RADIOMETRIC SORTING

The potential for the sorting of uranium ores displaying radiochemical equilibrium on the basis of natural gamma activity was recognized more than thirty years ago. During the 1950's a number of prototype machines were designed and several production machines installed on mines in North America. The world-wide reduction in uranium production and consumption during the 1960's encouraged the development of machines suitable for sorting other types of ore. Renewed activity in the uranium industry associated with increased interest in the generation of nuclear power led to the production of the Model 6 Radiometric Sorter. Anticipating further expansion of the industry, RTZ Ore Sorters committed itself to research into improved radiometric sorting techniques to permit the development of a machine that would overcome the limitations of previous models. The result of this research and development program was the design and production of the Model 17 Radiometric Sorter which, according to the manufacturer, is the best commercial equipment on the market today.

EQUIPMENT AND PRINCIPLE OF OPERATION

The Model 17, shown in Fig. 1 is a radiometric sorter that separates ores from waste by measurement of the natural gamma radiation, emitted by uranium ores. Designed as a multiple stream device it is available in configuration with five, four, three and two channels, depending on the size range of the material to be treated. The sorter is suitable for use in uranium mining operations in which significant quantities of run-of-mine material larger than 25 mm are available and in which the ore displays radio-chemical equilibrium.

In general, the bottom size limit is restricted to 25 mm, which is the minimum size at which particles emit levels of gamma radiation that permit effective sorting. However in certain applications where the uranium feed grade is relatively high, this can be reduced to 18 mm. The capacities of the various machines are given in Table 1.

Table 1. Feed size and capacity of Model 17 Sorter

Number of channels	Nominal size range of feed mm	Nominal capacity of machine t/h
2	-160 + 65	120
3	-125 + 50	110
4	- 90 + 40	75
5	- 65 + 25	40

The operation of the machine can be described by reference to its six basic sub-systems (Fig. 2):

- feed-preparation system
- feed-presentation system
- radiation-measurement system

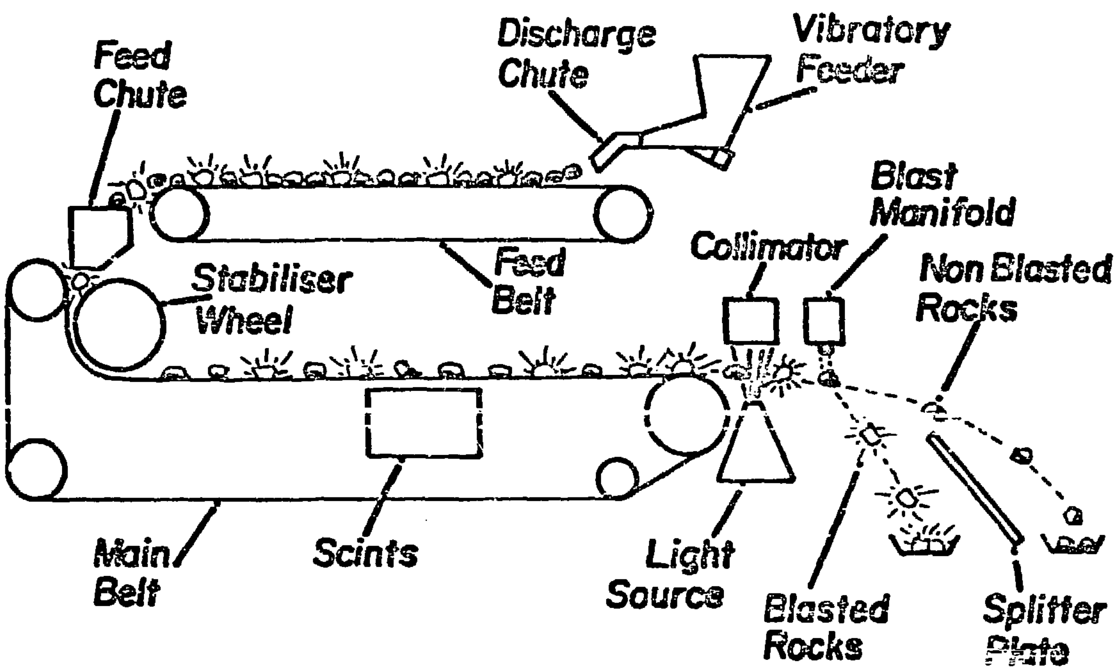

Figure I. MODEL 17 RADIOMETRIC ORE SORTER

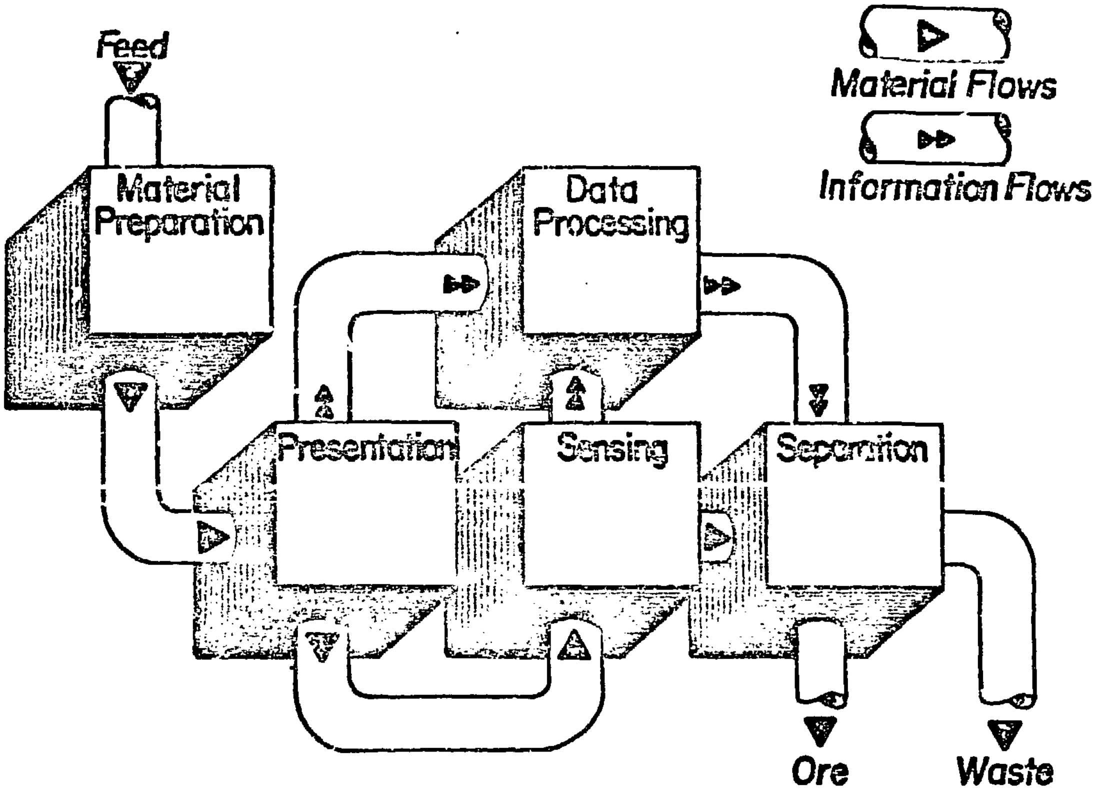

Figure 2 FLOW DIAGRAM OF THE MODEL 17 RADIOMETRIC ORE SOR

- data-processing system
- separation system
- controls and monitors

The Feed-Preparation System

A prerequisite for efficient sorting is the preparation of the feed material to allow optimum performance of the sorter functions. The ore is screened into size fractions as indicated in Table 1 and is washed to remove the fines, which could otherwise build up in the optical system, reducing the optical performance and could also build up in the radiation sensing zone and lead to an increase in background radiation. After screening and washing the material is delivered to the feed-presentation system.

Ideally, to give optimum sorter performance at maximum tonnage throughout, the sorter feed should be screened to within the recommended size ranges. However, it is possible, in some cases to increase the size range of the feed. While the sorter efficiency may not be significantly affected, the throughput can be dramatically reduced. For example, the feeding of material in the size range +40 - 160 mm through a two-channel machine would reduce the throughput to 90 t/h or less, particularly if the feed included significant quantities of material in the lower limits.

The Feed-Presentation System

Screened ore is fed from a large bin via vibrating feeders to channelizing chutes that guide the material to a channelized feed belt moving at 1.5 m/s. The material is transferred from the feed belt to the main belt via a stabilizer. During this transfer, the rocks are accelerated, spatially separated and stabilized on the main belt, which delivers them at a speed of 5 m/s to the radiation-detection zone for individual assessment of the gamma activity.

The Radiation-Measurement System

The stabilized streams of rocks are conveyed by the main belt over lead-shielded sodium iodide scintillometers located beneath the belt. The counts registered by the scintillometers for each rock are transmitted to the electronic processor, where they are summated and stored. Immediately downstream of the scintillometers, the rocks are projected into free flight and pass through an optical measuring zone where solid-state cameras determine their shape, channel position and cross-sectional areas. This information is transmitted to the processor.

It is said that the gamma-detection system is capable of detecting and sorting 25 mm-square mesh material with grades lower than 0.006% U_3O_8.

The Data-Processing System

Information obtained from the scintillometers and the optical-measurement system enables the electronic processor to provide a measure of counts per unit mass for each rock. This value is compared against pre-selected cut-off criteria and all rocks with a grade lower than the cut-off are rejected as waste. The separation system is then activated by the processor to deflect selected rocks from their free-flight trajectory. The option to deflect ore or waste is available to the operator, as best suits his needs. In addition, the processor provides the facility for the operator to adjust the U_3O_8 cut-off grade to meet the day-to-day requirements of the mine.

The Separation System

The separation system deflects rocks from their free-flight trajectory using high pressure air blasts. The system comprises of a manifold containing high-speed single-stage solenoid air-valves each of which is independently operable and responds to signals from the processor. These electronic signals cause the appropriate valves in the manifold to open in such a way that the air blast is tailored to match the shape and position of individual rocks in the stream. The selected rocks, diverted from their free-flight trajectory and the unblasted rocks diverge into two distinct streams of rock that are physically separated by a splitter-plate. The separated rocks are directed via two chutes to ore and waste conveyors.

Controls and Monitors

The control console and monitoring system of the Model 17 provide safety interlocks and, on a continuous basis, display the metallurgical performance and any failure conditions. The metallurgical information displayed includes the tonnage throughput, the percentage blasted and the feed, accept and reject grades. In addition to normal electrical interlocks, the equipment is protected and automatically stopped if unsafe conditions likely to damage the equipment occur.

APPLICATION

Radiometric sorters are currently operating in a number of installations, which, although differing substantially in their metallurgical applications, all sort on the basis of gamma emission. All the existing operations can be classified into four types of processes according to their functions.

Sorting of Uranium Ore

Run-of-mine material is separated into two fractions, namely, ore and waste. The ore fraction is milled for uranium extraction, and the waste is rejected direct to a dump. Mary Kathleen Uranium in Australia and West Rand Consolidated Mines in South Africa are two typical examples of this application. The latter however, should be treated as a special case, because although it is considered to be a primary uranium producer, it produces gold as a byproduct.

In 1979, Mary Kathleen Uranium installed two two-channel Model 17's to supplement the old Model 3 machines and to sort all the material between 40 and 150 mm. The Model 3's were retained to sort only the rocks larger than 150 mm. The accept portions from all the models are now combined and returned to the main plant for further treatment. The reject portions from all the models are also combined, and are conveyed to the waste dump. Each Model 17 is fed at the rate of 70 t/h, and each Model 3 at 20 t/h.

Sorting of Gold Ore

In certain South African gold deposits, gold is found in close association with uranium. Advantage is taken of this association, and the gamma emission from the uranium is used as a tracer to indicate the precence of gold. Feed to the sorting machines is separated into two fractions: gold-uranium ore, and waste. The waste is rejected direct to a dump, and the ore fraction subsequently milled and leached. The preselected sorting criteria are adjusted to ensure an acceptably low gold value in the reject. The viability of this type of sort depends on the correlation between gold and uranium, since any particle that contains economically extractable gold must also contain detectable quantities of uranium. Examples of the sorting of gold ore from waste are found at the Western Deep Levels and Vaal Reefs Gold Mines in the West Witwatersrand and Klerksdorp goldfields of South Africa.

The radiometric sorting plant at Vaal Reefs No. 3 shaft was installed in 1980 in a field assessment to study the feasibility of sorting ore from the Carbon Leader (Vaal Reef) mined from all shafts on the complex. Material in the size range between 65 and 115 mm is drawn from the existing screening circuit after being washed and sized to remove slimes and all rock smaller than 65 mm. It is then elevated to the sorter surge bin, where rocks are drawn at a controlled rate by an electromagnetic vibrating feeder and transferred to a second feeder, which presents an evenly distributed feed to the three-channel sorter.

Initially, the plant was operated in closed circuit, and the accept and reject fractions were recombined after sampling. It was intended that the initial system should be used until a full metallurgical investigation had been completed. However, the performance of the machine was such that, after a two-month trial, the mine elected to put the sorter into production. Accept material is routed to the metallurgical-treatment plants for the recovery of the gold and uranium, and the reject material is deposited as waste. The results of the first three months of open-circuit operations are shown in Table 2.

Table 2: Average of three months open-circuit operation (March to May 1981, inclusive), Vaal Reef, S.A.

Material	Total production t	Split % (by mass)	Gold grade g/t	Gold distribution kg/t	Uranium grade kg/t	Uranium distribution %
Feed	8136	100	2.40*	100	0.125*	100
Accept	4358	53.6	4.25	94.7	0.220	93.9
Reject	3778	46.4	0.28	5.3	0.017	6.1

Total sorting time: 260 h
*Calculated feed grade

Since the completion of the installation, the machine availability has been 97.2 per cent. The 2.8 per cent downtime is the result of optics cleaning, compressor failure and camera alignment.

Figures for operating costs are not currently available.

Sorting of High-Grade Ore

In this application, the metallurgical aim is to split run-of-mine material in such a way that a small proportion is separated as high-grade material containing the majority of the valuable mineral's, and the balance as low-grade product. Both fractions are subsequently milled and treated in separate circuits. At Free State Saaiplaas and Welkom Gold Mines in South Africa, the high-grade material contains gold and economically extractable uranium, and the low-grade material is treated only for gold.

At both these mines, the uranium grade in the size ranges of the sorter feed is too low to warrant economic extraction, and it is the revenue attributable to the uranium extracted from the sorter high-grade fraction that justified the initial capital expenditure.

During 1980, a four-channel machine was installed at Welkom Gold Mine to effect a split between high-grade and low-grade material in the size range 50 to 75 mm. Before the commissioning of the sorter, the source of feed for the high-grade circuit was generated exclusively by the screening of run-of-mine material at 6 mm, with the undersize reporting to the high-grade material and the oversize reporting to the low-grade. In subsequent milling, pebbles in the low-grade fraction between 50 and 75 mm were selected by screening for use as a grinding medium in both circuits. In effect, as the source of the grinding medium was the low-grade circuit, the pebbles diluted the high-grade slimes. The sorter was installed to produce high-grade pebbles for use in the high-grade circuit and so increase the overall recovery and production of uranium.

A summary of results for the first six months of sorter operation are shown in Table 3.

Table 3: Summary of first six months of operation at Welkom Gold Mine, S.A.

Material	Production t/m	Split % (by mass)	U_3O_8 grade kg/t	Gold grade g/t
Feed	21820	100	0.074	3.40
High-grade pebbles	3110	14.3	0.338	15.20
Low-grade pebbles	18710	85.7	0.030	1.44

The machine availability in the first six months of operation was 96.2 per cent. Operating costs in the same period were 19 South African cents per ton of feed and the figure quoted covers power, operating staff, maintenance, spares, compressed air, etc. The consumption of spares has so far been minimal, but it is expected that costs will increase to between 22 and 25 cents per ton of feed as the plant maintenance costs increase with time.

Sorting of Dump Material

The radiometric ore sorter is utilized to recover. from an otherwise uneconomic source such as a waste dump, and accept fraction of sufficient mineralization to warrant subsequent treatment.

In North America, a Model 17 reprocessed several low-value uranium dumps, producing an economically viable accept fraction. Since the dumps were scattered over a wide area, a mobile unit was constructed that was moved from site to site as each waste dump was reprocessed. The sorter, with associated control and feeding equipment mounted on low-bed trailers, was towed from one site to the next without being dismantled. This was the first fully mobile Model 17 unit.

Currently a number of waste dumps on South African gold mines are being tested to ascertain whether it is economically feasible to produce a low-mass accept fraction that could be leached for gold from rock that would otherwise be considered only as waste. This technique relies to a large extent on a good correlation between gold and uranium.

A list of radiometric sorter installations is given in Table 4.

Table 4: Radiometric sorter installations
October 1981

Machine Type	Customer	Location	Number of Machines	Status
6B	Cotter Corp.	Colorado	2	Operational
M17	Western Deep Levels	R.S.A.	5	Operational
M17	West Rand Consolidated (General Mining)	R.S.A.	2	Operational
M17	Mary Kathleen	Australia	2	Operational
M17	Welkom	R.S.A.	1	Operational
M17	F.A.S. Saaiplaas	R.S.A.	1	Operational
M17	Vaal Reefs	R.S.A.	1	Operational