150 years

BASF
We create chemistry

Gas Treatment Technology

BASF, Intermediates Division

Solving the O_2 problem in Amine Units

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GAS TREATING EXCELLENCE BY BASF

But we don't have oxygen in our gas streams… Or do we?

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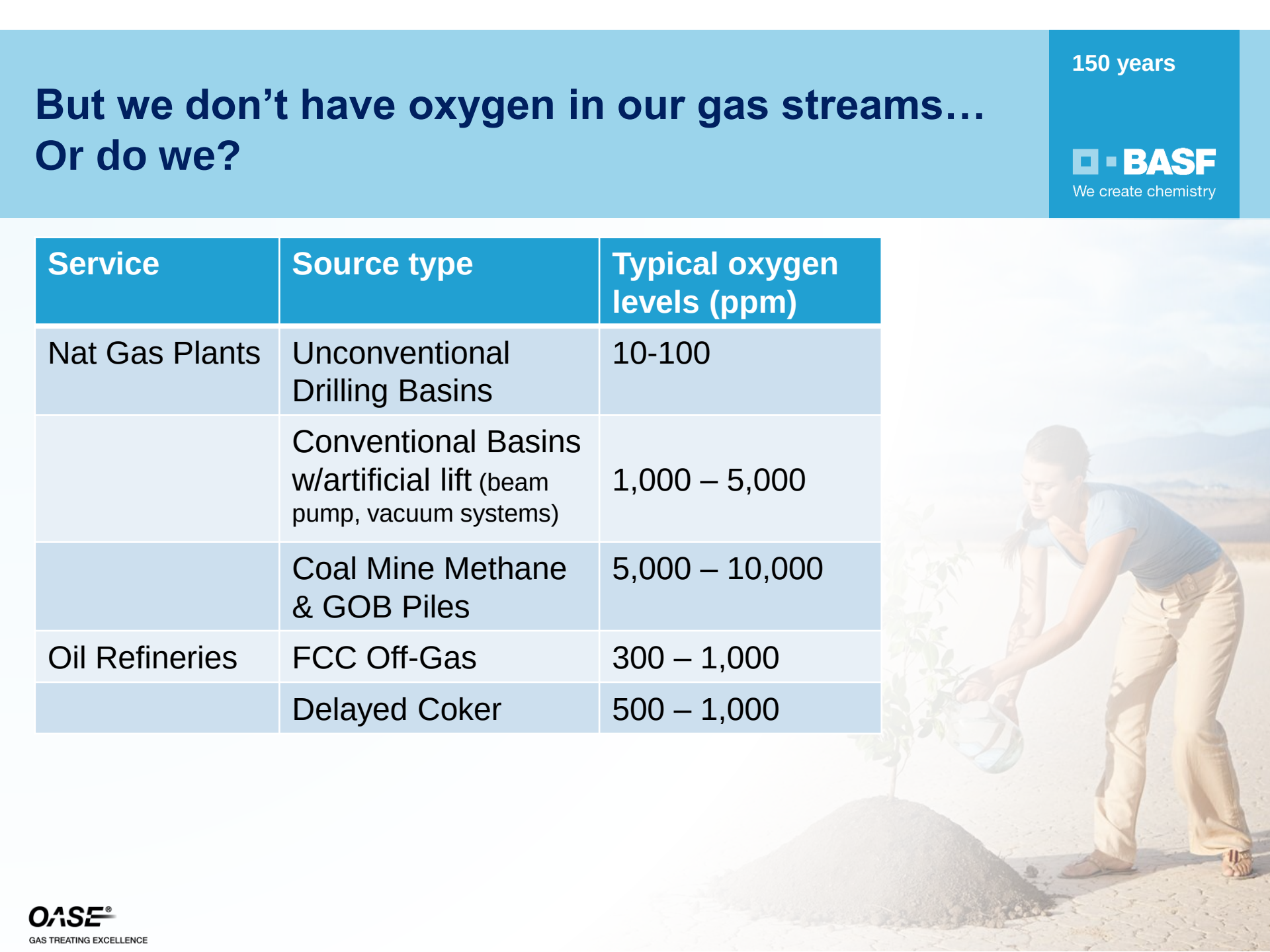
Service	Source type	Typical oxygen levels (ppm)
Nat Gas Plants	Unconventional Drilling Basins	10-100
	Conventional Basins w/artificial lift (beam pump, vacuum systems)	1,000 – 5,000
	Coal Mine Methane & GOB Piles	5,000 – 10,000
Oil Refineries	FCC Off-Gas	300 – 1,000
	Delayed Coker	500 – 1,000



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Any why is it a problem ?

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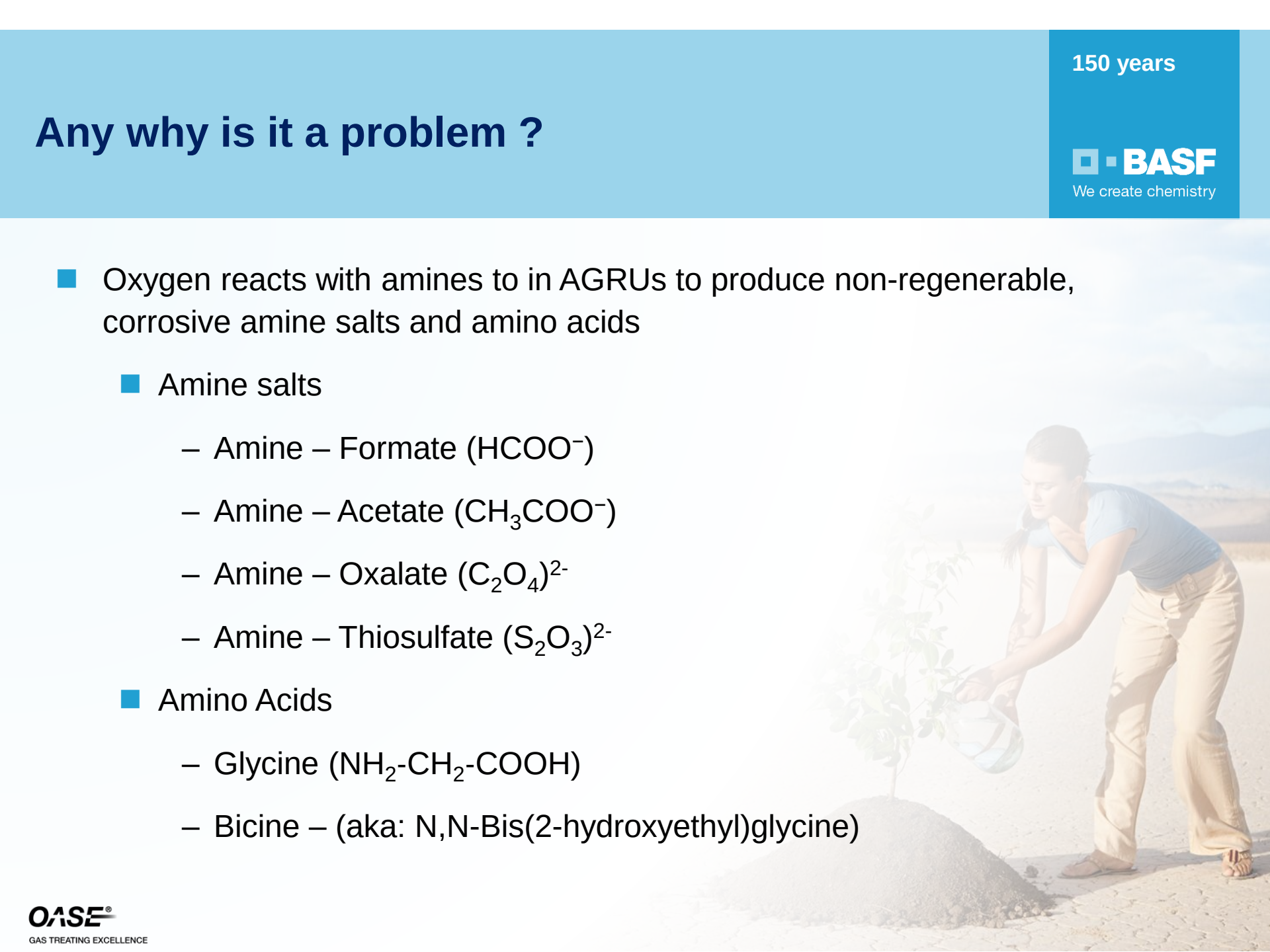
- Oxygen reacts with amines to in AGRUs to produce non-regenerable, corrosive amine salts and amino acids
  - Amine salts
    - Amine – Formate ($HCOO^-$)
    - Amine – Acetate (CH_3COO^-)
    - Amine – Oxalate $(C_2O_4)^{2-}$
    - Amine – Thiosulfate $(S_2O_3)^{2-}$
  - Amino Acids
    - Glycine (NH_2-CH_2-COOH)
    - Bicine – (aka: N,N-Bis(2-hydroxyethyl)glycine)



Technologies for removing Oxygen from Transmission Gas and Refinery Off-Gases

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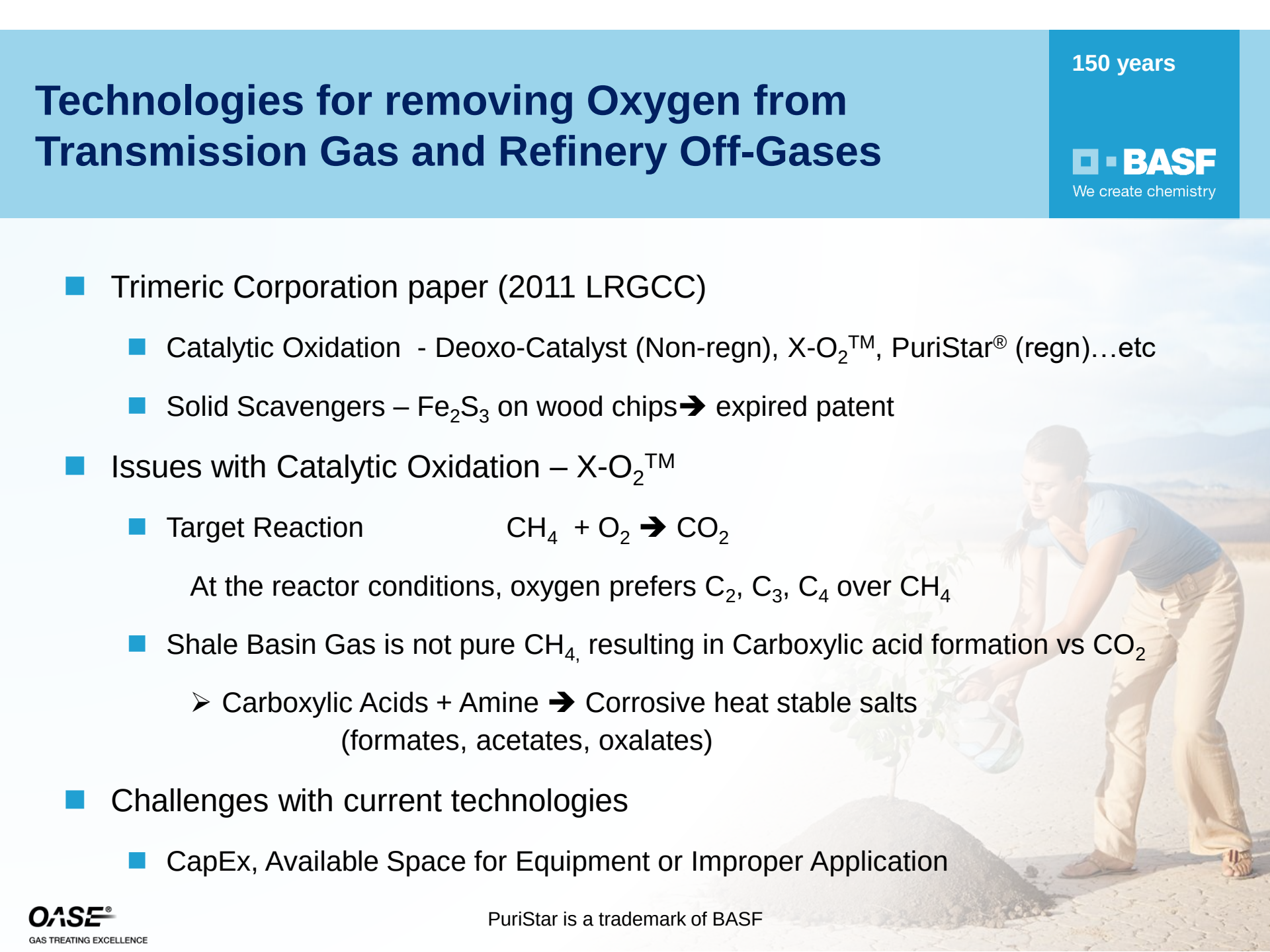
- Trimeric Corporation paper (2011 LRGCC)
  - Catalytic Oxidation - Deoxo-Catalyst (Non-regn), X-O_2™, PuriStar® (regn)…etc
  - Solid Scavengers – Fe_2S_3 on wood chips➔ expired patent
- Issues with Catalytic Oxidation – X-O_2™
  - Target Reaction $CH_4 + O_2 \rightarrow CO_2$

    At the reactor conditions, oxygen prefers C_2, C_3, C_4 over CH_4
  - Shale Basin Gas is not pure CH_4, resulting in Carboxylic acid formation vs CO_2

    ➢ Carboxylic Acids + Amine ➔ Corrosive heat stable salts (formates, acetates, oxalates)
- Challenges with current technologies
  - CapEx, Available Space for Equipment or Improper Application



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Technologies for removing or reducing corrosivity of degradation products

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- Removal of degradation products after they reach intolerable levels
  - Thermal Reclaimer (limited to ADEG® or MEA) [ABPG]
    - Increases amine losses, if not monitored (another unit to monitor)
  - Ion-Exchange or Vacuum distillation (all other amines)
- Neutralization with strong[e] CO_3 [ABPG]
  - Converts Amine-Salts to
  - May reduce corrosivity o[r]

Shield of protection between the amine and free radical oxygen ➔ mitigates the degradation reaction

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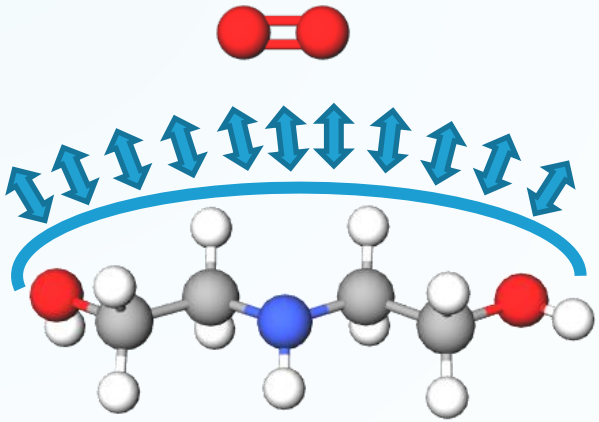
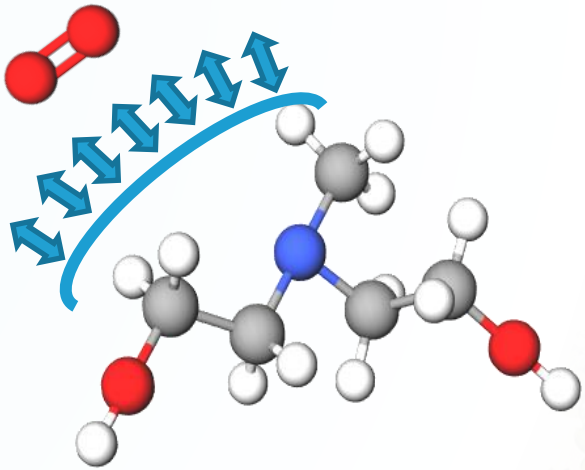
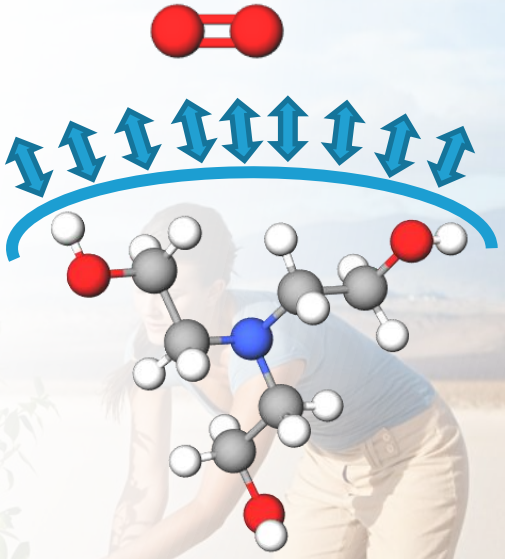


Diethanolamine
(DEA)



Methyl diethanolamine
(MDEA)



Triethanolamine
(TEA)

“Amine Stabilizer”

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BASF Amine Stabilizer

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Application

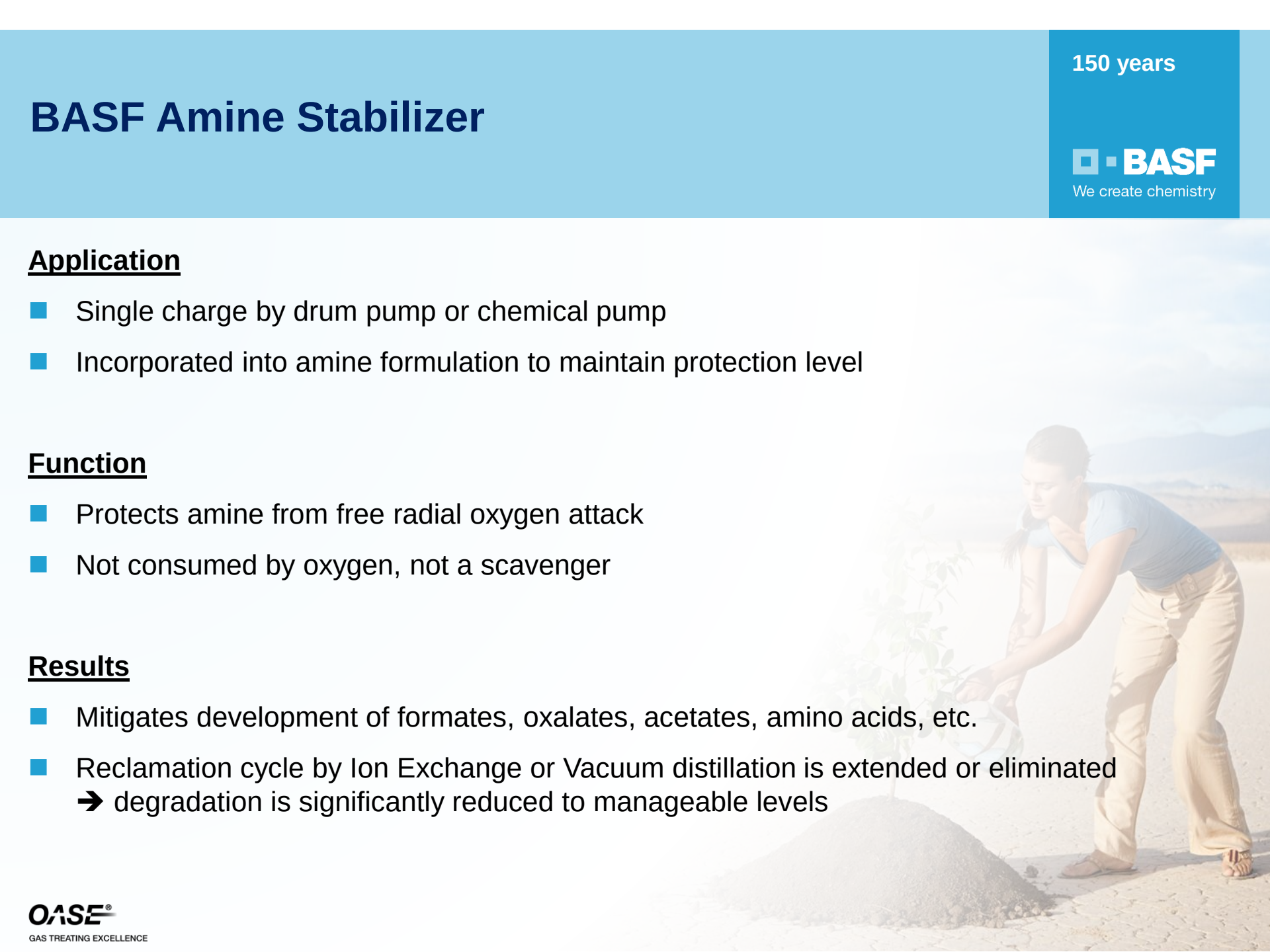
- Single charge by drum pump or chemical pump
- Incorporated into amine formulation to maintain protection level

Function

- Protects amine from free radial oxygen attack
- Not consumed by oxygen, not a scavenger

Results

- Mitigates development of formates, oxalates, acetates, amino acids, etc.
- Reclamation cycle by Ion Exchange or Vacuum distillation is extended or eliminated
  ➔ degradation is significantly reduced to manageable levels



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CNX Resources – Pine Bank Gas Plant

150 years

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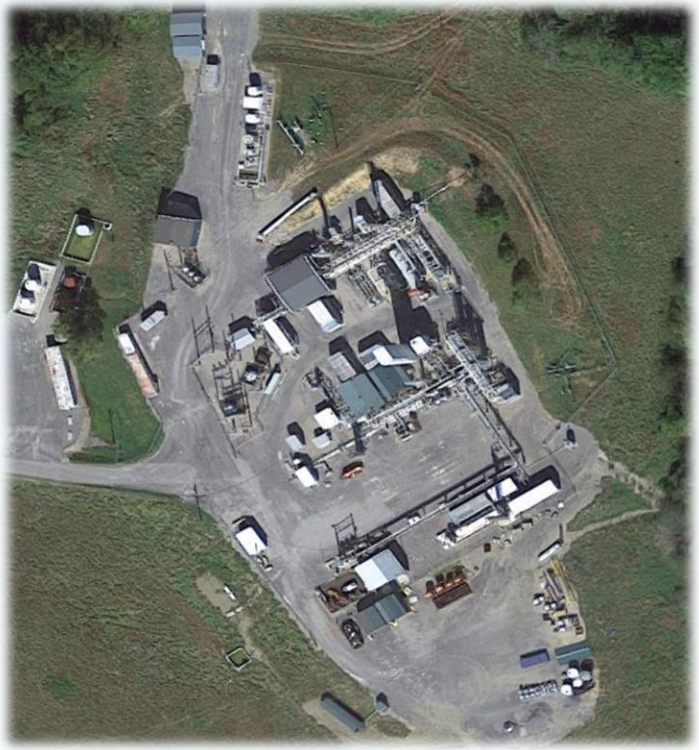

- 5 -7 ½ MMSCFD
- 830-920 Psig / 40º-77º F
- Coal Mine Methane & GOB Gas
- 10% CO_2, 80% CH4, 1% O_2

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History of Equipment Failures with High Bicine Levels

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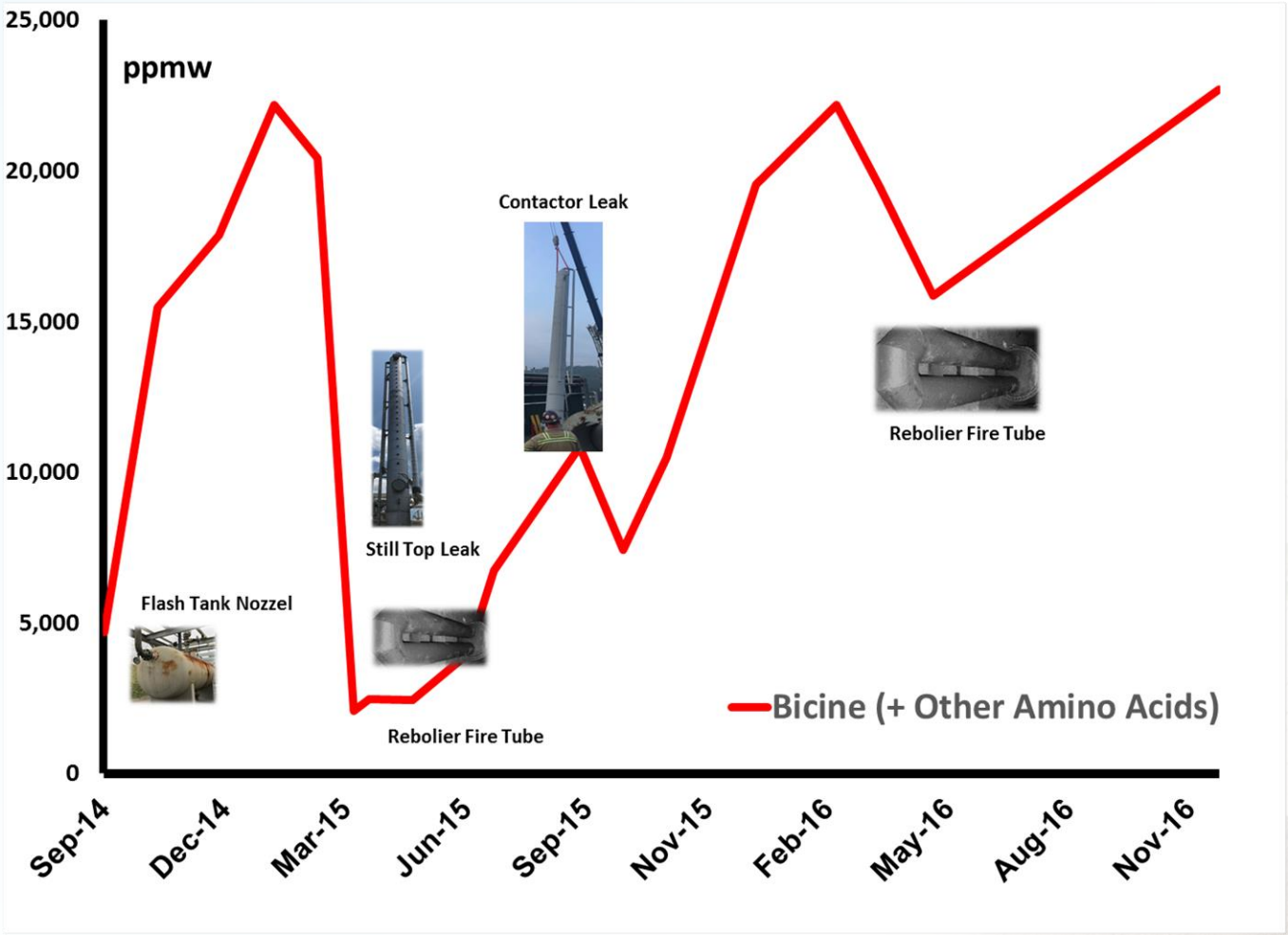

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Pin-hole Leak through High Pressure Contactor

150 years

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CNX Resources Results

150 years

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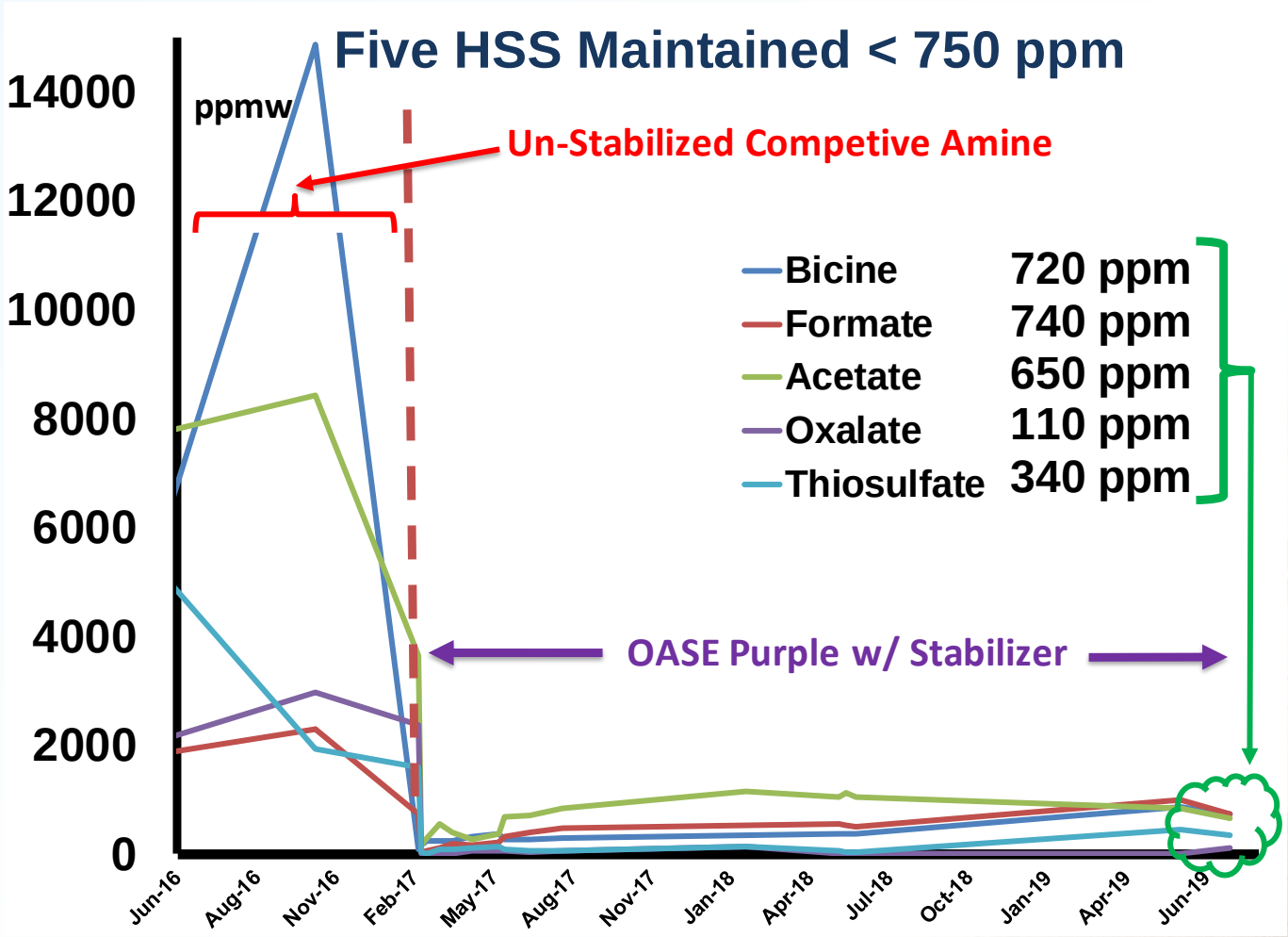

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Associated Gas from Vacuum to 980 Psig (0.1% - 0.5% O_2)

150 years

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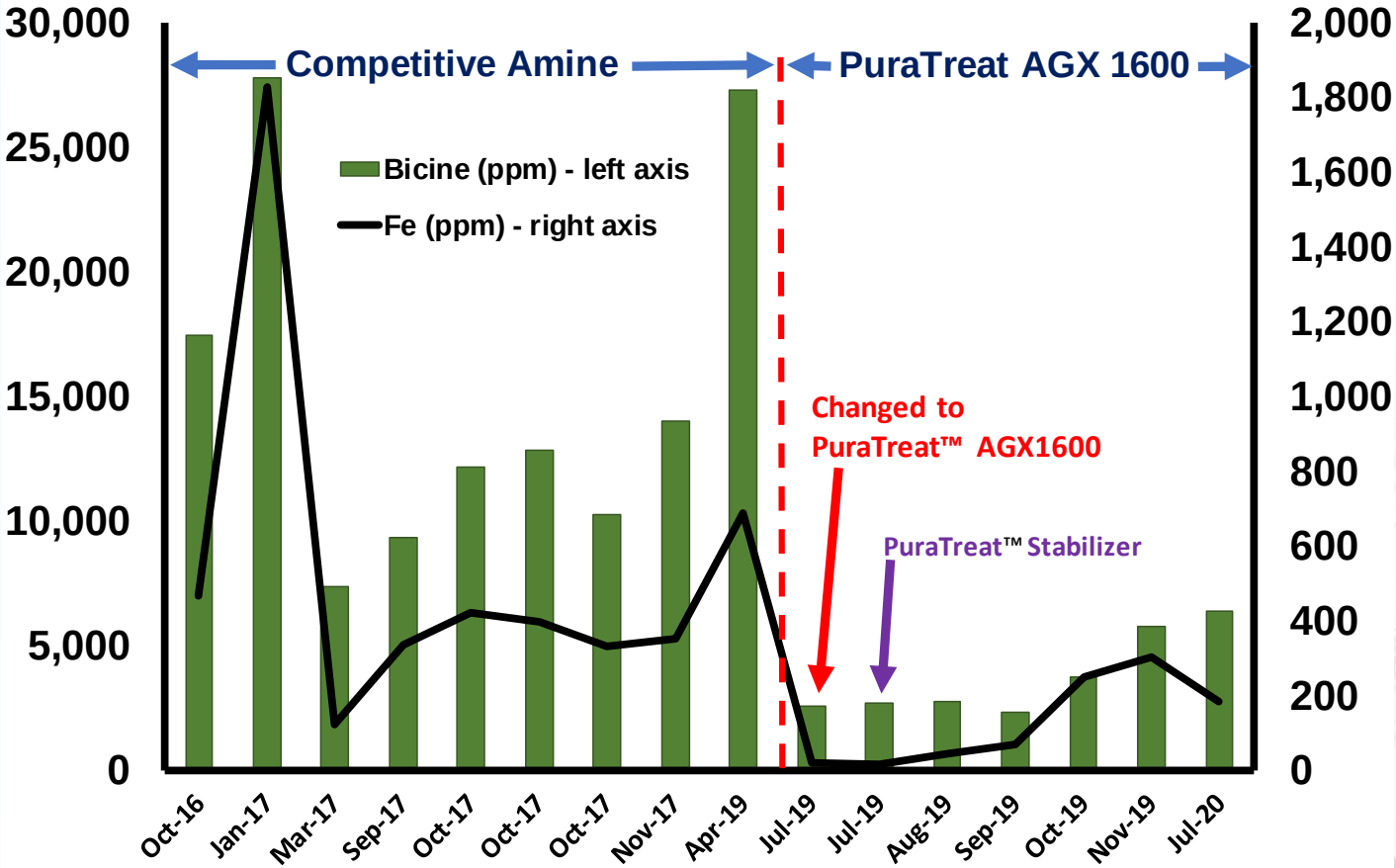

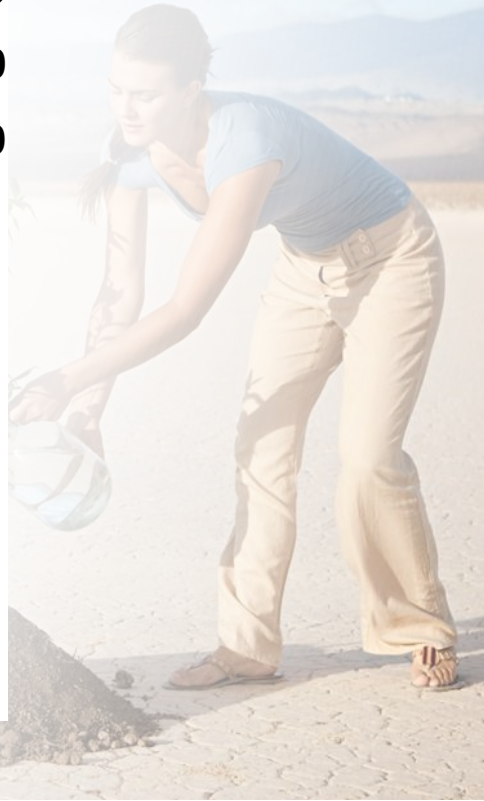

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Review of mitigation successes (5 operating years of results)

150 years

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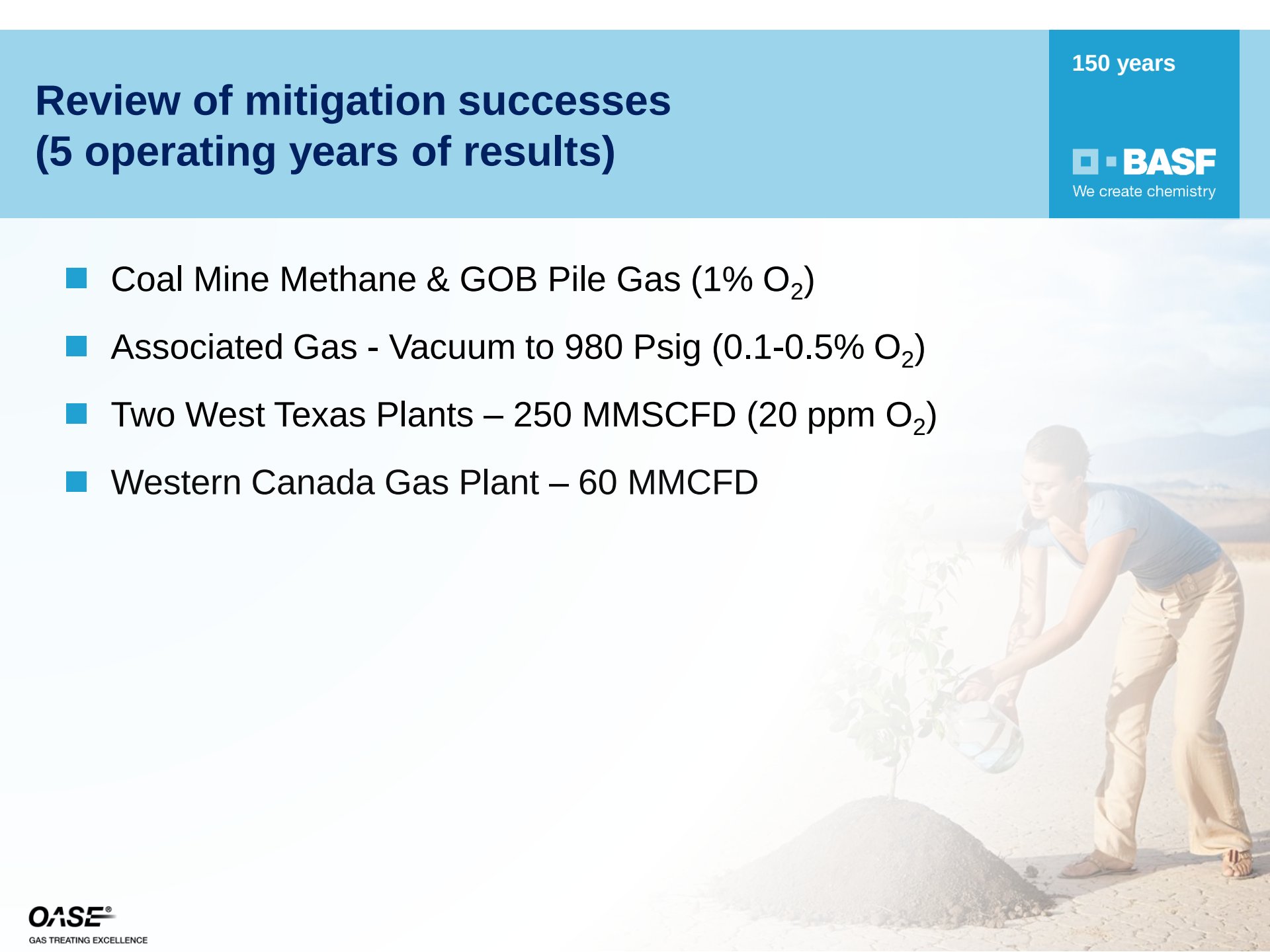
- Coal Mine Methane & GOB Pile Gas (1% O_2)
- Associated Gas - Vacuum to 980 Psig (0.1-0.5% O_2)
- Two West Texas Plants – 250 MMSCFD (20 ppm O_2)
- Western Canada Gas Plant – 60 MMCFD



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Questions and Answers

150 years

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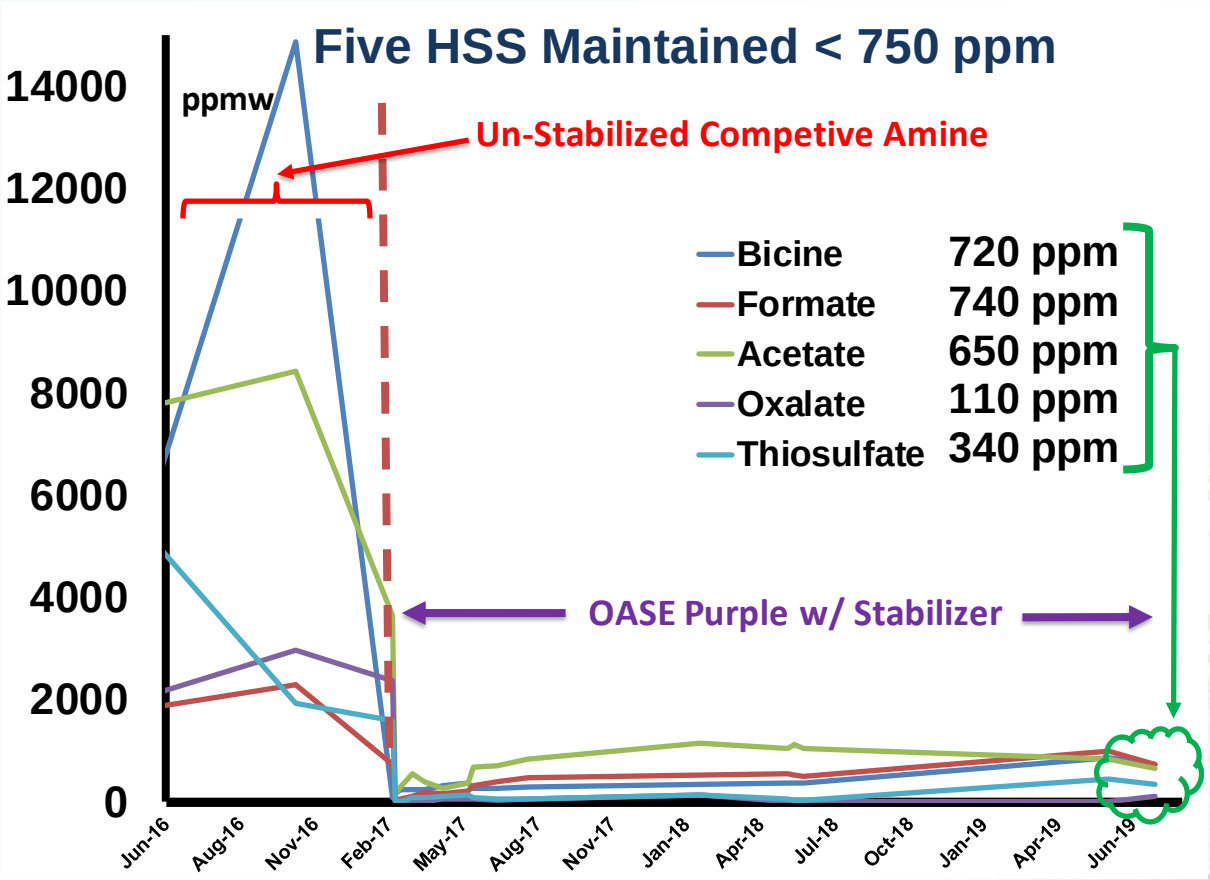

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