COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD No. 1965/213

ANALYSIS OF WATER FLOW THROUGH POROUS MEDIA USING RADIOACTIVE TRACER TECHNIQUES

by

G.L. COOKSON

Analysis of water flow through porous media
using radioactive tracer techniques. AAEC
Project No. 1A/3/2.

Preliminary investigations, 12-23 July, 1965

SUMMARY

Pending completion of equipment for this study, the suggested techniques were tried on a small experimental set up. Results suggest that channelling effects, already noticed in natural aquifers, will be encountered in the laboratory and can be studied quantitatively.

INTRODUCTION

The structure of a confined aquifer is simulated by compacted gravel in a plastic tube.

The hydraulic gradient in an aquifer is represented by the gravity head of water, which fills the voids between gravel particles, in the vertically mounted tube. Water flows from the base of the column; more water being added continuously at the top, to keep the hydrostatic head constant and the gravel submerged.

When flow conditions are steady, a small volume of water-soluble radio-active solution is added suddenly just beneath the water-gravel interface.

As the active material percolates down the gravel column, its flow pattern is recorded and subsequently analysed.

Correcting, where possible, for known and assumed errors, the results may be presented in graphical form, for various rates of flow and grades or mixtures of gravel.

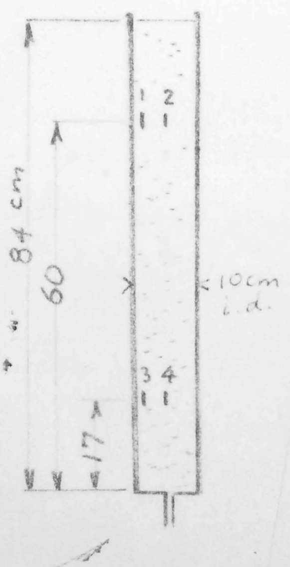
From these results, it may be expected that an empirical relationship between variables should emerge (a).

METHOD

The diagram with explanatory notes (Figure 1) should make the experimental procedure clear. Two detection techniques were considered.

i) The movement of active material and therefore of the water can be followed directly by recording counts per unit time at given points within the column, using Geiger Muller (GM) detectors.

ii) Autoradiographs of copper screens which have adsorbed active material during a flow test can be used to give an indirect indication of water movement down the column.



EXPERIMENTAL WORK (1)

A typical run down the column using GM tubes is set out below :

Four miniature GM tubes, encapsulated with limiting series resistors and with coaxial cables attached were placed as indicated in the sketch.

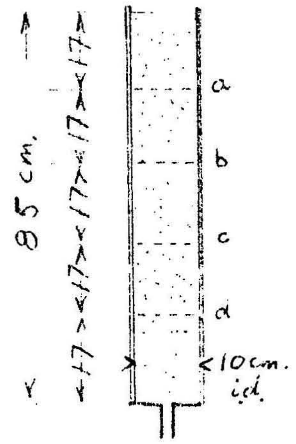
Water flow down the column was adjusted to about 75 ml/min. Two ml of active sodium iodide solution,

(I131 about 160 micro C) and 150 mg. of dissolved sodium thiosulphate (which inhibits adsorption onto the gravel) were added as in Fig. 1. The movement of activity was recorded by sampling the output from each GM tube in turn through a ratemeter and selector circuit (Fig. 2). A numbered printing wheel on the recorder in place of the conventional pen makes it possible to keep track of up to 24 GM tubes in sequence.

The characteristics of this run are summarised on Graph 1.

EXPERIMENTAL WORK (2)

The following results are characteristic of column-flow runs using copper screens to collect active material by adsorption.



Four screens were placed in the column, their angular orientation with respect to each other being recorded.

Two ml of active solution was injected as before having an approximate activity of 170 micro C. After emptying the column, the screens were cleaned with acetone to remove loose material and placed overnight on Ilford X-ray film plates (Figs. 3, 4, 5, 6). These show very clearly that lateral dispersion is small and that loss of active material down the column by gravel adsorption, is high. This is also shown by a low peak on the outflow water activity curve (Graph 1) which may be compared with that for the previous example.

RESULTS OF EXPERIMENTAL WORK

The GM tube runs were mainly to test the equipment, with which a good deal of trouble was experienced. During the run mentioned above, it was clear that the GM tubes near the axis of the column were detecting much more activity than were those near the wall. This must be expected, even for perfectly uniform flow conditions. The differences in recorded activity in this case suggest that water flowed preferentially down the axis of the tube. This is suggested much more emphatically by the auto-radiographs mentioned above. This effect, which has already been noticed in field work, is evidently reproducible. Both techniques tried suffer from several limitations. The GM tubes are very insensitive to gamma radiation, so that larger activities will be required for thorough tracing, with the consequent need for more elaborate safety and disposal arrangements. The tubes and leads will inevitably distort the flow pattern, just in the region being sampled. Moreover, these tubes detect gamma radiation in a spherical volume around them of about 2 inches radius. This is not serious in natural aquifers, (Ref. (b)) but will obscure detail in models. The greatest loss of detail is due to discontinuous recording of data. Ideally, each GM tube should report continuously through a ratemeter onto a recorder. Practically, this can only be approximated by scanning each tube in turn as already mentioned. For good statistical accuracy, the scanning time per tube must be several seconds and the repetition rate might be less than twice per minute.

Apart from some obstruction to waterflow offered by the copper screens, the second technique is limited by the quality of autoradiographs obtainable.

These are hard to read on a densitometer because of gravel shadows and strong contrasts between wire and holes in the mesh. The mesh should be fine enough to reduce this effect to an acceptable level, and still let the water through freely.

No other detection techniques are available at present. If necessary, a focussing collimator based on point source gamma ray emission could be developed, but would be expensive and, because it would have to scan the contents of the column, it would be open to one of the main objections to the GM tube technique. Its great advantage would be that no detection equipment at all need be embedded in the gravel.

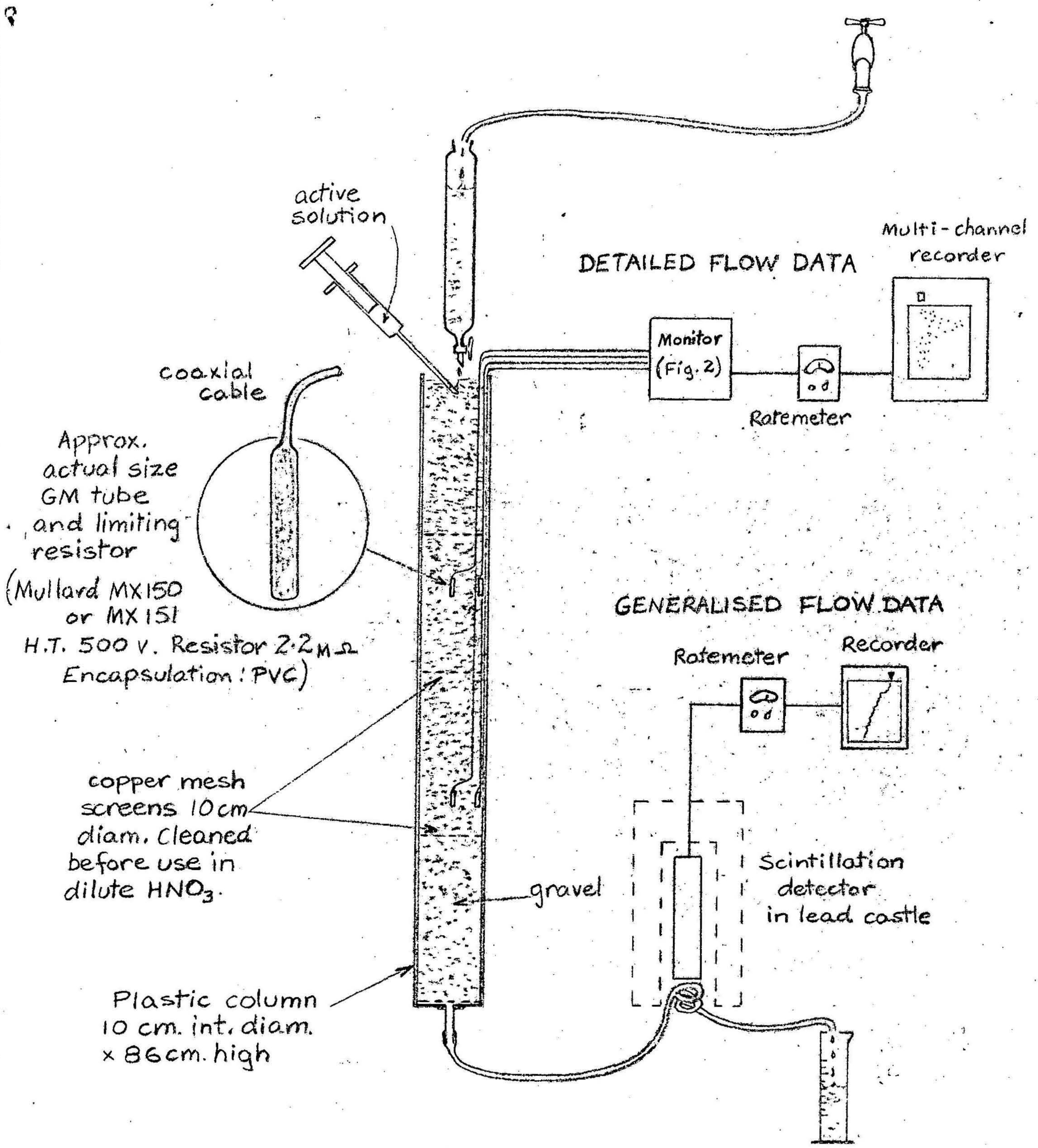
CONCLUSION

When the large vertical flow column under construction at AAEC becomes available for use, significant data should be obtainable. It will be less affected by unavoidable departures from the ideal aquifer, and by errors inherent in the techniques available for tracing radioactive materials.

REFERENCES

(a) "Dispersion" an analysis by W.A. Wiebenga (unpubl.)

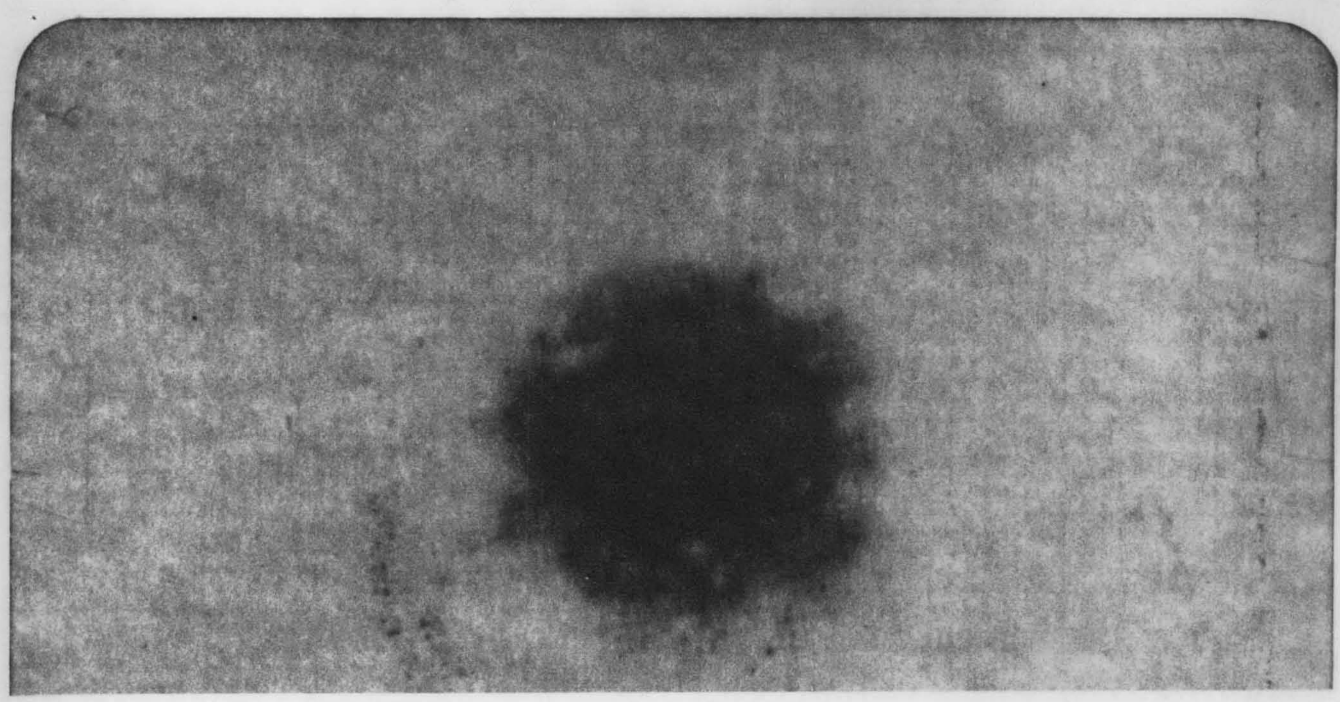
(b) "The Use of Radioisotopes as Ground-water Tracers." J.T.G. Andrew et al AAEC/E137



—Fig. 1—

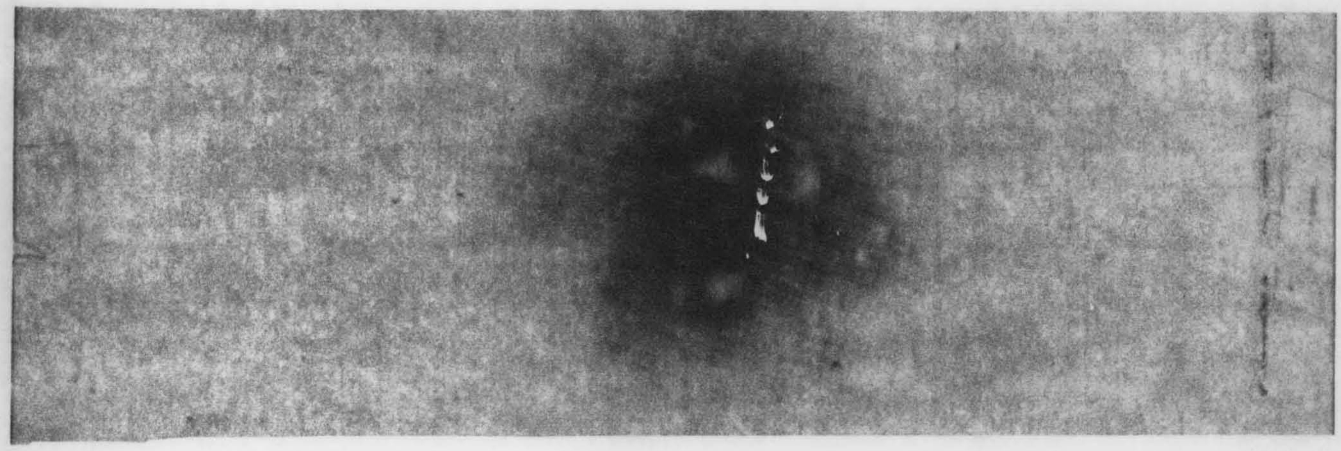
Water flow through porous media using radioactive tracers.

— Experimental set-up. —



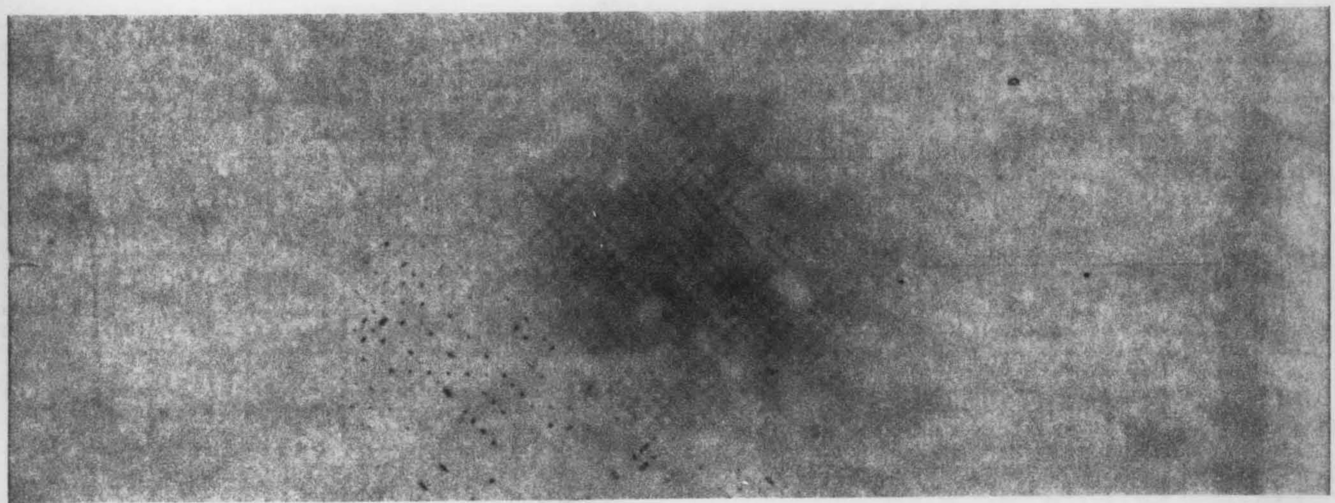
a
Fig 3

10 cm



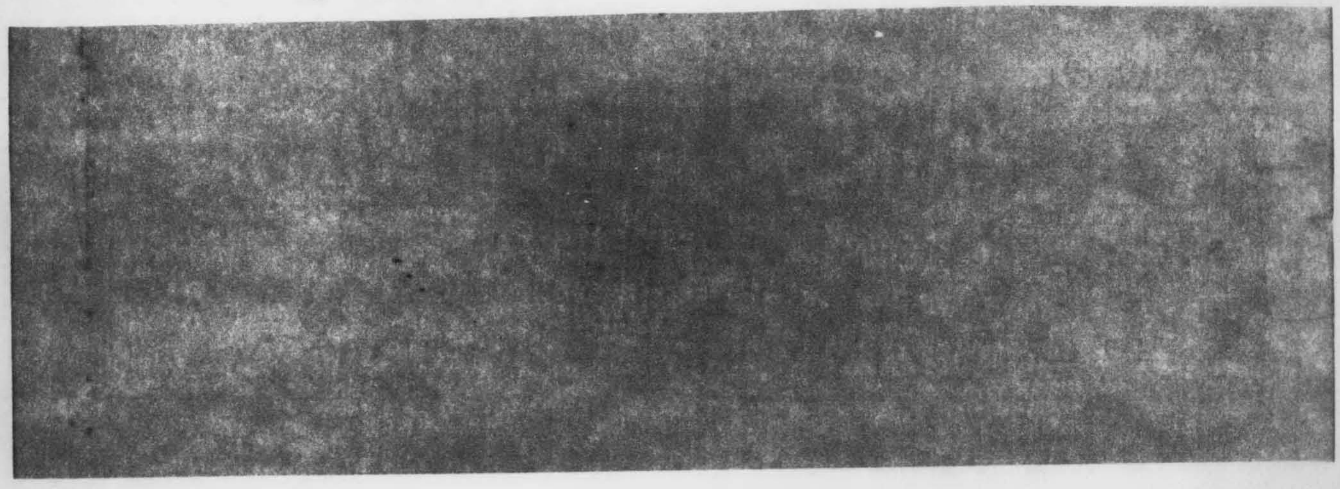
b
Fig 4

10 cm



c
Fig 5

10 cm



d
Fig 6

Autoradiographs

DRAWING No.	LOC.	DESCRIPTION	REQD.	REMARKS

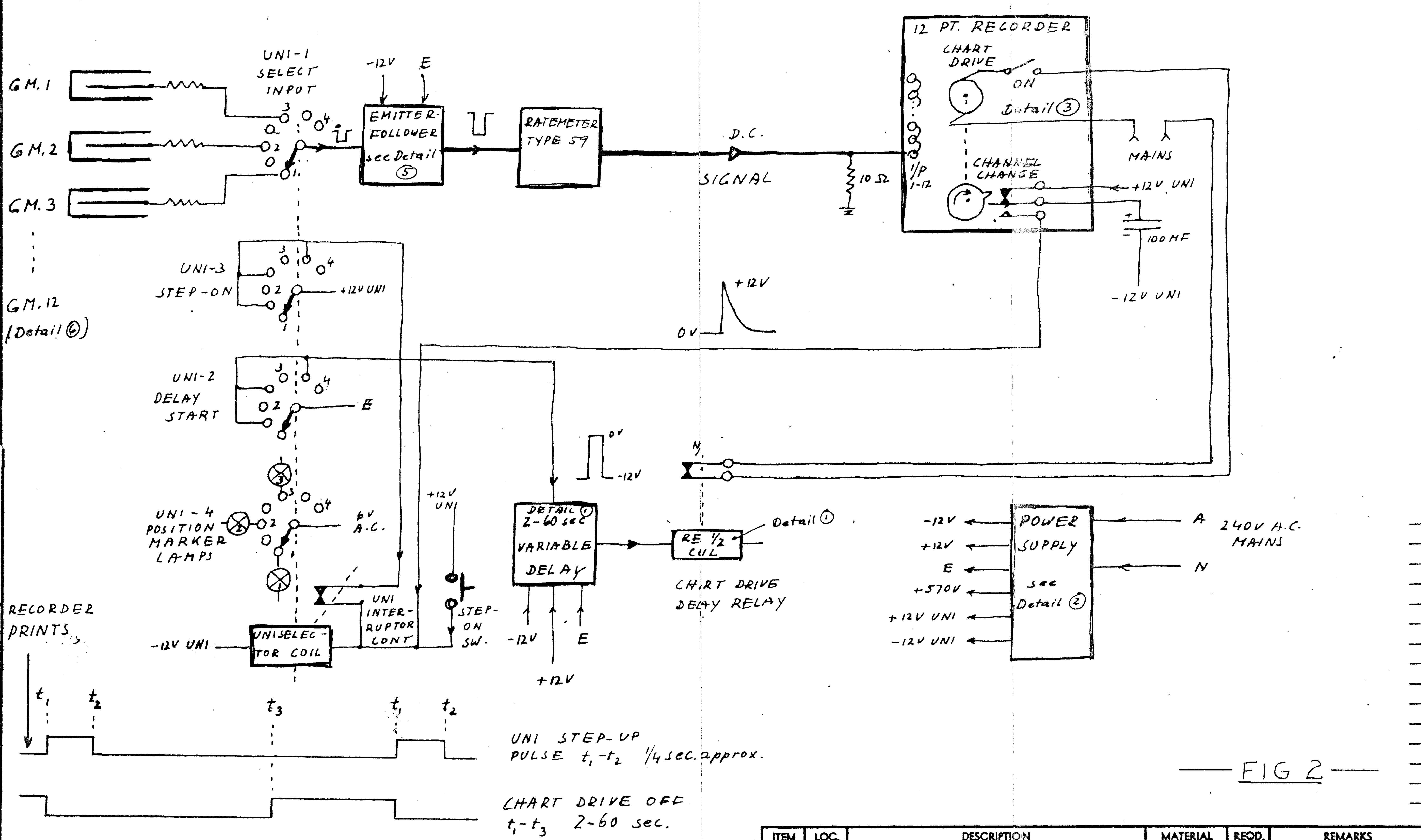


FIG 2

ITEM	LOC.	DESCRIPTION	MATERIAL	REQD.	REMARKS

AUSTRALIAN ATOMIC ENERGY COMMISSION

SHEET SIZE D — SK-GP-687

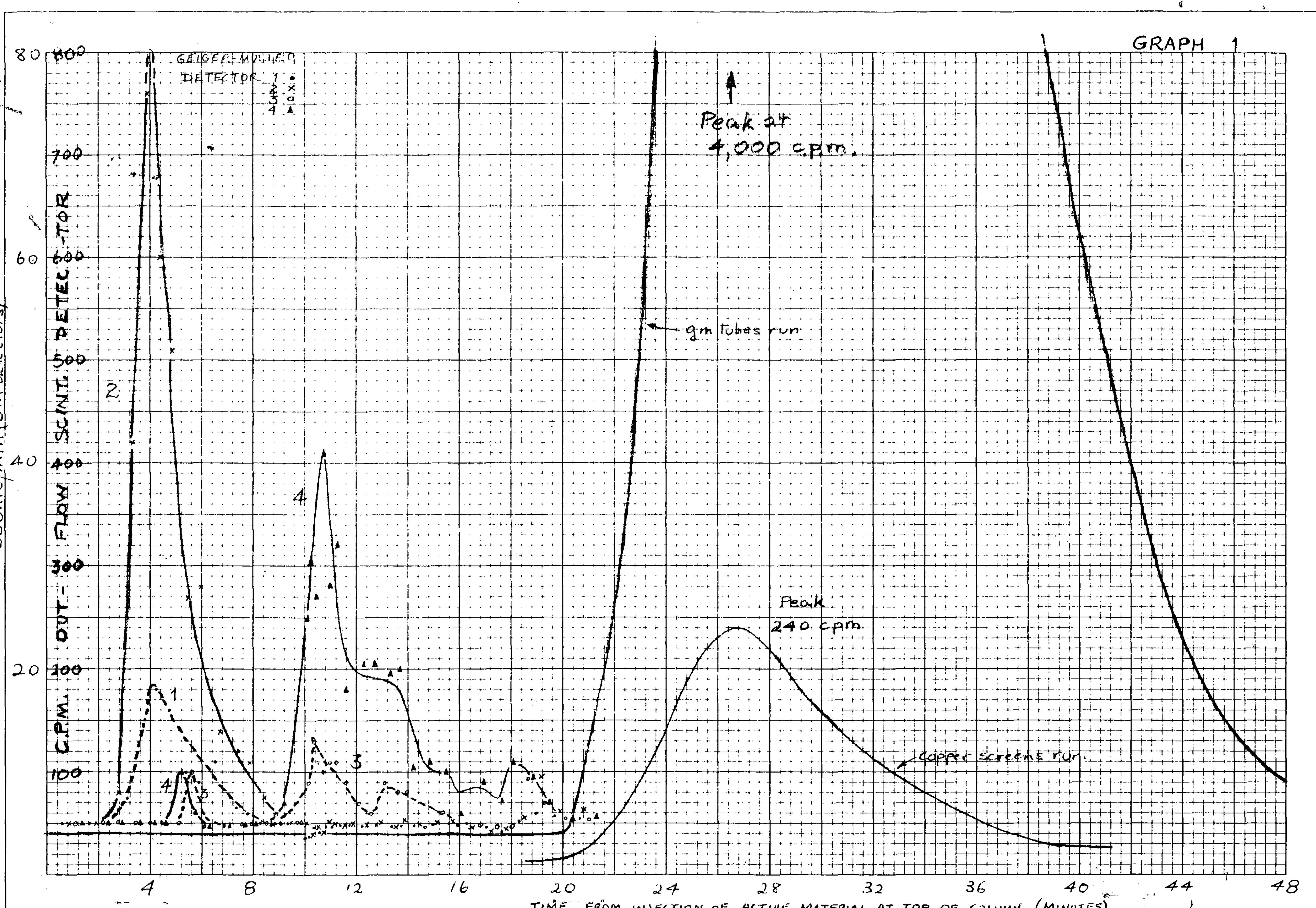
TYPE 220
SAND FLOW MONITOR
BLOCK SCHEMATIC

SCALE
DRN. K.E. CECERS — DATE 6-7-65
TCD. — RESP. OFFICER
CKD. — APPD.

TOLERANCES
Fractions
Decimals -
Unless otherwise stated
FIRST ANGLE PROJECTION
Remove sharp edges.

DRAWING REFERENCE
D.O. JOB No.

AMENDMENTS



GRAPH 1
GEIGER-MULLER DETECTOR 1 • 2 x 3 o 4 ▲
Peak at 4,000 c.p.m.
gm tubes run
Peak 240 c.p.m.
copper screens run
Counts/min (GM detectors)
C.P.M. OUT-FLOW SCINT. DETECTOR
TIME FROM INJECTION OF ACTIVE MATERIAL AT TOP OF COLUMN. (MINUTES).