MONITORING OF RADIOACTIVE FERROUS SCRAP AND PRODUCTS, CURRENT PRACTICES AND REGULATORY PROBLEMS IN NORTH-EASTERN ITALY

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ABSTRACT

Radioactive scrap metal is a major source of concern among the steel industries of north-eastern Italy, since most of the scrap supply comes from east-European countries and may originate from dismantled nuclear installations or dismissed radioactive devices. In this respect reliable monitoring procedures and consistent regulations are essential to face the many economic, legal and safety problems involved in the control and management of radioactive scrap and products. The authors describe the monitoring methods developed in more than two years practice at the steel works Ferriere Nord, Osoppo UD, Italy, as a realistic compromise between reliability, radiation protection and cost. They also discuss the drawbacks sometimes due to the lack of coherent monitoring protocols and exemption levels in Italian regulations, which leave some ways out for the uncontrolled recycling of radioactive metal scrap.

1 - FOREWORD

In the past ten years, in Italy as well as in other European countries, there have been a number of incidents at metal processing industries, where radioactive sources buried in metal scrap have been melted, resulting in significant contamination of plants and products.
The consequences of such incidents are potentially extremely serious. To prevent them the recent Italian law on the basic radiation protection criteria [1], which complies with the general safety directives of the Euratom Treaty, forces the importers and the recycling industries to control all incoming scrap.

However, the detection of either contaminated materials or radioactive sources buried in loads of scrap metal is a problem hard to get on with, on technical, economic, and legal points of view. First, control procedures must offer a good reliability level and an acceptable degree of accuracy, which are not easy goals when dealing with vehicles loaded with metal scrap. Then, they constitute a heavy economic burden, since they involve organisation problems, require the intervention of technical staff and are quite time-consuming. Finally, the law regulations do not tell anything about the technical aspects of control procedures, nor do they give definite clearance levels so far. As a matter of fact the customs, the local health authorities, and the national agency for the environment require different control procedures and clearance levels, which in the end are not perfectly consistent with each other.

In this work we give a concise presentation of the experience gained since 1995 at Ferriere Nord SpA, Rivoli di Osoppo, north-eastern Italy, in radiometric monitoring of both ferrous scrap and steel final products. Ferriere Nord is a steel plant which melts more than 1 million tons per year of scrap coming mostly from eastern-European countries, produces about 800,000 tons of steel material for building industry, and employs 800 people. When starting in 1995, the goal we set ourselves was to assure a good safety standard to the workers of the plant and a radiation-free final product with the maximum reliability level achievable at a reasonable cost, according to ALARA principle. We do not know whether we succeeded, however we think that our experience in the field offers some interesting hints for the application of the concepts of exemption and clearance in the management of metal scrap by recycling industries.

2 - MONITORING RADIOACTIVE FERROUS SCRAP ON VEHICLES

The cost of monitoring radioactive material and sources in scrap is high, especially as far as technical staff and time expenses are concerned--- the more accurate is the monitoring, the higher is the cost. Moreover, anyone who is familiar with the operations of transportation, storage and melting of scrap in steelworks is perfectly aware that a detailed monitoring of the scattered scrap [2] is not realistic, neither in technical and logistic terms, nor as far as the protection of workers is concerned. In fact it is usually very difficult, sometimes impossible to fetch, handle, store a source which is often either damaged and highly contaminating, or contained in metal structures of large size and weight, or both. Therefore the only possibility left is the radiometric monitoring of the external sides of wagons and lorries before unloading.

So, the basic questions one should answer in setting up a radiometric control system are i) below what probability level it is acceptable that some vehicles containing a gamma-emitting source of limited activity escape detection?, and ii) up to what operating cost it is acceptable that some *clean* load is rejected as radioactive? These questions, expressed in somehow different terms, are well-known to physicists dealing with very low-level radiation measurements [3,4] and of course, in the case of laboratory procedures, are directly related to the minimum detectable activity of the system. However, in our case the problem cannot be given a mathematical solution in statistical terms since, unlike in a laboratory, we cannot exactly know the false negative rate, nor are we able to measure activities.

If we increase the acceptable probability of false negatives we reduce the cost, but we would increase the number of sources - most likely of limited activity - that would be melted, ending up in contaminated smoke, smelter, slag and products. On the other end, increasing the acceptable false positives would mean rejecting an increasing number of vehicles which are either slightly contaminated, or contain only slightly contaminated scrap and would cause a negligible amount of contamination. It is obvious that the solution of the problem must be a wise compromise.

In this respect, the experience on the field demonstrates that control procedures required by Italian health authorities and customs are out of balance--- if they are carried on slavishly, then many scrap loads containing sources of relatively high activity could finish in the ladle. In fact they are based on the measurement of air kerma rate on the external sides of the vehicles, that has to be compared with either the local natural radiation background [5], or an absolute clearance limit [6] (figure 1).

Apart from the problem of assessing daily the natural radiation background within a sound precision range - which is not a simple matter - we must take into account that background radiation near the sides of a vehicle loaded with metal scrap is much lower than natural radiation background (figure 2a). Therefore, if somewhere on the side of vehicle we measure a kerma rate equal to, or even only slightly less than natural background, then we must conclude that the load contains a radioactive source - whose activity we do not know - and the vehicle should be rejected. In addition, the absolute clearance limit given by local health authority is obtained just multiplying by two a mean local background kerma rate, that is an unacceptably high value.

Moreover radiometric monitoring carried on manually, by means of a survey meter, is unlikely to cover uniformly the whole surface of the sides of a rail wagon in a reasonable time, whichever type of monitor is used. If a source is heavily screened by scrap on almost all the solid angle, except in just one direction along a narrow beam - which often is the case - most probably it shall not be detected (figure 2b). The conclusion is that the control directives and manual monitoring procedures do not offer sound efficiency, nor sensitivity features.

Finally, we must take into account that manual monitoring requires that the operators come near the loads for hours, without knowing the radiation level in advance. If some vehicles contain high activity sources which produce high kerma rates, the operators risk to get high radiation doses before detecting them and having the chance to get away at safety distance. The conclusion is that the control directives and manual monitoring procedures do not offer sound radiation protection features.

The ultimate compromise we have adopted for the solution of these problems is a much more accurate and complex, nevertheless economically acceptable control system, which consists of four separate steps (figure 3). The first step is the dynamic screening of the vehicles by means of a portal facility featuring large surface, high sensitivity plastic detectors. It offers three basic advantages: i) it assures the complete sweeping of both lateral sides of vehicles, ii) the alarm levels are self-adjusting on the average background count-rate detected on the sides of *clean* vehicles, and iii) it requires only a few seconds per vehicle.

The subsequent three steps are carried out by the operators only if a radioactive load has been detected by the screening, and only if the count rate is below some safety limit. In this case the hot spot on the side of the vehicle is manually localised by means of a large surface survey meter, the kerma rate is accurately measured by means of a small volume integrating counter, and the radionuclide is identified by means of a portable multichannel spectrometer.

These points may deserve some technical comments. When a radioactive vehicle moves through the portal detectors, the facility provides a rough localisation of the radioactive area, so that the subsequent manual detection of hot points is made easier. For this purpose the use of portable rate-meters with large surface probe is certainly suitable, however it is generally not suitable for the assessment of kerma rates, as the answer is a count-rate figure averaged on the whole active area of the probe. Now, we are looking for the *maximum* AKR (air kerma rate) and must consider the possibility that, as previously mentioned, the source is screened in all directions except along a narrow beam - say a few square centimetres. The use of a counter equipped with a small volume probe - say twenty cubic centimetres - is much more appropriate in this case. But the sensitivity of such a probe is consequently low, not adequate to the measurement of low-level radiation rates, so that in order to obtain a sufficient precision the counter must include an integrating device and the counting must be carried on for a sufficient time.

Accuracy is also important, in case that the results of our measurements should be compared with that obtained by other experts with different instrumentation. This means that the portable monitors must be accurately calibrated in terms of CPS (counts per second) per nGy/h. Accuracy is a somehow complex matter. First, the background AKR is measured by means of an adequate reference ionisation chamber, both far from and close to the side of a *clean* vehicle loaded with scrap. Then, the same procedure is carried out with the monitor. The result is a calibration chart in which the nGy/h scale is shifted to the left (figure 4), so that the zero reading of the monitor matches the background AKR measured with the reference chamber.

Not very often, sources detected in scrap loads that either come from Italy, or already went through Italian customs must be isolated and disposed of. In this case the transport regulations require that activity is measured, which usually is impossible. All that we can actually do after the source has been isolated and the nuclide has been identified, is measuring AKR at a suitable distance, estimating the geometric form [7] and the possible screening effect, then get a very rough assessment of the activity by means of a set of appropriate tables (figure 5).

3 - CONCLUSIVE REMARKS

As far as we know, the control system we have here described is not implemented in any other Italian steel works. It has been carried through in September 1995. Ever since, about 0.7 % of the controlled wagons have been found to contain radioactive sources, most often Ra-226, Co-60 an Cs-137 (figure 6). Of course, we don't know how many beta-emitting or low-energy gamma-emitting sources - as for instance Am-241 - remained undetected. Nevertheless, no radiation - other than normal natural background - has been noticed on the specimens of steel which are systematically analysed by gamma spectrometry after every casting. This eventually would prove that, if this happened, only low-activity sources escaped.

Altogether, it is certainly a complex system, which in some cases requires the intervention of qualified experts, nevertheless it is safe, fast and reliable. So reliable in fact, that it never gave rise to legal contentious actions, in the cases when scrap loads had been rejected. This is an important point which has to be taken into account, too, since one must not forget that a rejected vehicle involves high charges, which neither the steel works, nor the importers willingly accept.

There is a final point we would like to stress, which should be evident from our report and, we are afraid, will not facilitate the achievement of the objectives of this meeting. On one side, clearance levels of either radioactive metal scrap of known origin, or metal products from recycled scrap are a matter of collective risk limitation. They can be agreed on in terms of averaging masses and surfaces, estimating the percentages of all possible final fates of nuclides, calculating the effective collective doses [8]. On the other end, removable contamination amounts, activities, physical consistence of sources buried in scrap loads are generally unknown. No risk figure can be inferred when measuring the AKR on the outside, other than the dose estimation for the persons who approach the load. Therefore, in our opinion no *de minimis* criteria are applicable, nor any clearance level is appropriate as far as radioactive monitoring of scrap vehicles is concerned.

4 - REFERENCES

[1] REPUBBLICA ITALIANA, Decreto legislativo 17 marzo 1995, n. 230, "Attuazione delle direttive Euratom 80/836, 84/467, 84/466, 89/618, 90/641 e 92/3 in materia di radiazioni ionizzanti", Supplemento ordinario alla Gazzetta Ufficiale n. 136 (1995) 45.

[2] MINISTERO DELLA SANITA' della Repubblica Italiana, "Direttiva sul controllo della radioattività di rottami metallici", Circolari n. 30 (1993) e n. 10 (1994).

[3] ICRU, "Measurement of low-level radioactivity", ICRU Report No. 22 (1972).

[4] R. HOFFMAN, B. LEIDERBERG, "Optimisation of measurement techniques for very low-level radioactive waste material", final report CEC research contract F11D-0048 (1991).

[5] MINISTERO DELLE FINANZE della Repubblica Italiana, "Controlli radiometrici all'importazione di rottami metallici", Circolare n. 13/D (1996).

[6] REGIONE AUTONOMA FRIULI VENEZIA GIULIA, Direzione Regionale della Sanità, "Modalità di applicazione nel territorio regionale della circolare n. 30 del Ministero della Sanità", Circolare 16684 (1993).

[7] EUROPEAN COMMISSION, "Calculations of external exposures for radiation sources of different geometry", Luxembourg (1994), draft.

[8] EUROPEAN COMMISSION, "Recommended radiological Protection criteria for the recycling of metals from the dismantling of nuclear installations", Luxembourg (1995), draft.

MINISTERO DELLA SANITA`
CIRCOLARI N. 30, 29 LUGLIO 1993 e N. 10, 2 MAGGIO 1994

... THE RADIOMETRIC CONTROL OF METAL SCRAP SHALL BE PERFORMED BY THE FIRM WHILE UNLOADING THE SCRAP LOAD.

... IN THIS RESPECT THE POSSIBLE IDENTIFICATION OF RADIOACTIVE MATERIALS POSES THE SERIOUS PROBLEM OF DISPOSAL.

REGIONE AUTONOMA FRIULI VENEZIA GIULIA
DIREZIONE REGIONALE DELLA SANITA`, CIRCOLARE 2 SETT 1993

... THERE ARE TO BE CONSIDERED AS "NEGLIGIBLE" ... AIR KERMA RATES LESS THAN 150 nGy/h MEASURED AT 20 cm FROM THE LATERAL SURFACES OF THE RAIL WAGON OVER THE WHOLE HEIGHT OF THE LOAD.

... IF KERMA VALUES HIGHER THAN 150 nG/h HAVE BEEN DETECTED, THEY SHALL IMMEDIATELY NOTIFIED TO LOCAL HEALTH AUTHORITY, WHICH WILL ALERT THE HEALTH PHYSICS SERVICE.

... THE STEEL PLANT SHALL TEST BY GAMMA SPECTROMETRY, AT LEAST MONTHLY, A SIGNIFICANT SAMPLE OF SPECIMENS REPRESENTATIVE OF PRODUCTS.

... THE CERTIFICATES OF "NEGLIGIBLE RADIOACTIVITY" SHALL BE SENT MONTHLY TO THE PUBLIC HEALTH DEPARTMENT...

MINISTERO DELLE FINANZE
CIRCOLARE N. 13/D, 22 GENNAIO 1996

CERTIFICATE FOR THE IMPORTATION OF METAL SCRAP FROM NON-E.U. COUNTRIES

... RESULT OF MEASUREMENTS:
LOCAL MEAN NATURAL BACKGROUND AT THE MOMENT OF CHECK: F = ... ± .....µGy/h
MAXIMUM AKR WITHIN 20 cm FROM LOAD SIDES: F = ... µGy/h

THE UNDERSIGNED QUALIFIED EXPERT CERTIFIES THE MEASUREMENTS CARRIED OUT ON LOAD DID NOT RESULT IN VALUES HIGHER THAN THE MEAN FLUCTUATION OF LOCAL NATURAL RADIATION BACKGROUND ...

FIGURE 1 - ABSTRACT OF ITALIAN REGULATIONS

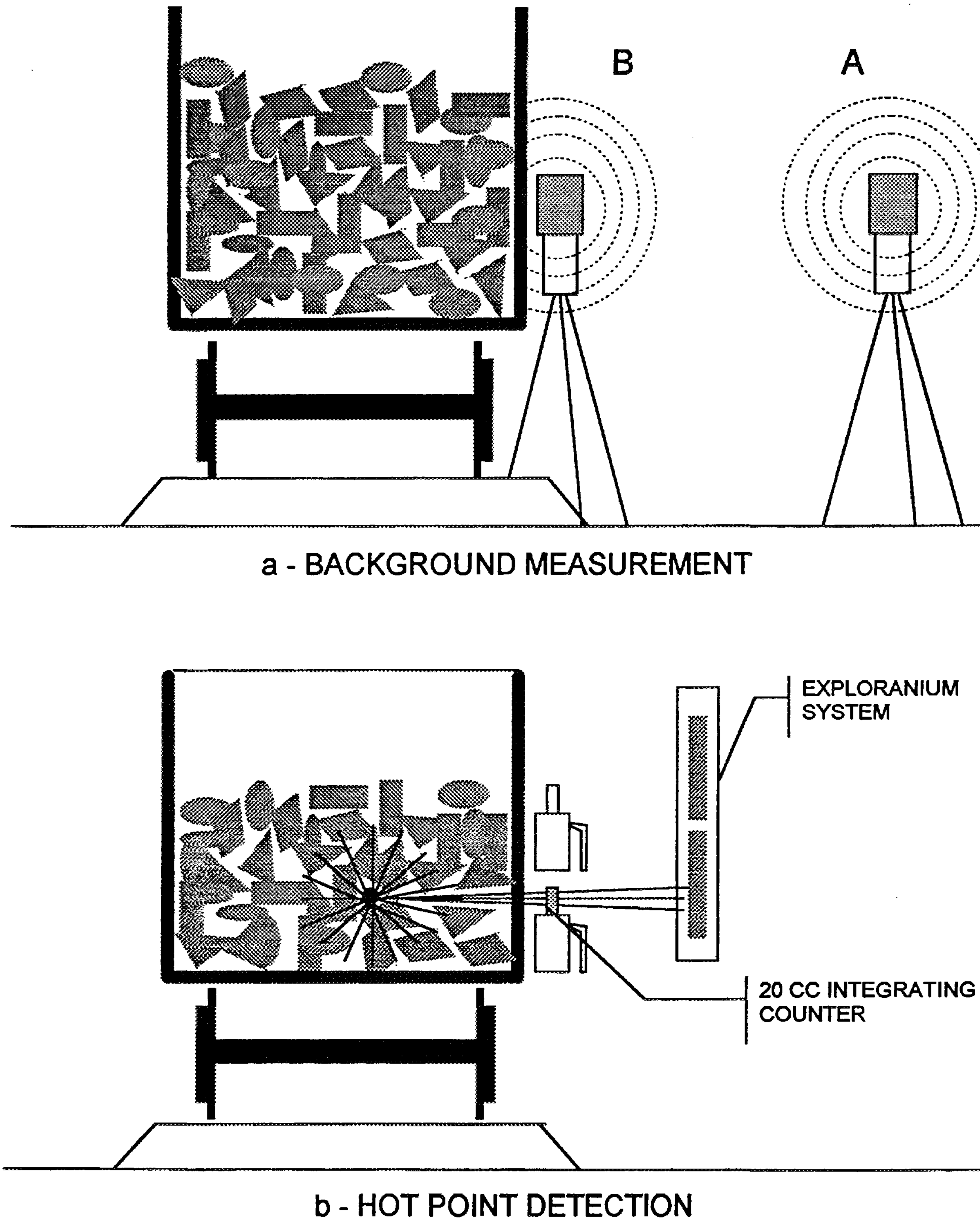
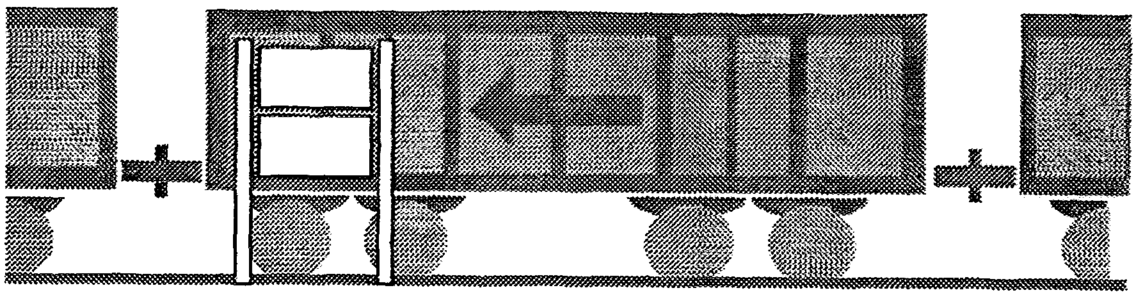
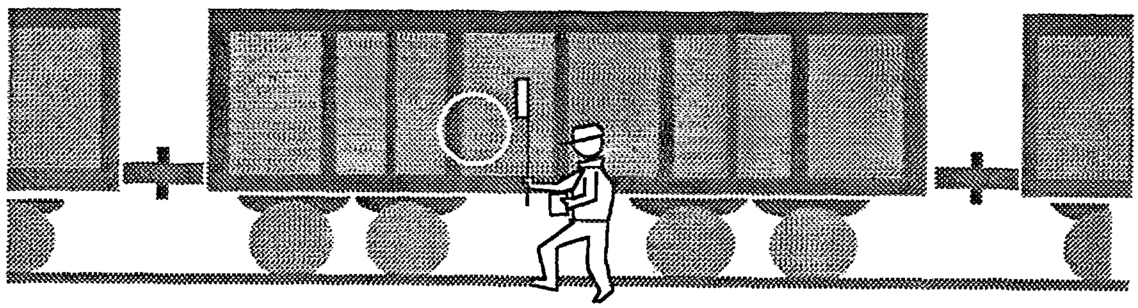


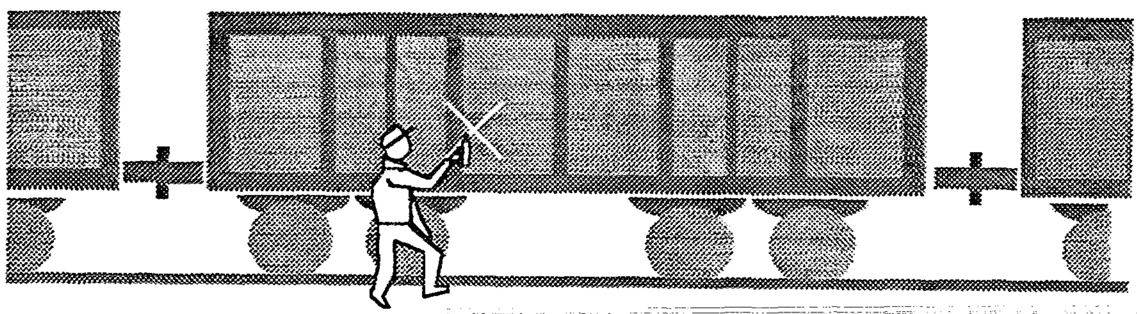
FIGURE 2 - MEASUREMENT AND DETECTION PROBLEMS



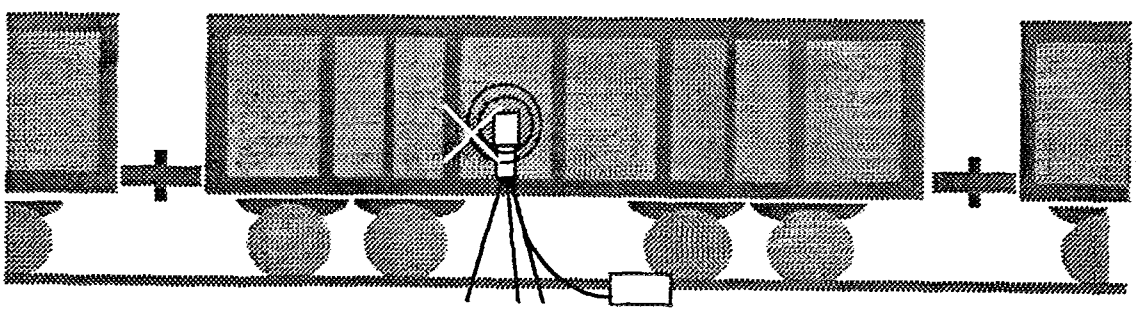
i - SCREENING BY PORTAL FACILITY: 10 seconds



ii - MANUAL RANGING OF SOURCE: 10 minutes



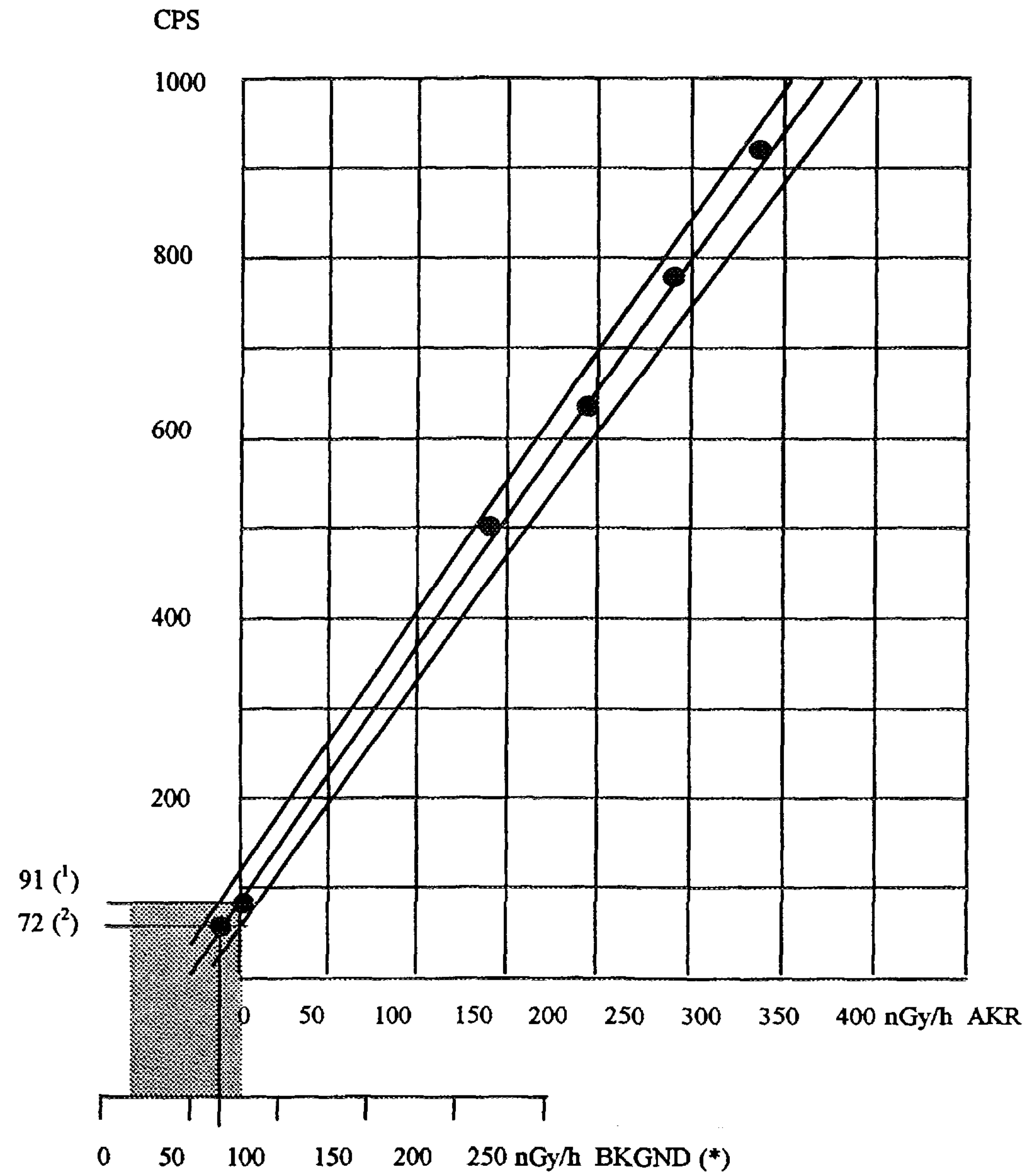
iii - HOT SPOT LOCALISATION AND AKR MEASUREMENT: 30 minutes



iv - RADIONUCLIDE IDENTIFICATION: 10 minutes

FIGURE 3 - VEHICLE MONITORING SYSTEM

TEMA S/N 3100/3033
SCRAP MONITORING CALIBRATION CHART



(1) *BKGND: 76 nGy/h (ionisation chamber Health Physics mod. 1010B, S/N 274)*
Same conditions as AKR exposures, 1 m above ground level
(2) *Same conditions as scrap monitoring: ferrous scrap lorry, 20 cm aside*

FIGURE 4 - CALIBRATION OF A SURVEY METER

CRAD - CENTRO DI RICERCA APPLICATA E DOCUMENTAZIONE VALUTAZIONE APPROSSIMATA DELL'ATTIVITÀ DI UN ROTTAME DI FERRO

1 - LA SORGENTE DEVE ESSERE ISOLATA, LE MISURE DI KERMA DEVONO ESERE ESEGUITE CON CAMERA A IONIZZAZIONE A DISTANZA DETERMINATA

I radionuclidi considerati in queste schede sono Co-60 e Ra-226
Le distanze previste per le misure sono: 20, 30, 50 cm dal centro della sorgente sull'asse normale
Fattori Γ: per il Co-60 : 0,357 μGy/h MBq @ 1 m; per il Ra-226 : 0,224 μGy/h MBq @ 1 m.
Attenuazione del ferro, TVL : per il Co-60 : 7 cm; per il Ra-226 : 8 cm

...

2.2 - NUCLIDE INGLOBATO E DIFFUSO NEL FERRO: FATTORE DI TRASMISSIONE C_A

spessore Fe in cm	1	2	3	4	5	6	7	8	9	10
C_A per il Co-60	0,86	0,74	0,64	0,56	0,50	0,44	0,40	0,36	0,33	0,30
C_A per il ra-226	0,89	0,79	0,71	0,64	0,58	0,52	0,49	0,45	0,42	0,40

...

3.2 - SORGENTE DI SUPERFICIE ESTESA: COEFFICIENTE GEOMETRICO C_G

area cm×cm	10×10	15×15	20×20	30×30	40×40	50×50	60×60	80×80	100×100
C_G a 20 cm	0.96	0.92	0.86	0.74	0.62	0.51			
C_G a 30 cm	0.98	0.96	0.93	0.86	0.78	0.70	0.62		
C_G a 50 cm	1.00	0.98	0.97	0.94	0.90	0.86	0.81	0.71	0.62

...

4 - VALUTAZIONE DELL'ATTIVITA' IN MBq, AKR MISURATO IN μGy/h

misura a 20 cm $A = (AKR \times 0.04) / (C_A \times C_G \times \Gamma)$

misura a 30 cm $A = (AKR \times 0.09) / (C_A \times C_G \times \Gamma)$

misura a 50 cm $A = (AKR \times 0.25) / (C_A \times C_G \times \Gamma)$

FIGURE 5 - APPROXIMATE ASSESSMENT OF SOURCE ACTIVITY

CRAD - CENTRO DI RICERCA APPLICATA E DOCUMENTAZIONE
CONTROLLO RADIOMETRICO SU CARICHI DI ROTTAMI DI FERRO PER FERRIERE NORD SPA, RIVOLI DI OSOPPO
ANNO 1996

	controllati	*rigettati*	*% mensile*	*% totale*
gennaio	239	3	1.26	1.26
febbraio	1290	13	1.01	1.05
marzo	650	6	0.92	1.01
aprile	732	6	0.82	0.96
maggio	673	4	0.59	0.89
giugno	666	4	0.60	0.85
luglio	664	12	1.81	0.98
agosto	475	2	0.42	0.93
settembre	927	8	0.86	0.92
ottobre	1017	3	0.29	0.82
novembre	1173	2	0.17	0.73
dicembre	943	2	0.32	0.69
totale	9449	65	0.69	0.69

		AKR µGy/h (*)	
		min	*max*
32	Ra-226	0.18	2.14
26	Co-60	0.11	0.52
4	Cs-137	0.12	0.37
1	K-40		0.39
1	Ag-108m		0.22
1	?		0.18

(*) punto caldo a 3 cm dalla fiancata; Radalert 1202 calibrato; tempo di integrazione 5 minuti.

FIGURE 6 - FERRIERE NORD: RADIOACTIVE LOADS IN 1996