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行政院勞工委員會

台灣區高壓氣體
工業同業公會

Asia Industrial
Gases Association

國立臺北科技大學

Oxygen Safety in ASU Design

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Bill has held a variety of positions with Praxair over the last 27 years in sales, engineering, and business management. Since arriving in Shanghai in 2010, Bill has supported the Asia country business teams in new on-site business acquisition, development of competitive supply systems, and new business strategies to sell merchant products.

A 1982 graduate of the Drexel University in Chemical Engineering with an MBA from Tulane University.

MURDOCH HACKGATE MESS CASTS ITS SHADOW OVER CAMERON GOVT | 14

16 die in Vizag Steel Plant blast

GM Too Killed During Trial Of Oxygen Unit

TIMES NEWS NETWORK

One of the injured at a hospital in Vizag

Visakhapatnam: In the worst-ever accident in the history of Visakhapatnam Steel Plant (VSP), 16 people, including general manager

▶Tragedy unprecedented: P7

Kalsi Naik, were burnt alive following a huge explosion in the recently commissioned oxygen plant in the steel melting shop II unit on Wednesday night. Fifteen workers were seriously injured and the death toll may go up, sources said.

The blast took place at around 8.45pm when the officials were conducting a trial run of the recently commissioned oxygen plant. Most of the victims were contract workers. At the time of the blast, at least 31 workers, including GM and DGM-rank officials, were on duty.

After the massive blast, a huge fire raged across the plant. The oxygen plant was completely gutted as flames swept through the unit.

All the workers and officials present in the oxygen plant were charred to death. The injured suffered 80%-90% burns and were taken to Seven Hills Hospital.

Gajuwaka MLA Venkataramaiah confirmed to TOI that 16 workers had died in the mishap. The steel plant management were not available for comment even a couple of hours after the accident. Trade union leaders allege that maintenance works in the plant had been neglected for more than a year.

The new SMS II wing, which was constructed as part of the expansion works of the plant, was commissioned recently.

Vol. 75 No. 165 Established 1938 | 40 PAGES | ₹2.50

14 burnt alive in explosion at VSP

DC CORRESPONDENT
VISAKHAPATNAM, JUNE 13

Relatives of VSP blast victims cry inconsolably at the hospital. — DECCAN CHRONICLE

In the biggest accident till date at the Visakhapatnam Steel Plant, at least 14 persons died and 11 were critically injured when the oxygen plant in the Steel Melt Shop-II exploded on Wednesday night.

Sources said that workers and two senior executives were checking for leaks in the converter belt when the accident took place. The new converter supplying oxygen to SMS-II was on a trial run as part of VSP's ambitious expansion plans.

At least three among the dead were in managerial posts and some were from a private construction company. Around three dead bodies were sent to the steel plant mortuary and staff were trying to retrieve the other bodies from the spot.

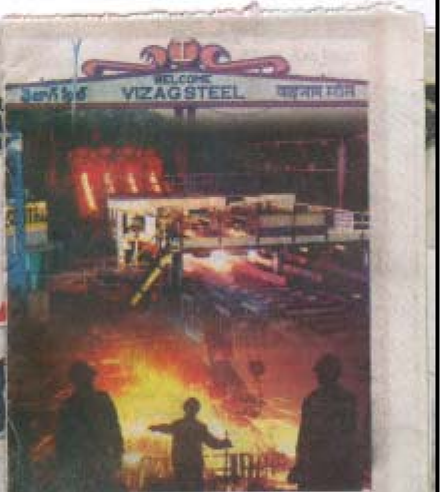
The severely injured were rushed to the Steel Plant General Hospital and other nearby corporate hospitals, where their condition is said to be critical.

"We fear that more than 12 persons died on the spot and around four received more than 86 per cent burns," said Gajuwaka MLA Ch. Venkata Ramaiah.

Intuc leader Gandham Venkat Rao said that it was a mistake on the part of the VSP management which was in a hurry to commission projects as part of expansion plan.

On May 22, a conveyor belt in Blast Furnace-III, carrying raw material had completely melted in the early morning hours as a result of which the entire production had come to a standstill.

It had also caused losses of about ₹1 crore. However, there had been no casualties then.



మృతులలో జీఎం, ముగ్గురు డీజీఎంలు!

ఆక్సిజన్

10 మంది దుర్మర

ఆరుగురు గల్లంతు.. 9 మందికి గా

Outline

- Goal
- Main condenser safety basics
- Factors impacting safety & design
- Main condenser design considerations
- Early period – Main condenser failures
- Learnings and condenser advancements
- Summary

Goal of this Presentation

- Trace the evolution of main condenser safety and its influence on operation and design
- Capture important lessons learned
- Create a knowledge framework for the safe operation of air separation units

Main Condenser/Reboilers

- At the heart of cryogenic air separation plant safety
- Contaminants that reach the distillation columns concentrate in the liquid oxygen stream that is vaporized in the main condenser.
- Main condenser design and operation significantly influence whether or not the contaminants can introduce a safety risk

Main Condenser Safety - Basics

- **Risk Triangle - Eliminate ANY one of 3 ingredients and there is NO reaction**
  - Oxidizer (Oxygen)
    - Unavoidably present In reboiler-condensers of ASUs
  - Ignition Starter
    - Cannot eliminate all ignition mechanisms
  - Fuel
    - Sufficient fuel (contaminant hydrocarbons – HCs) is available in feed air to ASUs, which if allowed can concentrate to LEL
    - **HCs (hydrocarbons) should not be allowed to reach the following limits at any location in the ASU**
      - The LEL
      - Concentration which forms a solid
      - Concentration that forms a second liquid phase

Main Condenser – Factors that Influence Safety

- **Contaminants in air**
- **Performance of air purification step, use of LOX absorbers**
- **Magnitude of contaminants enrichment in LOX entering the main condenser**
- **Main condenser design and operation**

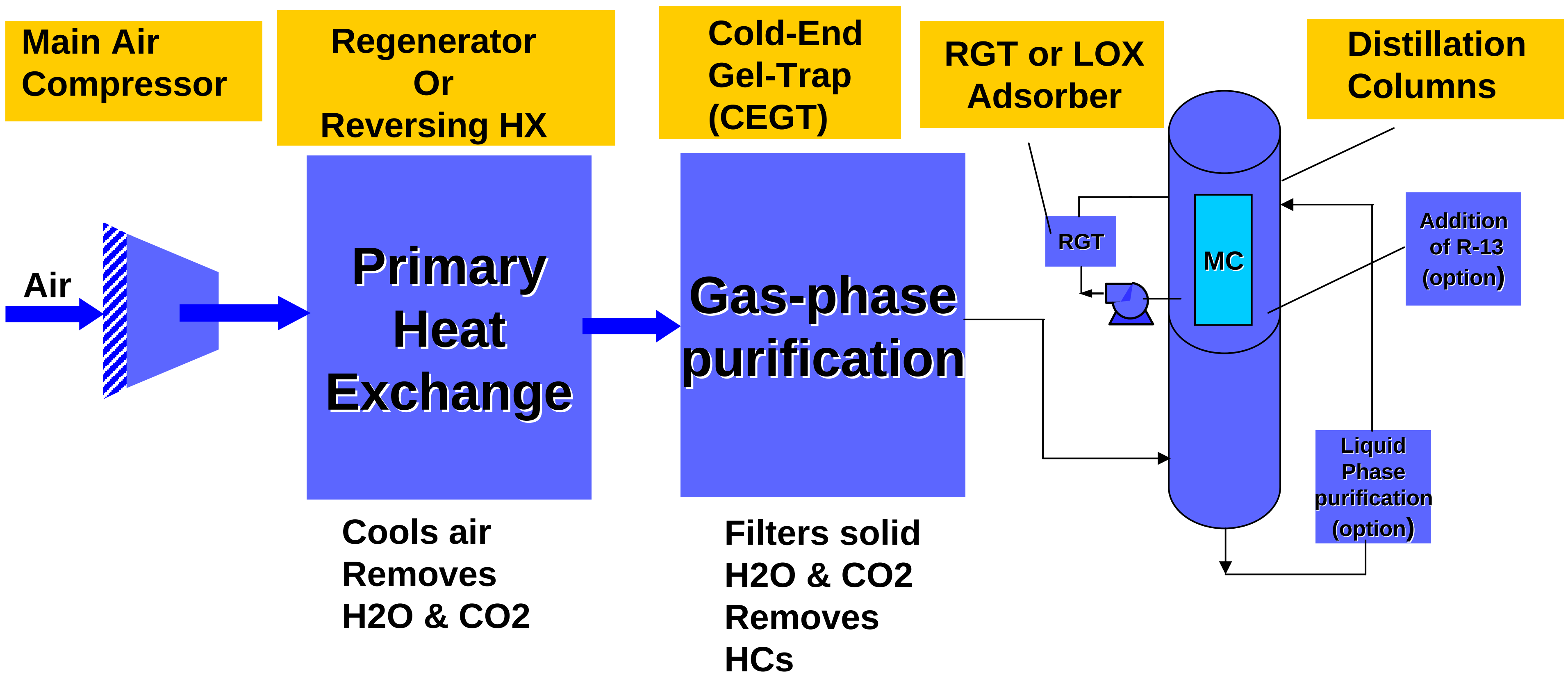
Contaminants in Ambient Air

- **An important factor in the design and operation**
- **Three types**
  - corrosive: acid gases, sulfur oxides, ammonia
  - plugging: H_2O, CO_2, N_2O, particulates (filterable, solids, aerosols)
  - flammable: Hydrocarbons
- **Plugging and flammable components directly affect safety**
- **Little control over air quality and difficult to measure**
- **Periodically monitor for unusual changes in air quality**

Air purification System

- Significant factor in main condenser and air separation plant safety
- Purification system evolution strongly linked to type of main heat exchangers employed.
- Purification system with varied levels of hydrocarbon (HC) removal impacts HC build-up and safety risks

Air purification (Earlier Plants)



Air purification System
Earlier Plants

- **Earlier plants used regenerators for main heat exchange that also removed moisture and CO2 from air, and a device to trap solid CO2 and ice.**

- **Removal of hydrocarbons and other impurities achieved by gas-phase or liquid-phase gel-traps (CEGT)**

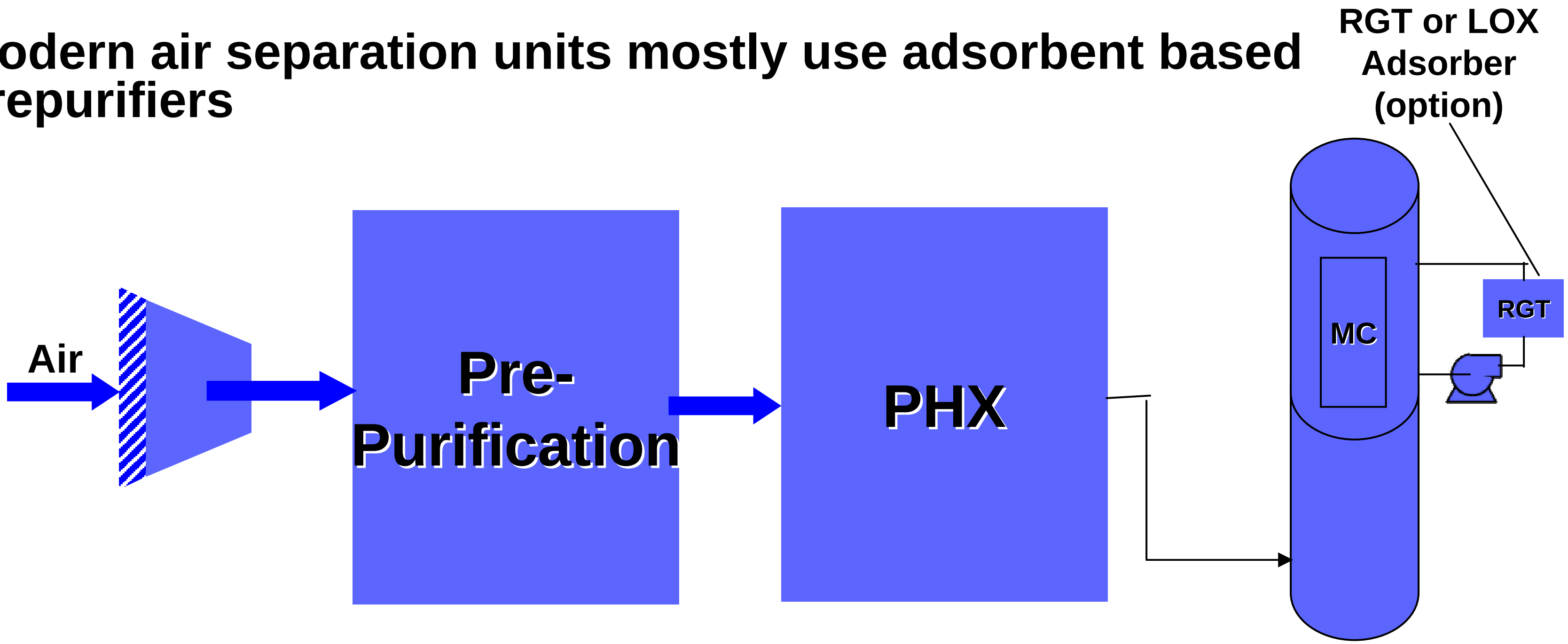
- **Gel traps did not remove all the hydrocarbons. Recirculation Gel Traps (RGT) near the MC was also added to offer additional protection - guard adsorbers/LOX filters.**

- **Regenerators were subsequently replaced by reversing heat exchangers that adopted the same air purification methods as above.**

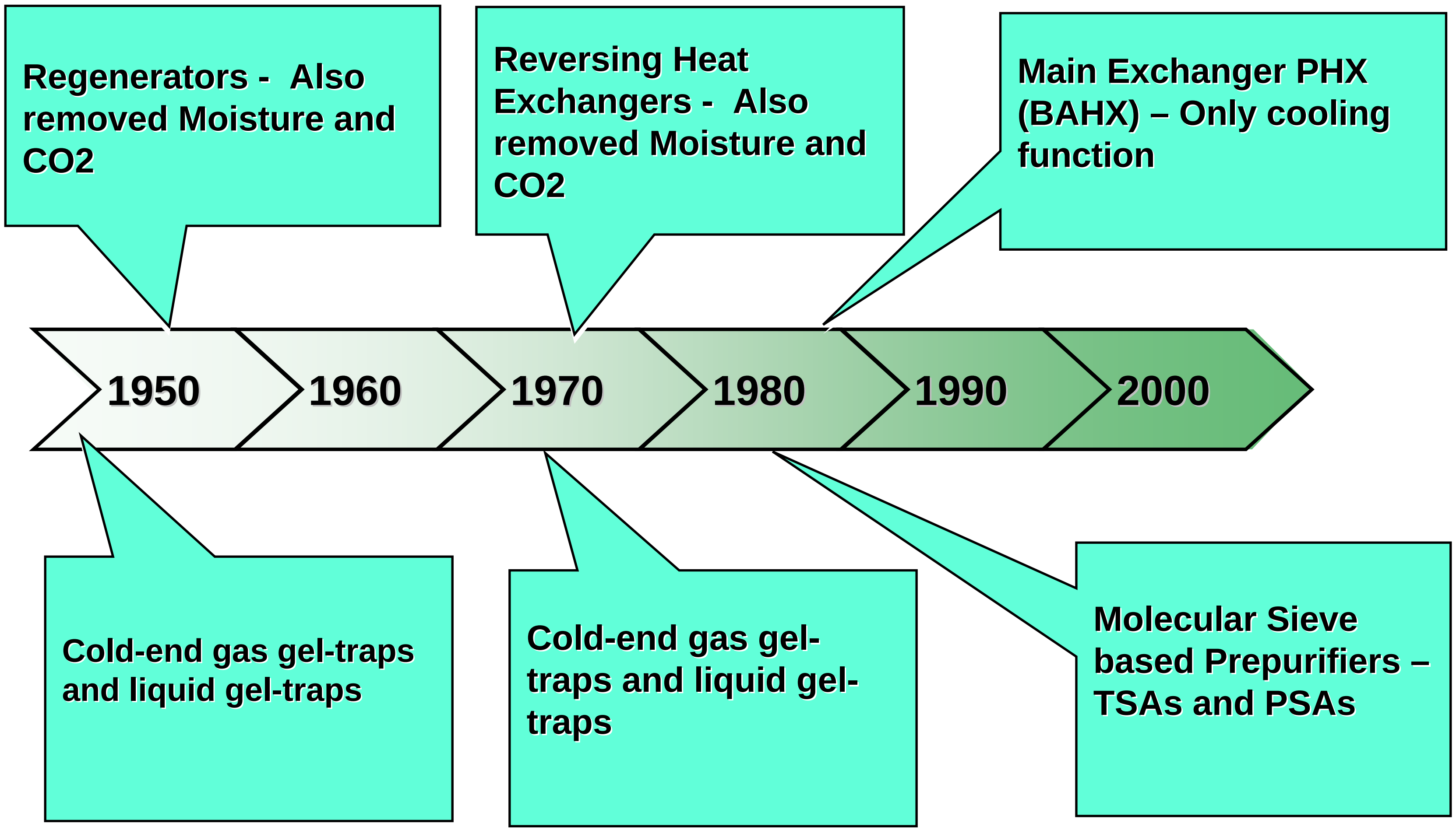
- **Addition of halocarbon R-13 was used to suppress boiling/concentrating of contaminant rich liquid solution in the main condenser.**

Air purification System
Current Practice

- Molecular sieve (adsorbent) based purifiers ahead of primary heat exchanger (PHX) – prepurifiers/front-end purifiers
- Extremely efficient contaminant removal system – water, acetylene & C4+ HC
- Modern air separation units mostly use adsorbent based prepurifiers



Technology Timeline
Air purification & Cooling



Process Dependent Enrichment of Contaminants in LOX Stream

- High boiling contaminants that enter the distillation columns (through air) tend to concentrate in the liquid Oxygen stream
- Concentration or accumulation of contaminants in the LOX stream depends on the process cycle (GOX from column or LOX pumped cycle)
- GOX cycles require purge to limit contaminant accumulation from unsafe levels in the main condenser sump

Process Dependent Enrichment of Contaminants in LOX Stream

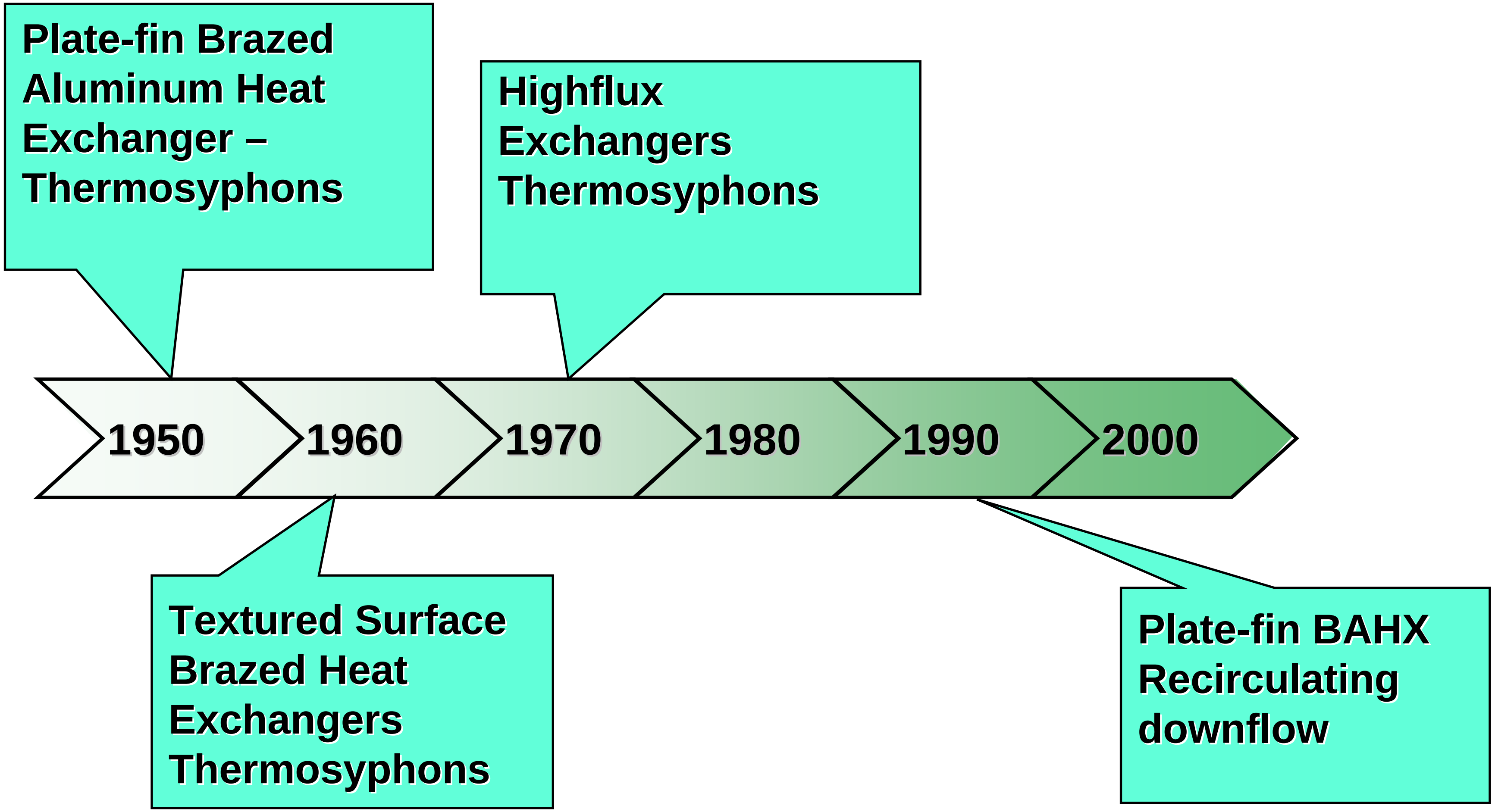
Contaminants	Concentration in air	Concentration at prepurifier exit	Concentration in LOX in MC sump (with 2% * O2 purge)	Concentration in LOX in MC sump (LOX pumped cycle)
THC			<300 ppm	<30 ppm
CO_2	~425 ppm	<0.1 ppm	<4 ppm	<400 ppb
N_2O	~350 ppb	~150 ppb	7.5 ppm	750 ppb

* 2% of air flow into the column

Main Condenser Design and Operation

- **Types of main condensers**
  - Plate-fin brazed aluminum heat exchanger
  - Textured surface plate-fin heat exchanger
  - Highflux main condenser
- **Operation**
  - Recirculating thermosyphons
  - Recirculating downflow
  - Once-through downflow

Main Condenser Technology Timeline – Praxair Practice



Main Condenser Early period Experience

- **Three Reboiler-Condenser Explosions in the Early 1960s**
  - 1960 Belle, WV Plant 1
    - Destroyed reboiler-condenser, damaged high and low pressure columns
  - 1963 Cleveland, OHIO
    - Major damage to heat exchangers, minor damage to surrounding equipment
  - 1964 Belle, WV Plant 2
    - Extensive plant damage

No serious injuries incurred in any of these cases

Typical Main Condenser Core Damage Cleveland, OHIO

Praxair Response

Investigation

- **~450 TPD plants – RHX (reversing heat exchanger)**
- **Main reboiler-condensers utilizing 17“x21”x90“ BAHX cores 14 FPI, no alignment, non-gapped**
- **No evidence of unusual atmospheric contamination**
- **Normal HC concentrations in sumps**
- **Ignition mechanisms could not be determined**
- **Belle 1 – Boiling to dryness**
  - Inadequate Operating Level
- **Cleveland - Dead-ended boiling**
  - Plugged Passages – perlite & water ice
- **Belle 2 - Dead-ended boiling**
  - Plugged Passages
  - Most Reboiler/ Condenser cores were undamaged!

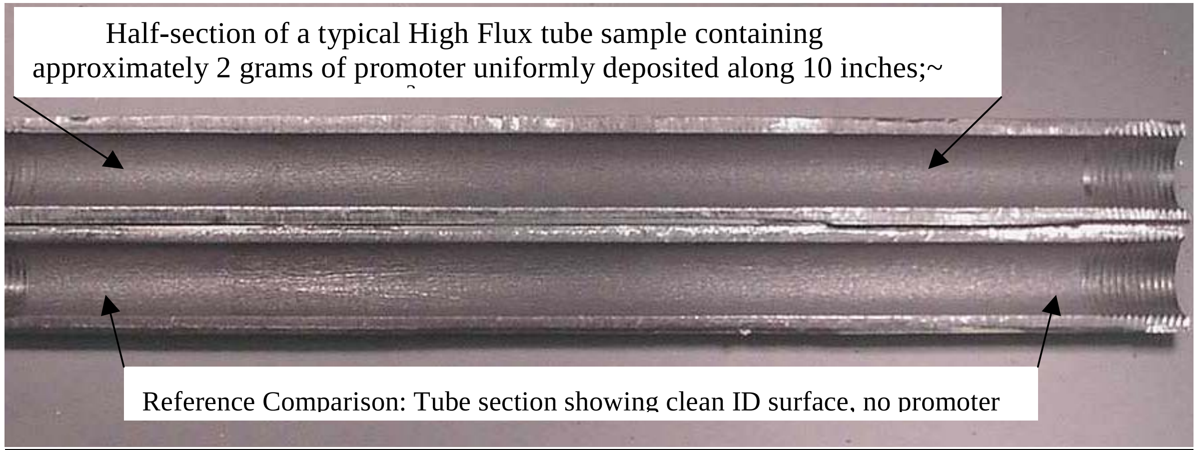
Praxair Response Praxair Fundamentals

- **Considerable effort - theoretical and laboratory Investigations**
- **Measurement and correlation of fundamental thermodynamic and flammability Data**
- **Improved understanding of contaminant behavior**
- **Tests involving conditions that would plug exchangers**
  - Exchanger flow area a key variable
  - Frozen contaminants
  - Permanent solids
- **Development of new types of heat exchangers.**

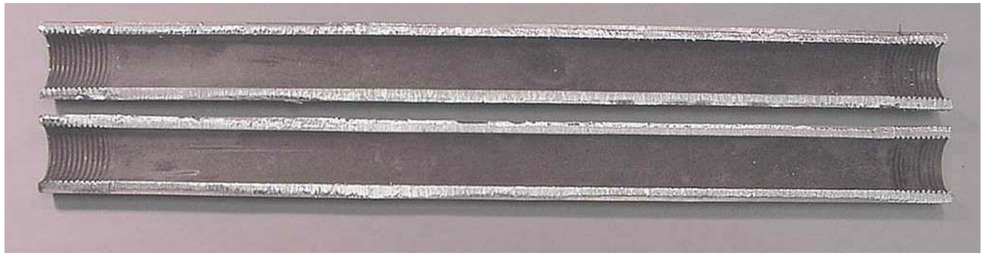
Praxair Response
Changes

- **Revisions to Operating Practice**
  - Increased Liquid levels in reboiler-condensers
  - Increased Recirculation Gel Trap flow & thaw frequency
  - Cold End Gel Trap installation & thaw
  - Fluorocarbon addition
- **Design of Reboilers-Condensers**
  - BAHX
    - Type of fins
    - Alignment & gapping
  - New designs
    - Textured Surface (TS) cores (BAHX with no fin in LOX passages)
    - HighFlux Main Condensers
      - Relatively large flow area
      - Thicker material
      - Promoted ignition tests – No cases of Aluminum participation in reaction

Highflux Tube Performance
Promoted Ignition Tests



Highflux tube with promoter – pre ignition tests

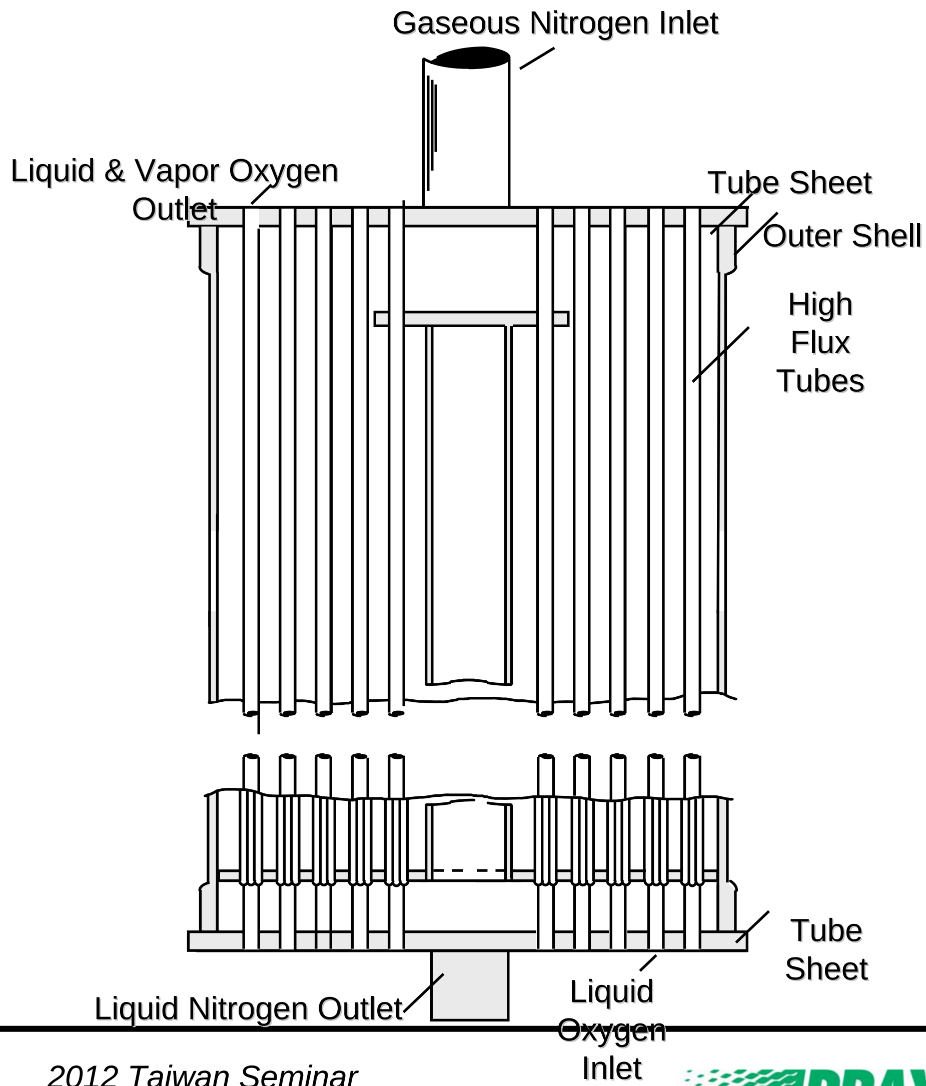


Test 7, Tube 11, 300psig LOX, static, 0.05g/cm2 promoter, 96% promoter consumed

Highflux tube – post ignition tests

Praxair Main Condenser Highflux Design

Praxair



Highflux Tube

Highflux Exchanger Enhancements

- **Large oxygen flow passage clearance**
  - Tube ID 16 mm vs. 1.5 mm in BAHX
- **Higher tube thickness**
  - Tube thickness 2.5 mm vs. 0.4 mm fin thickness
- **Failures, if any, would be isolated to individual tubes and contained by the nitrogen atmosphere surrounding it.**
- **Less flow resistance – very tolerant of lower liquid levels and still have no boiling to drynes**
- **More than 30 years of operating experience**

Main Condenser Design
Recent Developments

- BAHX downflow technology – Praxair’s practices
  - Designed for high recirculation rates to ensure complete wetting on boiling surface, and requires recirculation pump.
  - LOX pumped cycles and Molecular sieve prepurifier is a prerequisite
  - Requires a 3-year thaw period.

Summary

- **Over the past 4 to 5 decades, performance and safety of main condensers were concurrently improved through:**
  - Better identification of risk factors
  - Significant improvements in air purification technology
  - Significant improvements in condenser-reboiler technology
  - Better operation through monitoring and appropriate safeguards

- **CGA Publications P-8* “Safe Practices Guide for Cryogenic Air Separation Plants” and P-8.4** “Safe Operation of Reboiler/Condensers in Air Separation Units – EIGA 65/06 covers these learnings.**

***AIGA 056/08 , ** AIGA 035/06 are equivalent publications**

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