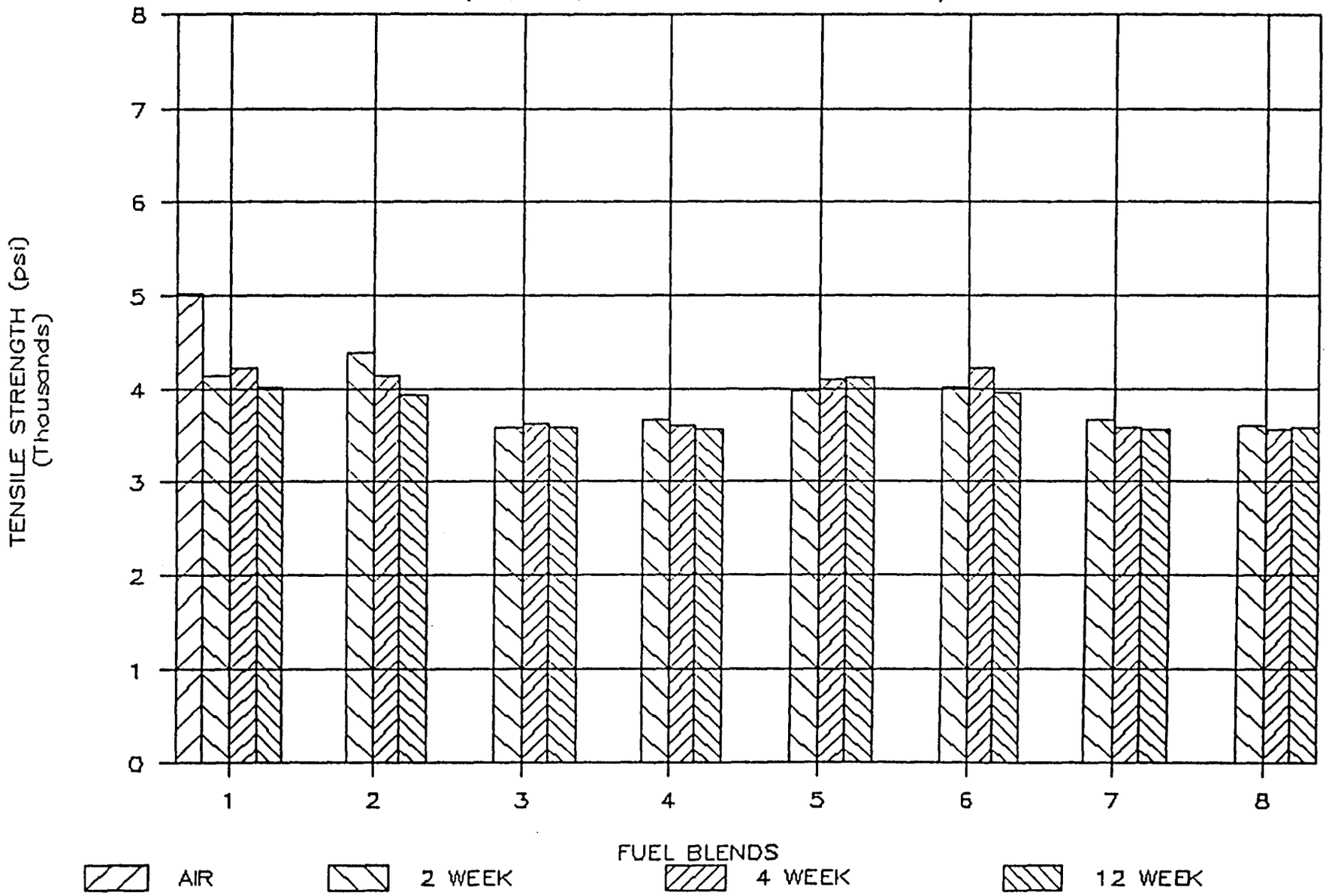
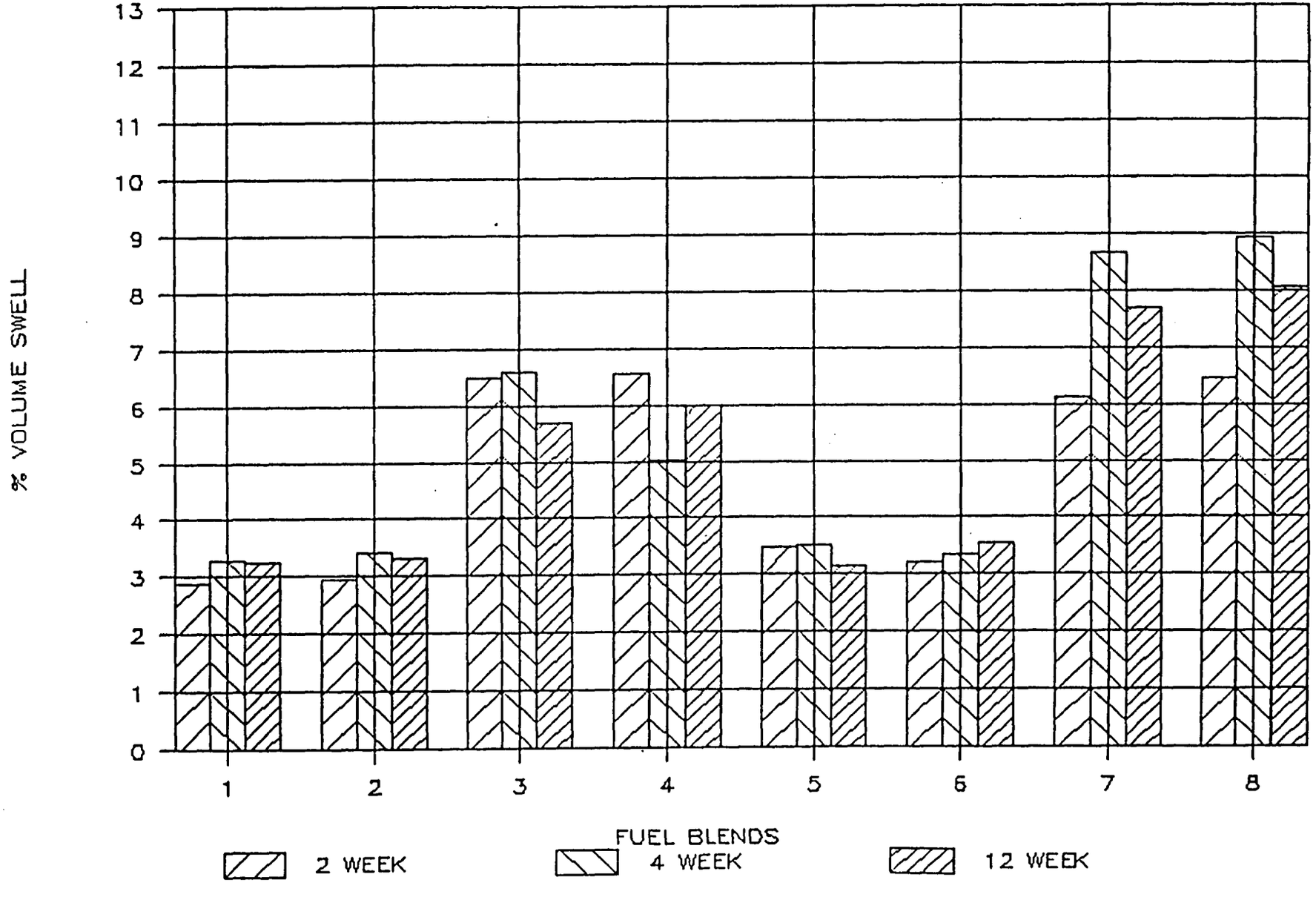
ETHYL FUEL COMPATIBILITY—NYLON 11

(AIR, TWO, FOUR & TWELVE WEEK DATA)



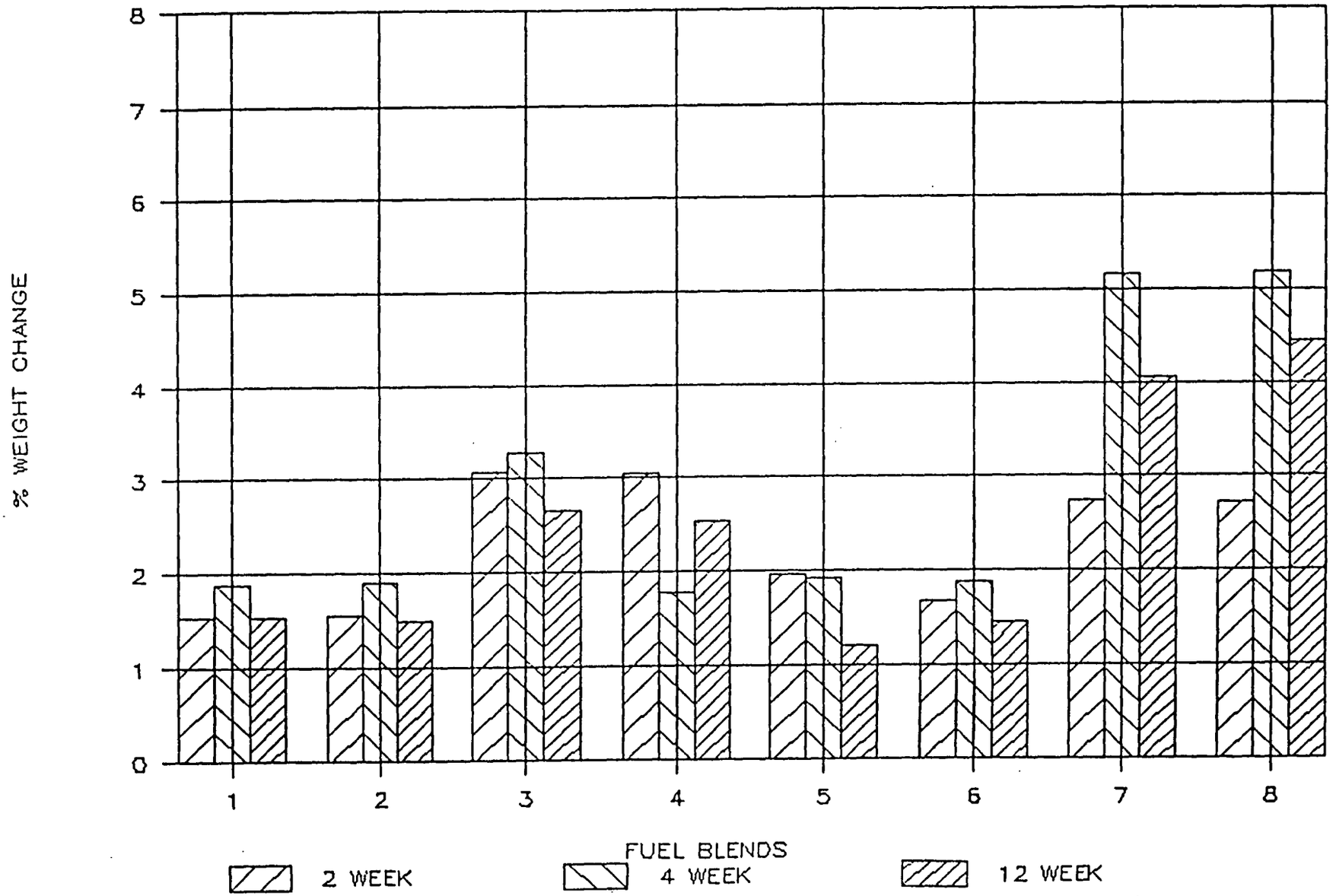
ETHYL FUEL COMPATIBILITY—NYLON 11

(TWO, FOUR & TWELVE WEEK DATA)



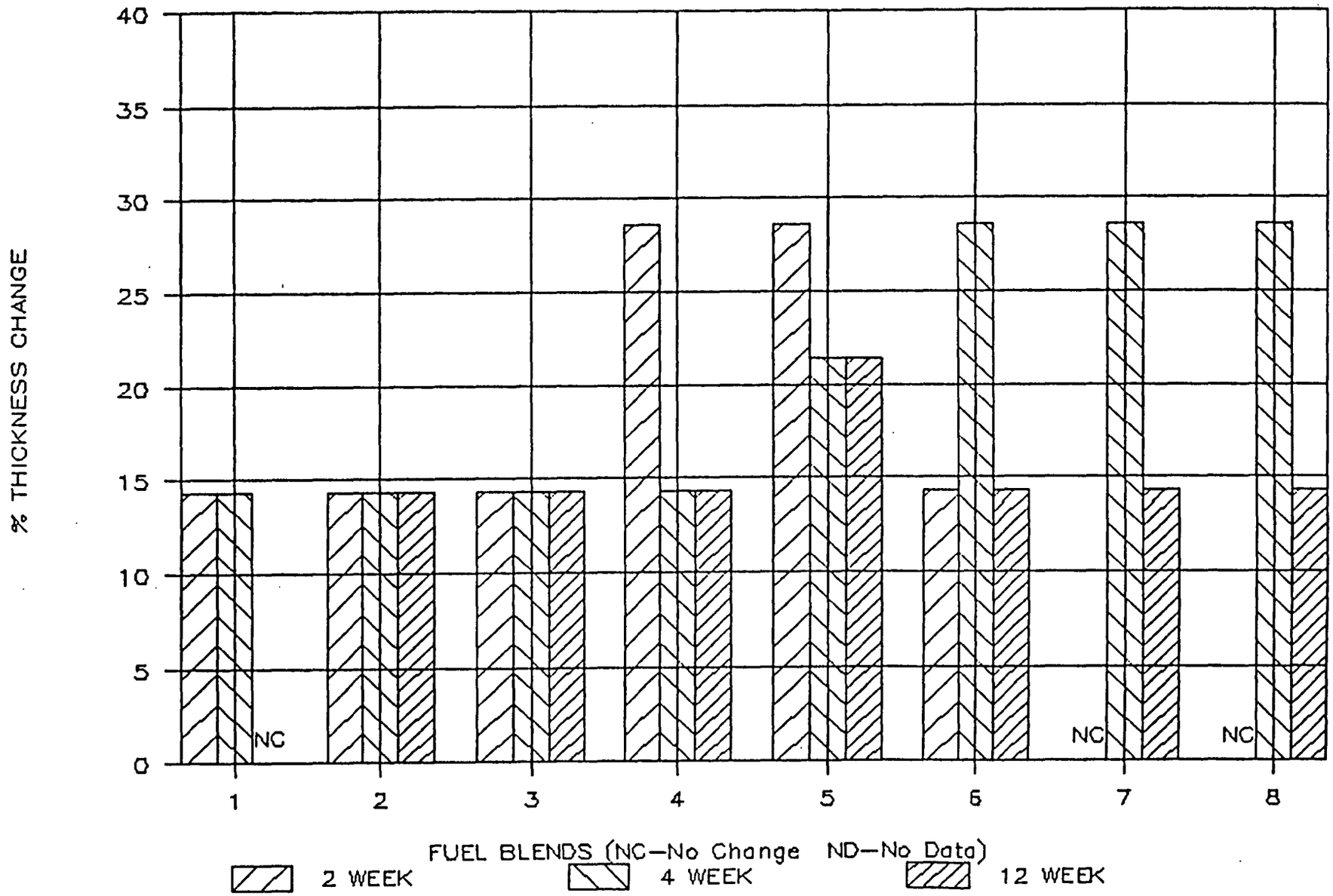
ETHYL FUEL COMPATIBILITY—NYLON 11

(TWO, FOUR & TWELVE WEEK DATA)



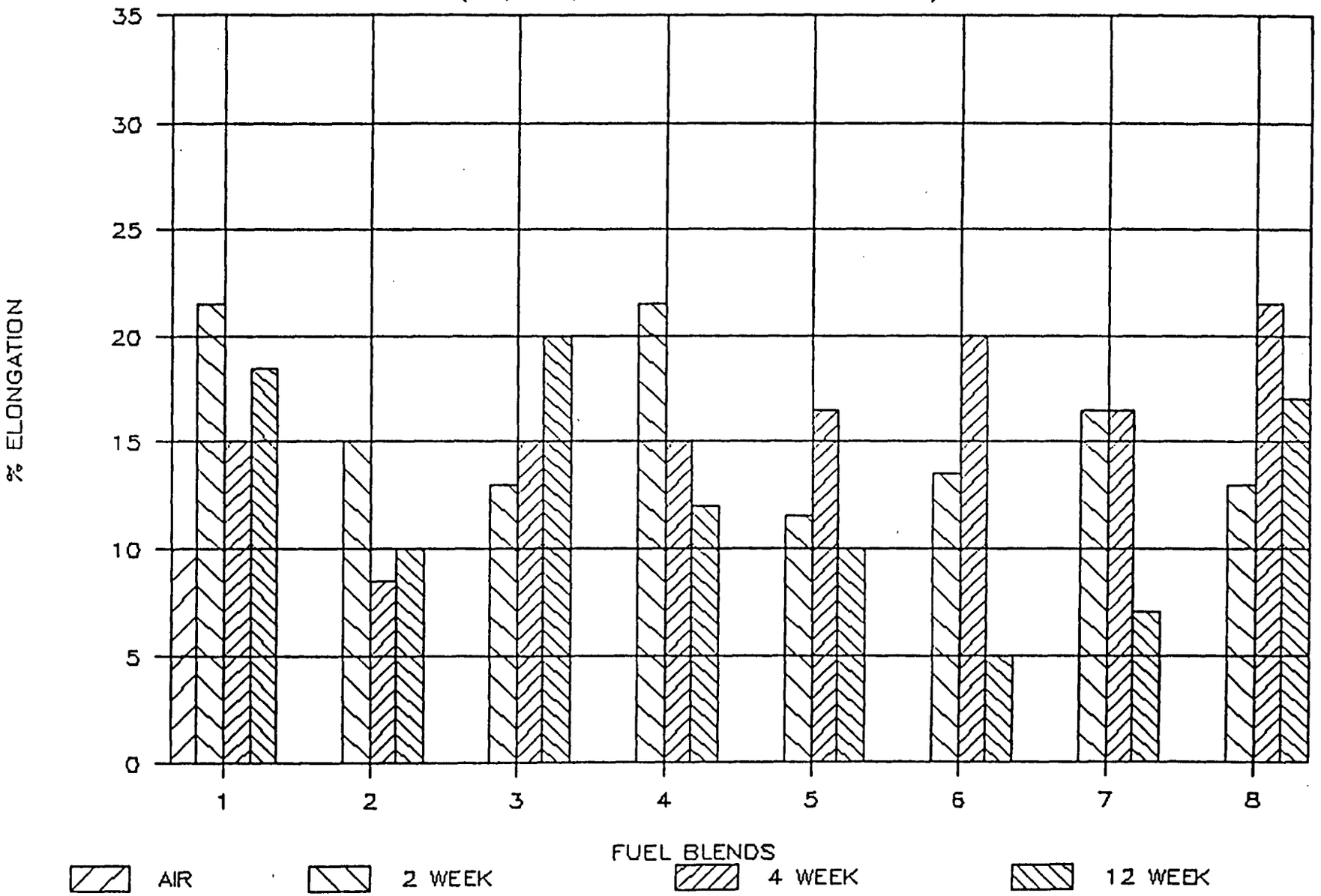
ETHYL FUEL COMPATIBILITY—PETG

(TWO, FOUR & TWELVE WEEK DATA)



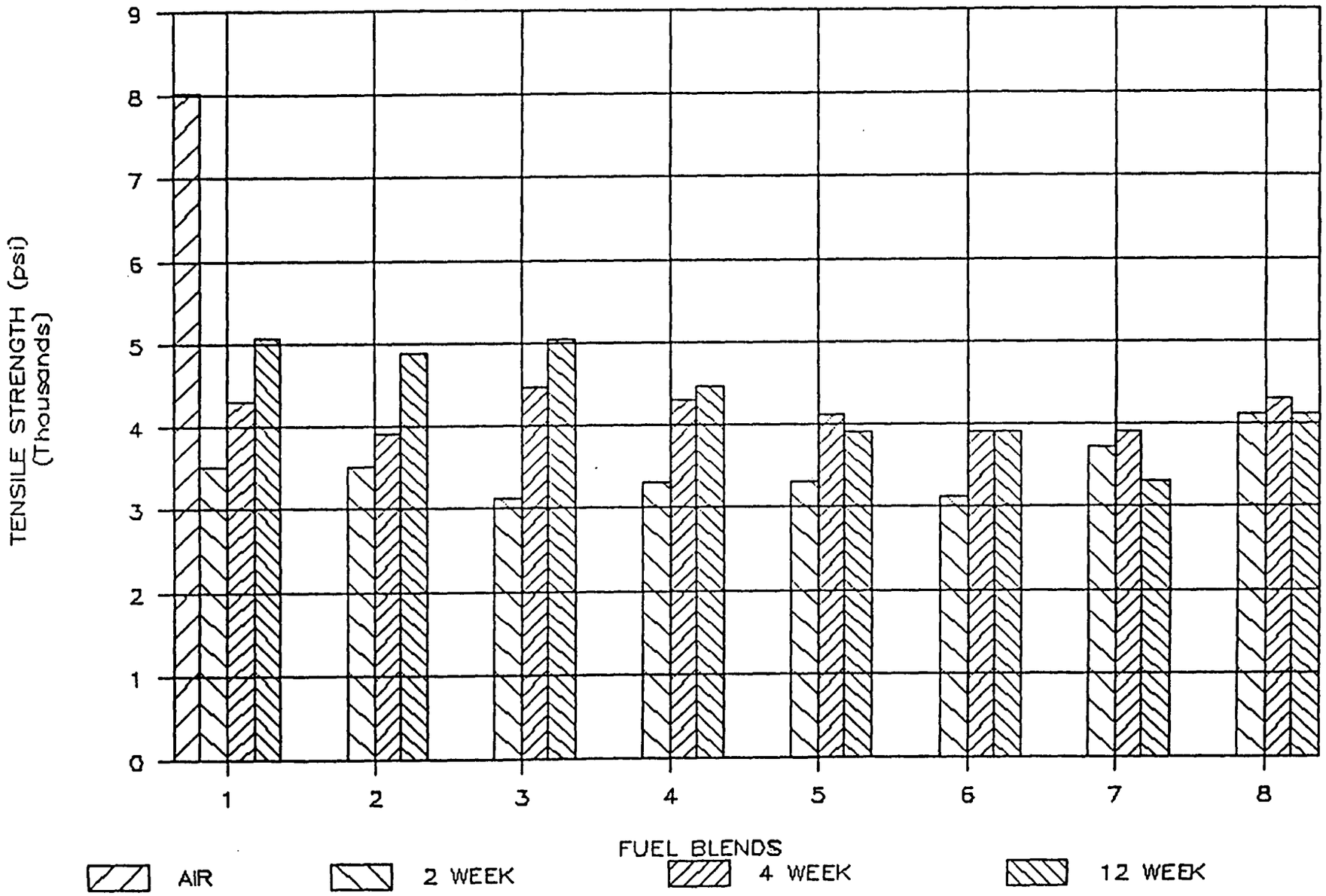
ETHYL FUEL COMPATIBILITY—PETG

(AIR, TWO, FOUR & TWELVE WEEK DATA)



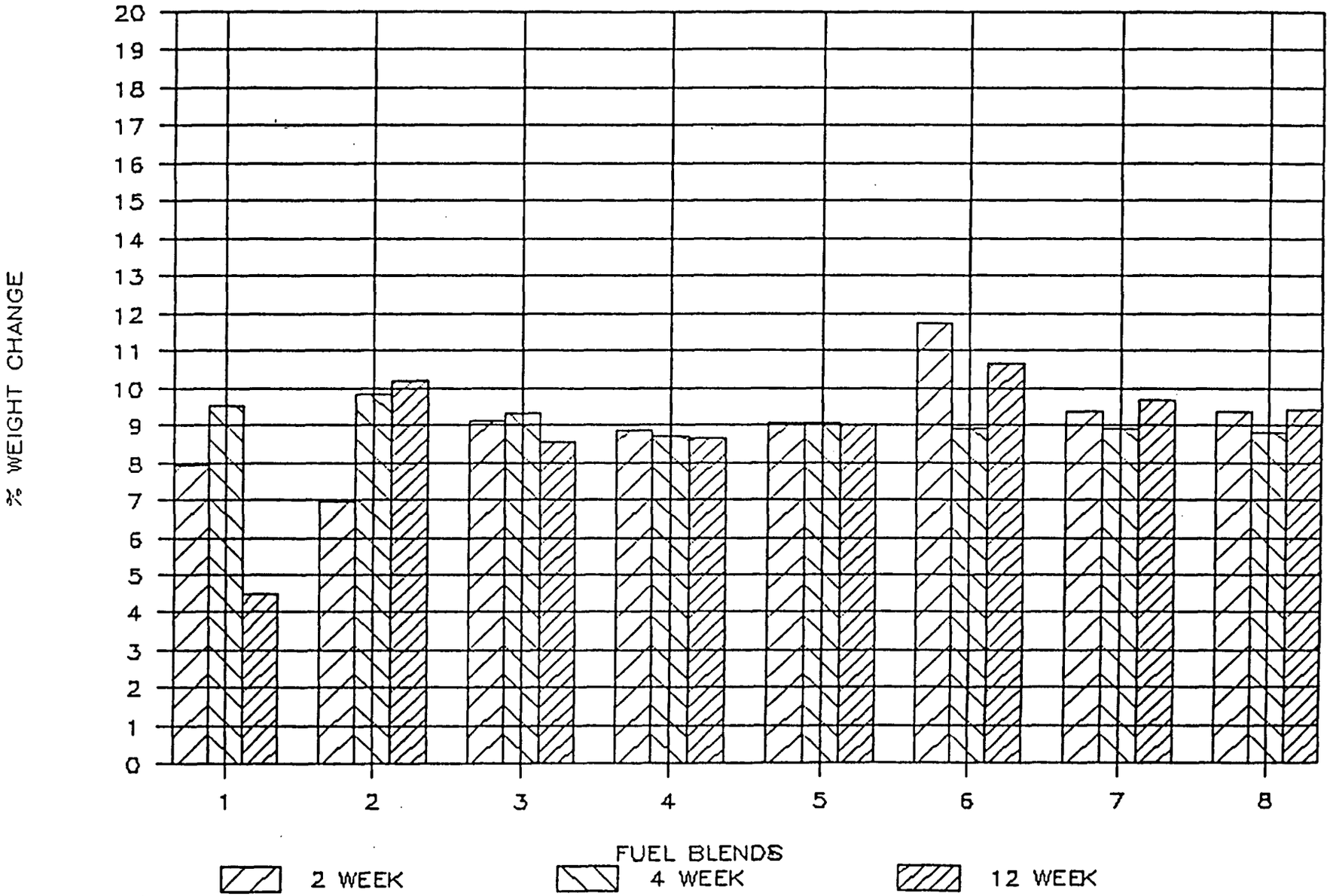
ETHYL FUEL COMPATIBILITY—PETG

(AIR, TWO, FOUR & TWELVE WEEK DATA)



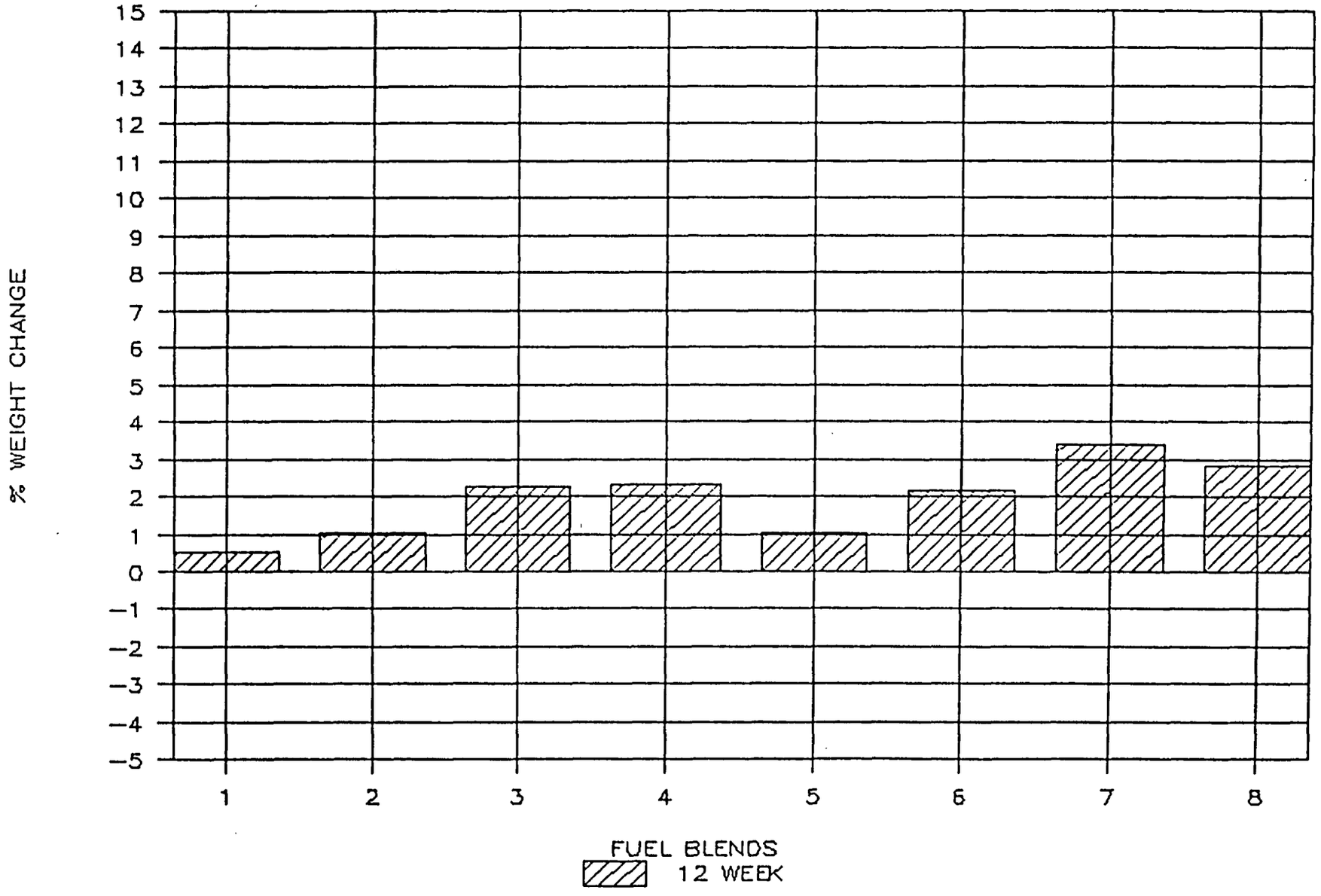
ETHYL FUEL COMPATIBILITY—PETG

(TWO, FOUR & TWELVE WEEK DATA)



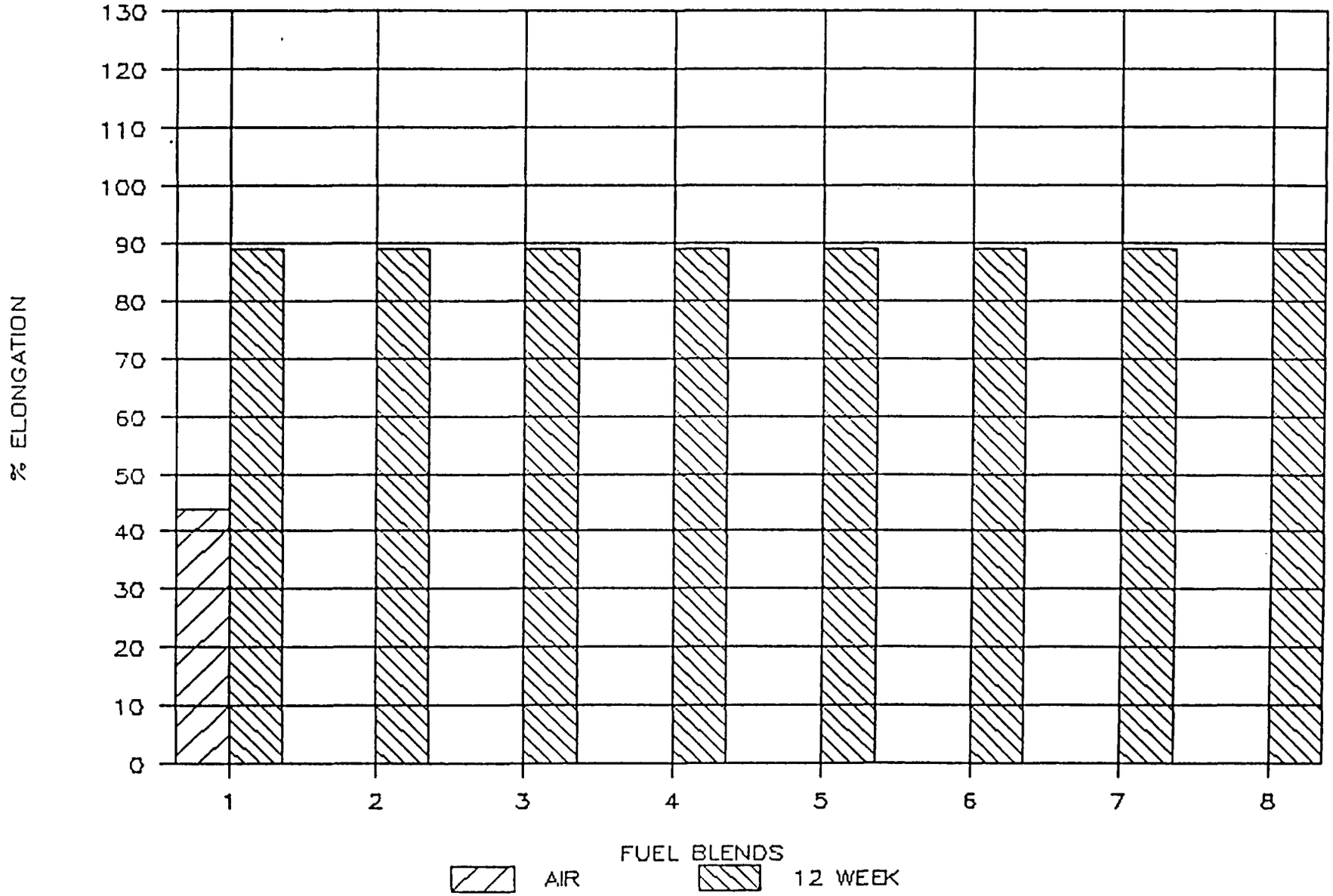
ETHYL FUEL COMPATIBILITY—DELRIN

TWELVE WEEK DATA



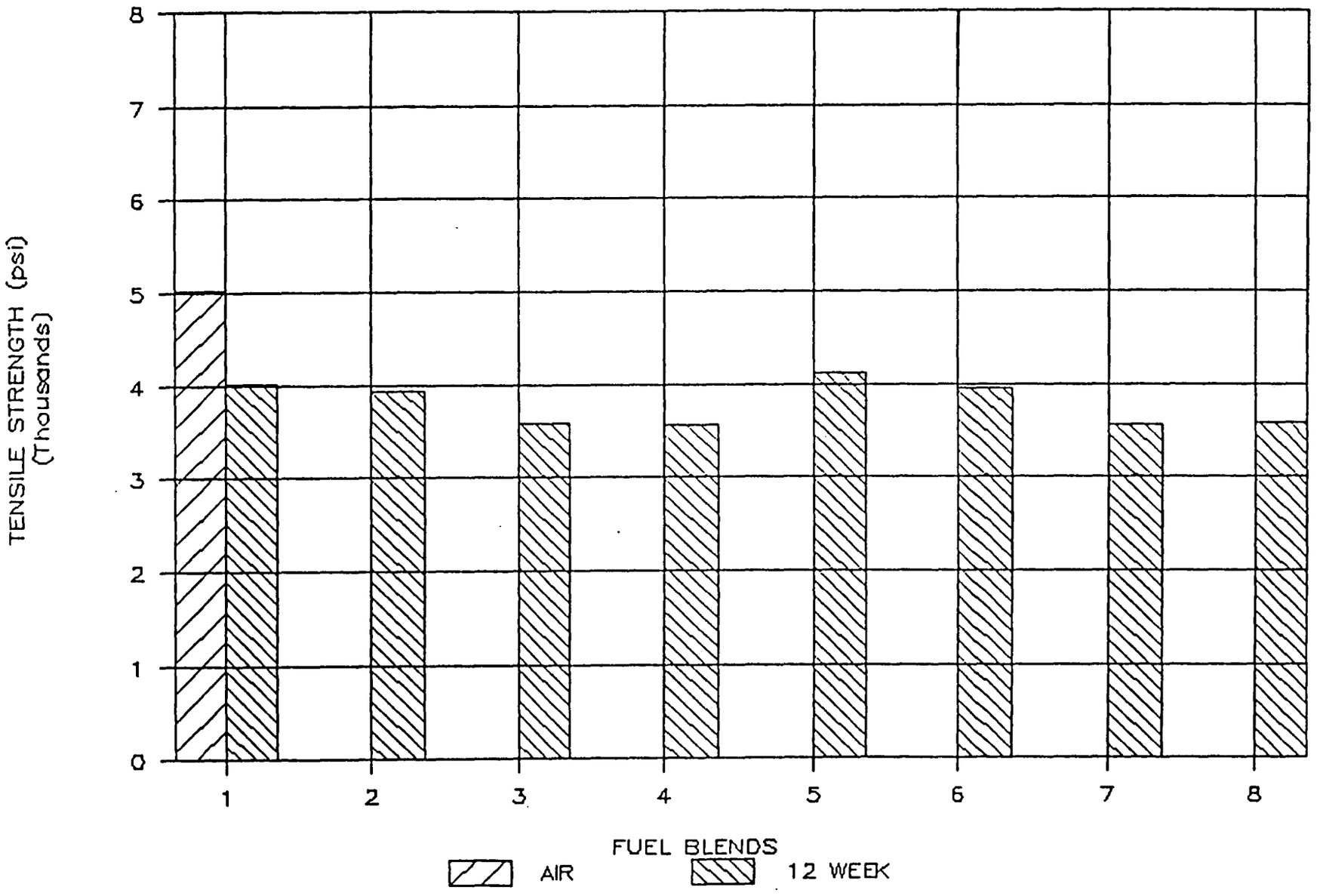
ETHYL FUEL COMPATIBILITY—NYLON 11

AIR AND TWELVE WEEK DATA



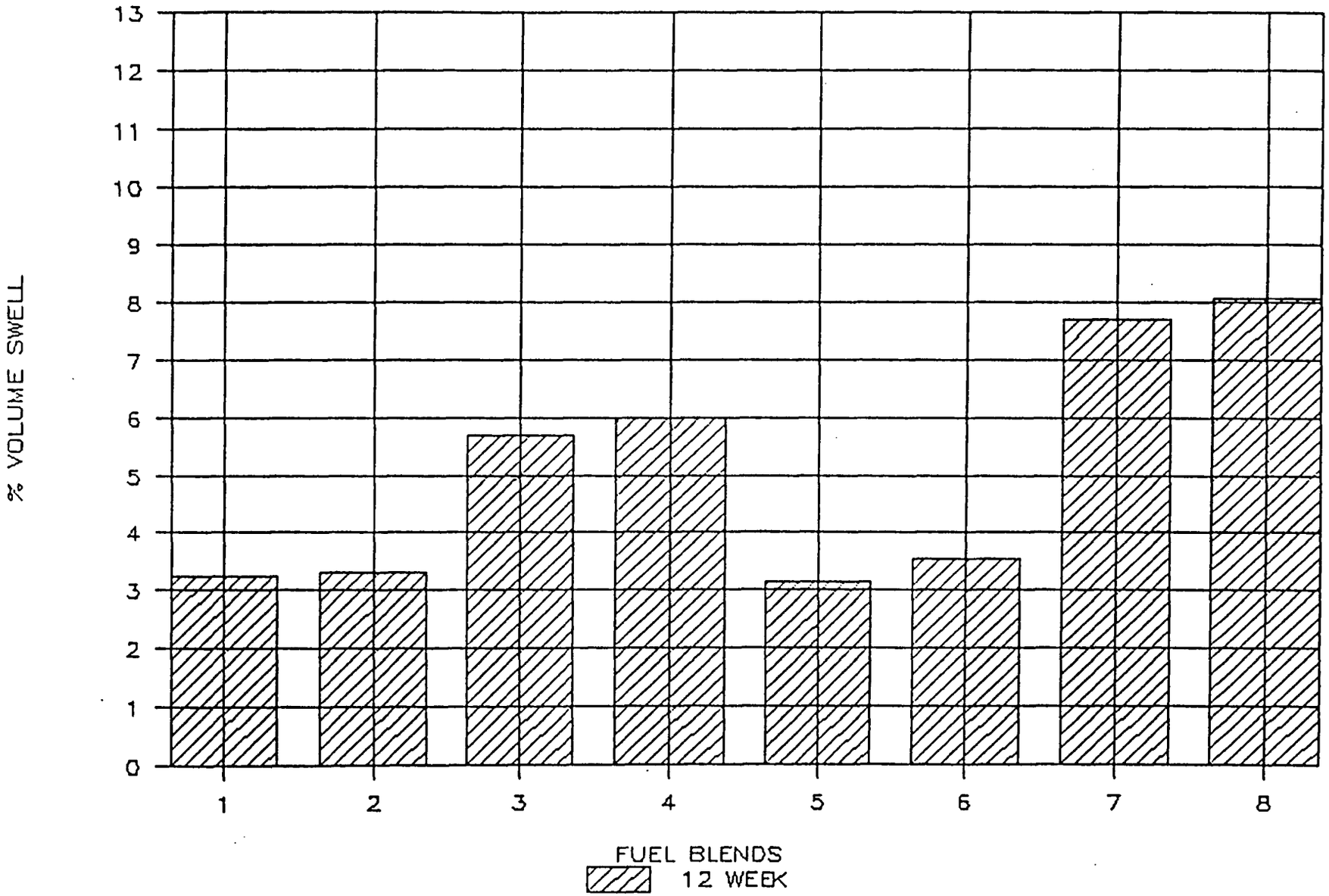
ETHYL FUEL COMPATIBILITY—NYLON 11

AIR AND TWELVE WEEK DATA



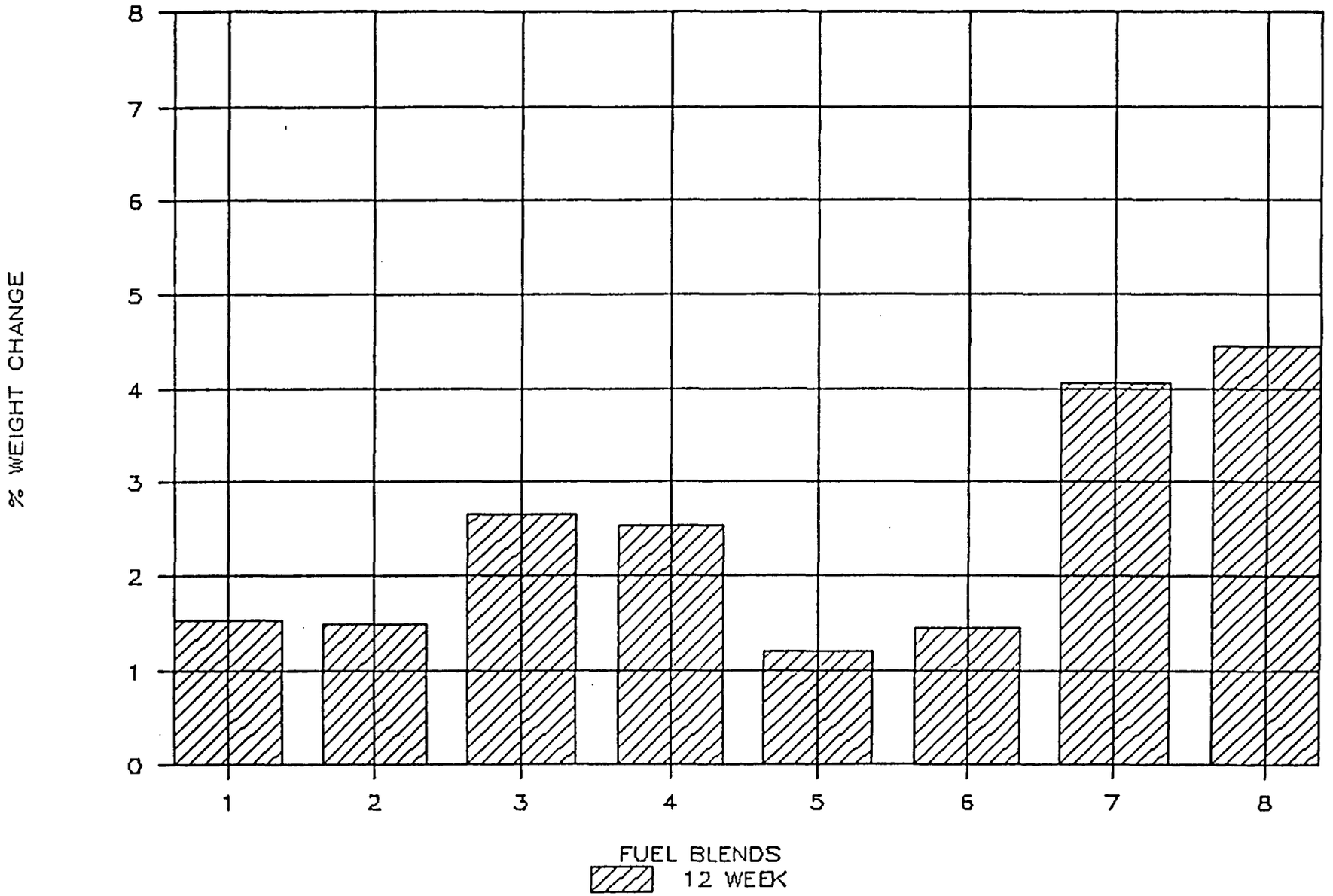
ETHYL FUEL COMPATIBILITY—NYLON 11

TWELVE WEEK DATA



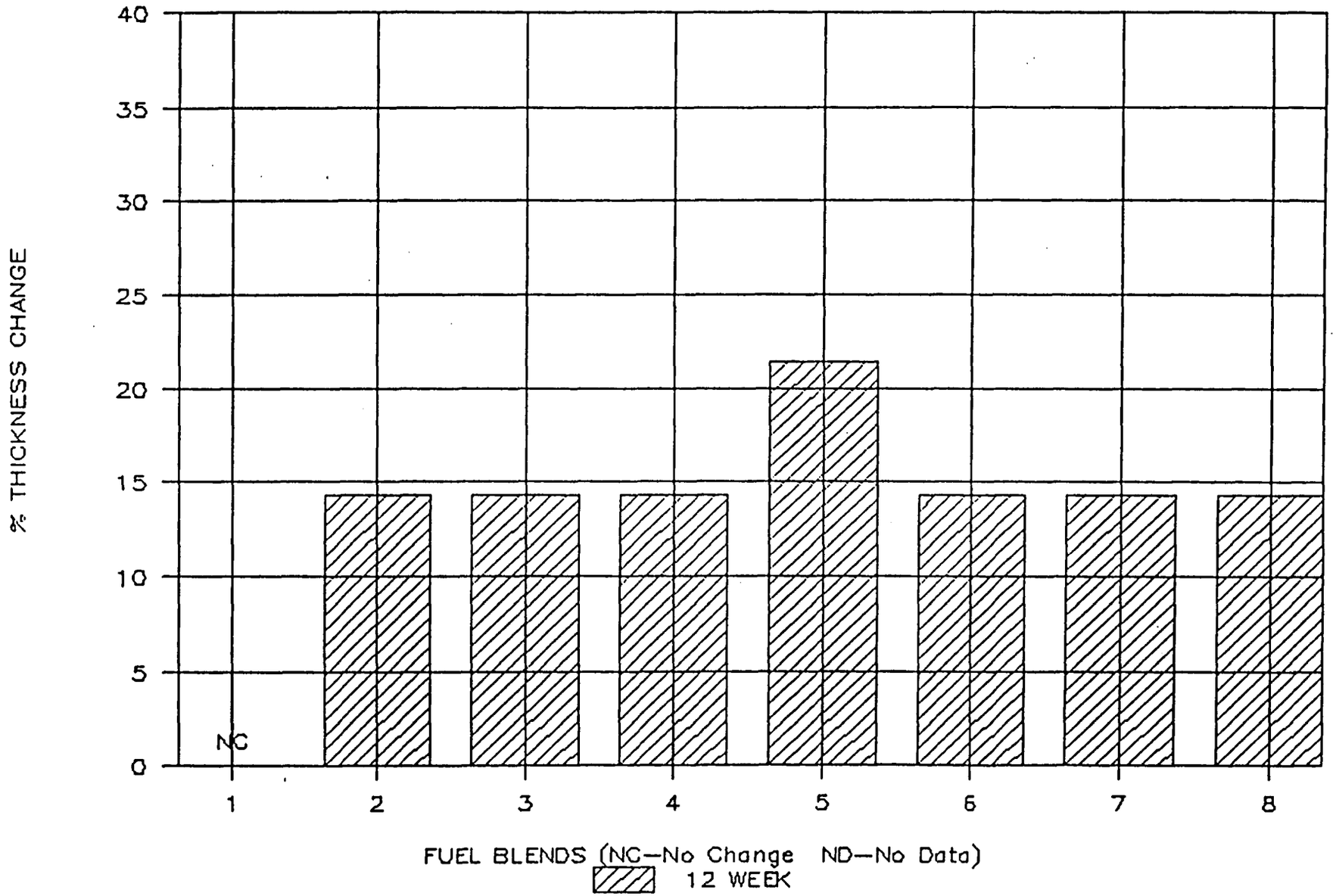
ETHYL FUEL COMPATIBILITY—NYLON 11

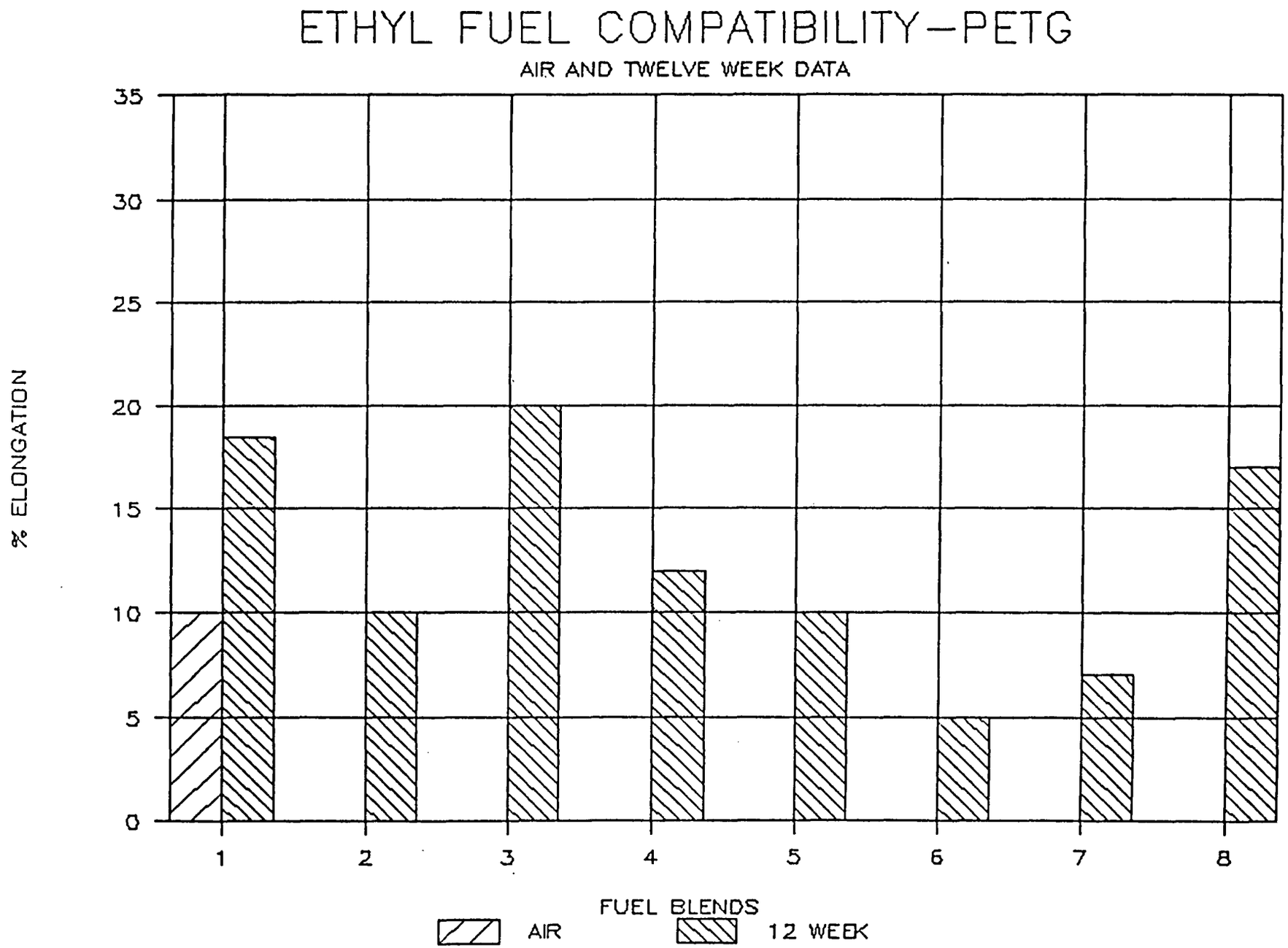
TWELVE WEEK DATA



ETHYL FUEL COMPATIBILITY—PETG

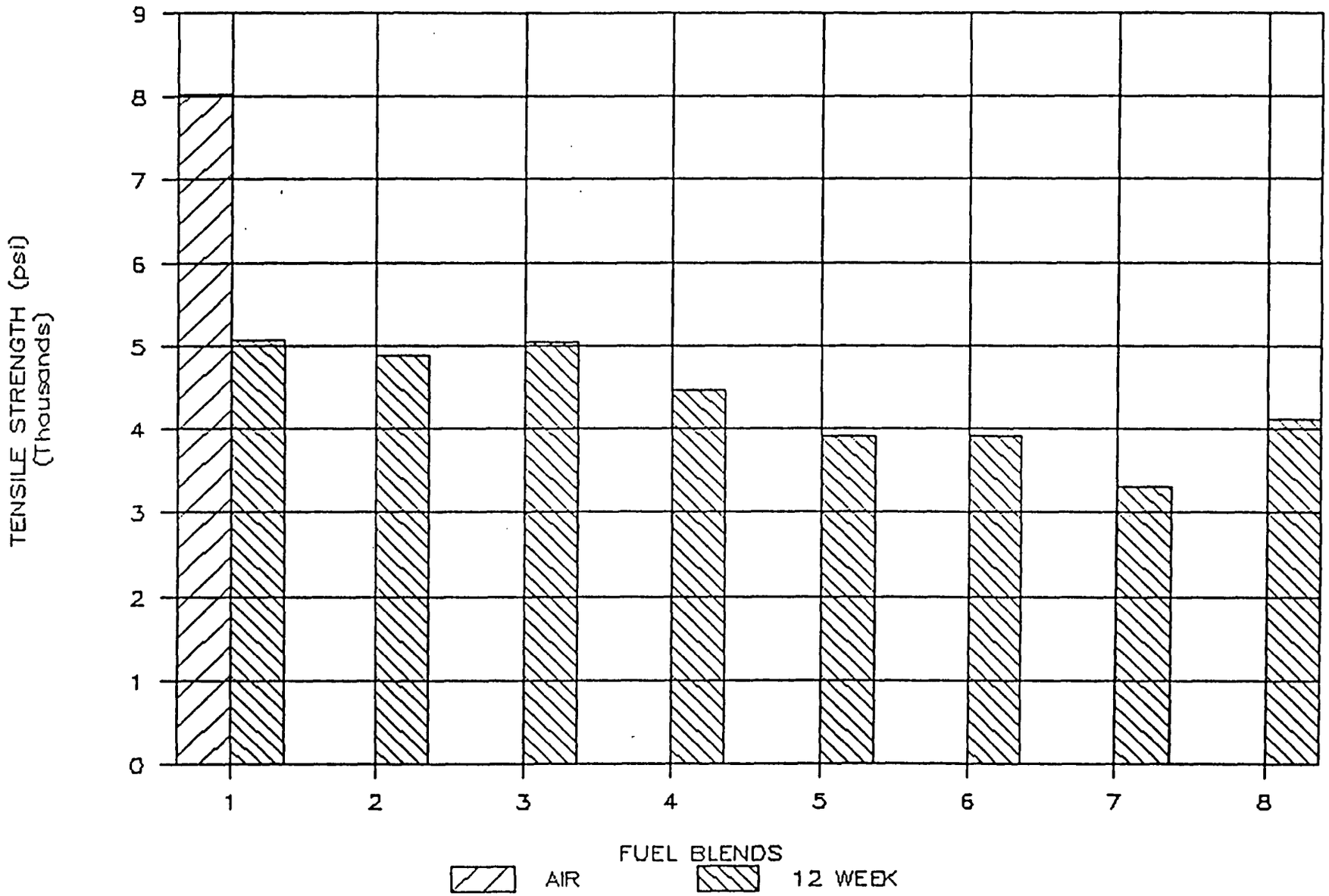
TWELVE WEEK DATA




ETHYL FUEL COMPATIBILITY—PETG
AIR AND TWELVE WEEK DATA
% ELONGATION
35
30
25
20
15
10
5
0
1
2
3
4
5
6
7
8
FUEL BLENDS
AIR
12 WEEK

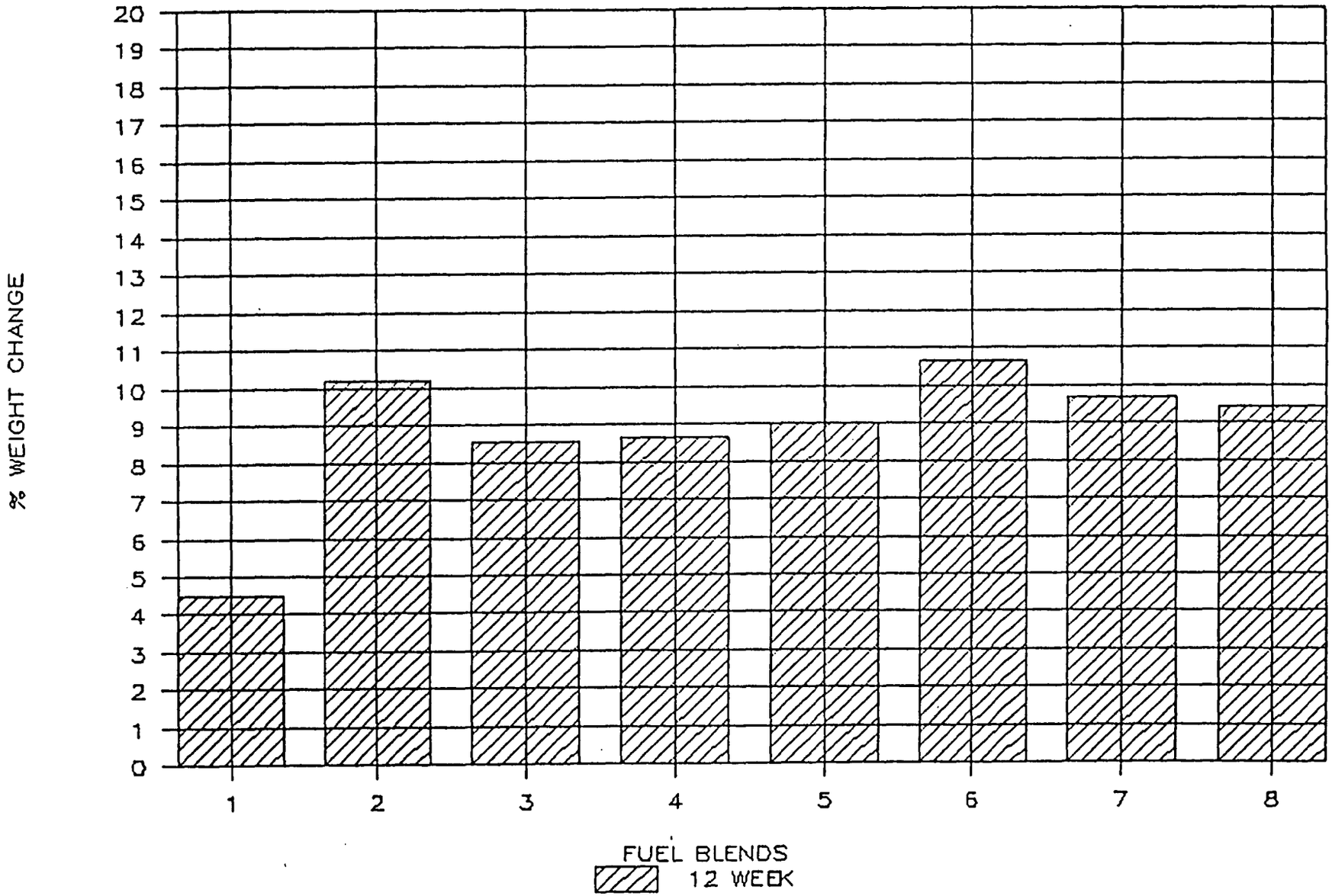
ETHYL FUEL COMPATIBILITY—PETG

AIR AND TWELVE WEEK DATA



ETHYL FUEL COMPATIBILITY—PETG

TWELVE WEEK DATA



APPENDIX

APPENDIX

1. Table I - Test Methods
2. Table II - Test Materials
3. Test Data
   a. 12 week exposure
   b. 4 week exposure
   c. 2 week exposure

TEST METHODS

TABLE I

Test Methods

A. Metals were evaluated for weight change per surface area and change in appearance. The weight change testing was performed in accordance with ASTM G31.

B. The metals were also evaluated for "Anti-rust properties of Cargoes in Petroleum Product Pipelines" a NACE Standard TM-0172-86.

C. The elastomers were evaluated according to ASTM methods as follows:

1. ASTM D412 "Rubber Properties in Tension"
   Tests for: Tensile strength at break
   % elongation at break
   Modulus at 100% load

2. ASTM D471 "Rubber Property - Effect of Liquids"
   Test for: % of Volume Swell

3. ASTM D2240 "Rubber Property - Durometer Hardness"
   Test for: Hardness

D. The plastics were evaluated according to ASTM methods as follows:

1. ASTM D543 "Resistance of Plastics to Chemical Reagents"
   Test for: Dimensional change or volume swell, and weight change

2. ASTM D638 "Tensile Properties of Plastics"
   Test for: Tensile strength at break
   % Elongation at break

MATERIALS

TABLE II

List of Materials Tested

Material Name		Specification or ID[1]
Metals		
1.	Carbon Steel	AISI 1010
2.	Aluminum Cast Alloy	ASTM 319 (SAE 329)
3.	Copper, Electrolytic	CDA 110
4.	Brass, ADMIRALTY	CDA 443
5.	Die Cast Zinc Alloy	ZIMAK 3
6.	Cadmium Plate on 1010 Steel	MILS-QQ-P-416 Thickness - .008" - 0.11"
7.	Terne coating on 1010 steel	85% Pb, 15% Sn Thickness - .0001" - .0002"
Elastomer		
1.	Viton - Low Fluorine	VITON - A, ART 401
2.	Viton - High Fluorine	VITON 6269, ART 400
3.	Hydrin	Epichlorhydrin, ART 146
4.	NBR	Acrylonitrile, ART 117
5.	Urethane	Urethane, ART 505
Plastics		
1.	HDPE	High density polyethylene (molded sheet)
2.	PETG	Polyethylene Terephytholote (extruded film)
3.	Delrin	Acetal Homopolymer (molded sheet)
4.	Nylon 6/6	Nylon (molded sheet)
5.	Nylon 11	Nylaflow LM, (tubing)

(1) ART Number identifies Applied Rubber Technology Batch No. All elastomers were compounded to approximately Dur. 80 hardness.

METALS

TABLE I

METALS STATIC STORAGE FOUR WEEK EXPOSURE RESULTS
(WEIGHT LOSS PER SPECIMEN IN GRAMS PER CM2)

FUEL BLENDS	STEEL 1010	CHANGE IN WEIGHT PER UNIT AREA (AREA Cm2=56.197)	ALUMINUM 329	CHANGE IN WEIGHT PER UNIT AREA (AREA Cm2=46.378)	ZINC ZIMAK 3	CHANGE IN WEIGHT PER UNIT AREA (AREA Cm2=57.142)
1	0.0072	0.0001281207	0.0005	0.00001078	0.0038	0.00006650
2	0.0064	0.0001138851	0.0003	0.00000647	0.0070	0.00012250
3	0.0050	0.0000889727	0.0000	0.00000000	0.0031	0.00005425
4	0.0071	0.0001263413	0.0001	0.00000216	0.0051	0.00008925
5	0.0075	0.0001334591	0.0000	0.00000000	0.0043	0.00007525
6	0.0065	0.0001156645	0.0000	0.00000000	0.0044	0.00007700
7	0.0095	0.0001690482	0.0000	0.00000000	0.0083	0.00014525
8	0.0051	0.0000907522	0.0001	0.00000216	0.0042	0.00007350

FUEL BLENDS	COPPER 110	CHANGE IN WEIGHT PER UNIT AREA (AREA Cm2=56.935)	ADM. BRASS 443	CHANGE IN WEIGHT PER UNIT AREA (AREA Cm2=56.834)	CADIUM PLATE ON CADIUM	CHANGE IN WEIGHT PER UNIT AREA (AREA Cm2=59.420)	TERNE COATING ON STEEL	CHANGE IN WEIGHT PER UNIT AREA (AREA Cm2=56.109
	0.0448	0.00078686	0.0256	0.00045043	0.0018	0.00003029	0.0031	0.00005525
	0.0514	0.00090278	0.0279	0.00049090	0.0034	0.00005722	0.0049	0.00008733
	0.0411	0.00072188	0.0463	0.00081465	0.0018	0.00003029	0.0001	0.00000178
	0.0219	0.00038465	0.0518	0.00091143	0.0031	0.00005217	0.0033	0.00005881
	0.0331	0.00058136	0.0344	0.00060527	0.0063	0.00010602	0.0028	0.00004990
	0.0041	0.00007201	0.0259	0.00045571	0.0034	0.00005722	0.0043	0.00007664
	0.0738	0.00129621	0.0580	0.00102052	0.004	0.00006732	0.0069	0.00012297
	0.0949	0.00166681	0.0528	0.00092902	0.0038	0.00006395	0.0083	0.00014793

TABLE 11

NACE TM-01-72 ANTI RUST TEST (4 WEEK DATA)
(APPEARANCE)

FUEL BLEND	METAL	COMMENTS
1	ALUMINUM	No discolor or stains; no corrosion, pits or rust build up.
2	ALLOY	No discolor, stains or corrosion spots (pits, rust).
3		No discolor, stains or corrosion spots (pits, rust).
4	SAE 329	No discolor, stains or corrosion spots (pits, rust).
5		No discolor, stains or corrosion spots (pits, rust).
6		No discolor, stains or corrosion spots (pits, rust).
7		No discolor, stains or corrosion spots (pits, rust).
8		No discolor, stains or corrosion spots (pits, rust).
1	C1010	Slightly dull gray, small corrosion spots with no pits.
2	METAL	Slightly dull gray, small corrosion spots with no pits.
3		Dull with no discolor and no corrosion or pits.
4	MILD	Dull with no discolor, no corrosion stains or pits.
5	STEEL	Dull with no discolor, few stains and no pits.
6		Dull with no discolor, no corrosion stians or pits.
7		Slightly dull gray with small area of oxidation (Fe_2O_3) build up.
8		Slightly dull gray with small area of oxidation.
1	CDA 110	Brownish deposit film covered the entire specimen.
2	METAL	Brownish deposit film covered the entire specimen.
3		Brownish deposit film covered the entire specimen.
4	COPPER	Brownish deposit film covered the entire specimen.
5	ELECTROLYTE	Brownish deposit film covered the entire specimen.
6		Brownish deposit film covered the entire specimen.
7		Brownish deposit film covered the entire specimen.
8		Brownish deposit film covered the entire specimen.
1	CDA 443	Brownish deposit film covered the entire specimen.
2	METALS	Brownish deposit film covered the entire specimen.
3		Brownish deposit film covered the entire specimen.
4	ADMIRABLY	Brownish deposit film covered the entire specimen.
5	BRASS	Brownish deposit film covered the entire specimen.
6		Brownish deposit film covered the entire specimen.
7		Brownish deposit film covered the entire specimen.
8		Brownish deposit film covered the entire specimen.
1	ZINC	Dull gray with various small areas of oxidation layers with no corrosion stains or pits.
2	ZIMACK 3	Dull gray with various areas of oxidation layers with no corrosion stains or pits.
3		No discolor, corrosion stains or pits.
4		No discolor, corrosion stains or pits.
5		No discolor, corrosion stains or pits.
6		No discolor, corrosion stains or pits.
7		Dull gray with slight oxidation layers and no pits.
8		Dull gray with slight oxidation layers and no pits.

TABLE II (cont.)

1	CADIUM PLATE ON STEEL	No color change, corrosion stains or pits.
2		No color change, corrosion stains or pits.
3		No color change, corrosion stains or pits.
4		No color change, corrosion stains or pits.
5		No color change, corrosion stains or pits.
6		No color change, corrosion stains or pits.
7		No color change, corrosion stains or pits.
8		No color change, corrosion stains or pits.
1	TERNE COATING ON STEEL	Dull gray with no visible corrosion stains or pits.
2		Dull gray with no visible corrosion stains or pits.
3		No discolor, corrosion stains or pits.
4		No discolor, corrosion stains or pits.
5		No discolor, corrosion stains or pits.
6		No discolor, corrosion stains or pits.
7		No discolor, corrosion stains or pits.
8		No discolor, corrosion stains or pits.

ELASTOMERS

FOUR WEEK DATA

(Averages of two specimens per fuel blend used for graphing)

TYPE ELASTOMER	FUEL BLEND	100% MODULUS	TENSILE	% ELONG	% CHANGE HARDNESS	% VOLUME SWELL
NBR	1	328.0	1046.4	616.5	-4.16830	10.10633
ART 117	2	298.0	1030.4	633.0	-5.47945	10.53534
	3	350.0	1312.0	616.5	-15.82157	17.94016
	4	352.0	1062.4	600.0	4.08182	-1.69540
	5	320.0	1070.4	567.0	-5.76923	4.03334
	6	336.0	1164.8	600.0	-5.26582	1.59498
	7	336.0	1086.4	516.5	-3.83035	2.71719
	8	328.0	1062.4	600.0	-3.89744	2.30425

TYPE ELASTOMER	FUEL BLEND	100% MODULUS	TENSILE	% ELONG	% CHANGE HARDNESS	% VOLUME SWELL
HYDRIN	1	430.0	1265.6	467.0	-5.6	8.2
ART 146	2	414.0	1172.8	466.5	-5.7	7.4
	3	422.0	1203.2	466.5	-8.6	15.4
	4	436.5	1156.8	450.0	-3.7	1.8
	5	430.0	1100.8	400.0	-5.5	4.6
	6	454.0	1094.4	416.5	-5.6	4.8
	7	422.0	1062.4	400.0	-8.0	9.7
	8	454.0	1155.2	450.0	-9.9	7.7
AIR						

TYPE ELASTOMER	FUEL BLEND	100% MODULUS	TENSILE	% ELONG	% CHANGE HARDNESS	% VOLUME SWELL
VITON (HI)	1	444.5	867.2	266.5	-9.1	10.9
ART 400	2	314.0	539.2	383.5	-13.8	13.9
	3	398.0	804.8	267.0	-9.9	13.4
	4	390.0	772.8	283.0	-8.1	11.1
	5	454.0	851.2	250.0	-8.6	12.8
	6	414.0	804.8	266.5	-8.6	12.0
	7	414.0	694.4	250.0	-9.8	11.9
	8	398.0	734.4	266.5	-9.3	11.9
AIR						

FOUR WEEK DATA

(Averages of two specimens per fuel blend used for graphing)

TYPE ELASTOMER	FUEL BLEND	100% MODULUS	TENSILE	% ELONG	% CHANGE HARDNESS	% VOLUME SWELL
VITON (LD)	1	290.0	796.8	583.5	-2.1	12.6
ART 401	2	306.0	859.2	650.0	-3.4	12.3
	3	282.0	774.4	683.0	-4.1	20.2
	4	266.0	748.8	716.5	-5.4	15.5
	5	290.0	734.4	633.0	-4.8	16.9
	6	282.0	740.8	700.0	-4.7	16.3
	7	258.0	758.4	699.5	-6.1	17.7
	8	274.0	678.4	650.0	-6.7	22.0
AIR						

TYPE ELASTOMER	FUEL BLEND	100% MODULUS	TENSILE	% ELONG	% CHANGE HARDNESS	% VOLUME SWELL
URETHENE	1	344.0	1476.8	750.0	-3.2	16.2
ART 505	2	360.0	1328.0	716.5	-7.6	15.1
	3	282.0	1468.8	983.0	-15.1	30.0
	4	290.0	1404.8	750.0	-17.5	8.9
	5	306.0	1476.8	750.0	-7.1	12.6
	6	350.0	1399.9	766.5	-5.1	12.2
	7	274.0	921.6	733.5	-21.0	15.7
	8	282.0	921.2	699.5	-26.8	17.2
AIR						

ETHYL FUEL COMPATIBILITY TEST

FOUR WEEK DATA

TYPE ELASTOMER	SPECIMEN NO.	FUEL BLEND	100% MODULUS	TENSILE	% ELONG	% CHANGE HARDNESS	% VOLUME SWELL	DUROMETER INITIAL	DUROMETER FINAL	WEIGHT INITIAL	WEIGHT FINAL	WEIGHT/H20 INITIAL	WEIGHT/H20 FINAL
NBR	3	1	298	1030.4	633	-5.4795	10.5353	73	69	4.1029	4.3093	0.72	0.57
ART 117	9	2	454	1360.0	467	-5.0633	2.9887	79	75	3.7248	3.7161	0.67	0.57
	15	3	358	1452.8	600	-15.8537	19.0977	82	69	4.1179	4.5730	0.74	0.55
	21	4	390	1094.4	600	4.1096	-2.0958	73	76	3.8092	3.6932	0.66	0.61
	27	5	342	1110.4	567	-3.8462	4.0290	78	75	4.2395	4.3013	0.72	0.64
	33	6	330	1376.0	600	-2.5316	-0.2382	79	77	4.1828	4.0746	0.74	0.64
	39	7	330	953.6	500	-5.0633	4.0664	79	75	3.9899	4.1049	0.67	0.65
	45	8	314	937.6	567	-2.6667	2.2153	75	73	3.8234	3.8737	0.65	0.63
BR	4	1	358	1062.4	600	-2.8571	9.6773	70	68	4.2189	4.4475	0.72	0.61
RT 117	10	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	16	3	342	1171.2	633	-15.7895	16.7827	76	64	3.8788	4.2490	0.66	0.49
	22	4	314	1030.4	600	4.0541	-1.2950	74	77	4.0490	3.9455	0.69	0.63
	28	5	298	1030.4	567	-7.6923	4.0377	78	72	4.1697	4.2502	0.69	0.63
	34	6	342	953.6	600	-8.0000	3.4281	75	69	3.9225	3.9540	0.67	0.59
	40	7	342	1219.2	533	-2.5974	1.3680	77	75	4.0953	4.1112	0.74	0.71
	46	8	342	1187.2	633	-5.1282	2.3932	78	74	4.2065	4.2697	0.73	0.71
HYDRIN	3	1	438	1203.2	467	-6.1728	8.3404	81	76	6.6666	6.9308	2.18	2.07
RT 146	9	2	374	1219.2	500	-6.3291	7.6032	79	74	6.5150	6.7384	2.13	2.02
	15	3	438	1251.2	500	-7.4074	15.4698	81	75	6.3877	6.8410	2.10	1.89
	21	4	467	1203.2	433	-3.7037	2.0503	81	78	6.4119	6.3701	2.11	1.98
	27	5	422	1171.2	367	-4.8780	5.3245	82	78	6.7769	6.8990	2.23	2.11
	33	6	454	1078.4	400	-4.9383	4.8991	81	77	6.0563	6.1460	1.98	1.87
	39	7	454	1046.4	333	-8.5366	10.6285	82	75	6.4608	6.7111	2.13	1.92
	45	8	454	1155.2	433	-11.1111	7.9963	81	72	6.4670	6.6938	2.13	2.01
YDRIN	4	1	422	1328.0	467	-5.0000	8.0287	80	76	6.2998	6.5402	2.06	1.96
RT 146	10	2	454	1126.4	433	-5.0000	7.2260	80	76	6.1209	6.3194	1.99	1.89
	16	3	406	1155.2	433	-9.8765	15.3811	81	73	6.5229	7.0155	2.15	1.97
	22	4	406	1110.4	467	-3.7037	1.5235	81	78	6.0958	6.0682	2.00	1.91
	28	5	438	1030.4	433	-6.1728	3.8358	81	76	5.9387	6.0017	1.95	1.86
	34	6	454	1110.4	433	-6.2500	4.6604	80	75	6.3822	6.4827	2.08	1.98
	40	7	390	1078.4	467	-7.5000	8.7371	80	74	6.1716	6.4028	2.04	1.91
	46	8	454	1155.2	467	-8.7500	7.3101	80	73	6.3745	6.5677	2.09	1.97
ITON (hi)	3	1	467	969.6	300	-9.7561	10.8548	82	74	6.8216	7.1234	3.12	3.02
RT 400	9	2	298	483.2	367	-13.7500	13.9850	80	69	6.7475	7.0990	3.09	2.93
	15	3	374	780.8	267	-9.7561	13.0546	82	74	6.7032	7.0575	3.07	2.95
	21	4	358	873.6	333	-8.7500	11.8731	80	73	7.4938	7.8263	3.43	3.28
	27	5	454	828.8	233	-8.6420	12.8014	81	74	7.4044	7.7683	3.39	3.24
	33	6	406	860.8	300	-8.6420	12.1981	81	74	6.9819	7.3020	3.21	3.07
	39	7	422	780.8	300	-8.6420	11.7736	81	74	6.7112	7.0199	3.07	2.95
	45	8	374	764.8	300	-8.7500	12.0738	80	73	7.1570	7.5051	3.28	3.16

ETHYL FUEL COMPATIBILITY TEST

FOUR WEEK DATA

TYPE ELASTOMER	SPECIMEN NO.	FUEL BLEND	100% MODULUS	TENSILE	% ELONG	% CHANGE HARDNESS	% VOLUME SWELL	DUROMETER INITIAL	DUROMETER FINAL	WEIGHT INITIAL	WEIGHT FINAL	WEIGHT/H20 INITIAL	WEIGHT/H20 FINAL
VITON (hi)	4	1	422	764.8	233	-8.5366	10.8719	82	75	6.8560	7.1600	3.14	3.04
ART 400	10	2	330	595.2	400	-13.7500	13.8581	80	69	7.3088	7.6988	3.34	3.18
	16	3	422	828.8	267	-10.0000	13.8290	80	72	7.1135	7.4964	3.26	3.11
	22	4	422	672.0	233	-7.4074	10.3277	81	75	6.1176	6.3592	2.81	2.71
	28	5	454	873.6	267	-8.6420	12.8140	81	74	7.2554	7.6084	3.33	3.18
	34	6	422	748.8	233	-8.6420	11.8972	81	74	7.3802	7.7269	3.37	3.24
	40	7	406	608.0	200	-10.9756	11.9539	82	73	6.9962	7.3288	3.21	3.09
	46	8	422	704.0	233	-9.8765	11.6316	81	73	7.2853	7.6342	3.34	3.23
VITON (lo)	3	1	298	764.8	567	-2.7397	12.3375	73	71	6.6450	6.9610	3.03	2.90
ART 401	9	2	298	873.6	700	-2.7778	12.2899	72	70	6.6904	7.0078	3.05	2.92
	15	3	282	828.8	733	-4.0541	21.4171	74	71	6.5281	7.0580	2.98	2.75
	21	4	266	732.8	700	-4.0541	14.7100	74	71	6.1163	6.4856	2.79	2.67
	27	5	266	764.8	733	-4.1096	17.3481	73	70	6.1316	6.5561	2.82	2.67
	33	6	266	732.8	767	-4.1096	16.5042	73	70	6.6615	7.0992	3.04	2.88
	39	7	282	688.0	599	-5.4054	17.3600	74	70	6.3101	6.7673	2.87	2.73
	45	8	282	748.8	733	-6.6667	18.0859	75	70	6.6599	7.1564	3.03	2.87
VITON (lo)	4	1	282	828.8	600	-1.3699	12.8957	73	72	6.6729	6.9901	3.05	2.90
ART 401	10	2	314	844.8	600	-4.1096	12.2228	73	70	6.6290	6.9489	3.03	2.91
	16	3	282	720.0	633	-4.0541	19.0170	74	71	5.9592	6.4052	2.72	2.55
	22	4	266	764.8	733	-6.7568	16.3368	74	69	6.2603	6.6758	2.86	2.72
	28	5	314	704.0	533	-5.4054	16.4829	74	70	6.5543	6.9918	2.99	2.84
	34	6	298	748.8	633	-5.2632	16.0251	76	72	6.3677	6.7718	2.91	2.76
	40	7	234	828.8	600	-6.7568	18.0196	74	69	6.6949	7.2053	3.03	2.88
	46	8	266	608.0	567	-6.6667	25.9086	75	70	6.0882	6.5179	2.77	2.34
URETHENE	3	1	330	1360.0	733	-3.8462	16.7808	78	75	4.3407	4.7964	0.91	0.79
ART 505	9	2	330	1251.2	733	-7.6923	14.8951	78	72	4.0048	4.3762	0.84	0.74
	15	3	266	1484.8	933	-15.5844	29.5164	77	65	4.1414	4.9270	0.87	0.69
	21	4	250	1404.8	700	-18.7500	6.6201	80	65	4.1407	4.3059	0.89	0.84
	27	5	282	1577.6	667	-7.7922	12.2531	77	71	4.1261	4.4363	0.86	0.77
	33	6	342	1267.0	633	-3.8961	12.8314	77	74	4.3113	4.6503	0.89	0.79
	39	7	266	1014.4	867	-21.5190	15.3045	79	62	4.2734	4.6405	0.96	0.82
	45	8	298	1014.4	733	-25.0000	17.1989	80	60	4.4029	4.8316	0.98	0.82
URETHENE	4	1	358	1593.6	767	-2.5316	15.5342	79	77	4.5065	4.9581	1.02	0.93
ART 505	10	2	390	1404.8	700	-7.5000	15.3286	80	74	4.2321	4.5952	0.95	0.81
	16	3	298	1452.8	1033	-14.6667	30.4382	75	64	4.0551	4.8185	0.89	0.69
	22	4	330	1404.8	800	-16.2500	11.1472	80	67	4.5303	4.7916	1.02	0.89
	28	5	330	1376.0	833	-6.4935	12.9682	77	72	4.2752	4.6142	0.89	0.79
	34	6	358	1532.8	900	-6.3291	11.5729	79	74	4.2097	4.4881	0.94	0.84
	40	7	282	828.8	600	-20.5128	16.1549	78	62	4.0905	4.4840	0.85	0.72
	46	8	266	828.0	666	-28.5714	17.2155	77	55	4.1023	4.5022	0.85	0.69

TWO WEEK DATA

(Averages of two specimens per fuel blend used for graphing)

TYPE ELASTOMER	FUEL BLEND	100% MODULUS	TENSILE	% ELONG	% CHANGE HARDNESS	% VOLUME SWELL
NBR	1	406.0	1008.0	416.5	-0.71429	9.01616
ART 117	2	507.0	1328.0	383.5	2.14487	3.91542
	3	390.0	1304.0	450.0	-3.45345	2.38987
	4	414.0	1108.8	483.5	-2.11268	3.71713
	5	531.0	1328.0	367.0	-1.89935	-1.19303
	6	672.0	1265.6	283.5	-5.82104	-0.75327
	7	547.0	1265.6	367.0	-3.95022	3.12306
	8	404.5	1296.0	483.0	-12.78075	6.51155
AIR		366.0	1304.0	550.0		

TYPE ELASTOMER	FUEL BLEND	100% MODULUS	TENSILE	% ELONG	% CHANGE HARDNESS	% VOLUME SWELL
HYDRIN	1	531.0	1092.8	300.0	-4.45472	5.81169
ART 146	2	483.0	1022.4	333.5	-4.37500	6.07067
	3	500.5	1148.8	350.0	-8.70370	7.21930
	4	507.0	1124.8	333.5	-10.55556	8.65864
	5	452.5	1110.4	333.5	-5.55556	5.32488
	6	499.0	1187.2	350.0	-5.51792	5.57133
	7	460.5	1116.8	317.0	-15.33424	8.14833
	8	452.5	1022.4	317.0	-12.96296	11.01952
AIR		438.0	1014.4	333.0		

TYPE ELASTOMER	FUEL BLEND	100% MODULUS	TENSILE	% ELONG	% CHANGE HARDNESS	% VOLUME SWELL
VITON (HI)	1	585.5	875.2	166.5	-9.25926	10.63213
ART 400	2	422.5	632.0	250.0	-11.75305	11.91729
	3	274.0	468.8	333.5	-15.00000	13.11341
	4	507.0	710.4	167.0	-9.93827	12.34325
	5	428.5	694.4	250.0	-11.26739	13.26445
	6	454.0	766.4	200.0	-7.45370	11.91075
	7	446.0	680.0	167.0	-12.43056	12.33629
	8	430.5	640.0	233.5	-23.00000	13.67077
AIR		366.0	764.8	416.5		

TWO WEEK DATA

(Averages of two specimens per fuel blend used for graphing)

TYPE ELASTOMER	FUEL BLEND	100% MODULUS	TENSILE	% ELONG	% CHANGE HARDNESS	% VOLUME SWELL
VITON (LO)	1	322.0	772.8	500.0	-4.66667	10.61694
ART 401	2	306.0	867.2	550.0	-2.06431	10.83042
	3	390.5	702.4	350.0	-6.07306	16.91213
	4	306.0	680.0	483.5	-7.37838	17.19981
	5	306.0	718.4	450.0	-6.75676	17.78230
	6	298.0	704.0	500.0	-5.36937	15.50201
	7	282.0	704.0	466.5	-12.16216	18.46548
	8	298.0	748.8	516.5	-13.41441	18.45335
AIR		298.0	828.8	650.0		

TYPE ELASTOMER	FUEL BLEND	100% MODULUS	TENSILE	% ELONG	% CHANGE HARDNESS	% VOLUME SWELL
URETHENE	1	414.0	1360.0	583.0	-4.48718	13.84174
ART 505	2	390.0	1320.0	550.0	-4.48718	13.46737
	3	360.0	1454.4	700.0	-16.21120	17.24004
	4	312.0	1062.4	650.0	-17.33520	18.87691
	5	382.0	1390.4	600.0	-9.60875	13.28316
	6	374.0	1369.0	600.0	-7.14286	12.97438
	7	314.0	835.2	550.0	-30.31136	21.06865
	8	306.0	975.7	550.0	-31.25000	21.66324
AIR		352.0	1420.8	583.5		

ETHYL FUEL COMPATIBILITY TEST

TWO WEEKS DATA

TYPE ELASTOMER	SPECIMEN NO.	FUEL BLEND	100% MODULUS	TENSILE	% ELONG	% CHANGE HARDNESS	% VOLUME SWELL	DUROMETER INITIAL	DUROMETER FINAL	WEIGHT INITIAL	WEIGHT FINAL	WEIGHT/H20 INITIAL	WEIGHT/H20 FINAL
R	1	1	422	1078.4	433	-1.4286	8.6522	70	69	4.2324	4.4563	0.72	0.64
RT 117	7	2	483	1296.0	367	-1.2658	4.0119	79	78	3.9304	3.9804	0.69	0.61
	13	3	422	1420.8	500	-1.3514	-0.0381	74	73	4.1528	4.0515	0.74	0.64
	19	4	422	1139.2	500	-1.4085	4.0765	71	70	4.0930	4.1305	0.72	0.62
	25	5	547	1328.0	367	-2.5000	-0.5803	80	78	3.9986	3.9094	0.69	0.62
	31	6	845	1328.0	200	-5.6180	-1.1061	89	84	4.1888	4.0622	0.88	0.79
	37	7	720	1420.8	267	1.1905	-1.2525	84	85	4.5765	4.5397	0.84	0.85
	43	8	467	1436.8	433	-16.4706	8.6860	85	71	3.9589	4.1111	0.71	0.58
R	2	1	390	937.6	400	0.0000	9.3801	70	70	3.8777	4.1014	0.64	0.56
T 117	8	2	531	1360.0	400	5.5556	3.8190	72	76	3.9805	4.0154	0.71	0.62
	14	3	358	1187.2	400	-5.5556	4.8178	72	68	4.3429	4.4060	0.75	0.64
	20	4	406	1078.4	467	-2.8169	3.3578	71	69	3.8894	3.9175	0.67	0.59
	26	5	515	1328.0	367	-1.2987	-1.8058	77	76	4.0570	3.9362	0.69	0.63
	32	6	499	1203.2	367	-6.0241	-0.4004	83	78	3.8768	3.7740	0.68	0.59
	38	7	374	1110.4	467	-9.0909	7.4986	77	70	4.1433	4.2715	0.70	0.57
	44	8	342	1155.2	533	-9.0909	4.3371	77	70	4.0809	4.1484	0.68	0.60
YDRIN	1	1	515	1139.2	333	-3.8462	6.6813	78	75	6.5169	6.7400	2.13	2.06
T 146	7	2	483	1030.4	367	-5.0000	5.8714	80	76	5.8899	6.0324	1.93	1.84
	13	3	454	1203.2	400	-10.0000	8.0788	80	72	6.6162	6.8254	2.17	2.02
	19	4	531	1014.4	300	-10.0000	8.1844	80	72	6.3210	6.5281	2.08	1.94
	25	5	422	1110.4	367	-7.4074	6.0331	81	75	6.2569	6.3895	2.07	1.95
	31	6	499	1171.2	333	-6.0976	5.0555	82	77	6.5551	6.6878	2.15	2.06
	37	7	467	1046.4	267	-15.8537	6.9981	82	69	6.1897	6.3508	2.03	1.90
	43	8	483	905.6	267	-13.5802	8.0680	81	70	6.5853	6.8504	2.06	1.96
DRIN	2	1	547	1046.4	267	-5.0633	4.9421	79	75	6.5732	6.6818	2.15	2.04
RT 146	8	2	483	1014.4	300	-3.7500	6.2700	80	77	6.4086	6.5781	2.11	2.01
	14	3	547	1094.4	300	-7.4074	6.3598	81	75	5.9863	6.1230	1.95	1.83
	20	4	483	1235.2	367	-11.1111	9.1329	81	72	6.8411	7.1004	2.25	2.09
	26	5	483	1110.4	300	-3.7037	4.6167	81	78	6.2630	6.3875	2.05	1.98
	32	6	499	1203.2	367	-4.9383	6.0872	81	77	6.6650	6.8174	2.19	2.07
	38	7	454	1187.2	367	-14.8148	9.2986	81	69	6.7379	6.9880	2.22	2.05
	44	8	422	1139.2	367	-12.3457	13.9711	81	71	6.1581	6.3355	2.24	1.87
TON (hi)	1	1	515	828.8	200	-8.6420	10.9062	81	74	7.1357	7.4373	3.27	3.15
T 400	7	2	515	748.8	167	-9.7561	11.0972	82	74	7.0898	7.3848	3.26	3.13
	13	3	282	515.2	367	-16.2500	13.2855	80	67	6.9508	7.3031	3.17	3.02
	19	4	483	688.0	167	-9.8765	12.4166	81	73	7.1421	7.4604	3.29	3.13
	25	5	499	889.6	233	-9.8765	12.3823	81	73	7.0858	7.4320	3.24	3.11
	31	6	454	844.8	233	-7.5000	11.8664	80	74	6.6207	6.9156	3.04	2.91
	37	7	454	688.0	167	-11.1111	11.7587	81	72	6.6504	6.9552	3.05	2.93
	43	8	531	796.8	167	-19.7500	12.7459	81	65	7.2897	7.6344	3.33	3.17

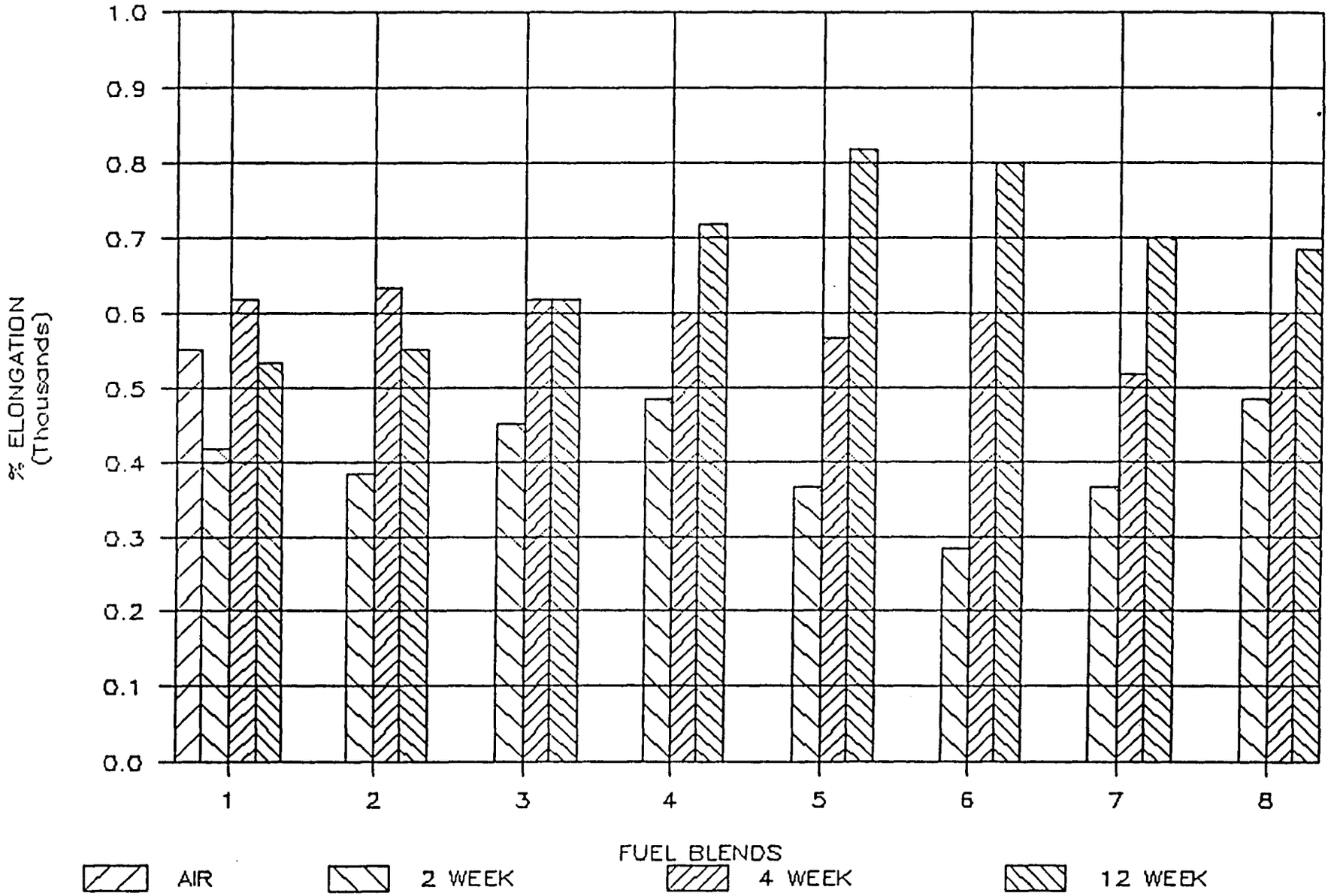
ETHYL FUEL COMPATIBILITY TEST

TWO WEEKS DATA

TYPE ELASTOMER	SPECIMEN NO.	FUEL BLEND	100% MODULUS	TENSILE	% ELONG	% CHANGE HARDNESS	% VOLUME SWELL	DUROMETER INITIAL	DUROMETER FINAL	WEIGHT INITIAL	WEIGHT FINAL	WEIGHT/H20 INITIAL	WEIGHT/H20 FINAL
ITON (hi)	2	1	656	921.6	133	-9.8765	10.3581	81	73	7.3775	7.6826	3.37	3.26
RT 400	8	2	330	515.2	333	-13.7500	12.7374	80	69	7.0581	7.4057	3.23	3.09
	14	3	266	422.4	300	-13.7500	12.9413	80	69	6.2337	6.5303	2.86	2.72
	20	4	531	732.8	167	-10.0000	12.2699	80	72	6.9282	7.2381	3.18	3.03
	26	5	358	499.2	267	-12.6582	14.1466	79	69	7.1812	7.5745	3.27	3.11
	32	6	454	688.0	167	-7.4074	11.9551	81	75	6.4890	6.7797	2.97	2.84
	38	7	438	672.0	167	-13.7500	12.8739	80	69	7.4987	7.8625	3.43	3.27
	44	8	330	483.2	300	-26.2500	14.5956	80	59	7.3897	7.8164	3.37	3.21
ITON (lo)	1	1	314	812.8	500	-4.0000	10.5058	75	72	6.5685	6.8555	2.98	2.89
RT 401	7	2	298	873.6	567	-1.3889	10.6896	72	71	6.4693	6.7555	2.95	2.86
	13	3	314	672.0	500	-5.4795	17.1097	73	69	6.1971	6.6232	2.83	2.68
	19	4	298	672.0	467	-8.0000	16.9342	75	69	6.3775	6.8030	2.92	2.76
	25	5	298	704.0	433	-6.7568	17.4987	74	69	6.4174	6.8459	2.94	2.76
	31	6	330	704.0	500	-5.4054	15.4645	74	70	6.0356	6.4137	2.75	2.62
	37	7	282	688.0	433	-12.1622	18.3744	74	65	6.3348	6.7896	2.88	2.70
	43	8	266	748.8	533	-12.1622	17.8610	74	65	6.3551	6.8240	2.89	2.74
ITON (lo)	2	1	330	732.8	500	-5.3333	10.7281	75	71	6.2644	6.5407	2.85	2.76
RT 401	8	2	314	860.8	533	-2.7397	10.9712	73	71	6.6258	6.9214	3.02	2.92
	14	3	467	732.8	200	-6.6667	16.7146	75	70	6.7025	7.1530	3.05	2.89
	20	4	314	688.0	500	-6.7568	17.4654	74	69	6.4246	6.8632	2.94	2.77
	26	5	314	732.8	467	-6.7568	18.0659	74	69	6.7189	7.1763	3.08	2.88
	32	6	266	704.0	500	-5.3333	15.5396	75	71	6.1012	6.4873	2.78	2.65
	38	7	282	720.0	500	-12.1622	18.5565	74	65	6.2515	6.6827	2.85	2.65
	44	8	330	748.8	500	-14.6667	19.0457	75	64	6.5283	6.9941	2.98	2.77
ETHENE	1	1	422	1267.2	533	-3.8462	13.7335	78	75	4.3432	4.7147	0.91	0.81
RT 505	7	2	374	1360.0	567	-5.1282	13.9226	78	74	4.2500	4.6178	0.89	0.79
	13	3	298	1392.0	767	-17.9487	15.4675	78	64	4.1962	4.5914	0.93	0.82
	19	4	266	1139.2	600	-15.1899	17.9162	79	67	4.4706	4.9624	1.00	0.87
	25	5	390	1360.0	567	-10.1266	12.9382	79	71	4.4673	4.8172	0.99	0.89
	31	6	358	1344.0	600	-7.7922	11.8938	77	71	4.0140	4.2927	0.83	0.73
	37	7	330	656.0	433	-28.5714	21.9265	77	55	4.1218	4.6270	0.86	0.65
	43	8	314	937.0	500	-30.0000	21.2224	80	56	4.0994	4.6090	0.85	0.67
ETHENE	2	1	406	1452.8	633	-5.1282	13.9499	78	74	4.3960	4.7709	0.92	0.81
T 505	8	2	406	1280.0	533	-3.8462	13.0121	78	75	4.0816	4.4221	0.85	0.77
	14	3	422	1516.8	633	-14.4737	19.0126	76	65	4.4140	4.9402	0.91	0.77
	20	4	358	985.6	700	-19.4805	19.8376	77	62	4.3338	4.8530	0.91	0.75
	26	5	374	1420.8	633	-9.0909	13.6281	77	70	4.3094	4.6754	0.89	0.79
	32	6	390	1392.0	600	-6.4935	14.0549	77	72	4.3266	4.6768	0.91	0.78
	38	7	298	1014.4	667	-32.0513	20.2108	78	53	4.2684	4.7712	0.89	0.71
	44	8	298	1014.4	600	-32.5000	22.1041	80	54	4.1141	4.6456	0.85	0.66

ETHYL FUEL COMPATIBILITY—NBR

(AIR, TWO, FOUR AND TWELVE WEEK DATA)



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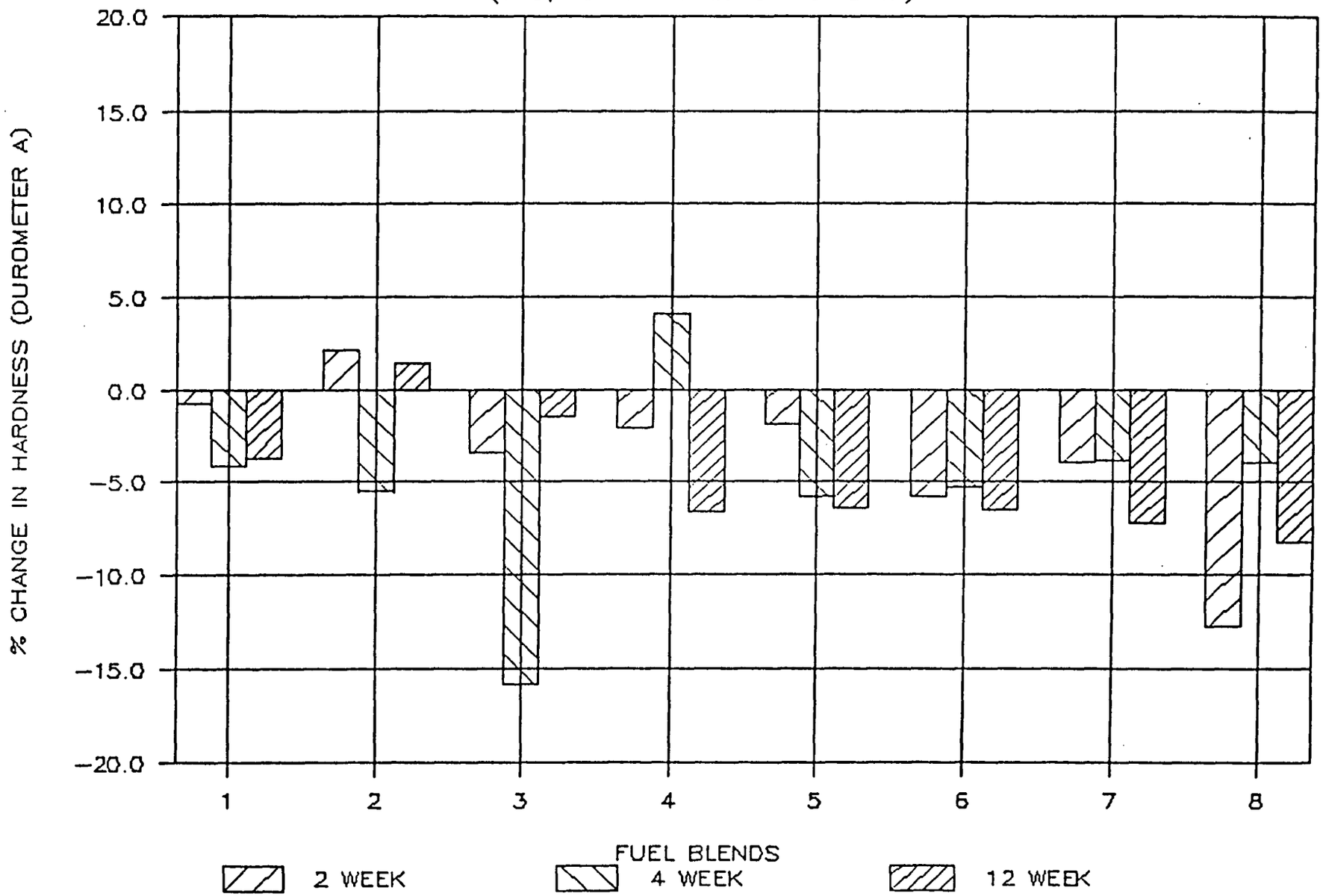

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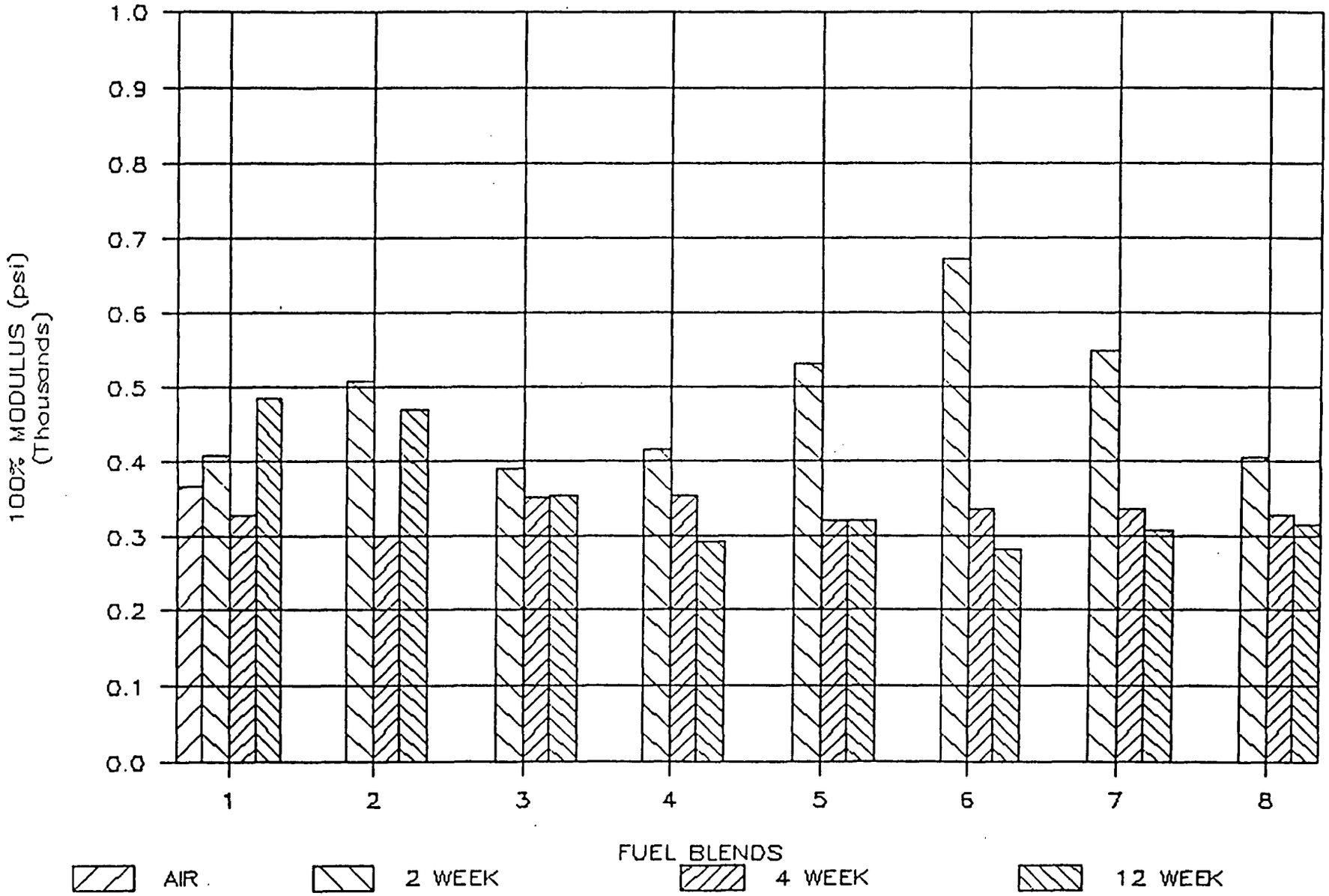

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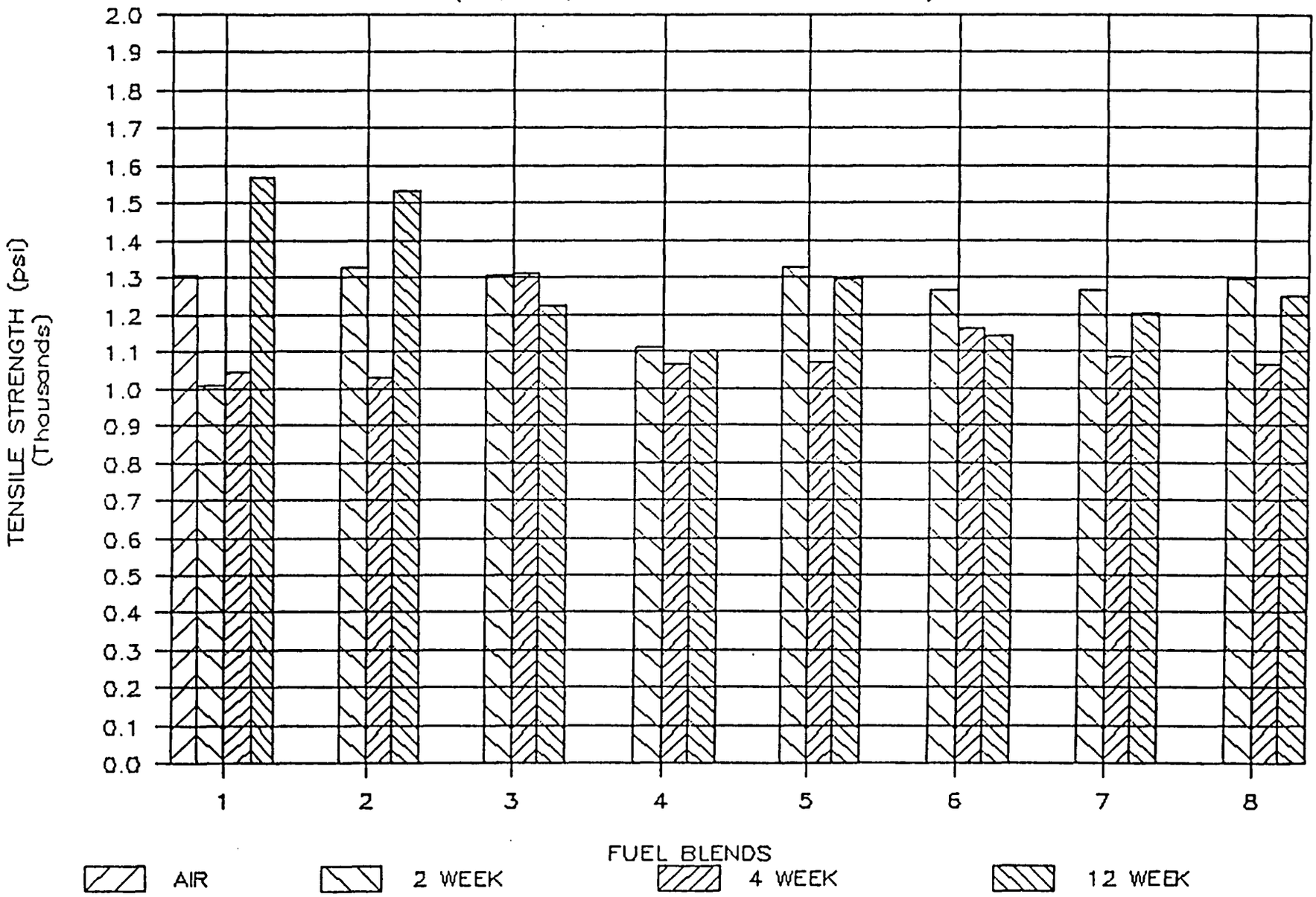

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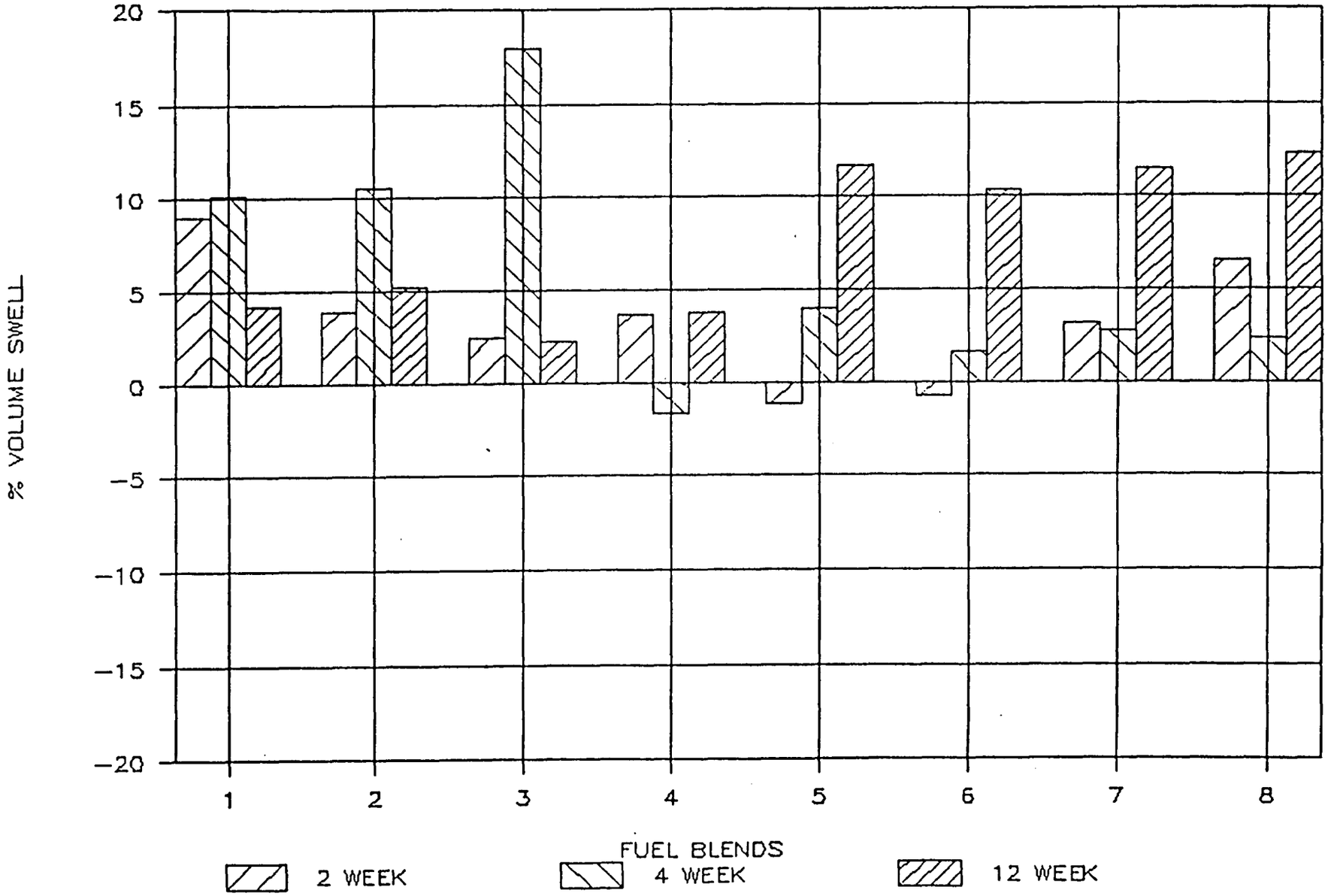

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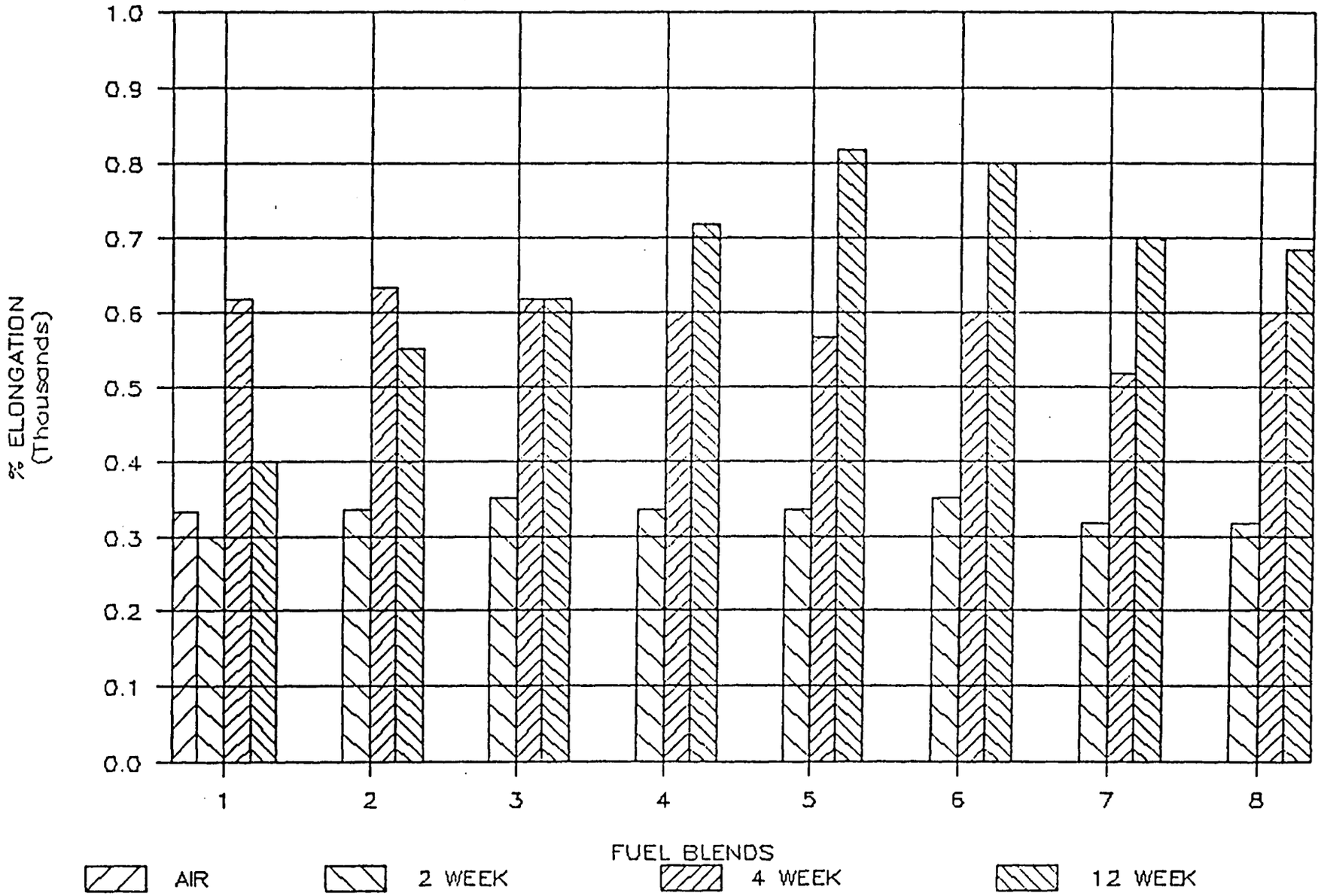

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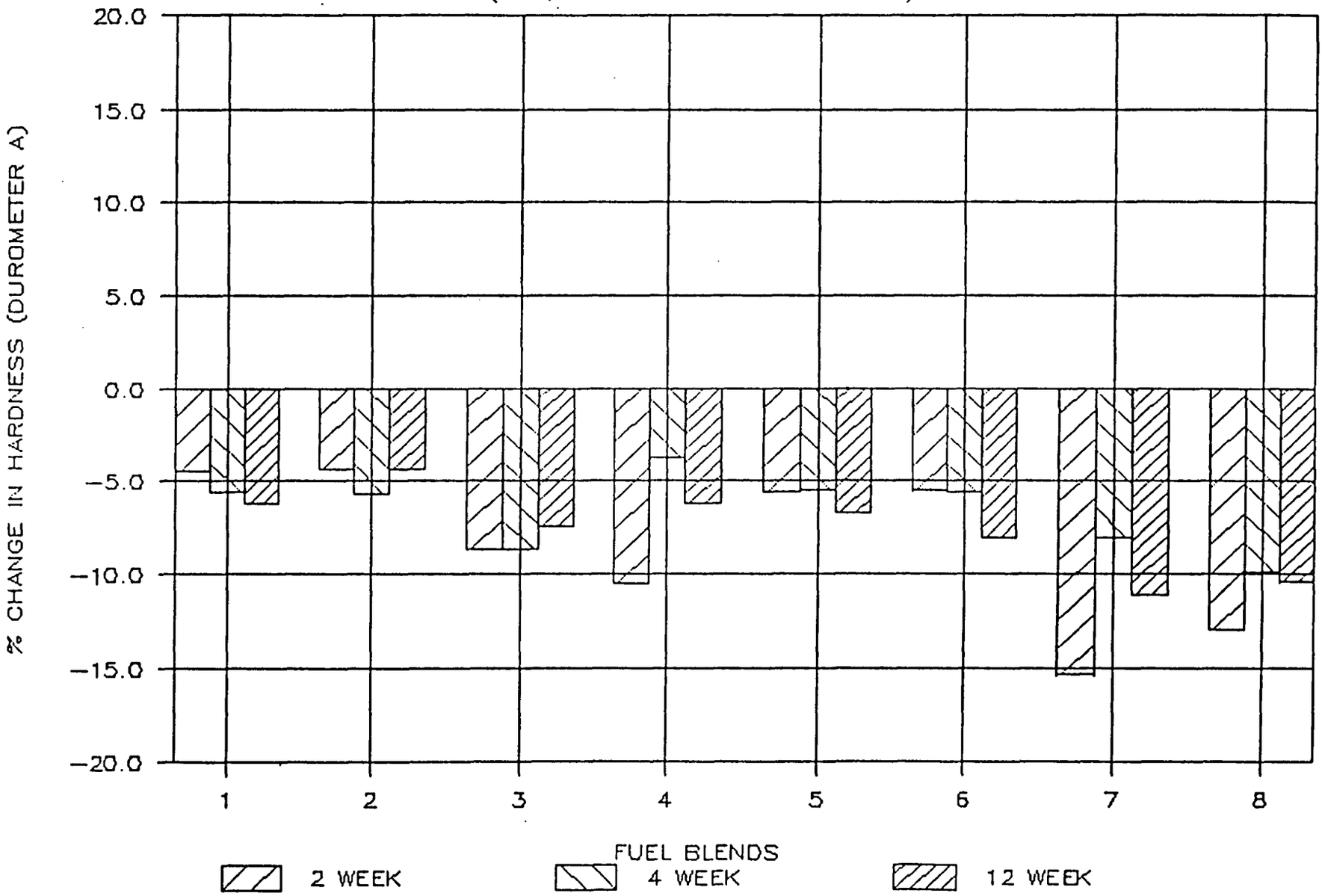

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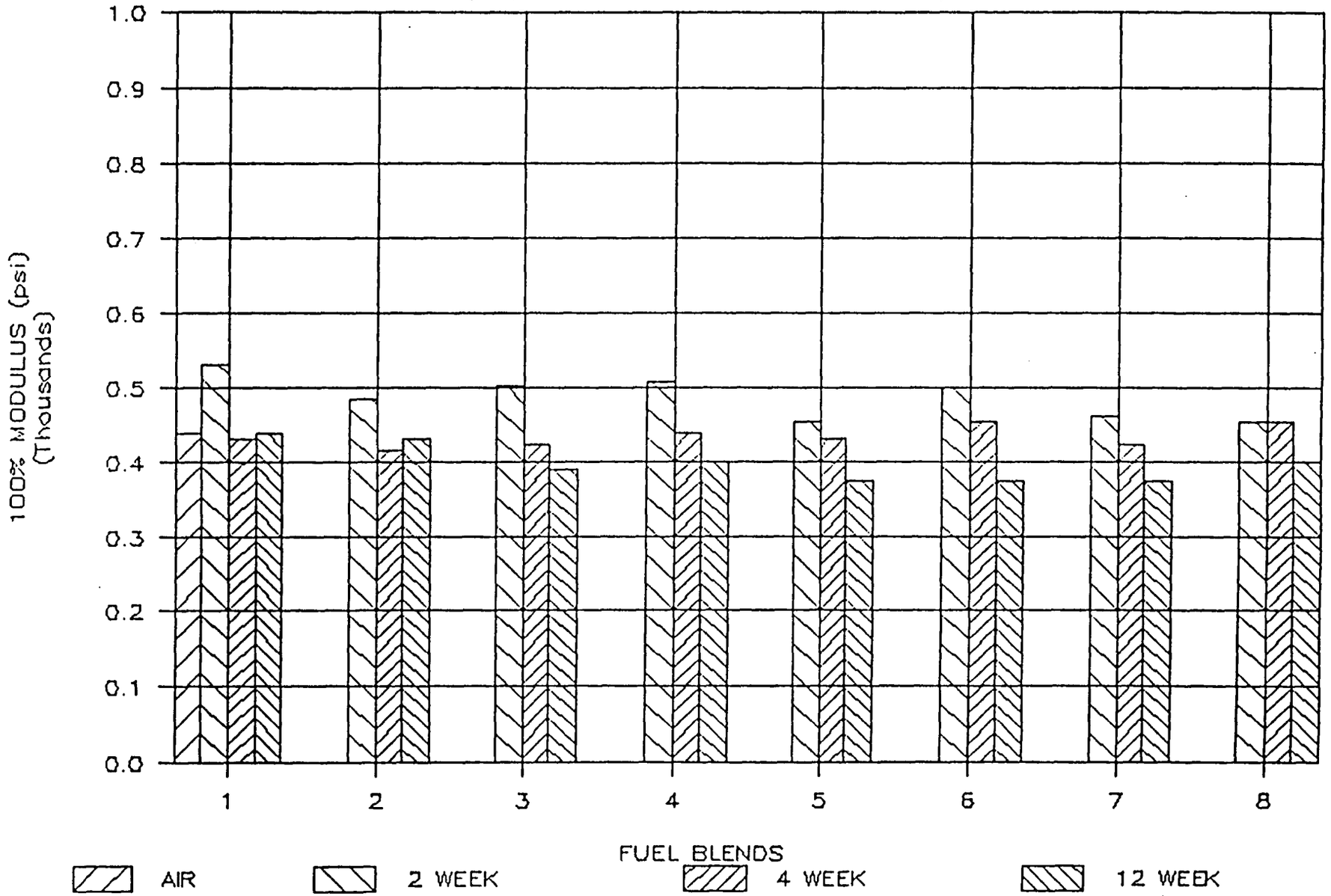

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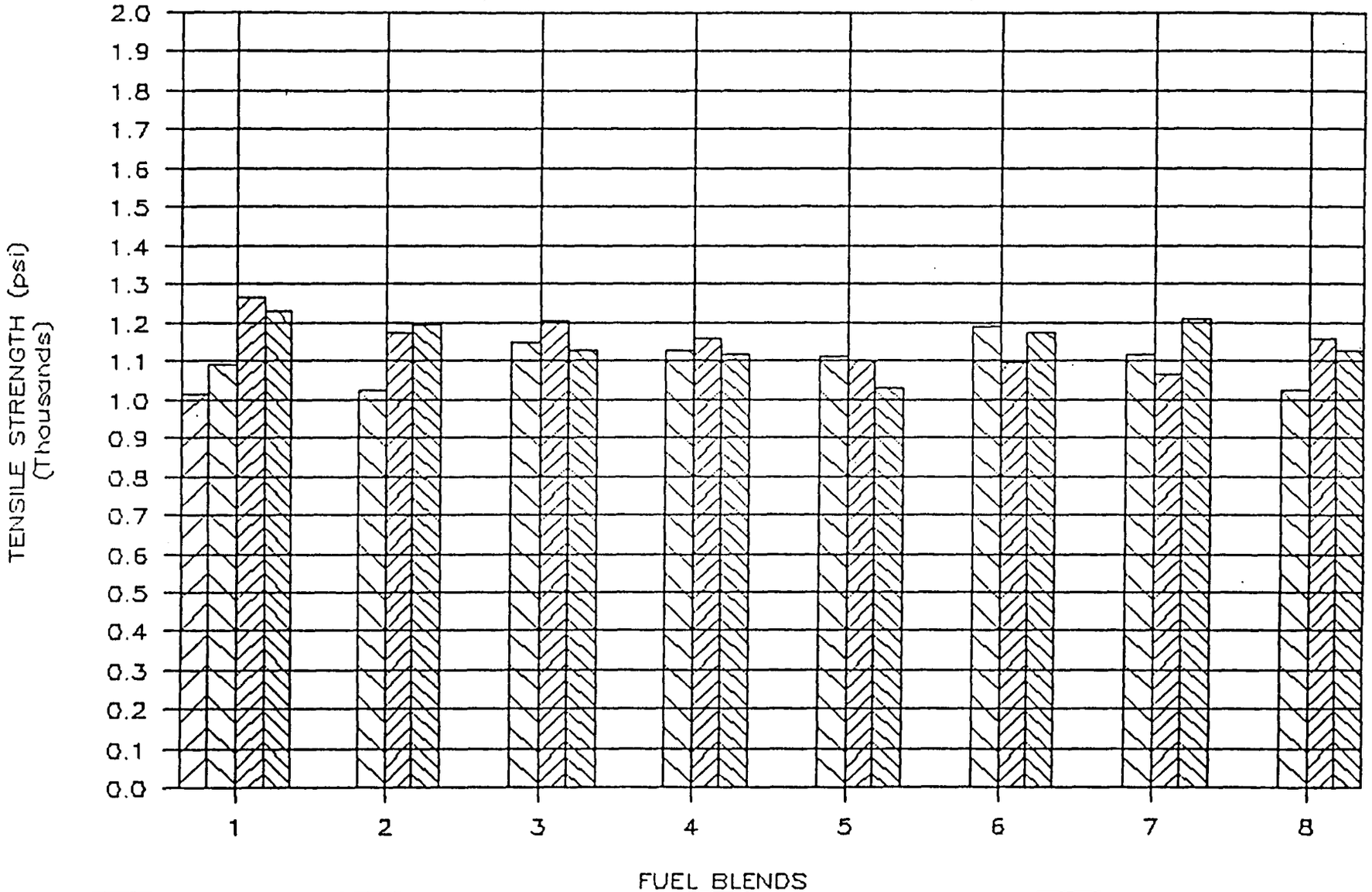

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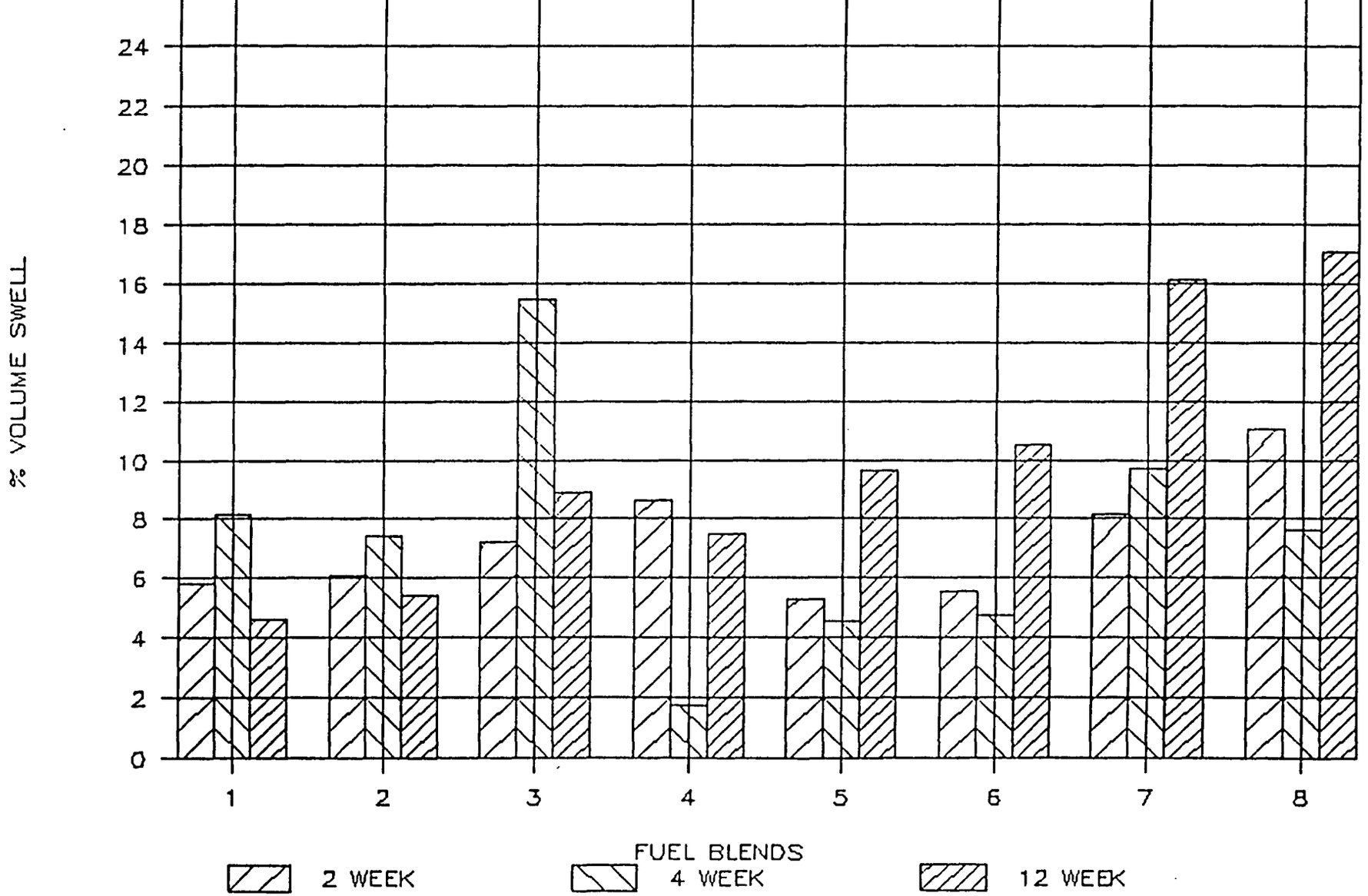

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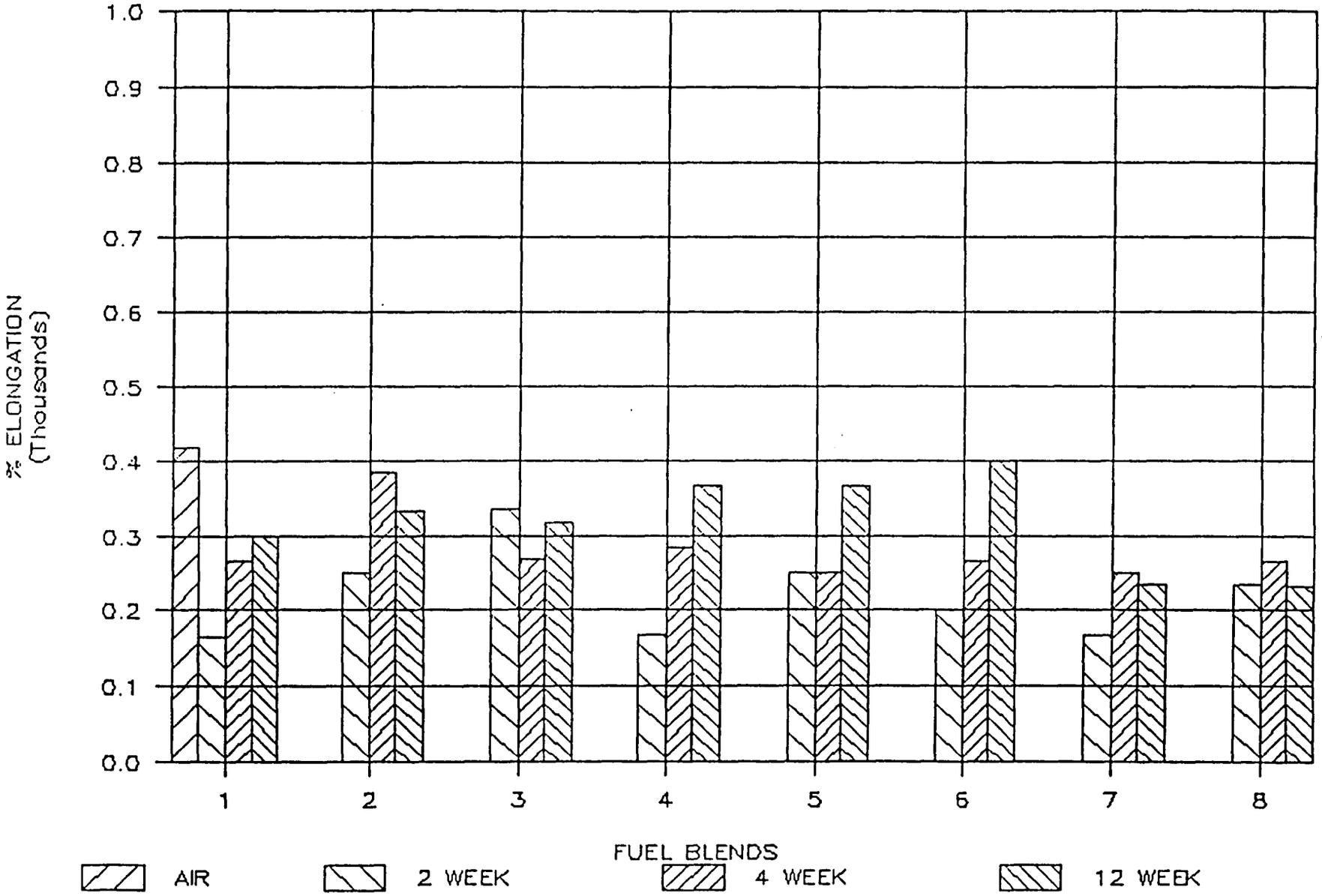

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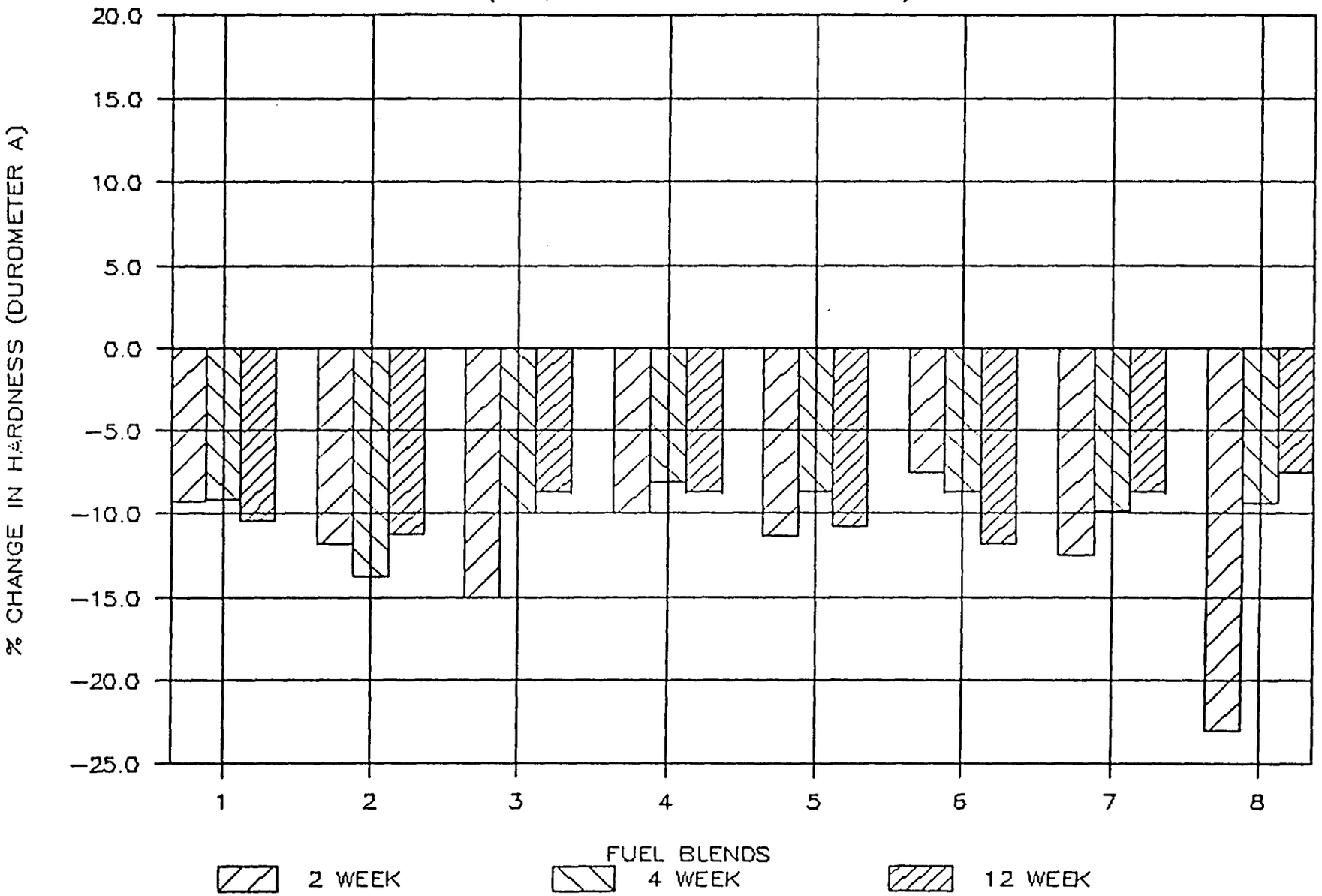

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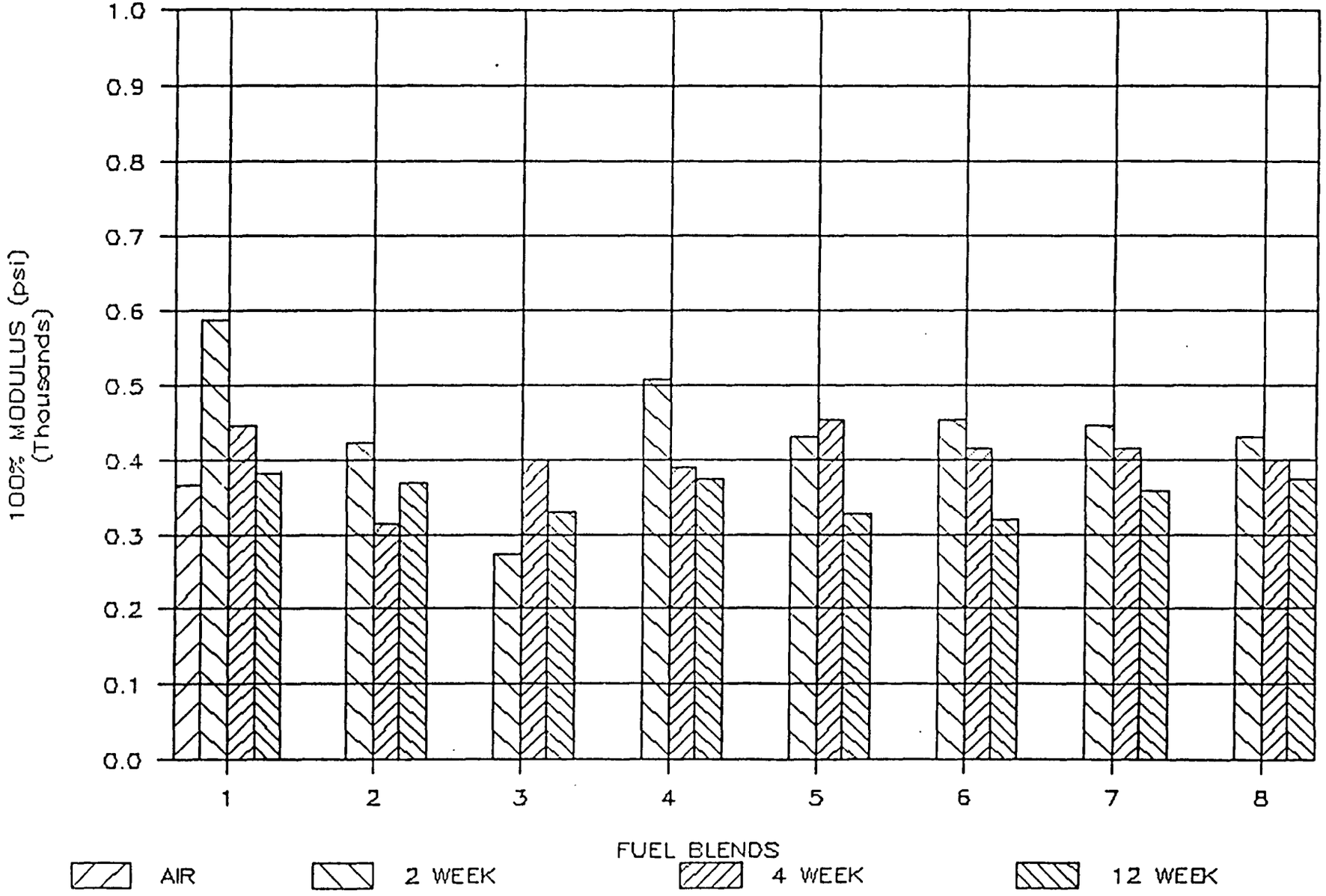

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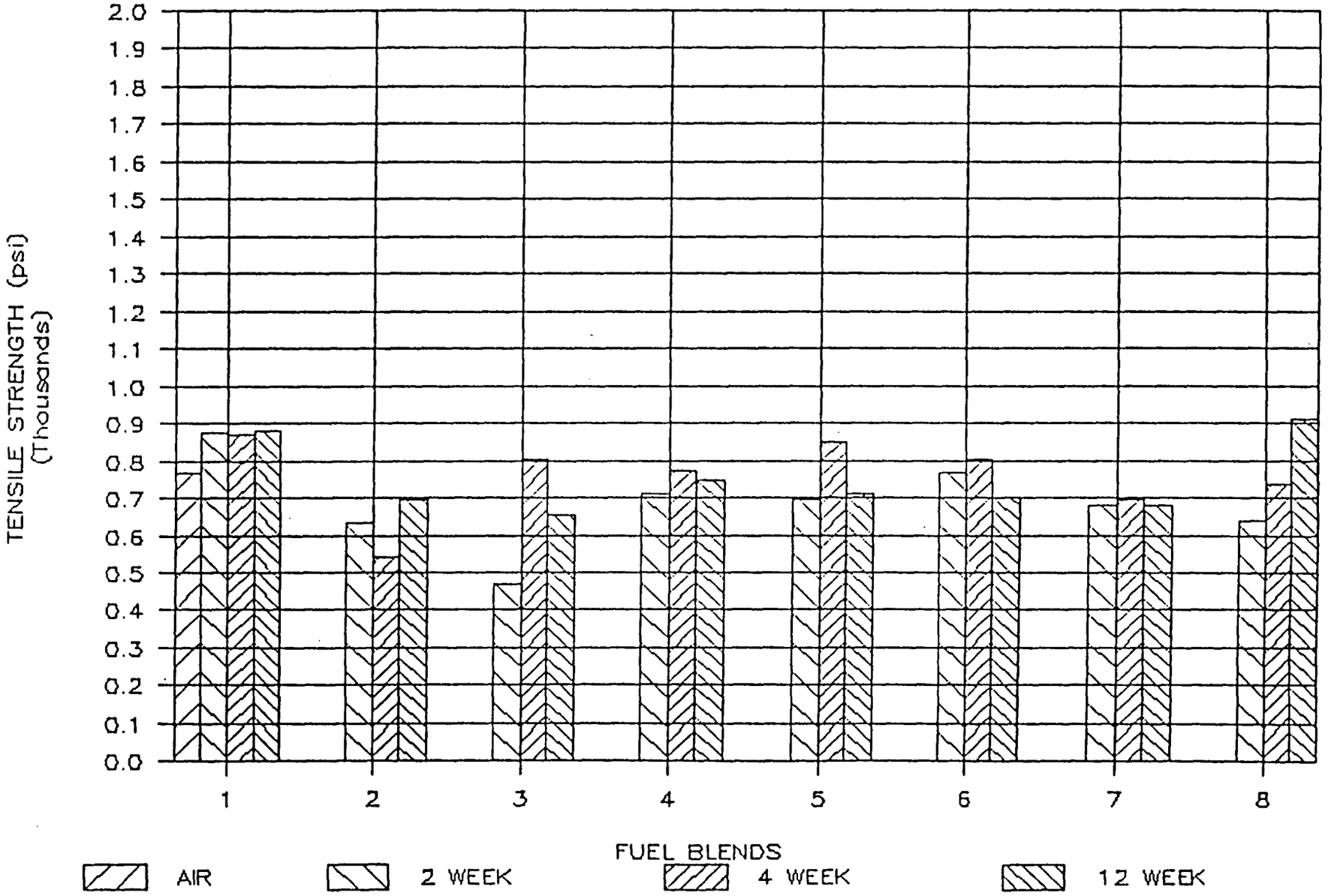

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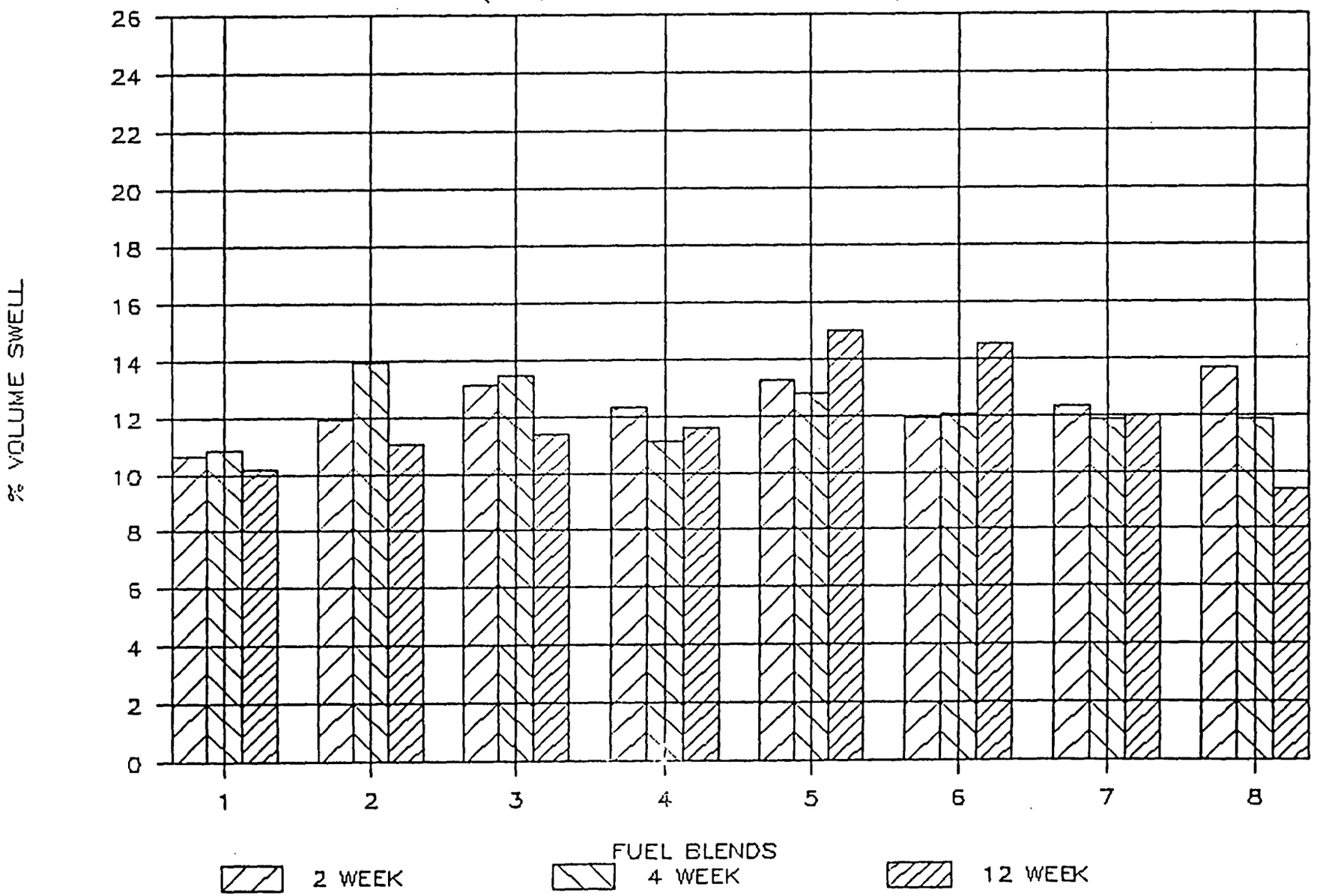

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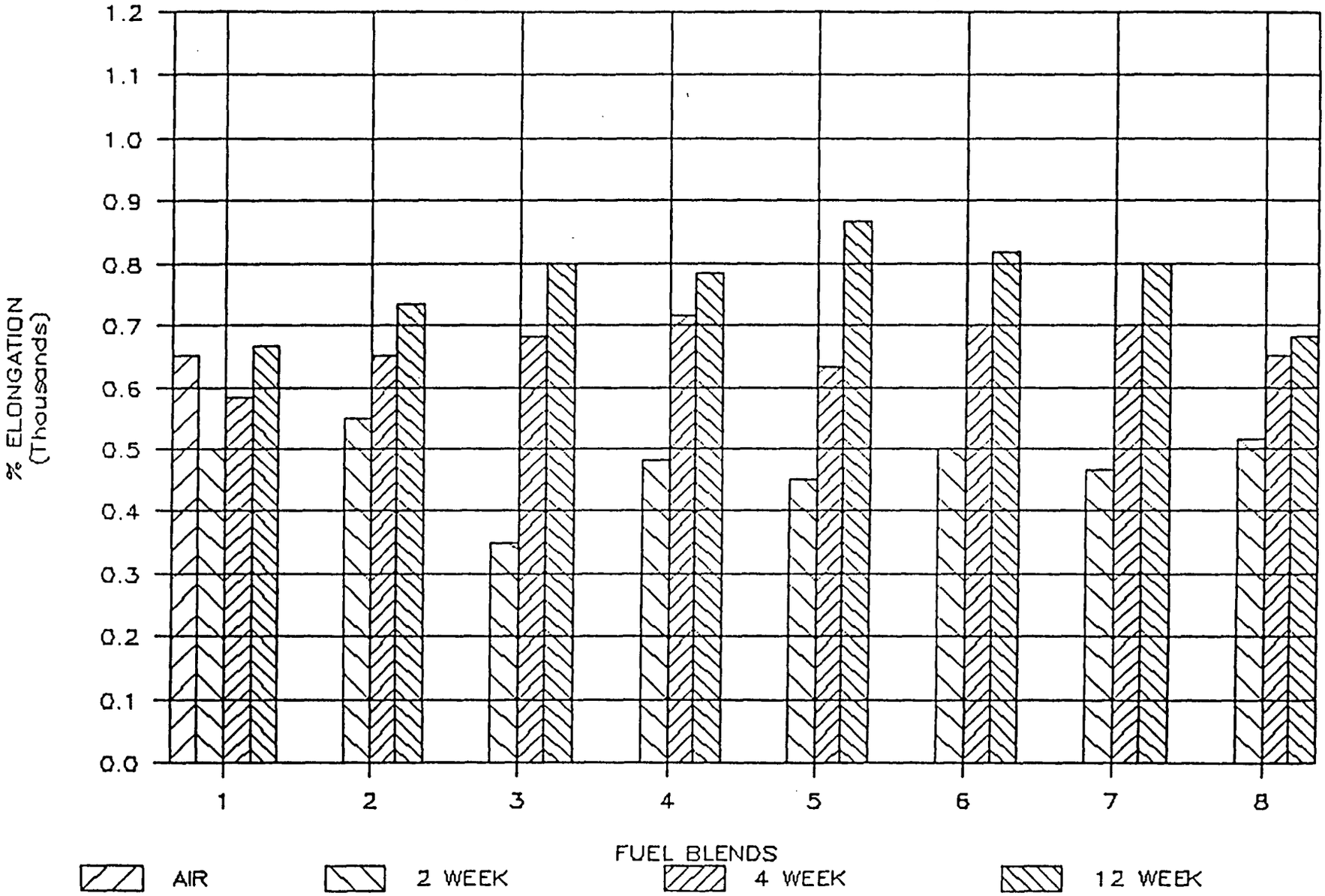

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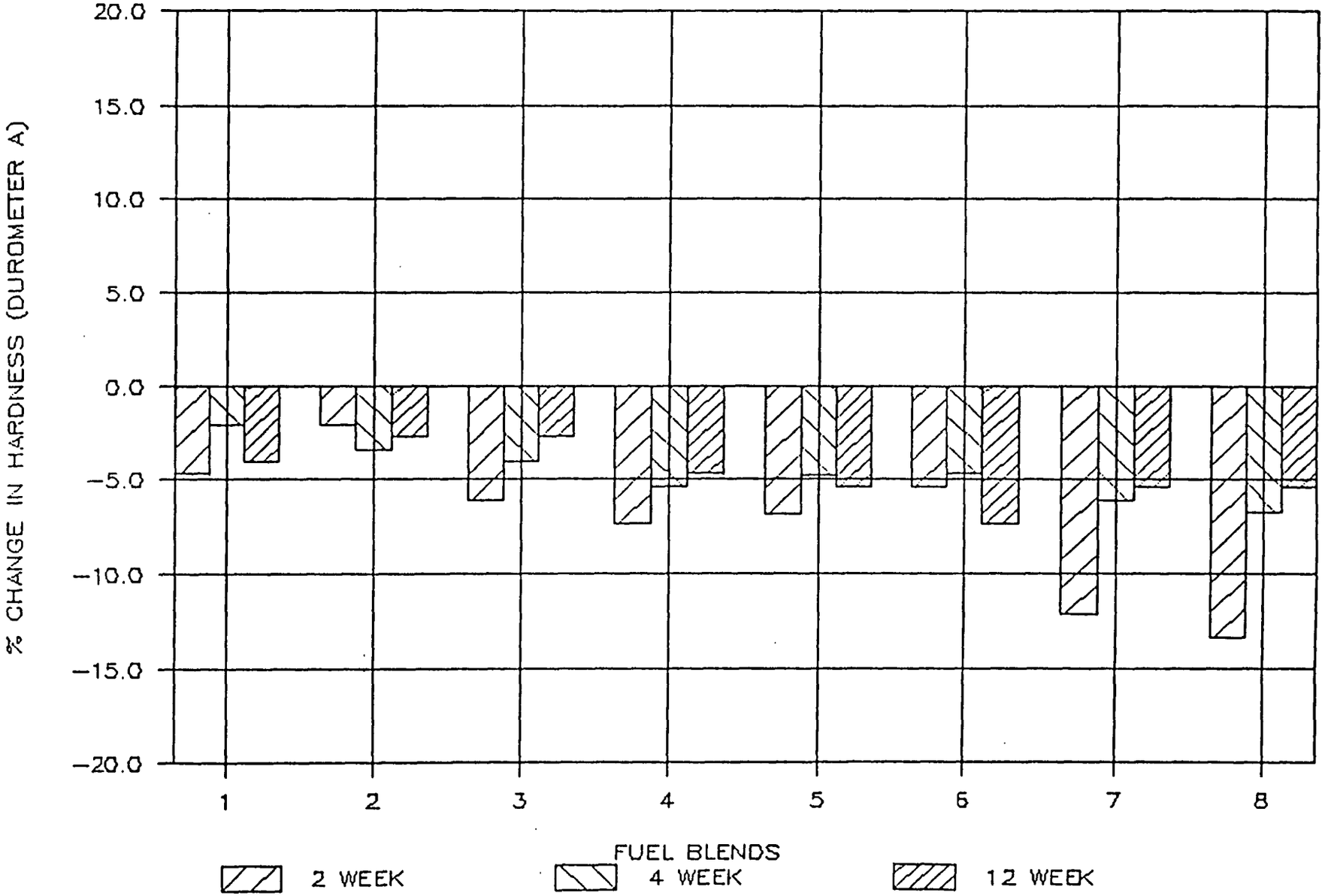

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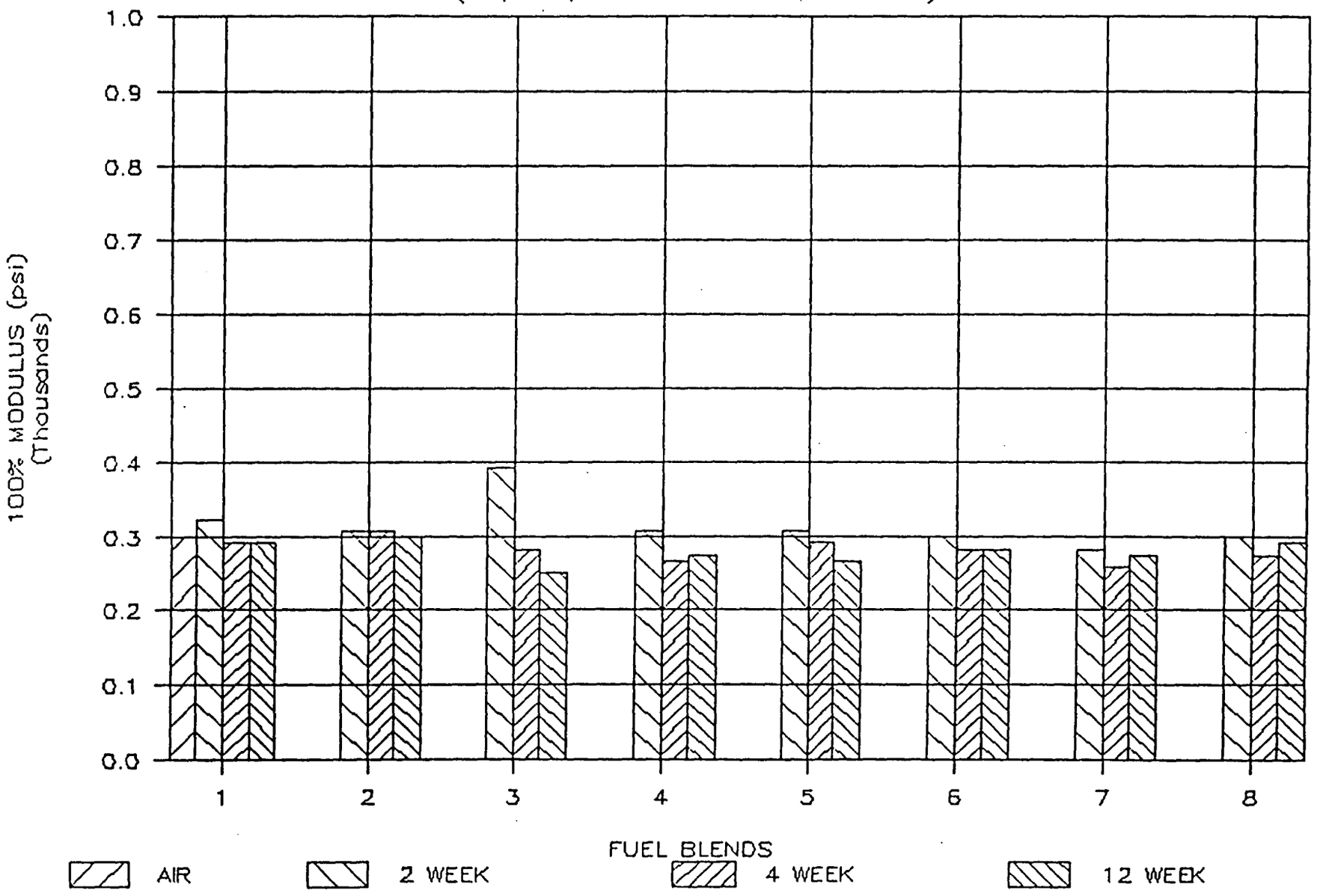

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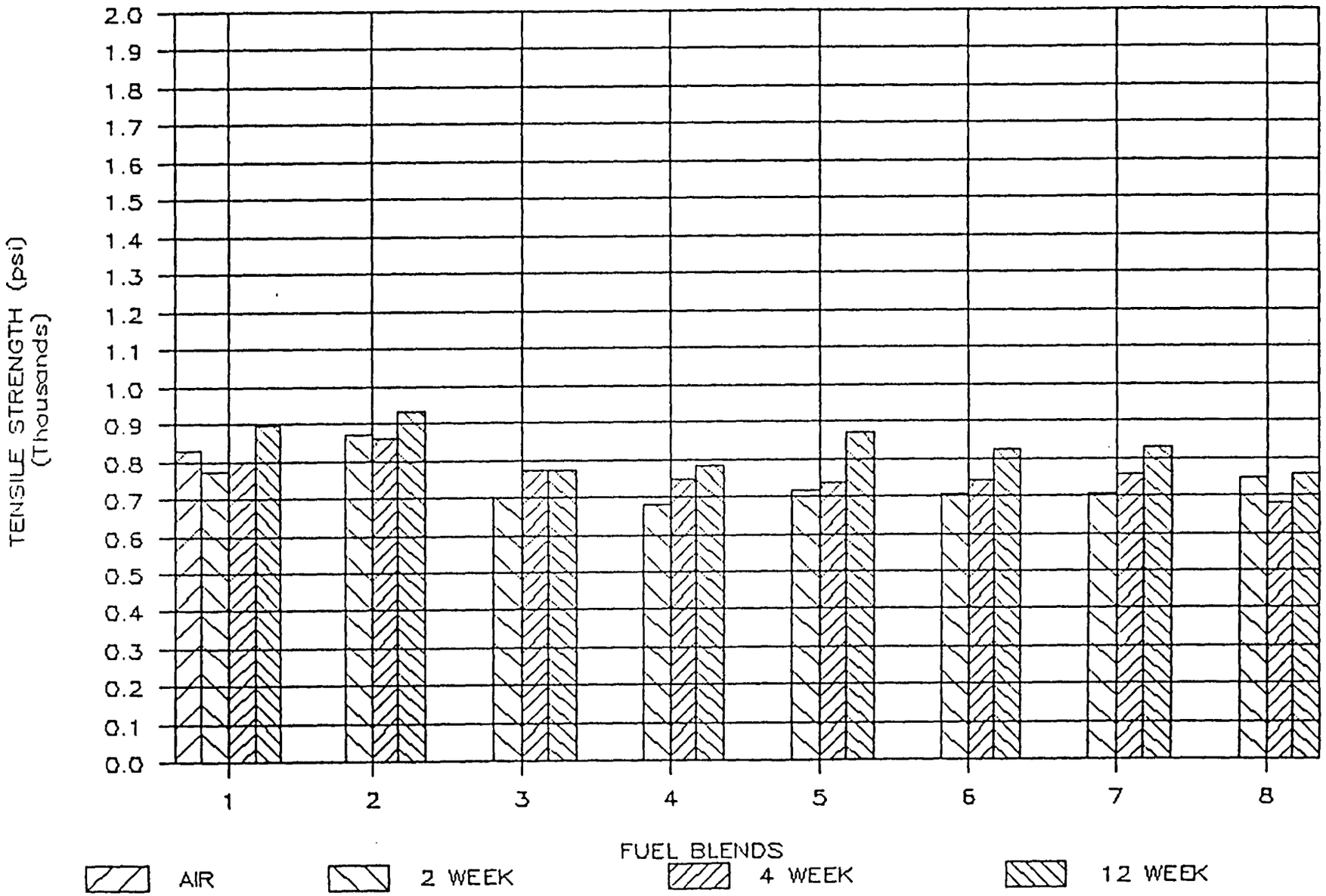

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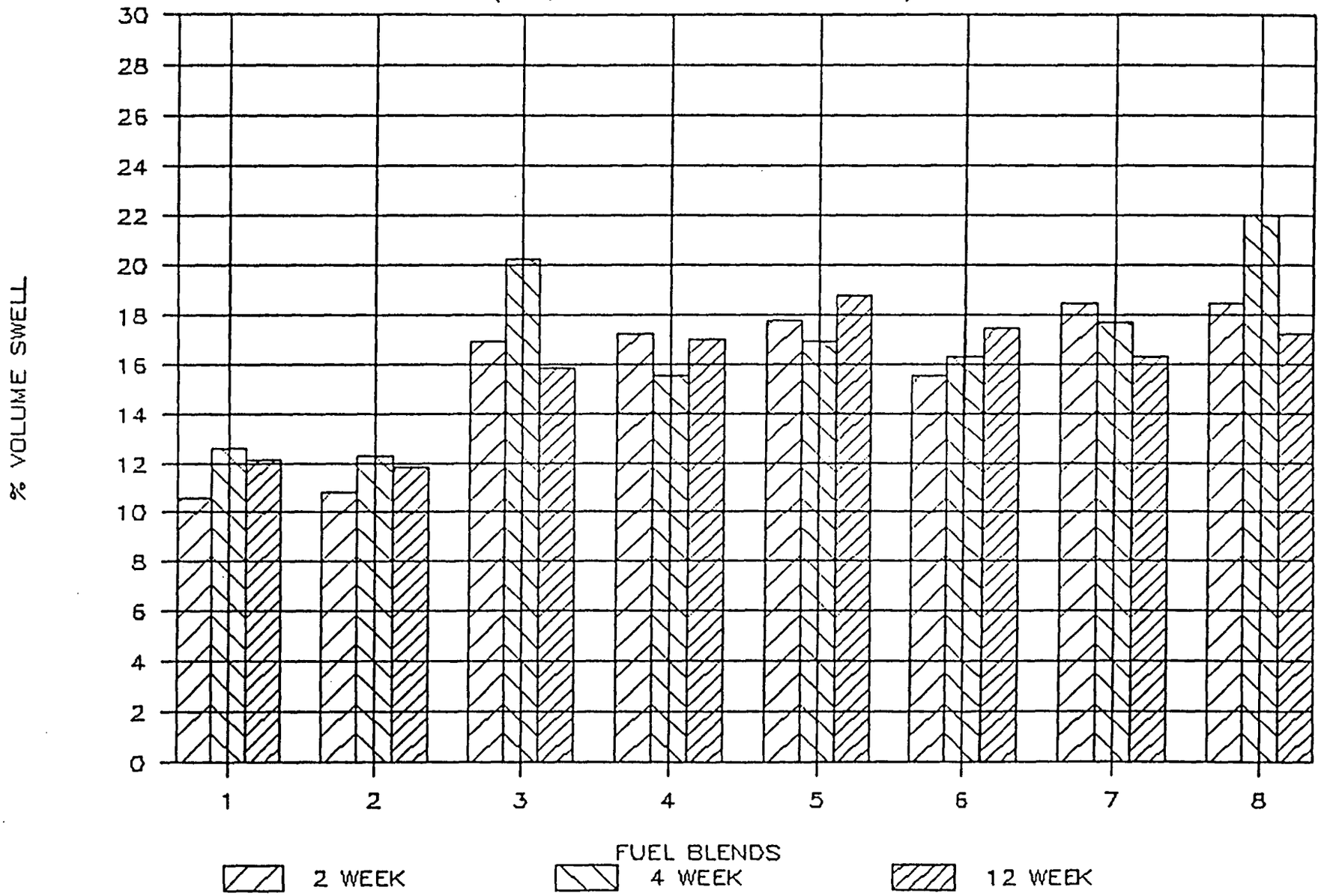

ETHYL FUEL COMPATIBILITY—URETHENE

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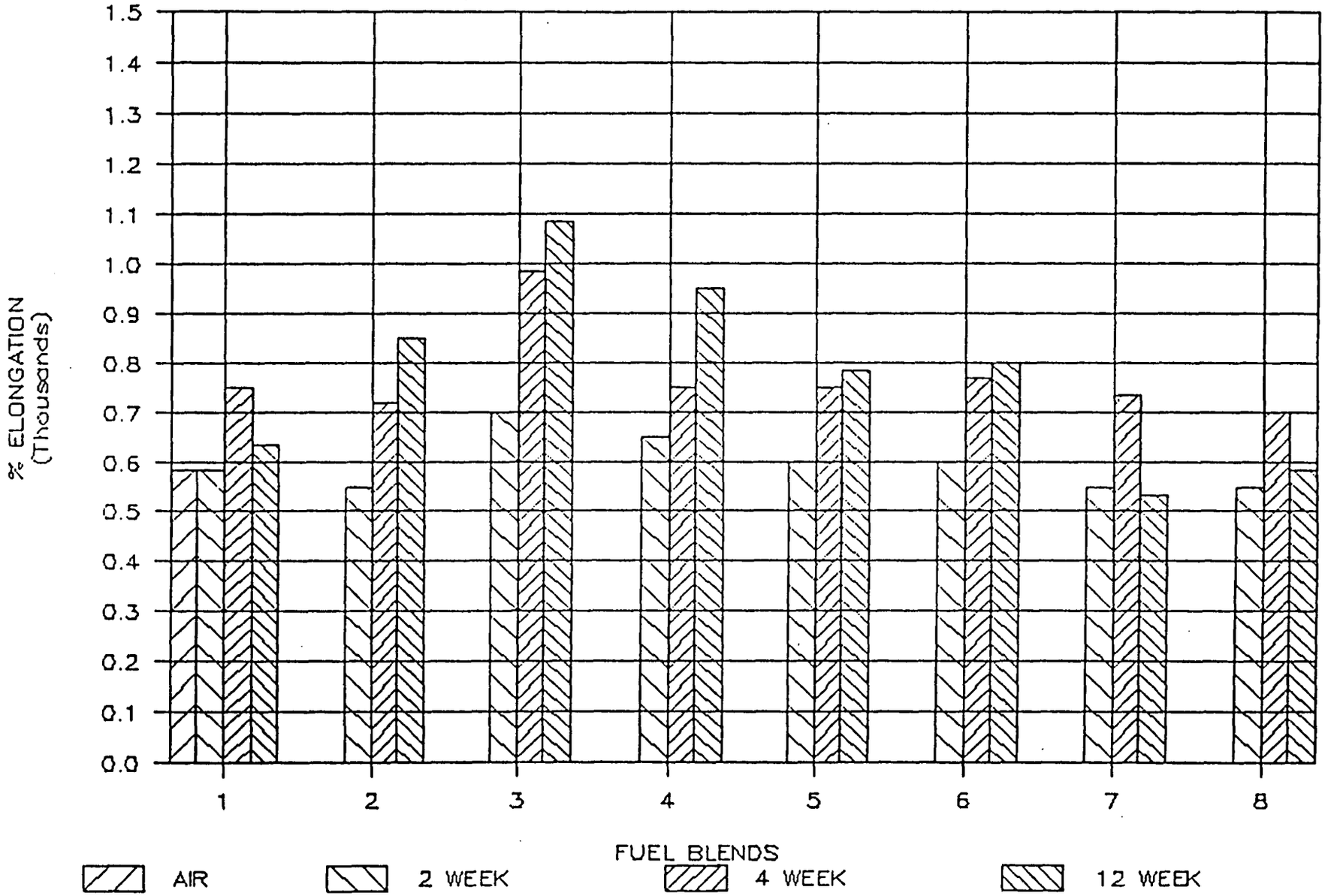

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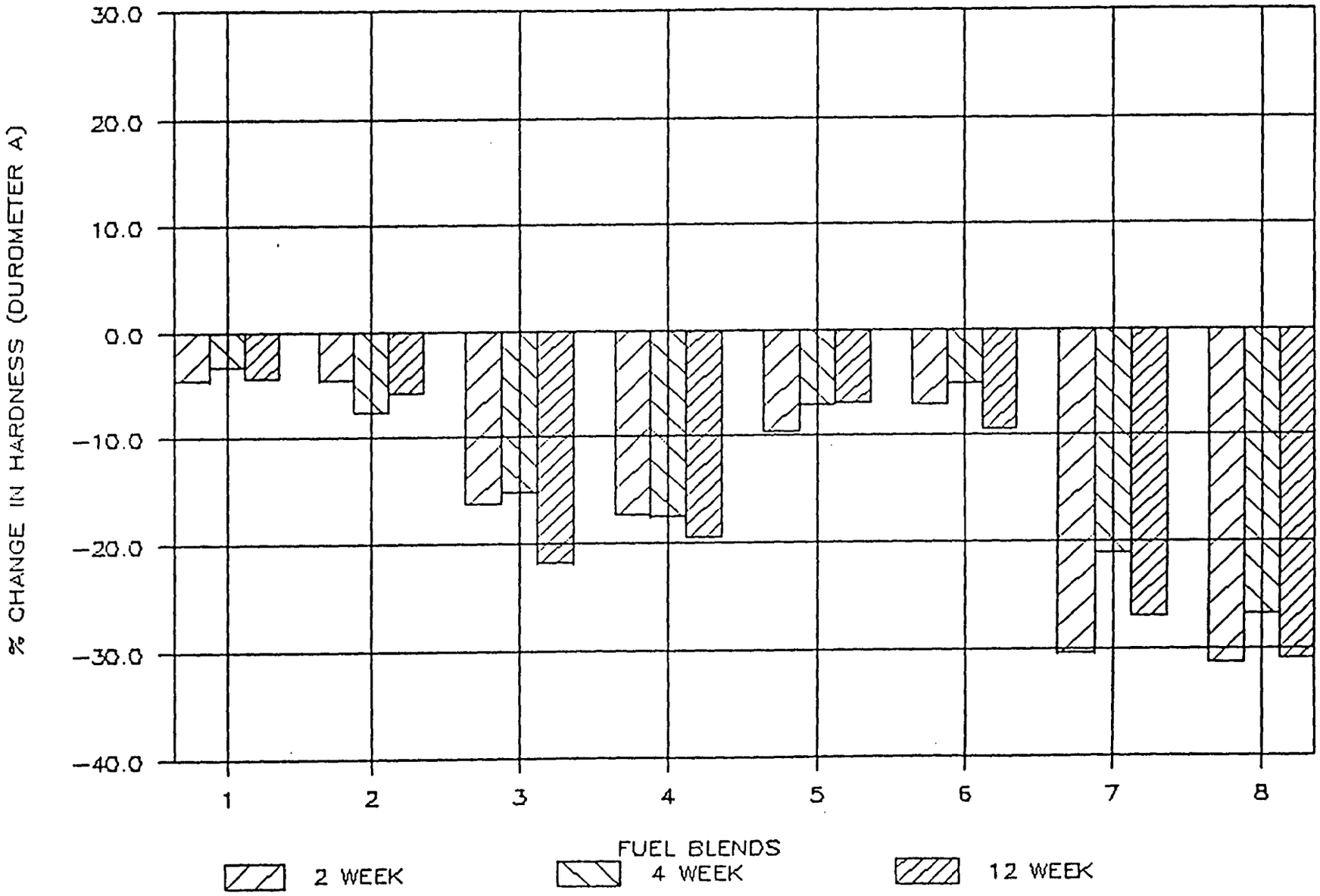

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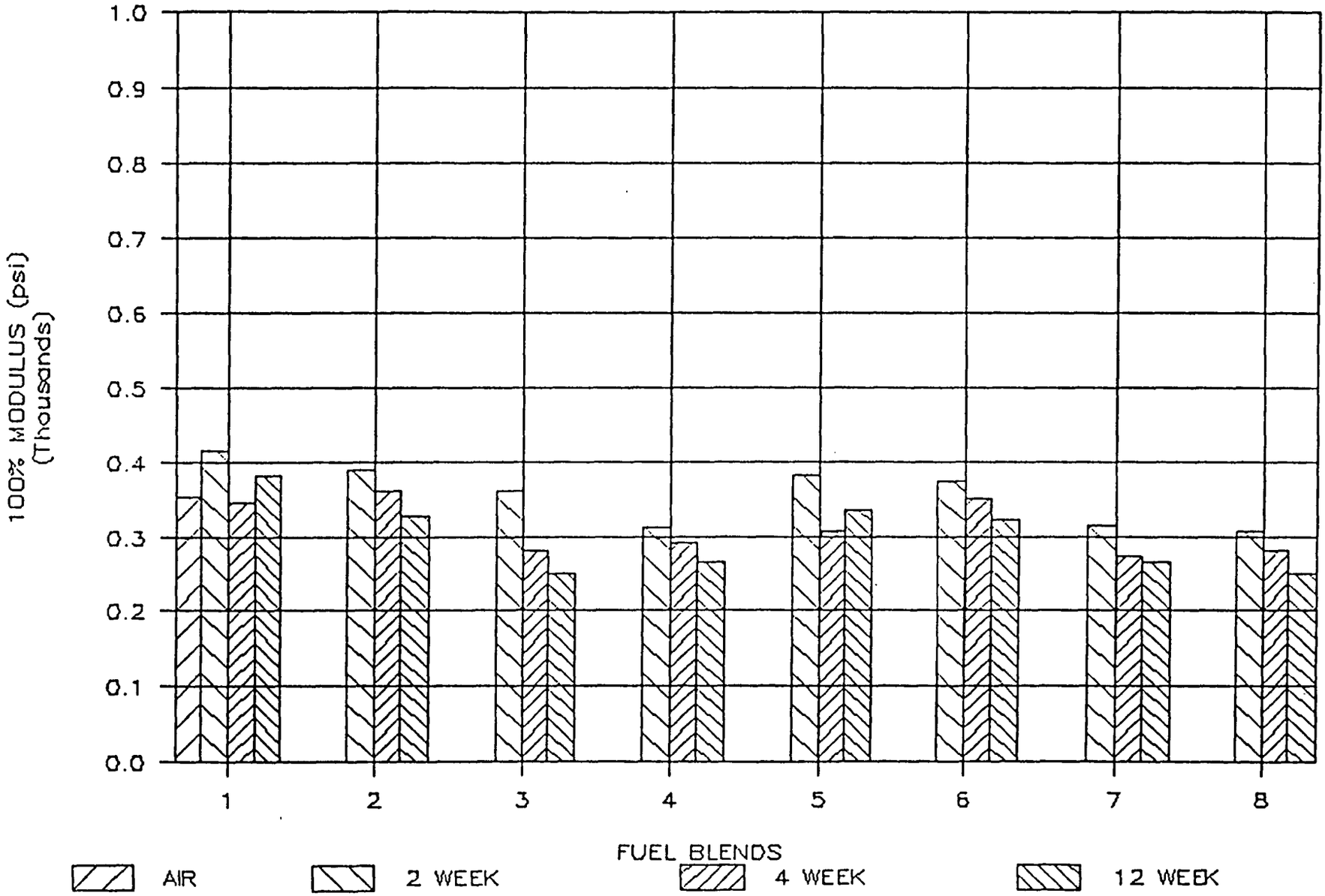

PLASTICS

ETHYL FUEL COMPATIBILITY—NYLON 6/6

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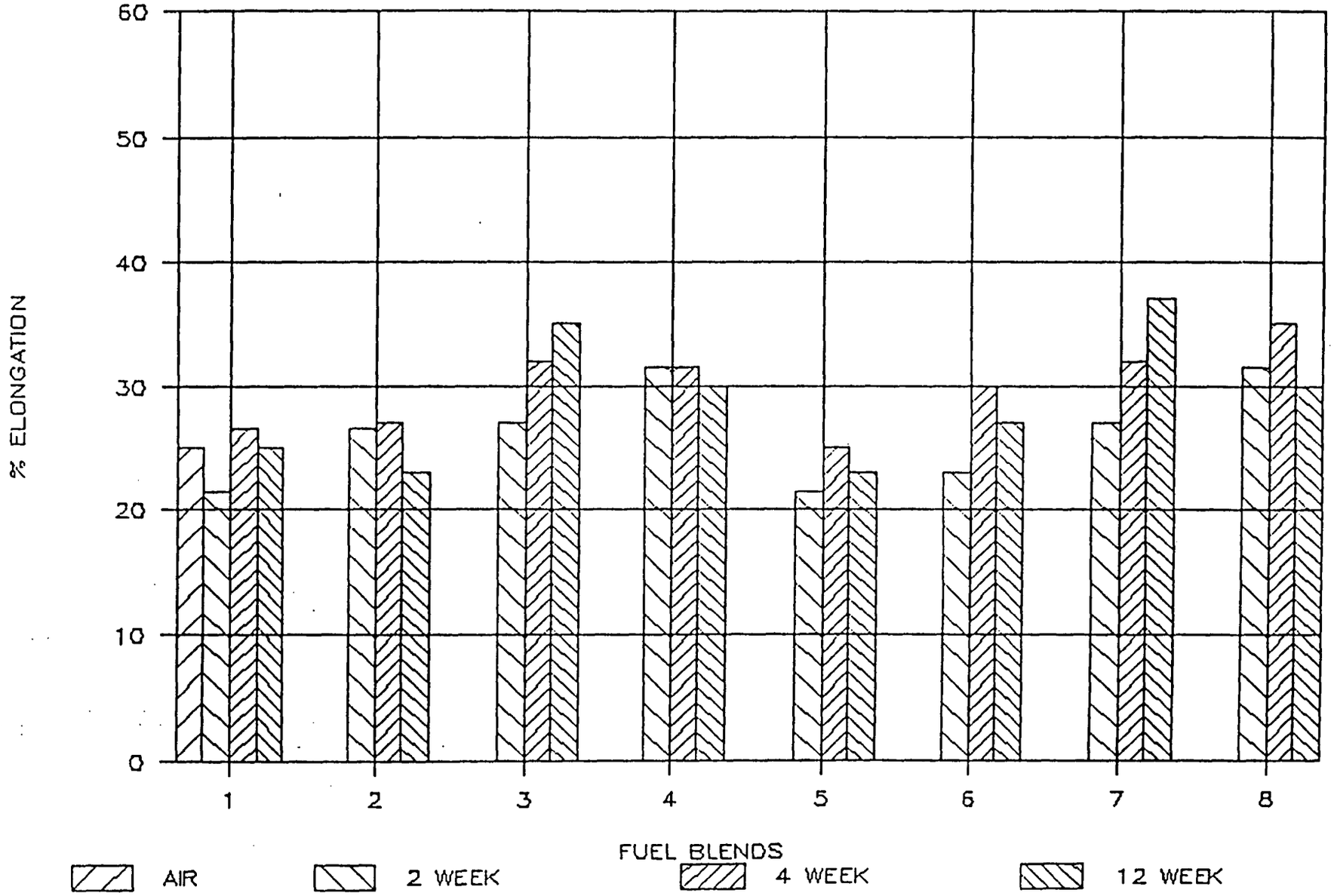

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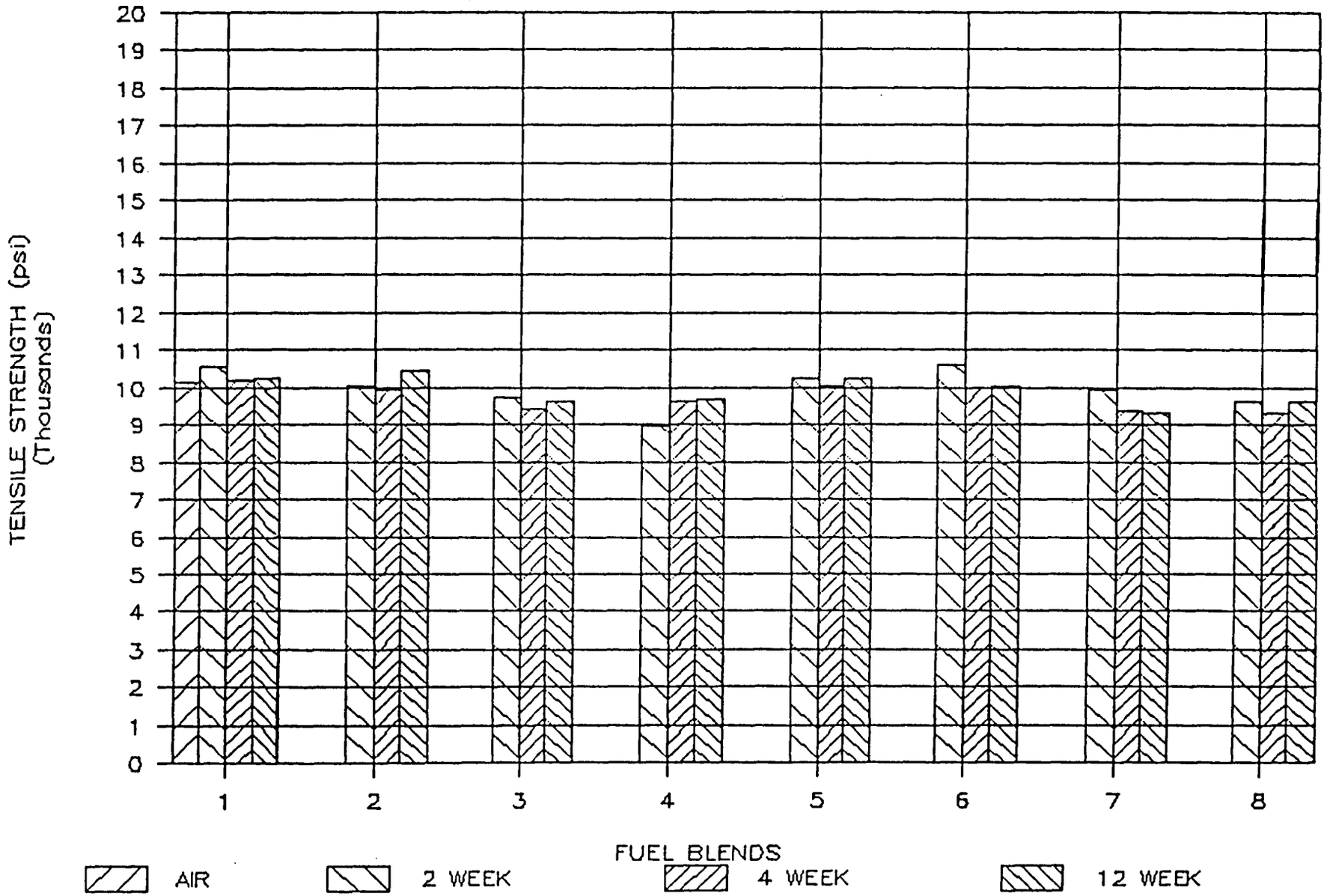

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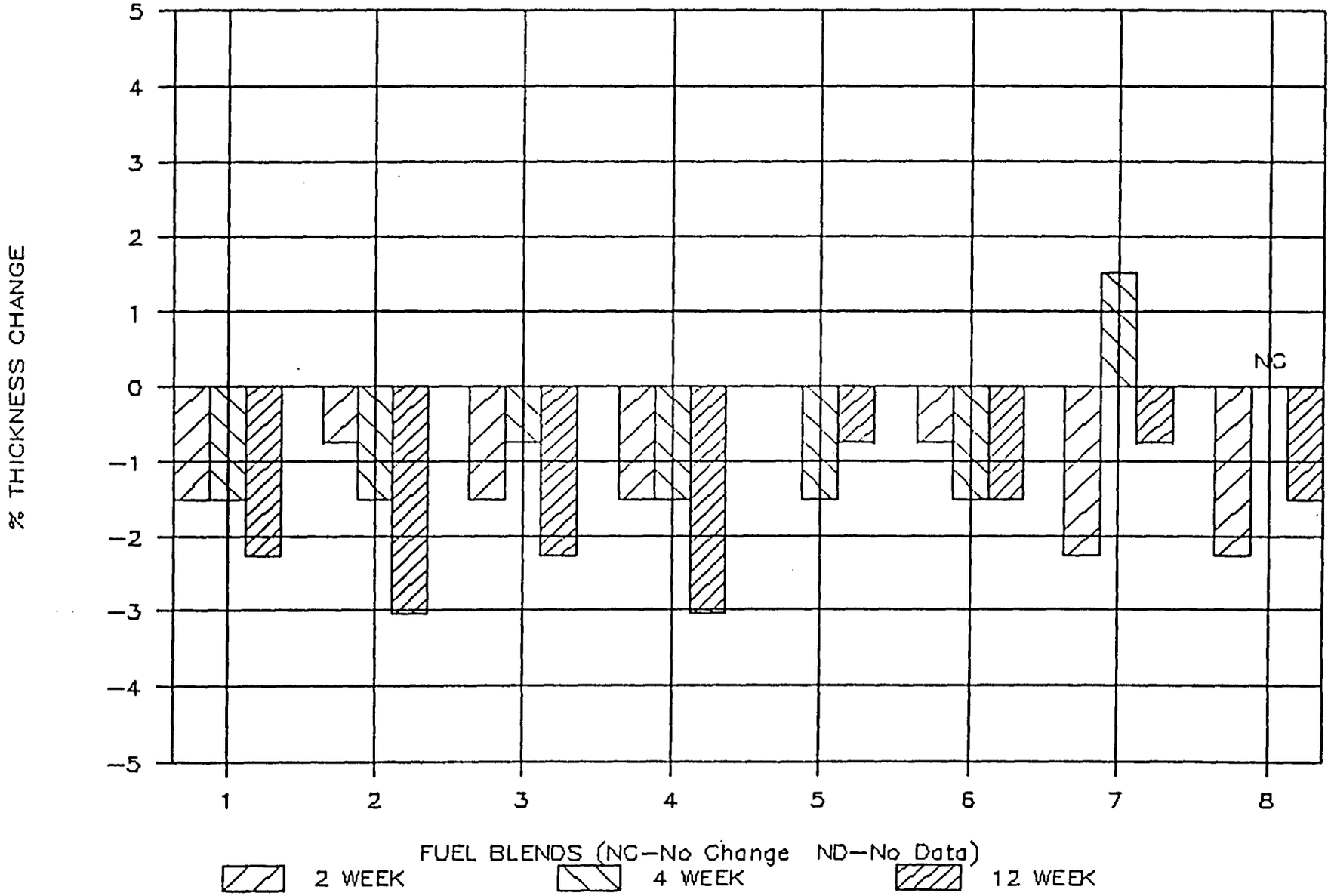

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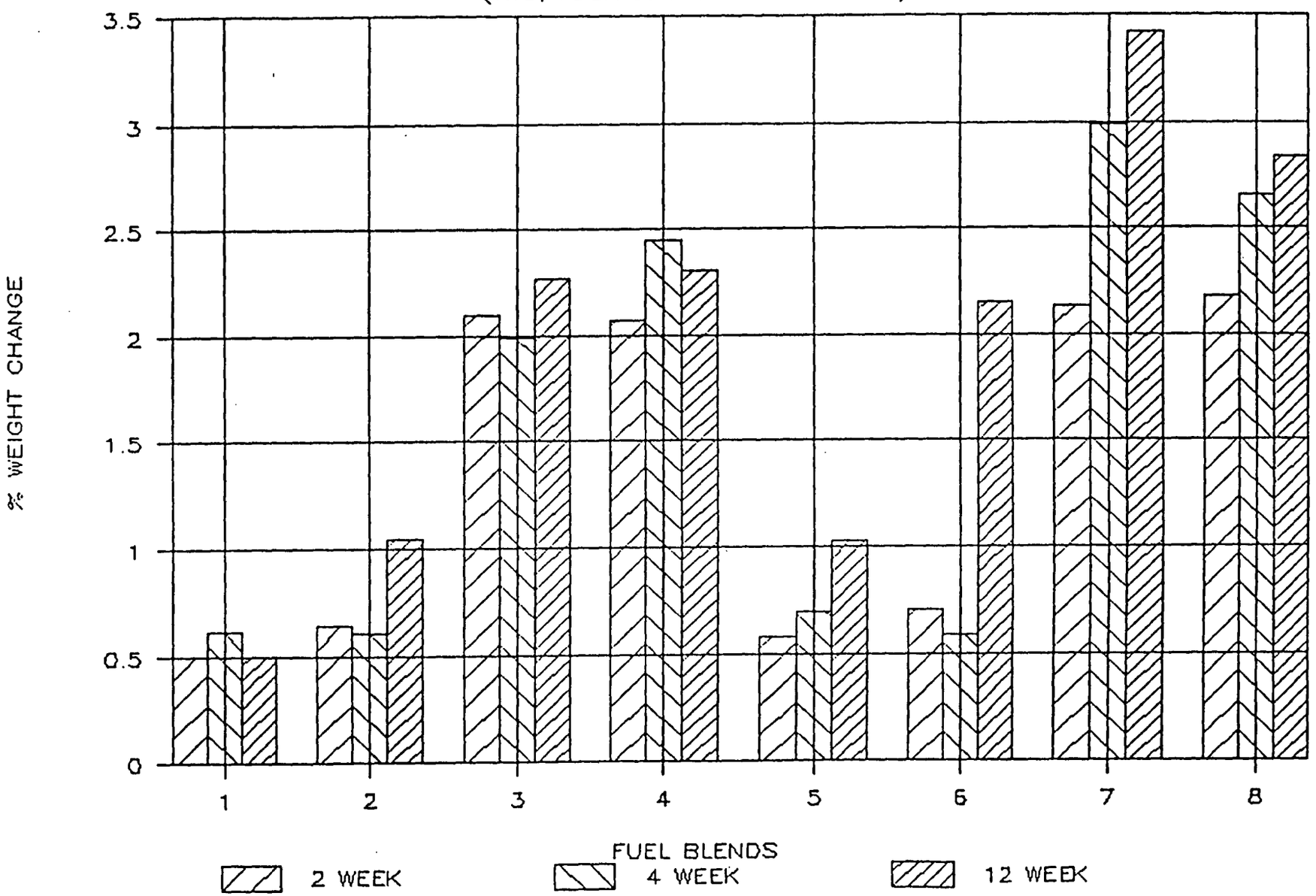

ETHYL FUEL COMPATIBILITY—HDPE

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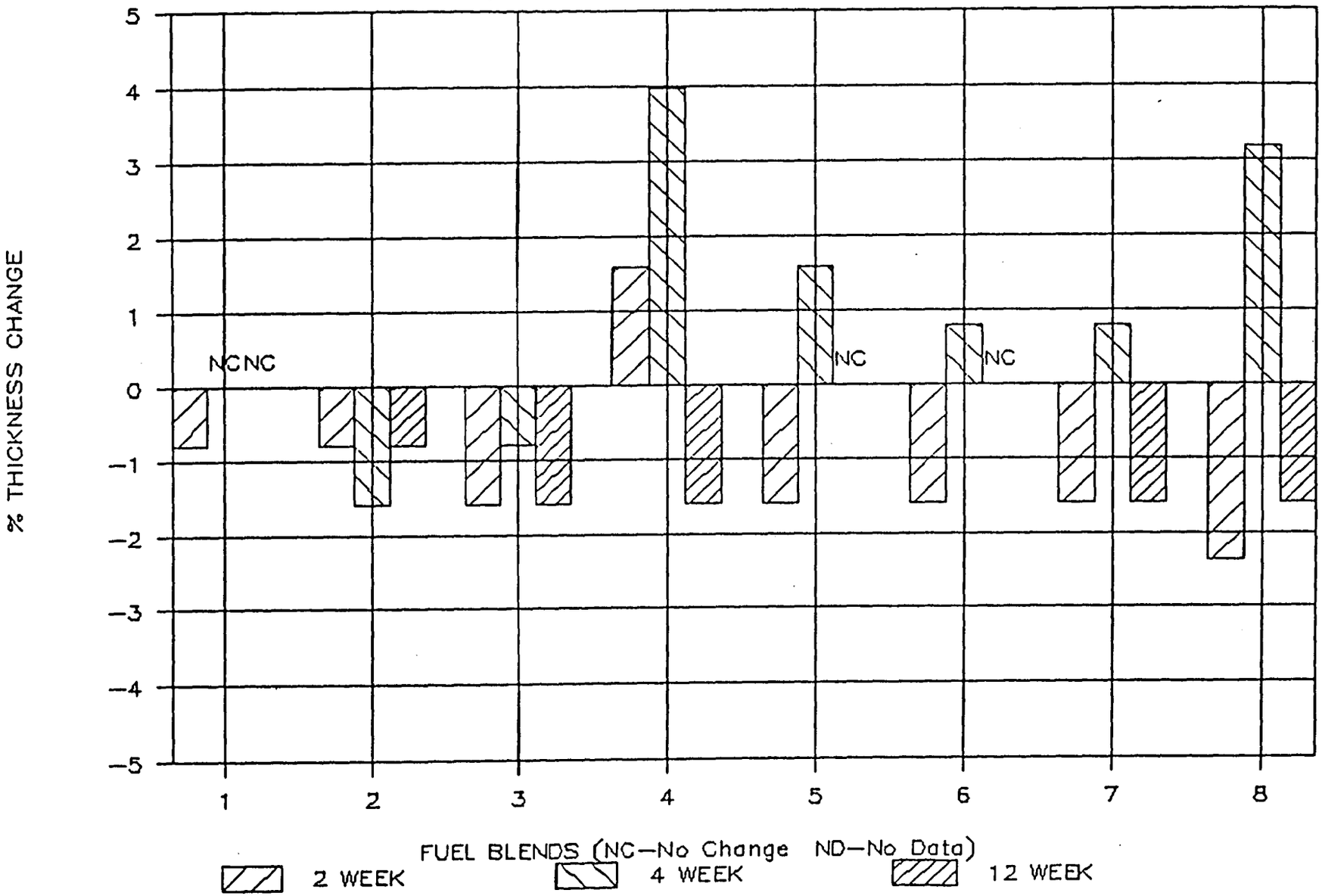

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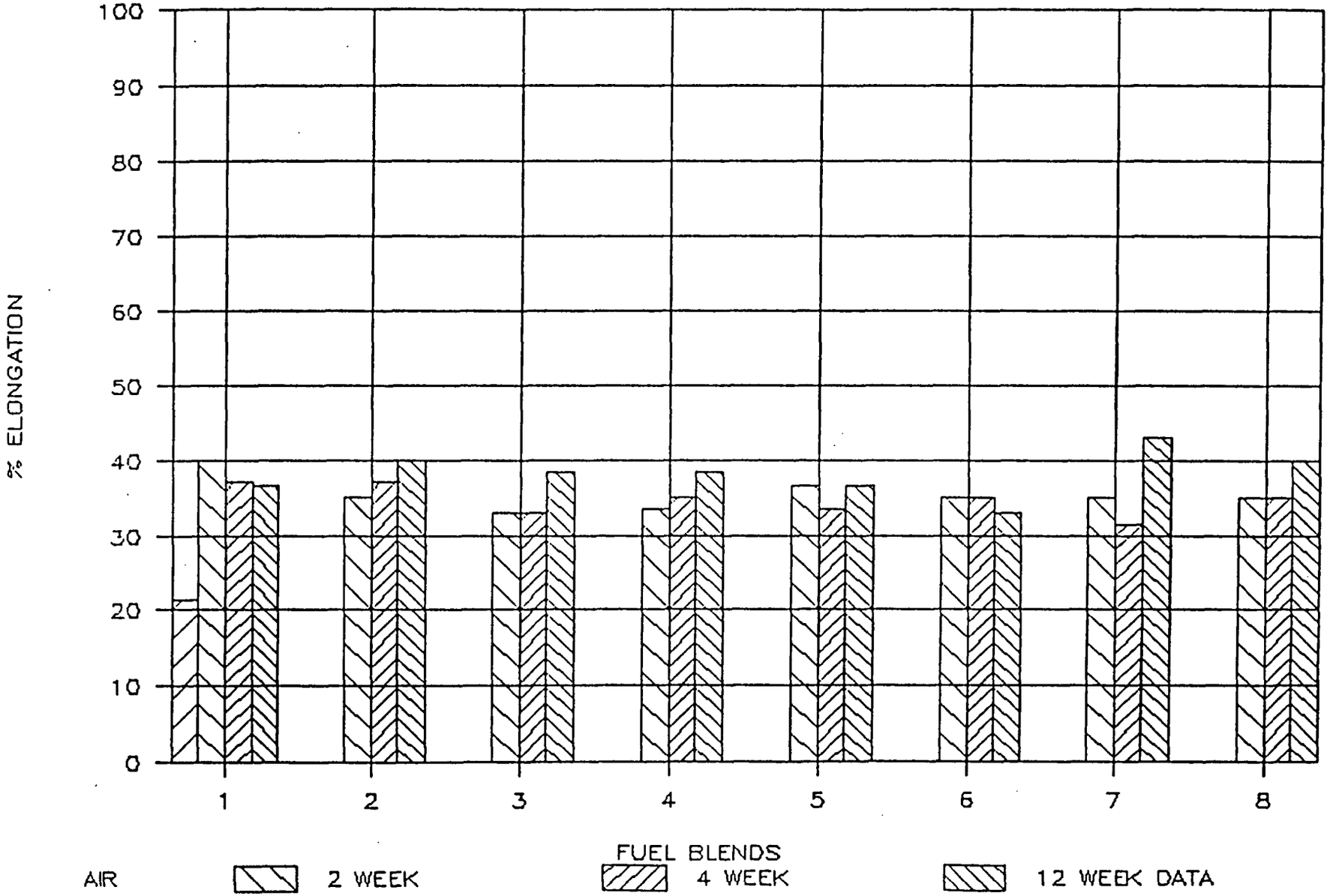

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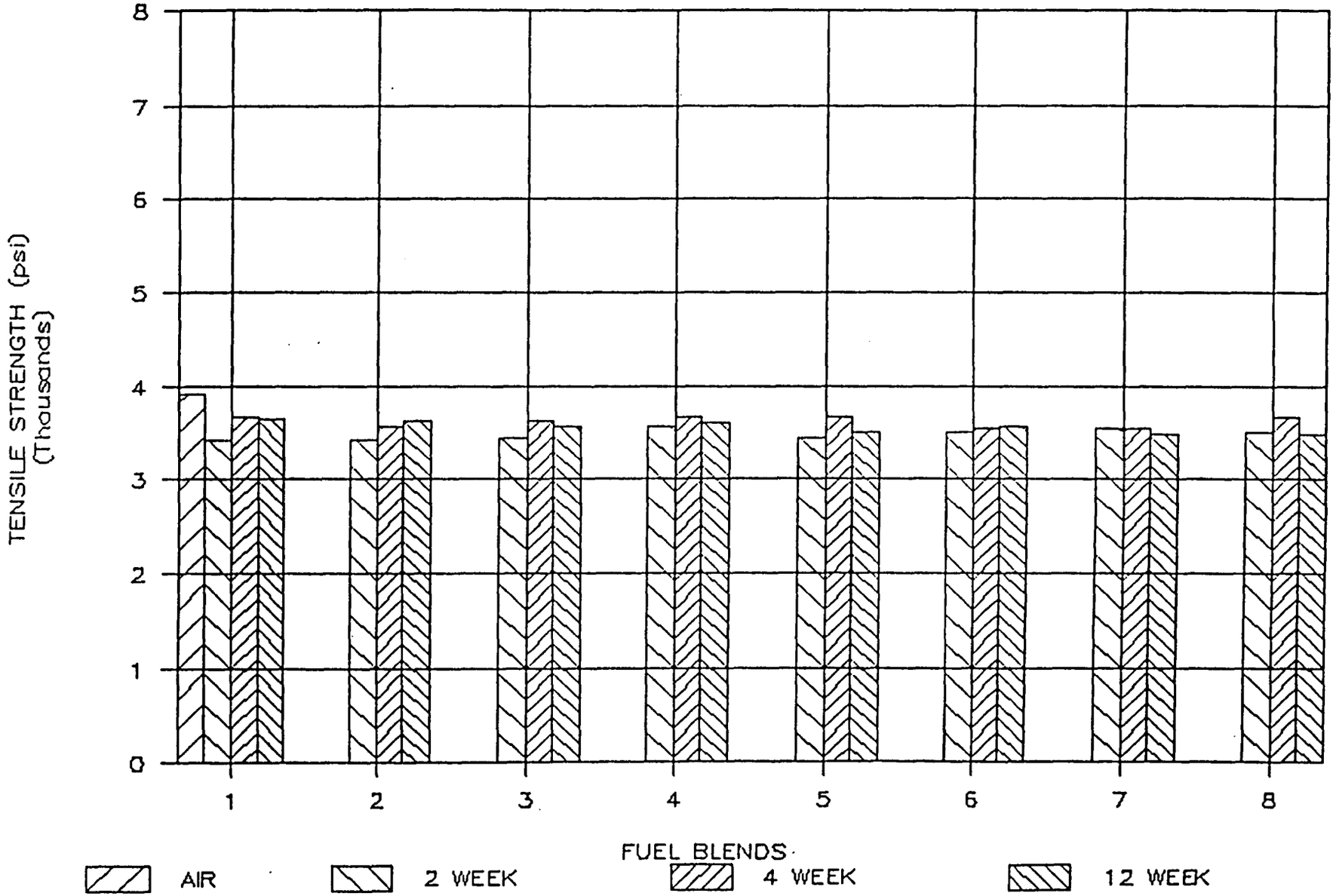

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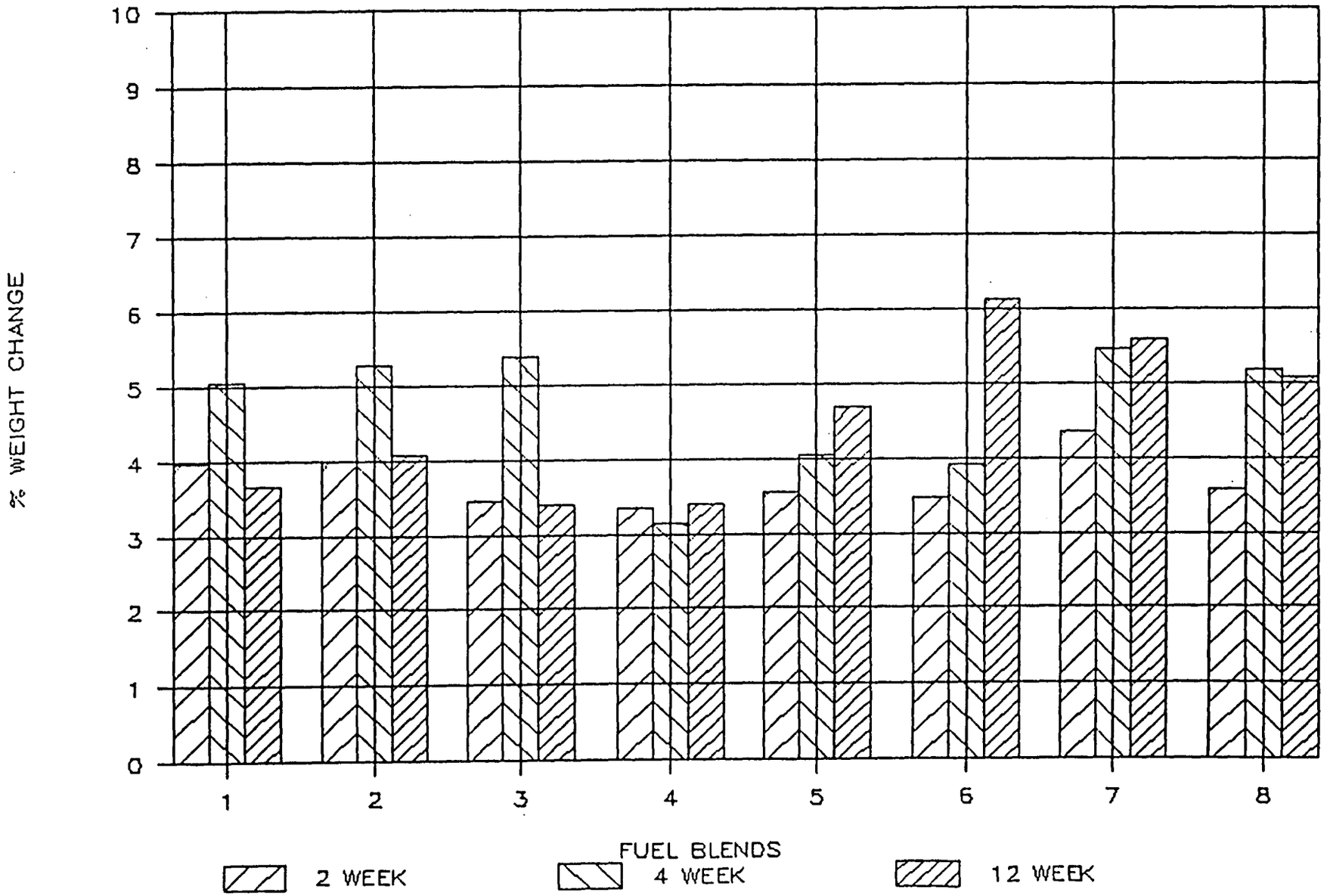
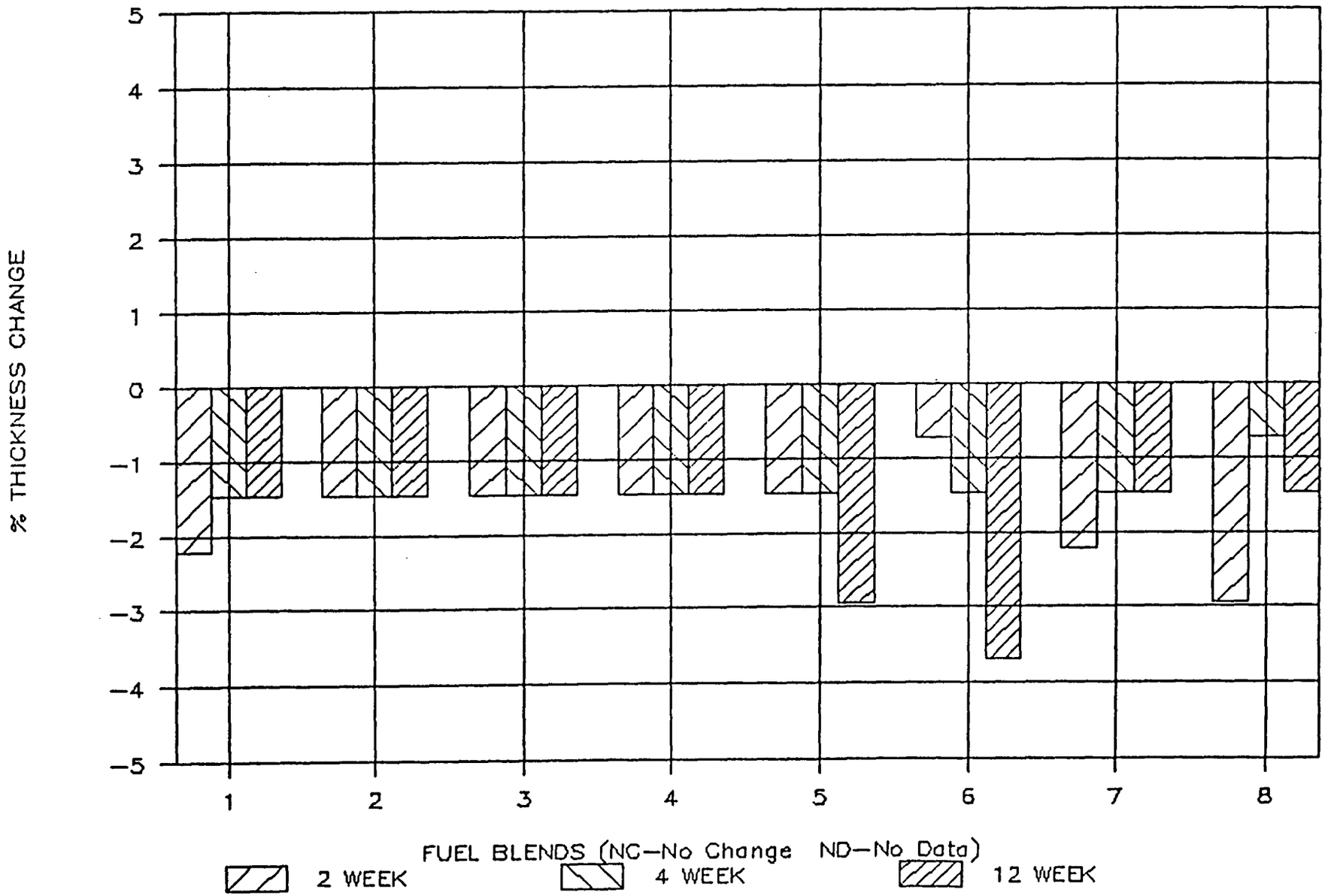


ETHYL FUEL COMPATIBILITY—DELRIN

TWO, FOUR & TWELVE WEEK



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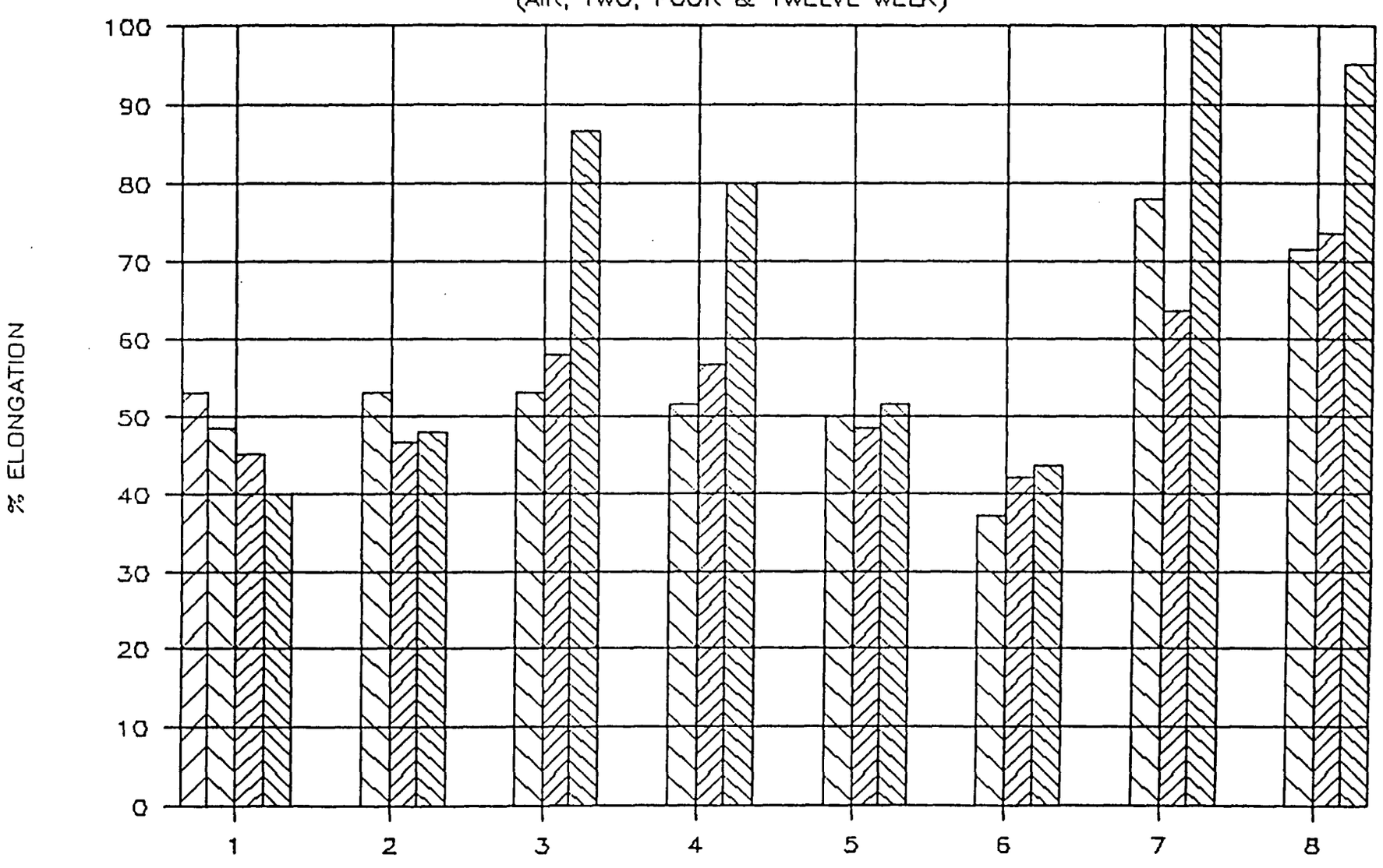

ETHYL FUEL COMPATIBILITY—DELRIN

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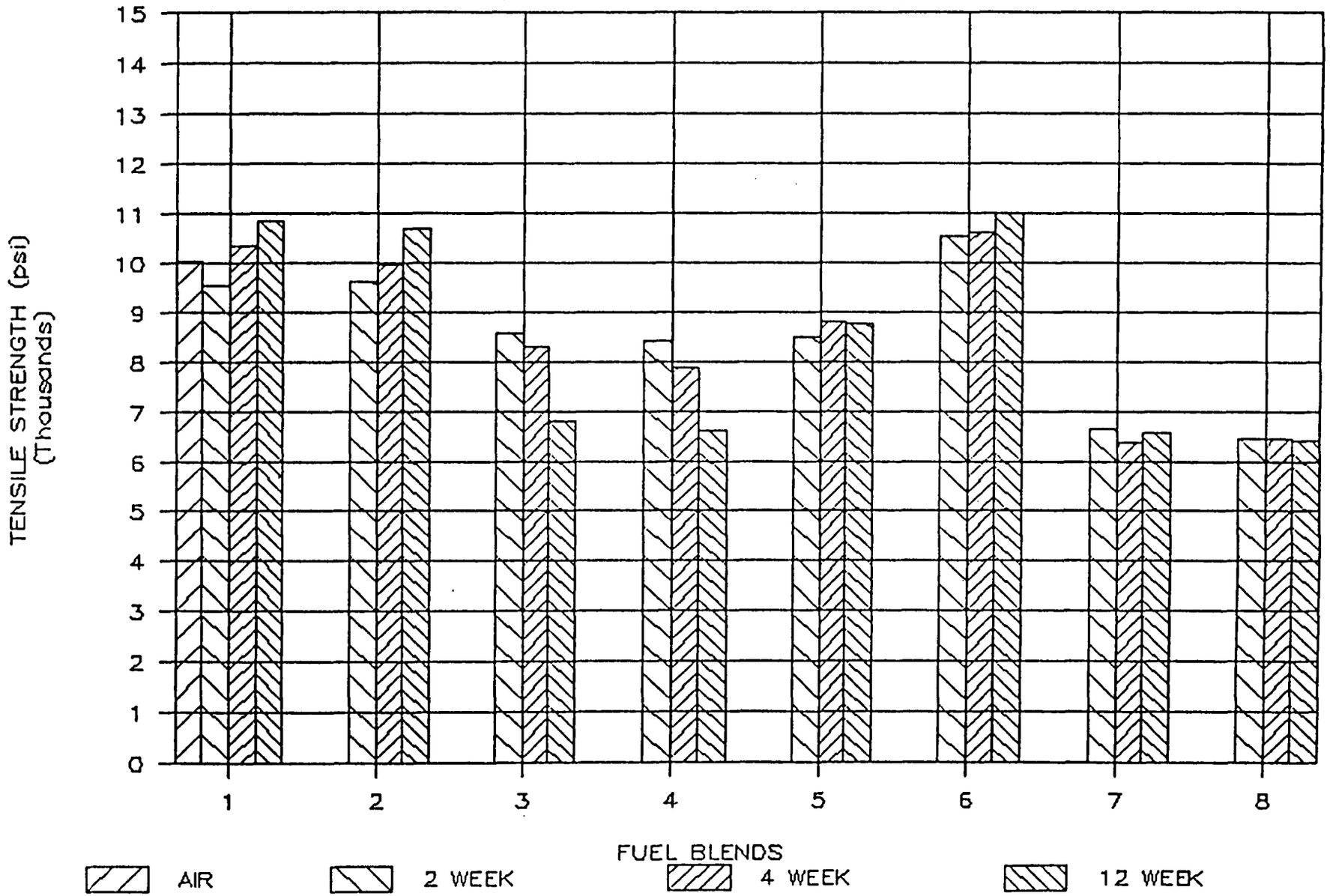

Appendix 4

Effects of the HiTEC 3000 Performance Additive on Hydrocarbon Species in Automobile Exhaust Emissions

I. Test Protocol

Southwest Research Institute (SWRI) is a nationally recognized independent test laboratory specializing in automotive emissions testing, and is one of the few labs capable of speciation testing of automobile exhaust hydrocarbons. For these reasons, Ethyl Corporation® ("Ethyl") chose SWRI to determine the effect of the HiTEC® 3000 Performance Additive ("HiTEC 3000") on the species of hydrocarbons emitted from the tailpipe.

SWRI conducted this testing, described in more detail below, on two vehicles from the 48-car durability test fleet described in Appendix 1. One of the vehicles (F-3) had accumulated 67,096 miles running on Howell EEE fuel containing 0.03125 gm of manganese per gallon as HiTEC 3000. The second car (F-5) had accumulated 66,578 miles running on clear Howell EEE fuel. Ethyl selected these vehicles for testing because they had what were considered to be advanced emission control systems, including close-coupled catalysts.

The cars were transported to SWRI in San Antonio, Texas by trailer. On arrival, SWRI checked the vehicles using the Federal Test Procedure (except for the SHED Test), to be sure that their emissions systems had not been damaged in transit. SWRI conducted this initial testing for regulated emissions only (HC, CO, and NO_x) and performed the tests with the fuel then in the tanks. The results of the last three tests in Detroit and this initial test in San Antonio are shown in Attachment 4-1. After comparing these results, Ethyl authorized the tests to proceed.

In the first part of the test program, cars were fueled with Howell EEE. SWRI then added 0.03125 gm manganese per gallon as HiTEC 3000 to car F-3, and added xylenes to the fuel in car F-5 to make the same octane as the HiTEC fuel. Mixed xylenes were selected as being representative of an aromatic stream from a refinery which might be used as an octane blend stock if HiTEC 3000 could not be used. The vehicles were run 500 miles and tested, and run another 500 miles and tested. At each test point, SWRI tested for speciation of hydrocarbons, and other regulated and unregulated emissions, as described in Attachment 4-2.

Next, SWRI conducted the same operation using a commercial fuel with added HiTEC 3000 or xylenes, (again blended to the same octane number) except that each car was run 1,000 miles, tested, then another 1,000 miles on the same fuel and tested again.

Following the commercial fuel tests, SWRI performed the same operation using a reformulated fuel.

A more detailed discussion of the test protocol is provided in Attachment 4-2. Analytical procedures describing the tests conducted by SWRI are provided in Attachment 4-3. Fuel specifications and analyses for the various test fuels are given in Attachment 4-4.

II. Summary of Test Results

Results, expressed as mg/mile, are given in Attachment 4-5,4-6, and 4-7 for each test of each of three fuels tested. The results are summarized in Attachment 4-8.

It can be seen in Attachment 4-8 that total hydrocarbon emissions were lower by about 10% when HiTEC 3000 Additive was present in the first two fuels tested. Total hydrocarbons were about the same in the reformulated fuel. However, the percentage of methane in the emissions increased in all three fuels with the HiTEC 3000 Additive. Therefore, in all three cases, the non-methane hydrocarbons were lower when the HiTEC 3000 Additive was present. Since methane is virtually non-reactive in ozone formation, this fact is significant. The amounts of reactive hydrocarbons in general are lower when the HiTEC 3000 Additive is used. The C_2-C_6 alkenes and alkynes are considerably lower with all three fuels when the additive is added. Aldehydes and ketones are also lower when the HiTEC 3000 is present. All of these reactive hydrocarbons are important in ozone formation. The combination of decreased reactive hydrocarbons and the significant lowering of NO_x due to the HiTEC 3000 Additive usage could be very important in controlling ozone levels in urban areas.

Attachment 4-1

Results of Federal Test Procedure For Regulated

Emissions on Cars F-3 and F-5 Prior to

Leaving Detroit, and on Arrival in San Antonio

Emissions in Gms/mile
Fuel: Howell EEE for Car F-5
Howell EEE Plus HiTEC 3000 for Car F-3

	At Detroit Mileage			At San Antonio Mileage
Car F-3	60M	65M	67M	67M
HC	0.607	0.559	0.576	0.49
NO_x	0.887	0.803	0.802	0.73
CO	1.537	1.404	1.435	1.30
Car F-5				
HC	0.519	0.530	0.498	0.52
NO_x	1.625	1.472	1.119	0.96
CO	2.761	2.658	2.208	1.74

Attachment 4-2

STEPWISE TEST SCHEDULE FOR SPECIATION TESTING

Step	Description
1	Obtain two test vehicles from Ethyl's Detroit test fleet. Run cold-start 3-bag FTP on each vehicle as received and report emissions data to Ethyl. If then directed to proceed by Ethyl, proceed to Step 2 (no hydrocarbon speciation obtained in Step 1).
2	On clear fuel car, drain and fill with Howell EEE + xylenes.
3	Perform 500 miles (half expressway and half 25 mph) driving with Howell EEE + xylenes.
4	Prep clear fuel car for first test.
5	Run FTP Test 1 on clear fuel car with Howell EEE + xylenes. Sample regulated exhaust emissions and conduct hydrocarbon speciation. Sample unregulated aldehyde and ketone exhaust emissions.
6	Repeat Step 5 as Test 2.
7	Repeat Steps 3 to 6 as Test 3 and 4.
8	Drain and fill clear fuel car with commercial unleaded gasoline + xylenes.
9	Perform 1,000 miles (half expressway and half 25 mph) driving with commercial unleaded gasoline + xylenes.
10	Prep clear fuel car.
11	Run FTP test 5 on clear fuel car with commercial unleaded gasoline + xylenes. Sample regulated exhaust emissions and conduct hydrocarbon speciation. Sample unregulated aldehyde and ketone exhaust emissions.
12	Repeat Step 22 as Test 6.
13	Repeat Steps 9 to 12 as Tests 7 and 8.
14	Drain and fill clear fuel car with reformulated fuel + xylenes.
15	Perform 1,000 miles (half expressway and half 25 mph) driving with reformulated fuel + xylenes.
16	Prep clear fuel car.
17	Run FTP Test 9 on clear fuel car with reformulated fuel + xylenes. Sample regulated exhaust emissions and conduct hydrocarbon speciation. Sample unregulated aldehyde and ketone exhaust emissions.
18	Repeat Step 17 as Test 10.

Attachment 4-2 (continued)

STEPWISE TEST SCHEDULE FOR ETHYL TASK

Step	Description
19	Repeat Steps 15 through 18 as Tests 11 and 12.
20	On HiTEC 3000 car, drain and fill with Howell EEE + HiTEC 3000.
21	Perform 500 miles (half expressway and half 25 mph) driving with Howell EEE + HiTEC 3000.
22	Prep HiTEC 3000 car for Test 13.
23	Run FTP Test 1 on HiTEC 3000 car with Howell EEE + HiTEC 3000. Sample regulated exhaust emissions and conduct hydrocarbon speciation. Sample unregulated aldehyde and ketone exhaust emissions.
24	Repeat Step 5 as Test 14.
25	Repeat Steps 21 to 24 as Tests 15 and 16.
26	Drain and fill HiTEC 3000 car with commercial unleaded gasoline + HiTEC 3000.
27	Perform 1,000 miles (half expressway and half 25 mph) driving with commercial unleaded gasoline + HiTEC 3000.
28	Prep HiTEC 3000 car.
29	Run FTP Test 17 on HiTEC 3000 car with commercial unleaded gasoline + HiTEC. Sample regulated exhaust emissions and conduct hydrocarbon speciation. Sample unregulated aldehyde and ketone exhaust emissions.
30	Repeat Step 29 as Test 18.
31	Repeat Steps 27 to 30 as Tests 19 and 20.
32	Drain and fill HiTEC 3000 car with reformulated fuel + HiTEC 3000.
33	Perform 1,000 miles (half expressway and half 25 mph) driving with reformulated fuel + HiTEC 3000.
34	Prep HiTEC 3000 car.
35	Run FTP Test 21 on HiTEC 3000 car with reformulated fuel + HiTEC 3000. Sample regulated exhaust emissions and conduct hydrocarbon speciation. Sample unregulated aldehyde and ketone exhaust emissions.
36	Repeat Step 35 as Test 22.
37	Repeat Steps 33 through 36 as Tests 23 and 24.

*Steps 2-19 will run concurrently with Steps 20-37.

Attachment 4-3

Analytical Test Procedures For Ethyl Speciation Task

Regulated exhaust emissions , a hydrocarbon speciation, and unregulated exhaust emissions (aldehydes and ketones) were evaluated. The analytical procedures are described below:

C_1 - C_3 Hydrocarbons, Benzene, and Toluene - For measurement of selected individual hydrocarbons, methane (CH_4), ethane (C_2H_6), ethylene (C_2H_4), acetylene (C_2H_2) propane (C_3H_8). and propylene (C_3H_6), benzene (C_2H_6), and toluene (C_7H_8), a sample of CVS-diluted exhaust is collected in a Tedlar bag. This bagged sample is then analyzed for individual hydrocarbons using a gas chromatographic system containing four separate columns and a flame ionization detector. The peak areas are compared to an external calibration blend and the individual hydrocarbon concentrations are obtained using a Hewlett-Packard 3353 computer system.

1.3-Butadiene - The procedure was developed to measure 1,3-butadiene in dilute vehicle exhaust. In addition to 1.3-butadiene, the procedure provides separation and exhaust concentrations for six other C_4 hydrocarbons including: isobutane, butane, 1-butene, isobutylene, cis-2-butene, and trans-2-butene. Standard CVS bag samples are analyzed for 1,3-butadiene using a gas chromatograph equipped with a flame ionization detector (FID). The gas chromatograph system utilizes a Perkin-Elmer Model 3920B gas chromatograph with an FID, two pneumatically-operated and electrically-controlled Seiscor valves, and an analytical column. The analytical column is a 9 ft. x 1/8 in. stainless steel column containing 80/100 Carbopack C with 0.19% picric acid. The carrier gas is helium, which flows through the column at a rate of 27 mL/min. The column temperature is maintained at 40° C for analysis. External 1,3 butadiene standards in zero air are used to quantify the results. Detection limits for the procedure are on the order of 0.03 ppm C in dilute exhaust for 1,3 - butadiene (0.5 mg/mile for the FTP).

C_5 - C_{10} Hydrocarbons

This procedure permits the quantitative determination of more than 80 individual hydrocarbon species in automotive emissions. The gas chromatograph system utilizes a Perkin-Elmer Model 3920B gas chromatograph equipped with subambient capabilities, a capillary column, and a flame ionization detector. The capillary column used in the system is a Perkin-Elmer F-50 Versilube, 150-ft x 0.02-in. WCOT stainless steel column. The column is initially cooled to -139°F (-95°C) for sample injection. Upon injection, the temperature is programmed at a 7°F (4°C) increase per minute to 185°F (85°C). The column temperature is held at 185°F for approximately 15 minutes to complete column flushing. A flow controller is used to maintain a 1.5 mL/min helium carrier flow rate. The 10 mL sample volume permits determination of 0.1 ppmC with the flame ionization detector.

Aldehydes and Ketones - The aldehydes and ketones that were included in this analysis are: formaldehyde, acetaldehyde, acrolein, acetone, propionaldehyde, crotonaldehyde, isobutyraldehyde/methylethylketone (not resolved from each other under normal operating conditions and so reported together), benzaldehyde, and hexanaldehyde. The measurement of the aldehydes and ketones in exhaust is accomplished by bubbling the dilute exhaust at 4 L/min through chilled glass impingers containing an acetonitrile solution of 2,4-dinitrophenylhydrazine (DNPH) and perchloric acid. The exhaust sample is collected continuously during the test cycle. For analysis, a portion of the acetonitrile solution is injected into a liquid chromatograph equipped with a UV detector. External standards of the aldehyde and ketone DNPH derivatives are used to quantify the results. These standards were prepared by making hydrazone derivatives of the various aldehydes and ketones. Sample sets were bracketed with standards analyzed before and after. Standard areas had to repeat within ± 10 percent for the sample analyses to be accepted. Detection limits for this procedure are on the order of 0.005 ppm aldehyde or ketone in dilute exhaust.

Sampling System - Two glass impingers in series, each containing 25 mL of an acetonitrile absorbing solution (0.625 g/L DNPH and five drops 1N perchloric acid), were used to collect exhaust samples for the analysis of aldehydes and ketones. These compounds are converted to their 2,4-dinitrophenylhydrazone derivatives in an acidic DNPH solution. The two glass impingers trap approximately 99+ percent of the carbonyl compounds. The temperature of the impingers was maintained at 0-5°C by an ice water bath, and the flow rate through the impinger was maintained at 4 L/minute by the sample pump. A dry gas meter was used to determine the total flow through the impinger during a given sampling period. A dryer was included in the system to prevent condensation in the pump, flowmeter, dry gas meter, etc. Upon completion of each driving cycle, the impingers were removed from the sampling cart and the contents transferred to a 25 mL volumetric flask. When sampling intervals allowed, additional acetonitrile was added to the impingers to adjust for evaporation losses. The addition of acetonitrile was generally required when sampling periods exceeded 20 minutes. The samples were refrigerated until analyzed to preserve the acrolein derivative.

Analytical Procedure - A Perkin Elmer Series 2/2 liquid chromatograph with a Perkin Elmer LC-15B fixed wavelength UV detector operating at a wavelength of 350 nm was used to analyze the sample. A 10 µL portion of the sample was injected into the liquid chromatograph system with the use of a model 7105 septumless injector. The analytical column is a 25 cm x 4.6 mm Zorbaz ODS column and is preceded in the system by a 5 cm x 4.6 mm Permaphase ODS guard column. The mobile phase is acetonitrile-water (72:28) with a gradient to 100 percent acetonitrile at a rate of 1 percent per minute. The solvent flow was maintained at 0.3 mL per minute for the analysis. Analysis time was on the order of 40 minutes. To quantify the results, the sample peak areas were compared to the peak areas of standard solutions. Detection limits for this procedure are on the order of 0.005 ppm aldehyde or ketone in exhaust.

Attachment 4-3 (Cont'd.)

The FTP Test Procedure was performed as specified in the Federal Register, except that only exhaust emission testing was conducted.

GASOLINE TEST FUELS FOR ETHYL CORPORATION

Fuel		EM-990-F 1A	EM-991-F 1B	EM-984-F 2A	EM-985-F 2B	EM-981-F 3A	EM-982-F 3B
Fuel ID No.	ID. No.	FL-1535G	FL-1530-G	FL-1533G	FL-1529G	FL-1532G	FL-1531G
Composition, V%							
Reformulated	FL-1528G	100.00	94.85	-	-	-	-
Commercial	FL-1525G	-	-	100.00	92.50	-	-
Howell EEE Gasoline	FL-1527G*	-	-	-	-	100.00	92.20
Mixed Xylenes	FL-1526G	-	4.47	-	6.10	-	6.60
Normal Butane	-	-	0.68	-	1.40	-	1.20
HiTEC 3000 Concentrate		24 ppm	-	24 ppm	-	24 ppm	-
TOTAL		100.00	100.00	100.00	100.00	100.00	100.00
Properties	Test Method						
Gravity, °API	D 1298	59.3	58.7	62.6	61.0	58.8	56.9
Specific Gravity, 60°F		0.7416	0.7440	0.7290	0.7351	0.7436	0.7511
Distillation, °F	D 86						
IBP/5		101/120	96/115	79/98	77/92	78/97	77/95
10/20		134/157	131/158	110/129	105/125	113/141	115/145
30/40		178/198	180/202	148/171	150/180	171/195	177/203
50/60		217/239	224/240	199/231	211/240	215/229	221/236
70/80		263/305	270/302	261/296	266/292	240/269	254/277
90/95		365/401	355/400	340/370	327/353	315/343	309/335
FBP		434	440	410	405	391	386
Recovery, V%		99.0	99.0	99.0	99.0	99.0	99.0
Reid Vapor Pressure, psi	D 323	6.95	7.10	10.55	10.50	8.95	9.05
Hydrocarbon Type, V%	D 1319						
Aromatics		25.2	26.4	29.8	36.4	32.6	37.0
Olefins		4.2	5.0	4.9	5.5	2.1	3.2
Saturates		70.6	68.1	65.3	58.1	65.3	59.8
Elemental, Wt%	D 3178						
Carbon		84.82	85.77	86.37	86.78	86.81	87.44
Hydrogen		13.84	14.04	13.79	13.60	13.26	13.05
Manganese, g/gal	D 3831	0.03	-	0.035	-	0.035	-
Octanes							
Research	D 2699	93.0	93.0	92.6	92.6	97.9	97.9
Motor	D 2700	83.8	84.0	82.5	82.5	87.9	87.8
R+M/2		88.4	88.5	87.6	87.6	92.9	92.9

Attachment 4-5

43142	2,3-DIMETHYLPENTANE/2-METHYLHEXANE	11.1	15.6	13.4	13.4	14.8	14.1
43273	CYCLOHEXENE	0.0	0.0	0.0	0.0	0.0	0.0
43294	5-METHYL-2-HEXENE	0.0	0.0	0.0	0.0	0.0	0.0
43295	3-METHYLHEXANE	1.5	1.7	1.6	2.4	1.7	2.1
43250	2,2,4-TRIMETHYLPENTANE	51.3	67.1	59.2	57.8	61.8	59.8
43232	N-HEPTANE	1.2	0.7	1.0	0.9	0.8	0.9
98054	2,4,4-TRIMETHYL-1-PENTENE	0.0	0.0	0.0	0.0	0.0	0.0
	2,2,4-TRIMETHYL-1-PENTENE	0.0	0.0	0.0	0.0	0.0	0.0
43261	METHYLCYCLOHEXANE	0.3	0.0	0.2	0.5	0.6	0.5
98055	2,4,4-TRIMETHYL-2-PENTENE	0.0	0.0	0.0	0.0	0.0	0.0
43141	2,4/2-5-DIMETHYLHEXANE	4.3	5.0	4.7	5.8	3.4	4.6
43252	2,3,4-TRIMETHYLPENTANE	4.6	7.2	5.9	6.3	5.3	5.8
43280	2,3,3-TRIMETHYLPENTANE	3.8	5.5	4.6	4.8	4.4	4.6
98090	2-METHYL-3-HEPTENE	0.0	0.0	0.0	0.0	0.7	0.4
90095	3,5,5-TRIMETHYL-1-HEXENE	0.0	0.0	0.0	0.0	0.7	0.3
43141	2-/4-METHYLHEPTANE	0.5	0.7	0.6	0.6	0.4	0.5
43298	3-METHYLHEPTANE	0.5	0.6	0.5	0.7	0.5	0.6
90068	2,5-DIMETHYL-1,5-HEXADIENE	0.2	0.6	0.4	0.3	0.0	0.2
98033	2,2,5-TRIMETHYLHEXANE	0.3	0.5	0.4	0.4	0.8	0.6
	2-ETHYL-1-HEXENE	0.0	0.0	0.0	0.0	0.0	0.0
98059	1-CIS-4-DIMETHYLCYCLOHEXANE	0.0	0.0	0.0	0.0	0.0	0.0
43233	OCTANE	0.0	0.0	0.0	0.0	0.0	0.0
90002	2,3,5-TRIMETHYLHEXANE	0.0	0.0	0.0	0.0	0.0	0.0
90003	2,4-DIMETHYLHEPTANE	0.0	0.0	0.0	0.0	0.0	0.0
43136	2,5/3,5-DIMETHYLHEPTANE	0.0	0.0	0.0	0.0	0.0	0.0
45203	ETHYLBENZENE	2.3	2.4	2.4	5.4	6.1	5.7
90006	2,3-DIMETHYLHEPTANE	0.0	0.0	0.0	0.0	0.0	0.0
90010	P-XYLENE/M-XYLENE	7.5	8.1	7.8	21.0	23.2	22.1
90008	2-METHYLOCTANE	0.0	0.0	0.0	0.0	0.0	0.0
90016	4-METHYLOCTANE	0.0	0.0	0.0	0.0	0.0	0.0
90015	3-METHYLOCTANE	0.0	0.0	0.0	0.0	0.0	0.0
45204	O-XYLENE	2.9	3.5	3.2	8.1	8.0	8.1
43235	NONANE	0.4	0.2	0.3	0.1	0.3	0.2
90034	TRANS-2-NONENE	0.0	0.1	0.1	0.0	0.6	0.3
45209	PROPYLBENZENE	0.9	0.6	0.8	0.8	1.1	0.9
99908	2,3-DIMETHYLOCTANE	1.3	1.4	1.4	2.0	2.0	2.0
45211	O-ETHYLTOLULENE	0.5	0.7	0.6	0.8	1.0	0.9
45208	1,2,4-TRIMETHYLBENZENE	3.9	3.2	3.6	4.0	6.5	5.3
45216	ISOBUTYLBENZENE	1.4	0.2	0.8	0.4	0.9	0.7
43238	DECANE	1.5	0.2	0.8	0.4	1.0	0.7
9917	P-CYMENE	1.6	0.0	0.8	0.2	0.6	0.4
98044	INDAN(E)	0.0	0.0	0.0	0.2	0.1	0.2
45241	4-PHENYL-1-BUTENE	0.0	0.0	0.0	0.1	0.0	0.1
45218	M-DIETHYLBENZENE	1.5	0.7	1.1	0.3	3.6	2.0
99916	1-METHYL-3-PROPYLBENZENE	0.0	0.0	0.0	0.1	0.0	0.0
45109	N-BUTYLBENZENE/P-DIETHYLBENZENE	0.0	0.3	0.2	0.2	2.7	1.5
45217	O-DIETHYLBENZENE	0.0	0.0	0.0	0.0	0.0	0.0
99918	2-METHYLDECANE	0.0	0.0	0.0	0.4	2.8	1.6
90033	BICYCLOPENTYL	0.0	0.0	0.0	0.0	0.0	0.0
43241	UNDECANE	0.0	0.0	0.0	0.2	0.0	0.1
45207	1,3,5-TRIMETHYLBENZENE	1.0	1.3	1.2	2.1	2.2	2.1
43294	C7 OLEFINS	0.0	0.1	0.1	0.0	0.9	0.4

Attachment 4-5 (continued)

43140	C9-C11 PARAFFINS, OLEFINS, AROMATIC	1.7	2.5	2.1	2.8	9.5	6.2
43502	FORMALDEHYDE	5.3	5.5	5.4	6.6	6.0	6.3
43503	ACETALDEHYDE	1.8	1.5	1.6	2.2	2.1	2.1
43505	ACROLEIN	0.0	0.0	0.0	0.0	0.0	0.0
43551	ACETONE	1.0	1.0	1.0	1.5	1.4	1.4
43504	PROPIONALDEHYDE	0.1	0.0	0.0	0.0	0.1	0.1
43515	CROTONALDEHYDE	0.1	0.1	0.1	0.0	0.1	0.1
43511	ISOBUTYRALDEHYDE	0.1	0.1	0.1	0.1	0.1	0.1
43552	METHYL ETHYL KETONE	0.1	0.1	0.1	0.1	0.1	0.1
45501	BENZALDEHYDE	0.5	0.5	0.5	0.8	0.7	0.7
43512	HEXANALDEHYDE	0.0	0.1	0.0	0.0	0.0	0.0
	HC	475.3	549.9	512.6	561.8	573.6	567.7
	CO	1350.6	1410.2	1380.4	2129.8	2287.8	2208.8
	CO2	462802.0	459736.9	461269.4	462502.6	462344.9	462423.8
	NOX	945.1	935.6	940.3	1210.5	1536.2	1373.4
				0.0			0.0
	ALKANES (C1-C6)	277.9	336.3	307.1	293.8	326.3	310.0
	ALKENES AND ALKYNES (C2-C6)	32.5	45.7	39.1	41.8	52.8	47.3
	AROMATICS	49.2	52.8	51.0	85.6	94.8	90.2

Attachment 4-b

Results of Speciation of Exhaust Hydrocarbons Using Commercial Gasoline Plus Additives as Shown

		Commercial Gasoline Plus HiTEC 3000 Fleet Car F-3			Commercial Gasoline Plus Xylenes Fleet Car F-5		
		1000 MI	2000 MI	AVERAGE	1000 MI	2000 MI	AVERAGE
CODE	COMPOUND	FTP MG/MI	FTP MG/MI		FTP MG/MI	FTP MG/MI	
43201	METHANE	137.3	127.3	132.3	128.5	95.2	111.9
43203	ETHYLENE	23.2	19.4	21.3	27.8	22.2	25.0
43202	ETHANE	31.5	30.3	30.9	27.8	21.6	24.7
43206	ACETYLENE	0.9	0.9	0.9	1.2	1.2	1.2
43204	PROPANE	1.9	2.1	2.0	2.6	1.5	2.0
43205	PROPYLENE	9.8	8.3	9.0	10.5	9.5	10.0
43218	1,3-BUTADIENE	1.1	1.0	1.0	1.1	1.1	1.1
43214	ISOBUTANE	4.2	4.2	4.2	3.7	4.0	3.8
43212	BUTANE	33.5	32.3	32.9	39.9	40.7	40.3
43213	1-BUTENE	1.5	1.3	1.4	1.9	1.8	1.8
43215	ISOBUTYLENE	3.3	2.8	3.0	3.8	3.7	3.7
43217	CIS-2-BUTENE	1.0	0.8	0.9	1.4	1.3	1.4
43216	TRANS-2-BUTENE	1.3	0.9	1.1	1.7	1.5	1.6
45201	BENZENE	7.4	6.6	7.0	10.9	10.9	10.9
45202	TOLUENE	10.7	8.4	9.6	13.1	10.9	12.0
43221	ISOPENTANE	45.6	58.8	52.2	45.4	57.3	51.4
43224	1-PENTENE	0.0	0.4	0.2	0.0	0.0	0.0
43220	PENTANE	20.4	21.6	21.0	19.5	20.8	20.1
43225	2-METHYL-1-BUTENE	0.8	0.0	0.4	0.4	0.0	0.2
43243	ISOPRENE(2-METHYL-1,3-BUTADIENE)	0.4	0.1	0.3	0.6	0.1	0.4
43226	TRANS-2-PENTENE	1.2	0.7	1.0	1.0	1.4	1.2
43227	CIS-2-PENTENE	0.8	0.6	0.7	0.3	0.0	0.2
43228	2-METHYL-2-BUTENE	4.8	1.5	3.2	3.4	3.4	3.4
43291	2,2-DIMETHYLBUTANE	1.0	0.4	0.7	0.4	0.2	0.3
43292	CYCLOPENTENE	0.1	0.0	0.0	0.0	0.0	0.0
43242	CYCLOPENTANE	0.2	0.0	0.1	0.2	0.2	0.2
43211	3-METHYL-1-PENTENE	0.2	0.0	0.1	0.2	0.2	0.2
90007	4-METHYL-1-PENTENE	0.2	0.0	0.1	0.2	0.2	0.2
43276	2,3-DIMETHYLBUTANE	3.1	5.5	4.3	2.8	4.4	3.6
43234	2,3-DIMETHYL-1-BUTENE	0.0	0.0	0.0	0.0	0.0	0.0
43229	2-METHYLPENTANE	7.2	7.4	7.3	6.5	7.9	7.2
43293	4-METHYL-2-PENTENE	7.0	7.2	7.1	6.3	7.8	7.0
43376	MTBE	0.0	0.0	0.0	0.0	0.0	0.0
43230	3-METHYLPENTANE	9.8	8.3	9.0	8.4	9.9	9.1
43289	2-METHYL-1-PENTENE/1-HEXENE	0.4	0.4	0.4	0.7	0.4	0.5
43231	HEXANE	5.0	3.7	4.4	3.1	5.4	4.3
43289	C6 OLEFINS	1.4	0.8	1.1	2.5	1.3	1.9
43247	2,4-DIMETHYLPENTANE	1.5	0.8	1.2	1.9	1.4	1.6
43262	METHYLCYCLOPENTANE	6.5	4.4	5.4	7.5	6.4	7.0
43248	CYCLOHEXANE	0.7	0.0	0.4	0.0	0.4	0.2
43272	METHYLCYCLOPENTENE	0.0	0.3	0.1	0.5	0.2	0.4
43289	3-METHYL-1,3-PENTADIENE	0.7	0.0	0.4	0.0	0.4	0.2
43142	2,3-DIMETHYLPENTANE/2-METHYLHEXANE	7.5	7.7	7.6	7.9	8.9	8.4
43273	CYCLOHEXENE	0.0	0.0	0.0	0.0	0.0	0.0

Attachment 4-6

43294	5-METHYL-2-HEXENE	0.0	0.0	0.0	0.0	0.0	0.0
43295	3-METHYLHEXANE	3.7	4.1	3.9	3.9	5.4	4.6
43250	2,2,4-TRIMETHYLPENTANE	12.6	10.4	11.5	14.1	11.8	13.0
43232	N-HEPTANE	1.2	0.7	1.0	1.5	1.4	1.4
98054	2,4,4-TRIMETHYL-1-PENTENE	0.0	0.0	0.0	0.0	0.0	0.0
	2,2,4-TRIMETHYL-1-PENTENE	0.0	0.0	0.0	0.0	0.0	0.0
43261	METHYLCYCLOHEXANE	1.6	0.9	1.2	1.5	1.6	1.5
98055	2,4,4-TRIMETHYL-2-PENTENE	0.0	0.0	0.0	0.1	0.0	0.1
43141	2,4/2-5-DIMETHYLHEXANE	2.4	1.3	1.9	2.6	2.8	2.7
43252	2,3,4-TRIMETHYLPENTANE	4.1	3.5	3.8	4.8	4.1	4.5
43280	2,3,3-TRIMETHYLPENTANE	5.9	5.0	5.4	5.8	5.2	5.5
98090	2-METHYL-3-HEPTENE	0.0	0.0	0.0	0.0	0.0	0.0
90095	3,5,5-TRIMETHYL-1-HEXENE	0.0	0.0	0.0	0.0	0.0	0.0
43141	2-/4-METHYLHEPTANE	2.0	1.6	1.8	2.2	3.2	2.7
43298	3-METHYLHEPTANE	1.8	1.5	1.7	2.0	2.2	2.1
90068	2,5-DIMETHYL-1,5-HEXADIENE	0.0	0.0	0.0	0.0	0.0	0.0
98033	2,2,5-TRIMETHYLHEXANE	1.2	0.9	1.1	1.3	2.0	1.6
	2-ETHYL-1-HEXENE	0.0	0.0	0.0	0.0	0.0	0.0
98059	1-CIS-4-DIMETHYLCYCLOHEXANE	0.0	0.0	0.0	0.0	0.0	0.0
43233	OCTANE	0.7	0.4	0.6	0.6	1.1	0.9
90002	2,3,5-TRIMETHYLHEXANE	0.0	0.0	0.0	0.0	0.0	0.0
90003	2,4-DIMETHYLHEPTANE	0.0	1.0	0.5	0.0	0.0	0.0
43136	2,5/3,5-DIMETHYLHEPTANE	0.2	0.3	0.3	0.0	0.3	0.2
45203	ETHYLBENZENE	2.5	1.8	2.1	5.2	4.7	5.0
90006	2,3-DIMETHYLHEPTANE	0.0	0.0	0.0	0.0	0.0	0.0
90010	P-XYLENE/M-XYLENE	8.3	8.1	8.2	20.5	20.3	20.4
90008	2-METHYLOCTANE	0.2	0.2	0.2	0.2	0.3	0.3
90016	4-METHYLOCTANE	0.2	0.2	0.2	0.2	0.3	0.3
90015	3-METHYLOCTANE	0.0	0.0	0.0	0.0	0.0	0.0
45204	O-XYLENE	3.5	2.9	3.2	7.7	7.4	7.6
43235	NONANE	0.4	0.4	0.4	0.4	0.5	0.4
90034	TRANS-2-NONENE	0.0	0.0	0.0	0.0	0.0	0.0
45209	PROPYLBENZENE	0.7	0.6	0.6	0.8	0.7	0.7
99908	2,3-DIMETHYLOCTANE	1.3	1.2	1.2	2.2	2.1	2.1
45211	O-ETHYLTOLULENE	0.7	0.7	0.7	0.9	1.3	1.1
45208	1,2,4-TRIMETHYLBENZENE	3.5	4.5	4.0	4.2	4.8	4.5
45216	ISOBUTYLBENZENE	1.2	1.9	1.6	0.3	0.2	0.2
43238	DECANE	1.3	2.0	1.7	0.3	0.2	0.3
9917	P-CYMENE	1.2	1.2	1.2	0.8	0.8	0.8
98044	INDAN(E)	0.1	0.1	0.1	0.4	0.3	0.3
45241	4-PHENYL-1-BUTENE	0.0	0.0	0.0	0.0	0.0	0.0
45218	M-DIETHYLBENZENE	2.2	0.9	1.6	0.5	0.5	0.5
99916	1-METHYL-3-PROPYLBENZENE	0.0	0.0	0.0	0.0	0.0	0.0
45109	N-BUTYLBENZENE/P-DIETHYLBENZENE	0.4	0.5	0.5	0.5	0.8	0.7
45217	O-DIETHYLBENZENE	0.0	0.0	0.0	0.0	0.0	0.0
99918	2-METHYLDECANE	0.5	0.5	0.5	0.7	0.9	0.8
90033	BICYCLOPENTYL	0.0	0.0	0.0	0.0	0.0	0.0
43241	UNDECANE	0.0	0.4	0.2	0.0	0.2	0.1
45207	1,3,5-TRIMETHYLBENZENE	1.2	0.9	1.1	1.8	2.4	2.1
43294	C7 OLEFINS	0.2	1.2	0.7	0.5	0.5	0.5
43140	C8-C9 OLEFINS	0.0	1.7	0.8	0.0	2.7	1.4
43140	C9-C11 PARAFFINS, OLEFINS, AROMATIC	1.5	0.6	1.0	2.9	2.4	2.7

Attachment 4-6

43502	FORMALDEHYDE	5.5	4.8	5.2	6.1	7.2	6.7
43503	ACETALDEHYDE	1.7	1.8	1.8	2.3	2.4	2.3
43505	ACROLEIN	0.1	0.0	0.1	0.0	0.0	0.0
43551	ACETONE	1.4	1.5	1.5	2.0	1.7	1.9
43504	PROPIONALDEHYDE	0.2	0.1	0.2	0.3	0.3	0.3
43515	CROTONALDEHYDE	0.1	0.1	0.1	0.1	0.1	0.1
43511	ISOBUTYRALDEHYDE	0.1	0.1	0.1	0.1	0.2	0.1
43552	METHYL ETHYL KETONE	0.1	0.1	0.1	0.1	0.2	0.1
45501	BENZALDEHYDE	0.2	0.3	0.3	0.4	0.5	0.4
43512	HEXANALDEHYDE	0.0	0.1	0.0	0.0	0.0	0.0
	HC	510.0	478.1	494.0	540.1	568.0	554.0
	CO	1723.8	1268.7	1496.3	2433.8	2319.6	2376.7
	CO2	450404.7	448752.8	449578.8	447878.6	443792.3	445835.4
	NOX	889.7	833.8	861.7	1262.0	1138.9	1200.5

Attachment 4-7
Results of Speciation of Exhaust Hydrocarbons Using Reformulated Gasoline Plus Additives as Shown

		Reformulated Gasoline Plus HiTEC 3000 Fleet Car F-3			Reformulated Gasoline Plus Xylenes Fleet Car F-3		
CODE	COMPOUND	1000 MILES FTP MG/MI	2000 MILES FTP MG/MI	AVERAGE FTP MG/MI	1000 MILES FTP MG/MI	2000 MILES FTP MG/MI	AVERAGE FTP MG/MI
43201	METHANE	156.5	165.2	160.8	147.7	149.6	148.7
43203	ETHYLENE	21.9	25.7	23.8	25.6	29.1	27.4
43202	ETHANE	37.1	39.1	38.1	32.0	32.6	32.3
43206	ACETYLENE	1.6	1.6	1.6	1.9	1.8	1.9
43204	PROPANE	2.6	2.7	2.6	2.1	2.0	2.0
43205	PROPYLENE	10.8	13.0	11.9	12.4	14.7	13.6
43218	1,3-BUTADIENE	0.8	1.3	1.1	1.1	1.3	1.2
43214	ISOBUTANE	1.2	1.7	1.4	1.9	2.4	2.1
43212	BUTANE	17.8	18.7	18.3	13.5	15.0	14.3
43213	1-BUTENE	1.3	1.7	1.5	1.7	2.0	1.9
43215	ISOBUTYLENE	8.0	9.8	8.9	9.4	11.5	10.5
43217	CIS-2-BUTENE	0.9	0.9	0.9	1.1	1.3	1.2
43216	TRANS-2-BUTENE	1.1	1.2	1.1	1.5	1.7	1.6
45201	BENZENE	6.8	9.3	8.1	8.1	9.8	9.0
45202	TOLUENE	6.1	7.4	6.7	8.5	9.2	8.9
43221	ISOPENTANE	51.2	53.3	52.2	52.6	54.7	53.6
43224	1-PENTENE	0.2	0.3	0.3	0.4	0.4	0.4
43220	PENTANE	9.9	7.8	8.8	6.7	8.5	7.6
43225	2-METHYL-1-BUTENE	0.0	0.0	0.0	0.3	0.0	0.2
43243	ISOPRENE(2-METHYL-1,3-BUTADIENE)	0.3	0.5	0.4	0.5	0.0	0.2
43226	TRANS-2-PENTENE	1.0	0.0	0.5	1.3	0.8	1.0
43227	CIS-2-PENTENE	0.6	0.0	0.3	0.5	0.5	0.5
43228	2-METHYL-2-BUTENE	1.8	1.2	1.5	2.9	1.6	2.3
43291	2,2-DIMETHYLBUTANE	0.1	0.0	0.1	0.1	0.8	0.5
43292	CYCLOPENTENE	0.3	0.0	0.2	0.0	0.5	0.3
43242	CYCLOPENTANE	0.3	0.2	0.2	0.2	0.3	0.2
43211	3-METHYL-1-PENTENE	0.3	0.2	0.2	0.2	0.3	0.2
90007	4-METHYL-1-PENTENE	0.3	0.2	0.2	0.2	0.3	0.2
43276	2,3-DIMETHYLBUTANE	8.8	9.7	9.3	6.5	8.8	7.7
43234	2,3-DIMETHYL-1-BUTENE	0.0	0.0	0.0	0.0	0.0	0.0
43229	2-METHYLPENTANE	5.0	8.4	6.7	6.1	7.5	6.8
43293	4-METHYL-2-PENTENE	4.9	8.2	6.6	6.0	7.4	6.7
43376	MTBE	5.8	5.5	5.7	9.6	6.7	8.1
43230	3-METHYLPENTANE	8.4	9.0	8.7	8.2	8.3	8.2
43289	2-METHYL-1-PENTENE/1-HEXENE	0.4	0.4	0.4	0.0	0.2	0.1
43231	HEXANE	2.5	3.1	2.8	2.9	2.4	2.7
43289	C6 OLEFINS	1.3	1.0	1.1	0.7	1.3	1.0
43247	2,4-DIMETHYLPENTANE	5.6	4.3	5.0	3.5	5.0	4.3
43262	METHYLCYCLOPENTANE	8.3	6.9	7.6	6.9	8.4	7.7
43248	CYCLOHEXANE	0.1	0.1	0.1	0.1	0.3	0.2
43272	METHYLCYCLOPENTENE	0.2	0.5	0.3	0.5	0.5	0.5
43289	3-METHYL-1,3-PENTADIENE	0.1	0.1	0.1	0.1	0.3	0.2
43142	2,3-DIMETHYLPENTANE/2-METHYLHEXANE	9.1	10.2	9.6	8.6	9.0	8.8
43273	CYCLOHEXENE	0.0	0.0	0.0	0.0	0.0	0.0

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43294	5-METHYL-2-HEXENE	0.0	0.0	0.0	0.0	0.0	0.0
43295	3-METHYLHEXANE	3.9	4.7	4.3	2.8	3.1	2.9
43250	2,2,4-TRIMETHYLPENTANE	31.0	33.3	32.1	26.8	27.7	27.2
43232	N-HEPTANE	1.4	0.9	1.1	0.9	1.2	1.0
98054	2,4,4-TRIMETHYL-1-PENTENE	0.0	0.0	0.0	0.0	0.0	0.0
	2,2,4-TRIMETHYL-1-PENTENE	0.0	0.0	0.0	0.0	0.0	0.0
43261	METHYLCYCLOHEXANE	2.4	2.7	2.5	2.7	2.8	2.7
98055	2,4,4-TRIMETHYL-2-PENTENE	0.0	0.0	0.0	0.5	0.0	0.2
43141	2,4/2-5-DIMETHYLHEXANE	5.5	6.0	5.8	3.9	5.7	4.8
43252	2,3,4-TRIMETHYLPENTANE	9.9	9.4	9.7	7.8	8.4	8.1
43280	2,3,3-TRIMETHYLPENTANE	11.6	13.6	12.6	10.6	11.6	11.1
98090	2-METHYL-3-HEPTENE	0.0	0.7	0.3	0.3	0.0	0.2
90095	3,5,5-TRIMETHYL-1-HEXENE	0.0	0.7	0.3	0.3	0.0	0.2
43141	2-/4-METHYLHEPTANE	1.1	1.5	1.3	1.1	1.4	1.2
43298	3-METHYLHEPTANE	1.0	1.1	1.1	0.9	1.1	1.0
90068	2,5-DIMETHYL-1,5-HEXADIENE	0.0	0.0	0.0	0.0	0.0	0.0
98033	2,2,5-TRIMETHYLHEXANE	7.6	8.5	8.1	6.5	7.7	7.1
	2-ETHYL-1-HEXENE	0.0	0.0	0.0	0.0	0.0	0.0
98059	1-CIS-4-DIMETHYLCYCLOHEXANE	0.7	0.0	0.4	0.7	0.0	0.3
43233	OCTANE	0.5	0.5	0.5	0.5	0.6	0.5
90002	2,3,5-TRIMETHYLHEXANE	0.0	0.7	0.3	0.0	0.6	0.3
90003	2,4-DIMETHYLHEPTANE	0.0	0.4	0.2	0.0	0.0	0.0
43136	2,5/3,5-DIMETHYLHEPTANE	0.3	0.5	0.4	0.6	0.6	0.6
45203	ETHYLBENZENE	1.4	1.7	1.5	3.2	4.5	3.9
90006	2,3-DIMETHYLHEPTANE	0.0	0.0	0.0	0.0	0.0	0.0
90010	P-XYLENE/M-XYLENE	4.3	4.2	4.2	12.6	14.2	13.4
90008	2-METHYLOCTANE	0.1	0.2	0.2	0.2	0.2	0.2
90016	4-METHYLOCTANE	0.1	0.2	0.2	0.2	0.2	0.2
90015	3-METHYLOCTANE	0.0	0.0	0.0	0.0	0.0	0.0
45204	O-XYLENE	2.1	2.8	2.5	4.9	6.6	5.7
43235	NONANE	0.5	0.5	0.5	0.7	0.7	0.7
90034	TRANS-2-NONENE	0.0	0.0	0.0	0.5	0.0	0.2
45209	PROPYLBENZENE	0.1	0.2	0.2	0.7	0.5	0.6
99908	2,3-DIMETHYLOCTANE	1.1	0.9	1.0	1.0	1.6	1.3
45211	O-ETHYLTOLULENE	0.5	0.5	0.5	0.4	0.6	0.5
45208	1,2,4-TRIMETHYLBENZENE	1.5	2.0	1.8	3.7	4.4	4.1
45216	ISOBUTYLBENZENE	0.2	0.0	0.1	1.0	0.2	0.6
43238	DECANE	0.0	0.0	0.0	1.0	0.2	0.6
9917	P-CYMENE	0.4	0.4	0.4	2.9	1.1	2.0
98044	INDAN(E)	0.0	0.0	0.0	0.0	0.0	0.0
45241	4-PHENYL-1-BUTENE	0.0	0.0	0.0	0.0	0.0	0.0
45218	M-DIETHYLBENZENE	0.4	0.5	0.5	2.5	1.1	1.8
99916	1-METHYL-3-PROPYLBENZENE	0.0	0.0	0.0	0.0	0.0	0.0
45109	N-BUTYLBENZENE/P-DIETHYLBENZENE	0.4	0.3	0.4	0.6	0.6	0.6
45217	O-DIETHYLBENZENE	0.0	0.0	0.0	0.0	0.0	0.0
99918	2-METHYLDECANE	0.4	0.2	0.3	1.1	0.8	1.0
90033	BICYCLOPENTYL	0.0	0.0	0.0	0.0	0.0	0.0
43241	UNDECANE	0.0	0.5	0.2	0.0	0.0	0.0
45207	1,3,5-TRIMETHYLBENZENE	0.9	1.6	1.3	1.3	2.1	1.7
43294	C7 OLEFINS	0.6	2.4	1.5	1.7	2.5	2.1
43140	C8-C9 OLEFINS	0.7	1.2	0.9	1.7	1.6	1.6
43140	C9-C11 PARAFFINS, OLEFINS, AROMATIC	0.0	2.1	1.0	0.7	1.6	1.2
43502	FORMALDEHYDE	5.7	6.4	6.1	6.3	7.0	6.6
43503	ACETALDEHYDE	0.9	2.0	1.5	1.6	1.8	1.7

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43551	ACETONE	1.6	2.5	2.1	1.5	2.7	2.1
43504	PROPIONALDEHYDE	0.0	0.0	0.0	0.0	0.0	0.0
43515	CROTONALDEHYDE	0.1	0.1	0.1	0.1	0.0	0.0
43511	ISOBUTYRALDEHYDE	0.2	0.0	0.1	0.1	0.0	0.1
43552	METHYL ETHYL KETONE	0.2	0.0	0.1	0.1	0.0	0.1
45501	BENZALDEHYDE	0.2	0.2	0.2	0.2	0.3	0.3
43512	HEXANALDEHYDE	0.1	0.0	0.0	0.0	0.0	0.0
	HC	529.5	604.9	567.2	535.8	589.7	562.7
	CO	1534.6	1680.5	1607.5	2397.2	2546.9	2472.0
	CO2	450876.2	451584.2	451230.2	446808.3	445041.5	445924.9
	NOX	959.7	1003.8	981.8	1515.1	1297.7	1406.4
	C1-C6 ALKANES	375.9	394.0	385.0	352.6	370.6	361.6
	C2-C6 ALKENES AND ALKYNES	57.5	67.6	62.6	68.2	77.3	72.7
	AROMATICS	24.9	30.4	27.6	47.6	53.8	50.7

Attachment 4-8

SUMMARY OF SPECIATION TEST RESULTS

Fleet Car F-3

COMPOUND	HOWELL EEE + HiTEC 3000 500 MILES FTP MG/MI *	1000 MILES FTP MG/MI	AVERAGE FTP MG/MI
HC	475.3	549.9	512.6
CO	1350.6	1410.2	1380.4
CO2	462802.0	459736.9	461269.4
NOX	945.1	935.6	940.3
ALKANES (C1-C6)	254.7	304.7	279.7
ALKENES AND ALKYNES (C2-C6)	29.3	39.7	34.5
AROMATICS	53.0	56.9	55.0
ALDEHYDES AND KETONES	9.1	8.7	8.9

Fleet Car F-5

COMPOUND	HOWELL EE+ XYLENES 500 MILES FTP MG/MI	1000 MILES FTP MG/MI	AVERAGE FTP MG/MI
HC	561.8	573.6	567.7
CO	2129.8	2287.8	2208.8
CO2	462502.6	462344.9	462423.8
NOX	1210.5	1536.2	1373.4
ALKANES (C1-C6)	266.8	299.4	283.1
ALKENES AND ALKYNES (C2-C6)	37.3	47.0	42.1
AROMATICS	94.5	103.8	99.1
ALDEHYDES AND KETONES	11.3	10.6	10.9

(Commercial Gasoline + HiTEC 3000)

COMPOUND	EM-985-F 1000 MILES FTP MG/MI	2000 MILES FTP MG/MI	AVERAGE FTP MG/MI
HC	510.0	478.1	494.0
CO	1723.8	1268.7	1496.3
CO2	450404.7	448752.8	449578.8
NOX	889.7	833.8	861.7
ALKANES (C1-C6)	274.4	276.4	275.4
ALKENES AND ALKYNES (C2-C6)	50.0	38.9	44.5
AROMATICS	42.5	37.8	40.1
ALDEHYDES AND KETONES	9.6	8.9	9.2

(Commercial Gasoline + Xylenes)

COMPOUND	EM-985-F 1000 MILES FTP MG/MI	2000 MILES FTP MG/MI	AVERAGE FTP MG/MI
HC	540.1	568.0	554.0
CO	2433.8	2319.6	2376.7
CO2	447878.6	443792.3	445835.4
NOX	1262.0	1138.9	1200.5
ALKANES (C1-C6)	267.4	241.1	254.3
ALKENES AND ALKYNES (C2-C6)	55.3	47.3	51.3
AROMATICS	66.4	64.8	65.6
ALDEHYDES AND KETONES	11.4	12.7	12

(Reformulated Gasoline + HiTEC 3000)

COMPOUND	EM-990-F 1000 MILES FTP MG/MI	2000 MILES FTP MG/MI	AVERAGE FTP MG/MI
HC	529.5	604.9	567.2
CO	1534.6	1680.5	1607.5
CO2	450876.2	451584.2	451230.2
NOX	959.7	1003.8	981.8
ALKANES (C1-C6)	375.9	394.0	385.0
ALKENES AND ALKYNES (C2-C6)	57.5	67.6	62.6
AROMATICS	24.9	30.4	27.6
ALDEHYDES AND KETONES	8.9	11.7	10.3

(Reformulated Gasoline + Xylenes)

COMPOUND	EM-991-F 1000 MILES FTP MG/MI	2000 MILES FTP MG/MI	AVERAGE FTP MG/MI
HC	535.8	589.7	562.7
CO	2397.2	2546.9	2472.0
CO2	446808.3	445041.5	445924.9
NOX	1515.1	1297.7	1406.4
ALKANES (C1-C6)	352.6	370.6	361.6
ALKENES AND ALKYNES (C2-C6)	68.2	77.3	72.7
AROMATICS	47.6	53.8	50.7
ALDEHYDES AND KETONES	9.9	11.8	10.9

* To convert to grams per mile the decimal point should be moved three spaces to the left. Thus, 475.3 mg per mile is equal to .4753 grams per mile.

Appendix 5

Final Report

APPENDIX 5: USE OF THE URBAN AIRSHED MODEL TO ASSESS THE EFFECTS OF HiTEC® 3000 PERFORMMANCE ADDITIVE ON URBAN AIR QUALITY

SYSAPP-90/038

4 May 1990

Prepared for

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Executive Summary

The fleet testing program developed and conducted by Ethyl Petroleum Additives, Inc. to support their waiver request for the use of HiTEC® 3000 Performance Additive (HiTEC 3000) in unleaded gasoline is one of the most comprehensive programs ever undertaken by a single company. The purpose of the test program was to demonstrate that the use of HiTEC 3000 will not cause or contribute to a failure of emission control systems or devices and thereby adversely affect air quality. In order to quantify the effects of HiTEC 3000 Ethyl, retained the services of Systems Applications, Inc. to analyze data from the Ethyl fleet testing and speciation programs and perform photochemical grid model simulations to determine the effect of HiTEC 3000 on urban air quality.

The Ethyl fleet testing program data was analyzed to determine the effects HiTEC 3000 has on mobile source exhaust emissions. The EPA mobile source emission program, MOBILE4, was modified to reflect the effect HiTEC 3000 has on deterioration rates for exhaust emissions of total hydrocarbons (THC), nitrogen oxides (NO_x), and carbon monoxide (CO). The standard MOBILE4 and MOBILE4 modified to account for the effects of HiTEC 3000 was then used to develop a light duty gas vehicle (LDGV) emission inventory for the year 1994 assuming full penetration of HiTEC 3000 into the LDGV fleet starting in 1991. The effect of HiTEC 3000 on LDGV exhaust emissions was to decrease NO_x and CO emissions and slightly increase THC emissions. Non-LDGV emissions were based on the 1985 National Acid Precipitation Assessment Program (NAPAP) inventory projected to 1994.

The Ethyl emissions speciation program data were utilized to define the chemical composition of the LDGV exhaust and evaporative THC emissions to reactive species needed by the Carbon Bond IV chemical mechanism used by the UAM. In the speciation program fuel octane was kept constant by adjusting aromatic content: when HiTEC 3000 was included in the test fuel, the aromatic content was lower. The

speciation data for the commercial fuel plus aromatics and commercial fuel plus HiTEC 3000 (i.e., constant octane fuels) were used for, respectively, the 1994 base case and 1994 HiTEC 3000 emission scenarios. The increase in reactive hydrocarbons associated with fuel containing the additional aromatics in gasoline more than compensated for the increase in THC emissions associated with HiTEC 3000 resulting in less reactive hydrocarbon emissions for the HiTEC 3000 emission scenario than the base case. Two sensitivity tests were also performed: one used the same LDGV exhaust and evaporative speciation profile to convert THC emissions to its reactive components for the base case and HiTEC 3000 emission scenario (i.e., different octane fuels) while the other eliminated all emissions from LDGV.

The UAM was exercised for two cities, Philadelphia and Atlanta, to assess the effects of HiTEC 3000 on urban air quality. The use of HiTEC 3000 had a very small effect on ozone concentrations. The peak calculated ozone concentration was reduced 0.5 percent due to the use of HiTEC 3000 in both cities. In Philadelphia, the use of HiTEC 3000 resulted in a decrease of the peak ozone concentration of 0.5 ppb, from 183.5 ppb to 183.0 ppb. This is compared to a reduction of the peak ozone concentration of 10.9 ppb when all LDGV emissions are eliminated. Thus the introduction of HiTEC 3000 in 1991 into all LDGV in Philadelphia is equivalent in terms of an ozone attainment strategy to taking 170,000 (5 percent) of the gasoline vehicles off the road. Similar results were seen in Atlanta where the peak ozone concentration was reduced 0.4 ppb (0.3 percent), from 125.9 ppb to 125.5 ppb, due to the use of HiTEC 3000 compared to a peak ozone concentration of 120.4 ppb when all LDGV emissions are eliminated. In Atlanta the use of HiTEC 3000 is equivalent to removing 129,000 (7 percent) of the gas vehicle fleet.

The ozone National Ambient Air Quality Standard (NAAQS) of 120 ppb is a health based standard in which reductions in pulmonary function have been observed in some people when exposed to ozone concentrations in excess of the NAAQS. It is calculated that the use of HiTEC 3000 in Philadelphia would result in 4,000 less people-hours of exposure to ozone concentrations in excess of the ozone NAAQS. Again similar results are seen in Atlanta where 400 less people-hours of exposure to ozone concentrations in excess of the NAAQS. It is also estimated that the use of HiTEC 3000 will reduce the area of ozone exceedances of the NAAQS by approximately 0.5 and 11.1 percent for the cities of Philadelphia and Atlanta, respectively.

The reduction in tailpipe NO_x and CO emissions due to HiTEC 3000 also results in reductions in ambient NO_2, NO_x, and CO concentrations. Reductions in peak ambient concentrations of these species ranged from 0.01 to 0.45 percent over the averaging times studied. An estimate of the maximum possible atmospheric manganese concentration due to HiTEC 3000 was over one million times smaller than the OSHA standard for manganese. It was also estimated that benzene concentrations would be reduced from 3 to 10 percent due to the use of HiTEC 3000.

A speciation sensitivity test was performed in which the same speciation profile, as defined in the EPA Air Emissions Speciation Manual, were used for LDGV emissions in both the 1994 base case and HiTEC 3000 emission scenarios. This sensitivity test represents a conservative estimate (i.e., overstating any disbenefits of HiTEC 3000 on air quality) because it is using the same speciation profile for fuels with different octanes and does not take into account the beneficial effects of using HiTEC 3000 as a replacement octane enhancer for aromatics. Even with these conservative assumptions, the use of HiTEC 3000 in Philadelphia still indicated an improvement in air quality; the peak ozone concentration was reduced by 0.2 percent. In Atlanta the peak ozone concentration increased by 0.2 percent due to the use of HiTEC 3000 in the speciation sensitivity test.

The effect of HiTEC 3000 on urban air quality is small and it is very doubtful that it could be observed using routinely available air quality monitors and current monitoring networks. However, the problem of not attaining the ozone standard in urban areas is the result of the cumulative effect of many sources. Any one ozone control measure is likely to produce a small reduction in ozone concentrations. It is the sum of all control measures that results in attainment of the ozone NAAQS, and the use of least-cost measures (such as HiTEC 3000) is what produces a cost-effective ozone control strategy. The use of HiTEC 3000 as a replacement octane enhancer for gasoline to aromatic hydrocarbon species appears to offer environmental benefits for all air quality indicators studied.

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1 INTRODUCTION

With the passage of the 1977 amendments to the Clean Air Act (CAA), Congress required that manufacturers of new fuels and fuel additives demonstrate that their products will not cause or contribute to the failure of emission control systems or devices to meet the emission standards for which the vehicles have been certified (42 U.S.C. 7545(F)(4)). Congress's intent in establishing a regulatory procedure for obtaining a waiver for the use of new fuels or fuel additives was not to prevent the introduction of "more efficient, less costly, and less polluting substitutes for conventional fuels." (American Methyl Corp vs. US EPA, 749 F2D 826, 839-840, D.C. CIR. 1984). Rather, Congress enacted legislation "to prevent the untested use of additives with cavalier disregard for harmful effects on emission control systems and devices." (1977 Legis. Hist. at 362). Furthermore, Congress encouraged the Environmental Protection Agency (EPA) to "give special emphasis" to the research and development of new fuels or fuel additives "which, when used , result in decreased atmospheric emissions." (1977 Legis. Hist. at 1465).

The test program developed and conducted by Ethyl Petroleum Additives, Inc. to support their waiver request for the use of the HiTEC® 3000 Performance Additive (HiTEC 3000) in unleaded gasoline is one of the most comprehensive programs ever undertaken by a single company. The emissions data available from this program were obtained through the testing of 48 vehicles, representing 53% of U.S. sales, operated over 75,000 miles. This large body of emissions data generated over a longer mileage accumulation period than ever previously evaluated by the EPA supported the use of advanced statistical methods to examine the probability that HiTEC 3000 does not cause or contribute to a failure of emission control systems to achieve compliance with applicable emission standards.

The statistical procedures used to determine the potential effects of HiTEC 3000 are documented in Appendix 2 of this waiver request. In general, the tests discussed in

Appendix 2 show that the use of HiTEC 3000 in unleaded gasoline will not cause or contribute to the failure of emission control systems or devices to meet applicable emission standards.

BACKGROUND AND PURPOSE

The EPA's previous analysis of fuel or fuel additive waiver requests has limited consideration of the air quality benefits that may occur from the "general use" of the approved product. Instead, they have relied heavily on the use of "reliable statistical sampling and fleet testing protocols" to achieve the proof required by an applicant to demonstrate that his product will not cause or contribute to failure of emission control systems and thereby adversely affect air quality (45 Federal Registrar, 1980).

Systems Applications, Inc. (SAI) was retained by Ethyl Petroleum Additives, Inc. to estimate the effects of HiTEC 3000 use on ambient air quality through the use of SAI's Urban Airshed Model (UAM-CB-IV). Since 1984, the EPA's Office of Air Quality Planning and Standards (OAQPS) has adopted the UAM as the preferred model for "photochemical pollutant modeling applications involving entire urban areas" (EPA, 1986), and has commented that the UAM "is the most widely applied and evaluated photochemical dispersion model in existence." (Seinfeld, 1988; Burton, 1988).

The estimation of the effects of HiTEC 3000 use in unleaded gasoline is of particular importance to this waiver application because it directly addresses the potential air quality improvements from the use of HiTEC 3000 on urban and/or regional reductions in ambient ozone, carbon monoxide (CO), NO_x and Mn. In addition, these analyses focus on the fundamental purpose of the Federal Motor Vehicle Control Program which is to improve and maintain air quality.

DESCRIPTION OF THE URBAN AIRSHED MODEL

The Urban Airshed Model (UAM) is a three-dimensional grid (Eulerian) model designed to calculate the concentrations of both inert and chemically reactive