

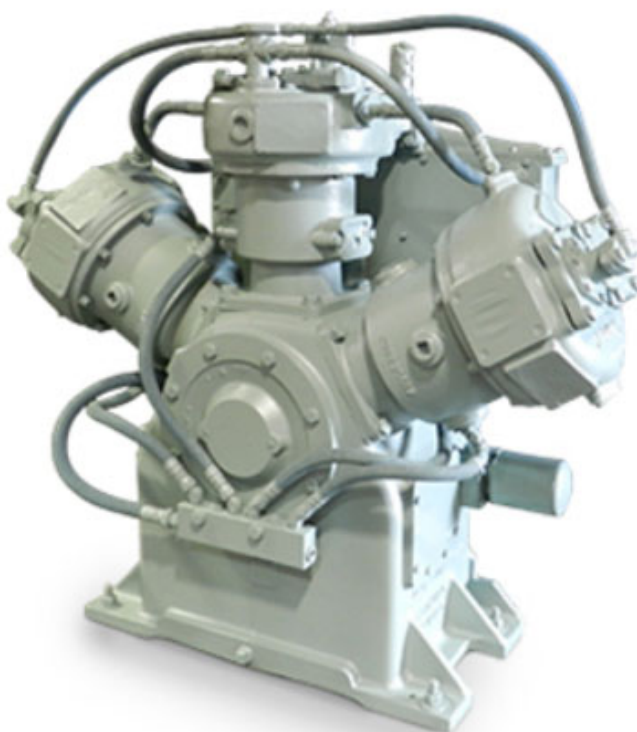


U.S. Department
of Transportation

**Federal Railroad
Administration**

**Office of Research,
Development and
Technology
Washington, D.C. 20590**

Oil-Free Air Compressor Research for Freight Locomotives



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August 3, 2026

ACTION MEMORANDUM TO THE SECRETARY

From: David A. Fink, Administrator
Federal Railroad Administration

Through: Devin Ure
Deputy Assistant Secretary for Budget and Programs and
Acting Chief Financial Officer

Subject: Oil-Free Compressor Research Report to Congress

ACTION REQUESTED

I request that you approve the Oil-Free Air Compressor Research for Freight Locomotives Technical Report and authorize me to sign and transmit the report to Congress.

SUMMARY

The Federal Railroad Administration (FRA) contracted with Ensco, Inc. to evaluate oil-free air compressor technology for potential applicability in freight rail locomotives and determine its cost and ability to reduce emissions. This report to Congress is an overview of the FRA Office of Research, Development, and Technology's evaluation of oil-free compressor technology and results from this study. FRA does not anticipate any negative reaction to the materials if Congress decides to make them public.

This recommendation addresses the U.S. Department of Transportation priorities of safety and transformation through research on the potential impacts on fuel efficiency, performance in cold weather, operations and maintenance, life-cycle costs, safety, and the applicability and availability of oil-free compressors for freight rail.

BACKGROUND

Research for this report was conducted between September 01, 2023 and November 30, 2024 at FRA's Transportation Technology Center in Pueblo, CO. Rail vehicles are equipped with air compressors for operation of the brake systems. Traditional designs for locomotive air compressors are oil-lubricated, reciprocating compressors. Researchers investigated the baseline compressor performance by comparing a range of different existing locomotive air compressor designs. They identified different types of commercially available oil-free air compressors, separated them into different use cases, and compared their technical capabilities.

Discussions with freight railroads revealed perceptions that the benefits of oil-free air compressors do not outweigh the costs. Oil-free air compressors can cost as much as 1.5 to three times more than conventional oil-lubricated air compressors. Locomotives are built and sold with conventional oil-lubricated air compressor technology, and there is no need for a railroad to replace the air compressor unless it fails. Therefore, though oil-free air compressor technology is feasible, the cost of the technology and operational limits may be a barrier to wider deployment in the freight rail sector.

STATEMENT OF LATENESS

The due date for the report to Congress on the mandated study of locomotive compressors, specifically oil-free compressors as directed by the House of Representatives Committee on Appropriations Report 117-402, was 1 year after the implementation of the Consolidated Appropriations Act of 2023, Division L – Transportation, Housing and Urban Development and Related Agencies Appropriations Act, 2023, Pub. L. No. 117-328 (December 29, 2022). FRA is submitting this final report late because FRA was unable to award a contract for the research until July 2023; the research project began September 1, 2023, and ended November 30, 2024. Upon receiving the final report, FRA conducted an internal review of the report, which identified information to be added before being approved for dissemination to Congress. FRA has provided regular updates to Congress on the timeline and schedule of the research. FRA does not anticipate any negative reaction to the report being late to Congress.

Key Points

- The research was broken down into two related areas: (1) an evaluation of current oil-free air compressor technology; and (2) a comparison of oil-free and oil-lubricated air compressor capabilities.
- Researchers found that the current state of oil-free compressor technology has the capability to generate a sufficient supply of compressed air for freight rail use.
- Several manufacturers of rail transit vehicle components produce oil-free air compressors intended for passenger transit vehicles, and their designs of oil-free air compressors for rail transit vehicles can provide insight into the potential use of this technology for freight rail.
- The information gathered indicates that oil-free air compressor technology generally struggles to cope with environmental extremes commonly found in the freight rail industry (*e.g.*, high temperatures).
- The research team found it likely that oil-free compressors would not be as cost-effective when compared with existing oil lubricated units.
- A small number of oil-free air compressors are deployed in revenue freight rail service in North America. This nascent deployment proves the technology's baseline technical compatibility with heavy freight operations, but the small sample size restricts the availability of long-term, fleet-wide operational and economic.

RECOMMENDATION

I recommend that you approve the Oil-free Air Compressor Research for Freight Locomotives Technical Report and authorize me to sign and transmit the report to Congress.

The Secretary

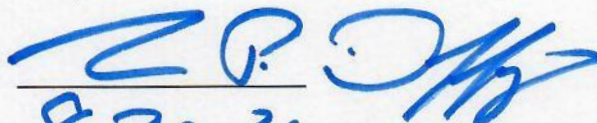
APPROVED:

DATE:

COMMENTS:

Attachments:

- Transmittal Letters
- Report to Congress


8.26.26

May 13, 2025

ACTION MEMORANDUM TO THE SECRETARY

From: David A. Fink, Administrator 
Federal Railroad Administration

Through: Devin Ure
Deputy Assistant Secretary for Budget and Programs

Subject: Oil-free Compressor Research Report to Congress

ACTION REQUESTED

I request that you approve the Oil-free Air Compressor Research for Freight Locomotives Technical Report and authorize me to sign letters transmitting the report to Congress.

SUMMARY

The Federal Railroad Administration (FRA) contracted Ensco, Inc. to evaluate oil-free air compressor technology for potential applicability in freight rail locomotives. This report to Congress is an overview of the FRA Office of Research, Development, and Technology's evaluation of oil-free compressor technology and results from this study. FRA does not anticipate any negative reaction to the materials if Congress decides to make them public.

This recommendation addresses the U.S. Department of Transportation priorities of safety and transformation by conducting research related to potential impacts on fuel efficiency, performance in cold weather, operations and maintenance, life-cycle costs, safety, and the applicability and availability of oil-free compressors for freight rail.

BACKGROUND

FRA contracted Ensco, Inc. to evaluate oil-free air compressor technology for potential applicability in freight rail locomotives and determine its cost and ability to reduce emissions. The research was conducted between March 2023 and August 2024 at FRA's Transportation Technology Center in Pueblo, Colorado.

Rail vehicles are equipped with air compressors for operation of the brake systems. Traditional designs for locomotive air compressors are oil-lubricated, reciprocating compressors. Researchers investigated the baseline compressor performance by comparing a range of different existing locomotive air compressor designs. They identified different types of commercially available oil-free air compressors, separated them into different use cases, and compared their technical capabilities.

Discussions with freight railroads revealed that the benefits of oil-free air compressors do not outweigh the costs. Oil-free air compressors can cost as much as 1.5 to 3 times more than conventional oil-lubricated air compressors. Locomotives are built and sold with conventional oil-lubricated air compressor technology, and there is no need for a railroad to replace the air compressor unless it fails. Therefore, although oil-free air compressor technology is feasible, the cost of the technology and operational limits may be a barrier to wider deployment in the freight rail sector.

STATEMENT OF LATENESS

The statutory due date for the report to Congress on the mandated study of locomotive compressors, specifically oil-free compressors was one year after the implementation of the Consolidation Appropriations Act of 2023, Division H – Transportation, Housing and Urban Development and Related Agencies Appropriations Act, 2023 (December 29, 2022). FRA is submitting this final report late because FRA was unable to award a contract for the research until July 2023, and the research project began September 1, 2023, and ended November 2024. Upon receiving the final report, FRA conducted an internal review of the report. The review identified information to be added before being approved for dissemination to Congress. FRA has provided regular updates to Congress on the timeline and schedule of the research. FRA does not anticipate any negative reaction to the report being late to Congress.

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- Researchers found that the current state of oil-free compressor technology has the capability to generate a sufficient supply of compressed air for freight rail use.
- Several manufacturers of rail transit vehicle components produce oil-free air compressors intended for passenger transit vehicles, and their designs of oil-free air compressors for rail transit vehicles can provide insight into the potential use of this technology for freight rail.
- The information gathered indicates that oil-free air compressor technology generally struggles to cope with environmental extremes commonly found in the freight rail industry (e.g., high temperatures).
- The team found it likely that oil-free compressors would not be as cost-effective when compared with existing oil lubricated units.
- A small number of oil-free air compressors are deployed in revenue freight rail service in North America.

RECOMMENDATION

I recommend you approve the submission of the Oil-free Air Compressor Research for Freight Locomotives Technical Report and authorize me to sign the attached letters transmitting the report to Congress.

The Secretary

APPROVED: _____

DATE: _____

COMMENTS:

Attachments:

- Transmittal Letters (4 Total)
- Oil-free Air Compressor Research for Freight Locomotives Report to Congress



U.S. Department
of Transportation

**Federal Railroad
Administration**

1200 New Jersey Avenue, SE
Washington, DC 20590

September 16, 2026

The Honorable Susan M. Collins
Chair
Committee on Appropriations
United States Senate
Washington, DC 20510

Dear Chair Collins:

The enclosed Oil-Free Air Compressor Research for Freight Locomotives Technical Report includes the results of a study assessing oil-free compressors in comparison to oil-lubricated compressors used in locomotives to understand better the potential environmental benefits of oil-free compressors, as directed by the House and Senate Committees on Appropriations.

The Federal Railroad Administration (FRA) contracted with Ensco, Inc. to evaluate oil-free air compressor technology for potential applicability in freight rail locomotives. The research was conducted between September 01, 2023 and November 30, 2024 at FRA's Transportation Technology Center in Pueblo, CO. The technical report provides insights on the evaluation and results of the research.

A similar letter has been sent to the Vice Chair of the Senate Committee on Appropriations and the Chairman and the Ranking Member of the House Committee on Appropriations.

Sincerely,

A handwritten signature in blue ink that reads "David A. Fink".

David A. Fink
Administrator

Enclosure



U.S. Department
of Transportation

**Federal Railroad
Administration**

1200 New Jersey Avenue, SE
Washington, DC 20590

September 16, 2026

The Honorable Patty Murray
Vice Chair
Committee on Appropriations
United States Senate
Washington, DC 20510

Dear Vice Chair Murray:

The enclosed Oil-Free Air Compressor Research for Freight Locomotives Technical Report includes the results of a study assessing oil-free compressors in comparison to oil-lubricated compressors used in locomotives to understand better the potential environmental benefits of oil-free compressors, as directed by the House and Senate Committees on Appropriations.

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Sincerely,

A handwritten signature in blue ink that reads "David A. Fink".

David A. Fink
Administrator

Enclosure



U.S. Department
of Transportation

**Federal Railroad
Administration**

1200 New Jersey Avenue, SE
Washington, DC 20590

September 16, 2026

The Honorable Rosa L. DeLauro
Ranking Member
Committee on Appropriations
U.S. House of Representatives
Washington, DC 20515

Dear Ranking Member DeLauro:

The enclosed Oil-Free Air Compressor Research for Freight Locomotives Technical Report includes the results of a study assessing oil-free compressors in comparison to oil-lubricated compressors used in locomotives to understand better the potential environmental benefits of oil-free compressors, as directed by the House and Senate Committees on Appropriations.

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A similar letter has been sent to the Chairman of the House Committee on Appropriations and the Chair and Vice Chair of the Senate Committee on Appropriations.

Sincerely,

A handwritten signature in blue ink that reads "David A. Fink".

David A. Fink
Administrator

Enclosure



U.S. Department
of Transportation

**Federal Railroad
Administration**

1200 New Jersey Avenue, SE
Washington, DC 20590

September 16, 2026

The Honorable Tom Cole
Chairman
Committee on Appropriations
U.S. House of Representatives
Washington, DC 20515

Dear Chairman Cole:

The enclosed Oil-Free Air Compressor Research for Freight Locomotives Technical Report includes the results of a study assessing oil-free compressors in comparison to oil-lubricated compressors used in locomotives to understand better the potential environmental benefits of oil-free compressors, as directed by the House and Senate Committees on Appropriations.

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Sincerely,

A handwritten signature in blue ink that reads "David A. Fink".

David A. Fink
Administrator

Enclosure

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Executive Summary

The Federal Railroad Administration (FRA) contracted with Ensco, Inc. to conduct research evaluating oil-free air compressor technology for potential applicability in freight rail locomotives. Oil-free air compressor technology is technically feasible as an alternative to oil-lubricated compressors for freight locomotives. A comprehensive, quantitative cost-benefit analysis was outside the scope of this research; however, discussions with freight railroads revealed perceptions in the industry that the benefits of oil-free air compressors do not outweigh their costs. Oil-free air compressors can cost as much as 1.5 to three times more than conventional oil-lubricated air compressors. Locomotives are built and sold with conventional oil-lubricated air compressor technology, and there is no need for a railroad to replace the air compressor unless it fails. Therefore, though oil-free air compressor technology is feasible for some freight rail applications, the cost of the technology, in comparison to conventional compressors, may be a barrier to wider deployment of the oil-free technology in the freight rail sector. Additional deployment of oil-free technology by freight railroads is needed to prove the reliability and benefits of oil-free compressors in meeting the operational requirements for freight locomotives, and to increase interest in the new technology.

Rail vehicles are equipped with air compressors for operation of the brake systems. Traditional designs for locomotive air compressors are oil-lubricated, reciprocating compressors. Researchers investigated the baseline compressor performance by comparing a range of different existing locomotive air compressor designs.

The research team collected data from industries that use air compressors to determine the current state of technological readiness of oil-free air compressors.

Researchers identified different types of commercially available oil-free air compressors, separated them into different use cases, and compared their technical capabilities. Over the past 10 years, a small number of oil-free compressors were deployed in North American rail operations.

Researchers compared the capabilities of the oil-free air compressors with several oil-lubricated locomotive air compressors to understand the differences in technical performance. The research team then contacted locomotive air compressor manufacturers and discussed the requirements for air compressor systems and the prospects for development of an oil-free version.¹ The researchers found that, while the manufacturers developed oil-free air compressor technology for freight locomotive use, past versions of the technology were not developed sufficiently to meet the needs of the freight rail industry. In the early stages of deployment there were reliability issues with some of the oil-free compressors; manufacturers then modified their products to improve performance. New York Air Brake (NYAB) provides an oil-free air compressor, VV1000-T, for the freight rail market and a small number of compressors using this technology are deployed on locomotives.

¹ The discussion did not provide specific information about designs and capabilities for oil-free locomotive compressors.

1. Introduction

The Federal Railroad Administration (FRA) contracted with Ensco, Inc. to evaluate oil-free air compressor technology for potential applicability in freight rail locomotives and determine the cost and ability to reduce emissions. The research was conducted between March 2023 and August 2024 at the Transportation Technology Center (TTC) in Pueblo, CO.

1.1 Background

Railroad freight trains use compressed air to activate on-board brake systems. Compressed air provides the force needed to apply and control train brakes. The locomotive air compressor system provides a sufficient supply of compressed air to operate the brakes on every car in a train.

Oil lubricant used in existing air compressors creates contamination and waste oil. Oil-free air compressor technology represents an opportunity to eliminate the contamination and waste products associated with oil-lubricated compressors.

1.2 Objectives

The objective of this effort was to evaluate the efficacy of oil-free air compressor technology and to understand better the potential benefits of oil-free compressors for use in locomotives.

1.3 Overall Approach

The research was broken down into two related areas of concern: (1) an evaluation of current oil-free air compressor technology; and (2) a comparison of oil-free and oil-lubricated air compressor capabilities.

1.3.1 *Technology Evaluation and Assessment*

The team identified different types of oil-free air compressors available for locomotives and compiled technical and economic data on currently available technology both through contact with manufacturers and research of publicly available literature.

1.3.2 *Comparison of Oil-free Compressors*

Researchers used information generated in the technology evaluation and assessment to compare oil-free compressor technology and oil-lubricated air compressors currently used in locomotives. The comparison included the impacts on air, water, and ground contamination, fuel efficiency, performance in weather extremes, operation and maintenance requirements, life-cycle costs, safety, and applicability and availability of oil-free air compressors for freight rail use.

1.4 Scope

The scope of the study was limited to a literature review of publicly available information regarding air compressor designs or capabilities and information obtained during a discussion with two air compressor manufacturers that provide products for railroad applications.

No testing or physical evaluation of oil-free or oil-lubricated air compressors was conducted under this effort.

1.5 Organization of the Report

[Section 2](#) provides background information about the need for compressed air on freight trains and existing types of oil-lubricated locomotive air compressors.

[Section 3](#) provides an overview of how oil-free air compressors are designed and operate.

[Section 4](#) presents research on available oil-free air compressors and examines their suitability for use in freight locomotives.

[Section 5](#) compares oil-free air compressors with oil-lubricated freight locomotive compressors. This section also discusses attempts to adapt oil-free technology for freight locomotive use.

[Section 6](#) summarizes the report and provides concluding remarks.

2. Air Compressors for Railroad Use

This section discusses conventional oil-lubricated air compressors used in North America rail operations and background information on automatic air brake systems. In North America, freight railroads operate in a wide variety of conditions, ranging from extreme heat and humidity to frigid arctic temperatures to desert areas with blowing sand. The freight rail industry establishes environmental range standards for equipment in a locomotive engine compartment where temperatures may range from -40 degrees Celsius to 140 degrees Celsius in a tunnel [1]. Humidity may range from 40 to 95 percent [1]. These standards also specify endurance for unique conditions such as exposure to salt fog from coastal areas or sand and dust in environments where those particles may become airborne [1]. Locomotive air compressors must be capable of prolonged operation in all these environments.

2.1 Railroad Air Brakes

Freight trains in North America use compressed air for several different purposes. The most important function of compressed air is to provide power and control for the train's braking system.

Both locomotives and freight cars are equipped with brakes that are actuated by compressed air. Freight cars receive compressed air via the brake pipe, a pressurized line of both rigid pipes and flexible hoses that runs the entire length of a freight train. Compressed air in the brake pipe is generated by air compressors onboard one or more locomotives. North American freight railroads generally operate with brake pipe pressures at approximately 90 psi [2]. Air reservoirs are storage tanks on each car that are supplied with compressed air via the brake pipe. When the lead locomotive in a train consist applies the brakes, the pressure in the brake pipe on subsequent rail cars decreases. This loss of pressure causes brake valves located on each car to send pressure from a car's air reservoir into a piston, applying brake shoes against the wheels to decelerate the rail car. When the lead locomotive brakes are released, compressed air from the locomotive is fed back into the brake pipe to raise the pressure. This increase in pressure releases the brakes on each car in a train and recharges the air reservoirs, ensuring sufficient air pressure is available to apply the brakes again whenever necessary. In this manner, compressed air generated by locomotive air compressors provides both the power and means of control for brake application on a freight train.

A simplified layout of a train brake system is shown in [Figure 1](#). Note that the Driver's Brake Valve in the figure refers to the train operator's brake control in the locomotive cab.

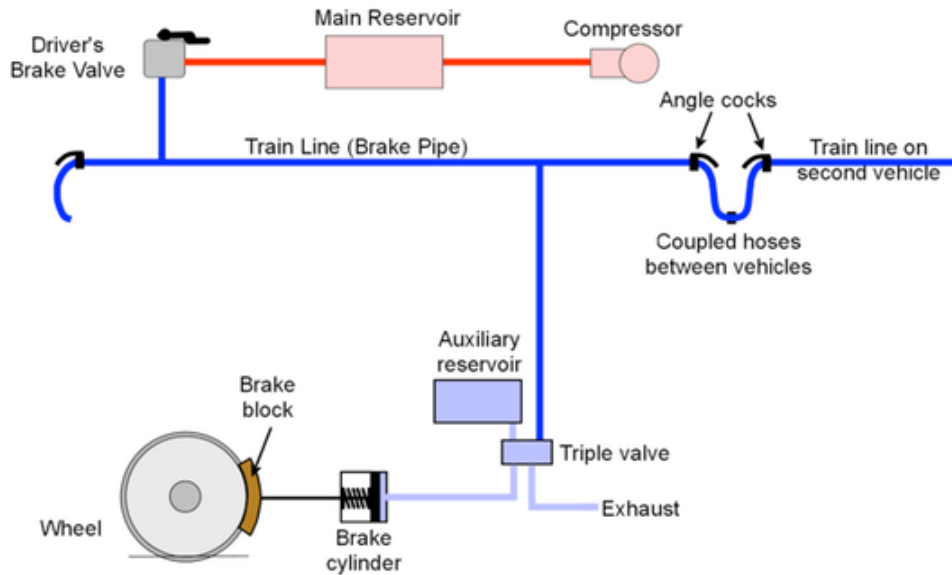


Figure 1. Diagram of Freight Train Air Brake System [2]

2.2 Freight Locomotive Air Compressors

Mainline locomotives must be equipped with air compressors capable of generating a sufficient supply of compressed air to operate the brake system on the entire freight train. The safety critical nature of the air brake system requires air compressor designs which are robust, easy to maintain, and well suited to a wide variety of operating environments. Though there are many different types of air compressors, most freight locomotives rely on a compressor design which has remained mechanically similar for several decades. Most diesel electric freight locomotives are equipped with an oil-lubricated reciprocating air compressor, which is a positive displacement type of air compressor. In this air compressor design, pistons move back and forth within one or more cylinders. When a piston moves down within a cylinder, air is drawn in. When the piston moves up within a cylinder, the volume of the air is reduced and the pressure increases [3].

Reciprocating air compressors for locomotives often share certain common features, even across different designs and manufacturers. These compressors commonly contain between three and six compression cylinders that are water or air cooled. The pistons in these cylinders are driven by a rotary crankshaft, powered by either an electric motor or a drive shaft connected directly to the locomotive's diesel engine. It is common for locomotive air compressors to have an output pressure of 140 psi, though the output of air capacity in cubic feet per minute (CFM) may vary by design. A common style of three-cylinder locomotive air compressor is shown in **Figure 2**.

These types of air compressors are designed to be robust. Oil lubrication on all moving parts both prevents excessive wear and assists in dissipating heat. The heat dissipation provided by lubrication and either air or water cooling enables these types of compressors to operate more effectively in the extreme heat environments that can be encountered in many parts of North America.

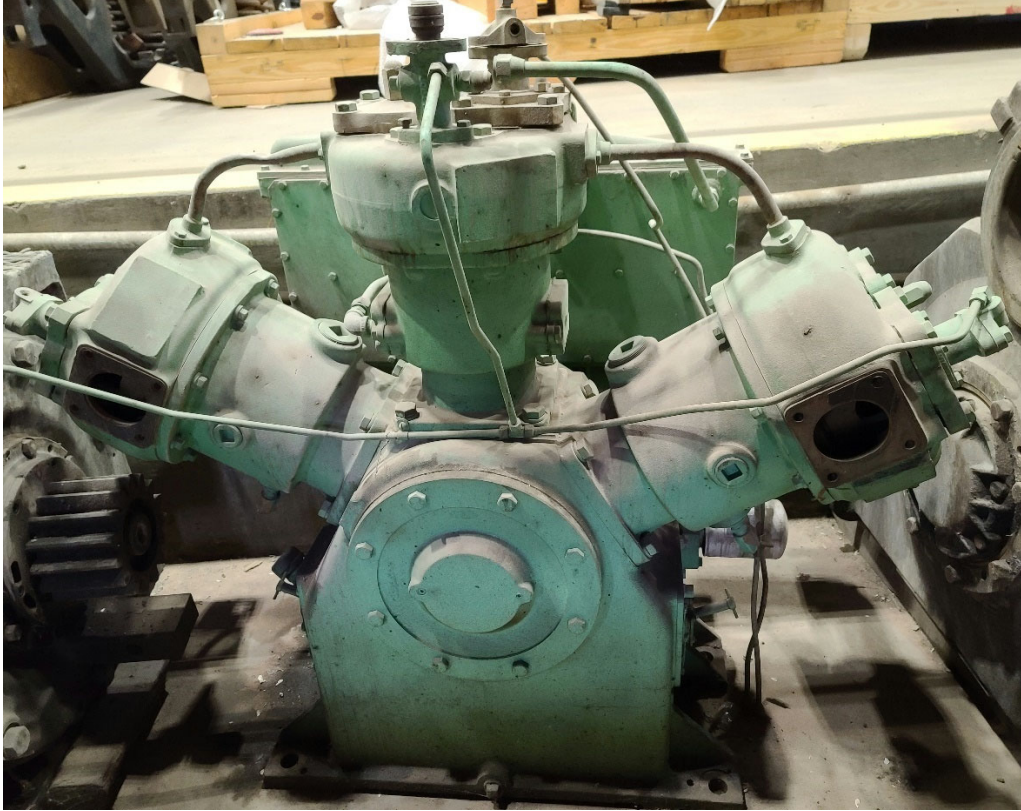


Figure 2. Three Cylinder Locomotive Air Compressor

3. Oil-free Compressor Technology

Oil-free air compressors are designed to produce compressed air in a manner similar to oil-lubricated compressors. The most significant difference between the two compressor types is how the moving parts of the compressor are lubricated. Rather than utilizing an oil coating, an oil-free air compressor minimizes friction by coating moving parts with water or replacing contact surfaces with a low friction liner, for example, a Teflon coating.

An important benefit of oil-free air compressors is the elimination of oil contamination from the end supply of compressed air. The oil in an oil-lubricated compressor is in contact with the working gas when a volume of air gets compressed. This causes small amounts of oil to become mixed with the end supply of compressed air. In several industries, such as food processing and medical industries, oil contamination presents an unacceptable hazard to the use of compressed air. Conventional oil-based air compressors have air dryers that remove oil contaminant from the air before it enters the main reservoir. Oil-free air compressors present an opportunity to create an air supply free of oil contamination when the air is first compressed.

3.1 Oil-Free Compressor Designs

Much like oil-lubricated air compressors, oil-free air compressors can utilize many different types of compressor technologies, including reciprocating compressors, screw compressors, and scroll compressors. The main differences in design between oil-free and oil-lubricated compressors are the design changes required to allow an oil-free air compressor to operate without oil lubrication. Oil-free compressors do not require oil reservoirs, oil filters, oil pumps, or the associated equipment required to power an oil pump. In addition, oil-free compressors must have moving parts and contact surfaces either lubricated with water or covered with a low friction coating. It is important to note that some air compressors which are considered oil-free use oil to lubricate some moving parts, but do not use oil to lubricate components which contact the working gas. These compressors are considered oil-free because there is no oil contamination in the compressed air supply.

In any compressor, as the pressure of the working gas pressure increases, its temperature will increase as well. In an oil-lubricated compressor, the oil will absorb a portion of the heat generated during compression and dissipate it. In an oil-free air compressor, this extra heat will be absorbed by the compressor's components and must be dissipated. As such, it is common for the design of oil-free air compressors to require additional cooling capacity, especially near components in contact with the working gas during the compression process.

Oil-free air compressors are commonly used to supply compressed air for many different purposes, from large stationary facility compressors to portable compressors. This wide range of uses combined with different compressor technologies means oil-free compressors are suitable for a wide range of capacities and operating environments.

3.2 Technology Status of Oil-Free Compressors

As part of this research effort, the research team gathered information regarding the current level of technological readiness of oil-free air compressor technologies in the industries in which they are used and evaluated their applicability for rail application. Companies that manufacture or sell both oil-free and oil-lubricated compressors provide publicly available information about both

types of compressors and provide data on the available air compressor technologies to educate potential customers as to which option would best fit their needs. Therefore, most of the information gathered is generalized and not specific to the railroad environment.

For many applications, oil-free air compressors have a higher upfront cost than conventional oil-lubricated air compressors [4]. However, oil-lubricated compressors have additional operating costs over their lifetimes associated with changing and maintaining oil levels and oil filters. Many oil-free compressors require minimal maintenance throughout their service life which can lead to lower overall costs in some circumstances.

Over time the low friction coatings in the moving parts of oil-free compressors tend to wear and lose effectiveness. As these coatings wear, friction between moving parts increases, which can cause some oil-free compressors to become less efficient. In some designs, the wear of the low friction coatings in oil-free compressors also tends to occur more quickly than wear in an oil-lubricated compressor where the oil has been well maintained. This tends to cause oil-free compressors to have a shorter service life from heat issues than well maintained oil-lubricated units [4]. NYAB provides the VV1000-T oil-free air compressor and the company claimed that the reliability of the VV1000-T has been verified over time through acceptable failure per locomotive year rate. The company did not specify the failure rate.

Air compressors generate heat both through their moving parts and due to the thermodynamics of compressing a working gas. As previously mentioned, in an oil-lubricated compressor, the oil will absorb a portion of this heat and dissipate it as it travels from the compressor's moving parts back to the oil reservoir. Oil-free compressors do not benefit from this method of heat dissipation and tend to require additional cooling to control heat buildup adequately. The tendency to produce more heat during normal operation can also lead to oil-free air compressors, increasing the temperature in the surrounding area, particularly if located in an enclosed or poorly ventilated space. If adequate cooling is not provided, oil-free air compressors will not operate as well when exposed to extreme heat. Conversely, while oil-free compressors may struggle to operate as well as oil-lubricated compressors in extreme heat, they can operate more effectively in extreme cold. Oil lubricant becomes more viscous in cold temperatures and requires more energy to be pumped to a compressor's moving parts. The low friction coatings in oil-free compressors are not susceptible to this increase in viscosity at cold temperatures and tend to operate more efficiently in these environments than oil-lubricated units. However, some oil-free air compressors still use oil to lubricate certain moving parts that do not interact with the working gas. These designs would still be subject to problems with increased lubricant viscosity at low temperatures.

As mentioned previously, because lubricant in an oil-lubricated compressor will encounter the working gas, it is common for small particles of lubricant to be carried over into the resulting compressed air during the compression process. The amount of contamination can vary significantly depending on variations to the operating state of a compressor but could be around 3-4 ppm [5]. The air dryer system installed downstream of the main reservoir is designed to remove moisture and contaminants from the compressed air before it is stored. It is not evident from the research that oil contamination in the compressed air is a major issue that the railroads are facing in using oil-lubricated air compressors. In the event of unanticipated mechanical failures or poor maintenance in this type of filtered, oil-lubricated air compressor, oil contamination in the compressed air supply can rise to unacceptable levels. If the purity of a compressed air supply is paramount, an oil-free compressor can be a more suitable alternative to an oil-lubricated compressor. Oil-free air compressors do not introduce oil contamination into

the air supply, which provides a comparatively simple method of producing compressed air with high purity. Maintenance costs for such an oil-free compressor system may be lower than a comparable filtered, oil-lubricated system due to the lack of both filter and oil replacements.

4. Oil-Free Compressors for Potential Freight Rail Use

In North America, most heavy freight rail locomotives are equipped with various designs of oil-lubricated, reciprocating air compressors that result in oil contamination in the compressed air supply. This contamination is released into the environment whenever compressed air is discharged from a train's air brake system or when air is discharged from any other point in the compressed air system. The total amounts of oil contamination released from brake systems on a freight train or within the railroad industry in general are not well understood and are not addressed by this research effort. However, in general the elimination of oil-lubricated compressors would result in the reduction of waste oil from those compressors.

4.1 Commercially Available Oil-Free Air Compressors

There are limited air compressor manufacturers offering oil-free air compressors for freight rail applications in North America even though there are a variety of oil-free air compressors available for use in many other industries. Therefore, researchers expanded the investigation to include oil-free air compressor designs commercially available for other industries to determine their capabilities and assess the current state of the technology.

4.1.1 *Oil-Free Air Compressors for Transit Rail Use*

Several manufacturers of rail transit vehicle components produce oil-free air compressors, including Atlas Copco in North America and Durr Technik in Europe. Much like freight trains, these rail transit vehicles are equipped with air brake systems that require a compressed air supply. The designs of oil-free air compressors for rail transit vehicles can provide insight into the potential use of this technology for freight rail. However, these vehicles are much lighter than freight locomotives and cars and often have more efficient braking systems, such as disc brakes. These vehicles are often articulated units, with one air compressor providing compressed air for multiple rail cars. In a freight train consist the compressors from two or three locomotives must provide compressed air to 100 or more freight cars. Ultimately, this means the oil-free air compressors onboard rail transit vehicles normally have a much lower capacity than those designed for freight locomotive use. An example of a transit vehicle equipped with oil-free compressor technology is shown in [Figure 3](#).

Atlas Copco manufactures a range of oil-free scroll-style air compressors. For this research, the team examined the Atlas Copco scroll-style oil-free air compressor offered with the highest capacity. The SFR 12-50 two-stage compressor has a rated pressure of 145 psi at a displacement capacity of 48.7 CFM (see **Figure 4**). This scroll style compressor is designed specifically for use in passenger rail vehicles and features elements intended both to increase reliability in a railroad environment and to avoid negatively affecting passenger comfort. This model of air compressor contains an integrated cooling fan which allows operation at a wide range of temperatures and a heavy-duty air filter for operation in dusty environments. The air compressor is also designed to minimize the generation of noise and is equipped with vibration dampeners to minimize the transfer of vibration to and from the unit. The technical details of this compressor are shown in **Table 1**.



Figure 3. An Example of Transit Vehicles Equipped with Oil-Free Compressors

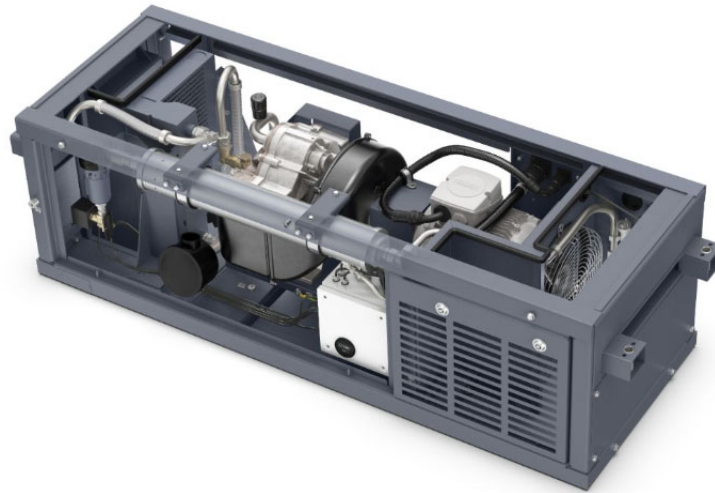


Figure 4. Atlas Copco SFR Oil-Free Scroll Compressor [6]

Table 1. Comparison of Oil-Free Compressors for Transit Vehicles [6] [7]

Manufacturer	Model	Rated Pressure	Displacement Capacity	Shaft Power	Temperature Range
Atlas Copco	SFR 12-50 2-stage	145 psi	48.7 CFM	12 kW	-40 to 122 F
Durr Technik	MC-1200	145 psi	43.1 CFM	15.8 kW	-40 to 131 F

Durr Technik manufactures several different types of oil-free air compressors for transit vehicles; this report examines the highest capacity compressor offered. The MC-1200 is an oil-free piston-style compressor with a rated pressure of 145 psi at a displacement capacity of 43.1 CFM (see **Figure 5**). This compressor also operates in a wide temperature range and is equipped with a robust case designed to protect the unit from dust and debris. The compressor's case is designed with sound insulation and wire rope vibration dampeners to prevent excessive noise and the

transfer of vibrations to and from the rail vehicle. The technical details of this compressor are shown above in **Table 1**.



Figure 5. Durr Technik MC Oil-Free Piston Compressor [7]

The specifications of these transit vehicle compressors are similar in many ways. Both compressors are designed to generate compressed air at 145 psi and have a supply capacity of between 40 and 50 CFM. Both compressors also are designed to operate at similar temperatures, being optimized for both low and high temperature extremes to ensure high reliability in a wide range of environments. Since both compressors are intended for use in passenger vehicles, they are also both designed to minimize noise and are equipped with vibration dampeners. It is also important to note that while these air compressors have similar capabilities, they operate based on two different types of compressor technologies. The SFR 12-50 is a scroll-style compressor, while the MC-1200 is a reciprocating piston-style compressor. Though not definitive, this indicates a possibility that different styles of oil-free air compressors could have the potential to be scaled up to freight rail use.

4.1.2 Oil-Free Air Compressors for Stationary Use and Rail Applications

Researchers found limited information on oil-free compressors for freight rail application. One supplier, NYAB, provided information about its oil-free air compressor technology. [Table 3](#) in the following section includes information on NYAB VV1000-T oil-free air compressor. This oil-free air compressor meets the requirements for a freight locomotive air compressor.

A significant application for oil-free compressors is to provide compressed air for facilities; therefore, more publicly available information was available for these types of oil-free air compressors. These stationary air compressors can be designed to use several different styles of compression technologies. Oil-free compressors designed for stationary use usually have a larger capacity than compressors designed for use in transit vehicles. This higher capacity offers insight into the applicability of this technology for freight rail use.

Compressors for freight locomotives range in displacement capacity from 170 CFM to 296 CFM. Oil-free air compressors for stationary use have similar capacity to freight locomotive compressors. However, application of these compressors for freight rail use presents a challenge because of the difference in operating environments. Stationary air compressors are often mounted on the ground or attached to a solid structure inside a building. By contrast, the

environment inside a locomotive engine compartment is exposed to the elements as well as the heat and vibration generated by the locomotive engine and other equipment. Therefore, stationary air compressors require modification before they can be adapted to the rail environment. However, an examination of their current capabilities can provide useful information.

There are numerous manufacturers of stationary oil-free air compressor systems. Researchers examined two models with similar operating characteristics which are both available in North America from Gardner Denver and Ingersoll Rand.

Gardner Denver manufactures stationary oil-free air compressors using a variety of technologies, including reciprocating piston, scroll, and screw systems. The EnviroAire TVS55 is a type of stationary, screw-style air compressor with a pressure of 150 psi at a displacement capacity of 269 CFM (see [Figure 6](#)). This model of compressor is designed with the ability to vary its speed to match its compressed air output with different levels of demand. Though this air compressor is designed with capabilities like a locomotive air compressor, the housing is too large to fit in the engine compartment of most freight locomotives (81.8 inches wide by 52 inches long by 76.7 inches tall). It is also not clear that this type of compressor could be adapted for operation in the railroad environment. The technical details of this compressor are shown in [Table 2](#).



Figure 6. Gardner Denver TVS Stationary Screw Compressor [8]

Table 2. Comparison of Stationary Oil-Free Compressors [8] [9]

Manufacturer	Model	Rated Pressure	Displacement Capacity	Input Power
Gardner Denver	EnviroAire TVS55	150 psi	269 CFM	55 kW
Ingersoll Rand	IRN55K-OF	150 psi	275 CFM	55kW

Ingersoll Rand also manufactures a wide range of oil-free air compressors for stationary use. The Nirvana IRN55K-OF is a screw-style compressor with an output pressure of 150 psi at a displacement capacity of 275 CFM (see [Figure 7](#)). This compressor is very similar to the TVS55 both in operating characteristics and its intended use. The IRN55L-OF is a stationary air compressor designed with variable speed capabilities to match its output with different levels of demand. The housing for this compressor system is 82 inches wide by 52 inches long by 77 inches high, which, like the TVS55, is also too large to fit within the engine compartment of a typical freight locomotive. The technical details of this compressor are shown in [Table 2](#) above.



Figure 7. Ingersoll Rand IRN55K-OF Stationary Screw Compressor [9]

Stationary oil-free air compressors are available in a wide range of capacities and designs, and the compressors examined in this research do not provide a full representation of existing technology. However, the capabilities of these compressors represent an intersection of oil-free designs and traditional locomotive air compressors in terms of capacity. These compressors are good candidates for further evaluation of oil-free technology and comparison with oil-lubricated designs. However, detailed information about operating environments for these compressors was not publicly available, and it is not clear how susceptible these designs are to malfunctions due to harsh operating conditions.

5. Comparison of Oil-Free and Oil-Lubricated Compressors

This section presents a comparison of oil-free air compressors and oil-lubricated designs, identifying distinctions between the operating capabilities of different types of air compressors. Information is presented regarding the status of oil-free air compressor technology in the freight rail industry.

5.1 Technical Specifications

Although technical information for some air compressors was presented in previous sections of this report, **Table 3** shows their specifications along with two selected oil-lubricated locomotive compressors. The power requirements for the oil-lubricated compressors are shown in both horsepower (HP) and kilowatts (kW), as these compressors can be driven from an electric motor or drive shaft connected to a locomotive engine. **Table 3** is not intended to be an exhaustive list of either available air compressor models or manufacturers.

Table 3. Comparison of Oil-Free and Oil-Lubricated Air Compressors [6] [7] [8] [9] [10] [11]

Manufacturer	Model	Oil or Oil-free	Intended Use	Compressor Type	Rated Pressure	Displacement Capacity	Input Power
Gardner Denver	EnviroAire TVS55	Oil-Free	Stationary	Screw	150 psi	269 CFM	55 kW
Ingersoll Rand	IRN55K-OF	Oil-Free	Stationary	Screw	150 psi	275 CFM	55kW
Atlas Copco	SFR 12-50 2-stage	Oil-Free	Transit	Scroll	145 psi	48.7 CFM	12 kW
Durr Technik	MC-1200	Oil-Free	Transit	Reciprocating	145 psi	43.1 CFM	15.8 kW
Gardner Denver	WLU	Oil	Freight Rail	Reciprocating	140 psi	170 CFM	48 HP (35 kW)
Wabtec	3CW	Oil	Freight Rail	Reciprocating	140 psi	296 CFM	68 HP (51 kW)
New York Air Brake	VV1000-T	Oil-Free	Freight Rail	Reciprocating	145 psi	185 CFM	49.6 HP (35 kW)

Freight locomotive air compressors are designed to generate compressed air at 140 psi. **Table 3** shows oil-free air compressors can generate compressed air at similar pressures.

Due to the variation of freight locomotive air compressor designs, the displacement capacity of these compressors also can vary. The VV1000-T, WLU and 3CW model compressors were selected for further evaluation because they represent reasonable bounds on the required displacement for currently available locomotive oil-lubricated air compressors. The 170 CFM from the WLU compressor represents the lower end of displacement capacity and the 3CW compressor with 296 CFM represents the upper end. The stationary air compressors shown fall within this air displacement range. However, these systems are not compatible for rail use as currently designed. In addition, the displacement range of oil-free compressors for rail transit vehicles is insufficient for freight rail applications because freight trains are heavier, longer and require more braking force than transit vehicles. The VV1000-T meets the requirements for freight locomotive air compressor needs.

5.2 Freight Railroads and Oil-Free Compressors

Researchers measured rail industry interest in adopting oil-free air compressor technology for freight locomotive use. An informal conversation with a North American manufacturer of air compressors for freight rail use yielded unique insight into the current state of oil-free air compressor technology for the North American freight rail industry.

The research team learned that an air compressor manufacturer first developed oil-free air compressor technology for freight locomotives more than a decade ago. Though few specific details regarding this effort were shared, researchers learned that viable oil-free air compressors for freight locomotives were designed and used in freight rail applications. In 2015 and 2018, a small number of these air compressors were built and fitted to diesel electric locomotives on unspecified Class I railroads for field testing. Within 6 to 12 months of testing, oil-free air compressors from one manufacturer were removed, and the locomotives were retrofitted to oil-lubricated air compressor units. The details of this oil-free air compressor field testing and specifics about how the compressors performed were not provided to the research team. However, because the railroads retrofitted their locomotives back to oil-lubricated air compressors after a period of 6 to 12 months of use, one can infer that the railroads had sufficient reason to do so.

Another manufacturer's units were recalled due to failure. The manufacturer modified the design of the oil-free air compressor, and they were redeployed on freight locomotives. No major issues were reported by the railroads since those initial episodes of failures. Manufacturers of oil-free air compressors indicated that the development and field testing of the technology is on-going. Freight railroads only replace air compressors when they fail because they are not repairable. New locomotives are built with oil-lubricated air compressors unless the railroad requires the locomotive manufacturer to install an oil-free air compressor.

The initial cost of an oil-free compressor for rail application can range from 1.5 times to three times the relative cost of a comparable oil-lubricated air compressor. Periodic maintenance costs for oil-free compressors are less than oil-lubricated air compressors, but this cost-saving must be evaluated against the cost of an oil-free air compressor over its full lifetime. The first overhaul for an oil-lubricated compressor is usually done after eight to 10 years of operation, and the second overhaul is done after roughly six additional years of operation. An oil-free air compressor generally requires overhaul between the first six to eight years of operation, with a second overhaul required after an additional five to six years of operation. The cost for each overhaul of an oil-free air compressor is about 25 to 30 percent of the original unit cost. The upfront costs of an oil-free air compressor and subsequent overhaul costs make oil-free air compressors less attractive to railroads despite the perceived benefits of lower maintenance and the elimination of oil contamination.

6. Conclusion

Researchers examined the current state of oil-free air compressor technology to determine if it would be suitable for use in freight locomotives. This research included a technological and limited economic evaluation of existing oil-free compressor technology and identified special considerations for air compressor use in freight rail applications.

The team determined that oil-free air compressors can utilize many different forms of compressor technology, including reciprocating, rotary screw, and scroll designs. The main difference between oil-lubricated variants of these compressors and their oil-free counterparts is that the moving components of oil-free compressors use low friction coatings such as Teflon and/or water lubrication instead of oil-based lubricant. Oil-lubricated air compressors generate waste oil and small amounts of oil contamination in the compressed air. Oil-free compressors eliminate oil contamination in the compressed air and can reduce or eliminate the generation of waste oil, depending on whether the oil-free design uses oil to lubricate components that do not come into contact with the working gas.

Manufacturers of oil-free compressors offer a wide variety of designs. However, there are limited sources for oil-free air compressors for freight rail application. NYAB currently supplies the VV1000-T oil-free air compressor for freight rail that meets the capacity and needs of the industry. Oil-free air compressors are more widely used in passenger rail transit vehicles, but those compressors have a lower required capacity than those needed for freight rail applications. Stationary oil-free air compressor designs may have the required capacity, but no information was found to determine if these designs could withstand the rugged operating environment onboard a freight locomotive.

Discussions with freight locomotive air compressor manufacturers revealed the existence of past efforts to develop and test oil-free air compressor technology. Prototype oil-free compressors were developed, and field tests were conducted in freight locomotives. Oil-free air compressors from one manufacturer were removed from service by the host railroads after service periods ranging from 6 to 12 months. Oil-free air compressors provided by another manufacturer went through a product recall. An updated version of the technology was deployed, performed adequately, and is currently available. At this time, there are a small number of oil-free air compressors installed on freight locomotives.

Researchers found that the current state of oil-free compressor technology has the capability to generate a sufficient supply of compressed air for freight rail use. However, sufficient information does not exist to determine the reliability and robustness of oil-free compressor technology in the railroad environment. The information gathered indicates that some oil-free air compressor technology struggles to cope with environmental extremes commonly found in the freight rail industry (*e.g.*, high temperatures). Discussions with railroads revealed that oil-free compressors are not perceived to be a cost-effective option when compared with existing oil lubricated air compressors. Additional field deployment of the technology would be necessary to understand better its reliability and cost/benefit for use in the freight railroad environment.

References

- [1] Association of American Railroads (2014). MSRP K-V. “Electronics Environmental Requirements and System Management.”
- [2] Brakes (2019). *The Railway Technical Website*. Retrieved from: [Brakes | The Railway Technical Website | PRC Rail Consulting Ltd \(railway-technical.com\)](#).
- [3] Gardner Denver (2024). *Reciprocating Air Compressors*. Retrieved from: [Reciprocating Compressors | Gardner Denver](#)
- [4] C.H. Reed (2023). “Oil vs. Oil-Free Air Compressors: Choosing the Best One for Your Needs.” Retrieved from: [Oil vs. Oil-Free Air Compressors | An Expert Guide \(chreed.com\)](#).
- [5] Mann, B. (2021). *Compressed Air Best Practices*. Retrieved from: [Exploring the Total Cost of Ownership of Oil-Injected vs. Oil-Free Compressed Air Systems | Compressed Air Best Practices](#).
- [6] Atlas Copco (2024). *Oil-Free Scroll Compressor SFR 2-12*. [Brochure]. Retrieved from: [SFR 2-12 brochure EN \(atlascopco.com\)](#).
- [7] Durr Technik (2022). *Oil-Free Compressor Solutions for Railway*. [Brochure]. Retrieved from: [DOWNLOADS - Oil-Free compressors by Dürr Technik \(durrtechnikusa.com\)](#).
- [8] Gardner Denver (2021). *EnviroAire T/TVS*. [Brochure]. Retrieved From: [Clean oil-free screw air compressor | EnviroAire TVS \(gardnerdenver.com\)](#).
- [9] Ingersoll Rand (2012). *Nirvana Variable Speed*. [Brochure]. Retrieved from: [Nirvana VS Oil-Free Rotary Screw Air Compressor 37-45 kW \(ingersollrand.com\)](#).
- [10] Gardner Denver (2017). *Locomotive Compressors*. [Brochure]. Retrieved from: [Locomotive Reciprocating Air Compressor | Gardner Denver](#).
- [11] Wabtec Corporation (2024). “3CW Compressor.” Retrieved from: [3CW™ Compressor | Wabtec Corporation](#).

Abbreviations and Acronyms

ACRONYM	DEFINITION
CFM	Cubic Feet per Minute
FRA	Federal Railroad Administration
HP	Horsepower
kW	Kilowatt
NYAB	New York Air Brake
TTC	Transportation Technology Center