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**Evaluation of Three Recent Models of UPS for Intersection  
Traffic Signals with LEDs**

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16. Abstract Uninterruptible Power Supply (UPS) systems are used to power the intersection traffic signals that have Light Emitting Diode (LED) signal modules, in case of a power failure. The objective of this study was to test the PB2000ITS UPS manufactured by US Traffic Corp., ME1000 UPS from TechPower Developments Inc and DUI 24M11 from Dimensions Unlimited Inc, and verify if they meet the Illinois DOT's specification for UPS systems for traffic signals with LED modules. These were the most updated models furnished by the manufacturers at the time. Multiple tests with full load (approximately 700 W) were conducted at room temperature to determine charge and discharge times. For PB2000ITS the average run time was 3:31 and average recharge time was 16:25 at room temperature. For ME1000, the average discharge and recharge times were 2:32 and 42:16 respectively at room temperature. For DUI 24M11 the average discharge and recharge times were 3:57 and 18:58 respectively at room temperature. All the UPS systems meet the majority of the IDOT Specification requirements, but had some minor shortcomings.					
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## OBJECTIVE

The objective of this study is to test the Uninterruptible Power Supply (UPS) systems provided by the manufacturers and verify whether they meet the Specification for UPS systems developed by the Illinois Department of Transportation (IDOT) (1). The evaluations were conducted at the Traffic Operations Lab at the University of Illinois. Myers Power Products, TechPower Developments, Inc. and Dimensions Unlimited, Inc. are prospective suppliers of UPS systems for IDOT. Myers Power Products furnished a unit of each of two of their UPS models: PB1250PC and PB2000ITS. Similarly, TechPower Developments, Inc. furnished a unit each of its M1000 and ME1000 UPS systems. The results of evaluation of Myers PB1250PC and TechPower M1000, which were supplied earlier, have been published (2,3). Dimensions Unlimited, Inc. furnished its DUI 24M11 UPS for evaluation. This report discusses the methodology for testing (the same methodology that was used for testing the earlier models) and the results of the evaluations of Myers PB2000ITS, TechPower ME1000 and DUI 24M11 UPS systems performed at room temperature conditions.

## METHODOLOGY

IDOT has developed a UPS Specification (1) that is modeled after the CalTrans Specification. Based on the discussions with IDOT representatives, the various requirements of (clauses) the UPS Specification were classified into four categories:

- Information that is in company literature
- Questions asked from manufacturers/suppliers
- Visual inspection of the unit
- Laboratory experiment

The categories in which each of the clauses was placed is shown in the Appendices A-C.

### *Company Literature*

The manufacturer's literature was reviewed to see to what degree the literature claims that the requirements of the Specification are met. In general the clauses which could not be easily verified in the Traffic Operations Laboratory were classified under this category. For example, operating temperature for both the inverter/power transfer relay and manual bypass switch shall be  $-37\text{ }^{\circ}\text{C}$  to  $+74\text{ }^{\circ}\text{C}$  (1.4 in IDOT Specification). For all the clauses grouped under this category it was decided that literature provided by the company would be used for verification. The literature provided by the companies was studied.

## *Questions for Manufacturers*

The manufacturers were contacted and requested to provide additional information if it was not clear from the literature whether their models satisfied certain clauses. Also they were asked to provide certifications for the claims made in their literature, if available. The clauses in section 5 of the Specification deal with the Quality Assurance program, design qualification testing, and Production quality control testing employed by the manufacturers. For example, QA process and test results documentation shall be kept on file for a minimum period of seven years (5.2 in IDOT Specification). Since this information is not public knowledge, it was decided that appropriate questions be sent to the manufacturers to ascertain if they satisfied these clauses. Questions were sent to the manufacturers and their responses have been incorporated in the report.

## *Visual Inspection*

For checking whether the UPS met certain clauses of the specification, visual inspection was sufficient. For example, the temperature sensor shall be external to the inverter/charger unit. The temperature sensor shall come with 2 meters (6'6") of wire (1.6.1 in IDOT Specification). A visual check was performed on the models and the results were incorporated.

## *Laboratory Experiment*

Certain clauses of the specification could be verified by running simple experiments, with readily available equipment, at the Traffic Operations Lab. For example, when the utility line power has been restored at above 105 VAC +/- 2 VAC for more than 30 seconds, the UPS shall dropout of battery backup mode and return to utility line mode (1.11 in IDOT Specification).

The experiments performed were essentially of three kinds: relay contact closures, switching from AC to UPS and back, and discharge and recharge times of the batteries.

## *NO and NC Relay Contact Closures*

The clauses under this group are related to the four NO and NC (Normally Open and Normally closed) relay contact closures that need to be provided and when they would be energized. They are clauses 1.3.1 through 1.3.4. For verifying these clauses the events that would result in energizing the closures were created and it was verified, if indeed the closures were energized. For example, for verifying 1.3.1, while monitoring the relay, AC power was shut down and it was checked if the "On Batt" closure was energized. Similar experiments were performed to verify the rest of the clauses while monitoring the relays.

### *Switching from AC to UPS and back*

The clauses under this group specify under what conditions the UPS should bypass/return to the utility power. Clauses 1.8, 1.11 and 1.12 come under this category. A variable transformer was used for creating the necessary modifications to the AC voltage and it was verified if the UPS performed as it is supposed to.

### *Discharge and Recharge Times*

The clauses under this category pertain to the duration the batteries can power the load and the duration of charging required for the batteries. They are 1.1.1 and 1.15.

Discharge Times: According to the specification, UPS STANDARD is required to power a minimum load of 700 W for a minimum of two hours at room temperature. Using the LED signal modules and the intersection panel available at the Traffic Operations Lab, a load of around 700 watts was set up.

For measuring the duration of normal operation, AC power was shut down and the time the load was powered before the batteries were shutdown by the UPS to avoid deep discharge was obtained.

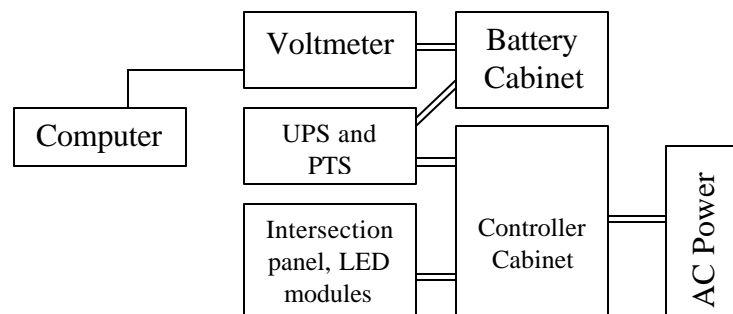


Figure 1. Block diagram of the experimental setup.

Recharge times: After every discharge experiment, the batteries were put to charge. While the batteries were being charged their voltage was monitored using a voltmeter that could log in the voltage readings into a computer. Once the batteries were fully charged, the voltage of the batteries would stabilize. Using the voltage data logged in to the computer by the voltmeter, the time for fully recharging the batteries was obtained.

It is expected that there would be some variability in the discharge and recharge times of the batteries. Therefore multiple tests are required to ascertain if the systems meet the specifications. Several tests were performed for obtaining the discharge and recharge times of the batteries at room temperature. Based on a 90 % confidence level, sample size

and the variance in the test results, the error in the estimate was obtained. It was found that in all the cases the error was significantly less than the tolerable error. Therefore further testing was not conducted. The results of these tests are discussed in the “Test Results” section of the report.

To compare the mean values returned by the tests to the specification requirements, t-tests were performed. The test associates a confidence level with which one can conclude that the mean value is greater or lesser than the specification requirement.

The findings of the evaluation are presented in Appendix A. For each clause of the specification, the “Does it meet the spec” column indicates if the UPS satisfies the requirements of the specification. In the course of the evaluation it was found that there were several instances when the answer to the question “Does it meet the specification?” is not a straightforward Yes or No. For this reason, based on our discussions with IDOT representatives, the responses in this column could be “Yes”, “No”, “Yes\*” and “No\*”. Yes and No clearly indicate that the system satisfies or does not satisfy the specification respectively. Yes\* and No\* indicate that the system satisfies or does not satisfy with some reservation. Please read the “Comments” column for an explanation of the specific answer.

## TEST RESULTS

The results for MyersPB2000ITS UPS are presented first followed by the results for TechPower ME1000 UPS and Dimension 24M11 UPS. These were the most updated models the manufacturer furnished us at that time. In each section the results for discharging the batteries at full load (700W) under room temperature are presented followed by the results for recharging.

### *Myers PB2000ITS*

The UPS model supplied by the manufacturer was PB2000ITS and the batteries were Chairman batteries (model AGM-12100T, the same batteries that were used for evaluating Myers PB1250PC UPS). The results of the discharge tests performed at full load for Myers PB2000ITS UPS at room temperature are shown in Table 1 and Figure 2.



Test Number	Date	Duration full load was powered (hh:mm)	Beginning voltage (V)	Cutoff voltage (V)
1	1/23/2004	3:20	13.055	9.096
2	1/27/2004	3:36	13.031	9.554
3	1/29/2004	3:42	-	9.865
4	2/3/2004	3:34	13.043	10.949
5	2/5/2004	3:24	13.066	11.211

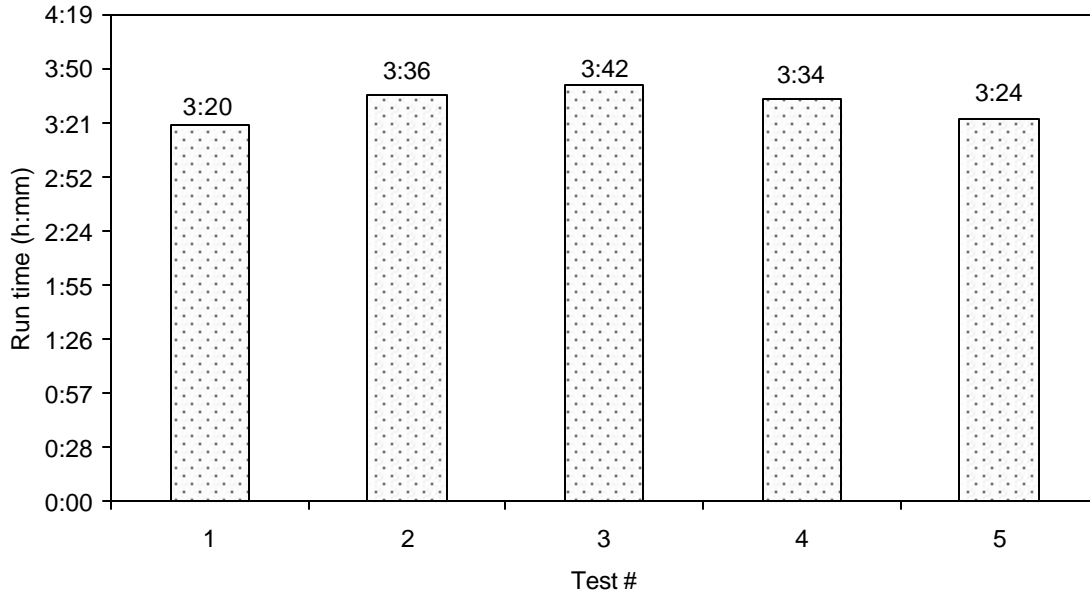
Table 1. Results of discharge tests performed at room temperature for Myers PB2000ITS UPS

To avoid deep discharge of the batteries, the UPS monitors the battery voltage and disconnects the batteries from the UPS when the battery voltage reaches a certain specified voltage. Therefore run time of the batteries is directly related to the specified cutoff voltage. In general, the deeper the discharge batteries go through, the fewer the number of cycles of charge and discharge the batteries can endure.

During the testing the battery voltage was monitored and the data was logged into a computer. Table 1 shows the day of test, the run time and the voltage of one of the batteries at the beginning of the test and when the batteries were disconnected by the UPS. The mean voltage at the beginning of the test was 13.047 VDC and the mean voltage at the shutdown point was 10.14 VDC. The voltage at shutdown varied from 9.096 to 11.221 VDC. The estimate of the error from the true mean, based on these observations, is 5.2 minutes which is 4.4% of 2 hours (IDOT specification requirement). Therefore more tests were not performed.

From Figure 2, we can see that the duration consistently exceeds the specification requirement of powering a full load for 2 hours. Based on the results, the average duration the batteries powered the full load was 3:31 and the minimum and the maximum values are 3:20 and 3:42. Based on these observations, and the results of t-test, it can be concluded that the estimated mean of 3:31 is greater than 2:00 with a confidence level greater than 99.9%. Therefore it can be concluded that this system meets the specification requirement for powering full load.

Figure 2. Run time of Myers PB2000ITS at room temperature



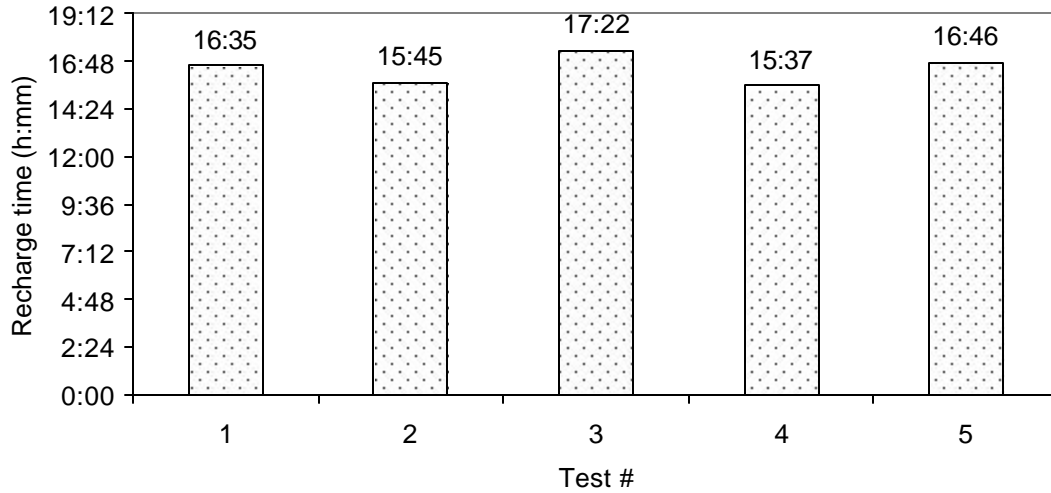
The results for fully charging the batteries for Myers UPS are shown in Table 2. The estimate of the error from the true mean, based on these observations, is 25.4 minutes which is 2.1% of 20 hours (IDOT specification requirement). Therefore more tests were not performed.

From Figure 3 we can see that the time to fully charge the batteries is consistently and significantly less than the specification requirement of 20 hours. The average time to charge the batteries fully was 16:25 and the minimum and maximum values are 15:37 and 17:22. The specification requires that the recharge time for the battery, from “protective low-cutoff” to 80% or more of full battery charge capacity, shall not exceed twenty (20) hours. Based on these observations, and the results of  $t$ -test, it can be concluded that the estimated mean of 16:25 is less than 20:00 with a confidence level greater than 99.9%. Therefore this system meets the specification requirement for charging the batteries.

Test Number	Date	Charging Time (hh:mm)
1	1/23/2004	16:35
2	1/27/2004	15:45
3	1/29/2004	17:22
4	2/3/2004	15:37
5	2/5/2004	16:46

Table 2. Results for fully charging the batteries for Myers PB2000ITS UPS.

Figure 3. Recharge times for Myers PB2000ITS at room temperature



### *TechPower ME1000*

The UPS system supplied by the manufacturer was ME1000 and the batteries were Optima batteries (model D34M, the same batteries that were used for evaluating TechPower M1000 UPS). The results of the discharge tests performed at full load for Techpower UPS are shown in Table 3 and Figure 4.

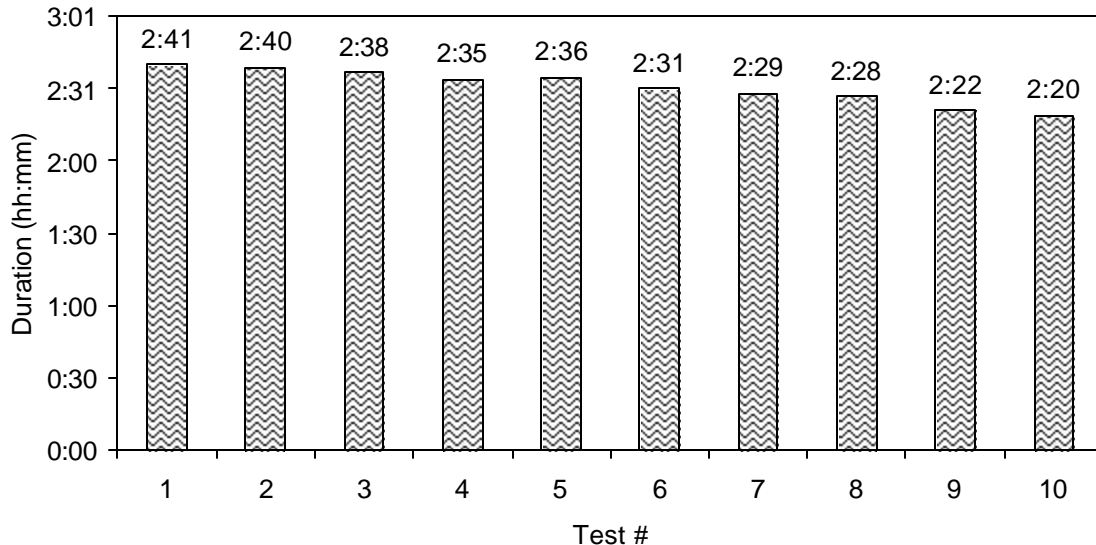
Test Number	Date	Duration full load was powered (hh:mm)	Beginning voltage (V)	Cutoff voltage (V)
1	10/17/2003	2:41	27.715	19.116
2	10/20/2003	2:40	27.106	18.993
3	10/24/2003	2:38	26.439	19.186
4	10/29/2003	2:35	27.238	19.132
5	11/3/2003	2:36	26.344	19.212
6	11/17/2003	2:31	27.283	19.093
7	11/19/2003	2:29	26.994	19.375
8	11/21/2003	2:28	26.862	19.057
9	12/2/2003	2:22	25.953	19.224
10	12/4/2003	2:20	26.561	19.166

Table 3. Results of discharge tests performed at room temperature for TechPower ME1000 UPS

During the testing the voltage of the battery string was monitored and the data was logged into a computer. Table 3 shows the day of test, the run time and the voltage of one of the batteries at the beginning of the test and when the batteries were disconnected by the UPS. The mean voltage at the beginning of the test was 26.85 VDC and the mean voltage at the shutdown point was 19.155 VDC. The voltage at shutdown varied from 18.993 to 19.375 VDC. It should be noted that TechPower UPS is a 24VDC system as opposed to Myers PB2000ITS which is a 48VDC system.

From Figure 4, we can see that the duration consistently exceeds the specification requirement of powering a full load for 2 hours. The estimate of the error from the true mean, based on these observations, is 4 minutes which is 3.4% of 2 hours (specification requirement). Therefore more tests were not performed. Based on the results, the average duration the batterie s powered the full load was 2:32 and the minimum and the maximum values are 2:20 and 2:41. Based on these observations, and the results of t-test, it can be concluded that the estimated mean of 2:32 is greater than 2:00 with a confidence level greater than 99.9%. Therefore it can be concluded that this system meets the specification requirement for powering full load.

Figure 4. Duration of battery power (hh:mm) at room temperature for TechPower ME1000 UPS



The results for fully charging the batteries for TechPower UPS are shown in Table 4. From Table 4 we can see that the duration to fully charge the batteries is consistently higher than 24 hours. It should be noted that the previous model furnished for evaluation also took longer than 24 hours for charging the batteries completely. The manufacturer claimed that the previous unit was defective and furnished the newer model. As it is evident from Table 4, the time to recharge the batteries completely ranged from 37:55 to 45:35. Therefore the TechPower ME1000 unit does not meet the specification requirement for charging the batteries.

Test Number	Date	Charging Time (hh:mm)
1	10/20/2003	42:58
2	10/24/2003	42:05
3	11/17/2003	42:48
4	11/19/2003	45:35
5	12/2/2003	37:55

Table 4. Results for fully charging the batteries for TechPower UPS.

### *Switching from AC to UPS and back*

The voltages at which the UPS switches from AC power to UPS were measured for TechPower ME1000 UPS and are presented in Table 5. As shown in Table 5 these are different from the values specified in the IDOT specification.

Scenario	Specification Requirement (VAC)	TechPower ME 1000 voltage (VAC)
Line to Battery	100 ± 2	75
Battery to Line	105 ± 2	80
Line to Battery	130 ± 2	> 140
Battery to Line	125 ± 2	unknown

Table 5. Switching voltages of TechPower ME 1000 Vs Specification requirements.

Some UPS systems provide power conditioning by using Buck and Boost features. When the line voltage drops below 110 VAC, but is greater than a lower limit, the UPS would step-up the line voltage to 110 VAC. This is called Boost. Similarly if the voltage is greater than 110 VAC, but lesser than an upper limit, the UPS would step-down the voltage to 110 VAC. This is called Buck. When the line voltage is greater than the upper limit or lesser than the lower limit, the UPS would disconnect the line power and supply battery power.

The TechPower ME 1000 uses Buck and Boost capability to run the system on AC power without switching to batteries. Therefore, the batteries are not used unless the AC voltage level falls to 75 V or goes above 140V. The actual thresholds it uses are shown in Table 6.

Scenario	Voltage (V)
From Boost to Battery	75
From Battery to Boost	80
From Line to Boost	105
From Boost to Line	109
From Buck to Line	122
From Line to Buck	128
From Battery to Buck	Unknown
From Buck to Battery	> 140

Table 6. Voltages at which switching takes place for TechPower ME 1000

From Table 6 it can be seen that ME1000 UPS switches to Boost mode when the AC voltage drops to 105 VAC and returns to Line mode when the voltage reaches 109 VAC. Similarly it goes into buck mode when the voltage exceeds 128 VAC and returns to Line mode when the voltage reaches 122 VAC. TechPower ME 1000 does not use the batteries unless the line voltage is less than 75VAC or greater than 140 VAC. Therefore it would use the batteries fewer number of times than what it would have if it were to follow the specification's thresholds for switching. Though it does not satisfy the IDOT specification, this feature of TechPower ME 1000 is advantageous from the practical point of view when the quality of AC power at an intersection is poor.

### *Dimensions 24M11*

The UPS model supplied by the manufacturer was 24M11 and batteries were Deka Unigy batteries (model AGM-12100T). It should be noted that this system is also (like

TechPower ME1000) a 24 VDC system. The results of the discharge tests performed at full load for Dimension 24M11 UPS at room temperature are shown in Table 7 and Figure 5.

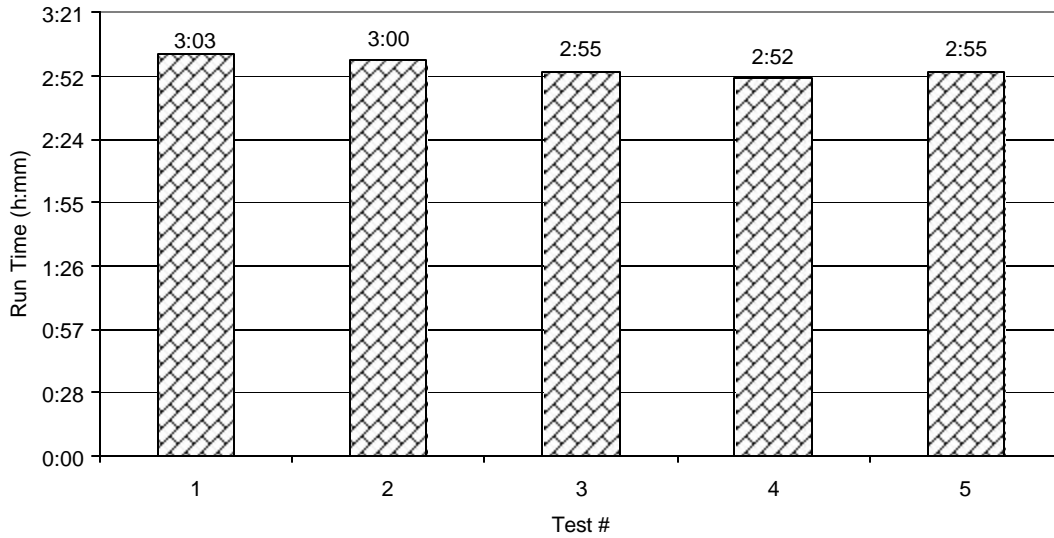
Test Number	Date	Duration full load was powered (hh:mm)	Beginning voltage (V)	Cutoff voltage (V)
1	1/21/2005	3:03	26.44	22.35
2	1/26/2005	3:00	26.50	22.37
3	1/27/2005	2:55	26.58	22.36
4	1/29/2005	2:52	26.46	22.38
5	1/31/2005	2:55	26.02	22.34

Table 7. Results of discharge tests performed at room temperature for Dimension 24M11 UPS

Table 7 shows the day of test, the run time and the voltage of the battery string at the beginning of the test and when the batteries were disconnected by the UPS. The mean voltage at the beginning of the test was 26.40 VDC and the mean voltage at the shutdown point was 22.36 VDC. The voltage at shutdown varied from 22.34 to 22.38 VDC. The estimate of the error from the true mean, based on these observations, is 26 minutes which is 2.1% of the IDOT specification requirement of 2 hours. Therefore more tests were not performed.

From Figure 5, we can see that the duration consistently exceeds the specification requirement of powering a full load for 2 hours. Based on the results, the average duration the batteries powered the full load was 2:57 and the minimum and the maximum values are 2:52 and 3:03. Based on these observations, and the results of t-test, it can be concluded that the estimated mean of 2:57 is greater than 2:00 with a confidence level greater than 99.9%. Therefore it can be concluded that this system meets the time requirement of the specification for powering full load.

Figure 5. Run Times of Dimensions 24M11 UPS at room temperature



The results for fully charging the batteries for Dimensions 24M11 UPS are shown in Table 8. The estimate of the error from the true mean, based on these observations, is 28.1 minutes which is 2.3% of the IDOT specification requirement of 20 hours. Therefore more tests were not performed.

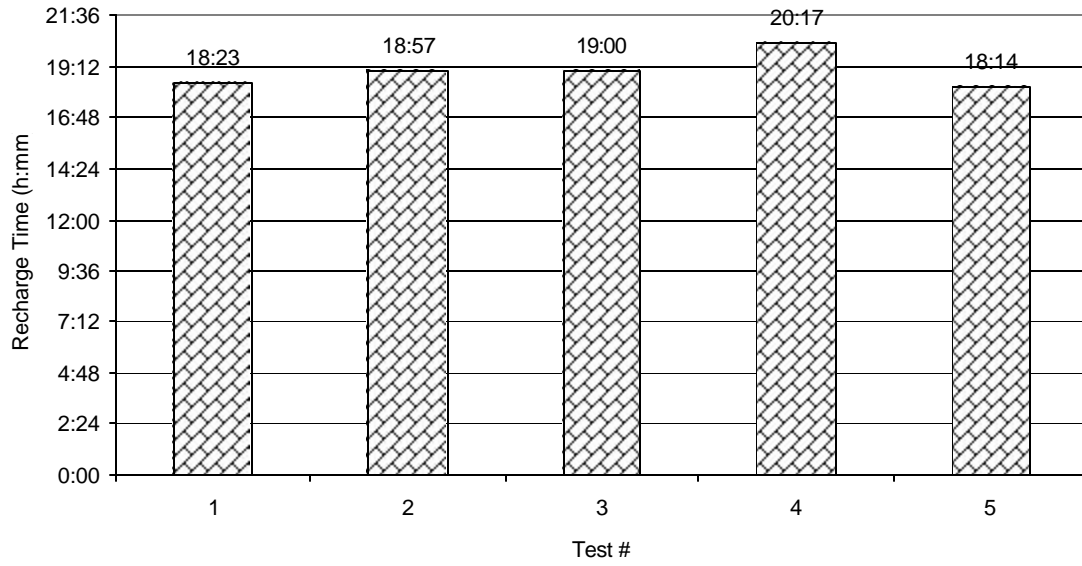
Figure 6 shows the time needed to fully charge the batteries. The average time to fully charge the batteries was 18:58 and the minimum and maximum values are 18:14 and 20:17. The specification requires that the recharge time for the battery, from “protective low-cutoff” to 80% or more of full battery charge capacity, shall not exceed twenty (20) hours. Based on these observations, and the results of t-test, it can be concluded that the estimated mean of 18:58 is less than 20:00 with a confidence level greater than 95%. Therefore this system meets the time requirement of the IDOT specification for charging the batteries.

Test Number	Date	Charging Time (hh:mm)
1	1/26/2005	18:23
2	1/29/2005	18:57
3	1/31/2005	19:00
4	3/30/2005	20:17
5	4/8/2005	18:14

Table 8. Results for fully charging the batteries for Dimensions 24M11 UPS.



Figure 6. Recharge Times for Dimensions 24M11 UPS at room temperature



## SUMMARY OF FINDINGS

The average run time with full load (approximately 700 W) at room temperature for Myers PB2000ITS was 3 hrs 31 min and the average time to charge the batteries fully at room temperature was 16 hrs 25 min. Myers PB1250PC UPS meets the specification requirements for run time and recharge time. The run time depends on temperature and cutoff voltage and the mean voltage of a battery at the shutdown point was 10.14 VDC. Details on how Myers PB2000ITS meets each specific requirement of the IDOT Specification are given in Appendix A. The major shortcomings of this model are: this model does not have a NO and NC contact closure for indicating inverter/charger failure. Also the fan in the battery cabinet runs on 48VDC as opposed to the specification requirement of running on AC power. This model has some minor shortcomings such as not providing sufficiently long cables, board-level schematic and wiring diagrams etc. In summary, Myers PB2000ITS UPS meets the majority of the IDOT Specification requirements. It has the two major and some minor shortcomings that can be corrected to satisfy all IDOT Specification requirements.

The average run time with full load (approximately 700 W) at room temperature for TechPower ME1000 was 2 hrs 32 min and the average time to charge the batteries fully at room temperature was 42 hrs 16 min. The run time at full load meets the specification requirements. However the TechPower ME1000 UPS does not satisfy the IDOT specification requirement for recharging the batteries. The mean voltage of the battery string at the shutdown point was 19.155 VDC. Details on how TechPower ME1000 meets each specific requirement of the IDOT Specification are given in Appendix B. The major shortcomings of this model are: The charge time at room temperature does not satisfy the specification requirements. This model does not have a NO and NC contact closure for indicating that the batteries reached a 40% level. The specification requires that each UPS be given a minimum 100 hr burn-in period to catch any premature failures. However, the manufacturer gives a 100 hr burn-in period only to randomly picked units. The supplied batteries are 55 Amp-hr while the specification requires them to be at least 65 Amp-hr. The UPS does not have a temperature sensor for measuring the temperature of the battery. Also the UPS does not shutdown the charging of the batteries when their temperature exceeds 50°C. The manufacturer is yet to supply a battery cabinet for evaluation. This model also does not satisfy some additional specification requirements. These include: The UPS switches to Line Power as soon as the power is restored instead of waiting for 30 seconds as required by the Specification. Also, the voltages at which the UPS bypasses line power are different from the Specification requirements. But as described previously, this feature of TechPower might actually be helpful in real world situations. In summary, TechPower ME1000 UPS has some major and minor shortcomings that can be corrected to satisfy all IDOT Specification requirements.

The average run time with full load (approximately 700 W) at room temperature for Dimensions 24M11 UPS was 2 hrs 57 min and the average time to charge the batteries fully at room temperature was 18 hrs 58 min. The run time at full load and the recharge time of the Dimensions 24M11 UPS meet the specification requirements. The mean

voltage of the battery string at the shutdown point was 22.36 VDC. Details on how Dimensions 24M11 meets each specific requirement of the IDOT Specification are given in Appendix C. The major shortcomings of this model are: This UPS is not line interactive and does not provide voltage regulation and power conditioning when utilizing utility power. This model does not have a NO and NC contact closure for indicating inverter/charger failure. The specification requires that each UPS be given a minimum 100 hr burn-in period to catch any premature failures. However, the manufacturer gives only a 3 hr burn-in period to the units. The manufacturer did not supply a battery cabinet for evaluation. This model also does not satisfy some additional specification requirements such as not providing board level schematic and wiring diagrams, and batteries not indicating maximum recharge data and recharging cycles. In summary, Dimensions 24M11 UPS has some major and minor shortcomings that can be corrected to satisfy all IDOT Specification requirements.

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2. Chitturi M.V. & R.F. Benekohal. Evaluation of UPS for Intersection Traffic Signals with LEDs: Findings for Myers PB1250PC UPS. University of Illinois Urbana-Champaign, TOL Series 7, Dec 2003.
3. Chitturi M.V. & R.F. Benekohal. Evaluation of UPS for Intersection Traffic Signals with LEDs: Findings for TechPower M1000 UPS. University of Illinois Urbana-Champaign, TOL Series 9, Dec 2003.

## Appendix A

### Findings for Myers PB2000ITS UPS

The table below shows the classification of the different clauses of the Specification into

- a) Company Literature
- b) Question for Manufacturer
- c) Visual Inspection
- d) Laboratory Experiment

Note: For rows which contain "Yes\*" or "No\*" in "Does it meet the spec" column, please read the "Comments" column

Clause #				Clause	Method	Comments	Does it meet the spec?
1	1			The UPS shall be line interactive and provide voltage regulation and power conditioning when utilizing utility power.	a	Manufacturer's reponse:"The UPS provides voltage regulation and power conditioning via buck and boost. The UPS is Line Interactive"	Yes
1	1	1		The UPS shall provide a minimum two (2) hours or a minimum six (6) hours of full run-time operation for an "LED-only" intersection (minimum 700W/1000VA active output capacity, with 80% minimum inverter efficiency). The two UPS, differing in the minimum duration of full run-time operation, shall be designated as UPS STANDARD and UPS EXTENDED respectively.	d	Ran five cycles of discharge at room temperature.	Yes for UPS STANDARD
1	2			The maximum transfer time from loss of utility power to switchover to battery backed inverter power shall be 65 milliseconds.	a	Manufacturer verified that the transfer time is 60 milliseconds.	Yes
1	3			The UPS shall provide the user with 4-sets of normally open (NO) and normally closed (NC) single-pole double-throw (SPDT) relay contact closures, available on a panel-mounted terminal block, rated at a minimum 120V/1A, and labeled so as to identify each contact (Manual Bypass Switch and Relay Contacts Standard).	c	Six Programmable contact closures are provided	Yes
1	3	1		The first set of NO and NC contact closures shall be energized whenever the unit switches to battery power. Contact shall be labeled or marked "On Batt."	d	Experimented	Yes

1	3	2		The second set of NO and NC contact closures shall be energized whenever the battery approaches approximately 40% of remaining useful capacity. Contact shall be labeled or marked "Low Batt."	d	Experimented	Yes
1	3	3		The third set of NO and NC contact closures shall be energized two hours after the unit switches to battery power. Contact shall be labeled or marked "Timer."	d	Experimented	Yes
1	3	4		The fourth set of NO and NC contact closures shall be energized in the event of inverter/ charger failure. Contact shall be labeled or marked "UPS Fail."	d		No*
1	4			Operating temperature for both the inverter/power transfer relay and manual bypass switch shall be -37 °C to +74 °C (-35 °F to 165 °F).	a	Verified with the Manufacturer	Yes
1	5			Both the Power Transfer Relay and Manual Bypass Switch shall be rated at 240VAC/30 amps, minimum.	a	Verified with the manufacturer	Yes
1	6			The UPS shall use a temperature-compensated battery charging system. The charging system shall compensate over a range of 2.5 – 4.0 mV/°C or (1.4 – 2.2 mV/°F) per cell.	a	Verified with the manufacturer	Yes
1	6	1		The temperature sensor shall be external to the inverter/charger unit. The temperature sensor shall come with 2 meters (6.5 ft) of wire.	c		Yes
1	7			Batteries shall not be recharged when battery temperature exceeds 50°C ± 3°C (122oF + 5oF).	a	Verified with the manufacturer	Yes
1	8			UPS shall bypass the utility line power whenever the utility line voltage is outside of the following voltage range: 100VAC to 130VAC (± 2VAC).	d	Used a variable transformer to modify line power	Yes
1	9			When utilizing battery power, the UPS output voltage shall be between 110 VAC and 125 VAC, pure sine wave output, £ 3% THD, 60Hz ±3Hz.	d	Voltage between 110 and 125 V, Frequency 60+/- 3 Hz	Yes
1	10			UPS shall be compatible with Illinois DOT's traffic controller assemblies utilizing NEMA TS 1 or NEMA TS 2 controllers and cabinet components for full time operation.	d	Tested UPS in TS2 Type 1 cabinet	Yes
1	11			When the utility line power has been restored at above 105 VAC ±2 VAC for more than 30 seconds, the UPS shall dropout of battery backup mode and return to utility line mode.	d	Used a variable transformer to modify line power	Yes

1	12			When the utility line power has been restored at below 125VAC $\pm 2$ VAC for more than 30 seconds, the UPS shall dropout of battery backup mode and return to utility line mode.	d	Used a variable transformer to modify line power	Yes
1	13			UPS shall be equipped to prevent a malfunction feedback to the cabinet or from feeding back to the utility service.	a	Verified with the manufacturer	Yes
1	14			In the event of inverter/charger failure, the power transfer relay shall revert to the NC state, where utility line power is reconnected to the cabinet.	d	Experimented	Yes
1	15			Recharge time for the battery, from "protective low -cutoff" to 80% or more of full battery charge capacity, shall not exceed twenty (20) hours.	d	Ran five cycles of discharge and recharge at room temperature.	Yes
2	1	1		Inverter/Charger Unit shall be rack or shelf -mounted.			Yes
2	1	2		(Reserved)			
2	1	3		All interconnect wiring provided between Power Transfer Relay, Bypass Switch and Cabinet Terminal Service Block shall be no less than 2 meters (6.5 ft) of #10 AWG wire.	c	Wire is #14 AWG	Yes*
2	1	4		Relay contact wiring provided for each set of NO/NC relay contact closure terminals shall be 2 meters (6'6") of #18 AWG wire.	c	Wire is #10 AWG	Yes*
2	1	5		To ensure interchangeability between all UPS manufacturers, UPS Power Transfer Relay and Manual Bypass Switch shall be interconnected with Type IV or Type V NEMA cabinets according to the Department standards.	c		Yes
2	1	6		(Reserved)			
2	2	*		(Reserved)			-
2	3	1		Inverter/Charger, Power Transfer Relay and manually operated Bypass Switch shall fit inside a typical fully equipped Type IV or Type V NEMA Cabinet that houses one NEMA TS 1 or NEMA TS 2 controller.	d	Inverter:Yes PTS:Probably no	No*
2	3	2		Batteries shall be housed in a NEMA Standard TS 2 rated cabinet, self supported and mounted on the concrete foundation according to the Department standards. This external battery cabinet shall conform to the IDOT Standard Specifications for the construction and finish of the cabinet.	c	Did not test for the conformance of the cabinet to IDOT Specification	Yes*
2	3	3		Batteries shall be mounted on individual shelves for the cabinet housing four (4) batteries and two (2) batteries per shelf for the cabinet housing eight (8) batteries.	c	Cabinet provided can accommodate only four batteries	Yes
2	3	4		Four shelves shall be provided. Each shelf shall support a load of 30 kg (66 lb) minimum for single battery or 60 kg (132 lb) minimum for dual batteries.	c		Yes
2	3	5		(Reserved)			
2	3	6		Cabinets housing four (4) batteries shall have nominal outside dimensions of width 356 mm (14 in.) depth 229 mm (9 in.) and height within 1143 mm to 1397 mm (45 in. to 55 in.). Cabinets housing eight (8) batteries shall have nominal outside dimensions of width 711 mm (28 in.) depth 229 mm (9 in.), and height within 1143 mm to 1397 mm (45 in. to 55 in.). Clearance between shelves shall be a minimum of 254 mm (10 in.).	c		Yes

2	3	7		The battery cabinet shall be ventilated through the use of louvered vents, filter, and one thermostatically controlled fan as per NEMA TS 2 specifications.	c	Vent,Fan and Filter are there.Vendor claims that fan meets NEMA TS2 Specification	Yes
2	3	8		The battery cabinet fan shall be AC operated from the same line output of the Manual Bypass Switch that supplies power to the Type IV or Type V Cabinet.	c	Fan runs on 48VDC, 1A	No
2	3	9		The battery cabinet shall have a door opening to the entire cabinet. The door shall be attached to the cabinet through the use of a continuous stainless steel or aluminum piano hinge. The cabinet shall be provided with a main door lock which shall operate with a traffic industry conventional No. 2 key. Provisions for padlocking the door shall be provided.	c	Visually inspected	Yes
2	3	10		The UPS with battery cabinet shall come with all bolts, conduits and bushings, gaskets, shelves, and hardware needed for mounting.	c	Visually inspected.	Yes
3	1			The UPS shall include a display and /or meter to indicate current battery charge status and conditions.	c	LCD panel can display battery voltage	Yes
3	2			The UPS shall have lightning surge protection compliant with IEEE/ANSI C.62.41.	a	Seeking certification from manufacturer	Yes*
3	3			The UPS shall be equipped with an integral system to prevent battery from destructive discharge and overcharge.	a	Verified with the manufacturer	Yes
3	4			The UPS and batteries shall be easily replaced with all needed hardware and shall not require any special tools for installation.	c		Yes
3	5			The UPS shall include a resettable front-panel event counter display to indicate the number of times the UPS was activated and a front-panel hour meter to display the total number of hours the unit has operated on battery power.	c	Yes, front panel event counter and hour meter display are resettable	Yes
3	6			Manufacturer shall include two (2) sets of equipment lists, operation and maintenance manuals, and board-level schematic and wiring diagrams of the UPS, and the battery data sheets.	c	Only O & M manuals are there. Others are not there	No*
4	1			Individual batteries shall be 12V type, 65 amp-hour minimum capacity at 20 hours, and shall be easily replaced and commercially available off the shelf.	a	Batteries are 12 V 100 amp-hour	Yes
4	2			Batteries used for UPS shall consist of 4 to 8 batteries with a cumulative minimum rated capacity of 240 amp-hours.	c	Provided 4 batteries each 100 Amp-hr	Yes
4	3			Batteries shall be deep cycle, completely sealed, prismatic lead-calcium based AGM/VRLA (Absorbed Glass Mat/ Valve Regulated Lead Acid) requiring no maintenance.	a		Yes
4	4			Batteries shall be certified by the manufacturer to operate over a temperature range of – 25°C to +71°C (-13oF to 160oF).	a	Brochure indicates the same range for battery operation. Verified with the manufacturer	Yes



4	5			The batteries shall be provided with appropriate interconnect wiring and corrosion-resistant mounting trays and/or brackets appropriate for the cabinet into which they will be installed.	c	Provided	Yes
4	6			Batteries shall indicate maximum recharge data and recharging cycles.	c	Batteries do not indicate any such data	No*
4	7			Battery interconnect wiring shall be via modular harness. Batteries shall be shipped with positive and negative terminals pre-wired with red and black cabling that terminates into a typical power-pole style connector. Harness shall be equipped with mating power-pole style connectors for batteries and a single, insulated plug-in style connection to inverter/charger unit. Harness shall allow batteries to be quickly and easily connected in any order and shall be keyed and wired to ensure proper polarity and circuit configuration.	c		Yes
4	8			Battery terminals shall be covered and insulated so as to prevent accidental shorting.	c		Yes
5	1			Each UPS shall be manufactured in accordance with a manufacturer quality assurance (QA) program. The QA program shall include two types of quality assurance: (1) Design quality assurance and (2) Production quality assurance. The production quality assurance shall include statistically controlled routine tests to ensure minimum performance levels of UPS units built to meet this specification and a documented process of how problems are to be resolved.	b	Manufacturer Response: Adheres to ISO 9001 and 900. Meets CalTrans Spec	Yes*
5	2			QA process and test results documentation shall be kept on file for a minimum period of seven years.	b	Manufacturer Response: Adheres to ISO 9001 and 900. Meets CalTrans Spec	Yes*
5	3			Battery Backup System designs not satisfying design qualification testing and the production quality assurance testing performance requirements described below shall not be labeled, advertised, or sold as conforming to this specification.	Conclusion of the test	Conclusion of this test	
5	4	1		The manufacturer, or an independent testing lab hired by the manufacturer, shall perform design Qualification Testing on new UPS designs, and when a major design change has been implemented on an existing design. A major design change is defined as a design change (electrical or physical) which changes any of the performance characteristics of the system, or results in a different circuit configuration.	b	Manufacturer Response: Yes as standard practice	Yes
5	4	2		A single unit for each design shall be submitted for Design Qualification Testing.	Vendor furnished		Yes
5	4	2	1	Test units shall be submitted to the Traffic Operations Lab, 1605 Titan Drive, Rantoul, IL 61866, after the manufacturer's testing is complete.	Vendor furnished		Yes
5	4	2	2	Manufacturer's testing data shall be submitted with test units for IDOT's verification of Design Qualification Testing data.	Vendor furnished		No

5	4	3		The sample systems shall be energized for a minimum of 5 hours, with full load of 700 watts, at temperatures of +74°C and -37°C (+165oF and -35oF), excluding batteries, before performing any design qualification testing.	b	Manufacturer Response: Yes as standard practice	Yes
5	4	4		Any failure of the UPS, which renders the unit non-compliant with the specification after burn-in, shall be cause for rejection.	b	Manufacturer Response: Yes as standard practice	Yes
5	4	5		For Design Qualification Testing, all specifications will be measured including, but not limited to:	b		
5	4	5	1	Run time while in battery backup mode, at full load.			Yes
5	4	5	2	Proper operation of all relay contact closures ("On-Batt", "Low-Batt", "Timer" and "UPS-Fail").			Yes
5	4	5	3	Inverter output voltage, frequency, harmonic distortion, and efficiency, when in battery backup mode.			Yes
5	4	5	4	All utility mode – battery backup mode transfer voltage levels. See UPS Spec 1.8, 1.11 and 1.12.			Yes
5	4	5	5	Power transfer time from loss of utility power to switchover to battery backed inverter power.			Yes
5	4	5	6	Backfeed voltage to utility when in battery backup mode.			
5	4	5	7	IEEE/ANSI C.62.41 compliance.		Seeking certification from manufacturer	Yes*
5	4	5	8	Battery charging time.		Verified at room temperature only.	Yes
5	4	5	9	Event counter and runtime meter accuracy.			Yes
5	5	1		Production Quality Control tests shall consist of all of the above listed tests and shall be performed on each new system prior to shipment. Failure to meet requirements of any of these tests shall be cause for rejection. The manufacturer shall retain test results for seven years.	b	On each unit, tests corresponding to 5.4.5.3, 5.4.5.5 and 5.4.5.6 are performed. One out of a batch of 300 units is picked and tests corresponding to 5.4.5.4 and 5.4.5.7 are performed.	No*
5	5	2		Each UPS shall be given a minimum 100-hour burn-in period to catch any premature failures.	b	Company reponse: 100 hours	Yes
5	5	3		Each system shall be visually inspected for any exterior physical damage or assembly anomalies. Any defects shall be cause for rejection.	b	Manufacturer Response: Yes as standard practice	Yes
5	6	1		The IDOT will perform random sample testing on all shipments, consistent with ANSI/ASQC Z1.4-1993 Sampling Procedures and Tables for Inspection by Attributes.			Under consideration
5	6	2		Sample testing will normally be completed within 90 days after delivery to the Traffic Operations Laboratory, barring deficiencies in the shipment, which would reset the clock.			Under consideration

5	6	3		All parameters of the specification may be tested on the shipment sample.			Yes
5	6	4		The number of units tested (sample size) shall be determined by the quantity in the shipment. The sample size and acceptance or rejection of the shipment shall conform to ANSI/ASQC Z1.4.			Under consideration
6	0			Manufacturers shall provide a two (2) year factory-repair warranty for parts and labor on the UPS from date of acceptance by the State. Batteries shall be warranted for full replacement for two (2) years from date of purchase. The warranty shall be included in the total bid price of the UPS.	a	Warranty states that the warranty is valid for 24 months from the date of Manufacture, NOT date of acceptance by the state. Also for batteries the warranty is provided by the original manufacturer and NOT Myers.	Yes*

## Appendix B

### Findings for TechPower ME1000 UPS

The table below shows the classification of the different clauses of the Specification into

- e) Company Literature
- f) Question for Manufacturer
- g) Visual Inspection
- h) Laboratory Experiment

Note: For rows which contain "Yes\*" or "No\*" in "Does it meet the spec" column, please read the "Comments" column

Clause #				Clause	Method	Comments	Does it meet the spec?
1	1			The UPS shall be line interactive and provide voltage regulation and power conditioning when utilizing utility power.	a	Line Interactive UPS. Verified with Manufacturer	Yes
1	1	1		The UPS shall provide a minimum two (2) hours or a minimum six (6) hours of full run-time operation for an "LED-only" intersection (minimum 700W/1000VA active output capacity, with 80% minimum inverter efficiency). The two UPS, differing in the minimum duration of full run-time operation, shall be designated as UPS STANDARD and UPS EXTENDED respectively.	d	Ran ten tests of discharge at room temperature.	Yes for UPS STANDARD
1	2			The maximum transfer time from loss of utility power to switchover to battery backed inverter power shall be 65 milliseconds.	a	Transfer time is between 2 and 6 milliseconds.	Yes
1	3			The UPS shall provide the user with 4-sets of normally open (NO) and normally closed (NC) single-pole double-throw (SPDT) relay contact closures, available on a panel-mounted terminal block, rated at a minimum 120V/1A, and labeled so as to identify each contact (Manual Bypass Switch and Relay Contacts Standard).	c	Four NO/NC contact closures are provided on a panel	Yes
1	3	1		The first set of NO and NC contact closures shall be energized whenever the unit switches to battery power. Contact shall be labeled or marked "On Batt."	d	Two sets of contact closures are provided. They are labeled "AC Off" and "On Battery". Both are energized when the unit switches to battery	Yes

1	3	2		The second set of NO and NC contact closures shall be energized whenever the battery approaches approximately 40% of remaining useful capacity. Contact shall be labeled or marked "Low Batt."	d	No relay is marked "Low Batt"	No
1	3	3		The third set of NO and NC contact closures shall be energized two hours after the unit switches to battery power. Contact shall be labeled or marked "Timer."	d	One of the relays is marked "flash". It is energized after a duration chosen by the user.	Yes*
1	3	4		The fourth set of NO and NC contact closures shall be energized in the event of inverter/ charger failure. Contact shall be labeled or marked "UPS Fail."	d	Experimented	Yes
1	4			Operating temperature for both the inverter/power transfer relay and manual bypass switch shall be -37 °C to +74 °C (-35 °F to 165 °F).	a	Verified with Manufacturer.	Yes
1	5			Both the Power Transfer Relay and Manual Bypass Switch shall be rated at 240VAC/30 amps, minimum.	a	Verified with Manufacturer.	Yes
1	6			The UPS shall use a temperature-compensated battery charging system. The charging system shall compensate over a range of 2.5 – 4.0 mV/°C or (1.4 – 2.2 mV/°F) per cell.	a	Verified with Manufacturer.	Yes
1	6	1		The temperature sensor shall be external to the inverter/charger unit. The temperature sensor shall come with 2 meters (6.5 ft) of wire.	c	No Temperature Sensor	No
1	7			Batteries shall not be recharged when battery temperature exceeds 50°C ± 3°C (122oF + 5oF).	a	Recharging of the batteries does not stop.	No
1	8			UPS shall bypass the utility line power whenever the utility line voltage is outside of the following voltage range: 100VAC to 130VAC (± 2VAC).	d	Bypasses Line power when below 75 VAC. Did not bypass even when utility power reached 141 VAC.	No*
1	9			When utilizing battery power, the UPS output voltage shall be between 110 VAC and 125 VAC, pure sine wave output, £ 3% THD, 60Hz ±3Hz.	d	Voltage between 110 and 125 V, Frequency 60+/- 3 Hz	Yes
1	10			UPS shall be compatible with Illinois DOT's traffic controller assemblies utilizing NEMA TS 1 or NEMA TS 2 controllers and cabinet components for full time operation.	d	Tested UPS in TS2 Type 1 Cabinet	Yes
1	11			When the utility line power has been restored at above 105 VAC ±2 VAC for more than 30 seconds, the UPS shall dropout of battery backup mode and return to utility line mode.	d	Immediately Restored	No*

1	12			When the utility line power has been restored at below 125VAC $\pm 2$ VAC for more than 30 seconds, the UPS shall dropout of battery backup mode and return to utility line mode.	d	Immediately Restored	No*
1	13			UPS shall be equipped to prevent a malfunction feedback to the cabinet or from feeding back to the utility service.	a	Verified with Manufacturer.	Yes
1	14			In the event of inverter/charger failure, the power transfer relay shall revert to the NC state, where utility line power is reconnected to the cabinet.	d	Experimented	Yes
1	15			Recharge time for the battery, from "protective low -cutoff" to 80% or more of full battery charge capacity, shall not exceed twenty (20) hours.	d		No
2	1	1		Inverter/Charger Unit shall be rack or shelf -mounted.			Yes
2	1	2		(Reserved)			
2	1	3		All interconnect wiring provided between Power Transfer Relay, Bypass Switch and Cabinet Terminal Service Block shall be no less than 2 meters (6.5 ft) of #10 AWG wire.	c		Yes
2	1	4		Relay contact wiring provided for each set of NO/NC relay contact closure terminals shall be 2 meters (6'6") of #18 AWG wire.	c		Yes
2	1	5		To ensure interchangeability between all UPS manufacturers, UPS Power Transfer Relay and Manual Bypass Switch shall be interconnected with Type IV or Type V NEMA cabinets according to the Department standards.	c		Yes
2	1	6		(Reserved)			
2	2	*		(Reserved)			
2	3	1		Inverter/Charger, Power Transfer Relay and manually operated Bypass Switch shall fit inside a typical fully equipped Type IV or Type V NEMA Cabinet that houses one NEMA TS 1 or NEMA TS 2 controller.	d	Inverter: Yes PTS: presently mounted on the cabinet door	Yes*
2	3	2		Batteries shall be housed in a NEMA Standard TS 2 rated cabinet, self supported and mounted on the concrete foundation according to the Department standards. This external battery cabinet shall conform to the IDOT Standard Specifications for the construction and finish of the cabinet.	c	No cabinet provided	No*
2	3	3		Batteries shall be mounted on individual shelves for the cabinet housing four (4) batteries and two (2) batteries per shelf for the cabinet housing eight (8) batteries.	c	No cabinet provided	No*
2	3	4		Four shelves shall be provided. Each shelf shall support a load of 30 kg (66 lb) minimum for single battery or 60 kg (132 lb) minimum for dual batteries.	c	No cabinet provided	No*
2	3	5		(Reserved)			
2	3	6		Cabinets housing four (4) batteries shall have nominal outside dimensions of width 356 mm (14 in.) depth 229 mm (9 in.) and height within 1143 mm to 1397 mm (45 in. to 55 in.). Cabinets housing eight (8) batteries shall have nominal outside dimensions of width 711 mm (28 in.) depth 229 mm (9 in.), and height within 1143 mm to 1397 mm (45 in. to 55 in.). Clearance between shelves shall be a minimum of 254 mm (10 in.).	c	No cabinet provided	No*

2	3	7		The battery cabinet shall be ventilated through the use of louvered vents, filter, and one thermostatically controlled fan as per NEMA TS 2 specifications.	c	No cabinet provided	No*
2	3	8		The battery cabinet fan shall be AC operated from the same line output of the Manual Bypass Switch that supplies power to the Type IV or Type V Cabinet.	c	No cabinet provided	No*
2	3	9		The battery cabinet shall have a door opening to the entire cabinet. The door shall be attached to the cabinet through the use of a continuous stainless steel or aluminum piano hinge. The cabinet shall be provided with a main door lock which shall operate with a traffic industry conventional No. 2 key. Provisions for padlocking the door shall be provided.	c	No cabinet provided	No*
2	3	10		The UPS with battery cabinet shall come with all bolts, conduits and bushings, gaskets, shelves, and hardware needed for mounting.	c	No cabinet provided	No*
3	1			The UPS shall include a display and /or meter to indicate current battery charge status and conditions.	c	No indication of battery status	No
3	2			The UPS shall have lightning surge protection compliant with IEEE/ANSI C.62.41.	a	Seeking certification from manufacturer	Yes
3	3			The UPS shall be equipped with an integral system to prevent battery from destructive discharge and overcharge.	a	Verified with Manufacturer.	Yes
3	4			The UPS and batteries shall be easily replaced with all needed hardware and shall not require any special tools for installation.	c		Yes
3	5			The UPS shall include a resettable front-panel event counter display to indicate the number of times the UPS was activated and a front-panel hour meter to display the total number of hours the unit has operated on battery power.	c	Resettable Event counter display provided. Hour meter not provided.	No*
3	6			Manufacturer shall include two (2) sets of equipment lists, operation and maintenance manuals, and board-level schematic and wiring diagrams of the UPS, and the battery data sheets.	c	Only one copy of User Manual provided. Others are not.	No*
4	1			Individual batteries shall be 12V type, 65 amp-hour minimum capacity at 20 hours, and shall be easily replaced and commercially available off the shelf.	a	Batteries are 12 V, 55 Amp-hour	No
4	2			Batteries used for UPS shall consist of 4 to 8 batteries with a cumulative minimum rated capacity of 240 amp-hours.	c	Provided 4 batteries, each 55 Amp-hour	No
4	3			Batteries shall be deep cycle, completely sealed, prismatic lead-calcium based AGM/VRLA (Absorbed Glass Mat/ Valve Regulated Lead Acid) requiring no maintenance.	a		Yes
4	4			Batteries shall be certified by the manufacturer to operate over a temperature range of – 25°C to +71°C (-13oF to 160oF).	a	Verified with Manufacturer.	Yes

4	5			The batteries shall be provided with appropriate interconnect wiring and corrosion-resistant mounting trays and/or brackets appropriate for the cabinet into which they will be installed.	c	None Provided. No Cabinet provided.	No*
4	6			Batteries shall indicate maximum recharge data and recharging cycles.	c	Batteries do not indicate any such data	No*
4	7			Battery interconnect wiring shall be via modular harness. Batteries shall be shipped with positive and negative terminals pre-wired with red and black cabling that terminates into a typical power-pole style connector. Harness shall be equipped with mating power-pole style connectors for batteries and a single, insulated plug-in style connection to inverter/charger unit. Harness shall allow batteries to be quickly and easily connected in any order and shall be keyed and wired to ensure proper polarity and circuit configuration.	c	Harness does not have mating power-pole style connectors. Everything else is OK.	No*
4	8			Battery terminals shall be covered and insulated so as to prevent accidental shorting.	c		No
5	1			Each UPS shall be manufactured in accordance with a manufacturer quality assurance (QA) program. The QA program shall include two types of quality assurance: (1) Design quality assurance and (2) Production quality assurance. The production quality assurance shall include statistically controlled routine tests to ensure minimum performance levels of UPS units built to meet this specification and a documented process of how problems are to be resolved.	b	Verified with Manufacturer.	Yes
5	2			QA process and test results documentation shall be kept on file for a minimum period of seven years.	b	Verified with Manufacturer.	Yes
5	3			Battery Backup System designs not satisfying design qualification testing and the production quality assurance testing performance requirements described below shall not be labeled, advertised, or sold as conforming to this specification.	Conclusion of the test	Conclusion of this test	
5	4	1		The manufacturer, or an independent testing lab hired by the manufacturer, shall perform design Qualification Testing on new UPS designs, and when a major design change has been implemented on an existing design. A major design change is defined as a design change (electrical or physical) which changes any of the performance characteristics of the system, or results in a different circuit configuration.	b	Manufacturer performs internally and also has an independent testing.	Yes
5	4	2		A single unit for each design shall be submitted for Design Qualification Testing.	Vendor furnished		Yes
5	4	2	1	Test units shall be submitted to the Traffic Operations Lab, 1605 Titan Drive, Rantoul, IL 61866, after the manufacturer's testing is complete.	Vendor furnished		Yes
5	4	2	2	Manufacturer's testing data shall be submitted with test units for IDOT's verification of Design Qualification Testing data.	Vendor furnished		No



5	4	3		The sample systems shall be energized for a minimum of 5 hours, with full load of 700 watts, at temperatures of +74°C and -37°C (+165oF and -35oF), excluding batteries, before performing any design qualification testing.	b	Verified with Manufacturer	Yes
5	4	4		Any failure of the UPS, which renders the unit non-compliant with the specification after burn-in, shall be cause for rejection.	b	Verified with Manufacturer.	Yes
5	4	5		For Design Qualification Testing, all specifications will be measured including, but not limited to:	b		
5	4	5	1	Run time while in battery backup mode, at full load.			Yes
5	4	5	2	Proper operation of all relay contact closures ("On-Batt", "Low-Batt", "Timer" and "UPS-Fail").			Yes
5	4	5	3	Inverter output voltage, frequency, harmonic distortion, and efficiency, when in battery backup mode.			Yes
5	4	5	4	All utility mode – battery backup mode transfer voltage levels. See UPS Spec 1.8, 1.11 and 1.12.			Yes
5	4	5	5	Power transfer time from loss of utility power to switchover to battery backed inverter power.			Yes
5	4	5	6	Backfeed voltage to utility when in battery backup mode.		Verified with Manufacturer.	Yes
5	4	5	7	IEEE/ANSI C.62.41 compliance.		Verified with Manufacturer.	Yes
5	4	5	8	Battery charging time.			Yes
5	4	5	9	Event counter and runtime meter accuracy.			Yes
5	5	1		Production Quality Control tests shall consist of all of the above listed tests and shall be performed on each new system prior to shipment. Failure to meet requirements of any of these tests shall be cause for rejection. The manufacturer shall retain test results for seven years.	b	Tests are performed on each new system and results are documented for seven years.	Yes
5	5	2		Each UPS shall be given a minimum 100-hour burn-in period to catch any premature failures.	b	Randomly chosen units are given a 100 hr burn-in period	No*
5	5	3		Each system shall be visually inspected for any exterior physical damage or assembly anomalies. Any defects shall be cause for rejection.	b	Verified with Manufacturer	Yes
5	6	1		The IDOT will perform random sample testing on all shipments, consistent with ANSI/ASQC Z1.4-1993 Sampling Procedures and Tables for Inspection by Attributes.			Under consideration
5	6	2		Sample testing will normally be completed within 90 days after delivery to the Traffic Operations Laboratory, barring deficiencies in the shipment, which would reset the clock.			Under consideration

5	6	3		All parameters of the specification may be tested on the shipment sample.			Yes
5	6	4		The number of units tested (sample size) shall be determined by the quantity in the shipment. The sample size and acceptance or rejection of the shipment shall conform to ANSI/ASQC Z1.4.			Under consideration
6	0			Manufacturers shall provide a two (2) year factory-repair warranty for parts and labor on the UPS from date of acceptance by the State. Batteries shall be warranted for full replacement for two (2) years from date of purchase. The warranty shall be included in the total bid price of the UPS.	a	Manufacturer verified that the warranty is valid for 2 years from the date of purchase	Yes

## Appendix C

### Findings for Dimensions 24M11 UPS

The table below shows the classification of the different clauses of the Specification into

- i) Company Literature
- j) Question for Manufacturer
- k) Visual Inspection
- l) Laboratory Experiment

Note: For rows which contain "Yes\*" or "No\*" in "Does it meet the spec" column, please read the "Comments" column

Clause #				Clause	Method	Comments	Does it meet the spec?
1	1			The UPS shall be line interactive and provide voltage regulation and power conditioning when utilizing utility power.	a	Verified with Manufacturer	No
1	1	1		The UPS shall provide a minimum two (2) hours or a minimum six (6) hours of full run-time operation for an "LED-only" intersection (minimum 700W/1000VA active output capacity, with 80% minimum inverter efficiency). The two UPS, differing in the minimum duration of full run-time operation, shall be designated as UPS STANDARD and UPS EXTENDED respectively.	d	Ran five tests of discharge at room temperature.	Yes for UPS STANDARD
1	2			The maximum transfer time from loss of utility power to switchover to battery backed inverter power shall be 65 milliseconds.	a	Caltrans Tested. Typical transfer time is 40 milliseconds.	Yes
1	3			The UPS shall provide the user with 4-sets of normally open (NO) and normally closed (NC) single-pole double-throw (SPDT) relay contact closures, available on a panel-mounted terminal block, rated at a minimum 120V/1A, and labeled so as to identify each contact (Manual Bypass Switch and Relay Contacts Standard).	c	Six NO/NC contact closures are provided on a panel	Yes
1	3	1		The first set of NO and NC contact closures shall be energized whenever the unit switches to battery power. Contact shall be labeled or marked "On Batt."	d	Two sets of contact closures are provided. Both are energized when the unit switches to battery	Yes

1	3	2		The second set of NO and NC contact closures shall be energized whenever the battery approaches approximately 40% of remaining useful capacity. Contact s hall be labeled or marked "Low Batt."	d	Two sets of contact closures are provided. Both are energized when the batteries reach 40% level.	Yes
1	3	3		The third set of NO and NC contact closures shall be energized two hours after the unit switches to battery power. Contact shall be labeled or marked "Timer."	d	Two sets of contact closures are provided. Both are energized two hours after the unit switches to battery power	Yes
1	3	4		The fourth set of NO and NC contact closures shall be energized in the event of inverter/ charger failure. Contact shall be labeled or marked "UPS Fail."	d		No
1	4			Operating temperature for both the inverter/power transfer relay and manual bypass switch shall be -37 °C to +74 °C (-35 °F to 165 °F).	a	Verified with Manufacturer.	Yes
1	5			Both the Power Transfer Relay and Manual Bypass Switch shall be rated at 240VAC/30 amps, minimum.	a		Yes
1	6			The UPS shall use a temperature-compensated battery charging system. The charging system shall compensate over a range of 2.5 – 4.0 mV/°C or (1.4 – 2.2 mV/°F) per cell.	a	Verified with Manufacturer.	Yes
1	6	1		The temperature sensor shall be external to the inverter/charger unit. The temperature sensor shall come with 2 meters (6.5 ft) of wire.	c		Yes
1	7			Batteries s hall not be recharged when battery temperature exceeds 50°C ± 3°C (122°F + 5°F).	a	Verified in the lab that the recharging of the batteries stops when the battery temperature exceeds 50°C ± 3°C (122°F + 5°F).	Yes
1	8			UPS shall bypass the utility line power whenever the utility line voltage is outside of the following voltage range: 100VAC to 130VAC (± 2VAC).	d		Yes
1	9			When utilizing battery power, the UPS output voltage shall be between 110 VAC and 125 VAC, pure sine wave output, £ 3% THD, 60Hz ±3Hz.	d	Voltage between 120 ± 5% V, Frequency 60 ±0.05 Hz	Yes
1	10			UPS shall be compatible with Illinois DOT's traffic controller assemblies utilizing NEMA TS 1 or NEMA TS 2 controllers and cabinet components for full time operation.	d	Tested UPS in TS2 Type 1 Cabinet	Yes
1	11			When the utility line power has been restored at above 105 VAC ±2 VAC for more than 30 seconds, the UPS shall dropout of battery backup mode and return to utility line mode.	d	Verified in the lab	Yes

1	12			When the utility line power has been restored at below 125VAC $\pm 2$ VAC for more than 30 seconds, the UPS shall dropout of battery backup mode and return to utility line mode.	d	Verified in the lab	Yes
1	13			UPS shall be equipped to prevent a malfunction feedback to the cabinet or from feeding back to the utility service.	a	Verified with Manufacturer.	Yes
1	14			In the event of inverter/charger failure, the power transfer relay shall revert to the NC state, where utility line power is reconnected to the cabinet.	d	Experimented	Yes
1	15			Recharge time for the battery, from "protective low -cutoff" to 80% or more of full battery charge capacity, shall not exceed twenty (20) hours.	d	Experimented	Yes
2	1	1		Inverter/Charger Unit shall be rack or shelf -mounted.			Yes
2	1	2		(Reserved)			
2	1	3		All interconnect wiring provided between Power Transfer Relay, Bypass Switch and Cabinet Terminal Service Block shall be no less than 2 meters (6.5 ft) of #10 AWG wire.	c		Yes
2	1	4		Relay contact wiring provided for each set of NO/NC relay contact closure terminals shall be 2 meters (6'6") of #18 AWG wire.	c		Yes
2	1	5		To ensure interchangeability between all UPS manufacturers, UPS Power Transfer Relay and Manual Bypass Switch shall be interconnected with Type IV or Type V NEMA cabinets according to the Department standards.	c		Yes
2	1	6		(Reserved)			
2	2	*		(Reserved)			
2	3	1		Inverter/Charger, Power Transfer Relay and manually operated Bypass Switch shall fit inside a typical fully equipped Type IV or Type V NEMA Cabinet that houses one NEMA TS 1 or NEMA TS 2 controller.	d		Yes
2	3	2		Batteries shall be housed in a NEMA Standard TS 2 rated cabinet, self supported and mounted on the concrete foundation according to the Department standards. This external battery cabinet shall conform to the IDOT Standard Specifications for the construction and finish of the cabinet.	c	No cabinet provided	No*
2	3	3		Batteries shall be mounted on individual shelves for the cabinet housing four (4) batteries and two (2) batteries per shelf for the cabinet housing eight (8) batteries.	c	No cabinet provided	No*
2	3	4		Four shelves shall be provided. Each shelf shall support a load of 30 kg (66 lb) minimum for single battery or 60 kg (132 lb) minimum for dual batteries.	c	No cabinet provided	No*
2	3	5		(Reserved)			
2	3	6		Cabinets housing four (4) batteries shall have nominal outside dimensions of width 356 mm (14 in.) depth 229 mm (9 in.) and height within 1143 mm to 1397 mm (45 in. to 55 in.). Cabinets housing eight (8) batteries shall have nominal outside dimensions of width 711 mm (28 in.) depth 229 mm (9 in.), and height within 1143 mm to 1397 mm (45 in. to 55 in.). Clearance between shelves shall be a minimum of 254 mm (10 in.).	c	No cabinet provided	No*

2	3	7		The battery cabinet shall be ventilated through the use of louvered vents, filter, and one thermostatically controlled fan as per NEMA TS 2 specifications.	c	No cabinet provided	No*
2	3	8		The battery cabinet fan shall be AC operated from the same line output of the Manual Bypass Switch that supplies power to the Type IV or Type V Cabinet.	c	No cabinet provided	No*
2	3	9		The battery cabinet shall have a door opening to the entire cabinet. The door shall be attached to the cabinet through the use of a continuous stainless steel or aluminum piano hinge. The cabinet shall be provided with a main door lock which shall operate with a traffic industry conventional No. 2 key. Provisions for padlocking the door shall be provided.	c	No cabinet provided	No*
2	3	10		The UPS with battery cabinet shall come with all bolts, conduits and bushings, gaskets, shelves, and hardware needed for mounting.	c	No cabinet provided	No*
3	1			The UPS shall include a display and /or meter to indicate current battery charge status and conditions.	c	LEDs indicate the state of charge of the batteries	Yes
3	2			The UPS shall have lightning surge protection compliant with IEEE/ANSI C.62.41.	a		Yes
3	3			The UPS shall be equipped with an integral system to prevent battery from destructive discharge and overcharge.	a	Verified with Manufacturer.	Yes
3	4			The UPS and batteries shall be easily replaced with all needed hardware and shall not require any special tools for installation.	c		Yes
3	5			The UPS shall include a resettable front-panel event counter display to indicate the number of times the UPS was activated and a front-panel hour meter to display the total number of hours the unit has operated on battery power.	c		Yes
3	6			Manufacturer shall include two (2) sets of equipment lists, operation and maintenance manuals, and board-level schematic and wiring diagrams of the UPS, and the battery data sheets.	c	Only one copy of User Manual provided. Others are not.	No*
4	1			Individual batteries shall be 12V type, 65 amp-hour minimum capacity at 20 hours, and shall be easily replaced and commercially available off the shelf.	a	Batteries are 12 V, 79 Amp-hour	Yes
4	2			Batteries used for UPS shall consist of 4 to 8 batteries with a cumulative minimum rated capacity of 240 amp-hours.	c	Provided 4 batteries, each 79 Amp-hour	Yes
4	3			Batteries shall be deep cycle, completely sealed, prismatic lead-calcium based AGM/VRLA (Absorbed Glass Mat/ Valve Regulated Lead Acid) requiring no maintenance.	a		Yes
4	4			Batteries shall be certified by the manufacturer to operate over a temperature range of – 25°C to +71°C (-13oF to 160oF).	a	Verified with Manufacturer.	Yes

4	5			The batteries shall be provided with appropriate interconnect wiring and corrosion-resistant mounting trays and/or brackets appropriate for the cabinet into which they will be installed.	c	None Provided. No Cabinet provided.	No*
4	6			Batteries shall indicate maximum recharge data and recharging cycles.	c	Batteries do not indicate any such data	No*
4	7			Battery interconnect wiring shall be via modular harness. Batteries shall be shipped with positive and negative terminals pre-wired with red and black cabling that terminates into a typical power-pole style connector. Harness shall be equipped with mating power-pole style connectors for batteries and a single, insulated plug-in style connection to inverter/charger unit. Harness shall allow batteries to be quickly and easily connected in any order and shall be keyed and wired to ensure proper polarity and circuit configuration.	c		Yes
4	8			Battery terminals shall be covered and insulated so as to prevent accidental shorting.	c		Yes
5	1			Each UPS shall be manufactured in accordance with a manufacturer quality assurance (QA) program. The QA program shall include two types of quality assurance: (1) Design quality assurance and (2) Production quality assurance. The production quality assurance shall include statistically controlled routine tests to ensure minimum performance levels of UPS units built to meet this specification and a documented process of how problems are to be resolved.	b	Verified with Manufacturer.	Yes
5	2			QA process and test results documentation shall be kept on file for a minimum period of seven years.	b	Verified with Manufacturer.	Yes
5	3			Battery Backup System designs not satisfying design qualification testing and the production quality assurance testing performance requirements described below shall not be labeled, advertised, or sold as conforming to this specification.	Conclusion of the test	Conclusion of this test	
5	4	1		The manufacturer, or an independent testing lab hired by the manufacturer, shall perform design Qualification Testing on new UPS designs, and when a major design change has been implemented on an existing design. A major design change is defined as a design change (electrical or physical) which changes any of the performance characteristics of the system, or results in a different circuit configuration.	b	Manufacturer performs internally and also has an independent testing.	Yes
5	4	2		A single unit for each design shall be submitted for Design Qualification Testing.	Vendor furnished		Yes
5	4	2	1	Test units shall be submitted to the Traffic Operations Lab, 1605 Titan Drive, Rantoul, IL 61866, after the manufacturer's testing is complete.	Vendor furnished		Yes
5	4	2	2	Manufacturer's testing data shall be submitted with test units for IDOT's verification of Design Qualification Testing data.	Vendor furnished		Yes

5	4	3		The sample systems shall be energized for a minimum of 5 hours, with full load of 700 watts, at temperatures of +74°C and -37°C (+165oF and -35oF), excluding batteries, before performing any design qualification testing.	b	Manufacturer tests for a minimum of 3 hrs at ambient. The units often spend more time. In addition every board is tested prior to assembly.	Yes *
5	4	4		Any failure of the UPS, which renders the unit non-compliant with the specification after burn-in, shall be cause for rejection.	b	Verified with Manufacturer.	Yes
5	4	5		For Design Qualification Testing, all specifications will be measured including, but not limited to:	b		
5	4	5	1	Run time while in battery backup mode, at full load.			Yes
5	4	5	2	Proper operation of all relay contact closures ("On-Batt", "Low-Batt", "Timer" and "UPS-Fail").			Yes
5	4	5	3	Inverter output voltage, frequency, harmonic distortion, and efficiency, when in battery backup mode.			Yes
5	4	5	4	All utility mode – battery backup mode transfer voltage levels. See UPS Spec 1.8, 1.11 and 1.12.			Yes
5	4	5	5	Power transfer time from loss of utility power to switchover to battery backed inverter power.			Yes
5	4	5	6	Backfeed voltage to utility when in battery backup mode.		Verified with Manufacturer.	Yes
5	4	5	7	IEEE/ANSI C.62.41 compliance.		Verified with Manufacturer.	Yes
5	4	5	8	Battery charging time.			Yes
5	4	5	9	Event counter and runtime meter accuracy.			Yes
5	5	1		Production Quality Control tests shall consist of all of the above listed tests and shall be performed on each new system prior to shipment. Failure to meet requirements of any of these tests shall be cause for rejection. The manufacturer shall retain test results for seven years.	b	Tests are performed on each new system and results are documented for seven years.	Yes
5	5	2		Each UPS shall be given a minimum 100-hour burn-in period to catch any premature failures.	b	88 hrs burn-in in charger mode and 12 hr burn-in in inverter mode.	Yes *
5	5	3		Each system shall be visually inspected for any exterior physical damage or assembly anomalies. Any defects shall be cause for rejection.	b	Verified with Manufacturer	Yes
5	6	1		The IDOT will perform random sample testing on all shipments, consistent with ANSI/ASQC Z1.4-1993 Sampling Procedures and Tables for Inspection by Attributes.			Under consideration
5	6	2		Sample testing will normally be completed within 90 days after delivery to the Traffic Operations Laboratory, barring deficiencies in the shipment, which would reset the clock.			Under consideration



5	6	3		All parameters of the specification may be tested on the shipment sample.			Yes
5	6	4		The number of units tested (sample size) shall be determined by the quantity in the shipment. The sample size and acceptance or rejection of the shipment shall conform to ANSI/ASQC Z1.4.			Under consideration
6	0			Manufacturers shall provide a two (2) year factory-repair warranty for parts and labor on the UPS from date of acceptance by the State. Batteries shall be warranted for full replacement for two (2) years from date of purchase. The warranty shall be included in the total bid price of the UPS.	a	Manufacturer verified that the warranty is valid for 2 years from the date of purchase	Yes