Where Does It Go?

An Introduction to the Placement of Process Equipment

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UOP – A Honeywell Company

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Why Is This Topic Important?

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- **The process equipment arrangement affects nearly every aspect of plant design and operation.**
  - Land requirements
  - Permits
  - Safety Systems
  - Civil
  - Construction
  - Piping arrangement and costs
  - Hydraulics
  - Operating costs
  - Future expansion/modification

Equipment Arrangement Timing

- **Once the P&ID and process specifications are complete, the paper requirements are turned into steel and concrete by the contractor**
- **One of the earliest steps is creation of the plot plan**
- **VERY difficult to significantly alter later**
  - Surrounding installations
  - Access
  - Downtime cost(s)
  - Safety considerations working in a plant

What is a Plot Plan?

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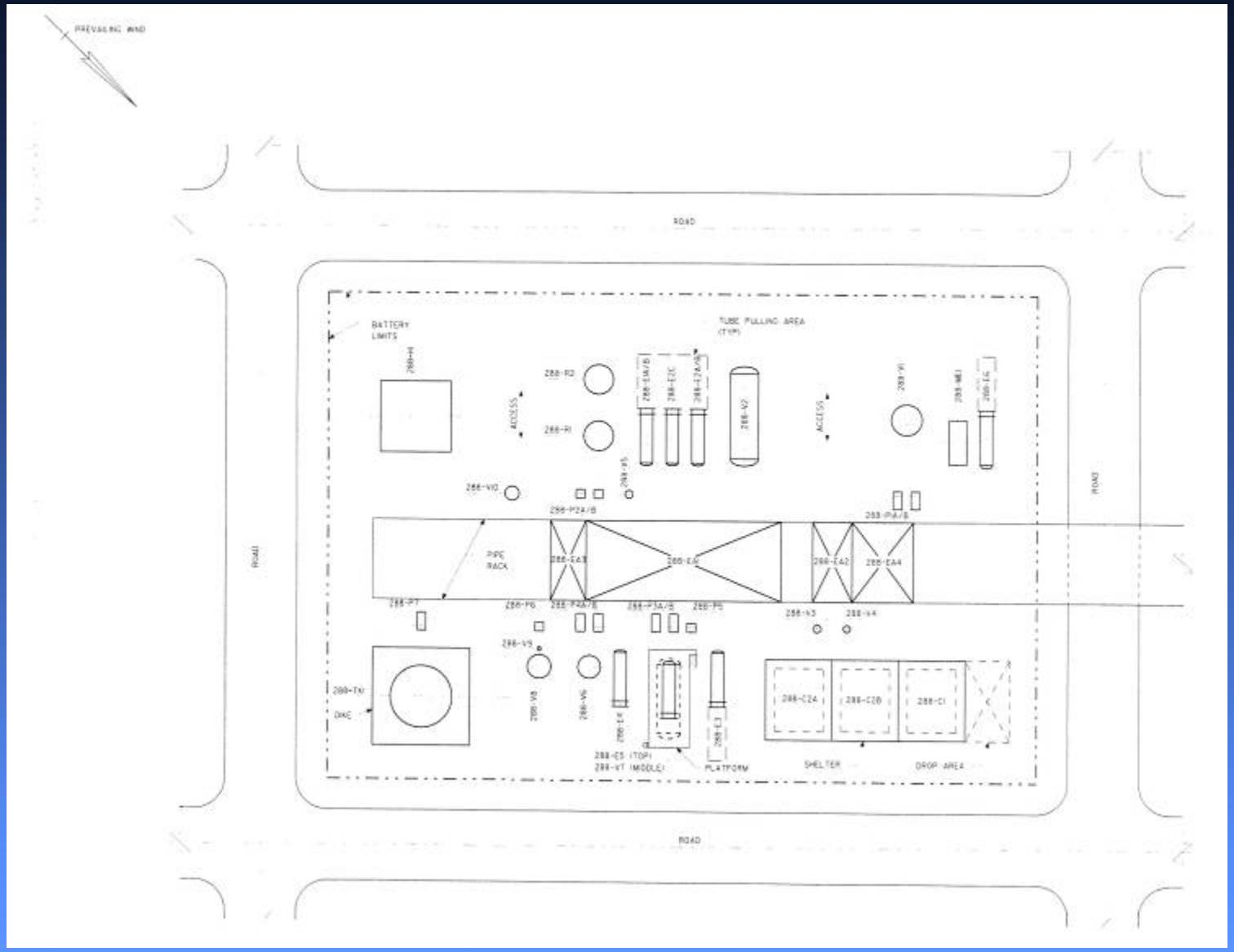
- Typically a simple plan ("birds eye") view indicating the relative placement of equipment.
  - Separate plans for each structure level
- Done to scale
- For additional clarity, elevation views may be included


PREVAILING WIND
ROAD
BATTERY LIMITS
TUBE PULLING AREA (TYP)
ACCESS
ACCESS
PIPE RACK
PLATFORM
SHELTER
DROP AREA
ROAD
ROAD
ROAD

Guideline Basis

- Where do things go??
- Most plot plan guidelines originated with major industrial insurers such as Industrial Risk Insurers, Lloyds, Sedwick, and others.
- Guidelines are generally experience based
- Analytical methods are applied for further detail and as enhancements

Plot Plan Types

- Location of the plant
- Process and other area locations within the plant
- Unit location within the process area
- Equipment location within the unit

Considerations in Plot Plan Development

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- Safety
  - Internal and external to the plant
  - Consider future changes, especially growth outside of the plant boundaries
- Process Functionality and Operation
  - e.g., P&ID requirements
- Constructability
- Maintenance
- Cost
  - Capital
  - Operating
  - Downtime (revamps)

Involved Personnel

- The selected plot plan will affect/impact nearly all plant operations for the life of the facility
- Decisions are often made with capital cost the prime motivator
- Should have a much wider involvement
  - Safety/Firefighting/Environmental
  - Insurance
  - Civil/Structural (e.g., soil conditions)
  - Construction
  - Maintenance
  - Operations
  - Inspection

Plot Plans and Safety

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Plant Safety is a Layered Approach

1. **Plant operations and maintenance and inspection practices – avoids the occurrence of unsafe situations**

2. **HAZOPS, relief systems, design factors of safety, redundancy, emergency operational procedures – Addresses prevention of escalation to a loss of containment**

3. **Fireproofing, firefighting and suppression, battery limit controls, PLOT PLANS – Control and minimization of effects of an event (e.g., loss of containment, fire).**
   - Prevent small events from becoming large
   - Control spread of releases
   - Limit secondary effects

Plot Plans and Safety

- **Plot plans provide a passive (inherent) means of control**
  - **No action by personnel, equipment, instrumentation, etc is necessary**
  - **Address secondary effects**
    - Rarely prevent the initial occurrence of a situation (e.g., loss of containment - vessel, piping, valve, flange failure, misoperation, etc)
    - Attempt to prevent the initial occurrence from becoming multiplied by secondary effects/failures
      - This is usually the source of the major catastrophic effects
  - **Provide time for other measures**
    - Personnel escape
    - Firefighting
    - Process isolation (e.g., feed shutoff)

Plot Plans and Safety - Types of Concerns

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- Vapor Leaks
  - Vapor clouds (toxic, polluting, flammable/explosive, odors)
  - Blast (shock) wave
  - Corrosion
  - Fog (e.g., Cooling Towers)
  - Shrapnel/equipment parts
- Liquid Leaks (vapor generation, pollution)
- Solids Emissions
  - Erosive
  - Corrosive
  - Friction/plugging
  - Vision obstruction ("sandstorm")
  - Dust Explosions
- Fires
  - Pool
  - Jet
  - BLEVE
  - Boil-over
  - Radiant heat effects
- Electrical shorts (moisture, solids entry)
- Miscellaneous Issues such as noise and light
- Escape and emergency response entry means

Plot Plans and Safety

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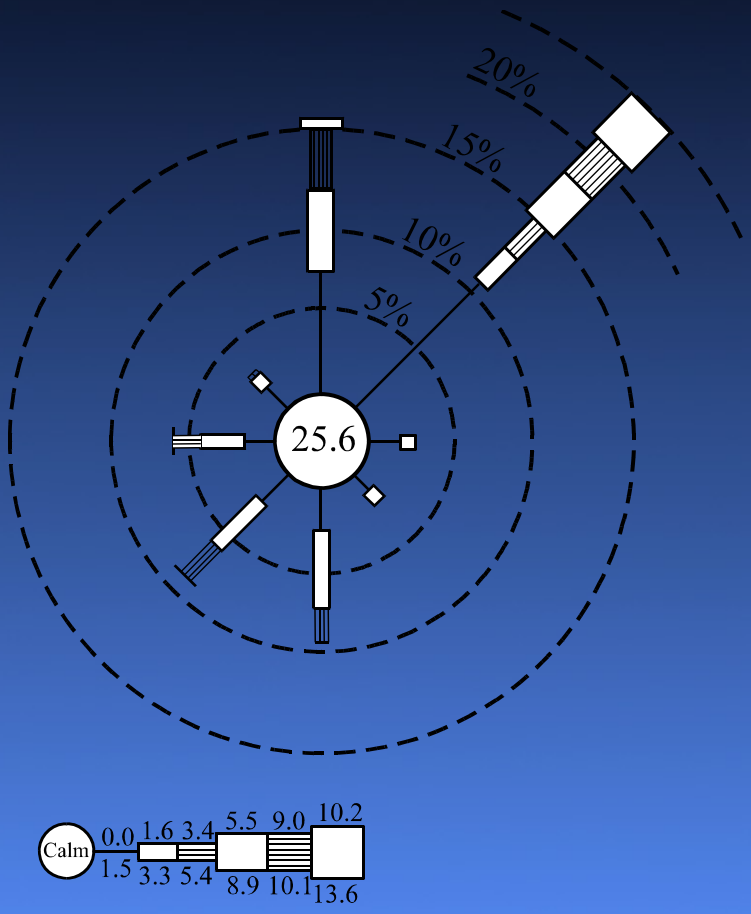
- **Plot plans make use of several simple considerations**
  - **Spacing between units and equipment**
    - Space/clearance is a simple and often very effective means of event control
    - Increased cost due to land requirements, piping length (including flexibility), hydraulics
  - **Topography, especially the ground slope.**
    - Determines where liquid releases will flow. Generation of vapor will follow
  - **Atmospheric conditions, especially wind direction**
    - Determines where vapor releases will be carried
    - Based upon wind rose for the site

Wind Rose


20%
15%
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25.6
Calm
0.0
1.5
1.6
3.3
3.4
5.4
5.5
8.9
9.0
10.1
10.2
13.6
Meters/Second

Procedures

- **Analytical methods exist**
  - **Performed by specialty companies with proprietary software and data**
  - **Begins with a preliminary equipment arrangement**
  - **Predict secondary effect on neighboring equipment and units**
    - Vapor cloud formation and ignition
    - Dispersion modeling (from stacks, flares, releases)
    - Radiant heat exposure and flame impingement (e.g., from jet fires)
    - Modeling is complex, approximate, and contains many assumptions
    - Incorporates Risk Based Analysis
      - Likelihood of scenarios
      - Consequences of scenarios
      - Determine acceptable levels of risk
  - **Minimize piping costs**
  - **Minimize hydraulics**

- **The remainder of this presentation concentrates on practical, and reliable, procedures based upon**
  - **experience**
  - **"common" sense**

Plant Location

- Separated (remote) from current and future public facilities and population centers
- Near feed/suppliers or users
- Good access to transportation (sea or river, pipeline, road, and/or rail)
- Level site
- Good load bearing soil

Public Facilities

- Consider public facilities and roads near the plant boundaries; Exposed to
  - Vapor discharges
  - Blast (shock) waves
  - Radiant heat
  - Solids discharges (e.g., catalyst)
  - Pollutants
  - Water vapor “fog” (roadways)
  - Light (e.g., flares)
  - Odors

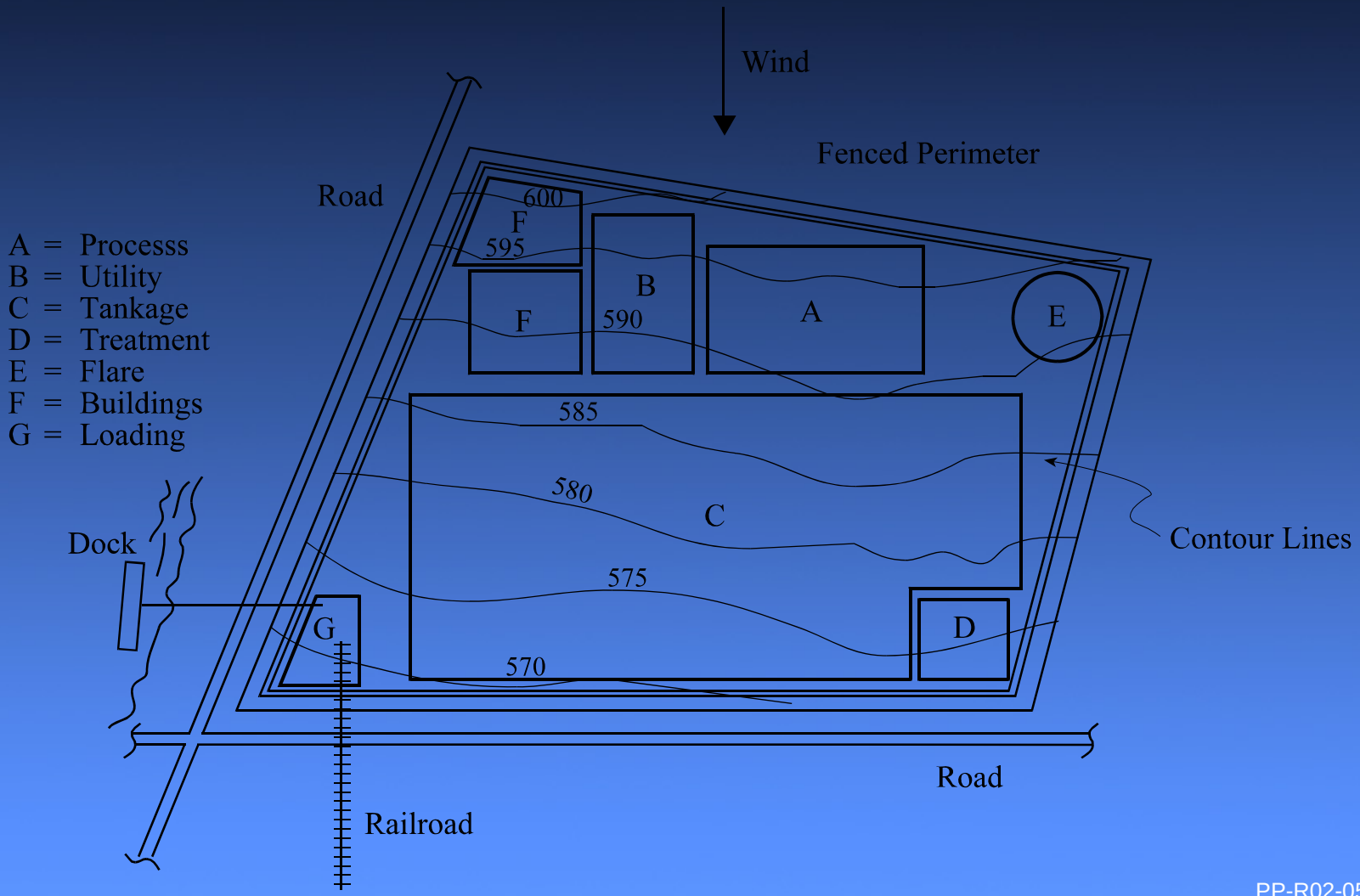
- AIChE/CCPS, “Guidelines for Facility Siting and Layout” is an excellent resource http://www.wiley.com/WileyCDA/WileyTitle/productCd-0816908990.html

Refinery Areas

- Process (and utility) areas upwind and uphill of other areas (especially tankage and loading facilities)
- Office building, labs, warehouses, workshops upwind and uphill of other areas and near roads (for escape)
- Tankage downhill and downwind
- Waste Treatment at low point and near plant boundary, downwind of occupied areas (within and outside plant).
- Loading areas separated from plant; downwind; separate entrance

Refinery Plot Area

Site Arrangement



Process Unit Location

- Generally arrange logically considering process flow
- Units with potentially dangerous effluents on process area periphery and downwind
  - Vapors will be carried away from the plant (and occupied areas)
  - Downwind to be uninhabited and clear
- Consider buffering dangerous units with less dangerous units; Alternate is to locate dangerous units together, limiting the area of most concern

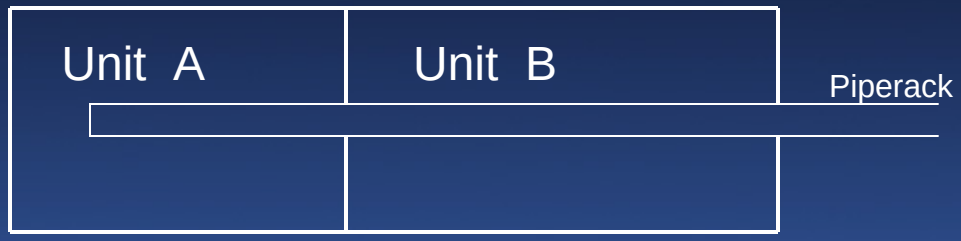
Process Unit Location

- **Roads on all sides of unit tract (battery limits)**
  - **Roads use the inter-tract spacing and act as firebreaks**
    - Raise slightly for secondary containment of unit spills
  - **Keep personnel and vehicles kept away from process equipment**
  - **All equipment directly accessible from a road**
  - **At least two means of access to each piece of equipment**
  - **At least one access to be free of overhead obstructions (e.g., piperacks)**
  - **Large units may require pass-through roads**

Process Unit Location

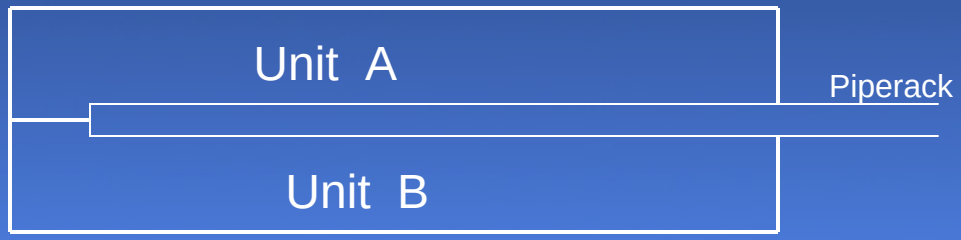
- Place units along (each side of) a straight piperack
  - A “fishbone” rack arrangement often works
  - Use elevated racks (not pipeways) to facilitate access through the unit
- If multiple units are along one process tract piperack
  - Arrange to permit any one (or more) to be “down” without operating lines passing through
  - Locate units on opposite sides of piperack rather than sequentially
  - Segregate the equipment for each unit

Unit Arrangements



Non-preferred Arrangement

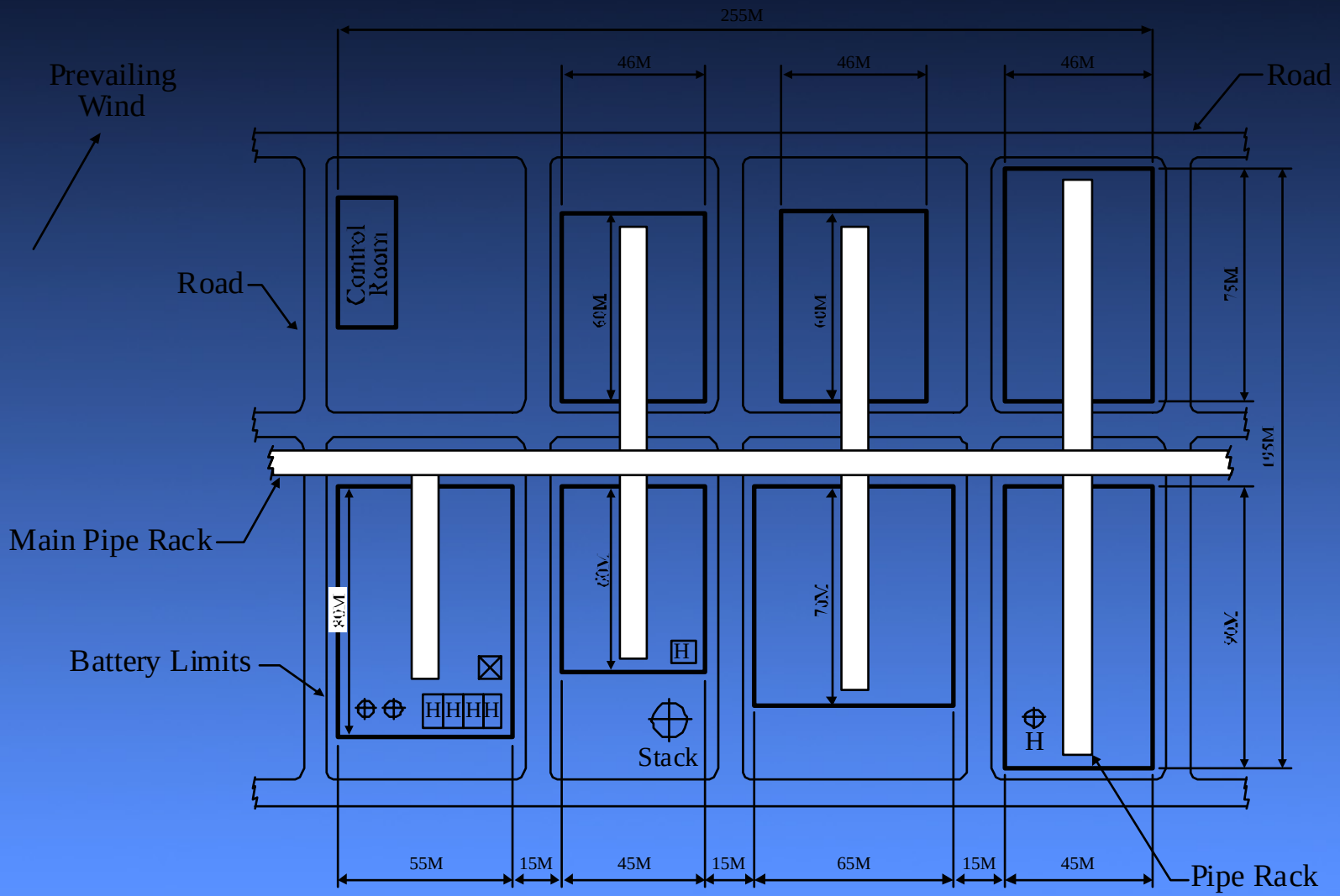
Units placed end to end along the pipe rack



Preferred Arrangement

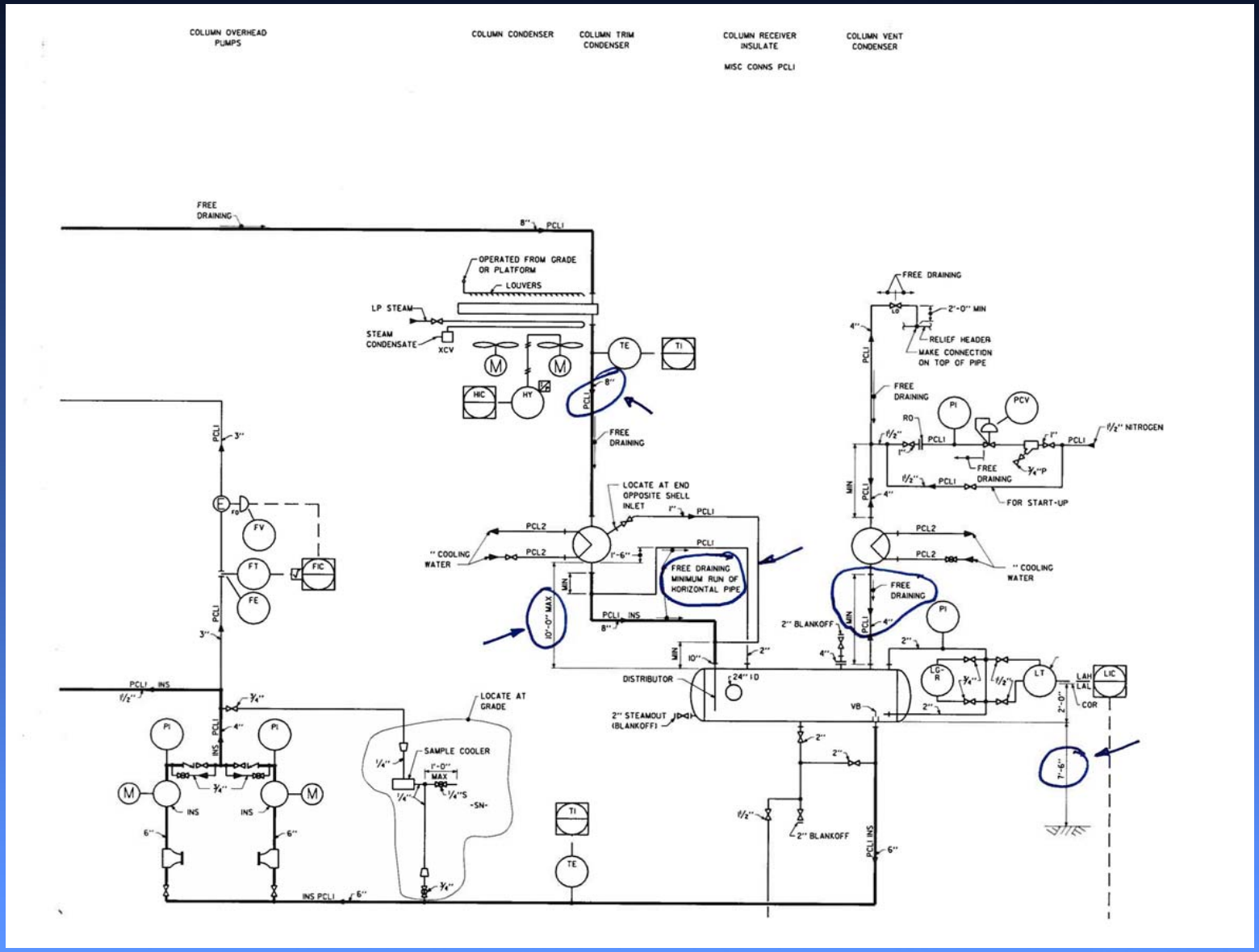
Units placed on opposite sides of the pipe rack

Unit Block Layout



Equipment Location

- **Generally arrange logically considering process flow and requirements (e.g., per P&ID)**
  - **Accommodate process requirements (e.g., free draining, elevations, equipment proximity. hydraulics, etc)**
  - **Additional guidelines apply to specific types of equipment**
- **Process equipment separated from inter-tract racks**
  - **Location of battery limit shutoffs**
    - Lack of access to shutoff valves has been a major contributor to many disasters
    - Provide water curtains or remote operated valves
    - Avoid placing fire potential equipment nearby
  - **Helps isolate issues to within one tract.**
- **Co-locate similar, hazardous, equipment (e.g., fired heaters, compressors, high pressure sections)**


COLUMN OVERHEAD PUMPS
COLUMN CONDENSER
COLUMN TRIM CONDENSER
COLUMN RECEIVER INSULATE
MISC CONNS PCLI
COLUMN VENT CONDENSER
FREE DRAINING
8" PCLI
OPERATED FROM GRADE OR PLATFORM
LOUVERS
LP STEAM
STEAM CONDENSATE
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TI
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FREE DRAINING
LOCATE AT END OPPOSITE SHELL INLET
PCL2
" COOLING WATER
FREE DRAINING MINIMUM RUN OF HORIZONTAL PIPE
10'-0" MAX
PCLI INS
DISTRIBUTOR
24" ID
2" STEAMOUT (BLANKOFF)
VB
FREE DRAINING
2'-0" MIN
RELIEF HEADER
MAKE CONNECTION ON TOP OF PIPE
PI
PCV
RO
1/2" NITROGEN
3/4"P
FOR START-UP
2" BLANKOFF
LT
LIC
LAH
LAL
COR
7'-6"
FV
FT
FIC
FE
LOCATE AT GRADE
SAMPLE COOLER
1'-0" MAX
1/4"S
-SN-
INS
6"
INS PCLI

Fired Heaters

- **Provide an open ignition source**
  - **Ignite leaking vapors**
    - From liquid
    - Vapor clouds
- **Place Upwind of process equipment**
  - **Vapor will tend to be carried away from the heater**
  - **Refer to wind rose (more complete and accurate than prevailing wind)**
- **Separate from process equipment**
  - **Typically 50 feet/15 meters minimum (more for compressors)**
  - **Applies to all process equipment (vessels, pumps, air coolers, exchangers, etc) with a very few exceptions**
- **Locate at the open end of the unit piperack**

Pumps

- Pumps to be at grade
  - NPSH requirements
  - Vibration
  - Maintenance access
  - Leaks and spills
- Locate pumps in a line next to (not under) the piperack
  - Drivers towards the rack for access beneath the rack
  - Process end several meters from the rack
  - Pumps are a common source of small fires (seal leaks, etc)
  - Piperack air coolers can rapidly make a small fire a large one
  - Involving the piperack involves process lines, fuel lines, and control cables
  - Do not locate beneath process equipment.

Shell and Tube Exchangers

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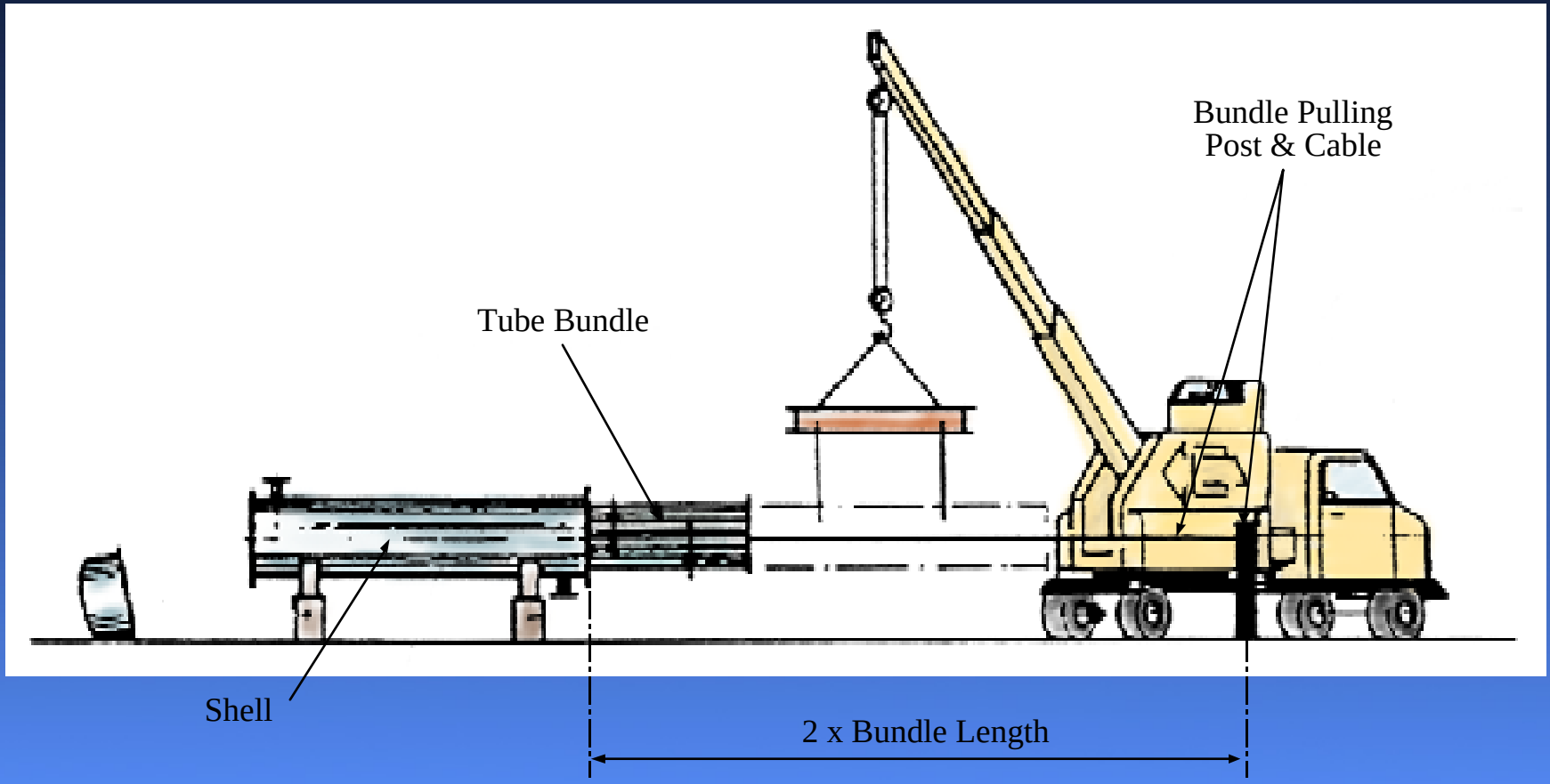
- Locate at grade for ease of maintenance
- Stack a maximum of two shells high
- Hot shell of multi-shell series exchangers near hot source/destination
- Do not stack parallel shells (facilitates symmetrical flow)
- Thermosyphon reboilers
  - Immediately adjacent to equipment served
  - Minimum elbows and length of piping

Bundle Pulling Post



Air Cooled Exchangers

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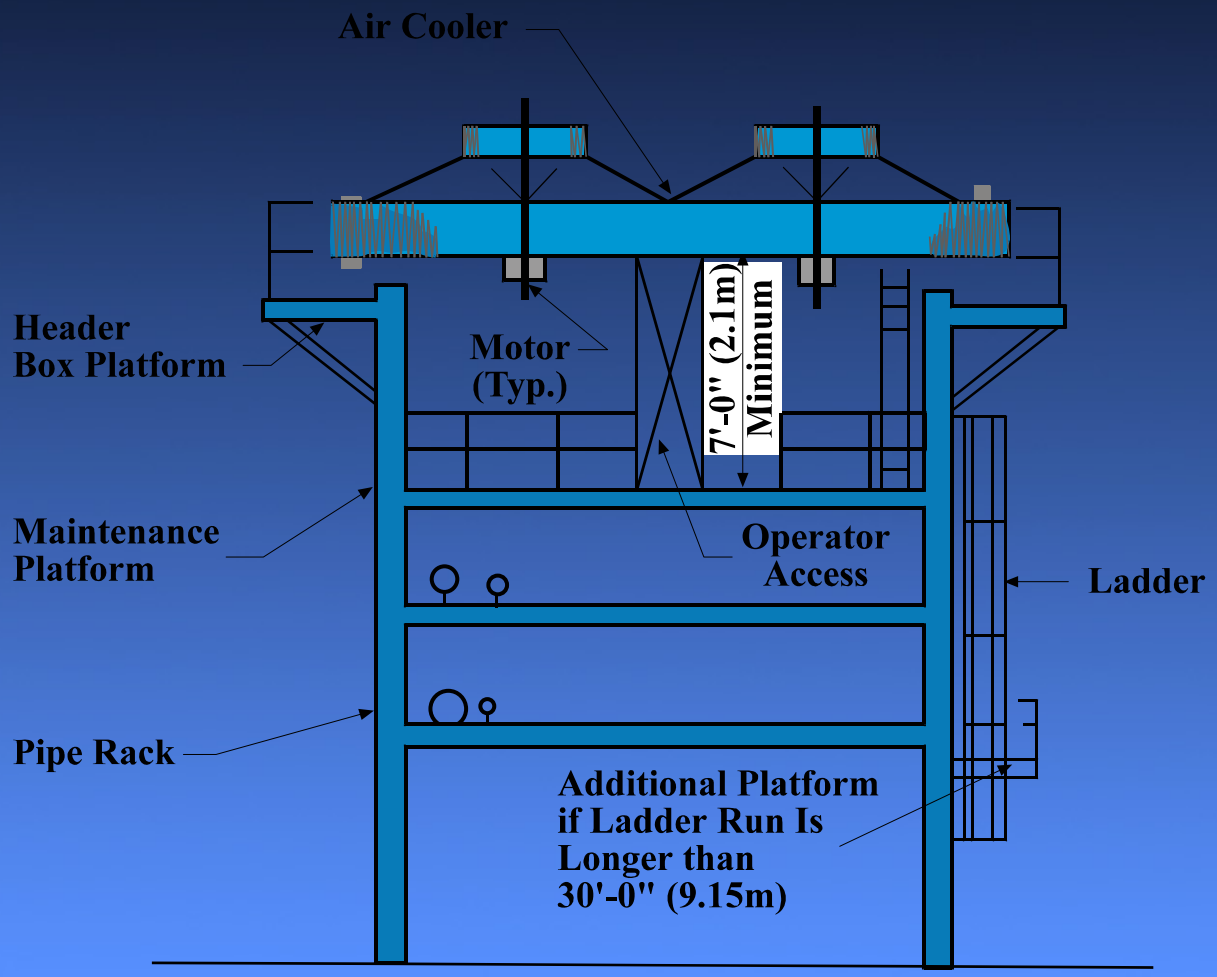
- Normally locate over the piperack
  - Do not locate over other equipment, especially pumps
  - If unavoidable provide firebreak floor and additional fire suppression/detection
- Provide accessways for maintenance
  - Avoid lifts over other equipment
- Ensure incoming air is not effluent from another air cooler
  - Nearby air coolers to be at the same elevation

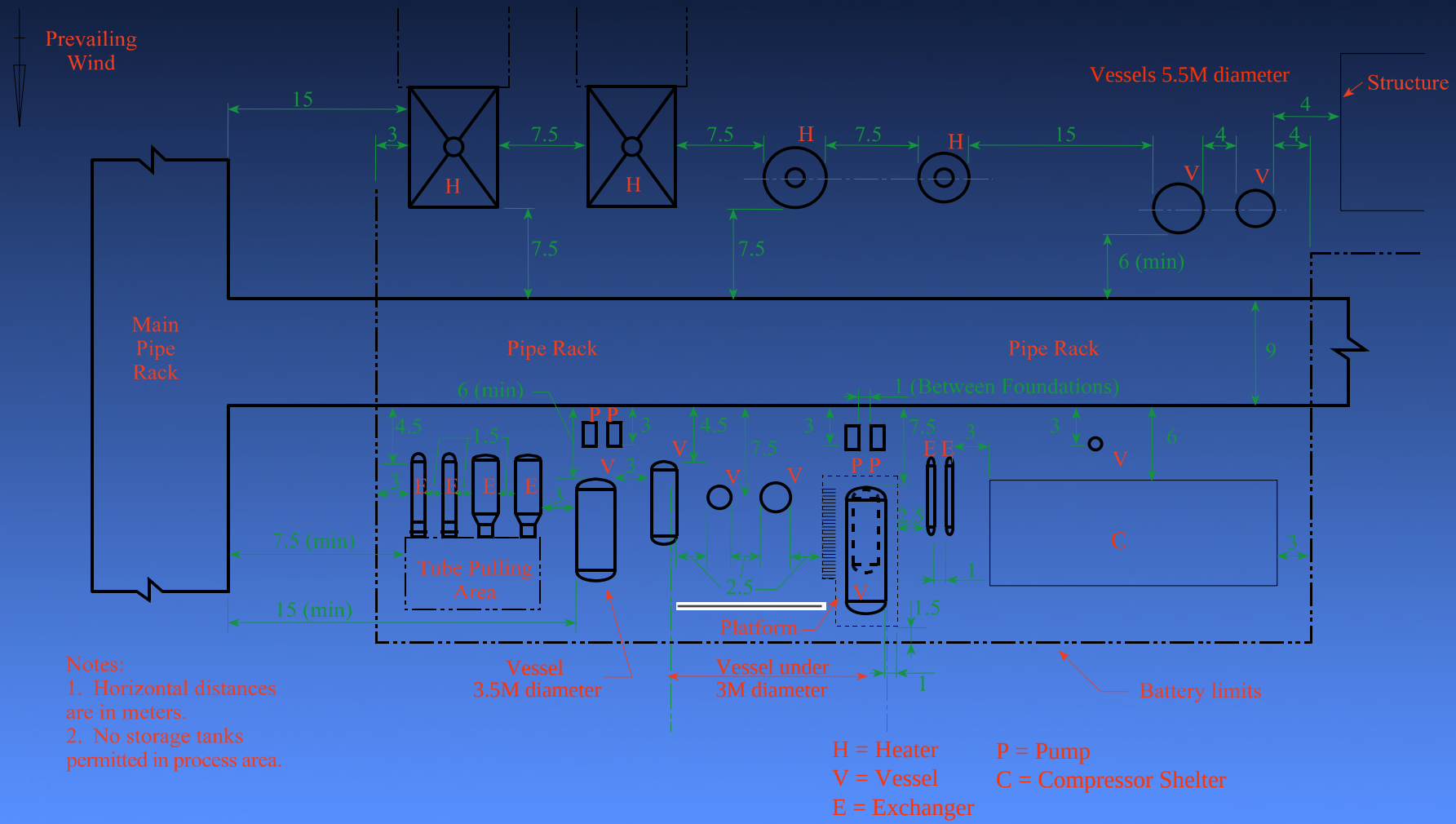
Typical Pipe Rack-Supported Air Cooler Arrangement



Compressors

- **Compressors are likely sources of vapor leaks**
  - **Separate from other process equipment**
    - Usually 30 feet (9 meters)
    - Associated equipment (e.g., knockout drums) is an exception
  - **Usually locate at the end of the unit/process tract**
- **Generally in a shelter (well ventilated, e.g., open sides, sloped roof to ventilation)**
  - **Contains noise**
  - **Tends to contain/control leaks**
- **Provide drop area and good road access for maintenance**

Equipment Arrangement



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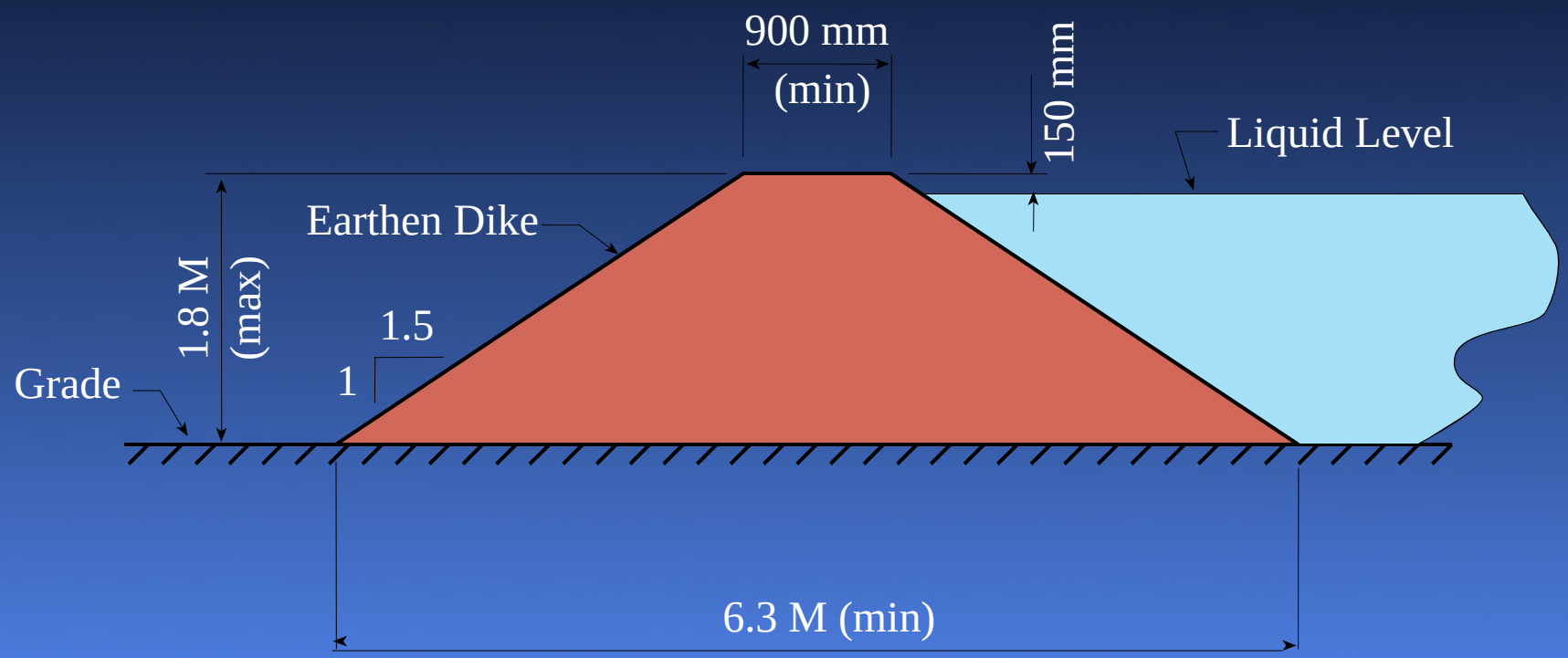
Elevated Flares

- Ignition source for vapor releases; May emit burning liquid that can carry a distance
- Locate “sidewind” (upwind is next best) and uphill of process equipment
- Using flare load and flame direction, determine spheres of radiant heat from the center of the flame
  - Greater than 1500 BTU/hr/sq ft – sterile area (no vegetation)
  - Less than 500 BTU/hr/sq ft – limit of lengthy human exposure
- Process equipment usually 300 feet (100 meters) away.
- Locate remote from public areas
  - Emissions
  - Heat
  - Light
  - Odor

Tanks

- Locate on-site tanks at the periphery of the process area, separated from process equipment.
- Tank farms shall be downhill and downwind of process areas to prevent spills/leaks from being carried to ignition sources
- Separate tanks to
  - minimize radiant heat affects
  - Provide for containment requirements
- Provide containment dikes
  - Berms for access/escape and firefighting; concrete in process areas
  - Contain at least a full spill for the largest contained tank
  - Each tank next to a dike and a road (not shielded)
  - Impoundment may be an alternative

Earthen Dike



Piping Considerations

- Cost (especially of alloy, hot, high pressure, large diameter, or heat traced lines)
- Hydraulics
- Minimization of length and direction changes of multiphase or flashing service lines
- Flexibility requirements

Maintenance Considerations

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- Provide sufficient room inside the battery limits
  - All maintenance (e.g., bundle pulling) is performed entirely within the unit boundary
  - Catalyst loading, tray change outs, air cooler access, compressor maintenance completely within the boundaries
  - Access roads to remain clear at all times.
  - Area to be entirely shutdown (no operating equipment or piping within the defined work area)
- Do not pull bundles or make other lifts (cranes, trolleys/hoists) over existing (especially operating) equipment or stairs (accessways)
- Consider that non-plant personnel are on site

Construction Considerations

- Sufficient access for large process and construction equipment
- Minimize large lifts
  - Minimize number of cranes
  - Minimize required crane locations
  - Make all lifts in a limited time
  - Swing area for crane (including counterweights)
- Laydown areas
- Congestion
- Hotwork
- Non-plant personnel on site

Miscellaneous

- **Safety measures are not limited to process equipment locations.**
  - **Locate control rooms upwind and remote from the process area (outside the blast zone)**
    - Change houses at the control room or between the control room and process area (upwind of process)
  - **Congested areas**
    - Confine vapor releases and making fires and explosions more likely
    - Interfere with maintenance work, firefighting, and access/escape
    - Concentrate blast energy
    - Result in more items affected by an event
  - **Do not make lifts over equipment or stairs**
    - Locate shell and tube exchangers at grade
    - Provide accessways to air cooled exchangers
    - Reactor loading/unloading

Miscellaneous Considerations

- **Do not locate hot equipment (e.g., above autoignition) beneath other equipment**

- **Stacks shall be at least 15 feet (5 meters) higher than the highest occupied platform within a 100 foot (30 meter) radius).**

- **Other than air cooled exchangers, do not place process equipment above or beneath piperacks**

- **Consider future expansion**
  - Allow space for anticipate future installation (e.g., parallel equipment)
  - Allow space for additional air cooled condenser bays

Miscellaneous Considerations

- If pumps or elevated temperature exchangers must be below, or air coolers above, other equipment provide
  - Firebreak floors (fireproof, no openings, sloped and drained to prevent spill collection
  - Additional fire detection and suppression measures
- Provide drop and loading/unloading areas in front of vessels
- Stair discharges
  - Shall not be amidst equipment
  - Shall point towards the battery limits

Summary

- Engineering judgment and common sense are perhaps the most important decision criteria
  - Each situation is unique
  - Principles are guides, not rules
  - The “right” answer in one instance may not be the best approach in another.
- Plot plans are a series of compromises between often at odds goals and priorities.
- There is no “correct” answer or perfect plot plan.

Summary (Continued)

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- Plot plan considerations include safety, functionality, maintenance, constructability, and cost

- Even more basic guidelines are the two S's:
  - Sense (common)
  - Space

References and Standards

- Many companies have their own guidelines (widely varying detail)
- Industrial insurers have guidelines
- Some government agencies have guidelines or limited requirements
- Industry standards, include:
  - AIChE/CCPS, "Guidelines for Facility Siting and Layout" http://www.wiley.com/WileyCDA/WileyTitle/productCd-0816908990.html
  - PIP PNE00003 "Process Unit and Offsite Guide" www.pip.org
  - GAP (Global Asset Protection) Guides www.xlgaps.com
  - AIChE/CCPS, "Guidelines for Chemical Process Quantitative Risk Analysis" http://www.wiley.com/WileyCDA/WileyTitle/productCd-081690720X.html

Acknowledgements

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- The views and opinions expressed in this presentation are those of the author and do not represent those of AIChE, UOP LLC or Honeywell International Inc.

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