ANALYSIS OF ETHYLENE GLYCOL-BASED ENGINE COOLANT AS A VEHICLE FIRE FUEL

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ABSTRACT

Engine coolants are among the combustible liquids onboard a vehicle which may be considered in a vehicle fire. Engine coolants are commonly based on ethylene glycol or propylene glycol, which are considered to have similar fire properties. This paper provides the vehicle fire investigator with an analysis of the characteristics of ethylene glycol-based coolants relative to this coolant's potential for being the first fuel in a vehicle fire. Among the considerations for the potential of ethylene glycol coolant to be the first fuel in a vehicle fire is whether or not the coolant exited the coolant system during a crash or by mechanical failure absent a crash. Another consideration is the coolant's water content and whether it was sprayed as a mist or was splashed onto or near a potential ignition mechanism. Other important considerations include the geometry and temperature of the ignition mechanism, the residency time of the liberated coolant, and the amount of ventilation at the ignition mechanism location. It is also necessary that the ignition mechanism provides an adequate quantity of energy in order for the vapor to develop into flaming combustion through an appropriate ignition mechanism. The energy from the ignition mechanism and from early combustion of the vapor must also be sufficient to sustain combustion of the vapor after ignition. Further, the ignition mechanism must be appropriately located, relative to other nearby combustibles, in order for the fire to progress beyond the initial burning of the vapor or pooled ethylene glycol. Among the factors of interest is the characteristic of ethylene glycol coolant to be essentially non-combustible when mixed with small quantities of water. This is in contrast to pure ethylene glycol, which boils at around 350°F, has an auto-ignition temperature of around 750°F, and a flash point of around 260°F. The ratio of water to ethylene glycol recommended by coolant manufacturers ranges from 50:50 to 30:70, with cautions not to exceed 30:70. However, even at the higher ethylene glycol concentrations, coolant liberated from an engine coolant system would likely still contain a small amount of water and remain essentially non-combustible when first liberated. Testing indicates that quantities of pure ethylene glycol sprayed onto hot surfaces do not ignite. Testing also shows that coolant containing small quantities of water, when sprayed onto burning ethylene glycol, will cause the fire to go out. Testing also shows that special geometric, heated pocketing of pure ethylene glycol must be closely coupled to a viable ignition source that is adjacent to where the heated pocketing of the ethylene glycol exists, for it to ignite. This paper provides an analysis and discussion of each of these important considerations for engine coolant as a first fuel in a vehicle fire, and relates the discussion to testing that has been performed by the authors and to testing reported in the technical literature. In this regard, it is of interest that the literature has very few reports, other than an

implication, that engine coolant was the first fuel in a vehicle fire. This is consistent with the testing performed by the authors and is consistent with the extensive array of flammability characteristics and conditions which are aligned against the instance of ethylene glycol being the first fuel in a vehicle fire.

IGNITABLE AUTOMOTIVE FLUIDS

The vehicle fire investigator is often faced with the challenge of making a determination as to whether one of the liquids in a motor vehicle was the first fuel in a vehicle fire. This determination gives rise to the need for the investigator to consider what role several candidate fluids may have played in the fire. The flammable liquids common to motor vehicles are the following:

1. Gasoline, diesel fuel or ethanol
2. Engine oil
3. Transmission gear oil
4. Automatic transmission fluid
5. Brake fluid
6. Power steering fluid
7. Engine coolant
8. Windshield wiper fluid

Table 1 lists, for comparison purposes, representative ignition temperatures for these candidate automotive fluids. Cleveland Open Cup testing, according to ASTM D 92-05a for the flash and flame point of representative automotive fluids, by the authors is presented in Table 2.

Table 1 – Representative Ignition and Boiling Point Temperatures
For Automotive Fluids

Fluid	Flash Point (°F)	Auto-Ignition Temperature (°F)	Boiling Point (°F)
Gasoline	-40	850	100 – 400
Diesel	120	450	300 – 575
Ethanol E85	-55 -55	495	N/A
Engine Oil	400	600	680
Transmission Gear Oil	400	730	700
Brake Fluid	300	550	450
Power Steering Fluid	350	N/A	N/A
Engine Coolant (Ethylene Glycol)	230- 270	750	350-390
Windshield Wiper Fluid	90	850	N/A

VEHICLE FIRE INVESTIGATION

Investigation of a vehicle fire, as in other fire investigations, involves consideration of all of the available information, including the physical evidence and witness statements. It also involves consideration as to the type of damage the vehicle sustained, the vehicle's position or orientation at its final rest position, the environmental conditions at the time of the fire, and the role that fire suppression activities may have played. A part of the analysis of the fire needs to include an evaluation of the liquids that may have been liberated from their normal containment at the start of the fire, the potential ignition mechanisms that were present, and whether they were adequate to start the fire. Performance of this analysis requires the investigator to rely on his background and experience, as well as his understanding of the technical aspects as to the characteristics of how readily the fluids ignite and how they respond to the type of ignition mechanism that is present. The goal of this paper is to provide additional information about ethylene glycol in order to aid the investigator in his determination of whether or not engine coolant was the first fuel in a fire.

Table 2 – Cleveland Open Cup Testing by the Authors, According to ASTM D92-05a for the Flash and Flame Point of Representative Automotive Fluids

Fluid	Flash Point (°F)	Flame Point (°F)
Valvoline Durablend Synthetic Motor Oil	427 - 433	478 - 480
Valvoline HP 80W-90 Gear Oil	369 - 370	557 - 558
Valvoline Dexron VI Automatic Transmission Fluid	400 - 402	439 - 442
Silicone Brake Fluid	572 - 576	700+
Pyroil Power Steering Fluid	406 – 407	450 – 451

While the authors tested a number of representative automotive fluids, this paper primarily addresses engine coolants.

Engine Coolants

The predominant engine coolants in common use are ethylene glycol and propylene glycol. In general, they are considered to have similar fire properties. These materials, commonly referred to as antifreeze, are mixed with water prior to adding the mixture to the vehicle's coolant system. Since antifreeze, especially ethylene glycol, is corrosive to metals, manufacturers add chemical corrosion inhibitors to the antifreeze in order to help protect the metals in the engine coolant system. The manufacturers also provide tables, to purchasers of antifreeze, which inform the users about the recommended temperature range of the coolant, according to what percentage water is added to the antifreeze. The manufacturers recommend 50% water to 50% antifreeze for normal use and for more extreme cold temperatures, to use up to 30% water to 70% antifreeze. They warn, however, against using more than a 70% ratio of antifreeze because it will lead to a breakdown of the chemical corrosion inhibitors, to reduced heat transfer performance from the coolant, and to decreased freeze protection.

These considerations led to the conclusion that the starting point for engine coolant in a vehicle fire is that the coolant, except for unusual use conditions, probably had a water content of 30 to 50 percent before the events leading to the fire began.

Engine Coolant Systems

The engine block of liquid-cooled engines contains passageways or water jackets that the engine coolant passes through. The coolant moving through the engine block removes heat from the engine. The coolant then carries the heat it removes back to the radiator through a system of hoses. In the radiator, heat is rejected from the coolant into the atmosphere, with the help of air flow through the radiator. The air flow is aided by forward movement of the vehicle and by a fan which draws air through the radiator, whether the vehicle is moving or stationary.

A thermostat in the coolant system between the engine and the radiator opens when the engine heats up to around 195°F and allows the coolant to circulate through the system with the aid of a water pump.

The radiator has a pressure cap that is set to approximately 15 psi above ambient. The function of the radiator cap is to maintain the pressure inside the cooling system at approximately two atmospheres, or 15 psi above ambient. This increased pressure allows the coolant in the radiator to attain higher temperatures before boiling. Table 3 provides a comparison between boiling points for representative water and ethylene glycol mixtures for one atmosphere (about 14.7 psi) and at two atmospheres (about 29.7 psi). The pressure cap is equipped with a tube that connects to a recovery reservoir where over-flow fluid from the radiator can flow if the pressure cap opens. The recovery reservoir, in turn, has an overflow drain that allows fluid to run out onto the ground if it overfills.

The pressure cap on the radiator acts as a relief valve in case the pressure inside the radiator rises above the approximate two atmosphere set pressure. This can happen if the engine begins to overheat, such as when it is heavily overloaded for an extended period of time. The overheated coolant will then expand and potentially begin to boil, which in turn can cause pressure in the radiator and the pressure cap to open.

It can then be expected that if overheating continues, some of the coolant will be expelled from the system, causing steam and hot coolant odors to be prevalent in the near vicinity of the vehicle. The coolant remaining in the vehicle, however, as a matter of probability will still contain a percentage of water. It is also likely that the longer the overheat-overflow condition continues, the percentage of water in the remaining coolant would decrease. Once enough coolant has been expelled to fill the recovery reservoir, the recovery reservoir will overflow and expel coolant from the system. The boiling point of the coolant (as indicated in Table 3) as the water percentage decreases would tend to increase and the overflow to be reduced, depending on the extent of engine overheating. At some point, the liquid level in the engine/radiator system would be reduced to a level such that only steam would be ejected through the radiator pressure cap.

It can be seen that when considering engine coolant as the first fuel in a fire, one needs to consider the use history of the vehicle prior to the fire. This would obviously be of interest when considering the characteristics of the coolant when it was liberated from the cooling system and splashed or sprayed onto items under the hood of the vehicle. This is true whether or not the coolant release was due to damage to the coolant system in a vehicle collision or if it was due to a coolant system rupture due to mechanical failure. It is seen from these considerations that the temperature of the coolant, and the water content of the coolant, when it arrives at a potential ignition location can be affected by the operating history of the system just prior to the system's rupture.

It should be noted that a vehicle that is seriously overheating would provide ample information to the driver, and to others that are near the vehicle, in the form of steam, hot liquids on the ground, and strong antifreeze odors.

Hot Surface Temperatures of Vehicle Components

The highest surface temperatures in the motor vehicle are the exhaust manifold, the exhaust "Y" where the exhaust piping from two sides of the engine join, and on the exhaust pipe near the catalytic converter. The exhaust manifold is often considered to have the highest temperature, with the exception of temperatures inside the catalytic converter. The temperature along the exhaust system generally becomes less as one moves away from the exhaust manifold toward the tail pipe. The temperature range of the exhaust system, quoted in the technical literature, is approximately 400°F to 1100°F, with the higher temperature being associated with malfunctioning or overloading of the engine for an extended period of time. In the case of normal operation, the upper temperature limit is around 900°F.[1]

Table 3 – Approximate Boiling Point Temperatures for Water and Ethylene Glycol Mixtures at One and Two Atmospheres[2]

Percentage Water (%)	One Atmosphere (°F)	Two Atmospheres (°F)
0	390	435
10	280	320
30	240	270
50	230	260
70	220	250
100	212	240

This data is of particular interest to the vehicle fire investigator when considering the potential for hot surface auto-ignition of ethylene glycol and its role as the first fuel in a fire. This is relevant in that the highest temperature of a target surface within the motor vehicle would be around 900°F for a normally operating vehicle, and 1100°F for a malfunctioning vehicle or one which had undergone heavy overloading just before the fire. This topic will be discussed further in conjunction with the testing performed by the authors on ethylene glycol.

Ethylene Glycol Technical Literature Review

Review of the technical literature concerning ethylene glycol as a fuel in a fire reveals articles and reports on investigations regarding the ignition of ethylene glycol by electrolysis. These include a study by NASA following the Apollo-Saturn incident in January 1967. The NASA study investigated chemically-induced ignition in electrical circuitry in aircraft and spacecraft by ethylene glycol and water solutions in air and in concentrated oxygen environments. They found that after a period of time, when a 22.5 volt battery was applied across bare silver-coated copper wires that were placed 1 millimeter apart, and drip flooded with ethylene glycol, an exothermic chemical reaction took place that led to smoking and flame at that location. In contrast, they found that bare copper wires, tin-coated copper wires, and nickel-coated copper wires did not react when similarly tested.[3]

A follow-up study by General Dynamics performed testing in air and found that a 28 volt direct current applied to closely spaced, bare electrical connector components could, after a period of time, also create an exothermic electrolysis cell that formed hydrogen, which then ignited and was consumed with smoke and flame.[4]

The points of interest in these studies for tests in air include the need for bare, closely-spaced electrical components, 22.5 to 28 volts direct current, a time delay of minutes or longer for an undisturbed electrolysis cell to develop, and with resultant fire damage typically confined locally to the electrical components that were involved. It is of interest that the test conditions that led to smoke and flame in these studies are absent from the typical motor vehicle.

A study by Washington State Transportation Center involved the collection of vehicle fire data in which engine coolant was suspected as being the first fuel in the fire. This was based on studies of the available information on a selection of 13 vehicle fires in which an automotive fluid was suspected of being the first fuel in the fire.[5] Criteria, used to establish whether engine coolant was the fluid of interest, was based on the fact that there was minimal collision damage to the engine compartment, the coolant was thought to be the only fluid in a particular region, and witnesses thought the fire had started in the same region. This paper will suggest that these and additional considerations should be taken into account when engine coolant is suspected as the first fuel in a vehicle fire.

In a study conducted by General Motors, automotive fluids were tested by two methods. The first method consisted of pouring samples of the fluids into a flat-bottomed cast iron heated crucible. In the second method, selected fluids were poured onto a heated metal hemisphere in order to obtain ignition temperature data.[6] Ethylene glycol was not poured on the heated hemispheres. Ethylene glycol and water mixtures of 25cc liquid were poured into a heated crucible having a 6-inch internal diameter, ½-inch thick walls, and 2-inch high ceramic insulated cylindrical sides. These tests indicated ethylene glycol ignition at temperatures ranging from 1160°F to 1250°F. It is of interest that the 25cc sample was slowly poured into the center of the heated crucible over a period of 2 to 3 seconds and that the sample quantity would create, at most, a 0.050-inch thick layer across the inside bottom of the crucible. In this test, ignition would require sufficient ethylene glycol vapors to be boiled off, providing vapor, in combination with the appropriate air mixture. The vapor would then be sufficiently heated, probably by the heated crucible walls, in static air flow conditions, before the mixture would auto-ignite. One should note that the similarity between the apparatus used in these tests and the configuration of components in a motor vehicle are very different. This includes the absence, from a typical motor vehicle, of a flat bottom 6-inch diameter heated surface with 2-inch heated circumferential enclosing walls, which could contain liberated engine coolant vapors in a static air environment and then ignite it.

A study conducted by Colwell and Reza involved a statistical evaluation of the ignition and non-ignition scatter of automotive and aircraft fluids that were dripped one drop at a time onto a stainless steel heated plate through the center of a 1-inch thick refractory insulation shield having a 4-inch by 6-inch rectangular opening.[7] In addition, the apparatus was surrounded on three sides by vertical draft shield walls to ensure static air flow conditions at the point where the fluid drop fell onto the heated plate from a height of approximately 10 inches. The authors noted that "some fluids, such as fuels and antifreeze, tended to shatter with smaller, secondary fluid drops moving radially away from the center as they were evaporating. Because the temperature increases along this radial path, ignition may have occurred locally at temperatures somewhat higher than the reported temperature at the center of the plate." The indicated drop size used for the antifreeze tests was 34.1 μL. This study arrived at an antifreeze drop ignition temperature range of 1000°F to 1100°F. The antifreeze used in this test program was indicated to be Prestone, with a flash point of 230°F and auto-ignition of 760°F. This data is consistent with the test fluid being 100% ethylene glycol. Note again that the test apparatus used in this study is not characteristic of the conditions found in the typical motor vehicle. This would include the absence of a 4-inch by 6-inch flat stainless steel heated plate surface with air draft shields to ensure static air flow conditions. It is also of interest that the ignition and dissipation of a single drop of fluid would not in itself satisfy the requirements for propagating a sustained fire. Testing by the authors indicate that ethylene glycol sprayed on a hot surface requires temperatures higher than those reported in this study to cause ignition of the spray.

Data published by Gregory Barnett on vehicle fire investigation indicates that based on 2000 tests he conducted, "Both ethylene glycol and propylene glycol will auto-ignite when exposed to a hot exhaust. However, the mixture needs to be nearly pure for auto-ignition. If the water content in the coolant is over 10-20 percent, then ignition is not likely." Mr. Barnett also states, "When coolant was purposely burned in testing, an auto-ignition was achieved at approximately 1,000°F. The flames produced were nearly colorless and of short duration." Mr. Barnett did not describe the tests he performed to arrive at his conclusions.[8]

Additional Engine Coolant Testing

The authors of this paper tested ethylene glycol-based engine coolant in test configurations which were designed to provide further insight into the behavior of engine coolant in environments similar to those in a motor vehicle. In this regard, it was found to be helpful to refer to the diagram shown in Figure 1, which depicts the ignition performance of fluids in the form of a plot of vapor pressure versus temperature.

In Figure 1, Point A represents the flash point temperature for a combustible fluid. This temperature is associated with the lowest temperature that will result in ignition of the vapor the fluid produces when it is heated. The temperature is referred to as the flash point. The Cleveland Open Cup test according to ASTM D92-05a is used to obtain this temperature. It is of interest that the conditions required by the test result in what can be considered as ideal conditions, since the fluid is heated in a brass cup with static air flow, while a pilot flame is passed over the cup in near proximity to the top of the liquid. The flash point is then the lowest boiling point temperature where sufficient vapors are generated at the top of the fluid, where the natural convection results in the proper air-vapor mixture at the place where the pilot flame is located. It should be noted that this test requires a quantity of the fluid to be contained by a heated cup for a sufficient amount of time to heat the fluid sufficiently, for the vapors coming off the surface of the fluid to be confined and properly mixed with air, and for the place where the vapors are confined to be the same place where the ignition mechanism is located. It is useful to consider whether or not these conditions would exist in a motor vehicle prior to a fire. Note also that Point A is at the left boundary of the region called the forced ignition region in Figure 1.

The region to the right of Point A in Figure 1 is where forced ignition of fluid vapors can occur at higher temperatures for non-ideal test conditions. This region also requires that the vapor mixture be between the upper and lower flammability limits and the piloted ignition mechanism has sufficient strength in terms of temperature and heat delivery capacity to cause ignition, such as a strong electric arc.

The authors used the Cleveland Open Cup procedure to test ethylene glycol and ethylene glycol water mixtures to obtain flash and flame point temperatures. The mixtures tested included ethylene glycol percentages of 100%, 90%, 80%, 70%, 60% and 25%. Each test sequence started with 70 ml of mixed fluid. Temperatures recorded from the tests included boiling point, flash point, flame point and the approximate amount of fluid that was boiled off between the start of the test and the flame point during the test. Table 4 indicates the results from these tests. It will be noted that even after boiling away significant percentages of the beginning fluid mixture, the residual fluid contains enough water to lower boiling point temperatures of the liquid remaining. This is an indication that engine coolant, when released before a fire incident, will still contain a percentage of water.

Additional piloted ignition tests using the Cleveland Open Cup apparatus were conducted where the pilot flame was replaced with a sparking system which was developed to create a spark using a standard coil from an eight cylinder engine and a spark plug. This apparatus was used to determine the flash and flame points for 100% ethylene glycol. These tests were repeated using a spark created by a gas furnace spark igniter. The results of the tests are shown in Table 5.

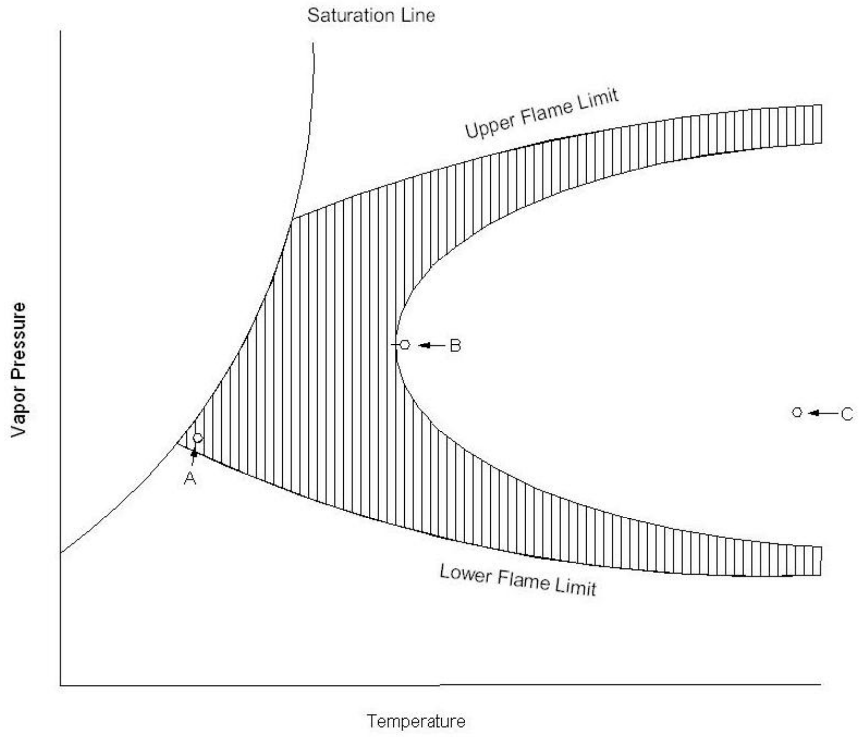

Figure 1 – Ignition Regime of Vapor Pressure Versus Temperature For Fluids Where:
A Represents the Flash Point Temperature
B Represents the Ideal Auto-Ignition Temperature and
C Represents a Non-ideal Auto-Ignition Temperature

The testing summarized in Table 4 and Table 5 indicates that, in the presence of an adequate pilot igniter, engine coolant vapors can be ignited as long as the ignition mechanism has sufficient energy delivery capacity, and that there is sufficient preheated, properly mixed fuel and air vapors confined to the same location as the ignition mechanism.

Table 4 – Cleveland Open Cup Test of
Ethylene Glycol-Based Engine Coolant Mixtures

Percentage Ethylene Glycol (%)	Percent Water (%)	Boiling Point (°F)	Flash Point (°F)	Flame Point (°F)	Volume Loss Flash to Flame Point (ml)
100	0	360 – 365	254 – 260	254 – 260	N/A
90	10	284 – 286	255 – 262	262 – 275	0
80	20	247 – 248	287 – 288	290 – 293	10
70	30	224 – 227	286 – 288	292 – 296	15 – 20
60	40	226 – 227	286 – 289	293 – 294	25 – 30
25	75	208 – 209	287 – 289	295 – 296	50

Table 5 – Cleveland Open Cup Testing of Ethylene Glycol Using a Spark Piloted Ignition

Type of Spark	Flash Point (°F)	Flame Point (°F)
Auto Spark Plug	254 – 316	254 – 316
Furnace Igniter	254 – 281	254 – 281

Further consideration of the ignition regime depicted in Figure 1 indicates that the forced or pilot ignition region is bounded by the ideal auto-ignition Point B. This point is based on a test of the fluid using the ASTM E 659 test apparatus as described in that standard. The special circumstances applicable to Point B are of particular interest with respect to whether or not conditions in the ASTM auto-ignition test are like the conditions present in a motor vehicle prior to a fire. This ASTM test makes use of a 500 ml glass flask containing air which is maintained at temperature while a drop of the fluid, about 100 µL in quantity, is dropped into the flask. The drop is then allowed to remain in the heated flask for up to 10 minutes to see if the vapors inside the flask ignite. The temperature of the flask and the size of the drop of fluid are varied until the lowest temperature that will result in ignition is obtained. It is of interest that there is an absence of air flow inside the flask during the test, and that the air inside the flask is heated along with the flask and the drop of fluid. It should also be noted that the drop of fluid vaporizes then flashes and is gone. It can be seen that this would not represent an ongoing sustained combustion process as would be required for a vehicle fire to occur. It is also obvious that this test configuration is not similar to the conditions present in a vehicle prior to a fire.

Another area of interest in Figure 1 is the area to the right of the Point B. The Point C area, which is referred to as the non-ideal auto-ignition region, can be thought of as the hot surface ignition region. In this region, a heated surface needs to have sufficient temperature and appropriate geometric characteristics, which enable delivery of heat to a confined, appropriately mixed quantity of vapor sufficient to cause the vapor to ignite. It is also noted that the ignition process can easily be stopped by the presence of small quantities of flowing air at the ignition mechanism location.

Additional testing was conducted to further characterize engine coolant performance in the non-ideal auto-ignition regime. One of the tests that was performed involved a small metal pocket that was welded to the face of a vertical metal plate that was heated by an electric hot plate. The metal plate and the attached pocket was heated up to 950°F with the pocket filled with 7.5 cc of 100% ethylene glycol. The ethylene glycol began to boil and the vapor from the boiling fluid passed vertically up the plate above the pocket without igniting. This data point is of interest in that, as stated previously, the highest temperature expected on the engine exhaust manifold for normal engine use is 900°F or less. The conclusion from this is that engine coolant will not start a fire by hot plate auto-ignition based on normal engine use prior to a fire.

Testing in the non-ideal ignition region was continued by conducting tests of ethylene glycol using a heated pipe. The steel pipe used in the test was 1.5-inches in diameter and was heated internally with an oxygen acetylene torch. A thermocouple welded to the area of the pipe where the tests were conducted was used to monitor the pipe temperature during the tests. In the tests, the pipe was brought up to temperature and 100% ethylene glycol was dripped onto the pipe. It was found that the pipe temperature range required to cause ignition was 1230°F to 1280°F.

The testing was continued using the heated pipe, however, in this test, 100% ethylene glycol was sprayed onto the pipe using a handheld misting container. In this test, it was found that the pipe temperature range required to cause ignition was 1350°F to 1450°F.

An additional test using the heated pipe involved making use of the brass cup from the Cleveland Open Cup test apparatus along with an electrical hot plate. The cup with 100% ethylene glycol was heated to boiling and the cup was placed below the heated pipe. The boiling fluid level in the cup was ½-inch from the bottom surface of the heated pipe. It was found in this test that the ethylene glycol vapors did not achieve flaming ignition until the pipe temperature reached 1250°F.

It will be noted that the metal surface temperatures required to cause ignition of 100% ethylene glycol in the heated pipe tests are higher than the temperatures anticipated (about 1100°F) even in malfunctioning engines and in vehicles in which the engine was heavily overloaded for an extended period of time. This observation leads to the conclusion that ethylene glycol will not be caused to auto-ignite by the hot surface in a motor vehicle and thereby cause a vehicle fire.

To further consider the properties of ethylene glycol, an additional test was conducted in which 100% ethylene glycol was placed in the Cleveland Open Cup and brought to boiling at approximately 254°F. The vapors above the cup were flame ignited. Flames were then allowed to stabilize above the liquid in the cup. At that point, ethylene glycol and water mixtures were sprayed onto the flame. It was found that mixtures containing more than 10% water would put the fire out.

DISCUSSION

Analysis of the information and test data presented in this paper indicates that engine coolant is not a good candidate for the first fuel in a vehicle fire. The exception to this requires that the investigator can substantiate that at the start of the fire, the conditions that ethylene glycol needs to ignite and burn, with sufficient energy to spread to other nearby combustible materials, were in existence. This process (absent electrolysis) as noted earlier, depends on many factors (in light of the heat limitations of the components in the motor vehicle) that include consideration of the percentage of water content of the coolant, having a quantity of the coolant pocketed where it can be heated to boiling, having essentially static air flow, having sufficient residency time in the pocketed heated condition to establish a vapor plume, having the vapors in the plume with the proper air-fuel mixture, and having an igniter of sufficient energy resident in the vapor plume for ignition.

The experienced investigator will recognize that the potential for all of these factors to co-exist at the start of a vehicle fire is, for all practical purposes, approximately zero. This analysis is aided by the determination, based on the available test data, that auto-ignition of engine coolant on heated automotive surfaces is likewise, for all practical purposes, approximately zero.

In considering whether or not an electrolysis process could ignite a vehicle fire, the available test data implies that factors needed for ethylene glycol to be a viable candidate include having pooled ethylene glycol on closely-spaced bare electrical conductors, having sufficient residency time (minutes to hours), having static air conditions, having adequate direct-current voltage applied across the bare conductors (22.5 to 28 volts). It is noted that the typical electrical system in the motor vehicle has 12 to 14 volts direct current rather than the 22.5 to 28 volts direct current. Again, based on the available data, it can be seen that the potential for an electrolysis process, resulting in ethylene glycol being the first fuel in a vehicle fire is, for all practical purposes, approximately zero.

The fire investigator should take note that published data, i.e., flash point, flame point and auto-ignition temperatures, is highly dependant on the specific test conditions. That is, that the conditions present in the test apparatus used to obtain the data will strongly influence how a fuel responds, and in general, great care should be exercised when extrapolating the data to different mechanisms and different surrounding conditions. This is particularly true in the case of engine coolant, since as seen in the test data reported here, one quickly jumps from the ideal, well-defined auto-ignition condition at Point B in Figure 1, 750°F, to the not well-defined, non-ideal auto-ignition condition at Point C, that can range up to 1450°F.

In this regard, it is useful to consider the difference between the temperatures required to ignite a single drop, or a small quantity of ethylene glycol that is poured slowly into a large heated flat-bottom crucible, compared to when it is sprayed onto a heated pipe. Indications are that cooling effects and residency time appear to play a significant role in the Point C type potential auto-ignition mechanisms present in a motor vehicle.

CONCLUSIONS

The test data concerning ethylene glycol engine coolants and the associated analysis presented in this paper has the following implications for the vehicle fire investigator:

1. Ethylene glycol coolants will not auto-ignite on the metal surfaces in a motor vehicle and cause a vehicle fire, except under very specific and unlikely conditions.
2. Ethylene glycol coolants released into an engine compartment will likely contain a percentage of water.
3. Water in ethylene glycol coolant inhibits ignition and combustion of the coolant.
4. In order to ignite ethylene glycol and water mixtures, the majority of the water must first be evaporated from the mixture.
5. In order to ignite ethylene glycol, it must first be located where it is pocketed and heated sufficiently to establish a vapor plume with a air-fuel mixture within the upper and lower flammability limits of the vapor in essentially static air flow conditions.
6. In order to ignite ethylene glycol, an adequate piloted ignition mechanism must be located within the vapor plume above a heated pocket of liquid ethylene glycol, in essentially static air flow conditions.
7. In order for ethylene glycol engine coolant to be the first fuel in a vehicle fire, the conditions listed in items 5 and 6 above must be present, and the burning plume of ethylene glycol vapors must be located such that nearby combustibles are ignited and that they continue to burn.
8. Malfunction of the engine or extended heavy overloading of the engine prior to the release of engine coolant could lead to the coolant having a lower concentration of water when it is released. It is, however, very likely that the coolant will continue to contain sufficient water to inhibit ignition or combustion of the coolant.
9. There is a very low probability that engine coolant released in a motor vehicle will find a place to be pocketed and heated, and then for a vapor plume to develop above the pocket, and that location to also have an electric arc sufficient to ignite the vapor plume in a static air flow location.
10. Based on available information, an electrolysis ethylene glycol reaction is considered to not be a viable ignition mechanism in motor vehicle fires.

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