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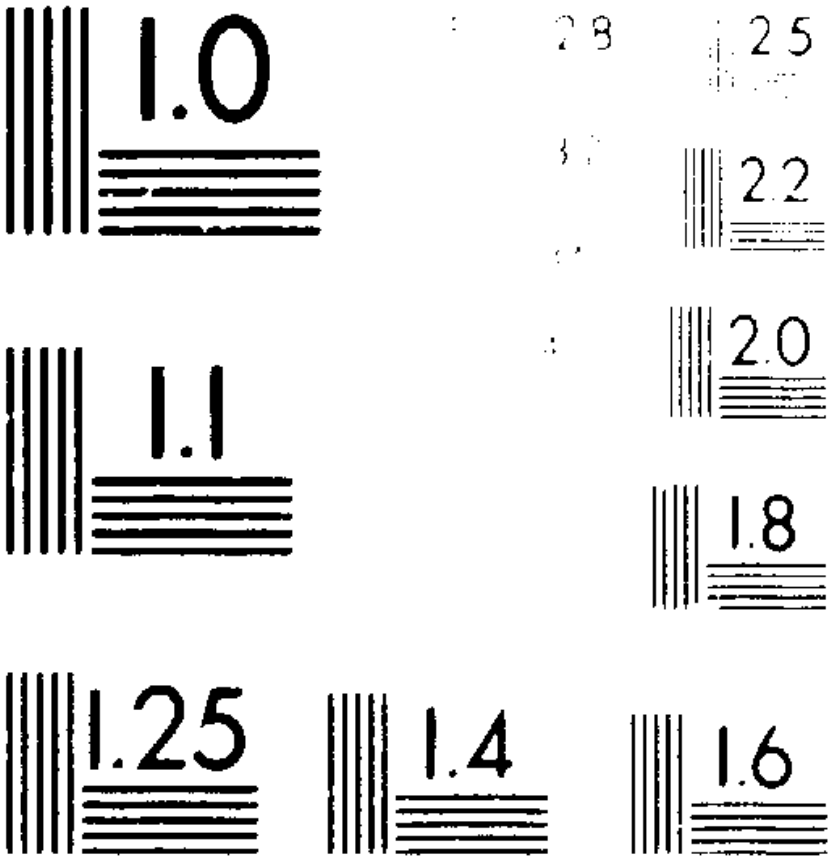

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1984

13962

FINAL MISSION REPORT

PLAPIQUI/PIDCOP, Bahia Blanca, Argentina (Chemical industry).

April 30 to June 15, 1984

Ref: DP/ARG/81/003/11-61

A. SUMMARY

This report details the presentations made at the request of the PIDCOP (Programa de Investigacion y Desarollo del Complejo Petroquimico de Bahia Blanca) program of PLAPIQUI (Planta Piloto de Ingenieria Quimica), and sponsored by the United Nations Industrial Development Organization. As detailed below, this teaching program was conducted with formal courses for two major topics - ammonia manufacture and absorption refrigeration -- and lectures and seminars for miscellaneous subjects. The presentations were all made in English, and did not require 'simultaneous' translation.

B. AGENDA

The tentative Agenda agreed to prior to the start of the mission is given in Appendix A. A national holiday closing (May 25th) and an all-day staff meeting (June 4th) resulted in the elimination of two topics (Pilot Plant Scale-up and Plant Commissioning Problems). Actual dates for some of the presentations were changed to suit the availability of attendees. The daily time allotted to some of the listed presentations was reduced to accomodate added activities - mainly computerization and the detailed process design for two industrial projects assigned to PLAPIQUI/PIDCOP.

C. ATTENDANCE

The announcements broadcast by PIDCOP to secure attendance for the two formal courses are given in Appendix B. These describe the contents of the courses and the teacher's qualifications. Added to these are the list of attendees taking these courses (pp. B-4 and B-6). As seen, these include not only members of PLAPIQUI, but also engineers from the Argentine chemical and petrochemical industry - and one from CEPED, a Brazilian organization similar to PLAPIQUI.

Local scheduling demands resulted in some modification of the timetable shown in the PIDCOP announcements. However, the topics listed were all covered to the necessary extent. This "Programa" was actually amplified, as shown in Section D, below.

D. FORMAL COURSES

1. Manufacture of Ammonia

This course emphasized the chemical and process engineering aspects of the design of plants to produce ammonia from diverse raw material (natural gas, light and heavy hydrocarbons, biomass and coal) via the steam-reforming and partial oxidation (gasification) techniques.

The Ammonia course proceeded from the basic chemistry of the requisite chemical reactions, their thermodynamics and catalysis, through the processing steps and equipment used to conduct these reactions, to their integration into an operable processing plant and the optimization of the net energy consumption and capital cost of the plant. State-of-the-art variations of the conventional ammonia process were presented, as well as suggestions for future improvements that might fit in with PIDCOP's research activities.

The course was presented in four day-long sessions, as listed in Appendix C. As reported below, use was made of the material taught here to initiate an industry-sponsored project for the design of an ammonia plant using raw materials available in Bahia Blanca.

2. Aqua-Ammonia Absorption Refrigeration (AAR)

a. "SHORT" (4-Day) COURSE

This course was designed for chemical engineers who are interested in the rationale of absorption refrigeration vs the conventional (mechanical) cycle and in the chemical engineering principles involved. These were presented as indicated in the Course Agenda, Appendix D. Emphasis was placed on the dangers of using certain short-cuts and simplifying assumptions (common to chemical engineering practise) created by the high degree of non-ideality of the ammonia-water binary system.

b. "INTENSIVE" AAR COURSE

The original plan for presentation in depth of this main topic was to take advantage of its exposition in my 18-chapter, 479-page textbook "Ammonia Absorption Refrigeration in Industrial Processes" (released by Gulf Publishing Co. in mid-1981) by having students read particular chapters prior to their presentation in class. However, only one copy of the book was found available in Bahia Blanca. The numerous theoretical developments already available in the book thus had to be repeated on the blackboard.

Applications of these basic chemical engineering principles were illustrated by starting with a published vendor's design (Borsig GmbH, with permission) for a two-level AAR unit. Its basic design was first analyzed, and flowsheet and equipment modifications made to it to determine their effect on the overall energy efficiency.

The same attack procedure was applied to an existing design made by PLAPIQUI on a proposed industrial AAR unit. By taking advantage

of the knowledge gained in this course, an improved flowsheet arrangement was generated that reduced the requisite heat input by about 20%.

E. LECTURES & SEMINARS

Short (ca. 2-hour) presentations were made at PLAPIQUI on topics of their choice:

1. Purification of Gases by Adsorption. The theory being well-documented, this talk concentrated on applications and on special apparatus for converting this normally-batch process to a continuous one.

2. Extractive Distillation. Fundamentals of this branch of non-ideal distillation were illustrated by the production of butadiene from refinery butane-butene fractions.

3. Acetylene-from-Hydrocarbons. The various pyrolysis routes (partial-oxidation and regenerative cracking) and electric arc processes were discussed, with emphasis on the numerous operating problems in commercial plants.

4. Fischer-Tropsch Synthesis. The presentation concentrated on the production of hydrocarbons in the liquid fuel range from natural gas (Brownsville, Texas) and coal (Sasol, South Africa), with oxygenated chemicals as by-products.

5. Catalysis. Presented as the application in the production of chemicals and petrochemicals of the fruits of research, development, and manufacture of commercial catalysts. The potential advantages of slurry reactors were noted.

Guest-lecturer seminars conducted:

6. Universidad Nacional del Sur (June 8).

For the benefit of the graduating class and graduate students, one of the typical rôles of the chemical engineer in industry - the process or development engineer - was illustrated by the skills required and tasks performed in the optimization of the process for manufacturing ammonia and in the integration of the operations into a commercial plant.

7. Instituto Petroquimico Argentino. (Buenos Aires, June 14)

Summary presentations of the main topics of the Mission - production of ammonia and absorption refrigeration, illustrated with slides of a modern world-scale ammonia plant.

8. Gas del Estado (Buenos Aires, June 15)

Presentation similar to item 7, above, with emphasis on their interest in the production of ammonia from natural gas as a means of upgrading excess gas for export credits. Approximately 3-dozen engineers attended each of the two lectures in Buenos Aires.

F. SPECIAL PROJECTS

1. Gas-plant Refrigeration.

Previous to this mission, PILCOP had generated a process design for an AAR unit for installation in a natural-gas processing plant of the Argentine state monopoly, Gas del Estado. Its purpose is to increase the recovery of LPG and gasoline-range hydrocarbons. This design was reviewed as part of the "Intensive AAR"course and efficiency-enhancing modifications investigated. A final design project was launched based on a compromise design concentrating on the simplicity and minimum attention needed for unattended operation of the plant.

2. Ammonia Production

The P. B. B. (Petroquimica Bahia Blanca) ethylene plant produces a hydrogen-rich off-gas stream, also containing carbon monoxide and methane and higher hydrocarbons. Responses to previous inquiries on the production of ammonia from this raw material were reviewed. These suffer from the low resulting ammonia production (ca. 200 to 300 ton/day) with its correspondingly high capital investment per ton and the need to use reciprocating compressors.

Continuing studies were inaugurated, adding other hydrogen-rich streams from the local petrochemical complex to boost the production level. A last alternate was added contemplating participation by Gas del Estado, supplying natural gas as a supplementary feed stock to boost the ammonia production to about 600 ton/day (allowing the use of centrifugal gas compressors) or on up to 1000-1500 ton/day to benefit from the enhanced economics of world-scale production. Although the peak production exceeds the present local ammonia demand, the surplus would allow a realization of a goal of Gas del Estado - creating export credits from Argentina's natural resources.

G. COMPUTERIZATION

Assistance was given in the computerization of the material presented in the Formal Courses (Item D, above) for use in project studies, particularly those of Item F, above. For this purpose, PIDCOP acquired operable programs prepared by me for the TI-59 programmable calculator:

1. Mass-and heat-balance and equilibrium calculations in the production of synthesis gas (mixtures of hydrogen and carbon oxides) by reacting raw materials (e.g. hydrocarbons, coal, biomass) with steam, air, oxygen, carbon dioxide and their mixture catalytically (steam-reforming) or non-catalytically (partial-oxidation, gasification).

2. Partial or near-total removal of carbon monoxide in synthesis gas by the catalytic ("water-gas shift") reaction with steam, producing hydrogen and carbon dioxide. The program performs mass-balance and equilibrium calculations, and the necessary heat balance for adiabatic reactors.

3. Mass- and heat-balance, flash and reaction equilibria calculations for three types of recycle synthesis "loops" wherein ammonia is produced via the catalytic reaction of hydrogen and nitrogen. Provision is made for the purging of non-reactants fed (e.g. argon, methane) to control their build-up.

Assistance was provided in adapting these programs for use via the PLAPIQUI computer (as in Item F-2, above). TI-59 programs donated for similar purposes include:

4. Ammonia/Methanol Plant Steam System balances: Accounts for the preheating of boiler feedwater and generation of high-pressure steam from hot process gases and exothermic reactions; reduction to medium- and low-pressure levels and to surface condensers by turbines driving the major gas compressors and pumps in the plant.

5. Mass- and heat-balance calculations for a combined evaporator-absorber unit in the ammonia absorption refrigeration cycle (with or without an economizer).

6. Miscellaneous short programs for estimating the physical and thermodynamic properties of ammonia and water and their mixtures.

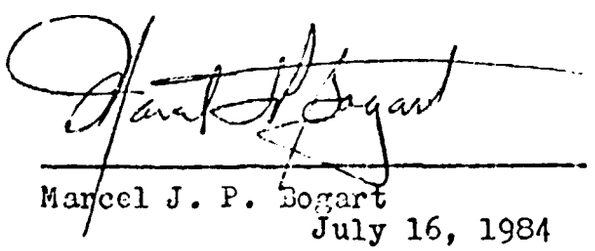
Time did not permit computerization of other procedures needed for PIDCOP's special projects beyond the development of the program's working equations and calculation sequence. Examples include:

1. Determination of the fuel requirements of a steam-reforming furnace and the options for heat recovery from the hot "flue-gas" leaving the firebox. When operational, this program will interface with Items G-1 and G-4, above.

2. Determination of the operating conditions for an AAR evaporator given the refrigeration duty and refrigerant boiling temperature. The operating pressure and stream enthalpies are first determined assuming the refrigerant to be anhydrous ammonia and ignoring entrainment and blowdown. Actual operating conditions (pressure; stream flows, compositions and enthalpies) are derived from these by correcting for water content and setting entrainment and blowdown rates.

3. Determination of the operating line constants for a binary distillation column with one or more condensers, feed or sidestream flows, reboilers, and overhead and bottoms product. The procedures are valid for any binary system and for initial estimates in multicomponent fractionation.

Respectfully submitted,



Marcel J. P. Bogart
July 16, 1984

JAN 29

PROPOSED AGENDA FOR PIDCOP / PLAPIQUI

MARCEL J. P. BOGART
CONSULTING CHEMICAL ENGINEER

10602 CORDOBA COURT
WHITTIER, CA 90601

1	MAY 1984	1	ARRIVE BAHIA BLANCA
1		2	ADSORPTION; EXTRACTIVE DISTILLATION
2		3	ACETYLENE FROM HYDROCARBON FEEDSTOCKS
3		4	FISCHER-TROPSCH; MOBIL METHANOL-TO-GASOLINE
4		7	PRODUCTION OF AMMONIA: STATE-OF-THE-ART TECHNOLOGY
5		8	FEED TREATING; SYNTHESIS GAS GENERATION
6		9	HEAT RECOVERY; SYNGAS PURIFICATION / COMPRESSION
7		10	AMMONIA SYNTHESIS LOOP. COMPUTERIZATION
8		11	REFRIGERATION, ENERGY BALANCE, STORAGE
9		14	PILOT PLANT SCALE-UP &
10		15	PLANT COMMISSIONING PROBLEMS
11		16	
12		17	AAR "20-HOUR" COURSE
13		18	
14		21	DETAILED COURSE: AQUA-AMMONIA ABSORPTION REFRIG'N: FUNDAMENTALS; ABSORPTION VS MECHANICAL
15		22	BASIC DATA; ELEMENTS OF AAR UNITS
16		23	DESIGN OF EVAPORATOR CASCADES
17		24	" " ABSORBER "
18		25	FRACTIONATOR FEED PREHEATING
19		28	FRACTIONATOR } SINGLE-STAGE
20		29	DESIGN } TWO-STAGE
21		30	UTILIZATION OF WASTE HEAT
22		31	INTEGRATION INTO PROCESS PLANTS
23	JUNE	1	INSTRUMENTATION; COMPUTERIZATION
24		4	ANALYSIS OF COMMERCIAL AAR DESIGN AND OF
25		5	ALTERNATE FLOWSHEET &
26		6	EQUIPMENT ARRANGEMENTS
27		7	
28		8	DISCUSSION OF PIDCOP AAR PROJECT(S)
29		11	
30		12	
31		13	
		14	DEPARTURE FOR BUENOS AIRES
		15	UND DEBRIEFING " "

APPENDIX A

APPENDIX B

PIDCOP

PROGRAMA DE INVESTIGACION Y DESARROLLO
DEL COMPLEJO PETROQUIMICO DE BAHIA BLANCA

SEDE EJECUTIVA
PLAPIQUI
12 DE OCTUBRE 1842
CASILLA DE CORREO 717
8000 BAHIA BLANCA
ARGENTINA
TEL. 30679-23439
TELEX 81758 PPINO AR

CURSO INTENSIVO PARA PROFESIONALES DE LA INDUSTRIA QUIMICA Y PETROQUIMICA

TEMA:	PRODUCCION DE AMONIACO Y METANOL
PROFESOR:	MARCEL P. BOGART
DESTINATARIOS:	PROFESIONALES CUYA ACTIVIDAD ESTA RELACIONADA CON EL DISEÑO Y OPERACION DE PROCESOS DE PRODUCCION DE AMONIACO Y METANOL.
SEDE:	BIBLIOTECA DE PLANTA PILOTO DE INGENIERIA QUIMICA. UNIVERSIDAD NACIONAL DEL SUR AVENIDA ALEM 1253 - 8000 BAHIA BLANCA
FECHA Y HORARIO:	8, 9, 10 y 11 DE MAYO DE 1984 9.00 a 12.00 y 15.00 a 18.00
IDIOMA DEL CURSO:	INGLES
CONSULTAS:	ING. HORACIO CAMPAÑA DRA. SUSANA BOTTINI
MATRICULA:	GENERAL: $a 1.800 MIEMBROS PIDCOP: $a 1.400 ENVIAR CHEQUE A NOMBRE DE: FUNDACION DEL SUR PARA EL DESARROLLO TECNOLOGICO 12 DE OCTUBRE 1842 8000 - BAHIA BLANCA

PIDCOP
PROGRAMA DE INVESTIGACION Y DESARROLLO
DEL COMPLEJO PETROQUIMICO DE BAHIA BLANCA

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MARCEL P. BOGART

Fecha de nacimiento: 13 de abril de 1913, Paris (Francia)

Educación:

— Ingeniero Químico (1933) Cooper Union Inst. of Technology (New York)
— Magister en Ingeniería (1934) Universidad de Michigan

Actividad Profesional

— Lummus Company 1935 - 1962 New York
Ingeniero de Procesos a Director de Desarrollo
1962 - 1966 London
Residente especialista en Procesos Químicos y Petroquímicos (European Technical Center)
— Fluor Corporation 1966 - 1968 London, Ireland, Germany
Puesta en marcha de plantas petroquímicas
1968 - 1983 Los Angeles
Jefe de División Desarrollo y Tecnología avanzada. Producción de fertilizantes químicos y petroquímicos. Desarrollo del proceso de refrigeración por absorción.

Actividad Académica

— Polytechnic Institute of Brooklyn (NY) (1947-1959)
Profesor Adjunto
— Columbia University (NY) 1950
Profesor visitante

Publicaciones

Más de 15 papers en temas de diseño de procesos petroquímicos. Un libro de Refrigeración por Absorción y más de 20 patentes de procesos en USA.

Otros

Miembro de American Institute of Chemical Engineers, Society of Sigma XI y American Association for the Advancement of Science.

B-3

PIDCOP
PROGRAMA DE INVESTIGACION Y DESARROLLO
DEL COMPLEJO PETROQUIMICO DE BAHIA BLANCA

SEDE EJECUTIVA
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12 DE OCTUBRE 1842
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CURSO INTENSIVO PARA PROFESIONALES DE LA INDUSTRIA QUIMICA Y PETROQUIMICA

TEMA:	REFRIGERACION POR ABSORCION
PROFESOR:	MARCEL P. BOGART CONSULTING CHEMICAL ENGINEER
DESTINATARIOS:	PROFESIONALES QUE DESARROLLEN ACTIVIDADES EN EL AREA DE INGENIERIA DE PROCESOS Y ESPECIALMENTE AQUELLOS RELACIONADOS CON TECNOLOGIA DE REFRIGERACION Y CONSERVACION DE ENERGIA.
SEDE:	BIBLIOTECA DE PLANTA PILOTO DE INGENIERIA QUIMICA. UNIVERSIDAD NACIONAL DEL SUR AVENIDA ALEM 1253 - 8000 BAHIA BLANCA
FECHA Y HORARIO:	16, 17 y 18 DE MAYO DE 1984 9.00 a 12.00 y 15.00 a 18.00.
IDIOMA DEL CURSO:	INGLES
CONSULTAS:	ING. HORACIO GALINDEZ DRA. SUSANA BOTTINI
MATRICULA:	GENERAL: $a 1.800 MIEMBROS PIDCOP: $a 1.400 ENVIAR CHEQUE A NOMBRE DE: FUNDACION DEL SUR PARA EL DESARROLLO TECNOLOGICO 12 DE OCTUBRE 1842 8000 - BAHIA BLANCA

B-5

PIDCOP
PROGRAMA DE INVESTIGACION Y DESARROLLO
DEL COMPLEJO PETROQUIMICO DE BAHIA BLANCA

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PROGRAMA

1. INTRODUCCION AL USO DE REFRIGERACION POR ABSORCION
2. DIFICULTADES CARACTERISTICAS DEL DISEÑO DE ESTOS PROCESOS
3. DISEÑO DE EVAPORADORES SIMPLE Y MULTIPLE ETAPA
4. DISEÑO DE ABSORBEDORES SIMPLE Y MULTIPLE ETAPA
5. DISEÑO DEL PROCESO DE DESTILACION DE SIMPLE O MULTIPLE ALIMENTACION Y SIMPLE O MULTIPLES NIVELES DE PRESION
6. GENERACION DE DIAGRAMAS DE FLUJO DEL PROCESO
7. APLICACIONES DEL PROCESO DE REFRIGERACION POR ABSORCION PARA INTEGRACION ENERGETICA Y OPTIMIZACION DE PROCESOS
8. EFICIENCIA Y OPERABILIDAD DEL PROCESO DE REFRIGERACION POR ABSORCION
9. COSTO DE CAPITAL DE PROYECTOS TIPO Y COMPARACION CON PROCESOS DE REFRIGERACION MECANICA.

El curso está basado en el texto de Marcel P. Bogart "Ammonia Absorption Refrigeration in Industrial Processes" (Gulf Publishing Company, Houston, Texas, 1981). De dicho libro existirán ejemplares disponibles para aquellos interesados en adquirirlo, a un costo reducido.

B-7

AGENDA

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AMMONIA

COURSE

SESSION ONE

OVERVIEW of OBJECTIVES

1. Basic chemistry (ex nat. gas)
   a. Chemical reactions
   b. Thermodynamics
   c. Catalysis
   d. Carbon formation
2. Heavier feedstocks
3. Basic processing steps
4. Block flow diagram
5. State-of-the-art technology
   a. Proprietary processes
   b. Future developments
6. Energy flow and transfer
   a. 'Stand-alone' plants
   b. Fertilizer complexes
7. Equipment requirements
   a. Design constraints
   b. Design methodology

SESSION TWO

SYNTHESIS GAS GENERATION

1. Steam-Reforming Furnaces
   a. Catalyst tube layout
   b. Metallurgical options
   c. Burner/firebox design
   d. Burner air preheating
   e. Convection section
2. Secondary Reformer
   a. Design requirements
   b. High pressure design
3. Partial-Oxidation Reactors
4. Heat Recovery system
   a. BFW preheating
   b. Steam generation
4. Water-gas Shift
   a. High-temp. reactor
   b. Low-temp. reactor

SESSION TWO (cont'd)

6. Acid-gas removal
   a. Chemical absorbents
   b. Physical solvents
7. Methanation
8. Gas Drying

SESSION THREE

AMMONIA SYNTHESIS

1. Gas Compression
   a. Fresh-feed gas
   b. Recycle gas
2. Synthesis reaction
   a. Thermodynamics
   b. Catalysis
3. Synthesis Converter
   a. Quench types
   b. Intercooling
4. Synthesis loop
   a. Ammonia recovery
   b. Recycle ratio
   c. Heat recovery
5. Purge gas treating
6. Methanol analogy

SESSION FOUR

ANCILLARIES/AUXILLIARIES

1. Refrigeration
   a. Vapor compression
   b. Ammonia absorption
2. Energy systems
   a. Compressor drives
   b. Feedwater treating
   c. Steam generation
   d. Emergency electrical
3. Ammonia storage
4. Plant start-up

APPENDIX C

APPENDIX D

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Program Description

	Program Title: 20 H SHORT AAR COURSE
1	**INTRODUCTION** - RATIONALE FOR ABSN. REFR. - LiBr vs AAR - PtxyhH DATA - BASIC PFD - VARIANTS - CONSTRAINTS - PROCEDURES - COMPUTER
2	**PITFALLS** - DECEPTIVENESS OF SIMPLICITY - NON IDEALITY NH_3-H_2O SYSTEM - H_2O IN REFRIGERANT - ENTRAINMENT IN ENAPS. & FRACTIONATORS
3	**EVAPORATORS** - DESIGN INPUTS - ΔP (H_2O) - E & P - BALANCES - SINGLE VS MULTI-STAGE - ALTERNATE CASCADES - SUPERHEATERS
4	**ABSORBERS** - INTEGRATION WITH EVAPORATORS - PROCESS DESIGN CONSTRAINTS - OPTIMUM ARRANGEMENTS - BALANCES - SINGLE VS MULTI-STAGE (SERIES VS PARALLEL).
5	**DISTILLATION** - PROCESS DESIGN CONSTRAINTS - SINGLE COL. VS DUAL - PRESSURE PAIR - SINGLE/MULTIPLE FEED STREAMS - OVERHEAD CONDENSATION ALTERNATES SINGLE VS MULTIPLE REBOILERS
6	GENERATING PREFERRED FLOWSHEET - ALTERNATE PREHEATING ARRANGEMENTS - MINIMUM REFLUX RATIO & PLATES - McCABE-THIELE VS PONCHON - SAVARIT GRAPHICAL DESIGN METHODS. - HEAT INPUT CONSIDE - RATIONS - SIDE-STREAM PRODUCT(S)
7	**INDUSTRIAL USES** - HEAT SUPPLY SOURCES - USE IN NORMALLY NON-REFRIG. PROCESSES - COMBINED AAR & VAPOR COMPRESSION REFRIG. CYCLES - INTEGRATION WITH INDUSTRIAL PROCESSES - COMMERCIAL INSTALLATIONS.
8	**EFFICIENCY & ECONOMICS** - OPTIMIZATION FOR SPECIFIC PROJECTS - CAPITAL COSTS AAR VS MECHANICAL CYCLE - OPERABILITY & CONTROL OF AAR UNITS - OPERATION OTHER THAN 100% OF DESIGN - ENVIRONMENTAL & SAFETY CONSIDERATIONS