UNIVERSITY OF WINDSOR

ELECTRICAL ENGINEERING CO-OP

IMPROVING BRAKES FIRST TIME CAPABILITY

FIAT CHRYSLER AUTOMOBILES

RESIDENT ENGINEERING

WINDSOR, ON

Submitted to: Mr. Moe Noutsi

Submitted by: Eric Parker

Submitted on: September 14, 2015

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September 14, 2015

Mr. Moe Noutsi
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2199 Chrysler Centre
Windsor, ON N8W 3Y6

Dear Mr. Nousti,

Please accept this report entitled "Improving Brakes First Time Capability" as my submission to fulfil my work term requirements.

It was an honour to complete my first work term at the Chrysler Windsor Assembly Plant in the Resident Engineering Department. Fiat Chrysler Automobiles (FCA) is one of the world's largest auto makers and is constantly striving for improvement within the quality divisions such as resident engineering. It was my pleasure to have the opportunity to participate in this growth. During my time at FCA, I was fortunate enough to learn several vehicle systems from many experienced engineers. I gained valuable work experience by leading many different projects throughout the plant of which resulted in a projected savings of over $600,000 annually for the company. Such projects awarded me the opportunity to work with hundreds of engineers from various departments with which I was able to develop a large network of engineering contacts.

This work term has provided me with valuable work experience and a deeper passion for applied technology. My submitted report outlines the importance of stratifying data in order to root cause issues and facilitate positive change within a world class manufacturing facility.

Finally, I would like to thank you, my manager, for sharing your experience and knowledge with me throughout my work term. I enjoyed learning from you and I am very grateful that you were willing to share information with me and answer my questions.

Sincerely,

Eric Parker

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The purpose of this report is to exemplify the data tracking and data stratification methods used to expose, root cause, and solve issues affecting the ability to correctly manufacture brake systems on the vehicles produced within the Chrysler Windsor Assembly Plant. By mining through and organizing vast amounts of plant data, irrefutable evidence can be formulated from the data necessary to drive change within a corporate environment. By learning from and utilizing unbiased plant data, engineers can solve issues very quickly, and quickness is indispensable to success in a manufacturing environment.

This report also provides readers with the fundamental theories behind the quality manufacturing arrangements in place to test brake systems, ultimately ensuring customers do not receive vehicles with defective braking systems. To be successful, a good resident engineer must combine a solid theoretical foundation of the vehicle system in question with strong data stratification techniques in order to effectively root cause and solve manufacturing issues.

Introduction:

This report outlines manufacturing problems that were addressed at the Chrysler Windsor Assembly Plant to improve First Time Capability (FTC) following the retooling that occurred in order to accommodate the production of the new 2017 Chrysler minivan.

FTC is a manufacturing concept developed by Chrysler which describes the ability to manufacture a product that leaves the assembly line with no defects and therefore doesn't require repair. FTC is a percentage value that can be calculated by dividing the number of non-defective vehicles produced by the total number of vehicles produced during a given time interval:

$$FTC = \frac{Number\ of\ Good\ Vehicles}{Total\ Number\ of\ Vehicles\ Built} * 100\%$$

In other words, FTC describes the percentage at which an assembly plant is producing vehicles without defects. Although a product may be designed effectively, when vehicles are produced in large quantities, human or process errors often lead to a defective product leaving the assembly line. To ensure the customer does not receive a defective product, there are many quality alert systems and federal tests that must be performed before the product is shipped to customers. By analyzing data and investigating the circumstances in station, quality engineers can find the root cause of an issue and address it accordingly. The job of a quality resident engineer is to root cause assembly issues and bring the correct team of experts together to formulate the best solution needed to fix the problem quickly. Resolving such issues ultimately leads to a higher FTC with the target of 100%. This report specifically outlines how issues were attacked in order to improve FTC of the vehicle's brakes system at the Windsor Assembly Plant.

I. Overview

Fiat Chrysler Automobiles is an international auto maker employing over 225,000 employees and including divisions such as Chrysler, Alfa Romeo, Dodge, Ferrari, Fiat, Maserati, Jeep, and Ram. The Windsor Assembly Plant is the manufacturing facility that supplies the entire world with every Dodge Grand Caravan and Chrysler Town and Country minivan. The company is a large corporation and is structured with many pay band levels leading up to executive management led by a Chief Executive Officer (CEO).

The responsibility of an employee within the Resident Engineering Department is to retain "ownership" of a system within the vehicle. For example, one resident engineer will own the air conditioning system, another will own wheel alignment, etc. Ownership of these systems assumes responsibility to that individual. In doing so, when quality issues occur for a given system, it is the responsibility of the resident engineer to root cause the issue, propose a potential solution, and seek the appropriate help from experts in certain fields in order to implement the best solution. Resident Engineering is a section within the quality department which also includes the Quality Assurance and the Quality Control departments. It employs about 30 individuals in the Windsor Assembly Plant, all of which require an engineering degree from an accredited university. As stated in the introduction, the main objective of the department is to analyze data to expose assembly issues and bring the correct team of experts together to formulate the best solution needed to fix the problem quickly. Resolving such issues ultimately leads to a higher FTC with the target of 100%. Since a new vehicle is built every 42 seconds, quickly reacting to issues is very important to the field of resident engineering to prevent defects from being recreated as vehicles are continuously produced.

When new issues are found (usually several issues are found per vehicle system each day), resident engineers must first “contain” the issue. In order to contain an issue, a quick, often costly solution must be implemented immediately to ensure the issue will be caught in the assembly plant so that a defective vehicle is not sent to the customer. Containment can be carried out in a number of ways including adding a temporary operator (line worker) whose only job is to check for that certain defect and alert the main quality system every time there is a defect in order to prevent shipment of that particular car until it is repaired, or adding another operator to assist with particularly difficult operations. The purpose of containment is to keep defective vehicles within the plant until a permanent, more economical solution has been formulated and implemented. Basically, containment is in place from the time at which the issue was discovered, to the time at which the permanent solution proposed by engineering has been implemented.

Once containment is in place, the responsible resident engineer must then root cause the issue; in other words, find exactly what is causing the issue and where it is coming from. To do this, they must analyze vast amounts of data looking to find trends that may indicate where the problem is coming from. If no trend can be determined within existing plant data, the engineer must run studies using one or more of hundreds of black belt manufacturing tools (a section of the Six Sigma manufacturing tools) in order to prove where the problem is originating from. Once a trend is apparent, the resident engineer must perform 3G/5G manufacturing techniques which consists of going to the job station of interest and acquiring more information directly from the source. Often times, this will give the input needed to solve the issue. Next, the engineer will discuss the issue with experts in that specific field in order to generate possible solutions. For example, if the resident engineer for the vehicle's air conditioning system had analyzed the data and noticed only machine #6 was failing vehicles, the engineer would want to contact the machine experts: in this case, the manufacturing engineer who is in charge of the air conditioning machines. The newly formed team of experts would discuss the issue and come up with potential solutions. Once this is done, the advantages and disadvantages of each solution would be considered such that the most advantageous solution is chosen for implementation. It is then up to the resident engineer to find out exactly what it would take (cost and/or man power) to implement the solution. The resident engineer will discuss possible changes with a supplier and have them (on a small-scale level) build the solution that was chosen. This process is known as a Production Evaluation Request (PER). Once the PER products are created and shipped to the Windsor Assembly Plant, the resident engineer will take the new products to the assembly line and install them in place of the old parts. Lastly, the engineer will evaluate the success of the PER and decide whether or not this is a good solution to the problem at hand. If yes, the supplier will change their existing processes to the newer method and the change will be implemented permanently. If no, the engineer will consult with the team in order to devise a new solution to the problem.

II. Observation of Problems

As a Resident Engineering co-op, the student may take ownership of an entire system of the vehicle just as a resident engineer does. The system focused on in this report is the vehicle's hydraulic braking circuit.

<u>Understanding Issues Impacting Brakes FTC</u>

The first indication of a problem with the brakes system is a low Brake EVAC and/or Pedal Pusher FTC. Before specific problems found within the plant are discussed, a fundamental understanding of how brake systems are tested in manufacturing facilities must be established.

Once a vehicle's brake lines, brake pedal, master cylinder, Antilock Braking System (ABS) pump, and front/rear brakes have been installed, the resulting hydraulic circuit must then be filled with brake fluid. Since air is much more compressible than brake fluid, it is very important that very little air is left in the circuit once the vehicle is filled with brake fluid or else the brake pedal feel (how far the pedal must be depressed in order to attain the required value of brake caliper piston force) will be inconsistent which can lead to fatal consequences for the customer. In order to ensure only insignificantly small quantities of air enter the braking system, vehicle manufacturers use a device called a Brake Evacuation and Fill machine (Brake EVAC machine). A picture of a typical Brake EVAC machine and the adapter used to connect the machine to the vehicle are shown in figure 1 and figure 2, respectively.

The overall goal of the Brake EVAC machine is to adequately fill the brakes system of a vehicle quickly enough for mass production while ensuring very little air is allowed in to the system. In order to do so, there a several phases to a Brake EVAC cycle. These phases consist of:

Primary Vacuum Test: This is the first phase of the Brake EVAC machine test cycle. After the machine adapter is mounted to the vehicle by an operator, this phase attempts to create a vacuum within the brake lines. To do this, a motor pumps out all of the air within the brake lines through the Brake EVAC adapter. Once the pumping is complete, the machine uses sensors within the adapter head to take a pressure measurement. If the pressure measurement is between zero and twenty millimeters of mercury, a sufficient vacuum has been created and the machine will move on to the next phase within the cycle. If a sufficient vacuum cannot be created, there is likely a large hole from which air is leaking in to the system. If a vehicle with a hole in its brake lines is filled with brake fluid, it would leak considerably. As a result, the test is automatically aborted by the machine before the vehicle is filled with brake fluid and the cycle is not completed. This vehicle would be considered a failed vehicle and would need to visit the brakes repair stall before being shipped.

Vacuum Decay Test: This is the second phase of the Brake EVAC machine test cycle. After creating the vacuum within the brakes system during the primary vacuum test, the vacuum decay test isolates this vacuum and allows time to pass. After some time has passed, the machine uses the pressure sensors located within the machine adapter to take another pressure measurement. It then compares this value to the pressure value that was recorded at the end of the primary vacuum test, and calculates the difference (the change in pressure). By doing this, the machine is essentially seeing if the brakes system is capable of maintaining a vacuum. In other words, it is checking to see if any air is leaking into the system through very small leaks. If the change in pressure is between zero and seven millimeters of mercury, then the vehicle passes the test and is filled with brake fluid. If not, the vehicle is considered a failed vehicle and as such must visit a brakes repair stall before being shipped. However, even the vehicles that fail this phase of the test are filled with brake fluid in order to help the repair personnel find where the small leak is coming from.

Remaining phases: There are more phases within the Brake EVAC test cycle, however they will not be discussed in detail as they do not pertain to the quality of the brake line circuit. These phases include: Brake Fill Second Fill Pressure, Brake Fluid Fill Volume, and Cycle Time.

Figure 1: A Typical Brake EVAC machine

Figure 2: A Typical Brake EVAC machine Adapter

Even if a vehicle has passed a complete Brake EVAC machine cycle and has been filled with brake fluid, there may be existing problems with the brake system that have still gone unnoticed. Therefore, before every vehicle produced can be shipped, it must pass a pedal pusher test. This is a federally required test that is performed by a pedal pusher machine. Similar to the Brake EVAC test, it consists of several phases which must all be passed in order to be considered a good vehicle ready to be shipped. The overall purpose of this test is to examine the entire brakes system (including the brake booster) testing several categories from pedal position to how “touchy” the pedals will feel to the driver. These phases (in order of which they are performed by the pedal pusher machine) consist of:

Vacuum Test: This phase checks whether or not a vacuum can be created within the brake booster. Similar to the primary vacuum test performed during the Brake EVAC machine cycle, all of the air inside the brake booster is pumped out and a pressure value is measured to see if the booster can maintain a vacuum. If a vacuum cannot be created, this phase will fail and the vehicle will have to go to a repair stall before it can be shipped.

Vacuum Decay Test: Similar to the vacuum decay test performed during the Brake EVAC cycle, this phase checks whether or not the brake booster can maintain the vacuum that was created during the previous vacuum test phase. It does this by allowing time to pass before taking another pressure measurement, and calculating the change in pressure over this time interval. If the brake booster cannot maintain the vacuum, there is likely a small hole or an improper seal from which air is leaking in to the system. Accordingly, this phase of the test will fail and the vehicle will have to go to a repair stall before it can be shipped.

Pedal Pickup Test: This test measures how far (in inches) the pedal pusher machine’s test head travels until it makes contact with the brake pedal. This test ensure the brake pedal is in the correct position in the car (the brake pedal may be out of position because it is damaged, etc.).

Stroke 1 and Stroke 2 Tests: These tests check how “touchy” the brake pedal is, therefore ensuring the brake system is reacting properly to the depression of the brake pedal. During these phases of the pedal pusher test, the test head pushes the brake pedal simulating a driver pressing on the brakes. During the Stroke 1 phase, the test head pushes until it detects 30 pounds of resistance, and measures how far (in inches) the head had travelled to reach this resistance. This is approximately the equivalent of a driver gradually slowing down to stop at a stop sign. A brake pedal that appears too soft to the driver will depress farther than the high test specification (in inches) because the driver has to push the pedal farther than a good vehicle to get the same brake caliper piston force. Conversely, a brake pedal that appears too hard to the driver will be too “touchy”. In other words, the brake pedal will provide the required caliper piston force when the pedal is barely depressed. Such vehicle’s brake pedals will depress a shorter distance than the low test specification because the driver barely has to touch the brake pedal in order to reach 30 pounds of resistance. Both the “soft” and the “touchy” brake pedal will fail the Stroke 1 and/or Stroke 2 test phases because of this reason and will therefore have to go to a brakes repair stall before being shipped. The Stroke 2 phase is exactly the same as the Stroke 1 phase, except this test measures the distance (in inches) that the brake pedal needs to be depressed before the pedal pusher test head records 100 pounds of resistance. This is the approximately the equivalent of a driver “slamming” on the brake pedal in order to stop very quickly.

Brake Pedal Stabilize Test: This phase consists of holding the brake pedal at the point where the Stroke 2 phase finished (holding the 100 pounds. of pressure) and allowing time to pass while recording how the brake pedal reacts to this. This test checks to see how far the brake pedal position changes over time. Ideally, the brake pedal should maintain approximately the same position, however problems with the brake booster may lead to the pedal moving too much during this time. If the change in brake pedal position is too great in either direction, the vehicle will fail this phase and will have to go to a brakes repair stall before being shipped.

Brake Pedal Leak Check Test: This test is exactly the same as the preceding Brake Pedal Stabilize test, but this test occurs next in sequence. Therefore, more time has passed so the brake pedal should have had time to stabilize and should hold almost exactly the same position. Therefore, the Leak Check test also holds 100 pounds of pressure, but the tolerance in which the brake pedal is allowed to move before failing is much tighter. If the change in brake pedal position is too great in either direction, the vehicle will fail this phase and will have to go to a brakes repair stall before being shipped.

Now that a solid understanding of the brakes system tests that must be performed before a vehicle can be shipped have been established, possible problems that arise can be better understood. It is very important for the resident engineer who owns the brakes system to deeply understand these test phases in order to root cause and fix brake issues that lower brakes FTC. By sorting through the Brake EVAC and pedal pusher test failures, categorizing these failures by the specific test phase that each vehicle failed for, and correlating this data to how the vehicle was repaired, the resident engineer can root cause the issue very quickly. This method of data tracking is referred to as linking test “Failure Modes” to repair data. This method of stratifying data is indispensable to the process needed to achieve issue resolution. This data also provides proof of where the issue is coming from. This means it provides exactly who (which department) is responsible for fixing the problem. This is particularly useful because in a corporate environment, the delegation of issues to the correct individuals is how the issue can be solved in the quickest way.

III. Applying Knowledge to Root Cause Issues

As previously mentioned, the first step necessary to solving issues within a large manufacturing facility is to understand what exactly is causing the problem. This is known as the "root cause" of an issue, and it is up to the resident engineer to provide the plant with this information. Once a fundamental understanding of a system has been established, the resident engineer can begin to root cause issues by stratifying data and establishing trends. This process exposes issues and identifies possible causes which can be further explored by the correct team of engineers. The remainder of the report will show how data stratification was used to expose and root cause issues which impacted brakes FTC. By resolving such issues in this way, brakes FTC rose well above target very quickly ensuring more vehicles were being built correctly within station and vehicles weren't being held in the yard awaiting repairs, both resulting in a combined savings of over $400,000 annually.

The first indication that many brakes issues needed to be addressed came when daily brakes FTC was analyzed and plotted against the Windsor Assembly Plant target of 98%. The graph below is plotted in a standard corporate format referred to as "glidepath". A glidepath plots FTC values (in this case, daily FTC values) on the same chart as vehicle build total and target FTC. In this case, Series 1 shows the daily target FTC percentage for brakes, Series 3 shows the actual daily FTC for brakes, and Series 4 shows the total number of vehicles built for each day. Please note that a vehicle that is considered a "Good Vehicle" to be used in the FTC equation shown on page six is any vehicle that passes the Brake EVAC and pedal pusher tests in station on the assembly line. As shown in the glidepath (figure 3), brakes FTC was consistently below target for the month of June. This prompted further analysis in order to root cause issues and resolve them. Data stratification in the form of a glidepath also allows the team to see if the countermeasures implemented are effective. If the solutions are effective, the team should watch the FTC rise above 98%. If not, they still have work to do.

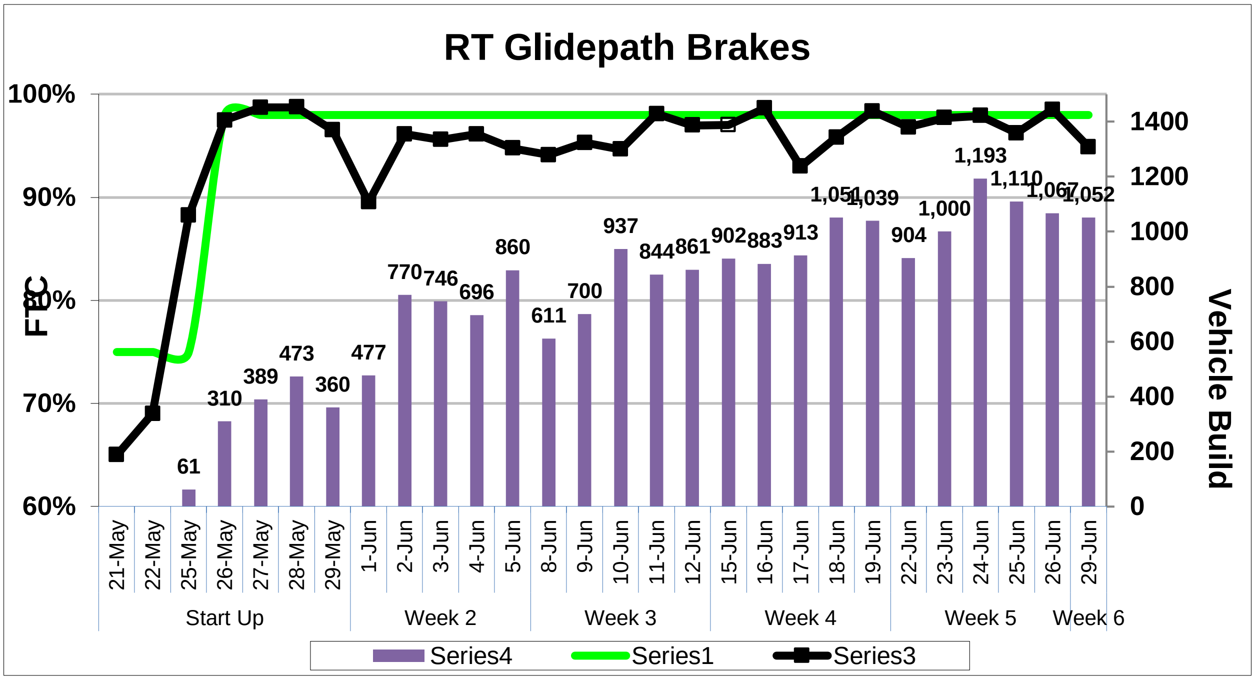


Figure 3: WAP Brakes Glidepath showing actual FTC (Series 3) consistently below target FTC (Series 1). Author: Eric Parker

Once a problem has been identified, it is the job of the responsible resident engineer to analyze more data to find exactly what is causing the issue. In this case, there was a multitude of issues that needed to be addressed. Each week, top issues were identified by correlating machine failures by failure mode to repair data from the brakes repair stalls. This information would indicate how the problem should be addressed.

Issue 1: Not Enough Information Available to Make Conclusions

For resident engineers, information is of extreme importance; in order to root cause issues in a manufacturing facility producing over 1400 vehicles a day, it is very difficult to find out exactly what happened to one specific vehicle unless the engineer is present at that station for the entire day. This is obviously not possible since the engineer has much more to do than stand around and wait for a failure. However, there are people in station at all times: the operators. By sharing information with the station operators, many issues can be tracked much more closely. This method of investigating in station and discussing issues with online operators is known as the 3G/5G method. By notifying operators of potential issues and causes, they are much more likely to watch for the issue and keep track of it. However, even in doing so, it is very hard to attain a true count of occurrences as input from the operators cannot be directly used to drive change because it doesn't provide enough real evidence. Thus, in order to create a trackable link between operators and management, an entirely new database was implemented and used by the operators in the Brake EVAC and pedal pusher stations. In doing so, it provided management with profound evidence that could be used to expose and track various vehicle and machine issues that would have gone otherwise unnoticed. The new database, which can be seen below (figures 4 and 5), was named the "End of Chassis Database" (EOC Database) because of its location in the plant, and it introduced real time data directly from the source as to why vehicles were failing the brake EVAC and pedal pusher machines.

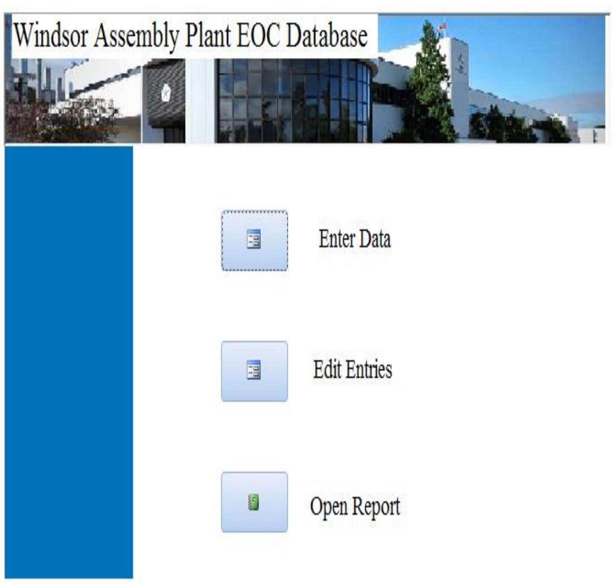
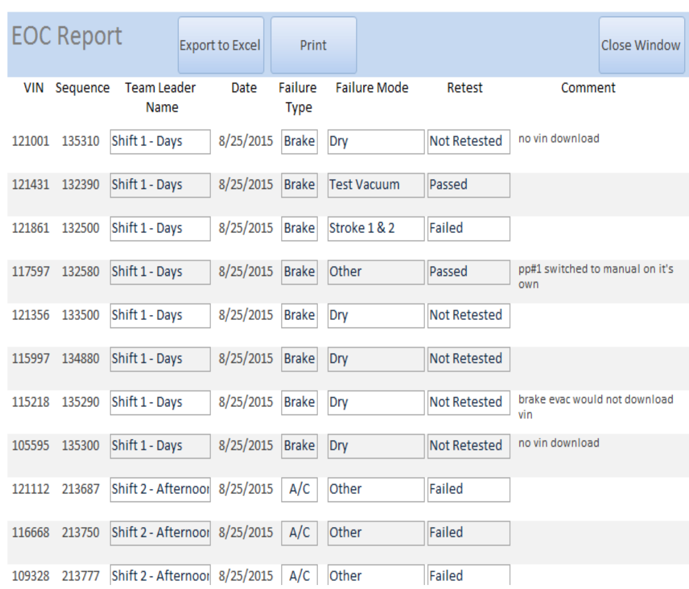


Figure 4: WAP EOC Database User Interface



VIN	Sequence	Team Leader Name	Date	Failure Type	Failure Mode	Retest	Comment
121001	135310	Shift 1 - Days	8/25/2015	Brake	Dry	Not Retested	no vin download
121431	132390	Shift 1 - Days	8/25/2015	Brake	Test Vacuum	Passed	
121861	132500	Shift 1 - Days	8/25/2015	Brake	Stroke 1 & 2	Failed	
117597	132580	Shift 1 - Days	8/25/2015	Brake	Other	Passed	pp#1 switched to manual on it's own
121356	133500	Shift 1 - Days	8/25/2015	Brake	Dry	Not Retested	
115997	134880	Shift 1 - Days	8/25/2015	Brake	Dry	Not Retested	
115218	135290	Shift 1 - Days	8/25/2015	Brake	Dry	Not Retested	brake evac would not download vin
105595	135300	Shift 1 - Days	8/25/2015	Brake	Dry	Not Retested	no vin download
121112	213687	Shift 2 - Afternoo	8/25/2015	A/C	Other	Failed	
116668	213750	Shift 2 - Afternoo	8/25/2015	A/C	Other	Failed	
109328	213777	Shift 2 - Afternoo	8/25/2015	A/C	Other	Failed	

Figure 5: Example Data input into the EOC Database

Issue 2: Large Leak Failures

By applying the data stratification techniques described earlier, the brakes team was able to identify top machine failures and how they were being repaired. By resolving the most frequent issues first, the team could save the greatest number of cars from having to be repaired which enable the company to save the most money. As seen in the graph below (figure 6), the machine failure data indicated that the most brake failures were “Large Leak” failures. “Large Leak” failures are vehicles that failed the Primary Vacuum Test phase of the brake EVAC test cycle. As previously stated, vehicles fail this test phase when a vacuum cannot be created within the brake line circuit. This usually indicates the presence of a hole within the brake lines where there is air leaking into the system. However, as seen in the figure 6, most of these vehicles were found to contain no defects whatsoever (the repair performed was Fill, Retest, No Trouble Found [NTF]).

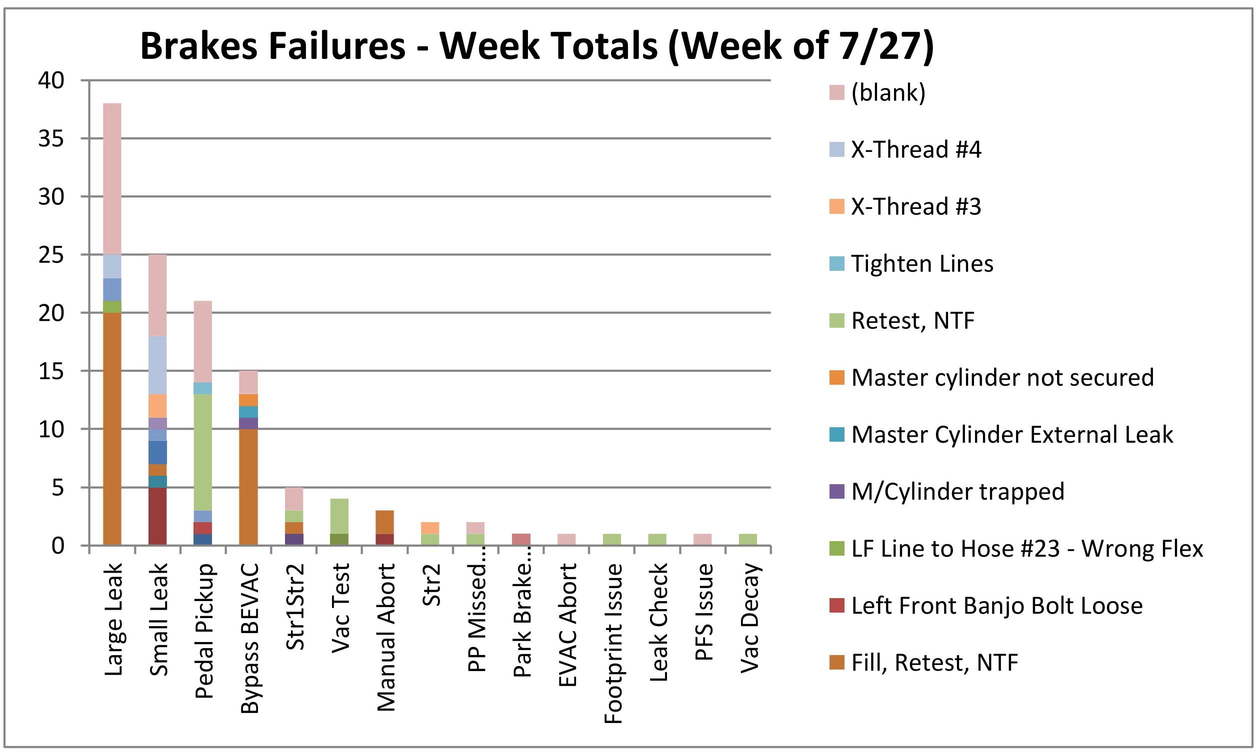


Figure 6: A Graph Showing Total Failures by Failure Mode and Repair. Author: Eric Parker

In other words, the machines were indicating the presence of a leak within the vehicles but the repair data stated there was no trouble with the cars. Since the machines were operating correctly and the vehicles were non-defective, it meant the air leak must have been coming from between the vehicle's brake fluid bottle and the Brake EVAC machine's adapter which mounts to the bottle. This issue could have been caused by two things: operators incorrectly seating the Brake EVAC adapter to the vehicle or a bad seal created by the Brake EVAC machine adapter.

Once this conclusion had been reached, both potential causes had to be investigated. By performing a 3G/5G investigation, it was apparent that the operators were correctly seating the adapters to the vehicle. This meant that the bad seal had to be coming from the machine adapter itself. Looking within the adapter head, the main point of contact between the vehicle and the head is made by a rubber ring called an "O-ring". Similar to the ring inside the lid of a reusable water bottle, the purpose of the Brake EVAC O-ring is to compress under pressure to create an air-tight seal. If the O-ring is worn or damaged, it will not be able to create an air-tight seal which will cause non-defective vehicles to fail. Discussing the issue with the maintenance department, the manufacturing engineers who worked in the brakes area, and the machine supplier (Dominion Technologies Group), the conclusion was reached that the O-rings should be changed more frequently to ensure they are not damaged and are capable of creating a good seal between the vehicle and the Brake EVAC machine adapter. As such, maintenance ran a PER which entailed changing the Brake EVAC O-rings every four hours instead of every 8 hours. This trial period began on Monday, August 3rd and continued until Saturday, August 8th. At the end of that week, the data was examined and the results were presented to maintenance. As shown in figure 7 below, the trial resulted in a drastic decrease in Large Leak failures. Since the cost of the extra O-rings ($0.10 CAD) was significantly less than the money saved by not having to perform repairs on these vehicles (about $34.00 CAD per failure), the solution was permanently implemented. An additional system to monitor both the frequency of the O-ring changes and overall O-ring quality was also set up to allow area supervisors to monitor the issue (figure 8).

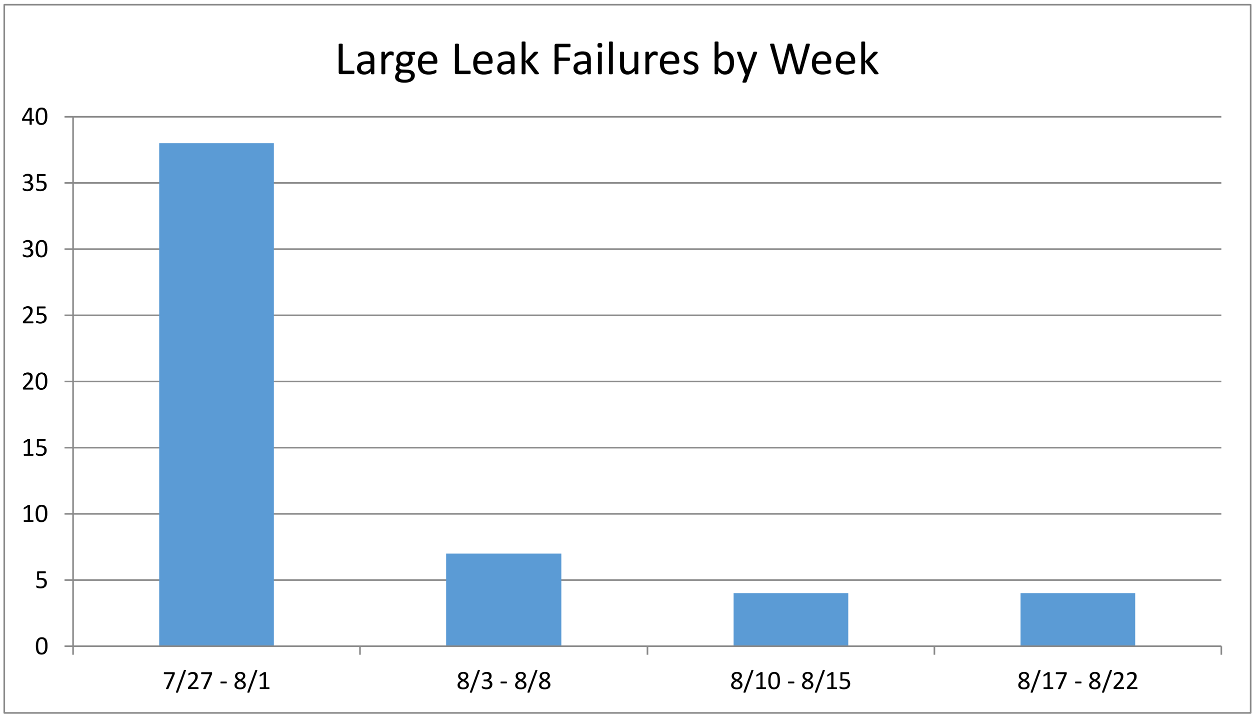


Figure 7: Total Large Leak Failures by Week. Author: Eric Parker

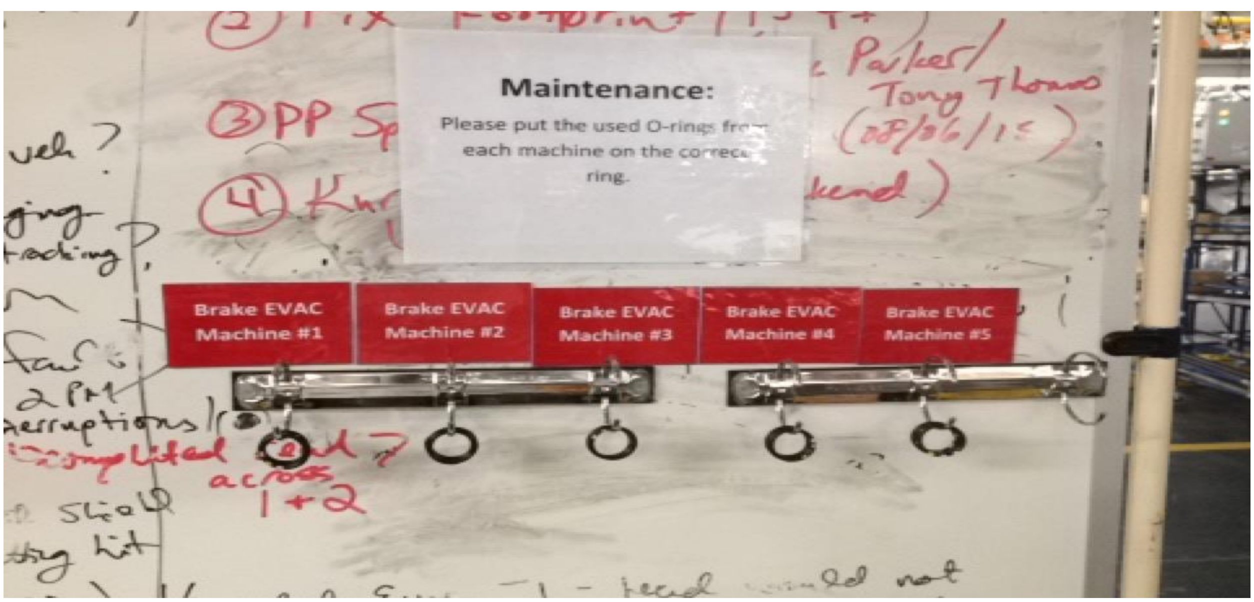


Figure 8: In Station O-ring Change Verification System

Issue 3: Pedal Pickup Failures

In addition to correlating machine failure modes to repair data, sometimes it is useful to sort data by machine number in order to isolate issues. There are multiple areas within the Windsor Assembly Plant that have more than one machine to perform the same test, for example there are five Bake EVAC machines and three pedal pusher machines. In certain circumstances, it may be that certain failures are only coming from vehicles tested on a specific machine number. This trend usually indicates a problem with the machine rather than the vehicle. One example of this that was encountered at the pedal pusher station happened with pedal pickup failures. As previously stated on page thirteen, the pedal pickup phase of the pedal pusher test cycle measures the distance the pedal pusher test head travels until it first makes contact with the brake pedal. As previously shown in figure 6, pedal pickup failures were one of the top issues from the week starting on Monday, July 27th. Also shown in figure 6, the majority of these vehicles passed a pedal pusher retest (Retest, NTF) in the brakes repair stalls indicating no actual issue with the vehicle. By further sorting the data by machine number, an obvious trend arose. Most of the pedal pickup failures were from style five vehicles (pedal style describes which brake pedal design gets installed into a given vehicle since there is more than one brake pedal design) tested on pedal pusher number one and number two (see figure 9). This data was presented to the supplier (Dominion Technologies Group) which prompted further investigation. Pedal pusher number three wasn't failing any style five vehicles because it contained an newly designed fixture (vehicle mount) that was not yet present on pedal pushers number one or number two. The old fixture positioned the test head too close to style five brake pedals, so these vehicles consistently failed under specification.

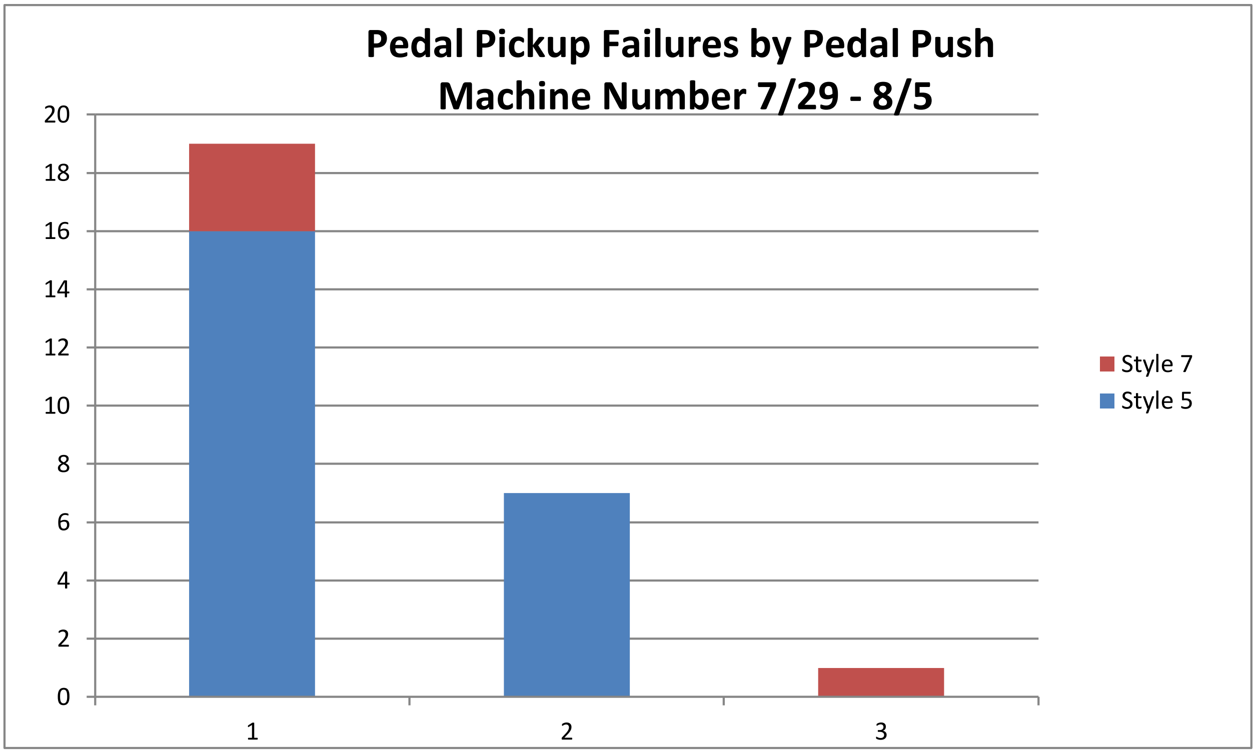


Figure 9: Pedal Pickup Failures Sorted by Pedal Pusher Machine Number. Author: Eric Parker

Clearly, the updated fixture worked well on pedal pusher number three (since figure 9 contains zero style 5 failures). Therefore, to solve the issue on pedal pushers number one and number two, the same solution was transferred over. Both pedal pusher number one and pedal pusher number two received the updated fixture on Wednesday, August 5th. As indicated in figure 10, the issue was no longer present following this change.

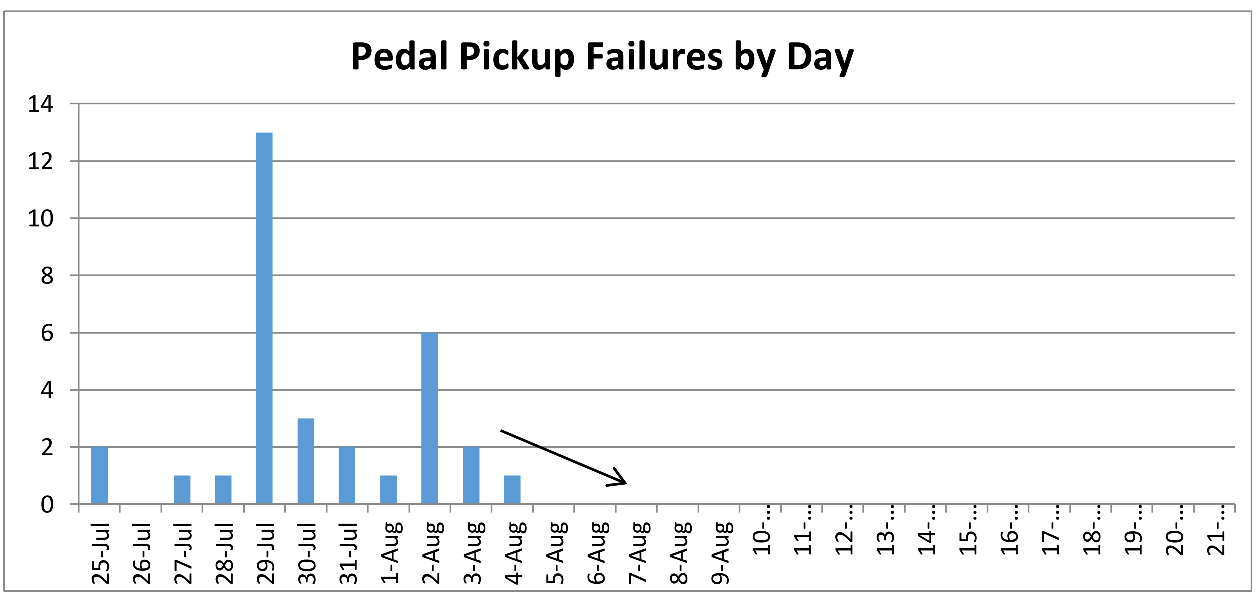


Figure 10: Pedal Pickup Failures by Day. Author: Eric Parker

Conclusion:

In order to reach solid conclusions and provide the true root cause of an issue, one must first develop a strong understanding of the systems they are working with. If a solid theoretical foundation has not been established, the tendency is to jump to conclusions and present false results before really considering what the cause must be. The importance of data mining and data stratification in the field of resident engineering is unparalleled. Data exposes issues, suggests the solution, and provides the evidence needed to drive change. Applying the data stratification and problem solving techniques used by resident engineers allowed the team responsible for improving brakes FTC within the Windsor Assembly Plant to identify, root cause, and solve issues very quickly and efficiently leading to a brakes FTC consistently over the target of 98% (figure 11). The proven techniques used by Chrysler resident engineers have been used countless times to solve FTC related issues and have proven very useful during the relaunch of the 2015 Dodge and Chrysler minivans following the plant's construction.

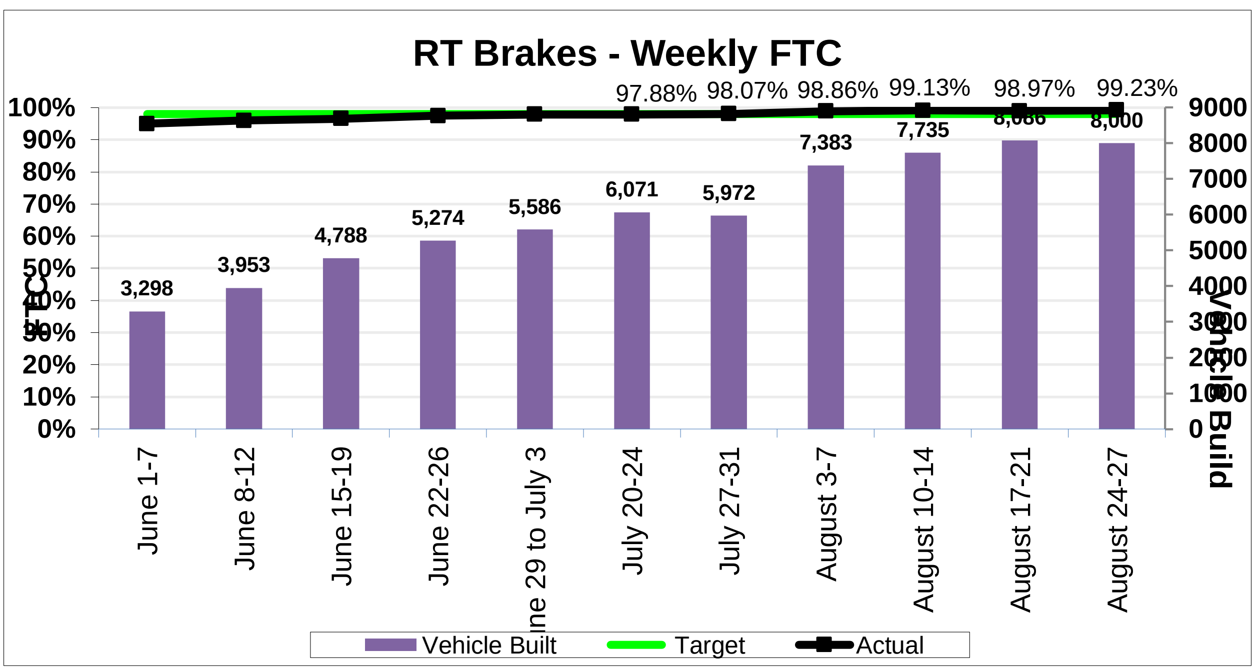


Figure 11: WAP Brakes Glidepath showing actual FTC (Black) consistently above target FTC (Green) for the month of August, 2015. This provides irrefutable proof that the methods used to solve issues were effective. Author: Eric Parker

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