Cost Reductions and Increased Brake Life:

What New and Advanced Technology
Can Do for the Transit Industry

By

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Abstract

Brake maintenance and repair accounts for the largest proportion of expense in any transit bus fleet budget. Managers continuously must balance the need for safety and performance against the urgent demands of price and supply chain realities.

While we cannot overestimate the need for training and consistency in our brake maintenance we must look to new technology to reduce our costs and increase the effectiveness of our brake systems. Several technologies have been found that utilize new integrated brake maintenance solutions engineered to improve brake longevity while maintaining safety and enhancing overall performance.

One such technology is a new process in the manufacturing of brake drums and rotors. The new process changes the physical characteristics of the drums and rotors. This paper provides an explanation of the technology employed in manufacturing foundation brake systems. Explained in greater detail is the answer to the recurring question: “Where does the heat go?”

The industry must simplify the entire approach to maintenance and repair, while integrating industry best practices. This must include a vigorous attitude in favor of technician training and reduction of inventory/logistics requirements. New technology must utilize associated metrics that demonstrate the performance and return on investment that the transit industry mandates.
Cost Reductions and Increased Brake Life

**Safety vs. Cost**

Regarding the responsibilities of any fleet maintenance manager, it almost goes without saying that when it comes to brakes the consideration of cost is, rightly so, secondary to safety and performance. Brakes must work well. Brakes must provide safety and security. Consequently in any transit fleet, downgrading brake safety would be an egregious violation of the public trust.

In the real world of fleet management limited resources and budgets are stretched to the breaking point. There is a virtual tug of war between the Procurement and Maintenance Departments. Purchasing departments are under continuous pressure to cut costs and do more with less. Maintenance is charged with the task of keeping vehicles out of the shop, operating safely and efficiently. For this system to function at all, agreement must be achieved between these departments, working toward a common goal. Usually this demands compromise in the process of choosing the best components at the lowest cost possible.

Taking it a step further, the concept of “lowest cost” must also be agreed upon by the Purchasing and Maintenance managers. To say that the lowest priced part provides the best budgetary value would be to over-simplify the concept of cost control; often a serious mistake. If this were the case, transit properties would purchase the cheapest tires, lubricants, tools, engines, and components available. Both Purchasing and Maintenance personnel must understand that lowest cost refers to the overall expenditure over the service life of each vehicle, i.e. “cost per mile.” Putting this knowledge into practice is often easier said than done.

Maintenance personnel must first comprehend the current principles and practices of braking and brake repair in order to make the most informed decisions regarding the purchase of quality components. As with any technical discipline, this takes years of training and practical experience in order to achieve a high level of competence and virtuosity. Understanding and implementing proper repair procedures along with keeping abreast of current and emerging technologies are requisite activities of any effective transit fleet Maintenance Manager. The reality is that with so many manufacturers and vendors offering the “latest and greatest” products, this has become more than a full-time job.

Brake manufacturers recognize the intense pressure for cost control at the fleet level. Given the current strength of technical proficiency, any new product must also provide tangible cost benefits to stand any shadow of success in today’s highly competitive brake parts market. Thus this extreme pressure creates a temptation to manufacture low cost products of questionable quality. The necessity for being the “low bidder” opens the door for the introduction of products of inferior quality at the expense, potentially, of safety.


**Current Conditions: Cumulative High Costs of Frequent Brake Relines**

Each transit property is unique in that it experiences different brake reline frequencies from other transit properties. Indeed, within each property different bus makes, models, routes and other various conditions provide for inconsistent and undesirable brake performance and longevity.

There are some generally pervasive conditions that seem to occur in transit fleets:

1. Severe braking environments beget short brake life and resultant high brake maintenance costs.
2. Rear axle relines outnumber front relines, usually two-to-one.

Product and process improvements are needed to solve the problem of short brake life. In attempts to replicate the longer brake life realized on new buses, many fleets are now insisting on “OEM Only” parts, in spite of the fact that many Original Equipment Manufacturers purchase components from aftermarket suppliers. Differing “maintenance cultures” in various shops create discordant results in brake repairs. Some facilities provide little training for technicians who learn procedures from co-workers. Shops that do provide training often lack a standardized curriculum.

Lack of front-to-rear brake balance cause larger rear brakes to wear out at a faster rate than front brakes. During the service life of the bus, the effectiveness of front brakes continue to decline, requiring the rear brakes to do an inordinate amount of the work necessary to stop the vehicle. This out-of-balance condition snowballs, increasing the necessity of repeated brake relines, thereby accumulating high brake repair expenses.

**Technology Based Solutions**

Several emerging technologies are helping to improve the efficiencies of brake systems. Some of these include electronic brake chamber stroke monitoring systems, improved automatic brake adjusters, advanced disc brakes, and engine/transmission retarders.

**Power Brake LLC of St. Petersburg, Florida** has developed a new process in the manufacturing of brake drums and rotors. The unique products are produced via a patent-pending process wherein specific elements are applied via extreme force into the cast iron surfaces of these components where they completely coalesce with the metal. It is not a coating or plating, nor does it involve cryogenics. Power Brake calls this process “Diamond Technology.”

The beginnings of Diamond Technology reside in military, industrial and theme park applications before evolution into endurance racing brakes. After years of experimentation and testing, Diamond brake drums and rotors were introduced into the commercial aftermarket in 1999. Since inception, brakes using the Diamond process have logged millions of miles of road case history data, including numerous dynamometer tests, passing FMVSS 121.
The Diamond process involves the use of specific materials introduced in the parent metal of the brake drum or rotor. This creates a more "friction friendly" surface, extending the service life of the brake shoes and/or disc pads. Diamond drums and rotors are stronger and harder than their conventional counterparts, thereby being less susceptible to the destructive heat-generating effects of braking.

Yield strength testing performed by Constellation Technology Analytical Services Laboratory using testing method ASTM-E8 (www.astm.org) demonstrates that drums and rotors processed with Diamond Technology reduce latent stresses and increase strength of brake drums and rotors.

Because of the extreme hardness of the Diamond drum or rotor compared to the conventional grey iron (GI-30) varieties, the Vickers hardness scale is used. Both Brinell and Rockwell B hardness scales do not register values when it comes to Diamond.

Diamond brake drums and rotors run cooler. This does not mean that they circumvent the natural laws of Conservation of Energy, Momentum and Thermodynamics where, in braking the energy of motion is exchanged for heat energy. Rather, they help prevent the entire wheel end from conducting heat, thereby reducing residual heat gain in drums, rotors, hubs, friction, hardware and other components.

Less heat gain allows for myriad advantages in brake performance and longevity.

- Reduced heat fade and improved stopping power
- Diminished drag and better modulation
- Reduced fretting of friction and contact areas
- Improved brake torque
- Extended component life (seals, springs, hardware) due to lower operating temperatures
- Better balance front-to-rear, side-to-side
- Reduced latent stresses in drums and rotors

These advantages provide for dramatically longer lasting brakes. Fewer relines, naturally, yield lower operating costs.
**Where Does the Heat Go?**

Diamond drums and rotors are designed to reduce stress, increase the surface hardness of the friction area and reduce the operating temperature of the wheel end during service.

**STRONGER DRUMS AND ROTORS** maintain their original configuration during brake cycles. Greater surface contact between the friction and the component during brake cycles provides maximum brake torque thereby creating shorter brake cycles and increased friction life.

**INCREASED SURFACE HARDNESS** reduces the wear of the drum and rotor, maintains the original surface finish and reduces drag.

**LESS STRESS** in the drum and rotor reduces cracking, heat checking, hot spots and distortion.

**Thermodynamics With Regard to Energy and Heat**

**HEAT:** A form of energy that manifests itself in the motion of molecules and atoms.

**CONDUCTION:** The transfer of energy (heat) by a medium without bulk movement of the medium itself. In conduction, heat spreads through a substance when faster atoms and molecules (hot) collide with neighboring slow atoms and molecules (cool) transferring (through flux) some of their kinetic energy to them. This action creates stresses within the structure itself.

**CONVECTION:** This is the act or process of conveying or transmission. Heat transfers in a gas or liquid by the circulation of currents (flux) from one region to another. The process of heat transfer through a gas or liquid by bulk motion of a hotter material into a cooler region (negative pressures to positive pressures) is a form of flux.

**RADIATION:** Heat energy vibrating the charged particles in the air creates a third method of heat transfer. When charged particles accelerate through vibrations, they emit electromagnetic waves which carry energy. This is the same energy gained from heat transfer. The amount of radiation can be related to the internal vibrations caused by charged particles.

Power Brake Diamond drums and rotors allow the wheel end to run cooler by reducing the residual heat gain. This occurs based on the following facts:

- The brake friction will not adhere to the Diamond surface during its service life. This allows the components to cool more quickly between brake cycles.

- The unique material added into the drum or rotor provides heat dissipation through thermal emissivity via radiation. While this is the primary condition occurring during the brake cycle, the completed cooling process takes place through convection. This convection is more prevalent in brake rotors due to the design and engineering of the rotor itself. The negative pressures at the small diameter and the positive pressures at the large diameter create maximum air flow.
• Finally, brake frictions, whether organic, semi-metallic, or ceramic each have unique conductive properties. The combination of Diamond components and ceramic friction provide an extremely efficient means for the transfer of heat.

**Cost Management from an Inventory Perspective**

Power Brake offers an unprecedented 100,000 mile Performance Guarantee “against failure due to excessive wear, distortion and/or cracking.” This pledge refers to its axle kit - a complete assortment of parts necessary to perform a standard brake job. A typical drum brake axle kit contains:

- 2 - Diamond brake drums
- 4 - Brake shoes
- 2 - Wheel hardware kits
- 2 – S-cams with bushings, seals and hardware
- 2 – Automatic brake adjusters
- 2 – Wheel seals and gaskets

It is true that Diamond Technology lies at the heart of the Power Brake program. However, it is only one aspect of its overall rationale aimed at cost reduction. Because Diamond brake systems are intended to remain service-free for at least 100,000 miles, it is imperative that the technician install each item found in the kit.

Stocking requirements and part number proliferation are common problems in fleet Parts Departments. Parts replacement, when left to the discretion of the technician will require Materials Managers to keep an overabundance of varied components. For example, technician “A” has a tendency to always replace camshafts with each reline, while technician “B” prefers only oil/grease seals from a particular manufacturer. Technician “C” does not share the seal preference of technician “B” because he once had this brand of seal fail. In order to appease all of the preferences in the shop, the Parts Manager keeps several of each component desired. And, to ensure that there is never a situation of a bus remaining out of service due to the want of any item, he/she will tend to accumulate an over-supply, or “safety” stock of parts. This gradual hoarding of inventory over time is a universal affliction among Materials Departments. “Parts Creep” eventually turns into dead stock as the fleet ages and newer vehicles replace older ones, requiring an entirely different array of replacement parts. Dead stock is often a massive waste of money.

The concept of the brake axle kit addresses the need for simplicity in inventory requirements. A solitary kit part number eliminates the necessity for Materials Managers to stock dozens of SKU’s. Parts departments will no longer need to overstock shelves and bins full of parts which will end up as obsolete waste. Instead, a single number complete with its own printed Bill of Materials, is all that is required.
**Return on Investment**

The implementation of Power Brake’s Diamond Brake Axle Kits significantly reduces a transit fleet’s brake maintenance expense. Although the unit price of a Diamond drum or rotor may exceed that of its non-Diamond counterpart, overall operating cost (cost-per-mile) is reduced. Just how much savings may be realized depends on several factors:

- Operating environment
- Vehicle make
- Current fleet maintenance policies and practices
- Prevailing parts and labor price points
- Route type and stopping frequencies

Considering brake maintenance as an aggregate cost over a period of months and years, just how quickly these expenditures accumulate differ from vehicle to vehicle and fleet to fleet. However, in every instance these sums are considerable. Brake repair costs comprise the largest proportion of any transit fleet’s maintenance budget.

Testing conducted through and data provided by one major metropolitan transit property illustrates how Power Brake’s Diamond drums break the cycle of frequent relines. Four different buses were outfitted with Diamond brake drums, each using a different friction. The brakes’ effectiveness and condition were monitored over a period of twenty months to two years. The results of the tests validated that during this period, and with no degradation in performance, the necessities of performing four to five brake jobs on each bus were eliminated.

The transit property, running Nabi 40’ low floor buses, typically performs rear brake relines every 18,000 miles. Front brake jobs are usually performed every other rear brake cycle, at approximately 36,000 miles. New brake drums are installed at each reline interval.

For simplicity’s sake let us regard rear brake relines only, on one bus representative of the entire fleet, and running their friction of choice - Marathon MBST. Costs provided at the time of the test are as follows:

<table>
<thead>
<tr>
<th>NABI REAR AXLE BRAKE JOB</th>
<th>PRICE EACH</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brake Drum (non-Diamond) x 2</td>
<td>$136.03</td>
<td>$272.06</td>
</tr>
<tr>
<td>Brake Shoe Kit x 2</td>
<td>$133.29</td>
<td>$266.58</td>
</tr>
<tr>
<td>Labor Man Hour x 6</td>
<td>$66.96</td>
<td>$401.76</td>
</tr>
<tr>
<td><strong>JOB TOTAL</strong></td>
<td><strong>$940.40</strong></td>
<td></td>
</tr>
</tbody>
</table>
Repeating this process every 18,000 miles, one can see the rapid accumulation of parts and labor costs:

<table>
<thead>
<tr>
<th>BRAKE JOB INTERVALS (MILES)</th>
<th>CUMULATIVE COSTS (REAR AXLE MAJOR BRAKE COMPONENTS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18,000</td>
<td>$940.40</td>
</tr>
<tr>
<td>36,000</td>
<td>$1,880.80</td>
</tr>
<tr>
<td>54,000</td>
<td>$2,821.20</td>
</tr>
<tr>
<td>72,000</td>
<td>$3,761.60</td>
</tr>
<tr>
<td>90,000</td>
<td>$4,702.00</td>
</tr>
<tr>
<td>108,000</td>
<td>$5,642.40</td>
</tr>
</tbody>
</table>

This Nabi test bus was outfitted with Power Brake Diamond drums and operated for 24 months before a rear brake reline was necessary at 108,000 elapsed miles. Without the charges of material, labor and downtime repeated every 18,000 miles no accumulation of cost occurs.

<table>
<thead>
<tr>
<th>BRAKE JOB INTERVALS (MILES)</th>
<th>CUMULATIVE COSTS (REAR AXLE MAJOR BRAKE COMPONENTS)</th>
<th>CUMULATIVE BRAKE COSTS WITH DIAMOND DRUMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>18,000</td>
<td>$940.40</td>
<td>$1,268.34</td>
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</tr>
</tbody>
</table>

NOTE – Does not include costs of bearings, seals, adjusters, camshafts, minor hardware, vehicle downtime, etc.

Savings of $4,374.06
Graphically representing this “Return on Investment” (ROI), the cost benefits of Power Brake’s Diamond Technology are manifest. Any drum price premium is returned before the second reline ordinarily would have been required.

**Bus XXXX Cumulative Brake Costs & Diamond ROI**

<table>
<thead>
<tr>
<th>Dollars (Cumulative)</th>
<th>Miles</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0</td>
<td>18000</td>
</tr>
<tr>
<td>$1,000</td>
<td>36000</td>
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**Training is an Integral Part of Cost Control**

In the battle to slash fleet maintenance budgets, technician training is often an early casualty. However in the quest to maximize maintenance effectiveness, training must be an essential part of the equation. It is generally agreed upon that as a fleet ages, repair costs increase. Proficiency, or lack thereof, of the maintenance technician will greatly impact these costs. The skills of the shop technician are brought to bear, not only in repairing current problems but in predicting and preventing more costly issues in the future. In worst case scenarios, poorly trained technicians may actually cause catastrophic and costly breakdowns.

Power Brake recognizes an essential need for a return to and standardization of basic best practices in brake maintenance. And, because of the changing paradigm brought about by new Diamond Technology, technicians must be instructed in this new approach. With this in mind Power Brake includes brake maintenance and troubleshooting training with every customer.
Conclusion

Conventional wisdom equates “low cost” with “poor quality.” Unfortunately, in many circumstances this adage is valid. Indeed, the “low cost/poor quality” proposition is so pervasive that it has become, mistakenly, a truism. As a result the assumption is born of the inverse, that products and services of the highest quality command a premium price. Fleet Managers believe they must compromise performance and safety to fit within budgetary constraints.

Because of the dramatic improvement in service life afforded by Diamond Technology, performance is improved while costs are reduced. Cooler wheel ends reduce the harmful effects on brake components, allowing them to work more efficiently. Longer lasting brakes save precious resources. Lower operating costs save money and time. Fewer brake jobs require fewer parts and generate less waste in spent materials, providing a more favorable environmental impact.

When it comes to brakes, efficient systems equate to cost savings. As a system, complete brake axle kits equipped with Diamond drums or rotors, effective friction, and high quality parts help to keep inventory requirements under control. When properly installed and maintained by skilled technicians, significant improvements in performance are achieved.