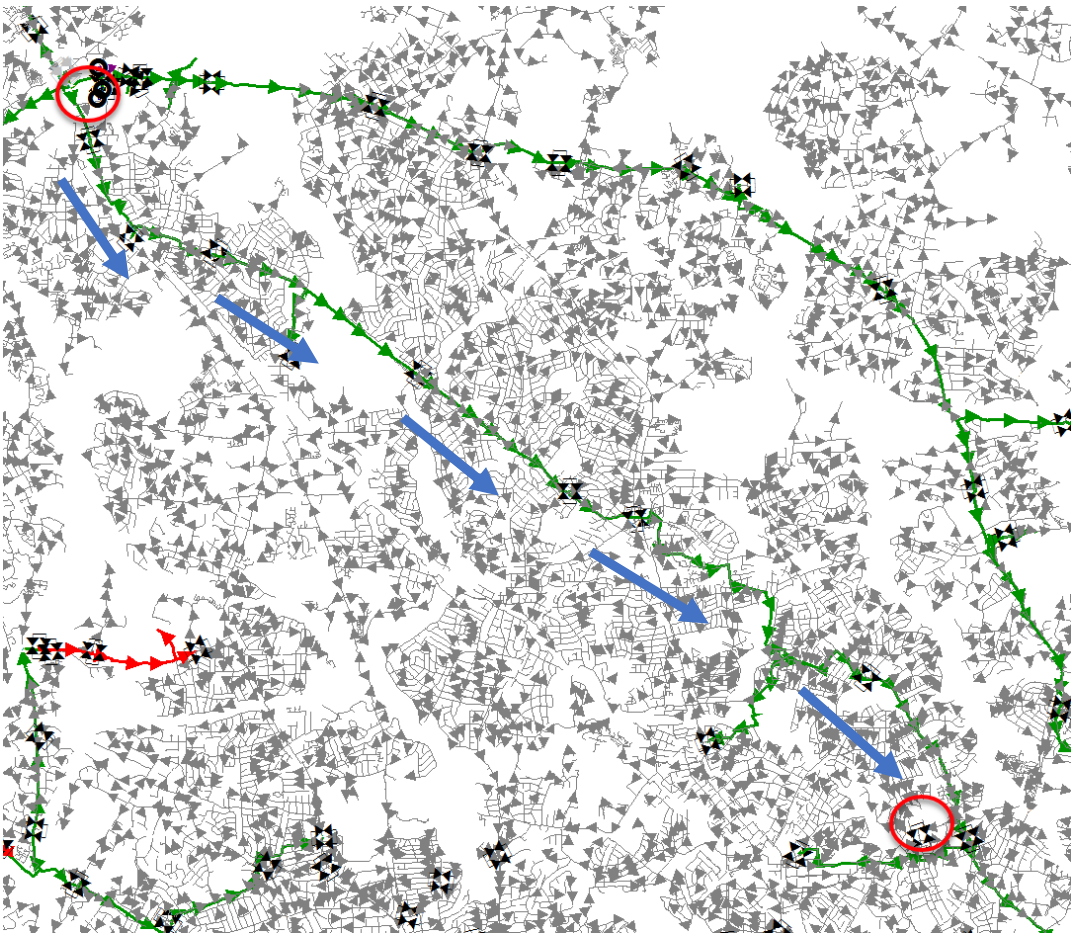
Gas Composition and Lower Explosive Limit (LEL)

8701 Arliss St, Silver Spring, MD, August 10, 2016

1. Background: On August 10, 2016, natural gas delivered to the Flower Branch apartment complex in Silver Spring, MD entered the Washington Gas system via the Rockville Gate Station in Rockville, MD. After travelling southeast along a high pressure pipeline, gas entered the medium pressure distribution system (which directly supplies the Flower Branch apartment complex) through a regulator station in Silver Spring, MD. The regulator station is located along University Boulevard, near the intersection of Seek Lane. This gas path is represented in the figure below, which shows the relative locations of the Rockville Gate Station (upper left, circled) and the Flower Branch Apartments (lower right, circled).



2. Gas Quality: A gas chromatograph at the Rockville Gate station analyzes the outlet gas stream for constituents which contribute to the heating value of gas, as measured in British Thermal Units (Btus) per standard cubic foot (SCF). Constituents include the following combustible and inert compounds:

   - Combustible: methane ("C1"), ethane ("C2"), propane ("C3"), isobutane ("i-C4"), normal butane ("n-C4"), and pentanes plus trace amounts of heavier hydrocarbons ("C5+")
   - Inert: carbon dioxide ("CO_2") and nitrogen ("N_2")

Combustible constituents contribute to the combustible range of gas, i.e., the concentrations at which the gas mixture is explosive (or flammable). Le Chatelier's mixing rule is used to calculate the limits of this mixture, from the lower bound (LEL) to upper bound (UEL). The mixing rule follows:

$$Limit = \frac{100}{\frac{P_1}{N_1} + \frac{P_2}{N_2} + \frac{P_3}{N_3} + \cdots}$$

where:

- P_1, P_2, P_3, etc. are the proportions of each flammable gas present in the mixture, free from inert gases.
- N_1, N_2, N_3, etc. are the limits of flammability (lower or upper), with the lower limit as follows:

Constituent	LEL (Lower Explosive Limit), % by volume
C1	5.0
C2	3.0
C3	2.1
i-C4	1.8
n-C4	1.8
C5+	1.2

3. Lower Explosive Limit, August 10, 2016. The Washington Gas Supervisory Control and Data Acquisition (SCADA) system generates a daily report of average gas composition data which spans 24 hours from 10 AM the previous day until 10 AM the day of the report. The Rockville Gate Station report from August 11, 2016 follows:

24 Hours Averages for Gas Day Ending: **Report Run Date:**

Thursday, August 11, 2016 10:00 AM 8/11/2016

Samples: 1415544

StationName	Component	Average	Minimum	Maximum
ROUT -- Downstream of Hex Inject (201)	Natural Gas C5+	0.110	--	--
	Natural Gas Propane	0.398	0.285	0.414
	Natural Gas i-Butane	0.033	0.023	0.036
	Natural Gas n-Butane	0.049	0.034	0.055
	Natural Gas Nitrogen	0.288	0.274	0.292

	Natural Gas Methane	93.475	93.260	95.097
	Natural Gas Carbon Dioxide	0.207	0.163	0.214
	Natural Gas Ethane	5.440	4.061	5.641
	Natural Gas BTU Dry	1063.483	1048.780	1066.190
	Natural Gas BTU Saturated	1044.980	1030.530	1047.630
	Natural Gas Specific Gravity	0.592	0.582	0.594
	Total Mole	99.827	99.925	99.695

Inserting the above data, using the Average composition as a basis, into Le Chatelier's mixing rule:

Component	Average	% Combustible (P_n)	LEL (N_n)	P_n/N_n
C1	93.475	93.940	5.0	18.788
C2	5.44	5.467	3.1	1.822
C3	0.398	0.400	2.1	0.190
i-C4	0.033	0.033	1.8	0.018
n-C4	0.049	0.049	1.8	0.027
C5+	0.110	0.111	1.2	0.092
sum:	99.505	100.000	**sum:**	**20.939**

LEL_mix 4.78

4. Conclusions: The lower explosive limit of the gas reaching the Flower Branch Apartment community on August 10, 2016 was approximately 4.8%. A source of ignition would need to be surrounded with gas at or near this concentration in order to initiate the development of a flame or explosion.