U.S. Department of Transportation
Research and Special Programs Administration

400 Seventh Street, S.W.
Washington, D.C. 20590

DEC 27 1989

Dr. Sumner P. Wolsky
President
Ansum Enterprises, Inc.
950 De Soto Road
Suite 3-B
Boca Raton, FL 33432

Dear Dr. Wolsky:

This is in response to your letter of December 11, 1989, regarding a cell identified as Sony US-61 produced by Sony Energytec.

Based on the information you have provided, the cells are not considered lithium batteries, or batteries filled with acid or alkali. For transportation in the United States, the batteries would be considered "Battery, dry" and not subject to the Department of Transportation (DOT) Hazardous Materials Regulations.

Sincerely,

J. Suzanne Hedgepeth

J. Suzanne Hedgepeth
Chief, Exemptions Branch
Office of Hazardous Materials
Transportation

ATTN: JACKIE SMITH

FAX TRANSMISSION

SANYO Energy (U.S.A.) Corporation
2001 Sanyo Ave., San Diego, CA 92173

☎ **(619) 661-6620** **(619) 661-6743**

Date: June 2, 1994 Fax No.: (202)366-3753

To: Mr. Anthony Lima

Company: US DOT Pages to Follow: 1

From: Jim Ross

Subject:

Mr Lima,

As we discussed this morning over the phone, I discussed this situation with Harpreet Singh of the exemption branch to determine a course of action that would assist Sanyo in classifying this battery. Although it is a carbon based battery it will be marketed under the name of **Lithium Ion**. As I stated in my cover letter, no lithium metal is present at any time, but with the **"Lithium"** marketing name it will be difficult for carriers to understand without a clear ruling from the DOT.

We have requested and received a determination on our Nickel Cadmium products and I will send you a copy of that ruling. Since the construction of the lithium ion battery is similar, and only the chemistry is different, Sanyo felt a similar determination could be made.

However, if this is not possible would we qualify for an exemption under 49CFR Part 173.185i. This subject was broached with exemptions branch, but no ruling was made.

I am requesting your assistance in this matter and offer any additional information you may require.

U.S. Department
of Transportation
**Research and
Special Programs
Administration**

400 Seventh Street, S.W.
Washington, D.C. 20590

JUL 26 1993

Mr. Jim Ross
Logistics Manager
Sanyo Energy Corp.
2001 Sanyo Avenue
San Diego, CA 92173

Dear Mr. Ross:

This is in response to your FAXs dated May 3 and 20, 1993 regarding classification of new and spent small, sealed, rechargeable nickel-cadmium batteries (nicads). Nicads are in several sizes, from AA to D cells, and often are combined to form a battery pack. Nicads are used in many household applications such as in flashlights, handheld vacuum cleaners, computers, cellular telephones, and power tools.

Based on the information you provided, it is our determination that new sealed nickel cadmium batteries may be classed as dry batteries. Dry batteries are not subject to any of the requirements of the Hazardous Materials Regulations (49 CFR Parts 171-180). However, spent sealed nickel cadmium batteries that meet the definition of hazardous waste in § 171.8 must be shipped using either of the following basic descriptions:

Hazardous waste, solid, n.o.s., 9, NA3077, III

or

Waste Environmentally hazardous substances, solid, n.o.s., 9, NA3077, III

If we can be of further assistance, please feel free to contact us.

Sincerely,

Delmer F. Billings
Acting Deputy Director, Office of
Hazardous Materials Standards

Applied P & Ch Laboratory
4066 E. Mission Blvd., Pomona, CA 91766
Tel: (909) 622-5148 Fax: (909) 622-3199

APCL Analytical Report

Submitted to:
Sanyo Energy (USA) Corporation
Attention: Anne Mossbarger
2001 Sanyo Ave.
San Diego, CA 92173
Tel: (619)661-6620 Fax: (619)661-6743

Service ID #: 801-942387
Collected by:
Collected on:
Sample description:
Battery

Received : 04/14/94
Tested : 04/29/94
Reported : 04/29/94

Characterization of Waste – Ignitability

801-942387 Page 1 of 1

Ignitability (Flashpoint)

Item #2 of section §261.21, 40 CFR, *Characteristic of Ignitability*, states that if a waste is not a liquid and is capable, under standard temperature and pressure, of causing fire through friction, absorption of moisture or spontaneous chemical changes and, when ignited, burns so vigorously and persistently that it creates a hazard, then it exhibits the characteristic of ignitability.

Since this sample is not a liquid or a gas, but a solid, only Item #2 of the ignitability criteria would apply to the sample. It is highly unlikely, under normal conditions, that this solid material would spontaneously ignite, or burn so persistently to create a hazard, thus, item #2's criteria do not substantiate ignitability.

Respectfully submitted,

Jack Zhang, Ph.D.
Applied P & Ch Laboratory

333 Pfingsten Road
Northbrook, Illinois 60062-2096
(708) 272-8800
FAX No. (708) 272-8129
MCI Mail No. 254-3343
Telex No. 6502543343

Underwriters Laboratories Inc.®

NOTICE OF AUTHORIZATION TO APPLY THE UL MARK

Northbrook Office

April 14, 1994

100 a century of public safety 1894-1994

TO: Sanyo Energy Corporation
2001 Sanyo Avenue
San Diego, CA 92173

Attn: Mr. Ken Goto

Our Reference: File Mh 12383, Project 93NK31781

Dear Mr. Goto,

We have completed our engineering investigation under the above project number and find the product complies with the applicable requirements.

This letter temporarily supplements the UL Follow-Up Services Inspection Procedure and serves as authorization to apply the UL Recognition mark to the above products constructed as described below:

According to the attached addendum.

This authorization is effective for 90 days only from the date of this Notice. Records covering the product are now being prepared and will be sent to you in the near future.

Products produced which bear the UL Mark shall be identical to those which were evaluated by UL and found to comply with UL's requirements. If changes in construction are discovered, authorization to use the UL Mark may be withdrawn and products that bear the UL Mark may have to be revised (in the field or at the manufacturer's facility) to bring them into compliance with UL's requirements.

Very truly yours,

M. D. Smith (42509)
Senior Project Engineer
Engineering Services

Reviewed by:

J. P. Allen (43103)
Engineering Group Leader
Engineering Services

A D D E N D U M

GENERAL:

Recognition has been established under the Lithium Battery Product Category, BBCV2, in accordance with UL 1642 for your Model UR 18560 Lithium Ion Rechargeable cell for use in User-replaceable applications. The cells are constructed according to the attached documents.

Listing has been established for your battery pack models UR 18650-2 and UR 18650-3 (which consist of 2 and 3 UR 18650 cells in a plastic enclosure respectively) under the Household and Commercial Battery Category, BBFS, in accordance with UL 2054. The battery packs are constructed according to the attached documents.

1. Composition material of Sanyo lithium ion battery

Positive electrode ; $LiCoO_2$ (Lithium cobaltate)

Negative electrode ; Graphite (Natural graphite)

Electrolyte ; EC + DEC / $LiPF_6$

The above is main composition material, and no lithium metal is used.

2. Cell reaction of lithium ion battery is as below

< Charge > $LiCoO_2$ + C → $Li_{(1-x)}CoO_2$ + Li_xC

(Positive electrode) (Negative electrode)

<Discharge > $Li_{(1-x')}CoO_2$ + $Li_{x'}C$ ← $Li_{(1-x)}CoO_2$ + Li_xC

At this time, figure 1 and 2 shows the structure of active material in each electrod.

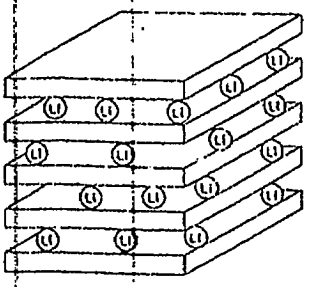


Fig. 1 Positive electrode ($LiCoO_2$)

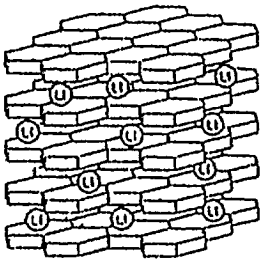


Fig. 2 Negative electrode (Graphite)

In this, Lithium is ionization state in the graphite.

From this result, state of the Lithium is different from lithium metal because is not metallic bond such as Li-Li.

Next, there are some reports about the state of lithium in the crystal structure of graphite, and the test result of Sanyo is as below.

Measurement result

(Method)

After the battery charged, the state of Lithium in the negative electrode was measured by the method of ESCA(Electron Spectroscopy for Chemical Analysis).

(Sample)

(A) Lithium metal
(B) Lithium in half charged battery (negative electrode:graphite)
(C) Lithium in full charged battery (〃)
(D) Lithium in full charged battery (negative electrode:coke)
(E) Lithium in comparison Li_2CO_3 (ion state of lithium).

(Result)

Table 1. show the results

Table 1. Binding energy of lithium

	State of lithium	Binding energy
(A)	Lithium metal	53.9eV
(B)	Lithium in half charged battery	54.6eV
(C)	Lithium in full charged battery	54.8eV
(D)	Lithium in full charged battery	54.8eV
(E)	Li_2CO_3 (ion state)	55.0eV

We measured the binding energy of lithium in charged battery by ESCA in order to clarify the state of the lithium.

The results are shown in this table 1.
These suggests that metal state of lithium dose not exist in both half and full charged batteries.

3. Test item of DOT

Table 2 show the test result.

Table 2. Test result of DOT

Test item	Criterion	Result	Judgement
Oven test	no leakage, distrction.	no problem.	○
Short circuit	no vent.	〃	○
Vibration	no out-gassing, leakage.	〃	○
Shock test	〃	〃	○
Vacuum test	〃	〃	○

This table 2 shown 2he results are satisfied with requirements of DOT.

Material Safety Data Sheet

OSHA's Hazard Comunication Standard 29 CFR 1910.1200.

IDENTITY
Lithium Ion Battery
Model : UR18650

SECTION I

Supplier's Name :
SANYO Electric Co., Ltd. Japan

Emergency Telephone Number

SANYO Energy (USA) Corporation
2001 Sanyo Ave., San Diego
California92173 TEL(619) 661-6620

SANYO Energy (Europe) Corporate GmbH
Hans-Stiessberger Strasse 2b, 8013 Haar,
Germany TEL(089)-4600950

Date Prepared : Apr. 27 1994

SECTION II—Hazardous Ingredients/Identity Information

	OSHA PEL	ACGIH TLV	CAS#
Lithium Cobaltate ($LiCoO_2$)	None Established		12190-79-3
Graphite (C)	2.5 mg/m³ (as dust)	2.5 mg/m³ (As dust)	7782-42-5
Ethylene Carbonate (EC)	None Established		96-49-1
Diethyl Carbonate (DEC)	None Established		105-58-8
Lithium Hexafluoro Phosphate ($LiPF_6$)	None Established	2.5 mg/m³ (as Flourine)	17084-13-8
Poly Vinylidine difluoride(PVdF)	None Established		24937-79-9

Weight of lithium per cell : 0g

SECTION III—Physical/Chemical Characteristics

Boiling Point : (℃)	: EC-244, DEC-126
Vapor pressure : (mmHg)	: EC-0.01, DEC-10
Vapor Density : (AIR=1)	: DEC-4.07,
Solubility in Water :	: EC:-complete, DEC-complete, $LiPF_6$:complete
Specific Gravity : (H_2O=1)	: $LiCoO_2$-4.95, Graphite-2.09~2.2 EC-1.32, DEC-0.975, $LiPF_6$-1.33
Melting Point : (℃)	: $LiCoO_2$-about 1130, $LiPF_6$-160, EC-36
Appearance and Odor :	: $LiCoO_2$ is a black, odorless powder. C is a black, odorless powder. DEC is a colorless or light yellow liquid. EC is a white solid. $LiPF_6$ is a white and crystalline, odorless powder.

MATERIAL SAFETY DATA SHEET

Type	:	UR 18650
System	:	C/$LiCoO_2$/org. elyt
Volts	:	3.6V
Capacity	:	1200mAh
Weight	:	37.9g

1. INGREDIENTS

1.1 ACTIVE MATERIALS	APPROXIMATE PERCENT OF TOTAL WEIGH %
LIthium Cobaltate ($LiCoO_2$)	26.9
Ethylene Carbonate (EC)	6.9
Diethyl Carbonate (DEC)	7.4
Lithium Hexa Fhoro PhospHate ($LiPF_6$)	1.6
Graphite (C)	15.2
Pigment Carbon (C)	0.6
POly Vinylidene di Flvoride (PVdF)	1.4

1.2 PASSIVE MATERIALS		APPROXIMATE PERCENT OF TOTAL WEIGHT %
BASE METAL	steel	17.4
Aluminum	sheet	4.0
Copper	sheet	12.1
OTHERS	plastic	6.5

SANYO Electric Co., Ltd.

SECTION IV—Fire and Explosion Hazard Data

Flash Point (Method Used) : DEC=25(℃)
Extinguishing Media : Water
Flammable Limits : Not Available
Special Fire Fighting Procedure :
In case of fire in an adjacent area, use water, CO_2 or dry chemical extingwshers if cell are packed in their original containers since the fuel of the fire is basically paper products. For bulk quantities of unpackaged cell use LITH-X (Graphite Base). In this case, use no water.

SECTION V—Reactivity Data

Stability : Stable
Conditions to Avoid : Do not heat or disassemble or overcharge.
Hazardous Decomposition or Byproducts : N/A
Hazardous polymerization will not occur.

SECTION VI—Health Hazard Data

Routes of Entry :
Inhalation? Yes
Skin ? Yes
Ingestion? Yes

Health Hazards (Acute and Chronic) :
These chemicals are contained in a sealed can. Risk of exposure occurs only if the battery is mechanically or electrically abused. The most likely risk is acute exposure when a cell vents. DEC is believed to be slightly to moderately toxic, and EC is considered to be non-toxic but moderately irritating to the eyes. $LiPF_6$ is irritating to skin, eyes and mucous membranes. Contact of electrolyte with skin and eyes should be avoided.

Carcinogenicity :
NTP : None IARC Monograph : None OSHA Regulated : None

Signs/Symptoms of Exposure :
DME may be a reproductive hazard.

Medical Conditions Generally Aggravated by Exposure :
An acute exposure will not generally aggravate any medical condition.

Emergenby & First Aid Procedures :
In case of skin contact with contents of battery, flush immediately with water. For eye contact, flush with copious amount of water of 15 minutes. Do not inhale vented material. If irritation persist, get medical help.

SECTION Ⅶ—Precautions for Safe Handling and Use

Steps to Be Taken in Case Material is Released or Spilled:
The preferred responce is to leave the area and allow batteries to cool and vapors to dissipate. Avoid skin and eye contact or inhalation of vapors. Remove spilled liquid with absorbent and incinerate.

Waste Disposal Method:
Dispose in accordance with appropriate regulations.
Open cells should be treated as hazardous wastes.

Precoutions to Be Taken in Handling an Storing:
Avoid mechamical or electrical abuse.

Other Precoutions:
Batteries may explode or cause burn, if disassembled, crushed, or exposed to fire or high temperature. Do not short nor install with incorrect polarity.

SECTION Ⅷ—Control Measure

Respiratory Protection (Specify Type):
Not necessary under conditions of normal use.

Ventilation:
Not necessary under conditions of normal use.

Protective Gloves:
Not necessary under conditions of normal use.

Eye protection:
Not necessary under conditions of normal use.

Other Protective Clothing or Equipment:
Not necessary under conditions of normal use.

CONFIDENTIAL

MATERIAL COMPOSITION FOR SANYO'S Li-ION RECHARGEABLE BATTERY

April 1st, 1994
Legal Dept.

Model:UR18650

Description	Chemical Formula	Weight(gram)	Weight(%)	Remarks
1. Positive Electrode · Lithium Cobaltate · Carbon · Poly Fluoro Vinylidine · Aluminum Sheet	 $LiCoO_2$ C $-(CH_2-CF_2)_n-$ Al	 10.2 g 0.6 g 0.5 g 1.5 g	 33.8 %	
2. Negative Electrode · Graphite · Copper Sheet	 C Cu	 5.4 g 4.6 g	 26.4 %	
3. Separator · Poly Ethylene	$-(CH_2-CH_2)_n-$	1.2 g	3.2 %	
4. Electrolyte · Ethylene Carbonate · Diethyl Carbonate · Lithium Hexa Fluoro Phosphate	 $C_3H_4O_3$ $(C_2H_5O)_2CO$ $LiPF_6$	 2.6 g 2.8 g 0.6 g	 15.8 %	
5. Insulating Plate · Poly Propylene	$-(CH_2-\overset{CH_3}{\overset{\vert}{C}}H)_n-$	0.2 g	0.53%	
6. Outer Can	Fe-Ni	6.6 g	17.4 %	
7. Sealing Cover	Al and Fe-Ni	1.0 g	2.6 %	
8. Gasket · Poly Propylene	$-(CH_2-\overset{CH_3}{\overset{\vert}{C}}H)_n-$	0.1 g	0.3 %	
TOTAL		37.9 g	100 %	

333 Pfingsten Road
Northbrook, Illinois 60062-2096
(708) 272-8800
FAX No. (708) 272-8129
MCI Mail No 254-3343
Telex No. 6502543343

Underwriters Laboratories Inc.®

5/ 4/1994

Type. R
File No. MH12383
Project No. 93NK31781

100 a century of public safety 1894-1994

SANYO ENERGY (U S A) CORP
UL REPRESENTATIVE
2001 SANYO AVE
SAN DIEGO CA 92173

PRODUCT: LITHIUM BATTERIES - COMPONENT

The following material resulting from the investigation under the above numbers is enclosed (see attached Addendum or below for page numbers):

Additional section for Follow-Up Service Procedure.

Revised or new pages and illustrations for Follow-Up Service Procedure.

Please file revised pages and illustrations in place of material of like identity. New material should be filed in its proper numerical order.

Please review this material and report any inaccuracies to MARTIN SMITH ext. 42509 referring to the above project number.

UNDERWRITERS LABORATORIES INC.

Enclosure: Rpt

cc: UL INSPECTION CENTER TOKYO
SANYO ELECTRIC CO LTD, HYOGO 656,JAPAN

UNDERWRITERS LABORATORIES INC. mrs

ADDENDUM TO TRANSMITTAL LETTER

File MH12383

Project 93NK31781

Revised Date 5-4-94

Report Date	Vol.	Sec.	Revised or New Material
-	1	Index	Revised Page 1
-	1	App. A	Revised Page 5
5-4-94	1	6	All Issued

Underwriters Laboratories Inc.®

333 Pfingsten Road
Northbrook, Illinois 60062-2096
(708) 272-8800
FAX No. (708) 272-8129
MCI Mail No. 254-3343
Telex No. 6502543343

100 a century of public safety 1894-1994

File MH12383
Project 93NK31781

May 4, 1994

REPORT

on

COMPONENT - LITHIUM BATTERIES

Sanyo Electric
San Diego, CA

MDS/JPA:mrs
PC Lbry:

D E S C R I P T I O N

PRODUCT COVERED:

Model UR-18650 lithium ion rechargeable cell.

GENERAL DESCRIPTION:

Model UR-18650 lithium ion batteries consist of carbon as a negative electrode material and lithium metal oxide as a positive electrode material. The voltage of lithium ion batteries is 3.6 V which is about three times that of Ni-Cd and nickel-hydrogen batteries. With their high voltage and high energy density, these batteries are suited as power supplies, particularly for compact, light and thin portable equipments. Carbon material as a negative electrode material not only make lithium ion batteries safer than secondary batteries that use lithium metal, but also exempt the batteries from dangerous material regulations published by the U.S. Department of Transportation. Our own unique highly crystallized graphite as a negative electrode material provides the lithium ion batteries with a higher energy density and a flatter discharge curve than any conventional lithium ion battery.

ELECTROCHEMISTRY:

These cells are rechargeable and have a nominal open circuit voltage of 3.6 V. The cell reactions are as follows:

Positive electrode

$$LiMeO_2 \underset{\text{Discharge}}{\overset{\text{Charge}}{\rightleftharpoons}} Li_{1-x}MeO_2 + xLi^+ + xe^-$$

Me: Transition metal

Negative electrode

$$C + xLi^+ + xe^- \underset{\text{Discharge}}{\overset{\text{Charge}}{\rightleftharpoons}} Li_xC$$

Total Reaction

$$LiMeO_2 + C \underset{\text{Discharge}}{\overset{\text{Charge}}{\rightleftharpoons}} Li_{1-x}MeO_2 + Li_xC$$

MDS/JPA:mrs
PC Lbry:

ENGINEERING CONSIDERATIONS (NOT FOR FIELD REPRESENTATIVE'S USE):

Use - For use only in products where the acceptability of the combination is determined by Underwriters Laboratories Inc.

Conditions of Acceptability - The use of these cells may be considered generally acceptable under the conditions given below:

1. The cells are identified in accordance with "Marking" as described below.

2. Unless the conditions of Par. 2A are met, these batteries are to be used only in devices where servicing of the battery circuit and replacement of the lithium battery will be done by a trained technician.

2A. These batteries are acceptable for use in user-replaceable applications when used in accordance with the following:

2A.1 The end product must be designed to prevent reverse polarity installation of the battery, or if the battery is reversed, the short- or open-circuiting of any protective component, one component at a time, shall not result in forced-discharge of the battery.

2A.2 The end product shall contain a permanent marking adjacent to the battery stating the following:

"Replace Battery With (Battery Manufacturer's Name or End-Product Manufacturer's Name), Part No. ( ) Only. Use Of Another Battery May Present A Risk Of Fire Or Explosion. See Owner's Manual For Safety Instructions."

If it is not feasible to include the above marking on the device, the marking may be included in the operating (or safety) instructions providing the battery compartment is marked with the following: "See operating (or safety) instructions for type of battery to be used."

2A.3 The instruction manual supplied with the end product shall also contain the above warning notice along with instructions to the user as to where replacement batteries can be obtained. The instruction manual shall also contain the following additional warning notice and information:

A. Caution: The battery used in this device may present a fire or chemical burn hazard if mistreated. Do not disassemble, heat above 100°C (212°F) or incinerate.

B. Complete instructions as to how to replace the battery ending with the statement: "Dispose of used battery promptly. Keep away from children."

3. The cells are intended for use at ordinary temperatures where anticipated high temperature excursions are not expected to exceed 100°C (212°F).

4. The cells should not be connected in series with an electrical power source that would increase the forward current through the cells.

5. The circuit for these cells should include protective circuitry to prevent any charging current in excess of 2.4 A.

6. The storage, handling and disposal of these cells should be in accordance with the "Warning Notice" described below.

WARNING NOTICE:

Each of the cells shall bear the following warning notice:

"CAUTION: Fire, Explosion, And Severe Burn Hazard. Do Not Disassemble, Heat Above 212°F, Or Incinerate."++

++ - This warning statement may contain additional precautions such as a warning about short circuiting the cells.

MARKING:

Company name and model designation on cell.

MARKING FOR REPLACEMENT BATTERY PACKAGING:

The following statements, or equivalent, shall be included on the smallest package containing replacement cells.

"CAUTION: Fire And Burn Hazard. Do Not Disassemble, Heat Above 212°F Or Incinerate. Keep Battery Out Of Reach Of Children And In Original Package Until Ready To Use. Dispose Of Used Batteries Promptly."

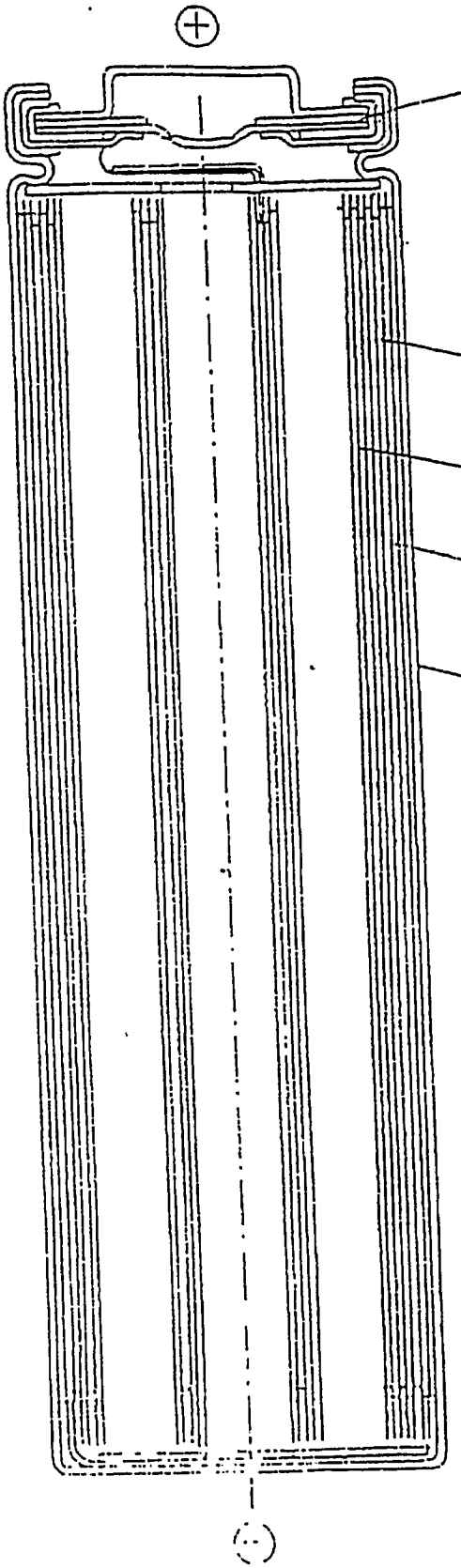
CONSTRUCTION DETAILS:

LITHIUM ION BATTERY

1. Model Number - UR-18650
2. Cell Case - Steel
3. Positive electrode - Lithium Metal Oxide
4. Negative Electrode - Carbon
5. Electrolyte - Organic Liquid
6. Separator - Polyolefin Film
7. Excess Current Protector - An electrical resistance will jump sharply from a very small value to one of several orders of magnitude larger, when high current is applied.
8. Terminals Tabs - (Not shown) - At the manufacturer's option these cells may be supplied with metal tabs or pins for both the positive and negative terminals.
9. Voltage - Open-Circuit Voltage of 2.50-4.10 V
10. Capacity and Dimensions - See table below.

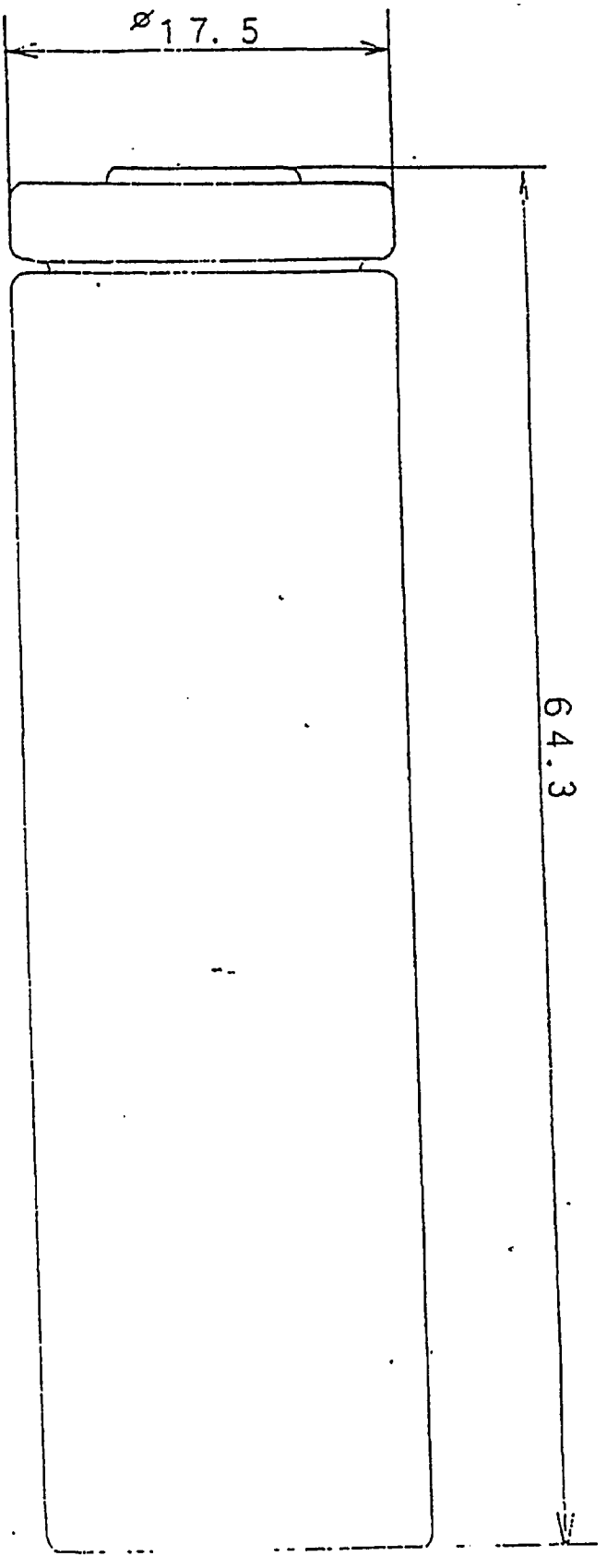
Model	Capacity, mAh	Diameter, mm (in.)	Height, mm (in.)
UR-18650	1200	17.0-19.0 (0.67-0.75)	64.0-65.0 (2.52-2.56)

MDS/JPA:mrs
PC Lbry:



MDS/JPA:mrs
PC Lbry:

SANYO Electric Co.,Ltd.
Soft Energy Business Headquart


⌀17.5
64.3

T E S T R E C O R D N O. 1

GENERAL:

The manufacturer provided the following conditioned cells.

SAMPLES:

The manufacturer furnished 200 samples of the Model UR-18650 cells for the tests conducted in this investigation.

CONDITIONING OF CELLS:

Conditioning of some of the test cells by oven exposure, temperature cycling, and partial discharge was conducted to simulate the effects of age, exposure to varying temperatures, and discharge. Cells conditioned as described were then used in other tests included under this investigation.

METHODS

Oven Exposure - Forty cells were exposed for 90 days in an air convection oven at 71°C (160°F). The temperature of the oven was monitored by means of an iron-constantan thermocouple connected to a recording potentiometer. The weight and open circuit voltages of the cells were measured before and after the exposure. The cells were examined after the exposure for any sign of change.

Temperature Cycling - Twenty cells were conditioned in this exposure. The cells were exposed to alternate temperatures of -54°C (-65°F) and 71°C (160°F) for a total of ten exposures at each temperature. The cells were exposed at each temperature for periods of 16 h with 8 h periods at room temperature between each exposure. The temperatures of the oven and the cold box were monitored by means of iron-constantan thermocouples connected to a recording potentiometer. The weight and open circuit voltages were measured before and after the series of temperature exposures. The cells were also examined after the exposures for any sign of change.

Complete and Partial Discharge - Cells were discharged completely and to one-half of their rated capacities. The cells were discharged by connecting the terminals of the cells through resistors selected to give the desired discharge in a 60 day interval. Cells were discharged at room temperature and also during exposure at 71°C (160°F) in an oven.

MDS/JPA:mrs
PC Lbry:

The following table shows the number of cells conditioned in this manner:

Conditions	Number of Cells Completely and Partially Discharged	
	Completely Discharged	One-Half Discharged
At room temperature	20	20
At 71°C (160°F)	40	40

RESULTS

Oven Exposure - The maximum weight loss was <2.0 grams and the maximum change in open circuit voltage was 3.6. There were no signs of any visible changes as a result of this exposure.

Temperature Cycling - None of the cells showed a weight loss greater than 2.0. There were no visible changes as a result of this exposure.

Partial Discharge - The cells showed no visible changes occurring as a result of the partial discharge.

SHORT CIRCUIT TESTS:

METHOD

The cells were shorted by connecting the positive and negative terminals with a short length of copper wire. The temperature on the exterior surface of the metal cell casing was monitored during the test by means of an iron-constantan thermocouple.

Short circuit tests were conducted on cells at room temperature and on cells at 60°C (140°F). The tests at 60°C (140°F) were conducted in an air convection oven. The cells were allowed to come to equilibrium at this temperature before they were shorted. After the tests, the cells were examined for any signs of change.

The following cells were used in these tests:

Previous Conditioning of Cells	Number of Cells At Room Temperature	At 60°C
Fresh cells	5	5
After oven exposure	5	5
After temperature cycling	5	5
Cells discharged at room temperature:		
One-half discharged	5	5
Cells discharged at 71°C (160°F):		
One-half discharged	5	5

RESULTS

There were no signs of case bulging, leaking, or any other visible changes as a result of these tests.

HEATING TESTS:

METHOD

The cells were heated in an oven. The temperature on the exterior surface of the metal cell casing was measured by means of an iron-constantan thermocouple. The heating range was controlled with a variable transformer and range of 1°C/min to 11°C/min. The heating was discontinued at 150°C (302°F). The cells were examined after the test for any sign of change.

The following cells were used in these tests:

Previous Conditioning of Cells	No. of Cells
Fresh cells	5
After oven exposure	5
After temperature cycling	5
Cells discharged at room temperature:	
One-half discharged	5
Completely discharged	5
Cells discharged at 71°C (160°F):	
One-half discharged	5
Completely discharged	5

RESULTS

No signs of bulging was noted of the cells tested.

CRUSH TESTS:

METHOD

The cells were crushed between a flat surface and a cylindrical surface having a radius of curvature of 5/16 in. In these tests, the cells were positioned with their long axis perpendicular to the long axis of the cylindrical surface and parallel to the flat surface. The cells were crushed at a point about midway between the ends. The force was applied by means of a hydraulic ram and the cells were crushed until the thickness at the point of maximum crushing was less than one-fourth of the original diameter of the cell. The temperature on the exterior surface of the metal cell casing was monitored by means of an iron-constantan thermocouple. The cells were examined after the test for any signs of reaction due to the crushing.

The following cells were used in these tests:

Previous Conditioning of Cells	No. of Cells
Fresh cells	5
After oven exposure	5
After discharge at 71°C (160°F):	
One-half discharged	5
Completely discharged	5

RESULTS

The cells ruptured releasing a few drops of electrolyte. There was slight heating but no other signs of reaction.

HUMIDITY TEST:

METHOD

The cells were tested in accordance with Method 507.1 of MIL-STD-810C. The cells were exposed to high humidity conditions in a chamber having controlled temperature and humidity. The temperature in the chamber was raised to 65°C (149°F) and the relative humidity to 90-100 percent over a period of 2 h and these conditions maintained for 6 h. The temperature of the chamber was then reduced to 30°C (86°F) in 16 h while maintaining a relative humidity of at least 85 percent. This procedure was repeated for a total of 10 c. After the test the cells were examined for signs of change.

MDS/JPA:mrs
PC Ibrv:

The following cells were used in this test:

Previous Conditioning of Cells	No. of Cells
Fresh cells	5
After oven exposure	5
Cells one-half discharged at 71°C (160°F):	5

RESULTS

The surface of the metal cell casings was slightly discolored but there were no other signs of any visible changes as a result of this test.

VIBRATION TEST:

METHOD

The cells were tested in accordance with Vibration Test I of MIL-B-18D. This method calls for the application of simple harmonic motion with an amplitude of 0.03 in. (0.06 in. total maximum excursion). The frequency was varied at the rate of 1 c/s/min between 10 and 55 c/s. Each cell was tested in three mutually perpendicular directions each covering the range of 10 to 55 c/s and return in not less than 90 nor more than 100 min. The cells were examined after the test for any signs of change.

The following cells were used in these tests:

Previous Conditioning of Cells	No. of Cells
Fresh cells	5
After oven exposure	5
Cells discharged at room temperature:	
One-half discharged	5
Completely discharged	5
After discharge at 71°C (160°F):	
One-half discharged	5
Completely discharged	5

RESULTS

There were no indications of any changes in these cells as a result of this test.

MDS/JPA:mrs
PC Lbry:

DROP TEST:

METHOD

These tests were conducted on the cells previously tested in the vibration test. Each cell was dropped nine times from a height of 6 ft onto a concrete floor. The cells were randomly oriented to obtain impacts in all positions. The cells were examined after each drop for any sign of change.

RESULTS

No changes in these cells were observed after these tests.

FORCED DISCHARGE AND ABNORMAL CHARGING TEST:

METHOD

The cells were force-discharged by connecting them in series with a 12 V dc power supply. The current was controlled by connecting a resistor of appropriate size in series with the cell. Additional cells were charged by being connected in opposition with a 12 V dc power supply. The current was controlled by connecting a resistor of the appropriate size in series with the cell. The test duration was based on the applied current and the capacity of the cells.

The cells were examined after these tests for any sign of change.

PUNCTURE AND LEAKAGE TESTS:

METHOD

Cells were punctured by cutting through the cell casing with a small grinding wheel until liquid or gas was released from the cell.

RESULTS

The cells were found to contain only a few drops of an organic liquid. The cells were not pressurized and no gas, liquid, or solid particles were sprayed from the cells.

EASE OF DISASSEMBLY:

METHOD

Tests were conducted to determine if these cells can be opened without at least the use of simple hand tools.

MDS/JPA:mrs
PC Lbry:

RESULTS

The cells could not be opened without the use of tools. A hacksaw or two pairs of pliers was needed to open the steel casing.

FIRE EXPOSURE TESTS:

METHOD

One sample was placed on a wire screen directly above a 2 in. diameter laboratory Meker burner fueled by methane gas at a pressure of 0.5 psig and a flow rate of 3.0 ft^3/h. The cells were heated until they exploded or until ultimate results were obtained. For protection and also to muffle the sound of any explosions, the cells were tested in a room separate from the observer. The results of this test were used to determine if further testing would be needed to evaluate the fire exposure hazard of these cells. Five fresh cells were used in this test.

RESULTS

Based on test results, the samples shot off platform. In view of this the Projectile (Barrier Penetration Test) test was needed.

BARRIER PENETRATION TESTS:

METHOD

A cage consisting of an octagon frame 2 ft across and 1 ft high covered with aluminum insert screening was placed around a test cell. The bottom of the cage was closed by a steel plate on which the cell was placed. The top of the cage was covered by a flat section of aluminum screening held in a frame 2 by 2 ft in size. The screen was made from 0.010 in. diameter aluminum wire with 16-18 wires per inch in each direction. The cell was heated by a gas flame as described above until the cell exploded. Ten cells were used in this test.

RESULTS

The samples did not penetrate the wire screen and therefore showed acceptable results.

MDS/JPA:mrs
PC Lbry: