Getting Full Use Out of the **GPSA Engineering Data Book**: Introduction to the Week-Long Training Class

2018 1Q Training  
Odessa, TX  
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Short Course Goals:
- Provide an introduction into the week-long GPSA Engineering Data Book Course
- Provide both in-depth and abbreviated review of numerous course sections, in order to provide attendees with an understanding of the lecturing concepts and types of problems that are performed during the full-length class
- Allow attendees to see how the full week-long course would benefit their daily work activities

Full Course Learning Objectives
- Learn
  - Understand what information is provided in the Data Book and how it applies to the natural gas industry
  - Interact
  - Work through classroom problems to understand how to use the detailed information and shortcut methods in the Data Book
- Apply
  - Understand how to best utilize the Data Book for daily gas processing / midstream job functions:
- The focus is not to teach gas processing, nor read you the Data Book word for word. Purpose is to teach how to use the Data Book for gas processing

Short Course Block Flow Diagram
Full Course Section Level of Detail
- In depth/task oriented (1.5 – 4 hrs/section)
  - Thorough review of entire EDB section
  - Numerous example problems, some in detail
  - Become familiar with GPSA EDB spreadsheets
- Light Education (45min – 1.5hrs/section)
  - Overview of fundamentals
  - Some example problems, mostly quick exercises
  - Some topics may be skipped
- Very Brief (15min – 30min/section)
  - High level summary of content

Short Course “Problem”
Use pieces of the full length course to solve common “problems” encountered during design and/or evaluation of a Fractionation System:

1. What do our higher value potential products look like and what are the potential specifications we need to meet?
2. How does Fractionation meet our goal to make higher value products?
3. How do we determine the basic design the mechanical equipment needed for Fractionation?
   a. Design one of the main pieces of equipment, a distillation tower (Deethanizer)
   b. Design of vessels (Reflux Accumulator)
   c. Design of pumps (Deethanizer Feed Pump)
   d. Design of heat exchangers (Feed/Bottoms Cross Exchanger)
4. How is the flow of feed to the Fractionation System controlled?
   a. Design of a control valve (feed flow control valve)
   b. Design of a flow meter (feed flowmeter)

NGL Fractionation and Product Specifications
Product Specifications – EDB Section 2
Learning Objectives
- Summary of Product Specifications section
- Understand what information is provided in the Data Book and how to use it for daily activities
- Understand why specifications are important to the gas processing/midstream industry and how they impact the extent of processing
- Review test method references

Information in the EDB
- Specifications are set by pipeline/end user authority, therefore there are limited single “standards” applicable to any given product
- There are standards available, but producer/buyer may not require those standards:
  - GPA Std. 2140: LPG Specifications
GPA Std. 2108: Fractionation Grade Product Specifications
EDB figures are provided for reference of various types of specifications, but are not all-inclusive
EDB information is based on typical U.S. specifications

Liquid Specifications in EDB
- Commercial Grade LPGs (HD-5 Propane): EDB Figs. 2-1, 2-5
- Fractionation Grade NGLs: EDB Fig. 2-2
- Ethane (range): EDB Fig. 2-3
- Y-Grade Product: EDB Fig. 2-9
- Other
  - Propane water content: EDB Fig. 2-6
  - Copper Strip Test: EDB Fig 2-7

Fractionation & Absorption – EDB Section 19

Learning Objectives
- Summary of fundamentals of fractionation and absorption section in the Data Book
- Understanding of NGL fractionation
- Perform quick tower sizing exercises for both trayed and packed towers
- Understand best uses of Data Book information

Full Course Topics
- Block Flow Diagram/Industry Application
- Types of Fractionators
- Fundamentals: Principles of Fractionation
- Tower Internals and Sizing (diameter)
  - Trayed internals
  - Packed bed internals
- Mechanical Considerations
  - Reboilers
  - Other internals that impact height (i.e. nozzles, baffles, etc)
- Heat Integration
- Absorption and Stripping
- Summary: Best Uses/Limitations of the Data Book

Applications: Types & Products
- EDB Pg. 19-4
- Bulk hydrocarbon fractionators:
  - Gas demethanizer: leanest gas, C2+
  - Gas deethanizer: lean gas, C3+
  - Condensate stabilizer: C4- to gas, C5+ liquid product
  - NGL stabilizer: C2-/C1 to gas, C3+/C2+ liquid
- NGL product fractionators:
  - Deethanizer: C2 product, C3+ liquid bottoms
- Depropanizer: C3 product, C4+ liquid bottoms
- Debutanizer: C4 product, C5+ bottoms
- Butane splitter (deisobutanizer): iC4, nC4 products
- Ethane/propane fractionator (depropanizer): C2/C3 product
- Propane/butane fractionator (debutanizer): C3/C4 product

Fundamentals: Principles of Fractionation

Fundamentals: Design Considerations

Tower sizing and internals

Fractionation & Absorption – EDB Section 19

Fundamentals: Design Considerations
- Minimum stages: theoretical minimum number of stages for a specific separation, occurs at total reflux
  - Eq. 19-3 to 19-6
- Minimum reflux ratio: theoretical minimum reflux ratio for a specific separation, occurs at infinite number of stages
  - Eq. 19-7, 19-8

Fundamentals: Determining # of Stages

Fundamentals: Typical Parameters

Fundamentals: Tower Design
- Utilize simulation for quick calculation/optimization
- Define feed conditions (flow, temperature, pressure)
- Define product specifications required
- Determine condensing medium (temperature) available, set tower pressure based on heat transfer approach (Pg. 19-6), keeping within range of Fig. 19-20 (< 80% critical pressure)
- Utilize Fig. 19-20 for starting points for:
  - Number of stages (actual trays X tray efficiency)
  - Reflux ratio
- Evaluate range of operation, i.e. changing reflux ratio and # of stages to optimize:
  - OPEX (reboiler duty), CAPEX (tower height, tower diameter)
  - Remain above min reflux ratio, min stages
  - Feed location
- Shortcut: find # stages/RR where change becomes minimal

Internals: Tray Design
- Based on gas and liquid rates through tower:
  - Number of valves (gas rate)
  - Size/dimensions of downcomers (liquid rate)
- Number of tray passes: Fig. 19-13
  - Higher liquid rates → larger downcomers, more passes
  - Larger diameter towers → more passes
- Tray spacing:
  - Dependent on density difference (liquid – vapor)
  - Higher vapor density → higher tray spacing
  - Fig. 19-16, 19-17
- Tray efficiency: Pg. 19-15, Eq. 19-22, Ex. 19-4
  - Fig. 19-19 (based on relative volatility, viscosity)
  - Fig. 19-20 (typical parameters)

Internals: Trays
- EDB Pgs. 19-10 to 19-16
- Liquid flows down across tray
- Vapor flows up through tray: Fig. 19-10
  - valves, sieves, bubble caps
- Many types, selection is dependent on:
  - Cost
  - Vapor/liquid loading
  - Turndown requirement
- Diameter of tower is set to optimize flow/mass transfer, minimizing diameter (cost), limited by:
  - *Jet flooding (vapor limit)
  - Downcomer flooding and backup (liquid limit)

Internals: Trays
- Figure 19-12 shows operational boundaries:
- Bubble cap tower animation:
  - Shows normal operation
  - Shows a flooded tower
  - https://vimeo.com/35147140
- Another bubble cap tower animation (0:45-1:10)
  - https://www.youtube.com/watch?v=82KHGne2TOw

Trays: Diameter Calculation Methods
- “C” Factor Method: Pg. 19-10
  - Souders-Brown equation method / Stokes law (similar to vessels)
  - Eqs. 19-11, 19-12, Fig. 19-13
- Nomograph Method: Pgs. 19-11, Fig. 19-15
  - Utilize figure with liquid rate and Vload
- Hand Method: Pg. 19-13, Eqs. 19-14 to 19-21
  - Closest to vendor sizing programs
  - Utilizes system (foaming) factor: Fig. 19-16
  - Downcomer velocity (liquid): Eq 19-14 & Fig. 19-17
  - Capacity factor (vapor): Eq. 19-15 & Fig. 19-18
Calculates flow path length across tray and downcomer area to determine tower diameter

- Example 19-3 compares all three methods

System Factors (Fig. 19-16)

Problem #1: Trayed Tower Diameter

- Determine
  - required tower diameter using nomograph method (Fig. 19-15) at top and bottom of tower, and above/below feed tray

- Results
  - Trayed Tower: Problem #1 GPSA EDB Methods
    - Top (stage 1) diameter = 8’ 0”
    - Bottom (stage 24) diameter = 11’ 6”
  - Trayed Tower: Vendor Software
    - Top (stage 1) diameter = 8’ 6” – 9’ 0” (depending on valve selection)
    - Bottom (stage 24) diameter = 11’ - 11’ 6” (dep on valve selection)

Separation (vessel sizing and internals)

Separation Equipment – EDB Section 7

Learning Objectives

- Understand the fundamentals of separation of gas, liquid phases, and solids
- Understand the different types of separators and separation devices used in the industry, their applications, and characteristics
- Determine how to use the information/tables given in the Data Book, applicable to separation equipment
- Perform a number of in-class problems to understand how to utilize the Data Book for separator design and operation
- Understand the strengths/weaknesses of the information in the Data Book

Fundamentals

- Goal of separation: separate fluid phases
  - Gas
  - Hydrocarbon liquid
  - Aqueous liquid
  - Solids
- Principles of physical separation:
  - Momentum
  - Gravity settling
  - Coalescing
- Fluids must be immiscible with different densities

Fundamentals: Types of Separators
• Two-Phase Separators:
  o Vapor/Liquid
  o Liquid/Liquid
  o Vapor/Solid
  o Liquid/Solid
• Three-Phase Separators:
  o Vapor/Liquid/Liquid
  o Vapor/Liquid/Solid

Info/Organization of EDB Section 7
• Separation theory/fundamentals: Pgs. 7-3 to 7-10
• Gas-liquid re-entrainment: Pg. 7-8
• Mist eliminators: Pgs. 7-10 to 7-12
• Liquid-liquid fundamentals: Pgs. 7-12 to 7-13
• Separator considerations/selection: Pgs. 7-13 to 7-17
• Types of separators: Pgs. 7-17 to 7-23
• Separator zones/sections: Pgs. 7-24 to 7-29
• Sizing examples/methodologies: Pgs. 7-29 to 7-33
• Gas-liquid-liquid design & example: Pgs. 7-34 to 7-38
• Filtration & coalescers: Pgs. 7-39 to 7-42
• Other separators (slug catchers, oil, water): Pgs. 7-43 to 7-46
• Debottlenecking & troubleshooting: Pgs. 7-46 to 7-47

Fundamentals
Gravity Separation
Separation by Impingement

Fundamentals: Mist Eliminators
• Pgs. 7-9, Souder’s-Brown K-values used to quantify capacity of vendor design
• Mist eliminators are used to enhance liquid removal from gas streams
• Mesh pads: 10 micron droplet removal
• Vane packs: 10-40 micron droplet removal
• Cyclones: Efficient removal at high pressures and high gas rates → small footprint required

Specification & Configurations – EDB Section 7 – Separation Equipment
Separation: What drives selection?

Horizontal Gas-Liquid Separators
• Horizontal separator (Fig. 7-25)
  o No internals
  o Vertical mesh pad or vane pack
  o Horizontal (hanging) mesh pad

Gravity Separation Section
Pgs. 7-25, 7-26
- Goal to remove bulk of liquid droplets
- Common calculation methods:
  - Determine max velocity to avoid re-entrainment
  - Use an empirical equation for maximum gas velocity (Fig. 7-37)

Liquid Accumulation Section
- Pgs. 7-28, 7-29
- Discussion of level heights: Pg. 7-28, Fig. 7-41
- Typical surge & retention times: Fig. 7-42

Degassing of vapors: Eq. 7-18 to 7-20
- Liquid outlet nozzle criteria

Sizing Methodology: Horizontal Separator
- EDB: Pgs. 7-31 – 7-33, Example 7-3
- Liquid volume to accommodate surge requirements, accommodate degassing, etc.
- Gas area above max liquid level to accommodate gas flowrate, ensure majority of separation upstream of mesh, and to ensure adequate area for mesh pad (either as hanging or vertical pad)
- Typically start with an assumed liquid full and L/D ratio (i.e. 70% to LAHH and 3/1 L/D):
  - Calculate liquid levels and surge/retention/degassing
  - Calculate gas settling zone area (max velocity, check for re-entrainment)
  - Calculate mesh pad area
  - Check nozzles and any physical dimensions
  - Iterate back if needed, or to optimize vessel diameter

Problem #3: Separator Sizing
Scope: NGL fractionation – Deethanizer reflux drum; partially condensing
- Determine:
  - Diameter
  - Length
  - Liquid levels
  - Nozzle sizes
- Considerations:
  - Surge times/internals:
  - Use vertical mesh pad
- Results
  - Vessel Size: 9’ 6” X 28’ 6”
  - Vessel levels:
    - LLLL = 1’ 6”
    - LLL = 2’ 4”
    - LLL = 4’ 1”
- HLL = 5’ 8”
- HHLL = 6’ 4”
  - Nozzles:
    - Inlet Nozzle: 10”
    - Gas Outlet Nozzle: 8”
    - Liquid Outlet Nozzle: 12”
  - Internals:
    - Inlet Baffle
    - Vertical Mesh Pad

Pumps (selection and sizing)
Pumps and Hydraulic Turbines – EDB Section 12

Learning Objectives
- Understand the different types of pumps used in the industry, their applications, and characteristics
- Determine how to use the information/tables given in the Data Book, applicable to pumps & hydraulic turbines
- Perform a number of in-class problems to understand how to utilize the Data Book for pump design and operation
- Understand the strengths/weaknesses of the information in the Data Book

Fundamentals
- Purpose of pumping:
  - Increase the pressure/head of a liquid or supercritical fluid
  - Move fluid from point A to point B
- Convert energy to pressure in flowing fluid
- Fundamentals in EDB:
  - Pages 12-3 to 12-8 (Figures 12-2 to 12-5)
  - Bernoulli’s Theorem, NPSH, differential head
- Fundamentals can apply to any pump type, main difference is how the machine increases head

Fundamentals: Bernoulli’s Theorem

Fundamentals: NPSHA & NPSHR
- NPSHA: Net Positive Suction Head Available
  - Relation of fluid to vapor formation
  - Primarily a function of fluid vapor pressure, static head, and suction piping friction (system design):
    - Other forms (Eq. 12-6a, 12-6b)
- NPSHR: Net Positive Suction Head Required
  - Relation of fluid to vapor formation
  - Primarily a function of pump physical design, speed, and flowrate (pump design)
  - NPSHR Reduction: Fig. 12-5 (vapor/liquid density relation, critical pressure approach)
Fundamentals: Cavitation
- NPSHA > NPSHR to avoid cavitation
- Safety margin: 0.5 - 1 meter between NPSHA, NPSHR
- Cavitation: formation of vapors at pump suction and the vapors being imploded back into liquid. The energy transfer causes a shockwave which damages the pump impeller and internals

Key Pump Design Criteria
- Process conditions:
  - Inlet/Outlet Pressures or Head
  - NPSHA
  - Required Flowrate
  - Fluid composition: SG/density, vapor pressure, gasses
  - Inlet Temperature, viscosity, specific heat
- Operational flexibility:
  - Discharge pressure range
  - Flow range
  - Entrained gasses, solids

Pump Types: Selection Metrics
- Centrifugal:
  - Benefits: med-high flow, low-high head, low maintenance, smaller plot space, cost
  - Negatives: limited head range with a single pump, plot space (multi-stage)
- Reciprocating:
  - Benefits: high head, high efficiency, low-mid flow, slurries/viscous fluids
  - Negatives: cost, lower reliability/high maintenance, plot space

Problem #2: Pump Selection
Scope: NGL Feed Pump: Storage to Deethanizer
Determine pump type using overall pump selection chart (Fig. 12-3)

Results:
- Either Centrifugal (Multistage) or Multi-cylinder Plunger

Heat exchangers
Heat Exchangers – EDB Section 9
Learning Objectives
- Brief overview of the types of heat exchangers discussed in the Data Book
- Perform some heat exchange problems to become familiar with heat exchangers and understand how to utilize the Data Book for heat exchanger design
- Understand possible uses of Data Book information

Heat Exchanger Fundamentals
• Energy change in each fluid (heat transferred to/from)
• Overall energy flow between fluids & across boundary
  - EDB Eqs. 9-5 and 9-6

Overall Heat Transfer Coefficient – U
• Typical Overall Heat Transfer Coefficients EDB Fig. 9-9
• Metal Thermal Conductivities EDB Fig. 9-8
• Typical Fouling Resistances EDB Figs. 9-9 (S&T), 9-45 (PHE)
• Film Resistance comparisons EDB Figs. 9-10 and 9-11

Problem #2 – Heat Exchanger Overall Calculation
Scope: Deethanizer Feed/Bottoms Exchanger

Determine:
• Log mean temperature difference (LMTD) (°F)
• LMTD correction factor
• CMTD
• Exchanger area (ft²)

Results:
• Log mean temperature difference (LMTD) = 130.9°F
• LMTD correction factor = 0.99
• CMTD = 129.6°F
• Exchanger area = 548 ft²

Instrumentation/control valves
Instrumentation – EDB Section 4
Learning Objectives
• Understand the fundamental concepts related to instrumentation and control; including sensing devices, control elements (i.e. valves), and control mechanisms
• Understand the methods used to properly size a control valve
• Determine how to use the information/tables given in the Data Book, related to instrumentation
• Understand the strengths/weaknesses of the information in the Data Book

Control Valves – EDB Section 4 –Instrumentation
Control Valves: Physical Information
• EDB Pgs. 4-21 to 4-26
• Control valves provide the means to increase or decrease flow of a fluid by variable restriction
• Made up of 3 parts:
  - Actuator: provides motive force
  - Bonnet: provides seal between process fluid and ambient, connects stem to valve internals
Valve Body: provides the internals that contact the process fluid for flow control

Control Valves: Actuators
- Provide the motive force to move the control valve: Pneumatic, electric, hydraulic, manual
- A spring moves the valve to its fail safe position (when no force is applied): Fig. 4-28
  - Fail Open (left valve): air to close
  - Fail Closed (right valve): air to open
  - Fail last: air to both close and open (video)

Control Valves: Valve Bodies
- EDB Fig. 4-27 shows a typical globe valve
- Contacts the process fluid, restriction opens or closes causing more or less fluid to pass through
- Bonnet: provides packing/seal
  - Different types:
    - Plug Globe (common control valve)
    - Cage globe
    - Ball
    - Butterfly
    - Gate

Control Valves: Flow Characteristics

Control Valve Sizing: Liquid Service
- Liquid valve sizing equations and constants: Figs. 4-35, 4-36
  - Flow ~ f(Cv, ΔP)
  - Cv= valve coefficient: Fig. 4-32/vendor for full open, calculate for req’d Cv
  - Nx= constant: Fig. 4-36
  - Fp= piping geometry factor: ANSI/ISA S75.01, if no fittings =1
  - P1, P2= inlet/outlet pressures
  - Specific weight, specific gravity
  - Pv= fluid vapor pressure at valve inlet temperature
  - FL= from vendor/ Fig. 4-32
  - FF= liquid critical pressure ratio factor: Fig. 4-33 (with input from Fig. 4-34 or determine critical pressure for mixture)
Flow measurement

Measurement – EDB Section 3

Learning Objectives

- Understand the fundamental concepts related to measurement devices, which measure the flow of gases and liquids at wellheads, through facilities, and pipelines
- Understand the equations and calculations required to determine flow through different measurement devices
- Understand the concepts to determine fluid composition, by sampling and chromatography
- Determine how to use the information/tables given in the Data Book, including a number of in-class problems, related to measurement
- Understand the strengths/weaknesses of the information in the Data Book

Why Measure?

- Custody transfer or sales of fluid/product from one owner to the next = revenue
- Accounting of process fluid disposition within a plant:
  - Inlets: Feed Streams
  - Outlets:
    - Products
    - Waste Streams
    - Flare Streams
  - Consumption: Fuel Gas
- Control measurement: used for direct process control
- Check measurement: used to verify process flows and adjust operating parameters

Fundamentals – EDB Section 3 – Measurement

Measurement Standards, Pg. 3-3


Problem #4: Liquid Orifice Calculation

Scope: C3+ NGL Feed to Fractionation Train: Sweet-Rich Composition

Desired results:

- Determine the orifice size based on a differential pressure of 175 in H2O
- Calculate actual flowrate at this differential pressure using the selected orifice
- Determine the orifice plate thickness

Results:

- Orifice size: 4.25 in
- Actual flowrate at this differential pressure using the selected orifice: 77,309 gph @ 174 inH2O
- Orifice plate thickness: 0.125 in