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Evaluation of UPS for Intersection Traffic Signals with LED: Findings for TechPower M 1000 UPS

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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 M 1000 UPS manufactured by TechPower Developments Inc. and verify if it meets the Illinois DOT's specification for UPS. Multiple tests with full load (approximately 700 W) and partial loads (flashing reds with about 350W) were conducted at room temperature to determine charge and discharge times. The time to fully charge the batteries was consistently greater than 24 hrs. The UPS powered a full load for 2hrs 37mins. When powering a full load, the UPS took 1hr 35min to reach 40% battery level. After reaching the 40% level, the UPS powered the flashing reds for 2hr 10min. TechPower M 1000 UPS has some major and some minor shortcomings that can be corrected to satisfy all IDOT Specification requirements. this model does not have a NO and NC contact closure for indicating that the batteries reached 40% level. The manufacturer gives a 5 hr burn-in period to each unit. The supplied unit was taking approximately 31 hours to fully charge the batteries. The supplied batteries are 55 Amp-hr while the specification requires them to be at least 65 Amp-hr.

17. Key Words	18. Distribution Statement
Uninterruptible Power Supply for Intersections, UPS, Intersection Traffic Signals, LED Signal Modules, Battery Back up System for Traffic Lights, BBS.	

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Acknowledgment and Disclaimer

This study was conducted by the Traffic Operations Laboratory (TOL) at the University of Illinois at Urbana-Champaign. The Illinois Department of Transportation sponsored the study. The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not reflect the official views or policies of the Illinois Department of Transportation. This report does not constitute a standard, specification, or regulation.

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OBJECTIVE

TechPower Developments Inc, a prospective supplier of UPS for Illinois Department of Transportation (IDOT) provided one M 1000 UPS system for evaluation. The objective of this study is to test the UPS model provided by the manufacturer and see whether it meets the Specification for UPS developed by IDOT. The evaluation was conducted at the Traffic Operations Lab at the University of Illinois. This report discusses the methodology for testing and the interim results of the evaluation of the M 1000 unit. In the course of the evaluation it was found that the supplied unit was not getting charged within the expected duration. The manufacturer claimed that the supplied unit had a defective charger. The manufacturer would be supplying a new unit for evaluation. The results of that evaluation will be added to the report.

METHODOLOGY

IDOT has developed an interim UPS Specification 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

Appendix A shows the category in which each of the clauses was placed.

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 °C to +74 °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 from 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 if 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). 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 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. Using the LED signal modules and the intersection panel available at the Traffic Operations Lab, a load of around 700 watts was set up.

The discharge times of the batteries obviously depend on the kind of the load that is being powered i.e., solid indications all through or solid indications followed by flashing red indications. Specifically, it is being considered that the intersection should go to flash operation after the batteries reach 40% level. Therefore a prospective user would be interested in the durations under these two kinds of operation.

For measuring the duration of Solid operation all through, 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.

It was necessary to visually observe the UPS to obtain the time at which the batteries reached 40% level. A continuity tester was connected between the common and normally open ends of the second relay contact closure. When the batteries reach 40% level, this relay would be energized and the continuity tester would glow indicating that batteries have reached 40% level. To obtain this time, a camcorder was used to record the UPS front panel during the test. The camcorder was run in interval recording mode using an interval of one minute and recording duration of 2 seconds. Therefore the time could have an error of one minute at the worst. The block diagram of the experimental setup is shown in Figure 1.

Once the batteries reached the 40 % level, the intersection was put on flash and the time the flashing load was powered before the batteries were shutdown by the UPS was obtained.

Under flashing conditions the load was approximately half of the full load. Therefore it would be expected that the batteries would power the flashing load for approximately twice the time they would have powered the full load. Using this concept, from this data the duration the batteries would have powered a full load can be estimated. If the time to reach 40% battery level is called t_1 and flashing duration after reaching 40% battery level is called t_2, the duration the batteries would have powered a full load (call it t_f) can be estimated using the following relationship.

$$t_f = t_1 + t_2/2$$

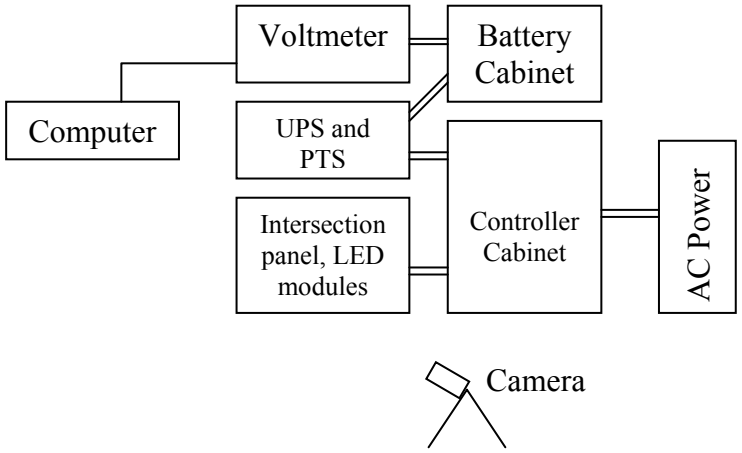


Figure 1. Block diagram of the experimental setup.

The average of these estimated values is compared with the average duration the batteries powered the full load. If these two numbers are close, that would further increase the confidence in the results of these tests.

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 are 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, "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 explanation of the specific answer.

TEST RESULTS

In this section the results of the charge and discharge tests are discussed. First the results for discharging the batteries at full load (700W) all through and recharging the batteries are presented. Following this the results for operating in flash condition after reaching 40% battery level are presented.

The UPS model supplied by the manufacturer was M 1000 and batteries were Optima batteries (model D34M). The results of the discharge tests performed at full load for Techpower UPS are shown in Table 1 and Figure 2.

Test Number	Date	Running time	Beginning voltage (V)	Lowest Voltage (V)
1	8/4/2003	2:20	13.527	9.468
2	8/7/2003	2:47	13.930	9.221
3	8/8/2003	2:27	13.421	9.281
4	8/10/2003	2:42	13.744	9.193
5	8/12/2003	2:40	13.803	9.109
6	8/14/2003	2:37	13.857	9.067
7	8/22/2003	2:40	13.820	9.372
8	8/26/2003	2:37	13.778	8.993
9	9/3/2003	2:38	13.958	9.155
10	9/8/2003	2:39	14.047	8.881

Table 1. Results of discharge tests performed at full load for TechPower UPS

From Figure 2 we can see that the duration of battery power for the first test is significantly lower compared to the other tests because the load in the first test was higher than the load used in the subsequent tests. The estimate of the error from the true mean, based on these observations is 4.3 minutes which is 3.6% of 2 hours (specification requirement). Therefore more tests were not performed.

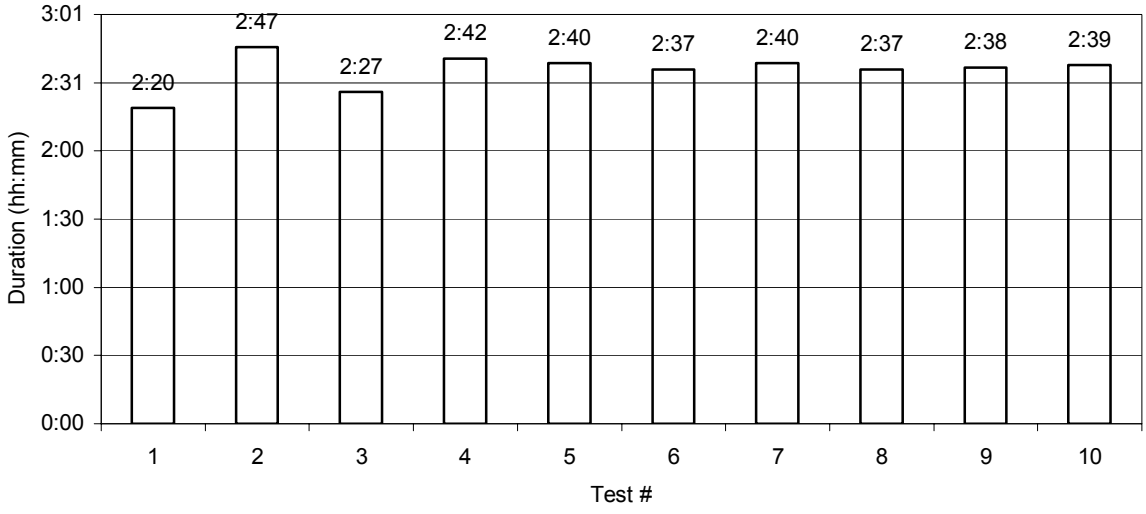
To avoid deep discharge of the batteries, the UPS monitors the battery voltage and disconnects the batteries from the UPS when the battery voltage reaches a certain specified voltage. Therefore run time of the batteries is directly related to the specified cutoff voltage. In general, the deeper the discharge batteries go through, the lesser 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 13.79 VDC and the mean voltage at the shutdown point was 9.17 VDC. The voltage at shutdown varied from 8.881 to 9.468 VDC.

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 2:37 and the minimum and the maximum values are 2:20 and 2:47. Based on these observations, from the results of t-test, it can be concluded that the estimated mean of 2:37 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.

From Figure 2 we can see that the run times for tests 1 and 3 are significantly lower than the rest. It was observed that for those two tests the batteries were not fully charged before the testing even though the batteries were charged for 24 hours.

Figure 2. Duration of battery power (hh:mm) at full load for TechPower UPS



The results for fully charging the batteries for TechPower UPS are shown in Table 2. From Table 2 we can see that the duration to fully charge the batteries is consistently higher than 24 hours. On contacting the manufacturer, the manufacturer claimed that this unit has a defective charger. The manufacturer would be shipping a new unit to the Traffic Operations Lab for testing.

Test Number	Date	Charging Time (hh:mm)
1	8/4/2003	> 24:00
2	8/7/2003	> 24:00
3	8/8/2003	31:20
4	8/10/2003	31:23
5	8/12/2003	29:47
6	8/14/2003	31:00
7	8/22/2003	> 24:00
8	8/26/2003	> 24:00
9	9/3/2003	31:27
10	9/8/2003	32:20

Table 2. Results for fully charging the batteries for TechPower UPS.

Because the supplied unit was claimed to be defective by the vendor, extensive testing for estimating the time taken by the batteries to reach 40% level under full load and the time the batteries powered the flashing load from that point were not performed. However, one test has been performed to get an estimate of these durations.

It should be noted that TechPower UPS does not have a relay that would be energized when the battery reaches 40% level. Therefore the duration the batteries would take to reach 40% level was estimated based on the data from the discharge tests at full load. It was observed that on the average the batteries took 95 minutes to reach 40% level when they were powering the full load. At the end of that duration, the load was changed to flashing manually. Thereafter the batteries powered the flashing load for 2hrs 10 minutes. Further testing would be performed on the new unit to be supplied by the manufacturer.

SUMMARY OF FINDINGS

The average run time with full load (approximately 700 W) at room temperature for Techpower M 1000 UPS was 2 hrs 37 min and the minimum and maximum values were 2 hrs 20 min and 2 hrs 47 min respectively. For all the ten tests that were performed to check the recharge time, the recharge time exceeded 24 hours. Statistical tests concluded that for run time at full load the TechPower M 1000 UPS meets the specification requirements. Also it was estimated that the UPS would take 1 hr 35 min on the average to reach 40% battery level (when operating on full load). After powering a full load for that duration, the controller was put to flash manually and the batteries powered flashing reds for 2 hrs 10 min more.

Details on how TechPower M 1000 meets each specific requirement of the IDOT Specification is given in Appendix A. The major shortcomings of this model are: this model does not have a NO and NC contact closure for indicating that the batteries

reached 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 5 hr burn-in period to each unit. The supplied unit was taking approximately 31 hours to fully charge the batteries. The manufacturer claimed that the supplied unit has a defective charger. The manufacturer has furnished a new unit for further testing. The supplied batteries are 55 Amp-hr while the specification requires them to be at least 65 Amp-hr. The manufacturer is yet to supply a battery cabinet for evaluation.

This model has several minor shortcomings. These include: The battery is not recharged when the temperature reaches 57° C. Also 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. These shortcomings can be fixed by the manufacturer.

In summary, TechPower M 1000 UPS has some major and several minor shortcomings that can be corrected to satisfy all IDOT Specification requirements.

Appendix A

Findings for TechPower M 1000 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	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 cycles of discharge and recharge 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	In Product Design Requirements under Operation in Clause 3 it is stated that "The switching.. Will occur in less than 4 milliseconds.” Verified with Manufacturer.	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	Brochure indicates the operating range for the unit as -40 C to +75 C. 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	Stated on pg.25 of the User Manual that it uses a temperature compensated system. Verified the range 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	Temperature Sensor is in-built.	No*
1	7			Batteries shall not be recharged when battery temperature exceeds 50°C ± 3°C (122oF + 5oF).	a	Battery is not recharged when the temperature reaches 57 C	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 91VAC. 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 ±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	Time to fully charge was approx 30 hrs. Manufacturer claims unit was defective. Further testing will be performed on the new unit to be provided.	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	Wire is #14 AWG and 3 inch shorter	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	LEDs indicate current battery charge status and conditions.	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 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 resetable 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	Resetable 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	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. 1 in 66 units along with the batteries undergo this test.	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.		Seeking certification from manufacturer	Yes*
5	4	5	7	IEEE/ANSI C.62.41 compliance.		Seeking certification from 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	Company Response: 5 hrs	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	Warranty on pg. 30 of User Manual states that the warranty is valid for 24 months from the date of delivery to the customer. For products sold by Techpower, but which do not bear their name the warranty is not provided by TechPower. The warranty provided by Optima includes 12 month free replacement and the remaining months prorated.	Yes*