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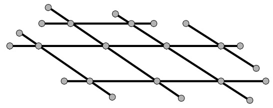
Introduction To Network Modeling



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Discussion Summary

- **Network Concepts**
  - Networks and Components
- **Modeling Basics**
  - Concepts
  - Data Features
  - Conventions

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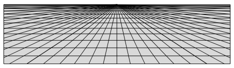
Network Concepts

- A network is any “system” of interconnected components.
- The components of a network interact and influence each other.



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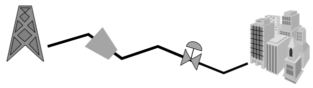
Gas System Network

- The gas system network is a series of components beginning at wells, connecting through gathering lines, compressors, pipelines, regulators, main lines, service lines, meters, and fuel lines, finally to the end use equipment.



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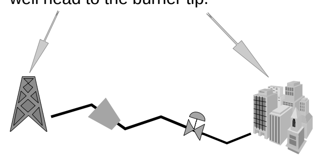
Gas System Network

- The entire system/network extends from the well head to the burner tip.



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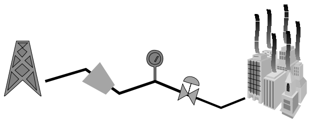
Gas Network Components

- “Material” things - pipe and equipment.
- “Measured” things - conditions and properties.



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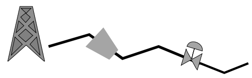
Material Components

- Pipes, Regulators, Valves, Compressors, Wells, Meters, and Fittings.



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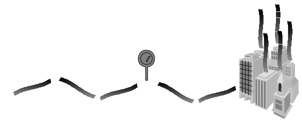
Measured Components

- Flows, Pressures, Temperatures, and Gas Properties.



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Component Interaction

- To demonstrate the component interaction, consider an example of one regulator, one pipe, and one customer.

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The Customer

- Customer has a furnace with a valve that opens and closes to let gas flow to the burner.
- The burner vents to the atmosphere through the “chimney”.

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The Regulator

- The Regulator is connected to a high pressure supply source.
- The Regulator senses downstream pressure and opens and closes to allow gas to flow into the Pipe.

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The Pipe

- The Pipe connects the Regulator to the Customer.
- Gas flows into the Regulator, through the Pipe, to and out of the burner/Customer.

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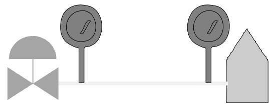
Initial Conditions

- The burner valve is closed. The burner is off. There is no load on the system. The pressures are constant and uniform.



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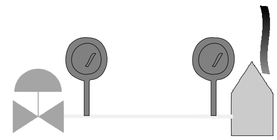
Demand Occurs

- The furnace burner valve opens and the burner turns on.



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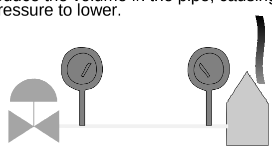
System Pressure Drops

- The flow through the burner begins to reduce the volume in the pipe, causing the pressure to lower.



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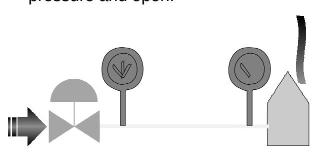
Regulator Opens

- Eventually the regulator will sense the lower pressure and open.



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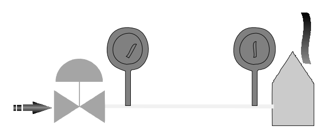
Steady State Condition

- When the flow into the regulator equals the flow leaving through the burner - the conditions are steady state.



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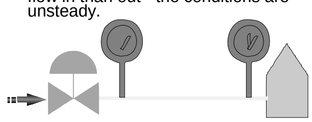
Unsteady Condition

- Eventually the burner valve closes, the burner turns off, but the regulator continues to feed until the pressure increases -more flow in than out - the conditions are unsteady.



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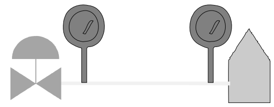
Final Conditions

- After the regulator closes, the system returns to its initial conditions - no load and constant and uniform pressures.



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Example Demonstrates...

- This example demonstrates the interaction between the material and measured components.
- The presence of steady and unsteady conditions.
- A basic characteristic of gas flow.

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Component Interaction

- The opening of the valve at the furnace burner (material) causes the gas to flow (measured).
- The pressure in the pipe (measured) lowers, causing the regulator (material) to open.
- The pipe (material) allows the gas to flow (measured) between the regulator and burner (material).

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Steady/Unsteady Conditions

- Initially the burner is closed, there is no flow (steady state).
- The burner opens, flow begins (unsteady).
- The regulator opens, pressure and flows stabilize (steady state).
- The burner closes, the regulator continues to feed (unsteady).
- Finally the regulator closes, no flow (steady state).

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Gas Flow...

- Let's consider why the gas began to flow in this example...
- The furnace burner is vented to the atmosphere.
- The pressure at the burner opening is the same as the atmosphere - basically zero.

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Gas Flow...

- The burner is connected to the regulator by way of the pipe.
- The regulator is connected to a high pressure supply source - a pressure higher than the atmospheric pressure.
- When the burner valve and regulator are open, the system pressure ranges from zero at the burner to a higher value at the regulator - basically from zero to the supply pressure.

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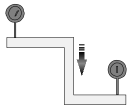
Gas Flow...

- The gas flows through the pipe from the high pressure supply at the regulator, to the low atmospheric pressure at the burner.
- Gas always flows from high to low pressure.



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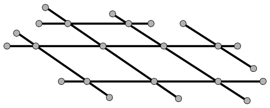
Modeling Basics



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Modeling - What is it?

- It is a way of simulating the conditions and interactions which occur in a network system.
- In our case it is used to simulate the pressures and flows in a gas system - as a way to understand the interactions between the demands, the pressures in the system, and the flows in the pipes.

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Modeling - How?

- By representing a piping system using mathematical equations.
- A network model uses flow and pressure drop equations to establish the relationships between the pipes and demands in the system.

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Modeling - How?

- These equations are manipulated to form the “model”.
- Their solution is generally complex and repetitious - it’s most efficiently done using specialized computer software.

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Modeling - Why?

- It is useful for design, analysis, and troubleshooting of a system.
- Ideas and designs can be tried in the office before implementing in the field.
- Configurations can be tried, pipe sizes checked, and the affect of changing demands explored.

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Model Components

- Pipes
- Customers
- Nodes

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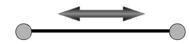
Pipes - Hydraulic Elements

- Represent the elements that the gas flows through. These are the “conducting“ elements such as pipes, valves, and regulators. They represent the material components of the network.



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Nodes - Connections

- Nodes represent pipe ends. They are locations where pipes are connected together and where pipes end. For example tees, reducers, and caps.

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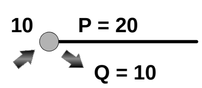
Nodes - Pressure & Load Points

- Nodes also represent locations where gas is allowed to leave or enter the system, and locations where pressure values are calculated. They are usually assigned a name or number to identify them.



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Customers - Demands

- The definition of a “customer” or demand depends on the system type...
- **Distribution -** Appliance and equipment usage.
- **Transmission -** Gate station and large plant flows.
- **Gathering -** Compressor flows or interconnects.

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Mathematical Concepts

- Flow Equations
- Kirchoff's Rules
- Solution Method

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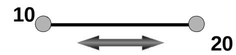
Flow Equations

- The "flow" equation relates the node pressures and pipe flows.



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General Pipe Flow

- $Q = (P_{IN}^2 - P_{OUT}^2)^{½} \div R$
- Where,

  Q = Volumetric flow rate

  $(P_{IN}^2 - P_{OUT}^2)^{½}$ = Pressure drop

  P_{IN} & P_{OUT} = Inlet and outlet pressures

  R = Pipe's resistance to flow

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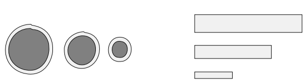
Resistance

- What affects resistance...
- Pipe size and length.
- Gas properties and temperature.



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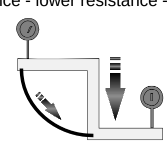
Resistance/Flow Relationship

- Flow tends to follow the path of least resistance - lower resistance - more flow.



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Kirchoff's Rules

- Basically two rules apply to a model of a gas system network...
- One is related to pressures
- One is related to flows

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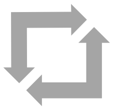
Kirchoff's Rules - Pressure

- The sum of the pressure drops around a loop must equal zero - in other words there can only be one pressure value at any location.



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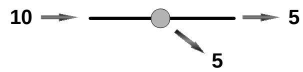
Kirchoff's Rules - Flow

- The sum of the flows in to and out of a node must equal zero - in other words gas cannot be produced or lost at a node -all the gas that enters a tee leaves a tee.



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Solution Method

- Uses the Flow Equations and Kirchoff Rules to establish the interactions between the pipes and nodes.
- Because of the complexity of the equations and interactions, it uses a trial and error solution.

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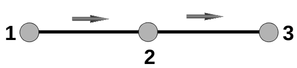
Solution Method

- Started by "guessing" the node pressures...



P_1, P_2, P_3 = Guess

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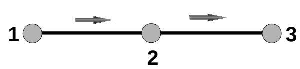
Solution Method

- From Flow Equations...



$$Q_{12} = (P_1^2 - P_2^2)^{½} \div R_{12}$$
$$Q_{23} = (P_2^2 - P_3^2)^{½} \div R_{23}$$

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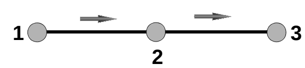
Solution Method

- From Kirchoff's Flow Rule...



$Q_{12} = Q_{23}$

Does it?

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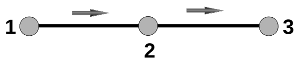
Solution Method

- Check Kirchoff Rule...



No - Because of Guesses

$$Q_{12} \neq Q_{23}$$

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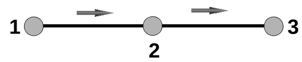
Solution Method

- The difference is referred to as the "error".



$$Q_{12} - Q_{23} = \text{Error}$$

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Solution Method

- The error is used to calculate new pipe flows, and the new pipe flows are used to calculate new node pressures.

Error >>> Q_{IN-New} , $Q_{OUT-New}$

$$P_{2-New} = (P_1^{\,2} - (Q_{IN-New} \times R_{12})^2)^{1/2}$$

$$P_{3-New} = (P_2^{\,2} - (Q_{OUT-New} \times R_{23})^2)^{1/2}$$

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Solution Method

- This process is performed for every node in the model.
- The Kirchoff Rule is then checked again and if not satisfied the errors are used to calculate new node pressures.
- This process is repeated again and again...

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Solution Method

- Each guess and check is referred to as an iteration.
- Iterations are performed until the Kirchoff Rule is satisfied
- Or so we say...

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Solution Method

- Because of the non-linear flow equations an exact solution cannot generally be obtained.
- The Kirchoff Rules cannot exactly be met.
- So, the idea of a tolerance is introduced.

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Tolerance

- The tolerance is used to specify how closely the Kirchoff Rule should be satisfied.
- It establishes the largest acceptable node "error" for the model solution.

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Tolerance

- Generally node errors start large and get smaller - this is called convergence.
- The model is said to be "balanced" when the "error" at each node "converges" to less than the tolerance.

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Summary...

- Network components are interrelated and affect other components.
- A gas system is a network consisting of material and measured components that can be represented by various mathematical equations.

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Summary...

- Gas moves from high pressure to low pressure - no demand, no flow. Gas flow tends to follow the path of least resistance.
- Changes in the system start at a steady-state, transition through a dynamic unsteady state to arrive at another steady state.

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Summary...

- Our modeling will only involve study of the steady state condition.
- Pipes carry gas, nodes connect pipes, and customers establish demands.

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Summary...

- The pipes and nodes are related by the pipe flow equations.
- A trial and error method is used to balance the system.
- And an exact solution is never achieved.

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Questions...

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