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DYNAMIC BEHAVIOUR OF THORON PROGENY IN LABORATORY EXPERIMENTS

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EXTENDED ABSTRACT

The behaviour of a ^{220}Rn/^{220}Rn progeny atmosphere was investigated under laboratory controlled conditions. Experiments were conducted in a large Radon/Thoron Test Facility (RTTF) of the walk-in type operated in a flow-through fashion at two air residence times of approximately 7 min and 14 min. A ^{232}Tn dry source of activity 3811 KBq was used as the source of ^{220}Rn. Experiments were conducted at two aerosol concentration ranges, namely 100 to 500 cm^{-3} (low concentration) and 8 x 10^3 - 1 x 10^4 cm^{-3} (moderate concentration). Aerosols (uranin) were mixed with ^{220}Rn in a mixing chamber prior to its injection into the RTTF. The aerosol/^{220}Rn atmosphere in the RTTF was thoroughly mixed by means of a fan of the rotating type covering an angle of about 100°. Temperature and relative humidity were maintained constant. The following variables were determined: [^{220}Rn], [^{212}Bi], [^{212}Pb], PAEC, aerosol concentration (N), β-particle activity and ^{220}Rn progeny plated-out on the RTTF. (Note: square brackets are used to denote activity concentration.) Plate-out measurements were conducted using filter material substrates placed on the walls and floor of the RTTF. The following are but a few of the experimental observations made:

1. [^{220}Rn] and PAEC were inversely proportional to the RTTF airflow rate, Q, i.e., directly proportional to the air residence time. The relative change in the values of the above radioactivity variables brought about by the change in Q were similar for the same N. A 23% increase in [^{220}Rn] and PAEC was brought about by a decrease in Q by a factor of 2. These data give an indication of the dynamic conditions in the RTTF.
2. Under constant Q, the ratio [^{212}Bi]/[^{212}Pb] was substantially reduced (50%) by a decrease in N from 5.3 - 9.4 x 10^3 cm^{-3} to 100 - 190 cm^{-3}. Under the same experimental conditions, the PAEC was also reduced by a factor of about 4.2.
3. Plate-out in the RTTF increased with decreasing aerosol concentration. The ratio of the plate-out activities under varying N conditions was identical to that found for PAEC (4.2).
4. The ratio (2.98) of the airborne β-particle activity under moderate N and low N was substantially lower than the ratio of PAEC under the reverse N

conditions. It is suggested that ^{212}Bi plates-out more readily than ^{212}Pb under low N conditions.

5. An axially symmetric plated-out activity profile was obtained which permitted airflow patterns in the RTTF to be mapped-out.

The data reported here are relevant for the control of ^{220}Rn progeny in working and living environments.

Key words: Thoron; Thoron progeny; Dynamic behaviour.

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INTRODUCTION

Thorium (^{232}Th) is a naturally occurring radioisotope which is found widely, and more or less uniformly, distributed in the crust of the Earth. This radioisotope is the parent of a natural radioactive decay chain, known as the natural thorium decay chain, which leads through a series of intermediate radioactive decay steps to the formation of the radionuclide ^{234}U, which in turn decays by α-particle emission to the radioactive gas, thoron (^{220}Rn). Because ^{220}Rn is a gas, it readily diffuses through materials finding its way with relative ease into working and living spaces.

Thoron, in turn, decays into its short-lived decay products (progeny) which are more important than ^{220}Rn from the health physics, occupational hygiene, and occupational exposure standpoints. Because of their presence in working and living spaces, ^{220}Rn and its progeny are of practical and theoretical interest.

This report presents and discusses the dynamic behaviour of ^{220}Rn and its progeny under laboratory controlled conditions attained in a Radon/Thoron Test Facility (RTTF) of the walk-in type. Experiments were conducted under steady-state conditions and under transient conditions.

EXPERIMENTAL VARIABLES MEASURED OR CONTROLLED

Experiments were carried out in a large Radon/Thoron Test Facility (RTTF) of the walk-in type. Radon-220, aerosols and air were injected into the RTTF. The following variables were carefully monitored:

1. ^{220}Rn concentration, i.e., [^{220}Rn];
2. ^{220}Rn progeny concentration, i.e., [^{212}Pb] and [^{212}Bi], and PAEC(Tn), i.e., Potential Alpha Energy Concentration. (Note: the square brackets are used to denote activity concentration. The symbol Tn in round brackets stands for ^{220}Rn.);
3. Aerosol concentration and size distribution;

4. Radioactive aerosol concentration and size distribution;
5. Airflow rate, Q, through the RTTF and air residence time, RT, in the chamber;
6. β-particle activity;
7. Relative humidity, and temperature.

In addition to the above, ^{220}Rn progeny plate-out measurements on the RTTF walls were made.

EXPERIMENTAL PROCEDURES AND MEASUREMENTS

A ^{232}Th dry source of activity 3811 kBq (model TH-1025 manufactured by Pylon Electronics Development, Ottawa) was used as the source of ^{220}Rn. Experiments were conducted at two aerosol concentration ranges, namely, 1.0×10^2 to 5.0×10^2 cm^{-3} (low concentration), and 8.0×10^3 to 1.0×10^4 cm^{-3} (moderate concentration). Aerosols (uranin) were mixed with ^{220}Rn in a mixing chamber prior to their injection into the RTTF. The uranin aerosols were generated and injected into the mixing chamber by means of a constant output atomizer, model 3076, in conjunction with an air supply system, model 3071, both manufactured by TSI (U.S.A.). The aerosol/^{220}Rn atmosphere was thoroughly mixed by means of a fan of the rotating type covering an angle of about 100°. Temperature (~20°C) and relative humidity were maintained constant.

Radon-220 concentration, [^{220}Rn], was measured using the two filter tube (2 FT) method. Rn-220 progeny concentration, [^{212}Pb] and [^{212}Bi], and PAEC(Tn) were determined using a two gross α-particle count method developed at this laboratory.

Beta-particle activity was measured by means of a GM tube of the pancake type, model HP-260, in conjunction with a scaler, model MS-2, both manufactured by Eberline (U.S.A.).

Aerosol concentration (N) in the size range ~0.005 μm to less than 1 μm was measured by means of two aerosol counters, namely, model Rich 200, manufactured by Environment One (U.S.A.), and a condensation nuclei counter (CNC), model 3020, manufactured by TSI (U.S.A.). The two counters monitored air in the RTTF at two different locations. These counters could also be used in conjunction with other instrumentation to characterize aerosol clouds (see below).

Aerosol size distribution, $N(D_p)$, i.e., the number of particles of size between D_p and $D_p + dD_p$, versus particle size (D_p), was determined using a Differential Mobility Particle Sizer (DMPS), model 3071, manufactured by TSI in conjunction with CNC model 3020, also developed by the same company. Aerosol size distribution was also measured using a Diffusion Battery, model 3040-1, in conjunction with an Automatic Switching Valve, model 3042, and CNC model 3020, all manufactured by TSI.

Radioactive aerosol size distribution was determined by electrostatic charge spectrometric methods and by using graded wire screens. (The latter measurements were conducted in collaboration with the Denver Research Center, U.S. Bureau of Mines, Denver, CO.)

The Radon/Thoron Test Facility (RTTF) operated in a flow-through fashion at two air residence times, RT, of approximately 7 min and 14 min.

Plate-out measurements were carried out using filter material substrates placed on the walls and floor of the RTTF. Substrates placed on the RTTF walls were located 1 m above the floor. The substrates were exposed for 24 h at a time, and their α-particle activity was measured at a fixed time after the end of the exposure period.

EXPERIMENTAL RESULTS AND DISCUSSION

Dynamic conditions in the Radon/Thoron Test Facility (RTTF) were investigated by studying the effect of airflow rate (Q), and aerosol concentration (N) on ^{220}Rn and its progeny, and on the ^{220}Rn progeny plated-out on the walls of the RTTF. For simplicity and ease of presentation, the experimental data have been divided into four main groups, namely:

A. Effect of airflow rate, Q, on ^{220}Rn and ^{220}Rn progeny, including airborne β-particle activity;

B. Effect of aerosol concentration, N, on ^{220}Rn progeny;

C. Transient effects caused by the sudden change, i.e., injection or interruption of ^{220}Rn and/or aerosols; and

D. Plate-out of ^{220}Rn progeny on the RTTF walls and ceiling. This study includes the effect of air turbulence on plate-out phenomena.

EFFECT OF AIRFLOW RATE ON ^{220}Rn AND ITS PROGENY

In these series of experiments, the RTTF was operated in the flow through configuration, i.e., single pass air, and hence no air recirculation. Two airflow rates were mainly used corresponding to air residence times in the RTTF of 7 min and 14 min, approximately. These air residence times, (RT), corresponded to airflow rates in the RTTF of about 4 m^3 min^{-1} and 2 m^3 min^{-1}, respectively.

Table 1 shows a summary of the data corresponding to the effect of airflow rate (Q) on ^{220}Rn concentration, [^{220}Rn], and the ^{220}Rn progeny Potential Alpha Energy Concentration, PAEC(Tn), in the RTTF. The table shows:

a) ^{220}Rn concentration and PAEC(Tn) are inversely proportional to the RTTF airflow rate, i.e., directly proportional to the air residence time, RT, defined as the ratio of the total volume of the test facility, V, and the airflow rate, i.e., RT = V/Q.

b) The relative change in the values of the above radioactivity variables brought about by the change in Q was similar for the same aerosol concentration, N. A 23% increase in [^{220}Rn] and PAEC(Tn) was brought about by a decrease in Q by a factor of approximately 2.

Item (a) is in complete qualitative agreement with theoretical expectations.

Table 2 shows the effect of airflow rate (Q) on ^{220}Rn progeny (see also

Table 1) and on the important ^{220}Rn progeny ratio [^{212}Bi]/[^{212}Pb]. This table has been compiled by selecting radioactivity data obtained under varying airflow conditions, but aerosol conditions as close as possible, i.e., in the low aerosol concentration range from 40 cm^{-3} to $\lesssim$ 400 cm^{-3}. The data of Table 2 shows the effect of Q on ^{220}Rn progeny in more detail than Table 1. But most importantly, it shows that the airflow rate also affects the ratio [^{212}Bi]/[^{212}Pb] significantly. Table 2 shows that under similar aerosol concentration conditions, the ratio [^{212}Bi]/[^{212}Pb] increases with decreasing airflow rate, and vice versa.

B. EFFECT OF AEROSOL CONCENTRATION ON ^{220}Rn PROGENY

The effect of aerosol concentration (N) on ^{220}Rn progeny was studied with the RTTF airflow system operating in the recirculation mode (100% recirculation), and in the flow through (100%) configuration. Data obtained in the flow through mode are shown in Table 3 for an airflow rate of about 4 m^{3} min^{-1} corresponding to RT ~7 min. The data of Table 3 were obtained at two aerosol concentration ranges, namely, low aerosol concentration (N = 40 to 400 cm^{-3}) and at moderate aerosol concentrations (~5.0 x 10^{3} to 9.4 x 10^{3} cm^{-3}).

Table 3 shows that, as would be expected on theoretical grounds, [^{212}Pb], [^{212}Bi], and hence PAEC(Tn) increased with increasing N. The data shown in this Table represent average values over at least 10 h of continuous RTTF operation under steady-state conditions. The same applies to Tables 1 and 2.

Table 4 shows data similar to that of Table 3 except that measurements were carried out under transient conditions, i.e., the aerosol concentration was varied with time during an 8 h period. Two independent days of experimentation are shown in Table 4.

Tables 3 and 4 clearly show that the radioactivity ratio [^{212}Bi]/[^{212}Pb] varies with aerosol concentration, N, increasing with increasing N, and vice versa.

In summary, the ratio [^{212}Bi]/[^{212}Pb] was substantially reduced (~50%), under constant airflow conditions, by a decrease in aerosol concentration from 5.3-9.4 x 10^{-3} to 100-190 cm^{-3}. The data also seem to indicate that ^{212}Bi plates-out more readily than ^{212}Pb.

C. TRANSIENT EFFECTS

In this section, the transient effects caused by varying N, Q and/or ^{222}Rn injection into the RTTF are examined.

1. Transient Effect on ^{220}Rn and its Progeny Caused by the Sudden Injection or Interruption of ^{220}Rn Injection in the RTTF

The effect on ^{220}Rn progeny caused by the injection and interruption of ^{220}Rn injection in the RTTF is shown in Figures 1 and 2. The data show a rapid decrease in [^{212}Pb], [^{212}Bi], and PAEC(Tn) with time after turning the ^{220}Rn source off. This is to be expected because in the air flow through mode, radioactive materials are rapidly removed from the RTTF if they are not constantly replenished by injection of ^{220}Rn. An interesting feature is the large increase of the ratio [^{212}Bi]/[^{212}Pb] versus time after the source of ^{220}Rn has been turned off (Figure 2). It can be seen that this ratio attains values greater than unity, i.e., the condition for radioactive equilibrium. This significant departure from equilibrium conditions can be explained by a combination of the following:

a) In the air flow through mode, airborne radionuclides are rapidly removed from the RTTF radioactive atmosphere. Hence, the concentrations of ^{220}Rn, and also ^{216}Po quckly diminish during the air residence time;

b) Because of the short radioactive half-lives corresponding to ^{220}Rn(~54.5 s) and ^{216}Po(~0.15 s), the concentrations of these two radionuclides decrease to very low levels during the air residence time in the RTTF; and

c) After turning the ^{220}Rn source off, all available airborne ^{220}Rn and ^{216}Po rapidly decay into ^{212}Pb. From this moment on (a few minutes), the concentration of ^{212}Pb, i.e., [^{212}Pb], decreases steadily by radioactive decay, giving rise to ^{212}Bi. Hence, ^{212}Bi builds up whereas ^{212}Pb decays away. Eventually, the state of 'equilibrium' between these two radioisotopes is significantly upset and the ratio [^{212}Bi]/[^{212}Pb] becomes greater than unity.

2. Transient Effect on ^{220}Rn Progeny Induced by the Sudden Injection or Interruption of Aerosol Injection in the RTTF

The effect of sudden changes in aerosol concentration, N, on ^{220}Rn progeny is shown in Figure 3 (see also Tables 3 and 4).

The increase in airborne ^{220}Rn progeny concentration with increasing aerosol concentration is consistent with earlier findings. The increase observed in ^{220}Rn progeny concentration when the latter comes into contact, i.e., interacts, with aerosols can be explained as follows. Recently formed ^{220}Rn progeny readily attach themselves to large surfaces such as walls and other large objects. However, if aerosol in the submicron size range are present in the ^{220}Rn progeny 'cloud', the latter attach themselves easily to these aerosols, and the rate of ^{220}Rn progeny plate-out (or deposition on surfaces) is reduced significantly. This decrease in the rate of attachment or deposition to surfaces is explained by the fact that the attached (to aerosols) ^{220}Rn progeny form much larger and heavier particles than the recently formed short-lived decay products of ^{220}Rn, i.e., 'unattached' fraction. Because larger particles diffuse less readily than smaller particles, the deposition rate of the 'combined' radioactive particles decreases, and hence, more ^{220}Rn progeny remain airborne. The converse phenomenon is equally true, namely, a decrease in aerosol concentration causes airborne [^{212}Pb], [^{212}Bi], and hence PAEC(Tn), to decrease because lacking an adequate material substrate, e.g., aerosols, unattached ^{220}Rn progeny diffuse rapidly to walls and/or large surfaces where they deposit.

The data also show that the ratio [^{212}Bi]/[^{212}Pb] increases significantly with increasing aerosol concentration, N. Another feature of interest is that the ratio [^{212}Bi]/[^{212}Pb] is smaller (~0.1-0.18) for the air flow through mode than for the recirculation mode (0.4-0.58) under the same airflow conditions, i.e., Q ~4 m^3 min^{-1}, and aerosol concentration.

D. PLATE-OUT OF ^{220}Rn PROGENY ON LARGE SURFACES

The rate of plate-out of ^{220}Rn progeny to fast moving large surfaces, such as the blades of an operating fan, is significantly larger than for a stationary surface, particularly at low aerosol concentration. In the present work the effect of a fan of the rotating type on ^{220}Rn progeny was investigated at low and moderate aerosol concentrations. Experiments were conducted operating the RTTF on the air flow through mode with an airflow rate Q ~1 m^3 min^{-1}.

The data obtained show a small effect (~6%) of the mixing fan on ^{220}Rn progeny at N ~1.0 x 10^4 cm^{-3}. As predicted, the operation of the fan decreased ^{220}Rn progeny in the RTTF. At much lower aerosol concentration, (N <10^3 cm^{-3}), however, the effect of the mixing fan was very pronounced decreasing [^{212}Pb], [^{212}Bi], and PAEC(Tn) to about half of their original values before operating the mixing fan.

Plate-out studies were also conducted using filter substrates on the surface of the RTTF as described in a former section. As before, the RTTF was operated in the air flow through mode at Q = 1 m^3 min^{-1}. The results obtained are shown in Figures 4 to 6. These figures summarize four different types of experiments with the fan and aerosol as variables, namely:

1. Fan on and no aerosols injected;
2. Fan off and no aerosols injected;
3. Fan on and aerosols injected; and
4. Fan off and aerosols injected.

Figures 4 to 6 have been plotted according to geometrical symmetry considerations, using the longitudinal axis of the RTTF as the axis of symmetry. The positions in the RTTF of the substrates used for plate-out studies are indicated in Figure 7.

Figure 4 shows the activity (Bqm^{-2}) plated-out on the filter substrates when no aerosol is injected in the RTTF ($N < 1.0 \times 10^3\ cm^{-3}$) with the fan on (upper graph), and with the fan turned off (lower graph). The data show that the plated-out activity was substantially larger when the fan was operated than when the fan was turned off. This result can be predicted on theoretical grounds. Close inspection of Figure 4 reveals the following:

1. There is symmetry in the plated-out activity (relative to the longitudinal axis of the RTTF) for the case of the fan on, as opposed to an obvious lack of symmetry when the fan was turned off. The reason for this is proper air mixing in the first case (fan on) which is absent when the fan was not operated. The slight asymmetry shown in the upper graph of the figure is most probably due to uneven angular rotation of the fan.
2. The ratio of the activity plated-out when the fan was on (A_{on}) to the activity when the fan was turned off (A_{off}), i.e., A_{on}/A_{off}, was dependent on the location in the RTTF. The ratio was, in general, substantially greater than unity (i.e., $A_{on} > A_{off}$). The maximum value was attained at position 6, for which $A_{on}/A_{off} \sim 4.5$. (Note: positions 6 and 4 mark the approximate limits of angular rotation for the fan.)
3. Because of the complex air patterns set up by the fan, cases for which $A_{on} \lesssim A_{off}$ should not be surprising.

Figure 5 shows similar qualitative features as Figure 4, the only difference between the two is that in the first case, aerosols were injected into the RTTF ($N \sim 1.0 \times 10^4\ cm^{-3}$). The most salient feature of the data shown in Figure 5 (obtained at moderate N) as compared with Figure 4 (under low N conditions) is that the values for the plated-out activity obtained in the former case are significantly lower than that corresponding to the latter case. A comparison of Figures 4 and 5 also indicates that the ratio of the plated-out activity under low aerosol conditions to the activity under aerosol injection conditions could easily attain values equal to or greater than 3.

Figure 6 shows values for the plated-out activity measured along the longitudinal axis of the RTTF, i.e., positions 4, 13, 14 and 10 for the four experimental conditions described earlier on. Again, the plated-out activities were significantly larger for the case of low aerosol conditions for the fan on, or the fan off, as compared with the data obtained under aerosol injection when the fan was on or off.

Finally, it should be noted that two additional filter substrates were located directly on the fan blades and the plated-out activity on them was measured for the four experimental conditions indicated above. The following was observed:

1. The plated-out activity measured on the fan blades for the case where the fan was off, and under low aerosol conditions, was about the same as that for the other substrates (i.e., 4, 13, 14 and 10) under the same experimental conditions.
2. A similar result as that described in item 1 was obtained under aerosol injection when the fan was not operated. The only difference between items 1 and 2 is that the plated-out activities corresponding to item 1 were substantially larger than for item 2, as previously discussed, and in agreement with theoretical expectations and previous experience.
3. The activity plated-out on the fan blades when the fan was operating was considerably larger (up to a factor of 30) than the activity plated-out on the other substrates anywhere in the RTTF. This was true irrespective of whether there was aerosol injection or not. Again, the plated-out activity on the blades, under low aerosol concentration conditions, was substantially larger than the activity measured under moderate and high aerosol concentration conditions.

The most important conclusion that can be drawn from the plate-out studies discussed above is that aerosol concentration, airflow conditions, and air turbulence greatly affect the rate of deposition of ^{220}Rn progeny on large surfaces.

MAIN CONCLUSIONS

1. [^{220}Rn] and PAEC(Tn) were inversely proportional to the RTTF airflow rate (Q), i.e., directly proportional to the air residence time. The relative change in the values of the above radioactivity variables brought about by the change in Q were similar for the same aerosol concentration N. A 23% increase in [^{220}Rn] and PAEC(Tn) was brought about by a decrease in Q by a factor of 2. These data give an indication of the dynamic conditions in the RTTF.
2. Under constant Q, the ratio [^{212}Bi]/[^{212}Pb] was substantially reduced (50%) by a decrease in N from 5.3-9.4 x 10^3 cm^{-3} to 100-190 cm^{-3}. Under the same experimental conditions, the PAEC(Tn) was also reduced by a factor of about 4.2.
3. Plate-out in the RTTF increased with decreasing aerosol concentration. The ratio of the plate-out activities under varying N conditions was identical to that found for PAEC(Tn), i.e., ~4.2.
4. The ratio (2.98) of the airborne β-particle activity under moderate N and low N was substantially lower than the ratio of PAEC(Tn) under the reverse N conditions. It is suggested that ^{212}Bi plates-out more readily than ^{212}Pb under low N conditions.
5. An axially symmetric plated-out activity profile was obtained which permitted airflow patterns in the RTTF to be mapped-out.

The results reported here are of general practical interest. These results are also quite relevant for the control of ^{222}Rn and ^{220}Rn progeny in working spaces such as U-mines as well as living environments.

Table 1 - Effect of airflow rate (Q) on ^{220}Rn concentration and PAEC(Tn) in the Radon/Thoron Test Facility (RTTF). (Air flow through configuration.)

Q (m^3 min^{-1})	[^{220}Rn] (Bq m^{-3})	PAEC(Tn) (μJ m^{-3})	N (cm^{-3})	RT (min)	T °C	RH %
4	$7.03x10^4$	19.4	100-190	7	~24.5	18
2	$8.66x10^4$	25.1	50-60	14	24.7	14

Notes: N, RT, T and RT stand, respectively, for aerosol concentration, residence time, temperature, and relative humidity in the RTTF.

The residence time, RT, is defined by the expression: RT = V/Q, where V is the volume of the facility including the airflow system.

Table 2 - Effect of airflow rate (Q) on the ratio [^{212}Bi]/[^{212}Pb] and other radioactivity data. (Air flow through configuration.)

[^{212}Pb] (Bq m^{-3})	[^{212}Bi] (Bq m^{-3})	[^{212}Bi]/[^{212}Pb]	PAEC(Tn) (μJ m^{-3})	Q (m^3 min^{-1})	N (cm^{-3})
277.2	29.0	0.104	19.4	4	100-190
332.2	36.7	0.111	23.3	4	40-400
350.6	43.9	0.125	24.6	4	70-140
427.2	67.6	0.158	30.1	2	60-100
356.9	57.2	0.158	25.1	2	50-60
296.0	44.5	0.150	20.8	2	~40

Note: N stands for aerosol concentration.

Table 3 - Effect of aerosol concentration (N) on ^{220}Rn progeny concentration (Q = 4 m^3 min^{-1}). (Air flow through configuration.)

[^{212}Pb] (Bq m^{-3})	[^{212}Bi] (Bq m^{-3})	[^{212}Bi]/[^{212}Pb]	PAEC(Tn) (μJ m^{-3})	N (cm^{-3})
1130.7	183.4	0.163	79.6	7.5x10^3
1146.6	175.8	0.153	80.6	5.3-9.4x10^3
1191.4	179.3	0.150	83.8	7.7x10^3
277.2	29.0	0.104	19.4	100-190
332.2	36.7	0.111	23.3	40-400
350.6	43.9	0.125	24.6	70-140

Table 4 - Effect of (transient) aerosol concentration (N) on ^{220}Rn progeny ($Q = 4\ m^3\ min^{-1}$). (Air flow through configuration.)

Day	Time of Meas.	[^{212}Pb] (Bq m^{-3})	[^{212}Bi] (Bq m^{-3})	$\frac{[^{212}Bi]}{[^{212}Pb]}$	PAEC(Tn) (μJ m^{-3})	N (cm^3)
1	13.50	350.6	43.9	0.125	24.6	70-140
	12:50	430.1	66.3	0.154	30.3	<900 & $\gtrsim$140
	9:50	647.6	105.2	0.162	45.6	~2x10^3
	8:50	702.9	117.3	0.167	49.5	2x10^3
	10:50	775.3	142.7	0.184	54.7	2.3x10^3*
2^{++}	10:50	384.6	45.0	0.117	27.0	200-520
	11:50	397.1	43.6	0.110	27.8	700
	9:50	624.6	113.5	0.182	44.1	1.2x10^3*
	12:50	441.6	58.3	0.132	31.0	4x10^{3+}
	13:50	455.7	63.1	0.138	32.0	4.1x10^{3+}

* Strong N transient behaviour.

$^+$ Abnormally high N due to unknown reasons.

$^{++}$ Aerosol injection stopped at 9:05 at which time N ~9x10^3 cm^{-3}.

Note: Data not in chronological order but arranged according to increasing aerosol concentration.

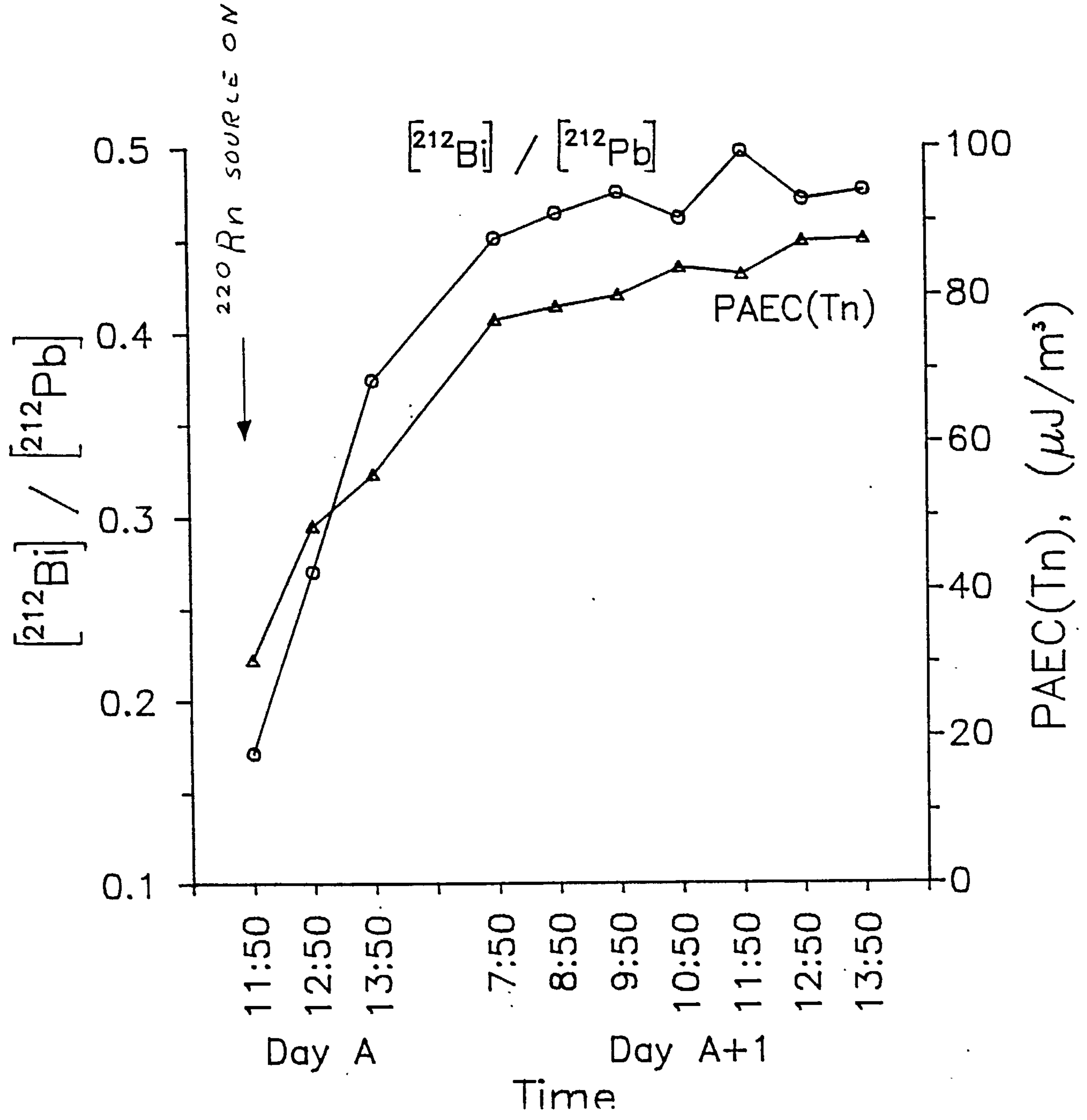

Fig. 1 - Effect of turning the ^{220}Rn source on, on the ^{220}Rn progeny level and [^{212}Bi]/[^{212}Pb] in the RTTF.

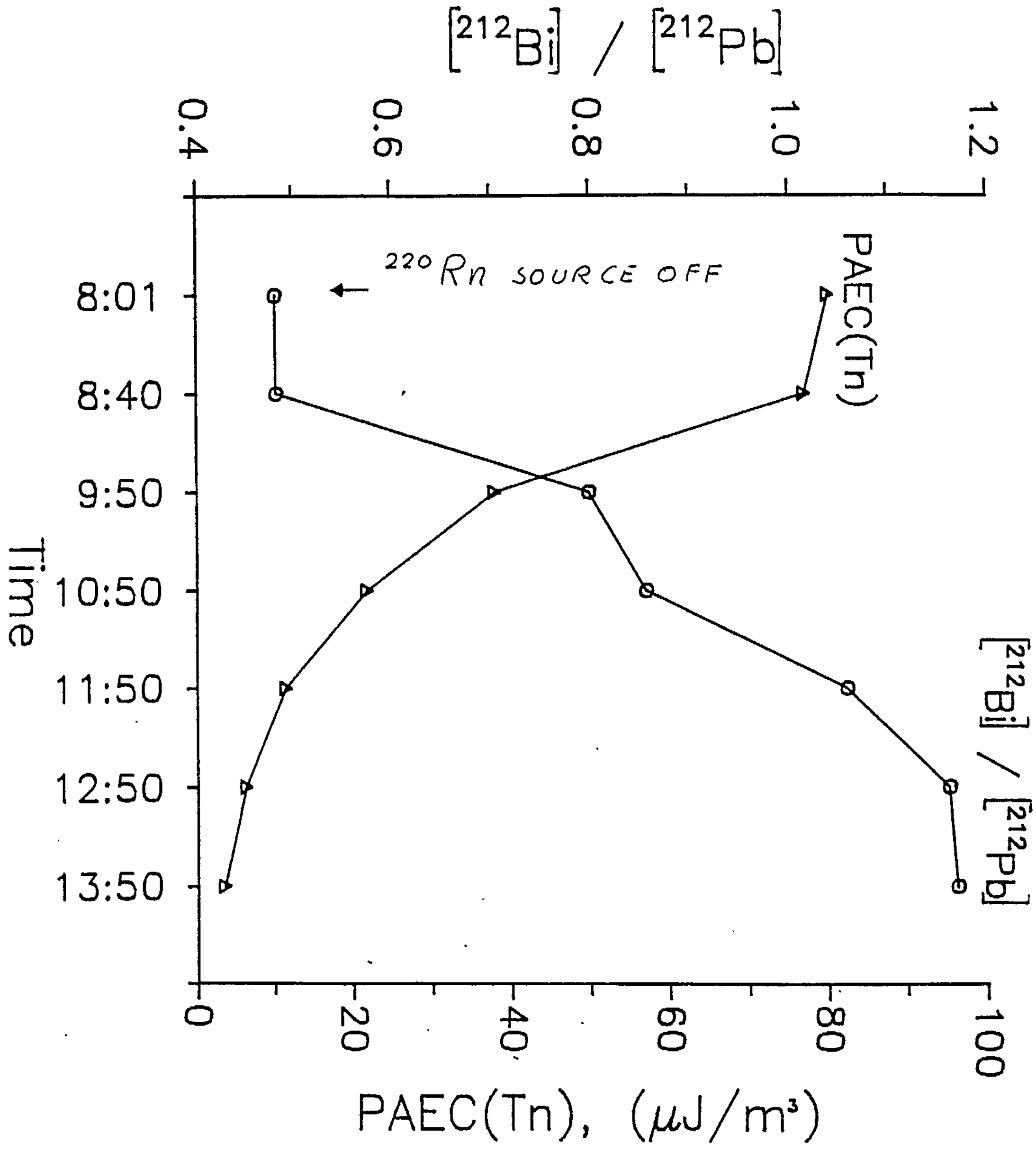

Fig. 2 - Effect of turning the ^{220}Rn source off, on the ^{220}Rn progeny level and [^{212}Bi]/[^{212}Pb] in the RTTF.

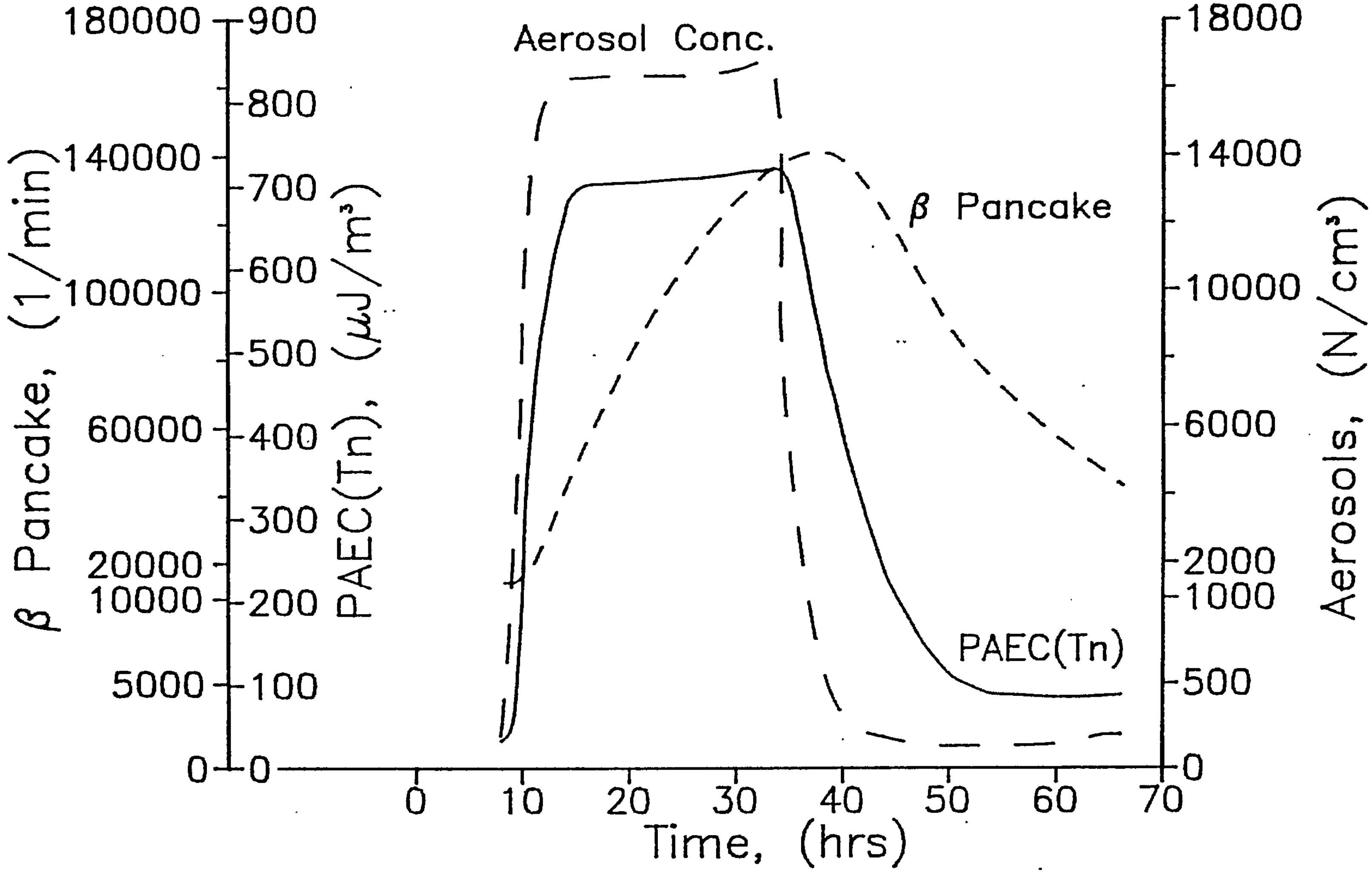

Fig. 3 - Effect of aerosol on the ^{220}Rn progeny levels in the RTTF.

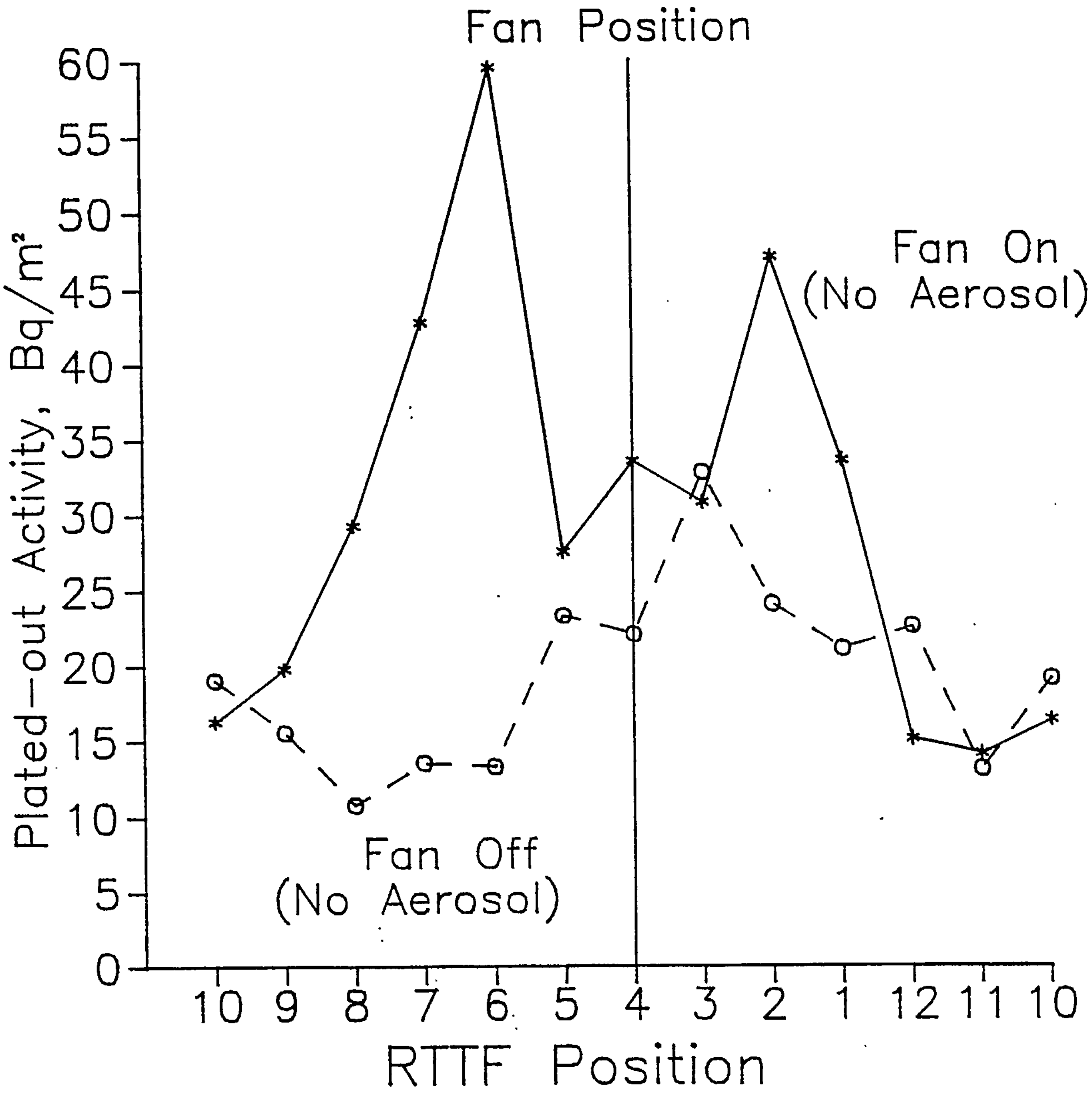

Fig. 4 - Plated-out activity on the RTTF walls measured at different locations (see Figure 7).

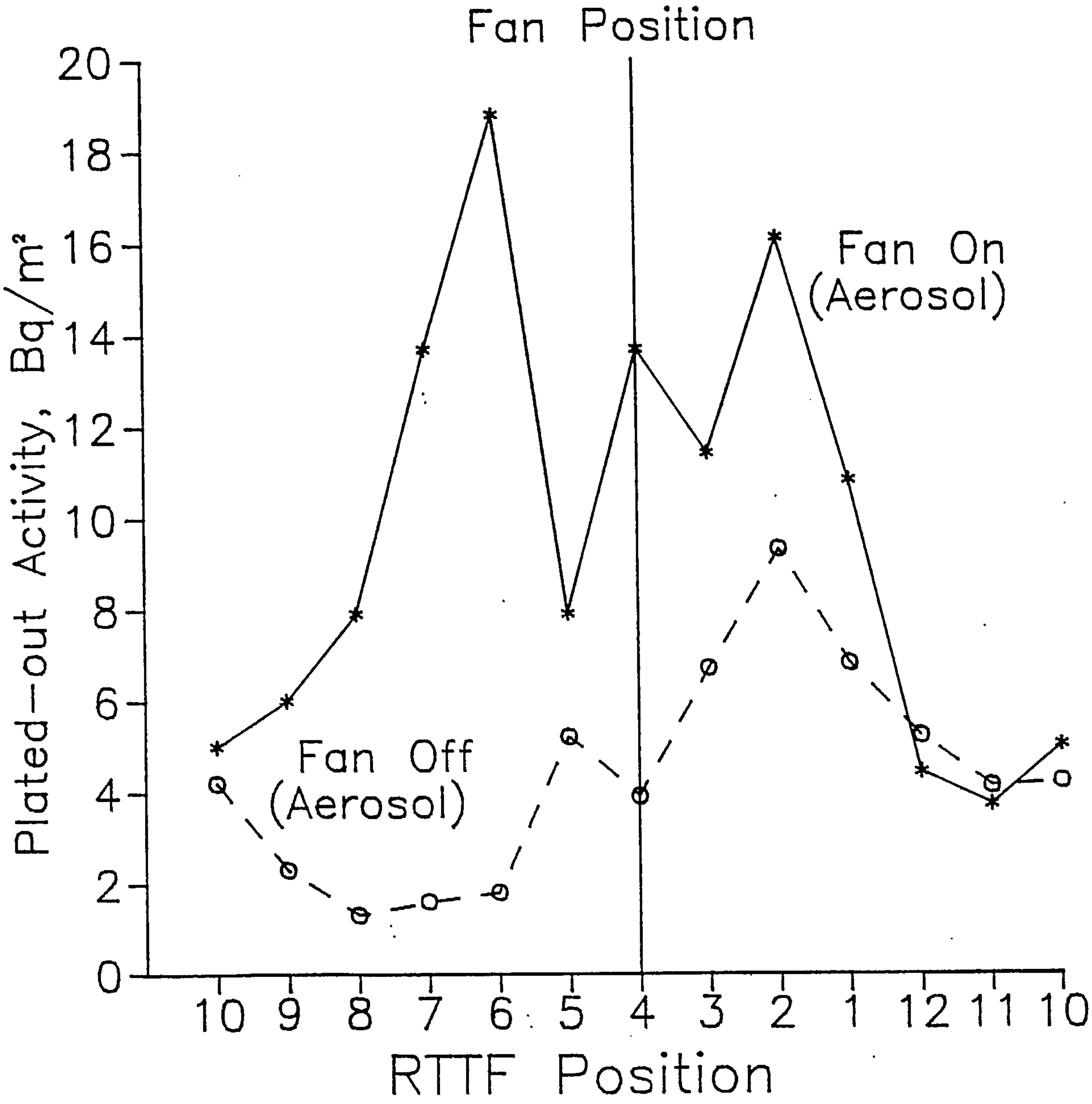

Fig. 5 - Plated-out activity on the RTTF walls measured at different locations (see Figure 7).

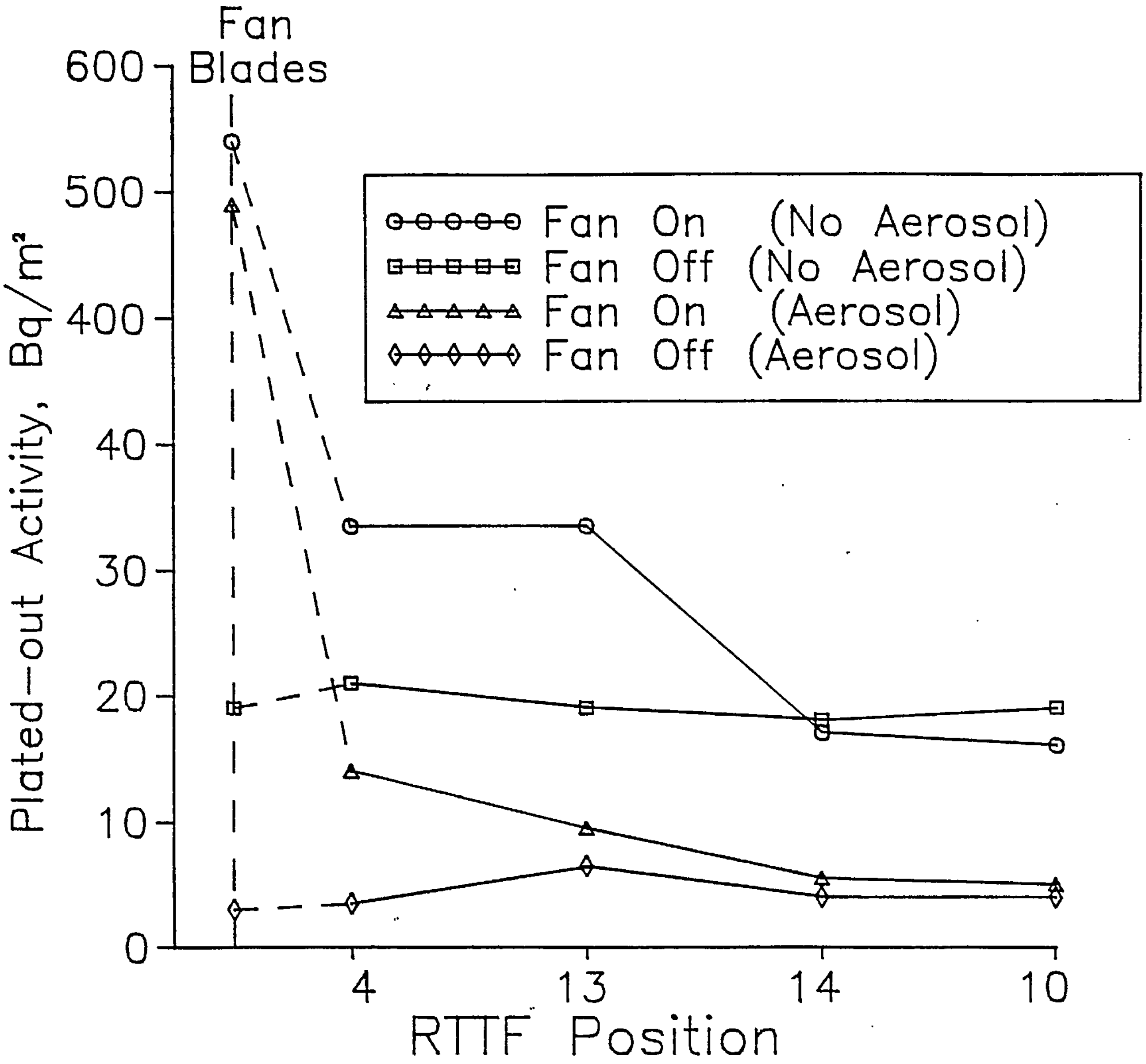

Fig. 6 - Plated-out activity on the RTTF walls measured at different locations (see Figure 7). Also shown is the plated-out activity on the fan blades.

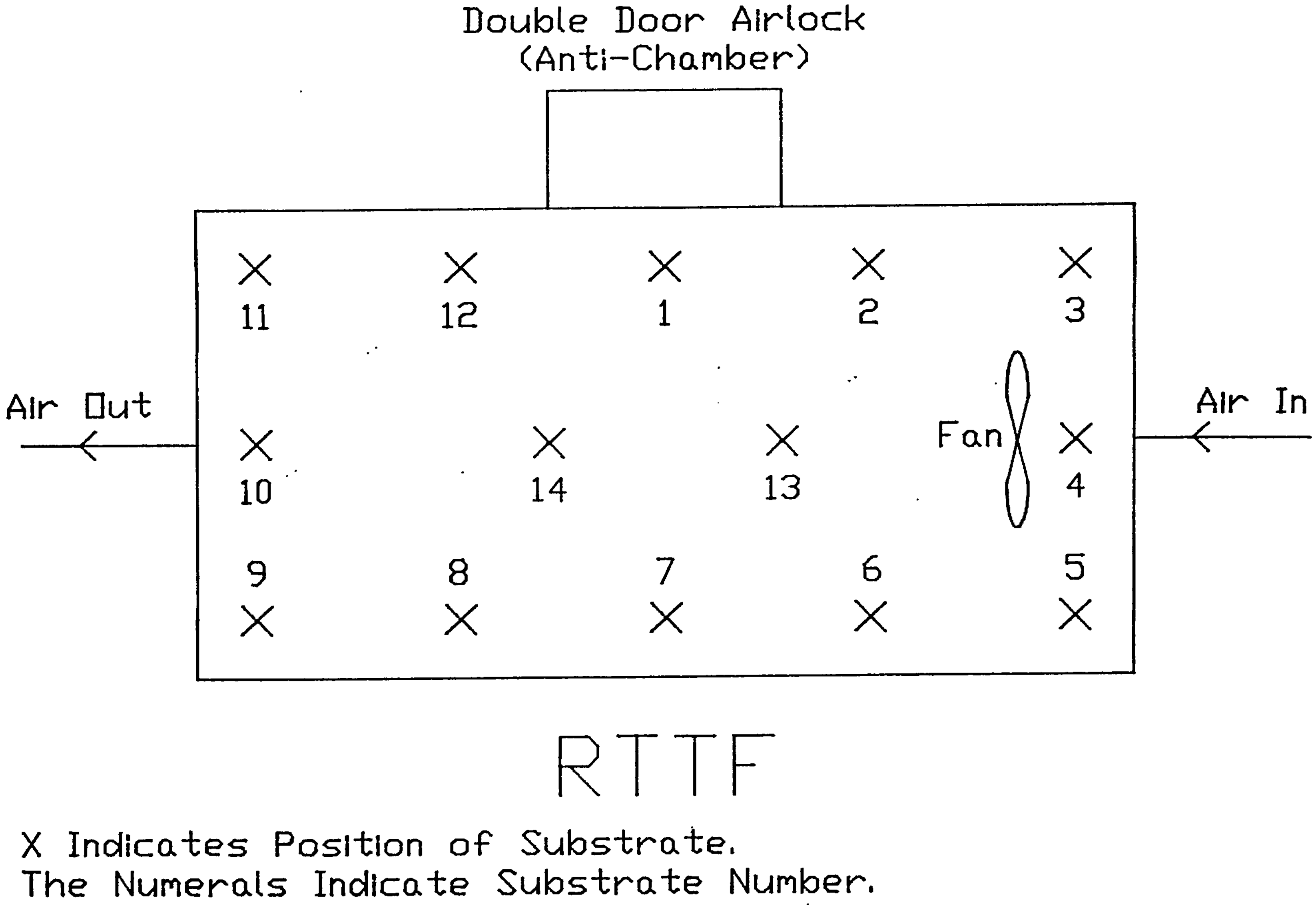

Fig. 7 - Locations in the RTTF where plate-out measurements were conducted.