International Civil Aviation Organization

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**WORKING PAPER**

# DANGEROUS GOODS PANEL (DGP)
# WORKING GROUP ON LITHIUM BATTERIES

**SECOND MEETING**

**Montréal, 7 to 11 April 2014**

**Agenda Item 1: Mitigating risks associated with the carriage of lithium metal batteries**

## LITHIUM PRIMARY BATTERIES

(Presented by the National Electrical Manufacturers Association (NEMA))

**SUMMARY**

This paper provides a primer on lithium primary batteries and data on air shipments of these items into, around and from the United States of America.

## 1. INTRODUCTION

1.1 By the close of DGP/24, the Dangerous Goods Panel had spent many hours deliberating whether to change the Technical Instructions as they apply to lithium metal batteries (UN 3090). At the DGP Chairman's briefing to the Air Navigation Commission, the President of the Commission emphasized the need for the Commission to be better informed of facts related to primary lithium batteries. This brief paper attempts to provide some of those facts available to the U.S. lithium primary battery industry, as represented by NEMA.

1.2 It is our understanding that currently over 2.5 billion lithium primary batteries were manufactured and shipped worldwide in 2013. While most of these batteries travel only via surface modes, some are shipped by air at least once – and, in some cases, multiple times – during their journey from the site of manufacture to the end-user.

## 2. LITHIUM PRIMARY CELLS AND BATTERIES

2.1 A battery is defined in International Electrotechnical Commission standards as "one or more cells electrically connected by permanent means, fitted in a case, with terminals, markings and protective devices etc., as necessary for use." The IEC defines a cell as a "basic functional unit, consisting of an assembly of electrodes, electrolyte, container, terminals, and usually separators, that is a source of electric energy obtained by direct conversion of chemical energy."

2.2 A primary cell or battery is a cell or battery "that is not designed to be electrically recharged."

2.3 A lithium cell contains "a non-aqueous electrolyte and a negative electrode of lithium or containing lithium."

2.4 A listing of the common chemistries of lithium primary batteries is provided in Annex A.

## 3. LITHIUM PRIMARY CELLS AND BATTERIES

3.1 Primary lithium batteries are produced in a variety of sizes and formats, ranging from CR123, CR-V3, CR-P2, "9V", "AA", and "AAA" sizes familiar to consumers to very small "coin" cells that are designated by their diameter in millimeters. For example, as of 31 March, 2014, the public website of a major U.S. distributor of electronic components and batteries offered for sale 252 different types of primary lithium batteries in manufacturer-format/size-capacity combinations[1]. In addition, there are a number of different formats for small and large primary lithium batteries designed specifically for medical, military and commercial-industrial applications. A non-exhaustive collection of example images of primary lithium battery formats is provided in Appendix B.

3.2 As discussed at DGP/24 and previous meetings of the Panel, primary lithium batteries are used in many medical, military, aerospace, automotive, consumer, industrial, and information technology applications. In all cases the battery is not manufactured in the same facility as the piece of equipment that derives electrical power from the battery. This necessitates shipment of the battery to the equipment manufacturer. An extensive but non-exhaustive listing of applications of primary lithium batteries is provided in Appendix C.

## 4. MANUFACTURERS AND SOURCE COUNTRIES

4.1 A large percentage of primary lithium batteries on the market are manufactured by large, globally active companies. In terms of the U.S. market, NEMA member companies are leaders in manufacturing, marketing, and shipping primary lithium batteries:

- Duracell
- Energizer
- Greatbatch
- Panasonic
- Saft
- Ray-O-Vac

4.2 NEMA members are aware of other major manufacturers and marketers of primary lithium batteries in other regions of the world. These include but are not limited to member companies of the Battery Association of Japan (BAJ) and the European Portable Battery Association (EPBA). We are aware that a significant share of the global market for lithium primary batteries is accounted for by manufacturers in China.

[1] http://www.digikey.com/product-search/en/battery-products/batteries-non-rechargeable-primary/394467, accessed on 31 March, 2014.

4.3 Most manufacturing of primary lithium batteries is undertaken in Europe, the U.S., and Asia. Based on information available to NEMA, these countries are (listed alphabetically):

- China
- France
- Germany
- Japan
- Indonesia
- Israel
- Singapore
- South Korea
- Switzerland
- Taiwan
- U.S.

## 5. INDUSTRY STANDARDS

5.1 The vast majority of primary lithium batteries are manufactured to comply with international standards for safety and interoperability.

These standards include:

- IEC 60086-1: Primary batteries - Part 1: General
- IEC 60086-2: Primary batteries - Part 2: Physical and electrical specifications
- IEC 60086-4: Primary batteries - Part 4: Safety of lithium batteries
- IEC 62281: Safety of primary and secondary lithium cells and batteries during transport
- American National Standards Institute (ANSI ) C18.3, Part 1, American National Standard for Portable Lithium Primary Cells and Batteries - General and Specifications
- American National Standards Institute (ANSI ) C18.3, Part 2, American National Standard for Portable Lithium Primary Cells and Batteries – Safety Standard
- UL 1642 (soon to be harmonized with IEC 60086-4)
- IEC 60601-1 (medical devices)
- IEC 60950-1 (information technology equipment)

5.2 Excerpts from IEC 60086-1: Safety of primary and secondary lithium cells and batteries during transport, are provided in Appendix D.

## 6. QUALITY MANAGEMENT SYSTEMS

6.1 Both the UN and ICAO require that primary lithium metal batteries be manufactured under a quality management system and all reputable manufacturers adhere to this requirement.

6.2 Thanks to modern battery design and stringent safety standards, a manufacturing defect that results in a failure of the unit would only extremely rarely develop into an event presenting a safety risk in transportation or storage. For example, one of the major manufacturers cited above has shipped

over 20 billion primary lithium batteries without incident. Manufacturers with quality systems follow existing standards, packaging instructions and requirements.

6.3 Most of the risk events and incidents associated with primary lithium batteries over the past 15 years are documented cases of non-compliance with existing regulations, standards and best practices, including battery mis-use, mis-handling or abuse, insufficient packaging or counterfeiting.

## 7. REACHING THE CUSTOMER – COMPLEXITY OF SUPPLY CHAINS

7.1 It is common for primary lithium metal batteries to travel by surface modes, either freight carrier or cargo vessel, to their first destination. This destination can be considered the final destination if the battery is to be installed in a piece of equipment as it is manufactured. This is often the case with batteries to be used in medical applications, in-device information technology applications and in military equipment. It is also not unusual for the first shipment of primary lithium coin cells or batteries to travel by air from the manufacturing or assembly facility to an Original Equipment Manufacturer's manufacturing or assembly facility.

7.2 Alternatively, the first destination for lithium metal batteries is often a distributor. Once the batteries are sold into distribution, the original manufacturer loses all visibility of the batteries' movements thereafter. Distributors deliberately do not want manufacturers to know who their customers are.

7.3 NEMA manufacturers and/or many of their customers routinely ship lithium primary coin cells and batteries by air under the provisions of Section II of Packing Instruction 968 of the Technical Instructions.

7.4 It is common to misunderstand and tempting to try to oversimplify the manner in which primary lithium batteries travel from the location at which they were manufactured to the end consumer. On their journey, these products may be shipped multiple times by multiple modes of transportation. Moreover, battery manufacturers quickly lose visibility of their product after it is delivered to their customer, whether that customer is an equipment manufacturers or a distributor that provides batteries to equipment manufacturers.

7.5 Several simplified but illustrative examples of routes taken by shipments of primary lithium batteries in commerce from manufacturer to an OEM or to an end consumer are included as flowcharts in Appendix E.

## 8. SHIPMENTS

8.1 According to U.S. government trade data, the U.S. imported approximately 317 million units 282 million units of primary lithium batteries from January to December 2013 (an increase over the 282 million units imported in 2012). In descending order of volume, the leading eight supply countries were Indonesia, China, Japan, Singapore, Israel, Switzerland, Korea, and France. (In 2012, the descending order was Japan, Indonesia, China, Singapore, Israel, Switzerland, France and Korea.) .

8.2 According to U.S. government trade data, the U.S. exported to the rest of the world 35.7 million units of primary lithium batteries in 2013 (an increase over 33.8 million units of primary lithium batteries in 2012). The leading recipient countries were, in descending order, Mexico, Canada, Japan, Belgium, India and the United Kingdom. (2012 recipients of U.S. shipments, in descending order: Mexico, Canada, Japan, Germany, Belgium and the United Kingdom.)

8.3 As discussed in Section 7 of this paper, due to complexity of distribution channels, the fact that batteries are exported from a country does not mean that they were manufactured in that country.

8.4 According to data compiled by NEMA from its member companies:

- NEMA companies shipped approximately 142 million lithium primary coin cells in the U.S. in 2013; and
- NEMA companies shipped approximately 130 million lithium non-coin batteries in the U.S. in 2013.

## 9. MODES OF TRANSPORTATION

9.1 While the vast majority of U.S. imports of lithium primary batteries will have reached U.S. shores via cargo vessel, a portion will have arrived by air shipment.

9.2 Air shipments of primary lithium batteries within the U.S. are restricted to cargo aircraft only. Significantly, air shipment of bulk quantities by manufacturers are made as needed to meet customer needs, such a manufacturing line in a short-supply situation. As noted above, manufacturers and other shippers often ship under the provisions of Section II of Packing Instruction 968. Air shipment of small consumer-type quantities is also possible via express carriers under Section II.

9.3 According to data compiled by NEMA from its member companies:

- approximately 50 percent of lithium coin cells imported into the U.S. by NEMA companies in 2013 entered the country by air cargo;
- approximately 10 percent of non-coin lithium primary batteries sourced into the U.S. by NEMA companies in 2013 traveled into the U.S. by air.

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# APPENDIX A

## COMMONLY FOUND CHEMISTRIES OF LITHIUM PRIMARY BATTERIES

Lithium Manganese Dioxide
Lithium Poly Carbon Monofluoride
Lithium Iron Disulfide
Lithium Thionyl Chloride
Lithium Sulfur Dioxide
Lithium Iodine

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# APPENDIX B

## EXAMPLES OF LITHIUM PRIMARY CELLS AND BATTERY FORMATS

*Note: Images not to scale*


CR2032


CR2450


CR123A


AA


9V


BA-5930 – Military radio-communication


AED battery

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# APPENDIX C

## LITHIUM PRIMARY CELL/BATTERY APPLICATIONS

The following is an illustrative, non-exhaustive list of applications of primary lithium batteries. The categories are not exclusive; each application is listed only once although it may fall into multiple categories (e.g. flashlight/torch).

*Aerospace*

Aircraft system memory back-up

*Automotive*

Keys (entry and ignition)
Tire pressure monitoring systems
Navigation system back-up
On-Star and similar on-board automotive systems
Highway toll transponder units (e.g. EasyPass)

*Household and Office*

Toys
Greeting cards with audio message
Smoke and carbon monoxide detection
Security Systems
Remote control units for audio-visual equipment, including game system controllers
Portable decorative lighting (flameless candles)

*Industrial*

Flashlights
Electric, gas and water metering systems and remote monitoring
Petroleum well monitoring equipment

*Medical (implantable devices)*

Cardiac pacemakers
Cardioverter/defibrillators (ICDs)
Cardiac monitor (for the detection or arrhythmias)
Cardiac resynchronization therapy devices
Spinal cord stimulators (for pain management)
Vagal nerve stimulators (for the treatment of epilepsy)
Deep brain stimulators (for the treatment of Parkinson’s Disease and Essential Tremor)

*Medical (external devices)*

Automatic external defibrillators (AEDs)
Blood glucose meters
Cardiac stent pressure me
IV pumps

*Military*

Communication radios
Night vision systems
Thermal weapons sighting
Rescue equipment
Global positioning system (GPS) devices
Chemical detection equipment
Respirators
Missile launch equipment
Remote detection, sensing, and communication
Submarine detection/tracking,
Mine seeking and destruction
Unmanned aerial vehicles (drones)

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# APPENDIX D

# LITHIUM PRIMARY BATTERY STANDARDS

Provided in this Appendix are the most relevant excerpts from IEC 60086-4: Safety of primary and secondary lithium cells and batteries during transport[2].

4 Requirements for safety

4.1 Design

Lithium batteries are categorized by their chemical composition (anode, cathode, electrolyte), internal construction (bobbin, spiral) and are available in cylindrical, button/coin and prismatic configurations. It is necessary to consider all relevant safety aspects at the battery design stage, recognizing the fact that they may differ considerably, depending on the specific lithium system, power capability and battery configuration.

The following design concepts for safety are common to all lithium batteries:

a) Abnormal temperature rise above the critical value defined by the manufacturer shall be prevented by design.
b) Temperature increases in the battery shall be controlled by a design which limits current flow.
c) Lithium cells and batteries shall be designed to relieve excessive internal pressure or to preclude a violent rupture under conditions of transport, intended use and reasonably foreseeable misuse.

See Annex A for guidelines for the achievement of safety of lithium batteries.

4.2 Quality plan

The manufacturer shall prepare a quality plan defining the procedures for the inspection of materials, components, cells and batteries during the course of manufacture, to be applied to the total process of producing a specific type of battery.

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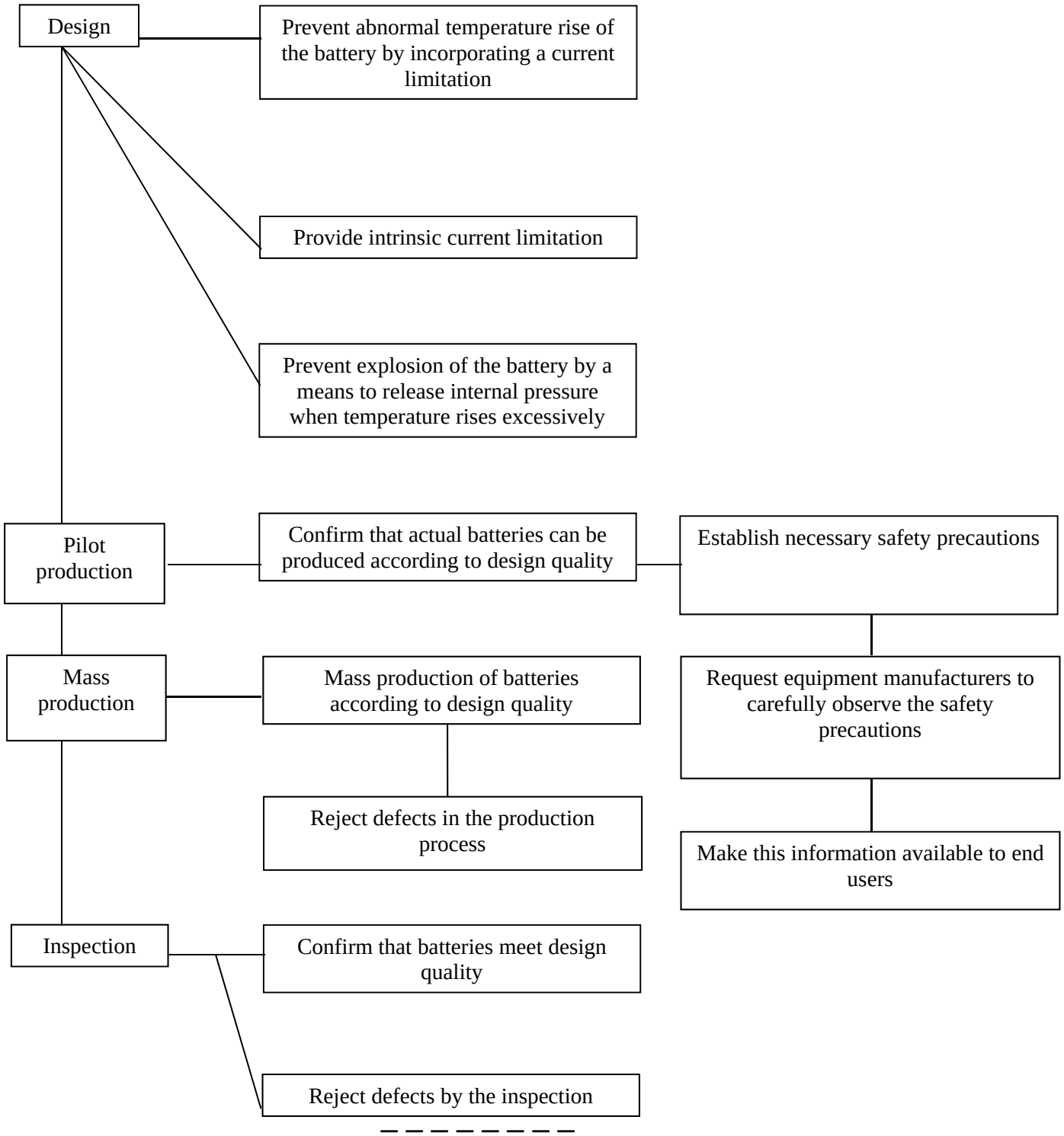
[2] Under an agreement with the U.S. National Committee of the International Electrotechnical Commission (IEC), this excerpt of an IEC publication is to be used solely for the purposes of further development of international standards. It may not be offered for further reproduction or for sale. The copyright rests with the IEC, Geneva, Switzerland.

**Annex A (to IEC 60086-4)**

The following guidelines were followed during the development of high power batteries for consumer use. They are given here for information.



## APPENDIX E

## ROUTES TO THE CONSUMER

The following diagrams illustrate various paths taken by a primary lithium battery to its point of use. Blue arrows indicate shipment by air. Red arrows indicate shipment by surface mode.

**FIGURE 1**

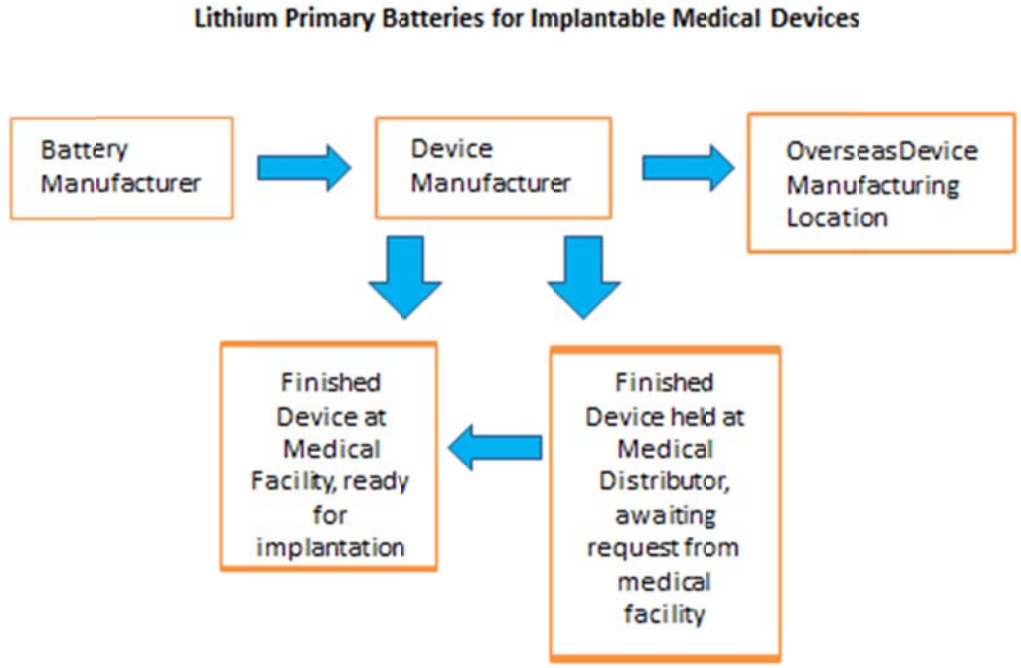


**FIGURE 2**

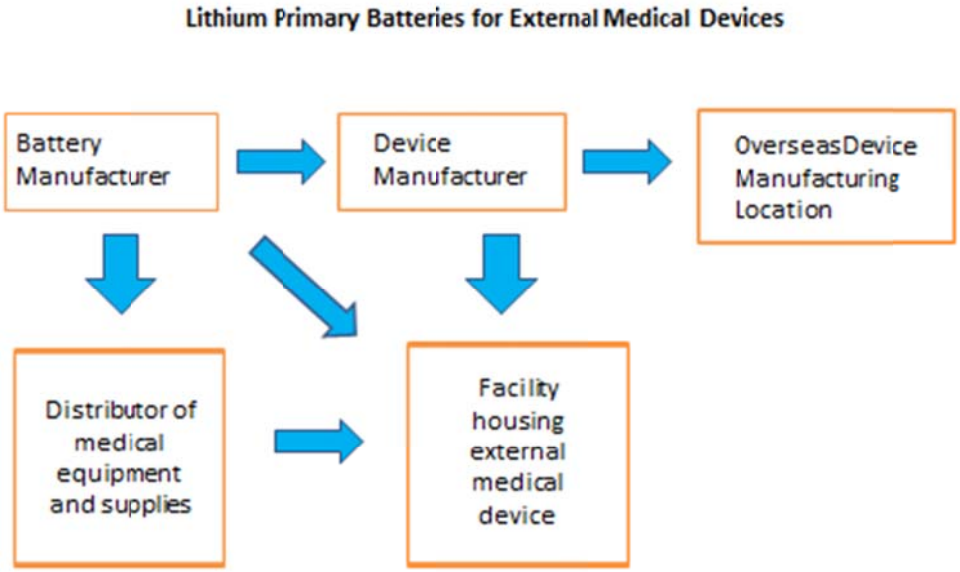

Lithium Primary Batteries for External Medical Devices
Battery Manufacturer
Device Manufacturer
OverseasDevice Manufacturing Location
Distributor of medical equipment and supplies
Facility housing external medical device

**FIGURE 3**

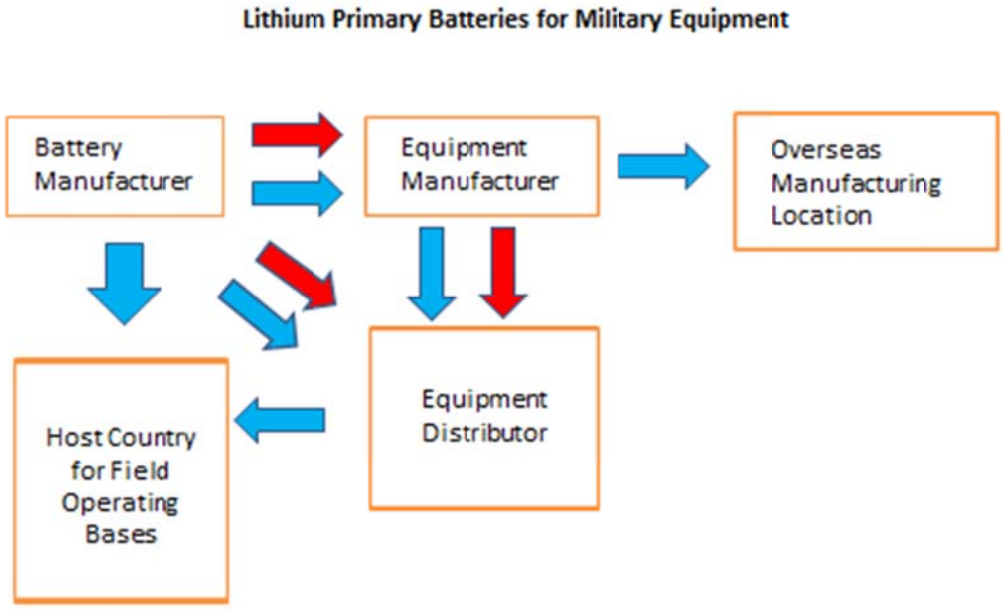
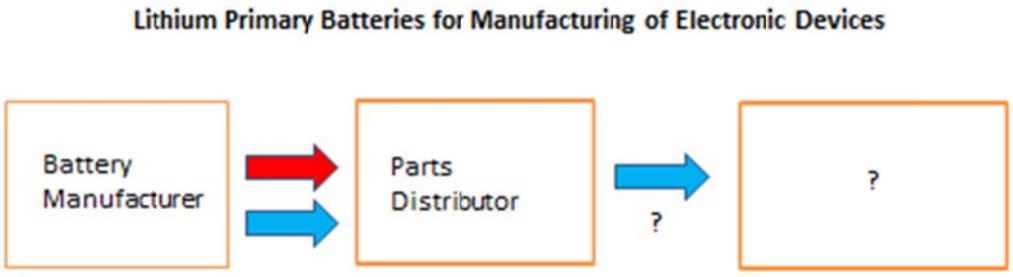

Lithium Primary Batteries for Military Equipment
Battery Manufacturer
Equipment Manufacturer
Overseas Manufacturing Location
Host Country for Field Operating Bases
Equipment Distributor

**FIGURE 4**


Lithium Primary Batteries for Manufacturing of Electronic Devices
Battery Manufacturer
Parts Distributor
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