Summary of the Fire Safety Impacts of Methanol as a Transportation Fuel

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ABSTRACT

Both for air quality and energy security reasons, a great deal of attention is currently being given to methanol as a candidate to complement petroleum to meet future transportation fuel needs. It is important that safety considerations also be taken into account when analyzing the appropriateness of alternative fuels such as methanol for use in the transportation sector. The current fire safety risk with gasoline is substantial: 216,000 fires resulting in 1,000 fatalities, 7,600 serious injuries, and $430 million in property damage. Due to the lower volatility and higher flammable limit of methanol, pure methanol (M100) is projected to result in as much as a 90 percent reduction in the number of automotive fuel related fires relative to gasoline. A smaller but significant reduction of 40 percent is projected for M85, a blend of 85 percent methanol and gasoline. Assuming that concerns over flame luminosity can be solved with a fuel additive, then due to the greatly reduced heat release rate from a fire, as much as a 95 percent reduction in fire related fatalities and injuries relative to gasoline may result with M100. As much as a 70 percent reduction in fatalities and injuries may be possible with M85. In addition to flame luminosity concerns, fuel tank flammability concerns also exist with M100. While a considerable difference of opinion exists on these issues, it is hoped that by implementing certain vehicle modifications and utilizing fuel additives, these concerns can be greatly reduced or eliminated.

BACKGROUND AND ASSUMPTIONS OF ANALYSIS - This paper addresses the safety aspects of methanol as a fuel, and does not address the feasibility of the functionality of a methanol powered vehicle. In addition to limitations of the data used as the basis for these comparisons (inaccurate reporting, small sample size for light-duty diesel vehicles, diesel data confounded with other Class II fuel data, no indication of whether the fuel cited as the material first ignited was the fuel on which the vehicle was being operated, differences in vehicle design and usage patterns), the analysis is also limited by our knowledge of the design of future methanol vehicles. It is assumed for purposes of this analysis that fuel leakage and spill rates from methanol vehicles will be no different than from current vehicles. Although material compatibility problems can exist with certain metal, plastic, and rubber components when methanol is substituted for gasoline, it is assumed that these parts will be replaced with methanol compatible parts, yielding no change in fuel release rates. It is further assumed that any other vehicle design changes will not significantly degrade the fire safety of the methanol vehicles relative to their gasoline counterparts. In particular, it is assumed that technology can be developed making cold start of light-duty M100 vehicles feasible, and that this technology will not
negatively impact safety. In addition, no effort has been made in this analysis to take into account the possible effects that the increase in fuel consumption associated with the methanol fuels might have on the frequency of fire or the hazard of a fire once it occurs.

**VEHICLE FIRES**

There are an estimated 500,000 collision and noncollision vehicle fires annually in the United States which are unintended, and for which arson is not suspected.\(^1\,^2\) These fires result in approximately 1,400 fatalities, 9,300 serious injuries, and $830 million in property damage.\(^1\,^2\)\(^*,\) The actual cost is much greater due to the lost productivity and medical expenses associated with the injuries and the value associated with the loss of life.

These estimates and those which follow are based primarily on an analysis of the Federal Emergency Management Administration's National Fire Incident Reporting System (NFIRS) for 1986.\(^1\) In the case of collision situations, however, this database underestimates the total number of fires, fatalities, and injuries. A previous EPA report analyzed a number of vehicle fire data reports to develop new estimates for the total number of collision related vehicle fires and the associated fatalities and injuries.\(^2\,^4\,^5\) The resulting estimates were based primarily on the National Highway Traffic Safety

\(^*\) Numbers in parentheses designate references at end of paper.

\(^*\) Since injuries, fatalities and property damage in vehicle collisions involving fire often occur as a result of the collision, not all of the fatalities, injuries, and property damage can be attributed to the fire. Although it is difficult to assess whether death or injury occurred due to the collision or the fire, it has been estimated in a NHTSA report that as many as 60 percent of the fatalities may be due to the fire, and this is assumed to be true for injuries and property damage as well.\(^3\) The values shown in this paper are thus scaled down by 40 percent.

Administration's (NHTSA) Fatal Accident Reporting System (FARS) and another NHTSA report. The collision results from the NFIRS database used here have been adjusted proportionally upwards to reflect the totals found in the EPA report.

**LIGHT-DUTY VEHICLE AND LIGHT-DUTY TRUCK FIRES** - Of the 500,000 annual vehicle fires, roughly 84 percent, or 420,000, are associated with light-duty vehicles and light-duty trucks (LDV/LDT).\(^1\) Similarly, roughly 72 percent of the fatalities, 70 percent of the serious injuries, and 60 percent of the property damage is associated with LDV/LDT fires.\(^1\) Figure 1 shows a breakdown of the fires, injuries, fatalities, and property damage into the different vehicle classifications.

**FIGURE 1**

**VEHICLE FIRE DISTRIBUTION**\(^1\,^2\)

| ALL 1986 FIRES | 2,141,000 Fires  
| 2,141,000 Fires  
| 4,000 Fatalities  
| 124,000 Injuries  
| $830 Million in Property Damage  
|  
| VEHICLE RELATED FIRES | 500,000 Fires  
| 1,400 Fatalities  
| 9,300 Injuries  
| $830 Million in Property Damage  
|  
| COLLISION FIRES | 17,300 Fires  
| 2,120 Fatalities  
| 9,300 Injuries  
| $124 Million in Property Damage  
|  
| NON-COLLISION FIRES | 480,000 Fires  
| 370 Fatalities  
| 4,000 Injuries  
| $177 Million in Property Damage  
|  
| LDV/LDT | 14,000 Fires  
| 3,210 Fatalities  
| 11,600 Injuries  
| $124 Million in P.D.  
|  
| LDV | 1,300 Fires  
| 510 Fatalities  
| 210 Injuries  
| $124 Million in P.D.  
|  
| HDV | 40,000 Fires  
| 2,120 Fatalities  
| 1,482 Million in Property Damage  
|  
| LDV/LDT | 510 Fires  
| 70 Fatalities  
| 250 Injuries  
| $15 Million in P.D.  
|  
| HDV | 161,000 Fires  
| 100 Fatalities  
| 1,250 Injuries  
| $1,700 Million in P.D.  
|  
| Gasoline | 9,000 Fires  
| 3,310 Fatalities  
| 1,160 Injuries  
| $15 Million in P.D.  
|  
| Class II Fuel | 230 Fires  
| 50 Injuries  
| 88 Million in P.D.  
|  
| Class II Fuel | 1,410 Fires  
| 0 Fatalities  
| 120 Injuries  
| 1.6 Million in P.D.  
|  
\(^*\) Only those 60 percent assumed to be due to the fire itself (based on a NHTSA report)  
\(^*\) Property Damage.
In roughly 58 percent of collision and 40 percent of noncollision LDV/LDT fires, gasoline is the material reported to be first ignited (See Table 1).(1) These gasoline fires account for roughly 70 percent of the fatalities and injuries in LDV/LDT collision situations, and 45 percent in noncollision situations. Thus, it is apparent that gasoline fires are some of the most hazardous vehicle fires. Figure 1 shows the number of fires which are attributable to gasoline, and the number of injuries, fatalities, and property damage which are in turn attributed to those fires. Even after the extensive improvements over the past few decades to reduce the frequency and size of leaks and spills from light-duty vehicles, fires with gasoline vehicles continue to pose a significant risk. This is attributable in large part to the extreme flammability of gasoline.

### Table 1

<table>
<thead>
<tr>
<th>Fires</th>
<th>Fatalities</th>
<th>Injuries</th>
<th>Property Damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>LDV/LDT</td>
<td>Gasoline Collision 58 73 69 60</td>
<td>Noncollision 40 45 43 35</td>
<td></td>
</tr>
<tr>
<td>Class II Fuels</td>
<td>Collision 0.4 0 0.4 1.2</td>
<td>Noncollision 0.4 0 0.3 0.3</td>
<td></td>
</tr>
<tr>
<td>HDV</td>
<td>Gasoline Collision 38 61 51 29</td>
<td>Noncollision 21 43 27 16</td>
<td></td>
</tr>
<tr>
<td>Class II Fuels</td>
<td>Collision 10 22 26 38</td>
<td>Noncollision 2 14 3 5</td>
<td></td>
</tr>
</tbody>
</table>

It is likely that the risk due to fire with gasoline is even greater than the estimates made here indicate, since these include only fires where gasoline was the material reported to be first ignited. Gasoline was probably involved in many more of the fires, especially the more severe fires which resulted in injury or death. Unfortunately, no data is presently available which provides any indication as to how many additional fires involved gasoline, or what fraction of the fatalities and injuries were associated with fires where gasoline became involved. As a result, only those fires where the fuel was the material reported to be first ignited are included in any further analysis in this paper. Thus, it should be kept in mind that the projections and estimates in this paper are conservative, and the actual hazard of gasoline may be significantly greater.

Despite the fact that diesel fuel accounted for approximately two percent of our Nation's LDV/LDT travel in 1986, all Class II fuels (the NFIRS database does not distinguish between diesel fuel and other Class II fuels), including diesel fuel were the materials reported to be first ignited in just 1,460 or 0.35 percent of the collision and noncollision LDV/LDT related fires.(1,6) Because of the low number of fires which occur with diesel LDV/LDTs, the database on injuries, and fatalities is extremely limited. No deaths were reported in 1986 to be due to Class II fuel fires, and only approximately 20 injuries. Refer to Figure 1.

In an attempt to quantify just the diesel portion of these Class II fuel fires, actual fire incident reports were obtained. At the time this paper was written, just 35 of the noncollision related LDV/LDT incident reports were obtained which contained enough information to determine the material which was first ignited. Just four, or 11 percent of the fires coded as Class II fuels were actually associated with diesel fuel. The remaining incidents were attributed to motor oil (37%), transmission fluid (17%), gasoline (11%), kerosene (6%), power steering fluid (3%), brake fluid (3%), and other substances (12%).

Thus, the LDV/LDT noncollision values in Table 2 for diesel fuel have been scaled down to reflect just 11 percent of the Class II fuel incidences as reported in NFIRS. While similar results could be expected with collision incidences (and heavy-duty vehicle incidents to be discussed later), until such time as the actual incident reports are obtained for these situations, no adjustment will be made. As a result, for LDV/LDT collision (and HDV) situations, diesel fuel fires, fatalities, injuries, and property damage can be considered to be significantly over reported.
Table 2

1986 U.S. LDV/LDT Fires and Deaths, Injuries, and Property Damage Due to Fire* (1,3,4)

<table>
<thead>
<tr>
<th></th>
<th>Collision</th>
<th>Noncollision</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fires</td>
<td>8,000</td>
<td>161,000</td>
<td>169,000</td>
</tr>
<tr>
<td>Fatalities</td>
<td>560**</td>
<td>100</td>
<td>660</td>
</tr>
<tr>
<td>Injuries</td>
<td>2,300**</td>
<td>1,250</td>
<td>3,550</td>
</tr>
<tr>
<td>Property Damage ($x100)</td>
<td>170</td>
<td>186</td>
<td>186</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Collision</th>
<th>Noncollision</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fires</td>
<td>10</td>
<td>135</td>
<td>205</td>
</tr>
<tr>
<td>Fatalities</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Injuries</td>
<td>10**</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td>Property Damage ($x100)</td>
<td>0.3</td>
<td>0.1</td>
<td>0.4</td>
</tr>
</tbody>
</table>

* Only those where the fuel was the material reported to be first ignited.(1)
** Only those estimated to be due to the fire - Assumed to be 60 percent based on a NHTSA report.(3)

Table 2 shows the breakdown of diesel fuel fires, fatalities, injuries, and property damage. Although there are a number of differences in the usage patterns of diesel fuel and gasoline, the low frequency of fire can be mostly attributed to the extremely low volatility of diesel fuel.

**HEAVY-DUTY VEHICLE FIRES**

Although the majority of the concern with vehicle fires resides with LDV/LDT fires, heavy-duty vehicle (HDV) fires also represent a significant concern. In 1986 there were approximately 180 fatalities, 1180 serious injuries, and $166 million in property damage as a result of the roughly 34,500 HDV fires (See Figure 1).(1,2) In roughly 39 percent of the collision and 21 percent of the noncollision HDV fires, gasoline was reported to be the material which was first ignited.(1) As shown in Table 1, these gasoline fires accounted for roughly 61 percent of the fatalities and 51 percent of the injuries in HDV collision situations, and 43 percent of the fatalities and 27 percent of the injuries in noncollision situations. As with LDV/LDTs, many more HDV fires may ultimately have involved gasoline, but no estimate which incorporates these fires can be made at this time. Figure 1 shows the number of HDV fires, fatalities, injuries, and property damage for which gasoline was the material reported to be first ignited.

Diesel fuel accounted for two-thirds of our Nation's HDV travel in 1986. Despite this, all Class II fuels, including diesel fuel were the material reported to be first ignited in just 31 percent of the collision and 9 percent of the noncollision HDV transportation fuel fires.(1,6) Based on a review of actual incident reports for LDV/LDTs, only about 11 percent of these Class II fuel incidents may be attributable to diesel fuel, due to reporting of other substances as Class II fuels. However, until such time as the heavy-duty incident reports can actually be reviewed, all of these Class II fuel fires will be assumed to be diesel fuel. While vehicle design and driving patterns may be somewhat different between gasoline and diesel HDV types, the vast difference between the numbers of fires is probably best explained by the extreme flammability of gasoline and the low flammability of diesel fuel. Figure 1 shows the total number of HDV fires and associated fatalities, injuries, and property damage annually for which Class II fuels were the material reported to be first ignited, and thus the total number which may potentially be attributed to diesel fuel.

**PROJECTED METHANOL VEHICLE FIRES**

**FUEL PROPERTY DISTINCTIONS**

Since there are no historical data with methanol fuels, comparisons between the fuels must be done theoretically, based on the characteristics of the fuels. As history with diesel fuel has shown, various fuel flammability characteristics can significantly impact the rate at which vehicle fires occur. A number of the properties of methanol cause it to be both less likely to ignite than gasoline, as well as less likely to cause injury if it does ignite. These properties include the volatility, lower flammable limit (LFL), vapor density, diffusivity in air, and a number of properties which affect the rate at which it gives off heat when it burns.
The issues of flame luminosity and fuel tank flammability are discussed in later sections. While a considerable difference of opinion exists on these issues, due to the belief that the overall hazard associated with them is small in comparison to the overall fire risk, and to the hope that these concerns can be minimized or eliminated entirely, no effort has been made to incorporate the risks associated with these issues into the following projections.

The fuel volatility determines in large part the rate at which vapor is produced from exposed fuel, and thus, the area surrounding a spill where a flammable concentration of fuel vapor may exist. This has a strong effect on the frequency with which ignition occurs. (3,7)

The volatility of pure methanol (M100) is 4.6 psi Reid vapor pressure (RVP) compared to 8 to 16 psi for gasoline, and 7 to 16 psi for a mixture of 85 percent methanol and 15 percent gasoline (M85). (7) Diesel fuel has an extremely low volatility, estimated to range from 0.04 to 0.4 psi RVP. (7) Gasoline is and M85 will be seasonally blended in order to allow for acceptable cold vehicle operation in winter, thus causing the wide range in fuel volatility. In future years, it is anticipated that the majority of gasoline marketed in the summer months will have a volatility of 9.0 psi, and if splash blended, M85 would then have a volatility of approximately 7.5 psi. (7)

In order to quantify the impact of fuel volatility, vehicle fire rate data as a function of the month of the year for the years 1978-84 were obtained for the State of Maryland from a recent NHTSA report. (3) As shown in Figure 2, by utilizing gasoline RVP survey data for the same region and average daily high temperatures for each month, the vehicle fire rate could be plotted as a function of the true vapor pressure (TVP) of the fuel. (8,9) The correlation with an r² of 0.89 is remarkable given the possible sources of error in such an analysis.

Extrapolation from the data in Figure 2 shows that the roughly 50 percent decrease in volatility of M100 relative to gasoline may result in as much as a 70 percent reduction in collision related vehicle fires. Due to the much higher volatility of M85, the reduction in the frequency of fire may only be as great as 20 percent relative to that of gasoline. * While the data used in this analysis were from collision situations, it should apply equally well to noncollision situations. This is supported by a comparison of the historical gasoline and diesel fire data. The ratio of diesel to gasoline fires was even lower in noncollision situations than in collision situations. (1)

Figure 2
Effect of Fuel Volatility on the Car Fire Rate (3,8,9)

The LFL determines the minimum concentration of fuel vapor in air which is required for ignition. The higher the LFL, the more unlikely that ignition will occur. The LFL for M100 is roughly 6.0 volume percent in air.

* For the purposes of this paper, the volatility of M85 is determined by assuming that M85 is produced by merely splash blending methanol and gasoline. If M85 is instead specially blended for cold start and driveability purposes to have a volatility which matches that of typical gasoline, as is currently being suggested, then there will be no volatility related safety benefit for M85 relative to gasoline. Cold start questions have also not been addressed in this paper with respect to M100 vehicles.
compared to 1.4 percent for gasoline, 0.6 percent for diesel fuel, and roughly 2 percent for M85.\(^{(7)}\) Thus, a concentration in air of more than four times that with gasoline and 10 times that with diesel fuel is required with M100 to achieve ignition. This alone could have a significant effect on the rate of occurrence of fire, and in combination with the low volatility of methanol, could have a dramatic effect on the frequency of fire.

The volatility and LFL can be combined and expressed as the flammability index (the ratio of the amount of vapor produced by exposed fuel to the minimum amount of vapor which is required to achieve ignition - a value greater than one is considered flammable). On a relative basis, the flammability index represents the area surrounding a fuel spill where a flammable vapor concentration might exist. As shown in Figure 3, the flammability index at common ambient temperatures for M100 is roughly 10 percent of that for gasoline. The flammability index for M85 is roughly 60 percent of that for gasoline. At common ambient temperatures the vapor produced by exposed diesel fuel is not flammable, while at temperatures below roughly 50°F, M100 is not flammable. (Here the flammability index of diesel fuel in approximated by that of undecane.\(^{(10)}\)) M100 and diesel fuel are, however, combustible at these temperatures. If an ignition source comes into direct contact with the fuel, and is of sufficient intensity to vaporize the fuel without being extinguished, then ignition is likely.

The high vapor density of gasoline (2 to 5 times that of air) and diesel fuel (5 to 10 times that of air) causes its vapor to travel along the ground to ignition sources, and settle into low areas, whereas the low vapor density of M100 (1.1 times that of air) causes it to disperse more evenly.\(^{(7)}\) This tends to decrease the likelihood of ignition with M100. The vapor density of M85 ranges from 1.1 to 5, and most closely resembles that of gasoline, since roughly 60 percent (on a volume basis) of the vapor initially emitted from exposed M85 is gasoline hydrocarbon.\(^{(11)}\)

The diffusivity of a fuel vapor determines how rapidly a flammable concentration of vapor will disperse to harmless levels in situations where natural and artificial ventilation are limited. The diffusion coefficient is roughly 2 1/2 times greater for M100 than for gasoline and diesel fuel (0.5 ft\(^2\)/hr vs 0.2 ft\(^2\)/hr). However, since in most situations ventilation dominates natural diffusion, this is seldom a significant factor.\(^{(7)}\)

In addition to having properties which reduce the frequency with which fire might be expected to occur, methanol's properties also cause it to be less likely to result in injury, death, and property damage, should a fire occur. These properties include: the heat of combustion, the heat of vaporization, the volatility, boiling point, and a number of other properties. These properties combine to cause M100 to burn at a rate roughly 40 percent of that for gasoline and 50 percent that for diesel fuel, and release heat at a rate which is estimated to be just 20 percent of that for gasoline and diesel fuel.\(^{(7)}\) Similarly, M85 is estimated to burn at a rate roughly 50 percent of that for gasoline and 60 percent of that for diesel fuel, and release heat at a rate just 30 percent of that for gasoline and diesel fuel.\(^{(7)}\) The result of this is that even if a fire occurs, the rate of death, injury, and property damage resulting from the fire should be much lower with the methanol fuels than with gasoline.
Modeling performed for Transport Canada demonstrates this fact.\(^{(12)}\) As shown in Figure 4, the distance from a pool fire where one percent of the people exposed will be killed is roughly just 10 and 17 percent, respectively, of that with gasoline when M100 and M85 are the fuel. Although diesel fuel was not included in this analysis, based on its heat release rate when it burns, the one percent fatality distance should be very similar to, if not slightly greater than for gasoline.

![Figure 4: 1% Fatality Distance From Fire's Edge\(^{(12)}\)]

In addition to the much lower heat release rate, M100 also produces no smoke when it burns, further decreasing the likelihood of property damage should a fire occur. In many cases the property damage produced by the smoke is more extensive than that of the fire itself. The lack of a visible flame under certain circumstances, however, will add to the hazard of some M100 fires. This will be discussed in a later section.

**PROJECTION BASED ON DIESEL FUEL**

- In order to estimate the overall risk of fire with M100, the overall fire risk associated with diesel fuel can serve as a surrogate. The significant reduction in vehicle fire rates associated with diesel fuel relative to gasoline is attributed to the extreme low volatility of diesel fuel. A similar effect is expected with M100 due to its low volatility. Although the volatility of methanol is not as low as that of diesel fuel, the lower flammability limit is approximately 10 times that of diesel fuel. Thus, as shown in Figure 3, relative to gasoline the flammability index for methanol is very similar to that of diesel fuel. The lower vapor density and higher diffusion coefficient of methanol relative to diesel fuel may make the actual likelihood of fire even more similar to that of diesel fuel. In addition, due to the much lower heat release rate of methanol from a fire relative to that of diesel fuel, should a fire occur, the fatalities, injuries, and property damage should be much less likely and severe than with diesel fuel. Thus, while M100 may be slightly more flammable than diesel fuel, the overall fire risk with diesel fuel may be very similar, and may serve as a reasonable projection for the risk with M100. As seen in Figures 5 and 6, the frequency of vehicle fires and associated property damage with M100 (assuming equivalence with diesel fuel) could be 94 percent lower than that with gasoline.\(^{**}\)

Similarly, as seen in Figures 7-10, the number of injuries and fatalities could be reduced by 83 percent.\(^{*}**,^{**}\) Thus, including only those fires where gasoline was reported to be the material first ignited, replacing the use of gasoline as our transportation fuel with M100 could result in a reduction of 166,000 vehicle fires, 630 fatalities, 3,400 serious injuries, and $202 million in property damage annually.

**PROJECTION BASED ON GASOLINE** - Relative to gasoline, methanol is a fairly nonflammable fuel. As shown in Figure 2, based on fuel volatility alone, as much as a 70 percent reduction in vehicle fires may occur with M100 relative to gasoline, and as much as a 20 percent reduction for M85. As shown in Figure 3, when the effects of

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* The values shown in Figures 5-10 reflect only those fires where gasoline or diesel fuel (Class II fuels) were the material reported to be first ignited.

** These estimates are probably conservative, since only in the case of noncollision LDV/LDT fires could diesel fuel incidents be separated from all Class II fuel incidents.
Figure 5
1986 LDV/LDT Fire Comparison
(Normalized) [1,2,3,6]

Figure 8
1986 HDV Fire Fatality Comparison
(Normalized) [1,2,3,6]

Figure 6
1986 HDV Fire Comparison
(Normalized) [1,2,3,5]

Figure 9
1986 LDV/LDT Fire Injury Comparison
(Normalized) [1,2,3,6]

Figure 7
1986 LDV/LDT Fire Fatality Comparison
(Normalized) [1,2,3,6]

Figure 10
1986 HDV Fire Injury Comparison
(Normalized) [1,2,3,6]
methanol's much higher LFL are combined with the effects of volatility, as much as a 90 percent reduction in the number of vehicle fires may be possible with M100 relative to gasoline, while for M85 as much as a 40 percent reduction may result. The lower vapor density and higher diffusion coefficient of the methanol fuels may argue for even greater reductions, but no attempt has been made here to quantify the effect of these properties.

In addition to being much less likely to ignite, as demonstrated by Figure 4, methanol fires are also much less likely to result in fatalities, injuries, and property damage. Although difficult to quantify, a reduction of 50 percent in the fatality, injury, and property damage rates per fire occurrence are assumed here due to the dramatic reduction in fire severity.

As shown in Figures 7 and 10, based on the assumptions made above, as much as a 95 percent reduction in fatalities, injuries, and property damage associated with fuel related vehicle fires is possible with M100 relative to gasoline. Similarly, for M85 as much as a 70 percent reduction may be possible. Thus, including only those fires where gasoline was reported to be the material first ignited, replacing the use of gasoline as our transportation fuel with M100 could result in a reduction of 159,000 vehicle fires, 720 fatalities, 3,900 serious injuries, and $204 million in property damage annually. For M85 the potential annual reductions are smaller, though also significant: 71,000 fires, 530 fatalities, 2,900 serious injuries, and $151 million in property damage.

NONVEHICLE FIRES

In 1986, there were approximately 1.64 million nonvehicle related fires in the United States. These fires were responsible for an estimated 5,700 fatalities, 62,000 injuries, and $8.2 billion in property damage. In roughly 1.6 percent, or 26,000 fires of these fires, gasoline was the material reported to be first ignited, and in another 0.6 percent, or roughly 10,000 fires Class II fuels such as diesel fuel, kerosene, and home heating fuel were the material first ignited.

ONE AND TWO FAMILY RESIDENTIAL FIRES - As shown in Figure 11, nearly 30 percent, or 477,000 of the nonvehicle fires occur in one and two family residential homes. Roughly 50 percent of the injuries and 70 percent of the fatalities each year in nonvehicle fires occur in one and two family residential homes. In roughly two percent, or 9,500 of the residential fires gasoline was the material reported to be first ignited. As shown in Figure 11, associated with these fires are roughly 100 fatalities, 1,800 injuries, and $89 million in property damage. When all of the different sources of ignition in residential homes are considered, it is remarkable that such a significant number are due to gasoline. This can probably be attributed to the extreme flammability of gasoline. Although a significant fraction of these fires are likely attributable to automotive uses of gasoline (spills and leaks from vehicles, carelessness during vehicle repairs, and misuse as a grease and oil solvent for cleaning automotive parts), many are also attributable to nonautomotive uses such as for lawn and garden equipment and watercraft. Unfortunately the available data did not allow for distinguishing between the uses of the gasoline which caused the fire.

Despite the fact that Class II fuels such as kerosene and home heating fuel are likely used in greater quantities in and around the home than gasoline, they were the material first ignited in just 1.3 percent, or 6,300 of the one and two family residential fires reported in 1986 in the United States. Diesel fuel likely represented only a very small portion of these fires since there are few uses for it in and around the home, and since light-duty diesel vehicles represented only approximately 1.8 percent of the light-duty vehicle fleet in 1986, causing little need to bring it into the home for automotive purposes. Associated with these Class II fuel fires were roughly 60 fatalities, 400 injuries, and $27 million in property damage.
fuels were the material reported to be first ignited are assumed to have been with diesel fuel, gasoline is still much more hazardous. Figures 12-14 show the gasoline and Class II fires, fatalities, and injuries normalized based on 1986 nationwide gasoline and diesel fuel consumption.

**SERVICE STATION FIRES** - In 1986, there were approximately 8,300 reported service station fires. Associated with these fires were approximately 20 fatalities, 500 injuries, and $67 million in property damage. As shown in Figure 11, in roughly 23 percent, or 1,900, of these fires gasoline was the material first ignited, resulting in 10 fatalities, 240 injuries, and $17 million in property damage. These compare to approximately 170 fires, no fatalities, 10 injuries, and $0.6 million in property damage with all Class II fuels. In comparison to residential situations, a greater fraction of the Class II fuel fires at service stations were likely to have been diesel fuel, due to its much greater use and presence at service stations. Nevertheless, based on the review of Class II fuel fire incident reports for LDV/LDTs discussed earlier, it is likely that only a small fraction of all of the Class II fuel fires were actually diesel fuel fires. Despite this, even if all service station fires where Class II
PROJECTED NONVEHICLE METHANOL FIRES - No actual fire reduction estimates can be made for nonvehicle fires, since the available data does not distinguish between the automotive uses of gasoline which are replaced with the use of methanol, and the nonautomotive uses of gasoline which, at least at present will remain unaffected by an alternative fuels program. In addition, no comparison can be based on the differences in the frequency of historical fires with gasoline and diesel fuel, since the data does not allow for distinguishing between diesel fuel and the other Class II fuel fires. Based on the earlier evaluation of the vehicle fires, the methanol fuels should result in a significant reduction in the number and hazard of nonvehicle automotive fuel related fires as well, but no projections are made here.

FUEL TANK FLAMMABILITY

Concern has been expressed with regard to the potential for a fuel tank explosion with M100, and the extreme hazard which that might represent. Methanol is in the flammable range inside fuel tanks at temperatures ranging from 45 to 109°F. Summer grade gasoline and M85 enter the flammable range inside fuel tanks at temperatures less than approximately -4 and 6°F respectively. For winter grade fuels these temperatures range from -20 to -30°F. Recent information from Phillips 66 Company, however, suggests that gasoline may be somewhat more likely to exist in its flammable range inside fuel tanks. The temperature ranges identified by them were roughly 10°F higher than those listed above, and in addition, they pointed out that weathering of the fuel (reduction in fuel volatility due to preferential evaporative loss of the higher volatility components of the fuel) during use may raise the temperature range an additional 4°F. Weathering likely has an even greater effect on M85, since such a small portion of the fuel is comprised of highly volatile components. M100, since it is a pure compound, does not weather. Phillips also pointed out that summer fuels which are stored for several months may easily exist in the flammable range if they are not used until the winter. In addition, new low volatility reformulated gasolines currently being considered by the oil industry may also exist in the flammable range in fuel tanks during periods of low temperature. On average diesel fuel is not in its flammable range inside fuel tanks until the temperature reaches 130°F, however, this ranges from 70°F to 205°F depending on the particular fuel sample.

Despite the increased potential for a fuel tank explosion with M100, it is, nevertheless, not expected to be a frequent occurrence. Fuel tanks are isolated environments with only a limited number of possible ignition sources. Ethanol, which is also in the flammable range at common ambient temperatures, has been used as a transportation fuel in Brazil for a number of years, apparently without any major safety problems. Even if ignition does occur, limited testing of methanol fuel tanks has shown that the "explosion" is minor and often contained by the fuel tank with no residual fire, and is not the huge fireball which has been suggested. Nevertheless, due to the potential hazard, precautions should be taken to mitigate the possibility for fuel tank ignition. Fortunately, this is not a difficult task. A number of simple vehicle design modifications can greatly reduce the chance of fuel tank ignition. These
include: the use of flame arresters on tank fill necks and vents, modification of in-tank fuel pumps and fuel level sending units to prevent electrical sparks, and the use of foam fillers in the fuel tank to prevent a flame from propagating through the tank. Foam fillers may be the most effective option since they prevent an explosion regardless of the ignition source. These foams are currently used in many military and racing applications with today's fuels, and with some development work should be available for use with methanol fuels as well.

Since safety precautions such as these are likely with widespread use of methanol fuels, there does not appear to be any justification for projecting additional fires or fatalities and injuries due to M100's potential for ignition inside fuel tanks. We would expect this aspect of fuel safety to be comparable to that with today's vehicles.

**FLAME LUMINOSITY**

The possibility that M100 fires would be invisible to the naked eye is another issue which has raised a great deal of concern with M100 and, in fact, is one of the reasons for the use of M85 today. Pure methanol burns with a flame which is not easily seen under well lit or daylight conditions, provided nothing else is burning along with it. Thus, there is the possibility that in situations where methanol is burning on a surface such as concrete in daylight conditions, a person may unknowingly enter the fire. Although situations such as this should be rare, the emotional and potential liability concerns may overwhelm the actual hazard associated with the fires. Heat radiation and visible heat waves from the fire should provide some warning of its existence, but it is not yet known if these alone would be adequate. To enhance the visibility of the flame, additives in low concentrations are being considered. Early efforts to find acceptable additives focused on various hydrocarbons. (16,17) However, preliminary results from more recent efforts by one of the larger oil companies indicate that various organic compounds at relatively low concentrations may be effective. Assuming continued success at developing these additives, it seems likely that they could be used in M100 should it be used on a widespread scale as a transportation fuel. Thus, there would appear to be no reason to project any increased hazard due to flame visibility concerns if M100 replaces gasoline as a transportation fuel.

**SUMMARY AND CONCLUSIONS**

No fuel can be made to be perfectly safe, but significant fire safety improvements over the current situation with gasoline can be expected with the use of methanol fuels. The greatest benefits occur with the use of M100. As much as a 95 percent reduction in fatalities, injuries, and property damage associated with fuel related vehicle fires is possible with M100 relative to gasoline. For M85 as much as a 70 percent reduction may be possible. Thus, including only those fires where gasoline was reported to be the material first ignited, replacing the use of gasoline as our transportation fuel with M100 could result in a reduction of 159,000 fires, 720 fatalities, 3,900 serious injuries, and $204 million in property damage annually. For M85 the potential annual reductions are smaller, though also significant: 71,000 fires, 530 fatalities, 2,900 serious injuries, and $151 million in property damage.

By implementing vehicle design modifications and by utilizing fuel additives, most of the concerns over the unique safety hazards of M100 can be eliminated or greatly reduced. Thus, in these areas we would expect the safety of methanol vehicles to be comparable to that with today's gasoline vehicles, and overall a significant improvement in fire safety.

**REFERENCES**

1. 1986 National Fire Incident Reporting System (NFIRS) operated by the Federal
Emergency Management Administration (FEMA).


