas of the surface of the leather covered grips at 3-4 and 8-9 o’clock, and a temperature on the blue areas of the leather covered grips of apx. 42-48.0° C, for a total ΔT of 27-33.0° C, when covered with fairly thick leather within 3 minutes of startup in a weather simulator producing a *constant* insolation of 450.0 W/m2, at a *constant* ambient air temperature of 40.0° C.

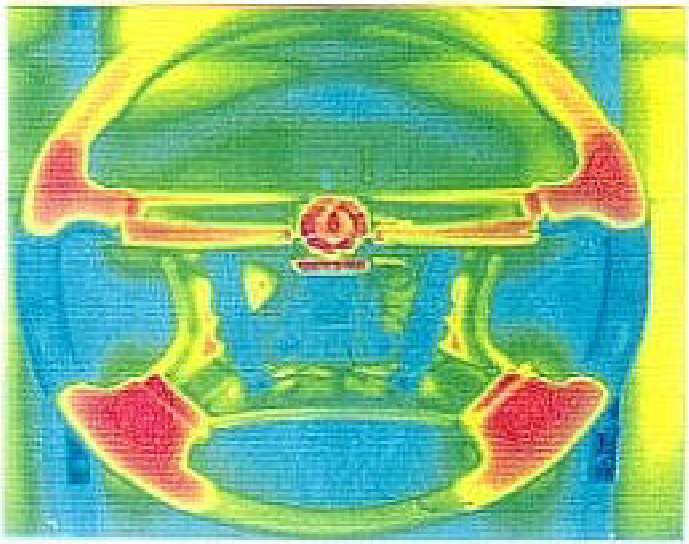

Fig. 15

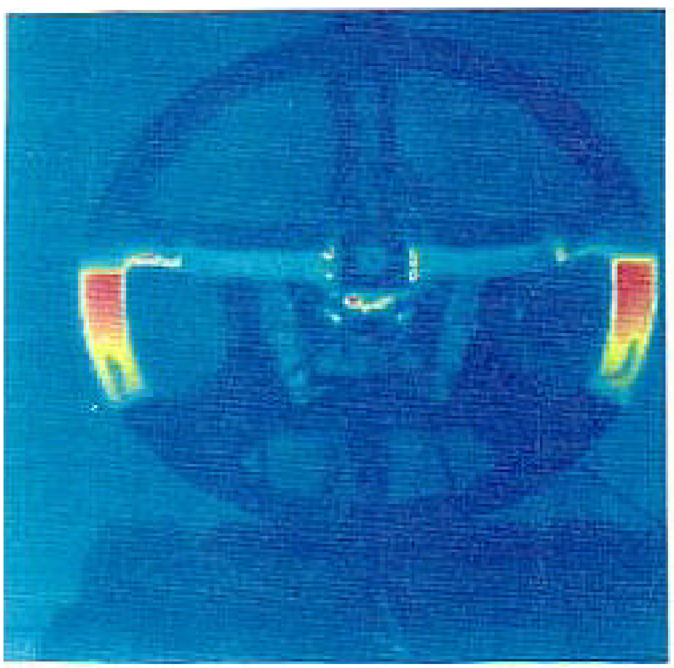

Fig. 16

Fig. 16 shows VTSW 1 in heating mode after 3 minutes at apx. -5.0° C *constant* ambient air temperature. The warmest parts of the VTSW grips are at apx. 13.0° C, for a ΔT of 18.0° C.

Fig. 17 shows VTSW 1 after 10 minutes of *constant* ambient air at -5.0° C. Because the upper end of the color /temperature scale was recalibrated for this thermograph, the warmest parts of the VTSW grips are now at 25-26.0° C, for a total ΔT of 30-31.0° C.

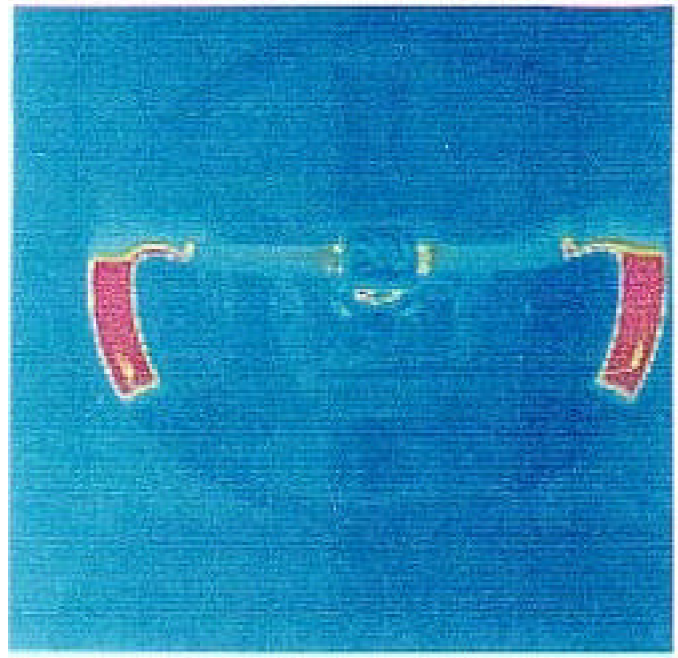

Fig. 17

CONCLUSIONS

The VTSW system is capable of cooling and heating from approximately 3-4 o'clock and 8-9 o'clock on the steering wheel relatively inexpensively, reliably, and safely, without harmful environmental considerations. The latest Type 3 prototype shows improved maximum ΔT in both cooling and heating modes with noticeably faster response time in both cooling and heating modes. Actual in-vehicle performance will be further improved in cooling mode with the use of AC and power windows to drop vehicle interior air temperature as quickly as possible, as well as by changes in vehicle orientation which reduce vehicle insolation as a result of vehicle motion.

It is possible to use a pager to control the VTSW by telephone in order to achieve full cool-down or full warm-up before entering the vehicle, and this can be accomplished without having to start the vehicle engine because the VTSW has relatively low power requirements and does not require engine rotation as does conventional central HVAC. The VTSW may also be used in conjunction with Variable Temperature Seats of either the thermoelectric (VTS) or Stirling Cycle (SVTS) type, in addition to vehicle central HVAC, in order to provide maximum driver and occupant thermal comfort and convenience.

ACKNOWLEDGEMENT

Thermographs courtesy Daimler-Benz.

ADDENDUM

Fig. 18 shows VTSW Prototype No.3, based on a new Range Rover steering wheel. The hand grip heat exchangers are bronze castings made to conform to the unique grip cross section of the wheel. The thermoelectric assembly is Type 3a, which is shorter and wider and achieves slightly higher dT’s in both cooling and heating modes in noticably less time than the first two prototypes 1 and 2.

Fig. 18