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A sampling procedure validated

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SYNOPSIS

Extensive work was done previously on the wear of grinding media and on the comminution processes operative in ball milling based on the determination of the number-size and mass-size distributions of samples of balls taken from ball mills by a specially designed device.

Proof that a sample is as nearly representative as possible of the whole mass of material from which it is drawn is usually extremely difficult. This paper reports a special case in which a direct comparison was made between the number-size and mass-size distributions obtained from a sample drawn from a mill and those from the whole ball charge emptied from the mill.

Exposure of the internal defects of the grinding balls caused them to develop irregular shapes after wear had reduced their diameters by about 50 per cent. As a result of the marked change in the morphology of the grinding components, an anomaly was observed between the proportion of small components collected by the sampler and that determined in the total charge.

Except for this anomaly, a marked similarity was found in the data relating to the larger components in the sample and the total charge, indicating that the sample obtained by the procedure outlined is representative of the mass of the grinding charge in a mill.

SAMEVATTING

Daar is voorheen omvangryke werk in verband met die slytasie van die maalmedia en die verpoeieringsprosesse wat op balmaling van toepassing is, gedoen aan die hand van die bepaling van die getalgrootte- en massa-grootteverdeling van balmonsters wat met 'n spesiaal ontwerpte toestel uit balmeule geneem is.

Dit is gewoonlik uiters moeilik om te bewys dat 'n monster akkuraat verteenwoordigend is van die hele massa materiaal waaruit dit geneem is. Hierdie referaat doen verslag oor 'n spesiale geval waar daar 'n regstreekse vergelyking getref is tussen die data vir die getal-grootte- en massa-grootteverdeling wat verkry is met 'n monster wat uit die meul geneem is, en die van die hele ballading wat uit die meul gehaal is.

Blootstelling van inwendige defekte in die maalballe het onreëlmatige vorms laat ontwikkel nadat die diameters, as gevolg van slytasie, met ongeveer 50 persent verminder is. As gevolg van die duidelike verandering in die morfologie van die maalkomponente, is daar 'n anomalie waargeneem tussen die verhouding van die klein komponente wat deur die monsternemer versamel is, en dié wat in die totale lading bepaal is.

Afgesien van hierdie anomalie was daar 'n duidelike ooreenkoms tussen die data betreffende die groter komponente in die monster en die totale lading, wat toon dat die monster wat verkry is deur die prosedure wat beskryf is, verteenwoordigend is van die massa van die maallading in diè meul.

Introduction

In many metallurgical processes, samples are necessary to provide data for the control of the process and involve the use of various sampling procedures. For example, samples may be required from a stream of molten metal flowing from a furnace or from the exposed surface of a vein of ore in an underground stope. In all cases, it is essential that the amount of material sampled should be as nearly representative as possible of the whole mass under consideration.

In an earlier investigation[1], extensive work was carried out in which the comminution forces operating within a rotary mill were studied with particular reference to ball mills. The data essential for that study were obtained from samples of the grinding charge drawn from the mill. The sampling device used, which was developed at Mintek, is basically simple and can be easily attached to and detached from the mill (Fig. 1). A sample of approximately 1 t is obtained in one revolution of the mill. The balls in the sample were separated into specific size ranges, and the numbers and masses of the components in each size range were determined. Only indirect confirmation could be offered at that stage that the samples were reasonably representative of the charge in the ball mill—an uncertainty common to all industrial sampling procedures.

Subsequently, a unique opportunity arose for the investigation in some detail of the degree to which a sample can be considered representative of a whole charge. On one of the ball mills at Libanon Gold Mine, a full-scale plant test had been planned so that comparative data could be obtained on the performance of a new type of grinding ball. Management had decided that the entire grinding charge should be removed and that a complete charge of the new type of ball should be added to the mill.

Before the mill was emptied, a sample of the existing charge was drawn and, after the mill had been emptied, the complete charge of balls was separated into specific size ranges, and the numbers and masses within each size range were determined. This allowed for a close comparison between the data obtained from the sample and those obtained from the total charge.

Results

The grinding elements from the mill charge were sized as follows. The balls were rolled along lengths of channel iron in which seven round holes within the range 37,2 to 100 mm had been drilled. All the balls larger than 37,2 mm were counted and weighed, and the total mass of the components smaller than 37,2 mm was found to be less than 200 kg.

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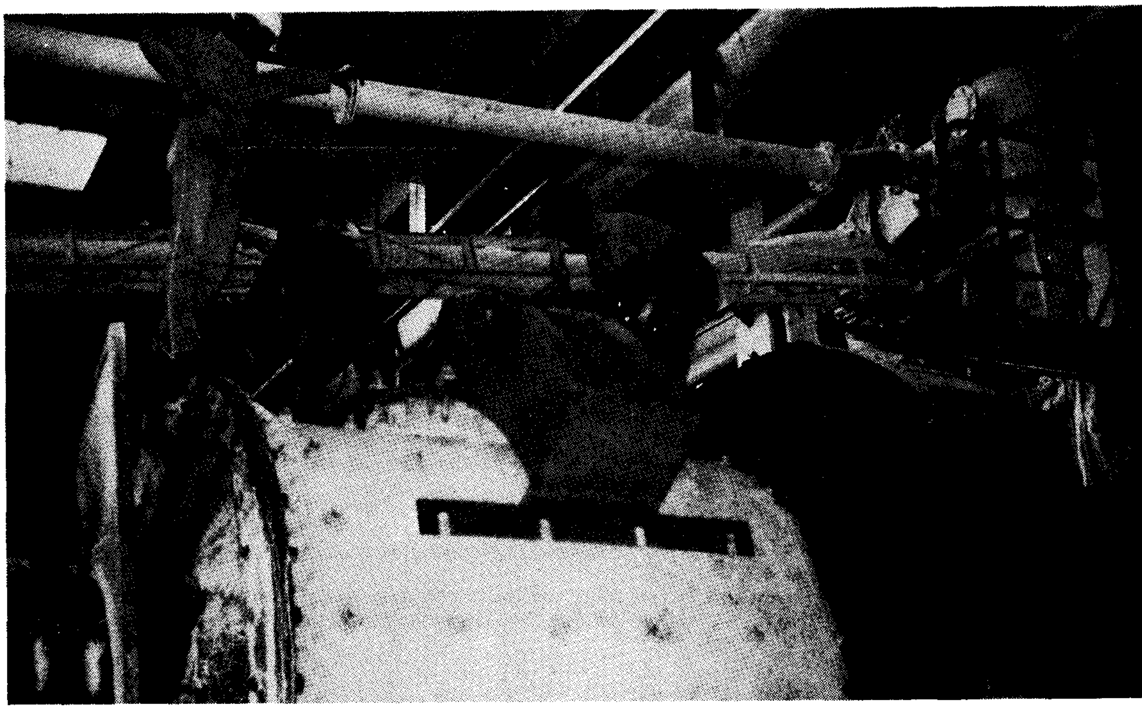

Fig. 1—The sampler being fitted to the manhole of a ball mill at Libanon Gold Mine

The results are given in Table I which includes calculated values of the number and mass fractions of balls in a size interval (columns 3) and the cumulative number and mass fractions of balls passing size X. From the table it is clear that the components larger than 37,2 mm in the charge comprised 20 956 balls with a total mass of 23 937 kg. A ball mill of the size under consideration (2,75 by 3,05 m) would normally contain a mass of balls in excess of 30 t—substantially greater than the mass of the charge measured. When the test was carried out, the mill was not operating under steady-state conditions, but had been allowed to run down to some extent. This apparent abnormality in mill operation is not relevant to the comparison of the sample and the total ball charge—a comparison that involves only the number-size and mass-size distributions of the components in the two cases.

The histograms in Fig. 2 are the number-size and mass-size frequency distributions obtained from the division of the results in columns 3 of Table I by the width of the corresponding size interval. Fig. 2 shows clearly that, in general, the number-size and mass-size distributions of the elements in the sample and in the ball charge are very similar. An anomaly does exist in regard to the results for the grinding elements within the size interval 37,2 to 49,5 mm, a difference of more than 30 per cent being evident in both the number and the mass fractions for the sample as compared with those for the total charge.

Fig. 3 indicates clearly that the grinding components in this size range are markedly non-spherical. They are characterized by exposed cavities and/or gross porosity, holes through components being fairly frequent. Internal defects in the originally spherical components become exposed after wear. Such defects are an inevitable feature of these cast semi-steel balls, which are produced in an automatic casting machine equipped with water-cooled copper moulds.

The difference between the results for the material in this size range (37,2 to 49,5 mm) in the sample and those in the charge is a consequence of the segregation of such components within the body of the charge in the mill. The movement of these irregularly shaped components through the mass of the charge probably differs significantly from the movement of the larger, more-rounded components. This is believed to constitute a basic factor in the segregation of these components, which affects the proportion of the irregularly shaped objects collected by the sampling device.

To assign such irregularly shaped and pitted components to a specific size range is difficult. Calculations based on the results given in Table I show that the average diameter of the equivalent spheres of these components is less than 37,2 mm—the lower limit of the size interval to which they had been assigned. These uncertainties, and the fact that the material in this size range comprises less than 4,5 per cent of the total mass of the grinding charge, provided the grounds for the decision that the contribution made by these components should be ignored, and that the size distributions of the sample and the charge should be recalculated, as shown in Table II.

The number-size and mass-size frequency distributions of all the components in the charge that are larger than 49,5 mm can be seen in Fig. 4, which shows clearly the marked similarity of the size distributions in the charge and in the sample. This is confirmed by Fig. 5, which shows the cumulative number of balls in the charge plotted against the cumulative number of balls in the sample. The results are extremely well correlated, and the small intercept, which will no doubt vary in magnitude from sample to sample, indicates that the numbers of balls, as determined for the size intervals in the sample and in the charge, are approximately proportional. Similar results were obtained when the cumulative mass of the charge was plotted against that of the sample (Fig. 6).

TABLE I
THE SIZE DISTRIBUTION OF BALLS LARGER THAN 37,2 mm IN THE NO. 1 BALL MILL AT LIBANON GOLD MINE ON 6TH JULY, 1988

As found in the sample

Size range mm	Number 1 Number	Number 2 Cumulative number	Number 3 Number fraction	Number 4 Cumulative fraction	Mass 1 Mass, kg	Mass 2 Cumulative mass, kg	Mass 3 Mass fraction	Mass 4 Cumulative fraction
37,2 to 49,5	114	114	0,1541	0,1541	26,0	26,0	0,0282	0,0282
49,5 to 59,5	169	283	0,2284	0,3824	73,9	99,9	0,0802	0,1085
59,5 to 71,0	140	423	0,1892	0,5716	116,7	216,6	0,1267	0,2352
71,0 to 78,0	103	526	0,1392	0,7108	147,3	363,9	0,1599	0,3951
78,0 to 88,3	102	628	0,1378	0,8486	202,2	566,1	0,2195	0,6146
88,3 to 99,2	76	704	0,1027	0,9514	212,1	778,2	0,2303	0,8449
99,2 to 103,5	36	740	0,0486	1,0000	142,9	921,1	0,1551	1,0000

As found in the total charge

Size range mm	Number 1 Number	Number 2 Cumulative number	Number 3 Number fraction	Number 4 Cumulative fraction	Mass 1 Mass, kg	Mass 2 Cumulative mass, kg	Mass 3 Mass fraction	Mass 4 Cumulative fraction
37,2 to 49,5	4933	4933	0,2395	0,2395	998,3	998,3	0,0417	0,0417
49,5 to 59,5	4406	9339	0,2139	0,4535	2029,8	2029,8	0,0848	0,1265
59,5 to 71,0	3509	12848	0,1704	0,6238	3210,3	6238,1	0,1341	0,2606
71,0 to 78,0	2790	15638	0,1355	0,7593	4081,0	10319,1	0,1705	0,4311
78,0 to 88,3	2266	17904	0,1100	0,8693	4665,1	14984,2	0,1949	0,6260
88,3 to 99,2	1849	19753	0,0898	0,9591	5594,2	20578,4	0,2337	0,8597
99,2 to 103,5	843	20596	0,0409	1,0000	3358,7	23937,1	0,1403	1,0000

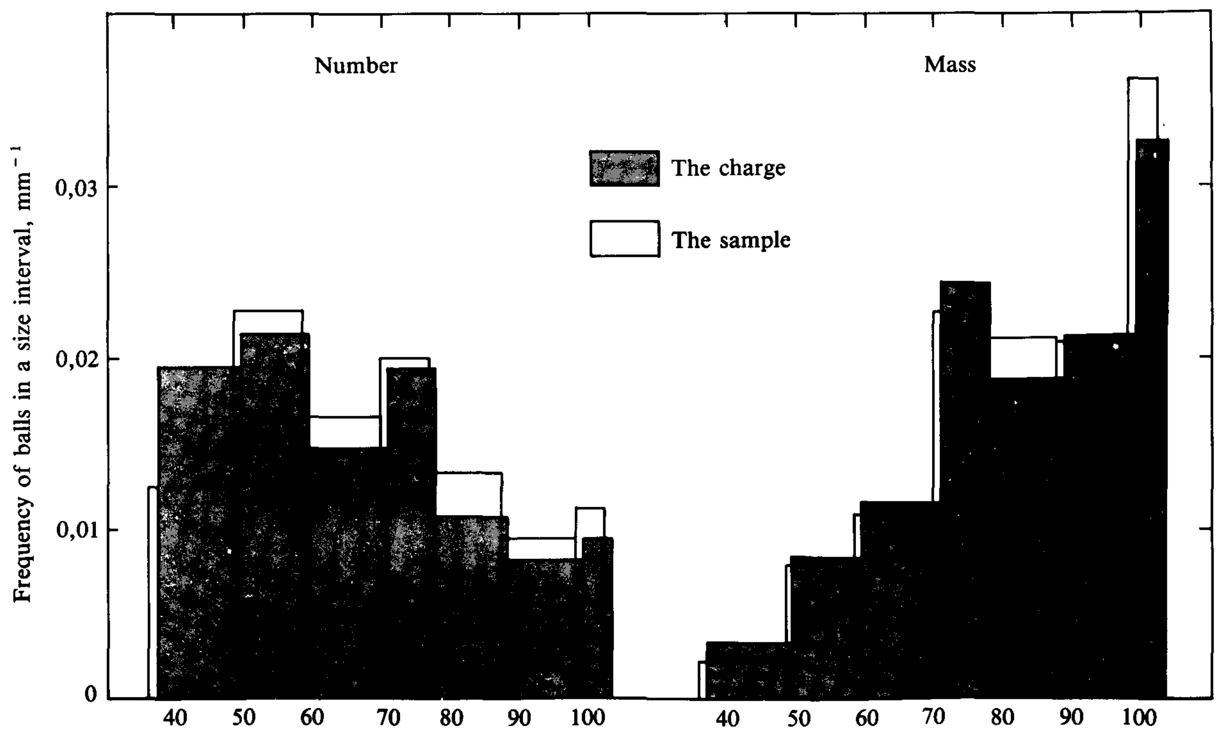

Fig. 2—Number-size and mass-size frequency distributions of the grinding components larger than 37,2 mm in the No. 1 ball mill at Libanon Gold Mine on 6th July, 1988. The results for the sample are offset slightly for greater clarity

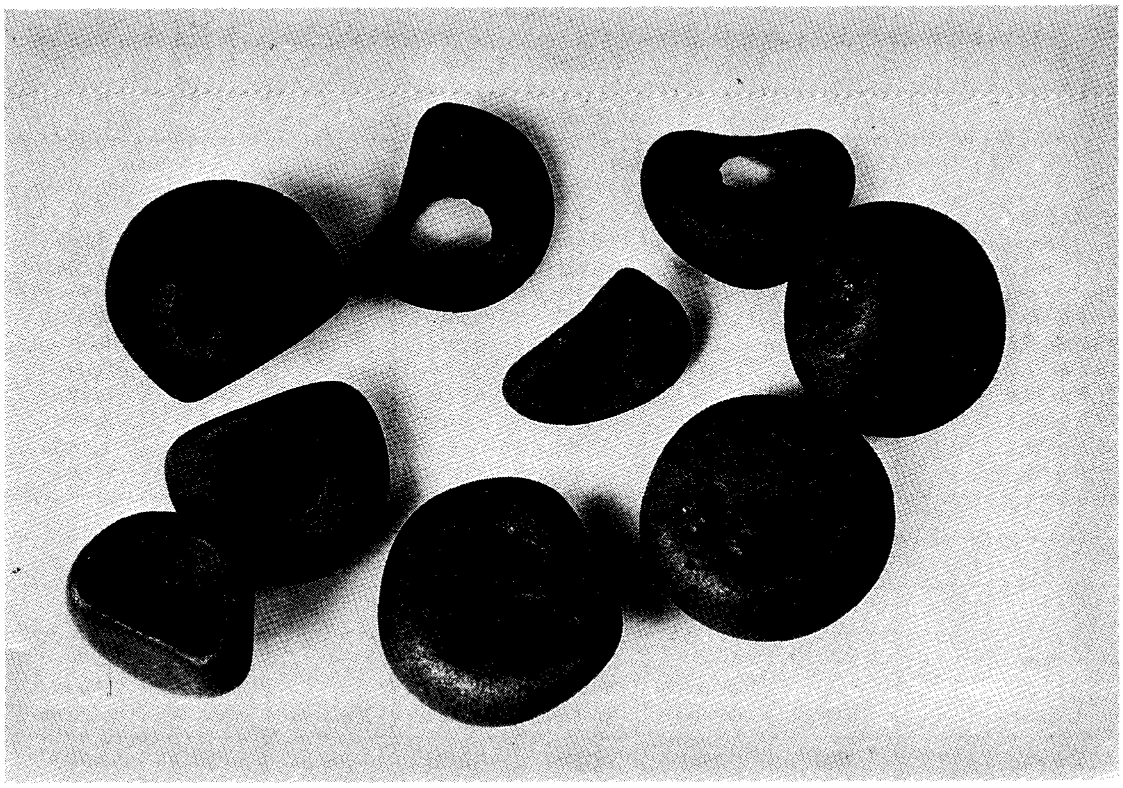

Fig. 3—Characteristic shapes of the components in the size range 37,2 to 49,5 mm

TABLE II

THE SIZE DISTRIBUTION OF BALLS LARGER THAN 49,5 mm IN THE NO. 1 BALL MILL AT LIBANON GOLD MINE ON 6TH JULY, 1988

As found in the sample

Size range mm	Number				Mass			
	1 Number	2 Cumulative number	3 Number fraction	4 Cumulative fraction	1 Mass, kg	2 Cumulative mass, kg	3 Mass fraction	4 Cumulative fraction
49,5 to 59,5	169	169	0,2700	0,2700	73,9	73,9	0,0826	0,0826
59,5 to 71,0	140	309	0,2236	0,4936	114,7	190,6	0,1304	0,2129
71,0 to 78,0	103	412	0,1645	0,6581	147,3	337,9	0,1646	0,3775
78,0 to 88,3	102	514	0,1629	0,8211	202,2	540,1	0,2259	0,6034
88,3 to 99,2	76	590	0,1214	0,9425	212,1	752,2	0,2370	0,8404
99,2 to 103,5	36	626	0,0575	1,0000	142,9	845,1	0,1596	1,0000

As found in the total charge

Size range mm	Number				Mass			
	1 Number	2 Cumulative number	3 Number fraction	4 Cumulative fraction	1 Mass, kg	2 Cumulative mass, kg	3 Mass fraction	4 Cumulative fraction
49,5 to 59,5	4406	4406	0,2815	0,2815	2029,5	2029,5	0,0885	0,0885
59,5 to 71,0	3509	7915	0,2240	0,5055	3210,3	5239,8	0,1400	0,2284
71,0 to 78,0	2790	10705	0,1781	0,6836	4081,0	9230,8	0,1779	0,4063
78,0 to 88,3	2266	12971	0,1447	0,8283	4665,1	13985,9	0,2034	0,6097
88,3 to 99,2	1849	14820	0,1180	0,9460	5594,2	19580,1	0,2439	0,8536
99,2 to 103,5	843	15663	0,058	1,0000	3358,7	22938,8	0,1464	1,0000

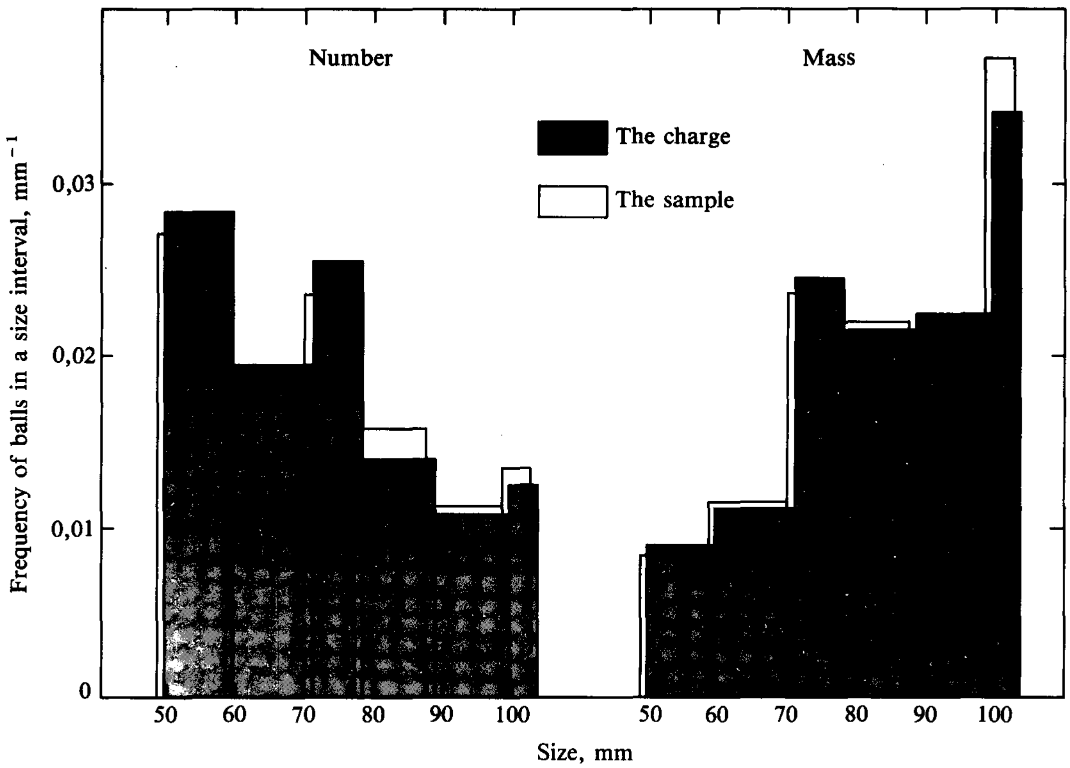

Fig. 4—Number-size and mass-size frequency distributions of the components larger than 49,5 mm

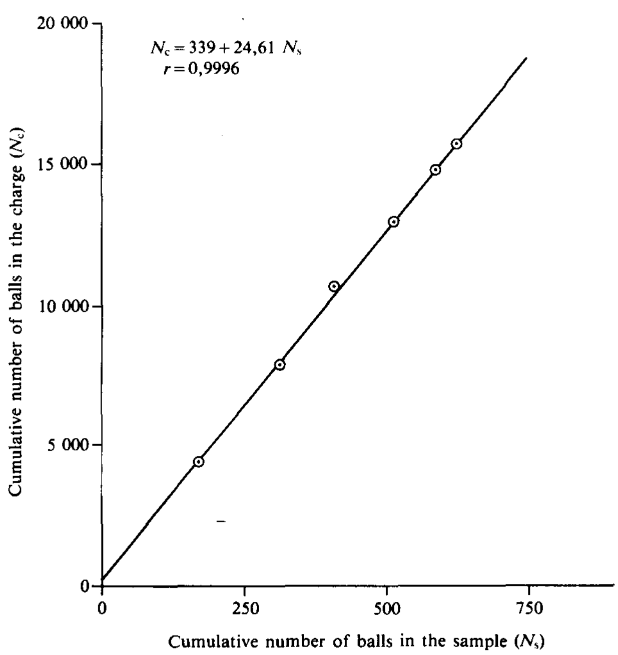

Fig. 5—Correlation between the cumulative number of balls in the charge and that in the sample

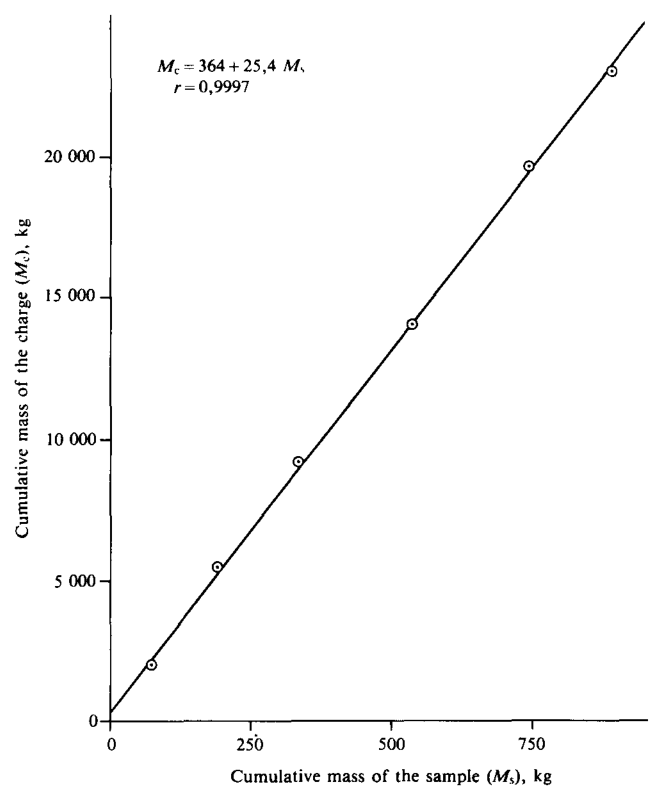

Fig. 6—Correlation between the cumulative mass of balls in the charge and that in the sample

An objective assessment of the similarity of the distributions was obtained by use of the χ^2-test, which gave values for χ^2 of 2,6 and 5,3 for the number and mass distributions respectively, the number of degrees of freedom being 5. Hence, both the number- and the mass-distribution results confirm that, for all components larger than 49,5 mm, the sample is representative of the charge. The Kolmogorov–Smirnov test could also be applied to the cumulative results as a test of linearity, but this would merely confirm[2] the results of the χ^2-test.

Summary and Conclusions

(1) A device, which was designed and constructed at Mintek, and which can be bolted to the manhole in a ball mill, proved capable of drawing a sample of approximately 1 t from the grinding charge during one revolution of the mill.
(2) An unusual set of circumstances enabled a comparison to be made between a sample drawn from the mill by the use of this device and the entire charge emptied out of the mill immediately afterwards. Every grinding component larger than 37,2 mm in the grinding charge was measured, counted, and weighed, and the number-size and mass-size distribution data were compared.
(3) For material smaller than 49,5 mm, an anomaly was found for the data relating to the sample and to the grinding charge.
(4) For grinding components larger than 49,5 mm, the number-size and mass-size distribution results were markedly similar for the sample and the grinding charge, indicating strongly that the sample obtained by the device is representative of the ball charge within the mill.

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1. Vermeulen, L.A., and Howat, D.D. Ball-size distributions—an aid to the study of wear and comminution processes in ball milling. Randburg, Council for Mineral Technology, *Report* M387. 1989.
2. Boyd, A.V. University of the Witwatersrand, private communication, 1989.

IMM awards

Given below are details of the trust funds, etc., to which applications are invited for grants, etc., payable in 1990. Application forms, which must be returned to the Secretary before 15th March, 1990, are available on request. Applicants should note that, in general, preference will be given to members of the Institution.

Bosworth Smith Trust Fund

Approximately £2500 will be available in 1990 for grants from the Bosworth Smith Trust Fund for the assistance of post-graduate research in metal mining, nonferrous extraction metallurgy, or mineral dressing. Applications will be considered for grants towards working expenses, the cost of visits to mines and plants in connection with such research, and the purchase of apparatus.

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Applications are invited from the income of the G. Vernon Hobson Bequest, established for the 'advancement of teaching and practice of geology as applied to mining'. It is expected that approximately £500 will be available in 1990. One or more awards may be made for travel, research, or other objects in accordance with the terms of the Bequest.

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Applications are invited for Stanley Elmore Fellowships, which are awarded by the Institution and are tenable at United Kingdom universities, for research into all branches of extractive metallurgy and mineral processing. One or two Fellowships, to a value of between £1500 and £7500 per annum, will be available from October 1990.

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The Edgar Pam Fellowship will be awarded in October 1990 for post-graduate study in subjects within the Institution's fields of interest, which range from exploration geology to extractive metallurgy. Those eligible for the award are young graduates domiciled in Australia, Canada, New Zealand, South Africa, or the United Kingdom who wish to undertake advanced study or research in the United Kingdom. The value of the Fellowship, which is tenable for one year, will be of the order of £1000.

General

Applicants for these awards must ensure that the particular fund from which support is being sought is relevant to their fields of interest. Applications that do not meet the terms and conditions of any field and those which are received by the Secretary after 15th March, 1990, will not be considered by the Awards and Grants Committee. Equally, applications for which the appropriate letters of support have not been received by 15th March, 1990, will not be submitted to the committee.

Application forms for the Institution awards can be obtained from

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