UNITED STATES
DEPARTMENT OF
COMMERCE
PUBLICATION

NBS TECHNICAL NOTE 557

The Brake Pedal Force Capability of Adult Females

U.S.
DEPARTMENT
OF
COMMERCE
National
Bureau
of
Standards

UNITED STATES DEPARTMENT OF COMMERCE
Maurice H. Stans, Secretary
NATIONAL BUREAU OF STANDARDS ● Lewis M. Branscomb, Director

NBS TECHNICAL NOTE 557

ISSUED OCTOBER 1970
Nat. Bur. Stand. (U.S.), Tech. Note 557, 25 pages (Oct. 1970)
CODEN: NBTNA

The Brake Pedal Force Capability of Adult Females

Richard W. Radlinski and James I. Price

Office of Vehicle Systems Research
Institute for Applied Technology
National Bureau of Standards
Washington, D.C. 20234

NBS Technical Notes are designed to supplement the Bureau's regular publications program. They provide a means for making available scientific data that are of transient or limited interest. Technical Notes may be listed or referred to in the open literature.

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402.
(Order by SD Catalog No. C 13.46:557). Price 35 cents

CONTENTS

THE BRAKE PEDAL FORCE CAPABILITY OF ADULT FEMALES*

R. W. Radlinski and J. I. Price

ABSTRACT

A survey of the brake pedal force capability of 105 women employees at the National Bureau of Standards, Washington, D. C., was performed utilizing two stationary passenger automobiles as test vehicles. Results showed that over 50% of the test subjects could not achieve an average sustained brake pedal force of 200 lb, a value which is considered an acceptable braking system input force under certain conditions of the current Federal Motor Vehicle Safety Standard (FMVSS No. 105) for passenger vehicle braking system performance.

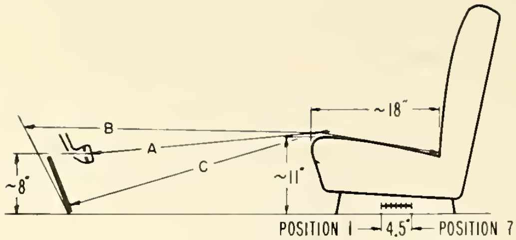
Key words: Automotive braking systems; brakes; brake pedal forces; Federal Motor Vehicle Safety Standards; pedal effort; women, strength of

1. INTRODUCTION

Federal Motor Vehicle Safety Standard No. 105 [1] and SAE Recommended Practice J937a, Service Brake System Performance Requirements - Passenger Car [2], allow brake pedal forces up to 200 lb under certain conditions. Since women in general are physically weaker than men, their pedal force capabilities are an important factor in establishing a maximum acceptable level for brake system input forces. There has been considerable discussion recently in government and industry as to

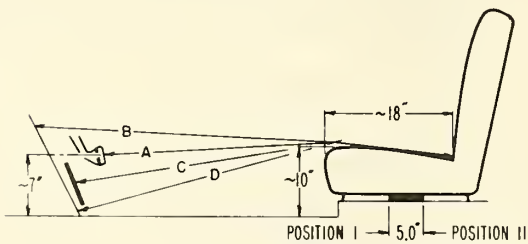
---

*This work was carried out at the National Bureau of Standards under the sponsorship of the Department of Transportation, National Highway Safety Bureau. The opinions, findings and conclusions expressed are those of the authors and not necessarily those of the National Highway Safety Bureau.



REFERENCE POINT	DISTANCE FROM UNDEFLECTED SEAT BACK, INCHES	
	SEAT LOCATION	
	POSITION 1	POSITION 7
A - Center of undeflected brake pedal	32	37
- Center of brake pedal with 100 lb force	35	40
- Center of brake pedal with 100 lb force and hydraulic failure simulated	38	43
B - Floor behind brake pedal	41	46
C - Accelerator pedal	37	41

DIMENSIONS FOR VEHICLE "A"



REFERENCE POINT	DISTANCE FROM UNDEFLECTED SEAT BACK, INCHES	
	SEAT LOCATION	
	POSITION 1	POSITION 11
A - Center of undeflected brake pedal	33	38
- Center of brake pedal with 100 lb force	36	41
B - Floor behind brake pedal	41	46
C - Accelerator pedal	36	41
D - Floor behind accelerator pedal	39	44

DIMENSIONS FOR VEHICLE "B"

FIG I—DIMENSIONS OF TEST VEHICLES

whether the 200 lb force allowed is realistic when consideration is given to actual brake usage conditions and the pedal force capabilities of the weaker portion of the driving population.

The object of this test program was to obtain data on the brake pedal force capabilities of females of driving age. All testing was done in stationary vehicles. It is recognized that testing in a moving vehicle with simulated emergency or panic situations may have in some cases produced higher pedal efforts. However, people react differently under emergency conditions and some pedal efforts may have been lower. It is believed that the results obtained in this test program are a reasonable basis for establishing maximum pedal effort requirements.

2. PROCEDURE

2.1 Apparatus and Instrumentation

Two late model cars were used for the tests. Both vehicles were equipped with standard (non-power) brakes. The driver seat in vehicle A was of the conventional adjustable bench type and the seat in vehicle B was a bucket type with fore and aft adjustment. Both contained lap type seat belts. Sketches of the brake pedal to seat relationship for the two vehicles are shown in figure 1.

Both vehicles were equipped with split hydraulic braking systems. The split system consists of two separate hydraulic circuits operated by tandem pistons in a common master cylinder. One circuit actuates the front brakes and the other actuates the rear brakes. In the event of a leak or rupture in one circuit, the other circuit remains operational. However, because of the construction of the master cylinder, brake pedal travel is increased when fluid loss occurs. A hydraulic system failure therefore is accompanied by an increase in the distance between the seat and brake pedal with the brake in the applied position. To evaluate the effect of increased pedal travel on maximum pedal force capabilities a failure simulated system was installed in vehicle A. The system, diagrammed in figure 2, consists of a solenoid operated

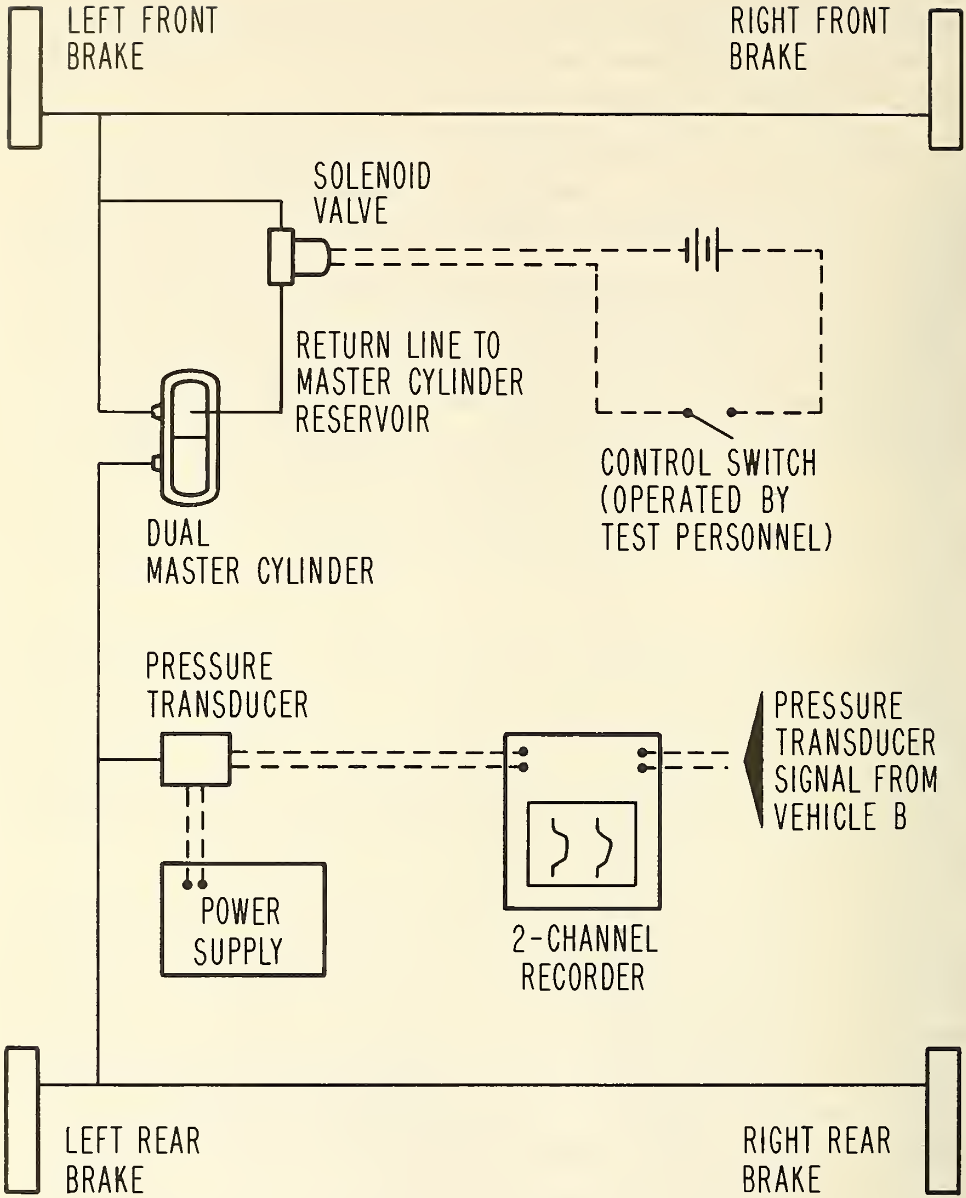


FIG 2—SCHEMATIC OF BRAKE HYDRAULIC SYSTEM IN VEHICLE "A" SHOWING INSTRUMENTATION AND FAILURE SIMULATION SYSTEM

valve which when energized returns displaced fluid in the front hydraulic circuit to the master cylinder reservoir. The simulated failure caused an increase of about 3 inches in pedal travel at a pedal force of 100 pounds.

Effective pedal forces were obtained by measuring fluid pressure in the brake systems. The instrumentation is shown schematically in figure 2. This system consisted of a pressure transducer for each vehicle, a dc power supply and a 2-channel recorder. The transducer provided an electrical output proportional to pressure which was recorded versus time on the recorder. With the non-power brakes there was a linear relationship between pedal force and line pressure and the system could be calibrated to read directly in pedal force. This was achieved by using a pedal force transducer attached to the brake pedal to indicate force applied. A known force was applied normal to the brake pedal pad and the recorder gain control was adjusted to produce the desired span on the pedal force axis.

Position of the driver's seat during the test was considered to be a possibly important factor for use in analyzing results. A simple pointer and scale device was installed in each vehicle to indicate seat position. The seat in vehicle A was adjustable to seven equally spaced positions over a distance of 4.5 inches. The seat in vehicle B was adjustable to eleven equally spaced positions over a distance of 5 inches.

2.2 Test Subjects

Test subjects were obtained on a volunteer basis and consisted of female persons, the great majority of whom were employed at the National Bureau of Standards. They ranged in height from 59 to 69 inches, in weight from 102 to 206 pounds and in age from 18 to 62 years. The test group was of working age and thus no older persons were included.

2.3 Data Acquisition

Each subject was informed before entering the vehicle that the purpose of the test was to determine how hard she could push on the brake pedal. Each subject, except number 5, was first tested in vehicle A and then vehicle B. Four brake applications were made in vehicle A; two with the system intact and two with a simulated failure. Two brake applications were made in vehicle B. It was thought that as short a time as practicable should be used for each application since test subject fatigue could affect the results of the later applications. All applications were maintained for approximately five seconds. This interval was chosen because it is representative of the approximate time required to bring a vehicle to a complete stop from 60 mph in a panic situation. Pedal force versus time was recorded on a chart recorder for all applications.

The tests were conducted as follows:

(a) Brake Application Number 1 - The subject was asked to sit in vehicle A, adjust the seat to a comfortable driving position and fasten the seat belt. The tester noted the seat position on an information card. The seat was not moved by the individual test subject after the initial adjustment. The subject was asked to push as hard as possible on the brake pedal until told to release it. After a five second interval she was told to release the pedal in this and all subsequent applications.

(b) Brake Application Number 2 - The subject was asked to push again and encouraged to try to push harder until told to release.

(c) Brake Application Number 3 - The subject was told that pedal travel was going to be increased (at this point the solenoid valve was opened, simulating a system failure) and to push again as hard as possible until told to release.

(d) Brake Application Number 4 - The subject was asked to push again (with the simulated failure existing) and encouraged to try to push harder.

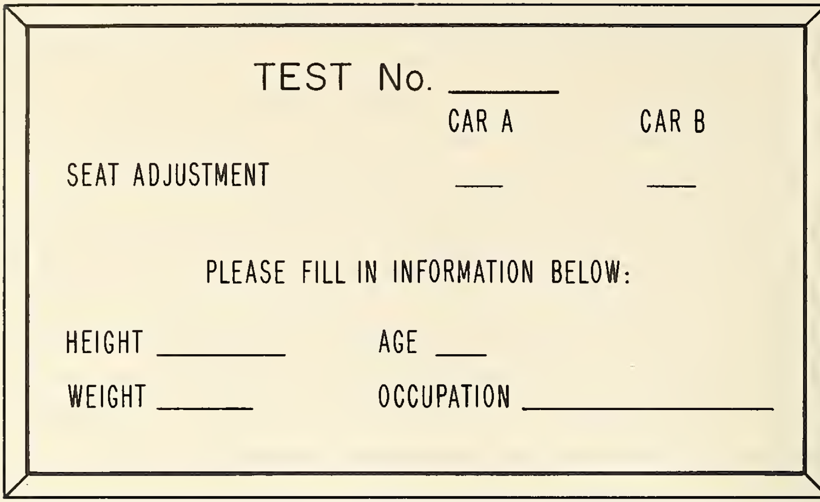
(e) Brake Application Number 5 - The subject was asked to leave vehicle A and sit in vehicle B. The instructions to adjust the seat to a comfortable driving position and fasten the seat belt were repeated and seat position was noted. The subject was asked to push as hard as possible on the brake pedal until told to release.

(f) Brake Application Number 6 - The subject was asked to push again and encouraged to try to push harder until told to release.

The subject was informed that the test was complete and requested to fill out an information card giving height, weight, age and occupation. The subject dropped the card into a box and was not requested to give her name or show the card to testing personnel. This was an attempt to eliminate any hesitation on the part of the subject to provide this information. Information cards were related to recorder charts by assigning a test number to each subject. A sample information card is shown in figure 3.

3. RESULTS OF TEST

A sample recorder trace for a single brake pedal application is shown in figure 4. This sample is marked to clarify its meaning. For each subject there are six traces of this type since six pedal applications were made. For each trace two pieces of data were tabulated for analysis; the maximum pedal force reached during the application and the average pedal force sustained for a five second interval. The average sustained pedal force was obtained by a simple graphical integration approximation. This consisted of positioning a straight line with a length representing 5 seconds parallel to the time axis and intersecting the pedal force trace so that the area between the line and trace above the line is estimated to equal the area between the line and the trace below the line. The point of intersection of the line and trace represents the average pedal force sustained for five seconds. Results of applications 2, 4 and 6 are summarized in table 1 below.


TEST No. ______

	CAR A	CAR B
SEAT ADJUSTMENT	___	___

PLEASE FILL IN INFORMATION BELOW:

HEIGHT ________ AGE ___

WEIGHT ______ OCCUPATION ________________

FIG 3—SAMPLE SUBJECT INFORMATION CARD

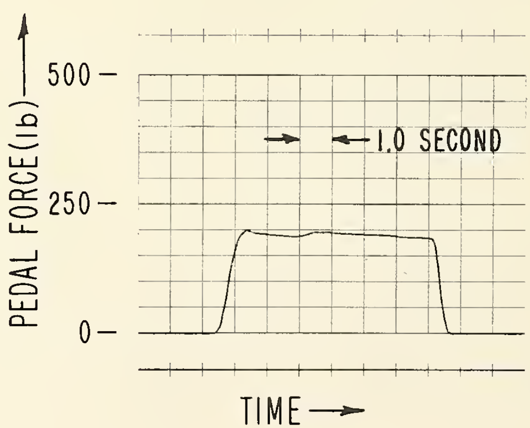


FIG 4—SAMPLE RECORDER TRACE FOR A SINGLE BRAKE PEDAL APPLICATION

TABLE 1. AVERAGE SUSTAINED PEDAL FORCE FOR 5 SECONDS FOR SELECTED PERCENTILES

Percentile	Brake application number 2 Vehicle A normal pedal	4 Vehicle A low pedal	6 Vehicle B normal pedal
	Pedal force, pounds		
95	260	200	275
90	240	180	250
80	220	160	235
50	175	130	190
20	135	100	165
10	120	80	135
5	90	65	125

Data from the subject information cards is shown in table 2. Maximum and average pedal force data for each of the six pedal applications are shown in table 3.

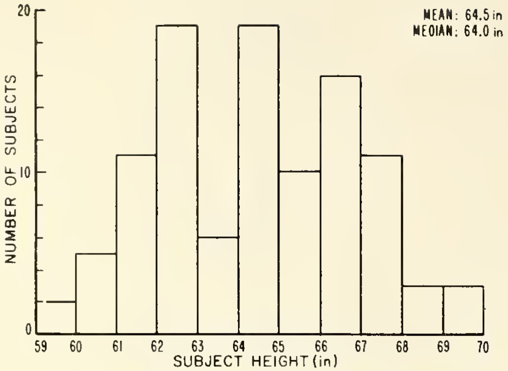
4. DISCUSSION OF RESULTS

4.1 Test Subject Sample

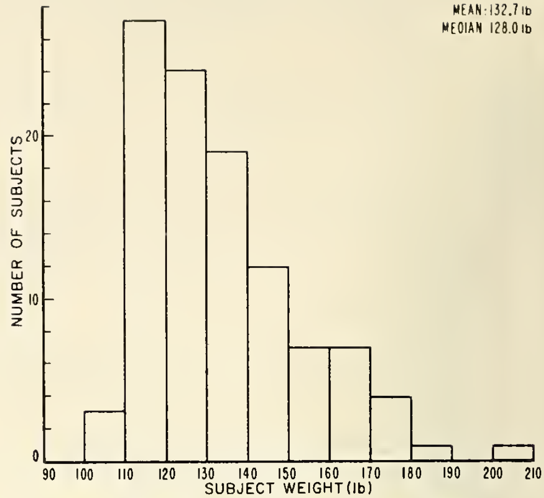
Frequency distributions (histograms) of height, weight and age of test subjects are shown in figure 5. Comparison of this data to information in Reference 1 of a random sampling of 58,343 women 18-79 years of age indicates that the present sample of test subjects contained no serious distortions.

4.2 Motivational Considerations

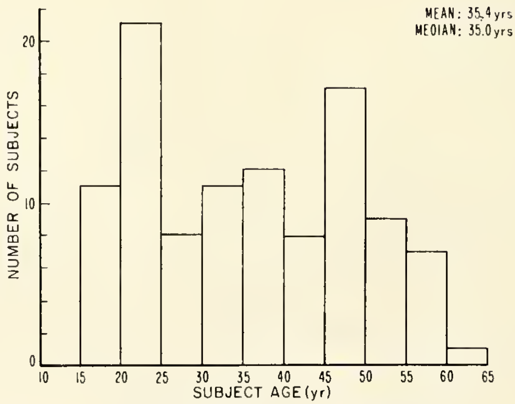
There are many factors which might affect the pedal force capabilities of drivers in the stationary test situation as well as while driving when an emergency occurs. Some factors difficult to assess in a test series are motivation and cooperation of the test subjects and



TEST SUBJECT HEIGHT HISTOGRAM



TEST SUBJECT WEIGHT HISTOGRAM



TEST SUBJECT AGE HISTOGRAM

FIG 5—TEST SUBJECT INFORMATION HISTOGRAMS

TABLE 2. DESCRIPTION OF TEST SUBJECTS AND SEAT POSITIONS

Subject number	Height, in	Weight, lb	Age	Occupation	Seat position, Vehicle A	Seat position, Vehicle B
1[a]	61	110	18	Secretary	1	1
2	59	125	35	Cafeteria	2	1
3	65	112	19	Typist	2	2
4	63	130	18	Typist	2	1
5	64	110	21	Typist	1	1
6	67	175	30	Cafeteria	3	3
7	67	139	43	Admin. Aid	5	6
8	64	135	23	Secretary	3	1
9	65	121	18	Typist	5	6
10	61	128	48	Clerk	2	1
11	64	158	48	Cafeteria	3	5
12	66	115	20	Typist	3	3
13	62	135	25	Typist	1	1
14	67	185	53	Clerk	4	5
15	63	115	59	Cafeteria	2	5
16	68	150	20	Secretary	4	5
17	62	140	28	Typist	4	2
18	62	115	33	Clerk	2	1
19	60.5	102	46	Typist	2	1
20	64	110	18	(Not given)	2	1
21	62.5	125	39	Clerk	2	1
22	67	160	58	Clerk	5	8
23	64	115	26	Comp. Prog.	3	2
24	67	163	46	Housewife	3	4
25	60.5	110	38	Lib. Tech.	1	1
26	67	157	43	Clerk	5	7
27	63	118	19	Clerk	1	1
28	61	120	24	Supervisor	1	1
29	62	130	47	Clerk	1	1
30	64	125	22	Clerk	3	2
31	64	169	47	(Not given)	3	2
32	65	150	34	Clerk	1	3
33	62	140	49	Analyst	1	1
34	66	140	38	Clerk	4	6
35	64	116	23	Secretary	2	3

[a] Used left foot

(Continued)

TABLE 2 (Cont'd)

Subject number	Height, in	Weight, lb	Age	Occupation	Seat position, Vehicle A	Seat position, Vehicle B
36	64	150	54	Typist	4	7
37	62	135	56	Accountant	4	6
38	64	114	19	Secretary	2	1
39	61	114	30	Secretary	2	3
40	61	125	30	Comp. Prog.	1	1
41[a]	66	120	42	Analyst	6	8
42	67.5	140	54	Analyst	4	4
43	62.5	119	20	Clerk	1	1
44	64	124	21	Clerk	4	6
45	64	125	37	Clerk	2	1
46	60	110	40	Chemist	2	1
47	66	170	45	Physicist	5	9
48	66	138	49	Adm. Asst.	5	7
49	62	118	48	Typist	3	1
50	69	165	50	(Not given)	3	7
51	59	125	62	Acct. Tech.	3	7
52	63	115	32	Supervisor	1	1
53	64	109	21	Clerk	3	5
54	66	130	38	Physicist	5	7
55	61	128	49	Math. Tech.	1	1
56	62	137	20	Bookkeeper	2	1
57	67	126	20	Secretary	7	7
58	66	133	19	Clerk	2	4
59	64	142	31	Supervisor	3	4
60	61.75	125	20	Typist	1	1
61	61	135	25	Clerk	1	1
62	64	160	22	Secretary	3	4
63	62.5	117	42	(Not given)	1	1
64	63	115	20	Secretary	1	1
65	65	115	23	Personnel	3	2
66	67.5	146	20	Clerk	4	6
67	64	150	55	Personnel	4	2
68	64	140	53	Procurement	4	2
69	62	115	25	Adm. Aid	1	2
70	67	135	36	Tech.Info.Spec.	3	2

[a] Used left foot

(Continued)

TABLE 2 (Cont'd)

Subject number	Height, in	Weight, lb	Age	Occupation	Seat position, Vehicle A	Seat position, Vehicle B
71	66.5	122	41	Secretary	4	4
72	61	116	45	Secretary	1	1
73	61	120	56	Secretary	1	1
74	63	145	27	Secretary	4	1
75	61	110	43	Secretary	1	1
76	69	149	25	Physicist	7	9
77	62	115	34	Clerk	1	1
78	68	158	18	Secretary	7	7
79	62	137	48	Laborer	2	4
80	66	176	55	Laborer	3	6
81	68	135	51	Budget Analyst	5	7
82	65.5	160	27	Key Punch	2	1
83	65	140	46	Adm. Asst.	4	7
84	62	113	31	Personnel	1	1
85	66.5	125	20	Clerk	4	6
86	65	108	30	Statistician	3	3
87	66	125	51	Physicist	3	1
88	65	130	21	Clerk	3	3
89	69	140	38	Physicist	4	6
90	67	206	36	Personnel	6	7
91	62	125	38	Personnel	2	1
92	66	120	48	Clerk	3	5
93	61.5	124	48	Sys. Analyst	1	1
94	66	165	51	Mgmt. Analyst	5	8
95	60	134	36	Secretary	2	3
96	65	135	22	Clerk	2	3
97	64	130	53	Physicist	2	2
98[a]	65	140	34	Statistician	6	7
99	64	175	23	Mathematician	4	4
100	66	119	19	Typist	4	4
101	62	125	17	Clerk	2	1
102	66	110	37	R.N.	3	-
103	66	130	55	Budget Analyst	6	8
104	60	128	41	Mathematician	1	1
105	62.5	128	48	Info. Spec.	4	3

[a]Used left foot

TABLE 3. MAXIMUM AND AVERAGE BRAKE APPLICATION FORCES IN TWO AUTOMOBILES

Subject number	Brake Application Number											
	Vehicle A								Vehicle B			
	1		2		3		4		5		6	
	Max	Av	Max	Av	Max	Av	Max	Av	Max	Av	Max	Av
	Pedal force, pounds											
1	165	145	150	140	65	60	100	85	130	120	145	135
2	140	130	200	180	65	60	135	120	150	130	195	175
3	185	180	245	230	175	160	155	145	220	205	215	210
4	280	250	290	250	220	175	180	170	240	220	255	235
5	225	220	235	220	165	150	170	150	165	150	245	230
6	160	140	260	235	190	180	195	170	200	195	265	235
7	130	115	165	140	120	110	125	115	150	145	200	185
8	110	105	195	180	95	80	115	85	160	135	145	135
9	115	110	180	160	95	90	125	110	185	165	180	170
10	140	110	175	135	75	50	95	60	185	160	190	170
11	145	115	170	140	110	105	120	110	180	160	190	160
12	175	165	210	190	200	180	225	210	245	235	260	250
13	220	210	200	195	195	180	200	185	195	180	245	235
14	225	200	240	200	200	170	190	155	210	175	240	195
15	165	150	165	150	175	150	170	155	200	185	155	140
16	180	175	200	190	200	190	210	190	235	220	270	255
17	75	70	140	130	100	85	115	105	120	105	165	160
18	120	115	150	135	70	65	85	80	90	75	105	100
19	70	65	95	85	70	65	95	80	75	70	105	95
20	190	180	180	175	165	150	170	160	195	190	220	210
21	150	145	205	175	105	100	130	110	135	120	210	190
22	210	195	240	230	145	140	165	155	190	180	210	200
23	140	120	210	185	130	100	145	115	170	150	175	140
24	100	85	170	160	125	105	150	120	165	145	220	210
25	165	155	185	180	150	145	160	145	180	175	210	200
26	230	225	265	260	180	140	170	150	230	225	225	215
27	235	210	270	260	190	170	185	175	220	200	250	245
28	190	180	210	205	110	100	115	100	185	160	210	205
29	180	160	220	180	100	90	145	130	165	145	205	170
30	100	90	100	95	85	50	80	65	150	120	145	135
31	180	165	235	230	160	155	170	160	220	215	260	255
32	155	145	255	240	130	130	210	200	265	255	265	260
33	180	80	150	120	130	80	105	95	125	120	220	185
34	115	110	190	175	90	80	115	100	165	160	175	165
35	160	150	160	140	105	95	65	65	200	190	215	200

(Continued)

TABLE 3 (Cont'd)

Subject number	Vechicle A, 1 Max	1 Av	2 Max	2 Av	3 Max	3 Av	4 Max	4 Av	Vehicle B, 5 Max	5 Av	6 Max	6 Av
	Pedal force, pounds											
36	200	180	225	205	145	120	145	120	210	190	190	180
37	170	145	155	135	105	85	130	95	180	155	205	180
38	150	145	140	135	90	85	90	85	130	125	135	125
39	185	180	225	190	130	120	135	100	190	175	240	210
40	115	110	175	155	120	110	115	95	185	180	195	180
41	125	110	100	90	65	60	60	50	125	115	160	145
42	185	180	250	245	160	155	165	155	230	220	250	240
43	90	85	115	100	125	110	130	115	160	130	145	135
44	125	115	155	140	105	95	120	105	140	135	190	175
45	70	60	90	90	105	80	130	100	110	80	160	135
46	135	120	175	160	95	75	80	65	145	140	170	165
47	145	145	160	155	150	145	150	125	160	155	190	185
48	150	145	185	175	120	105	140	140	175	160	185	175
49	130	120	165	150	110	100	135	115	160	150	175	165
50	185	155	150	120	125	120	145	140	170	160	185	165
51	135	130	160	145	70	65	110	95	135	130	165	150
52	130	130	180	175	110	100	160	130	195	180	185	170
53	155	120	155	120	90	75	105	80	195	170	200	170
54	110	100	135	130	155	140	155	150	190	185	200	190
55	120	115	150	145	130	115	150	135	205	195	220	205
56	160	145	190	185	125	125	140	130	200	195	215	210
57	195	190	225	220	155	150	190	185	220	210	220	220
58	115	105	125	115	120	115	145	130	140	130	185	170
59	150	125	185	175	120	100	145	130	155	140	215	190
60	170	165	200	195	150	145	170	155	210	200	230	215
61	110	105	95	90	110	100	120	110	195	185	230	220
62	260	235	320	290	250	240	235	210	320	305	330	310
63	250	235	295	275	220	210	260	250	340	320	310	300
64	190	170	215	180	215	205	210	205	260	240	260	240
65	105	100	175	165	90	85	130	120	210	200	245	235
66	175	170	240	235	50	45	155	150	215	210	250	240
67	100	95	150	145	140	130	125	120	110	105	175	170
68	175	160	180	175	100	95	100	95	190	170	185	180
69	220	205	220	205	130	120	120	115	175	170	210	195
70	245	230	250	240	185	180	190	180	265	250	285	275

(Continued)

TABLE 3 (Cont'd)

Subject number	1 Max	1 Av	2 Max	2 Av	3 Max	3 Av	4 Max	4 Av	5 Max	5 Av	6 Max	6 Av
	Brake Application Number											
	Vehicle A								Vehicle B			
	Pedal force, pounds											
71	150	130	240	170	90	65	165	130	215	190	240	220
72	180	175	200	190	115	105	135	130	135	130	150	145
73	190	175	205	195	140	135	140	135	210	185	230	205
74	110	105	140	130	45	45	60	60	110	100	160	140
75	250	235	255	240	160	145	160	135	190	175	215	205
76	215	205	285	270	210	195	180	175	280	250	285	275
77	125	120	135	120	105	100	165	135	125	125	220	205
78	130	125	155	150	145	135	160	145	160	155	200	190
79	180	175	215	205	105	100	125	105	190	180	195	185
80	195	195	270	260	175	165	175	170	250	230	230	225
81	130	115	140	130	180	130	180	150	180	135	200	175
82	170	140	180	165	160	150	205	180	---	---	---	---
83	165	155	215	205	120	115	145	130	200	190	220	210
84	225	200	300	250	220	180	240	220	270	230	285	250
85	90	85	125	120	125	120	150	140	130	120	190	180
86	110	105	175	165	110	105	125	115	165	150	185	180
87	185	160	170	160	125	115	160	140	170	150	200	185
88	170	160	180	175	165	145	150	140	195	185	205	195
89	110	110	180	170	170	135	155	140	170	140	195	180
90	200	200	240	225	180	165	210	190	225	220	300	290
91	225	205	260	240	165	145	195	180	270	250	300	275
92	150	140	190	170	140	135	185	170	210	200	225	220
93	85	80	130	120	70	65	110	100	90	85	140	125
94	115	105	170	165	140	110	140	110	155	145	200	180
95	195	185	200	185	120	115	145	140	180	175	205	190
96	170	165	200	180	180	155	185	180	180	165	155	150
97	180	180	195	175	150	135	155	150	220	210	225	220
98	150	135	200	190	125	110	120	110	180	165	200	185
99	140	100	155	140	105	85	145	140	155	120	180	170
100	95	95	150	135	105	95	145	120	125	120	155	145
101	235	225	250	235	190	180	195	180	285	270	305	295
102	85	80	85	85	75	60	70	70	80	75	95	90
103	165	165	165	165	130	120	140	130	205	195	245	230
104	115	115	195	180	120	110	90	90	170	155	210	190
105	205	180	240	195	130	120	150	140	250	210	280	240

how well they understand and carry out the instructions. Drivers are conditioned to pushing on the brake pedal up to a certain force level under normal driving conditions and may have no understanding of what force level might be required under unusual circumstances.

Some test subjects used unusual techniques to obtain maximum pedal force. Some braced their shoulders against the back of the seat and others pulled on the steering wheel. All subjects were restrained by a lap belt which, when properly fastened, would reduce the effectiveness of these techniques. Subjects were not instructed as to rate of force application. Some preferred to "slam" on the pedal while others applied the force more gradually. It has been suggested that force acting on the pedal in a decelerating vehicle might be higher than that measured in a static situation for a given driver due to additional force developed as a result of the inertia of the driver's body mass. This might be true if the driver's leg was straight and acted like a rigid link in compression. However, it is more reasonable to assume that the leg would be bent at the knee to at least some extent and thus require muscle strength to transmit inertial force. Therefore pedal force would be limited to the same muscle capability as that measured in the static situation. In any case, inertial forces do not become significant until a very high rate of deceleration is attained.

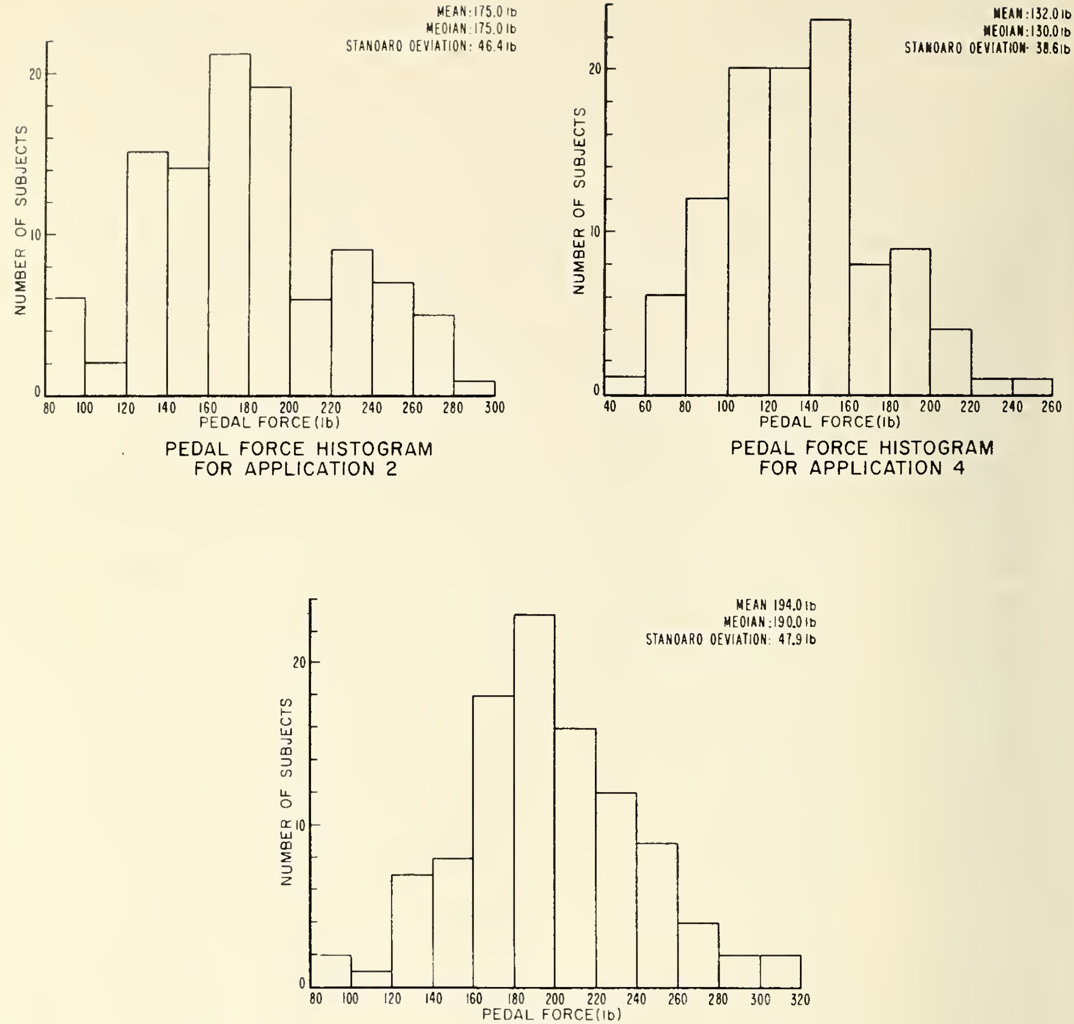
4.3 Pedal Force Results

The six brake pedal applications for each of the test subjects can be broken down into three separate groups.

(a) Two applications (numbers 1 and 2) in vehicle A with a normal pedal height.

(b) Two applications (numbers 3 and 4) in vehicle A with a reduced pedal height (failure simulated).

(c) Two applications (numbers 5 and 6) in vehicle B with a normal pedal height.



PEDAL FORCE HISTOGRAM
FOR APPLICATION 6

FIG 6—PEDAL FORCE HISTOGRAMS
FOR THREE BRAKE APPLICATIONS

The subject had no indication how hard she was pushing. It is believed that the second brake pedal application under each condition (numbers 2, 4 and 6) is more indicative of the maximum capability of the test subject. The subject was more familiar with the system after the first try and with encouragement from the tester was on the average able to push harder on the second try of each group. Therefore, applications 2, 4 and 6 are of primary interest. In addition, the average pedal force sustained for five seconds during the applications is of more interest than the maximum value since the area under the force-time curve has a direct relationship to vehicle stopping distance.

Frequency distributions (histograms) of average pedal force for applications 2, 4 and 6 are shown in figure 6. Each of these figures also shows mean, median and standard deviation calculated from the data. Histograms for maximum pedal forces would be similar in shape to those for average pedal force since plots of maximum versus average pedal force showed a linear relationship between the two values.

The histograms in figure 7 show a comparison of seat positions selected in the two vehicles. Since the number of available positions was different in each vehicle they were divided into five intervals measured from the most forward position. A similarity in the distributions of the selected positions in the two vehicles is readily apparent. As expected, further examination of the data showed a correlation between subject height and preferred seat position. Eighty-five percent of all subjects 63 inches in height and shorter selected seat position 1 or 2. Twenty-five subjects (24%) in vehicle A and forty-one (39%) in vehicle B adjusted the seat to the forwardmost position. This position was used more than any other on both cars and it could be inferred that some subjects would have moved the seat further forward if more adjustment had been available.

A comparison of the means (or medians) for applications 2 and 4 shows that reduced capability results when pedal travel is increased. Thus when the pedal moves further away from the seat the subject cannot

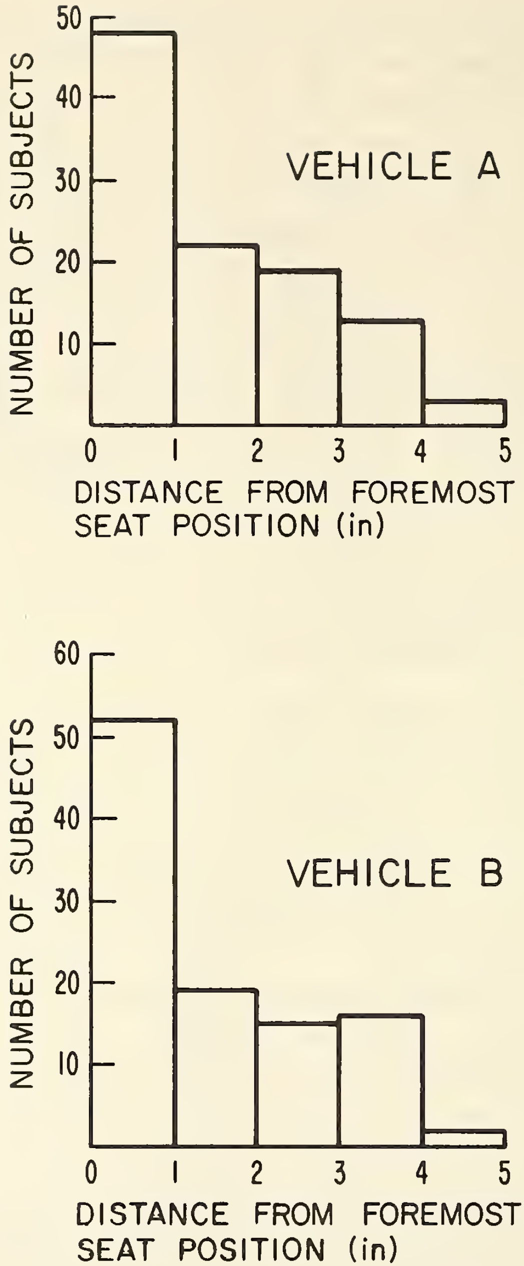
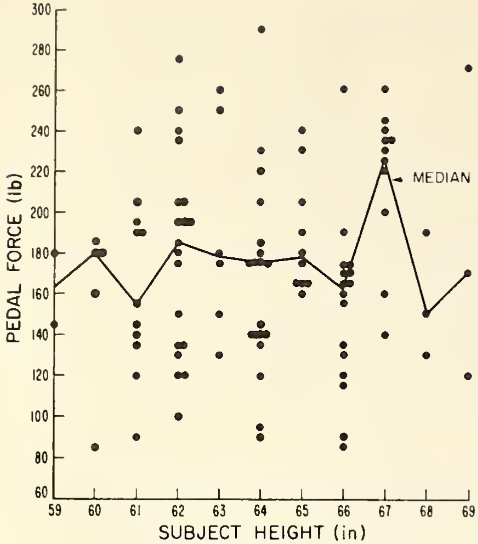


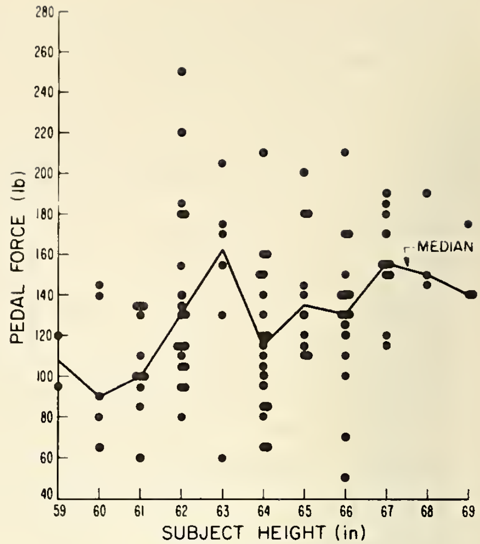
FIG 7 — SEAT ADJUSTMENT BY TEST SUBJECTS push as hard and a question is raised if enough adjustment is available so that shorter subjects can reach their full capability under normal and increased pedal travel conditions. Plots of pedal force (average sustained) versus subject height were made for vehicles A and B with normal pedal travel (applications 2 and 6 respectively) and are shown in figure 8. Both plots show a wide scattering of results and indicate little, if any, relationship between subject height and pedal force capability. It does not appear then that the shorter subjects were limited by available seat positions. To investigate the increased pedal travel condition, a plot of pedal force (average sustained, application 4) versus subject height was made for vehicle A with a simulated hydraulic failure. This plot is shown in figure 8 and also indicates a wide scattering of results. The line connecting the medians for application 4 does indicate a slight upward trend in pedal force for taller subjects but the wide scattering of results prohibits any definite conclusions.

The effect of subject weight and age on pedal force capability was also investigated but no relationship was found.

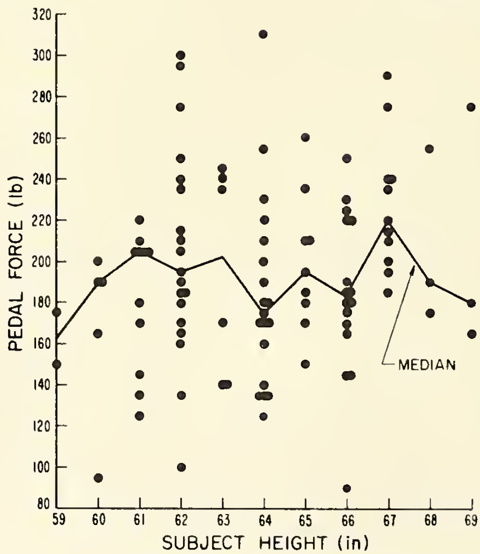
A comparison of the results obtained in vehicles A and B with normal pedal travel indicates that subjects applied a greater force in vehicle B. For example, the median pedal force for application 2 (vehicle A) was 175 lb while the median for application 6 (vehicle B) was 190 lb. This difference could be due to some physical difference between the vehicles and/or mental conditioning of the test subject and familiarity with the test procedure. A comparison of dimensions in figure 1 indicates little geometrical difference between vehicles; however, the seat in vehicle B appeared to be firmer than the seat in vehicle A and could account for some difference in subject capability.



PEDAL FORCE vs SUBJECT HEIGHT
FOR APPLICATION 2



PEDAL FORCE vs SUBJECT HEIGHT
FOR APPLICATION 4



PEDAL FORCE vs SUBJECT HEIGHT
FOR APPLICATION 6

FIG 8—PEDAL FORCE vs SUBJECT HEIGHT
FOR THREE BRAKE APPLICATIONS

5. CONCLUSIONS

Serious consideration should be given to reducing the 200 lb pedal force allowed under certain conditions. Twenty percent of the test subjects could not exceed an average sustained pedal force of 135 lb in vehicle A with a normal pedal height, 100 lb in vehicle A with a reduced pedal height (simulated failure) or 165 lb in vehicle B with a normal pedal height. Fifty percent of the test subjects could not achieve an average sustained pedal force of 200 lb in either vehicle.

6. REFERENCES

[1] Federal Motor Vehicle Safety Standard No. 105, Hydraulic Service Brake, Emergency Brake, and Parking Brake Systems, Passenger Cars, issued by the U. S. Department of Transportation, Federal Highway Administration, National Highway Safety Bureau, January 1, 1968.

[2] SAE Recommended Practice J937a, Service Brake System Performance Requirements - Passenger Car, 1970 SAE Handbook, Society of Automotive Engineers, 2 Pennsylvania Avenue, New York, New York 10001.

[3] Weight, Height and Selected Body Dimensions of Adults, United States 1960-1962. National Center for Health Statistics, Series 11, Number 8, June 1965. U. S. Department of Health, Education and Welfare.

USCOMM-NBS-DC

Latest developments in the subject area of this publication, as well as in other areas where the National Bureau of Standards is active, are reported in the NBS Technical News Bulletin. See following page.

HOW TO KEEP ABREAST OF NBS ACTIVITIES

Your purchase of this publication indicates an interest in the research, development, technology, or service activities of the National Bureau of Standards.

The best source of current awareness in your specific area, as well as in other NBS programs of possible interest, is the TECHNICAL NEWS BULLETIN, a monthly magazine designed for engineers, chemists, physicists, research and product development managers, librarians, and company executives.

If you do not now receive the TECHNICAL NEWS BULLETIN and would like to subscribe, and/or to review some recent issues, please fill out and return the form below.

(cut here)

Mail to: Office of Technical Information and Publications
National Bureau of Standards
Washington, D. C. 20234

Name ______________________________

Affiliation ______________________________

Address ______________________________

City ______________ State ________ Zip ________

☐ Please send complimentary past issues of the Technical News Bulletin.

☐ Please enter my 1–yr subscription. Enclosed is my check or money order for $3.00 (additional $1.00 for foreign mailing).
Check is made payable to: SUPERINTENDENT OF DOCUMENTS.

TN 557

NBS TECHNICAL PUBLICATIONS

PERIODICALS

JOURNAL OF RESEARCH reports National Bureau of Standards research and development in physics, mathematics, chemistry, and engineering. Comprehensive scientific papers give complete details of the work, including laboratory data, experimental procedures, and theoretical and mathematical analyses. Illustrated with photographs, drawings, and charts.

Published in three sections, available separately:

- **Physics and Chemistry**

Papers of interest primarily to scientists working in these fields. This section covers a broad range of physical and chemical research, with major emphasis on standards of physical measurement, fundamental constants, and properties of matter. Issued six times a year. Annual subscription: Domestic, $9.50; foreign, $11.75*.

- **Mathematical Sciences**

Studies and compilations designed mainly for the mathematician and theoretical physicist. Topics in mathematical statistics, theory of experiment design, numerical analysis, theoretical physics and chemistry, logical design and programming of computers and computer systems. Short numerical tables. Issued quarterly. Annual subscription: Domestic, $5.00; foreign, $6.25*.

- **Engineering and Instrumentation**

Reporting results of interest chiefly to the engineer and the applied scientist. This section includes many of the new developments in instrumentation resulting from the Bureau's work in physical measurement, data processing, and development of test methods. It will also cover some of the work in acoustics, applied mechanics, building research, and cryogenic engineering. Issued quarterly. Annual subscription: Domestic, $5.00; foreign, $6.25*.

TECHNICAL NEWS BULLETIN

The best single source of information concerning the Bureau's research, developmental, cooperative and publication activities, this monthly publication is designed for the industry-oriented individual whose daily work involves intimate contact with science and technology—*for engineers, chemists, physicists, research managers, product-development managers, and company executives.* Annual subscription: Domestic, $3.00; foreign, $4.00*.

* **Difference in price is due to extra cost of foreign mailing.**

NONPERIODICALS

Applied Mathematics Series. Mathematical tables, manuals, and studies.

Building Science Series. Research results, test methods, and performance criteria of building materials, components, systems, and structures.

Handbooks. Recommended codes of engineering and industrial practice (including safety codes) developed in cooperation with interested industries, professional organizations, and regulatory bodies.

Special Publications. Proceedings of NBS conferences, bibliographies, annual reports, wall charts, pamphlets, etc.

Monographs. Major contributions to the technical literature on various subjects related to the Bureau's scientific and technical activities.

National Standard Reference Data Series. NSRDS provides quantitative data on the physical and chemical properties of materials, compiled from the world's literature and critically evaluated.

Product Standards. Provide requirements for sizes, types, quality and methods for testing various industrial products. These standards are developed cooperatively with interested Government and industry groups and provide the basis for common understanding of product characteristics for both buyers and sellers. Their use is voluntary.

Technical Notes. This series consists of communications and reports (covering both other agency and NBS-sponsored work) of limited or transitory interest.

Federal Information Processing Standards Publications. This series is the official publication within the Federal Government for information on standards adopted and promulgated under the Public Law 89–306, and Bureau of the Budget Circular A–86 entitled, Standardization of Data Elements and Codes in Data Systems.

Order NBS publications from: Superintendent of Documents
Government Printing Office
Washington, D.C. 20402

U.S. DEPARTMENT OF COMMERCE
WASHINGTON, D.C. 20230

OFFICIAL BUSINESS

PENALTY FOR PRIVATE USE, $300

POSTAGE AND FEES PAID
U.S. DEPARTMENT OF COMMERCE