Production Optimization and Forecasting

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Production Optimization and Forecasting…

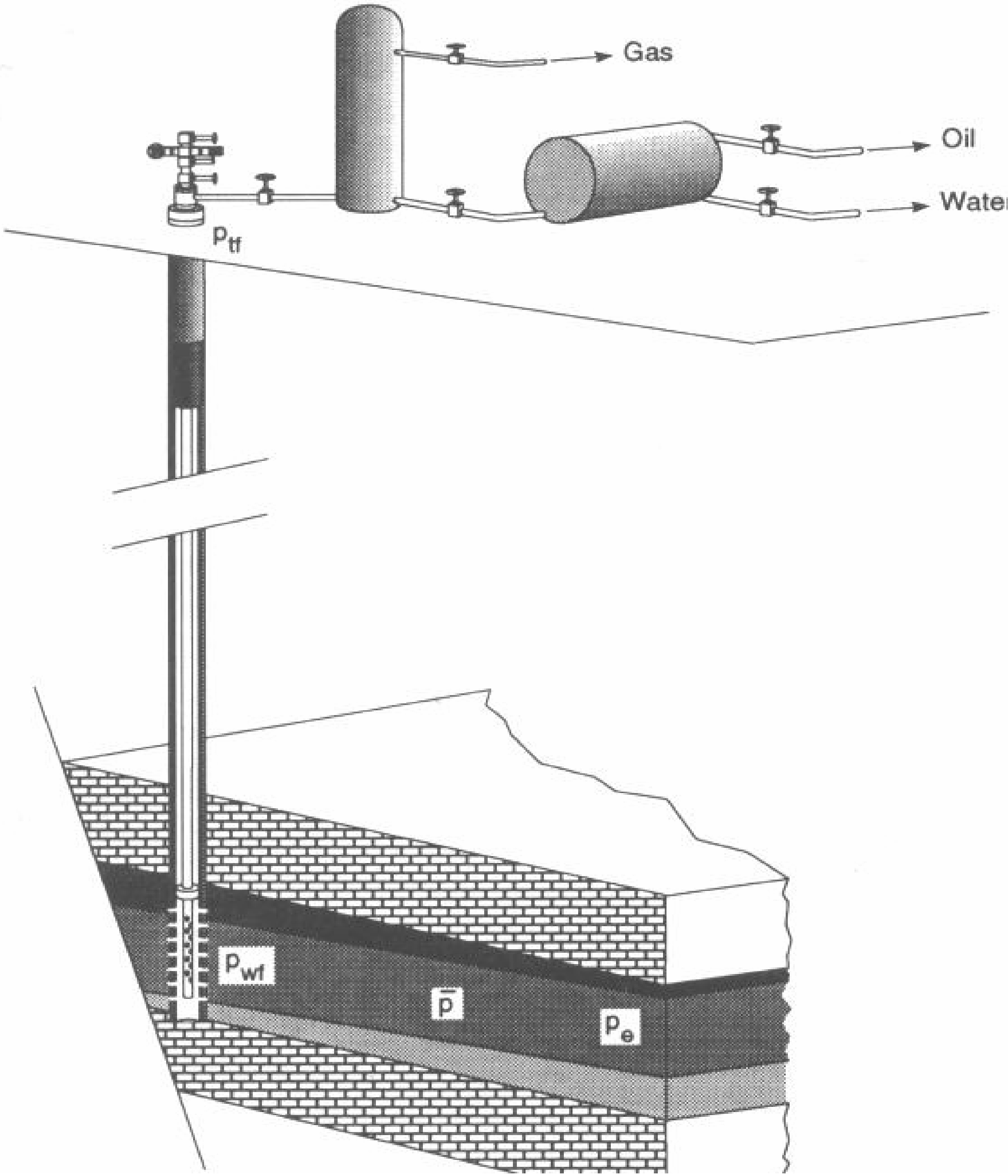
- Production optimization means – Balance between production rate / deliverability and demand
- Production optimization includes a good understanding about Production Systems & Reservoir fluid

Production Systems

- Production Systems includes
  - ➢Reservoir (Inflow Performance Relationship)
  - ➢Wellbore (Completions, Tubing etc)
  - ➢Surface Facilities (Flow lines, Separator, Pipelines, etc)
- Production systems can be very simple to complex
  - ➢ Simple – Reservoir, completion, tubing, surface facilities
  - ➢ Complex- Artificial lift system, Water injection and Multiple wells

Reservoir Fluid

- Properties of the reservoir fluid, like
  - FVF (Formation Volume Factor), Bo, Bg
  - Produced Gas/Oil Ratio (GOR) Rp,
  - Solution Gas Oil Ratio, Rs
  - Compressibilities Co, Cg
  - Bubble Point
  - Gas and Oil Gravities
  - Densities & Viscosities


Gas
Oil
Water
p_{tf}
p_{wf}
$\bar{p}$
p_e

Production Systems…

- Movement or Transport of reservoir fluid from reservoir to surface requires **energy** to overcome the frictional losses or the pressure drop
- The pressure drop of the fluid at any time would be the initial fluid pressure minus the final fluid pressure

$$\Delta P = P_i - P_{sep}$$

$$\Delta P = \bar{P}_r - P_{sep}$$

Production Systems…

- Design of a production systems never be separated into reservoir and piping systems
  - ❖ The amount of Oil and Gas flowing into the well from reservoir depends on pressure drop in the piping system
  - ❖ Piping system pressure drop depends on amount of the fluid flowing through it
- Therefore, entire production systems must be analyzed as a unit

A Hypothetical Case

- A new offshore gas condensate field has been discovered in the Bay of Bengal
- Seismic studies and Well tests suggest a very large anticline structure, with possible reserves of 7.8 TCF of gas and 400 million barrels of condensate liquids
- The offshore field is 150 miles off from the shore line

Considerations

- Reservoir deliverability
- Lifting of Hydrocarbon
- Transport to Market Place
- Flow assurance & Operability
- Future oil and gas price, Time value of Money etc

Deliverability

- Provides information on the production rate & Total production as a function of Time
  - Simplified Approach
    - Inflow Performance Relationship
    - Decline Curve Analysis
  - Analytical Solutions
  - Reservoir Simulations

Lifting Hydrocarbon

- Flow in Wellbore
  - Natural Flow
  - Artificial Flow (Water flooding, CO_2 flooding)
- Flow in Tubing
  - Natural Flow
  - Artificial Lift (Gas lift, Beam Pump, ESP)
- Flow Characteristics
  - Single phase
  - Multiple phase

Transport

- Ways and Means of transportations
    - ➢ Pipeline
    - ➢ Tankers
    - ➢ Others
- Flows in pipes and piping components
- Flow Control and Conditioning
    - ➢ Flow rate adjustment
    - ➢ Separation and disposal of “unwanted’
    - ➢ Pressure Maintenance (compressor & Pumps)

Flow Assurance and Operability

- Hydrate formation
- Paraffin & Asphaltene deposition
- Severe Slugging
- Start up and Shutdown
- Scale Formation

System Analysis

- Deliverability of a well can be **severely restricted** by the **performance of only one component** in the system
- If the effect of each component on the total system performance can be isolated, the system performance can be optimized in more economic way
- In system analysis we use a method where we consider whole production system as a single unit. Then we choose a point with in the unit where input and output pressure are same.
- This is **Nodal Analysis***

Nodal Analysis

- **Node** is a point where –
  - Flow into the node equals flow out of the node
  - only one pressure exist in the node
- Upstream of node is called **inflow**
- Down stream of node is called **outflow**
- Node pressures are
  - Inflow to the node

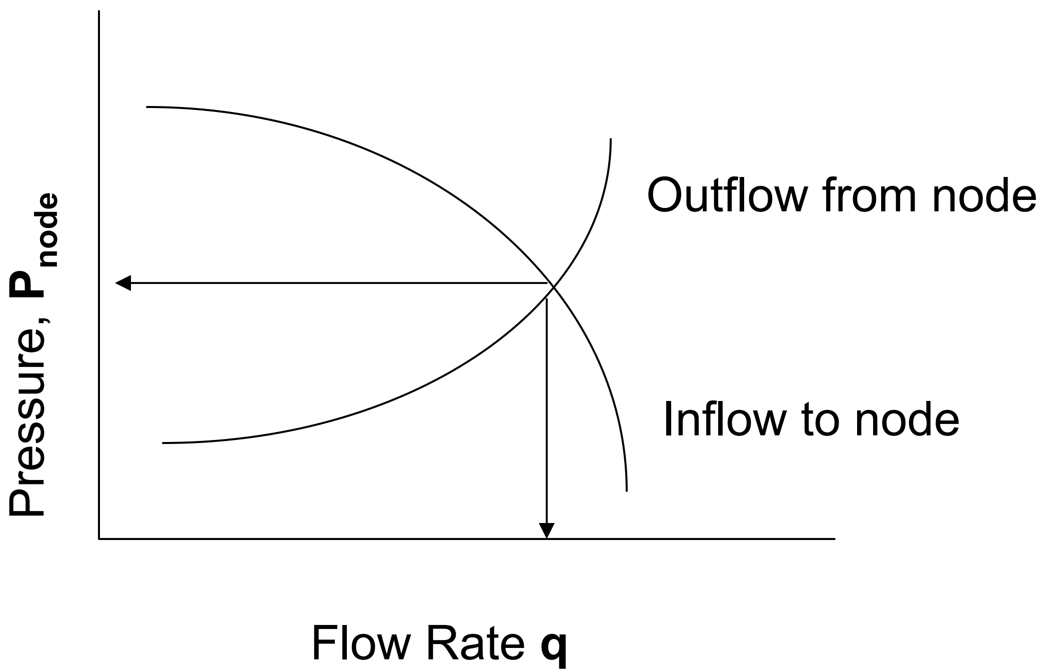
$$\bar{P}_R - \Delta P_{upstream} = P_{node}$$

  - Outflow from the node

$$\bar{P}_{sep} + \Delta P_{downstream} = P_{node}$$

Nodal Analysis…

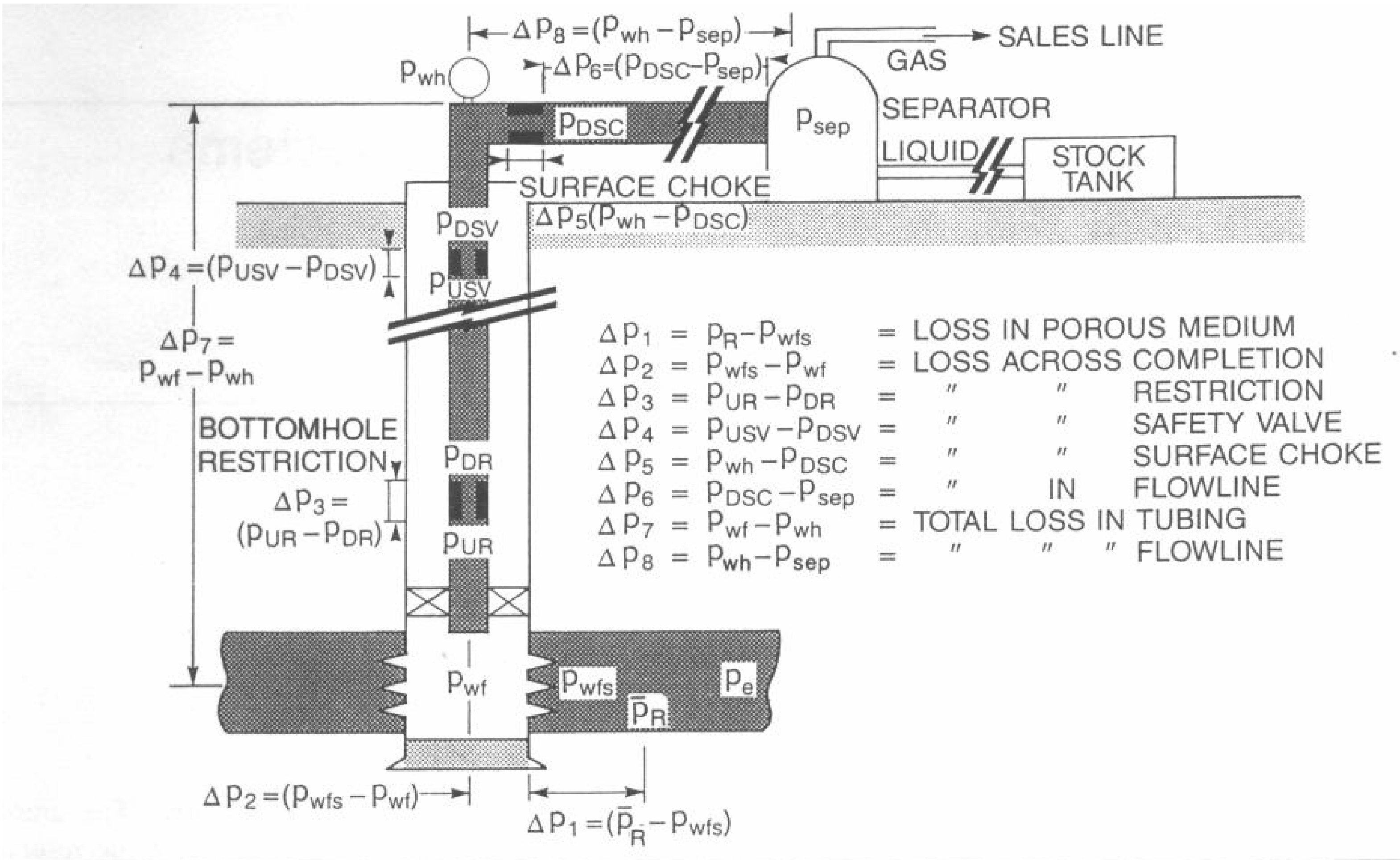
- Pressure drop dP varies with the flow rate q
- Pressure VS. Flow rate will produce two curves



Nodal Analysis…

- Intersection of Inflow and outflow satisfy the conditions
- This P is the optimum for that flow rate
- If any change is made anywhere ie inflow or outflow then only that curves will be shifted and other will be same
- Intersection will be changed

Nodal Analysis…



Nodal Analysis…

- Node at the well head
  - Inflow to Node

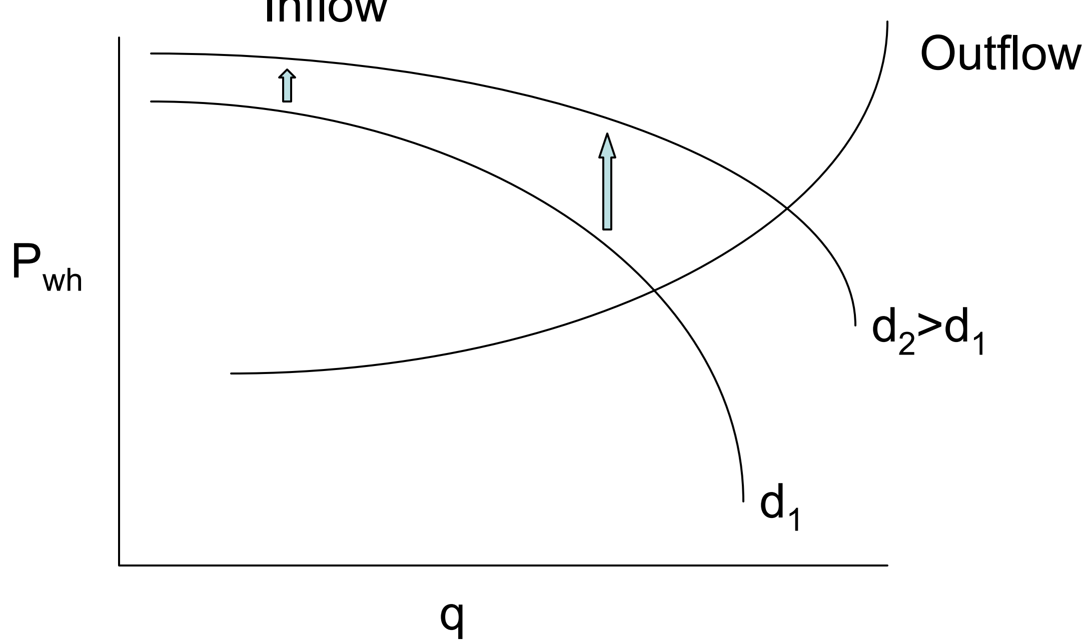
$$\bar{P}_R - \Delta P_{res} - \Delta P_{tubing} = P_{wh}$$

  - Outflow from Node

$$P_{sep} + \Delta P_{flowline} = P_{wh}$$

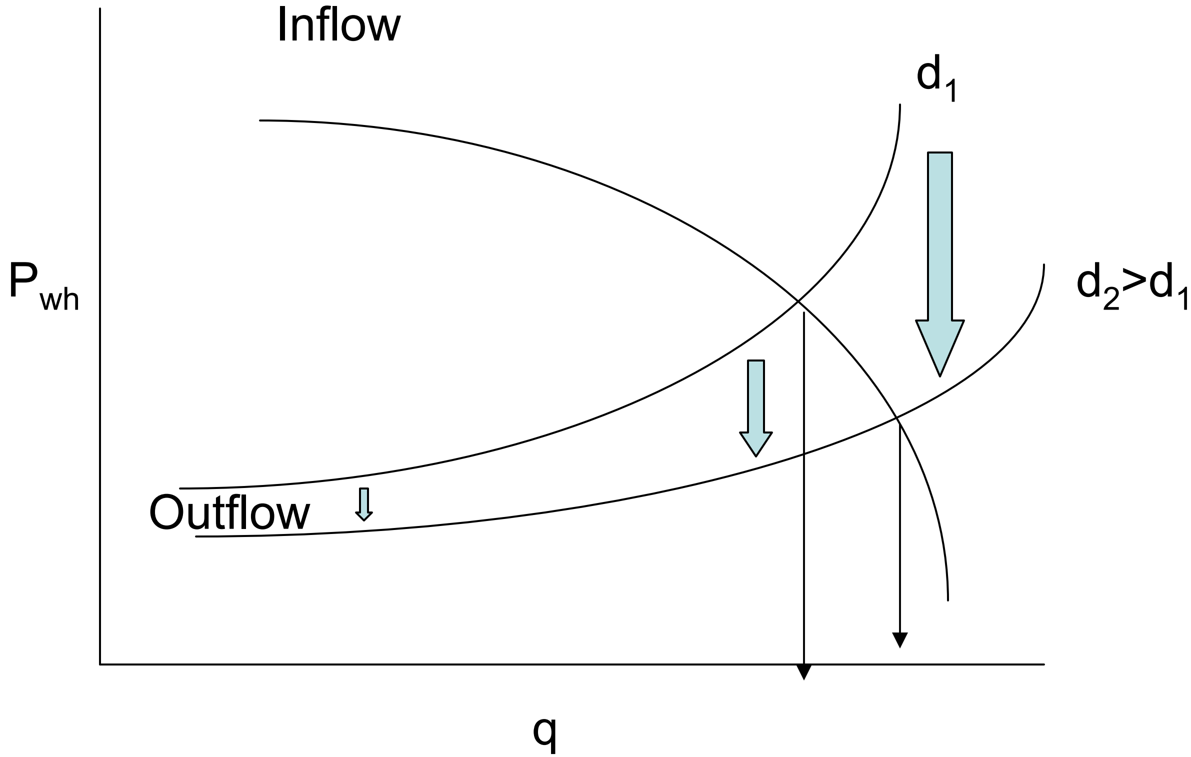
Nodal Analysis…

- If tubing size increases- which will give less pressure drop so the inflow curve move upward



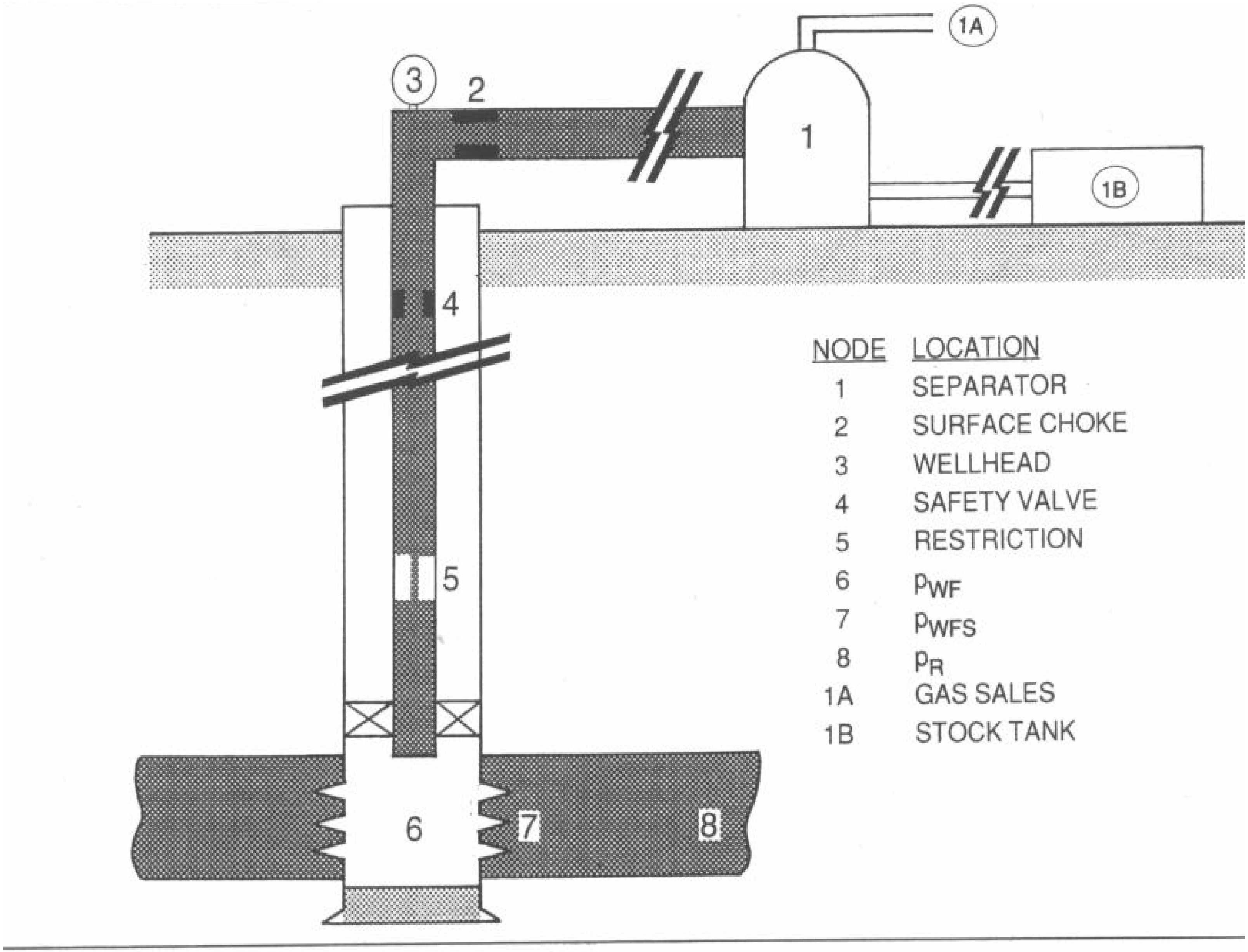
Nodal Analysis…

- If flow line diameter increases then the out flow curve will shift downward



Nodal Analysis

- Node can be select anywhere in the production system
- List of possible positions of node
    1. Separator (Sales or Stock tank)
    2. Surface Choke
    3. Wellhead
    4. Safety Valve
    5. Restriction
    6. Bore hole Pwf
    7. Sand Face Pwfs
    8. Reservoir
- Most of the cases node is placed in number 6
- System will divide into Reservoir and Piping Components

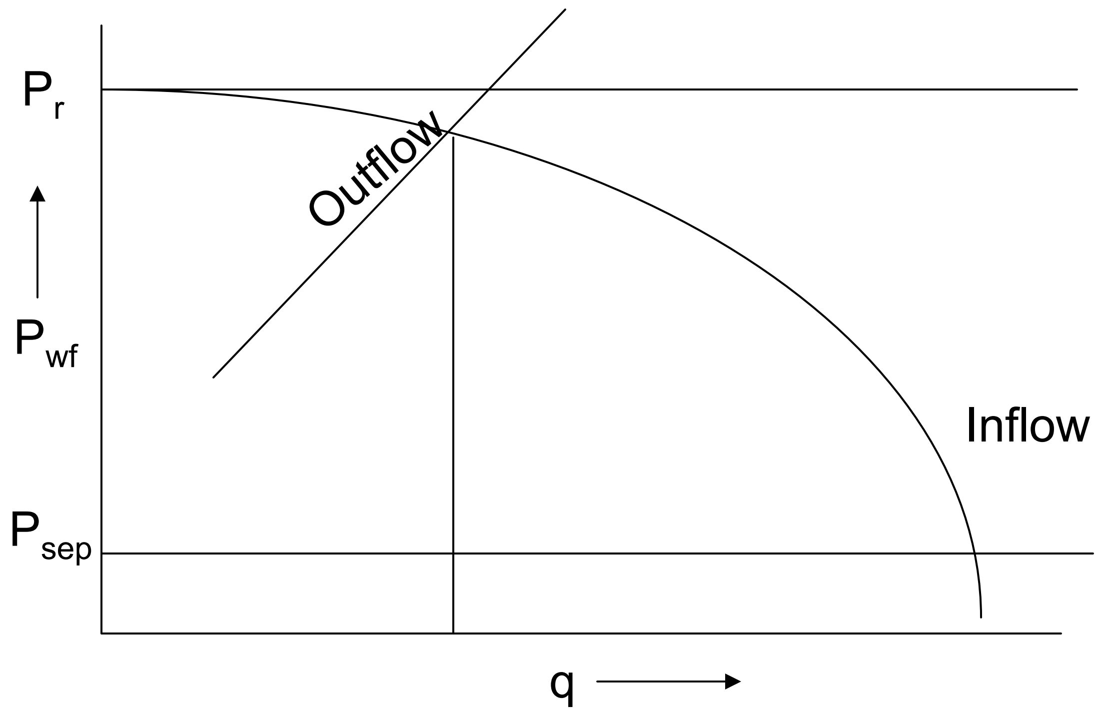

1A
3
2
1
1B
4
5
6
7
8
NODE LOCATION
1 SEPARATOR
2 SURFACE CHOKE
3 WELLHEAD
4 SAFETY VALVE
5 RESTRICTION
6 p_{WF}
7 p_{WFS}
8 p_R
1A GAS SALES
1B STOCK TANK

Nodal Analysis…

- Selecting Tubing: Node at the point 6
- Inflow to Node $\bar{P}_r - \Delta P_{res} = P_{wf}$
- Out Flow from Node $P_{sep} + \Delta P_{flowline} + \Delta P_{tubing} = P_{wf}$
- Total System pressure drop $P_r - P_{sep}$ is fixed, production capacity depends on where excessive pressure drop occurs.

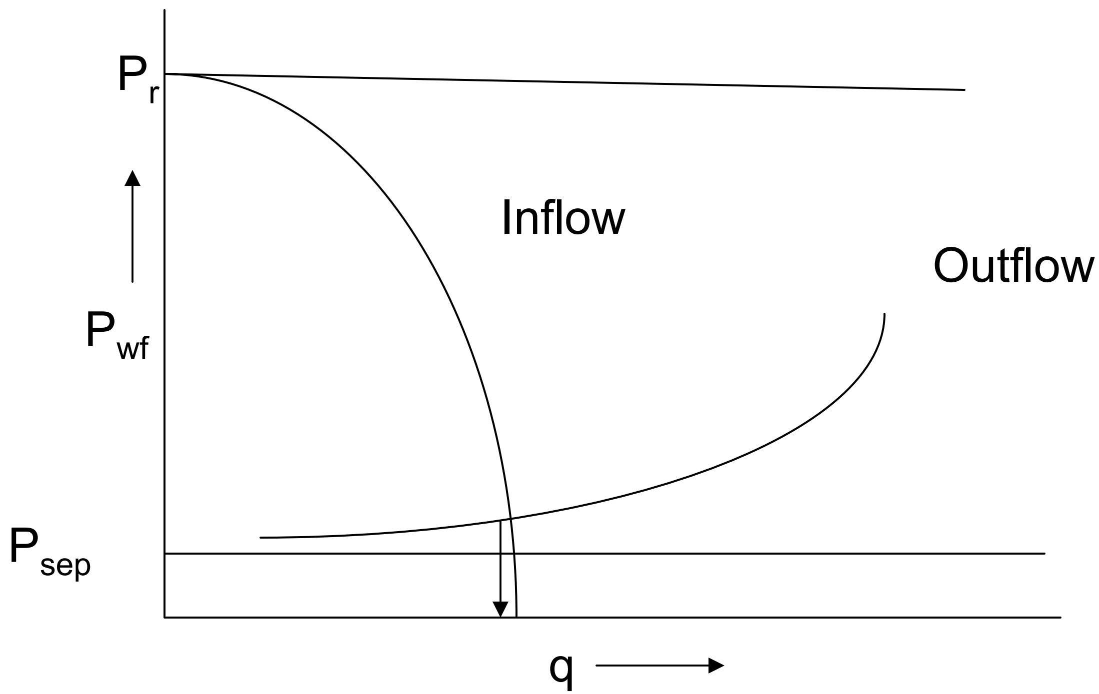
Tubing Size Optimization

- If the excessive pressure drop occurs in tubing then flow is restricted by tubing



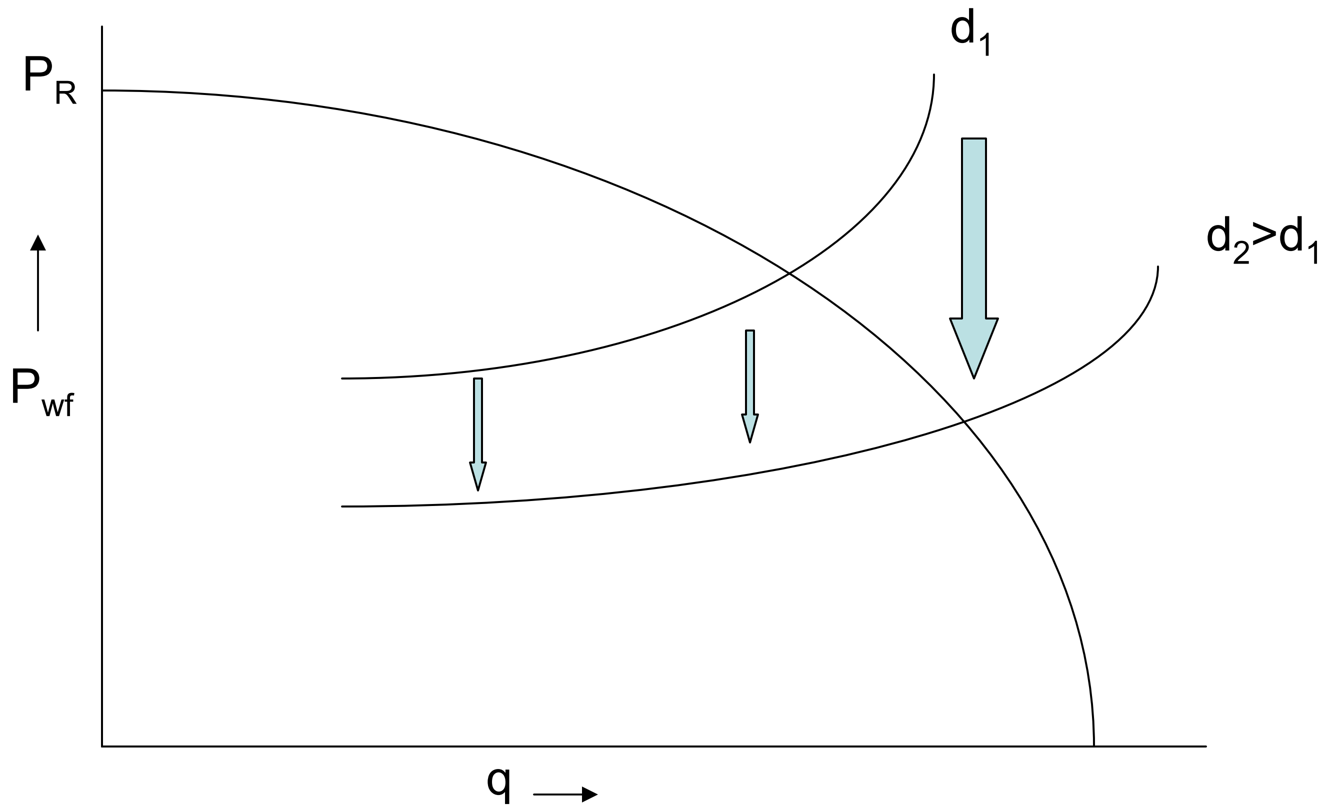
Tubing Size Optimization…

- Restricted flow by Reservoir



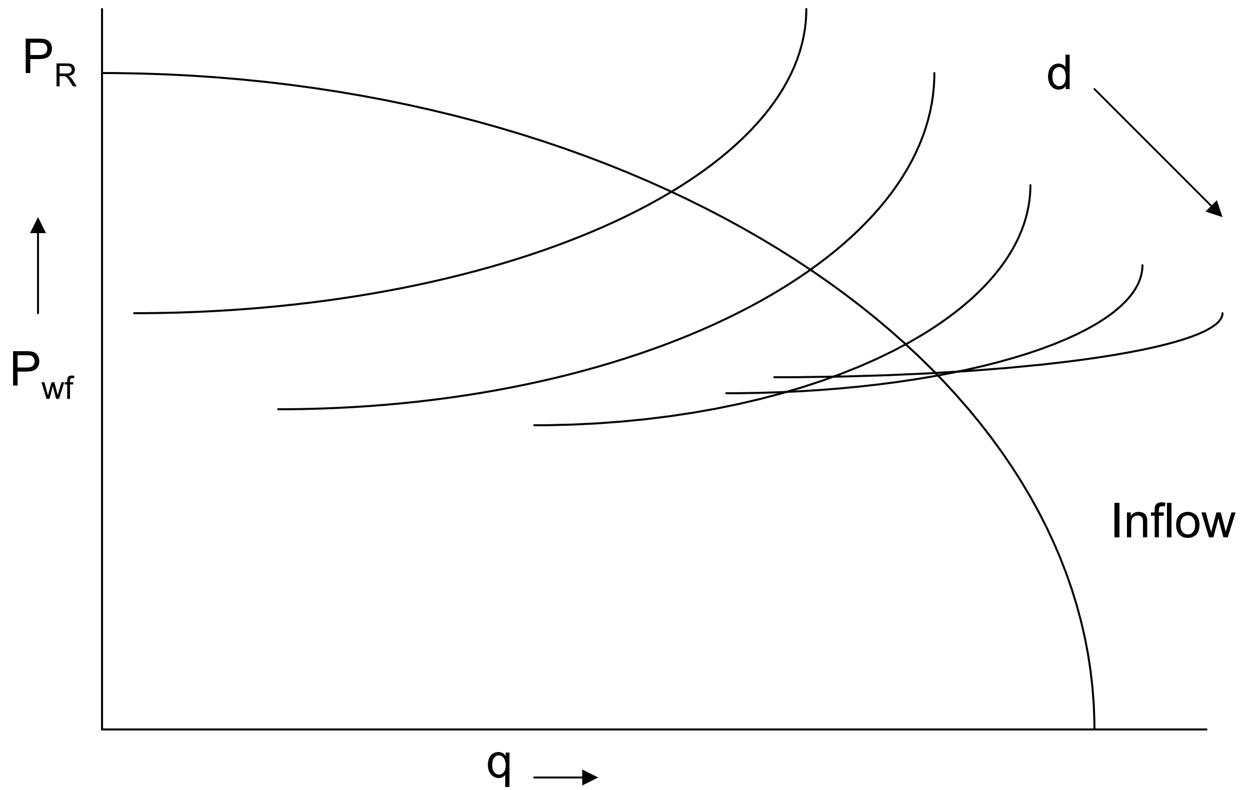
- Not suitable for tubing optimization
- Formation Damage or Inadequate Perforation

Tubing Size Optimization…



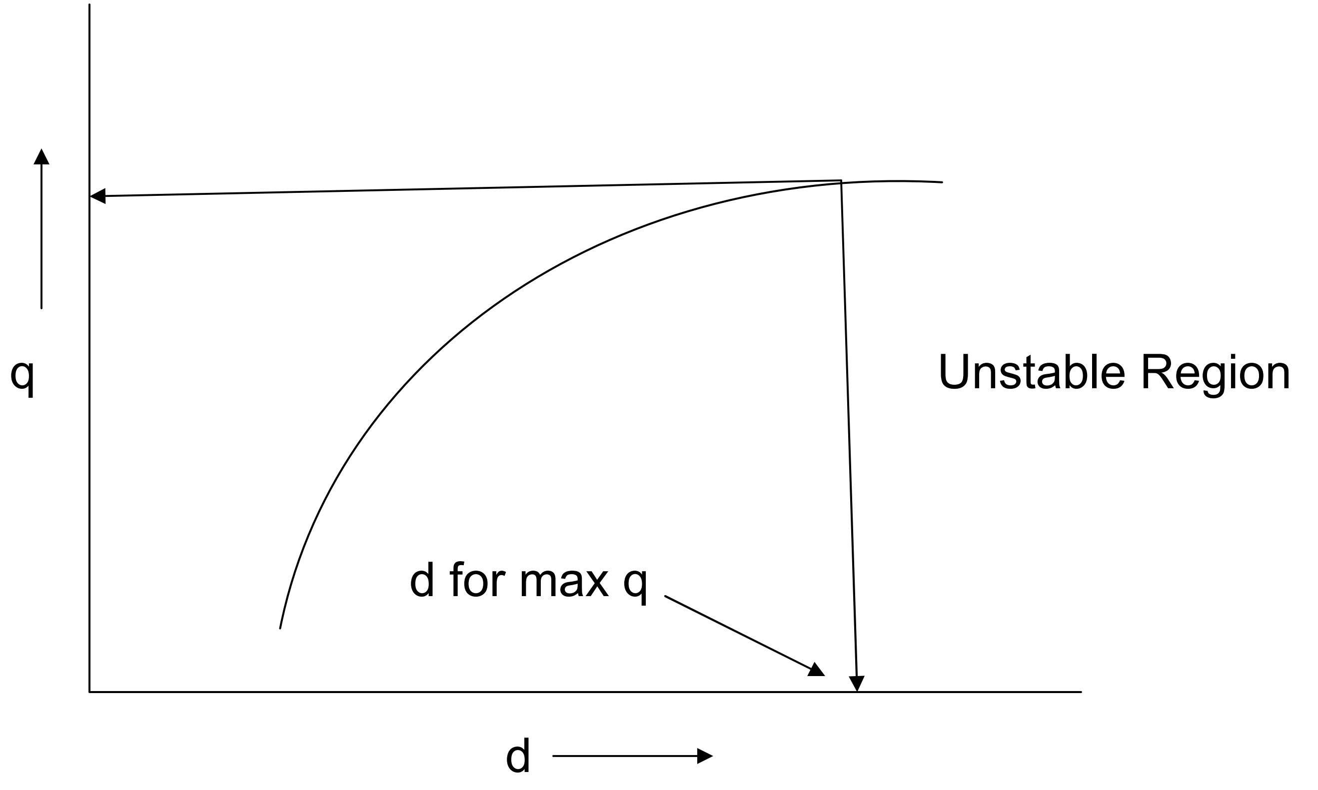
Tubing Size Optimization…

Effect of tubing Size



Tubing Size Optimization…

- Optimum Tubing Size



Optimize Perforation

- Select bottom hole flowing pressure as a node
- Inflow relationship is pressure drop through rock and pressure drop through perforations
- Inflow to Node

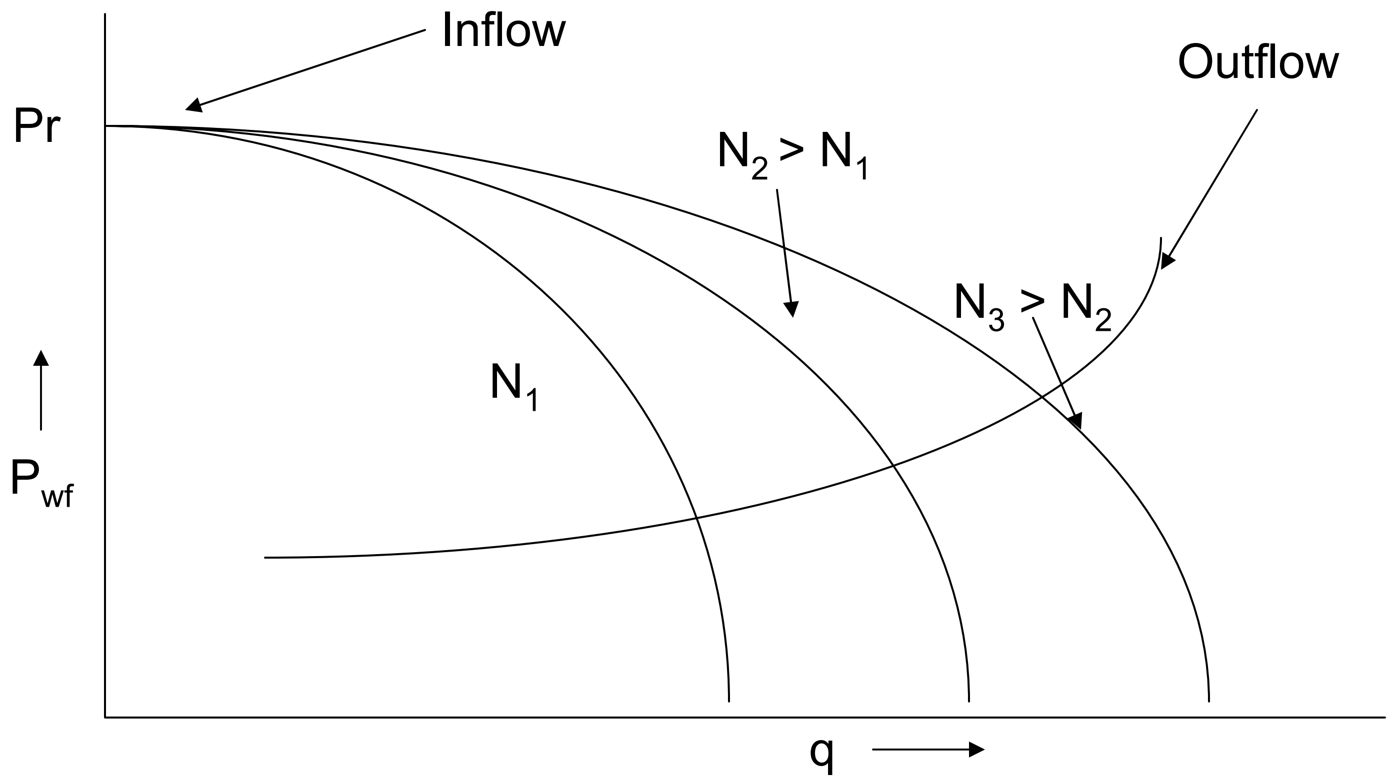
$$\bar{P}_r - \Delta P_{res} - \Delta P_{perfs} = P_{wf}$$

- Outflow from Node

$$\Delta P_{tubing} + \Delta P_{flowline} + \bar{P}_{sep} = P_{wf}$$

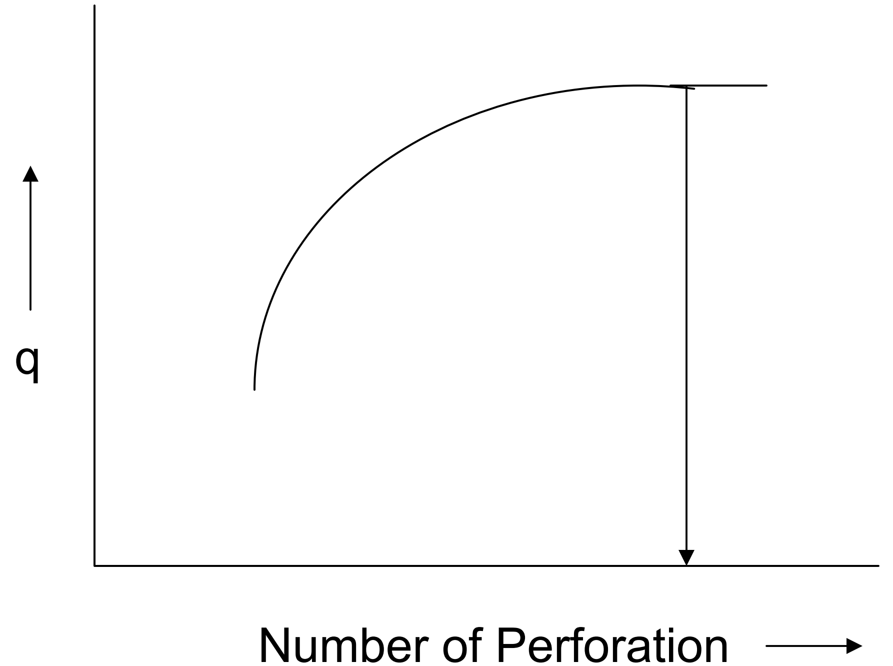
Optimize Perforation…

- Increase in Perforation will increase the flow



Optimize Perforation..

- Increase in perforation number increases flow



Optimization Procedure

- Identify the components in the system
- Select one component to be optimized
- Select the node location that will best emphasize the effect of change
- Develop expression for inflow and outflow
- Calculate pressure drop versus rate for all components
- Determine the effect of changing the characteristics of the selecting component

Optimization Procedure…

- Repeat the procedure for each component
- Optimize the production system

Applications

- Selecting Tubing Size
- Selecting Flow line Size
- Gravel Pack Design
- Surface Choking Sizing
- Subsurface Safety Valve Sizing
- Analyze Abnormal Flow Restriction
- Artificial Lift Design
- Well Simulation Evaluation

Applications…

- Analyze the effect of compression on gas well
- Analyze the perforating density
- Predicting the effect of depletion
- Allocating Injection gas among gas well lift
- Analyzing the multiwell producing system
- Relating field performance to time

Production Forecasting

- For future time
  - Construct future time IPR – Standing or Fetkovich Method
  - For Gas well Construct IPR by Jones, Blunt and Glaze method
  - select the restrictive component
  - Use Nodal analysis
  - Analyze future performance of a production system

Summary

- Very flexible approach
- Extensively used in Oil and Gas Field
- Need to calculate pressure drop accurately to and from the node
- Fluid characteristics (single or Multiple phase) are very important in pressure drop calculations
- Need good reservoir engineering concept

Summary…

- For tubing & flow line pressure drop calculation – understanding of multiphase flow is important
- It optimize one component at a time and eventually optimize the system

Conclusion

- Robust technique to analyze and optimized the system
- Widely used in the industries
- Any production software (like Pipesim, Perform etc) use this analytical technique

References

- Beggs, H. Dale: Production Optimization using nodal analysis, 2nd edition, OGCI, Petroskills, May,2003
- Nind, T.E.W.: Principals of well production, McGraw-Hill,1964
- Brown,K.E. and Beggs, H.D.: The technology of Artificial lift Methods, Vol-1, Penn Well Publ. Co, Tulsa,Oklahoma,1978
- Gilbert, W.E.: Flowing Gas-Lift Well Performance" API Drill. Production Prctice,1954

Questions ???

Correlations

- Vogel

$$q_o = q_b + \frac{JP_b}{1.8}\left[1 - 0.2\frac{P_{wf}}{P_b} - 0.8\left(\frac{P_{wf}}{P_b}\right)^2\right]$$

- Fetkovitch

$$q_o = C\left(\overline{P}_r^{\,2} - P_{wf}^{\,2}\right)^n$$

$$q_o = C_1\left(P_b^2 - P_{wf}^{\,2}\right) + C_2\left(\overline{P}_r - P_b\right)$$

- Standing

$$\frac{q_o}{q_{\max}} = \left(1 - \frac{Pwf}{\overline{P}_R}\right)\left(1 + 0.8\frac{P_{wf}}{\overline{P}_R}\right)$$

$$q_{o(F)} = q_{o(\max)F}\left[1 - 0.2\frac{p_{WF}}{\overline{P}_{RF}} - 0.8\left(\frac{P_{wf}}{\overline{P}_{RF}}\right)^2\right]$$