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O T T A W A July 30, 1945.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1915.

Effects of Bentonite, Cereal Flour, Silica Flour and Water on the Moulding Characteristics of a #60 Sand.

(Copy No. 4.)

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Report of Investigation
No. 1915, July 30, 1945.
HHF:AEM:LB.

Bureau of Mines
Division of Metallic
Minerals.

Physical Metallurgy
Research Laboratories

CANADA

DEPARTMENT
OF
MINES AND RESOURCES

Mines and Geology Branch

O T T A W A July 30, 1945.

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Investigation No. 1915.

Effects of Bentonite, Cereal Flour, Silica Flour and Water on the Moulding Characteristics of a #60 Sand.

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Origin of Request:

This work is carried out at the request of Mr. H. P. Coplan, President, Hull Iron and Steel Foundries Limited, Hull, Quebec.

Nature of Project:

The usual ingredients of Hisco moulding sand are #60 sand, water, bentonite, silica flour, and cereal flour. This report deals with some test mixtures made to determine the effects of these ingredients upon the properties of the moulding sand. The resultant information may be of some use to those making up sand mixtures.

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(1) EFFECT OF MOISTURE ON HOT STRENGTH AT 2500° F. AND 1800° F.

It is normally thought that moisture in the original sand has no effect after the sand is dried and heated. Test results in Tables I and II show the amazing increase in hot strength obtained by increased water in the sand.

Why does wet sand have higher hot strength? One possibility is that, with wetter sand, the grains are packed more tightly together.

TABLE I. - Effect of Moisture on Hot Strength at 2500° F.

Mixture No.*	Moisture, per cent	Compressive Strength at 2500° F., p.s.i.
8.	2.2	13.5
	3.4	32.0
	4.0	50.0
11.	2.8	16
	3.4	23
	5.8	34

TABLE II. - Effect of Moisture on Hot Strength at 1800° C.

Mixture No.*	Moisture, per cent	Compressive Strength at 1800° F. p.s.i.
12.	2.3	250
	2.9	565
	3.1	745

* Mixtures are given in Table VI on Page 15.

(2) EFFECT OF BENTONITE AND SILICA FLOUR UPON HOT STRENGTH PROPERTIES.

Figure 1 shows the hot strength obtained with different amounts of bentonite and silica flour. Bentonite increases hot strength very rapidly both at 1800° F. and at 2500° F. Silica also increases hot strength to a considerable degree.

Figure 2 shows how plastic the sand is with various proportions of bentonite and silica. Note that bentonite increases hot plasticity, both at 1800° F. and 2500° F. Silica flour makes the sand more plastic at 1800° F. but has little effect upon plasticity at 2500° F.

(Figures 1 and 2)
(appear on pages)
(4 and 5.)

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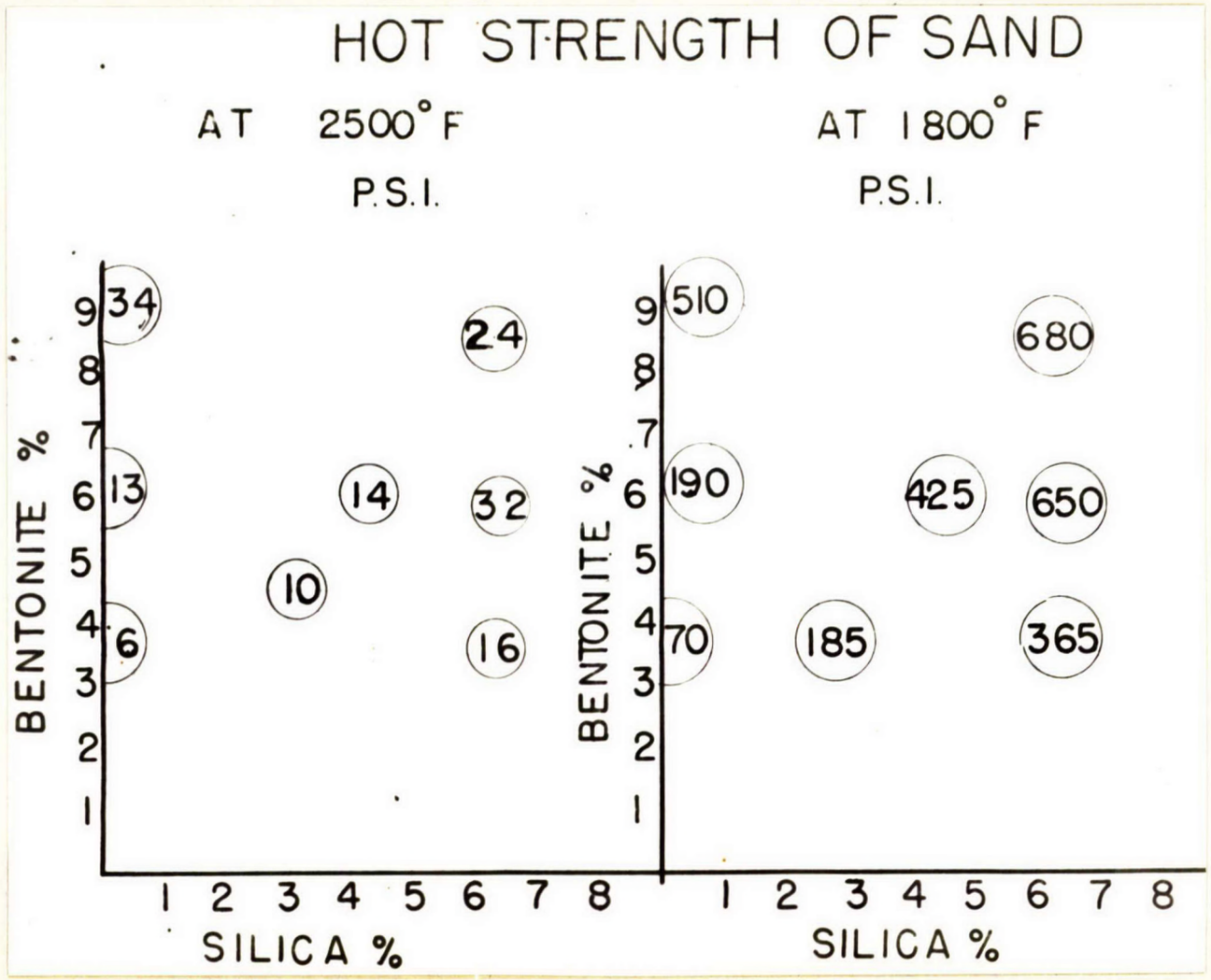
HOT STRENGTH OF SAND
AT 2500° F
P.S.I.
AT 1800° F
P.S.I.
BENTONITE %
SILICA %
34
13
6
10
14
24
32
16
510
190
70
185
425
680
650
365

Figure 1.

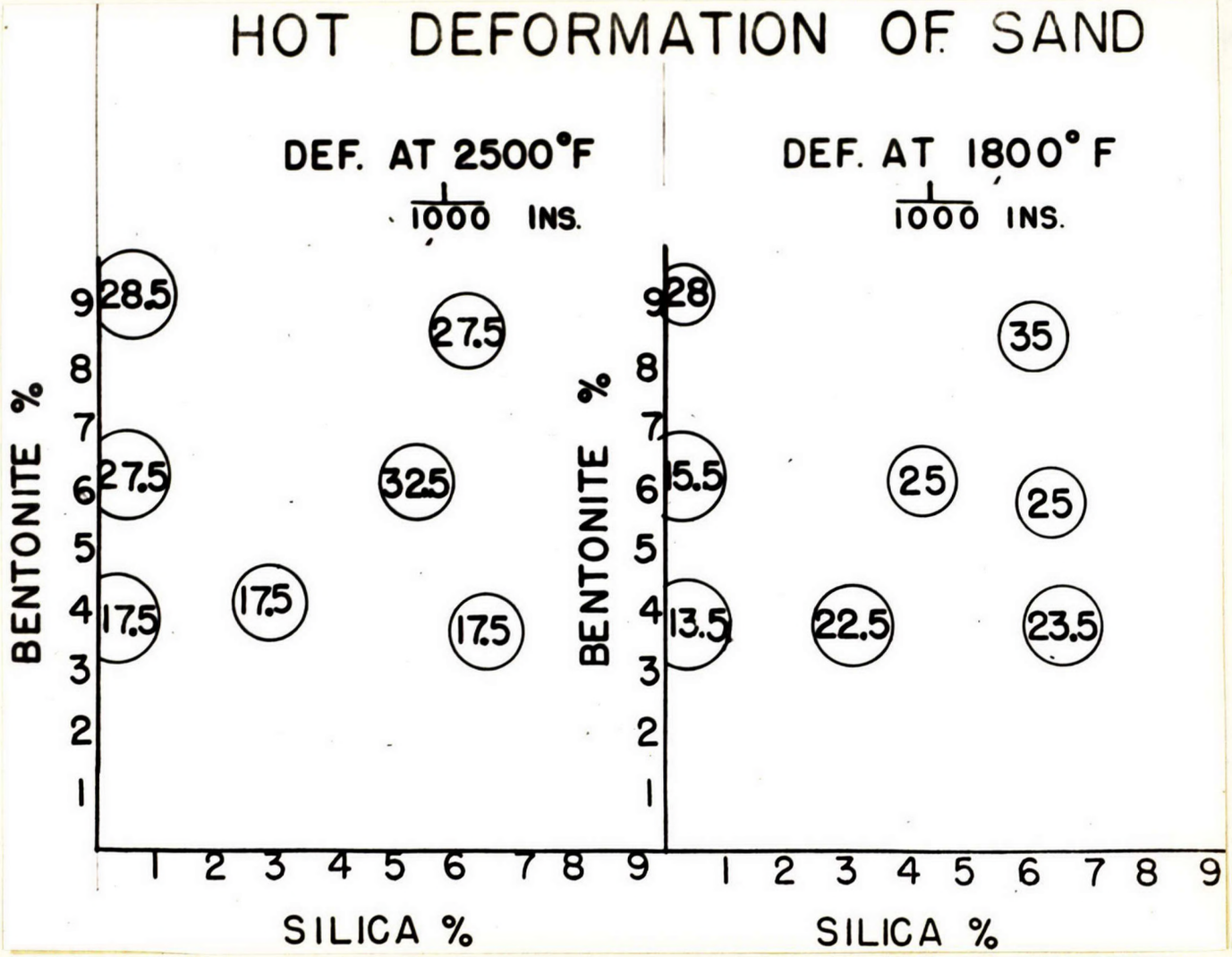
HOT DEFORMATION OF SAND
DEF. AT 2500°F
1/1000 INS.
DEF. AT 1800° F
1/1000 INS.
BENTONITE %
SILICA %
28.5
27.5
27.5
32.5
17.5
17.5
17.5
28
35
5.5
25
25
13.5
22.5
23.5

Figure 2.

(3) EFFECT OF BENTONITE UPON SAND PROPERTIES.

Figures 3 and 4 show the effect of bentonite upon the sand properties. As more bentonite is added

- moisture for best temper is increased,
- plasticity increases,
- bond increases,
- permeability decreases,
- flowability decreases,
- dry bond increases,
- toughness increases.

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(Figures 3 and 4 follow, on pages 7 and 8.)

Figure 3.

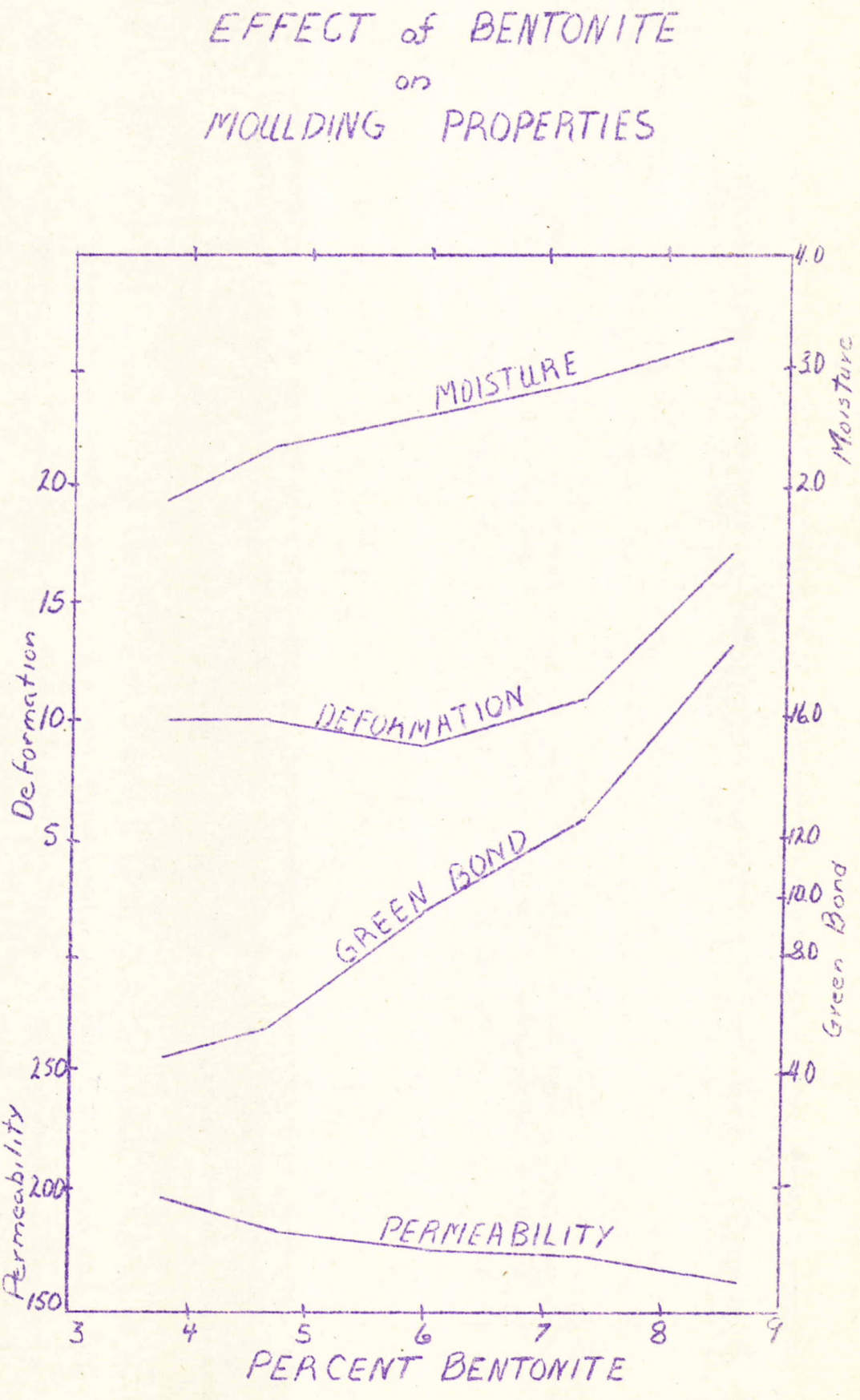
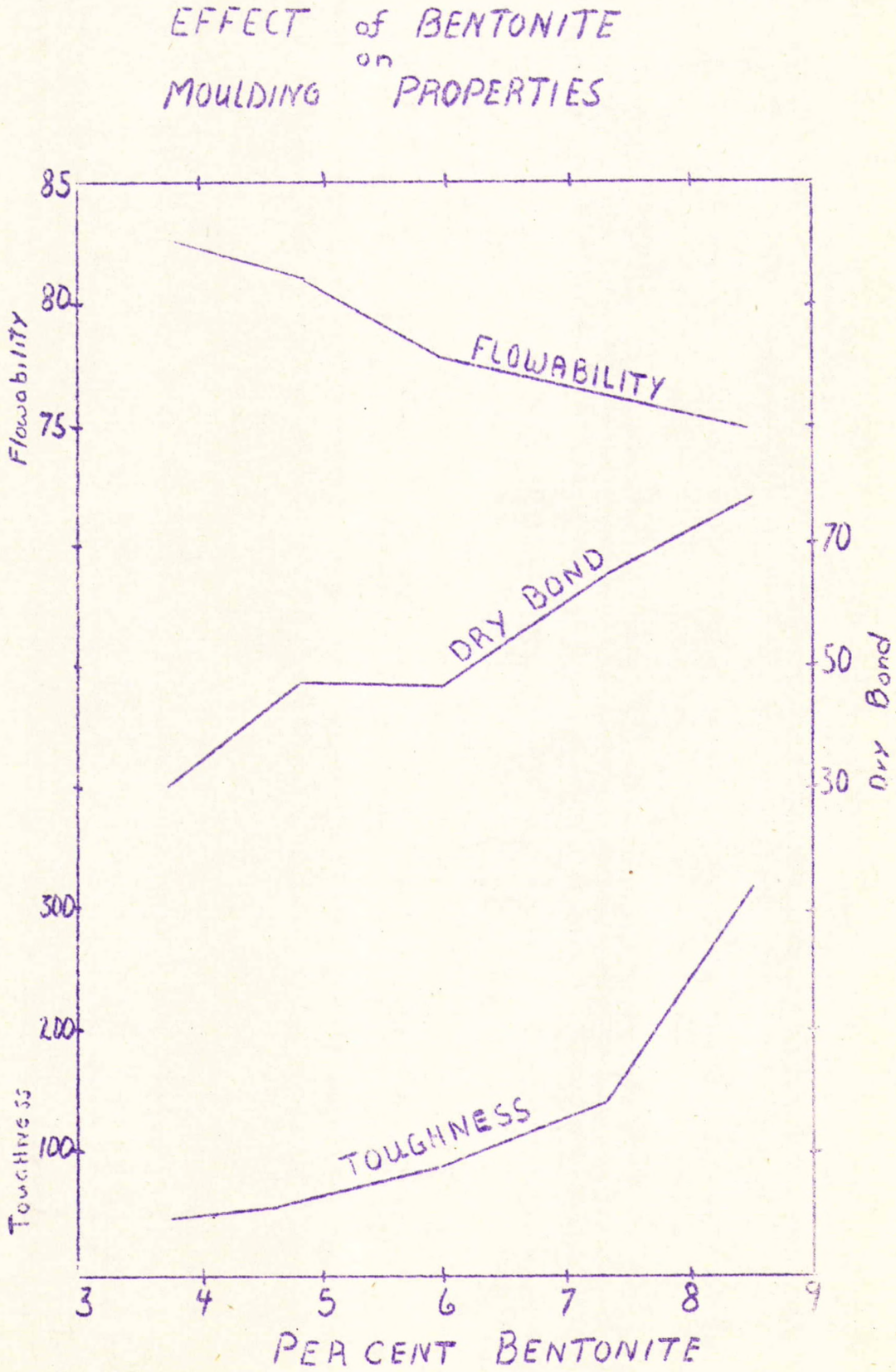

EFFECT of BENTONITE
on
MOULDING PROPERTIES
MOISTURE
DEFORMATION
GREEN BOND
PERMEABILITY
De formation
Permeability
Moisture
Green Bond
PERCENT BENTONITE
4.0
3.0
2.0
160
120
100
80
40
20
15
10
5
250
200
150
3
4
5
6
7
8
9

Figure 4.


EFFECT of BENTONITE on MOULDING PROPERTIES
85
80
75
Flowability
FLOWABILITY
DRY BOND
70
50
30
Dry Bond
300
200
100
Toughness
TOUGHNESS
3
4
5
6
7
8
9
PER CENT BENTONITE

(4) EFFECT OF SILICA FLOUR UPON SAND PROPERTIES.

Figures 5 and 6 show the effect of silica flour upon moulding sand properties.

Only two properties are markedly changed. The permeability is reduced and the moisture necessary for optimum temper is increased.

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(Figures 5 and 6)
(comprise Pages)
(10 and 11.)

Figure 5.

EFFECT of SILICA FLOUR on MOULDING PROPERTIES

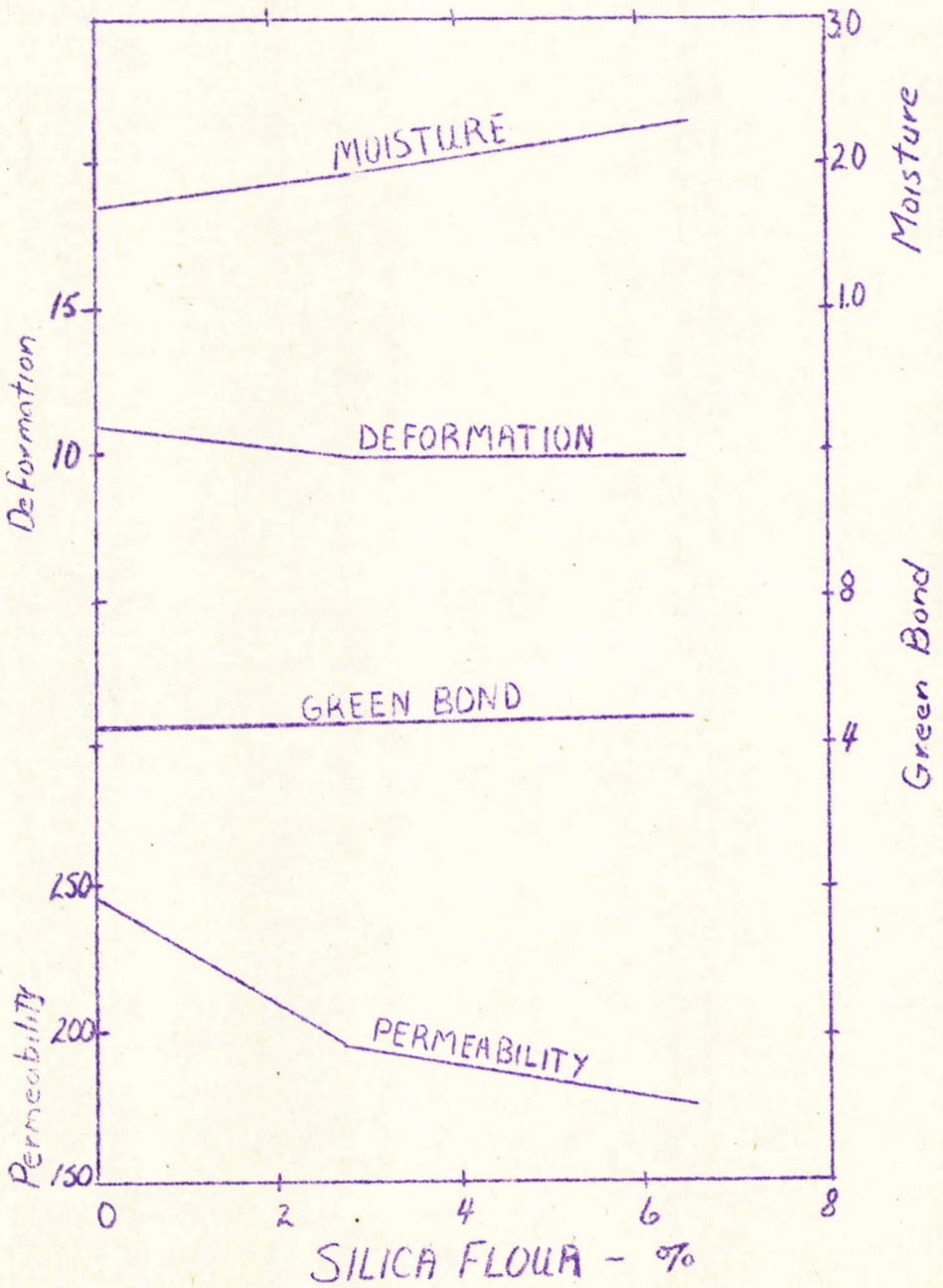
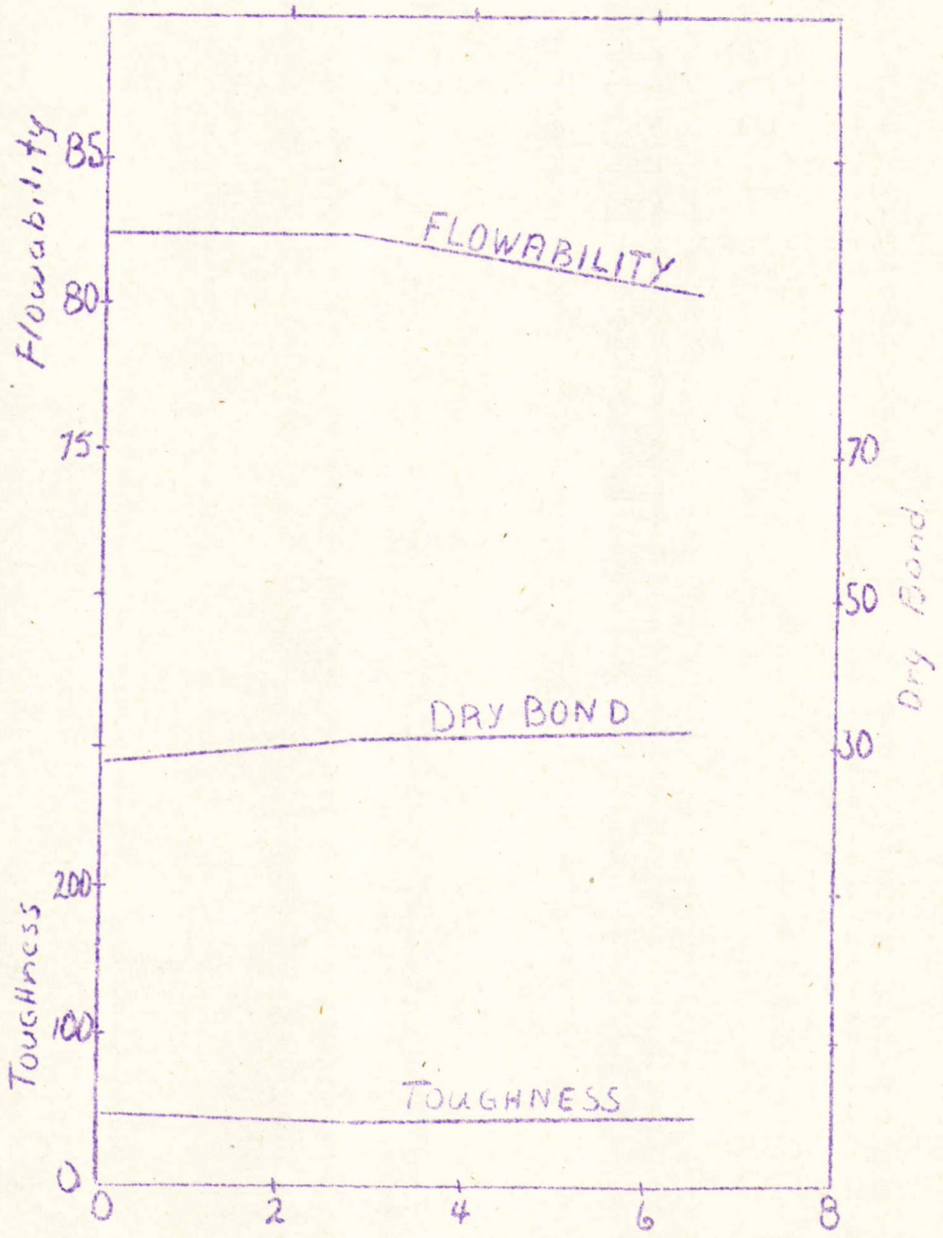


Figure 6.

EFFECT of SILICA FLOUR
on
MOULDING PROPERTIES



SILICA FLOUR - %

(5) EFFECT OF CEREAL FLOUR UPON SAND PROPERTIES.

Cereal flour is a more powerful addition agent than clay or silica (see Figure 7). One per cent of cereal will change:

- dry bond, +20 p.s.i. high
- toughness, +75 units
- deformation, +0.008 in./in.
- green bond, +2 p.s.i.
- permeability, +50
- water for best temper, +0.3 per cent
- flowability, 0.003 inch.

Cereal flour is therefore used to make the sand tougher, more springy, and to obtain higher dry bond.

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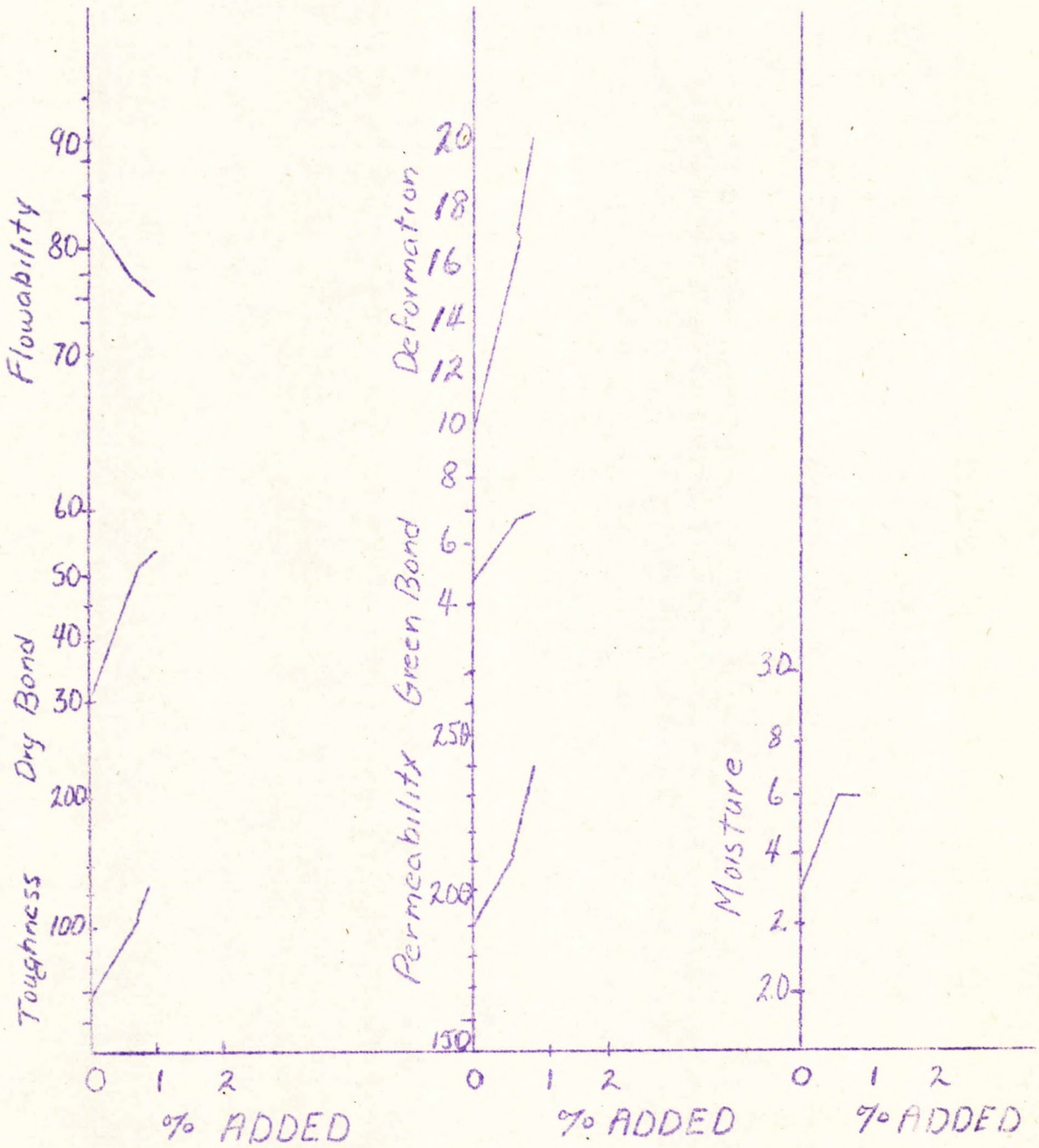
(Figure 7 follows,
on Page 13.)

Figure 7.

EFFECT of CEREAL FLOUR on SAND PROPERTIES MIXES #6, #7, #8.



(6) METHOD OF TESTING.

All materials used were obtained from HISCO. Materials were mixed in a Simpson Muller for 8 minutes. The optimum moisture content for each mixture was determined before final tests were reported.

All specimens tested at elevated temperatures were dried to a constant weight in a drying oven at 105° to 110° C., and cooled to room temperature in a desiccator.

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(7) MIXTURES USED.

TABLE III. - Mixtures Used.

Mixture	BENTONITE		SILICA FLOUR	CEREAL BINDER		Moisture, per cent
	Per cent	Sand:Bentonite Ratio	Per cent	Per cent	Sand:Cereal Flour Ratio	
1	8.5	10:1	6.1			3.3
2	7.3	12:1	5.25			2.9
3	5.95	15:1	4.4			2.6
4	4.6	20:1	3.2			2.3
5	3.75	25:1	2.7			1.9
6	3.6	25:1	6.4			2.3
7	3.6	25:1	6.4	0.67	200:1.5	2.6
8	3.6	25:1	6.4	0.89	100:1	2.6
9	3.85	25:1				1.7
10	6.25	15:1				2.3
11	9.1	10:1				2.9
12	5.8	15:1	6.3			2.8

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(8) TABULATIONS OF TEST RESULTS.

TABLE IV. - Effect on Moulding Properties

Mixture No.	Moisture, per cent	Permeability	Green Bond, p.s.i.	Deformation, in./in.	Toughness	Flowability	Dry Bond, p.s.i.
1	3.3	163	18.5	0.017	314	75	78
2	2.9	173	12.7	0.011	140	76.5	66
3	2.6	176	9.5	0.009	85.5	78	47
4	2.3	185	5.5	0.010	55	81	48
5	1.9	198	4.6	0.010	46	82.5	30.5
6	2.3	178	4.8	0.010	48	80.5	33
7	2.6	230	6.7	0.0155	104	76	52
8	2.6	270	6.9	0.019	131	74	32
9	1.7	248	4.5	0.011	49.5	82.5	28

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(Tabulations of Test Results, cont'd) -

TABLE V. - Effect on Elevated Temperature Properties.

Mixture No.	Temp., °F.	Compressive Strength, p.s.i.	Deformation, in./in.	Moisture, per cent
1	1800	680	0.035	3.3
1	2500	24	.0275	3.3
3	1800	425	.034	2.6
3	2500	14	.0325	2.6
5	1800	185	.0225	1.9
5	2500	10	.0175	1.9
6	1800	365	.0235	2.3
6	2500	16	.0175	2.3
8	2500	50	.035	4.0
8	2500	32	.024	3.4
8	2500	13.5	.0065	2.2
9	1800	70	.0135	1.7
9	2500	6	.0175	1.7
10	1800	190	.0155	2.3
10	2500	13	.0275	2.3
11	1800	510	.028	2.8
11	2500	34		5.8
11	2500	23		3.4
11	2500	16	.0285	2.8
12	1800	745	.029	3.1
12	1800	565	.025	2.9
12	1800	250	.020	2.3
12	2500	32	.0275	2.9

—

The results plotted on the charts, Figures 1 to 7, are taken from the tests that are listed below:

TABLE VI.

	Mixture No.
Effect of bentonite on sand properties -	1, 2, 3, 4, 5.
Effect of silica flour on moulding properties -	5, 6, 9.
Effect of cereal flour on moulding properties -	6, 7, 8.

(Tabulations of Test Results, cont'd) -

TABLE VI. (cont'd)

	Mixture No.
Effect of bentonite on properties at elevated temperatures	- 9, 10, 11, 1, 7, 12.
Effect of silica flour on properties at elevated temperatures	- 9, 5, 6, 10, 3, 12.
Effect of moisture on properties at elevated temperatures	- 8, 11, 12.

(9) CONCLUSIONS.

1. Mixture No. 8, containing 3.6 per cent bentonite, 6.4 per cent silica flour and 0.9 per cent cereal flour, is the one which approximates most closely the average mixture reported by Dietert and Woodliff (Trans. A.F.A., 1938, Vol. 46, p. 257, "A Study of Steel Moulding Sands"). The following table compares the moulding properties of Mixture No. 8 at 2.6 per cent moisture (maximum permeability) and 2.8 per cent moisture (minimum flowability) with the properties of the average sand described by Dietert and Woodliff. The mixture felt dry at 2.6 per cent moisture, and "right" at 2.8 per cent moisture.

	Mixture No. 8		Reported by Dietert and Woodliff
Moisture, per cent -	2.6	2.8	3.7
Permeability -	270	248	160
Green Bond, p.s.i. -	6.9	5.7	5.8
Deformation, in./in.	0.0190	0.0230	0.0240
Toughness -	131	131	142
Flowability -	74	73	77
Dry Bond, p.s.i. -	32	54	--
Dry Shear, p.s.i. -			36

These same moulding properties, with different hot strength characteristics, could be obtained by varying the proportions of bentonite, silica flour and cereal bond.

2. Water content is the most important variable studied in this report. It is about 10 times as effective

(Conclusions, cont'd) -

as bentonite or silica flour in raising hot strength at 1800° F. and is equal to silica flour in raising the hot strength at 2500° F. Water content should therefore be closely controlled, to within a limit of ±0.2 per cent if possible.

3. Bentonite increases green and dry bond, and hot strength at 1800° F. At 2500° F. an excess of bentonite in the presence of silica flour will lower the hot strength. Bentonite is not very efficient in raising the deformation at room temperatures but is the most effective material studied in raising hot deformation, that is, toughness at high temperatures.

4. Cereal flour influences moulding properties while having little influence on hot strength. It is most effective in raising the deformation and lowering the flowability; hence, sands without cereal flour may be brittle and those which contain an excess are springy and gummy.

5. Silica flour imparts hot strength, while having little influence on the moulding properties, except permeability. It has little, if any, effect on deformation at 2500° F.

6. The property of mould gas pressure was not covered in this report. Since it probably has a great effect upon castings, some comments are added.

Both silica flour and bentonite will increase mould gas pressure by reducing the permeability. Recently at Hisco, plant officials have stated that (1) adding silica flour to the moulding sand gave better results on some castings, and (2) a high content of bentonite without cereal or silica flour in the sand gave good results.

Both of the above results are understandable when it is considered that both mixtures have high hot strength and high mould gas pressure in common.

(Conclusions, cont'd) -

If mould gas pressure is desirable, cereal flour can be used. It has the added advantage of increasing dry bond.

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