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NATIONAL BUREAU OF STANDARDS REPORT

7486

QUARTERLY REPORT

ON

EVALUATION OF REFRACTORY QUALITIES OF
CONCRETES FOR JET AIRCRAFT WARM-UP, POWER CHECK,
MAINTENANCE APRONS, AND RUNWAYS

by

W. L. Pendergast, E. C. Tuma, D. K. Ward



U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

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NATIONAL BUREAU OF STANDARDS REPORT

NBS PROJECT

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Sponsored by:

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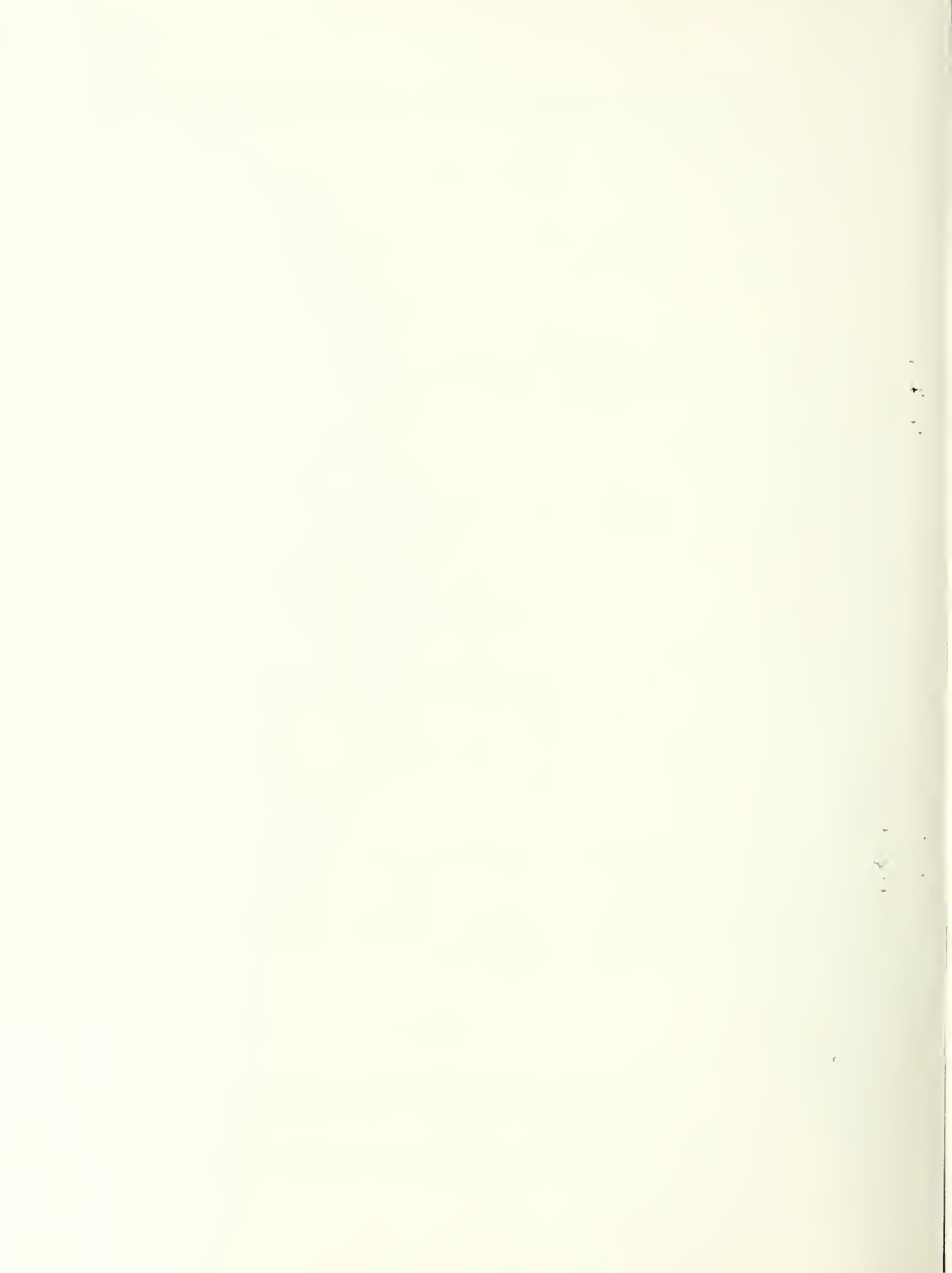
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U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS



QUARTERLY REPORT
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CONCRETES FOR JET AIRCRAFT WARM-UP, POWER CHECK,
MAINTENANCE APRONS, AND RUNWAYS

1. INTRODUCTION

The purpose of this project is the development of criteria for the fabrication of jet exhaust resistant concretes. Concretes under development are evaluated by exposure to hot gases from a combustion chamber. The combustion chamber delivers these gases at velocities and temperatures approaching field conditions.

2. ACTIVITIES

A. Concretes Submitted from Naval Facilities

Seven jet impingement tests were conducted during this quarter on panels submitted from the following power check facilities.

The third panel of a set of three from the Naval Air Station, Whidbey Island, Oak Harbor, Washington, was tested after a 68 day drying period at 73°F and 50 percent relative humidity. This panel, as did the two other panels in the set previously reported, evidenced no failure.

One set of three panels from the Naval Air Station, Los Alamitos, Long Beach, California, was subjected to jet blast impingement after 28, 42, and 72 days drying. None of the panels evidenced any failure.

The remaining set of three panels from the Naval Air Station, Oceana, Virginia Beach, Virginia was tested after 28, 62, and 76 days drying. The first and third panels tested showed significant failure, the second evidenced no failure. Since the information on the curing history of these panels was not furnished and they were not properly packed during shipment this might account for the magnitude and order of failure.

Detailed data on panels during moist curing, drying, and jet impingement appears in Table I.

The flexural strengths of beams, cut from these panels and from other panels previously subjected to the jet impingement tests, were determined during this quarter. The results of these determinations appear in Table II.

The results continue to indicate that the loss in flexural strength, between that reported as the 28 day moist curing strength and that after jet-blast exposure, is due to water loss during the drying period rather than due to the heat treatment during the jet-blast test.

These tests complete the series that were planned for concrete specimens submitted by U. S. Navy power check facilities.

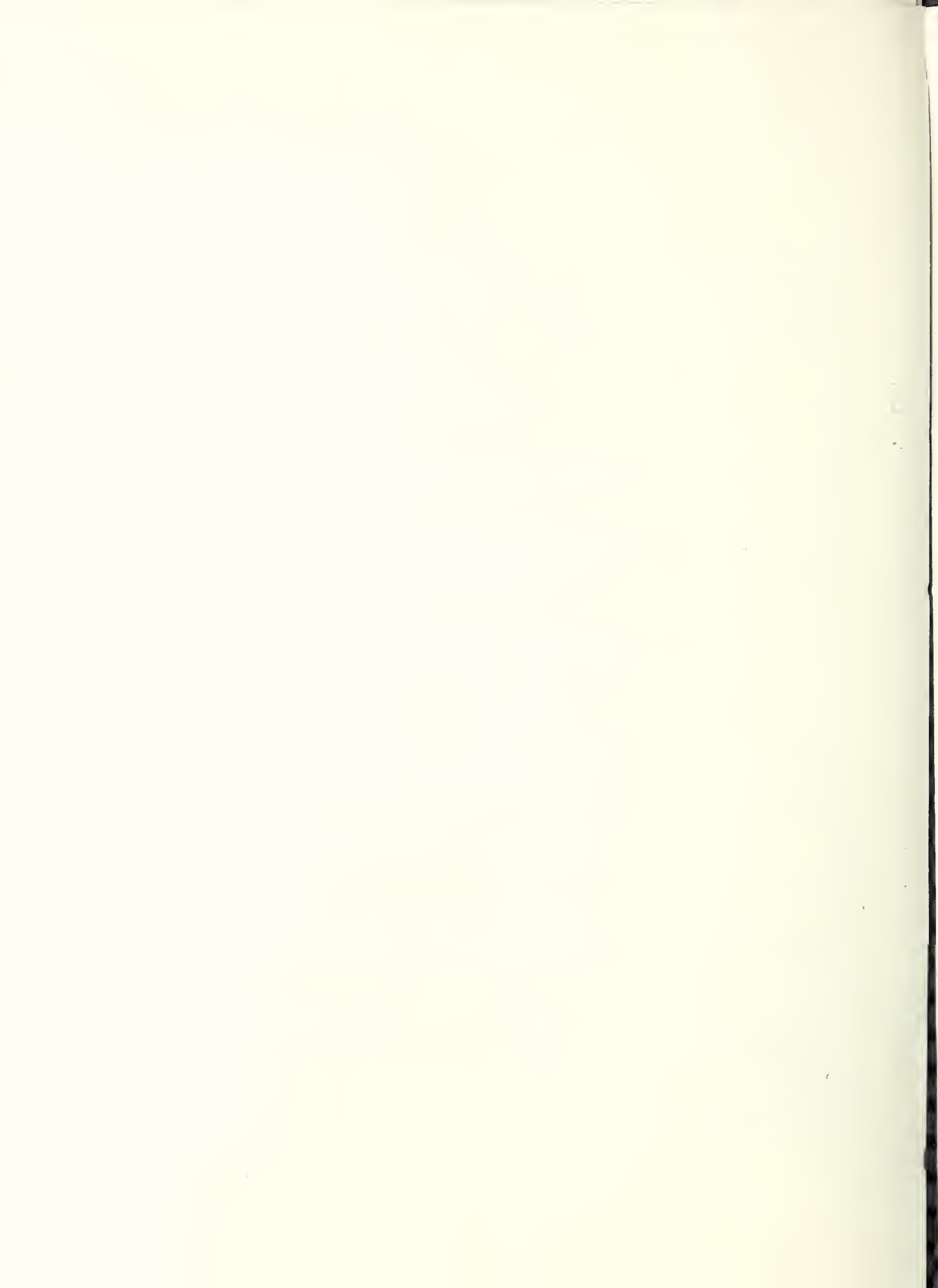


Table I. Data on Panels During Moist Curing, Drying, and Jet Impingement

Identification	Panel Number	Days in Sawdust	Water ^{1/} Content of Sawdust %	Weight Change ^{2/} of Panel During Sawdust Storage %	Storage in Fog-room days	Weight Change ^{2/} of Panel During Drying %	Drying Period days	Loss in Drying %	Spalling		Flexural ^{3/} Strength psi
									Loss by Spalling c.c.	Loss by Sand Volume c.c.	
5th Naval Dist.	1	15	38	-0.13	13	0.00	36	0.40	43.6	15.4	480
N.A.S. Norfolk, Virginia	2	15	do	-0.26	13	0.00	50	0.67	45.3	None	465
	3	14	do	-0.13	13	+0.14	68	0.82	90.6	1.20	455
	4	14	do	-0.13	13	+0.14	84	0.89	225.3	119.34/	395
8th Naval Dist.	A	15	60.5	-0.14	13	+0.06	42	0.63	149.5	70.24/	370
N.A.A.S. Kingsville, Texas	B	15	60.5	-0.58	13	+0.16	58	0.87	43.9	24.6	430
	C	15	60.5	-0.58	13	+0.16	Note ^{2/}	---	---	---	---
	D	17	52.0	-0.43	10	0.00	87	0.86	87.2	22.6	415
8th Naval Dist.	A	17	52.0	+0.57	10	0.00	42	0.57	303.0	226.04/	370
N.A.A.S. Beeville, Texas	B	17	do	+0.14	10	+0.14	59	0.83	43.6	26.2	495
	C	17	do	+0.69	10	0.00	70	0.79	34.5	None	460
11th Naval Dist.	1	28	54.0	+2.26	6/	6/	42	8.20	68.0	None	135
U.S.M.C.A.S.	2	28	39.0	+3.02	"	"	56	8.22	206.5	"	130
El Toro, California	3	28	38.0	+1.86	"	"	71	5.49	96.3	Slight	205
13th Naval Dist. ^{2/}	1	32	61.0	+0.23	6/	6/	43	1.70	49.9	None	485
N.A.S. Whidbey Is.	2	32	62.0	+0.34	"	"	56	2.00	50.7	"	400
Oak Harbor, Washington	3	32	57.0	+0.21	"	"	71	2.45	None	"	415
6th Naval Dist.	1	28	53.0	+0.76	6/	6/	42	0.79	50.7	9.0	385
N.A.S. Sanford, Florida	2	28	53.0	+0.57	"	"	56	1.11	51.5	Slight	275
	3	28	53.0	+0.57	"	"	71	0.94	514.6	331.04/	390
11th Naval Dist.	1	37	60.0	-0.32	6/	6/	42	0.96	51.8	None	325
U.S.M.C.A.A.S.	2	37	60.0	-0.48	"	"	56	1.43	31.1	do	300
Yuma, Arizona	3	37	60.0	-0.16	"	"	70	1.13	93.0	do	300
6th Naval Dist.	2	120	47.5	+0.77	6/	6/	56	0.46	10.5	None	475
U.S.M.C.A.A.S.	4	"	"	+1.15	"	"	70	0.23	55.0	16.9	-505
Beaufort, S.C.	5	"	9/	None	"	"	70	0.44	45.0	16.0	415
6th Naval Dist.	1	50	49.0	+2.31	6/	6/	42	0.45	38.0	None	365
N.A.S. Glynco Georgia	2	43	49.0	+0.71	"	"	56	0.31	68.0	Slight	465
	3	42	49.0	+2.62	"	"	70	0.71	237.0	181.04/	490
5th Naval Dist.	1	20	43	+0.29	8	+0.06	42	0.40	98.0	59.0	445
M.C.A.S.	2	20	50	+0.29	8	None	56	0.43	48.0	38.0	570
Cherry Point, N.C.	3	20	52	+0.16	8	+0.06	70	0.47	93.0	76.0	490
6th Naval Dist.	1	47	18	-0.42	6/	6/	42	0.54	54.0	29.0	390
N.A.S.	2	"	27	None	"	"	56	0.42	82.0	None	515
Jacksonville, Fla.	3	"	65	None	"	"	70	0.72	28.0	None	565
11th Naval District	1	38	40	+0.77	6/	6/	6	0.68	161	None	170
N.A.S.	2	38	40	0.00	"	"	13	0.21	116	None	280
Miramar, California	3	38	40	-0.85	"	"	20	0.17	116.5	None	245

Table I - Continued

Identification	Panel Number	Days in Sawdust	Water ^{1/} Content of Sawdust %	Weight Change ^{2/} of Panel During Storage %	Storage in Fog-room days	Weight Change ^{2/} of Panel During Fog-room Curing %	Drying Period days	Loss in Drying %	Spalling Loss by Wt. c.c.	Spalling Loss by Sand Volume c.c.	Flexural ^{3/} Strength psi
12th Naval District ^{10/}											
N. A. S. Lemoore, California	1	28	37	+0.97	6/	6/	17	0.48	170.0	None	365
	2	do	do	+0.54			8	None	60.0	do	370
	3	do	do	+0.41			22	0.81	57.0	do	375
	1	28	38	+0.42	6/	6/	29	0.83	68.0	None	315
	2	do	do	+0.37			36	1.00	125.0	34	335
	3	do	do	+0.42			42	1.04	68.0	Slight	335
	1	28	53	+0.79	6/	6/	9	0.59	651.0	500.0 ^{4/}	395
	2	do	do	+0.79			20	None	65.0	None	380
	3	do	do	+1.09			23	0.86	26.0	None	405
	1	28	37	None	6/	6/	30	1.00	79.0	None	300
	2	do	do	+0.05			37	0.85	65.0	None	370
	3	do	do	+1.00			43	0.98	Not Tested	Not Tested	Not Tested
	1	28	69	+0.32	6/	6/	29	0.92	35.0	None	320
	2	do	do	+1.03			35	1.00	57.0	None	290
	3	do	do	+0.48			Not Tested	Not Tested	Not Tested	Not Tested	Not Tested
Southeast Division	1	21	41	-0.32	7	+0.16	14	0.19	105.0	26.0	310
N.A.S.	2	do	41	-0.10	7	+0.03	28	0.64	105.0	44.0	210
Meridian, Mississippi	3	do	41	-0.13	7	+0.03	56	0.84	54.0	None	325
Southwest Division	1	92	36	+1.90	6/	6/	21	3.97	82.0	None	240
N. O. Test Station	2	do	do	+1.47			35	6.21	334.0	None	120
China Lake, California	3	do	do	+2.97			50	5.84	108.0	None	115
Cecil Field Florida	1	14	36	+0.06	14	+0.25	15	0.44	270.0	227.0 ^{4/}	350
	2	do	34	+1.45	do	+0.32	29	0.89	164.0	164.0 ^{4/}	320
	3	do	41	+0.48	do	+0.32	43	0.96	6.2	Slight	290
13th Naval Dist.	1	9/	9/	9/	6/	6/	40	0.34	37.0	None	495
N.A.S. Whidbey Island	2	do	do	do	do	do	54	0.29	45.0	None	455
Oak Harbor, Wash.	3	do	do	do	do	do	68	0.15	47.0	None	415
U.S.N.A. Oceana	1	9/	9/	9/	6/	6/	28	1.13	180.0	107.0	572
Virginia Beach	2	do	do	do			62	0.34	2.7	None	587
Virginia	3	do	do	do			76	0.96	10.0	72.0	760
Southwest Division	1	29	65	+0.08	6/	6/	28	2.00	374.0	None	220
N.A.S. Los Alamitos	2	do	55	-0.17			42	2.18	80.0	None	250
Long Beach, California	3	do	53	-0.25			70	3.42	85.0	None	220

1/ wet weight - dry weight X 100.
2/ wet weight

3/ Based on one-day weight.

4/ Determined on beams cut from panels after jet impingement tests.

5/ Results of this magnitude indicate complete destruction of test surface.

6/ Flexural strength determined on 3 beams cut from panel at request of Budocks.

7/ Considered as moist cured during transit, 28 or more days.

8/ The water in the sawdust was frozen through to the panels on receipt.

9/ Since the concrete from which these panels were fabricated was rejected, as failing to meet flexural strength requirements, additional panels will be shipped fabricated from concrete used in new installation.

10/ Data not complete.

11/ Not packed in sawdust.

12/ Power Check Station number.



TABLE II EFFECT OF JET IMPINGEMENT ON THE FLEXURAL STRENGTH OF CONCRETE BEAMS

Power Check Facility	Aggregate	Cement	Specimens Cut From	
			Outside Test Area	Within Test Area
Beeville	Diabase	Portland I	459	494
Oak Harbor	"	Portland II	400	336
"	"	"	414	400
Sanford	Blast-furnace slag	Portland I	384	394
Cherry Point	Diabase	Portland I	490	460 ^{1/}
Miramar	Expanded shale	High Alumina Hydraulic	170	190 ^{1/}
"	"	"	245	275 ^{1/}
Meridian	Blast-furnace slag	Portland I	310	295 ^{1/}
"	"	"	210	305 ^{1/}
"	"	"	325	305 ^{1/}
China Lake	Expanded shale coated	High Alumina Hydraulic	240	
"	"	"	120	
"	"	"	115	125
Oak Harbor	Diabase	Portland Type II	495	552
"	"	"	524	510

^{1/} Beams cut from outside test area and water soaked for 48 hour before testing.

B. Steam Pressure Developed Within Concrete During Rapid Heating

Four concrete specimens have been cast in molds instrumented as shown in Fig. 1. Two of the specimens contain blast-furnace slag as the aggregate, while the remaining two contain diabase aggregate. Portland cement was used in all specimens. The base of these specimens will be subjected to steam pressures up to 300 psi.

In past tests, leakage occurring between the concrete specimen and the mold, and around the thermocouple leads and probe tubes, made it impossible to record pressures and temperatures of any significant value.

The improvements in the design of the mold and measuring probes should correct this difficulty. The conical shape of the specimen has proven to be an effective way of reducing or even preventing leakage between the mold and the specimen.

C. The Effect of High Pressure Air on the Permeability of Concrete

Permeability determinations were made during this period on brick-shape specimens cut from samples of concrete submitted by various Naval Air Station power-check facilities. Each of the concretes selected contained one of the following aggregates: crushed diabase, blast-furnace slag, expanded shale, or expanded shale coated. Portland cement was used with the diabase and blast-furnace slag. High alumina hydraulic cement, Fondu, was used with the expanded shales.

The permeability values were determined, at low head pressure, (less than 0.5 psi) on each of the concretes before and after exposure to high pressure air. The pressures to which the specimen were exposed were 100, 200, and 300 psi. The pressure to which a specimen could be exposed was limited by its strength. For this reason the lightweight aggregate concrete specimens were not exposed to 300 psi.

The specimen, while exposed to high pressure, absorbed air in amounts proportional to the pore and capillary volume. This was indicated by observation of the rate and duration of de-gassing. When the pressure on the specimen is reduced, the air within the specimen is slowly released as de-gassing occurs. The rate at which de-gassing occurs in a particular concrete is proportional to the pressure to which the specimen was subjected. The permeability, after high pressure exposure, was not determined until the pressure within the specimen has returned to atmospheric.

In general the permeability of concrete is increased by exposure to high pressure air. The magnitude of this increase seems to depend on the permeability of the concrete before exposure.

Some modifications are being made on the permeability apparatus to permit measurements of permeability at high pressure differentials (100, 200, or 300 psi). Until now, permeability determinations could only be made at pressure differentials of several inches water pressure.

When water, inherently present in concrete, is confined within a specimen during jet-blast impingement, high steam pressure will develop. This is one of the factors that causes explosive spalling. The pore space determined for the concretes made using four different aggregates, Table III, is a measure of their ability to permit the escape of water or steam.

Table III shows that concretes having low bulk density and high pore space lose more water during drying and jet-blast impingement. These concretes also gain in weight more rapidly during moist curing than the dense concretes, such as those made with diabase and blast furnace slag aggregate.

Since a study of temperatures during jet impingement gives an indication of the steam pressures involved, further data is required.

D. The Effect of Water Present in Concrete on Temperature Gradients

The data thus far obtained on temperature gradients, as they occur in concrete during jet-blast impingement, is of value, but does not give sufficient detail on the behavior of the top quarter inch of concrete where spalling actually occurs. To determine temperature and the rapid rate of change of temperature near the start of the jet-blast test, at depths of less than 1/8 inch, molds have been constructed and instrumented with thermocouples positioned in this critical area. Specimens to be used in this work have been prepared. We plan to improve our temperature recording facilities by using a continuous, high-speed, multi-channel recorder to obtain a time/temperature record of sufficient accuracy to calculate gradients near the surface of concrete specimens during jet-blast exposure.

Table III Properties and Performance of Concretes Submitted for Tests from Four Naval Air Stations

Type of Concrete	Bulk Specific Gravity	Absolute Specific Gravity	Total ^{1/} Pore Space %	Open ^{2/} Pore Space %	Closed Pore Space %	Permeability ^{3/}	Average Loss in Wt. ^{4/} of Test Panels During Drying %	W/C Ratio	Cement Content
aggregate cement	g/cm ³		%	%	%		%		sacks/yd ³
Diabase Portland Type II	2.35	2.60	11.1	6.8	4.3	67 X 10 ⁻⁶	0.25	0.49	6.75
Blast-Furnace Slag Portland Type I	2.09	2.66	21.3	15.8	5.5	287 X 10 ⁻⁶	1.17	0.39	7.50
Expanded Shale	1.58	2.52	37.3	15.3	22.0	190 X 10 ⁻⁶	2.50	0.47	6.75
Expanded Shale Coated	1.49	2.60	42.6	31.7	10.9	1370 X 10 ⁻⁶	5.34	0.47	6.75

1/ $\frac{\text{Bulk Specific Gravity}}{\text{Absolute Specific Gravity}} \times 100.$

2/ $\frac{\text{Wet Weight} - \text{Dry Weight}}{\text{Wet Weight} - \text{Suspended Weight}} \times 100.$

3/ $\frac{\text{cm}^4}{(\text{g}) \text{ sec.}}$ of dry air at room temperature.

4/ Assumed to be water.

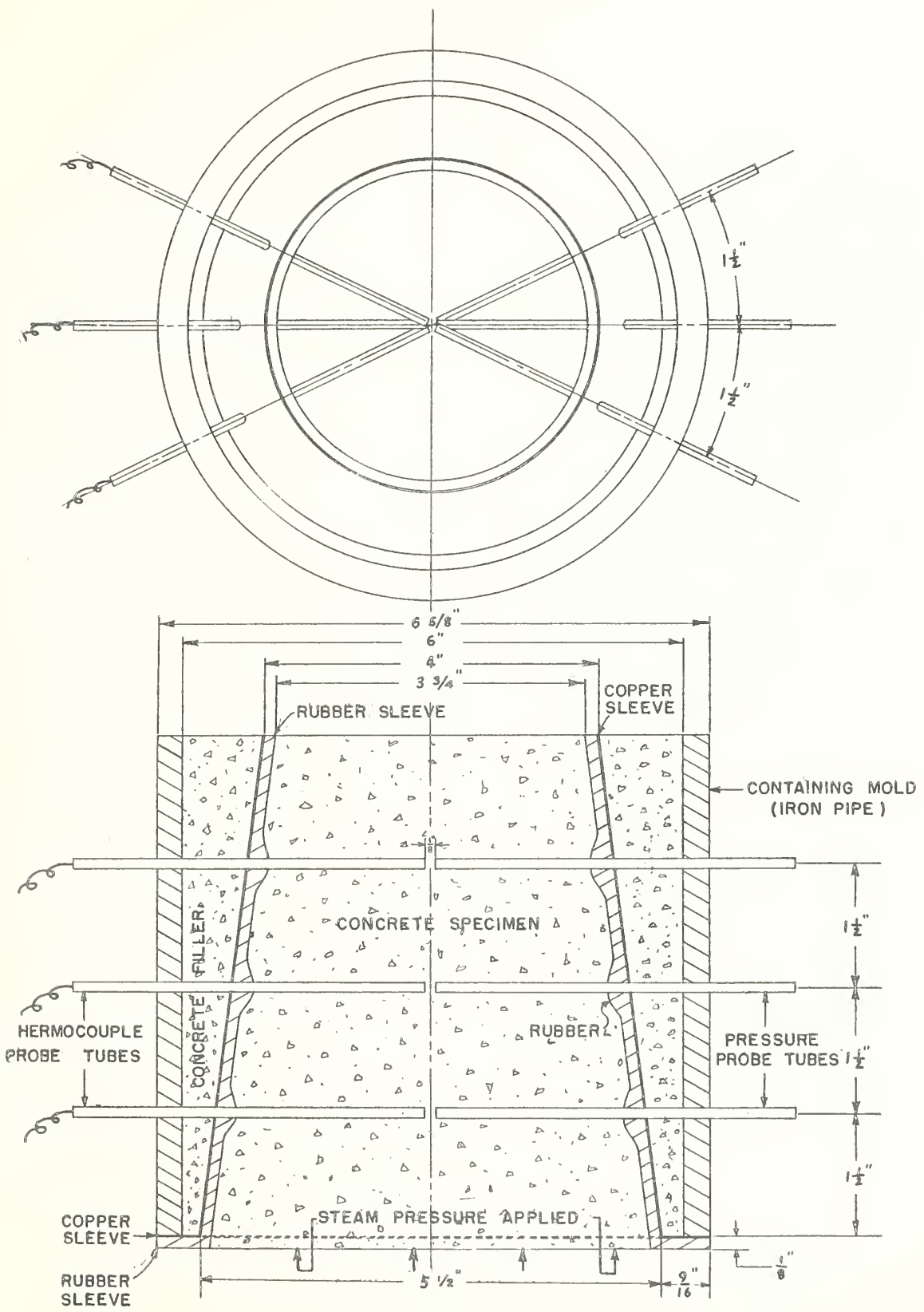


FIGURE 1. APPARATUS USED IN DETERMINING THE EFFECT OF STEAM PRESSURE APPLIED TO CONCRETE



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