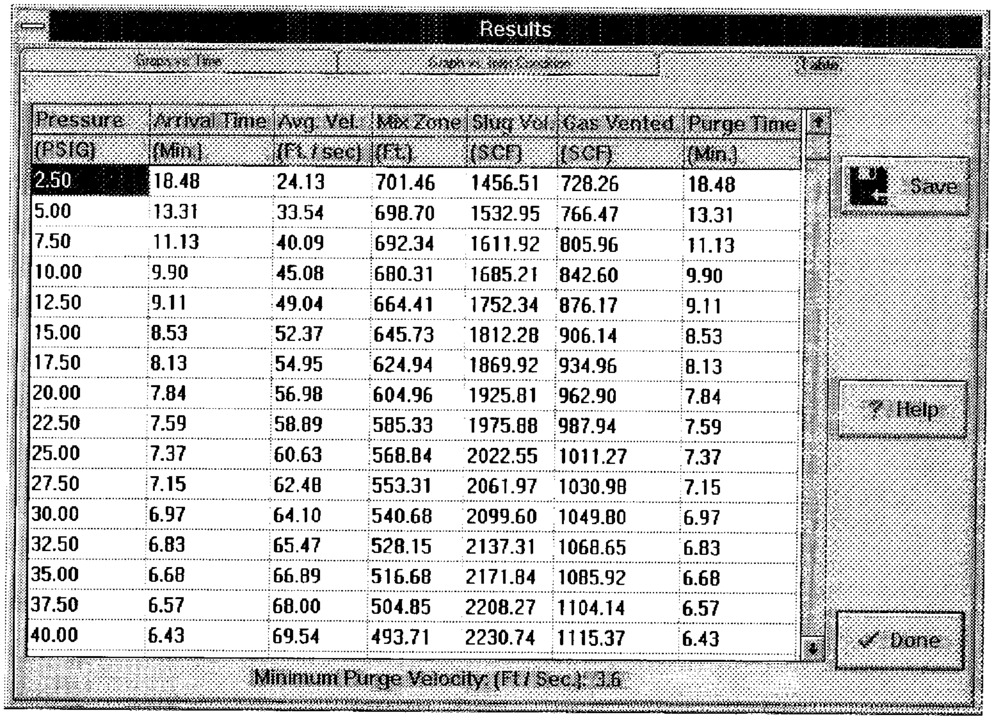

Results

Pressure (PSIG)	Arrival Time (Min.)	Avg. Vel. (Ft / sec)	Mix Zone (Ft)	Slug Vol. (SCF)	Gas Vented (SCF)	Purge Time (Min.)
2.50	18.48	24.13	701.46	1456.51	728.26	18.48
5.00	13.31	33.54	698.70	1532.95	766.47	13.31
7.50	11.13	40.09	692.34	1611.92	805.96	11.13
10.00	9.90	45.08	680.31	1685.21	842.60	9.90
12.50	9.11	49.04	664.41	1752.34	876.17	9.11
15.00	8.53	52.37	645.73	1812.28	906.14	8.53
17.50	8.13	54.95	624.94	1869.92	934.96	8.13
20.00	7.84	56.98	604.96	1925.81	962.90	7.84
22.50	7.59	58.89	585.33	1975.88	987.94	7.59
25.00	7.37	60.63	568.84	2022.55	1011.27	7.37
27.50	7.15	62.48	553.31	2061.97	1030.98	7.15
30.00	6.97	64.10	540.68	2099.60	1049.80	6.97
32.50	6.83	65.47	528.15	2137.31	1068.65	6.83
35.00	6.68	66.89	516.68	2171.84	1085.92	6.68
37.50	6.57	68.00	504.85	2208.27	1104.14	6.57
40.00	6.43	69.54	493.71	2230.74	1115.37	6.43

Save

? Help

✓ Done

Minimum Purge Velocity (Ft / Sec): 3.6

Figure 4-2. Results of the purging program for the example shown in Figure 4-1. For each different purge pressure, the purge time, purge velocity, and the vented gas are calculated.

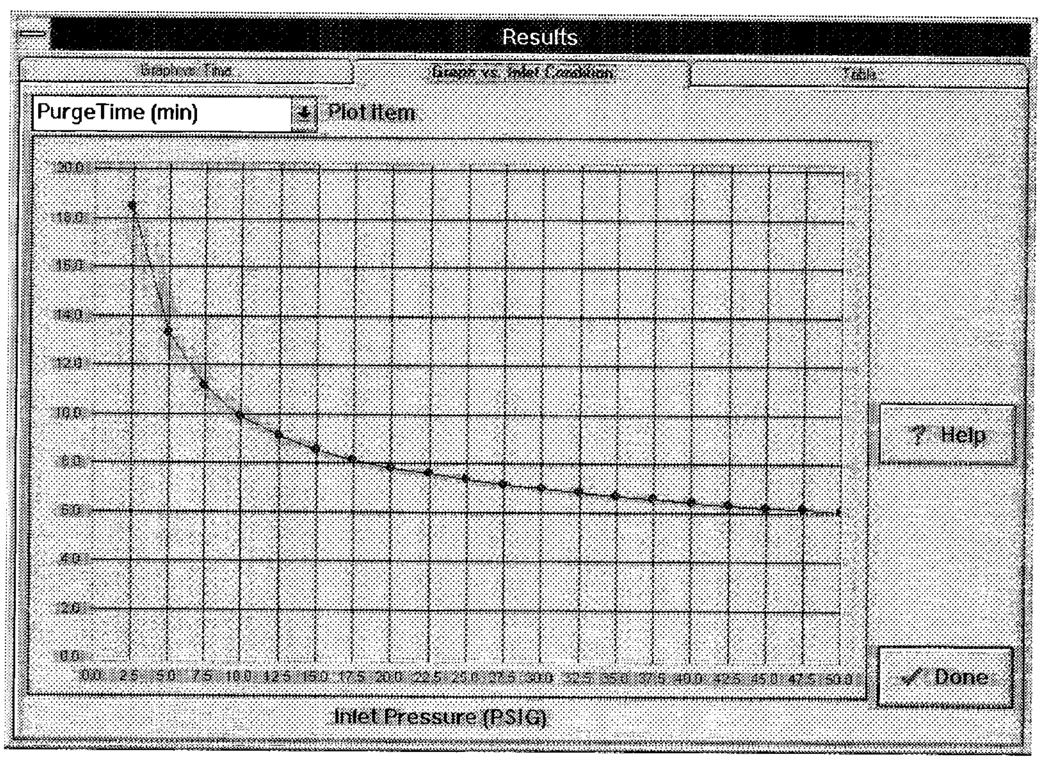

Figure 4-3. Plot from the purging program showing the effect of the purge pressure on the purge time. Note that the purge time is most sensitive to the purge pressure at the lower purge pressures.

5.0 RECOMMENDATIONS FOR A.G.A. PURGING MANUAL

Guidelines for planning a pipeline purge are found in Chapter 8 of the A.G.A. Purging Manual. As a result of the work accomplished in the present research, changes are recommended in several subsections of Chapter 8.

5.1 Motivation For Review And Change

(1) The most recent review and change to Chapter 8 was accomplished in the second revision of the Purging Manual in 1975. Pipeline sizes and lengths that must be purged in many present day situations are outside the range of Table 8.1. Guidance is needed for purging operations beyond the range of application of the current table.

(2) Many present day purging operations are faced with very long lengths of pipe to be economically purged. As such, the interface region between gases within the pipeline has much more time to diffuse. This situation applies to both direct and inert slug purging operations. For inert slug purging, it is very important to maintain a slug of sufficient length to isolate the combustible gas and air during the purge. Therefore, the slug shortening data within Chapter 8 were in need of review.

(3) Some of the earliest work on purging procedures was accomplished in the early 1940's. As such, not all of the supporting documentation has been archived in a way accessible to A.G.A. As a by product of the current work, complete documentation in areas recommended for change, especially for the data provided in Table 8.1, is provided.

5.2 General Areas Changed And Not Changed

This research resulted in specific recommendations for revision of Chapter 8 of the Purging Manual. To summarize the impact of this research, it is important to recognize the areas where major emphasis was placed for change and also to recognize areas not reviewed for change.

Recommendations for change are included in four areas within the Purging Manual. They are:

(1) The inclusion of a stratification velocity criteria for various pipe diameters (see Figure 2-6) to replace the old "must exceed 100 ft/min" for all pipe diameters criteria.

(2) The replacement of the old Table 8.1 (Figure 5-1) with an extended range table that has been completely recomputed based upon a criteria of obtaining an interface velocity of exactly 2 minutes/mile (44 ft/sec).

(3) The complete revision of Section **8.9** on the estimates of slug shortening (new figures, new graphs, (Figure 5-2) a revised Table **8.4,** (Figure 5-3) "Nitrogen Required for Inert Slug," and a deletion of Table 8.5 because the old Table 8.5 information is included in the new Table **8.4).**

(4) The reworking of example problems involving slug shortening because of the impact of new minimum stratification velocities (which are higher than 100 ft/min).

Areas of Chapter **8** where no recommendations are provided by this research program include the following:

(1) Small diameter pipe (except for specifying that a minimum stratification velocity is attained or exceeded during a purge).

(2) Purging of residential fuel lines and service lines.

(3) Capacity information on various air movers.

(4) Inert purging by complete filling with inert gas.

5.3 Anticipated Impact Of Change

The anticipated impact of a potentially revised Chapter **8** per the recommendations provided herein may be as follows:

Impact of minimum purge velocity

The lowest minimum velocity for a purging operation is about 100 ft/min and that is for pipe sizes in the 3- to 4-inch diameter range. The minimum recommended purge velocity for all other sizes of pipe (smaller and larger in diameter) is greater than 100 ft/min. For example, the minimum velocity for 48-inch diameter pipe is approximately **360** ft/min or a factor of ***3.6*** times higher. Generally, attainment of the minimum velocities are quite easy, and in practice, these minimums are usually exceeded. Obviously, the higher the velocity of the purge, the shorter the time a crew needs to be engaged in the purging operation. The only reason one may want to just exceed the minimum may be if limited pumping capacity is present on site.

Impact of changes in Table 8.1

By inspection of the old table compared to the new table, several changes are evident. Purging pressures contained in the new table are for the most part lower than the one contained in the old table. If one uses the purge pressures in the old table, the resultant gas velocity will generally exceed 44 ft/sec by a significant amount. Pressures in the new table have been derived such that by use of these pressures, the velocity attained in the pipeline will be very close to 44 ft/sec. Obviously, higher pressures will produce higher pipeline velocities.

One will note that the table contains no purge pressure greater than 100 psi. If detonation were to occur in a pipeline (for what ever reason) the overpressure attained is in the range of 10 times the initial pressure. In other words, a detonation of gas in a pipeline containing 100 psi combustible gas would most likely reach pressures somewhere in the line of approximately 1000 psi. For transmission piping, this pressure would most likely be contained, but use of the lowest practical purging pressure **is** recommended. Special care is advised for distribution piping whose structural limits are generally lower than those for transmission lines.

Impact of Slug Shortening Recommendations

Deviations from the old estimates of slug shortening are small for all pipe sizes that are generally shorter than three miles. There are significant deviations from the old slug shortening estimates for longer pipe lines and one must be aware that the deviations are pipeline diameter sensitive. Once the pipeline length exceeds approximately 10 miles, one will observe that the old slug shortening curves under predict slug shortening which could lead to a situation where the fuel gas can mix with air much sooner than anticipated. Hence, use of the new slug shortening graph will generally mean that more inert gas will be needed for the longer pipeline purges compared to present operations.

Table 8-1. Purging Data for Inlet Control Procedure

Minimum Inlet Pressures - **PSIG**

(**By** Line Size)

PIPELINE LENGTH	2" B/OFF VALVE Inlet Pressure (psig)		4" BLOWOFF VALVE Inlet Pressure (psig)				6" BLOWOFF VALVE Inlet Pressure (psig)					
(MILE)	4" Pipe	6" Pipe	6" Pipe	8"Pipe	10" Pipe	12" Pipe	12" Pipe	16" Pipe	18" Pipe	20" Pipe	22" Pipe	24" Pipe
1	6	9	3	3	3	5	2	3	4	5	8	12
2	12	13	7	5	5	7	3	4	5	6	8	12
3	18	17	10	7	7	8	5	5	5	7	9	13
4	24	21	13	10	9	10	6	6	6	8	10	14
5	32	25	16	12	11	11	7	7	7	8	11	15
6	40	30	20	14	12	13	9	8	8	9	12	15
7	49	35	24	17	14	14	10	9	9	10	12	16
8	59	41	28	20	16	16	11	10	10	11	13	17
9	71	46	33	22	18	18	13	11	11	12	14	18
10	83	52	38	25	20	19	14	12	12	13	15	19
11	97	59	43	28	22	21	16	13	13	14	16	20
12		66	48	31	25	23	17	14	14	15	17	20
13		73	54	35	27	25	19	15	15	15	17	21
14		81	60	38	29	27	21	16	16	16	18	22
15		90	67	42	32	29	22	18	17	17	19	23
20				63	45	40	31	24	22	22	24	28
25				90	62	52	42	31	28	28	29	33
30					81	66	54	39	35	33	34	38
35						82	68	47	42	40	40	44
40							84	57	50	46	46	50
45								67	58	54	53	56
50								79	67	61	60	63

PIPELINE LENGTH	8" BLOWOFF VALVE Inlet Pressure (psig)			10" BLOWOFF VALVE Inlet Pressure (psig)			12" BLOWOFF VALVE Inlet Pressure (psig)			
(MILE)	20" Pipe	22" Pipe	24" Pipe	24" Pipe	26" Pipe	30" Pipe	34" Pipe	36" Pipe	42" Pipe	48:" Pipe
1	2	3	3	2	2	3	2	3	6	10
2	3	3	4	2	3	3	3	3	6	11
3	3	4	5	3	3	4	3	4	6	11
4	4	5	5	3	4	5	4	4	6	11
5	5	5	6	4	4	5	4	4	7	12
6	6	6	6	5	5	5	4	5	7	12
7	7	7	7	5	5	6	5	5	7	12
8	7	7	8	6	6	6	5	6	8	12
9	8	8	8	6	6	7	6	6	8	13
10	9	9	9	7	7	7	6	6	8	13
11	10	9	10	8	7	8	6	7	9	13
12	10	10	10	8	8	8	7	7	9	14
13	11	11	11	9	9	9	7	7	9	14
14	12	12	12	9	9	9	8	8	10	14
15	13	12	12	10	10	10	8	8	10	15
20	17	16	16	13	13	12	10	10	12	16
25	22	20	19	17	16	15	12	12	14	18
30	27	24	23	20	19	17	14	14	15	20
35	32	29	27	24	22	20	17	16	17	22
40	38	34	32	28	26	23	19	18	19	24
45	44	39	36	32	29	26	21	21	21	25
50	51	45	41	37	33	29	24	23	23	27

Purge pressures that exceed 100 psig are not shown in the table. Possible detonation of flammable gases could create unsafe pipeline pressures. Longer purge times (greater than 2 min/mile) and lower purge pressures should be used.

Figure 5-1. Recommend new fable 8.1 to replace current version of Table 8.1. Found in A.G.A. Purging Manual (Printed 1990). Inlet pressures recommended will drive purging flows to a velocity of 44 ft/sec for a pipeline geometry as shown in Figure 4.1.

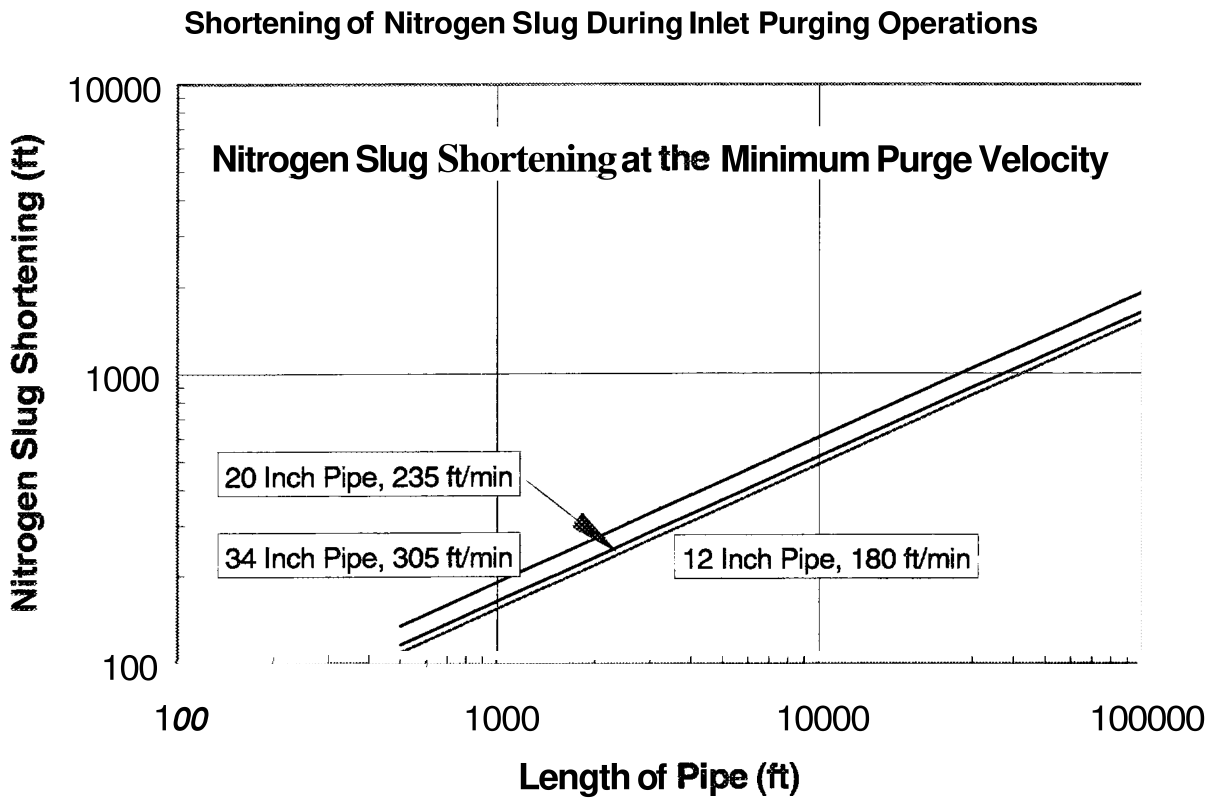

Figure 5-2. New graph for estimating slug shortening to replace Figures 8-6, 8-7, and 8-8 in current A.G.A. Purging Manual (Printed 1990). Supporting information is found in Appendix D.

Table 8-4. Nitrogen Required for Inert Slug

Pipe Size (inch)	Pipe Volume per Foot (CF/ft)	Minimum Slug Velocity (ft/min)	Injection Rate (CFM)	Cubic Feet of Nitrogen for an Inert Slug Pipe Length in Feet						
				500	1000	2000	5000	10000	20000	50000
4	0.09	125	11	19	23	29	40	53	71	107
6	0.22	130	29	46	56	70	98	129	173	261
8	0.37	150	56	77	94	117	164	217	291	439
10	0.58	165	96	121	147	184	257	340	457	688
12	0.83	180	149	173	211	263	368	486	653	985
16	1.3	210	273	280	342	430	605	802	1,080	1,632
18	1.67	220	367	360	440	553	777	1,030	1,387	2,097
20	2.08	235	489	448	548	689	968	1,283	1,728	2,611
22	2.51	245	615	541	661	831	1,168	1,548	2,085	3,151
26	3.51	265	930	757	925	1,162	1,633	2,165	2,916	4,406
30	4.67	285	1,331	1,007	1,230	1,546	2,173	2,880	3,880	5,863
34	5.97	305	1,821	1,400	1,733	2,204	3,137	4,189	5,677	8,630
36	6.72	315	2,117	1,576	1,951	2,480	3,531	4,716	6,391	9,714

Figure 5-3. Recommend new Table 8-4 to replace current Tables 8.4 and 8.5 in current A.G.A. Purging Manual (Printed 1990).

6.0 CONCLUSIONS AND RECOMMENDATIONS

Based upon the research conducted herein, conclusions drawn and recommendations offered are as follows:

1. By using the recommended control pressures indicated in Table **8.1** of the current **A.G.A.** Purging Manual (1990 printing), the resultant pipeline velocities will ensure that gas stratification will not occur for the applicable piping configurations (a straight pipe with inlet and outlet risers).

2. The range of pipe diameters in Table **8.1** has been expanded from the current limitation of **34** inches to **48** inches and the range of pipe lengths have been expanded from the current limitation of **15** miles to **50** miles.

3. **A** mathematical model for predicting the velocity of the gas interface in long pipelines has been developed and the model predicts purge time to within approximately ± 10% compared to experimental data gathered from field observations.

4. **A** mathematical model of the S-shaped concentration profile is applicable for calculating slug shortening (inert slug purge) as well as the length of the mixed region between the purging gas and the purged gas. Predictions of the mixed zone length (for *air* and natural gas) derived from the model match field observations to within approximately ± 40% for direct purge operations.

5. Errors in predicating the mixed zone length contribute little toward inaccuracies in predicting time to complete a purge because the length of the mixed zone is generally very small compared to the length of the pipeline being purged (of order ***2%*** of the pipeline length).

6. Stratification of gases can be avoided by exceeding the "gravity wave" speed. **A** new coefficient, approximately equal to 0.7, for the stratification velocity equation (or alternately the gravity wave equation) has been derived for pipelines based on experimental data.

7. The length of the mixed zone is proportional to the square root of the gas diffusion coefficient. Unfortunately, gas diffusion coefficients applicable to long pipelines are not well supported by experimental data and improvements in their accuracy will lead to direct improvements in predicting mixed zone lengths.

8. Due to the number of variables that impact uncertainty estimates, "safety factors" have not been included in the computer code, but rather it is recommended that one use the code to evaluate the effects of various parameters (pressure, temperature, pipe roughness, and effective constriction size) on purge time once the pipeline geometry has been established.

9. Specific recommendations for further studies leading to enhanced accuracy of the present model are:

- Develop diffusion coefficients for large diameter pipelines. The recommended approach is to gain access to a long pipeline where controlled and accurately measured experiments can be performed and where repeated tests can be accomplished (replica and variation in parameter runs).

- Develop a more accurate coefficient for the stratification velocity equation. The 0.7 factor used in Equation **2-2** appears reasonable based upon experimental data available in the literature. During the conduct of the diffusion experiments recommended above, one could easily run low velocity purging cases to better characterize the gravity wave physics and establish the accuracy of the 0.7 factor.

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