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# A BASIC LABORATORY SAFE HANDLING GUIDE FOR STABILIZED LITHIUM METAL POWDER (SLMP®)AND SLMP® PRODUCT VARIANTS

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# DISCLAIMER

In preparing this guide, Livent has utilized the best information known and available at the time of printing. Livent recognizes that over time techniques, methods and equipment related to the safe handling of lithium metal will evolve; dating the information within this guide.

Additionally, the information presented in this guide has been written to address most typical situations, environments and facilities, based upon Livent's experiences. However, Livent recognizes that each customer's situation is different and necessitates specific solutions to fit those requirements. This guide is intended to assist in the handling of small quantities of SLMP® and SLMP® product variants in a laboratory environment.

Livent seeks to provide up-to-date solutions to the questions or concerns that our customers may have. Please contact us to discuss your specific needs.

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# INTRODUCTION

This guide is provided for the application and use of Stabilized Lithium Metal Powder (SLMP®) and SLMP® product variants. Non-stabilized lithium metal powder is pyrophoric, has to be stored under heavy organic oils, is dangerous to handle, and requires special handling and environmental conditions. SLMP® is non-pyrophoric by US Department of Transportation definition - *DOT regulations, 49 CFR 173 Appendix E, and the UN Manual of Tests & Criteria (33.3).* SLMP® can be transported by air and sea and can be handled with care under controlled environmental conditions.

SLMP® is protected by US Patents 5,567,474; 5,776,369; 6,706,447; 7,588,623 and other patents pending and is not for commercial purposes. This product is currently for Research and Development only.

# INTRODUCTION (CONT.)

**SLMP® can be combined with other components to produce a treatment suspension.**

SLMP® can be combined with a compatible solvent to produce a treatment suspension. SLMP® can also be combined with a compatible solvent, binder and rheology modifier to produce a treatment slurry.

General handling guidelines put forth in this document should be followed for both SLMP® powder and SLMP® product variants.

# PHYSICAL PROPERTIES

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# PROPERTIES OF LITHIUM METAL

**Lithium** is a soft, silver-white metal in elemental form

**Lithium** is the lightest metal

**Lithium** has a high electrochemical potential (more negative standard electrode potential relative to Standard Hydrogen Electrode)

**Lithium** metal is combustible as well as air and water reactive

# PROPERTIES OF LITHIUM METAL

Lithium metal, like other alkali metals, is very reactive toward water and air. The degree of the metal's reactivity is proportional to its surface area. Large pieces of lithium metal will react relatively slowly with moisture in air while lithium metal as a finely divided powder can react very rapidly.

$$2\,Li + H_2O \rightarrow Li_2O + H_2$$

$$Li_2O + H_2O \rightarrow 2LiOH$$

Lithium metal will react with nitrogen in the air to form lithium nitride. This reaction is catalyzed by the presence of moisture in the air. Lithium should be stored under argon.

$$6\,Li + N_2 \rightarrow 2Li_3N$$

For this reason, lithium metal is usually stored and handled under argon, in oil and/or in a dry room. Even in a dry room environment finely divided dry lithium powder will react with the oxygen in the air.

$$4\,Li + O_2 \rightarrow 2Li_2O$$

The coating on SLMP® will slow the reaction with air making the lithium metal powder non-pyrophoric however a dew point of -25 °C or drier is required for handling SLMP® in air.

# HANDLING

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# HANDLING OF SLMP®

While SLMP® has a coating that partially mitigates many of the difficulties with handling lithium metal powder, precautions are still required with its handling. Detailed information on material hazards, handling and storage is provided in the Safety Data Sheet. It should be noted that handling under argon is preferred to minimize the opportunity for reaction, and that the extent of the hazard depends on the quantity of lithium present.

| Hazards | Controls |
|---|---|
| **SLMP® will react violently with water and polar solvents.** | Remove all sources of water from area.<br>Remove all polar solvents from the area. For example NMP, acetone etc.<br>Use in a dry room (small quantity only) or under argon. |
| **SLMP® can form an explosive dust.** | Use in an argon glovebox or under a blanket of argon in a fume hood. If using small quantities in a dry room use a fume hood and fire-resistant PPE.<br>Avoid creating a dust cloud.<br>Eliminate ignition sources such as static (use grounded non-sparking tools and metal trays, and personal static dissipation devices (grounding straps)). |
| **SLMP® can react with moisture in the skin, eyes and lungs and cause irritation or burns.** | Use anti static gloves for powder handling (ensure tools are grounded if using non-conductive gloves).<br>Use Nomex® (fire retardant) laboratory coat.<br>Use dust mask or surgical mask (natural fiber).<br>Wear eye protection (safety glasses/goggles, e.g. 3M Part #70071647336).<br>Closed toe leather shoes to protect the feet from spills. |
| **SLMP® is incompatible with many chemicals.** | SLMP® should be stored in a closed container under argon when not in use. |
| **Abrasions can remove coating or create heat or sparks.** | Threads and sealing surfaces should be clean prior to tightening lid on SLMP® containers.<br>Maintain awareness of any other sources of friction in the process. The act of wiping up powder spills can smear the soft SLMP® particles. See slide #18 for guidance. |

# SUGGESTED PPE

Dust Mask

Chemical resistant goggles

Fire retardant lab coat

Chemical resistant gloves

Closed toe leather shoes

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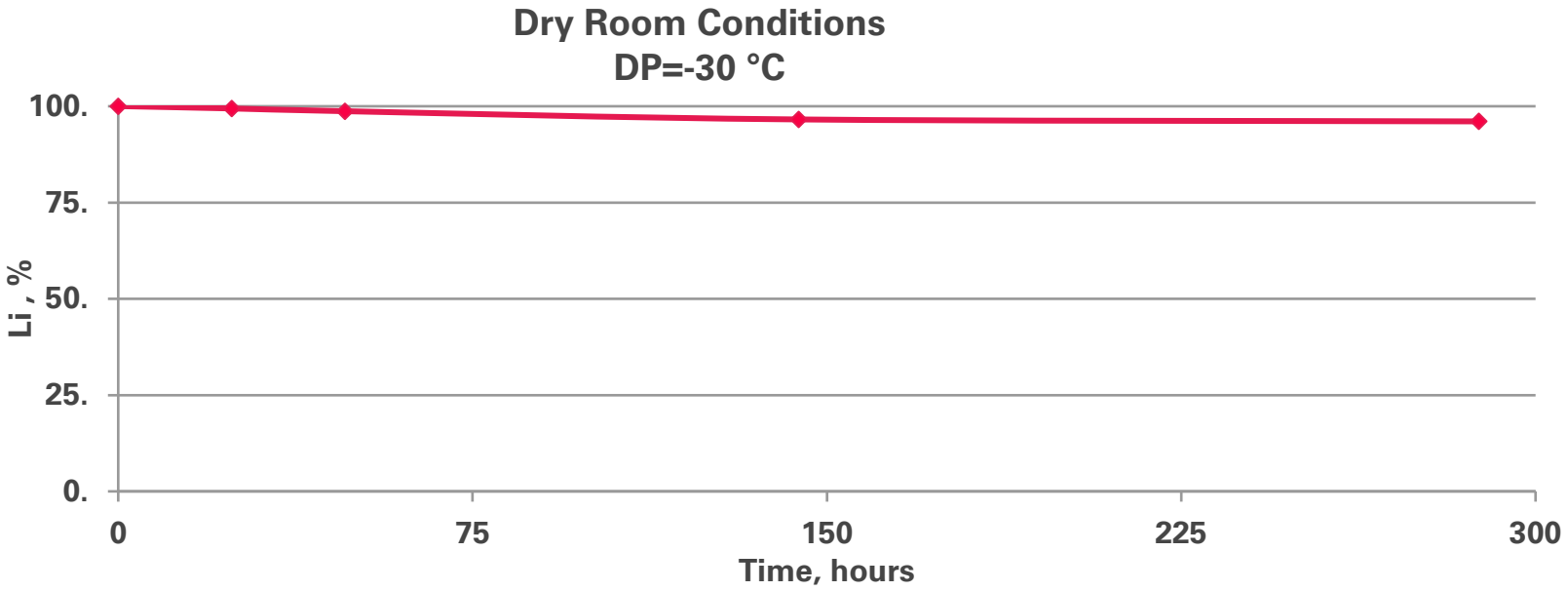
# HANDLING OF SLMP®

SLMP® should not be handled outside of a dry room atmosphere (dew point of -25°C or lower) except under an inert argon atmosphere. Studies conducted at -30°C dew point show <1% loss in metallic lithium content after 50 hours.



# COMPATIBILITY OF SLMP®

SLMP® is incompatible with many chemicals. Users should exercise caution and conduct a safety assessment when mixing SLMP® with other chemicals. Some compatibility data is available from Livent upon request.

SLMP® compatibilities to consider and analyze more closely:

- Solvents
- Binders
- Electrolytes
- Substrates
- Moisture in chemicals
- Atmospheric gases

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# FIRE FIGHTING

SLMP® is a non-pyrophoric powder (DOT regulations, 49 CFR 173 Appendix E, and the UN Manual of Tests & Criteria (33.3)) but it is still combustible and can cause a flash fire. Any area where SLMP® will be handled should be equipped with one of the following fire extinguishers:

- **Copper powder**
- **Lith-X®**
- **Dry lithium chloride**

Never use sand for fire fighting. Any area where SLMP® is being used should be designed to address a flash fire if it occurs, and personnel should be protected with the proper PPE and trained to use the fire extinguishing equipment provided.

# MAIN SAFETY CONCERNS WITH SLMP®

The key potential safety concerns with SLMP® are:

- **Reaction with water**
- **Static discharge or other ignition sources**
- **Compromising the stabilized coating**

Any of the above can cause a flash fire.

Any area where SLMP® is being used should be designed to address a flash fire if it occurs, and personnel should be protected.

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# SLMP® DUST HAZARD ASSESSMENT

**Additional information on combustible dust, self heating and explosion hazards:**

- Volume Resistivity (ohm.m) at low humidity = 80
- Charge Decay Time (sec) at low humidity = < 1
- Modified Self-Heating Substance Test – Positive; UN 4.2, PG II
- Maximum Explosion Pressure (bar) = 7.3
- Maximum Rate of Pressure Rise (bar/s) = 431
- Kst Value (bar m/s) = 117
- Minimum Ignition Energy – Dust cloud (mJ) = < 3
- Minimum Ignition Temperature – Dust Layer (°C) = 160 – 180 (argon diluent gas)
- Limiting Oxygen Concentration (% by volume, Ar diluent) = 0.75 – 1.0
- Minimum Explosible Concentration (g/m3) = 30 – 40

# CLEAN-UP & DISPOSAL

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# WASTE DISPOSAL PRACTICES

The following slides contain information about how SLMP® waste materials are managed inside of Livent.

- It is the responsibility of the individual user to understand waste management practices and regulations within their own facility.
- Livent will provide information regarding the properties of SLMP®.
- Livent will share practices and experience regarding handling of SLMP®.
- The safe handling and disposal of SLMP® is ultimately the responsibility of the individual user.

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# WASTE DISPOSAL PRACTICES

Lithium is more stable when stored under dry mineral oil (< 100 ppm water, and checked that no aqueous layer is present), which should be sufficiently heavy (Initial Boiling Point > 250°C). Small amounts can be addressed by:

- If contained in a grounded metal tray, the material can be washed into a grounded metal waste container using dry mineral oil. The waste container should contain mineral oil and be designated for SLMP® waste with no incompatible materials. This process mitigates potential friction and static issues.
- If outside containment, the SLMP® should be thoroughly wetted with dry mineral oil, including both pouring as well as spraying a fine mist of mineral oil to be sure the surface of the SLMP® is covered. It should then be gently wiped up with a mineral oil saturated cloth (natural fiber). The entire cloth should be thoroughly soaked with mineral oil by dousing to ensure complete wetting. The used cloth should be placed in a metal container for disposal. Cloth should be dried before use, for example by storage in dry room conditions or -40°C DP or better for 24 hours to ensure low level of moisture prior to use.
- It is important to avoid abrasive actions which may damage the coating, generate static, or cause localized heat sufficient to ignite SLMP® particles.
- Flammables and combustibles should be removed from the area during handling of SLMP®.

# WASTE DISPOSAL PRACTICES

At Livent, oil soaked cloths contaminated with waste SLMP® are safely disposed of by submerging in mineral oil in an enclosed metal container with the head space purged with argon.

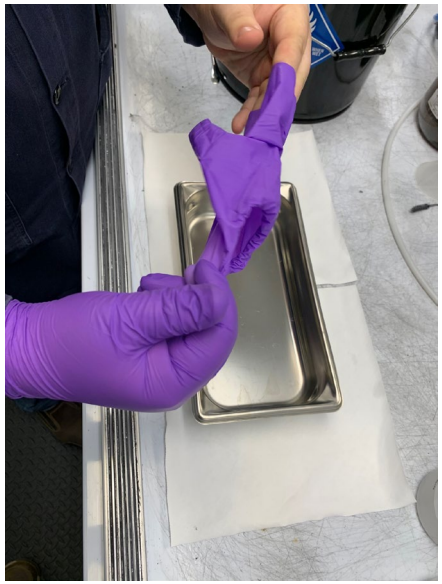
- **When full the container should be purged with argon and sealed tightly for disposal according to company policies and local regulations.**

Waste SLMP® surface treated electrodes can be disposed of by submerging the materials in a metal grounded vessel containing mineral oil. The vessel should be purged with argon, sealed and disposed of according to company policies and local regulations.

# EXAMPLE WASTE CONTAINER AND GLOVE HANDLING

Waste Pail

Waste Pail with Lid



Glove Removal

Glove Staging for Drying

- The waste vessel should have a locking lid to prevent spillage. The vessel should contain sufficient oil to fully submerge the waste. Additional oil should be added as the container fills with waste.

- PPE such as nitrile gloves that are contaminated with SLMP® should be removed by turning inside out and allowed to dry completely before disposal. At Livent we segregate contaminated gloves in a separate waste bucket to prevent introduction of lithium metal waste to moisture.

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# LIVENT'S SLMP® IN HYDROCARBON SOLVENT WASTE DISPOSAL PRACTICES

Livent disposes of SLMP® in hydrocarbon solvents by placing the material in sealed glass bottles under argon then overpacking in a 5 gallon bucket with vermiculite for shipment off site for disposal.

# APPLICATION METHODS

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# SLMP® APPLICATION METHODS

**Surface application** - an SLMP® suspension is applied to a prefabricated anode sheet.

**Slurry application** - a conventional electrode preparation method is employed and both binder and solvent must be compatible (non-reactive) with lithium.

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# SLURRY APPLICATIONS

SLMP® can be combined with a compatible solvent for use as an electrode treatment solution. When conducted in a dry room the user should take the following precautions:

- Wear the recommended PPE and use proper static dissipation measures (see earlier slide).
- Work in a fume hood to contain any flammable solvent vapors.
- Limit the quantity of SLMP® solution to only the amount necessary to perform the task. Only small amounts of solution should be used outside of an argon atmosphere or argon purged container.
- Use a container with an opening only as large as necessary to perform transfers; thereby limiting exposure.
- Use containment, such as a grounded metal pan, in case of spills or fire.
- Consider materials of construction for any tool (i.e. spark resistant) used to apply the slurry to the electrode surface.
- Keep SLMP® container closed and under argon when not in use. Do not store slurries for long periods of time. See earlier slides for guidance on disposal.

# IMPORTANT INFORMATION

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# OTHER IMPORTANT INFORMATION

SLMP® can maintain a high level of lithium metal content for days in low relative humidity air (dew point lower than -25°C).

- Time required for complete reaction will depend upon the thickness of the SLMP® layer (a thin layer of SLMP® will react more rapidly than a thick layer) and the dew point/relative humidity of the ambient air. Note that for thick layers of SLMP® that the top layer may react completely while leaving unreacted SLMP® underneath that may react when exposed.

When handling SLMP® in an argon filled glove box, care should be taken that the recirculation train or exhaust are properly filtered to prevent exposure of SLMP® to moist air or other incompatible materials.

- The glove box filter cartridges should be submerged in mineral oil inside the glove box and sealed in an argon purged vessel for proper disposal.
- Material of construction of filters should be compatible with SLMP®.

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# SLMP® SPECIFICATIONS

| | |
|---|---|
| **Metallic Lithium Content:** | 97 wt. % minimum |
| **Particle Size (D50):** | 30 – 60 micron |
| **$Li_2CO_3$ Content:** | 0.5 wt. % minimum |

# FOR FURTHER INFORMATION

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# APPENDIX

**DUST HAZARD DEFINITIONS/TEST DETAILS;**

**Volume Resistivity** - Volume resistivity is a measure of the electrical resistance for a unit volume of material and is the primary criterion for classifying powders and dusts as low, moderately, or highly insulating.

**Charge Decay Time** - Charge decay time is measured by placing a powder or dust sample in a test cell and charging the sample using a corona source. The cell is then grounded and the time required for the charge on the sample to relax is measured.

**Modified Self Heating Substances Test** - This test is done to determine if a substance is self heating and is used to determine the proper DOT classification for the material for shipping.

**Maximum Explosion Pressure** - Dust is dispersed in a pressure chamber at different concentrations and ignited. The maximum explosion pressure is the maximum pressure rise in the chamber that was recorded for the different dust concentrations ignited.

**Maximum Rate of Pressure Rise** - Dust is dispersed in a pressure chamber at different concentrations and ignited. The maximum rate of pressure rise in the chamber is recorded for the different dust concentrations ignited.

**Kst (Dust deflagration index)** - The deflagration index is the maximum rate of pressure rise normalized for a 1 m3 volume.

**Minimum Ignition Energy Test - Dust Cloud -** The minimum ignition energy (MIE) test determines the lowest spark energy capable of igniting a sample when dispersed in the form of a dust cloud.

**Minimum Ignition Temperature Test - Dust Layer** - The MIT-Layer test determines the lowest surface temperature capable of igniting a powder or dust.

**Minimum Explosible Concentration Test** - The minimum explosible concentration (MEC) test determines the smallest concentration of material in air that can give rise to flame propagation upon ignition when in the form of a dust cloud. Limiting Oxygen Concentration Test - The limiting oxygen concentration (LOC) determines the minimum concentration of oxygen (displaced by nitrogen) capable of supporting combustion.

**Explosion Severity Test (Maximum Explosion Pressure)** - A powder or dust sample is dispersed within a 20 liter sphere, ignited by chemical igniters, and the pressure of the resulting explosion is measured.