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The Role of Basic Design Data in Preventing Explosions within Fired Equipment:

A Case Study

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AGENDA

- Facility Background
- Problem – Solution – Benefit
- Collection of Basic Design Data (BDD)
- Incident Description
- Lessons Learned
- Summary and Conclusions
- Questions

Facility Background

- Manufactures Expandable Polystyrene (EPS)-type product
- Isopentane (i-C_5) is used as the blowing agent
- Isopentane emissions from multiple sources throughout the process
  - Reactors
  - Hold Tanks
  - Packaging Operations

Problem – Solution - Benefit

- Expansions planned for the facility to increase production capacity ~800% over 3 – 4 year period

- Isopentane emissions would have to be collected and destroyed for compliance with Environmental emissions permitting

Problem – Solution - Benefit

- Two classes of i-C_5 streams in the process:
  - *Contaminated Air Stream* (LVOC)
    low levels of Isopentane mixed in air
  - *Contaminated Inert-Gas Stream* (HVOC)
    variable levels of Isopentane mixed in nitrogen

- LVOC: Continuous, Steady Concentration
- HVOC: Intermittent, Variable Concentration

Problem – Solution - Benefit

- Catalytic Thermal Oxidizer (TOx) technology chosen
- Well suited for moderate-to-high Volatile Organic Compound (VOC) concentrations
- Well suited for processes that frequently cycle on and off
- Estimated Destruction and Removal Efficiency (DRE) >99% on a continuous basis

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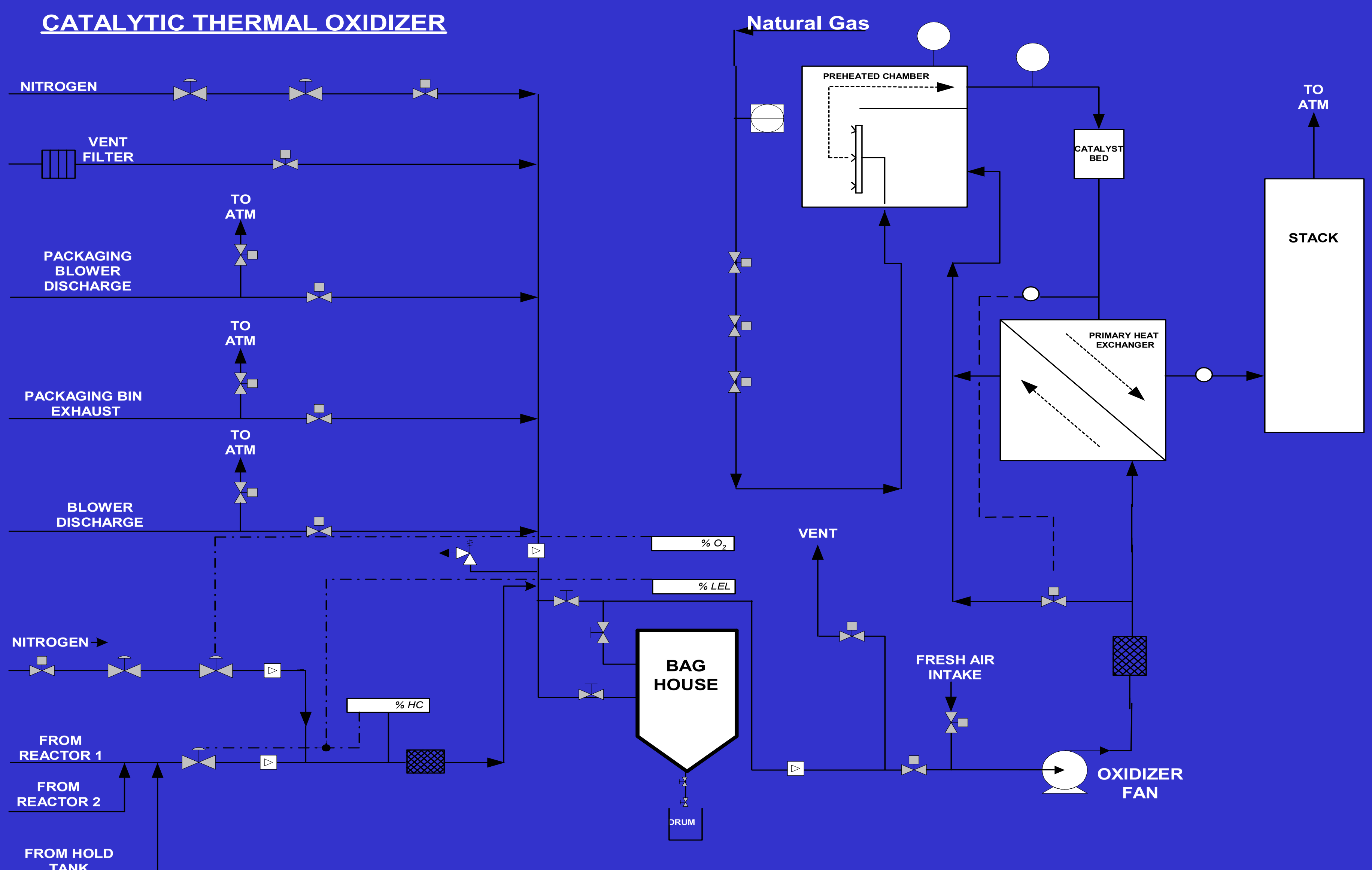
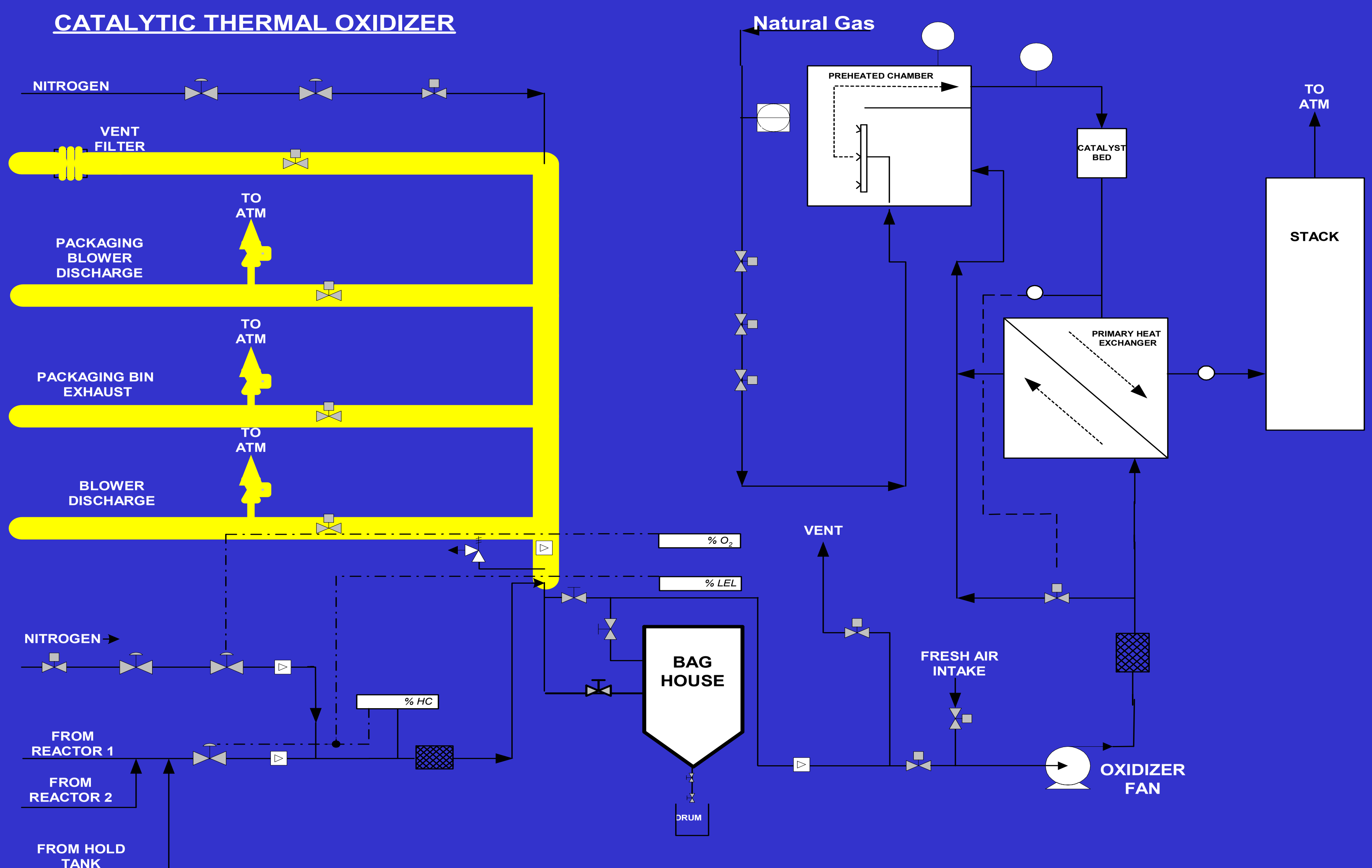
Properties of Isopentane

Molecular Weight	72.2
Boiling Point	82 deg F / 28 deg C
Flash Point	-60 deg F / -51 deg C
Autoignition Temp	800 deg F / 426 deg C
LFL, v% fuel in air	1.4
UFL, v% fuel in air	7.6
MOC, v% oxygen	12

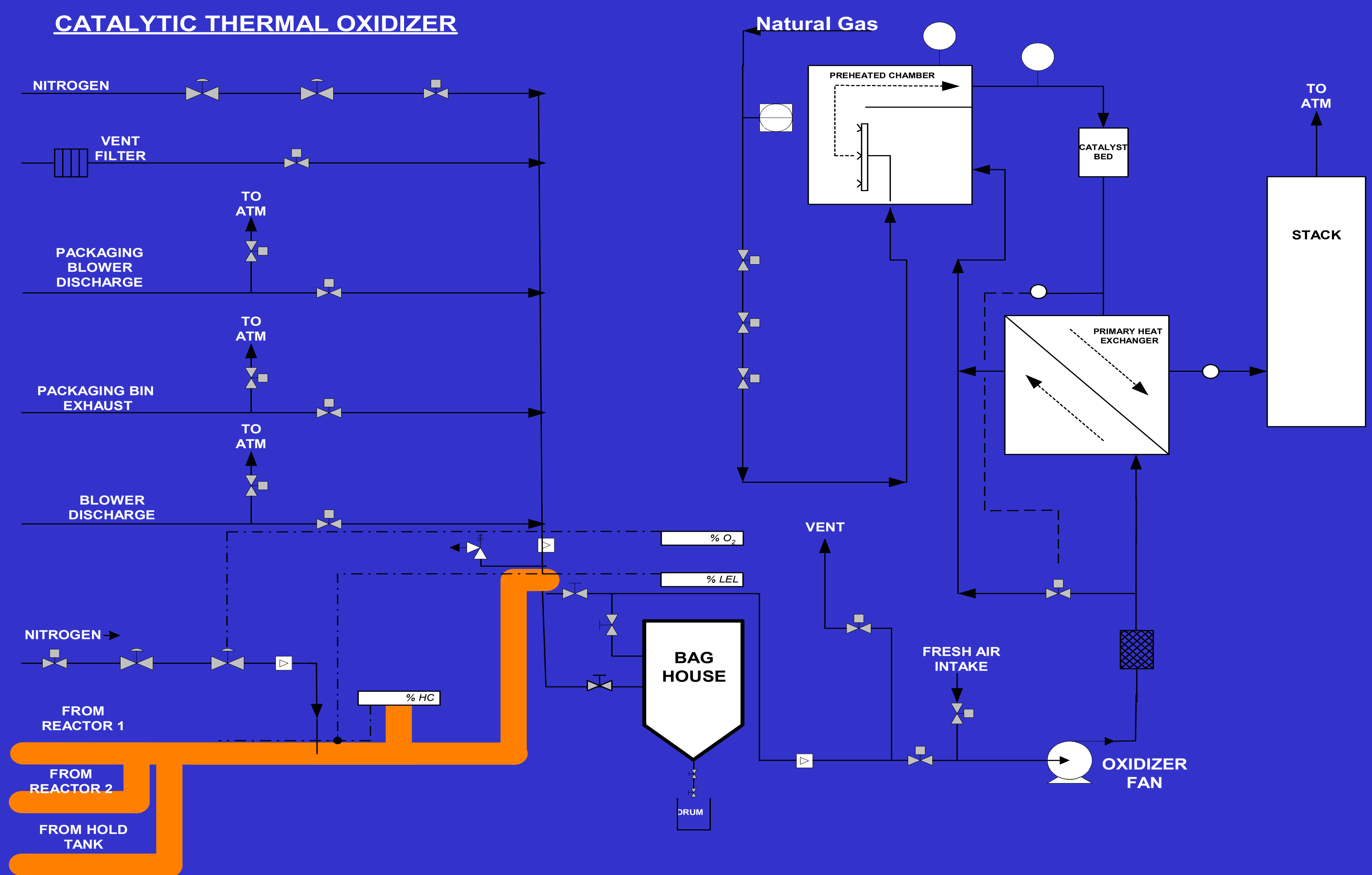
TOx Process Flow Diagram



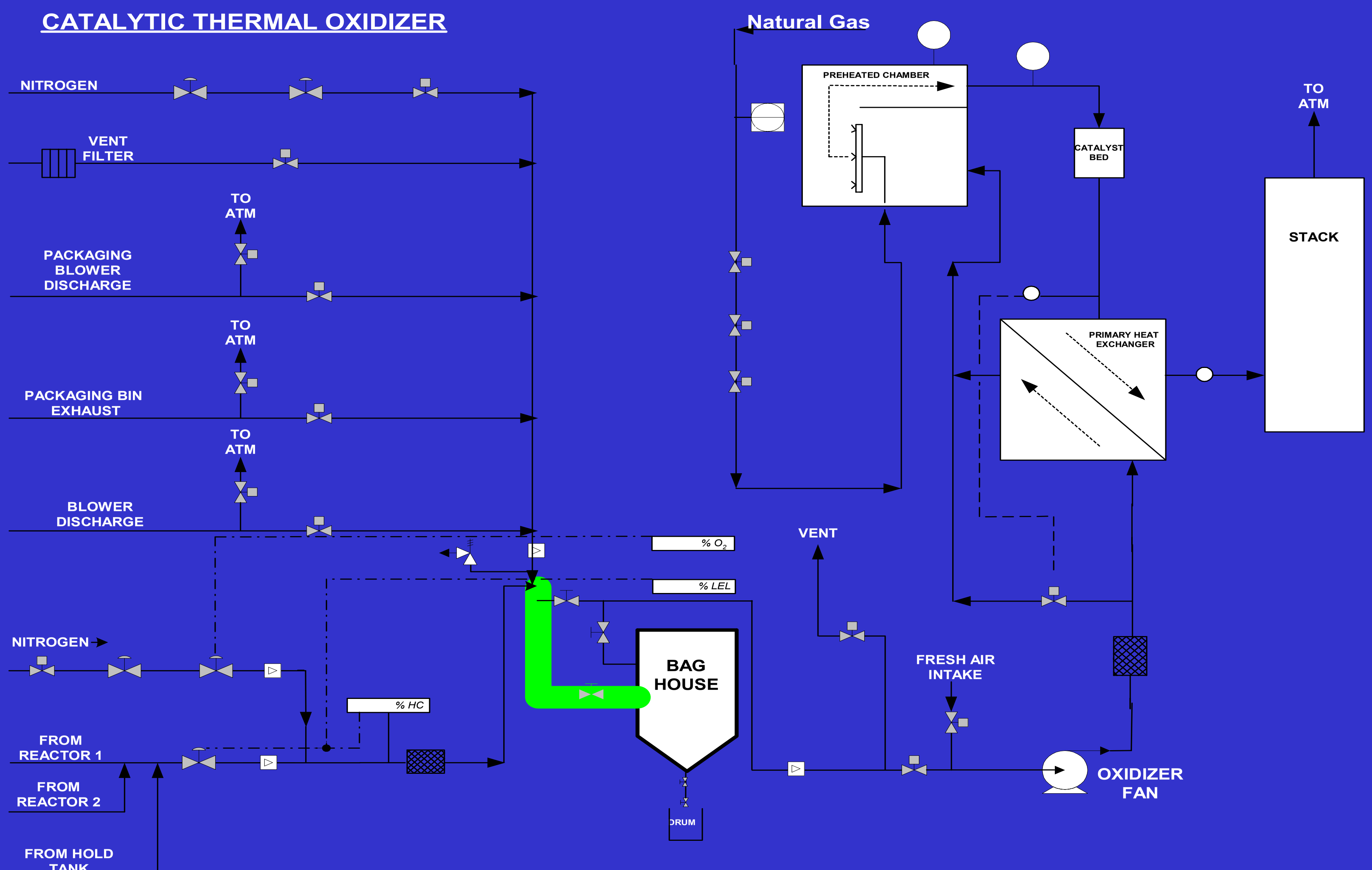
LVOC Sources



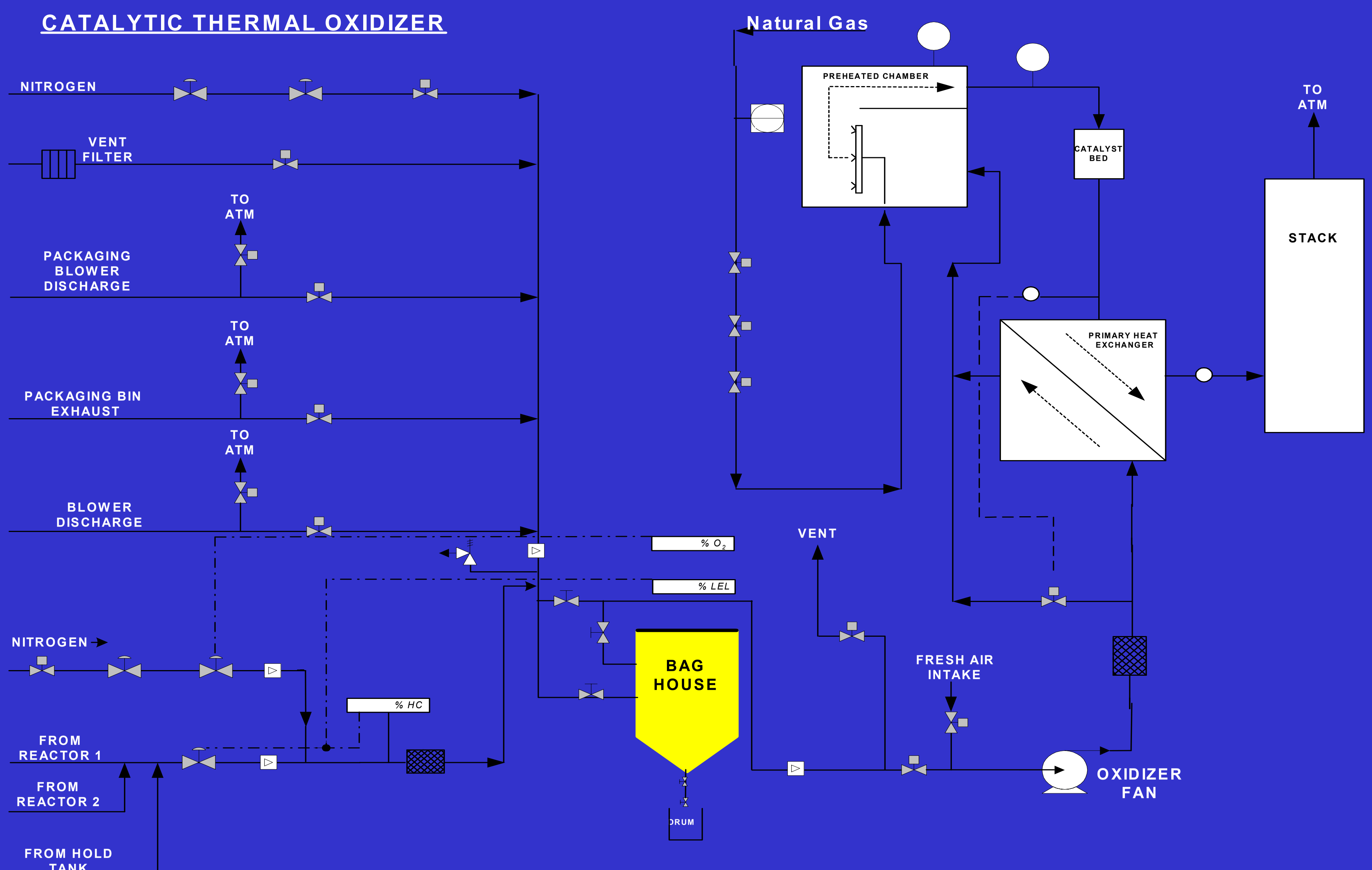
HVOC Sources



HVOC & LVOC Mixing Region

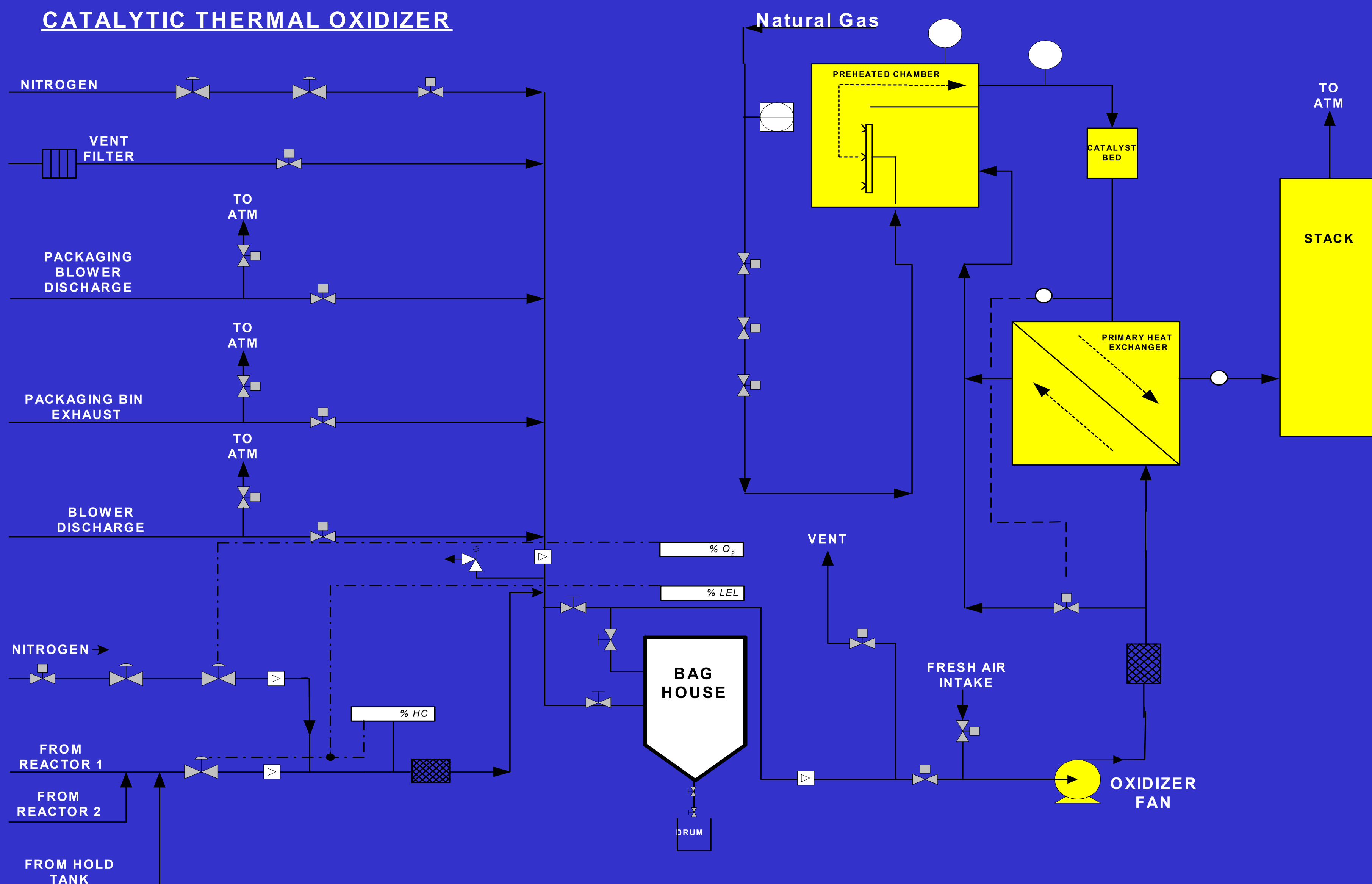


Bag House with Rupture Panel



Combustion Chamber (288 – 350 deg C)

Catalyst Bed (300 – 600 deg C)



TOx Feed Analysis (Design Basis)

Source	Type	Avg Flow (SCFM)	Max Flow (SCFM)	Avg Conc (% i-C5)	Max Conc (% i-C5)
Reactor Vent/Purge	Batch	55	68	6.7	8.0
Conveyor Exhaust	Continuous	643	665	0.33	0.56
Packaging Vent	Continuous	102	103	0.016	0.058
Packaging Exhaust	Continuous	897	970	0.18	0.32
Oxidizer Design Basis	Continuous	1,855	2,100	0.24	0.30

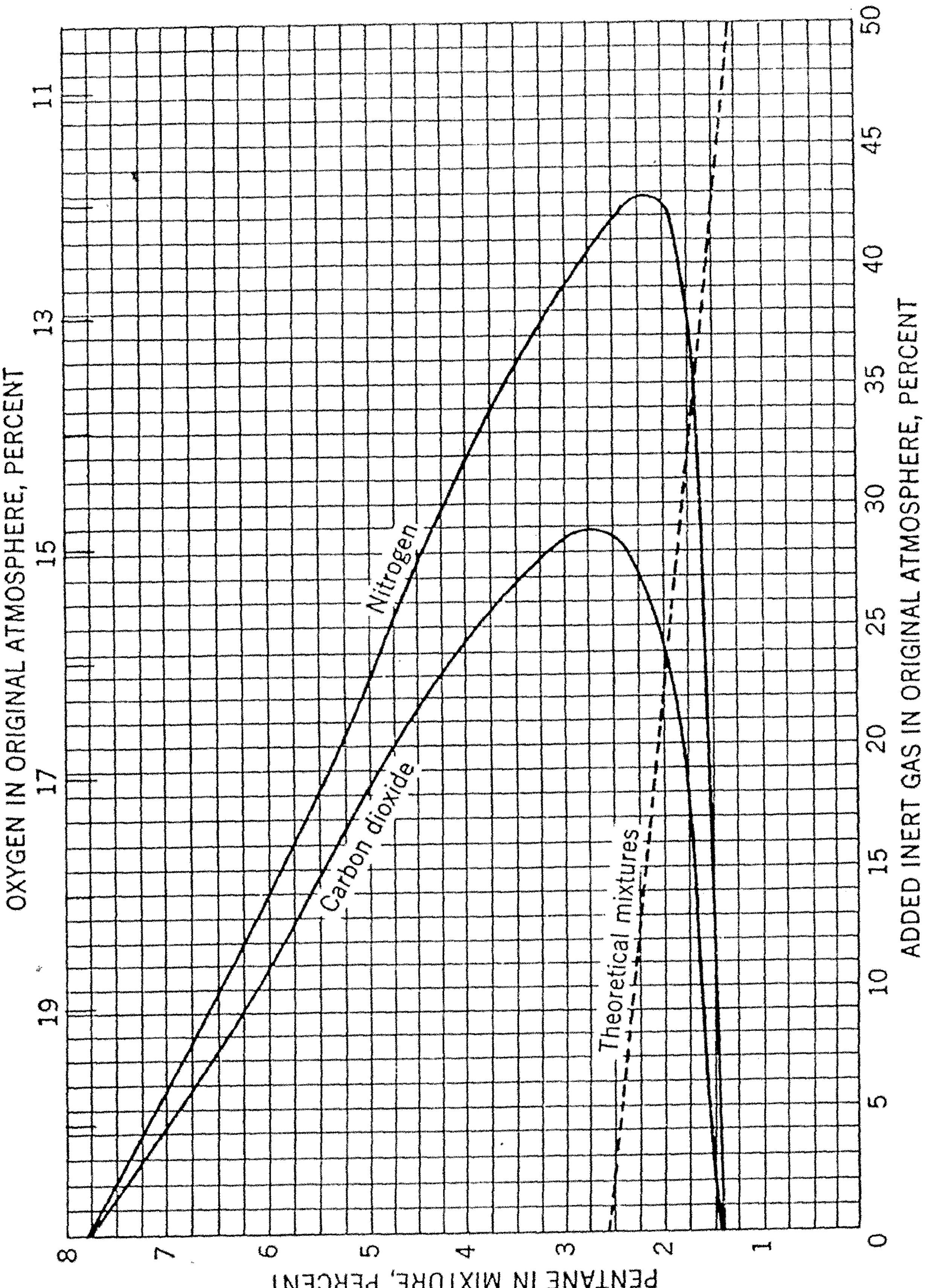
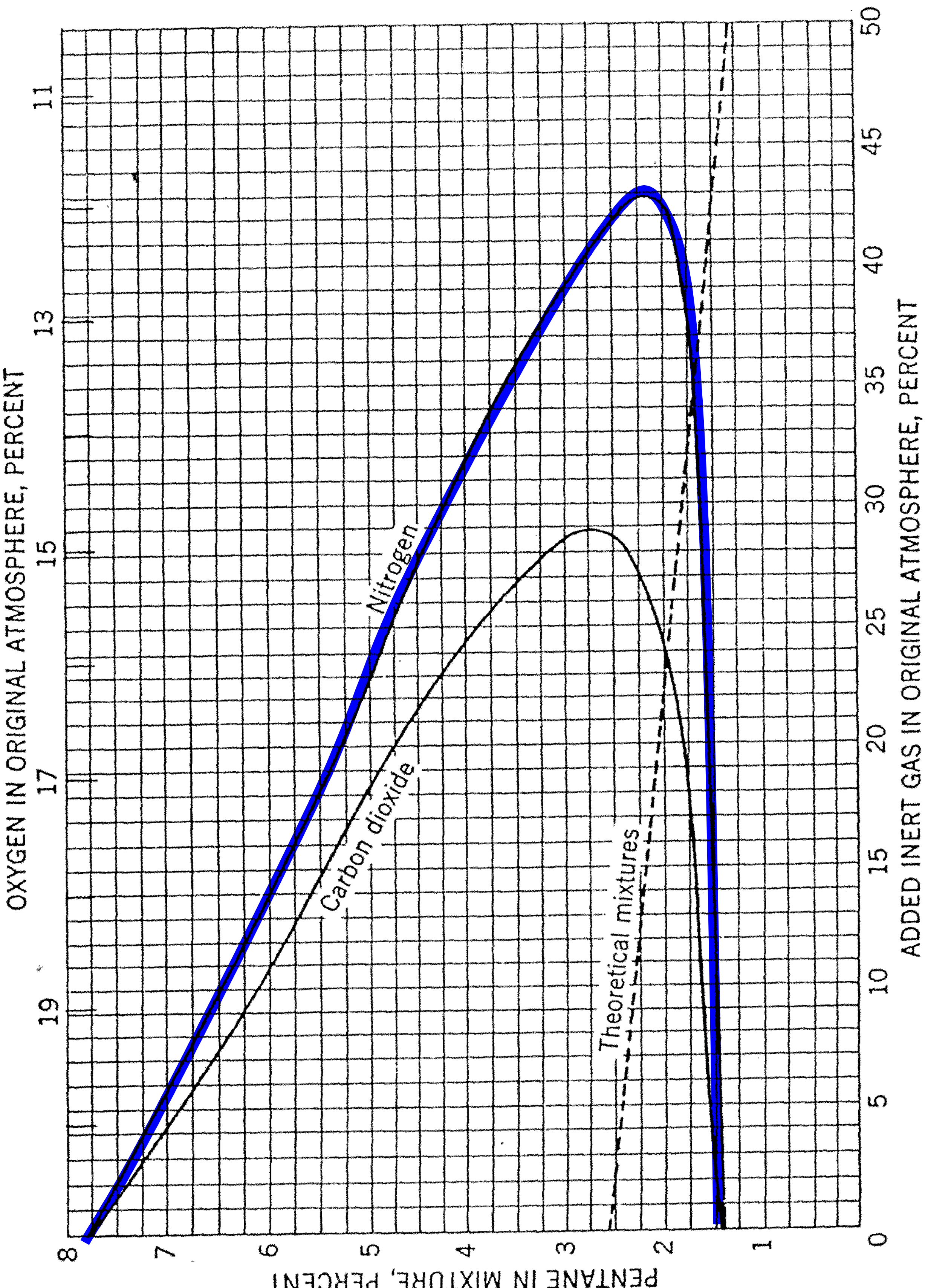


FIGURE 35.—Limits of Flammability of Pentane in Mixtures of Air and Nitrogen, and of Air and Carbon Dioxide.



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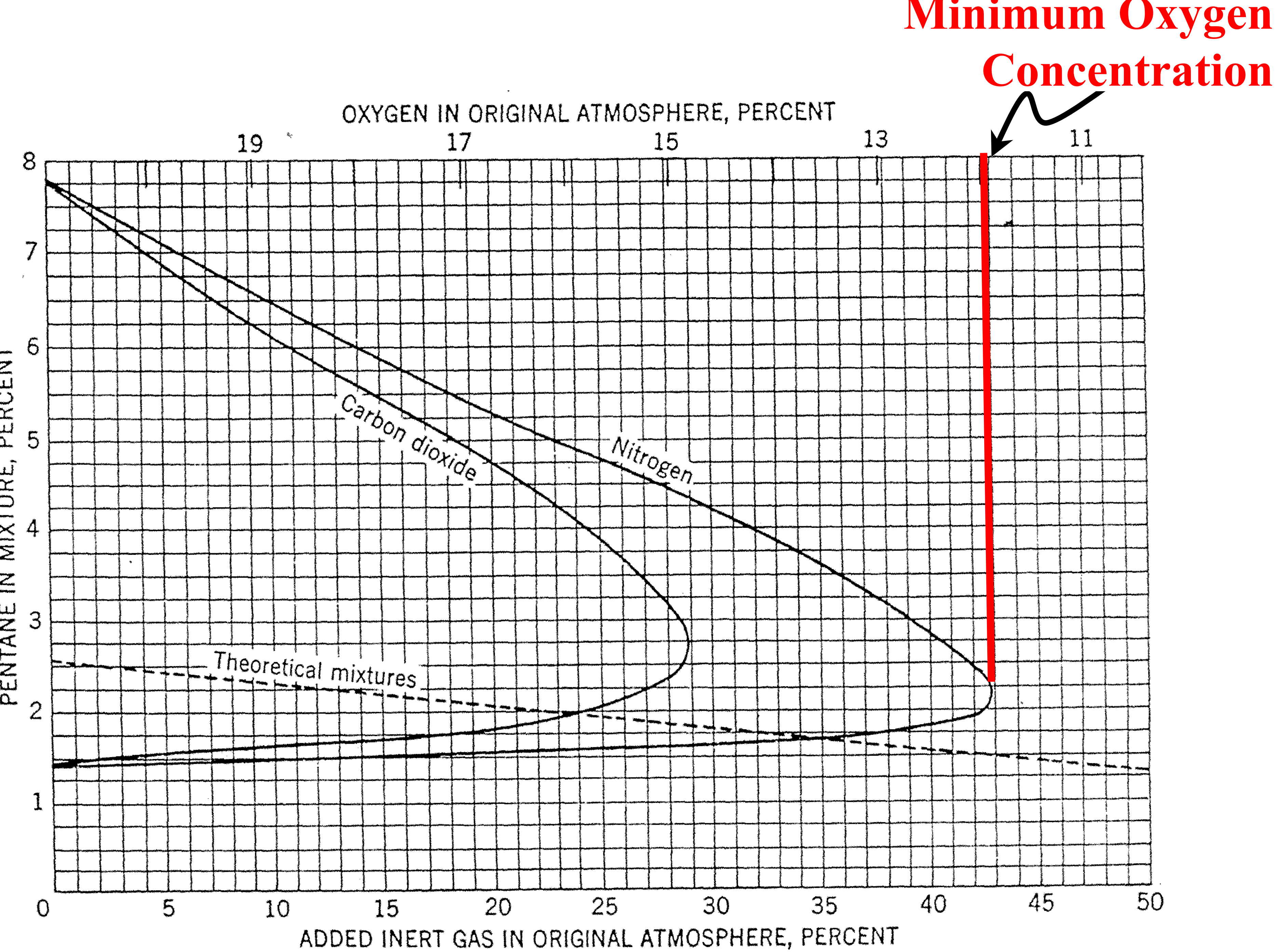

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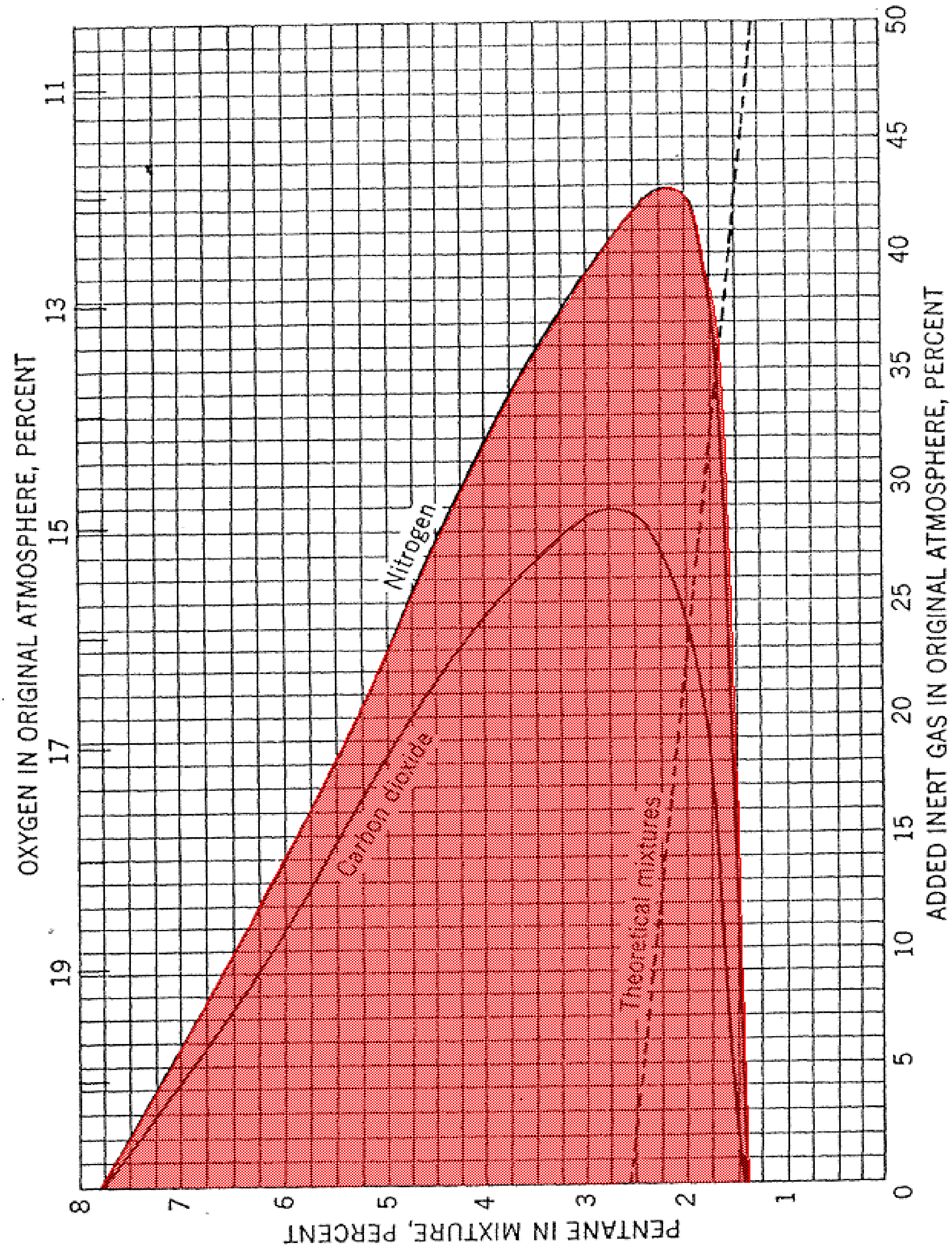

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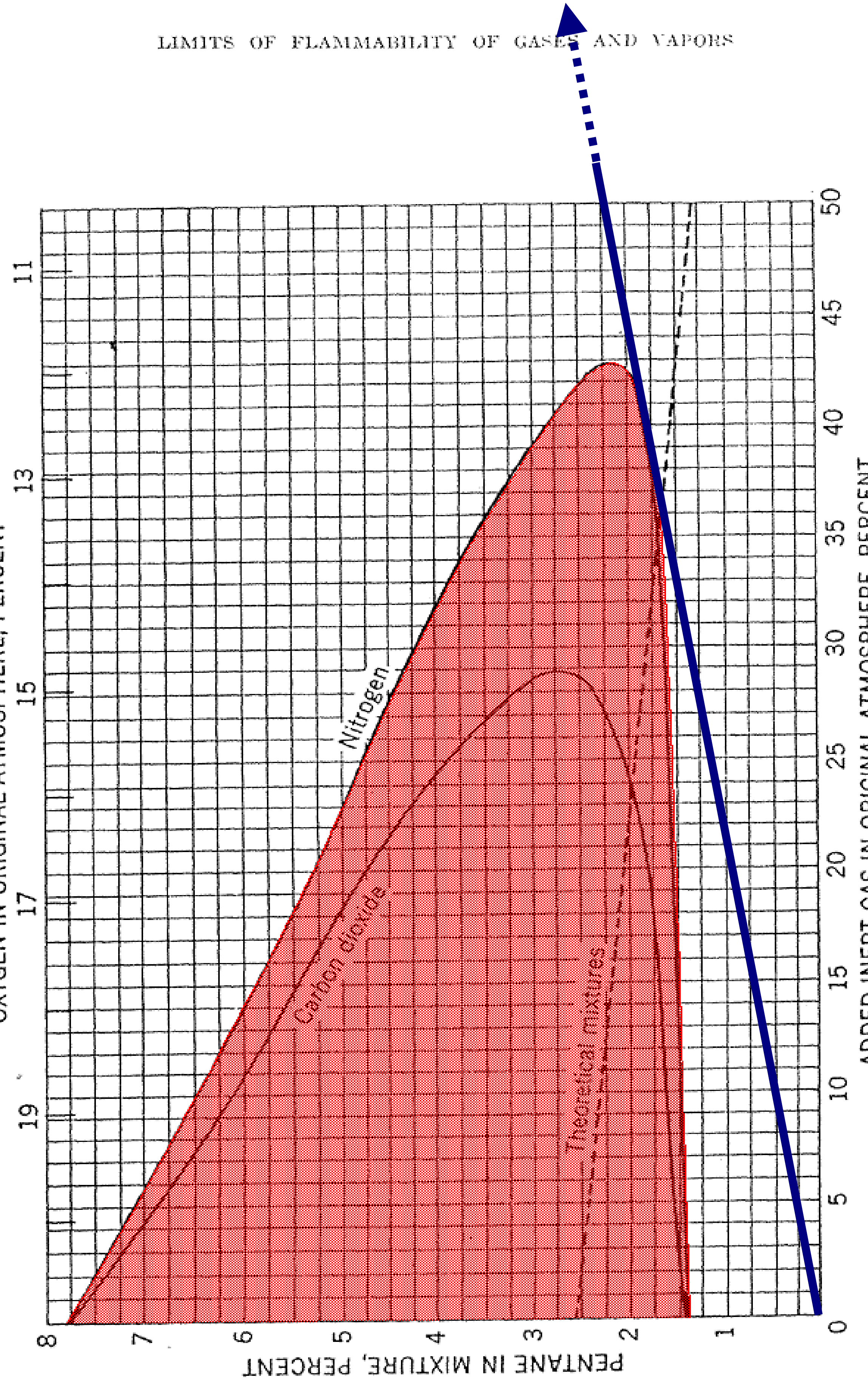

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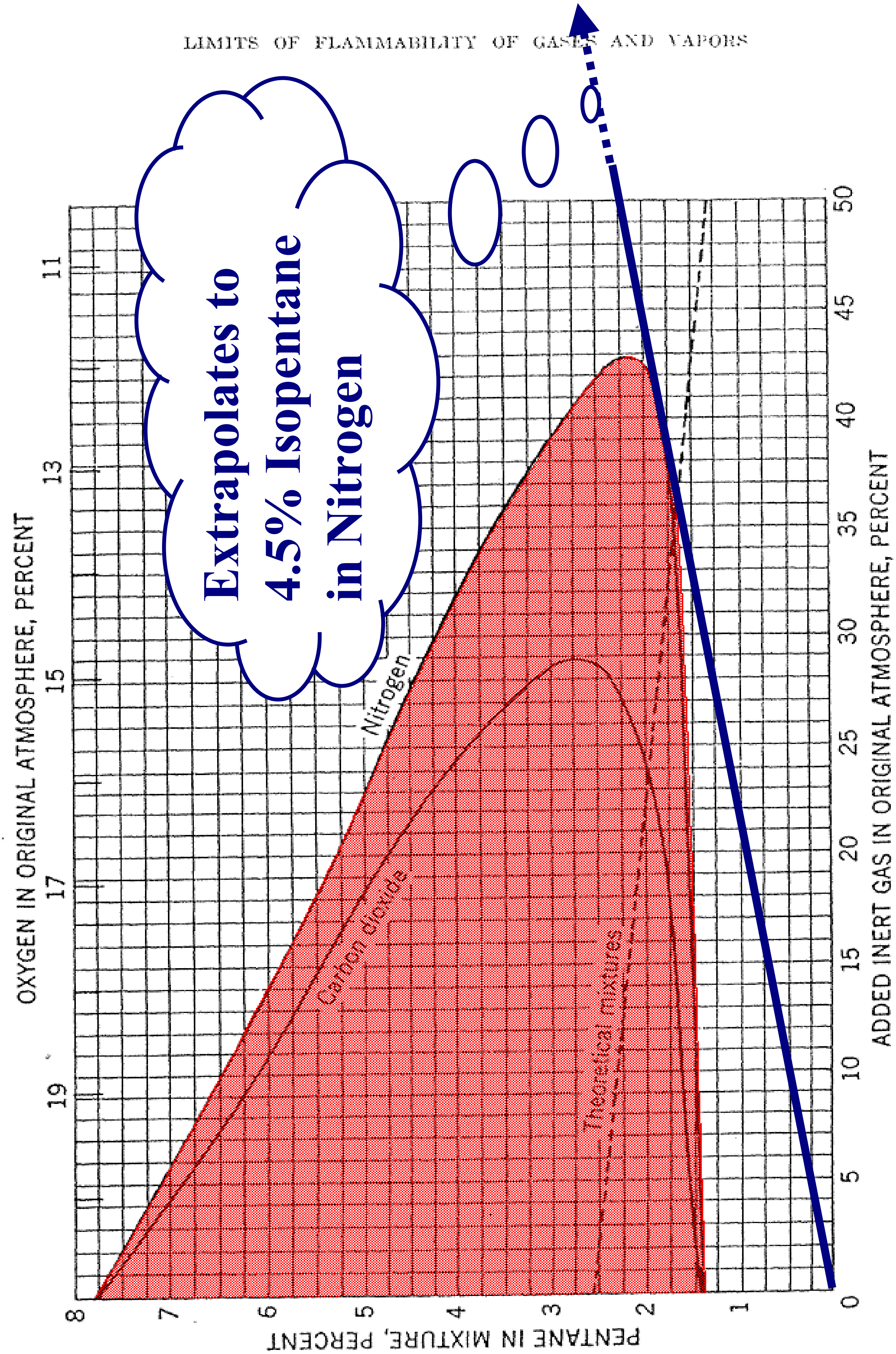

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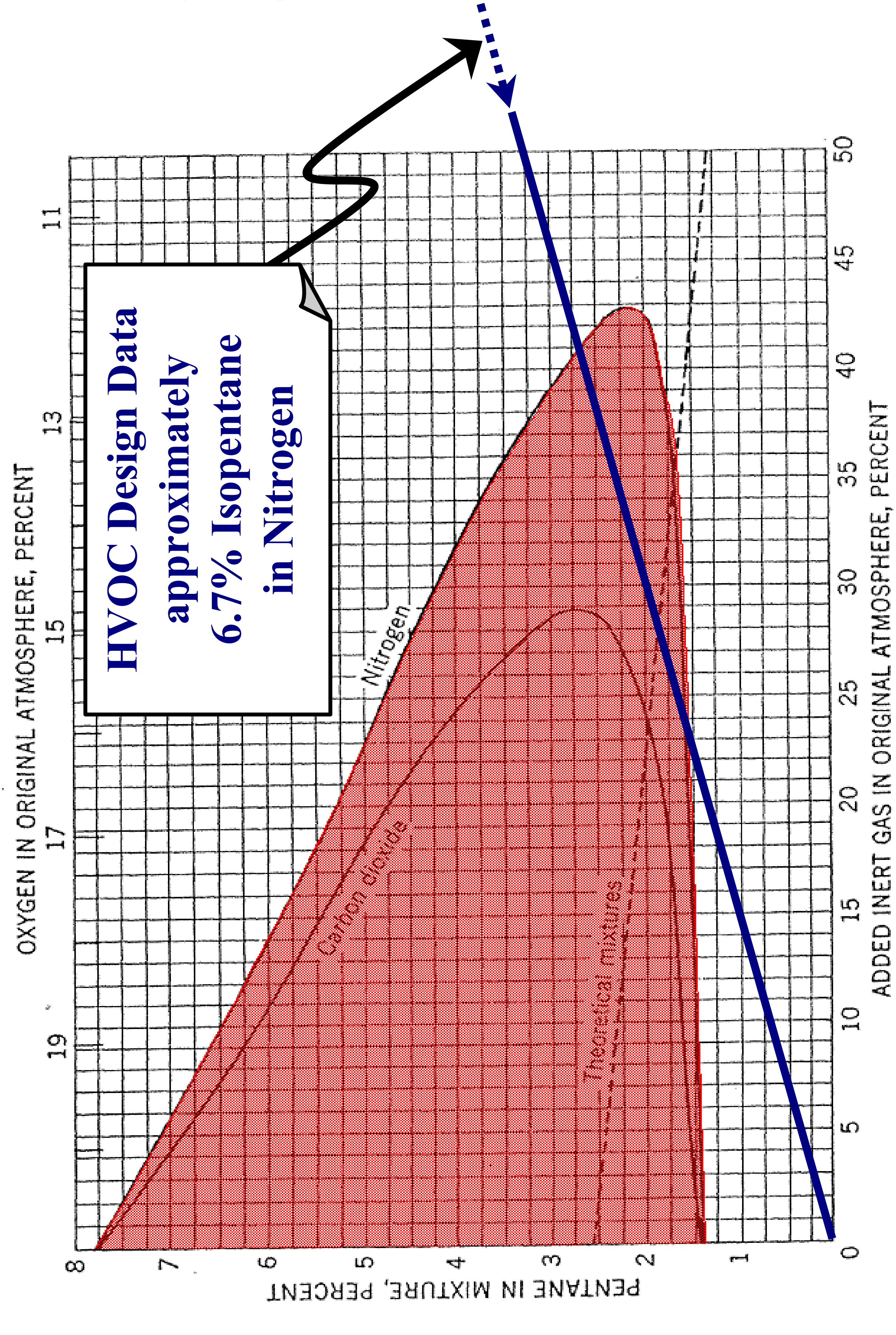

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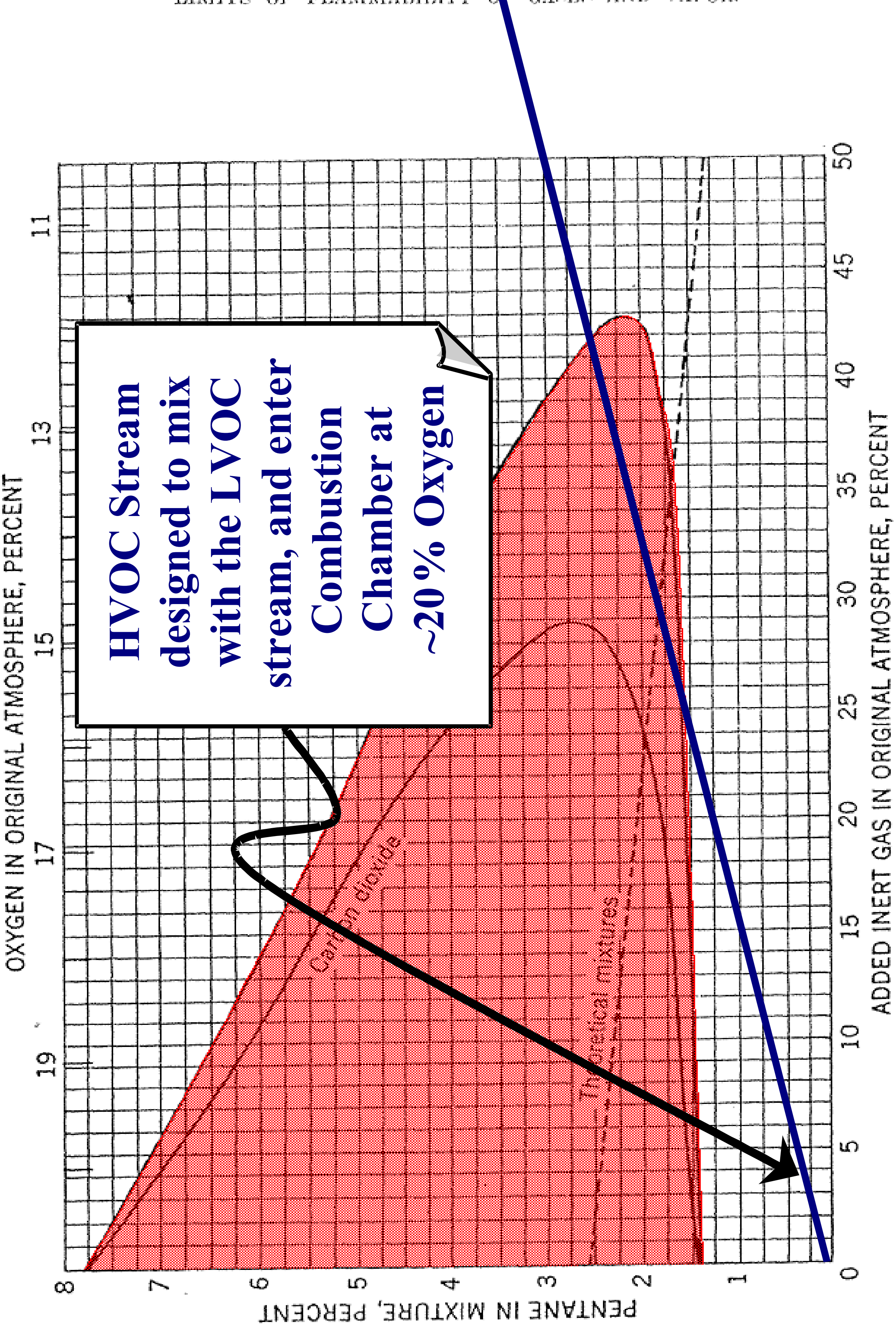

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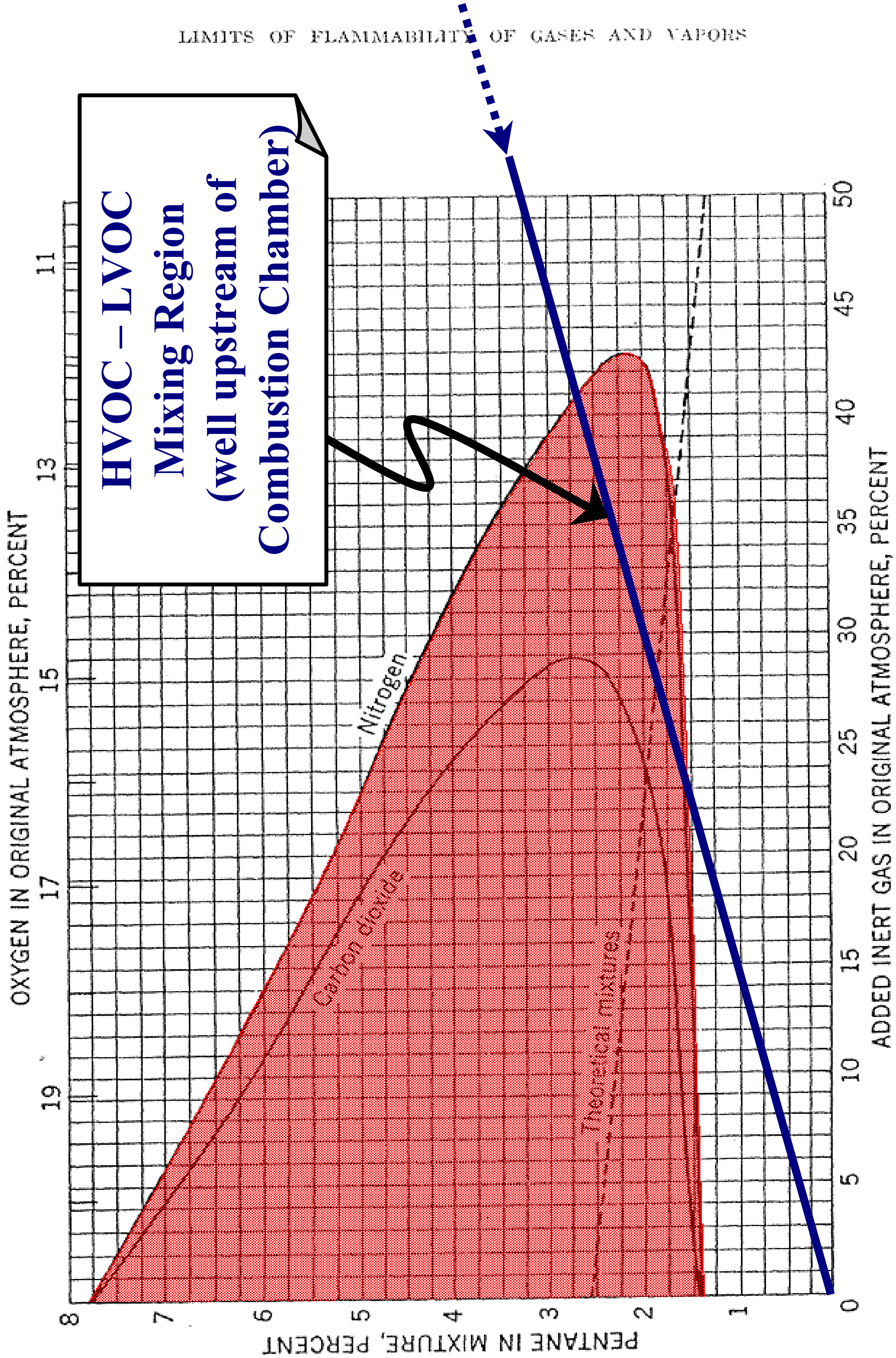

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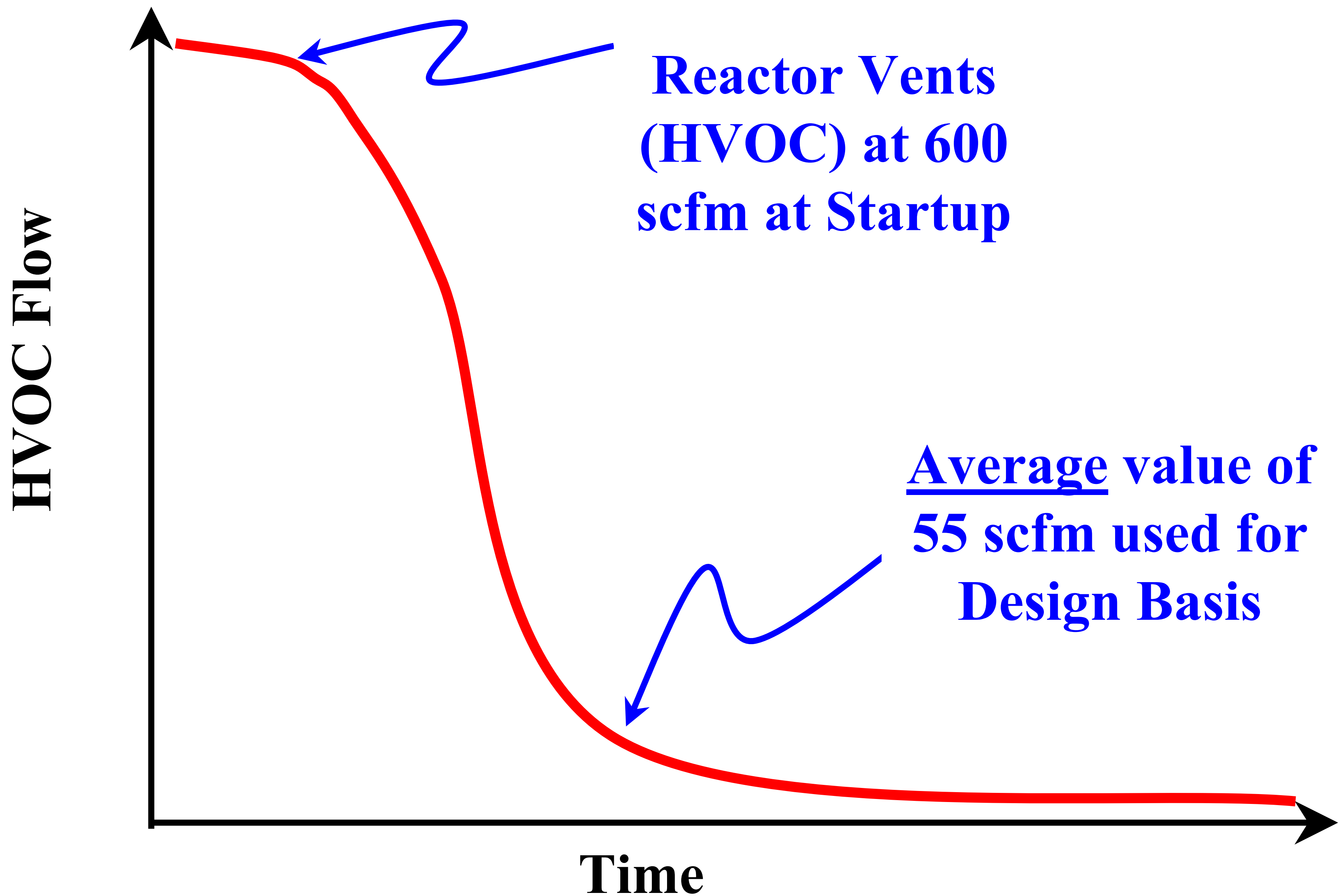
Incident Description – What Happened?

- Initial Startup was performed using Reactor Venting (HVOC) Stream
- **IMMEDIATELY upon venting the reactor, the HVOC flow rate was 600 SCFM!**
- Recall: Basic Design Data specified an HVOC flow rate of ONLY 55 scfm
- How did this happen?

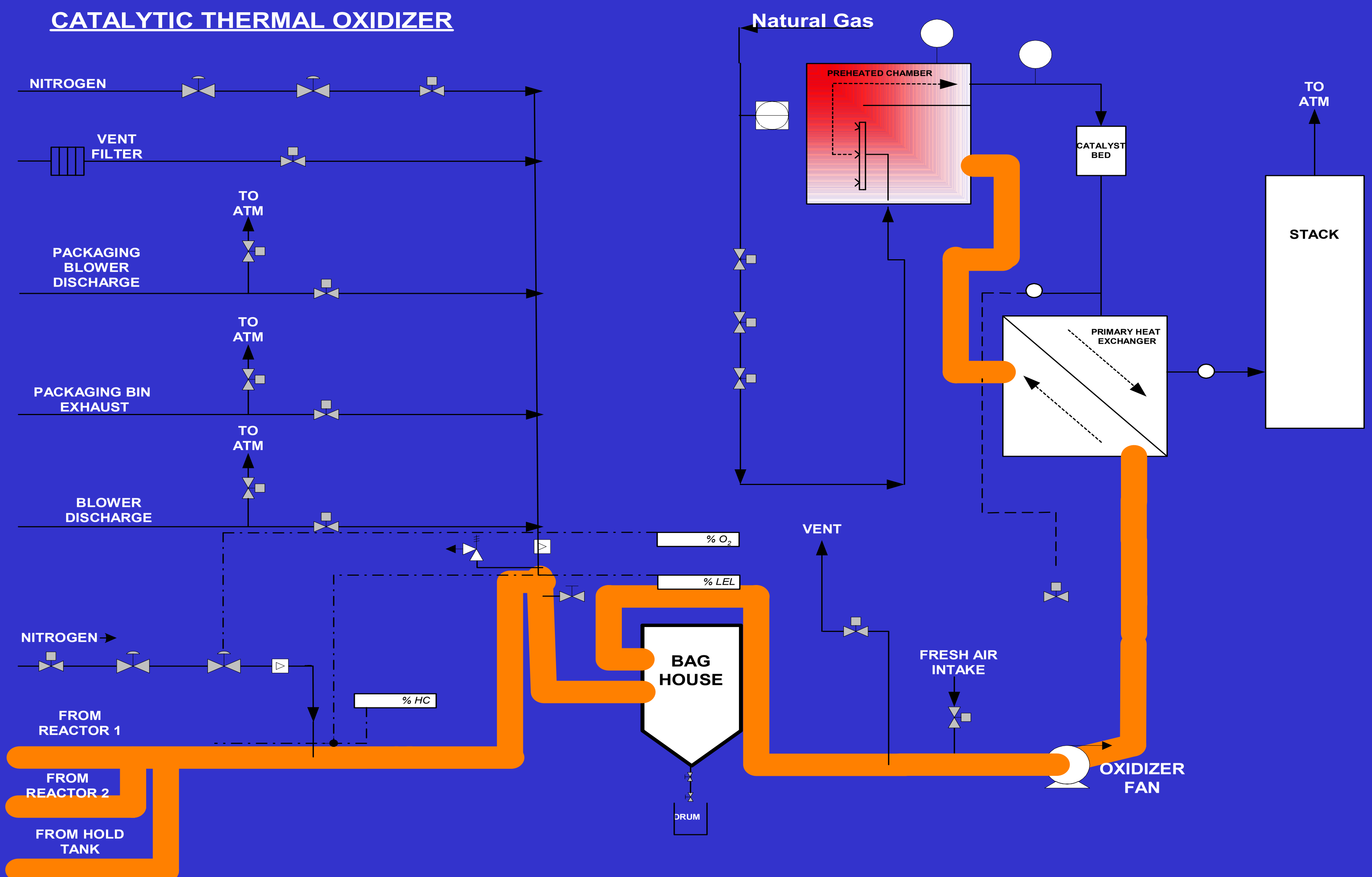
Reactor Venting Rates as a Function of Time



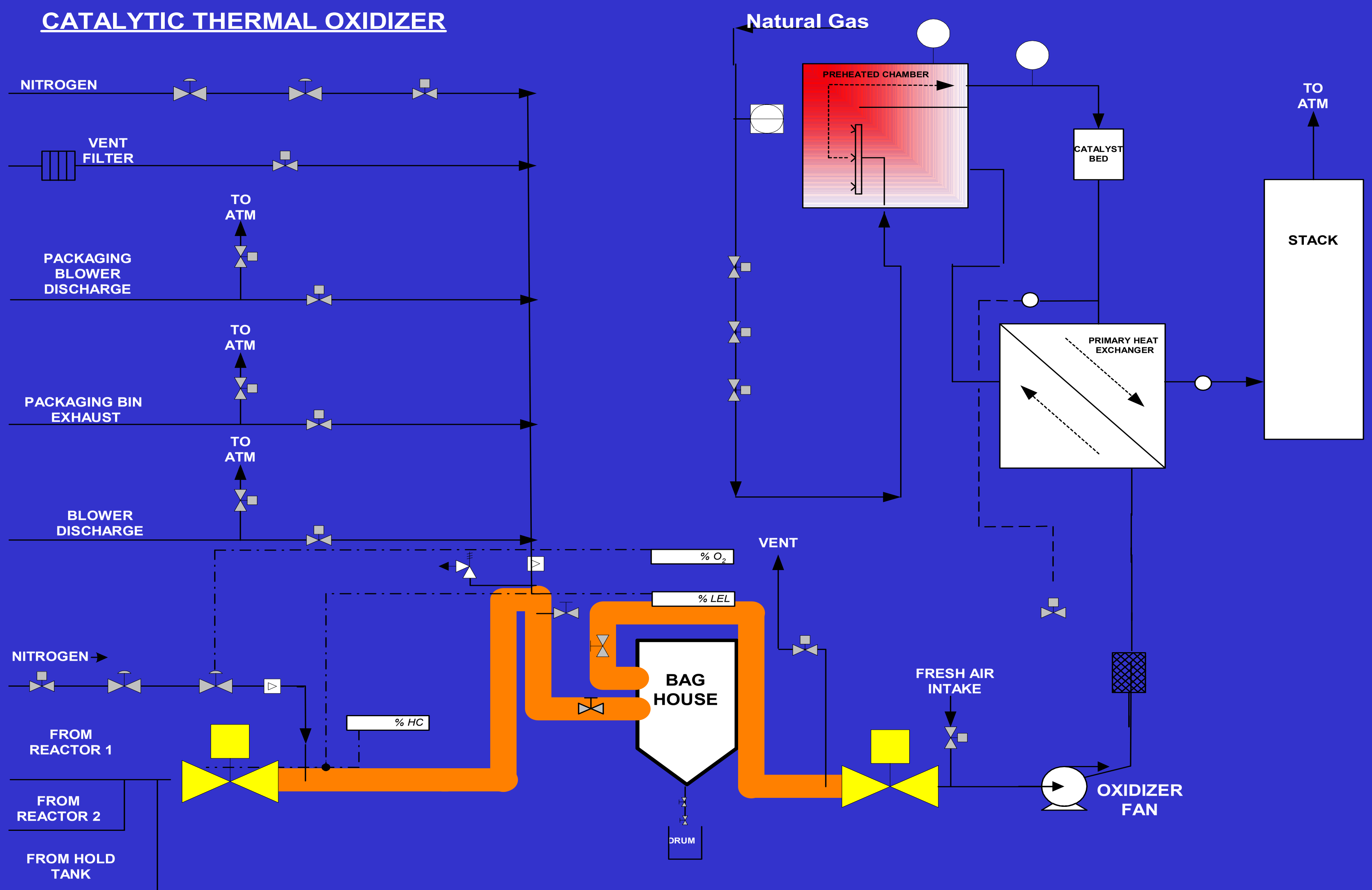
Incident Description – Event Sequence

- 600 scfm from Reactor Vent led to a flameout condition in the Burner Chamber
- Damper inlet interlocked to close upon flameout
- Second damper valve closed, and valve sequencing caused an over-pressure
- Rupture panel on Bag House burst, introducing atmospheric air to the system!

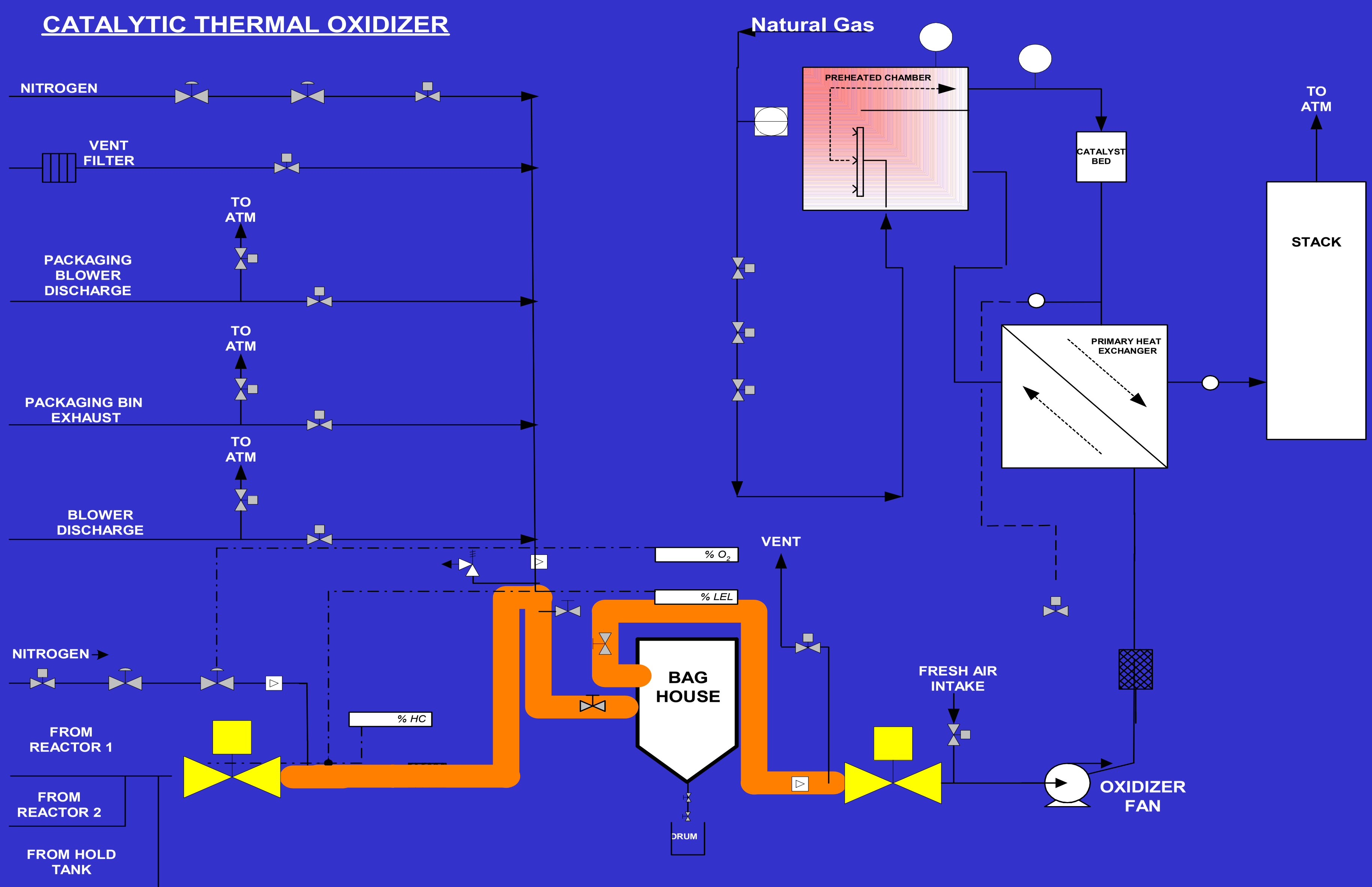
600 SCFM = FLAMEOUT!



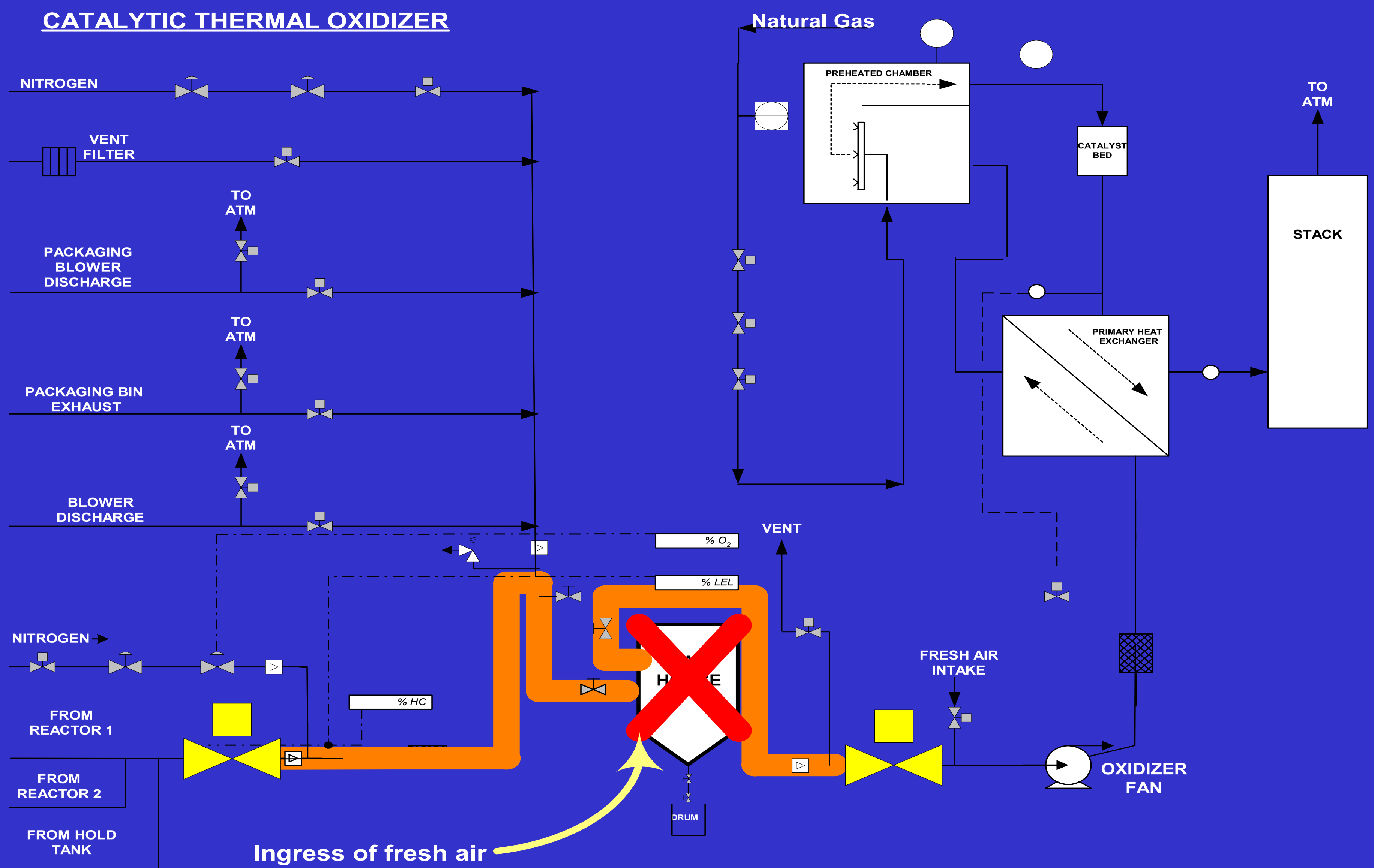
Interlocking Action….



Valve sequencing leads to over-pressure….



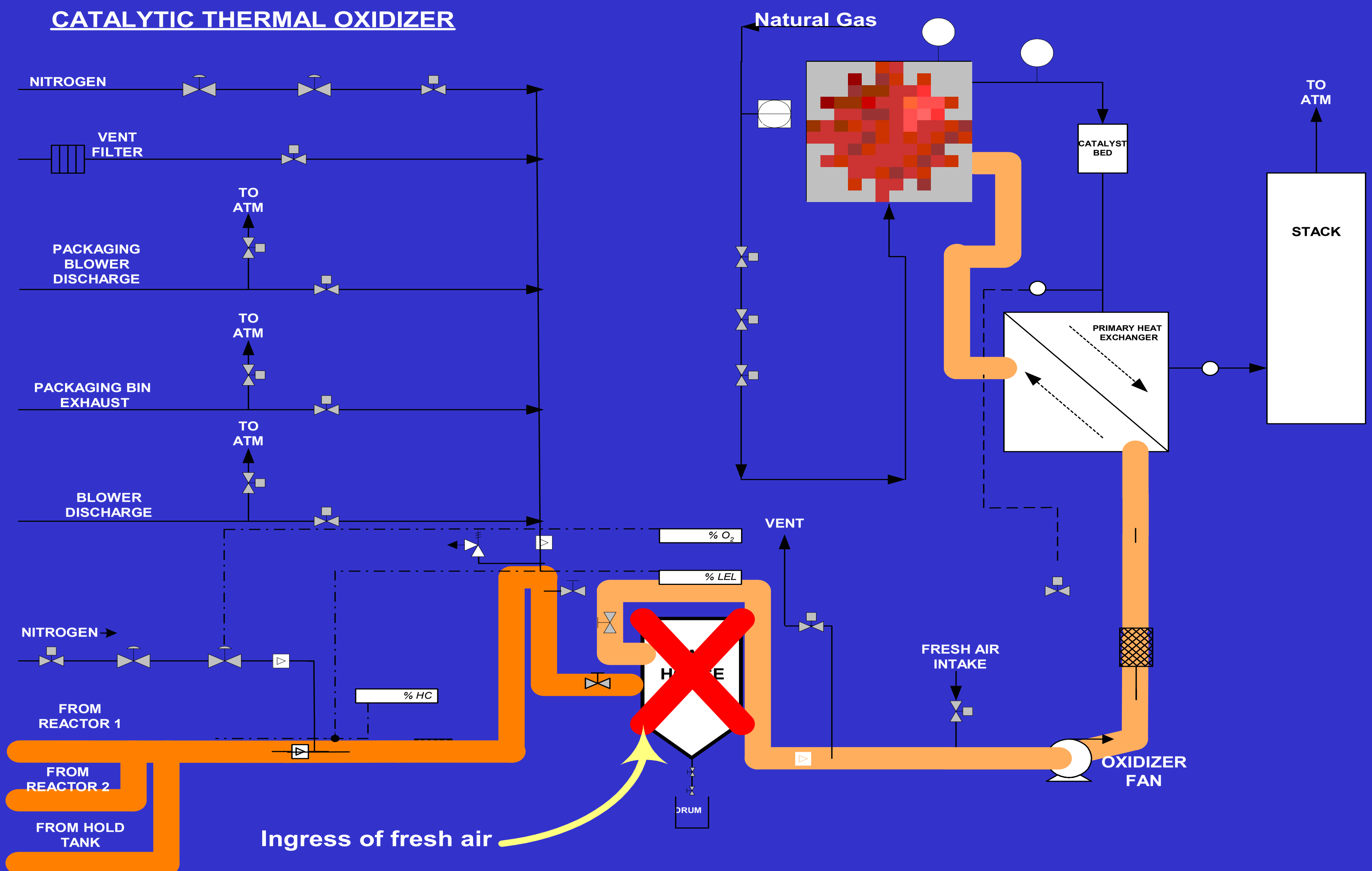
….and Rupture Panel BURSTS from overpressure

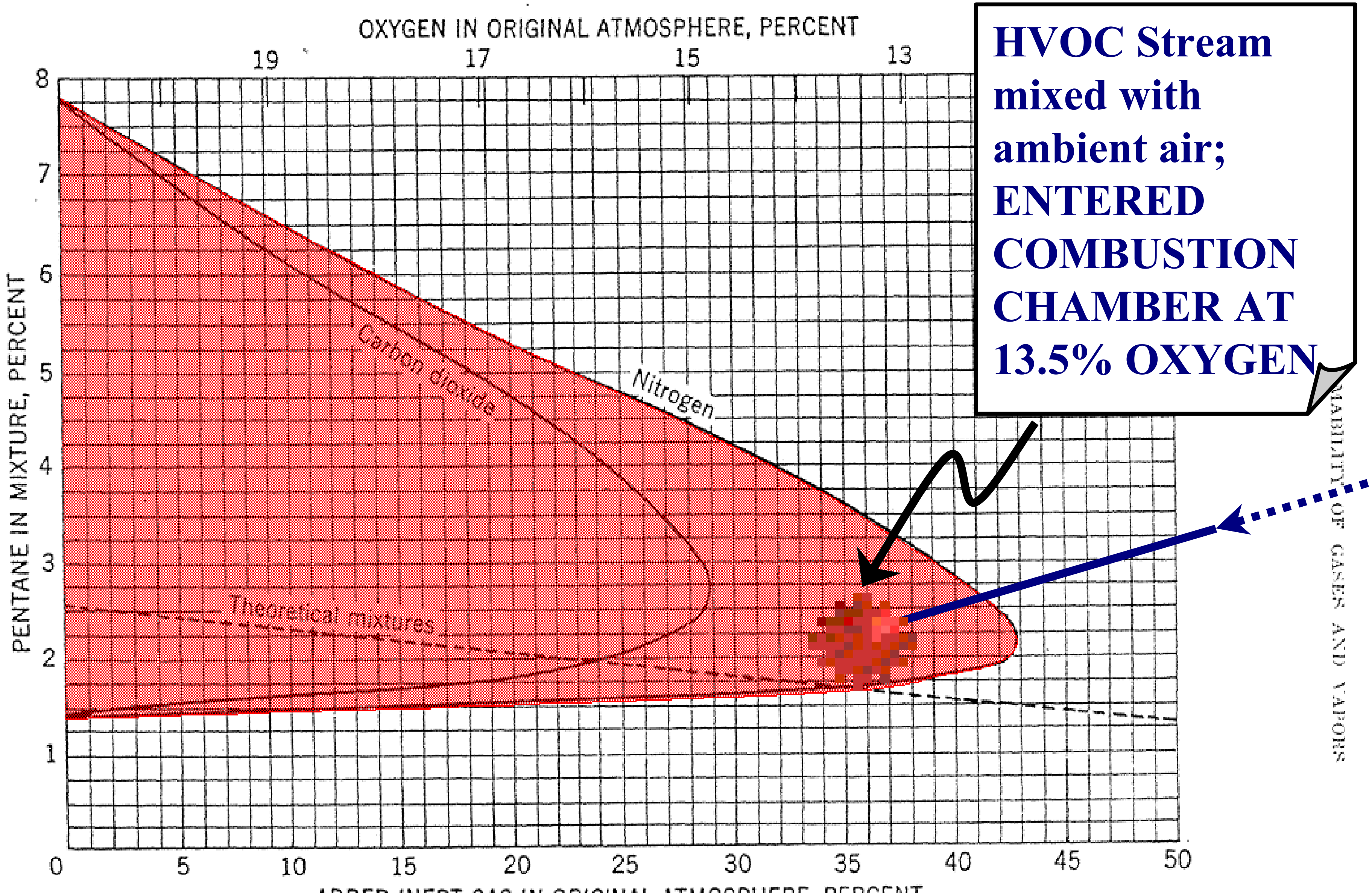


Incident Description – Event Sequence

- **Burst Rupture Panel went undetected by Operations**
- **TOx was re-started minutes later**
- **HVOC gases trapped in the header MIXED with atmospheric air upstream of the Combustion Chamber**
- **CONFINED DEFLAGRATION resulted**

Unburned Fuel + Air Ingress = Explosion





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Lessons Learned

- **HVOC flow rate from Reactor must be measured and controlled, independent of Reactor pressure**
- **The maximum concentration of Isopentane in Nitrogen that can be safely diluted with air without passing through the flammable envelope is 4.5%**
- **Bag House rupture panel failures must have remote indication and alarming**

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Loss Prevention Standards

- Basic Design Data (BDD) must be auditable, i.e., the data and its source must be documented and made available in a format that allows easy retrieval
- Critical BDD should be confirmed independently
- Persons responsible for collecting experimental BDD should ensure the data has been interpreted correctly by designers

Loss Prevention Standards

- Measures to prevent explosions in Fired Equipment must include minimizing accumulations of unburned fuels during combustion upsets – particularly on the fired-side of the equipment

- Flammability Diagrams must be used when designing Fired Equipment, such as Vent Collection and Destruction Systems (VCDS)

Questions?