Physics of Gas Piping

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We make things work for you.

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We have the **energy** to make things better … for you, for our investors and for our stakeholders

Physics of Gas Piping – Agenda

- Ideal Gas Equation
  - Avogadro's Law
  - Charles' Law
  - Boyle's Law
- Sizing Gas Piping
  - Longest Length Method
  - Branch Length Method
- PSE&G's HTNP Requirements (Revised – 2016)
- Web Access
  - PSE&G Gas Appliance & Piping (GAP) Manual
  - PSE&G Construction Inquiry

Ideal Gas Equation

- The "Ideal Gas Equation" is formulated from a combination of 3 Gas Laws:
  - **Boyle's Law** (relates P and V),
  - **Charles' Law** (relates V and T) and
  - **Avogadro's Law** (relates V and chemical amount)

Ideal Gas Equation – History

- **Benoit Clapeyron** (1799–1864) was a French engineer and physicist known for his work in Thermodynamics.
- Designed several railroads and steam engines.
- Expanded on work of Nicolas Carnot (known for "Carnot Engine Cycle").
- Formulated the "Ideal Gas Equation".

Ideal Gas Equation

- "**Ideal Gas**": Hypothetical gas whose molecules occupy negligible space and have no interactions.
- Ideal Gas is just a concept since real gas molecules take up space and interact with each other.
- Good "rule-of-thumb" approximation of gases under **low pressure** and **high temperature.**
  - Accurate within 5%.

Ideal Gas Equation

- A gas has 4 measurable characteristics that describe its physical state:
  - Volume (V)
  - Pressure (P)
  - Temperature (T)
  - Mass
- These 4 characteristics are related by the Ideal Gas Equation:

$$PV = nRT$$

Where:

- **R**: universal gas constant: 8.314 J/(mol K), convert units as needed
- **n**: # of moles (chemical amount – measure of mass)
- **T**: Absolute temperature scale where 0 degrees is the lowest temperature.
- **P**: absolute pressure (gauge + atmospheric).

Ideal Gas Equation

- Rearrange : $\frac{PV}{nRT} = 1$
- Equate a gas at 2 different states:

$$\frac{P_1V_1}{n_1RT_1} = \frac{P_2V_2}{n_2RT_2}$$

Absolute Temperature and Pressure

Absolute Temperature:

- Temperature scale where 0 degrees is the lowest possible temperature.
- Units:
  - Kelvin: [°K] = [°C] + 273.15
  - Rankine: [°R] = [°F] + 459.67

Absolute Pressure:

- Pressure scale where 0 is a perfect vacuum, as opposed to gauge pressure which measures atmospheric pressure as 0.
- Units: Psia: PSI (Absolute) includes 14.7 PSI at sea level: [psia] = [psi] + 14.7

Avogadro's Law

- *Based on concept that "any gas under the same conditions will occupy a specified volume".*

Avogadro's Law

- **Amadeo Avogadro** (1776-1856) was an Italian chemist who hypothesized that volume of a gas is related to number of molecules under constant temperature and pressure.
- **Avogadro's Law**: As the number of molecules of a gas increases, the volume increases.
- It was proven to be true, and in 1909 "Avogadro's Number" was quantified.

Avogadro's Law

- **Avogadro's Number**: Number of molecules of *any* gas under standard temperature (0°C), and pressure (atmospheric) occupying 22.4 liters: 6.022×10^{23} (602 sextillion) molecules = 1 mole ("n")
- 1 mole of ***any gas*** at standard temperature and pressure will occupy 22.4 liters.

Charles' Law – History

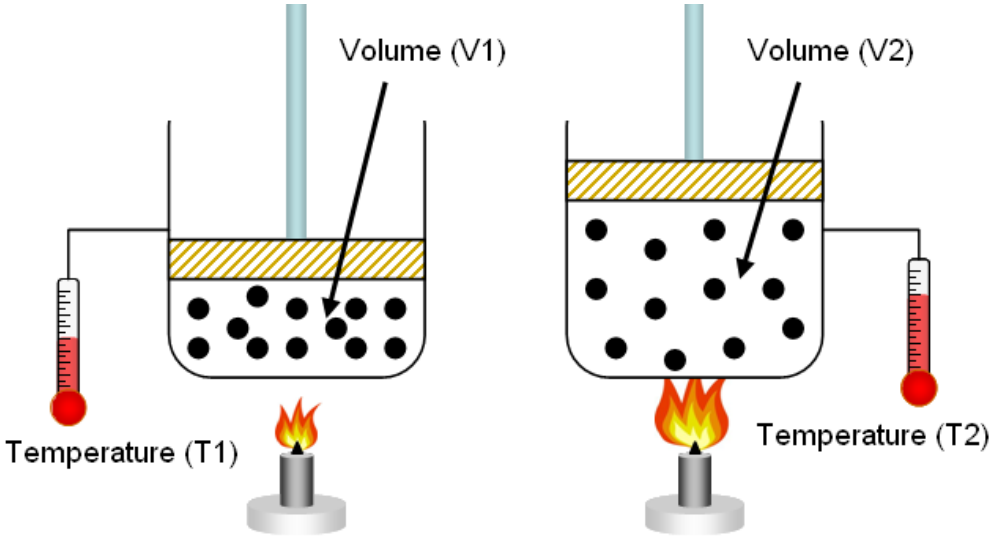
- Formulated by **Joseph Louis Gay-Lussac** in 1802, and attributed to unpublished work by **Jacques Charles**.
- **Jacques Charles** (1746-1823) was a French inventor, scientist, financier, mathematician, and balloonist.
- Worked with Robert brothers to develop the world's first unmanned hydrogen balloon in Aug1783.
- Was the first to ride a hydrogen balloon, and ascended 1,800 ft.
  - Hydrogen was produced from a reaction of sulfuric acid and iron.

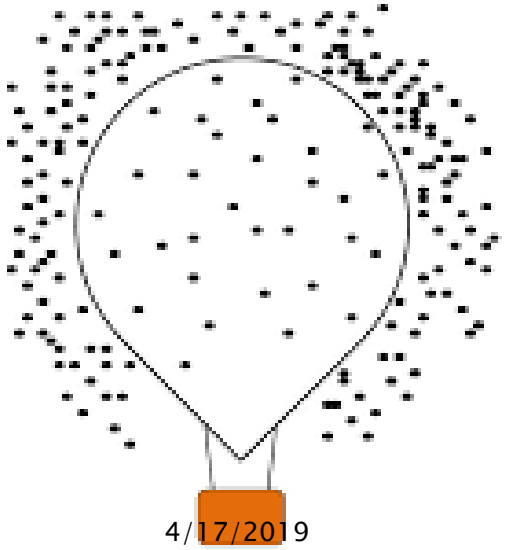
Charles' Law

Charles' Law: Volume of a gas is directly proportional to its absolute temperature (temperature scale where 0 degrees is the lowest temperature) under constant pressure.

- **Gases expand when heated!** Heating a gas gives the molecules more energy to bounce off the walls, causing it to expand.

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$





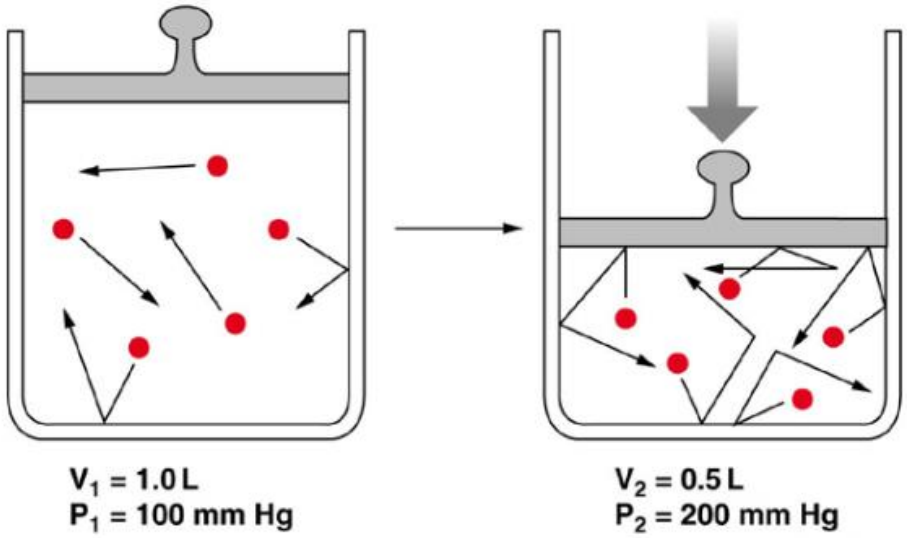
Boyle's Law – History

Robert Boyle (1627–1691) was the most influential scientist born in Ireland. He was a philosopher, chemist, physicist, and inventor; also considered as "father of chemistry."

- Left Ireland for England out of frustration and for a better education.
- **Boyle's Law**: Relationship between pressure and volume of gas under constant temperature. This observation was confirmed through experiments, and was published in 1662.

Boyle's Law

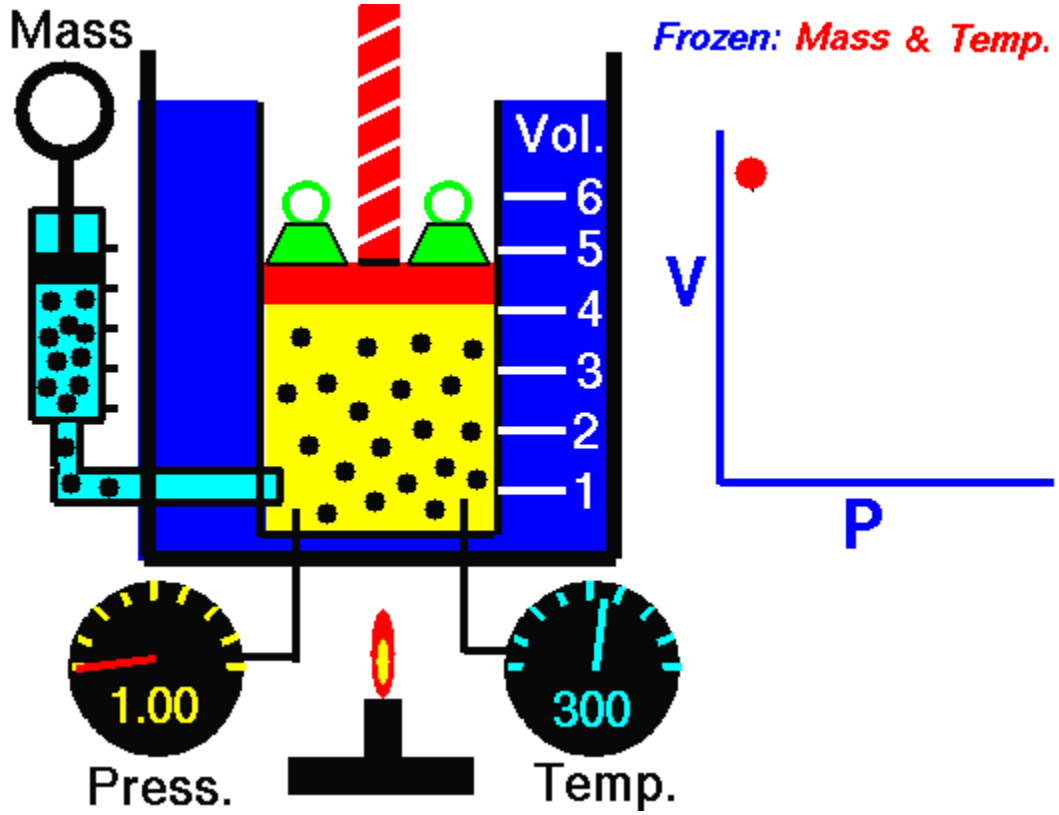
- **Equation**: $P_1 V_1 = P_2 V_2$ (from: $\frac{P_1 V_1}{n_1 R T_1} = \frac{P_2 V_2}{n_2 R T_2}$)
- **Units**: Keep them consistent – Make sure they cancel properly.
- **Explanation**: Product of pressure and volume of container is constant for a gas under constant Temp. and mass.



Decreasing volume increases collisions and increases pressure.

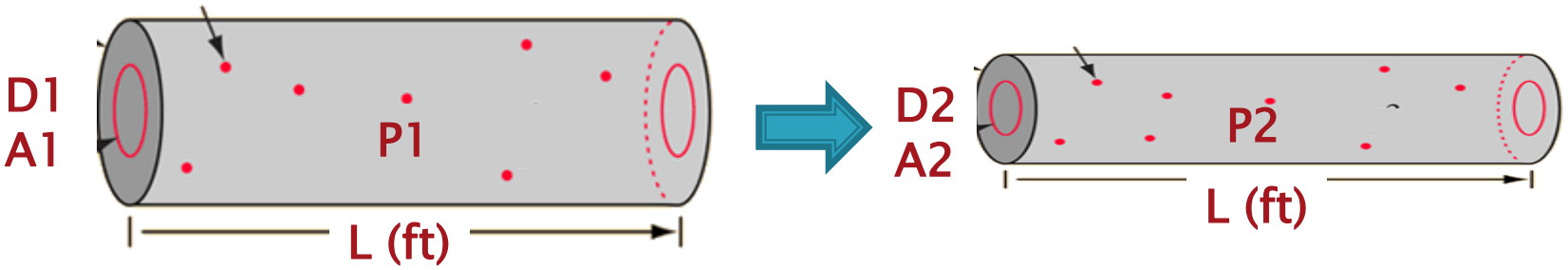
Boyle's Law

Decreasing volume increases collisions and increases pressure.



Boyle's Law – Gas Piping

- Boyle's Law applied to gas piping tells us that, under constant temperature (and holding the amount of gas/load constant), the product of absolute pressure and volume of the container is constant.
- **Volume**: Cross sectional area x Length of pipe
- The same amount ("mass") of gas ("load") in a smaller diameter pipe will have higher pressure.



$$(P_1)(\pi {r_1}^2)L = (P_2)(\pi {r_2}^2)L$$

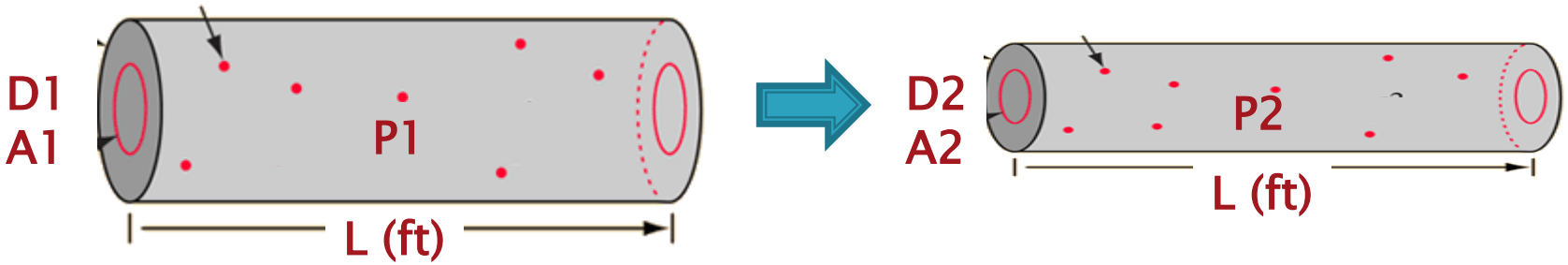
P1 < P2; V1 > V2

$* \ r = d/2$

Boyle's Law – Gas Piping

- **Effect of pipe sizing on pressure with constant load:**

- **Example**: Gas pressure through 30 ft of ¾" nominal diameter house piping is ¼ psi (7" w.c). If the piping is replaced with ½" piping, what will the new pressure be?



Boyle's Law – Gas Piping

- **Effect of pipe sizing on pressure with constant load:**
- **Example**: Gas pressure through 30 ft of ¾" nominal diameter house piping is ¼ psi (7" w.c). If the piping is replaced with ½" piping, what will the new pressure be?

$$P_1\left(\pi\left(\frac{D_1}{2}\right)^2 L\right) = P_2\left(\pi\left(\frac{D_2}{2}\right)^2 L\right) \qquad * \; r = d/2$$

$$P_2 = \frac{V_1 P_1}{V_2} = \frac{\left(\pi\left(\frac{D_1}{2}\right)^2 L\right) P_1}{\left(\pi\left(\frac{D_2}{2}\right)^2 L\right)} = \frac{D_1^2 \; P_1}{D_2^2}$$

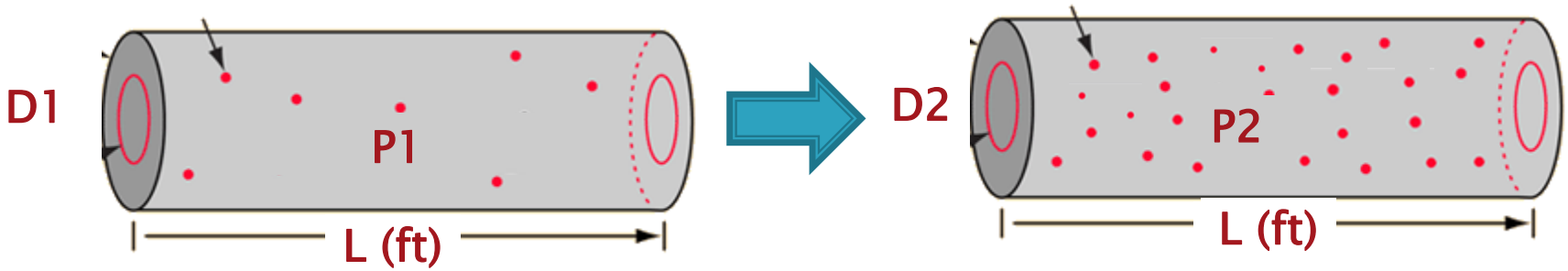
$$= \frac{(0.75")^2(0.25 + 14.7)psia}{(0.5")^2} = 33.6 \text{ psia} = \boxed{18.9} \text{ psi gauge}$$

Boyle's Law Example – Increasing Load

Increasing load without changing pipe size (volume), will affect pressure:

$$\frac{P_1 V_1}{n_1 R T_1} = \frac{P_2 V_2}{n_2 R T_2} \rightarrow \frac{P_1}{n_1} = \frac{P_2}{n_2} \rightarrow \frac{P_1}{\text{capacity}_1} = \frac{P_2}{\text{capacity}_2}$$

Increased capacity → Increased pressure



(More collisions with container)

Effect of Load Changes

- Effect on **pressure** from increasing **load** without changing pipe size:
- **Ex**: Gas pressure through ¾" house piping is 1/4 psi (7" w.c.) which supplies a 40,000 BTU/hr appliance. If the appliance is replaced by a 90,000 BTU/hr appliance without changing pipe sizing, what will the new pressure be?

$$\frac{P_1V_1}{n_1RT_1} = \frac{P_2V_2}{n_2RT_2} \rightarrow \frac{P_1}{n_1} = \frac{P_2}{n_2} \rightarrow \boxed{P_2 = \frac{Capacity_2 P_1}{Capacity_1}}$$

- Absolute P= gauge P+ atmospheric P (14.7 psi)

$$P_2 = \frac{capacity_2 P_1}{capacity_1} = \frac{\left(90{,}000\frac{BTU}{hr}\right)(0.25+14.7)psia}{\left(40{,}000\frac{BTU}{hr}\right)} =$$

$$33.6\ psia = \boxed{18.9}\ \text{psi gauge}$$

Sizing Gas Piping

- Refer to IFGC Section 402.3 (Pipe Sizing) and 402.4 (sizing tables and equations) for more details:
  - https://codes.iccsafe.org/content/IFGC2018/chapter-4-gas-piping-installations
- Must use:
  - Pipe sizing tables or equations in sections 402.4 or 402.5
  - Sizing tables in manufacturer's instructions
  - Other approved engineering method

Gas Pipe Sizing Equations

Use proper pipe sizing equation from IFGC depending on inlet pressure.

Low-pressure gas equation (<1.5 psi):

$$D = \frac{Q^{0.381}}{19.17\left(\frac{\Delta H}{C_r * L}\right)^{0.206}}$$

High-pressure gas equation (>1.5 psi):

$$D = \frac{Q^{0.381}}{18.93\left[\left(\frac{(P1^2 - P2^2) * Y}{C_r * L}\right)\right]^{0.206}}$$

- D: actual inner diameter (in.)
- Q: maximum capacity (CFH)
- L: equivalent length of pipe (ft)
- ΔH: pressure drop (in. w.c) – *(27.7 in. w.c = 1 psi)
- P1: Upstream pressure (psia – add 14.7)
- P2: Downstream pressure (psia – add 14.7)
- C_r: Factor for viscosity, and T (0.6094 for natural gas)
  Y: Super expansibility factor (0.9992 for natural gas)

Gas Pipe Sizing Equations

- **Example**: Calculate pipe diameter for 600 CFH, 30 ft long pipe, with inlet pressure <0.25 psi (7 in w.c.), and a pressure drop of 0.5 in. w.c.:

Use low-pressure gas equation (<1.5 psi):

$$D = \frac{Q^{0.381}}{19.17\left(\frac{\Delta H}{C_r * L}\right)^{0.206}}$$

$$D = \frac{(600\ CFH)^{0.381}}{19.17\left(\frac{(0.5\ in\ w.c.)}{0.6094 * 30\ ft}\right)^{0.206}} = \boxed{1\ {}^{1}/_{4}"}$$

Gas Pipe Sizing Table

Use proper natural gas pipe sizing table from IFGC depending on:

- Pipe material
- Inlet pressure
- Pressure drop
- Specific gravity

Table below from IFGC 2012 Table 402.4(2):

SCHEDULE 40 METALLIC PIPE

GAS:	**NATURAL**
INLET PRESSURE:	**LESS THAN 2 PSI**
PRESSURE DROP:	**0.5 in w.c.**
SPECIFIC GRAVITY:	**0.60**

PIPE SIZE (inch)														
NOMINAL:	1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3	4	5	6	8	10	12
ACTUAL ID:	0.622	0.824	1.049	1.380	1.610	2.067	2.469	3.068	4.026	5.047	6.065	7.981	10.020	11.938
LENGTH (ft)	**CAPACITY IN CUBIC FEET OF GAS PER HOUR**													
10	172	360	678	1,390	2,090	4,020	6,400	11,300	23,100	41,800	67,600	139,000	252,000	399,000
20	118	247	466	957	1,430	2,760	4,400	7,780	15,900	28,700	46,500	95,500	173,000	275,000
30	95	199	374	768	1,150	2,220	3,530	6,250	12,700	23,000	37,300	76,700	139,000	220,000
40	81	170	320	657	985	1,900	3,020	5,350	10,900	19,700	31,900	65,600	119,000	189,000
50	72	151	284	583	873	1,680	2,680	4,740	9,660	17,500	28,300	58,200	106,000	167,000
60	65	137	257	528	791	1,520	2,430	4,290	8,760	15,800	25,600	52,700	95,700	152,000
70	60	126	237	486	728	1,400	2,230	3,950	8,050	14,600	23,600	48,500	88,100	139,000
80	56	117	220	452	677	1,300	2,080	3,670	7,490	13,600	22,000	45,100	81,900	130,000
90	52	110	207	424	635	1,220	1,950	3,450	7,030	12,700	20,600	42,300	76,900	122,000

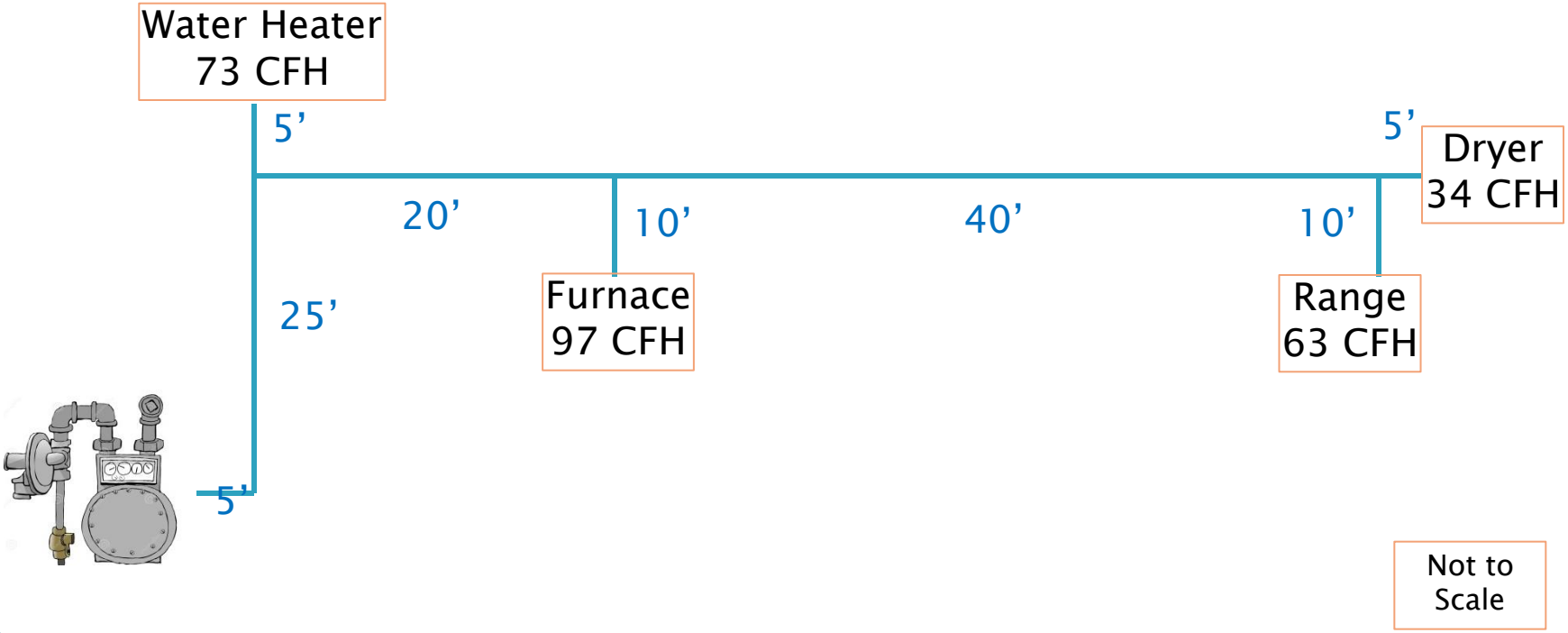
Sizing Gas Piping

- **Longest Length Method**: (see IFGC 402.4.1)
  - **1)** Obtain capacity for each appliance (CFH). Use proper energy content (1,030 BTU/CF for PSE&G).
  - **2)** Measure the longest path from meter to appliance (ft). Use that distance and capacity of downstream appliances to obtain pipe size from the table.
  - **3)** Get pipe size from appropriate table.

Note: Account for equivalent length of pipe due to fittings when determining length of pipe.

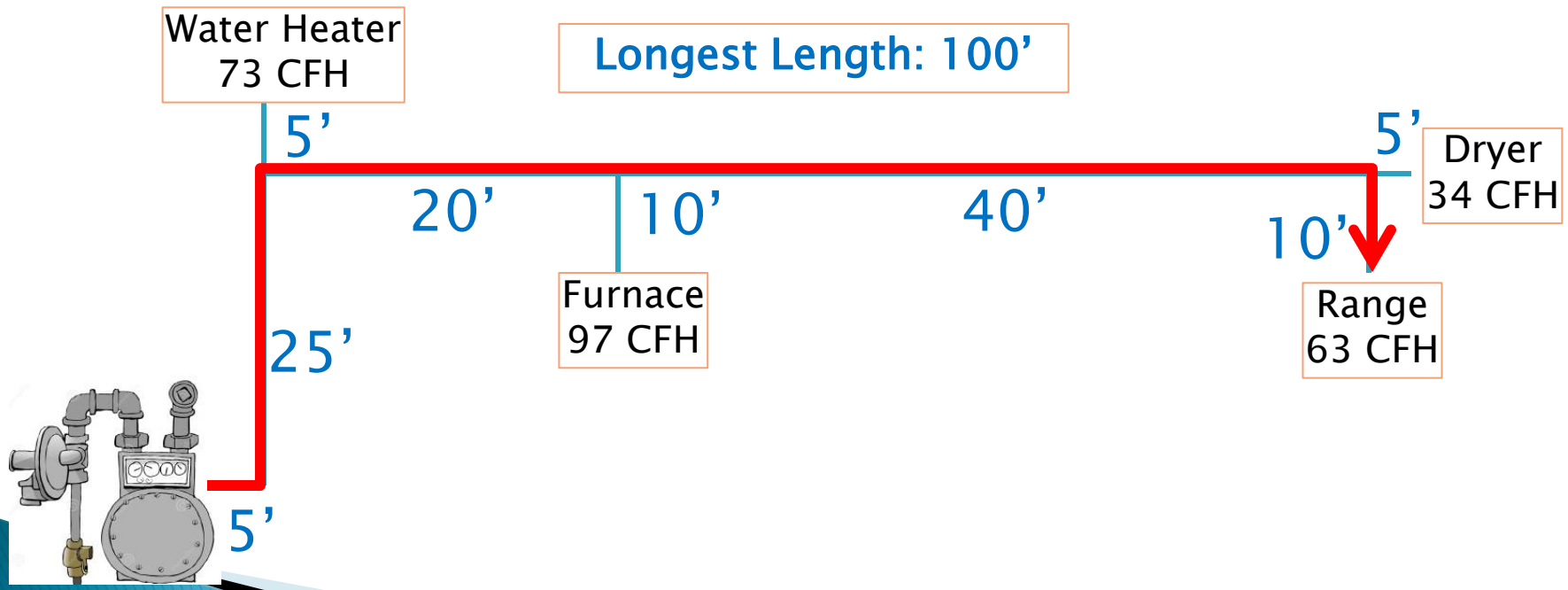
Ex 1: Longest Length Method

Q: The schematic below shows lengths of gas piping to 4 appliances with max usage listed. Determine pipe sizing for all sections:



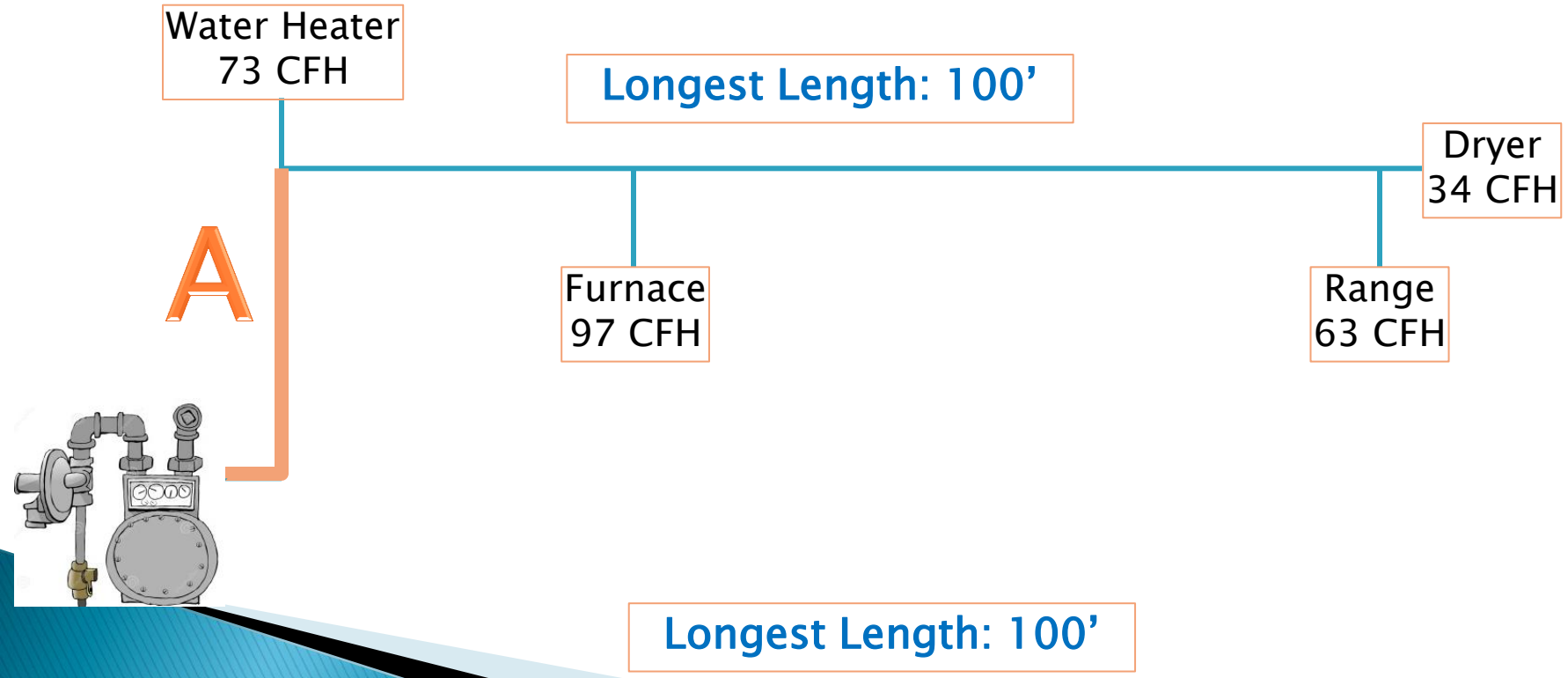
Ex 1: Longest Length Method

- First, determine **longest length** of pipe from meter to appliance. Use this for sizing **all** sections of pipe.
- For each pipe section, add loads of all downstream appliances and use longest length. Then, determine pipe size from table.



Ex 1: Longest Length Method

- Start with section A:
  - Load: add **all** appliances:
    - 73 CFH + 97 CFH + 63 CFH + 34 CFH = **267 CFH**
  - Use longest length of **100'**



Ex 1: Longest Length Method

- Start with section A:
  - Load: **267 CFH**; length: **100'**
  - Nominal pipe diameter from table: **1 ¼"**
  - **Note:** Round up length and capacity to nearest values in the table.

SCHEDULE 40 METALLIC PIPE

										GAS:	NATURAL			
										INLET PRESSURE:	LESS THAN 2 PSI			
										PRESSURE DROP:	0.5 in w.c.			
										SPECIFIC GRAVITY:	0.60			
PIPE SIZE (inch)														
NOMINAL:	1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3	4	5	6	8	10	12
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LENGTH (ft)	CAPACITY IN CUBIC FEET OF GAS PER HOUR													
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30	95	199	374	768	1,150	2,220	3,530	6,250	12,700	23,000	37,300	76,700	139,000	220,000
40	81	170	320	657	985	1,900	3,020	5,350	10,900	19,700	31,900	65,600	119,000	189,000
50	72	151	284	583	873	1,680	2,680	4,740	9,660	17,500	28,300	58,200	106,000	167,000
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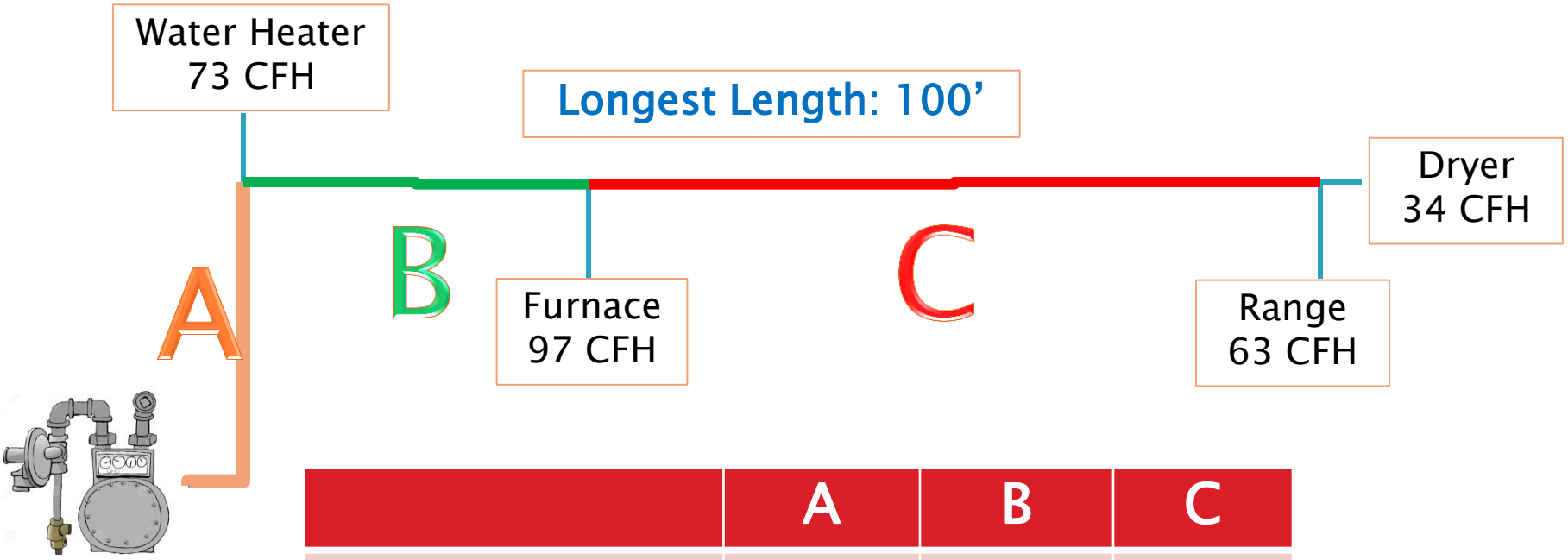
90	52	110	207	424	635	1,220	1,950	3,450	7,030	12,700	20,600	42,300	76,900	122,000
100	50	104	195	400	600	1,160	1,840	3,260	6,640	12,000	19,500	40,000	72,600	115,000
125	44	92	173	355	532	1,020	1,630	2,890	5,890	10,600	17,200	35,400	64,300	102,000

Ex 1: Longest Length Method

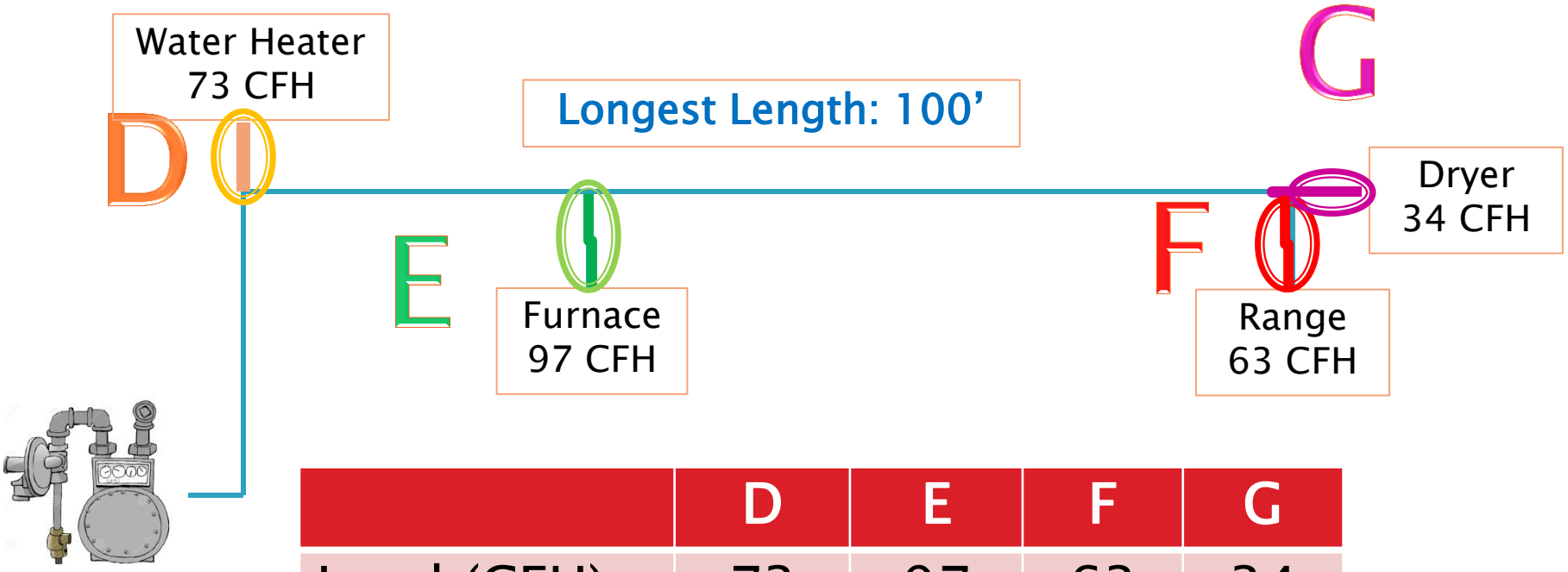
- Repeat for all other pipe sections:



	A	B	C
Load (CFH)	267	194	97
Length (ft)	100	100	100
Pipe Size (in)	1 ¼“	1”	¾”

Ex 1: Longest Length Method

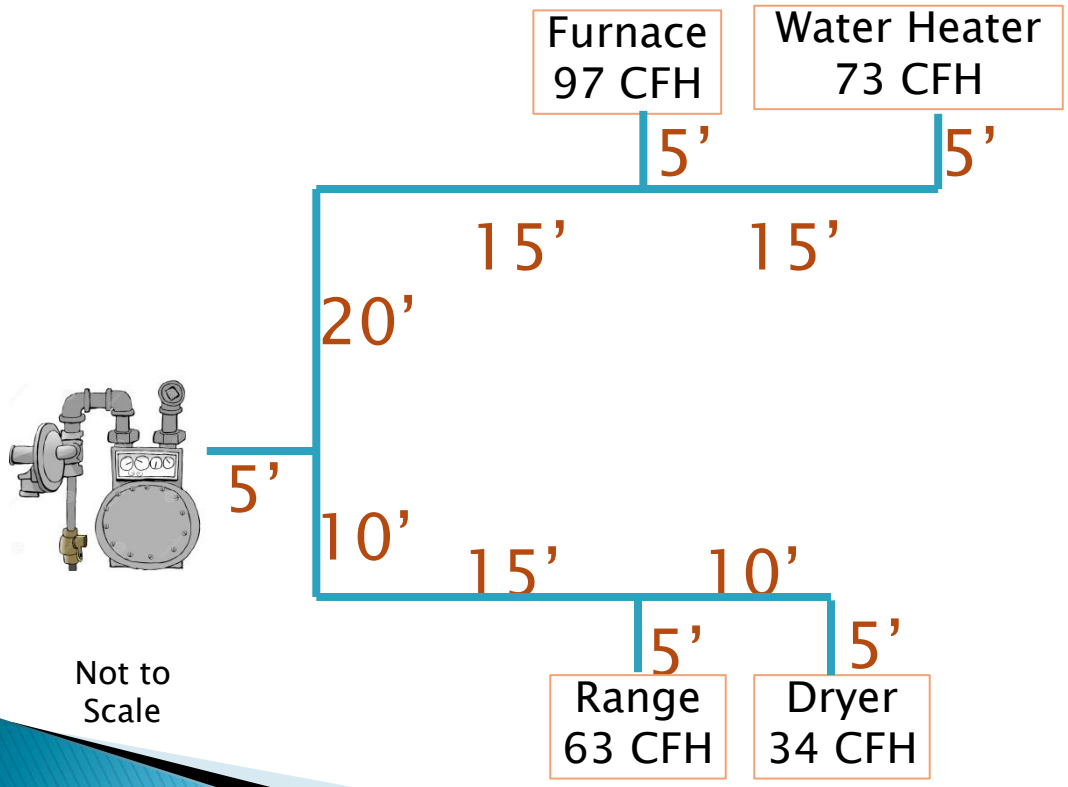
- Repeat for all other pipe sections:



	D	E	F	G
Load (CFH)	73	97	63	34
Length (ft)	100	100	100	100
Pipe Size (in)	¾"	¾"	¾"	½"

Ex 2: Branch Length Method

Q: The schematic below shows lengths of gas piping to 4 appliances with max usage listed. Determine pipe sizing for all sections:



This layout has 2 branches.

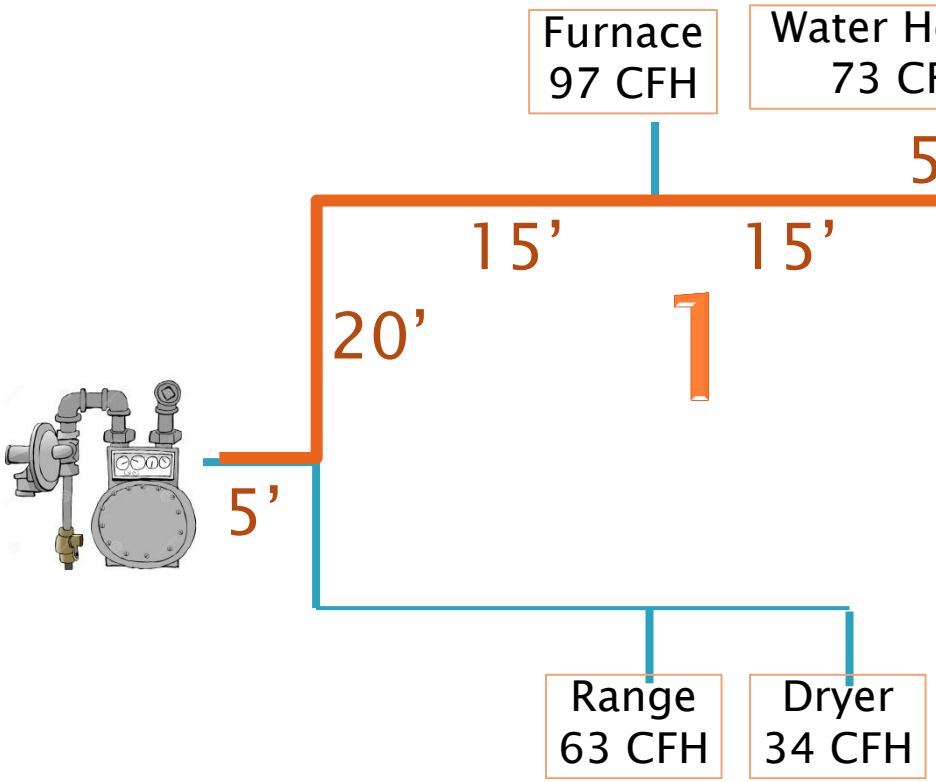
Step 1: Determine longest length for **each branch.**

Step 2: Use this length and sum of all downstream appliances for each section.

Step 3: Look up pipe size in table.

For more information, see IFGC section 402.4.2

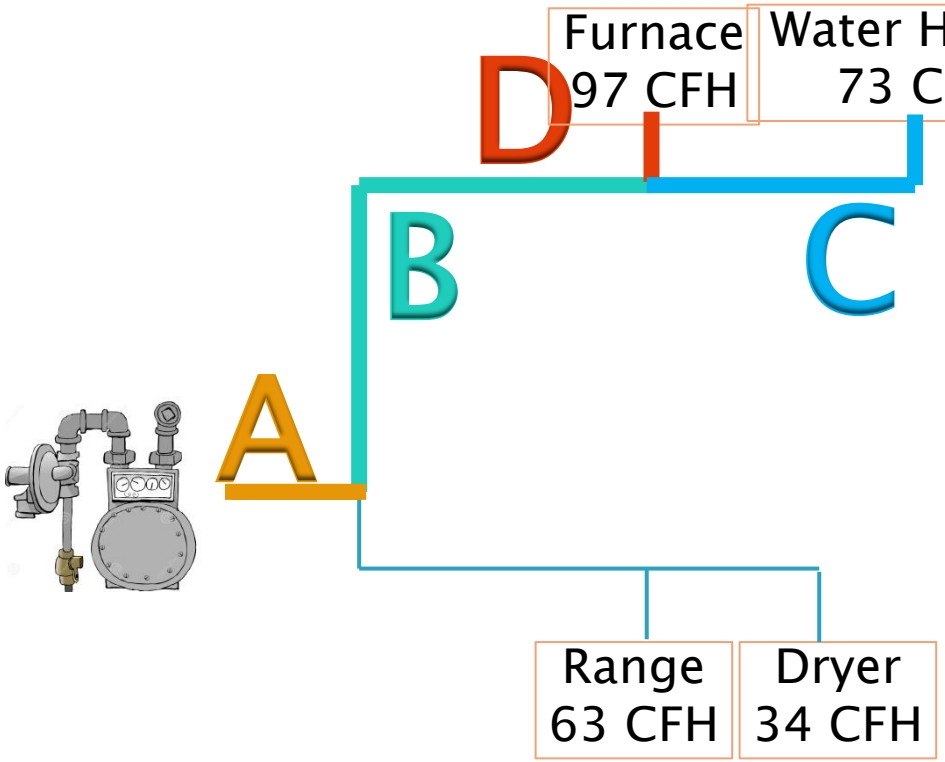
Ex 2: Branch Length Method



Step 1: Determine longest length for **each branch.**

Start with longest branch:
Branch 1: **65'**

Ex 2: Branch Length Method



Branch 1 longest length: 65’

Step 2: Use this length and sum of all downstream appliances for each section.

	A	B	C	D
Load (CFH)	267	170	73	97
Length (ft)	65’	65’	65’	65’
Pipe Size (in)	1 ¼“	1”	¾”	¾”

Ex 2: Branch Length Method

Step 3: Look up pipe size in table.

Note: Round up to nearest values in the table.

SCHEDULE 40 METALLIC PIPE

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PRESSURE DROP:	0.5 in w.c.
SPECIFIC GRAVITY:	0.60

PIPE SIZE (inch)														
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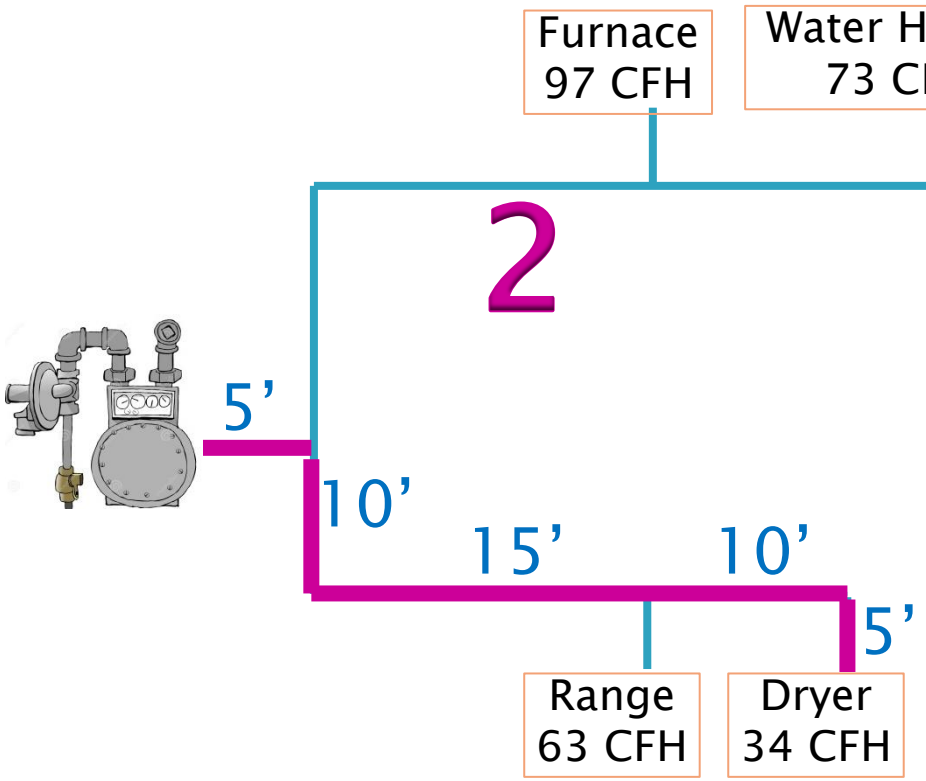
125													64,300	102,000

	A	B	C	D
Load (CFH)	267	170	73	97
Length (ft)	65’	65’	65’	65’
Pipe Size (in)	1 ¼“	1”	¾”	¾”

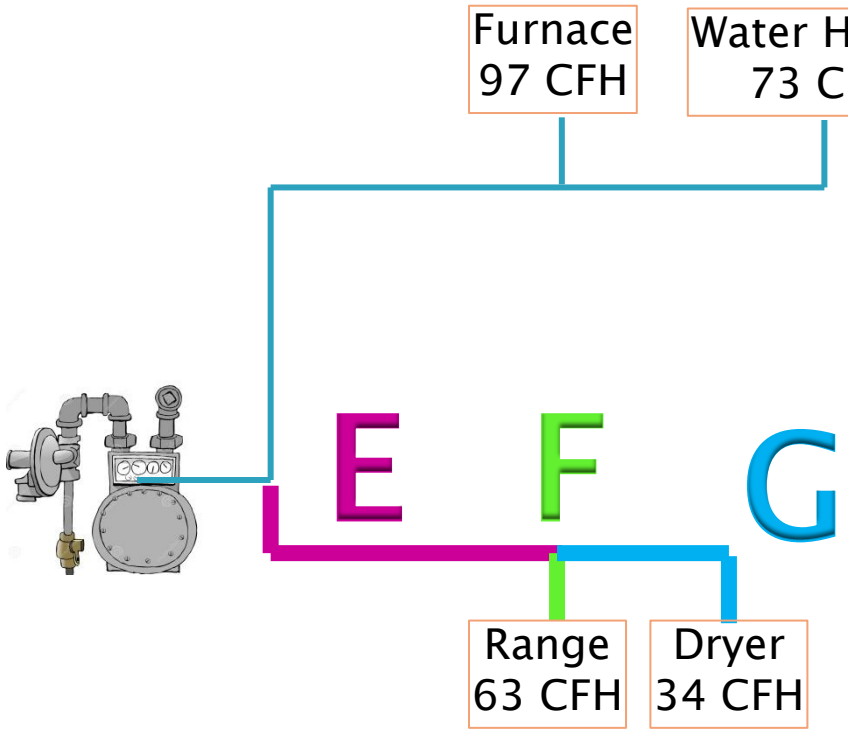
Ex 2: Branch Length Method



Repeat for 2nd branch:
Branch 2 longest length: 4**5’**

Step 2: Use this length and sum of all downstream appliances for each section.

Ex 2: Branch Length Method



Repeat for 2nd branch:
Branch 2 longest length: 45’

Step 2: Use this length and sum of all downstream appliances for each section.

Step 3: Look up pipe size in table.

	E	F	G
Load (CFH)	97	63	34
Length (ft)	45’	45’	45’
Pipe Size (in)	¾”	½”	½”

PSE&G's Higher than Normal Pressure (HTNP) Requirements

- New HTNP Regulator Installations (1 PSIG)
  - Customer's "Lock-Up" Medium Pressure (MP) regulator must be approved under the following conditions:
    - Must contain a manufacturer's inlet rating of 5 psig or better.
    - Must comply with IFGC Section 410 for MP regulators.
  - For CSST/Copper, the delivered pressure cannot exceed 3 psig upon regulator failure.

PSE&G's Higher than Normal Pressure (HTNP) Requirements

- Pressure Test Requirements:
  - Residential CSST or copper tubing receiving 1 psi shall be tested to 3 psi.
  - All other piping receiving regulated HTNP shall be tested to 15 psi.
  - In accordance with IFGC Section 406.3.3, where the piping system is connected to appliances or equipment designed for operating pressures of less than the test pressure, such appliances or equipment shall be isolated from the piping system by disconnecting them and capping the outlet(s).

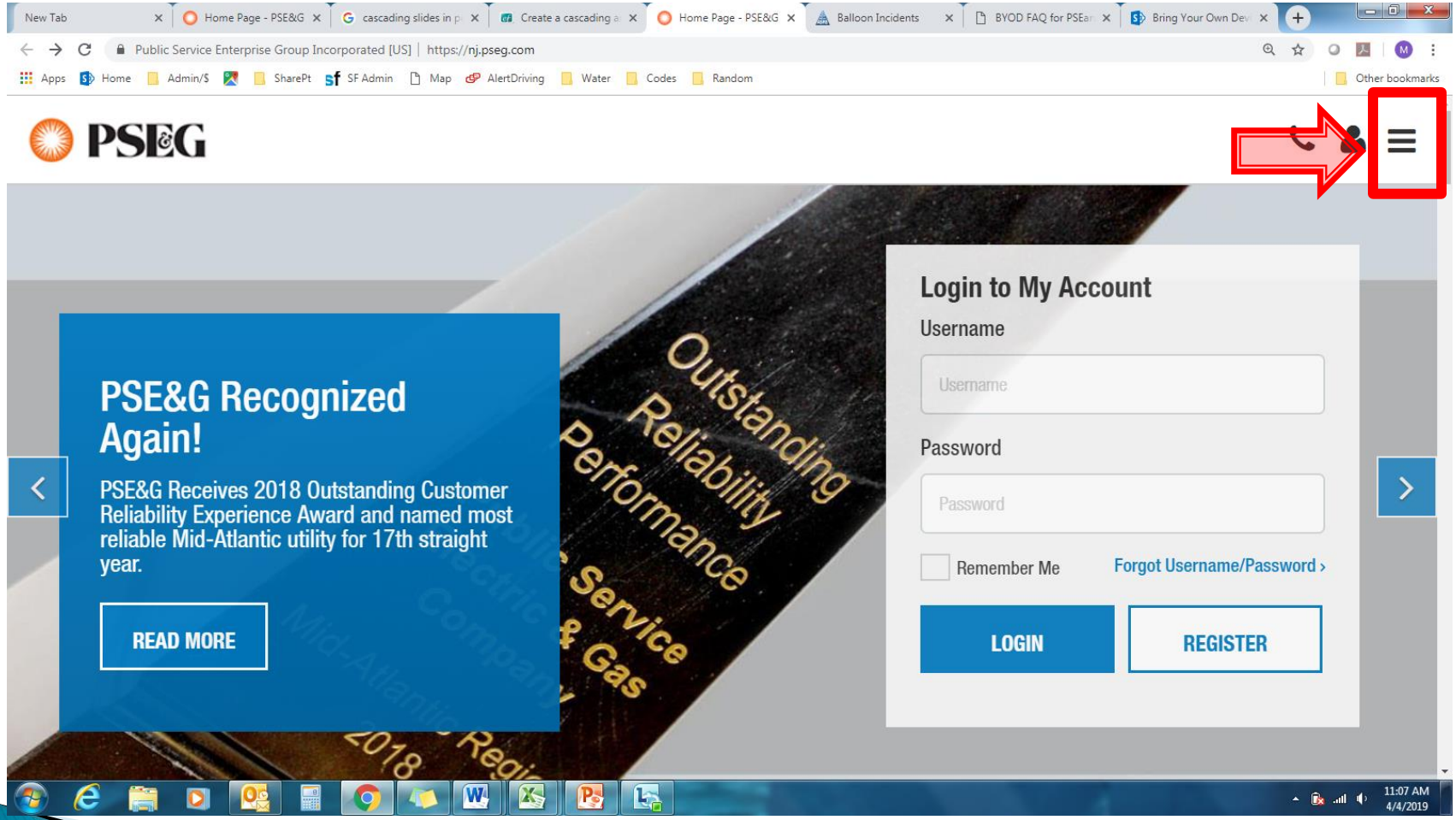
PSE&G's Higher than Normal Pressure (HTNP) Requirements

- Pressure Test Requirements (cont'd):
  - All piping receiving line pressure shall be tested to 1.5 times the system design pressure of the gas distribution system.
  - Pressure tests shall be observed & certified by the local code enforcement official.

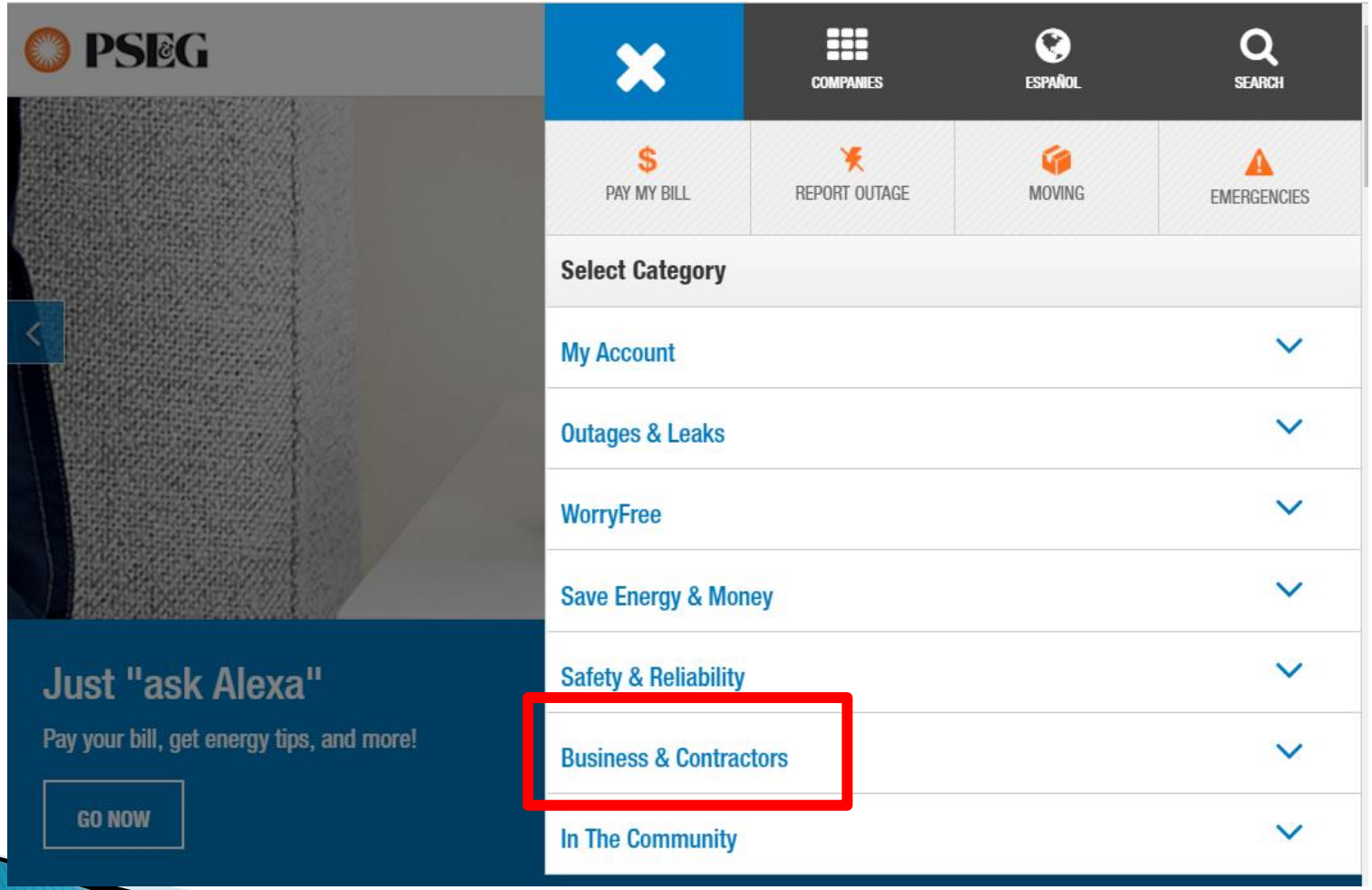
PSE&G's Higher than Normal Pressure (HTNP) Requirements

- Equipment Requirements:
  - The person requesting Residential HTNP service for CSST is responsible to ensure the equipment connected to the piping is rated for the pressure requested and can also handle a regulator failure pressure equal to 3 psi.
  - For Industrial & Commercial applications, regulators shall be supplied and installed by the customer after the meter when necessary to protect equipment or to provide different pressures from the same meter.

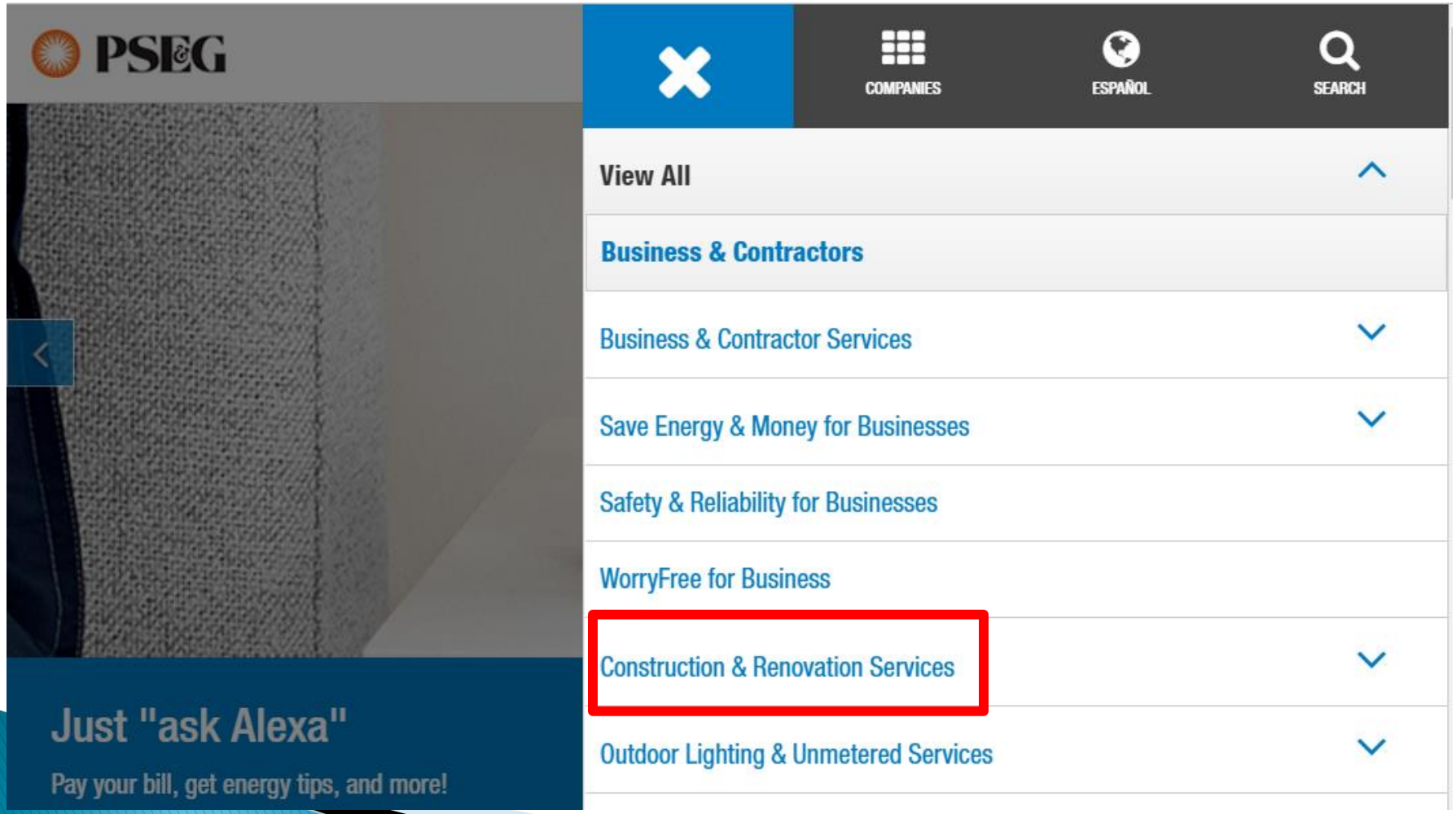
PSE&G Gas Requirements – Gas Appliance & Piping (GAP) Manual



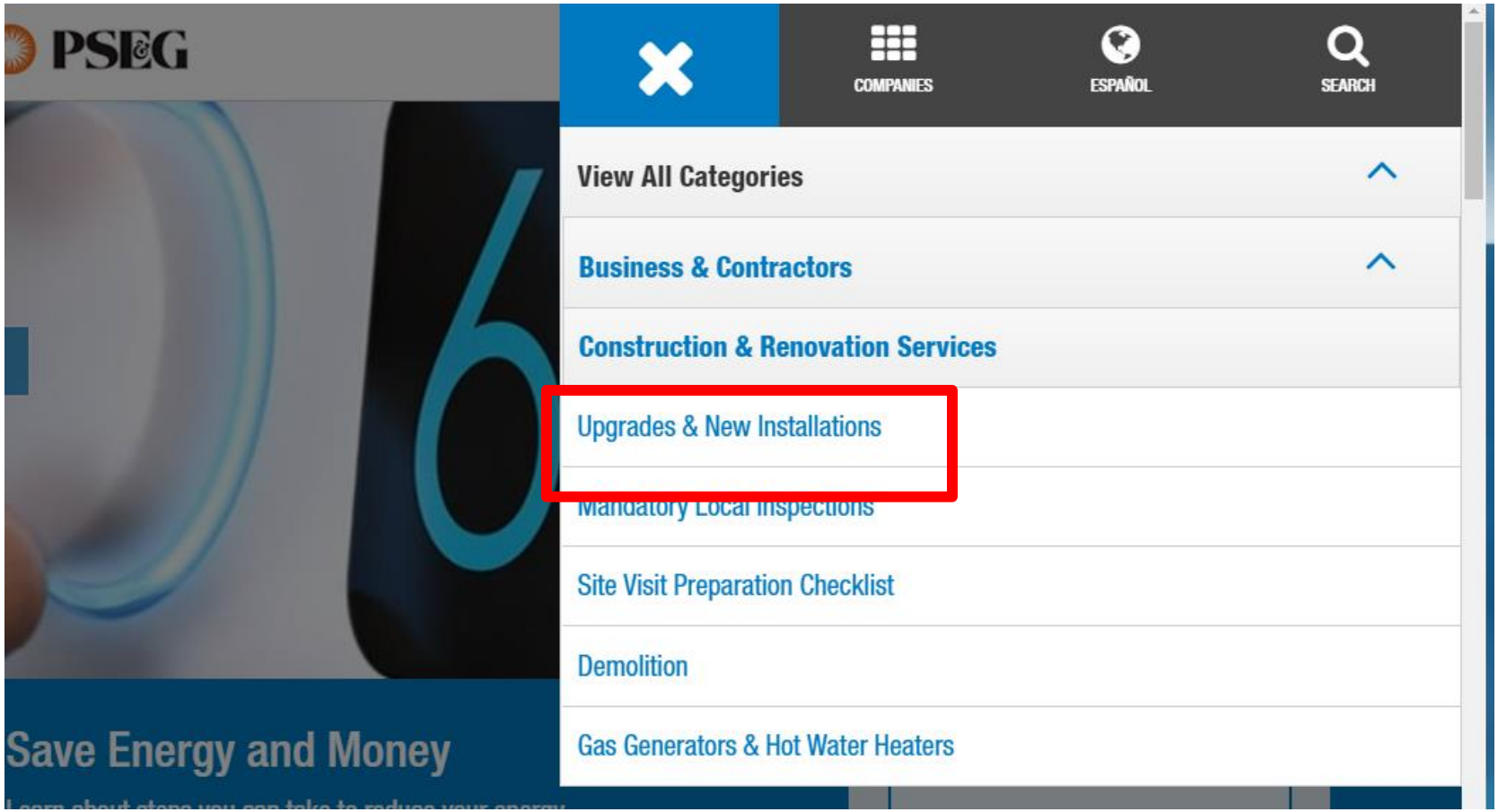
PSE&G's Electric and Gas Requirements – (GAP) Manual



PSE&G's Electric and Gas Requirements – (GAP) Manual



PSE&G's Electric and Gas Requirements – (GAP) Manual



PSE&G's Electric and Gas Requirements – (GAP) Manual

Scroll down…

Before you apply

Plan in advance - Residential service requests may take up to six weeks to complete. Commercial or industrial requests may take longer. Availability of service, the acquisition of road opening permits, and municipal inspections may cause time frames to vary. Submit your completed applications as early as possible, as they are processed in the order they are received. Call to speak with a Construction Inquiry representative if you need guidance.

Read our installation requirements

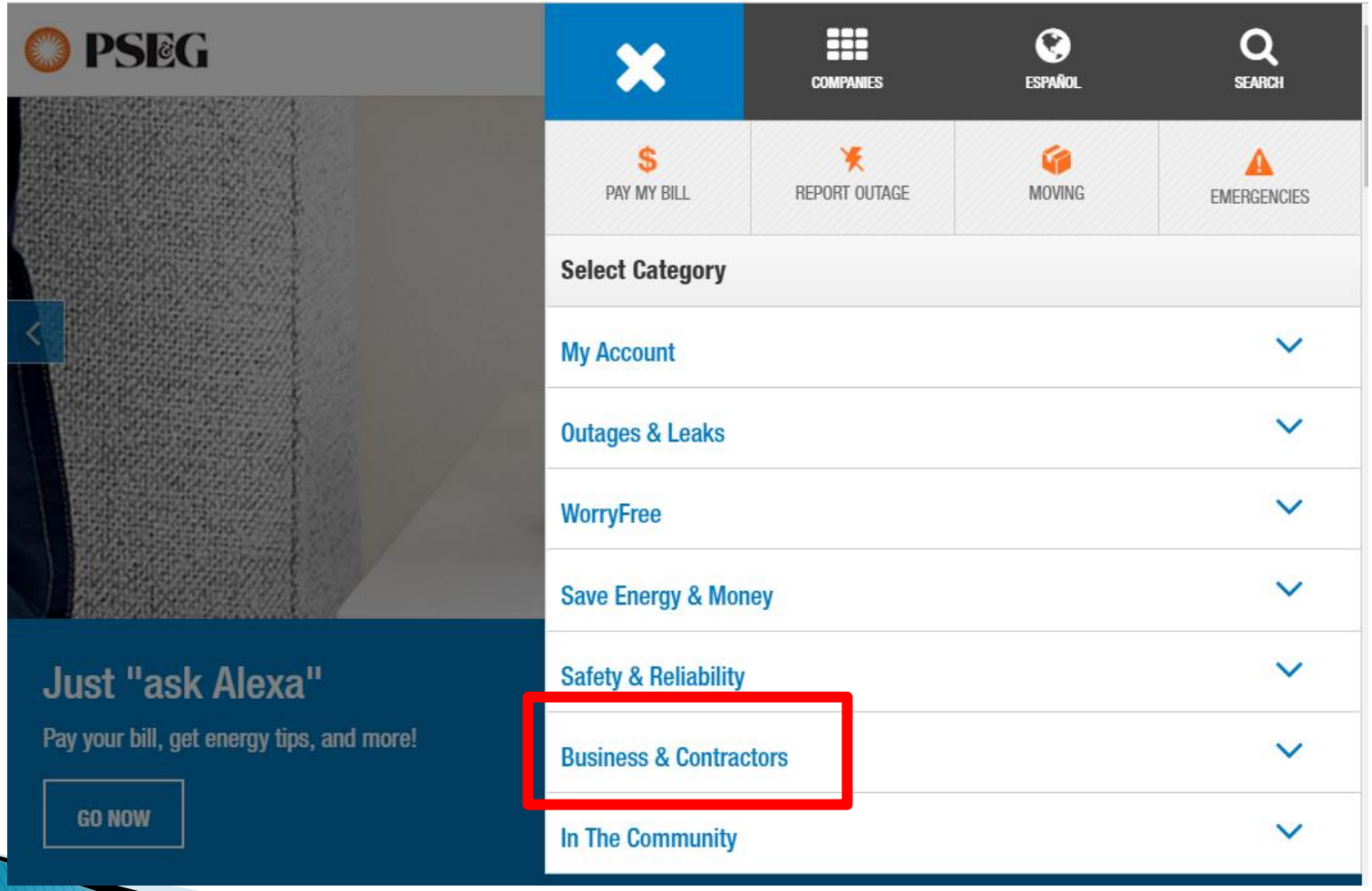
Applicants or their representatives requesting service, should be familiar with PSE&G's specific service characteristics and installation requirements.

- Electric Service: PSE&G's Information & Requirements for Electric Service
- Gas Service: General Criteria for Installation of Gas Appliances and Gas Piping

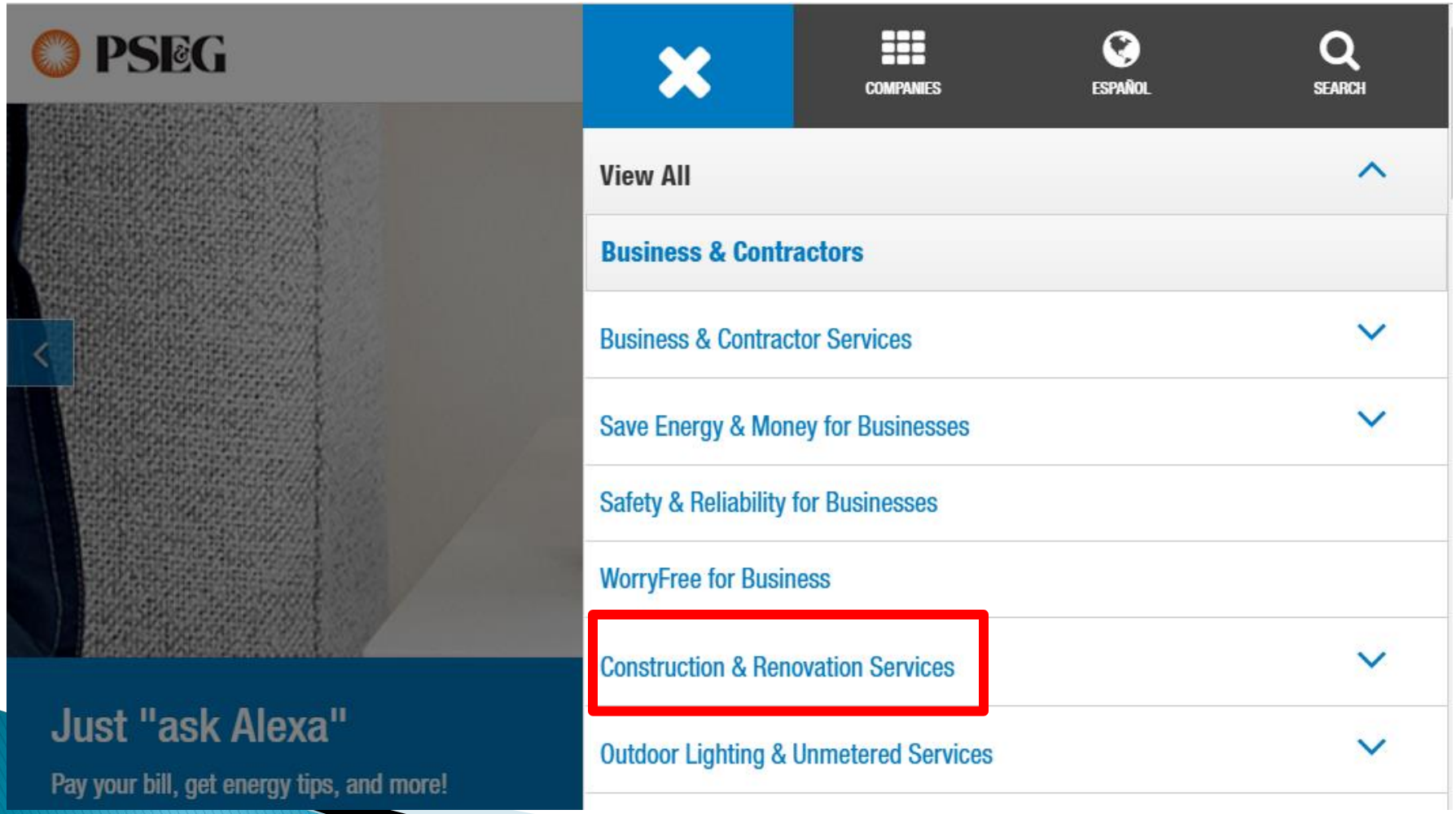
Additional Builder/Developer Resources:

- High Voltage Proximity Act

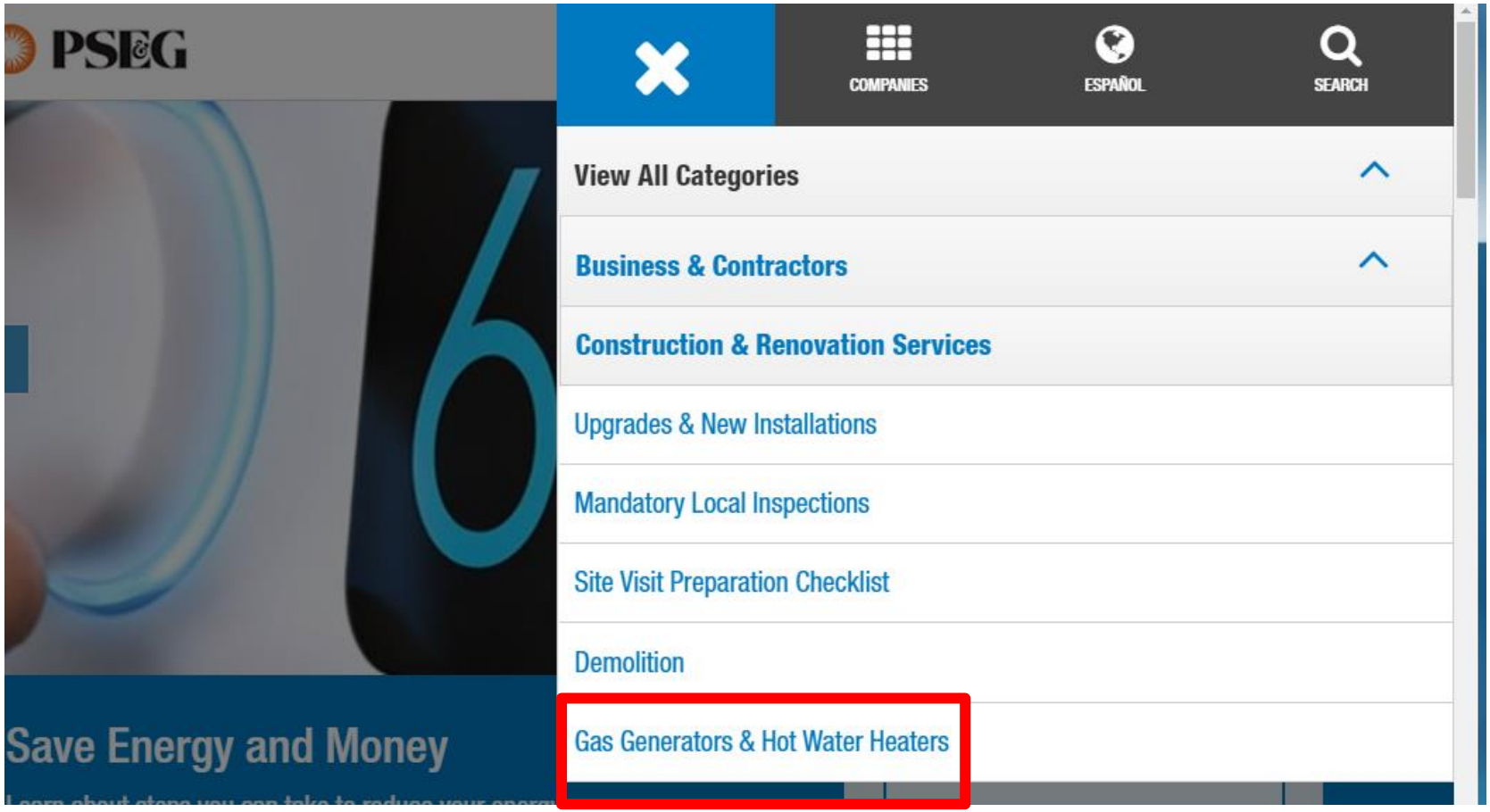
PSE&G Construction Inquiry



PSE&G Construction Inquiry



PSE&G Construction Inquiry



PSE&G Construction Inquiry

Business and Contractor Services / Construction and Renovation Services

Gas Generators and Hot Water Heaters

- Upgrades and New Installations
- Mandatory Local Inspections
- Site Visit Preparation Checklist
- Demolition
- Gas Generators and Hot Water Heaters

Apply to Add Service

Want to add a gas generator or tankless hot water heater? Use the forms below.

Residential

Get the application forms to add service to your residential account.

Get Forms ›

Commercial

Get the application forms to add service to your commercial account.

Get Forms ›

PSE&G Construction Inquiry

Instructions for the PSE&G Residential Application for Gas Service

The application must be filled out completely in order to avoid delays in providing service.

- The residential gas load data sheet is to be used for new service/changes to gas load and excess flow valve requests for single family or multi-family (up to three residential units and a house meter).
- For buildings having 4 or more residential units, use the commercial form.
- When completing an application for generators and/or tankless water heaters, specification sheets are essential, especially when fuel pressure requires a minimum of 7" water column or higher. Please specify make, model of equipment, and pressure requirement.
- Site plans are required for gas layout to begin when no foundation at the site. Plans must be full size and to scale; include footprint of building and show at least one cross street. Site plans may be mailed to the appropriate address below.

PSE&G Construction Inquiry

For Construction Inquiry purposes,
PSE&G service territory is divided into Northern & Southern Counties.

*Note: Emails below are for completed load data sheets only. For all inquiries call the appropriate phone number below.

Northern Counties:
Bergen, Essex, Hudson, Hunterdon, Middlesex, Morris, Passaic, Somerset, and Union

Public Service Electric and Gas Company
Attn: Construction Inquiry
P.O. Box 1023
Cranford, NJ 07016

call 1-800-722-0256, option 1

Please fill out this form and

*email it to: **ConstructionNorth@pseg.com**
Or fax to: 908-497-1762 **or** 908-497-0107

Southern Counties:
Burlington, Camden, Gloucester, Mercer, Monmouth, and Ocean

Public Service Electric and Gas Company
Attn: Construction Inquiry
410 Route 130 South
Bordentown, NJ 08505

call 1-800-832-0076, option 1

Please fill out this form and

*email it to: **ConstructionSouth@pseg.com**
Or fax to: 609-324-1065

FOR MORE INFORMATION

- **Paul Pirro**
  - Manager – AS Technical Support
  - AS Technical Services – Springfield
  - 24 Brown Avenue
    Springfield, NJ 07081
    973-912-3239
  - paul.pirro@pseg.com