ANDY THOMPSON

Senior Vice President – Manager of the Calgary Office

Andrew Thompson has over 30 years of diversified technical experience. His primary areas of expertise include reserves evaluations, reservoir modeling, drilling and completions, well testing and abandonment operations. Reservoir studies have included primary, secondary and tertiary recovery methods and analysis of unconventional low permeability and highly fractured reservoirs.

Thompson was instrumental in developing and maintaining business operations in Calgary at Ryder Scott during his employment from 1995 to 2008. As the Manager of the Calgary office, he was a lead engineer and primary contact for several clients.

Thompson is a member of the Association of Professional Engineers and Geoscientists of Alberta and Society of Petroleum Engineers. He has a BS degree in Petroleum Engineering from the New Mexico Institute of Mining and Technology.

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HELIUM EVALUATION AND REPORTING

By Andy Thompson

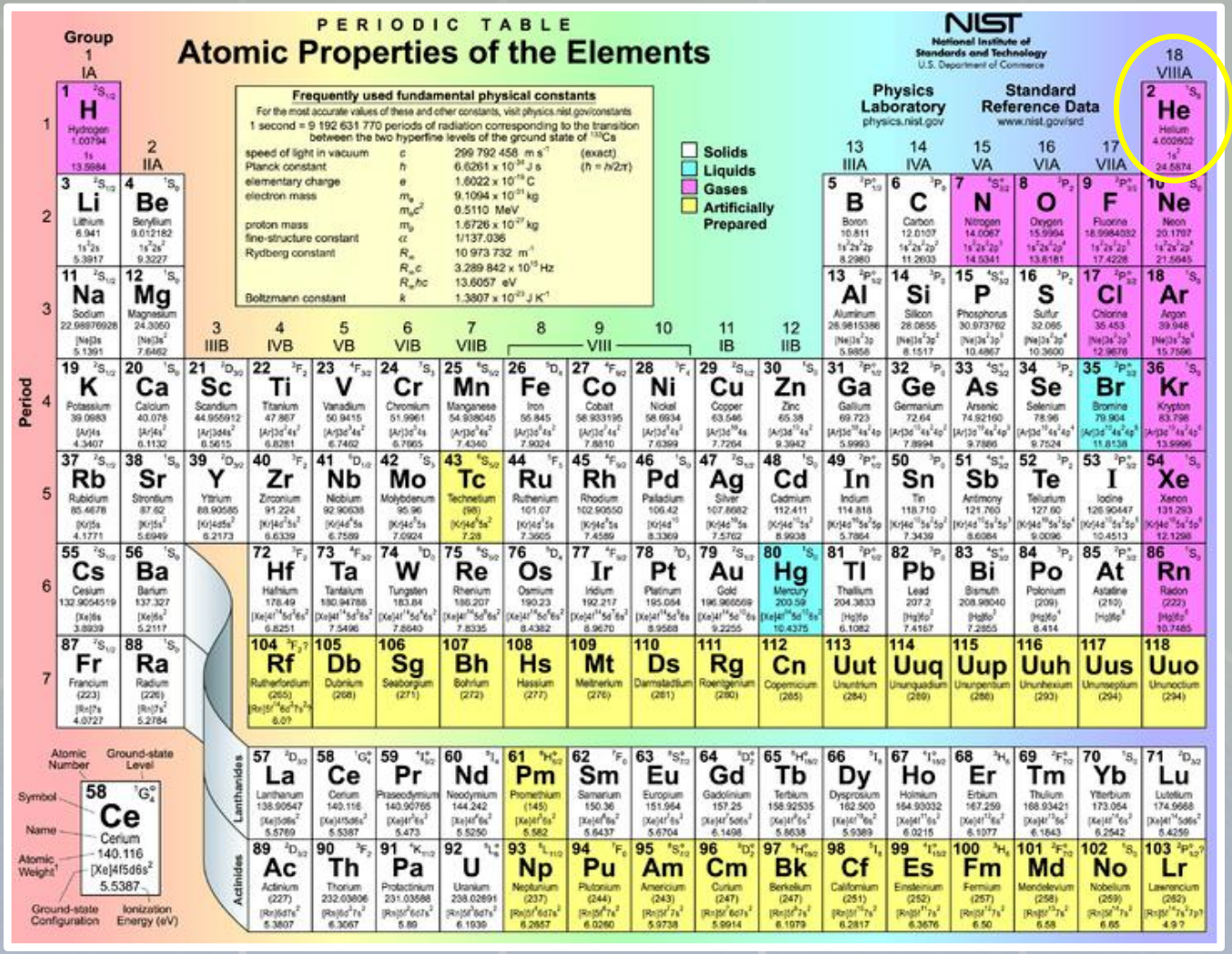
INTRODUCTION

- Andrew Thompson, P.Eng., Senior Vice President with Ryder Scott Company.
- Manager of the Ryder Scott – Canada Office located in Calgary, Alberta.
- New Mexico Institute of Mining and Technology – B.Sc. Petroleum Engineering, 1989.
- Employed by Ryder Scott Company for ~14 years and have conducted numerous resource and reserves evaluations and audits both domestic and international.

INTRODUCTION

- Helium Element - What is it, its unique properties, how is it generated and uses.
- Helium Supply - Major producing countries and accumulations
- Bureau of Land Management – US Helium storage changes
- Helium Pricing
- Helium Processing and Transportation
- Helium Evaluation Methodology
- Helium Reporting
- Questions

HELIUM ELEMENT



- Helium, chemical element with atomic number 2 on the periodic table, is an inert gas and the second lightest member of the noble gases next to Hydrogen.
- Helium is colorless, odorless and tasteless and becomes a liquid at -268.9^{o}C (-452°F).
- Unlike volatile Hydrogen, Helium is nonflammable and its unique chemical properties make it an irreplaceable finite commodity that is in extremely high demand today.
- Isotopes of helium exist but only those with mass numbers of 3 and 4 are considered stable. Helium 4 is the most plentiful of the stable isotopes on Earth.

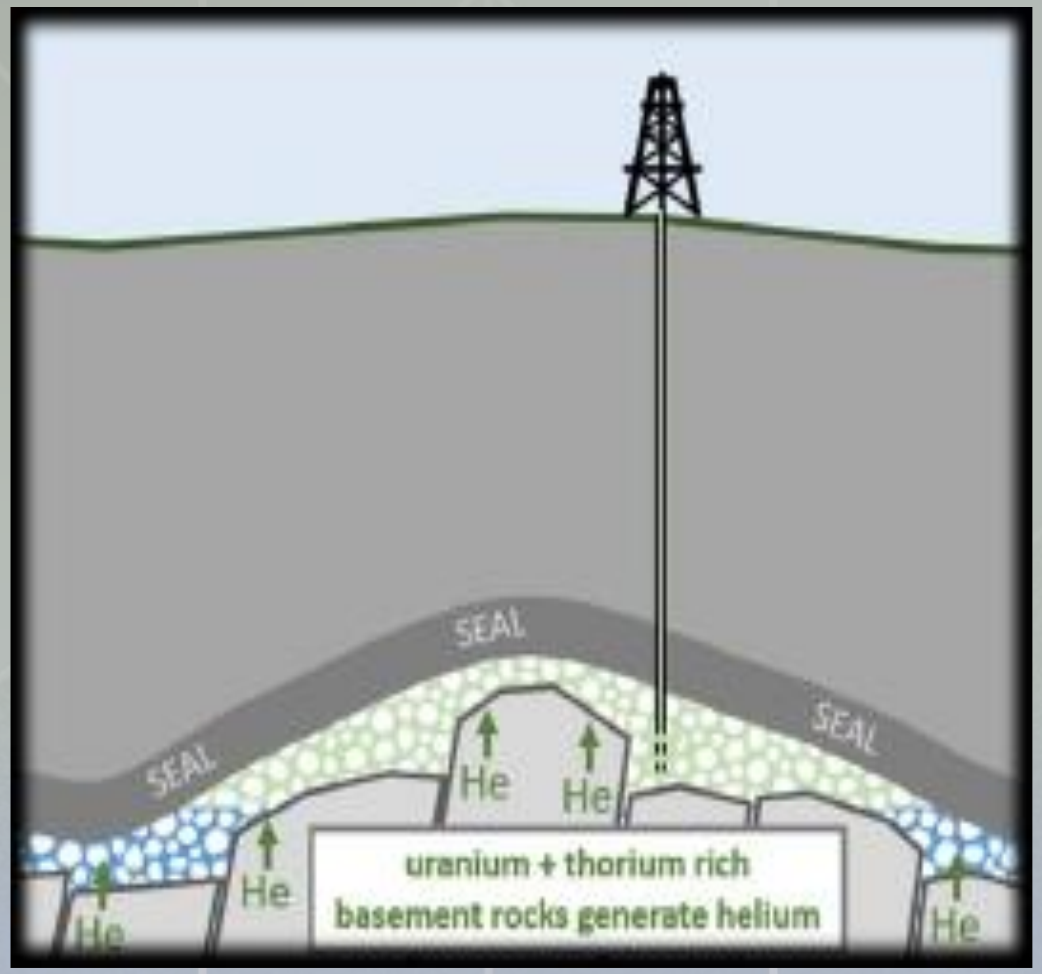
Source: National Institute of Standards and Technology

HELIUM ELEMENT

British chemist Sir William Ramsay and Swedish chemists Per Teodor Cleve and Nils Abraham Langlet, are known to have discovered the existence of Helium on Earth in ~1895 by obtaining a sample of the uranium bearing mineral cleveite. Upon heating the sample Ramsay found a unique bright yellow line in its spectrum that matched that of the D_3 line observed in the spectrum of the sun. Ramsay and Fredrick Soddy further determined that **helium is a product of the spontaneous disintegration of radioactive substances.**

(Source: Encyclopedia Britannica)

HELIUM ELEMENT



- Helium is generated deep underground through the natural radioactive decay of elements such as Uranium and Thorium.
- Helium seeps up through the Earth's crust and gets trapped in pockets of natural gas or nitrogen accumulations.
- It can be economically extracted through drilling operations at concentrations of ~0.4% (mole percent) or higher depending on the helium pricing, production tax's or royalties, transportation, capital and operating costs.

HELIUM ELEMENT

Helium is not just for party balloons, it has many very important uses including:

- arc welding
- rocket propulsion
- meteorology
- cryogenics
- high-pressure breathing operations
- MRI scanners
- as a cooling medium for nuclear reactors
- semiconductor manufacturing
- fibre optic manufacturing
- many other important uses

Helium demand continues to rise as current sources are depleting rapidly.

HELIUM SUPPLY

Current Helium Statistics
in million cubic meters (e6m3)

	Mine Production 2021	Mine Production 2022e	Resources e6m3
United States (extracted from natural gas)	69	60	8490
United States (from Cliffside Field)	7	15	60.7
	76	75	8551
Algeria	14	9	8200
Australia	4	4	
Canada	1	2	2000
China	1	1	1100
Poland	1	1	
Qatar	61	60	10100
Russia	5	5	6800
South Africa	1	1	
Others		3	3100
	88	85	31300
World Total (rounded)	164	160	39851

Data source: Helium Statistics and Information | U.S. Geological Survey (usgs.gov)

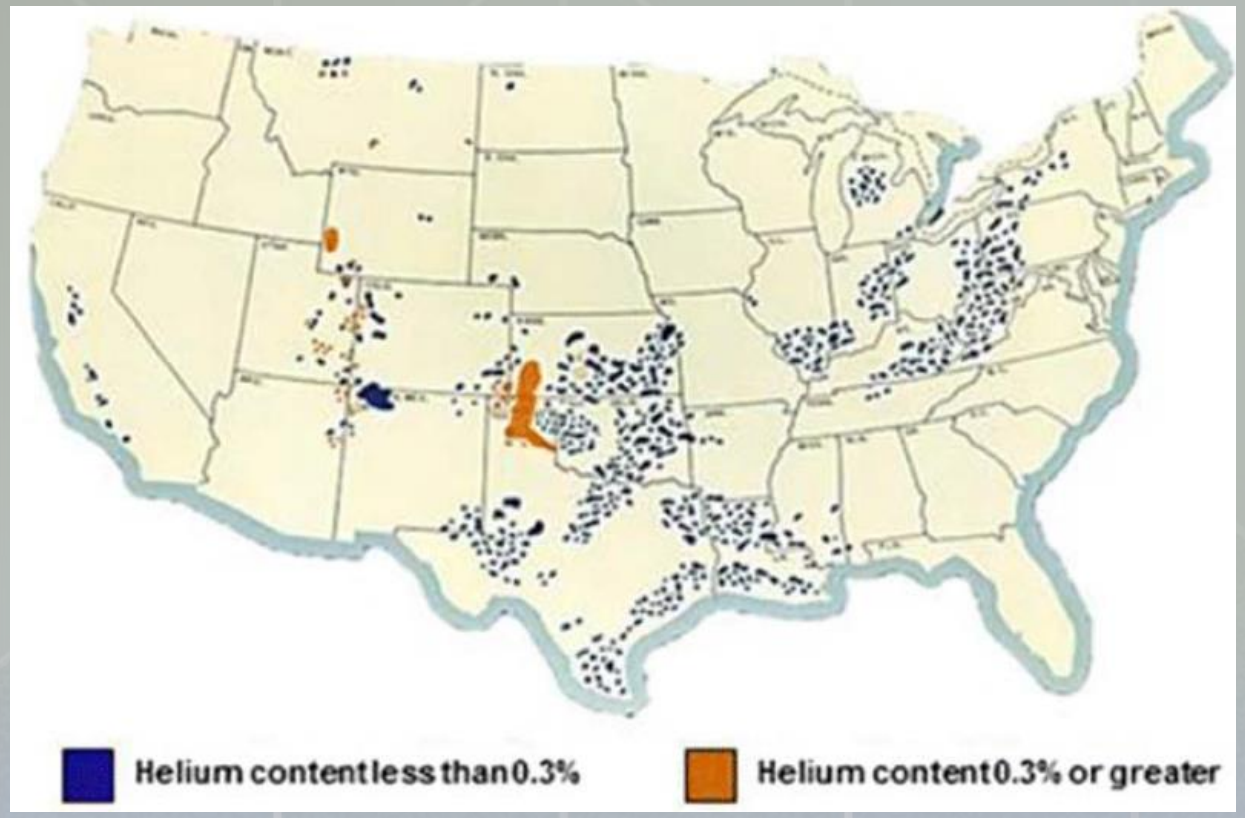
- In North America, Helium is economically recovered from natural gas reservoirs and nitrogen accumulations.
- Other source countries include Qatar, Algeria, Australia, Russia and Poland.
- Less than 10 facilities accounted for ~90% of the world annual production of helium of ~5.8 Bcf in 2022. North America produced ~2.8 Bcf in 2022.
- The BLM storage supply has been the major source of helium for North America but is essentially depleted.
- If the decline in helium production in North America cannot be arrested there will be more reliance on less stable regions of the globe.

HELIUM SUPPLY

2020 Helium Global Supply		Estimated 2030 Global Supply	
North America	55%	Qatar	37%
Qatar	33%	North America	33%
Algeria	6%	Russia	26%
Australia	3%	Algeria	3%
Russia	3%	Australia	1%

- It is estimated that by 2030, ~2/3rds of the global supply will be coming from Russia, Qatar and Algeria.
- Russia's helium production will grow to ~26% by 2030 following the construction of the mega Amur plant in Siberia.
- The liquefied natural gas (LNG) company in Qatar, RasGas, is a major source of helium production extracted as a methane and LNG by-product.
- Algeria's helium production is extracted alongside oil and gas operations.

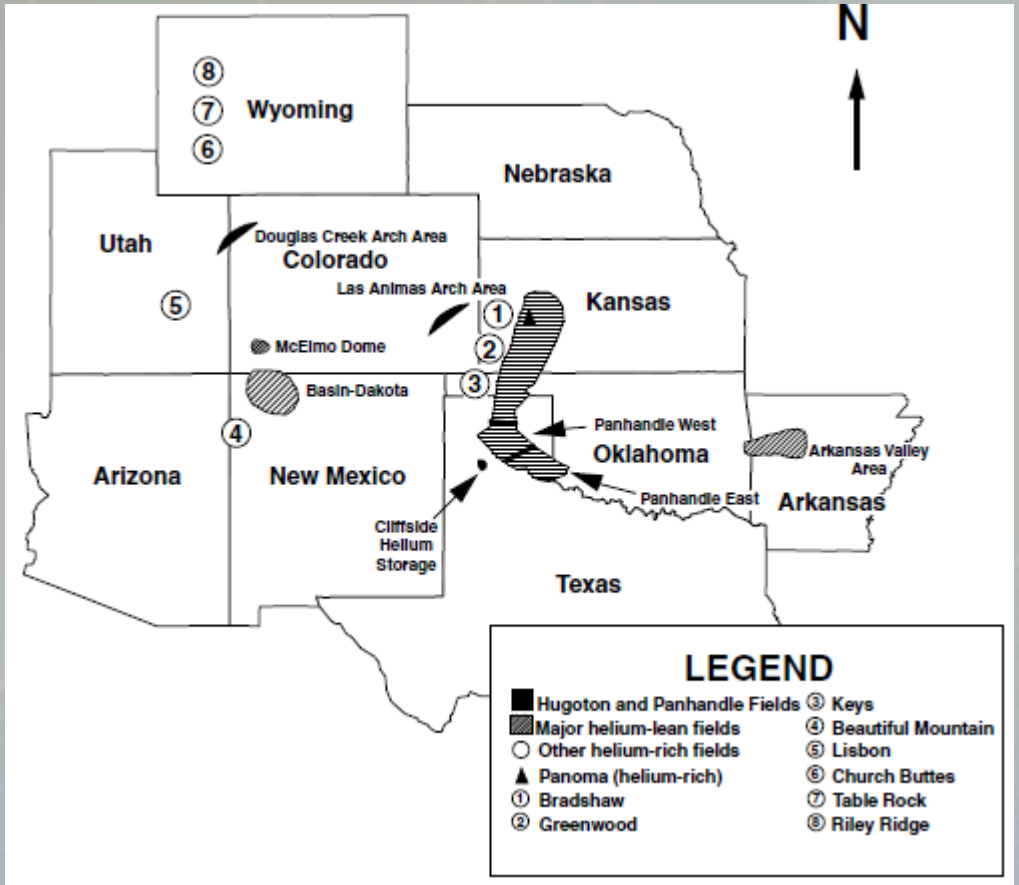
HELIUM SUPPLY



Source: U.S. Bureau of Land Management

- The BLM has compiled gas analysis data for the US as part of the helium stewardship act of 2013.
- Geologic conditions in Texas, Oklahoma, and Kansas make the natural gas deposits in these areas helium-rich with concentrations between 0.3% and 2.7%.

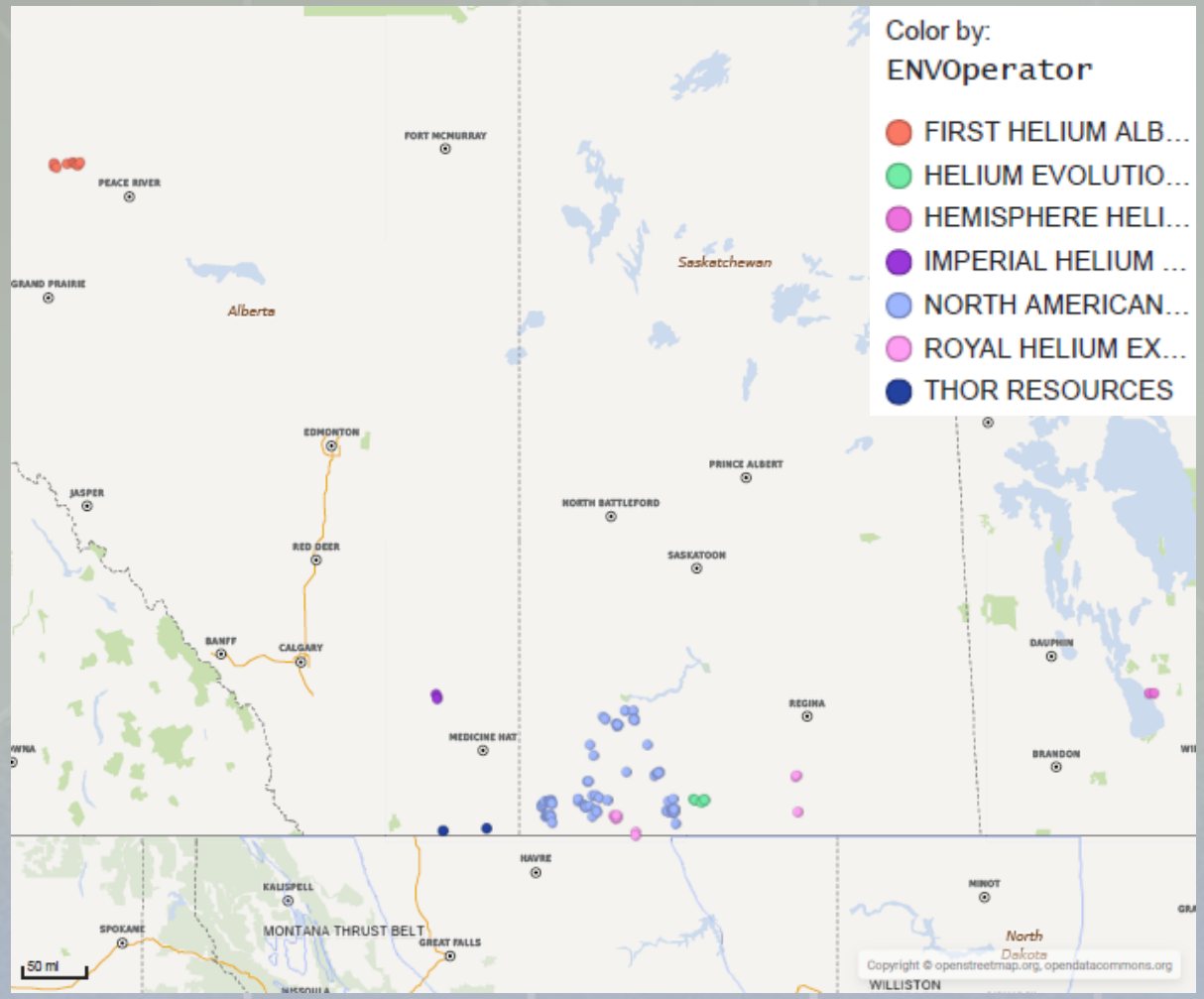
HELIUM SUPPLY



Source: U.S. BLM, Helium Resources of the United States - 2007

- Major helium-bearing natural gas fields in the US include the Hugoton, Kansas and Texas and Oklahoma Panhandle fields.
- Existing producing natural gas fields that have high helium concentrations are depleting.
- New helium exploration and production companies are active in the four corners area of the US and northern Montana where helium-rich nitrogen accumulations are found.

HELIUM SUPPLY

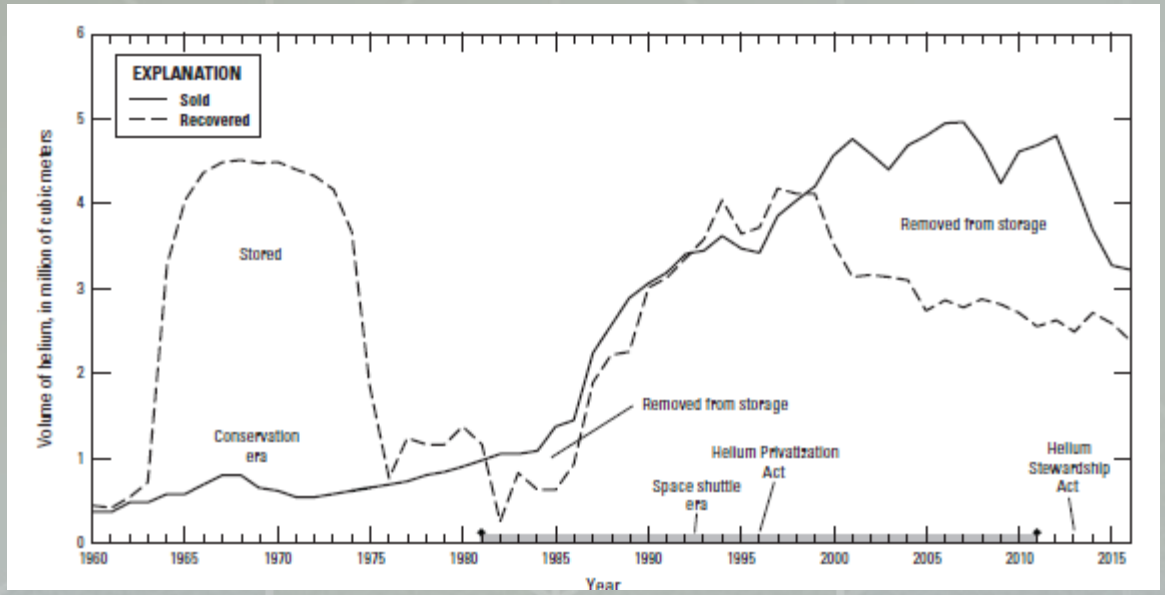


- Helium exploration and production companies in Canada are active in the southern Saskatchewan and southeastern Alberta regions targeting helium-rich nitrogen accumulations.
- Approximately 65 wells have been drilled by helium exploration and production companies in Canada.
- The Southern Saskatchewan helium 21-year lease terms and 4.25% net royalty are more reflective of mining rather than oil and gas (5-year terms).
- Saskatchewan's helium action plan provides significant exploration and capital incentives.
- The well and plant permit processes are transparent and have significantly shorter approval timeframes than other jurisdictions.
- Major investments by the oil & gas industry including seismic, drilled wells, road and power infrastructure reduce costs for helium exploration and development.

HELIUM SUPPLY

- In Tanzania's rift valley region high helium concentrations of 8-10% have been reported from natural gas sampling of bubbling ground seepage near mineral springs.
- The rift valley region is currently being explored for potential drilling locations.

HELIUM AND THE BUREAU OF LAND MANAGEMENT



Source: USGS 2016 Mineral Yearbook - Helium

- Under the Helium Stewardship Act of 2013, the BLM managed the US federal helium program which was responsible for the conservation and sale of federally owned helium.
- The BLM operated and maintained a helium storage reservoir, enrichment plant and pipeline system near Amarillo, Texas that in 2021 supplied ~12% of the domestic demand for helium.
- The BLM supplied crude helium to private helium refining companies which in turn refined the helium and marketed it to consumers.

HELIUM AND THE BUREAU OF LAND MANAGEMENT

- On April 16, 2020, the BLM announced the disposal process for the federal helium system. The BLM no longer managed the federal helium system as of September 30, 2021.
- Excess helium remaining as of September 30, 2021 was transferred to the General Services Administration (GSA).
- Federal in-kind users had access until September 30, 2022 at which point there was 57.2 million cubic meters (2.06 Bcf) of privately owned helium storage in the Cliffside field.
- In 2023, all privately owned helium will be produced from the field.
- The end of the federal helium program marked the beginning for federal in-kind users to seek new sources on the open market to meet their helium requirements. The demand for new sources of helium has been on the rise since the federal helium program ended and is expected to continue to be in high demand for the foreseeable future.

HELIUM ELEMENT

Salient Statistics – USA	Units	2018	2019	2020	2021	2022[e]
Helium extracted from natural gas[1]	e6m^3	62	72	76	69	60
Withdrawn from storage[2]	e6m^3	28	17	7	7	15
Grade-A helium sales	e6m^3	90	89	83	76	75
Imports for consumption	e6m^3	8	7	7	9	8
Exports	e6m^3	[3]58	58	52	47	40
Consumption, apparent[4]	e6m^3	40	38	38	38	43

[e] - Estimated
[1] Both Grade – A and crude helium
[2] Extracted from natural gas in prior years
[3] Exports adjusted for by USGS for 2018
[4] Grade – A helium. Defined as sales + imports - exports
27.737 cubic meters of helium = 1,000 cubic feet of helium at 101.325 kilopascals absolute (14.696 psia) and 21.1°C (70°F)

Source USGS

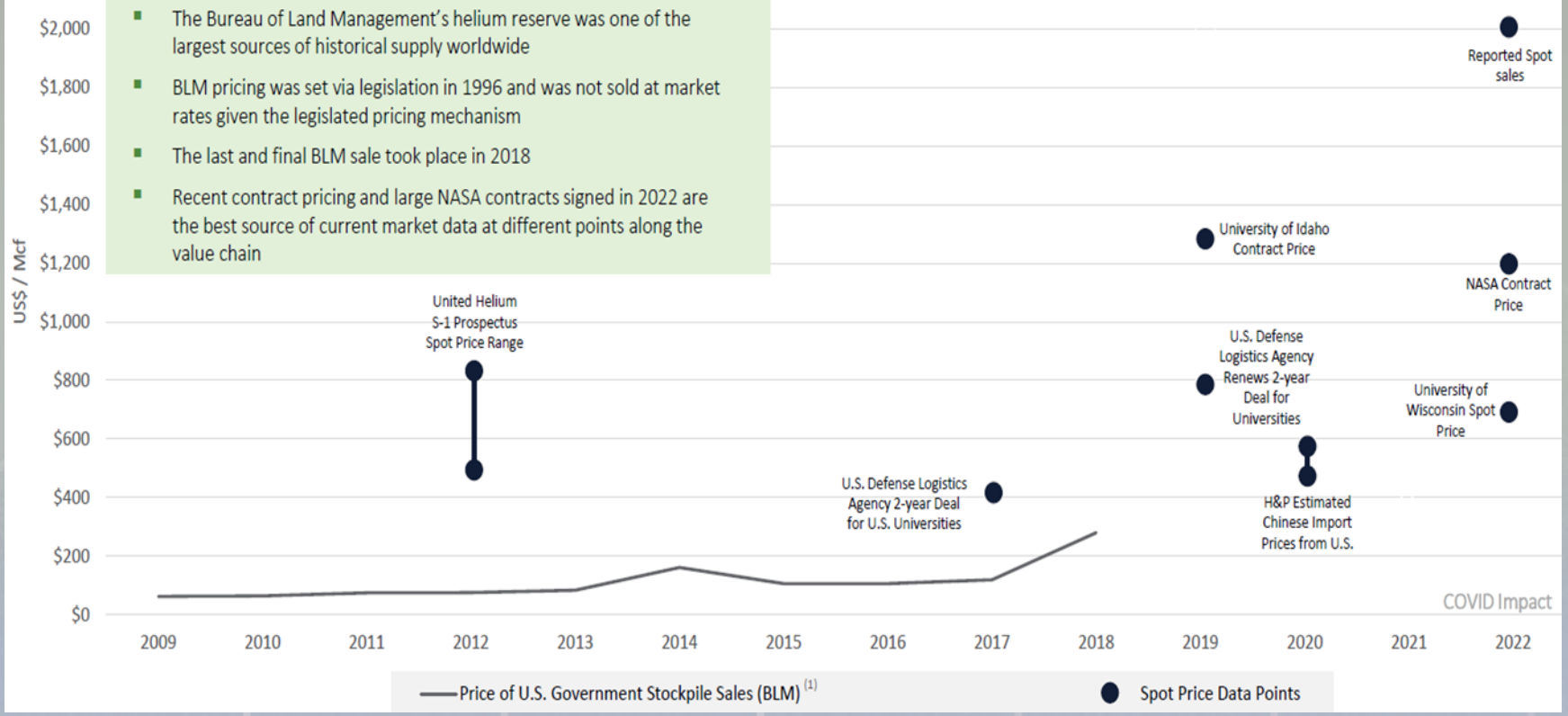
- There is no current pricing transparency for helium as it is not a traded commodity and pricing is normally based on long-term confidential contracts.
- The helium market is controlled by a few major industrial companies like Linde, Air Liquide, Air Products, Messer Group and Matheson that wield strong pricing power.
- The estimated value of Grade-A helium (99.997% or greater) sold during 2022 by private industry was about $820m.
- In 2022, the estimated US domestic apparent consumption of Grade –A helium was 1.5 Bcf.
- The estimated price for private industry's Grade-A helium was ~$310/Mcf, with some producers posting surcharges to this price.
- Most of the helium sold today is Grade 5 (99.999% purity) which has received sale prices much higher than $310/Mcf.

HELIUM PRICING

AVAILABLE HELIUM PRICING DATA CORROBORATES PRICING UPSIDE

WHILE HELIUM PRICING IS OPAQUE, RECENT PUBLICLY AVAILABLE DATA POINTS ILLUSTRATE THE EXPECTED ELEVATED FUTURE PRICING AS BLM SUPPLY IS REMOVED FROM THE MARKET

- The Bureau of Land Management's helium reserve was one of the largest sources of historical supply worldwide
- BLM pricing was set via legislation in 1996 and was not sold at market rates given the legislated pricing mechanism
- The last and final BLM sale took place in 2018
- Recent contract pricing and large NASA contracts signed in 2022 are the best source of current market data at different points along the value chain



- Although, helium pricing is not transparent there are publicly available pricing points that suggest pricing is increasing substantially since the BLM ended auction sales in 2018.

Source: Hannam & Partners, Company data & management estimates; North American Helium Inc

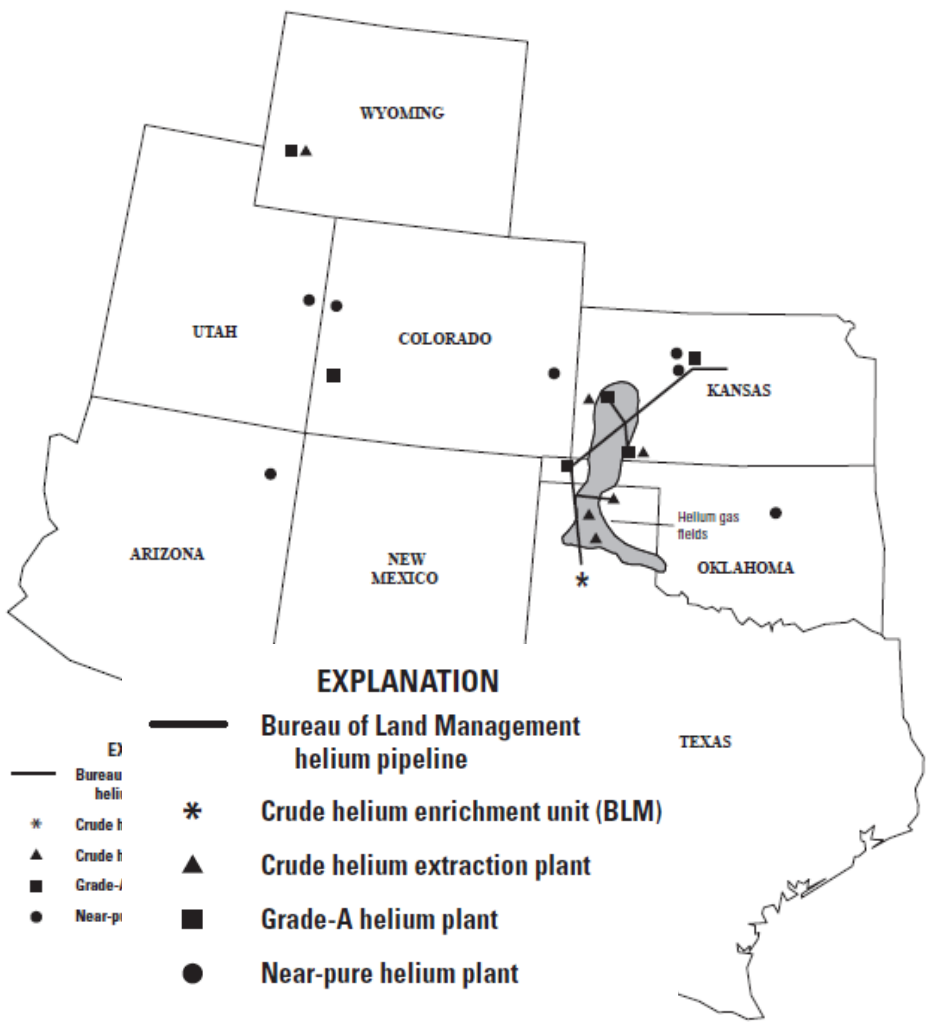
. 1Price for Government stockpile sales in 2014 and 2018 reflect average price of winning bids in a competitive auction, although additional non-competitive "allocated" sales were conducted at lower prices set by the BLM in each of those years. 2018 was the final year of sales from the BLM stockpile to industry

HELIUM PROCESSING AND TRANSPORTATION

Helium Purification Facility

- Helium extraction, purification and transportation processes include:
  - Crude helium enrichment units, where mainly helium and nitrogen are extracted from natural gas
  - Cryogenic
  - Membrane
  - Pressure Swing Adsorption (PSA)
  - Liquefaction for optimum transport

HELIUM PROCESSING AND TRANSPORTATION



- The Cliffside enrichment plant near Amarillo, Texas, pumps helium from storage to the crude helium enrichment unit where it was enriched to 78% helium and 21% nitrogen and less than 1% methane. The crude helium is sold to private industry for further refinement and distribution.

Source: USGS 2016 Mineral Yearbook - Helium

HELIUM PROCESSING AND TRANSPORTATION

Helium Purification

- Cryogenic Process – uses low temperatures to cause different gases to condense off as a liquid in a fractionation tower. Helium's low condensation point makes the cryogenic separation process ideally suited to helium however the process is more capital intensive and requires a large scale.
- Membranes – high pressure membranes purify helium through selective diffusion of relatively smaller gas molecules as nitrogen rich gas is produced through microscopic fibers.
- Pressure Swing Adsorption (PSA) - uses pressure to cause selective adsorption of different sized gas molecules. The PSA technology can be deployed at a small scale but may be less efficient than the cryogenic process in terms of energy and product loss. The PSA process consists of four stages, with each stage composed of three parallel adsorption beds.
  - Stage 1 removes carbon dioxide, ethane, propane and butane allowing methane, nitrogen and helium through.
  - Stage 2 rejects methane as the heavy product allowing helium and nitrogen through.
  - Stage 3 adsorbs and removes most of the nitrogen and allows helium through.
  - Stage 4 adsorbs the remaining nitrogen allowing purified helium to pass through as the final light product.
  - The Stage 4 waste product of mostly nitrogen is compressed and optionally recycled back into Stage 3 to boost overall helium recovery.
- The combination of membranes (hydrocarbon and nitrogen rejection) coupled with PSA technology to clean-up the carbon dioxide and small amount of nitrogen remaining, yields recovery factors of 95-99% and a purity of easily >99%. The membrane and PSA combination can be used on small scale single well accumulations.

HELIUM PROCESSING AND TRANSPORTATION

- Private producers or distributors ship helium predominately as a liquid so that it will fill a smaller volume.
- In the larger helium plants the liquefied helium is stored into specialized 40-foot long ISO intermodal shipping containers.
- The liquid helium can be re-gasified at trans-fill stations and used as a pure gas for most applications.
- It can also be shipped as a gas in high-pressure tube trailers, although shipping costs as a gas are higher than in liquid form.

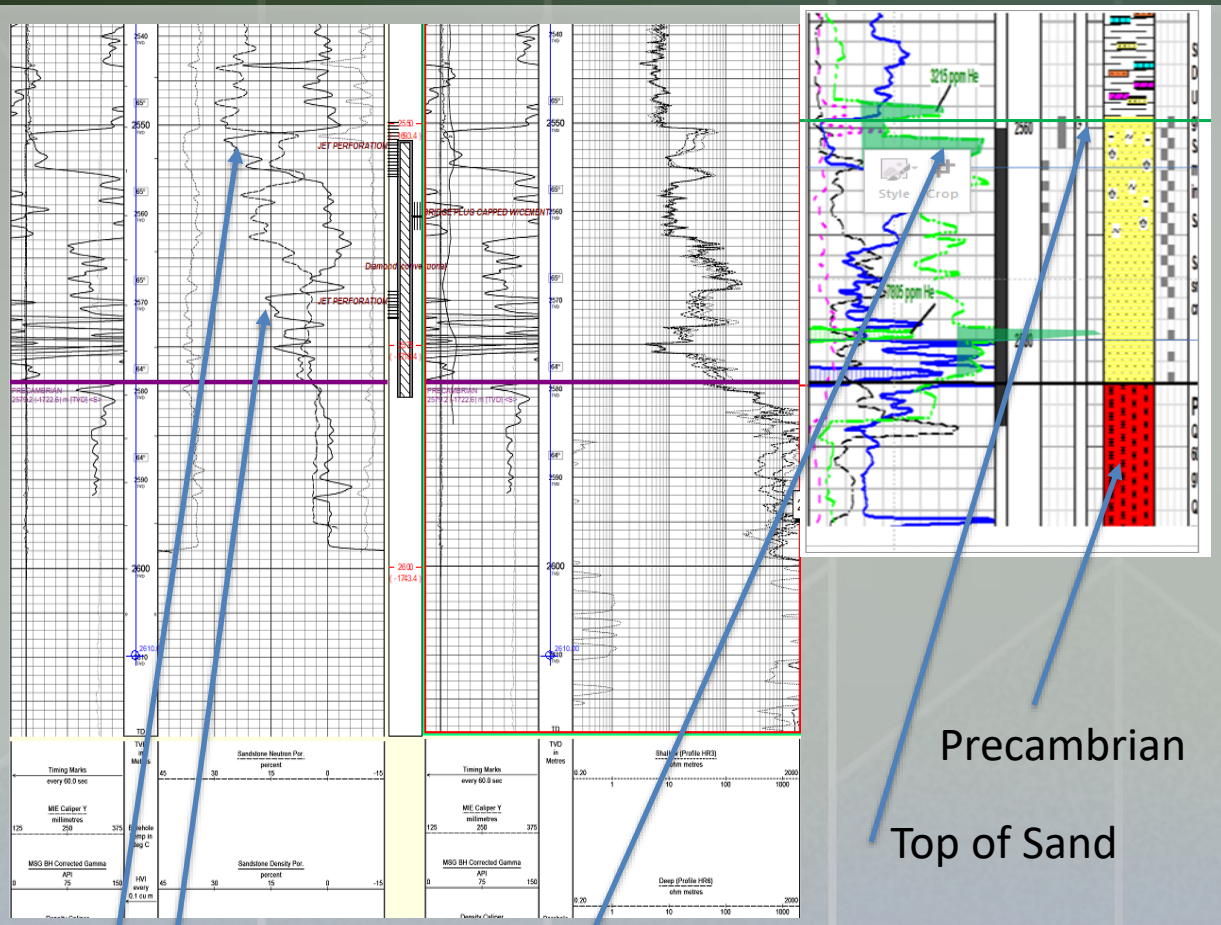
HELIUM EVALUATION METHODOLOGY

- Helium rich natural gas reservoirs or nitrogen accumulations are evaluated similarly to any natural gas reservoir with respect to source rock, migration path, porous reservoir rock and structural or stratigraphic trap.
- As previously mentioned, Helium is derived from the decay of uranium and thorium which is found in granitic rocks of the Precambrian Basement.
- Migration, similarly to hydrocarbons is through faults or fractures, but can also be found in reservoir rock in direct contact with the source rock. This is seen in many of the reservoirs in southwestern Saskatchewan.
- Traps, similarly to any hydrocarbon reservoir are structural or stratigraphic requiring a robust seal. With helium being roughly half the size of a molecule of methane the seal is of utmost importance for accumulation to occur. As with any natural gas reservoir stratigraphic traps are harder to seal and even more so with helium.

HELIUM EVALUATION METHODOLOGY

- Seismic structure anomalies are identified using 2D and 3D seismic data.
- Seismic anomalies are drilled and tested and an Original-Raw-Gas-In-Place (ORGIP) is calculated volumetrically using wellbore parameters.
- Helium-in-place volumes are calculated by multiplying the Raw Gas volumes by the helium fraction found in the reservoir.
- When drilling a well where helium is the main product of interest, it is highly recommended that cores, conventional or sidewall are taken to establish accurate reservoir porosity.
- The neutron log is sensitive primarily to the amount of hydrogen in a formation. Inert gas reservoirs don't have hydrogen so in theory, the neutron log should be zero, or very close to zero. When calculating porosity from well logs, the standard gas corrected neutron density estimation could be low when compared to core derived porosities.

HELIUM EVALUATION METHODOLOGY



Precambrian

Top of Sand

Perf Interval X-Over
Neutron not Zero

Helium Detection while Drilling

- In practice, most of the reservoirs we see have a positive neutron response in inert nitrogen based accumulations and the porosity from log data appears to be fairly accurate. The positive neutron response could be due to the presence of minor amounts of methane that is present in some of the wells that we have evaluated.
- Gas chromatography specifically used in detecting helium is also highly recommended while drilling in order to establish zones of interest.

HELIUM EVALUATION METHODOLOGY

- The same gas chromatograph that is used for natural gas analysis (C1 through C7) can be altered to detect helium.
  - In a normal chromatograph, the machine has helium in it as the carrier gas
  - In order to detect the helium peak, substitute the carrier gas with Argon
- It is essential that the gas is analyzed to determine helium concentrations within the natural gas or nitrogen accumulation. The gas analysis should be carefully conducted in a manner that limits air contamination.
- Pressure-Volume-Temperature (PVT) Analysis –
  - Differential (gradual pressure drop) and flash (rapid pressure drop) liberation where gas is separated from reservoir fluids in a continuous cycle in a laboratory. Determines Bg, pseudo critical properties and gas composition.

HELIUM EVALUATION METHODOLOGY

	Mole Fraction
	Air Free
Component	as Received
H2	0.0000
HE	0.0090
N2	0.9707
CO2	0.0020
H2S	0.0000
C1	0.0176
C2	0.0005
C3	0.0001
iC4	Trace
nC4	Trace
iC5	Trace
nC5	Trace
C6	Trace
C7+	0.0001
Total	1.0000

- Typical PVT correlations built into reservoir engineering tools allow correction for "contaminants" such as N2, H2S, CO2.
- Correlations do not work well where N2 is the principle component.
- One possible solution is to use the Equation of State (EOS) PVT model to obtain PVT properties (Z-factor).
- It is straight forward to use the EOS in the case of N2/He fluids since no C7+ tuning is required.
- N2 is mostly an incompressible gas.

HELIUM EVALUATION METHODOLOGY

- In typical helium-producing fields wells are rate constrained by the maximum inlet capacity of the helium purification plant.
- Helium separation is optimum when the plant is loaded close to 100% of the design inlet capacity for as long as possible. Once the total field flow rate drops to ~50% of the initial design capacity the efficiency of the helium separation process drops as well.
- This poses some challenges to helium production forecasting since wells are typically not on the decline and cannot be evaluated using Arp's decline curve analysis by extrapolation of the established decline trends.
- Helium reserves are typically assigned using a combination of the volumetric methods, rate transient analysis, and results obtained from the field-wide gas deliverability model.
- There are very few helium-rich nitrogen accumulations that reached a terminal development stage at this point. However, a typical range of recovery factors from the natural gas reservoirs are expected to be achieved in the N2/He reservoirs as well.

HELIUM EVALUATION METHODOLOGY

- A classic material balance (P/Z) is also a widely applicable method adapted from classic natural gas reservoir engineering by properly modeling Z factors of the N2 that allow the determination of the ORGIP.
- When enough production and flowing pressure data exists rate transient analysis that includes flowing material balance and analytical modeling become a useful forecasting tool. Here again, as in the case of static PZ, one needs to properly model PVT behavior of the N2 reservoir fluid.
- All production forecasts are generated using a field-wide gas deliverability model. This allows for proper treatment of the plant inlet pressure and rate constraints, accounts for the possible interference between wells, and models an optimum well drilling schedule.
- In summary, all classic reservoir engineering techniques for the natural gas reservoirs apply to the N2/He accumulations with proper consideration given to the PVT properties of N2.

HELIUM EVALUATION METHODOLOGY

- Apply the helium concentration and plant recovery efficiency to the raw gas production forecast (helium yield) to generate a helium production forecast.
- Similar to large natural gas projects, helium is also sold based on long term contract pricing and are generally EX-Works meaning it is sold at the plant gate so normally transportation costs (tolling) will be built into the contract.
- An average helium price beyond the contract period to an economic limit may be applied.
- Apply working interests and burdens and other economic factors such as Ad Valorem production tax's or royalties and any capital or operating costs.

HELIUM REPORTING

- Helium reporting guidelines are in the early stages and are evolving following increasing attention from capital markets.
- The PRMS (Petroleum Resources Management System) has gained worldwide acceptance for the classification and categorization of petroleum reserves and resources, and it is recognized that the principles of the PRMS are beginning to be applied to substances other than hydrocarbons including helium.
- The OGRC (Oil & Gas Reserves Committee) has become aware of other situations where PRMS principles have been considered for, or even applied to, non-hydrocarbon situations such as helium.
- In the cases of gaseous and solution extraction of resources from underground reservoirs, the fundamental physics and processes used mirror those applicable in the oil and gas industry.
- The OGRC believes that there is a reasonable foundation for the application of PRMS principles to situations such as helium recovery, considering the similarities in exploration, evaluation, and exploitation processes throughout the life-cycle of a project.
- SPE/OGRC (Society of Petroleum Engineers/Oil and Gas Reserves Committee) does not object to the application of the PRMS to these situations that result in the extraction of non-hydrocarbon resources, as long as it is made clear that while such application is outside the scope of the PRMS, PRMS principles have been followed, while involving other subject matter expert parties as appropriate, and applied as though the extracted resources were considered as petroleum.

HELIUM REPORTING

- The SEC has not changed their definitions or reporting requirements as it relates to helium as of yet. Increasing interest for capital investment, the increasing number of companies exploring for helium and the ESG-GHG reporting changes may influence some need to update certain guidelines.
- In March of 2021, Ryder Scott Company issued the first helium report utilizing SEC parameters (constant prices and costs). However, the Ryder Scott third party study does not conform to the current SEC hydrocarbon reporting requirements since helium is not considered a hydrocarbon product.
- In Canada, reporting Issuers (RI's) engaged in oil and gas activities that produce helium from a property as a by-product of a product type such as natural gas will be expected to provide the disclosure required by National Instrument 51-101 (NI51-101) in respect of helium. Although not considered a requirement, RI's otherwise producing helium are encouraged to consider the requirements and principles of the COGEH (Canadian Oil and Gas Evaluation Handbook), appropriately adapted for helium.
- In London, the AIM market requires a Competent Persons Report. Recently, a Competent Persons Report utilizing SPE-PRMS principles to determine risked and un-risked undiscovered prospective helium resources initially in place was included in a company prospectus.

QUESTIONS & ANSWERS