AUTOMOTIVE ENGINEERING CONSULTANTS, INC.

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September 23, 20__

Mr. ____________________
Attorney at Law
Law Offices of __________________
_________________________, Suite ___
_____________, WA ____________

Re: Style: ____
Subject: Preliminary report.
File No.: Ours. _________.

Dear Mr. ________:

On September 12, 2006, at approximately 4:35 p.m., a single vehicle accident occurred approximately three miles east of ________, Washington, on _______ _____ Road. The accident occurred when a runaway Chevrolet C65 medium size work truck turned over in a curve, left the roadway, went through the guard rail and down into a ravine, came to rest on its side and caught fire.

At the time of the crash, the truck was being operated by Mr. _____ __ L________ , who had chased after and jumped into the unoccupied runaway truck and attempted to bring it under control. The truck's braking system did not restrain the truck from becoming a runaway. Mr. L________ died as a result of the accident.

Your office asked me to investigate the circumstances of the accident. The following is my report.

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AUTHOR'S QUALIFICATIONS

The author's qualifications are found in his curriculum vitae located in the appendix beginning on page 32 of this report.

ABSTRACT

This report presents a distillation of data related to a S_________ Contracting, Inc. work truck accident that took place on September 12, 2006, at 4:35 p.m., at a work site on _______ _____ Road, three miles east of ________, Washington. Two men, the truck driver and a helper, were working outside the truck erecting road signs.

Documents examined in preparation of this report included: State of Washington Police Traffic Collision Report, Washington State Patrol Report of Investigation, Washington State Patrol Commercial Enforcement Division Vehicle Examination Report, Department of Labor & Industries WISHA Services Division Witness Statements, deposition transcripts, M____ supplemental parking brake technical data, PSI Forensics Investigation, Investigative Report by Hall-Wade Engineering Services, S________ Safety Plans, Vehicle Maintenance Records and others.

The report describes the genesis of this fatal accident, particularly the manner in which the work truck was parked on a mountain grade using only a M____ supplemental hydraulic parking brake system for restraint.

None of the manufacturer's warnings, nor good practices and regulations, were complied with regarding the full use of the truck's parking brake, deployment of outriggers and the use of chocks, prior to the use of the supplemental hydraulic parking brake system, allowing the accident to develop.

The truck became a runaway when its single circuit hydraulic brake system failed completely, causing the supplemental hydraulic parking brake to simply let loose and the truck to roll away down the mountain.

The helper ran after the truck, jumped in and tried to stop the truck from escaping down the mountain grade. The truck's service brakes were no longer functioning. The truck left the roadway at a curve 1.6 miles down the road, crashed and burned.

The helper, Mr. _____ __ L________ , died in the crash.

This report describes the maneuverability of the downhill runaway truck and its attached trailer, illustrates the geometry of the highway at the location of the crash of the truck, and describes the weather and light conditions at the time of the accident.

A failure analysis of the truck's brake system is presented. The analyses in the report include calculations for the volume of brake fluid loss required for the M____ supplemental hydraulic parking brake to completely lose pressure and allow the parked truck to freely roll away. The pressure drop occurred suddenly due to a ruptured flexible brake hose. The service brake functionality was completely lost.

The loss of functioning service brakes was the root cause of the of truck rolling away and Mr. L________'s subsequent inability to control the truck.

FACTUAL INFORMATION

1. DESCRIPTION OF THE ACCIDENT LOCATION

The Police Traffic Collision Report states the accident occurred on September 12, 2006 at 1635 (4:35 p.m.) on _______ _____ Road three miles east of ________, Washington.

_______ _____ Road is a generally east/west two-lane county highway with multiple left and right hand curves, steep grades and protective guard rails at various locations. The lanes are delineated by a painted double yellow center line at the location of the crash.

At the time of the accident, _______ _____ Road was a construction site in the vicinity. Traffic was limited to one way with pilot truck service.

At the work site, the point where the accident began, the Labor & Industries report states "The grade is approx. 1-1/2 to 2% " and ". . . varies from being flat/level to 7 or 8 percent or greater in areas, from where the incident started . . ."

The accident developed over the course of 1.6 miles down the roadway, from the roadside work site to the down hill crash location.

The weather was described in the Washington State Patrol Report as being clear and sunny, temperature 75 degrees, visibility good and the roadway bare and dry.

Photograph 1, next page, is a photograph of the point where the accident truck and trailer left the roadway and crashed through the guard rail.

Figure 1, next page, is a schematic drawing from the Police Traffic Collision Report of the crash location where the truck left the roadway.

Photograph 1

Where the truck left the roadway.

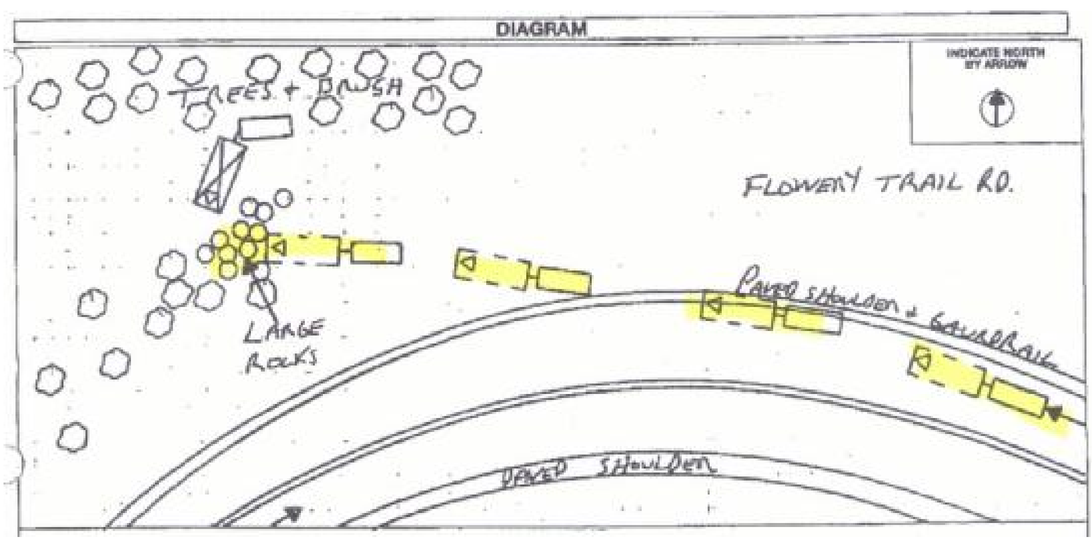

Figure 1

Police report schematic drawing of the crash scene.

THE TRUCK INVOLVED IN THE ACCIDENT

2. The truck involved in the accident was owned and operated by S________ Contracting, Inc.

The accident truck was a 1978 Chevrolet C65 Medium Duty Truck, Vehicle Identification Number CCE668V135310 and bearing Washington state license number TE 1640.

The truck was equipped with a manual shift transmission, a power take-off unit, a boom mounted auger and outriggers.

The brake system in the accident truck is a single circuit hydraulic brake system utilizing a second, tandem master cylinder with a vacuum power brake booster.

The front brakes, rear brakes and parking brake are all drum type brakes.

A supplemental hydraulic parking brake, a M_______ Lever Lock (a brake line pressure lock device) had been installed on the truck.

Photograph 2
Accident truck shortly after purchase in 1991.

The truck was equipped with power steering, utilizing an engine driven power steering pump generating pressure assist through a power cylinder attached to the truck's tie rod.

3. A work trailer was being towed by the truck at the time of the accident. The trailer was equipped with electric brakes, controlled from inside the cab of the truck.

4. Accident scene. The S________ Contracting, Inc. auger truck and work trailer lie at the bottom of the ravine after leaving the roadway, crashing through the guard rail, coming to rest and catching fire.

Photograph 3

S________ accident truck and work trailer at accident scene.

5. BRAKE SYSTEM IN THE S________ CHEVROLET C65 MEDIUM DUTY ACCIDENT TRUCK.

Figure 2 is from the Chevrolet C65 Medium Duty Truck Service Manual and is representative of the brake system in the accident truck.

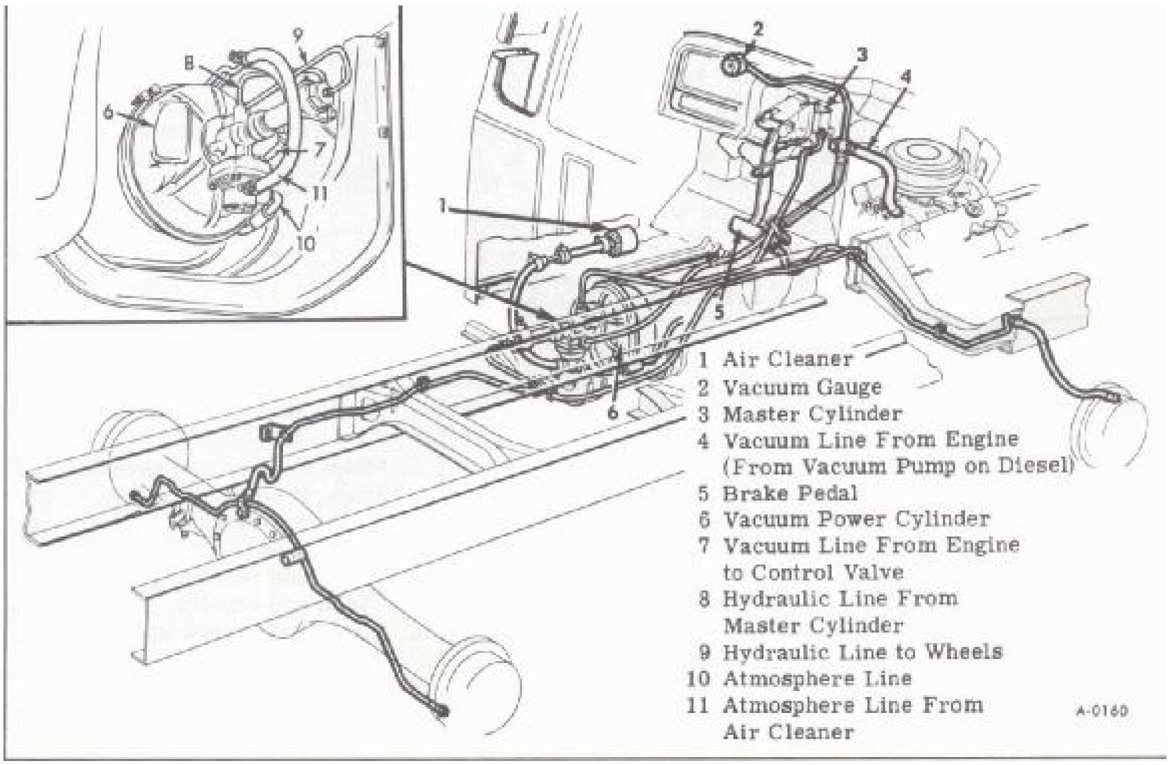

Figure 2
Chevrolet C65 Brake System

Service Brakes

The service brake system begins with the brake pedal connected to a master cylinder. The master cylinder converts the driver's foot pressure on the pedal to hydraulic fluid pressure in the brake lines and on to the brakes located at each wheel.

The Chevrolet Medium Duty Truck is considerably heavier than a typical automobile and, to have effective brakes, needs more force in the brake system than a driver can easily provide

That additional force is provided by a second, larger power assisted master cylinder in tandem with the brake pedal master cylinder. The second master cylinder is assisted by a powerful vacuum booster, noted at position 6 in Figure 2, labeled Vacuum Power Cylinder.

Parking Brake

The standard Chevrolet C65 parking brake is a transmission mounted drum brake coupled to the truck's drive shaft. The parking brake is manually activated from inside the cab of the truck by a rather large parking brake lever.

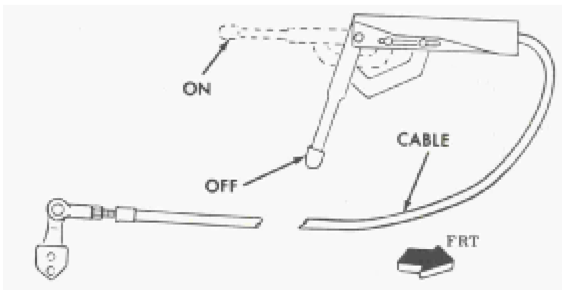

Figure 3
GMC Medium Duty Truck
Parking Brake Lever

Supplemental Hydraulic Parking Brake

The S________ Contracting truck was equipped with an aftermarket, supplemental hydraulic parking brake, a M________ Lever Lock. The complete M_______ kit is shown in photograph 4.

Photograph 4
M________ Lever Lock Kit

Once installed in the truck and plumbed into the truck's hydraulic brake pipe system, the M____ Lever Lock can be activated by the small lever on the front of the device.

The M____ Lever Lock operates through an internal check valve that holds the brake line pressure that the driver generates by stepping on the brake pedal with the lever engaged.

Figure 4 below, shows the M____ Lever Lock check valve, the active element of the device.

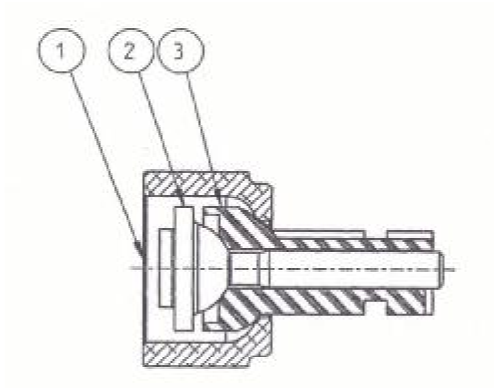

Figure 4
M____ Lever Lock check valve.

The check valve is located internal to the M____ Lever Lock (Photograph 4) in the red section approximately in the middle of the device.

The M____ Lever Lock is a simple, straightforward device that, when engaged, holds the brake line system pressure for a period of time.

When the truck driver pushes on the brake pedal, brake fluid pressure is generated, directionally, from the right side of the drawing past the check valve, (2), and the pressure goes into the brake line system towards the left side of the figure (1) and onward to the brakes at each wheel.

When the brake pedal is released with M____ Lever Lock engaged, the high brake line pressure holds the check valve, (2), against the seat, (3), and retains the brake line pressure for a period of time, thereby holding the service brakes as the driver's foot on the brake pedal would.

The ability of the M____ Lever Lock to hold the brakes is only as good as the integrity of the M____ Lever Lock and the truck's complete brake system downstream from the Lever Lock.

The M____ Lever Lock is equipped with an electrical switch that is intended to be connected to the vehicle's horn, to warn of brake system pressure bleed-off at approximately 500 p.s.i.

The M____ single circuit Lever Lock was installed by Mr. __________ of ____________________ __ , replacing a previously installed M____ Dual (dual circuit) 670 Accumulock.

Mr. ______ had recommended that the truck owners approve replacement of the existing dual system with a similar dual system. They declined and supplied a less expensive, single circuit M____ Lever Lock for installation, as sold to them by a local NAPA auto parts outlet.

Outriggers

Outriggers are arms that can be extended outward from the truck to help stabilize the truck during boom operations. When engaged with the surrounding ground, the outrigger picks up some of the truck's weight off the tires and onto the steel outrigger arms.

Photograph 5.
Outrigger deployed

The outriggers not only stabilize the truck from side to side, but also help prevent the truck from rolling. Although not a part of the brake system proper, the accident truck was equipped with outriggers.

Photograph 5 illustrates deployed outriggers stabilizing a truck during boom operations. The arrow points to the left side outrigger, extended to the ground.

Chocks

Chocks are safety blocks, large wedges of material placed under wheels of a vehicle to prevent it from rolling.

They may be simple blocks of wood or more highly developed, formed and manufactured wedges made from wood, plastic, steel or other materials to fit the curvature of the tire.

On level ground, chocks may be placed in front of and behind a vehicle's tires to prevent rolling in either direction.

On downhill grades, chocks may be placed on the downhill side of the vehicle's tires. As chocks are simply a block of material with no moving parts, adequately sized chocks are very dependable devices for preventing a vehicle from rolling.

Chocks improvised from left-over sign post cuttings were used at times by S________ workers to chock the wheels of their trucks. Other S________ trucks were equipped with chocks. The accident truck was not so equipped.

ANALYSIS

THE DEVELOPMENT OF THE CRASH.

6. The accident occurred at approximately 4:35 p.m., September 12, 2006, approximately three miles east of ________, Washington, on _______ _____ Road.

The truck was parked on an incline, facing downhill and westbound on the north side of the road.

The work truck, a Chevrolet C65 auger truck with an attached four wheel trailer, was parked at a roadside work site with two workers present outside the truck: one driver/operator and a helper. The two man crew was putting up road side signs.

The Labor & Industries report states "The truck began to roll while the crew was putting up the last sign of the day."

Mr. _____ L________, the helper and ". . . victim, chased the truck, got into it and tried to get it stopped". Mr. L________ was not a qualified operator for the truck. The ". . . truck went about a mile down the road, through a guardrail, over an embankment, and caught fire . . ."

The Traffic Safety Supervisor witness statement in the police report states "I saw the truck coming down dragging hose . . . Saw his coworker waving at me . . . He said their brakes failed . . . We headed down the hill . . . S________ truck quickly gained speed . . . we only caught glimpses of him losing posts & tools off of the trailer . . . did not see actual crash . . . truck went into ravine . . . must have instantly caught fire . . ."

"Having a safety block under tire would have prevented truck from rolling."

Mr. L________ died in the crash.

FACTORS CONTRIBUTING TO THE TRUCK ROLLING AWAY

7. The truck was restrained from rolling away from the work site only by a M _____ Lever Lock, the manually activated hydraulic pressure lock device installed in the truck's brake line system.

There is no indication that the truck's manual parking brake or the trailer's electric brakes were employed to provide additional restraint to the parked truck to prevent it from rolling away on the incline.

The outriggers of the truck were not deployed at the time the truck rolled away. There is no indication that chocks were available, improvised or used to provide additional restraint for the parked truck.

At the work site where the accident began, the grade is approximately 1-1/2% to 2%. The Labor & Industries report states that over the course that the runaway truck followed. "The grade varies from being flat/level to 7 or 8 percent or greater."

The truck's hydraulic brake system had obviously failed.

MANEUVERABILITY AND CONTROLLABILITY OF THE WORK TRUCK AND ITS TRAILER.

8. The attached trailer was a significant destabilizing factor to the truck, as it gained speed and approached loss of control.

In this developing situation the Chevrolet C65 Medium Duty Truck has poor maneuverability negotiating downhill curves with no brakes at high rate of speed with a trailer attached.

A trooper in a patrol car performed a roll test across the course of the accident, attained a speed of 79 m.p.h. and stated he was uncomfortable in the patrol car and had to slow down before reaching the point where the truck left the roadway.

The runaway truck would have attained a similar speed and been less maneuverable than the patrol car. The truck could not negotiate the curves at the high speeds it attained.

The lack of functioning service brakes was the root cause of the of truck rolling away and Mr. L________'s subsequent inability to control the truck.

Genesis of the Accident

9. The genesis of this fatal crash began with the manner in which the Chevrolet C65 work truck and its attached trailer were parked.

   The truck was parked on a downhill grade using <u>only</u> the supplemental M____ Lever Lock brake system to keep the truck from rolling down the hill. The truck was left unattended.

   There is no evidence of use of the truck's original equipment parking brake, chocks placed under the wheels, outriggers put in place, or any other restraint method to keep the truck from rolling.

   A work trailer, equipped with electric brakes, was coupled to the truck. There is no evidence the electric brakes on the trailer were engaged.

   The hydraulic line pressure in the truck's service brake system failed completely, allowing the truck to roll away.

10. Safety regulations and good practices dictate the use of parking brakes, chocks and outriggers to guard against just such failures leading to runaway trucks.

    The 1978 S________ Chevrolet truck owner's manual devotes several pages to the description of the parking brake system and its use.

    The Washington State Commercial Driving Guide has multiple references to the use of the parking brake and chocks with commercial trucks.

    The federal Occupational Safety and Health Administration and the Washington State OSHA recommend the use of chocks in restraining parked trucks and have included the use of chocks and parking brakes in Fatality Assessment and Control Evaluation (FACE) program recommendations.

BRAKE SYSTEM FAILURE ANALYSIS

FAILURE MODES OF THE TRUCK'S HYDRAULIC BRAKE SYSTEM.

The major components of the S________ Chevrolet C65 work truck brake system are (1) Brake Pedal and Master Cylinder, (2) the second tandem master cylinder with vacuum power assist, (3) M _______ Lever Lock Supplemental Parking Brake, (4) Steel Brake Lines, (5) Flexible rubberized brake lines and (6) the Wheel Cylinders located at the brakes at each wheel.

Failure modes of each of these components are discussed as follows:

11. Brake Pedal and Master Cylinders.

The truck's brake system did not fail due to simply being out of brake fluid. The brake pedal, master cylinder and second tandem master cylinder all performed their intended functions up to the point of the truck being parked at the work site.

The brake master cylinder reservoir, had it been out of or too low on fluid at the time the truck was parked, would have malfunctioned and brake system pressure could not have been raised to allow the M _______ Lever Lock to be used as a parking brake.

If the hydraulic brake system had a slow leak over time, to have been a contributing factor in this accident, the level in the brake fluid reservoir would have dropped sufficiently that pressure could not have been developed through the tandem master cylinder for parking on the hill.

When the truck arrived at the work site, the brake master cylinder and the complete system required sufficient brake fluid in the reservoir to pressurize the brake system for parking,

This indicates the truck's brake system had sufficient fluid from the master cylinder reservoir down to the M _______ Lever Lock mounted below the floor of the truck, next to the vacuum brake unit, and from that point throughout the system.

There was no evidence of a brake fluid leak at the parking location of the truck at the work site The brake system was functional at the time the truck was parked at the work site.

There was no failure of the brake system between the foot pedal down to the aftermarket M____ Lever Lock.

12. M _______ Lever Lock Supplemental Parking Brake

Brake line pressure is raised by the driver's foot on the brake pedal and the M____ Lever Lock is engaged to retain that brake line pressure. The S________ crew worked for a period of time with the Lever Lock engaged and the truck restrained by only the Lever Lock.

Although the M____ Lever Lock is capable of failure, primarily by leak-back through the check valve, a failure of the Lever Lock would not have disabled the truck's complete service brake system. The brakes would still have functioned properly and been capable of stopping the truck when Mr. L________ pushed on the brake pedal.

The brake system failed downstream of the M____ Lever Lock.

13. The remaining possible downstream failure locations are, in order of location: (1) the steel brake lines, (2) the flexible rubber brake lines and (3) the brake wheel cylinders, one at each wheel.

The failure analysis of these three remaining components follow here out of order. Component failure analysis is a process of elimination and a failure of components (1) the steel brake lines and (3) the brake wheel cylinders, was clearly eliminated leaving component (2) the flexible rubber brake lines, the analysis of which is presented last.

<u>Steel Brake Lines</u>

After the accident, the investigators pressurized the steel brake lines with air and tested for leaks with soap bubbles. These tests showed no leaks and indicated the steel lines were functioning properly.

No evidence was found of a leaking or failed steel brake line.

<u>Wheel Cylinders</u>

Leaking wheel cylinders usually leak down in a slow manner over time and occasionally develop a major leak suddenly.

Slow leaks make themselves known by requiring frequent replenishing of the master cylinder reservoir. Leaks also contaminate the brake shoes resulting in grabbing brakes at that wheel.

Both slow and fast wheel cylinder leaks present themselves by coating the inside of the wheel and tire with the leaked fluid and are obvious upon visual inspection.

After the accident, investigators checked all the truck's wheel cylinders for dampness or leakage on the inside of the dust covers at each of the cylinders. No leakage was found. The wheel cylinders were functioning properly at the time of the accident.

There was no failure of the brake wheel cylinders.

That leaves only the flexible rubber brake hoses as the point of failure for the loss of brake fluid and brake line pressure.

Flexible Rubber Brake Lines

There are two flexible rubber brake lines at the front axle and one at the rear axle of the truck. The lines were either damaged or consumed in the fire and could not be examined for failure.

SAE J1401 requires a burst pressure strength of 4,000 to 5,000 p.s.i. for new hoses, a pressure far above the operating parameters of the truck's master cylinder and service brake system.

For a brake hose to fail under the lower operating pressures of up to 1,700 p.s.i., it must be physically damaged or the hose material deteriorated to allow the hose to rupture.

Possible reasons for the deterioration of the brake hoses are damage from road debris and/or previous contamination with the addition of hydraulic oil to the brake system.

The failure of a brake line hose is consistent with the drop in line pressure allowing the M ____ Lever Lock to let go and the evident failure of the truck's brake system to stop the truck once Mr. L ________ entered the truck.

A flexible rubber type brake hose failed and simply ruptured at the M _______ Lever Lock's high operating pressure, causing the brake line hydraulic line pressure to immediately drop to zero.

Failure Mode Discussion

14. The truck's lone restraint, the M _______ supplemental parking brake system, could not hold the truck on the hill due to a sudden depressurization of the service brake system.

The truck's brake system failed suddenly due to a flexible brake hose rupture, causing the brake line pressure to abruptly drop to zero and the truck to roll away down the hill.

The M _______ operating brake line pressures of 500 p.s.i. and 1,700 p.s.i. are thirty-four to well over one hundred times that of the atmospheric pressure surrounding the truck's brake system components. The ultimate failure mode of such highly pressurized lines is therefore very, very fast.

Steel brake lines that fail due to rust and corrosion, such as from salted roads, will hold braking pressures until either the line becomes so thin at one point that the weak point suddenly gives way under pressure or until a higher than usual brake line pressure is applied and the weak point gives way.

In either case, steel brake line or rubberized flexible brake line, the failure and pressure drop is immediate. The high hydraulic brake line pressure simply pushes the brake fluid out at the point of failure.

The required volume of brake fluid loss to drop the line pressure from 1,000 p.s.i., to 0 p.s.i. is very, very small and is evacuated, for all practical purposes, immediately.

The failure mode of the truck's brake system was complete. It allowed the truck to begin to roll downhill immediately. The release of the supplemental hydraulic parking brake was as if the driver simply took his foot off the brake pedal.

15. The brake line failure resulted in a sudden loss of all brake system pressure and the complete loss of the service brake system. From that point on, no brakes were available through the brake pedal to slow down or stop the truck.

VOLUME OF BRAKE FLUID LOSS REQUIRED FOR THE TRUCK TO ROLL DOWN THE HILL.

The truck's brake system failed to hold due to the sudden loss of approximately one-third of a teaspoon of highly pressurized brake fluid.

<u>Compressibility of Materials (and Brake Fluid)</u>

16. Compressibility of materials is a concept outside our normal day-to-day thinking. The term compressibility refers to how much the volume of the material decreases under pressure.

Solids are barely compressible, liquids somewhat more compressible than solids and gases are very compressible.

An example of compressibility would be to take a foam rubber ball and squeeze it down with your foot. The ratio of how hard you pressed down with your foot to how much the ball squeezed down (how much its volume decreased) would be a measure of the foam rubber ball's compressibility.

All materials, including brake fluid, are to some degree compressible. For day-to-day use in a hydraulic brake system, the compressibility of brake fluid is negligible.

The volume of brake fluid that was compressed in the truck's brake system is the volume of brake fluid loss required for the brake line pressure to drop to zero, allowing the brake system to completely let go.

17. When the driver's foot pushes down on the brake pedal, the brake master cylinder pressurizes the complete hydraulic line system downstream, to force the brake shoes against the brake drums at each of the wheels, to engage the brakes. In this process the brake fluid is slightly compressed under the very high brake line pressure.

The installed M _______ Lever Lock can then be engaged to hold that brake line pressure in the system, for a period of time, after the foot is removed from the pedal.

18. The S________ Chevrolet C65 Medium Duty work truck involved in this accident used a standard brake fluid, DOT 3, often referred to as a Glycol-Ether fluid.

The compressibility of the brake fluid and the applied brake line pressure are used to calculate the quantity of brake fluid loss required for brake system failure.

The Society of Automotive Engineers (SAE) paper 810803 gives a value for the compressibility of glycol brake fluid of approximately 0.3%. That means three-tenths of 1%, or 0.003, a very small number and a very small volume of fluid.

This 0.3% compressibility figure is given at a pressure of 800 p.s.i. and a temperature of 75 ^{0}F, approximately the ambient temperature on _______ _____ Road at the time of the accident.

This means that if the parked work truck were to lose three-tenths of one percent of its pressurized brake fluid downstream of the Lever Lock parking brake, the brake system would simply let go and the truck would roll down the hill.

19. The active volume of brake fluid in the brake system downstream of the M____ Lever Lock is approximately one pint, or 16 fluid ounces. “Fluid ounces” are a measure of volume.

To calculate the volume of brake fluid necessary to lose the Lever Lock parking braking, using familiar terms:

> One pint of brake fluid contains 16 fluid ounces.
>
> 1 fluid ounce = 6 teaspoons. There are 96 teaspoons of brake fluid in one pint.
>
> 0.3% lost = 0.003 of the brake fluid lost, so:
>
> 0.003 lost x 16 fluid ounces = 0.048 fluid ounces of brake fluid required to lose braking.
>
> or
>
> 0.003 lost x 96 teaspoons = 0.288 teaspoons lost, or about 1/3 of a teaspoon of brake fluid loss to lose braking.

The loss of less than 1/3 of a teaspoon of brake fluid at 800 p.s.i. will drop the brake line pressure to zero and cause the truck to simply roll away down the hill.

20. The M _______ Lever Lock installed in the truck is designed and tested to hold brake line pressures up to 1,700 p.s.i. Actual brake line pressures of 1,000 p.s.i. and more are achieved during normal use in a hydraulic brake system.

The M _______ Lever Lock has designed pressure electrical switch trip points at approximately 500 and 750 p.s.i.

These pressures, 500, 750, 1,000 and 1,700 p.s.i., are used to determine the amount of brake fluid loss required at each or these various pressures for the truck to simply roll away, as occurred in this accident.

The required volume of brake fluid loss, at the various line pressures of interest in this accident, to allow M _______ Lever Lock to fail to hold the truck are calculated in Appendix I, pg. 29. The results follow here for convenience:

At 500 p.s.i. $K = 1 - 0.998 = 0.2$ % ==> 0.030 fluid ounces = 0.180 teaspoons

At 750 p.s.i. $K = 1 - 0.997 = 0.3$% ==> 0.045 fluid ounces = 0.270 teaspoons

At 1,000 p.s.i. $K = 1 - 0.996 = 0.4$% ==> 0.060 fluid ounces = 0.360 teaspoons

AT 1,700 p.s.i. $K = 1 - 0.994 = 0.6$% ==> 0.102 fluid ounces = 0.611 teaspoons

At the full range of pressures, the loss of less than a teaspoon of brake fluid under the high line pressures in the brake system will allow the truck to simply roll away.

Such a small amount of fluid lost would still allow a truck’s brake system to function and bring the truck to a stop, had the brake system been intact. Something more happened.

The truck’s single circuit brake line system was breached by a failed flexible brake hose, preventing any further brake line pressure from being developed. Pumping the brake pedal simply pumped brake fluid overboard.

OBSERVATIONS AND CONCLUSIONS

21. A slow leak gradually depleting the brake system reservoir would not have allowed the truck to have been driven to the work site. The brake system could not have been pressurized to allow the M _______ lever lock to be engaged to hold the truck on the mountain grade.

    When a brake line under pressure ruptures, the time required to lose less than a teaspoon of brake fluid and for the line pressure to drop to zero is, for all practical purposes, immediate. When a brake line loses pressure, the M _______ Lever Lock lets go and loses the ability to restrain the vehicle from rolling down a grade.

    The failure mode of a brake line at high pressure is bursting, not slow leakage. A flexible rubberized brake hose will fail in bursting at these high pressures of around 1000 p.s.i. When the brake line ruptures, it fails suddenly. This is true of steel brake lines as well. Once pressure containment has failed due to deterioration or damage, the pressure drop is quite sudden.

    The S________ Chevrolet truck's hydraulic brake system did not fail as a result of a slow leak, it failed as a result of a sudden pressure drop from a ruptured brake line.

21. When Mr. L________ jumped into the truck to prevent it from rolling away, he had jumped into a truck with a hydraulic brake system that had completely ceased to function.

    The brake system still had brake fluid throughout the system. Mr. L________ would have found at first that the brake pedal offered some resistance, giving the impression that the brakes could be pumped to slow the truck.

    If the truck had only a small, dripping leak at this point in time, the service brakes could have been used successfully and would have been completely effective in stopping the truck.

    However, with a ruptured brake line, pumping the brakes simply pushed more brake fluid from the upper part of the system out the brake line failure point, having no braking effect at the wheels. With no possibility of being slowed by the brakes, the truck rapidly gained speed.

22. The best possibility of mechanically retarding the acceleration of the truck with no brakes would have been through immediately putting the transmission in gear, allowing the resistance of the engine to oppose the acceleration of rolling down hill.

There is some speculation as to whether the truck's engine was running with the ignition on, at the time Mr. L________ entered the truck. According to the Washington State Patrol report, the Labor & Industries investigator stated that driver Wright "explained that the truck's engine was definitely running".

. The advantage of a running engine would be to better enable the driver to shift the transmission into gear by first raising the engine speed to match that of the truck, shifting into gear, releasing the clutch and then allowing engine compression to aid in slowing the truck.

A running engine would have immediately provided power steering and power assist to the brake pedal, but that power brake assist would only have aided in the pumping of brake fluid out of the ruptured brake line system.

One witness stated he heard the gears grinding, as if the truck's driver were attempting to shift the truck into gear.

Had the truck been in gear and the engine rotating, both the power steering and the power brake assist would have been completely functional, ignition on or not.

Mr. L________ successfully negotiated several downhill curves at high speed between the work site and the crash site.

Such a high level of controllability would have been most likely with the power steering functioning, and the development of such high speeds only likely with a complete failure of the service brake system.

Even so, with the engine rotating, the power brake assist would only have aided in the pumping of brake fluid out of the ruptured brake line system. The truck had no functioning service brakes.

23. The accident truck's outriggers were not deployed and in use at the time of the accident, and could not help keep the truck from rolling.

There is no evidence that chocks were in use at the time of this accident of this S________ truck.

There is no evidence that the trailer's electric brakes were engaged at any time during the development of the truck running away from the work site to the point of the crash.

24. M _______, by the year 2006, should not have recommended installing a single circuit supplemental hydraulic parking brake in a single circuit road vehicle's brake system. M____ should have only recommended one of their dual systems.

Dual circuit brakes have been installed in virtually all U.S. automobiles since the 1960s and since that time in trucks as well. The safety advantages of dual circuit brakes are well known.

A dual circuit supplemental system would transform a vehicle's single circuit brake system to a dual circuit system when the supplemental hydraulic brake system was in use.

M _______ would have positioned themselves well as safety advocates, in recommending only the installation of dual circuit lever lock parking brake systems in older single circuit road vehicles, especially trucks. Implementing such a recommendation could have prevented this accident.

25. __________ ______ _____, a hydraulic shop, did not make the electrical hook-up to the truck's horn from the M _______ Lever Lock switch, to make the horn a low pressure warning device. The truck was still equipped with the same pressure monitoring device from the previous M____ Lever Lock installation, a brake line pressure gauge.

26. The installation of a warning horn would have made no difference in this accident. The pressure drop, a horn alarm and the brake release would have all occurred virtually simultaneously.

Anyone entering the truck would have discovered after a few pumps of the brake pedal, that there were no functioning service brakes.

Even had someone been sitting in the cab of the truck at the time of this brake failure, the circumstances would have been the same. The truck had no working service brakes.

27. The installation in the truck of a warning horn, sound generating alarm, lights, other warnings or a Lever Lock interlock device on the M _______ Lever Lock, all would have had no effect on the total failure of the truck's brake hydraulic system in this accident.

A brake hose ruptured suddenly under high pressure, rendering the truck's service brakes inoperable. The brake failure was sudden and complete.

The loss of functioning service brakes was the root cause of the of truck rolling away and Mr. L________'s subsequent inability to control the truck.

28. This accident could have been prevented simply by the use of the parking brake, chocks and outriggers.

BASIS OF OPINIONS

In the course of my investigation, I examined the following documents:

1. State of Washington Police Traffic Collision Report by Officer K. Isom.
2. Washington State Patrol Report of Investigation.
    A. by S. S. (signature unreadable).
    B. Narrative by Trooper J. A. McKee.
    C. Narrative by Trooper Halle.
    D. Supplemental Report, Narrative by Trooper James D. Halle.
3. Washington State Patrol Commercial Enforcement Division Vehicle Examination Report.
    A. Narrative by CVEO Steve Erickson.
4. Department of Labor & Industries WISHA Services Division Witness Statements by:
    A. William C. Wright.
    B. Jack A. Mezzanatto.
5. Deposition transcript of John ______, foreman and mechanic.
6. Deposition transcript of _____ __ _____, d/b/a ___________ ______ _____.
7. Deposition transcript of Brent P. _______, M____ President.
8. Deposition transcript of James Vincent _______, Junior, M____ Vice President of Engineering.
9. 599 photographs of the accident truck, trailer and accident scene taken by others.
10. M____ 02-xxx-125:
    A. Table of Contents.
    B. Prints (engineering drawings).
    C. Assembly Instructions.
    D. Test Specifications.
    E. General Guidelines, Installation and Service Instructions.
11. M____ Brake Lock Application Guide 2010, including 02-xxx-147 Accumulock including:
    A. M____ Brake Lock Application Guide 2002 including the xxx Brake Lock System and electronic controls.
    B. Dexter Axles Maintenance Schedule.
    C. Dexter Axle Operation Maintenance Service Manual.
    D. Tekonsha Breakaway Switch, Battery Charger Installation.

10\. PSI Forensics Investigation:
    A. Memorandum September 28, 2006.
    B. Memorandum October 12, 2006.
    C. Memorandum October 17, 2006.
    D. Memorandum October 24, 2006.

E. Six schematics of truck brake system and trailer.

E. Letter to Steve Halpain.

F. Various notes and additional Memoranda.

11. Labor & Industries Report.
12. Industrial Brake Accident Investigation.
13. S________ Safety Plans.
14. S________ Vehicle Maintenance Records.
15. M____ Questions.
16. M____ additional records regarding revisions.
17. California FACE Report #94CA007; OR-FACE 2007-11-1; FACE/WA Report # 47-8-2005; OSHA Safety and Health Topics: OSHA Assistance for the Trucking Industry.
18. Federal Motor Carrier Safety Administration 49 CFR 393, Subpart G – Brakes, 49 CFR 396 regarding inspection repair and maintenance, Unsafe operations, Inspection of motor vehicles in operation, Driver vehicle inspections, Periodic inspection, Inspector qualifications.
19. SAE Technical Paper 810803 *Alpine Testing of Silicone Brake Fluids*.
20. SAE Brake Standard J1401 Jun 2003.
21. Media Reports.
22. Investigative Report of S________ Truck Incident by Hall-Wade Engineering Services.
23. Letter of opinions and Clevis Assembly/Application Interlock by Rudy Limpert, PhD.
24. Brake Lock Assembly Retrofit System #1 and System #2 by D.H. Parr & Assoc.

Of my own work product:

25. Calculations: Glycol brake fluid bulk modulus, compressibility and required fluid loss for brake failure at line pressures of interest.
26. Three photos of the M____ Lever Lock kit.

APPENDIX I

CALCULATIONS: COMPRESSIBILITY OF BRAKE FLUID.

The purpose of these calculations is to demonstrate the very tiny volume of brake fluid loss required for the truck to roll away under the very high system pressures of the M____ Lever Lock holding the S________ truck on the hillside grade.

Compressibility *K* and its inverse, Bulk Modulus B, is the material property of the brake fluid that is required to determine the quantity of brake fluid loss.

The relationship of Compressibility *K* to Bulk Modulus *B* is expressed as *K* = 1/*B*.

The definition of bulk modulus *B* is:

$$B = -V \frac{\partial P}{\partial V}$$

where *P* = pressure
V = volume

Rearranging:

$$\partial P = -B \frac{\partial V}{V}$$

Integrating

$$P = -B \int_{Vo}^{Vo-\Delta V} dV/V$$

$$= -B \left[\ln (V) \right]_{Vo}^{Vo-\Delta V}$$

$$= -B \left[\ln (Vo-\Delta V) - \ln (Vo) \right]$$

$$P = -B \ln \left[(Vo-\Delta V) / (Vo) \right]$$

In the figure below, from SAE paper 810803 , the compressibility of glycol brake fluid (DOT 3) at 75 ^{0}F is given as 0.3%.   The two upper lines labeled 1200 p.s.i and 800 p.s.i. are for silicone brake fluid. The accident truck was equipped with glycol brake fluid.

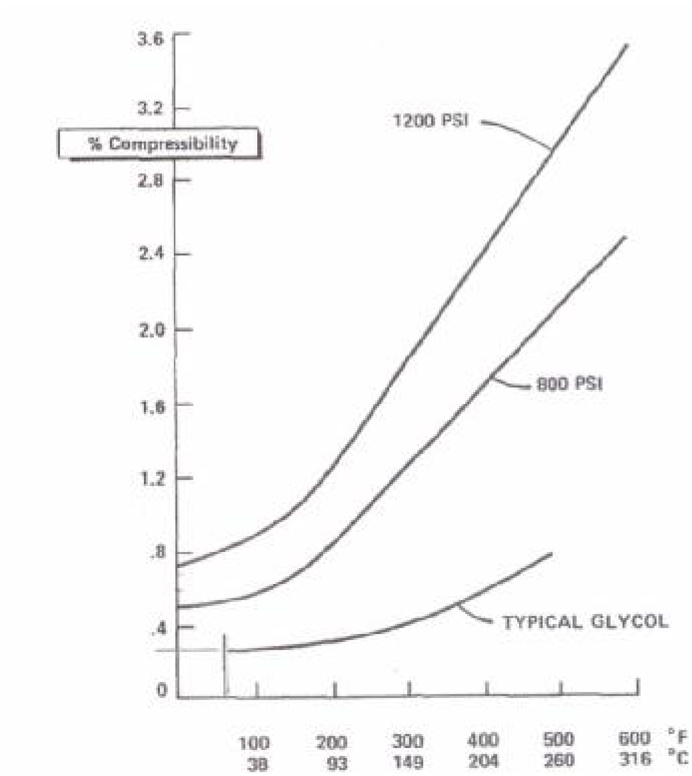

Figure 4.
Compressibility of Brake Fluid

This gives $- \ln (Vo - aV) - \ln (Vo) \bullet = 0.003$,

$Vo = 1$ and $(Vo - aV) = 0.997$

$$P = -B \ln \bullet 0.997$$

Solving for B, the bulk modulus of DOT 3 brake fluid:

$$B = -P / \ln \bullet 0.997$$

where 1 p.s.i. = 6.89 ...* x 10^{-3} MPa = 0.00689... MPa

and P = 800 p.s.i. = 5.51... MPa = 0.00551... GPa

= 1.835... GPa

$$B = 1.84 \text{ GPa}$$

* ... indicates additional significant digits.

The M____ Lever Lock has designed electrical switch pressure trip points at approximately 500 and 750 p.s.i. Working pressures of approximately 1,000 p.s.i. are attainable, and the M____ brake lock is tested to 1,700 p.s.i. These pressures are used to determine the amount of brake fluid loss required for the truck to simply roll away at each of these pressure points.

With B = 1.84 GPa, the amount of the brake fluid compressed (K) by the Chevrolet truck master cylinder, can be calculated for the range of brake line pressures of interest by:

$K = aV$

where $aV = 1 - e^x$ and $x = - aP / B$

where K x 16 ounces = number of fluid ounces lost
and the number of fluid ounces lost x 6 = number of teaspoons lost.

For 500 p.s.i.

500 p.s.i x 0.00689...* MPa / p.s.i. = 3.44... MPa = 0.00344... GPa

$x = - aP / B$ = - 0.00345... GPa / 1.83... GPa = - 0.00187... = x

e^x = 0.998...

$aV = 1 - e^x$ = 1- 0.998... = 0.00187... = 0.188%

K = 1 - 0.998 = 0.2 % ==> 0.030 fluid ounces = 0.180 teaspoons

Similarly, for the other pressures of interest:

For 750 p.s.i. K = 1 - 0.997 = 0.3% ==> 0.045 fluid ounces = 0.270 teaspoons

For 1,000 p.s.i. K = 1 - 0.996 = 0.4% ==> 0.060 fluid ounces = 0.360 teaspoons

For 1,700 p.s.i. K = 1 - 0.994 = 0.6% ==> 0.102 fluid ounces = 0.611 teaspoons

In all cases, the loss of less than a teaspoon of brake fluid under the high brake line pressures held by the M____ Lever Lock, will drop the line pressure to zero and allow the truck to roll away.

* ... indicates additional significant digits.

APPENDIX II

Donald B. H. Jeffers, P.E. Curriculum Vitae

A graduate of the University of Michigan with experience in the automotive, aerospace and chemical industries, Mr. Jeffers has a broad background in the design and failure analysis of transportation vehicles and industrial machinery.

Mr. Jeffers is a strong practical engineer with a scientific background. His hands-on experience ranges from research, design and development to manufacture, testing and the solution of machinery problems in the field. He is a versatile professional with skills in the mechanical, structural, electrical and aerodynamic areas. An expert diagnostician and accomplished mechanic, he thoroughly understands procedures used by field service personnel. His specialties are automotive engineering and industrial machinery.

His vehicular failure analysis and accident reconstruction experience includes trucks ranging from small pickups to multiple unit tractor-trailers; automobiles including sports cars, sedans, station wagons and sport utility vehicles; bicycles, motorcycles, all terrain vehicles, motorhomes, recreational vehicles, buses, farm machinery, skidders, self-propelled cranes, trains, pleasure boats, deep water boats, light aircraft and pre- and post accident fire. Mr. Jeffers' expertise in vehicle systems allows for the precise determination of systems failure and accident causative elements.

Mr. Jeffers completed his basic engineering studies at the University of Texas in Austin and went on to the University of Michigan at Ann Arbor for specialized studies and research in automotive engineering, internal combustion engines, machine design and aerospace structures.

EDUCATION AND PROFESSIONAL ASSOCIATIONS

The University of Michigan	MSE (Mechanical Engineering) 1976	Shell Fellow
The University of Michigan	BSE (Mechanical Engineering) 1974	cum laude

Member of the Society of Automotive Engineers.

Licensed Professional Engineer in the States of Michigan and Texas.

EMPLOYMENT HISTORY

Omitted from this exemplar report. Contact our office for a complete CV

PROFESSIONAL EXPERIENCE

Omitted from this exemplar report. Contact our office for a complete and current C.V.

PROFESSIONAL EXPERIENCE

Omitted from this exemplar report. Contact our office for a complete and current C.V.

MACHINERY EXPERIENCE

AUTOMOTIVE

All systems and components including brakes, tires, wheels, suspension, steering; hydraulic systems; vehicle computer controls including anti-skid braking, electronic fuel injection, electronic ignition, cruise control; electrical, lighting; air bags, seats, seat belts, supplemental restraint systems; diesel and spark ignition engines, manual and automatic transmissions, differentials; engine and chassis dynamometer testing, emissions testing; fuel tanks, crash-worthiness, automotive structures, chassis development, hybrid automobiles, articulated vehicles and the construction of unique vehicles.

INDUSTRIAL

Steam and gas turbines; centrifugal, reciprocating, hyper-reciprocating, rotary, and diaphragm compressors; axial, centrifugal, vane, and roots blowers; vibration and control systems, lube/seal oil systems, hydraulic systems, pumps, gearboxes, large and small electric motors and generators, blenders, extruders, packers, belt and screw conveyors, cranes, hammer mills, heat exchangers, chillers, cooling towers, HVAC systems, elevators, deep space vacuum systems, clean rooms, medical prostheses, sea going barges; plant emissions systems, bag houses, electrostatic scrubbers, and others.

EDUCATION ABSTRACT

BRIEF DESCRIPTION OF GRADUATE DEGREE WORK: Vehicle Dynamics; Automotive Chassis Design; Internal Combustion Engines; Aerospace Structures (Statics and Dynamics of Monocoques, Beams, Plates, Composites, Elastic and Plastic Deformation, Creep, and Visco-elasticity); Stress, Strain, and Fatigue Considerations in Design; Dynamics of Mechanical Systems; Machine Design; Advanced Thermodynamics; Fourier Series; Matrix Algebra.

GRADUATE RESEARCH: Modeling by Semi-monocoque Methods; Stress Analysis, Dynamic Considerations and Design Optimization of a Composite Automotive Chassis Structure.

SUBSIDIARY SUBJECTS: Studies in Automotive Engineering and Aerospace Structures focusing on Engine Design, Chassis Design and Vehicle Structures with undergraduate courses in Automotive Engineering, Vehicle Dynamics, Internal Combustion Engines, Machine Design, Aerodynamics, Structural Mechanics, Materials Sciences and Manufacturing Processes.

ELECTRICAL-COMPUTER ENGINEERING: Included circuit analysis, logic circuitry, electro-mechanical devices, instrumentation, and automatic control.

DIRECTED STUDIES: The Effects of Combustion By-products and Noise on Plant and Animal Life from the Medical, Natural Science, and Legal Perspectives; Similitude in Machinery and Nature; Reciprocating Crank Train Dynamics; Centrifugal-Axial Compressor Flow and Surge.

PROFESSIONAL DEVELOPMENT COURSES: Roadway Engineering Concepts - Texas A & M University; Rotor Bearing Dynamics of Turbo Machinery - University of Virginia; Rotor Characterization, Balance and Spectrum Analysis - Hewlett Packard; Rotating Machinery Symposium - West Virginia University.

CONTINUING EDUCATION COURSES: Hybrid Vehicle Technologies; Biofuels as an Alternative Energy Fuel; Diesel Engines; Batteries; Fuel Cells, New Energy for the Future; Matter, Energy and Electricity; Electrical Science; Unique Properties of Water; Structure of Metals; Materials Science; Electrochemistry of Corrosion; General Procedures for Failure Analysis; Types of Failure and Stress; Wear Failures; Fatigue Failure; Ductile and Brittle Fractures; Thermal Shock; Brittle Fracture; Failure of Cast and Wrought Metals; Failures of Welded, Brazed and Soldered Joints; Lubricating Oils; Failures of Shafts and Bearings; Failures of Gears.

This report is based on the information made available to me at this time. Should additional information become available, I reserve the right to determine the effect, if any, of the new information on my opinions and conclusions, and to revise my opinions and conclusions if necessary and warranted by the discovery of additional information.

Should you have any questions or require additional assistance, please do not hesitate to call.

Sincerely,

Donald B. H. Jeffers, P.E. RPT191110.230910