Horizontal-belt filtration at Randfontein Estates Mine

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SYNOPSIS

The paper describes tests on horizontal-belt filters for the filtration of gold and uranium. The promising results led to the installation of 17 such filters (ten of them 120 m² in size) in the mine's metallurgical plants, and their operation is discussed. Although several problems were encountered both in operation and maintenance, it is concluded that, with correct operation and suitable filter cloths, exceptionally good metallurgical recoveries can be achieved at filtration rates twice to three times higher than those on rotary filters.

SAMEVATTING

Die referaat beskryf toetse in verband met horisontalebandfilters vir die filtrering van goud en uraan. Die belowende resultate het gelei tot die installering van 17 sulke filters (tien daarvan met 'n grootte van 120 m²) in die myn se metallurgiese aanlegginge en hul werking word bespreek. Hoewel daar verskeie probleme in verband met sowel die bedryf as die onderhoud ondervind is, word die gevolgtrekking gemaak dat daar met die korrekte bedryf en geskikte filtreerdoeke buitengewoon goeie metallurgiese herwinnings verkry kan word teen filtreertempo's twee tot drie maal hoër as wat dié met draaifilters is.

Introduction

In view of the re-commissioning of the old uranium plant at Millsite, as well as the construction of a new 250 000 t/m integrated gold and uranium plant near the new Cooke Section of Randfontein Estates Gold Mining Company, alternative methods for liquid–solids separation had to be considered. The uranium rotary filters had, since the closure of the plant in 1964, been converted to gold filters.

It is well established that, for uranium, two stages of rotary-drum filtration are needed with countercurrent wash and repulping between the stages to reduce the dissolved losses to an acceptable level, usually in the 5 to 0,5 per cent range[1]. This liquid–solids separation step, based on rotary-drum filters, constitutes a significant portion of the capital cost of the total plant.

Comparative studies were undertaken with a conventional filtration plant as the base case. The alternatives considered included the use of horizontal-belt filters (HBF) and of countercurrent decantation (CCD).

These studies showed that both HBF and CCD had decided capital cost advantages compared with the conventional plant. The comparison between HBF and CCD indicated that there would be a cost advantage in favour of HBF, particularly when the downstream continuous ion-exchange and solvent-extraction sections were taken into account. With HBF, they would be handling considerably less flow owing to the lower wash ratios used with belt filters. The same conclusions have been obtained and reported by others[2].

The Test Filter

The 120 m² test filter consists of a driven rubber belt with an overlying filter cloth. The rubber belt is split into three longitudinal sections, with a stainless-steel vacuum box running along the centre line of each section. The vacuum seal incorporates water-lubricated wear belts running between the rubber belt and the vacuum box. Apart from the area over the vacuum seals, the rubber belts float on an aircushion, which reduces the drag due to friction. The filter cloth is lifted away from the rubber belt at the drive pulley and run over a series of rollers to break the cake, which then discharges spontaneously at the last roller, after which the cloth is cleaned by a series of water sprays washing into the repulper and into a separate wash-collection box.

The filter is driven by two Hägglund hydraulic motors connected directly to each side of the drive pulley. The original cloth-tracking system consisted of four 230 mm wide Foxwell pinch trackers, but these were soon replaced by a steering roller because of excessive wear on the trackers themselves, as well as on the edges of the filter cloth. This steering roller is moved by a double-acting air-cylinder on the one side, which changes the angle of the roller as determined by a sensor that feels the position of the cloth edge.

It has also been necessary to introduce angled pinch rollers 900 mm wide to pull out folds and creases, which tend to develop in the cloth.

The filtration area is divided into four distinct zones: a zone in which the feed slurry is dewatered, two wash zones, and a final zone in which the cake is dried sufficiently for proper discharge. These filtration zones are divided by rubber flaps that rest against the filter cake.

On the uranium filters, the vacuum boxes can be separated into sections by means of spades, and thus give three different filtrates. The initial filtrate, drawn before cake formation, contains an appreciable amount of solids and is therefore returned to the dewatering zone.

Filter wash can be added either countercurrently in

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two stages as on the uranium filters, or concurrently as illustrated in Figs. 1 and 2. Concurrent washing is used in the gold filtration.

After being dewatered, the cake enters the first wash zone, which is flooded with barren wash solution that has previously been used to wash the cloth. The vacuum action uniformly displaces the mother liquor in the cake with wash solution owing to the complete flooding of the wash zone. Liquid drawn in this zone into the vacuum boxes is collected, together with pregnant solution from the dewatering zone, into the product receiver, from which it is pumped for further processing. After a short distance of drying, the cake enters the second wash zone, where, in the case of the flowsheet shown in Fig. 2, the filtrate is also collected in the product receiver. When the countercurrent method of washing is used, this filtrate is collected, together with that from the following drying zone, into a separate receiver, from where it is pumped to the cloth-cleaning sprays, collected in the washbox, and returned to the first wash zone.

Operation of the Filters

The successful operation of the belt filters is based on the achievement of a classification of the filter cake in such a way that the coarse particles, because of their

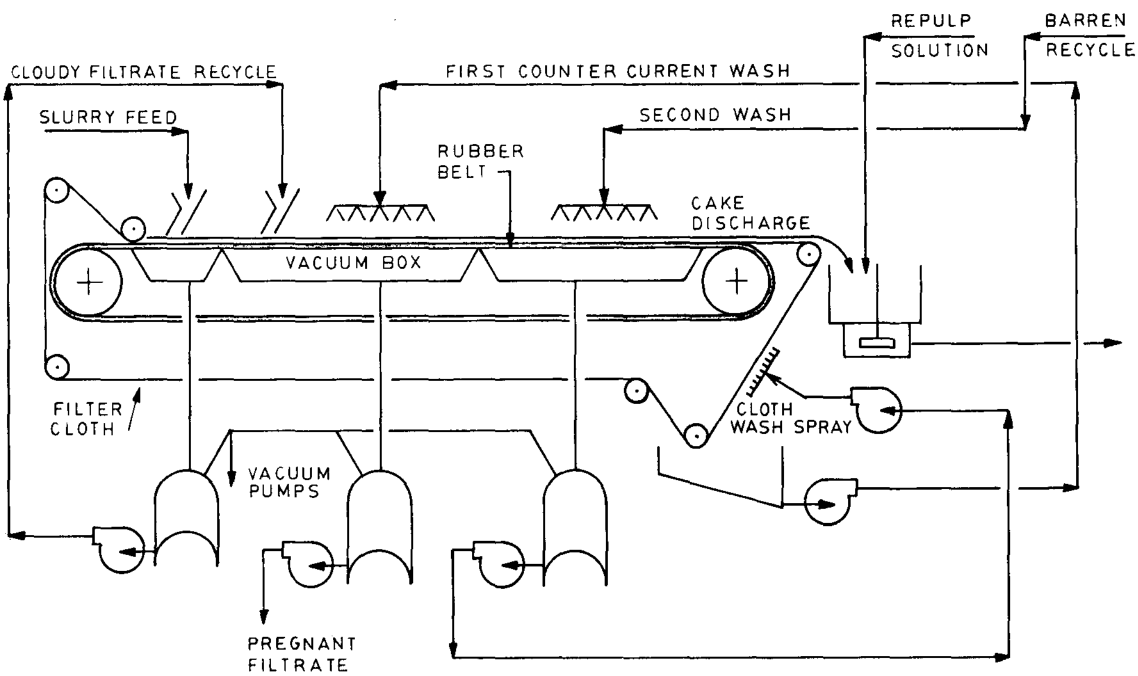

Fig. 1—Filtrate and wash arrangement for the uranium filters

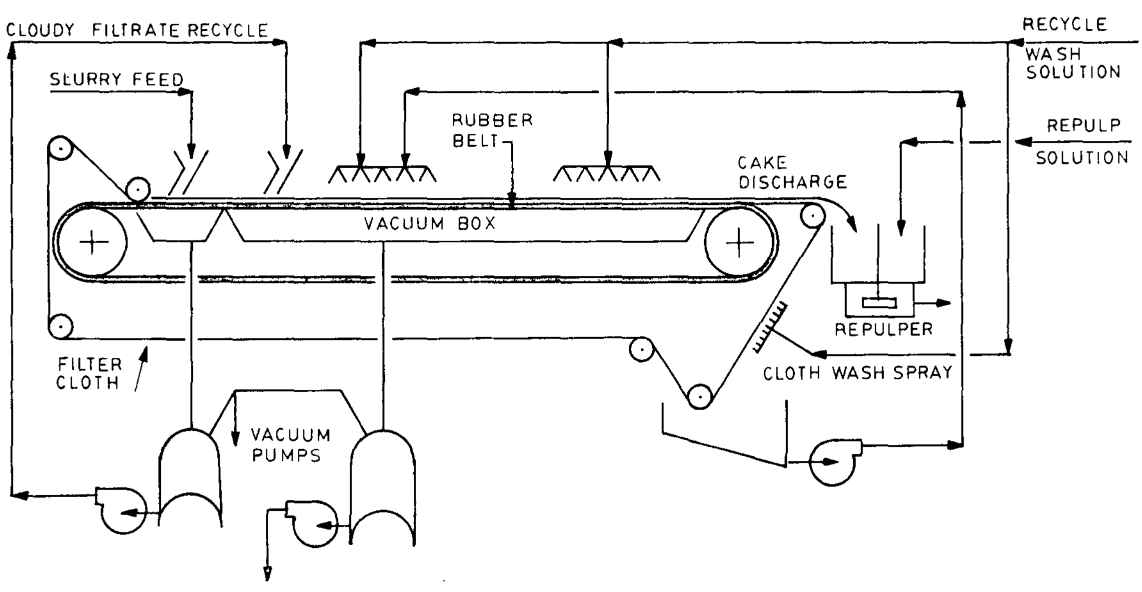

Fig. 2—Filtrate and wash arrangement for the gold filters

higher settling rate, are closest to the cloth. This gives a cake-cloth system of highest permeability, and thus filtration rate. It was found, however, that with the original feed system, where the slurry was introduced in a direction opposite to that of the belt travel, the feed point had to be brought up to 3 metres downstream of the point where vacuum is applied to avoid spillage due to wave action. This led to a tendency for the coarser particles to settle below the feeders, whereas the fines flowed backwards towards the incoming, clean cloth. This caused a thin layer of fine slime to block the pores in the filter cloth, which led to poor filtration rates and incomplete cake discharge.

This was overcome by the incorporation of a flow deflector in the feed system upstream of the point where vacuum is first applied, with the fish tails feeding into the deflector. Apart from ensuring the correct cake classification, this has also resulted in the elimination of spillage due to wave action.

Tests at Millsite

Construction at Millsite commenced in December 1975, and commissioning in April 1976. An initial fear of problems with the rubber-belt tracking proved to be unfounded; this went very smoothly with the individual belt-tracking rollers provided. However, serious problems were encountered with the dimensional stability of the filter cloths.

At that time no local suppliers were capable of weaving cloths as wide as 5 metres, and narrower rotary-filter cloths were therefore stitched together in three longitudinal sections. The stitching proved to be very difficult, resulting in unequal tension in the three sections. Typical cloth life for the first six months was 150 to 200 hours, and some cloths did not handle any pulp at all owing to shrinkage or stretching during the initial wetting. However, it was possible to conduct a number of reliability, as well as metallurgical performance, tests in the period between July and September, 1976.

As a test of metallurgical performance, the filter was operated in parallel with rotary filters on gold slurry.

The rotary-filter plant was run by the regular operating staff. Only four filters were run to allow an adequate feed to the belt filter. The estimated throughput on these was 70 t/h, which is equivalent to a duty of 6,4 t/m^2 per day.

The belt filter was run as shown in Fig. 2, and the throughput was measured as 77,1 t/h, or 15,4 t/m^2 per day. The corresponding figure for Randfontein ore on a 0,5 m^2 pilot-plant filter was 19 t/m^2 per day.

Potable water was used for washing, and precipitated gold solution for repulping.

The results of the first of these tests are shown in Table I.

After the first test, the filter was converted so that precipitated gold solution was used for washing as well as repulping, and was then put into production in parallel with the rotary filters. From that time solution recoveries of 99,8 per cent were continually achieved.

A cloth of full width achieved 860 hours, but had then shrunk to such an extent that slurry was bypassing the edge into the filtrate system. Apart from the shrinkage, the cloth was in good condition.

Adoption of Belt Filters

In view of the results obtained from the Millsite tests, a decision was taken to use belt filters on the Millsite plant, and at the new Cooke plant. At the latter they would be used both for the liquid–solids separation after uranium and gold leaching, and for the filtration of ammonium diuranate (ADU) slurry and precipitated gold slime in the smelthouse.

Table II lists the horizontal-belt filters at present in use in Randfontein's metallurgical plants.

All the Delkor filters work on the same principle, with a continuously moving rubber belt as previously described. The ADU filters are operated pneumatically in such a manner that a loose-lying filter cloth is moved intermittently while the vacuum is switched off, thus requiring very little drive power. During the vacuum-on period, the cloth is stationary, thus providing an excellent seal against air leaks. This

TABLE I

RECOVERY OF DISSOLVED GOLD (COMPARATIVE TEST)

			Au, g/t			
	sp. gr.	Solids %	Assay	Per ton of solids, gross	Net	Recovery %
Feed	1,426	47,5	15,35	16,992	16,992	100,0
Rotary residue	1,371	43,0	0,148	0,296	0,182	98,9
HBF residue	1,594	59,2	0,075	0,052	0,047	99,7

TABLE II

HORIZONTAL-BELT FILTERS AT PRESENT IN USE

Type	No.	Size m^2	Duty	Manufacturer
Millsite U-filter	1	120	Uranium slurry	Delkor Technik (Pty) Ltd
Millsite dewatering	2	35	Uranium slurry	Delkor Technik (Pty) Ltd
Cooke U-filter	4	120	Uranium slurry	Delkor Technik (Pty) Ltd
Cooke Au-filter	5	120	Gold slurry	Delkor Technik (Pty) Ltd
Gold slime	1	2	Precipitated gold slime	Delkor Technik (Pty) Ltd
ADU, Millsite	2	7,5	Yellow cake	Johnson-Progress, U.K.
ADU, Cooke	2	10	Yellow cake	Johnson-Progress, U.K.

results in a very good vacuum, which was considered essential in view of the sometimes difficult filtration characteristics of ADU slurry. The Randfontein product has proved to be very easy to filter so that the units are only utilized part of the time. The absence of blow-off makes the operation clean, little or no dust being emitted to the atmosphere.

Filter Operation at Millsite

After the 120 m^2 filters had been incorporated in the flowsheet of the uranium plant at Millsite, and two 35 m^2 dewatering units had been constructed, the plant was commissioned (starting in July 1977). Problems were still being experienced with filter-cloth life, although a local manufacturer was then in a position to supply cloths of full width. Experimentation is still in progress in an attempt to achieve the desired cloth life of 3000 hours. The longest life to date is about 1000 hours, and a considerable effort is being made to improve this. The problems are still associated with dimensional stability, but it has also become evident that fine silica particles embed themselves in the fibre, causing internal abrasion with subsequent weakening of the fabric. This is being overcome by the installation of sprays capable of penetrating the cloth and thus dislodging the embedded particles. This can be achieved either by the use of very high pressures in the regular fixed sprays or by the installation of oscillating-type sprays. The use of needlefelt cloth has lately led to a considerable improvement in cloth life, mainly due to improved dimensional stability.

A further problem encountered at Millsite was the rapid wear of the high-density polyethylene (HDPE) wear surfaces on the vacuum boxes, which failed after about three months of operation. A stainless-steel wear strip was fitted on top of the HDPE surface, and this vastly improved the wear resistance. Other suitable materials used include double-sintered ultra-high-density polyethylene.

Another major problem to date has been corrosion of the main filter frame at the discharge end, where, owing to the acidic sprays (pH 1,6), the steelwork is continuously damp. The original steelwork was epoxy-coated mild steel. The entire discharge frame had to be changed after nine months of operation for irathane-coated mild steel. However, for uranium duty, Millsite experience shows that stainless steel should be used whenever there is a risk of continuous acidic wetting.

It is also essential that, in areas where spray water is being used, proper enclosures are provided to contain the spray mist within the acid-proof environment.

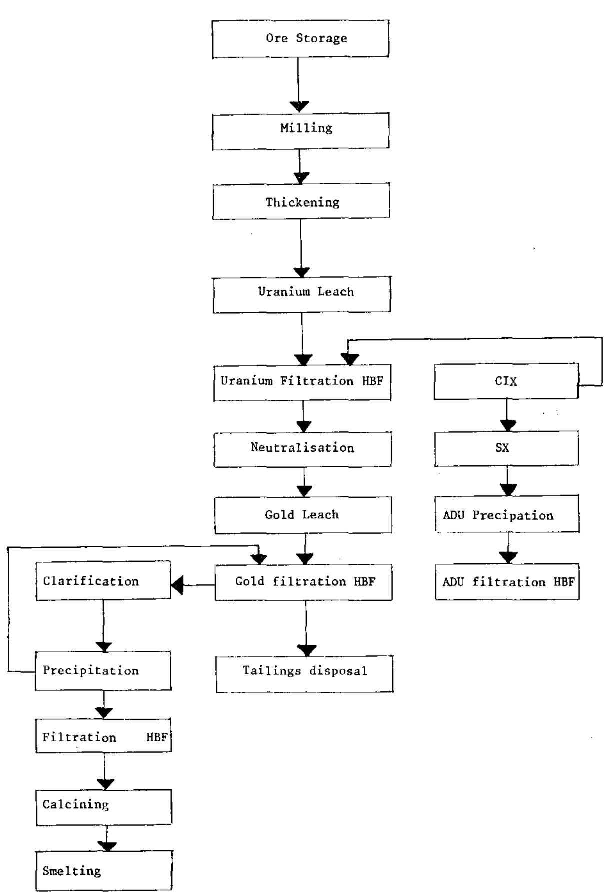

Fig. 3—Flowsheet at Cooke Plant

Filter Operation at Cooke Plant

The flowsheet at Cooke Plant is shown in Fig. 3.

Commissioning commenced in March 1978, and the problems encountered have been very similar to those at Millsite, although particular difficulties have been experienced with the hydraulic drives, which have caused several breakdowns. The problems proved to have been caused by a too rigid mounting of the hydraulic motor torque arm, and, since this was changed to a flexible mounting, the problem has been largely overcome. A larger motor has also been fitted to one side of the drive pulley to reduce the operating pressures in the hydraulic system.

A number of changes were made to the design of the filters compared with the filters in the test unit. Not all of these were entirely successful. Among these changes were a reduction in the number of cloth return rollers, which led to a sagging of the cloth and to the formation of pools of water. This water was shown to be the main cause of folding and creasing, and additional rollers, as in the Millsite design, were installed to alleviate this.

The filtration section is proving to be very maintenance-intensive, especially in the uranium section handling acid slurries and solutions. This is particularly true in respect of the engineering man-hours required, for the staff force must be able to keep the average availability above 85 per cent. With machines of such large unit capacity as 120 m^2, a short-term availability problem is created when two machines are off-line at the same time.

The operation of a single unit depends on many items of peripheral equipment such as repulper, filtrate pumps, spray-discharge nozzles, feed control, and cloth tracking. Routine maintenance is essential for these items, and unscheduled outage time is very much reduced if a regular programme of maintenance is followed.

In the treatment of the acid slurry, it has been found that the numerous bearings associated with the HBF

TABLE III

RESULTS FROM NO. 5 FILTER, COOKE PLANT

Date	Time	Cake	Belt speed	Production	Vacuum	Total ppt	Ppt as wash	Repulper	Total gold in res.	Total gold in res. soln	Total DG g/t of solids	Total gold in ppt	DG due to ppt g/t of solids	Total UG g/t of solids	Total due to filter g/t of solids
		mm	m/min	t/h	kPa	m³/h	m³/h	sp. gr.	g/t	g/t		g/t			
31.3	09h00	15	13,1	88	±62	96	±70			0,038					
31.3	10h00	14	13,1	82	±60	102	±75			0,034					
31.3	16h00	14,5	15,2	99	62	95	±70			0,032					
1.4	10h00	15	12,8	86	61	85	±60	1,540	0,26	0,029	0,023	0,008	0,002	0,0237	0,021
1.4	11h30	15,5	15,2	105	62	97	±70	1,637	0,25	0,033	0,020	0,013	0,004	0,230	0,016
3.4	10h00	13	14,5	84	56	94	±55	1,46	0,25	0,040	0,040	0,052	0,015	0,225	0,025
4.4	09h15	13	15,0	87	55	90	±50	1,56	0,28	0,065	0,049	0,041	0,012	0,243	0,037
4.4	11h15	14	15,0	94	53	90	±50	1,59	0,26	0,050	0,035	0,033	0,009	0,234	0,026
4.4	15h20	14	15,0	94	54	90	±50	1,62	0,26	0,051	0,033	0,012	0,003	0,230	0,030
		Average	x=	91										0,233	0,026
			s=	7,6										0,006	0,007

Summary

Date	Head grade g/t	Filter efficiency %
1.4	8,00	99,76
3.4–4.4	8,74	99,66

must receive considerable attention. Other items that require more maintenance than was expected are the vacuum seals and the wear belts. This aspect is aggravated by poor feed control, which results in spillage over the curbs and poor discharge. Proper discharge is also dependent on correct flocculant control and the condition of the spray nozzles. The curbing also leads to outages when the bonding with the main belt fails. It requires at least a six-hour shut-down to repair a curb.

Cloth life, as well as being a heavy maintenence-cost item, has contributed to the downtime. However, substantial progress is being made. The longer life of the needlefelt cloth now being used has reduced outage, and therefore downtime. At the same time, the increased life and less costly cloth are bringing about an overall reduction in running costs. However, the direct effects of corrosion continue to be a problem, and greater use of stainless steel would seem to be the long-term solution.

During the initial operation at Cooke Plant, solution recoveries were very erratic and not as good as those achieved during the Millsite testwork. This was certainly to some extent caused by the on–off nature of the operation during commissioning. However, once full production had been reached, these problems persisted, and recoveries of 98 per cent and less were reported.

One of the gold filters was set aside for testwork in an attempt to find the cause for the low recoveries. The first action taken was to set up the filter geometrically similar to the Millsite test filter, i.e. 18 per cent of the vacuum area for cake forming, 30 per cent for first wash, 37 per cent for second wash, and 15 per cent for drying. Grab samples had clearly indicated that a considerable leakage of solution took place between the various filtration zones, giving a theoretical floor value of the dissolved gold (DG) considerably higher than the precipitate (ppt) solution, in cases up to 15 times higher. It was therefore shown that, for maximum recoveries, the cake should be allowed a short drying zone between the filtration zones to ensure that no supernatant solution was being carried downstream. As a further safeguard, it is good practice to operate with increasingly higher solution levels towards the discharge end and so force any leakage to occur in the upstream direction.

The results of these controlled tests are given in Table III, which shows that the recoveries are very close to those obtained during the early Millsite tests.

These experiences indicate that excellent washing can be achieved on the filters in accordance with theoretical predictions, and that mal-operation may have very serious consequences. Thus, operators must be aware of procedures and controls not normally employed in a filter plant, such as the analysis of wash water *on* the filter and not simply of the incoming precipitate solution.

Conclusion

In somewhat less than two years, a total of seventeen horizontal-belt filters have been installed in Randfontein's metallurgical plants. This involved a very bold upscaling of the belt-filter idea, and led to a series of unexpected difficulties such as cloth shrinkage and torque problems. Problems were also associated with the proper operation of the units since standard operating procedures had to be established by experiment, and sometimes by trial and error, and this had to be done while maintaining production.

There is no doubt, however, that this pioneering effort has been worth while: with the correct operation and suitable cloths, exceptionally good metallurgical recoveries can be achieved at filtration rates two or three times higher than those on rotary filters.

Certain mechanical problems specifically related to the horizontal-belt filters will have to be overcome before a reliable metallurgical machine is achieved, but it can safely be expected that, as additional plants are installed and as experience is gained, the mine's metallurgists and engineers, together with the equipment manufacturers, will create a filtration apparatus that will serve metallurgical plants in the future as well, or better, than the rotary-drum filter has done in the past.

Acknowledgement

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Light metals

The programme of the 7th International Light Metal Congress (Leoben and Vienna, 22nd to 26th June, 1981) will cover the following groups of subjects: technical and economic perspectives for aluminium; environmental protection; energy; modern techniques in smelting, manufacturing, and recycling; materials; and physical metallurgy. The programme is devoted mainly to aluminium.

The organizers are the University for Mining and Metallurgy in Leoben, the Austrian Aluminium Industry, and the Austrian Metals Industry Association in cooperation with the Aluminium-Zentrale Düsseldorf.

Further information is available from the Aluminium-Zentrale e.V., Konigsallee 30, Postfach 1207, D-4000 Düsseldorf 1, West Germany.