IPN: 61300001

Material Safety Data Sheet

Vodik Labs Solid Hydrogen Storage Canisters **MSDS No. TXO 200,006**

May 11, 2009 – Revised June 11, 2012

Section 1 - Chemical Product and Company Identification

Product/Chemical Name: Hydrogen Storage Canister
Chemical Formula: Hydrogen in a metal hydride storage system
Model Numbers: 85G250B, 85G555B, 85G694B, 25G250B, 25G555B, 25G694B, 10G250B, 10G555B, 10G694B, 7G250B, 7G555B, & 7G694B
General Use: Fuel Gas
Manufacturer: Vodik Labs, LLC; 6657 Corporation Parkway, Suite 200; Fort Worth, Texas 76126
Phone (817) 560-1660, FAX (817) 560-1660 (8:00 a.m. – 5:00 p.m. Mon. – Fri.)

HMIS	
H	0
F	4
R	0
PPE†	
†Sec. 8	

24 Hour Emergency phone number (CHEMTREC): (800) 424-9300 *

**Call emergency number only for spills, leaks, exposure, or transportation accidents involving this product. For routine information, contact supplier.*

Section 2 - Composition / Information on Ingredients in Aluminum Canister

Ingredient Name	CAS Number
Cylinder	
Aluminum	7429-90-5
Contents of Cylinder	
Hydrogen	1333-74-0
Chromium	7440-47-3
Iron	7439-89-6
Manganese	7439-96-5
Vanadium	7440-62-2
Titanium	7440-32-6
Zirconium	7440-67-7
Aluminum	7429-90-5
Tin	7440-31-5

	OSHA PEL		ACGIH TLV
Ingredient	**TWA**	**STEL**	**TWA**
Aluminum	5 mg/m^3	none established	10 mg/m^3
Hydrogen	none established	none established	Simple asphyxiant
Chromium	1 mg/m^3	none established	0.5 mg/m^3
Iron	none established	none established	1 mg/m^3
Manganese	5 mg/m^3 (fume)	none established	0.2 mg/m^3
Vanadium	none established	none established	none established
Titanium	none established	none established	none established
Zirconium	5 mg/m^3	10 mg/m^3	5 mg/m^3
Tin	0.1 mg/m^3	0.2 mg/m^3	0.1 mg/m^3

Section 3a - Physical and Chemical Properties of Hydrogen Gas

Appearance and Odor: Colorless and Odorless
Gas Density: 0.00521 lb/ft^3 (0.08342 kg/m^3)
Specific Gravity (H_2O=1, at 4 °C): 0.06960
Molecular Weight: 2.016
LFL: 4% (hydrogen)
UFL: 75% (hydrogen)
Water Solubility: Reactive
Boiling Point: -423.0 F (-252.8 C)
Melting Point: -434.55 (-259.2 C)
% Volatile: 100
Auto ignition Temperature: 932°F (500 °C)

Section 3b - Physical and Chemical Properties of Hydridable Metal Alloy

Appearance and Odor: Silver / gray metallic color
Gas Density: 0.00521 lb/ft^3 (0.08342 kg/m^3)
Specific Gravity (H_2O=1, at 4 °C): 0.06960
Molecular Weight: 2.016
LFL: 4% (hydrogen)
UFL: 75% (hydrogen)
Water Solubility: Reactive
Boiling Point: -423.0 F (-252.8 C)
Melting Point: -434.55 (-259.2 C)
% Volatile: 100
Auto ignition Temperature: Self heating and igniting on contact with air or other oxidizer

Section 4 - Fire-Fighting Measures

Flammability Classification: If contents are released, hydrogen gas and hydridable metal alloy powder are extremely flammable and may self-ignite.

Extinguishing Media: Water if canister is intact. Cool canister if it is hot. If cylinder has ruptured releasing metal powder, smother with sand or METL-X fire extinguishing powder, if necessary. Otherwise allow to burn out while protecting surrounding area.

Unusual Fire or Explosion Hazards: Canister may be under pressure and may release some hydrogen gas or rupture under extreme heat from fire conditions. Hydrogen is a flammable gas and the flame is nearly invisible. The canister is equipped with a pressure relief device. Escaping gas may ignite spontaneously. If venting occurs, do not extinguish flame because hydrogen gas can form explosive mixtures with air and oxidizing agents.

Hazardous Combustion Products: Irritating fumes and/or toxic gases.

Fire-Fighting Instructions: Contents of canister are extremely flammable and may self-ignite if exposed to air. Contents burn rapidly, releasing dense, white, irritating fumes. Use of water on internal contents may cause its dispersal with fire spreading through dispersed material. Material may re-ignite after fire is extinguished. Eliminate ignition sources. Immediately deluge intact canister with water from a safe distance until cool, then move them away from fire area if this can be done without risk. Withdraw immediately in case of hissing sound from venting safety devices or discoloration of canister. Do not extinguish flames emitted from canister; allow to burn out while protecting the surrounding area.

Fire-Fighting Equipment: Because fire may produce toxic thermal decomposition products, wear a self-contained breathing apparatus (SCBA) with a full face piece operated in pressure-demand or positive-pressure mode.

Section 5a - Stability and Reactivity of Hydrogen Gas

Stability: Hydrogen is stable at room temperature in closed containers under normal storage and handling conditions. In air hydrogen gas is flammable and may attain explosive mixtures.
Polymerization: Hazardous polymerization cannot occur.
Chemical Incompatibilities: Hydrogen is extremely flammable and may attain explosive mixtures with oxidizers (including air)
Conditions to Avoid: Extreme heat
Hazardous Decomposition Products: none.

Section 5b - Stability and Reactivity of Hydridable Metal Alloy

Stability: Granular or compacted granular material is self-heating and pyrophoric.
Polymerization: Hazardous polymerization cannot occur.
Chemical Incompatibilities: 1. Granular or compacted granular media reacts with oxidizers (including air).
Conditions to Avoid: 1. Oxidative atmosphere
2. Flammable materials in the immediate area.
Hazardous Decomposition Products: Thermal oxidative decomposition of product can produce irritating fumes and/or toxic gases.

Section 6 - Health Hazard Information

Potential Health Effects

*Under normal conditions, it is not expected that any of the contents of the product will be released. In the event of a **hydrogen gas release**, the following health effects may occur:*

Primary Entry Routes: Inhalation
Target Organs: Lungs and upper respiratory tract
Acute Effects
Inhalation: Asphyxiant. Effects are due to lack of oxygen. Moderate concentrations may cause headache, drowsiness, dizziness, excitation, excess salivation, vomiting, an odd-sounding high pitched voice, and unconsciousness.
Eye: No harm expected in the absence of superheating.
Skin: Burns possible if canister contents ignite, if released hydrogen gas ignites or if solid contents of canister contact the body.

Carcinogenicity: IARC, NTP, and OSHA do not list product as a carcinogen.
Medical Conditions Aggravated by Long-Term Exposure: 1. The toxicology and the physical and chemical properties of hydrogen suggest that overexposure is unlikely to aggravate existing medical conditions. 2. Long term exposure to canister contents cannot occur since it oxidizes to metal oxides rapidly on exposure to air.
Chronic Effects: No harm expected.

Emergency and First Aid Procedures

Inhalation: Move victim to fresh air. Call 911 or emergency medical service. Apply artificial respiration if victim is not breathing. If breathing is difficult, qualified personnel may give oxygen.
Eye Contact: Flush eyes thoroughly with water for at least 15 minutes. Seek medical attention immediately.
Skin Contact: Wash with soap and water. If irritation persists, seek medical attention.
Ingestion: An unlikely route of exposure for a gas.
Special Precautions/Procedures/Note to Physician: There is no specific antidote. Treatment of overexposure should be directed at the control of symptoms and the clinical condition of the patient.

Section 7 - Spill, Leak, and Disposal Procedures

Spill /Leak Procedures: Released hydrogen gas and metal hydride powder are extremely flammable. Immediately evacuate area. Release of metal hydride powder will cause ignition of flammable materials.
Spills: In the event of a powder spill, cover with dry earth, dry sand, or METL-X powder.
Containment: Do not release into sewers or waterways.
Cleanup: Do not use compressed air or a vacuum cleaner to clean up powder. Powder dispersed in air with an ignition source can cause an explosion or deflagration. The container contents are a self-heating and self-igniting material and should be handled appropriately for that material.
Regulatory Requirements: Follow applicable OSHA regulations (29 CFR 1910.120).
Disposal: Do not incinerate or throw away in garbage. Contact your supplier for detailed recommendations for disposal of canister. Follow applicable Federal, state, and local regulations.

EPA Regulations:
RCRA Hazardous Waste Number (40 CFR 261.21): D001
CERCLA Hazardous Substance (40 CFR 302.4): Chromium, Manganese
CERCLA Reportable Quantity (RQ): Not listed
SARA Toxic Chemical (40 CFR 372.65): Aluminum, Chromium, and Manganese
SARA EHS (Extremely Hazardous Substance) (40 CFR 355): Not listed
OSHA Regulations:
Air Contaminant (29 CFR 1910.1000, Table Z-1, Z-2, Z-3): Aluminum, Chromium, Manganese, Tin, and Zirconium
State Regulations: In California and Pennsylvania, check with your state regulatory agency for any special regulations.

Note: The Hydrogen Storage Systems do not exceed any regulatory limits.

Section 8 - Exposure Controls / Personal Protection

Engineering Controls: Such controls or protection is not required for normal handling or use.
Ventilation: Use canister in a ventilated area.
Administrative Controls: Such controls or protection is not required for normal handling or use.
Respiratory Protection: Such controls or protection is not required for normal handling or use. If responding to a spill or leak, use SCBA with a full facepiece operated in pressure-demand or positive-pressure mode. Follow OSHA respirator regulations (29 CFR 1910.134).
Protective Clothing/Equipment: Such controls or protection is not required for normal handling and use. However, in the event of a spill or leak, wear chemically protective gloves, boots, aprons, and gauntlets to prevent prolonged or repeated skin contact. Wear protective eyeglasses or chemical safety goggles, per OSHA eye- and face-protection regulations (29 CFR 1910.133). Contact lenses are not eye protective devices. Appropriate eye protection must be worn instead of, or in conjunction with contact lenses.
Safety Stations: Such controls or protection is not required for normal handling or use. However, make emergency eyewash stations, safety/quick-drench showers, and washing facilities available in work area.
Contaminated Equipment: Such controls or protection is not required for normal handling or use. In the event of responding to a spill or leak, separate contaminated work clothes from street clothes. Launder before reuse. Remove this material from your shoes and clean personal protective equipment.
Comments: Such controls or protection is not required for normal handling and use. In the event of responding to a spill or leak, practice good personal hygiene after using this material, especially before eating, drinking, smoking, using the toilet, or applying cosmetics.

Section 9 - Special Precautions and Comments

Handling Precautions: Protect canister from damage. Canister may be heavier than anticipated. Do not drop canister. Damage can occur. Do not tamper with valve opening. Do not expose to heat or flame, and prolonged exposure to sunlight. Do not disassemble or puncture.
Storage Requirements: Store and use with adequate ventilation. Keep away from extreme heat or flame, and prolonged exposure to sunlight.
Canister Recertification
The canister must be re-certified or removed from service five years after its manufacture date.

DOT Transportation Data (49 CFR 172.101):

Shipping Name: Hydrogen in a metal hydride storage system
Hazard Class of Container: 2.1
ID No.: UN3468
Packing Group: N/A
Label: Flammable Gas
Special Provisions: A current copy of DOT SP-15599 must be carried aboard each motor vehicle, vessel, or aircraft used in transportation.

Packaging Authorizations
a) Exceptions: none
b) Non-bulk Packaging: (173.214) DOT SP-15599
c) Bulk Packaging: none

Quantity Limitations
a) Passenger Aircraft : Forbidden
b) Cargo Aircraft Only: 100kg gross
c) Motor Vehicle or Rail Freight: none

Vessel Stowage Requirements
a) Vessel Stowage: Deck
b) Other: NA

Prepared By: Stephen Niemuth, Evan Butts, Ned Stetson, Paul Boucard, Mike Zelinsky, Kirby Smith
Revision notes:
11/4/05 – remove Texaco, update model numbers
4/10/06 – revise fire-fighting measures, change headers/title to match users manual
5/11/09 – update to reference competent authority approval CA2008050020 rather than DOT-SP13280, remove 20G---B models, add 10G---B and 25G---B models
6/11/12 – update to reference competent authority approval DOT SP-15599 rather than CA2008050020.

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VODIK LABS USER MANUAL

Canisters have been desorbed of Hydrogen and blanketed with Inert Helium Gas (10-14psi) for shipping.

Follow Initial Purge and Charge Procedures Prior to Use.

Letter from the President:

During this past decade, we've experienced extraordinary growth and change here at Vodik Labs, thanks largely to our continued commitment to teamwork, technology-focused product strategies and to our policy of placing the trust of our customers like you above all else.

We've successfully reached key milestones in sales both globally and domestically, increased research and development initiatives, achieved significant technological advancements and strengthened our position as the premier manufacturer and developer of Hydrogen Storage/ Production/ Use technologies.

Vodik Labs is building the Hydrogen tools of tomorrow. We hear the markets' demands and we are ready to meet their challenges. We know what's coming around the bend and we couldn't be more excited. Watch us closely; the next five years will be a defining notch in Vodik Labs timeline.

Thank you for choosing Vodik Labs as your Hydrogen Storage provider. Your business and support of our company is of upmost importance. We look forward to a long and beneficial business relationship together.

Sincerely,

Carey Hilton
President and CEO

*PLEASE READ BEFORE USE OF VODIK LABS HYDROGEN STORAGE PRODUCTS.

Related Documents and Specifications.

The following information is to enable users to safely and appropriately use, store and refill Vodik Labs Hydrogen Storage canisters.

The instructions and specifications of these documents must be carefully followed. Failure to follow these instructions may result in degradation of the Vodik Labs Solid Hydrogen Storage Canisters, damage to equipment, and possible personal injury.

It is essential that all activities, operations, and materials used in canister charging confirm to the specifications contained in this manual. Use of out-of-specification materials may degrade canister performance and may present a hazard to personnel and downstream equipment.

a. **Canister Inspection.** CGA C-6.1, "Standards for Visual Inspection of High Pressure Aluminum Compressed Gas Cylinders".

b. **DOT Regulations.** 49CFR 180.201 through 180.215 (Subpart C), Qualification, Maintenance and Use of Cylinders.

1. Safety Equipment and Training

The following equipment must be on hand during all refilling and blanketing activities. Furthermore, all work area personnel must be trained and proficient in its use.

a. **Personal Protective Equipment.** All operators and personnel in the work area must employ (use or wear, as applicable) personal protective equipment that is appropriate for handling flammable and explosive gases. Such equipment includes; but is not limited to, eye protection and any other precaution deemed necessary for safe performance of the procedures described in this manual.

b. **Area Safety Equipment.** The work area must be free of all ignition sources, including but not limited to, spark producing tools, open flames, strong oxidizers, and sources of static electricity. Any automatic fire detection and suppression equipment and alarms must be fully operational in and around the work area.

2. Charging Equipment Required

The following equipment is recommended for refilling and blanket activities. Furthermore, all work area personnel must be trained and proficient in its use.

a. **Area Ventilation.** A chemical hood and/or other ventilation equipment should be available, fully functional, and used during any gas charging operation. A positive displacement ventilation system with a vertical stack to the atmosphere is the preferred method for exhausting gases used in the Vodik Labs Solid Hydrogen Storage canisters.

b. **Canister Charging Device.** This device must be certified for use with hydrogen gas and be specifically designed to connect to, and securely hold, canisters of the Vodik Labs Solid Hydrogen Storage canisters. This canister charging device must include a delivery system capable of providing and adequate flow of hydrogen gas at a regulated pressure of 250 psig +/- 10 psig.

c. **Hydrogen Gas supply.** The hydrogen gas supply must meet 99.999% purity specifications for optimum canister performance.

d. **Inspection and Cleaning Tools and Equipment.** All tools that are necessary for visual inspection and surface cleaning, such as a flashlight and lint-free swabs, must be on hand and readily available.

e. **Leak Detection Equipment.** A hydrogen or combustible gas lead detection system capable of measuring leakage rates of 2.2×10^{-3} cm^3 s^{-1} (8 cm^3h^{-1}) must be on hand at all times. Soap solution lead detection liquids should also be available.

f. **Pressure Gauge.** A hydrogen compatible gas pressure gauge capable of accurately measuring pressure of the range displayed on the equilibrium pressure-temperature plot for the applicable canister must be on hand or readily available.

g. **Analytical Balance.** A scale (preferably digital electronic) capable of weighing the mass of a filled canister with an accuracy of at least +/- 0.5 grams must be on hand or readily available.

h. **Cooling System.** To expedite the filling process, a cooling system consisting of a circulating water bath that is capable of cooling the canister to a temperature of 15°C (59°F) or less is recommended. This cooling system should also be capable of maintaining a temperature of between 15°C and 30°c (59°F and 86°F) during the charging process.

i. **Mass Flowmeter.** A hydrogen gas mass flowmeter capable of measuring the amount of hydrogen gas that has left the charging manifold and entered the canister.

3. Inspection

Canisters must be inspected before each refill.

Vodik Labs Solid Hydrogen Storage canisters are much heavier than they appear to be. Hence, use caution when handling and transporting. Canisters are easily dropped and can cause serious personal injury.

a. **Date of Manufacture.** Locate the date of manufacture; it is stamped on the dome of the cylinder in the format MMXYY, where X is an inspector's mark. If this date is older than five (5) years, then the **canister cannot be refilled** until it is re-qualified by a DOT authorized re-tester.

b. **Canister Inspection.** Thoroughly inspect the entire canister for any signs of physical damage or deformation in accordance with CGA C-6.1 prior to refilling. **Damaged or deformed canisters shall not be refilled and must be removed from service.**

NEVER REFILL A DAMAGED OR DEFORMED CANISTER. Structural failure may result with the sudden release of hydrogen gas and pyrophoric metal-hydride alloy powder. An explosion and a fire with unconventional incendiary activity may result. Such fires do NOT respond to normal fire fighting techniques and may even be exacerbated by them. Thermal oxidative decomposition of both of these products may produce irritating fumes and/or toxic gases. Hence, it is very important that nothing except pure, dry, clean hydrogen gas or an inert gas blanket enter the canister.

c. **Coupling Inspection.** Visually inspect the canister coupling assembly. During this inspection, pay particular attention to threaded areas and their mating surfaces, and O-ring seals and their mating surfaces. Inspect for scratches, cuts, voids, damage, deformation, etc. Clear the threaded and coupling mating surfaces from debris. **Remove the canister from service if proper cleaning cannot be accomplished or any damage is observed.**

NEVER REFILL A CANSITER WITH A DAMANGED COUPLING. NEVER REFILL A CANISTER IF DEBRIS CANNOT BE COMPLETELY REMOVED FROM ITS COUPLING. Failure to follow these precautions may result in an uncontrolled hydrogen gas leak. Explosion and fire may result if these precautions are not strictly followed.

4. Initial Purge Prior to Charging

The following procedure applies only to those canisters that have been back-filled with a blanket of inert gas for shipping. For canisters that have been previously charged with hydrogen, proceed to Step 6 Vodik Labs Hydrogen Storage Canister Charging Procedure.

a. **Canister Connection.** Connect the canister to a vent line or place it in an air removal system that is **properly vented to the atmosphere**. If the canister is equipped with a valved coupling, simply opening the manual shut-off is not sufficient to vent. The canister must be connected to an appropriate mating connector.

b. **Bleed the Canister.** Open the canister shut-off valve; allow the canister to vent for 15-30 minutes, then close the shut-off valve.

c. **Flush with Hydrogen.** Disconnect the vent line and connect the canister to the refilling equipment.

   1) **Pressurize Canister.** Set the hydrogen supply regulator to 50 psig. And pressurize the canister 50 psig with hydrogen.

   2) **Remove Hydrogen Supply.** Close the canister shut-off valve once the pressure has reached 50 psig, then turn off the regulated hydrogen supply line.

   3) **Vent Canister.** Remove the canister from the refilling equipment and vent as before for 15 to 30 minutes, then close the shut-off valve.

d. **Disconnect Vent.** Disconnect the vent line from the canister.

e. **Measure Canister Pressure.** Connect an appropriate pressure gauge assembly to the canister; open the shut-off valve and measure and note the canister internal pressure, then close the shut-off valve.

   1) **Low Pressure Condition.** If the canister internal pressure is less than 5 psig, remove the pressure gauge assembly and repeat initial purge procedure.

   2) **High Pressure Condition.** If the canister internal pressure is greater than 5 psig, reattach the vent line and continue to bleed off residual inert gas. Repeat this process, as required, until a low pressure condition has been achieved.

5. Hydrogen Purity

Vodik Labs hydrogen storage alloys bond with impurities as readily as they do with hydrogen, with one major exception. Whereas hydrogen can be released with changes in temperature and pressure, the impurities remain bonded with the metal, reducing hydrogen storage capacity.

a. **Capture of Impurities by Vodik Labs Hydrogen Storage Alloys.** It is not uncommon for the hydrogen coming out of the canister to be purer than the hydrogen used to fill it. This phenomenon results from the bonding of impurities with the Vodik Labs hydrogen storage alloy.

b. **Diminished Capacity with impurity Accumulation.** Over time and numerous recharges, the hydrogen storage capacity of the canister will diminish as impurities accumulate. Therefore, the purer the hydrogen used, the more recharges and the higher the recharge capacity of the canister will be. Conversely, an increase in impurities will reduce the number and capacity of successful canister recharges.

c. **Recharge with Fuel Cell Grade Hydrogen.** It is recommended that only fuel cell grade (99.999%) hydrogen be used to refill canisters.

6. Vodik Labs Hydrogen Storage Canister Charging Procedure

This section details the steps to be followed for charging (filling) Vodik Labs Solid Hydrogen Storage canisters with a 250 psig rating. Canisters with custom alloy formulations are charged according to modified procedures provided with the canisters.

As hydrogen is introduced into the canister and absorbed by the storage alloy, heat will be generated and the canister may warm to temperatures approaching 50°C (122°F).

Refill Methods. The heat generated in the hydrogen absorption process slows the rate at which the canister can be charged. Thus, the faster this heat can be removed, the shorter the time required to charge the canister. All of the following charging methods will produce the same results, however, the amount of time required to complete charging will vary inversely with the rate of heat removal from the canister. This is particularly observable in larger canisters.

1) **Ambient Thermal Exchange.** Simply charge the canister with a regulated hydrogen supply at 250 psig. During this process, the canister surface temperature may rise to as much as 50°C (122°F); this is normal. Using this procedure will take up to an entire day to completely charge the canister depending on the size of the canister and its initial state of fill.

2) **Ambient Air Cooling.** Charge canister as above with a regulated hydrogen supply at 250 psig. However, during charging, circulate cooling air across the canister using a fan, fume hood, compressed air, etc. Using this procedure will reduce the time required to charge the canister by as much as 2/3, depending on the ambient conditions, the size of the canister, and its initial state of fill.

NOTE Following either of the above two methods, it is not possible to overcharge the canister by leaving the 250psig regulated hydrogen supply connected to the canister for an extended period of time under normal room temperature conditions. Charging of the metal-hydride alloy is an equilibrium process; once equilibrium is reached, charging will automatically cease.

3) **Cooling Bath.** Charge canister with a regulated hydrogen supply at 250 psig. During charging, actively cool the canister using a water bath, ice bath, etc. Cooling the canister to 15°C (59°F) or less will accelerate the charging process and reduce the charging time to less than one hour.

Overcharging may occur if canisters are either charged at pressures greater than 250 psig or if a cooling bath is used and the charging process is allowed to continue for an extended period of time. Overcharged canisters may release hydrogen through their relief mechanisms if exposed to elevated temperatures.

7. Charge Measurement

The weight measurement method must be used if canisters are cooled during the charging process. When using the weight method, it is not necessary to allow the canister to equilibrate to room temperature. Weight is the most accurate method of checking the refill level.

Weight Measurement. The weight of each fully charged canister is noted on a label at its base.

a. Note the fully charged canister weight.

b. Using a digital scale, weigh the canister and note its weight.

1) If the canister is overweight then it is overcharged. Bleed excess hydrogen from the canister and retest.

2) If the canister is at the correct weight then it is properly charged.

3) If the canister is underweight then it is undercharged. Add 250 psig regulated hydrogen to the canister and retest.