Process Integration : Managing the Design Process to Minimize Waste

I&EC Special Symposium
American Chemical Society
Atlanta, GA
September 1995

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What is Process Integration?

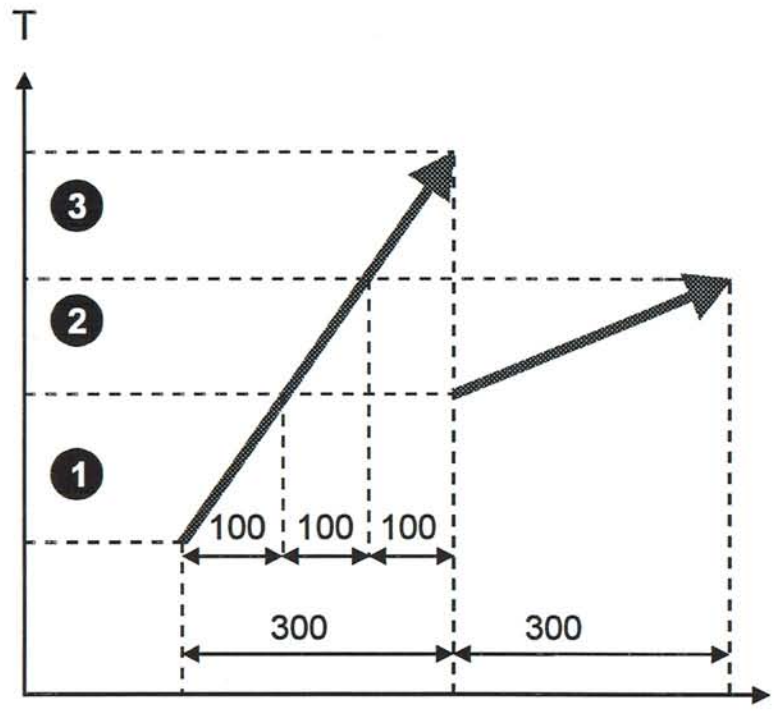
- Integrated procedures for designing or improving processes
- Start from process overview, not individual units

Process Integration Methods:

1. **Pinch Analysis™**
2. Knowledge-Based Approaches
3. Numerical/Graphical Methods

Pinch Analysis™ - The Basics

- Rigorous thermodynamic procedure
- Incorporates approximate economics
- Systematically assesses heat and mass flow in processes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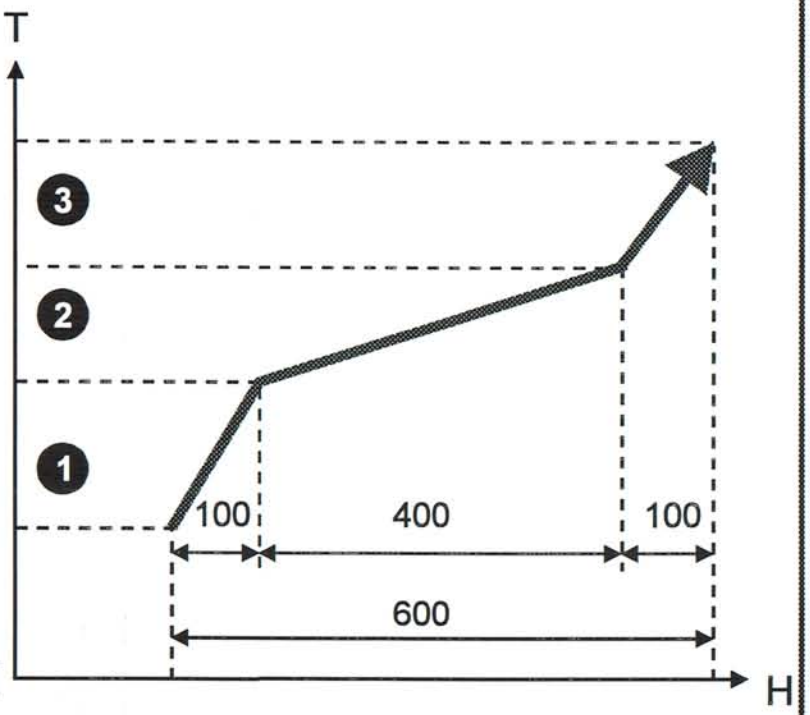
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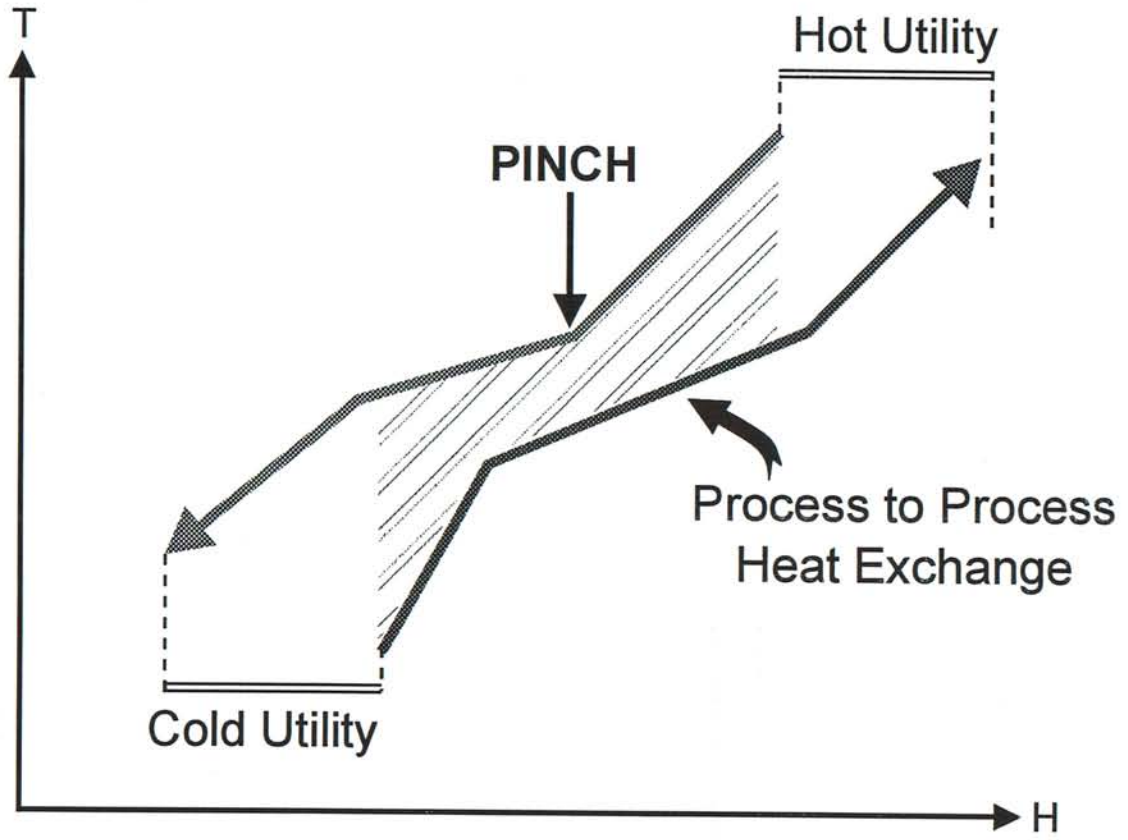
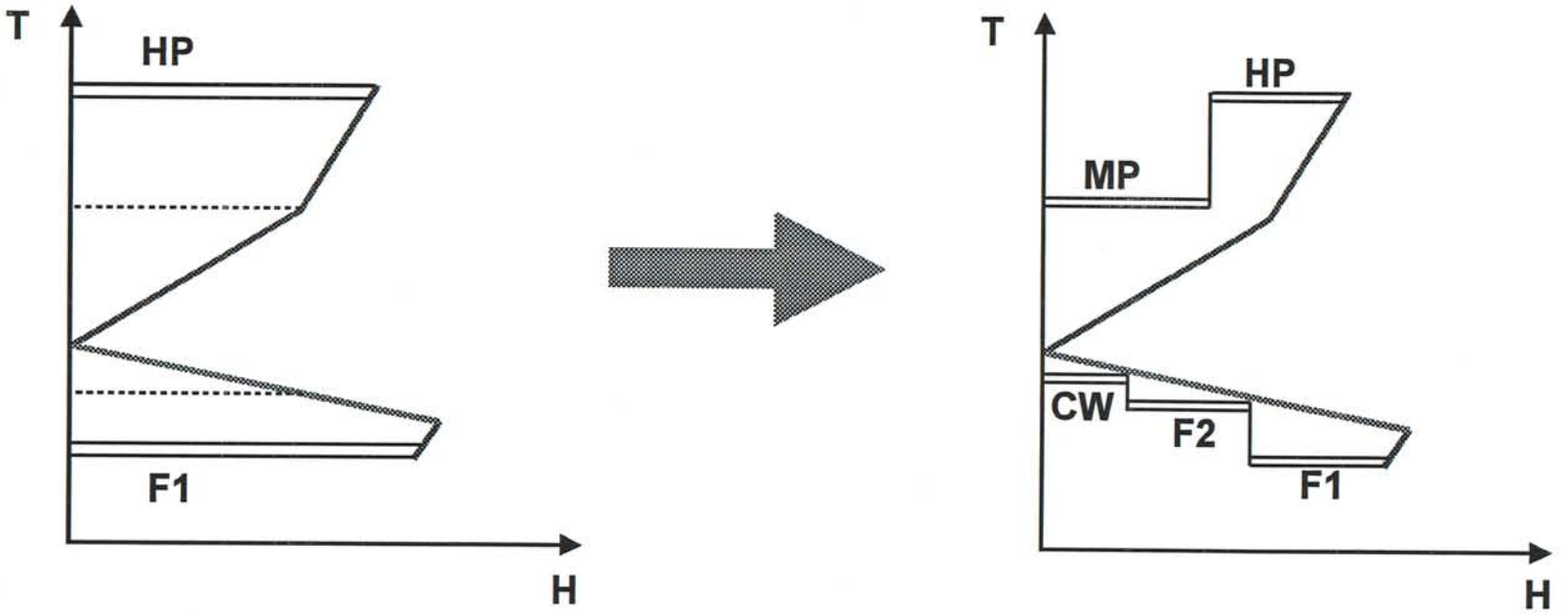


Hot and Cold Composite Curves

The Grand Composite Curve



Pinch Analysis™ - Applications

- Heat exchanger network design
- Cogeneration
- Site utility system design
- Process improvements
- Wastewater minimization

Pinch Analysis™ - Typical Benefits

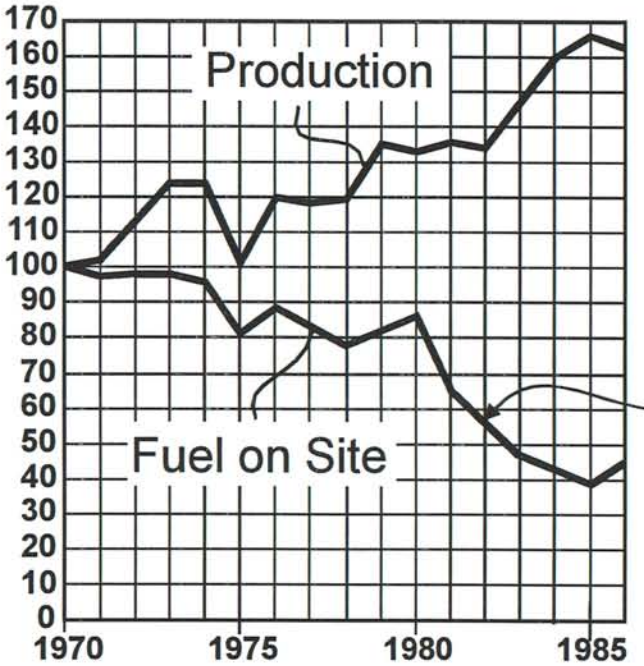
- Energy savings of 10% to 30%
- Capacity debottlenecking
- Improved planning of capital expenditure
- **Reduced emissions**

Pinch Analysis™ and Air Emissions

BASF

Ludwigshafen, Germany

BASF



Pinch Analysis™
Campaign
Starts 1982

(VDI, 1987)

BASF Ludwigshafen Results

Carbon Dioxide	240	ton/hr
Sulphur Dioxide	1.5	ton/hr
Nitrogen Oxides	0.8	ton/hr
Ash	46	lb/hr
Carbon Monoxide	15	lb/hr
Waste Water from Water Treatment	77	ton/hr

Southern California Edison
Los Angeles Area

Customer Technical Assistance Program (CTAP) (1987-1989) :

Initially to help industrial customers identify energy savings

Results also highlighted air emission abatement opportunities

Southern California Edison CTAP Results

Customer	Energy Savings		Pollution Abatement			Capacity Increase (%)
	Elec (kw)	Fuel (MW)	CO_2/SO_x (%)	NO_x (%)	BOD (t/a)	
Paper Mill #1	940	3.1	19	35	1100	0
Brewery	940	8.8	36	59	2700	40
Wallboard Plant	-500	2.2	8	15	0	30
Oil Refinery	not eval'd	14.7	25	44	0	0
Glass Plant #1	540	3.8	22	38	0	0
Glass Plant #2	190	3.1	20	36	0	0
Paper Mill #2	180	0.8	13	25	0	20
TOTAL	2290	36.5	22	39	3800	n/a

Bayer Leverkusen, Germany

German Federal Government goal: 25% reduction in CO_2 emissions (relative to a 1987 base-line) by the year 2005.

Total Site™ Results (1993):

Scope for reducing CO_2 emissions by heat integration:

Maximum potential	28%
Potential with 3 year incremental payback	8%

Pinch Analysis™ and Aqueous Effluents

WaterPinch™ Analysis

- See next presentation

Process Integration Methods:

1. Pinch Analysis™

2. **Knowledge-Based Approaches**

3. Numerical/Graphical Methods

Knowledge-Based Approaches - Basics

- Consider "universal features" of processes
- Use "knowledge base" of proven ideas

Types of Knowledge-Based Methods

- Lists of process ideas or options
- Data bases
- Hierarchical design & review
- Artificial intelligence

Hierarchical Design & Review - Basics

- Progressively evolve structural details
- At each step:
  - Question design choices
  - Review economics
- Define preferred design option(s)

Main Hierarchy Levels

Level 1: Processing Mode: Batch vs Continuous

Level 2: Input-Output Structure of the Flowsheet

Level 3: Recycle Structure and Product Formation Considerations

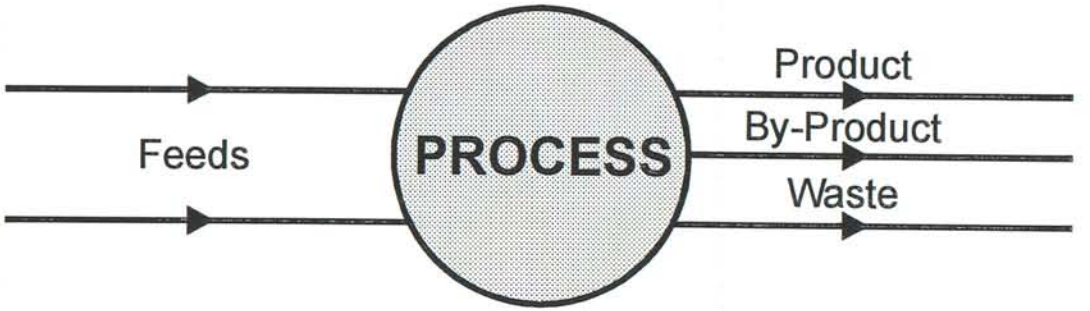
Level 4: Separation System

Level 5: Product Drying

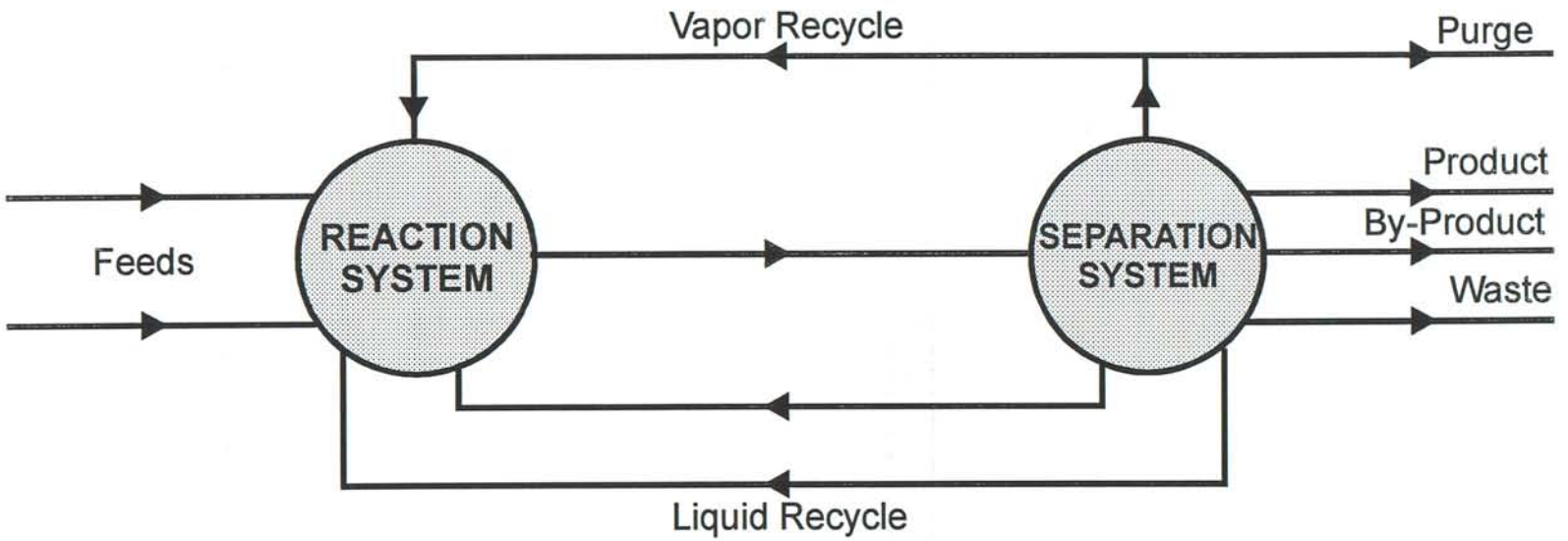
Level 6: Energy Systems

Level 7: Equipment and Pipework Specifications

Typical Process Input-Output Structure



Typical Process Recycle Structure (Vapor-Liquid)



Recycle Structure : Review Questions for Pollution Prevention

- Do any "waste" output streams contain feed or product material that could be recovered and recycled?
- Can reaction conditions be altered to minimize formation of "waste" by-products?
- Can "waste" by-products be recycled to extinction?

Amoco Yorktown Refinery
Hierarchical Review Study Results

Potential benefits from identified projects include:

- elimination of the surplus water in the sour water system, reducing a major source of odors
- 30% reduction in desalter brine flow
- recovery of up to 7,300 barrels/year of crude oil
- savings of more than 30 MMBtu/hr in fuel firing
- recovery of an additional 20 MMBtu/hr in fuel gas

Process Integration Methods:

1. Pinch Analysis™

2. Knowledge-Based Approaches

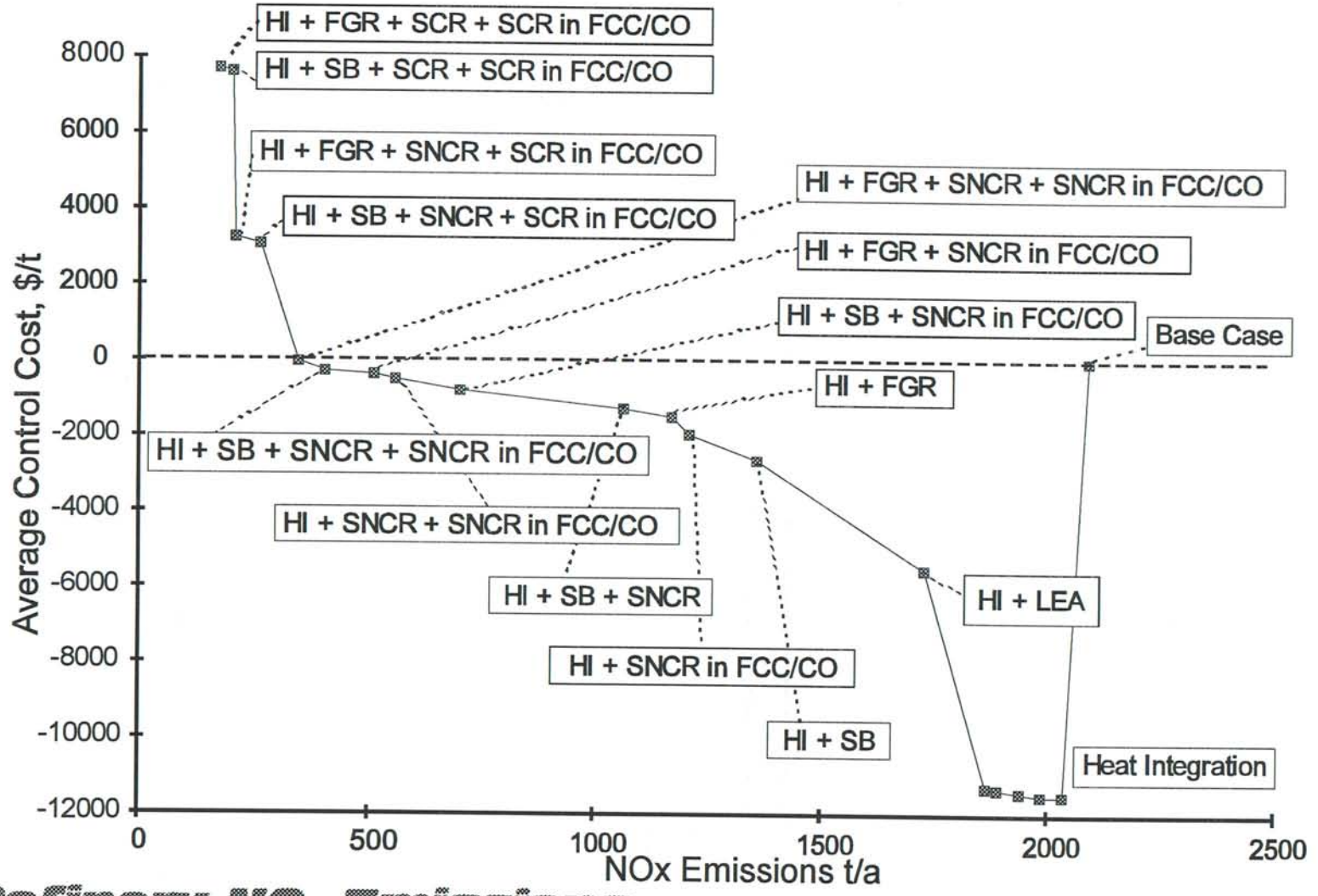
3. **Numerical/Graphical Methods**

Numerical/Graphical Methods - Basics

- Mathematical model
- Optimization procedure

Types of Numerical/Graphical Methods

- Simple cost model plus graphical optimization
- Linear programming (LP)
- Non-linear programming (NLP)
- Mixed integer LP
- Mixed integer NLP

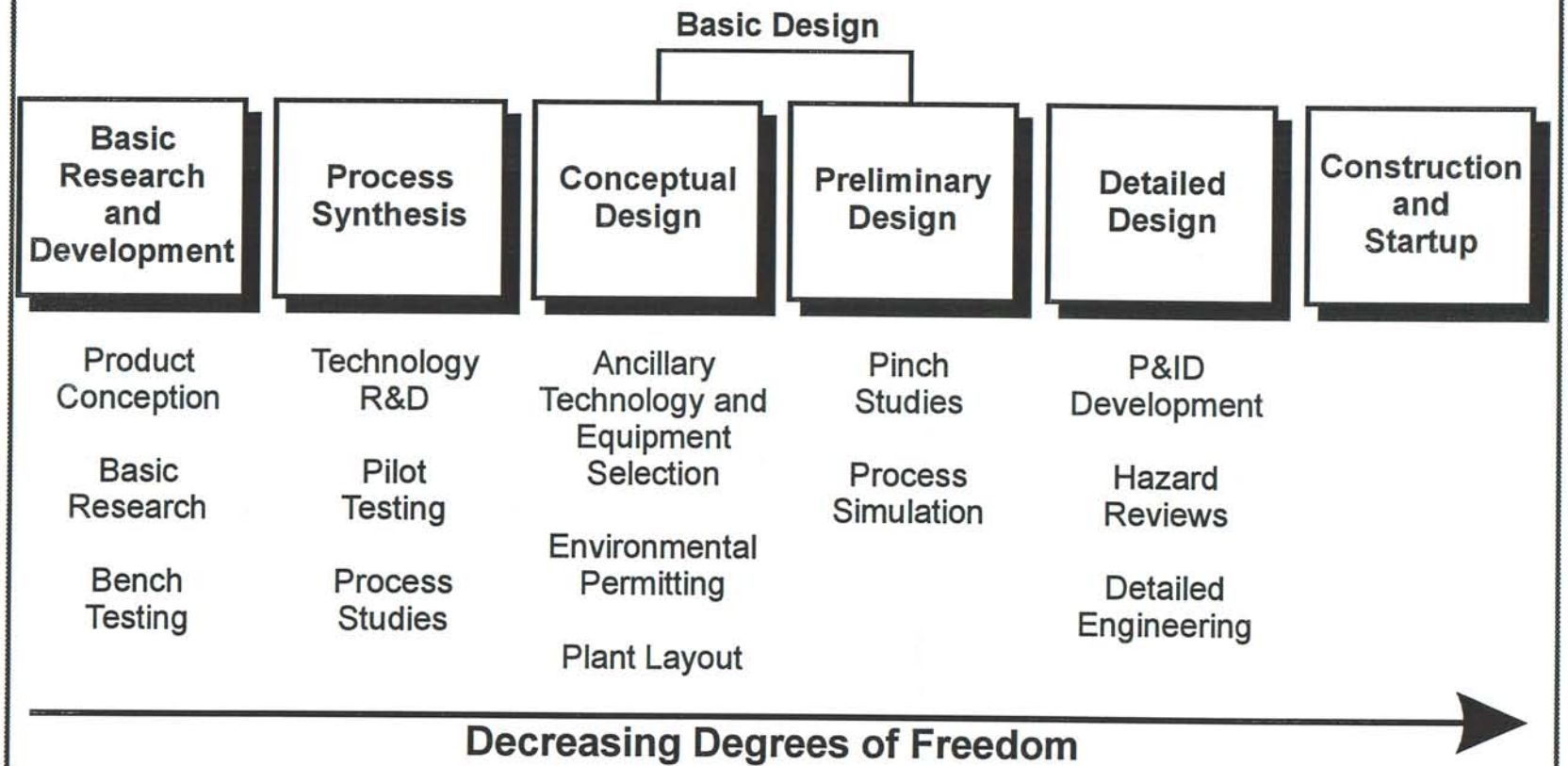


Refinery NOx Emissions - Minimum Average Control Cost

Applications of Process Integration Methods in Process Design

- New plant design
- Revamps

Traditional Process Design Work Flow



Process Integration and Process Design Work Flow