Low Temperature Solutions for GIL

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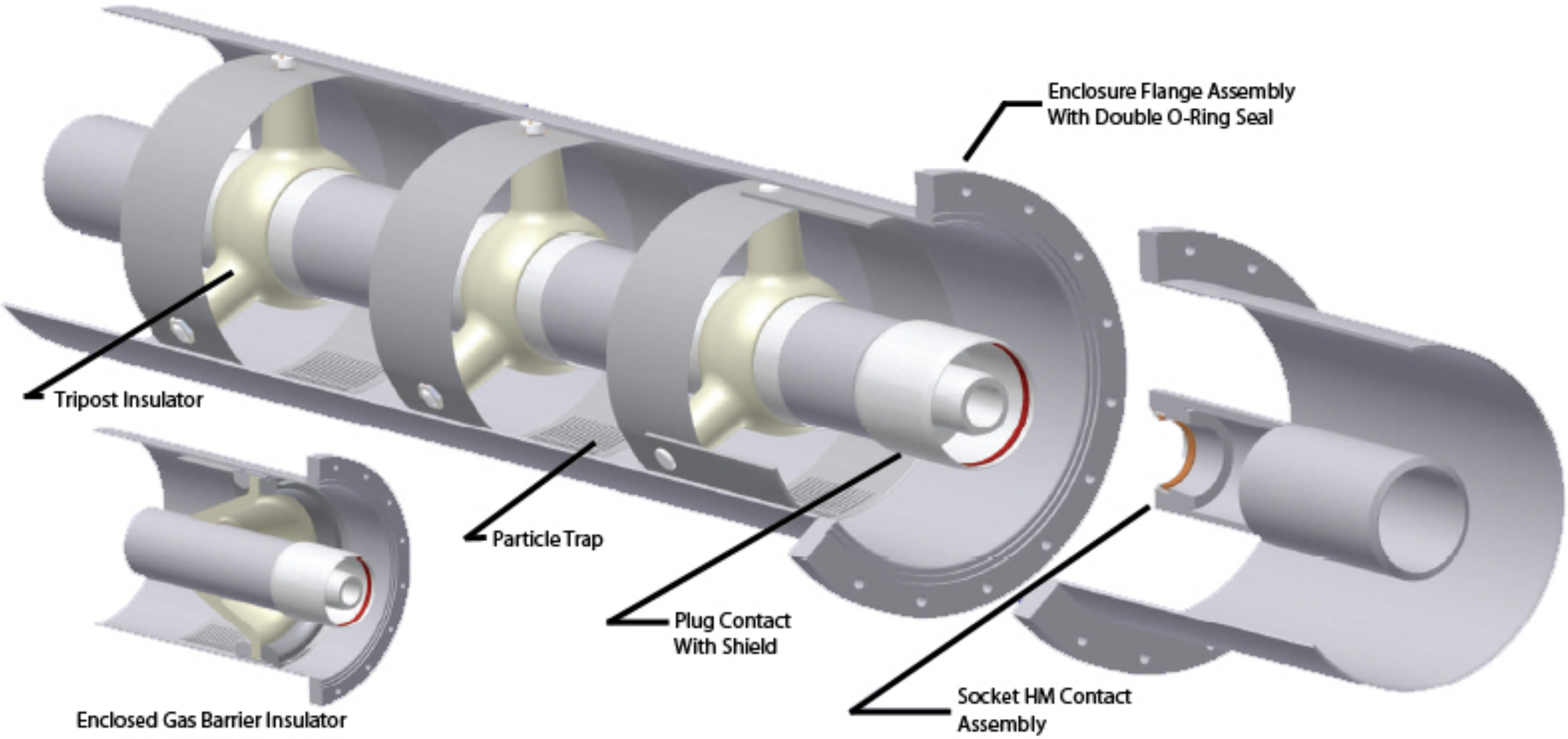
AZZ HV Bus Systems

GIL Overview



SF_6 Concerns

Environmental Impact

Lifespan | 3,200 years

100-year Global Warming Potential (GWP) | 23,900[1]

A small amount can have a **BIG** impact

1: Source: Climate Change 1995, The Science of Climate Change: Summary for Policymakers and Technical Summary of the Working Group I Report, page 22
Retrieved from: http//unfccc.int/process/transparency-and-reporting/greenhouse-gas-data/greenhouse-gas-data-unfccc/global-warming-potentials

Efforts to Control SF_6 Leaks

Early Designs (40 – 50 years ago)

- Allowable leak rate < 2%/ per year
- Differential pressure monitoring with tubes to gas cabinets
- Metal to metal flange seals with single O-rings
- Gas quality monitoring by drawing a sample from equipment
- Loose control of SF_6 in manufacturing facilities

Current Designs

- Allowable leak rate < 0.5% / per year
- Equipment mounted gas density monitors
- Improved machining of seal surfaces and dual O-ring seals
- Gas monitoring machines that detect SF_6 purity, arc decomposition containments, and moisture
- Tighter control of SF_6 in factories and testing without SF_6

SF_6 Gas Density Monitoring - Old

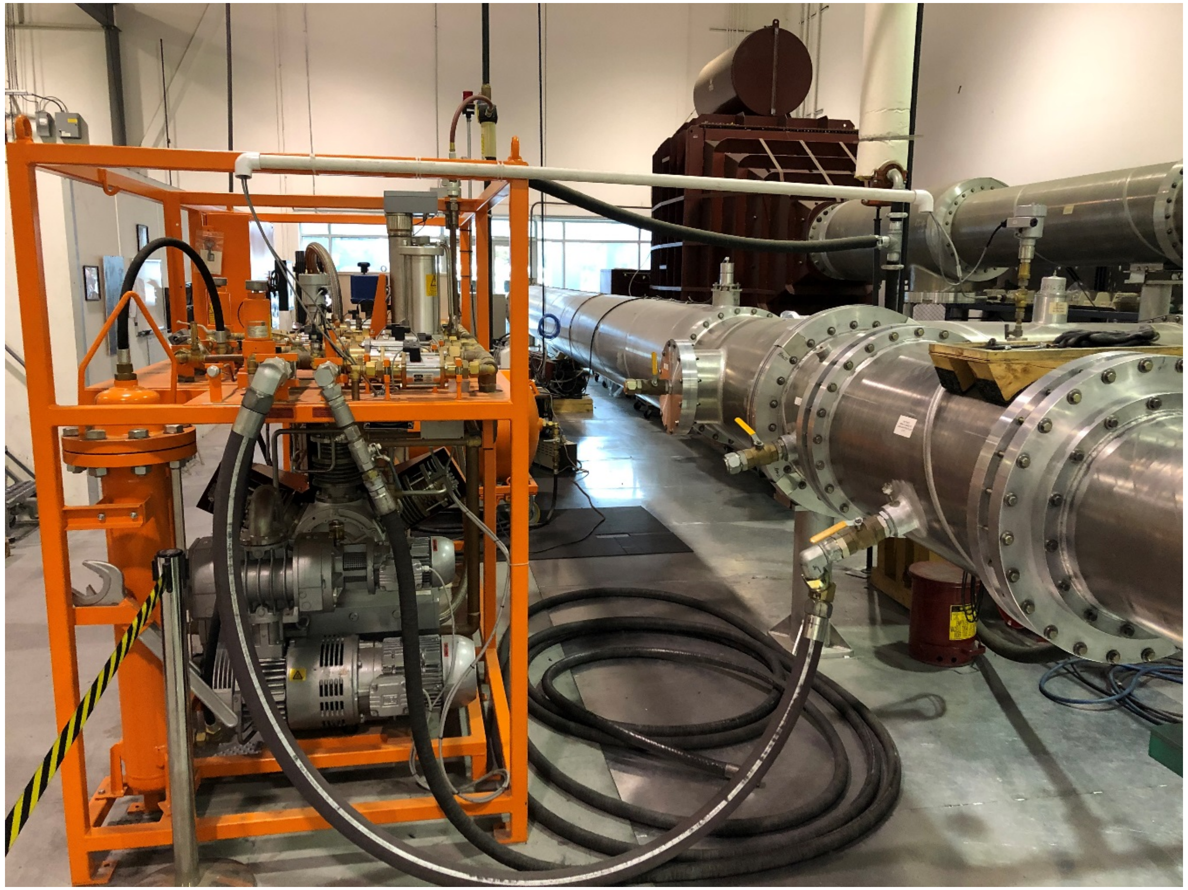
- GIS/GIL systems monitor gas density because it remains constant, whereas pressure varies with temperature.
- Early GIB systems monitored differential pressure between adjacent phases. This required pressure inputs from all three phases into a gas monitoring cabinet via tubing
- The tubing often became the gas leak

SF_6 Gas Density Monitoring - New

- GIS/GIL systems monitor gas density because it is constant, whereas pressure varies with temperature.
- New GIB systems use gas density monitors (GDM) that are directly coupled to the GIB. These monitors measure the temperature and pressure of the GIB and convert to gas density.
- Relays internal to the GDM are triggered when the gas density drops below 10% and 20% reduction in gas density

Factory GIL Testing & Control

- GIL sections are fully tested in the factory and shipped to site with a slight positive pressure (3 – 5 psig) of Nitrogen
- Factory testing includes:
  - Pressure test
  - Leak test
  - Contact resistance test
  - Electrical test



Factory SF_6 Testing & Control

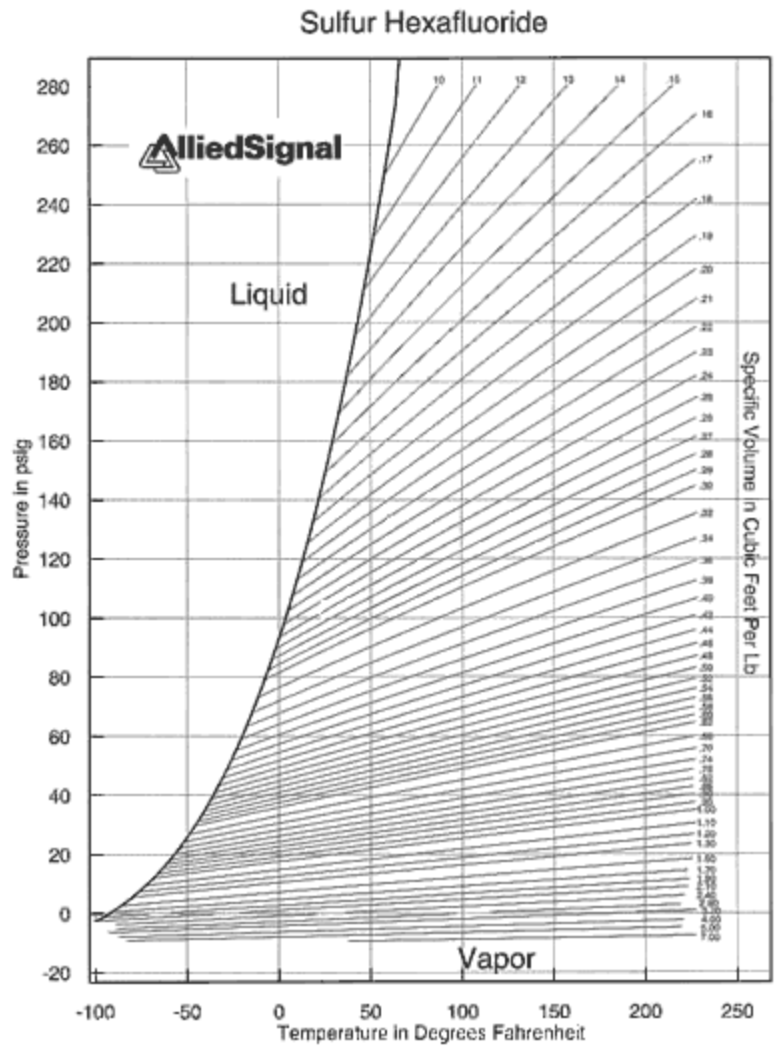
- After the pneumatic pressure test, GIL section is evacuated and filled with SF_6 for leak testing. We use an electron capture leak detector capable of detecting leaks to $1.0 * 10^{-7}$ cc/sec. No detectable leaks are allowable.
- After leak check is complete all SF_6 is returned to the reclaimer cart tank

Job Site SF_6 Testing & Control

- Site conditions do not allow for leak testing with the sensitive leak detectors used in the controlled factory environment.
- The GIL is subjected to a vacuum rise test to verify leak tight conditions.
- Each flange joint is bagged and after the GIL is filled with SF_6 the bags are penetrated with a leak detector. No allowable leaks are permitted

SF_6 Mollier Diagram

- While SF_6 is an ideal dielectric gas for GIS/GIL it does have one major disadvantage . . . A relatively high liquefaction point.
- This is a bigger issue for SF_6 breakers that typically operate in the 70 – 95 psig range
- GIL can operate at lower pressure because they do not deal with switching or arc interruption



▲ Figure 4: Pressure Variation of SF_6 at Constant Specific Volumes

Outdoor GIL Solutions

- "G3" and "AirPlus" are SF_6 alternative gasses that are derived from 3M Novec 4710 and 5110 Dielectric Fluids. Neither of these can support outdoor GIL applications below -25 ^oC.
- Typical GIS/GIL solutions are applied in extreme cold, Desert and high sand, and densely populated urban areas. Operating limits to only -25 ^oC would require special installation provisions in nearly half of our historical supply locations
- Typical outdoor GIL min ambient temperatures in the major Northeast US markets are -40 ^oC and in some Canadian markets -50 ^oC.
- For the Canadian markets at ≤ -50 ^oC, some utilities are using SF_6/N_2 designs as well as SF_6/CF_4 in equipment up to 500kV

GIL Special Provision Options for Below -25 ^{o}C Project Applications

4TH ANNUAL SF_6 GAS
GAS MANAGEMENT SEMINAR 2019

1. Enclose the entire GIS, including the GIL, in a building that is maintained at temperatures above -25 ^{o}C

2. Route GIL circuits in below grade trenches or tunnels kept at above -25 ^{o}C

Option 1 - GIL Enclosed within the GIS Building

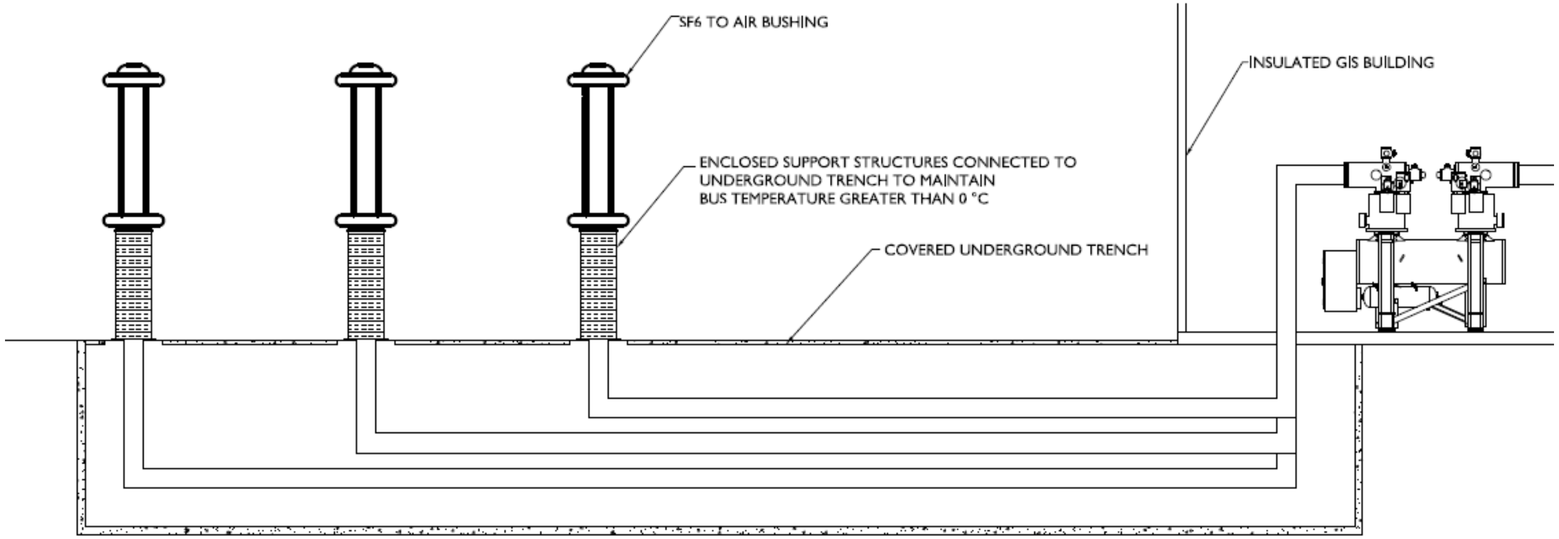
- There are current GIS/GIL installations in -50 ^oC minimum temperature regions using pure SF_6. SF_6 (at our nominal 50 psig fill) begins to liquefy at -40 ^oC.
- To prevent SF_6 liquefaction, these substations were designed so that only the bushings were exposed to the outside environment. The GIS and the GIL exits circuits were enclosed within a building enclosure that was maintained at temperatures above the liquefaction temperature (Typically 0 ^oC)
- Bushings were either solid dielectric or oil filled to avoid liquefaction.
- This same solution could be used for alternative gas systems with - 25 ^oC liquefaction temperatures

Option 1 - GIL Enclosed within GIS Building (BC Hydro Peace Canyon 500kV Substation)

Option 2 – Hohhot PSPP Project Reference

- AZZ supplied a 550kV System in Mongolia (China)
- Rated -50C
- Pumped Storage Power Plant (PSPP)
- GIL exit circuits were routed in below grade trenches (maintained warm)
- GIL exiting the below grade trench is encapsulated with an enclosure between the trench and the live portion of the bushing

Option 2 - GIL Enclosed in a Below Grade Trench That Extends From GIS Building



AltaLink Heartland GIL Project

- Background:
  - This project was part of the Heartland Bulk Transmission System Development Project that took place near Edmonton, Alberta, Canada
  - A new double circuit 550 kV OHL to connect two substations was planed. The preferred route of this new OHL crossed over existing OHL. GIL was used to avoid crossing conflicts where these existing transmission lines were.
- The new line is rated for 550kV, 1800kV BIL, 4000 amps
- Rated temperatures for this equipment is -50C to 40C
  - CGIT Systems Supplied a larger enclosure size than its standard 550 kV solution, and the pressure was lowered to 31 psig to prevent liquefaction of the SF_6

AltaLink Heartland GIL Project

- The solution:
  - CGIT 550 kV painted GIL rated:
    - 4000 Continuous Current
    - 100kA for 3 seconds short circuit current
    - 1800kV BIL Turnkey installation utilizing local labor for installation
  - Total scope of supply includes 3,580 feet of bus with:
    - 96 sections
    - 20 elbows
    - 12 gas compartments
    - 12 CGIT manufactured SF6 to composite bushings
  - Partial Discharge System was installed
  - The GIL has been in continuous service since October 2013

Leak Rate Verification at -50°C

Leak Rate Verification at -50°C

Summary of Results:

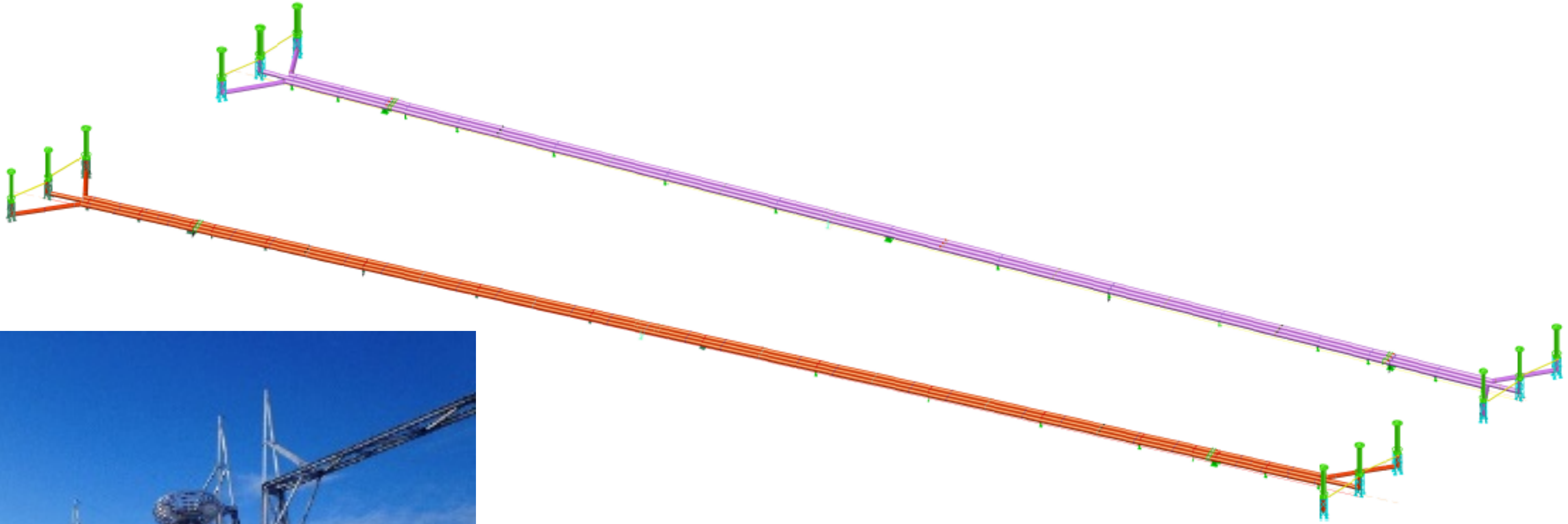
The maximum SF6 gas or mixed gas leakage to atmosphere for the installed GIL system is not permitted to exceed 0.5% by weight per year per specification AL-STN-18000 section 6.7. Thermal testing conducted during the week of 12/10/12 at NTS consisted of subjecting the test vessel to a temperature cycle and dwell (soak) protocol in an atmospheric controlled chamber. The dwell temperatures used per specification were:

Low temperature: -50°C minimum

High temperature: 80°C maximum.

All critical flange joints and sidewall connections of the test vessel were bagged and sampled for gas leakage using an SF6 gas leak detector (ISM) calibrated in volumetric leakage rate units of cc($x10^{-7}$)/sec. The maximum rate measured was $5.0x10^{-7}$cc/sec at the flange joint at the end of the second low temperature soak. The leakage rate was converted to a value in the units of weight% per year using the test vessel volume of ~$0.387m^3$ (26" diameter x ~44.5" long) and the change in density of the SF6 gas at atmospheric pressure. The resulting maximum leak rate of 0.0011% by weight per year is well within the specification requirements. Thus, the testing serves as validation for the mechanical design basis and manufacturing processes for the flange joints and sidewall connection bosses and seal materials.

AltaLink Heartland GIL Project



Cold Weather Lessons Learned

- Don't attempt doing the installation in the Winter
- Make sure you are using well maintained SF_6 servicing equipment
- Gas handling took days instead of hours
- Overall installation was slowed due to multiple crew breaks to warm up

The Right Tools = Project Success