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FUEL RESEARCH INSTITUTE
OF SOUTH AFRICA

ONDERWERP:
SUBJECT: CONTRIBUTION TO THE ASSESSMENT OF COKE STRENGTH.

COMPARATIVE RESULTS OBTAINED FROM

MICUM AND B.S. STRENGTH AND ABRASION TESTS.

AFDELING:
DIVISION: COKE.

NAAM VAN AMPTENAAR:
NAME OF OFFICER: DR. C.C. la GRANGE & MR. P.J.A.BEUKES.

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FUEL RESEARCH INSTITUTE OF SOUTH AFRICA.

REPORT NO. 16 OF 1963.

CONTRIBUTION TO THE ASSESSMENT OF COKE STRENGTH. COMPARATIVE RESULTS OBTAINED FROM MICUM AND B. S. SHATTER AND ABRASION TESTS.

ABSTRACT.

Formerly metallurgical coke testing in South Africa was virtually limited to the B.S. shatter and abrasion tests. Recently samples of more than 200 experimental cokes made in Iscor's commercial coke ovens were taken by the Fuel Research Institute and subjected to B.S., micum and modified micum tests. The results have been compared and statistically correlated.

There are so many points in favour of the micum test, essentially modified in that +25 mm instead of +60 mm coke is used for testing, that its adoption in South Africa for assessing blast furnace cokes is recommended.

INTRODUCTION .../

INTRODUCTION:

For well-known reasons metallurgical coke has to be highly resistant to breakage and breeze formation when used in furnaces or when transported or handled mechanically before such use. Strength and hardness tests have, therefore, had to be devised in order to be able to predict this resistance and to express it quantitatively. These tests are invariably designed with a view to provide a convenient, accurate and fast means of assessing the behaviour of the coke when in use, in order to avoid recourse to the tedious, possibly expensive and sometimes impracticable alternative method of trial and error.

Basically, the test methods involve the subjection of a representative sample of the sieved coke to some deliberate rough treatment simulating or exceeding in severity that endured by the coke in practice, followed by a determination of the size degradation imparted thereby to the coke.

Numerous methods for assessing the strength of metallurgical cokes are in use or have been proposed. The best known of these in the Western World are undoubtedly the British standard shatter and abrasion tests[1)], the A S T M drop shatter test and tumbler test[2)] and the micum test[3)].

Until comparatively recently only the two British standard tests have been applied in South Africa. Due to the similarity of the two A S T M tests to the British tests* there .../

* There is virtually no difference between the A S T M drop shatter test and the B.S. shatter test.

there was no point of introducing the A S T M tests and they will not be given further consideration in this report.

THE MICUM* TEST.

The micum test was originally largely limited to the European continent where, however, differences existed from country to country both as regards the apparatus used and the procedure followed. As a result of the efforts of the International Organization for Standardization (ISO) good progress has, however, been made in the standardization of the micum test to more rigid specifications, with the result that the test has gained favour even in Britain where the B.S. shatter and abrasion tests had been so well established. It was only logical, therefore, that attention should also be given in South Africa to the possibilities of this promising test which may soon become an internationally accepted standard[3)].

As the finally recommended ISO method for the micum test has not yet been published it is desirable to give the following essential details of the apparatus, used at the Institute, which is based largely on the ISO proposals.

The cylindrical test drum is of 1000 mm internal length and 1000 mm internal diameter, and is constructed of 5/16 in. (7.94 mm) thick mild steel plate.** The four lifters,

each .../

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* The name MICUM is derived from the initials of the name of the allied control mission which adapted the test in 1924 from an existing drum test previously developed at Breslau in Germany. The name (in French) of the mission was: "Mission Interalliée de Contrôle des Usines et des Mines". The test was used to check the quality of coke delivered as reparations from Germany under the Treaty of Versailles[4)].

** It is stressed by ISO that the minimum thickness as used, i.e. even after wear, shall not be less than 5 mm.

each 1000 mm long and spaced at 90^{o} intervals (parallel to the axis of the drum), consist of unequal angle irons with sides measuring 100 mm by 50 mm, and 10 mm thick, fixed inside the drum so that the 100 mm sides point towards the centre and the 50 mm sides opposite to the direction of rotation. An opening and tight fitting curved cover, which enables the charging and discharging of the coke under test, is provided in the cylindrical wall of the drum, equidistantly from the ends. When the cover is in position its inside is level with the internal surface of the drum.

The drum has two stub axles at the ends (i.e. the axle does not pass through the drum). These axles enable it to be rotated on the horizontal axis at a constant speed of 25 revolutions per minute. A predetermining revolution counter stops the drum after 100 revolutions.

(The testing procedure, as well as certain modifications to the apparatus and procedure, is dealt with later.)

COKE SAMPLES TESTED AND METHOD OF SAMPLING:

All the coke samples used for obtaining the test results discussed in this report (more than 200 samples) were taken by officers of the Fuel Research Institute at Iscor, Pretoria, during the course of full scale coking investigations carried out by the Corporation, in collaboration with the Institute, on various potential and regular coking coals and blends. (The coals and blends were also sampled and analysed, but the results will not be discussed in this report.)

The ..../

The cokes were sampled on the first conveyor belt transporting the coke from the wharf to the coke storage bunkers. It is thus clear that the coke as sampled had received some handling — pushing, quenching and dropping on the wharf before being removed by the first conveyor belt. This handling was, however, appreciably less than the full amount of handling and rough treatment (and attendant degredation and stabilization) normally endured by coke before it finally enters the blast furnaces.

Each coke sample was composed of increments spread uniformly over the particular batch of experimental coke which in most instances consisted of the coke made in one full oven, i.e. about 11 tons of coke. The conveyor belt was purposely stopped intermittently for the purpose of taking the increments.

Each increment weighed about 45 lb. and consisted of all the coke, i.e. all sizes (including breeze) in their naturally occurring ratios present on a certain length of the stopped belt. In order to facilitate matters the load of coke on the belt was purposely kept reasonably low. As the load varied somewhat and the aim was to obtain increments of approximately equal weight it was not possible to fix the length of belt cleared per increment.

A total of 48 increments per batch of experimental coke was normally taken, but alternate increments were placed in separate containers with a capacity of 90 lb. of coke each. These containers, with their contents, were subsequently systematically divided in a

predetermined ..../

predetermined manner calculated to eliminate any bias, to give two bulk samples contained in 10 and 14 containers (20 and 28 increments), respectively. The smaller bulk sample (X) was used for B.S. tests and the larger one (Y) for micum tests.

The accuracy of sampling was not tested. In view of the fact that ungraded coke was being sampled, special care was necessary to ensure that increments would not be biased with regard to size composition, and this would have been very difficult if they had weighed only 10 lb. as recommended in B.S. 2074 of 1954[5].

Manning's recommendation[6] is that the "increment should be large enough to contain 5 to 10 of the largest particles with roughly the appropriate proportion of the smaller particles". Investigations revealed that individual lumps of coke weighing 2 - 4 lb. were quite common in many of the samples tested and an increment weight of about 45 lb. is therefore by no means unrealistic. While it was necessary to follow a sampling procedure which conformed to the practical demands of the whole investigation, the attitude adopted was rather to sacrifice some accuracy by taking fewer increments than would normally be specified, than to run the risk of increments being biased due to their smallness.

PHYSICAL TESTING OF COKE:

Both the B.S. specification[1] and the ISO documents[3] stipulate that the moisture content of the coke must be below a certain level* before the coke can be tested .../

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* The maximum values quoted are:-
B.S.:- 8 per cent; ISO:- 5 per cent.

be tested for physical strength. The moisture content of the coke samples studied varied considerably, the coke, or at least some of it, often being visibly wet*. In order to exclude the possibility of exceeding moisture limits the standard practice of completely drying all coke samples before commencing with physical testing has been adopted at the Institute. For this purpose relatively large electrically heated drying ovens with forced hot air circulation and provision for ventilation are in use. The temperature in these ovens can be thermostatically controlled to any desired level up to about 190°C. The coke to be dried is placed in shallow galvanized iron trays before insertion in an oven which has a capacity of up to 600 lb. of coke. When an oven is fully charged with visibly wet coke it takes about eight hours to dry the coke to constant weight.

Before proceeding with the strength tests the coke is sieved** using sieves as indicated in Table 1. The method of hand placing of individual lumps is followed with sieves having openings of 1½" or 40 mm and larger, while hand shaking is applied with sizes smaller than these.

TABLE 1. .../

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* The investigation concerned only strength and hardness tests on the cokes, and determinations of total moisture contents were therefore not made.

** The bulk density of coke is seldom determined at the Institute, but if required it has to be determined (preferably on the dried coke) <u>before</u> the sieve analysis.

TABLE 1.

Size and Shape of Openings of Perforated Plate Sieves.

Coke Sample X	Coke Sample Y
Inches, Square Holes	Millimeters, Round Holes
Etc.	Etc.
.	.
.	.
7	175
6	150
5	125
4	100
3	80
2½	60
2	40
1½	25
1	20
½	10
Coke subsequently used for :-	
B.S. Shatter and Abrasion Tests.	Micum Tests.

With both the B.S. shatter test and the micum test the coke taken for the test has to be above a certain minimum size* and the size grading has to be similar to that of the bulk sample from which material smaller than the minimum size specified has been excluded. In order to comply with this size consist requirement, care is taken that proportional amounts of the size fractions concerned are included in the quantity of coke actually subjected to the test.

Strength ..../

* Only coke above 2 in. is used for the B.S. shatter and abrasion tests (-3 in. + 2 in. coke for the latter) and coke above 60 mm for the standard micum test.

Strength or hardness indices for cokes are obtained by sieving the coke after a test using various specified sieves. For example, the 2 in., 1½ in. and ½ in. B.S. shatter indices are given by the percentage material retained on 2 in., 1½ in., and ½ in. sieves, respectively; the B.S. abrasion index represents the percentage material retained on an ⅛ in. sieve; the M_{40} index of the micum test represents the percentage material retained on a 40 mm. sieve*, but with the M_{10} index it is the percentage material passing the 10 mm. sieve. (Other indices which have been calculated and reported are explained in Appendix — see page 29).

VIEWS ON EXISTING AND PROPOSED STRENGTH TESTS.

The B.S. tests can be criticized in that the shatter test (4 drops of six feet each) is not severe enough, while the abrasion test is too severe (1000 revolutions in the drum). On the other hand the micum test (100 revolutions) may be regarded as a compromise between the two extreme sets of conditions. It has the advantage of reducing two separate tests (shatter and abrasion) to one mechanized test yielding information on the same two physical characteristics of the coke, thereby saving time and labour.

Officials at Iscor have recently proposed a new test for evaluating their own coke[7)]. A sample of coke taken on the same conveyor belt as mentioned above and composed of all the sizes (including breeze) is dropped 8

times .../

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* Indices of material retained on sieves with larger apertures may also be determined if desired.

times through six feet in the shatter test apparatus. The total percentage of $-\frac{1}{2}$ in. breeze subsequently found in the sample, representing the breeze originally present in the run-of-oven coke combined with that subsequently formed, is taken as the 'breeze index'. It is claimed that this index agrees reasonably well with the total amount of $-\frac{1}{2}$ in. breeze normally screened out immediately before the coke is charged to the blast furnaces under working conditions.

Only a limited number of these tests were carried out at the Institute. Results representing mean values for five of them are given in Table 2. Strength indices were also determined on these coke samples before and after the dropping procedure in order to illustrate the stabilizing effect of dropping on the coke.

The eight-drop treatment of the coke had the effect of virtually doubling the breeze content from 5.4 to 10.0 per cent, and the mean size was also much reduced.

Except for the B.S. abrasion index — which apparently constitutes an exception — all the strength indices, including the M_{10m} and M_{10} indices, indicate that stabilization results in a product which will be more resistant to size degradation during subsequent handling than the original coke.

The importance of standardizing and recording the point where increments of coke are taken so that the test results on the samples may be comparable is also evident from the data in Table 2.

TABLE 2. .../

TABLE 2.

Effect of Dropping Coke Samples Eight Times Through Six Feet in the Shatter Test Apparatus. Changes in Physical Characteristics of the Coke due to Stabilization.

Condition of Coke			Before Stabilization by Dropping	After Stabilization by Dropping
Inches, square holes	Size Anal., %	+2 in.	74	53
		$-\frac{1}{2}$ in.	5.4	10.0
	Mean Size, in.		2.80	2.10
	B. S. Shatter Index on	2 in.	70	79
		$1\frac{1}{2}$ in.	87	91
		$\frac{1}{2}$ in.	96.6	97.6
	B. S. Abrasion Index		73.6	72.4
	SASS Value		36	43
Millimeters, round holes	Size Anal., %	+60 mm	72	48
		+25 mm	93	89
	Mean Size, mm		80.5	60.3
	Coke size used for micum test: +25 mm	M'_{40}*	65	67
		M_{20m}*	84	86
		M_{10m}*	13.9	11.5
		$MMSS_m$*	53	67
		$CMTV_m$*	56	59
	Coke size used for micum test: +60 mm	M_{40}	65	72
		M_{10}	14.5	12.8
		MMSS	48	60
		CMTV	56	63

* These indices are explained in the next section.
(Reference should also be made to the Appendix - see page 29.)

It is .../

It is agreed that the eight-drop procedure may be a sound practical test, designed to eliminate any correlation factor between test result and coke losses resulting from breeze formation under working conditions. However, at other works where the system of coke transport and handling may be different, it may not be possible to dispense with a correlation factor without altering the number of drops. The attitude at the Institute at this stage is rather not to exchange the standard tests for an entirely new test which may later prove not to be generally acceptable.

MODIFICATION OF MICUM TEST.

There is reason to believe that South African blast furnace cokes may in the future tend to become somewhat smaller in size than they have been up to now. This may result from factors such as: (a) better washing of the coking coals (elimination of a greater proportion of the inert constituents which promote the formation of relatively large lumps of coke by counteracting to some extent the development of excessive shrinkage cracks when coking a blend with rather high volatile matter content); (b) a decreasing proportion of the highest rank coals in blends as such coals become scarcer in the future; (c) substitution of the conventional methods of charge preparation by different methods (e.g. the drying of blends before charging to the coke oven).

Provided that the proportion of breeze does not increase, a reduction in the mean size of the coke in itself need not necessarily be a matter for undue concern —

there are also known methods for increasing coke size if required. On the contrary, smaller coke size may even be advantageous in view of the recognized desirability of narrowing the size range of materials charged to furnaces.

A scrutiny of the results obtained in the present investigation revealed that the percentages above 60 mm and above 25mm of cokes of different mean sizes varied considerably. However, the values shown in Table 3 give some indication of what was observed with the coke types investigated.

TABLE 3.

Some Size Characteristics of Present and Possible Future Blast Furnace Cokes.

Mean Size		Expected Percentage of		Comment on mean size of coke
mm	(in.)	+60 mm*	+25 mm	
90	(3.09)	82	>90	Fairly large coke
80	(2.77)	75	>90	(About the average of the (samples tested.
70	(2.45)	65	>90	Possible in the future
65	(2.29)	58	>90	(About the smallest coke (to be expected in future.

Concerning coke testing it has already been pointed out that only coke above certain defined sizes is used in the micum and B.S. tests (+60mm and +2 in. coke, respectively). Hence according to Table 3, a reduction in coke size may mean an appreciable reduction in the proportion of coke which may be used for testing, and this is an unsatisfactory aspect.

The .../

* Similar percentages of +2 in. coke (i.e. the size required if the coke has to be subjected to B.S. shatter and abrasion tests) may be expected from cokes of corresponding mean sizes. (For the B.S. abrasion test only coke lying in the -3 in. +2 in. size range is used. This, in effect, reduces the amount available for the B.S. tests.)

The position may be met by adopting the proposal of workers in Britain[8] to use "above 25 mm" instead of "above 60 mm" coke in a modified micum test, subsequently using 20 mm and 10 mm sieves for determining the extent of size degradation in the test.

This principle was also adopted at the Institute with the present investigation and the decision is supported by the data in Table 3, which indicate that more than 90 per cent of a coke sample should be available for the test, whatever its mean size.

A further argument in favour of a reduction in the bottom size of the coke tested is that the material subjected to the test then agrees more closely with the size actually charged to the blast furnaces (e.g. +½ in. coke at Iscor).

In addition to 10 mm and 20 mm sieves for determining micum indices, the 40 mm sieve was also used at the Institute. In order to indicate that these micum indices had been obtained by a modified procedure, i.e. by starting with +25 mm instead of +60 mm coke, the indices were marked by adding the letter m, e.g. M_{40m}, M_{20m} and M_{10m}*.

It is clear that any M_{40m} index obtained is somewhat meaningless in view of the -40 +25 mm material already present in the sample placed in the drum for testing. The index is therefore adjusted by correcting for this material as follows:-

M'_{40} .../

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* With the modified micum test (starting with +25 mm coke) M_{40m} and M_{20m} represent the percentages of material retained on 40 and 20 mm sieves, respectively, and M_{10m} the percentage material passing the 10 mm sieve, after the test.

$$M'_{40} = \frac{M_{40m} \times 100}{Z}$$

= (Adjusted modified micum index, on (40mm,

where Z represents the percentage of +40 mm material in the +25 mm coke sample used for the test.

As will be shown later there is a good correlation between M'_{40} and the internationally recognized index M_{40}, and there is, therefore, a good deal of justification for maintaining M'_{40} even though it is no longer a straightforward index when carrying out the modified micum test.

Another proposal of the British workers[8)] which was followed was to use a micum drum similar to that described earlier, but with the internal length reduced from 1,000 to 500 mm. The amount of coke used for testing in such a half-length micum drum is reduced from 50 kg to 25 kg, whether the size of the coke tested is +60 mm or +25mm.

The claim made by the British workers[8)] that results were identical whether the test was carried out on 50 kg in the full-length micum drum or on 25 kg in the half-length drum was investigated at the Institute by subjecting 10 different cokes to such tests. The results obtained — see Table 4 — indicated that the claim was justified*.

TABLE 4 .../

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* Some tests using a drum of standard diameter, but only 200 mm long (one fifth-length) were also carried out, working with 10 kg of coke at a time. The results did not check satisfactorily with those obtained from full- or half-length drum tests, but this was probably due mainly to the fact that 10 kg of coke is not enough to be reasonably representative of the bulk sample of coke.

TABLE 4.

Comparison of Micum Indices Obtained from Tests on +60 mm Coke in Full-length and Half-length Drums

Micum Index	M_{40}		M_{10}	
Length of Drum	Full	Half	Full	Half
Coke No.				
5R	64	66	18.3	17.7
13R	65	66	17.2	16.4
14R	65	65	17.8	18.0
15R	68	67	16.2	15.7
17R	65	66	16.2	15.8
18R	72	69	7.0	7.8
61/509	65	66	15.4	16.4
Is 2	59	63	8.9	9.1
Is 3	66	66	11.8	12.8
Is 4	64	64	12.2	11.3
Mean for 10 Tests	65.3	65.8	14.1	14.1

In view of the greater convenience in handling the smaller amount of coke when carrying out the test and the relatively small amount of coke sometimes available for testing*, it has virtually become standard practice at the Institute to carry out micum tests in the half-length drum. All further micum results discussed in this report were obtained by using such an apparatus. The test is referred to as the half-micum test, but when testing +60 mm coke the micum indices are simply reported or quoted as if no modification had been made. Only when testing +25 mm coke — half-micum test (modified) — the additional modification is indicated with the indices as already explained.

STATISTICAL .../

* e.g. from experimental coke oven tests.

STATISTICAL EVALUATION AND DISCUSSION OF RESULTS.

The results obtained from a minimum of 206 test cokes, sampled and tested as described above, were available for statistical investigation. Virtually all the strength indices obtained represent the mean of at least three tests, fewer tests being carried out in only a few exceptional cases where enough coke was not available.

By plotting pairs of values obtained for the different physical characteristics of the same coke — e.g. M_{40} against 1½ in. shatter index, etc.— for all the cokes investigated the correlation between the characteristic values selected could be visually judged. In some instances the correlation appeared to be poor or only fair, but in others it was undoubtedly very good.

In view of the large number of data available, they were subjected to statistical investigation and linear correlation coefficients and expressions for linear regression lines were calculated. These are shown in Tables 5 to 9.

Also included in these tables are the maxima, minima and mean values of the variables concerned, as well as the spreads (95 percent confidence limits) at the intersection points of the regression lines*. It should be remembered that these spreads also include the inaccuracies of the samples used in the investigation.

Examples .../

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* The regression lines intersect at the mean values of the variables, i.e. at points around which the values of the particular variables are concentrated. The spreads increase somewhat with distance along the regression lines on either side of the point of intersection.

TABLE 5.

Linear Correlation of Mean Size, mm, Round Holes (x) and Mean Size, in, Square Holes (y).

Variables		Linear Regression Line		Linear Correln. Coefft. r	Range of Variables				Spread (±) at Intersection of Regress. Lines**
x	y	y on x	x on y			Max.	Min.	Mean*	
mm, rd	in, sq	y' = 0.032x + 0.209	x' = 27.979y + 2.609	0.946	x	106.4	38.6	80.7	6.16
					y	3.56	1.52	2.79	0.209

TABLE 6.

Linear Correlation of +25 mm Micum Results (x) and +60 mm Micum Results (y).

M'_{40}	M_{40}	y' = 0.938x + 5.32	x' = 1.004y - 1.74	0.970	x	77	28	61.6	3.9
					y	78	30	63.3	3.7
M_{10m}	M_{10}	y' = 1.005x + 0.398	x' = 0.972y - 0.048	0.988	x	42.3	7.4	14.6	1.53
					y	46.2	8.0	15.1	1.55
$CMTV_m$	CMTV	y' = 0.978x + 2.09	x' = 0.979y + 0.22	0.978	x	71	18	52.9	3.6
					y	71	19	53.9	3.6
$MMSS_m$	MMSS	y' = 0.868x + 3.10	x' = 0.983y + 4.52	0.924	x	65	38	52.6	3.2
					y	61	31	47.9	3.0

TABLE 7.

Linear Correlation of +60 mm Micum Results (x) and B.S. Test Results (y).

M_{40}	2"SI	y' = 0.593x + 31.02	x' = 0.800y + 8.43	0.689	x	78	30	63.3	11.1
					y	84	45	68.4	9.6
M_{40}	1½"SI	y' = 0.431x + 58.26	x' = 1.763y - 87.52	0.872	x	78	30	63.3	7.5
					y	93	68	85.4	3.7
M_{10}	½"SI	y' = -0.324x + 101.23	x' = -2.669y + 272.27	-0.929	x	46.2	8.0	15.1	3.77
					y	98.6	84.3	96.3	1.32
M_{10}	BSAI	y' = -1.009x + 87.45	x' = -0.881y + 78.75	-0.943	x	46.2	8.0	15.1	3.40
					y	83	49	72.2	3.7

* Points of intersection of the two regression lines.

** 95 percent confidence limits.

TABLE 8.

Linear Correlation of +25 mm Micum Results (x) and B.S. Test Results (y).

Variables x	Variables y	Linear Regression Line: y on x	Linear Regression Line: x on y	Linear Correln. Coefft. r	Range of Variables	Max.	Min.	Mean*	Spread (±) at Intersection of Regress. Lines**
M'_{40}	2"SI	y' = 0.621x + 30.11	x' = 0.887y + 0.92	0.742	x	77	28	61.6	11.0
					y	84	39	68.4	9.2
M'_{40}	1½"SI	y' = 0.437x + 58.53	x' = 1.835y - 95.17	0.895	x	77	28	61.6	7.3
					y	93	66	85.4	3.6
M'_{40}	½"SI	y' = 0.145x + 87.42	x' = 2.998y - 227.31	0.660	x	77	28	61.6	12.3
					y	98.6	84.3	96.3	2.71
M_{10m}	½"SI	y' = -0.347x + 101.41	x' = -2.778y + 282.28	-0.982	x	42.3	7.4	14.6	1.90
					y	98.6	84.3	96.3	0.67
M_{10m}	BSAI	y' = -1.021x + 87.13	x' = -0.817y + 73.61	-0.913	x	42.3	7.4	14.6	4.08
					y	83	49	72.2	4.6
M_{10m}	SASS	y' = -0.721x + 44.35	x' = -0.805y + 41.84	-0.762	x	42.3	7.4	14.6	6.49
					y	47	17	33.8	6.2
$CMTV_m$	SASS	y' = 0.504x + 7.19	x' = 1.679y - 3.97	0.920	x	71	18	52.9	6.8
					y	47	17	33.8	3.8

* Points of intersection of the two regression lines.
** 95 percent confidence limits.

TABLE 9.

Linear Correlation of +25 mm Micum Results.

Variables		Linear Regression Line		Linear Correln. Coefft. r	Range of Variables				Spread ($\pm$) at Intersection of Regress. Lines**
x	y	y on x	x on y			Max.	Min.	Mean*	
M'_{40}	M_{20m}	y' = 0.510x + 51.12	x' = 1.088y - 28.22	0.745	x y	77 91	28 53	61.6 82.5	11.0 7.5
M'_{40}	$MMSS_m$	y' = 0.246x + 36.48	x' = 0.980y + 11.03	0.490	x y	77 65	28 38	61.6 52.6	14.3 7.2
M_{20m}	M_{10m}	y' = -0.836x + 83.57	x' = -1.046y + 97.75	-0.935	x y	91 42.3	53 7.4	82.5 14.6	4.0 3.53
M_{20m}	$MMSS_m$	y' = 0.593x + 2.68	x' = 1.103y + 24.59	0.809	x y	91 65	53 38	82.5 52.6	6.6 4.9
M_{20m}	$CMTV_m$	y' = 1.180x - 44.47	x' = 0.492y + 56.47	0.762	x y	91 71	53 18	82.5 52.9	7.3 5.3
M_{10m}	$CMTV_m$	y' = -1.389x + 73.23	x' = -0.445y + 38.16	-0.786	x y	42.3 71	7.4 18	14.6 52.9	6.07 10.8
$MMSS_m$	M_{10m}	y' = -1.003x + 66.31	x' = -0.674y + 61.41	-0.822	x y	65 42.3	38 7.4	52.6 14.6	4.7 5.69
$MMSS_m$	$CMTV_m$	y' = 1.355x - 17.02	x' = 0.303y + 35.60	0.640	x y	65 71	38 18	52.6 52.9	6.3 13.4

* Points of intersection of the two regression lines.
** 95 percent confidence limits.

Examples of relatively poor linear correlation are those between M'_{40} and $MMSS_m$ (Table 9), and between M'_{40} and ½ in. shatter index (Table 8). Good correlation was found between M_{10m} and M_{10}, and between M'_{40} and M_{40} (Table 6).

The equations in Tables 5 to 9 may be used for estimating a characteristic of a coke provided another characteristic with which it has been tied, and with which good correlation has been established, is known.

For instance, suppose the M'_{40} index (x) of a particular coke is known then according to Table 6 an estimate of the M_{40} index (y') can be obtained by using the equation

$$y' = 0.938x + 5.32$$

Alternatively, if M_{40} (y) is known M'_{40} (x') can be estimated using the equation

$$x' = 1.004y - 1.74$$

In a few instances — Figure 1a to f — the regression lines have been drawn to illustrate how the equations given in Tables 5 to 9 can be used to obtain an estimate by graphical means of one characteristic of a coke sample from another. It will be observed that the higher the correlation coefficient the smaller the acute angle of intersection of the two lines.

From Table 5, the mean values for mean size at the point of intersection of the regression lines are 80.7 mm (round holes) and 2.79 in.(square holes), respectively. Hence the ratio of the diameter of the round aperture to the side of the equivalent square aperture at this mean size of the cokes tested is

$$\frac{80.7}{25.4} \div 2.79 = 1.14.$$

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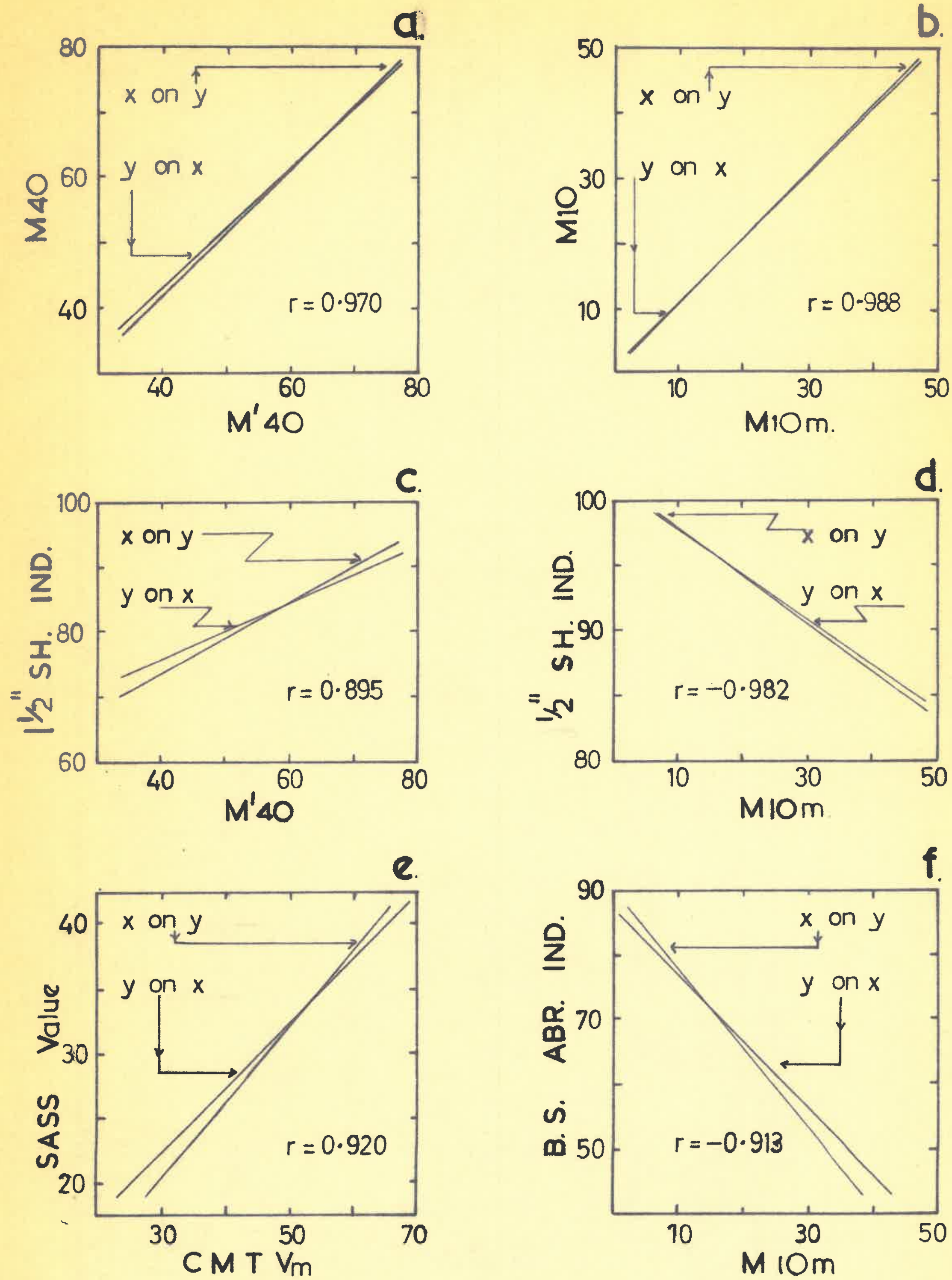

FIGURE 1

Relation between various coke characteristics as given by calculated regression lines.

This ratio is somewhat lower than the value 1.16 recommended by the British Standards Institution for coal[9], but agrees with the value found for British cokes[8].

In trying to assess the relative merits, in particular the selectivity of the various test methods and indices used, use was made of the "resolution index" also used by other workers[8]. The resolution index of a test is defined as $^b/_a$, where 'a' is the expected range of results for a single coke and 'b' is the range in mean values for a series of cokes. It is clear that a high resolution index, i.e. good selectivity would indicate that a test is capable of distinguishing between nearly similar cokes.

The resolution indices obtained for the cokes investigated, as well as some values published by British workers, are given in Table 10.

TABLE 10.

Selectivity of Test Methods and Indices as Indicated by Resolution Index Values.

Test and Index			a*	b**	Resolution Index	
					$^b/_a$	Published Values[8]
B. S. Shatter Index		2 in.	4.5	39	9	-
B. S. Shatter Index		1½ in.	2.2	25	11	16
B. S. Shatter Index		½ in.	0.51	14.3	28	9
B. S. Abrasion Index			1.85	34	18	3
Half-length drum	+25 mm Micum	M'_{40}	2.6	49	19	-
Half-length drum	+25 mm Micum	M_{20m}	1.14	38	33	19
Half-length drum	+25 mm Micum	M_{10m}	0.97	34.9	36	16
Half-length drum	+60 mm Micum	M_{40}	2.4	48	20	16
Half-length drum	+60 mm Micum	M_{10}	1.11	38.2	34	9

* 'a' is the expected range of results for a single coke. (The values recorded simply represent the mean values of the ranges obtained.)

** 'b' is the range in mean values for a series of cokes.

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It will be observed that there is virtually no difference between the selectivities of the M_{40} index (+60 mm micum) and the M'_{40} index (+25 mm micum). Considering the M_{10} and M_{10m} indices, however, the +25 mm micum test appears to be slightly superior to the +60 mm micum test in respect of both repeatability (as indicated by the 'a' values) and resolution index. The M_{10m} index is the most selective criterion of coke quality used in the present investigation. M_{20m} is slightly inferior to M_{10m}.

The M_{20m} index may prove to be useful if it can be correlated with the amount of breeze (below about ½ in.) screened from coke charged to blast-furnaces but such a study was not possible during the present investigation.

With the shatter indices only the ½ in. shatter index shows good selectivity while the B.S. abrasion index is inferior to M_{10} or M_{10m} in this respect.

Appreciable discrepancies between the two sets of resolution indices recorded will be observed. The values published by the British workers[8)] are generally much lower than the others. Their relatively high resolution index for the 1½ in. shatter index was not confirmed in the present investigation. To some extent this remark is also applicable to the M_{40} index, i.e. if the comparatively large differences found between corresponding values of the other resolution indices are taken into consideration.

CONCLUSION .../

CONCLUSION:

The impression gathered from the literature is that, in European countries at least, more importance is generally attached to the M_{40} than to the M_{10} index. The reason may be that as a result of the relatively high proportion of active or fusible constituents in the coking coals, good fusion and cementing of particles is generally obtained during coking and thus good resistance to abrasion.

Fissuring of the coke thus probably presents a more serious problem and this is better judged by its lowering effect on the M_{40} index.

In South Africa the problem appears to be somewhat different. The coals or blends used so far for coking are known to be relatively deficient in fusible constituents. Hence poor resistance to abrasion assumes rather more importance as compared with fissuring. Low resistance to abrasion (indicated by a high M_{10} or M_{10m} index) results in the formation of much breeze during handling and use of the coke. This leads not only to a serious loss of the available furnace coke (i.e. lumps above a certain minimum size) but also to unsatisfactory furnace performance.

The severity of conditions causing coke breakage in an average foundry cupola is probably less than in a blast-furnace. Moreover, authorities recommend that coke below 2 in. in size should preferably not be charged to cupolas[10)]. The modified micum test may, therefore, not be as suitable for testing foundry cokes as the standard (ISO) micum test or the less severe shatter test (2 in. shatter index). In fact, workers in the U.S.A. have

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declared that the standard micum test is considered appropriate for blast-furnace cokes but not for foundry or special cokes[4].

It may be mentioned that the B.S. abrasion test appears to be falling into disuse and the test is seldom mentioned or the index reported in recent publications, including those from Great Britain. The index, no doubt, reflects an important fundamental coke property, but as the test is so severe (1000 drum revolutions) the results can hardly be expected to be an indication of coke behaviour under practical conditions. On the other hand, there is no indication that the M_{10} index will similarly fall into disuse as it appears to be invariably reported where micum tests are carried out. For reasons stated above it would be out of the question in South Africa to dispense with an abrasion test in coke evaluation and the M_{10} or M_{10m} index obtained from a micum test is considered to be the most suitable yard-stick for the purpose.

So much evidence in favour of the micum test — modified in that +25 mm instead of +60 mm coke is used for testing, and the drum length and weight of coke tested are reduced by half — has been produced in the present investigation that the adoption of the modified test in South Africa for assessing blast-furnace cokes can be confidently recommended.

The test, suitably adapted, may also prove useful for determining the mechanical stability of briquettes and other solid smokeless fuels.

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REFERENCES.

1. British Standards Institution. "Methods for the Analysis and Testing of Coal and Coke. Part 13. Tests Special to Coke". B.S.1016: Part 13: 1961.

2. American Society for Testing Materials. A.S.T.M. D141-48: "Drop Shatter Test for Coke"; A.S.T.M. D294-50: "Tumbler Test for Coke".

3. International Organization for Standardization. "Determination of the Micum Indices of Coke". (Unpublished ISO Documents.)

4. Baker, K.F. "Observations on International Methods for the Mechanical Testing of Coke". Commonwealth of Australia. C.S.I.R.O., Division of Coal Research. Miscellaneous Report 224 (March 1963).

5. British Standards Institution. "Size Analysis of Coke". B.S. 2074:1954.

6. Manning, A.B. "Size Analysis of Coke". Coke and Gas, 16, No. 178, 104 (March 1954).

7. Private information.

8. British Coke Research Association. "The Use of the Shatter Test, the B.S. Abrasion Test, the ASTM Tumbler Test and the Micum Test in the Assessment of Coke Strength". Coke Research Report 7, February, 1961.

9. .../

9. British Standards Institution. "Screen Analysis of Coal". B.S. 1293:1946.

10. Waters, P.L. "Use of Coke in Cupolas". Commonwealth of Australia. C.S.I.R.O., Division of Coal Research. Miscellaneous Report 228, (March 1963).

11. la Grange, C.C. "Some Coking Experiments Aimed at Coke Improvement and Using Mainly Certain Natal Coking and Anthracitic Coals". J.S.A. Inst. Mining & Metallurgy, 63, No. 5, 151 (Dec. 1962).

APPENDIX .../

APPENDIX.

The methods used for calculating 'mean size' (M) 'shatter mean size stability' (SMSS), 'abrasion mean size stability (AMSS) and 'shatter and abrasion size stability' (SASS) were explained in a previous publication[11])* and need not be repeated.

The 'micum mean size stability' (MMSS or $MMSS_m$) is numerically equivalent to:

$$\frac{100\ (\text{Mean size of sample after micum test})}{\text{Mean size of sample charged to micum drum}}.$$

The procedure for calculating this index is thus similar to those followed for calculating SMSS and AMSS mentioned above.

Most workers expect a good coke to yield a high percentage of +40 mm and a low percentage of -10 mm material after testing in the micum drum. These are two independent indices describing two distinct inherent properties of a sample of coke. They have, therefore, to be considered individually when judging the relative merits of different cokes. However, it is often convenient to have a single index (instead of two) enabling one to compare different cokes or to classify them according to probable usefulness. Such an index is the 'comparative micum test value' (CMTV or $CMTV_m$) which serves the same purpose as the SASS value mentioned above and which is calculated as follows:

$$CMTV = \frac{M_{40}\ (100 - M_{10})}{100}$$

$$\text{or} \quad CMTV_m = \frac{M'_{40}\ (100 - M_{10m})}{100}$$

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*See Appendix I in the publication.

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