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AN EVALUATION OF THE JENTZSCH FUEL TESTER

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ABSTRACT

This report presents an evaluation of the Jentzsch method as a laboratory procedure for the determination of the ignition quality of Diesel fuels.

A number of widely differing fuels were tested by the Jentzsch method, and it was found that a qualitative but not quantitative relationship exists between the Jentzsch comparison number and cetane number.

A series of cooperative tests on eight selected fuel cuts was conducted at the Engineering Experiment Station, Annapolis, Md., the Naval Boiler and Turbine Laboratory, Philadelphia, Pa., and this Laboratory. Good reproducibility of results among laboratories was not obtained. The most important single factor in the determination of comparison numbers is the low bubble number, which was the least reproducible of the experimental values. It appears that the lack of reproducibility was due to differences in the construction of the Jentzsch instruments which caused them to react differently to different fuels.

PROBLEM STATUS

This is a final report on this phase of the problem; work is continuing on other phases.

AUTHORIZATION

NRL Problem C01-09D
(NS-072-003)

AN EVALUATION OF THE JENTZSCH FUEL TESTER

INTRODUCTION

A laboratory method was desired for the evaluation of the ignition quality of small samples of fuels without recourse to tests on a cetane-rating engine. This report is limited to that phase of the problem which deals with the evaluation of the Jentzsch tester, and in particular, presents the results of a cooperative test among the Engineering Experiment Station, Annapolis, Md., the Naval Boiler and Turbine Laboratory, Philadelphia, Pa. and this Laboratory.

The Jentzsch tester was devised in Germany soon after World War I by Prof. Jentzsch, who spent a number of years in developing his apparatus. It was finally accepted by the German Navy prior to World War II. The apparatus was designed to measure the ignition characteristics of combustible materials. The German Navy became interested in the instrument as a fuel rating device to take the place of engine tests and accepted it for shipboard use to assist in the purchase of fuels and in trouble shooting. Since the tester is small and light, it represents a great saving in space and weight as compared to a test engine.

During and after World War II, the U.S. Navy obtained several of the Jentzsch testers. Since there was some question as to the accuracy and reproducibility of the results obtained with these testers, the Bureau of Ships initiated a cooperative program to evaluate them critically. This program consisted essentially of the determination and comparison of the experimental values characteristic of the same fuels at the three laboratories. Other work with the Jentzsch tester will be the subject of further reports.

DESCRIPTION OF APPARATUS

The Jentzsch tester is essentially an electrically-heated combustion chamber in which ignitions and other fuel properties are determined. Coupled with this is an accurate oxygen-metering system. A schematic drawing of the apparatus is shown in Figure 1.

The combustion block (1) of stainless steel contains four symmetrical holes or chambers, three of which receive oxygen from a central inlet. The fourth chamber is used for temperature measurement. The furnace (2) surrounding the combustion block is electrically heated by coil-type elements. A rod (3) supports a lamp (4), a mirror for chamber observation (5), and a wing-tip air pipe (6) which is equipped with a rubber bulb (7).

Oxygen is supplied from a tank (8), through a reducing valve (9), thence to a fine needle valve (10) and to a bubble counter (11) and flowmeter (12), from where it is piped (13) to a combustion chamber (1). A rubber bulb (14) may be used for flushing the combustion chamber with air.

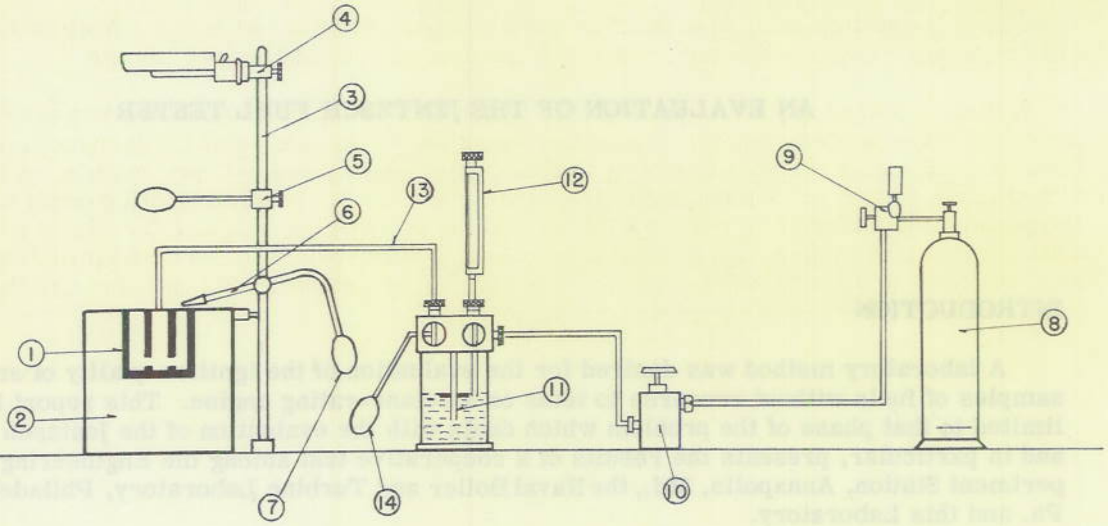

Figure 1 - Jentzsch ignition tester

During the ignition tests, a shallow steel ignition dish is placed in the bottom of each chamber as a fuel receptacle.

Special high-temperature thermometers designed to fit in an ignition dish were received with the instrument. However, because of the inaccuracy and thermal lag of these thermometers, a special thermocouple was designed and used with a Brown "Electronik" high-speed recording potentiometer for temperature measurements. The thermocouple was made of 24-gauge fiberglas-insulated duplex iron-constantan wire, shielded by a two-hole ceramic tube over that portion of the wires which fitted inside the combustion chamber. At the bottom of the ceramic tube, the wires were spread and welded to an ignition dish. In the cooperative tests, all testers were equipped with thermocouples instead of thermometers.

The iron-constantan thermocouples were calibrated against a standard Pt-PtRh thermocouple calibrated by the Bureau of Standards. The iron-constantan thermocouple readings agreed with the Pt-PtRh readings within one degree Centigrade in the range 120° to 600°C.

In order to test the constancy of the temperatures in the various chambers, the heating block was brought to a constant temperature and each of the four chambers was tested with an iron-constantan thermocouple. No significant difference in temperature was found.

Supply of oxygen to the ignition chambers is controlled by a worm gear needle valve which permits very fine adjustment. The rate of oxygen delivery is expressed in terms of bubbles per minute. For low values the bubble rate is determined by actual count using a stop watch; for higher flow rates the flowmeter is used. Twelve bubbles is approximately equal to one milliliter of oxygen.

PROCEDURES

Self-Ignition Point (SIP)

The self-ignition point is defined as the lowest temperature at which a drop of fuel will ignite when oxygen is being supplied at the rate of 300 bubbles per minute.

A dish is placed in each chamber, the oxygen flow is set at 300 bubbles per minute, and the block is heated rapidly to approximately 200°C. At this point the furnace is regulated by means of a rheostat to give a temperature rise of about 5°C per minute. A drop of fuel is added to a preheated clean dish in the front chamber. If no ignition occurs within 30 seconds, the chamber is purged with air and the test is repeated at intervals of about 5° until ignition takes place. After this approximate determination of the self-ignition temperature, the tests are repeated at slowly rising and falling temperatures until the self-ignition point has been determined to the nearest degree.

Before using the ignition dishes, they are cleaned by heating in a Bunsen burner flame and then polished metal-bright with an electrically-driven steel wire brush.

Low Bubble Number (Bu)

The low bubble number is defined as the smallest number of bubbles of oxygen per minute at which a drop of fuel can be ignited within the temperature range of the self-ignition point and 40°C above it.

After the self-ignition temperature is established, the oxygen flow is set at 90-100 bubbles per minute and the temperature increased slowly until ignition occurs. The oxygen flow is then cut by 10 or 15 bubbles per minute and the temperature again increased until ignition occurs. This process is repeated, using smaller and smaller decrements of oxygen flow, until the point is reached at which the lowest possible number of bubbles of oxygen per minute which will ignite the fuel is determined, within the primary ignition range, which lies between the self-ignition point and 40°C above it.

Upper Ignition Point (UIP)

The upper ignition point is defined as the lowest temperature at which a drop of fuel will ignite with no oxygen supplied through the inlet tube. It is determined in essentially the same manner as the self-ignition point, except that no oxygen is supplied to the chamber. In addition to the usual purging, air is swept through the orifices into the bottom of the chambers by means of a rubber bulb (14), shown in Figure 1.

Time-Boiling Number (BN)

The time-boiling number is the percentage of fuel evaporated in a given time at a given temperature. Three milliliters of fuel is placed in a special graduated tube and inserted in the furnace, which is maintained at exactly 500°C. After exactly four minutes the tube is removed and allowed to cool. From the decrease in the volume of fuel, the percentage which has evaporated is calculated. The average of three determinations is recorded as the time-boiling number.

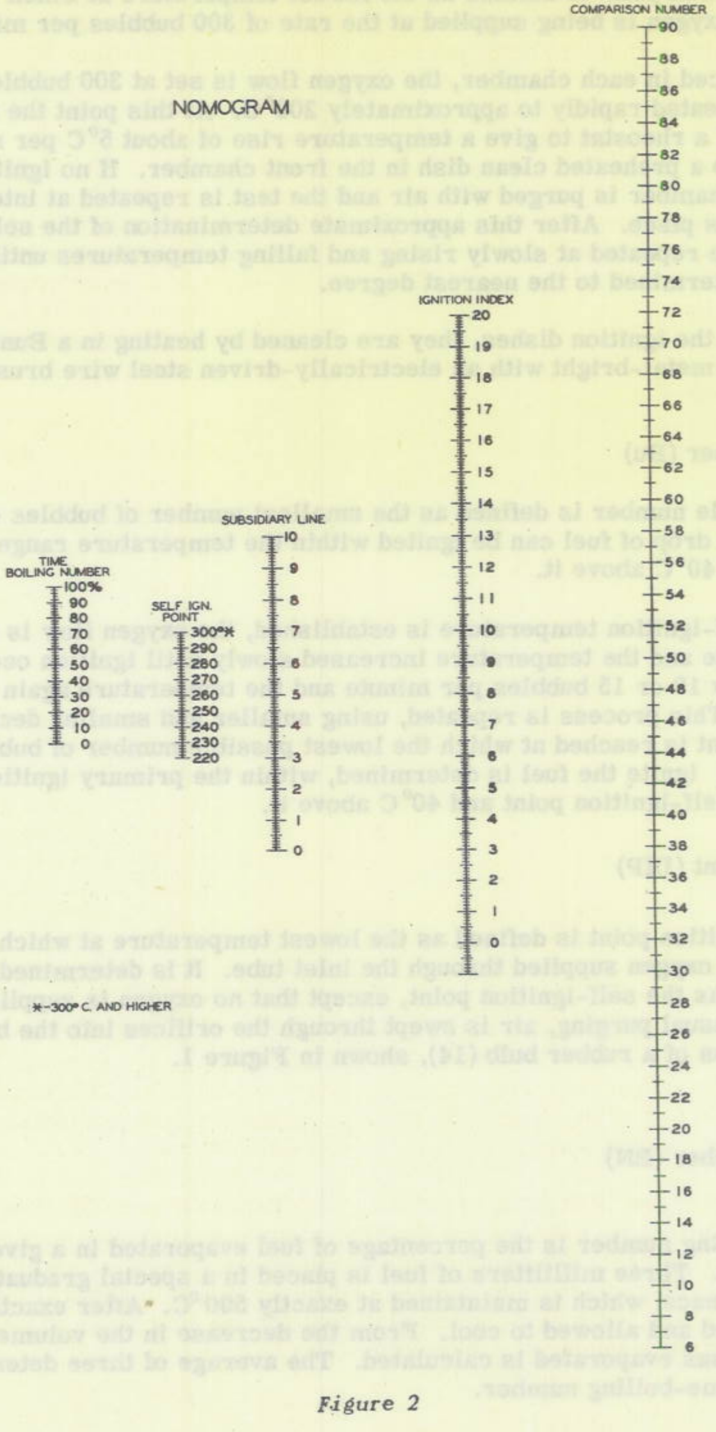
NOMOGRAM
COMPARISON NUMBER
90
88
86
84
82
80
78
76
74
72
70
68
66
64
62
60
58
56
54
52
50
48
46
44
42
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
IGNITION INDEX
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
SUBSIDIARY LINE
10
9
8
7
6
5
4
3
2
1
0
TIME
BOILING NUMBER
100%
90
80
70
60
50
40
30
20
10
0
SELF IGN.
POINT
300°*
290
280
270
260
250
240
230
220
*-300° C. AND HIGHER

Figure 2

CALCULATIONS

In order to determine the ignition quality of a diesel fuel by the Jentzsch method, a value called the comparison number (C) is obtained from the four experimental factors described above by means of a nomograph shown in Figure 2. In addition to the experimental values, the nomograph requires the use of a calculated factor called the ignition index (I). The ignition index is obtained from the following equation:

$$\text{Ignition Index (I)} = \frac{\text{UIP} - \text{SIP}}{\text{Bu} + 1}$$

For a given fuel, the values obtained for time-boiling number and self-ignition point are located on the first two columns of the nomograph and a straight-edge is laid across them to the third column or subsidiary line. The straight-edge is then projected from this point on the subsidiary line across the calculated value for ignition index (I) in the fourth column to the fifth column and the comparison number is obtained. The comparison number was considered by Jentzsch to be the equivalent of the cetane number of a diesel fuel as determined by the CFR engine method.

If the comparison number falls above 90, it can be calculated, assuming the same relationships hold for values above and below 90. By taking suitable information from the Jentzsch nomograph the following equations were derived:

$$\text{Subsidiary line value} = \frac{\text{SIP} - 220}{11.5} - \frac{\text{BN}}{27.7} + 2.6$$

$$\text{Comparison number} = 4\text{I} - 2(\text{Subs. line}) + 26$$

RESULTS AND DISCUSSION

Determination of Comparison Numbers of Some Whole Fuels

A variety of diesel fuels covering a range of cetane numbers from 29 to 83.7 was obtained from the USN Engineering Experiment Station. Their composition is given in Table 1. These fuels were subjected to the series of tests as outlined by Jentzsch for the determination of comparison numbers. The data so obtained are given in Table 2, in addition to the calculated values for the ignition index and the comparison numbers as derived from the Jentzsch nomograph. The comparison number for fuel No. 1 was calculated, since it exceeded the limit of the nomograph.

When the results are plotted on ordinary graph paper (Figure 3), it is seen that there is a qualitative relationship between comparison number and cetane number. The straight line on the graph represents the equivalence of comparison number and cetane number stated by Jentzsch. The comparison numbers found here are in general much higher than is predicted by this line. It may be noted also that for the four fuels of cetane number from 50 to 52, the comparison numbers range from 51 to 68.

TABLE 1
Composition of Test Fuels

Fuel No.	Composition	Cetane Number
1	Fischer-Tropsch Fuel	83.7
2	40% Fischer-Tropsch Fuel 60% 29 Cetane Fuel	50.1
3	50% Fischer-Tropsch Fuel 50% 7-0-2e Fuel	70.7
4	29 Cetane Fuel	29.0
5	7-0-2e Fuel	52.0
6	50% 29 Cetane Fuel 50% 7-0-2e Fuel + carbamate dope	50.0
8	50% 29 Cetane Fuel 50% 7-0-2e Fuel + peroxide dope	52.0

TABLE 2
Comparison Numbers of Test Fuels

Fuel No.	Self Ignition Point	Upper Ignition Point	Low Bubble Number	Time Boiling Number	Ignition Index	Comparison No.	Cetane Number
1	252	550	10.5	68	25.9	124*	83.7
2	272	580	23	72	12.8	68	50.1
3	260	540	15.5	70	17.0	87	70.7
4	282	560	39	75	7.0	43	29.0
5	267	540	22	68	11.9	65	52.0
6	273	520	28	70	8.5	51	50.0
8	272	560	28	77	9.9	57	52.0

* *Calculated value*

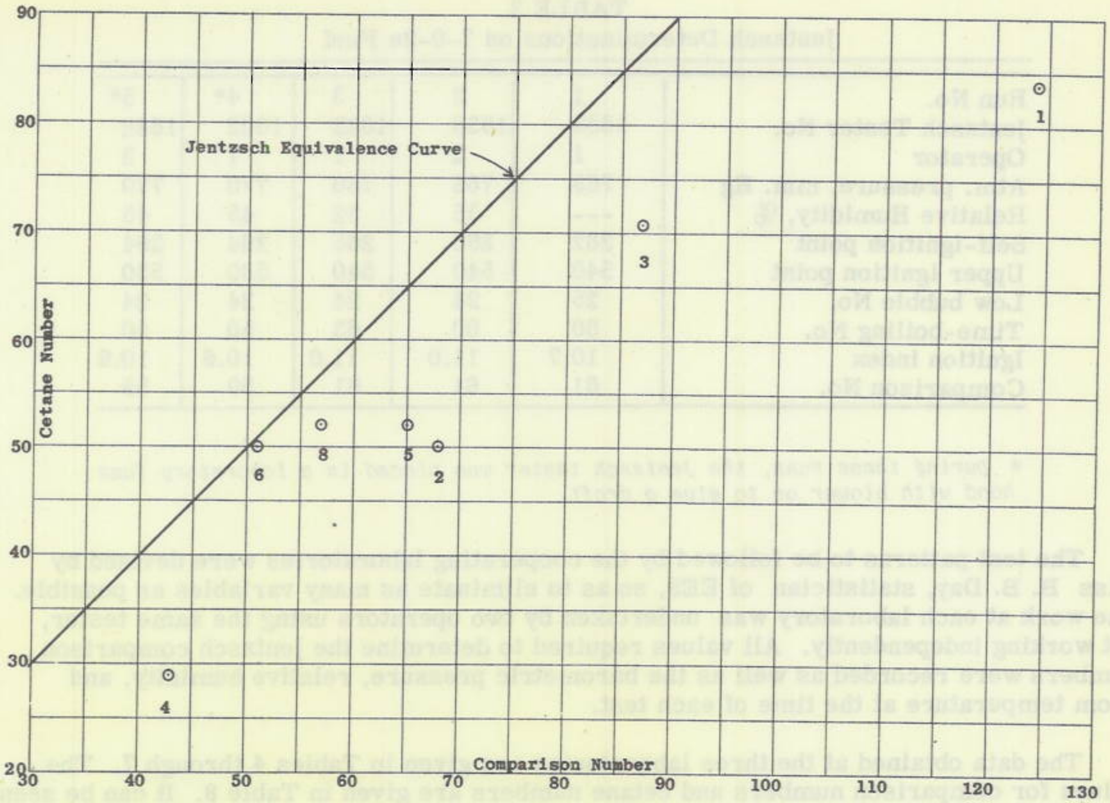

Figure 3

The reproducibility of comparison number determinations is demonstrated in Table 3 by the results obtained in five runs on a sample of Navy Spec. 7-0-2e fuel (cetane no. 52). These data were obtained on two different testers by two different operators. Runs 4 and 5 were made with the Jentzsch tester set up in a laboratory hood to provide a strong draft. The draft had no appreciable effect on any of the experimental values except the time-boiling number. While the comparison numbers found do not check well with cetane number, the comparison number itself was reasonably reproducible.

Cooperative Tests on Diesel Fuel Cuts

A 29-cetane catalytically cracked fuel and an 83.7-cetane Fischer-Tropsch fuel were selected by the Bureau of Ships for use in diesel fuel studies. These two fuels were fractionated into one-half percent cuts by the Bureau of Mines laboratories at Bartlesville, Oklahoma. The physical and chemical properties of these cuts were determined by the Bureau of Mines and the cetane numbers by the Engineering Experiment Station, Annapolis, Maryland.

Four cuts from each of these fuels were selected for cooperative studies of the Jentzsch tester by Mr. W. E. Robbins of EES and the experiments were carried out at EES, NBTL and this Laboratory.

TABLE 3
Jentzsch Determinations on 7-0-2e Fuel

Run No.	1	2	3	4*	5*
Jentzsch Tester No.	1638	1638	1622	1622	1622
Operator	1	2	1	1	2
Atm. pressure, mm. Hg	765	768	760	770	770
Relative Humidity, %	---	35	32	45	45
Self-ignition point	262	265	265	264	264
Upper ignition point	540	540	540	530	530
Low bubble No.	25	24	24	24	24
Time-boiling No.	60	60	63	50	50
Ignition index	10.7	11.0	11.0	10.6	10.6
Comparison No.	61	61	61	59	59

* *During these runs, the Jentzsch tester was placed in a laboratory fume hood with blower on to give a draft.*

The test patterns to be followed by the cooperating laboratories were devised by Miss B. B. Day, statistician of EES, so as to eliminate as many variables as possible. The work at each laboratory was undertaken by two operators using the same tester, but working independently. All values required to determine the Jentzsch comparison numbers were recorded as well as the barometric pressure, relative humidity, and room temperature at the time of each test.

The data obtained at the three laboratories are given in Tables 4 through 7. The values for comparison numbers and cetane numbers are given in Table 8. It can be seen from Table 8 that, for the most part, the comparison number values obtained at all three laboratories checked very poorly among themselves and with the cetane numbers of the samples. Variations between laboratories were large in contrast to the relatively consistent values obtained within a given laboratory.

Factors Bearing on the Reproducibility of the Comparison Number

Because of the wide divergence of the comparison numbers obtained at the three laboratories, it seemed advisable to study the reproducibility and importance of each individual value used in the determination of comparison numbers.

It can be seen from Table 7 (and Tables 4 and 6) that, on a percentage basis, the low bubble number is by far the least reproducible of the values used to determine the ignition index. From the formula

$$I = \frac{UIP - SIP}{Bu + 1}$$

it may be seen that, because Bu is a small value compared to the others, the experimental variations found for Bu have a much larger effect on the ignition index than the corresponding variations in the other values. This in turn is magnified in the determination of the comparison number, as shown in the following formula

$$\text{Comparison Number} = 4I - 2\,(\text{Subs. line}) + 26.$$

TABLE 4
Determinations of Self-Ignition Point

Fuel Cut and Operator	Self-Ignition Point °C		
	EES	NRL	NBTL
AX-1-3			
Operator 1	254,261	251,247	255,251
" 2	254,257	251,251	254,252
Average	256.5	250.0	253.0
AX-1-32			
Operator 1	249,250	248,247	246,244
" 2	249,250	247,246	246,244
Average	249.5	247.0	245.0
AX-1-124			
Operator 1	243,244	241,248	245,245
" 2	242,241	245,247	245,245
Average	242.5	245.2	245.0
AX-1-164			
Operator 1	242,243	244,243	243,244
" 2	240,242	245,245	245,244
Average	241.8	244.2	244.0
X-18			
Operator 1	283,283	275,280	277,279
" 2	282,283	277,279	278,277
Average	282.8	277.8	277.8
X-28			
Operator 1	285,282	282,285	282,280
" 2	284,284	284,279	282,283
Average	283.8	282.5	281.8
X-118			
Operator 1	281,284	284,282	283,278
" 2	282,280	281,280	282,280
Average	281.8	281.8	280.8
X-149			
Operator 1	289,289	288,288	283,283
" 2	290,289	292,290	287,286
Average	289.2	289.5	284.8

TABLE 5
Determination of Boiling Number

Fuel Cut and Operator	Boiling Number		
	EES	NRL	NBTL
AX-1-3			
Operator 1	96,97	95,97	97,97
" 2	97,93	93,97	97,97
Average	95.8	95.5	97.0
AX-1-32			
Operator 1	93,93	93,92	93,93
" 2	93,97	96,93	93,92
Average	94.0	93.5	92.8
AX-1-124			
Operator 1	90,11	89,89	87,87
" 2	92,19	76,90	87,87
Average	53.0	86.0	87.0
AX-1-164			
Operator 1	0,3	2,1	1,1
" 2	0,3	2,0	1,1
Average	1.5	1.3	1.0
X-18			
Operator 1	96,97	91,94	93,93
" 2	97,97	93,96	92,92
Average	96.8	93.5	92.5
X-28			
Operator 1	93,90	92,94	90,90
" 2	97,97	93,90	90,91
Average	94.2	92.2	90.2
X-118			
Operator 1	70,90	91,89	87,88
" 2	67,90	88,89	87,87
Average	79.2	89.2	87.2
X-149			
Operator 1	3,27	35,18	1,1
" 2	0,22	63,59	1,1
Average	13.0	43.8	1.0

TABLE 6
Determinations of Upper Ignition Point

Fuel Cut and Operator	Upper Ignition Point °C		
	EES	NRL	NBTL
AX-1-3			
Operator 1	537,535	575,547	541,525
″ 2	533,534	540,538	545,540
Average	534.8	550.0	537.8
AX-1-32			
Operator 1	526,530	580,560	513,516
″ 2	527,532	572,571	524,532
Average	528.8	570.8	521.2
AX-1-124			
Operator 1	528,540	572,574	501,527
″ 2	528,539	580,578	546,528
Average	533.8	576.0	525.5
AX-1-164			
Operator 1	538,537	570,570	511,535
″ 2	541,539	570,570	540,534
Average	538.8	570.0	530.0
X-18			
Operator 1	549,538	551,560	530,529
″ 2	538,534	550,550	530,526
Average	539.8	552.8	528.8
X-28			
Operator 1	538,534	566,565	533,531
″ 2	537,534	550,600	532,526
Average	535.8	570.2	530.5
X-118			
Operator 1	541,545	565,557	544,532
″ 2	545,537	562,560	547,532
Average	542.0	561.0	538.8
X-149			
Operator 1	575,570	605,604	552,553
″ 2	574,564	612,599	561,568
Average	570.8	605.0	558.5

TABLE 7
Determination of Low Bubble Number

Fuel Cut and Operator	Low Bubble Number		
	EES	NRL	NBTL
AX-1-3			
Operator 1	34,34	16,12.5	22.5,22
″ 2	26,34	13,13	24,23.5
Average	32.0	13.6	23.0
AX-1-32			
Operator 1	15,17	10,11	20,20
″ 2	15,19	9,11	20,20
Average	16.5	10.2	20.0
AX-1-124			
Operator 1	9,15	8, 4.5	12.5,10.5
″ 2	7,16	1, 9	12, 10
Average	11.8	5.6	11.2
AX-1-164			
Operator 1	21,25	10,14	14,10
″ 2	22,24	12,11.5	13,14
Average	23.0	11.9	12.8
X-18			
Operator 1	50,44	28,26	27,27
″ 2	49,52	26,28	26.5,28
Average	48.8	27.0	27.1
X-28			
Operator 1	58,63	35,35	31.5,32
″ 2	59,62	35,38	32.5,33
Average	60.5	35.8	32.2
X-118			
Operator 1	41,40	28,26	28,27.5
″ 2	40,48	26,27	28,26.5
Average	42.2	26.8	27.5
X-149			
Operator 1	86,87	76,71	79,86
″ 2	89,89	53,76	82,87
Average	87.8	69.0	83.5

TABLE 8
Determination of Comparison Number

Fuel Cut and Operator	Comparison Number			Cetane Number
	EES	NRL*	NBTL	
AX-1-3				
Operator 1	54,52	99,112	70,70	60.6
" 2	63.2,53	104,104	68,69	
Average	55.6	104.8	69.2	
AX-1-32				
Operator 1	91,84	143,127	73,75	78.3
" 2	90,78.7	153,131	76,78	
Average	85.9	138.5	75.5	
AX-1-124				
Operator 1	>90,>90	171,261	>90,>90	94.7
" 2	>90, 88.6	692,155	>90,>90	
Average	>90	319.8	>90	
AX-1-164				
Operator 1	72,62	135,104	>88,>90	95.6
" 2	68.2,62.6	117,120	> 90, 90	
Average	66.2	119.0	>90	
X-18				
Operator 1	37.5,39.2	56,59	54,53	36.3
" 2	37.6,35.5	58,55	54,52	
Average	37.4	57.0	53.2	
X-28				
Operator 1	33.1,32	48,48	47,47	30.8
" 2	33.2,32.4	46,50	46,45	
Average	32.7	48.0	46.2	
X-118				
Operator 1	40,41	55,57	52,53	33.3
2	40.4,37.8	58,57	53,54	
Average	39.8	56.8	53.0	
X-149				
Operator 1	22.5,23	28,28	23,22	24.4
2	21,22.6	31,29	22,22	
Average	22.3	29.0	22.2	

* *values above 90 were calculated by means of a derived equation.*

Because of their magnitude and lesser mathematical importance, the experimental variations in UIP have a much smaller although significant effect on the comparison number. An important factor in the variations in UIP is that air must reach the sample in the combustion chamber by convection from above; good reproducibility is therefore rather unlikely. No explanation has been found for the consistently higher UIP values found at NRL.

On the other hand, the variations found for SIP and BN are of little significance. This is because the SIP values are easily reproduced and the BN has low mathematical importance. Furthermore, the lack of reproducibility for the BN in the cooperative tests was due to the very narrow boiling range of the fuel cuts used, and is not typical of what would result using whole fuels.

It may be mentioned that differences in barometric pressure, relative humidity and room temperature had no consistent effect on the comparison number. Analyses of the oxygen used at the three laboratories showed better than 99% purity in all cases.

In order to determine the effect of changes in gauge pressure on the oxygen flow through the bubbler, the following experiment was carried out. The fine adjustment valve was kept at a constant setting and the gauge pressure was varied from 12 to 18 p.s.i. The bubble rate and amount of oxygen delivered were measured. Although the bubble rate varied from 7.8 to 13.3 bubbles per minute, calculation of the volume of oxygen per bubble showed no appreciable variation with gauge pressure. This information is given in Table 9.

TABLE 9
Effect of Gauge Pressure on Oxygen Flow

Gauge pressure lb./sq.in.	Bubbles per minute	Time, minutes	Total oxygen collected, ml	Flow rate ml /min	Volume in ml /bubble
12	7.8	9.0	5.08	0.56	
		9.0	4.95	0.55	
		10.0	5.45	0.55	
			Average	0.55	.071
14	9.6	--	--	--	--
15	10.4	5.0	3.84	0.77	
		5.0	3.80	0.76	
		5.0	3.82	0.76	
			Average	0.76	.073
16	11.5	--	--	--	
18	13.3	5.0	4.85	0.97	
		6.0	5.68	0.95	
			Average	0.96	.072

A suggested explanation for the differences in low bubble numbers was the possibility of a variation in the size of oxygen bubbles delivered by each apparatus. Calibration data for the bubble counters are given in Table 10. These were determined by measuring the volume of oxygen delivered in 60 seconds at a given flow rate.

Table 10 shows that, at flow rates of 30 and 60 bu/min, the amount of oxygen delivered by the tester at EES was much smaller than at the other laboratories. Furthermore, it may be seen from Tables 7 and 11 that most of the low bubble numbers obtained experimentally were less than 60. Therefore, if the absolute flow of oxygen is the controlling factor, the low bubble number values obtained at EES should have been larger than those at the other laboratories. Conversely, those for NBTL should have been the smallest. Qualitatively, EES did obtain the largest values, but NBTL obtained intermediate values instead of the smallest.

TABLE 10
Calibration Data for Bubble Counters

Flow Rate bubbles/min.	Oxygen delivery (ml/min)			Ratios of oxygen delivery		
	EES	NRL	NBTL	NBTL/NRL	EES/NRL	EES/NBTL
30	1.0	2.35	2.5	1.07	0.43	0.40
60	3.5	4.5	4.9	1.09	0.78	0.72
90	7.65	7.0	7.4	1.06	1.09	1.03

TABLE 11
Comparison of Low Bubble Numbers

Sample	Averages			Ratios		
	EES	NRL	NBTL	NRL/NBTL	NRL/EES	NBTL/EES
AX-1-124	11.8	5.6	11.2	0.50	0.48	0.95
AX-1-32	16.5	10.2	20.0	0.51	0.62	1.21
AX-1-164	23.0	11.9	12.8	0.93	0.52	0.56
AX-1-3	32.0	13.6	23.0	0.59	0.43	0.72
X-118	42.2	26.8	27.5	0.98	0.64	0.65
X-18	48.8	27.0	27.1	1.00	0.55	0.56
X-28	60.5	35.8	32.2	1.11	0.59	0.53
X-149	87.8	69.0	83.5	0.83	0.79	0.95

In addition, Table 10 shows a constant ratio of oxygen delivery at NBTL as compared with NRL. Therefore, if the supply of oxygen is the controlling factor, the low bubble numbers found at these two laboratories should also be in a constant ratio, since the numerical values for the ratios in Tables 10 and 11 (for any two laboratories) should be the same for any given bubble number. That no agreement exists may be seen from Table 11, where the ratio varies from 0.50 to 1.11. Similarly, if the ratios for oxygen delivery and for bubble numbers between EES and NRL, or NBTL, are compared, no agreement can be demonstrated. When the differences instead of the ratios in bubble numbers were compared for any two laboratories, again no agreement could be found. Therefore, no simple correction factor could be applied to bring the results in line.

The possibility remained that, in spite of all precautions taken, slight differences in techniques were being used at the three laboratories which were affecting the results significantly. In order to test this, one operator from EES retested fuels at NRL and one operator from NRL retested the same fuels at EES. The results are summarized in Table 12.

TABLE 12
Results of Retest on Two Fuels

Test-Fuel	EES ave.	NRL operator at EES	EES operator at EES	EES operator at NRL	NRL ave.
Low Bubble Number					
X-28	60.5	58	--	33	35.8
AX-1-32	16.5	21	26	13	10.2
Low Ignition Temp. °C					
X-28	320.8	302	--	322	321.5
AX-1-32	286.5	282	282	284	275.2
Self Ignition Point °C					
X-28	284	273	--	282	283
AX-1-32	249.5	247	253	250	247
Upper Ignition Point °C					
X-28	536	571	--	570	570
AX-1-32	529	555	561	546	571
Comparison Number					
X-28	32.7	38.4	--	50.5	48
AX-1-32	85.9	81.5	67	107.6	138.5

Note: The "boiling numbers" were not obtained in the retest experiments. For determination of the "comparison numbers," boiling numbers from the cooperative tests were used. The "comparison numbers" having a value above 90 were calculated from an equation derived at this Laboratory, the others were obtained using the Jentzsch nomograph.

The data given in Table 12 show that differences in techniques are not responsible for lack of concordance in obtaining either low bubble numbers or comparison numbers. This is particularly obvious for the X-28 sample, where there was a large difference in the NRL and EES average values for the low bubble number, and yet check results were obtained at a given laboratory by operators from both laboratories.

An alternative explanation for the lack of concordance in results is that there is some unknown difference in the inherent construction or behavior of the instruments used which causes them to react differently to different fuels. If this is generally true, use of the Jentzsch tester by the prescribed Jentzsch method to give reproducible and accurate results could not be expected from one instrument to another, and little reliance could be placed on any results obtained.

SUMMARY AND CONCLUSIONS

1. A wide variety of Diesel fuels and blends was tested by the Jentzsch method.

2. It was found that a qualitative, but not quantitative, relationship exists between the Jentzsch comparison number and cetane number.

3. A series of controlled tests was conducted cooperatively with two other Naval laboratories on eight specially selected fuel cuts.

4. It was found that, using the Jentzsch method, experimental values and comparison numbers could be reproduced within a given laboratory, but not between laboratories.

5. The most important single factor in the determination of comparison numbers was found to be the low bubble number, which was the least reproducible of the experimental values.

6. Studies as to the cause for poor reproducibility among laboratories indicated that there is some unknown difference in the construction or behavior of the instruments which causes them to react differently to different fuels.

7. The use of the Jentzsch tester by the prescribed Jentzsch method does not give results of sufficient accuracy to be satisfactory for the laboratory determination of cetane numbers.

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