Winter Road Treatments Cause Damage to Fire Apparatus

Michael T. Patterson

Burlington Fire Department, Burlington, Massachusetts

Certification Statement

I hereby certify that this paper constitutes my own product, that where the language of others is set forth, quotation marks so indicate, and that the appropriate credit is given where I have used the language, ideas, expressions, of writings of another.

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Abstract

The Burlington Fire Department is down one front-line fire engine. The engine was taken out-of-service because of corrosion damage to the trucks electrical harness and frame rails. Reports back from the manufacturer stated that the corrosion damage was most likely caused by the chemicals that are placed on our roadways during the winter months. This situation led to the creation of a problem statement. Treatments used to prevent icing and aid in the clearing of snow from our roadways during the winter months contain chemicals that corrode the underside of fire apparatus. The purpose of this research paper is to identify the chemicals that are used to treat our roadways during the winter months and study the effect these chemicals have on fire apparatus. The descriptive research method was used in order to answer the following research questions, what type of treatments are being placed on our roadways during the winter months? Does the chemicals contained in these treatments cause corrosion? What impact do these treatments have on the trucking industry as well as fire apparatus? What preventative measures currently exist that slow the corrosion process down? A literature review, questionnaire, and interview process was conducted to answer the research questions. The result of this research revealed that treatments used in the winter months contain chemicals that damage fire apparatus. Corrosion damage causes fire apparatus to be taken out of service which effects response capability. Corrosion damage leads to increased maintenance costs and a reduction in the life expectancy of the apparatus. Recommendations to slow the harmful effects of corrosion include, strong corrosion protection language in specifications for new apparatus, improved preventative maintenance procedures, and implementation of an undercarriage washing program.

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Introduction

The Northeast region of the United States faces harsh winter conditions each and every year. Icy roadways and large accumulations of snow are common occurrences during the winter months. A typical winter season in Massachusetts begins in December and extends through March. Because of these harsh winters, large amounts of taxpayer dollars are budgeted toward snow and ice removal at both the state and local level. In order for people to get to work and children to get to school our taxpayers demand that their roadways are kept clear and safe. It is the responsibility of our state and local department of public works to ensure that this goal is achieved. Methods that are currently being used by our public works departments have proven to be successful in reducing icy conditions and removing large amounts of snow. These same methods being used to keep our roads clear and safe are causing the automobile and trucking industry major problems. The treatments being placed on our roadways are accelerating the corrosion process on all motor vehicles. Fire departments that operate in the Northeast are being negatively impacted by these methods being used to treat the roadways. Many fire departments are now witnessing corrosion damage to their apparatus that are only ten years of age. This researchers department is currently faced with a major budgetary issue that is directly related to this topic. Burlington Fire Department's Engine One which is a front-line engine that is operated out of Fire Headquarters is out-of-service and is waiting for funding to be appropriated by Town Meeting to refurbish the ten year old engine. The cost of the refurbishment project is estimated to be 250,000.

The focus of this research paper is clearly defined by the following problem statement. Treatments used to prevent icing and aid in the clearing of snow from our roadways during the winter months contain chemicals that corrode the underside of fire apparatus.

The purpose of this research project is to identify the chemicals used to treat our roadways in the winter months and study the effect these chemicals have on fire apparatus. As a result of this research project, the Burlington Fire Department would like to create and institute a preventative maintenance program that would address slowing the damaging corrosion process down.

This researcher chooses the descriptive research method. Much of the research conducted will center on Burlington Fire Departments current situation of being one front-line engine down. A literature review, interviews with individuals in the related fields, and a questionnaire that was sent out to local fire chiefs and public works superintendents will be used to answer the following research questions. What types of treatments are being placed on our roadways during the winter months to prevent icing and assist in the removal of snow? Do the treatments placed on our roadways during the winter months contain chemicals that cause corrosion? What impact do the treatments placed on our roadways during the winter months have on the trucking industry? What impact do the treatments placed on our roadways during the winter months have on fire apparatus? Finally, what preventative measures currently are in place that slows the corrosion process down?

Background and Significance

The Town of Burlington is located 13 miles Northwest of Boston, Massachusetts. Burlington is comprised of 11.88 square miles. The 2012 population for the town is listed at 25,052. ("Burlington At A Glance," 2012). It is important to note that Burlington's daytime population is estimated at over 150,000. Because of Burlington's location, many businesses are attracted to the town. Two of the better known locations in Burlington are the Burlington Mall and the Lahey Clinic.

Burlington is governed by an elected Board of Selectman and a Representative Town Meeting. A Town Administrator functions as the Chief Executive Officer. According to Burlington's Operating Budget for Fiscal Year 2013, total expenditures equal 112,362,517. ("Burlington Operating Budget," 2012, p. 9)

The Burlington Fire Department is comprised of fifty seven uniformed personnel, four civilian dispatchers, one emergency vehicle technician, and three clerical personnel. The Department is led by a Fire Chief and Assistant Fire Chief. The total operating budget for the fire department is 6,078,989. Total salaries account for 5,515,539. ("Burlington Operating Budget," 2012, p. 39). The Burlington Fire Department is operated out of two fire stations. Fire Headquarters is located at 21 Center Street and Station Two is located at 114 Terrace Hall Avenue. Each group is comprised of thirteen firefighters and one civilian dispatcher. A Captain serves as the Shift Commander and responds from Fire Headquarters. Each group is staffed by a Captain, two Lieutenants', ten firefighters, and one civilian dispatcher. Minimum manning for the Department is eleven firefighters and one dispatcher.

The Burlington Fire Department provides fire and emergency medical services to the Town and its citizens. The Department staffs two basic life support ambulances. The Department has a Fire Prevention Division, Training Division, and a Maintenance Division. According to the Departments Massachusetts Fire Incident Reporting System, we responded to 3,928 fire related incidents in 2011. We also responded to 2,797 EMS incidents in 2011 according to our AmbuPro Reporting System. When you combine both fire and EMS incidents, the Burlington Fire Department responded to a total of 6,725 incidents in 2011.

The Burlington Fire Departments vehicle inventory consists of four engines, one tower truck, two ambulances, one rescue truck, one forestry truck, one mechanic pick up truck, and six command cars. (Appendix A).

The Burlington Fire Department designated its engine inventory as front-line, back-up, and reserve. The Departments front-line engines are comprised of a 2008 Pierce Arrow XT which is capable of delivering 1500 gallons per minute (GPM). A 2002 Pierce Quantum which is also capable of delivering 1500 GPM. The 2008 Pierce Arrow XT is housed at Station Two, while the 2002 Pierce Quantum is housed at Headquarters. The Departments back-up engine is a 1998 Pierce Quantum which is capable of delivering 1250 GPM. This engine is housed at Headquarters and is considered the second engine out of Headquarters. The Departments reserve engine is a 1990 Pierce Arrow. This engine is capable of delivering 1250 GPM. The importance of having a reliable reserve engine cannot be overstated. Often times a front-line engine or the back-up engine is taken out of service for scheduled or unscheduled maintenance. When this occurs our reserve engine is moved to a back-up position. This allows the Department to keep three engines in-service at all times.

Currently our 2002 Pierce Quantum is out-of-service. It has been determined by the manufacturer of the apparatus that the electrical harness and frame rails of the truck has been damaged by corrosion and is in need of a refurbishment. Because of this damage, the Burlington Fire Department will be looking at a costly refurbishment of the truck and will be forced to move our reserve engine into back-up status. This will leave the Department with three operating engines and no reserve. If one of the remaining engines is taken out of service for maintenance, we will be forced to operate with only two engines. The Departments ability to respond to all emergency incidents in a timely manner will be negatively impacted if we operate with only two

engines. Because of the Burlington Fire Departments strong relationship with a neighboring community, a plan has been formulated that would allow our department to borrow their reserve engine, only if it was available.

Through communications with local fire chiefs, this researcher found that we were not the only department that was experiencing corrosion related damage. Several other local departments were experiencing similar situations. Like our department, many of these corrosion issues involved apparatus that was in-service for approximately ten years. Most of the discussions this researcher had with local chiefs were centered on the treatments that are placed on the roadways during the winter months. Most concerning to us was the use of the liquid treatments that were placed on our roads prior to a storm. It is the belief of many local chiefs that chemicals found in these treatments accelerate the corrosion process to the undercarriage of fire apparatus.

The Burlington Fire Department has been aware of corrosion damage for years. Back in 2006, the Departments 1990 Pierce tower failed an Underwriters Laboratory aerial inspection and was permanently taken out-of-service because of major corrosion damage to the trucks torque box, frame rails, and outriggers.

Even with a knowledge of the damage corrosion can cause, the Burlington Fire Department has done very little to slow the corrosion process down in our other apparatus. Like many departments, we routinely wash the exterior of our apparatus. Very little thought is given to washing under our apparatus, especially during the winter months. In order for our Department to keep a full compliment of engines in-service, reduce maintenance costs, and maximize the life expectancy of our apparatus, the Department will have to create and implement procedures that will slow the harmful effects of corrosion.

Not only will new procedures need to be created but a change in organizational culture will need to take place. Tradition plays an important role in every fire department. Many of the methods that are currently used are in place because that is the way we have always done it. The Executive Development course of the National Fire Academy's Executive Fire Officer Program discusses change at length. Unit Seven of the Executive Student Manual discusses leading cultural change. E. H. Schein describes how leaders can affect change and the role that the Executive Fire Officer can use to affect change. ("Executive Development," 2011)

There is a definitive link between understanding what is causing our apparatus to corrode which leads to out-of-service-time and increased maintenance costs to changing the current methods that we use which are ineffective in slowing the corrosion process down. The Executive Fire Officer will develop, along with others, new preventative maintenance procedures that will slow the damaging effects of corrosion.

There is also a linkage between understanding what is causing our apparatus to corrode and two of the U.S. Fire Administration's Goals. Improve local planning and preparedness and improve the fire and emergency services capability for response to and recovery from all hazards. By creating new procedures that will slow the corrosion process down, we will reduce maintenance costs to the Town, extend the life expectancy of our fire apparatus, and have a fully operational fleet of apparatus that will be able to respond for all calls for service in a timely manner.

Literature Review

A literature review was conducted by this researcher to obtain information pertaining to the five research questions posed. The first research question asks what types of treatments are being placed on our roadways during the winter months to prevent icing and assist in the removal

of snow. This researcher is going to focus on the specific treatments that are used by the department of public works and the different methods they use to apply the treatments.

Snow removal and ice control requires the timely application of chemicals, abrasives, or a mixture of chemicals and abrasives along with snowplowing. (*Winter Maintenance*, 2012, p. 3)

The use of salt plays an important role in snow and ice removal. Salt when mixed with water becomes a brine solution. The brine solution reduces the freezing temperature of water. The benefit of using liquid salt or salt that is pre-wetted is that freezing points of water are reduced faster than when solid product is put on the roads. The goal of placing liquid salts on the roads is to prevent ice from forming on the roadway. When the salt becomes extremely diluted with water it looses its effectiveness, thus freezing can re-occur. For situations such as this, it becomes necessary to reapply a salt treatment. (Salt Institute, 2011, para. 1-4).

Sodium chloride brine is effective when road temperatures are at or above -6 degrees Fahrenheit. Liquid calcium chloride and liquid magnesium chloride is used when extremely low temperatures are expected. These treatments are effective but more expensive than the sodium chloride solution. (Salt Institute, 2011, para. 4-5)

According to a 2010 report, Rubin, et al. (2010, p.7) there are five primary types of chemicals that are used for snow and ice control. They are;

- Sodium Chloride (NaCl)
- Calcium Chloride (CaCl2)
- Magnesium Chloride (MgCl2)
- Potassium Acetate (KA)
- Calcium Magnesium Acetate (CMA)

Another common method used for snow and ice removal is the application of sand or abrasives. These materials are commonly placed on roadways that are already covered by snow and ice. Sand or abrasive materials have no melting capability. (Mussato et al., 2007, p. 13)

"Application strategy is an important aspect of snow and ice removal. Application depends on weather conditions, site-specific factors, and service goals. An agencies options regarding application include selection of materials as well as the timing, rate, and frequency of application." (Mussato et al., 2007, p. 18)

Two of the most common application methods for snow and ice removal are anti-icing methods and deicing methods. Anti-icing methods are used to prevent ice from forming on the road, while deicing is used to remove snow and ice after they begin to accumulate. ("Breaking The Ice," 2010, para. 2-3).

Anti-icing materials are placed on the roadways prior to a storm arriving. The anti-icing material when mixed with water is able to lower the freezing point of the mixture. Because of this, snow and ice is able to be removed from the roadway and less salt is required to be placed on the roadway. ("Breaking The Ice," 2010, para. 10).

Deicing methods involve placing chemicals on top of the snow after it has accumulated. Solid sodium chloride or rock salt is commonly used for deicing procedures. A problem that is encountered by deicing methods is that the product can be removed from the roadways by traffic movement. (Mussato et al., 2007, p.19)

Two other processes that are commonly used for snow and ice removal include mixing a salt product with an abrasive and stockpile treatments. Salt and abrasives are mixed together with half representing salt and half representing the abrasive. The use of this 50/50 mixure is not as effective as using a straight chemical solution.

Stockpile treatments involve wetting a solid pile of chemicals. Wetting the solid pile prevents the product from hardening and forming lumps which make the product difficult to spread. (Mussato et al., 2007, p. 20)

In order for this researcher to identify what type of chemicals are used in Massachusetts, I turned to the Massachusetts Department of Transportations website. (Massachusetts Department of Transportation [MassDOT], 2012, para. 6) This section described the methods used by MassDOT as well as the materials used during snow and ice operations. The Town of Burlington has two major highways and one major route that pass through the town. MassDOT is responsible for treating and plowing these roads. Common treatments used by MassDOT include;

- Sodium Chloride
- Sand
- Pre-mix of Sodium Chloride and Calcium Chloride
- Liquid Calcium Chloride
- Liquid Magnesium Chloride

In November of 2012, MassDOT unveiled a new 250,000 dollar Brine Xtreme Machine. Currently the State is using a liquid magnesium chloride solution on the roadways. This new piece of equipment will allow magnesium chloride to be mixed with a salt brine solution. The combined solution will result in a lower salt concentration than pure magnesium chloride. This mixture is intended to replace the straight magnesium chloride solution. MassDOT believes this new technique will be more environmentally friendly as well as being cost effective. This new mixture will be capable of being applied to the roadways two days in advance of a storm. The

old method of applying magnesium chloride could only be put down two hours prior to the storm. (Wysocki, 2012, p.A1, A4)

Scott Venuti works for the Massachusetts Department of Transportation. He is assigned to the District Four Snow and Ice Division. District Four is responsible for treating and removing snow from all State roadways in Burlington. Mr. Venuti reports that MassDOT uses liquid magnesium chloride on Route 128, Route 3, and Cambridge Street. Venuti reported that MassDOT pre-treats the roadways under certain conditions. If temperatures will remain under 32 degrees the liquid is sprayed on the roads. Venuti also stated that MassDOT pre-wets sodium chloride with small amounts of magnesium chloride as the product is being placed on the roadway. (S. Venuti, personal communication, November 21, 2012)

In order for this researcher to identify what types of chemicals are used in Burlington, an interview was conducted with the Burlington Department of Public Works Superintendent. John Sanchez reports that Burlington has used a product called Safe Melt for the past four winters. This product is made up of 40% organic byproducts and 60% calcium chloride brine. Sanchez stated that only the town's main roadways and streets with hills are pre-treated with this product. Sanchez reported that the DPW uses eight gallons of liquid to one ton of mixture. Sanchez also stated that the DPW uses a 50/50 sand/salt mixture to treat the roads. (J. Sanchez, personal communication, November 21, 2012)

This researcher previously identified the treatments and methods commonly used for snow and ice removal. The second question researched was, do the treatments placed on our roadways during the winter months contain chemicals that cause corrosion.

"Corrosion is the undesired destruction of materials through chemical or electrochemical reaction with their surroundings that originates from the surface." (Moller & Muller, 2011 Rev. ed., p. 1)

Kelting and Laxson define corrosion as "the electrochemical degradation of metals and alloys due to interaction with the environment." (Kelting & Laxson, 2010, p. 45)

"Atmospheric corrosion is one of the most important degradation processes that limits the life of motor vehicles and roadside infrastructure where snow and ice control materials are used for winter maintenance. (Mussato et al., 2007, p. 71) "The air humidity has the biggest influence on atmospheric corrosion."(Moller & Muller, 2011 Rev. ed., p. 6)

A 2002 report prepared by the Colorado Department of Transportation studied the usage of magnesium chloride. "Magnesium chloride has high viscosity, high crystallization potential and strong hydrophilicity, so it can stick on the surface of a metal and become solution again in humid environment." (Xi & Xie, 2002, p. 65)

Mussato et al. (2007, pp. 71-72) lists the various forms of corrosion that is commonly associated with motor vehicles. These forms of corrosion include; uniform, crevice, poultice, pitting, galvanic, and filiform corrosion. The following is a description of each form of corrosion.

- Uniform – Spreads out at the same rate over a metal surface. This form of corrosion is particularly damaging to motor vehicles because it affects the underside of the vehicles including electrical harnesses.
- Crevice – Localized form of corrosion that affects metals that are attached or immediately next to one another. One of the metals may be shielded from the full effect of the environment.

- Poultice – Occurs when roadside salts and debris accumulate on ledges that are located within the motor vehicle. The accumulation of these materials is kept moist by the environment and the washing of vehicles. Damage to vehicles occurs during the drying process.
- Pitting – Occurs to metals that are not fully resistant to corrosion. Cell action produces cavities within the surface of the metal.
- Galvanic – Is an accelerated form of corrosion that occurs when two dissimilar metals come in contact with one another. One of the biggest problems that occur in motor vehicles is when aluminum and steel come in contact with one another.
- Filiform - This type of corrosion occurs under the surface of an organic coating. This type of corrosion is seen with aluminum and magnesium alloy metals. This form of corrosion will occur when voids are created in the organic coating.

Kelting and Laxson (2010, p. 46) report that motor vehicle corrosion can be divided into three categories. They are functional, structural, and cosmetic.

- Functional – Affects how a vehicle operates. The braking system is considered functional.
- Structural – Affects the main components of the motor vehicle such as frame rails.
- Cosmetic – Involves the change of appearance of the vehicle such as rusting or staining.

Road splash that is created when motor vehicles travel over icy and snowy roads adhere to the metal surfaces of motor vehicles. These chemicals can build up in several locations within the vehicle. These deposits can lead to crevice and poultice corrosion. Massato et al. (2007, p.73).

Sodium chloride, calcium chloride, and magnesium chloride are all highly corrosive to motor vehicles. "The hydroscopic chlorides are more corrosive because deposits remain moist and allow corrosion to occur for a much longer period." (Massato et al., 2007, p.74)

Many treatments that are used on our roadways during the winter months contain corrosion inhibitors. Corrosion inhibitors will reduce the corrosion rate on a metal or alloy. Xi and Xie (2002, p. 64) state that corrosion inhibitors are "metal specific and salt specific." No one corrosion inhibitor will prevent corrosion to all metals. Corrosion inhibitors may show significant corrosion reduction in a metal being tested in a laboratory. However the same test on a different metal may produce different results. (Mussato et al., 2007, p.93).

Scott Venuti of MassDOT District Four reported that liquid calcium chloride was very corrosive. Because of this MassDOT switched to liquid magnesium chloride four or five years ago. Venuti stated that the magnesium chloride comes with a corrosion inhibitor. (S. Venuti, personal communication, November 21, 2012)

Burlington DPW Superintendent John Sanchez believes that corrosion issues have slowed since the town began using the liquid product. Sanchez stated that today's product is far less corrosive than those used in the past. He stated that the straight calcium brine solution caused corrosive effects. (J. Sanchez, personal communication, November 21, 2012)

The next question researched was, what impact do treatments placed on our roadways during the winter months have on the trucking industry. Yorke (2012, para. 1) suggests that the methods used to clear roadways of snow and ice, which allows trucks to use the roadways during inclement weather, is also creating problems for the trucking industry. "The very chemicals that are used to clear roads of snow and ice and permit bad weather operations are destroying their

equipment." Vertin states, "The salt age is dawning in North America, and road salts are creating an epidemic corrosion problem for America's transit systems." (Vertin, 2011, para. 1)

"Corrosive road salts attack a variety of metal components to include frame rails, crossmembers, suspension components, air tanks, fuel tanks, battery boxes, brackets, brake shoes, electrical systems, air conditioning condensers, radiators, metal coolant tubing and steel wheels."(Vertin, 2011, para. 2)

Vertin (2011, para. 8) believes that the introduction of calcium chloride and magnesium chloride has led to the recent increase in corrosion to the underbodies and electrical systems of fleet vehicles. Lockridge (2008, para. 6) states that the calcium chloride and magnesium chloride produce a fine mist that is able to travel to the underside of vehicles and penetrate components.

"Calcium and magnesium chlorides get quite viscous as water evaporates, collecting sand and dirt and form compacted deposits in recessed areas. These difficult to remove deposits are the source of major chloride corrosion."(Vertin, 2011, para. 5)

"To complicate the situation further, if the road salts are not removed from the vehicle, magnesium chloride and calcium chloride will pull moisture out of the atmosphere, rewet and continue their corrosive action." (Vertin, 2011, para. 5)

Lockridge (2007, p 74) reports that vehicles can be damaged even when their equipment is dry and the weather is dry. The chemicals that are present on the vehicle will continue to mix with water and the result is that this mixture may seep into cracks and cause further damage.

Electrical systems are susceptible to being damaged by corrosion. These systems are prone to moisture and contaminants from the roadways. (Lockridge, 2008, par. 6).

Vertin (2011, para. 8) warns of the threat to drivers and passengers if corrosion damages load-bearing structures.

In order to better understand how corrosion has impacted the trucking industry, I interviewed Bob Theroux the Automotive Manager for the United Parcel Service. UPS has a major distribution center located in Chelmsford, MA. UPS is known for their strong fleet preventative maintenance program. Theroux spoke primarily about the typical brown UPS delivery truck. Theroux is very aware of corrosion related problems. He has seen numerous electrical issues involving lights and electronic modules which are exposed under the trucks. He speaks of frequently having to replace brake lines because of corrosion. Theroux stated he couldn't remember the older trucks having as many issues as today's trucks. He used to get twenty years out of a truck. Today he gets between ten and fifteen years. (B. Theroux, personal communication, November 26, 2012)

Theroux was very aware of the products that are placed on the roadways during the winter months. He stated that the roadways are treated with rock salt and pre-treated with liquids. He stated the liquid products sprays up into the undercarriage of the trucks and festers. Theroux stated he looks at the costs of repairing vehicles versus buying new. If the truck will require costly repairs he may recommend to management that the truck be disposed of. (B. Theroux, personal communication, November 26, 2012)

Joseph Lydon works at Palmer Spring located in Woburn, MA. Lydon reports that Palmer Spring deals with corrosion on a daily basis. He has seen corrosion damage to springs, frames, exhaust systems, and air valves. He speaks of the treatments being used on the roadways during the winter months. He stated that the spray after the storms corrode everything. He reports seeing DPW trucks that put these chemicals on the road rotting away. Lydon stated that

the liquid is vicious against steel. The liquid gets into the cracks and crevices and causes more damage. Lydon stated he could tell the difference between vehicles that come from a town that uses liquid treatments versus those that did not. Lydon believes there is a correlation between vehicle life expectancy and corrosion. (J. Lydon, personal communication, November 29, 2012)

The next question to be researched is what impact do treatments placed on our roadways during the winter months have on fire apparatus. Limited information on this question could be obtained during the literature review. This researcher believes that many of the issues listed in the previous research question hold true for fire apparatus. Fire apparatus suffer from the same effects that all trucks do that operate on roadways that are treated with chemicals. Quite often during the winter months the only trucks you may see on the roadways are DPW trucks and fire trucks. Often the fire truck is behind the DPW sander as product is being placed on the roadway. For this research question, this researcher is going to look at the impact corrosion has on the life expectancy of fire apparatus, review first hand reports from mechanics who work on fire apparatus, and study the costs that are associated with vehicles that are damaged by corrosion.

According to Brewer (2010, pp. 27-28) there are many factors that affect the life expectancy of fire apparatus. Some of these factors include the type of climate or conditions in which the apparatus operates in, the quality of the workmanship by the manufacturer, and the number of incidents that the apparatus responds to. Brewer states that one of the most important factors related to the life expectancy of fire apparatus is the quality of a fire departments maintenance division. Preventative maintenance must begin with the purchase of the truck and continue through the life of the apparatus.

A recent article in Fire Chief Magazine discussed a new approach used by a Virginia Fire Department in replacing front-line engines and extending the life expectancy of their apparatus.

Back in 1996, the Henrico County Division of Fire replaced front-line engines after ten years of service. The plan was based on the experiences of the department related to call volume, type of driving environment, and the quality of their maintenance division. This plan was based on assumption, not fact. A new plan was put in place to replace apparatus when a trucks life-to-date maintenance costs exceeded the original purchase price of the truck. When a truck reached 60 percent of the maintenance to acquisition cost, the truck was removed from front-line status. More importantly the truck still had 40 percent of its maintenance to acquisition cost remaining. This means that a truck would be placed in reserve with serviceable years ahead. Henrico realized the importance of having serviceable reserve engines. At any time a reserve engine could be placed in front-line status. Henrico found that by using this maintenance to acquisition formula, front-line engines were reaching the 60 percent maintenance to cost acquisition at ten years. (McDowell, 2012, pp. 41-42)

NFPA 1901 states that it is recommended that fire apparatus greater than fifteen years of service, that has been properly maintained, and are in serviceable condition be placed in reserve status as well as being upgraded to NFPA 12 Standards.(National Fire Protection Agency [NFPA], 2009 ed.) NFPA 1901 further states that apparatus that is over twenty five years of age should be replaced.

The above statements both indicate that the life expectancy of a fire apparatus should be greater than ten years. Henrico Fire clearly illustrates the importance of having serviceable reserve apparatus. These statements also reflect the devastating impact a department faces when an apparatus is taken prematurely out-of- service due to corrosion damage.

Chapter Six of NFPA 1911 discusses what a chief officer can do when faced with a fire apparatus that has been damaged. It is the responsibility of the Authority Having Jurisdiction to

take a piece of fire apparatus or a defective portion of the apparatus out-of-serve. (National Fire Protection Agency [NFPA], 2007 ed.) The apparatus shall be placed back in service only when the defects have been corrected and retested.

This researchers department was forced to make this decision twice in the past six years. This past October, the Chief of Department was forced to take a front-line engine out of service because of corrosion damage to the electrical harness and frame rails. Back in 2006, the Department's 1990 Pierce 95 foot tower was also taken out of service for corrosion related problems. The tower was taken out of service following an Underwriters Laboratory aerial device examination and test. The following is a brief narrative of the findings of the report. (Underwriters Laboratories INC [UL], 2006)

- Delaminating corrosion was found where the torque box meets the framerails.
- Steel hydraulic lines that run along the outside of the torque box were found corroded.
- Heavy delaminating corrosion was found on the tandem axle suspension.
- Heavy delaminating corrosion found on the left side framerail just forward of the rear tandem axle.
- Corrosion was found on the counter weight carriage assembly located at the rear of the truck
- Early signs of delaminating corrosion were found inside all horizontal stabilizer housings and on all footpads.
- Light surface corrosion was found on the outside wall of all vertical stabilizer housings.

- Heavy corrosion was found on the stabilizer control valve line fittings.

Eric Moran is the Emergency Vehicle Technician for the Burlington Fire Department. He has been a member of the department for the last six years. Prior to that, he worked for the Burlington DPW. Moran first noticed significant corrosion damage to the 2002 Pierce Quantum about three years ago. Heavy corrosion damage was present toward the rear of the truck. The frame, wiring, and air valves were all corroded. Moran reported problems with the trucks electronics, some of which he blamed on the manufacturer. He spoke specifically about the trucks dill box that houses electronics and relays. He stated that truck vibration caused damage to the housing of the box which resulted in water and salts entering the box leading to corrosion. While working at the DPW, Moran reported numerous electrical and corrosion issues with vehicles. He believes that treatments placed on the roadways are a major cause of vehicle corrosion (E. Moran, personal communication, November 29, 2012)

Jeffrey Kelland is an Emergency Vehicle Technician at Minuteman Trucks located in Walpole, MA. Minuteman Trucks is the local Pierce Dealership. Kelland reports seeing corrosion damage to frame rails, cross members, torque boxes, and outriggers. He has seen electrical damage to fire apparatus in the past but not to this extent. He believes the problem he is seeing with electrical systems is associated with the splicing of electrical harnesses. He stated that chemicals can enter the harnesses and wick up electrical wiring several inches. The wiring turns a greenish color. Kelland speaks of not being able to break apart electrical components at the connections because of corrosion. Because of this he is forced to jump wiring. Kelland believes that the treatments being placed on the roadways during the winter months are causing corrosion, especially the liquid treatments. Even if the truck is undercoated, any scratch provides an opening to the chemicals. Kelland speaks of Minuteman Truck recently building a

million dollar paint facility in order to deal specifically with body corrosion. (J. Kelland, personal communication, November 29, 2012)

Significant corrosion damage to electrical systems and frame rails will lead to an apparatus being taken out of service. The result of an apparatus being taken out of service has both an operational and budgetary impact on the department. This leads to a difficult question for the chief officer. Do we replace the apparatus with a new truck or do we refurbish the damaged truck. When the 1990 Pierce tower was removed from service the department was forced to rent an older model ladder truck to provide coverage for the town. Town Meeting was forced to approve 850,000 dollars for a replacement truck. Currently this researchers department is faced with a similar situation. A 2002 Pierce Quantum is out of service and is in need of refurbishment or replacement. The estimated cost of purchasing a similar new apparatus is 650,000 dollars. Estimates to refurbish the Quantum are approximately 250,000 dollars.

The costs of replacing fire apparatus has increased steadily over the recent years. This can be attributed to new emission standards for fire apparatus, new and improved safety features which are now being incorporated into new fire apparatus, and the increased cost of materials. (Shand & Wilbur, 2012, p 77).

Because of the above statement, many fire departments are turning to refurbishing their damaged apparatus. NFPA warns that fire chiefs should exercise special care when evaluating the cost of refurbishing versus the cost of purchasing new apparatus. (NFPA, 2007 ed.) NFPA 12 states that refurbishing a fire apparatus generally involves a major investment and should be treated as such. (National Fire Protection Agency [NFPA], 2006 ed.).

Depending on the damage to the apparatus, two levels of refurbishment exist. Level I refurbishment results in the assembly of a new fire apparatus using new components or

components from existing fire apparatus. Level II refurbishment results in an upgrade of major components that comply with or exceed the standards that were in effect the time the apparatus was originally manufactured. (NFPA, 2006 ed.)

William Doucette is a Gloucester MA. Firefighter/Mechanic. Doucette was recently involved in a major refurbishment project involving an engine in his department. Doucette stated he started noticing flakes coming off the frame rails of a 1998 Pierce Saber. He noticed that the brake reservoir and valves were corroded as well. Doucette believed if the department did not address the corrosion problem immediately they most likely would get only another year of service out of the truck. The department chose to refurbish the truck at a cost of 220,000 dollars. (W. Doucette, personal communication, October 18, 2012)

The final research question asks what preventative measures currently are in place that slows the corrosion process down. For this research question this researcher is going to focus on preventative language in specifications, current maintenance standards, and preventative maintenance methods.

As stated in previous sections of this Applied Research Project, the undercarriage of the apparatus is most susceptible to the damaging effects of chemicals used in winter road treatments. Because of this, this area of the vehicle should be the considered a "critical maintenance area." (Ballam, 2010, para. 1)

Fire departments should take a proactive approach when it comes to corrosion. This can be accomplished by including corrosion prevention language in all new apparatus specifications. By including corrosion prevention language in specifications, life expectancy of fire apparatus can be extended and out-of-service time caused by corrosion can be reduced. Particular attention

should be given to separating dissimilar metals including frame rails, hinges, door handles, and light with a corrosion prevention coating. (Nay Sr, 2012, para. 10).

E-ONE is addressing this very issue. In locations were dissimilar metals come in contact with one another, E-ONE is protecting its new fire engines with a product called ECK. ECK is the acronym for "Electrolysis, Corrosion, Kontrol." ("E-ONE," 2009, para. 1).

Protective coatings will provide a degree of separation between the surface of a metal and the environment. However, these coatings do not provide total protection. (Kolman, 2010, para. 43). Even when protective coatings are applied to these surfaces, corrosion can still occur. Corrosion can form in surfaces where the protective coating has been damaged by road debris. It is critical to keep these protective coatings in place. (Gelinas, 2011, para. 11).

As we can see from the above, corrosion can not be completely eliminated, but it can be reduced with strong specification language for new equipment and good preventative maintenance practices. (Hartley, 2010, para. 2). Frequent inspections of equipment and preventive maintenance measures are far more effective that corrective maintenance. Preventative maintenance results in reduced costs and less work. "The objective needs to be to attack corrosion before it becomes a serious problem." (Kolman, 2010, para. 34)

Chapter Seven of NFPA 1911 addresses the inspection and maintenance of fire apparatus chassis. All frame rails and members shall be inspected for defects, structural integrity, corrosion, perforations, and missing or loose parts. (NFPA, 2007 ed.)

One of the problems associated with corrosion is that it can go undetected for lengthy periods of time before a major problem begins to surface. If corrosion can be identified early and correct measures are taken, the damaging effects of corrosion can be reduced. (Kolman,

2010, para. 8). When fire apparatus has been worked on protective coatings should be re-applied to areas that may have been damaged by the process. (Nay Sr, 2012, para. 9).

Electrical systems should also be inspected on a regular basis. The corrosive chemicals can also damage electrical wiring. The chemicals will damage any wiring that is exposed such as connections or areas of wiring that have been spliced into. These openings provide an avenue for damaging salt creep. (Gelinas, 2011, para.14).

Chapter Eight of NFPA 1911 discusses inspection and maintenance of low voltage electrical systems. All wiring and wire looms shall be inspected for security of mounting, tight connections, proper routing, presence of grommets, condition, and cleanliness. (NFPA, 2007 ed.)

Washing equipment that is exposed to winter treatments is also a must. Washing should occur frequently. (Hartley, 2010, para.16).

A Pierce Manufacturing Service Bulletin was released in January of 2009. The author of the service bulletin encouraged representatives of Pierce Manufacturing to share this bulletin with their customers. Service Topic 274 addresses undercarriage corrosion. The following are suggestions from the author to slow the effects of corrosion. (Barry, 2009)

- Thoroughly pressure-wash the undercarriage of the apparatus frequently to remove salt and chemicals.
- Apply a rust proofing compound to the undercarriage of the apparatus.
- Inspect the undercarriage frequently to identify corrosion at an early stage.
- Hose the radiator with plain water.
- Keep mud flaps in good repair to minimize the salt spray.
- Avoid splicing into wires.

- Clean out electrical connectors regularly with plain water and re-grease with dielectric grease.

During interviews with Jeffery Kelland of Minuteman Trucks and Joseph Lydon of Palmer Spring, a discussion took place about preventative measures that fire departments should take to protect themselves from damaging corrosion. Kelland stated that Pierce recommends the usage of stainless steel in many locations of the new apparatus. This includes stainless steel bodies. He believes that fire departments need to keep an eye on apparatus undercoating. When the undercoating bubbles up, you need to sand it off, add rust proof, prime, and paint. If you do nothing about it, problems will occur. Kelland believes the truck needs to be washed every time it goes out the door. There is no need to pressure wash. He feels pressure washing could actually damage components. You could drive the product into cracks which could lead to corrosion. (J. Kelland, personal communication, November 29, 2012)

Joseph Lydon speaks of the importance of using dielectric grease on all electrical connections. He believes this will extend the life of the electrical system. Lydon speaks of the importance of washing the undercarriage of the vehicle. He cautions about the use of pressure washers. He states that pressure washing could push the chemicals further into cracks and crevices. He also warns of washing after every run. He believes problems with icing may occur if the truck goes back out in below freezing temperature. (J. Lydon, personal communication, November 29, 2012)

Thomas Conway is the Chief of the Billerica Fire Department. Chief Conway stated he just purchased a pressure washer to clean their apparatus. Conway stated he purchased this piece of equipment based on the recommendations of fire apparatus manufacturer E-ONE. This washer would become part of his department's preventative maintenance program. Chief

Conway stated that E-One recommended washing the underside of the apparatus four times a year. Chief Conway plans to develop a checklist to document every time the department pressure washes the underside of their apparatus. (T. Conway, personal communication, November 26, 2012)

In summary, the literature review conducted by this researcher affirms the belief by many in the fire service, that the treatments used to prevent icing and assist in the clearing of snow and ice contain chemicals that damage the underside of fire apparatus through the process of corrosion. This researcher now has an understanding of what type of chemicals are placed on our roadways and the damaging effects these chemicals can cause. This researcher has a better understanding of the corrosion process that effects all motor vehicles and can personally relate to several of the different forms of corrosion that have been found on fire apparatus. Fire apparatus is particularly susceptible to corrosion damage to electrical systems and frame rails. Such damage leads to costly maintenance repairs, refurbishment, or replacement of the apparatus.

Another finding as the result of this research was recognizing the importance of a preventative maintenance program specifically focused on slowing the corrosion process down. Through this research a new focus on corrosion prevention will be developed to reduce maintenance costs and increase the life expectancy of fire apparatus.

Procedures

This researcher attended the National Fire Academy's Executive Development course from June 18, 2012 to June 29, 2012. Once returning home this researcher began to give thought to choosing a topic for his Applied Research Project. In early October of 2012, a major problem developed in this researcher department. A front-line engine that operates out of our Headquarters Station was taken out-of-service because of corrosion damage to the electrical

harness and frame rails of the truck. How could an engine be taken out-of-service after only ten years of duty? The manufacturer of the apparatus indicated that the corrosion damage was most likely caused by road salts that are placed on our roadways during the winter months. As a result of our current situation, I chose to research the relationship between treatments used during the winter months to prevent icing and assist in the removal of snow to corrosion damage of fire apparatus. This researcher created a purpose statement, which was to identify the chemicals used to treat our roadways in the winter months and study the effects these chemicals have on fire apparatus. The descriptive research method was chosen and five research questions were developed in order to accomplish the intended purpose. Once the problem statement, purpose, research questions, research method, and research approach was completed, this researcher forwarded the Applied Research Proposal to my assigned evaluator for approval.

Once the proposal was approved, a literature search began. This researcher turned to the internet to search for related articles pertaining to each question. This researcher traveled to the resources center at the local library to search for related articles, journals, and reports on the subject. This researcher also searched for related material that was located in his own department.

Initially this researcher was disappointed in the limited amount of literature he could find related to the research questions. Because of this I felt it would be in my best interest to interview individuals in the related fields as well as develop a questionnaire to send to individuals in the related fields.

Two questionnaires were developed by this researcher. This researcher became a member of Survey Monkey which is located on www.surveymonkey.com. The purpose of interviewing and sending questionnaires was to fill in the gaps that were created by the lack of

information available during the literature review. This researcher formulated questions based on his fire service experience as well as his knowledge on the topics that was being acquired as a result of the literature search.

The questionnaires were developed with the intention of using the responses for more than one research question. For example, responses obtained from the Fire Apparatus Corrosion questionnaire could be used in the results section to answer research question four and five. Two questionnaires were developed and forwarded to individuals in the related fields. The first questionnaire entitled Fire Apparatus Corrosion was sent to all members of the Fire Chief's Association of Massachusetts, Inc. This was accomplished by posting the questionnaire on the Association's corkboard located on www.fcam.org. (Appendix K). The second questionnaire entitled Winter Road Treatments was sent to the Town of Burlington's DPW Superintendent John Sanchez. Mr. Sanchez distributed the questionnaire to local DPW Superintendent's through his group email. (Appendix J) No follow up procedures were used by this researcher. 51 Fire Chiefs replied to the Fire Apparatus Corrosion questionnaire. 22 DPW Superintendent's replied to the Winter Road Treatments questionnaire.

Interviews were also conducted by this researcher. Once again it was the intent of this researcher to interview individuals in the related fields. These interviews were conducted in person at outside locations, in person at Fire Headquarters, and by phone. This researcher interviewed a neighboring fire chief, two fire department mechanics, one apparatus dealership mechanic, one public works superintendent, one state highway employee, and two individuals that work in the field of truck maintenance. (Appendix B through Appendix I). This researcher believed by interviewing a wide assortment of individuals in the related fields an accurate assessment of the problem statement could be obtained.

Limitations to the research became evident when completing the procedures section of the Applied Research Project. This researcher was not aware of the total number of individuals that that received the questionnaires. Because of this, this researcher believes that he failed to assure the 95 percent confidence level. It is also the belief of this researcher that the two questionnaires were developed prior to the researcher having sufficient knowledge on each research question topic.

The final aspect of completing the Applied Research Project was to organize all the information obtained, write a draft, and review it prior to creating a final version. In order to complete these tasks, this researcher used three resources. The 4th edition of the Executive Development Student Manual, The Executive Development Applied Research Self-Study Course Guide, and the 6th edition of the Publication Manual of the American Psychological Association.

Results

The purpose of this Applied Research Project was to identify the chemicals used to treat our roadways in the winter months and study the effects these chemicals have on our fire apparatus. In order to determine if there was a relationship between winter treatments and fire apparatus corrosion a series of research questions were developed. The first research question asked what types of treatments are placed on our roadways during the winter months to prevent icing and assist in the removal of snow. In order to answer this question, a literature review was conducted, questionnaire responses were evaluated, and the results of interviews were revealed.

The literature review revealed that five primary types of chemicals are used for snow and ice removal. They are sodium chloride, calcium chloride, magnesium chloride, potassium acetate, and calcium magnesium acetate. (Rubin, 2010, p. 7).

Common chemicals that are used in the State of Massachusetts include sodium chloride, sand, pre-mix blend of sodium chloride and calcium chloride, liquid calcium chloride, and liquid magnesium chloride. (MassDOT, 2012, para. 6).

A questionnaire was developed by this researcher entitled Winter Road Treatments. This questionnaire was distributed to local DPW superintendents. 22 superintendents replied to the questionnaire. Three of nine questions pertain to this research question.

1. What type of treatments are placed on your roadways during the winter months to prevent icing and assist in snow removal?

All respondents answered this question. 95.5% of the respondents report using rock salt or sodium chloride, 50% report using liquid calcium chloride, 45.5% report using sand, 9.1% report using liquid magnesium chloride, and 4.5% report using all of the above.

2. The main reason reasons we use liquid calcium chloride or liquid magnesium chloride is?

Four respondents skipped this question. Of the remaining respondents 38.9% report they used the product to prevent icing, 38.9% report they use the product to assist in snow removal, 27.8 % report they use the product for all the listed reasons, 27.8% report they use the product for none of the listed reasons, 11.1% reported the product was less costly, and 5.6% reported the product was easier to apply.

6. If using liquid calcium chloride or liquid magnesium chloride, are these treatments sprayed on your roadways in advance of a coming storm?

Eight respondents skipped this question. Of the remaining respondents 64.3% stated yes, 35.7% stated no.

A questionnaire was developed by this researcher entitled Fire Apparatus Corrosion. This questionnaire was sent to fire chiefs through the Fire Chief's Association of Massachusetts, Inc website. 51 fire chiefs replied to the questionnaire. One of the nine questions pertains to this research question.

3. What type of treatments are placed on your roadways during the winter months to prevent icing and assist in snow removal?

All respondents answered this question. 49% reported rock salt, 45.1% reported sand, 45.1% reported a combination of the above, 43.1% reported liquid calcium chloride, 3.9% reported liquid magnesium chloride, and 3.9% reported they were not sure.

In order for this researcher to determine what products were being placed on the roadways of Burlington, interviews were conducted with the Town of Burlington's DPW Superintendent John Sanchez and MassDOT Region Four Snow and Ice Division employee Scott Venuti.

John Sanchez stated that the Town of Burlington used a product called Safe Melt for the past four winters. Safe Melt is comprised of 40% organic by-product and 60% calcium chloride brine. Sanchez also stated that the DPW uses a 50/50 sand/salt mixture. (J. Sanchez, personal communication, November 21, 2012). Scott Venuti stated that MassDOT uses liquid magnesium chloride on State roadways in Burlington. Venuti also stated the MassDOT uses sodium chloride mixed with small amounts of liquid magnesium chloride. (S. Venuti, personal communication, November 21, 2012)

Now that this researcher has knowledge of what type of treatments are placed on the roadways during the winter months it is now time to focus on the chemicals that make up the treatments. Research question two asks do the treatments placed on our roadways during the

winter months contain chemicals that cause corrosion. In order to answer this question, a literature review was conducted, questionnaire responses were evaluated, and the results of interviews were revealed.

The literature review revealed the definition of corrosion. Kelting and Laxson (2010, p.35) best described corrosion as "the electrochemical degradation of metals and alloys due to interaction with the environment." Mussato et al. (2007, pp. 71-72) revealed the common forms of corrosion that is associated with motor vehicles. These forms of corrosion include, uniform, crevice, poultice, pitting, galvanic, and filiform. Kelting and Laxson (2010, p.46) reported that motor vehicle corrosion can be divided into three categories, functional, structural, and cosmetic. Massato et al. (2007, p.74) further revealed that sodium chloride, calcium chloride, and magnesium chloride are all highly corrosive to motor vehicles. Xi & Xie, (2002, p. 65) state "Magnesium chloride has high viscosity, high crystallization potential, and strong hydrophilicity so it can stick on the surface of a metal and become solution again in humid environment." Xi and Xie (2002, p.64) also reveal that no one corrosion inhibitor will prevent corrosion from occurring in all metals.

A questionnaire was developed by this researcher entitled Winter Road Treatments. This questionnaire was distributed to local DPW superintendents. 22 superintendents replied to the questionnaire. Two of the nine questions pertain to this research question.

3. Are you aware of the corrosive effect of liquid calcium chloride and liquid magnesium chloride?

All respondents answered this question. 95.5% of the respondents reported yes. 4.5% reported no.

4. If using liquid calcium chloride or liquid magnesium chloride do you include corrosion inhibitors in the product?

Eight respondents skipped this question. 57.1 % of the respondents reported yes. 42.9% reported no.

A questionnaire was developed by this researcher entitled Fire Apparatus Corrosion. This questionnaire was sent to fire chiefs through the Fire Chief's Association of Massachusetts, Inc website. 51 fire chiefs replied to the questionnaire. One of the nine questions pertains to this research question.

4. What corrosive affect does liquid calcium chloride and liquid magnesium chloride have on fire apparatus?

One respondent skipped this question. Of the remaining respondents 38% reported not sure, 26% reported severe, 24% reported moderate, 10% reported slight, and 2% reported none.

In order for this researcher to gain additional information on the relationship between treatments and corrosion, this researcher interviewed Burlington DPW Superintendent John Sanchez and Scott Venuti of MassDOT District Four Snow and Ice Division.

John Sanchez believes the corrosion issues have slowed since the town began using the liquid product. Sanchez stated that today's products are far less corrosive than those used in the past. (J. Sanchez, personal communication, November 21, 2012). Scott Venuti reported that liquid calcium chloride was very corrosive. Because of this MassDOT switched to liquid magnesium chloride with a corrosion inhibitor. (S. Venuti, personal communication, November 21, 2012).

This researcher has identified the treatments that are placed on our roadways during the winter months and further identified that the chemicals contained within these treatments are

corrosive. Research question three asks what impact do the treatments placed on our roadways during the winter months have on the trucking industry. In order to answer this question, a literature review was conducted, questionnaire responses were evaluated, and the results of interviews were revealed.

The literature review revealed that the trucking industry is impacted by the chemicals that are placed on the roadways during the winter months. Vertin (2011, para. 8) describes the damage that road salts have on trucks. He lists several components of the vehicle that are damaged as a result of corrosion. Some of these components include frame rails, suspensions, electrical systems, and radiators. Lockridge (2008, para. 10) describes how susceptible electrical systems are to the damaging effects of corrosion.

A questionnaire was developed by this researcher entitled Winter Road Treatments. This questionnaire was distributed to local DPW superintendents. 22 superintendents replied to the questionnaire. Two of the nine questions pertain to this research question.

7. Are you faced with corrosion related issues to your own fleet?

Three respondents skipped this question. Of the remaining respondents 84.2% reported yes. 15.8% reported no.

8. Has vehicles in your own fleet ever been taken out of service because of corrosion to the frame rails and/or electrical harnesses?

Two respondents skipped this question. Of the remaining respondents 90% reported yes. 10% stated no.

In order for this researcher to get a greater understanding of the impact road treatments have on the trucking industry, this researcher interviewed Bob Theroux of UPS and Joseph Lydon of Palmer Spring. Theroux spoke of numerous electrical issues with lights and electronic

modules located under the trucks. He reports frequently having to replace brake lines because of corrosion. Theroux stated he used to get twenty years out of a truck. Today he gets between ten and fifteen years. (B. Theroux, personal communication, November 26, 2012). Joseph Lydon reports he has seen damage to springs, frames, exhaust systems, and air valves. Lydon reports seeing DPW trucks that put these chemicals on the road rotting away. (J. Lydon, personal communication, November 29, 2012).

Fire apparatus suffers from many of the same corrosion related problems that are seen in the trucking industry. Research question four asks what impact do the treatments placed on our roadways during the winter months have on fire apparatus. For this research question, this researcher looked at the impact corrosion has on the life expectancy of fire apparatus, reviewed first hand reports from mechanics who work on fire apparatus, and study costs that are associated with apparatus that are damaged by corrosion. In order to answer this question, a literature review was conducted, questionnaire responses were evaluated, and the results of interviews were revealed.

The literature review revealed that the environment that apparatus operated in has an impact on life expectancy. Brewer (2010, p.27) stated that the climate or conditions in which fire apparatus operates in affects life expectancy of fire apparatus. McDowell (2012, p.34) reports that one of the factors that the Henrico Division of Fire used to determine life expectancy of their front-line apparatus was the type of environment the engine operated in.

NFPA 1912 reports that the costs associated with refurbishing fire apparatus generally involves a major investment. (NFPA, 2006 ed.)

A questionnaire was developed by this researcher entitled Fire Apparatus Corrosion. This questionnaire was sent to fire chiefs through the Fire Chief's Association of Massachusetts,

Inc website. 51 fire chiefs replied to the questionnaire. Six of the nine questions pertain to this research question.

1. What is the average life expectancy of fire apparatus?

All respondents answered this question. 47.1% of the respondents reported 15-20 years. 39.2% reported greater than 20 years. 13.7% reported 10-15 years.

6. Has your fire apparatus ever suffered corrosion damage to any of the following components that required the apparatus to be removed from service for an extended period of time?

All respondents answered this question.

	Yes	No	Not Sure
Battery Boxes	68%	30%	2%
Electrical Systems	67.3%	26.5%	6.1%
Fuel Tanks	62%	36%	2%
Suspension	53.1%	38.8%	8.2%
Frame Rails	44%	54%	2%
Cross Members	38.8%	55.1%	2%

7. Has your department ever refurbished a fire apparatus because of corrosion to the frame rails and/or the electrical harnesses located within the frame rails?

All respondents answered this question. 74.5% of the respondents reported no. 25.5 % reported yes.

8. What number best represents the average total cost of a fire engine refurbishment?

21 respondents skipped this question. Of the remaining respondents 36.7% reported 100,000, 33% reported 150,000, 20% reported 200,000, 3.3% reported 250,000, and 6.7% reported 300,000.

9. If your department refurbished a fire apparatus, what would be the anticipated life expectancy of the refurbished apparatus?

14 respondents skipped this question. Of the remaining respondents 48.5 % reported 5-10 years, 32.4% reported 10-15 years, 16.2% reported 0-5 years, and 2.7% reported greater than 15 years.

In order for this researcher to get a greater understanding on the impact that road treatments have on fire apparatus, I interviewed Burlington Fire Department's Emergency Vehicle Technician Eric Moran, Minuteman Truck's Emergency Vehicle Technician Jeffery Kelland, and Gloucester Firefighter/Mechanic William Doucette. Moran noticed significant corrosion damage to the rear of the 2002 Pierce Quantum. He stated the trucks frame, wiring, and air valves were all corroded. Moran also spoke on electrical problems with the truck. He spoke of the trucks dill box that houses electronics and relays. Water and salt entered this box leading to corrosion damage. (E. Moran, personal communication, November 29, 2012). Jeffrey Kelland reports seeing damage to frame rails, cross members, torque boxes, and outriggers. Kelland speaks of recently seeing an increase in corrosion damage to electrical harnesses, particularly electrical harnesses that have been spliced into. (J. Kelland, personal communication, November 29, 2012). William Doucette was recently involved in a refurbishment project involving an engine. Doucette reported seeing flakes coming off the frame rails of a 1998 Pierce Saber. He noticed that the brake reservoir and valves were corroded as

well. The total cost of the refurbishment project was 220,000 dollars. (W. Doucette, personal communication, October 18, 2012).

Throughout the course of this project, this researcher has learned what types of treatments are placed on our roadways during the winter months. I have learned that these treatments contain chemicals that cause corrosion. I have learned how these chemicals affect both the trucking industry and fire apparatus. For the final research question, this researcher chose to look at what preventative measures currently are in place that slows the corrosion process down. In order to answer this question, a literature review was conducted, questionnaire responses were evaluated, and the results of interviews were revealed.

The literature review revealed the importance of having corrosion protection language included in all new apparatus specifications. Particular attention should be given to separating dissimilar metals with a corrosion prevention coating. (Nay Sr, 2012, para. 10). Kollman (2010, para. 43) warns that corrosion can form in surfaces where protective coatings have been damaged by road debris. Gelinas (2011, para. 11) stated the importance of keeping protective coatings in place.

Hartley (2010, para. 2) reports that corrosion can not be completely eliminated, but it can be reduced with strong specification language for new equipment and good preventative maintenance practices. Kollman (2010, para. 35) states that frequent inspections of equipment and preventative maintenance measures are far more effective than corrective maintenance. He warns that one of the problems associated with corrosion is that it can go undetected for lengthy periods of time before a major problem begins to surface. If corrosion can be identified early and corrective measures are taken, the damage can be reduced. Gelinas (2011, para. 11) states electrical systems should also be inspected on a regular basis. Chemicals will damage any

wiring that is exposed. Hartley (2010, para. 16) reports washing equipment that is exposed to winter treatments is a must.

A Pierce Manufacturing Service Bulletin released in 2009 makes the following suggestions to slow the effects of corrosion. (Barry, 2009) Thoroughly pressure washing the undercarriage of the apparatus frequently to remove salt and chemicals. Apply a rust proofing compound to the undercarriage of the apparatus. Inspect the undercarriage frequently to identify corrosion at an early stage. Hose the radiator with plain water. Keep mud flaps in good repair to minimize the salt spray. Avoid splicing into wires and clean out electrical connectors regularly with plain water and re-grease with dielectric grease.

A questionnaire was developed by this researcher entitled Fire Apparatus Corrosion. This questionnaire was sent to fire chiefs through the Fire Chief's Association of Massachusetts, Inc website. 51 fire chiefs replied to the questionnaire. Two of the nine questions pertain to this research question.

5. Does you department currently have a procedure in place to wash the underside of your apparatus during the winter months? If so please describe.

Two respondents skipped this question. Of the remaining respondents 65.3% reported they had no department procedure, 30.6% reported they had a procedure, 4.1% did not appropriately respond. Common descriptions to this question included, after each run, supposed to wash the undercarriage, and difficult to reach the undercarriage.

10. When creating apparatus specifications, do you include language that addresses reducing the damaging effects of corrosion? If so, please describe.

Five respondents skipped this question. Of the remaining respondents 52.2% reported no, 39.1% reported yes, 8.7% did not appropriately respond. Common descriptions to this

question included, specifying stainless steel components, evaluate warranties, and undercoat undercarriage.

In order for this researcher to gain a better understanding of preventative measures that currently exist that slow the corrosion process down, this researcher interviewed Minuteman Truck Emergency Vehicle Technician Jeffery Kelland, Joseph Lydon of Palmer Spring, and Chief Thomas Conway of the Billerica Fire Department. Kelland stated that Piece Manufacturing recommends the usage of stainless steel in many locations of the apparatus. He believes that fire departments need to keep an eye on the undercoating. When undercoating bubbles up, you need to sand it off, add rust proof, prime, and paint. Kelland believes trucks should be washed every time it goes out the door. There is no need to pressure wash. He believes pressure washing could damage components. You can also drive product into cracks which could lead to corrosion. (J. Kelland, personal communication, November 29, 2012).

Joseph Lydon speaks of the importance of using dielectric grease on all electrical connections. He believes this will extend the life of the electrical system. Lydon speaks of the importance of washing the undercarriage but warns of using pressure washers. Pressure washing will push chemicals further into cracks and crevices. (J. Lydon, personal communication, November 29, 2012).

Chief Thomas Conway just purchased a pressure washer for his department. He purchased this equipment based on the recommendation of apparatus manufacturer E-ONE. E-ONE recommended washing the undercarriage of the apparatus four times a year. Conway plans to develop a checklist to document every time the department pressure washes the undercarriage of their apparatus. (T. Conway, personal communication, November 26, 2012).

Discussion

In early October of this year, this researchers department placed our 2002 Pierce Quantum out-of-service. This truck had been experiencing electrical related issues over the past several years. Warning lights and scene lights began to stop functioning or operated intermittently. Within the past year, these problems became more significant. The truck would not always start when the ignition was engaged. The pump operator would not be able to increase throttle pump pressure at the pump operator's panel. The truck was taken out-of-service on numerous occasions and sent out for repair. Each one of these occasions resulted in the department receiving a substantial invoice for repair. The last time the truck was sent out to the manufacturers dealership for repair, an emergency vehicle technician was forced to make an emergency maneuver in order to stop the truck from moving, even with the emergency brake applied, this occurred after the trucks ignition was started. Based on this latest incident involving the 2002 Quantum it was decided that this truck posed a safety threat to our firefighters and that the truck could no longer be depended on. The manufactures dealership believed they could correct the existing problem but could not guarantee that the problem would not reoccur.

A representative of Pierce Manufacturing in Wisconsin flew to Massachusetts to evaluate the truck. It was determined that the electrical harness located within the frame rails of the truck had been damaged by corrosion. Significant corrosion damage was also found on the frame rails of the truck as well as the rear undercarriage of the truck. It was the belief of both Minuteman Truck and the Pierce representative from Wisconsin that this damage was caused by the chemicals that are put down on the roadways during the winter months.

This researchers department has had a history with fire apparatus being damaged by corrosion. Back in October 2006, a 1990 Pierce tower was taken out of service for extensive

corrosion damage. The tower at the time was sixteen years old, so taking the apparatus out-of-service at that time was expected. It provided aerial coverage to the town for sixteen years and was scheduled for replacement. We move ahead six years and we are faced with a similar situation. This time extensive corrosion damage has occurred to a ten year old apparatus. What is causing this extensive corrosion damage to our apparatus? Is it the chemicals that are placed on our roadways during the winter months? Is it poor quality of materials used to construct the apparatus? Is it poor quality paint or a lack of undercoating? Is this something that fire departments in the Northeast just accept as a function of operating in poor weather conditions, or is there something we can do to slow the corrosion process down?

In order to better understand if the treatments used during the winter months contain chemicals that corrode the underside of fire apparatus, this researcher first had to find what types of treatments are being placed on our roadways. Through research, I was able determine through the MassDOT website that Massachusetts use sodium chloride, sand, a pre-mixed blend of sodium chloride and calcium chloride, liquid calcium chloride, and liquid magnesium chloride. (MassDOT, 2012) An interview conducted with Scott Venuti of MassDOT further revealed that MassDOT uses liquid magnesium chloride on State roads in Burlington as well as sodium chloride which is mixed with liquid magnesium chloride. (S. Venuti, personal communication, November 21, 2012). Burlington DPW Superintendent John Sanchez was interviewed by this researcher and revealed the Burlington DPW used a product called Safe Melt which is comprised of 40% organic by-product and 60% calcium chloride. Sanchez also stated the DPW uses a 50/50 mixture of sand/salt. (J. Sanchez, personal communication, November 21, 2012). The responses to the questionnaires did not reveal any other products. The questionnaire did reveal

that the majority of fire chiefs were aware of what types of products were being placed on their streets.

Once the treatments placed on our roadways was identified, the next question posed was do these treatments contain chemicals that cause corrosion. Massato et al. (2007, p. 74) revealed that sodium chloride, calcium chloride, and magnesium chloride are all highly corrosive to motor vehicles. Xi & Xie, (2002, p. 65) state, "Magnesium chloride has high viscosity, high crystallization potential and strong hydrophilicity, so it can stick on the surface of a metal and become solution again in humid environment." This becomes a problem for fire apparatus in conditions where magnesium chloride is applied. If the chemical is not immediately washed off the truck, it will dry on the metals once the truck returns to a heated apparatus bay. This dried product can once again become a solution when the truck is exposed to humidity furthering the corrosion process. Many of today's road treatments come with a corrosion inhibitor added to the mixture. However, no single corrosion inhibitor will prevent corrosion from occurring in all metals. (Xi & Xie, 2002, p.64). Twenty-two DPW superintendents were asked if they were aware of the corrosive effect of liquid calcium chloride and liquid magnesium chloride. 95.5% of the responders stated yes.

Burlington DPW Superintendent John Sanchez believes the corrosion issues have slowed since the town began using a liquid product. He believes that today's products are far less corrosive than the products used in the past. (J. Sanchez, personal communication, November 21, 2012). Scott Venuti stated that liquid calcium chloride was very corrosive. Because of this MassDOT switched to magnesium chloride with a corrosion inhibitor. (S. Venuti, personal communication, November 21, 2012).

Throughout the course of researching this topic, this researcher has learned that methods are constantly being evaluated to determine what type of product is best suited for snow and ice removal. The impact on the environment is always the major concern. Most of the treatments used today have a corrosion inhibitor added to the mixture. However, the majority of the products being used are still comprised of chlorides which are corrosive. A question posed to 22 DPW superintendents revealed that not all of our local communities add corrosion inhibitors to their treatments. 42.9% of the respondents reported that they did not use corrosion inhibitors.

Research question three asked what impact does the treatments placed on our roadways during the winter months have on the trucking industry. "Corrosive road salts attack a variety of metal components to include frame rails, crossmembers, suspension components, air tanks, fuel tanks, battery boxes, brackets, brake shoes, electrical systems, air conditioning condensers, radiators, metal coolant tubing and steel wheels."(Vertin, 2011, para. 2). Lockridge (2008, para. 10) stated electrical systems are particularly vulnerable to corrosion.

What was of particular interest to this researcher was the responses of the DPW superintendents when asked are you faced with corrosion related issues to you own fleet? 84.2% of the respondents stated yes. When asked if vehicles in your own fleet have ever been taken out of service because of corrosion to the frame rails or electrical harnesses? 90% stated yes.

Bob Theroux of UPS speaks of numerous electrical issues with lights and electronic modules located under the trucks. He reports frequently having to replace brake lines because of corrosion. (B. Theroux, personal communication, November 26, 2012). Joseph Lydon of Palmer Spring reports seeing damage to springs, frames, exhaust systems, and air valves. (J. Lydon, personal communication, November 29, 2012).

Many of the statements made regarding the impact road treatments have on the trucking industry relate directly to the fire service, particularly this researchers department. The department's 2002 Pierce Quantum was taken out of service because of corrosion damage to the electrical harness and frame rails. Because we operate in the Northeast, our apparatus is exposed to these road treatments. Fire departments operate twenty four hours a day, seven days a week. We respond to calls for service in all types of poor weather conditions. Because of this our apparatus is susceptible to damage caused by corrosion.

Brewer (2010, p.27) stated that the climate or conditions in which fire apparatus operates in affects the life expectancy of fire apparatus. McDowell (2012, p.34) reports that one of the factors used by the Henrico Division of Fire to determine life expectancy of front-line apparatus was the type of environment the engine operated in.

One of the questions posed to the Fire Chief's of Massachusetts was, what is the average life expectancy of fire apparatus? 47.1% of the respondents reported 15-20 years, 39.2 reported greater than twenty years, and 13.7% reported 10-15 years. Over 86% of the chiefs who responded to the questionnaire expect to get a minimum of 15 years out of their apparatus.

Anther question that deserves discussion is that 68% of the Fire Chief's of Massachusetts reported they have taken their fire apparatus out-of-service for corrosion damage to the battery boxes and 68% of the chief's removed apparatus as the result of corrosion damage to a trucks electrical system.

Burlington Fire Department's Emergency Vehicle Technician reported that the 2002 Pierce Quantum had corrosion damage to the trucks frame, wiring, and air valves. (E. Moran, personal communication, November 29, 2012).

Jeffery Kelland of Minuteman Truck speaks of seeing damage to frame rails, croass members, torque boxes, and outriggers. He also reports a recent increase in damage to fire apparatus electrical systems. (J. Kelland, personal communication, November 29, 2012)

When fire apparatus is damaged by corrosion and removed from service it affects the operation of the department as well as impacting the budget. This researchers department operates with three engines in-service and one reserve engine. When a front-line engine is taken out of service, such as the 2002 Pierce Quantum, the department's reserve engine is placed in-service. This leaves our department with no reserve engine. If one of the remaining three engines is taken out-of-service our department would be forced to operate with only two engines. This situation would impact our ability to respond to emergency incidents as well as increase our engine response times.

The financial impact of removing a piece of apparatus from service is also devastating to the department. When this researcher's department was forced to take its 1990 tower truck out of service in 2006, the taxpayers were forced to approve 850,000 dollars for its replacement. Six years later, once again we will be asking for 250,000 dollars to refurbish the 2002 Pierce Quantum. If the department were to replace the 2002 Pierce Quantum with a new engine with similar specifications, the new engine would cost taxpayers approximately 640,000. A question posed to the Fire Chief's of Massachusetts revealed that 80% of the chiefs believed that refurbishing a fire apparatus would cost between 100,000 and 200,000 dollars. Gloucester Fire Department just recently refurbished a 1998 Pierce engine for a cost of 220,000. (W. Doucette, personal communication, October 18, 2012).

In order for our department to begin to maximize the life expectancy of our fire apparatus we will need to look at what type of preventative measures currently exist that slow the corrosion

process down. Nay Sr. (2012, para. 9) speaks of the importance of including corrosion protection language in all new apparatus specifications. This researcher was recently involved in creating a specification for a new fire engine. One of the main focuses of the specification was the inclusion of corrosion protection. Many of the components specified included stainless steel. Particular attention was given to undercoating language.

Hartley (2010, para 2) reports that corrosion can not be completely eliminated, but it can be reduced with strong specification language and good preventative maintenance practices. This last statement is particularly important because these researchers department has lacked in this area over the years.

Kollman (2010, para. 35) speaks on the importance of frequent inspections of equipment. He states that preventative maintenance is far more effective than corrective maintenance. If corrosion damage is detected early and corrective measures taken, damage can be reduced. This is an area this researchers department can improve. What is particularly concerning to this researcher is that not many fire departments address the issue of corrosion. 65.3% of the fire chiefs responded their department had no procedure in place to wash the underside of apparatus during the winter months. When creating specifications for new apparatus 52.2% of the chiefs reported that they do not include language that addresses reducing the damaging effects of corrosion.

In January of 2009, Pierce Manufacturing issued a Service Bulletin in which a number of suggestions were made in order to inhibit the effects of corrosion. Many of these suggestions will be incorporated into the recommendation section of this Applied Research Project.

This researcher believes that corrosion reduction begins with the creation of new apparatus specifications. Those of us who operate in the Northeast are fully aware of the

challenges that winter weather brings. Icy conditions and heavy snow are common occurrences during the winter months. Because of this our apparatus is often asked to respond to calls for service in inclement weather. Because of this our apparatus needs to be designed to withstand these types of conditions. The use of stainless steel bodies and components is one method to slow the effects of corrosion. Insuring that all exposed metals are protected with rust proofing and undercoating is extremely important. Several methods commonly used to protect fire apparatus from corrosion increases the overall cost of the fire apparatus. This researcher believes that the benefits outweigh the costs.

This researcher also recognizes the importance of a preventative maintenance program. In order to maximize the life expectancy of our apparatus, we need to take better care of our fire apparatus. Fire departments that work in adverse weather conditions need to create and implement new policies and procedures to combat the corrosion process.

Finally, fire departments need to be aware of the treatments being used in their own communities and the potential impact these treatments will have on their fire apparatus. They need to be aware that frequent minor electrical problems could be an indicator of a potential major problem within the trucks electrical system.

If fire departments continue to not address the issue of corrosion they should expect to see an increase in apparatus down time, an increase in maintenance costs, and a reduction in the life expectancy of their fire apparatus.

Recommendation

The Burlington Fire Department is currently down one front-line fire engine. The truck was taken out-of-service due to corrosion damage to the electrical harness as well as the frame rails. This is the second piece of apparatus that has been removed from service because of

corrosion in the last six years. In October 2006 the department's tower truck was taken out of service because of extensive corrosion damage. Since then the department has done very little to prevent this damage from occurring again. As a result, in early October of this current year, a ten year old fire engine was taken out-of- service. This researcher's department can no longer afford to ignore this problem. Quite simply, we are not maximizing the life expectancy of our fire apparatus. A new policy and procedure needs to be developed within the department and instituted as soon as possible. Many members of the department are fully aware of the corrosion problem. Many of these same members are looking to the department's administration for leadership in creating new procedures in order to combat this major issue. The creation of new policies and procedures will lead to decreased maintenance costs, a reduction in apparatus down time, and an increase in apparatus life expectancy. This researcher makes the following recommendations in order to slow the corrosion process down.

- Fire departments need to identify what types of treatments are being placed on their roadways. This can easily be accomplished through communication with the local DPW Superintendent.
- If the State is responsible for treating roadways in your community, fire departments need to identify the product that the state is using. This can be easily accomplished through communication with the State DOT.
- All members of the department need to be informed of the corrosive effect of the treatments that are placed on the roadways during the winter months.
- All members of the department need to be made aware of the early signs of corrosion. This includes the bubbling of paints and electrical components

not functioning or operating intermittently. All members must be told to report these findings immediately.

- When creating specifications for new apparatus an emphasis must be placed on corrosion prevention language.
- If dissimilar metals are to come in contact with one another they to be treated with corrosion protection.
- The undercarriage of new apparatus needs to be protected by the best rust proofing and undercoating materials available.
- Apparatus components should be constructed of stainless steel. Examples include the body, water tank cradle, fuel tanks, and brake lines.
- When new apparatus is inspected prior to acceptance, attention should be given to ensure all exposed areas have been completely rust proofed and undercoated. Any signs of thin areas or unpainted areas need to be addressed.
- When the new apparatus is inspected prior to acceptance, attention should be given to the trucks electrical system. All harnesses shall be secured and protected.
- Fire departments should focus on preventative maintenance rather than corrective maintenance.
- The inspection of frame rails and cross members need to be conducted on a regular basis.
- Any corrosion damage located must be addressed immediately by sanding down the affected area, rust proof the area, prime, and paint.

- Any damage to undercoating and paint during maintenance procedures require re-applying of rust proofing, prime, and paint.
- The inspection of the electrical system needs to be conducted on a regular basis.
- Avoid splicing into electrical harnesses.
- Clean out electrical connections regularly and re-grease with dielectric grease.
- All inspections need to be documented on newly created department maintenance forms.
- Keep all mud flaps in good working order.
- Wash the undercarriage when the apparatus is exposed to snow and ice treatments. Focus on the undercarriage behind the cab of the truck.
- Consider pressure washing the undercarriage of the apparatus when the truck is taken out of service for preventative maintenance. Only personnel familiar with the mechanics of fire apparatus should be allowed to pressure wash the undercarriage of apparatus.
- When the apparatus is sent out to the manufacturer's dealership for repair have the dealership inspect the undercarriage and electrical harnesses.
- Apparatus dealerships should offer fire departments that operated in inclement weather the opportunity to add protective coatings to their apparatus on a yearly basis.

This researcher believes that all these recommendations are achievable. If a department's preventative maintenance program is enhanced by focusing on corrosion reduction, the

department will see a reduction in maintenance costs, the maximizing of life expectancy, and most important, the department will have a full complement of fire apparatus including reliable reserve apparatus that is able to respond to all calls for service.

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Appendix A

Burlington Fire Department Vehicle Inventory

Burlington Fire Department
Vehicle Inventory

Designation	Year	Make	Life Expectancy	Replacement
Engine 1	**2002**	**Pierce Quantum 1500gpm**	**15 Years**	**2017**
Engine 2	**2008**	**Pierce Arrow XT 1500gpm**	**15 Years**	**2023**
Engine 3	**1998**	**Pierce Quantum 1250gpm**	**15 Years**	**2013**
Engine 4*	**1990**	**Pierce Arrow 1250gpm**	**15 Years**	**2013**
Tower 1	**2008**	**Pierce Dash 100' Tower**	**15 Years**	**2023**
Amb 1	**2010**	**Horton Navistar**	**10 Years**	**2020**
Amb 2	**2005**	**Horton Navistar**	**10 Years**	**2015**
Rescue 1	**1988**	**Chevrolet/Hackney**		
Forestry 1*	**1995**	**International**		**2013**
C1	**2005**	**Chevrolet Trailblazer**	**8**	**2013**
C2	**2008**	**Ford Escape**	**8**	**2016**
C3	**2010**	**Ford Expedition**	**8**	**2018**
C4	**2005**	**Chevrolet Impala**	**8**	**2013**
C5	**2010**	**Ford Escape**	**8**	**2018**
C6	**2001**	**Chevrolet Tahoe**	**10**	**2011**

*** Apparatus being replaced Fiscal Year 2013**

Appendix B

Interview with MassDOT

Interview with MASSDOT
11/21/2012

- Burlington is covered by MassDOT District 4 out of Arlington, MA.
- The phone number for District 4 is 781-641-8300.
- I spoke to Mr. Scott Venuti of the Snow and Ice Division.
- The State uses liquid magnesium chloride on 128/Route 3 and on Cambridge Street.
- They do have a vehicle located off Grant Ave that is capable of applying the material.
- They place the material on the ground pre-storm under certain conditions.
- If weather reports indicate snow and the temperatures will remain under 32 degrees the liquid is sprayed on the roads.
- Pre-treatment of magnesium chloride is released at a rate of 20 gallons per lane mile.
- MassDOT switched from liquid calcium chloride to liquid magnesium chloride four of five years ago.
- The reason for this is that magnesium chloride comes with a corrosion inhibitor while calcium chloride does not.
- During a storm MassDOT uses a pre-wetting blend.
- The sodium chloride is mixed with small amounts of magnesium chloride to wet the product as it is being sprayed.
- The pre-wetting solution is released at eight to twelve gallons per ton.
- Scott stated that calcium chloride was very corrosive.
- He also spoke of the problems associated with sand. He stated it was presented a clean up problem as well as abrasion issues to vehicles. He also stated that sand contributed to the corrosion issue.
- He spoke on his knowledge of streams in the area of Burlington and Woburn but stated he believed that there were no designated low salt areas. He did say they are careful when applying the product.
- When asked why liquid over solid, he stated that by going to a liquid we did not have to treat roads as much.
- By pre-wetting the salt it prevents the salt from bouncing on the road and ending up on the shoulder of the roadways.
- MassDOT is seeing better results using this program.

Appendix C

Interview with John Sanchez

Interview with John Sanchez
11/21/2012

- John Sanchez is the DPW Superintendent for the Town of Burlington.
- He has been the Superintendent for the past five years.
- He informed me that the Town of Burlington has used a product called Safe Melt for the past four winters.
- This coming winter The Town plans to use a product called Magic-O.
- Safe Melt 40/60 is made up of 40 % organic byproduct performance enhancer and 60% calcium chloride brine.
- The Town also used a 50/50 sand/salt mix or a 3 to 1 sand salt mix.
- Safe-Melt pre-treats the roads.
- The Town uses an 8 gallon to 1 ton of material mixture.
- The material is pre-mixed before applying.
- The Town applies this to main roads as a liquid/salt or salt/sand mixture.
- They do not pre-treat the entire town.
- Mr. Sanchez states that they pre-treat the roads to prevent the ice and snow from bonding to the roads.
- They also will pre-treat a couple of roads that have hills in Town.
- The State is responsible for only Cambridge Street in Burlington.
- John stated that he believes the State uses ten times the amount of salt that the Town would use.
- John describes the benefits of pre-treating the roads.
- He discusses by pre-treating the roads you prevent bonding from occurring. Because of this you are putting down less salt.
- If bonding occurs you must treat snow and ice from the top down.
- The anti-icing method is far more effective.
- When speaking of dry materials, Mr. Sanchez speaks of the material bouncing off the street or being removed by automobiles.
- When the material is wet, it stays on the ground. The material sticks to the road surface better when wet.
- Mr. Sanchez reports his people are not reporting any corrosion related damage to their vehicles. He did state that a oily coating is created on the sanders.
- There procedure is to empty the product from the trucks and wash them down the following morning.
- Mr. Sanchez believes the corrosion issues have slowed since using this liquid product.
- He stated that in the older days the straight calcium brine solution caused corrosive effects.
- He stated the older products and today's products are like night and day.
- Mr. Sanchez stated we stopped using calcium chloride twenty years ago.
- The reason Mr. Sanchez switched to the Magic O product is because the solution filters better.
- Mr. Sanchez believes the State does not order a product with organic agricultural byproducts.
- He stated that the MA product is clear while the Town's product is brown.
- Mr. Sanchez stated that the Safe-Melt product is too thick and can clog his sprayers.
- He made the change from a pure operational reason.
- Mr. Sanchez stated that Superintendents would not use a product that would damage their equipment.
- He stated that his equipment is on the road much more than our equipment during storms and he has no corrosion related issues.
- He once again stated that that the old calcium chloride product no doubt caused damage.

Appendix D

Interview with Bob Theroux

UPS Customer Center
90 Brick Kiln Road
Chelmsford, MA 01824

On November 26, 2012, I drove up to the UPS facility located in Chelmsford, MA. At the guard house, I asked to speak to a member of the fleet maintenance division. After a brief wait, I was introduced to the plant engineer for the facility. I informed the plant engineer of the reason behind my visit. I informed him that I was doing a research paper and wished to speak to a member of fleet maintenance. The plant engineer walked me over to the vehicle maintenance building. There we were met by a gentleman who was responsible for fleet maintenance. I informed both individuals that I was enrolled in the Executive Fire Officer program at the National Fire Academy. I also informed them that I was doing a research paper on the effects of the treatments that are placed on our roadways during the winter months and the corrosive effects these products have on our apparatus. I informed them that the UPS website states the company has a very progressive preventative maintenance program and that I would be interested in learning how UPS combats corrosion.

The fleet manager identified himself as Bob Theroux.

The fleet manager recognizes there is an issue when it comes to vehicle corrosion. He specifically spoke on the typical UPS brown delivery truck. He stated that his fleet had experienced wiring issues such as lights, electronics, and modules that were exposed within the frame rails. He spoke of having to often replace break lines due to corrosion. He stated that he did not recall the older vehicles having as much problems as today's vehicles. He stated you used to get twenty years out of the trucks. The average life expectancy of trucks today is between ten to fifteen years.

When asked what does UPS do with vehicles that are damaged, the fleet manager stated they look at the costs of making repairs versus buying new. If the vehicle requires costly maintenance, the vehicles are disposed of. This is a recommendation he makes to upper management. The vehicles are then chopped up. The fleet manager spoke of using Donovan Spring located in Londonderry, NH for repair work. He stated that if I contacted them I would be able to obtain articles on liquid calcium chloride.

The fleet manager stated they had more corrosion related issues with the brown delivery trucks than the trailers. He stated they could get 15 to 18 years out of the trailers.

When asked if he was involved in spec-ing out new vehicles, he stated he was not involved. He did say that when they order new trucks they are made with galvanized steel. He believes the brake lines are made with stainless steel. He stated that he seens problems with straps and tanks. He stated that they used to undercoat the under carriages in the past but not anymore with the galvanized steel.

When asked if UPS washes the under carriage of its fleet, the manager stated they do not. He stated that all vehicles are run through two wash tunnels that are located on the property during the winter months. Just the exterior of the trucks are washed.

When asked if he was aware of what types of treatments are placed on the roads during the winter, the manager stated rock salt and also that the roads are pre-treated with a liquid. He stated that the liquid sprays up into the undercarriage. He stated that the liquid product was more corrosive because it festers. It keeps chewing at the undercarriage.

Appendix E

Interview with Joseph Lydon

Joseph Palmer Inc.
Palmer Spring Company
11/29/2012

- I interviewed Joe Lydon of Palmer Spring Company located in Woburn, MA
- Palmer Spring works on a variety of vehicles.
- We spoke specifically about corrosion.
- Joe stated that Palmer deals with corrosion on a daily basis. He stated that springs, frame hangers and exhaust systems all rot away. He stated that stamped steel will rot.
- He stated that air valves rot. They initially may be bolted to the frame but he has seen these lines just hanging under the frame.
- He stated that aluminum becomes pitted and corrodes quickly.
- He stated that galvanized steel also pits. White metals get eaten away.
- He stated that cross-members can be made of stamped steel and will rot away.
- Joe stated that vehicle manufactures are very aware of the corrosion issue.
- He spoke of Jeeps recall of lower control arms in the front suspension. He stated that Lawless, the areas local Jeep dealership has hundreds of these arms in stock. These arms are becoming corroded in the northeast and are failing.
- Joe spoke of the treatments being used on the roadways. He stated that the spray after the storms rots everything away.
- He stated that the road salts turn auto grease into a hard substance. He speaks of the importance of keeping fresh lube going to everything. He spoke of the Vogel system that we currently spec out on our apparatus.
- We spoke of UPS how their bodies when made with aluminum rot away. He stated that liquid calcium is real bad.
- He spoke of the liquid calcium rotting away the DPW trucks that put the chemical down on the road. He stated that this liquid is viscous against steel.
- He stated that the liquid mist gets into all the cracks and crevices and causes more damage.
- When speaking specifically about fire apparatus, he states that the product eats away at the wiring especially at the connectors. The product will chew through seels. He stated that the chemical wicks its way up a wire. He has seen electrical harnesses filled with both sand and water when removed.
- Joe stated he can see the difference between vehicles that come from a town that uses the liquid treatments versus those that do not use the liquid. Those vehicles that are damaged by corrosion are more likely to come from a town that uses the liquid.
- Joe stated that corrosion is an age old problem. Aluminum corrodes and wiring turns green.
- Joe believes there is a correlation between corrosion and the reduced life expectancy of a vehicle.
- Palmer can also tell the difference between vehicles that are out in the poor weather conditions versus those that are not.
- Joe states that something needs to be done to better protect wiring harnesses and connections. He speaks of using dielectric grease on all connections. He believes this will extent the life of the system.
- He states that electrical problems are a New England problem. He stated that every manufacturer uses a different brand of connections. He stated that some connectors are better than others. He believes in this area it would be good to have the manufacturers use the strongest connectors.
- Joe speaks of instances where corrosion will not allow components to be opened at connections.
- When asked how we can slow the corrosion process, Joe once again speaks of using dielectric material on connections. He speaks of frequent washing of the undercarriage.
- When asked about pressure washing, he cautioned that pressure washing can push the chemicals further into cracks and crevices. He stated that cleaning is a good idea, but not the end all.
- He spoke of a fire department in Martha's Vineyard that uses a drive through under carriage washer to wash beach sand and salt of its apparatus.

- Joe warned about washing after every run. He stated that if you went right back out on a freezing day, problems could occur when the water freezes.
- When asked about undercoating, Joe stated that as the undercoating gets older it can crack. The salt product can now enter the crack and get underneath the undercoating causing further damage.

Appendix F

Interview with Eric Moran

Eric Moran
November 29, 2012

- Eric has been the fire department mechanic for the past six years. Over that period he has obtained eight emergency vehicle technician certificates. Prior to working for the fire department Eric worked for the DPW as a mechanic.
- Eric started to see significant corrosion with the under carriage of Engine One three years ago.
- He would see bubbling of the paint on the frame rails and rust as well.
- He could see rust forming in between the frame rails and the paint on the frame rails.
- He would sand down the areas that were accessible and would re-paint the area.
- While working on electrical issues, Eric would see poor electrical connections which originated from the factory. Wires were poorly connected to some of the electronics. Pins were pushed out at connections with no corrosion issue.
- Eric stated that were they run the wiring, inside the frame rails, leaves the wiring susceptible to the weather.
- In order to get some electronics to work, Eric had to use jumper wires.
- Eric stated that warning lights often were problematic.
- He spoke specifically about the dill box with housed electrical equipment was particularly exposed to the weather. Over time vibration caused damage to the housing that allowed salt and water to enter the box which electronics to corrode. The relays located in this box suffered from corrosion issues.
- The truck had problems starting. Eric added an exterior electronic starter to use if the vehicle would not start from the cab.
- Eric reported issues with the fire pump. The idle would not function when the pump was engaged.
- Because of this the truck was sent to Minuteman Trucks for repair. We paid over 3,000.00 for the repair. The same issue repeated two weeks later.
- Eric reports corrosion damage throughout the under carriage. The more heavy corrosion damage is to the rear of the truck. The frame, wiring, and air valves were all corroded.
- Eric reported that the engine, transmission, and fire pump are all in good shape.
- When asked if any of our other apparatus has similar corrosion damage, Eric stated that Engine Four had corrosion damage, but that piece is a 1990.
- Eric used to work for the Town DPW. He was familiar with the sanding practices of the Town during the winter months.
- He believed the Town used calcium chloride on the Mall Road and used a mixed sand/salt mix throughout the Town.
- He was familiar with the practice of adding liquid to the sand/salt mixture after 1998.
- While working at the DPW he reported numerous electrical issues as well as corrosion issues on DPW trucks.
- Eric believes that the treatment placed down on our roads during the winter months is a major cause of the corrosion on the truck.
- He hears stories from other mechanics at his monthly mechanics meetings where this topic is discussed as well as apparatus refurbishment.
- When asked how we could slow down the corrosion process he stated, put in a wash system. He stated that you need to wash the product off before it dries. If the product dries, you are just wetting it all over.
- He would recommend washing the underside with cold water. He feels this simple wash would remove 90% of the chemicals. He feels that using hot water will heat up the paint on the frame rails.
- He was against using a high pressure cleaner. He believes this would only force the product into existing cracks. He also stated that this could lead to problems with electrical connections.

Appendix G

Interview with Jeffery Kelland

Jeffery Kelland
Minuteman Trucks
11/29/2012

- Jeff has worked at Minuteman Trucks for the past ten years. He is a certified EVT. Minuteman Trucks is the Massachusetts dealership for Pierce Manufacturing.
- Prior to working at Minuteman, Jeff worked in the heavy trucking industry for 27 years.
- When asked specifically about corrosion that he has witnesses personally at Minuteman, Jeff stated that he primarily sees corrosion issues involving frame rails, cross members, torque boxes and outriggers.
- He also stated he is seeing damage to brake cans in which the spring fails due to corrosion. He has seen this the past six or seven years.
- He stated that he sees corrosion where chemicals collect.
- Jeff is also beginning to see electrical damage to fire apparatus. He mentioned our issues as well as Salem, NH.
- He has seen damage to wiring harnesses in the past, but not to this extent. He has seen more damage in the past ten years.
- He also speaks of making splices in the wiring harness. He stated that the chemicals can enter the harnesses at these locations. He stated that the chemical wicks up the electrical wiring six to eight inches which turns the wiring a greenish color.
- He speaks of mechanics being unable to break apart electrical components because of corrosion and that because of this mechanics must now jump the wiring.
- Jeff stated that he believes the corrosion he is seeing on fire apparatus is caused by the chemicals put down on the roadways during the winter months.
- He stated that the liquid product is accelerating the corrosion.
- He stated that the liquid mist can travel and coat the undercarriage of the apparatus. He stated the same reason that chemicals clear the roadways also holds true for fire apparatus. The process accelerated the clearing and corrosion process.
- Jeff stated that the liquid disperses far less than the traditional rock salt.
- Jeff stated that the corrosive issue does not just affect his manufacturer's apparatus but all manufacturers. He stated that all vehicles are susceptible to corrosion.
- Jeff speaks on the process to determine how to proceed with corroded frame rails. He spoke of the rule of thumb for frame rail thickness. If the frame rail thickness is reduced by 33% or greater the frame rails will need to be replaced. The frame rails are given an UL ultra sound test to determine thickness.
- Jeff points out that the frame rails are always moving.
- When asked what Pierce is doing to slow the corrosion process, he stated that they recommend specifying stainless steel bodies. He stated that stainless steel is used in more locations, bonding agents are now being used to seal seems. Electronics are better protected at connections.
- Jeff stated that all trucks are manufactured the same way. He stated that there is no Northeast specification. He stated that when building a truck, the manufacturer looks at the worse case scenario at builds the truck according to that scenario.
- Jeff believes that today's paints are not as effective as the older paints. He believes that EPA regulations which restrict certain additives like lead, reduces the effectiveness of the paint. It is safer but not as effective.
- Jeff speaks of a new building that Minuteman just constructed for over a million dollars which includes spray booth capabilities. This was done in order to deal with body corrosion.
- Jeff speaks of protective measures that were designed ten years ago to slow the corrosion process break down which leads to corrosion. He stated that undercoating slows the corrosion process, however if the undercoating is scratched, an opening for the chemicals is provided.

- Jeff stated that departments need to keep an eye on the undercoating. If the undercoating bubbles, you need to sand it off, add a rust preventer, prime and paint. He believes this will stop the spread.
- The problem occurs when departments notice the corrosion and do nothing to stop it.
- Jeff recommends thoroughly inspecting your apparatus. If you observe signs of corrosion you need to address it. You will never stop corrosion but you will be able to slow the process.
- Ideally you need to wash the apparatus every time out. You need to wash under the truck. Jeff believes there is no need to pressure wash. He believes that you could actually damage components. He stated that you actually drive the product into cracks which could lead to corrosion.
- He agrees that departments that have highways go through them are more susceptible to corrosion damage.

Appendix H

Interview with William Doucette

Gloucester Fire Department

- Spoke to William Doucette Firefighter/Mechanic on 10/18/2012 by phone.
- 1998 Pierce Saber.
- Refurbished in 2012.
- Had no electrical problems.
- Had issue with Dover Roll-Up Doors.
- Lack of maintenance issue with doors.
- Door alarms not working.
- Started noticing flakes coming off frame rails.
- Brake Reservoir, valves corroded.
- Went to the chief informing him of corrosion issue. "We may only get one more year out of the truck if we don't address this."
- Initial estimate was 175K – 220K.
- Have contingency money. "They will find addition problems when the body is removed."
- Would like to get another 10 years out of the piece.
- Changed over to LED lights.
- Created a Spec for work. Review it well.
- "Any damage will be covered under the listed price."
- When asked about warranty, Pierce stated that corrosion was caused by chemicals.
- Undercoated during refurbishment.
- Add Chevron Striping.
- Look at fuel tank.
- They had their pump rebuilt but not the piping.
- He mentioned a town down the Cape that did a similar project 3 years ago.
- He mentioned Brookline.

Appendix I

Interview with Thomas Conway

Chief Thomas Conway
Billerica Fire Department
11/26/2012

- Tom Conway is the Billerica Fire Chief. He has been chief for close to one year. He has been a member of Billerica Fire Department for the past 29 years.
- I became aware that Billerica Fire purchased a steam cleaner with an attachment that can be rolled under the apparatus to clean the undercarriage of their vehicles.
- I interviewed Chief Conway on the topic of corrosion and was interested to learn his plan for the new steam cleaner.
- Chief Conway informed me that he often has conversations with his mechanic about corrosion related issues. He stated that he has become more aware of corrosion damage to his apparatus. He stated that his mechanic is always fixing something that has become corroded. He spoke of air canisters under the truck, mounts and brackets.
- When spec-ing out a new piece of apparatus, he focuses on having no exterior equipment that will be exposed to the elements. We need to make the equipment last. The last four pieces of apparatus purchased includes all equipment being stored in compartments, not exposed to the weather.
- Chief Conway speaks of including the Vogel automatic lubrication system in all his new apparatus.
- He speaks of designing his bodies with aluminum or stainless steel.
- He stated that Billerica has had some minor electrical issues with their apparatus such as warning lights.
- Chief Conway informed me of corrosion issues that Lawrence Fire was having with two of their Emergency One apparatus. He suggested that I contact Chief Bergeron.
- Chief Conway informed me that the Billerica DPW just recently replaced eight to ten medium duty trucks because of corrosion.
- When asked about his new washing system, Chief Conway stated that he purchased the unit based on the recommendation of Emergency One. This washer would become part of their preventative maintenance program. He stated that Emergency One recommended washing the underside of his apparatus and the aerial four times a year.
- Chief Conway plans on developing a checklist to document every time they wash the undercarriage and aerial.
- Chief Conway stated that he has spoken to the DPW superintendent about addressing the corrosion issue that they both face. They would like to see a new DPW facility include a truck wash system that could be used by all Town departments.
- Chief Conway stated that Billerica does not pre-treat its roads but that MassDOT pre-treats a portion of 3A and Route 3 along with all the overpasses and ramps.
- When asked about his apparatus replacement plan, Chief Conway stated that the Town follows the plan when they can. He reports that his apparatus are front line for 15 to 18 years then they get placed in reserve status after that. He stated that a 1998 engine is his oldest front line apparatus.
- He attempts to replace an engine every three to five years.
- When asked about refurbishing apparatus, he stated that Billerica has refurbished two pieces in the past. One of which was a brush truck that lasted several years.
- Chief Conway stated that for today, a little bit more money you can buy a new piece of apparatus.

Appendix J

Winter Road Treatments

1. What type of treatments are placed on your roadways during the winter months to prevent icing and assist in snow removal?

- ☐ Rock Salt
- ☐ Sand
- ☐ Liquid Calcium Chloride
- ☐ Liquid Magnesium Chloride
- ☐ All of the Above
- ☐ None of the Above

2. The main reasons we use liquid calcium chloride or liquid magnesium chloride is?

- ☐ Prevent Icing
- ☐ Assist in Snow Removal
- ☐ Easier to Apply
- ☐ Less Costly
- ☐ All of the Above
- ☐ None of the Above

3. Are you aware of the corrosive effect of liquid calcium chloride and liquid magnesium chloride?

- ◯ Yes
- ◯ No

4. If using liquid calcium chloride or liquid magnesium chloride do you include corrosion inhibitors in the product?

- ◯ Yes
- ◯ No

5. If you do not include corrosion inhibitors in liquid calcium chloride or liquid magnesium chloride is cost the primary reason?

- ◯ Yes
- ◯ No

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Winter Road Treatments

6. If using liquid calcium chloride or liquid magnesium chloride, are these treatments sprayed on your roadways in advance of a coming storm?

- ◯ Yes
- ◯ No

7. Are you faced with corrosion related issues to your own fleet of vehicles?

- ◯ Yes
- ◯ No

8. Has vehicles in your own fleet ever been taken out of service because of corrosion to the frame rails and/or electrical harnesses?

- ◯ Yes
- ◯ No

9. List the name of the city or town in which you work.

Appendix K

Fire Apparatus Corrosion

1. What is the average life expectancy of your departments fire engines?

- ◯ 0 - 10 Years
- ◯ 10 - 15 Years
- ◯ 15 - 20 Years
- ◯ Greater than 20 years

2. Does your department have an apparatus replacement plan in place that identifies the number of years a fire engine is expected to remain in service as a front-line, back-up, and reserve apparatus? Please explain.

3. What type of treatments are placed on your roadways during the winter months to prevent icing and assist in snow removal?

- ☐ Rock Salt
- ☐ Sand
- ☐ Liquid Calcium Chloride
- ☐ Liquid Magnesium Chloride
- ☐ A Combination of the Above
- ☐ Not Sure

4. What corrosive affect does Liquid Calcium Chloride and Liquid Magnesium Chloride have on fire apparatus?

- ◯ Severe
- ◯ Moderate
- ◯ Slight
- ◯ None
- ◯ Not Sure

5. Does your department currently have a procedure in place to wash the underside of your apparatus during the winter months? If so, please describe.

Fire Apparatus Corrosion

6. Has your fire apparatus ever suffered corrosion damage to any of the following components that required the apparatus to be removed from service for an extended period of time?

	Yes	No	Not Sure
Frame Rails	◯	◯	◯
Cross Members	◯	◯	◯
Suspension Components	◯	◯	◯
Fuel Tanks	◯	◯	◯
Electrical Systems	◯	◯	◯
Battery Boxes	◯	◯	◯

7. Has your department ever refurbished a fire apparatus because of corrosion to the frame rails and/or the electrical harnesses located within the frame rails?

◯ Yes

◯ No

8. What number best represents the average total cost of a fire engine refurbishment?

◯ 100,000

◯ 150,000

◯ 200,000

◯ 250,000

◯ 300,000

9. If your department refurbished a fire apparatus, what would be the anticipated life expectancy of the refurbished apparatus?

◯ 0 - 5 Years

◯ 5 - 10 Years

◯ 10 - 15 Years

◯ Greater than 15 years

10. When creating an apparatus specification, do you include language that addresses reducing the damaging effects of corrosion? If so, please describe.

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