NATIONAL BUREAU OF STANDARDS REPORT

6807

FUEL POTENTIAL TEST METHOD

by

J. J. Loftus, D. Gross

and

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NBS

U. S. DEPARTMENT OF COMMERCE
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ABSTRACT

Modifications have been made to a method, currently a standard of the French government, for assessment of the combustible characteristics of building materials. This method makes use of bomb combustion calorimetric techniques in which the combustion of small quantities of combustible in an otherwise inert material is insured by use of a combustion accelerator which is added prior to test. By performing calorimetric measurements both before and after exposure to a "standardized fire" (muffle at 750°C with controlled air supply) the difference may be considered as the fuel potential. A series of measurements of this property have been made for a variety of building materials and the results reported. A discussion is included on the precision of the test method.

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1. INTRODUCTION

The extent to which building construction materials burn and add fuel to fires involving buildings is considered of importance by code officials. Because of this, they have incorporated in their codes various requirements with respect to the "noncombustible" properties of materials to be used in different portions or types of buildings. However, the test methods which have most frequently been proposed or used for measuring this property of materials (1, 2, 3, 4, 5) have been qualitative in nature. The results obtained with their use have often been a function of the flammable, smouldering, and heat release characteristics of the material tested with emphasis varying, depending on the characteristics of the material tested. As a result, there has been considerable uncertainty as to exactly what material property was being measured.

Because of this situation, it has been difficult to select a method of test which could be considered satisfactory for standardization on a national level.

Calorimetric test methods of various types have been considered for measurement of the heat release of materials on exposure to fires. The Factory Mutual Association (6) has recently described a calorimetric furnace by means of which measurements are made of heat release rates for four-foot square test samples of constructions. This is surely a useful and pertinent test method for this purpose. Bomb combustion calorimetric measurements have also been considered, but these have, in the past, been rejected because the combustion characteristics in an oxygen pressurized bomb are much different from those effective during building fires. The former results in complete oxidation of many metals which are relatively unaffected by building fires. However, the French government (7) has recently standardized a test method making use of a differential bomb calorimetric method.

The present paper describes the further development of a similar test procedure and presents the results of measurements of the "fuel potential" of a wide variety of building materials.

2. TEST METHOD

The method may, perhaps, be most briefly described by reference to Figure 1. Two samples are removed from the material to be tested. One of these is ground, pelletized and then burned in a high pressure oxygen atmosphere as described in reference (8), yielding a measure of the higher heating value of the material. In the case of materials of low fuel potential, a combustion accelerator is added prior to pelletizing the specimen for test in the combustion calorimeter. A second specimen of approximately 1/2- x 3/4- x 3-in. size is exposed to an oxidizing atmosphere for two hours at a temperature of 750 C (1382 F). The weight loss of this specimen is noted and the residue remaining is ground or pulverized. A portion of this resulting powder corresponding to a known weight of the original material is mixed with a combustion accelerator, pelletized, and burned in the combustion calorimeter as previously described. After correcting for the heat produced by the combustion accelerator, the difference in heating values of the two specimens is reported as the fuel

potential. It is evident from this diagram that the fuel potential measurement is not a direct one but is obtained by difference measurements. It is indicative of the quantity of heat released during exposure of the specimen to the heat of the muffle furnace.

3. PROCEDURAL DETAILS

The detailed techniques which have been developed for standardization of the test method are described in the appendix. A brief discussion will be presented in this section of the reasons for selection of these details.

3.1 MUFFLE CONDITIONS

The conditions under which the specimen is heated in the muffle furnace have an influence on the measurements made. The temperature of 750°C (1382°F) was selected because of its long use in this and other countries for exposure of the specimen in combustibility test methods. The temperature is lower than the maximum which would be expected in fires of even brief duration, It is, however, high enough to permit the ignition of magnesium. Aluminum, on the other hand, will melt and not become inflamed. These results are believed typical of actual fire experience. The specimen size, air feed rate, and duration of high temperature exposure were selected to insure complete combustion, if possible, of fuel in cinder concrete specimens and oxidation of carbon resulting from pyrolysis of wooden specimens.

3.2 COMBUSTION ACCELERATOR

The use of a fuel additive to the specimen prior to burning in the bomb is intended to insure that combustion of fuel content is complete even when present in small quantities. The additive used was benzoic acid of known heating value (9). Determination of the quantity of acid required was made by measurement of the percentage of fuel consumed when mixtures of benzoic acid and aluminum oxide were fired in the combustion calorimeter. The results are shown in Figure 2. It is evident that when the quantity of acid in the sample is less than about 30 per cent, combustion may be incomplete and reliable results should not be expected. Because of this, materials suspected or known to have low fuel potential are only burned after addition of about 50 per cent benzoic acid. Such large acid additions are not required with materials such as woods and some plastics involving high combustible content.

3.3 SPECIMEN PREPARATION

The material to be tested was pulverized to permit incorporation of the fuel additive prior to pelletizing. This was accomplished by means of a hand mill for all but the hardest materials. A mortar and pestle as well as files or rasps have been found useful for some otherwise difficult materials.

4. RESULTS

As a means for demonstrating the sensitivity and usefulness of this method of measuring the heat release potential of building materials, a series of tests were performed with the use of plaster of Paris specimens to which various additions of charcoal had been made. The mixtures of dry plaster and charcoal were made in the dry state. These were then hydrated and the hardened mixtures used for fuel potential determinations. From analysis of the plaster the hemihydrate content was determined as equal to 94 per cent. On the basis of this and the assumption of high accuracy in the preparation of the specimens, computed values of the fuel potential were prepared and are presented in Table Table I. Comparison of these with the experimentally determined values of fuel potential show very close agreement. It is therefore evident that when benzoic acid was used in weight concentrations of 50 per cent complete combustion was achieved in the calorimeter even for mixtures showing very low fuel potential.

Table II presents the results of fuel potential measurements made on a variety of building materials. The materials listed here were selected largely to provide an indication of the manner in which the test method would classify materials. It should not be assumed that all materials which conform to the brief descriptions given will show the same fuel potential. Fuel potential is tabulated here as heat release per unit weight and unit volume, or unit area for impermeable materials subject only to surface reactions. For discussion purposes, Table II also presents the flame spread index of those materials which have been tested by the radiant panel method (10).

Examination of this table shows that, for the materials studied, fuel potential varies from about -300 BTU/lb to 17,000 BTU/lb. Materials such as brick, asbestos-cement board, some concretes and the gypsum plasters showed very low fuel potentials while cork, polystyrene, and asphalt impregnated building paper showed very high values. Expanded metal lath, gypsum lath and wall board exhibited quite similar fuel potentials which were low but not zero.

Some materials such as woods and plastics exhibited so low a residue after muffling that it seemed unnecessary to run a second calorimeter experiment. In cases such as these, the fuel potential reported was considered equivalent to the higher heating value of the material.

The high fuel potential of woods was not noticeably affected by impregnation with fire retardant treatments for which studies were made. The apparent reduction of fuel potential on a weight basis may be largely attributed to an increase in density resulting from the treatment process. Fire endurance tests of laminated panels (11) have shown only minor increase in the time to burn through treated panels as compared with that for untreated specimens. In one pair of panels of 2-1/2 in. overall thickness built up with tongue and grooved core and 3/16 in. veneer crossbanding, the times to flamethrough were 72.1 and 69.2 minutes for retardant treated and untreated specimens, respectively. Other studies on built-up wood partitions of 4- and 6- in. thicknesses have shown up to 33 per cent improvement in fire endurance resulting from complete impregnation.

While one plastic, polystyrene, showed the highest fuel potential measured during the study, two others showed fuel potentials similar to that of woods when compared on a weight basis.

The so-called noncombustible insulation materials tested exhibited fuel potentials which, while low, were not negligible. That for glass fiber material resulted from the phenolic binder used for bonding the material. In the case of the rock wool insulation, the specimens tested included the paper package enclosure.

The concretes in general exhibited low fuel potentials. Those for expanded slag, shale, and the silicious aggregates were nearly zero. The fuel potential for the concrete incorporating a calcareous aggregate was found to be slightly negative. This latter effect would be expected as a result of the heat absorption required for calcination of the aggregate. The negative value shown seems to imply that some calcination does take place during the brief high temperature exposure within the bomb. The cinder aggregate concrete specimens tested exhibited significantly positive values of fuel potential. The effect of the unburned coal contributing to the severity of building fires has been noted during burnout tests at the National Bureau of Standards. Studies by

Menzel in which he performed fire endurance tests on walls of concrete masonry units have also shown the effect of varying addition of solid fuels to cinder aggregates in reducing the gas requirement for performance of the fire endurance test (13). This latter effect would, of course, be indicative of heat release by the specimen since control of the gas feed is such as to maintain a fixed time temperature exposure relationship.

The plaster specimens tested showed low or negative fuel potentials. The gypsum wallboard specimens tested showed higher fuel potentials than were observed for the plasters. This resulted from combustion of the paper facing and any finish which was applied.

The laths studied included both gypsum board and expanded metal lath. The fuel potential of the gypsum product was quite similar to that of gypsum wall boards of the same thickness. That for the metal lath was largely due to the paint which had been applied and the surface oxidation of the metal.

Of the metals tested, only steel, copper, and brass did not melt at the muffle temperature. Magnesium burned and was completely oxidized; its fuel potential was considered equivalent to the heat of combustion. The fuel potential values reported for the other materials which melted were computed on the basis of the weight change during muffling and the assumption that an oxidation reaction was involved. For those metals which did not melt in the muffle, it seemed proper to report fuel potential on the basis of the exposed surface of the material. In making these measurements, thin sheets of the metals involved were exposed to the muffle conditions. With the single exception of magnesium, the oxidation of the metals studied was not severe and fuel potentials should be considered low but not zero.

4.1 Precision and Accuracy of Method

Standard combustion calorimetric techniques would be expected to yield highly precise measurements of the heating values of fuels. Perhaps precisions as great as ± 30 BTU/lb would be normal for good quality work with standard laboratory equipment and specimen weights on the order of one gram. Such precisions cannot be expected with the test procedure described here since not only are differences of two measurements reported, but the method involves mixing combustion accelerators with the specimen as well as the additional complexity of accounting for weight changes resulting from the

specimen exposure within the muffle furnace. As a result, errors of somewhat greater magnitude are to be expected.

The data presented in Table I provide some indication of the magnitude of errors in both precision and accuracy. Here, the apparent error in measurement is reported as the deviation of the experimentally determined value from the computed value of fuel potential. These errors, while in some instances larger than appears desirable, appear to be of a random nature.

Another method of exploring the precision of the method is to compare the difference between duplicate measurements of the individual calorimetric determinations with the heating value observed during the measurement. This was done for the data on the unmuffled specimens. It was found that the differences between duplicates were essentially independent of the fuel potential of the material being tested and assumed an average value of 100 BTU/lb. Similar treatment of the muffled specimens yielded an average of 34 BTU/lb. These averages correspond to standard deviations of 89 and 30 BTU/lb for individual unmuffled specimens or about 63 and 21 BTU/lb for the average of two determinations. The precision of the fuel potential measurement would then be the root of the sum of the squares of these two or about 94 for one and 66 BTU/lb for the average of two determinations.

5. DISCUSSION

Experience with the test procedure described indicates that it is applicable to a wide variety of building materials. It appears to provide a useful tool for measuring the fuel potential or that portion of the heat of combustion which will be liberated during prolonged exposure in an oxidizing atmosphere at 750°C. The method has the advantage over previously used combustibility test methods of providing a quantitative measurement of the heat release during such exposure.

The only remotely similar technique known to be used in this country at the present time is the FM Construction Materials Calorimeter (6). This method requires a large specimen 4 x 4 ft in size and representative in thickness and construction of the building structure to be simulated.

It provides a useful means for measuring the rate at which the structure will liberate heat during fire exposure on one surface. Also, by integration techniques, it can provide an indication of the heat release for fires of various durations. However, because of the problems associated with heat losses through the specimen, it seems doubtful whether this method is suitable for total heat release measurements. Heat losses through the specimen may present a considerable problem for proper analysis of results. It seems likely that for the case of very thin panels of translucent combustible materials, such as plastics, such losses could very well exceed the heat of combustion.

Probably the two methods should be considered as complimentary, one providing a laboratory method for measurement of total heat release with small specimens while the other makes possible the measurement of the rate at which heat generation by the large specimen exceeds the losses through it. Certainly, studies performed with the use of this large-scale test method would prove useful in showing the appropriate manner to be used in application of the laboratory test results.

During the studies performed, only one material, graphite, was observed to fail to burn in the bomb, but was consumed in the muffle. The problems of calorimetric measurements with graphite have been reported in the literature (14). Accordingly, when the presence of graphite is suspected, the residue from the bomb should be examined, and, if necessary, muffled to determine the amount of unconsumed carbon by weight loss measurements. Charcoal which comprises carbon with chemically bonded hydrogen was not subject to this difficulty and was readily burned in the bomb.

Some brief mention should be made of the fact that the calorimetric methods used, result in the condensation of water formed as a product of combustion. Because of this, the heats reported are representative of the higher heating value of the materials and, as such, include the heat liberated on condensation of the water vapor. It appears beyond the scope of this paper to present a complete discussion of this aspect of the procedure. However, the data in Table III are presented for the purpose of estimating the magniture of this effect. The heat of vaporization data presented here was computed on the assumption of steam table data for change of heat content of water on heating from 20°C to 750°C at atmospheric temperature. It was further assumed that the

combined and free water initially present in the material remained in the form of water. Actually this latter assumption appears likely to be proper for all materials listed with the single exception of gypsum. The negative fuel potential listed in Table II for gypsum appears to result from at least partial chemical reduction of the water present. Because of this, the measured fuel potential of gypsum shows very close agreement with the estimate of the correction which would apply to the material. For the other materials listed, the applicable correction is but a small fraction of the value of the fuel potential. Table III is presented here only for discussion purposes. It appears inadvisable to attempt correction of experimental fuel potential data for the purpose of compensation of these heat of vaporization effects.

6. CONCLUSIONS

The following conclusions seem justified on the basis of the work reported:

1. Techniques have been developed for measurement of the fuel potential of materials during exposure to an oxidizing atmosphere at 750°C.

2. The test methods developed have been used for measurement of the fuel potential of a variety of building materials.

3. For gypsum, the chemical reduction reactions which occur during combustion in the bomb result in a fuel potential for this material which appears to partially account for endothermic losses during fire exposure. This effect was not observed for other materials in which fuel potential values measured should be considered indicative of the combined heat of combustion and heat of condensation of water vapor.

7. REFERENCES

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APPENDIX

Experimental Procedure

The following paragraphs describe the procedures used in performing the measurements reported in this paper. These procedures are suitable for non-metallic or mixtures of metallic and non-metallic materials in which the metallic component is not a major constituent.*

Magnesium was the only metallic material found to burn when exposed to the conditions of the muffle furnace. The other metals were subject to surface oxidation, and thus, fuel potential data were computed from weight changes and heat of formation data of the oxide on the assumption of no volatile loss of the metallic component.

*Caution should be observed when performing bomb calorimetric measurements containing significant proportions of metallic materials. Apart from the high reaction temperatures which may occur with the resulting possible involvement of portions of the bomb, another difficulty involves the possibility of electrical shorts in the ignition system.

<u>Specimen</u>:

Two air-dry test samples are required for each determination, both must be truly representative of the material or assembly involved. Treatment of these two samples will be described separately:

A. <u>Specimen for Direct Bomb Test</u>

1. All or a truly representative portion of this specimen was pulverized into a form suitable to pass a 60-mesh screen.

2. A one-gram pellet of a representative sample of the powder formed in step 1 was prepared.

3. This pellet was used as the test specimen following the procedures for determination of calorific value recommended in reference (8).

4. The fuel capsule was examined after firing the bomb. If the pellet burned completely, leaving no significant amount of ash, the calorific value computed on an air-dry basis was recorded and steps 5 through 7 were omitted.

5. If the pellet did not burn or a significant amount of ash remained after step 4, a second one-gram pellet was prepared with an intimate mixture of the powdered sample and a standard sample of benzoic acid in equal weight proportions.

6. The pellet prepared under step 5 was used as the test specimen following the same procedures as for item 3 above.

7. A correction for the heat content of the benzoic acid present in the pellet was applied to the measured heat released by the specimen. The calorific value was then computed on an air-dry basis.

B. Specimen for Muffle and Bomb Test

1. A truly representative air-dry specimen of the material, or assembly, was cut in the form of a rectangular prism having dimensions of 1/2 x 3/4 x 3 in. In the case of sheet materials, folded or laminated assemblies were formed to these dimensions.

2. The weighed specimen was supported in a fused silica container of 1-1/4 in. inside diameter by 4-in. length. The specimen and container cap and a tube for supply of air to the bottom of the container were then fitted. The assembly was then placed in an electric muffle furnace operated at 750°C. Air was supplied at a rate of 0.1 cu ft/min. measured under laboratory conditions, to assist in oxidation of the specimen. In cases where ignition occurred immediately, application of air was delayed until initial flaming had stopped. Heating of the specimen was continued for two hours.

3. The silica container with specimen was removed and placed in a desiccator to cool. Measurements were then made to determine the weight loss of the specimen.

4. If the residue from the muffle procedure was less than ten per cent of the initial specimen weight, the following steps were omitted and the calorific value determined under paragraph A, Section 3 or 7 was reported as the fuel potential of the material.

5. If the residue from step 4 was in excess of ten per cent of the specimen weight, this residue was pulverized and the same procedures used as for steps 5 through 7, under paragraph A. The resulting calorific value was reported as that of the residue.

6. The calorific value of the residue was multiplied by the ratio of the residue weight to the original specimen weight.

7. The fuel potential of the material was then determined by subtracting the calorific value resulting from step 6 from that obtained under paragraph A, Section 7. The resulting difference in calorific values represented the heat released ruring specimen exposure in the muffle and was reported as the fuel potential.

Table I

Comparison of Computed* and Measured** Fuel Potential of Mixtures of Plaster and Charcoal

Charcoal in mixture		Fuel Potential		Apparent error in Measurement
Dry Plaster Basis	Hydrated Plaster Basis	Computed	Measured	
%	%	BTU/lb	BTU/lb	BTU/lb
0	0	-288	-288	-
1	0.852	-170	-172	-2
2	1.705	-47	-29	+18
5	4.28	+318	+357	+39
10	8.64	934	833	-101
30	26.7	3,489	3,320	-169
50	45.4	6,142	6,140	-2
100	100.0	13,873	13,873	-

*Computations were made on the assumption of exact specimen preparation and fuel potentials for charcoal and hydrated plaster of 13,873 BTU/lb and -288 BTU/lb respectively.

**Measured valves are averages of two determinations with combustion acceleration in concentrations of 50 per cent.

Table II

Fuel Potential and Flame Spread Properties of Selected Materials

Material	Dimensions and/or Composition	Thickness	Density	Weight Loss at 105°C	Residue after Muffling	Higher Heat of Combustion Raw Material	Higher Heat of Combustion After Muffling	Fuel Potential Weight Basis	Fuel Potential Volume Basis	Fuel Potential Unit Area Basis	Flame Spread Index
		in.	lb/ft^3	%	%	BTU/lb	BTU/lb	BTU/lb	BTU/ft^3	BTU/ft^2	I_s
1. Woods											
a. Douglas Fir	Untreated	3/4	38.0	9.1	0.0	8402	*	8402	319.3x10^3		69
b. " "	Fire Retardant Treatment "A"	3/4	37.2	8.4	1.9	8288	*	8288	308.3 "		5
c. " "	" " " "B"	3/4	47.2	11.0	1.6	7855	*	7855	370.8 "		3
d. " "	" " " "C"	3/4	38.8	12.7	4.5	7048	*	7048	273.5 "		1
e. Maple, Soft	Untreated	1	39.5	10.3	0.4	7944	*	7944	313.8 "		82
f. Hardboard	"	1/4	59.8	4.4	0.6	8531	*	8531	510.2 "		150
2. Plastics											
a. Polystyrene	Wall tile 8 1/2" sq. light green	0.075	65.4	0.05	2.3	17417	*	17417	.139.1 "		335
b. Rigid Polyvinyl chloride	Retardant treated, dark gray	0.147	86.0	0.14	0.0	9291	*	9291	799.0 "		10
c. Phenolic Laminate	Dark gray	0.063	76.4	3.2	1.4	7745	*	7745	591.7 "		107
d. Polycarbonate Resin	Transparent amber	1/4	78.7	0.12	0.0	13332	*	13332	1049.2 "		56
3. Insulation											
a. Glass fiber	Semi-rigid no vapor barrier	1	3.0	1.6	59.4	3023	-35	3044	9.1 "		
b. Rock wool batting	Full thick - batting	3	2.4	0.6	91.4	1213	180	1049	2.5 "		
c. Roof insulation board		1	10.4	1.8	65.9	3352	-40	3378	35.1		61
d. Cork	Reconstituted cork sheet	1/4	14.8	7.4	0.4	11113	*	11113	164.5 "		
e. Cellulose mineral board		2	47.8	10.8	48.4	2284	58	2256	107.8 "		1.3
4. Concrete											
a. Cinder aggregate	9% Cement 7% Fly Ash 84% Aggregate	-	93.0	2.4	94.0	3258	192	3078	286.3 "		-
b. Slag "	8% " 9% Pozzualana 83% "	-	110.1	0.9	94.8	40	-43	81	8.9 "		-
c. Shale "	12% " 4% Fly Ash 84% "	-	80.5	1.0	95.3	-25	-34	7	.5 "		-
d. Calcarious gravel aggregate	4% " 4% Silica Flour 92% "	-	133.1	0.4	82.2	-239	12	-249	-3.3 "		-
e. Silicious " "	12% " 38% Sand 49% "	-	166.8	2.4	96.2	-67	-28	-40	-66.7 "		-
5. Cement Board											
a. Asbestos cement board	-	3/16	117.0	2.1	81.2	129	61	79	9.2 "		0.0
b. " " " + 20 mil paint	-	3/16	159.2	1.7	79.0	398	7	392	62.4 "		0.7
6. Gypsum											
a. Ca SO$_4$.2H$_2$O	Hydrated neat gypsum	0.41	137.9	23.5	79.9	-590	-378	-288	-39.7 "		0.0
b. Perlite aggregate plaster	79% Plaster 21% Aggregate Nominal 1:2 1/2	1	53.2	14.7	84.1	-318	-467	75	4.0 "		0.0
c. Sand " "	32% " 68% " " 1:2	1	101.8	7.0	92.1	-108	-60	-53	-5.4 "		0.0
d. Vermiculite " "	85% " 15% " " 1:2	1	51.2	17.9	82.1	-459	-451	-89	-4.6 "		0.0
e. Gypsum board "A"		3/8	50.5	17.2	81.2	175	-722	761	38.4 "		14.3
f. " " " with paper removed	-	3/8	46.6	.06	78.6	-719	-573	-269	-12.5 "		0.0
g. " " " + Alkyd gloss paint	-	3/8	46.7	14.4	74.4	408	-638	883	41.2 "		8.0
h. Gypsum board "B"	-	1/2	51.2	21.8	73.6	98	-743	645	33.0 "		7.9
7. Lath											
a. Gypsum A	-	3/8	55.3	16.7	74.9	-20	-438	308	17.0 "		
b. Metal diamond mesh	-	.025	405	0.0	102.6	3630	2340	1630	-	1373	0.0
c. Metal diamond mesh paint removed	-	.019	401	0.0	102.6	3063	2340	663	-	420	0.0
8. Metals			lb/ft^2								
a. Structural steel - unpainted	8 x 1/2 x 0.0598 in.	.060	0.828	0.0	101.8	2858	2583	229	-	190	
b. Magnesium	-	-	-	0.0	0.0	10646	-	10646	-	-	-
c. Aluminum	24 x 3/4 x .004 in.	.004	.028	0.0	100.95	13317	-	142$^+$	-	4.0$^+$	-
d. Brass	24 x 25/32 x .004 in.	.004	.087	0.0	100.8	1651	-	53$^+$	-	4.6$^+$	-
e. Copper	12 x 3/4 x .024 in.	.024	.514	0.0	-	1051	-	-	-	-	-
f. Lead	12 x 3/4 x .036 in.	.036	1.0	0.0	100.32	455	-	19$^+$	-	19 $^+$	-
9. Miscellaneous											
a. Paint "E"	50 mil paint film removed	.05	-	-	0.0	3640	*	3640		-	30
b. Asphalt shingles	Fire retardant	1/4	70.7	0.3	50.3	8288	-66	8321	588.3 "	-	123
c. Building paper	Asphalt impregnated	.042	42.8	0.6	2.1	13615	*	13615	582.7 "	-	385
d. Building paper	Rosin sized	.018	23.6	6.0	0.0	7653	*	7653	180.6 "	-	192
e. Linoleum tile	Laminated tile 90in. square marbelized	1/8	86.0	1.5	45.4	7720	-83	7758	667.2 "	-	106
f. Brick red-face	-	2 1/4	139.1	.07	99.7	62	46	16	2.2 "	-	0.0

* Fuel potential was assumed equal to the higher heating value of the raw material because of the low residue after muffling.

\+ These fuel potential values are based on weight changes and assumed oxidation reactions as described in the text.

Table III

Estimated Corrections to Fuel Potential Measurements for Heat of Vaporization Effect*

Material	Water present or resulting from combustion	Fuel Potential Correction
	% by weight	BTU/lb
Douglas Fir	66	-1130
Styrene	69	-1180
Vinyl chloride	82	-1410
Gypsum plaster (neat)	21	- 360
Concrete	6	- 102

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* Based on enthalpy difference at atmospheric pressure between that of water at 20°C and steam at 750°C.

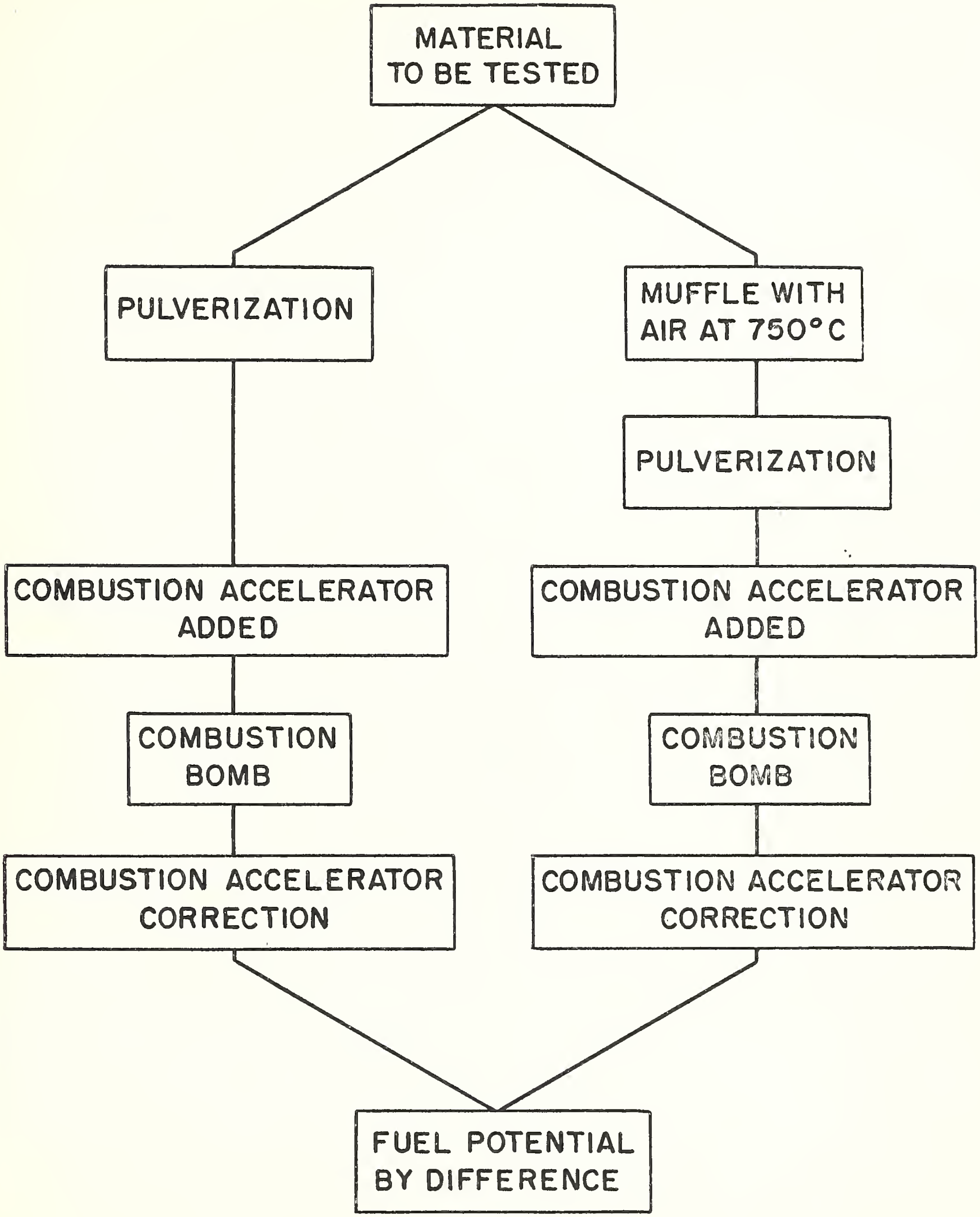
MATERIAL TO BE TESTED
PULVERIZATION
MUFFLE WITH AIR AT 750°C
PULVERIZATION
COMBUSTION ACCELERATOR ADDED
COMBUSTION ACCELERATOR ADDED
COMBUSTION BOMB
COMBUSTION BOMB
COMBUSTION ACCELERATOR CORRECTION
COMBUSTION ACCELERATOR CORRECTION
FUEL POTENTIAL BY DIFFERENCE

FIGURE I

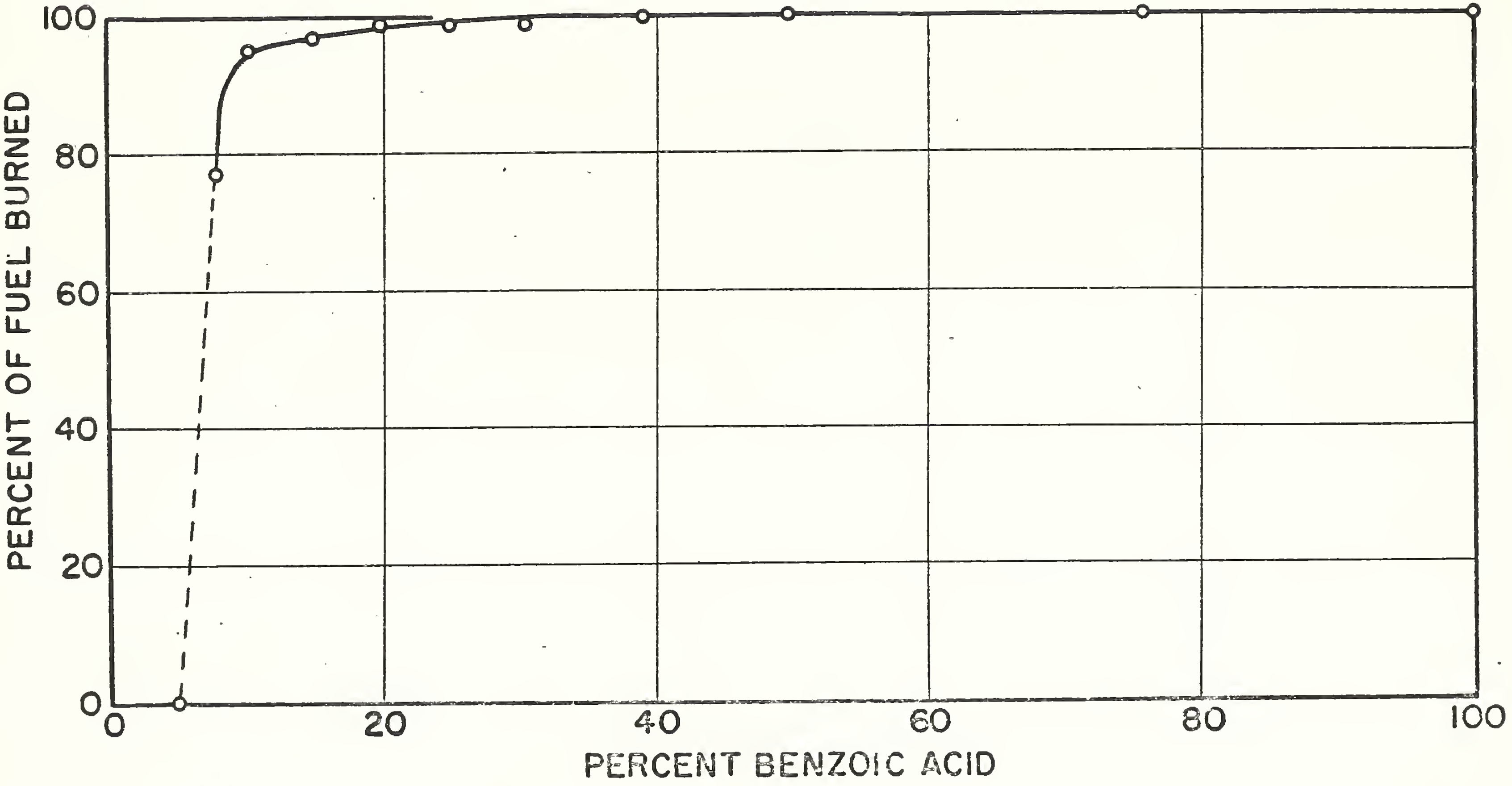
100
80
60
40
20
0
PERCENT OF FUEL BURNED
0
20
40
60
80
100
PERCENT BENZOIC ACID

FIGURE 2

U.S. DEPARTMENT OF COMMERCE
Frederick H. Mueller, *Secretary*

NATIONAL BUREAU OF STANDARDS
A. V. Astin, *Director*

THE NATIONAL BUREAU OF STANDARDS

The scope of activities of the National Bureau of Standards at its major laboratories in Washington, D.C., and Boulder, Colorado, is suggested in the following listing of the divisions and sections engaged in technical work. In general, each section carries out specialized research, development, and engineering in the field indicated by its title. A brief description of the activities, and of the resultant publications, appears on the inside of the front cover.

WASHINGTON, D.C.

Electricity and Electronics. Resistance and Reactance. Electron Devices. Electrical Instruments. Magnetic Measurements. Dielectrics. Engineering Electronics. Electronic Instrumentation. Electrochemistry.

Optics and Metrology. Photometry and Colorimetry. Photographic Technology. Length. Engineering Metrology.

Heat. Temperature Physics. Thermodynamics. Cryogenic Physics. Rheology. Molecular Kinetics. Free Radicals Research.

Atomic and Radiation Physics. Spectroscopy. Radiometry. Mass Spectrometry. Solid State Physics. Electron Physics. Atomic Physics. Neutron Physics. Radiation Theory. Radioactivity. X-rays. High Energy Radiation. Nucleonic Instrumentation. Radiological Equipment.

Chemistry. Organic Coatings. Surface Chemistry. Organic Chemistry. Analytical Chemistry. Inorganic Chemistry. Electrodeposition. Molecular Structure and Properties of Gases. Physical Chemistry. Thermochemistry. Spectrochemistry. Pure Substances.

Mechanics. Sound. Mechanical Instruments. Fluid Mechanics. Engineering Mechanics. Mass and Scale. Capacity, Density, and Fluid Meters. Combustion Controls.

Organic and Fibrous Materials. Rubber. Textiles. Paper. Leather. Testing and Specifications. Polymer Structure. Plastics. Dental Research.

Metallurgy. Thermal Metallurgy. Chemical Metallurgy. Mechanical Metallurgy. Corrosion. Metal Physics.

Mineral Products. Engineering Ceramics. Glass. Refractories. Enameled Metals. Constitution and Microstructure.

Building Technology. Structural Engineering. Fire Protection. Air Conditioning, Heating, and Refrigeration. Floor, Roof, and Wall Coverings. Codes and Safety Standards. Heat Transfer. Concreting Materials.

Applied Mathematics. Numerical Analysis. Computation. Statistical Engineering. Mathematical Physics.

Data Processing Systems. SEAC Engineering Group. Components and Techniques. Digital Circuitry. Digital Systems. Analog Systems. Application Engineering.

- Office of Basic Instrumentation.
- Office of Weights and Measures.

BOULDER, COLORADO

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Radio Propagation Physics. Upper Atmosphere Research. Ionospheric Research. Regular Propagation Services. Sun-Earth Relationships. VHF Research. Radio Warning Services. Airglow and Aurora. Radio Astronomy and Arctic Propagation.

Radio Propagation Engineering. Data Reduction Instrumentation. Modulation Research. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Propagation Obstacles Engineering. Radio-Meteorology. Lower Atmosphere Physics.

Radio Standards. High Frequency Electrical Standards. Radio Broadcast Service. High Frequency Impedance Standards. Electronic Calibration Center. Microwave Physics. Microwave Circuit Standards.

Radio Communication and Systems. Low Frequency and Very Low Frequency Research. High Frequency and Very High Frequency Research. Ultra High Frequency and Super High Frequency Research. Modulation Research. Antenna Research. Navigation Systems. Systems Analysis. Field Operations.


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