Derenzo Environmental Services
Consulting and Testing

AIR EMISSION TEST REPORT

Title	AIR EMISSION TEST REPORT FOR THE VERIFICATION OF AIR POLLUTANT EMISSIONS FROM LANDFILL GAS FUELED INTERNAL COMBUSTION ENGINES
Report Date	September 24, 2018
Test Dates	September 11, 2018

Facility Information	
Name	North American Natural Resources, Inc.
Street Address	21545 Cannonsville Rd.
City, County	Pierson, Montcalm

Facility Permit Information			
PTI No.:	45-17	Facility SRN :	N2804

Testing Contractor	
Company	Derenzo Environmental Services
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Project No.	1711015

AIR EMISSION TEST REPORT
FOR THE
VERIFICATION OF AIR POLLUTANT EMISSIONS
FROM
LANDFILL GAS FUELED INTERNAL COMBUSTION ENGINES

NORTH AMERICAN NATURAL RESOURCES, INC.
AT THE CENTRAL LANDFILL

1.0 INTRODUCTION

North American Natural Resources, Inc. (NANR) (Facility SRN: N2804) owns and operates one (1) Caterpillar (CAT®) Model No. G3516 landfill gas (LFG) fueled reciprocating internal combustion engines (RICE) and one (1) CAT® Model No. G3520C LFG fueled RICE at the Central Landfill in Pierson, Montcalm County, Michigan. The CAT® Model No. G3516 engine is identified as Emission Unit ID: EUENGINE2 and the CAT® Model No. G3520C engine is identified as Emission Unit ID: EUENGINE1 (collectively as FGRICEENG) in Permit to Install (PTI) No. 45-17.

Air emission compliance testing was performed to satisfy the following requirements contained in PTI No. 45-17:

- Test both engines from FGRICEENG for emissions of carbon monoxide (CO), nitrogen oxides (NO_x) and sulfur dioxide (SO_2); and
- Test both engines from FGRICEENG for emissions formaldehyde (CH_2O).

The compliance testing was performed by Derenzo Environmental Services, a Michigan-based environmental consulting and testing company. Derenzo Environmental Services representatives Blake Beddow, Brad Thome and Andrew Rusnak performed the field sampling and measurements September 11, 2018.

The exhaust gas sampling and analysis was performed using procedures specified in the Test Plan that was reviewed and approved by the Michigan Department of Environmental Quality (MDEQ). MDEQ representatives Mr. Tom Gasloli and Mr. Dave Morgan observed portions of the testing project.

Questions regarding this emission test report should be directed to:

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Report Certification

This test report was prepared by Derenzo Environmental Services based on field sampling data collected by Derenzo Environmental Services. Facility process data were collected and provided by NANR employees or representatives. This test report has been reviewed by NANR representatives and approved for submittal to the MDEQ.

I certify that the testing was conducted in accordance with the specified test methods and submitted test plan unless otherwise specified in this report. I believe the information provided in this report and its attachments are true, accurate, and complete.

Report Prepared By:

Andy Rusnak, QSTI
Technical Manager
Derenzo Environmental Services

2.0 SOURCE AND SAMPLING LOCATION DESCRIPTION

2.1 General Process Description

Landfill gas (LFG) containing methane is generated in the Central Landfill from the anaerobic decomposition of disposed waste materials. The LFG is collected from both active and capped landfill cells using a system of wells (gas collection system). The collected LFG is transferred to the NANR LFG power station facility where it is treated and used as fuel for the two (2) RICE. Each RICE is connected to an electricity generator that produces electricity that is transferred to the local utility.

2.2 Rated Capacities and Air Emission Controls

The CAT® Model No. G3516 RICE has a rated output of 1,148 brake-horsepower (bhp) and the connected generator has a rated electricity output of 800 kilowatts (kW). The engine is designed to fire low-pressure, lean fuel mixtures (e.g., LFG).

The CAT® Model No. G3520C RICE has a rated output of 2,233 brake-horsepower (bhp) and the connected generator has a rated electricity output of 1,600 kilowatts (kW). The engine is designed to fire low-pressure, lean fuel mixtures (e.g., LFG) and is equipped with an air-to-fuel ratio controller that monitors engine performance parameters and automatically adjusts the air-to-fuel ratio and ignition timing to maintain efficient fuel combustion.

The engine/generator sets are not equipped with add-on emission control devices. Air pollutant emissions are minimized through the proper operation of the gas treatment system and efficient fuel combustion in the engines.

The fuel consumption rate is regulated automatically to maintain the heat input rate required to support engine operations and is dependent on the fuel heat value (methane content) of the treated LFG.

2.3 Sampling Locations

The RICE exhaust gas is directed through mufflers and is released to the atmosphere through dedicated vertical exhaust stacks with vertical release points.

The exhaust stack sampling ports for the CAT® Model G3516 engine (EUENGINE2) are located in the horizontal exhaust duct, prior to the muffler, with an inner diameter of 10.0 inches. The stack is equipped with two (2) sample ports, opposed 90°, that provide a sampling location 39 inches (3.9 duct diameters) upstream and greater than 120.0 inches (>10 duct diameters) downstream from any flow disturbance and satisfies the USEPA Method 1 criteria for a representative sample location.

The exhaust stack sampling ports for the CAT® Model G3520C engine (EUENGINE1) are located in the horizontal exhaust duct, prior to the muffler, with an inner diameter of 13.5 inches. The stack is equipped with two (2) sample ports, opposed 90°, that provide a sampling location 39 inches (2.8 duct diameters) upstream and greater than 120.0 inches (>9 duct diameters) downstream from any flow disturbance and satisfies the USEPA Method 1 criteria for a representative sample location.

Individual traverse points were determined in accordance with USEPA Method 1.

Appendix 1 provides diagrams of the emission test sampling locations.

3.0 SUMMARY OF TEST RESULTS AND OPERATING CONDITIONS

3.1 Purpose and Objective of the Tests

The conditions of PTI No. 45-17 require NANR to test each engine contained in FGRICEENG for carbon monoxide (CO), nitrogen oxides (NO_x), sulfur dioxide (SO_2) and formaldehyde (CH_2O) every five (5) years. Therefore, each engine contained in FGRICEENG was sampled for CO, NO_x, SO_2 and CH_2O emissions and exhaust gas oxygen (O_2) and carbon dioxide (CO_2) content.

3.2 Operating Conditions During the Compliance Tests

The testing was performed while the NANR engine/generator sets were operated at maximum operating conditions (800 kW or 1,600 kW electricity output +/- 10%). NANR representatives provided the kW output in 15-minute increments for each test period. The EUENGINE2 generator kW output ranged between 798 and 810 kW for each test period. The EUENGINE1 generator kW output ranged between 1,545 and 1,600 kW for each test period.

For the testing performed on EUENGINE2 fuel flowrate (scfm), fuel methane content and the air to fuel ratio were recorded by NANR representatives in 15-minute increments for each test period. The EUENGINE2 fuel consumption rate ranged between 316 to 347 scfm, fuel methane content ranged between 53.4 to 54.3% and the air to fuel ratio was set at 8.0 during the test periods.

For the testing performed on EUENGINE1 fuel flowrate (scfm) and fuel methane content were recorded by NANR representatives in 15-minute increments for each test period. The EUENGINE1 fuel consumption rate ranged between 489 to 505 scfm and the fuel methane content ranged between 53.1 to 53.6%.

The MDEQ required that the LFG be sampled for hydrogen sulfide (H_2S) concentration once during the testing period using a Draeger® tube. The results of the sampling indicated a LFG H_2S concentration of approximately 700 parts per million (ppm).

Appendix 2 provides operating records provided by NANR representatives for the test periods and photographs of the Draeger® tubes.

A lower heating value of 909 Btu/ft^3 was used to calculate the LFG heating value.

Table 3.1 presents a summary of the average engine operating conditions during the test periods.

3.3 Summary of Air Pollutant Sampling Results

The gases exhausted from the sampled LFG fueled RICE (EUENGINE2 and EUENGINE1) were each sampled for three (3) one-hour test periods during the compliance testing performed September 11, 2018.

Table 3.2 presents the average measured CO, NO_x, SO_2 and CH_2O emission rates for the engines (average of the three test periods for each engine).

Test results for each one hour sampling period and comparison to the permitted emission rates are presented in Section 6.0 of this report.

Table 3.1 Average engine operating conditions during the test periods

Engine Parameter	EUENGINE2	EUENGINE1
Generator output (kW)	802	1,575
Engine LFG fuel use (scfm)	332	498
LFG methane content (%)	53.8	53.3
LFG lower heating value (Btu/ft^3)	489	484
Air to fuel ratio	8.0	-

Table 3.2 Average measured emission rates for each engine (three-test average)

Emission Unit	CO Emission Rates (lb/hr)	NO_x Emission Rates (lb/hr)	SO_2 Emission Rates (lb/hr)	CH_2O Emission Rates (lb/hr)
EUENGINE2	2.99	0.75	1.90	0.53
Permit Limit	*7.9*	*5.1*	*1.5*	*0.71*
EUENGINE1	10.0	2.73	3.60	1.62
Permit Limit	*20.9*	*9.9*	*2.6*	*2.1*

4.0 SAMPLING AND ANALYTICAL PROCEDURES

A test protocol for the air emission testing was reviewed and approved by the MDEQ. This section provides a summary of the sampling and analytical procedures that were used during the NANR testing periods.

4.1 Summary of Sampling Methods

USEPA Method 1	Exhaust gas velocity measurement locations were determined based on the physical stack arrangement and requirements in USEPA Method 1
USEPA Method 2	Exhaust gas velocity pressure was determined using a Type-S Pitot tube connected to a red oil incline manometer; temperature was measured using a K-type thermocouple connected to the Pitot tube.
USEPA Method 3A	Exhaust gas O_2 and CO_2 content was determined using a paramagnetic and infrared instrumental analyzer.
USEPA Method 6C	Exhaust gas SO_2 concentration was determined using a pulsed fluorescence instrumental analyzer.
USEPA Method 7E	Exhaust gas NO_x concentration was determined using a chemiluminescence instrumental analyzer.
USEPA Method 10	Exhaust gas CO concentration was measured using an infrared instrumental analyzer.
ASTM D6348	Exhaust gas formaldehyde concentration was measured using a Fourier transform infrared spectroscopy (FTIR) analyzer.

4.2 Exhaust Gas Velocity Determination (USEPA Method 2)

The RICE exhaust stack gas velocities and volumetric flow rates were determined using USEPA Method 2 prior to and after each test. An S-type Pitot tube connected to a red-oil manometer was used to determine velocity pressure at each traverse point across the stack cross section. Gas temperature was measured using a K-type thermocouple mounted to the Pitot tube. The Pitot tube and connective tubing were leak-checked prior to each traverse to verify the integrity of the measurement system.

The absence of significant cyclonic flow for the exhaust configuration was verified using an S-type Pitot tube and oil manometer. The Pitot tube was positioned at each velocity traverse point with the planes of the face openings of the Pitot tube perpendicular to the stack cross-sectional plane. The Pitot tube was then rotated to determine the null angle (rotational angle as measured from the perpendicular, or reference, position at which the differential pressure is equal to zero).

Appendix 3 provides exhaust gas flowrate calculations and field data sheets.

4.3 Exhaust Gas Molecular Weight Determination (USEPA Method 3A)

CO_2 and O_2 content in the RICE exhaust gas stream was measured continuously throughout each test period in accordance with USEPA Method 3A. The CO_2 content of the exhaust was monitored using a Servomex 4900 single beam single wavelength (SBSW) infrared gas analyzer. The O_2 content of the exhaust was monitored using a Servomex 4900 gas analyzer that uses a paramagnetic sensor.

During each sampling period, a continuous sample of the RICE exhaust gas stream was extracted from the stack using a stainless steel probe connected to a Teflon® heated sample line. The sampled gas was conditioned by removing moisture prior to being introduced to the analyzers; therefore, measurement of O_2 and CO_2 concentrations correspond to standard dry gas conditions. Instrument response data were recorded using an ESC Model 8816 data acquisition system that monitored the analog output of the instrumental analyzers continuously and logged data as one-minute averages.

Prior to, and at the conclusion of each test, the instruments were calibrated using upscale calibration and zero gas to determine analyzer calibration error and system bias (described in Section 5.0 of this document). Sampling times were recorded on field data sheets.

Appendix 4 provides O_2 and CO_2 calculation sheets. Raw instrument response data are provided in Appendix 5.

4.4 SO_2, NO_x and CO Concentration Measurements (USEPA Methods 6C, 7E and 10)

SO_2, NO_x and CO pollutant concentrations in the RICE exhaust gas streams were determined using a Thermo Environmental Instruments, Inc. (TEI) Model 43i pulsed fluorescence SO_2 analyzer, a TEI Model 42c High Level chemiluminescence NO_x analyzer and a TEI Model 48i infrared CO analyzer.

Throughout each test period, a continuous sample of the engine exhaust gas was extracted from the stack using the Teflon® heated sample line and gas conditioning system and delivered to the instrumental analyzers. Instrument response for each analyzer was recorded on an ESC Model 8816 data acquisition system that logged data as one-minute averages. Prior to, and at the conclusion of each test, the instruments were calibrated using upscale calibration and zero gas to determine analyzer calibration error and system bias.

Appendix 4 provides CO, NO_x and SO_2 calculation sheets. Raw instrument response data are provided in Appendix 5.

4.5 Determination of Formaldehyde Emissions (ASTM D6348)

Formaldehyde and moisture concentration in the RICE exhaust gas streams was determined using a MKS Multi-Gas 2030 Fourier transform infrared (FTIR) spectrometer.

Samples of the exhaust gas were delivered directly to the instrumental analyzer using a Teflon® heated sample line, heated head pump and heated filter to prevent condensation. The sample to the FTIR analyzer was not conditioned to remove moisture. Therefore, formaldehyde measurements correspond to standard conditions with no moisture correction (wet basis).

A calibration transfer standard (CTS), ethylene standard, and nitrogen zero gas were analyzed before and after each test run. Analyte spiking, of each engine, with acetaldehyde and sulfur hexafluoride was performed to verify the ability of the sampling system to quantitatively deliver a sample containing the compound of interest from the base of the probe to the FTIR. Data was collected at 0.5 cm^{-1} resolution. Instrument response was recorded using MKS data acquisition software.

Appendix 4 provides formaldehyde calculation sheets. Instrument response data for the FTIR is provided in Appendix 6.

5.0 QA/QC ACTIVITIES

5.1 NO_x Converter Efficiency Test

The NO_2 – NO conversion efficiency of the Model 42c analyzer was verified prior to the testing program. A USEPA Protocol 1 certified concentration of NO_2 was injected directly into the analyzer, following the initial three-point calibration, to verify the analyzer's conversion efficiency. The analyzer's NO_2 – NO converter uses a catalyst at high temperatures to convert the NO_2 to NO for measurement. The conversion efficiency of the analyzer is deemed acceptable if the measured NO_2 concentration is within 90% of the expected value.

The NO_2 – NO conversion efficiency test satisfied the USEPA Method 7E criteria (measured NO_x concentration was 99.1% of the expected value, i.e., within 10% of the expected value as required by Method 7E).

5.2 Gas Divider Certification (USEPA Method 205)

A STEC Model SGD-710C 10-step gas divider was used to obtain appropriate calibration span gases. The ten-step STEC gas divider was NIST certified (within the last 12 months) with a primary flow standard in accordance with Method 205. When cut with an appropriate zero gas, the ten-step STEC gas divider delivered calibration gas values ranging from 0% to 100% (in 10% step increments) of the USEPA Protocol 1 calibration gas that was introduced into the system. The field evaluation procedures presented in Section 3.2 of Method 205 were followed prior to use of gas divider. The field evaluation yielded no errors greater than 2% of the triplicate measured average and no errors greater than 2% from the expected values.

5.3 Instrumental Analyzer Interference Check

The instrumental analyzers used to measure NO_x, SO_2, CO, O_2 and CO_2 have had an interference response test preformed prior to their use in the field (July 26, 2006, June 12, 2014, November 12, 2015 and April 19, 2016), pursuant to the interference response test procedures specified in USEPA Method 7E. The appropriate interference test gases (i.e., gases that would be encountered in the exhaust gas stream) were introduced into each analyzer, separately and as a mixture with the analyte that each analyzer is designed to measure. All of analyzers exhibited a composite deviation of less than 2.5% of the span for all measured interferent gases. No major analytical components of the analyzers have been replaced since performing the original interference tests.

5.4 Instrument Calibration and System Bias Checks

At the beginning of each day of the testing program, initial three-point instrument calibrations were performed for the NO_x, SO_2, CO, CO_2 and O_2 analyzers by injecting calibration gas directly into the inlet sample port for each instrument. System bias checks were performed prior to and at the conclusion of each sampling period by introducing the upscale calibration gas and zero gas into the sampling system (at the base of the stainless steel sampling probe prior to the particulate

filter and Teflon® heated sample line) and determining the instrument response against the initial instrument calibration readings.

The instruments were calibrated with USEPA Protocol 1 certified concentrations of CO_2, O_2, NO_x, and CO in nitrogen and zeroed using hydrocarbon free nitrogen. The SO_2 instrument was calibrated with USEPA Protocol 1 certified concentrations of SO_2 in air and zeroed using hydrocarbon-free air. A STEC Model SGD-710C ten-step gas divider was used to obtain intermediate calibration gas concentrations as needed.

5.5 Determination of Exhaust Gas Stratification

A stratification test was performed for each RICE exhaust stack. The stainless steel sample probe was positioned at sample points correlating to 16.7, 50.0 (centroid) and 83.3% of each stack diameter. Pollutant concentration data were recorded at each sample point for a minimum of twice the maximum system response time.

The recorded concentration data for each RICE exhaust stack indicated that the measured CO, O_2 and CO_2 concentrations did not vary by more than 5% of the mean across each stack diameter. Therefore, the RICE exhaust gas was considered to be unstratified and the compliance test sampling was performed at a single sampling location within the RICE exhaust stack.

5.6 FTIR QA/QC Activities

At the beginning of each day a calibration transfer standard (CTS, ethylene gas), analyte of interest (acetaldehyde) and nitrogen calibration gas were directly injected into the FTIR to evaluate the unit response.

Prior to and after each test run the CTS was analyzed. The ethylene was passed through the entire system (system purge) to verify the sampling system response and to ensure that the sampling system remained leak-free at the stack location. Nitrogen was also passed through the sampling system to ensure the system is free of contaminants.

Analyte spiking, of each emission unit, prior to and after sampling, with acetaldehyde was performed to verify the ability of the sampling system to quantitatively deliver a sample containing the compound of interest from the base of the probe to the FTIR and assured the ability of the FTIR to quantify that compound in the presence of effluent gas. The spike target dilution ratio was 1:10 (1 part cal gas; 9 parts stack gas).

As part of the data validation procedure, reference spectra were manually fit to that of the sample spectra (two spectra from each test period) and a concentration was determined. Concentration data was manually validated using the MKS MG2000 method analyzer software. The software used multi-point calibration curves to quantify each spectrum. The software-calculated results were then compared with the measured concentrations to ensure the quality of the data.

5.7 Meter Box Calibrations

The Nutech Model 2010 sampling console, which was used for exhaust gas moisture content sampling, was calibrated prior to and after the testing program. This calibration uses the critical orifice calibration technique presented in USEPA Method 5. The metering console calibration exhibited no data outside the acceptable ranges presented in USEPA Method 5.

The digital pyrometer in the Nutech metering consoles were calibrated using a NIST traceable Omega® Model CL 23A temperature calibrator.

Appendix 7 presents test equipment quality assurance data (NO_2 – NO conversion efficiency test data, instrument calibration and system bias check records, calibration gas and gas divider certifications, interference test results, meter box calibration records, Pitot tube calibration records, stratification checks and FTIR QA/QC data).

6.0 RESULTS

6.1 Test Results and Allowable Emission Limits

Engine operating data and air pollutant emission measurement results for each one hour test period are presented in Tables 6.1 and 6.2.

The measured air pollutant concentrations and emission rates for EUENGINE2 are less than the following allowable limits specified in Permit to Install No. 45-17:

- 5.1 lb/hr for NO_x;
- 7.9 lb/hr for CO; and
- 0.71 lb/hr for CH_2O.

The measured air pollutant concentrations and emission rates for EUENGINE1 are less than the following allowable limits specified in Permit to Install No. 45-17:

- 9.9 lb/hr for NO_x;
- 20.9 lb/hr for CO; and
- 2.1 lb/hr for CH_2O.

The measured SO_2 concentrations and emission rates exceeded the following allowable limits specified in Permit to Install No. 45-17:

- 1.5 lb/hr for EUENGINE2; and
- 2.6 lb/hr for EUENGINE1.

6.2 Variations from Normal Sampling Procedures or Operating Conditions

The testing for all pollutants was performed in accordance with USEPA methods and the approved test protocol. The engine-generator sets were operated within 10% of maximum output (800 kW or 1,600 kW generator output) and no variations from normal operating conditions occurred during the engine test periods.

Table 6.1 Measured exhaust gas conditions and NO_x, CO, SO_2 and CH_2O air pollutant emission rates for EUENGINE2

Test No.	1	2	3	
Test date	9/11/18	9/11/18	9/11/1818	Three Test
Test period (24-hr clock)	746-846	903-1003	1017-1117	Average
Fuel flowrate (scfm)	328	333	335	332
Generator output (kW)	801	806	800	802
LFG methane content (%)	53.9	53.9	53.5	53.8
LFG heat content (Btu/scf)	490	490	486	489
Air to fuel ratio	8.0	8.0	8.0	8.0
Exhaust Gas Composition				
CO_2 content (% vol)	11.7	12.0	12.0	11.9
O_2 content (% vol)	8.15	7.76	7.91	7.94
Moisture (% vol)	12.4	13.6	13.6	13.2
Exhaust gas flowrate (dscfm)	2,076	2,081	2,178	2,112
Exhaust gas flowrate (scfm)	2,371	2,408	2,521	2,433
Nitrogen Oxides				
NO_x conc. (ppmvd)	37.7	61.4	49.4	49.5
NO_x emissions (lb/hr)	0.56	0.92	0.77	0.75
Permitted emissions (lb/hr)	-	-	-	5.1
Carbon Monoxide				
CO conc. (ppmvd)	337	315	320	324
CO emissions (lb/hr)	3.06	2.87	3.04	2.99
Permitted emissions (lb/hr)	-	-	-	7.9
Sulfur Dioxide				
SO_2 conc. (ppmv)	90.6	89.3	90.6	90.2
SO_2 emissions (lb/hr)	1.88	1.86	1.97	1.90
Permitted emissions (lb/hr)	-	-	-	1.5
Formaldehyde				
CH_2O conc. (ppmv)	45.2	47.5	47.7	46.8
CH_2O emissions (lb/hr)	0.50	0.54	0.56	0.53
Permitted emissions (lb/hr)	-	-	-	0.71

Table 6.2 Measured exhaust gas conditions and NO_x, CO, SO_2 and CH_2O air pollutant emission rates for EUENGINE1

Test No.	1	2	3	
Test date	9/11/18	9/11/18	9/11/1818	Three Test
Test period (24-hr clock)	1232-1332	1346-1446	1500-1600	Average
Fuel flowrate (scfm)	495	500	500	498
Generator output (kW)	1,559	1,577	1,588	1,575
LFG methane content (%)	53.4	53.3	53.3	53.3
LFG heat content (Btu/scf)	485	484	484	484
Exhaust Gas Composition				
CO_2 content (% vol)	11.6	11.5	11.6	11.6
O_2 content (% vol)	8.35	8.35	8.36	8.35
Moisture (% vol)	13.2	13.2	13.2	13.2
Exhaust gas flowrate (dscfm)	4,063	4,278	3,923	4,088
Exhaust gas flowrate (scfm)	4,682	4,930	4,521	4,711
Nitrogen Oxides				
NO_x conc. (ppmvd)	93.3	92.2	93.8	93.1
NO_x emissions (lb/hr)	2.72	2.83	2.64	2.73
Permitted emissions (lb/hr)	-	-	-	9.9
Carbon Monoxide				
CO conc. (ppmvd)	560	563	565	563
CO emissions (lb/hr)	9.94	10.5	9.67	10.0
Permitted emissions (lb/hr)	-	-	-	20.9
Sulfur Dioxide				
SO_2 conc. (ppmv)	88.1	89.3	87.1	88.2
SO_2 emissions (lb/hr)	3.58	3.81	3.41	3.60
Permitted emissions (lb/hr)	-	-	-	2.6
Formaldehyde				
CH_2O conc. (ppmv)	73.9	73.4	73.1	73.5
CH_2O emissions (lb/hr)	1.62	1.69	1.55	1.62
Permitted emissions (lb/hr)	-	-	-	2.1