# World’s Largest Liquid Hydrogen Tank Nearing Completion

Adam Swanger / NASA-KSC

March 11, 2022

Construction of the world’s largest liquid hydrogen ($LH_2$) storage tank is almost complete at launch pad 39B at NASA Kennedy Space Center (KSC) in Florida. With a usable capacity of 4732 $m^3$ (1.25 Mgal), this new vessel is roughly 50% larger than its sister tank, which is located 170 m (550 ft) to the southeast. Once the new sphere is fully commissioned these two tanks will provide a combined $LH_2$ storage capacity of 7950 $m^3$ (2.1 Mgal) to fuel the new Space Launch System rocket in support of future Artemis exploration missions to the Moon and Mars.

As with its sister tank, which was erected during the 1960s as part of the original construction of the launch pad to accommodate the Saturn V moon rocket, Chicago Bridge & Iron Company (CB&I, now part of McDermott International) again played a central role in the design and construction of the new $LH_2$ sphere. It is similar in design to the legacy tank as well, being double-walled and vacuum insulated; albeit it with a larger outer diameter of 25 m (83 ft) versus 21.4 m (70.2 ft). Where it does make substantial departures from the old design however is in the inclusion of two new technologies pioneered by the Cryogenics Test Laboratory at KSC (CSA CSM): glass bubble bulk-fill insulation as a replacement for the more traditional perlite, and an Integrated Refrigeration and Storage (IRAS) heat exchanger[1] for future controlled storage capability.

Over the past twenty years, NASA has extensively tested glass bubbles for insulating $LH_2$ tanks; focused primarily on the K1-type product from the 3M corporation. Field testing of a 190 $m^3$ (50,000 gal), perlite-insulated $LH_2$ storage tank at NASA Stennis Space Center in Mississippi, which was retrofitted with K1 glass bubbles in 2008, yielded a 44% reduction in boil-off, and improved over time to around 48% in 2015[2]. Taking advantage of this substantial performance benefit glass bubble provides, it is estimated that the new sphere will have a normal evaporation rate (or boil-off rate) on par with that of the perlite-filled legacy tank, around 0.03% per day, even though it is significantly larger. Filling of the annular space with an estimated 1.3 quadrillion individual K1 bubbles, roughly 2000 $m^3$ (537,000 gal) worth, was completed in early January 2022, at which point focus turned to pumping down the annular space to its operational warm vacuum pressure in anticipation of initial chill down.

Inclusion of the internal IRAS heat exchanger as part of the intrinsic tank design was crucial to accessing all the benefits of ‘full control storage’ in the future, such as zero-loss tank chill-down from ambient temperature, tank thermal cycle management (i.e. isothermalization between fill/drain cycles), zero-loss $LH_2$ tanker offloads, long duration zero-boiloff, in-situ hydrogen liquefaction, and liquid densification (i.e. increased energy density). Economic analysis of zero boiloff testing on a smaller scale IRAS system at KSC in 2015-16 known as the Ground Operations Demonstration Unit for Liquid Hydrogen[3] revealed that for every dollar spent on electricity to power the system, roughly 7 dollars’ worth of $LH_2$ was saved (based on \$0.06/kWh electricity cost and \$5.20/kg $LH_2$ cost); a fact that played an important role in infusing the technology into the new launch pad sphere.

The heat exchanger is ASME code compliant and constructed of 43 m (141 ft) of fully welded, 38 mm (1.5 in) diameter, 316L stainless steel tubing, with round coils located at the 75% and 25% fill levels. Total heat transfer area in contact with the hydrogen is roughly 5.2 $m^2$ (56 $ft^2$). Gaseous helium refrigerant supplied by a future closed-loop external refrigeration system will be routed to and from piping interfaces located on the lower part of the external tank, and piping within the annular space makes the connection between the external interfaces and internal coils. The entire heat exchanger is supported by an internal tower suspended from the upper dome of the inner sphere. Helium supply will be split into parallel paths upon entering the heat exchanger, travel through either the upper or lower coil first depending on the desired flow path, and make its way vertically to the other coil before collimating at the annular piping interface and returning to the refrigeration system.

Overall construction of the new $LH_2$ sphere and ancillary systems is now compete, with coating of the outer vessel completed in February 2022. Final checkouts are currently underway, including a warm vacuum retention test, and initial $LH_2$ loading is scheduled to begin in September 2023.

More information about the design of the new tank, glass bubbles, and IRAS can be found through reference 4.

## *References*

1. NASA Press Release, Innovative Liquid Hydrogen Storage to Support Space Launch System, 2018, https://www.nasa.gov/feature/innovative-liquid-hydrogen-storage-to-support-space-launch-system
2. NASA Technical Memo, Fesmire J.E., Research and Development History of Glass Bubbles Bulk-Fill Thermal Insulation Systems for Large-Scale Cryogenic Liquid Hydrogen Storage Tanks, 2017, https://ntrs.nasa.gov/api/citations/20180006604/downloads/20180006604.pdf?attachment=true
3. Notardonato W.U., Swanger A.M., Fesmire J.E., Jumper K.M., Johnson W.L., and Tomsik T.M., Final test results for the ground operations demonstration unit for liquid hydrogen, Cryogenics, Volume 88, 2017), Pages 147-155, ISSN 0011-2275, https://doi.org/10.1016/j.cryogenics.2017.10.008
4. Proceeding of the DOE/NASA Advances in Liquid Hydrogen Storage Workshop (virtual), August 8th, 2021, https://www.energy.gov/eere/fuelcells/advances-liquid-hydrogen-storage-workshop

**Figure 1**. New NASA $LH_2$ Storage Tank After During Painting
(Courtesy CB&I)

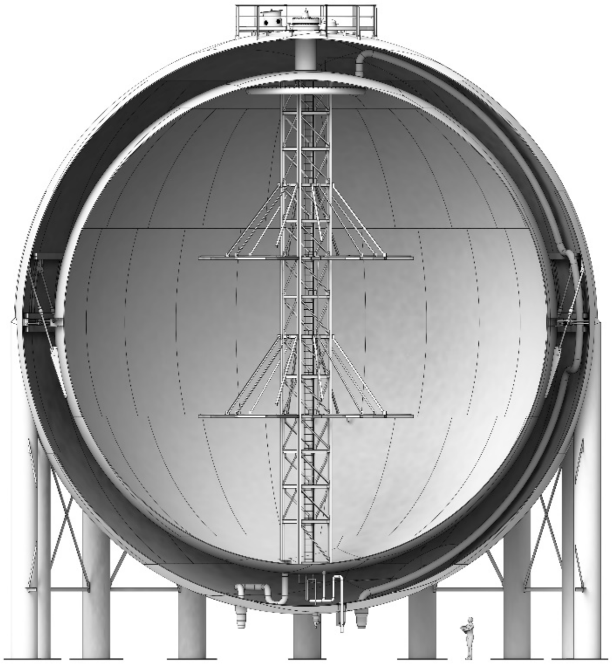

**Figure 2**. Cutaway of the New NASA Sphere Showing the IRAS Heat Exchanger Support Tower (Courtesy CB&I)