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NATIONAL BUREAU OF STANDARDS REPORT

6995

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, Bruce Foster

NBS

U. S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

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NBS PROJECT | **NBS REPORT**

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W. L. Pendergast, E. C. Tuma, Bruce Foster
Inorganic Building Materials Section
Building Research Division

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Raymond L. Blaine, Chief
Inorganic Building Materials Section

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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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

2.1 Fabrication of Test Specimens

Twelve brick shape concrete specimens were fabricated for the purpose of studying the effect of the vacuum method of placing concrete on the resultant permeability. The mix used for one set of six specimens was portland-diabase concrete, referred to in many previous reports as $P\text{-}D_i$-. The mix used in the second set of six specimens was a portland cement-blast furnace slag concrete, referred to in previous reports as P-BF-. In each set of six specimens four were evacuated immediately after placing. Two of the four were evacuated from the top surface, as positioned in the mold, two were evacuated from the bottom surface, and the remaining two were conventionally placed.

In that phase of the project dealing with pressure developed within concrete during exposure to rapid heating, such as occurs during jet exhaust impingement, three specimens were fabricated using the aforementioned mix $P\text{-}D_i$-. These specimens were instrumented with axially slotted probe tubes with the open end positioned at one-sixteenth of an inch from the surface which is to be exposed to jet exhaust.

Four molds were so constructed that hypodermic needles as probe tubes could be positioned in the concrete specimen when cast. These needles were soldered to a plate which became integral with the back of each specimen when removed from the mold. Four specimens were cast using the $P\text{-}D_i$ mix. The needle sizes were B & S 13, 19, 20, and 21.

2.2 Testing of Specimens

The permeability, change in water content, and modulus of elasticity were determined on the 12 brick shape specimens mentioned in 2.1. These properties were determined at varying moist curing

and drying periods, indicated in Tables I and II, and additional measurements of modulus of elasticity were made at seven day intervals during moist curing.

2.3 Results

The data obtained on the specimens fabricated using mix P-D_1- appears in Table I and that for specimens fabricated using mix P-BF- appears in Table II.

The changes in water content during curing and drying are illustrated in Figures 1 and 2 for the evacuation and conventional placing methods. The effect of duration of the test on permeability values is shown in Figure 3. Figures 4 and 5 show the effect of moist curing and drying on permeability.

2.3.1 Weight Change

As shown in Figures 1 and 2 the specimens fabricated by the vacuum method gained more water in the fog room than those conventionally placed. However, the conventionally placed specimens lost much more weight, assumed to be water, in the early stages of drying than the specimens fabricated by the vacuum method.

The water/cement ratio of the conventionally placed specimens was considerably higher than that remaining after fabrication by the vacuum process as given in Tables I and II. It may be speculated that somewhat more water enters into chemical combination with the cement in the vacuum process. This is also indicated by the modulus of elasticity data.

2.3.2 The Effect of the Duration of the Permeability Test on Permeability Values

The duration of the flow of permeating gases through a specimen has been shown to affect the value of permeability for some materials.* The extent of this effect on two concrete specimens as shown in Figure 3. The variation in permeability values with the time of flow in the permeability test depends on the history of the specimen. The conventionally placed specimen when tested during moist curing had less stability in permeability than it had after drying treatments. The specimen of similar composition which was placed by the vacuum method was comparatively stable in permeability during moist curing and drying. The instabilities were probably due to water transportation and/or evaporation of water.

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*"Permeability and Some Other Properties of a Variety of Refractory Materials I and II." J. American Ceramic Society, Vol. 36 [7] and [8] (1953), G. B. Massengale et al.

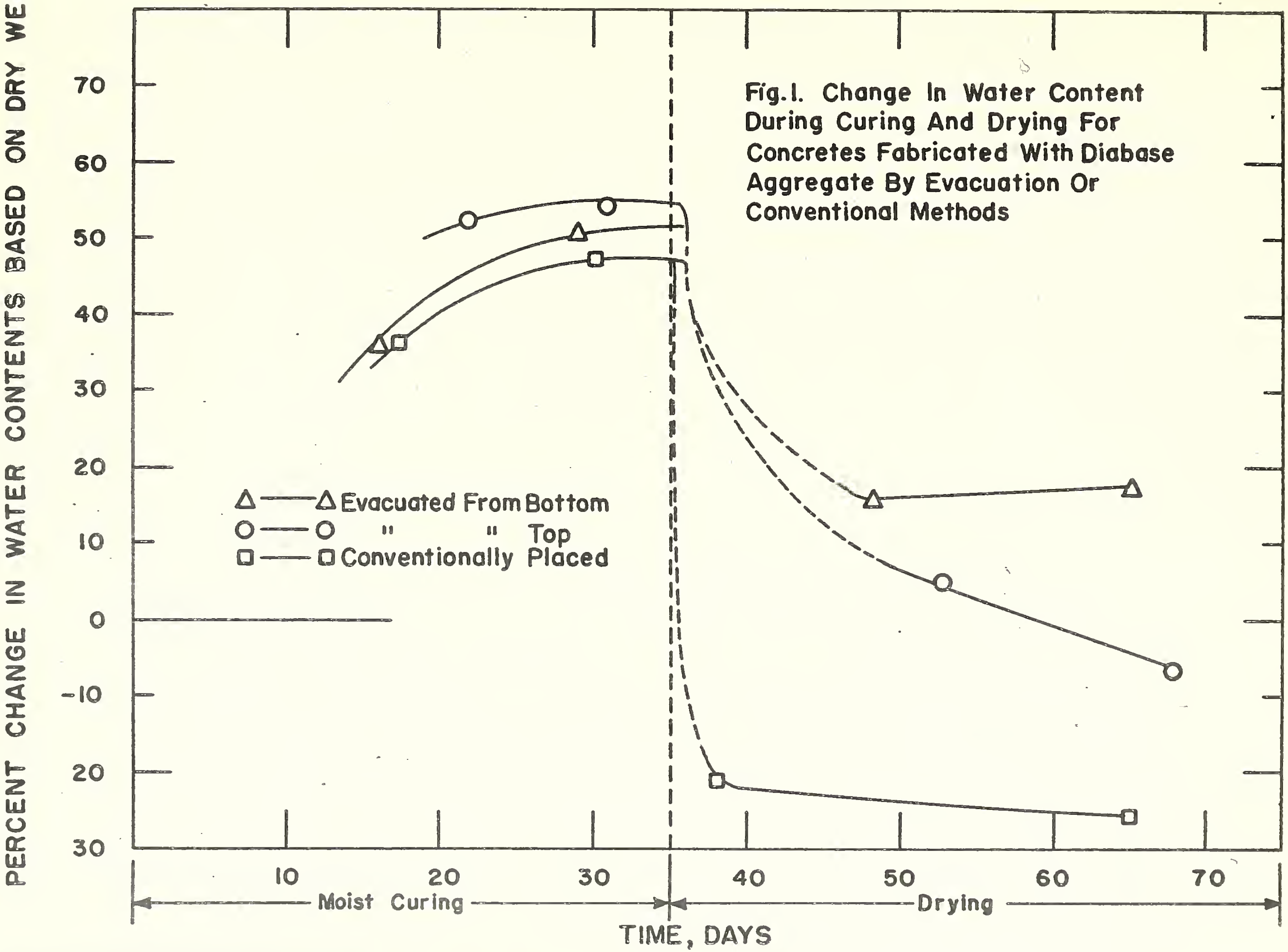


Fig. I. Change In Water Content During Curing And Drying For Concretes Fabricated With Diabase Aggregate By Evacuation Or Conventional Methods

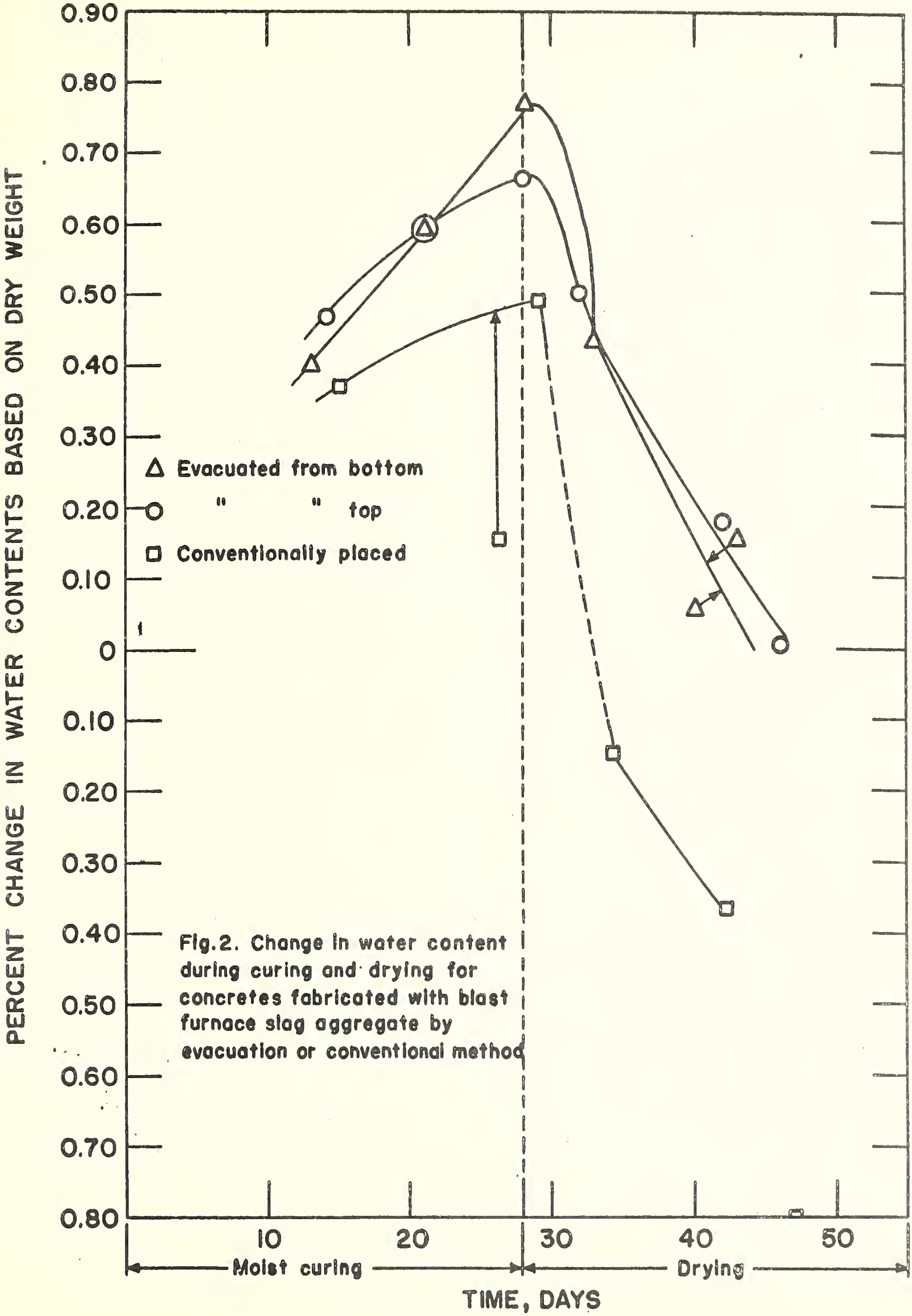


Fig.2. Change in water content during curing and drying for concretes fabricated with blast furnace slag aggregate by evacuation or conventional method

Table I. The Permeability, Modulus of Elasticity, and Change in Water Content During Moist Curing and Drying for Evacuated and Conventionally Placed Diabase Concrete Specimens.

Designation 1/	W/C of Specimen	Moist Curing	Drying 2/	Change in Weight 3/	Change in Weight During Test 4/	Modulus of Elasticity 5/ 1 Day Old	Permeability Test before	Permeability Test after	Permeability 6/
		Days	Days	%	%	psi x 10^6			$x10^6$
P-Di-12-1B	.264	0	-	-	-	6.156			
		16	-	+0.36	-0.13		7.776		2.96
		35	13	+0.15	-0.08		7.929	7.928	262.00
P-Di-12-2B	.264	0	-	-	-	6.218			
		29	-	+0.50	-0.13		7.785		17.07
		35	30	+0.17	-0.02		8.209	8.032	37.65
P-Di-12-3T	.276	0	-	-	-	6.075			
		22	-	+0.52	-0.18		8.281		150.05
		35	18	+0.05	0.00		8.064	8.064	939.00
P-Di-12-4T	.276	0	-	-	-	5.874			
		31	-	+0.54	-0.12		8.545		13.58
		35	33	-0.07	-0.03		7.889	7.887	2930.00
P-Di-12-5C	.493	0	-	-	-	4.895	-		
		30	-	+0.47	-0.13		5.816		7/
		35	30	-0.26	-0.03		6.672	6.547	1.76
P-Di-12-6C	.493	0	-	-	-	4.563	-		
		17	-	+0.36	-0.01		7.438		1.01
		35	14	-0.21	-0.02		6.752	6.752	1.56

1/ P = Portland Cement; Di = Diabase Aggregate; First Numeral (12) denotes mix; Second Numeral (1 to 6) denotes number of specimen; Letter B = Specimen evacuated from bottom, immediately after placing; Letter T = Specimen evacuated from top, immediately after placing; Letter C = Specimen Conventionally placed.

2/ 50% relative humidity 73°F.

3/ Based on one-day-old weight.

4/ Based on weight before permeability test.

5/ Dynamic Modulus, Flexure.

6/ $\frac{Cm^4}{(g)(Sec)}$ of dry air at room temperature.

7/ No flow detected.

Table II. The Permeability, Modulus of Elasticity and Change in Water Content During Moist Curing and Drying for Evacuated and Conventionally Placed Blast Furnace Slag Concrete Specimens.

Designation 1/	W/C of Specimen	Moist Curing	Drying 2/	Change in Weight 3/	Change in Weight During Test 4/	Modulus of Elasticity 5/ 1 Day Old	Modulus of Elasticity 5/ Permeability Test before	Modulus of Elasticity 5/ Permeability Test after	Permeability 6/
		Days	Days	%	%	psi x 10^{-6}			$x10^6$
P-BF-7-1B	.359	0	-	-	-	3.453			
		13	-	+0.40	-0.15		4.723	4.900	202.0
		28	5	+0.43	-0.04		4.911	4.909	83.7
		28	12	+0.05	-0.01		5.033	5.008	129.0
P-BF-7-2B	.359	0	-	-	-	4.052			
		21	-	+0.59	-0.11		5.164	5.158	33.4
		28	-	+0.77	-0.04		5.173	5.171	20.7
		28	15	+0.15	-0.01		4.941	4.905	65.5
P-BF-7-3T	.377	0	-	-	-	4.083			
		14	-	+0.46	-0.17		5.108	5.214	1370.0
		28	-	+0.66	-0.25		5.164	5.273	70.2
		28	14	+0.17	-0.06		5.232	5.091	1540.0
P-BF-7-4T	.377	0	-	-	-	4.026			
		21	-	+0.59	-0.17		5.112	6.300	413.0
		28	4	+0.50	-0.06		5.086	5.060	718.0
		28	18	0.00	-0.04		4.880	4.876	1080.0
P-BF-7-5C	.631	0	-	-	-	3.556			
		15	-	+0.37	-0.12		4.409	5.011	7/
		28	-	+0.49	-0.07		5.120	5.120	7/
		28	14	-0.37	-0.02		4.885	4.837	0.73
P-BF-7-6C	.631	0	-	-	-	2.789			
		26	-	+0.15	-0.15		4.935	4.951	.119
		28	6	-0.15	-0.23		4.920	4.909	1.80
		28	19	-0.81	-0.05		4.828	4.826	1.54

1/ P = Portland Cement; BF = Blast Furnace Slag Aggregate; First numeral denotes mix; Second numeral denots number of Specimen; Letter B = Specimen evacuated from bottom immediately after placing; Letter T = Specimen evacuated from top immediately after placing; Letter C = Conventionally placed.

2/ 50 % relative humidity 73°F.

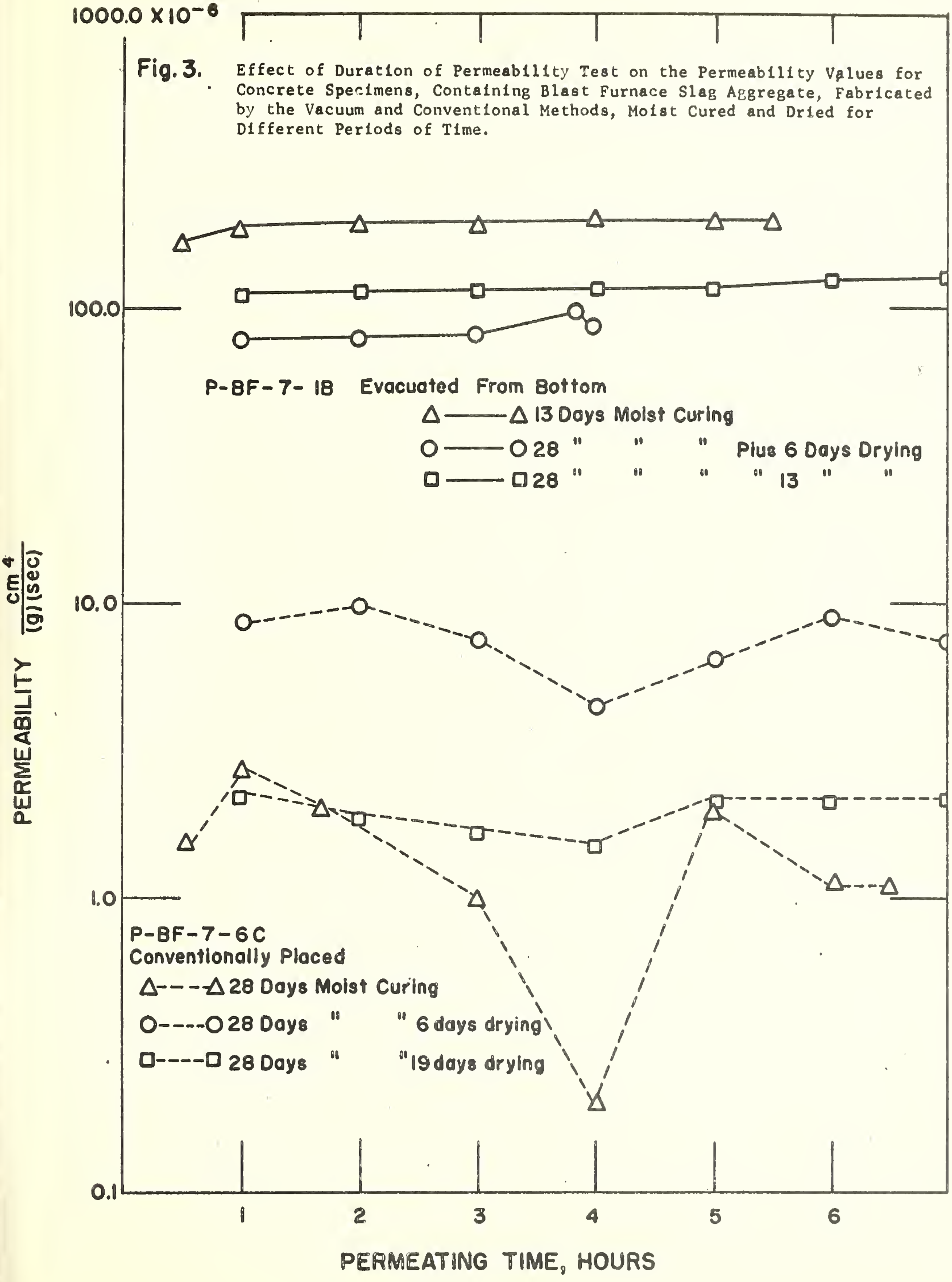
3/ Based on one-day-old weight.

4/ Based on weight before permeability.

5/ Dynamic Modulus, Flexure.

6/ $\frac{Cm^4}{(g)(Sec)}$ of dry air at room temperature.

7/ No flow detected.


1000.0 X10⁻⁶
Fig. 3. Effect of Duration of Permeability Test on the Permeability Values for Concrete Specimens, Containing Blast Furnace Slag Aggregate, Fabricated by the Vacuum and Conventional Methods, Moist Cured and Dried for Different Periods of Time.
100.0
P-BF-7- 1B Evacuated From Bottom
13 Days Moist Curing
28 " " " Plus 6 Days Drying
28 " " " " 13 " "
10.0
PERMEABILITY cm⁴/(g)(sec)
1.0
P-BF-7-6C
Conventionally Placed
28 Days Moist Curing
28 Days " " 6 days drying
28 Days " "19 days drying
0.1
1
2
3
4
5
6
PERMEATING TIME, HOURS

2.3.4 Change in Permeability with Curing and Drying

For concrete P-BF the permeability after 28 days moist curing was less than that at shorter curing periods, Figure 5. This data and that given in NBS Reports 6653 and 6909 show that permeability usually increased for most concretes during the early stages of drying, or capillary water is lost.

Concretes fabricated by the evacuation method developed greater permeabilities than those of the conventionally placed, irrespective of the type of aggregate or method of evacuation. Data indicates that some of the connected pores formed during evacuation are retained after curing and drying. The difference in permeability for the evacuated and conventionally placed concretes was more pronounced for the concretes having the blast furnace slag as aggregate. The range of permeabilities was about the same for the concretes made from the porous blast furnace slag aggregate as it was for concretes made using the dense diabase aggregate. This data together with that previously reported indicates that the pores in the blast furnace slag aggregate, do not greatly effect the permeability of the resulting concrete.

2.3.5 Moduli of Elasticity

The modulus of elasticity of the portland-diabase concretes, when placed by the vacuum method, gave values higher than when placed by the conventional method, especially during the early moist curing periods and remained higher for ages up to 40 days drying. The concretes made with blast furnace slag aggregate and fabricated by the vacuum method also had higher moduli at the early curing ages than the conventionally placed, but the moduli of specimens fabricated by both methods were practically equal after three weeks drying.

2.4 Pressure Developed within Concrete During Rapid Heating

Three jet impingement tests were made on concrete specimens for the purpose of determining the pressure developed within concrete during rapid heating. The pressure transducer method was used to detect rise in pressure with accompanying rise in temperature. The results were unsatisfactory, indicating less than 10 psi pressure.

Some additional apparatus was obtained with the intent to improve the instrumentation in the study of pressure developed within concrete during exposure to the jet impingement test. The schematic arrangement of this apparatus was similar to a Direct Venous Pressure instrument. The three-way valve, the filling syringe, and the hypodermic needle will be used. The manometer, however, will be replaced by a closed end, gas filled, capillary pressure tube suitable for higher pressures. The hypodermic needles will serve as miniature probe tubes and will be cast in place in the concrete test specimens. Paragraph 3 of Part 2.1 describes molds used and specimens cast for this phase of the project.

2.5 Cooperative Jet Impingement Tests

Two panels of a series of seven, that were fabricated at the National Bureau of Standards laboratory to be used in cooperative jet impingement tests with NAVCERELAB, have been subjected to our laboratory jet test. Both evidenced slight failure, the first after 51 days and the second after 105 days drying at 50% relative humidity and 73°F. The second panel, due to the 54 days additional drying, had ten percent less loss caused by jet impingement.

2.6 A Study of Concreting Materials and Concretes for Naval Facilities

Four concrete test panels (18 x 18 x 6 inches) were received from the Fifth Naval District. These panels were fabricated with the concrete used in placing, "Turn-up Pads," at the Naval Air Station, Norfolk, Virginia. The panels were shipped in wet saw dust, well packed, and received in good condition. After being moist cured for 28 days, they will be dried at 73°F and 50% relative humidity for different periods of time before subjecting them to the jet impingement test.

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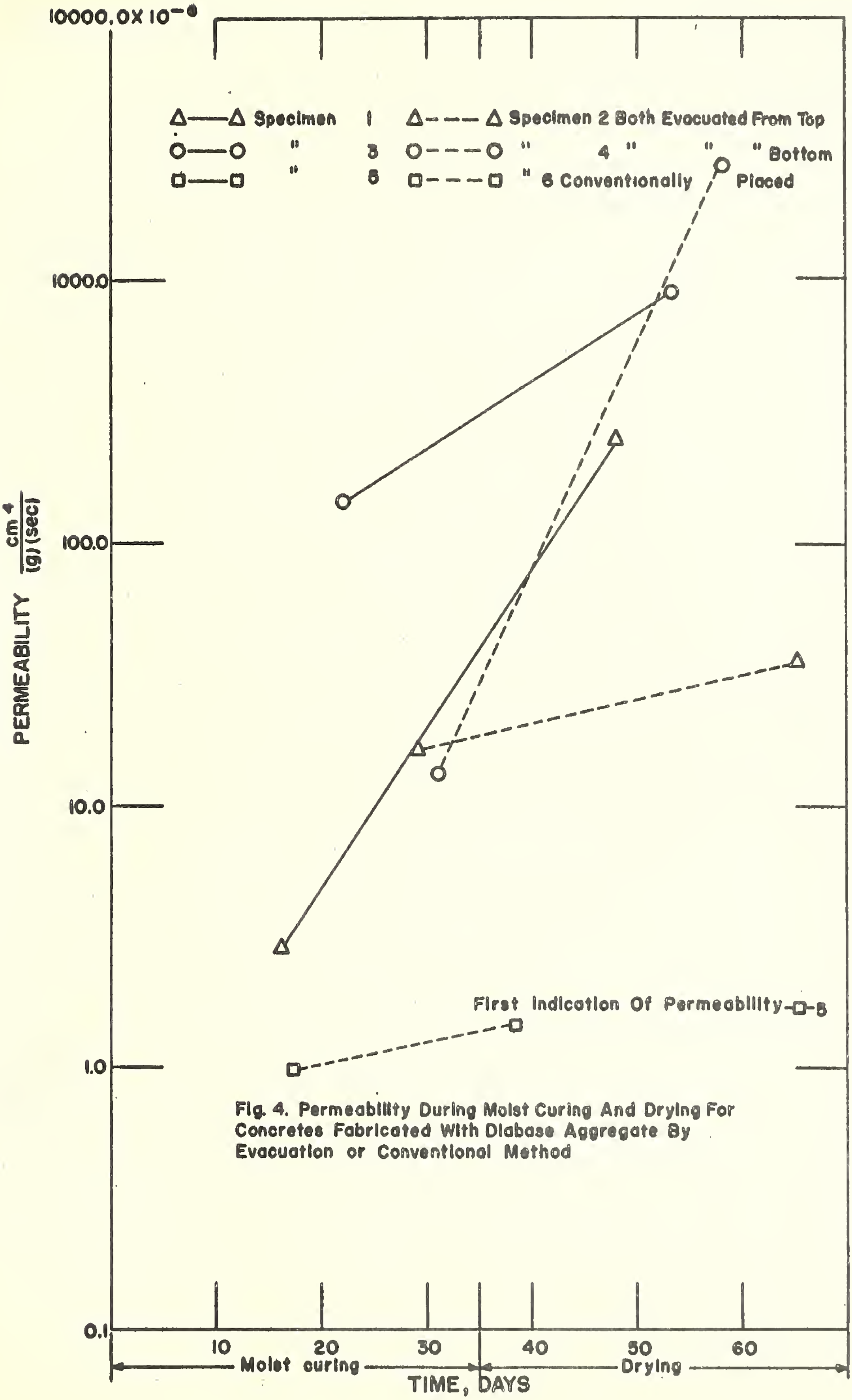

Fig. 4. Permeability During Moist Curing And Drying For Concretes Fabricated With Diabase Aggregate By Evacuation or Conventional Method

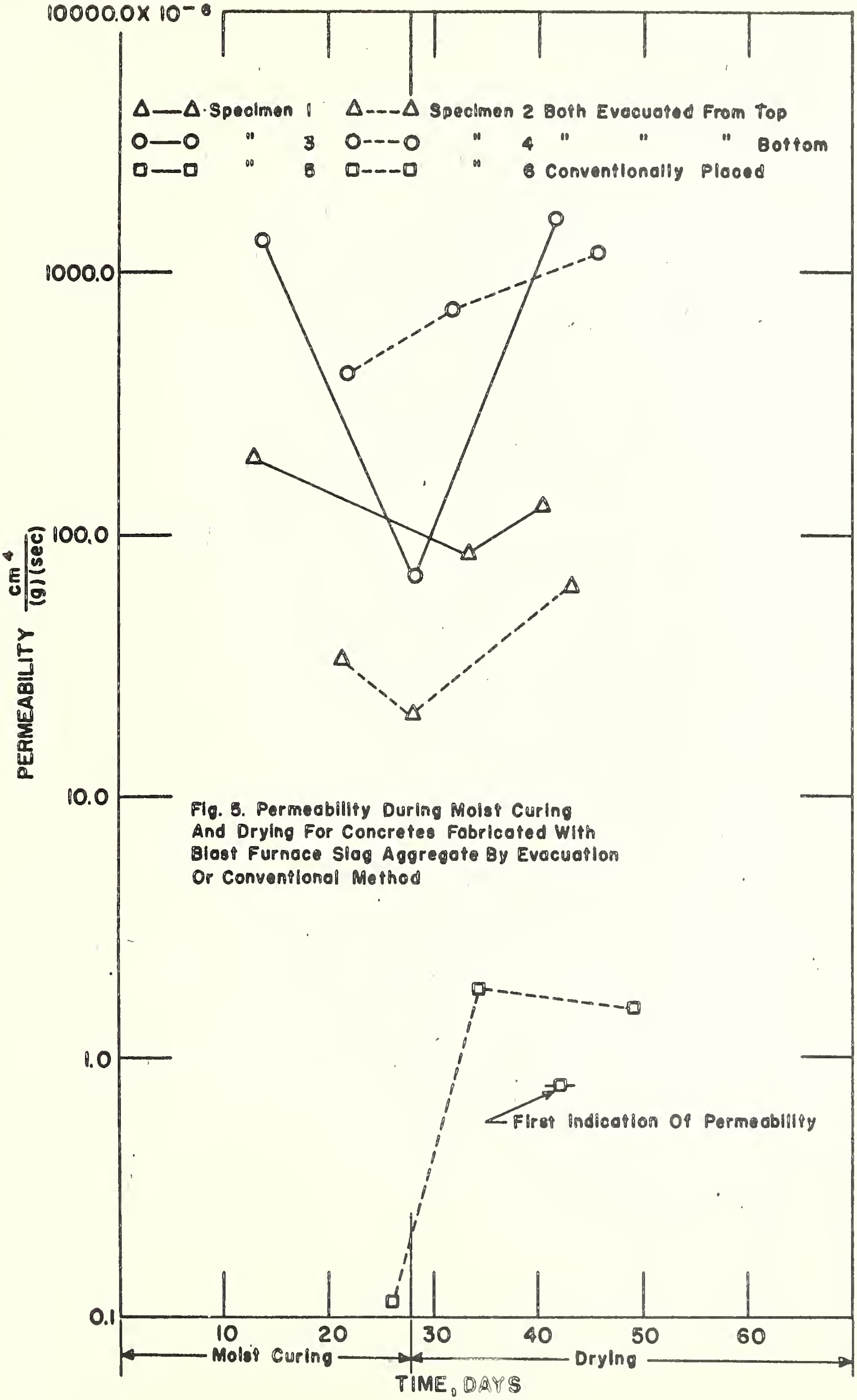

Fig. 5. Permeability During Moist Curing And Drying For Concretes Fabricated With Blast Furnace Slag Aggregate By Evacuation Or Conventional Method

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METROLOGY. Photometry and Colorimetry. Refractometry. Photographic Research. Length. Engineering Metrology. Mass and Scale. Volumetry and Densimetry.

HEAT. Temperature Physics. Heat Measurements. Cryogenic Physics. Rheology. Molecular Kinetics. Free Radicals Research. Equation of State. Statistical Physics. Molecular Spectroscopy.

RADIATION PHYSICS. X-Ray. Radioactivity. Radiation Theory. High Energy Radiation. Radiological Equipment. Nucleonic Instrumentation. Neutron Physics.

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

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

ORGANIC AND FIBROUS MATERIALS. Rubber. Textiles. Paper. Leather. Testing and Specifications. Polymer Structure. Plastics. Dental Research.

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MINERAL PRODUCTS. Engineering Ceramics. Glass. Refractories. Enameled Metals. Constitution and Microstructure.

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CRYOGENIC ENGINEERING. Cryogenic Equipment. Cryogenic Processes. Properties of Materials. Gas Liquefaction.

IONOSPHERE RESEARCH AND PROPAGATION. Low Frequency and Very Low Frequency Research. Ionosphere Research. Prediction Services. Sun-Earth Relationships. Field Engineering. Radio Warning Services.

RADIO PROPAGATION ENGINEERING. Data Reduction Instrumentation. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Propagation-Terrain Effects. Radio-Meteorology. Lower Atmosphere Physics.

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RADIO SYSTEMS. High Frequency and Very High Frequency Research. Modulation Research. Antenna Research. Navigation Systems. Space Telecommunications.

UPPER ATMOSPHERE AND SPACE PHYSICS. Upper Atmosphere and Plasma Physics. Ionosphere and Exosphere Scatter. Airglow and Aurora. Ionospheric Radio Astronomy.

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