Transportation of Natural Gas Containing Helium from Wellhead to Refinery

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ABSTRACT

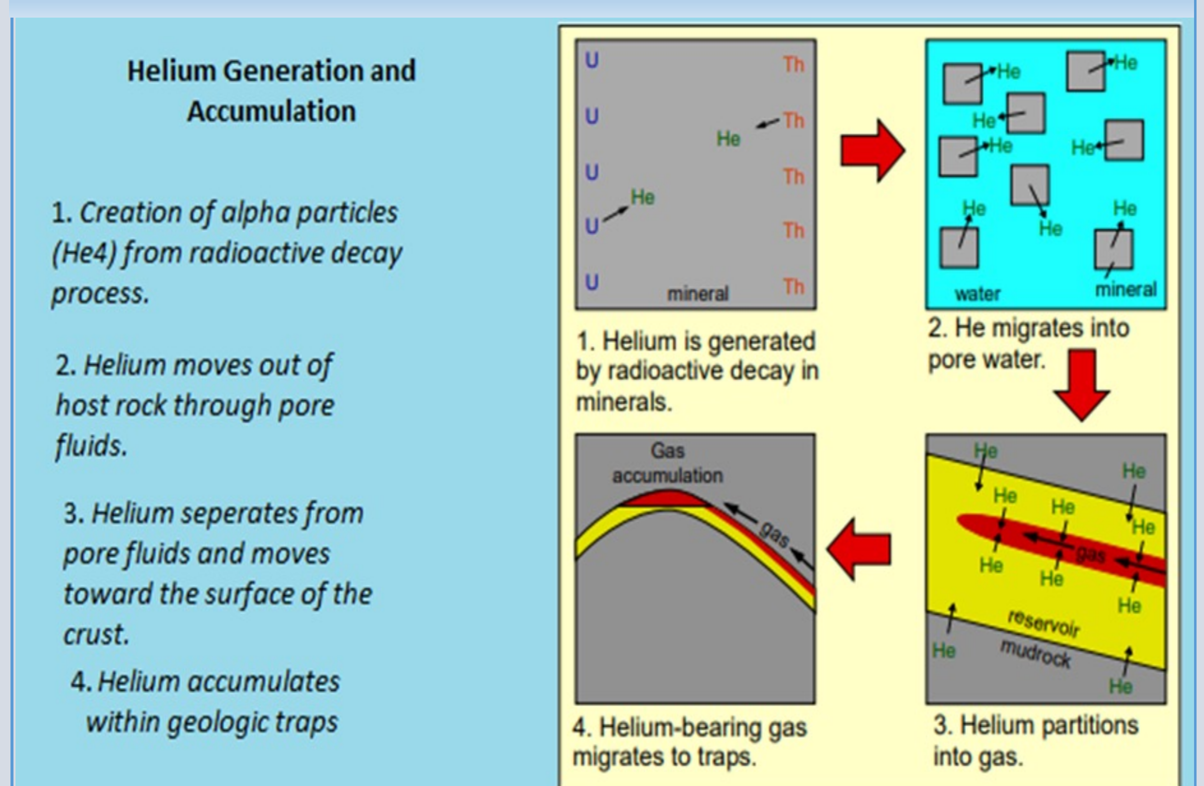
The small size of a helium atom creates unique challenges to its containment during transportation and storage. This project focuses on the transportation of natural gas containing helium, the factors affecting leakage rates, and an evaluation of ideal conditions for minimizing the loss of Helium during transport from a wellhead to a refinery. An examination of the natural helium generation within the Earth's crust, establishing the source of mined helium, is followed by an assessment of the supply chain, industry leaders, transportation regulations, and standard equipment and valves used for the containment of helium. These criteria are used to outline the framework for the overall general industry practices. Helium leak detection methods are considered to establish accuracy and precision protocols regarding helium leakage rates in closed systems, and, by exploring the effusion and diffusion of mixed gases, it is possible to identify the variables that directly increase or decrease the leakage rate. These variables are then used to model leakage rates under various operating conditions while assuming the use of polychlorotrifluoro-ethylene (PCTFE) gasket seating material. Modeling the variations allows for the establishment of ideal conditions for the transportation of a natural gas containing helium from wellhead to refinery. Through this development, an outline of general procedures, process controls, and specifications can be established to control the parameters that directly increase helium loss, and therefore increase the overall profitability of helium operations.

OBJECTIVES

- Establish native helium production background and likely location of occurrences.
- Review the current U.S. helium supply chain.
- Primary transportation options for transporting raw helium containing natural gases from wellhead to refinery
- Overview of industry leaders and common practices.
- Exploration of valve types used for liquid and gaseous helium containment.
- Summary of industry practices for the storage and transportation of refined helium products.
- Helium leak detection technologies and their application in industry.
- Helium and its mechanisms of escape are explained using Kinetic Molecular Theory and Graham's Laws of Effusion and Diffusion.
- Modeling of helium escape scenarios using PCTFE type gasket seating material.
- Generalization of ideal conditions for the transportation of raw helium containing natural gases.

METHODS

Figure 1: Native helium Generation and Accumulation(Brown, 2010)



METHODS

Figure 2: Schematic of helium processing and refinement(Helium Recovery and Liquefaction 2016).

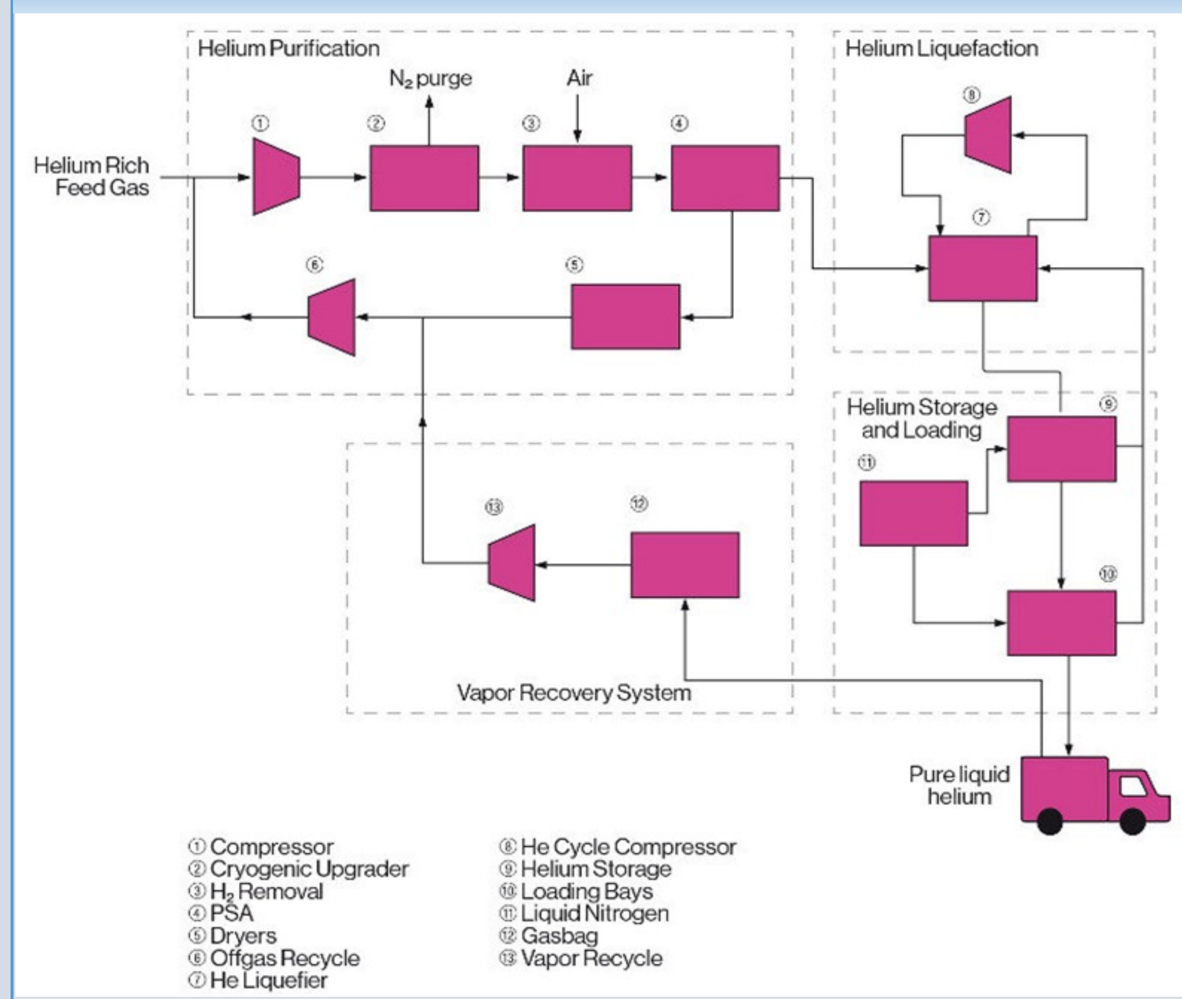


FIGURE 3: Industry Leaders in Transportation and Storage of helium using ISO/UN Storage Vessels (UN-Portable-Tank-for-Helium, n.d.).

Figures 4 & 5: Leak Detection Technologies(Leak Testing 101 – Part 4 (InterTech Development Company) | InterTech, n.d.), (Leakdetection-Technology.Com, n.d.)

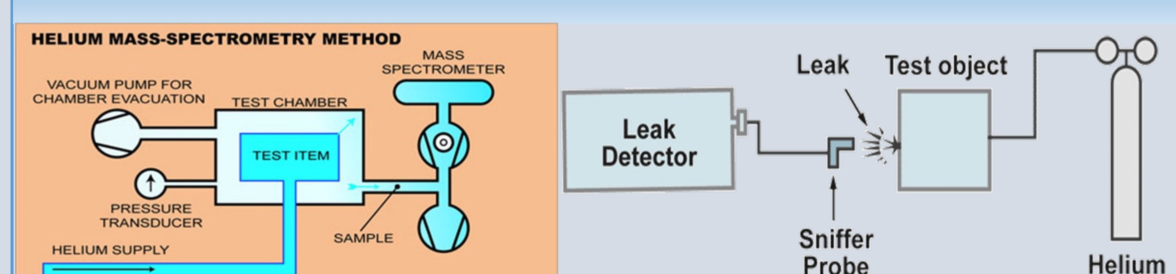


Figure 6: Transportation Tanker used in Modeling Scenarios

RESULTS

Table 1: He Leak Rate VS. Temperature and Pressure Increases

Scenario	Kelvin	ATM	Leak Rate Mol/s
1	163.95	163.948	1.989E-03
2	165.62	165.619	1.999E-03
3	167.29	167.289	2.009E-03
4	168.96	168.960	2.019E-03
5	170.57	170.571	2.029E-03
6	172.24	172.241	2.039E-03
7	173.91	173.912	2.049E-03
8	175.58	175.582	2.059E-03
9	177.19	177.193	2.068E-03
10	178.86	178.864	2.078E-03
11	180.53	180.534	2.087E-03
12	182.21	182.205	2.097E-03
13	183.88	183.875	2.107E-03
14	185.49	185.486	2.116E-03
15	187.16	187.157	2.125E-03
16	188.83	188.827	2.135E-03
17	190.50	190.498	2.144E-03
18	192.11	192.108	2.153E-03
19	193.78	193.779	2.163E-03
20	195.45	195.449	2.172E-03
Average	179.70	179.705	2.082E-03

Figure 7: Effect on Helium Leakage Rates with Increases to Temperature

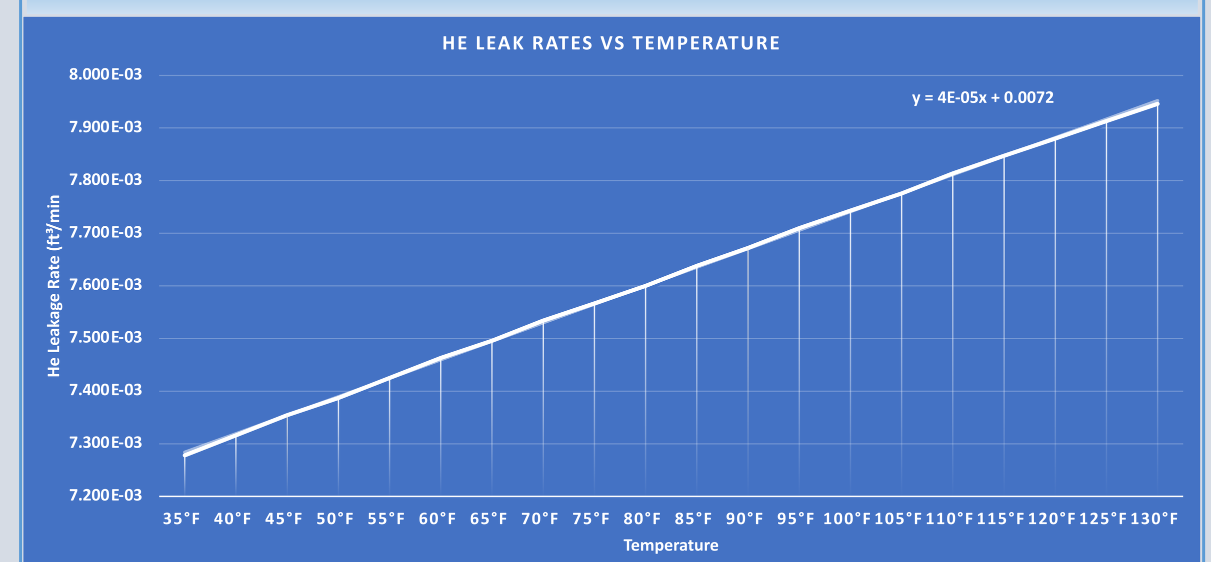
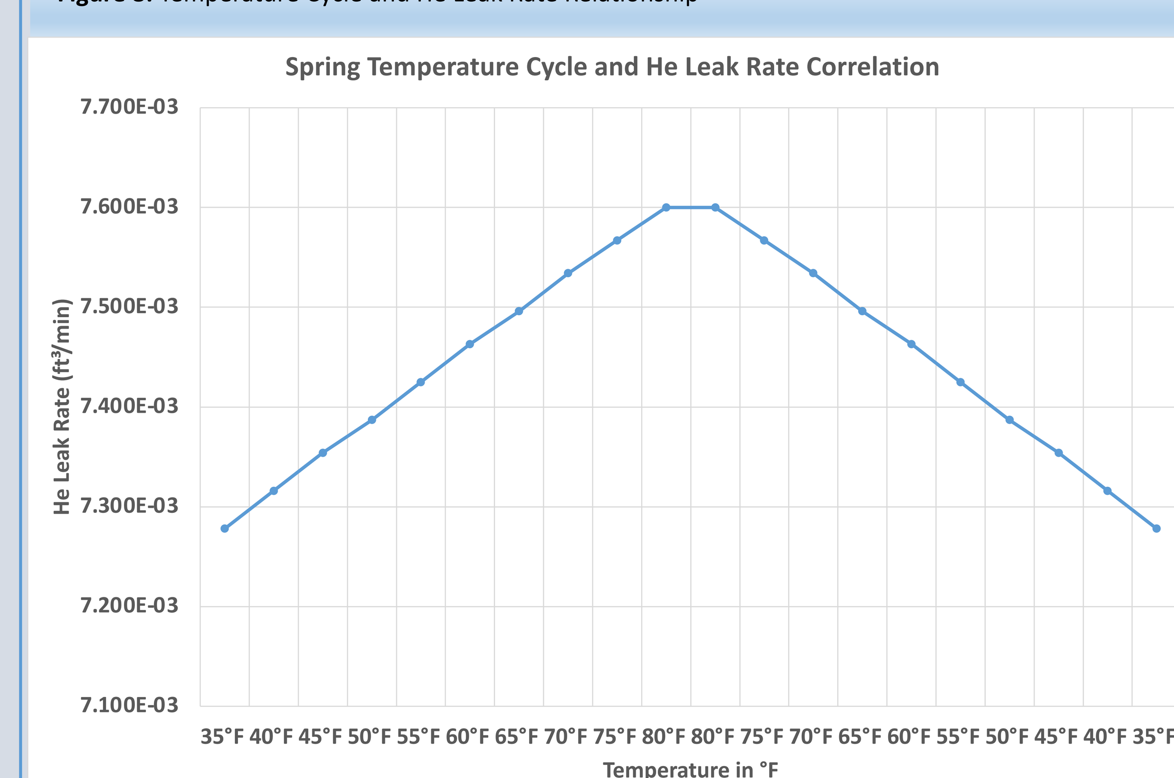


Table 2: Total volume of Helium leakage using previous temperature/pressure scenarios over time.

Scenarios	15 min	30 min	45 min	60 min	75 min	90 min	105 min	120 min
35°F/163.9 ATM	0.109 ft^3	0.218 ft^3	0.328 ft^3	0.437 ft^3	0.546 ft^3	0.655 ft^3	0.764 ft^3	0.873 ft^3
40°F/165.6 ATM	0.110 ft^3	0.219 ft^3	0.329 ft^3	0.439 ft^3	0.549 ft^3	0.658 ft^3	0.768 ft^3	0.878 ft^3
45°F/167.3 ATM	0.110 ft^3	0.221 ft^3	0.331 ft^3	0.441 ft^3	0.552 ft^3	0.662 ft^3	0.772 ft^3	0.882 ft^3
50°F/167.0 ATM	0.111 ft^3	0.222 ft^3	0.332 ft^3	0.443 ft^3	0.554 ft^3	0.665 ft^3	0.776 ft^3	0.886 ft^3
55°F/170.6 ATM	0.111 ft^3	0.223 ft^3	0.334 ft^3	0.446 ft^3	0.557 ft^3	0.668 ft^3	0.780 ft^3	0.891 ft^3
60°F/172.2 ATM	0.112 ft^3	0.224 ft^3	0.336 ft^3	0.448 ft^3	0.560 ft^3	0.672 ft^3	0.784 ft^3	0.896 ft^3
65°/173.9 ATM	0.112 ft^3	0.225 ft^3	0.337 ft^3	0.450 ft^3	0.562 ft^3	0.675 ft^3	0.787 ft^3	0.900 ft^3
70°F/175.6 ATM	0.113 ft^3	0.226 ft^3	0.339 ft^3	0.452 ft^3	0.565 ft^3	0.678 ft^3	0.791 ft^3	0.904 ft^3
75°F/177.2 ATM	0.114 ft^3	0.227 ft^3	0.341 ft^3	0.454 ft^3	0.568 ft^3	0.681 ft^3	0.795 ft^3	0.908 ft^3
80°F/178.9 ATM	0.114 ft^3	0.228 ft^3	0.342 ft^3	0.456 ft^3	0.570 ft^3	0.684 ft^3	0.798 ft^3	0.912 ft^3
85°F/180.5 ATM	0.115 ft^3	0.229 ft^3	0.344 ft^3	0.458 ft^3	0.573 ft^3	0.687 ft^3	0.802 ft^3	0.917 ft^3
90°F/182.2 ATM	0.115 ft^3	0.230 ft^3	0.345 ft^3	0.460 ft^3	0.575 ft^3	0.690 ft^3	0.806 ft^3	0.921 ft^3
95°F/183.9 ATM	0.116 ft^3	0.231 ft^3	0.347 ft^3	0.463 ft^3	0.578 ft^3	0.694 ft^3	0.810 ft^3	0.925 ft^3
100°F/185.5 ATM	0.116 ft^3	0.232 ft^3	0.348 ft^3	0.465 ft^3	0.581 ft^3	0.697 ft^3	0.813 ft^3	0.929 ft^3
105°F/187.2 ATM	0.117 ft^3	0.233 ft^3	0.350 ft^3	0.467 ft^3	0.583 ft^3	0.700 ft^3	0.816 ft^3	0.933 ft^3
110°F/188.8 ATM	0.117 ft^3	0.234 ft^3	0.352 ft^3	0.469 ft^3	0.586 ft^3	0.703 ft^3	0.820 ft^3	0.938 ft^3
115°F/190.5 ATM	0.118 ft^3	0.235 ft^3	0.353 ft^3	0.471 ft^3	0.589 ft^3	0.706 ft^3	0.824 ft^3	0.942 ft^3
120°F/192.1 ATM	0.118 ft^3	0.236 ft^3	0.355 ft^3	0.473 ft^3	0.591 ft^3	0.709 ft^3	0.827 ft^3	0.946 ft^3
125°F/193.8 ATM	0.119 ft^3	0.237 ft^3	0.356 ft^3	0.475 ft^3	0.593 ft^3	0.712 ft^3	0.831 ft^3	0.950 ft^3
130°F/195.4 ATM	0.119 ft^3	0.238 ft^3	0.358 ft^3	0.477 ft^3	0.596 ft^3	0.715 ft^3	0.834 ft^3	0.954 ft^3

Figure 8: Temperature Cycle and He Leak Rate Relationship



CALCULATIONS FOR LEAK RATES

Rate of Diffusion = (Amount of gas passing through an area)/(per unit of time) (OpenStax, 2016)

$$u_{rms} = \sqrt{\frac{3RT}{\mathcal{M}}} \text{(Tro, 2016)}$$

In which:

U_{rms}=Root Mean Square Velocity

3 = Proportionality Constant

R = Gas Constant

T = Temperature in K

M = Molar Mass in kg/mol

$$r = \frac{PA}{\sqrt{2\pi MRT}}$$ (*Statistical Mechanics – Rate of Effusion in Kinetic Molecular Theory, n.d.*)

Where:

r = Rate in mol/s

P = Pressure in ATM

A = Area of hole in m^2

M = Molecular weight

R = Gas constant 8.314 J/mol •K

T = Temperature in K

CONCLUSION

The common industry practice in the transportation and storage of refined Helium products uses ISO/UN type vessels and valves designed to store liquid or gaseous phases of Helium. The same type of vessels and valves can also be used in the transportation of raw natural gas containing Helium. These valves and vessels are designed to minimize the quantity of Helium that escapes during the storage and transportation processes. By modeling various conditions during the transportation process from wellhead to refinery, it was possible to identify ideal operating conditions. These ideal operating conditions consider the volume of natural gases transported and the total quantity of helium leakage for the duration of transportation. Additional modeling focused on actual field conditions and timeframes, should be used to fine-tune procedures for the most efficient and cost-effective transportation practices.

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