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Fuel Performance Catalyst (FPC) Fuel Additive

Brake Specific Fuel Consumption
Field Test Report

Prepared For: FerroMex

Prepared By: FPC International, Inc.
South Point, Ohio, USA

January 24, 2012

Test Equipment

The locomotive being tested had to be instrumented so that the brake specific fuel consumption could be determined. The sensors used are detailed in the sub-sections that follow. Each sensor was wired to a central data logger, which took a reading from all of the sensors every two seconds. The data was obtained by FerroMex personnel to guarantee data integrity.

Fuel Consumption Instrumentation

The test locomotive was instrumented with fuel flow meters from Hoffer Flow Controls, Inc. Flow rates in both the supply and return fuel lines of the test locomotive were measured. These volumetric flow meters measure fuel flow in gallons-per-minute. Platinum RTD (resistance temperature detector) sensors were placed at the flow meters to record the fuel temperature as it passed through the flow meter. The temperature of the fuel and the fuel density, as determined by hydrometer measurements, were used to convert the fuel consumption from volumetric (gallons-per-hour) measurements to gravimetric (pounds-per-hour) measurements.

Per the flow meter's specification sheet, the measuring repeatability is better than ±0.1% over their calibration range. The NIST-traceable calibration reports for the flow meters can be found in Appendix 1.

Figure 1 shows the locomotive's fuel lines before any instrumentation was installed. Figure 2 shows how the flow meters and temperature sensors were added to the line for the testing. Insulating material was added over the temperature sensors to eliminate any cooling that might be caused by wind.

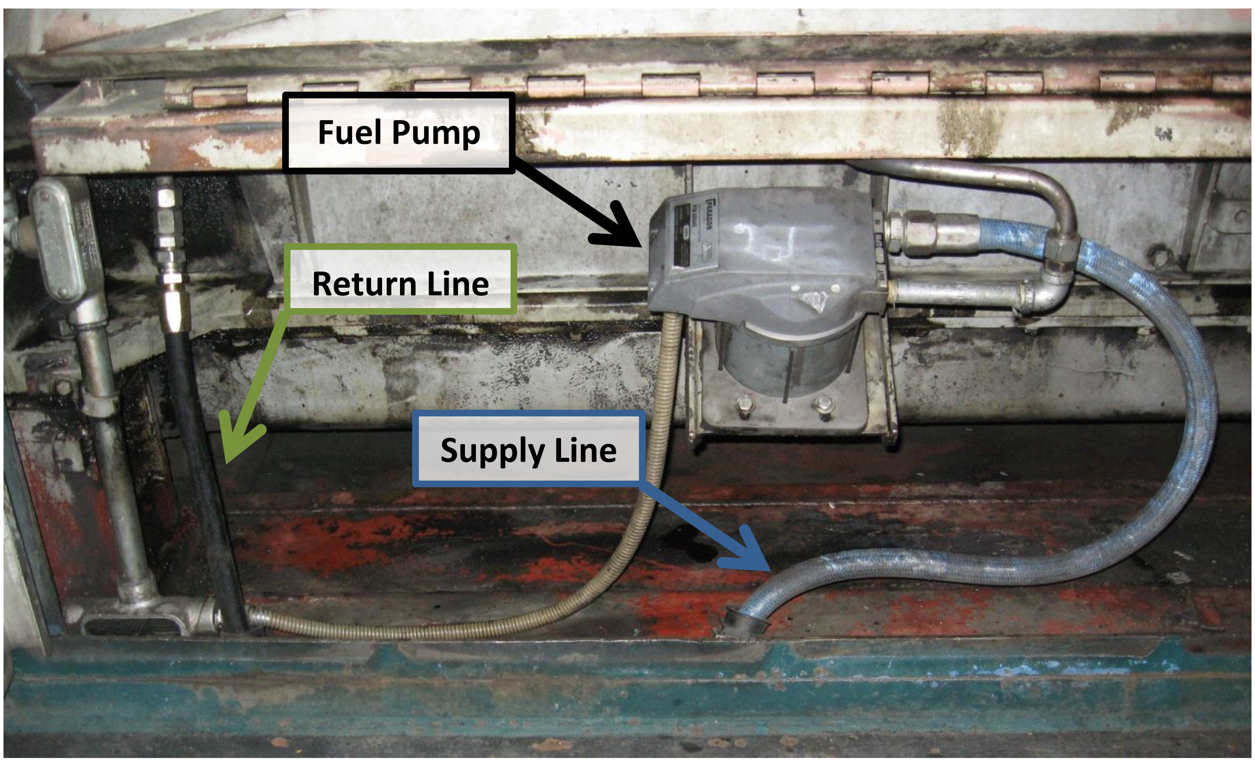


Figure 1 – Locomotive Fuel Lines before Flow Meter Installation

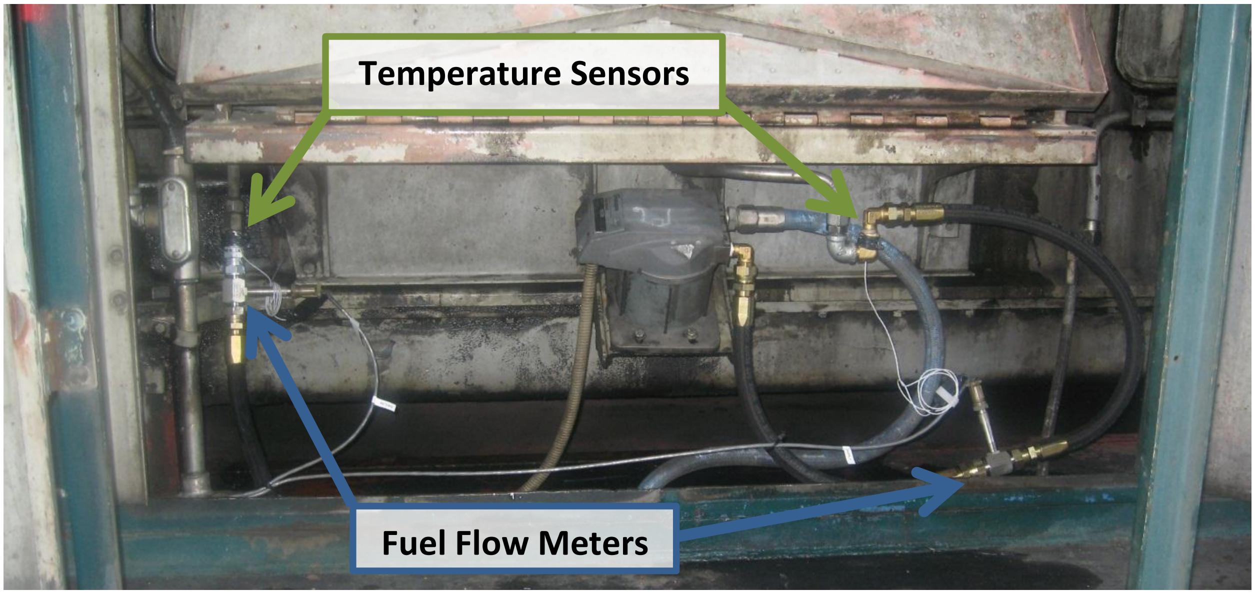


Figure 2 – Locomotive Fuel Lines with Flow Meters and Temperature Sensors Installed

Power Generation Instrumentation

The locomotive being tested was a direct current (DC) unit which can generate up to 1050 volts and 2600 amperes.

A true-RMS (root-mean-squared) voltage transducer from Ohio Semitronics was used to monitor the voltage potential. The unit used has an accuracy of ±0.25% and outputs a 4-20mA signal to provide immunity to any electromagnetic interference. The installation is shown in Figure 3 and Figure 4.

A hall-effect current sensor was used to measure the DC current from the generator. The sensor was connected to a true-RMS transducer, which converted the raw measurements from the hall-effect sensor to a 4-20mA signal to provide immunity to electromagnetic interference. The sensor has an accuracy of ±1%. Figure 5 shows the unit on the wires that make up the main power bus in the locomotive.

Data Logging

Figure 6 shows the data logging system and the DC-to-DC power transformer that was used to shift the 72 volts generated by the locomotive to 12 volts, which powered the data logger and the sensors. The data logger was configured to acquire data from all of the sensors every two seconds. Data was stored to the data logger's internal Compact Flash memory and downloaded using USB memory sticks.

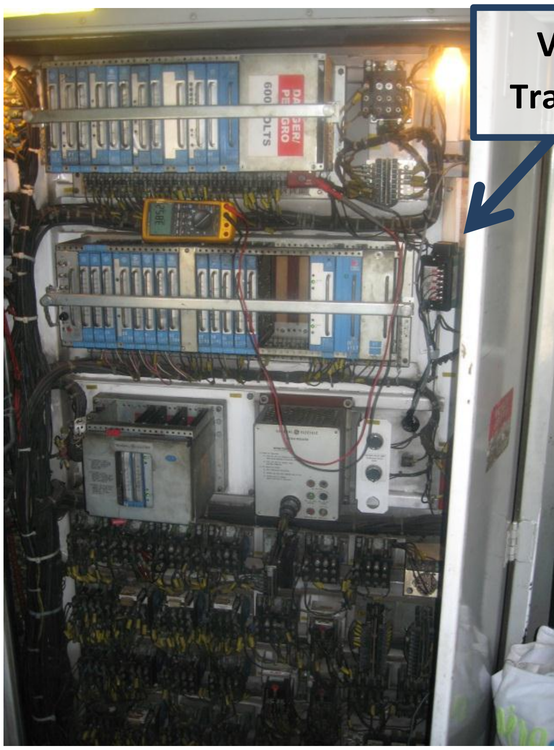


Figure 3 – Locomotive Electrical Cabinet

Figure 4 – Close Up of Voltage Transducer in Locomotive Electrical Cabinet

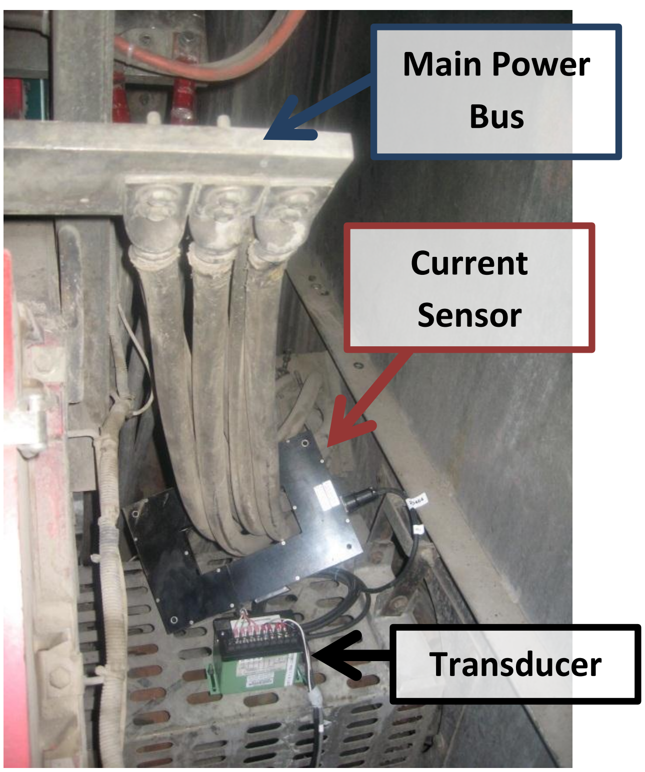


Figure 5 – Hall-Effect Current Transducer

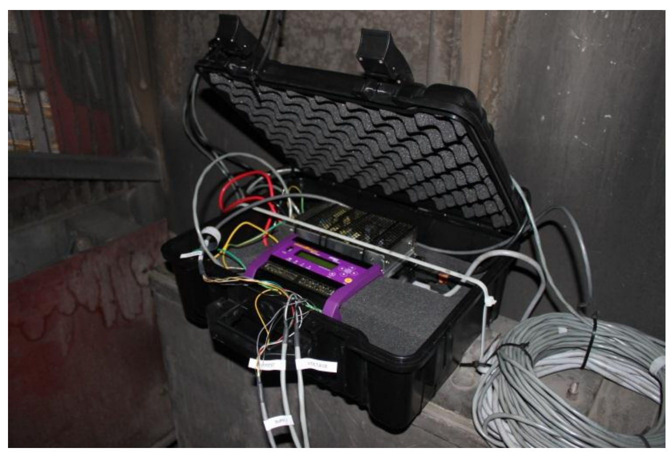


Figure 6 – Data Logger and DC-to-DC Power Transformer

Test Procedure

The locomotive was connected to a load box and run at throttle notches 2, 4, 6, and 8 for two hours at each notch. This process was repeated on three days to obtain data with baseline fuel and then repeated again for three days with fuel treated with FPC. With the data logger recording data every two seconds, nearly 3600 data points were collected during each 2 hour trial for a given notch setting. This was done to validate that the sensor system was repeatable and that the data was accurate. More than 86000 data points were collected over the course of the testing.

Figure 7 – Load Box used to Dissipate Power from Test Locomotive

Figure 8 – Load Box Connected to Test Locomotive

Between the baseline testing and the treated testing, the locomotive was returned to active service and run for approximately 200 operating hours. These 200 operating hours were needed to condition the engine on the treated fuel. Figure 9 shows the plotted results from the Southwest Research Institute's (SwRI) AAR RP-503 test, which shows a slow gradual increase in performance over the course of a 200-hour conditioning cycle. The SwRI testing was done on a new locomotive engine, so this conditioning period has nothing to do with engine cleaning or carbon buildup removal.

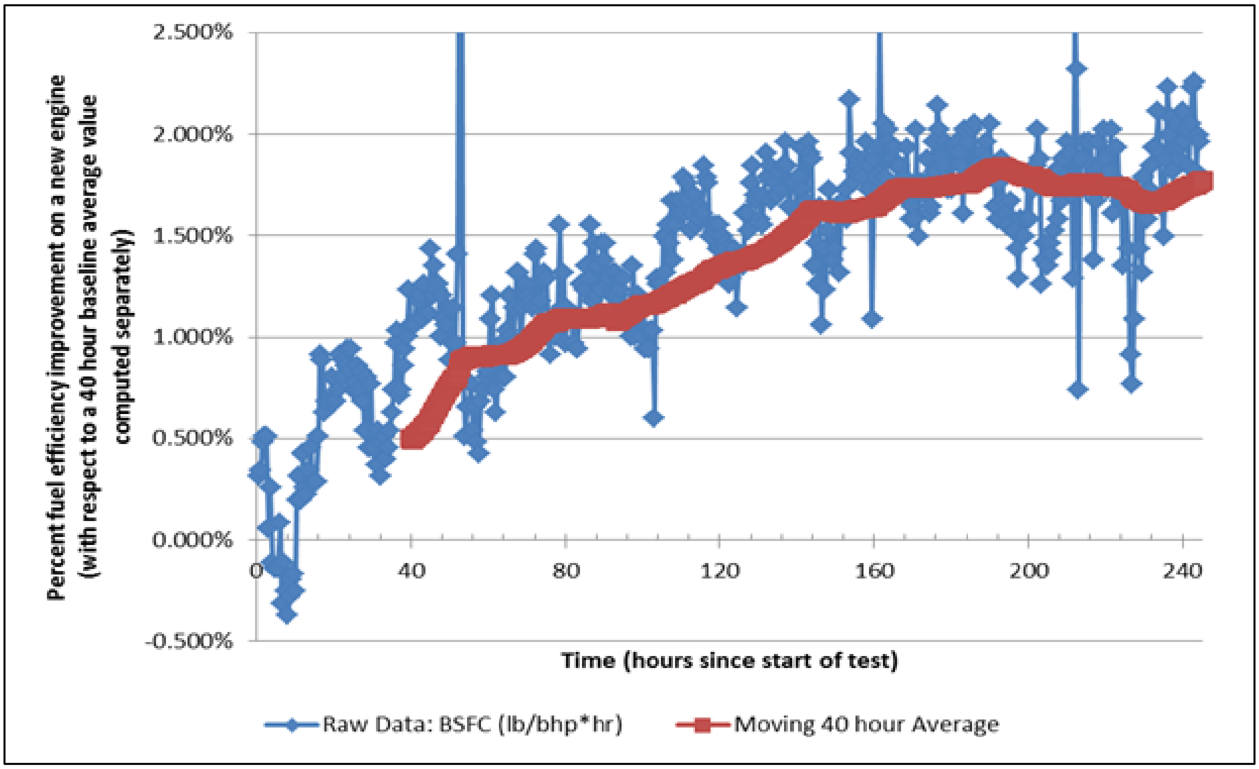


Figure 9 – Southwest Research Institute Test Results with FPC on a New Locomotive Engine

Data Processing

The raw data returned from the data logger included the following data items in a comma-separated-variable file:

- A time stamp that included the date and time.
- The DC voltage, in volts, generated by the locomotive.
- The DC current, in amperes, generated by the locomotive.
- The temperature, in degrees Celsius, of the fuel through the supply fuel line.
- The frequency of pulses generated by the supply flow meter.
- The total number of pulses generated by the supply flow meter.
- The temperature, in degrees Celsius, of the fuel through the return fuel line.
- The frequency of pulses generated by the return flow meter.
- The total number of pulses generated by the return flow meter.

Flow Meter Analysis

The data logger recorded the frequency and total count of pulses from both the supply and return flow meter every two seconds. To convert the frequency to a flow rate (i.e. gallons-per-minute) the Flowmeter Calibration

Report must be used. The calibration report is available in Appendix 1 and provides a NIST-traceable calibration for each of the flow meters at 12 different test points.

A least squares linear regression technique was used to fit the results at the 12 different test points to a third-order (quintic) function. The result is the third-order equation that best fits the calibration data. For the fuel supply flow meter, the equation was found to be:

$$GPM = -1.900609 \times 10^{-10} \times f^3 + 4.535365 \times 10^{-7} \times f^2 + 0.026199 \times f + 0.016228$$

where GPM is the resulting flow rate in gallons-per-minute and f is the pulse frequency from the supply flow meter. For the fuel return flow meter, the equation was found to be:

$$GPM = -2.11522 \times 10^{-10} \times f^3 + 3.91198 \times 10^{-7} \times f^2 + 0.026427 \times f + 0.002884$$

The calibration test data points and the results of the curve fitting are shown in Figure 10 and Figure 11.

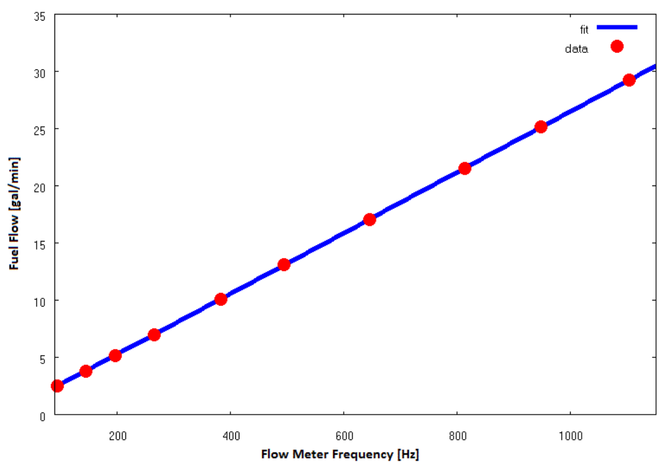


Figure 10 – Supply Flow Meter Calibration Curve Fit

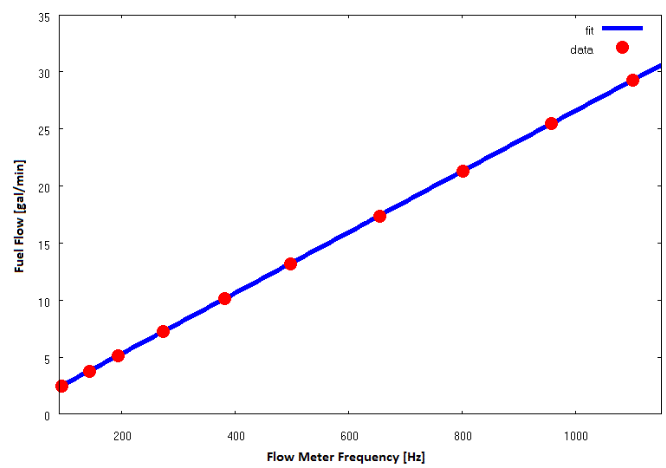


Figure 11 – Return Flow Meter Calibration Curve Fit

Throughout the entire course of testing the fuel supply flow meter output stayed between 258 hertz and 281 hertz. The error from the curve fitting in this range is less than 0.005179 gallons-per-minute. The output from the fuel return flow meter stayed between 163 hertz and 270 hertz. The error from the curve fitting in this range is less than 0.007631 gallons-per-minute.

With the flow rates calculated in gallons-per-minute, the next step was to correct for temperature. The volume of fuel changes with temperature. The procedure defined by ASTM D1250-80 was used to perform the volume corrections. Using the fuel's density and temperature, Table 54B of ASTM D1250-80 was used to determine a Volume Correction Factor (VCF) that normalizes the volumetric flow rate to 15 degrees Celsius.

The density of the fuel was measured by hydrometer. The hydrometer readings were also normalized to 15 degrees Celsius. This was done using Table 53B of ASTM D1250-80, which takes a hydrometer reading at an observed temperature and provides a density value at 15 degrees Celsius. Figure 12 and Figure 13 show the hydrometer and temperature readings used to compute the fuel density. 0.831 kilograms-per-liter was used as the density of the baseline fuel and 0.833 kilograms-per-liter was used as the density of the treated fuel.

It should be noted that FPC does not change the density of the fuel, or any fuel specification for that matter. The density of the treated fuel is different from the density of the baseline fuel because the fuel came from a different batch of fuel. The locomotive was run for 200 operating hours on FPC treated fuel between the baseline testing and treated testing. This conditioning period was introduced because of the findings of the Southwest Research Institute (SwRI) AAR- RP-503 test results.

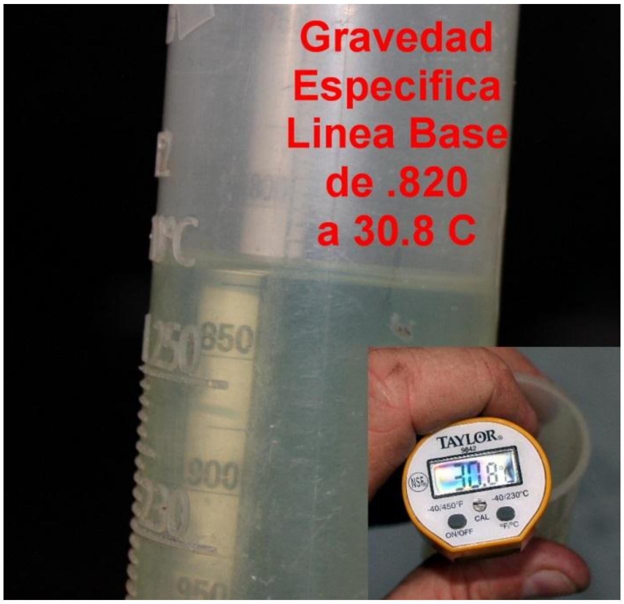


Figure 12 – Baseline Fuel Specific Gravity Measurement

Figure 13 – FPC Treated Fuel Specific Gravity Measurement

With the fuel results normalized to volumetric (e.g. gallons-per-minute) flow rates at 15 degrees Celsius the next step was to convert the data to gravimetric (e.g. pounds-per-minute) flow rates. By doing this the data is corrected for both temperature and density and the brake specific fuel consumption can be determined and compared. The gravimetric flow rate was determined by multiplying the volumetric flow rate by the fuel density.

Power Analysis

The power produced was determined by multiplying the measured DC voltage by the measured DC current. This provided the power in watts. This was then converted to units of horsepower.

Results

The recorded data for each of test days is shown in Figure 14 through Figure 19. The brake specific fuel consumption results are shown in green and match up with the values on the vertical axis on the left-side of the charts. The power and fuel consumption values match up with the values on the vertical axis on the right-side of the charts. Data was collected once every two seconds. Two hours of data was collected for throttle notch 2, 4, 6, and 8. This 8 hour test was repeated three times on baseline fuel and then three times again on FPC treated fuel.

On the first baseline test the power and fuel fluctuated while in throttle notch 8. It seemed to drop to a level that would be expected at notch 7. It is not known what caused this anomaly. The data during the periods where the power and fuel consumption decreased was not used to determine the average brake specific fuel consumption results for notch 8 on this day.

The charts show that the data is quite consistent implying that the sensors used had good repeatability.

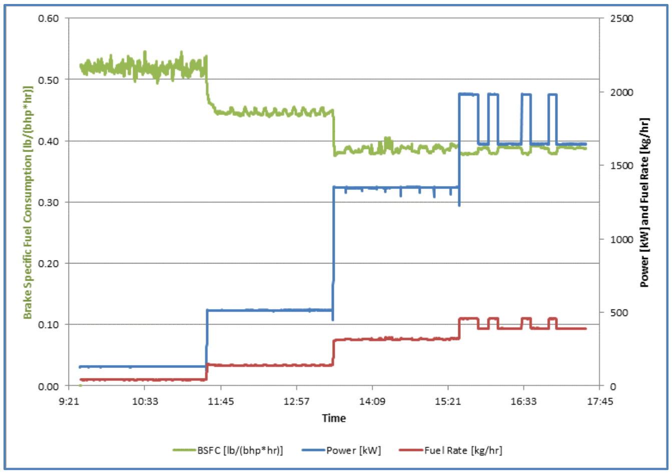


Figure 14 – Results from First Baseline Test (14-September-2011)

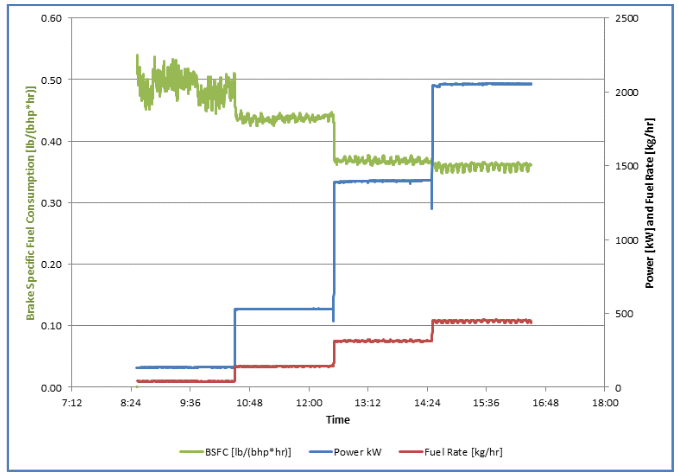


Figure 15 – Results from First Treated Test (28-November-2011)

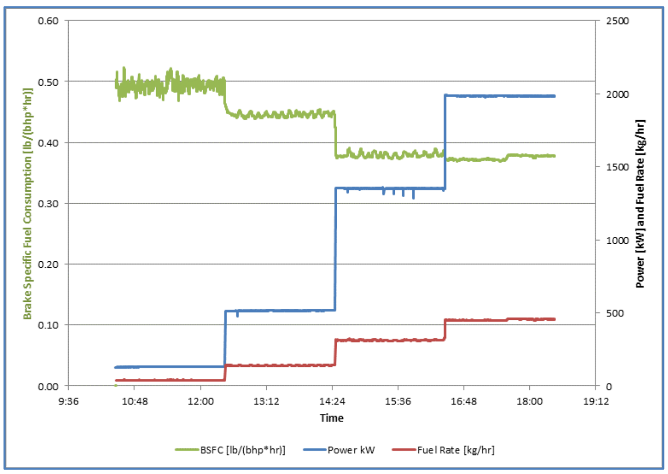


Figure 16 – Results from Second Baseline Test (22-September-2011)

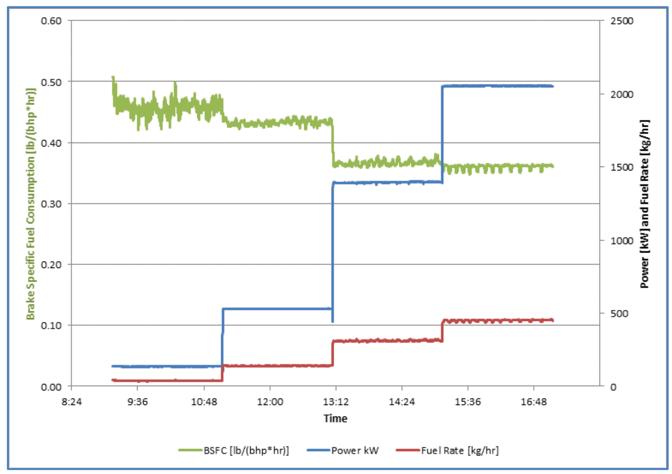


Figure 17 – Results from Second Treated Test (29-November-2011)

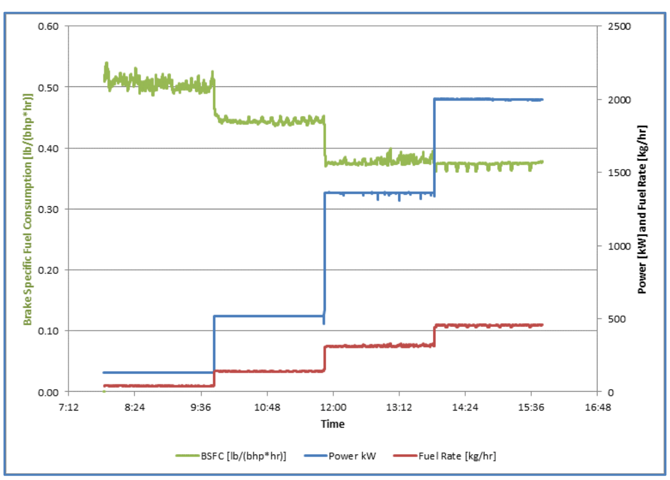


Figure 18 – Results from First Baseline Test (23-September-2011)

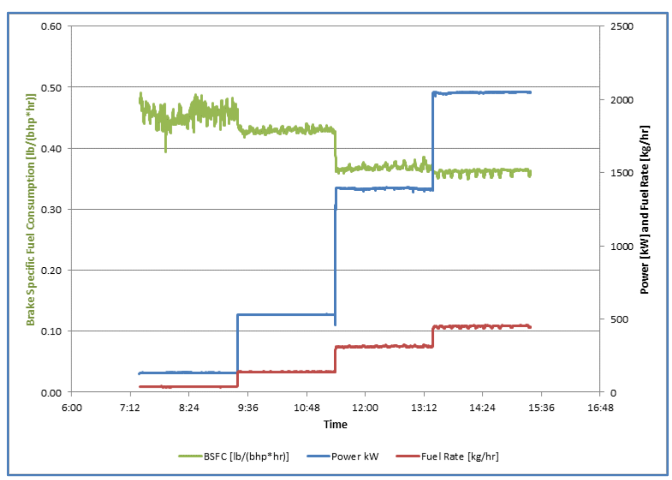


Figure 19 – Results from Third Treated Test (30-November-2011)

The AAR RP-503 provides a process to statistically analyze the results. This procedure was used to generate Table 1 and Table 2. At each throttle notch, the percentage improvement from using FPC treated fuel was more than two standard deviations from the mean value obtained with untreated fuel: therefore the results are considered significant from a statistical standpoint.

The average of the improvements across all of the throttle notches is 4.51%.

Table 1 – Baseline Test Results

	BSFC in Throttle Position			
Time Interval	**8**	**6**	**4**	**2**
Baseline Day 1	0.379	0.386	0.447	0.519
Baseline Day 2	0.375	0.379	0.446	0.494
Baseline Day 3	0.373	0.377	0.444	0.506
Baseline Average BSFC	0.376	0.381	0.446	0.506
Standard Deviation (σ)	0.00329	0.00442	0.00126	0.01266
Variation in Baseline Results (2σ/Avg BSFC)	1.75%	2.32%	0.57%	5.00%

Table 2 – FPC Treated Fuel Test Results

	BSFC in Throttle Position			
Time Interval	**8**	**6**	**4**	**2**
Treated Day 1	0.359	0.368	0.437	0.489
Treated Day 2	0.360	0.366	0.433	0.458
Treated Day 3	0.361	0.368	0.430	0.456
Treated Average BSFC	0.360	0.368	0.433	0.468
Percent Difference Between Baseline and Treated	**4.21%**	**3.44%**	**2.77%**	**7.60%**

Note that lower brake specific fuel consumption (BSFC) numbers indicate an improvement in fuel efficiency. Per the AAR RP-503, the variation in baseline results is calculated with the following equation:

$$\frac{100 \times (2 \times Standard\ Deviation\ in\ BSFC)}{Baseline\ Average\ BSFC}$$

Per the AAR RP-503, the percentage difference between the baseline and treated values is calculated with the following equation:

$$\frac{100 \times (Baseline\ Average\ BSFC - Treated\ Average\ BSFC)}{Baseline\ Average\ BSFC}$$

Positive values of percentage difference between baseline and treated indicate an improvement in fuel efficiency using the treatment. The percentage difference between baseline and treated must be greater than the variation in baseline results to be considered significant.

Instrumentation Verification

The sensors and data logger used for the testing was all new equipment, so the instrumentation was well calibrated during the testing. The certificates of calibration are all available in the Appendices of this report.

Handheld sensors were used to confirm that the data obtained was reasonably accurate during the testing. The handheld sensors used were not calibrated before this testing so they should not be taken as being correct or more accurate than the data obtained and recorded by the test sensors and data logger. Their purpose was only to provide a secondary measurement to provide confidence in the readings obtained by the data logger.

Figure 20, Figure 21, and Figure 22 show readings reported from external sources and those recorded by the data logger for various readings.

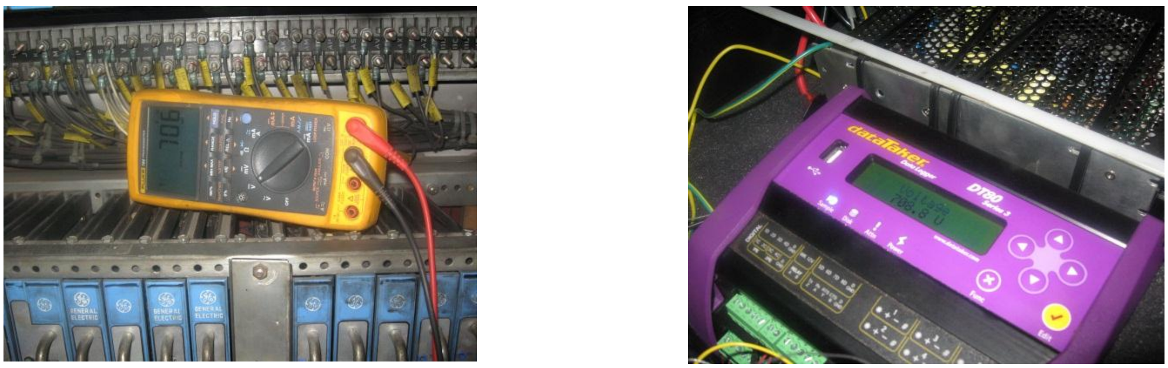


Figure 20 – A Handheld Voltmeter Measured 706 volts when the Sensor System Measured 708.8 volts

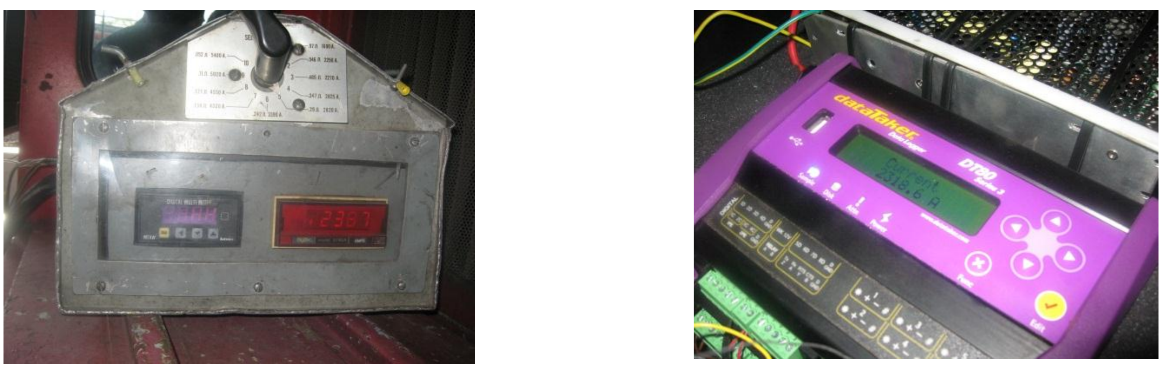


Figure 21 – The Load Box Controller Measured 2387 amps when the Sensor System Measured 2318.6 amps

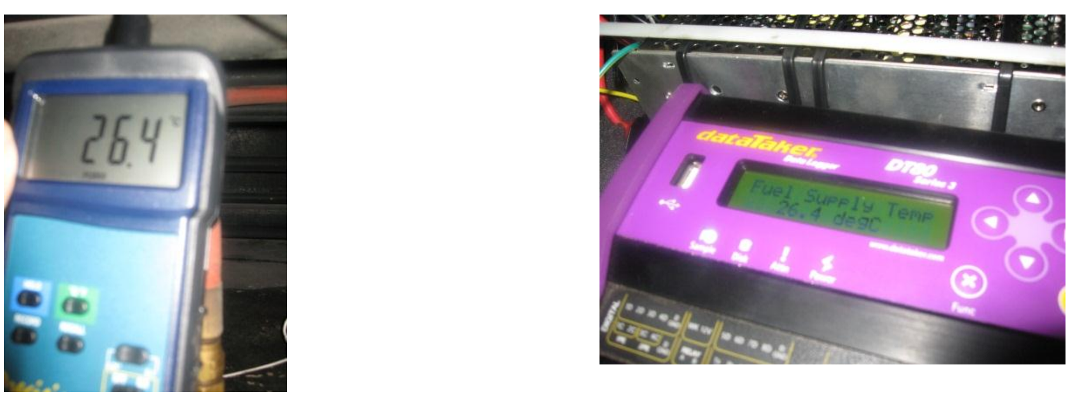


Figure 22 – A Handheld Digital Thermometer Measured 26.4°C when the Sensor System Measured 26.4°C for the Fuel Supply Temperature

Conclusion

A GE Super-7 DC locomotive was used to test and measure the fuel efficiency changes caused by using FPC fuel additive. Data was recorded every two seconds for a period of two hours at four different throttle notch settings. This testing was repeated three times on baseline fuel and three times on treated fuel. More than 43200 data points were recorded and processed to verify that the data was repeatable and accurate.

Analysis of the data showed very consistent results with a very small standard deviation. The improvements from FPC use were all larger than the significance test set by the Association for American Railroads (AAR) RP-503 test procedure. **An overall average of 4.51% improvement in fuel economy was demonstrated across all operating notches with improvements of 7.60%, 2.77%, 3.44%, and 4.21% at notches 2, 4, 6, and 8.**

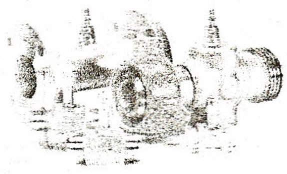
This testing is in line with results obtained from testing done with other FPC users in the railroad industry and the results obtained by Engine Systems Development Centre (ESDC), an independent railroad engine testing facility in Canada, on in-service locomotives.

Appendix 1

The following pages contain the flow sensor calibration certifications for the fuel flow sensors used to measure the supply and return fuel flows on the locomotive.

HOFFER FLOW CONTROLS, INC.
Perfecting Measurement™

107 Kitty Hawk Lane • P.O. Box 2145 • Elizabeth City, North Carolina 27906-2145
1-800-628-4584 • (252) 331-1997 • FAX (252) 331-2886
www.hofferflow.com • Email: info@hofferflow.com



feed
Alimentación

Flowmeter Calibration Report

Model:	HO3/4X3/4-2.5-29-BP-1(RPRO1S)-MS-X				
Customer:	ERIC MARTINEAU				
Account:	11027	Date: 8/19/11	Stand 1		
Cust. PO:	VERBAL	Fluid: CALIBRATION FLUID			
Job Number:	63747	Test range (gpm):	2.498	to	29.196
Meter S/N:	140855	Linearity (%):		+/-	0.24
Coil:	RP-R-O-1-S	K' Average (pulses/gal)			2271.010

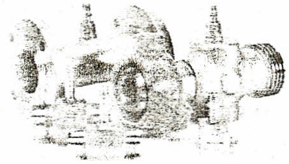
	Frequency Hz	Flowrate GPM	Roshko # Hz/cSt 70F	Strouhal # pul/gal 70F	Fluid Temp Deg. F	Kin. Visc. cSt
1	94.603	2.498	94.603	2272.293	70.000	1.000
2	94.641	2.499	94.641	2272.293	70.000	1.000
3	143.710	3.788	143.710	2276.466	70.000	1.000
4	195.510	5.153	195.507	2276.455	70.000	1.000
5	265.590	7.008	265.590	2274.003	70.000	1.000
6	382.380	10.094	382.377	2272.872	70.000	1.000
7	494.760	13.073	494.761	2270.723	70.000	1.000
8	644.900	17.026	644.896	2272.576	70.000	1.000
9	813.630	21.539	813.635	2266.452	70.000	1.000
10	947.850	25.103	947.852	2265.554	70.000	1.000
11	1102.500	29.195	1102.533	2265.867	70.000	1.000
12	1102.571	29.196	1102.571	2265.867	70.000	1.000

We certify that all test equipment used in calibrations are traceable to NIST, and that our quality assurance system is certified to ISO 9001-2008.

Operator: BK

Eng. approval:

HOFFER FLOW CONTROLS, INC.
Perfecting Measurement™
107 Kitty Hawk Lane • P.O. Box 2145 • Elizabeth City, North Carolina 27906-2145
1-800-628-4584 • (252) 331-1997 • FAX (252) 331-2886
www.hofferflow.com • Email: info@hofferflow.com



Retorno
Return

Flowmeter Calibration Report

Model:	HO3/4X3/4-2.5-29-BP-1(RPRO1S)-MS-X			
Customer:	ERIC MARTINEAU			
Account:	11027	Date: 8/19/11	Stand 1	
Cust. PO:	VERBAL	Fluid: CALIBRATION FLUID		
Job Number:	63747	Test range (gpm):	2.498 to	29.259
Meter S/N:	140856	Linearity (%):	+/-	0.28
Coil:	RP-R-O-1-S	K' Average (pulses/gal)		2260.273

	Frequency Hz	Flowrate GPM	Roshko # Hz/cSt 70F	Strouhal # pul/gal 70F	Fluid Temp Deg. F	Kin. Visc. cSt
1	94.207	2.498	94.207	2262.786	70.000	1.000
2	94.245	2.499	94.245	2262.786	70.000	1.000
3	143.322	3.794	143.322	2266.574	70.000	1.000
4	193.500	5.122	193.495	2266.568	70.000	1.000
5	272.640	7.238	272.641	2260.070	70.000	1.000
6	381.550	10.139	381.552	2258.010	70.000	1.000
7	496.510	13.190	496.512	2258.548	70.000	1.000
8	653.610	17.383	653.612	2255.989	70.000	1.000
9	800.250	21.288	800.249	2255.544	70.000	1.000
10	956.080	25.450	956.077	2253.972	70.000	1.000
11	1099.819	29.258	1099.819	2255.398	70.000	1.000
12	1099.845	29.259	1099.845	2255.398	70.000	1.000

We certify that all test equipment used in calibrations are traceable to NIST, and that our quality assurance system is certified to ISO 9001-2008.

Operator: BK

Eng. approval:

Appendix 2

The following page contains the data logger's calibration certificate.

dataTaker

Certificate of Traceable Calibration

Product Description

Model: DT80-3
Serial: 093121

Kernel Assembly: AS1208C0 1465-415
Terminal Assembly: AS1210C0 1463-164
Firmware: 80 Version 8.08.0001

Calibration Details

Calibration Date: 2011/06/28 15:08:00
Test Location: Apptek, Unit 1, 2 Pinacle Street Brendale QLD 4500
Ambient Temperature: 30.6 °C
NATA Certified Reference: Fluke 8840A Serial 5141011
Calibration Reference: DT8x Tester JIG-251 Version 1.48.0009, Calibrated 2011/06/07 08:20:31

Calibration Results

The following table lists measurements performed against traceable references.

Range	Channel(options)	Reference	Actual Reading	Allowable Error[1]	Error	Status
+30 V	1+HV(GL30V)	+2.4957 V	+2.4957	± 0.1 %	0.001 %	PASS
+3000 mV	1*V(GL3V)	+2500.2 mV	+2500.4	± 0.1 %	0.007 %	PASS
+300 mV	1+V(GL300MV)	+250.01 mV	+250.04	± 0.1 %	0.012 %	PASS
+30 mV	1-V(GL30MV)	+25.009 mV	+25.008	± 0.1 %	-0.006 %	PASS
-30 V	1+HV(GL30V)	-2.4957 V	-2.4963	± 0.1 %	0.026 %	PASS
-3000 mV	1*V(GL3V)	-2500.4 mV	-2500.9	± 0.1 %	0.022 %	PASS
-300 mV	1+V(GL300MV)	-250.03 mV	-250.06	± 0.1 %	0.012 %	PASS
-30 mV	1-V(GL30MV)	-25.001 mV	-25.008	± 0.1 %	0.029 %	PASS
10 k Ω	1R(4W,I)	100.0055 Ω	100.007	± 0.2 %	0.002 %	PASS

[1]Allowable Error indicates the maximum allowable difference between the Reference and the Actual Reading, specified as a percentage of the Actual Reading, when the ambient temperature is between 5°C and 40°C.

The product covered by this certificate meets or exceeds the required performance specified by Datataker P/L for the product.

The measurements performed to generate this certificate are traceable to Australian national standards of measurement.

This product has been manufactured under an ISO9001:2000 quality system.

Appendix 3

The following pages contain the specification sheets for the sensors used to measure the voltage and current on the test locomotive.

DC & RMS VOLTAGE TRANSDUCERS *MODELS* VT7- & VT8-

DC TO 10KHZ FREQUENCY RANGE

DESCRIPTION

The **Model VT7 Series** (dc) voltage transducer produces an output which is directly proportional to the input from dc to 10KHz. It functions as a millivolt dc shunt or a high voltage isolator.

The **Model VT8 Series** (RMS) voltage transducer provides a dc output directly related to the true RMS value of the input over the dc to 10KHz frequency range. Inputs range from 50mv to 1000 volts. Input/output dielectric test of 2500Vac. Consult factory for special ranges.

FEATURES

- 2500 Vac dielectric test
- Wide frequency range
- VT8 Provides a dc output which is proportional to the RMS value of the ac/dc input.

APPLICATIONS

- Accurate measurement of dc and non-sinusoidal ac components.
- Shunt isolator

5 YEAR WARRANTY

* INPUT mV	STANDARD OUTPUTS MODEL VT7- or VT8-			
	***1mA	4-20mA	***10V	***5V
0 - 50	015B	015E	015D	015X5
0 - 100	016B	016E	016D	016X5
0 - 200	017B	017E	017D	017X5
0 - 250	018B	018E	018D	018X5
INPUT VOLTS	**STANDARD OUTPUTS MODEL VT7- or VT8-**			
	***1mA	4-20mA	***10V	***5V
0 - 10	001B	001E	001D	001X5
0 - 25	002B	002E	002D	002X5
0 - 50	003B	003E	003D	003X5
0 - 100	004B	004E	004D	004X5
0 - 150	005B	005E	005D	005X5
0 - 250	006B	006E	006D	006X5
0 - 300	007B	007E	007D	007X5
0 - 400	008B	008E	008D	008X5
0 - 500	009B	009E	009D	009X5
0 - 600	010B	010E	010D	010X5
** 0 - 700	011B	011E	011D	011X5
** 0 - 800	012B	012E	012D	012X5
** 0 - 900	013B	013E	013D	013X5
** 0 - 1000	014B	014E	014D	014X5

*** Shunt inputs ** Supplied with external multiplier box.**
*****Bi-directional (±) on VT7 Series**
SAVE $ "-11 & -22 models which utilize a low cost, linear power supply"

ORDERING INFORMATION

Example: 0-50mVdc Input with
4-20mAdc Output and
125Vdc Instr. Pwr.
VT7-015E

ORDERING INFORMATION

Example: 0-100Vac Input with
0-10Vdc Output and 115Vac Instr. Pwr.
VT8-004D-11

Instrument Power Options

Option **"-11"** 95-135Vac, 50/60Hz, 5VA

Option **"-22"** 230 Vac, 50/60Hz, 5VA, ± 15%

Option **"-12, -15, -24, -37, -48",** 150mA max. 12Vdc thru 48Vdc, ± 10%

SPECIFICATIONS

INPUT

Voltage .... See Table
Frequency Range dc-10kHz
Overload .. 0.05-600V .... 2 X F.S. or 600Vac/850Vdc max.
700V-1000V(w/external multiplier box)...1.25 X F.S.
Burden (Ohms) .... > 100K
Dielectric Test............(Direct Input/Output/Case) 2500Vac
Inst. Power .... 85-265Vac, 48-420Hz, 5VA or 110-370Vdc, 5VA
See available instr. pwr. options
Temperature Effects...(-10^{O}C to +60^{O}C) .... ± 1.0% Rdg.
Field Adjustable Cal. .... ± 10%

OUTPUT

ACCURACY

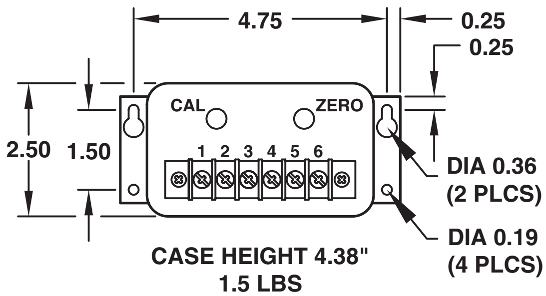
Includes effects of linearity, setpoint and repeatability.
VT7 Models .... **± 0.25% F.S.@ DC**
VT8 Models .... **± 0.25% F.S.@ 48-420Hz**

Response Time
VT7 Models .... (to 90%) ....50 microseconds
VT8 Models .... (to 90%) .... 100 milliseconds

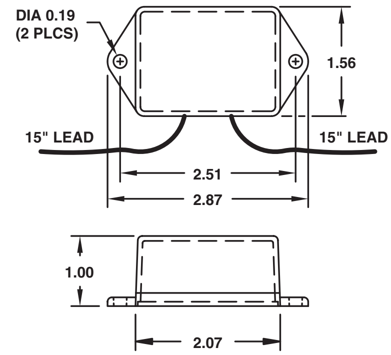
Output Loading (Ohms)
1mA 0-10K
10V, 5V .... > 2K
20mA 0-500

CASE DIMENSIONS

Model VT7 & VT8



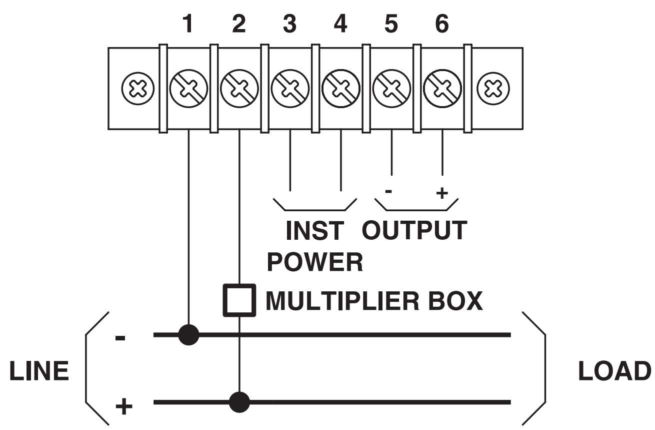
Multiplier Box



All Dimensions In Inches

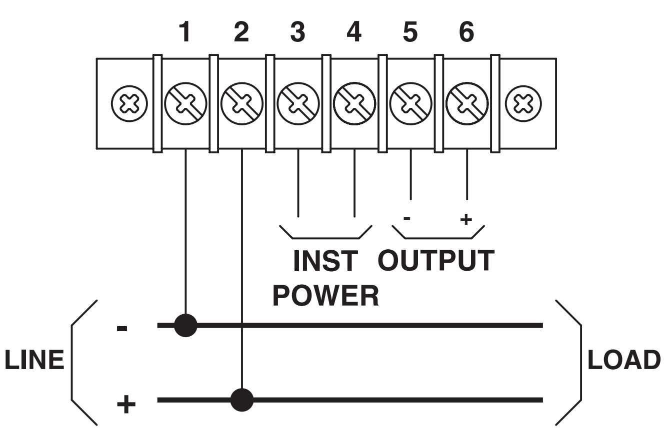
CONNECTION DIAGRAMS

700V - 1000V Models

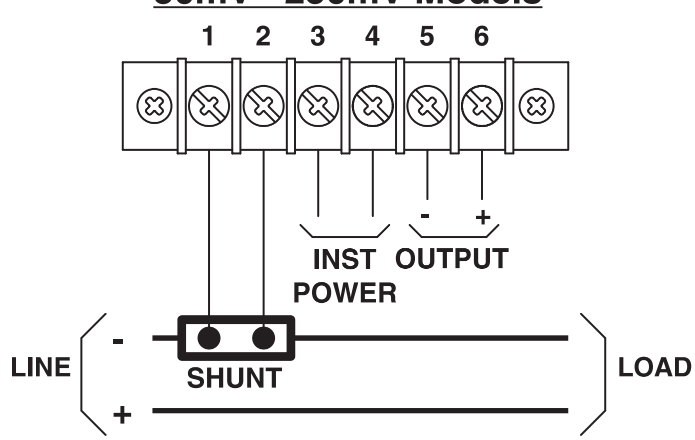


Note: All models above 600V input require a multiplier box in series with the input terminal #2.
Do not connect the input voltage directly, damage to the VT7/8 will result if not properly connected.

10V - 600V Models



Shunt Isolator
50mV - 250mV Models



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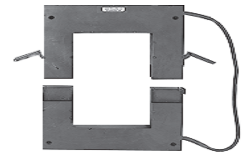
RECTANGULAR WINDOW (BUS BAR) MODELS

CURRENT RANGE	MODEL NUMBER	TYPICAL OUTPUT	SENSOR SIZE
0 to 2500A	CTL-502/2500	75mV	G
0 to 3000A	CTL-502/3000	90mV	G
0 to 4000A	CTL-502/4000	120mV	G
0 to 5000A	CTL-502/5000	150mV	G
0 to 5000A	CTL-103S/5000	50mV	H
0 to 6000A	CTL-103S/6000	60mV	H
0 to 7000A	CTL-103S/7000	70mV	H
0 to 8000A	CTL-103S/8000	80mV	H
0 to 9000A	CTL-103S/9000	90mV	H
0 to 10000A	CTL-103S/10000	100mV	H
0 to 12000A	CTL-203S/12000	60mV	H
0 to 15000A	CTL-203S/15000	75mV	H
0 to 18000A	CTL-203S/18000	90mV	H
0 to 20000A	CTL-203S/20000	100mV	H
0 to 25000A	CTL-303S/25000	85mV	HH*
0 to 30000A	CTL-303S/30000	100mV	HH*
0 to 35000A	CTL-403S/35000	90mV	HH*
0 to 40000A	CTL-403S/40000	100mV	HH*

Sensor size G is supplied in either solid or split-core models.
Add suffix "**S**" to model number to indicate split core.
Sensor sizes H and HH are supplied as split core only.

Window Size
G......3 x $6\frac{1}{2}$"
H.......$5\frac{1}{2}$ x 8"
HH ...13 x 13"



5 YEAR WARRANTY

c UL us LISTED

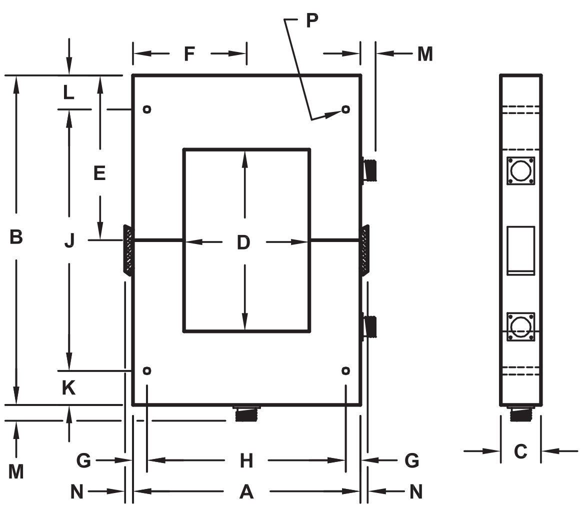
Measuring Equipment 7N93

ORDERING INFORMATION

Example: 2500 Amp, Split-Core Current Sensor with Extended Temperature Range.

CTL-502TS/2500
(Order in combination with appropriate CTA Signal Conditioner)

CASE DIMENSIONS G, H, HH



SPECIFICATIONS

INPUT
Current Range ....(See Table) .... dc/peak ac
Over-current (without damage)...........................50 X rating
Excitation Current 200mA
Resistance
500-5000A models ....23Ω ±5Ω
6000A + models ....12Ω ±5Ω

OUTPUT
Typical Output (@ 200mA excitation) ....Nominal ±30%
Resistance
500-5000A models ....25Ω ±15Ω
6000A + models ....32Ω ±10Ω
Initial Offset .... <±2mV

DIELECTRIC TEST
Conductor Through Window to Output 2200Vac
Suitable for installation on 600Vac or 850Vdc uninsulated bus.

ACCURACY & LINEARITY (When calibrated with CTA)
502 and 103 models ....±1% F.S.
203, 303, and 403 models ....±2% F.S.

TEMPERATURE
Operating Range
Standard...-10ºC to +40ºC
Extended ....Add suffix "**T**" ....-40ºC to +65ºC
Effect...±1% F.S.
20,000A models & up, Extended Range ....±2% F.S.

CABLE LENGTH
All models are supplied with detachable 8-foot cable.
Longer cables are available.

Specifications are for unidirectional operation.
For bidirectional operation, consult factory.

*Note: For HH case, remove red screws before unlatching head halves.

SENS. SIZE	SENSOR DIMENSIONS (inches)														WT LBS.
	A	B	C	D	E	F	G	H	J	K	L	M	N	P	
G	$7\frac{3}{4}$	12	$1\frac{3}{4}$	3 x $6\frac{1}{2}$	6	$3\frac{7}{8}$	$\frac{5}{8}$	$6\frac{1}{2}$	$10\frac{3}{4}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{16}$	$\frac{5}{16}$	12.3
H	10	$13\frac{3}{4}$	$1\frac{3}{4}$	$5\frac{1}{2}$ x 8	$6\frac{1}{2}$	5	$\frac{5}{8}$	$8\frac{3}{4}$	$11\frac{1}{2}$	$1\frac{1}{2}$	$\frac{3}{4}$	$\frac{5}{8}$	$\frac{5}{16}$	$\frac{5}{16}$	13
HH*	21	21	2	13 x 13	$10\frac{1}{2}$	$10\frac{1}{2}$	$1\frac{1}{2}$	18	18	$1\frac{1}{2}$	$1\frac{1}{2}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{8}$	44

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INSTALLATION INSTRUCTIONS

1. Installation should be performed by qualified electricians only!
2. Make sure electrical service is disconnected before making any electrical connections.
3. Branch circuit protection is required to be provided in accordance with the National and Local codes of the inspection authority.
4. Route wires as required and secure to terminals per connection diagram on this sheet and on the unit.
5. Transducers are suitable for installation on 600Vac lines.
6. To prevent contact with live circuits, when installed on a bare bus bar, the transducer is required to be mounted in an enclosure that requires the use of a tool for access. When installed on an insulated cable this second enclosure is not required.

OPERATING INSTRUCTIONS

1. This unit is intended for indoor use at altitudes up to 2000 meters.
2. Transient overvoltages according to Installation Category (overvoltage category) II, pollution Degree 2.
3. If cleaning of the exterior surface is necessary, de-energize all services of supply (both measuring and instrument power circuits) and brush with a soft brush or blow off with low-pressure air. Use appropriate eye protection. Not suitable for hose-down cleaning.
4. Maximum relative humidity 80 percent for temperatures up to 31°C decreasing linearly to 50 percent relative humidity at 40°C.
5. Maximum operating temperature range is -20°C to 60°C.

C UL US LISTED

UL approved for USA and Canada

≂

Both Direct (dc) and Alternating (ac) current

WARRANTY STATEMENT

Ohio Semitronics Inc. warrants this unit to be free of defects in material and workmanship for a period of five years from date of shipment. This unit must not be used in any manner other than as specified in this document.

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CTA SIGNAL CONDITIONERS — MODEL CTA

DESCRIPTION

The CTA Signal Conditioner provides the excitation current (instrument power) that the CTL Hall-effect sensor requires, as well as amplifying the low-level (mV) signal into a more typical signal. The CTA is calibrated to the output of the specific CTL selected for the application. Each CTA model has a specific input range (mV) which corresponds to the output of the CTL.

The CTA family has two different types; Direct and RMS. Direct models provide an isolated output that is directly proportional to the amplitude and frequency of the input signal. If the input signal is ac, then the output signal is ac. If the input signal is dc, then the output signal is dc.

The RMS output models provide an output which is directly proportional to the RMS of the input signal. The output is dc regardless of whether the input is ac or dc. Each type has four output options: 1mAdc, 4-20mAc, 10Vdc, or 5Vdc. DC instrument power options are available from 12 to 48Vdc.

The table on the following page shows appropriate CTL/CTA combinations with available CTA output options.

ORDERING INFORMATION

Example: 0-2000Adc CTL Input through 2" Window, 4-20mAdc CTA Output (direct, not RMS), ±0.5% Accuracy and Linearity, Split-Core

CTL-202S/2000 and CTA212P

CTA SPECIFICATIONS

INPUT (to CTA)

Standard (no option letter in model)........................0-50mV

Option "**R**"	0-35mV	Option "**W**"	0-90mV
Option "**F**"	0-40mV	Option "**P**"	0-100mV
Option "**G**"	0-60mV	Option "**N**"	0-120mV
Option "**H**"	0-75mV	Option "**K**"	0-150mV
Option "**J**"	0-80mV	Option "**L**"	0-200mV

Frequency Range (of CTA Signal Conditioner only)... dc-5000Hz

OUTPUT

Field-adjustable Gain 25%

Loading
- Models with 1mA output 0-10kΩ
- Models with 10V or 5V output .... 2kΩ min.
- Models with 4-20mA output..................................0-500Ω

Response time (to 90%)
- Direct models 40μs
- RMS models...200ms

INSTRUMENT POWER

Standard 115Vac, 50-400Hz, 2VA
Option "**-22**"....................................230Vac ±15%, 50/60Hz
Option "**-12**".. 9-18Vdc
Option "**-24**".. 18-36Vdc
Option "**-48**".. 36-60Vdc

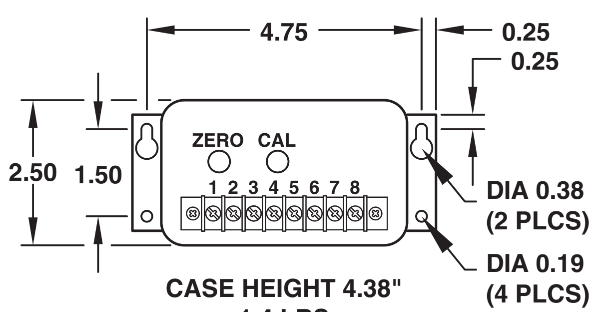
ACCURACY

Linearity .... ± 0.1% F.S.
Output Ripple ....Less than 0.25% F.S.

TEMPERATURE

Operating Range...0°C to +70°C
Effect...±0.005%/°C

CTA CASE DIMENSIONS



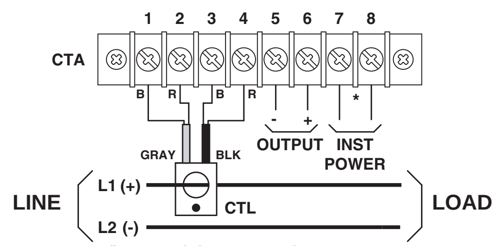
CASE HEIGHT 4.38"
1.4 LBS

All dimensions in inches

Dwg# 0902-00922-B

CONNECTION DIAGRAMS

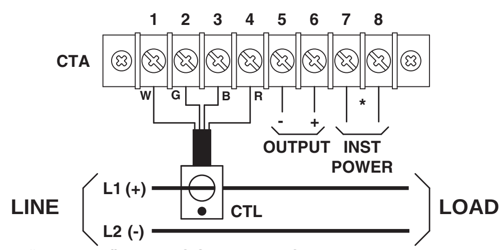
Caution: Connect CTL to CTA terminals 1, 2, 3, & 4 before applying instrument power to CTA terminals 7 & 8.



"Red dot" side of CTL must face positive supply.

CTL SENSOR SIZES A, C, D (solid core)

CABLE	WIRE	SIGNAL
GRAY	BLACK	OUTPUT (-)
GRAY	RED	OUTPUT (+)
SHIELD	SHIELD	SHIELD
BLACK	BLACK	EXCITATION (-)
BLACK	RED	EXCITATION (+)



"Red dot" side of CTL must face positive supply.

CTL SENSOR SIZES E, EE, F, G, H, HH

PIN	COLOR	SIGNAL
A	WHITE	OUTPUT (-)
B	GREEN	OUTPUT (+)
C	BLACK	EXCITATION (-)
D	RED	EXCITATION (+)
E	SHIELD	SHIELD

CTL SENSOR SIZES D (split core), Z, & ZZ

PIN	COLOR	SIGNAL
1	WHITE	OUTPUT (-)
2	GREEN	OUTPUT (+)
3	SHIELD	SHIELD
6	BLACK	EXCITATION (-)
8	RED	EXCITATION (+)

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When ordered together, CTL/CTA combinations are factory calibrated as a set. To select the proper CTA model, locate the preferred CTL model and move to the right, selecting either direct or RMS style and the desired output signal.

CTA MODEL SELECTION

INPUT CURRENT (THROUGH CTL WINDOW)	MODEL CTL CURRENT TRANSDUCER	ACC (% OF F.S.)	WINDOW DIA. (INCHES)	SENS. SIZE	DIRECT MODELS - AC/DC OUTPUT PROPORTIONAL TO AC/DC INPUT — STANDARD OUTPUT MODEL CTA				RMS MODELS - DC OUTPUT PROPORTIONAL TO RMS OR DC INPUT — STANDARD OUTPUT MODEL CTA			
					±5V	±10V	4-20mA	±1mA	0-5Vdc	0-10Vdc	4-20mAdc	0-1mAdc
0-35A	CTL-51(T)/35	±0.5	3/8	A	201RX5	201R	212R	201RA	213RX5	213R	215R	214R
0-50A	CTL-51(T)/50	±0.5	3/8	A	201X5	201	212	201A	213X5	213	215	214
0-50A	CTL-101(TS)/50	±0.5	3/4	C	201X5	201	212	201A	213X5	213	215	214
0-75A	CTL-101(TS)/75	±0.5	3/4	C	201HX5	201H	212H	201HA	213HX5	213H	215H	214H
0-100A	CTL-101(TS)/100	±0.5	3/4	C	201PX5	201P	212P	201PA	213PX5	213P	215P	214P
0-150A	CTL-201(TS)/150	±0.5	1 1/8	D	201HX5	201H	212H	201HA	213HX5	213H	215H	214H
0-200A	CTL-201(TS)/200	±0.5	1 1/8	D	201PX5	201P	212P	201PA	213PX5	213P	215P	214P
0-300A	CTL-401(TS)/300	±0.5	1 1/8	D	201HX5	201H	212H	201HA	213HX5	213H	215H	214H
0-400A	CTL-401(TS)/400	±0.5	1 1/8	D	201PX5	201P	212P	201PA	213PX5	213P	215P	214P
0-500A	CTL-601(TS)/500	±0.5	2	E	201FX5	201F	212F	201FA	213FX5	213F	215F	214F
0-500A	CTL-601F(T)S/500	±0.5	2 1/4	F	201FX5	201F	212F	201FA	213FX5	213F	215F	214F
0-500A	CTL-202H(T)S/500	±1	4 1/2 x 1 1/4	Z	201X5	201	212	201A	213X5	213	215	214
0-600A	CTL-601(TS)/600	±0.5	2	E	201X5	201	212	201A	213X5	213	215	214
0-600A	CTL-601F(T)S/600	±0.5	or 2 1/4	F	201X5	201	212	201A	213X5	213	215	214
0-800A	CTL-202(TS)/800	±0.5	2	E	201FX5	201F	212F	201FA	213FX5	213F	215F	214F
0-800A	CTL-202F(T)S/800	±0.5	2 1/4	F	201FX5	201F	212F	201FA	213FX5	213F	215F	214F
0-1000A	CTL-202(TS)/1000	±0.5	2	E	201X5	201	212	201A	213X5	213	215	214
0-1000A	CTL-202F(T)S/1000	±0.5	2 1/4	F	201X5	201	212	201A	213X5	213	215	214
0-1000A	CTL-202EE(T)S/1000	±0.5	4 1/4	EE	201PX5	201P	212P	201PA	213PX5	213P	215P	214P
0-1000A	CTL-202H(T)S/1000	±1	4 1/2 x 1 1/4	Z	201PX5	201P	212P	201PA	213PX5	213P	215P	214P
0-1000A	CTL-202ZZ(T)S/1000	±1	4 1/2 x 2 2/5	ZZ	201PX5	201P	212P	201PA	213PX5	213P	215P	214P
0-1500A	CTL-202(TS)/1500	±0.5	2	E	201HX5	201H	212H	201HA	213HX5	213H	215H	214H
0-1500A	CTL-202F(T)S/1500	±0.5	2 1/4	F	201HX5	201H	212H	201HA	213HX5	213H	215H	214H
0-1500A	CTL-202EE(T)S/1500	±0.5	4 1/4	EE	201KX5	201K	212K	201KA	213KX5	213K	215K	214K
0-1500A	CTL-202H(T)S/1500	±1	4 1/2 x 1 1/4	Z	201KX5	201K	212K	201KA	213KX5	213K	215K	214K
0-1500A	CTL-202ZZ(T)S/1500	±1	4 1/2 x 2 2/5	ZZ	201KX5	201K	212K	201KA	213KX5	213K	215K	214K
0-2000A	CTL-202(TS)/2000	±0.5	2	E	201PX5	201P	212P	201PA	213PX5	213P	215P	214P
0-2000A	CTL-202F(T)S/2000	±0.5	2 1/4	F	201PX5	201P	212P	201PA	213PX5	213P	215P	214P
0-2000A	CTL-202EE(T)S/2000	±0.5	4 1/4	EE	201LX5	201L	212L	201LA	213LX5	213L	215L	214L
0-2000A	CTL-202H(T)S/2000	±1	4 1/2 x 1 1/4	Z	201LX5	201L	212L	201LA	--	--	--	--
0-2000A	CTL-502H(T)S/2000	±1	4 1/2 x 1 1/4	Z	--	--	--	--	213GX5	213G	215G	214G
0-2000A	CTL-202ZZ(T)S/2000	±1	4 1/2 x 2 2/5	ZZ	201LX5	201L	212L	201LA	--	--	--	--
0-2500A	CTL-302EE(T)S/2500	±0.5	4 1/4	EE	201JX5	201J	212J	201JA	--	--	--	--
0-2500A	CTL-502H(T)S/2500	±1	4 1/2 x 1 1/4	Z	201HX5	201H	212H	201HA	213HX5	213H	215H	214H
0-2500A	CTL-302ZZ(T)S/2500	±1	4 1/2 x 2 2/5	ZZ	201NX5	201N	212N	201NA	--	--	--	--
0-2500A	CTL-502(TS)/2500	±1	3 x 6 1/2	G	201HX5	201H	212H	201HA	213HX5	213H	215H	214H
0-3000A	CTL-302EE(T)S/3000	±0.5	4 1/4	EE	201PX5	201P	212P	201PA	--	--	--	--
0-3000A	CTL-502H(T)S/3000	±1	4 1/2 x 1 1/4	Z	201WX5	201W	212W	201WA	213WX5	213W	215W	214W
0-3000A	CTL-302ZZ(T)S/3000	±1	4 1/2 x 2 2/5	ZZ	201KX5	201K	212K	201KA	--	--	--	--
0-3000A	CTL-502(TS)/3000	±1	3 x 6 1/2	G	201WX5	201W	212W	201WA	213WX5	213W	215W	214W
0-4000A	CTL-502H(T)S/4000	±1	4 1/2 x 1 1/4	Z	201NX5	201N	212N	201NA	--	--	--	--
0-4000A	CTL-502(TS)/4000	±1	3 x 6 1/2	G	201NX5	201N	212N	201NA	--	--	--	--
0-5000A	CTL-502H(T)S/5000	±1	4 1/2 x 1 1/4	Z	201KX5	201K	212K	201KA	--	--	--	--
0-5000A	CTL-502(TS)/5000	±1	3 x 6 1/2	G	201KX5	201K	212K	201KA	--	--	--	--
0-5000A	CTL-103(T)S/5000	±1	5 1/2 x 8	H	201X5	201	212	201A	213X5	213	215	214
0-6000A	CTL-103(T)S/6000	±1	5 1/2 x 8	H	201GX5	201G	212G	201GA	213GX5	213G	215G	214G
0-7000A	CTL-103(T)S/7000	±1	5 1/2 x 8	H	201HX5	201H	212H	201HA	213HX5	213H	215H	214H
0-8000A	CTL-103(T)S/8000	±1	5 1/2 x 8	H	201JX5	201J	212J	201JA	213JX5	213J	215J	214J
0-9000A	CTL-103(T)S/9000	±1	5 1/2 x 8	H	201WX5	201W	212W	201WA	--	--	--	--
0-10000A	CTL-103(T)S/10000	±1	5 1/2 x 8	H	201PX5	201P	212P	201PA	--	--	--	--
0-12000A	CTL-203(T)S/12000	±2	5 1/2 x 8	H	201GX5	201G	212G	201GA	213GX5	213G	215G	214G
0-15000A	CTL-203(T)S/15000	±2	5 1/2 x 8	H	201HX5	201H	212H	201HA	--	--	--	--
0-18000A	CTL-203(T)S/18000	±2	5 1/2 x 8	H	201WX5	201W	212W	201WA	--	--	--	--
0-20000A	CTL-203(T)S/20000	±2	5 1/2 x 8	H	201PX5	201P	212P	201PA	--	--	--	--
0-25000A	CTL-303(T)S/25000	±2	13 x 13	HH	201JX5	201J	212J	201JA	--	--	--	--
0-30000A	CTL-303(T)S/30000	±2	13 x 13	HH	201PX5	201P	212P	201PA	--	--	--	--
0-35000A	CTL-403(T)S/35000	±2	13 x 13	HH	201WX5	201W	212W	201WA	--	--	--	--
0-40000A	CTL-403(T)S/40000	±2	13 x 13	HH	201PX5	201P	212P	201PA	--	--	--	--

OHIO SEMITRONICS, INC.
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SUPPLEMENTAL SPECIFICATION SHEET

MODEL NUMBER CTL-502TS/4000Y106

THIS MODEL HAS THE SAME SPECIFICATIONS AS MODEL CTL-502TS/4000
WITH THE FOLLOWING REQUESTED CHANGES.

SPECIFICATION CHANGES:

Calibrate with CTA215N at 4000A_{RMS} input.

REMARKS:

ALL SPECIFICATIONS FOR STANDARD MODEL NUMBER WILL APPLY EXCEPT FOR CHANGES LISTED ABOVE.

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