



# Summary Report of Verification Testing for RYPOS ActiveDPF/C3+<sup>TM</sup>

## Active Diesel Particulate Filter for Rubber Tire Gantry Cranes



*Prepared For:*  
The Port of Los Angeles  
The Port of Long Beach  
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*Prepared by:*  
RYPOS, Inc.  
[www.rypos.com](http://www.rypos.com)  
508-429-4552



This summary report was prepared by Rypos, Inc. to document work performed under the San Pedro Bay Ports Clean Air Action Plan Technology Advancement Program (TAP) for the Port of Los Angeles and the Port of Long Beach. The opinions, findings, conclusions, and recommendations are those of the author and do not necessarily represent the views of the Port of Long Beach or Port of Los Angeles (Ports). The Ports, its commissioners, employees, contractors, and subcontractors make no warranty, expressed or implied, and assume no legal liability for the information in this report.

Questions or comments regarding this report should be addressed to Teresa Pisano, Port of Los Angeles, at [tpisano@portla.org](mailto:tpisano@portla.org), or Rose Siengsubcharti, Port of Long Beach, at [rose.sieng@polb.com](mailto:rose.sieng@polb.com).

## 1. PROGRAM SUMMARY

Rypos has a history of providing diesel emission reduction solution systems for various mobile and stationary engine applications. By early 2012, the CARB verified Rypos Active DPF/C Level 2+ system had been installed on over 40 Rubber Tired Gantry cranes (RTG) located at terminals in both the Port of Los Angeles and the Port of Long Beach and all 40+ systems had met or exceeded customer expectations. It was recognized, however, that Rypos and its port customers had a need for a level 3+ solution. In April of 2012, TraPac Terminal purchased four CARB verified Rypos Active DPF/C level 2+ systems, and agreed to allowing Rypos to install an experimental Rypos Active DPF/C3+ system on one of their Mitsui/Paceco RTG cranes. In May of 2012, Rypos built the first Active DPF/C3+ experimental unit and installed the unit at TraPac. After accumulating 50-100hrs, an initial PM test was conducted, and the filter achieved a greater than 85% reduction in PM. This led to a CARB Level 3+ conditional verification. From May to December, the durability portion of the process to achieve CARB final verification was performed (1000 hrs of runtime) after which an emissions test was performed, a full laboratory report compiled, and the results submitted to CARB, resulting in the approval and issuance of a final verification.

The DPF/C3+ emissions test and report project was sponsored by the Port of Los Angeles and the Port of Long Beach under the joint Technology Advancement Program (TAP). The cost of the project was \$144,520, with Rypos providing a fifty-percent cost share. The balance of funds, \$72,260, was provided by the TAP.

## 2. PROJECT PARTICULARS

**Type of Verified Diesel Emission Control(VDEC):** The RYPOS ActiveDPF/C3+™ is an active diesel particulate filter system with diesel oxidation catalysts.

**Type of Verification:** Final Level 3+ Verification for RYPOS ActiveDPF/C3+™ for use in Rubber Tired Gantry (RTG) cranes both diesel-electric and diesel-hydraulic.

**Emission Control Group:** Pre-Tier 1 or newer diesel engines a certified PM emission rate no greater than 0.4 g/hp-hr. Engines in this control group are listed in Appendix G.2.

**Emission Reduction Claim:** diesel particulate matter. Reduction of 85% or greater diesel particulate matter (Level 3+) while conforming to the NO<sub>2</sub> emission limit for January 2009.

**Description of Intended Application:** RYPOS ActiveDPF/ C3+™, an active diesel particulate filter, is intended to remediate emissions from the exhaust of diesel powered Rubber Tired Gantry cranes (RTGs, both diesel-electric and diesel-hydraulic).

## 3. DESCRIPTION OF RYPOS DPF SYSTEM AND OPERATION

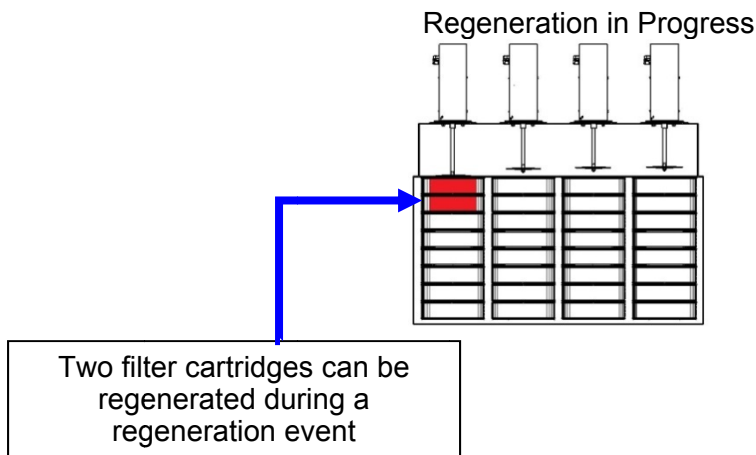
### General Description of the Diesel Emission Control Strategy

RYPOS ActiveDPF/C3+™ is an active diesel exhaust filter system. It consists of a filter housing, electrical control circuit, and filter cartridges made of sintered metal fibers. RYPOS ActiveDPF/C3+™ uses controlled electric heating for reliable regeneration of the filter cartridges. A Diesel Oxidation Catalyst (DOC) attached to the outlet of the filter is added to remove the Soluble Organic Fraction (SOF) while reducing carbon monoxide (CO) and total hydrocarbon emissions (THC).

### System Operation

The ActiveDPF/C3+™ operation is controlled by a microprocessor which monitors back pressure and run time. The proprietary Rypos filter cartridges are energized individually to locally raise temperatures and periodically oxidize the collected soot. Power from the generator, transformer or alternator provides the required electrical current to heat the filter cartridge to the temperatures required.

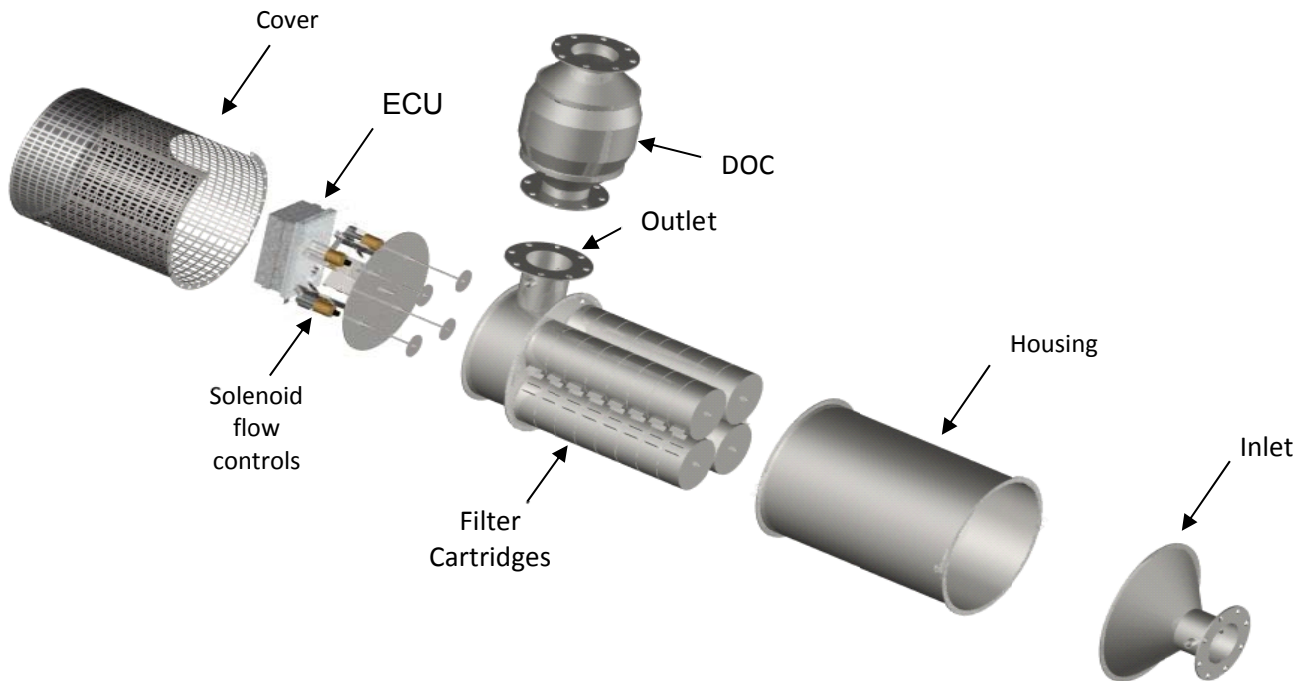
**Figure 1: Example of Regeneration Event**



### Electronics Control Assembly

RYPOS has designed and developed the ECU for use in ActiveDPF/C3+™ systems. There are currently 2 models of the ECU. The differences are only in the number of chambers and cartridges that can be controlled. The RC404 model can control 4 chambers and up to 32 cartridges per ECU. The RC604 can control 6 chambers and up to 48 cartridges per ECU.

**Figure 2: Exploded View of RYPOS ActiveDPF/C3+™ Model RA408L-C**



## Fuel Requirements and Misfueling Considerations

Rypos ActiveDPF/C™ filters require the use of Ultra Low Sulfur fuel (15ppm or lower). The Rypos ActiveDPF/C3+™ can be used with biodiesel blends up to B20 and engine OEM approved fuel additives and low ash lubricating oils.

## Installation Requirements

RYPOS ActiveDPF/C3+™ is installed in place of a muffler. Electrical power for regeneration is obtained by a transformer connected to the output of the electrical generator, from the generator output directly, or by the vehicle alternator, and is protected by a circuit breaker or fuse. The RYPOS ActiveDPF/C3+™ does not rely on exhaust temperature so it may be mounted wherever it is best suited for a given application.



## **Pre-installation Compatibility Assessment Procedures**

The engine in the application needs to have a measured PM level below 0.4 g/bhp-hr. The only other pre-installation compatibility assessment that needs to be done is to review the specific application with Rypos for proper system sizing based on the space available for the RYPOS ActiveDPF/C3+™. Rypos will then decide which of the Rypos filter configurations best match up with the space available for the installation.

## **Normal Maintenance Requirements**

An annual inspection to test for proper functioning of the system, and for the removal of ash if needed, is sufficient. Visually inspect installation, including mounting brackets, wiring, connections, and piping for problems. If repair is needed, disconnect from power before proceeding.

## **Description of Noise Level Control Compliance**

The noise level attenuation of the RYPOS ActiveDPF/C3+™ is equivalent to an industrial grade silencer.

## **4. SUMMARY OF VERIFICATION AND DURABILITY TESTING**

### **Testing Overview**

The Rypos ActiveDPF/C3+™ was installed on RTG #13 operated by TraPac, Inc. at the Port of Los Angeles Terminal. The RTG had 13978 hours on it when the test filter system was installed. The system was instrumented with a data logger to measure engine backpressure and exhaust temperature once every second with 10 second averages. Engine speed was not measured as the genset is a constant speed device operating at 1800 rpm.

Emission testing was conducted on the RTG with the Rypos ActiveDPF/C3+™ filter system after 98 hours of normal operation to de-green the filter. This emission testing was conducted to make sure the system would produce the minimum 85% filtration efficiency before continuing with further testing. Emission testing was again conducted by Best Environmental with the engine hour meter at 15375, or after 1397 hrs of durability testing.

### **Durability Test Facility Location**

Los Angeles Terminal, TraPac facility (Berths 136-142) RTG #13  
920 West Harry Bridges Blvd.,  
Wilmington, CA 90744-5230

### **Independent Emission Reduction Test Organization**

BEST ENVIRONMENTAL (BE)  
6261 Southfront Road  
Livermore, CA 94551



**Photo 1: TraPac RTG in operation at the Port of Los Angeles**





**Photo 2: Best Environmental team conducting emission measurements**

## Description of Test Engine (Make, Model Year, Engine Family Name, etc.)

Engine Make:	Cummins
Model:	NTA855 G-2
Year:	2000
Engine Family:	Non EPA certified
Engine Serial #:	12025736
Displacement:	14.0 liter
Compression Ratio:	14.0:1
Combustion System:	Direct Injection
Aspiration:	Turbocharged, Aftercooled
Engine Power	465BHP

## Description of Test Fuel

CARB ULSD fuel was used for emission testing.

## Description of Maintenance During Durability Testing

The vehicles and engines were maintained by TraPac, Inc. using their normal process and intervals as recommended by OEM. The RYPOS Active DPF/C3+™ was be maintained per the recommendations provided in the owner’s manual.

## Test Procedure Description

One Model RA408L-C RYPOS ActiveDPF/C3+™ was installed onto RTG #13 at Trapac for durability and emission testing. The system was emission tested after 98 hours of normal operation in order to be sure that the design changes incorporated would indeed allow it to pass CARB Level 3 PM criteria (85% reduction) The RTG then continued to operate in normal day to day operation until it accumulated 1397 hrs of durability testing. At that time the emissions reduction performance of the DPF was measured using the ISO 8178-4:1996 8.4.1 D2 test cycle. CARB ULSD diesel fuel was used during the entire durability test and for emission testing. A load bank was used to load the generator as shown below. PM was measured using CARB method 5. NOx, CO, VOC, CO2 and O2 was measured using EPA method 7E, 10, 25A, and 3A.

ISO 8178 D2 Test Cycles					
<b>Mode</b>	1	2	3	4	5
<b>Load, %</b>	100	75	50	25	10
<b>Speed</b>	Rated Speed (1800 rpm)				
<b>Weighting Factors</b>	0.05	0.25	0.3	0.3	0.1

## Test results and Comments

Emission Testing was conducted after the RYPOS Active DPF/C3+™ filter had accumulated 98 hours of durability testing, and again after accumulating 1397 hrs of durability test operation. The exhaust stream was sampled both before and after the DPF. The baseline was run without the DPF installed. All data points are an average of 3 emission test runs at the same operating condition. Below is a summary of the degreened and aged DPF filter reduction results:

	RYPOS ActiveDPF/C3+ Emission Reduction Efficiency at 98 hrs	RYPOS ActiveDPF/C3+ Emission Reduction Efficiency at 1397 hrs
Nox (g/bhp-hr) (CARB)	0%	-4%
CO (g/bhp-hr)	93%	92%
THC (g/bhp-hr)	72%	76%
PM (g/bhp-hr) post DPF	89%	92%



Photo 3: Emission samples being gathered and measured by Best Environmental

## Outcome of Durability and Emission Testing

On September 10, 2013, the California Air Resources Board issued EXECUTIVE ORDER DE-13-002 thereby providing final verification for the RYPOS Active Diesel Particulate Filter (ActiveDPF/C3+™). The executive order follows.

**State of California  
AIR RESOURCES BOARD**

**EXECUTIVE ORDER DE-13-002**

Pursuant to the authority vested in the Air Resources Board by Health and Safety Code, Division 26, Part 5, Chapter 2; and pursuant to the authority vested in the undersigned by Health and Safety Code section 39515 and 39616 and Executive Order G-02-003;

Relating to Verification under sections 2700 through 2710 of title 13 of the California Code of Regulations (CCR),

RYPOS, Inc.  
Active Diesel Particulate Filter (RYPOS ActiveDPF/C3+™)

The California Air Resources Board (ARB) staff has reviewed RYPOS' request for verification of their active diesel particulate filter and diesel oxidation catalyst system (RYPOS ActiveDPF/C3+™). Based on an evaluation of the data provided, and pursuant to the terms and conditions specified below, the Executive Officer of the ARB hereby finds that the RYPOS ActiveDPF/C3+™ reduces emissions of diesel particulate matter (PM) consistent with a Level 3 device (greater than or equal to 85 percent reduction) (title 13 CCR sections 2702 (f) and (g) and section 2708) and complies with the CARB January 1, 2009, NO<sub>2</sub> limit (title 13 CCR Appendix A section 2702 (f) and section 2706 (a)). Accordingly, the Executive Officer determines that the RYPOS ActiveDPF/C™ merits verification as a Level 3 Plus system for diesel engines on rubber tired gantry (RTG) cranes, subject to the terms and conditions specified below.

This verification is subject to the following terms and conditions:

- The engine must be used in a RTG crane application.
- The engine is greater than 50 hp and a certified Tier 3, 2, or 1, or pre-certification nonroad diesel engine.
- The engine must be in its original certified configuration if it was certified to Tier 1, Tier 2, or Tier 3 nonroad diesel engine emission standards.
- The engine must not employ exhaust gas recirculation.
- The engine must not have a pre-existing oxidation catalyst.
- The engine must not have a pre-existing diesel particulate filter.
- The engine can be a two or four-stroke.
- The engine can be turbocharged or naturally-aspirated.

- The engine must be certified for use in California or pre-certification.
- RYPOS must review actual operating conditions (duty cycle, baseline emissions, and engine backpressure) prior to retrofitting an engine with the RYPOS ActiveDPF/C3+™ to ensure compatibility.
- The engine should be well maintained and not consume lubricating oil at a rate greater than that specified by the engine manufacturer.
- The other terms and conditions specified in Table 1 below.

<b>Parameter</b>	<b>Value</b>
PM Verification Level	Level 3 Plus: <ul style="list-style-type: none"> <li>• PM - at least 85 percent reduction.</li> <li>• NO<sub>2</sub> - meets January 2009 limit.</li> </ul>
Regeneration System	Active
Applications	Both diesel-electric and diesel-hydraulic rubber tired gantry (RTG) crane applications.
Engine Type	Diesel-fueled, with or without turbocharger, certified Tier 3, 2, or 1 or pre-certified off-road engines.
Engine Models	Tier 3 or older off-road engines.
Engine Horsepower	Greater than 50 hp.
Fuel	California diesel fuel with less than or equal to 15 ppm sulfur or a biodiesel blend provided that the biodiesel portion of the blend complies with ASTM D6751, the diesel portion of the blend complies with title 13 (CCR), sections 2281 and 2282, and the blend contains no more than 20 percent biodiesel by volume.
Minimum Exhaust Temperature for Filter Regeneration	Not Applicable (NA). Active DPF.
Maximum consecutive minutes at idle	NA. Active DPF.
Number of Hours of Operation Before Cleaning of Filter Required	Inspect every 1000 hours and clean if needed. Active DPF.

The RYPOS ActiveDPF/C3+™ consists of a filter housing, electrical control circuit, and filter cartridges made of sintered metal fibers, referred to as an active sintered metal diesel particulate filter, and a downstream diesel oxidation catalyst.

Since there may be significant engine configuration and operation variations from application-to-application, RYPOS will review operating conditions (duty cycle, baseline emissions, engine backpressure, maintenance history, and lube oil consumption) prior to retrofitting an engine with a RYPOS ActiveDPF/C3+™ to ensure compatibility. The product must not be used with any other systems or engine modifications without ARB and manufacturer approval.

Furthermore, the engine on which the RYPOS ActiveDPF/C3+™ is installed should be well maintained and not consume lubricating oil at a rate greater than that specified by the engine manufacturer.

Proper engine maintenance is critical for the proper functioning of the diesel emission control strategy. The owner of the vehicle on which the diesel emission control strategy is installed is strongly advised to adhere to all good engine maintenance practices. Failure to document proper engine maintenance, including keeping records of the engine's oil consumption, may be grounds for denial of a warranty claim.

RYPOS, Inc., must ensure that its installation recommendations for the RYPOS ActiveDPF/C3+™ conforms to all applicable industrial safety requirements. The RYPOS ActiveDPF/C3+™ must not be located over any occupied space (RTG crane operator compartments), or be installed in a way which would result in any noncompliance with any applicable safety standards, or in any location deemed unacceptable by RYPOS.

The terms and conditions of this verification must be satisfied regardless of where the system is sold in order for the system to be considered verified. Systems sold as verified, or which carry an ARB-approved label, must satisfy all the terms and conditions of this Executive Order.

This Executive Order is valid provided that installation instructions for RYPOS ActiveDPF/C3+™ do not recommend tuning the engine to specifications different from those specified by the engine manufacturer.

No changes are permitted to the device unless approved by the ARB. ARB must be notified in writing of any changes to any part of the RYPOS ActiveDPF/C3+™ and these changes must be evaluated and approved by ARB. Failure to report any changes shall invalidate this Executive Order.

Changes made to the design or operating conditions of RYPOS ActiveDPF/C3+™ which adversely affect the performance of the engine's pollution control system shall invalidate this Executive Order.

Marketing of the RYPOS ActiveDPF/C3+™ using identification other than that shown in this Executive Order or for an application other than that listed in this Executive Order shall be prohibited unless prior approval is obtained from ARB.

As specified in the Diesel Emission Control Strategy Verification Procedure (title 13 CCR section 2706 (g)), the ARB assigns each Diesel Emission Control Strategy a family name. The designated family name for the verification as outlined above is:

**CA/RYP/2013/PM3+/N00/OF/DPF01**

This identification number should be used in reference to this verification as part of the system labeling requirement. Labels attached to the RYPOS ActiveDPF/C3+™ and the engine must be identical.

Additionally, as stated in the Diesel Emission Control Strategy Verification Procedure, RYPOS, Inc., is responsible for honoring the record keeping requirements (section 2702), their warranty (section 2707) and conducting in-use compliance testing (section 2709).

In addition to the foregoing, ARB reserves the right in the future to review this Executive Order and the verification provided herein to assure that the verified system continues to meet the standards and procedures of California Code of Regulations, title 13, section 2222, et seq and California Code of Regulations, title 13, sections 2700 through 2710.

Systems verified under this Executive Order shall conform to all applicable California emissions regulations. This verification does not release RYPOS, Inc., from complying with all other applicable regulations.

RYPOS, Inc., must comply with all the terms and conditions delineated in the supplemental letter dated September 10, 2013. If RYPOS, Inc., fails to fulfill any of these requirements within the specified time, this Executive Order automatically terminates.

Violation of any of the above conditions shall be grounds for revocation of this Executive Order.

Executed at Sacramento, California, this 10<sup>th</sup> day of September 2013.

Richard W. Corey  
Executive Officer  
by



Cynthia Marvin, Chief  
Stationary Source Division