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THE COLLEGE OF AERONAUTICS[®]

CRANFIELD



ASSESSMENT OF BLASTED SURFACES

PROGRESS REPORT No. 2



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THE COLLEGE OF AERONAUTICS

DEPARTMENT OF MATERIALS

Assessment of blasted surfaces

Progress Report No. 2

- by -

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Introduction

Previous work^{**} had shown that the conditions of grit blasting markedly affected the reflectivity of a mild steel surface and that measurement of reflectivity thus offered a method for the assessment of blasted surfaces. The increase in reflectivity of a series of blasted specimens was found to relate to decreasing surface quality and, after metal spraying, to decreasing bond strength between the base and the sprayed metal. However, one series of specimens did not show any correlation between reflectivity and surface quality and it was decided that an examination of a considerable number of specimens prepared under more carefully controlled conditions was necessary for the next stage of the work.

The present report gives the results of reflectivity and bond strength measurements on some 300 specimens of mild steel blasted under a number of different conditions by three suppliers. Reflectivity measurements again showed that specimens prepared by any one supplier could be placed in a series of increasing reflectivity, although some difficulties were still encountered in relating the result of different suppliers. These difficulties were most marked with specimens blasted with worn grit. However, correlation between reflectivity, pull-off strength and blasting conditions was good with the series of specimens provided by two suppliers. The series from a third supplier has not been fully tested yet, but very little difference in reflectivity readings has been found.

Equipment

The equipment for measuring surface reflectivity (Figure 1) remained electrically the same as detailed previously, although the size of the carrying-case containing the voltmeter and amplifier was considerably reduced (Figures 1 and 2). A slight modification to the sensing head was also carried out to enable the light source and photodiode to be rotated without turning the sensing head on the blasted surface. This method avoided any danger of damage to the test surface.

With the present design of amplifier the use of a 24 volt d.c. battery supply was found to be inadequate during constant use. The drain on the battery was such that the control provided by the variable resistance in the amplifier circuit was insufficient to ensure reproducible meter readings. The problem has been solved temporarily by use of a voltage stabiliser to supply the amplifier.

Materials

Pieces of mild steel $4'' \times 2'' \times \frac{1}{4}''$ were supplied for grit blasting. All the steel was provided by one company to ensure uniformity, and had a

*

Progress Report No. 1.

Diamond Pyramid Hardness of 180, in accordance with the requirements of BS.2569: Part 1: 1955 for basis metal for a reference surface.

Experimental

Grit blasting

Blasting was carried out by three separate companies to provide three series of specimens. Each company was provided with 100 pieces of mild steel and asked to blast them according to the ten specific conditions listed in Table 1. Ten specimens were to be produced under each condition listed to allow a check on reproducibility. These conditions covered those likely to be used in both good and bad practice and included blasting with 'new chilled iron grit' and with 'well worn grit with rounds' at several different blasting angles and pressures. One condition included dipping in penetrating oil to simulate the use of a contaminated air supply or grit.

Two companies supplied the full range of specimens requested but the third was unable to blast with well worn grit immediately, although these have now been received. Specimens were supplied sealed in polythene packets to prevent deterioration of the surfaces.

Samples of grit used for blasting were provided for each series of specimens.

Visual inspection

All specimens were inspected visually when removed from their polythene packets. Samples contaminated with oil were readily recognisable due to oil staining of their polythene packets. Certain specimens had a 'dull' appearance, and it was assumed that these had been blasted with well worn grit containing considerable amounts of fines, some of which had actually become attached to the surface. The dull appearance was uniform in Series B, but patchy in Series A.

Reflectivity

The procedure for measuring reflectivity remained basically the same as that detailed in Progress Report No. 1. The light source was switched on and the mains input voltage, as indicated on the meter, adjusted by means of a variable resistance to give a standard reading (4.2 on the meter used). The sensing head was then placed on a piece of white paper (the 'standard' surface) and the meter switched to read the output from the bridge circuit (Figure 1), one arm of which was formed by the photodiode. The meter reading was then adjusted to a standard mark (6.0 on the meter used) by means of coarse and fine variable resistances in the outlet amplifier circuit. This standardisation procedure was carried out before each test.

After standardisation the sensing head was placed on the test surface

and the light source and photodiode rotated through 90°, the maximum meter reading being recorded as a measure of reflectivity.

For convenience, each series was divided into ten batches containing specimens blasted under every test condition and, originally, six readings of reflectivity were taken. When it was found that variations in the amplifier output were affecting reflectivity readings, further readings were made with a voltage stabiliser in the light source circuit. Unfortunately, the course of the variation in meter readings was not realised until the specimens had been cut in two, and one half sprayed with aluminium. Thus these latter readings were made on the halves of the specimens that had been stored for several days in a desiccator.

Test for surface contamination

As noted above, specimens that had been dipped in oil and drained were readily detectable visually. In order to apply the solvent test for oil (see Progress Report No. 1) the excess oil was wiped from the specimen with rag before a spot of carbon tetrachloride was dropped on the test surface. The appearance of a dark ring around the original edge of the drop after evaporation confirmed the presence of oil in each case. Other selected specimens were also tested for surface oil or grease, with negative results.

The specimens of Series B that had apparently been blasted with well worn grit were also tested with a solvent, and these gave a faint dark ring around the edge of the solvent drop. A darker mark could be obtained by washing one end of the specimen for several seconds in alcohol. This reaction could not be obtained with any specimens in Series A.

Spraying

After testing each specimen was cut in half, one half being stored in a desiccator for reference and the other half being sprayed with aluminium. Spraying was carried out within two hours of removal of the specimen from its polythene packet. The spraying conditions (Table II) were maintained constant for all specimens, the coating being applied in two passes to give a uniform coating thickness estimated to be not less than 0.005".

Bond strength

Pull-off tests using the method detailed in Progress Report No. 1, were carried out on a proportion of specimens. Machining of specimens was not carried out until at least 5 days after spraying whilst pull-off tests were performed from 3-5 days after machining. By these means it was hoped that the bond strength would have reached a reasonably uniform value for all specimens.

Examination of blasting media

The samples of grit used for blasting were examined under a low

powered binocular microscope, and subsequently photographed (Figures 3 - 6).

Results

Blasting conditions

The blasting code for each series of specimens is given in Table I.

Visual inspection

The results of a visual inspection in detecting specimens contaminated with oil, or blasted with well worn grit, are given in Table III.

Reasonable confidence was felt in the identification of those specimens from Series B which were blasted with worn grit, but identification of similar specimens from Series A was much more subject to doubt. For this series the inspector relied on the presence of slight surface smears which were not readily visible to all observers.

Slight traces of contamination (probably rusting) were observed on most specimens from Series C. Testing of these specimens was continued, however, and some further specimens have now been received and are undergoing test. Results of these tests will be reported later.

Reflectivity

Results of reflectivity measurements are given in Table IV - VIII for Series A, B and C. Initially, six readings were taken for each specimen and the average of these readings are given in Table IV. However, when it was realised that meter drift was occurring further readings were made on the retained halves of the specimens with the voltage stabiliser in circuit, and these results are summarized in Table V. No meter drift occurred when the voltage stabiliser was used, results being completely reproducible. In all cases, some variation occurred between specimens in a series blasted under nominally the same conditions, as might be expected.

The order of specimens in each series are given in Table VI - VIII and it may be noted that, for Series A and B, the use of a voltage stabiliser does give some change in the order of surface quality. With Series C, very little difference in reflectivity could be detected (Table VIII) - it was considered that this might be due to the slight surface rusting.

Test for surface oil

Surface oil was readily detectable both visually and by the solvent test.

Bond strength

The results of pull-off tests on sprayed samples for Series A and B

are given in Tables VI and VII. In cases where the pull-off strength is given as 0, the specimen broke during or after machining. Results are reasonably consistent and compare favourably with the scatter obtained by other workers.

Blasting media

The grits used for blasting Series A and B are shown in Figures 3 - 6. The new grit used for both series (Mesh size 24) is virtually identical but the well worn grit differs markedly. The grit used for Series A resembles the new grit except for a blunting of the edges, whereas that used for Series B contains a large proportion of 'fines'. This would account for the differences observed in the specimens of both Series that had been blasted with worn grit.

Discussion

Complete results are only available for Series A and B and the discussion will be largely confined to these Series.

With both Series A and B it was possible to identify visually those specimens blasted with worn grit. Identification was very easy with specimens from Series B, which was fortunate since the high proportion of fines in the grit gave a very dull surface (Figure 7) with an acceptable level of reflectivity. The worn grit used for Series A was blunted and contained very few fines - the resultant surfaces gave a few faint smears which indicated the use of worn grit, but identification was more difficult than with the equivalent specimens from Series B. However, in the case of Series A the surfaces prepared with worn grit had a reflectivity sufficiently high to ensure rejection.

Agreement between blasting conditions, reflectivity and bond strength is good (Table IX) for new grit with both series. Although the reflectivity readings for these two series do not completely correspond, it is close enough to set a reflectivity limit, say 5.4 on the arbitrary scale used, which would apply to both series. A reflectivity below 5.4 would indicate a surface that could be sprayed with aluminium to give a bond strength of 600 p.s.i. or greater, whereas a reflectivity above 5.4 would be unsatisfactory for spraying.

The reflectivity results obtained with worn grit show a dependence on the grit itself; if the grit was merely blunted (Series A) it would give a comparatively bright surface and would be rejected by the reflectivity test, whereas if the grit had broken down to give a quantity of fines, the blasted surface would be dull with a 'dirty' appearance and would be rejected on visual examination.

Considerable variation occurred in the bond strength of surfaces prepared under identical conditions, as found by previous workers. However, surfaces blasted under recommended conditions rarely had bond strengths below



700 p.s.i. Individual strengths of surfaces blasted with worn grit or at acute angles could be quite high, but the average bond strength of several specimens was generally low (Table IX).

The relative importance on blasting pressure and angle on bond strength is extremely interesting, although the limited number of tests make conclusions only tentative. Reducing the blasting pressure from 60 p.s.i. to 30 p.s.i. had little effect on bond strength. A change of blasting angle from 90° to 60° also had no deleterious effect, but an angle of 30° caused a reduction in bond strength, whilst at 15° the bond strength was very low.

The results for Series C are disappointing in that reflectivity figures for all specimens are close together and show little correlation with blasting conditions. With the exception of the oiled specimen, all specimens blasted with new grit showed signs of surface rusting and this might explain a reduction in surface reflectivity for some samples, but it can hardly explain the higher reflectivity found with specimens blasted at 90° (Table IX). The specimens blasted with blunt grit also showed lower reflectivities than expected. These results were even more surprising since a previous series from the same suppliers (Progress Report No. 1, Series IV) had given reasonable correlation between reflectivity and blasting conditions.

Although the suitability of reflectivity measurements for assessing grit blasted surfaces has not been proven fully, it is considered that the results are sufficiently promising to justify a limited number of field trials. Initially these trials will be undertaken in co-operation with the suppliers of previous specimens. Further work will also be carried out to study the effect of grit size and blasting times.

TABLE I Grit Blasting Conditions and Codes for Series A, B and C.

Blasting Conditions			Code		
Grit	Air Pressure p.s.i.	Blasting Angle	Series A	Series B	Series C
New chilled iron	30	90°	1	MD	7
- do -	45	90°	2	MB	2
- do -	60	90°	6	MI	6
- do -*	60	90°	10	ME	5
- do -	60	60°	3	MG	10
- do -	60	30°	5	MH	9
- do -	60	15°	4	MC	4
Well worn grit with rounds	60	90°	7	MF	8
- do -	60	60°	8	MA	3
- do -	60	30°	9	MJ	1

* Dipped in oil.

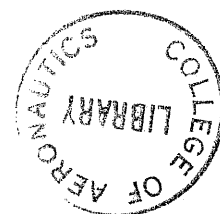


TABLE II Spraying conditions

Acetylene pressure	15 p.s.i.
Oxygen pressure	21 p.s.i.
Air pressure	65 p.s.i.
Wire used	2 mm. diameter aluminium wire
Wire extension	2 mm. (equal to wire diameter)
Spraying distance from surface	6" approximately
Estimated minimum thickness	0.005"

TABLE III Visual Examination

Estimated Surface condition	Series A	Series B	Series C
Oily	10	ME	5
Blasted with worn grit	7, 8, 9	MA, MF, MJ	
Blasted with new chilled grit	1, 2, 3, 4, 5, 6	MB, MC, MD, MG, MH, MI	

TABLE IV Reflectivity tests* made without voltage stabilisation

Series A

Specimen No.	Batch No.									
	1	2	3	4	5	6	7	8	9	10
1	3.3	3.9	4.3	4.5	4.55	5.0	5.0	5.1	4.95	5.1
2	3.7	3.9	4.1	4.7	4.6	5.0	5.0	5.1	5.0	5.0
3	3.0	3.8	3.6	4.35	4.35	5.0	5.0	4.9	4.65	4.8
4	7.5	6.5	6.9	6.3	5.9	6.0	6.4	6.4	6.1	6.2
5	4.4	5.0	4.85	5.1	5.1	5.4	5.4	5.3	5.3	5.2
6	3.25	3.9	3.65	4.6	4.55	5.0	5.0	5.0	5.0	4.85
7	3.5	5.0	5.3	5.05	4.2	5.3	5.55	5.6	5.55	5.5
8	4.0	5.2	5.1	5.3	5.3	5.3	5.5	5.6	5.4	5.4
9	6.4	5.9	6.0	5.85	6.0	6.0	5.6	5.9	5.8	5.3
10	2.0	3.7	3.8	3.15	3.1	4.2	4.2	4.2	4.85	4.9

Series B

Specimen No.	Batch No.									
	1	2	3	4	5	6	7	8	9	10
MA	3.5	4.5	3.8	2.4	2.0	2.3	3.1	2.8	2.35	3.05
MB	3.1	3.35	4.7	3.4	3.0	4.2	3.9	3.2	3.2	3.3
MC	5.9	6.0	5.0	5.9	5.9	5.9	3.9	6.4	6.3	6.1
MD	3.5	4.8	3.55	4.3	3.23	3.3	4.15	3.5	3.6	3.6
ME	2.8	3.2	3.0	2.55	3.0	2.6	2.8	3.0	3.2	4.8
MF	2.8	3.6	2.3	2.85	2.2	4.4	2.8	3.75	2.2	2.2
MG	3.4	4.4	3.5	3.4	3.5	4.15	3.55	3.5	4.8	3.6
MH	4.6	4.8	4.4	4.5	5.2	4.55	5.4	5.25	4.7	4.4
MI	3.2	3.25	3.2	4.8	3.2	4.2	3.4	3.4	3.5	5.9
MJ	3.4	4.3	4.7	3.2	4.9	3.0	3.6	3.7	3.2	3.8

Series C

Specimen No.	Batch No.							Average
	1	2	3	4	5	6	7	
1								
2	5.2	5.1	5.2	5.2	5.2	5.2	5.1	5.2
3								
4	5.3	5.2	5.25	5.3	5.1	5.2	5.3	5.25
5	5.05	5.1	4.25	4.5	4.6	4.9	4.8	4.75
6	5.2	5.2	5.1	5.2	5.2	5.2	5.15	5.2
7	5.0	5.05	5.0	5.0	5.15	5.2	5.2	5.1
8								
9	5.15	5.0	5.1	5.15	5.2	5.15	5.3	5.15
10	4.9	4.9	4.9	4.9	5.2	5.2	5.1	5.0

* Each reading is the mean of six tests

TABLE V Reflectivity tests*made with the voltage stabiliser in circuit

Series A

Specimen No.	Batch No.										Average
	1	2	3	4	5	6	7	8	9	10	
1	5.1	5.0	5.0	5.0	5.0	5.1	4.8	5.0	5.0	5.0	5.00
2	5.0	5.0	5.2	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.02
3	4.8	4.7	4.8	4.8	4.9	4.8	4.8	4.8	4.8	4.8	4.80
4	5.8	6.0	6.4	6.8	5.8	6.1	6.2	6.0	6.1	6.1	6.13
5	5.5	5.5	5.5	5.5	5.5	5.5	5.2	5.4	5.4	5.5	5.45
6	5.0	5.0	4.8	5.0	5.0	4.8	5.0	5.0	4.8	5.0	4.94
7	5.4	5.7	5.0	5.2	5.4	5.7	5.7	5.4	5.7	5.7	5.49
8	5.2	5.6	5.5	5.6	5.6	5.5	5.5	5.5	5.5	5.5	5.50
9	5.9	5.9	5.9	6.1	6.1	6.0	6.0	6.0	6.0	6.1	6.00
10	4.8	4.9	4.8	4.9	4.4	4.4	4.9	5.0	4.8	4.4	4.73

Series B

Specimen No.	Batch No.										Average
	1	2	3	4	5	6	7	8	9	10	
MA	4.2	4.3	4.3	4.2	4.2	4.2	4.3	4.1	4.2	4.3	4.23
MB	4.6	4.6	4.6	4.6	4.6	4.7	4.6	4.6	4.7	4.7	4.63
MC	5.3	5.6	5.4	6.0	5.4	5.8	6.0	6.4	6.0	6.2	5.81
MD	4.6	4.6	4.7	4.9	4.8	4.6	4.6	4.6	4.7	4.7	4.68
ME	4.2	4.4	4.4	4.4	4.4	4.5	4.3	4.4	4.4	4.4	4.38
MF	4.0	4.0	4.1	4.0	4.0	4.0	4.0	4.1	4.0	4.0	4.02
MG	4.9	4.8	4.7	4.9	4.9	4.8	4.8	4.8	4.6	4.8	4.78
MH	5.8	5.6	5.2	5.4	5.2	5.4	5.4	5.4	5.8	5.4	5.46
MI	4.3	4.4	4.5	4.4	4.3	4.4	4.3	4.4	4.5	4.3	4.38
MJ	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8

Series C

Specimen No.	Batch No.						Average
	1	2	3	4	5	6	
1	5.35	5.40	5.35	5.40	5.35	5.35	5.35
2	5.3	5.2	5.2	5.0	5.3	5.1	5.20
3	5.25	5.2	5.2	5.4	5.2	5.2	5.24
4	5.3	5.1	5.2	5.2	5.3	5.2	5.20
5	4.9	4.8	4.8	4.3	4.4	4.9	4.70
6	5.2	5.3	5.3	5.1	5.1	5.2	5.20
7	5.2	5.2	5.3	5.2	5.2	5.2	5.20
8	5.5	5.45	5.4	5.4	5.35	5.4	5.41
9	5.3	5.1	5.1	4.9	5.2	5.1	5.10
10	5.2	5.2	5.1	5.1	5.0	5.2	5.10

* Consistent results were obtained on each specimen.

Table VI Relation between reflectivity, blasting conditions and bond strength for Series A

Order of Increasing Reflectivity	Estimated Surface Conditions	Blasting Conditions			Pull off Strength in P.S.I.						Average
		Type of Grit	Air Pressure	Angle of Blast	i	ii	iii	iv	v	vi	
10 (4.73)	Coated with oil	New C.I.	60 p.s.i.	90°	940*	740*	39.8				840
3 (4.80)	New grit	New C.I.	60 p.s.i.	60°	1053	955.5	992				1000
6 (4.94)	New grit	New C.I.	60 p.s.i.	90°	382	378	698	1111	1126	655	725
1 (5.00)	New grit	New C.I.	30 p.s.i.	90°	807	883	830	727			812
2 (5.02)	New grit	New C.I.	45 p.s.i.	90°	727	714	627				689
5 (5.45)	New grit	New C.I.	60 p.s.i.	30°	655.1	610	735				667
7 (5.49)	Old grit	Well worn steel	60 p.s.i.	90°	256.6	179.5	0				145
8 (5.50)	Old grit	Well worn steel	60 p.s.i.	60°	0	0	0	530	875	730	356
9 (6.00)	Old grit	Well worn steel	60 p.s.i.	30°	259.1	28.51	0	0			72
4 (6.13)	New grit small angle	New C.I.	60 p.s.i.	15°	314.0	419	0	0	0	0	122

Degreased before spraying

N.B. The value of the reflectivity reading is shown in the first column.

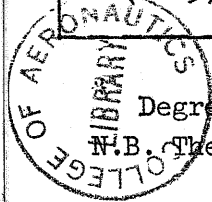


Table VII Relation between reflectivity, blasting conditions and bond strength for Series B

Order of Increasing Reflectivity	Estimated Surface Conditions	Blasting Conditions			Pull off Strength in P.S.I.						Average
		Type of Grit	Air Pressure	Angle of Blast	i	ii	iii	iv	v	vi	
MF (4.02)	Old grit	Well worn chilled grit with rounds	60 p.s.i.	90°	852	475.1					664
MA (4.23)	Old grit	- do -	60 p.s.i.	60°	470	285.1					378
ME (4.38)	Coated with oil	New chilled iron grit (oil dipped)	60 p.s.i.	90°	1120*	855*	804*				926
MI (4.38)	New grit	New chilled iron grit	60 p.s.i.	90°	758	855	812	1128			888
MB (4.63)	New grit	- do -	45 p.s.i.	90°	920	1475	1015				1133
MD (4.68)	New grit	- do -	30 p.s.i.	90°	1375	798	494	846	895	587	833
MG (4.78)	New grit	- do -	60 p.s.i.	60°	758	870	1115	900			911
MJ (4.8)	Old grit	Well worn grit with grounds	60 p.s.i.	30°	0	0	0	134			34
MH (5.46)	New grit	New chilled iron grit	60 p.s.i.	30°	665	228	375	470			435
MC (5.81)	New grit small angle	- do -	60 p.s.i.	15°	0	0	0	0			0

* Degreased before spraying

N.B. The value of the reflectivity reading is shown in the first column.

Table VIII Relation between reflectivity and blasting conditions for Series C

Order of Increasing	Estimated Surface	Blasting Conditions		
		Type of Grit	Air Pressure	Angle
5 (4.70)	Coated with Oil	New chilled iron	60 p.s.i.	90°
9 (5.11)	-	New chilled iron	60 p.s.i.	30°
10 (5.14)	-	New chilled iron	60 p.s.i.	60°
2 (5.18)	-	New chilled iron	45 p.s.i.	90°
4 (5.22)	-	New chilled iron	60 p.s.i.	15°
6 (5.20)	-	New chilled iron	60 p.s.i.	90°
7 (5.22)	-	New chilled iron	30 p.s.i.	90°
3 (5.24)	-	Well worn grit	60 p.s.i.	60°
1 (5.35)	-	Well worn grit	60 p.s.i.	30°
8 (5.41)	-	Well worn grit	60 p.s.i.	90°

TABLE IX Comparison of results for Series A, B and C

Blasting Conditions			Reflectivity			Average Pull-Off Strength p.s.i.		
Grit	Air Pressure	Angle	Series A	Series B	Series C	Series A	Series B	Series C
New	60 p.s.i.	90°	4.73	4.38	4.70	840*	926*	-
New	60 p.s.i.	90°	4.94	4.38	5.20	725	888	-
New	60 p.s.i.	60°	4.80	4.78	5.10	1000	911	-
New	60 p.s.i.	30°	5.45	5.46	5.10	667	435	-
New	60 p.s.i.	15°	6.13	5.81	5.20	122	0	-
New	45 p.s.i.	90°	5.00	4.63	5.20	689	1133	-
New	30 p.s.i.	90°	5.02	4.68	5.20	812	833	-
Worn	60 p.s.i.	90°	5.49	4.02	5.41	145	664	-
Worn	60 p.s.i.	60°	5.50	4.23	5.24	356	378	-
Worn	60 p.s.i.	30°	6.00	4.80	5.35	72	34	-

* After degreasing.

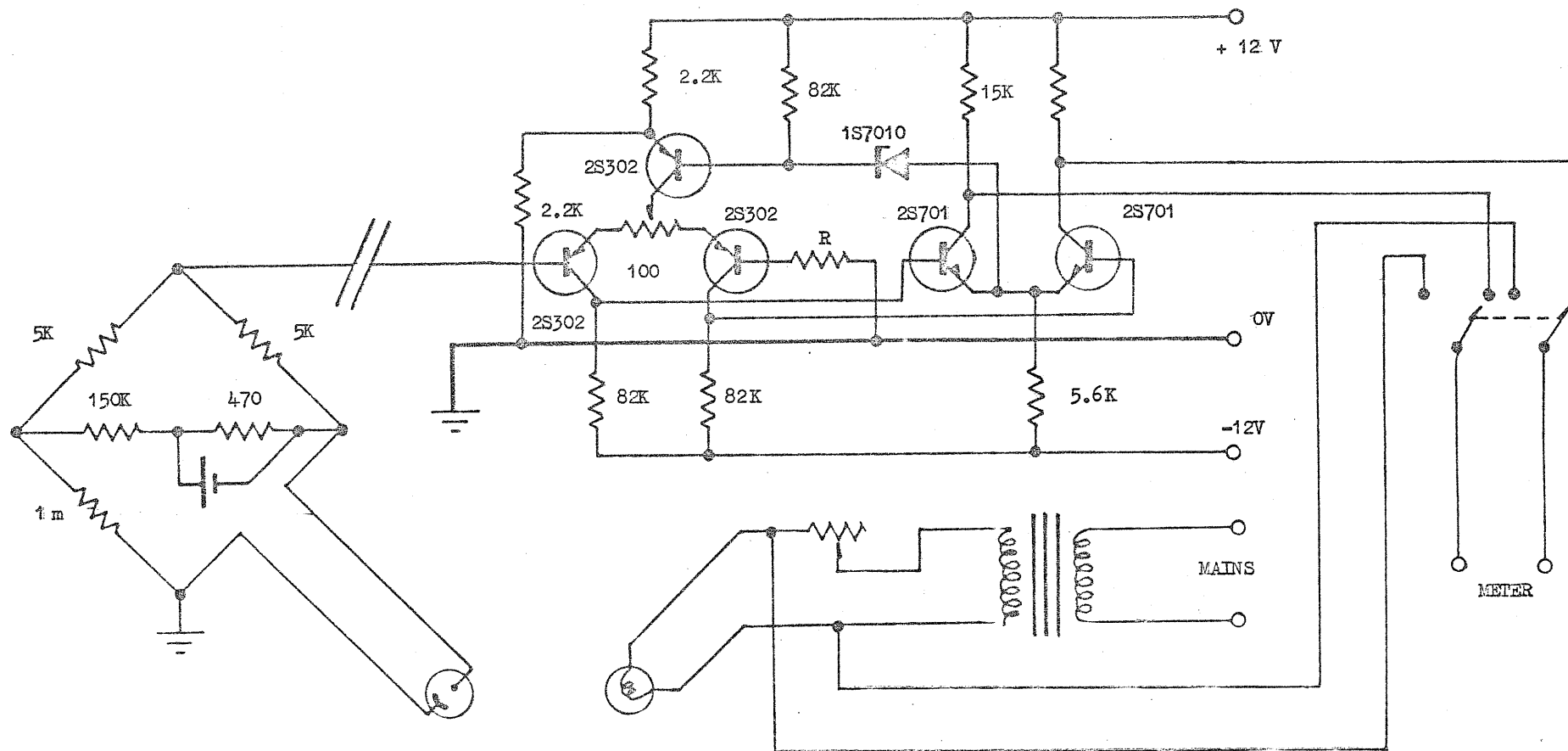


FIG. 1 CIRCUIT OF REFLECTIVITY EQUIPMENT

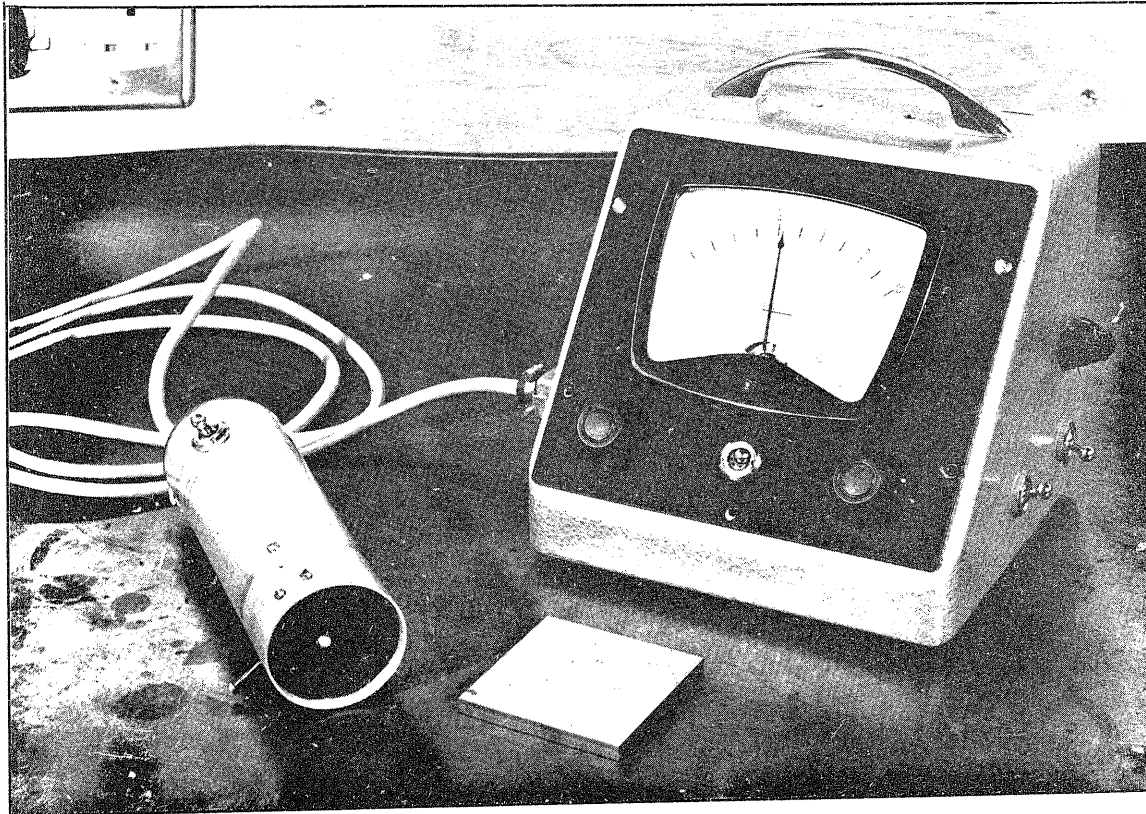


FIG.2 PHOTOGRAPH OF REFLECTIVITY EQUIPMENT

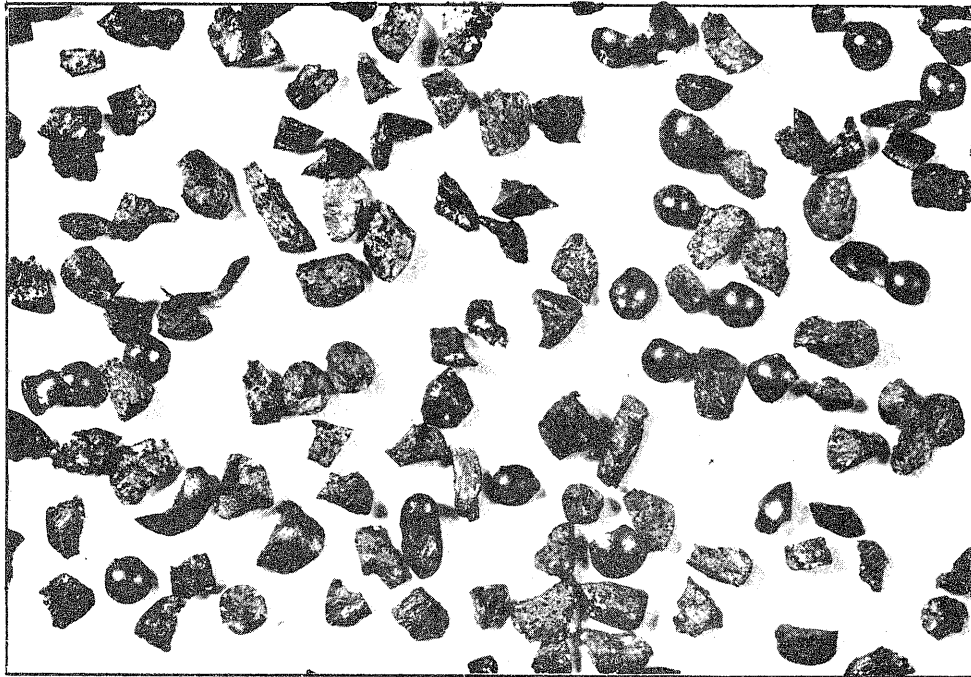


FIG.3 SERIES A - NEW ANGULAR CHILLED IRON GRIT X5

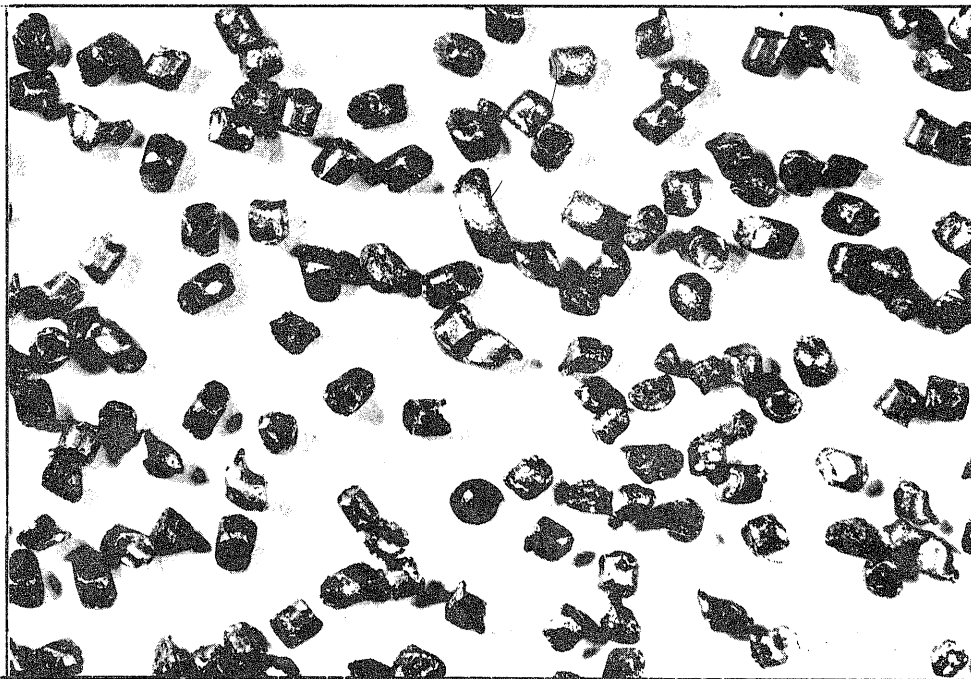
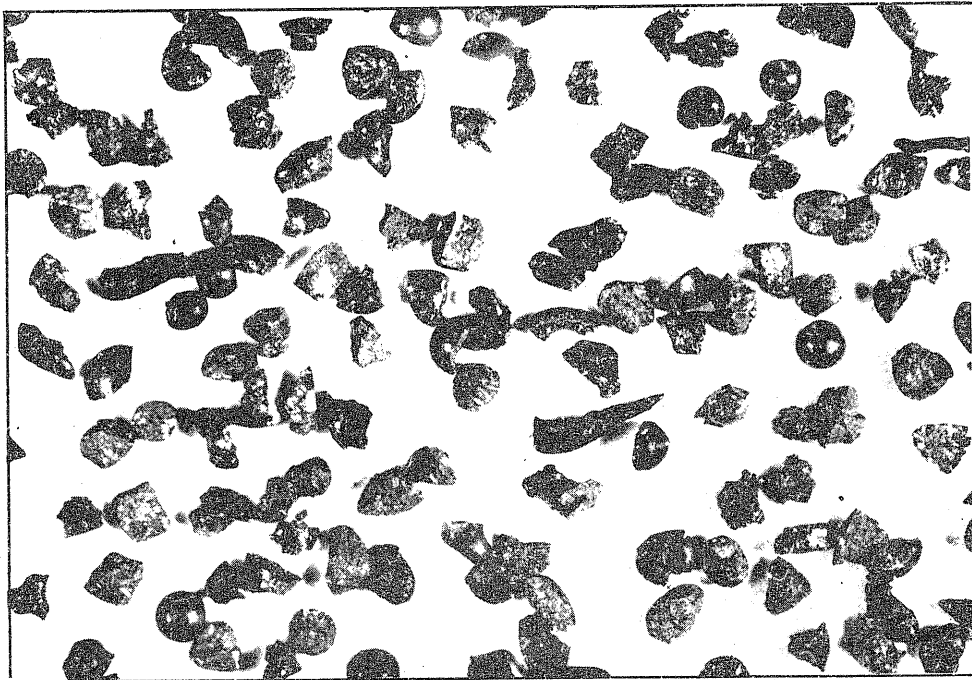
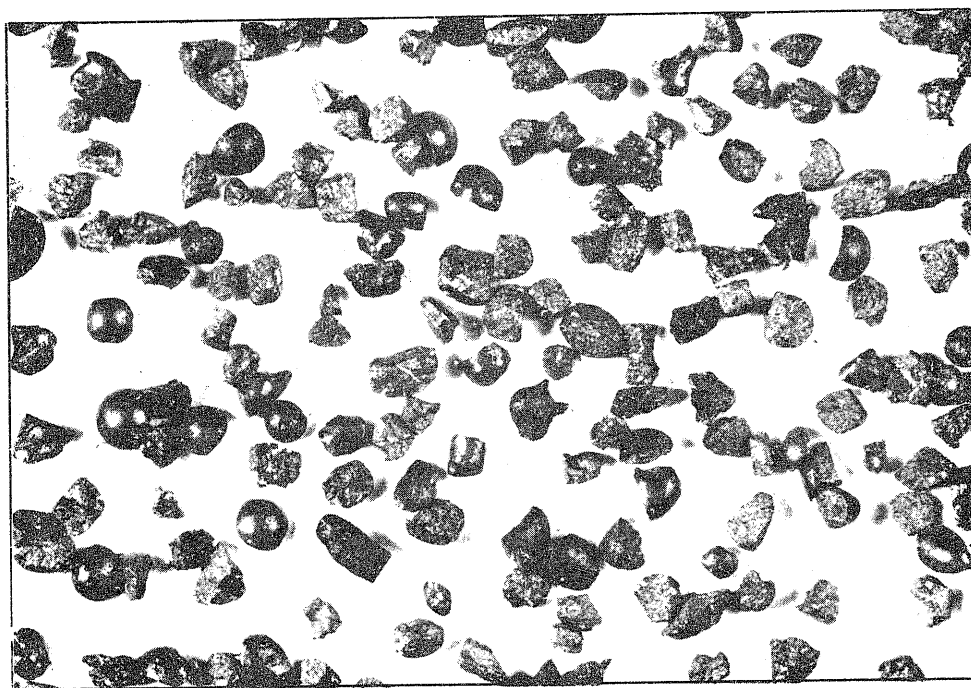


FIG.4 SERIES A - WORN STEEL GRIT X5

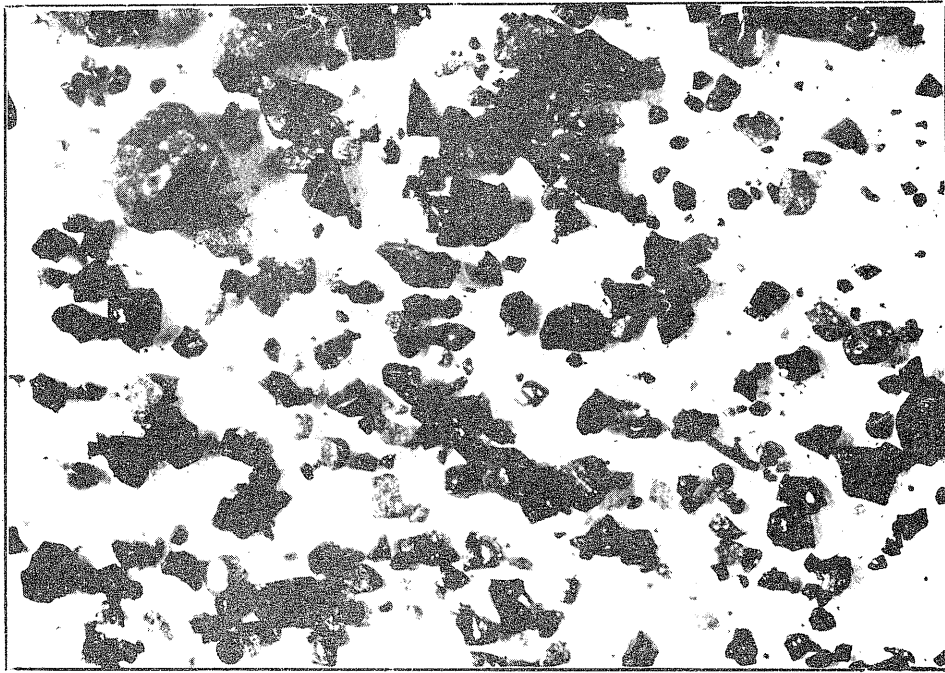


(a)

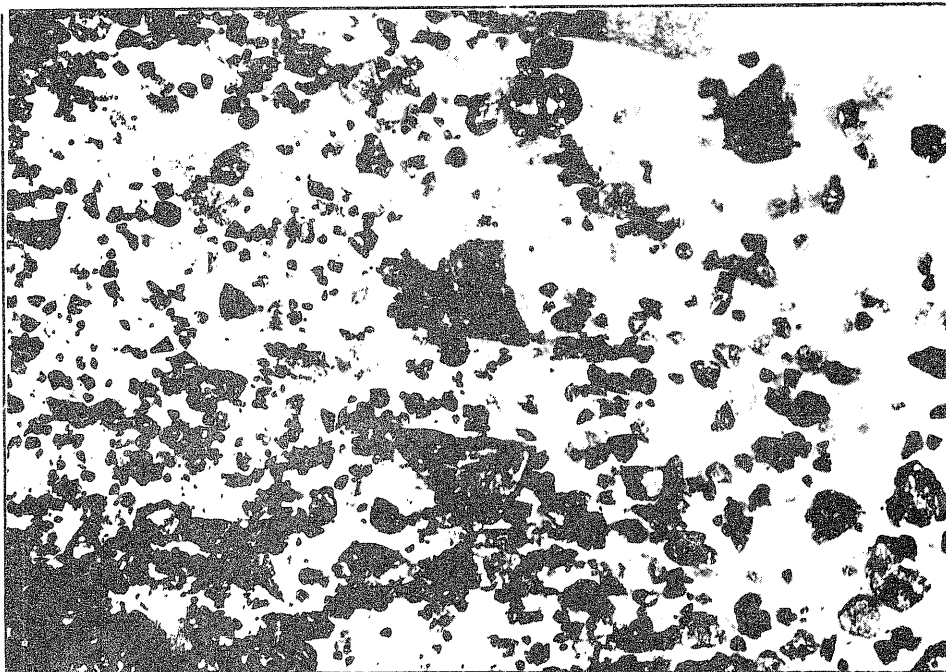


(b)

FIG.5 SERIES B - NEW ANGULAR CHILLED IRON GRIT X5
(a) BEFORE USE (b) AFTER USE

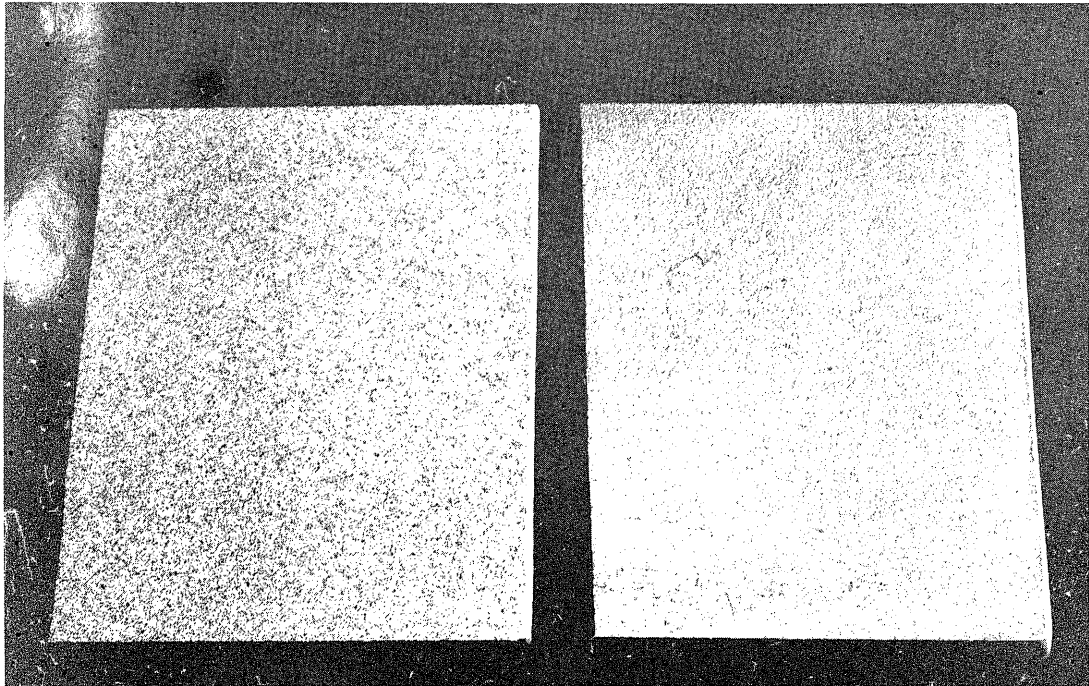


(a)



(b)

FIG.6 SERIES B -- WORN STEEL GRIT X10
 (a) BEFORE USE (b) AFTER USE



(a) (b)

FIG. 7 COMPARISON BETWEEN SURFACES BLASTED WITH (a) NEW AND (b) WORN GRIT IN SERIES B