IMPROVED REACTION -TO – FIRE TEST FOR PARTICULATE METALS AND METHOD TO EVALUATE THE EFFICACY AND LIMIATIONS OF LIQUID SUPPRESSANT AGENT(S) FOR METAL FIRES AND WASTE HAZARD REDUCTION

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RISK MANAGEMENT AND MITIGATION (RM-3, RM-4, ET-5, PI-4)

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PROPOSED TECHNICAL APPROACH

B-1 BACKGROUND

The goal of the fully-developed proposed method and technology is to improve the current test method for combustible metals, alloys and mixtures in order to ensure proper hazard classification for transportation through a well-defined evaluation process and one that will further aid in identifying methods to prevent, reduce or suppress particulate metal fire hazards, including combustible metal waste.

From particulate metal powders for 3-D printing to particulate metal waste, a large cross section of metals are subject to transportation. The first step in determining if a particulate metal is combustible, explosible or a flash fire hazard is to perform a reaction-to-fire test. For transportation, the reaction to fire test is the UN Test N.1 Test Method for Readily Combustible Solids. Some particulate metals are readily ignited by low energy ignition sources and burn explosively; others will not ignite and burn unless conditions are extreme. Some particulate metals offered for waste rely on a non-reactive passivating layer, agent or heat sink to prevent ignition. If passivation is lost or water is removed, the ignition propensity and burning rate can change. Other particulate metals can evolve flammable gases including hydrogen gas when exposed to water. Once ignited, particulate metals in a combustible form can burn with extreme temperatures and are difficult to extinguish; the quantity and packaging of nearby other combustible materials including metals can influence the spread of fire.

Initial research by Fire and Materials Research Laboratory, LLC, funded by the International Titanium Association (ITA), resulted in the identification of gaps and deficiencies in the current UN/DOT test method used to assign, or fail to assign, particulate titanium metal including titanium-based waste to hazard classes or categories for transportation. The gap analysis included an industry survey which exposed discrepancies in understanding what metals were covered by the test method and in executing the same test method such as ignition source selection. As a result, a need was identified to improve upon the test method for particulate metals that will adequately characterize the type and range in hazard(s) of various metals, alloys and mixtures that will benefit various stakeholders. At the same time, research is needed to assess hazard reduction technologies aimed to prevent or reduce ignition or, if ignited, potential extinguishment, thus mitigating serious metal fire hazards. Hydrogen evolution, another recognized hazard of particulate metal waste and swarf, will be considered.

Identified limitations of the current test method for particulate metals, which potentially inhibits appropriate classification, are due to one or more of the following:

- poorly defined ignition source, type and duration,
- lack of basic material characterization,
- limited data output,
- no meaningful examples or comparisons,
- no guidance for mixtures containing metals,
- not well-suited for spherical powders, and
- limited to no guidance on non-powder forms of particulate metal.

The same test method with different criterion is used to determine if other metals are in a combustible form for storage, use, and handling per the National Fire Protection Association (NFPA).

Analysis of the metal industry loss history shows that when a metal hazard is not correctly identified, the material is potentially improperly labeled for shipment, improperly identified for appropriate actions based on the ERG and NFPA safety regulations and could result in confusing and/or inadequate information on safety data sheets. Proposed hazard reduction concepts such as mixing or dilution or treatment with a liquid suppressant agent prior to transportation may further reduce risks with regards to metal waste streams.

This white paper describes a proposed method to better characterize particulate metal hazards, why a robust combustibility test is important, gaps identified in the current test method(s) and proposed basic research and clarifying language toward a more meaningful, scientific ignition propensity and burn rate test that will addresses the above described test limitations and properly characterizes ignition propensity and fire hazards of particulate metals.

B-2 SCOPE OF WORK

Many forms of metal, not just powders that present potential fire hazards or exhibit reactivity with water, are produced and shipped everyday worldwide. These include fines, chip, turnings, swarf, flake, sponge, nano-powders, waste, etc. some of which do not conform to the test method's prismatic train. The UN Test N. 1 Test Method for Readily Combustible Solids is typically the first and sometimes only test performed to assess the physical hazard of particulate metals but mentions only metal powders. The proposed major research, testing and analysis activities will focus on: 1) proper characterization of metal particulate which influence the fire risk; 2) scientific and instrumented bench- and intermediate-scale testing to characterize the physical hazards, in range and magnitude, from ignition propensity to burning rate, burning intensity, and reactivity including water reactivity; 3) evaluation of the efficacy of potential hazard reduction agents; and 4) make recommendations to improve the existing test method and hazard assignment for all forms of particulate metals.

In addition to an improved test method for hazard recognition, the results will include proposed language for a new section in the TDG and Figure 33.2.1.3 Flow Chart for Assigning Readily Combustible Solids, Except Metal Powders to Division 4.1 (e.g., clarify instead of except metal powders) and a modification to accommodate particulate metals that do not readily conform to the prismatic train. The current UN/DOT test method does not include or have examples of commonly recognized particulate metal or metal mixtures or wastes; examples of common metals burning rate test results will be reported for consideration.

B-3 PROJECT'S RELATIVE IMPORTANCE

The purpose of this proposal is to present a strategy for an improved, more scientific test method specifically for all particulate metals and mixtures containing metals, provide examples and draft clarifying language to assist the test operator and stakeholder and avoid confusion and unreliable test results. A consistent method of documenting results will prevent incorrect interpolation if one or more variables regarding the sample under consideration changes.

A test method that correctly identifies the hazards of particulate metals is valuable for numerous stakeholders. The UN Test N.1 test method is generally adopted by other regulatory agencies to assess the physical hazards of various solids. For fire codes NFPA 652 *Standard on the Fundamentals of Combustible Dust* and NFPA 484 *Standard for Combustible Metals* that address production, finishing, handling, storage, recycling, use and waste management, there is support for an improved test method that better identifies the range in hazard(s) of a particulate metal, alloy or mixtures. With an improved test method, manufacturers/producers/generators of particulate metals, alloys and mixtures including waste will have more and reliable test data on which to base transportation and waste characterization, fire prevention, and fire protection decisions.

The proposed research will strive for harmony between the transportation, use, handling, storage, recycling and waste recognizing the hazard of a material can change during the life of a material or product. Manufacturers, shippers, distributors and users of particulate metal will have better characterization and recognition of metal hazard conditions as a function of form over time.

If accepted, the full proposal will detail the design of experiments, test and analysis plan. The magnitude and scope of the hazard, major metals involved and industry comments have already been investigated as part of the gap analysis for the ITA. The short-term effects and importance of the proposed project will be to clearly identify and demonstrate the deficiencies of the test method and the hazards that may be propagated forward if the test for transportation is not improperly performed and/or the range of hazards of a particular metal or form or mixture is not realized. This will keep the momentum of the project and various stakeholders interested. There are multiple intermediate effects. The first would be to collect, present and assess the impact of the data gathered at both bench and intermediate scale as bases required to convince interested related regulatory agencies, such as IGUS OES, of the gaps, false negatives and resulting hazard mis-identification. Further, the efficacy and limitations of potential liquid non-reactive suppressing agents for waste before, during and after transportation and some industrial processes will be studied. The long-term effects are to properly characterize and identify by testing the hazards of particulate metals in order to affect safe transport, use, handling and storage or to reliably treat to reduce or prevent ignition thereby eliminating the hazard of readily ignitable particulate metals.

The author believes the proposed project touches upon the four PHMSA OHMS research priorities, but most specifically the Risk Management and Mitigation of particulate metal hazards including waste.

C. SCHEDULE AND PRICE ESTIMATE

The full proposal will detail the proposed project with respect to identifying, characterizing and testing various forms, size ranges, types and concentrations of metals, alloys and mixtures and an evaluation of various liquid agents to suppress a metal fire, prevent or reduce ease of ignition and/or prevent or reduce hydrogen evolution accumulating in drums or packaging containers over time.

FMRL has a laboratory equipped for characterizing materials and performing small and intermediate scale tests with energetic, high burning temperature materials. In-house characterization and test instrumentation includes but is not limited to microscopy, National Instruments data acquisition and software, thermocouples, heat flux transducers, thermal imaging cameras, optical high temperature pyrometers, moisture analyzers and sieves for particle size and classification.

Post full proposal preparation, major milestones are:

1) Identify, receive and characterize test materials (2 months)
2) Set up and execute instrumented tests with baseline data (4 months)
    a. Small/ bench scale testing, and
    b. Intermediate testing for proof of concept and verification
3) Reduce data, prepare report with appendices and presentation (2 months)

A cost estimate for the proposed project scope and execution is $625,000.