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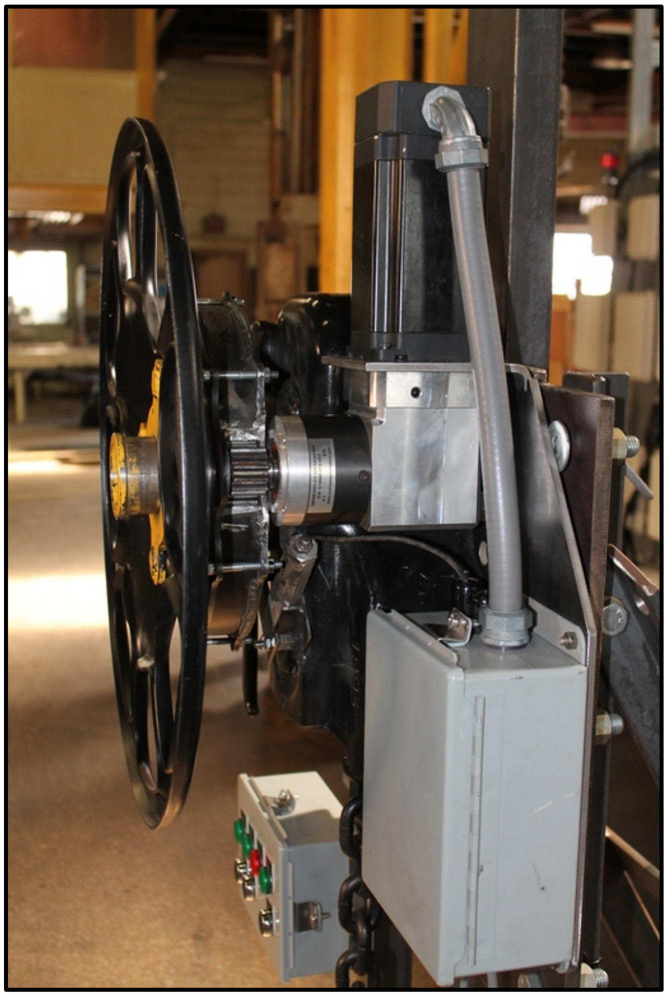
Federal Railroad Administration

Railroad Freight Car Remote Controlled Electrically Driven Set & Release Hand Brake (EDHB) – Optimization for Increased Reliability and Performance

Office of Research, Development
and Technology
Washington, DC 20590



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13. ABSTRACT (Maximum 200 words)

The Federal Railroad Administration (FRA) and Sharma & Associates, Inc. (SA) developed prototype Electrically Driven Set and Release Hand Brakes (EDHB) that provided automatic set and release functions remotely from push buttons mounted on the side of a car. The EDHB improves the safety of railroad operations in several ways, including making it easier to ensure that freight cars are parked effectively. Additionally, it eliminates the injury and fatality risks for railroad employees resulting from having to get between cars, climb ladders and physically operate hand brakes. Previously, a prototype EDHB was designed and verified in the lab and field, and a draft specification was developed that is under the Association of American Railroads (AAR) review for possible use by the industry when designing and implementing remotely controlled hand brakes. This report documents further development that included increasing the efficiency of the drive train, improving the efficacy of the motor's power, improving the control system, and the development of a more positive feedback system to ensure the appropriate torque is applied to the hand wheel drive shaft to meet hand brake application input specification.

14. SUBJECT TERMS

Electrically, Electrically Driven Set and Release Hand Brakes, EDHB, driven, hand brake, remote control, release sensor, electro-pneumatic, application sensor, vertical wheel, Group N, Group O, specification, standard, performance, prototype

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METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in)	=	2.5 centimeters (cm)
1 foot (ft)	=	30 centimeters (cm)
1 yard (yd)	=	0.9 meter (m)
1 mile (mi)	=	1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2)	=	6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2)	=	0.09 square meter (m^2)
1 square yard (sq yd, yd^2)	=	0.8 square meter (m^2)
1 square mile (sq mi, mi^2)	=	2.6 square kilometers (km^2)
1 acre = 0.4 hectare (he)	=	4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz)	=	28 grams (gm)
1 pound (lb)	=	0.45 kilogram (kg)
1 short ton = 2,000 pounds (lb)	=	0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp)	=	5 milliliters (ml)
1 tablespoon (tbsp)	=	15 milliliters (ml)
1 fluid ounce (fl oz)	=	30 milliliters (ml)
1 cup (c)	=	0.24 liter (l)
1 pint (pt)	=	0.47 liter (l)
1 quart (qt)	=	0.96 liter (l)
1 gallon (gal)	=	3.8 liters (l)
1 cubic foot (cu ft, ft^3)	=	0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3)	=	0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

[(x-32)(5/9)] °F = y °C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm)	=	0.04 inch (in)
1 centimeter (cm)	=	0.4 inch (in)
1 meter (m)	=	3.3 feet (ft)
1 meter (m)	=	1.1 yards (yd)
1 kilometer (km)	=	0.6 mile (mi)

AREA (APPROXIMATE)

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1 square meter (m^2)	=	1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2)	=	0.4 square mile (sq mi, mi^2)
10,000 square meters (m^2)	=	1 hectare (ha) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gm)	=	0.036 ounce (oz)
1 kilogram (kg)	=	2.2 pounds (lb)
1 tonne (t)	=	1,000 kilograms (kg)
	=	1.1 short tons

VOLUME (APPROXIMATE)

1 milliliter (ml)	=	0.03 fluid ounce (fl oz)
1 liter (l)	=	2.1 pints (pt)
1 liter (l)	=	1.06 quarts (qt)
1 liter (l)	=	0.26 gallon (gal)
1 cubic meter (m^3)	=	36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3)	=	1.3 cubic yards (cu yd, yd^3)

TEMPERATURE (EXACT)

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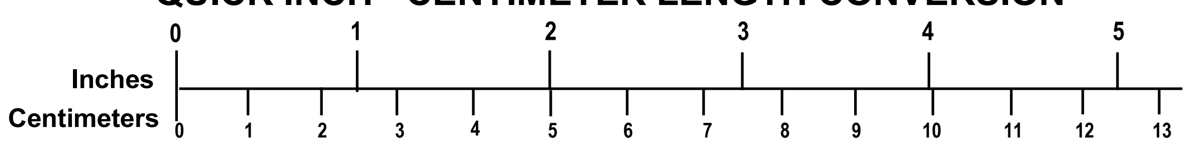
QUICK INCH - CENTIMETER LENGTH CONVERSION



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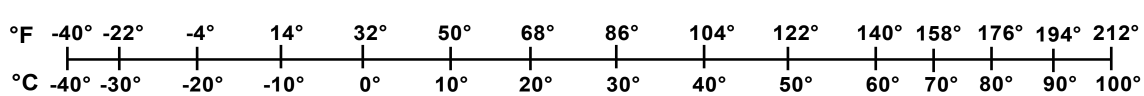

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Executive Summary

From April 2014 to September 2019, the Federal Railroad Administration's (FRA) Office of Research, Development and Technology worked with Sharma & Associates, Inc. (SA) on an ongoing project to develop prototype Electrically Driven Set and Release Hand Brakes (EDHB) that were engineered and tested for freight car use. After successfully passing a set of in-lab and field performance requirements laid out by the Association of American Railroads' (AAR) Geared Hand Brake Mechanical Engineering Committee (GHBMEC), its Remote Operation Hand Brake (ROB) task force, and SA, the consensus was to continue to improve the EDHB design.

This project focused on the improvement of the EDHB controls, feedback and drive-train efficiency, thereby effectively enhancing the brake's efficiency, accuracy, and reliability.

Freight railroads have continually worked to eliminate train crew injuries that occur during the process of applying and releasing freight car hand brakes. Still, currently, a person must crank a handle or turn a wheel at awkward positions to get a hand brake to set at the appropriate chain load (approximately 138 lbs. applied at the hand brake wheel). This often leads to back injuries or trips/falls. If the operator slips or a brake mechanism fails to engage, injuries can occur. Also, there are inherent safety issues with the physical climbing of ladders to operate the brakes and the need to sometimes go in between cars to access the brakes. Releasing hand brakes sometimes causes injuries due to many of the same reasons as those that cause injuries when applying a hand brake. The goal is to develop a hand brake that requires minimal effort by a human to operate, eliminates the need to climb up ladders and get between cars, and improves the likelihood of hand brakes being applied and released when needed.

Additionally, past tragic events—as in the event at Lac Megantic—highlighted the need for ensuring that a sufficient number of hand brakes are fully applied on any parked train to eliminate the potential for 'runaway' trains. The use of systems where hand brakes can be applied from the side of the car by 'push button' rather than by strenuous human physical effort, especially at the end of a long shift, makes a big difference in ensuring that trains are safely secured when parked.

Further, SA designed the EDHB to impart controlled application and release input forces which will reduce equipment damage. The design includes clearer feedback about the status of the hand brake that will improve safety in operations, and ensure reduced wheel set and track damage normally caused by to unreleased hand brakes upon train movement.

The main challenge to the deployment of an EDHB was the lack of electrical power on freight cars that can be used to operate a motor to apply the hand brake. Things are starting to change in that regard. Currently, electronically controlled pneumatic (ECP) train line brakes are utilized in the industry. Also, a parallel power line that uses electrical power from locomotives is being developed and may be implemented on freight cars. Finally, SA's EDHB design is very power efficient and estimated to operate with one set of two 12 VDC batteries (no supplemental charging) for over a year.

Improvements of the control, feedback and mechanical design of the EDHB are now implemented and are reported herein. This project was successful in that it met the intended

objectives of improving the functioning and reliability of the EDHB design, which takes the EDHB another step closer to industry acceptance and implementation.

1. Introduction

The Federal Railroad Administration's (FRA) Office of Research, Development and Technology and Sharma & Associates, Inc. (SA) developed prototype Electrically Driven Set and Release Hand Brakes (EDHB) that were engineered and tested for freight car use. After successfully passing a set of in-lab and field performance requirements laid out by the Association of American Railroads' (AAR) Geared Hand Brake Mechanical Engineering Committee (GHBMEC), its Remote Operation Hand Brake (ROB) task force, and SA, three prototype units were field tested as part of the Facility for Accelerated Service Testing (FAST) train at the Transportation Technology Center (TTC).

Based on observations and results from previous testing, this proposed effort seeks to optimize the prototype design to improve control and feedback, and to improve application and release times, effectively enhancing the reliability and safety offered by these systems.

1.1 Background

For years, freight railroads attempted to eliminate train crew injuries that occur during the process of applying and releasing freight car hand brakes. Currently, a person must crank a handle or turn a wheel in awkward positions to set hand brakes to the appropriate chain load (approximately 138 lbs. applied at the hand brake wheel). This often leads to back injuries or trips/falls. If the operator slips or the brake's mechanisms fail to engage, injuries occur. Also, there are inherent safety issues with the physical climbing of ladders to operate the brakes and the need to sometimes go in between cars to access the brakes. Releasing hand brakes sometimes causes injuries due to many of the same reasons as those that cause injuries when applying a hand brake. The goal is to develop a hand brake that requires minimal effort by a human to operate, which eliminates the need to climb up ladders and get between cars and improves the likelihood of hand brakes being applied and released when needed.

A critical safety issue related to hand brakes was highlighted by the tragic events at Lac-Megantic; that is the need to ensure that a sufficient number of hand brakes are fully applied on any parked train to eliminate the potential for 'runaway' trains. The use of systems where the hand brakes can be applied from the side of the car by 'push button' rather than by extreme physical effort, especially at the end of a long shift, would make a big difference in ensuring that trains are safely parked.

Further, controlled application and release forces will reduce equipment damage and feedback of application/release will ensure safety during application and reduce wheel set and track damage due to unreleased hand brakes upon train movement. Hand brakes are often unintentionally left applied during car movement for various reasons. These unreleased hand brakes result in slid flats or otherwise damaged wheels which in turn increase stress on rolling stock and track.

The main challenge to the deployment of an EDHB was the lack of electrical power on freight cars that can be used to operate a motor to apply the hand brake. Currently, electronically controlled pneumatic (ECP) train line brakes are being introduced to the industry. Also, a parallel power line is being developed and may be implemented on freight cars. With such electrical power on board, a whole new realm of possibilities for new technology implementation exists such as an EDHB.

As noted previously, SA and FRA's RD&T developed prototype EDHBs that were engineered and successfully tested for freight car use. FRA then decided to further optimize the prototype design to improve control and feedback, the mechanical design efficiency, and to improve application and release times, thus effectively enhancing the reliability and safety offered by EDHB.

SA currently implemented these improvements; this report discusses the methods and subsequent results due to the implementation.

1.2 Objectives

The EDHB system was conceived and is developed to improve the safety and reliability of freight railroad switching operations. The main objective of this phase of the project is to further enhance the EDHB for improved performance by optimizing its controls, feedback method, mechanical drive train efficiency and application and release completion times.

1.3 Overall Approach

This phase of EDHB development was focused on the improvement of its control system, feedback method for indicating hand brake applied and released states, the mechanical drive train efficiency to reduce electrical power requirements, and the reduction of application and release durations to improve time efficiencies during operations. The enhancements took the initial design features, discussed below, and focused on improving the functionalities of these four areas.

1.3.1 Initial Design Features

The following are design features of the EDHB.

Proven Core (Base Hand Brake)

The EDHB design began by selecting an existing AAR Group N vertical wheel hand brake to serve as the core of the EDHB system. One requirement for the selection was that it would be more suitable if the hand brake had an extended history of successful operations in interchange service and, moreover, was AAR inter-change compliant. Several commercially available hand brake designs have long and successful histories; one of them, Cardwell Westinghouse's U-9300 from their Universal brand was selected for this effort as it was a good representative. Thorough knowledge of the design and functionality were critical in the design of the EDHB system, and allowed for successful retrofit, see Figure 1, without adversely affecting its core performance.

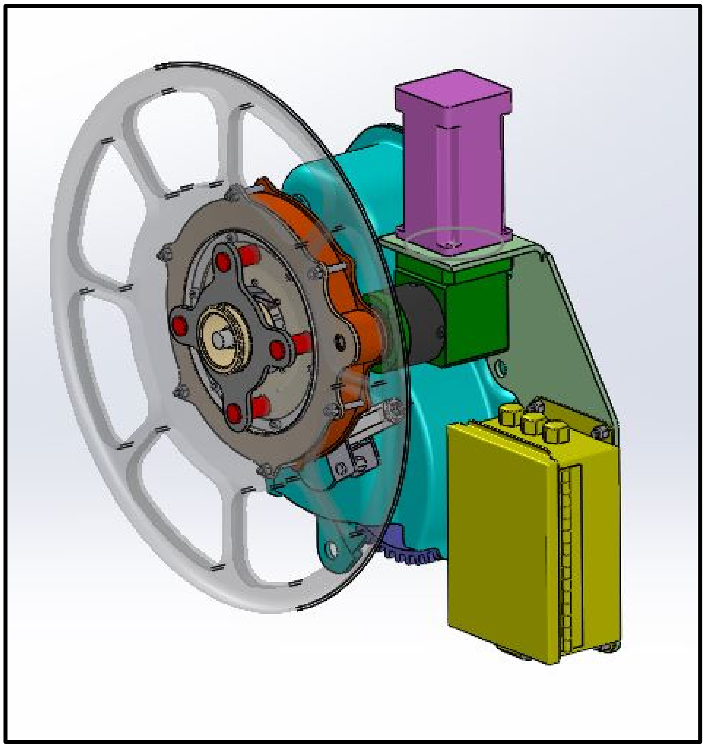

Figure 1 – EDHB Retrofitted Components

Manual Operations

One key to the success of the EDHB design is the ability to disengage the remote controlled, electrically driven part of the system, allowing the hand brake to be used as a normal, conventional hand brake. This was the first decision made in the design and development of this system. With this capability, the risks of implementing the EDHB system are minimized because the hand brake remains fully functional even if there is a failure in the electrical system or EDHB retrofit. Thus, the advantages gained by EDHB implementation far outweigh the risks.

AAR Compliance

As the EDHB design began with an existing hand brake that already underwent and passed AAR certification testing, the only concerns regarding final AAR certification are the modifications and additions required for the added EDHB functionality.

Existing AAR standards do not include a specification for advanced hand brake designs that are remotely controlled and electrically actuated. Therefore, no existing specifications constrained the functional aspects of development. However, existing specifications do constrain some physical properties of the hand brake. All specifications regarding physical constraints for Conventional Group N and Intermediate Group O hand brakes in the AAR Manual of Standards and Recommended Practices, including overall depth, clearance between the rim of the wheel and any part of the housing, and mounting hole locations, were adhered to in the EDHB design.

Electrical Power

The existing freight railroad infrastructure does not have any provisions for electrical power on freight cars. The EDHB system was developed with a focus on this limitation. The EDHB is currently designed to operate off a 24 VDC power source, which is a voltage commonly used in industrial control systems. At the time of the design, this allowed for a wider selection of commercially available equipment to power the system.

Also, due to the lack of an existing electrical power infrastructure, the system design incorporates features to conserve the amount of energy consumed, which allows the system to be powered for extended periods using only batteries. Hand brakes require a considerable amount of power to both apply and release. However, hand brakes are typically not used frequently. Assuming a hand brake goes through a complete application-release cycle every 3 days and the total cycle time is 3.2 minutes, the duty cycle is 0.07 percent. Due to the low duty cycle, the average power required is only a fraction of the peak power requirement. The controller design minimizes idle energy consumption by either disabling or removing supply power from non-essential circuits. Additionally, the microcontroller is placed in sleep mode and is only activated upon receiving a command from the operator control station. Considering the duty cycle, engineering calculations indicate that idle periods are responsible for less than 2 percent of the total energy consumption, while the application and release cycles are responsible for over 98 percent due to the high power required for operation.

The feedback indicators incorporated into the design are all LED-based to further conserve energy. Additionally, the indicators provide active feedback only when the system is active and for a couple of seconds following the completion of an operation. The current state of the hand brake at any moment in time is seen by activating the indicators on any of the control interfaces, at which point they will remain active for only a few seconds before deactivating once again. An additional benefit of utilizing LED technology for the indicators is the extended life and reduced maintenance compared with using incandescent indicators.

The power control features engineered into the design allow the system to be operated from battery power for extended periods, without intervention. Engineering estimates based on the above duty cycle assumption, theoretical power consumptions, and battery specifications show that the system can be powered by two 100 Ah capacity 12 V SLA batteries wired in series to provide 24 V to the system for a period of over 400 days. Due to the efficiency of the EDHB system design, the natural self-discharge of the batteries is a significant factor in battery life, contributing over 42 percent of the overall battery drain.

Interface

The operator interface is one of the key components of the EDHB system. Through the operator interface, personnel can quickly determine the status of the hand brake on EDHB equipped cars. Additionally, the feedback indications provided by the EDHB system through the operator interface are a more reliable indication of the hand brake status than observation of the chain tension or ‘feeling’ the torque applied/required to further turn the hand wheel. The ability to quickly and accurately determine the status of a hand brake can make operations safer and more cost effective by reducing the number of incorrectly applied and/or released hand brakes during operations. See Figure 2 below as an example operator interface.

Figure 2 – Example of Operator Interface

The EDHB controller is designed with simple discrete digital interface capabilities. This allows the system to be used with operator interfaces ranging from simple push button enclosures mounted on the car sides to computer-based interfaces mounted in a locomotive cab.

The controller includes three discrete inputs for controlling the system, one for starting a hand brake application cycle, one for starting a hand brake release cycle, and one for showing the status of the hand brake. The three inputs can be electrically configured as either sinking or sourcing. This allows the flexibility to interface with most common 24-volt signaling systems, in addition to dry contacts.

Four discrete outputs are included to provide feedback of the system status to the operator. Indications are provided for Hand Brake Applied, Hand Brake Released, System Active, and System Error. The circuitry for these outputs is 24 VDC and can be configured as either sinking or sourcing.

Any control system capable of interfacing with 24 V discrete signals can be used to control the EDHB system. This includes control systems that include wireless Input/Output (I/O) capabilities where, for example, an interface can be located in a locomotive cab and a remote I/O block can be located near the EDHB system allowing an operator in the locomotive cab the ability to both control and monitor the EDHB system without leaving the cab.

Initial Design Summary

From the beginning, the EDHB system was designed with the goals of improving the safety and reliability of existing freight railroad hand brake operations, while at the same time ensuring the system will be cost effective.

1.4 Scope

This enhancement phase included the increase of EDHB reliability, robustness and usability by improving the control system, mechanical drive train, more effectively sensing and/or approximating the chain tension, and reducing the time required for application and release functions. Accomplishing these goals makes the system more robust, efficient and user friendly, thereby increasing the chances of widespread adoption and implementation which will increase the safety of railroad operations.

1.5 Organization of the Report

The report covers the enhancement of the EDHB system. Section 2 includes the discussions of how the focused design features were addressed and improved. This section also covers the drive train, feedback, controls, and discusses the fact that the new controller was designed for easy adaptation for wireless communications. Section 3 provides the conclusion and recommendations for further development.

2. EDHB Redesign and Enhancement

This proposed effort seeks to optimize the prototype design to improve control and feedback, improve application and release times, and effectively enhance the reliability and safety offered by those systems. This section describes the methods with which those improvements were incorporated and the related results.

2.1 Improved Design Features

2.1.1 Improved Drive Train

SA's originally designed EDHB gearbox is shown in Figure 3. The design is a three-gear system with low friction bearings to transfer the motor's output torque to apply the appropriate torque to the brake's hand wheel gear.

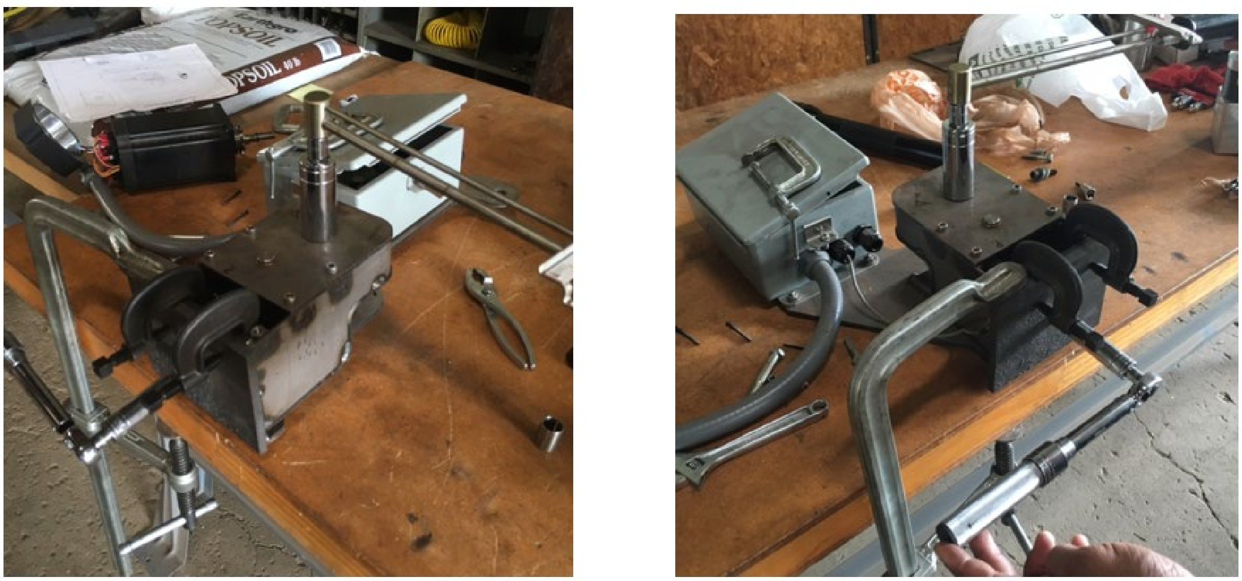

Figure 3 – Original EDHB Gearbox

The original design had a calculated efficiency that met the required hand wheel torque (approximately 138 lbs. applied tangentially at the hand brake wheel). However, the measured gearbox efficiency was much less. SA determined the most probable cause for the discrepancy was slight gear misalignment due to machining tolerances. Despite efforts to more accurately mate the gears and improve power transmission, the shaft location prevented any realizable gains in efficiency.

Subsequently, a search was initiated to locate a commercially available gearbox that would meet the requirements of the application. While no gearboxes were located that were an exact fit for the requirements, a gearbox was found that SA felt could be adapted to meet the requirements. The new gearbox is shown in Figure 4.

Figure 4 – New EDHB Gearbox

The new gearbox had two discrepancies to be addressed. The first was that the output shaft of the gearbox was not the correct diameter for the mating gear. To rectify this issue, the output shaft of the gearbox was modified to appropriately mate with the gear.

The second discrepancy was that the gear ratio of the new gearbox was slightly different than the original. The original gearbox had a 6:1 gear ratio. This ratio was chosen by taking into consideration the torque and power requirements of the system as well as the capabilities of the selected motor. The new gearbox has a gear ratio of 8:1. While the lower ratio has the advantage of being able to produce more torque, this advantage is offset by the fact that the motor would be required to run faster to meet the EDHB cycle-time goals. The specified motor, like all stepper motors, has a characteristic that the torque capability decreases significantly with higher rotational speeds. Since the increase in torque due to the changed gear ratio would be at least somewhat offset by the required increase in motor speed, it was imperative that the efficiency of the new gearbox be greater than the old gearbox. To confirm an increase in efficiency, quasi-static testing was performed on the two gearboxes. The gearboxes were tested independently while not assembled in the EDHB. Each gearbox was properly secured to a table for testing and a known input torque was applied while the output torque was measured. All torque measurements were taken using torque wrenches.

A torque of 4 ft-lbf. was applied to the input shaft of each gearbox. The torque measured on the output shaft of the original gearbox was 15.5 ft-lbf. The torque measured on the output shaft of the newer gearbox was 27.5 ft-lbf. Considering the different gear ratios, gearbox efficiency was calculated for both units. The efficiency calculation is a ratio that is calculated by dividing the measured torque by the expected torque of a gearbox and indicates how well the input torque is transferred to the output shaft. The calculated efficiencies of the gearboxes show a significant increase in efficiency from the original gearbox to the new gearbox with the efficiencies being 65 percent and 86 percent, respectively. These test results along with the calculations are shown in Table 1.

Table 1 – Gearbox Static Test Results

	Input Torque (ft-lbf)	Measured or Actual Output Torque (ft-lbf)	Theoretical or Ideal Output Torque (ft-lbf)	Efficiency (Actual/Ideal) (%)
Original Gearbox	4	15.5	24	64.6
New Gearbox	4	27.5	32	85.9

Based on the successful test results, the EDHB design was modified to fit the new gearbox. See Figure 5 below that shows the new gearbox implemented into the system design.

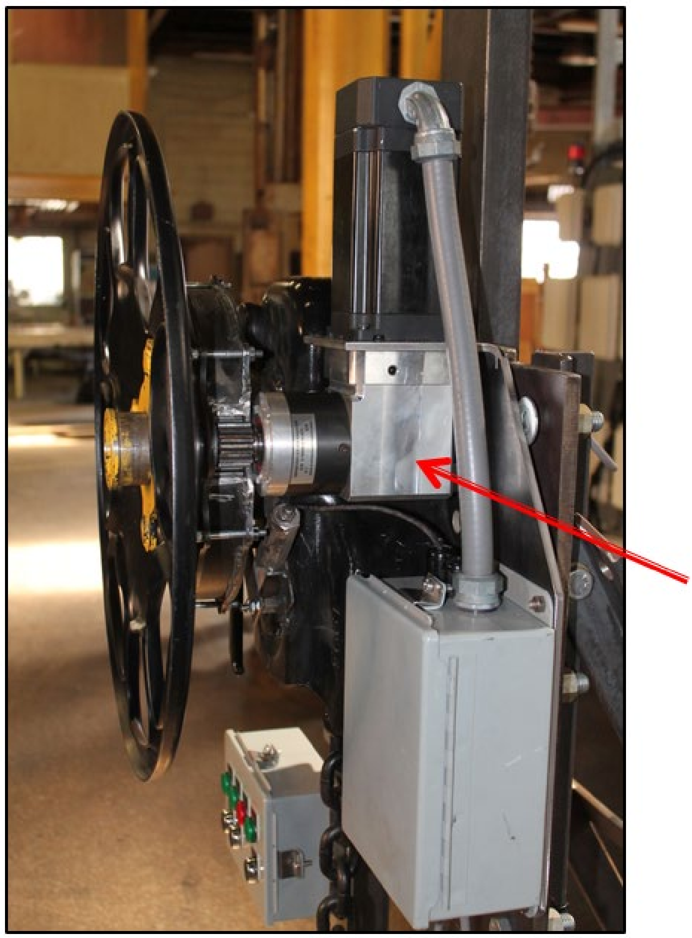

Figure 5 – New Gearbox Installed in New System

2.1.2 Improved Feedback

Prior generations of the EDHB design relied on the fact that the motor torque could be controlled and that the determination of hand brake application success could be accomplished by monitoring motor synchronization. (Note: *The speed of the motor is determined by the frequency of the input signals. When the load on the motor becomes too much for the motor, the motor begins to slip and no longer rotates at the speed at which it is being electrically driven. When* *this happens, the motor is said to have lost synchronization.)* This methodology resulted in somewhat inconsistent hand wheel application torques following application cycles.

The current design integrates a strain sensor to more closely monitor the chain load as a reference for hand wheel application torque. Engineering analysis was performed to find the most suitable location on the hand brake housing where a strain gage could be mounted that would represent the chain load with enough accuracy to be used to determine hand wheel input status. Figure 6 shows the strain gage mounted to the brake housing.

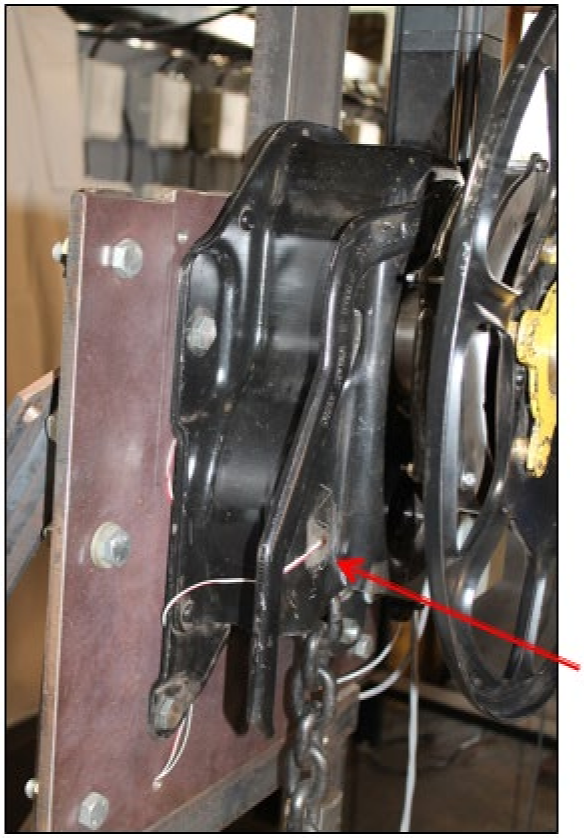

Figure 6 – Strain Gage on Hand Brake (Not Necessarily Actual Application Location)

Testing of the new design shows that the feedback from the active monitoring results in application chain loads that are much more consistent between cycles, providing a higher degree of confidence over the previous design that the hand wheel torque is applied appropriately and consistently.

2.1.3 Improved Application and Release Times

The new controller design includes a dedicated motor driver integrated circuit (IC) that directly controls the bridges supplying power to the motor, based on commands received from the system microcontroller. This dedicated driver generates all bridge control signals and timing internally, which results in more precise switch timing than was achieved directly from the microcontroller. The driver IC manages ramping profiles, current limit switching, direction, and blanking time, among other details required for driving the motor, leaving the microprocessor free to handle the overall system control without having to maintain a primary focus on precision error-free timing for motor control.

Testing of the new system shows improvements in motor stability and torque, as well as a significant reduction of resonance induced drive vibrations. Moreover, the change in control and timing improved the application and release times for the hand brake from approximately 130 seconds to 100 seconds per function.

Increased Motor Voltage Supply Not Needed

To increase the torque capability of the system, the new driver was designed to be able to use higher voltages to drive the motor. The specified driver utilizes current limiting technologies for motor control, rather than voltage. However, because motors are primarily inductive systems, the rate of increase of the torque controlling current is limited by the relatively large L/R time constant, where L and R are the inductance and resistance of the motor, respectively. The time constant of an inductive circuit determines how quickly the current can change. It takes a duration of five multiples of the time constant for the current to reach above 99 percent of the steady state value. The motor torque output is limited to less than maximum during this period. The inductive and resistive properties of the system are basically fixed. However, the time for the current to reach the limit set by the driver can be reduced by increasing the supply voltage, which results in an increased change in current over time (di/dt) during the initial stage of voltage application to the motor coil. This allows the system to more quickly reach the current threshold and maintain that current for a longer portion of each step which increases the torque output of the motor.

Testing of the system showed that the combination of design improvements resulted in a system that could operate effectively using the original design supply voltage of 24 VDC, without a strict requirement to utilize a higher voltage. Time constraints prohibited further testing with higher voltages, however, it is anticipated that higher voltages would allow for a reduction in cycle time and may also allow the utilization of a smaller motor. A smaller motor might increase the mechanical durability of the system. However, these possible future enhancements would likely result in higher production costs.

2.1.4 Controller Hardware Development

The control system is designed as a two-part system: a controller and a driver. Each of these units is a discrete printed circuit board utilizing both surface mount and through hole technologies. The separation was influenced primarily by two factors, the higher voltage capabilities of the driver and the addition of analog circuitry for feedback sensing. Other factors also influenced the design such as ease of maintenance and design flexibility. Figure 7 shows the controller and driver installed in the control box of the redesigned EDHB system.

Figure 7 – Redesigned Controller Installed in the EDHB Control Box

The system controller includes a microcontroller that is interfaced to external switches and indicators for operational control and feedback. Also, included on the controller board is the analog circuitry responsible for conditioning the feedback signal from the feedback strain gage mounted on the hand brake housing. The controller is designed to be powered by a 24 VDC supply and generates all other required voltages onboard. Separate voltage regulators are included for digital and analog circuits to minimize interference between the circuits.

The motor driver is a separate circuit board that includes the motor driver IC and two full bridges required for driving the motor. The driver is designed to be powered by a 24 VDC supply, but includes provisions for interfacing external DC/DC converters to boost the bridge voltage to higher levels such as 48 VDC, which was envisioned for the design but is now not needed. All other required voltages are generated onboard.

The two subject boards are interfaced with a stacking connector that provides the required electrical connections when the boards are physically mounted in the control enclosure.

All electrical connections between the boards and external devices are made with spring loaded electrical connectors to eliminate connection failures due to the expected vibrations the system will experience in railroad service.

2.1.5 Controls – Improved Electrical Power Conservation

Because the system is designed to be powered by batteries, power conservation is essential. When the system is not actively applying, or releasing the hand brake, power to most systems external to the microcontroller is either switched off or the devices are placed in a low power standby mode. The microcontroller itself is placed in a sleep mode which eliminates almost all power consumption by the processor. When the system is in this state, only inputs generated by operator actions will activate a fully active state. The system is designed with the following three possible inputs: Apply Hand Brake, Release Hand Brake, and Show Status.

When the system is inactive, all the external status indicators are also inactive to conserve energy. The Show Status input is included to allow an operator to check the status of the hand brake. Upon activating the Show Status function, the system momentarily illuminates the appropriate system status indicators before automatically switching back to sleep mode.

2.1.6 Controls - Improved EDHB Operation

Hand brake application is accomplished in two phases. Upon receiving the application command from the operator, the controller accelerates the drive motor from standstill to a high speed. This speed is maintained until the system feedback member indicates the chain load has begun to increase (no more chain slack). This phase is intended to quickly take up the chain slack in the system. At higher speeds, the motor has less torque capability than at lower speeds and cannot produce the torque required for proper hand brake application. Therefore, following the take-up of the chain slack, the controller decelerates the motor to a slower speed that provides sufficient torque for proper hand brake application. The motor continues at this rate until the system feedback member indicates sufficient hand brake application. Once sufficient application is achieved, the motor is decelerated to a standstill (motor is stopped) and the mechanical system load (chain load) rests on a mechanical stop internal to the hand brake.

The hand brake release process is achieved by reversing the operations implemented for hand brake application. Initially, the motor is accelerated to a slow speed. At this slower speed the motor produces sufficient torque to overcome the requirements for releasing the brake from a sufficiently applied state. The motor continues at this speed until the feedback member indicates that the hand brake is nearly unloaded. At this point the motor is accelerated to a higher speed. The higher speed is maintained until the hand brake release sensor indicates to the controller that the hand brake is near full release. Upon receiving the signal from the release sensor, the controller quickly decelerates the motor to a standstill (motor is stopped) and ensures that the hand brake is fully released (no load on chain).

2.1.7 Wireless Control

The new controller was designed in anticipation of future interfacing with a wireless control unit which would allow the hand brake to be communicated with and controlled wirelessly; this will enable the ability to check status and control brake functions from operations vehicles adjacent to tracks or from the locomotive cab.

The previous controller did not maintain status signals when the system was not operational. This presented a challenge when interfacing with remote systems in that the remote controllers would read invalid status signals when the EDHB controller went into low power sleep mode. The new design includes provisions that allow wireless control units to interface with signals separate from the signals that drive the external indicators. This allows for the wireless interface signals to remain active even when the external status indicators are disabled in sleep mode.

3. Conclusion and Recommendations

This effort resulted in the enhancement of the prototype Electrically Driven Set and Release Hand Brakes (EDHB).

Improvements were made to the EDHB drive train and communications and control system. These improvements have resulted in a more robust and efficient EDHB system add-on to the Group N hand brake. The speeds of application and release have both improved 23 percent based on a decrease from 130 seconds to 100 seconds per application or release. The system efficiency of input by hand wheel to output by the EDHB mechanism improved 33 percent from 65 percent of ideal to an amount that is 86 percent of ideal.

It is recommended to further optimize the design through possible combinations of higher drive voltages, a smaller drive motor, and enhanced control algorithms as revisions to the design, when possible, during the future evolution of the EDHB.

For now, there are two logical next steps for improving or amending the EDHB design to further increase the likelihood of early implementation for the improvement of safety in freight railroad operations. These are as follows:

1. The development of wireless communications and control of EDHB.
2. The development of the utilization of Electrically Controlled Pneumatic Braking (ECP) control of EDHB.

The short-term recommendation is that both the above amendments be addressed. These further developments would increase the likelihood of the implementation of EDHB in freight railroad operations. Item 1, above, would allow for another avenue of communications that could be beneficial to crews when they need to know if hand brakes are either set or released. It would make it much easier to locate hand brakes that need to be set and/or released and also, to set and release them. Item 2, would fit perfectly with ECP-wired unit trains such as coal or tank trains. The addition of EDHB systems on ECP utilized equipment would have a very positive synergetic effect due to the combination of both types of safety systems enhancing the benefits of the other. A unit train crew could assess all the hand brakes on their train from the locomotive cab and ensure the proper operating status of each hand brake along the full length of the train.

Abbreviations and Acronyms

Abbreviations	Acronyms
AAR	Association of American Railroads
Ah	Amp-hour(s)
CFR	Code of Federal Regulations
VDC	Direct Current Volt(s)
EDHB	Electrically Driven Set and Release Hand Brake
FAST	Facility for Accelerated Service Testing
FRA	Federal Railroad Administration
IC	Integrated Circuit
k	Kilo
MSRP	Manual of Standards and Recommended Practices
PTT	Precision Test Track
RFC	Request for Comments
SLA	Sealed Lead-Acid
SA	Sharma & Associates, Inc.
TTC	Transportation Technology Center
V	Volt(s)
W	Watt(s)
Wh	Watt-hour(s)