



National Weather Service Upper Air Station Weather Balloon Inflation Hydrogen Conversion Hydrogen Inflation Safety System Questions and Answers



This informational document describes work that FP2FIRE (FP2) has performed for the National Weather Service (NWS) in the Eastern Region to convert Upper Air Stations from balloon inflation with only helium to hydrogen as primary with helium as a backup and how similar installations can benefit other NWS Weather Forecast Office (WFO) sites.

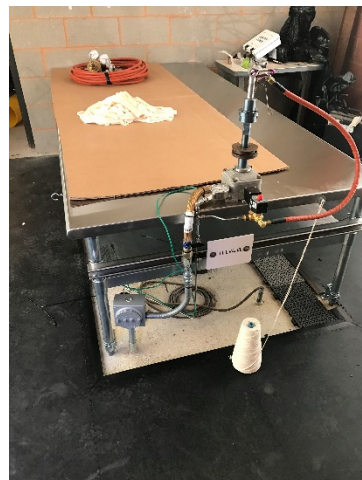
Please see the Table of Contents (next page) for common questions and click on the link to see the response.

Additional information available at www.FP2FIRE.com

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Cost Summary

- Hydrogen is significantly less expensive than helium. (~4 to seven times less)
- Hydrogen is readily available and can be made onsite
- Helium is a noble gas that is relatively scarce on earth.
- Cost savings from converting to hydrogen can be \$25,000-75,000 per site per year depending on the cost of helium locally.
- Converting all 35 existing helium sites to hydrogen could result in a nationwide annual operational cost savings of \$1.2M.

What are the main components of a Converted Site?

Key components include:

- HISS Controller
- outdoor hydrogen storage
- outdoor regulator, source valve and solenoid valve, and emergency shutoff
- Mass flow meter
- Fill valve and fill table
- Hydrogen/Helium selector valve

Hydrogen Inflation Safety System – Control Unit

HISS Controller

- Contains electronics with safety logic built in.
- 4 Operator control buttons (Remote controller if needed).
- Controls and monitors exhaust fans.
- Controls solenoid valve.
- Controls excess fill time (30-minute shutoff).
- Provide Emergency Stop (Red button).

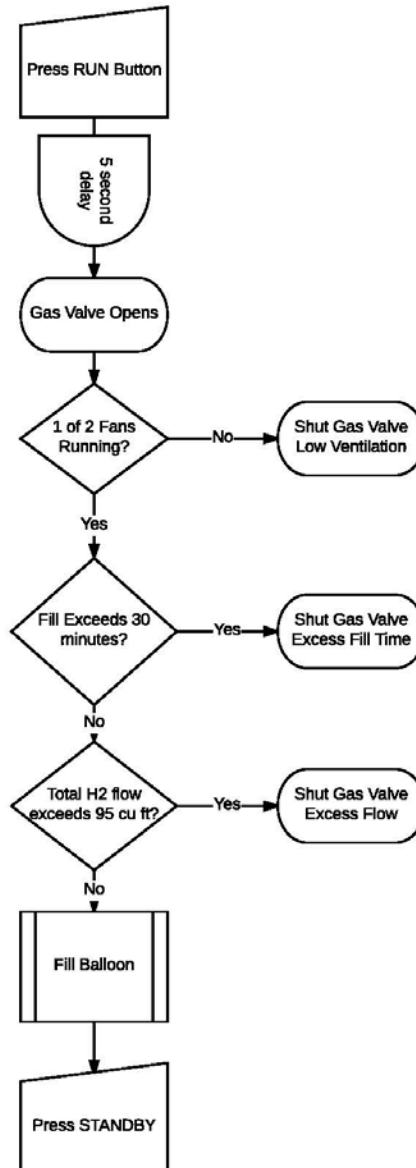
Typical HISS Controller Panel - Exterior and Interior Views, Remote Controller



The HISS controller provides automatic control of key safety features as follows:

1. Ventilation – system shuts down if active ventilation is not operating
2. Excess fill time – If a fill ever takes longer than 30 minutes, the system shuts down.
3. Excess gas flow – If a fill ever uses more than 95 cu. ft. of hydrogen the fill automatically shuts down.

The logic diagram for the hydrogen safety system is shown graphically below.



Outdoor Hydrogen Storage

- Code compliant.
- Solves MAQ violations with indoor H2 cylinders.
- Cages provide security and weather protection.
- Outdoor hydrogen storage is much safer. No indoor H2 storage.
- Piping all stainless steel.
- Use of two connected and manifolded H2 6 packs allows ~2 weeks' worth of fills prior to changing gas sources (A and B) and ordering two replacement 6 packs.
- Source selector valve outside.

Typical Outdoor Storage – Four 6 Packs Total



Outdoor Regulator, Solenoid Valve, Source Valve

- Emergency shutoff valve outside – accessible during an emergency.
- Regulator steps down pressure before entering building
- Gas source valve (3-way) outside.
- Normally closed solenoid valve outside.
 - Hydrogen lines in building not normally pressurized
 - Controlled by HISS controller.

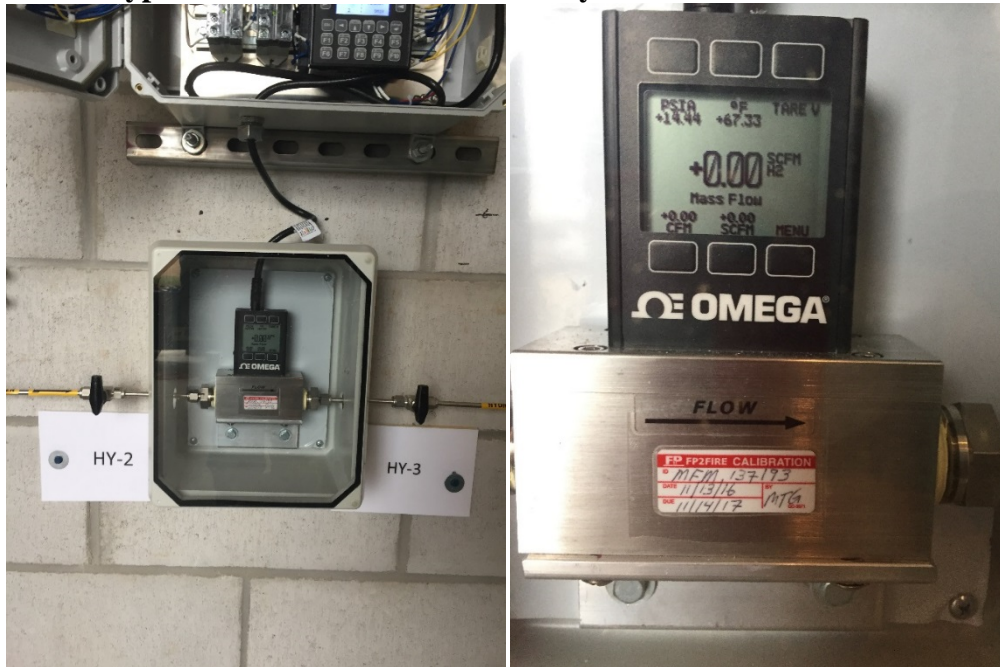
**Typical Outdoor Control Features
Regulator, Solenoid Valve, Emergency Shutoff, Gas Supply Valve**



Mass Flow Meter

- Measures volume of gas flowed for each fill event.
- Automatic shutoff if excess (>95 cu. ft.) H₂ flow for a fill event.
- Provides input to controller.

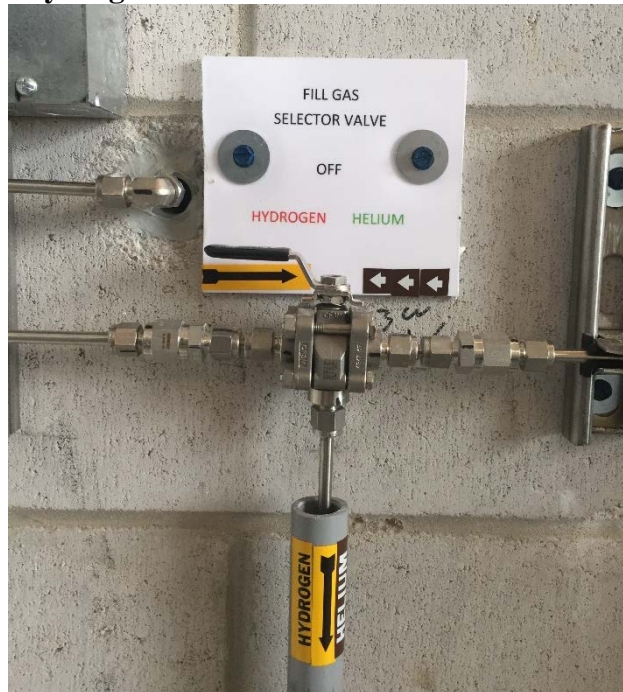
Typical Mass Flow Meter – Directly below HISS Enclosure



Hydrogen/Helium Selector Valve

- Allows use of helium during off normal conditions
- Out of hydrogen
- Controller maintenance/repair
- Gusty winds
- Helium bypasses HISS components

Typical Hydrogen/Helium Gas Source Selector 3-Way Valve



Is balloon inflation with hydrogen legal?

No. The fire codes used in the US prohibit filling of balloons with any flammable gas. Pertinent citations provided below.

2015 IFC §5305.8 Use of compressed gas for inflation. Inflatable equipment, devices or balloons shall only be pressurized or filled with compressed air or inert gases.

NFPA 2 §7.1.22 Use of GH₂ for Inflation. Inflatable equipment, devices, or balloons shall not be pressurized or filled with GH₂.

NFPA 55 §7.3.1.10 Use of Compressed Gases for Inflation. Inflatable equipment, devices, or balloons shall only be pressurized or filled with compressed air or inert gases.

If filling with Hydrogen is Prohibited, how can it be done?

With specific justification, the fire code does allow hydrogen inflations. Using the Alternative Methods or Materials (AMM) process allowed by all fire codes, FP2 has justified the use of hydrogen as an inflation gas at 4 existing NWS sites. The report is customized for the site and

stamped by Martin Gresho a registered professional fire protection engineer. This process is equivalent to code compliance and is allowed by the International Fire Code (IFC). Approval by the local code officials may be required.

2015 IFC §104.6.4 Administrative. Application for modification, alternative methods or materials and the final decision of the fire code official shall be in writing and shall be officially recorded in the permanent records of the fire code official.

How can filling balloons with hydrogen be justified.

As part of the AMM report, a hydrogen safety system is specified. The system backs up the manual system currently used by the NWS by providing 3 separate automatic fail safe features:

1. Fill timer – gas flow shuts off automatically if a fill exceeds 30 minutes.
2. Ventilation – gas flow shuts off if the powered fans installed in the building are not working.
3. Excess Flow – Gas flow shuts off automatically if the total amount of hydrogen used exceeds 95 cu. ft. (~150% of normal).

These are the main automatic engineered safety features used to justify filling with hydrogen. There are quite a few other features of the system as well – these are discussed below. A converted site achieves code compliance for all requirements.

Is hydrogen safe?

Hydrogen is a flammable gas so it must be treated with respect. Because hydrogen is much lighter than air, it does not stick around in the case of a leak like heavier than air flammable gases (e.g. propane) or gasoline vapors.

How many UAIBs has FP2 visited?

Fifteen (15). FP2 has performed AMM analyses at 15 NWS sites. Some sites currently use helium and some use hydrogen as an inflation gas. The conclusion of these was that all sites visited could safely use hydrogen with some modifications.

What types of violations are common?

The helium sites have fewer violations currently than the hydrogen sites. All violations can be corrected. Typical findings include:

Hydrogen in balloons – this is corrected through the AMM analysis and the safety system.

Maximum Allowable Quantity (MAQ) – All hydrogen sites that use cylinders for a gas source have too many cylinders located inside. Most commonly, the limit per the fire code is 5 cylinders. Most sites exceed this amount significantly. The fire code is restrictive for hydrogen storage indoors. Outdoors is a much safer location. Converted sites locate the hydrogen outdoors in secure cages.

Piping, Tubing – Hydrogen needs to be in stainless steel tubing with positive (threaded) connections. Many sites use rubber hose for hydrogen and some use friction type (hose clamp) connections. These



violations are corrected once a site gets converted and the only remaining rubber hose is from the fill valve solenoid to the balloon nozzle. This hose is required and is justified in the AMM.

Isolation valves – An isolation valve is required at the source and at the point of use. Some sites lack these. These violations are corrected at a converted site.

Signage – Hydrogen requires several warning signs, mostly for responding firefighters. These signs are installed as part of a site conversion.

Why not just continue with helium?

The primary reason is cost. Helium is 4-7 times costlier than hydrogen and the market price fluctuates significantly. Costs can be controlled and predicted better using hydrogen.

Can a UAIB that uses hydrogen just keep on using hydrogen?

Yes – But the existing code violations will not be addressed. This exposes the NWS to liability if an accident occurs.

Cost Details

Cost per fill H₂ -VS-Helium

For sites that currently inflate with helium from cylinders and are considering inflation with hydrogen from cylinders the cost savings due to the cost of gas would be about \$25,000 - \$75,000 per site per year. This is based on a cost of hydrogen of \$40.00 per cylinder and the cost of helium assumed to be a representative 4 - 7 times the cost of hydrogen. The calculation shown below has assumptions stated and is representative.



Cost Savings – compare costs He v H

National Weather Service			
Cost Analysis - Balloon Fill Gas			
Helium or Hydrogen			
Hydrogen is 8% more buoyant than helium.			
Average fill with hydrogen: 75 cu ft			
Average fill with helium: 81 cu ft			
Industrial grade gas for both			
K cylinders for both			
Assume regulator setting of 23 psi for hydrogen	2.25 cu ft left in each cylinder		
Assume regulator setting of 25 psi for helium	2.5 cu ft left in each cylinder		
Hydrogen K bottle at 2000 psi holds 196 cu ft			
Amount available = 194 cu ft (~2.5 balloons/bottle)			
Cost per cyl.	\$ 40.00		
Cost per cu ft.	\$ 0.21		
Cost per Fill	\$ 15.46		
Helium K Bottle at 2200 psi holds 217 cu ft			
Amount available = 214 cu. ft. (~2.6 balloons/bottle)			
Cost per cyl	\$ 124.00	\$ 280.00	
Cost per Cu ft	\$ 0.58	\$ 1.31	
Cost per fill	\$ 46.93	\$ 105.98	
Savings with H2	\$ 31.47	\$ 90.52	
2 launches per day 365 days per year	730 launches per year		
additional launches per year	100		
	830 total launches per year		
Savings of \$30 - \$90 per launch			
Roughly \$25,000 - 75,000 savings per site per year depending on the local cost of helium (4-7 times H2 cost)			

Annual Operational Savings Potential

If all existing helium sites were converted the potential savings could be:

34 sites (includes 4 already converted) × \$35 K savings per site per year = **\$1.2M**

Conversion Installation Costs

- Typical Installation cost is \$105-115K depending on site details.
- For helium sites, this is offset by of ~\$35K per year because hydrogen is less expensive.
- 3-4 year payback on installation costs.



Nationwide Program Possibility

Nationwide, a conversion program could look like:

FP2 recommends code compliance with a balanced approach. Most findings for the Upper Air Stations (UAS) evaluated were due to issues related to hydrogen storage and use. FP2 feels comfortable with the NWS experience with handling and manually launching balloons due mostly to the competency, professionalism and training of the operators. However, improvements in code compliance are warranted and will help control both risk and future financial liability in the event of an incident. Therefore, a balanced path towards code compliance for the UAIBs is recommended. While code compliance does not eliminate all risk of a fire incident, it does manage risk and strikes a balance with cost to a widely acceptable level (nationally accepted codes) and thereby places the NWS in a stronger position if an incident occurs than voluntary non-compliance.

Hydrogen is likely OK as a fill gas at most UAS sites not visited but sites in dense urban settings or on upper stories should be evaluated first.

Strategy

For the UAIBs a strategy of gradual compliance achievement is recommended. For sites that currently use helium, significant operational cost savings (\$25-75K per year per site) can be realized by converting to a hydrogen site. Payback on the installation costs could be realized in 2-5 years depending upon the local cost of helium. The operational cost savings can be used to pay for additional conversions and minimize overall budget impact of installation costs.

To minimize cost impact and level expenditures, a strategy of converting several sites per year (assume 5-12 sites) would allow the operational cost savings from converted sites to offset the installation costs of new conversion sites. To achieve balanced annual costs and construction budgets, a 10-year program is proposed.

NWS records observations at 102 Upper Air Stations (UASs), including 92 NWS facilities in the U.S. and its territories; 69 in the conterminous United States, 13 in Alaska, nine in the Pacific, and one in Puerto Rico. NWS also supports the operation of 10 other stations in the Caribbean.¹

Upper Air Stations	Quantity
Continental US (CONUS)	69
Alaska Region	13
Pacific Region	9
Puerto Rico	1
Caribbean	10
Total	102

Currently, 31 NWS UASs use helium as a lifting gas and 71 NWS UASs use hydrogen as a lifting gas.

¹ Text originally drafted and delivered by Mr. Hiram Escabi, of the National Weather Service at a presentation on August 19, 2014 at the NWS Facility in Newport, NC. Text has been paraphrased and updated for use in this report.



Primary Lift Gas	Quantity
Hydrogen	71
Helium	31
Total	102

The primary advantage of converting helium sites is reduced operational cost while maintaining code compliance and safety.

The primary advantage of converting hydrogen sites is improved safety, reduced risk, reduced liability exposure, and code compliance.

Program Implementation Costs and Timeline

For most sites, the costliest component of achieving compliance is the installation of the HISS which usually includes relocation of hydrogen storage to outdoors. The table below presents one of many possible budgetary approaches.

Program costs assumptions:

1. 4 sites already converted
2. 31 helium sites to convert
3. 67 hydrogen sites to convert
4. 10-year program duration
5. Operational cost savings range from \$25-75K per year for helium sites – use conservative number of \$35,000 per site per year.
6. Convert helium sites 1st to maximize operational cost savings.
7. Target level (or nearly) budget for initial years.
8. Cost savings from purchasing H₂ rather than Helium will be put into construction costs for 10 years of program.
9. Costs for Alaska and Pacific (and Caribbean) sites will be higher but offset by nearly compliant hydrogen sources at most sites.
10. At end of 10-year program all UAS sites are converted to hydrogen with a safety system and all sites are code compliant.



NWS HISS Installation Program Cost Estimate									
	He to H2 sites	Unconverted H sites	Converted H sites	Conversion Cost per site	H sites	Operational Cost Savings per site	Total operational cost savings (from previous converted sites)	Construction cost	Net Cost
		31	4						
2017	5	26	9	\$ 115,000	0	\$ 35,000	\$ 140,000	\$ 575,000	\$ 435,000
2018	7	19	16	\$ 115,000	0	\$ 35,000	\$ 315,000	\$ 805,000	\$ 490,000
2019	9	10	25	\$ 115,000	0	\$ 35,000	\$ 560,000	\$ 1,035,000	\$ 475,000
2020	10	0	35	\$ 115,000	0	\$ 35,000	\$ 875,000	\$ 1,150,000	\$ 275,000
2021	0	0	35	\$ 115,000	12	\$ 35,000	\$ 1,225,000	\$ 1,380,000	\$ 155,000
2022	0	0	35	\$ 115,000	11	\$ 35,000	\$ 1,225,000	\$ 1,265,000	\$ 40,000
2023	0	0	35	\$ 115,000	11	\$ 35,000	\$ 1,225,000	\$ 1,265,000	\$ 40,000
2024	0	0	35	\$ 115,000	11	\$ 35,000	\$ 1,225,000	\$ 1,265,000	\$ 40,000
2025	0	0	35	\$ 115,000	11	\$ 35,000	\$ 1,225,000	\$ 1,265,000	\$ 40,000
2026	0	0	35	\$ 115,000	11	\$ 35,000	\$ 1,225,000	\$ 1,265,000	\$ 40,000
			35		67				
				102					

HISS Conversion -v- Autosonde Comparison

The NWS has two (2) functioning automatic balloon launchers that fill and launch balloons automatically. FP2 is familiar with these installations. The table below presents some considerations of these two possible approaches.

Issue	HISS Conversion	Autosonde
Installation Cost (per site)	\$105-115K per site	\$750K Autosonde \$250-500K Installation \$1 – 1.25M Total per site
Building	Uses existing UAIB	New pad and location. Some sites may require demolition of the UAIB for space.
Personnel	No change from existing. NWS personnel still manually inflate and launch balloons.	No personnel needed for balloon inflation and launching. This is safer than manual fills/launches. 24 balloon capacity. Must be reloaded with balloons and sondes every 12 days.
Lift Gas	Hydrogen or helium	Hydrogen or helium
Technology	Simple. Uses proven technologies and a simple programmable logic	Technically complex but well designed and safe. Involved software and operator



Issue	HISS Conversion	Autosonde
	controller for automated functions. No user interface to PLC. Program cannot be altered.	interface through computer. Software updates and revisions can sometimes have unexpected consequences. Should re-check basic safety functions after any updates.
Servicing Requirements	Swap empty 6 packs for full every 2 weeks. Annual service needed.	Same. Sites with hydrogen generators do not need cylinders. Servicing per Viasala requirements
Commissioning	Required – included with installation.	Required – FP2 had performed this at 2 existing installations. 1 day process with operator if all goes well. Checks that software functions correctly during off normal events.

FP2 Installation Services

CONUS – Installation crew and Jobsite Trailers

- One job trailer/crew for eastern states
- One job trailer/crew for central/western states.
- Experienced Installation crew. Installations complete at:
 - Sterling (Baltimore) WFO
 - Pittsburgh WFO
 - Wilmington, OH WFO
 - Morehead City WFO

How does FP2 get the work done?

Two crews.

One in eastern US and one in Western


Fully equipped job work trailer parked at site for duration of installation.


How long does it take?

3-4 months start to finish for engineering site specific design, approvals, and pre-assembly of major components, installation, commissioning, training.

7-10 days onsite for a typical installation.

Meet the Installation Crew

Name	Role	Experience	Regional Availability
Martin Gresho, PE 	Design Engineer Installer SS tubing installation. Primary POC Commissioning Agent Trainer Hydrogen SME Fire Safety SME Warranty issues	Professional Fire Protection Engineer 32 years FPE engineering experience. Owner FP2FIRE 17 years' hydrogen experience National fire code committee member Chair NFPA 2, <i>Hydrogen Technologies</i> , 10 years Swagelok certified installer	National
John Nellenback	Job site supervisor. Electrician Installer Mechanical (ventilation and tubing)	40+ years specialized electrical installation experience. Existing IDIQ contract holder nationwide. Prime contractor for 4 existing HISS installations.	Eastern
Steve Kurpick	Electrician Installer Mechanical Electrical Tubing	20+ years electrical installation experience. Installer for 4 existing HISS installations	National

Name	Role	Experience	Regional Availability
Dean Johnen 	Job site supervisor Installer Mechanical Electrical	38 years' construction experience. 20+ years supervisory experience.	National
Paul Bell	Job site supervisor Installer Mechanical Electrical	30+ years construction experience. 20+ years supervisory experience.	National

After Installation

Full onsite commissioning.

FP2 also includes a copy of the Commissioning Report with the system documentation.

Training

Training for NWS crew (1 session standard, additional sessions optional).

FP2 provides an onsite training to get the NWS Observers trained and comfortable operating the system.

Training documentation will be provided so NWS can train additional personnel as needed.

Support

1 year full warranty.

Annual Calibration and Service

Annual calibration of the mass flow meter is required.

FP2 provides the annual service onsite which includes all required services.



Item	Activity
Regulator (NWS part)	Visual inspection of gauges and condition. Set for proper nozzle discharge pressure (<15 psig).
Gas tubing and valves	Visual inspection of valve and tubing components for damage. Check valve operation. Replace any damaged handles or valve components Confirm all valves mounted securely. Repair/replace as needed.
Signage	Visual Inspection – damaged or missing. Valve labels, NFPA 704 placards, hydrogen warning signs, tubing labels, operational signs. Repair replace as needed.
Leak check of all hydrogen tubing and fittings	With lines pressurized (HISS in RUN with all HY valves open) spray “SNOOP” leak detection solution on each fitting. Repair any leaks noted.
Mass Flow Meter calibration	Remove MFM and replace with calibrated unit with updated calibration sticker. Annual calibration required.
MFM functional test	Confirm that gas flow shuts off after flowing ~ 100 cu. ft. of gas into a balloon. .
Fan functional test	Lift power supply to fan and confirm system shuts down after ~ 10 sec. Apply simulated load to fan circuit and confirm fan shuts down after ~ 10 sec.
Check E Stop function	Activate E stop at 4 button switch. Confirm system shut down.
Hydrogen Solenoid Valve	Confirm stoppage of gas flow upon valve closure.
Component Enclosures	Inspect for sealing, operation and no damage. Repair replace as needed.
Bleed valve	Confirm functionality

Cost for annual service: \$5,000 per site per year.

Extended Warranty

FP2 will provide onsite service to repair or replace any HISS component that fails with an initial site visit within 15 working days of notification at a CONUS site. The site will use helium to launch balloons until the HISS is repaired. The following parts are covered due to failure from normal operation.

1. Mass Flow Meter.
2. HISS controller, switches, pushbuttons and all interior components.
3. Solenoid valve
4. Fans
5. All valves associated with the Hydrogen and Helium gas systems.
6. All stainless-steel tubing and convoluted flexible lines.
7. Gauges
8. Component enclosures.



9. Gas cages

Damage from external sources (vehicle impact, falling ice, extreme weather, lightning strike, falling objects, etc. is not covered under the warranty but can be repaired for an additional fee.)

Client Responsibilities:

- Provide access.
- Send photos and description of any system known system damage prior to site visit.
- Provide inventory of gas on site (helium and hydrogen) – at least one full 6 pack of hydrogen and 2 full cylinders of helium.

Cost: \$2,500 per year per site. Only available if FP2 performs annual service as described above.

Are all Installations the Same?

NO – But many are similar.

Of the sites that FP2 has converted the Wilmington, OH site was the most standard configuration in terms of the UAIB layout. However, the components of the conversion can be located to suit a site and connected accordingly. The installation is flexible. The layout drawing for Wilmington is shown below.

