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Stirling Air Conditioned Variable Temperature Seat (SVTS) and Comparison with Thermoelectric Air Conditioned Variable Temperature Seat (VTS)

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ABSTRACT

The thermoelectric Variable Temperature Seat, (VTS), offers automotive OEMs a new approach to occupant comfort enhancement in both hot and cold weather. The VTS is capable of both cooling and warming the vehicle occupant relatively efficiently and relatively quietly through the use of conditioned air flow through the seat pad structure.

The subject of this paper, the Stirling Variable Temperature Seat, (SVTS), is the latest advancement in seat cooling and heating technology, and significantly improves upon the thermoelectric, (Peltier), VTS in several significant ways.

INTRODUCTION

This paper will explain the differences between the SVTS and the VTS, and how the SVTS successfully addresses the following concerns associated with the VTS:

1. Moderate air ΔT in cooling mode.
2. Low efficiency in cooling mode, particularly as air ΔT increases.
3. Less than normal orthopedic seat support and comfort.

Drawings and tables, based upon prototype test results and use experiences with both technologies, are included to illustrate the conclusions drawn in this paper.

BACKGROUND

CONCERNS NO. 1 AND 2 – Moderate air ΔT increases perceived cool-down time. Moderate air ΔT is particularly significant for leather covered seats since leather is a fairly good thermal insulator, so perceived cool-down time is increased even further over body cloth covered seats. The greater the available ΔT in cooling mode, the faster the seat will in fact cool down and will be perceived to cool down, especially under conditions of relatively very high vehicle interior air and surface temperatures, for example above ~120.0°F/49.0°C.

The basic reason for the difference in thermal perception is that vehicle occupant body skin surface temperature averages around 96.0°F/35.6°C, and perceived seat temperature is relative to occupant skin surface temperature, not ambient air temperature. If the available air ΔT is too small, then as vehicle interior air and surface temperatures rise, the temperature of the air flowing into the seat will be closer and closer to occupant skin temperature, resulting in a reducing perception of cooling power because of the reduced difference in temperature, or ΔT, between seat air and occupant skin surface temperature.

The definition of adequate, or sufficient, ΔT in cooling mode would then appear to be that ΔT which would provide an effective thermal transfer, and hence a perception of effective cooling, even under the worst case of high vehicle interior air and surface temperatures. The SVTS is capable of meeting this requirement, even at vehicle interior air and surface temperatures of 150.0°F/65.6°C, because it is capable of an air ΔT of ~76.0°F/42.0°C, (see Table 1). This ΔT enables SVTS seat air at ~74.0°F/23.3°C, at and ambient vehicle interior air temperature of 150.0°F/65.6°C.

Low cooling mode efficiency is a concern because the electrical load placed upon the average car is increasing, and ever-increasingly more expensive alternators are becoming necessary to supply the demand for electrical power. At maximum cool-down power in cooling mode, the VTS operates at approximately 40-50% electrical efficiency. The VTS operates at much higher efficiency in heating mode, because the input power I2R is additive in heating mode, however heating mode efficiency is not nearly as important as cooling mode efficiency, because in cold weather, prodigious amounts of waste heat are available from the internal combustion engine to heat the vehicle interior. It's cooling power that is most needed, at the highest efficiency possible, to offer the opportunity for rapid cool-down and fuel savings by not having to always use central AC in hot weather.

CONCERN NO. 3 – Less than normal orthopedic seat support and comfort. This has been a concern in the past because of an effect referred to as the "Snowshoe Effect" in SAE paper 931111, entitled Thermoelectric Air Conditioned Variable Temperature Seat (VTS) and Effect Upon Vehicle Occupant Comfort, Vehicle Energy Efficiency, and Vehicle Environmental Compatibility, by the same author. The Snowshoe Effect results from the use of an array of ~12.7 mm diameter helically wound steel coils forming an air flow layer or spacer assembly, placed between the body cloth covering the seat and the support foam underneath.

The steel coil assembly is made by coiling steel wires and interlocking adjacent rows of coiled wire, similarly to the way chain link fencing rows are intertwined with adjacent rows.

Because the steel coil assembly spreads the occupant's weight over the load bearing support foam, the foam doesn't deform as it ordinarily would, particularly in the areas of the ischial tuberosities, often resulting in a sensation or sense of not quite settling into the seat, or of sitting on top of the seat instead of sitting in the seat. Those occupants who feel that they're sitting on top of the seat instead of in it will often also experience a lack of orthopedic support.

STIRLING VARIABLE TEMPERATURE SEAT (SVTS)

CONCERNS NO. 1 AND 2 – Figure 1 shows the basic components of a free-piston Stirling cycle heat pump. Although the Stirling cycle has been known for many years, as both a prime mover and a heat pump, until Sunpower, Inc., Athens, Ohio produced the first free-piston type machines, Stirling cycle heat pumps and engines were generally considered to be of limited practicality. The free-piston concept eliminates sliding or rotating seals and the friction, wear, and leakage associated with them, resulting in a much more reliable, efficient, and cost effective mechanical interpretation of the Stirling cycle. Other developments, including materials and assembly techniques have resulted in a new machine that has unique advantages over other technologies, in certain applications. One of the more significant applications is the SVTS. The Stirling SVTS is up to 600% more efficient than the Peltier thermoelectric VTS, and the potential efficiency of Stirling in the future is even higher.

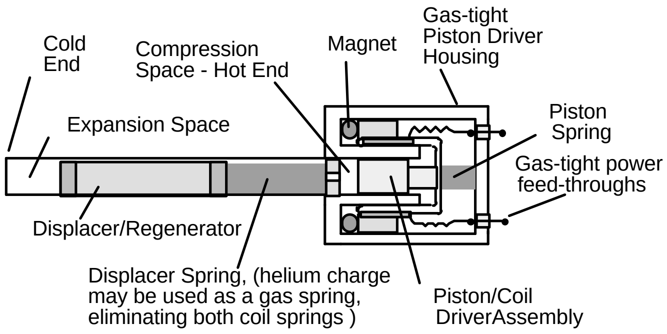

Figure 1.

Figure 2 shows the general configuration of the actual SVTS Stirling machine, set up to deliver cooled or heated air to the seat. A PTC heater is shown in contact with the cold end or "cold head" of the machine, and is only used for heating mode. The Stirling machine is not energized when the system is in heating mode. It is not feasible to reverse the direction of heat flow in this Stirling machine, so a resistive heater is used for heating mode. By attaching the heater to the cold end, it is possible to make use of the main heat exchanger in both modes, saving space, weight, complexity, and expense over having a totally separate heating sub-system.

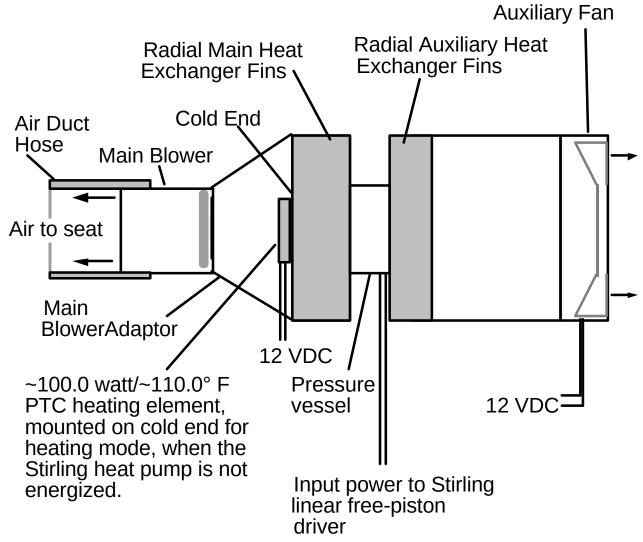

Figure 2.

In practice, the PTC heater is clamped between the cold end and another small heat exchanger, Figure 6, in order to allow the PTC heater to dissipate heat from both sides into the seat air stream. If this is not done, the PTC heater will reach it's Curie, or anomaly point, too easily, in effect, overheating at a lower than desired output air temperature.

Figure 2 is based upon the first SVTS prototype, Type M223a/SVTS, which is a free-piston Stirling machine with a maximum rating of 100.0 watts of cooling power, which was originally developed for a completely different application, and which was modified for the SVTS application. The next SVTS machines will be designed and built specifically for the SVTS application, and will have a maximum cooling capacity of 40.0 watts, and will be much smaller and lighter.

Figure 3 illustrates how fast the SVTS cools down in cooling mode compared to the VTS in a vehicle interior cooled by conventional A/C under hot, sunny weather conditions. Before the VTS output air drops to a comfortable level, and long before the average interior air temperature drops to a comfortable level, the SVTS has reached a more effective cooling ΔT.

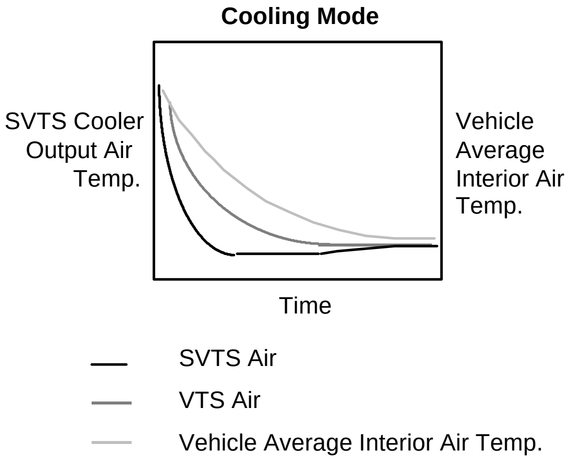

Figure 3.

Since the SVTS gets cooler faster in cooling mode, the occupant perceives the cooling effect sooner, especially with a leather covered seat, hence, the occupant is satisfied faster with the SVTS than with the VTS. The SVTS provides more immediate gratification, and relieves the occupant from a hot seat sooner than the VTS. Since the SVTS is capable of greater air DTs than the VTS, it provides much more effective occupant cooling at higher vehicle interior air temperatures as well.

SVTS power consumption is easier and less expensive to control. The reason for this is primarily that the Stirling machine is so much more efficient. Because the SVTS is so much more efficient, it takes less input power for a given unit of cooling power output, therefore for a given cooling power level, the input power is much less. Since SVTS input power is approximately 16-17.0% of VTS input power for the same net cooling power, (and the SVTS can produce a much greater ΔT simultaneously), the SVTS control system can be much smaller, lighter, and less expensive.

SVTS power is controlled by varying the amplitude of a sine wave, or by varying the duty cycle of a pulse width modulator operating at a harmonic of the piston oscillation frequency, driving the linear electric motor that oscillates the piston back and forth. Stirling machine piston frequency is constant, only the amplitude is varied to control cooling power. At low power levels, the amplitude of the input power pulse is small, and at modest ΔTs, the COP, (Coefficient of Performance), will rise above the already high rated COP of 2.5-3.0.

There are a number of ways of controlling SVTS cooling power:

1. Variable air flow to the seat.
2. Variable seat air temperature, as a function of the variable amplitude piston driver setting.
3. Both variable air flow and temperature.

In cooling mode, a thermistor or thermocouple is used to sense the temperature of the cold end of the Stirling machine, or the temperature of the air downstream of the cold end main heat exchanger. This may be used in a closed loop to control piston driver amplitude as a function of a preselected temperature. An open loop may also be used, allowing the occupant to adjust the amplitude of the piston directly. In most instances, practically speaking, a closed loop with temperature select is more appropriate for general use, however, it is also possible to design the controller for both capabilities.

With a closed loop control, as the air in the interior of the vehicle cools down from the use of central AC and/or as a result of opening the windows and using the IP blower to bring outside ambient air into the interior of the vehicle, SVTS heat pump output air temperature will not drop below the selected temperature, because, as the thermal sensor reads a drop in cold end temperature or output air temperature, the amplitude of the piston driver is automatically adjusted to maintain the preselected temperature.

With an open loop control, under the above conditions, output air temperature will drop somewhat proportionally to any drop in ambient air temperature, so the occupant must adjust the piston driver amplitude manually to maintain the same seat air temperature/cooling power.

In heating mode, the PTC resistance heating element automatically maintains a maximum preselected design point temperature, given a constant input voltage to the PTC heater.

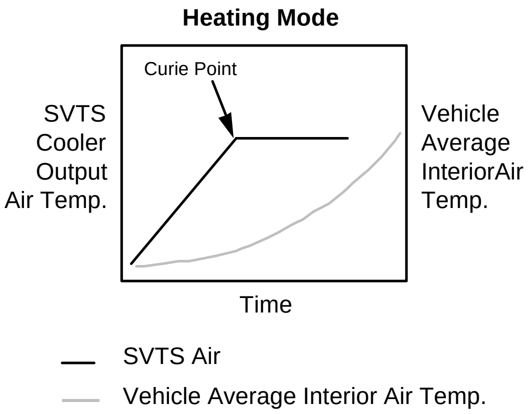

Figure 4.

Figure 4 shows how relatively fast the SVTS heats up in heating mode versus the interior of a vehicle being heated with engine heat. A comparison with VTS heating mode is not shown because both are very similar in heating mode, except for control simplicity provided by the PTC heater in the SVTS. The SVTS is not quite as efficient in heating mode as the VTS, however, as mentioned at the beginning of this section on Concerns No. 1 & 2, heating mode efficiency is far less significant than cooling mode efficiency because of the availability of engine heat for interior space heating purposes, and the small loss in heating efficiency, (~15-25%), is a very small price to pay for such a significant gain in cooling efficiency, (up to 600%).

The SVTS does offer the enhanced simplicity of PTC heater control in heating mode. This means that it is virtually impossible for the heating element to overheat as long as input voltage is within specification. The design maximum air temperature will never be exceeded over the entire range of seat air flow, which is a function of main blower speed, and which is used to regulate net heating power in heating mode, and/or as a result of interior air temperature rise from the use of engine heat, or changes in ambient conditions.

In heating mode, VTS output air temperature increases as main blower air flow is reduced, and/or as interior air temperature rises from the use of engine heat, necessitating control of electrical power, manually or automatically, to the thermoelectric VTS in order to limit maximum air temperature over the entire range of seat air flow.

Figure 5 is an end view of Figures 2 and 6, showing the PTC heater attached to the cold end, which is surrounded by the main heat exchanger radial fins.

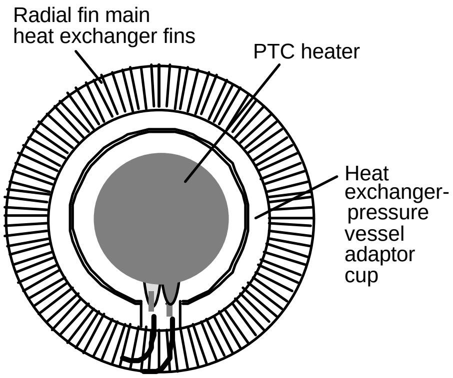

Figure 5.

Figs. 5 & 6 also show views of the main heat exchanger-to-pressure vessel adaptor cup. This cup fits over the cold end of the Stirling machine and serves as the base-plate for the main heat exchanger radial fins, the PTC heater, and the PTC auxiliary heat exchanger. The adaptor cup is threaded in order to enable relatively quick and easy assembly and disassembly of the PTC heater assembly with thermal grease, preferably of the silver bearing type. Very importantly, the adaptor cup allows the cold end to absorb heat from process air from the PTC auxiliary heat exchanger, via the PTC heater and PTC auxiliary threads and circumferential contact face, in cooling mode, thereby increasing the efficiency of the Stirling machine in cooling mode. This can be seen more clearly in Figure 6.

The thermal conductivity of the PTC heater is only about 2.0 w/cm/°C, however, in addition to providing a balanced area on both sides of the PTC heater for better heating mode operation, the PTC auxiliary heat exchanger increases the heat transfer area of the cold end in cooling mode. In addition to this, the thermal path from the center of the cold end to the center of the PTC auxiliary heat exchanger is shorter and more efficient in both cooling mode and heating mode.

The PTC auxiliary heat exchanger addresses an important thermal efficiency problem which has been an issue with respect to the practical use of Stirling coolers for air conditioning purposes for many years.

Because Stirling coolers are dry machines, and do not use a circulating refrigerant, such as R-134a or R12 for example, but use helium or other gases or combinations of gases as working fluids, the heat exchanger area is relatively small compared to Rankine cycle refrigerators, which can circulate refrigerant through serpentine paths in relatively large heat exchangers that allow for efficient thermal transfer from relatively large amounts of air with little pressure drop and with little ΔT across the heat exchanger as a whole.

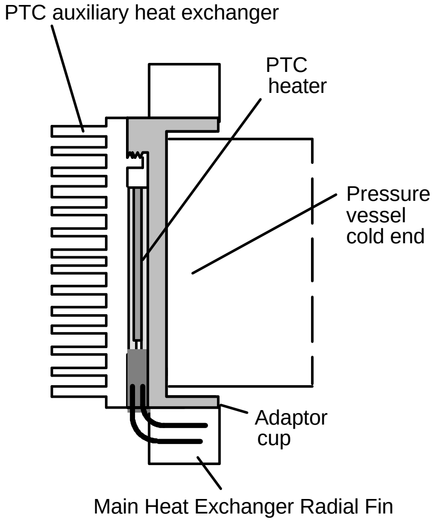

Figure 6.

The Stirling main heat exchanger has to be relatively small because all of the heat absorbed by the machine is being absorbed by a relatively small area at the cold end of the machine. If the main heat exchanger is made too big, it will become inefficient in terms of r-theta, or degrees rise or fall/watt absorbed or rejected.

By extending the area of the main heat exchanger, and reducing the total thermal path length between the process air and the cold head, Stirling machine efficiency is improved.

It's important to note that the Stirling machine is still much more efficient than Peltier devices in cooling mode, even without the PTC auxiliary heat exchanger, because cooling mode air flow and thermal load, of even a high performance air conditioned seat, lie within the capacity range of a small Stirling cooler with a relatively small radial finned main heat exchanger. The charts at the end of this paper are the result of early prototype tests without the PTC auxiliary heat exchanger. When new SVTS machines are built with the PTC auxiliary heat exchanger, performance and efficiency in both cooling and heating mode will be enhanced.

The PTC auxiliary heat exchanger is preferably of the radial fin or "pin-fin" type, which allow air to flow in circumferentially around the perimeter of the heat exchanger through the fins, or pins, to the main blower. Since seat air first travels through the main heat exchanger, which is annular, it's more efficient to draw the air into the PTC auxiliary exchanger from around it's larger area perimeter because that also requires the smallest change in the direction of air flow that is established through the radial main heat exchanger fins.

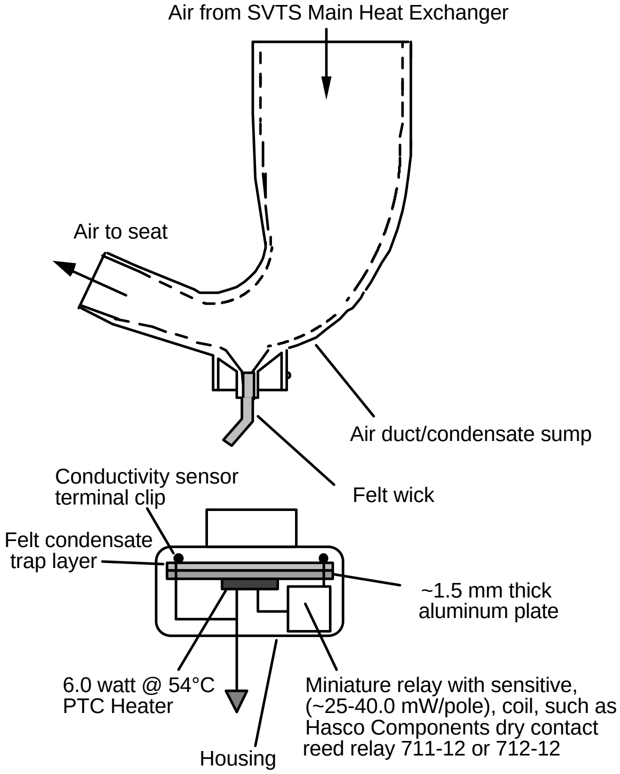

Figure 7.

Figure 7 illustrates the SVTS condensate control, which is crucial to the operation of the SVTS in hot and humid environments. Because the Stirling cooler is so much more efficient, it pumps more heat for a given power input. The Stirling machine is also capable of pumping heat at temperatures considerably further below ambient temperature than the Peltier thermoelectric VTS. Because the SVTS operates at lower temperatures, or greater ΔTs in cooling mode, it is capable of condensing more moisture out of unconditioned ambient air that is being cooled and then blown through the seat air flow pads. Seat air at lower humidity is also more comfortable for the occupant in a humid environment than seat air that has been cooled, but not cooled enough to effect a more desirable level of dehumidification. Drier air is also able to absorb more moisture from the occupant's posterior, resulting in a more comfortable seat initially, especially if the occupant is already perspiring upon entering the vehicle.

Because the Stirling machine is capable of condensing more water out of the seat cooling air in cooling mode, the SVTS requires a condensate management system that has the capacity to handle the worst of circumstances, within the smallest possible space, and with minimal weight, complexity, and cost.

The VTS uses a system of condensate control that involves the use of a wick to move modest levels of condensate under humid conditions to the warm side of the thermoelectric heat pump assembly in cooling mode.

The SVTS condensate control system is different from the VTS control in that it is electrically powered, specifically to re-vaporize condensate, and will only energize, automatically, at a condensation rate requiring active condensate control.

Condensate accumulates in the condensate sump, Figure 7, which also forms the main air duct downstream from the Stirling machine main blower outlet. In this configuration, the SVTS machine is assumed to be mounted a few degrees from vertical within the seat backrest. If the machine is mounted horizontally under the seat, the sump/air duct has to be shaped accordingly.

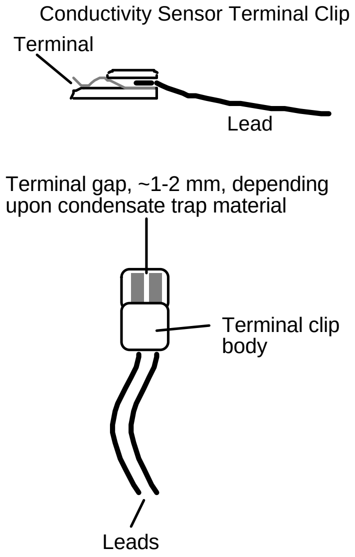

Figure 8.

If enough condensate accumulates to soak the short wick that is embedded within the lower wall of the sump, condensate drips down onto a felt pad that is bonded to a thin aluminum plate. If the felt pad is wetted with enough condensate to make a circuit between the two metal terminals of the conductivity sensor clip, shown in Figure 8, the sensitive relay shown in Figure 7 closes, which energizes a small PTC heating element that heats the aluminum plate, vaporizing the condensate back into the ambient air stream flowing through the vehicle.

If the condensation rate never reaches a level sufficient to fully wet the felt condensate trap, the PTC condensate vaporizer will not energize.

The sensor clips, Figure 8, are simple and easy to assemble by clipping over the edge of the felt condensate trap and aluminum heat spreader plate.

Figure 9 is a plan view of the air duct/condensate sump of Figure 7, looking down into the inlet. The rectangular box located asymmetrically on the left is the snap-on housing for the felt trap and heater section of the condensate control system, with a slotted vent to allow re-vaporized water to escape to ambient.

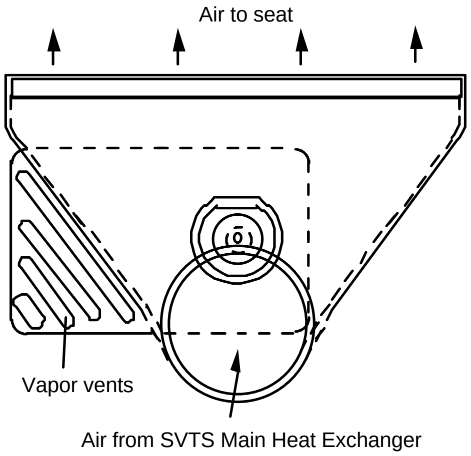

Figure 9.

CONCERN NO. 3 – Figure 10 is an end elevation view of TriLock Spacer Fabric, woven by Pittsfield Weaving Co., in Pittsfield, NH. This material may be woven using different fibers and combinations of fibers, including polypropylene, saran, nylon, etc. The structure of TriLock allows air to flow longitudinally through the woven tubes as well as laterally through the woven tube walls, without collapsing when sat upon. The tubes deflect a small amount when bearing a load, giving the SVTS contact surface added resilience.

TriLock is available in different thicknesses, with correspondingly different tube diameters. For Stirling Variable Temperature Seat use, 6-10 mm is best, because it is very flexible as a sheet, conforming readily to the shape of the user. It also allows for a thinner seatrest and backrest assembly, which is important for optimum vehicle interior space efficiency. It is possible to use a thin layer of Trilock for seating because the seatrest and backrest lengths are usually between 330-406 mm. Mattress pads, for example, require a 12-13 mm diameter TriLock pad because the air flow path is considerably longer, between 1.83-2.03 m in length.

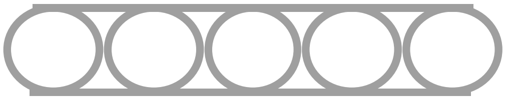

Figure 10.

An excellent 6.35 mm diameter TriLock for the SVTS air flow layer is 9006-007-1, and is made of saran and polyethylene fibers, roughly 70-30. Fiber diameters are .533

mm and .305 mm. Mesh is 8.27/cm with the warp and 8.66/cm across the warp throughout the structure of the material, except for where adjacent tubes interconnect, where the mesh doubles both with and across the warp. TriLock comes off of the weaving machine with the tubes going across the machine, so the warp is perpendicular to the normal axis of the tubes.

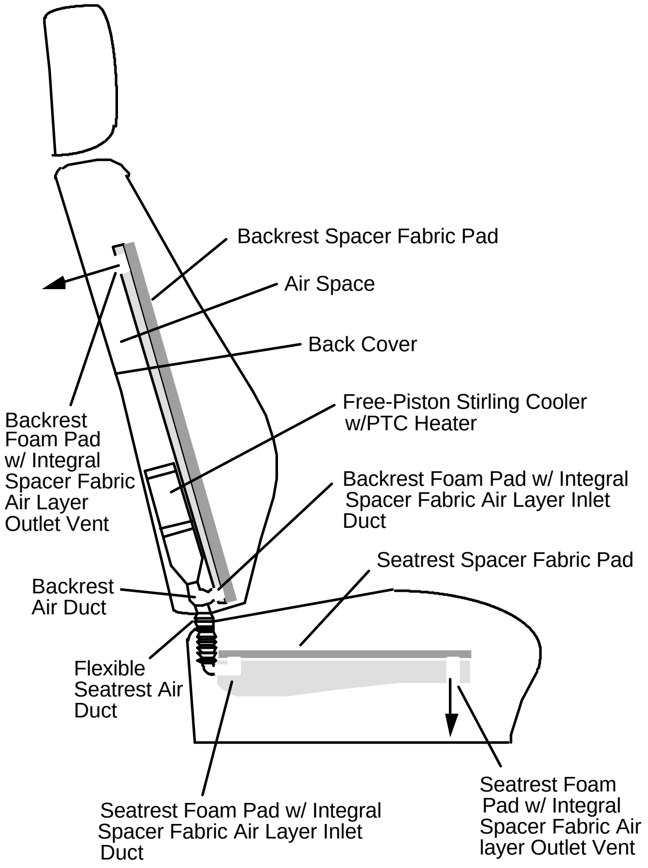

Figure 11.

TriLock has been is daily use for over 3 years as of September 1997, and is in excellent condition. It is a unique material with low air flow pressure drop and long-term durability combined with a high degree of suppleness and conformability. TriLock 007 is self-extinguishing, so it exceeds both the FMVSS 302 rating of 10.16 cm/min. and Ford Motor Co. rating of 5.1 cm/min.

Trilock may be glued to the seat foam, and the air inlet ducts leading to and from the TriLock layers on both the seatrest and the backrest may be molded into the foam as shown in Figure 11, which also shows Spacer Fabric air layer outlet vents molded into the front and top ends of the seat support foam. Figure 11 also shows a flexible seatrest air duct with a bellows section that allows the backrest to be positioned within it's range of angular movement with respect to the seatrest.

Table 1 shows some test numbers obtained using an adjustable resistive thermal conduction load on the cold end of the free-piston Stirling machine. It can be appreciated that the machine achieved a maximum cold end ΔT below ambient of 76.1°F/42.0°C at a sensible COP of 1.83, and achieved a COP of 3.0 at a cold end ΔT of 22.9°F, or 12.6°C below ambient.

This means it is possible to obtain seat air at 74-75.0°F/ 23.3-23.8°C, at a vehicle interior air temperature of 150.0°F/65.6°C.

Table 2 shows test numbers obtained with the radial finned main heat exchanger and convective thermal load, (air), flowing at the indicated rates in cubic feet per minute. Sensible lift and COP simply mean that the condensing rate, under the test conditions, including relative humidity and air DT, was not significant enough to be readily considered in calculating total cooling power. It is sufficient at this point to know that, if any condensing rate were to be considered in calculating total cooling power, it would result in a alatent COP greater than the already impressive sensible COPs shown in the charts.

Table 2 also shows the difference between SVTS Sensible COP and VTS Sensible COP, (Peltier), under similar conditions of ambient temperature and cold side ΔT. It can be seen that the SVTS is much more efficient than the VTS in cooling mode.

Tests shown in Tables 1 and 2 were done with a closed loop driver controller with a cold end temperature setting of ~43-47°F/6.3-8.4°C, measured with a thermistor mounted on the cold end.

Heating mode is not charted because it is relatively straightforward. The COP in heating mode is very close to 1.0. It is not 1.0 exactly because there are some thermal impedances in the heating mode assembly, such as r-theta from the PTC heater to the tips, or crests of the main heat exchanger fins. I2R in the wiring also diverts a minute amount of power that would otherwise be used in raising the temperature of the seat air. However, the COP in heating mode is near 1.0 because the thermal impedances are not very large, and most of them are in the vicinity of seat air flow anyway.

Thermal impedances that reduce COP in heating mode are those which do not contribute to raising the temperature of seat air in heating mode.

Table 1. Cooling Mode Resistive Load Tests

Tamb. °F/C	Tcold °F/C	dTcold °F/C	Twarm °F/C	dTwarm °F/C	Total dT °F/C	Input W	Lift W	Sens. COP
66.2/19.2	43.3/6.3	22.9/12.6	80.4/26.9	14.2/7.8	37.1/20.5	11.6	34.6	3.00
67.6/19.8	44.4/6.9	23.2/13.0	98.9/37.2	31.3/17.3	54.5/30.5	20.6	50.6	2.46
68.2/20.0	43.9/6.6	24.3/13.4	106./41.1	37.8/20.9	62.1/34.2	31.4	70.5	2.25
104./40.0	47.1/8.4	56.9/31.5	119./48.5	15.3/8.4	72.2/40.8	26.3	53.1	2.02
118./47.9	42.3/5.7	75.9/41.9	140./60.1	21.9/12.0	97.9/54.0	26.8	46.5	1.74
121./49.5	44.9/7.2	76.1/42.0	138./58.9	16.9/9.3	93.1/51.0	20.0	36.5	1.83

Table 2. Cooling Mode Air Tests

Input Volts	Input Watts	Tamb. °F/C	RH	CFM/m3/hr.	dTcold °F/C	Sens. Lift W	Sens. COP	x Peltier
12.1	19.72	75.4/24.1	64.0%	8.0/13.6	18.5/10.2	45.67	2.32	4.6
12.1	23.84	78.5/25.8	64.0%	8.0/13.6	24.5/13.5	60.50	2.54	6.0

CONCLUSIONS

Consequences of the much higher efficiency of the SVTS over the VTS include:

1. Because the SVTS is so much more efficient than the VTS, there is much less concern about additional alternator cost, weight, and energy consumption. Even multiple Stirling Variable Temperature Seats, installed in minivans and luxury cars, for example, will have an almost negligible effect upon fuel economy in conventional vehicles, or on battery range in electric vehicles.
2. Because the SVTS is more efficient than the VTS at substantially greater ΔT's, cooling mode performance is greatly improved over the VTS under high vehicle interior air temperature hot soak conditions. It is now possible to cool leather seats almost as quickly and powerfully as cloth seats.
3. The noise level of the SVTS is lower because it does not need to move as much air over the auxiliary, or rejector, heat exchanger in cooling mode, in order to do an even greater amount of cooling.
4. Because the SVTS is so much more efficient than the VTS in cooling mode, the controls are smaller, lighter, and less expensive, because less power moves much more heat. An SVTS machine with a maximum cooling power rating of 40.0 watts, and with a PTC auxiliary heat exchanger, will require a maximum power input of approximately 13.0 watts, or ~1.1 amp at 12.0 VDC, at maximum power. The main blower need not use more than .6-.7 watt, and the auxiliary fan need not use more than ~3.0 watts. Total wattage: 16.6-16.7. The controller, however, need not control more than about 13.0 watts. The main blower, at a rating of .6-.7 watts, may be controlled with a simple potentiometer, or with a very inexpensive logic-switched resistor network for a more automated control approach.

Other important considerations are:

1. Because the SVTS uses helium as the working fluid, it is as harmless to the environment as the thermoelectric VTS.
2. Manufacturing costs are expected to be approximately equal to optimized thermoelectric systems at similar production levels.
3. From the standpoint of reliability and durability, although Peltier thermoelectric systems are extremely reliable and durable when properly designed and engineered, the basic free-piston Stirling machine, which has been in development for over twenty years, although very sophisticated from a design and engineering standpoint, is mechanically simple and robust.
4. The Spacer Fabric air flow layer material is the major component of the dramatic improvement in orthopedic support and comfort, as well as uniformity and efficiency of thermal transfer, of the SVTS over the VTS. Thin layers of TriLock Spacer Fabric are supple enough to be used with all types of adjustable lumbar supports, including automatic cycling lumbar units, and may also be extended to the seat side bolsters as well. TriLock has also been made with self-extinguishing fibers.

For all practical intents and purposes, there is no difference in environmental compatibility, durability, and reliability between the SVTS and the VTS, however, the SVTS dramatically outperforms the VTS in cooling mode in terms of efficiency, ΔT, and perceived cool-down time, while offering enhanced control simplicity in heating mode with a relatively very small reduction in heating mode efficiency, resulting in a heating mode efficiency that is virtually the same as conventional resistance wire heated seats.

Important advantages of convective, (air), heating over resistance wire heating are:

1. It is virtually impossible for a vehicle occupant to be burned by warm air that is temperature limited by the PTC heating element. Even if the input voltage to the PTC heating element were to exceed specification, the PTC heater can be specified taking potential overvoltage into account because the total convective heating power is spread out over a larger area than with resistance wire seat heaters, which are limited to producing heat at the actual wire grid itself, which is a relatively small area. This means that the resistance wires have to get hotter in order to convey the same effective occupant heating wattage as convective heating can convey at lower temperatures because of the larger effective thermal transfer area percentage of the seat contact surface.
2. Because the total heating power is so relatively evenly spread out over the entire seat contact area, the heating intensity at any given point is lower than than for resistance wire heated seats, resulting in gentle yet effective heating without hot spots while maintaining the same, or even greater, total heating capacity.

Orthopedic support and comfort are significantly improved because the new spacer fabric air flow layer structure is transparent to the user, while preserving high air flow efficiency and very even thermal distribution over the entire seat contact surface.