

ALCOHOL SCHOOL

**DISTILLATION AND
MOLECULAR SIEVES:**

A PRACTICAL VIEWPOINT



KATZEN

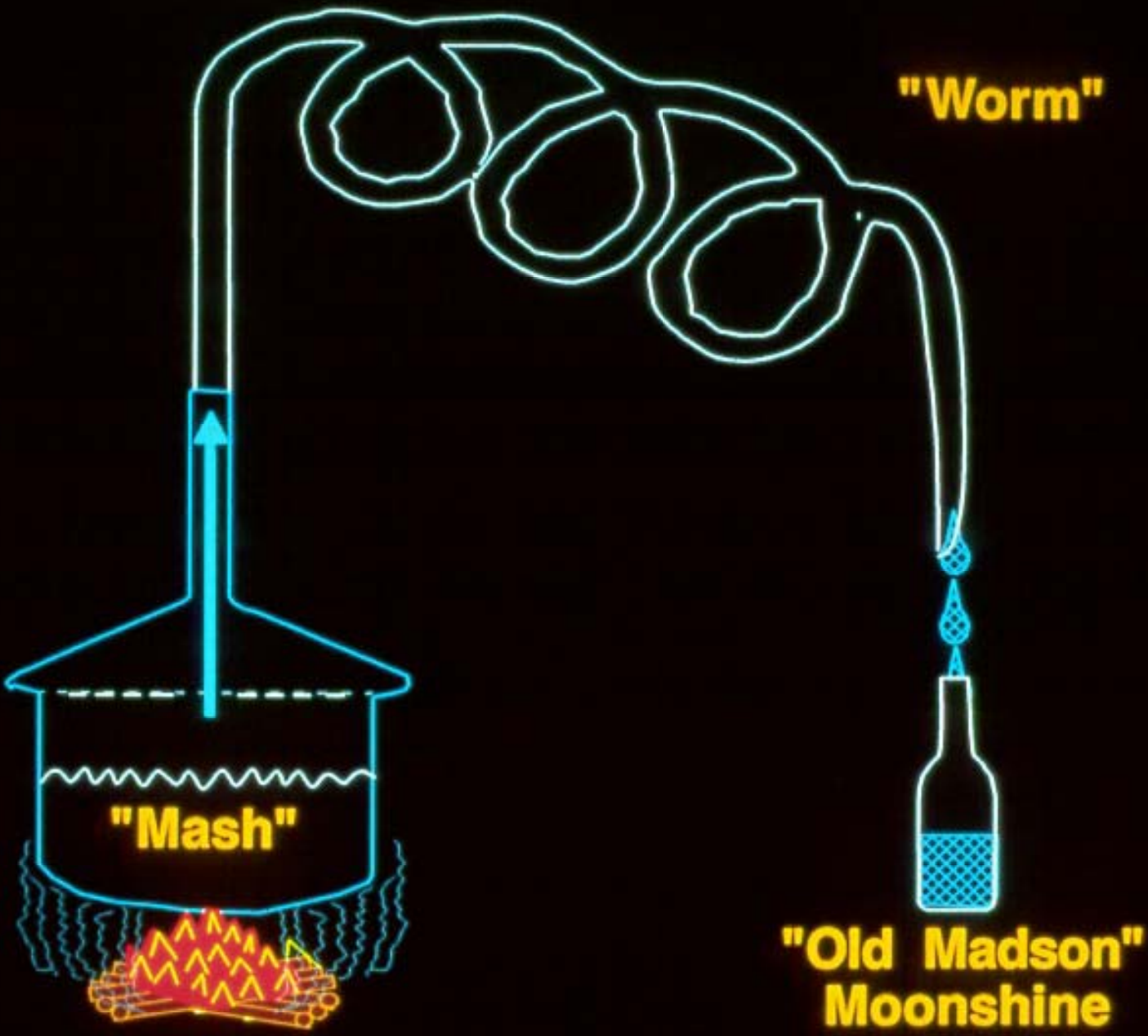
INTERNATIONAL, INC.

Technology & Engineering

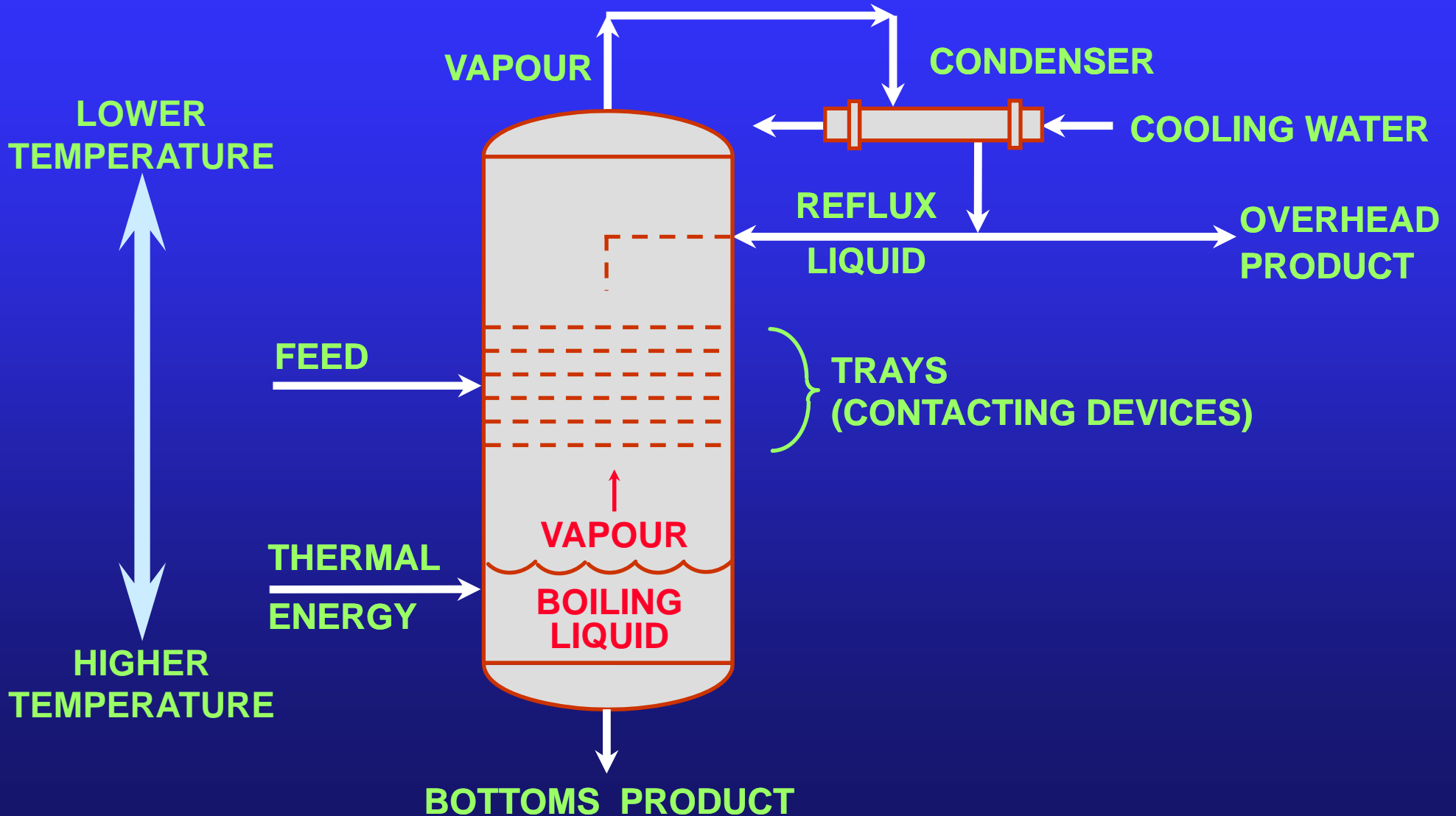
Cincinnati, Ohio U S A

Philip W. Madson
President

FUNDAMENTALS OF DISTILLATION

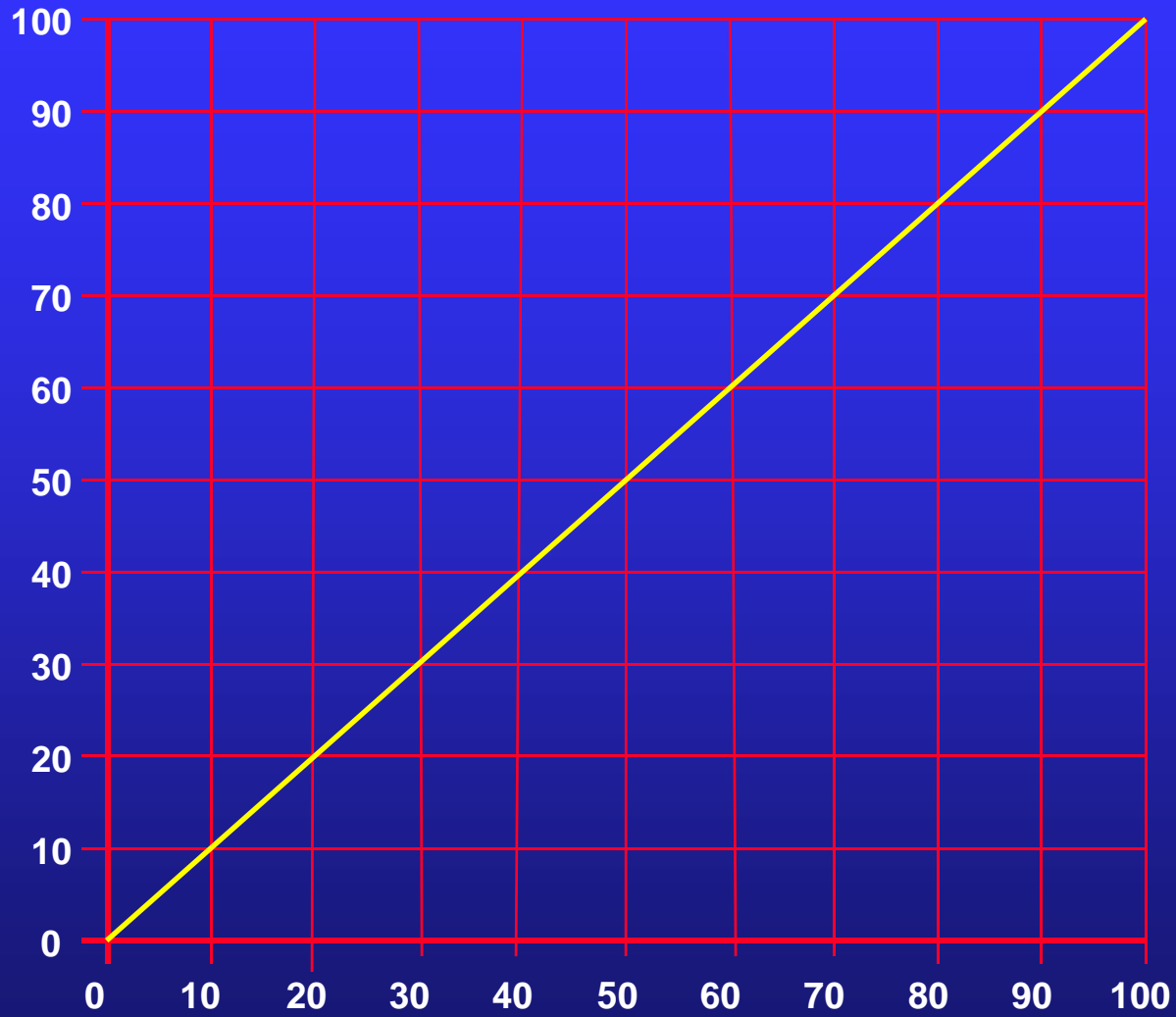


TYPICAL DISTILLATION RELATIONSHIPS



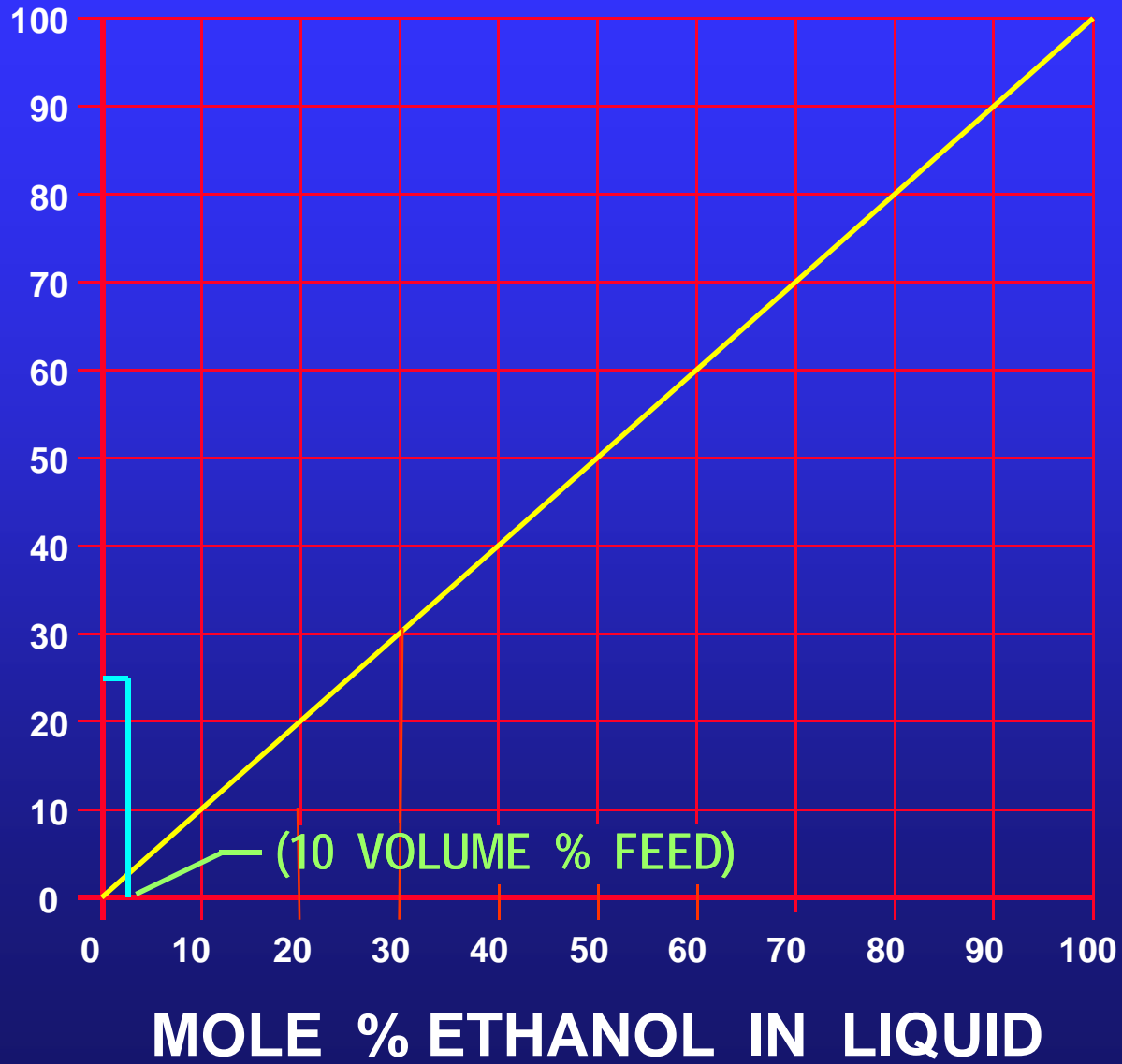
**VAPOUR-LIQUID EQUILIBRIUM
ETHANOL-WATER**

**MOLE %
ETHANOL
IN VAPOUR**

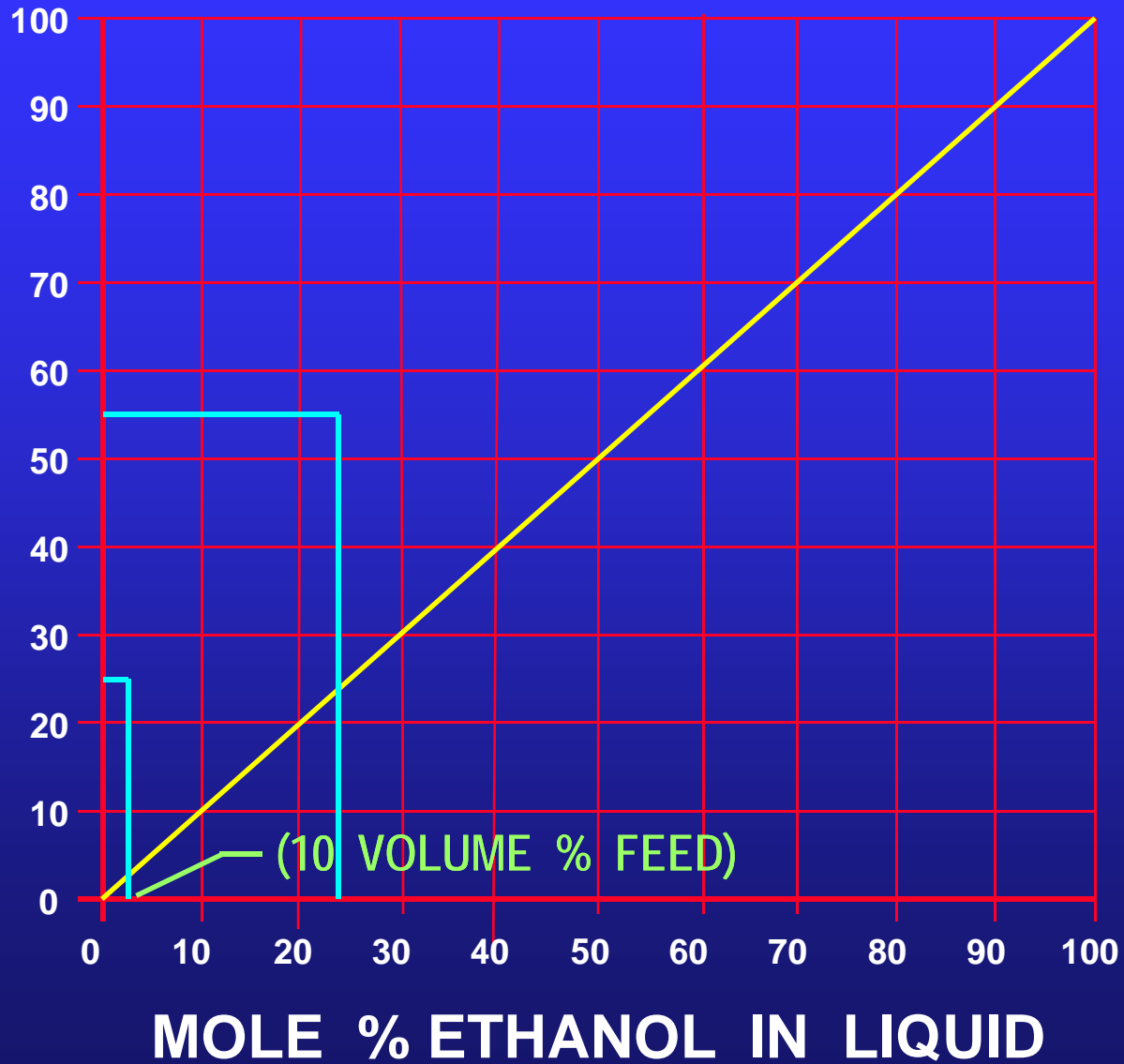


MOLE % ETHANOL IN LIQUID

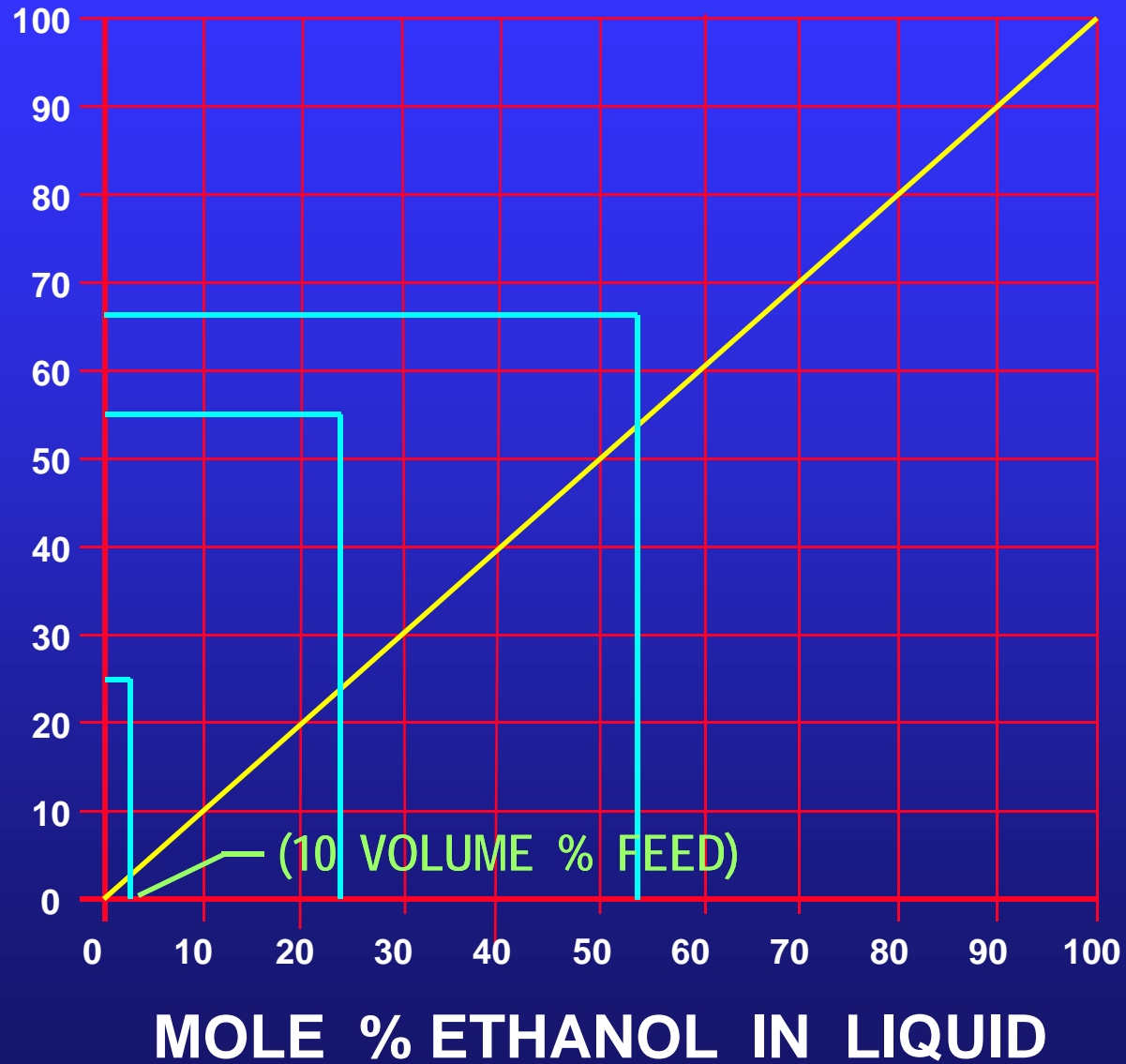
**MOLE %
ETHANOL
IN VAPOUR**



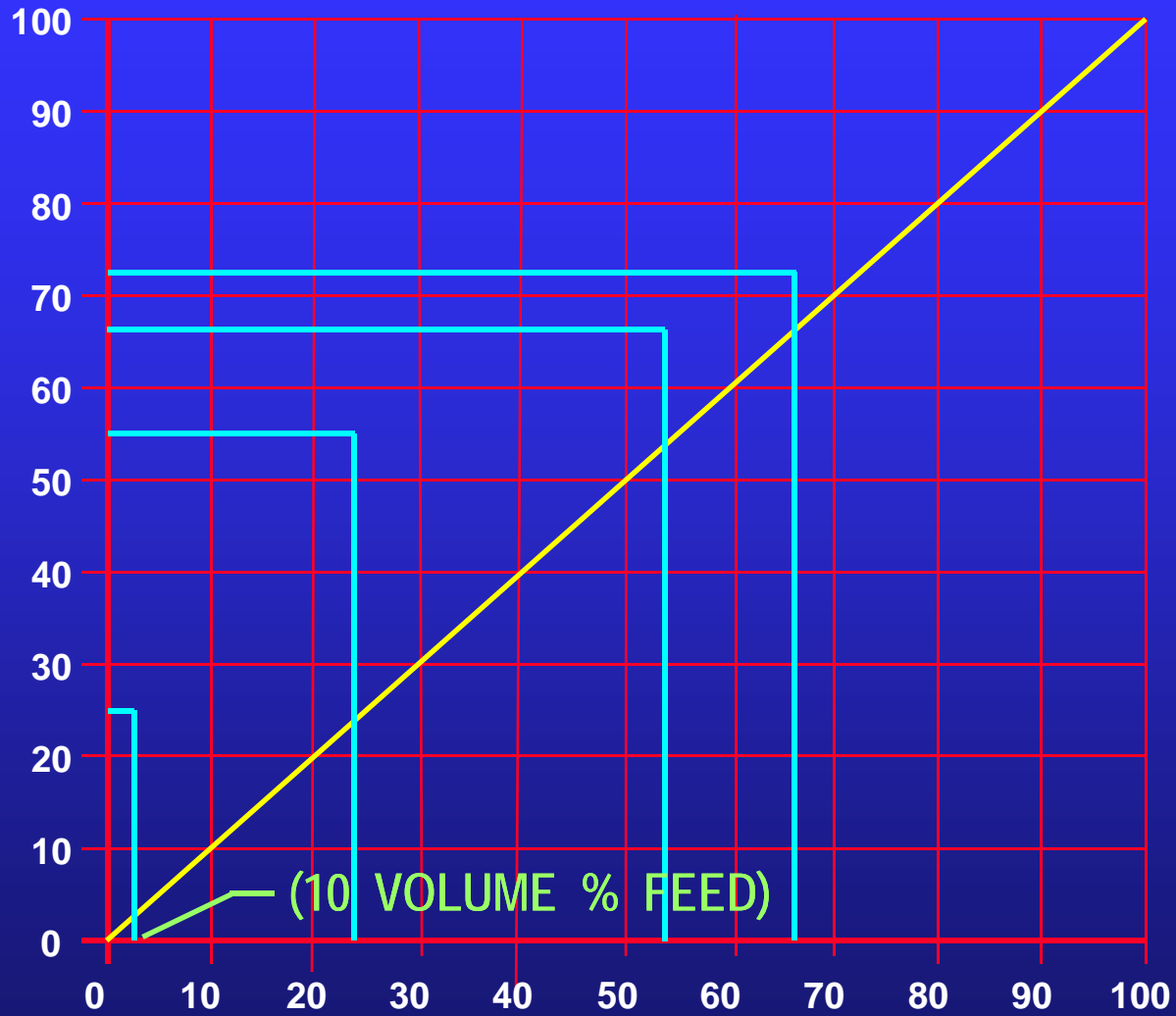
**MOLE %
ETHANOL
IN VAPOUR**



**MOLE %
ETHANOL
IN VAPOUR**

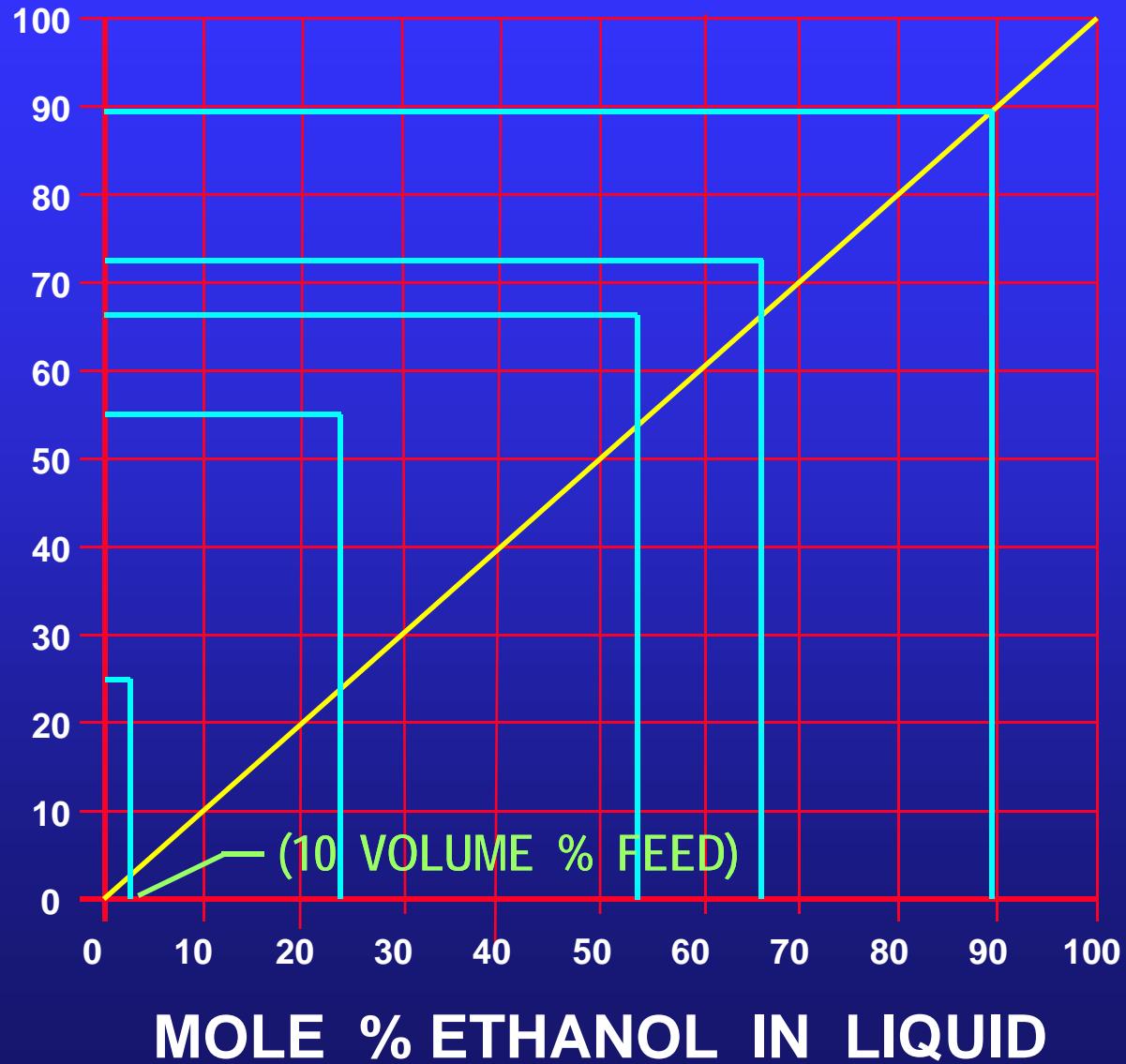


**MOLE %
ETHANOL
IN VAPOUR**

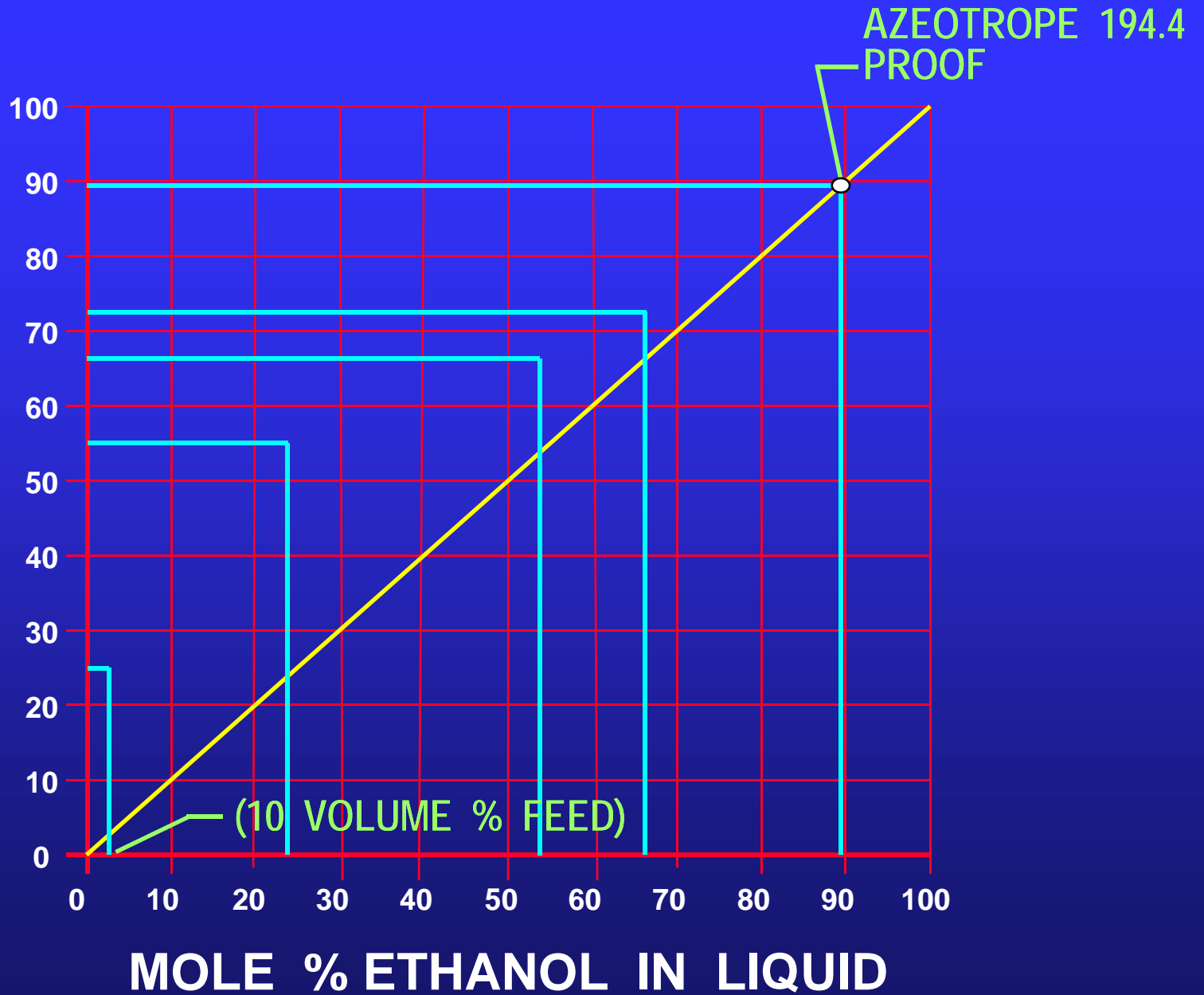


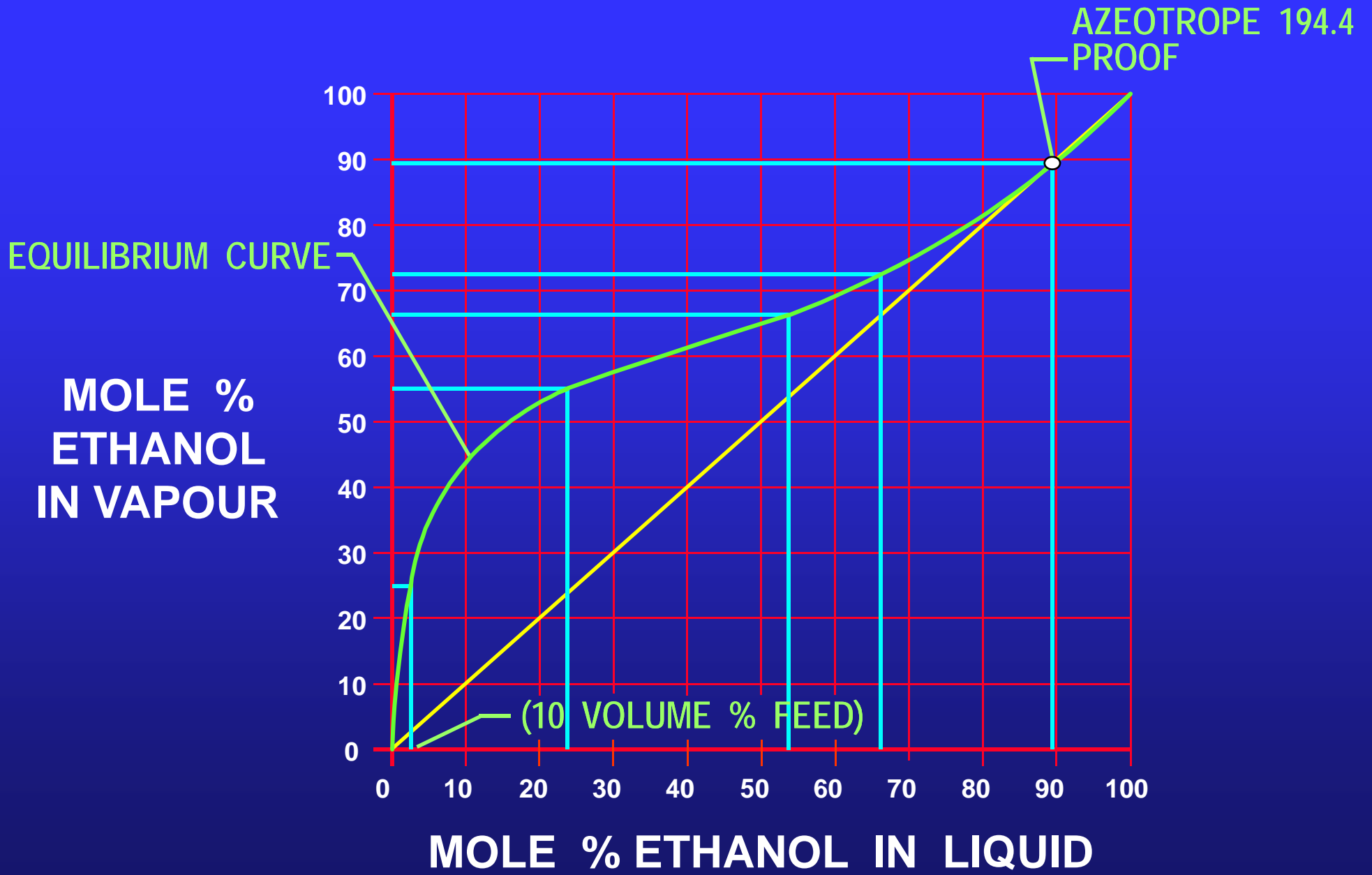
MOLE % ETHANOL IN LIQUID

**MOLE %
ETHANOL
IN VAPOUR**

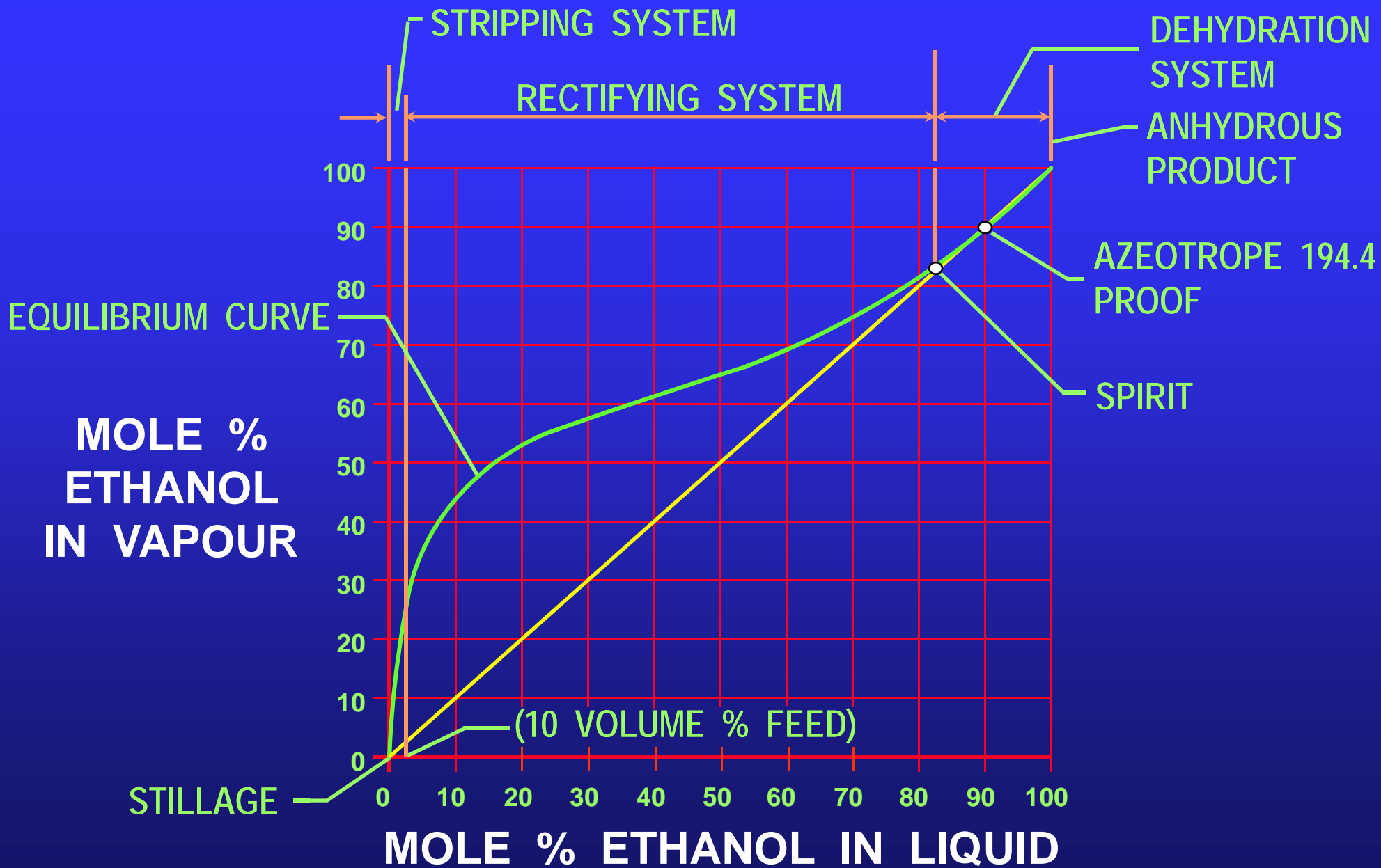


**MOLE %
ETHANOL
IN VAPOUR**





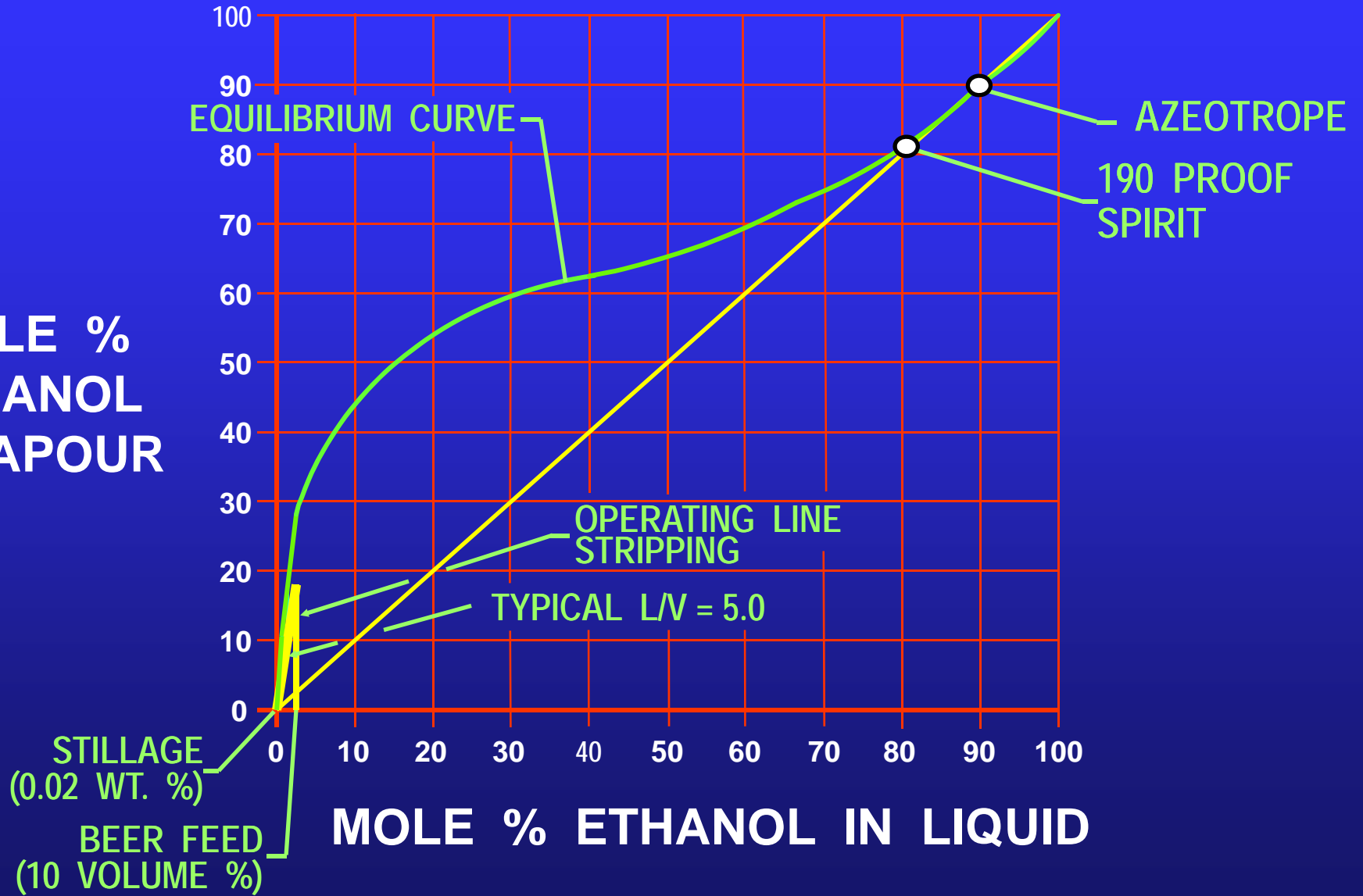
STRUCTURING THE DISTILLATION SYSTEM STRATEGY



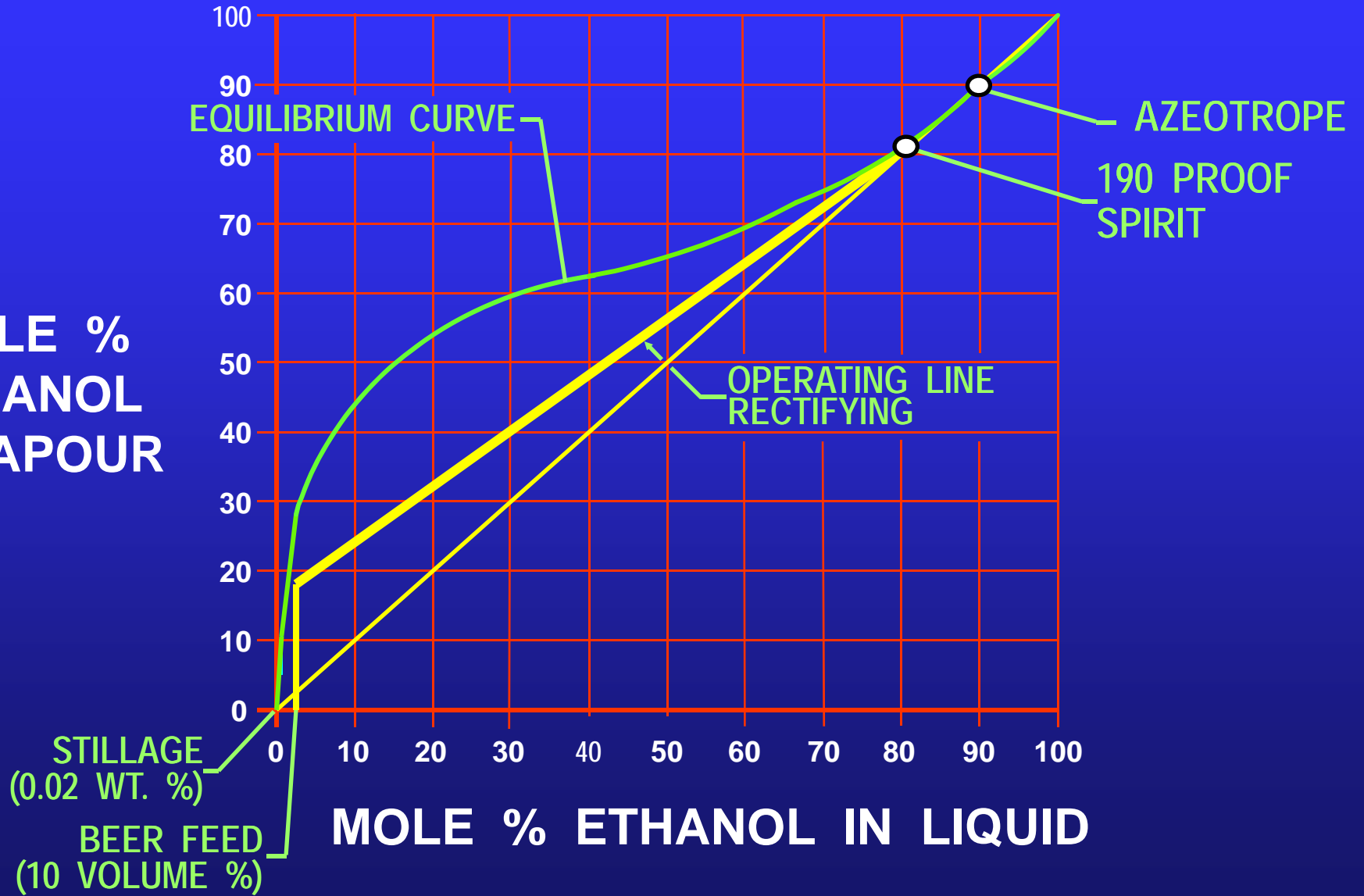
OPERATING LINE

Locus of possible concentrations of liquid and vapour passing in tower for a given energy input

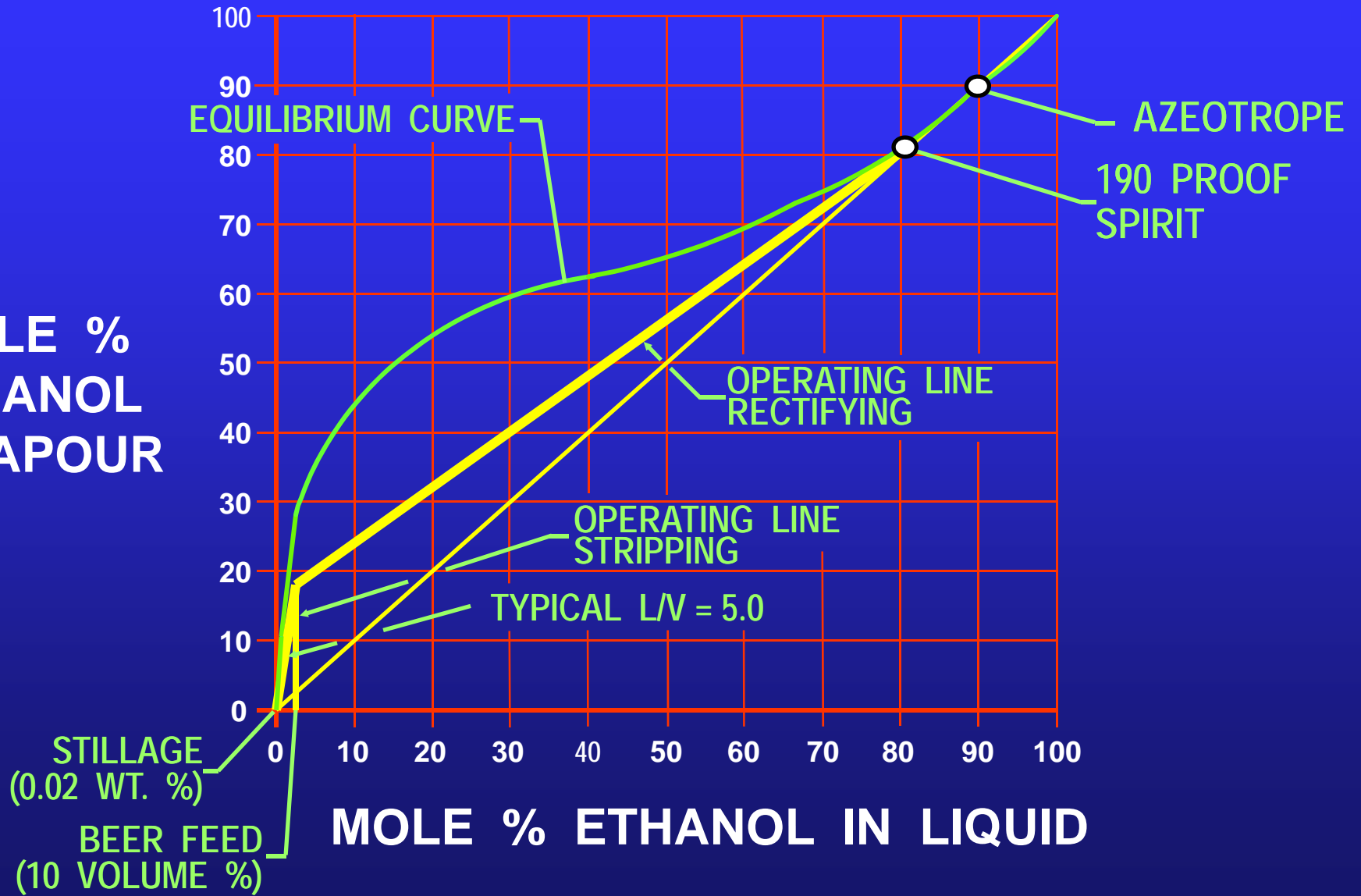
**MOLE %
ETHANOL
IN VAPOUR**



**MOLE %
ETHANOL
IN VAPOUR**

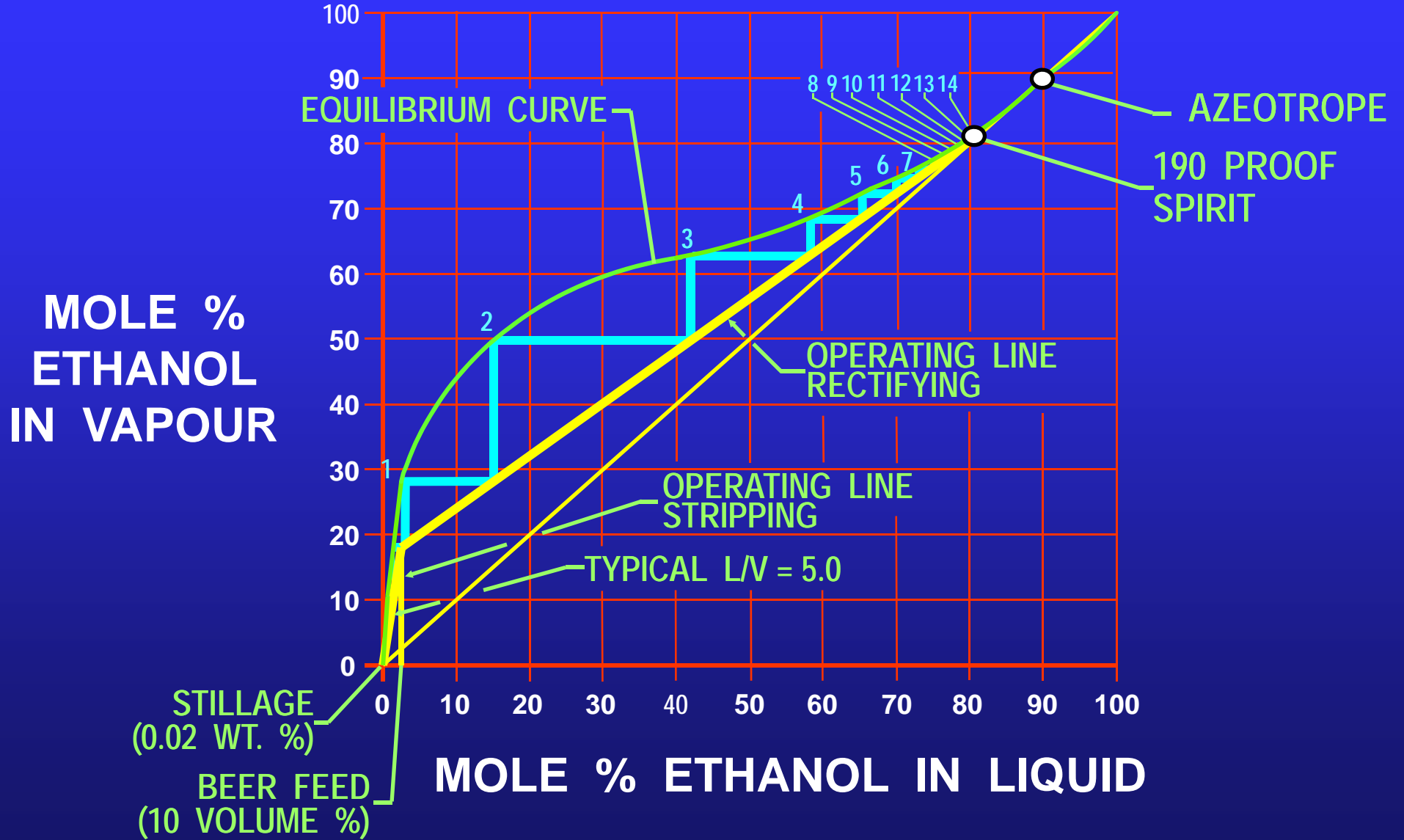


**MOLE %
ETHANOL
IN VAPOUR**



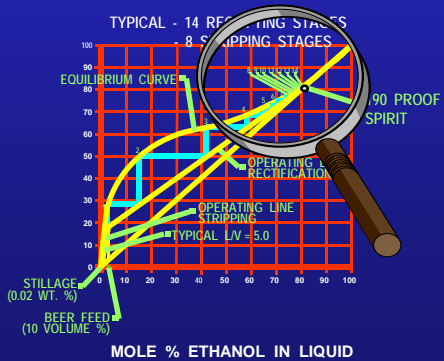
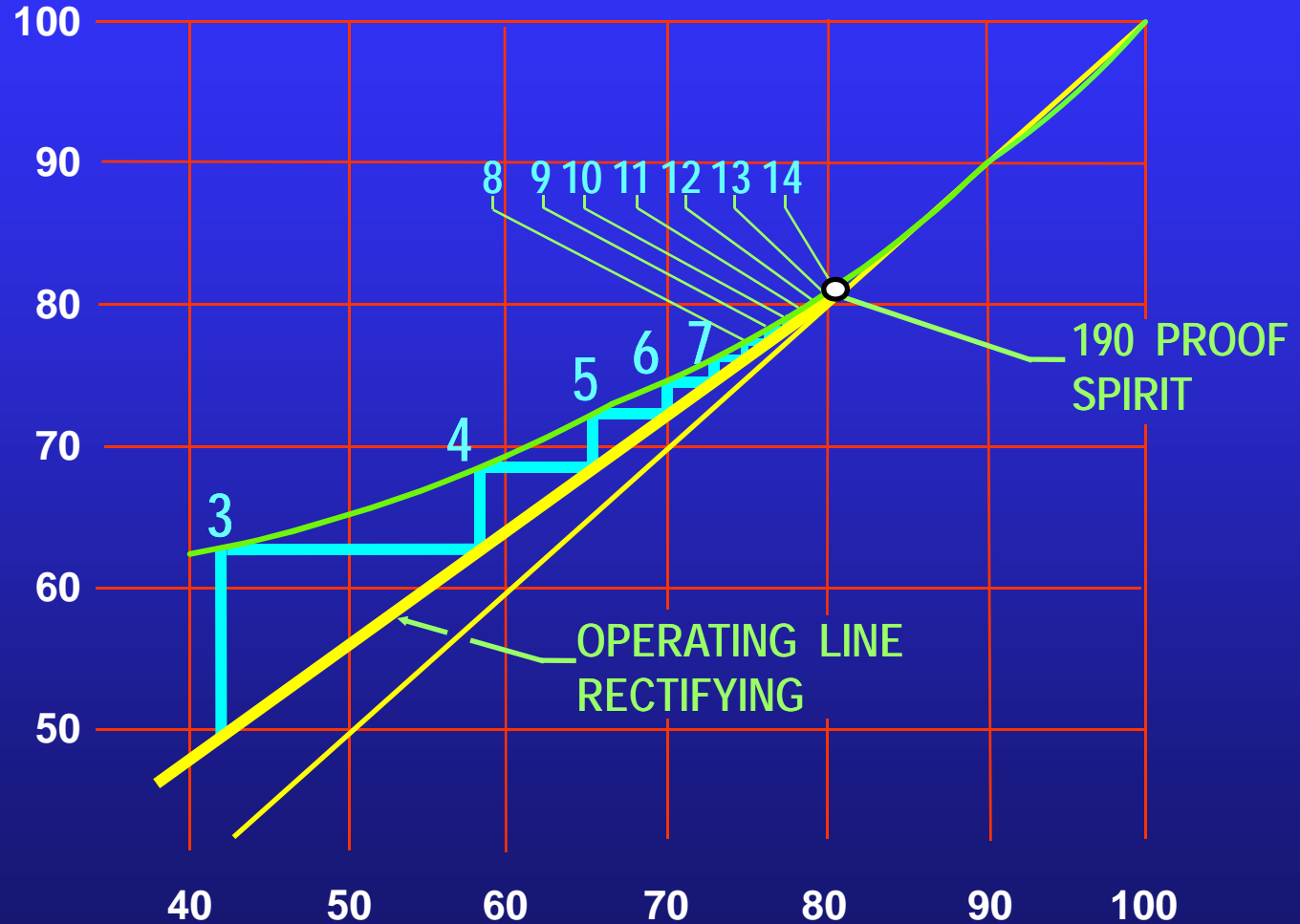
VAPOUR-LIQUID EQUILIBRIUM STAGE ANALYSIS

TYPICAL - 14 RECTIFYING STAGES
- 8 STRIPPING STAGES



VAPOUR-LIQUID EQUILIBRIUM STAGE ANALYSIS

MOLE %
ETHANOL
IN VAPOUR

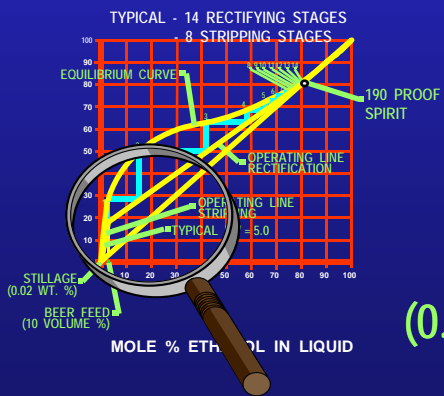
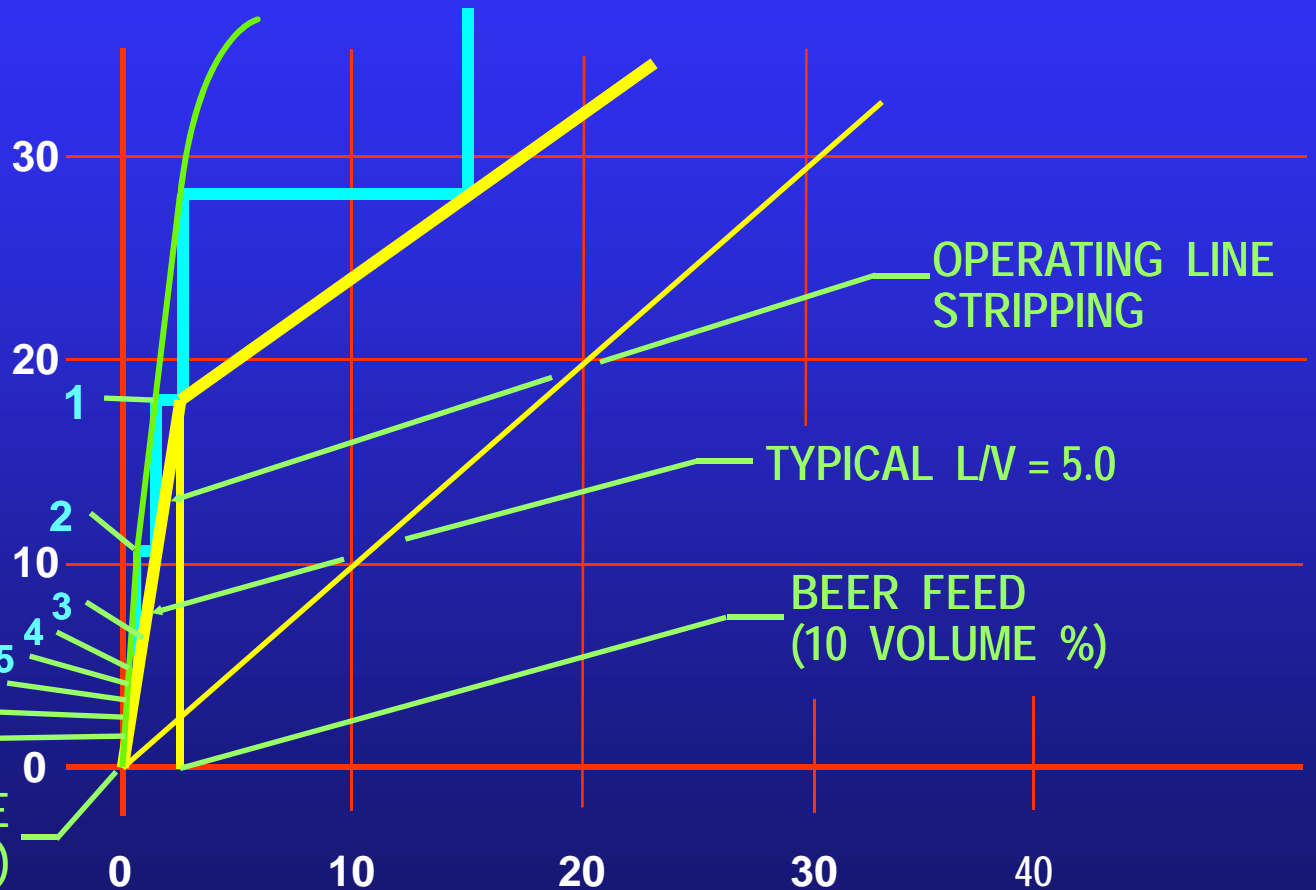


VAPOUR-LIQUID EQUILIBRIUM STAGE ANALYSIS

MOLE %
ETHANOL
IN VAPOUR

STILLAGE
(0.02 WT. %)

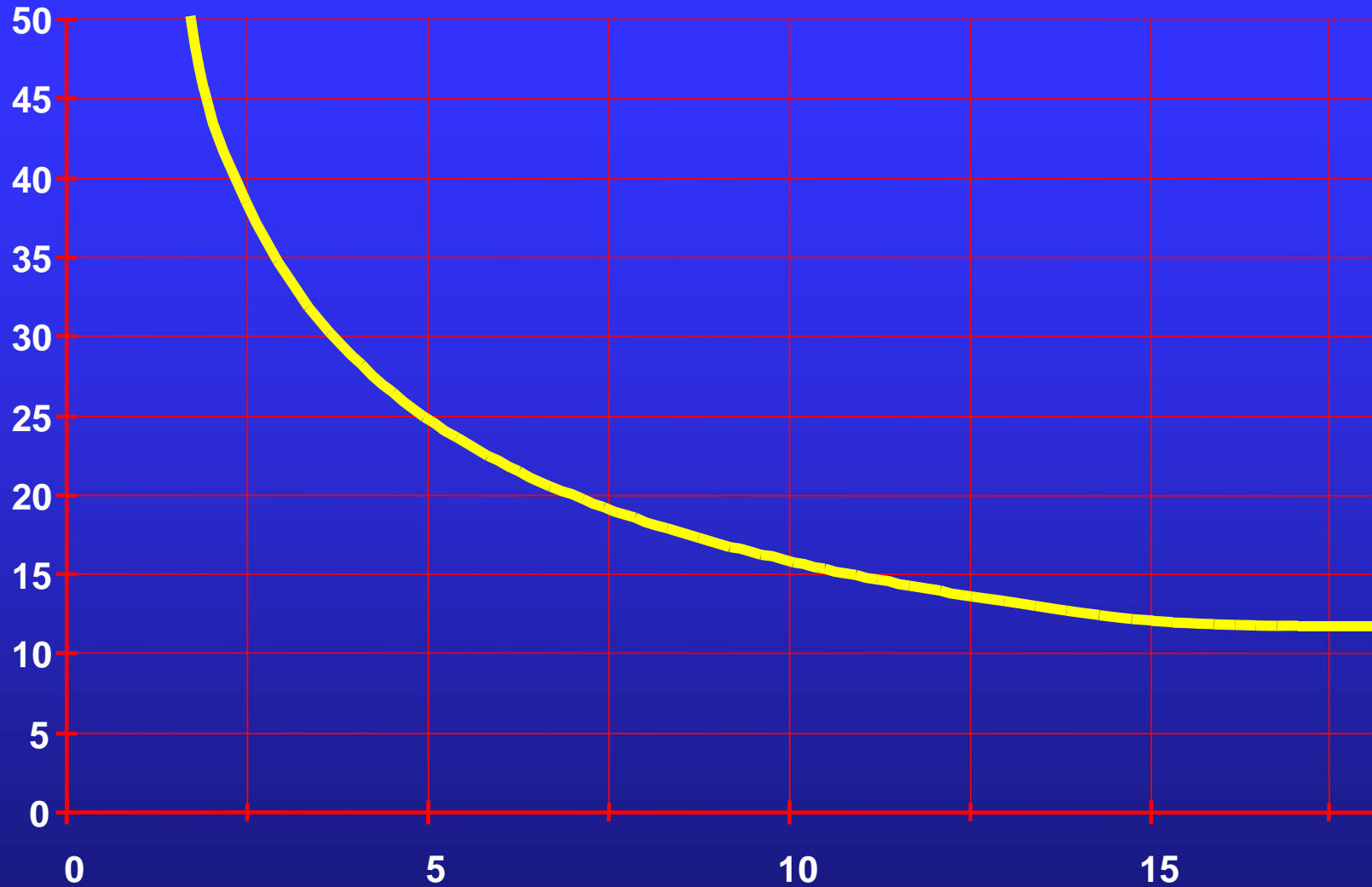
MOLE % ETHANOL IN LIQUID



DISTILLATION ENERGY CONSUMPTION

STEAM REQUIREMENTS
ETHANOL STRIPPER-RECTIFIER

**BTU (In 1000's)
PER GALLON
ETHANOL
(ANHYDROUS
BASIS)**

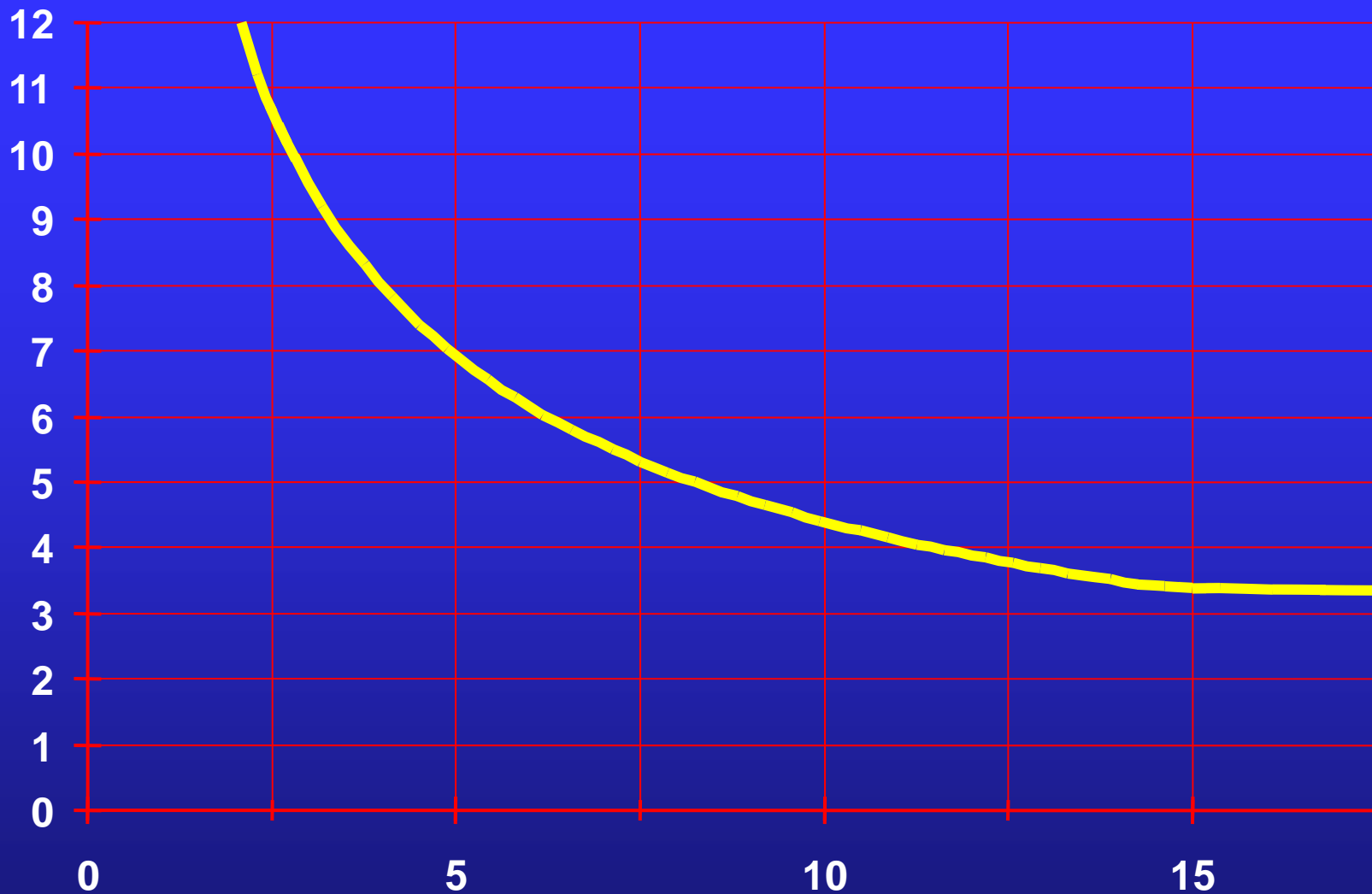


**BEER CONCENTRATION
(VOLUME %)**

CONSTRAINTS:

- 190 PROOF PRODUCT
- 0.02% (WT.) BOTTOMS
- SATURATED FEED

**MJ
PER LITER
ETHANOL
(ANHYDROUS
BASIS)**



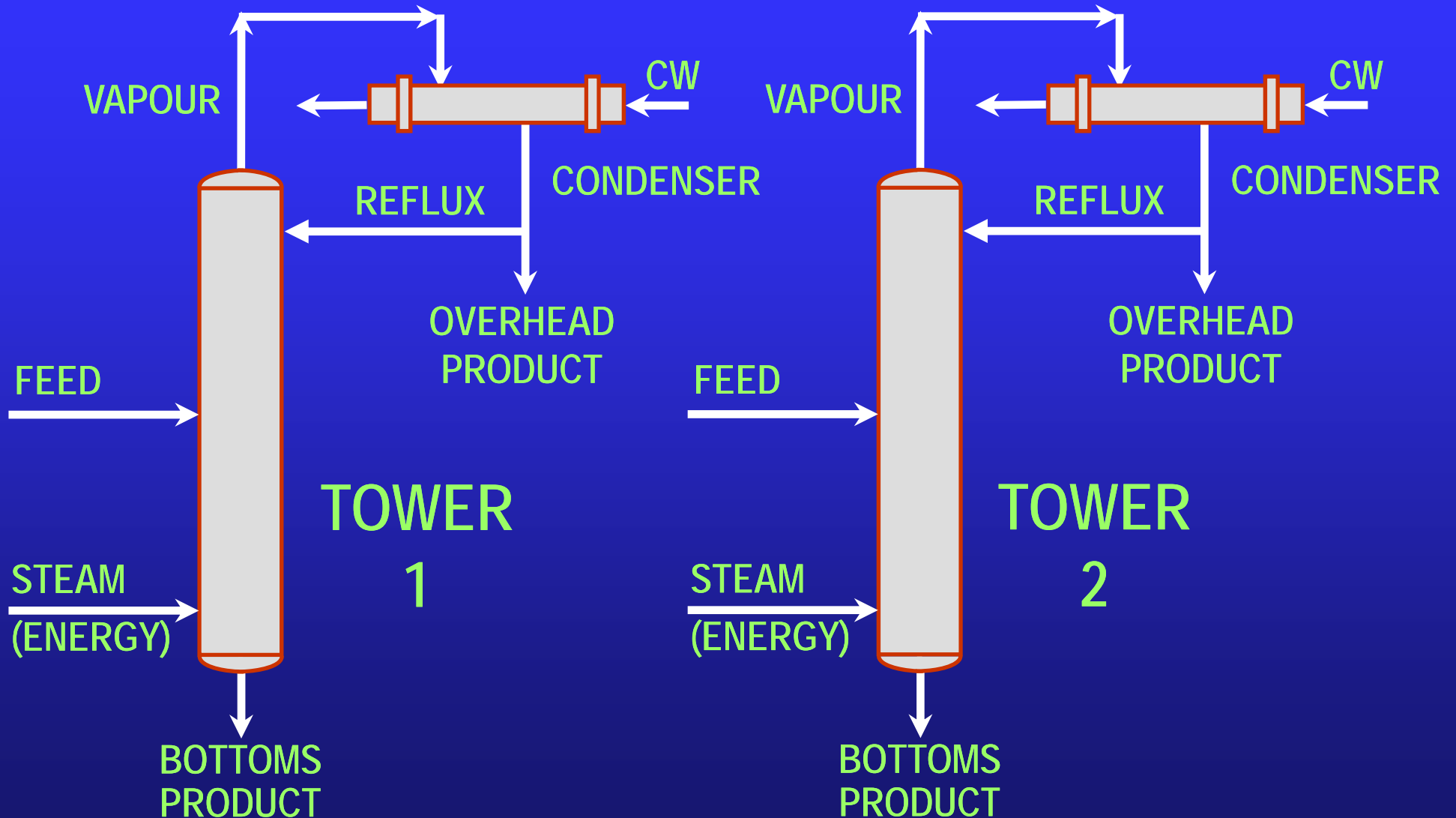
**BEER CONCENTRATION
(VOLUME %)**

CONSTRAINTS:

- 190 PROOF PRODUCT
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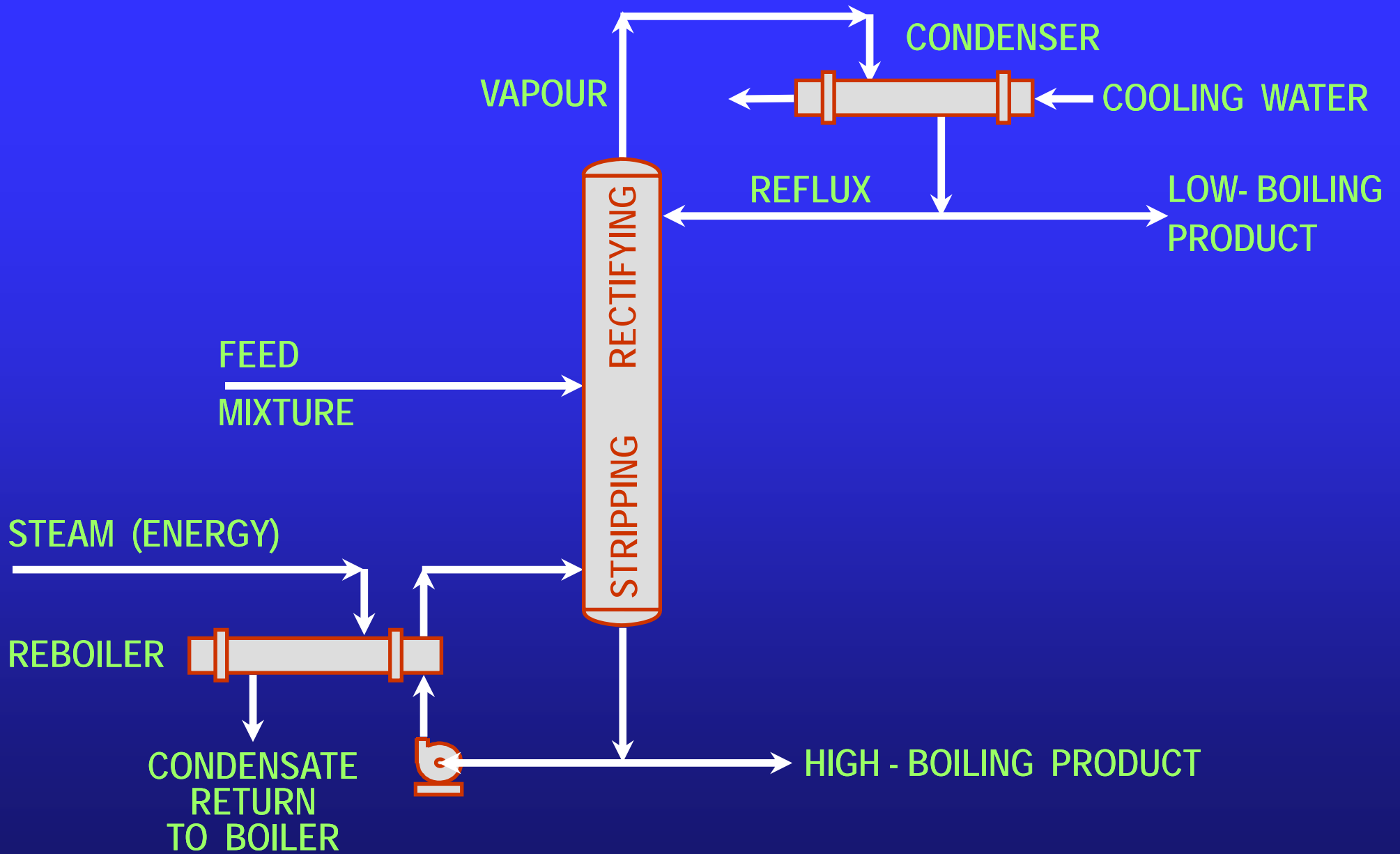
ENERGY EFFICIENCY

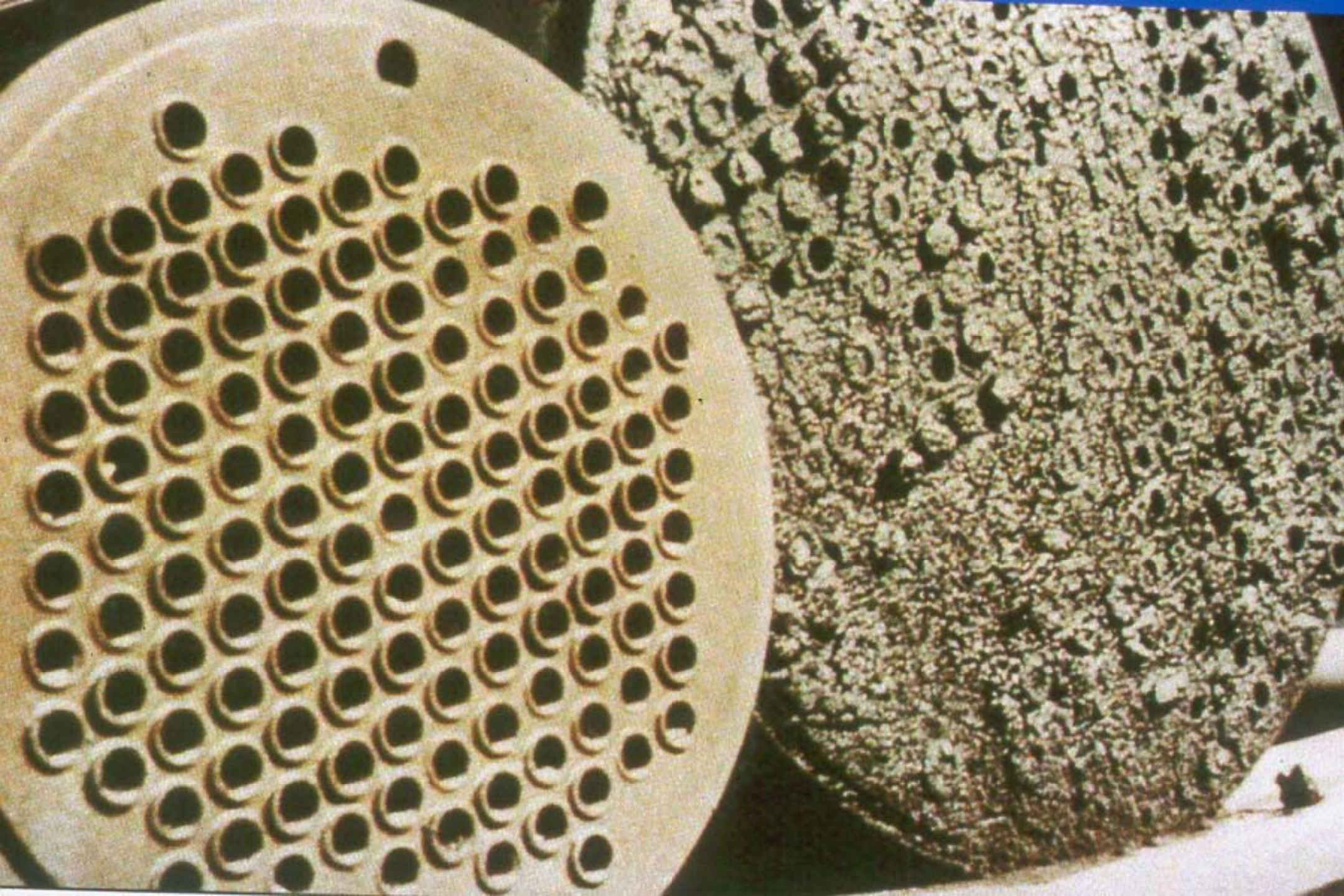
TRADITIONAL



Energy Inefficient

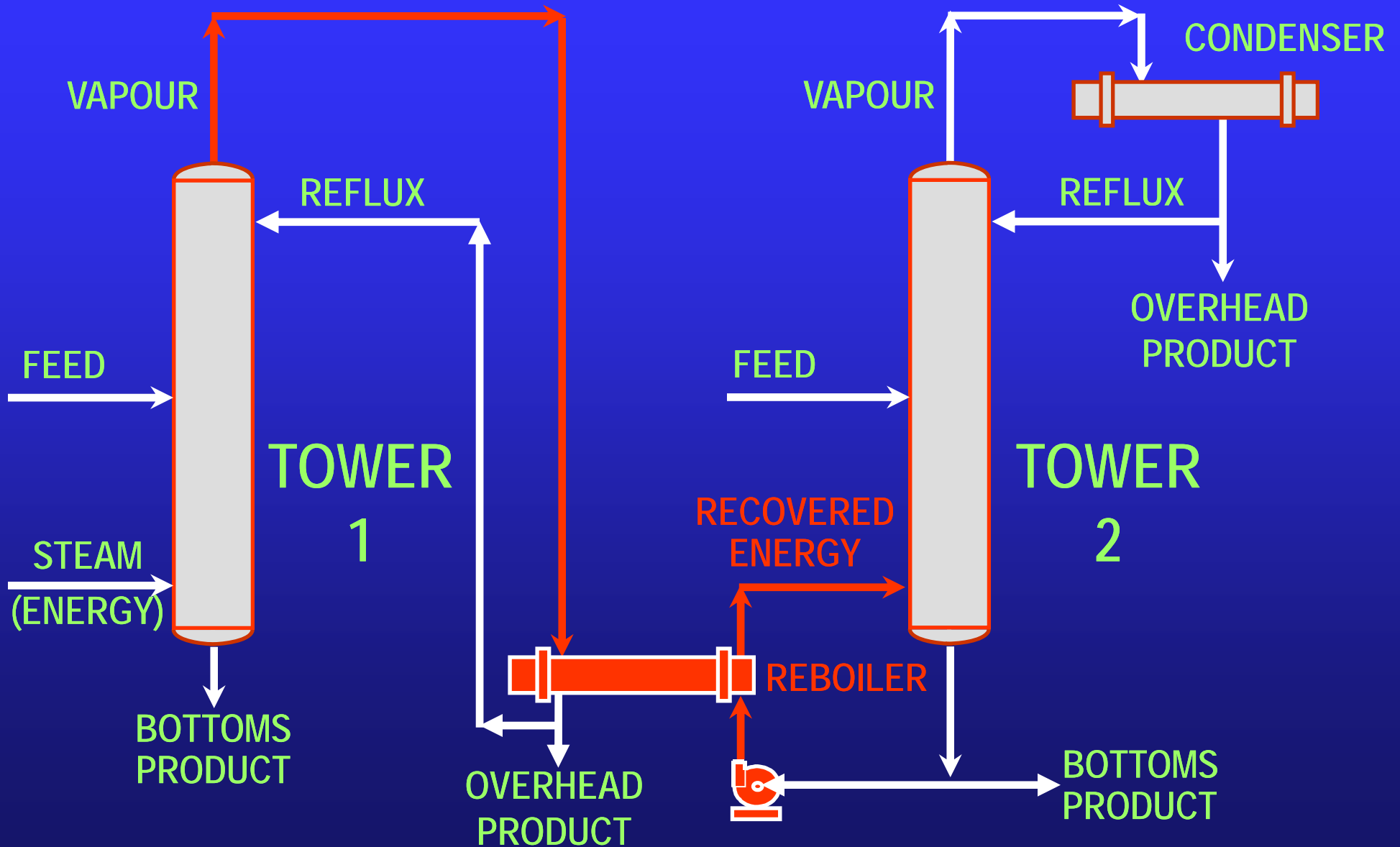
**ENERGY TRANSFER BY
FORCED - CIRCULATION
REBOILER**



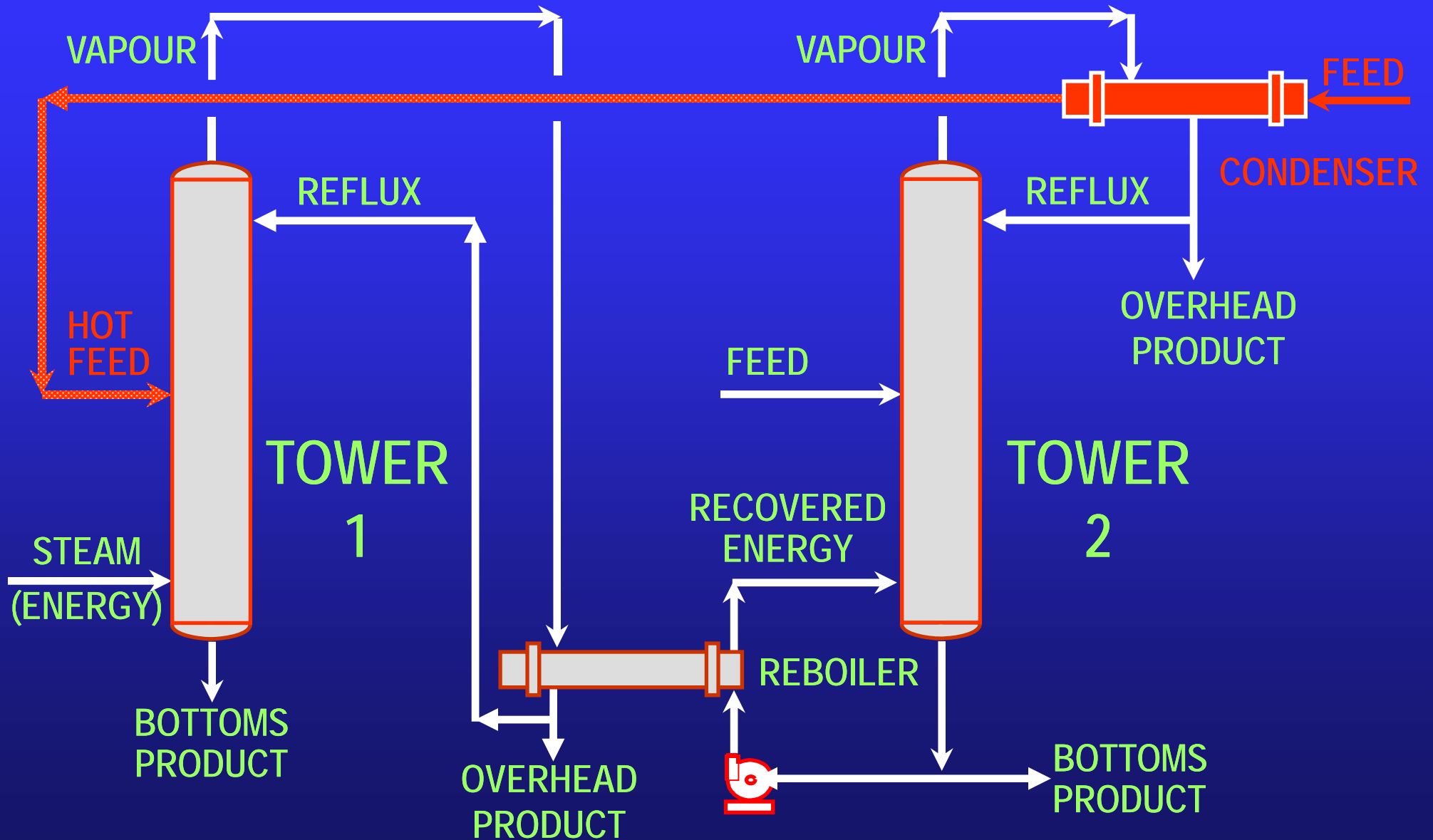


**ONE - LEVEL
ENERGY
CASCADE**

ENERGY CASCADE

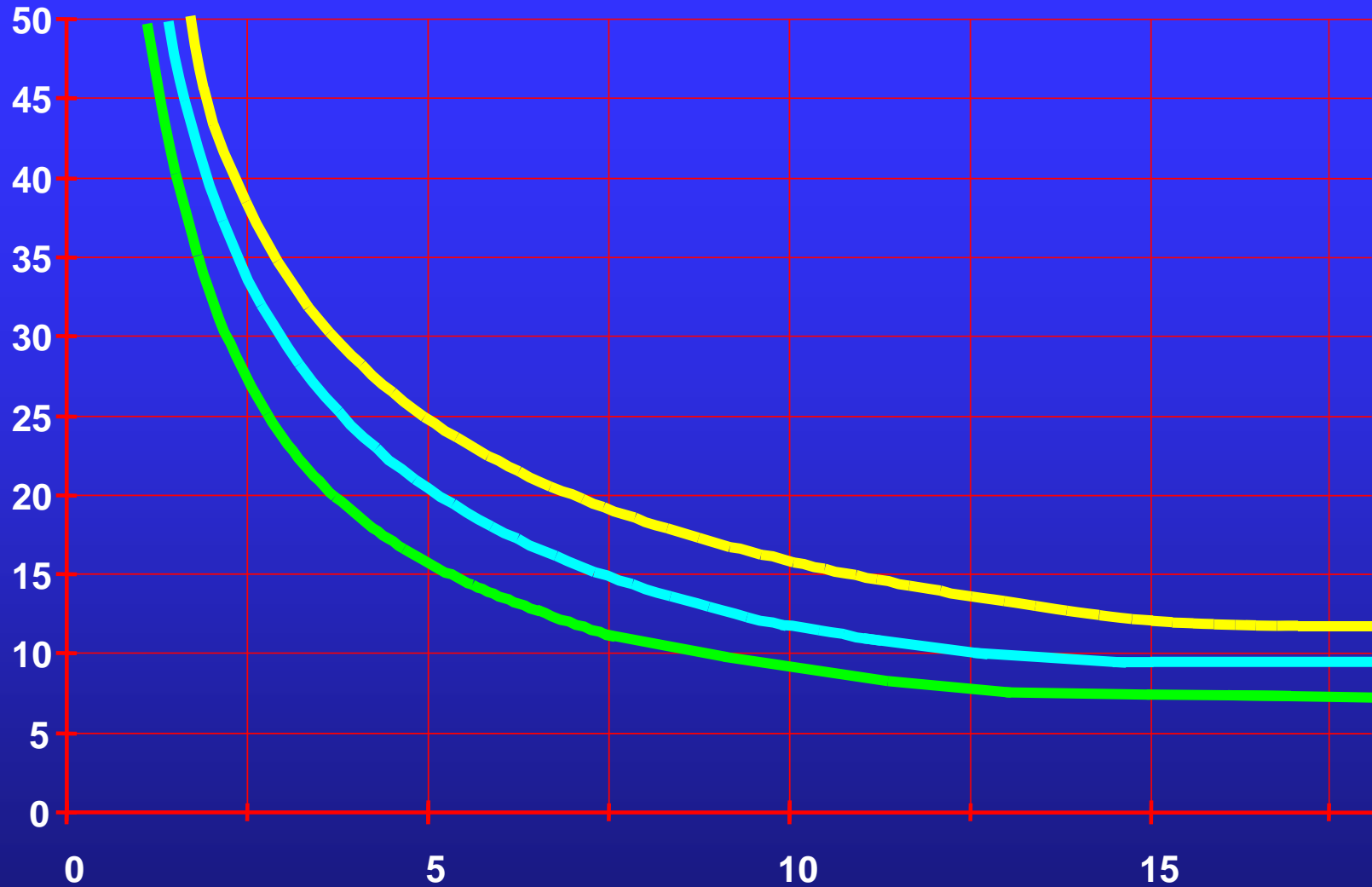


ENERGY CASCADE - FEED PREHEAT



**TWO - LEVEL
ENERGY
CASCADE
(3 – TOWER)**

**BTU (In 1000's)
PER GALLON
ETHANOL
(ANHYDROUS
BASIS)**

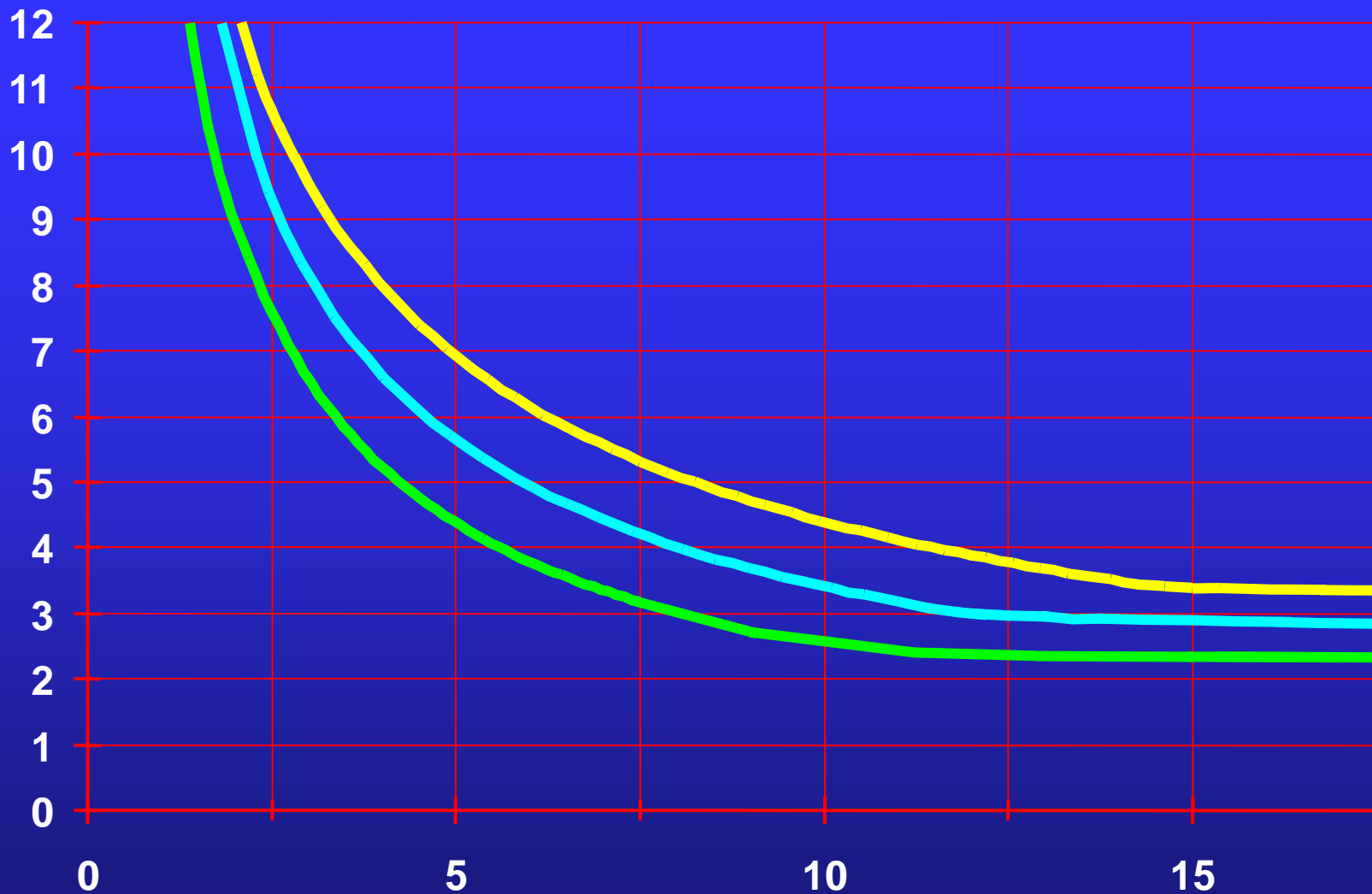


**BEER CONCENTRATION
(VOLUME %)**

CONSTRAINTS:

- 190 PROOF PRODUCT
- 0.02% (WT.) BOTTOMS
- SATURATED FEED

**MJ
PER LITER
ETHANOL
(ANHYDROUS
BASIS)**



**BEER CONCENTRATION
(VOLUME %)**

- CONSTRAINTS:**
- 190 PROOF PRODUCT
 - 0.02% (WT.) BOTTOMS
 - SATURATED FEED

ENERGY REQUIREMENTS

BASIC

Stripping-Concentrating

14 lb STEAM per U.S. GALLON (absolute)

or

1.7 Kg STEAM per LITER

ENERGY REQUIREMENTS

ADVANCED-INTEGRATED

Stripping-Concentrating

9 lb STEAM per U.S. GALLON (absolute)

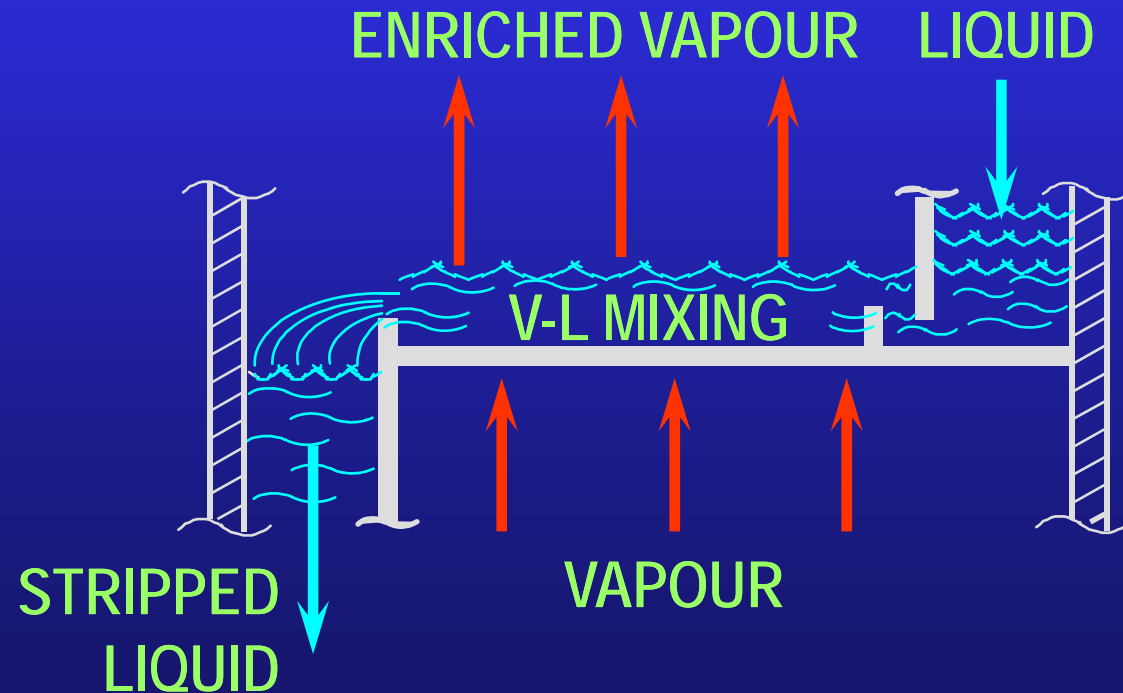
or

1.1 Kg STEAM per LITER

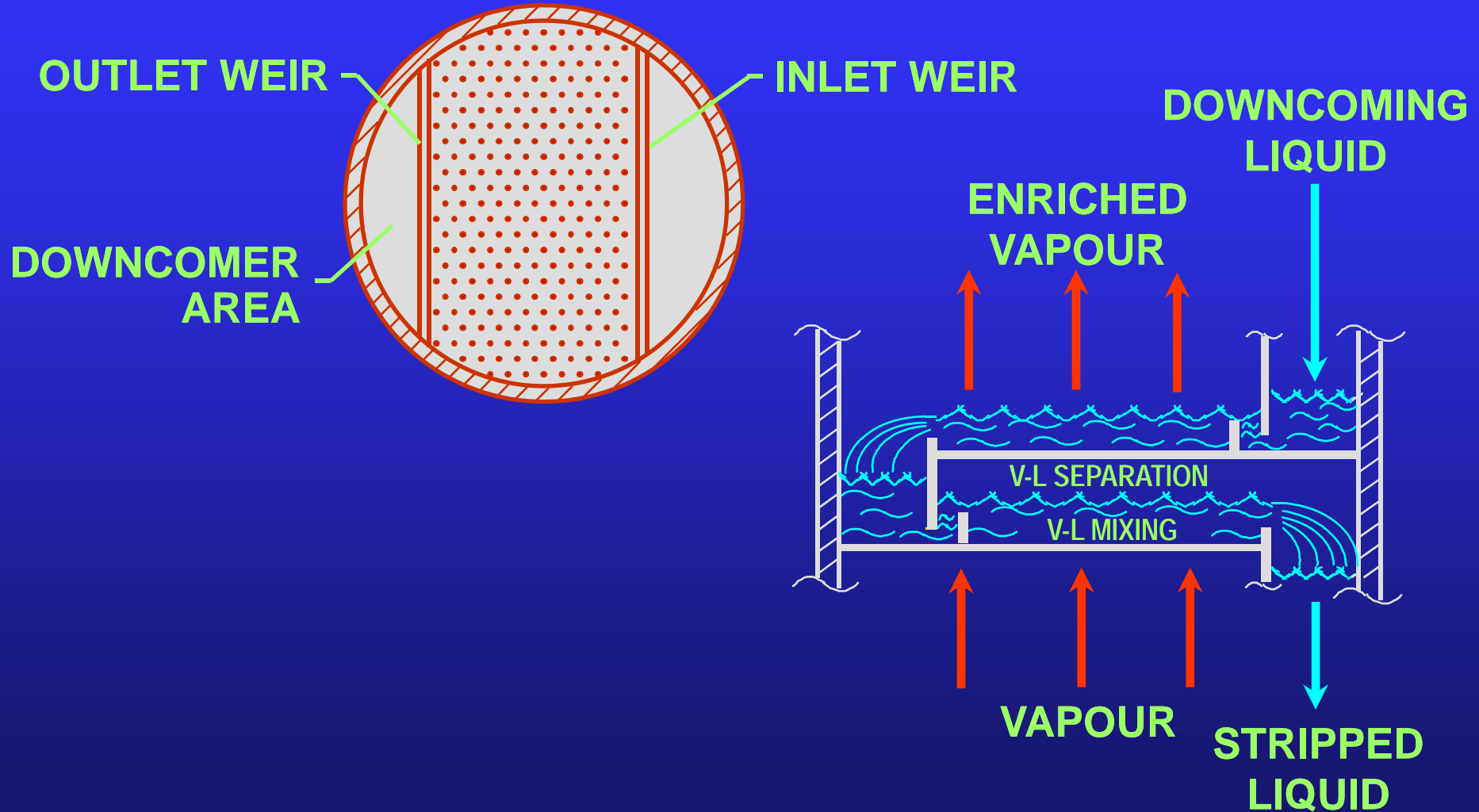
CONTACTING DEVICES (TRAYS)

DISTILLATION TRAY FUNCTIONS

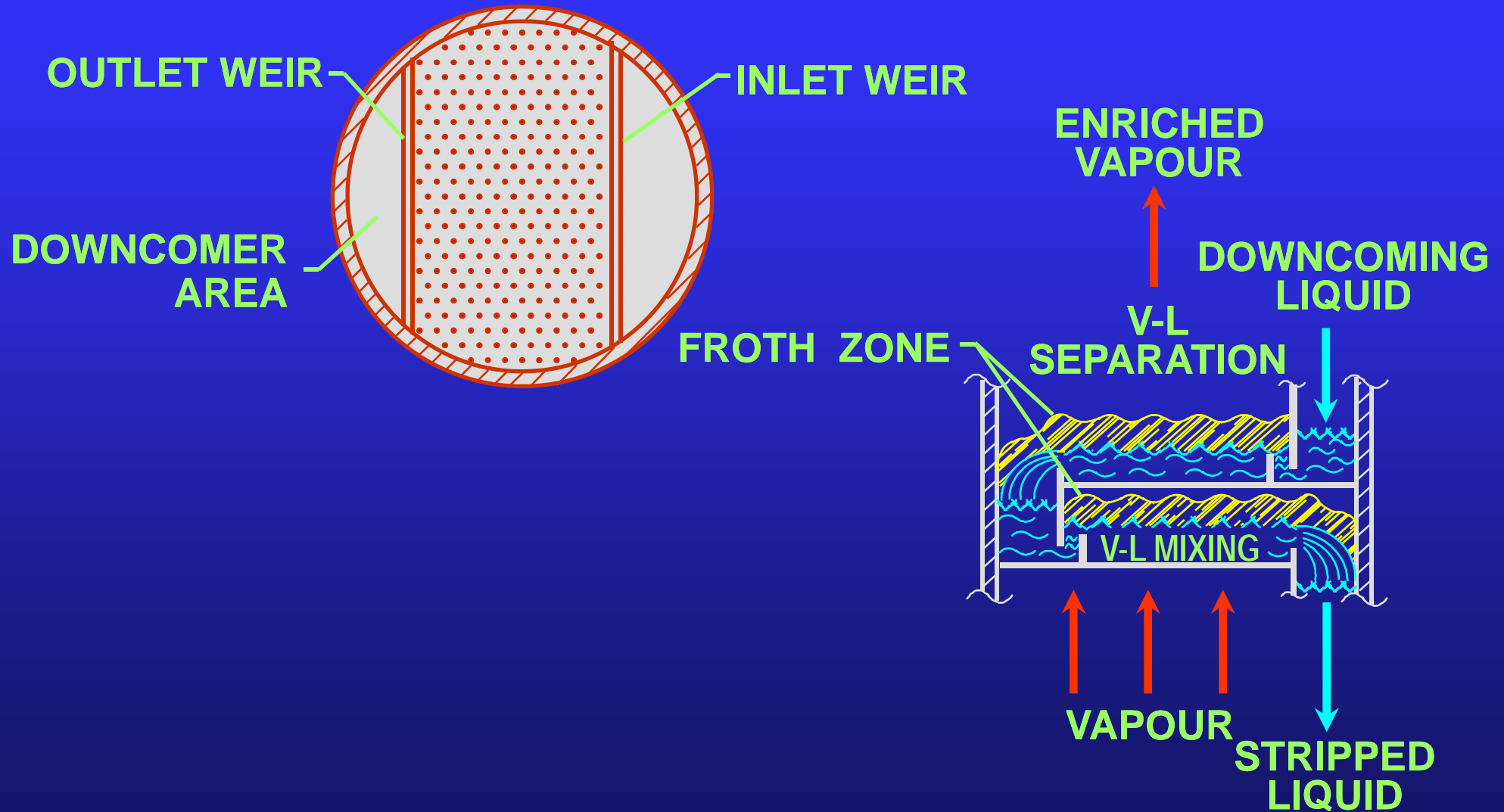
- MIX RISING VAPOUR WITH FALLING LIQUID
- ALLOW FOR SEPARATION AFTER MIXING
- PROVIDE PATH FOR LIQUID TO PROCEED DOWN THE TOWER
- PROVIDE PATH FOR VAPOUR TO PROCEED UP THE TOWER



PERFORATED TRAYS



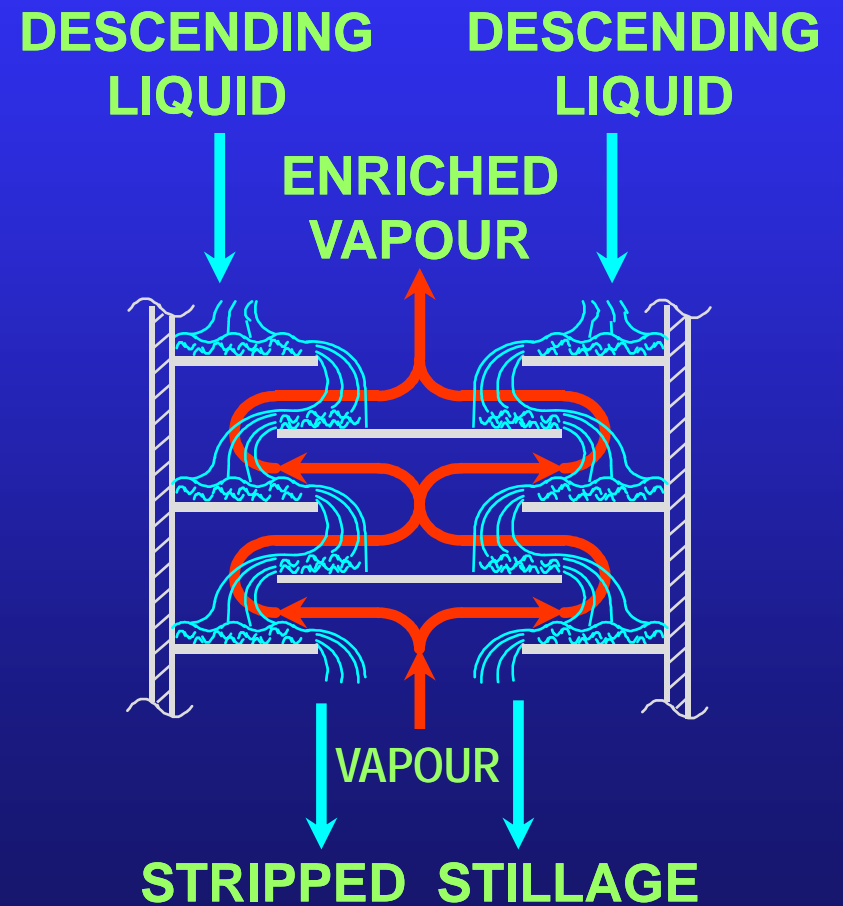
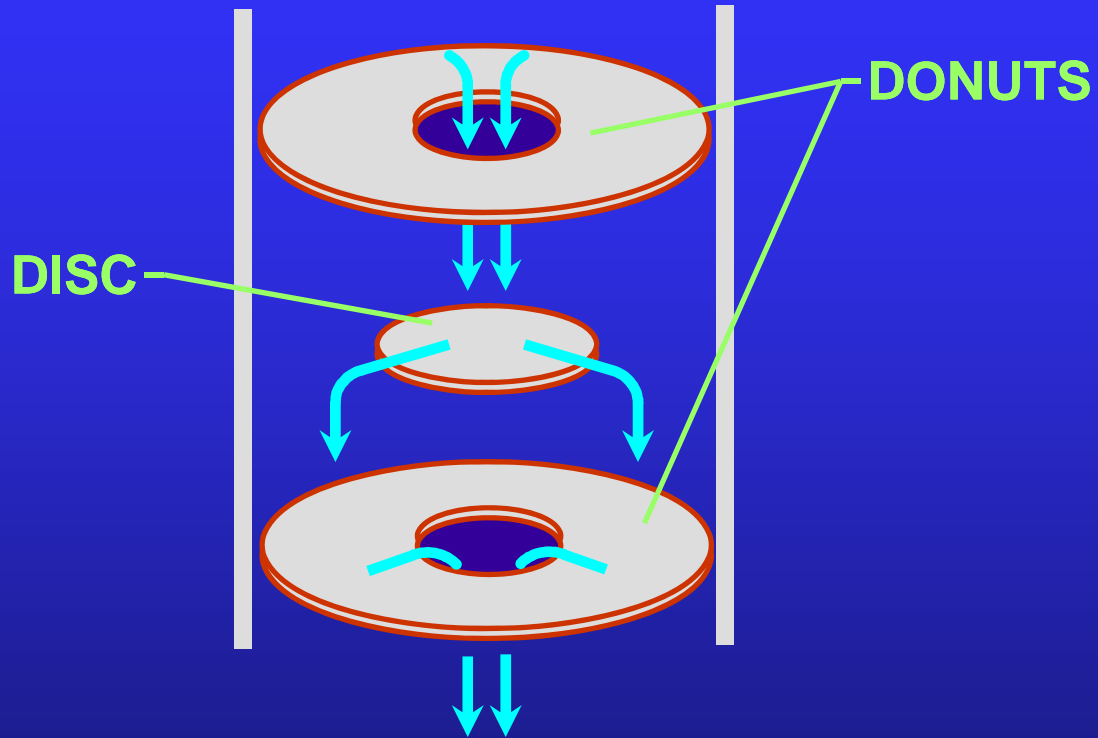
PERFORATED TRAY FROTHING

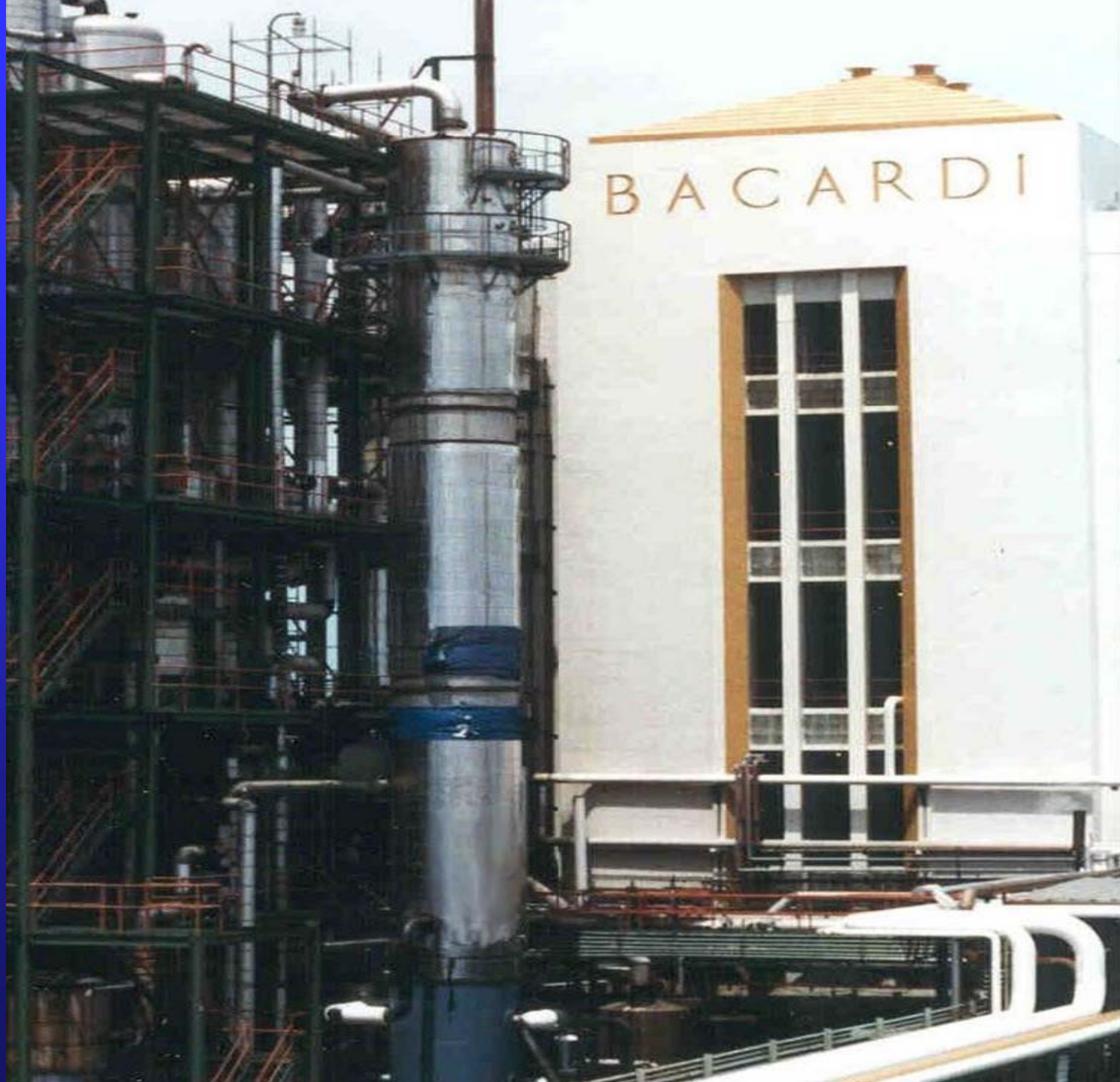


RELIABILITY

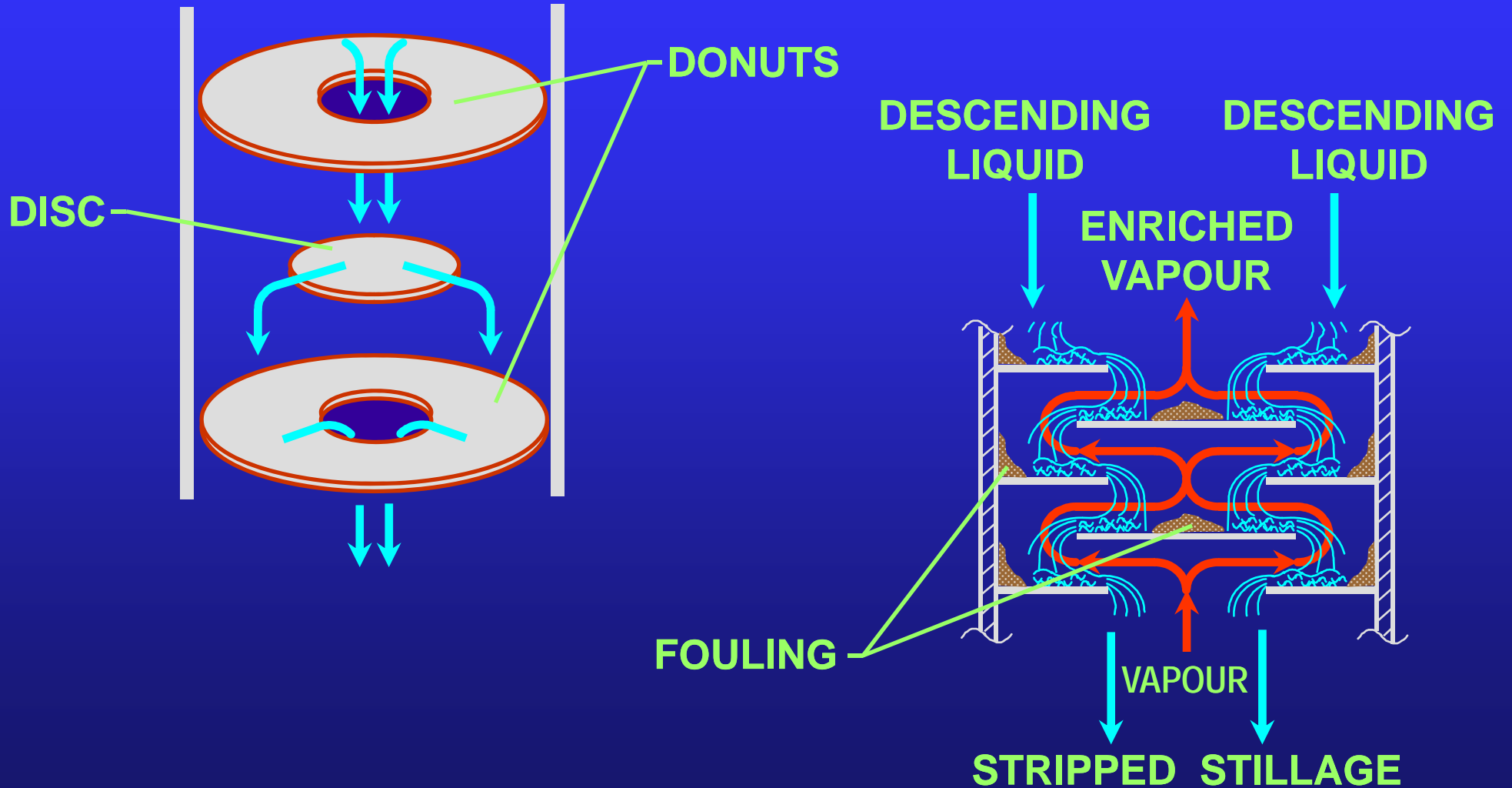
**BEER STRIPPER
FOULING**

DISC-DONUT TRAYS

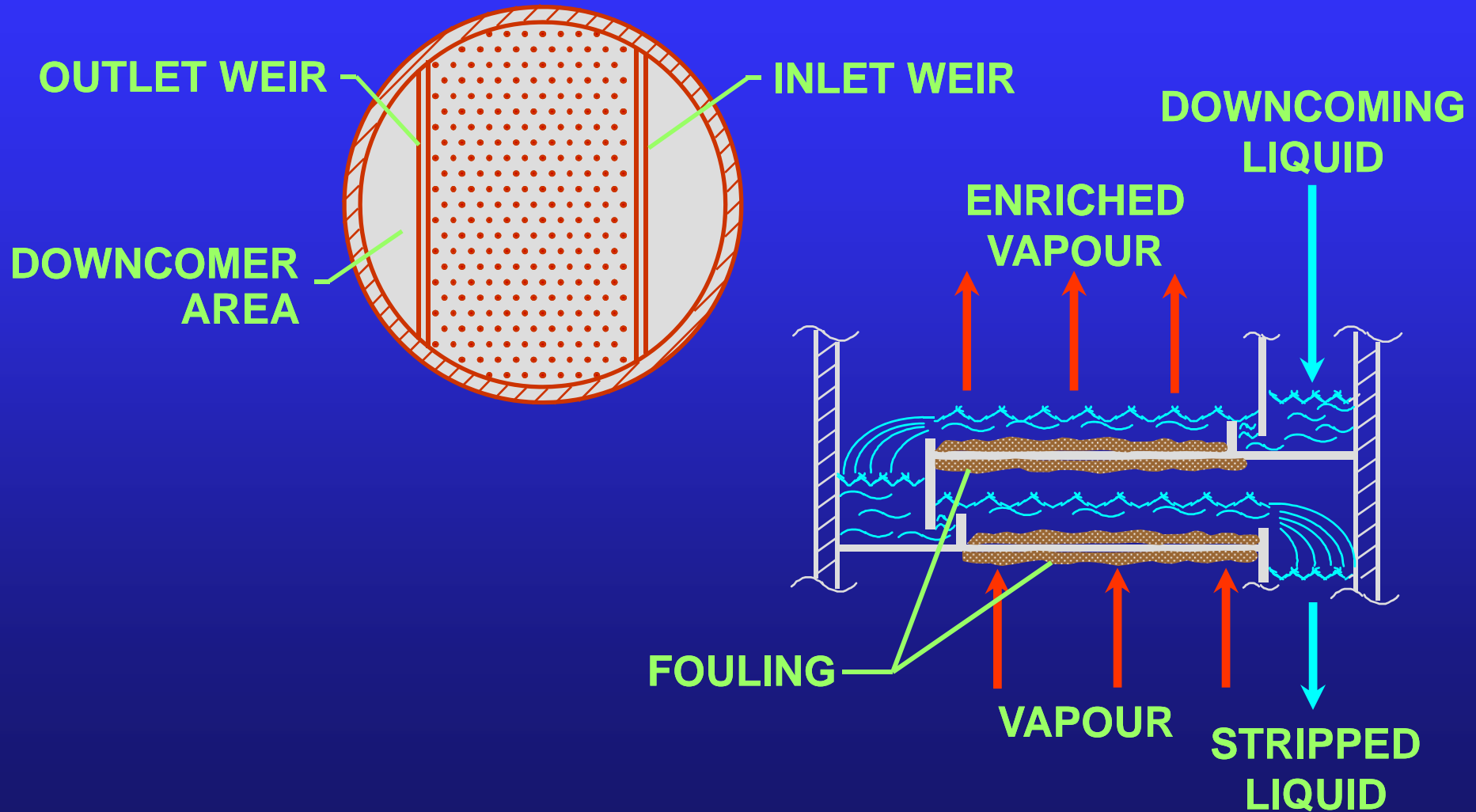


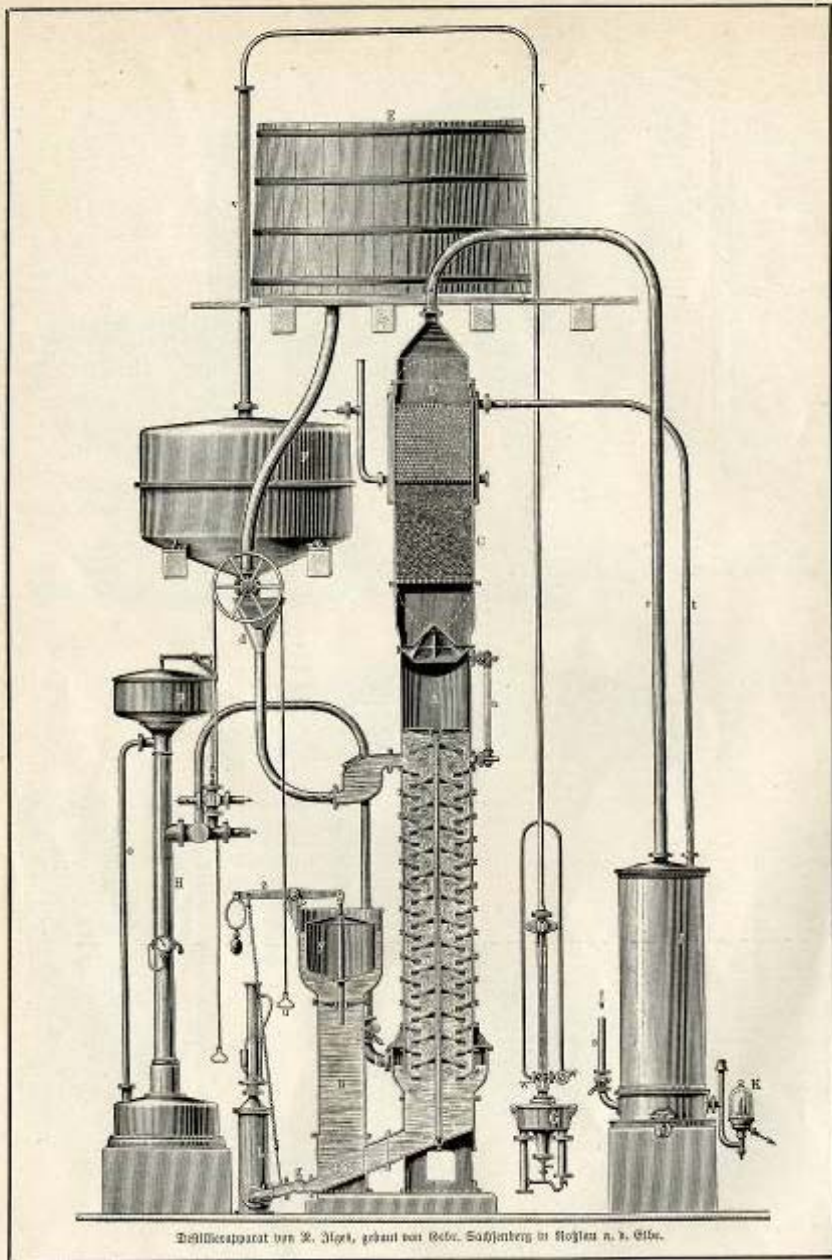


DISC-DONUT TRAYS



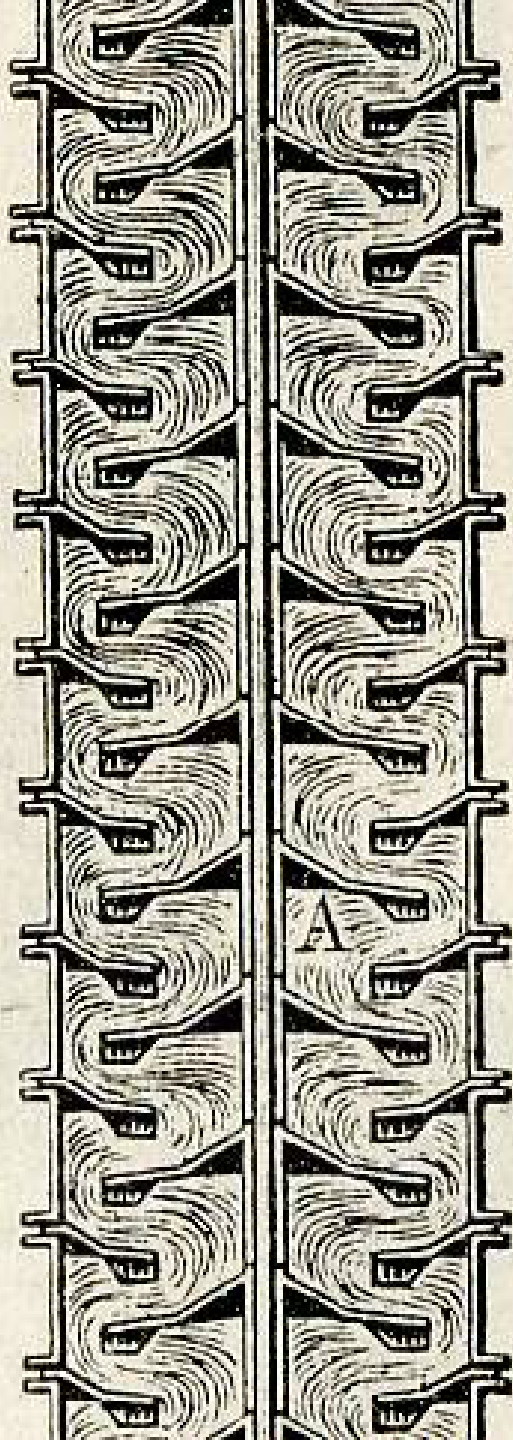
PERFORATED TRAYS





Destillationsapparat von K. Alget, gebaut von Robt. Schönlberg in Hofen a. N. Rhe.

Zu dem Artikel „Alkohol“ (Zahl II).



BAFFLE - TRAY EXPERIENCE

- **39 COMMERCIAL SYSTEMS**
 - SULFITE PULPING LIQUOR
 - FERMENTED SULFITE LIQUOR
 - FERMENTED LIGNO-CELLULOSE HYDROLYZATE
 - FERMENTED WHOLE GRAIN
 - **ALCELL** PULPING LIQUOR
 - FERMENTED CHEESE WHEY
 - FERMENTED CANE MOLASSES

BAFFLE - TRAY EXPERIENCE

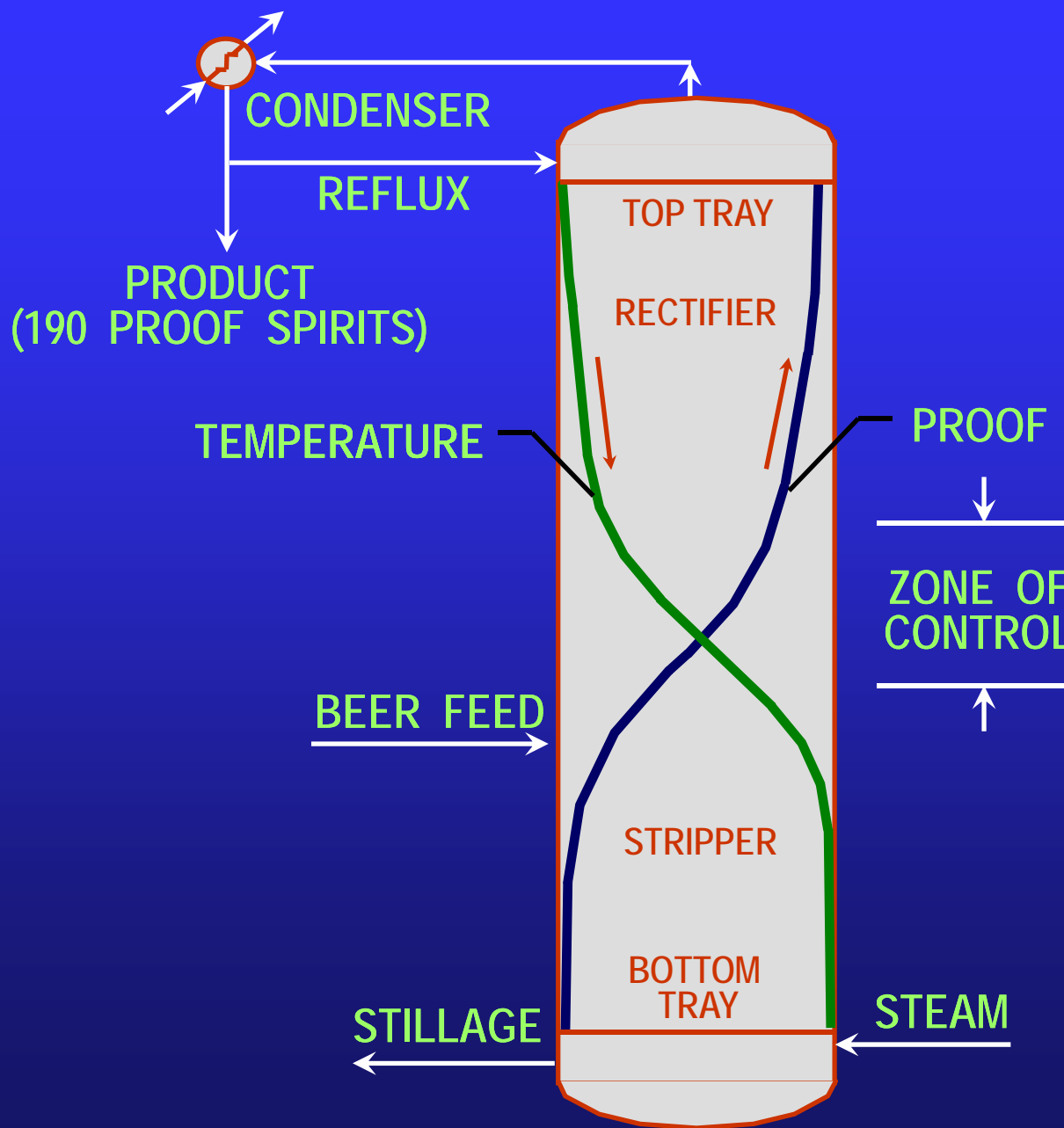
- **5 YEAR CLEANING CYCLE
FERMENTED GRAIN**
- **1 YEAR CLEANING CYCLE
FERMENTED CHEESE WHEY**
- **ELIMINATED ANTI-FOAM AND ANTI-
SCALANT**
- **6-12 MONTH CLEANING CYCLE
FERMENTED “C” MOLASSES**

RECOMMENDED TRAY DESIGNS

BEERSTILLS (ALL FOULING FEEDSTOCKS)	- BAFFLE TRAY
RECTIFIERS	- PERFORATED TRAY
EXTRACTIVE TOWERS	- PERFORATED TRAY
TECHNICAL ALCOHOL TOWERS	- PERFORATED TRAY - PACKED (< 24")

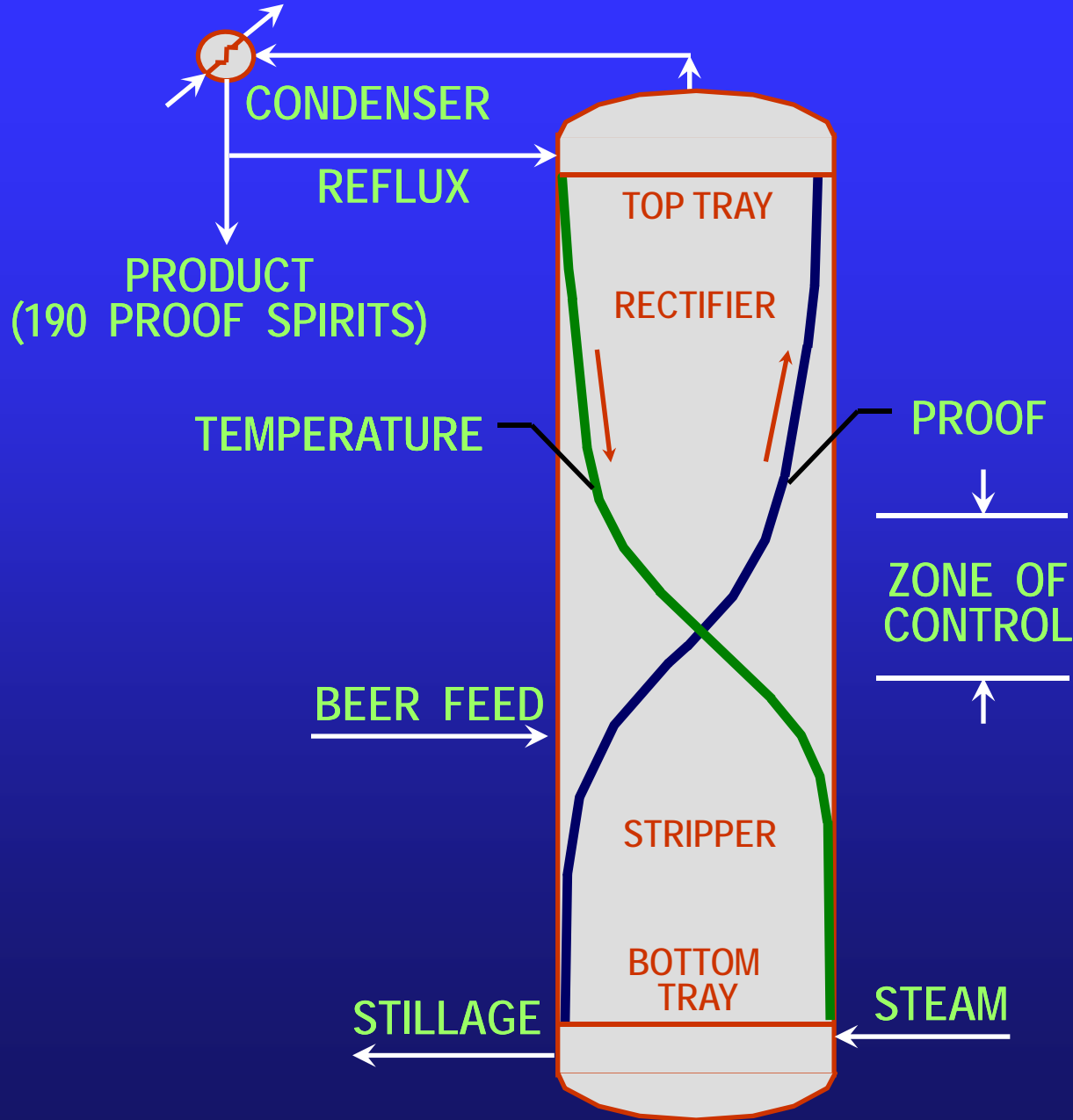
CONTROL STRATEGIES

TEMPERATURE AND PROOF PROFILE

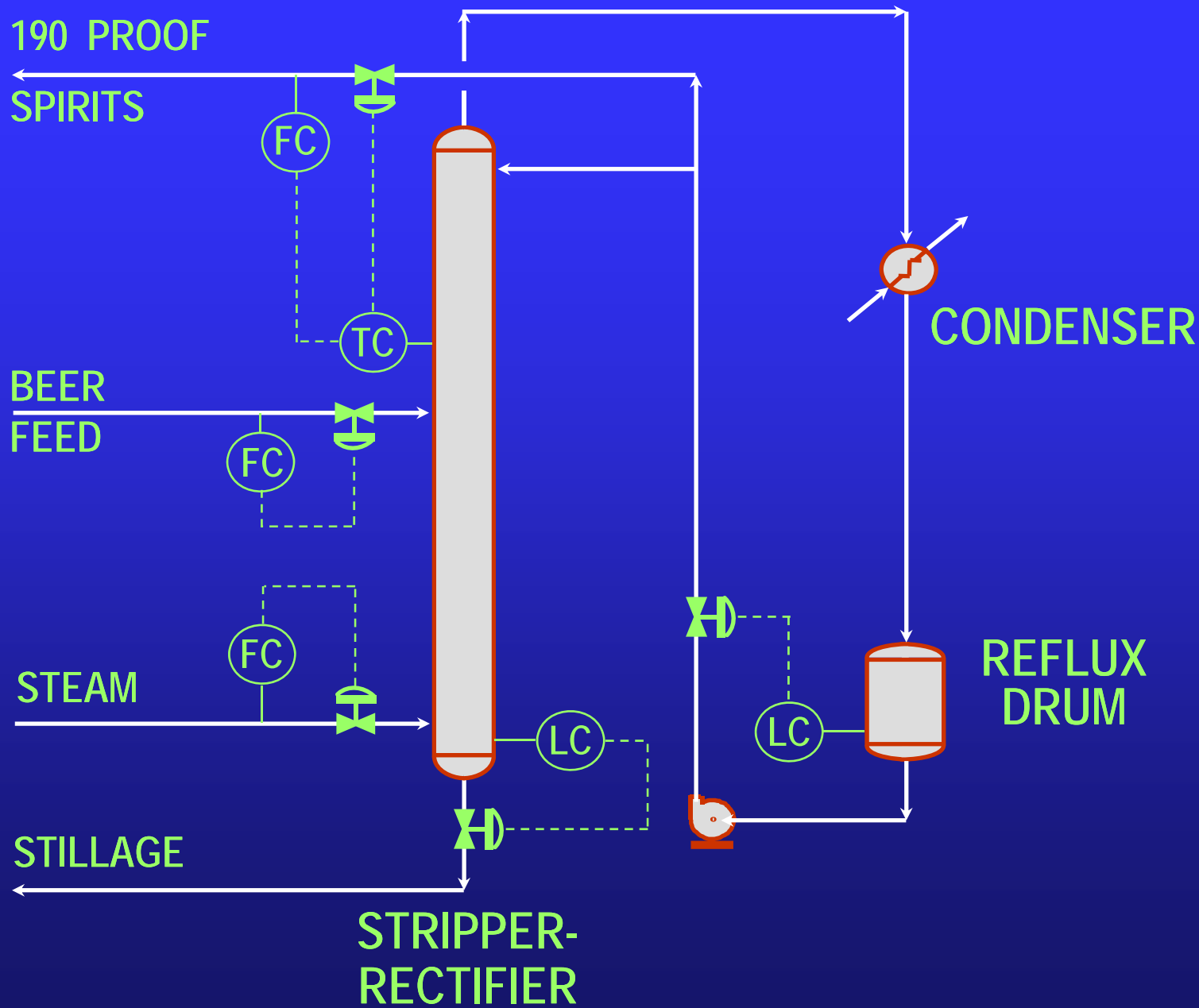


<u>TEMP. (°C)</u>	<u>°GL</u>
77	95
77	94.5
77	94
78	93
78	91.5
79	89
80	84
84	75
85	69
93	60
98	40
102	20
106	5
106	1.5
107	0.5
107	0.005
107	0.00005

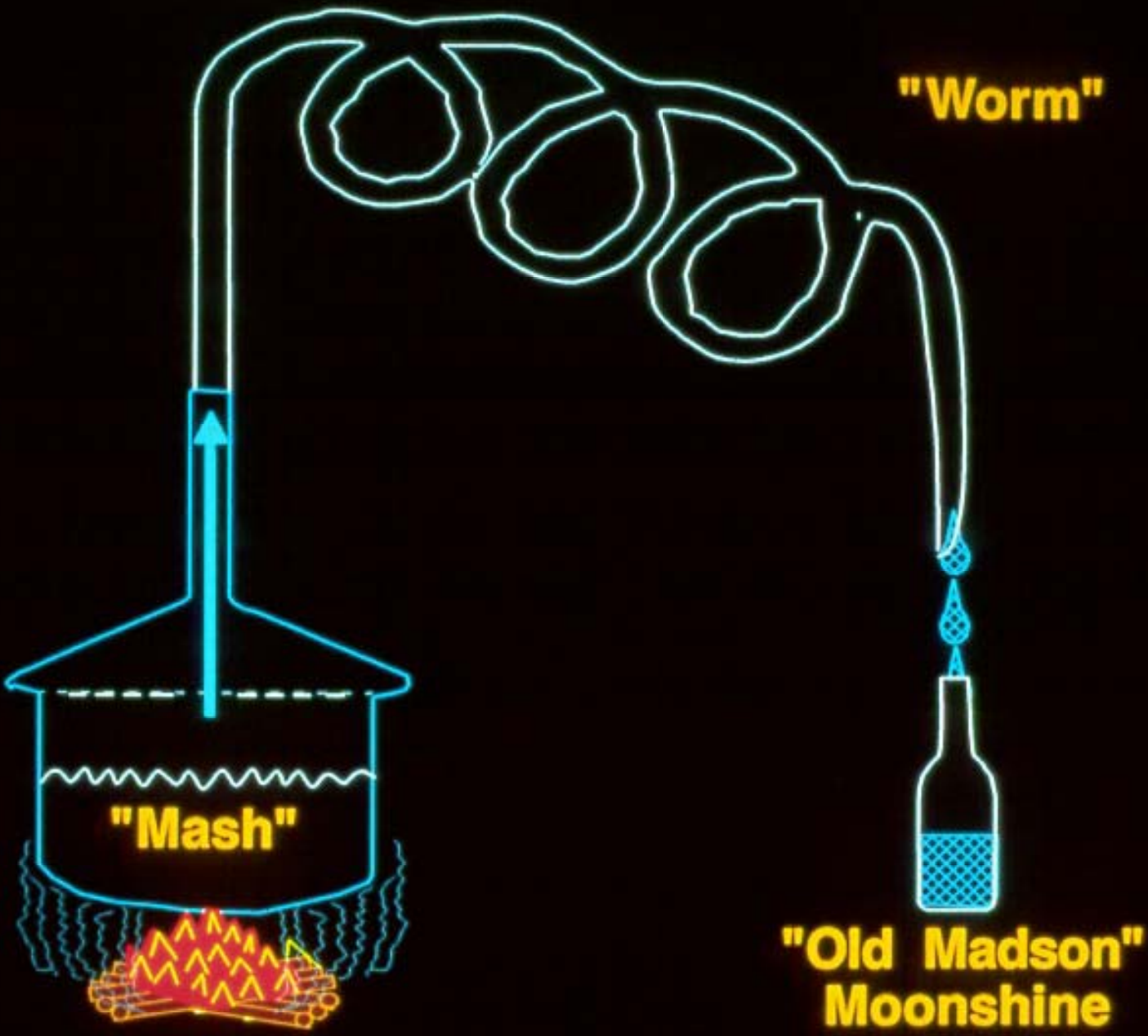
TEMPERATURE AND PROOF PROFILE



<u>TEMP. (°F)</u>	<u>°PR. (U.S.)</u>
170	190
170	189
171	188
172	186
173	183
174	178
176	168
184	150
191	138
199	120
208	80
216	40
222	10
223	3
224	1
225	0.01
225	0.0001

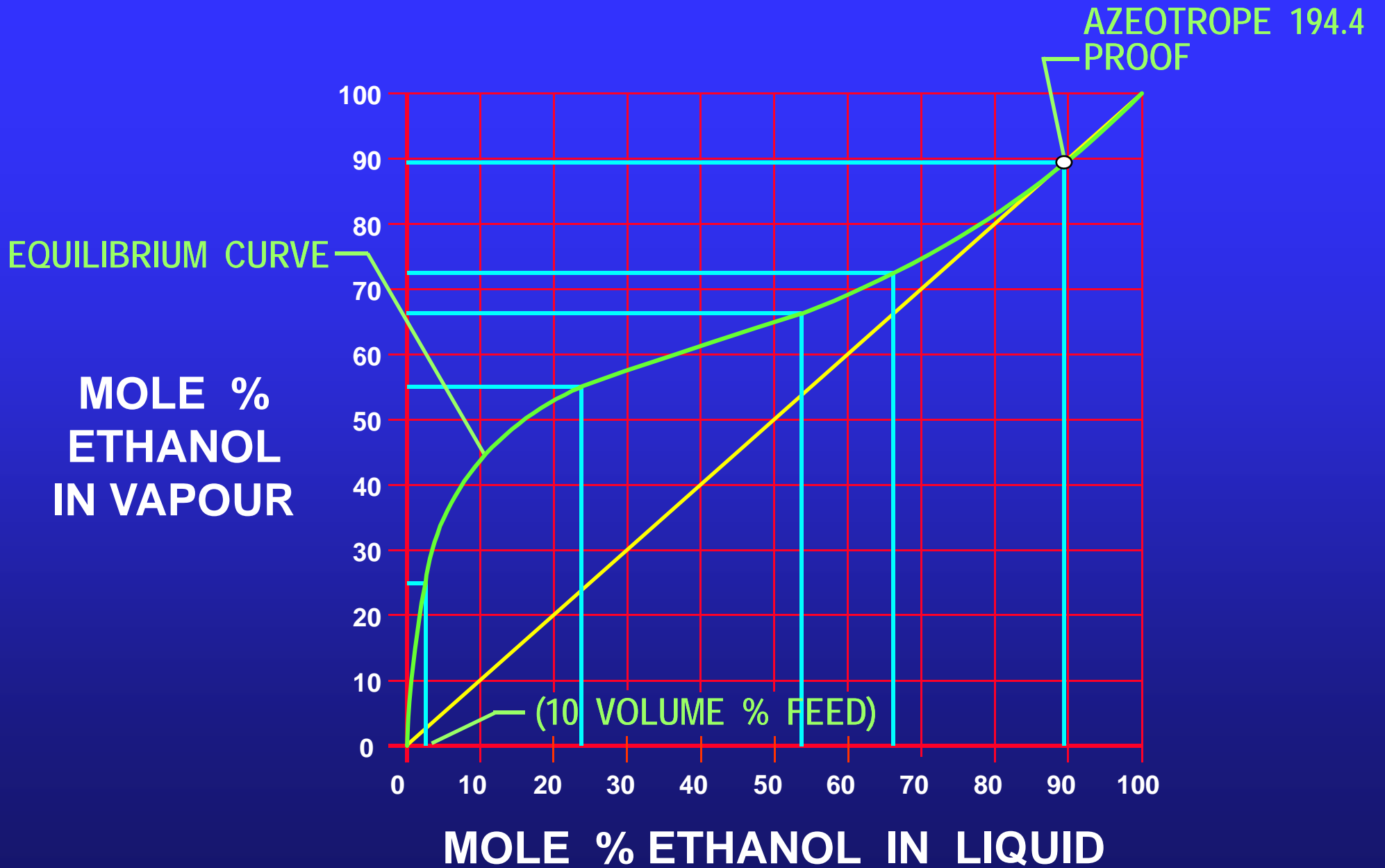


DEHYDRATION

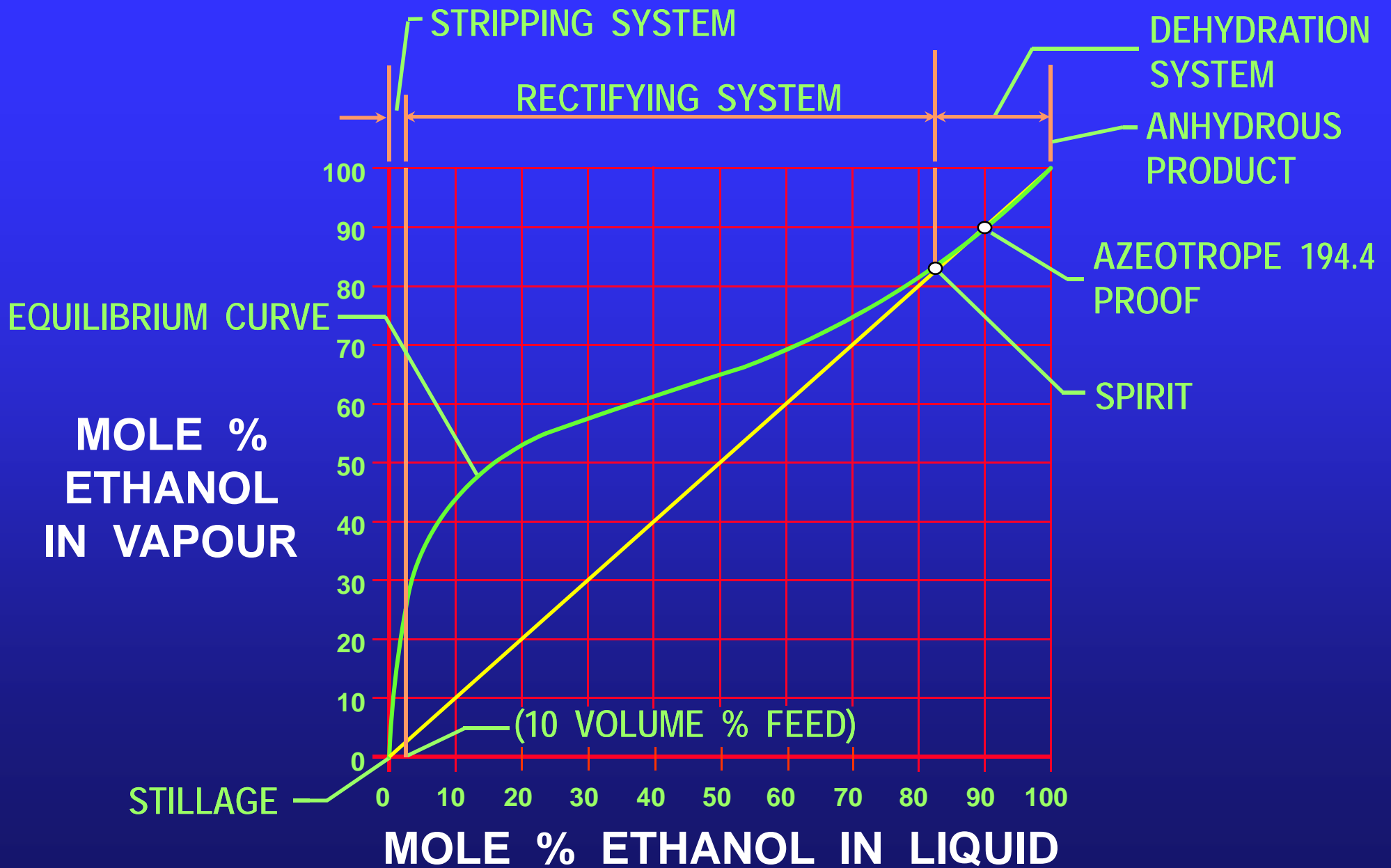




**VAPOUR-LIQUID EQUILIBRIUM
ETHANOL-WATER**

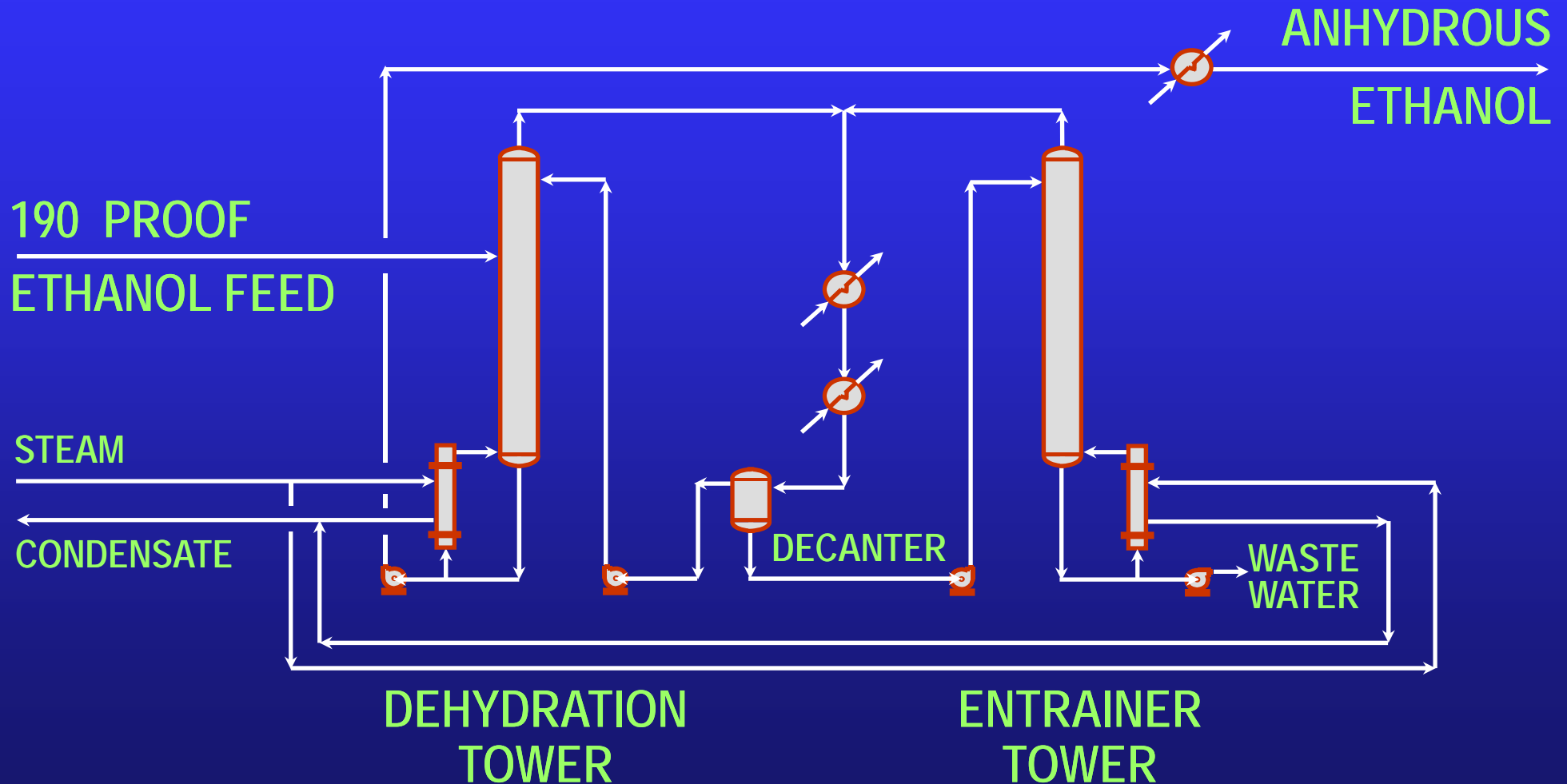


STRUCTURING THE DISTILLATION SYSTEM STRATEGY

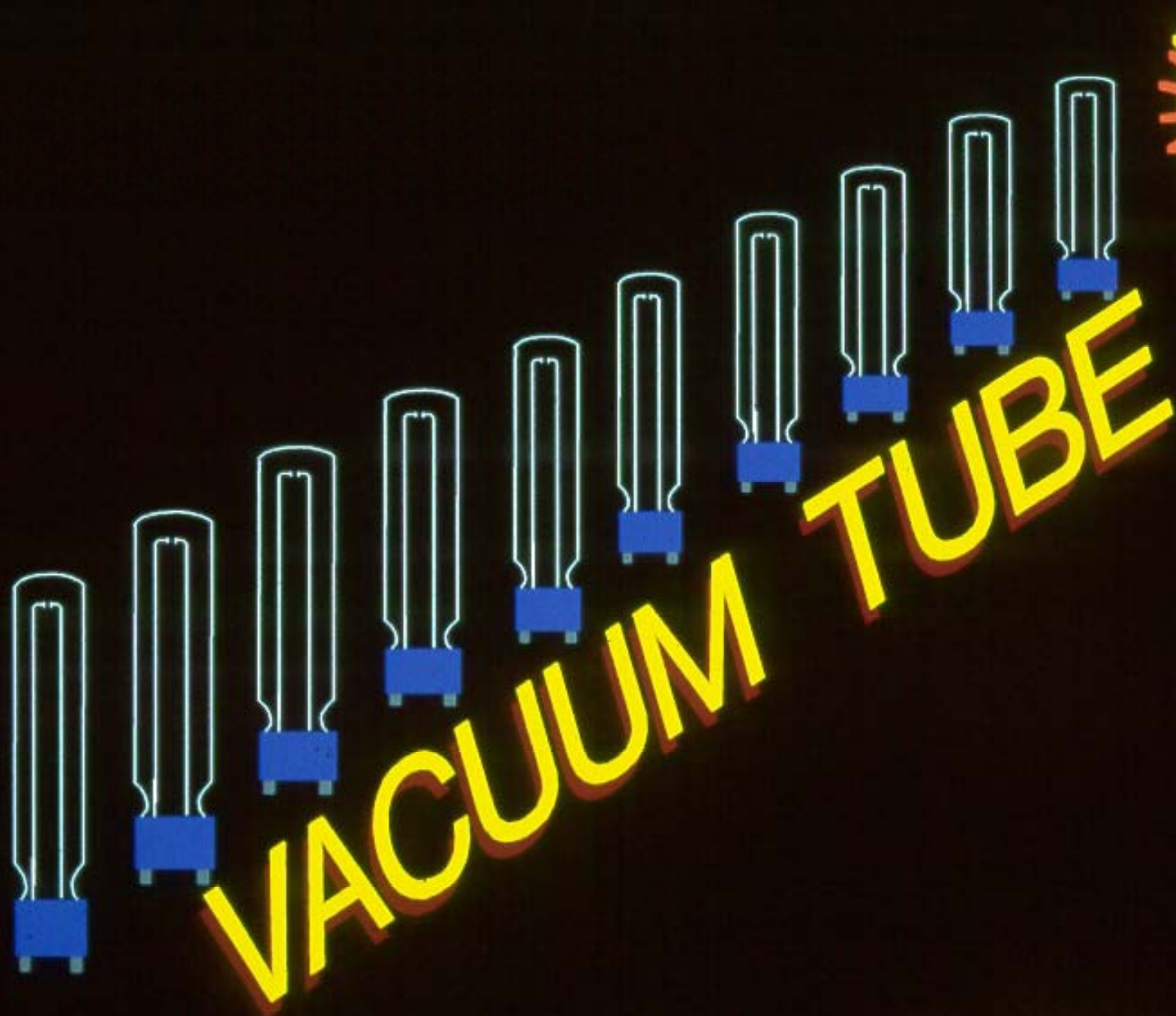


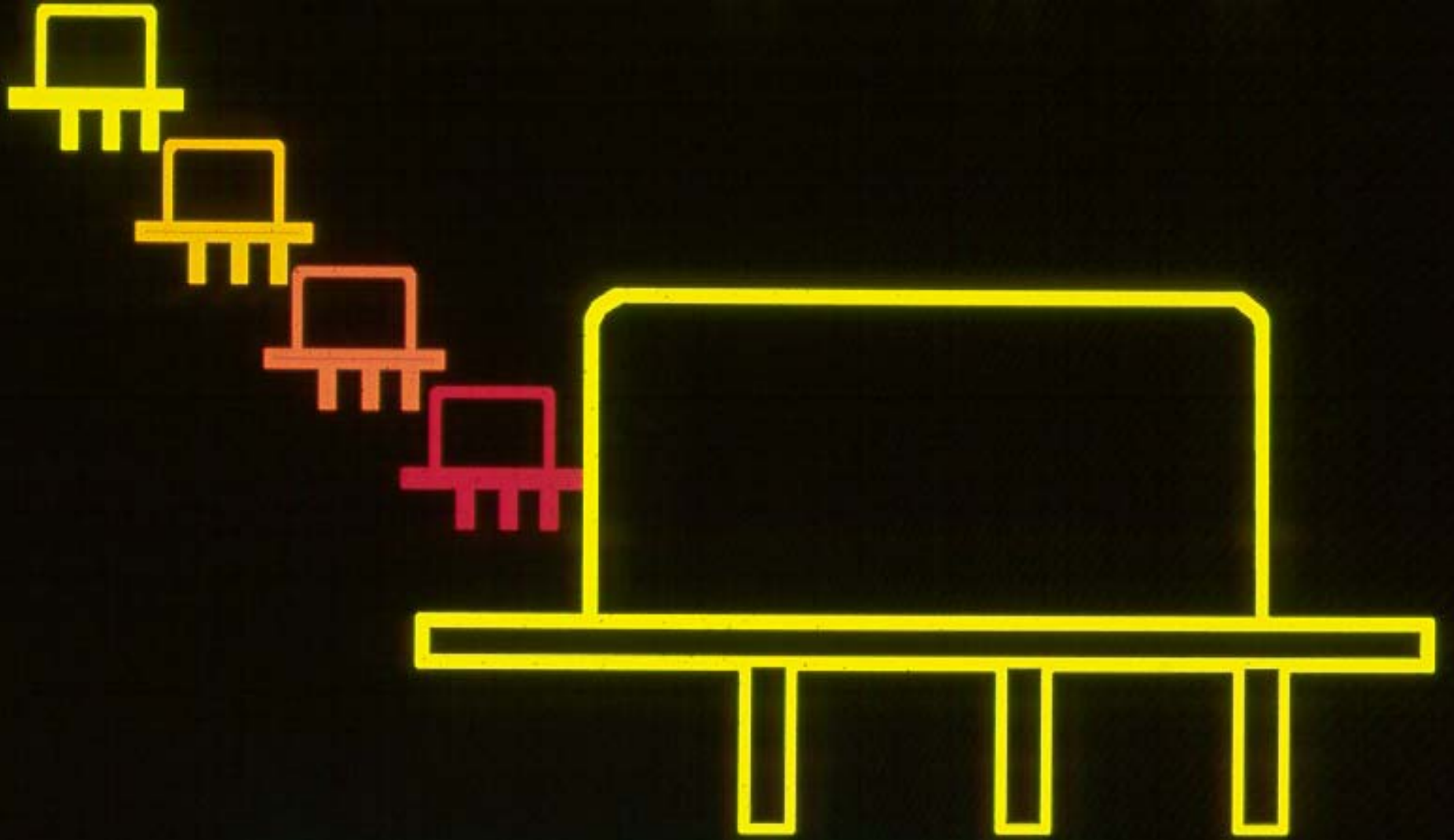
**TERNARY
AZEOTROPE
DEHYDRATION**

ANHYDROUS ETHANOL SYSTEM









TRANSISTOR

MOLECULAR SIEVE DEHYDRATION

- ◆ VAPOUR PHASE ADSORPTION
- ◆ NO ENTRAINER
- ◆ LOW ENERGY

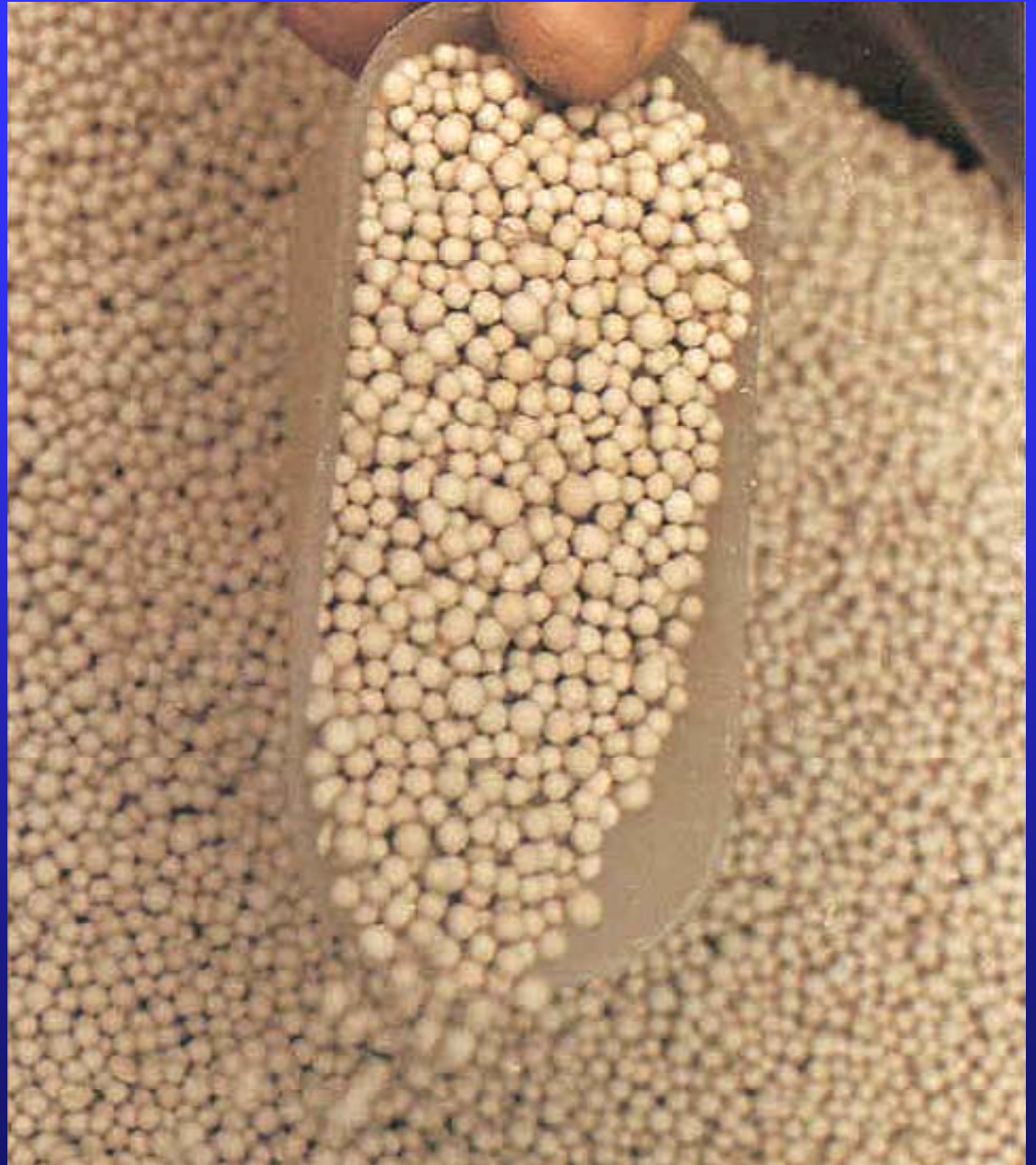
MOLECULAR SIEVE TYPE 3A

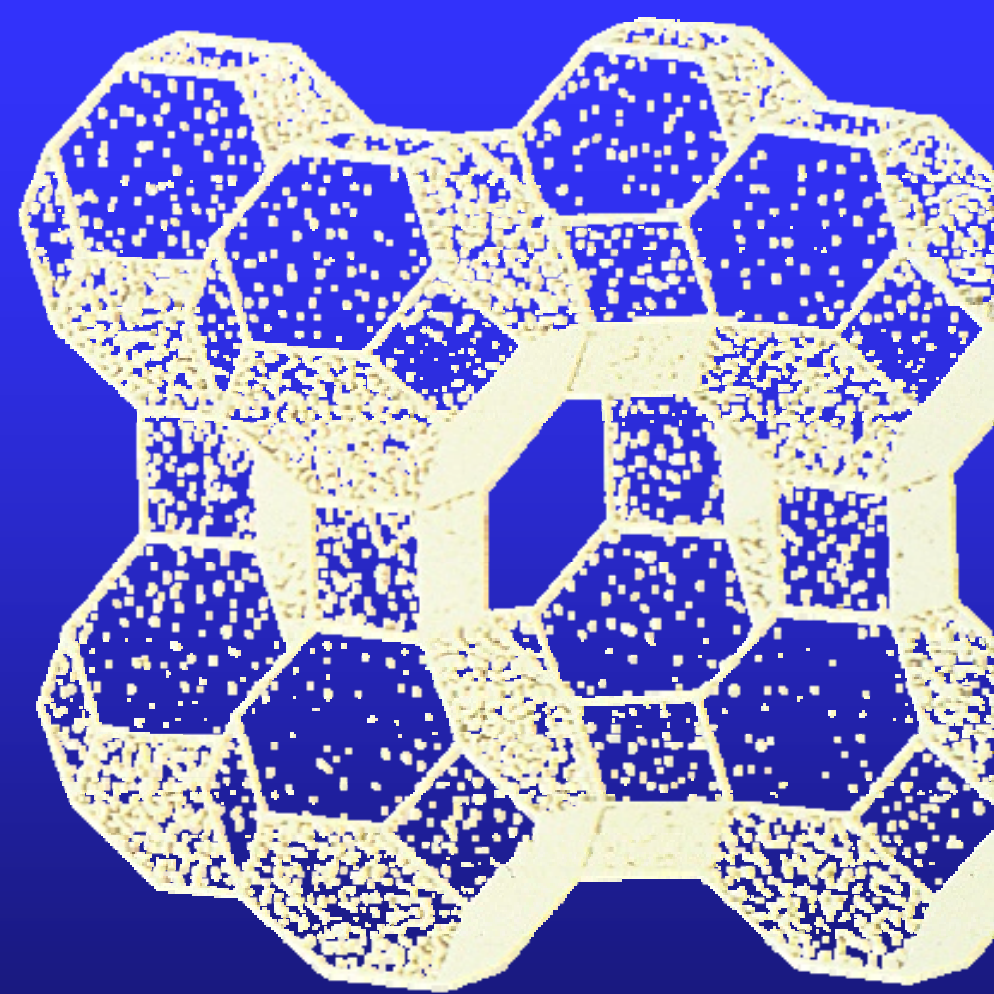
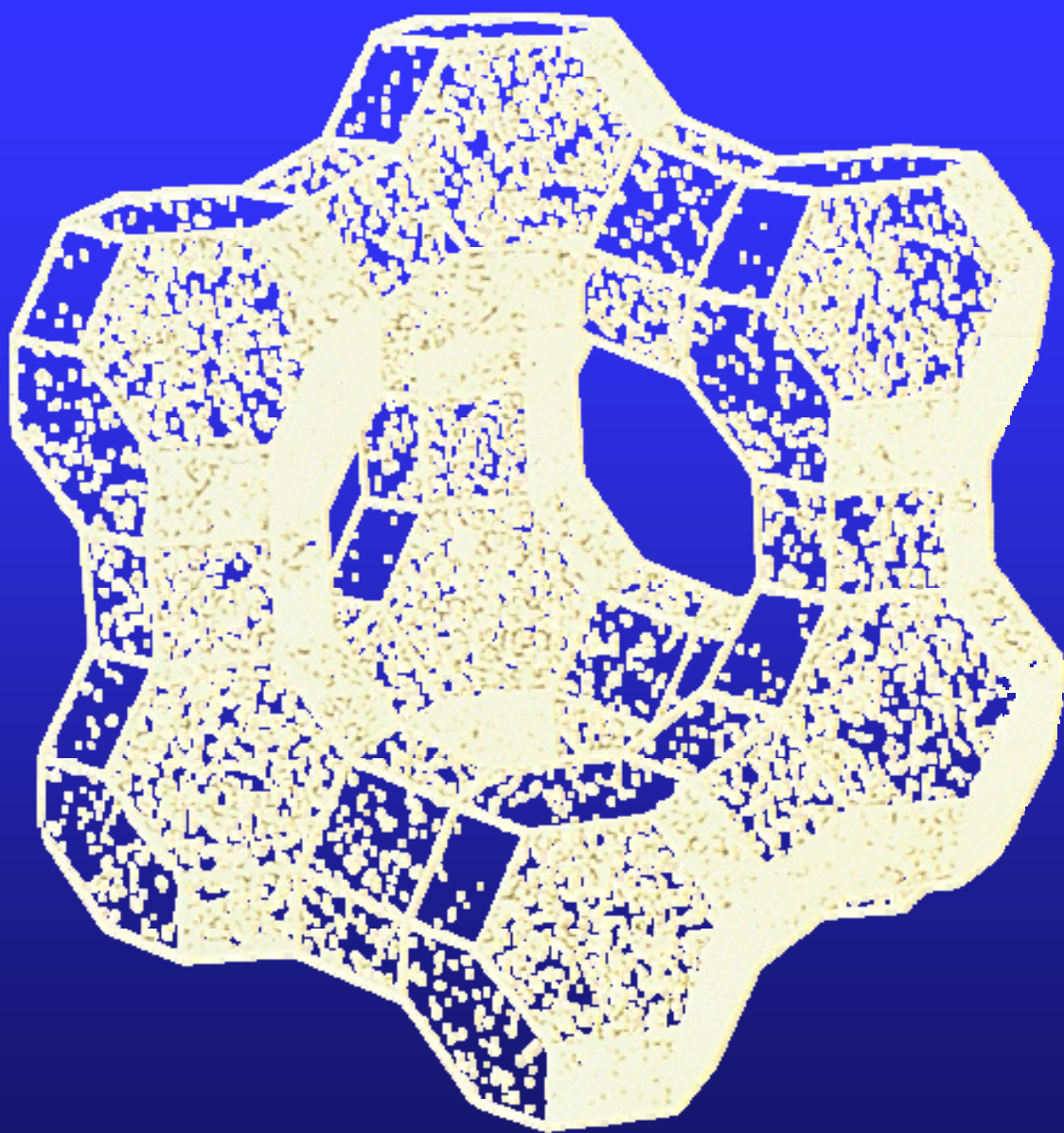
CHEMICAL FORMULA:

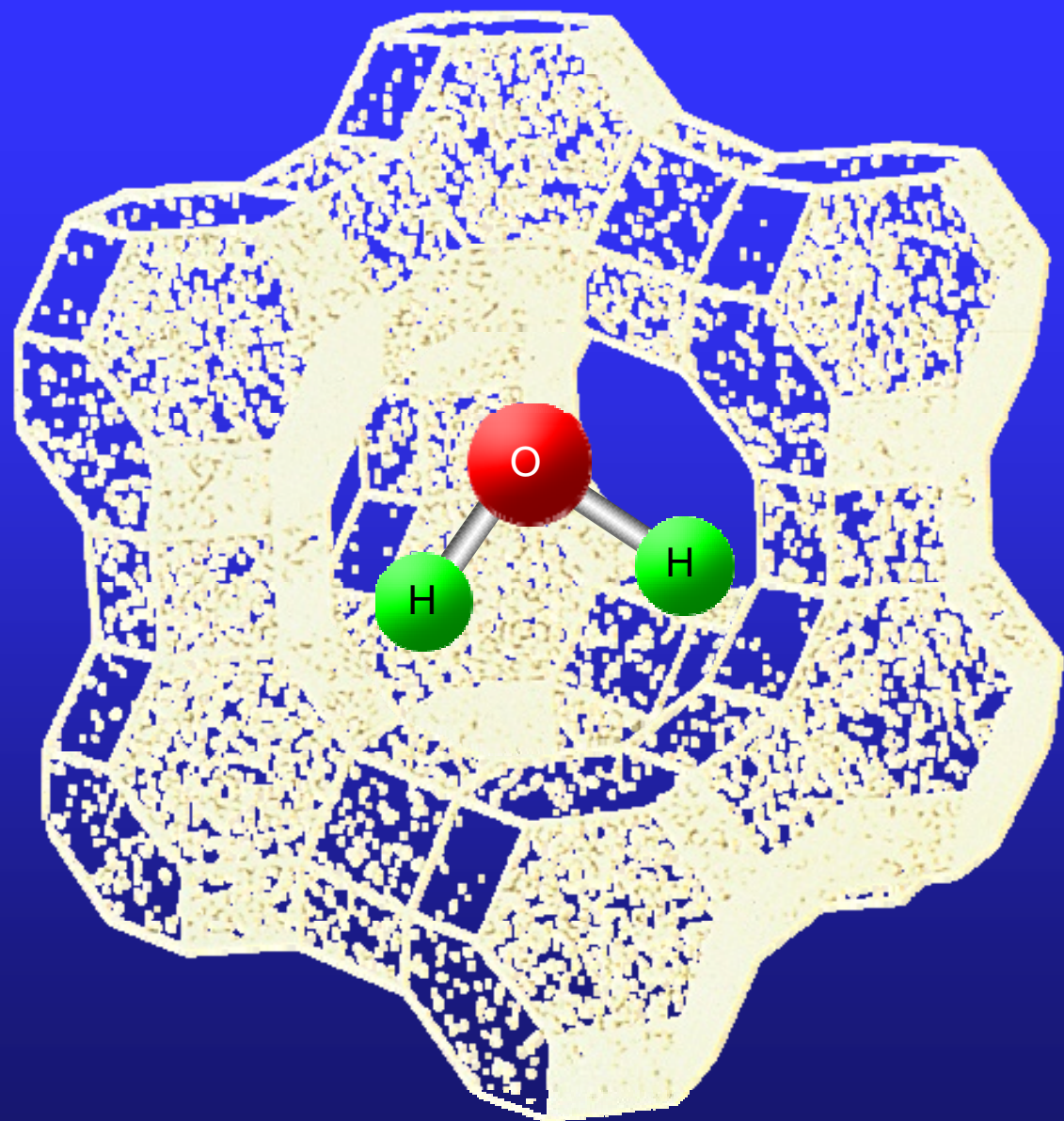


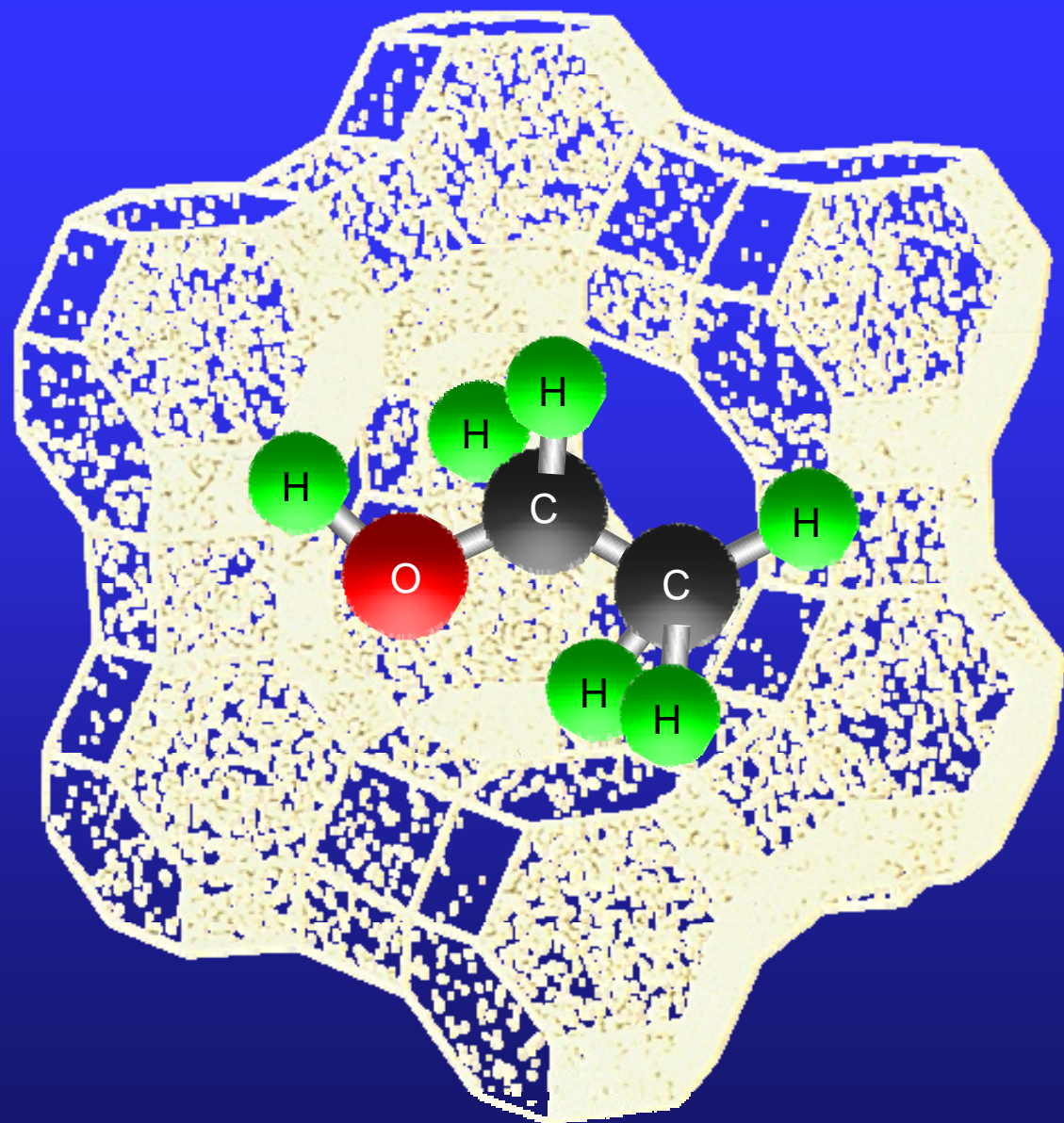
Molecular Sieve Media

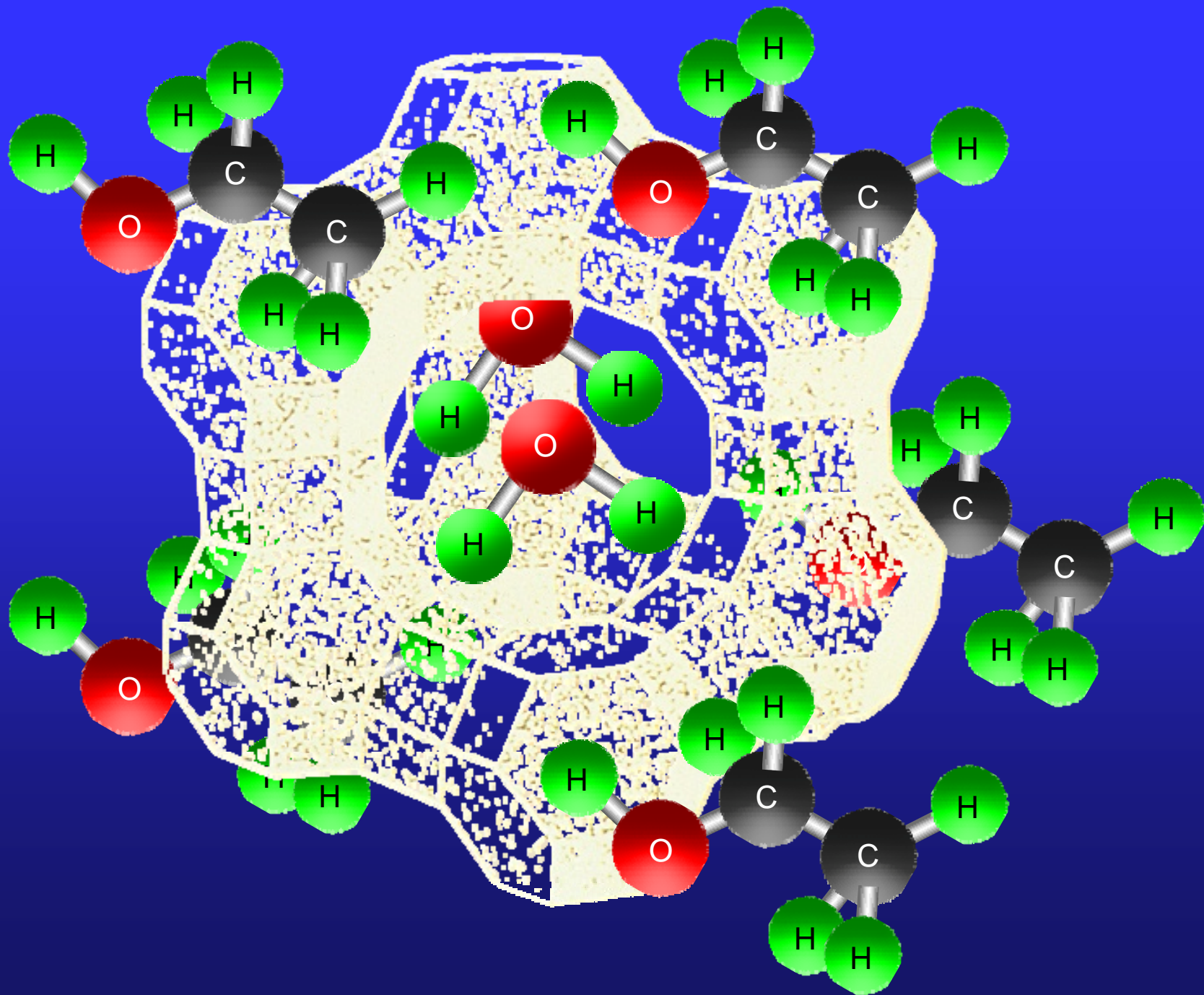
Type
3A



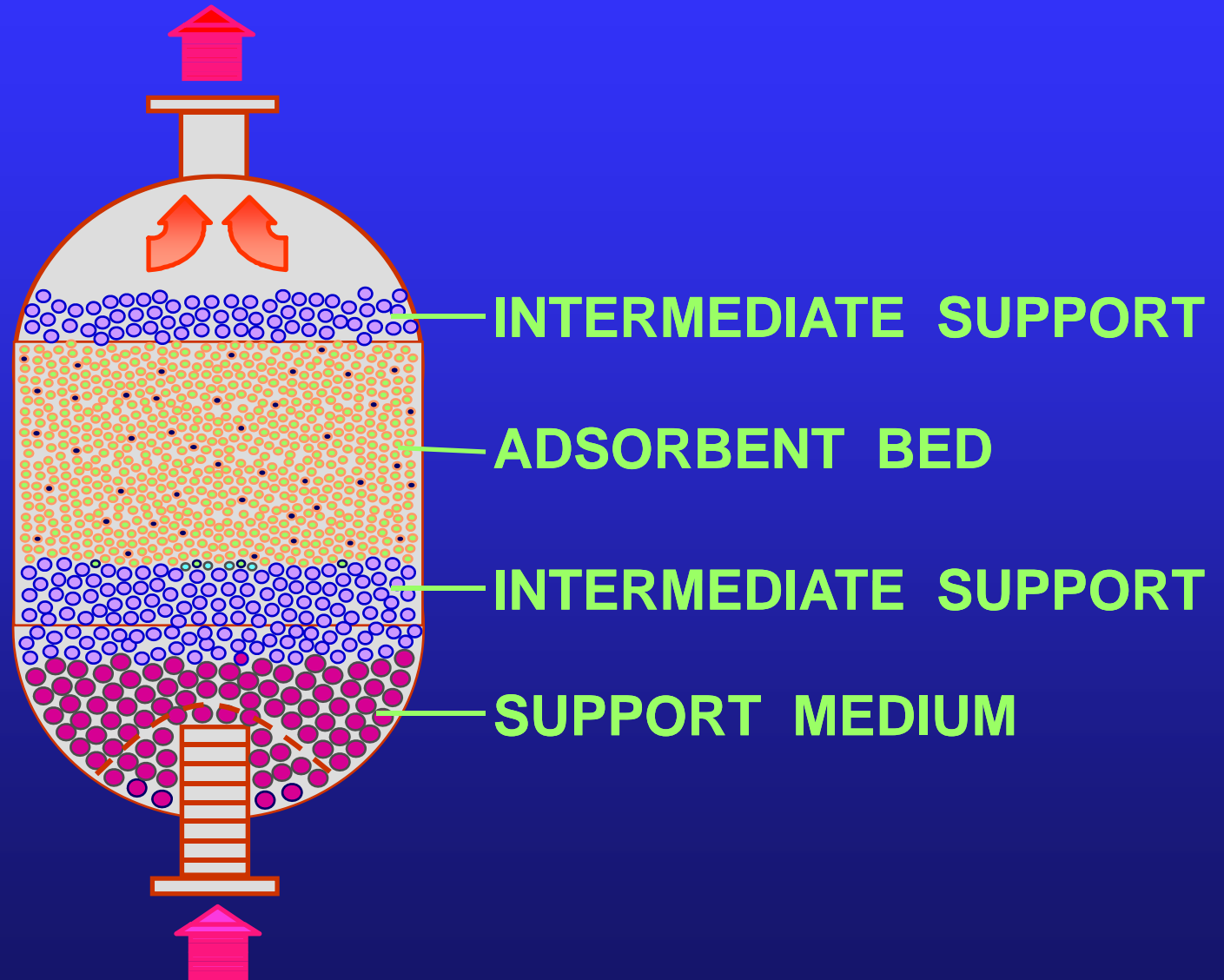




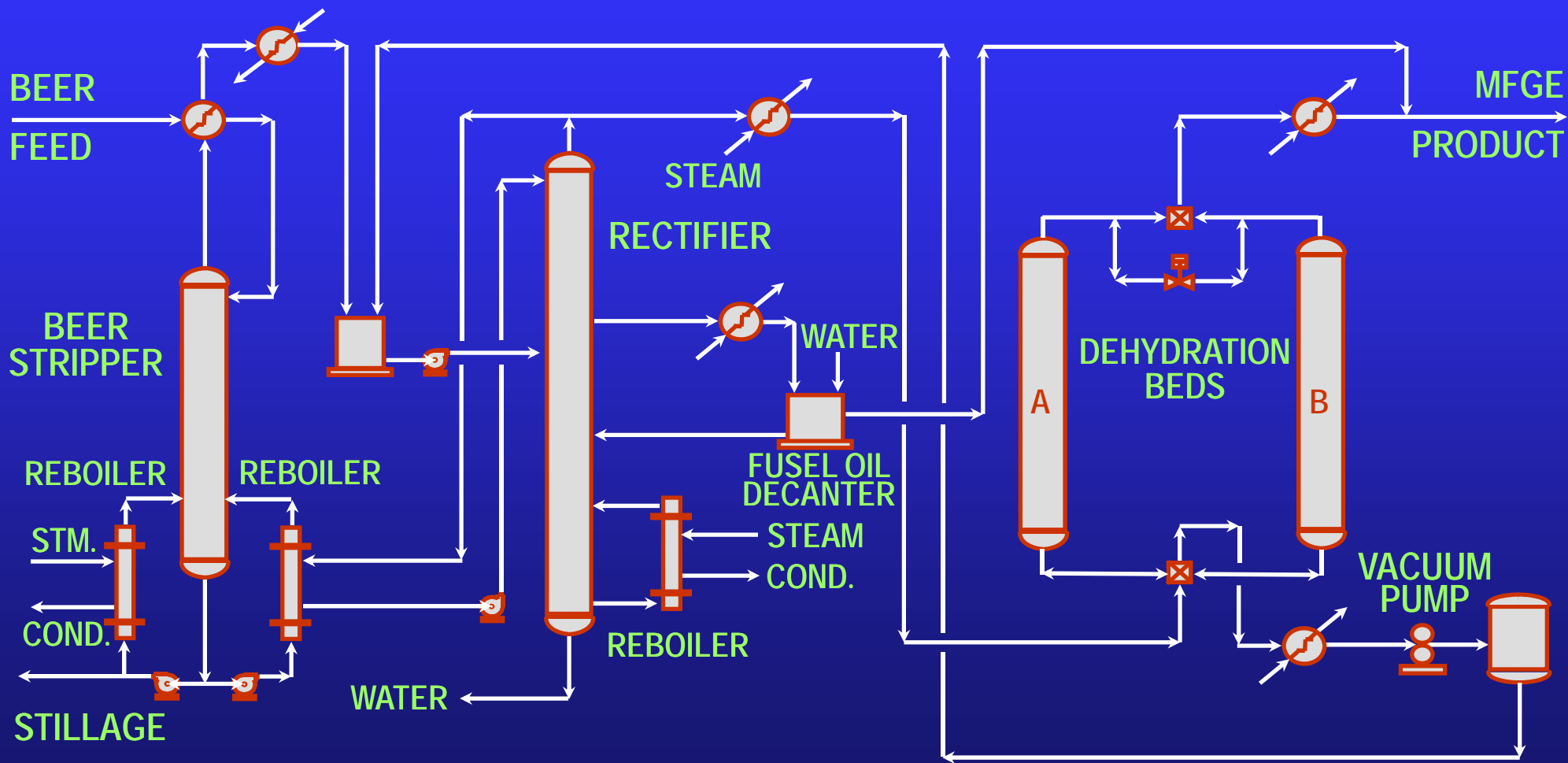




MOLECULAR SIEVE BED



MFGE DISTILLATION & DEHYDRATION PSA MOLECULAR SIEVE











SEP 2





DISTILLATION-DEHYDRATION TECHNOLOGY

	<u>TYPE</u>	<u>DEHYDRATION TECHNOLOGY</u>	<u>ENERGY (MJ/L)</u>	<u>(BTU/Gal)</u>
1970's	STANDALONE	AZEOTROPIC	9.5	34,000
1980's	INTEGRATED COMPLEX	AZEOTROPIC	4.7	17,000
1990's	INTEGRATED USER FRIENDLY	MOLECULAR SIEVE	3.9	14,000
2000's	ADDITIONAL INTEGRATION			





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