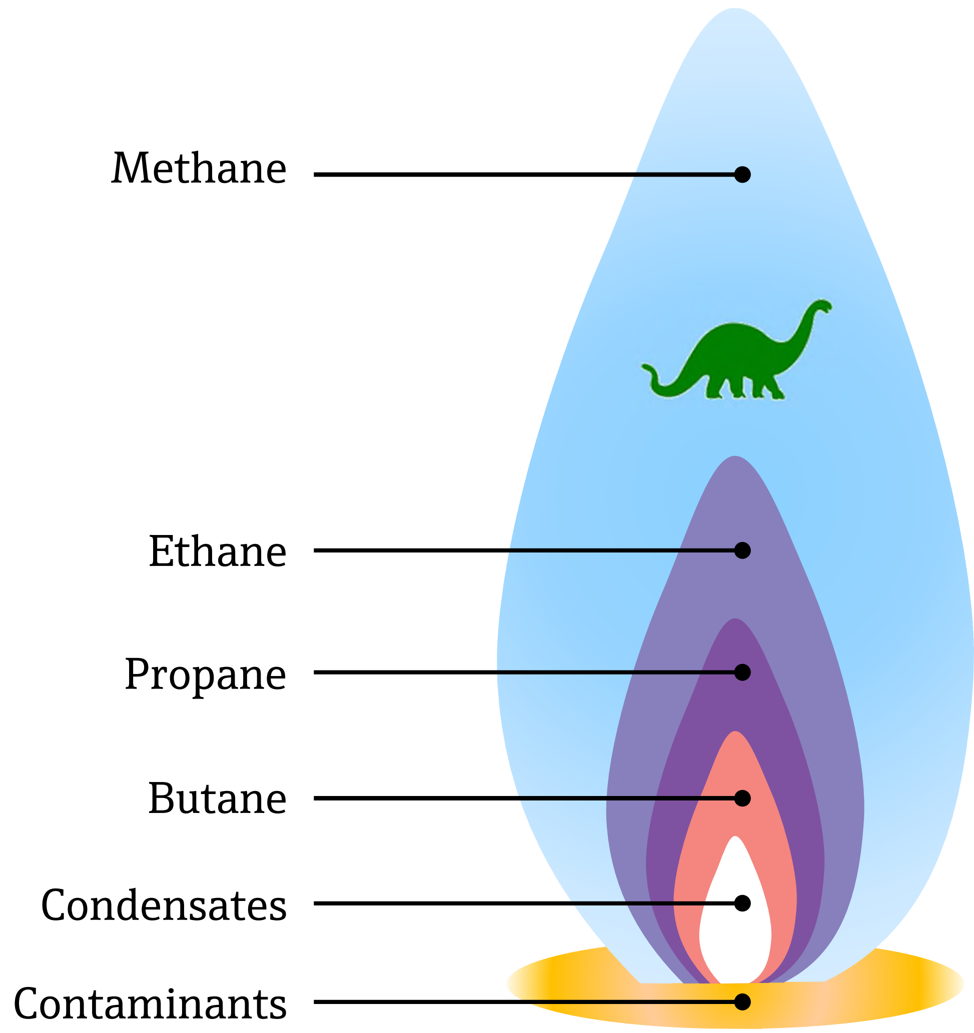
WGMSC
western gas measurement short course
SAN FRANCISCO
2026

Introduction to Natural Gas Quality

Western Gas Measurement Short Course, San Francisco, May 2026

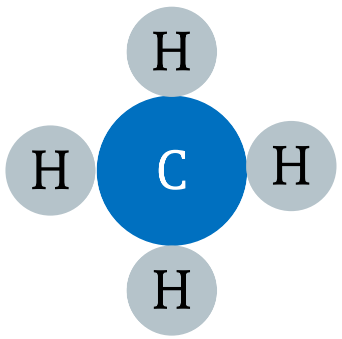
What is Natural Gas?

- Natural Gas is a fossil fuel; like oil and coal
- Natural Gas is hydrocarbon gas mixture consisting primarily of methane, plus other light hydrocarbons such as Ethane, Propane, Butane and Pentane
- It is colorless as well as odorless, and non-toxic
- Natural Gas is used as a fuel and to make materials (i.e. plastics) as well as chemicals
- Natural Gas is less chemically complex than oil
- Its combustion results in less pollution compared to oil or coal

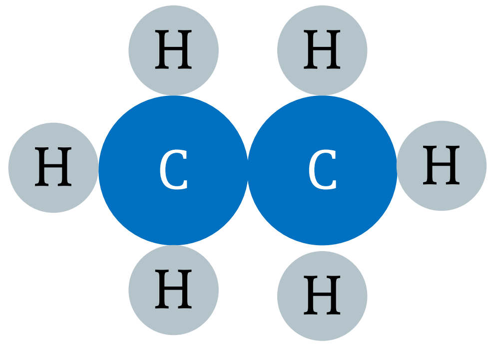


Light Hydrocarbon Gas Chemistry

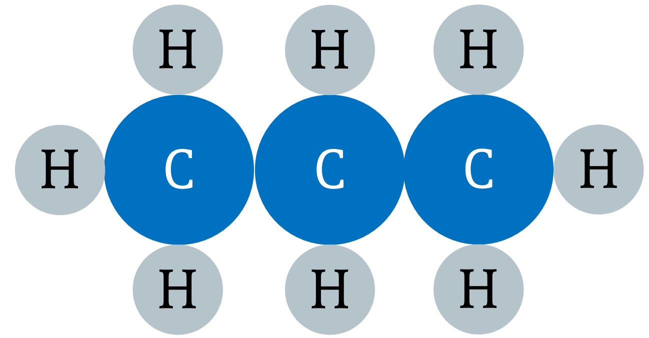
Methane – CH_4 (**C1**)



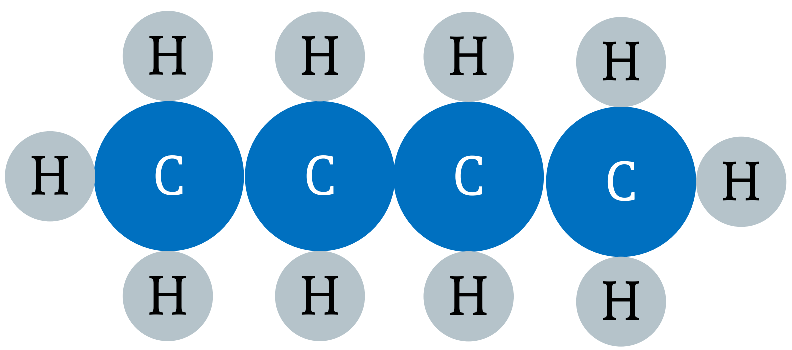
Ethane – C_2H_6 (**C2**)



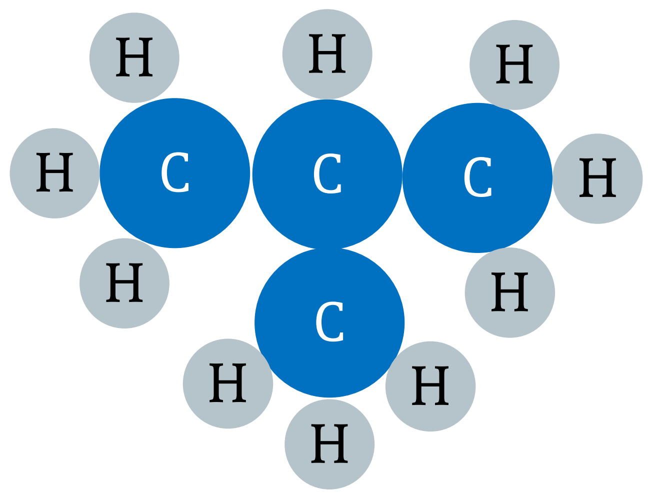
Propane – C_3H_8 (**C3**)



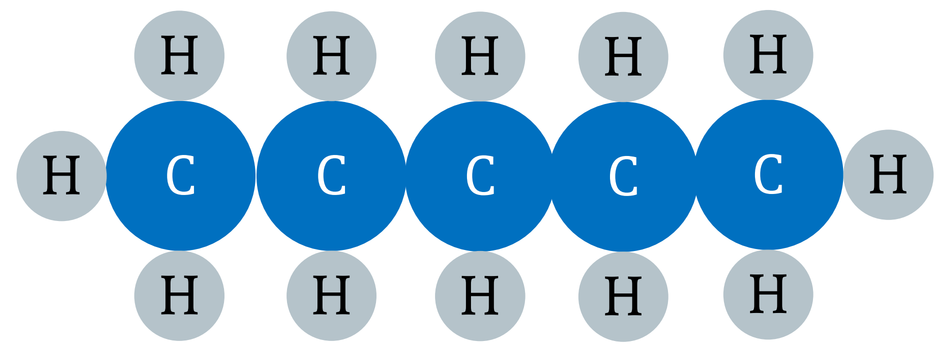
Butane – C_4H_{10} (**nC4**)



Isobutane – C_4H_{10} (**iC4**)



Pentane – C_5H_{12} (**nC5**)



Natural Gas Composition Ranges

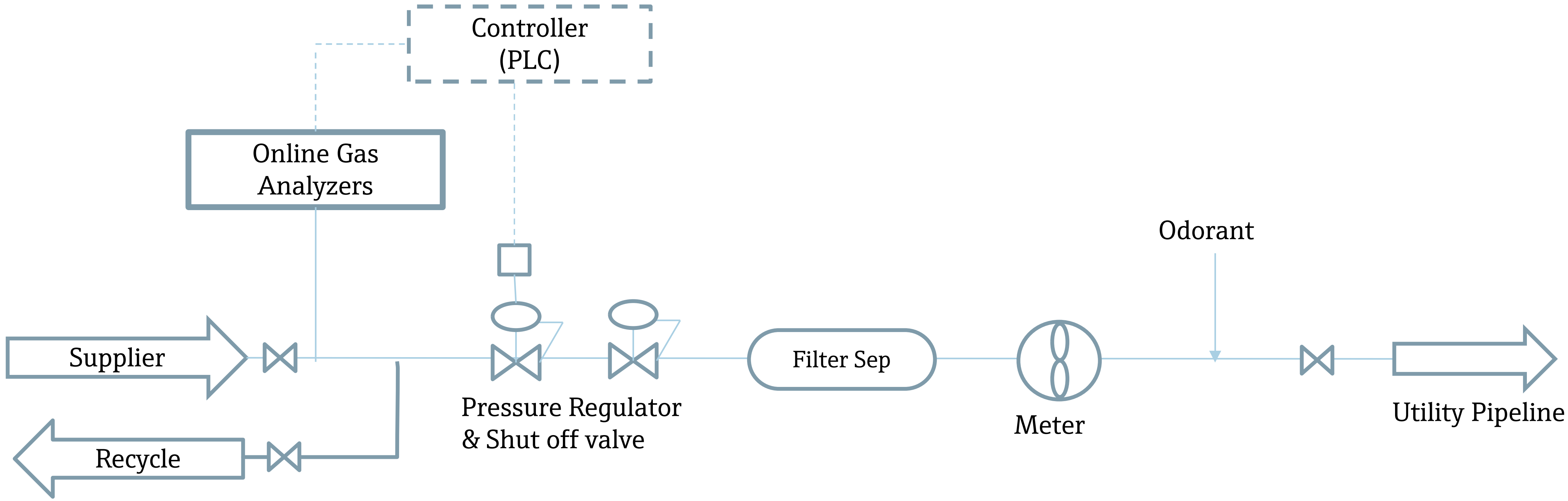
Component	Abbreviation	Sales Gas Table 1	Production Gas Table 2
Methane	C_1	90 - 100%	50 - 100%
Ethane	C_2	0 - 7%	0 - 20%
Propane	C_3	0 - 2%	0 - 15%
Butanes	C_4	0 - 1%	0 - 5%
Pentanes	C_5	0 - 0.2%	0 - 2%
Hexanes and Heavier	C_6+	0 - 0.2%	0 - 2%
Carbon Dioxide	CO_2	0 - 3%	0 - 20%
Nitrogen and other Inerts	N_2	0 - 10%	0 - 20%
Hydrogen Sulfide	H_2S	0 – 10 ppmv	0 - 5%
Water	H_2O	0 – 200 ppmv	0 – 5000 ppmv

Gas Quality Issues

Gas Quality Issues	Concerns
Carbon Dioxide	Corrosion
Oxygen	Corrosion, Safety
Total Inerts	Interchangeability, Capacity
Hydrogen Sulfide, Total Sulfur	Corrosion, Regulations
Moisture	Corrosion, Hydrates
Particles (liquid, solid)	Possible Condensation, Pipeline integrity

Gas Quality Monitoring and Enforcement

- Continuous online gas analyzers alarms and the controller will automatically shut off the access valve if gas is not compliant.
- Rejected gas is recycled through the supplier's process plant.
- The shut off valve will open when the alarm clears.



Common test methods for natural gas quality

Gas Quality Parameter	Sample Collection Method	Analytical Method (typical)
Gas Composition High Heating Value	Sample bottle Analyzer Sample stream	Gas Chromatograph
Carbon Dioxide	Sample bottle Analyzer Sample stream	Gas Chromatograph TDLAS
Oxygen	Sample bottle Analyzer Sample stream	Gas Chromatograph (less common) Electrochemical, Quenched Florescence
Water	Analyzer Sample stream	Chilled Mirror, TDLAS,
Hydrogen Sulfide	Tedlar Bag Analyzer Sample stream	Gas Chromatograph (less common) TDLAS, Lead Acetate Tape
Total Sulfur	Tedlar Bag, inerted container Analyzer Sample stream	Gas Chromatograph UV / Lead Acetate Tape
Dew points	Analyzer Sample stream Calculated	Chilled Mirror or Chilled “ATR” Extended Gas Chromatograph

On-line gas quality analyzers

Hydrogen

Oxygen

H_2O
CO_2

H2S

Gas Chromatograph:

- HHV
- Total inert
- CO2
- Wobbe

Western US utility and pipeline companies

Shorthand	Full name	Role
SDG&E	San Diego Gas & Electric	CA gas & electric utility
SCG	Southern California Gas (SoCalGas)	Largest US gas utility
SWG	Southwest Gas	AZ–NV–CA gas utility
PG&E	Pacific Gas & Electric	Northern CA utility
NGTL	NOVA Gas Transmission Ltd.	Western Canada pipeline
Dominion	Dominion Energy	US gas & power utility
Fortis	Fortis Inc. / FortisBC	Canadian gas utility
Oregon	NW Natural	Oregon gas utility
NWP	Northwest Pipeline (Williams)	Interstate gas pipeline

Carbon Dioxide

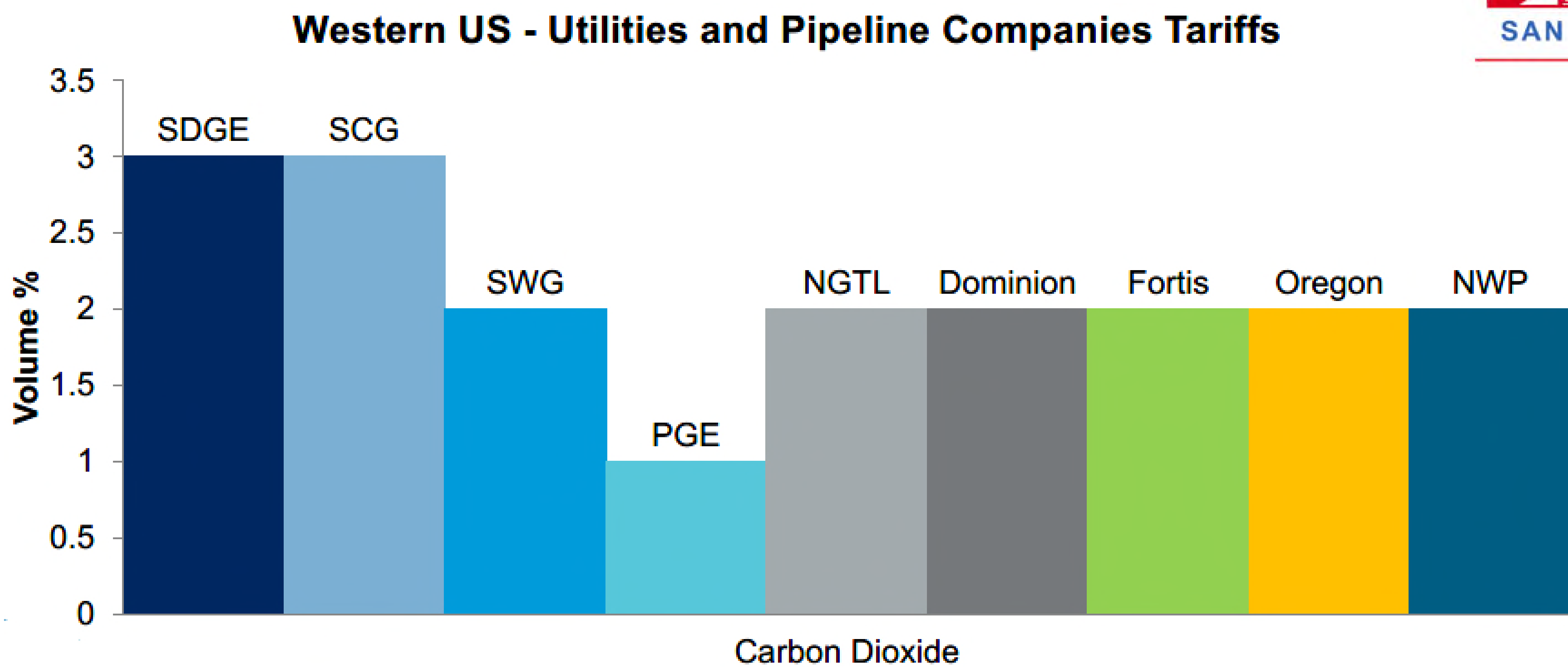
- Carbon Dioxide
  - CO2 dissolved in water forms carbonic acid, will corrode pipelines

$$H_2O_{liq} + CO_2 \rightarrow H_2CO_3$$

$$H_2CO_3 + Fe \rightarrow FeCO_3 + H_2$$

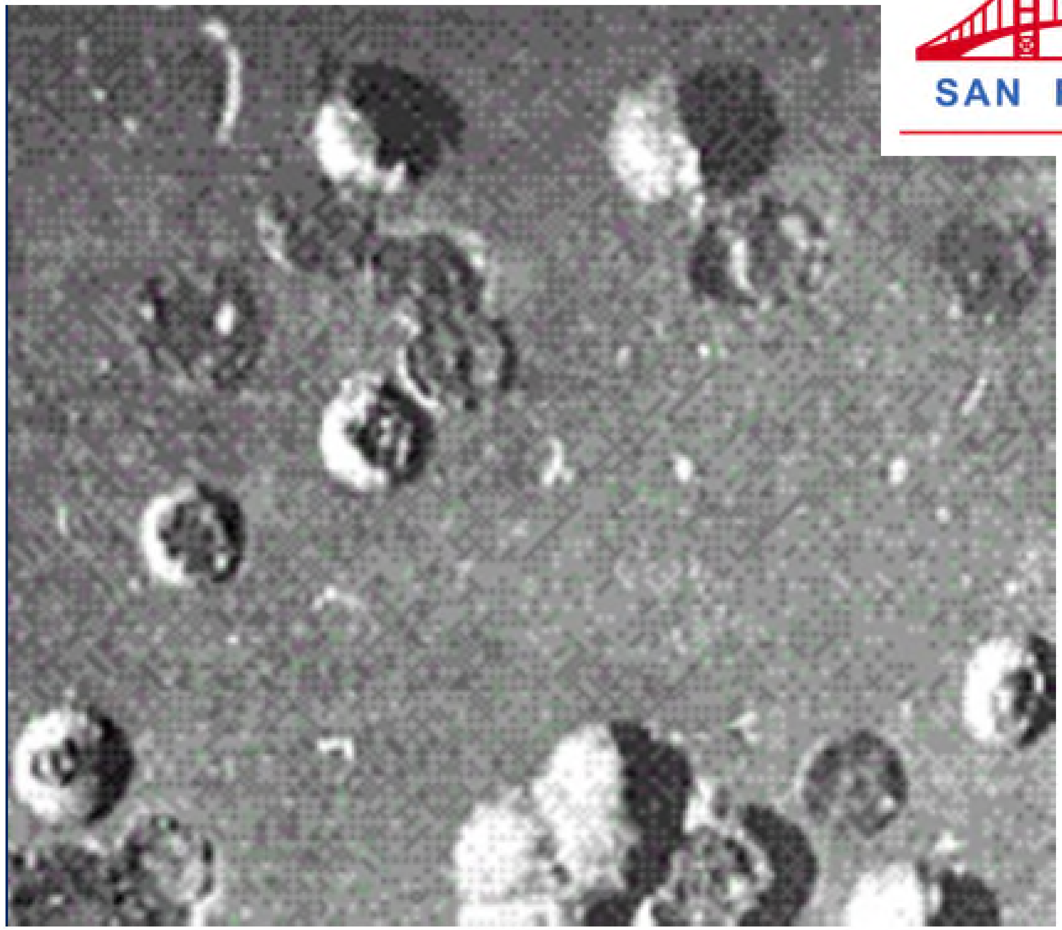
$$3FeCO_3 + \tfrac{1}{2}O_2 \rightarrow Fe_3O_4 + 3CO_2$$

Carbon Dioxide



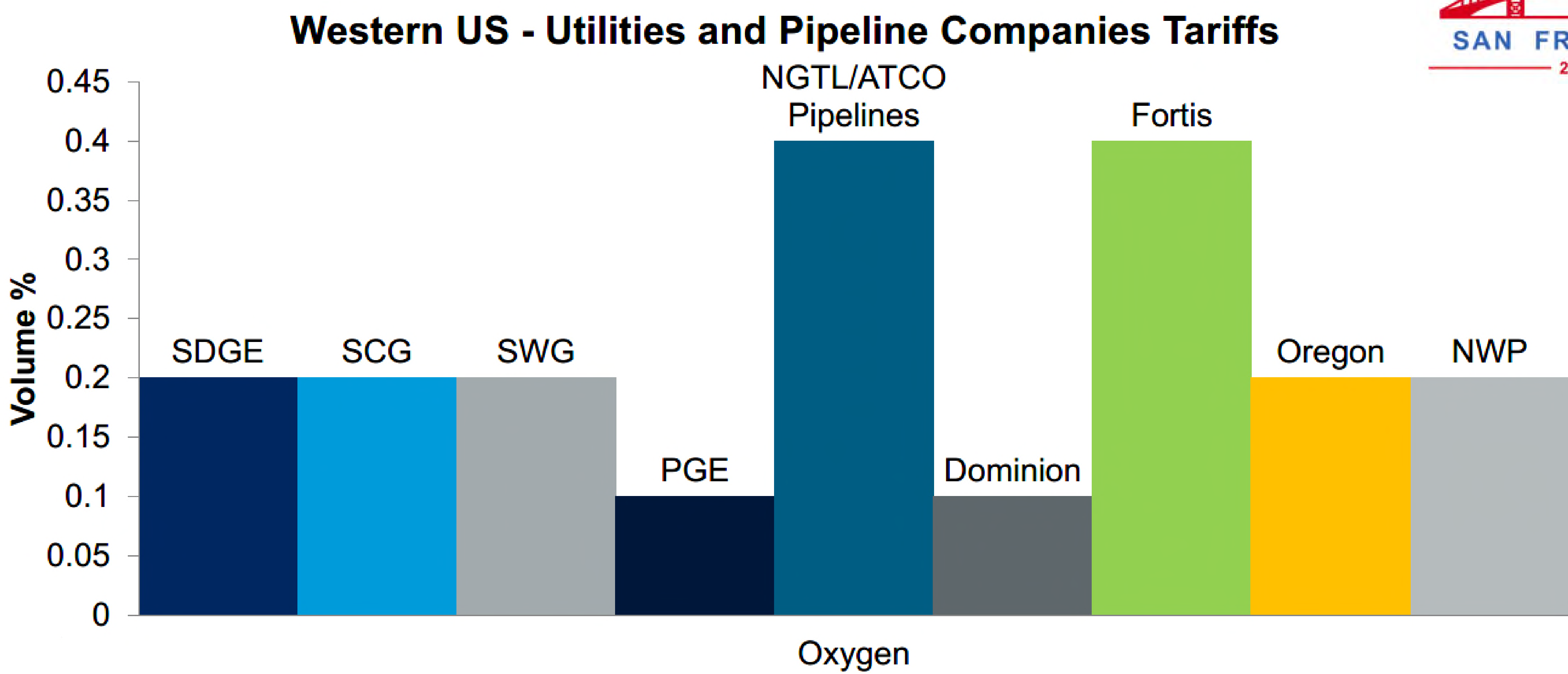
Oxygen

- Oxygen
  - O_2 can increase pitting corrosion rates 10X
  - O_2 in the presence of CO_2 or H_2S drastically increases their corrosivity
  - Direct oxidation of pipeline forms iron oxides



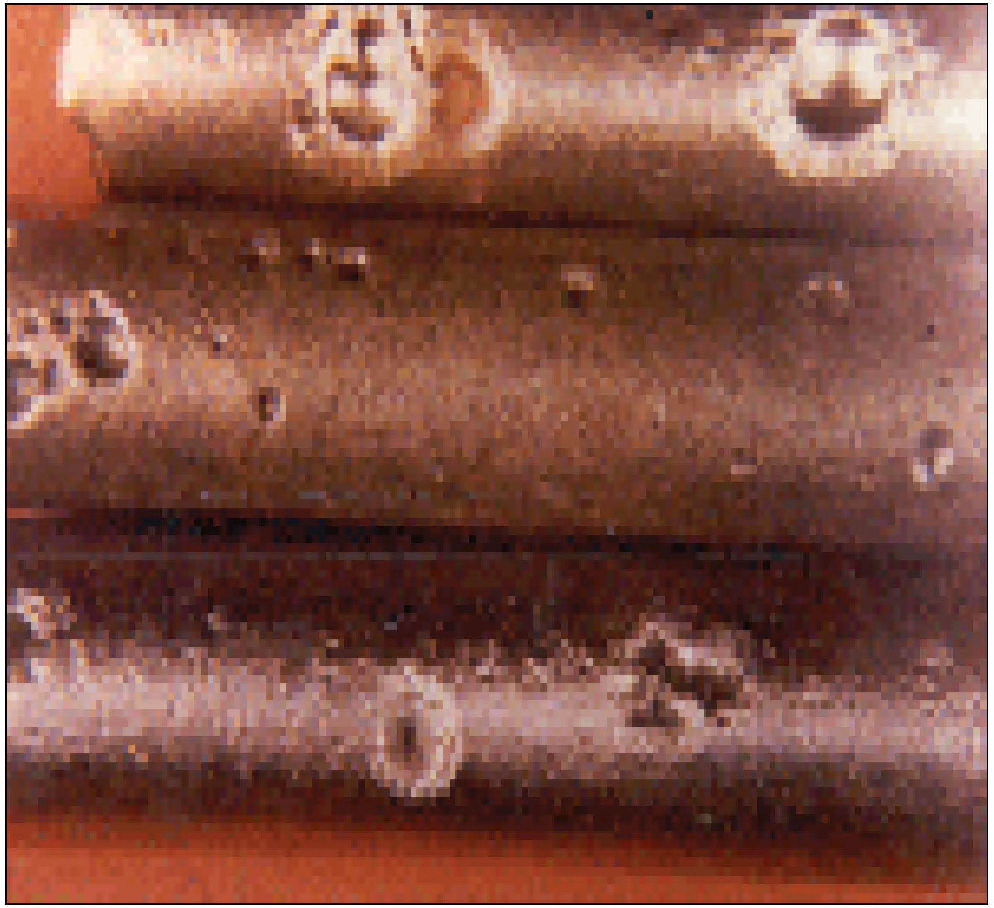
A common source of O2 intrusion are vapor recovery systems or vacuum wells

Oxygen

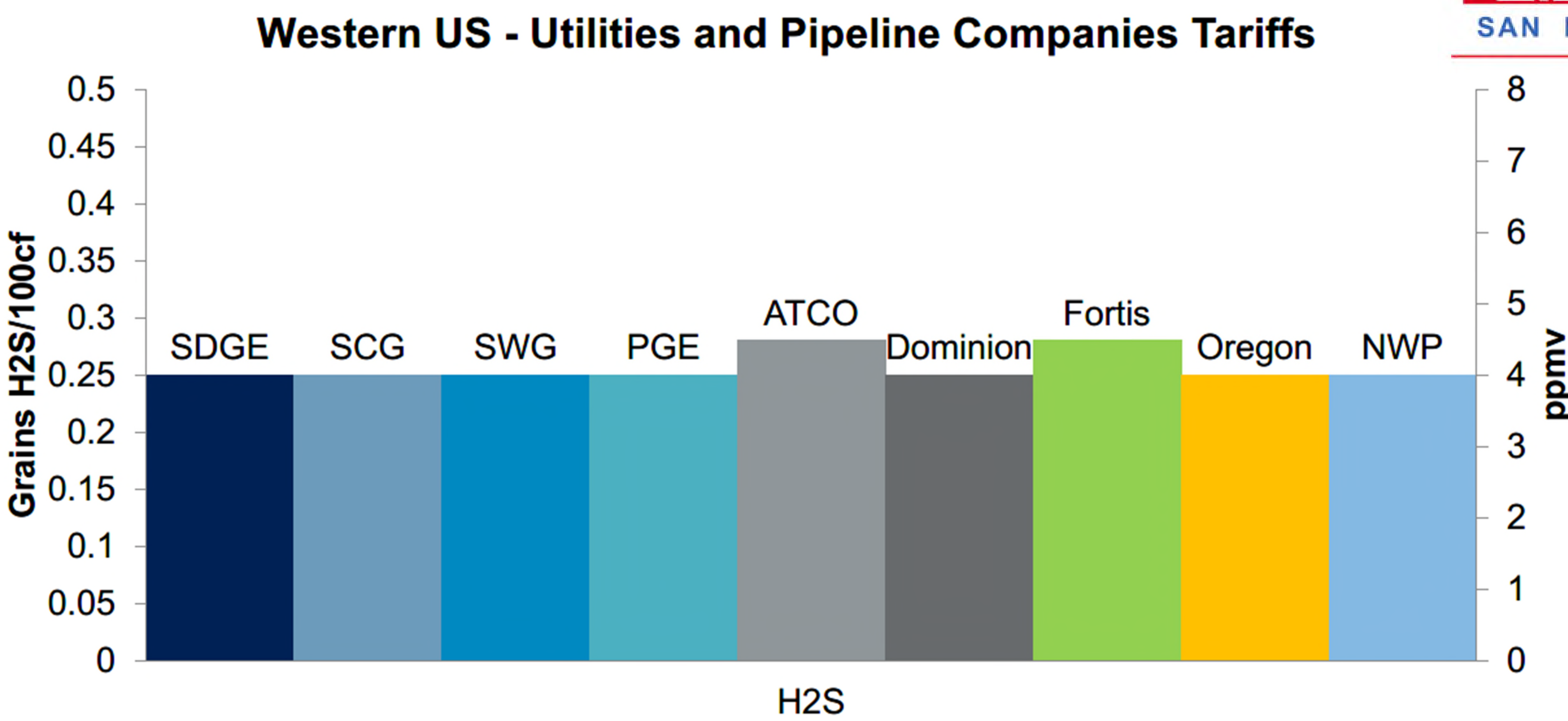

Western US - Utilities and Pipeline Companies Tariffs
Volume %
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
SDGE
SCG
SWG
PGE
NGTL/ATCO Pipelines
Dominion
Fortis
Oregon
NWP
Oxygen

Hydrogen Sulfide

- Hydrogen Sulfide
  - $H_2S + H_2O$ dissolves to form a weak acid which can then dissolve iron creating iron sulfide.
  - SOx emissions
  - Health and safety issues

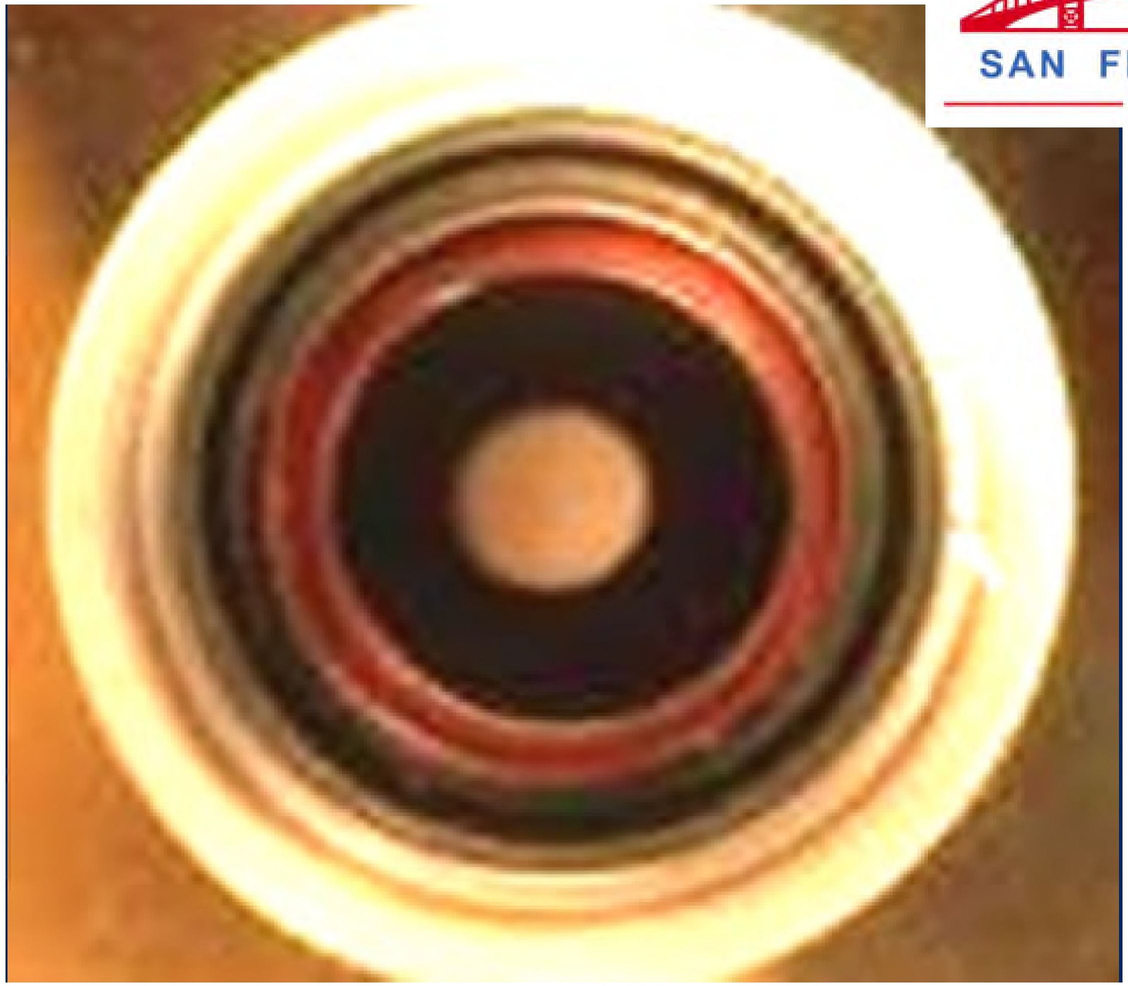


Hydrogen Sulfide



Liquids

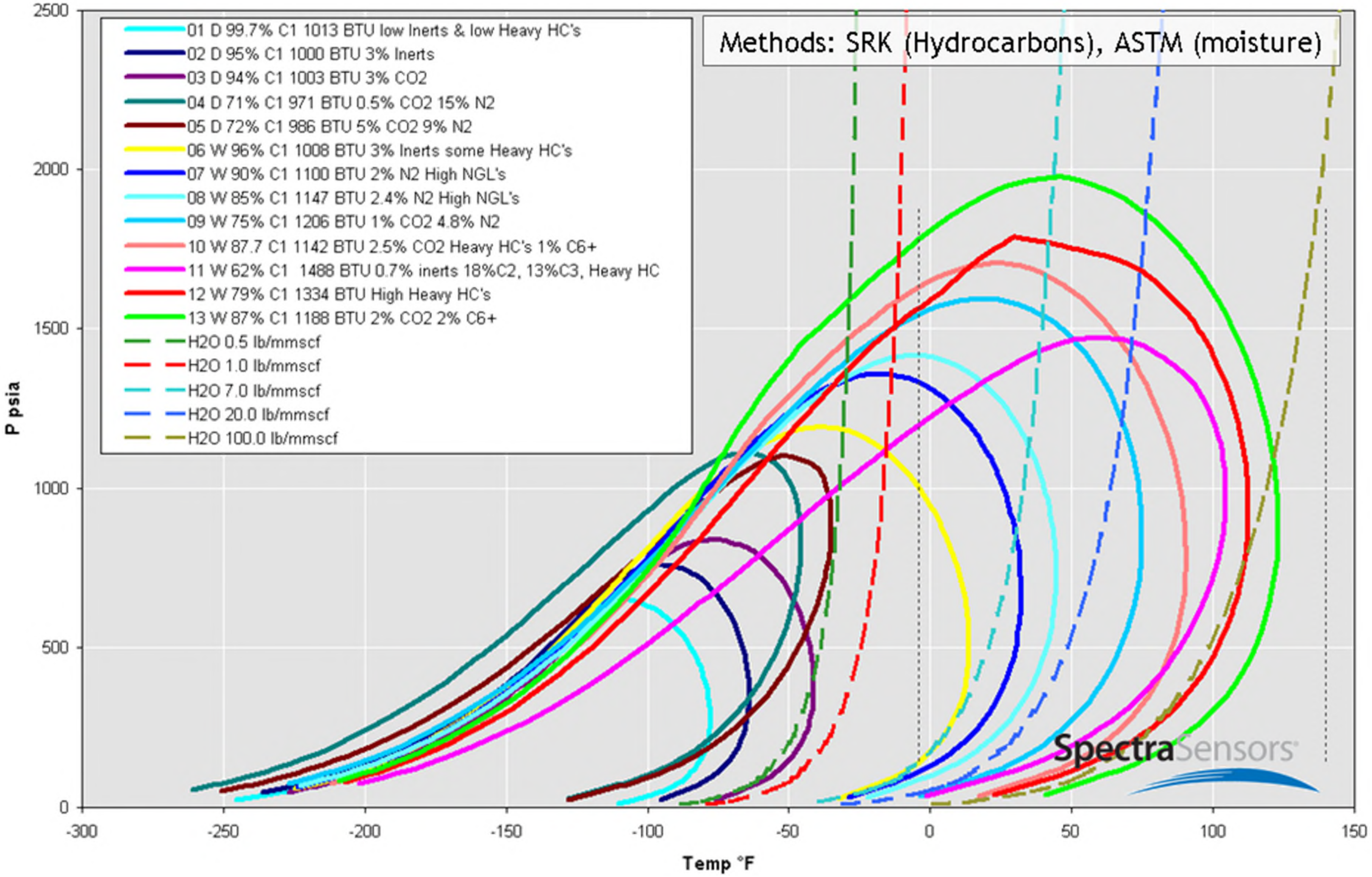
- Liquid water
  - Corrosion in wet environment
  - MIC occurs in water
- Hydrocarbon liquids
  - Hydrocarbon Dew points
- Condensation
- Accumulation in low spots

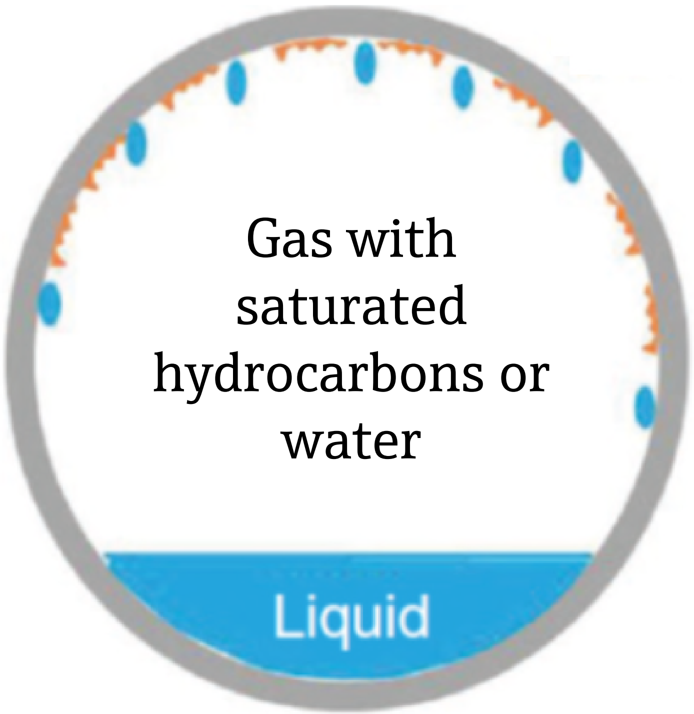


MIC = Microbiologically Influenced Corrosion

Dewpoint

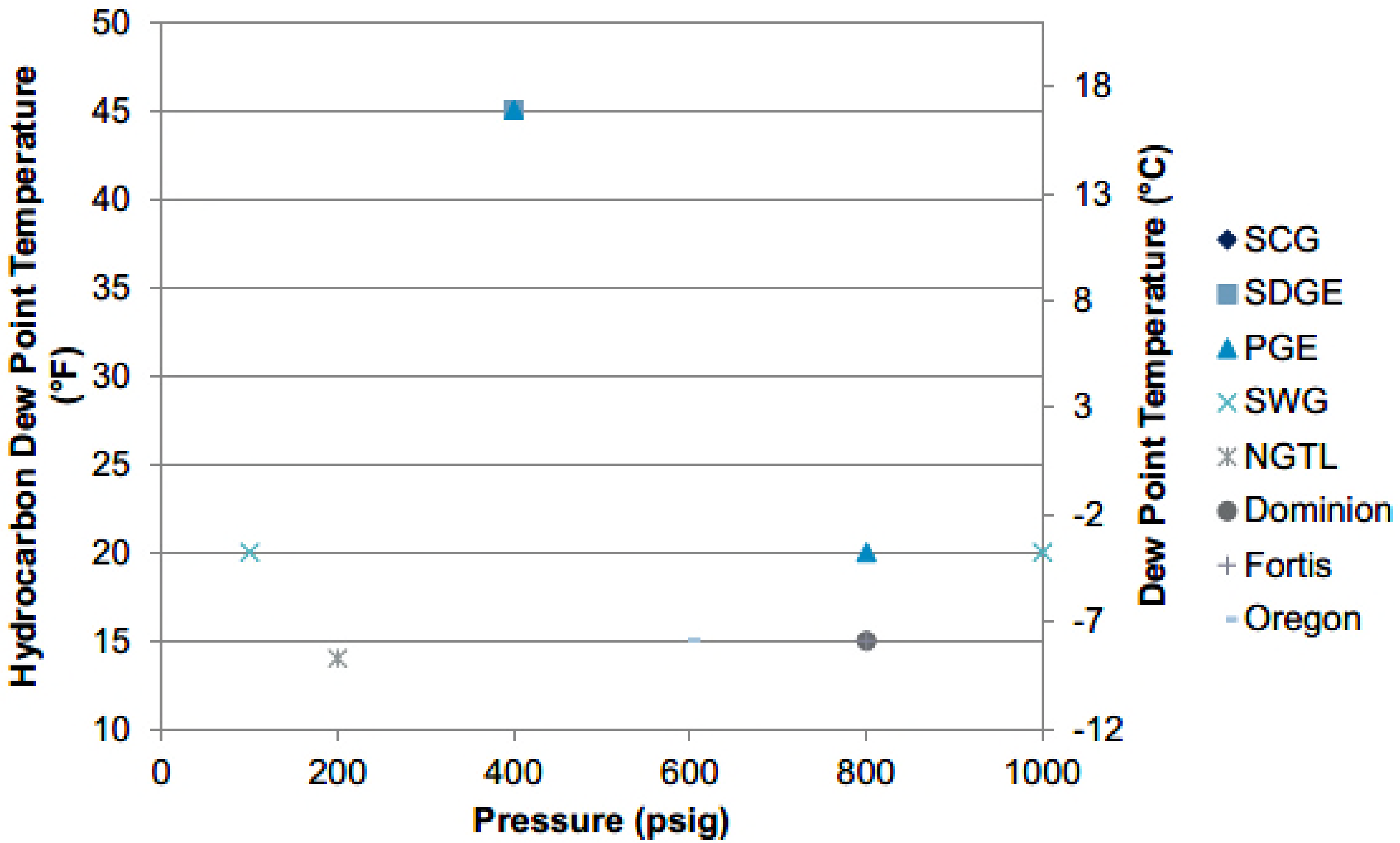
When gas temperature falls below the dewpoint; the gas may condense in the pipe



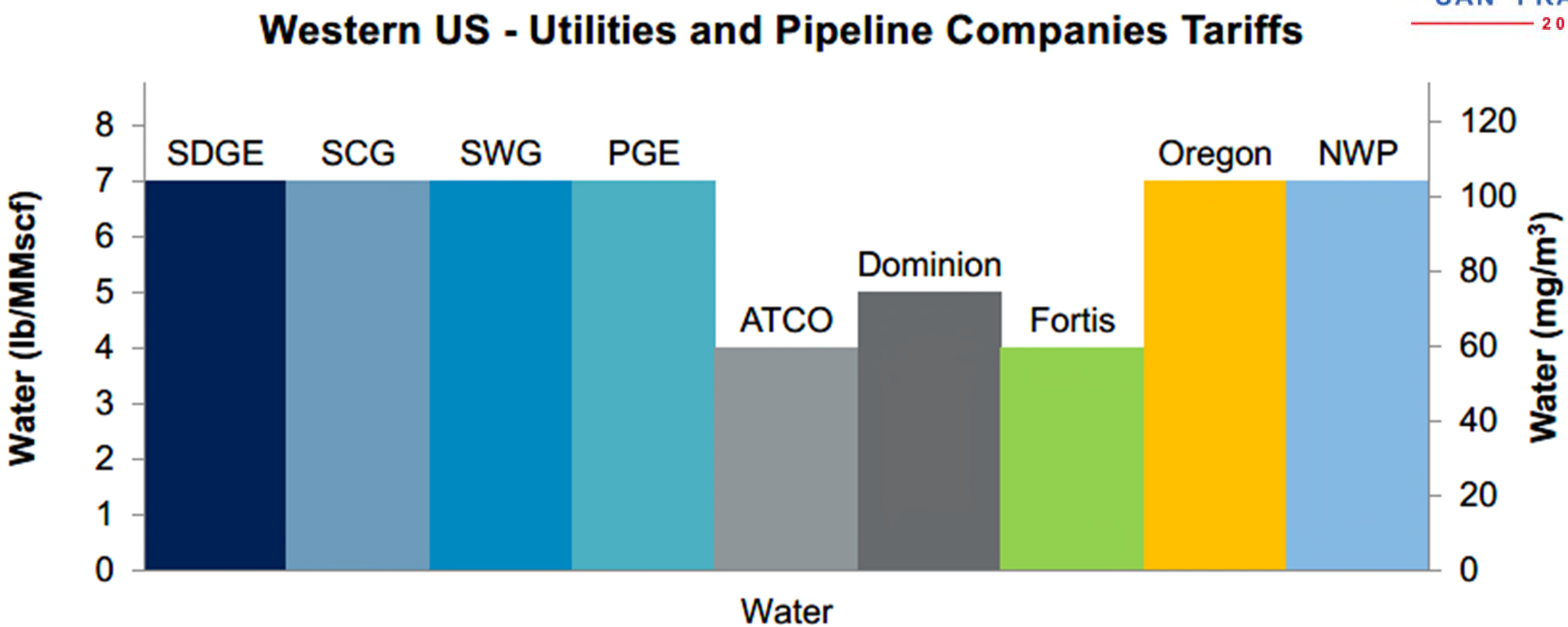


Gas Quality Specifications – Dew point

» **Western US- Utilities and Pipeline Companies Tariffs**



Gas Quality Specifications – Water



H_2O Units Conversion Table

Reference Condition Description	Source of reference condition	T (°C)	P (bara)	mg/m^3 per 1 ppmv	lb/MMscf per 1 ppmv	ppmv per lb/mmscf
Normal	Note 4 in ISO 13443:1996	0.0	1.01325 (14.70 psi)	0.8038	0.0502	19.930
Standard SI Units	ISO 13443, ISO 5024, ASTM D1071	15.0	1.01325 (14.70 psi)	0.762	0.0476	21.024
Standard Inch-Pound Units	ASTM D1071, AGA 8	15.56 (60°F)	1.01560 (14.73 psi)	0.762	0.0476	21.016

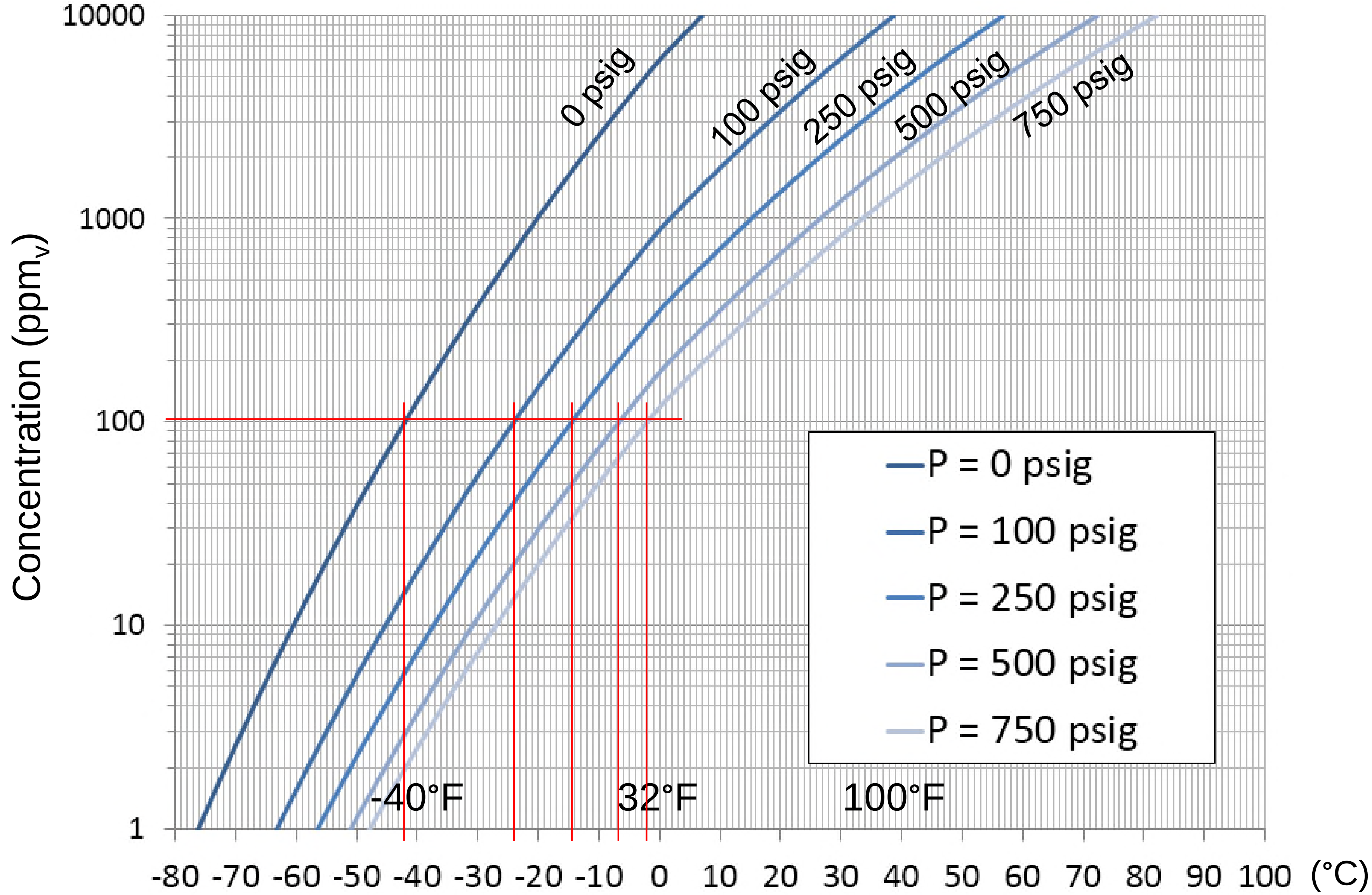
1 lb/mmscf ≈ 21 ppmv

- 1,000 ppb = 1 ppm
- 10,000 ppm = 1%
- ppmw – Calculated using weight of water per weight of natural gas. Weight of natural gas depends on stream composition and on the reference conditions

H_2O concentration vs. dewpoint

Notice how:

100 ppmv converts to different dewpoints depending on the pressure

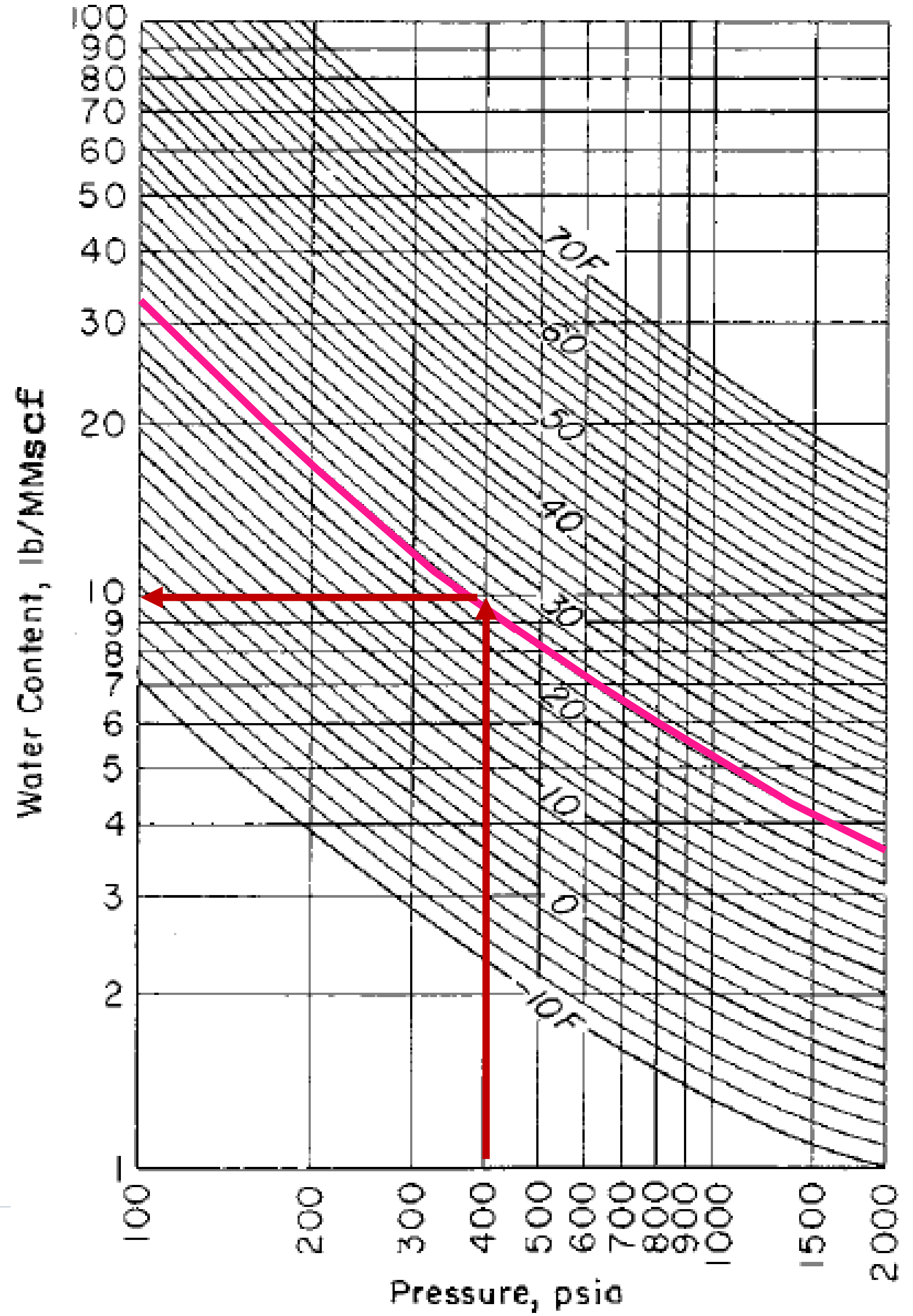


Endress+Hauser

H_2O concentration vs. dewpoint (ASTM D1142)

Manual Chart:

1. Read the dewpoint with chilled mirror (e.g. 25 °F)
2. Find pipeline pressure on X-axis (e.g. 400 psi)
3. Read the water content on Y-axis (e.g. 10 lbs/MMscf)



H_2O analyzer related standards

- **ASTM D7904** Standard Test Method for Determination of Water Vapor (Moisture Concentration) in Natural Gas by Tunable Diode Laser Spectroscopy (TDLAS)
- **ASTM D5454** Standard Test Method for Water Vapor Content of Gaseous Fuels Using Electronic Moisture Analyzers
- **ASTM D4888** Standard Test Method for Water Vapor in Natural Gas Using Length-of-Stain Detector Tubes
- **ASTM D1142** Standard Test Method for Water Vapor Content of Gaseous Fuels by Measurement of Dew-Point Temperature
- Also See **ISO 18453** Correlation water dew point

Technologies For Measuring Moisture

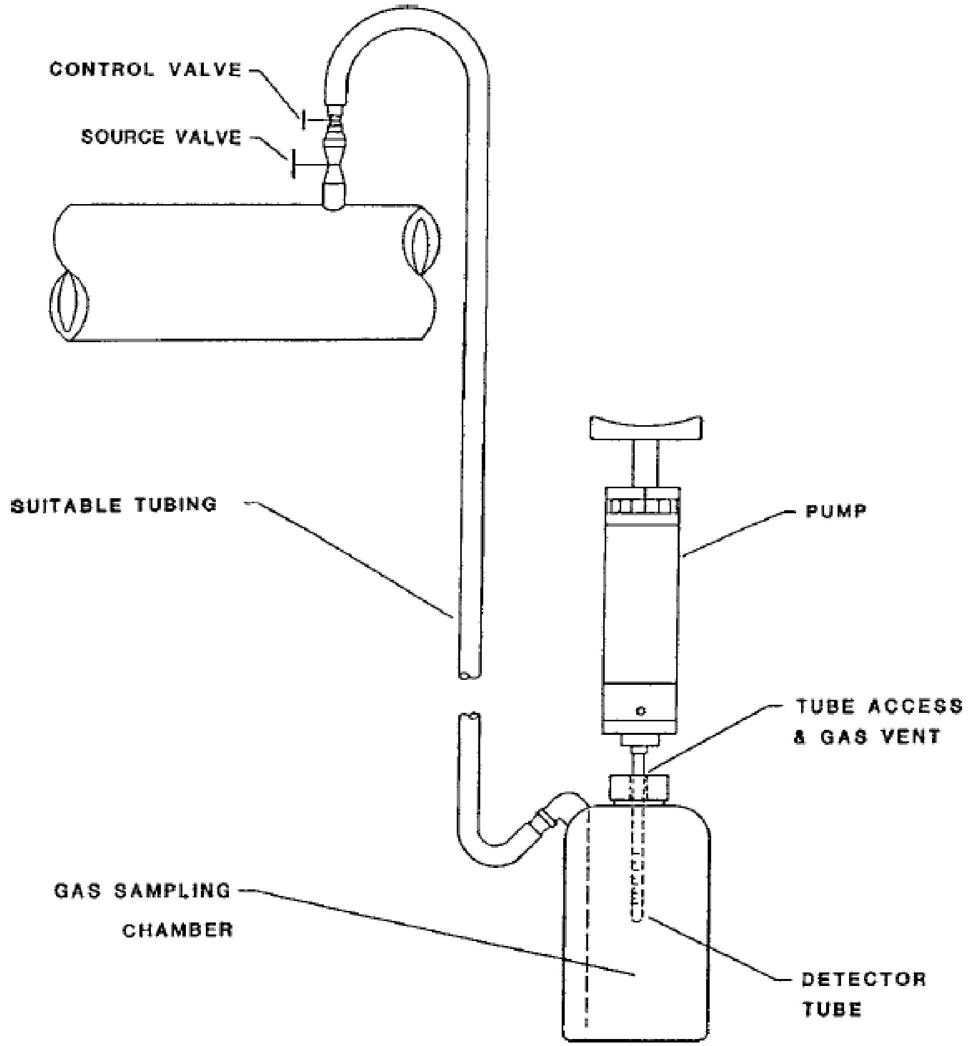
- Stain Tubes
- Electrochemical-based sensors
- Vibrating quartz crystal
- Chilled mirrors
- Laser Spectroscopy

H_2O measurement - Stain tubes

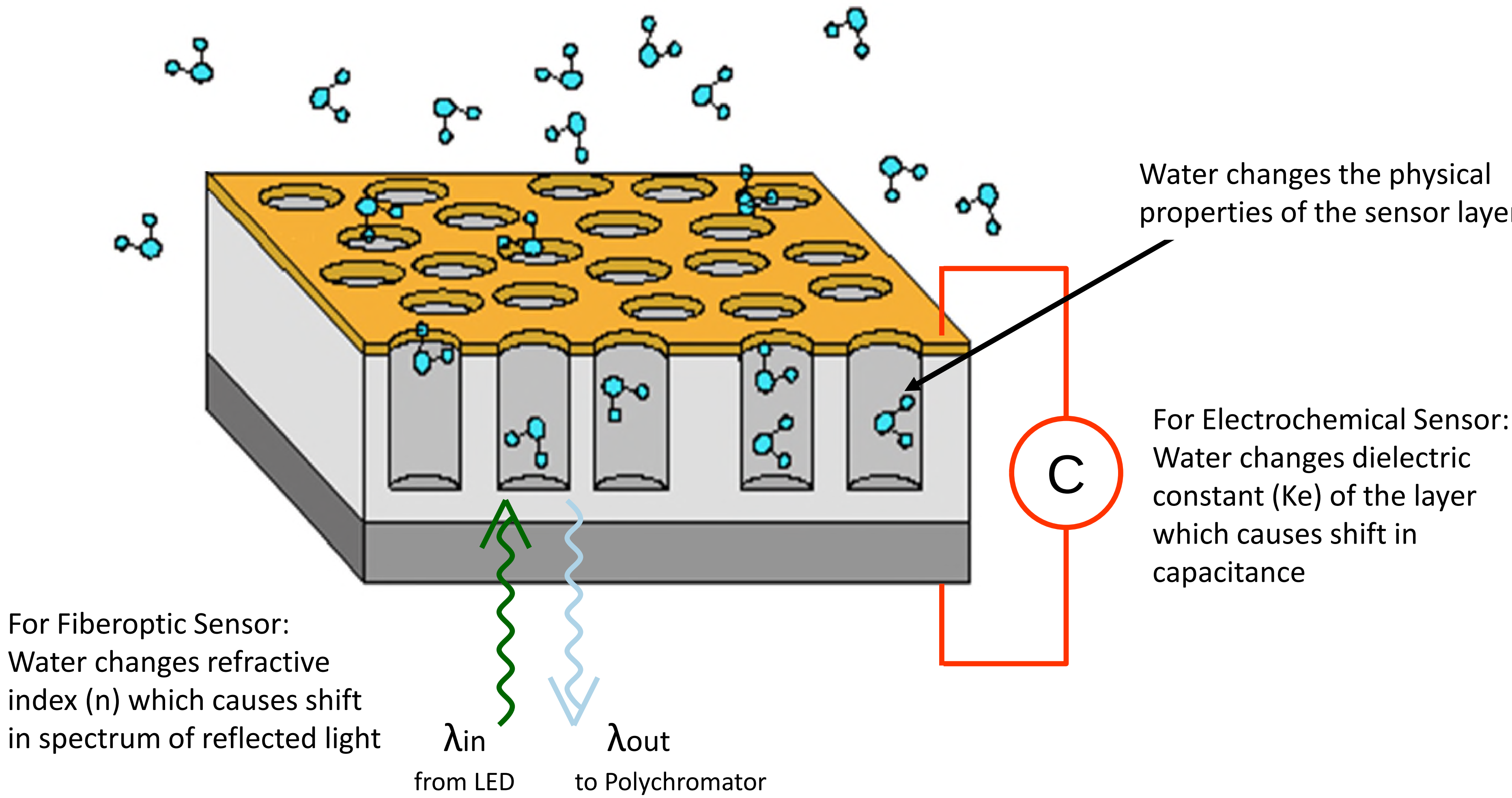
- Far less than $100 ea; one time use
- Operator skill dependent (exactly follow the ASTM method)
- Not an "Online" measurement (cannot be automated)

Colored by timed exposure to moisture

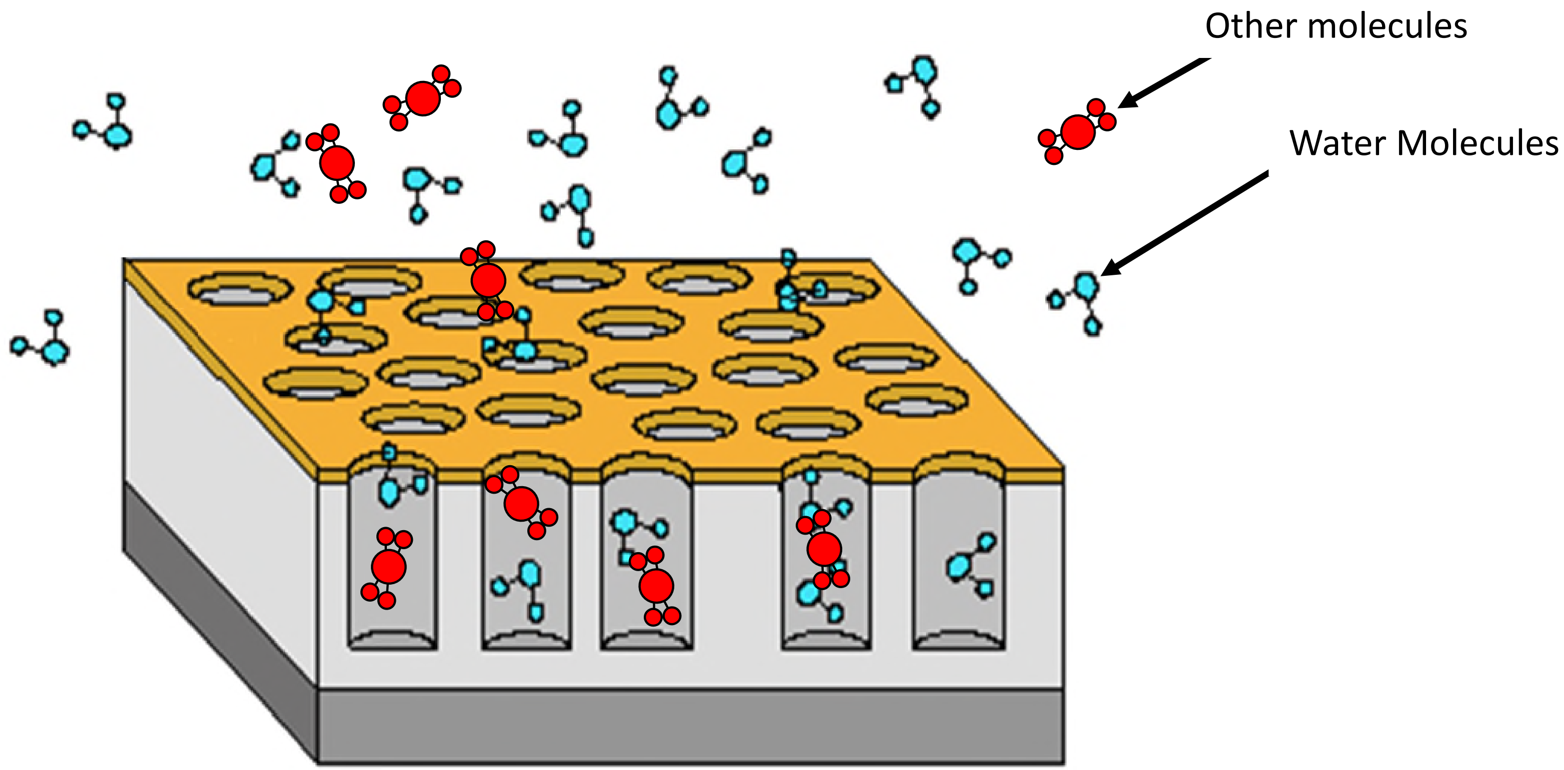
H_2O measurement - Stain tubes - Pump and Tube Apparatus



H_2O measurement – electrochemical (aluminum oxide)

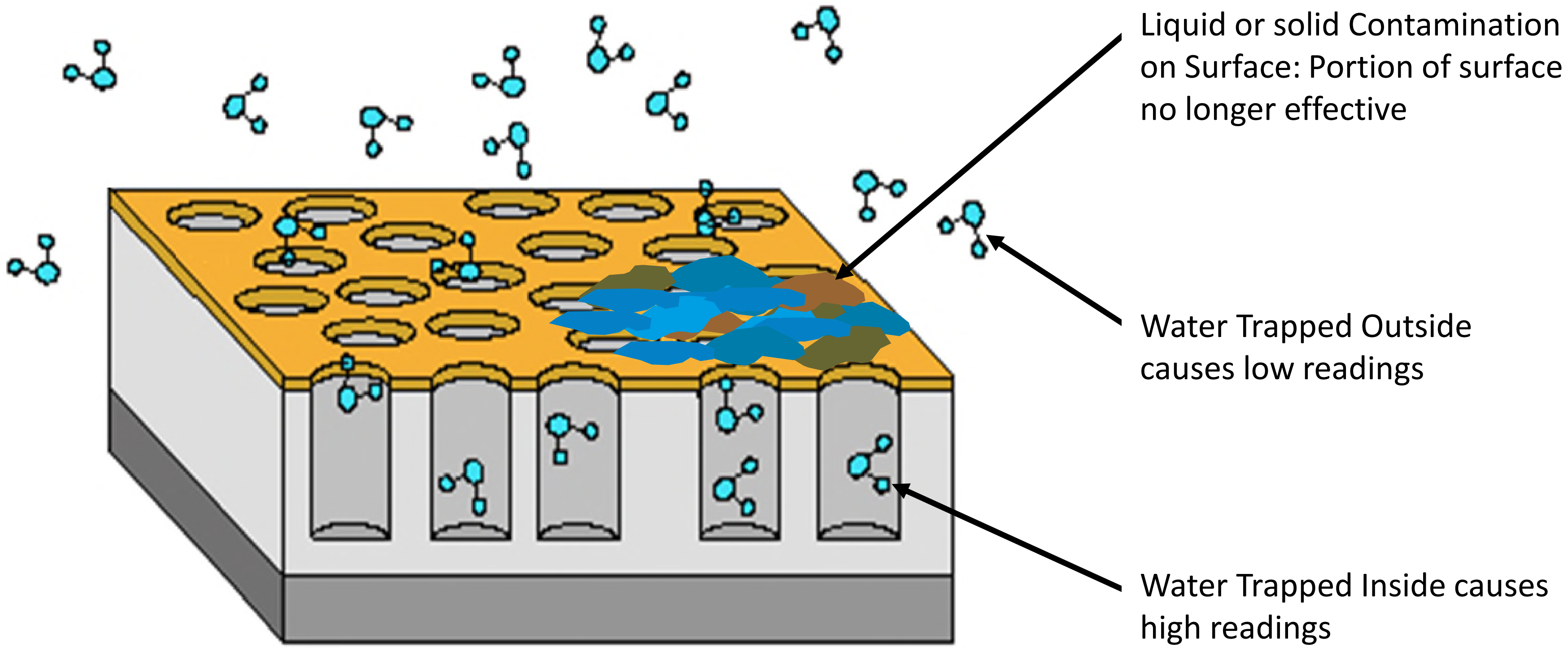


H_2O measurement – electrochemical (aluminum oxide)



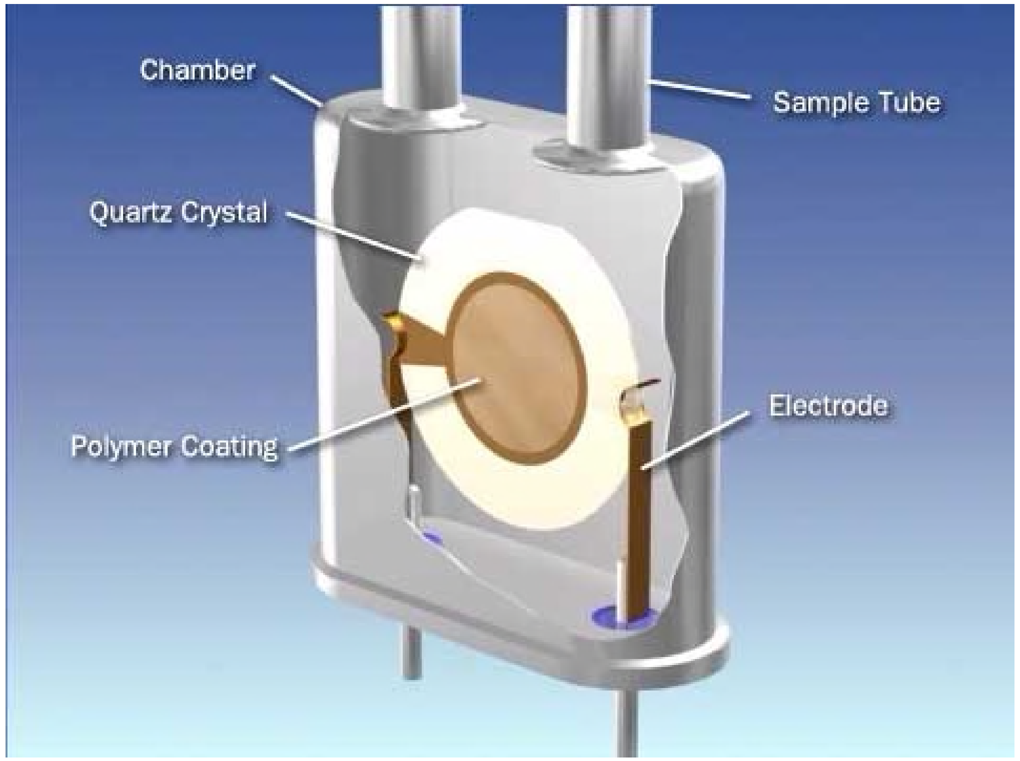
Possible Interference from Glycol or Methanol

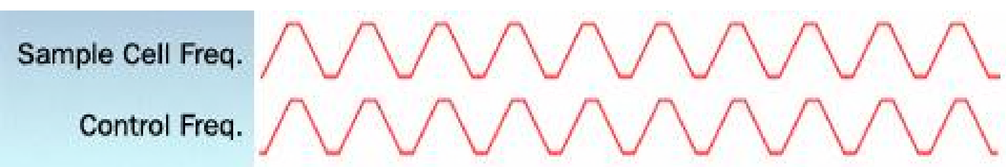
H_2O measurement – electrochemical (aluminum oxide)



Sample Conditioning is essential!

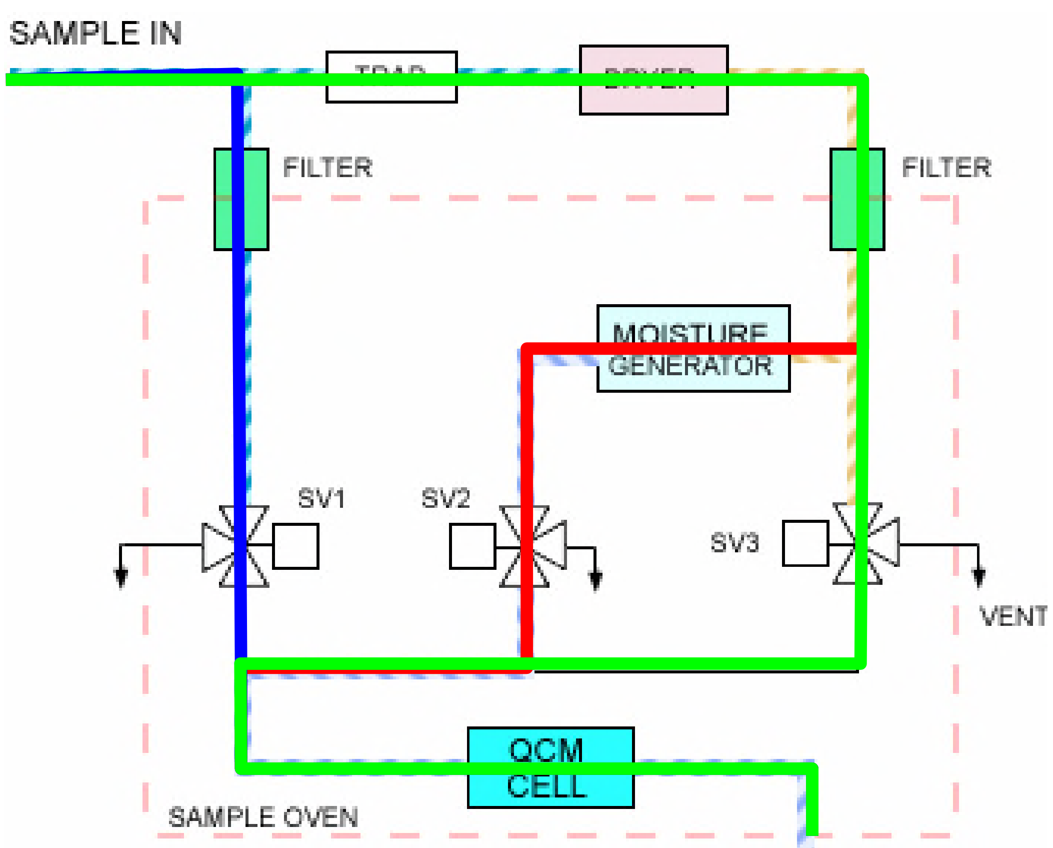
H_2O measurement – Quartz Crystal Microbalance (QCM)





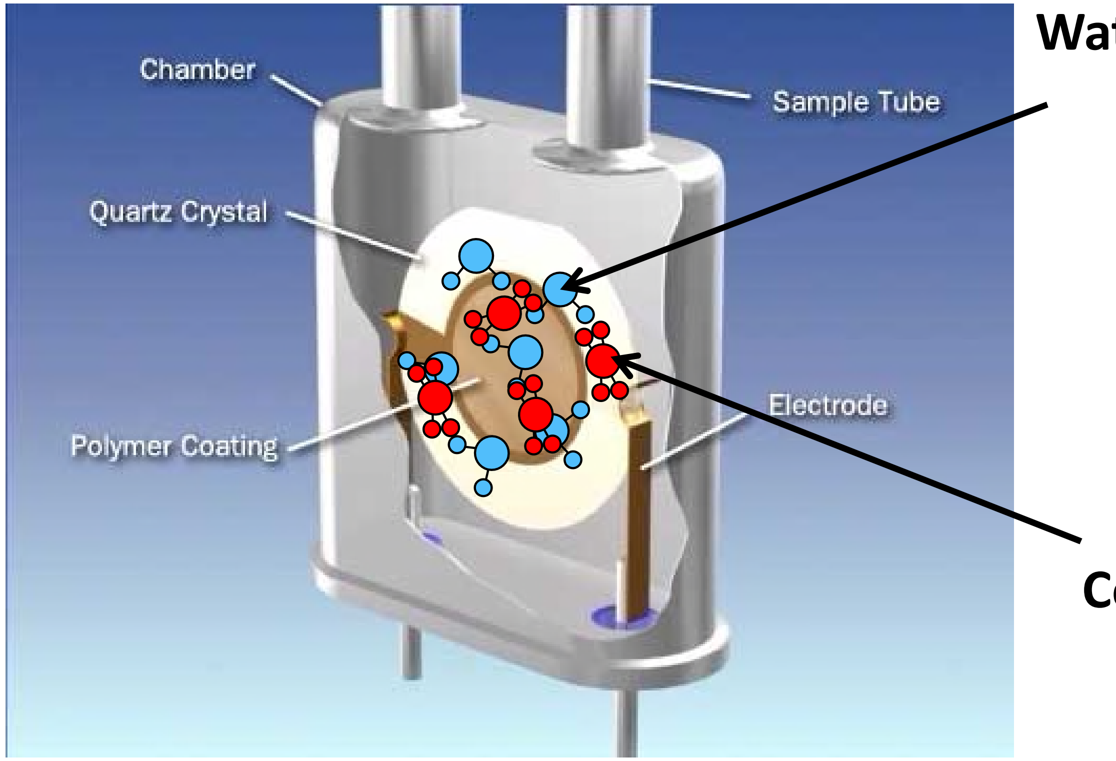
- Pair of electrodes support QCM sensor
- Voltage applied → Very stable oscillation occurs
- Faces of oscillator covered with hygroscopic polymer
- Moisture sorbs onto polymer
- Mass of QCM changes → corresponding change in frequency of oscillation

H_2O measurement – Quartz Crystal Microbalance (QCM)



- Sensor is very precise but does not have inherent accuracy…
- Moisture generator is used to calibrate the sensor on a regular basis

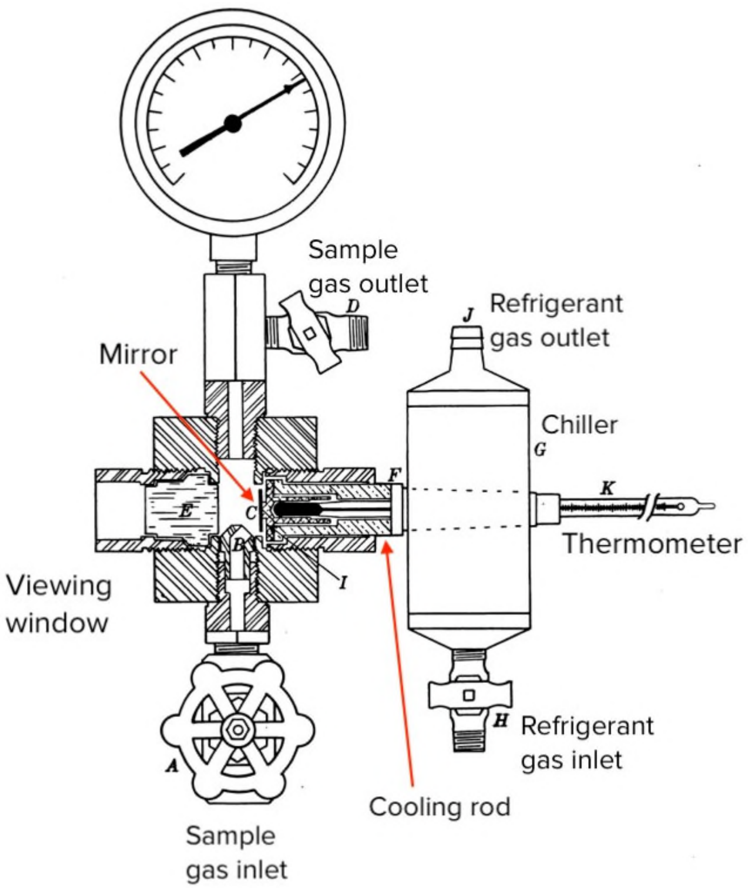
H_2O measurement – Quartz Crystal Microbalance (QCM)



Interference from Glycol, Methanol, Damage from H_2S

Proper Sample Conditioning Essential!

H_2O measurement – Chilled Mirror



Moisture Dew Point


Clean Mirror


Moisture Dew Point


Advanced Moisture Dew Point


Ice Point

Hydrocarbon Dew Point
(Using Gasoline)

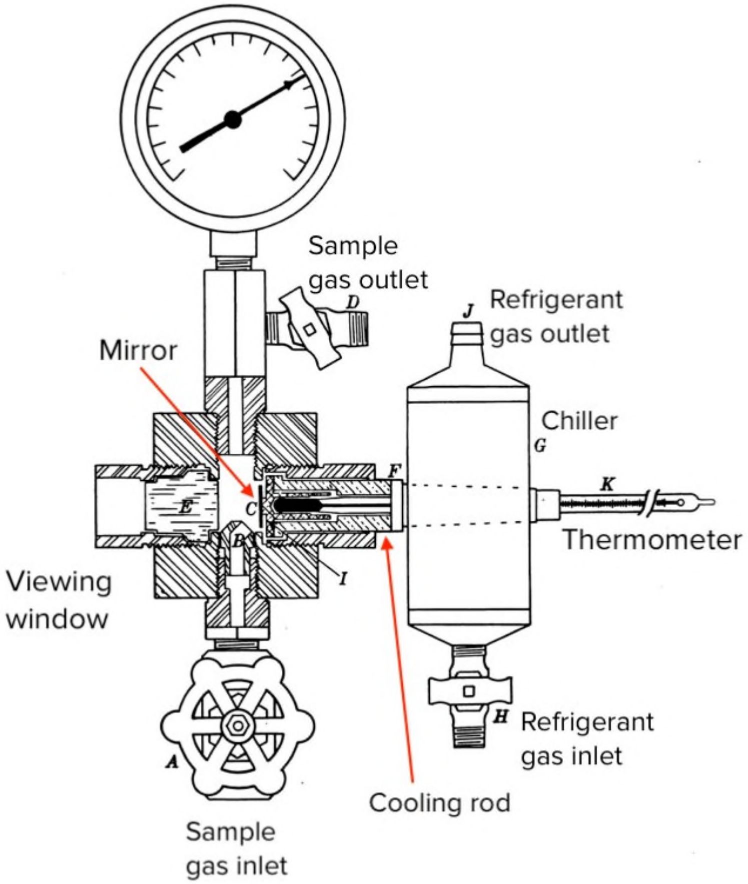

Iridescent Ring


Hydrocarbon Dew Point


Hydrocarbon II


Advanced Hydrocarbon

H_2O measurement – Chilled Mirror



Hydrocarbon Dew Point
(Using Propane)


Hydrocarbon Dew Point


Hydrocarbon II


Hydrocarbon III


Advanced Hydrocarbon

Miscellaneous Dew Points

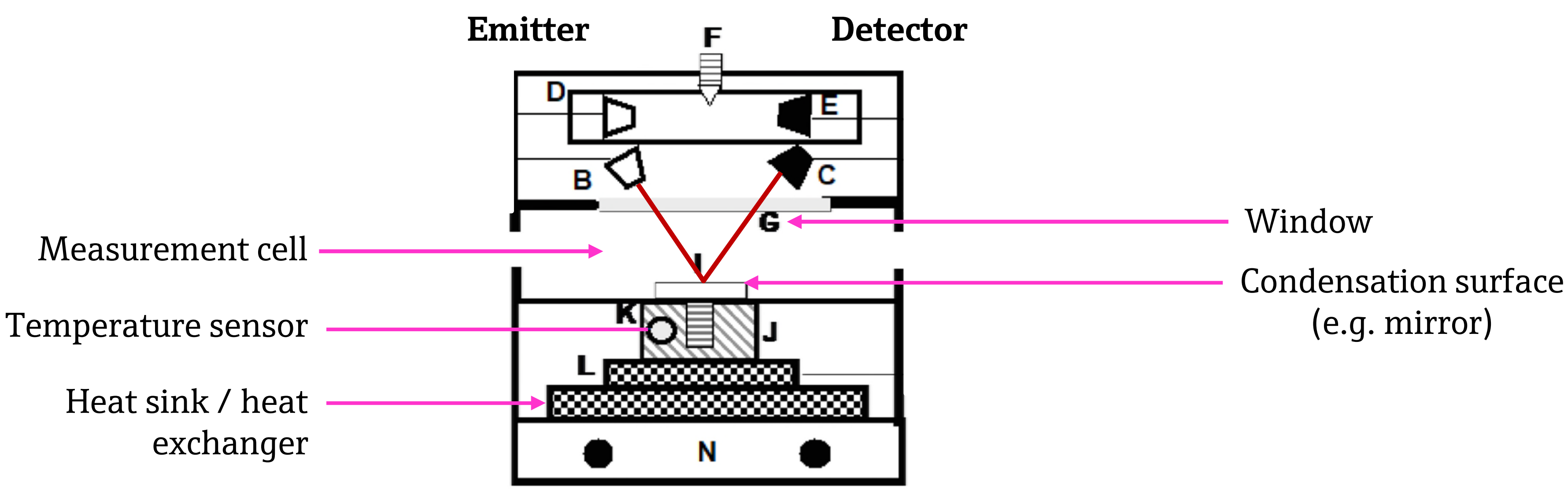

Alcohol Dew Point


Alcohol II


Advanced Alcohol


Glycol Dew Point

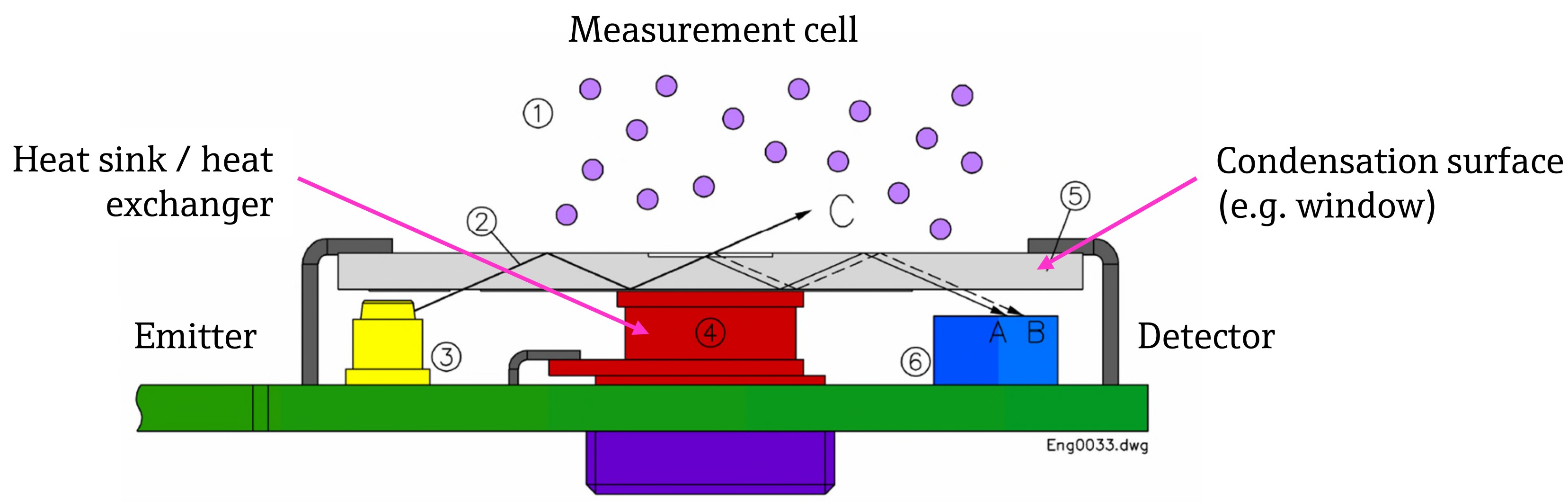
H_2O measurement – Automated Chilled Mirror



- Good for lab measurements (also available for field use)
- Used as a reference standard to calibrate field analyzers
- Slow response time due to temperature cycling process

Source: Moisture measurement technologies for natural gas, March 2025, Gerard McKeogh, Panametrics

H_2O measurement – Automated Chilled Mirror “chilled ATR”

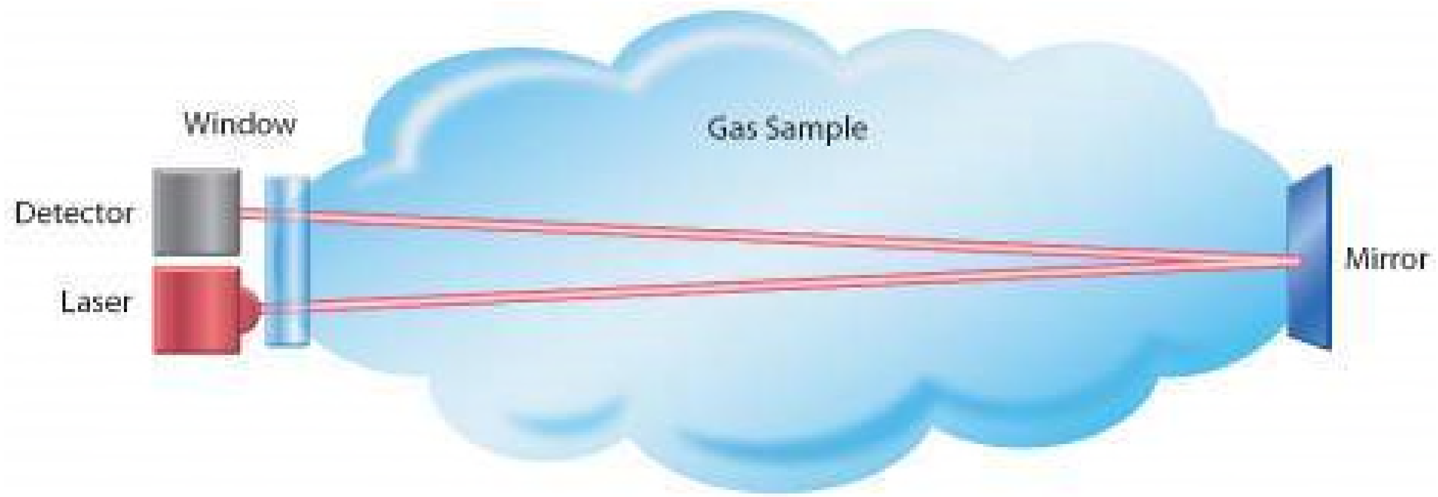


- Made for field measurements. Optics are not exposed to gas.
- May discriminate between H_2O, methanol, hydrocarbons
- Slow response time due to temperature cycling process.

Source: Bartec

H_2O measurement – Laser-based optical absorption spectroscopy

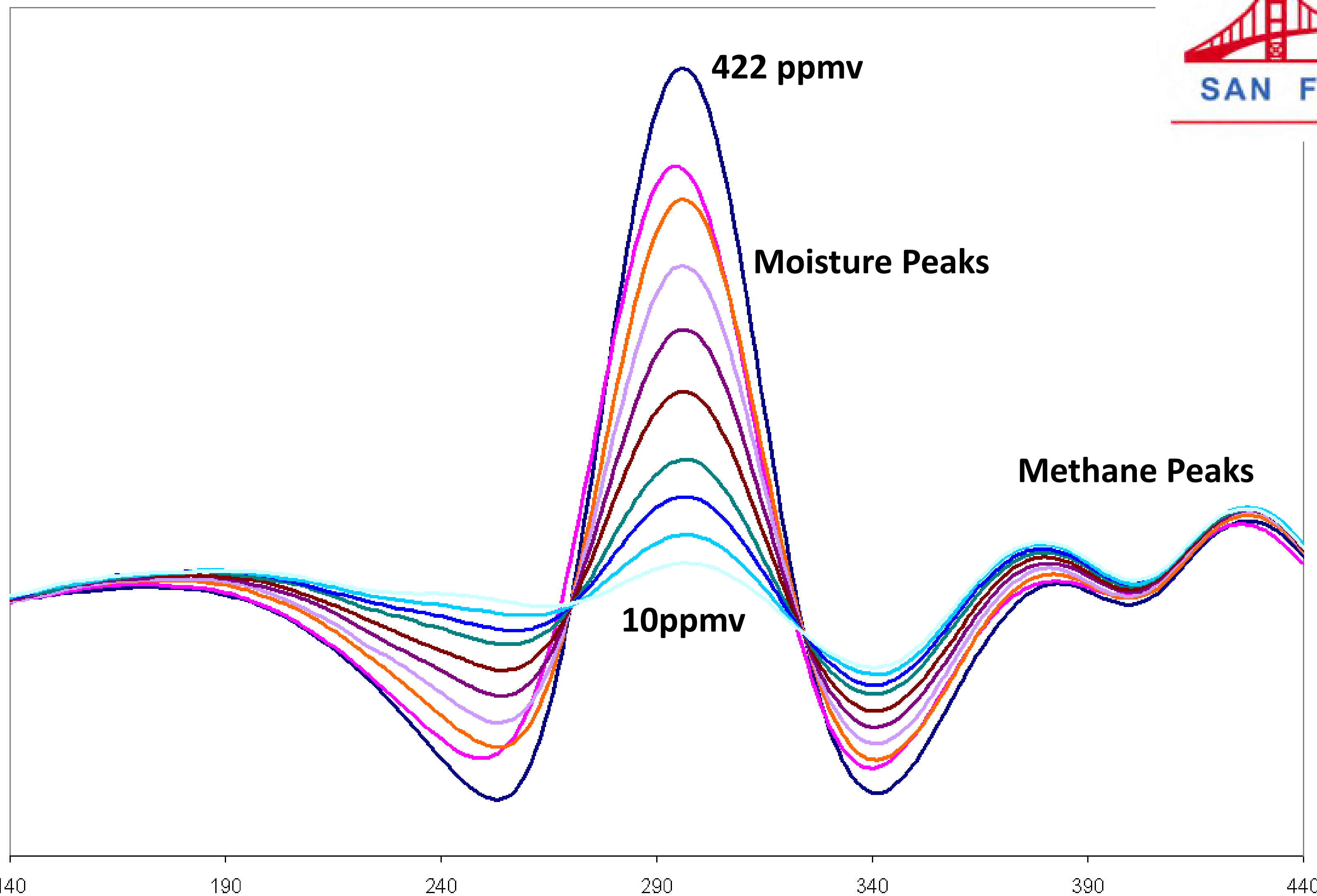
- TDLAS analyzers measure absorption of light in near-infrared spectrum to determine moisture concentration in the gas sample.
- Simple: Light that does not arrive at the detector gives us the optical absorbance i.e. concentration of water vapor in the gas stream



Source: Endress+Hauser

H_2O measurement – Laser-based optical absorption spectroscopy

- Graph shows various water spectrum in natural gas and demonstrates excellent signal to noise ratio – these are actual spectrum downloads
- No methanol (or other) interferences
- Real time response



Hydrates

- **Presence of "Free" Water**: Hydrates may form with liquid water or high water vapor saturation
- **Low Temperatures:** Temperatures must be at or below the hydrate formation threshold for a given pressure
- **High Operating Pressures:** Elevated pressures stabilize the crystalline structure
- Hydrates can form at temperatures above freezing if the pressure is sufficiently high

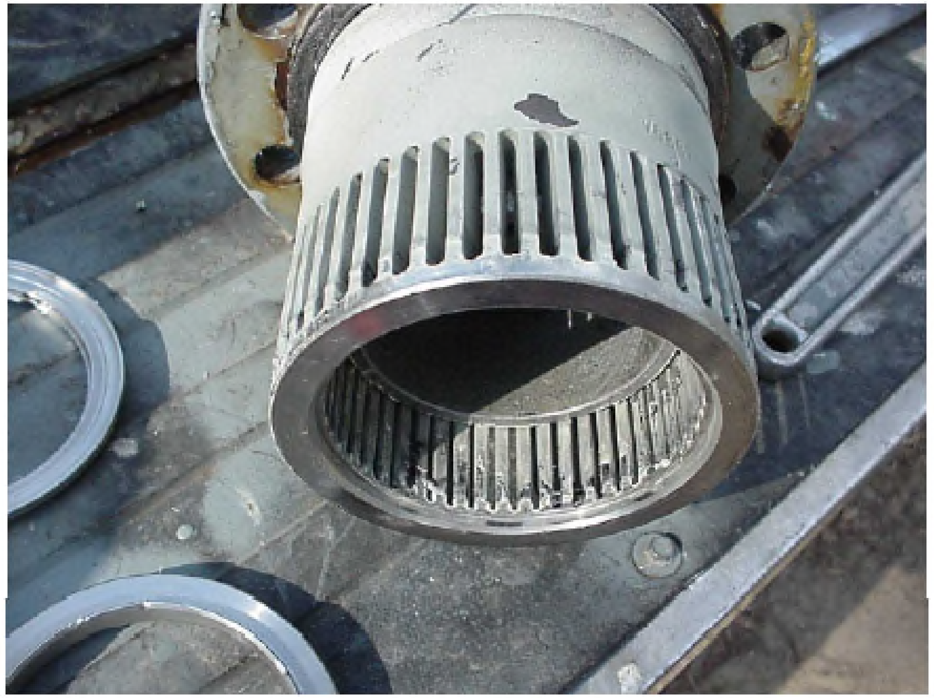
Sulfur

Gaseous

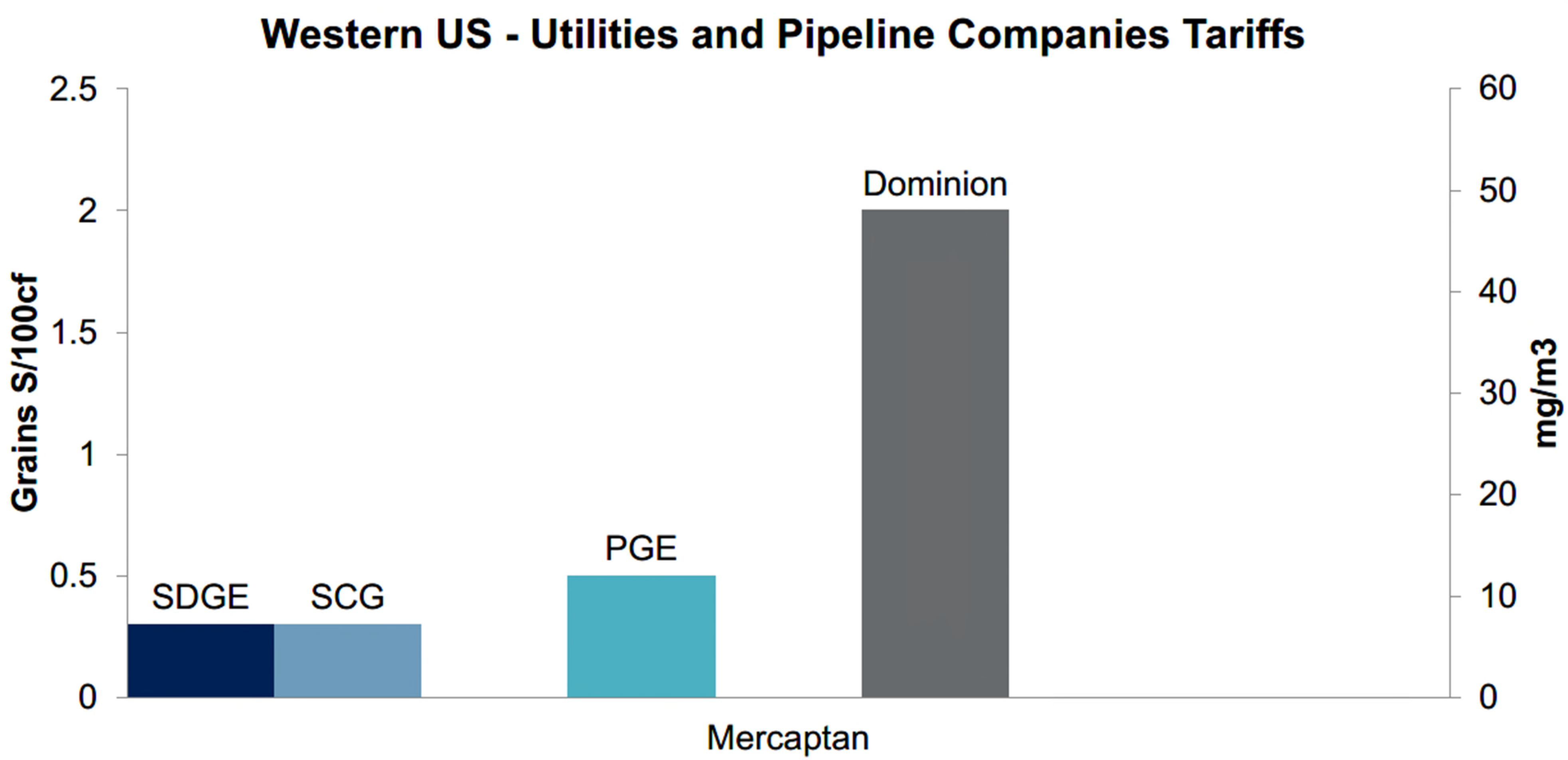
- Hydrogen Sulfide
- Mercaptans
- Odorant
- Total Sulfur

Solid

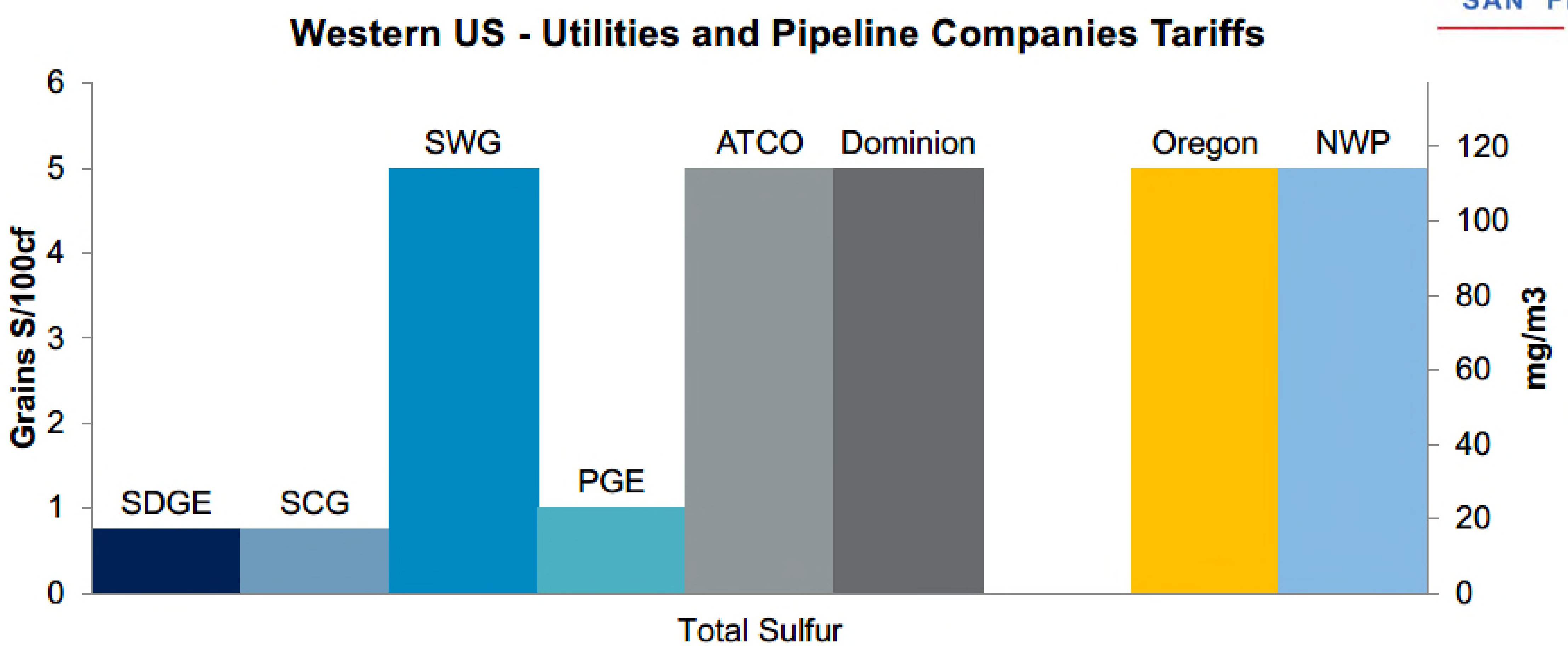
- Elemental sulfur (S_8)
- Dithiazine (solid byproduct formed when H_2S reacts with triazine (a H_2S scavenger)



Gas Quality Specifications - Mercaptans



Gas Quality Specifications - Sulfur



Common Sulfur Compounds

Name	Chemical Formula	Abbreviation	Molecular Weight
Sulfides			
Hydrogen Sulfide	H_2S	H_2S	32.08
Carbonyl Sulfide	COS	COS	60.07
Dimethyl Sulfide	CH_3SCH_3	DMS	62.13
Methylethyl Sulfide	$CH_3SCH_2CH_3$	MES	76.16
Diethyl Sulfide	$CH_3CH_2SCH_2CH_3$	DES	90.19
Diallyl Sulfide	$CH_2CHCH_2SCH_2CHCH_2$	DAS	114.21
Dipropyl Sulfide	$CH_3(CH_2)_2S(CH_2)_2CH_3$	DPS	118.24
Dibutyl Sulfide	$CH_3(CH_2)_3S(CH_2)_3CH_3$	DBS	146.30
Mercaptans			
Methyl Mercaptan	CH_3SH	MeSH	48.11
Ethyl Mercaptan	CH_3CH_2SH	EtSH	62.13
Popyl Mercaptan	$CH_3CH_2CH_2SH$	PrSH	76.17
iso-Propyl Mercaptan	$(CH_3)_2CHSH$	i-PrSH	76.17
Normal Butyl Mercaptan	$CH_3(CH_2)_3SH$	n-BuSH	90.19
Secondary Butyl Mercaptan	$CH_3CH(SH)CH_2CH_3$	s-BuSH	90.19
iso-Butyl Mercaptan	$(CH_3)_2CHCH_2SH$	i-BuSH	90.19
Tertiary Butyl Mercaptan	$(CH_3)_3CSH$	t-BuSH	90.19
Disulfides			
Carbon Disulfide	CS_2	CS2	76.13
Dimethyl Disulphide	$CH_3S_2CH_3$	DMDS	94.20
Methylethyl Disulfide	$CH_3S_2CH_2CH_3$	MEDS	108.23
Diethyl Disulfide	$CH_3CH_2S_2CH_2CH_3$	DEDS	122.25
Dipropyl Disulfide	$CH_3(CH_2)_2S(CH_2)_2CH_3$	DPDS	150.31
Tetrahydro Thiophene	$CH_2CH_2CH_2CH_2S$	THT	88.00

Arrows indicate main sulfur compounds in Natural Gas

H2S, Total Sulfur measurement techniques

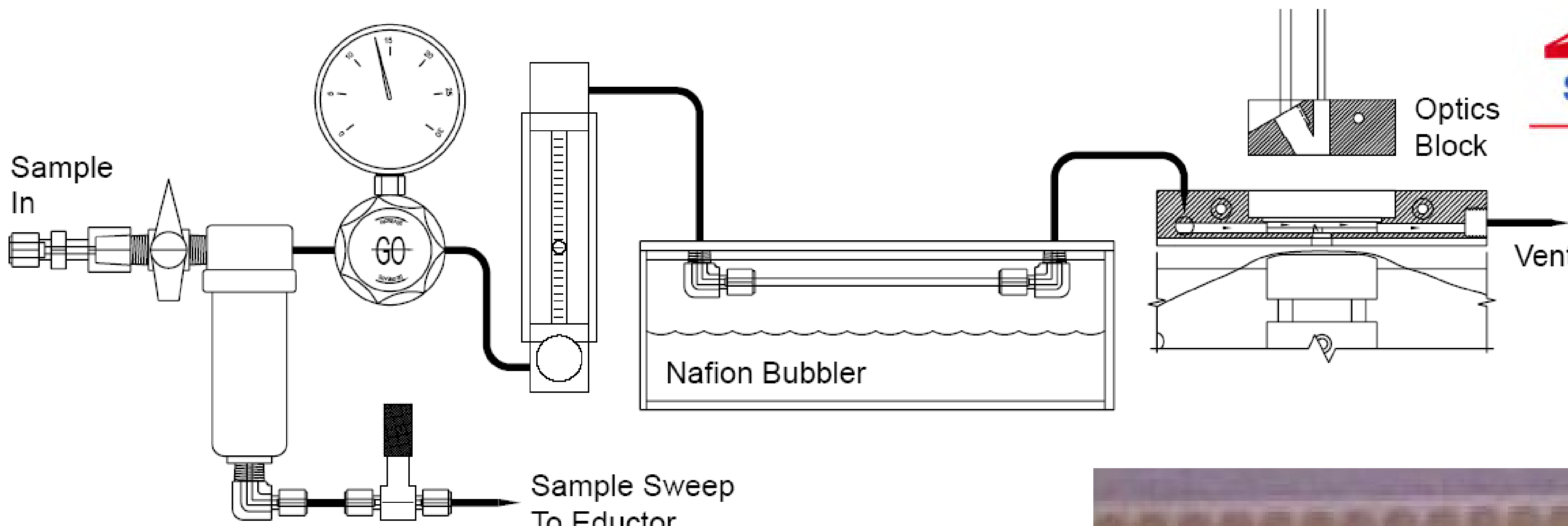
- Electrochemical
- Lead Acetate Tape
- Gas Chromatography
- Ultraviolet (UV) Photometer
- Laser Spectroscopy

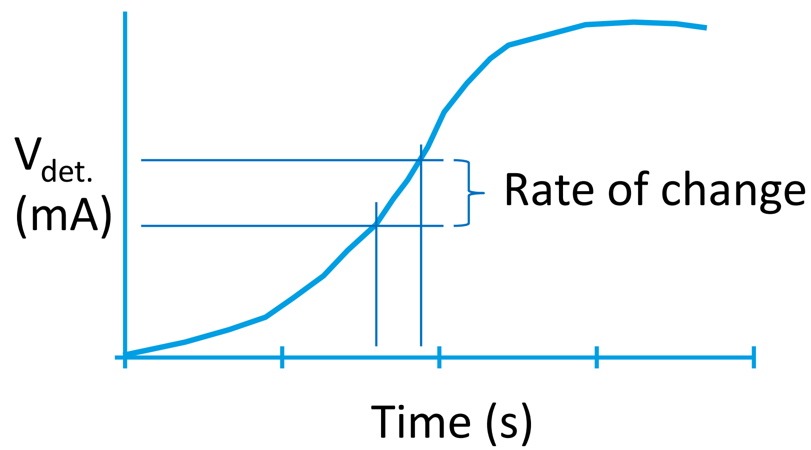
H2S Measurement - Electrochemical

- Compact and inexpensive
- On-line or portable uses
- Significant interferences with Methyl Mercaptan, Sulfur Dioxide SO2
- Susceptible to damage by corrosives and condensables
- Decays with time, requires recalibration
- Generally used as area monitors

H2S Measurement - Lead Acetate Tape Analyzer

- Lead sulfide is brown and darkens the tape
- Rate of change of darkness is proportio… H2S
- Typically, every 3-5 minutes, the tape advances

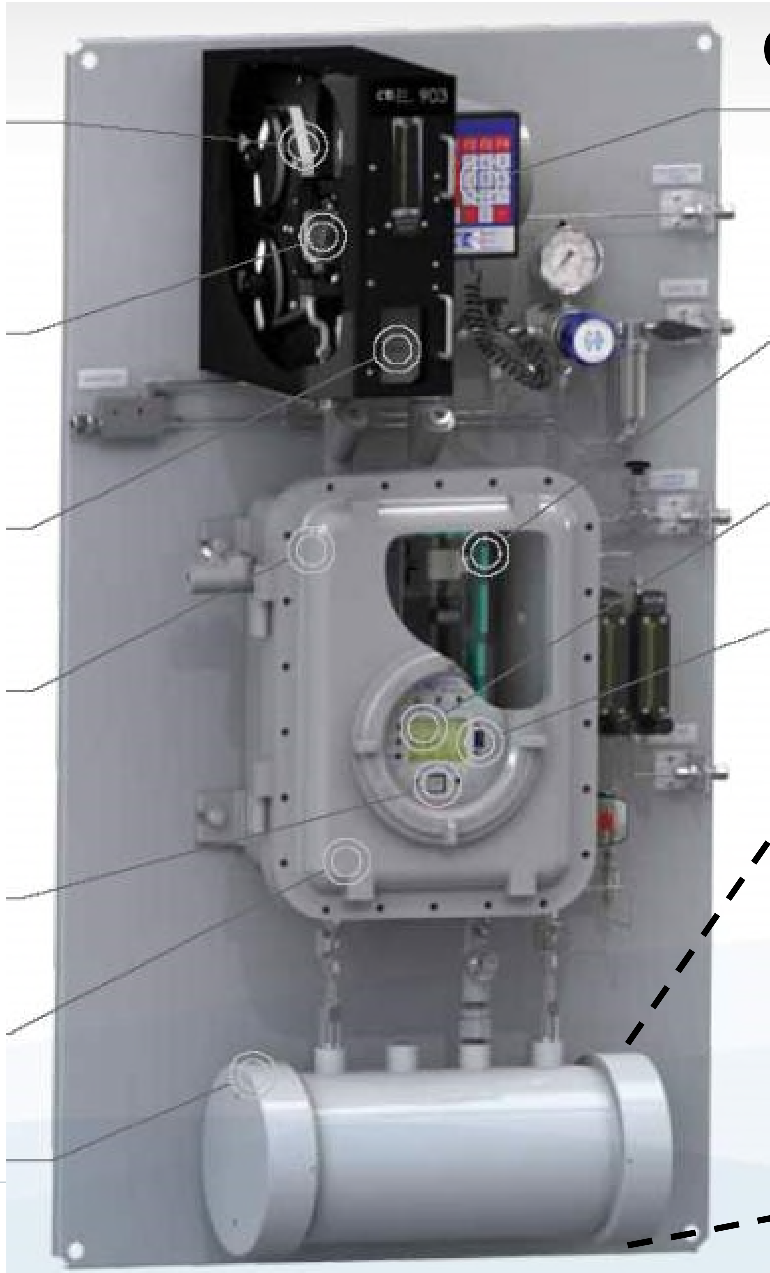




Maintenance Items:

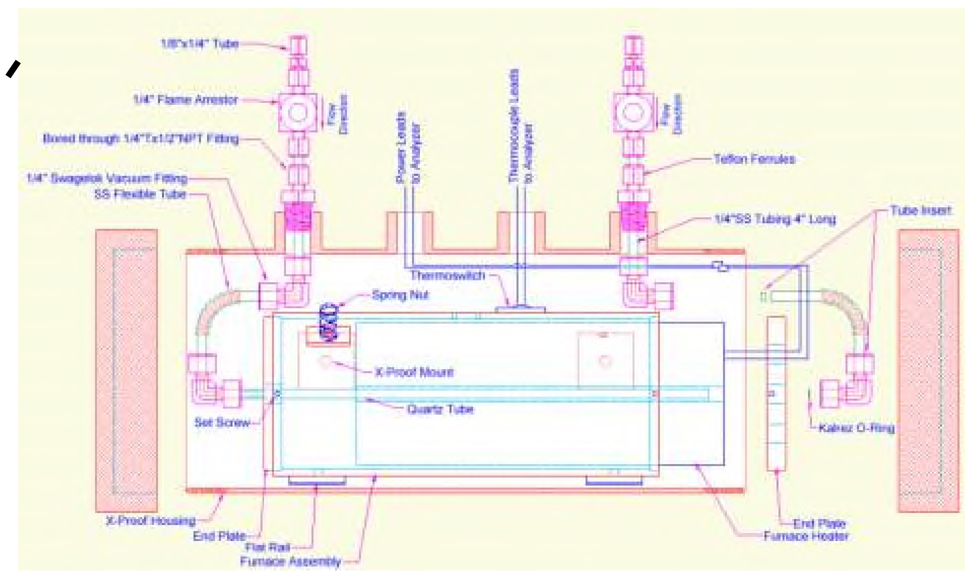
- Tape Cartridges
- Acetic Acid
- Light Source
- Tape Drive System

H2S Measurement - Lead Acetate Tape w/Total Sulfur

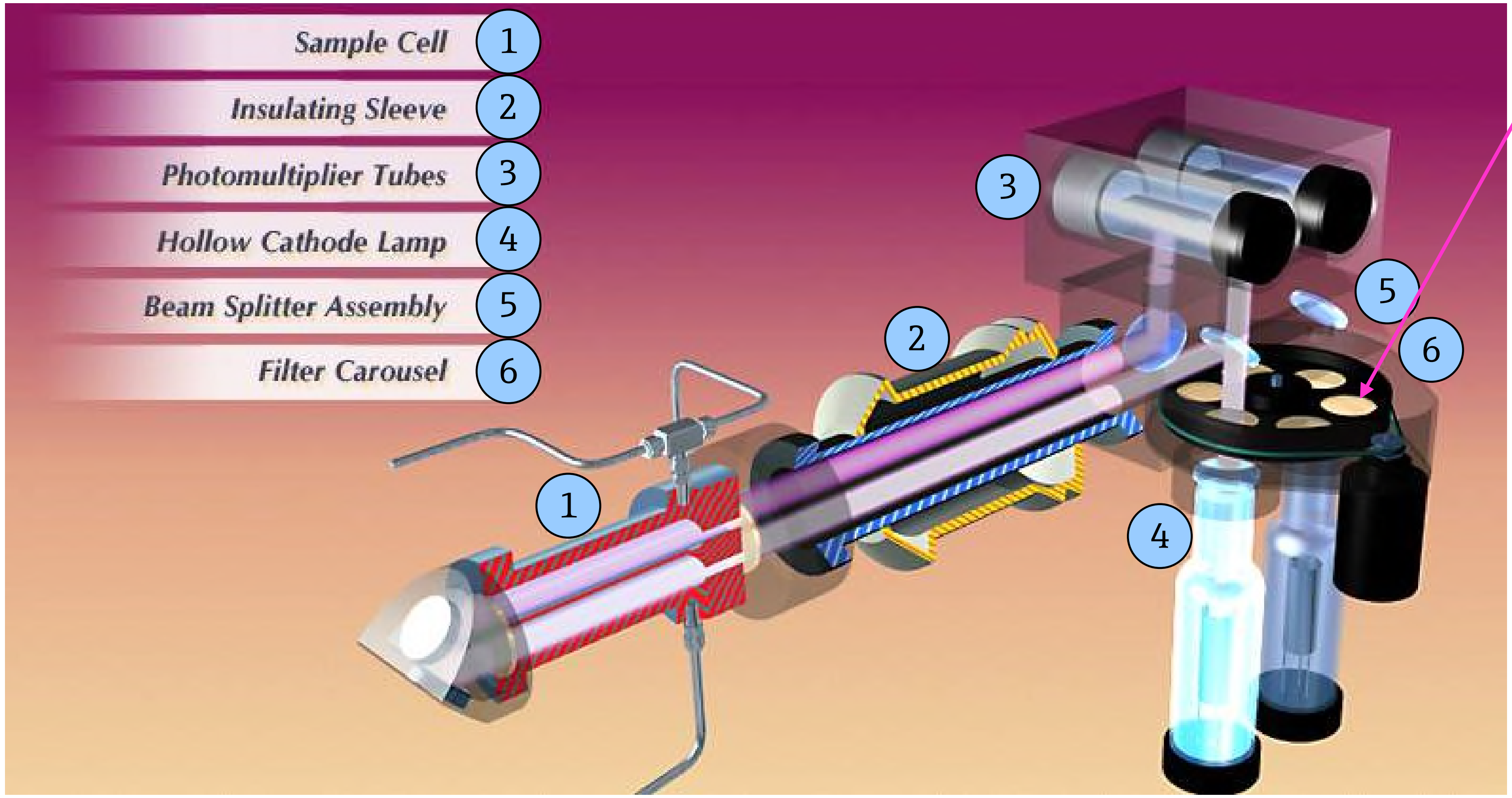


Optional Furnace for Total Sulfur

- Sample is mixed with hydrogen and passed through a quartz tube at 1000 degrees C
- All sulfur compounds are converted to H_2S and measured at the tape
- Coking–Buildup of carbon residue in quartz tube. Caused by lack of hydrogen. If coking is persistent, increase the hydrogen to sample flow ratio



H2S Measurement - Ultraviolet (UV) Photometer



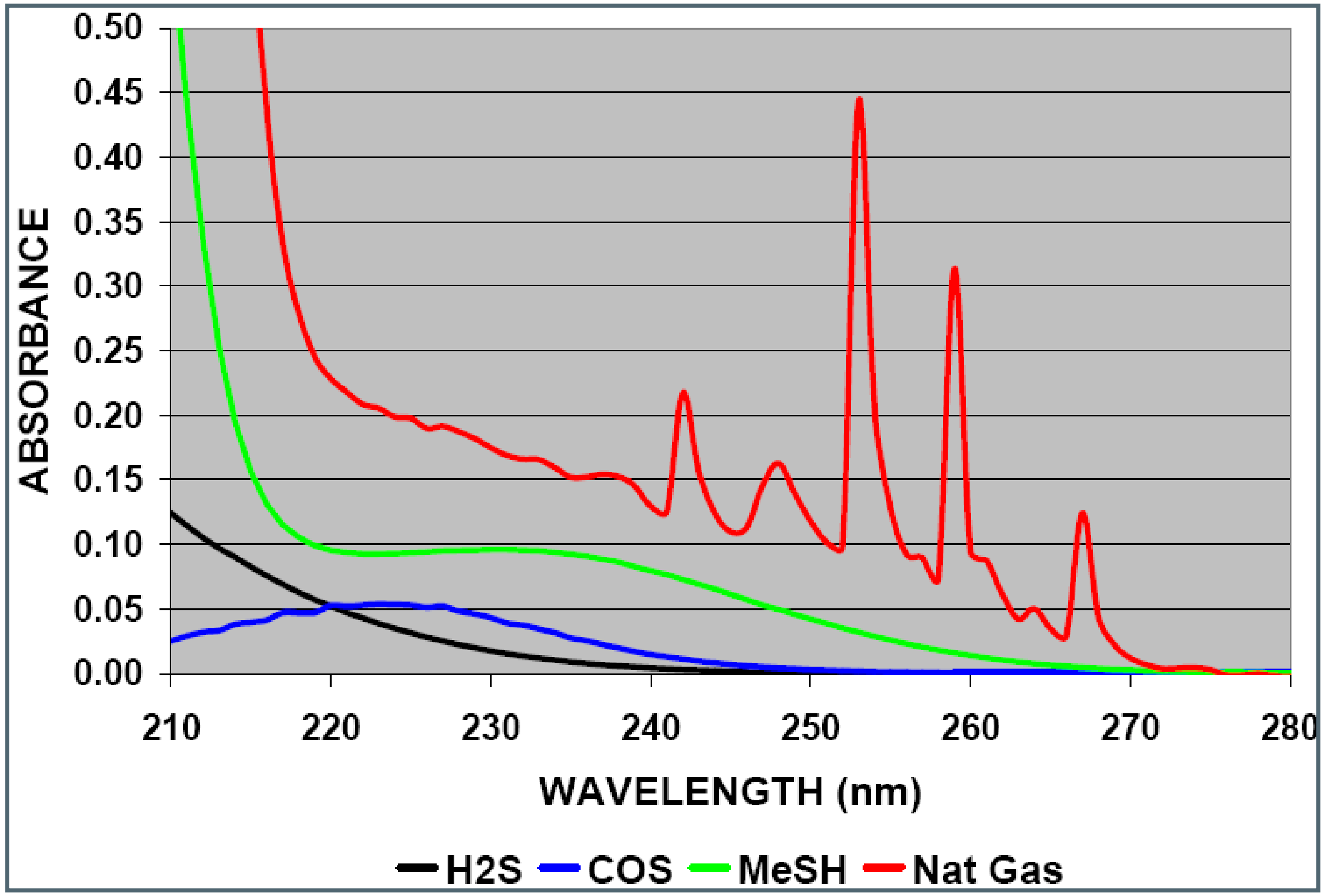
Filter wheel Carousel

Cathode Lamp (qty 2)

Photomultiplier Tube (qty 2)

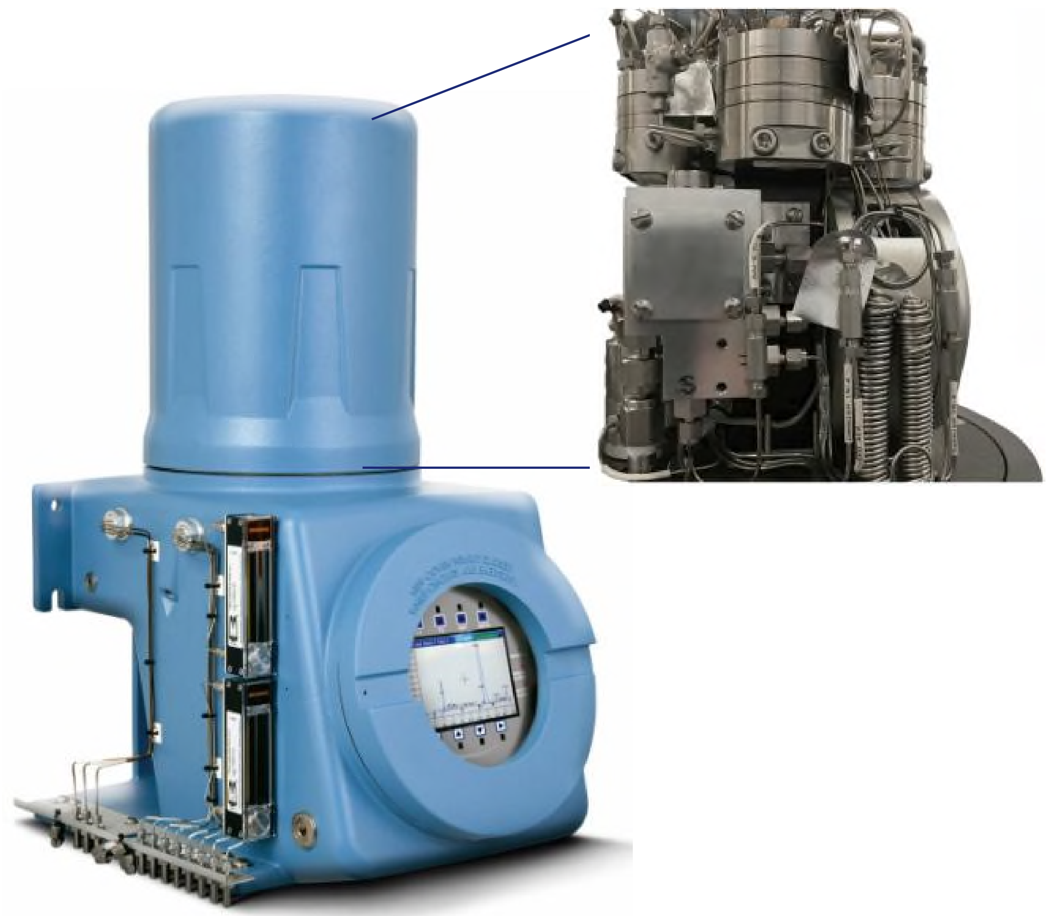
H_2S Measurement - UV with Frontal Elution Chromatography

Interference Requires Speciation of H_2S



Source: ISA-AD 2010, Harris, Harris, & Admin, AMETEK P&AI

H_2S Measurement - Sulfur GC



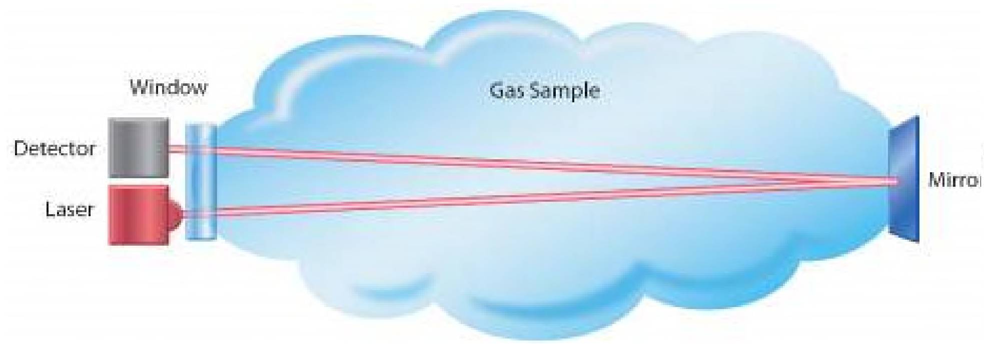
Source: Emerson’s Rosemount 700XA GC, with a µFPD

Compound	Formula		
Hydrogen sulfide	H_2S	●	●
Carbonyl sulfide	COS	●	●
Methyl mercaptan	CH_3SH	●	
Ethyl mercaptan	CH_4CH_3SH		
Dimethyl sulfide	CH_3SCH_3		
Carbon disulfide	CS_2		
2-Propanethiol	$CH_3SCH_2H_5$		
tert-Butyl mercaptan	$(CH_3)_3CSH$		
1-propanethiol	$CH_3(CH_2)_2SH$		● “RSH+”
Thiophene	C_4H_4S		
n-Butyl mercaptan	$CH_3(CH_2)_3SH$		
Diethyl sulfide	$CH_3CH_2SCH_2CH_3$		
Methyl ethyl sulfide	$CH_3SCH_2CH_3$		
2-Methyl-1-propanethiol	$(CH_3)_2CHCH_2SH$		
1-Methyl-1-propanethiol	$CH_3CH_2CHSHCH_3$		

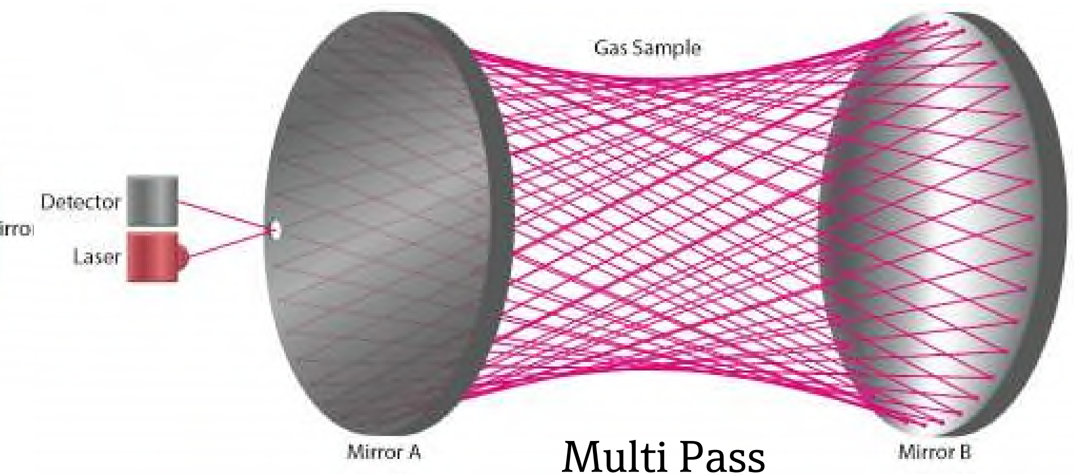
- ● Available with UV
- ● Available with GC

H_2S Measurement – Laser spectroscopy

- Infrared Analyzer → TDLAS analyzers use a focused laser beam
- Light travels through gas
- Transmitted Light (It) reflects back to a solid-state detector
- Transmitted Light (It) is measured with respect to Initial Light (I0)
- Absorbed light is used to determine concentration
  - Target molecule will absorb specific wavelengths (colors) of light



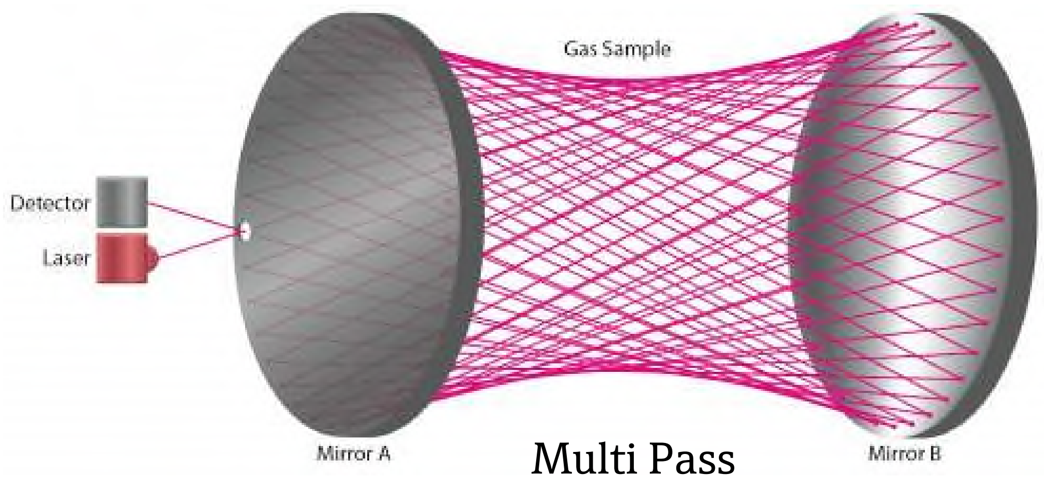
Two Pass



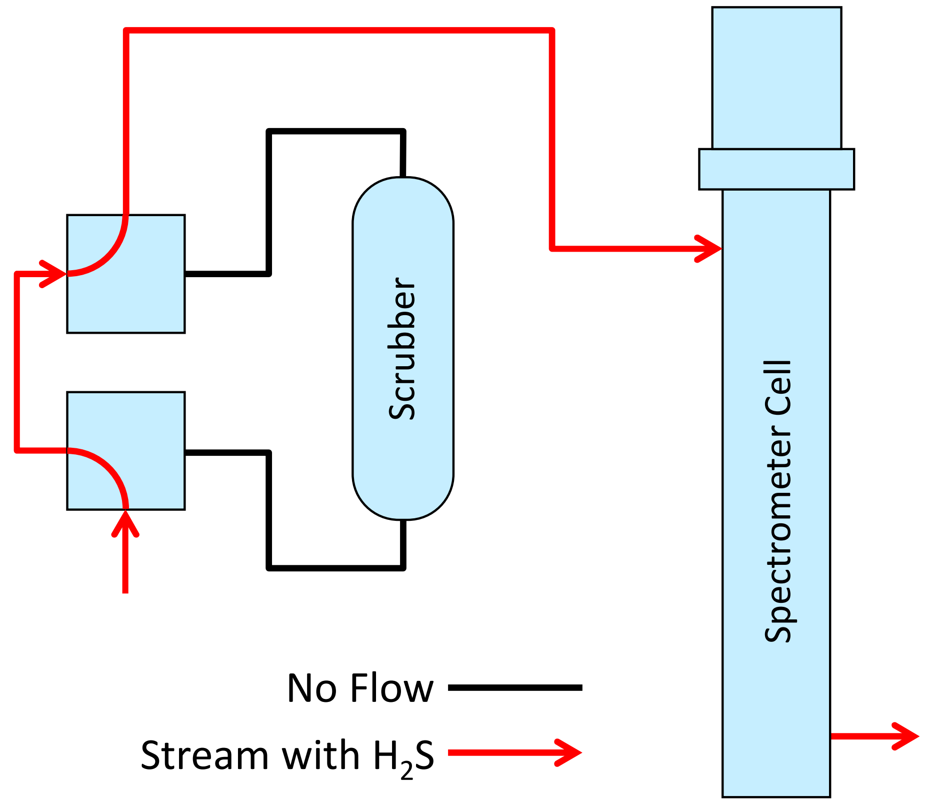
Multi Pass

H_2S Measurement – Differential laser spectroscopy

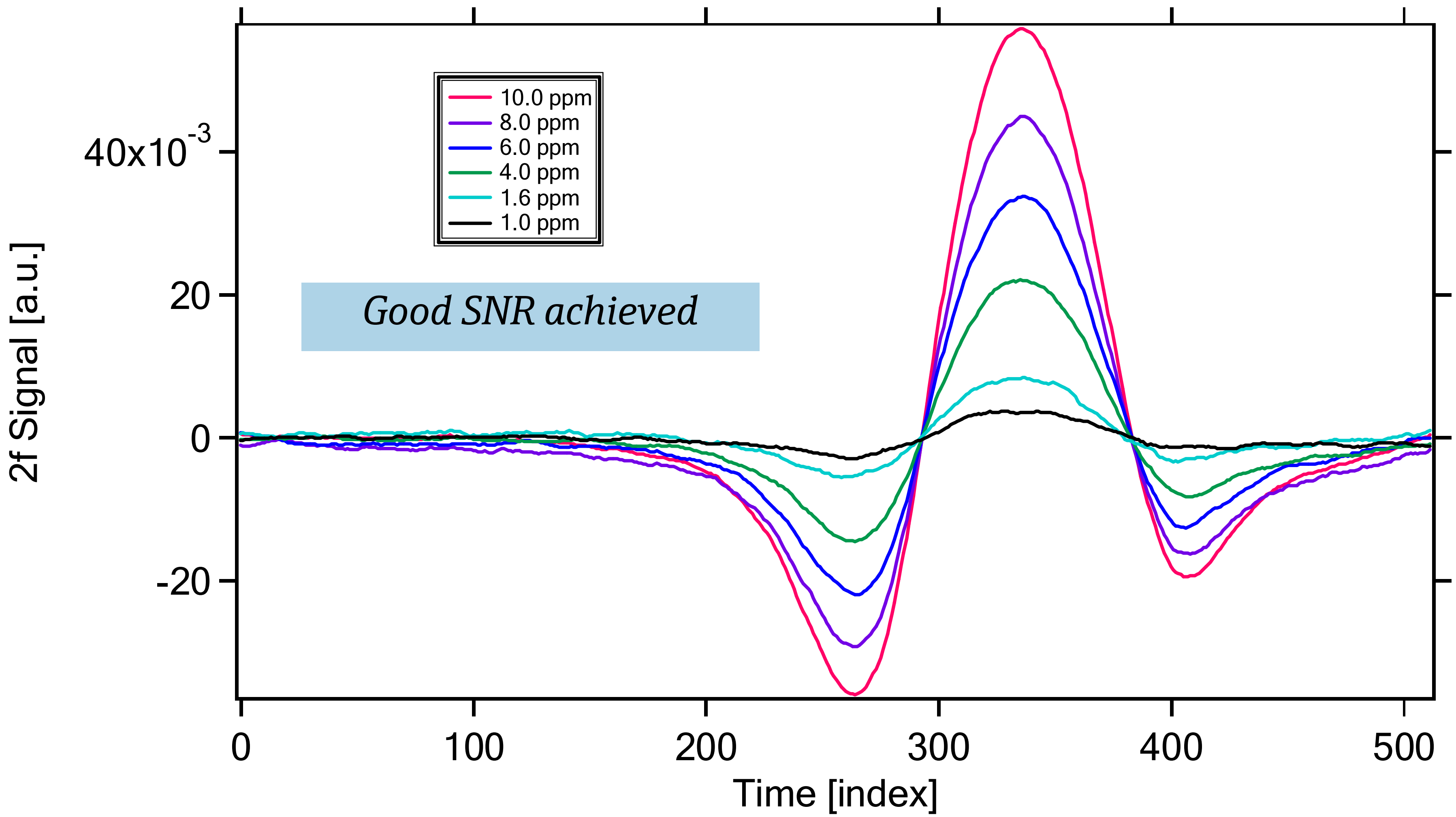
- Infrared Analyzer → TDLAS analyzers use a focused laser beam
- Light travels through gas
- Transmitted Light reflects back to a solid-state detector
- Transmitted Light is measured with respect to Initial Light
- Absorbed light is used to determine concentration
    - Target molecule will absorb specific wavelengths (colors) of light



Multi Pass



H_2S Measurement – Differential laser spectroscopy

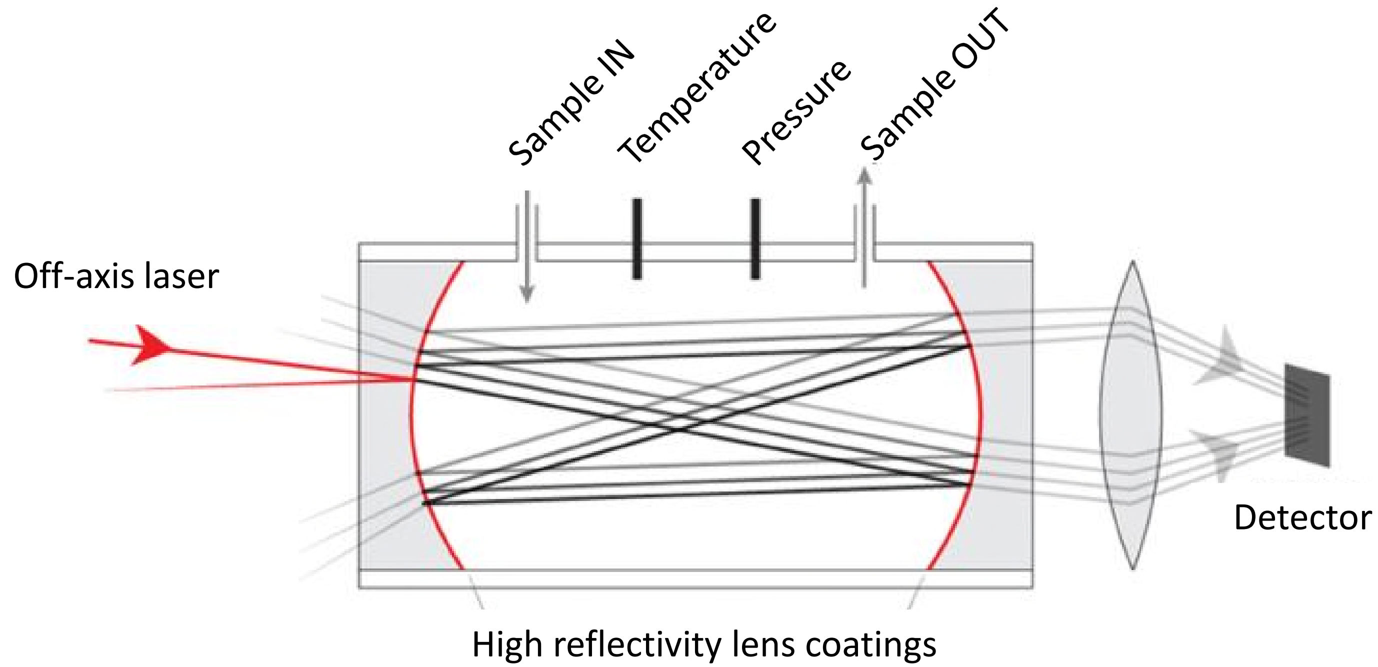


H_2S Measurement – Laser spectroscopy

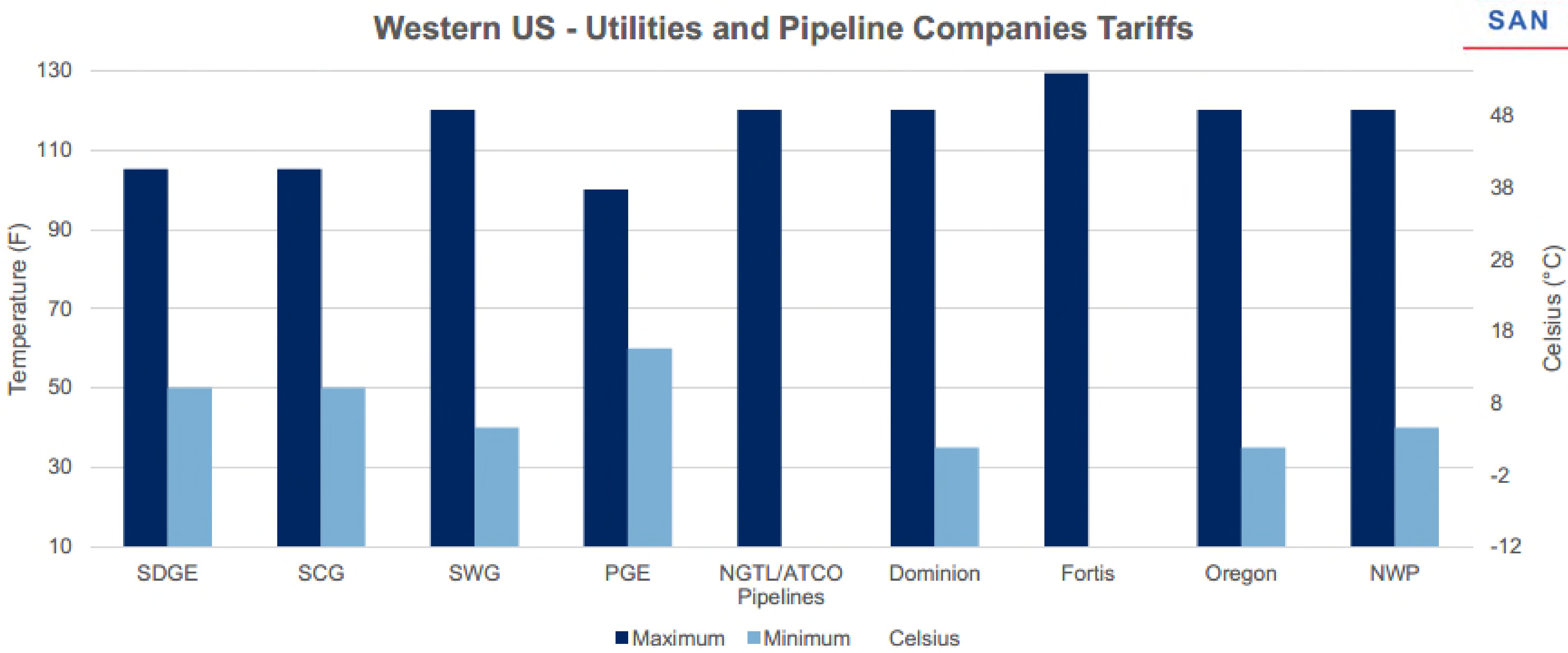
Cavity Enhanced Spectroscopy (CES) (e.g. ICOS, CEAS, CRDS)

- Kilometers of laser path → Good sensitivity
- Faster than lead tape, GC
- Multiple analytes possible (H_2S, H_2O, CO_2, etc.)

- Requires vacuum pump (will require some maintenance)
- Super high reflectivity mirrors (sample filtration is critical)
- Low cavity throughput; if background absorption is strong, SNR reduced (heavy hydrocarbons not possible; e.g. C3+ must be <6%)



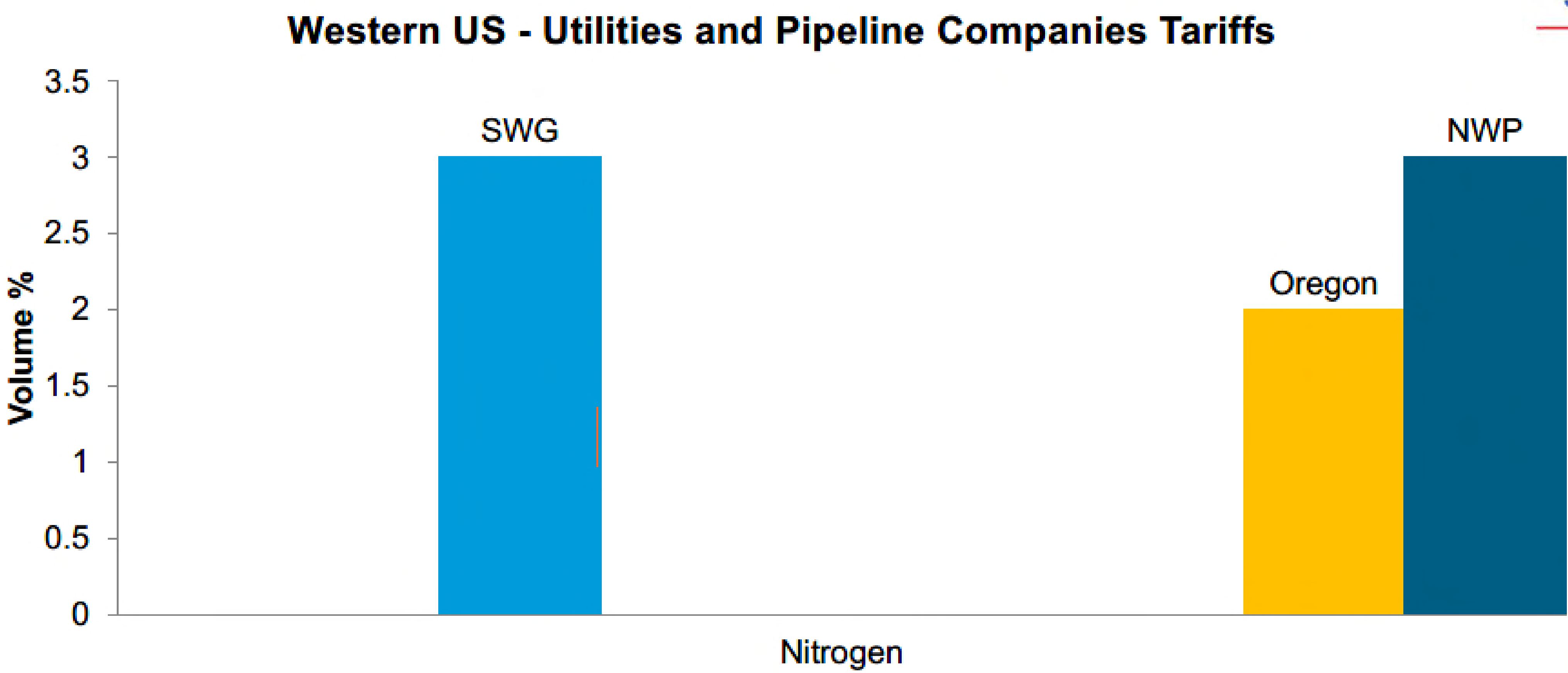
Gas Quality Specifications - Temperature



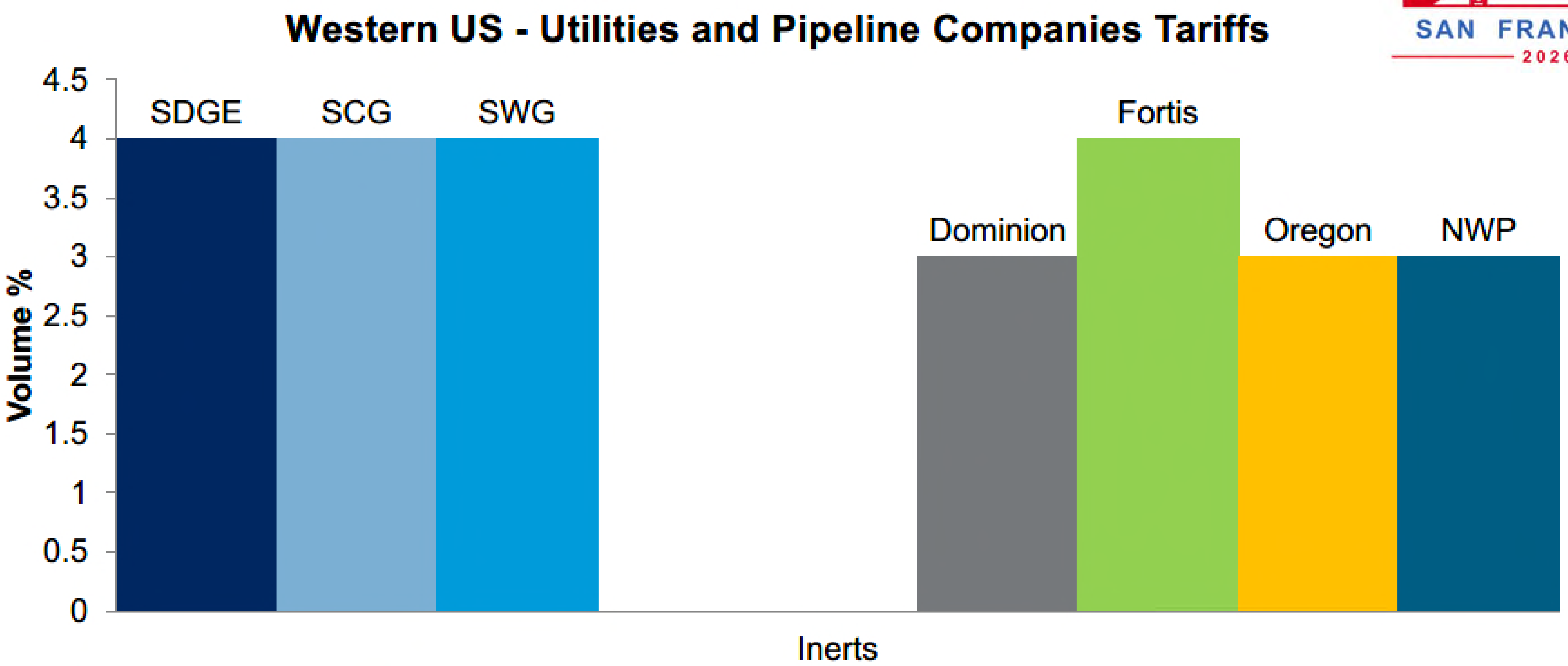
Other Gas Quality Parameters for Measurement

- Inerts (nitrogen, carbon dioxide)
  - Lowers the heating value
  - Lowers the wobbe number
- Heating value (HHV, BTU)
  - Consistent HHV
  - Billing or BTU districts
- Uniform gas composition

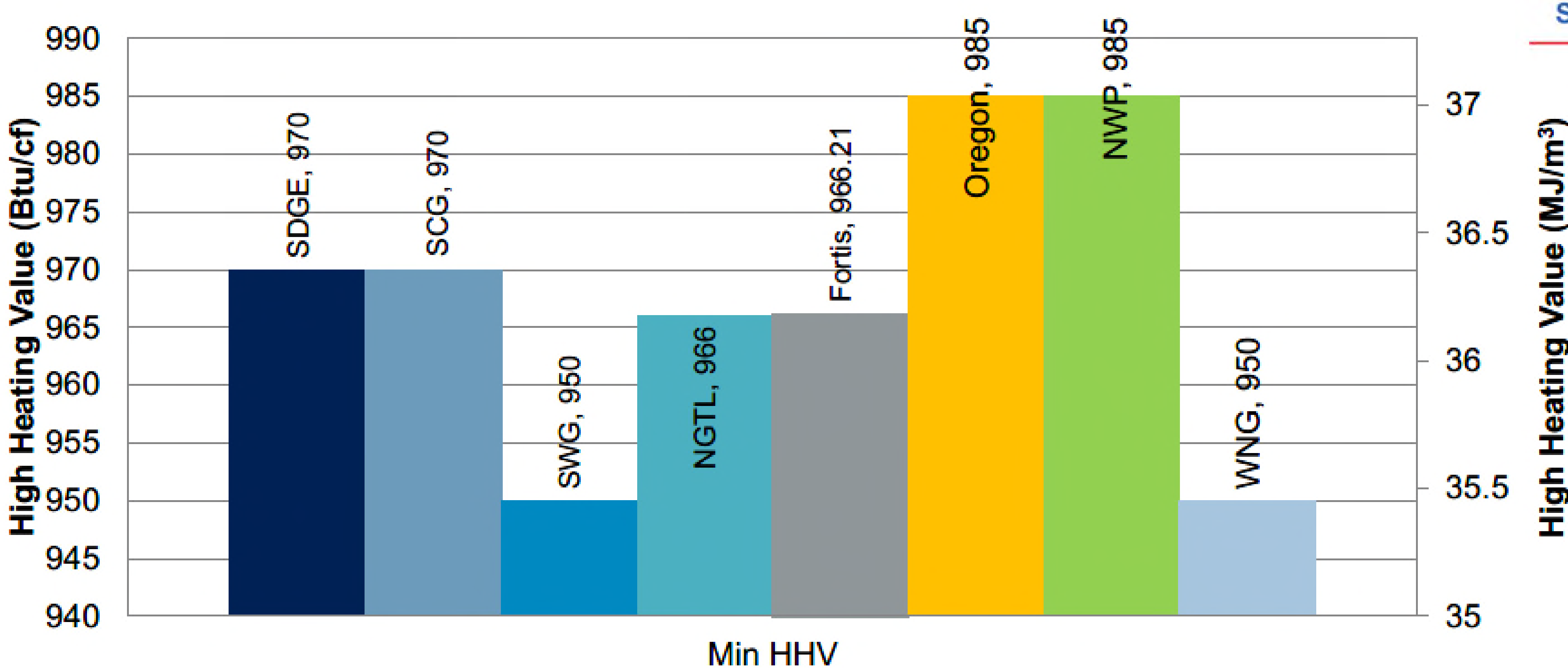
Gas Quality Specifications - Nitrogen



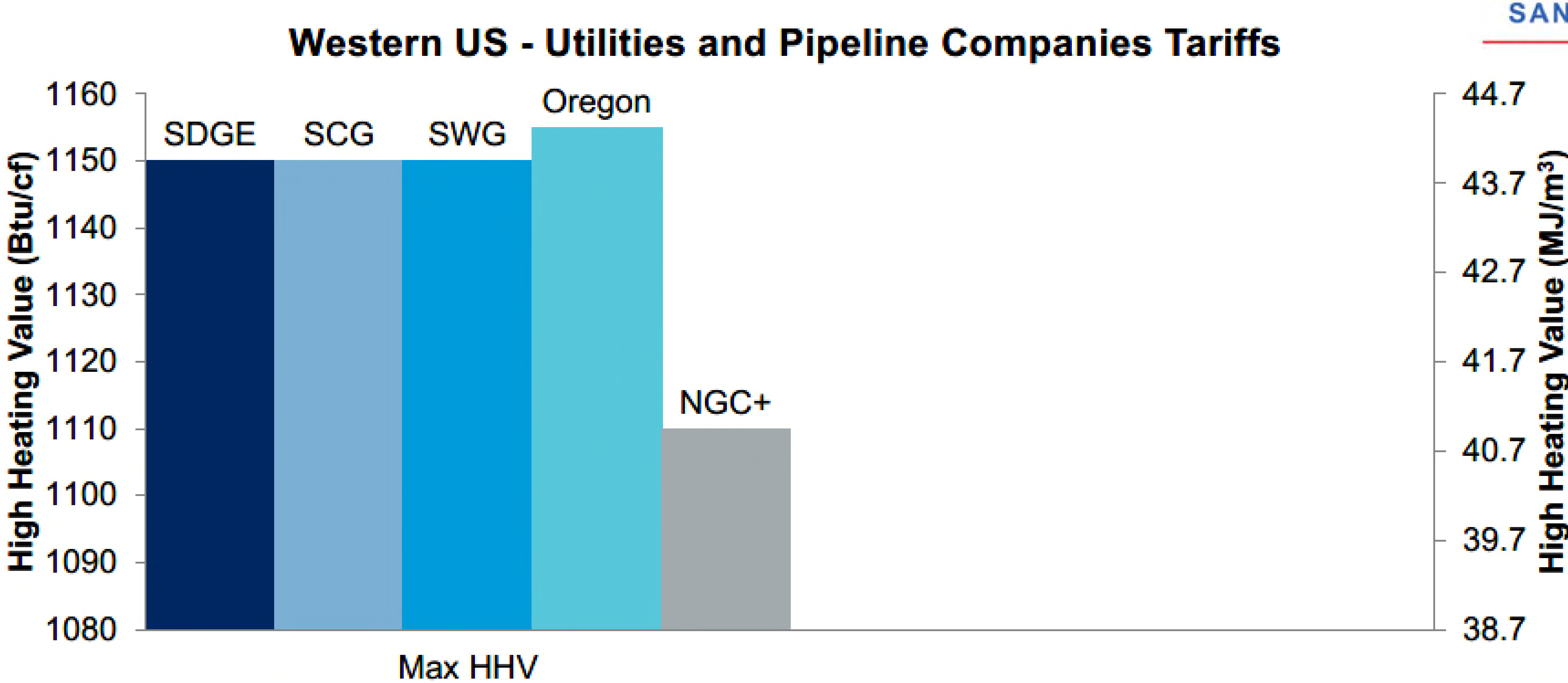
Gas Quality Specifications - Inerts



Gas Quality Specifications – Minimum Heating Value



Gas Quality Specifications – Maximum Heating Value



Gas Quality Specification – Wobbe Index

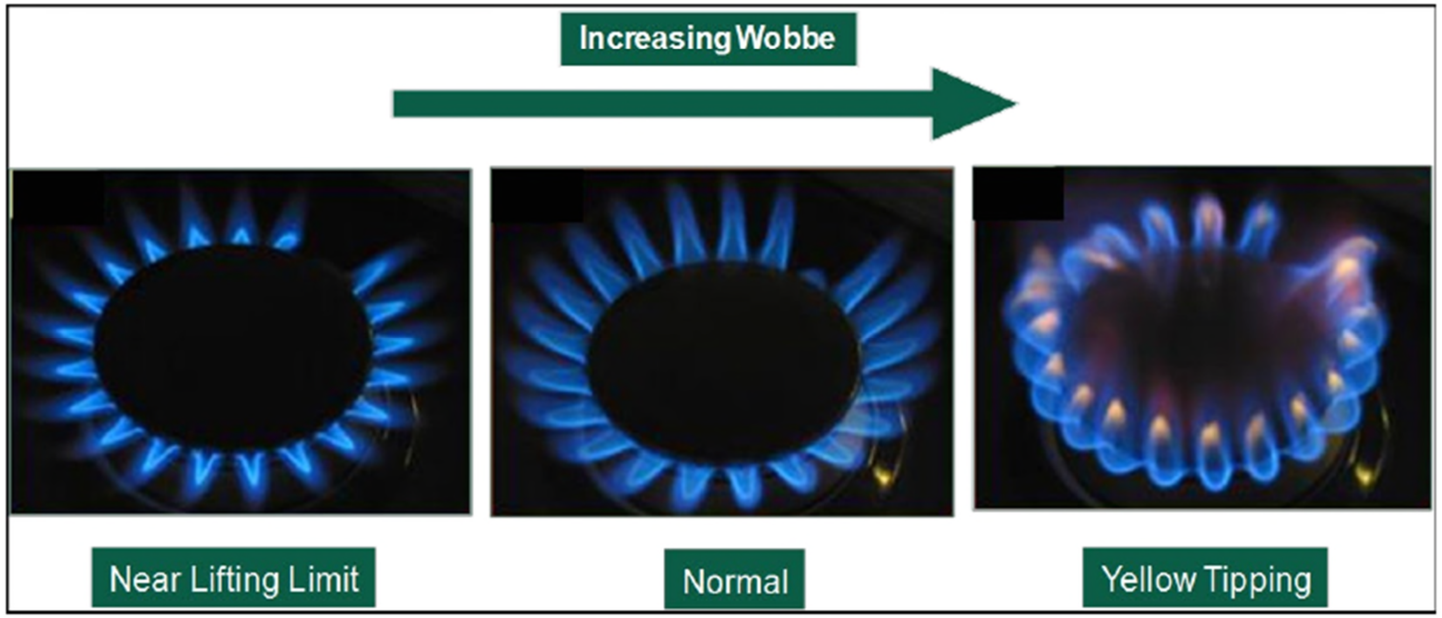
- Wobbe number is the firing rate or heat release rate, which is stated as heat released (Btu) per flow of gas (scf).

$$W = HHV * Q$$

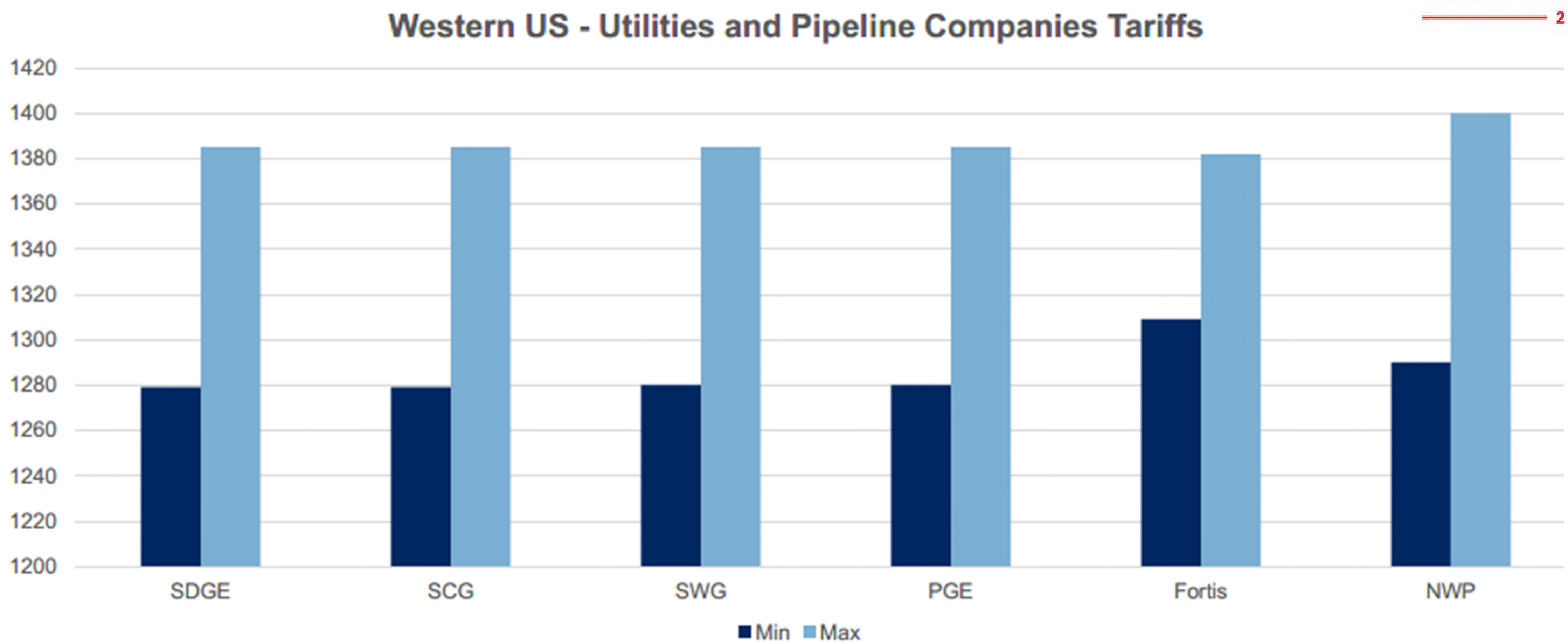
- Since we obtained the following in the previous slide: $Q \propto {}^{1}/_{\sqrt{\rho}}$

- The Wobbe Number equation is:

$$W \propto HHV/\sqrt{sg}$$



Gas Quality Specification – Wobbe Index



Where to find gas quality specifications

- Company websites
- Interconnect Agreements
- Contractual Agreements
- State Public Utility Commissions
- FERC Tariffs
  https://www.ferc.gov/industries/gas/gen-info/fastr/htmlall/index.asp
- Only natural gas quality specifications contained in a FERC approved tariff can be enforced
- Limits will vary from company to company
  - Dependent on source of gas
  - Pipeline operating conditions
  - Customer equipment

Thank you very much for your attention.

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