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TEST REPORT

# TEST OF A NON CATALYTIC WOOD BURNING STOVE FOR EMISSIONS AND EFFICIENCY

PER EPA METHODS 28R AND ASTM E2515 and ASTM E2780, MAY 2015

Client: J.A. Roby
Model Name: Polaris; Sirius; Véga; Antares; Centauri; Rigel

Attention: Rafaël Sanchez

TESTED BY:

Services Polytests
695-B Gaudette
St-jean-sur-Richelieu, QC, J3B 7S7

TEST DATES:
REPORT DATE: 2016 January 12th
Project number: PI-20119



Tested:

Maxime Martin

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Verified (third party certifier):

Intertek representative

C.Pelland, Eng.

# SUMMARY

# List of appendix

# 1 INTRODUCTION

## 1.1 GENERAL

Laboratory

- Location: Services Inc., 695-B Gaudette St-jean-sur-Richelieu QC, Canada J3B 7S7
- Elevation: 100 feet above sea level

Test program

- Purpose: unit qualification NSPS 2020
- Test dates: November 20th to 27th 2013
- Test methods used:
  - Particulate emissions: ASTM E2780-10 ; ASTM E2515-11 methods 28R and as referred into 40 CFR Part 60 Subpart AAA
  - Efficiency: CSA B415.1-10

## 1.2 TEST UNIT INFORMATION

General

- Manufacturer: J.A. Roby
- Product type: non-catalytic freestanding wood stove
- Combustion system: Non-cat with tube as post combustion system
- Unit tested: Polaris

Particularities

Series of six models only esthetical difference as listed below:

- Options: Round door, Legs and no ash pan ( POLARIS) ;Round door, Legs and ash pan (CENTORI) ; Round door, Pedestal and ash pan ( VÉGA) ; Square Door, legs and no ash pan (SIRIUS) ; Square Door, pedestal and ash pan (ANTARES); Square door, legs and ash pan (RIGEL). All drawing and difference listed in appendix 6 Drawing and specification.

## 1.3 RESULTS

Emission results obtained

- Weighted average emission rate: 1.36 grams/hour
- Maximum rate cap: 2.65 grams/hour at run 4

Conformity: NSPS Phase 2020

### 1.4 PRETEST INFORMATION

Unit condition: The unit was received by carrier during month of august. The 50hrs of aging is made in month of October 2015.

Set up

- Venting system type: 6 inch steel pipe and insulated chimney
- System height from floor: 15 feet
- Particularities: none

Break in period

- Duration: the unit received from the manufacturer and run for at least 50 hours at a category 2 burn rate with adequate documentation of fuel additions and flue and unit temperatures during the month of October 2015.
- Fuel: cordwood

## 2 SUMMARY OF TEST RESULTS

### 2.1 EMISSIONS

| Run Number | Test Date | Burn Rate (kg/hr) | Emission Rate (g/hr) | Heating Efficiency (% Overall) | 1st hour Emission Rate (g/hr) | CSA B415.1 CO emission Gr/hr |
|---|---|---|---|---|---|---|
| 1 | 02-11-2015 | 1,525 | 0,26 | 73,7% | 0.44 | 32.62 |
| 2 | 03-11-2015 | 1,102 | 1,15 | 77,8% | 3.2 | 49.28 |
| 3 | 04-11-2015 | 1,077 | 1,47 | 74,8% | 5.23 | 69.9 |
| 4 | 05-11-2015 | 0,843 | 2,65 | 77,9% | 11.34 | 43.2 |
| 5 | 06-11-2015 | 1,389 | 0,55 | 74,7% | 0.92 | 32.1 |

## 2.2 WEIGHTED AVERAGE CALCULATION

| Test No. | Burn Rate | (E) Ave. Emission Rate g/hr | (OHE) | Heat Output (BTU/HR) | Prob. | (K) Weighting Factor |
|---|---|---|---|---|---|---|
| 4 | 0,84 | 2,650 | 78,00 | 11759 | 0,2472 | 0,4388 |
| 3 | 1,08 | 1,470 | 75,00 | 15141 | 0,4388 | 0,4396 |
| 5 | 1,39 | 0,550 | 75,00 | 19500 | 0,6868 | 0,3286 |
| 1 | 1,53 | 0,260 | 74,00 | 20841 | 0,7674 | 0,3132 |
| | | | | | sum | 1.36 |

Weighted Average Emissions Rate: 1.36 g/hr
Weighted Average Overall Efficiency: 75.66%

## 2.3 TEST FACILITY CONDITIONS

| Run Number | Room Temperature | | Barometric pressure | | Relative humidity | | Air Velocity | |
|---|---|---|---|---|---|---|---|---|
| | Before (F) | After (F) | Before (in.Hg) | After (in.Hg) | Before (%) | After (%) | Before (ft/min) | After (ft/min) |
| 1 | 71 | 70 | 30,062 | 29,973 | 42,1 | 35 | 21 | 20 |
| 2 | 74 | 82 | 30,091 | 30,121 | 43 | 28 | 18 | 25 |
| 3 | 72 | 78 | 30,268 | 30,150 | 38,1 | 34,4 | 26 | 24 |
| 4 | 73 | 78 | 30,209 | 30,121 | 37,2 | 38,4 | 24 | 21 |
| 5 | 74 | 73 | 29,796 | 29,825 | 54 | 49 | 19 | 25 |

## 2.4 FUEL QUALITIES

| Run Number | Pre-test Load | | | Test Load | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Loading Weight Wet Basis (lbs) | Moisture Content Dry Basis (%) | Coal bed Weight (lbs) | Weight Wet Basis (lbs) | Density Wet Basis (lbs/cuft) | Moisture Content Dry Basis (%) | Piece Length (in.) | Number of 2X4's | Number of 4x4's |
| 1 | 11,16 | 21,00 | 2,5 | 10,96 | 7,071 | 20,73 | 11,25 | 2 | 2 |
| 2 | 10,25 | 22,00 | 2,4 | 10,17 | 6,561 | 21,31 | 10,75 | 2 | 2 |
| 3 | 10,48 | 22,00 | 2,2 | 10,03 | 6,471 | 21,27 | 10,875 | 2 | 2 |
| 4 | 10,03 | 22,00 | 2,1 | 10,08 | 6,503 | 21,01 | 11,5 | 2 | 2 |
| 5 | 10,20 | 22,00 | 2,3 | 10,11 | 6,523 | 22,27 | 12 | 2 | 2 |

## 2.5 DILUTION TUNNEL FLOW RATE MEASUREMENTS AND SAMPLING DATA (5G-3)

| Average dilution tunnel measurements | | | | Sam pie Data | | | |
|---|---|---|---|---|---|---|---|
| Run Number | Burn Rate (Min) | Volumetrie Flow Rate (dscf/min) | Total Temperatures (°R) | Volume sampled (DSCF) | | Particulate catch (mg) | |
| | | | | 1 | 2 | 1 | 2 |
| 1 | 162 | 158,36 | 560,44 | 35,079 | 33,838 | 1,00 | 0,90 |
| 2 | 207 | 160,76 | 555,17 | 37,388 | 35,865 | 4,60 | 4,10 |
| 3 | 209 | 159,95 | 551,78 | 37,052 | 35,668 | 5,40 | 5,70 |
| 4 | 269 | 162,75 | 548,30 | 47,867 | 46,067 | 13,60 | 11,90 |
| 5 | 162 | 151,10 | 564,19 | 29,382 | 33,375 | 1,70 | 2,10 |

## 2.6 DILUTION TUNNEL DUAL TRAIN PRECISION

| Run Number | Sam pie Ratio | | Total Emission (g) | | |
|---|---|---|---|---|---|
| | Train 1 | Train 2 | Train 1 | Train 2 | % Deviation |
| 1 | 731,33 | 758,15 | 0,73 | 0,68 | 3,47% |
| 2 | 890,05 | 927,83 | 4,10 | 3,82 | 3,52% |
| 3 | 902,26 | 937,27 | 4,87 | 5,35 | 4,67% |
| 4 | 914,61 | 950,34 | 12,44 | 11,31 | 4,73% |
| 5 | 833,10 | 733,42 | 1,44 | 1,54 | 3,48% |

## 2.7 GENERAL SUMMARY OF RESULTS

| Run Number | Burn Rate (kg/hr) | Average Surface Temperature (F) | Change in surface Temperature (F) | Initial Draft (in. $H^2O$) | static pressure tunnel (in. $H^2O$) | Primary Air Setting | Run Time (min) |
|---|---|---|---|---|---|---|---|
| 1 | 1,525 | 402,34 | -42,3 | 0,017 | 0,220 | Full open | 162 |
| 2 | 1,102 | 356,57 | -14,9 | 0,015 | 0,220 | Full close | 207 |
| 3 | 1,077 | 344,12 | 4,6 | 0,014 | 0,200 | Full close | 209 |
| 4 | 0,843 | 331,17 | -23,5 | 0,013 | 0,220 | Full close | 269 |
| 5 | 1,389 | 389,16 | -21,8 | 0,015 | 0,220 | midpoint open | 162 |

# 3 PROCESS DESCRIPTION

## 3.1 DISCUSSION

At the reception of the unit we do preliminary test run to ensure the unit can reach the limit of the standard. We use those run for the aging of the unit

## 3.2 UNIT DIMENSIONS

Baffle

- Location: between top of combustion chamber and hearth
- Restriction: 1 in x 18 1/2 in. at the front of unit
- Dimensions: covers the hearth area minus the restriction at front
- Material: refractory brick and 1 insulation (ceramic wool)

Bricks

- Inside Firebox refractory brick 1inch. tick cover all the sides, bottom and the back of the combustion chamber

Flue gas exhaust

- Location: top flue located at the top
- Dimensions: 6 in. diameter
- Material: Steel

Gasket

- Location:
- door (1/2 round fiberglass rope
- Glass (3/16 flat fiberglass),

Overall unit dimension

- Firebox dimensions : 18 1/4 in wide x 14 5/16 in. deep x 10 to 10 5/8 in. high
- Usable volume : 1.55 cuft

Convection fan

- Manufacturer : Optional blower supplied with unit
- Model : CFA11512038LB
- Spec. : 110V / 60HZ ; 0.2Amps, UL listed component

Catalyst

- none

Door

- Ceramic glass door

## 3.3 AIR SUPPLY SYSTEM

Description

- Primary air: window wash design with air intake at the back of unit
- Secondary air: secondary tube design with air intake at the back of unit

Characterization

The following table shows the inlet and outlet sections of each system. The air introduction system number is referred on a set of drawings in Appendix 6.

| AIR INTRODUCTION SYSTEM | | INLET (1) sq. in. | | | OUTLET |
|---|---|---|---|---|---|
| Identification | Type | Imin | Imax | Controlled | (sq. in.) |
| A * | Primary | 0.39 | 5.14 | Yes | 4.62 |
| B * | Secondary | 0.60 | 2.10 | Yes | 1.86 |
| C * | Pilot | None | None | None | None |

* This section would be filled by measuring and comparing with the manufacturer's drawings included in the test report.

Legend

Identification: Tag name referred on drawings in Appendix 14, section airflow pattern
Type: Characterization of air intake
Imin: Minimum air intake of a particular air channel
Imax: Maximum air intake of a particular air channel
Controlled: Determines if a provision for air control is present
Outlet: Total air outlet of a particular air channel

Note: surfaces are expressed in sq. Inches

## 3.4 OPERATION DURING TEST

Run #1
This run was performed on November 2nd 2015. It lasted 162 minutes and a category 3 burn rate was obtained at 1.53 kg/hr & emission at 0.26 gr/hr. the optional blower was at on position

Run #2
This run was performed November 3rd 2015. It lasted 207 minutes and a category 2 burn rate was obtained at 1.10 kg/hr & emission at 1.15 gr/hr. The optional blower was at on position

Run #3
This run was performed November 4th 2015. It lasted 209 minutes and a category 2 burn rate was obtained at 1.07 kg/hr & emission at 1.47gr/hr. the optional blower was at off position for confirmation test

Run #4
This run was performed November 5th 2015. It lasted 269 minutes and a category 2 burn rate was obtained at 0.84 kg/hr & emission at 2.65 gr/hr. The optional blower was at on position.

Run #5
This run was performed November 6th . It lasted 162 minutes and a category 3 burn rate was obtained at 1.39 kg/hr & emission at 0.55gr/hr. the optional blower was at on position

- Details: Refer to the front page of each test run data sheets found in appendix for the detailed test sequence showing air supply settings and adjustments, fuel bed adjustments and operational specifics of the test unit.

Test fuel cribs

- Type of wood: Douglas fir, grade c or better, 19 to 25% dry basis moisture content
- Description: for each test, description of the fuel crib is found on the front page of each test run data sheet together with photograph in appendix.

## 3.5 STAR-UP OPERATION

The complete manufacturer's firing procedure of each burn rate category is fully described in appendix 13.

## 3.6 SAMPLING LOCATIONS

Particulate samples are collected from the dilution tunnel at a point 15 feet from the tunnel entrance. The tunnel has two elbows and two mixing baffles in the system ahead of the sampling section. The sampling section is a continuous 10 foot section of 6 inch diameter pipe straight over its entire length. Tunnel velocity

pressure is determined by a standard pitot tube located 48 inches from the beginning of the sampling section. Thermocouple is installed on the pitot tube to measure the dry bulb temperature. MC is assumed, as allowed, to be 4%. Tunnel samplers are located 56 inches downstream of the pitot tube and 16 inches upstream from the end of this section.

## 3.7 DRAWINGS

Various drawings of the stack gas sampling train and of dilution tunnel system are found in Appendix 1.

## 3.8 EMISSIONS EFFICIENCY TESTING EQUIPMENT LIST

The complete test equipment list together with all corresponding calibration data can be found in Appendix 3.

# 4 SAMPLING METHODS

## 4.1 PARTICULATE SAMPLING

Particulates were sampled in strict accordance with ASTM 2515. This method uses two identical sampling systems with Gelman AIE 61631 binder free (or equivalent), 47 mm diameter filters. The dryers used in the sample systems are filled with "Drierite" before each test run.

# 5 QUALITY ASSURANCE

## 5.1 INSTRUMENT CALIBRATION

### 5.1.1 GAS METERS

At the conclusion of each test program the gas meters are verified using the reference dry gas meter. This process involves sampling the train operation for 1 cubic foot of volume. With readings made to .01 fr', the resolution is 1 %, giving an accuracy higher than the 2% required by the standard.

### 5.1.2 SCALES

Before each test program, the different scales used are checked with traceable calibration weights to ensure their accuracy.

### 5.1.3 GAS ANALYZERS

The continuous analyzers are zeroed and spanned before each test with NBS traceable gases. A mid-scale multi-component calibration gas is then analyzed (values are recorded). At the conclusion of a test, the instruments are checked again with zero, span and calibration gases (values are recorded only). The drift in each meter is then calculated and must not exceed 5% of the scale used for the test.

## 5.2 TEST METHOD PROCEDURES

### 5.2.1 LEAK CHECK PROCEDURES

Before and after each test, each sample train is tested for leaks. Leakage rates are measured and must not exceed 0.02 CFM or 4% of the sampling rate. Leak checks are performed checking the entire sampling train. Pre-test and post-test leak checks are conducted with a vacuum of 5 inches of mercury. Vacuum is monitored during each test and the highest vacuum reached is then used for the post test vacuum value. If leakage limits are not met, the test run is rejected. During these tests, the vacuum is typically less than 2 inches of mercury. Thus, leakage rates reported are expected to be much higher than actual leakage during the tests.

### 5.2.2 TUNNEL VELOCITY FLOW MEASUREMENT

The tunnel velocity is calculated from a center point pitot tube signal multiplied by an adjustment factor. This factor is determined by a traverse of the tunnel as prescribed in EPA Method 1. Final tunnel velocities and flow rates are calculated from EPA Method 2, Equation 6.9 and 6.10. (Tunnel cross sectional area is the average from both lines of traverse.)

Pitot tubes are cleaned before each test and leak checks are conducted after each test.

### 5.2.3 PM SAMPLING PROPORTIONALITY (ASTM 2515)

Proportionalities were calculated in accordance with ASTM 2515. The data and results are found in appendix.