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8131

EXPERIMENTAL FIRES IN ENCLOSURES C.I.B. TEST RESULTS

by

D. Gross

U. S. DEPARTMENT OF COMMERCE National Bureau of Standards NATIONAL BUREAU OF STANDARDS A. V. Astin, Director



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U. S. DEPARTMENT OF COMMERCE NATIONAL BUREAU OF STANDARDS

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Abstract

The results of a series of model fire experiments performed under an international cooperative program are reported.

1. Introduction

Following the original suggestion by the British Joint Fire Research Organization (J.F.R.O.) in 1959, for a systematic investigation of the growth of fires in rooms using small-scale models [1], a preliminary series of tests under the sponsorship of the Working Party on Fire Research of the Conseil International du Batiment (C.I.B.) was undertaken by eight laboratories in six countries including the U. S. National Bureau of Standards [2]. The results from that series of eight tests were analyzed by J.F.R.O., who concluded that too great a variation existed between laboratories to permit the start of a larger program without more detailed specification of experimental techniques. More specific test procedures were subsequently suggested in both report form [3] and through a series of letters.

Ten laboratories in eight countries are participating in the current program and this report is the summary record of tests performed at N.B.S.

2. Experimental Procedures

2.1 Test Schedule

The testing scheme outlined in reference [3] provides for examining the effect of six parameters on the rate of burning, temperature and radiation in a compartment containing a wooden crib and a single window opening. The parameters, with the number of combinations in parentheses, were: Shape (5), Scale Size (3), Window Opening (3), Fire Load, or Quantity of Fuel (3), Fuel Dispersion (3) and Fuel Dimension (4). In addition, one laboratory was to examine the effect of wind speed in three directions. The tests assigned to each laboratory were divided into two series. Series 1 comprised eight tests each repeated so as to provide an estimate of experimental variation and to establish a common base between laboratories. The Series 2 program assigned to NBS was considerably larger than could reasonably be handled and was deferred.

2.2 Test Compartment

The compartment was constructed according to detailed drawings provided by a cooperating laboratory, Brandveiligheidsinstituut T.N.O., Holland. It consisted of an angle steel framework and asbestos-cement sheets held together with screws (see Figure 1). An asbestos-cement board partition was used for those tests requiring a compartment only one-half the overall length of 2 meters. The width and height were 2 meters and 1 meter, respectively. A removable window assembly was constructed as a single member rather than in two halves.

The prescribed properties of the asbestos sheets were as follows:

Thickness:	0.95	cm (3/8 in.)
Density:	1.5	g/cc

Thermal

Conductivity: 0.00085 cal/sec cm °C

Although an asbestos-cement board of these properties was obtained and used in the initial program in 1959, it was found to be no longer available on this continent. Therefore, and because of the severe fire exposure to which the compartment walls were to be subjected, it was considered necessary to purchase and use the currently available "Superbestos," rated by its manufacturer, Atlas Asbestos Co., Ltd., Montreal, to possess a higher degree of thermal stability during fire exposure. It had the following properties:

Thickness:	0.95 cm
Density:	0.67 g/cc
Thermal	
Conductivity:	0.00029 cal/sec cm °C

Severe cracking was experienced nonetheless during the first preliminary test, so that a means of patching was required. The method which proved most satisfactory and was used several times during the program, involved a light spray application of a fire-resistant gypsum plaster with perlite aggregate (avg. applied density 0.43 g/cc, thermal conductivity .00028 cal/sec cm °C.) The same plaster was also applied by trowel to fill in large cracks.

Tests were conducted only after preheating and drying of the compartment to remove moisture absorbed by the asbestos-cement sheets and the plaster. This was done by burning a minimum of 40 kg of scrap wood at the start of each day's testing and, where possible, by consecutive testing. All tests were conducted in the prescribed sequence during the period October 18 to November 4, 1963.

After the first few tests, a noticeable distortion of the window opening was observed and which remained fairly constant throughout the series. Whereas the original design opening was 48 cm, the opening became barrel-shaped and varied from approximately 48.0 cm at the top and bottom to approximately 49.5 cm near the center.

2.3 Wood Cribs

The fuel consisted of wood sticks of nominally square section arranged in cribs with a lattice-type construction. The type of wood prescribed was spruce with a density of $0.39 \text{ g/cc} \pm 10 \text{ percent}$ when oven dry. The wood used was select grade Engelmann spruce (Picea engelmannii) which was smooth-sawed to size and preassembled into cribs using a thermosetting urea resin adhesive and a small quantity of nails. Details of the construction, composition and average density of each crib are given in Table 1. Cribs were conditioned to constant weight in an atmosphere controlled at 73 ± 2 F and 50 ± 5 percent rh. Prior to test, each crib was adjusted to its prescribed weight by the addition or removal of wood. The average moisture content of each crib at the time of test is also listed in Table 1. In each case, the crib weight comprised the spruce crib, the glue and the fiberboard wicks, but excluded the weight of nails and kerosene.

2.4 Weight Measurements

The tests were performed with one side of the compartment approximately 1.5 meters from the wall of a very large and essentially draft-free room. The compartment was suspended in a steel cradle so that its floor was approximately 1 meter above the building floor. The entire cradle and compartment was suspended and weighed by means of a commercial load cell of the strain gage type. In order to prevent load cell erros due to thermal effects, a cooling water jacket was placed around it. The temperature of the load cell case was monitored in all tests and never exceeded 46°C, the permissible temperature limit for complete conformance to specifications. The load cell output was adjusted to 0.0662 mv/kg (0.0300 mv/1b) and checked out perfectly before and after the test program using known weights. The millivolt output signal was digitally recorded at one minute intervals.

The compartment was levelled prior to each test and required slight relevelling (by means of sliding weights) during a few tests. No account was taken of the buoyancy effect, the magnitude of which might possibly be 4 kg for the scale 1, shape 221 compartment with 160 kg lead.

It was found in a typical test that the weight of the compartment and crib would decrease to a minimum value, corresponding to approximately 1 to 10 kg negative, and regain approximately 5 kg upon cooling to room temperature. The weight of ashes was usually between 0.2 and 0.7 kg.

2.5 Temperature Measurements

Thermocouples for indicating "ceiling" and "floor" temperatures were of 0.0508 cm (0.020 in.) diameter (B & S 24 gauge) chromel and alumel wires with asbestos and glass, silicone impregnated insulation. The beads were bare and unshielded. The thermocouples were inserted through a small hole in the top of the compartment and new thermocouples were used for each test. Temperatures were recorded directly and automatically in digital form at one minute intervals. Window (opening) radiation was monitored by Radiometer "H/14" for all tests and the calibration provided by J.F.R.O. (and checked at NBS) was used for conversion of millivolt output readings to intensity values in cal/sec cm². This radiometer was mounted on an outrigger frame attached to the compartment and at a distance of 2 meters from the compartment face for all tests. Except for the first test (NBS No.1, C.I.B. No. 1), all succeeding tests were conducted using a sheet metal screen immediately in front of the radiometer so as to minimize the contribution of radiation from flames above the window opening [4].

Flame radiation was monitored by a similar radiometer placed centrally 10 cm above the top of the compartment and in the plane of the opening. It was fabricated at NBS according to the published description [5], and its cone was blackened to reduce reflections [4]. Radiometer "R 1" was used for all tests with the exception of Test Nos. 7, 15 and 16 (NBS chronological designation), where Radiometer "R 2" was used.

Calibration curves for the three radiometers used are shown in Figure 2.

2.7 Data Recording

Data were automatically recorded in digital form by means of a scanning and recording system [6] programmed to provide a complete set of readings at one minute intervals. Since the measuring potentiometer contained two balancing slidewires, it was possible to obtain both direct temperature readings (with the use of chromel-alumel thermocouples) in the range 0 to $1400^{\circ}C$ ($\pm 4^{\circ}C$ accuracy) and millivolt readings in the range 0 to 14.00 mv ($\pm 0.04 \text{ mv}$ accuracy). For those cases in which the output from the flame radiometer exceeded 14 mv, a 10 mv bucking signal was used to extend the range of the potentiometer to 24 mv.

For the scanning sequence used, the actual measuring times for each one minute cycle were as follows:

Quantity	Channel	Time	
		min:sec	
Laclosure Weight, mv	0	0:00(and e minut	ach succeeding e)
Window Radiation, mv	31	0:08	11
Flame Radiation, mv	32	0:09	31
deiling Temperature, °	C 33	0:10	T
Floor Temperature, °C	34	0:11	31

In the listing and analysis of data, however, it was assumed that all readings were made at the time corresponding to the weight reading.

3. Results

The results of the sixteen tests performed in the prescribed sequence are listed in the standard form at the end of this report. Statistical averages were computed as requested for the time periods corresponding to 80 and 55 percent of the initial weight (80/55) and to 55 and 30 percent of the initial weight (55/30). The radiation and temperature averages were based upon the appropriate measured values at one-minute intervals, with no attempt at curvefitting or interpolation. However, the rate of weight loss averages were based upon the interpolated 30, 55 and 80 percent times from a smooth curve drawn through the oneminute readings. Table 2 presents a summary list of all average values for the test series.

4. Observations

The following additional observations were visually noted during the test series:

The entire crib was not involved in flaming simultaneously, but rather burning proceeded from the front third, where the kerosene-soaked wicks were ignited, toward the rear. After burning had involved the front face of the crib, the increasingly taller flames were bent backwards by the inrush of air. The normal pattern of air inflow at and near the floor level, then up and around at the rear of the compartment, and the exhaust of hot gases and flames at the ceiling level was then always obvious. However, for those tests with only 1/4 window opening, strong fire whirls were observed in the front corners of the compartment near the start of the test. These flaming vortices, which rose directly toward the ceiling and were drawn out of the window opening, lasted only until the burning had increased sufficiently to establish the normal pattern.

It was observed that with the 1/4 window opening the exiting flames and gases filled a larger portion (up to two-thirds) of the window opening than with the full open window (up to one-third). In addition, the flames extended to a greater height outside the compartment (up to 3 meters) in those tests with the 1/4 window opening.

During the major portion of those tests with the full window opening, a definite pattern of flame pulsations with accompanying "swoosh" sounds was noticed. These pulsations occurred with a frequency of approximately one per second. In both instances of a test with a 1/4 window opening (C.I.B. 3), a single rapid burst or mild explosion followed by momentarily increased flaming was observed.

The crib retained its lattice structure until almost the entire weight loss had occurred and then gradually crumbled, this again proceeding from front to rear as the charcoal glowing took place. The weight of the remaining ashes never amounted to more than one percent of the initial crib weight.

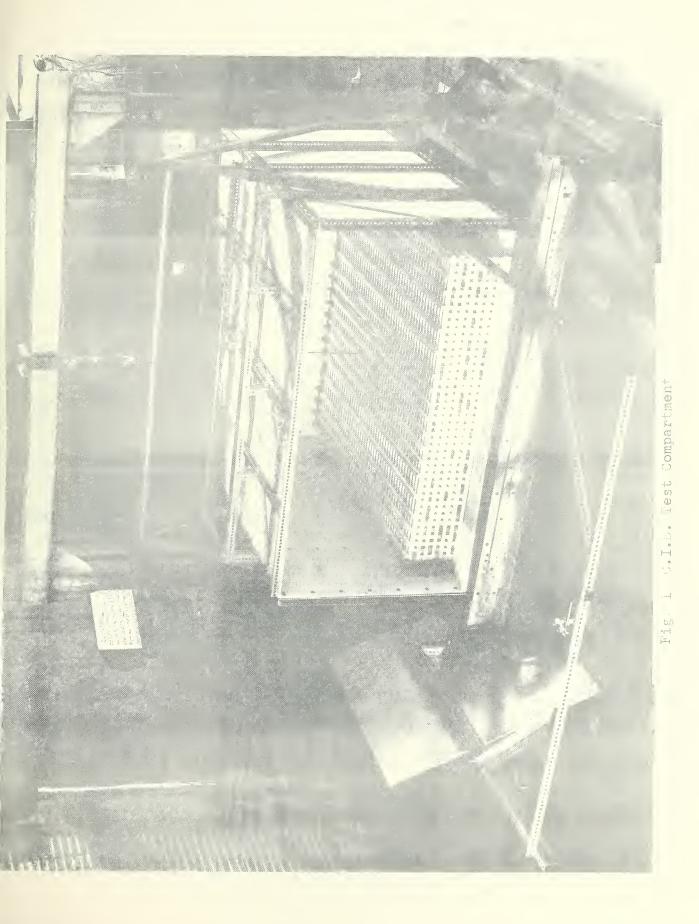
Dark, dense smoke was common to all tests, and for those tests with 80 and 160 kg cribs, the entire building of over 3000 m³ became completely smoke-logged with visibility at eye level reduced to as little as 25 cm.

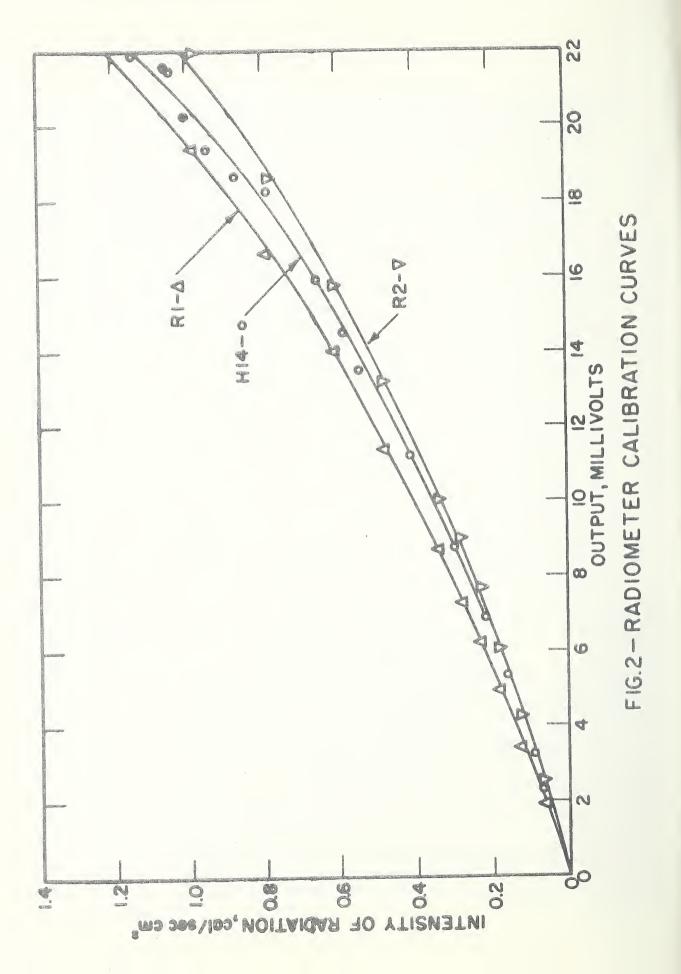
5. Acknowledgments

I am pleased to acknowledge the aid of John Klein and James Turner in the assembly of the cribs and of David Newman in the efficient performance of the tests and in the summary of the data. Edward Bender, Garnett Robinson and Melvin Womble assembled the compartment and attended to its repair and maintenance throughout.

6. References

- [1] Lawson, D. I., "International Co-operation in Modelling Fires, A Suggested Programme," F.R.W.P./G.T.F. No. 59/11 (U.K.), June 1959.
- [2] Gross, D., Ward, D. and Shoub, H. "Fires in Model Rooms, Results of Preliminary Experiments Under an International Cooperative Program," NBS Technical Report No. 6888, July 1960.
- [3] Thomas, P. H., and Mather, J. "Proposals for Next Stage of C.I.B. Programme on Fires in Compartments," C.I.B./C.T.F. No. 61/49 (U.K.), September 1961.
- [4] Letter from P. H. Thomas, dated April 2, 1962.
- [5] McGuire, J. H. and Wraight, H. "A Radiometer for Field Use," J. Sci. Inst. <u>37</u>, p. 128, April 1960.
- [6] Gross, D., Bailey, W. H., Bender, E. W. and Robertson, A. F. "Central Furnace Control and Recording Facility," NBS Technical Report No. 7015, November 1960.





Date	NBS No.	CIB No.	Designation	Crib No.	Stick Height	Size ^a Width	Packing Density	Weight Nails	Weight Glue (wet)	Test b Weight ^b	Mean D As Condi.	ensity Dry Basis	Moisture Content Dry Basis
1001					cm	сш		kg V	kg	kg	g/cm3	g/cm3	Y
10-18			221-20-1/4	∞	1.99	2.09	0.91	0.73	0.58	79.3	°. ⊔.16	and the second s	ł
10-21	2	5	221-20-1	\sim	l.98	1.95	1.05	0.22	0.83	79.8	°.,21	.391	7.6
	~	T	221-40-1/4	10 1	1.98	2.09	0.91	0.53	1.6 ^{4.}	160.0	.395	.366	7.8
10-23	Ť, (0	221-4·0-1	2	1.99	2.00	J.00	0.38	1.67	160.0	°, 4.09	· 377	8 • ¹ .
10-24	5	9	211-4.0-1/4.	1 ⁺	1.98	2.09	0.91	0.18	1.16	80°0	• 4.02	• 369	8.9
- 1		\sim	211-20-1/4	15	1.98	2.09	16.0	0.12	0.36	Ŋ.O . O	° 1.08	.385	6.0
1	~		211-0-1	ļ Ţ	1.99	2.13	0.88	0.16	0.81	80.0	· 14.07	.367	10.9
1	. 00	6	211-20-1	12	1.99	2.13	0.88	0.12	0 , ¹ , 1	Ŋ.O ₀ O	, h.05	• 373	00°57
1	0	, i>-	211-4.0-1	0	1.99	2.13	0.88	0 . 1 ^{4.}	0°°0	80.0	• 398	• 367	8 • 4.
10-30	10		221-20-1/ ^l i	!	1.98	1.93	Ι.07	0.29	0.96	80.0	°. 4.08	• 376	8. 7
10-31	1	0	221-4.0-1	Ţ.	1.99	2.00	J.00	0.87	1 ° 4.4.	160.0	° 1.06	• 3 7 ^{4.}	8.7
	12	0	211-20-1	07	1.99	2.13	0.88	0.07	0.32	4.0.0	, 4:34.	.396	9.6
E.	7	. 0	211-40-1/4	5	1.99	2 .:00	l.00	0.19	1	80.0	4.0.7°	.371	9°7
11-1	17	\sim	211-20-1/4	9	1.99	2.00	L.00	0 ° 08	0.31	Ъ ₁ .О • О	• 4·65	. 4.22	10.1
	1-77		221-20-1	N	l.98	1.93	1.07	0.10	1.01	80.0	• 4. 1 4.	• 378	9.6
-	1												(

Total weight after conditioning includes fiberboard wicks and dry glue, but excludes nails or kerosene.

Uniformity within a single crib varied from ±2% to ±10%. Length = 83 cm or 167 cm nominal.

9.3

.358

• 391

160.0

1.68

0.49

0 • 88

2.13

l.99

13

221-4.0-1/4.

÷

16

11-4.

. ਕ Based on drying at 105°C of a portion of a stick removed from individual crib just prior to test. ů

Table 1. Properties of Test Cribs

Date 1763	NBS No.	CIB No.	Designation	1	Rate o Weight Lo	Loss Loss	an adi	Window ation	die	rlame tion	Ceiling Temperature	ing ature	Mean F. Tempera	Floor rature
				- 17 - 11	NS/ III	111	CAL/ SEC			sec cm-			~	2
				t80	80/55	55/30	80/55	55/30	80/55	55/30	80/55	55/30	80/55	55/30
10-18	Ч	!	221-20-1/ ⁴	- 9	3.54	2.87	,181	.161	crea	9	919	1090	906	104.8
10-21	10	Ч	221-20-1/ ¹ 4	8 ° 0	3 ° 56	2.93	, 164	.156	,250	.216	902	1028	895	1009
10-31	9	m	211-20-1/4	5.4	3.45	2.22	∘ 1 ¹ 4·O	. 169	. 694	.482	1027	1078	1016	1031
111	14.	\sim	211-20-1/4	2.0	3.45	2.22	. 173	.176	. 628	°4.17	1074	1093	1055	1023
10-24	m	4	221-4.0-1/4	14.5	3.31	2.44	° 1 ¹ +8	• 1 ⁴ -3	•729	, 62 ⁴ .	570	995	872	985
10-25	16	4	221-4.0-1/4.	13.7	3.31	2.44	. 14.6	• 1 ⁴ 1	. 562	• 4.38	857	952	857	952
10-29	77	9	211-4.0-1/4	8.4	3 • 23	2 , 56	.154	. 164	• 808	.672	964	1056	94-7	974.
10-30	13	9	211-4.0-1/4	°.	3.28	2.50	.151	.163	. 805	• 684	936	1027	927	958
10-22	2	2	221-20-1	6.2	6.06	lt. , 00	°, 4.06	.317	· 554	. 291	977	1002	959	980
10-23	12	2	221-20-1	20	5.26	Lt. 00	• 14.24:O	•378	•618	.370	959	1028	94.9	998
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11 - 4	12	9	211-20-1	5°.0	2,56	1 . 96	. 194	.181	.102	• 054	660	556	737	709
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10-29		0	221-40-1	00 00 00	5.88	4.12	• ⁴ ·21	.359	.738	.359	946	1027	94:3	995
11-1	2	X	211-40-1	8.7	3.64	2.53	.360	.308	,407.	.225	969	93 ^{4.}	98 <u>1</u>	94.9
	0.	\bowtie	211-4:0-1	8.1	3.70	2 . 67	• 3 74	.312	• 534	.318	166	961	1006	990

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Flame Radiation, cal/sec cm ²	ation, m ²	000 *	.000 .005 .055 .430 .605	• 055	.430	. 605	. 625	• 250	.180 .	.100 .	• 080 •	• 055 •	· 040 ·	.025	. 010 .	.010						98 m III - 1 (1994) y	
Time, min			42	44	99	4.8	50	52	54	2.0	00 1/1	60	62	64	66	68	70	72	74	76	78	80,	409
Weight, kg																						400 t (Å t	
Temp. Ceiling,	ing, °C'										•											1 d - en gra pg	
Temp. Floor,	or, °C												٠									agrants an	
Window Rediation, cal/sec cm ²	liation, m ²																				·	· .	
Flame Radiation, cal/sec cm ²	ation, m2																					1800 (ann 1 d) an 2 d	
STATISTICS													1				8				-		
Rate Wt.	Rate Wt. Loss kg	1	Ceil	ing	Ceiling Temp.°C	daren arrestation	Floor	r Teu	Temp.°C	generalizing	Window Rad		cal sec cm ²	permittant	Flame	Rad	cal sec cm ^Z	170	5°0	Time to orig. wt.	t. min	20	
R80/55	R55/30		0e 80	1/55 (0e 80/55 0e 55/30		0880/55	55 0b	$\theta_{\mathbf{b}}^{55/30}$		I°80/55	H	I _• 55/30	0	I _f 80/55		I _f 55/30	30		5	t80		
6.06	4.00		977		1002	nghalanta dingh	959		980	4.	.406		317		.554		.291			6.2		··· · · .	
		•													a Current de la calegaria de la							eșe.	
						•																1	•

•	34 63 35 38 54 40 68.3 63 55 58.7 54 40 959 978 1032 1059 952 973 1023 1045	.140 .140 .140 .130 .620 .600 .575 .520	74 76 78 80 6,6 5.2 4,4 3.5 1021 994 952 907 922 902 871 827 .105 100 .085 .070	.080.045 .040 .030	Time to 80% orig. wt.min t30	14.5
MENTS C. P.O kg/m ² spacing cm. side	⁴ 78.5 73.4 944 960 937 953	.155 .150 .735 .685	5 1 ⁷ 0.5 72 7 1061 1034 8 978 947 5 .115 .110	5 .110 .100	d. cal sec cm ² I _f 55/30	624
D. D.	26 90.5: 926 923	5 .155 .155 0 .745 .770	64 666 68 17.0 ^{14.7} 12.5 1.084 1082 1077 1015 1033 1018 .110 .115 .115	.175 .150 .135	Flame Rad. I _f 80/55	.729
IN SIMP] ds, Wash: 3) t of Fue rsion of sion of	9.4, 22 96.4 9.4, 103.0 96.4 879 893 891 884 892 889	.150 .155 .155 .755 .765 .730	60 62 6. 21.5 19.4 17 1068 1076 10 1046 1.081 10 .105 .110 .1	135 ،170 ،1	Rad. cal sec cm ² I_55/30	.143
of St 4	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$.135 .140 .1 .690 .710 .7	56 58 27.1 24.1 21 1076 1079 10 1019 1067 10 .115 .110 .1	.190 .180	Window R I.80/55	.148
	36.9 _{130.1} 12 773 808 760 814	.120 .130 . .500 .615 .	52 54 33.2 30.2 2 1103 1088 1 1021 1015 1 .115 .115	• 235 • 245 •	or Temp.°C	985
INTERNATIONAL U. S. Nation C.I.B. Test D Shape: Scale: Window Opening	49. ⁸ 7143.6 ¹ 717753 717753 299600	.020 .065 .095 .050 .200 .385	50 36.1 1106 1007 .115	.355 .255	°C Floor 7 30 0 ₈ 80/55	5 872
H	156. ⁵ 154.3 ¹ 327 511 59 118		44 46 45.7 42.2 1081 1109 1052 1048 .125 .120	.480 .425 .385 .355	Ceiling Temp.°C	995
SITI	$\begin{array}{c} 160.0 \\ 160.0 \\ 159.1 \\ \circ C \\ 25 \\ 54 \\ \circ C \\ 21 \\ 26 \end{array}$	-000 -000				870
EXPERIMENTAL RESULTS	ing, r, °C	Window Radiation, .005 .005 .010 cal/sec cm ² Flame Radiation, .000 .000 .030 cal/sec cm ²	Time, min Weight, kg Temp. Ceiling, °C Temp. Floor, °C	Cal/sec cm cal/sec cm ² STATISTICS	Rate Wt. Loss ^{kg} R80/55 R55/30	31 2.44
EXPERI	Time, min Weight, kg Temp. Ceil Temp. Floo	Window cal/s Flame cal/s	Time, min Weight, kg Temp. Ceil Temp. Floo Window Rad	Flame Radi cal/sec c STATISTICS	Rate R80	3.31

ng ng kabang kadadi danén akan anan gunda klon da él mara bi akan dané na sa s K	93803	.140	.035	80			а фоненски столого 6 -		1	
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•	<i>с</i>	•	75 .045	78		·		to to	80 8	9.8
	36.2 8 937 4 934		5 •075	76				Time	110	
	34 39.8 984	0	.105	74			-	-	-	
	4 3 20 4 4 .00 1008 976	٩	.125	72	315 349	.030	• 000	In	f ^{55/30}	5
side	30 48.9 1054 986	. 250	* 205	70,				2	I £55	• 405
C C C	54.2 1062	°255	•375	68 1 • 4	359 406	.040	000°	e Rad	f ^{80/55}	78
D D D	26 60.1 1057 987	. 285	. 355	2.3	381 438	•045	• 005	Flame	1 _£ 8(• 778
	666.3 1068 994	.295	.405	64 2.9	435 474	• 050	•005	· 61		
SIMPLE Washin Fuel n of Fu	22 73.4 1052	010	. 480	624 4.4	437 516		•010	cal.2	I.55/30	291
FIRES IN S Form andards, W((NBS 4) Amount of 1 Dispersion Dimension (80.5 1029	.330	.515	60 5 • 9	486 569		.010	Rad.	йн	
	18 88.4 1023 1 1023 1		. 610	582	539 623		.015	Window R	I.o80/55	396
of	96.8 96.8 1005 1		• 745 •	56 9.0	566 654		.020 .	Win	I.08	
IONAL EXPERIMENTS Repo National Bureau of Test Designation Shape: 221 Scale: 1 meter pening: 1	5 5 6		• 865	11.2	586 5		.020 .(0	0b55/30	<mark>984</mark>
1 22 s1	0	0	• 770	52 11 3.4	656 <u>5</u> 688 (•	.030 .0	Temp.°C	0 ^b 55	6
TIONAL EX National Test Des Shape: 2 Scale: Opening:	10 116.2 26.8 1 927 941		· 016	508 5 13	645 6 735 6		.035 .0	Floor	0.80/55	980
E O	6	۰.	¢.			•		E4	98	
INTERNA U. S. C.I.B. Window	6 138 9.1 814 8: 77 9:	е е 00.	50 •5	6 48 18.2	676 669 797 749	.1.	0	°.	/30	1049
1	£ 4	٠	.005 .005 .030 .260 .560	2 ⁴⁶ 6		•	•050 •030 •030 •030	Ceiling Temp.°C	0e55/30	10
÷	2 155,8 155,8 155,8 53 351	- 04 - 04	2 • 03	44 5 23.6	844 721 901 866	0.13	0 • 03	iling	0 _e 80/55	2
	N . N .	× 10	00 .	42 26.5	844 901	.14(• 05(Ge	Oe	982
SI	160,0 22 22	.00	00.							
RESUL		, ion	° uo		ູ່. ເ	ion,	«uo	ss <mark>kg</mark>	R55/30	3.20
NTAL	ļņ,	adiat cm2	diati cm ²	c 89		adiat cm ²	diati cm ²	CS I	R	
EXPERIMENTAL RESULTS	Time, min Weight, kg Temp. Ceiling,	Window Radiation, cal/sec cm ²	Flame Radiațion, cal/sec cm ²	Time, mín Weight, kg	Temp. Ceiling, Temp. Floor.°	Window Radiation, cal/sec cm ²	Flame Radiation, cal/sec cm ²	STATISTICS Rate Wt. Loss kg	R80/55	4.88
EXPE	Time Weig Temp	Wind cal	Flan cal	Time Weig	Temp	Wind cal	Flar cal	STAT Ra	R .	7

•			07			i Ó		80						20	.1. 8.4	
			00 00		936	.100	.150	73						10 10	2 00 L	8.4
			36	1.2	956	· 112 ·	•185	76						Time to 80%	- 27	00
			34	3.9	971	.120	.230	74								
			32	6.7 1068		.115	。245	72						al cm2	30	
-		/m ² ing side	30	9.7		.130	°310	.70							1 £55/	.672
MENTS C.		40 kg/m ² spacing cm. sid	50	1089		.140	.375	00 VO						Rad	22	
COMPARTMENTS		2 H 6		16.8 J		.140	.430	99						Flame	1 _f 80/9	, 308
1 60		Fuel		20.6 1		.150	• 490	64						prof annor		madacrosomilaci
		f Fuel on of Fue 1 of Fuel		25.1 2 1087 1		.155 .	.560	62			,		5	cal sec cm		.164
N FIRES IN t Form Standards,	5)	Amount of Fuel Dispersion of Fuel Dimension of Fuel		29.8 2 1067 1		.160 .	. 610	60						Rad		
N FIRES t Form Standar	(NBS	Amo D1s D1m		35.0 2		.165	. 690	200						Window F	°80/55	.154
012	9 UQ	t a		40.0		.170	• 770	56						ITM	I°8	
EXPERIMENTS Repo	Designation	211 1 meter 1/4	4	45.9 2 998 1		.170	.820	54						 	55/30	974
1 9	Desig			51.9 / 985	975	.160	. 840	52						Temp.°C	0	0
INTERNATIONAL EX U. S. National	Test	Shape: Scale: Opening:		58.5 945	951	.150	. 835	50						Floor	0 ₈ 80/55	947
TERNA U.S.	C.I.B.	Window (889	.120	• 685	48								1000000000000
I	0	Wír	9	768 826 885	828	• 080	415	46	•					Temp.°C	0 ₆ 55/30	1056
	*		4	768	225	030	090	44		,				ng Te		
<i>.</i> .					40	.010 .030	005 .	42						Ceiling	0 _e 80/55	964
			0	80.0 /8.9 58 169		• 005	.000 .005 .060 .415							(10-10-10-10))		
		EXPERIMENTAL RESULTS		°,					Э° с	0	fon,	. uo		Loss kg	R55/30	2.56
		INTAL	u] .	kg eilins	001,	sadia cm2	adiat cm2	kg	iling	. 00T 9	cm2	adiati cm2	CCS	Wt. Lo		
		EXPERIME	Time, min	Weight, kg Temp. Ceiling.	Temp. Floor,	Window Radiation, cal/sec cm ²	Flame Radiation, cal/sec cm ²	Time, min Weight, kg	Temp. Ceiling,	Temp. Floor,	Window Rediation, cal/sec cm ²	Flame Radiation, cal/sec cm ²	STATISTICS	Rate W	R80/55	3.23

THENTS C fg/m ² Spacing cm. side cm. side 28 30 32 34 36 38 28 30 32 74 76 78	Flame Rad. cal Time to 80%	OF EX	.482 5.4
ng ide 70 72 74	cal	OFTR	
10 72 ^m 30 32	cal		82
30 70 .	ame Rad. cal	1 _f 55/30	182
	ame Rad. ca	1 <u>55</u>	6
NN • Xa a a a a a a a a a a a a a a a a a	ame Rad	1	4.
6 5 5 2 CBP C	ac	£80/55	94
	Fla	E S	•694
SIMPLE COMP Washington, Washington, n of Fuel: n of Fuel: 055 .050 .0 055 .050 .0 055 .054 6 62 64 6	NE	30	
	cal sec cm ²	I.55/30	.169
RES dard dard dard dard 61 (61 (61 (61 (61 (61 (61 (61 (61 (61 (W Rad	55	
	Window Rad	I.80/55	.140
EXPERIMENTS ON Report Report Report 1		30	
EXPERIMEN R al Bureau esignatio 211 211 1 meter :1/4 2 14 95 .120 .00 5 .135 .00 5 .135 .00	Temp.°C	0 _b 55/	1031
	Floor T	0 ⁸ 80/55	16
	FI	0,8	1016
NTEH U. 22. 22. 22. 22. 4.	э.	/30	ω
11 4 6 15.9 29.6 130 130 130 .725 130 .725 44 66	Temp	0e 55/30	1078
2 4 5.6 35.9 59 746 005 .130 005 .130	Celling Temp.°C	0 _e 80/55	2
2 2 38.6 9 59 50 42	Ce	0	1027
	kg	10	
L RESUT C C C C C C C C C C C C C C C C C C C	k oss ^m t	R55/30	2.22
EXPERIMENTAL RESULTS Time, min Weight, kg 4 Temp. Ceiling, °C Temp. Floor, °C Window Radiation, °C al/sec cm ² cal/sec cm ² Time, min Weight, kg Temp. Floor, °C Temp. Floor, °C Window Rediation, °C Temp. Floor, °C Window Rediation, °C Temp. Floor, °C	STATISTICS Rate Wt. Loss kg	R80/55	3.45

15.

INTERN U. S	C.I.B		EXPERIMENTAL RESULTS	0 2 4 6 8	Weight, kg 80.0 79.7 77.9 73.8 66.6	Temp. Ceiling, [°] C 22 37 191 715 957	Temp. Floor, °C 20 25 65 331 969	Window Radiation, .005.010 .020 .100 .315 cal/sec cm ²	Flame Radiation, .005 .005 .010 .080 .470 cal/sec cm ²	42 44 46 48	Weight, kg 2.9 2.0 1.0 .0	Temp. Ceiling, °C 359 322 325 273	Temp. Floor, °C 383 363 358 324	Window Radiation, .070 .065 .060 .050 cal/sec cm ²	Flame Radiation, .010 .010 .030 .000 cal/sec cm ²	STATISTICS	Rate Wt. Loss kg Celling Temp.°C	R55/30 820/55 825/30	2.53 969 934
INTERNATIONAL EXPERIMENTS ON Report U. S. National Bureau of S	B. Test Designation	Shape: 211 Scale: 1 meter	· 9	10 12 14	58.4 51.0 44.8 3	987 950 962	997 978 978	•380 •365 •345 •3	.525 .370 .285 .	50 52 54							Floor Temp. C	00/55 055/30	676 I86
NTS ON FIRES IN Report Form u of Standards,	Y (NBS		CIN2MY A	16 18 20	38.9 33.4 28.6	999 977 895	981 977 931	•345 •315 •290	.280 .255 .170	56 58 60							Window Rad	Ie80/55	.360
SIMPLE Washing	7)	Amount of Fuel Dispersion of Fuel Dimension of Fuel	1	22 24	6 24.2 20.7	5 751 724	1 863 849	0 .230 .210	0 • 085 • 075	. 62 64							sec cm ²	Ie55/30	. 308
COMPARTMENTS		: 40 kg 1: 1 spac	. L CH.	26 28	17.9 15.0	625 560	829 841	.170 .155	• 050 • 04 <mark>0</mark>	66 68							Flame Rad	I _E 80/55	. 407
		/m ² ing	שדרש	30 32	12.4 11.1	463 440	827 827	.130 .115	.030 .020	70 72						• .	cal sec cm ^Z	If55/30	.225
				34 36	8.8 7.1	429 387	682 667	.105 .090	.020 .015	74 76					511		Time	C	QD
				38 40	5.3 3.9	349 356	461 418	• 085 • 075	.010 .010	78 80				•		y	to 80%		00 . 7

9°.-

20.8 17.8 519 529 555 552 .165 .150 .055 .040 52 54	m 6 5 5	259 451 266 501 035 .080 . 005 .030 . 44 46
	519 555 .165 .055 .055 .52	451 691 594 519 529 501 719 646 555 552 080 .195 .190 .165 .150 .030 .115 .085 .055 .040 46 48 50 52 54

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EXPERIMENTAL RESULTS Time, min 0 Weight, kg 80.0 Weight, kg 80.0 Temp. Floor, °C 42 Temp. Floor, °C 20 Window Radiation, .000 cal/sec cm ² Tame Radiation, .000 cal/sec cm ² Temp. Floor, °C 'emp. Floor, °C	2 2 314 189 0 010 0 010 42 42 42 6 <u>6</u> 80	4 75.9 495 396 .030 .030 .050 .050	IN Wi Wi 764 764 764 764 764 764 764 764 764 764	C C C C C C C C C C C C C C C C C C C	TIONAL E Nationa Test De Scale: Scale: 0pening: 873 91 873 91 .160 .17 .250 .28 .250 .28 .250 .28 .250 .28 .160 .17 .10 .17 .160 .17 .150 .52 .50 52 .50 52	Tem Tage 175 175 175 175 175 175 175 175	RIMEN ureau ureau neter 4 14 12.7 3967 175 .275 .275 .275 .275 .275 .275 .275 .2	S 0 6 6 6 6 70 70 70 70 3 3 3 3 3 	N FIRE t Form Standar (NBS 1 Amour Dimer 13 2 30.6 2 30.6 2 1024 10 1024 10 .150 .1 .215 .1 .215 .1 .215 .1 .164 16 164		IIMPLE ashin fruel of Fu of Fu 0.1 15 0.1 15 0.1 15 0.1 15 0.1 15 0.1 15 0.1 15 0.1 15 0.1 15 0.2 6 0.2 6 0.2 6 0.2 5 0.1 15 0.2 6 0.5 730	E COMP E COMP Fuel: Fuel: fuel: fuel: 5.7 12 5.7 12 1105 11 120 .1 .120 .1 .220 .22	ARTMENT D. C. D. C. 2 Cu. 2 Cu. 2 Cu. 2 Cu. 17 1098 94 1021 10 .105 80 .130 30 .130 30 .130 25 68				36 1.1 817 728 .055 .055 .020- .020- .020- .020- .020- .020- .020- .025 .020- .025 .020- .025 .020- .025 .020- .025 .020- .025 .020- .020- .025 .020-	38 28 633 633 633 633 633 78 78 78 78 78 78 530 530 530 530 530 530 530 530 530 530	40 3 697 551 80	RNATIONAL EXPERIMENTS ON FIRES IN SIMPLE COMPARTM Report Form S. National Bureau of Standards, Washington, D.	S. National Bureau of Standards, Washington, D. B. Test Designation 1 (NBS 10)	. Test Designation 1	. Test Designation 1	· Test Designation I	Test Designation 1	. Test Designation 1	. Test Designation 1	· IESC DESIGNACION I		101 A Martin La Wallet	221 Amount of Fuel	1 mater Dienersion of Ruel. 1	L meter Dimension of Firel : 2 cm.	MITHON OLEHTING C CHI	IMENTAL RESULTS		0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38	80.0 78.1 75.9 70.2 63.4 56.6 49.3 42.7 36.3 30.6 25.1 20.1 15.7 12.0 8.8 6.1 4.1 2.4 1.1 .2	°C 42 314 495 764 842 874 921 967 1011 1036 1106 1112 1105 1117 1098 1052 1001 910 817 736	••• •• •• 180 206 7/1 838 873 017 037 00/ 107/ 1077 1098 108/ 1071 0/5 013 222 778 633		.000 .010 .030 .102 .140 .160 .175 .175 .170 .150 .130 .125 .120 .110 .105 .100 .095 .075 .055	.000 .010 .050 .385 .145		42 44 46 48 50 52 54 56 58 60 62 64 66 68 70 72 74 76 78	t, kg			w Rediation, sec cm ²	Radiațion,	sec cm [*]	STTCS	Trocke for the or him or him of him o	CELILING LEMP. U FLOOT LEMP. U WINDOW KAG. CT FLAME KAG. SEC CM 2 DIR.	R55/30 0 _e 80/55 0 _e 55/30 0 _b 80/55 0 _b 55/30 I.80/55 I.55/30 I.80/55 I.55/30	2.93 902 1028 895 1009 .164 .156 .250 .216
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FIRES IN SIMPLE COMPARTMENTS Form andards, Washington, D. C. (NBS 11) Amount of Fuel : 40 kg/m ² Dispersion of Fuel: 1 spacing Dimension of Fuel : 2 cm. side	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	5 1065 1061 1045 1018 995 932 843	1009 999 991 972 972 952 952 947 935 925	360 .340 .325 .285 .280 .245 .235 .225 .200 .170 .160	345 .280 .220 .095 .075 .025 .015 .000010010010	3 60 62 64 66 68 70 72 7A 76 78 80					ۍ ۲		w Rad. cal Flame Rad. cal Time to 80%	I.o55/30 If80/55 If55/30 t80	• 359 • 738 • 359 • 8.8
PLE COMPARTMENT ington, D. C. al : 40 kg Fuel: 1 spac Fuel : 2 cm.	51.8 26 238 51.8 45.9	1065 1061 1045	991 972 972	.325 .285 .280	•220 •095 •075	66 68)		•			۰. ب	al Flame Rad.	30 I _f 80/55 1	
<pre>S ON FIRES IN port Form of Standards, 0 (NBS 11) Amount of Dispersion Dimension</pre>			- 1009	° .			1 .0	470 444	638 527	•075.070	•015-**015		l s	I°80/55	•421 •3
TIONAL Nation Test D Shape: Scale: Scale: Opening	$\begin{array}{c} 10 & 12 \\ 107.1 \\ 119.8 \\ 95.9 \\ 95.9 \end{array}$	914 941 969	940 962	•405 •425 •435	.780 .885 .740	50 52 54	7 4.3	530 491 475	744 713 705	.110 .095 .085	010010010015-0015		Floor Temp.°C	080/55 055/30	943 995
U. S. C.I.B. Window	.53.8 6 132.7 144.3	135 579 773 851	23 54 684 851	010 090 240 340	.000 .005 .140 .325 .665	. 44 46 48	15.5 12.5 10.2. 7.8	679 637 614 568	818 797 787 777	.150 .140 .135 .120	010010010010-		Ceiling Temp.°C	0e 80/55 0e 55/30	946 1027
EXPERIMENTAL RESULTS	Time, min 160.0 2 1 Weight, kg 158.2	°C 25	21	window Kadiation, .000 .00 cal/sec cm ²	Flame Radiation, .000 .00 cal/sec cm ²	Time, min 42	Weight, kg 15.	Temp. Ceiling, °C 6:	lemp. Floor, °C 81	Vindow Radiation, .1. cal/sec cm ²	<pre>?lame Radiation,01 cal/sec cm²</pre>	STATISTICS	Rate Wt. Loss ^{kg} Ce	R30/55 R55/30 0e	5.88 4.12 9

,						s. n	National		Bureau	5001 040	t rorm Standards,		Washington,	ngton	, D.	:0						
				.	0I	с. н. С. н.	Test	1	Designation	6	(NBS 12	12)					e					
					540 (24)	Window	Shape: Scale: Opening:		E E E	Ø .	Amou Disp Dine	Amount of F Dispersion Dimension o	Face of Face	L HUC	- N	20 kg/m ² spacing cm. sid	ing side		Ţ			
EXPERIMENTAL	AL RESULTS	S					a	}							-							
Time, min		0	Ś	d b	V9	60	0		prod	Q/ port	00	20	2	2k	26	00 5	000	32	<i>*</i>	90	60 (^)	
Weight, kg		40.04	40.0 38.3		36.1 .31.5	26.1	21 . 2	00 	13.2 1	10.4	0.2	5	4.3	5.0	бл ,	Ś	.0.					
Temp. Ceiling,	ing, °C	30	364	367	594	686	608	573	21 10 10	469	403	0	342	3000	00 ∎€	310	277					
Temp. Floor,	с, ,	20	203	5.50	209	00 00 00	101	00/	725	506	617	337	339	360	325	324	300					
Window Radiation, cal/sec cm ²	iation, a2	• 002	.025	.060	.140	. 200	.130	087.	.120	.130	. 110	° 060°	.085				°055				T	
Flame Radiațion, cal/sec cm ²	ar i on ,	000.	.000	.015	.000 .005 .015 .075 .095	.095	.070	.060	.045	.030	• 020	.010	• 010 •	• 010	.010	- 002	. 005					
																				1	ł	
Time, min			62	63.03	¢1	00 (†	0	2	3	95	00 1/1	00	62	4	Q) Q	00 \0	0	0	74	9 M	00	
Weight, kg																						
Temp. Ceiling,	ing, °C																					
Temp. Floor,	с.			b																		
Window Rediation, cal/sec cm ²	iation, a2												0				1					
Flame Radiation, cal/sec cm ²	arion,																				8	
													C		Ŀ							
STATISTICS Rate Wt.	Loss		e G	Ceiling	Temp.	ç	HOOL M		Temp.°C		Window F	Rad	cal sec cm	,	Flame	peu	1 01	Ne	0	e stro	to 80% wt.min	06 CT
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		EXPERIMENTAL RESULTS	Time, min	Weight, kg	Temp. Ceiling,	Temp. Floor,	Window Radiation, cal/sec cm ²	Flame Radiation, cal/sec cm ²	Time, min	Weight, kg	Temp. Ceiling,	Temp. Floor,	Window Redigtion, cal/sec cm ²	Flame Radiation, cal/sec cm ²	STATISTICS		R80/55	3.28

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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.

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Metrology. Photometry and Colorimetry. Refractometry. Photographic Research. Length. Engineering Metrology. Mass and Volume.

Heat. Temperature Physics. Heat Measurements. Cryogenic Physics. Equation of State. Statistical Physics. Radiation Physics. X-ray. Radioactivity. Radiation Theory. High Energy Radiation. Radiological Equipment. Nucleonic Instrumentation. Neutron Physics.

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Mechanics. Sound. Pressure and Vacuum. Fluid Mechanics. Engineering Mechanics. Rheology. Combustion Controls.

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Building Research. Structural Engineering. Fire Research. Mechanical Systems. Organic Building Materials. Codes and Safety Standards. Heat Transfer. Inorganic Building Materials. Metallic Building Materials.

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

Data Processing Systems. Components and Techniques. Computer Technology. Measurements Automation. Engineering Applications. Systems Analysis.

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Instrumentation. Engineering Electronics. Electron Devices. Electronic Instrumentation. Mechanical Instruments. Basic Instrumentation.

Physical Chemistry. Thermochemistry. Surface Chemistry. Organic Chemistry. Molecular Spectroscopy. Elementary Processes. Mass Spectrometry. Photochemistry and Radiation Chemistry. **Office of Weights and Measures**.

BOULDER, COLO.

CRYOGENIC ENGINEERING LABORATORY

Cryogenic Processes. Cryogenic Properties of Solids. Cryogenic Technical Services. Properties of Cryogenic Fluids.

CENTRAL RADIO PROPAGATION LABORATORY

lonosphere Research and Propagation. Low Frequency and Very Low Frequency Research. Ionosphere Research. Prediction Services. Sun-Earth Relationships. Field Engineering. Radio Warning Services. Vertical Soundings Research.

Troposphere and Space Telecommunications. Data Reduction Instrumentation. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Spectrum Utilization Research. Radio-Meteorology. Lower Atmosphere Physics.

Radio Systems. Applied Electromagnetic Theory. High Frequency and Very High Frequency Research. Frequency Utilization. Modulation Research. Antenna Research. Radiodetermination.

Upper Atmosphere and Space Physics. Upper Atmosphere and Plasma Physics. High Latitude lonosphere Physics. Ionosphere and Exosphere Scatter. Airglow and Aurora. lonospheric Radio Astronomy.

RADIO STANDARDS LABORATORY

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Joint Institute for Laboratory Astrophysics - NBS Group (Univ. of Colo.).



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