MR No. E4K27

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WARTIME REPORT

ORIGINALLY ISSUED

November 1944 as
Memorandum Report E4K27

F-3 AND F-4 ENGINE TESTS OF SEVERAL HIGH-ANTIKNOCK COMPONENTS OF AVIATION FUEL

By Harry S. Imming, Henry C. Barnett
and Russell S. Genco

Aircraft Engine Research Laboratory
Cleveland, Ohio

NACA

WASHINGTON

NACA WARTIME REPORTS are reprints of papers originally issued to provide rapid distribution of advance research results to an authorized group requiring them for the war effort. They were previously held under a security status but are now unclassified. Some of these reports were not technically edited. All have been reproduced without change in order to expedite general distribution.

3 1176 01364 8473

NACA MR No. E4K27

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

MEMORANDUM REPORT

for the

Army Air Forces, Air Technical Service Command

F-3 AND F-4 ENGINE TESTS OF SEVERAL HIGH-ANTIKNOCK COMPONENTS OF AVIATION FUEL

By Harry S. Imming, Henry C. Barnett, and Russell S. Genco

SUMMARY

Knock-limited performance data for various fuels were obtained in F-3 and F-4 engines at standard operating conditions. Triptane, hot-acid octane, diisopropyl, neohexane, mixed xylenes, cumene, benzene, toluene, and methyl tert-butyl ether were investigated in 0- to 100-percent blends with virgin base stock, aviation alkylate, and one-pass catalytic stock; isopentane in 0- to 60-percent blends with virgin base stock and in 0- to 40-percent blends with aviation alkylate and one-pass catalytic stock was also investigated. All fuels and blends were leaded to 4 ml TEL per gallon.

Laboratory inspection data were obtained for all pure fuel stocks and blends.

Results of the F-3 engine study indicated that methyl tert-butyl ether, neohexane, triptane, and diisopropyl were the most satisfactory blending agents for increasing the lean-mixture knock-limited performance. Results of the F-4 engine study indicated that methyl tert-butyl ether and toluene were the most satisfactory blending agents for increasing the rich-mixture knock-limited performance.

INTRODUCTION

An investigation is being conducted at the Cleveland laboratory of the NACA in order to evaluate the advantages in knock-limited engine performance to be gained by the use of high-antiknock compounds as components of aviation fuel. As part of the program, binary blends of 10 compounds blended with each of three base fuels were tested in F-3 and F-4 rating engines. These compounds, the base fuels, and the blend concentrations are listed in the following table:

Component[1]	Percentage in base fuel		
	Virgin base stock	Aviation Alkylate	One-pass catalytic stock
Triptane (2,2,3-trimethylbutane) Hot-acid octane	0,20,40, 60,100	0,20,40,60, 80,100	0,20,40,60, 80,100
Isopentane (2-methylbutane)	0,20, 40,60	0,20,40	0,20,40
Diisopropyl (2,3-dimethylbutane) Neohexane (2,2-dimethylbutane) Mixed xylenes Cumene (isopropylbenzene) Benzene Toluene (methylbenzene) Methyl tert-butyl ether	0,20,40 60,80,100	0,20,40,60, 80,100	0,20,40,60, 80,100

[1]All blends and pure fuel stocks were leaded to 4 ml TEL/gal.

The fuel base stocks and high-performance compounds were obtained through the Army Air Forces, Air Technical Service Command.

The purpose of the present report is to summarize in the form of tables and figures the F-3 and F-4 performance data and the laboratory inspection data for all of the blends tested.

APPARATUS AND TEST PROCEDURE

The blends and blending agents were tested in F-3 and F-4 rating engines (CRC designations F-3-544 and F-4-443). The F-3 engine was provided with a barometrically controlled dry-air supply instead of the dehydrating ice tower. The F-4 engine was installed with a 106360D piston instead of a 106360G piston and was provided with a cathode-ray oscilloscope in conjunction with a magnetostriction pickup unit for detecting knock. In the F-4 engine tests, the fuel-air ratio was enriched from 0.055 to a value past that at which maximum knock-limited indicated mean effective pressure was obtained unless the limit of fuel flow was reached or the test fuel preignited.

Because of the numerous fuel blends tested, the F-4 ratings were estimated from a reference-fuel framework (fig. 1). All of the F-4 performance ratings for the fuels were estimated from the reference-fuel framework in figure 1 with the exception of the ratings for the three base fuels, which were obtained by standard F-4 procedure and are superimposed on figure 1.

TEST RESULTS

Laboratory inspection data obtained for all pure fuel stocks and for all blends are presented in table I. Table II lists the F-3 and knock-limited F-4 performance ratings for the fuels tested. Performance numbers are given for all values below 161. Performance numbers between 161 and 200 were estimated by multiplying the performance number of S-3 reference fuel plus 6 ml TEL per gallon by the ratio of the knock-limited indicated mean effective pressure of the test fuel to the knock-limited indicated mean effective pressure of S-3 reference fuel plus 6 ml TEL per gallon.

Figure 2 shows the day-to-day variation of the F-4 engine. Figures 3 to 12 present the knock-limited performance data for binary blends of the 10 high-antiknock compounds with each of the three base fuels. With the exception of the data for fuels and fuel blends shown in figures 3(a) and (b); 5(a), (b), and (c); 6(a) and (b); 9(a); and 11(a), each group of tests of an antiknock component and one base fuel were made on a single operating day.

The data presented in figure 2 allow an estimate of the reproducibility of the F-4 rating engine. For each of the three base fuels, the average indicated mean effective pressure, the arithmetical mean deviation from the average indicated mean effective pressure, and the ratio of arithmetical mean deviation to average indicated mean effective pressure (expressed as percentage) have been calculated. The results are summarized in table III. A curve (fig.13) faired through the weighted averages of the percentage mean deviations of the three base fuels shows that knock-limited performance tests in an F-4 engine are considerably less reproducible at low fuel-air ratios than at high ratios.

Testing of each of the aromatics (mixed xylenes, cumene, benzene, and toluene, data presented in figs. 8 to 11) in the F-4 engine caused severe burning of the second piston land and excessive ring wear. The following table indicates the ring wear that resulted from aromatic blending agents as compared with the wear that resulted from paraffinic blending agents:

Engine running time (hr)	Blending agent tested	Ring-gap clearance (in.)				
		Compression rings			Oil rings	
		Top	Center	Bottom	Top	Bottom
[a]0	----------	0.020	0.020	0.020	0.018	0.018
150	Paraffins	.042	.045	.078	.035	.050
70	Mixed xylenes	.100	.118	.121	.058	.066
80	Methyl tert-butyl ether and benzene	.100	.153	.189	.072	.057
54	Toluene	.125	.132	.161	.078	.074

[a]Maximum ring-gap clearances specified for F-4 rating engine.

SUMMARY OF RESULTS

Results of knock-limited performance tests of binary blends of 10 high-antiknock compounds with each of three base fuels in F-3 and F-4 rating engines are summarized as follows:

1. Tests by the F-3 rating method indicated that methyl tert-butyl ether, neohexane, triptane, and diisopropyl were the most satisfactory blending agents for increasing the lean-mixture knock-limited performance.

2. Tests by the F-4 rating method indicated that methyl tert-butyl ether and toluene were the most satisfactory blending agents for increasing the rich-mixture knock-limited performance.

3. Inspection tests indicate that all blending agents examined can be used in aviation-fuel blends without digression from present Army-Navy fuel specifications. The concentrations in which any given blending agent can be used will necessarily be determined by specific properties such as heat of combustion, freezing point, and volatility. Mixed xylenes, cumene, benzene, toluene, and methyl tert-butyl ether had low heats of combustion; triptane, mixed xylenes, and benzene had high freezing points; isopentane, neohexane, methyl tert-butyl ether, and diisopropyl had high Reid vapor pressures.

Aircraft Engine Research Laboratory,
National Advisory Committee for Aeronautics,
Cleveland, Ohio, November 27, 1944.

NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS

TABLE I - INSPECTION DATA FOR PURE

[The following abbreviations are used throughout the table: one-pass stock for one-pass catalytic stock;

Fuel	Fuel composition		A.S.T.M. distillation data								
	Components	TEL concentration (ml/gal)	Initial boiling point (°F)	10% point (°F)	40% point (°F)	50% point (°F)	90% point (°F)	Final boiling point (°F)	Sum of 10 and 50% points (°F)	Residue (percent)	Loss (percent)
A-202	VBS	0	114	145	172	180	229	298	325	0.4	1.1
A-118	50% alkylate + 50% VBS	4.04	112	150	188	200	254	336	350	0.7	1.1
A-203	Alkylate	0	113	160	215	226	272	364	386	.5	1.0
A-132	30% one-pass stock + 70% VBS	4.08	112	140	170	182	251	319	322	0.5	1.3
A-116	50% one-pass stock + 50% VBS	4.06	103	134	170	184	269	321	318	.5	1.0
A-119	80% one-pass stock + 20% VBS	4.05	116	130	171	190	285	326	320	.4	1.4
A-122	30% one-pass stock + 70% alkylate	3.96	110	147	202	218	272	345	365	0.6	1.2
A-117	50% one-pass stock + 50% alkylate	4.00	105	140	194	213	280	341	353	.5	1.0
A-121	80% one-pass stock + 20% alkylate	4.04	106	131	181	204	288	334	335	.7	1.3
A-204	One-pass stock	0	105	128	170	193	287	332	321	.5	1.0
A-136	20% triptane + 80% VBS	4.10	124	150	172	178	218	299	328	0.7	0.8
A-137	40% triptane + 60% VBS	4.05	128	156	172	177	205	287	333	.6	.6
A-138	60% triptane + 40% VBS	4.08	142	162	174	176	194	274	338	.7	.5
A-272	20% triptane + 80% alkylate	(d)	122	164	202	210	259	346	374	0.9	0.6
A-273	40% triptane + 60% alkylate	(d)	130	167	192	198	251	335	365	.7	.8
A-274	60% triptane + 40% alkylate	(d)	144	169	183	188	230	326	357	.8	.7
A-275	80% triptane 20% alkylate	(d)	158	172	178	180	202	296	352	.8	.2
A-276	20% triptane + 80% one-pass stock	(d)	107	136	172	186	281	321	322	0.4	1.4
A-277	40% triptane + 60% one-pass stock	(d)	120	147	174	183	275	320	330	.9	.9
A-278	60% triptane + 40% one-pass stock	(d)	128	156	174	179	234	316	335	.4	.6
A-279	80% triptane + 20% one-pass stock	(d)	141	166	177	179	196	304	345	.5	.5
A-206	Triptane	0	172	174	174	174	175	180	348	.4	.8
A-397	20% diisopropyl + 80% VBS	(d)	120	143	160	168	224	287	311	0.9	0.8
A-398	40% diisopropyl + 60% VBS	(d)	123	138	151	156	214	285	294	.7	1.5
A-399	60% diisopropyl + 40% VBS	(d)	128	138	146	148	197	258	286	.9	1.1
A-400	80% diisopropyl + 20% VBS	(d)	130	136	140	142	165	254	278	.7	1.0
A-405	20% diisopropyl + 80% alkylate	(d)	120	151	187	202	263	344	353	1.1	0.7
A-406	40% diisopropyl + 60% alkylate	(d)	120	140	155	162	252	330	302	1.2	.3
A-407	60% diisopropyl + 40% alkylate	(d)	127	140	150	156	246	322	296	1.1	.6
A-408	80% diisopropyl + 20% alkylate	(d)	130	136	141	143	208	295	279	1.0	.6
A-401	20% diisopropyl + 80% one-pass stock	(d)	112	132	157	172	287	322	304	0.5	1.5
A-402	40% diisopropyl + 60% one-pass stock	(d)	117	133	150	157	277	321	290	.8	.9
A-403	60% diisopropyl + 40% one-pass stock	(d)	121	133	143	147	257	315	280	.4	1.2
A-404	80% diisopropyl + 20% one-pass stock	(d)	127	134	138	140	169	305	274	.7	.7
A-433	Diisopropyl	0	132	134	135	135	135	136	269	None	1.2
A-411	20% neohexane + 80% VBS	(d)	118	138	157	165	227	289	303	0.9	0.9
A-412	40% neohexane + 60% VBS	(d)	118	133	145	151	219	285	284	.8	.9
A-413	60% neohexane + 40% VBS	(d)	113	127	135	138	201	266	265	.6	1.3
A-414	80% neohexane + 20% VBS	(d)	118	123	126	128	161	241	251	.9	1.1
A-415	20% neohexane + 80% alkylate	(d)	116	146	183	203	265	345	349	1.1	0.8
A-416	40% neohexane + 60% alkylate	(d)	117	134	157	169	257	332	303	1.2	.8
A-417	60% neohexane + 40% alkylate	(d)	116	125	136	142	247	322	267	1.1	1.1
A-418	80% neohexane + 20% alkylate	(d)	116	122	127	129	220	290	251	.9	1.4
A-420	20% neohexane + 80% one-pass stock	(d)	107	127	151	167	283	323	294	0.6	1.3
A-421	40% neohexane + 60% one-pass stock	(d)	110	125	140	148	275	318	273	.5	1.4
A-422	60% neohexane + 40% one-pass stock	(d)	112	121	130	134	259	313	255	.5	1.2
A-423	80% neohexane + 20% one-pass stock	(d)	116	120	125	126	181	302	246	.6	1.6
A-500	Neohexane	0	119	120	120	120	121	123	240	None	1.2
A-123	20% isopentane + 80% VBS	4.06	102	122	148	160	224	297	282	0.7	1.3
A-124	40% isopentane + 60% VBS	4.06	96	108	124	134	216	291	242	.7	2.8
A-134	60% isopentane + 40% VBS	4.16	90	98	106	110	200	266	208	.8	2.4
A-375	20% isopentane + 80% alkylate	(d)	104	127	175	208	262	344	335	0.9	2.0
A-376	40% isopentane + 60% alkylate	(d)	97	110	134	154	256	335	264	.7	1.4
A-388	20% isopentane + 80% one-pass stock	(d)	102	118	146	167	288	322	285	0.4	2.4
A-389	40% isopentane + 60% one-pass stock	(d)	96	106	121	129	278	318	235	.6	2.1
A-209	Isopentane	0	80	82	85	86	90	92	168	None	3.5

[a]Estimated by change in refractive index following adsorption on silica gel. Correction made for olefins.
[b]Calculated by using average molecular weight from distillation curve (Universal Oil Products Method H-173-40).

FUEL STOCKS AND FOR FUEL BLENDS

VBS for virgin base stock; alkylate for aviation alkylate; and MTB ether for methyl tert-butyl ether.]

Fuel	Specific gravity at 60° F	Copper-dish gum (mg/100 ml)	Reid vapor pressure (lb/sq in.)	Aromatics[a] (percent by volume)	Freezing point (°F)	Hydrogen-carbon ratio	Net heat of combustion (Btu/lb)	Refractive index n_D at 68° F	Bromine number (cg/g)	Olefins[b] (percent by weight)
A-202	0.713	None	5.9	7.3	Below -76	0.175	19,000	1.3988	2.8	1.7
A-118	0.707	-------	5.9	----------	---------	---------	--------	1.3957	-------	----------
A-203	.698	2	4.7	None	Below -76	0.189	19,100	1.3928	0.2	0.1
A-132	0.723	-------	6.0	----------	---------	---------	--------	1.4043	-------	----------
A-116	.727	-------	7.1	----------	---------	---------	--------	1.4080	-------	----------
A-119	.735	-------	7.4	----------	---------	---------	--------	1.4141	-------	----------
A-122	0.718	-------	5.8	----------	---------	---------	--------	1.4005	-------	----------
A-117	.721	-------	6.5	----------	---------	---------	--------	1.4051	-------	----------
A-121	.732	-------	7.2	----------	---------	---------	--------	1.4123	-------	----------
A-204	.739	-------	7.9	24.8	Below -76	0.155	18,700	1.4177	30.4	17.6
A-136	0.712	-------	6.0	----------	Below -76	---------	--------	1.3969	-------	----------
A-137	.707	-------	5.3	----------	Below -76	---------	--------	1.3953	-------	----------
A-138	.704	-------	4.5	----------	[c]Below -76	---------	--------	1.3938	-------	----------
A-272	0.701	-------	4.4	----------	Below -76	---------	--------	----------	-------	----------
A-273	.701	-------	4.1	----------	Below -76	---------	--------	----------	-------	----------
A-274	.700	-------	4.0	----------	Below -76	---------	--------	----------	-------	----------
A-275	.699	-------	3.6	----------	Below -76	---------	--------	----------	-------	----------
A-276	0.734	-------	6.7	----------	Below -76	---------	--------	----------	-------	----------
A-277	.725	-------	5.9	----------	Below -76	---------	--------	----------	-------	----------
A-278	.716	-------	5.1	----------	Below -76	---------	--------	----------	-------	----------
A-279	.710	-------	4.2	----------	Below -76	---------	--------	----------	-------	----------
A-206	.694	1	3.0	----------	-18	0.191	19,200	1.3896	-------	----------
A-397	0.705	-------	6.6	----------	---------	---------	--------	----------	-------	----------
A-398	.695	-------	5.8	----------	---------	---------	--------	----------	-------	----------
A-399	.686	-------	5.8	----------	---------	---------	--------	----------	-------	----------
A-400	.677	-------	7.0	----------	---------	---------	--------	----------	-------	----------
A-405	0.695	-------	5.5	----------	---------	---------	--------	----------	-------	----------
A-406	.687	-------	6.3	----------	---------	---------	--------	----------	-------	----------
A-407	.681	-------	6.4	----------	---------	---------	--------	----------	-------	----------
A-408	.675	-------	6.8	----------	---------	---------	--------	----------	-------	----------
A-401	0.728	-------	6.9	----------	---------	---------	--------	----------	-------	----------
A-402	.713	-------	7.1	----------	---------	---------	--------	----------	-------	----------
A-403	.698	-------	7.2	----------	---------	---------	--------	----------	-------	----------
A-404	.683	-------	7.3	----------	---------	---------	--------	----------	-------	----------
A-433	.666	None	7.4	----------	Below -76	0.196	19,100	----------	-------	----------
A-411	0.705	-------	7.0	----------	---------	---------	--------	----------	-------	----------
A-412	.694	-------	7.5	----------	---------	---------	--------	----------	-------	----------
A-413	.683	-------	8.1	----------	---------	---------	--------	----------	-------	----------
A-414	.672	-------	9.1	----------	---------	---------	--------	----------	-------	----------
A-415	0.693	-------	5.9	----------	---------	---------	--------	----------	-------	----------
A-416	.686	-------	6.0	----------	---------	---------	--------	----------	-------	----------
A-417	.677	-------	7.9	----------	---------	---------	--------	----------	-------	----------
A-418	.670	-------	9.8	----------	---------	---------	--------	----------	-------	----------
A-420	0.728	-------	7.9	----------	---------	---------	--------	----------	-------	----------
A-421	.712	-------	8.3	----------	---------	---------	--------	----------	-------	----------
A-422	.696	-------	8.5	----------	---------	---------	--------	----------	-------	----------
A-423	.678	-------	9.1	----------	---------	---------	--------	----------	-------	----------
A-500	.658	1	9.7	----------	---------	0.197	19,100	----------	-------	----------
A-123	0.702	-------	9.3	----------	---------	---------	--------	1.3907	-------	----------
A-124	.679	-------	11.8	----------	---------	---------	--------	1.3822	-------	----------
A-134	.664	-------	14.4	----------	---------	---------	--------	1.3732	-------	----------
A-375	0.687	-------	8.4	----------	---------	---------	--------	----------	-------	----------
A-376	.673	-------	11.6	----------	---------	---------	--------	----------	-------	----------
A-388	0.720	-------	9.9	----------	---------	---------	--------	----------	-------	----------
A-389	.699	-------	12.5	----------	---------	---------	--------	----------	-------	----------
A-209	.824	None	19.6	----------	Below -76	0.202	19,100	1.3544	-------	----------

[c]Cloudy.
[d]Approximately 8 ml TEL/gal.

NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS

NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS

TABLE I - INSPECTION DATA FOR PURE FUEL

Fuel	Fuel composition		A.S.T.M. distillation data								
	Components	TEL concentration (ml/gal)	Initial boiling point (°F)	10% point (°F)	40% point (°F)	50% point (°F)	90% point (°F)	Final boiling point (°F)	Sum of 10 and 50% points (°F)	Residue (percent)	Loss (percent)
A-139	20% hot-acid octane + 80% VBS	4.10	118	154	184	193	232	298	347	0.5	1.0
A-140	40% hot-acid octane + 60% VBS	4.04	123	166	198	206	234	290	372	.6	1.2
A-141	60% hot-acid octane + 40% VBS	4.02	122	176	209	216	234	272	392	.7	.5
A-367	20% hot-acid octane + 80% alkylate	(d)	112	169	218	225	259	341	394	1.2	0.6
A-368	40% hot-acid octane + 60% alkylate	(d)	124	184	223	227	253	342	411	.8	1.2
A-369	60% hot-acid octane + 40% alkylate	(d)	132	193	224	226	243	315	419	.8	1.5
A-370	80% hot-acid octane + 20% alkylate	(d)	144	208	224	225	239	279	433	.8	1.4
A-371	20% hot-acid octane + 80% one-pass stock	(d)	114	142	189	208	282	322	350	0.4	1.4
A-372	40% hot-acid octane + 60% one-pass stock	(d)	124	155	206	218	269	321	373	.6	1.4
A-373	60% hot-acid octane + 40% one-pass stock	(d)	115	165	215	222	250	310	387	.8	1.1
A-374	80% hot-acid octane + 20% one-pass stock	(d)	129	195	222	224	240	294	419	.7	.5
A-205	Hot-acid octane	0	174	216	224	224	230	257	440	.6	.9
A-148	20% mixed xylenes + 80% VBS	4.07	116	152	191	203	272	296	355	0.4	0.6
A-444	40% mixed xylenes + 60% VBS	(d)	122	167	215	232	277	288	399	.3	.5
A-445	60% mixed xylenes + 40% VBS	(d)	128	196	252	264	277	287	460	.3	.4
A-446	80% mixed xylenes + 20% VBS	(d)	140	220	266	270	278	283	490	.4	.6
A-149	20% mixed xylenes + 80% alkylate	3.96	121	176	234	242	276	342	418	0.8	0.7
A-262	40% mixed xylenes + 60% alkylate	(d)	124	191	249	255	281	320	446	.5	1.3
A-263	60% mixed xylenes + 40% alkylate	(d)	130	217	262	266	280	306	483	.5	.5
A-264	80% mixed xylenes + 20% alkylate	(d)	136	238	268	271	279	295	509	.8	.8
A-150	20% mixed xylenes + 80% one-pass stock	4.10	106	146	200	230	285	315	376	0.3	0.9
A-266	40% mixed xylenes + 60% one-pass stock	(d)	115	159	244	262	284	311	421	.8	.8
A-267	60% mixed xylenes + 40% one-pass stock	(d)	115	154	251	264	282	303	418	.1	1.1
A-268	80% mixed xylenes + 20% one-pass stock	(d)	126	222	273	275	280	294	497	.2	.8
A-237	Mixed xylenes	0	273	275	276	276	277	278	551	.2	None
A-163	20% cumene + 80% VBS	4.12	116	152	188	202	294	321	354	0.5	0.7
A-244	40% cumene + 60% VBS	(d)	123	161	218	238	300	330	399	.4	.9
A-246	60% cumene + 40% VBS	(d)	126	180	265	284	302	335	464	.6	.6
A-247	80% cumene + 20% VBS	(d)	130	228	296	298	306	339	526	.5	.5
A-164	20% cumene + 80% alkylate	3.99	116	170	234	244	300	342	414	0.7	0.5
A-249	40% cumene + 60% alkylate	(d)	118	188	257	267	302	340	455	.4	.8
A-250	60% cumene + 40% alkylate	(d)	124	206	271	280	304	339	486	.5	.5
A-251	80% cumene + 20% alkylate	(d)	140	262	293	296	304	342	558	.5	.5
A-165	20% cumene + 80% one-pass stock	3.91	106	136	203	234	299	325	370	0.6-	0.4
A-253	40% cumene + 60% one-pass stock	(d)	110	144	240	268	301	330	412	1.0	1.0
A-254	60% cumene + 40% one-pass stock	(d)	120	174	285	289	303	336	463	.4	1.1
A-255	80% cumene + 20% one-pass stock	(d)	125	216	292	295	303	340	511	1.0	1.0
A-238	Cumene[c]	0	293	298	300	300	305	349	598	.5	.5
A-170	20% benzene + 80% VBS	4.11	118	148	167	174	218	299	322	0.5	0.5
A-342	40% benzene + 60% VBS	(d)	126	154	168	173	204	286	327	.5	1.0
A-343	60% benzene + 40% VBS	(d)	144	164	171	174	185	266	338	.4	1.1
A-344	80% benzene + 20% VBS	(d)	148	168	172	174	179	238	342	.4	.6
A-168	20% benzene + 80% alkylate	3.92	120	156	190	200	258	345	356	0.7	0.3
A-359	40% benzene + 60% alkylate	(d)	126	162	180	186	245	333	348	.8	1.2
A-360	60% benzene + 40% alkylate	(d)	143	166	177	179	219	324	345	.6	.9
A-361	80% benzene + 20% alkylate	(d)	154	170	175	176	185	293	346	.6	.6
A-169	20% benzene + 80% one-pass stock	4.08	107	134	170	182	282	321	316	0.3	0.9
A-363	40% benzene + 60% one-pass stock	(d)	117	147	171	179	273	318	326	.5	1.0
A-364	60% benzene + 40% one-pass stock	(d)	122	153	173	177	227	314	330	.4	1.1
A-365	80% benzene + 20% one-pass stock	(d)	143	164	173	175	191	316	339	.4	.8
A-210	Benzene	0	170	173	173	173	174	175	346	.2	.8

[a]Estimated by change in refractive index following adsorption on silica gel. Correction made for olefins.

[b]Calculated by using average molecular weight from distillation curve (Universal Oil Products Method H-173-40).

[c]Cloudy.

STOCKS AND FOR FUEL BLENDS - Continued

Fuel	Specific gravity at 60° F	Copper-dish gum (mg/100 ml)	Reid vapor pressure (lb/sq in.)	Aromatics[a] (percent by volume)	Freezing point (°F)	Hydrogen-carbon ratio	Net heat of combustion (Btu/lb)	Refractive index n_D at 68° F	Bromine number (cg/g)	Olefins[b] (percent by weight)
A-139	0.715	5	5.8	----------	----------	----------	--------	1.3992	-------	----------
A-140	.716	6	5.0	----------	----------	----------	--------	1.3997	-------	----------
A-141	.715	6	4.3	----------	----------	----------	--------	1.4002	-------	----------
A-367	0.703	-------	4.4	----------	----------	----------	--------	----------	-------	----------
A-368	.707	-------	3.8	----------	----------	----------	--------	----------	-------	----------
A-369	.710	-------	3.1	----------	----------	----------	--------	----------	-------	----------
A-370	.714	-------	2.9	----------	----------	----------	--------	----------	-------	----------
A-371	0.737	-------	6.5	----------	----------	----------	--------	----------	-------	----------
A-372	.732	-------	5.5	----------	----------	----------	--------	----------	-------	----------
A-373	.727	-------	4.5	----------	----------	----------	--------	----------	-------	----------
A-374	.722	-------	3.6	----------	----------	----------	--------	----------	-------	----------
A-205	.715	6	2.7	None	Below -76	0.188	19,200	1.4009	2.6	1.7
A-148	0.746	-------	5.3	26.4	Below -76	----------	--------	1.4180	-------	----------
A-444	.775	-------	4.2	----------	----------	----------	--------	----------	-------	----------
A-445	.805	-------	3.0	----------	----------	----------	--------	----------	-------	----------
A-446	.824	-------	2.2	----------	----------	----------	--------	----------	-------	----------
A-149	0.731	1	3.9	20.5	Below -76	----------	--------	1.4132	-------	----------
A-262	.768	-------	3.0	----------	----------	----------	--------	----------	-------	----------
A-263	.799	-------	2.2	----------	----------	----------	--------	----------	-------	----------
A-264	.821	-------	1.9	----------	----------	----------	--------	----------	-------	----------
A-150	0.767	-------	6.5	42.3	Below -76	----------	--------	1.4333	-------	----------
A-266	.793	-------	5.2	----------	----------	----------	--------	----------	-------	----------
A-267	.800	-------	4.4	----------	----------	----------	--------	----------	-------	----------
A-268	.838	-------	2.4	----------	----------	----------	--------	----------	-------	----------
A-237	.867	2	.5	----------	-40	0.106	17,600	1.4959	-------	----------
A-163	0.737	-------	5.3	25.6	Below -76	----------	--------	1.4169	-------	----------
A-244	.775	-------	4.4	43.0	Below -76	----------	--------	1.4353	-------	----------
A-246	.804	-------	3.2	62.0	[c]Below -76	----------	--------	1.4538	-------	----------
A-247	.832	-------	2.0	----------	[c]Below -76	----------	--------	----------	-------	----------
A-164	0.732	3	4.0	19.7	Below -76	----------	--------	1.4122	-------	----------
A-249	.767	-------	3.2	39.0	Below -76	----------	--------	1.4320	-------	----------
A-250	.787	-------	2.6	----------	Below -76	----------	--------	----------	-------	----------
A-251	.831	-------	1.4	----------	Below -76	----------	--------	----------	-------	----------
A-165	0.769	-------	6.4	40.0	Below -76	----------	--------	1.4325	-------	----------
A-253	.787	-------	5.3	----------	[c]Below -76	----------	--------	----------	-------	----------
A-254	.815	-------	3.8	----------	Below -76	----------	--------	----------	-------	----------
A-255	.836	-------	2.4	----------	Below -76	----------	--------	----------	-------	----------
A-238	.863	3	.3	----------	[e]Below -76	0.113	17,800	1.4903	-------	----------
A-170	0.748	-------	6.0	26.0	-38	----------	--------	1.4175	-------	----------
A-342	.772	-------	5.6	----------	----------	----------	--------	----------	-------	----------
A-343	.823	-------	4.6	----------	----------	----------	--------	----------	-------	----------
A-344	.844	-------	4.2	----------	----------	----------	--------	----------	-------	----------
A-168	0.734	4	4.8	19.5	-24	----------	--------	1.4124	-------	----------
A-359	.770	-------	4.7	----------	----------	----------	--------	----------	-------	----------
A-360	.803	-------	4.4	----------	----------	----------	--------	----------	-------	----------
A-361	.841	-------	3.7	----------	----------	----------	--------	----------	-------	----------
A-169	0.768	-------	7.0	40.0	-53	----------	--------	1.4333	-------	----------
A-363	.822	-------	6.0	----------	----------	----------	--------	----------	-------	----------
A-364	.841	-------	5.2	----------	----------	----------	--------	----------	-------	----------
A-365	.850	-------	4.4	----------	----------	----------	--------	----------	-------	----------
A-210	.883	1	3.5	----------	45	0.084	17,400	1.4989	-------	----------

[d]Approximately 4 ml TEL/gal.

[e]At 14° F a small quantity of an impurity, probably water, separated and formed a cloud. When sample was dried over sodium, no cloud formation was observed to -76° F.

NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS

TABLE I - INSPECTION DATA FOR PURE FUEL

Fuel	Fuel composition		A.S.T.M. distillation data								
	Components	TEL concentration (ml/gal)	Initial boiling point (°F)	10% point (°F)	40% point (°F)	50% point (°F)	90% point (°F)	Final boiling point (°F)	Sum of 10 and 50% points (°F)	Residue (percent)	Loss (percent)
A-145	20% toluene + 80% VBS	4.10	122	157	186	194	230	294	351	0.6	0.9
A-322	40% toluene + 60% VBS	(d)	126	163	193	201	231	282	364	.4	.6
A-323	60% toluene + 40% VBS	(d)	135	179	208	215	230	256	394	.5	1.0
A-324	80% toluene + 20% VBS	(d)	148	203	222	224	230	252	427	.1	.9
A-146	20% toluene + 80% alkylate	3.96	118	172	216	223	254	349	395	1.0	0.5
A-326	40% toluene + 60% alkylate	(d)	119	185	221	224	241	334	409	.8	.7
A-327	60% toluene + 40% alkylate	(d)	131	203	223	225	233	311	428	1.1	.1
A-328	80% toluene + 20% alkylate	(d)	155	216	226	227	231	263	443	1.1	.1
A-147	20% toluene + 80% one-pass stock	4.05	106	140	192	213	274	320	353	0.6	0.9
A-332	40% toluene + 60% one-pass stock	(d)	119	158	212	224	259	322	382	.3	1.2
A-333	60% toluene + 40% one-pass stock	(d)	119	180	223	228	246	313	408	.5	.7
A-334	80% toluene + 20% one-pass stock	(d)	138	209	226	228	244	286	437	.3	.5
A-232	Toluene	0	224	226	226	226	227	228	452	None	.8
A-171	20% MTB ether + 80% VBS	3.99	117	138	157	165	222	294	303	0.6	1.2
A-337	40% MTB ether + 60% VBS	(d)	120	135	147	152	194	282	287	.8	1.0
A-338	60% MTB ether + 40% VBS	(d)	119	130	138	142	190	263	272	.7	.8
A-339	80% MTB ether + 20% VBS	(d)	124	130	134	136	153	242	266	.7	1.1
A-172	20% MTB ether + 80% alkylate	4.02	114	144	181	200	262	346	344	0.8	1.2
A-348	40% MTB ether + 60% alkylate	(d)	116	134	155	167	251	333	301	1.0	1.0
A-349	60% MTB ether + 40% alkylate	(d)	120	132	142	147	240	316	279	1.1	.9
A-350	80% MTB ether + 20% alkylate	(d)	124	130	135	137	191	304	267	.6	.9
A-173	20% MTB ether + 80% one-pass stock	4.04	108	127	152	165	278	321	292	0.4	1.4
A-352	40% MTB ether + 60% one-pass stock	(d)	110	126	143	150	273	318	276	.5	1.5
A-353	60% MTB ether + 40% one-pass stock	(d)	114	127	136	140	252	315	267	.6	1.4
A-354	80% MTB ether + 20% one-pass stock	(d)	121	128	133	134	170	301	262	.5	1.0
A-236	MTB ether	0	125	128	129	129	130	133	257	None	1.0

[a]Estimated by change in refractive index following adsorption on silica gel. Correction made for olefins.

[b]Calculated by using average molecular weight from distillation curve (Universal Oil Products Method H-173-40).

NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS

STOCKS AND FOR FUEL BLENDS - Concluded

Fuel	Specific gravity at 60° F	Copper-dish gum (mg/100 ml)	Reid vapor pressure (lb/sq in.)	Aromatics[a] (percent by volume)	Freezing point (°F)	Hydrogen-carbon ratio	Net heat of combustion (Btu/lb)	Refractive index n_D at 68° F	Bromine number (cg/g)	Olefins[b] (percent by weight)
A-145	0.746	-------	5.3	26.2	Below -76	---------	--------	1.4178	-------	----------
A-322	.760	-------	5.1	----------	---------	---------	--------	----------	-------	----------
A-323	.792	-------	4.0	----------	---------	---------	--------	----------	-------	----------
A-324	.823	-------	2.6	----------	---------	---------	--------	----------	-------	----------
A-146	0.733	-------	4.0	19.8	Below -76	---------	--------	1.4126	-------	----------
A-326	.766	-------	3.3	----------	---------	---------	--------	----------	-------	----------
A-327	.800	-------	2.6	----------	---------	---------	--------	----------	-------	----------
A-328	.832	-------	2.0	----------	---------	---------	--------	----------	-------	----------
A-147	0.766	-------	6.6	44.0	Below -76	---------	--------	1.4333	-------	----------
A-332	.793	-------	5.1	----------	---------	---------	--------	----------	-------	----------
A-333	.817	-------	3.9	----------	---------	---------	--------	----------	-------	----------
A-334	.848	-------	2.3	----------	---------	---------	--------	----------	-------	----------
A-232	.871	1	1.1	----------	Below -76	0.096	17,500	1.4962	-------	----------
A-171	0.721	-------	5.8	----------	Below -76	---------	--------	1.3924	-------	----------
A-337	.725	-------	7.1	----------	---------	---------	--------	----------	-------	----------
A-338	.731	-------	7.3	----------	---------	---------	--------	----------	-------	----------
A-339	.738	-------	7.3	----------	---------	---------	--------	----------	-------	----------
A-172	0.709	-------	5.7	----------	Below -76	---------	--------	1.3876	-------	----------
A-348	.717	-------	6.5	----------	---------	---------	--------	----------	-------	----------
A-349	.726	-------	6.8	----------	---------	---------	--------	----------	-------	----------
A-350	.736	-------	7.2	----------	---------	---------	--------	----------	-------	----------
A-173	0.742	-------	7.6	----------	Below -76	---------	--------	1.4090	-------	----------
A-352	.744	-------	7.6	----------	---------	---------	--------	----------	-------	----------
A-353	.744	-------	7.6	----------	---------	---------	--------	----------	-------	----------
A-354	.745	-------	7.4	----------	---------	---------	--------	----------	-------	----------
A-236	.747	None	8.8	----------	Below -76	0.201	15,200	1.3697	-------	----------

[d]Approximately 4 ml TEL/gal.

NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS

TABLE II - PERFORMANCE RATINGS OBTAINED IN F-3 AND F-4 ENGINES

[For each fuel there are three rows of values: The first row is imep, lb/sq in.; the second row for F-3 ratings is octane number or tetraethyl lead in S-3 reference fuel, ml/gal; the second row for F-4 ratings is percentage S-3 reference fuel in M-4 reference fuel or tetraethyl lead in S-3 reference fuel, ml/gal; the third row is performance number. The following abbreviations are used throughout the table: VBS for virgin base stock; alkylate for aviation alkylate; one-pass stock for one-pass catalytic stock; and MTB ether for methyl tert-butyl ether.]

Fuel	Fuel composition[a] (by volume)	F-3 ratings	F-4 ratings					
			Fuel-air ratio					
			0.065	0.070	0.085	0.095	0.100	0.110
A-355	VBS	-------	73	83	122	137	141	143
		90.7	96.6	99.8	0.08	99.8	99.0	97.8
		75	91	99	103	99	97	94
A-118	50% alkylate + 50% VBS	-------	86	99	143	159	162	165
		98.8	0.10	0.19	0.34	0.33	0.29	0.24
		96	104	107	111	111	110	109
A-356	Alkylate	-------	104	129	176	190	195	201
		0.64	0.55	0.93	1.57	1.71	1.87	2.14
		119	117	124	134	135	137	140
A-132	30% one-pass stock + 70% VBS	-------	72	71	116	130	136	145
		90.6	93.8	90.0	100	98.0	97.5	97.7
		75	84	78	100	94	94	94
A-116	50% one-pass stock + 50% VBS	-------	64	76	116	137	145	156
		90.9	88.6	93.1	100	0.01	0.01	0.06
		76	76	84	100	101	101	103
A-119	80% one-pass stock + 20% VBS	-------	67	76	114	142	154	165
		92.7	90.6	93.1	99.2	0.09	0.16	0.24
		79	78	84	97	104	106	109
A-122	30% one-pass stock + 70% alkylate	-------	82	103	152	172	178	182
		0.15	100	0.26	0.45	0.58	0.75	0.83
		106	100	110	114	117	121	123
A-117	50% one-pass stock + 50% alkylate	-------	76	91	143	167	176	186
		100	96.3	0.06	0.34	0.44	0.58	1.17
		100	91	103	111	114	117	129
A-121	80% one-pass stock + 20% alkylate	-------	72	79	123	149	160	177
		96.3	93.8	95	0.09	0.19	0.26	0.48
		88	84	96	104	107	110	115
A-410	One-pass stock	-------	73	83	125	151	164	179
		93.4	96.6	99.8	0.12	0.16	0.28	0.49
		81	91	99	105	106	110	115
A-136	20% triptane + 80% VBS	-------	74	90	134	155	162	167
		94.2	95.0	0.05	0.23	0.27	0.27	0.28
		83	88	102	108	110	110	110
A-137	40% triptane + 60% VBS	-------	100	119	164	191	201	205
		0.18	0.43	0.55	0.96	1.75	2.07	2.07
		107	114	117	125	136	139	139
A-138	60% triptane + 40% VBS	-------	117	142	224	260	264	269
		0.67	1.20	1.58	5.54	-------	-------	-------
		120	129	134	160	175	175	175
A-272	20% triptane + 80% alkylate	-------	90	126	185	213	225	237
		1.08	0.19	0.88	2.13	3.17	3.79	4.57
		127	106	123	140	148	152	156
A-273	40% triptane + 60% alkylate	-------	98	126	225	262	274	283
		2.43	0.38	0.88	5.69	-------	-------	-------
		142	113	123	160	177	182	184
A-274	60% triptane + 40% alkylate	-------	111	159	275	316	326	334
		2.70	0.90	2.76	-------	-------	-------	-------
		145	124	145	195	213	216	218
A-275	80% triptane + 20% alkylate	-------	139	190	314	-------	-------	-------
		3.06	2.59	5.90	-------	-------	-------	-------
		147	144	161	-------	-------	-------	-------

[a]Each fuel contains approximately 4 ml TEL/gal.

NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS

TABLE II - PERFORMANCE RATINGS OBTAINED IN F-3 AND F-4 ENGINES - Continued

Fuel	Fuel composition[a] (by volume)	F-3 ratings	F-4 ratings					
			Fuel-air ratio					
			0.065	0.070	0.085	0.095	0.100	0.110
A-276	20% triptane + 80% one-pass stock[b]	------- 98.8 96	66 90.0 77	72 90.7 78	117 0.01 101	146 0.14 105	160 0.26 110	186 1.17 135
A-277	40% triptane + 60% one-pass stock[b]	------- 0.08 103	81 99.4 99	89 0.05 101	139 0.29 111	176 0.88 124	195 1.77 136	231 3.86 152
A-278	60% triptane + 40% one-pass stock[b]	------- 0.48 115	100 0.43 114	109 0.36 113	171 1.36 131	218 3.52 150	244 ------ 162	291 ------ 190
A-279	80% triptane + 20% one-pass stock[b]	------- 1.80 136	126 1.63 134	147 1.82 137	290 ------ ------	361 ------ ------	391 ------ ------	------ ------ ------
A-271	Triptane[b]	------- 3.30 149	204 ------ 191	262 ------ ------	[c]393 ------ ------	------ ------ ------	------ ------ ------	------ ------ ------
A-397	20% diisopropyl + 80% VBS	------- 96.6 90	77 96.9 91	91 0.08 103	132 0.20 108	149 0.19 107	154 0.16 106	165 0.04 101
A-398	40% diisopropyl + 60% VBS	------- 0.09 103	81 99.4 98	96 0.16 106	143 0.34 112	167 0.44 114	175 0.50 116	180 0.67 120
A-399	60% diisopropyl + 40% VBS	------- 0.33 111	96 0.33 111	108 0.34 112	163 0.90 124	187 1.55 134	197 1.86 137	207 2.21 141
A-400	80% diisopropyl + 20% VBS	------- 1.17 128	111 1.10 127	141 1.56 134	202 3.23 148	226 4.14 153	236 5.07 158	250 ------ 163
A-405	20% diisopropyl + 80% alkylate	------- 0.90 124	125 1.78 136	146 1.78 136	192 2.58 144	210 2.97 146	217 3.21 146	222 3.24 148
A-406	40% diisopropyl + 60% alkylate	------- 1.45 132	138 2.47 143	158 2.67 144	206 3.49 150	227 4.29 154	234 4.80 156	240 5.00 157
A-407	60% diisopropyl + 40% alkylate	------- 1.40 132	132 1.91 138	154 2.29 141	212 3.87 152	240 ------ 162	252 ------ 167	263 ------ 171
A-408	80% diisopropyl + 20% alkylate	------- 2.10 139	136 2.24 141	162 3.05 147	226 5.85 161	261 ------ 176	275 ------ 182	292 ------ 190
A-401	20% diisopropyl + 80% one-pass stock	------- 96.1 88	79 98.1 95	89 0.05 102	132 0.20 108	163 0.39 113	177 0.67 120	195 1.60 134
A-402	40% diisopropyl + 60% one-pass stock	------- 0.06 102	84 0.05 102	99 0.20 108	150 0.43 114	177 0.95 125	189 1.48 133	209 2.34 142
A-403	60% diisopropyl + 40% one-pass stock	------- 0.24 108	96 0.33 111	114 0.44 114	165 1.02 126	196 2.00 138	210 2.72 145	235 4.29 154
A-404	80% diisopropyl + 20% one-pass stock	------- 0.68 120	120 1.34 131	143 1.65 135	197 2.90 146	229 4.57 155	245 ------ 162	272 ------ 177
A-393	Diisopropyl[d]	------- 2.41 142	147 3.33 150	173 4.11 153	246 ------ 175	289 ------ 195	304 ------ ------	324 ------ ------

[a]Each fuel contains approximately 4 ml TEL/gal.
[b]Knock-limited performance of the engine with one-pass catalytic stock was low on the day these fuels were tested.
[c]Estimated value.
[d]Values for knock-limited imep were averaged from three curves.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TABLE II - PERFORMANCE RATINGS OBTAINED IN F-3 AND F-4 ENGINES - Continued

Fuel	Fuel composition[a] (by volume)	F-3 ratings	F-4 ratings					
			Fuel-air ratio					
			0.065	0.070	0.085	0.095	0.100	0.110
A-411	20% neohexane + 80% VBS	------- 94.5 84	74 95.0 88	86 100 100	124 0.10 104	142 0.09 103	147 0.05 102	150 99.2 96
A-412	40% neohexane + 60% VBS	------- 0.05 102	81 99.4 98	97 0.17 106	138 0.28 110	138 0.31 111	164 0.32 111	167 0.28 110
A-413	60% neohexane + 40% VBS	------- 0.36 112	93 0.26 110	108 0.34 112	159 0.67 120	178 1.03 126	183 1.17 128	187 1.25 130
A-414	80% neohexane + 20% VBS	------- 2.00 138	108 0.75 121	130 1.06 127	182 1.95 138	203 2.48 143	208 2.57 143	210 2.41 142
A-415	20% neohexane + 80% alkylate	------- 1.10 127	112 0.95 125	130 1.06 127	172 1.41 132	193 1.85 137	199 1.95 138	202 1.91 138
A-416	40% neohexane + 60% alkylate	------- 1.50 133	118 1.25 130	137 1.38 131	186 2.19 140	203 2.48 143	207 2.50 143	209 2.35 142
A-417	60% neohexane + 40% alkylate	------- 2.57 143	124 1.53 133	146 1.78 136	195 2.78 145	212 3.10 147	215 3.07 147	216 2.83 145
A-418	80% neohexane + 20% alkylate	------- 3.36 149	137 2.35 142	158 2.67 144	208 3.61 151	224 3.93 152	227 3.93 152	226 3.52 150
A-420	20% neohexane + 80% one-pass stock	------- 96.6 90	79 98.1 95	95 0.14 105	146 0.38 113	171 0.50 116	180 0.92 124	190 1.38 131
A-421	40% neohexane + 60% one-pass stock	------- 0.10 104	86 0.10 104	107 0.33 111	165 1.02 126	190 1.70 135	197 1.86 137	203 1.96 138
A-422	60% neohexane + 40% one-pass stock	------- 0.33 111	108 0.75 121	138 1.43 132	192 2.58 143	210 2.97 146	215 3.07 147	217 2.90 146
A-423	80% neohexane + 20% one-pass stock	------- 1.66 135	132 1.91 138	162 3.05 147	214 4.00 153	230 4.72 156	233 4.67 156	234 4.14 153
A-394	Neohexane[e]	------- 6.00 161	159 4.76 156	187 5.58 160	230 ------ 163	240 ------ 162	242 5.87 161	243 5.43 159
A-123	20% isopentane + 80% VBS	------- 94.4 83	72 93.8 84	87 0.02 101	127 0.14 106	141 0.07 103	146 0.03 101	149 98.9 99
A-124	40% isopentane + 60% VBS	------- 99.1 97	80 98.8 96	99 0.20 108	139 0.29 110	151 0.21 108	155 0.18 107	159 0.12 105
A-134	60% isopentane + 40% VBS	------- 0.23 108	87 0.12 105	112 0.41 114	153 0.46 114	168 0.46 114	172 0.45 114	174 0.42 113
A-375	20% isopentane + 80% alkylate	------- 0.92 124	121 1.39 131	144 1.69 135	186 2.19 140	201 2.34 142	204 2.29 141	204 2.00 138
A-376	40% isopentane + 60% alkylate	------- 0.99 125	121 1.39 131	144 1.69 135	191 2.52 143	203 2.48 143	205 2.36 142	204 2.00 138
A-388	20% isopentane + 80% one-pass stock	------- 95.8 87	78 97.5 94	87 0.02 101	132 0.20 108	160 0.34 111	173 0.47 115	188 1.29 130
A-389	40% isopentane + 60% one-pass stock	------- 100 100	85 0.07 103	97 0.17 107	140 0.30 111	168 0.46 115	180 0.92 124	192 1.47 133

[a]Each fuel contains approximately 4 ml TEL/gal.
[e]Values for knock-limited imep were averaged from two curves.

NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS

TABLE II - PERFORMANCE RATINGS OBTAINED IN F-3 AND F-4 ENGINES - Continued

Fuel	Fuel composition[a] (by volume)	F-3 ratings	F-4 ratings					
			Fuel-air ratio					
			0.065	0.070	0.085	0.095	0.100	0.110
A-139	20% hot-acid octane + 80% VBS	------- 94.3 83	70 92.5 83	83 98.0 94	128 0.15 106	147 0.16 106	151 0.11 105	154 0.02 101
A-140	40% hot-acid octane + 60% VBS	------- 100 100	74 95.0 94	89 0.03 101	143 0.34 111	168 0.46 114	173 0.47 115	179 0.58 117
A-141	60% hot-acid octane + 40% VBS	------- 0.18 107	84 0.05 102	106 0.31 111	165 1.02 126	191 1.75 136	198 1.91 138	207 2.21 140
A-367	20% hot-acid octane + 80% alkylate	------- 0.82 123	121 1.39 131	142 1.60 134	188 2.32 141	205 2.62 144	210 2.72 145	215 2.76 145
A-368	40% hot-acid octane +60% alkylate	------- 0.72 121	125 1.58 134	148 1.87 137	200 3.10 147	219 3.59 150	226 3.86 152	235 4.29 154
A-369	60% hot-acid octane + 40% alkylate	------- 0.88 124	129 1.77 136	154 2.29 141	216 4.31 154	240 ------ 162	248 ------ 164	257 ------ 168
A-370	80% hot-acid octane + 20% alkylate	------- 0.72 121	129 1.77 136	154 2.29 141	238 ------ 169	269 ------ 182	276 ------ 183	280 ------ 182
A-371	20% hot-acid octane + 80% one-pass stock	------- 95.1 86	80 98.8 95	90 0.06 102	138 0.28 110	170 0.49 115	185 1.30 130	206 2.14 140
A-372	40% hot-acid octane + 60% one-pass stock	------- 100 100	88 0.14 105	97 0.17 107	154 0.48 115	192 1.80 136	208 2.57 143	229 3.73 151
A-373	60% hot-acid octane + 40% one-pass stock	------- 0.18 107	90 0.19 107	101 0.23 108	164 0.96 125	203 2.48 143	220 3.43 149	245 5.71 160
A-374	80% hot-acid octane + 20% one-pass stock	------- 0.45 115	99 0.41 114	115 0.45 115	187 2.26 141	224 3.93 152	240 5.60 160	268 ------ 175
A-330	Hot-acid octane[e]	------- 1.08 127	131 1.86 137	159 2.76 145	250 ------ 178	289 ------ 195	304 ------ ------	317 ------ ------
A-257	20% mixed xylenes + 80% VBS	------- 92.6 79	68 91.3 79	78 94.7 86	114 99.2 97	132 98.7 96	138 98.1 94	148 98.6 96
A-258	40% mixed xylenes + 60% VBS	------- 95.5 86	69 91.9 80	78 94.7 86	117 0.03 101	147 0.16 106	160 0.26 110	182 0.83 123
A-259	60% mixed xylenes + 40% VBS	------- 95.2 86	74 95.0 87	85 99.3 99	146 0.38 113	194 1.90 137	216 3.14 148	253 ------ 165
A-260	80% mixed xylenes + 20% VBS	------- 0.04 101	84 0.05 102	95 0.14 105	214 4.00 153	------ ------ ------	------ ------ ------	------ ------ ------
A-261	20% mixed xylenes + 80% alkylate	------- 0.52 116	88 0.14 105	101 0.23 108	158 0.65 119	194 1.90 137	208 2.87 143	227 3.59 150
A-262	40% mixed xylenes + 60% alkylate	------- 0.27 110	82 100 100	95 0.14 105	153 0.46 115	206 2.69 144	252 ------ 167	287 ------ 187
A-263	60% mixed xylenes + 40% alkylate	------- 0.14 106	85 0.07 103	98 0.19 107	181 1.89 137	274 ------ 165	------ ------ ------	------ ------ ------
A-264	80% mixed xylenes + 20% alkylate	------- 0.27 110	87 0.12 105	103 0.27 110	260 ------ 185	336 ------ ------	370 ------ ------	------ ------ ------

[a]Each fuel contains approximately 4 ml TEL/gal.
[e]Values for knock-limited imep were averaged from two curves.

NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS

TABLE II - PERFORMANCE RATINGS OBTAINED IN F-3 AND F-4 ENGINES - Continued

Fuel	Fuel composition[a] (by volume)	F-3 ratings	F-4 ratings					
			Fuel-air ratio					
			0.065	0.070	0.085	0.095	0.100	0.110
A-265	20% mixed xylenes + 80% one-pass stock[b]	------- 94.7 84	71 93.1 83	74 92.0 81	111 97.9 94	138 0.03 101	151 0.11 105	178 0.50 116
A-266	40% mixed xylenes + 60% one-pass stock[b]	------- 97.5 92	80 98.8 95	86 100 100	133 0.21 108	172 0.58 118	196 1.81 136	246 5.86 161
A-267	60% mixed xylenes + 40% one-pass stock[b]	------- 98.8 96	95 0.31 111	100 0.22 108	184 2.06 139	251 ------ 169	282 ------ 187	339 ------ ------
A-268	80% mixed xylenes + 20% one-pass stock[b]	------- 0.16 106	102 0.48 115	106 0.31 111	351 ------ ------	------ ------ ------	------ ------ ------	------ ------ ------
A-256	Mixed xylenes[b,d]	------- 0.92 124	105 0.60 118	122 0.69 120	------ ------ ------	------ ------ ------	------ ------ ------	------ ------ ------
A-245	20% cumene + 80% VBS	------- 92.4 78	67 90.6 78	72 90.7 78	98 92.5 82	123 95.7 88	134 96.9 91	154 0.02 101
A-244	40% cumene + 60% VBS	------- 92.7 79	67 90.6 78	70 89.3 76	95 91.3 80	117 93.7 84	130 95.6 88	160 0.14 105
A-246	60% cumene + 40% VBS	------- 94.2 83	67 90.6 78	72 90.7 78	94 90.8 78	118 94.0 85	132 96.3 91	174 0.42 114
A-247	80% cumene + 20% VBS	------- 96.0 88	77 96.9 91	76 93.3 84	90 89.2 76	120 94.7 86	151 0.11 105	------ ------ ------
A-248	20% cumene + 80% alkylate	------- 0.32 111	98 0.38 113	102 0.25 109	143 0.34 111	172 0.58 117	187 1.39 131	215 2.76 145
A-249	40% cumene + 60% alkylate	------- 0.11 105	71 93.1 84	76 93.3 84	113 98.8 95	148 0.17 106	171 0.44 114	233 4.00 153
A-250	60% cumene + 40% alkylate	------- 0.03 101	77 96.9 91	76 93.3 84	94 90.8 78	124 96.0 90	149 0.08 103	277 ------ 180
A-251	80% cumene + 20% alkylate	------- 97.7 93	74 95.0 87	73 91.3 80	86 87.5 73	114 92.7 82	160 0.26 110	------ ------ ------
A-252	20% cumene + 80% one-pass stock	------- 93.0 80	70 92.5 82	69 88.6 75	91 89.6 76	120 94.3 85	137 97.8 93	175 0.44 114
A-253	40% cumene + 60% one-pass stock	------- 93.6 82	70 92.5 82	67 87.4 74	75 82.9 67	95 86.3 72	112 90.0 77	168 0.30 111
A-254	60% cumene + 40% one-pass stock	------- 93.0 80	66 90.0 78	62 84.0 68	65 78.8 62	81 81.3 65	94 84.4 69	153 100 100
A-255	80% cumene + 20% one-pass stock	------- 95.0 85	66 90.0 78	63 84.8 69	70 80.8 64	98 87.3 74	141 99.1 98	------ ------ ------
A-240	Cumene[d]	------- 95.0 85	77 96.9 91	75 92.7 83	87 87.9 74	122 95.3 88	------ ------ ------	------ ------ ------

[a]Each fuel contains approximately 4 ml TEL/gal.

[b]Knock-limited performance of the engine with one-pass catalytic stock was low on the day these fuels were tested.

[d]Values for knock-limited imep were averaged from three curves.

NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS

TABLE II - PERFORMANCE RATINGS OBTAINED IN F-3 AND F-4 ENGINES - Continued

Fuel	Fuel composition[a] (by volume)	F-3 ratings	F-4 ratings					
			Fuel-air ratio					
			0.065	0.070	0.085	0.095	0.100	0.110
A-341	20% benzene + 80% VBS	------- 91.4 76	78 97.5 93	85 99.4 97	134 0.22 108	155 0.27 110	162 0.29 110	168 0.30 111
A-342	40% benzene + 60% VBS	------- 92.4 78	81 99.4 97	89 0.05 102	146 0.37 112	178 1.03 126	190 1.63 134	208 2.28 141
A-343	60% benzene + 40% VBS	------- 94.2 83	78 97.5 93	85 99.4 97	244 ------ 173	346 ------ ------	384 ------ ------	------ ------ ------
A-344	80% benzene + 20% VBS	------- 96.2 88	98 0.38 113	115 0.45 115	------ ------ ------	------ ------ ------	------ ------ ------	------ ------ ------
A-358	20% benzene + 80% alkylate	------- 0.43 114	117 1.20 129	127 0.92 124	182 ..95 137	212 3.10 147	222 3.57 150	234 4.14 153
A-359	40% benzene + 60% alkylate	------- 0.12 105	102 0.48 115	112 0.41 114	182 1.95 137	230 4.72 156	253 ------ 168	295 ------ 192
A-360	60% benzene + 40% alkylate	------- 100 100	102 0.48 115	110 0.38 113	336 ------ ------	------ ------ ------	------ ------ ------	------ ------ ------
A-361	80% benzene + 20% alkylate	------- 98.3 94	119 1.30 130	178 4.63 156	------ ------ ------	------ ------ ------	------ ------ ------	------ ------ ------
A-362	20% benzene + 80% one-pass stock	------- 93.8 82	77 96.9 91	86 100 100	142 0.33 111	172 0.58 118	184 1.25 130	203 1.96 138
A-363	40% benzene + 60% one-pass stock	------- 92.0 78	82 100 100	79 95.3 88	160 0.73 121	213 3.17 148	238 5.33 159	264 ------ 172
A-364	60% benzene + 40% one-pass stock	------- 91.5 77	68 91.3 80	72 90.7 78	191 2.52 143	254 ------ 172	280 ------ 186	328 ------ ------
A-365	80% benzene + 20% one-pass stock	------- 93.0 80	94 0.29 110	93 0.11 105	------ ------ ------	------ ------ ------	------ ------ ------	------ ------ ------
A-340	Benzene[e]	------- 87 68	199 ------ 186	------ ------ 196	------ ------ ------	------ ------ ------	------ ------ ------	------ ------ ------
A-321	20% toluene + 80% VBS	------- 93.7 82	85 0.07 103	96 0.16 106	137 0.26 110	156 0.29 110	164 0.32 111	172 0.27 110
A-322	40% toluene + 60% VBS	------- 95.1 85	92 0.24 109	96 0.16 106	175 1.57 134	228 4.43 155	245 ------ 162	266 ------ 173
A-323	60% toluene + 40% VBS	------- 97.0 91	88 0.14 105	95 0.14 105	204 3.36 149	303 ------ ------	346 ------ ------	425 ------ ------
A-324	80% toluene + 20% VBS	------- 98.8 96	101 0.45 115	113 0.42 114	340 ------ ------	------ ------ ------	------ ------ ------	------ ------ ------

[a]Each fuel contains approximately 4 ml TEL/gal.

[e]Values for knock-limited imep were averaged from two curves.

NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS

TABLE II - PERFORMANCE RATINGS OBTAINED IN F-3 AND F-4 ENGINES - Concluded

Fuel	Fuel composition[a] (by volume)	F-3 ratings	F-4 ratings					
			Fuel-air ratio					
			0.065	0.070	0.085	0.095	0.100	0.110
A-325	20% toluene + 80% alkylate	------- 0.48 115	121 1.39 131	139 1.47 132	191 2.52 143	221 3.73 151	232 4.53 155	249 ------ 162
A-326	40% toluene + 60% alkylate	------- 0.54 116	108 0.75 121	128 0.97 125	223 5.38 159	275 ------ 186	308 ------ ------	348 ------ ------
A-327	60% toluene + 40% alkylate	------- 0.25 109	100 0.43 114	105 0.30 111	300 ------ ------	------ ------ ------	------ ------ ------	------ ------ ------
A-328	80% toluene + 20% alkylate	------- 0.16 106	108 0.75 121	116 0.47 115	------ ------ ------	------ ------ ------	------ ------ ------	------ ------ ------
A-331	20% toluene + 80% one-pass stock	------- 95.1 85	80 98.8 95	90 0.06 103	137 0.26 110	169 0.47 115	184 1.25 130	212 2.55 143
A-332	40% toluene + 60% one-pass stock	------- 95.3 86	85 0.07 103	92 0.09 103	151 0.44 114	202 2.41 142	224 3.72 151	262 ------ 171
A-333	60% toluene + 40% one-pass stock	------- 97.4 91	91 0.21 108	95 0.14 105	178 1.73 135	270 ------ 182	319 ------ ------	------ ------ ------
A-334	80% toluene + 20% one-pass stock	------- 0.10 104	102 0.48 115	106 0.31 111	------ ------ ------	------ ------ ------	------ ------ ------	------ ------ ------
A-320	Toluene[e]	------- 0.57 118	134 2.00 138	140 1.51 133	------ ------ ------	------ ------ ------	------ ------ ------	------ ------ ------
A-336	20% MTB ether + 80% VBS	------- 98.8 96	95 0.31 111	101 0.23 108	144 0.30 111	170 0.49 115	179 0.83 121	187 1.25 130
A-337	40% MTB ether + 60% VBS	------- 0.12 105	112 0.95 125	113 0.42 114	165 1.02 126	204 2.55 143	223 3.64 151	253 ------ 165
A-338	60% MTB ether + 40% VBS	------- 0.92 124	192 ------ 180	163 3.14 148	228 ------ 162	281 ------ 190	307 ------ ------	355 ------ ------
A-339	80% MTB ether + 20% VBS	------- 2.61 144	------ ------ ------	239 ------ ------	309 ------ ------	379 ------ ------	------ ------ ------	------ ------ ------
A-347	20% MTB ether + 80% alkylate	------- 1.68 135	143 3.06 146	155 2.38 142	230 ------ 163	258 ------ 174	268 ------ 178	281 ------ 183
A-348	40% MTB ether + 60% alkylate	------- 2.30 141	166 5.43 159	174 4.21 154	256 ------ 183	312 ------ ------	338 ------ ------	377 ------ ------
A-349	60% MTB ether + 40% alkylate	------- 2.50 143	258 ------ ------	229 ------ 193	327 ------ ------	406 ------ ------	442 ------ ------	------ ------ ------
A-350	80% MTB ether + 20% alkylate	------- 6.0 161	307 ------ ------	271 ------ ------	374 ------ ------	------ ------ ------	------ ------ ------	------ ------ ------
A-351	20% MTB ether + 80% one-pass stock	------- 96.1 88	87 0.12 105	91 0.08 103	144 0.35 112	179 1.10 127	194 1.72 135	218 2.97 146
A-352	40% MTB ether + 60% one-pass stock	------- 0.14 105	113 1.00 126	112 0.41 114	163 0.85 123	204 2.55 143	225 3.79 152	269 ------ 175
A-353	60% MTB ether + 40% one-pass stock	------- 0.47 115	185 ------ 173	160 2.86 146	230 ------ 163	289 ------ 195	319 ------ ------	376 ------ ------
A-354	80% MTB ether + 20% one-pass stock	------- 1.00 126	269 ------ ------	237 ------ 200	301 ------ ------	370 ------ ------	------ ------ ------	------ ------ ------
A-335	MTB ether[e]	------- >6.00 > 161	------ ------ ------	330 ------ ------	406 ------ ------	------ ------ ------	------ ------ ------	------ ------ ------

[a]Each fuel contains approximately 4 ml TEL/gal.
[e]Values for knock-limited imep were averaged from two curves.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TABLE III - REPRODUCIBILITY OF THE F-4 RATING ENGINE

Item	Fuel-air ratio							
	0.065	0.070	0.075	0.085	0.095	0.100	0.110	0.120
Virgin base stock plus 4 ml TEL per gallon								
Average imep	73	82	95	118	133	137	140	136
Mean deviation	4.0	4.8	5.2	5.2	4.2	3.4	2.1	2.3
Percentage mean deviation	5.5	5.9	5.5	4.4	3.1	2.5	1.5	1.7
Aviation alkylate plus 4 ml TEL per gallon								
Average imep	112	129	147	175	193	198	200	196
Mean deviation	9.1	8.2	7.4	6.8	6.1	5.1	3.6	3.4
Percentage mean deviation	8.1	6.4	5.1	3.9	3.2	2.6	1.8	1.7
One-pass catalytic stock plus 4 ml TEL per gallon[1]								
Average imep	75	82	95	124	153	165	181	183
Mean deviation	4.7	4.1	4.3	5.6	5.8	5.0	4.0	3.3
Percentage mean deviation	6.3	5.0	4.5	4.5	3.8	3.0	2.2	1.8

[1]The knock-limited indicated mean effective pressures for one-pass catalytic stock plus 4 ml TEL/gal (from figs. 3(c) and 8(c)) were omitted in making the calculations because the engine operation was unsatisfactory when these data were obtained.

National Advisory Committee
for Aeronautics

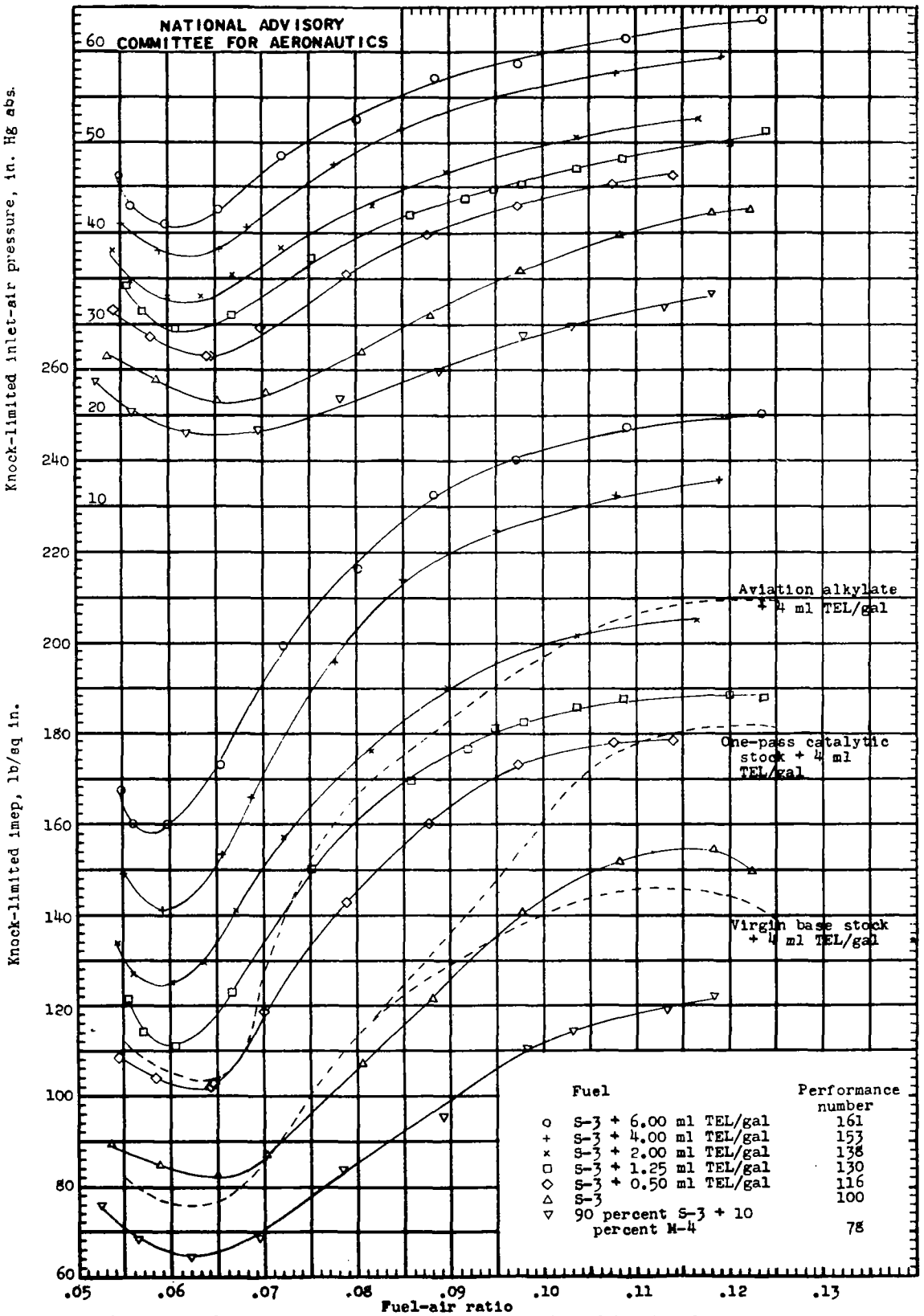


Figure 1. - Knock-limited performance of reference fuels and bracketed performance of base fuels as determined in an F-4 rating engine.

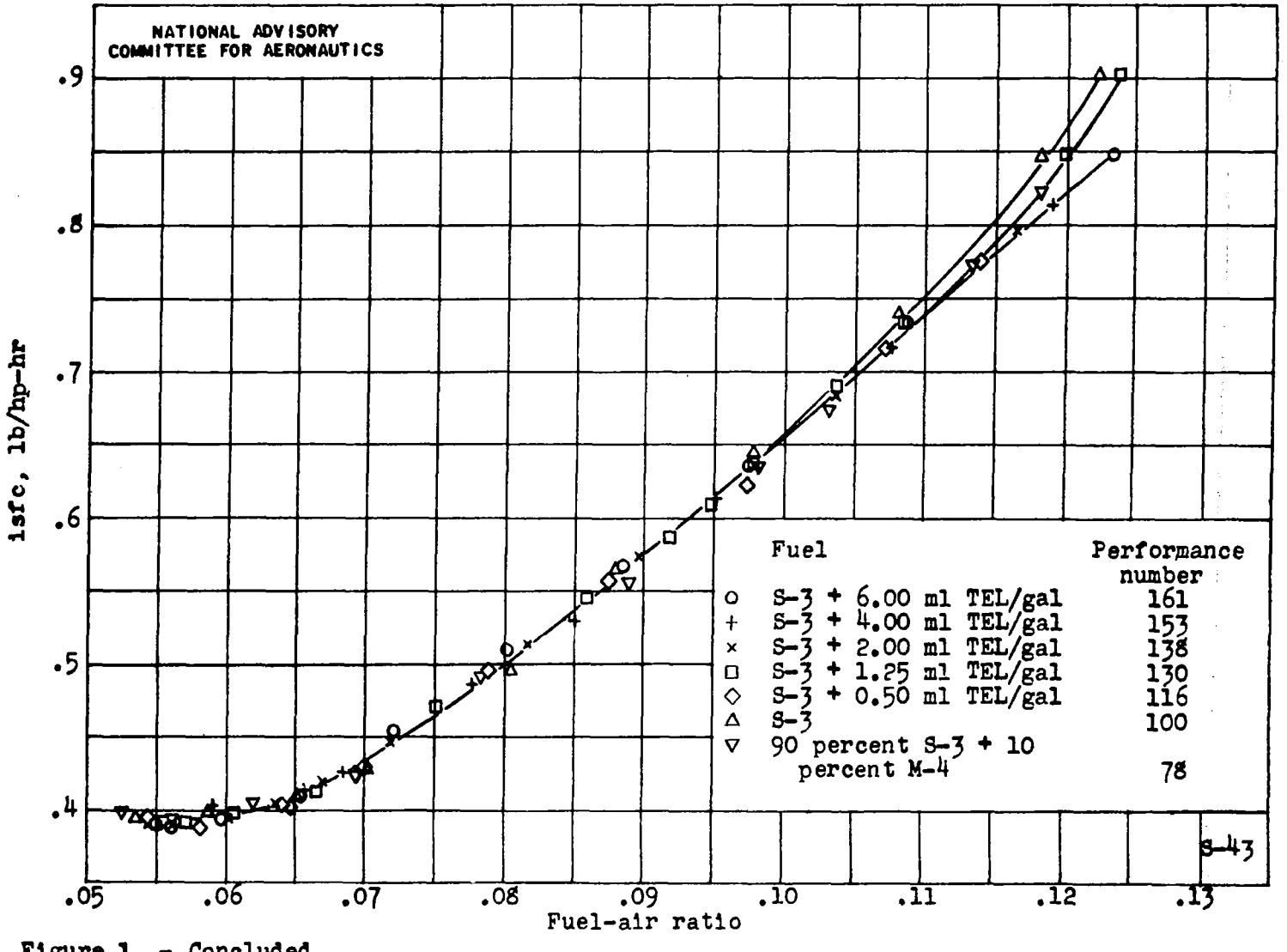
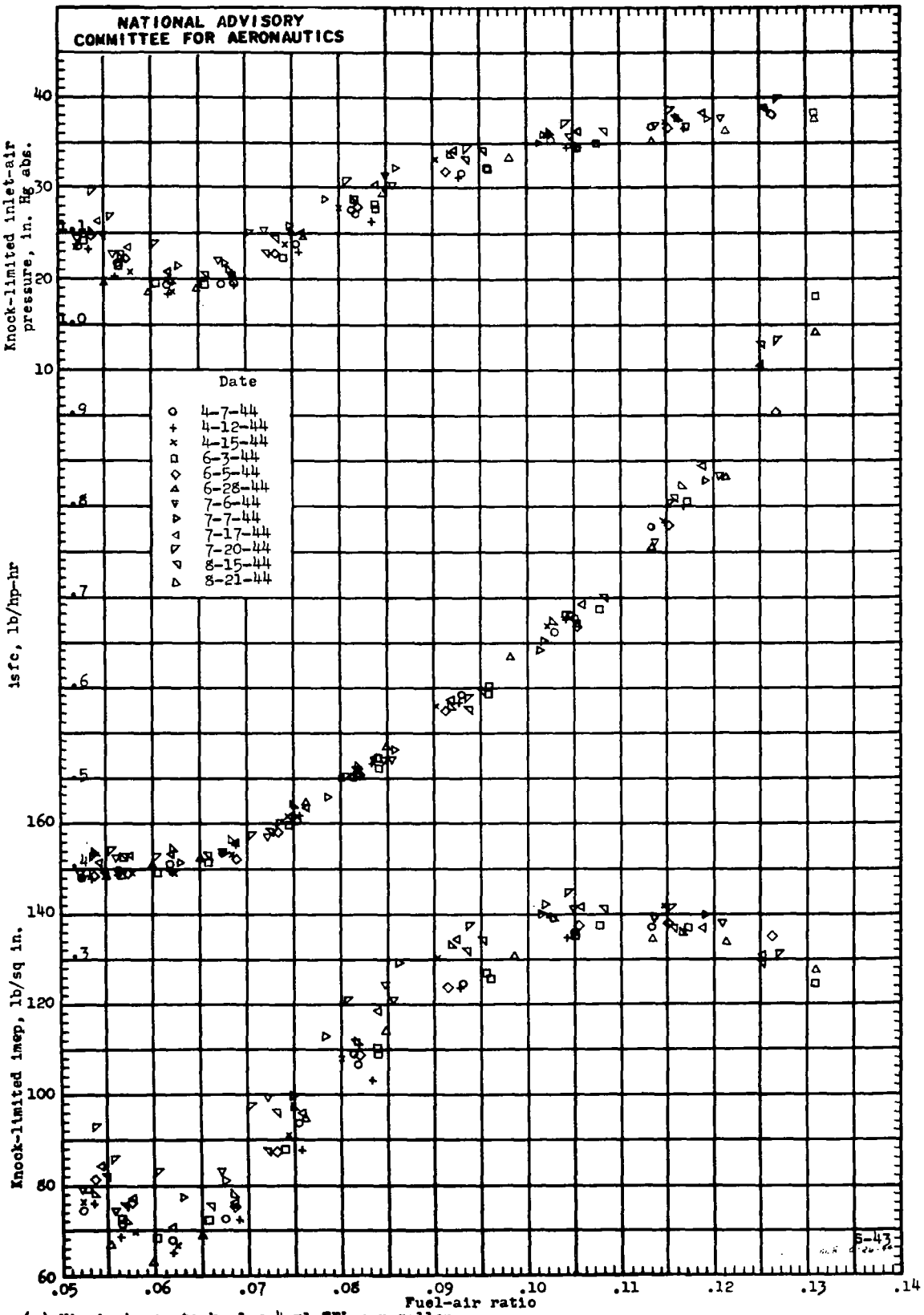
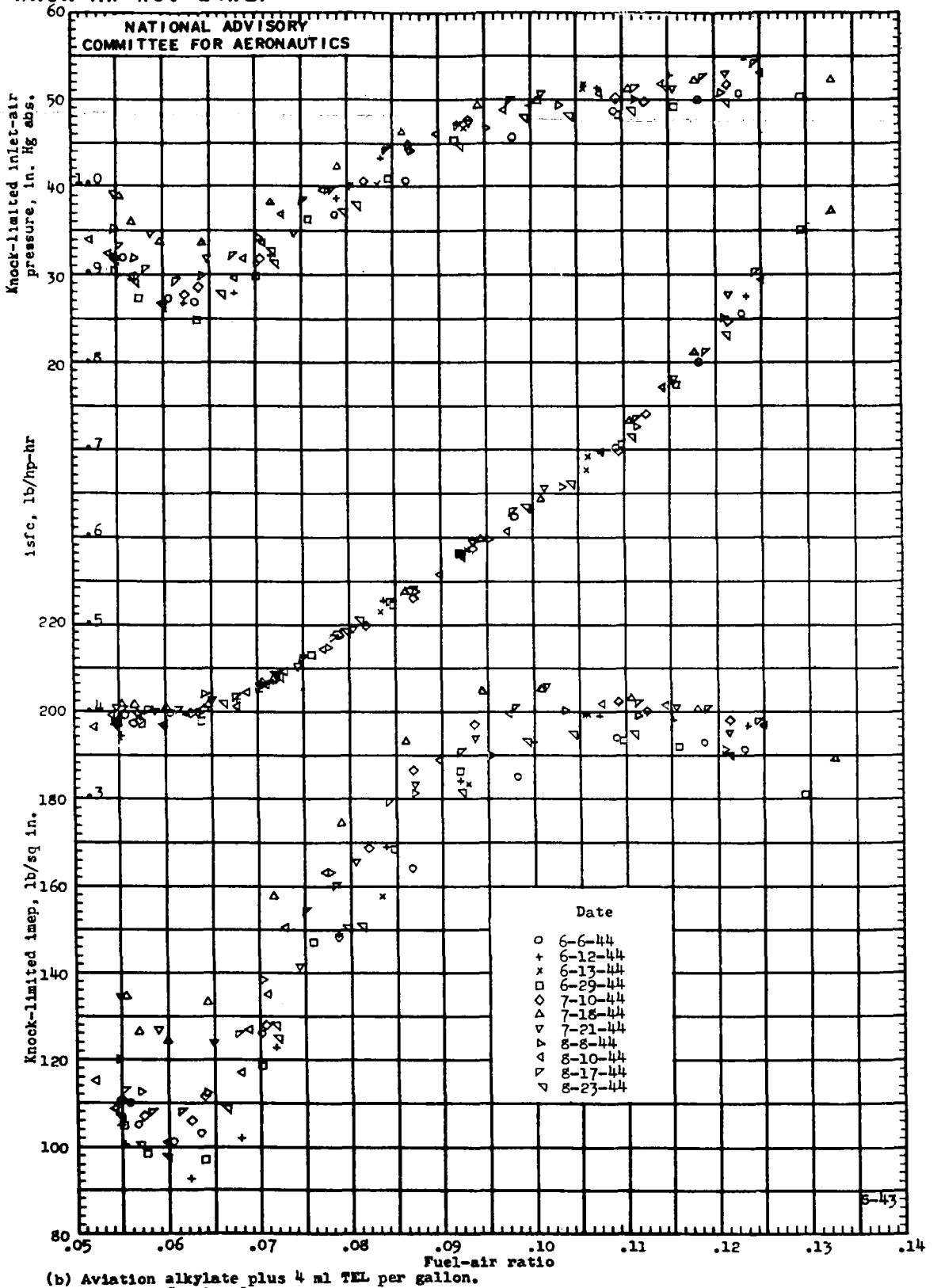


Figure 1. - Concluded.

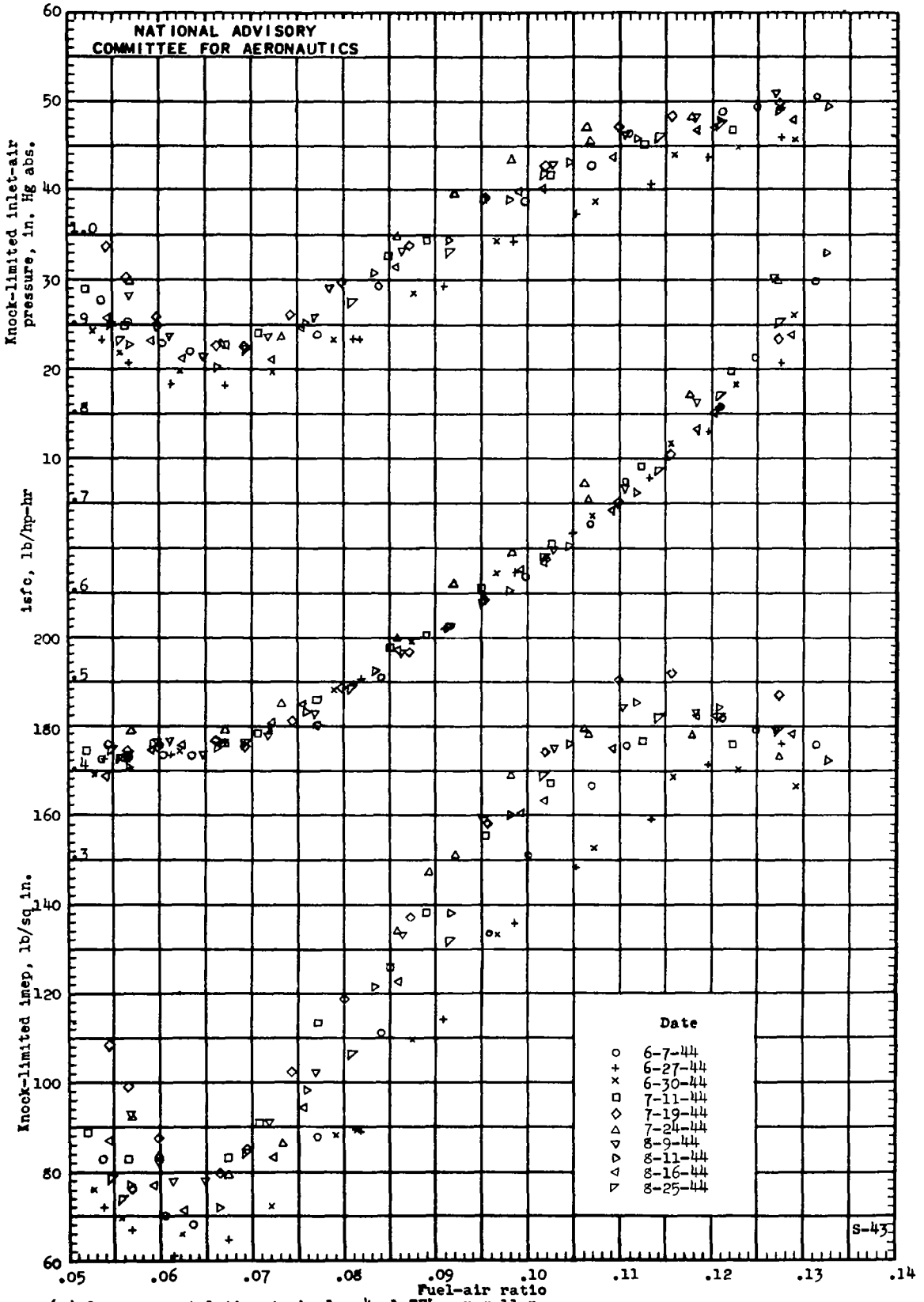


(a) Virgin base stock plus 4 ml TEL per gallon.

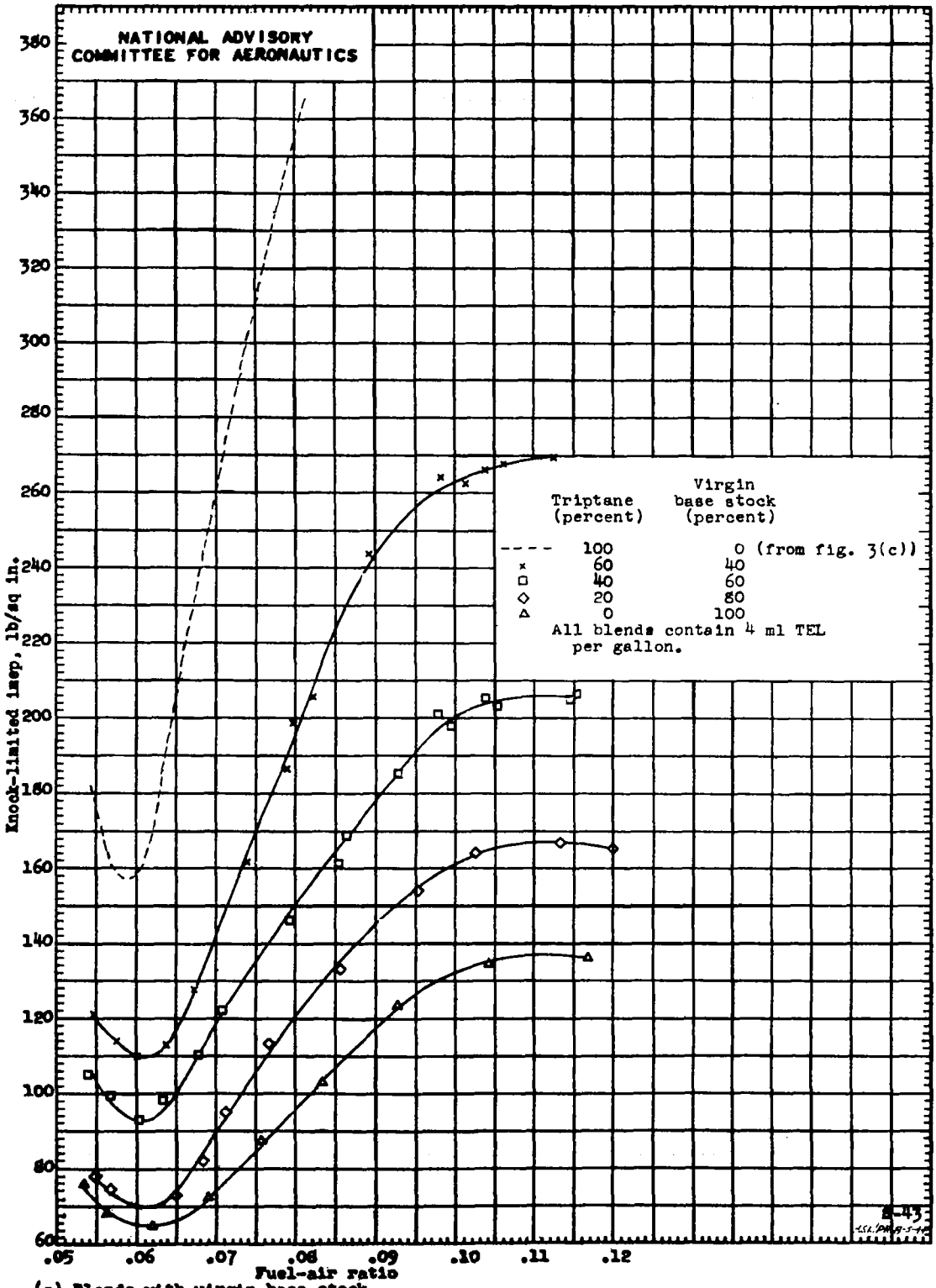
Figure 2. - Reproducibility of engine results obtained in an F-4 rating engine.



(b) Aviation alkylate plus 4 ml TEL per gallon.
Figure 2. - Continued.

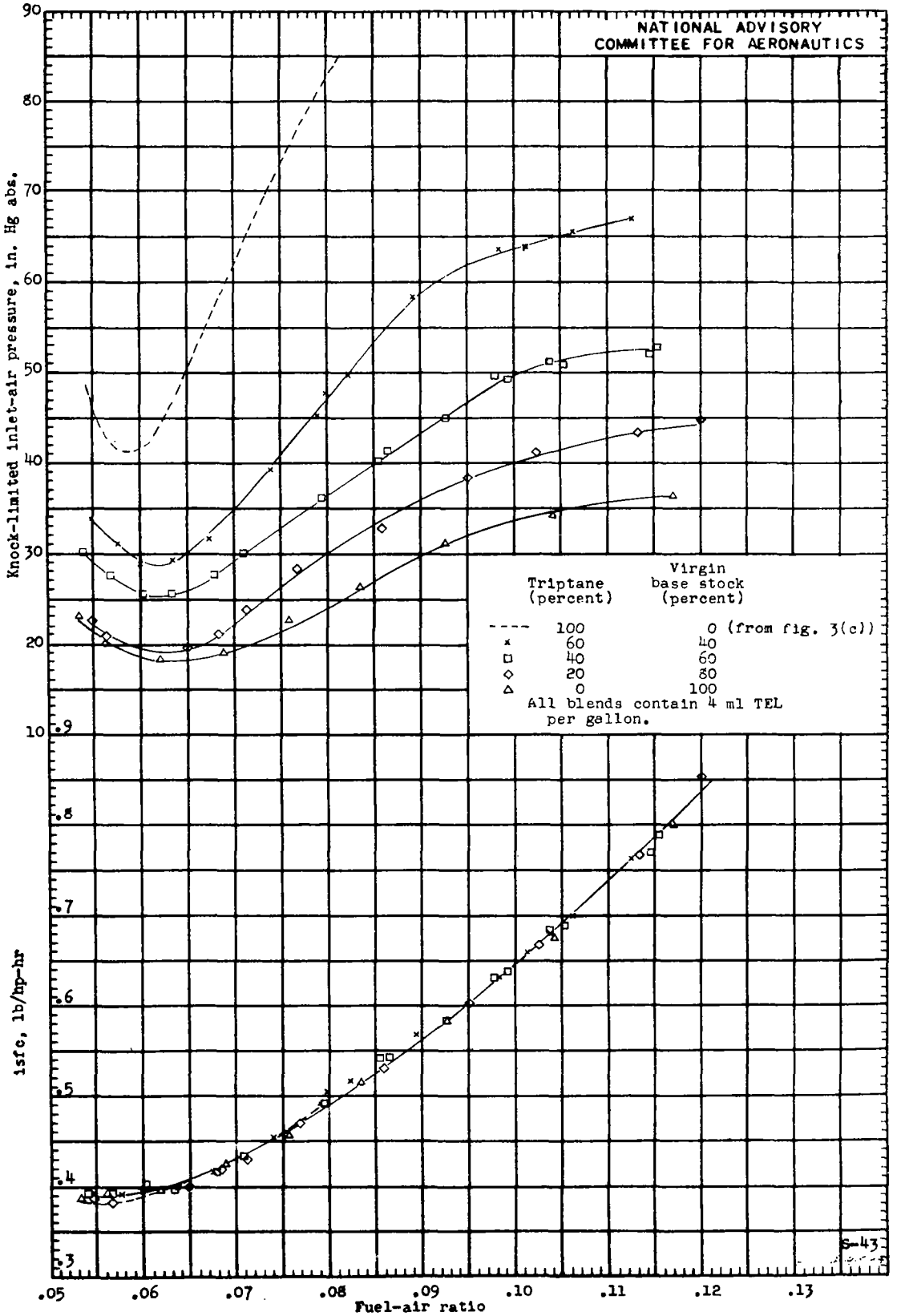


(c) One-pass catalytic stock plus 4 ml TEL per gallon.
Figure 2. - Concluded.

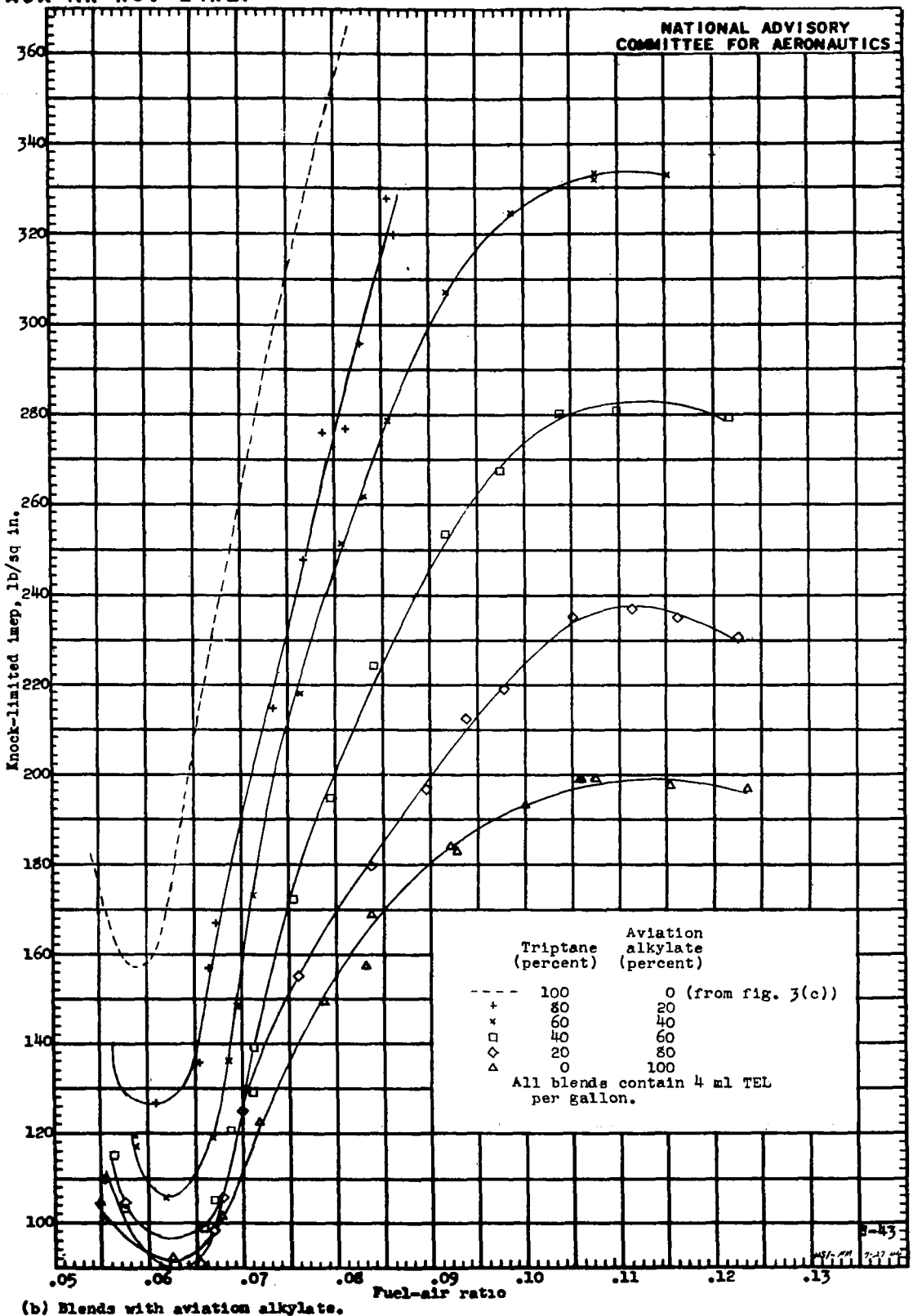


(a) Blends with virgin base stock.

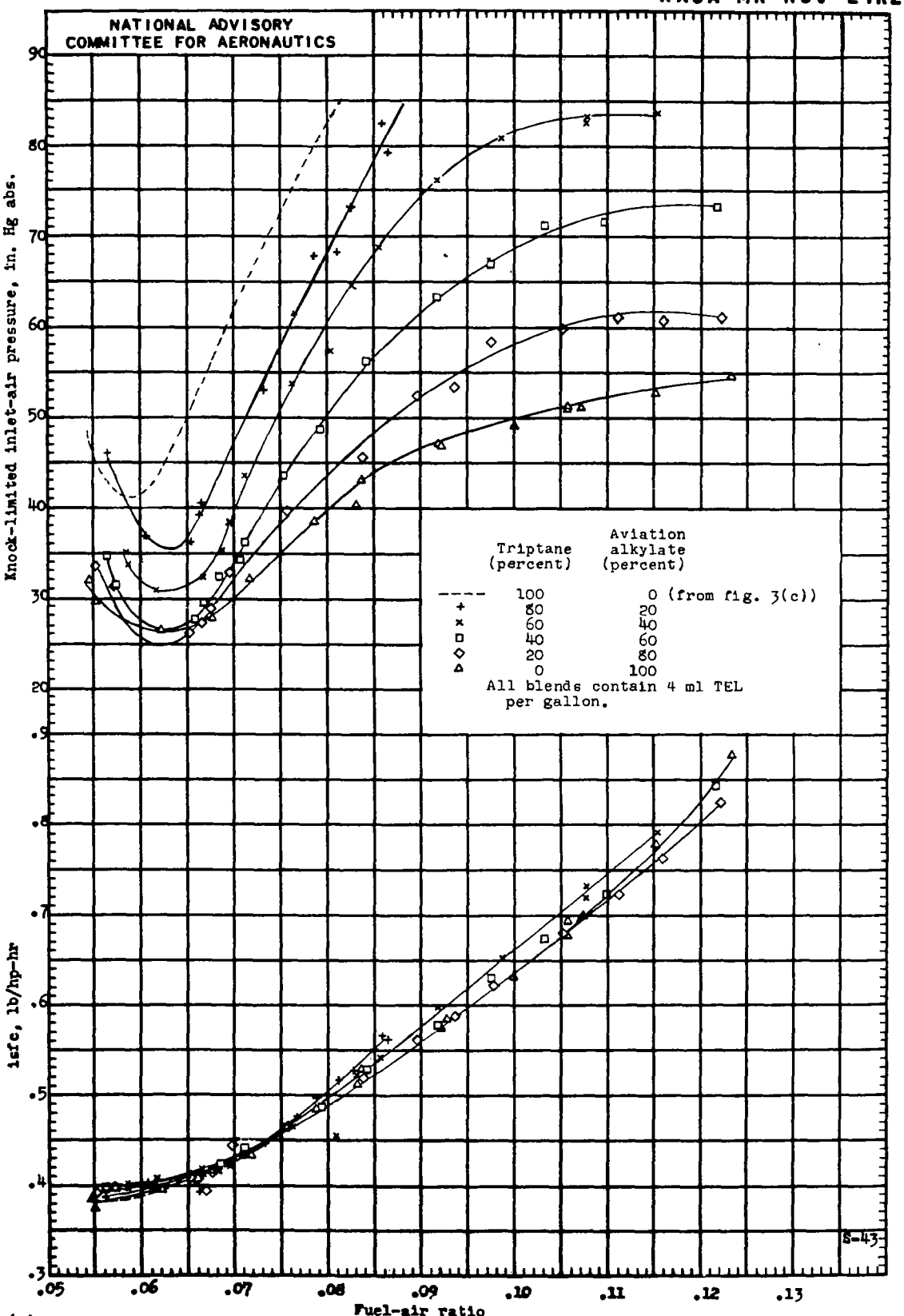
Figure 3. - Knock-limited performance of blends of triptane (2,2,3-trimethylbutane) with virgin base stock, aviation alkylate, and one-pass catalytic stock as determined in an F-4 rating engine.



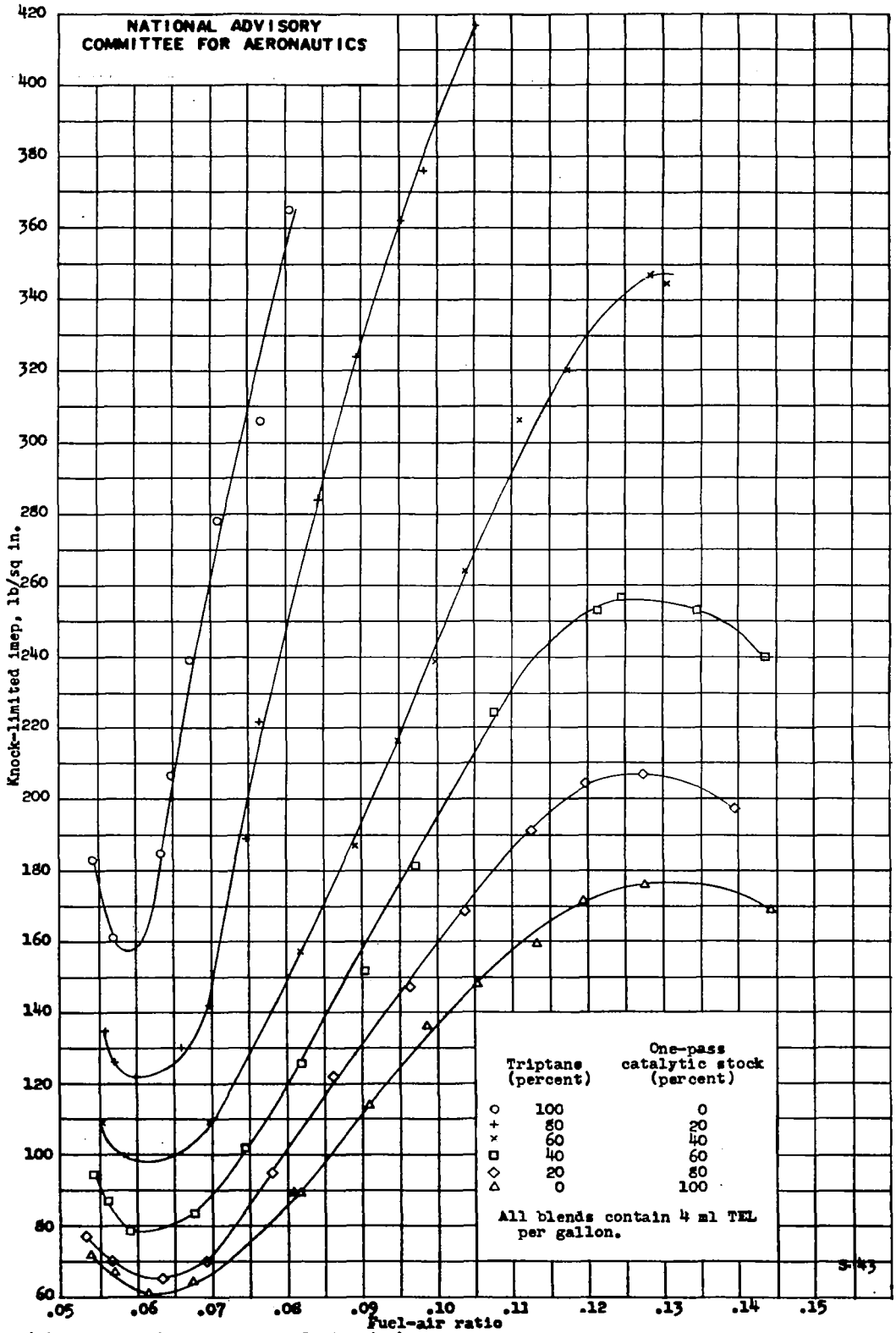
(a) Concluded.
Figure 3. - Continued.



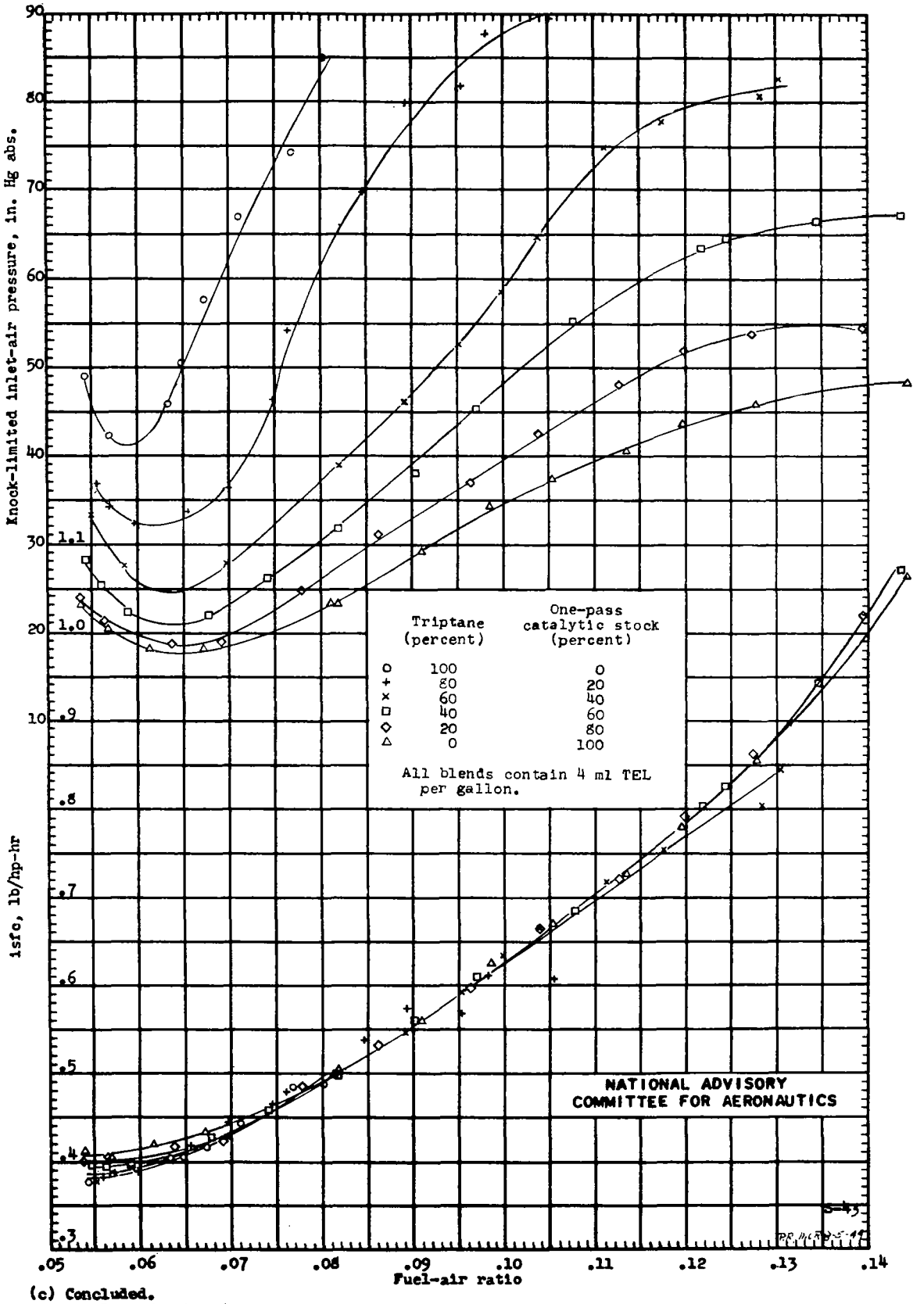
(b) Blends with aviation alkylate.
Figure 3. - Continued.



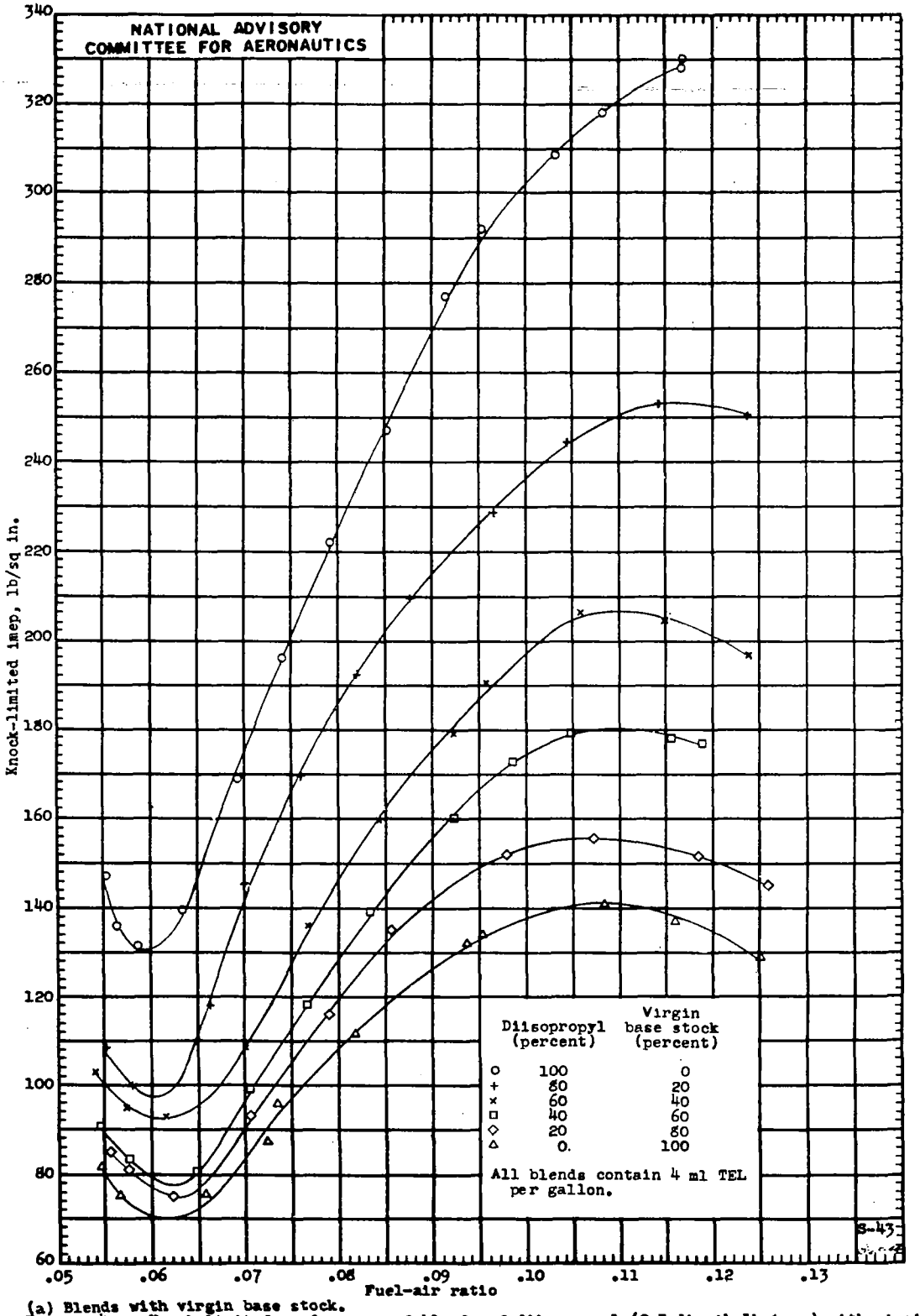
(b) Concluded.
Figure 3. - Continued.



(c) Blends with one-pass catalytic stock.
Figure 3. - Continued.

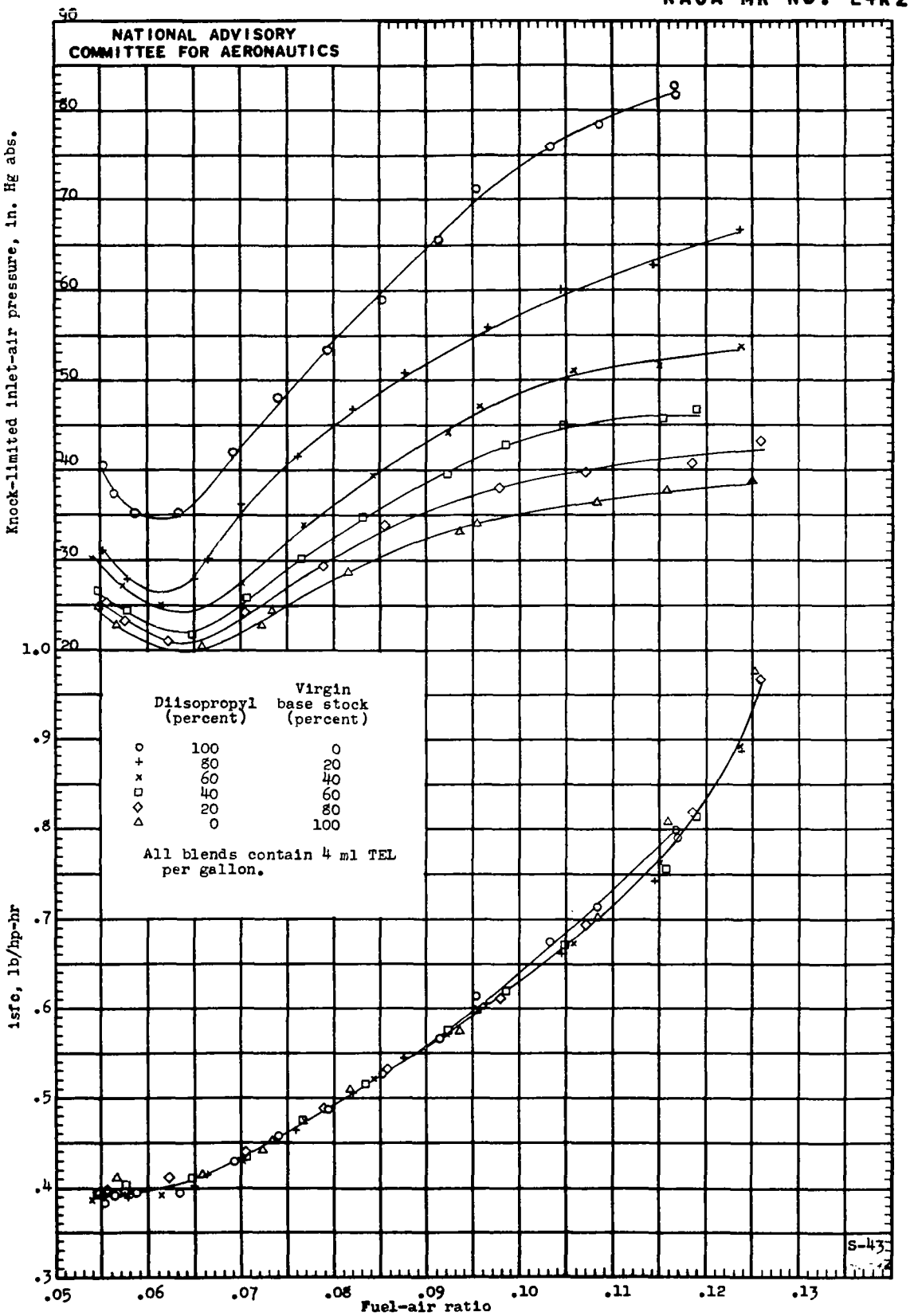


(c) Concluded.
Figure 3. - Concluded.

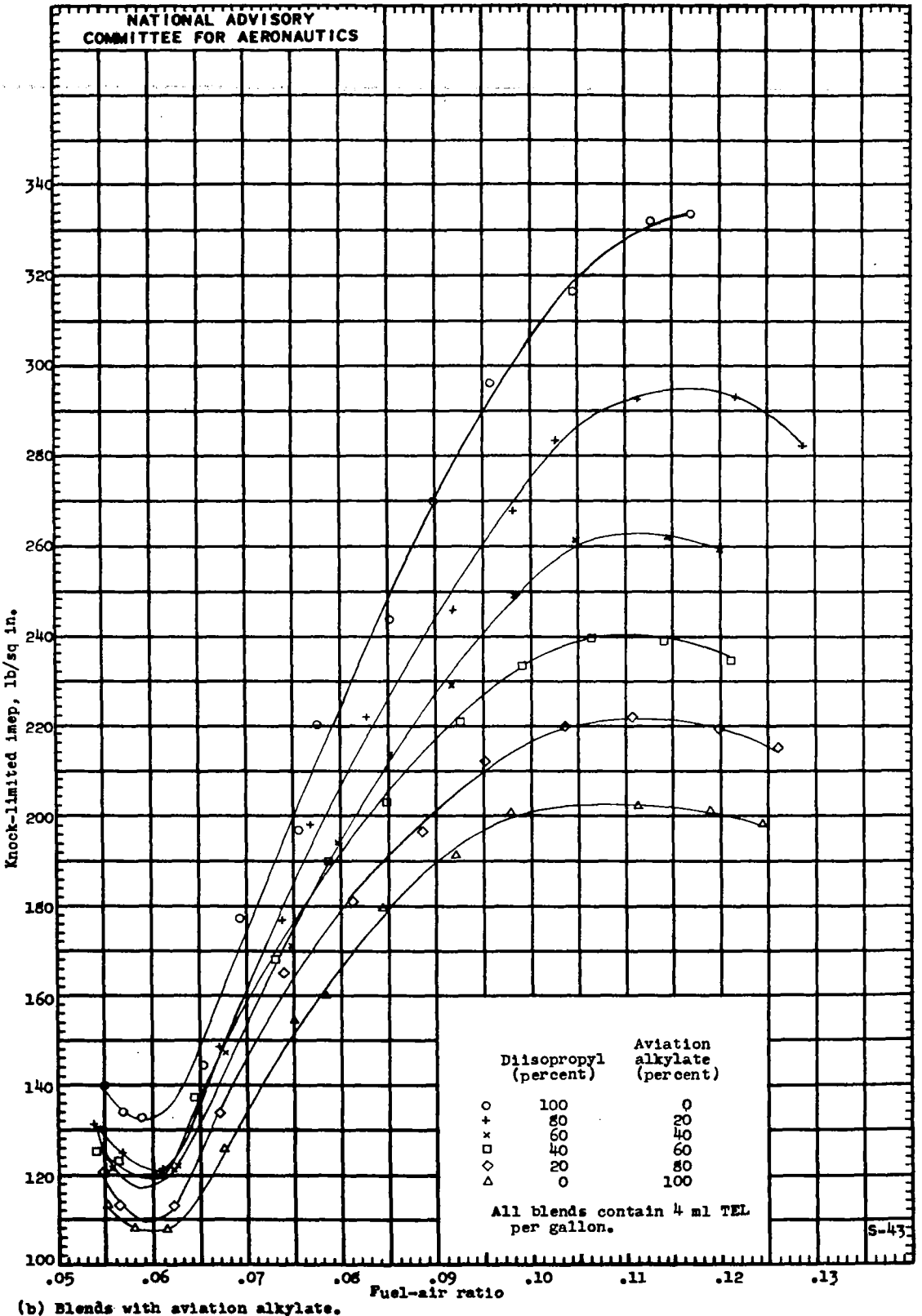


(a) Blends with virgin base stock.

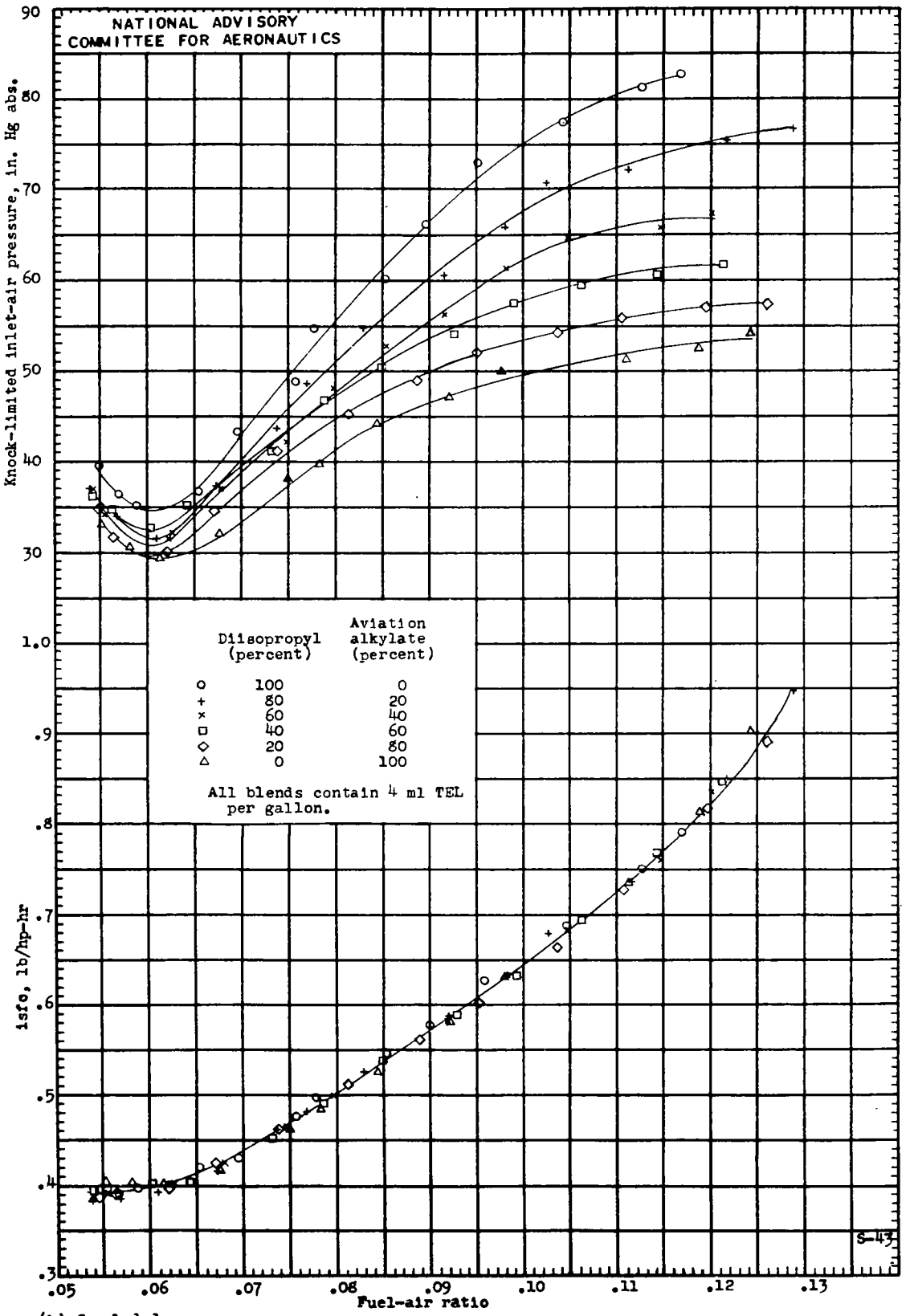
Figure 4. - Knock-limited performance of blends of diisopropyl (2,3-dimethylbutane) with virgin base stock, aviation alkylate, and one-pass catalytic stock as determined in an F-4 rating engine.



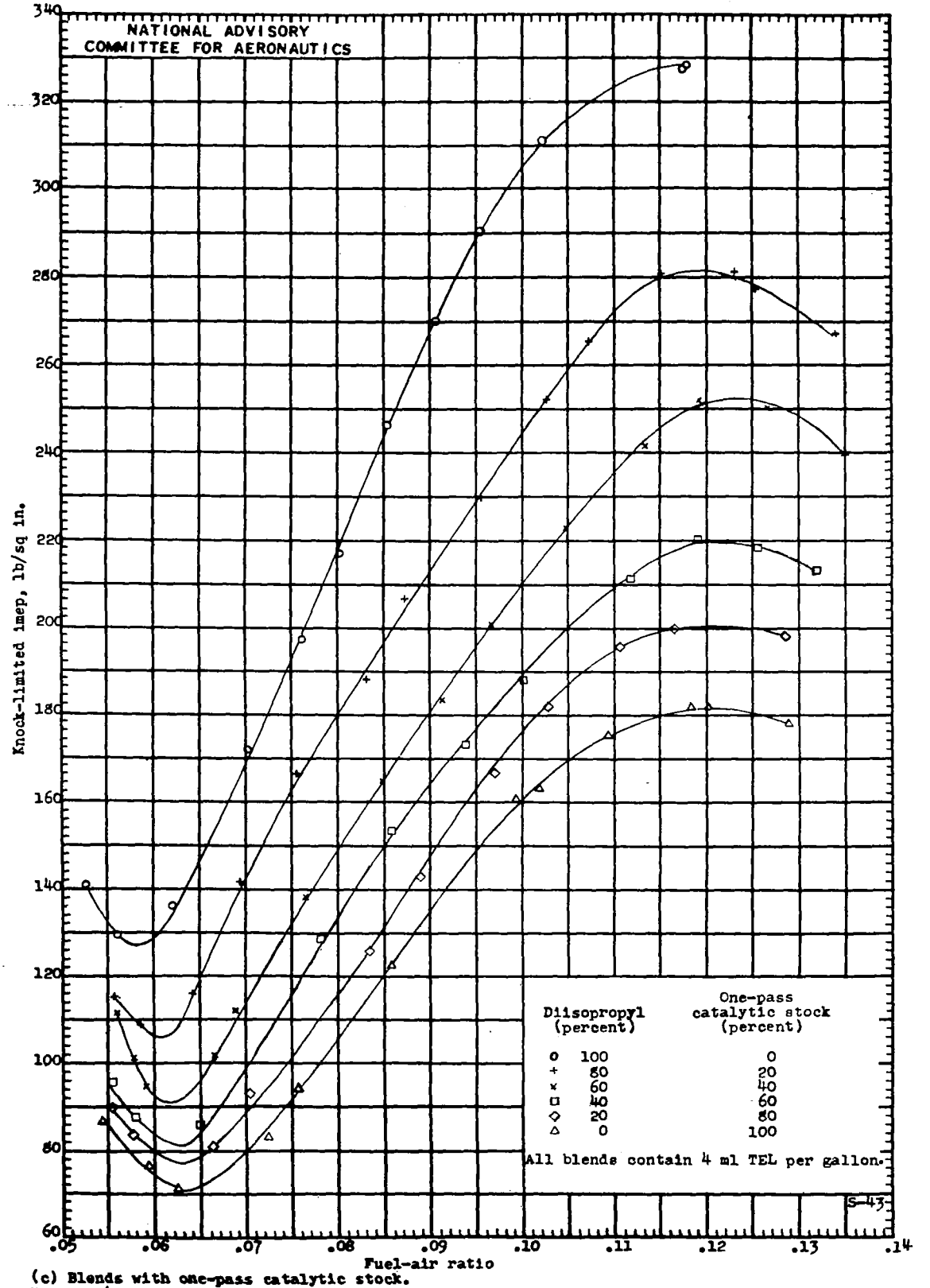
(a) Concluded.
Figure 4. - Continued.



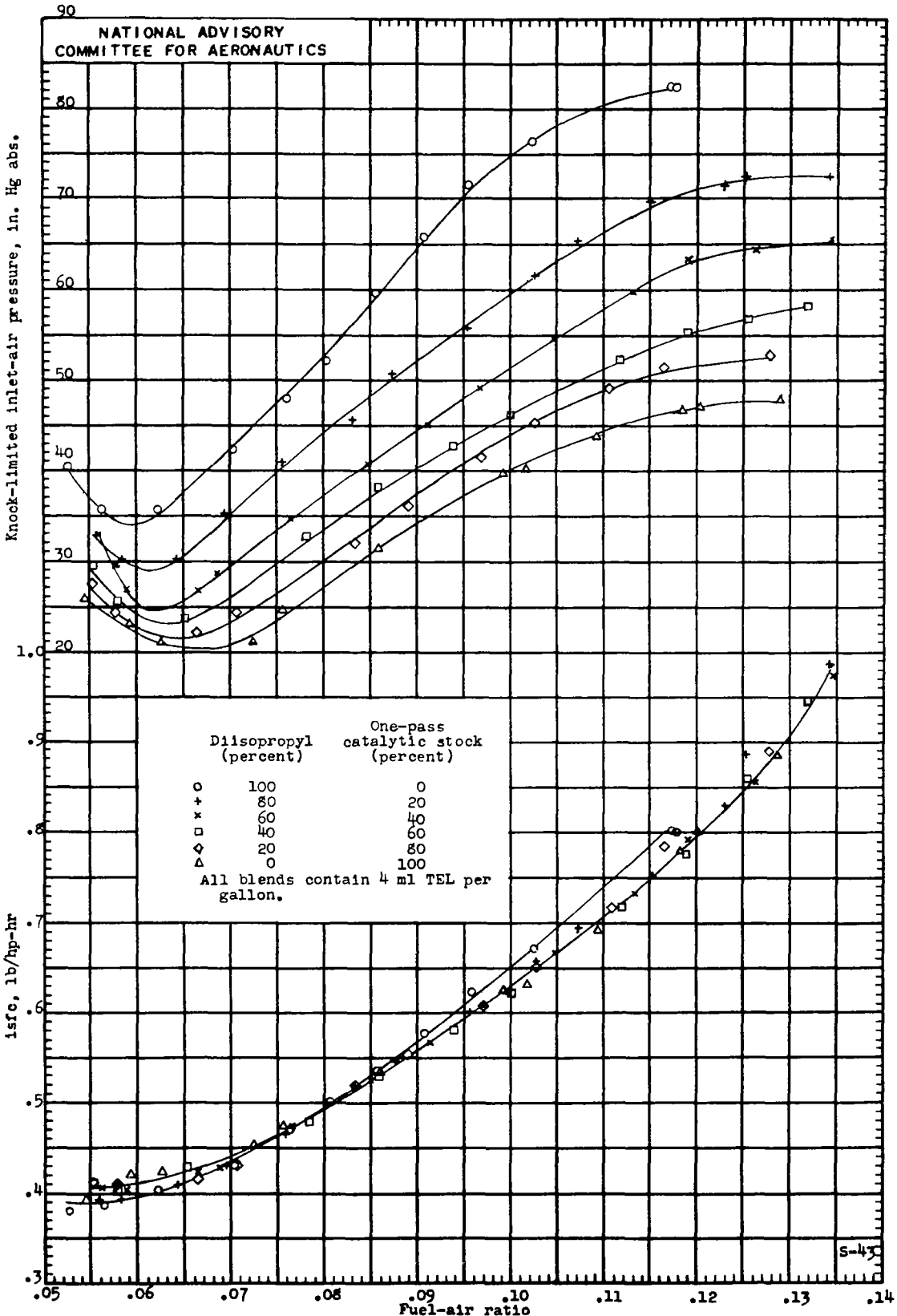
(b) Blends with aviation alkylate.
Figure 4. - Continued.



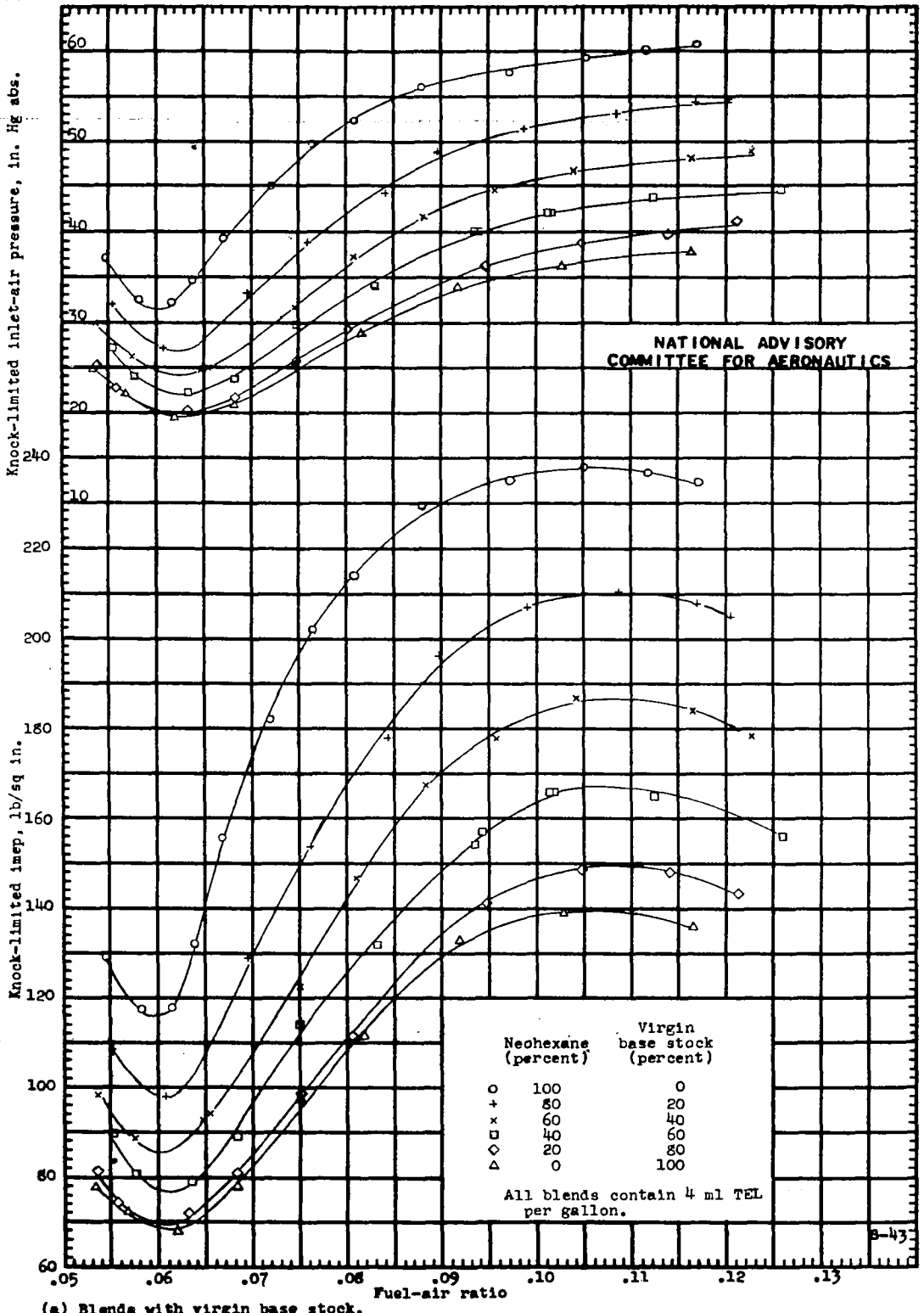
(b) Concluded.
Figure 4. - Continued.



(c) Blends with one-pass catalytic stock.
Figure 4. - Continued.

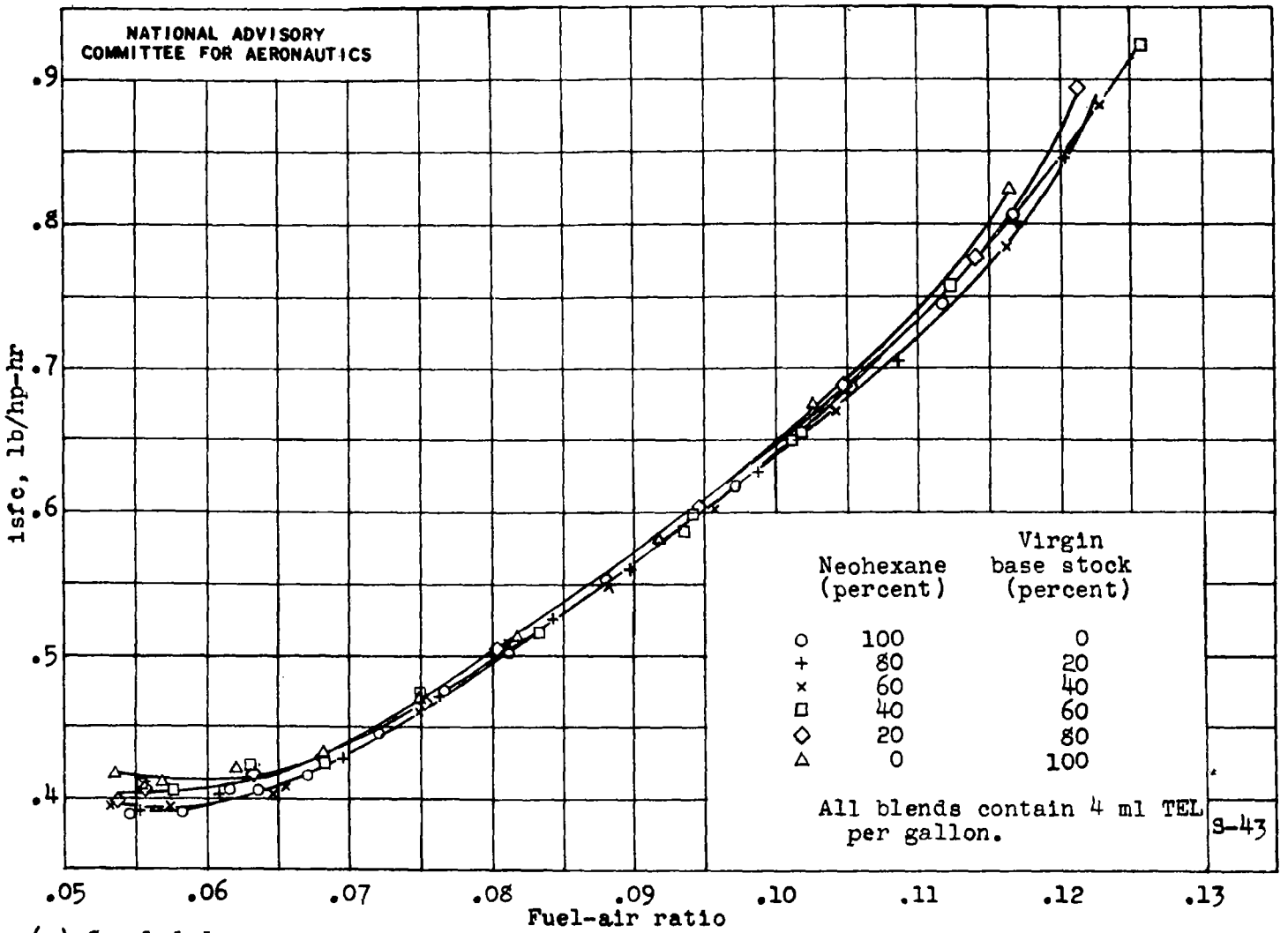


(c) Concluded.
Figure 4. - Concluded.

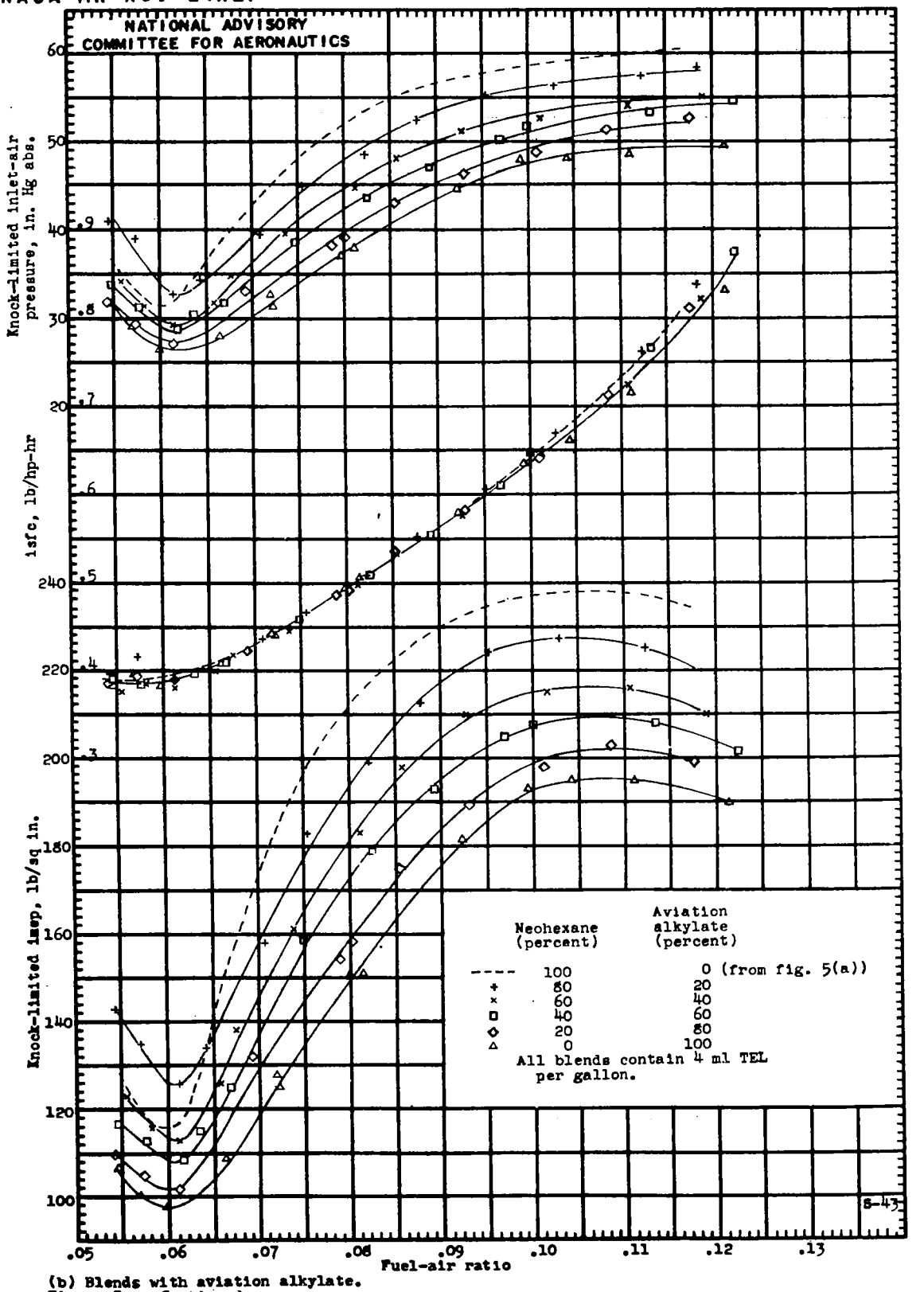


(a) Blends with virgin base stock.

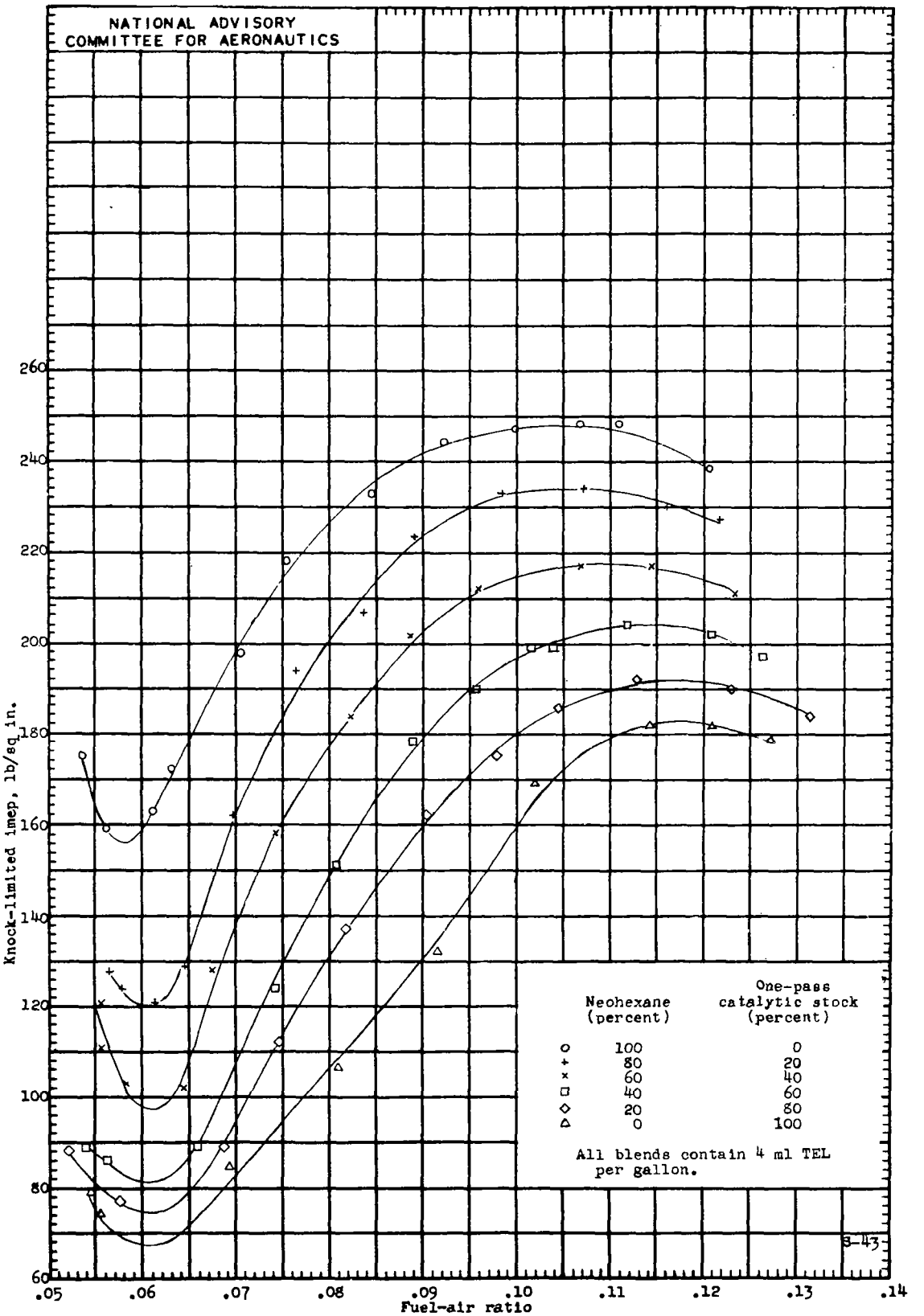
Figure 5. - Knock-limited performance of blends of neohexane (2,2-dimethylbutane) with virgin base stock, aviation alkylate, and one-pass catalytic stock as determined in an F-4 rating engine.



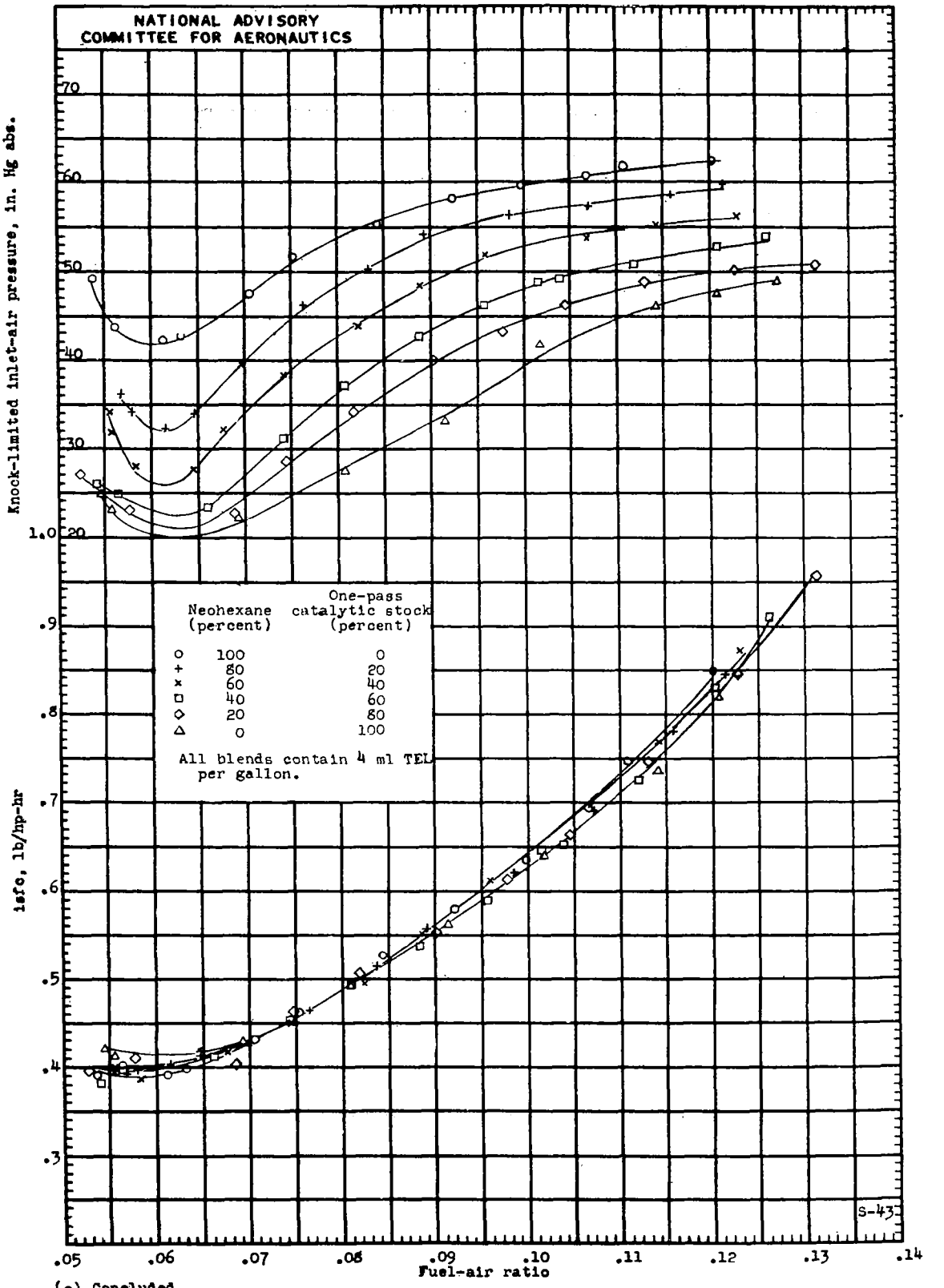
(a) Concluded.
Figure 5. - Continued.



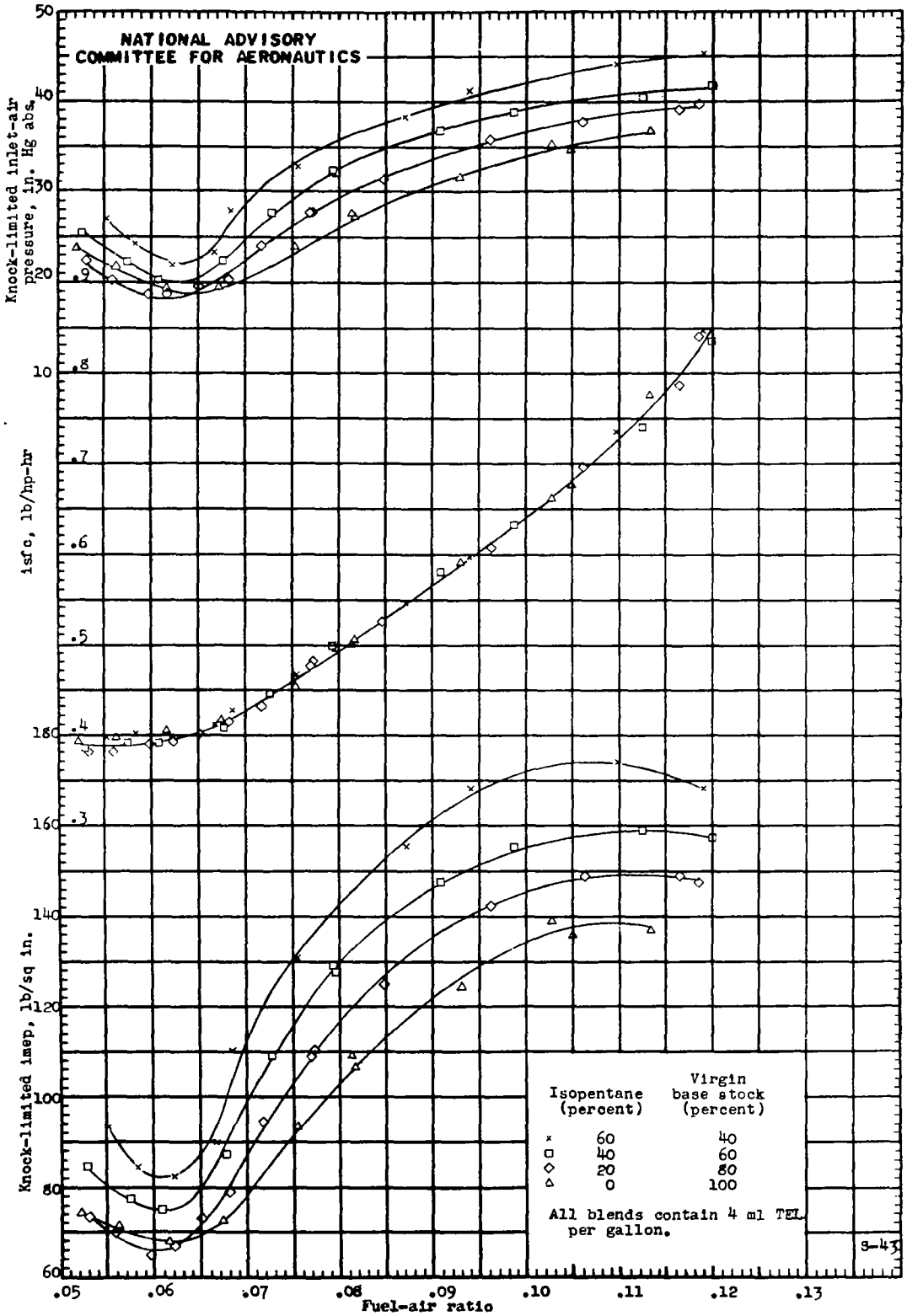
(b) Blends with aviation alkylate.
Figure 5. - Continued.



(c) Blends with one-pass catalytic stock.
Figure 5. - Continued.

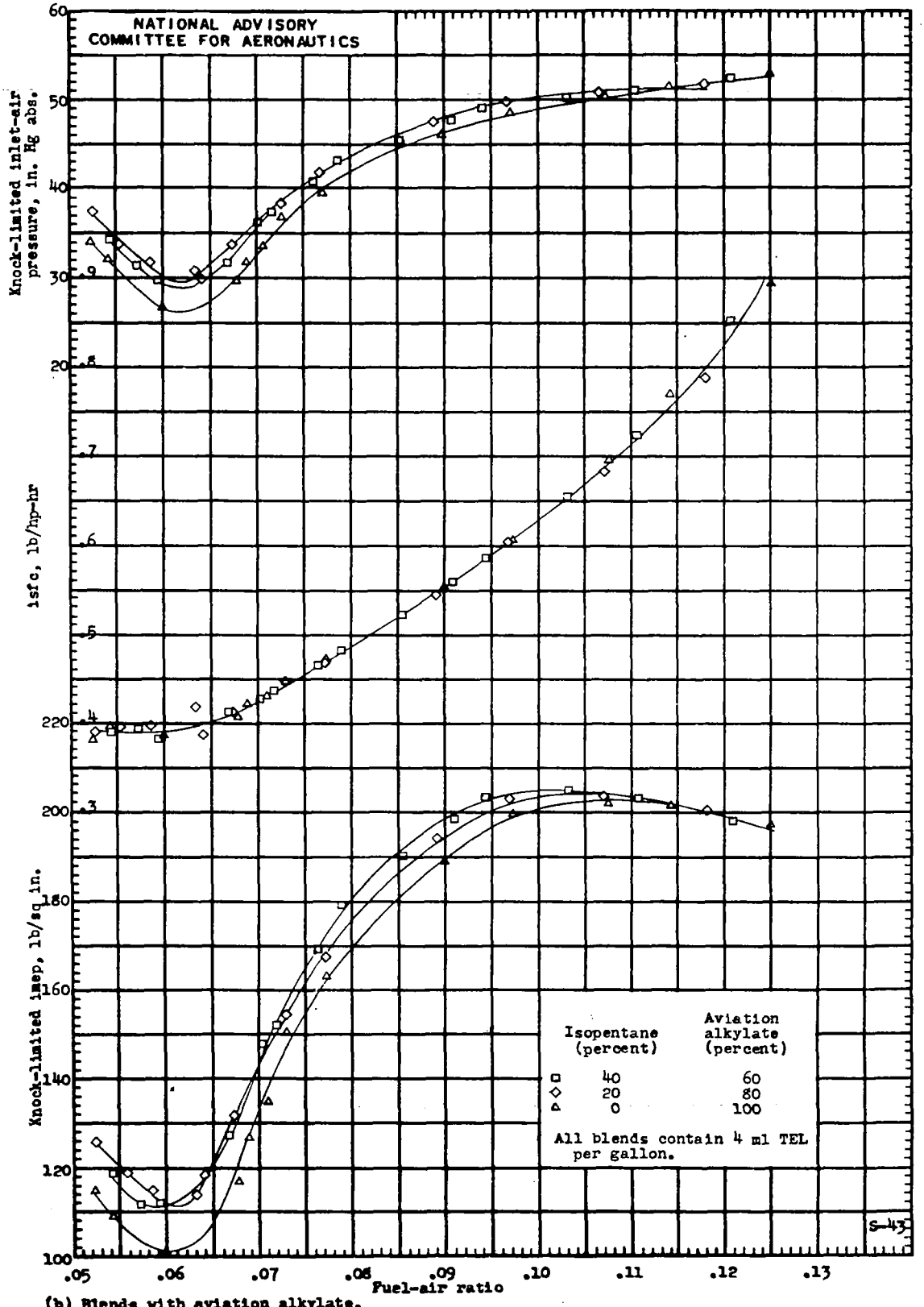


(c) Concluded.
Figure 5. - Concluded.

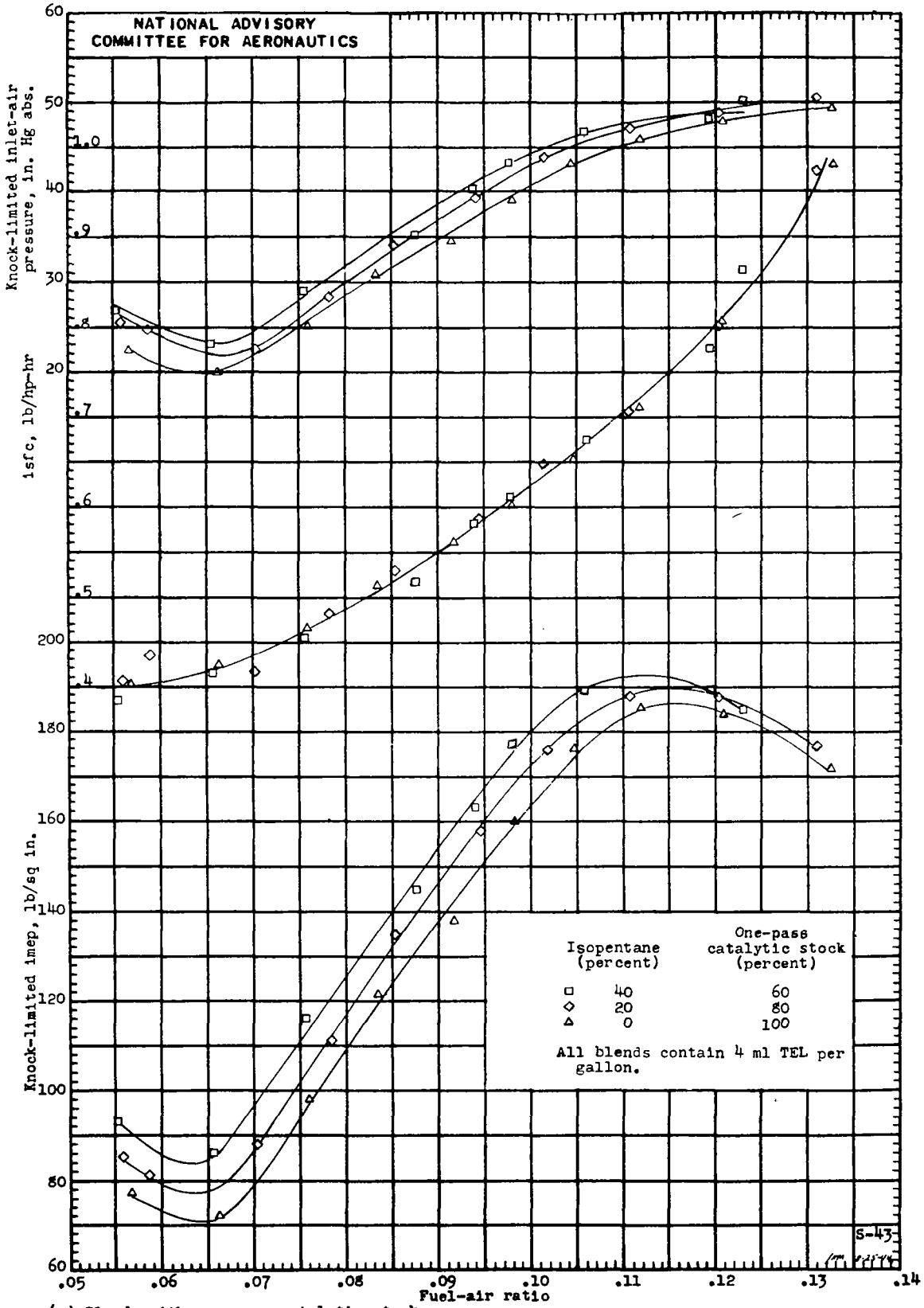


(a) Blends with virgin base stock.

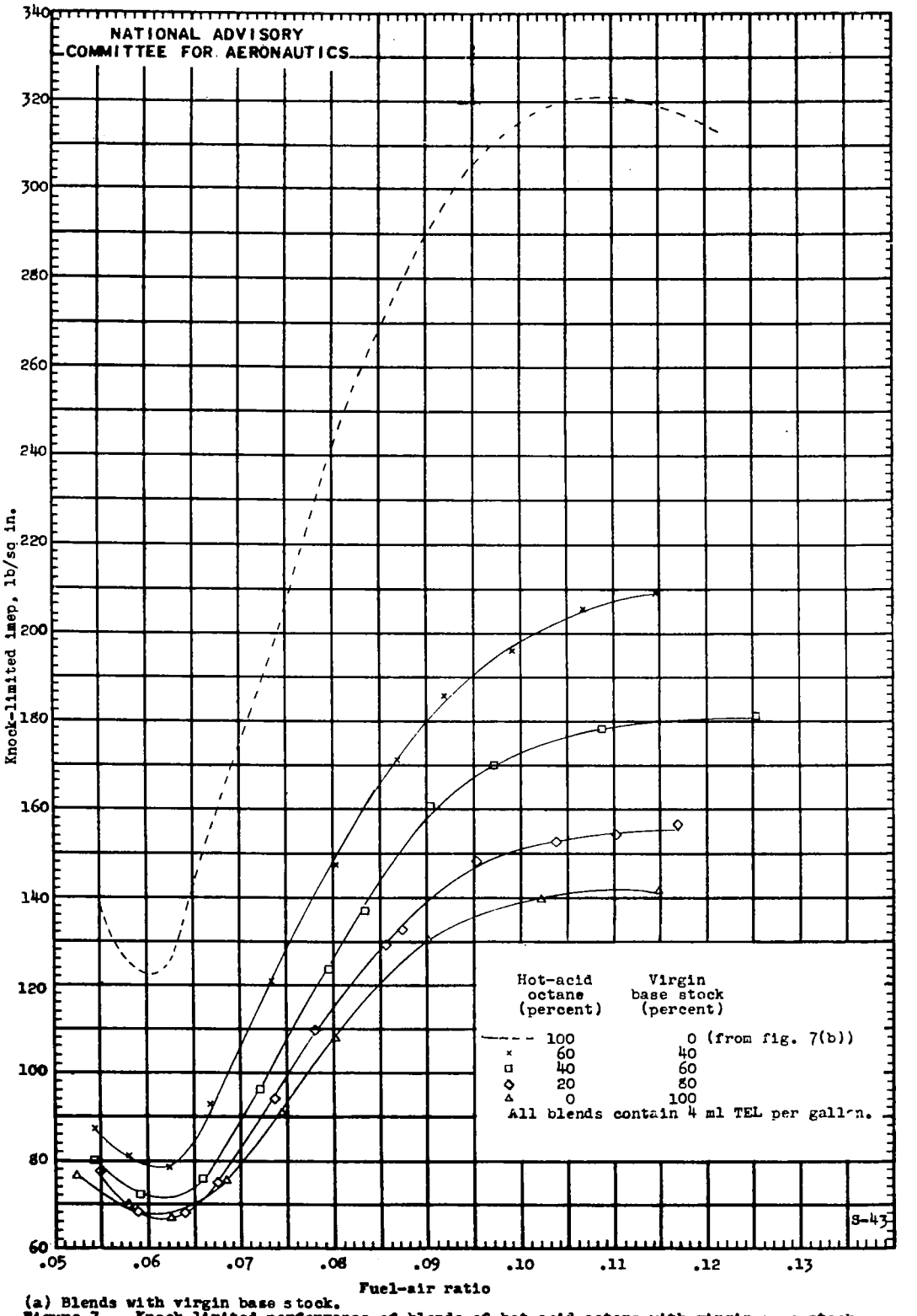
Figure 6. - Knock-limited performance of blends of isopentane (2-methylbutane) with virgin base stock, aviation alkylate, and one-pass catalytic stock as determined in an F-4 rating engine.



(b) Blends with aviation alkylate.
Figure 6. - Continued.

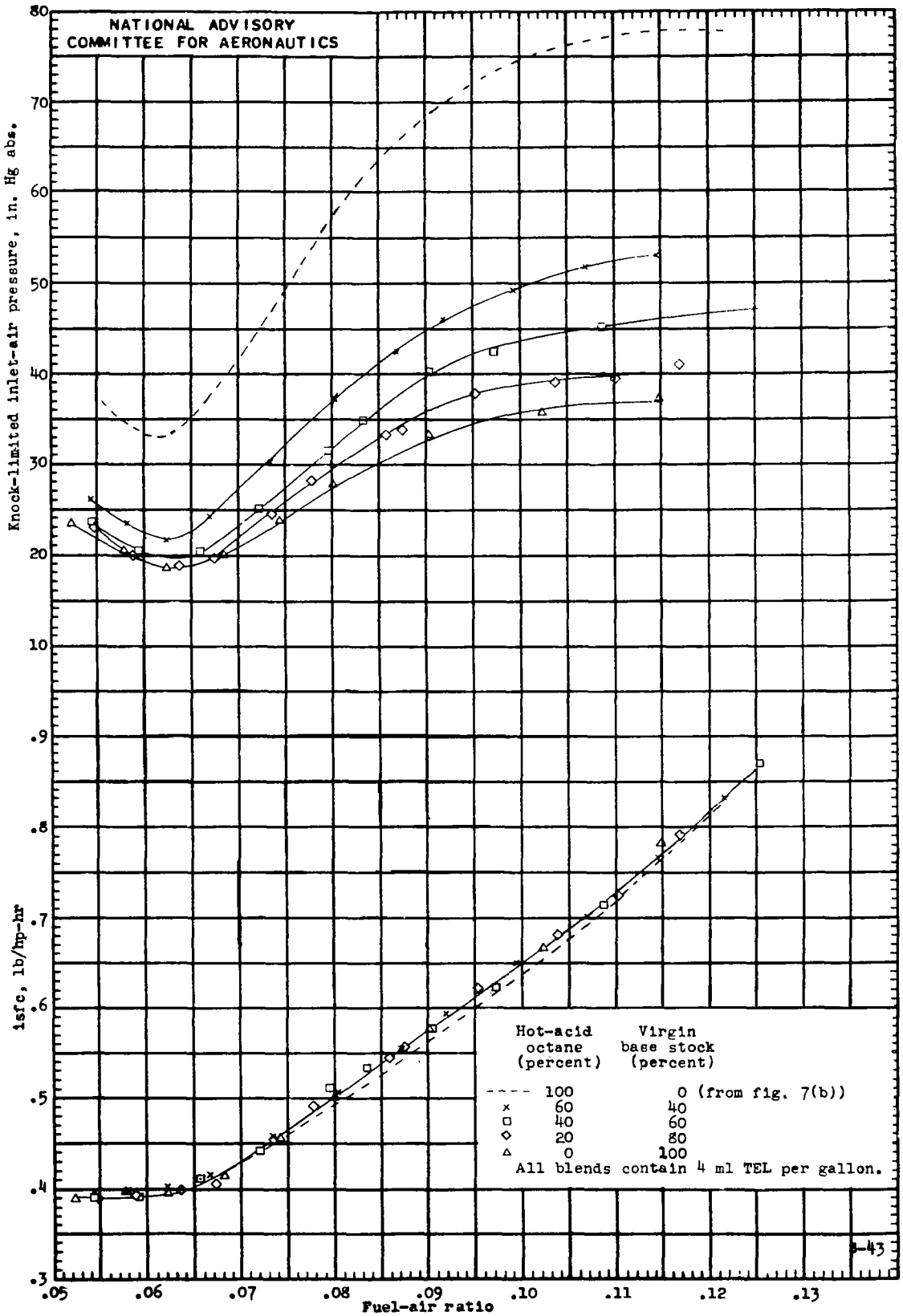


(c) Blends with one-pass catalytic stock.
Figure 6. - Concluded.

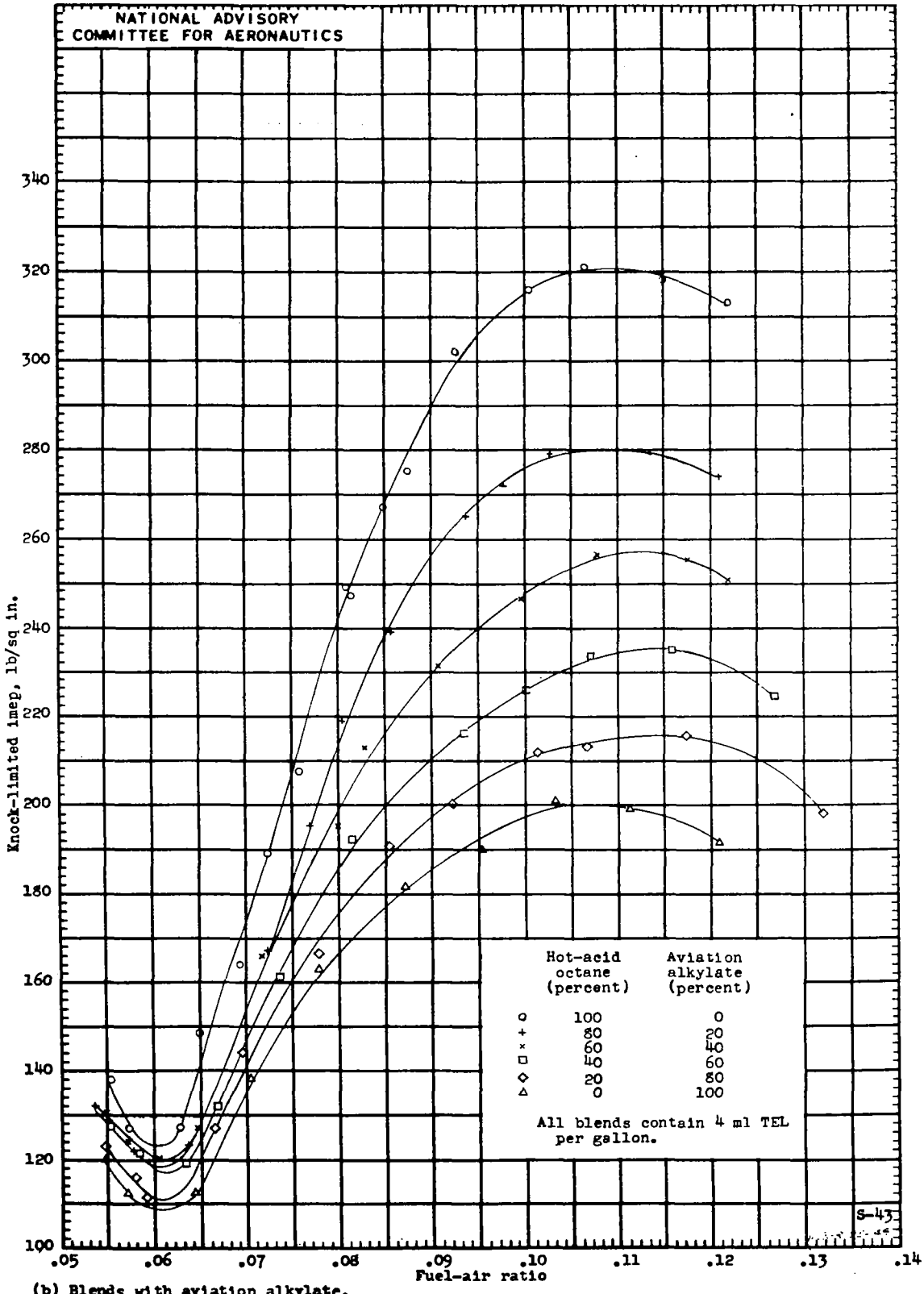


(a) Blends with virgin base stock.

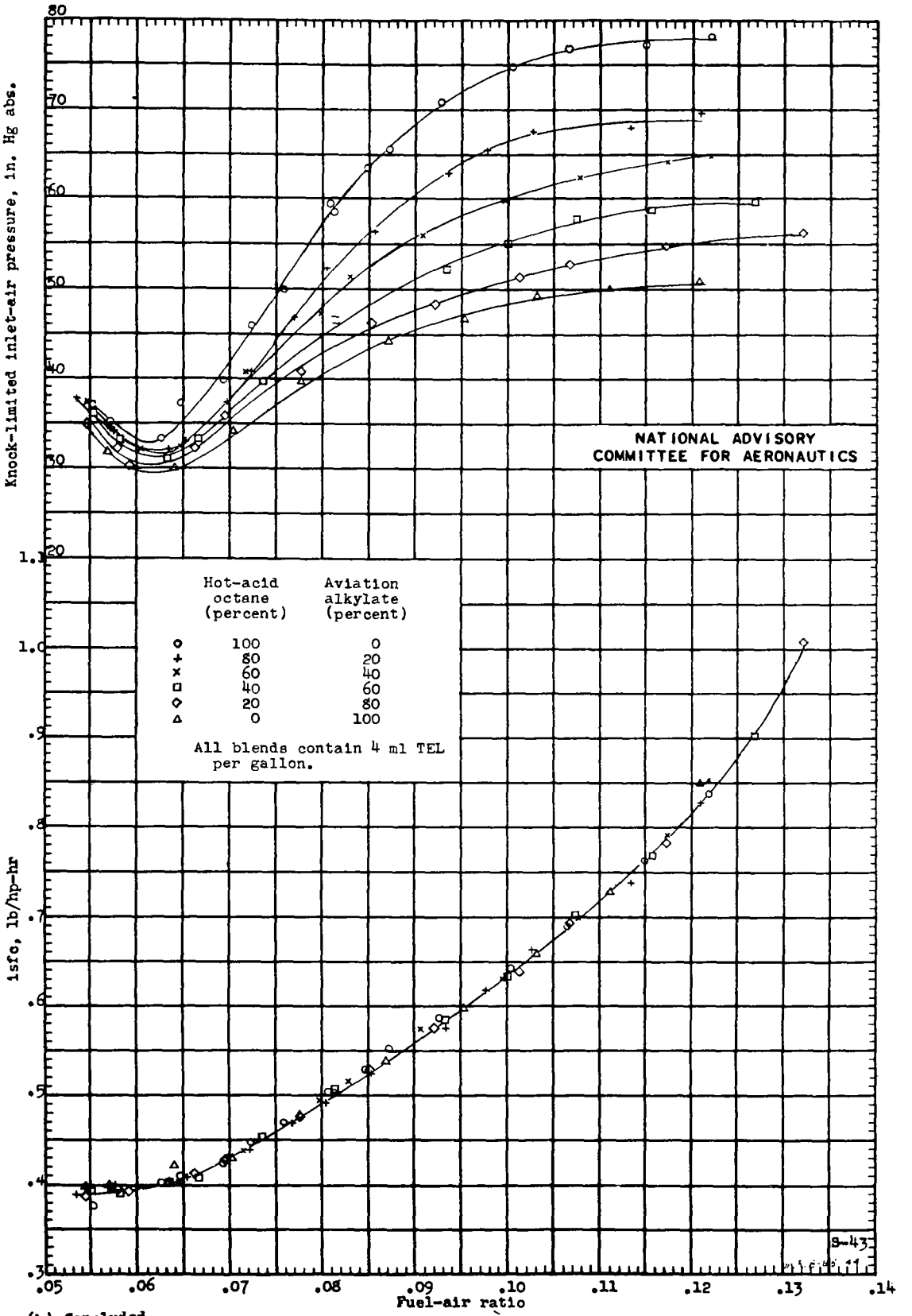
Figure 7. - Knock-limited performance of blends of hot-acid octane with virgin base stock, aviation alkylate, and one-pass catalytic stock as determined in an F-4 rating engine.



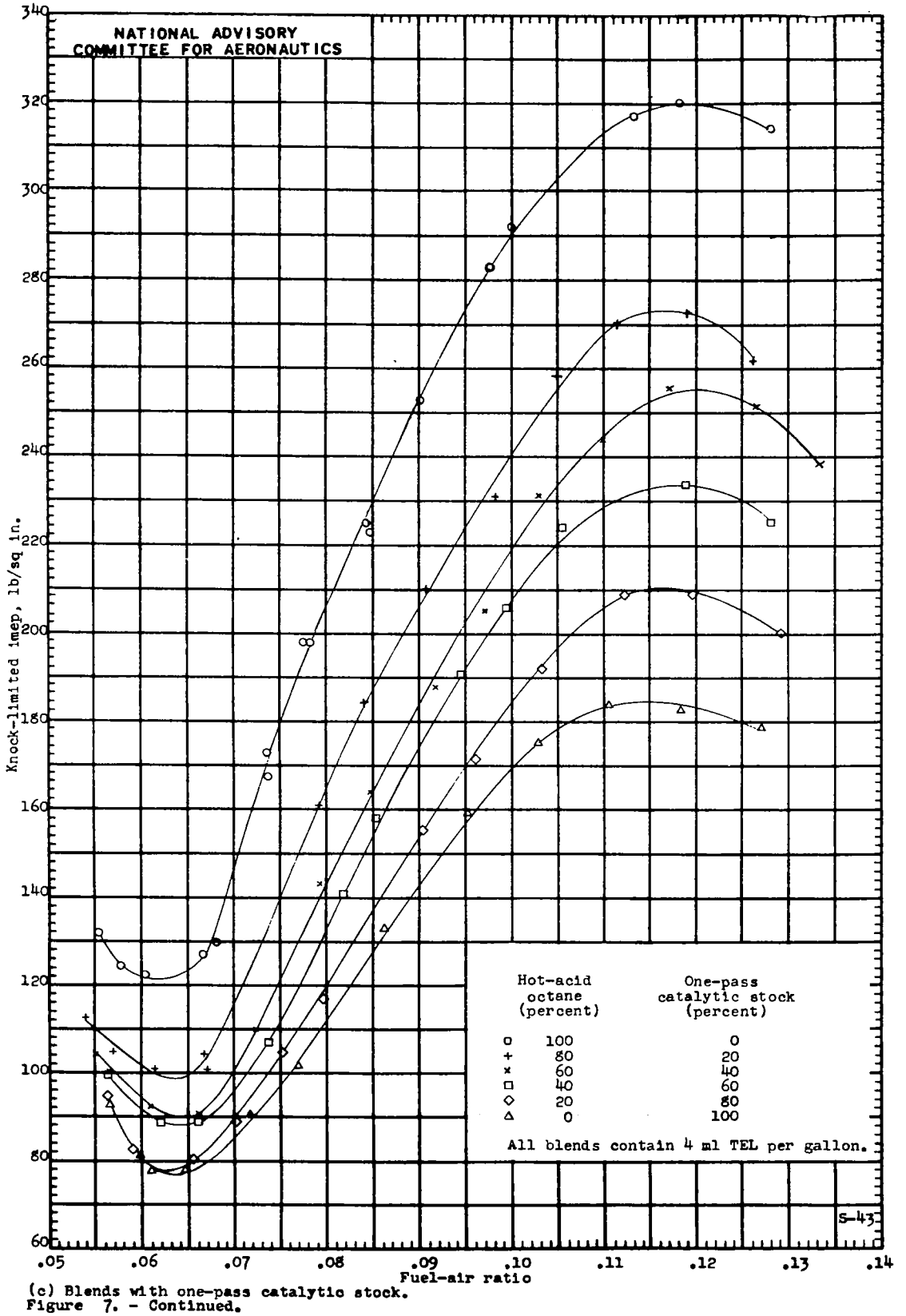
(a) Concluded.
Figure 7. - Continued.



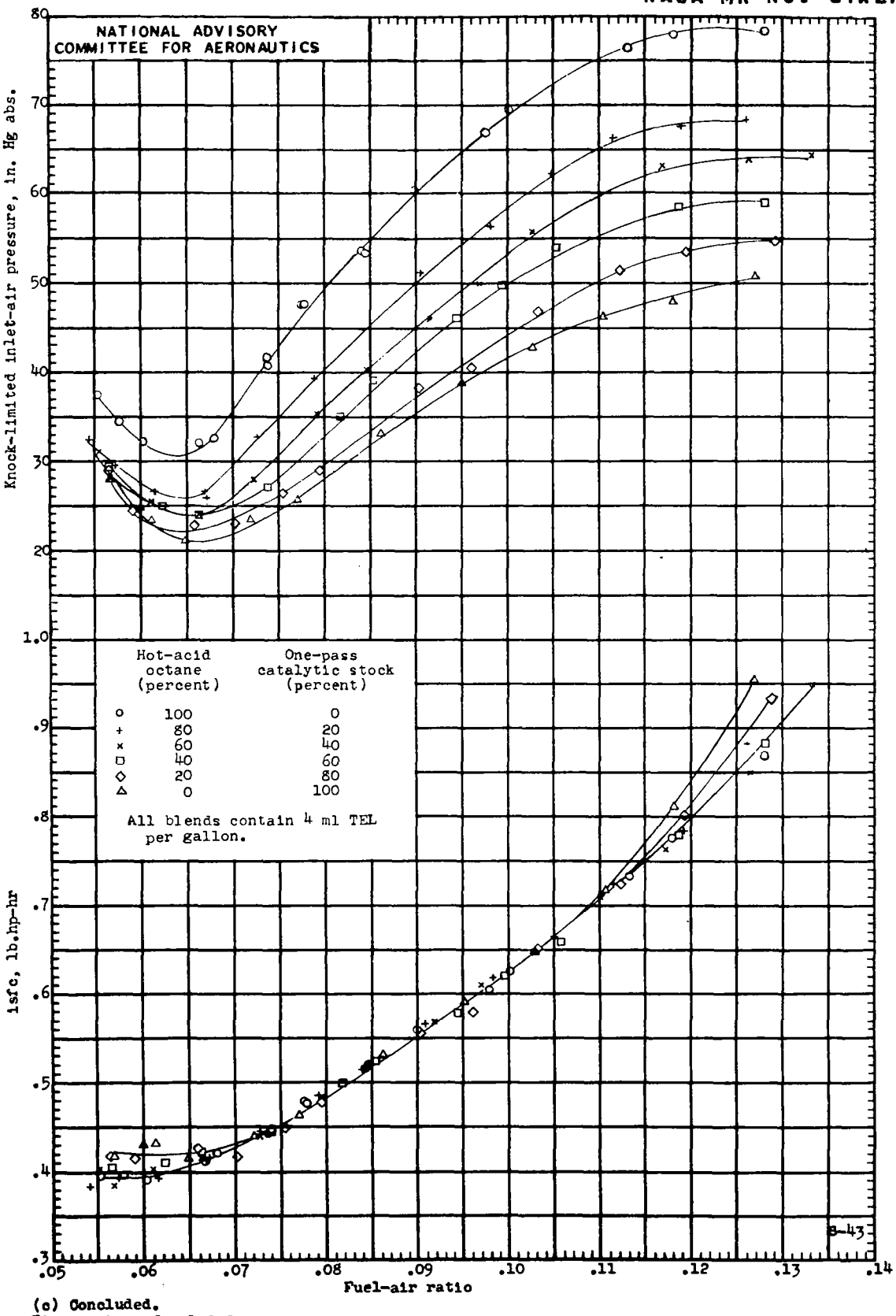
(b) Blends with aviation alkylate.
Figure 7. - Continued.



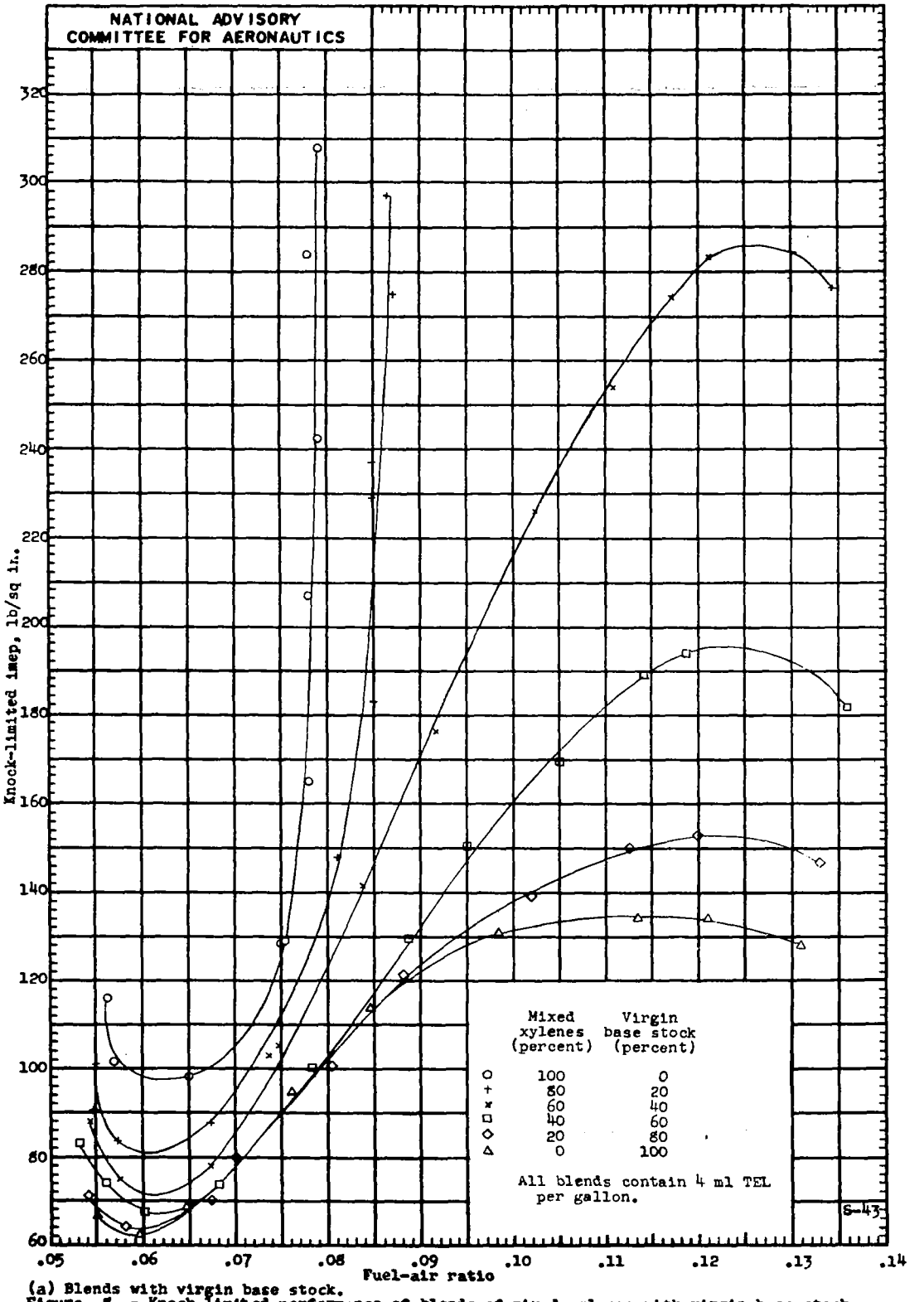
(b) Concluded.
Figure 7. - Continued.



(c) Blends with one-pass catalytic stock.
Figure 7. - Continued.

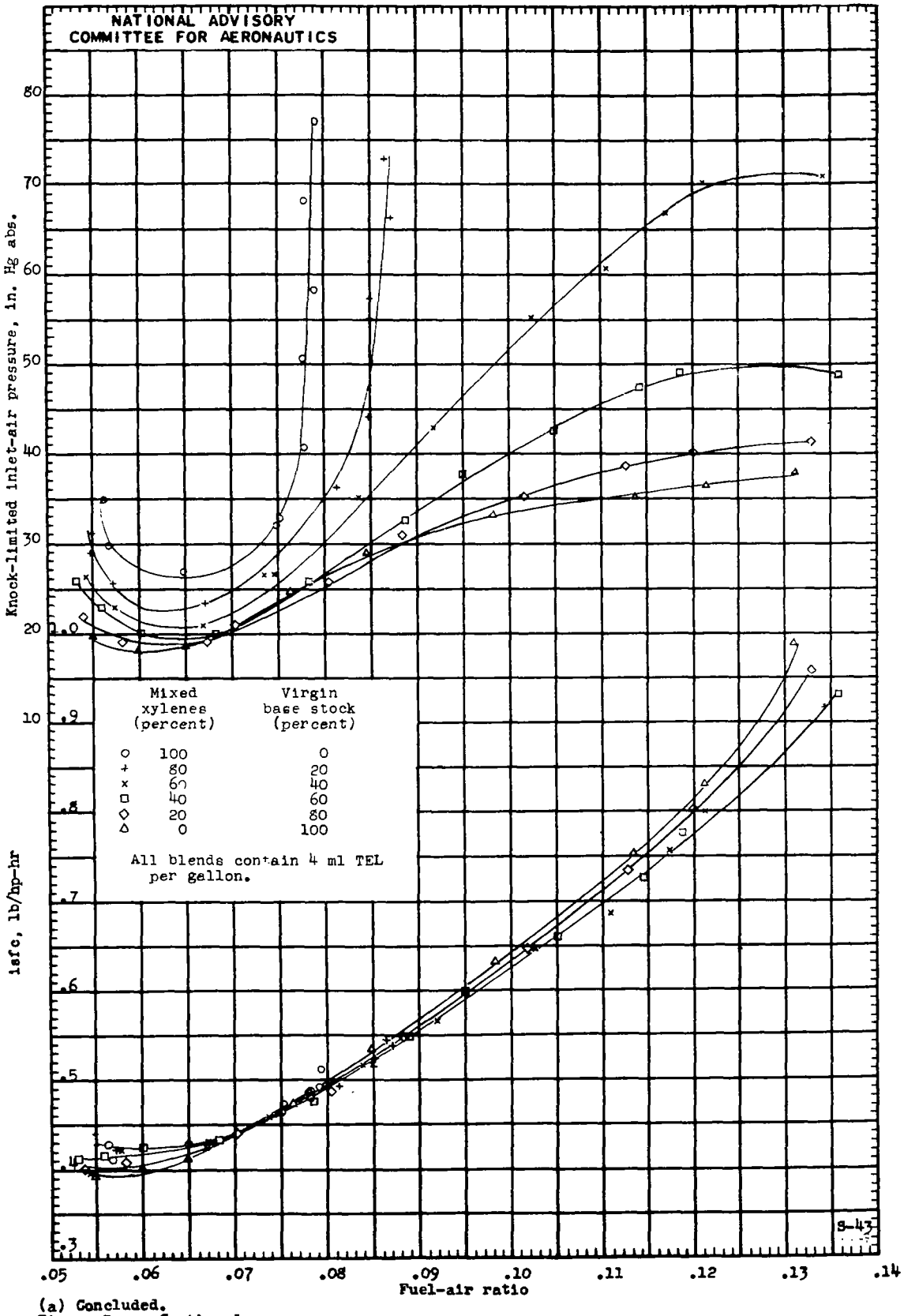


(c) Concluded.
Figure 7. - Concluded.

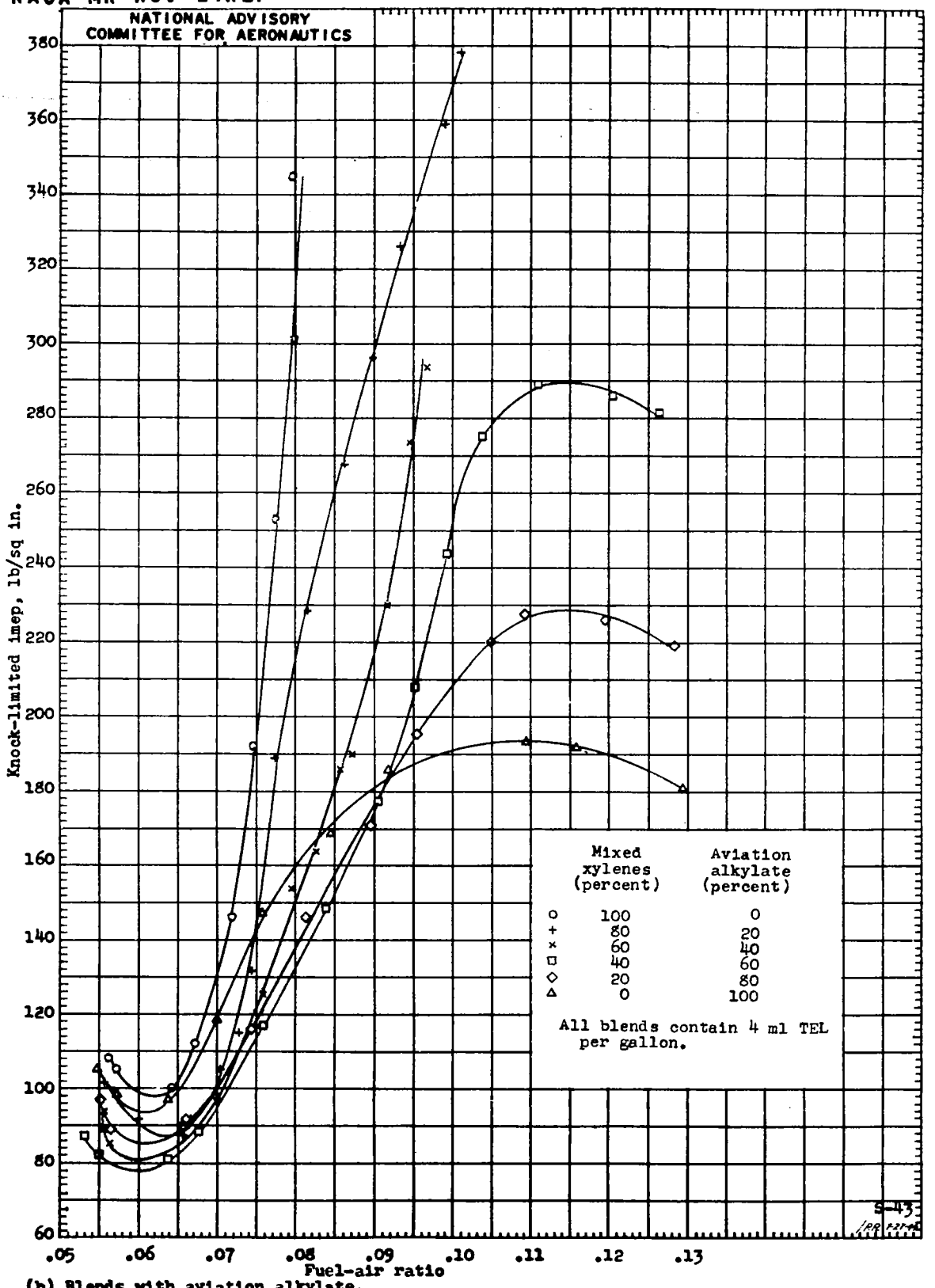


(a) Blends with virgin base stock.

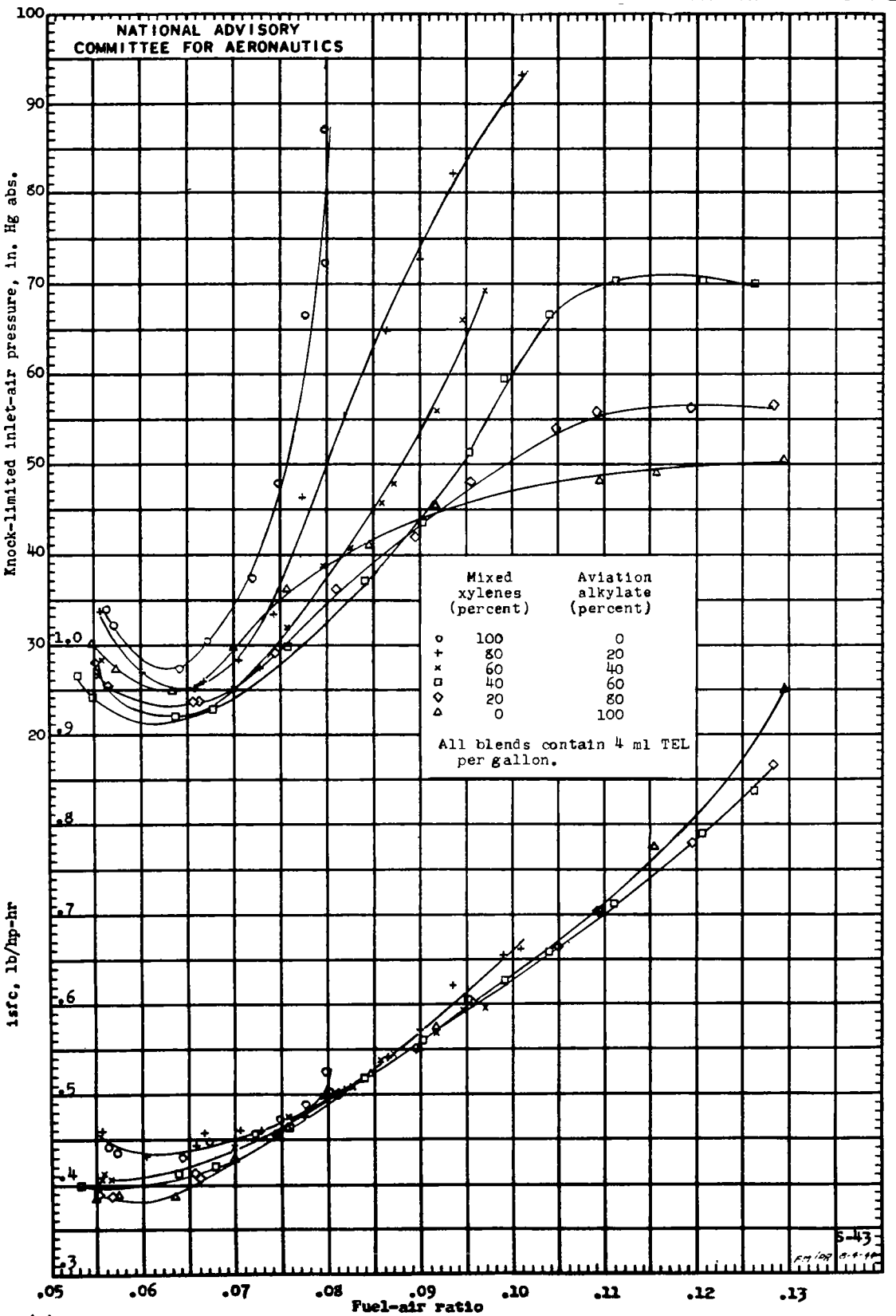
Figure 8. - Knock-limited performance of blends of mixed xylenes with virgin base stock, aviation alkylate, and one-pass catalytic stock as determined in an F-4 rating engine.



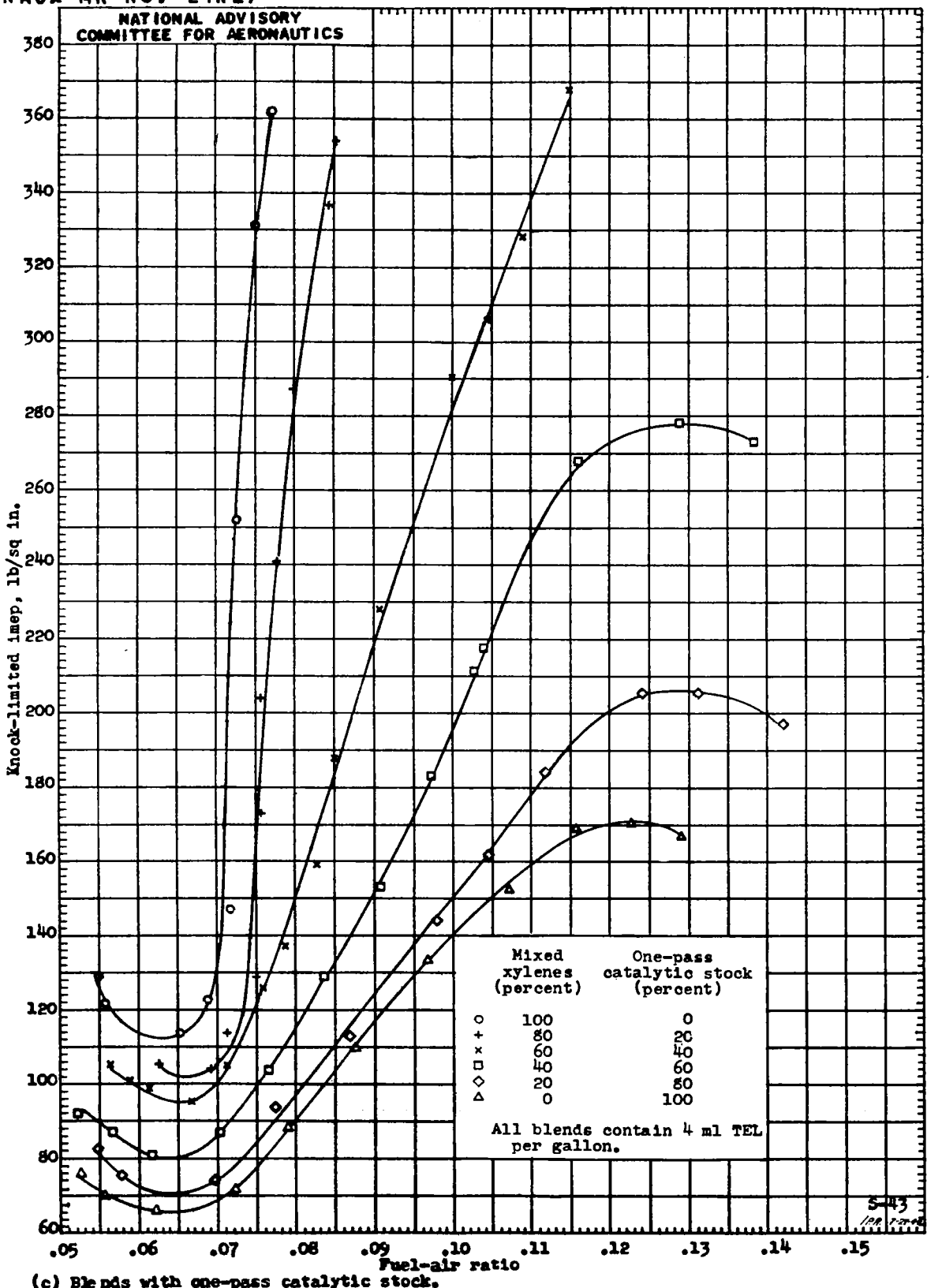
(a) Concluded.
Figure 8 . - Continued.



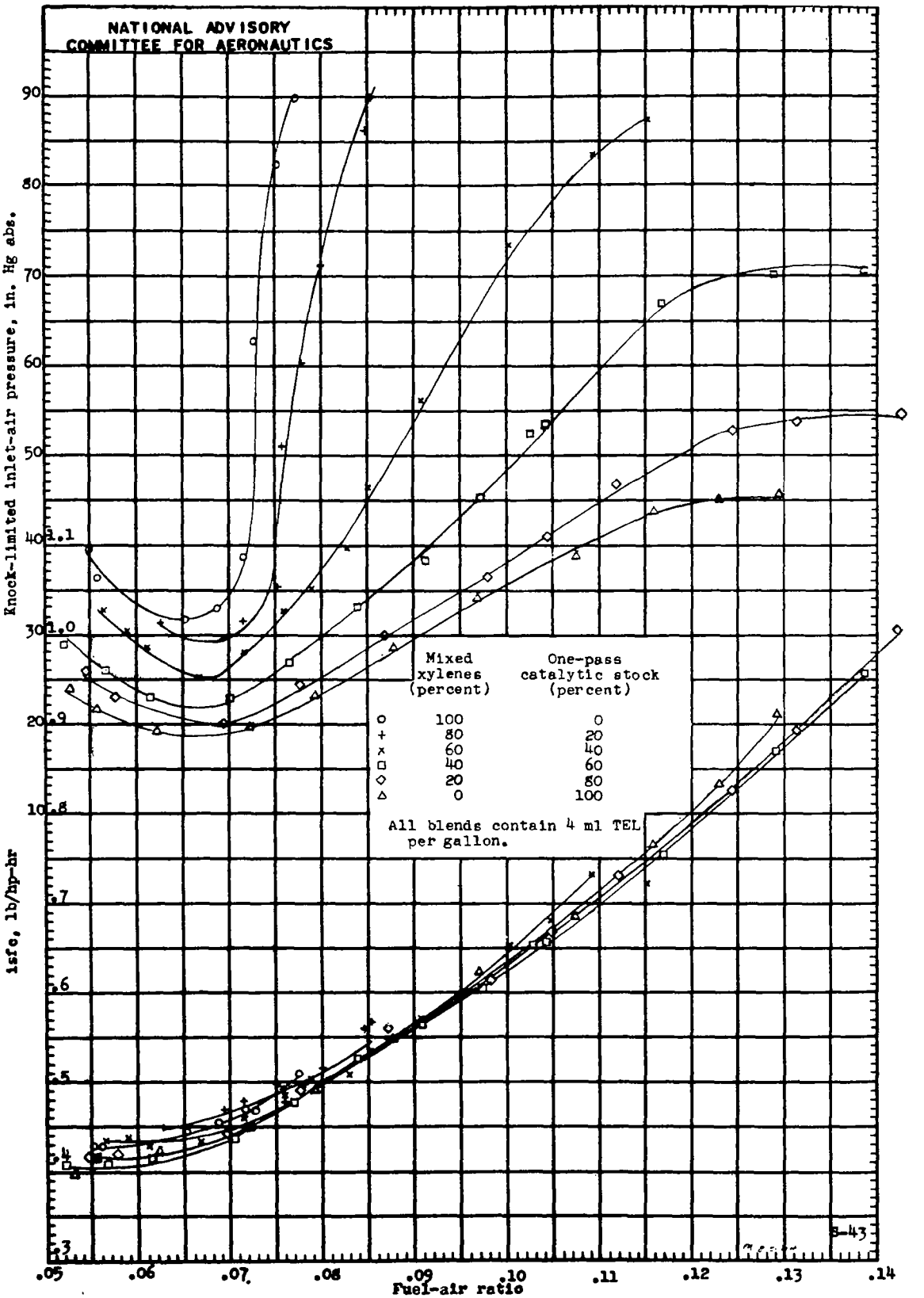
(b) Blends with aviation alkylate.
Figure 8. - Continued.



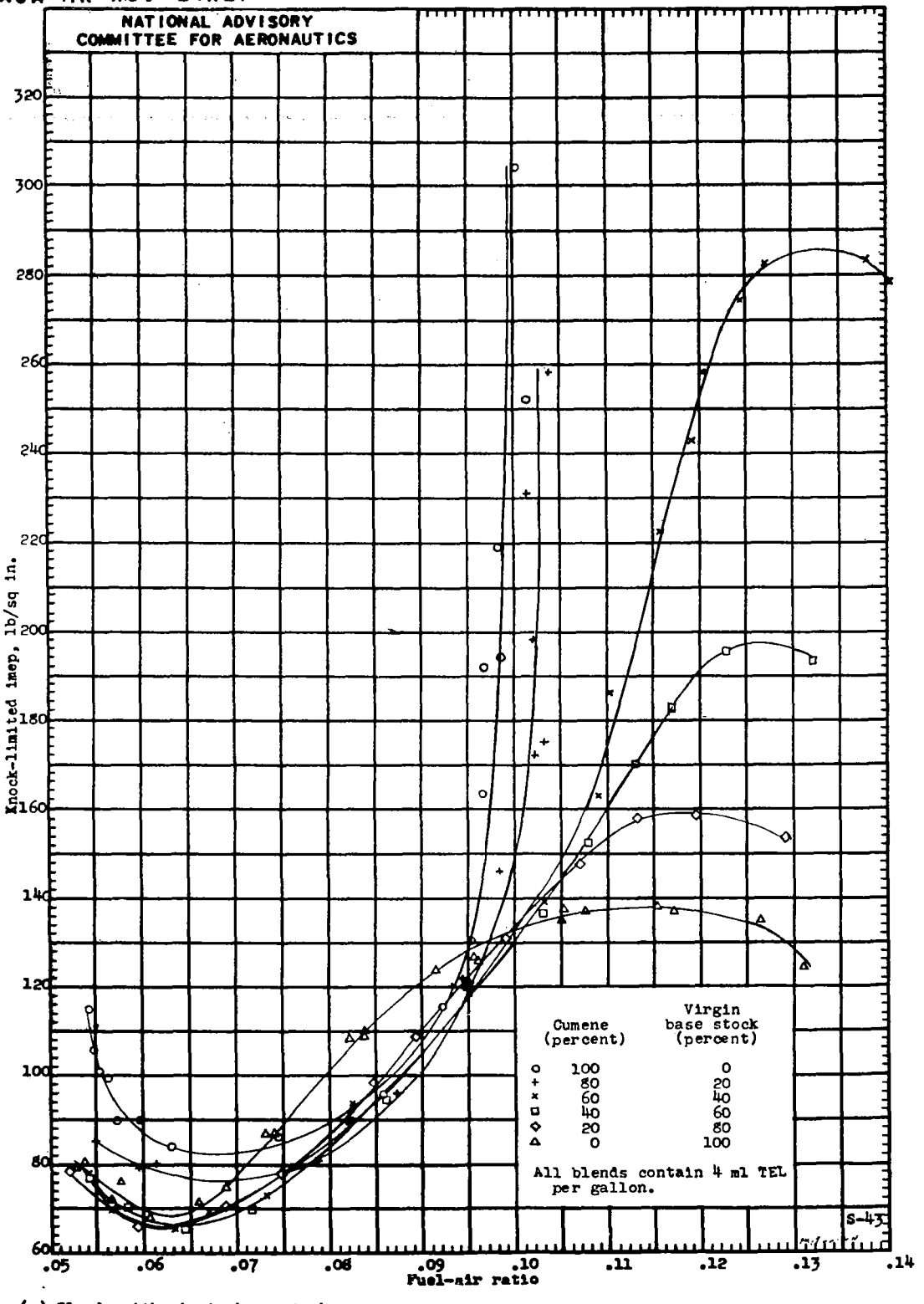
(b) Concluded.
Figure 8. - Continued.



(c) Blends with one-pass catalytic stock.
Figure 8. - Continued.

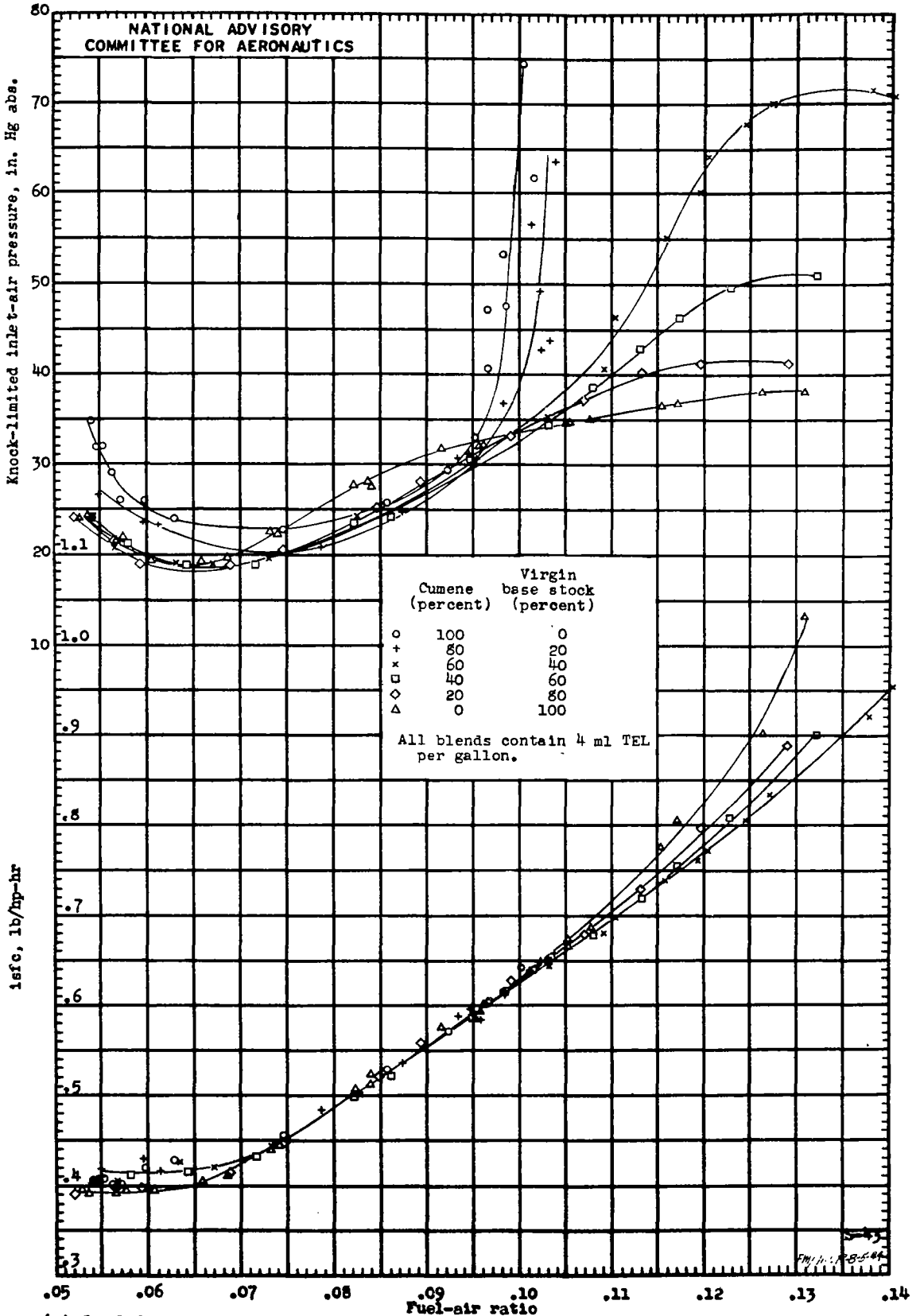


(c) Concluded.
Figure 8. - Concluded.

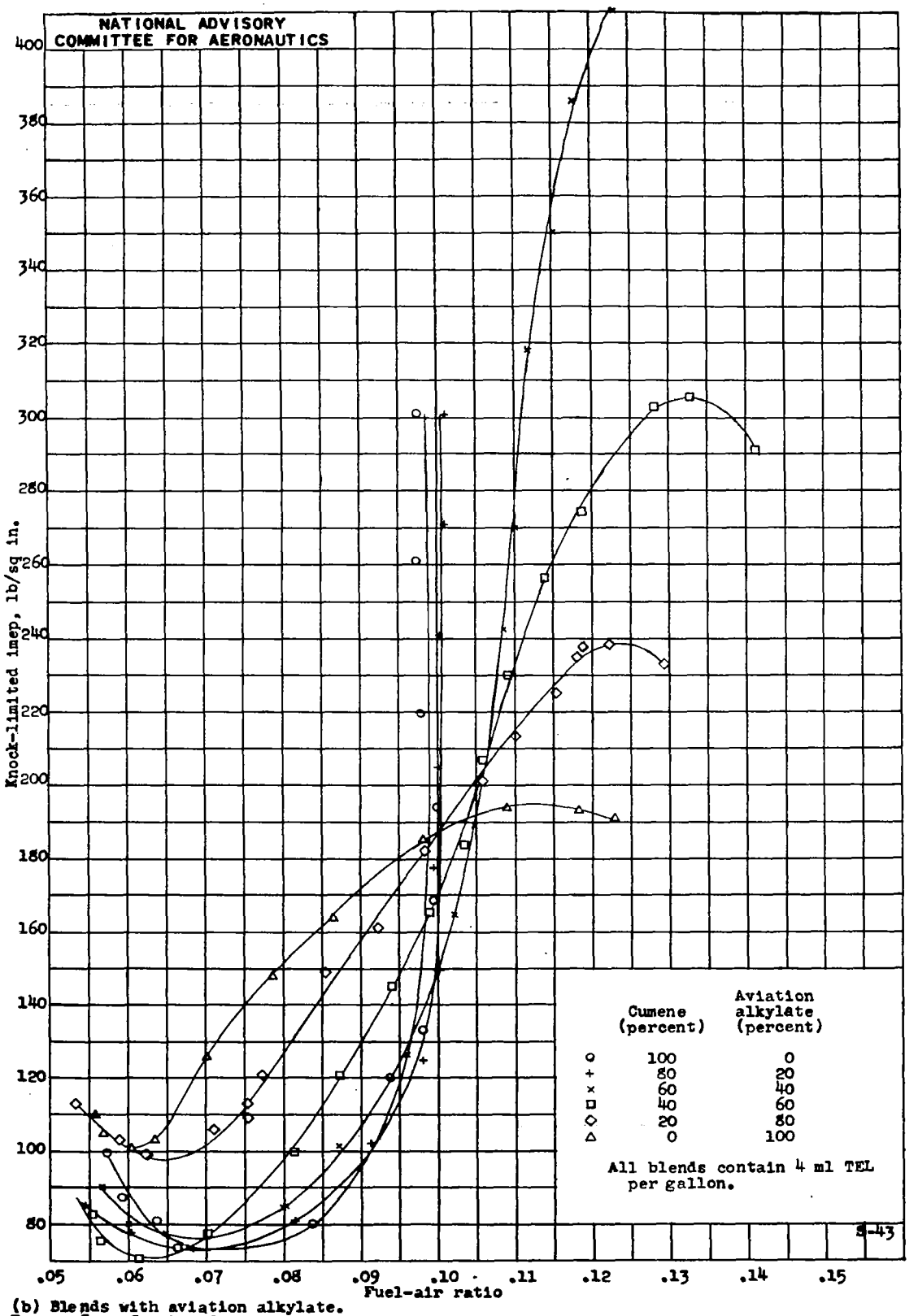


(a) Blends with virgin base stock.

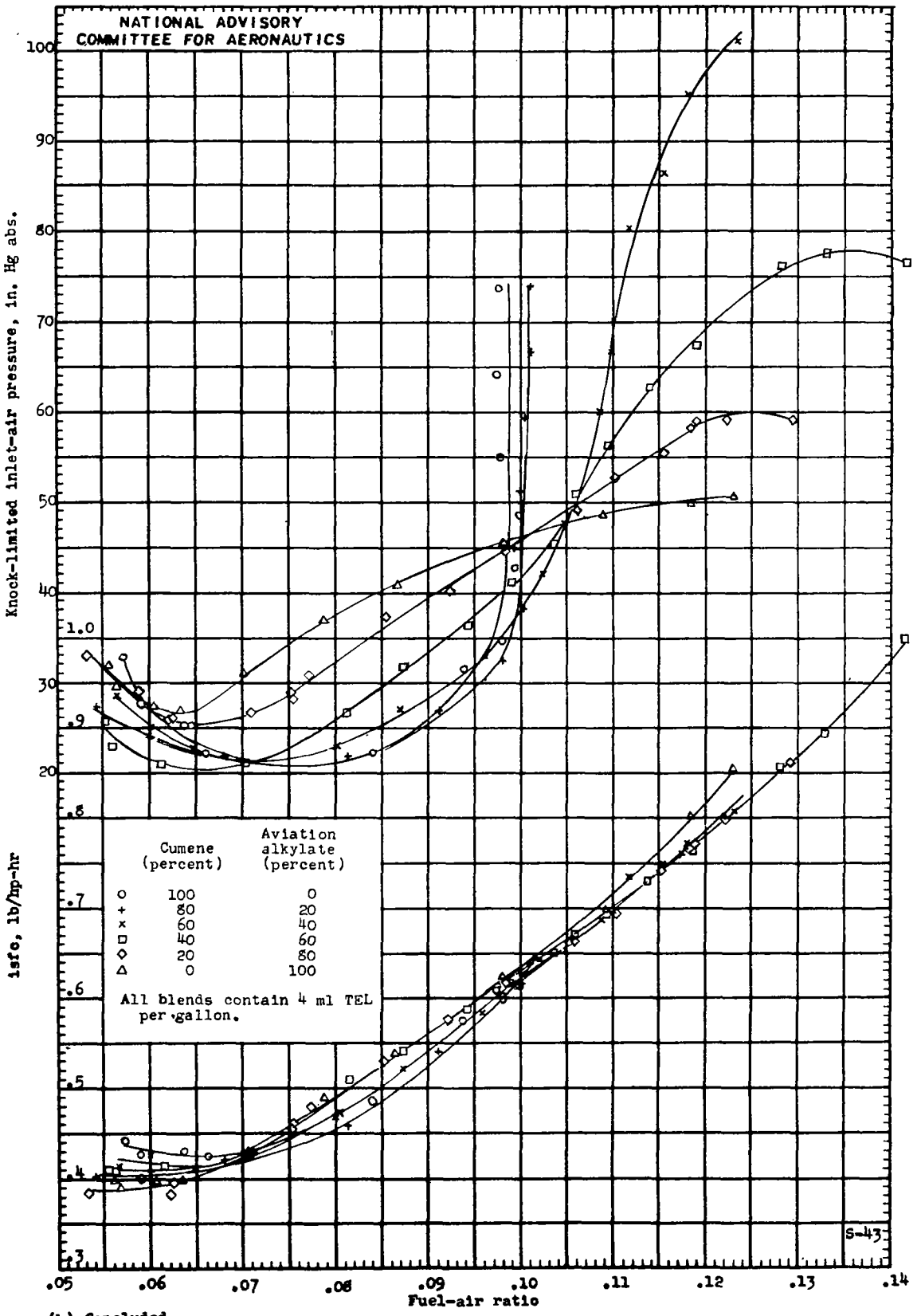
Figure 9. - Knock-limited performance of blends of cumene (isopropylbenzene) with virgin base stock, aviation alkylate, and one-pass catalytic stock as determined in an F-4 rating engine.



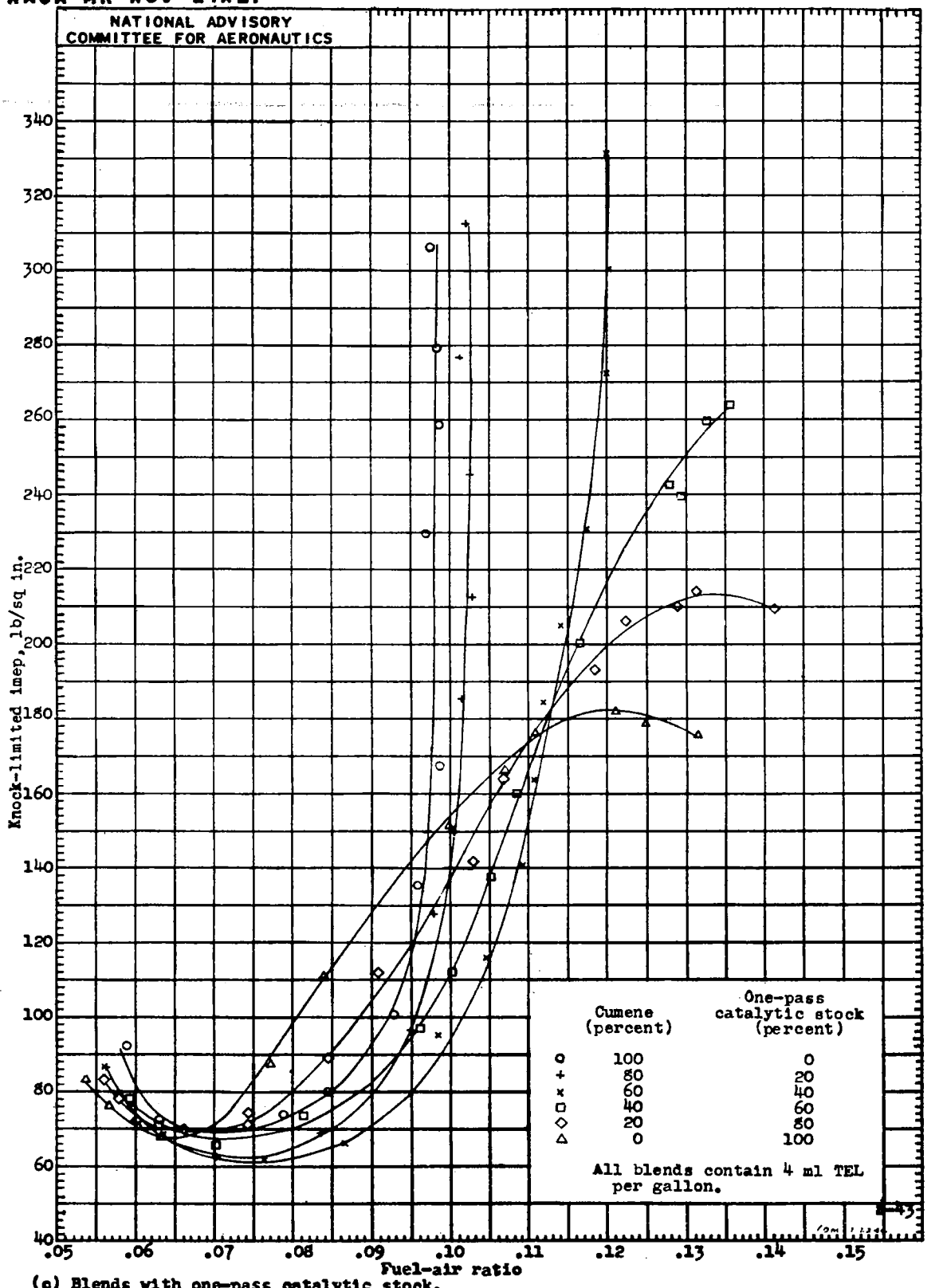
(a) Concluded.
Figure 9. - Continued.



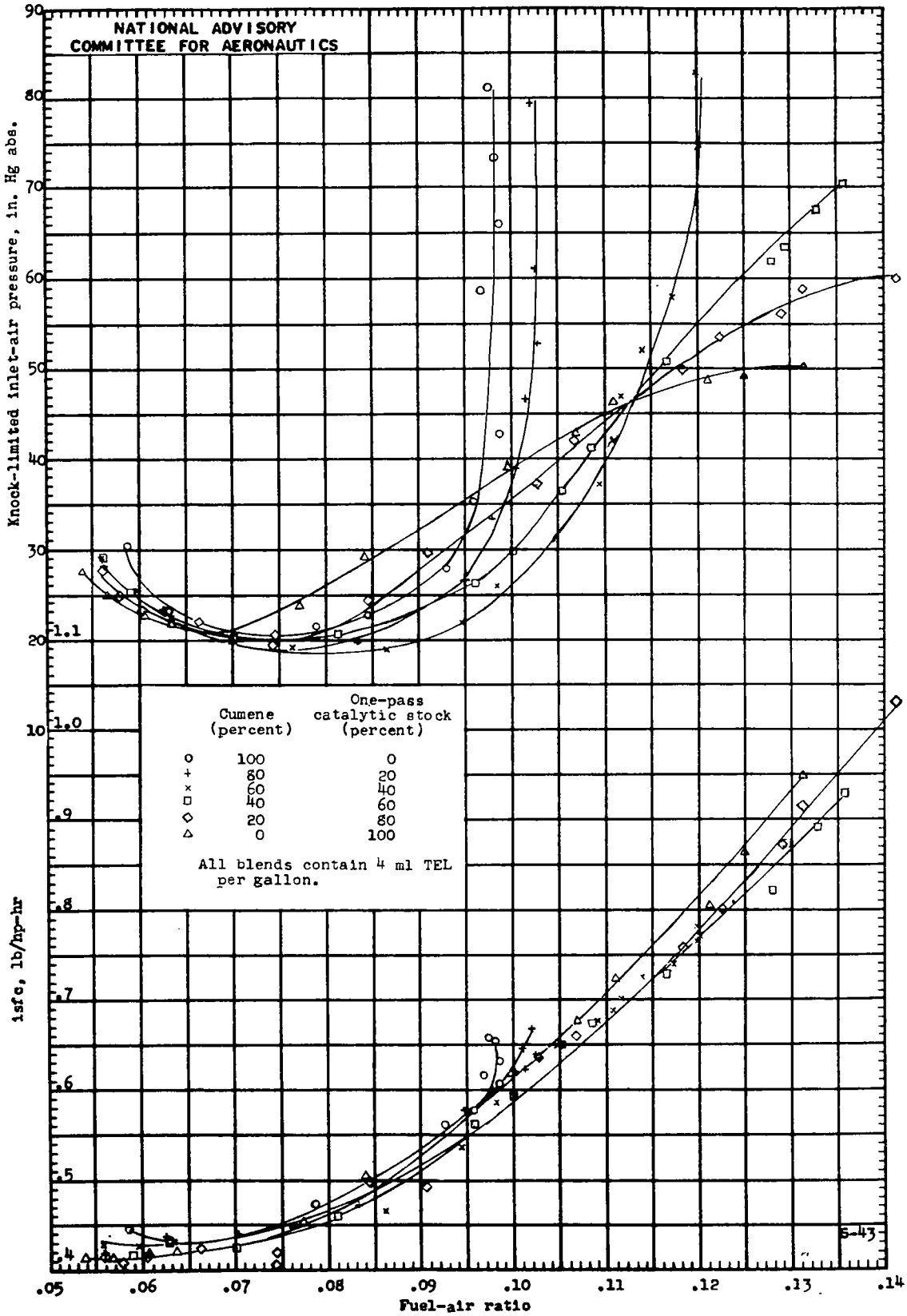
(b) Blends with aviation alkylate.
Figure 9. - Continued.



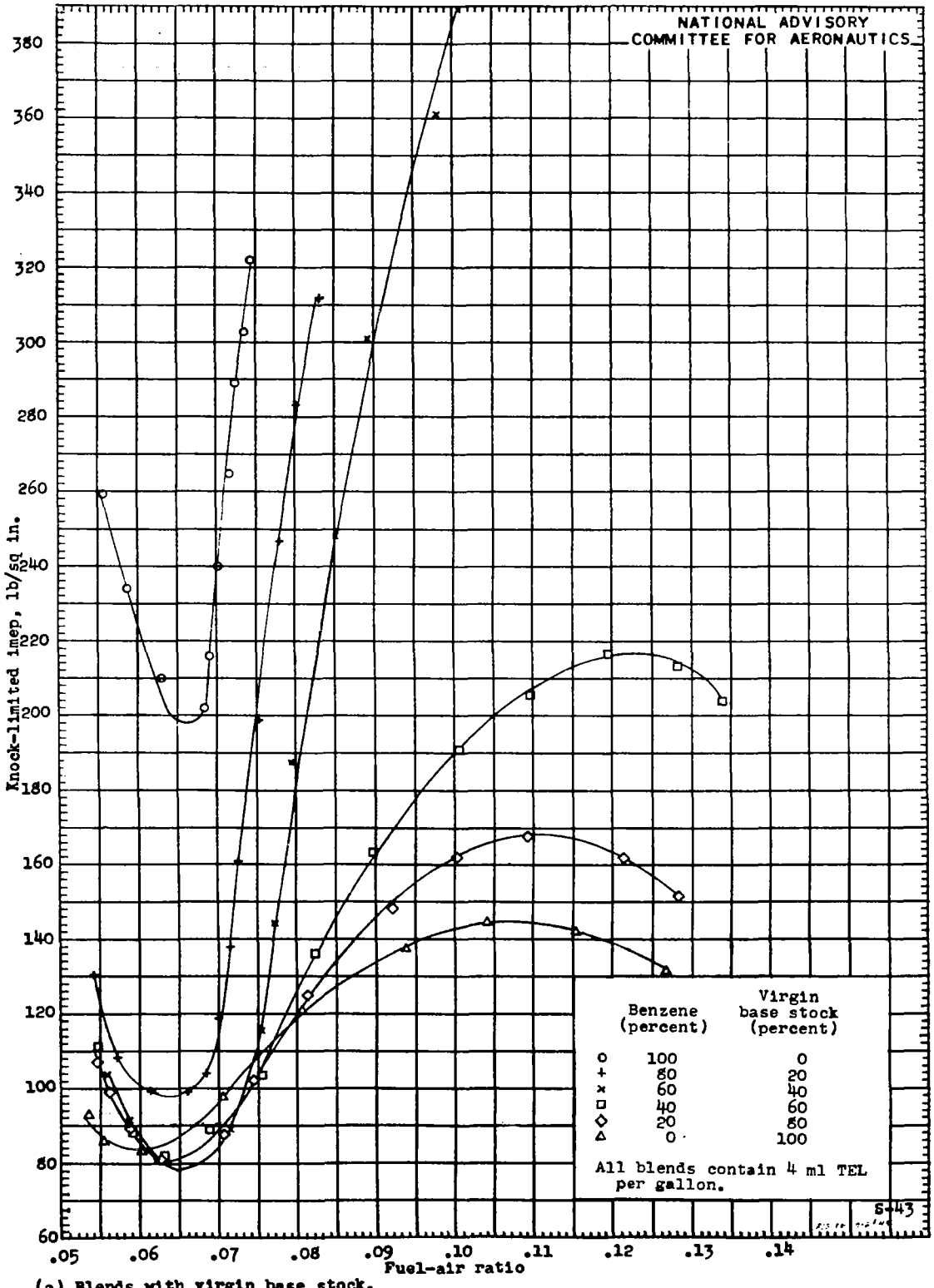
(b) Concluded.
Figure 9. - Continued.



(c) Blends with one-pass catalytic stock.
Figure 9. - Continued.

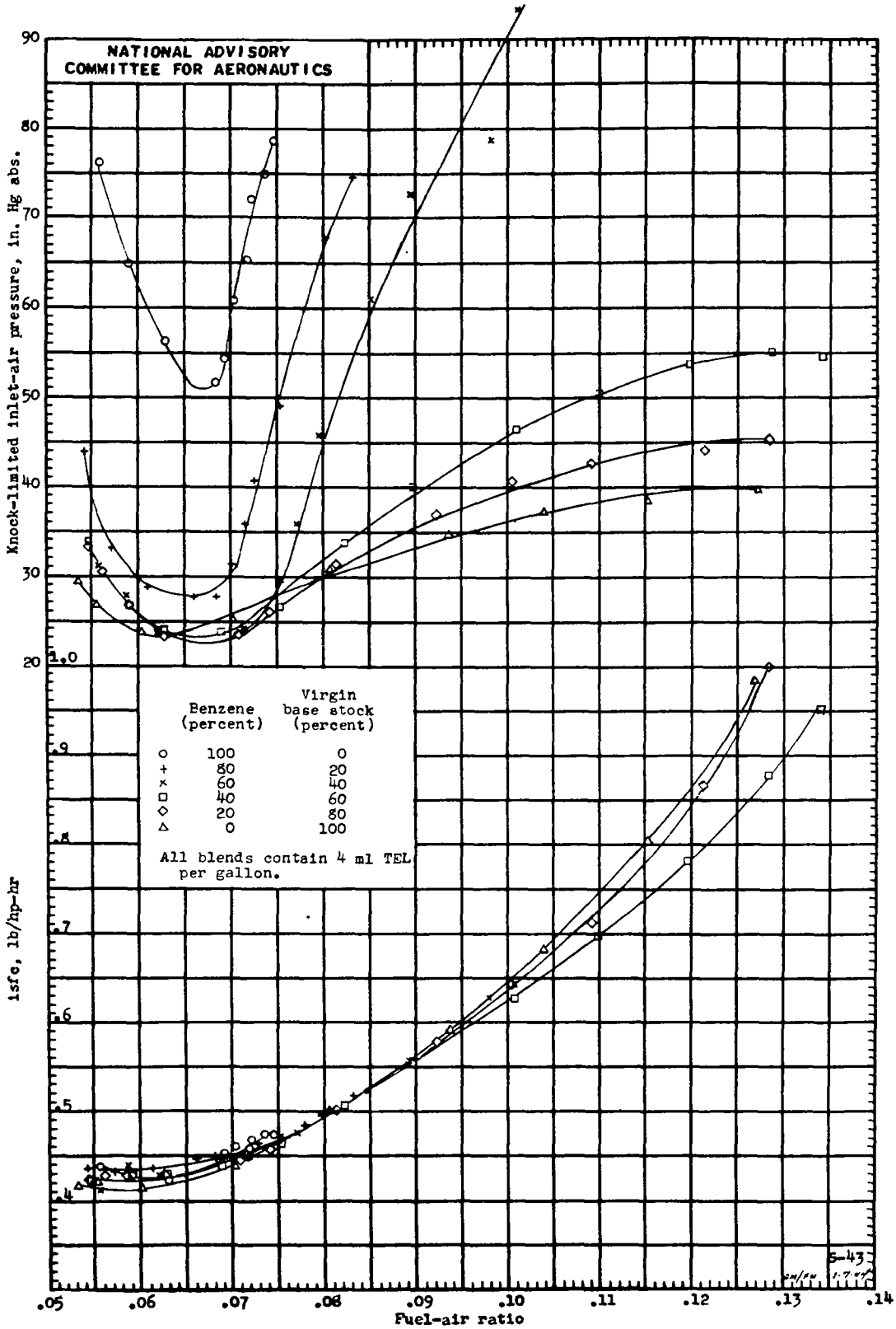


(c) Concluded.
Figure 9. - Concluded.

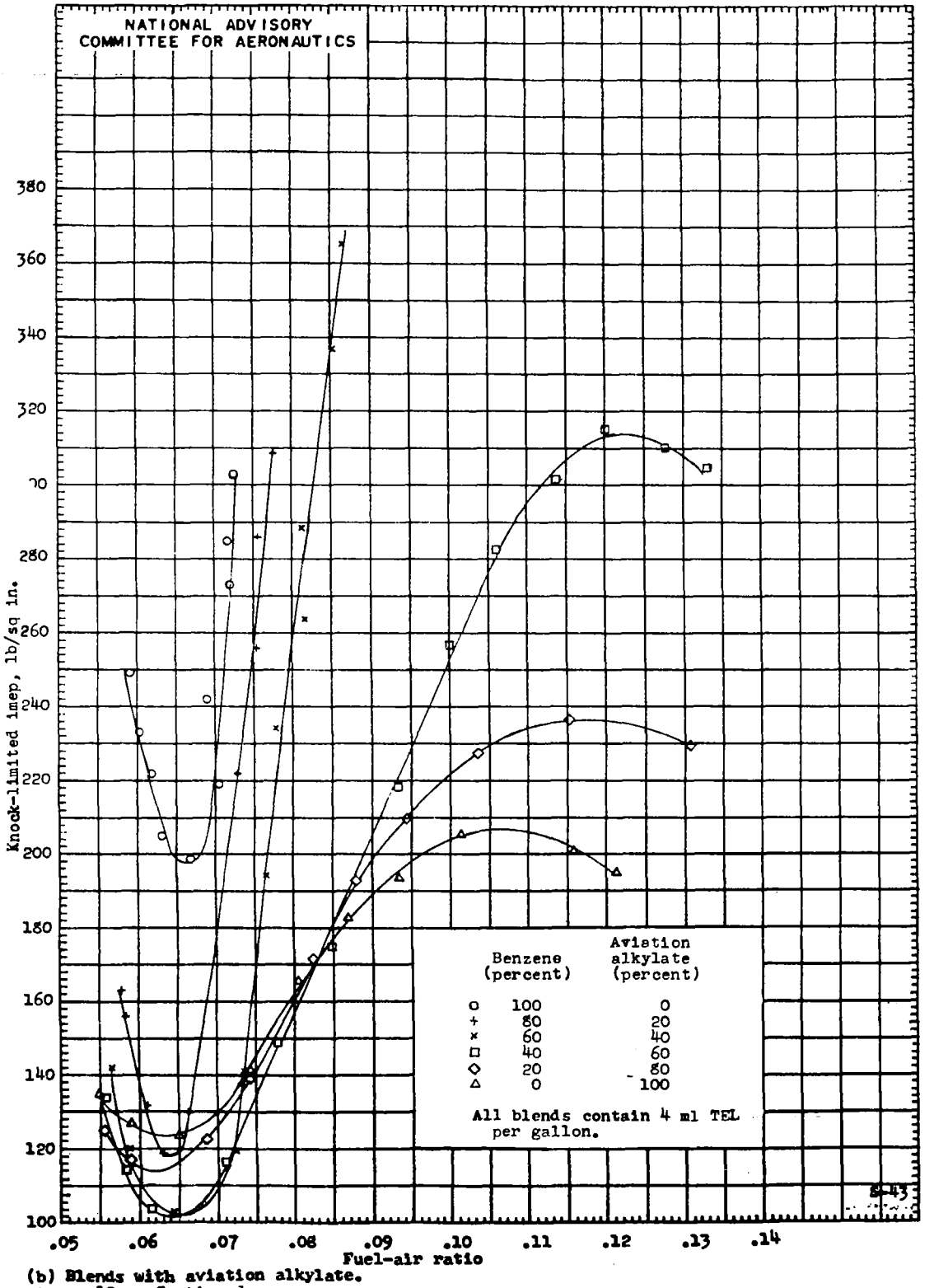


(a) Blends with virgin base stock.

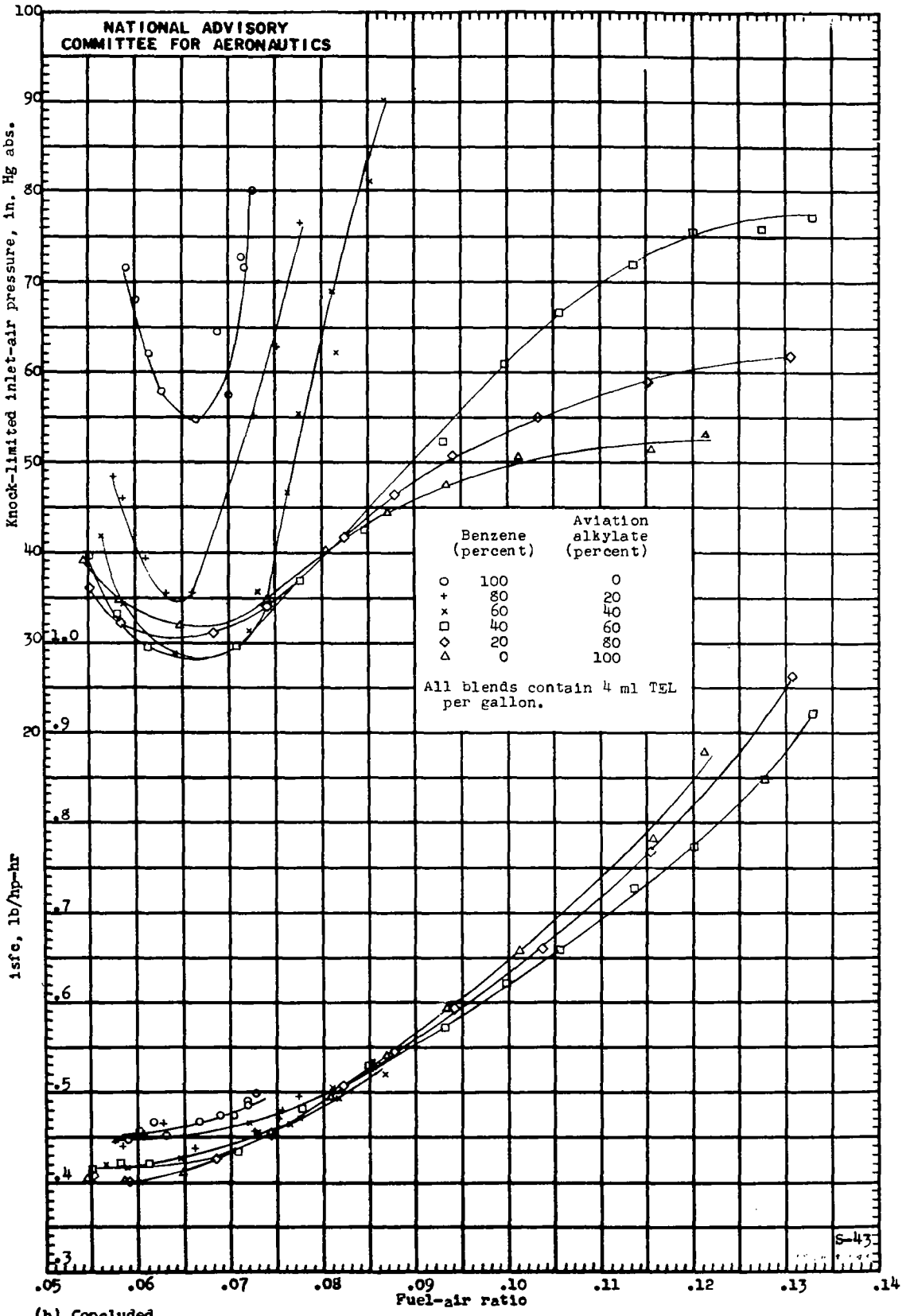
Figure 10. - Knock-limited performance of blends of benzene with virgin base stock, aviation alkylate, and one-pass catalytic stock as determined in an F-4 rating engine.



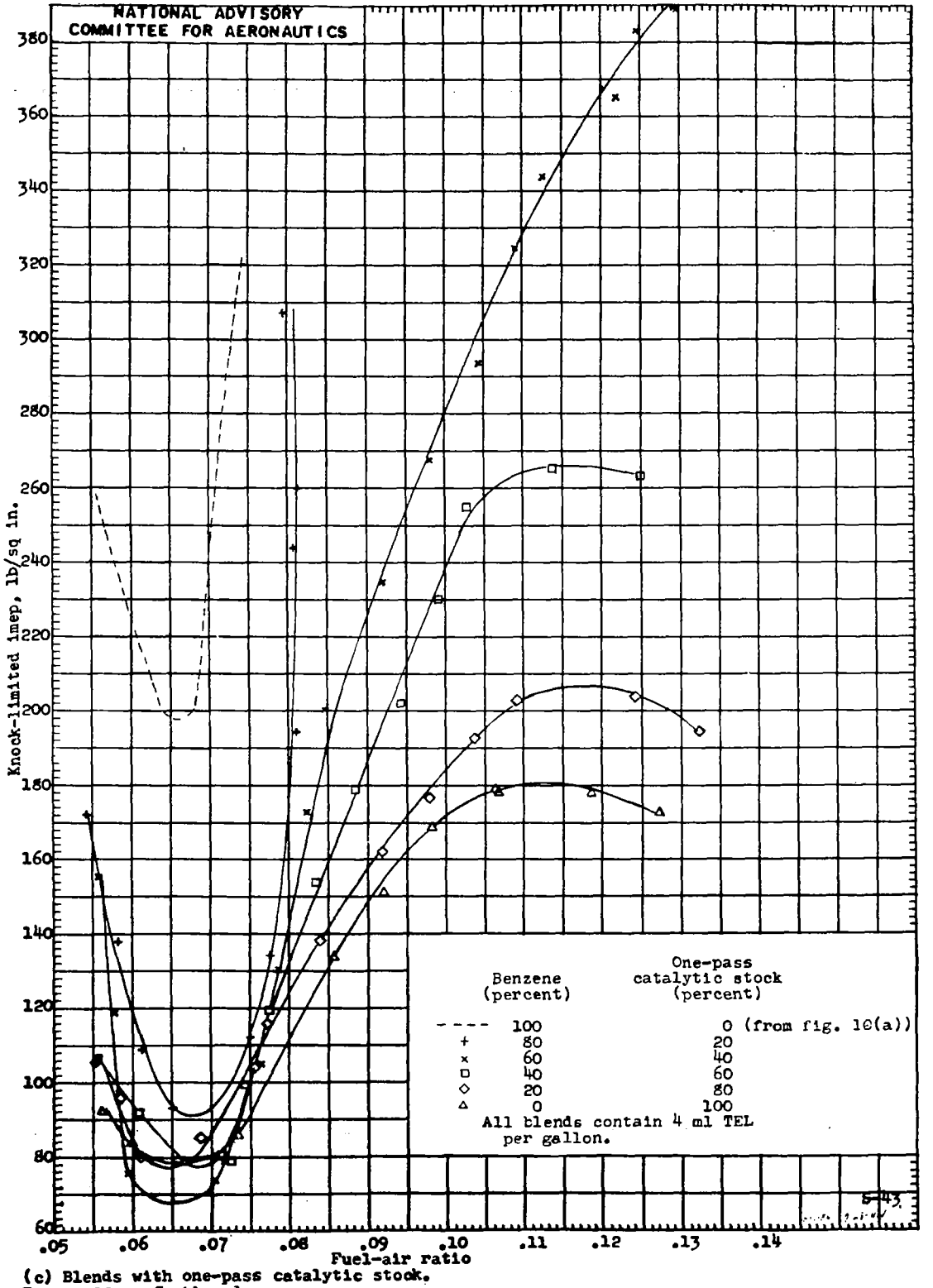
(a) Concluded.
Figure 10. - Continued.



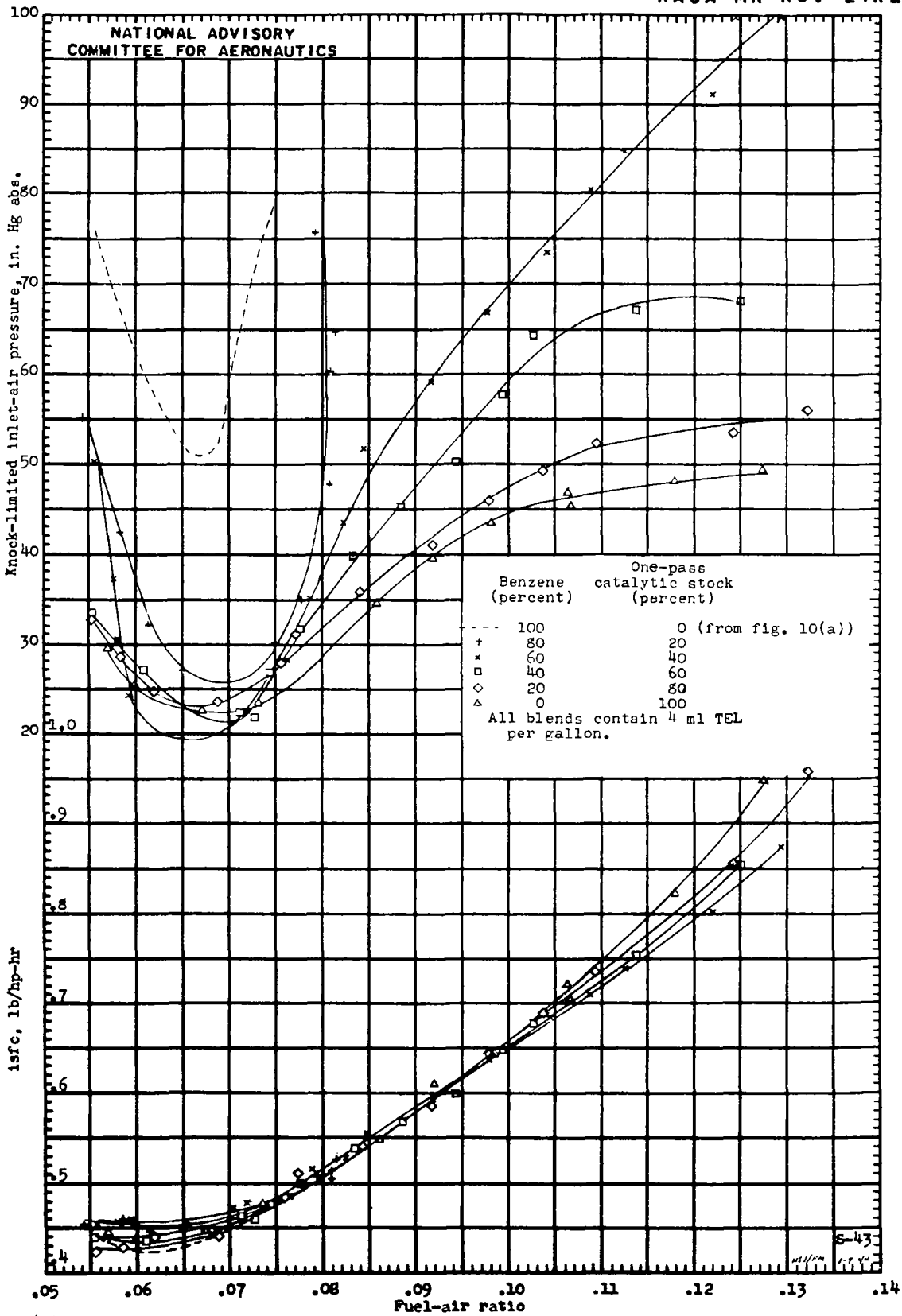
(b) Blends with aviation alkylate.
Figure 10. - Continued.



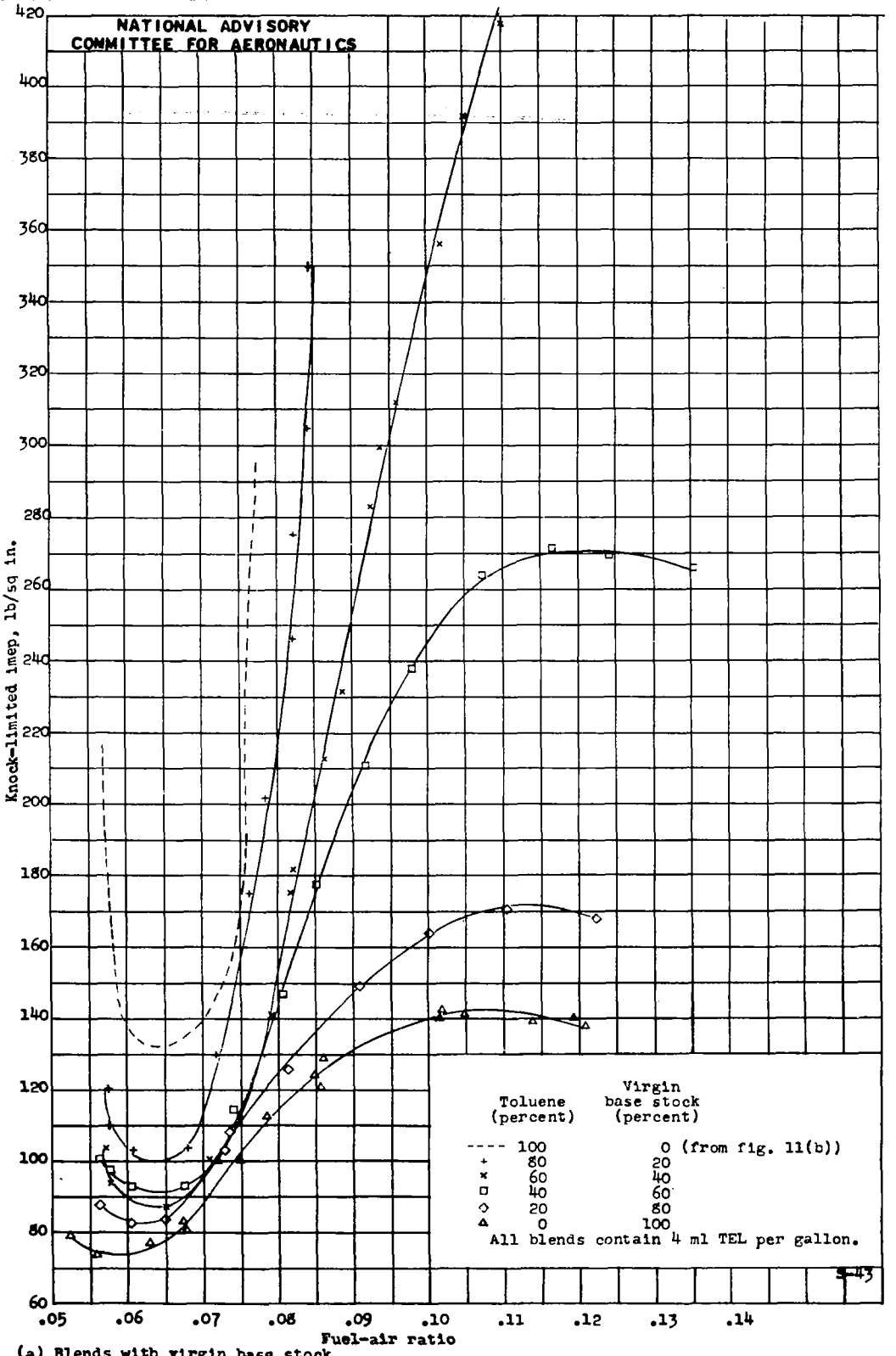
(b) Concluded.
Figure 10. - Continued.



(c) Blends with one-pass catalytic stock.
Figure 10. - Continued.

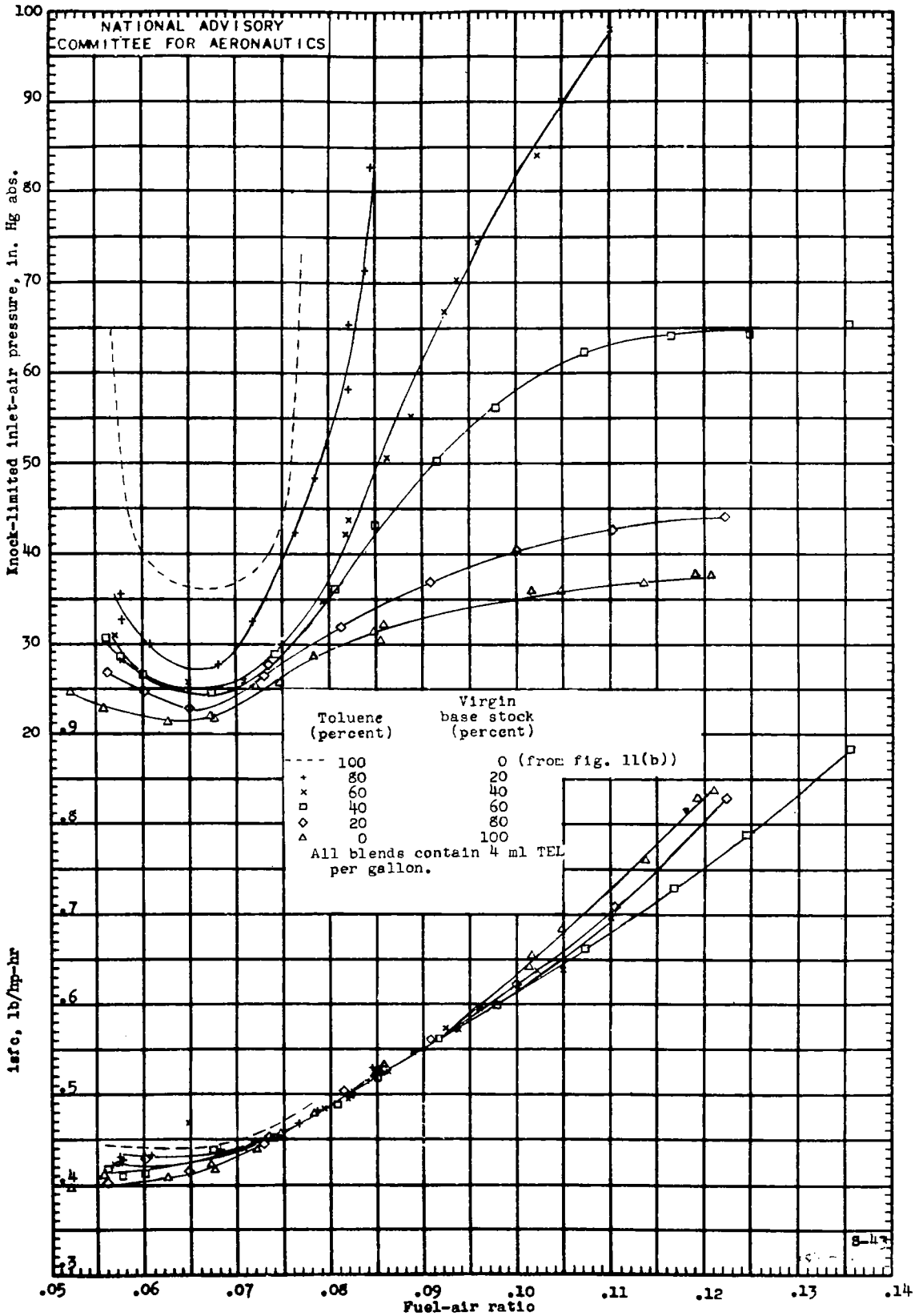


(c) Concluded.
Figure 10. - Concluded.

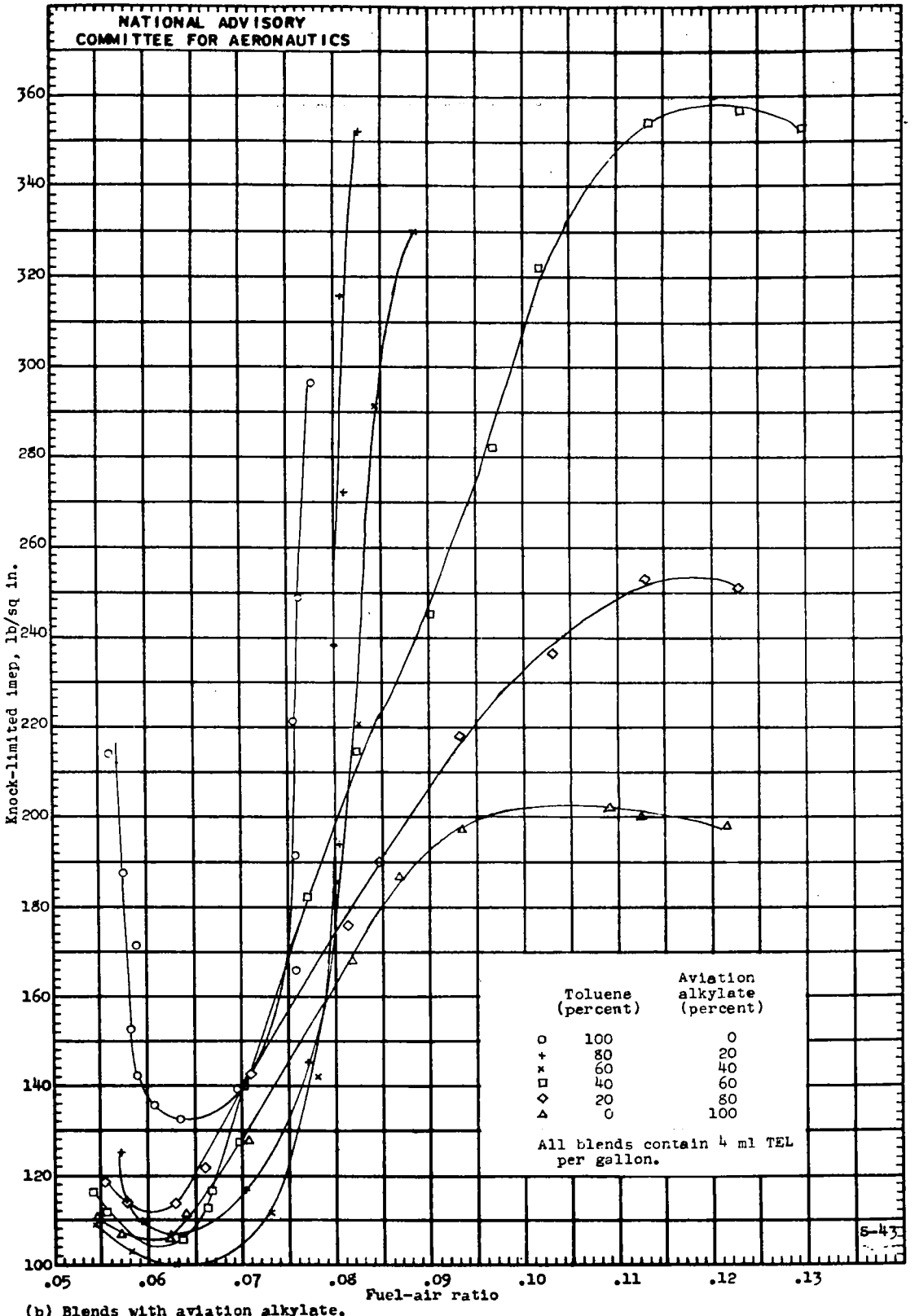


(a) Blends with virgin base stock.

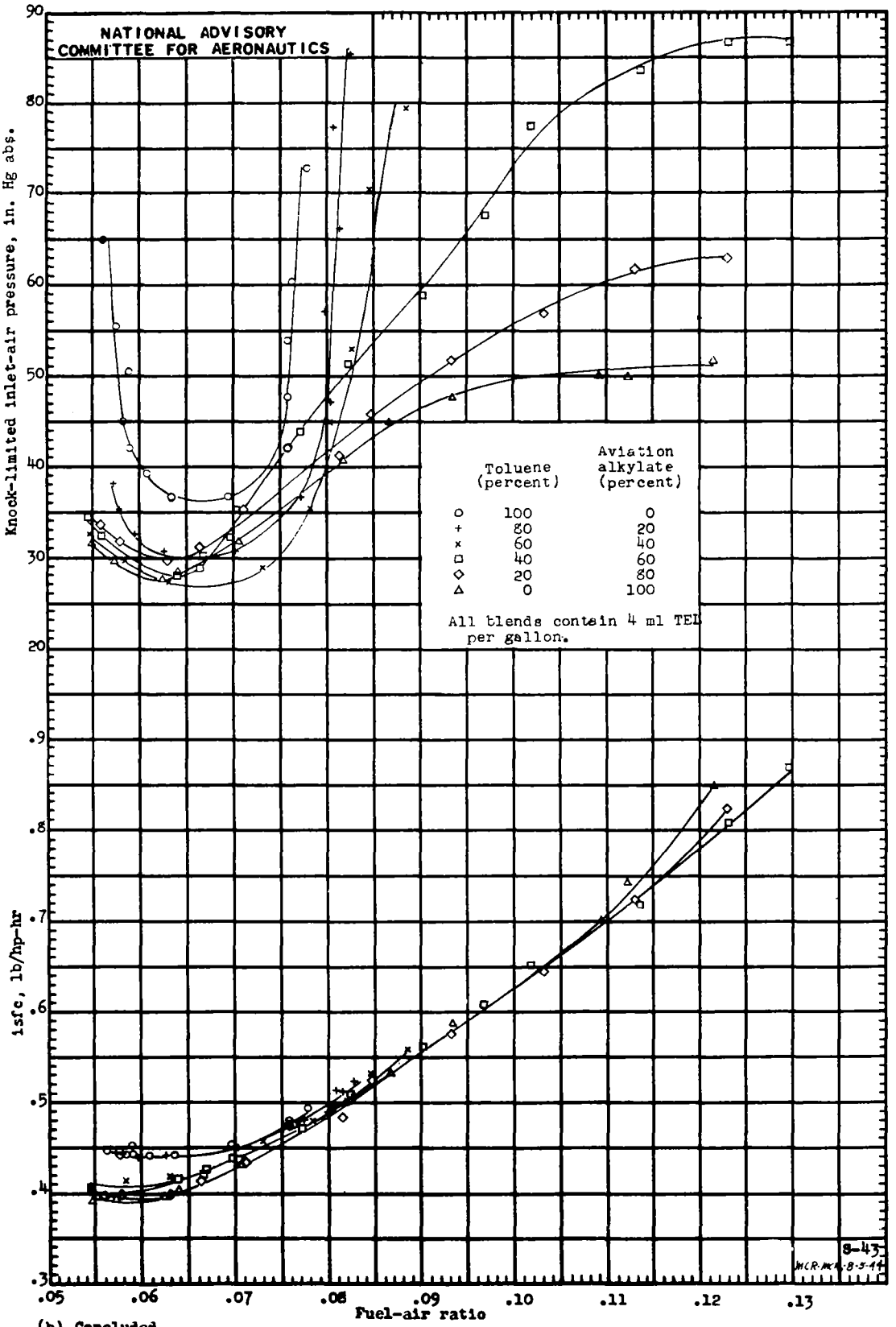
Figure 11. - Knock-limited performance of blends of toluene (methylbenzene) with virgin base stock, aviation alkylate, and one-pass catalytic stock as determined in an F-4 rating engine.



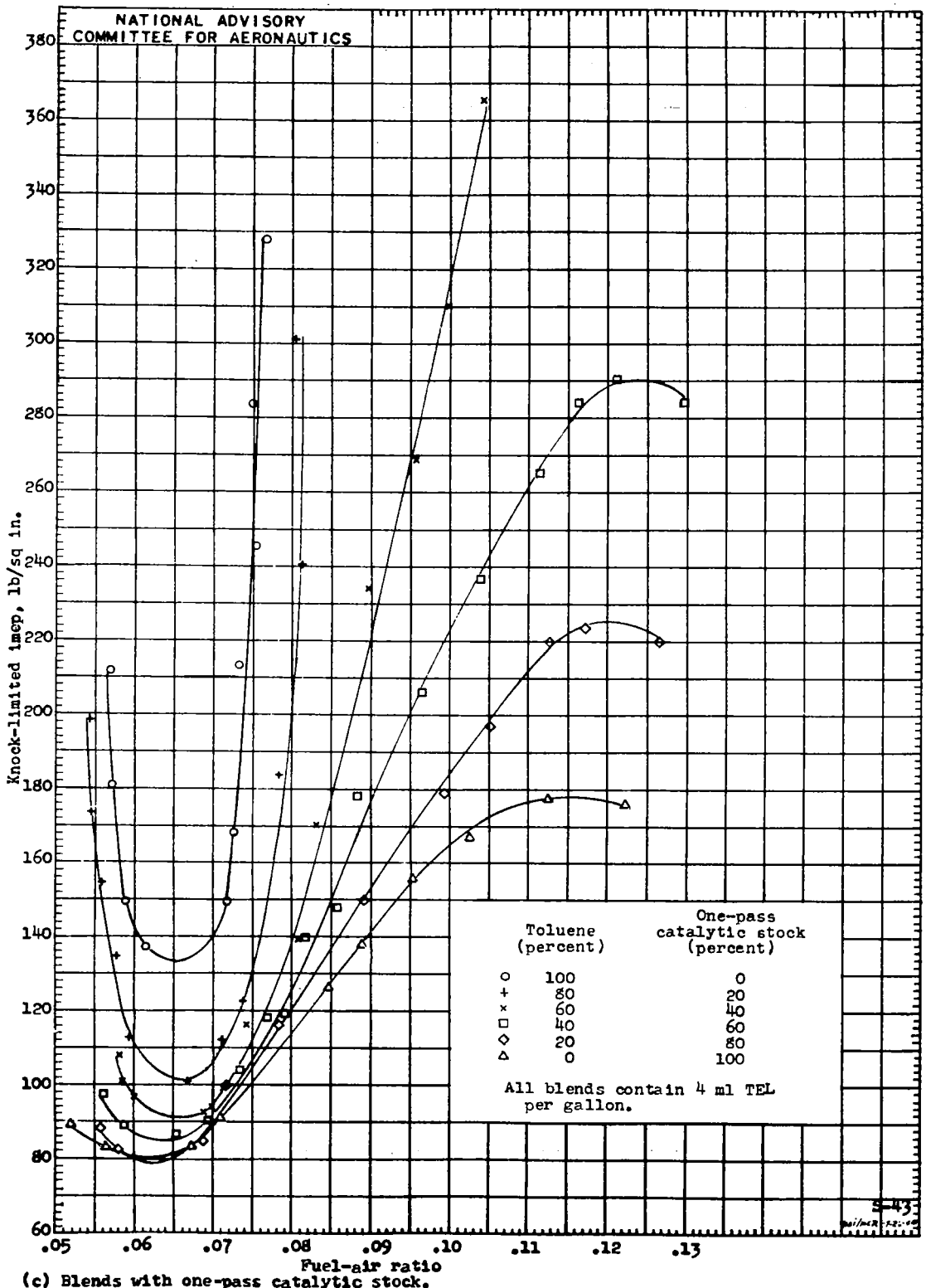
(a) Concluded.
Figure 11. - Continued.



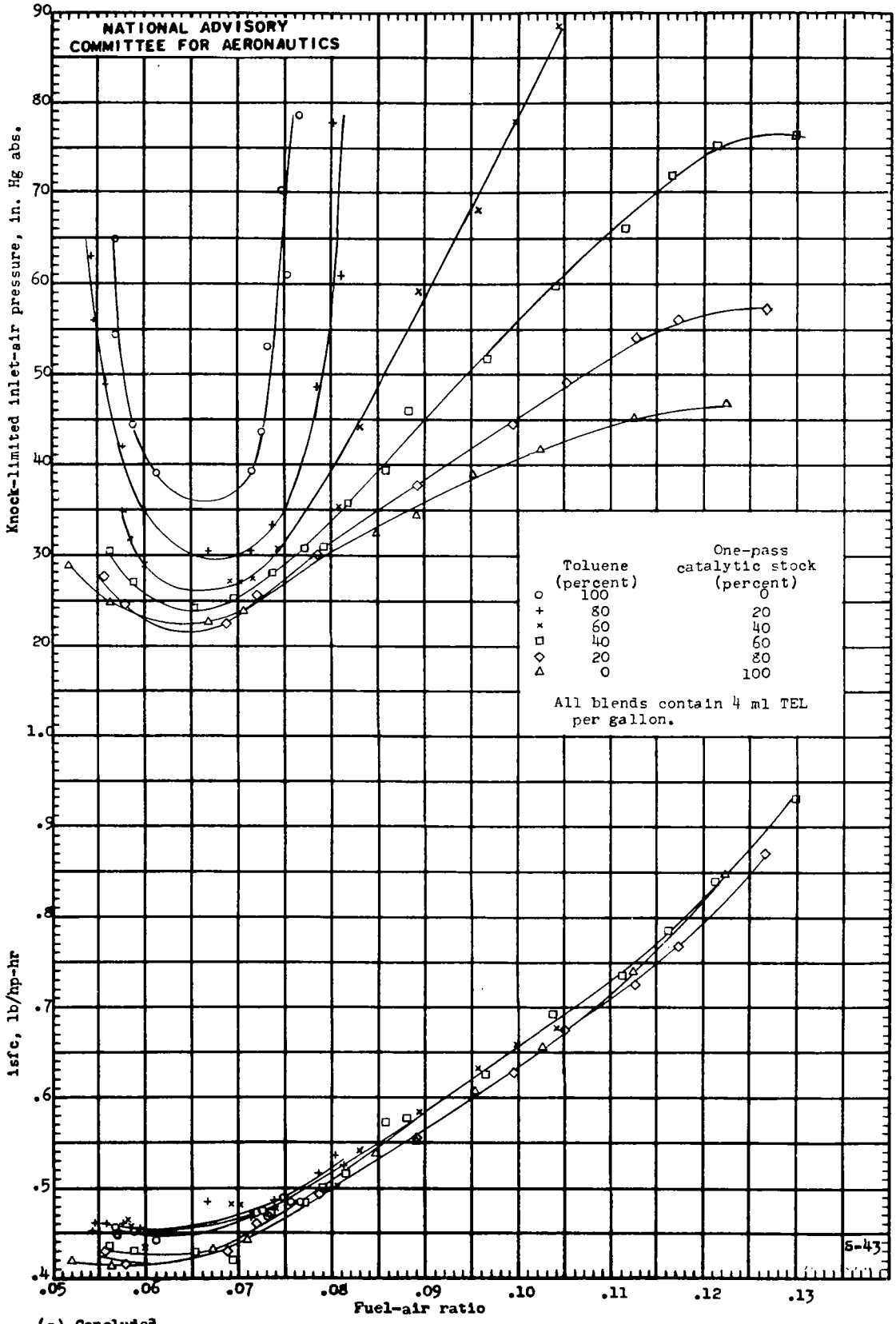
(b) Blends with aviation alkylate.
Figure 11. - Continued.



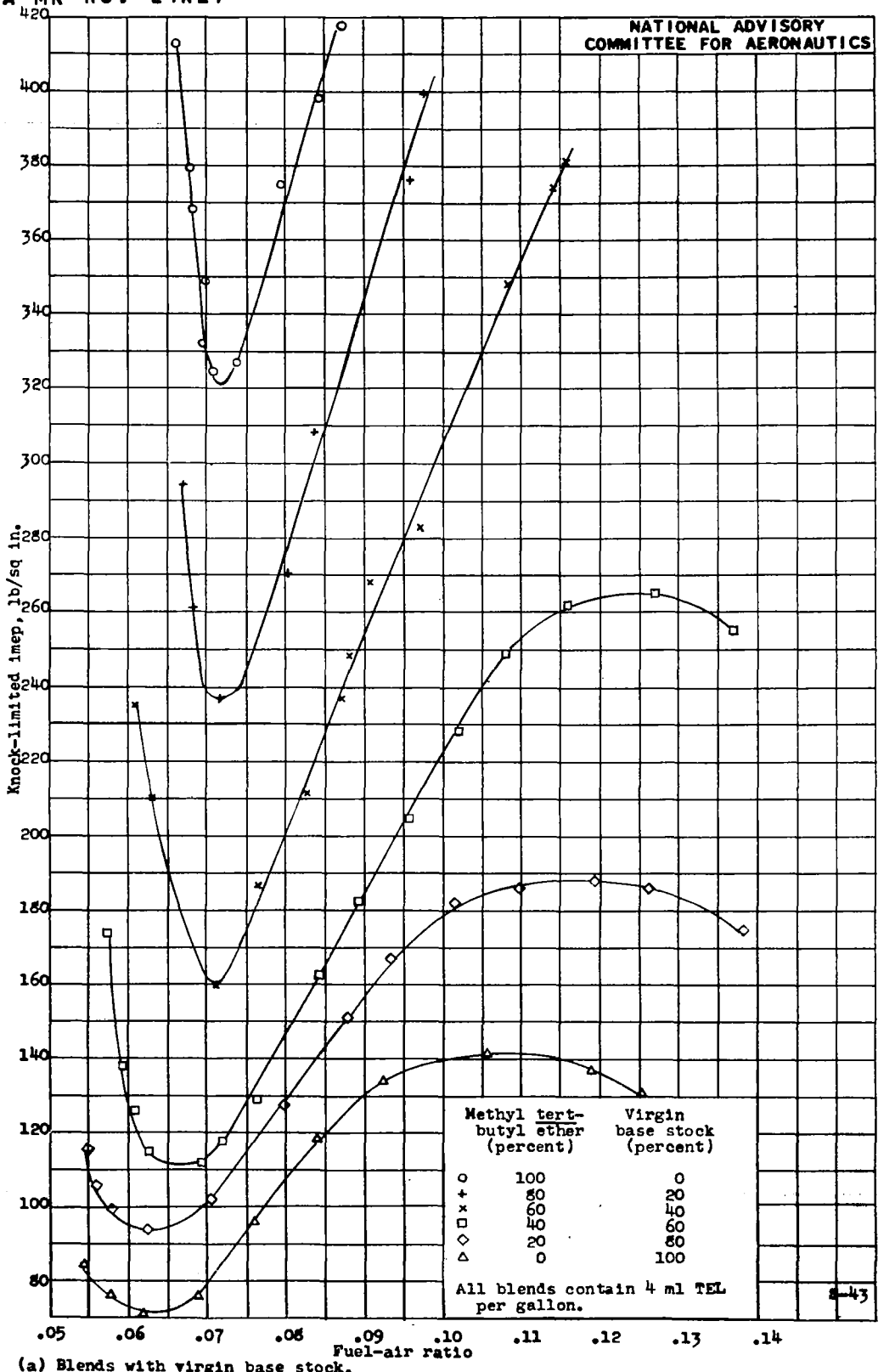
(b) Concluded.
Figure 11. - Continued.



(c) Blends with one-pass catalytic stock.
Figure 11. - Continued.

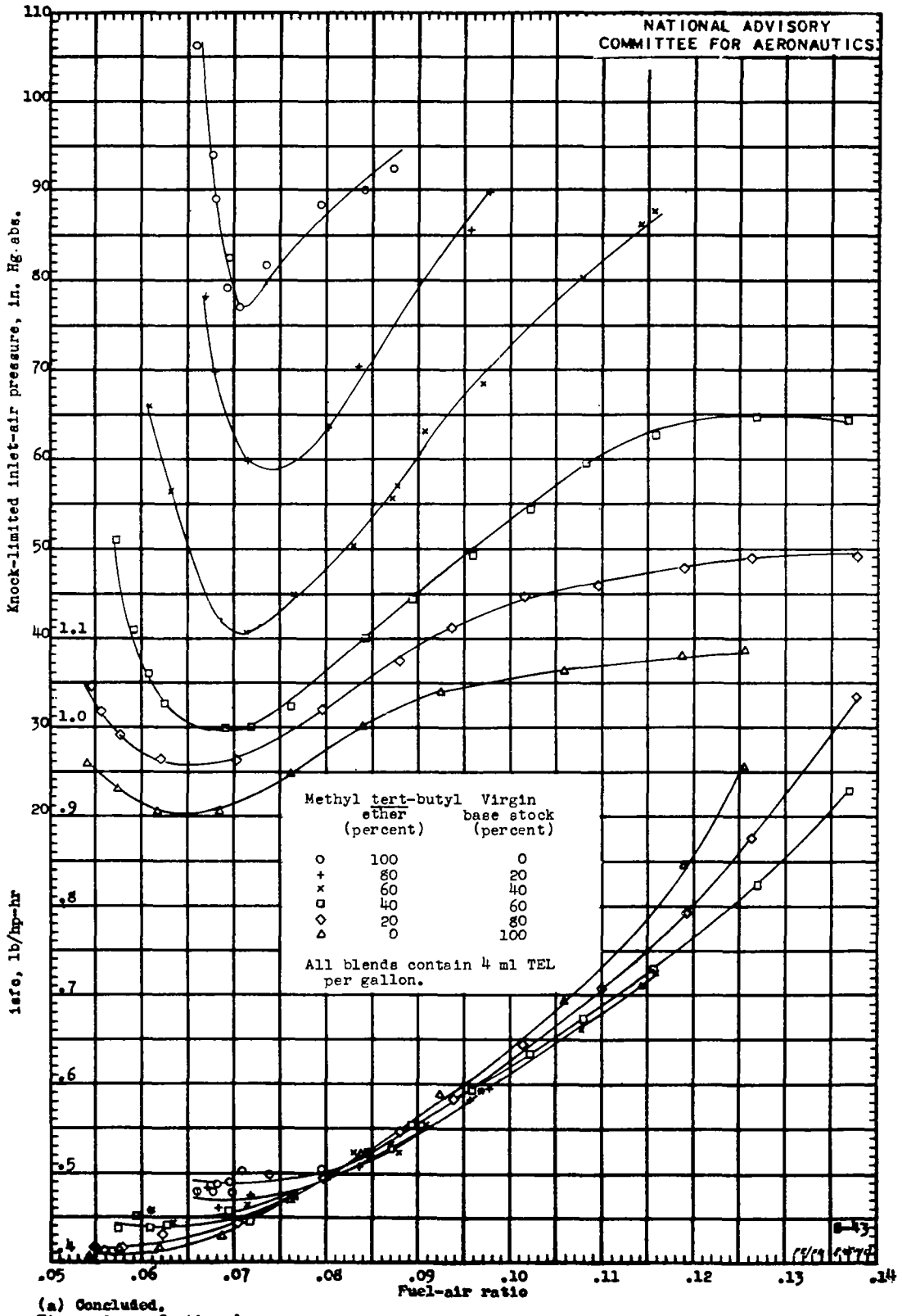


(c) Concluded.
Figure 11. - Concluded.

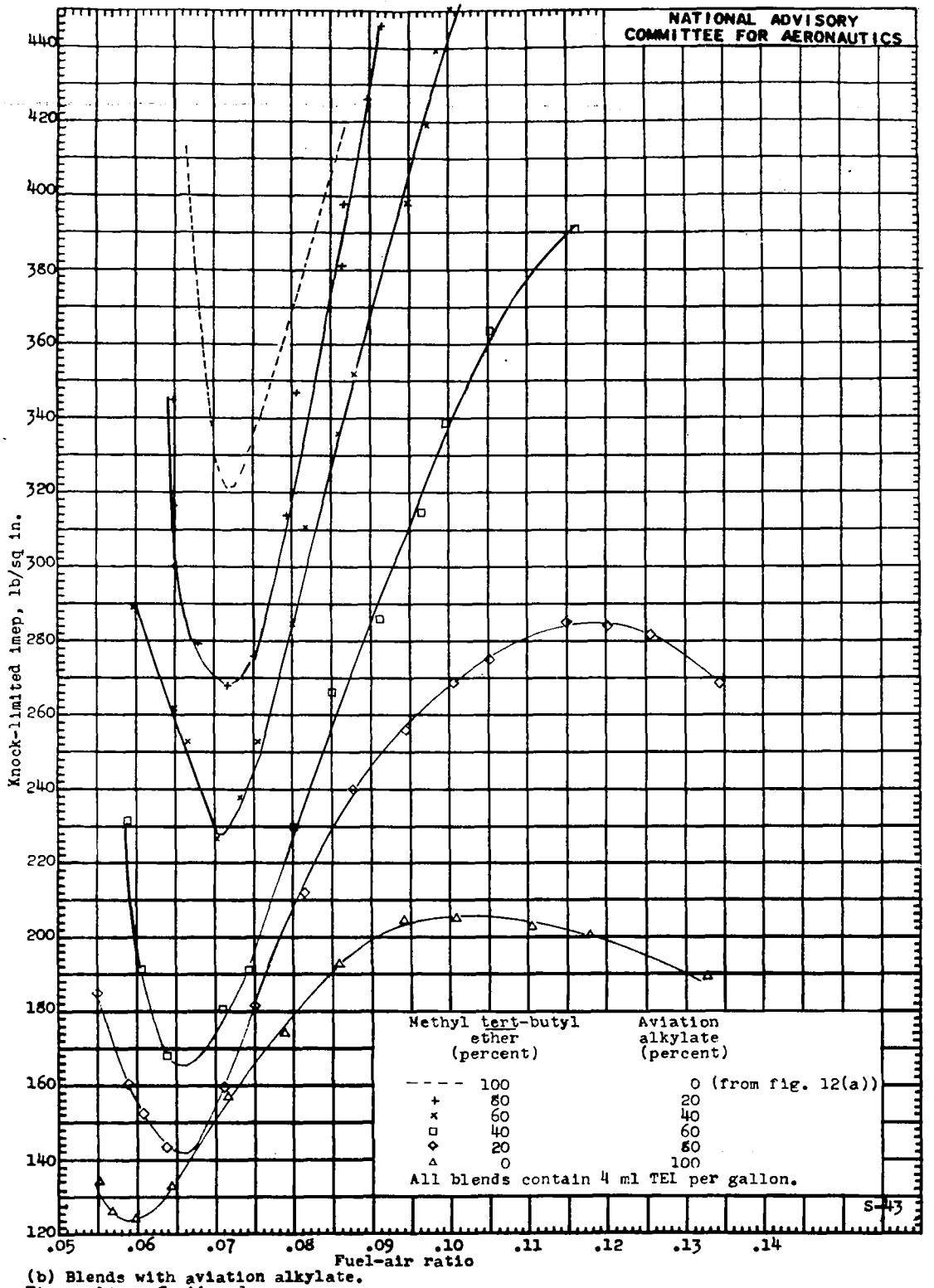


(a) Blends with virgin base stock.

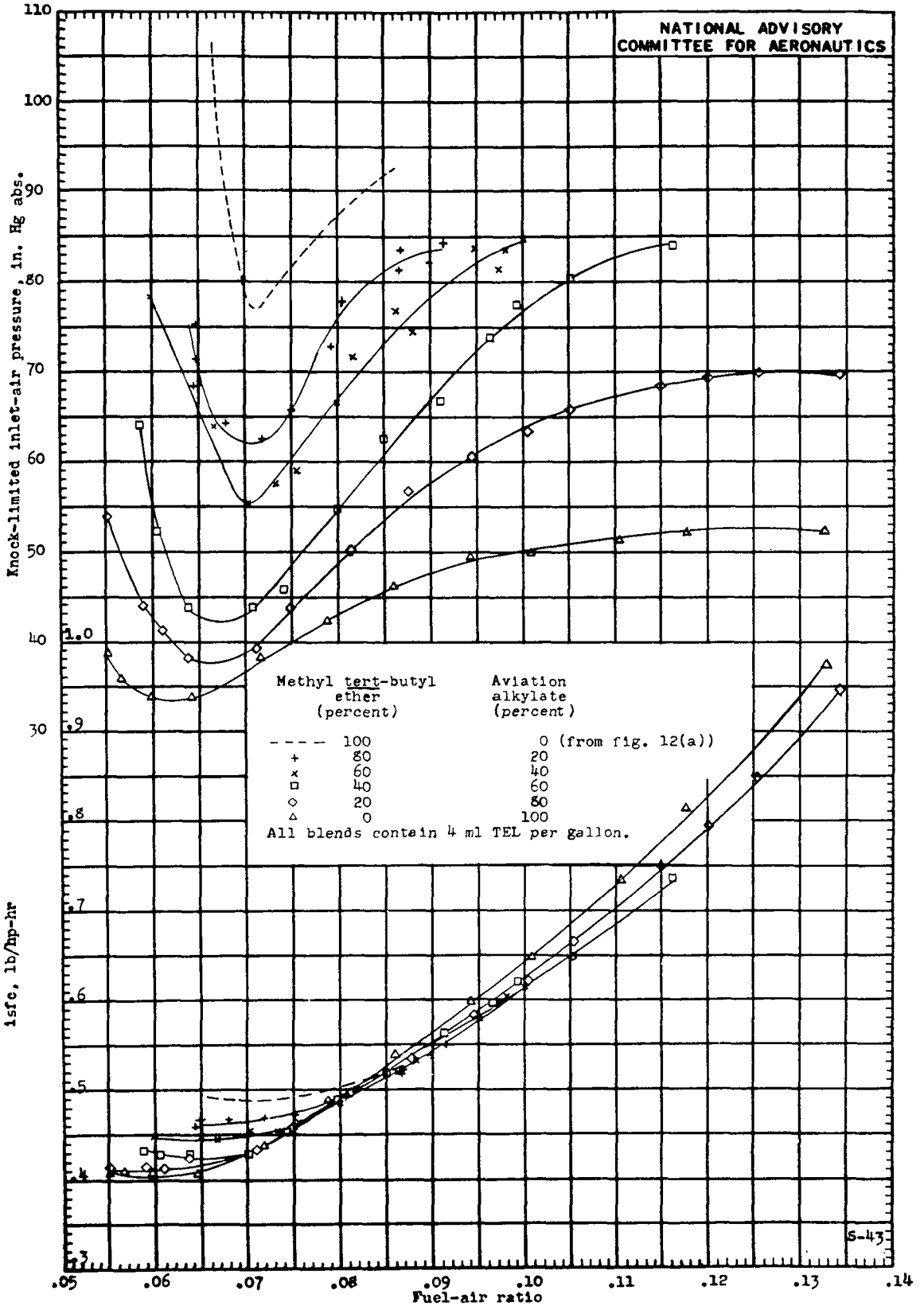
Figure 12. - Knock-limited performance of blends of methyl tert-butyl ether with virgin base stock, aviation alkylate, and one-pass catalytic stock as determined in an F-4 rating engine.



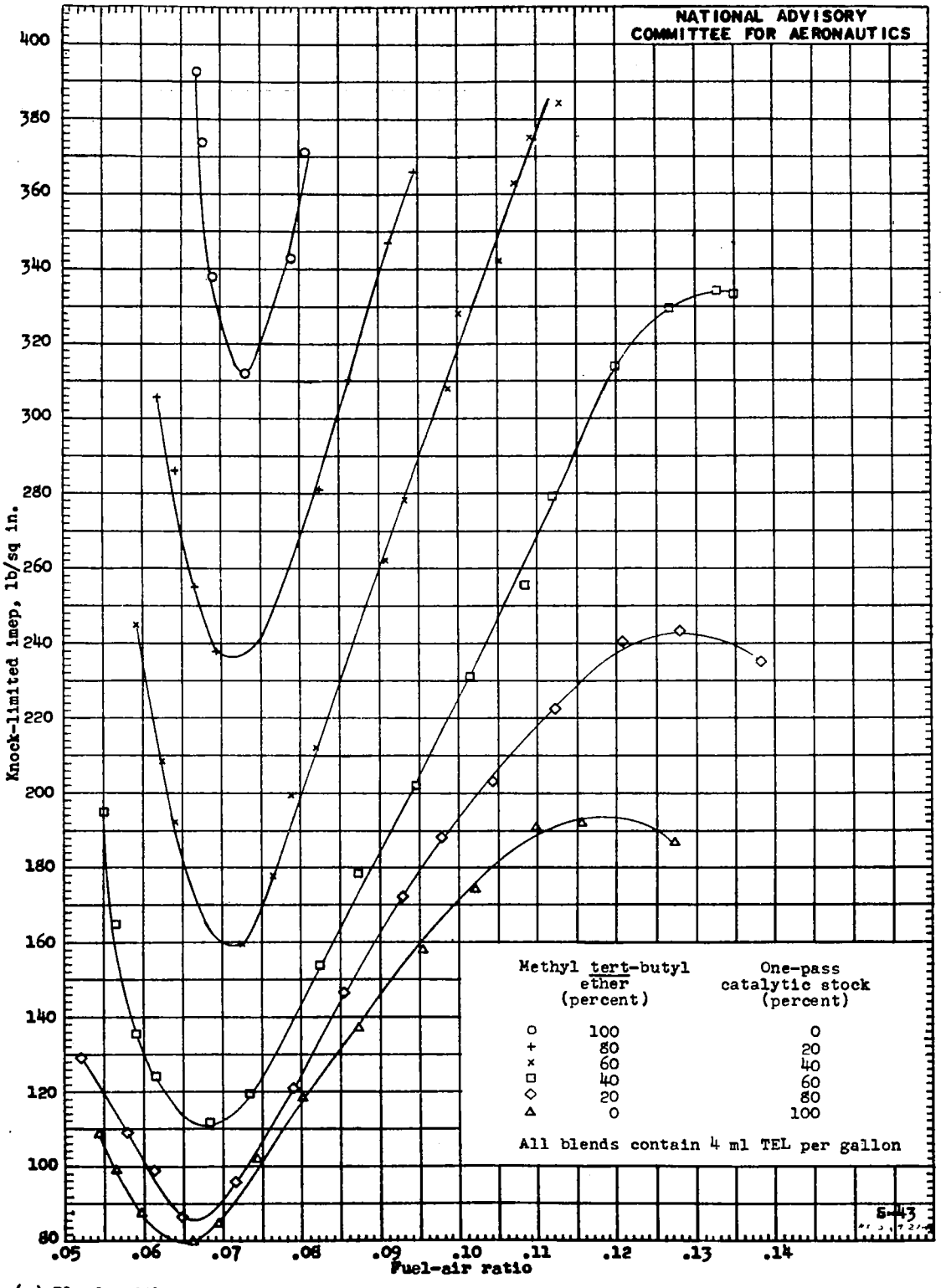
(a) Concluded.
Figure 12. - Continued.



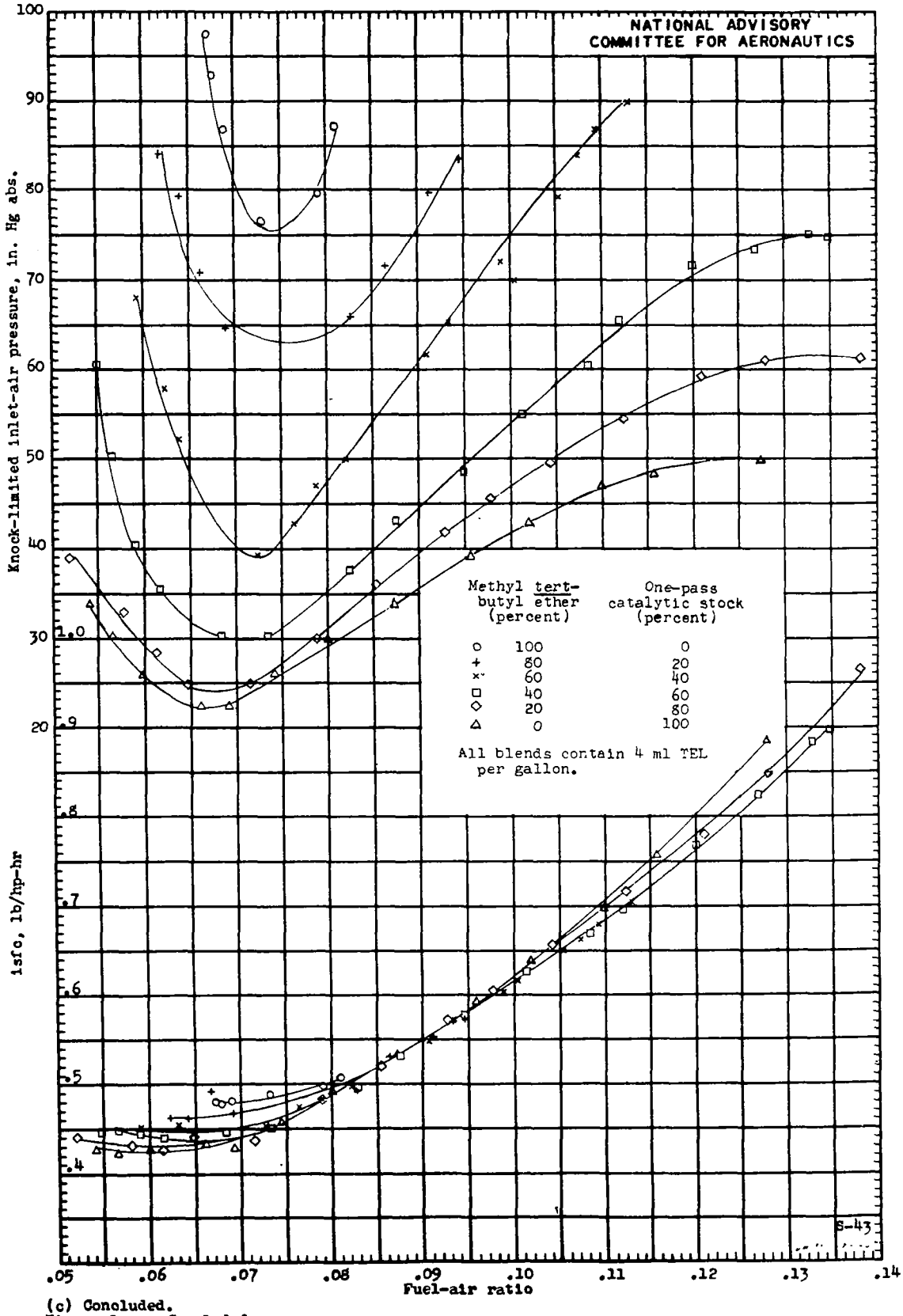
(b) Blends with aviation alkylate.
Figure 12. - Continued.



(b) Concluded.
Figure 12. - Continued.



(c) Blends with one-pass catalytic stock.
Figure 12. - Continued.



(c) Concluded.
Figure 12. - Concluded.

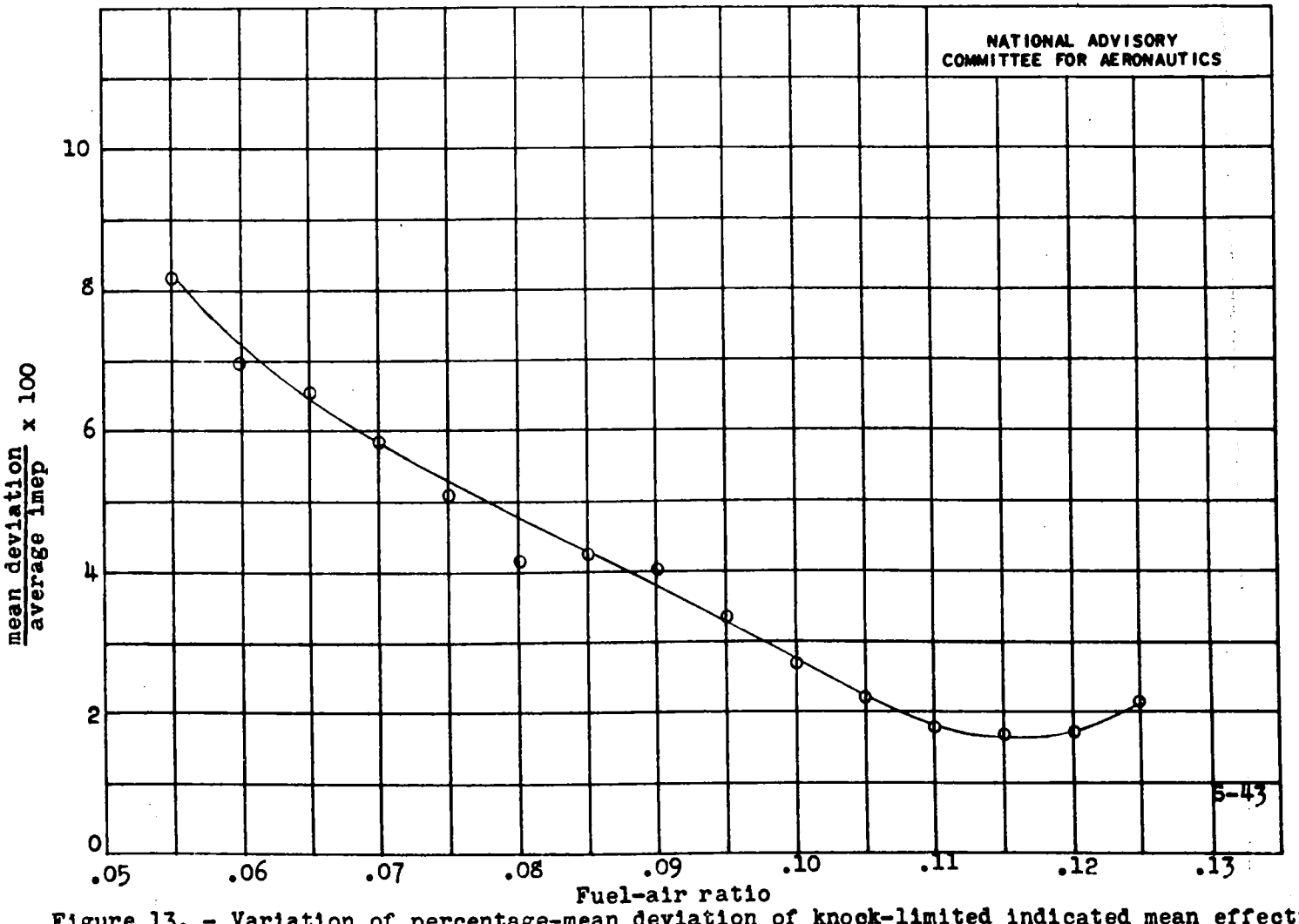


Figure 13. - Variation of percentage-mean deviation of knock-limited indicated mean effective pressure [(mean deviation/average imep) x 100] with fuel-air ratio as determined in an F-4 rating engine. (Calculated from fig. 2.)

LANGLEY RESEARCH CENTER
3 1176 01364 8473