Thermoelectric Generator Installation at Divide Road Weather Information Systems (RWIS)

Cover: AKDOT RWIS site Divide, Seward Highway MP 11.7
Photo Credit: Jay Scrimshaw March 28, 2016

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REPORT DOCUMENTATION PAGE			Form approved OMB No.
Public reporting for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestion for reducing this burden to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-1833), Washington, DC 20503			
1. AGENCY USE ONLY (LEAVE BLANK) 4000(160)	2. REPORT DATE April 13, 2016	3. REPORT TYPE AND DATES COVERED Final Report (February 2016– April 2016)	
4. TITLE AND SUBTITLE Installation of GenTherm 5060 Thermoelectric Generator (TEG) at Divide RWIS site			5. FUNDING NUMBERS AKSAS # 76321 IRIS # HFHWY00006 Federal Number 4000(160)
6. AUTHOR(S) Jay Scrimshaw			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Marsh Creek LLC 2000 E 88th Avenue Anchorage, AK 99507			8. PERFORMING ORGANIZATION REPORT NUMBER 4000(160)
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Alaska Department of Transportation and Public Facilities Research, Development &Technology Transfer 3132 Channel Drive Juneau, Alaska 99811-2500			10. SPONSORING/MONITORING AGENCY REPORT NUMBER 4000(160)
11. SUPPLEMENTARY NOTES			
12a. DISTRIBUTION / AVAILABILITY STATEMENT No restrictions. Copies available online at http://www.dot.alaska.gov/stwddes/research/search_lib.shtml			12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

The Department of Transportation and Public Facilities (DOT&PF) has a network of Road Weather Information System (RWIS) environmental sensor stations (ESS) deployed along the road network. Six of the stations do not have access to commercial power and are off-grid. DOT&PF has used power modules with propane generators for these sites for the past 12 years. The generators and electronics have outlived the life expectancies and all of the sites have failed.

New technology was suggested in the "*Review of Power Sources for Alaska DOT Road Weather Information System (RWIS): Phase I"* final report completed in August, 2014 with the Institute of Northern Engineering. This report documents the installation of a Thermoelectric Generator (TEG) at the Divide Road Weather Information System (RWIS) Located at mile post 11.7 on the Seward Highway.

14. KEYWORDS: Road Weather Information System (RWIS), Environmental Sensor Stations (ESS), Thermoelectric Generator (TEG), Commercial Power, Off-grid power sources, Propane generator, Divide Road, Seward Highway			15. NUMBER OF PAGES 9
			16. PRICE CODE N/A
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT None

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3 m^3
	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

Introduction:

The Department of Transportation and Public Facilities (DOT&PF) has a network of Road Weather Information System (RWIS) environmental sensor stations (ESS) deployed along the road network. Six of the stations do not have access to commercial power, i.e., they are off-grid. DOT&PF has used power modules with propane generators for these sites for the past 12 years. The generators and electronics have outlived the life expectancies; all of the sites have failed.

DOT&PF has upgraded two of the sites with the Kohler 6VSG propane generators. The Turnagain Pass installation has performed reasonably well. However, the Richardson Highway Stuart Creek site has been down more than up. One on the issues is the Kohler unit is not designed to be installed inside and venting has been an issue. The electrical components that control the run time have not worked satisfactorily, resulting in excessive maintenance trips to the sites. DOT&PF received an Acumentrics RP20 Remote Power Generator, based on fuel cell technology, from the Department of Administration's Enterprise Technology Service. The RP20 fuel cell was installed at the Klondike Highway border crossing site. The unit has required extensive repairs and the electrical controllers have not operated as designed. Therefore, DOT&PF is looking for a suitable remote power supply that can be easily deployed, operated at lower cost, and have higher in-service operational rates.

DOT&PF completed a research project (*Review of Power Sources for Alaska DOT Road Weather Information System (RWIS): Phase I* final report, August, 2014 with the Institute of Northern Engineering - for DOT&PF to address potential off-grid power replacements. The completed research: (1) reviewed existing power sources that are being used for off-grid applications, (2) analyzed the power consumption for sensors, communication, and operation for the environmental sensor station (ESS), and (3) provided alternatives for powering ESS in the off-grid environment. The report recommended developing a scaled-down version of the Federal Aviation Administration (FAA) thermoelectric generator (TEG) for ESS operations. The DOT&PF RWIS project manager has visited the FAA test center in Anchorage and had a favorable view of the TEG installation and operation.

DOT&PF initiated a Department Research, Development, and Technology Transfer Needs Statement in 2015. The DOT&PF Research Board approved the project in April 2015. Marsh Creek Energy Systems was contracted to procure and install the TEG, retrofit the existing power module site for the TEG, and commission the site. The remainder of the report will cover Marsh Creek's experience with the TEG installation and include:

Installed Equipment:

(1) Gentherm 5060 Thermoelectric Generator

(4) Trojan 8D-AGM 12V 230 AH @ 20-Hr Rate installed in parallel

(1) Ethertek Circuits RMS-300 Remote Monitoring System (mounting box, conduit, and wiring)

(1) Simpson Electric Company current shunt 10A @ 50mV

(1) Sixnet ET-5ES 5-Port industrial Ethernet Switch

(1) Marsh Creek fabricated external TEG platform

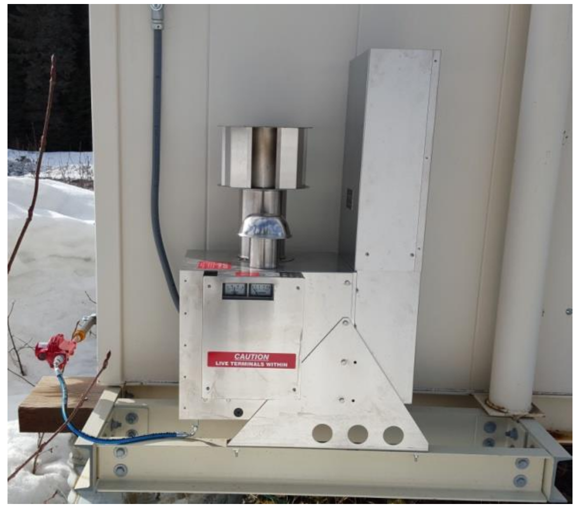
(1) Marsh Creek fabricated external mounted hard propane line.

(1) Fischer R122H propane regulator

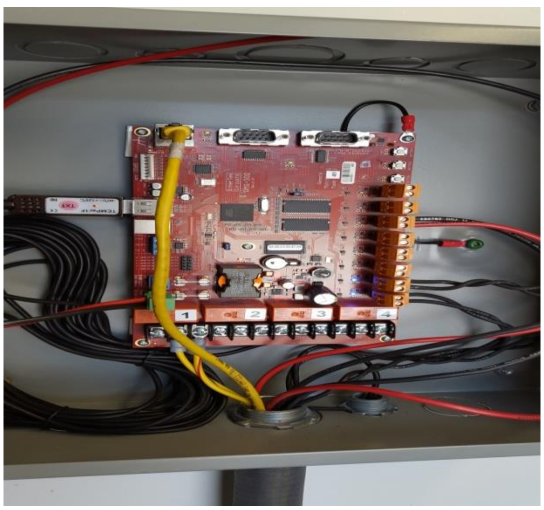
(1) Aeroquip FC-300-12 flexible propane hose with Aeroquip FBM series reusable fittings (hose end and adapters)

Installation:

External Mounted TEG and propane line/regulator

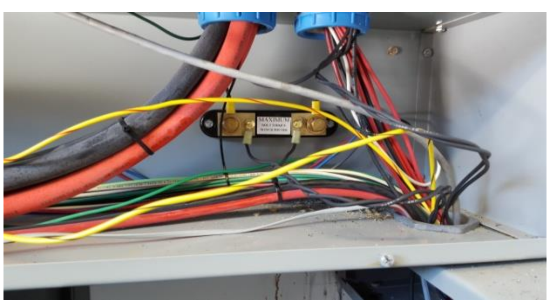


External Mounted TEG on custom platform

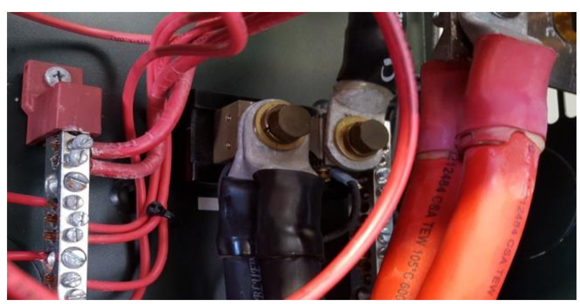


RMS-300 Remote Monitoring System

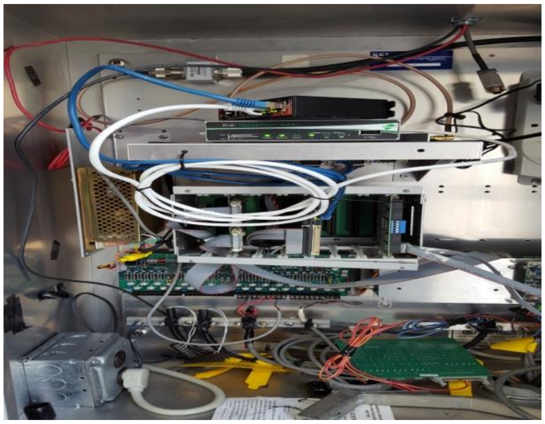
Installation of RMS-300 in control box and conduit



TEG Current Shunt 10A @ 50mV



Existing Battery Shunt 500A @ 50mV



Existing Comms cabinet with Sixnet Ethernet Switch

Existing DC breaker panel with labeled TEG breaker

Power Budget:

An estimation of input power systems, battery storage, and sensor power usage can be made to determine future operation, storage and power strategies. As of this date all sensor systems are in operation and the TEG is providing enough power during the night to supply the systems. In the day time the solar charger/inverter takes over and supplies all the systems and recharges the batteries as needed.

The power output of the TEG is rated at about 50 watts continuously and is currently putting out about 55watts and operating as advertised.

The currently installed solar panel system is rated at about 720 Watts (6 x 120 watts panels) and appears to be fully functional and operational. Based on the "Review of Power Sources for Alaska DOT RWIS Phase I" report, the minimum amount of available solar energy during December is 0.18 KWh/day. This would represent the worst case scenario for solar energy available.

Marsh Creek installed four (4) Trojan 8D-AGM 12 Volt batteries with a 230 AH storage @ 20-Hr rate at 77 Degrees Fahrenheit. 4 x 230 = 920 AH can be delivered over a 20 hour period. However the battery storage will be de-rated at lower temperatures and will only store about 80% of charge at around 40 degrees Fahrenheit, so 920 AH x 80% = 736 AH over a 20 hour period of discharge. Broken down into hours is 736A/20H = 36.8 Amps per hour. It is a nominal 12 Volts system so power will be about 36.8 x 12 Volts = 441 Watts of energy storage available per hour for 20 hours. The associated Outback Inverter has a rated efficiency at about 90%, so useful energy storage is about 400 Watts per hour.

The "Review of Power Sources for Alaska DOT RWIS Phase I" report identifies a power demand of all sensors and camera (without heat) at about 55 watts. Marsh Creek installed an RMS-300 and the Ethernet Switch adding about another 5 watts of energy draw for a total of 60 watts. However the list of installed devices provided by Vaisala Field Service Engineer (located in list of currently installed devices) suggests there is about 110 Watts of power consumption if every device was operating full time, but they are not all operating full time and are often in dormant or idle mode unless called upon to be used.

Issues and Challenges with Deployment:

Marsh Creek configured and installed a remote monitoring system (RMS-300) that would monitor TEG output power, battery input/output power consumption and draw, battery voltage, and internal shelter temperature. The RMS-300 is connected to the Ethernet switch and will allow remote log into the system to monitor the data collection. The RMS-300 system would allow us to have e-mailed notices sent for any possible monitoring scenario that we would want to be informed about such as battery voltage, extreme temperature, and many other feature currently not configured at the moment (i.e., alarm input pins, general I/O pins, controllable power relays, USB Ports for cameras, USB flash drives, temperature sensors, watch dog reset circuits, etc)

The RMS-300 is currently collecting data and storing that info.

Assessment and analysis for the installation, operation, batteries, sensors, maintenance, and long term viability:

In order to better understand the future needs and operational characteristics of the site; the Outback solar charge controller/Inverter needs to be upgraded and/or integrated into the RMS-300 for data collection and analysis. Right now the RMS-300 is only collecting data on the TEG and load draw/charge of the batteries, so no real usable data is being collected with the solar power source and inverter to understand the overall efficiency of the system. The Outback system has data collection and monitoring but it is not accessible remotely or integrated into a proper data collection system like the RMS-300.

The TEG is operating 100% of the time and is the primary energy source for the site. Any extra energy draw comes from the storage of the batteries (or solar if collecting) and is then recharged when the solar system is collecting good sun energy. For minimal power draw around 60 watts this is a viable system and should last 7-10 years based on battery life.

The TEG has a suggested maintenance interval of one year. To include measurement of the "Vset" parameter, replacement of the fuel filter in the pressure regulator, draining of the pressure regulator sediment bowl, and a clean and inspect the interior cabinet and cooling fins. All of which can be found in the Gentherm 5060 operating manual. However it would be recommended that an assessment be performed at 4-6 month intervals until it was determined that one year was enough.

List of currently installed power consuming devices used at Divide RWIS site:

The following list of devices was provided by Brian Findley (Field Service Engineer for Vaisala)

Line Powered Linux RPU: This is the power supply for all sensors and can output a max of 60 watts at +12, -12 and +5 volts DC. Power consumption by the device alone without any sensors attached is 11.5 Watts.

RavenX cell modem: Dormant/Idle 1.3 Watts, Receiving 2.5 Watts, Transmitting 2.5 Watts

ClearM2M-S cellular amplifier: Idle 3 Watts, Operational 12 Watts

AXIS P1354-E Network Camera: PoE Max 25.5 Watts

Cantronics IR Illuminator: Max 55 Watts

Sixnet ET-5ES Ethernet Switch: Max 4 Watts

Remote Monitoring System RMS-300: 1.2 Watts

Recommendations on future site conversions:

There are many outdated and obsolete devices in the RWIS module, some of which may be drawing power that is not being used by any device. It was already observed that relays and circuit boards were being powered in control cabinets that are not currently being used. It is recommended that all of these devices and control cabinets be removed and any excess wires be removed and groomed proper. Remove the old propane generator and all associated battery chargers and wiring.

There is a slow, but noticeable water leak which seems to be coming from the roof, leaking into the walls and exiting to the floor of the module in the corner below the main DC breaker. This leak needs to be identified and sealed.

If greater loads are to be expected, then the battery storage capabilities needs to increase and/or a second TEG would need to be installed. It would seem the solar panels would be adequate enough to refresh the batteries when the sun is shining with December being the only questionable month with only 0.18 KWh/day of useful energy.

A full blown test would need to be executed in order to fully understand the efficiency of the system/s. For example install a small electric heater with known power draw of about 100 watts and place that on a timer with various on off cycles programmed in. Integrate the Outback system into the RMS-300 and run the system for a month to collect data. If successful, then more loads could be applied with intervals of 100 watts to find the limits of useful power draw and recovery by the solar system.

In order to fully understand the energy consumption of devices and energy production of TEG and Solar, all of the devices will need to be monitored and connected to the RMS-300 for data collection.