EVALUATION OF AN AUTOTHERM
ENERGY CONSERVATION SYSTEM

FINAL REPORT

by

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ABSTRACT

Six AUTOTHERM Energy Conservation Systems were field tested on a like number of Department of Transportation and Public Facilities vehicles during the 1981-82 winter. Operator acceptance and use of the systems were evaluated by interviewing vehicle operators. The fuel savings and air pollution reduction potentials of the AUTOTHERM system were estimated. None of the test applications had a good economic rate of return nor caused any significant reduction in vehicle emissions. Although the AUTO-THERM system was shown to work reliably, we were not able to identify an application within the DOTPF vehicle fleet where the system could be economically justified.
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INTRODUCTION

In early 1981, Department of Transportation and Public Facilities (DOTPF) was approached by Alaska Department of Environmental Conservation (ADEC) regarding evaluation of the AUTOTHERM Energy Conservation System because of its potential for reducing vehicle emissions and saving energy. ADEC had been in contact with representatives of AUTOTHERM, Inc. in Barrington, Illinois, and seven sample systems were supplied to DOTPF Research in Fairbanks for testing purposes.

Additional test systems went to ADEC in Juneau and the Alaska State Troopers in Anchorage. This report covers only those systems evaluated by DOTPF in Fairbanks.

DESCRIPTION OF AUTOTHERM SYSTEM

The AUTOTHERM system makes use of the sensible heat stored in the block, coolant and lubricating oil of a hot engine to keep the vehicle interior warm during relatively short non-use periods so that the vehicle does not have to be left idling in cold weather for this purpose. Fuel consumption and air emissions are said to be reduced in accordance with the amount of engine idling that is eliminated due to the AUTOTHERM system.

The AUTOTHERM Energy Conservation System has the following component parts (see Figure 1):

Circulating pump - A small, magnetically coupled, electric motor driven circulator is spliced into one of the two vehicle heater hoses as shown in Figure 2. It automatically continues circulation of the engine coolant through the vehicle heater whenever the engine is turned off. The vehicle battery supplies 12 volt power for this unit. It requires only about 0.5 amps, while typical heaters draw 3.5 to 6.5 amperes on the "low" or "medium" setting (according to AUTOTHERM).

Thermostat unit - This component, which is installed in series with
Figure 1 -- Main components of AUTOTHERM Energy Conservation System.

Figure 2 -- Circulator and thermostat installed in 1979 Plymouth research vehicle.
the circulator in the same hose, stops the circulator and vehicle
heater fan whenever the coolant temperature falls below 95°F. It is
designed to keep the vehicle battery from being run down by continued
operation of the circulator and heater fan.

Switch and pilot light - These components, which are installed in the
vehicle instrument panel, are used to manually turn the system on or
off and to indicate when the circulator is operating.

Hour meters - These units are optional. When installed, they record
the AUTOTHERM system running time, engine operating time and/or the
amount of time that a vehicle operator occupies the driver's seat. The
information gained with them can be used as an indicator of how much
the system is being used and the amount of idling time that is being
eliminated. With an hour meter recording engine hours and "seat
occupied" hours, the difference gives a measure of the engine idling
that occurs while the operator is not in his vehicle. Any reduction
of this difference after an AUTOTHERM system is installed is a direct
measure of reduced idling time. This meter is simply wired into the
seat pressure switch that opens the ignition circuit on some cars
when the driver or passenger fails to fasten his seat belt. The
limitations of this setup, however, are that it does not indicate how
much time the operator may be idling the engine while occupying the
vehicle, and only a few models are equipped with a seat pressure
switch.

When the AUTOTHERM system is properly installed in a vehicle, the circu-
lator will run whenever the engine is shut off (and the on-off switch is
on). This will continue until the coolant temperature is lowered to
approximately 95°F at which time the thermostat will shut off the circu-
lator and vehicle fan. The fan would normally be left in the low or medium
position to extend the length of time the car interior would receive heat
and minimize draw on the vehicle battery.
STUDY DESIGN

In late September and early October 1981, AUTOTHERM systems were installed by State maintenance people on six DOTPF vehicles described in Table I. Five were selected because they were among the Fairbanks DOTPF vehicles considered likely to have a large amount of idling time during winter. The sixth was a Research Section vehicle and was selected so that the researchers could have first hand experience with the system and test it more intensively if desired. The vehicle was also slated for use on a project where idling time was expected to be high.

All six vehicles were installed with double hour meters, one on the engine and the other on the AUTOTHERM circulator. None of the vehicles had a seat pressure switch.

The six vehicles were used in their normal modes of operation by assigned vehicle operators through the 1981-82 winter. Operators were questioned informally during January about the performance of their AUTOTHERM systems. They were then interviewed in May at which time survey forms were completed regarding their impressions and experiences with the systems.

A series of tests was run on the Research vehicle during January 1982 to determine how long the AUTOTHERM system would run and how warm the car interior would stay at 10°F ambient temperature.

Based on the information generated in the manner indicated above, calculations were made to show the economic factors and air pollution reduction potential involved with AUTOTHERM use.

SUMMARY OF RESULTS

Operational Testing on In-Use Vehicles
Results of an AUTOTHERM performance survey, which included an interview with operators of each of the six vehicles, are given in Table I. The table shows one good, one fair-to-good, three poor, and one very poor
## TABLE 1
Survey of Autotherm Performance
During the Period September 1981 to May 1982

<table>
<thead>
<tr>
<th>Vehicle Description</th>
<th>Operator</th>
<th>Overall Assessment</th>
<th>Problems Encountered</th>
<th>Estimated Idling Time Saved per Work Day (minutes)</th>
<th>Autotherm Hours</th>
<th>Engine Hours</th>
<th>Estimated Effective Temperature Range (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>79 Dodge Pickup, 8 cyl, 318 CID</td>
<td>Road Maintenance Foremen (two)</td>
<td>Good</td>
<td>Battery ran down during cold period.</td>
<td>55</td>
<td>72.5</td>
<td>801.5</td>
<td>-20 to 32</td>
</tr>
<tr>
<td>79 Plymouth Station Wagon, 8 cyl, 440 CID</td>
<td>Research Engineers and Technicians</td>
<td>Poor</td>
<td>Vehicle use was not suited to Autotherm use.</td>
<td>0</td>
<td>8.7*</td>
<td>375.0</td>
<td>0 to 30</td>
</tr>
<tr>
<td>78 Ford Pickup, 6 cyl, 300 CID</td>
<td>Road Maintenance Foreman</td>
<td>Very Poor</td>
<td>Vehicle had poor cab heater. Autotherm made it worse.</td>
<td>0</td>
<td>0**</td>
<td>721.1</td>
<td>--</td>
</tr>
<tr>
<td>80 Dodge Pickup, 8 cyl, 318 CID</td>
<td>Supply Section Expediter</td>
<td>Fair-Good</td>
<td>Battery ran down during cold period. Did not use thereafter.</td>
<td>30***</td>
<td>0.2**</td>
<td>237.8</td>
<td>-20 to 20</td>
</tr>
<tr>
<td>81 Chevrolet Crewcab, 8 cyl, 350 CID</td>
<td>Road Maintenance Foreman</td>
<td>Poor</td>
<td>Caused circulating heater to air lock.</td>
<td>&lt;5</td>
<td>150.7</td>
<td>856.3</td>
<td>15 to 32</td>
</tr>
<tr>
<td>79 Dodge Pickup, 8 cyl, 318 CID</td>
<td>Equipment Section Expediter</td>
<td>Poor</td>
<td>Operation of Autotherm circulator was intermittent. Battery ran down once.</td>
<td>&lt;5</td>
<td>102.5</td>
<td>638.5</td>
<td>--</td>
</tr>
</tbody>
</table>

* Autotherm hour meter was not operational prior to 1/21/82.
** Autotherm hour meter did not work.
*** Used at this rate only half the winter. Was not used after battery ran down in late December, 1981.
rating. The only significant operational problem experienced was that the current draw of the circulator and heater fan had a tendency to run the vehicle battery down in extremely cold weather.

Estimated reduction in vehicle idling time ran from zero to 55 minutes per work day, although the 55 minute estimate is not supported by the AUTOTHERM hours recorded. This figure was actually the average of estimates by two operators who used the vehicle alternately. The first operator, who used the vehicle only in the fall and spring gave an estimate of 90 minutes per day. The other operator estimated 18-20 minutes per day, which is probably a more realistic figure.

The temperature range over which the AUTOTHERM system was believed useful varied from -20°F to +15°F on the low side and from 20°F to 30°F on the high side.

The most common complaint from vehicle operators was that the system did not keep the vehicle interior warm enough long enough during cold weather to make it worth using. In extreme cold, heat is lost so rapidly from the engine to the surroundings that there isn't enough to keep the inside of the vehicle warm more than a few minutes. The problem is compounded by a high rate of heat loss from the vehicle interior, particularly when wind accompanies low temperature weather.

**Controlled Testing on Research Vehicle**

The Research vehicle (440 CID stationwagon) was used for a series of tests to see how long the AUTOTHERM would run and how warm the passenger compartment would stay at an ambient temperature of 10°F. As shown in Table II, the average AUTOTHERM running time was 51 minutes; the car interior averaged 38°F at the end of the tests and 56°F at the start. When the heater fan was placed on medium speed (instead of low), AUTOTHERM running time dropped from about 50 minutes to 35 minutes. In Test 2, higher wind speed apparently caused a significant reduction in car interior temperature although it did not affect AUTOTHERM running time.
<table>
<thead>
<tr>
<th>Test</th>
<th>Fan Setting</th>
<th>Ambient Temp. (°F)</th>
<th>Car Interior Temperature (°F)</th>
<th>AUTOThERM Running Time (Minutes)</th>
<th>Wind Speed (mph)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Low</td>
<td>10</td>
<td>62 Start 50 End</td>
<td>50</td>
<td>0-5</td>
<td>(a)</td>
</tr>
<tr>
<td>2</td>
<td>Low</td>
<td>9</td>
<td>57 Start 23 End</td>
<td>50</td>
<td>15-20</td>
<td>(b)</td>
</tr>
<tr>
<td>3</td>
<td>Med</td>
<td>9</td>
<td>- Start - End</td>
<td>35</td>
<td>15-20</td>
<td>(b)</td>
</tr>
<tr>
<td>4</td>
<td>Low</td>
<td>9</td>
<td>52 Start 32 End</td>
<td>70</td>
<td>2-15, Gusty</td>
<td>(a)</td>
</tr>
<tr>
<td>5</td>
<td>Low</td>
<td>9</td>
<td>52 Start 46 End</td>
<td>50</td>
<td>2-15, Gusty</td>
<td>(c)</td>
</tr>
</tbody>
</table>

Averages: 56, 38, 51

(a) Car warmed up to operating temperature in parking lot.
(b) Car driven 7 miles.
(c) Placed 3 1/2 inches of foil back insulation over engine. Hood did not close all the way.
DISCUSSION OF RESULTS

Operator Acceptance
Operators of only two out of the six vehicles reported that they liked having the AUTOTHERM system, and the operator of one of these did not use his system after mid-winter when he attributed its use to a run down battery. When asked about whether they would consider installing AUTOTHERM systems on their own personal vehicles, the answer was a unanimous "no". Two operators were quick to point out that this was only because their own vehicles did not have the kind of use that would make an AUTOTHERM installation economical.

In general, operator acceptance was fair to poor. Most of the operators liked the units in late fall when the weather was moderate (around zero °F). During winter, the systems were found to be ineffective in extreme cold and even appeared to cause battery problems. Several operators then became sour on AUTOTHERM and did not begin using their systems as spring approached.

Another factor in this regard is the large amount of solar energy available in Fairbanks during late February, March and April. It is collected quite efficiently by vehicles parked in the sun. The AUTOTHERM system may rarely be needed during the day in this period, even though ambient temperatures are within the range considered appropriate for its use.

Fuel Savings & Economic Analysis
Assuming high operator acceptance and use, fuel savings due to reduction in vehicle idling is the key factor in economic attractiveness of the AUTOTHERM system. If a given vehicle does not normally have an appreciable amount of engine idling for personal comfort in its use schedule, little or no energy can be saved by installing an AUTOTHERM system regardless of how much the operator likes it and uses it.

First, let us consider the reduction in vehicle idling needed to provide a reasonably good payback on the investment for the system. We will assume that the AUTOTHERM is installed on a DOTPF pickup truck. Pickups are
reported to have an average fuel consumption during warm idling of 0.756
gallons per hour. 4 May 1982, unleaded gasoline prices for DOTPF bulk
supply tanks averaged about $1.25/gallon. AUTOTHERM systems are available
through a Fairbanks retailer (B & C Supply Co.) at $207.75 each. If we use
the current DOTPF shop rate of $62/hour and the installation time experi-
enced for the six test units of 2.0 hours per vehicle, total cost of the
system is shown as follows:

\[
\begin{align*}
\text{Retail price for AUTOTHERM.} & \quad \$208. \\
\text{DOTPF installation cost (2hrs x $62/hr).} & \quad 124. \\
\text{Total} & \quad 332.
\end{align*}
\]

We believe that a two year payback of the total initial costs is the
longest that would be reasonably attractive from an economic standpoint.
This period would have to incorporate the following reduction in idling
time:

\[
\begin{align*}
332 \times \frac{1 \text{ gal fuel}}{1.25 \text{ $/gal}} \times \frac{1 \text{ hr}}{0.756 \text{ gal fuel}} &= 351 \text{ hours/2 yr} \\
&= 176 \text{ hours/year} \\
&= 176 \text{ hours/26 winter weeks} \\
&= 176 \text{ hours/130 winter days (5 days/wk)} \\
&= 1.35 \text{ hours/winter day}
\end{align*}
\]

The cost of the AUTOTHERM systems could be reduced substantially by buying
direct from AUTOTHERM, Inc. in Barrington, Illinois. The cost of installa-
tion could probably be reduced considerably by using service station labor
at $35/hr to install the AUTOTHERMS. Prices from the factory were quoted
on May 27, 1982 as follows:

<table>
<thead>
<tr>
<th>No. units</th>
<th>Price Each* (without hour meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - 4</td>
<td>163.95</td>
</tr>
<tr>
<td>5 - 24</td>
<td>160.25</td>
</tr>
<tr>
<td>25 - 49</td>
<td>157.70</td>
</tr>
<tr>
<td>50 - 99</td>
<td>155.45</td>
</tr>
<tr>
<td>100 - 249</td>
<td>150.60</td>
</tr>
</tbody>
</table>

*An additional $4.00 each must be added for air freight to Fairbanks.
If we use a quantity price from the factory of $160 each and service station installation labor of $70 each, the two year payback is reduced to 122 hours/yr or 56 minutes/winter day of idling time.

A less conservative economic analysis can be made by considering the time value of money and using an interest rate for opportunity capital of 15%. If the AUTOTHERM unit is not removed from a vehicle when it is sold, a useful life of three years seems likely. Assuming that the presence of an AUTOTHERM system would not add to the sales price of a used vehicle, and the system does not require any maintenance, the economics are straightforward. A three year expected life gives a capital recovery factor of 44%, i.e. the AUTOTHERM would have to return 44% of its installed cost per year in order to provide a 15% return on the investment. This amounts to $101 of reduced fuel costs each year for the $230 installation described above. It is equivalent to 107 hours per year or 50 minutes per winter day of reduced idling.

Based on the Fairbanks experience (Table I), only one vehicle had a reduction in idling time close to this amount. It was a 318 CID pickup used alternately by two maintenance foremen. As shown in Table I, however, this was probably a high estimate. The AUTOTHERM hour meter on this vehicle showed a total of only 72.5 hours for the entire winter. Since many of these hours are not reduced idling time, 10 to 15 minutes per day is probably a more realistic estimate.

The next closest vehicle was a 318 CID pickup used by an expediter in the DOTPF Supply Section. He experienced an estimated reduction in vehicle idling of 30 minutes per day until mid-winter when the AUTOTHERM system apparently ran his battery down during a period of extreme cold. After that, the expediter no longer used the system even though he was encouraged to do so.

The four other Fairbanks vehicles had small or negligible reductions in idling time. On account of its actual use schedule (it was not used for a project in remote areas as originally planned), the Research vehicle was
idled very little for personal comfort. Any idling that it did, as with most Fairbanks vehicles, was for the purpose of warming up the engine and vehicle interior after a cold soak period.

The Equipment Section vehicle idled a good deal for personal comfort, but intermittent operation of the circulator caused the operator to lose confidence in the AUTOTHERM system and he did not rely on it. DOTPF equipment maintenance people tried to trouble shoot the system but were not successful in locating the problem.

The remaining two maintenance foremen vehicles had very little reduction in idling due to low acceptance of the AUTOTHERM systems by the people using them. The foreman operating the 350 CID crew cab did not consider the system useful except in the fall when the weather was moderate. In addition, his vehicle use characteristics apparently did not lend themselves to much idling for personal comfort. He said that he is dressed warm and does not really need the output of heat provided by the AUTOTHERM system. He did leave his system on all the time, however, and recorded a total of 151 AUTOTHERM hours during the winter.

The other maintenance vehicle was a six cylinger, 300 CID pickup. Its AUTOTHERM system received the worst rating of all. The maintenance foreman operating this vehicle did not use the system except for a few initial tries, and he had nothing positive to say about it. He believes that the circulator and thermostat units installed in the heater hose restrict coolant flow to the cab heater and were at least partially responsible for a chronic problem with insufficient heater output. Because of low heater capacity, the foreman did not want to remove any additional heat from the engine block by using the AUTOTHERM. He believes that this delays the time when the heater starts delivering maximum heat when the vehicle is being warmed up after a relatively short shutdown period.

Air Pollution Impact
A reasonably good estimate of the impact that warm idle emission reduction (due to less engine idling as a result of AUTOTHERM use) would have on air pollution can be made by using a warm idle emission rate of 15 grams of
carbon monoxide (CO) per minute for a 1975 model 300 CID engine of American manufacture.\textsuperscript{1,2} Since the majority of CO emissions in Fairbanks have been shown to result from cold starts,\textsuperscript{1,2,3} a comparison with these cold start emissions is instructive.

Past work has shown that a cold start emission of 389 grams is typical for the 300 CID engine mentioned above at 0°F.\textsuperscript{2} The length of warm idle time that has the same amount of CO emission is calculated as shown:

\[
\frac{1 \text{ minute}}{15 \text{ g. CO}} \times 389 \text{ g. CO} = 26 \text{ minutes}
\]

In other words, the CO emitted during cold start is equivalent to that given off during 26 minutes of warm idling. Since none of the test vehicles averaged even 26 minutes per day of warm idle reduction over the entire winter, the impact on air emissions would be small. There undoubtedly are a few vehicles in Fairbanks (such as taxis) that are idled for personal comfort more than an hour per day, all winter long, but the number of these vehicles is so limited as to make the potential of the AUTOTHERM for air pollution reduction in Fairbanks almost negligible.

\textbf{AUTOTHERM Reliability and Vehicle Operating Problems}

As noted above, the Equipment Section vehicle had a problem with intermittent operation of the circulator. It was probably due to a defective thermostat, but may have been in the circulator itself. When the operator left the vehicle with the AUTOTHERM system turned on, the circulator might not be running (as it should have been). When he came back 10 or 20 minutes later, the circulator may or may not have started working during his absence. There appeared to be no pattern to the sequence of operating or not operating.

There were no other operational problems noted with any of the AUTOTHERM systems, except that three of the six AUTOTHERM hour meters did not accumulate hours of AUTOTHERM operations as they were supposed to. One of them was on the Research vehicle. In mid-winter, its hour meter started working after a new "bite" was taken on the electrical wire from the thermostat with the clamp-on wire connector.
Lack of AUTOTHERM hour data did not affect the outcome of the tests since this information was rather ambiguous. Because the systems are normally left on, the AUTOTHERM runs each time the vehicle is shut off. The hours accumulated have no direct relationship to the amount of idling that is being eliminated—only to the number of times the vehicle is shut off and the length of time before it is started up again.

The most significant problem that apparently related to use of the AUTOTHERM systems was increased battery problems in cold weather. Three of the six primary operators reported that the unit ran their vehicle batteries down at least once in very cold weather. As might be expected, these operators were reluctant to use their AUTOTHERM systems after experiencing battery trouble, and there was a great deal less use of the units in the spring than in the fall.

The battery discharge problems could probably be rectified by installing larger (or dual) batteries in vehicles to be equipped with AUTOTHERM systems. The cost of this modification would be substantial, however. A more cost effective solution might be to turn off the systems below a certain temperature. There is some question, however, about whether an operator would turn the system on and off as the temperature fluctuates around a given point. For one thing, he has to know the temperature at all times in order to respond to it. Even if he knows the temperature, the operator must have sufficient motivation to take this action.

One other problem caused by the AUTOTHERM was interference with the operation of the engine circulating heater on one vehicle. An airlock reportedly formed at the circulator on occasion. The connection then had to be broken and the engine and cab heater run in order to restore the engine heater's capability for circulating warmed antifreeze.

**Personal Comfort and Use of the System**

While great claims are made by AUTOTHERM for the gain in personal comfort resulting from use of their system, it should be noted that there is actually a decrease in comfort compared to allowing the vehicle to idle.
From the car interior temperature data in Table II, it becomes obvious that a lower temperature will be encountered by the operator if he uses the AUTOTHERM (even at $+10^\circ F$) than if he had idled the vehicle with the heater on medium or high. The "end" temperatures averaged $18^\circ F$ lower than the "start" temperatures, and the latter were obtained by vehicle idling.

A vehicle with an idling engine would be providing maximum heater output when an operator returned to it, whereas one that had an operating AUTOTHERM system would have to be run for a few minutes before the engine warmed up to normal operating temperature. Thus there is a sacrifice in operator comfort, especially at low temperatures.

The only real improvement in comfort results in a comparison with running the AUTOTHERM system vs. shutting off the engine without the system. But here, we are not talking about any economic gain. The comfort gained by using the AUTOTHERM system must be enough to offset the sacrifice in comfort resulting from not idling the vehicle's engine in order for the operator to want to use the AUTOTHERM system. Operator attitude and ambient temperature also play a major role in AUTOTHERM use. During extreme cold, many Fairbanks vehicle operators let their vehicles idle because they are afraid they might not get them to re-start. Comfort is only an added benefit, because most people usually dress warm enough to endure the cold.
CONCLUSIONS AND RECOMMENDATIONS

The AUTOTHERM Energy Conservation System is a reliable, low maintenance device that does what it is designed to do. It was not very well accepted, however, by operators of six DOTPF vehicles in which the system was installed. Its usefulness is limited by vehicle engine size and heating system characteristics, the mode and schedule of vehicle use, ambient temperature and the attitude of vehicle operators.

None of the six vehicles tested had a good economic rate of return based on the typical installed cost of an AUTOTHERM system. The AUTOTHERM system is not recommended for fleet wide application to DOTPF vehicles in Fairbanks or elsewhere. It is worthy of consideration, however, for individual vehicles idled for personal comfort more than 50 minutes per day, five days per week, 26 weeks per year (107 hours/year). Because the system is not as effective below 0°F and is generally ineffective below -20°F, it is less applicable to the colder parts of Alaska.

Because its usefulness is limited to a relatively small number of special purpose vehicles, the potential impact for Statewide energy savings and air pollution reduction is very small.

Vehicles equipped with the AUTOTHERM system in areas as cold as Fairbanks should have extra heavy duty or dual batteries installed in them to minimize the risk of battery run-down in extreme cold due to additional current draw by the AUTOTHERM system. This, of course, will make the system even more difficult to justify economically.
REFERENCES


