

**A Comparison between an Automatic Track Reader Using  
Alfascan<sup>(TM)</sup><sup>1</sup> Software and Manual Counting**

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**"A Comparison between an Automatic Track Reader Using Alfascan\* Software and Manual Counting", John R. Peggie**

(In-house paper written by ARL, the Australian Radiation Laboratories, a Federal Australian department charged with national monitoring of ionising and non-ionising radiation. This paper very favourably compares the performance of our automated image-processing system, based on the AS3000 stage, with that of human operators in the process of analysing CR39 radiation badges which have been subjected to alpha particle radiation).

\*Alfascan was the DOS-based precursor of our AutoScope software.

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<sup>1</sup> AlfaScan (TM) software by Autoscan Systems Pty Ltd P.O. Box 112 Ormond Victoria, Australia.

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# A Comparison of the Automatic Track Reader with Manual Counting

## Introduction

The Australian Radiation Laboratory has offered a radon analysis service to the public for some years through its Personnel Radiation Monitoring Service section. Any person or organisation can make a request to have an estimate made of the concentration of radon gas present in their home or office. The method normally used to evaluate the gas concentration involves placing a small plastic jar containing a piece of polycarbonate (CR-39) in the home for a period of three months. CR-39 is known as a Solid State Nuclear Track Detector (SSNTD). When CR-39 is struck by alpha particles, the material is damaged or altered in the immediate vicinity of the collision path. This damaged material is more susceptible to chemical attack than the undamaged bulk of the material. At the end of the exposure period in a dwelling, the material is etched by immersion in 6.25 Molar KOH at temperature of 70°C for 6 hours. This causes small pits in the material to develop which are due to the alpha particle collisions. They can be seen through a microscope at a magnification of approximately X80.

The number of pits or tracks per unit area is proportional to the average concentration of radon gas present in the atmosphere over the period of exposure. The small jar housing the SSNTD is kept closed during the exposure period. Radon gas enters the jar by diffusing along the screw thread of the jar lid. The calibration of these devices was carried out in the ARL radon chamber in which the radon was maintained at a known concentration for the duration of the exposure. A typical calibration factor is approximately  $0.12 \text{ tracks cm}^{-2} \text{ Bq}^{-1} \text{ day m}^{-3}$ .

When the exposed SSNTD is received from the user, it is etched along with a CR-39 detector that has been given a known exposure in the radon chamber at ARL. This standard or reference detector is counted using the same magnification as those

detectors issued to the public for radon analysis. An unexposed detector, which is kept in an environment free of radon gas, serves as an estimate of the detectors background radiation exposure. An identical number of areas are counted for the standard, background and issued detectors. The results are then calculated using expression (1) below

$$E = \frac{(T_S - T_B)}{(T_R - T_B)} A \quad (1)$$

where E is the exposure given to the sample detector.  
(Bq.day.m<sup>-3</sup>)

T<sub>S</sub> is the number of tracks per unit area for the sample detector given an unknown exposure.

T<sub>B</sub> is the number of tracks per unit area for the background CR-39. This is a detector that has not been exposed and has been kept in a radon free enclosure.

T<sub>R</sub> is the number of tracks per unit area for the reference CR-39. The reference detector is one that is given a known exposure in the radon chamber.

A is the exposure given to the reference detector  
(Bq.day.m<sup>-3</sup>)

The number of tracks is determined by counting the tracks manually using a microscope with a magnification of approximately X80. This is carried out for each CR-39 detector by five operators. The results are averaged and the exposure determined. Counting manually is time consuming and tedious. When the automatic counting system became available it was necessary to compare its performance against the manual operators.

A comparison was made between manual and automatic counting using six CR-39 detectors etched under the same conditions in November 1992. Five of the detectors measured were sent from the laboratory to people requesting radon analysis. The sixth detector was the standard Rn5450, which was exposed in the radon chamber for two days. The total exposure was 13.5 kBq.day/m<sup>3</sup>.

On their return, the six CR-39 detectors were counted by five people to determine the numbers of tracks/cm<sup>2</sup>. Each person counted thirty areas from each of the CR-39 samples. A statistical comparison was then made between each person and the automatic reader. A comparison of the actual distributions of the areas of the tracks was also made by the automatic system. This was carried out as changes in the distribution could require different filter parameters in searching for tracks (see below). The calculated track density varied by a ratio of 4:1 over the six different detectors.

The automatic reader was set up using a different magnification to that used for manual reading and 100 areas were counted. The area size in each case was 0.00169 cm<sup>2</sup> for automatic reading and 0.00083 cm<sup>2</sup> for manual reading. The total area counted for the automatic and manual counting was therefore 0.169 cm<sup>2</sup> and 0.0249 cm<sup>2</sup> respectively.

### Equipment

The automatic system consists of an Olympus CH model microscope equipped with a Pulnix CCD camera model TM.6CN. A computerised stage attached to the microscope is controlled by software that locates and counts tracks within a specified number of the viewing areas. The software<sup>2</sup> was run on an IBM compatible personal computer. The computer also requires a number of full length cards to manipulate the stage and for frame grabbing images from the CCD camera. The software keeps information on both the detected and rejected tracks and places this information into separate files. The type of information kept includes the area, perimeter, circularity and location co-ordinates of each track. The number of tracks located in each field of view is also available. Many other parameters are also included. Tracks are rejected or accepted depending on the value of certain parameters called filters.

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<sup>2</sup> Alfaskan (TM) software by Autoscan Systems Pty Ltd P.O. Box 112 Ormond, Victoria.

## Operation of the Automatic System.

### a) Filters.

Unlike manual operators who use their experience in judging whether a track is a true track, or an artefact of the CR-39, the automatic counter relies on four main parameters, namely the area, perimeter and circularity of the tracks and the grey scale or optical density of the track. These parameters are known as filters. The area, circularity and perimeter filters are given a maximum and minimum value. Any tracks with parameters outside these set ranges are not counted. The optical density is set up to eliminate tracks or background artefacts that have little or no depth and have a transparent appearance.

The filters were set up by analysing the parameters of a small sample of tracks, judged by the operator to be tracks that would normally be counted.

The following filter parameters were used throughout the comparison.

Area 78 to 510  $\mu\text{m}^2$

Perimeter 21 to 89  $\mu\text{m}$

Circularity 1 to 1.65

These parameters are not independent and if two parameters are chosen the third is fixed. For instance if area and circularity ranges are accepted in the list above the perimeter range should be 31 to 103  $\mu\text{m}$ . The relationship between the filters is given by the equations 2 and 3 below:

$$\text{Circularity} = \frac{(\text{Perimeter})^2}{4\pi \times \text{Area}} \quad (2)$$

or rearranging

$$\text{Perimeter} = \sqrt{\text{Area} \times \text{Circularity} \times 4\pi} \quad (3)$$

The optical density setting is dependent on the intensity of the

light source. The measurements of all six Cr-39 detectors, labelled 'Auto1' in Table 1 were made using the same light intensity. The measurements labelled 'Auto2' were made on the six detectors using a slightly different light intensity. It was found that a change in light intensity was important as it required care to reset the grey-scale parameter so that the same number of tracks was counted for the same sample. However, if the light source was felt to have changed in intensity, the standard was read again in order to check on any change of sensitivity for finding tracks. As all measurements are made relative to an exposed standard CR-39 sample, changes in the sensitivity between batches of measurements should be compensated by a corresponding change in the standard. Optical density was also found to be related to the circularity. As circularity increases, i.e. the track becomes more elliptical, the tracks are found to be shallower and therefore less optically dense.

#### **b) Focusing.**

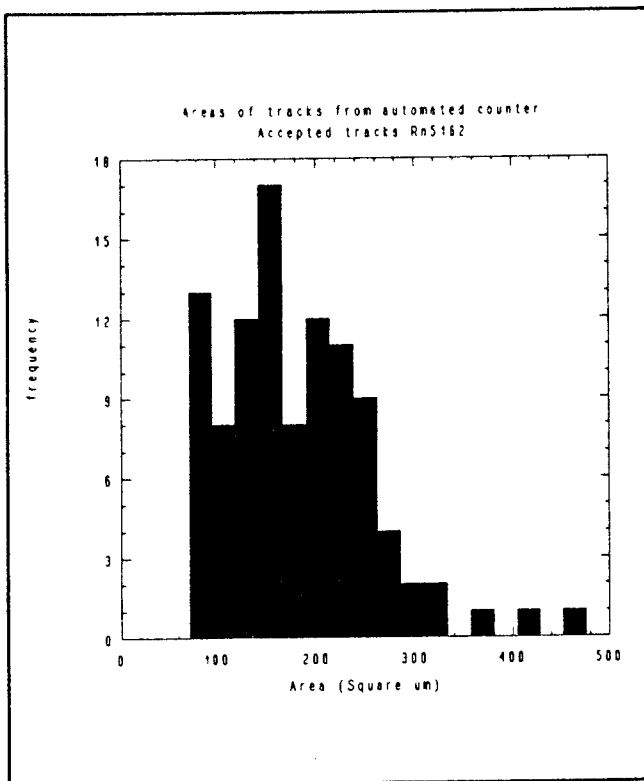
The focus of the microscope was found to be best adjusted when it produced a dark image of the track with optical density increasing towards the track's centre. When the focused image contained highlights or light areas in the middle of the track's image, the grey scale filter would often reject tracks with higher circularity. This was due to the horseshoe shape traced by the grey scale boundary as it joins pixels of the same optical density to form the perimeter of the track, i.e. the optical density of those pixels set as the threshold for a legitimate track. This resulted in a large perimeter and small area being assigned to the track. Fewer tracks were then counted and hence statistical errors were greater than optimum.

The microscope used in the experiment sometimes slipped out of focus and needed an operator to adjust the focus from time to time. Out of focus images were found to result in fewer tracks being counted as smaller tracks loose definition and hence have a lower optical density than when in sharp focus. This causes grey scale filter rejection.

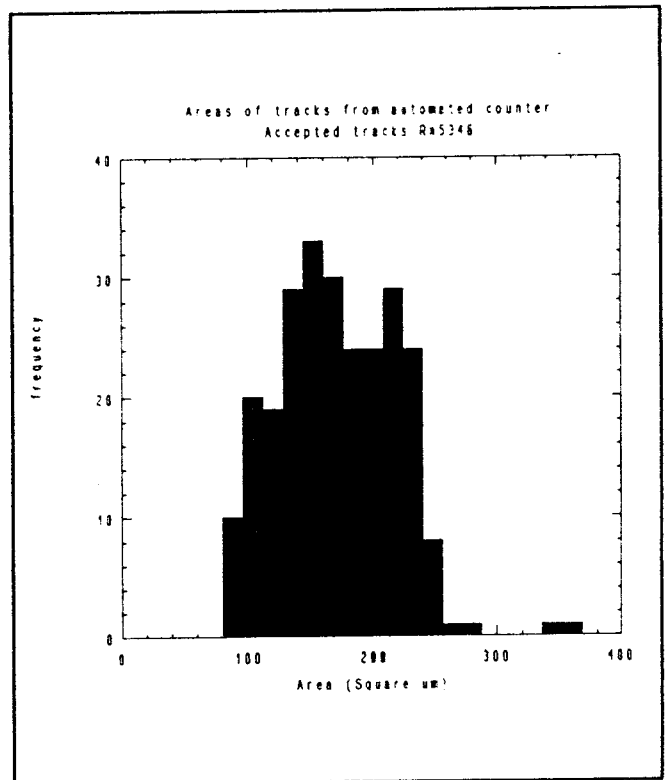
As all the measurements made at the laboratory are compared to an exposed standard CR-39 sample, many of the problems mentioned above are minimised, provided the standard has tracks with parameters representative of those detectors returned to the laboratory for evaluation.

**c) Setting of Filter Parameters.**

The parameters can be set by plotting a histogram of area, circularity and perimeter for the standard CR-39. If the tracks from approximately one hundred areas are plotted the parameters can be set accurately. This can be achieved by combining the files produced for accepted and rejected tracks and analysing them using a program that can plot frequency histograms, eg Spreadsheets (Borland's Quattro, Microsoft's Excel) or statistical programs (Statgraphics). Examples of area histograms for the CR-39 detectors used in this comparison are shown in Figures 1 to 6 below. The program used was Statgraphics which can import the data files produced by the automatic counter.



**Figure 1 Area Sizes Rn5162.**



**Figure 2 Area sizes Rn5346.**

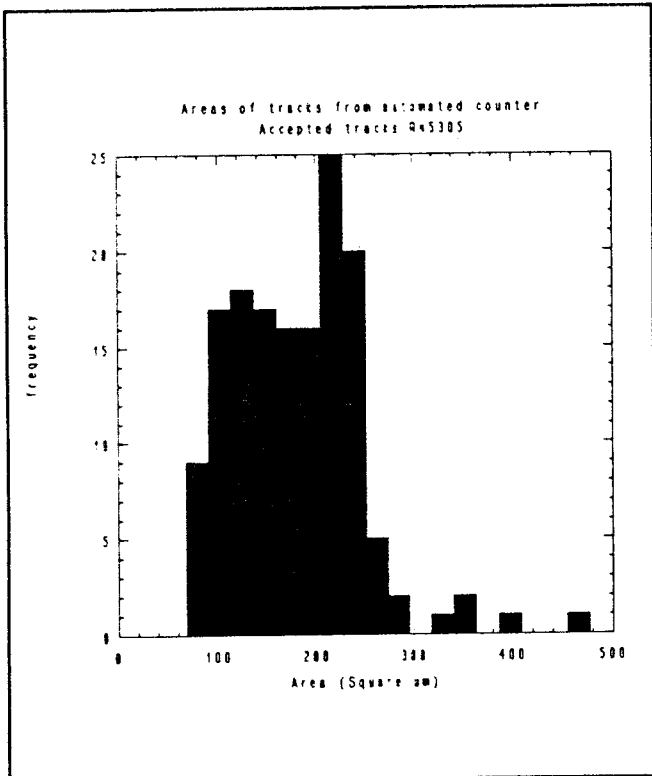


Figure 3 Area sizes Rn5305.

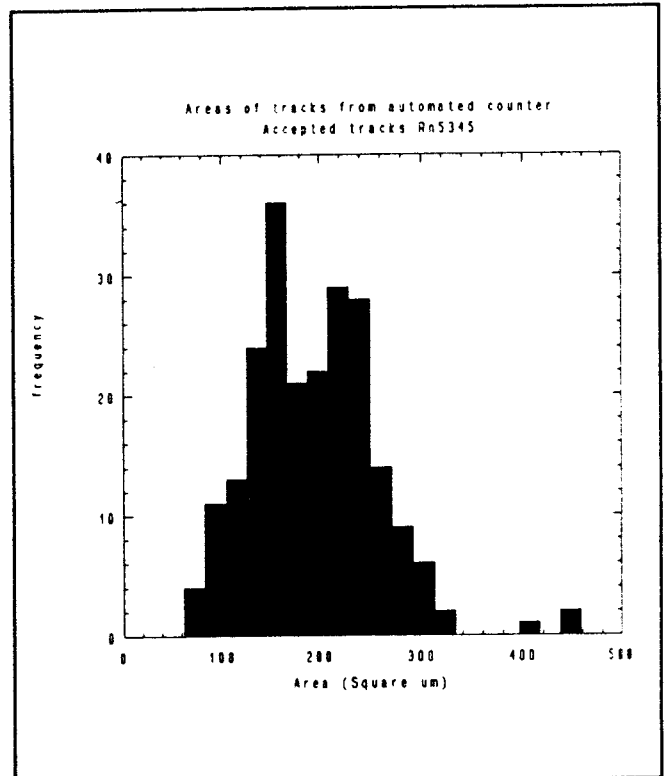


Figure 4 Area sizes Rn5345.

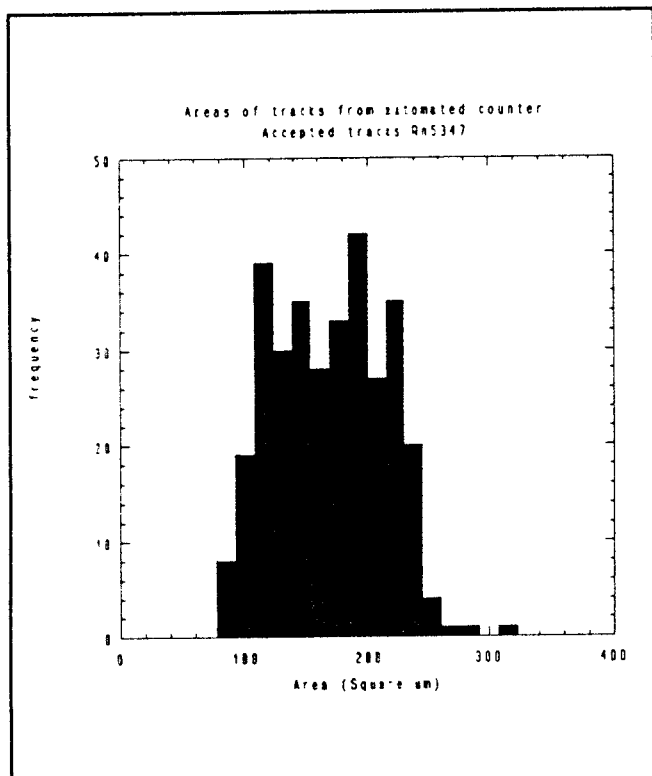


Figure 5 Area sizes Rn5347.

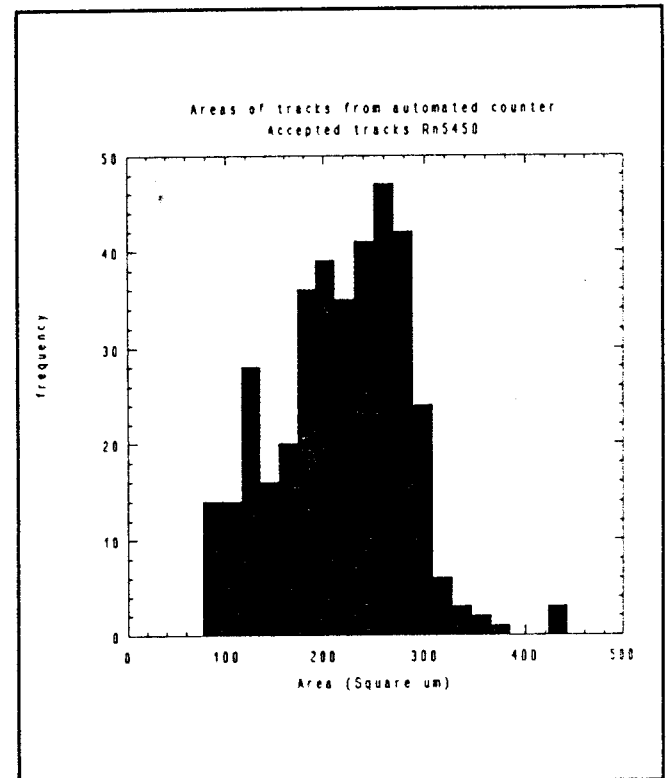


Figure 6 Area sizes Rn5450.

The distribution of areas for each detector, for tracks that pass the filters, is shown in the six histograms. Figure 6 shows the histogram for sample Rn5450. This is the standard, exposed to a known concentration of radon in the ARL radon chamber. The distribution of the areas of the tracks seems to vary from sample to sample. The reason for this variation is unknown. It may be due to the etching procedure, the CR-39 material, or microscope focusing to name a few possibilities. This needs investigation, as the filters are set using a single sample, and the distribution of areas for the detectors are assumed to be the same for each. The mean areas for each sample are shown in figure 7 below. The difference between the standard's mean area and those of the other detectors is approximately 20%. In this particular case the range of areas chosen as a filter is quite broad so that the overall results are unlikely to be altered by the standard's larger mean area. However had the detectors contained much larger tracks than that of the standard this may have resulted in a poor choice of filters. Since the files generated by the program contain accepted and rejected tracks it is possible to rectify a poor choice of filters, apart from the choice of grey-scale filters, after the measurements have been made.

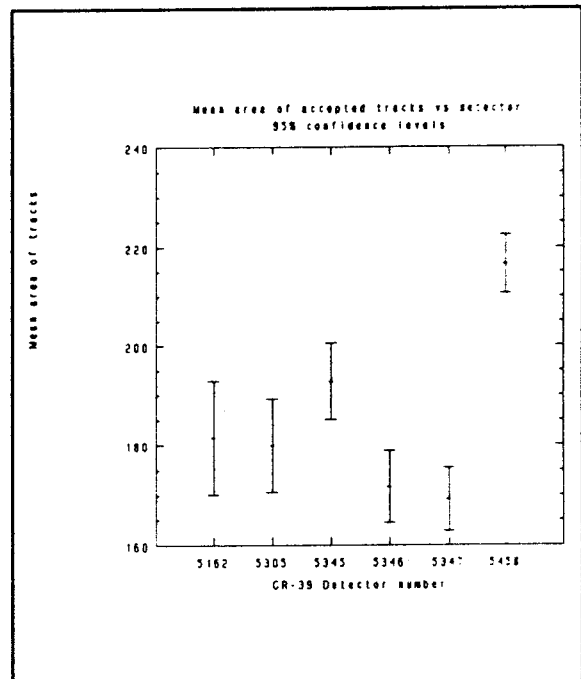


Figure 7 Mean track areas for detectors.

### Advantages and Disadvantages of the Automatic Counting System.

There are advantages and disadvantages in using the automatic system as it is presently configured. They can be listed as follows:

#### *Advantages*

1. Manual counting is tedious particularly when large numbers of detectors are to be counted.

2. More information is obtained and stored about the sample than that obtained by manual reading, eg area, shape and size of tracks. The data files can be used to recount the tracks using different filters after the measurements have been completed. These data may also provide a means of checking on etching procedures and improving quality control. Statistical tests may be carried out on these data to provide such information as the uniformity of the distribution of tracks.

3. The software is simple to use.

4. The system initially used a slow IBM compatible 286 computer. This resulted in counting speeds slower than those of a manual operator. The change to an IBM 386 compatible enabled counting to proceed at a faster speed than obtainable by manual operators where the stage is moved manually and data recording must take place after each area counted. The software also enables areas without tracks to be scanned rapidly. This gives a particularly useful increase in speed where the detector's track densities are low.

#### *Disadvantages*

1. No filter setup is required by manual counters whereas the automatic system needs adjusting prior to a batch of CR-39 being counted.

2. At present the stage can carry only one sample at a time. It would be better to use a stage which carries several detectors with software capable of automatically switching from one detector to another.

## Results

The raw data for track counting for each person's manual counting for a total of 30 areas each of  $8.3 \times 10^{-4} \text{ cm}^2$  are shown in Table 1. The manual counters are labelled one to five. Two automatic counts were made on each sample. These are labelled Auto1 and Auto 2 and were made using 100 areas each of  $1.69 \times 10^{-3} \text{ cm}^2$ . The standard CR-39 sample which was exposed in the ARL radon chamber is number Rn5450. The data in Table 2 may be used to compare the total number of tracks read by each reader. The error in each reader's total is assumed to follow the Poisson distribution. Figure 8 shows the totals for each reader and the error bars represent one standard deviation. It can be seen that the readers differ significantly. To overcome this problem each person's readings were normalized to their standard exposure reading. In Table 2 the results of Table 1 have been recalculated as fractions of the standard's result. This is normal procedure at ARL and enables each person's results and the results of the automatic system to be compared.

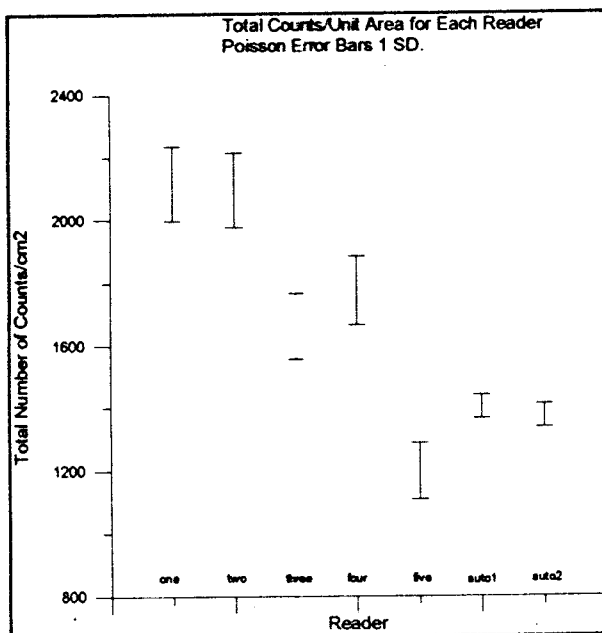


Figure 8 Total counts/unit area

**Table 1.**

CR-39	one	two	three	four	five	Auto1	Auto2
Rn5450	66	68	66	66	49	371	338
Rn5162	14	6	7	17	18	102	93
Rn5305	35	30	23	23	22	150	162
Rn5345	51	66	47	42	23	222	206
Rn5346	61	51	45	42	32	254	239
Rn5347	89	92	60	75	35	323	355
Total	316	313	248	265	179	1422	1393

**Table 2.**

CR-39	one	two	three	four	five	Auto1	Auto2
Rn5162	0.212	0.088	0.106	0.258	0.367	0.27	0.28
Rn5305	0.530	0.441	0.348	0.348	0.449	0.40	0.48
Rn5345	0.773	0.971	0.712	0.636	0.469	0.60	0.61
Rn5346	0.924	0.750	0.682	0.636	0.653	0.68	0.71
Rn5347	1.348	1.353	0.909	1.136	0.714	0.87	1.05

To find whether a significant difference exists between readers of the CR-39 detectors after normalizing the readings against the standard CR-39, a two-way analysis of variance was made on the data in Table 2.

The analysis was made using a two way analysis of variance on the logarithms of the ratios in Table 2. The model used is given by equation 4.

$$\log(\text{ratio})_{ij} = \mu + \alpha_i + \beta_j + \epsilon_{ij} \quad (4)$$

where  $\mu$  = grand mean,  
 $\alpha_i$  = CR-39 effect,  
 $\beta_j$  = reader effect,  
 $\epsilon_{ij}$  = error.

The weights are given as :

$$w_{ij} = 1 / (\text{variance}[\log(\frac{C_{ij}}{S_{ij}})]) = 1 / (\frac{1}{C_{ij}} + \frac{1}{S_{ij}})$$

The results of the analysis of variance are shown in Table 3 below. This table shows the significance level or P-value for all the readers of the CR-39 detectors is 0.124, i.e. there is an 12.4% probability of exceeding the given F-ratio by chance. The results show a significant difference between CR-39 detectors, which is to be expected as they were exposed at different locations. There is no statistically significant difference between the readers of the detectors if a confidence level of 95% is chosen. This results shows how important it is to normalize all results to a standard exposure for each reader.

**Table 3.**

<b><u>Source of variation</u></b>	<b><u>Sum of squares</u></b>	<b><u>d.f.</u></b>	<b><u>Mean square</u></b>	<b><u>F-Ratio</u></b>	<b><u>Sig Level</u></b>
Reader	14.339	6	2.390	1.89	0.124
CR-39	312.60	4	78.15	69.87	0.000
Error	30.315	24	1.263		

