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ELECTRONIC CONCENTRATION OF ORES WITH THE LAPOINTE PICKER BELT

by

C. M. Lapointe and R. D. Wilmot
RADIOACTIVITY DIVISION

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ELECTRONIC CONCENTRATION OF RADIOACTIVE ORES WITH THE LAPOINTE PICKER BELT *

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INTRODUCTION

A picker belt system for the concentration of radioactive ores by electromechanical means was invented in 1946 at the Mines Branch laboratories in Ottawa by C.M. Lapointe, and in the work to date, has been referred to as the Lapointe Picker. In addition to laboratory and pilot plant tests the system has been operated on full plant scale at Port Radium and at Port Hope(1) for the grading up of jig concentrates.

Sized rock is carried on a belt under a detector of radioactivity where an electronic device operates to separate ore from waste. As in gravity or heavy media concentration, the uranium minerals must be reasonably free but the automatic picker is not affected by lack of gravity differential of the ore constituents.

In 1947 a pilot plant to treat minus 2½" ore was installed in the field and in 1948 this plant was modified to treat ore in sizes up to 12".

Depending upon the type of ore, the system permits the discard of from 40 to 60 per cent of mine ore, with uranium losses as low as four per cent, thus allowing a potential major reduction in the capital outlay and operating costs involved in subsequent processes.

The belt may be applied to any ore containing uranium sufficiently segregated to make mechanical separation from barren rock feasible.

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* The rights to the Lapointe Picker Belt are covered by Canadian patent No. 467482, British Patent No. 658574, and United States Patent No. 2617526, all of which are assigned to Eldorado Mining and Refining Limited.

(1) L.A. Kaufman, Radiogenic Concentration of Uranium Ores, C.I.M. Trans. 53/301-4, 1950.

The type of ore which can be treated most readily by the picker belt comes from deposits containing uranium in narrow veins or small pockets separated by barren rock and so spaced that selective mining is not possible. Pitchblende deposits are often of this nature.

The most suitable size range for ore to be treated on the belt is -10 + 1 3/8 inches. Thus, for most ores, only the + 10 inch fraction need be crushed. Treatment of ore finer than 1 3/8 inches is generally impractical because of reduced belt capacities and higher reject assays. The chief factor in determining the fraction of the mined ore which can be treated by picker belts is the size-weight distribution of the mined ore. Although dependent upon the friability of the ore and upon mining methods, generally 60 to 70 per cent of the mine production could be obtained in the + 1 3/8 sizes by suitable arrangement of the crushing facilities.

As 70 to 90 per cent of the treated ore can be rejected, only 40 to 60 per cent of the mined tonnage, including the - 1 3/8 inch fraction will be left for subsequent treatment.

A second application of the picker belt is to scalp off a shipping grade concentrate leaving the remaining ore to be retreated by another electronic picker and/or some other process.

Alternatively, when waste rock is visually distinguishable from ore, the belt may be used in conjunction with hand cobbing methods in which barren pieces are removed by hand from the mill feed and fed to the picker belt. Hand sorters are thus able to remove more waste ore with the assurance that any active pieces will be detected and returned to the mill circuit. Although only semi-automatic in operation, this method has the advantage in that it eliminates the need for sizing the mill feed which consequently can be handled on one belt.

An auxiliary belt feeder for the picker belt can also be eliminated as the waste rock is merely thrown down a chute feeding the picker belt.

Part I of this report describes the application of the picker belt to the concentration of radioactive ores and its overall performance. Part 2 deals with the electrical components of the system.

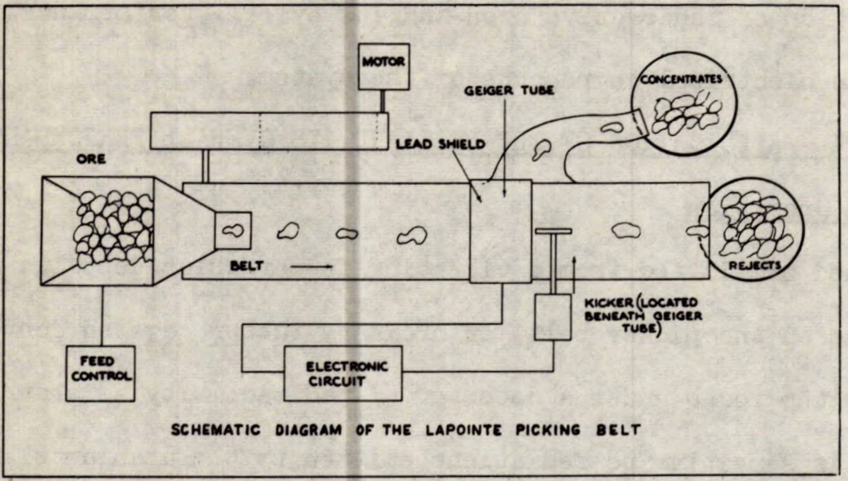
PART I - APPLICATION OF THE BELT AND ITS OVERALL PERFORMANCE

Equipment and Operation

Sized ore is fed from a vibrating feeder which deposits individual pieces in line on the picker belt, an ordinary rubber covered conveyor belt which carries the rocks under a detector of radioactivity as shown in Figure 1. The detector is sensitive to radiations emitted by the uranium elements and utilizes the natural radioactivity of individual ore pieces to separate them from waste rock. Sufficiently active pieces actuate an electronic circuit which operates a kicker or chute-gate at the end of the belt and diverts uranium-bearing rock for further treatment.

As there may be a variation of more than 200 to 1 in uranium content between individual pieces of active rocks, high grade pieces would influence the detector before they were directly under it. Hence, not only the active rock but the piece ahead of it, whether active or not, would be diverted into the concentrate chute. This limitation is remedied by placing a low sensitivity gamma detector and associated picker ahead of the high sensitivity unit. The high grade concentrate from the first picker is then combined with the low grade concentrate or middlings from the second unit for mill treatment.

When the head assay is less than 0.5 per cent U_3O_8 the first detector unit can usually be omitted as it is unlikely that such ore would contain a sufficient number of pieces above 6 per cent U_3O_8 to necessitate a two stage picker belt.



SKETCH A

Fig. 1 - Operating principle of picker circuit.

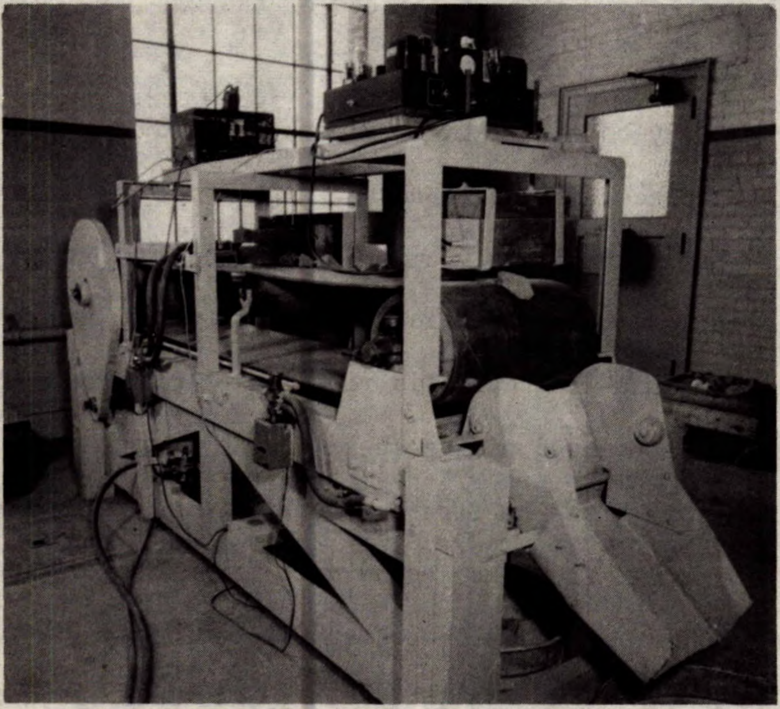


Fig. 2 - End view of two stage picker, experimental model.

Details of the experimental picker belt may be seen in Figure 2 which shows the experimental model of the two stage picker belt. The gamma-sensitive unit for removing high grade may be seen at the far end where ore is fed to the belt. The electronic circuits are directly above the lead shields housing the detector. In practice these would be some distance from the belt. In the experimental picker, the two shields were suspended by threaded rods for ready adjustment of the clearance between them and the feed. Below the first lead shield may be seen the piston operated ram which pushes high grade pieces across the belt into the high grade chute at the right. The double acting piston is operated by compressed air at 15 p.s.i., from the air valve(1) pictured at the left and controlled by the electronic circuit.

In a similar fashion, the high sensitivity picker unit at the right operates a piston controlled selector gate which diverts moderately active pieces into a chute under the belt. In its normal position the gate allows waste rock to drop into the end chute.

Radiation detector

Although the sensitivity of the picker is ultimately dependent upon the sensitivity of the radiation detector, the magnitude of the "background" unavoidably present in the detector determines the lowest grade of ore which may be selected from the picker feed.

For maximum sensitivity, experience has shown that a well shielded, beta-sensitive Geiger tube, preferably of the end window type, is most satisfactory for detecting low grade ore.

(1) Model No. SV254 Cowan Goodridge Standard Company, Montreal, Quebec.

To avoid premature triggering of the kicker by high grade ore, removal of such ore may be necessary by means of a preliminary picker using a gamma-sensitive Geiger tube detector of relatively low efficiency.

Size of ore

High sensitivity is achieved by keeping the distance between the radiation detector and the rock surface as short as possible. Hence there is need for fairly close sizing of the picker feed. Suitable sizes are (+ 5"), (-5" + 3 1/2"), (-3 1/2" + 2 1/2"), (2 1/2" + 1 3/4"), and possibly (- 1 3/4" + 1"). The potential increase in uranium content of rocks in the + 5" fraction compensates for discrepancies in height which may occur in the unsized feed. More efficient operation results from using slotted rather than square mesh screens, as wide, flat slabs will pass through to be included in the smaller sized groups. A water spray should be used during the screening operation to remove uranium-bearing fines which cover mine ore.

For the same average grade the uranium content of individual rocks varies directly with their mass. Hence, larger tonnages and, in general, higher recoveries will result from treatment of the larger sizes. Picker belt treatment of sizes finer than 1 1/4" - 1 1/2" is generally impractical because of the large number of belts required to handle the smaller sizes.

Spacing and alignment of the feed

Picker efficiency is improved by a feeder system which ensures relatively uniform spacing between the pieces. If this spacing is too large, belt capacity is wasted, and if too close, dilution of the concentrate will result. The distance between the selector gate at the end of the belt and its detector unit is also a limiting factor in the spacing between rocks because the circuit is insensitive from the time the activity is detected until the selector gate has operated. A spacing of seven inches for the belt pictured in Figure 2 was found to be the minimum spacing consistent with these requirements. In addition, the geometry of the detector unit requires the ore pieces to pass through it in a fixed path for maximum detector efficiency and minimum equipment requirements. The positioning of the ore pieces may be done either by passing them through trough-shaped vibrating feeders, or by use of an intermediate belt with a number of aligning guides. These systems have been tested on the -2 inch and -5 inch sizes respectively and they could be scaled up to handle the larger sizes.

Belt speed

The decreased mass of the smaller sizes may be compensated for by a longer exposure to the detector. Hence, the smaller the size, the slower must be the belt speed and the less the picker capacity. A belt speed of 30 feet per minute is suitable for treating the - 4 + 1 1/2" range while faster speeds may be used with the + 4" sizes. Still higher speeds of about 60 feet per minute, are practical for scalping off high grade ore.

Tonnage rates

The following are pilot plant results for ore sizes from - 5 to + 1 inches at a belt speed of 30 feet per minute.

Size	Tons per hour per belt
- 5" + 3 1/2"	2.03
- 3 1/2" + 2 1/2"	1.57
- 2 1/2" + 1 3/4"	0.56
- 1 3/4" + 1"	0.31

The belt capacity drops sharply for ore sizes under 1". Figures below are for belt speeds of 20 and 15 feet per minute for the - 1 + 1/2 and - 1/2 + 1/4 inch sizes, respectively.

Size	Tons per hour per belt
- 1" + 3/4"	0.11
- 3/4" + 1/2"	0.074
- 1/2" + 3/8"	0.025
- 3/8" + 1/4"	0.01

The drop in capacity in treating the smaller sizes makes treatment of the minus one-inch fraction on a large scale impractical.

The number of picker belts required depends on the daily tonnage and ore size distribution. One may be guided by the following belt requirements for a mill treating 200 tons a day, the ore size distribution being typical of a representative ore.

Table 1

Picker belt requirements for a 200-ton plant

Ore Size	Tons/24 hrs.	Capacity, Tons/belt Tons/hr.	Tons/12 hrs.	No. of belts required
-6" + 4 "	11.0	5.05	60.6	0.18 or 0 belts(1)
-4" + 3 "	50.0	2.35	28.2	1.77 or 2 belts installed
-3" + 2 "	35.4	0.90	10.8	3.25 or 4 belts installed
-2" + 1 3/8"	19.0	0.31	3.72	5.1 or 5 belts installed
-1 3/8" + 1"	18.8	0.10	1.20	15.7 or 16 belts installed
-1"	65.4	Not treated on picker belt		
				Total 27 belts

(1) Crush + 4 inch ore to - 4 inch.

As indicated in Table 1 the required number of belts could be more than halved by treating sizes above 1 3/8". This may be the smallest size that could be treated economically in mills except under special circumstances.

Tables of calculated hourly tonnages for the various size groups and spacings are included in Appendix 1. Agreement with actual mill tonnages has been remarkably close.

A schematic flow sheet illustrating the handling of ore by picker belts is shown in Figure 3.

Typical Results of Test Work on Uranium Ores

Extensive pilot plant test work has been carried out in the field (Ore A) and at the Mines Branch on ores from other areas (Ores B and C). Typical results were as follows:

Table 2
Treatment of -5 + 1 inch(Ore A)

Product	Per cent weight	Per cent U_3O_8 assay	Content	Per cent distribution
Undersize (-1")	46.8	0.83	0.39	52.8
Picker conc.	11.3	2.88	0.33	44.2
Picker reject	41.9	0.05	0.02	3.0
Head	100.0	0.74	0.74	100.0

In the above test, ore was treated in the following size ranges: (-5" + 2 1/2"), (-2 1/2" + 1 3/4") and (-1 3/4" + 1"). The +5" fraction was crushed to -5".

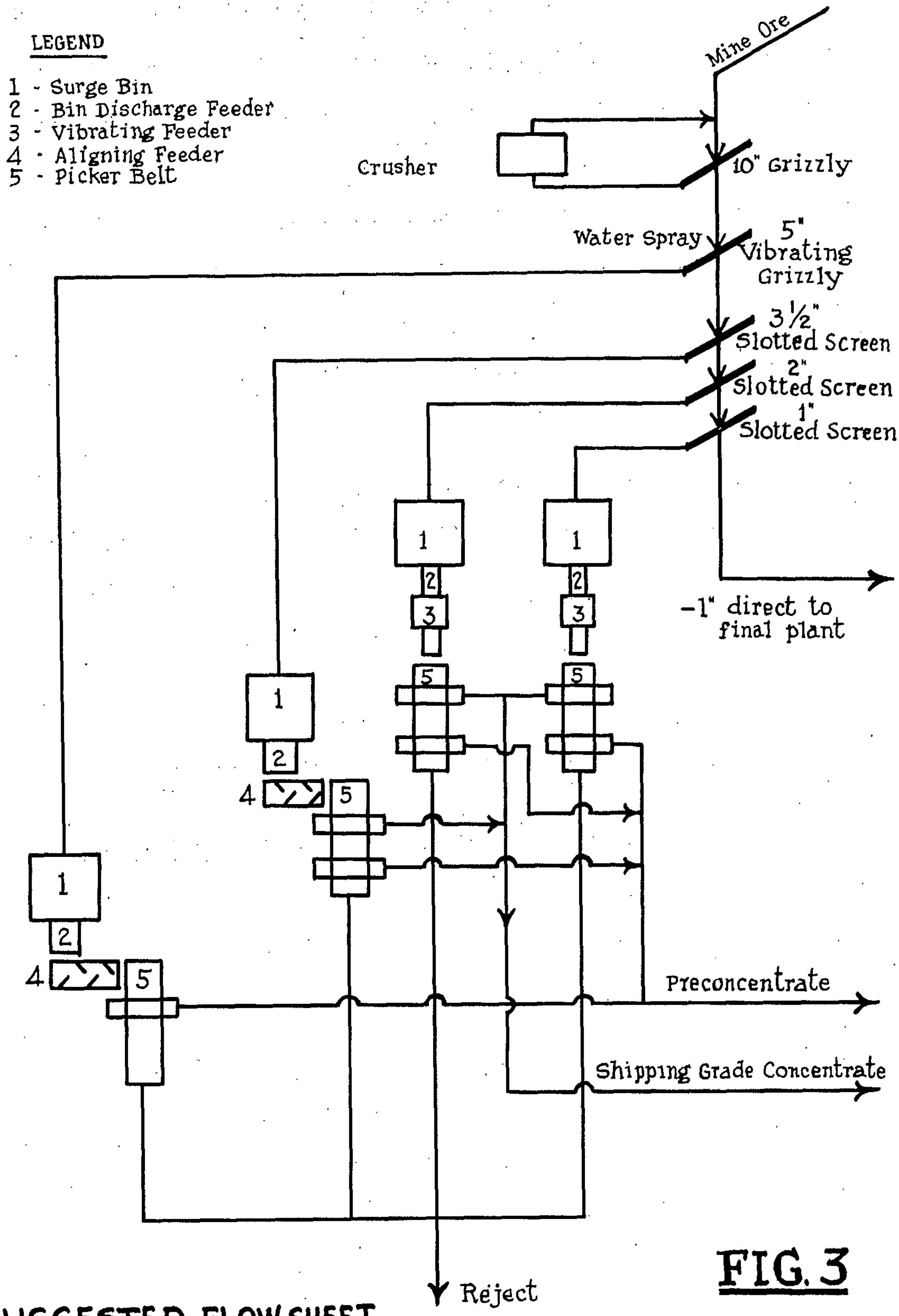


FIG. 3

SUGGESTED FLOW SHEET FOR PICKER BELT TREATMENT OF MINE ORE

Table 3

Treatment of Ore A in the 1" to 12" size range

Size, inches	Per cent weight	Per cent U_3O_8	Content	Per cent distribution
Concentrate				
-1 3/4 + 1	2.3	4.05	0.093	12.2
-2 1/2 + 1 3/4	2.1	1.90	0.040	5.3
-3 1/2 + 2 1/2	3.2	2.52	0.081	10.7
-5 + 3 1/2	1.0	2.35	0.024	3.2
-12 + 5	2.3	14.50	0.334	44.0
Total	10.9	5.25	0.572	75.4
Reject				
-1 3/4 + 1	11.9	0.117	0.014	1.8
-2 1/2 + 1 3/4	10.0	0.04	0.004	0.5
-3 1/2 + 2 1/2	12.0	0.06	0.007	0.9
-5 + 3 1/2	4.3	0.03	0.001	0.1
-12 + 5	13.5	0.02	0.003	0.4
Total	51.7	0.056	0.029	3.7
Fines (untreated by picker belt)				
Sands	2.5	0.35	0.009	1.2
-1" Fines	34.9	0.43	0.150	19.7
Total	37.4	0.425	0.159	20.9

Table 4

Summary of Table 3

Product	Per cent weight	Per cent U_3O_8	Content	Per cent distribution
Fines (-1")	37.4	0.425	0.159	20.9
Concentrate	10.9	5.25	0.572	75.4
Reject	51.7	0.056	0.029	3.7
Head	100.0	0.76	0.760	100.0

Table 5

Picker belt treatment of Ore B in four size ranges from -4" to + 1 3/8"

Size range	Product	Per cent weight		Per cent U_3O_8 assay	Per cent distribution of U_3O_8		
		Within size range	Overall		Conc. plus Middling	In size	Overall
-4" + 3"	Conc.	10.6	3.24	4.18)	95.9	85.3	21.07
	Middling	12.4	3.78	0.43)		10.6	2.62
	Rejects	77.0	23.48	0.028		4.1	1.01
		100.0	30.50	0.52		100.0	24.70
-3" + 2"	Conc.	4.8	0.85	6.02)	96.4	74.0	8.07
	Middling	8.1	1.43	1.07)		22.4	2.44
	Rejects	87.1	15.42	0.016		3.6	0.39
		100.0	17.70	0.38		100.0	10.90
-2" + 1 3/8"	Conc.	5.1	0.48	12.2)	97.3	91.9	9.19
	Middling	10.5	1.00	0.35)		5.4	0.54
	Rejects	84.4	8.02	0.022		2.7	0.27
		100.0	9.50	0.67		100.0	10.00
-1 3/8" + 1"	Conc.	6.6	0.62	12.8)	96.2	92.7	12.42
	Middling	5.6	0.53	0.57)		3.5	0.47
	Rejects	88.0	8.25	0.042		3.8	0.51
		100.0	9.40	0.91		100.0	13.40
Fines -1"	(Untreated)	100.0	32.90	0.80		100.0	41.00
Mine ore			100.00	0.66			100.00

In Table 5 the treated ore rejected totalled 82.3 per cent corresponding to a rejection of 55.2 per cent of the mine ore. The waste rock rejected assayed 0.026 per cent U_3O_8 and the loss of uranium was 3.8 per cent of the treated ore content or 2.25 per cent of the mine ore.

The ore available for further concentration would assay 1.40 per cent U_3O_8.

The results are summarized as follows:

Table 6

Condensation of data from Table 5

Product	Per cent weight	Per cent U_3O_8 assay	Per cent distribution
Concentrate	5.19	6.26	50.80
Middling	6.74	0.56	5.95
Reject	55.17	0.026	2.25
Untreated (-1")	32.90	0.80	41.00
	100.00	0.64	100.00
Preconcentrate for further treatment	44.83	1.40	97.75

Other tests indicated that a considerable amount of pitchblende concentrates of marketable grade could be produced by reducing the + 2" concentrate to a minus 2" and retreating on the electronic sorting belt.

Treatment of a Weathered Ore Not Amenable to Gravity Concentration

The efficiency of the picker belt in concentrating ore in which the uranium was too dispersed and too weathered for gravity separation, is illustrated in Table 7.

Only - 1" + 3/4" size range is shown since the ore as received, Ore C, was unfortunately crushed to - 1". Normally the size range treated on the picker belt would be all + 1".

Table 7

Treatment of Ore C

Product	Per cent weight	Assay per cent U_3O_8	Per cent distribution U_3O_8
Concentrate	4.96	1.12	33.5
Middling	18.30	0.47	52.5
Reject	76.74	0.030	14.0
Size - 1" + 3/4"	100.00	0.164	100.0
Preconcentrate for further treatment	23.26	0.60	86.0

Assuming a normal size-weight distribution in crushing this ore to - 6", i.e. about 30 per cent in - 1 1/2" fines, about 50 per cent of the mined ore could be rejected by treating the + 1 1/2" fraction on the picker belt.

PART 2 - ELECTRICAL CIRCUITS FOR THE LAPOINTE PICKER BELT

The electronic system responds to the radiation emitted by the ore passing under the detector and transforms the resulting electrical pulses into an impulse large enough to actuate the mechanical kicker or selector gate. Its main components consist of the radiation detector, i.e. a Geiger tube in the present system, an amplifying and pulse forming circuit, and the power system for operating the removal mechanism. These are shown schematically in Figure 4.

In all cases, reliability and simplicity are primary considerations. Circuit performance may be evaluated by simple tests but overall picker effectiveness is largely dependent upon the dispersion of the activity in the feed.

Associated regulated voltage supplies operate from a 110-volt 60 cycle source.

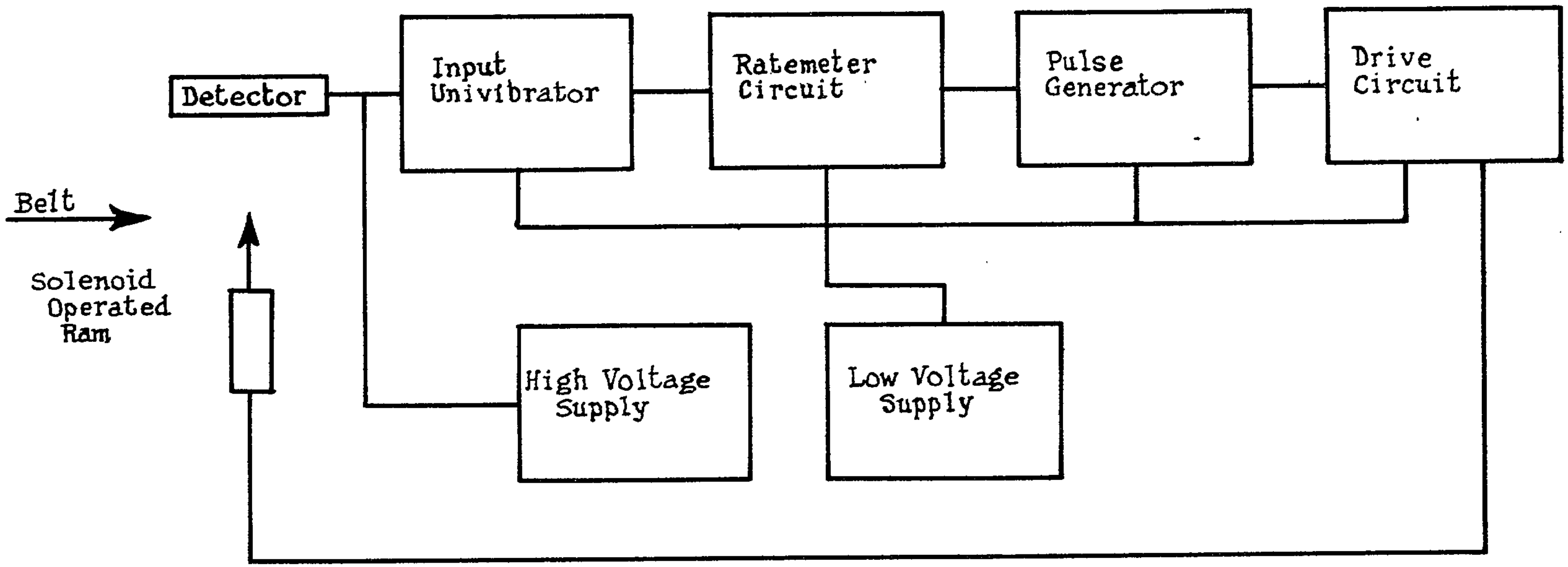


FIG. 4 BLOCK DIAGRAM OF PICKER CIRCUIT

Design Considerations

Type of radiation and detector

Of the three types of radiation from uranium ore, only beta and gamma rays have sufficient power of penetration to be useful indicators of the presence of radioactivity. Gamma rays are not greatly attenuated by several inches of rock whereas the most energetic beta ray from uranium ore is absorbed by approximately half an inch of rock. However, as beta-sensitive Geiger detectors are three to four times as efficient as the best gamma ray detectors of comparable geometry, the former are useful for detecting small amounts of activity which may be present in ore sizes under one inch. They are also used for the detection of weakly active rocks up to eight inches in size.

Both scintillation and gamma-sensitive Geiger tubes are suitable detectors for ore of higher radioactive content but the latter are preferable here because of adequate sensitivity, simpler associated circuits, and low replacement cost.

Exposure

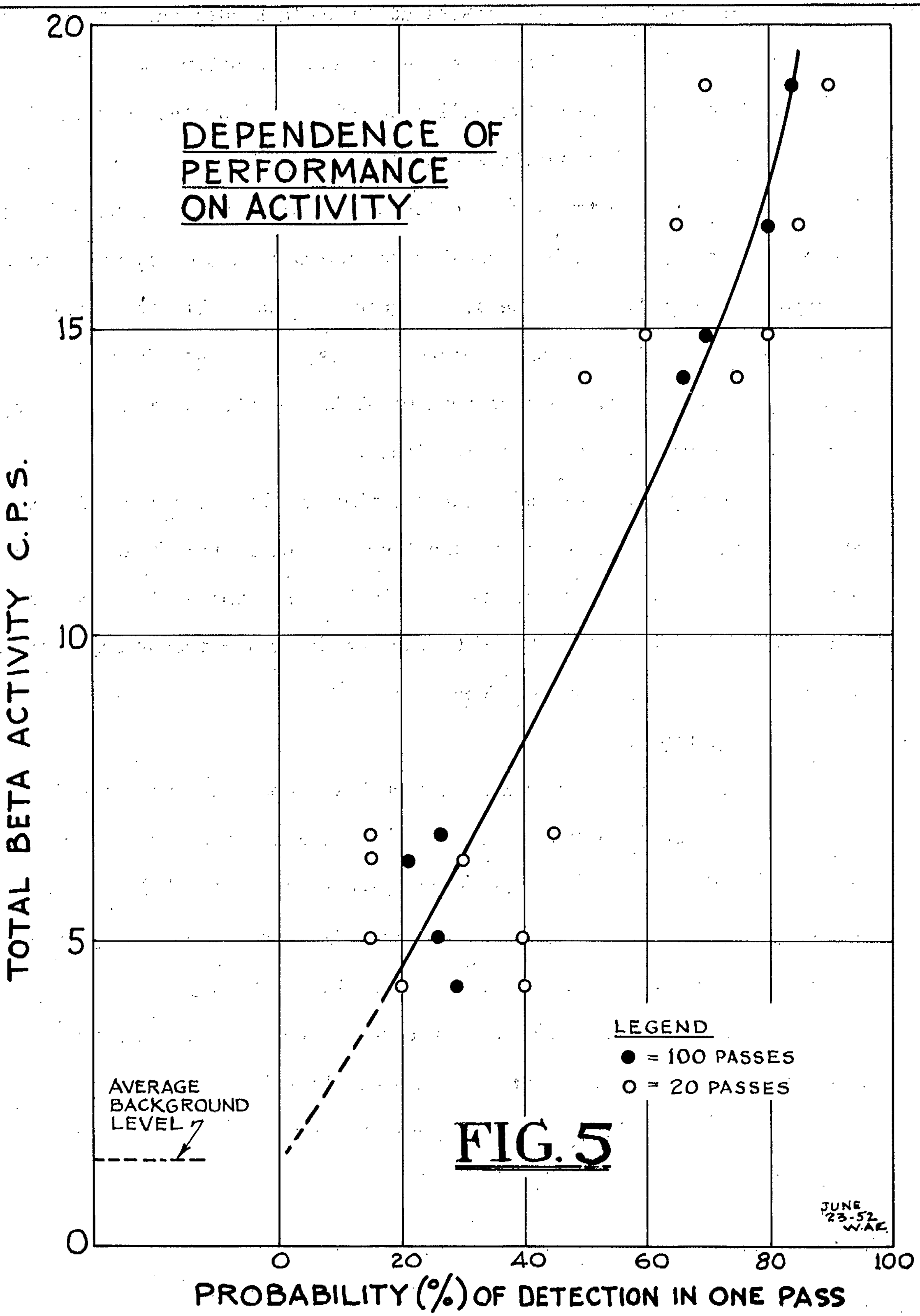
It is convenient to define the exposure of an individual piece of ore to the detector as the product of the time taken for a point on the piece to pass through the angle of vision of the detector, and the total area viewed by the detector. The exposure thus depends on the belt speed, the size of rock, the height of detector above the belt, the configuration of the viewing slit, and the distance from the detector to the slit. The latter two should be adjusted to prevent approaching high grade ore from operating the removal mechanism prematurely but to allow ample viewing time for the lower grades.

In practice, a belt installation would handle only one size of ore so that all but the first of these factors are determined. Belt speed, and hence its capacity, will then be limited by the sensitivity of the detector which determines the minimum exposure necessary to detect low grade pieces. In treating the larger ore sizes the operating period of the selector gate which is usually one third of a second, will impose an upper limit on the belt speed. In general, the smaller the size of the feed, the greater the number of barren pieces, and if the feed is low grade and spotty it may be more economical to operate at higher belt speeds even if the occasional middling is missed.

It might be well to point out that in the foregoing definition of exposure, it is convenient to consider the total area of an individual piece as that seen by the detector. Actually only the radioactive areas are effective in operating the detector but these are proportional to the ore size for a given grade of feed.

Removal mechanism

Two types of removal mechanism have been used successfully to date. The earlier electro-magnetic picker utilizes a blade placed directly under the detector to sweep active ore pieces across the belt into a concentrate chute. The width of the blade is made approximately equal to the spacing between individual ore pieces which may vary from one to eight inches, depending upon the size of the feed. However, for a given size of feed the detector may view a portion of the belt up to four times the width of the picker blade, so that premature or late triggering is possible.



DEPENDENCE OF PERFORMANCE ON ACTIVITY

FIG. 5

The two stage picker belt was developed to offset the effect of premature viewing, since high grade ore is removed in the first stage by the use of a low sensitivity gamma detector before it can affect the high sensitivity unit.

The second type of removal mechanism is a plunger operated selector gate at the end of the belt. In its normal position waste ore is channelled into the reject chute, while more active pieces cause the horizontally hinged gate to open and are deflected by it into a second chute. This gate can handle all sizes including 10-inch ore, the largest so far treated in the picker. The gate is operated by a double acting air piston, controlled by a two way, solenoid operated, air valve. About six line cycles are necessary to operate the solenoid but, as the detector unit sees the rock before it has dropped into the selector gate, the pulse to the solenoid must be delayed by about one-fifth of a second to permit the previous rock to be disposed of. Hence, the output pulse from the last picker circuit must be at least 18 line cycles in duration for satisfactory operation of the two stage picker described in Part 1 of this report.

Circuit Description and Operation

The detector is a beta-sensitive Geiger tube with a maximum wall thickness of 30 mg/cm^2. Both the six inch cylindrical(1) and the 1.8 inch diameter end-on(2) variety have been used successfully as high sensitivity detectors. In the two stage picker the first detector is a gamma-sensitive tube(3) while a beta tube is used near the end of the belt as the high sensitivity detector.

(1) Such as Anton Type 108 or Victoreen 1B85.
(2) Such as Anton Type 1001 H.
(3) Such as Ballantine Type C6E10, 4" long, 1" diameter, brass type.

Output pulses from both types of detector are similar in shape although the amplitude depends on the overvoltage applied to the Geiger tube. When operated about 70 volts above threshold and with a 250 mmfd. coupling condenser, the Geiger tubes will produce a 10 microsecond negative pulse of approximately 1/4 volt at the input grid.

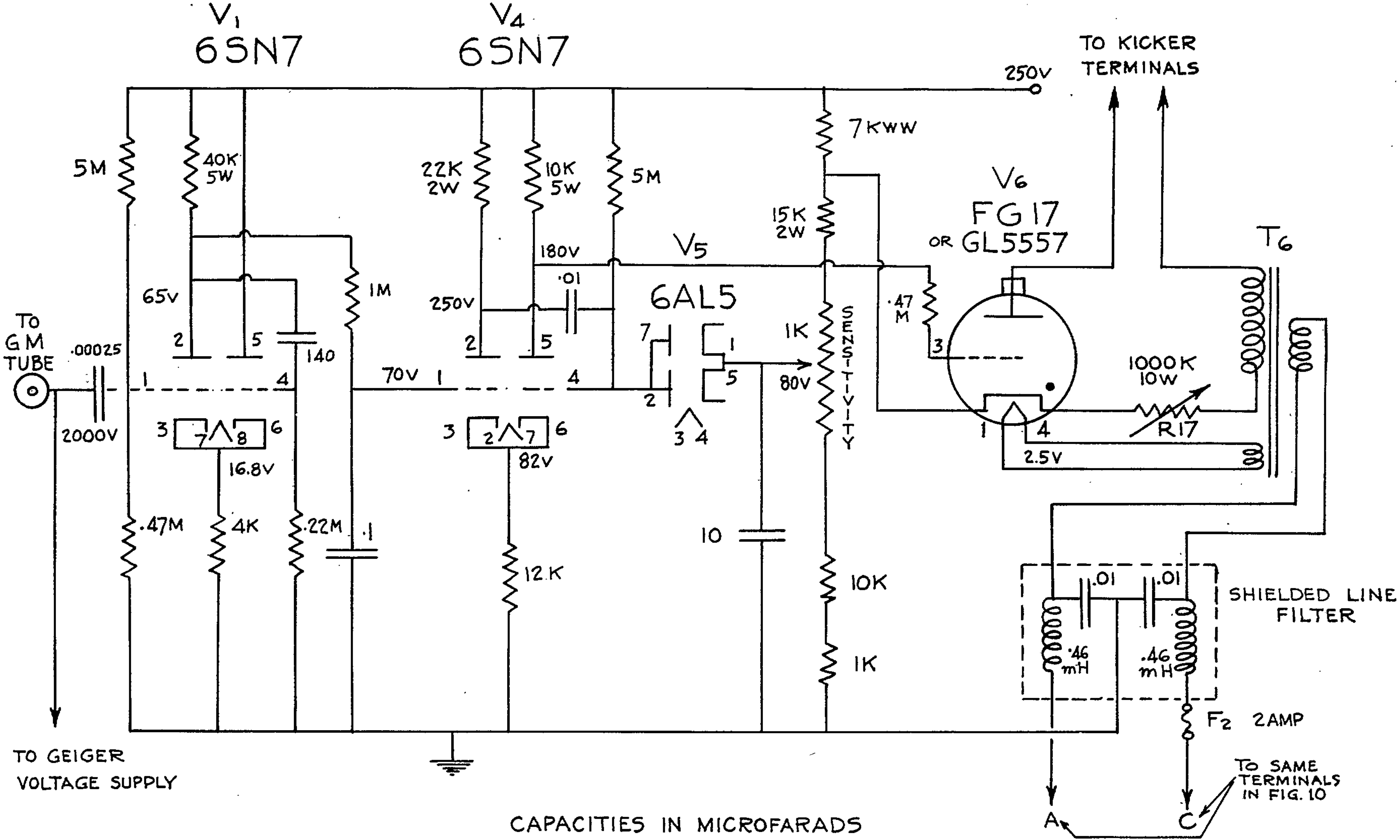
As shown in Figure 6, the Geiger pulse is amplified by the first univibrator which delivers a positive pulse of about 700 microseconds in duration and 180 volts in amplitude to the ratemeter circuit.

The ratemeter is necessary to distinguish between the slowly occurring background pulses and actual counts from low grade ore. Its time constant is approximately equal to the time taken to scan an individual ore piece. The resulting voltage across the integrating condenser is applied to the grid of the pulse-forming univibrator stage, V_2. At normal sensitivity settings, when the instantaneous Geiger pulse arrival rate exceeds 10 per second, the input grid of V_2 is driven sufficiently positive to trigger the univibrator. This stage generates a 100-volt positive pulse of sufficient duration (about 1/10 second) but of insufficient power to operate the plunger or selector gate.

To obtain sufficient power the pulse is then applied to the grid of a thyratron, such as the FG17, which is capable of operating the ram type kicker directly. A further step is required in operating the selector gate at the end of the belt to compensate for the time taken for the ore to travel from the detector to the edge of the vertical gate (Figure 2). This has been done with an adjustable time-delay relay(1) in series with the line supply and the electromagnetic valve controlling the compressed air to the double acting piston operating the selector gate. The time taken for the ore to travel from the

(1) Such as Agastat Model No. NE-11-A.

PICKER CIRCUIT I



T6 = SEC. 220V 1 AMP.
FIL. 2.5V. 5AMP.

CAPACITIES IN MICROFARADS
RESISTORS 1 WATT UNLESS
OTHERWISE INDICATED
VALUES K = 1000 OHMS
M = 1 MEGOHM
ADJUST R17 FOR PROPER GATE OPERATION

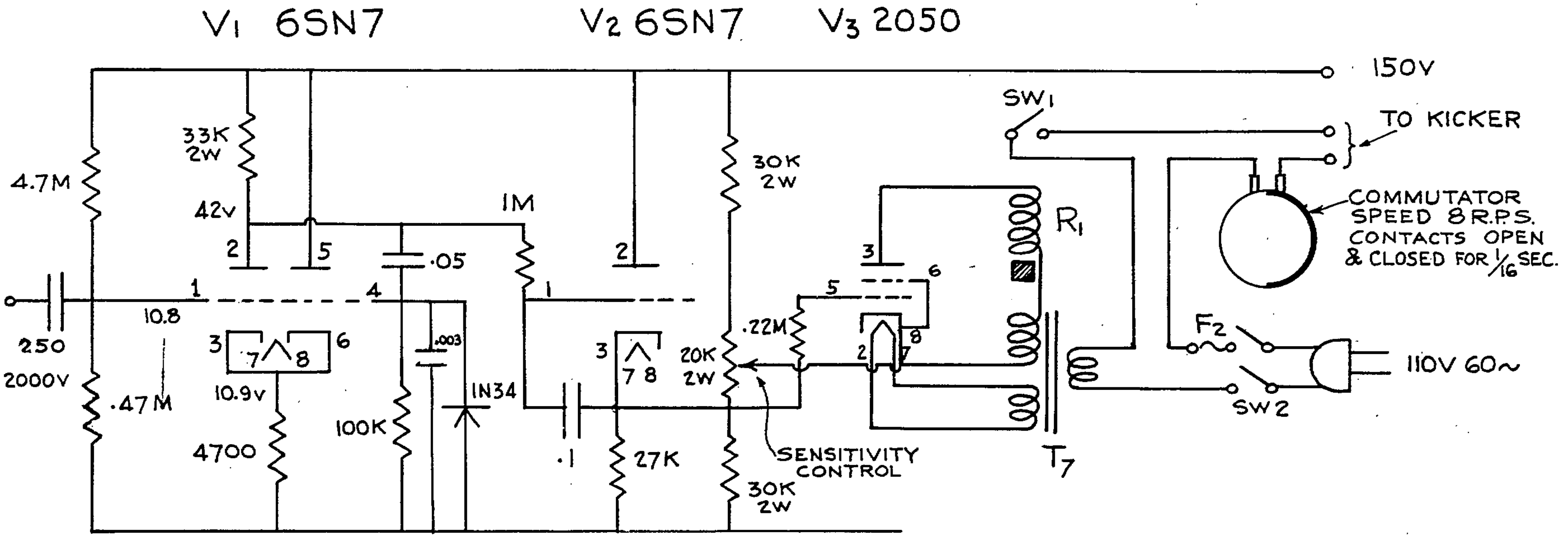
FIG. 6

detector to the gate should be kept to a minimum as the circuit is insensitive from the time the ore is first detected until the gate has swung back to its normal position. This reduces the picker capacity by imposing a minimum ore spacing on the belt.

For maximum operating rates, the pulse to the removal mechanism should be just long enough to operate the ram or gate reliably, followed by a dead period sufficiently long to permit the ram or gate to return to its normal position. In this circuit the duration and minimum separation between adjacent pulses are determined by the pulse forming stage V_2, although the time-delay relay both shortens and delays the application of the pulse to the gate.

In the second picker circuit, illustrated in Figure 7, there is no pulse forming stage corresponding to V_2 as shown in Figure 6. Instead, the voltage developed across the ratemeter circuit is applied through a cathode follower stage V_2 to the control grid of the thyratron stage V_3. The latter will remain conducting as long as the voltage across the ratemeter condenser exceeds its quiescent voltage by a few tenths of a volt. The conducting period thus depends on the number of Geiger pulses received during the exposure period. This will usually exceed the minimum time, measured in line cycles corresponding to the mains frequency, necessary to operate the ram. For this reason the duration of the pulse to the kicker is controlled externally by a motor driven commutator in series with the power mains. The commutator provides alternate pulses of 4 line cycles on and 4 line cycles off to the ram as long as the ore is viewed by the detector. This design has one less tube than that shown in Figure 6 and requires only one commutator for all pickers in the immediate area. As the circuit cannot produce a pulse of sufficient duration to operate the selector gate through a time-delay relay, its use, is restricted to the ram type mechanism. Unless the commutator contacts are in a favourable position when the relay

PICKER CIRCUIT II



R_1 = KURMAN TYPE RELAY
WITH SPST MICROSWITCH SW_1

T_7 = HAMMOND TYPE

F_2 = AT LEAST 2AMPS BUT DEPENDS
ON CURRENT REQUIREMENTS OF
REMOVAL MECHANISM

ALL RESISTORS 1W UNLESS OTHERWISE INDICATED

FIG. 7

closes, there may be a lapse of up to 1/15 second in the application of the pulse to the ram.

The regulated plate supply circuit is shown in Figure 8. It provides a continuously variable voltage from 150 to 250 volts at 40 mA load with a regulation of 0.7 per cent for a ± 10 per cent fluctuation in line voltage.

Interference suppression

If power to the picker unit and to the removal mechanism is supplied by the same source, spurious echo kicks are likely to occur in spite of well regulated high and low voltage power supplies. Voltage surges developed across the common line impedance by the large initial kicker currents may reach the input univibrator through the low voltage supply and cause adjacent picker units to operate resulting in "sympathetic kicks." This trouble is overcome in the circuit illustrated in Figure 6 by the use of low pass line filters shown in the lower right hand portion in series with the primary of the transformer supplying power to the removal mechanism.

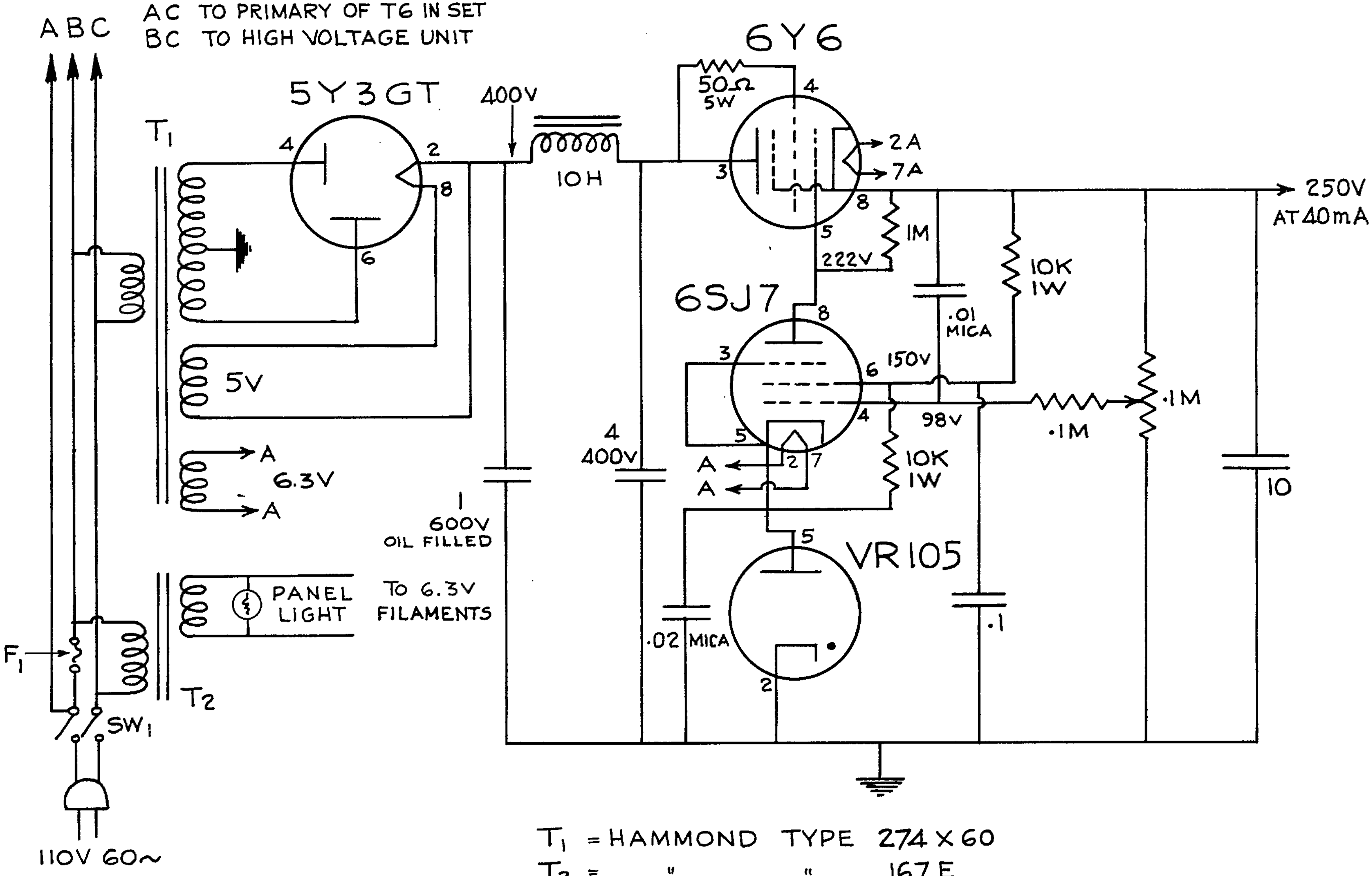
Power to the commutator as shown in Figure 7 and to the picker circuit should be provided by separate line circuits. If interference is still present it may be necessary to equip each picker circuit with an electrostatically shielded line isolation transformer.

Operating Adjustments

Height of detector above belt

The height of the detector block above the belt is adjustable and is determined by the size of the feed. It should be kept to a minimum consistent with a safety margin of about one-third of the smaller screen dimension. Rectangular mesh screens should be used to permit closer sizing.

REGULATED PLATE SUPPLY



AC TO PRIMARY OF T6 IN SET
BC TO HIGH VOLTAGE UNIT

T1 = HAMMOND TYPE 274 X 60
T2 = " " 167 E
F1 = 1 AMP

FIG. 8

Belt speed

Permissible belt speeds increase with the size of the feed and are shown in Appendix 1.

Geiger voltage supply

A suitable voltage supply for the Geiger tubes is detailed in Figure 9. It provides a continuously variable voltage from 650 to 1500 volts with a regulation of better than 0.05 per cent. It may be built on the same chassis as the picker circuit or in a separate cabinet to serve all picker units in the vicinity.

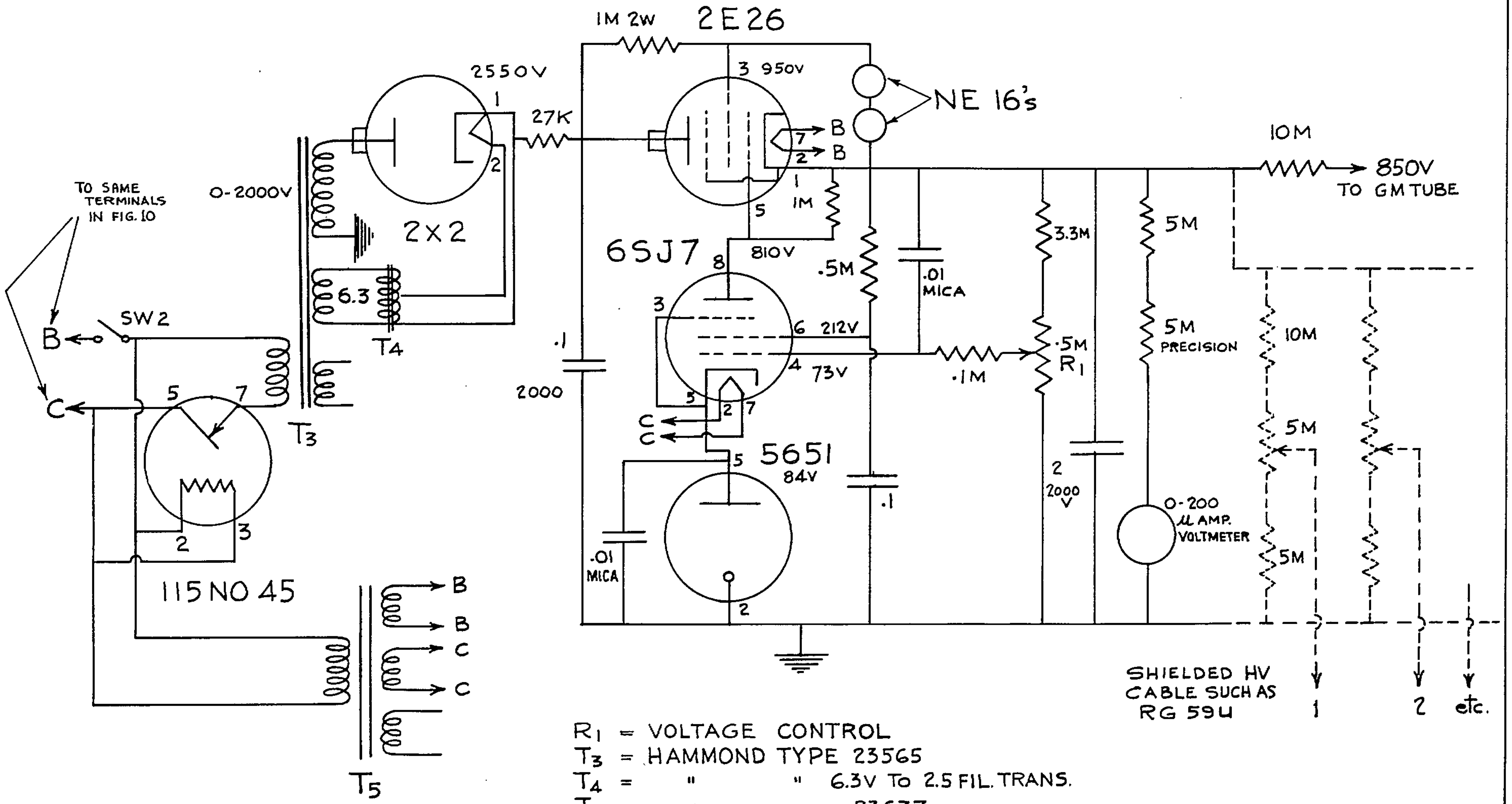
As a particular belt will generally handle only one size of feed, the operating adjustments are the sensitivity control and Geiger tube voltage. Correct operating voltage is determined by first decreasing the supply voltage to 700 V and slowly increasing it until the "threshold" is found, as indicated by the registration of individual background pulses. For this adjustment the sensitivity control should be in its most sensitive position. The high voltage is then increased from 50 to 100 volts above the threshold and left there until the next check. If halogen-filled Geiger tubes are used(1), the initial adjustment should last indefinitely. With other types the threshold voltage rises as the tube ages, necessitating a threshold check about once a week. The rated life of such tubes is 10^7 counts so that their actual lifetime depends on the background and the grade of the feed. One or two months of service may be expected from the 1B85 in normal operation.

Sensitivity setting

This control determines the arrival rate of Geiger pulses needed to operate the pulse forming univibrator and hence the picker. As background pulses are random in time, the instantaneous arrival rate averaged over the particle

(1) Such as the Anton Type 106 tube.

REGULATED GEIGER VOLTAGE SUPPLY



R1 = VOLTAGE CONTROL
T3 = HAMMOND TYPE 23565
T4 = " " 6.3V To 2.5 FIL. TRANS.
T5 = " " 23637

FIG. 9

scanning time which is about 1/5 of a second, may be sufficiently high to operate the picker and to produce an occasional background kick. If the sensitivity setting is reduced to eliminate all background response, much low grade ore will be missed especially with the smaller sizes. For optimum performance the background in the detector should be kept below 40 cpm per cubic inch of detector volume(1) by proper shielding of the detector tube around the feeder bin, and by isolation of the pickers from large concentrations of ore.

Under these conditions proper operation will be obtained when the sensitivity control is set to give an average background count of four to eight per minute, averaged over at least two minutes. This should be done in the absence of ore on the belt and after the detector housing has been cleaned out by an air blast or with rags soaked in a grease solvent so as to remove radioactive dust which may accumulate in operation unless the feed is watered.

Background check

Once the normal setting of the sensitivity control has been established, the average background count over a two minute interval will indicate whether the picker is operating under normal conditions. In routine operation the feed is shut off once an hour to check individual backgrounds. A high background indicates the need for cleaning the Geiger tube and housing while a low background indicates the need for checking the threshold and operating voltage of the Geiger tube. After this has been done, normal backgrounds should be obtained with the same setting of the sensitivity control. If normal background kicking rates cannot then be obtained with more than a slight adjustment of the control, the belt must be shut down until the source of the trouble is located by competent personnel.

(1) This corresponds to 100 cpm for the 1B85 tube.

Performance

Apart from the characteristics of its associated Geiger tube, performance of the picker circuit is determined by factors external to itself. In order of their importance these include: background intensity measured in the absence of ore on the feed belt, the dispersion of the activity in the feed, and the spacing of the feed on the belt.

Background intensity and minimum detectable activity

As the circuit has no way of distinguishing between true activity from low grade ore and sufficiently rapid background pulses, its sensitivity and performance are limited to the average background level. Hence it is most important to reduce the background to a minimum, especially in treating ore assaying 0.3 per cent U_3O_8 or less. Although the background level provides a lower theoretical limit, the minimum activity that can be detected with a probability of 50 per cent is about seven times the average background registered by the Geiger detector.

This is illustrated graphically in Figure 5 in which probability of detection in a single pass under the detector is plotted against the measured beta activity. It is difficult to correlate the latter to the uranium assay unless the dispersion of the activity in the piece is uniform and unless the pieces are of similar surface area. It should be noted that for a given activity which includes the background, there is considerable fluctuation in the probability of it being detected. This is chiefly due to the fact that the circuit is measuring the instantaneous activity (for about 1/5 second) of a particle, whereas the activity indicated on the graph was measured over a one-minute interval. Over such short time intervals, the background intensity may exceed that of a sample whose average activity is three or four times the average background.

Dispersion of activity in the feed

In the pitchblende type of uranium deposits, the pitchblende commonly occurs in the form of stringers or veinlets in relatively barren gangue. Such ore is well suited to treatment on the picker belt with recoveries as high as 95 per cent for a rejection ratio of 20 to 1. On the other hand, ore in which the activity is uniformly disseminated cannot be concentrated at all by the belt which can treat only relatively coarse sizes. The majority of radioactive ores fall between these extremes and hence the recovery and rejection ratio are dependent on this aspect of the feed. On a pilot run the circuit shown in Figure 6 has produced a concentrate averaging 0.103 per cent from feed of 0.024 per cent with a recovery of 64.3 per cent and a weight rejection of 85 per cent. This preconcentrate could then be treated by leaching.

Spacing of the feed on the belt

The importance of regular spacing has been emphasized in Part 1. In summary, insufficient spacing may dilute the concentrate or may cause the kicker to miss an active bit of ore if there is insufficient spacing between two active pieces. Up to a point, these considerations may be of secondary importance to the increase in belt capacity.

Maintenance

Test for sensitivity

The hourly background check is a convenient means of testing the overall operation of the picker. In the event that excessive counting rates are still present after cleaning and checking the voltage to the Geiger tube, the following steps may be followed in locating the trouble.

Symptom: background higher than normal.

If all picker backgrounds are high, one may suspect:

(1) The presence of additional radioactivity in the proximity possibly due to the temporary storage of additional ore or concentrate.

(2) Trouble in the common high voltage supply. If this cannot be eliminated by successively replacing each tube with a new one, the unit should be examined for loose internal connections. If this is unsuccessful, voltages at the various points indicated in Figure 8 should be compared with those shown in the circuit.

When electronic servicing facilities are not available, at least one spare high voltage unit should be kept on hand for every two in operation.

Symptom: background lower than normal or non-existent

(1) If the Geiger tube is operating at its proper overvoltage of 60 to 100 volts above threshold, a background less than 30 per cent of its normal background averaged over a two minute interval indicates the removal of active material from the vicinity. In doubtful cases the Geiger tube should be replaced by a new one.

(2) If there is no background even at the highest sensitivity setting as evidenced by non-operation of the removal mechanism, the Geiger voltage should be slowly increased to a maximum of 200 volts above its previously established threshold. An

operating log should be maintained for every picker unit including a record of the installation and removal dates, thresholds, and operating voltages of the Geiger tube. If no counts are registered, the tube should be replaced by one known to be good. If this fails the picker set should be replaced by a spare unit. Non-operation of the new unit indicates that the leads to the Geiger tube from the circuit and from the high voltage supply should be checked for a shortened or open circuit.

If this has not located the trouble,the fault must lie in the removal mechanism such as an open circuit or failure in the power supply, possibly a blown fuse.

Circuit failures

If normal operation is obtained by replacing the inoperative unit with a spare one, the former should be examined to locate the trouble. A suitable test kit consists of a tube tester, a simple oscilloscope, a vacuum tube voltmeter, and an assortment of electronic parts.

As a preliminary step in tracing the trouble, all tubes in the set should be tested. The wiring should be examined for obvious flaws such as open and loose connections. Voltages at various points in the circuit should be measured and compared with the corresponding values as shown in Figure 6. Deviations greater than 10 per cent should be investigated with the oscilloscope. Particular attention should be paid to the cathode voltages of the input and pulse-forming univibrator stages. A reading of 22 volts across the cathode resistor of the input stage indicates that V_1 is self-oscillating. This can be remedied by replacing the cathode resistor with one of 10 per cent higher resistance. Self-oscillation of V_4 is indicated by a 30-volt drop in the cathode voltage and by a higher than normal voltage at the second anode. However, this is far less likely to occur than in the first stage.

These circuit troubles are evidenced externally by the removal mechanism remaining in the open or remove position as long as the set is on. Failure of the set to operate the kicker after its tubes have been tested and found to be good should be traced down using the oscilloscope. A test Geiger tube should be connected to the input for the test and a 100-watt light bulb at the output. Observe whether the input univibrator is functioning properly by placing the oscilloscope probe on pin 2 of V_1. Positive rectangular pulses about 10 V in amplitude and 700 microseconds in duration should be present, corresponding to the background pulses from the test Geiger tube. If there are no pulses, check all voltages at the tube base to determine the source of the trouble. The cathode bias should be just sufficient to cut off the right triode of V_1, nominally about 16 volts for a plate supply of 250 volts.

If pulses are visible on pin 2 of V_1, pin 5 of V_4 should be checked. If this stage is operating properly, positive rectangular pulses about 80 V in amplitude and 1/10 second in duration should be visible. The sensitivity control should be advanced to its most sensitive position for this test. Failure of this stage to operate may be located by measuring the various voltages at the tube base.

Finally, if pulses are visible at pin 5 of V_4 and at pin 3 of V_6, check the voltages on V_6 to locate the trouble.

Inoperative removal mechanism

This will be indicated by satisfactory operation of the test lamp on background pulses and may be located by a circuit continuity test or by visual inspection of the mechanical system.

Conclusions

The Lapointe picker has several advantages over gravity and heavy media methods for the concentration of uranium ores since it detects radioactivity from the uranium mineral itself. This property enables the picker to concentrate uranium-bearing ores in the presence of heavy gangue. On occasion, the picker may be used to produce a preliminary concentrate when the uranium mineral is too finely disseminated for successful application of gravity methods, provided there is sufficient localization of the total uranium to permit concentration. Good recoveries have been obtained on pitchblende ores, these ores being especially suited to picker belt treatment because the activity is often concentrated in narrow veins.

The most economical application of the picker is to the size range from -8" to + 1 1/2" although coarser and finer ores may be treated.

The rejection of approximately 50 per cent of the mine ore as waste with low uranium loss is an obvious advantage, particularly where marginal ores are mined or where a leaching process must be used in the recovery of uranium.

A picker unit may be useful in small operations for sorting mine dump ore to produce a shipping grade concentrate.

In larger scale operations, the installation and operating costs of a picker plant would be small in comparison with the resultant saving in capital and operating costs of the final treatment plant. Since the electronic picker is a concentrating device specifically designed for the treatment of radioactive ores in the coarser sizes, it should be an important addition to the present methods for concentration of uranium.

APPENDIX I

Calculated Hourly Tonnage

Part 1

Variation of weight with size

Size, inches	Av. diam. inches	Volume		Weight	
		Cu. inches	cc.	gm.	lb.
-3/8 + 1/4	5/16	0.0159	0.262	0.734	0.00162
-1/2 + 3/8	7/16	0.0435	0.717	2.01	0.0443
-3/4 + 1/2	5/8	0.127	2.09	5.85	0.0129
-1 + 3/4	7/8	0.351	5.78	16.2	0.0357
-13/8+ 1	1 3/16	0.869	14.3	40.0	0.0882
-2 + 1 3/8	1 11/16	2.52	41.5	11.6	0.256
-3 + 2	2 1/2	8.15	134	375	0.826
-4 + 3	2 1/2	22.5	371	1040	2.29
-6 + 4	5	65.4	1074	3010	6.84

Density 2.8 gm/cc

Part 2

Pieces per operating hour

Av. diam.	Av. spacing	Pieces per foot	Feet per min.	Pieces per min.	Pieces 50 min.
5/16"	0.75 + 0.156 = 0.906	13.2	15	198	9900
7/16"	0.75 + 0.219 = 0.969	12.4	15	185	9250
5/8"	1 + 0.312 = 1.31	9.15	20	183	9150
7/8"	2 + 0.437 = 2.44	4.92	20	98	4900
1 3/16"	7 + 0.594 = 7.59	1.58	30	47.4	2370
1 11/16"	7 + 0.844 = 7.84	1.53	30	46.9	2345
2 1/2"	7 + 1.25 = 8.25	1.45	30	43.5	2178
3 1/2"	7 + 1.75 = 8.75	1.37	30	41.0	2050
5"	7 + 2.5 = 9.5	1.27	30	37.9	1475

Part 3

Variation of belt capacity with rock size(1)

Size	Wt. lb.	No. of particles in 50 mins.	Capacity lb./operating hr.
-3/8 + 1/4"	0.00162	9900	16
-1/2 + 3/8"	0.00443	9250	41
-3/4 + 1/2"	0.0129	9150	118
-1 + 3/4"	0.0357	4900	175
-1 3/8 + 1 "	0.0882	2370	209
-2 + 1 3/8"	0.256	2345	610
-3 + 2"	0.826	2178	1800
-4 + 3"	2.29	2050	4690
-6 + 4"	6.84	1475	10,000

(1) Running time - 50 min. per hour.

APPENDIX II

Choice of Detector

Considering the two detector system, the sensitivity of the first detector should not be high as it need only respond to relatively high grade material. Such pieces are then swept across the belt into a chute by an air-operated ram. The second detector is mounted as close to the end of the belt as is practical, and activates the air-operated chute gate which separates the reject product or waste from the middlings. The sensitivity of the second detector should be as high as possible.

These detector requirements are best met by gamma and beta Geiger tubes, respectively. They are readily obtainable and inexpensive in comparison with the more sensitive scintillation detectors.

Although the gamma type Geiger tube is about one-twentieth as sensitive, volume for volume, as the sodium iodide scintillation detector, it has ample sensitivity as a detector of high grade ore. A gamma tube four inches long and about one inch in diameter can easily detect one gram of U_3O_8 in radioactive equilibrium corresponding to an assay of 2.5 per cent U_3O_8 in the $- 1\ 3/8 + 1$ inch size range. This gives ample sensitivity for use with the high grade picker unit on a two stage picker belt.

Beta-sensitive Geiger tubes, on the other hand, are extremely efficient detectors of most of the beta radiation from uranium ores, both the cylindrical and end-on varieties being suitable for the picker belt. The former are made with thin walls of either glass(1) or aluminum(2) and

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(1) Nuclear Instrument & Chemical Corp., Type D12.
(2) Victoreen Type 1B85 or Anton Type 106.

are slightly sensitive to gamma radiation. This adds to their background count and necessitates two or three inches of lead shielding. An improvement over the cylindrical beta counter is the end-on type(3) so constructed as to minimize the gamma-sensitive volume, and hence the background count. The high beta sensitivity of the end-on type results from the use of a thin mica window. This may be offset by a smaller window area but with consequent loss in geometry.

In summary then, beta Geiger tubes have a high detection efficiency for most of the beta particles emitted by uranium ores. Beta detectors are primarily sensitive to surface activity since beta particles emitted below the surface are absorbed by the rock itself. Since the gamma sensitivity of the cylindrical beta tube is nearly equal to that of a gamma tube of comparable volume, it will add to the effectiveness of this type as a detector of weakly active rocks. Hence, the end-on beta tube or a well shielded cylindrical type makes an excellent high sensitivity detector for medium and low grade pieces.

Gamma-sensitive Geiger tubes, though low in efficiency, respond to activity below the rock surface, since gamma radiation will penetrate several inches of rock without undue attenuation. Such tubes are able to scan the entire volume of all but the largest sizes treated on the picker belt, thus partially compensating for their low efficiency. Their chief application here is in the two stage picker belt for removing high grade ore.

(3) Such as Tracerlab Type TGC-1, Amperex Model 100C, or Anton Type 1001H.

APPENDIX III

Background

Background as is evidenced by random operation of the picker is the residual count in the detector when there is no ore on the belt. Cosmic rays and nearby radioactive sources, such as stored ore in the feeder, are the chief causes of this background count. It should be minimized as it determines the minimum activity that can be distinguished in low grade ore.

This is best done by shielding the detector on all sides with two or three inches of lead. The viewing slot below the detector should be so proportioned as to minimize premature viewing of active rocks as they approach the detector and to be consistent with adequate scrutiny of each piece. The gamma-sensitive volume of the detector may be reduced by using an end-on beta tube. Even after these precautions, the picker detector will probably register higher than normal background as it is not practical to shield it from all gamma rays from adjacent masses of ore.

In routine operation, the belt should be stopped at intervals, depending upon the amount of radioactive dust in the feed, to note the rate of "accidental kicks" which are a measure of the background. The sensitivity control on the picker circuit should be adjusted at the start of the shift for a background rate of from five to eight kicks per minute averaged over a three-minute interval. A higher background rate is inadvisable since an accidental kick may occur as a barren piece of rock is passing under the detector thus including this piece with the concentrates. On the other hand, if the accidental kicking rate is reduced to one or two counts per minute by reducing the sensitivity of the circuit, experience shows that low grade ore will be missed at the recommended belt speeds.

One may expect slight deviations from these optimum kicking rates, depending upon the nature of the ore, background intensity, and the sensitivity of the detector.

Any increase in the accidental kicking rate after operation usually indicates that radioactive dust has contaminated the detector. The latter should be carefully removed and both it and the shield cleaned with an air blast or a grease solvent. Other possible sources of high background are Geiger tube failure and, very infrequently, aging of the tubes in the picker circuit.