U.S. Department
of Transportation

**Pipeline and Hazardous
Materials Safety
Administration**

1200 New Jersey Avenue, SE
Washington, D.C. 20590

JUN 2 7 2016

Mr. Fred Marks
Consultant to Bosh Global Services
727 Regent Ct.
Gaithersburg, MD 20878

Ref. No.: 16-0015

Dear Mr. Marks

This responds to your January 19, 2016 e-mail and subsequent conversations with a member of my staff, requesting clarification of the Hazardous Materials Regulations (HMR; 49 CFR Parts 171-180). Specifically, you ask several questions concerning the applicability of the T.7 test found in the United Nations Manual of Tests and Criteria, 5th Revised Edition (UN Manual of Tests and Criteria), including Amendments 1 and 2, to your particular battery configuration. You state that your battery assembly consists of six batteries each containing four lithium ion cells and a Watt-hour rating (Wh) of 98 Wh. You note that your battery assembly has a pack protection cap (PPC) containing a charge protection module (PCM) that ensures the battery never has an overvoltage applied to it. This PPC is only removed during the use of the battery and remains in place during charge, storage, and transport. You further note that charging of the battery is only possible with the PPC snapped to the battery as a part of the battery assembly. You state it is not possible to charge the battery without the PPC in place without deliberate damage to the battery assembly to permit access to internal terminals and nodes. Your questions are paraphrased and answered as follows:

Q1. Are batteries that do not have overcharge protection that are designed for use only as a component in a battery assembly that provides overcharge protection afforded the exception from test T.7 in the UN Manual of Tests and Criteria in section 38.3.3(d)?

A1. The answer to your question is yes. Section 38.3.3(d) clearly states that batteries not equipped with overcharge protection that are designed for use only in a battery assembly which affords such protection are not subject to the requirements of test T.7.

Q2. Do batteries that are designed for use only as a component of a battery assembly equipped with a removable PPC providing overcharge protection that is only removed during use and remains in place during charge, storage, and transport need to pass the T.7 test of the UN Manual of Tests and Criteria?

A2. The UN Manual of Tests and Criteria do not delineate between permanently installed overcharge protection and removable overcharge protection. As noted in the information you have provided, it is only possible to charge the battery assembly without the "PPC" in place by means of deliberate damage to the battery assembly to permit access to internal terminals and nodes. In the absence of such deliberate damage to the battery assembly the "PPC" will provide overcharge protection. It is the opinion of this Office, based on the information you have provided, the "PPC" component of your battery assembly provides overcharge protection meeting the requirements in 38.3.3(d) and consequentially batteries designed only for use in such battery assemblies equipped with your "PPC" overcharge protection are not required to pass the T.7 test in the UN Manual of Tests and Criteria. To be clear, the PPC would need to be installed in the battery assembly while in transportation.

Q3. Is the battery assembly that includes the PPC required to undergo test T.7 as an assembly?

A3. The answer to your question is yes. Section 38.3.3(f) of the UN Manual of Tests and Criteria requires a lithium ion battery assembly, with a Watt-hour rating of not more than 6,200 Wh, that is assembled from batteries that have passed all applicable tests, to test one battery assembly in a fully charged state under tests T.3, T.4 and T.5, and, in addition, test T.7 in the case of a rechargeable battery assembly. For a rechargeable battery assembly, the assembly shall have been cycled at least 25 cycles. For a lithium ion battery, with a Watt-hour rating of more than 6,200 Wh, the battery assembly does not need to be tested if it is equipped with a system capable of monitoring the battery assembly and preventing short circuits, or over discharge between the batteries in the assembly and any overheat or overcharge of the battery assembly.

I hope this answers your inquiry. If you need additional assistance, please contact the Standards and Rulemaking Division at (202) 366-8553.

Sincerely,

Charles E. Betts

for Duane A. Pfund
International Standards Coordinator
Standards and Rulemaking Division

Webb
§173.185.(a)(1)
Batteries
16-0015

Dodd, Alice (PHMSA)

From: Webb, Steven (PHMSA)
Sent: Thursday, January 21, 2016 1:15 PM
To: Goodall, Shante CTR (PHMSA); Dodd, Alice (PHMSA)
Subject: Interpretation Request
Attachments: Request to DoT for LOI for raven packs.doc

Please log this in as an interpretation request. I would like this to be assigned to me if possible. I have been working with the gentleman for a week now on this letter and have a pretty good idea of the response needed. Let me know if additional info is needed.

Thanks

Steve Webb
Transportation Specialist- International Standards
Pipeline & Hazardous Materials Safety Administration (PHMSA) -U.S. DOT
Office of Hazardous Materials Safety
1200 New Jersey Avenue S.E., E24-422, Washington D.C. 20590
E24-422
steven.webb@dot.gov
202-366-4579

From: Fred Marks [mailto:fred@fmadirect.com]
Sent: Tuesday, January 19, 2016 9:14 PM
To: Webb, Steven (PHMSA)
Subject: Re: Request to DoT for LOI re Raven Battery Assembly_Edits

Steven,

The revised request is attached. Thank you for your good effort. Please let me know how I may help expedite the issuance of the LOI. The Army is moving along with a project that will place the new equipments in the field , perhaps as early as July 2016. Some design decisions are being based on the expectation that the LOI will be issued as we have discussed.

Sincerely,

Fred Marks

From: steven.webb@dot.gov
Sent: Tuesday, January 19, 2016 3:03 PM
To: fred@fmadirect.com
Subject: Request to DoT for LOI re Raven Battery Assembly_Edits

Fred,

See my attached edits to your proposed letter of interpretation. Feel free to take what you want and leave what you don't like. I tried to simplify the request a bit by taking out some of the background info and focusing on the questions. I included a few comments that it would prove helpful if you addressed. Whenever you get a final draft ready you can simply email it back to me and I will get it submitted for the official interpretation process to begin. I will try and get it assigned to me, but there is no guarantee. Timelines are tricky too, but they generally take 2-3 months. This one could potentially move a bit quicker.

V/R

Steve Webb
Transportation Specialist- International Standards
Pipeline & Hazardous Materials Safety Administration (PHMSA) -U.S. DOT
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Fred M. Marks
Consultant to Bosh Global Systems
727 Regent Ct.
Gaithersburg, MD 20878
Jan 19, 2016

U.S. DOT
PHMSA Office of Hazardous Materials Standards
Attn: PHH-10
East Building
1200 New Jersey Avenue, SE
Washington, DC 20590 – 0001

Dear Sir or Madam,

I am requesting a letter of interpretation as a consultant to the US Army. I am reaching out to you for further clarification of an issue addressed in a previously issued letter of interpretation, Reference No 15-0019. Interpretation 15-0019 contains the following question and answer:

Q1. Must batteries that do not have overcharge protection, and are designed for use only in a battery assembly that does not have overcharge protection, pass test T.7 before being offered for transport as batteries?

A1. Yes. **The exception from test T.7 applies only to batteries that do not have overcharge protection, and are designed for use only in a battery assembly which affords such protection**. Batteries that do not have overcharge protection and are designed for use in a battery assembly that does not have overcharge protection must successfully pass test T.7 prior to being offered for transportation.

I have attached various documents illustrating the design of a battery assembly per ASTM Battery Standard F3005 – 14a Par 3.2.6 *pack, n*—a single cell or composition of battery cells connected in series or in parallel or both plus monitoring electronics, structure, and connector(s) that are used in small unmanned aircraft systems. Each of these batteries within the battery assembly is equipped with a thermistor that provides, in addition to overvoltage protection, the ability to stop charge if and when a cell failure amongst the cells causes temperature rise that might presage a thermal runaway. Additionally the completed battery assembly has a Pack Protection Cap (PPC) containing a Charge Protection Module (PCM) that ensures the battery subassembly never has overvoltage applied to it. The PPC is only removed during flight and remains in place during charge, storage, and transport. Charging of the battery assembly is only possible with the PPC snapped to the battery pack as part of the battery assembly. It is not possible to charge the battery sub-assembly without the PPC in place because the pack can only be accessed via the PPC or by deliberate violation of instructions on the battery sub-assembly case and by damage to the battery assembly to permit access to battery terminals and nodes.

My questions are:

Q1. Are batteries that do not have overcharge protection that are only designed for use in a battery assembly that provides overcharge protection afforded the exception for test T.7 in the United Nations Manual of Tests and Criteria, 5th Revised Edition (Manual of Tests and Criteria) in section 38.3.3(d)?

Q2. Do batteries that are designed for use only in battery assemblies equipped with a removable PPC providing overcharge protection that is only removed during use and remains in place during charge, storage and transport need to pass the T.7 test of the Manual of Tests and Criteria.

Q3. Is the battery assembly that includes the PPC required to undergo test T.7 as an assembly?

Respectfully submitted,
Fred M. Marks,
Consultant to Bosh Global Services

ATTACHMENTS:
1. Reference # 15-0019
2. Standard for Batteries for Use in US Army sUAS
3. How PPC Works
4. Raven Battery Sub - Assembly
5. Raven Battery – pack sub-assembly

ATTACHMENT 1 - Reference # 15-0019

U.S. Department of Transportation

Pipeline and Hazardous Materials Safety Administration

1200 New Jersey Avenue SE
Washington, DC 20590

JUL 3 1 2015

Mr. Gene Sanders
Manager
W.E. Train Consulting
8710 W. Hillsborough Ave. #112
Tampa, FL 33615

Reference No. 15-0019

Dear Mr. Flaherty:

This is in response to your January 27, 2015 e-mail requesting clarification of the Hazardous Materials Regulations (HMR; 49 CFR Parts 171-180) applicable to the T.7 overcharge testing requirements for lithium batteries. You note that the United Nations Manual of Tests and Criteria, 5th Revised Edition in section 38.3.3(d) provides that "batteries not equipped with overcharge protection that are designed for use only in a battery assembly, which affords such protection, are not subject to the requirements of this test". Your questions are paraphrased and answered as follows:

Q1. Must batteries that do not have overcharge protection, and are designed for use only in a battery assembly that does not have overcharge protection, pass test T.7 before being offered for transport as batteries?

A1. Yes. The exception from test T.7 applies only to batteries that do not have overcharge protection, and are designed for use only in a battery assembly which affords such protection. Batteries that do not have overcharge protection and are designed for use in a battery assembly that does not have overcharge protection must successfully pass test T.7 prior to being offered for transportation.

Q2. For a battery assembly that does not have overcharge protection and is itself assembled from batteries that do not have overcharge protection, would it be compliant with the UN Manual of Tests and Criteria and the HMR if only the battery assembly passed test T.7 even though the batteries in the battery assembly did not pass test T.7?

A2. Based on the information provided in your specific scenario, batteries without overcharge protection intended for installation in a battery assembly that also does not have overcharge protection, both the batteries and the battery assembly are subject to test T.7.

I trust this information is helpful. If you have further questions, please do not hesitate to contact this office.

Sincerely,

Duane A. Pfund

Duane A. Pfund
International Standards Coordinator
Standards and Rulemaking Division

ATTACHMENT 2 - : Standard for Batteries for Use in US Army Small Unmanned Aircraft System (sUAS) Raven

1. Scope

1.1 This standard defines the requirements for batteries used in US Army small Unmanned Aircraft Systems (sUAS), specifically Raven.

1.2 This standard does not define requirements for the Raven systems in which sUAS battery packs may be utilized.

1.3 This standard therefore is subordinate to standards for Raven.

1.4 . Air transport regulations still shall be adhered to when air transport is used for lithium cells or batteries in bulk.

2. Referenced Documents

2.2 *System Standards for Raven and Puma*

2.3 *Other Standard*:

UL1642 (Applicable only to Section 5.1 for cell suppliers)
ANSI/ASQ Z1.4-2008

3. Terminology

3.1 *Definitions and Acronyms* — the standard terminology for sUAS as defined in higher level standard applies in general to this standard except as noted below.

3.2 *Definitions and Acronyms Specific to This StandardArmy*:

3.2.1 *C-rating, n* — maximum steady-state current (amps) at which the battery cell or pack may be discharged without having pack temperature exceed the CTT of its constituent cell(s) or result in a reduction in cell life. C-rating is expressed as a multiple of the capacity. For example, a battery with a nominal capacity of 4 Ah may have a C-rating of 5C, meaning that 20 A would be considered its maximum safe current.

3.2.2 *Characteristic Thermal Threshold, CTT, n* — the temperature beyond which a rechargeable battery cell of particular chemistry and structure may self initiate thermal runaway and will exhibit permanent deterioration of its critical performance parameters as evident upon subsequent charge/discharge cycles. Cell capacity and internal resistance are critical performance parameters. CTT is rated at both upper and lower thresholds.

3.2.3 *Depth of Discharge, DOD, n* — ratio of cell or pack capacity expended relative to its nominal capacity.

3.2.4 *Supplier, n* — any entity engaged in the design or production of a battery pack or any component of a pack used in a sUAS. The *cell supplier* is the manufacturer of the fundamental cell(s) constituent in a battery core. Various suppliers contribute to the production of a pack, and any differences between them are described both explicitly and by context throughout the document.

3.2.5 *Battery Assembler, n* — that supplier which performs the manufacturing processes which integrate the essential components into a functional pack. In the event that multiple suppliers are involved in the assembly process, the pack assembler is that supplier which performs the final electrical connection(s). One supplier may weld solderable tabs to batch of cells, a second supplier may connect circuitry, wiring and a connector, and yet a third may install the assembly in a plastic housing. In this example, the second supplier would be the pack assembler.

3.2.6 *Pack, n* — a single cell or composition of battery cells connected in series and/or in parallel or combination thereof plus monitoring electronics, structure, and connector(s).

3.3 *Acronyms*

CTT — Characteristic Thermal Threshold
COTS — Commercial off the Shelf
DOD — Depth of Discharge
IC — Internal Combustion
Li — Lithium
LiFe — Lithium Ferrite
LiIon — Lithium Ion
LiPo — Lithium Polymer
$LiFePO_4$ — Lithium Iron Phosphate
MSDS — Material Safety Data Sheet
PCM — Protective Circuit Module
PVC — Polyvinyl Chloride

4. Applicability

4.1 This standard relates to and is referenced by other Raven and Puma system level**14995 Shady Grove Rd Ste 250** standards as listed in Section 2.

4.2 Criticality of this standard is derived from safety risk analysis. The following failures are critical and are listed hierarchically, the first being the most critical:

4.2.1 Loss of independent power for flight termination by any means requiring battery power, resulting in inability to terminate the flight safely;

4.2.2 Failure of primary power for the FCS resulting in loss of control to permit safe flight or recovery;

5. Cells

5.1 *Responsibility of Cell Suppliers* — as a minimum, the cell supplier shall possess and provide the following:

5.1.1 *Process Control Plan* for the specific cell being provided, including *Quality Control Procedures* and *Recording Methods*;

5.1.2 A *Quality Assurance Plan* for the specific cell being provided, including compliance with UL 1642 requirements for cells;

5.1.3 *MSDS*;

5.1.4 *Technical Data Sheet* — shall be a formal document, not preliminary or informal (Note : The manufacturer's datasheet shall include standard of the upper CTT);

5.1.5 Every cell shall be marked with its *Lot Number* and *Supplier's Name* to aid failure analysis, facilitate traceability, and minimize the extent of a recall should such action become necessary.

5.2 Responsibility of Pack Assembler

5.2.1 *Lot Testing* — Each lot of cells shall be subjected to capacity testing and physical inspections. The sample shall undergo one complete charge-discharge cycle to verify the integrity of the lot. A charge-discharge cycle is defined as a full charge followed by a full discharge to the depth typical for the subject chemistry. Additionally, the physical inspections listed in 5.2.3 shall be performed on the sample. The capacity tests and physical inspections may, but are not required to be performed on the same cells. Sampling shall be in accordance with ANSI/ASQ Z1.4-2008. Any alternate plan must be approved by the Army project office (Right?). The sampling plan shall accept on zero defects.

5.2.2 *Received-Voltage Test* — The pack assembler shall measure this voltage on every cell before any load or charge has been applied to the cell. The measurement is taken directly at the cell tab, bypassing any protection circuitry that may be connected. The received voltage shall not vary significantly from what is considered the typical chemistry-specific storage voltage or the mean measurement for the bulk of the lot. The received voltage for a lot will typically vary little from cell to cell and certainly should remain within a 10 % window. (For example, a LiPo will normally be shipped in a half-charge state, holding at about 3.8 V). If the cell is within this range, the inspections given in 5.2.3 are not required, although procedures should be put in place to observe those conditions during the assembly process. The received-voltage test may be performed as part of the assembly process rather than as an incoming test.

5.2.3 *Physical Inspections* — In the event that a cell's received voltage is outside the limits that the particular chemistry is designed to produce, the cell shall be discarded. If, however the cell is within those limits but the received voltage is outside the criteria of 5.2.2, the entire exterior of the cell shall be inspected to ensure its integrity. A subject cell is to be discarded for any of the following conditions:

5.2.3.1 *Swelling*;

5.2.3.2 *Electrolyte leakage*;

5.2.3.3 *Out-gassing*;

5.2.3.4 *Odor* — even in the absence of visible electrolyte leakage, an obvious odor shall be considered evidence of a deteriorated cell;

5.2.3.5 *Deformed or damaged casing*;

5.2.3.6 *Punctures*;

5.2.3.7 *Tab condition* — Seals are to be undamaged, and welds are to be unbroken and of satisfactory quality. If a cell is supplied with a PCM connected, accessible solder connections to the tabs shall also be inspected. If a solder connection is unacceptable, it may be reworked by the pack assembler.

5.2.4 *Records and Certifications* — The pack assembler shall obtain and make available to the procuring entity pertinent information regarding the pack assembly. These data shall be available so long as that pack model is marketed or sold and for a minimum of three years thereafter. These data shall either be shipped with the pack(s), provided upon request or be accessible by other means such as the pack assembler's website:

5.2.4.1 *The technical data sheet from the cell supplier for cells used in the pack*;

5.2.4.2 *The MSDS for the cell type used in the pack*;

5.2.4.3 *The data items, by lot, listed under 5.1.3 – 5.1.5* (i.e. the pack assembler is to carry forward the data provided by the cell supplier);

5.2.4.4 *Pack assembler's specified shipping/storage voltage* — These data are not intended to be a record of measured voltage for each pack but to stipulate the voltage range that the procuring entity can expect to measure upon receipt of a pack for the particular chemistry;

5.2.4.5 *The lot number of constituent cells used in a pack traceable to the pack serial number*;

5.2.4.6 *Date of manufacture of the pack* — As defined in Section 6, the date may be codified in the serial number.

5.2.5 *Pack Assembly Requirements* — A multi-cell pack shall not contain cells from more than one lot. An exception may be made if three conditions are met: (1) the date of manufacture of the cells are within a six-month span; (2) all cells to be used in the pack are tested for capacity and found to be within 5 % of each other; and (3) all of the cells were manufactured recently enough to be considered acceptable for use in new construction for the particular chemistry.

5.2.6 Final Test — As a minimum, each completed pack shall be subjected to two charge-discharge cycles, following which the pack shall be charged to its appropriate, chemistry-specific shipping/storage voltage. A charge-discharge cycle is defined as a full charge followed by a full discharge to the depth typical for the subject chemistry. The pack shall demonstrate its rated capacity by means of this testing to be acceptable for delivery to the procuring entity.

6 Mechanical Design and Assembly

6.1 *Cell Connections* — Cells shall be interconnected using techniques that minimize failure caused by vibration and impact. If tab-to-tab connection of individual cells is used to form a pack, the connection shall be resistance-welded to the individual cell terminal. If cells are interconnected using double-sided printed circuit connecting boards, these boards shall have plated-through tab slots or holes.

6.2 Wiring — All power and cell-sensing wiring shall be strain relieved at the junction with the cell or interconnect tabs and secured at a point before exiting the pack.

6.3 Vibration — The pack assembly may be surrounded with impact and vibration-absorbent material such that the assembled pack meets governing-body requirements for shipment by air. *Puncture Resistance* — An assembled pack having one or more non-rigid cells shall be housed in a protective material that provides resistance to mechanical penetration beyond that of the bare, unprotected cell. LiPo cells are one such example of a non-rigid cell and shall as a minimum be sheathed in a conforming PVC wrap or other similar material. Other means of housing non-rigid cells, such as a plastic or metal casing may be employed. Since the pack is being designed for Raven, the required protection shall be defined at the system level. Pack identification is required as follows:
6.4 Identification — At a minimum, the pack assembler must place the information specified under Par 3.1.5 of the parent specification on each pack.

6.4 Safety Warnings — Appropriate safety warnings particular to the battery chemistry shall be affixed to the pack. In the case of packs too small or otherwise unable to accommodate all such warnings, the information may appear on the smallest quantity container in which the pack(s) are shipped. The following shows an example of a typical warning label for a lithium battery:

CAUTION:
DO NOT DISPOSE OF IN FIRE
DO NOT HEAT ABOVE 60C (140F)
DO NOT DISASSEMBLE
DO NOT PUNCTURE OR CRUSH
DO NOT ALLOW TERMINALS TO SHORT
SEE OWNER'S MANUAL FOR ADDITIONAL DETAILS

7 Electrical Design

Cells used for Raven are anticipated to be LiIon, LiFe, $LiFePO_4$,or LiPo,. The Electrical design and performance criteria are as follows:

7.1 *Capacity* — The capacity stated on the pack label is to be based either on the typical capacity of a newly manufactured pack or that of a "broken-in" pack, **whichever is less**. The "broken-in" capacity is defined as the typical capacity observed at the flattest portion of the discharge-cycle curve for the pack. Data on the broken-in capacity of constituent cells may be used to aid in determining the broken-in capacity of a new pack design if these data exist. The pack designer shall perform the testing and research on the pack design necessary to ascertain capacity before stating it on pack marking or by other statements. The capacity test should be done under lab conditions of 25C, ambient humidity and no forced cooling. The capacity of any pack that carries a nominal claimed capacity should be within 1 Sigma of the nominal capacity so stated in which the statistical sample is 100%.

7.2 *Charge* — Before storage or shipping from the pack assembler, the pack shall be charged/discharged to a level that is optimal for transport and long-term storage for the particular chemistry.(I believe this can be used to mitigate against the UN/DOT requirement for overcharge to 18V since the cells are never charged in transit and can never see 18V / cell in transit.)

7.3 *Wiring* — Wiring used shall be of sufficient gauge and capacity that the wire temperature does not exceed the thermal rating of the insulation type during highest normal expected load.

7.4 *Connectors* — Any connector that is part of the pack assembly shall conform to the following criteria: (Do not yet know what the Raven & Puma connectors are.)

7.4.1 *Contacts* — Connector contacts shall be gold-plated or otherwise treated to optimize conductivity and to aid in the prevention of oxidation or corrosion. Contact resistance shall be low enough that the connector body temperature does not exceed temperatures that would cause failure of the connector materials or pose other hazards to the pack under the highest normal expected load during discharge.

7.4.2 *Configuration* — The connector may include heavy-duty pins for power and smaller pins for the cell-balance nodes in packs with series-connected cells. If single pins are used for main power and return lines, the pin itself shall have multiple points of contact (at least two) to preclude power failure as a result of loss of a single point of contact. Alternatively, the use of multiple single-point pins could satisfy the need for redundancy.

7.4.3 *Non-Electrical Materials* — Connectors shall be selected having housing material that is rated to withstand temperatures at which the particular cell chemistry can operate safely. (Do not yet know what the max expected current drain is for Raven or Puma.)

7.5 *Node Access* —The design shall provide connector access to the nodes between individual serial sub-packs or cells. Charge of pack end-to-end voltage alone is not satisfactory; the intra-cell nodes in any pack with series-connected cells shall be accessible to facilitate monitoring of overcharge conditions. Even if a pack design includes integrated cell-balancing, a node access connector shall be included to facilitate a sUAS which might monitor node voltages for safety purposes. (The charge current, thus charge time, is limited by use of BPM in the pack. This, in turn mandates a much larger quantity of packs in the field. Let's consider what to do about this.)

7.6 *Thermal Performance* —Life cycle and cell capacity deteriorate when a cell reaches temperatures beyond the characteristic thermal threshold (CTT) specific to the particular chemistry. In the case of lithium chemistries the upper CTT is herein defined as 140°F (60°C). The battery pack shall therefore be designed to minimize internal heat generation during operational discharge. Effects of cell internal resistance, tab resistance and pack capacity should be considered in combination when evaluating their effect on self-heating. If a continuous discharge current is to be specified for the pack, that rating is to be for operation at no greater than the CTT of its constituent cells. Performance to this criteria shall be validated and recorded by the pack designer or independent operational testing.

8 Maintenance

Maintenance of the pack and the recording of maintenance data is the responsibility of the user.(Who do your assign the maintenance to in the field?) The pack chemistry and demands of the application determine the frequency of periodic testing required to evaluate the performance of the pack throughout its life cycle. The designer of the sUAS system shall perform a reasonable amount of testing to determine this frequency and the minimum capacity that is required for the pack to be deemed flight-worthy.

8.1 *Charging* — Charging systems designed for the specific battery chemistry shall be used. Multi-chemistry chargers are acceptable but shall be programmed such that the specific pack chemistry is charged accordingly.

8.1.1 *Series-Cell Balancing (Lithium Chemistries)* — All Li batteries shall be charged using equipment that provides precise balance charging. Alternatively, a conventional bipolar charger may be used if the pack has integrated cell-balancing circuitry. The charge current, thus charge time, is limited by use of CPM in the pack.

8.1.2 For added safety, charging may be done in a flame- and explosion-resistant enclosure.

8.1.3 *Temperature Change (Lithium Chemistries)* — A decrease in capacity of a lithium cell can result from receiving a charge at low temperatures or from temperature decrease following a full charge cycle. A lithium pack should therefore be subjected to a load or protected from significant temperature decrease after receiving a full charge. To further aid in mitigation of this risk, the charging system should test the battery condition before charge, adjust for ambient temperature and provide recording and diagnostics for all charges.

8.1.4 *Physical Inspection* — Prior to charging, every pack shall be inspected per the criteria established by 8.4.1. If no defects are found the pack may be charged.

8.2 *Routine Evaluation* — Pack capacity should be measured and recorded once each 100 cycles during normal operations. The following provide guidance for the service-life of a pack:

8.2.1 *Test Marking* — As a minimum, the recording of data obtained by periodic testing should be implemented by labeling the individual pack with its capacity and the date on which it was tested.

8.2.2 *High Utilization* — In an environment in which operations regularly require DOD exceeding 80 %, additional emphasis should be placed on periodic maintenance to ensure that capacity is retained.

8.2.3 *Low Utilization* — Pack capacity should be validated and the data recorded in a battery log at any time a pack is utilized after storage for a period of three months or more.

8.2.4 *Service Limit* — Packs that have lost 20% of their rated capacity should be removed from service.

8.3 *Storage* — The pack shall be charged/discharged to a level that is optimal for storage based on the particular chemistry. All Li packs should be stored at approximately one-half capacity (Nominally 3.8 V) or at the supplier-specified charge level for long term storage any time a pack is out of service for more than one month. Note: Most Li chemistries have very low self-discharge rates (depending on the current draw of any integral circuitry), but are susceptible to degradation if subjected to temperature decrease when left fully charged. Recommendations provided by the supplier should be followed.

8.4 *Damage Evaluation* — A pack that has been involved in a crash or any event that has resulted in physical damage shall be evaluated to determine if it must be disposed of or if it is repairable and fit to return to service.

8.4.1 *Disposal* — The pack shall be disposed of if any of the following conditions are observed:

8.4.1.1 *Electrolyte leakage;*

8.4.1.2 *Odor* (Even in the absence of visible damage, an obvious odor shall be considered evidence of a deteriorated pack);

8.4.1.3 *Punctured or crushed casing*;

8.4.1.4 *Severe swelling* (Moderate swelling in LiPo packs is typical and not cause for disposal);

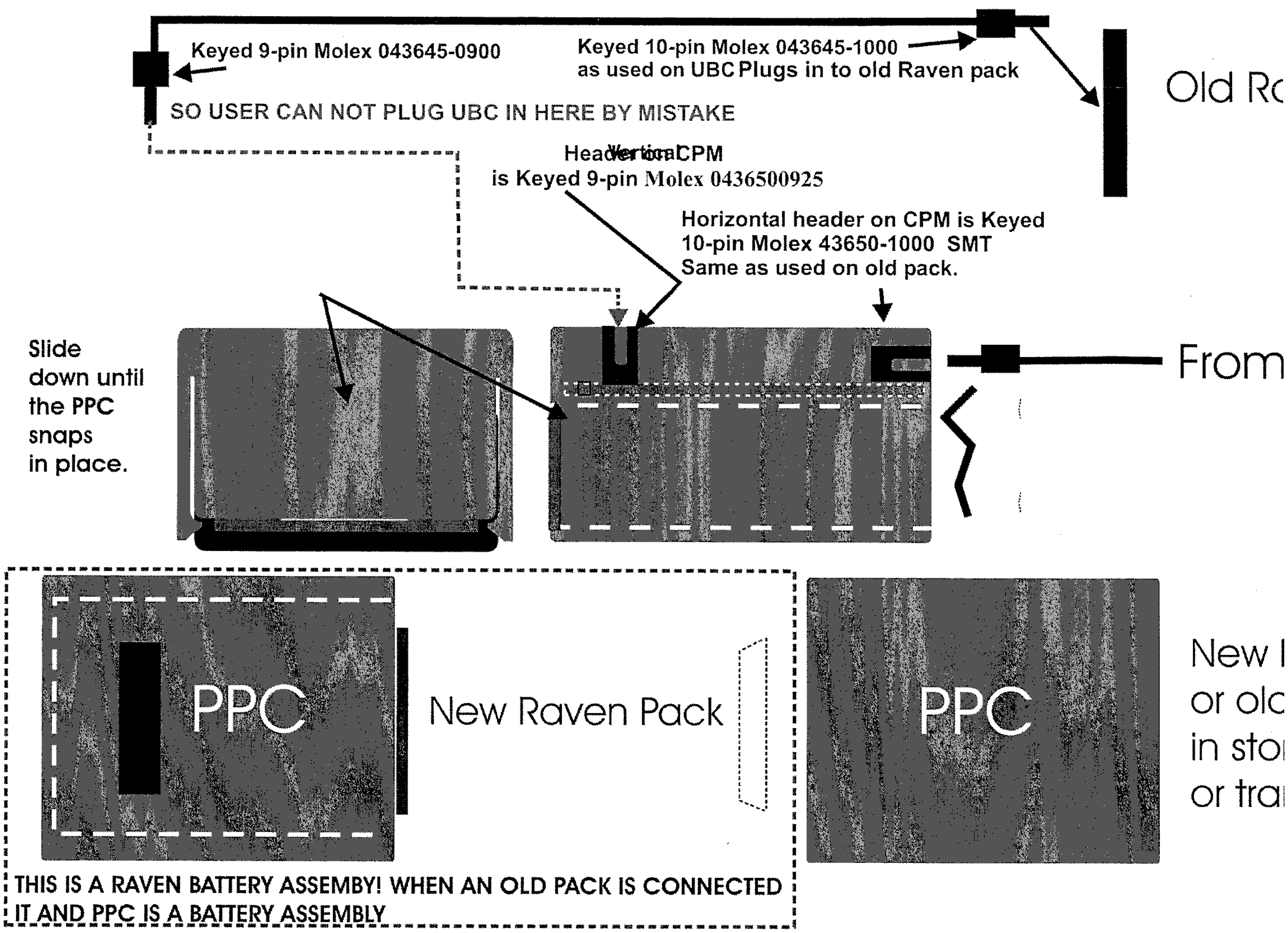
8.4.1.5 *Mechanically stressed electrical connector.*

8.4.2 *Return to Service* — To be deemed fit for service; the pack shall be subjected to a complete charge/discharge cycle to verify its capacity is within the service limit per 8.2.4. A permanent record of the pack, identified by serial number shall be created describing the damage, the date of the incident and any repairs made.

ATTACHMENT 3-

UBC PIGTAIL - Only used when charging an old pack.

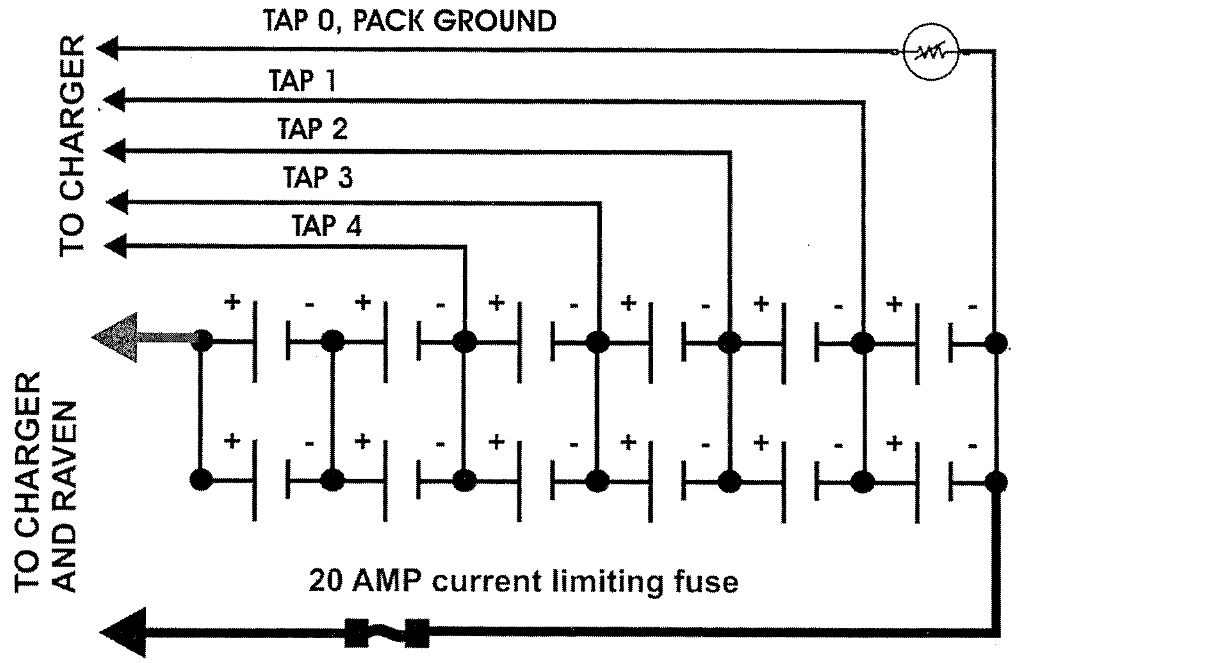
HOW RAVEN PACK PROTECTC



NOTES:

1. Empty pack protector becomes the dust cover for storage. The PPC snaps onto the pack
2. When you charge a new pack, plug the snap-on PPC onto the pack (left)
3. When you charge an old pack, DO NOT HAVE PPC on a new pack but rather,
4. Plug the pigtail into the nine-pin header on the PPC and the 10-pin header on the other end of the
5. The empty dust cap stays on a pack unless charging or flying.

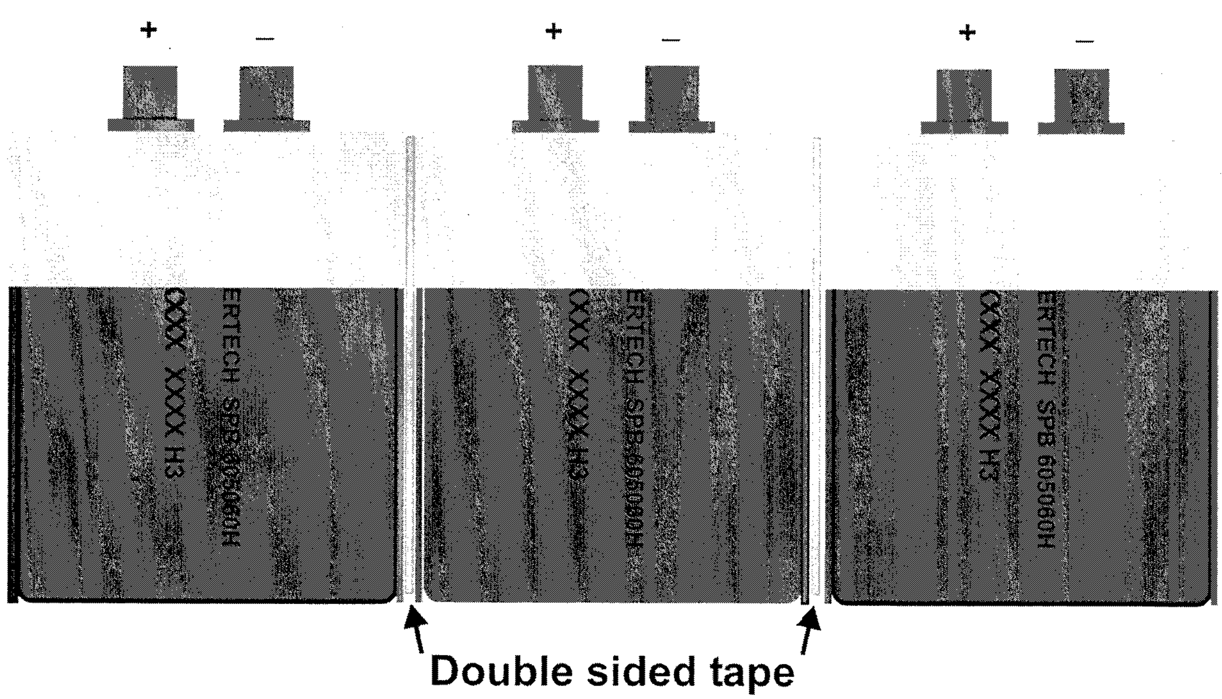
RAVEN MOD 1 PACK CONSTRUCTION MANUAL SHT 2 OF 6



BATTERY SUB- ASSEMBLY SCHEMATIC

Step 3 Apply double - sided tape to LH side of the two RH cells as shown below.
Step 4 Place three cells side-by-side as shown and press together to bond tape.
Step 5 NOTE: these are cells 10;11;and 12 in the 2P6S pack. Take care that cell polarityis maintained as shown. The 3S sub-pack will appear as shown in the picture of a Raven pack pictured on Sheet 3.
Step 6 Construct three more sets of 3S sub packs as in steps 1-5.

You will use four sets of the 3S sub-pack to assemble the 2P6S pack shown in the schematic



ATTACHMENT 5 – Raven Battery – pack sub-assembly
NOTE: The blue component is a thermistor.